



AEROSPACE MATERIAL SPECIFICATION

AMS4987**REV. E**Issued 1995-12
Revised 2015-01

Superseding AMS4987D

Titanium Alloy, Forgings
10V - 2Fe - 3Al
Consumable Electrode Melted, Single-Step Solution Heat Treated and Overaged
140 ksi (965 MPa) Tensile Strength
(Composition similar to UNS R56410)

RATIONALE

AMS4987E 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 (3.5.1.1.2 and 8.5), the addition of AS6279 (3.7) and revises the report paragraphs (4.4).

1. SCOPE

1.1 Form

This specification covers a titanium alloy in the form of forgings 4.00 inches (101.6 mm) and under in nominal cross-sectional thickness and of forging stock of any size.

1.2 Application

These forgings have been used typically for parts in high stress and stress-corrosion-resistant applications requiring higher fracture toughness and allowing lower tensile properties than AMS4984 and AMS4986, 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.

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2.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA, www.sae.org).

AMS2249	Chemical Check Analysis Limits, Titanium and Titanium Alloys
AMS2750	Pyrometry
AMS2808	Identification, Forgings
AS6279	Industry Standard Practices for 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	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 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.

3.2.2 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

Solution heat treated, overaged, 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 by heating to a temperature 60 to 100 °F (16 to 38 °C) 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 producer.

3.4.1.2 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).

3.4.2 Aging Heat Treatment

Heat to a temperature within the range 1050 to 1150 °F (566 to 621 °C), hold at the selected temperature within ± 15 °F (± 8 °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 for forgings 4.00 inches and under (101.6 mm) in nominal cross-sectional thickness, 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	140 ksi (965 MPa)
Yield Strength at 0.2% Offset	130 ksi (896 MPa)
Elongation in 4D	8%
Reduction of Area	20%

3.5.1.1.1 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 (62.5 mm) in length can be obtained.

3.5.1.1.2 Mechanical property requirements for product outside the range covered by 3.5.1.1 shall be agreed upon between purchaser and producer.

3.5.1.2 Fracture Toughness

K_{IC} shall be not lower than 80 ksi $\sqrt{\text{inch}}$ (88 MPa $\sqrt{\text{m}}$), determined in accordance with ASTM E399 for all specimen orientations. To facilitate determination of fracture toughness a tensile specimens 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 as approved by purchaser.

3.5.1.2.1 Forgings not meeting the minimum fracture toughness requirements may be re-aged in accordance with 3.4.2 and retested for fracture toughness and tensile properties.

3.5.1.3 Microstructure

Microstructural examination shall be conducted using a magnification of not less than 200X on a suitably etched metallographic specimen.

3.5.1.3.1 The microstructure shall consist of primary alpha phase in a matrix of aged beta. An unbroken, continuous alpha phase network along prior beta phase grain boundaries is not acceptable unless purchaser and producer have agreed that such phase is acceptable and tensile and fracture toughness properties are met.

3.5.1.3.2 There shall be no evidence of rejectable beta flecks (See 8.2.2). A rejectable beta fleck exhibits no primary alpha in a 0.030 inch by 0.030 inch or equivalent area.

3.5.1.4 Surface Contamination

Except as specified in 3.5.1.4.2, forgings shall be free of any oxygen-rich layer (See 8.3), such as alpha case, or other surface contamination, determined by microscopic examination at not lower than 400X magnification or other method acceptable to purchaser.

3.5.1.4.1 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, shall be evidence of unacceptable surface contamination.

3.5.1.4.2 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 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 June 01, 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), 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 temperature (3.4.1.2) are acceptance tests and shall be performed on each heat or lot as applicable.

4.2.2 Periodic Tests

Grain flow of die forgings (3.6.1) and tests 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 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 producer'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 measured.

4.3.1.2.2 Location and orientation 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: transverse or longitudinal for tensile specimens and S-T, T-L, or L-T 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}/P_Q 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 Where sufficient material does not exist for retest of the forging having invalid results, the retest may be performed from another forging from the same lot.

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.

4.3.1.5 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 and beta transus temperature of each heat and for hydrogen content, tensile and fracture toughness properties, micrographs of microstructure, and results of surface contamination examination, as applicable, of each lot and state that the product conforms to the other technical requirements. This report shall include the purchase order number, heat and lot numbers, AMS4987E, mill produced size or part number (if applicable), quantity, heat-treat cycle, and the size and melt source of stock used to make the forgings. The producer of forging stock shall furnish with each shipment a report showing the results of tests for chemical composition and beta transus temperature of each heat and hydrogen content of each lot. This report shall include the purchase order number, heat number, AMS4987E, size, and quantity.

4.4.2 Report the nominal metallurgically worked cross sectional size and the cut size, if different.

4.4.3 When the product size is outside the range covered by 3.5.1.1, the report shall contain a statement to that effect.

4.5 Resampling and Retesting

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 3.5.1.2.2 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.