SAE Aerospace
An SAE International Group

AEROSPACE MATERIAL SPECIFICATION

SAE AMS 4941D

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Superseding AMS 4941C

Titanium Tubing, Welded
Annealed, 40 ksi (276 MPa) Yield Strength
(Composition similar to UNS R50400)

1. SCOPE:

1.1 Form:

This specification covers one grade of commercially pure titanium in the form of welded tubing.

1.2 Application:

This tubing has been used typically for parts, such as low-pressure fluid-conducting lines and conduits, requiring strength up to 400 °F (204 °C) and oxidation resistance up to 600 °F (316 °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 canceled and no superseding document has been specified, the last published issue of that document shall apply.

2.1 SAE Publications:

Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001 or www.sae.org.

AMS 2244	Tolerances, Titanium and Titanium Alloy Tubing
AMS 2249	Chemical Check Analysis Limits, Titanium and Titanium Alloys
AMS 2368	Sampling and Testing of Wrought Titanium Raw Material Except Forgings and Forging Stock
AMS 2809	Identification, Titanium and Titanium Alloy Wrought Products
AMS-H-81200	Heat Treatment of Titanium and Titanium Alloys

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

2.2 ASTM Publications:

Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959 or www.astm.org.

ASTM E 8	Tension Testing of Metallic Materials
ASTM E 120	Chemical Analysis of Titanium and Titanium Alloys
ASTM E 1409	Determination of Oxygen in Titanium and Titanium Alloys by the Inert Gas Fusion Technique
ASTM E 1447	Determination of Hydrogen in Titanium and Titanium Alloys by the Inert Gas Fusion Thermal Conductivity Method

3. TECHNICAL REQUIREMENTS:

3.1 Composition:

Shall conform to the percentages by weight shown in Table 1; oxygen shall be determined in accordance with ASTM E 1409, hydrogen in accordance with ASTM E 1447, and other elements by wet chemical methods in accordance with ASTM E 120, by spectrochemical methods, or by other analytical methods acceptable to the purchaser.

TABLE 1 - Composition

Element	min	max	
Carbon	--	0.10	
Oxygen	--	0.25	
Iron	--	0.20	
Nitrogen	--	0.05	(500 ppm)
Hydrogen	--	0.015	(150 ppm)
Residual Elements, each (3.1.1)	--	0.05	
Residual Elements, total (3.1.1)	--	0.15	
Titanium	remainder		

3.1.1 Determination not required for routine acceptance.

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

3.1.3 Sample size when using ASTM E 1447 for hydrogen may be as large as 0.35 gram.

3.2 Melting Practice:

3.2.1 Alloy shall be produced by electron beam melting or shall be multiple melted with the final melting cycle under vacuum. When multiple melted, the first melt shall be made by consumable electrode, nonconsumable electrode, electron beam, or plasma arc melting. The subsequent melt or melts shall be made using consumable electrode practice.

3.2.1.1 The atmosphere for nonconsumable electrode melting shall be vacuum or shall be inert gas at a pressure not higher than 1000 mm of mercury.

3.2.1.2 The electrode tip for nonconsumable electrode melting shall be water-cooled copper.

3.3 Condition:

Gas-metal-arc welded, cold drawn, annealed in accordance with AMS-H-81200, and descaled.

3.4 Properties:

Tubing shall conform to the following requirements:

3.4.1 Tensile Properties: Shall be as shown in Table 2, determined in accordance with ASTM E 8 with the rate of strain maintained at 0.003 to 0.007 inch/inch/minute (0.003 to 0.007 mm/mm/minute) 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 inch/inch/minute (0.005 mm/mm/minute) through the yield strength and a minimum crosshead speed of 0.10 inch (2.5 mm) per minute above the yield strength.

TABLE 2 - Minimum Tensile Properties

Property	Value
Tensile Strength	50.0 ksi (345 MPa)
Yield Strength at 0.2% Offset	40.0 to 65 ksi (276 to 448 MPa)
Elongation in 2 inches (50.8 mm)	20%

3.4.2 Flattening:

3.4.2.1 Tubing with Nominal Wall Thickness Less than 10% of Nominal OD: Shall withstand, without cracking, flattening under a gradually applied load until the distance between platens is equal to 5 times the nominal wall thickness of the tubing.

3.4.2.1.1 If tubing does not pass the flattening test, a section of the tube shall withstand, without cracking, bending at room temperature through an angle of 180 degrees around a diameter equal to 3 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.

3.4.3 Flarability: Specimens as in 4.3.2.1 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 1.30 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 (S) of 40.0 ksi (275 MPa) in the tubing wall except that a diametric permanent set of 0.002 inch per inch (0.002 mm/mm) of diameter is acceptable. The hydrostatic pressure (P) shall be determined from Equation 1.

$$P = S \frac{D^2 - d^2}{D^2 + d^2} \quad \text{(Eq. 1)}$$

where:

P = Test pressure in ksi (MPa)
S = 40.0 ksi (275 MPa) tensile stress
D = Nominal OD
d = Nominal ID

3.4.5 Surface Contamination: Tubing shall be free of any oxygen-rich layer, such as alpha case (See 8.2), or other surface contamination, determined by microscopic examination at not lower than 400X magnification or by other method agreed upon by purchaser and vendor.

3.5 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.

3.6 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 for vendor'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 the specified requirements.

4.2 Classification of Tests:

4.2.1 Acceptance Tests: Composition (3.1), tensile properties (3.4.1), flattening (3.4.2), pressure test (3.4.4), surface contamination (3.4.5), and tolerances (3.6) are acceptance tests and shall be performed on each heat or lot as applicable.