AEROSPACE MATERIAL SPECIFICATION

AMS4950™	REV. F

Issued 1996-08
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Superseding AMS4950E

Titanium Alloy, Bars, Wire, Forgings, and Rings
6.0Al - 4.0V
Solution Heat Treated and Aged
Modified Strength
(Composition similar to UNS R56400)

RATIONALE

AMS4950F results from a Five-Year Review and update of the specification with changes to prohibit unauthorized exceptions (3.5.1.1.2, 3.5.1.1.4, and 8.4), relocate definitons (2.3), update applicable documents (Section 2), and ordering information (8.6).

1. SCOPE

1.1 Form

This specification covers a titanium alloy in the form of bars, wire, forgings, and flash welded rings 4.000 inches (101.60 mm) and under in nominal diameter or least distance between parallel sides and of stock for forging or flash welded rings of any size (see 8.6).

1.2 Application

These products have been used typically for parts which are machined after being solution heat treated and aged, and are suitable 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; 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.

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**

For more information on this standard, visit
https://www.sae.org/standards/content/AMS4950F/

2.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (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

AMS2368 Sampling and Testing of Wrought Titanium Raw Material, Except Forgings and Forging Stock

AMS2750 Pyrometry

AMS2808 Identification, Forgings

AMS2809 Identification, Titanium and Titanium Alloy Wrought Products

AMS7498 Rings, Flash Welded, Titanium and Titanium Alloys

ARP982 Minimizing Stress-Corrosion Cracking in Wrought Titanium Alloy Products

AS1814 Terminology for Titanium Microstructures

AS6279 Standard Practice for Production, Distribution, and Procurement of Metal Stock

AS7766 Terms Used in Aerospace Metals Specifications

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 E3 Preparation of Metallographic Specimens

ASTM E8/E8M Tension Testing of Metallic Materials

ASTM E399 Linear-Elastic Plane-Strain Fracture Toughness of Metallic Materials

ASTM E539 Analysis of Titanium Alloys by Wavelength Dispersive X-Ray Fluorescence Spectrometry

ASTM E1409 Determination of Oxygen and Nitrogen in Titanium and Titanium Alloys by Inert Gas Fusion

ASTM E1447 Determination of Hydrogen in Reactive Metal and Reactive Metal Alloys by Inert Gas Fusion with Detection by Thermal Conductivity or Infrared Spectrometry

ASTM E1941 Determination of Carbon in Refractory and Reactive Metals and Their Alloys by Combustion Analysis

ASTM E2371 Analysis of Titanium and Titanium Alloys by Direct Current Plasma and Inductively Coupled Plasma Atomic Emission Spectrometry (Performance-Based Test Methodology)

ASTM E2994 Analysis of Titanium and Titanium Alloys by Spark Atomic Emission Spectrometry and Glow Discharge Atomic Emission Spectrometry (Performance-Based Method)

2.3 Definitions

Terms used in AMS are defined in AS7766.

2.3.1 Terminology relating to titanium microstructures is presented in AS1814.

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 E1941, hydrogen in accordance with ASTM E1447, oxygen and nitrogen in accordance with ASTM E1409, and other elements in accordance with ASTM E539, ASTM E2371, or ASTM E2994. 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	--	0.0125 (125 ppm)
Yttrium (see 3.1.1)	--	0.005 (50 ppm)
Other Elements, each (see 3.1.1)	--	0.10
Other Elements, total (see 3.1.1)	--	0.40
Titanium	remainder	

3.1.1 Determination not required for routine acceptance.

3.1.2 Check Analysis

Composition variations shall meet the applicable requirements of AMS2249; no variation over maximum shall be permitted for yttrium.

3.2 Melting Practice

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

3.2.1 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.

3.2.2 The electrode tip for nonconsumable electrode melting shall be water-cooled copper.

3.3 Condition

The product shall be supplied in the following conditions:

3.3.1 Bars

Hot finished with or without subsequent cold reduction, solution heat treated, aged, and descaled. 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, solution heat treated, aged, and descaled.

