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

AEROSPACE MATERIAL SPECIFICATION

Submitted for recognition as an American National Standard

AMS 4981C

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Superseding AMS 4981B

TITANIUM ALLOY BARS, WIRE, AND FORGINGS
6.0Al - 2.0Sn - 4.0Zr - 6.0Mo
Solution and Precipitation Heat Treated

UNS R56260

1. SCOPE:

1.1 Form: This specification covers a titanium alloy in the form of bars, wire, forgings, and forging stock.

1.2 Application: Primarily for parts requiring high strength up to 1000°F (538°C). Certain processing procedures and service conditions may cause these products to become subject to stress-corrosion cracking. ARP982 recommends practices to minimize such conditions.

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 2241 - Tolerances, Corrosion and Heat Resistant Steel, Iron Alloy, Titanium, and Titanium Alloy Bars and Wire
MAM 2241 - Tolerances, Metric, Corrosion and Heat Resistant Steel, Iron Alloy, Titanium, and Titanium Alloy Bars and Wire
AMS 2249 - Chemical Check Analysis Limits, Titanium and Titanium Alloys
AMS 2808 - Identification, Forgings
AMS 2809 - Identification, Titanium and Titanium Alloy Wrought Products

2.1.2 Aerospace Recommended Practices:

ARP982 - Minimizing Stress-Corrosion Cracking in Wrought Titanium Alloy 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 21 - Elevated Temperature Tension Tests of Metallic Materials
ASTM E 120 - Chemical Analysis of Titanium and Titanium Alloys
ASTM E 139 - Conducting Creep, Creep-Rupture, and Stress-Rupture Tests of Metallic Materials
ASTM E 292 - Conducting Time-for-Rupture Notch Tension Tests of Materials

2.3 U.S. Government Publications: Available from Naval Publications and Forms Center, Attn: NPODS, 5801 Tabor Avenue, Philadelphia, PA 19120-5099.

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

3. TECHNICAL REQUIREMENTS:

3.1 Composition: Shall conform to the following percentages by weight, Ø determined by wet chemical methods in accordance with ASTM E 120, by spectrochemical methods, or by other analytical methods acceptable to purchaser:

	min	Max	
Aluminum	5.50 -	6.50	
Zirconium	3.50 -	4.50	
Tin	1.75 -	2.25	
Molybdenum	5.50 -	6.50	
Iron	--	0.15	
Oxygen	--	0.15	
Carbon	--	0.04	
Nitrogen	--	0.04	(400 ppm)
Hydrogen (3.1.1)	--	0.0125	(125 ppm)
Yttrium *(3.1.2)*	--	0.005	(50 ppm)
Residual Elements, each (3.1.2)	--	0.10	
Residual Elements, total (3.1.2)	--	0.40	
Titanium	remainder		

3.1.1 Hydrogen content of forgings may be as high as 0.0150 (150 ppm).

3.1.2 Determination not required for routine acceptance.

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

3.2 Condition: The product shall be supplied in the following condition:

3.2.1 Bars: Hot finished, solution and precipitation heat treated, and descaled.

3.2.2 Wire: Cold drawn, solution and precipitation heat treated, and descaled.

3.2.3 Forgings: Solution and precipitation heat treated and descaled.

3.2.4 Forging Stock: As ordered by the forging manufacturer.

3.3 Heat Treatment: Bars and forgings 0.50 inch (12.7 mm) and over in nominal Ø diameter or least distance between parallel sides shall be solution heat treated by heating in a suitable atmosphere to 1500° - 1675°F (816° - 913°C), holding at the selected temperature within ± 25°F (± 14°C) for not less than 1 hour, and cooling at a rate equivalent to an air cool or faster, and precipitation heat treated by heating to 1100°F ± 15 (593°C ± 8), holding at heat for 4 - 8 hours, and cooling in air. Heat treatment for product under 0.50 inch (12.7 mm) nominal diameter or least distance between parallel sides shall be as agreed upon by purchaser and vendor. Furnace surveys and calibration of temperature controllers and recorders shall be in accordance with MIL-H-81200.

3.3.1 Water-quenching from the solution heat treatment temperature is prohibited.

3.4 Properties: The product shall conform to the following requirements:

3.4.1 Bars, Wire, and Forgings: Product 4.000 inches (101.60 mm) and under in nominal diameter or least distance between parallel sides shall have the following properties; properties of product over 4.000 inches (101.60 mm) in nominal diameter or least distance between parallel sides shall be as agreed upon by purchaser and vendor.

3.4.1.1 Tensile Properties:

3.4.1.1.1 At Room Temperature: Shall be as specified in Table I, 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.

TABLE I

Form	Nominal Diameter or Distance Between Parallel Sides, Inches	Tensile Strength, psi, min	Yield Strength at 0.2% Offset, psi, min	Elongation in 4D, %, min		Reduction of Area, %, min	
				L	T	L	T
Wire	Up to 0.500, incl	170,000	160,000	10	8	20	15
Bars	Over 0.500 to 2.500, incl	170,000	160,000	10	8	20	15
Bars	Over 2.500 to 3.000, incl	165,000	155,000	8	6	15	12
Forgings	Up to 3.000, incl	170,000	160,000	10	8	20	15
Bars and Forgings	Over 3.000 to 4.000, incl	160,000	150,000	8	6	15	12

TABLE I (SI)

Form	Nominal Diameter or Distance Between Parallel Sides, Millimetres	Tensile Strength, MPa, min	Yield Strength at 0.2% Offset, MPa, min	Elongation in 4D, %, min		Reduction of Area, %, min	
				L	T	L	T
Wire	Up to 12.70, incl	1172	1103	10	8	20	15
Bars	Over 12.70 to 63.50, incl	1172	1103	10	8	20	15
Bars	Over 63.50 to 76.20, incl	1138	1069	8	6	15	12
Forgings	Up to 76.20, incl	1172	1103	10	8	20	15
Bars and Forgings	Over 76.20 to 101.60, incl	1103	1034	8	6	15	12

