

Submitted for recognition as an American National Standard

TITANIUM ALLOY TUBING, SEAMLESS, HYDRAULIC,
3A1 - 2.5V, Texture Controlled,
105,000 psi (724 MPa) Yield Strength

UNS R56320

1. SCOPE:

1.1 Form: This specification covers a titanium alloy in the form of seamless, cold worked, stress relieved, and texture controlled (See 8.1) tubing.

1.2 Application: Primarily for parts, such as hydraulic lines, requiring strength and oxidation resistance up to 600°F (316°C) and weldability.

2. APPLICABLE DOCUMENTS: The following publications form a part of this specification to the extent specified herein. The latest issue of Aerospace Material Specifications and Aerospace Standards 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 Alloy
AMS 2350 - Standards and Test Methods
AMS 2634 - Ultrasonic Inspection, Thin Wall Metal Tubing

2.1.2 Aerospace Standard:

AS4076 - Contractile Strain Ratio Testing of Titanium Hydraulic Tubing

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 E8M - Tension Testing of Metallic Materials (Metric)
ASTM E120 - Chemical Analysis of Titanium and Titanium Alloys

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2.3 U.S. Government Publications: Available from Commanding Officer, Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, PA 19120.

2.3.1 Military Specifications:

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

2.3.2 Military Standards:

MIL-STD-163 – Steel Mill Products, Preparation for Shipment and Storage
MS33611 – Tube Bend Radii

2.3 ANSI Publications: Available from American National Standards Institute, Inc., 1430 Broadway, New York, NY 10018.

ANSI B46.1 – Surface Texture

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, or by other analytical methods acceptable to purchaser:

	min	max
Aluminum	2.50	3.50
Vanadium	2.00	3.00
Iron	--	0.30
Oxygen	--	0.12
Carbon	--	0.05
Nitrogen	--	0.020 (200 ppm)
Hydrogen	--	0.015 (150 ppm)
Yttrium (3.1.1)	--	0.005 (50 ppm)
Residual Elements, each (3.1.1)	--	0.10
Residual Elements, total (3.1.1)	--	0.40
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 worked and stress relieved by heating to not lower than 700°F (371°C) for not less than 30 minutes. Furnace surveys and calibration of temperature controllers and recorders shall be in accordance with MIL-H-81200 or with an acceptable survey and calibration program certified by the vendor as meeting the intent of MIL-H-81200.

3.3 Properties: Tubing shall conform to the following requirements:

- 3.3.1 Tensile Properties: Shall be as follows, determined in accordance with ASTM E8 or ASTM E8M with the rate of strain maintained at 0.003 – 0.007 inch/inch/minute (0.003 – 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 cross head speed of 0.10 inch (2.5 mm) per minute above the yield strength.

Tensile Strength, minimum	125,000 psi (862 MPa)
Yield Strength at 0.2% Offset, minimum	105,000 psi (724 MPa)
Elongation in 2 inches (50.8 mm) minimum	
Nominal Wall Thickness	
Up to 0.016 inch (0.41 mm), incl	8%
Over 0.016 inch (0.41 mm)	10%

- 3.3.2 Flarability: Specimens as in 4.3.3 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 OD.
- 3.3.3 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 105,000 psi (724 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:

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

where, P = Test pressure in psi (MPa)
S = 105,000 psi (724 MPa)
D = Nominal OD
d = Nominal ID

- 3.3.4 Bending: Tubing shall not develop cracks, tears, breaks, or other flaws when bent 180 degrees around a suitable bend die having a centerline radius equal to three times the nominal OD of the tubing. A solid rod or ball-type retractable mandrel inserted to the tangent of the bend shall be used to support the inside of the tube during bending to restrict flattening to a value that does not exceed 3% of the nominal OD of the tube. Flatness shall be measured in accordance MS33611.