3.3.3 Forgings and Flash Welded Rings

Solution heat treated, aged, and descaled.

3.3.3.1 Flash welded rings shall not be supplied unless specified or permitted on the 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 solution heat treated by heating in a suitable atmosphere to 1750 °F ± 25 °F (954 °C ± 14 °C), holding at heat for 1 to 2 hours, and quenching in agitated water, and aged by heating to a temperature within the range 900 to 1150 °F (482 to 621 °C), holding at the selected temperature within ±15 °F (±8 °C) for 4 to 8 hours, and cooling in air. Pyrometry shall be in accordance with AMS2750.

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 Tensile Properties

Shall be as shown in Table 2 for round, square, and hexagonal bars, forgings, and flash welded rings, determined in accordance with ASTM E8/E8M with the rate of strain set at 0.005 in/in/min (0.005 mm/mm/min) and maintained within a tolerance of ±0.002 in/in/min (±0.002 mm/mm/min) through the 0.2% offset yield strain.

3.5.1.1.1 Tensile property requirements apply in both the longitudinal and transverse directions, but tests in the transverse direction are not required on product tested in the longitudinal direction. Transverse tensile properties of Table 2 apply only to product from which a test specimen not less than 2.50 inches (63.5 mm) in length can be obtained.

3.5.1.1.2 Tensile properties for rectangles shall be as agreed upon by purchaser and producer and reported per 4.4 (see 8.6).

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.

Table 2A - Minimum tensile properties, inch/pound units

Nominal Diameter or Least Distance Between Parallel Sides Inches	Tensile Strength ksi	Yield Strength at 0.2% Offset ksi	Elongation[1] in 2 Inches or 4D % L	Elongation[1] in 2 Inches or 4D % T	Reduction of Area % L
Up to 0.500, incl	165	155	10	-	20
Over 0.500 to 0.625, incl	158	144	10	-	20
Over 0.625 to 1.000, incl	150	137	10	-	20
Over 1.000 to 1.500, incl	145	129	10	-	20
Over 1.500 to 2.000, incl	140	129	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

[1] Minimum elongation shall be 8%, longitudinal, and 6%, transverse, for all size forgings.

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[1] in 50.8 mm or 4D % L	Elongation[1] in 50.8 mm or 4D % T	Reduction of Area % L
Up to 12.70, incl	1138	1069	10	--	20
Over 12.70 to 15.88, incl	1089	993	10	--	20
Over 15.88 to 25.40, incl	1034	945	10	--	20
Over 25.40 to 38.10, incl	1000	889	10	--	20
Over 38.10 to 50.80, incl	965	889	10	--	20
Over 50.80 to 76.20, incl	931	862	10	8	20
Over 76.20 to 101.60, incl	896	827	10	6	20

[1] Minimum elongation shall be 8%, longitudinal, and 6%, transverse, for all size forgings.

3.5.1.1.4 Mechanical property requirements for product outside the size range covered by 1.1 shall be agreed upon between the purchaser and producer and reported per 4.4.4 (see 8.6).

3.5.1.2 Fracture Toughness Properties

When specified (see 8.6), the product shall be subjected to fracture toughness testing. Method of test, specimen orientation, and standards for acceptance shall be as agreed upon by the purchaser and producer. Recommended method of test is ASTM E399.

3.5.1.3 Microstructure

Shall be that structure resulting from processing within the alpha-beta phase field. Microstructure shall conform to 3.5.1.3.1 or 3.5.1.3.2 (see 2.3.1).

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

3.5.1.3.2 Primary alpha in an aged, transformed beta matrix.

3.5.1.4 Surface Contamination

Except as specified in 3.5.1.4.1 and 3.5.1.4.2, 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 the purchaser.

3.5.1.4.1 An oxygen-rich layer (see 8.2) not greater than 0.001 inch (0.025 mm) in depth will be permitted on bars other than rounds.

