ADOPTION NOTICE

SAE-AMS 4984, "Titanium Alloy, Forgings 10V - 2Fe - 3Al Consumable Electrode Melted, Solution Heat Treated and Aged 173 ksi (1193 MPa) Tensile Strength" was adopted on 22 May 1995 for use by the Department of Defense (DoD). Proposed changes by DoD activities must be submitted to the DoD Adopting Activity: Air Force, ASC/ENSI, Building 125, 2335 Seventh Street, Suite 6, Wright-Patterson AFB OH 45433-7809. DoD activities may obtain copies of this standard from the Standardization Document Order Desk, 700 Robbins Avenue, Building 4D, Philadelphia, PA 19111-5094. The private sector and other Government agencies may purchase copies from the Society of Automotive Engineers Inc., 400 Commonwealth Drive, Warrendale, PA 15096-0001.

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AEROSPACE MATERIAL SPECIFICATION

SAE AMS 4984A

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Superseding AMS 4984

Submitted for recognition as an American National Standard

TITANIUM ALLOY FORGINGS
10V - 2Fe - 3Al
Consumable Electrode Melted, Solution Heat Treated and Aged
173 ksi (1193 MPa) Tensile Strength

1. SCOPE:

1.1 Form:

This specification covers a titanium alloy in the form of forgings 3.0 inches (76 mm) and under in nominal cross-sectional thickness and of stock for forging.

1.2 Application:

These products have been used typically for parts in high stress and stress-corrosion-resistant applications, but usage is not limited to such applications.

2. APPLICABLE DOCUMENTS:

The following publications form a part of this specification to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order.

2.1 SAE Publications:

Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

AMS 2249 Chemical Check Analysis Limits, Titanium and Titanium Alloys
AMS 2750 Pyrometry
AMS 2808 Identification, Forgings

2.2 ASTM Publications:

Available from ASTM, 1916 Race Street, Philadelphia, PA 19103-1187.

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 384 Microhardness of 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 Alloys by the Inert Gas Fusion Thermal Conductivity Method

2.3 U.S. Government Publications:

Available from DODSSP, Subscription Services Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.

MIL-STD-163 Steel Mill Products, Preparation for Shipment and Storage

3. TECHNICAL REQUIREMENTS:

3.1 Composition:

(R)

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
Vanadium	9.0	11.0
Aluminum	2.6	3.4
Iron	1.6	2.2
Oxygen	--	0.13
Carbon	--	0.05
Nitrogen	--	0.05 (500 ppm)
Hydrogen (3.1.1)	--	0.015 (150 ppm)
Yttrium (3.1.2) (3.1.3)	--	0.005 (50 ppm)
Residual Elements, each (3.1.2)	--	0.10
Residual Elements, total (3.1.2)	--	0.30
Titanium	remainder	

3.1.1 (R) Sample size may be as large as 0.35 g.

3.1.2 Determination not required for routine acceptance.

3.1.3 (R) Check Analysis: Composition variations shall meet the applicable requirements of AMS 2249. If yttrium content is determined, no variation over maximum will be permitted for yttrium.

3.2 Melting Practice:

3.2.1 (R) Alloy shall be multiple melted; the final melting cycle shall be under vacuum. The first melt shall be made by consumable electrode, nonconsumable electrode, electron beam, or plasma arc melting practice. The subsequent melt or melts shall be made using consumable electrode practice with no alloy additions permitted in the last consumable electrode melt.

3.2.1.1 (R) The melting atmosphere for nonconsumable electrode melting shall be vacuum or argon and/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 conditions:

3.3.1 Forgings: Descaled, pickled, solution heat treated, and aged.

3.3.2 Forging Stock: As ordered by the forging manufacturer.

3.4 Heat Treatment: (R)

Forgings shall be solution heat treated and aged as follows; pyrometry shall be in accordance with AMS 2750:

3.4.1 (R) Forgings shall be single solution heat treated in accordance with 3.4.1.1. unless a double solution heat treatment in accordance with 3.4.1.1 and 3.4.1.2 is specified by purchaser.

3.4.1.1 Forgings shall be heated to a temperature 60 to 100 °F (16 to 38 °C) below the beta transus (See 8.2),held at heat for not less than 30 minutes, and either furnace cooled or air cooled to room temperature.

