SAE Aerospace
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# AEROSPACE MATERIAL SPECIFICATION

SAE AMS6947

Issued 2011-07

## Titanium Alloy, Bars, Wire, Forgings, Rings, and Drawn Shapes
## 4Al - 2.5V -1.5 Fe
## Annealed, Heat Treatable

(Composition similar to UNS R54250)

RATIONALE

AMS6947 is a new specification for annealed, heat treatable UNS R54250 bar products.

1. SCOPE

1.1 Form

This specification covers a titanium alloy in the form of bars, wire, forgings, flash welded rings, drawn shapes, 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.

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





**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

**SAE values your input. To provide feedback on this Technical Report, please visit**
**http://www.sae.org/technical/standards/AMS6947**

AMS2808 Identification, Forgings

AMS2809 Identification, Titanium and Titanium Alloy Wrought Products

AMS7498 Rings, Flash Welded, Titanium and Titanium Alloys

ARP 982 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 / E 8M Tension Testing of Metallic Materials

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 Determination of Carbon in Refractory and Reactive Metals and Their Alloys

ASTM E 2371 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 2371. 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 (3.1.2) | -- | 0.015 | (150 ppm) |
| Other Elements, each (3.1.1) | -- | 0.1 | |
| Other Elements, total (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

3.2.1 Alloy shall be multiple melted. The first melt shall be made by 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.

3.2.1.1 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 and Drawn Shapes

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. Bar shall not be cut from plate. The product shall be processed to the final thickness/diameter by metallurgical working operations prior to any dimensional sizing or surface finishing operations.

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 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.

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 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 within the range 1600 to 1650 °F ± 25 (871 to 899 °C ± 14), 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 (427 to 482 °C ± 8), 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 E 8 / E 8M with the rate of strain set at 0.005 inch/inch/minute (0.005 mm/mm/minute) and maintained within a tolerance of ±0.002 inch/inch/minute (0.002 mm/mm/minute) 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 101.6, 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.

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 gage length varying not more than 15 degrees from parallel to the grain flow for the longitudinal requirements of Table 2, and specimens shall be taken in the circumferential direction from flash welded rings.

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 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.

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

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 shall provide a copy of the original material manufacturer's (producer's) report (material certification) including: producer name, and country where the metal was melted (e.g., final melt in the case of metal processed by multiple melting operations). This report shall document the results of tests for composition of each heat and for the hydrogen content and tensile properties 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 number, AMS6947, product form and mill produced size (and/or part number, if applicable), 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 Report the nominal metallurgically worked cross sectional size and the cut size, if different (See 3.3.1).