SAE Aerospace
An SAE International Group

AEROSPACE MATERIAL SPECIFICATION

AMS 4986C

Issued JAN 1987
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Superseding AMS 4986B

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

(Composition similar to UNS R56410)

RATIONALE

AMS 4986C results from a Five Year Review and update of this specification.

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 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 724-776-4970 (outside USA), www.sae.org.

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

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

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 E 8	Tension Testing of Metallic Materials
ASTM E 384	Microhardness of Materials
ASTM E 399	Plane-Strain Fracture Toughness of Metallic Materials
ASTM E 1409	Determination of Oxygen and Nitrogen 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/Infrared Detection Method
ASTM E 1941	Determination of Carbon in Refractory and Reactive Metals and Their Alloys
ASTM E 2371	Analysis of Titanium and Titanium Alloys by Atomic Emission Plasma 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 E 1941, hydrogen in accordance with ASTM E 1447, oxygen and nitrogen in accordance with ASTM E 1409, and other elements in accordance with ASTM E 2371. 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 (3.1.3)	--	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 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

Alloy shall be multiple melted. Melting cycle(s) prior to the final melting cycle shall be made using vacuum consumable electrode, nonconsumable electrode, electron beam cold hearth, or plasma arc cold hearth melting practice. The final melting cycle shall be made under vacuum using vacuum arc remelting (VAR) practice with no alloy additions permitted.

3.2.1 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.

3.2.2 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 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.

3.4.1.2 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 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 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 for all specimen orientations. 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 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 vendor 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 when examined at a magnification of 50-100X (See 8.2.2). A rejectable beta fleck exhibits no primary alpha in 0.030 inch by 0.030 inch (0.762 mm by 0.762 mm) or equivalent area.

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.

3.5.1.5 Surface Contamination

Except as specified in 3.5.1.5.2, forgings shall be free of any oxygen-rich layer, such as alpha case, or other surface contamination, as determined by microscopic examination at not lower than 400X magnification, or by other method acceptable to purchaser.

3.5.1.3.3 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.

3.5.1.3.4 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, 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.

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 (3.4.1.2) 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), grain flow of die forgings (3.6.1), 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 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 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 had 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.