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INTERNATIONAL
400 Commonwealth Drive, Warrendale, PA 15096-0001

AEROSPACE MATERIAL SPECIFICATION

SAE AMS 4950A

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Superseding AMS 4950

Titanium Alloy, Bars, Wire, Forgings, and Rings
6.0Al - 4.0V
Solution Heat Treated and Aged
Modified Strength

(Composition similar to UNS R56400)

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.

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 canceled and no superseding document has been specified, the last published issue of that document shall apply.

QUESTIONS REGARDING THIS DOCUMENT: (724) 772-7161 FAX: (724) 776-0243
TO PLACE A DOCUMENT ORDER: (724) 776-4970 FAX: (724) 776-0790
SAE WEB ADDRESS: http://www.sae.org

2.1 SAE Publications:

Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001 or www.sae.org.

AMS 2241	Tolerances, Corrosion and Heat Resistant Steel, Iron Alloy, Titanium, and Titanium Alloy Bars and Wire
MAM 2241	Tolerances, Metric, Corrosion and Heat Resistant Steel, Iron Alloy, Titanium, and Titanium Alloy Bars and Wire
AMS 2249	Chemical Check Analysis Limits, Titanium and Titanium Alloys
AMS 2750	Pyrometry
AMS 2808	Identification, Forgings
AMS 2809	Identification, Titanium and Titanium Alloy Wrought Products
AMS 7498	Rings, Flash Welded, Titanium and Titanium Alloys
ARP982	Minimizing Stress-Corrosion Cracking in Wrought Titanium Alloy Products

2.2 ASTM Publications:

Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959 or www.astm.org.

ASTM E 3	Preparation of Metallographic Specimens
ASTM E 8	Tension Testing of Metallic Materials
ASTM E 8M	Tension Testing of Metallic Materials (Metric)
ASTM E 120	Chemical Analysis of Titanium and Titanium Alloys
ASTM E 338	Sharp-Notch Tension Testing of High-Strength Sheet Materials
ASTM E 399	Plane-Strain Fracture Toughness of Metallic Materials
ASTM E 1409	Determination of Oxygen 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 Method

3. TECHNICAL REQUIREMENTS:

3.1 Composition:

Shall conform to the percentages by weight shown in Table 1; oxygen shall be determined in accordance with ASTM E 1409, hydrogen in accordance with ASTM E 1447, and other elements by wet chemical methods in accordance with ASTM E 120, by spectrochemical methods, or by other analytical methods acceptable to 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 (3.1.1, 3.1.4)	--	0.0125 (125 ppm)
Yttrium (3.1.3)	--	0.005 (50 ppm)
Residual Elements, each (3.1.2)	--	0.10
Residual Elements, total (3.1.2)	--	0.40
Titanium	remainder	

3.1.1 Hydrogen content of forgings may be as high as 0.0150 (150 ppm).

3.1.2 Determination not required for routine acceptance.

3.1.3 Check Analysis: Composition variations shall meet the requirements of AMS 2249; no variation over maximum will be permitted for yttrium.

3.1.4 When using ASTM E 1447 for hydrogen determination, sample size may be as large as 0.35 gram.

3.2 Melting Practice:

Alloy shall be multiple melted; melting cycle(s) prior to final melting cycle shall be made using consumable electrode, nonconsumable electrode, electron beam, or plasma arc melting practices. The final melting cycle shall be made under vacuum using consumable electrode practice with no alloy additions permitted.

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.

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 AMS 7498.

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 ± 25 (954 °C ± 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 ±15 °F (±8 °C) for 4 to 8 hours, and cooling in air. Pyrometry shall be in accordance with AMS 2750.

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 E 8 or ASTM E 8M with the rate of strain maintained at 0.003 to 0.007 inch/inch/minute (0.003 to 0.007 mm/mm/minute) 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 inch/inch/minute (0.005 mm/mm/minute) through the yield strength and a minimum cross head speed of 0.10 inch per minute (0.04 mm/second) above the yield strength.

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 vendor.

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 Distance Between Parallel Sides Inches	Tensile Strength ksi	Yield Strength at 0.2% Offset ksi	Elongation[1] in 2 Inches or 4D % L	Elongation[1] in 2 Inches or 4D % T	Reduction of Area % 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

[1] Minimum elongation shall be 8%, longitudinal, and 6%, transverse, for all size forgings.

TABLE 2B - Minimum Tensile Properties, SI Units

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

[1] Minimum elongation shall be 8%, longitudinal, and 6%, transverse, for all size forgings.

3.5.1.2 Fracture Toughness Properties: When specified, the product shall be subjected to fracture toughness testing. Method of test and standards for acceptance shall be as agreed upon by purchaser and vendor. Recommended methods of test are ASTM E 338 for product under 0.500 inch (12.70 mm) in nominal section thickness and ASTM E 399 for product 0.500 inch (12.70 mm) and over in nominal section thickness.

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 Essentially complete field of equiaxed and/or elongated alpha with or without intergranular beta and with no continuous network of alpha at prior beta grain boundaries.

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 re-entrant grain flow.

3.7 Tolerances:

Bars and wire shall conform to all applicable requirements of AMS 2241 or MAM 2241.

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 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 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 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.

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 Other Requirements: One or more specimens from each lot for microstructure and surface contamination shall be prepared in accordance with ASTM E 3. Machined or centerless ground bar to be used as forging stock need not be checked for surface contamination.

4.4 Reports:

4.4.1 The vendor of bars, wire, forgings, and flash welded rings 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. This report shall include the purchase order number, heat and lot numbers, AMS 4950A, specific aging 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 The vendor of stock for forging or flash welded rings shall furnish with each shipment a report showing the results of tests for chemical composition of each heat and for the hydrogen content of each lot. This report shall include the purchase order number, heat number, AMS 4950A, size, and quantity.

4.5 Resampling and Retesting:

If any specimen used in the above tests fails to meet 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 specified requirements shall be cause for rejection of the product represented. Results of all tests shall be reported.

5. PREPARATION FOR DELIVERY:

5.1 Identification:

Shall be as follows:

5.1.1 Bars and Wire: In accordance with AMS 2809.

5.1.2 Forgings: In accordance with AMS 2808.

5.1.3 Flash Welded Rings and Stock for Forging or Flash Welded Rings: As agreed upon by purchaser and vendor.

5.2 Packaging:

5.2.1 The product shall be prepared for shipment in accordance with commercial practice and in compliance with applicable rules and regulations pertaining to the handling, packaging, and transportation of the product to ensure carrier acceptance and safe delivery.