AEROSPACE MATERIAL SPECIFICATION

AMS5586™	REV. J

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Superseding AMS5586H

(R) Nickel Alloy, Corrosion- and Heat-Resistant, Welded Tubing 57Ni - 19.5Cr - 13.5Co - 4.2Mo - 2.9Ti - 1.4Al - 0.006B - 0.08Zr (Waspaloy) Consumable Electrode Remelted or Vacuum Induction Melted, Annealed (Composition similar to UNS N07001)

RATIONALE

AMS5586J is the result of a Five-Year Review and update of the specification. The revision adds the common alloy name to the Title, updates composition testing and reporting (see 3.1 and 3.1.2), clarifies processing requirements including bore conditioning and cleanliness evaluations (see 3.3 and 3.4), adds strain rate control to tensile testing (see 3.5.1.1.1 and 3.5.2.1.1), adds white cloth/plug requirements (see 3.6.2), adds NDT requirements (see 3.6.3, 4.2.1, and 4.4), clarifies tubing type (see 5.2), and updates the prohibition of exceptions requirements (see 3.5.3 and 8.5).

1. SCOPE

1.1 Form

This specification covers a corrosion- and heat-resistant nickel alloy in the form of welded and drawn 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.

1.2 Application

This tubing has been used typically for parts requiring high strength up to 1500 °F (816 °C) and oxidation resistance up to 1750 °F (954 °C), 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 cancelled and no superseding document has been specified, the last published issue of that document shall apply.

2.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), or www.sae.org.

AMS2263 Tolerances, Nickel, Nickel Alloy, and Cobalt Alloy Aircraft Tubing

AMS2269 Chemical Check Analysis Limits, Nickel, Nickel Alloys, and Cobalt Alloys

TO PLACE A DOCUMENT ORDER: Tel: 877-606-7323 (inside USA and Canada)
Tel: +1 724-776-4970 (outside USA)
Fax: 724-776-0790
Email: CustomerService@sae.org
SAE WEB ADDRESS: http://www.sae.org

For more information on this standard, visit
https://www.sae.org/standards/content/AMS5586J/

AMS2283 Composition Testing Methods for Nickel- and Cobalt-Based Alloys

AMS2371 Quality Assurance Sampling and Testing, Corrosion and Heat-Resistant Steels and Alloys, Wrought Products and Forging Stock

AMS2634 Ultrasonic Inspection, Thin Wall Metal Tubing

AMS2700 Passivation of Corrosion Resistant Steels

AMS2807 Identification, Carbon and Low-Alloy Steels, Corrosion- and Heat-Resistant Steels and Alloys, Sheet, Strip, Plate, and Aircraft Tubing

AS7766 Terms Used in Aerospace Metals Specifications

2.2 ASTM Publications

Available from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959, Tel: 610-832-9585, www.astm.org.

ASTM B751 Standard Specification for General Requirements for Nickel and Nickel Alloy Welded Tube

ASTM B829 Nickel and Nickel Alloys Seamless Pipe and Tube

ASTM E8/E8M Tension Testing of Metallic Materials

ASTM E18 Rockwell Hardness of Metallic Materials

ASTM E112 Determining Average Grain Size

ASTM E139 Conducting Creep, Creep-Rupture, and Stress-Rupture Tests of Metallic Materials

ASTM E140 Hardness Conversion Tables for Metals Relationship Among Brinell Hardness, Vickers Hardness, Rockwell Hardness, Superficial Hardness, Knoop Hardness, Scleroscope Hardness, and Leeb Hardness

ASTM E426 Electromagnetic (Eddy-Current) Examination of Seamless and Welded Tubular Products, Austenitic Stainless Steel and Similar Alloys

ASTM E1417/E1417M Liquid Penetrant Testing

2.3 Definitions

Terms used in AMS are defined in AS7766 and the following:

2.3.1 BORE CONDITIONING

Any mechanical cleaning method that is used in the bore of tubing to improve the final surface appearance, with no resultant change in tubing size beyond the allowable tolerances.

3. TECHNICAL REQUIREMENTS

3.1 Composition

Composition shall conform to the percentages by weight shown in Table 1, determined in accordance with AMS2283 or by other analytical methods acceptable to the purchaser.

Table 1 - Composition

Element	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
Boron (see 3.1.1)	0.003	0.010
Zirconium	0.02	0.15
Iron	--	2.00
Copper	--	0.10
Nickel	remainder	

3.1.1 Boron may be less than 0.003% by weight, 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 The producer may test for any element not listed in Table 1 and include this analysis in the report of 4.4. Reporting of any element not listed in the composition table is not a basis for rejection unless limits of acceptability are specified by the purchaser.

