

AEROSPACE MATERIAL SPECIFICATION

Issued JAN 2004
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Superseding AMS 6930

Titanium Alloy Bars, Forgings and Forging Stock
6.0Al - 4.0V
Solution Heat Treated and Aged
(Composition Similar to UNS R56400)

RATIONALE

Revision "A" corrects tensile properties in Table 3 by limited scope ballot and methods of chemical analysis and editorial text were brought current.

1. SCOPE:

1.1 Form:

This specification covers a titanium alloy in the form of bars, forgings, and stock for forging.

1.2 Application:

These products have been used typically for parts which are machined after solution heat treatment and aging and are suitable for parts requiring high strength-to-weight ratios up to moderately elevated temperatures, 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 724-776-4970 (outside USA), www.sae.org.

AMS 2241	Tolerances, 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 2368	Sampling and Testing of Wrought Titanium Raw Materials, Except Forging and Forging Stock
AMS 2631	Ultrasonic Inspection, Titanium and Titanium Alloy Bar and Billet
AMS 2643	Structural Examination of Titanium Alloys, Chemical Etch Inspection
AMS 2808	Identification, Forgings
AMS 2809	Identification, Titanium and Titanium Alloy Wrought Products
AMS-H-81200	Heat Treatment of Titanium and Titanium Alloys
ARP982	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	Tension Testing of Metallic Materials
ASTM E 8M	Tension Testing of Metallic Materials, Metric
ASTM E 539	Standard Test Method for X-Ray Emission Spectrometric Analysis of 6Al-4V Titanium Alloy
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 Method
ASTM E 1937	Standard Test Method for Determination of Nitrogen in Titanium and Titanium Alloys by the Inert Gas Fusion Technique
ASTM E 1941	Standard Test Method for Determination of Carbon in Refractory and Reactive Metals and Their Alloys
ASTM E 2371	Standard Test Method for 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 539 or ASTM E 2371. Other analytical methods may be used if acceptable to the 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 (3.1.2)	--	0.015 (150 ppm)
Yttrium (3.1.1)	--	0.005 (50 ppm)
Other Elements, each (3.1.1)	--	0.10
Other Elements, total (3.1.1)	--	0.40
Titanium	remainder	

3.1.1 Determination not required for routine acceptance.

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

3.1.3 Check Analysis: Composition variations shall meet the applicable requirements of AMS 2249.

3.2 Melting Practice:

3.2.1 Alloy shall be multiple melted. Melting cycle(s) prior to the final melting cycle shall be made using vacuum consumable electrode, nonconsumable electrode, electron beam cold hearth, or plasma arc cold hearth melting practice. The final melting cycle shall be made under vacuum using vacuum arc remelting (VAR) practice with no alloy additions permitted.

3.2.1.1 The atmosphere for nonconsumable electrode melting shall be vacuum or shall be argon 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, solution heat treated, aged, and descaled. A machined or ground surface is permitted unless prohibited by the purchaser.

3.3.2 Forgings: Solution heat treated, aged, and descaled.

3.3.3 Stock for Forging: As ordered by the forging manufacturer.

3.4 Heat Treatment:

Bars and forgings shall be solution heat treated and aged in accordance with AMS-H-81200.

3.5 Properties:

The product shall conform to the following requirements:

3.5.1 Bars and Forgings as Solution Heat Treated and Aged: Shall be as shown in Table 2 for round, square, and hexagonal bars, and forgings, and as shown in Table 3 for rectangular bars. Properties of forgings having shapes and dimensions not readily classified by nominal diameter or distance between parallel sides as in Table 2 shall be as agreed upon by purchaser and vendor.

3.5.1.1 Tensile Properties: Shall be 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 (2.5 mm) per minute above the yield strength.

3.5.1.1.1 Tensile property requirements apply in both the longitudinal and transverse directions. Transverse tensile properties of Table 2 and Table 3 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 Longitudinal requirements in Table 2 and Table 3 apply to specimens from product taken with the axis of the specimen within 15 degrees of parallel to the grain flow.

3.5.1.1.3 Yield strength and reduction of area requirements do not apply to product under 0.125 inch (3.18 mm) in nominal diameter.

TABLE 2 - Minimum Tensile Properties, Rounds, Squares, Hexagons (See 8.2)

Nominal Diameter or Least Distance Between Parallel Sides Inch (mm)	Tensile Strength ksi (MPa)	Yield Strength At 0.2% Offset ksi (MPa)	Elongation in 2 Inches (50.8 mm) or 4D, %	Reduction of Area %
Up to 0.500 (12.70) incl	165 (1137)	155 (1068)	10	20
Over 0.500 (12.70) to 1.00 (25.40) incl	160 (1103)	150 (1034)	10	20
Over 1.00 (25.40) to 1.50 (38.10) incl	155 (1068)	145 (999)	10	20
Over 1.50 (38.10) to 2.00 (50.40) incl	150 (1034)	140 (965)	10	20
Over 2.00 (50.40) to 3.00 (76.20) incl	140 (965)	130 (896)	10	20

