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

AEROSPACE MATERIAL SPECIFICATION

AMS 4941A
Superseding AMS 4941

Issued 7-1-56
Revised 12-15-74

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

1. SCOPE:

1.1 Form: This specification covers a commercially pure grade of titanium in the form of welded tubing.

1.2 Application: Primarily for parts such as low-pressure fluid-conducting lines and conduits requiring oxidation resistance up to 600° F (316° 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, Pennsylvania 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, Pennsylvania 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, Pennsylvania 19120.

2.3.1 Federal Standards:

Federal Test Method Standard No. 151 - Metals; Test Methods

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
Carbon	--	0.10
Oxygen	--	0.25
Nitrogen	--	0.05 (500 ppm)
Hydrogen	--	0.015 (150 ppm)
Iron	--	0.20
Other Elements, total (3.1.1)	--	0.15
Titanium	remainder	

Ø 3.1.1 Determination not required for routine acceptance.

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

3.2 Condition: Gas-metal-arc welded, cold drawn, annealed, and free of scale.

3.3 Properties: Tubing shall conform to the following requirements and shall be capable of meeting Ø these requirements after being heated to 1300° F ± 25 (704.4° C ± 14), held at heat for at least 30 min., cooled in air, and descaled.

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 - 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. per min. (2.54 mm per min.) above the yield strength.

Tensile Strength, min	50,000 psi (345 MPa)
Yield Strength at 0.2% Offset	40,000 - 65,000 psi (276 - 448 MPa)
Elongation in 2 in. (50.8 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 (3.14 rad) 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 of 10% or More of Nominal OD: Flattening requirements Ø shall be as agreed upon by purchaser and vendor.

3.3.3 Flarability: Tubing shall be capable of being flared without formation of cracks or other visible Ø defects. The specimen shall, at room temperature, be 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 permanent expanded OD not less than 1.30 times the original nominal OD.

3.3.4 Pressure Testing: Tubing shall show no bulges, leaks, or other defects when subjected to an internal hydrostatic pressure (P) sufficient to cause a tensile stress of 40,000 psi (276 MPa) in the tubing wall except that a diametric permanent set of 0.002 in. per in. (0.002 mm/mm) of diameter is ø acceptable. The hydrostatic pressure (P) shall be determined from the formula:

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

where,

P = Test pressure in psi (MPa)
S = 40,000 psi (276 MPa)
D = Nominal OD
d = Nominal ID

3.4 Surface Contamination: The product shall be free of any oxygen enriched layer, such as alpha case, ø or other surface contamination.

3.5 Quality: Tubing shall be uniform in quality and condition and shall have a workmanlike finish conforming to the best practice for high quality tubing. It shall be smooth, clean, and free from heavy scale or oxide, burrs, seams, tears, grooves, laminations, slivers, pits, and other injurious conditions. ø 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. The removal of surface imperfections is not required.

3.6 Tolerances: Unless otherwise specified, tolerances shall conform to all applicable requirements of ø AMS 2244; standard tolerances shall apply.

4. QUALITY ASSURANCE PROVISIONS:

4.1 Responsibility for Inspection: The vendor of tubing shall supply all samples and shall be responsible ø 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 assure 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 (3.3.1), ø flattening (3.3.2), pressure tests (3.3.4), surface contamination (3.4), and tolerance (3.6) requirements are classified as acceptance or routine control tests.

4.2.2 Qualification Tests: Tests to determine conformance to flarability (3.3.3) requirements are classi- ø fied as qualification or periodic control tests.

4.3 Sampling: Shall be in accordance with the following; a lot shall be all material of the same nominal ø 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 ø from each lot.

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 Bend Test Specimens: Specimens for the alternate bend test of 3.3.2.1.1 shall be not less than 1/2 in. (12.7 mm) in length, shall embrace 1/3 to 1/2 the circumference of the tube and shall include the weld zone. Cut edges of the specimen shall be smooth and free from burrs.

ø 4.3.2 Qualification Tests: As agreed upon by purchaser and vendor.

4.3.2.1 Flarability Test Specimens: Shall be full tubes or sections cut from tubes. 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 the tubing shall furnish with each shipment three copies of a report of the results of tests for chemical composition of each heat in the shipment, the results of tests on each lot to determine conformance to the hydrogen and tensile property requirements, and a statement that the tubing conforms to all 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 Wall Thickness and 0.500 In. (12.70 mm) and Over in OD, Minor Axis, or Least Width of Flat Surface: Shall be marked in a row of characters recurring at intervals not greater than 3 ft (914 mm) with AMS 4941A, heat number, manufacturer's identification, and nominal wall thickness. The characters shall be of such a 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 capable of being removed in hot alkaline cleaning solution without rubbing. The markings shall have no deleterious effect on the material 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 Wall Thickness or Under 0.500 In. (12.70 mm) in OD, Minor Axis, or Least Width of Flat Surface: Shall be securely bundled and identified by a durable tag marked with the above information and attached to each bundle or shall be boxed and the box marked with the same information.

5.1.3 Coiled Tubing: Shall be securely bundled and identified by a durable tag marked with the purchase order number, AMS 4941A, heat number, nominal OD and wall thickness, and manufacturer's identification and attached to each coil or shall be boxed and the box marked with the same information.