



AEROSPACE MATERIAL SPECIFICATION

AMS6940™**REV. C**Issued 2004-01
Revised 2024-10

Superseding AMS6940B

Titanium Alloy Bars, Forgings and Forging Stock
3.0Al - 2.5V
Annealed

(Composition similar to UNS R56320)

RATIONALE

AMS6940C results from a Five-Year Review and update of this specification with changes to prohibit unauthorized exceptions (see 3.5.1.1.4, 3.5.1.2.1, and 8.6), relocate Definitions (see 2.3) and note related to statistical analysis of properties (see 3.5.1.1.5), and update Applicable Documents (see Section 2), wording related to the use of the immediate prior revision of this specification (see 8.5), and Ordering Information (see 8.7).

1. SCOPE

1.1 Form

This specification covers a titanium alloy in the form of bars up through 1.000 inch (25.40 mm) in diameter or least distance between parallel sides, inclusive, forgings of thickness up through 1.000 inch (25.40 mm), inclusive, high-strength fastener stock up through 1.250 inch (31.75 mm), inclusive, and stock for forging of any size (see 8.7).

1.2 Application

This material has been used typically for parts requiring strength and oxidation resistance up to 600 °F (316 °C) and weldability, 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

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For more information on this standard, visit
<https://www.sae.org/standards/content/AMS6940C/>

AMS2368	Sampling and Testing of Wrought Titanium Raw Material, Except Forgings and Forging Stock
AMS2631	Ultrasonic Inspection, Titanium and Titanium Alloy Bar, Billet, and Plate
AMS2643	Structural Examination of Titanium Alloys, Chemical Etch Inspection Procedure
AMS2750	Pyrometry
AMS2808	Identification, Forgings
AMS2809	Identification, Titanium and Titanium Alloy Wrought Products
AS1814	Terminology for Titanium Microstructures
AS6279	Standard Practice for Production, Distribution, and Procurement of Metal Stock
AS7766	Terms Used in Aerospace Metals Specifications

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 E399	Plane-Strain Fracture Toughness of Metallic Materials
ASTM E539	Analysis of Titanium Alloys by Wavelength Dispersive X-Ray Fluorescence Spectrometry
ASTM E1409	Determination of Oxygen and Nitrogen in Titanium and Titanium Alloys by Inert Gas Fusion
ASTM E1447	Determination of Hydrogen in Reactive Metals and Reactive Metal Alloys by Inert Gas Fusion with Detection by Thermal Conductivity or Infrared Spectrometry
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 (Performance-Based Test Methodology)
ASTM E2994	Analysis of Titanium and Titanium Alloys by Spark Atomic Emission Spectrometry and Glow Discharge Atomic Emission Spectrometry (Performance-Based Method)

2.3 Definitions

Terms used in AMS are defined in AS7766.

2.3.1 Terminology relating to titanium microstructures is presented in AS1814.

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 E539, ASTM E2371, or ASTM E2994. Other analytical methods may be used if acceptable to the purchaser.

Table 1 - Composition

Element	Min	Max
Aluminum	2.50	3.50
Vanadium	2.00	3.00
Iron	--	0.30
Oxygen	--	0.12
Carbon	--	0.050
Nitrogen	--	0.020 (200 ppm)
Hydrogen	--	0.015 (150 ppm)
Yttrium (see 3.1.1)	--	0.005 (50 ppm)
Other Elements, each (see 3.1.1)	--	0.10
Other Elements, total (see 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 requirements of AMS2249.

3.1.2.1 No variation over maximum will be permitted for yttrium.

3.2 Melting Practice

3.2.1 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 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 Including High-Strength Fastener Stock

Hot finished with or without subsequent cold reduction, annealed, 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

Annealed and descaled.

3.3.2.1 Stock for Forging

As ordered by the forging manufacturer.

3.4 Heat Treatment

Pyrometry shall be in accordance with AMS2750.

3.4.1 Bars and Forgings

Bars and forgings shall be annealed at 1200 to 1450 °F (649 to 788 °C), held at the selected temperature within ± 25 °F (± 14 °C) for a time commensurate with section thickness and the heating equipment and procedure used, and cooled at a rate equivalent to an air cool or slower.

3.4.2 High-Strength Fastener Stock

High-strength fastener stock shall be annealed at 1100 °F (593 °C), held within ± 25 °F (± 14 °C) for a time commensurate with section thickness and the heating equipment and procedure used, and cooled at a rate equivalent to an air cool or slower.

3.5 Properties

The product shall conform to the following requirements:

3.5.1 Bars and Forgings

3.5.1.1 Tensile Properties for Bars and Forgings (see 3.4.1)

Shall be as specified in Table 2, determined in accordance with ASTM E8/E8M, with the rate of strain set at 0.005 in/in/min (0.005 mm/mm/min) and maintained within a tolerance of ± 0.002 in/in/min (± 0.002 mm/mm/min) through the 0.2% offset yield strain.

