SAE The Engineering Society For Advancing Mobility Land Sea Air and Space

400 COMMONWEALTH DRIVE, WARRENDALE, PA 15096

AEROSPACE MATERIAL SPECIFICATION

Submitted for recognition as an American National Standard

AMS 4981B

Issued 11-15-72
Revised 7-1-87

Superseding AMS 4981A

TITANIUM ALLOY BARS 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 (540°C). Certain processing procedures and service conditions may cause these products to become subject to stress-corrosion cracking. ARP 982 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 Aerospace Material Specifications and Aerospace Recommended Practices 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 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 2350 - Standards and Test Methods
AMS 2375 - Control of Forgings Requiring First Article Approval
AMS 2808 - Identification, Forgings
AMS 2809 - Identification, Titanium and Titanium Alloy Wrought Products

2.1.2 Aerospace Recommended Practice:

ARP 982 - Minimizing Stress Corrosion Cracking in Wrought Titanium Alloy Products

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 E18 - Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials
ASTM E21 - Elevated Temperature Tension Tests of Metallic Materials
ASTM E120 - Chemical Analysis of Titanium and Titanium Alloys
ASTM E139 - Conducting Creep, Creep-Rupture, and Stress-Rupture Tests of Metallic Materials
ASTM E292 - Conducting Time-for-Rupture Notch Tension Tests of Materials

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

3. TECHNICAL REQUIREMENTS:

3.1 Composition: Shall conform to the following percentages by weight, Ø determined by wet chemical methods in accordance with ASTM E120 or by spectrochemical or other analytical methods approved by 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 in. (12.5 mm) and over in section thickness shall be solution heat treated by heating in a suitable atmosphere to 1500° - 1675°F (815° - 915°C), holding at the selected temperature within ± 25°F (± 15°C) for not less than 1 hr, and cooling at a rate equivalent to air cool or faster, and precipitation heat treated by heating to 1100°F ± 15 (595°C ± 8), holding at heat for 4 - 8 hr, and cooling in air. Heat treatment for section thicknesses under 0.50 in. (12.5 mm) 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 or a survey and calibration program certified by the vendor as meeting the intent of 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:

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 E8 with the rate of strain maintained at 0.003 - 0.007 in./in. per min. (0.003 - 0.007 mm/mm per 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./in. per min. (0.005 mm/mm per min.) through the yield strength and a minimum cross head speed of 0.10 in. (2.5 mm) per min. 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 2 in. or 4D %, min		Reduction of area %, min	
				L	T	L	T
Forgings	Up to 3.000, incl	170,000	160,000	10	8	20	15
Bars and Wire	Up 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
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 50 mm or 4D %, min		Reduction of area %, min	
				L	T	L	T
Forgings	Up to 75.00, incl	1170	1105	10	8	20	15
Bars and Wire	Up to 62.50, incl	1170	1105	10	8	20	15
Bars	Over 62.50 to 75.00, incl	1140	1070	8	6	15	12
Bars and Forgings	Over 75.00 to 100.00, incl	1105	1035	8	6	15	12

3.4.1.1.2 At 800°F (425°C): Product 4.000 in. (100.00 mm) and under in nominal diameter or distance between parallel sides shall meet the following requirements, determined in accordance with ASTM E21 on specimens heated to 800°F ± 5 (425°C ± 3), held at heat for 20 - 30 min. before testing, and tested at 800°F ± 5 (425°C ± 3) using strain rates as specified in 3.4.1.1.1:

Tensile Strength, min	135,000 psi (930 MPa)
Yield Strength at 0.2% Offset, min	105,000 psi (725 MPa)
Elongation in 2 in. (50 mm) or 4D, min	10%
Reduction of Area, min	30%

3.4.1.1.3 Tensile properties for bars over 4.000 in. (100.00 mm) in nominal diameter or distance between parallel sides and for forgings having any section over 4.000 in. (100.00 mm) in nominal thickness at time of heat treatment shall be as agreed upon by purchaser and vendor.