3.1.3 Check Analysis

Composition variations shall meet the applicable requirements of AMS2269.

3.2 Melting Practice

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 that have been produced by vacuum induction melting shall be used for remelting.

3.3 Condition

Tubing shall be annealed. Cooling from the annealing temperature shall be at a rate equivalent to an air cool or faster. Annealing shall be performed in an atmosphere yielding a bright finish. Alternately, product shall be chemically cleaned to produce a uniform finish. It is permissible to pickle prior to final cleaning treatment. Final chemical cleaning may take place after any final finishing (see 3.4.4). After final chemical cleaning, tube cleanliness shall be verified using the corrosion-resistance test methods specified in AMS2700 for class 2 parts, or alternate method acceptable to the purchaser.

3.4 Fabrication

Tubing 2.00 inches (50.8 mm) and under in nominal OD shall be produced by a welded and drawn process.

3.4.1 Any surface finishing operation applied to remove objectionable pits and surface blemishes shall be performed prior to final annealing heat treatment. A light polish to improve external surface appearance may be employed after annealing, and if performed, the product shall be subsequently chemically cleaned.

3.4.2 Tubing 2.00 inches (50.8 mm) and under shall have been cold worked sufficiently to ensure proper weld reinforcement height and roundness in the weld reinforcement area.

3.4.3 Bore conditioning (see 2.3) is permitted after final anneal provided the tubing is not sized by metal removal methods beyond the original tolerances. If bore conditioning is used, 100% visual inspection of each tube shall be performed. The tube ID shall be uniformly shiny with no evidence of remnant material.

3.4.4 Tubing shall be chemically cleaned after any ID or OD finishing that occurs after heat treatment.

3.5 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:

3.5.1 As Annealed

3.5.1.1 Tensile Properties

Tensile properties shall be as shown in Table 2, determined in accordance with ASTM E8/E8M.

Table 2 - Tensile properties

Property	Value
Tensile Strength, max	145 ksi (1000 MPa)
Yield Strength at 0.2% Offset, max	80 ksi (552 MPa)
Elongation in 2 Inches (50 mm) or 4D, min	35%

3.5.1.1.1 Unless otherwise specified, the strain rate shall be set at 0.005 in/in/min (0.005 mm/mm/min) and maintained within a tolerance of ±0.002 in/in/min (±0.002 mm/mm/min) through 0.2% offset yield strain. After the yield strain, the speed of the testing machine shall be set between 0.05 and 0.5 in/in (0.05 and 0.5 mm/mm) of the length of the reduced parallel section (or distance between the grips for specimens not having a reduced section) per minute. Alternatively, an extensometer and strain rate indicator may be used to set the strain rate between 0.05 and 0.5 in/in/min (0.05 and 0.5 mm/mm/min). The requirement for compliance becomes effective for material produced 1 year after the publication date of this specification.

3.5.1.2 Flarability

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.

3.5.1.3 Average Grain Size

Average grain size shall be ASTM No. 5 or finer, determined in accordance with ASTM E112.

3.5.2 Response to Solution, Stabilization, and Precipitation Heat Treatment

Samples of tubing shall meet the requirements of 3.5.2.1, 3.5.2.2, and 3.5.2.3 after being solution heat treated by heating in a suitable atmosphere to 1825 °F ± 25 °F (996 °C ± 14 °C), holding at heat for 2 hours ± 0.25 hour, and cooling at a rate equivalent to an air cool or faster; stabilization treated by heating to 1550 °F ± 15 °F (843 °C ± 8 °C), holding at heat for 4 hours ± 0.25 hour, and cooling at a rate equivalent to air cooling; and precipitation treated by heating to 1400 °F ± 15 °F (760 °C ± 8 °C), holding at heat for 16 hours ± 1 hour, and cooling at a rate equivalent to air cooling.

3.5.2.1 Tensile Properties - Response to Heat Treatment

Response to heat-treatment tensile properties shall be as shown in Table 3, determined in accordance with ASTM E8/E8M.

Table 3 - Minimum tensile properties - response to heat treatment

Property	Value
Tensile Strength	160 ksi (1103 MPa)
Yield Strength at 0.2% Offset	105 ksi (724 MPa)
Elongation in 2 Inches (50 mm) or 4D	15%

3.5.2.1.1 Unless otherwise specified, the strain rate shall be set at 0.005 in/in/min (0.005 mm/mm/min) and maintained within a tolerance of ±0.002 in/in/min (±0.002 mm/mm/min) through 0.2% offset yield strain. After the yield strain, the speed of the testing machine shall be set between 0.05 and 0.5 in/in (0.05 and 0.5 mm/mm) of the length of the reduced parallel section (or distance between the grips for specimens not having a reduced section) per minute. Alternatively, an extensometer and strain rate indicator may be used to set the strain rate between 0.05 and 0.5 in/in/min (0.05 and 0.5 mm/mm/min). The requirement for compliance becomes effective for material produced 1 year after the publication date of this specification.

