SAE The Engineering Society For Advancing Mobility Land Sea Air and Space®
INTERNATIONAL
400 Commonwealth Drive, Warrendale, PA 15096-0001

AEROSPACE MATERIAL SPECIFICATION

SAE AMS 4941C

Issued JUL 1956
Revised APR 1984
Reaffirmed APR 1994

Submitted for recognition as an American National Standard

Superseding AMS 4941B

Titanium Tubing, Welded
Annealed, 40,000 psi (275 MPa) Yield Strength

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:

Primarily for parts, such as low-pressure fluid-conducting lines and conduits, 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 SAE, 400 Commonwealth Drive, Warrendale, PA 15096.

2.1.1 Aerospace Material Specifications:

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

2.2 ASTM Publications:

Available from ASTM, 1916 Race Street, Philadelphia, PA 19103.

ASTM E8	Tension Testing of Metallic Materials
ASTM E120	Chemical Analysis of Titanium and Titanium Alloys

QUESTIONS REGARDING THIS DOCUMENT: (724) 772-7154 FAX: (724) 776-0243
TO PLACE A DOCUMENT ORDER: (724) 776-4970 FAX: (724) 776-0790
SAE WEB ADDRESS: http://www.sae.org

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 Specifications:

MIL-H-81200 Heat Treatment of Titanium and Titanium Alloys

2.3.3 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 analytical methods approved by purchaser:

	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 requirements of AMS 2249.

3.2 Condition:

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

3.3 Properties:

Tubing shall conform to the following requirements:

3.3.1 Tensile Properties: Shall be as specified below, determined in accordance with ASTM E8 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.

Tensile Strength	50,000 psi (345 MPa)
Yield Strength at 0.2% Offset, min	40,000 - 65,000 psi (275 - 450 MPa)
Elongation in 2 inches (50 mm), min	20%

3.3.2 Flattening:

3.3.2.1 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.

3.3.2.1.1 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 deg around a diameter equal to 3 times the nominal wall thickness of the tubing. The axis of bend shall be parallel to the axis of the tube and the inside of the tube shall be on the inside of the bend.

3.3.2.2 Tubing with Nominal Wall Thickness 10% or More of Nominal OD: Flattening requirements shall be as agreed upon by purchaser and vendor.

3.3.3 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 deg included angle to produce a flare having a permanent expanded OD not less than 1.30 times the original nominal OD.

3.3.4 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 40,000 psi (275 MPa) in the tubing wall except that a diametric permanent set of 0.002 inch/inch (0.002 mm/mm) of diameter is acceptable. The hydrostatic pressure (P) shall be determined from the equation:

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

where:

P = Test pressure in psi (MPa)
S = 40,000 psi (275 MPa) tensile stress
D = Nominal OD
d = Nominal ID

3.3.5 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 100X magnification or by other method agreed upon by purchaser and vendor.

3.4 Quality:

3.4.1 Alloy shall be multiple melted; at least one of the melting cycles shall be under vacuum. The first melt shall be made by consumable electrode, nonconsumable electrode, electron beam, or plasma arc melting practice. The subsequent melt or melts shall be made using consumable electrode practice.

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

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

3.4.2 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 imperfections is not required.

3.5 Tolerances:

Unless otherwise specified, tolerances shall conform to all applicable requirements of AMS 2244 or MAM 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 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 any confirmatory testing deemed 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 requirements for composition (3.1), tensile properties (3.3.1), flattening (3.3.2), pressure test (3.3.4), surface contamination (3.3.5), and tolerances (3.5) are classified as acceptance tests and shall be performed on each heat or lot as applicable.

4.2.2 Periodic Tests: Tests to determine conformance to requirements for flarability (3.3.3) are classified as periodic tests and shall be performed at a frequency selected by the vendor unless frequency of testing is specified by purchaser.

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 and annealed in the same furnace charge:

4.3.1 For 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 sample from each lot.

4.3.1.2.1 Specimens for the alternate bend test of 3.3.2.1.1 shall be not less than 0.500 inch (12.50 mm) in length, shall embrace one-third to one-half the circumference of the tube, and shall include the weld zone. Cut edges of the specimen shall be smooth and free from burrs.

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

4.3.2.1 Specimens for flarability (3.3.3) test 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.