3.4.1.1.4 Yield strength and reduction of area requirements do not apply to wire under 0.125 in. (3.00 mm) in nominal diameter.

3.4.1.1.5 Ø 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 in. (62.5 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 Hardness: Shall be 33 - 45 HRC, or equivalent, determined in accordance with ASTM E18.

3.4.1.3 Room-Temperature Notched Stress-Rupture Test: A test specimen machined to the dimensions shown in Fig. 1 and Table II, 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 (70 MPa) at intervals of not less than 5 hours. Test shall be conducted in accordance with ASTM E292.

3.4.1.4 Ø Creep Test at 800°F (425°C): A smooth tensile specimen shall be maintained at 800°F ± 5 (425°C ± 3) under continuously applied axial stress of 95,000 psi (655 MPa). Time to 0.2% plastic deformation shall be not less than 35 hours. If plastic deformation is less than 0.2% after 35 hr, the test may be discontinued; the amount of plastic deformation in 35 hr shall be reported. Gauge 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 E139.

3.4.1.5 Ø Microstructure: Shall be essentially that resulting from alpha-beta processing. The specific alpha plus beta microstructure shall not be cause for rejection unless standards for acceptance have been agreed upon by purchaser and vendor except that no continuous network of alpha in prior beta grain boundries shall be acceptable.

3.4.1.6 Surface Contamination: Except as specified in 3.4.1.6.1 and 3.4.1.6.2, Ø product shall be free of any oxygen-enriched layer, 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.

3.4.1.6.1 An oxygen-rich layer (See 8.2) not greater than 0.001 in. (0.025 mm) Ø in depth will be permitted on bars other than round.

3.4.1.6.2 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 produced by multiple melting using consumable electrode practice. The final melting cycle shall be under vacuum.

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 all applicable requirements of 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 4.5. 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 to determine conformance to the following requirements are classified as 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 Ø Hydrogen content (3.1), room-temperature tensile properties (3.4.1.1.1), hardness (3.4.1.2), microstructure (3.4.1.5), and surface contamination (3.4.1.6) 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 to determine conformance to the following requirements are classified as periodic tests and shall be performed at a frequency selected by the vendor unless frequency of testing is specified by purchaser:

4.2.2.1 Tensile properties at 800°F (425°C) (3.4.1.1.2), room-temperature notched stress-rupture properties (3.4.1.3), and creep properties at 800°F (425°C) (3.4.1.4) of bars, wire, and forgings.

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

4.2.3 Preproduction Tests: Tests of forgings to determine conformance to all Ø applicable technical requirements of this specification when AMS 2375 is specified are classified as preproduction tests and shall be performed prior to or on the first-article shipment of a forging to a purchaser, when a change in material, processing, or both requires reapproval as in 4.4, and when purchaser deems confirmatory testing to be required.

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

4.3 Sampling: 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 Ø 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.

4.4 Approval: When specified, approval and control of forgings shall be in accordance with AMS 2375.

4.5 Reports:

4.5.1 The vendor of the product 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 number, AMS 4981B, 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.

4.5.2 The vendor of finished or semi-finished parts shall furnish with each shipment a report showing the purchase order number, AMS 4981B, contractor or other direct supplier of material, part number, and quantity. When material for making parts is produced or purchased by the parts vendor, that vendor shall inspect each lot of material to determine conformance to the requirements of this specification and shall include in the report either a statement that the material conforms or copies of laboratory reports showing the results of tests to determine conformance.

4.6 Resampling and Retesting: If any specimen used in the above tests fails to meet the specified requirements, disposition of the product 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 product represented and no additional testing shall be permitted. Results of all tests shall be reported.

5. PREPARATION FOR DELIVERY:

5.1 Identification: Shall be as follows:

5.1.1 Bars and Wire: In accordance with AMS 2809 as applicable to bars.
Ø

5.1.2 Forgings: In accordance with AMS 2808.

5.1.3 Forging Stock: As agreed upon by purchaser and vendor.

5.2 Packaging: