AEROSPACE MATERIAL SPECIFICATION

AMS4964	REV. B

Issued 2000-07
Revised 2011-06
Reaffirmed 2015-04

Superseding AMS4964A

Titanium Alloy Bars, Wire, Forgings, and Rings
4.5Al - 3V - 2Fe - 2Mo
Annealed

RATIONALE

AMS4964B has been reaffirmed to comply with the SAE five-year review policy.

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 ring.

1.2 Application

These products have been used typically for parts requiring good fatigue strength, formability, and strength up to 480 °F (249 °C), but usage is not limited to such applications. The alloy is superplastic below 1520 °F (827 °C) and hot formable from 1200 to 1560 °F (649 to 849 °C).

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.

AMS2241 Tolerances, Corrosion and Heat-Resistant Steel, Iron Alloy, Titanium, and Titanium Alloy Bars and Wire

AMS2249 Chemical Check Analysis Limits, Titanium and Titanium Alloys

AMS2750 Pyrometry

AMS2808 Identification, Forgings

AMS2809 Identification, Titanium and Titanium Alloy Wrought Products

AMS7498 Rings, Flash Welded, Titanium and Titanium Alloys

TO PLACE A DOCUMENT ORDER: **Tel: 877-606-7323 (inside USA and Canada)**
Tel: +1 724-776-4970 (outside USA)
Fax: 724-776-0790
Email: CustomerService@sae.org
SAE WEB ADDRESS: **http://www.sae.org**

SAE values your input. To provide feedback on this Technical Report, please visit
http://www.sae.org/technical/standards/AMS4964B

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 / E 8M Tension Testing 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	4.00	5.00	
Vanadium	2.50	3.50	
Molybdenum	1.80	2.20	
Iron	1.70	2.30	
Oxygen	--	0.18	
Carbon	--	0.08	
Nitrogen	--	0.05	(500 ppm)
Hydrogen (3.1.1)	--	0.015	(150 ppm)
Yttrium (3.1.2)	--	0.005	(50 ppm)
Other Elements, each (3.1.2)	--	0.10	
Other Elements, total (3.1.2)	--	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 Determination not required for routine acceptance.

3.1.3 Check Analysis

Composition variations shall meet the applicable requirements of AMS2249.

3.2 Melting Practice

3.2.1 Alloy shall be multiple melted. The first melt shall be made by consumable electrode, nonconsumable electrode, electron beam cold hearth, or plasma arc cold hearth melting practice. The subsequent melt or melts shall be made under vacuum using vacuum arc remelting (VAR) practice. Alloy additions are not permitted in the final melt cycle.

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 before annealing. The product shall be processed to the final thickness/diameter by metallurgical working operations prior to any straightening, dimensional sizing or surface finishing operations. Bar shall not cut from plate.

3.3.2 Wire

Cold drawn, annealed, and descaled.

3.3.3 Forgings and Flash Welded Rings

Annealed and descaled. Unless prohibited by purchaser, product may be solution heat treated before 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 AMS7498.

3.3.4 Stock for Forging or Flash Welded Rings

As ordered by the forging or flash welded ring manufacturer.

3.4 Heat Treatment

Bars, wire, forgings, and flash welded rings shall be heat treated as follows; pyrometry shall be in accordance with AMS2750.

3.4.1 Solution Heat Treatment

When solution heat treatment is used, heat to a temperature within the range 50 to 150 °F (28 to 83 °C) degrees below the beta transus, hold at the selected temperature within ±25 °F (±14 °C) for a time commensurate with section thickness and the heating equipment and procedure used, and cool at a rate equivalent to an air cool or faster.

3.4.2 Annealing

Heat to a temperature within the range 1250 to 1400 °F (677 to 760 °C), hold at the selected temperature within ±25 °F (±14 °C) for a time commensurate with section thickness and the heating equipment and procedure used, and cool at a rate which will produce product meeting the requirements of 3.5.

3.5 Properties

The product shall conform to the following requirements and shall also meet the requirements of 3.5.1.1 and 3.5.1.2 after being heated to any temperature up to 1250 °F (677 °C), held at heat for 20 minutes ± 3, cooled in air, and descaled.

3.5.1 Bar, Wire, Forgings, and Flash Welded Rings

Product, 6 inches (152 mm) and under in nominal diameter or distance between parallel sides, shall have the following properties:

3.5.1.1 Tensile Properties

Shall be as specified in Table 2, determined in accordance with ASTM E 8 / E 8M on specimens as in 4.3.1.2 with the rate of strain set at 0.005 inch/inch/minute (0.005 mm/mm/minute) and maintained within a tolerance of ±0.002 inch/inch/minute (0.002 mm/mm/minute) through the 0.2% offset yield strain.