3.4.1.2 Forgings shall be heated to a temperature 60 to 100 °F (16 to 38 °C) below the beta transus (See 8.2), held at heat for not less than 30 minutes, and quenched in water.

3.4.1.3 Other solution heat treatments may be employed when agreed upon by purchaser and vendor.

3.4.2 (R) Aging Heat Treatment: Heat to a temperature within the range 900 to 975 °F (482 to 524 °C), hold at the selected temperature within ±10 °F (±6 °C) for not less than eight hours, and cool to room temperature.

3.4.2.1 (R) If a lot of forgings does not meet the minimum fracture toughness requirement of 3.5.1.2, the lot of forgings may be re-aged by heating to a temperature within the range 900 to 975 °F (482 to 524 °C), holding at the selected temperature within ±10 °F (±6 °C) for up to eight hours, cooling to room temperature, and retested for fracture roughness and tensile properties.

3.4.3 (R) Beta Transus Determination: The beta transus temperature shall be determined by any method acceptable to purchaser. Thermal controls and readouts shall be calibrated to an accuracy of ±5 °F (±3 °C). Beta transus accuracy shall be ±15 °F (±8 °C).

3.5 Properties:

The aged product shall conform to the following requirements:

3.5.1 Forgings:

3.5.1.1 Tensile Properties: Shall be as specified in Table 2, 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 per minute (0.003 to 0.007 mm/mm per 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 per minute) through the yield strength and a minimum cross head speed of 0.10 inch per minute (0.04 mm/s) above the yield strength. Tensile requirements apply in both the longitudinal and transverse directions but tests in the transverse direction need be made only on forgings from which a specimen not less than 2.50 inches (63.5 mm) in length can be taken.

TABLE 2 - Minimum Tensile Properties

Property	Value
Tensile Strength	173 ksi (1193 MPa)
Yield Strength at 0.2% Offset	160 ksi (1103 MPa)
Elongation in 4D	4%
Reduction of Area	Shall be reported except when flat sheet-type specimens are used

3.5.1.2 (R) Fracture Toughness: K_{IC} shall not be lower than 40 ksi $\sqrt{\text{inch}}$ (44 MPa $\sqrt{\text{m}}$), determined in accordance with ASTM E 399.

3.5.1.2.1 (R) Reduction of Test Data: Test data shall be reduced in accordance with ASTM E 399 to calculate a K_Q value and to determine if a valid K_{IC} value has been measured. Tensile coupons shall be provided for validity verification wherever fracture toughness coupons are specified. In checking for validity, the yield strength value used shall be yield strength measured for the same forging from which the fracture toughness specimen was obtained. Not less than one tensile specimen taken immediately adjacent to the location of the fracture toughness specimen is required. Fracture planes of tensile and K_{IC} specimen shall be in the same direction. If a tensile specimen cannot be excised from the forging with the fracture plane in the same direction as that of the fracture toughness specimen, the orientation of the tensile specimen shall be approved by the purchaser.

3.5.1.3 Microstructure: Shall consist of primary alpha phase in a matrix of aged beta phase when examined at 500x magnification. An unbroken, continuous alpha phase network along prior beta phase grain boundaries in any field of view is not acceptable unless purchaser and vendor have agreed that such phase is acceptable if tensile and fracture toughness properties are met.

3.5.1.3.1 No beta flecks shall be visible in material which has been heated up to 1425 °F (774 °C) or 45 °F (25 °C) below the beta transus temperature of the matrix, whichever is higher (See 8.3).

3.5.1.4 Macrostructure and Grain Flow: The grain flow pattern of macroetch sections taken from designated areas of a forging during initial evaluation shall generally conform to the part shape. If areas are not designated by purchaser, two sections shall be taken normal to the parting line in areas having the greatest section variation. If standards are not established, photomacrographs of acceptable macrostructure of a forging from the first production lot shall be the standard. Presence of laps, seams, folds, etc. is not acceptable.

3.5.1.4.1 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.

3.5.1.5 (R) Surface Contamination: Forgings shall be free of any oxygen-rich layer, such as alpha case, or other surface contamination, determined as in 3.5.1.5.1, by microscopic examination at not lower than 100X magnification, or by other method acceptable to purchaser and vendor.

3.5.1.5.1 Microhardness Differential: A surface hardness more than 40 points higher than the subsurface hardness, determined in accordance with ASTM E 384 on the Knoop scale using a 200-gram load, is evidence of unacceptable surface contamination.

