SAE The Engineering Resource For Advancing Mobility®
400 COMMONWEALTH DRIVE WARRENDALE PA 15096

AEROSPACE MATERIAL SPECIFICATION

AMS 4936B
Superseding AMS 4936A

Issued 11-15-71
Revised 10-1-84

TITANIUM ALLOY EXTRUSIONS AND FLASH WELDED RINGS
6Al - 6V - 2Sn
Beta Extruded Plus Annealed, Heat Treatable UNS R56620

1. SCOPE:

1.1 Form: This specification covers a titanium alloy in the form of extruded bars, tubes, and shapes, and of flash welded rings and stock for flash welded rings.

1.2 Application: Primarily for parts that require machining or flash butt welding, or both, in the annealed condition and require high strength-to-weight ratio up to 750°F (400°C) after solution and precipitation heat treatment. Certain processing procedures and service conditions may cause these products to become subject to stress-corrosion cracking; ARP 982 recommends practices to minimize such conditions.

2. APPLICABLE DOCUMENTS: The following publications form a part of this specification to the extent specified herein. The latest issue of Aerospace Material Specifications and Aerospace Recommended Practices shall apply. The applicable issue of other documents shall be as specified in AMS 2350.

2.1 SAE Publications: Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096.

2.1.1 Aerospace Material Specifications:

AMS 2245 - Tolerances, Titanium and Titanium Alloy Extruded Bars, Rods, and Shapes
MAM 2245 - Tolerances, Metric, Titanium and Titanium Alloy Extruded Bars, Rods, and Shapes
AMS 2249 - Chemical Check Analysis Limits, Titanium and Titanium Alloys
AMS 2350 - Standards and Test Methods
AMS 7498 - Rings, Flash Welded, Titanium and Titanium Alloys

2.1.2 Aerospace Recommended Practices:

ARP 982 - Minimizing Stress-Corrosion Cracking in Wrought Titanium Alloy Products

2.2 ASTM Publications: Available from American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM E8 - Tension Testing of Metallic Materials
ASTM E120 - Chemical Analysis of Titanium and Titanium Alloys
ASTM E146 - Chemical Analysis of Zirconium and Zirconium Alloys

2.3 U.S. Government Publications: Available from Commanding Officer, Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, PA 19120.

2.3.1 Federal Standards:

Federal Test Method Standard No. 151 - Metals; Test Methods

2.3.2 Military Specifications:

MIL-H-81200 - Heat Treatment of Titanium and Titanium Alloys

2.3.3 Military Standards:

MIL-STD-163 - Steel Mill Products, Preparation for Shipment and Storage

3. TECHNICAL REQUIREMENTS:

3.1 Composition: Shall conform to the following percentages by weight, Ø determined by wet chemical methods in accordance with ASTM E120, by spectrographic methods in accordance with Federal Test Method Standard No. 151, Method 112, except that hydrogen shall be determined in accordance with ASTM E146; other methods of analysis may be used provided such methods are approved by purchaser:

	min	max
Aluminum	5.00	6.00
Vanadium	5.00	6.00
Tin	1.50	2.50
Iron	0.35	1.00
Copper	0.35	1.00
Oxygen	--	0.20
Carbon	--	0.05
Nitrogen	--	0.04 (400 ppm)
Hydrogen	--	0.015 (150 ppm)
Yttrium (3.1.1)	--	0.005 (50 ppm)
Residual Elements, each (3.1.1)	--	0.10
Residual 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 Ø requirements of AMS 2249. No variation over maximum will be permitted for yttrium unless otherwise agreed upon by purchaser and vendor.

3.2 Condition: The product shall be supplied in the following conditions:

3.2.1 Bars, Tubes, and Shapes: Extruded, annealed, straightened and detwisted Ø as required, and descaled.

3.2.1.1 Extrusions shall be descaled by wet or dry abrasive blasting, by Ø chemical procedures, or by other methods approved by purchaser.

3.2.2 Flash Welded Rings: Fabricated in accordance with AMS 7498 and annealed.

3.2.3 Stock for Flash Welded Rings: As ordered by the flash welded ring manufacturer.

3.3 Heat Treating: At the option of the extrusion manufacturer, straightening Ø and detwisting operations may be performed in conjunction with annealing. Furnace surveys and calibration of temperature controllers and recorders shall be in accordance with MIL-H-81200.

