SAE Aerospace
An SAE International Group

AEROSPACE MATERIAL SPECIFICATION

SAE AMS 4964A

Issued JUL 2000
Revised AUG 2005

Superseding AMS 4964

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

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 form 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 canceled and no superseding document has been specified, the last published issue of that document shall apply.

2.1 SAE Publications:

Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001 or 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
AMS 7498	Rings, Flash Welded, Titanium and Titanium Alloys

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

SAE 100 Leading Our World In Motion

2.2 ASTM Publications:

Available from ASTM, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959 or www.astm.org.

ASTM E 8	Tension Testing of Metallic Materials
ASTM E 8M	Tension Testing of Metallic Materials (Metric)
ASTM E 1409	Determination of Oxygen 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 Method
ASTM E 1937	Standard Test Method for Determination of Nitrogen in Titanium and Titanium Alloys by the Inert Gas Fusion Technique
ASTM E 1941	Standard Test Method for Determination of Carbon in Refractory and Reactive Metals and Their Alloys
ASTM E 2371	Standard Test Method for 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 in accordance with ASTM E 1409, nitrogen in accordance with ASTM E 1937, 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 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, or plasma arc melting practice(s). The final melting cycle shall be made under vacuum using consumable electrode 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: Annealed, and descaled. Unless prohibited by purchaser, bars may be solution heat treated before annealing.

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 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:

Bars, wire, forgings, and flash welded rings shall be heat treated as follows; pyrometry shall be in accordance with AMS 2750.

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 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 or ASTM E 8M on specimens as in 4.3.1.2 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/minute (0.04 mm/s) above the yield strength.

TABLE 2A - Minimum Tensile Properties, Inch/Pound Units

Nominal Diameter or 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 Distance Between Parallel Sides Millimeters	Tensile Strength MPa (3)	Yield Strength at 0.2% Offset MPa (3)	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 (4)
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) Tensile and yield strength requirements apply in both the longitudinal and transverse directions.
(4) See 8.3.

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

3.5.1.1.2 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.

3.5.1.1.3 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 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 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 as received.

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 (see 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 or ASTM 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.

4.4 Reports:

4.4.1 The vendor of bars, wire, forgings, and flash welded rings shall furnish with each shipment a report showing the results of tests for composition of each heat and for the hydrogen content and tensile properties of each lot, and stating that the product conforms to the other technical requirements. This report shall include the purchase order number, lot number, AMS 4964A, size, specific heat treatment used, and quantity. If forgings are supplied, the part number and size and melt source of stock used to make the forgings shall be included.

4.4.2 The vendor of stock for forging or flash welded rings shall furnish with each shipment a report showing the results of tests for chemical composition of each heat. This report shall include the purchase order number, lot number, AMS 4964A, size and quantity.

4.5 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, (See 8.4) for each original nonconforming specimen. Failure of any retest specimen to meet the specified requirements shall be cause for rejection of the product represented. 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.

5.1.2 Forgings: In accordance with AMS 2808.

5.1.3 Flash Welded Rings and Stock for Forging or Flash Welded Rings: As agreed upon by purchaser and vendor.

5.2 Packaging:

The product shall be prepared for shipment in accordance with commercial practice and in compliance with applicable rules and regulations pertaining to the handling, packaging, and transportation of the product to ensure carrier acceptance and safe delivery.

6. ACKNOWLEDGMENT:

A vendor shall mention this specification number and its revision letter in all quotations and when acknowledging purchase orders.

7. REJECTIONS:

Product not conforming to this specification, or to modifications authorized by purchaser, will be subject to rejection.

8. NOTES:

8.1 A change bar (|) located in the left margin is for the convenience of the user in locating areas where technical revisions, not editorial changes, have been made to the previous issue of a specification. An (R) symbol to the left of the document title indicates a complete revision of the specification, including technical revision. Change bars and (R) are not used in original publications, nor in specifications that contain editorial changes only.

8.2 An oxygen-rich layer, such as alpha case, is hard and brittle and results in marked lowering of fatigue properties.

8.3 Values listed for elongation and reduction of area (LT up to 2.000 Inches (50.8 mm) and all values for reduction of area in the ST direction have not been substantiated by the AMS statistical procedure.

8.4 AMS 2368, titled "Sampling and Testing of Wrought Titanium Material - Except Forgings and Forging Stock" is cited for the applicable paragraph (3.3) which requires retests, when required, of three additional specimens.

8.5 Dimensions and properties in inch/pound units and the Fahrenheit temperatures are primary; dimensions and properties in SI units and the Celsius temperatures are shown as the approximate equivalents of the primary units and are presented only for information.

8.6 Terms used in AMS are clarified in ARP1917.

8.7 Purchase documents should specify not less than the following:

AMS 4964A
Form and size of product desired
Quantity of product desired.