

AEROSPACE MATERIAL SPECIFICATION



AMS 4963A

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Superseding AMS 4963

Titanium Alloy, Bars, Wire, Forgings, and Rings

6.0Al - 4.0V

Annealed, Heat Treatable, Modified Strength

(Composition similar to UNS R56400)

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.

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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 2808	Identification, Forgings
AMS 2809	Identification, Titanium and Titanium Alloy Wrought Products
AMS 7498	Rings, Flash Welded, Titanium and Titanium Alloys
ARP982	Minimizing Stress-Corrosion Cracking in Wrought Titanium Alloy Products
AMS-H-81200	Heat Treatment of Titanium and Titanium Alloys

2.2 ASTM Publications:

Available from ASTM, 100 Barr Harbor Drive, 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 120	Chemical Analysis of Titanium and Titanium Alloys
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

3. TECHNICAL REQUIREMENTS:

3.1 Composition:

Shall conform to the percentages by weight shown in Table 1; oxygen shall be determined in accordance with ASTM E 1409, hydrogen in accordance with ASTM E 1447, and other elements by wet chemical methods in accordance with ASTM E 120, by spectrochemical methods, or by other analytical methods acceptable to 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)
Residual Elements, each (3.1.3)	--	0.10
Residual 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, 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: 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.

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 in accordance with AMS-H-81200.

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 or ASTM E 8M 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:								Elongation	Elongation	Reduction
Nominal Diameter or Distance Between Parallel Sides Inches				Tensile Strength ksi	Yield Strength at 0.2% Offset ksi	in 4D %	in 4D %	of Area %		
						L	T	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:				Tensile	Strength at	Elongation	Elongation	Reduction
Nominal Thickness				Strength	0.2%	in 4D	in 4D	of Area
Inch				ksi	Offset	%	%	%
					ksi	L	T	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:					Elongation	Elongation	Reduction
Nominal Diameter or Distance Between Parallel Sides Millimeters		Tensile Strength MPa	Yield Strength at 0.2% Offset MPa	in 4D %	in 4D %	of Area %	
				L	T	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:			Tensile	Strength at	Elongation	Elongation	Reduction
Nominal Thickness Millimeters		Nominal Width Millimeters	Strength MPa	0.2% Offset MPa	in 4D %	in 4D %	of Area %
					L	T	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 re-entrant 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: Tests of 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.

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 chemical 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, heat and lot numbers, AMS 4963A, size, specific heat treatment used, and quantity. If forgings are supplied, the part number and the size and melt source of stock used to make the forgings shall also be included.

4.4.2 The vendor of stock for forging, flash welded rings, or heading shall furnish with each shipment a report showing the results of tests for chemical composition of each heat and for the hydrogen content of each lot. This report shall include the purchase order number, AMS 4963A, heat number, 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 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.