AEROSPACE MATERIAL SPECIFICATION

AMS4984	REV. F

Issued 1987-01
Revised 2015-07

Superseding AMS4984E

Titanium Alloy Forgings
10V - 2Fe - 3Al
Consumable Electrode Melted, Solution Heat Treated and Aged
173 ksi (1193 MPa) Tensile Strength
(Composition similar to UNS R56410)

RATIONALE

AMS4984F results from a Five Year Review and update of this specification that includes the removal of sample size allowance for hydrogen of Table 1 (covered by ASTM E1447), requires agreement on mechanical property values for material outside specification ranges (3.5.1.1.1 and 8.5), the addition of AS6279 (3.8) and revises the report paragraph (4.4).

1. SCOPE

1.1 Form

This specification covers a titanium alloy in the form of forgings 3.000 inches (76.20 mm) and under in nominal cross-sectional thickness and of stock for forging of any size.

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 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.

AMS2249 Chemical Check Analysis Limits, Titanium and Titanium Alloys

AMS2750 Pyrometry

TO PLACE A DOCUMENT ORDER: **Tel: 877-606-7323 (inside USA and Canada)**
Tel: +1 724-776-4970 (outside USA)
Fax: 724-776-0790
Email: CustomerService@sae.org
SAE WEB ADDRESS: **http://www.sae.org**

SAE values your input. To provide feedback on this Technical Report, please visit
http://www.sae.org/technical/standards/AMS4984F

AMS2808 Identification Forgings

AS6279 Production, Distribution, and Procurement of Metal Stock

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 E384 Knoop and Vickers Hardness of Materials

ASTM E399 Linear-Elastic Plane-Strain Fracture Toughness of Metallic Materials

ASTM E1409 Determination of Oxygen and Nitrogen in Titanium and Titanium Alloys by the Inert Gas Fusion Technique

ASTM E1447 Determination of Hydrogen in 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

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 E2371. Other analytical methods may be used if acceptable to the 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	--	0.015 (150 ppm)
Yttrium (3.1.1) (3.1.2)	--	0.005 (50 ppm)
Other Elements, each (3.1.1)	--	0.10
Other 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 AMS2249. If yttrium content is determined, no variation over maximum will be permitted for yttrium.

3.2 Melting Practice

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 under vacuum using vacuum arc remelting (VAR) practice. Alloy additions are not permitted in the final melt cycle.

3.2.1 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.

3.2.2 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

Solution heat treated, aged, descaled and pickled.

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 AMS2750:

3.4.1 Forgings shall be single solution heat treated in accordance with 3.4.1.2 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 (33 to 56 °C) below the beta transus (See 8.3.2), 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 (33 to 56 °C) below the beta transus (See 8.3.2), 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 producer.

3.4.2 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 8 hours, and cool to room temperature.

3.4.2.1 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 8 hours, cooling to room temperature, and retested for fracture toughness and tensile properties.

3.4.3 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 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 E8/E8M 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.

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

3.5.1.1.1 Mechanical property requirements for product outside the size range covered by 1.1 shall be agreed upon between purchaser and producer.

3.5.1.2 Fracture Toughness

K_{IC} shall be not lower than 40 ksi $\sqrt{inch}$ (44 MPa $\sqrt{m}$), determined in accordance with ASTM E399 for all specimen locations.

To facilitate determination of fracture toughness, a tensile specimen taken immediately adjacent to the location of the fracture toughness specimen is 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 as approved by purchaser.

3.5.1.2.1 Reduction of Test Data

Test data shall be reduced in accordance with ASTM E399 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 producer have agreed that such phase is acceptable and tensile and fracture toughness properties are met.

3.5.1.3.1 No beta flecks shall be visible in material that 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 when examined at a magnification of 50 to 100X (See 8.3). A rejectable beta fleck exhibits no primary alpha in a 0.030 x 0.030 inch (0.762 x 0.762 mm) or equivalent area.

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.

3.5.1.5 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 agreed upon by purchaser and producer.

3.5.1.5.1 Microhardness Differential

A surface hardness more than 40 points higher than the subsurface hardness, determined in accordance with ASTM E384 on the Knoop scale using a 200-gram load, is evidence of unacceptable surface contamination.

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 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.

3.6.1 Grain flow of die forgings, except in areas that contain flash-line end grain, shall follow the general contour of the forgings showing no evidence of reentrant grain flow.

3.7 Production, distribution, and procurement of metal stock shall comply with AS6279. This requirement becomes effective September 1, 2016.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for Inspection

The producer of the product shall supply all samples for producer'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 specified requirements.

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 Periodic Tests

Macrostructure (3.5.1.4) and grain flow (3.6.1) 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 producer unless frequency of testing is specified by purchaser.

4.3 Sampling and Testing

Shall be in accordance with 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 producer's inspection at one time; a heat shall be the consumable electrode remelted ingots produced from alloy originally melted as a single furnace charge.

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 measured.

4.3.1.2.2 Location of tensile and fracture toughness specimens shall be as agreed upon by purchaser and producer. If not defined by purchaser, producer 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 ST, TL, or LT in accordance with ASTM E399 for fracture toughness specimens.

4.3.1.2.3 If a K_Q value is invalid solely on the basis of either W-a is less than 2.5 $(K_Q/TYS)^2$ or P_{max}/PQ is greater than 1.10, and the thickest possible specimen has been used, 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 For Periodic Tests

As agreed upon by purchaser and producer 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 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 hydrogen content, tensile properties, and fracture toughness of each lot, macrographs of grain flow (if required), micrographs of microstructure, results of surface contamination examination, and beta transus temperature of each heat of forgings and state that the product conforms to the other technical requirements. This report shall include the purchase order number, heat and lot number, AMS4984F, size, quantity, heat-treat cycle, part number, and the size and melt source of stock used to make the forgings.