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

AEROSPACE MATERIAL SPECIFICATION

AMS 4942B
Superseding AMS 4942A

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TITANIUM TUBING, SEAMLESS
Annealed, 40,000 psi (276 MPa) Yield Strength

1. SCOPE:

1.1 Form: This specification covers one grade of commercially-pure titanium in the form of seamless tubing.

1.2 Application: Primarily for parts such as fluid-conducting lines requiring strength up to 400° F (205° C) and oxidation resistance up to 600° F (315° C).

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 2244 - Tolerances, Titanium and Titanium-Base Alloy Tubing
AMS 2249 - Chemical Check Analysis Limits, Titanium and Titanium Alloys
AMS 2350 - Standards and Test Methods

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 E120 - Chemical Analysis of Titanium and Titanium-Base Alloys

2.3 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 E120, by spectrographic methods in accordance with Federal Test Method Standard No. 151, Method 112, or by other approved analytical methods:

	min	max
Iron	--	0.30
Oxygen	--	0.25
Carbon	--	0.10
Nitrogen	--	0.03 (300 ppm)
Hydrogen	--	0.015 (150 ppm)
Residual Elements, each (3.1.1)	--	0.10
Residual Elements, total (3.1.1)	--	0.30
Titanium	remainder	

3.1.1 Determination not required for routine acceptance.

3.1.2 Check Analysis: Composition variations shall meet the requirements of AMS 2249.

3.2 Condition: Cold reduced and vacuum annealed or annealed and descaled.

3.3 Annealing: Tubing shall be annealed by a procedure which will provide tubing meeting the requirements of 3.4.

3.4 Properties: Tubing shall conform to the following requirements and shall meet the requirements of 3.4.1, 3.4.2, 3.4.3, and 3.4.4 after being heated to any temperature up to 1300° F (705° C), held at heat for 30 - 35 min., and cooled. Surface contamination may be removed before testing.

3.4.1 Tensile Properties: Shall be as specified below, determined in accordance with ASTM E8 with the rate of strain maintained at 0.003 - 0.007 in. per in. per min. (0.003 - 0.007 mm/mm/min.) through the yield strength and then increased so as to produce failure in approximately one additional minute. When a dispute occurs between purchaser and vendor over the yield strength values, a referee test shall be performed on a machine having a strain rate pacer, using a rate of 0.005 in. per in. per min. (0.005 mm/mm/min.) through the yield strength and a minimum crosshead speed of 0.10 in. (2.5 mm) per min. above the yield strength.

Tensile Strength, min	50,000 psi (345 MPa)
Yield Strength at 0.2% Offset, min	40,000 - 65,000 psi (276 - 448 MPa)
Elongation in 2 in. (50.8 mm), min	20%

3.4.2 Flattening:

3.4.2.1 Tubing with nominal wall thickness of 7 - 15% of the nominal OD shall withstand, without cracking on the OD surface, flattening sideways at room temperature under a load applied gradually until the outside dimension under load is equal to 7 times the nominal wall thickness.

3.4.2.1.1 If tubing does not pass the flattening test, a section of tube shall withstand, without cracking, bending at room temperature through an angle of 180 deg (3.14 rad) around a diameter equal to 5 times the nominal wall thickness of the tubing. The axis of the bend shall be parallel to the axis of the tube and the inside of the tube shall be on the inside of the bend.

3.4.2.2 Tubing with nominal wall thickness less than 7% or greater than 15% of the nominal OD shall have flattening or bending properties as agreed upon by purchaser and vendor.

3.4.3 Flarability: Tubing 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 deg (1.29 rad) included angle to produce a flare having a permanent expanded OD not less than 1.30 times the original nominal OD.

3.4.4 Pressure Testing: Tubing shall show no bulges, leaks, pin holes, cracks, or other defects when subjected to an internal hydrostatic pressure (P) sufficient to cause a tensile stress of 20,000 psi (138 MPa) in the tubing wall. The hydrostatic pressure (P) shall be determined from the equation:

$$P = S \frac{D^2 - d^2}{D^2 + d^2}$$

where, P = Test pressure in psi (MPa)
S = 20,000 psi (138 MPa)
D = Nominal OD
d = Nominal ID

3.4.5 Surface Contamination: Tubing shall be free of any oxygen-rich layer, such as alpha case, or other surface contamination.

3.5 Quality:

3.5.1 Alloy shall be multiple melted; at least one of the melting cycles shall be under vacuum. The first melt shall be made by either consumable or nonconsumable electrode practice. The subsequent melt or melts shall be made using consumable electrode practice.

