The Engineering Society For Advancing Mobility Land Sea Air and Space®
INTERNATIONAL
400 Commonwealth Drive, Warrendale, PA 15096-0001

AEROSPACE MATERIAL SPECIFICATION

SAE AMS 4985B

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Submitted for recognition as an American National Standard

Superseding AMS 4985A

(R) TITANIUM ALLOY, INVESTMENT CASTINGS
6Al - 4V
130 UTS, 120 YS, 6% EL
Hot Isostatically Pressed
Anneal Optional or When Specified

UNS R56401

1. SCOPE:

1.1 Form:

This specification covers a titanium alloy in the form of investment castings.

1.2 Application:

These castings have been used typically for parts of intricate design requiring a combination of good strength-to-weight ratio and corrosion resistance, 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 2694 Repair Welding of Aerospace Castings
AMS 2804 Identification, Castings

2.2 ASTM Publications:

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

ASTM B 600	Descaling and Cleaning Titanium and Titanium-Alloy Surfaces
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 155	Reference Radiographs for Inspection of Aluminum and Magnesium Castings
ASTM E 192	Reference Radiographs of Investment Steel Castings of Aerospace Applications
ASTM E 1320	Reference Radiographs for Titanium Castings
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

2.3 U.S. Government Publications:

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

MIL-H-81200	Heat Treatment of Titanium and Titanium Alloys
MIL-STD-453	Inspection, Radiographic
MIL-STD-2175	Castings, Classification and Inspection of
MIL-STD-6866	Inspection, Liquid Penetrant

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 in accordance with ASTM E 120, by spectrochemical methods, or by other analytical methods acceptable to purchaser (See 8.2.1 and 8.2.2).

TABLE 1 - Composition

Element	min	max
Aluminum	5.50	6.75
Vanadium	3.50	4.50
Iron	--	0.30
Oxygen	--	0.20
Carbon	--	0.10
Nitrogen	--	0.05 (500 ppm)
Hydrogen (3.1.2)	--	0.015 (150 ppm)
Yttrium (3.1.1)	--	0.005 (50 ppm)
Residual Elements, each (3.1.1)	--	0.10
Residual Elements, total (3.1.1)	--	0.40
Titanium	remainder	

3.1.1 Determination not required for routine acceptance.

3.1.2 For hydrogen analysis conducted in accordance with ASTM E 1447, sample size may be as large as 0.35 gram.

3.1.3 Check Analysis: Composition variations shall meet the requirements of AMS 2249.

3.2 Melting Practice:

3.2.1 Castings and specimens shall be poured, at the casting vendor's facility, either from a remelt (See 8.2.3) of a master heat or directly from a master heat.

3.2.1.1 Remelt for Casting: The metal for castings and specimens shall be remelted and poured under inert gas pressure in accordance with 3.2.2.1, or under vacuum without loss of vacuum between melting and pouring.

3.2.1.2 If authorized by purchaser (See 8.2.4), portions of two or more qualified master heats of 3.2.3 may be remelted together and poured into castings using a procedure acceptable to purchaser.

3.2.1.3 Remelt for casting shall be performed using consumable electrode-practice or other method authorized by purchaser.

3.2.2 Master Heat Preparation: A master heat shall be prepared from any combination of elemental and revert materials which are melted and refined as necessary in a single furnace charge. Single or multiple melting shall be accomplished using consumable electrode, nonconsumable electrode, electron beam, or plasma arc practice(s).

3.2.2.1 The atmosphere for melting shall be vacuum or shall be argon and/or helium at an absolute pressure not higher than 1000 millimeters of mercury.

3.2.2.2 Revert (gates, sprues, risers, and rejected castings) may be used in the preparation of master heats.

3.2.2.3 Solidification of the master heat into pigs or ingots before remelting and pouring of castings is permitted.

3.2.2.4 The master heat source shall establish effective control procedures, including parameters for the critical variables that will consistently produce material suitable for remelting of castings, meeting the requirements of this specification. Control procedures shall be acceptable to purchaser and casting vendor,

3.2.3 Master Heat Qualification: Each master heat shall be qualified by evaluation of chemical analysis and tensile specimens.