3.5.2 (R) 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 a sample taken directly from the forging stock and heat treated as in 3.4 conforms to the requirements of 3.5.1.1, then testing of a forged coupon is not required.

3.6 Quality:

The product, as received by purchaser, shall be uniform in quality and condition, sound, and free from foreign material and from imperfections detrimental to usage of the product.

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 performing 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 requirements of this specification.

4.2 Classification of Tests:

4.2.1 Acceptance Tests: Composition (3.1), beta-transus temperature (3.4.3), tensile properties (3.5.1.1), fracture toughness (3.5.1.2), microstructure (3.5.1.3), and surface contamination (3.5.1.5) are acceptance tests and shall be performed on each heat or lot as applicable.

4.2.2 (R) Periodic Tests: Macrostructure and grain flow (3.5.1.4) and ability of forging stock to meet required properties (3.5.2) are periodic tests and shall be performed at a frequency selected by the vendor unless frequency of testing is specified by purchaser.

4.3 (R) Sampling and Testing:

Shall be not less than the following; a lot shall be all forgings of the same nominal size and configuration, from the same heat, processed at the same time under the same fixed conditions, and presented for vendors inspection at one time:

4.3.1 For Acceptance Tests:

4.3.1.1 Composition: One sample from each ingot except that for hydrogen determinations, one sample from each lot obtained after thermal and chemical processing is completed.

4.3.1.2 Tensile and Fracture Toughness Properties:

4.3.1.2.1 (R) Two samples from a forging or forging prolongations from each lot, sufficient to provide two test specimens for each property to be measured.

4.3.1.2.2 (R) Location of tensile and fracture toughness specimens shall be as agreed upon by purchaser and vendor. If not defined by purchaser, vendor shall select test specimens from the heaviest section and shall select orientation in the following order of preference: longitudinal or transverse for tensile specimens and S-T, T-L, or L-T in accordance with ASTM E 399 for fracture toughness specimens.

4.3.1.2.3 (R) If a K_Q value is invalid solely on the basis of either B is less than 2.5 $(K_Q/TYS)^2$ or P_{max}/PQ is greater than 1.10, the K_Q value may be used as K_{IC} to satisfy the requirements of 3.5.1.2. K_Q values invalid on the basis of criteria other than listed above (e.g., crack front curvature, etc) shall not be used, but an additional specimen shall be tested for each of these invalid specimens.

4.3.1.2.4 Tensile and fracture toughness properties shall be retested on forgings re-aged in accordance with 3.4.2.1.

4.3.1.3 Microstructure and Surface Contamination: One or more samples from each lot. Microstructural evaluations may be taken from any convenient location outside the machined part envelope for surface examination and from broken test specimens for general microstructure.

4.3.1.4 Beta Transus Determination: One sample each from the top and bottom of an ingot produced from a heat or one sample from each lot except that any lot comprising a full ingot shall be sampled on the top and bottom of the ingot.

4.3.2 (R) For Periodic Tests: As agreed upon by purchaser and vendor and as follows:

4.3.2.1 Photographs of the macrostructure and grain flow pattern shall be provided to purchaser.

4.4 Reports:

4.4.1 (R) The vendor of forgings shall furnish with each shipment a report showing the results of tests for chemical composition of each heat and for hydrogen content, tensile properties, and fracture toughness of each lot, macrographs of grain flow, micrographs of microstructure, results of surface contamination examination, and beta transus temperature of each heat of forgings. This report shall include the purchase order number, heat and lot number, AMS 4984A, size, quantity, heat-treat cycle, part number, and the size and melt source of stock used to make the forgings.

4.4.2 The vendor of forging stock shall furnish with each shipment a report showing the results of tests for chemical composition of each heat. This report shall include the purchase order number, heat number, AMS 4984A, size, and quantity.

4.5 Resampling and Retesting:

(R) If any specimen used in the above tests fails to meet the specified requirements, disposition of the product may be based on the results of testing three additional specimens for each original nonconforming specimen except that for fracture toughness tests, resampling is not permitted except as specified by 3.4.2.1 or as specified by 4.3.1.2.3. Failure of any retest specimen to meet the specified requirements shall be cause for rejection of the product represented. Results of all tests shall be reported.