



AEROSPACE MATERIAL SPECIFICATION

AMS5589™**REV. G**

Issued 1996-09
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Superseding AMS5589F

Nickel Alloy, Corrosion and Heat-Resistant, Seamless Tubing
52.5Ni - 19Cr - 3.0Mo - 5.1Cb (Nb) 0.90Ti - 0.50Al - 18Fe
Consumable Electrode Remelted or Vacuum Induction Melted
1775 °F (968 °C) Solution Heat Treated
(Composition similar to UNS N07718)

RATIONALE

AMS5589G prohibits unauthorized exceptions (3.9), revises Composition (3.1) to remove test procedures, Fabrication (3.4), Hardness (3.6.2.2), clarifies stress-rupture testing for small diameter or thin wall tubing (3.6.2.3.3), revises Quality (3.7.1), Reports (4.4.1) and Identification (5.2.1), and results from a Five-Year Review and update of this specification.

1. SCOPE

1.1 Form

This specification covers a corrosion and heat-resistant nickel alloy in the form of seamless tubing 0.125 inch (3.18 mm) and over in nominal OD with nominal wall thickness 0.015 inch (0.38 mm) and over (see 8.6).

1.2 Application

This tubing has been used typically for fluid lines and components requiring resistance to creep and stress-rupture up to 1300 °F (704 °C) and oxidation resistance up to 1800 °F (982 °C), particularly those parts which are formed or welded and then heat treated to develop desired properties, 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), www.sae.org.

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

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

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

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**SAE values your input. To provide feedback
on this Technical Report, please visit
<http://standards.sae.org/AMS5589G>**

- AMS2750 Pyrometry
- AMS2807 Identification, Carbon and Low-Alloy Steels, Corrosion and Heat-Resistant Steels and Alloys Sheet, Strip, Plate, and Aircraft Tubing.
- ARP1917 Clarification of 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 B829 General Requirements for 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 E354 Chemical Analysis of High-Temperature, Electrical, Magnetic, and Other Similar Iron, Nickel, and Cobalt Alloys

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 E354 or by other analytical methods acceptable to purchaser.

Table 1 - Composition

Element	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 (Niobium)	4.75	5.50
Titanium	0.65	1.15
Aluminum	0.20	0.80
Cobalt	--	1.00
Tantalum	--	0.05
Boron	--	0.006
Copper	--	0.30
Iron	remainder	

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

3.3 Condition

Cold drawn or pilgered, solution heat treated, and descaled.

3.4 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 external surface appearance may be employed after solution heat treatment. Bore conditioning is permitted after final anneal provided the tubing is not sized by metal removal methods and the tubing is passivated after any such conditioning (see 8.3.1).

3.5 Solution Heat Treatment

Solution heat treat by heating in a protective atmosphere within the range 1725 to 1825 °F (941 to 996 °C), holding at the selected temperature within ± 25 °F (± 14 °C) for a time commensurate with cross-sectional thickness, and cooling at a rate equivalent to an air cool or faster. Pyrometry shall be in accordance with AMS2750.

3.6 Properties

Tubing shall conform to the following requirements:

3.6.1 As Solution Heat Treated

3.6.1.1 Tensile Properties

Tubing, 0.125 inch (3.18 mm) and over in nominal OD with nominal wall thickness 0.015 inch (0.38 mm) and over, shall have the properties shown in Table 2, determined in accordance with ASTM E8/E8M.

Table 2 - Tensile properties

Property	Value
Tensile Strength, max	155 ksi (1069 MPa)
Yield Strength at 0.2% Offset, max	95 ksi (655 MPa)
Elongation in 2 Inches (50.8 mm), min	30%

3.6.1.2 Average Grain Size

Shall be ASTM No. 5 or finer, determined in accordance with ASTM E112.

3.6.1.3 Flareability

Specimens as in 4.3.1 from tubing 0.188 to 2.000 inches (4.78 to 50.80 mm), inclusive, in nominal OD and with OD/wall thickness ratio of 10:1 or less 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 1.20 times the original nominal outside diameter.