3.5.2.2 Hardness

Hardness shall be 34 to 44 HRC, or equivalent (see 8.2), determined in accordance with ASTM E18.

3.5.2.3 Stress-Rupture Properties

Stress rupture shall be determined in accordance with ASTM E139. The test at 1500 °F (816 °C) (see 3.5.2.3.2) need be run only if the tubing fails to pass the test at 1350 °F (732 °C). Tubing that passes the test of 3.5.2.3.2 will be acceptable.

3.5.2.3.1 At 1350 °F (732 °C)

A tensile specimen, maintained at 1350 °F ± 3 °F (732 °C ± 2 °C) while a load sufficient to produce the initial axial stress shown in Table 4 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 4.

Table 4A - Stress rupture requirements, inch/pound units

Nominal Wall Thickness Inches	Stress ksi	Elongation in 2 Inches or 4D %, Min
0.015 to 0.020, incl	62.5	4
Over 0.020 to 0.030, incl	65.0	4
Over 0.030 to 0.050, incl	67.5	4
Over 0.050	70.0	5

Table 4B - Stress rupture requirements, SI units

Nominal Wall Thickness Millimeters	Stress MPa	Elongation in 50 mm or 4D %, 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

3.5.2.3.2 At 1500 °F (816 °C)

A tensile specimen, maintained at 1500 °F ± 3 °F (816 °C ± 2 °C) while a load sufficient to produce an initial axial stress of 37.5 ksi (259 MPa) or higher is applied continuously, shall not rupture in less than 23 hours. Elongation after rupture, measured at room temperature, shall be not less than 5% in 2 inches (50.8 mm).

3.5.2.3.2.1 The test of 3.5.2.3.2 may be conducted using incremental loading. In such case, the load required to produce an initial axial stress of 37.5 ksi (259 MPa) or higher shall be used to rupture or for 23 hours, whichever occurs first. After the 23 hours and at intervals of 8 hours, minimum, the stress shall be increased in increments of 2.5 ksi (17 MPa). Time to rupture and elongation requirements shall be as specified in 3.5.2.3.2.

3.5.3 Mechanical property requirements for product outside of the range covered by 1.1 shall be agreed upon between the purchaser and producer and reported per 4.41.

3.6 Quality

Tubing as received by the 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 grease, oil and other matter, 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.

3.6.1 If weld reinforcement is present at the weld on the inner surface of tubing over 2.00 inches (50.8 mm) in nominal OD, such weld reinforcement 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 weld reinforcement.

3.6.2 A clean white cloth or plug drawn or blown through the length of the bore of a test sample at least 12 inches (30 cm) in length shall show no visual evidence of metallic flakes or particles. Discoloration of the cloth or plug, without the presence of flakes or particles, is acceptable. Alternate methods for evaluating tube cleanliness may be used for tubing 0.500 inch (12.7 mm) and under ID.

3.6.3 When no inspection is specified by the purchaser, tubing shall be subjected to either ultrasonic or eddy current inspection in accordance with ASTM B751 or ASTM B829 except that suspect indications shall not be accepted based on visual observation (i.e., indications must be either rejected or reconditioned and retested to pass the test). Alternate methods of inspection may be used for tube 0.25 inch (0.64 cm) and under in nominal diameter.

3.6.4 When specified by the purchaser, tubing shall be subjected to fluorescent penetrant testing in accordance with ASTM E1417/E1417M, to ultrasonic inspection in accordance with AMS2634, to electromagnetic (eddy current) inspection in accordance with ASTM B751 except that suspect indications shall not be accepted based on visual observation (i.e., indications must be either rejected or reconditioned and retested to pass the test), or to any combination thereof. When not specified, any one test may be performed at the discretion of the producer. Tubing shall meet the requirements of acceptance criteria established by the cognizant engineering organization.

3.7 Tolerances

Tolerances shall conform to all applicable requirements of AMS2263.

3.8 Exceptions

Any exceptions shall be authorized by the purchaser and reported as in 4.4.1.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for Inspection

The producer of tubing shall supply all samples for the producer's tests and shall be responsible for the performance of all required tests. The purchaser reserves the right to sample and to perform any confirmatory testing deemed necessary to ensure that the tubing conforms to specified requirements.