Society of Automotive Engineers, Inc.
400 COMMONWEALTH DRIVE, WARRENDALE, PA. 15096

AEROSPACE MATERIAL SPECIFICATION

AMS 5589A
Superseding AMS 5589
Issued 9-30-66
Revised 4-1-81

UNS N07718

ALLOY TUBING, SEAMLESS, CORROSION AND HEAT RESISTANT
52.5Ni - 19Cr - 3.0Mo - 5.1(Cb + Ta) - 0.90Ti - 0.50Al - 18Fe
Consumable Electrode or Vacuum Induction Melted
1750°F (955°C) Solution Heat Treated

1. SCOPE:

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

1.2 Application: Primarily for fluid lines and structural components requiring resistance to creep and stress-rupture up to 1300°F (705°C) and oxidation resistance up to 1800°F (980°C), particularly those parts which are formed or welded and then heat treated to develop desired properties.

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) 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 2263 - Tolerances, Nickel, Nickel-Base, and Cobalt-Base Alloy Tubing
AMS 2269 - Chemical Check Analysis Limits, Wrought Nickel Alloys and Cobalt Alloys
AMS 2350 - Standards and Test Methods
AMS 2371 - Quality Assurance Sampling of Corrosion and Heat Resistant Steels and Alloys, Wrought Products Except Forgings and Forging Stock

2.2 ASTM Publications: Available from American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM E8 - Tension Testing of Metallic Materials
ASTM E18 - Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials
ASTM E112 - Estimating the Average Grain Size of Metals
ASTM E139 - Conducting Creep, Creep-Rupture, and Stress-Rupture Tests of Metallic Materials
ASTM E354 - Chemical Analysis of High-Temperature, Electrical, Magnetic, and Other Similar Iron, Nickel, and Cobalt Alloys

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 E354, 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	--	0.08
Manganese	--	0.35
Silicon	--	0.35
Phosphorus	--	0.015
Sulfur	--	0.015
Chromium	17.00	21.00
Nickel	50.00	55.00
Molybdenum	2.80	3.30
Columbium + Tantalum	4.75	5.50
Titanium	0.65	1.15
Aluminum	0.20	0.80
Cobalt	--	1.00
Boron	--	0.006
Copper	--	0.30
Iron	remainder	

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

3.2 Condition: Cold drawn, solution heat treated, and descaled. No specific solution heat treating instructions are specified but it is recommended that the tubing be solution heat treated by heating in a suitable protective atmosphere to 1750°F ± 25 (955°C ± 15), holding at heat for approximately 30 min., and cooling at a rate equivalent to air cool or faster.

3.3 Fabrication: Tubing shall be produced by a seamless process. The external and internal surface finishes may be produced by pickling, bright annealing, or any method which will provide the required surface condition and which will not affect limits of wall thickness or corrosion resistance with the exception that a centerless-ground finish is not acceptable. A light polish to improve surface appearance may be employed.

3.4 Properties: Tubing shall conform to the following requirements:

3.4.1 As Solution Heat Treated:

3.4.1.1 Tensile Properties: Tubing having nominal OD of 0.125 in. (3.12 mm) and over with nominal wall thickness 0.015 in. (0.38 mm) and over shall have the following properties, determined in accordance with ASTM E8:

Tensile Strength, max	155,000 psi (1069 MPa)
Yield Strength at 0.2% Offset, max	95,000 psi (655 MPa)
Elongation in 2 in. (50 mm), min	30%

3.4.1.1.1 Tensile property requirements for tubing under 0.125 in. (3.12 mm) in nominal OD or under 0.015 in. (0.38 mm) in nominal wall thickness shall be as agreed upon by purchaser and vendor.

3.4.1.2 Grain Size: Shall be predominantly 5 or finer with occasional grains as large as 3 permissible, determined by comparison of a polished and etched specimen with the chart in ASTM E112.

3.4.1.3 Flarability: Specimens as in 4.3.1 from tubing 0.188 to 2.000 in. (4.70 to 50.00 mm), incl, in nominal OD and with OD/wall thickness ratio of 10:1 or less shall withstand flaring without formation of cracks or other visible defects. The specimen shall, at room temperature, be forced axially with steady pressure over a hardened and polished tapered steel pin having a 74 deg included angle to produce a flare having a permanent expanded OD not less than 1.20 times the original nominal diameter.