- 3.3.5 Flattening: The inside and outside surfaces of tubing shall show no cracks, tears, breaks, opened die marks, or opened polishing marks when a full section of the tube is flattened between parallel plates under a load applied gradually and perpendicularly to the longitudinal axis until the distance between the plates is not greater than shown in Table I. After examination of the outside surfaces, the samples shall be split longitudinally and the inside surfaces examined. Examination of tube surfaces shall be at a magnification of 5 to 10X.

TABLE I

Outside Diameter To Wall Thickness Ratio OD/t	Distance Between Plates (t = Wall Thickness)
Up to 12, incl	Not Required
Over 12 to 16, incl	12t
Over 16 to 30, incl	15t
Over 30 to 50, incl	17t

- 3.3.5.1 As an alternate flattening test, a half-tube sample shall be pressed to produce a flat surface approximately 3/8 inch (9.5 mm) wide on the tubing ID.
- 3.3.6 Microstructure: Shall be predominantly an elongated wrought structure but some areas of partially transformed beta structure will be acceptable. Standards shall be as agreed upon by purchaser and vendor. 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.
- 3.3.7 Surface Cleanliness: The ID and OD surfaces of the tubing shall be free from grease and other foreign matter. Metallic flakes or particles shall not be collected by a clean, white cloth when it is drawn through the length of the bore of a test sample. Discoloration of the cloth, without the presence of flakes or particles, is acceptable.

- 3.3.8 Contractile Strain Ratio: The contractile strain ratio for tubing wall thicknesses as shown in Table II shall not be less than a value of 1.3, using the test method in accordance with AS4076.

Table II

Size		Maximum Wall Thickness	
inch	mm	inch	mm
3/16	4.8	0.020	0.51
1/4	6.4	0.022	0.56
3/8	9.5	0.032	0.81
1/2	12.7	0.043	1.09
5/8	15.9	0.054	1.37
3/4	19.0	0.065	1.65
1	25.4	0.051	1.30

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 melting practice. The subsequent melt or melts shall be made using consumable electrode practice with no alloy additions permitted in the last consumable electrode melt.
- 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 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 or straightening marks, 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.
- 3.4.3 Each tube shall be ultrasonically inspected in accordance with AMS 2634, Class AA, for ID, OD, and subsurface imperfections of all types and orientation (longitudinal and transverse).
- 3.4.4 Surface Condition:
- 3.4.4.1 OD Surface: Shall show a uniformly acid-pickled surface finish; not less than 0.001 inch (0.025 mm) shall have been chemically removed from the wall thickness as a finishing operation. Soft, belt polishing prior to the pickling operation is permissible; traces of the polishing marks may remain after the pickling operation. Centerless grinding or other mechanical operations are not permitted.

3.4.4.2 ID Surface: Shall show a uniform matte finish, produced by abrasive blasting with grit not larger than 100 mesh (150 μ m) followed by forced-flow, acid pickling to remove not less than 0.0005 inch (0.013 mm) from the wall thickness.

3.4.4.3 Surface Texture: Shall be not greater than 63 microinches (1.6 μ m) on the ID and be not greater than 32 microinches (0.8 μ m) on the OD, determined in accordance with ANSI B46.1.

3.5 Tolerances: Shall conform to all applicable requirements of the following:

3.5.1 Diameter: Shall be as specified in Table III; tolerances shown include ovality.

TABLE III

Nominal OD Inches	Tolerance, Inch	
	plus	minus
Over 0.093 to 0.188, incl	0.002	0.000
Over 0.188 to 0.500, incl	0.003	0.000
Over 0.500 to 1.000, incl	0.004	0.000
Over 1.000 to 1.500, incl	0.004	0.001
Over 1.500 to 2.000, incl	0.005	0.001

TABLE III (SI)

Nominal OD Millimetres	Tolerance, Millimetre	
	plus	minus
Over 2.36 to 4.78, incl	0.05	0.00
Over 4.78 to 12.70, incl	0.08	0.00
Over 12.70 to 25.40, incl	0.10	0.00
Over 25.40 to 38.10, incl	0.10	0.25
Over 38.10 to 50.80, incl	0.13	0.25

3.5.1.1 Diameter tolerances for tubing 0.093 inch (2.36 mm) and under or over 2.000 inches (50.80 mm) in nominal OD shall be as agreed upon by purchaser and vendor.

3.5.2 Wall Thickness: All tubing 1.500 inches (38.10 mm) and under in nominal OD shall not vary more than +10%, -5%; tubing over 1.500 inches (38.10 mm) in nominal OD shall not vary more than $\pm 10\%$.

3.5.3 Length and Straightness: Shall conform to AMS 2244 or MAM 2244.

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 4.5. 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 all technical requirements of this specification except pressure testing 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 pressure testing (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.

4.2.3 Preproduction Tests: Tests to determine conformance to all technical requirements of this specification are classified as preproduction tests and shall be performed prior to or on the initial shipment of tubing to a purchaser, when a change in material and/or processing requires reapproval as in 4.4.2, and when purchaser deems confirmatory testing to be required.

4.2.3.1 For direct U.S. Military procurement, substantiating test data and, when requested, preproduction tubing shall be submitted to the cognizant agency as directed by the procuring activity, contracting officer, or request for procurement.

4.3 Sampling: Shall be in accordance with the following; a lot shall be all tubing of the same nominal size from the same ingot, same processing and finishing operations; and stress relieved in the same furnace charge:

4.3.1 Composition: One sample from each heat except that for hydrogen determinations one sample from each lot obtained after thermal and chemical processing is completed. An ingot analysis obtained from the alloy producer may be utilized to substantiate heat requirements.

4.3.2 Tensile Properties: One sample for each 1000 feet (305 m) or 3 samples from each lot, whichever is greater.

4.3.3 Flarability: One sample per tube for lot sizes of four or less tubes and four samples for lot sizes of 5 to 39 tubes. For lot sizes of 40 or more tubes, one sample from one end of 10% of the tubes.

4.3.3.1 Specimens for flarability (3.3.2) test shall be full tubes or sections cut from a tube. The end of the specimens to be flared shall be cut square, with the cut end smooth and free from burrs, but not rounded.

4.3.4 Pressure Test: As agreed upon by purchaser and vendor.

4.3.5 Bending: Two samples from each lot.

4.3.6 Flattening: One sample for each 135 feet (41 m) of tubing or 10 samples from each lot, whichever is less. Each specimen shall be not less than 2 inches (51 mm) long, cut in half with the cuts parallel to the axis of the tube.

4.3.7 Microstructure: One sample from each lot.

4.3.8 Surface Condition: Each tube, except that ID surface inspection need be made only on each sample selected for the flattening test.

4.3.9 Ultrasonic Inspection and Tolerances: Each tube.

4.3.10 Contractile Strain Ratio: Three per lot.

4.4 Approval:

4.4.1 Sample tubing, and process sheets showing the parameters for the process control factors for producing the tubing, shall be approved by purchaser before tubing for production use is supplied, unless such approval be waived by purchaser.

4.4.2 Vendor shall establish parameters for the process control factors which will produce tubing meeting the technical requirements of this specification. If necessary to make any change in parameters for the process control factors, vendor shall submit for reapproval revised process sheets and, when requested, sample tubing. Tubing incorporating the revised operations shall not be shipped prior to receipt of reapproval.

4.4.2.1 Control factors for producing tubing include, but are not limited to, the following:

- Acceptance criteria for tube hollows
- Conditioning practice for tube hollows
- Cold working procedures
- Intermediate tube annealing, conditioning, and inspection procedures
- Tube ID and OD finishing operations
- Final inspection procedures

4.4.2.1.1 Any of the above process control factors for which parameters are considered proprietary by the vendor may be assigned a code designation. Each variation in such parameters shall be assigned a modified code designation.

4.5 Reports:

4.5.1 The vendor of tubing shall furnish with each shipment a report showing the results of tests for chemical composition of each heat and for the hydrogen content, tensile properties, flarability, bending, flattening, contractile strain ratio testing, and microstructure 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, lot number, AMS 4945, size, and quantity.