



# AEROSPACE MATERIAL SPECIFICATION

AMS4950

REV. D

Issued 1996-08  
Revised 2015-01

Superseding AMS4950C

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

## RATIONALE

AMS4950D results from a Five Year Review and update of this specification that includes the removal of sample size allowance for hydrogen of Table 1 (covered by ASTM E1447), removal of the higher allowance of hydrogen for forgings, requires agreement on mechanical property values for material outside specification ranges (3.5.1.1.4 and 8.6), the addition of AS6279 (3.8) and revises the report paragraph (4.4).

## 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.

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SAE WEB ADDRESS:

## 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](http://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
ARP982	Minimizing Stress-Corrosion Cracking in Wrought Titanium Alloy Products
AS6279	Industry Standard Practices for Production, Distribution, and Procurement of Metal Stock

## 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](http://www.astm.org).

ASTM E3	Preparation of Metallographic Specimens
ASTM E8 / E8M	Tension Testing of Metallic Materials
ASTM E399	Plane-Strain Fracture Toughness of Metallic Materials
ASTM E539	Analysis of Titanium Alloys by X-Ray Fluorescence Spectrometry
ASTM E1409	Determination of Oxygen and Nitrogen in Titanium and Titanium Alloys by the Inert Gas Fusion Technique
ASTM E1447	Determination of Hydrogen in Titanium and Titanium Alloys by the Inert Gas Fusion Thermal Conductivity/Infrared Detection Method
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

## 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 or ASTM E2371. 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 (3.1.2)	--	0.005 ( 50 ppm)
Other Elements, each (3.1.1)	--	0.10
Other Elements, total (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 under vacuum 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 condition:

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 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  $\pm$  25 (954 °C  $\pm$  14), 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  $\pm$ 15 °F ( $\pm$ 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 inch/inch/minute (0.005 mm/mm/minute) and maintained within a tolerance of  $\pm$ 0.002 inch/inch/minute (0.002 mm/mm/minute) 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.

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 <sup>1</sup> in 2 Inches or 4D %	Elongation <sup>1</sup> in 2 Inches or 4D %	Reduction of Area %
			L	T	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

<sup>1</sup> Minimum elongation shall be 8%, longitudinal, and 6%, transverse, for all size forgings.

**Table 2B - Minimum tensile properties, SL units**

Nominal Diameter or Least Distance Between Parallel Sides Millimeters	Tensile Strength MPa	Yield Strength at 0.2% Offset	Elongation <sup>1</sup> in 50.8 mm or 4D	Elongation <sup>1</sup> in 50.8 mm or 4D	Reduction of Area
		Mpa	% L	% T	% 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

<sup>1</sup> 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 Table 2 shall be agreed upon between purchaser and producer.

### 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 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.

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 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 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 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. This requirement becomes effective June 01, 2016.

## 4. QUALITY ASSURANCE PROVISIONS

### 4.1 Responsibility for Inspection

The producer of the product shall supply all samples for producer's tests and shall be responsible for the performance of all specified 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), tensile properties (3.5.1.1), fracture toughness (3.5.1.2) when specified, microstructure (3.5.1.3), and surface contamination (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 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 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.