AEROSPACE MATERIAL SPECIFICATION

AMS6948	REV. A

Issued 2011-07
Revised 2015-07

Superseding AMS6948

Titanium Alloy Bars, Wire, Forgings, Rings, and Drawn Shapes 4Al - 2.5V -1.5 Fe Annealed (Composition similar to UNS R54250)

RATIONALE

AMS6948A 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), agreement on mechanical property values for material outside specification ranges (3.5.1.1.3 and 8.6), the addition of AS6279 (3.8), adds AMS2368 (4.3 and 4.5) 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, flash welded rings, drawn shapes 5.000 inches (127.00 mm) and under, and stock for forging or flash welded rings of any size.

1.2 Application

These products have been used typically for parts requiring a combination of moderate strength and good ductility with a maximum service temperature up to 750 °F (400 °C) depending on time at temperature where the product is to be used in the annealed condition, but usage is not limited to such applications.

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 +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

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/AMS6948A

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

AS6279 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.

ASTM E8/E8M Tension Testing of Metallic Materials

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 E2371. 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)
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

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.

3.2.1.1 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 before annealing. The product shall be processed to the final thickness/diameter by metallurgical working operations prior to any dimensional sizing or surface finishing operations (See 8.6). 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 descaled. Unless prohibited by purchaser, product may be solution heat treated before annealing.

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 Drawn Shapes

Drawn, annealed, and descaled. Unless prohibited by purchaser, drawn shapes may be solution heat treated before annealing.

3.3.5 Stock for Forging or Flash Welded Rings

As ordered by the forging or flash welded ring manufacturer.

3.4 Heat Treatment

Bars, wire, forgings, rings, and drawn shapes shall be heat treated as follows; pyrometry shall be in accordance with AMS2750.

3.4.1 Solution Heat Treatment

When solution heat treatment is used, heat to a temperature within the range 50 to 200 °F (28 to 93 °C) degrees below the beta transus, hold at the selected temperature within ±25 °F (±14 °C) for a time commensurate with section thickness and the heating equipment and procedure used, and cool at a rate equivalent to an air cool or faster.

3.4.2 Annealing

Heat to a temperature within the range 1250 to 1400 °F (677 to 760 °C), hold at the selected temperature within ±25 °F (±14 °C) for not less than 1 hour, and cool as required.

3.5 Properties

The product shall conform to the following requirements and shall also meet the requirements of 3.5.1.1 and 3.5.1.2 after being heated to any temperature up to 1200 °F (649 °C), held at heat for 20 minutes ± 3, cooled in air, and descaled:

3.5.1 Bars, Wire, Forgings, and Flash Welded Rings

Product, 5.000 inches (127.00 mm) and under in nominal diameter or least distance between parallel sides, shall have the following properties:

3.5.1.1 Tensile Properties

Shall be as specified in Table 2, determined in the longitudinal direction in accordance with ASTM E8/E8M on specimens as in 4.3.1.2 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 2 Inches or 4D %	Reduction of Area %
Less than 0.500	145	135	15	30
0.500 to less than 1.000	145	125	15	30
1.000 to less than 2.000	139	125	15	30
2.000 to 5.000, incl	135	125	15	30

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 50.8 mm or 4D % Long.	Reduction of Area % Long.
Less than 12.70	1000	931	15	30
12.70 to less than 25.40	1000	862	15	30
25.40 to less than 50.80	958	862	15	30
50.80 to 127.00, incl	931	862	15	30

3.5.1.1.1 Specimens for the longitudinal requirements in Table 2 shall be taken with the axis of the specimen approximately parallel to the grain flow for bars and wire and shall be taken in the circumferential direction from flash welded rings.

3.5.1.1.2 Yield strength and reduction of area requirements do not apply to wire and drawn shapes with maximum section thickness under 0.125 inch (3.18 mm) in nominal diameter or least distance between parallel sides.

3.5.1.1.3 Mechanical property requirements for product outside the size range covered by 1.1 shall be agreed upon between purchaser and producer.

3.5.1.2 Microstructure

Shall be that structure resulting from processing within the alpha-beta phase field. Microstructure shall conform to 3.5.1.2.1 or 3.5.1.2.2, or 3.5.1.2.3.

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

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

3.5.1.2.3 Partially broken and distorted grain boundary alpha with plate-like alpha.

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

3.5.1.3 Surface Contamination

Except as permitted by 3.5.1.3.1 and 3.5.1.3.2, 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 100X magnification or other method acceptable to purchaser.

3.5.1.3.1 An oxygen-rich layer not greater than 0.001 inch (0.025 mm) in depth will be permitted on bars other than round, and drawn shapes.

3.5.1.3.2 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 having a degree of mechanical working not greater than the forging and heat treated as in 3.4, specimens taken from the heat treated coupon shall conform to the requirements of 3.5.1.1. If specimens taken from the stock after heat treatment as in 3.4 conform to the requirements of 3.5.1.1, the tests shall be accepted as equivalent to tests of a forged coupon.

3.5.3 Stock for Flash Welded Rings

A sample of stock heat treated as in 3.4 shall conform to the requirements of 3.5.1.1.

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.

3.8 Production, distribution, and procurement of metal stock shall comply with AS6279. This requirement becomes effective September 1, 2016.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for Inspection

The producer of the product shall supply all samples for producer's test 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 and hydrogen content of each lot.

4.2.1.2 Tensile properties (3.5.1.1), microstructure (3.5.1.2), and surface contamination (3.5.1.3) of each lot of bars, wire, forgings, flash welded rings, and drawn shapes, as received.

4.2.1.3 Tolerances (3.7) of bars and wire.

4.2.2 Periodic Tests

The following requirements are periodic tests and shall be performed at a frequency selected by the producer unless frequency of testing is specified by purchaser:

4.2.2.1 Tensile properties (3.5.1.1) of bars, wire, forgings, flash welded rings, and drawn shapes after reheating as in 3.5.

4.2.2.2 Ability of forging stock (3.5.2) and stock for flash welded rings (3.5.3) to develop required properties.

4.2.2.3 Grain flow of die forgings (3.6.1).

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 annealed as a 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. The number, location, and orientation of samples from each lot of forgings shall be as agreed upon by purchaser and producer.

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

At least one sample from each lot.

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), 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, lot number, AMS6948A, 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 of stock used to make the forgings shall also be included. The producer of stock for forging or flash welded rings 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) and the results of tests for chemical composition of each heat. This report shall include the purchase order number, heat number, AMS6948A, size, and quantity.

4.4.2 Report the nominal metallurgically worked cross sectional size and the cut size, if different (See 3.3.1 and 8.6).

4.4.3 When the bar, wire, forging, flash welded ring, or drawn shape size is outside the range covered by 1.1, the report shall contain a statement to that effect.