3.3.1 Annealing: Extruded shapes and flash welded rings shall be annealed by Ø heating in a suitable atmosphere to a temperature within the range of 1300° - 1500°F (705° - 815°C), holding at the selected temperature within ±25°F (±15°C) for 2 hr ± 0.25 and cooling.

3.3.2 Stress-Relieving: When specified by purchaser, extruded shapes and flash Ø welded rings shall be stress-relieved after any forming operation performed below 1050°F (565°C) for dimensional control, sizing, or proof testing. Product shall be stress-relieved by heating in a suitable atmosphere to a temperature within the range 900° - 1100°F (480° - 590°C), holding at the selected temperature within ±25°F (±15°C) for 2 - 4 hr, and cooling in air.

3.4 Properties: The product shall conform to the following requirements:

3.4.1 Bars, Tubes, Shapes, and Flash Welded Rings:

3.4.1.1 As Annealed, Formed, or Formed and Stress-Relieved:

3.4.1.1.1 Tensile Properties: Shall be as specified in Table I for product 4.0 in. (100 mm) and under in nominal diameter or distance between parallel sides, determined in accordance with ASTM E8 with the rate of strain maintained at 0.003 - 0.007 in./in. per min. (0.003 - 0.007 mm/mm per min.) through the yield strength and then increased so as to produce failure in approximately one additional minute. When a dispute occurs between purchaser and vendor over the yield strength values, a referee test shall be performed on a machine having a strain rate pacer using a rate of 0.005 in./in. per min. (0.005 mm/mm per min.) through the yield strength and a minimum cross head speed of 0.10 in. (2.5 mm) per min. above the yield strength.

TABLE I

Nominal Diameter or Distance Between Parallel Sides, Inches	Tensile Strength psi, min	Yield Strength at 0.2% Offset psi	Elongation in 4D %, min		Reduction of Area %, min	
			L	LT	L	LT
Up to 1.50, incl	150,000	140,000 - 165,000	10	8	20	15
Over 1.50 to 3.00, incl	145,000	135,000 - 160,000	10	8	20	15
Over 3.00 to 4.00, incl	140,000	130,000 - 155,000	10	8	20	15

TABLE I (SI)

Nominal Diameter or Distance Between Parallel Sides, Millimetres	Tensile Strength MPa, min	Yield Strength at 0.2% Offset MPa	Elongation in 4D %, min		Reduction of Area %, min	
			L	LT	L	LT
Up to 37.50, incl	1035	965 - 1140	10	8	20	15
Over 37.50 to 75.00, incl	1000	930 - 1105	10	8	20	15
Over 75.00 to 100.00, incl	965	895 - 1170	10	8	20	15

3.4.1.1.1.1 Tensile property requirements for extrusions over 4.000 in. (100.00 mm) in nominal diameter or distance between parallel sides and for flash welded rings over 4.000 in. (100.00 mm) in nominal radial thickness shall be as agreed upon by purchaser and vendor.

3.4.1.1.1.2 Tensile properties shall be determined in the long-transverse direction on product from which tensile specimens not less than 2.50 in. (62.5 mm) in length can be obtained. Tests in the longitudinal direction are not required on product tested in the transverse direction.

3.4.1.1.2 Surface Contamination: The product shall be free of any oxygen-rich layer, such as alpha case, or other surface contamination.

3.4.1.1.3 Microstructure: Shall be essentially that resulting from beta processing. Microstructure shall not be cause for rejection unless standards have been agreed upon by purchaser and vendor.

3.4.1.2 After Solution and Precipitation Heat Treatment: Product 4.0 in. (100 mm) and under in nominal diameter or distance between parallel sides shall have the following properties after being solution heat treated by heating to 1650°F ± 25 (900°C ± 15), holding at heat for 1 hr ± 0.1, and quenching in agitated oil or water and precipitation heat treated by heating to 1050°F ± 15 (565°C ± 8), holding at heat for 4 hr ± 0.25, and cooling in air.

