SAE Aerospace
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AEROSPACE MATERIAL SPECIFICATION

AMS 4967J

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Superseding AMS 4967H

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

(Composition similar to UNS R56400)

RATIONALE

AMS 4967J is 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, heading, or flash welded rings.

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, such as pressure vessels and other aerospace structures, 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; 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 2750	Pyrometry
AMS 2808	Identification, Forgings

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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

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	Standard Test Method for 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	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 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)	--	0.0125	(125 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 Hydrogen content of forgings may be as high as 0.0150 (150 ppm).

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 cold hearth, or plasma arc cold hearth melting practice. The final melting cycle shall be made 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.

3.3.2 Wire

Cold drawn, annealed, and descaled.

3.3.3 Forgings and Flash Welded Rings

Annealed and rough machined or 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, Flash Welded Rings, or Heading

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

3.4 Annealing

Bars, wire, forgings, and rings shall be annealed by heating to a temperature within the range 1300 to 1450 °F (704 to 788 °C), holding at the selected temperature within ±25 °F (±14 °C) for not less than one hour, and cooling at a rate which will produce product meeting the requirements of 3.5. 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 As Annealed

3.5.1.1.1 Microstructure

Shall be that structure resulting from processing within the alpha-beta field. Microstructure shall conform to 3.5.1.1.1.1 or 3.5.1.1.1.2.

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

3.5.1.1.1.2 Essentially complete field of equiaxed and/or elongated alpha with no continuous network of alpha at prior beta grain boundaries.

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 (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 acceptable to purchaser.

3.5.1.1.2.1 An oxygen-rich layer not greater than 0.001 inch (0.025 mm) in depth will be permitted 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.

3.5.1.2 After Solution and Precipitation Heat Treatment

Product, 4.000 inches (101.60 mm) and under in nominal diameter or least distance between parallel sides, 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. When permitted by purchaser, other heat treatments may be used but the entire product of each lot shall be given the same heat treatment.

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.

3.5.1.2.1.1 Tensile and yield strength requirements apply in both the longitudinal and transverse directions. Transverse properties apply only to product from which a transverse tensile specimen not less than 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.

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 1.000, incl	160	150	10	--	20
Over 1.000 to 1.500, incl	155	145	10	--	20
Over 1.500 to 2.000, incl	150	140	10	--	20
Over 2.000 to 3.000, incl	135	125	10	8	20
Over 3.000 to 4.000, incl	130	120	10	6	20

Rectangles Nominal Thickness Inches	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 25.40, incl	1103	1034	10	--	20
Over 25.40 to 38.10, incl	1069	1000	10	--	20
Over 38.10 to 50.80, incl	1034	966	10	--	20
Over 50.80 to 76.20, incl	931	862	10	8	20
Over 76.20 to 101.60, incl	897	828	10	6	20

Rectangles Nominal Thickness Millimeters	Nominal Width mm	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

3.7 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 to determine ability of forging stock (3.5.2) and of stock for flash welded rings or heading (3.5.3) to develop required 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 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

At least one sample from bars, wire, and flash welded rings from each lot. 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 at least one specimen 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.

4.3.1.4 Other Requirements

As agreed upon by purchaser and vendor.

4.3.2 For Periodic Tests

As agreed upon by purchaser and vendor.

4.4 Reports

4.4.1 The vendor of the product 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, heat and lot number, AMS 4967J, size, product form, 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 4967J, heat number, size, product form, 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.

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, Flash Welded Rings, or Heading

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 The change bar (l) 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 this specification. An (R) symbol to the left of the document title indicates a complete revision of the specification, including technical revisions. 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 Terminology for titanium microstructures is presented in AS1814.

8.4 Terms used in AMS are clarified in ARP1917.

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 Purchase documents should specify not less than the following:

AMS 4967J
Form and size or part number of product desired
Quantity of product desired.