



AEROSPACE MATERIAL SPECIFICATION

AMS6950™**REV. A**Issued 2017-05
Revised 2022-10

Superseding AMS6950

Titanium Alloy Bars, Forgings, and Forging Stock
4Al - 2.5V - 1.5 Fe
Single Hearth Melted, Annealed
(Composition similar to UNS R54250)

RATIONALE

AMS6950A results from a Five-Year Review and update of the specification with changes to update general agreement language related to unauthorized exceptions (3.5.1.1.2, 3.9, 4.4.3, 8.4), update applicable documents (Section 2), composition (3.1), microstructure (3.5.1.2), reports (4.4.1), and ordering information (8.6), and allow use of immediate prior specification revision (8.5).

1. SCOPE

1.1 Form

This specification covers a titanium alloy in the form of bars and forgings 14.000 inches (355.60 mm) and under in nominal diameter or least distance between parallel sides and stock for forging (see 8.6).

1.2 Application

These products have been used typically for parts requiring a combination of moderate strength and good ductility with a maximum service temperature up to 750 °F (400 °C) depending on time at temperature when the product is to be used in the annealed condition, 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
AMS2368	Sampling and Testing of Wrought Titanium Raw Material, Except Forgings and Forging Stock

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For more information on this standard, visit
<https://www.sae.org/standards/content/AMS6950A/>

AMS2750	Pyrometry
AMS2808	Identification, Forgings
AMS2809	Identification, Titanium and Titanium Alloy Wrought Products
ARP1917	Clarification of Terms Used in Aerospace Metals Specifications
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 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 Titanium and Titanium Alloys by the Inert Gas Fusion Thermal Conductivity/Infrared Detection Method
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 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 for 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	3.5	4.5
Vanadium	2.0	3.0
Iron	1.2	1.8
Oxygen	0.20	0.30
Carbon	--	0.08 (800 ppm)
Nitrogen	--	0.03 (300 ppm)
Hydrogen	--	0.015 (150 ppm)
Other Elements, each (3.1.1)	--	0.1
Other Elements, total (3.1.1)	--	0.3
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.

3.2 Melting Practice

Alloy shall be cold hearth melted. Either electron beam cold hearth melting or plasma arc cold hearth melting may be used.

3.2.1 The melt source shall establish effective control procedures, including parameters for the critical variables that will consistently produce material suitable for the production of bars and forgings meeting the requirements of this specification.

3.3 Condition

The product shall be supplied in the following condition:

3.3.1 Bars

Hot finished with or without subsequent cold reduction, annealed, and descaled. Unless prohibited by purchaser, bars may be solution heat treated before annealing. The product shall be processed to the final thickness/diameter by metallurgical working operations prior to any dimensional sizing or surface finishing operations (see 8.6). Bar shall not be cut from plate.

3.3.2 Forgings

Annealed and descaled. Unless prohibited by purchaser, product may be solution heat treated before annealing.

3.3.3 Stock for Forging

As ordered by the forging manufacturer.

3.4 Heat Treatment

Bars and forgings shall be heat treated as follows; pyrometry shall be in accordance with AMS2750.

3.4.1 Solution Heat Treatment

When solution heat treatment is used, heat to a temperature within the range 50 to 200 °F (28 to 93 °C) below the beta transus, hold at the selected temperature within ± 25 °F (± 14 °C) for a time commensurate with section thickness and the heating equipment and procedure used, and cool at a rate equivalent to an air cool or faster.

3.4.2 Annealing

Heat to a temperature within the range 1250 to 1400 °F (677 to 760 °C), hold at the selected temperature within ± 25 °F (± 14 °C) for not less than 1 hour, and cool as required.

