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INTERNATIONAL
400 Commonwealth Drive, Warrendale, PA 15096-0001

AEROSPACE MATERIAL SPECIFICATION

SAE AMS-4922

Issued 1990-10-01

Submitted for recognition as an American National Standard

TUBING, SEAMLESS, HYDRAULIC, TITANIUM ALLOY 15V - 3.0Cr - 3.0Al - 3.0Sn Cold Worked and Precipitation Heat Treated

1. SCOPE:

1.1 Form: This specification covers a titanium alloy in the form of seamless tubing.

1.2 Application: Primarily for parts, such as high-pressure hydraulic lines, requiring high strength and oxidation resistance up to 550°F (288°C) and weldability.

2. APPLICABLE DOCUMENTS: The following publications form a part of this specification to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order.

2.1 SAE Publications: Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

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-2634 - Ultrasonic Inspection, Thin Wall Metal Tubing
AMS-2809 - Identification, Titanium and Titanium Alloy Wrought Products

2.2 ASTM Publications: Available from ASTM, 1916 Race Street, Philadelphia, PA 19103-1187.

ASTM E 8 - Tension Testing of Metallic Materials
ASTM E 8M - Tension Testing of Metallic Materials (Metric)
ASTM E 120 - Chemical Analysis of Titanium and Titanium Alloys

2.3 U.S. Government Publications: Available from Standardization Documents Order Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.

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

2.4 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 E 120, by spectrochemical methods, or by other analytical methods acceptable to purchaser:

	min	max
Vanadium	14.0	16.0
Chromium	2.5	3.5
Aluminum	2.5	3.5
Tin	2.5	3.5
Iron	--	0.25
Carbon	--	0.05
Oxygen	--	0.13
Nitrogen	--	0.050 (500 ppm)
Hydrogen	--	0.015 (150 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 and Heat Treatment: Cold worked and precipitation heat treated by heating to a temperature within the range 900° - 1250°F (482° - 677°C) and holding at the selected temperature within ±25°F (±14°C) for not less than 2 hours. 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 E 8 or ASTM E 8M 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	135,000 psi (931 MPa)
Yield Strength at 0.2% Offset, minimum	125,000 psi (862 MPa)
Elongation in 2 Inches (50.8 mm), minimum	
Nominal Wall Thickness	
Up to 0.020 Inch (0.51 mm),incl	10%
Over 0.020 Inch (0.51 mm)	12%

3.3.2 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 equal to 125,000 psi (862 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 below but shall not exceed 20,000 psi (138 MPa):

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

where, P = Test pressure in psi (MPa)
S = 125,000 psi (862 MPa)
D = Nominal OD
d = Nominal ID

3.3.3 Bending: Tubing shall not develop cracks, tears, breaks, or other flaws when bent 180 degrees around a suitable 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, or an appropriate tube filler, shall be used to support the inside of the tube during bending to restrict flattening to a value that does not exceed 5% of the nominal OD of the tube. Flattening shall be determined in accordance with the following formula:

$$\text{Flatness \%} = \frac{\text{Maximum OD} - \text{Minimum OD}}{\text{Nominal OD}} \times 100$$

3.3.4 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 5 to 10X magnification.

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

3.3.4.1 Alternate Flattening: When specified, sample(s) shall be sectioned longitudinally along the tube diameter and flattened between parallel plates until the distance between the plates is equal to the wall thickness of the tube sample. The inside and outside surfaces of tubing shall show no cracks, tears, breaks, opened die marks, or polishing marks.

3.3.5 Microstructure: Shall be predominantly a cold-worked, precipitated beta structure with dispersed, fine alpha precipitate. Tubing shall be free of any oxygen-rich layer, such as alpha case (See 8.1), or other surface contamination, determined by microscopic examination at not less than 100X magnification or by other method acceptable to purchaser.

3.3.6 Surface Cleanliness: The ID and OD surfaces of the tubing shall be free from grease and other foreign matter. A clean, white cloth, when passed through the length of the bore of a test sample, may show discoloration but shall not collect grit or metallic flakes.

3.4 QUALITY

3.4.1 Alloy shall be multiple melted; the final melting cycle 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 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 argon and/or helium at an absolute pressure not higher than 1000 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.

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) of metal shall have been chemically removed from the wall thickness as a finishing operation. Belt polishing or buffing of the OD surface with a grit size of 400 or finer is permissible prior to the pickling operation. Centerless grinding or other mechanical operations are not acceptable.

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

3.4.4.3 Surface Texture: Shall be not greater than 63 microinches (1.6 µm) on the ID and be not greater than 32 microinches (0.8 µm) 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 II; tolerances shown include ovality.

TABLE II

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 II (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	0.025
Over 38.10 to 50.80, incl	0.13	0.025

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 ±10%.

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

4. QUALITY ASSURANCE PROVISIONS:

4.1 Responsibilty for Inspection: The vendor of tubing shall supply all samples for vendor's tests and shall be responsible for performing 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 requirements of this specification.

4.2 Classification of Tests:

4.2.1 Acceptance Tests: Tests for all technical requirements except pressure testing are acceptance tests and shall be performed on each heat or lot as applicable.

4.2.2 Periodic Tests: Tests for pressure testing (3.3.2) are periodic tests and shall be performed at a frequency selected by the vendor unless frequency of testing is specified by purchaser.

4.3 Sampling and Testing: Shall be in accordance with the following; a lot shall be all tubing of the same nominal size from the same heat of alloy processed at the same time and precipitation heat treated in the same furnace charge.

4.3.1 Composition: One sample from each lot of tubing for hydrogen, oxygen, and nitrogen determinations shall be obtained after thermal and chemical processing is completed. An ingot analysis obtained from the alloy producer may be utilized to substantiate other requirements.

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

4.3.3 Bending: Two samples from each lot.

4.3.4 Flattening: One sample from each 135 feet (41 m) of tubing or 10 samples from each lot, whichever is less, unless a sampling plan has been agreed upon by purchaser and vendor. Each sample shall be not less than 2 inches (51 mm) long, cut in half with the cuts parallel to the axis of the tube.

4.3.5 Microstructure: One sample from each lot.

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

4.3.7 Ultrasonic Inspection and Tolerances: Each tube.

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

4.4 APPROVAL:

4.4.1 When specified by purchaser, 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.

4.4.2 Vendor shall establish parameters for the process control factors which will produce tubing meeting the technical requirements. 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 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.