3.5.1.1 The atmosphere for nonconsumable electrode melting shall be vacuum or shall be inert gas at a pressure not higher than 250 mm of mercury.

3.5.1.2 The electrode tip for nonconsumable electrode melting shall be either graphite or water-cooled copper.

3.5.2 Tubing shall be uniform in quality and condition, and shall have a finish conforming to the best practice for high quality tubing. It shall be smooth, and free from heavy scale or oxide, burrs, seams, tears, grooves, laminations, slivers, pits, and other injurious conditions. 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.

3.6 Tolerances: Unless otherwise specified, tolerances shall conform to all applicable requirements of AMS 2244; standard tolerances for diameter and wall thickness shall apply.

4. QUALITY ASSURANCE PROVISIONS:

4.1 Responsibility for Inspection: The vendor of tubing shall supply all samples 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 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 composition (3.1), tensile property (3.4.1), flattening (3.4.2), pressure test (3.4.4), surface contamination (3.4.5), and tolerance (3.6) requirements as received are classified as acceptance tests.

4.2.2 Periodic Tests: Tests to determine conformance to tensile property (3.4.1), flattening (3.4.2), and pressure test (3.4.4) requirements after reheating as in 3.4 and to flarability (3.4.3) requirements as received and after reheating are classified as periodic tests.

4.3 Sampling: Shall be in accordance with the following; a lot shall be all tubing of the same nominal size from the same heat processed at the same time:

4.3.1 Acceptance Tests:

4.3.1.1 Composition: One sample from each heat except that for hydrogen determinations one sample from each lot, obtained after thermal and chemical processing is completed.

4.3.1.2 Tensile Properties, Flattening Tests, Pressure Tests, and Surface Contamination: At least one ø sample from each lot.

4.3.1.2.1 Specimens for the alternate bend test of 3.4.2.1.1 shall be not less than 0.500 in. (12.70 mm) in length and shall embrace 1/3 to 1/2 the circumference of the tube. Cut edges of the specimen shall be smooth and free from burrs.

4.3.2 Periodic Tests: As agreed upon by purchaser and vendor.

4.3.2.1 Specimens for flarability test may be cut from any portion of a tube or an entire tube may be used as a specimen. 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:

4.4.1 The vendor of tubing shall furnish with each shipment three copies of a report showing the results of tests for chemical composition of each heat and for the hydrogen content, tensile properties, and surface contamination of each lot, and stating that the tubing conforms to the other technical requirements of this specification. This report shall include the purchase order number, heat number, lot number, material specification number and its revision letter, size, and quantity from each heat.

4.4.2 The vendor of finished or semi-finished parts shall furnish with each shipment three copies of a report showing the purchase order number, material specification number and its revision letter, contractor or other direct supplier of tubing, part number, and quantity. When tubing for making parts is produced or purchased by the parts vendor, that vendor shall inspect each lot of tubing to determine conformance to the requirements of this specification, and shall include in the report a statement that the tubing conforms, or shall include copies of laboratory reports showing the results of tests to determine conformance.

4.5 Resampling and Retesting: If any specimen used in the above tests fails to meet the specified requirements, disposition of the tubing may be based on the results of testing three additional specimens for each original nonconforming specimen. Failure of any retest specimen to meet the specified requirements shall be cause for rejection of the tubing represented and no additional testing shall be permitted. Results of all tests shall be reported.

5. PREPARATION FOR DELIVERY:

5.1 Identification: Tubing shall be identified as follows:

5.1.1 Straight Tubes 0.029 In. (0.74 mm) and Over in Nominal Wall Thickness and 0.500 In. (12.70 mm) and Over in Nominal OD, Minor Axis, or Least Width of Flat Surface: Shall be marked in a row of characters recurring in intervals not greater than 3 ft (914 mm) with AMS 4942B, heat number, manufacturer's identification, and nominal wall thickness. The characters shall be of such size as to be clearly legible, shall be applied using a suitable marking fluid whose residue shall contain not more than traces of halogen-bearing compounds, and shall be removable in hot alkaline cleaning solution without rubbing. The markings shall have no deleterious effect on the tubing or its performance and shall be sufficiently stable to withstand normal handling.

5.1.2 Straight Tubes Under 0.029 In. (0.74 mm) in Nominal Wall Thickness or Under 0.500 In. (12.70 mm) in Nominal OD, Minor Axis, or Least Width of Flat Surface: Shall be securely bundled and identified by a durable tag marked with the information of 5.1.1 and attached to each bundle or shall be boxed and the box marked with the same information.