3.5 Properties

The product shall conform to the following requirements and shall also meet the requirements of 3.5.1.1 and 3.5.1.2 after being heated to any temperature up to 1200 °F (649 °C), held at heat for 20 minutes $\pm$ 3 minutes, cooled in air, and descaled:

3.5.1 Bars and Forgings

Product, 14.000 inches (355.60 mm) and under in nominal diameter or least distance between parallel sides, shall have the following properties:

3.5.1.1 Tensile Properties

Shall be as specified in Table 2, determined in the longitudinal direction in accordance with ASTM E8/E8M on specimens as in 4.3.1.2 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 2A - Minimum tensile properties, inch/pound units

Nominal Diameter or Least Distance Between Parallel Sides Inches	Tensile Strength ksi	Yield Strength at 0.2% Offset ksi	Elongation in 2 Inches or 4D %	Reduction of Area %	
				L	T
Less than 2.000	139	125	15	30	25
2.000 to less than 5.000	135	125	15	30	22
5.000 to 14.000, incl	129	122	12	24	10

Table 2B - Minimum tensile properties, SI units

Nominal Diameter or Least Distance Between Parallel Sides Millimeters	Tensile Strength MPa	Yield Strength at 0.2% Offset MPa	Elongation in 50.8 mm or 4D %	Reduction of Area %	
				L	T
Less than 50.80	958	862	15	30	25
50.80 to less than 127.00	931	862	15	30	22
127.00 to 355.60, incl	889	841	12	24	10

3.5.1.1.1 Specimens for the longitudinal requirements in 3.5.1.1 shall be taken with the axis of the specimen approximately parallel to the grain flow for forgings.

3.5.1.1.2 Mechanical property requirements for product outside the size range covered by 1.1 shall be agreed upon between purchaser and producer and reported per 4.4.3 (see 8.6).

3.5.1.2 Microstructure

Shall be that structure resulting from processing within the alpha-beta phase field (see 2.3.1). Microstructure shall conform to 3.5.1.2.1 or 3.5.1.2.2.

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 Partially broken and distorted grain boundary alpha with plate-like alpha.

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 permitted by 3.5.1.3.1 and 3.5.1.3.2, 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 100X magnification or other method acceptable to purchaser.

3.5.1.3.1 An oxygen-rich layer not greater than 0.001 inch (0.025 mm) in depth will be permitted on bars other than round.

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

3.5.2 Forging Stock

When a sample of stock is forged to a test coupon having a degree of mechanical working not greater than the forging 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 Grain flow of die forgings, except in areas that contain flash-line and grain, shall follow the general contour of the forgings showing no evidence of reentrant grain flow.

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 per 4.4.3.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for Inspection

The producer of the product shall supply all samples for producer's test 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 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 and hydrogen content of each lot.

4.2.1.2 Tensile properties (3.5.1.1), microstructure (3.5.1.2), and surface contamination (3.5.1.3) of each lot of bars and forgings.

4.2.1.3 Tolerances (3.7) of bars.

4.2.2 Periodic Tests

The following requirements are periodic tests and shall be performed at a frequency selected by the producer unless frequency of testing is specified by purchaser:

4.2.2.1 Ability of forging stock (3.5.2) to develop required properties.

4.2.2.2 Grain flow of die forgings (3.6.1).

4.3 Sampling and Testing

Shall be in accordance with AMS2368 and 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 annealed as a heat treat batch.

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 bars from each lot. The number, location, and orientation of samples from each lot of forgings shall be as agreed upon by purchaser and producer (see 8.6).

4.3.1.3 Microstructure and Surface Contamination

At least one sample from each lot.

4.4 Reports

4.4.1 The producer shall furnish with each shipment a report showing producer identity, country where the metal was melted (e.g., final melt in the case of metal processed by multiple melting operations), the results of tests for composition of each heat and for the hydrogen content microstructure, surface contamination, and tensile properties of each lot, and state that the product conforms to the other technical requirements. This report shall include the purchase order number, lot number, AMS6950A, product form and mill produced size (and/or part number, if applicable), specific heat treatment used, and quantity. If forgings are supplied, the part number and the size of stock used to make the forgings shall also be included. The producer of stock for forging shall furnish with each shipment a report showing producer identity, country where the metal was melted (e.g., final melt in the case of metal processed by multiple melting operations) and the results of tests for chemical composition of each heat. This report shall include the purchase order number, heat number, AMS6950A, size, and quantity.

4.4.2 Report the nominal metallurgically worked cross sectional size and the cut size, if different (also see 3.3.1 and 8.6).

4.4.3 When material produced to this specification is beyond the sizes allowed in the scope or tables, or other exceptions are taken to the technical requirements listed in Section 3, the report shall contain a statement "This material is certified as AMS6950A(EXC) because of the following exceptions:" and the specific exceptions shall be listed.

4.5 Resampling and Retesting

In accordance with AMS2368.