



AEROSPACE MATERIAL SPECIFICATION	AMS6947™	REV. C
	Issued	2011-07
	Revised	2024-12
Superseding AMS6947B		
Titanium Alloy, Bars, Wire, Forgings, Rings, and Drawn Shapes, 4Al - 2.5V -1.5 Fe, Annealed, Heat Treatable (Composition similar to UNS R54250)		

RATIONALE

AMS6947C results from a Five-Year Review and update of the specification with changes to add a Yttrium limit to the composition (see Table 1); prohibit unauthorized exceptions (see 3.5.1.2.1.3 and 8.4); relocate Definitions (see 2.3); add grain flow of die forgings as a periodic test (see 4.2.2); remove specific reference to check analysis from Hydrogen (see Table 1) as the paragraph applies more generally; and update Applicable Documents (see Section 2), wording related to test direction for flash-welded rings (see 3.5.1.2.1.2), presentation of sampling and testing to Microstructure and Surface Contamination (see 4.3.1.3), product forms listed (see 5.1.3), and Ordering Information (see 8.6).

1. SCOPE

1.1 Form

This specification covers a titanium alloy in the form of bars, wire, forgings, flash-welded rings, and drawn shapes 4.000 inches (101.60 mm) and under and stock for forging, heading, or flash-welded rings of any size (see 8.6).

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.

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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 E8/E8M	Tension Testing 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 for 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	3.5	4.5
Vanadium	2.0	3.0
Iron	1.2	1.8
Oxygen	0.20	0.30
Carbon	--	0.08 (800 ppm)
Nitrogen	--	0.03 (300 ppm)
Hydrogen	--	0.015 (150 ppm)
Yttrium (see 3.1.1)	--	0.005 (50 ppm)
Other Elements, each (see 3.1.1)	--	0.1
Other Elements, total (see 3.1.1)	--	0.3
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.

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 condition:

3.3.1 Bars and Drawn Shapes

Hot finished with or without subsequent cold reduction, annealed, and descaled. Unless prohibited by the purchaser, bars may be solution heat treated below the beta transus prior to annealing. The product shall be processed to the final thickness/diameter by metallurgical working operations prior to any dimensional sizing or surface finishing operations. Bar shall not be cut from plate.

3.3.2 Wire

Hot finished with or without subsequent cold reduction, 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 the purchaser's part drawing. When supplied, rings shall be manufactured in accordance with AMS7498.

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, rings, and drawn shapes shall be annealed by heating to a temperature within the range 1250 to 1400 °F (677 to 760 °C), holding at the selected temperature within ± 25 °F (± 14 °C) for not less than 1 hour, and cooling at a rate that will produce product meeting the requirements of 3.5. Pyrometry shall be in accordance with AMS2750.

3.5 Properties

The product shall conform to the following requirements:

3.5.1 Bars, Wire, Forgings, Flash-Welded Rings, and Drawn Shapes

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 (see 2.3.1).

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.

3.5.1.1.1.3 A microstructure showing a continuous network of alpha in prior beta grain boundaries is not acceptable.

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 the 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 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.

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 within the range 1600 to 1650 °F ± 25 °F (871 to 899 °C ± 14 °C), holding at heat for 1 to 2 hours, and quenching in agitated water and precipitation heat treated by heating within the range 800 to 900 °F ± 15 °F (427 to 482 °C ± 8 °C), holding at heat for at least 8 hours, and cooling in air:

3.5.1.2.1 Tensile Properties

Shall be as shown in Table 2, determined in the longitudinal direction 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.

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 in 4D %	Reduction of Area %
Up to	0.500	170	150	10	20
0.500 to less than	1.000	160	144	10	20
1.000 to less than	1.500	155	138	10	20
1.500 to less than	2.000	150	135	10	20
2.000 to	4.000, incl	145	130	10	20

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 in 4D %	Reduction of Area %
Up to	12.70	1172	1034	10	20
12.70 to less than	25.40	1103	993	10	20
25.40 to less than	38.10	1069	952	10	20
38.10 to less than	50.80	1034	931	10	20
50.80 to	101.60, incl	1000	896	10	20

- 3.5.1.2.1.1 Yield strength and reduction of area requirements do not apply to wire under 0.125 inch (3.18 mm) in nominal diameter or least distance between parallel sides.
- 3.5.1.2.1.2 Specimens from bars, wire, forgings, and drawn shapes shall have the axis of specimen in the area of the gauge length varying not more than 15 degrees from parallel to the grain flow for the longitudinal requirements of Table 2. Specimens from flash-welded rings shall be taken in the circumferential direction.
- 3.5.1.2.1.3 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 4.4.3 (see 8.6).

3.5.2 Forging Stock

A sample of stock shall be forged to a test coupon and heat treated as in 3.5.1.2, and specimens taken from the heat-treated coupon shall conform to the requirements of 3.5.1.2.1. Alternately, specimens taken from stock after heat treatment as in 3.5.1.2 that conform to the requirements of 3.5.1.2.1 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 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 that 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 4.4.3.

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 required 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) of each lot of bars, wire, forgings, flash-welded rings, drawn shapes, forging stock, stock for flash-welded rings and heading, microstructure (see 3.5.1.1.1), and surface contamination (see 3.5.1.1.2) of each lot of bars, wire, forgings, flash-welded rings, and drawn shapes as annealed.

4.2.1.3 Tensile properties (see 3.5.1.2.1) of each lot of bars, wire, forgings, flash-welded rings, and drawn shapes after solution and precipitation heat treatment.

4.2.1.4 Tolerances (see 3.7) of bars and wire.

4.2.2 Periodic Tests

Tests to determine ability of forging stock (see 3.5.2) and of stock for flash-welded rings or heading (see 3.5.3) to develop required properties and grain flow of die forgings (see 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 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, flash-welded rings, and drawn shapes from each lot. One longitudinal specimen from each lot of forgings from a section having maximum thickness and from a section having minimum thickness.