3.2.3.1 Specimens shall be either separately-cast, integrally-cast (See 8.2.5), or machined from a casting, and shall conform to 3.2.1.

3.2.3.2 If specimens are separately-cast, vendor shall have a written procedure acceptable to purchaser. Control factors of 4.4.2.2 shall apply.

3.2.3.3 Specimens used for master heat tensile qualification tests shall be hot isostatically pressed, and annealed, as specified in the written procedure of 3.2.3.2.

3.2.3.4 Specimens used for master heat tensile qualification tests may be hot isostatically pressed, and annealed, separate from castings.

3.2.3.5 The acceptance tests of 4.2.1 may be used to satisfy the qualification requirements of 3.2.3.

3.3 Condition:

3.3.1 Castings shall be hot isostatically pressed.

3.3.2 A separate annealing operation may be performed, but it is not required.

3.3.2.1 A separate annealing operation is not required if castings are hot isostatically pressed.

3.3.3 The vendor shall record the type of thermal processing performed as a control factor of 4.4.2.2.

3.3.4 If welding is performed (See 3.7.5.1), castings shall be hot isostatically pressed and/or annealed after welding (See 3.7.5.2).

3.4 Test Specimens:

3.4.1 Chemical Analysis Specimens: Shall be of any convenient size and shape.

3.4.2 Tensile Specimens: Shall be of standard proportions in accordance with ASTM E 8 or ASTM E 8M (See 8.3) with 0.250 inch (6.35 mm) diameter at the reduced parallel gage section.

3.4.2.1 Separately-cast and integrally-cast specimens may be either cast to size or cast oversize and subsequently machined to 0.250 inch (6.35 mm) diameter.

3.4.2.1.1 After machining or chemical cleaning, tensile specimens shall be free of oxygen-rich layer, such as alpha case, or other surface contamination.

3.4.2.2 When integrally-cast specimens and specimens machined from castings are specified, specimen size and location shall be agreed upon by purchaser and vendor (See 8.2.7 and 8.5).

3.5 Thermal Processing:

Castings and representative tensile specimens shall be hot isostatically pressed in accordance with 3.5.1. When performed, annealing shall be in accordance with 3.5.2.

3.51 Hot Isostatic Pressing: Process at not less than 14.5 ksi (100 MPa) within the range 1650 to 1750 °F (899 to 954 °C), hold at the selected temperature within ±25 F (±14 C) degrees for 2 to 4 hours, and cool under inert atmosphere in the autoclave to below 800 °F(427 °C).

3.5.2 Anneal: Process in vacuum or inert atmosphere at a temperature within the range 1300 to 1550 °F (704 to 843 °C), hold at the selected temperature within ±25 F (±14 C) degrees for 2 to 4 hours, and cool in the furnace to below 1000 °F (538 °C), and cool in air to room temperature. The provisions of MIL-H-81200 shall apply.

3.6 Properties:

Castings and separately-cast tensile specimens shall conform to the following requirements; conformance to the requirements of 3.6.1.1 shall be used for acceptance of castings unless purchaser specifies that requirements of 3.6.1.2 apply.

3.6.1 Tensile Properties: Shall be as specified in 3.6.1.1 or 3.6.1.2 determined in accordance with ASTM E 8 or ASTM E 8M (See 8.3) 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.

3.6.1.1 Separately-Cast Specimens: Shall be as shown in Table 2.

TABLE 2 - Minimum Tensile Properties

Property	Value
Tensile Strength	130 ksi (896 MPa)
Yield Strength at 0.2% Offset	120 ksi (827 MPa)
Elongation in 4D	6%

3.6.1.2 Integrally-Cast Specimens and Specimens Machined from a Casting: Shall be as shown in Table 3 for designated areas and Table 4 for nondesignated areas,

3.6.1.2.1 Designated Areas: Shall be as shown in Table 3.

TABLE 3 - Minimum Tensile Properties

Property	Value
Tensile Strength	130 ksi (896 MPa)
Yield Strength at 0.2% Offset	120 ksi (827 MPa)
Elongation in 4D	6%

3.6.1.2.2 Nondesignated Areas: Shall be as shown in Table 4.

TABLE 4 - Minimum Tensile Properties

Property	Value
Tensile Strength	125 ksi (862 MPa)
Yield Strength at 0.2% Offset	108 ksi (745 MPa)
Elongation in 4D	4.5%

3.6.2 Surface Contamination: Castings shall be free of any oxygen-rich layer, such as alpha case, compounds, such as residue from halogenated solvents, and quenchants, or other surface contamination.