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

Nominal Diameter or Least Distance Between Parallel Sides Inches	Tensile Strength ksi (3)	Yield Strength at 0.2% Offset ksi (3)	Elongation in 2 inches or 4D, % Long.	Elongation in 2 inches or 4D, % LT	Elongation in 2 inches or 4D, % ST	Reduction of Area, % Long.	Reduction of Area, % LT	Reduction of Area, % ST (2)
Up to 2.000, incl (1)	135	125	10	10 (4)	--	25	20 (4)	--
Over 2.000 to 4.000, incl	130	120	10	10	10	25	20	15
Over 4.000 to 6.000, incl	130	120	10	10	8	20	20	15

TABLE 2B - MINIMUM TENSILE PROPERTIES, SI UNITS

Nominal Diameter or Least Distance Between Parallel Sides Millimeters	Tensile Strength MPa	Yield Strength at 0.2% Offset MPa	Elongation in 50.8 mm or 4D, % Long.	Elongation in 50.8 mm or 4D, % LT	Elongation in 50.8 mm or 4D, % ST	Reduction of Area, % Long.	Reduction of Area, % LT	Reduction of Area, % ST (3)
Up to 50.80, incl (1)	931	862	10	10 (4)	--	25	20 (4)	--
Over 50.80 to 101.60, incl	896	827	10	10	10	25	20	15
Over 101.60 to 152.40, incl	896	827	10	10	8	25	20	15

Long. = Longitudinal
LT = Long-Transverse
ST = Short-Transverse

Notes for Tables:

(1) Tensile strength of 130 ksi (896 MPa) minimum and yield strength of 120 ksi (827 MPa) minimum are permitted for wire or rod for fastener applications and for flash welded rings made from extrusions up to 2.000 inches (50.80 mm), inclusive, in distance between parallel sides.
(2) Short-transverse reduction of area is waived for flash welded rings made from extrusions.
(3) See 8.3.

3.5.1.1.1 Tensile and yield strength requirements apply in the longitudinal and the long and short transverse directions. Transverse requirements in Table 2 apply only to product from which a tensile specimen not less than 2.50 inches (63.5 mm) in length can be obtained.

3.5.1.1.2 Tests in the transverse directions are not required on product tested in the longitudinal direction unless specified on the purchase order.

3.5.1.1.3 Specimens for the longitudinal requirements in Table 2 for bars and wire shall be taken with the axis of the specimen approximately parallel to the grain flow and for flash welded rings shall be taken in the circumferential direction.

3.5.1.1.4 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 Microstructure

Shall be that structure resulting from processing within the alpha-beta phase field. Microstructure shall conform to 3.5.1.2.1 or 3.5.1.2.2.

3.5.1.2.1 Equiaxed and/or elongated primary alpha in a transformed beta matrix with no continuous network of alpha at prior beta grain boundaries.

3.5.1.2.2 Essentially complete field of equiaxed and/or elongated alpha with or without intergranular beta and with no continuous network of alpha at prior beta grain boundaries..

3.5.1.3 Surface Contamination

Except as permitted by 3.5.1.3.1 and 3.5.1.3.2, the product shall be free of any oxygen-rich 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.

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

3.5.1.3.2 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.

3.5.2 Forging Stock

When a sample of stock is forged to a test coupon having a degree of mechanical working not greater than the forging 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

A sample of stock heat treated 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.

3.6.1 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 AMS2241.

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 and hydrogen content of each lot.

4.2.1.2 Tensile properties (3.5.1.1), microstructure (3.5.1.2), and surface contamination (3.5.1.3) of each lot of bars, wire, forgings, and flash welded rings.

4.2.1.3 Tolerances (3.7) 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 (3.5.1.1) of bars, wire, forgings, and flash welded rings after reheating as in 3.5.

4.2.2.2 Microstructure (3.5.1.2) of bars, wire, forgings, and flash welded rings after reheating as in 3.5.

4.2.2.3 Ability of forging stock (3.5.2) and stock for flash welded rings (3.5.3) to develop required properties.

4.2.2.4 Grain flow of die forgings (3.6.1).

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. When processing includes heat treatment, product shall have been heat treated in one or more furnaces in the same load or sequentially heat treated in a series of furnaces or a continuous furnace.

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, forgings, and flash welded rings from each lot. Unless otherwise agreed upon by purchaser and vendor, location and orientation of samples shall be in accordance with ASTM E 8 / E 8M.

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

One or more samples from each lot.