SAE Aerospace
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AEROSPACE MATERIAL SPECIFICATION

SAE AMS 4981D

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Superseding AMS 4981C

Titanium Alloy Bars, Wire, and Forgings
6.0Al - 2.0Sn - 4.0Zr - 6.0Mo
Solution and Precipitation Heat Treated

(Composition similar to 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:

This alloy has been used typically for parts requiring high strength up to 1000 °F (538 °C), but usage is not limited to such applications.

1.2.1 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 issue of the following documents in effect on the date of the purchase order forms a part of this specification to the extent specified herein. The supplier may work to a subsequent revision of a document unless a specific document issue is specified. When the referenced document has been cancelled and no superseding document has been specified, the last published issue of that document shall apply.

TO PLACE A DOCUMENT ORDER: **Tel: 877-606-7323 (inside USA and Canada)**
Tel: 724-776-4970 (outside USA)
Fax: 724-776-0790
Email: custsvc@sae.org
SAE WEB ADDRESS: **http://www.sae.org**

2.1 SAE Publications:

Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001 or www.sae.org.

AMS 2241	Tolerances, 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
AMS-H-81200	Heat Treatment of Titanium and Titanium Alloys
ARP982	Minimizing Stress-Corrosion Cracking in Wrought Titanium Alloy Products

2.2 ASTM Publications:

Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959 or www.astm.org.

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
ASTM E 1409	Determination of Oxygen in Titanium and Titanium Alloys by the Inert Gas Fusion Technique
ASTM E 1447	Determination of Hydrogen in Titanium and Titanium Alloys by the Inert Gas Fusion Thermal Conductivity Method

3. TECHNICAL REQUIREMENTS:

3.1 Composition:

Shall conform to the percentages by weight shown in Table 1; oxygen shall be determined in accordance with ASTM E 1409, hydrogen in accordance with ASTM E 1447, and other elements by wet chemical methods in accordance with ASTM E 120, by spectrochemical methods, or by other analytical methods acceptable to the purchaser.

TABLE 1 - Composition

Element	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.

3.1.4 Sample size when using ASTM E 1447 for hydrogen may be as large as 0.35 gram.

3.2 Melting Practice:

3.2.1 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 with no alloy additions permitted in the last consumable electrode melt.

3.2.1.1 The atmosphere for nonconsumable electrode melting shall be vacuum or shall be inert gas at a pressure not higher than 1000 mm of mercury.

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

3.3 Condition:

The product shall be supplied in the following condition:

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

3.3.1.1 Round bars shall be solution and precipitation heat treated and ground or turned.

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

3.3.3 Forgings: Solution and precipitation heat treated and descaled.

3.3.4 Forging Stock: As ordered by the forging manufacturer.

3.4 Heat Treatment:

Bars and forgings 0.50 inch (12.7 mm) and over in nominal diameter or least distance between parallel sides shall be solution heat treated by heating in a suitable atmosphere to 1500 to 1675 °F (816 to 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 to 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 AMS-H-81200.

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

3.5 Properties:

The product shall conform to the following requirements:

3.5.1 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:

3.5.1.1 Tensile Properties:

3.5.1.1.1 At Room Temperature: Shall be as specified in Table 2, determined in accordance with ASTM E 8 or ASTM E 8M 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 cross head speed of 0.10 inch (2.5 mm) per minute above the yield strength.

TABLE 2A - Minimum Tensile properties, Inch/Pound Units

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

TABLE 2B - Minimum Tensile properties, SI Units

Form	Nominal Diameter or Distance Between Millimeters	Tensile Strength MPa	Yield Strength at 0.2% Offset MPa	Elongation in 4D %		Reduction of Area %	
				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

3.5.1.1.2 At 800 °F (427 °C): Product shall meet the requirements shown in Table 3, determined in accordance with ASTM E 21 on specimens heated to 800 °F ± 5 (427 °C ± 3), held at heat for 20 to 30 minutes before testing, and tested at 800 °F ± 5 (427 °C ± 3) using strain rates as specified in 3.5.1.1.1:

TABLE 3 - Minimum Tensile Properties at 800 °F (427 °C)

Property	Value
Tensile Strength	135 ksi (931 MPa)
Yield Strength at 0.2% Offset	105 ksi (724 MPa)
Elongation in 4D	10%
Reduction of Area	30%

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

3.5.1.1.4 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.

3.5.1.2 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 ksi (1310 MPa) is applied continuously, shall not rupture in less than 5 hours. The initial stress may be less than 190 ksi (1310 MPa) and increased to 190 ksi (1310 MPa), based on the initial diameter at root of notch, in increments of 10 ksi (69 MPa) at intervals of not less than 5 hours. Test shall be conducted in accordance with ASTM E 292.

3.5.1.3 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 ksi (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 (See 8.6). Test shall be conducted in accordance with ASTM E 139.

3.5.1.4 Microstructure: Shall be that structure resulting from alpha-beta processing. Microstructure shall conform to any one of the following: 3.5.1.4.1, 3.5.1.4.2, or 3.5.1.4.3 (See 8.5).

3.5.1.4.1 Equiaxed alpha in a transformed beta matrix.

3.5.1.4.2 Equiaxed alpha and elongated alpha in a transformed beta matrix.

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

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

3.5.1.5 Surface Contamination: Except as specified in 3.5.1.5.1 and 3.5.1.5.2, 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 400X magnification or by other method agreed upon by purchaser and vendor.

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

3.5.1.5.2 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.

3.5.2 Forging Stock: When a sample of stock is forged to a test coupon and heat treated as in 3.4, specimens taken from the coupon shall conform to the requirements of 3.5.1.1.1 and 3.5.1.2. If specimens taken from the stock after heat treatment as in 3.4 conform to the requirements of 3.5.1.1.1 and 3.5.1.2, the tests shall be accepted as equivalent to tests of a forged coupon.

3.6 Quality:

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.

3.7 Tolerances:

Bars and wire shall conform to the applicable requirements of AMS 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 the performance of all required tests. Purchaser reserves the right to sample and to perform any confirmatory testing deemed necessary to ensure that the product conforms to the specified requirements.

4.2 Classification of Tests:

4.2.1 Acceptance Tests: The following requirements 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 (3.5.1.1.1), microstructure (3.5.1.4), and surface contamination (3.5.1.5) of each lot of bars, wire, and forgings.

4.2.1.3 Tolerances (3.6) of bars and wire.

4.2.2 Periodic Tests: The following requirements 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) (3.5.1.1.2), room-temperature notched stress-rupture properties (3.5.1.2), and creep properties at 800 °F (427 °C) (3.5.1.3) of bars, wire, and forgings.

4.2.2.2 Ability of forging stock to develop required properties (3.5.2).

4.3 Sampling and Testing:

Shall be in accordance with the following; a lot 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.

4.4 Reports:

4.4.1 The vendor of bars, wire, and forgings shall furnish with each shipment a report showing the results of tests for chemical composition of each heat and the results of tests on each lot to determine conformance to the hydrogen and tensile property requirements and, when performed, to the periodic test requirements, and stating that the product conforms to the other technical requirements of this specification. This report shall include the purchase order number, heat and lot numbers, AMS 4981D, specific solution heat treatment temperature used, size, and quantity. If forgings are supplied, the part number and the size and melt source of stock used to make the forgings shall also be included.