3.5.1.1.1 Tensile property requirements apply in both the longitudinal and transverse directions. The transverse tensile properties of Table 2 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 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 or least distance between parallel sides.

Table 2 - Minimum tensile properties (see 3.5.1.1.5)

Nominal Diameter or Least Distance Between Parallel Sides Inches (Millimeters)	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 1.000 (25.40), incl	90 (620)	75 (517)	15	30

3.5.1.1.4 Tensile property requirements for bar and forging sizes outside Table 2 shall be as agreed upon by the purchaser and producer and reported per 4.4.3 (see 8.7).

3.5.1.1.5 These mechanical properties for bars and forgings up through 1.000 inch (25.40 mm) have been taken from MIL-T-9047 and have not been substantiated by AMS statistical procedures.

3.5.1.2 Tensile Properties for High-Strength Fastener Stock (see 3.4.2)

Shall be per Table 3, determined in accordance with ASTM E8/E8M, with the rate of strain set at 0.005 in/in/min (0.005 mm/mm/min) and maintained within a tolerance of ± 0.002 in/in/min (± 0.002 mm/mm/min) through the 0.2% offset yield strain.

Table 3 - Minimum tensile properties

Nominal Diameter or Least Distance Between Parallel Sides Inches (Millimeters)	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 1.250 (31.75), incl	102 (703)	84 (579)	17	30

3.5.1.2.1 Tensile property requirements for high-strength fastener stock sizes outside Table 3 shall be as agreed upon by the purchaser and producer and reported per 4.4.3 (see 8.7).

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 (see 2.3.1).

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, 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 400X magnification or by other method agreed upon by the purchaser and producer (see 8.7).

3.5.1.4.1 When permitted by the 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.

3.5.1.5 Fracture Toughness

When specified, the product shall be subjected to fracture toughness testing. ASTM E399 is a recommended method of test for product over 0.5 inch (12.7 mm) in nominal thickness. Method of test and standards for acceptance shall be as agreed upon by the purchaser and producer (see 8.7).

3.5.1.6 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 3.4.1, 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 3.4.1 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 the 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) and over in nominal thickness, diameter, or least distance between parallel sides shall meet Class A1 requirements of AMS2631 (see 8.4).

3.7 Tolerances

Bars shall conform to all applicable requirements of AMS2241.

3.8 Production, distribution, and procurement of metal stock shall comply with AS6279.

3.9 Exceptions

Any exceptions shall be authorized by the purchaser and reported as in 4.4.3.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for Inspection

The producer of the product shall supply all samples for the producer's tests and shall be responsible for the performance of all required tests. The 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 (see 3.1) of each heat.

4.2.1.2 Hydrogen content (see 3.1), tensile properties (see 3.5.1.1 or 3.5.1.2), microstructure (see 3.5.1.3), surface contamination (see 3.5.1.4), macrostructure (see 3.5.1.6), and, when specified, fracture-toughness (see 3.5.1.5) of each lot of bars, high-strength fastener stock, and forgings.

4.2.1.3 When applicable, ultrasonic quality (see 3.6.1) of each bar, forging, or forging stock.

4.2.1.4 Tolerances (see 3.7) of bars.

4.2.2 Periodic Tests

Ability of forging stock (see 3.5.2) to develop specified properties is a periodic test and shall be performed at a frequency selected by the producer unless frequency of testing is specified by the 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 and high-strength fastener stock from each lot. The number, location, and orientation of samples from each lot of forgings shall be as agreed upon by the purchaser and producer (see 8.7).

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 producer shall furnish with each shipment a report showing: the producer's identity; country where the metal was melted (e.g., final melt in the case of metal processed by multiple melting operations); results of tests for chemical composition of each heat; and results of tests for the hydrogen content, tensile properties, surface contamination, when specified, fracture toughness, and ultrasonic quality of each lot. The report shall state that the product conforms to the other technical requirements and shall include the purchase order number, heat and lot numbers, AMS6940C, product form and mill-produced size (and/or part number, if applicable), specific annealing treatment used, and quantity. If forgings are supplied, the size and melt source of stock used to make the forgings shall also be included. When material is ordered and produced as high-strength fastener stock, the product form designation shall include "Bar, High-Strength Fastener Stock."

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

4.4.3 When material produced to this specification is beyond the sizes allowed in the scope or tables, or other exceptions authorized by the purchaser are taken to the technical requirements listed in Section 3, the report shall contain a statement "This material is certified as AMS6940C(EXC) because of the following exceptions:" and the specific exceptions shall be listed (see 5.1.1).

4.5 Resampling and Retesting

Shall be in accordance with AMS2368.

5. PREPARATION FOR DELIVERY

5.1 Identification

5.1.1 Bars

In accordance with AMS2809, as applicable. When technical exceptions are taken (see 4.4.3), the material shall be marked with AMS6940C(EXC).

5.1.2 Forgings

In accordance with AMS2808, except that marking shall be applied using a marking fluid whose residue shall contain no more than traces of halogen-containing compounds.