3.4.1.1.2 At 800°F (427°C): Product shall meet the following requirements, determined in accordance with ASTM E 21 on specimens heated to 800°F ± 5 (427°C ± 3), held at heat for 20 - 30 minutes before testing, and tested at 800°F ± 5 (427°C ± 3) using strain rates as specified in 3.4.1.1.1:

Tensile Strength, minimum	135,000 psi (931 MPa)
Yield Strength at 0.2% Offset, minimum	105,000 psi (724 MPa)
Elongation in 4D, minimum	10%
Reduction of Area, minimum	30%

3.4.1.1.3 Yield strength and reduction of area requirements do not apply to wire under 0.125 inch (3.18 mm) in nominal diameter.

3.4.1.1.4 Tensile property requirements apply in both the longitudinal and transverse directions but tests in the transverse direction need be made only on product from which specimens not less than 2.50 inches (63.5 mm) in length can be taken. Tests in the longitudinal direction are not required on product tested in the transverse direction.

3.4.1.2 Ø Room-Temperature Notched Stress-Rupture Test: Notched cylindrical specimens machined to the dimensions shown in ASTM E 292, maintained at room temperature while a load sufficient to produce an initial axial stress of 190,000 psi (1310 MPa) is applied continuously, shall not rupture in less than 5 hours. The initial stress may be less than 190,000 psi (1310 MPa) and increased to 190,000 psi (1310 MPa), based on the initial diameter at root of notch, in increments of 10,000 psi (69 MPa) at intervals of not less than 5 hours. Test shall be conducted in accordance with ASTM E 292.

3.4.1.3 Creep Test at 800°F (427°C): A smooth tensile specimen shall be maintained at 800°F ± 5 (427°C ± 3) under continuously applied axial stress of 95,000 psi (655 MPa). Time to attain 0.2% plastic deformation shall be not less than 35 hours. If plastic deformation is less than 0.2% after 35 hours, the test may be discontinued; the amount of plastic deformation in 35 hours shall be reported. Gage dimensions of specimen and technique used to measure creep shall be as agreed upon by purchaser and vendor. Test shall be conducted in accordance with ASTM E 139.

3.4.1.4 Ø Microstructure: Shall be that structure resulting from alpha-beta processing. Microstructure shall conform to 3.4.1.4.1, 3.4.1.4.2, or 3.4.1.4.3.

3.4.1.4.1 Ø Equiaxed alpha in a transformed beta matrix.

3.4.1.4.2 Equiaxed alpha and elongated alpha in a transformed beta matrix.
Ø

3.4.1.4.3 Partially broken and distorted grain boundary alpha with plate-like
Ø alpha.

3.4.1.4.4 A microstructure showing a continuous network of alpha in prior beta
Ø grain boundaries is not acceptable.

3.4.1.5 Surface Contamination: Except as specified in 3.4.1.5.1 and 3.4.1.5.2, product shall be free of any oxygen-enriched layer (See 8.2), such as alpha case, or other surface contamination, determined by microscopic examination at not lower than 100X magnification or by other method agreed upon by purchaser and vendor.

3.4.1.5.1 An oxygen-rich layer not greater than 0.001 inch (0.025 mm) in depth will be permitted on bars other than round.

3.4.1.5.2 When permitted by purchaser, forgings to be machined all over may have an oxygen-rich layer provided such layer is removable within the machining allowance on the forgings.

3.4.2 Forging Stock: When a sample of stock is forged to a test coupon and heat treated as in 3.3, specimens taken from the coupon shall conform to the requirements of 3.4.1.1.1 and 3.4.1.2. If specimens taken from the stock after heat treatment as in 3.3 conform to the requirements of 3.4.1.1.1 and 3.4.1.2, the tests shall be accepted as equivalent to tests of a forged coupon.

3.5 Quality:

3.5.1 Alloy shall be multiple melted; at least one of the melting cycles shall
Ø 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.

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

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

3.5.2 The product, as received by purchaser, shall be uniform in quality and condition, sound, and free from foreign materials and from imperfections detrimental to usage of the product.

3.6 Tolerances: Bars and wire shall conform to AMS 2241 or MAM 2241.

4. QUALITY ASSURANCE PROVISIONS:

4.1 Responsibility for Inspection: The vendor of the product 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 product conforms to the requirements of this specification.

4.2 Classification of Tests:

4.2.1 Acceptance Tests: Tests for the following are acceptance tests and shall be performed on each heat or lot as applicable:

4.2.1.1 Composition (3.1) of each heat.

4.2.1.2 Hydrogen content (3.1), room-temperature tensile properties (3.4.1.1.1), microstructure (3.4.1.4), and surface contamination (3.4.1.5) of each lot of bars, wire, and forgings.

4.2.1.3 Tolerances (3.6) of bars and wire.

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

4.2.2.1 Tensile properties at 800°F (427°C) (3.4.1.1.2), room-temperature notched stress-rupture properties (3.4.1.2), and creep properties at 800°F (427°C) (3.4.1.3) of bars, wire, and forgings.

4.2.2.2 Ability of forging stock to develop required properties (3.4.2).

4.3 Sampling and Testing: Shall be in accordance with the following; a lot Ø shall be all product of the same nominal size from the same heat, processed at the same time and heat treated in the same batch:

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: At least one sample from each lot of bars and wire. One longitudinal specimen from each lot of forgings from a section having maximum thickness and from a section having minimum thickness.

4.3.1.3 Other Requirements: As agreed upon by purchaser and vendor.

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