3.6.2.1 Cleaning shall be performed in accordance with ASTM B 600 or other method(s) acceptable to purchaser.

3.6.2.2 After cleaning, and prior to any subsequent processing involving temperatures over 500 °F (260 °C), castings shall be handled in a manner to preclude surface contamination. Handling with clean, dry, white cotton gloves is recommended.

3.7 Quality:

Castings, as received by purchaser, shall be uniform in quality and condition, sound, and free from foreign materials and from imperfections detrimental to usage of the castings. Castings shall be free of cracks, laps, hot tears, and cold shuts.

3.7.1 Castings shall be produced under radiographic control. This control shall consist of radiographic examination of each casting part number until foundry manufacturing controls, in accordance with 4.4.2, have been established. Additional radiography shall be conducted in accordance with the frequency of inspection specified by purchaser and as necessary to ensure continued maintenance of internal quality.

3.7.1.1 Radiographic inspection shall be conducted in accordance with MIL-STD-453 or other method specified by purchaser.

3.7.2 When specified, castings shall be subjected to fluorescent penetrant inspection in accordance with MIL-STD-6866 or other method specified by purchaser.

3.7.3 Acceptance standards for radiographic, fluorescent penetrant, visual, surface contamination, and other inspections shall be as agreed upon by purchaser and vendor.

3.7.3.1 MIL-STD-2175 may be used to specify frequency of inspection (casting class).

3.7.3.2 ASTM E 1320, ASTM E 155, and ASTM E 192 may be used to specify radiographic standards (casting grade).

3.7.4 Castings shall not be peened, plugged, impregnated, or welded unless authorized by purchaser.

3.7.4.1 When authorized by purchaser, in-process welding in accordance with AMS 2694 or other welding program acceptable to purchaser may be used.

3.7.4.2 Unless otherwise specified by purchaser, castings shall be hot isostatically pressed and/or annealed after welding, except that castings which are hot isostatically pressed before welding need not be hot isostatically pressed after welding.

4. QUALITY ASSURANCE PROVISIONS:

4.1 Responsibility for Inspection:

The vendor of castings 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 (3.6.1), surface contamination (3.6.2), and quality requirements (3.7) are acceptance tests and shall be performed as specified in 4.3.

4.2.2 Periodic Tests: Radiographic soundness (3.7.2) is a periodic test and shall be performed at a frequency selected by the vendor unless frequency of testing is specified by purchaser.

4.2.3 Preproduction Tests: All technical requirements are preproduction tests and shall be performed on sample castings (4.3.2), when a change in control factors (4.4.2.2) occurs, and when purchaser deems confirmatory testing to be required.

4.3 Sampling and Testing:

Shall be in accordance with the following:

4.3.1 One chemical analysis specimen in accordance with 3.4.1 from each master heat or a casting from each master heat shall be tested for conformance to Table 1.

4.3.1.1 Except as specified in 4.3.1.2, hydrogen determination shall be on each lot (See 8.2.8) if chemical cleaning (See 8.2.9) is performed after thermal processing, if final anneal heat treatment is performed under inert atmosphere, or if castings are delivered in the hot isostatically pressed condition without subsequent vacuum anneal heat treatment.

4.3.1.2 Hydrogen determination is permitted on each master heat if final anneal heat treatment is performed in vacuum, and if no further chemical cleaning is performed after vacuum anneal heat treatment.

4.3.2 One preproduction casting in accordance with 4.4 shall be tested to the requirements of the casting drawing and to all technical requirements.

