SAE Aerospace
An SAE International Group

AEROSPACE MATERIAL SPECIFICATION

AMS 4978E

Issued MAY 1970
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Superseding AMS 4978D

Titanium Alloy Bars, Wire, Forgings, and Rings
6Al - 6V - 2Sn
Annealed

(Composition similar to UNS R56620)

RATIONALE

AMS 4978E results from a Five Year Review and update of this specification.

1. SCOPE

1.1 Form

This specification covers a titanium alloy in the form of bars, wire, forgings, flash welded rings, and stock for forging or flash welded rings.

1.2 Application

These products have been used typically for parts which require high mechanical properties in the annealed condition and a high strength to weight ratio up to 750 °F (399 °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.

2.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), 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 2368	Sampling and Testing of Wrought Titanium Raw Materials, Except Forging and Forging Stock
AMS 2750	Pyrometry
AMS 2808	Identification, Forgings
AMS 2809	Identification, Titanium and Titanium Alloy Wrought Products

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

AMS 7498 Rings, Flash Welded, Titanium and Titanium Alloys

ARP982 Minimizing Stress-Corrosion Cracking in Wrought Titanium Alloy Products

2.2 ASTM Publications

Available from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959, Tel: 610-832-9585, www.astm.org.

ASTM E 8 Tension Testing of Metallic Materials
ASTM E 399 Plane-Strain Fracture Toughness of Metallic Materials
ASTM E 1409 Determination of Oxygen and Nitrogen 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/Infrared Detection Method
ASTM E 1941 Determination of Carbon in Refractory and Reactive Metals and Their Alloys
ASTM E 2371 Analysis of Titanium and Titanium Alloys by Atomic Emission Plasma Spectrometry

3. TECHNICAL REQUIREMENTS

3.1 Composition

Shall conform to the percentages by weight shown in Table 1; carbon shall be determined in accordance with ASTM E 1941, hydrogen in accordance with ASTM E 1447, oxygen and nitrogen in accordance with ASTM E 1409, and other elements in accordance with ASTM E 2371. Other analytical methods may be used if acceptable to the purchaser.

TABLE 1 - COMPOSITION

Element	min	max
Aluminum	5.00	6.00
Vanadium	5.00	6.00
Tin	1.50	2.50
Iron	0.35	1.00
Copper	0.35	1.00
Carbon	--	0.05
Oxygen	--	0.20
Nitrogen	--	0.04 (400 ppm)
Hydrogen	--	0.015 (150 ppm)
Yttrium (3.1.1) (3.1.4)	--	0.005 (50 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 applicable requirements of AMS 2249.

3.1.3 When using ASTM E 1447 for hydrogen determination, sample size may be as large as 0.35 gram.

3.1.4 No variation over maximum will be permitted for yttrium.

3.2 Melting Practice

3.2.1 Alloy shall be multiple melted. Melting cycle(s) prior to the final melting shall be made using vacuum consumable electrode, nonconsumable electrode, electron beam cold hearth, or plasma arc cold hearth melting practice. The final melting cycle shall be made under vacuum using vacuum arc (VAR) practice with no alloy additions permitted.

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 with or without subsequent cold reduction, annealed, and descaled. The product shall be produced using standard industry practices designed strictly for the production of bar stock to the procured size. Cut plate shall not be supplied in lieu of bar.

3.3.2 Wire

Cold drawn, annealed, and descaled.

3.3.3 Forgings and Flash Welded Rings

Annealed and descaled.

3.3.3.1 Flash welded rings shall not be supplied unless specified or permitted on purchaser's part drawing. When supplied, rings shall be manufactured in accordance with AMS 7498.

3.3.4 Stock for Forging or Flash Welded Rings

As ordered by the forging or flash welded ring manufacturer.

3.4 Heat Treatment

3.4.1 Annealing

Bars, wire, forgings, and flash welded rings shall be annealed by heating to 1300 - 1450 °F (704 – 788 °C), holding at heat for 1-2 hours, and cooling as required. Pyrometry shall be in accordance with AMS 2750.

3.5 Properties

The product shall conform to the following requirements:

3.5.1 Bars, Wire, Forgings, and Flash Welded Rings

3.5.1.1 Tensile Properties

Shall be as specified in Table 2, determined in accordance with ASTM E 8 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.

3.5.1.1.1 Tensile property requirements apply in both the longitudinal and transverse directions. Transverse tensile properties of Table 2 apply only to product from which a test specimen not less than 2.50 inches (63.5 mm) in length can be obtained.

3.5.1.1.2 Longitudinal requirements in Table 2 apply to specimens from bars and wire taken with the axis of the specimen within 15 degrees of parallel to the grain flow and to specimens from flash welded rings taken in the circumferential direction.

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.

TABLE 2A - TENSILE PROPERTIES, INCH/POUND UNITS

Nominal Diameter or Distance Between Parallel Sides Inches	Tensile Strength ksi, min	Yield Strength at 0.2% Offset ksi	Elongation in 2 inches or 4D %, min Long.	Elongation in 2 inches or 4D %, min Trans.	Reduction of area %, min Long.	Reduction of area %, min Trans.
Up to 2.000, incl	150	140 to 165	10	8	20	15
Over 2.000 to 4.000, incl	145	135 to 160	10	8	15	15

TABLE 2B - TENSILE PROPERTIES, SI UNITS

Nominal Diameter or Distance Between Parallel Sides Millimeters	Tensile Strength MPa, min	Yield Strength at 0.2% Offset MPa	Elongation in 50.8 mm or 4D %, min Long.	Elongation in 50.8 mm or 4D %, min Trans.	Reduction of Area %, min Long.	Reduction of Area %, min Trans.
Up to 50.80, incl	1034	965 to 1138	10	8	20	15
Over 50.80 to 101.60, incl	1000	931 to 1103	10	8	15	15

3.5.1.2 Microstructure

Shall be that structure resulting from processing within the alpha-beta phase field. Microstructure shall conform to 3.5.1.2.1, 3.5.1.2.2, or 3.5.1.2.3 (See 8.2).

3.5.1.2.1 Equiaxed alpha in a transformed beta matrix.

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

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

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

3.5.1.3 Surface Contamination

Except as specified in 3.5.1.3.1 and 3.5.1.3.2, the product shall be free of any oxygen-rich layer (See 8.3), 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.

3.5.1.3.1 An oxygen-rich layer not thicker than 0.001 inch (0.025 mm) is permitted on bars other than round.

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

3.5.1.4 Fracture-Toughness

When specified, the product shall be subjected to fracture toughness testing. ASTM E 399 is a recommended method of test for product over 0.5 inch (12.7 mm) in nominal thickness. Method of test and standards for acceptance shall be as agreed upon by purchaser and vendor.

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 heat treated coupon shall conform to the requirements of 3.5.1.1. If specimens taken from the stock after heat treatment as in 3.4 conform to the requirements of 3.5.1.1, the tests shall be accepted as equivalent to tests of a forged coupon.

3.5.3 Stock for Flash Welded Rings

Specimens taken from the stock after heat treatment as in 3.4 shall conform to the requirements of 3.5.1.1.

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 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 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 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), tensile properties (3.5.1.1), microstructure (3.5.1.2), surface contamination (3.5.1.3), and when specified, fracture-toughness (3.5.1.4) of bars, wire, forgings, and flash welded rings.

4.2.1.3 Tolerances (3.7) of bars and wire.

4.2.2 Periodic Tests

Ability of forging stock (3.5.2) and stock for flash welded rings (3.5.3) to develop specified properties 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 AMS 2368 and as follows: 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

At least 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 bars, wire, and flash welded rings from each lot. The number, location, and orientation of samples from each lot of forgings shall be as agreed upon by purchaser and vendor.

4.3.1.2.1 Specimens from flash welded rings shall be from parent metal not including the weld heat-affected zone.