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INTERNATIONAL
400 Commonwealth Drive, Warrendale, PA 15096-0001

AEROSPACE MATERIAL SPECIFICATION

SAE AMS 4986A

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Superseding AMS 4986

Titanium Alloy, Forgings
10V - 2Fe - 3Al
Consumable Electrode Melted, Single Solution Heat Treated and Overaged
160 ksi (1103 MPa) Tensile Strength

1. SCOPE:

1.1 Form:

This specification covers a titanium alloy in the form of forgings 4.0 inches (102 mm) and under in nominal cross-sectional thickness and of forging stock.

1.2 Application:

These forgings have been used typically for parts in high-stress and stress-corrosion-resistant applications requiring higher fracture toughness, but permitting lower tensile properties, than AMS 4984, 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
AMS 4984	Titanium Alloy, Forgings, 10V - 2Fe - 3Al, Consumable Electrode Melted, Solution Heat Treated and Aged, 173 ksi (1193 MPa) Tensile Strength

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2.2 ASTM Publications:

Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

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 and Titanium Alloys by the Inert Gas Fusion Thermal Conductivity Method

3. TECHNICAL REQUIREMENTS:

3.1 Composition:

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 (3.1.3)	--	0.015 (150 ppm)
Yttrium (3.1.1) (3.1.2)	--	0.005 (50 ppm)
Residual Elements, each (3.1.1)	--	0.10
Residual Elements, total (3.1.1)	--	0.30
Titanium	remainder	

3.1.1 Determination not required for routine acceptance.

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

3.1.3 Sample size when determining hydrogen content in accordance with ASTM E 1447, may be as large as 0.35 gram.

3.2 Melting Practice:

3.2.1 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 The melting atmosphere for nonconsumable electrode melting shall be vacuum or shall be 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 condition:

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

3.3.2 Forging Stock: As ordered by the forging manufacturer.

3.4 Heat Treatment:

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

3.4.1 Solution Heat Treatment: Forgings shall be single solution heat treated by heating to a temperature 60 to 100 F (33 to 56 C) degrees below the beta transus (See 8.2), holding at heat for not less than 30 minutes, and quenching in water.

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

3.4.2 Aging Heat Treatment: Heat to a temperature within the range 950 to 1050 °F (510 to 566 °C), hold at the selected temperature within ±10 °F (±6 °C) for not less than 8 hours, and cool to room temperature.

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 per 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	160 ksi (1103 MPa)
Yield Strength at 0.2% Offset	145 ksi (1000 MPa)
Elongation in 4D	6%
Reduction of Area	10%

3.5.1.2 Fracture Toughness: K_{IC} shall be not lower than 55 ksi $\sqrt{inch}$ (60 MPa $\sqrt{m}$), determined in accordance with ASTM E 399.

3.5.1.2.1 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. One or more tensile specimens, taken immediately adjacent to the location of the fracture toughness specimen, are required. Fracture planes of tensile and K_{IC} specimens 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 acceptable to purchaser.

3.5.1.2.2 Any lot of forgings not meeting the minimum fracture toughness requirements of 3.5.1.2 may be re-aged in accordance with 3.4.2 and retested for fracture toughness and tensile properties.

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.

3.5.1.3.1 No beta flecks shall be visible in material which has been heated at temperatures up to 1425 °F (774 °C) or 45 F (25 C) degrees below the beta transus temperature of the matrix, whichever is higher (See 8.2.2).

3.5.1.4 Macrostructure and Grain Flow: The grain flow pattern of macroetched 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 become 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 and grain, shall follow the general contour of the forgings showing no evidence of re-entrant grain flow.:

3.5.1.5 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.

3.5.1.5.1 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.

3.5.1.6 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).

3.5.2 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, 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 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 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 conform to specified requirements.

4.2 Classification of Tests:

4.2.1 Acceptance Tests: Composition (3.1), tensile properties (3.5.1.1), fracture toughness (3.5.1.2), microstructure (3.5.1.3), surface contamination (3.5.1.5), and beta transus determination (3.5.1.6) are acceptance tests and shall be performed on each heat or lot as applicable.

4.2.2 Periodic Tests: Macrostructure and grain flow (3.5.1.4) and tests of forging stock (3.5.2) to demonstrate ability to develop required properties are periodic tests 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 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 vendor's 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 Two samples from a forging or forging prolongations from each lot. Sufficient to provide two test specimens for each property to be evaluated.

4.3.1.2.2 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 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 3.5.1.2.2.

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 tensile specimens for general microstructure.