4.3.2.1 Dimensional inspection sample quantity shall be as specified by purchaser.

4.3.3 Tensile tests shall be conducted to determine conformance with 3.6.1. Sampling and test frequency is dependent upon the type and origin of specimen specified by purchaser (See 3.6) or selected by vendor (See 4.3.3.4).

4.3.3.1 For separately-cast specimens in the representative condition of 3.5, one or more specimens from each master heat shall be tested for conformance to 3.6.1.1.

4.3.3.2 For integrally-cast specimens in the representative condition of 3.5, at least two specimens from each lot (See 8.2.8) shall be randomly selected and tested for conformance with 3.6.1.2.1 for designated areas and/or 3.6.1.2.2 for nondesignated areas.

4.3.3.3 For specimens machined from a casting, one or more castings in the representative condition of 3.5 shall be randomly selected from each lot (See 8.2.8) and tested at each location shown on the engineering drawing for conformance with 3.6.1.2.1 for designated areas and/or 3.6.1.2.2 for nondesignated areas.

4.3.3.3.1 If designated areas are evaluated, the nondesignated areas need not be tested.

4.3.3.4 When acceptable to purchaser, specimens machined from a casting may be used in lieu of both separately-cast and integrally-cast specimens, and integrally-cast specimens may be used in lieu of separately-cast specimens. In each case, the resultant properties must conform to the requirements of 3.6.1.2 for that origin and type of specimen.

4.3.3.4.1 When specimens are selected for test as in 4.3.3.4 from an origin other than that specified by purchaser, vendor shall include in the report of 4.5, a description of the origin of the specimen that was tested.

4.3.3.5 When casting size, section thickness, gating method, or other factors do not permit conformance to 4.3.3.2 or 4.3.3.3, the sampling and testing shall be agreed upon by purchaser and vendor.

4.3.4 Castings shall be inspected in accordance with 3.7 to the methods, frequency, and acceptance standards specified by purchaser.

4.3.5 Freedom from surface contamination shall be evaluated on a casting or representative specimen from each lot after completion of all thermal treatments, or by evaluation of castings or representative specimens taken individually from each hot isostatic press, and anneal if applicable, process batch.

4.3.5.1 Techniques used for metallographic examination shall be acceptable to purchaser.

4.4 Approval:

4.4.1 Sample casting(s) from new or reworked master patterns produced under the casting procedure of 4.42 shall be approved by purchaser before castings for production use are supplied, unless such approval is waived by purchaser.

4.4.2 For each casting part number, vendor shall establish parameters for process control factors that will consistently produce castings and test specimens meeting the requirements of the casting drawing and this specification. These parameters shall constitute the approved casting procedure and shall be used for production of subsequent castings and test specimens. If necessary to make any change to these parameters, vendor shall submit a statement of the proposed change for purchaser reapproval. When requested, vendor shall also submit test specimens and/or sample castings to purchaser for reapproval.

4.4.2.1 Production castings produced prior to receipt of purchaser's approval shall be at vendors risk.

4.4.2.2 Control factors for producing castings and separately-cast specimens include, but are not limited to, the following factors. Suppliers procedures shall identify tolerances, ranges, and/or control limits, as applicable. Control factors for separately-cast specimens must generally represent, but need not be identical to, those factors used for castings:

Master heat metal source
Composition of ceramic cores, if used
Arrangement and number of patterns in the mold (including integrally-cast specimens, if applicable)
Size, shape, and location of gates and sprues
Mold refractory formulation, including prime and backup materials
Mold backup material (weight, thickness, or number of dips)
Type of furnace, atmosphere control, and charging and melting practices
Mold preheat and metal pouring temperatures
Solidification and cooling procedures
Cleaning operations (mechanical and chemical/electrochemical)
Annealing heat treatment, if applicable
Hot isostatic pressing treatment
Straightening procedures, if applicable
Final inspection methods
Location of specimens machined from a casting, if applicable

4.4.2.2.1 Any of the above control factors for which parameters are considered proprietary by vendor may be assigned a code designation. Each variation in such parameters shall be assigned a modified code designation.

4.4.2.2.1.1 Unless otherwise agreed upon by purchaser and vendor, purchaser shall be entitled to review proprietary control factor details and coding at vendor's facility.