SAE Aerospace
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AEROSPACE MATERIAL SPECIFICATION

SAE AMS6930 REV. D

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Superseding AMS6930C

Titanium Alloy Bars, Forgings and Forging Stock
6.0Al – 4.0V
Solution Heat Treated and Aged

(Composition similar to UNS R56400)

RATIONALE

AMS6930D results from a correction in Table 3 that was not included in AMS6930C. AMS6930B resulted from a Five Year Review and update of the specification (See 8.1.1).

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 that 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.

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

AMS2368 Sampling and Testing of Wrought Titanium Raw Material, Except Forgings and Forging Stock

AMS2631 Ultrasonic Inspection, Titanium and Titanium Alloy Bar and Billet

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AMS2643 Structural Examination of Titanium Alloys, Chemical Etch Inspection Procedure

AMS2750 Pyrometry

AMS2808 Identification, Forgings

AMS2809 Identification, Titanium and Titanium Alloy Wrought Products

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 / E 8M Tension Testing of Metallic Materials

ASTM E 539 X-Ray Emission Spectrometric Analysis of 6AI-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/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 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	

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

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 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 AMS2750.

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 specified in Table 2 for round, square, and hexagonal bars, and forgings, and as specified 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.

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3.5.1.1 Tensile Properties

Shall be determined 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.

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 that a test specimen not less than 2.50 inches (63.5 mm) in length can be obtained.

3.5.1.1.2 Specimens for the longitudinal requirements in Table 2 and Table 3 shall be 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 Distance Between Parallel Sides Inches (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 Inches (mm)	Width Inches (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	Up to 8.00 (203.2) incl	160 (1103)	150 (1034)	10	25
Over 0.500 (12.70) to 1.000 (25.4) incl	Over 0.500 (12.70) to 4.00 (101.6) incl	155 (1068)	145 (999)	10	20
	Over 4.00 (101.6) to 8.00 (203.2) incl	150 (1034)	140 (965)	10	20
Over 1.000 (25.40) to 1.500 (38.10) incl	Over 1.00 (25.4) to 4.00 (101.6) incl	150 (1034)	140 (965)	10	20
	Over 4.00 (101.6) to 8.00 (203.2) incl	145 (999)	135 (930)	10	20
Over 1.500 (38.10) to 2.000 (50.80) incl	Over 1.50 (38.1) to 4.00 (101.6) incl	145 (999)	135 (930)	10	20
	Over 4.00 (101.6) to 8.00 (203.2) incl	140 (965)	130 (896)	10	20
Over 2.000 (50.80) to 3.000 (76.20) incl	Over 2.00 (50.8) to 8.00 (203.2) incl	135 (930)	125 (861)	10 [6]	20 [10]
Over 3.000 (76.20) to 4.000 (101.6) incl	Over 3.00 (76.2) to 8.00 (203.2) 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).

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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 Primary alpha in an aged transformed beta matrix.

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

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 inches (38.10 mm) inclusive in nominal thickness, diameter or least distance between parallel sides shall meet Class A1 requirements of AMS2631. Product over 1.500 inches (38.10 mm) in nominal thickness, diameter or least distance between parallel sides shall meet Class A requirements of AMS2631.

3.7 Tolerances

Bars 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 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.

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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), and macrostructure (3.5.1.4), of each lot of bars and forgings.

4.2.1.3 Ultrasonic quality (3.6.1) of each bar, forging or forging stock.

4.2.1.4 Tolerances (3.7) of bars.

4.2.2 Periodic Tests

Ability of forging stock (3.5.2) 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 AMS2368 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 (12.7 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 AMS2643. 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	150	3
151	to	500	5
	over	500	4 + amount shown above over 500

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, tensile properties, and surface contamination of each lot, ultrasonic quality of all product, and state that the product conforms to the other technical requirements. The report shall include the purchase order number, heat and lot numbers, AMS6930D, product form and mill produced size (and/or part number, if applicable), specific solution heat treatment and aging treatment used to develop aged properties, and quantity. If forgings are supplied, the size and melt source of stock used to make the forgings shall also be included.

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