3.6.2 After Precipitation Heat Treatment

Tubing 0.125 inch (3.08 mm) and over in nominal OD with nominal wall thickness 0.015 inch (0.38 mm) and over shall meet the requirements of 3.6.2.1, 3.6.2.2, and 3.6.2.3 after being precipitation heat treated by heating to 1325 °F ± 15 °F (718 °C ± 8 °C), holding at heat for 8 hours ± 0.5 hours, furnace cooling to 1150 °F ± 15 °F (621 °C ± 8 °C) holding at 1150 °F ± 15 °F (621 °C ± 8 °C) until a total precipitation time of 18 hours has been reached, and cooling at a rate equivalent to an air cool or faster. Tubing shall also meet the requirements of 3.6.2.1, 3.6.2.2, and 3.6.2.3 after being re-solution heat treated by heating to 1750 °F ± 25 °F (954 °C ± 14 °C), holding at heat for not less than 30 minutes, and cooling at a rate equivalent to an air cool or faster and precipitation heat treated as above.

3.6.2.1 Tensile Properties

Shall be as shown in Table 3, determined in accordance with ASTM E8/E8M.

Table 3 - Minimum tensile properties

Property	Value
Tensile Strength	185 ksi (1276 MPa)
Yield Strength at 0.2% Offset	150 ksi (1034 MPa)
Elongation in 2 Inches (50.8 mm)	12%

3.6.2.2 Hardness

Not lower than 36 HRC, determined in accordance with ASTM E18 or equivalent (see 8.2), but the tubing shall not be rejected on the basis of hardness if the tensile property requirements of 3.6.2.1 are acceptable, determined on specimens taken from the same sample as that with nonconforming hardness, or from another sample with similar nonconforming hardness.

3.6.2.3 Stress-Rupture Properties at 1300 °F (704 °C)

A tensile specimen, maintained at 1300 °F ± 3 °F (704 °C ± 2 °C) while a load sufficient to produce an initial axial stress of 72.5 ksi (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.

3.6.2.3.1 The test of 3.6.2.3 may be conducted using a load higher than required to produce an initial axial stress of 72.5 ksi (500 MPa) but load shall not be changed while test is in progress. Time to rupture and elongation requirements shall be as specified in 3.6.2.3.

3.6.2.3.2 The test of 3.6.2.3 may be conducted using incremental loading. In such case, the load required to produce an initial axial stress of 72.5 ksi (500 MPa) shall be used to rupture or for 23 hours, whichever occurs first. After the 23 hours and at intervals of 8 hours minimum, thereafter, the stress shall be increased in increments of 5000 psi (34.5 MPa). Time to rupture and elongation requirements shall be as specified in 3.6.2.3.

3.6.2.3.3 When the finished tube size precludes obtaining a test specimen of suitable size, the stress-rupture test sample may be taken from the same tubing stock earlier in the process. When this is done, it shall be noted on the test report that stress-rupture specimens were extracted prior to reaching finished dimensions.

3.6.3 Mechanical properties for product outside the range covered by 1.1 shall be agreed upon by purchaser and producer.

3.7 Quality

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 imperfections is not required.

3.7.1 Tubing shall be subjected to either ultrasonic or eddy current inspection in accordance with 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).

3.7.2 Tubing shall be free from grease or other foreign material. Metallic flakes or particles shall not be collected on a clean white cloth drawn through the bore of a test sample. Discoloration of the cloth, without the presence of flakes or particles, is acceptable.

3.8 Tolerances

Shall conform to all applicable requirements of AMS2263. Tolerances for tubing 1.50 to 4.50 inches (38.1 to 114.3 mm) OD shall be as shown in Table 4.

Table 4A - Large tubing tolerances, inch/pound units

Nominal OD Inches	Tolerance Plus and Minus Inch
1.50 to 3.50, incl	0.015
Over 3.50 to 4.50, incl	0.020

Table 4B - Large tubing tolerances, SI units

Nominal OD Millimeters	Tolerance Plus and Minus Millimeter
38.1 to 88.9, incl	0.38
Over 88.9 to 114.3, incl	0.51

3.9 Exceptions

Any exception shall be authorized by 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 producer'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 tubing 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), quality (3.7), and tolerances (3.8).