3.5.1.4.2 When permitted by the 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.

3.5.2 Forging Stock

When a sample of stock is forged to a test coupon and heat treated as in 3.4, specimens taken from the heat-treated coupon shall conform to the requirements of 3.5.1.1, 3.5.1.2 when specified, 3.5.1.3, and 3.5.1.4. If specimens taken from the stock after heat treatment as in 3.4 conform to the requirements of 3.5.1.1, 3.5.1.2 when specified, 3.5.1.3, and 3.5.1.4, the tests shall be accepted as equivalent to tests of a forged coupon.

3.5.3 Stock for Flash-Welded Rings

Specimens taken from the stock after heat treatment as in 3.3 shall conform to the requirements of 3.5.1.1, 3.5.1.2 when specified, 3.5.1.3, and 3.5.1.4.

3.6 Quality

The product, as received by the 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.

3.8 Production, distribution, and procurement of metal stock shall comply with AS6279.

3.9 Exceptions

Any exceptions shall be authorized by the purchaser and reported as in 4.4.4.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for Inspection

The producer of the product shall supply all samples for the producer's tests and shall be responsible for the performance of all specified tests. The 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 (see 3.1) of each heat.

4.2.1.2 Hydrogen content (see 3.1), tensile properties (see 3.5.1.1), fracture toughness (see 3.5.1.2) when specified, microstructure (see 3.5.1.3), and surface contamination (see 3.5.1.4) of each lot of bars, wire, forgings, and flash welded rings.

4.2.1.3 Tolerances (3.7) of each lot of bars and wire.

4.2.2 Periodic Tests

Ability of forging stock (3.5.2) and stock for flash welded rings (3.5.3) to develop required properties, and grain flow of die forgings (3.6.1) are periodic tests and shall be performed at a frequency selected by the producer unless frequency of testing is specified by the purchaser.

4.3 Sampling and Testing

Shall be in accordance with AMS2368 and the following: a lot shall be all product of the same nominal size from the same heat processed at the same time and solution heat treated and aged 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 determination one sample from each lot obtained after thermal and chemical processing has been completed.

4.3.1.2 Tensile Properties

One or more sample(s) from bars, wire, and flash welded rings from each lot. One longitudinal specimen from a forging from each lot 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 Other Requirements

One or more specimens from each lot for microstructure and surface contamination shall be prepared in accordance with ASTM E3. Machined or centerless ground bar to be used as forging stock need not be checked for surface contamination.

4.4 Reports

4.4.1 The producer shall furnish with each shipment a report showing producer identity, country where the metal was melted (e.g., final melt in the case of metal processed by multiple melting operations), results of tests for composition of each heat, the hydrogen content, tensile properties, fracture toughness properties (when specified), results of surface examination, as applicable, of each lot and state that the product conforms to the other technical requirements. This report shall include the purchase order number, heat and lot numbers, AMS4950F, product form and mill produced size (and/or part number, if applicable), specific aging 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 producer of stock for forging or 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 of each lot. This report shall include the purchase order number, heat number, AMS4950F, size, and quantity.

4.4.3 Report the nominal metallurgically worked cross-sectional size and the cut size, if different (see 3.3.1).

4.4.4 The producer of stock for forging shall furnish with each shipment a report showing producer identity, country of origin and the results of tests for composition of each heat, hydrogen content of each lot and ultrasonic quality, when required. This report shall include the purchase order number, heat number, AMS4950F, size, and quantity.

4.4.5 When material produced to this specification is beyond the sizes allowed in the scope or tables, or exceptions authorized by the purchaser are taken to the technical requirements listed in Section 3, the report shall contain a statement "This material is certified as AMS4950F(EXC) because of the following exceptions:" and the specific exceptions shall be listed (see 5.1.1).

4.5 Resampling and Retesting

In accordance with AMS2368, except that for forgings and forging stock, if any specimen used in the above tests fails to meet 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 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 AMS2809. When technical exceptions are taken (see 4.4.4), the material shall be marked with AMS4950F(EXC).