SAE Aerospace
An SAE International Group

AEROSPACE MATERIAL SPECIFICATION

SAE AMS 4963B

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Superseding AMS 4963A

Titanium Alloy, Bars, Wire, Forgings, and Rings
6.0Al - 4.0V
Annealed, Heat Treatable, Modified Strength

(Composition similar to UNS R56400)

RATIONALE

AMS 4963B 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, flash welded rings, or heading.

1.2 Application

These products have been used typically for parts to be rough machined prior to solution and precipitation heat treatment and for parts requiring high strength-to-weight ratios at or near room temperature, 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; ARP 982 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 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 539 X-Ray Emission Spectrometric Analysis of 6Al-4V Titanium Alloy
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 539 or ASTM E 2371. Other analytical methods may be used if acceptable to the purchaser.

TABLE 1 - COMPOSITION

Element	min	max
Aluminum	5.50	6.75
Vanadium	3.50	4.50
Iron	--	0.30
Oxygen	--	0.20
Carbon	--	0.08
Nitrogen	--	0.05 (500 ppm)
Hydrogen (3.1.1,3.1.2)	--	0.0125 (125 ppm)
Yttrium (3.1.3)	--	0.005 (50 ppm)
Other Elements, each (3.1.3)	--	0.10
Other Elements, total (3.1.3)	--	0.40
Titanium	remainder	

3.1.1 Sample size when using ASTM E 1447 may be as large as 0.35 gram.

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

3.1.3 Determination not required for routine acceptance.

3.1.4 Check Analysis

Composition variations shall meet the applicable requirements of AMS 2249.

3.2 Melting Practice

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

3.2.1.1 The atmosphere for nonconsumable electrode melting shall be vacuum or shall be argon and/or helium at an absolute 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. Unless prohibited by purchaser, bars may be solution heat treated below the beta transus prior to annealing. 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 rough machined or descaled. Unless prohibited by purchaser, product may be solution heat treated below the beta transus prior to annealing.

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, Flash Welded Rings, or Heading

As ordered by the forging, flash welded ring, or heading manufacturer.

3.4 Heat Treatment

Bars, wire, forgings, and flash welded rings shall be annealed as follows; pyrometry shall be in accordance with AMS 2750:

3.4.1 Heat to a temperature within the range 1300 to 1450 °F (704 to 788 °C), hold at the selected temperature within ±25 °F (±14 °C) for 1 to 2 hours, and cool as required.

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 As Annealed

3.5.1.1.1 Microstructure

Shall be that structure resulting from alpha-beta processing. Microstructure shall conform to any one of the following: 3.5.1.1.1.1, 3.5.1.1.1.2, 3.5.1.1.1.3, or 3.5.1.1.1.4. A microstructure showing a continuous network of alpha in prior beta grain boundaries is not acceptable.

3.5.1.1.1.1 Lamellar alpha with some equiaxed alpha in a transformed beta matrix.

3.5.1.1.1.2 Equiaxed alpha in a transformed beta matrix.

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

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

3.5.1.1.2 Surface Contamination

Except as specified in 3.5.1.1.2.1 and 3.5.1.1.2.2, 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 400X magnification or by other method acceptable to purchaser.

3.5.1.1.2.1 An oxygen-rich layer (See 8.2) not greater than 0.001 inch (0.025 mm) in depth is permissible on bars other than rounds.

3.5.1.1.2.2 When permitted by purchaser, forgings and flash welded rings to be machined all over may have an oxygen-rich layer provided such layer is removable within the machining allowance on the forging or flash welded ring.

3.5.1.2 After Solution and Precipitation Heat Treatment

The product shall have the following properties after being solution heat treated by heating in a suitable atmosphere to 1750 °F ± 25 (954 °C ± 14), holding at heat for 1 to 2 hours, and quenching in agitated water and precipitation heat treated by heating to 1000 °F ± 15 (538 °C ± 8), holding at heat for 4 to 8 hours, and cooling in air.

3.5.1.2.1 Tensile Properties

Shall be as shown in Table 2, determined in accordance with ASTM E 8 with the rate of strain maintained at 0.003 to 0.007 inch/inch per minute (0.003 to 0.007 mm/mm per 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 per minute (0.005 mm/mm per minute) through the yield strength and a minimum cross head speed of 0.10 inch per minute (0.04 mm/s) above the yield strength.

TABLE 2A - MINIMUM TENSILE PROPERTIES, INCH/POUND UNITS

Rounds, Squares, Hexagons, Forgings, and Flash Welded Rings: Nominal Diameter or Distance Between Parallel Sides Inches	Tensile Strength ksi	Yield Strength at 0.2% Offset ksi	Elongation in 4D % L	Elongation in 4D % T	Reduction of Area % L
Up to 0.500, incl	165	155	10	--	20
Over 0.500 to 0.624, incl	158	144	10	--	20
Over 0.624 to 0.999, incl	150	137	10	--	20
Over 0.999 to 1.499, incl	145	129	10	--	20
Over 1.499 to 1.999, incl	140	129	10	--	20
Over 1.999 to 2.999, incl	135	125	10	8	20
Over 2.999 to 3.999, incl	130	120	10	6	20