4.2.1.2 Tensile properties (3.6.1.1) and average grain size (3.6.1.2) of each lot as solution heat treated.

4.2.1.3 Tensile properties (3.6.2.1) and hardness (3.6.2.2) of each lot after precipitation heat treatment.

4.2.2 Periodic Tests

The following requirements are periodic tests and shall be performed at a frequency selected by the producer unless frequency of testing is specified by purchaser:

4.2.2.1 Flarability (3.6.1.3) as solution heat treated.

4.2.2.2 Stress-rupture properties (3.6.2.3) after precipitation heat treatment.

4.2.2.3 Tensile properties (3.6.2.1), hardness (3.6.2.2), and stress-rupture properties (3.6.2.3) after re-solution and precipitation heat treatment.

4.3 Sampling and Testing

Shall be in accordance with AMS2371 and the following:

4.3.1 Specimens for flarability test (3.6.1.3) 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.

4.4 Reports

The producer of the product shall furnish with each shipment a report showing the producer's name and country where the metal was melted (i.e., the final melt in the case of metal processed by multiple melting operations), and the results of tests for composition of each heat, and for tensile properties and average grain size solution heat treated of each lot, and tensile properties and hardness precipitation heat treated of each lot, and stating that the product conforms to the other technical requirements. This report shall include the purchase order number, heat and lot numbers, AMS5589G, size, product form and quantity.

4.4.1 When material produced to this specification has exceptions authorized by purchaser taken to the technical requirements listed in Section 3 (see 5.2.1), the report shall contain a statement "This material is certified as AMS5589G(EXC) because of the following exceptions:" and the specific exceptions shall be listed.

4.5 Resampling and Retesting

Shall be in accordance with AMS2371.

5. PREPARATION FOR DELIVERY

5.1 Sizes

Except when exact lengths or multiples of exact lengths are ordered, straight tubing will be acceptable in mill lengths of 6 to 24 feet (1.8 to 7.3 m) but not more than 25% of any shipment shall be supplied in lengths shorter than 10 feet (3 m).

5.2 Identification

Shall be in accordance with AMS2807.

5.2.1 When technical exceptions are taken (see 4.4.1), the material shall be marked with AMS5589G(EXC).

5.3 Packaging

Tubing shall be prepared for shipment in accordance with commercial practice and in compliance with applicable rules and regulations pertaining to the handling, packaging, and transportation of the tubing to ensure carrier acceptance and safe delivery.

6. ACKNOWLEDGMENT

A producer shall mention this specification number and its revision letter in all quotations and when acknowledging purchase orders.

7. REJECTIONS

Tubing not conforming to this specification, or to modifications authorized by purchaser, will be subject to rejection.

8. NOTES

NOTICE

This specification may reference the use of substances, products or procedures that are restricted or banned by local (regional) chemical substance regulations. Users of this specification should consider the implications of local legislation on the products, substances, and processes referred to within the document.

8.1 Revision Indicator

A change bar (I) located in the left margin is for the convenience of the user in locating areas where technical revisions, not editorial changes, have been made to the previous issue of this document. An (R) symbol to the left of the document title indicates a complete revision of the document, including technical revisions. Change bars and (R) are not used in original publications, nor in documents that contain editorial changes only.

8.2 Hardness conversion tables for metals are presented in ASTM E140.

8.3 Terms used in AMS are clarified in ARP1917 and as follows:

8.3.1 Bore conditioning is any mechanical cleaning method that is used in the bore of tubing to improve the final surface appearance, with no resultant dimensional change.

8.4 Dimensions and properties in inch/pound units and the Fahrenheit temperatures are primary; dimensions and properties in SI units and the Celsius temperatures are shown as the approximate equivalents of the primary units and are presented only for information.

8.5 Unless otherwise specified, the material producer shall work to the revision of this specification (AMS5589) in effect on the date of order placement. Unless otherwise specified, material manufactured and certified to the immediately previous revision of this specification (AMS5589) may be procured and used until inventory is depleted.

8.6 Purchase documents should specify not less than the following:

AMS5589G

Product form and size of tubing desired

Quantity of tubing desired

Property and acceptance requirements from the cognizant engineering organization applicable to sizes outside the range listed in 1.1

Acceptance standards for nondestructive testing if required (see 3.7.1)

PREPARED BY AMS COMMITTEE "F"