3.4.1.2.1 Tensile Properties: Shall be as specified in Table II, determined as in 3.4.1.1.1 and 3.4.1.1.1.1.

TABLE II

Nominal Diameter or Distance Between Parallel Sides, Inches	Tensile Strength psi, min	Yield Strength at 0.2% Offset psi	Elongation in 4D %, min		Reduction of Area %, min	
			L	T	L	T
Up to 2.000, incl	150,000	140,000 - 165,000	10	8	20	15
Over 2.000 to 4.000, incl	145,000	135,000 - 160,000	10	8	15	15

TABLE II (SI)

Nominal Diameter or Distance Between Parallel Sides, Millimetres	Tensile Strength MPa, min	Yield Strength at 0.2% Offset MPa	Elongation in 4D %, min		Reduction of Area %, min	
			L	T	L	T
Up to 50.00, incl	1035	965 - 1140	10	8	20	15
Over 50.00 to 100.00, incl	1000	930 - 1105	10	8	15	15

3.4.1.2.1.1 Tensile property requirements for sizes over 4.000 in. (100.00 mm) in nominal diameter or distance between parallel sides shall be as agreed upon by purchaser and vendor.

3.4.2 Stock for Flash Welded Rings: Specimens taken from the stock after heat treatment as in 3.3 shall meet the requirements of 3.4.1.1.1 and, after further heat treatment as in 3.4.1.2 shall meet the requirements of 3.4.1.2.1.

3.5 Quality:

3.5.1 Alloy shall be multiple melted; at least one of the melting cycles shall be under vacuum. The first melt shall be made by consumable electrode, nonconsumable electrode, electron beam, or plasma melting practice. Subsequent melt or melts shall be made using consumable electrode practice.

3.5.1.1 The atmosphere for nonconsumable electrode melting shall be vacuum or shall be inert gas at a pressure not higher than 250 mm of mercury.

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

3.5.2 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 Tolerances: Unless otherwise specified, tolerances for extrusions shall conform to all applicable requirements of AMS 2245 or MAM 2245.

4. QUALITY ASSURANCE PROVISIONS:

4.1 Responsibility for Inspection: Ø The vendor of the product shall supply all samples for vendor's tests and shall be responsible for performing all required tests. Results of such tests shall be reported to the purchaser as required by 4.4. Purchaser reserves the right to sample and to perform any confirmatory testing deemed necessary to ensure that the product conforms to the requirements of this specification.

4.2 Classification of Tests:

4.2.1 Acceptance Tests: Ø Tests to determine conformance to the following requirements are classified as acceptance tests and shall be performed on each heat or lot as applicable.

4.2.1.1 Ø Composition (3.1) of each heat.

4.2.1.2 Ø Hydrogen content (3.1), tensile properties (3.4.1.1), surface contamination (3.4.2), and microstructure (3.4.3) of each lot of bars, tubes, shapes and flash welded rings in the annealed, formed, or formed and stress relieved condition.

4.2.1.3 Tolerances (3.6) of extrusions.

4.2.2 Periodic Tests: Ø Tests of the product to determine conformance to requirements for tensile properties (3.4.1.2.1) after solution and precipitation heat treatment and of stock for flash welded rings to demonstrate ability to develop specified properties (3.4.2) are classified as periodic tests and shall be performed at a frequency selected by the vendor unless frequency of testing is specified by purchaser.

4.3 Sampling: 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:

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 each lot.

4.3.1.3 Surface Contamination and Microstructure: At least one sample from each lot.

4.3.2 For Periodic Tests: As agreed upon by purchaser and vendor.

4.4 Reports:

4.4.1 The vendor of the product shall furnish with each shipment a report showing the results of tests for chemical composition of each heat and for the hydrogen content and tensile properties of each lot and stating that the product conforms to the other technical requirements of this specification. This report shall include the purchase order number, heat number, AMS 4936B, size, specific annealing or stress relieving treatment used, and quantity from each heat.

4.4.2 The vendor of finished or semi-finished parts shall furnish with each shipment a report showing the purchase order number, AMS 4936B, contractor or other direct supplier of material, part number, and quantity. When material for making parts is produced or purchased by the parts vendor, that vendor shall inspect each lot of material to determine conformance to the requirements of this specification and shall include in the report either a statement that the material conforms or copies of laboratory reports showing the results of tests to determine conformance.

4.5 Resampling and Retesting: If any specimen used in the above tests fails to meet the 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 the specified requirements shall be cause for rejection of the product represented and no additional testing shall be permitted. Results of all tests shall be reported.

5. PREPARATION FOR DELIVERY:

5.1 Identification: The product shall be identified as follows:

5.1.1 Bars, Tubes, and Shapes: