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400 COMMONWEALTH DRIVE, WARRENDALE, PA 15096

# AEROSPACE MATERIAL SPECIFICATION

Submitted for recognition as an American National Standard

AMS 4974B

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Superseding AMS 4974A

## TITANIUM ALLOY BARS AND FORGINGS
## 11Sn - 5.0Zr - 2.3Al - 1.0Mo - 0.21Si
## Solution and Precipitation Heat Treated

UNS R54790

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 and toughness and good creep resistance up to 900°F (482°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 Practices:

ARP982 - 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 19130.

ASTM E8 - Tension Testing 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, by spectrochemical methods, or by other analytical methods acceptable to purchaser:

| | min | max | |
|---|---|---|---|
| Tin | 10.50 - | 11.50 | |
| Zirconium | 4.00 - | 6.00 | |
| Aluminum | 2.00 - | 2.50 | |
| Molybdenum | 0.80 - | 1.20 | |
| Silicon | 0.15 - | 0.27 | |
| Oxygen | -- | 0.15 | |
| Iron | -- | 0.12 | |
| Carbon | -- | 0.04 | |
| Nitrogen | -- | 0.04 | (400 ppm) |
| Hydrogen | -- | 0.0125 | (125 ppm) |
| Yttrium (3.1.1) | -- | 0.005 | ( 50 ppm) |
| Residual Elements, each (3.1.1) | -- | 0.10 | |
| Residual Elements, total (3.1.1) | -- | 0.30 | |
| 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; no variation over maximum will be permitted for yttrium.

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

3.2.1 Bars: Hot finished with or without subsequent cold reduction, 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, wire, and forgings shall be solution heat treated by heating to 1650°F ± 25 (899°C ± 14), holding at heat for 60 minutes ± 5, and cooling at a rate equivalent to air cool or faster and precipitation heat treated by heating to 930°F ± 15 (499°C ± 8), holding at heat for 24 hours ± 0.5, and cooling in air.

3.3.1 Furnace surveys and calibration of temperature controllers and recorders Ø shall be in accordance with MIL-H-81200.

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

3.4.1 Bars, Wire, and Forgings: Product 1.00 inch (25.4 mm) and under in nominal diameter or distance between parallel sides shall have the following properties; product over 1.00 inch (25.4 mm) in nominal diameter or distance between parallel sides shall have properties as agreed upon by purchaser and vendor:

3.4.1.1 Tensile Properties: The following requirements apply in both the longitudinal and transverse directions but tests in the transverse direction need be made only on product from which a specimen not less than 2.50 inch (63.5 mm) in length can be taken. Tests in the longitudinal direction are not required on product tested in the transverse direction.

3.4.1.1.1 At Room Temperature: Shall be as follows, determined in accordance with ASTM E8 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.

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|---|---|
| Tensile Strength, minimum | 145,000 psi (1000 MPa) |
| Yield Strength at 0.2% Offset, minimum | 135,000 psi ( 931 MPa) |
| Elongation in 4D, minimum | 10% |
| Reduction of Area, minimum | 20% |

3.4.1.1.2 At 800°F (427°C): Shall be as follows, determined in accordance with ASTM E21 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):

| | |
|---|---|
| Tensile Strength, minimum | 105,000 psi (724 MPa) |
| Yield Strength at 0.2% Offset, minimum | 80,000 psi (552 MPa) |
| Elongation in 4D, minimum | 15% |
| Reduction of Area, minimum | 30% |

3.4.1.2 Stress-Rupture Properties: Shall be as specified in 3.4.1.2.1 and 3.4.1.2.2; room-temperature tests shall be conducted in accordance with ASTM E292 and 1000°F (538°C) tests in accordance with ASTM E139.

3.4.1.2.1 Room-Temperature Notched: A standard cylindrical combination smooth-and-notched specimen conforming to ASTM E292, maintained at room temperature while a load sufficient to produce an axial stress of 165,000 psi (1138 MPa) is applied continuously, shall not rupture in less than 5 hours. The initial stress may be less than 165,000 psi (1138 MPa) and increased to 165,000 psi (1138 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.

3.4.1.2.2 At 1000°F (538°C): A tensile specimen, maintained at 1000°F ± 3 (538°C ± 2) while a load sufficient to produce an initial axial stress of 70,000 psi (483 MPa) is applied continuously, shall not rupture in less than 23 hours. The test shall be continued to rupture without change of load. Elongation after rupture, measured at room temperature, shall be not less than 10% in 4D.

3.4.1.2.2.1 The test of 3.4.1.2.2 may be conducted using a load higher than required to produce an initial axial stress of 70,000 psi (483 MPa), but load shall not be changed while test is in progress. Time to rupture and elongation requirements shall be as specified in 3.4.1.2.2.

3.4.1.2.2.2 When permitted by purchaser, the test of 3.4.1.2.2 may be conducted using incremental loading. In such case, the load required to produce an initial axial stress of 70,000 psi (483 MPa) shall be used to rupture or for 23 hours, whichever occurs first. After the 23 hours and at intervals of 8 - 16 hours, preferably 8 - 10 hours, thereafter, the stress shall be increased in increments of 5000 psi (34 MPa). Time to rupture and elongation requirements shall be as specified in 3.4.1.2.2.

3.4.1.3 Creep Properties at 800°F (427°C): A tensile specimen, maintained at 800°F ± 3 (427°C ± 2) while a load sufficient to produce an initial axial stress of 70,000 psi (483 MPa) is applied continuously for 100 hours, shall not exceed 0.2% creep elongation. Gage dimensions of specimens and techniques used to measure creep shall be as agreed upon by purchaser and vendor. Tests shall be conducted in accordance with ASTM E139.

3.4.1.4 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.

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3.4.1.4.1 Equiaxed alpha in a transformed beta matrix.

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

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

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

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

3.4.1.5.1 An oxygen-rich layer (See 8.2) 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 forging.

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 heat treated coupon shall conform to the requirements of 3.4.1.1, 3.4.1.2, and 3.4.1.3. If test specimens taken from the stock after heat treatment as in 3.3 conform to the requirements of 3.4.1.1, 3.4.1.2, and 3.4.1.3, 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; at least one of the melting cycles 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 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 each lot 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 (427°C) (3.4.1.1.2), stress-rupture properties (3.4.1.2.1 and 3.4.1.2.2), and creep properties (3.4.1.3) of bars, wire, and forgings.

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

4.2.3 Preproduction Tests: Tests of forgings to determine conformance to all applicable technical requirements of this specification when AMS 2375 is specified are classified as preproduction tests and shall be performed on the first-article shipment of a forging to a purchaser, when a change in material and/or processing 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 activity, contracting officer, or 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:

4.3.1 For Acceptance Tests:

4.3.1.1 Composition: One sample from each heat, except for hydrogen determination one sample from each lot obtained after thermal and chemical processing is completed.

4.3.1.2 Tensile Properties: At least one sample from bars and wire from each lot. The number, location, and orientation of samples from forgings shall be as agreed upon by purchaser and vendor.

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