Rectangles: Nominal Thickness Inch	Nominal Width Inches	Tensile Strength ksi	Yield Strength at 0.2%Offset ksi	Elongation in 4D % L	Elongation in 4D % T	Reduction of Area % L
Up to 0.500, incl	Over 0.500 to 8.000, incl	160	150	10	10	25
Over 0.500 to 1.000, incl	Over 1.000 to 4.000, incl	155	145	10	10	20
	Over 4.000 to 8.000, incl	150	140	10	10	20
Over 1.000 to 1.500, incl	Over 1.500 to 4.000, incl	150	140	10	10	20
	Over 4.000 to 8.000, incl	145	135	10	10	20
Over 1.500 to 2.000, incl	Over 2.000 to 4.000, incl	145	135	10	10	20
	Over 4.000 to 8.000, incl	140	130	10	10	20
Over 2.000 to 3.000, incl	Over 3.000 to 8.000, incl	135	125	10	8	20
Over 3.000 to 4.000, incl	Over 4.000 to 8.000, incl	130	120	10	6	20

TABLE 2B - MINIMUM TENSILE PROPERTIES, SI UNITS

Rounds, Squares, Hexagons, Forgings, and Flash Welded Rings: Nominal Diameter or Distance Between Parallel Sides Millimeters	Tensile Strength MPa	Yield Strength at 0.2% Offset MPa	Elongation in 4D % L	Elongation in 4D % T	Reduction of Area % L
Up to 12.70, incl	1138	1069	10	--	20
Over 12.70 to 15.85, incl	1089	993	10	--	20
Over 15.85 to 25.37, incl	1034	945	10	--	20
Over 25.37 to 38.07, incl	1000	889	10	--	20
Over 38.07 to 50.77, incl	965	889	10	--	20
Over 50.77 to 76.17, incl	931	862	10	8	20
Over 76.17 to 101.57, incl	896	827	10	6	20

Rectangles: Nominal Thickness Millimeters	Nominal Width Millimeters	Tensile Strength MPa	Yield Strength at 0.2% Offset MPa	Elongation in 4D % L	Elongation in 4D % T	Reduction of Area % L
Up to 12.70, incl	Over 12.70 to 203.20, incl	1103	1034	10	10	25
Over 12.70 to 25.40, incl	Over 25.40 to 101.60, incl	1069	1000	10	10	20
	Over 101.60 to 203.20, incl	1034	966	10	10	20
Over 25.40 to 38.10, incl	Over 38.10 to 101.60, incl	1034	966	10	10	20
	Over 101.60 to 203.20, incl	1000	931	10	10	20
Over 38.10 to 50.80, incl	Over 50.80 to 101.60, incl	1000	931	10	10	20
	Over 101.60 to 203.20, incl	966	897	10	10	20
Over 50.80 to 76.20, incl	Over 76.20 to 203.20, incl	931	862	10	8	20
Over 76.20 to 101.60, incl	Over 101.60 to 203.20, incl	897	828	10	6	20

3.5.1.2.1.1 Tensile and yield strength requirements apply in both the longitudinal and transverse directions but transverse properties need be determined only on product from which a transverse tensile specimen not less 2.50 inches (63.5 mm) in length can be obtained.

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

3.5.1.2.1.3 Longitudinal requirements in Table 2 apply to specimens from bars, wire, and forgings with axis of specimen in the area of the gage length varying not more than 15 degrees from parallel to the grain flow and to specimens taken in the circumferential direction from flash welded rings.

3.5.2 Forging Stock

When a sample of stock is forged to a test coupon and heat treated as in 3.5.1.2, specimens taken from the heat treated coupon shall conform to the requirements of 3.5.1.2.1. If specimens taken from the stock after heat treatment as in 3.5.1.2 conform to the requirements of 3.5.1.2.1, the tests shall be accepted as equivalent to tests of a forged coupon.

3.5.3 Stock for Flash Welded Rings or Heading

A sample of stock heat treated as in 3.5.1.2 shall conform to the requirements of 3.5.1.2.1.

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.

3.6.1 Grain flow of die forgings, except in areas which contain flash-line end grain, shall follow the general contour of the forgings showing no evidence of reentrant grain flow.

3.7 Tolerances

Bars and wire shall conform to all 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 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), microstructure (3.5.1.1.1), and surface contamination (3.5.1.1.2) of each lot of bars, wire, forgings, and flash welded rings as annealed.

4.2.1.3 Tensile properties (3.5.1.2.1) of each lot of bars, wire, forgings, and flash welded rings after solution and precipitation heat treatment.

4.2.1.4 Tolerances (3.7) of bars and wire.

4.2.2 Periodic Tests

Forging stock (3.5.2) and of stock for flash welded rings or heading (3.5.3) to demonstrate ability to develop required properties and grain flow of die forgings 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 the following; a lot shall be all product of the same nominal size from the same heat processed at the same time and annealed in the same heat treat 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

One or more samples from bars, wire, and flash welded rings from each lot after solution and precipitation heat treatment. One longitudinal specimen from each lot of forgings from a section having maximum thickness and from a section having minimum thickness.

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

4.3.1.3 Microstructure and surface contamination evaluation shall be made on one or more specimens from each lot prepared metallographically. Machined or centerless ground bar to be used for forging stock need not be sampled for microstructure or surface contamination.