TABLE 3 - Minimum Tensile Properties, Rectangles (See 8.2)

Least Distance Between Parallel Sides Inch (mm)	Cross Sectional Area, Square Inches (Square cm)	Tensile Strength ksi (MPa)	Yield Strength At 0.2% Offset ksi (MPa)	Elongation in 2 Inches (50.8 mm) or 4D, %	Reduction of Area %
Up to 0.500 (12.70) incl	0.50 (3.23) to 8.00 (51.62) incl	160 (1103)	150 (1034)	10	25
Over 0.500 (12.70) to 1.000 (25.40) incl	1.00 (6.45) to 4.00 (25.81) incl	155 (1068)	145 (999)	10	20
	4.00 (25.81) to 8.00 (51.62) incl	150 (1034)	140 (965)	10	20
Over 1.000 (25.40) to 1.500 (38.10) incl	1.50 (9.68) to 4.00 (25.81) incl	150 (1034)	140 (965)	10	20
	4.00 (25.81) to 8.00 (51.62) incl	145 (999)	135 (930)	10	20
Over 1.500 (38.10) to 2.000 (50.80) incl	2.00 (12.90) to 4.00 (25.81) incl	145 (999)	135 (930)	10	20
	4.00 (25.81) to 8.00 (51.62) incl	140 (965)	130 (896)	10	20
Over 2.000 (50.80) to 3.000 (76.20) incl	3.00 (19.36) to 8.00 (51.62) incl	135 (930)	125 (861)	10 [6]	20 [10]
Over 3.000 (76.20) to 4.000 (101.60) incl	4.00 (25.81) to 8.00 (51.62) incl	130 (896)	120 (827)	8 [6]	15 [10]

3.5.1.1.4 Values in brackets [] apply to the short transverse direction for short transverse dimensions of 3.00 inches or greater.

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 (See 8.3).

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 or without intergranular beta and with no continuous network of alpha at prior beta grain boundaries.

3.5.1.3 Surface Contamination: Except as specified in 3.5.1.3.1, the product shall be free of any oxygen-rich layer (See 8.4), such as alpha case, or other surface contamination, determined by microscopic examination at not lower than 400X magnification or by other method agreed upon by purchaser and vendor.

3.5.1.3.1 When permitted by purchaser, product to be machined all over may have an oxygen-rich layer, provided such layer is removable within the machining allowance on the product.

3.5.1.4 Macrostructure: Product shall be uniform in quality and condition, homogenous, sound, and free from foreign materials and from internal imperfections detrimental to fabrication or performance of parts.

- 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. 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.

3.6 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 Ultrasonic Inspection: Product 0.500 inch (12.70 mm) to 1.500 (38.10 mm) inclusive in nominal thickness, diameter or least distance between parallel sides shall meet Class A1 requirements of AMS 2631. Product over 1.500 inch (38.10 mm) in nominal thickness, diameter or least distance between parallel sides shall meet Class A requirements of AMS 2631.

3.7 Tolerances:

Bars shall conform to all applicable requirements of AMS 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 required tests. Purchaser reserves the right to sample and to perform any confirmatory testing deemed necessary to ensure that the product conforms to the 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), microstructure (3.5.1.2), surface contamination (3.5.1.3), macrostructure (3.5.1.4), and ultrasonic quality (3.6.1) of each lot of bars and forgings.

4.2.1.3 Tolerances (3.7) of bars.

- 4.2.2 Periodic Tests: Ability of forging stock (3.5.3) to develop specified properties is a periodic test 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 AMS 2368 and as follows: 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: At least one sample from each heat, except that for hydrogen determinations, one sample from each lot obtained after all thermal and chemical processing is completed.
- 4.3.1.2 Tensile Properties: At least one sample from bars from each lot. The number, location, and orientation of samples from each lot of forgings shall be as agreed upon by purchaser and vendor.
- 4.3.1.3 A specimen at least 0.5 inch (6.3 mm) long by full cross-section from each end of the bars selected for sampling shall be macrostructurally examined for conformance to the quality requirements. Unless otherwise specified, macrostructural examination shall be performed in accordance with AMS 2643. The number of bars selected for examination shall not be less than the amounts shown in Table 4.

Table 4 - Number of Bars selected for Macrostructural Examination

Number of Bars in Lot		Number of Bars Selected
1 to	15	1
16 to	50	2
51 to	100	3
151 to	500	5
over	500	4 + amount shown above over 500

4.4 Reports:

The vendor of the product shall furnish with each shipment a report showing the results of tests for composition of each heat and for the hydrogen content, tensile properties, ultrasonic quality, and surface contamination of each lot, and stating that the product conforms to the other technical requirements. The report shall include the purchase order number, heat and lot numbers, AMS 6930A, size, specific solution heat treatment and aging treatment used to develop precipitation hardened properties, and quantity. If forgings are supplied, the size and melt source of stock used to make the forgings shall also be included.

4.5 Resampling and Retesting:

Shall be in accordance with AMS 2368.