3.4.1.3.1 Flarability requirements for tubing with nominal OD less than 0.188 in. (4.70 mm) or greater than 2.000 in. (50.00 mm) or with OD/wall thickness ratio greater than 10:1 shall be as agreed upon by purchaser and vendor.

3.4.1.4 Pressure Test: Tubing shall show no bulges, leaks, or other defects when subjected to an internal hydrostatic pressure of 5000 psig (34.5 MPag) 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

3.4.2 After Precipitation Heat Treatment: Tubing having nominal OD of 0.125 in. (3.12 mm) and over with nominal wall thickness 0.015 in. (0.38 mm) and over shall meet the requirements of 3.4.2.1, 3.4.2.2, and 3.4.2.3 after being precipitation heat treated by heating to 1325°F ± 15 (720°C ± 8), holding at heat for 8 hr ± 0.5, furnace cooling to 1150°F ± 15 (620°C ± 8), holding at 1150°F ± 15 (620°C ± 8) until a total precipitation time of 18 hr has been reached, and cooling at a rate equivalent to air cool or faster. Tubing shall also meet the requirements of 3.4.2.1, 3.4.2.2, and 3.4.2.3 after being re-solution heat treated by heating to 1750°F ± 25 (955°C ± 15), holding at heat for not less than 30 min., and cooling at a rate equivalent to air cool or faster and precipitation heat treated as above. Tensile, hardness, and stress-rupture properties of tubing less than 0.125 in. (3.12 mm) in nominal OD or under 0.015 in. (0.38 mm) in nominal wall thickness shall be as agreed upon by purchaser and vendor.

3.4.2.1 Tensile Properties: Shall be as follows, determined in accordance with ASTM E8:

Tensile Strength, min	185,000 psi (1276 MPa)
Yield Strength at 0.2% Offset, min	150,000 psi (1034 MPa)
Elongation in 2 in. (50 mm), min	12%

3.4.2.2 Hardness: Should be not lower than 36 HRC or equivalent, determined in accordance with ASTM E18, but the 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 at 1300°F (704°C): A tensile test specimen, maintained at 1300°F ± 3 (704°C ± 2) while a load sufficient to produce an initial axial stress of 72,500 psi (500 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 4D. Test shall be performed in accordance with ASTM E139.

3.4.2.3.1 The test of 3.4.2.3 may be conducted using a load higher than required to produce an initial axial stress of 72,500 psi (500 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.

3.4.2.3.2 When permitted by purchaser, the test of 3.4.2.3 may be conducted using incremental loading. In such case, the load required to produce an initial axial stress of 72,500 psi (500 MPa) shall be used to rupture or for 23 hr, whichever occurs first. After the 23 hr and at intervals of 8 - 16 hr, preferably 8 - 10 hr, thereafter, the stress shall be increased in increments of 5,000 psi (34.5 MPa). Time to rupture and elongation requirements shall be as specified in 3.4.2.3.

3.4.2.3.3 The stress-rupture test is not required on tubing which will not yield a suitable specimen but the material from which the tubing was made shall conform to the requirements of 3.4.2.3.

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, unless otherwise permitted by purchaser. 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, shallow pits, and scale pattern will not be considered injurious if the imperfections are removable within the tolerances specified for wall thickness but removal of such surface imperfections is not required.

3.5.3 When specified by purchaser, tubing shall be subjected to nondestructive testing. Methods of testing and standards for acceptance shall be as agreed upon by purchaser and vendor.

3.6 Sizes: Except when exact lengths or multiples of exact lengths are ordered, straight tubing Ø will be acceptable in mill lengths of 6 - 24 ft (1.8 - 7.3 m) but not more than 25% 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 AMS 2263.

4. QUALITY ASSURANCE PROVISIONS:

4.1 Responsibility for Inspection: The vendor of tubing 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 4.4. Purchaser reserves the right to sample and to perform such confirmatory testing as he deems necessary to ensure that the tubing 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:

Ø 4.2.1.1 Composition (3.1), quality (3.5.2), and tolerances (3.7).

Ø 4.2.1.2 Tensile properties (3.4.1.1) and grain size (3.4.1.2) as solution heat treated.

4.2.1.3 Tensile properties (3.4.2.1) and hardness (3.4.2.2) after precipitation heat treatment.

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: