SAE Aerospace
An SAE International Group

AEROSPACE MATERIAL SPECIFICATION

SAE AMS4962 REV. A

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Superseding AMS4962

Titanium Alloy, Investment Castings 6Al - 4V Hot Isostatically Pressed

RATIONALE

AMS4962A has been reaffirmed to comply with the SAE five-year review policy.

NONCURRENT NOTICE

This specification has been declared "NONCURRENT" by the Aerospace Materials Division, SAE, as of September, 2003. It is recommended, therefore, that this specification not be specified for new designs.

"NONCURRENT" refers to those specifications that have been widely used and may be required on some existing designs in the future. The Aerospace Materials Division, however, does not recommend these specifications for future use in new designs. "NONCURRENT" specifications are available from SAE upon request.

AMS 4992 is a similar, but no identical specification..

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SAE values your input. To provide feedback on this Technical Report, please visit
http://www.sae.org/technical/standards/AMS4962A

1. SCOPE:

1.1 Form:

This specification covers a premium grade 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 up to 550 °F (288 °C), 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 2750	Pyrometry
AMS 2804	Identification, Castings

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 1320	Reference Radiographs for Titanium Castings
ASTM E 1409	Determination of Oxygen in Titanium and Titanium Alloys by the Inert Gas Fusion Techniques
ASTM E 1417	Liquid Penetrant Examination
ASTM E 1447	Determination of Hydrogen in Titanium and Titanium Alloys by the Inert Gas Fusion Thermal Conductivity Method
ASTM E 1742	Radiographic Examination

2.3 U.S. Government Publications:

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

AMS-H-81200B	Heat Treatment of Titanium and Titanium Alloys
AMS-STD-2175	Castings, Classification and Inspection of

3. TECHNICAL REQUIREMENTS:

3.1 Composition:

Castings 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 (See 3.1.3), and other elements by wet chemical methods in accordance with ASTM E 120, by spectrochemical methods, or by other analytical methods acceptable to purchaser (See 8.1.2).

TABLE 1 - Composition

Element	min	max
Aluminum	5.75	6.50
Vanadium	3.60	4.50
Oxygen	0.13	0.17
Nitrogen	0.01	0.03 (100 ppm to 300 ppm)
Iron	--	0.25
Carbon	--	0.07
Yttrium	--	0.005 (50 ppm)
Hydrogen	--	0.01 (100 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 Check Analysis: Compositional variations shall meet the requirements of AMS 2249.

3.1.3 Sample size when using ASTM E 1447 may be as large as 0.35 gram.

3.2 Melting Practice:

3.2.1 Castings and specimens shall be poured, at the casting vendor's facility, either from a remelt 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 3.2.3 or under vacuum without loss of vacuum between melting and pouring.

3.2.1.2 If authorized by purchaser, portions of two or more qualified master heats 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.

3.2.1.4 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.

3.2.1.5 The electrode tip for nonconsumable electrode melting shall be water-cooled copper.

3.2.2 Portions of two or more qualified master heats may be melted together and poured into castings using a procedure authorized by purchaser (See 8.1.6).

3.2.3 Casting shall be poured under vacuum, or under partial inert gas pressure (See 3.2.1) without loss of vacuum or atmosphere control between melting and pouring.

3.2.4 Vendor shall have a written procedure, approved by purchaser (See 8.1.6) in accordance with 4.4, which defines the process control factors, tests, and traceability criteria for castings. All production castings shall be poured at the vendor's facility in accordance with the written procedure. Changes to the written procedure shall be made only as approved by purchaser in accordance with 4.4.

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

3.3 Condition:

Castings shall be furnished in the hot isostatically pressed (HIP) condition (See 3.5).

3.4 Test Specimens:

3.4.1 Chemical Analysis Specimens: Shall be removed from castings, casting prolongations, or gating as required to determine conformance to 3.1 for each casting lot or master heat as applicable (See 4.3). Specimens shall be of any convenient size and shape suitable for the methods of analysis. HIP processing shall be completed prior to removing specimens for analysis for oxygen, nitrogen, and hydrogen. Chemical or electrochemical processing, if used, shall be completed prior to removal of specimens for hydrogen analysis.

3.4.2 Tensile Specimens: Shall be removed from castings as required to determine conformance to 3.6 for each casting lot (See 4.3). Specimens shall be machined or cast to standard proportions in accordance with ASTM E 8 or ASTM E 8M. Where ASTM E 8M is used, the gage length shall be equal to four times the nominal diameter of the reduced section of the tensile specimen.

3.4.2.1 Specimen location shall be as agreed upon by purchaser and vendor (See 8.1.8).

3.4.2.2 When casting size or section thickness do not permit the removal of standard test specimens in accordance with ASTM E 8 or ASTM E 8M, sampling and testing for tensile properties shall be as agreed upon by purchaser and vendor.

3.4.2.3 HIP processing, and, when performed, annealing after welding (See 3.9.2.3), shall be completed prior to removing tensile specimens.

3.5 Hot Isostatic Processing (HIP):

Castings shall be hot isostatically pressed at 15 ksi ± 0.5 (100 MPa ± 3) at a temperature of 1650 °F ± 25 (899 °C ± 14) for not less than 2 hours, and cooled in the autoclave to below 800 °F (427 °C). Pyrometry shall be in accordance with AMS 2750.

3.6 Room Temperature Tensile Properties:

Shall be as shown in Table 2 for casting or sections of castings 1.00 inch (25.4 mm) and under in thickness, determined in accordance with ASTM E 8 or ASTM E 8M (see 3.4.2). 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/minute (0.005 mm/mm/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.

TABLE 2 - MInimum Room Temperature Tensile Properties

Property	Value
Tensile Strength	125 ksi (862 MPa)
Yield Strength at 0.2% Offset	120 ksi (827 MPa)
Elongation in 4D	5%

3.7 Surface Contamination:

Castings, as received by purchaser, shall be free of any oxygen rich layer, such as alpha case, or other surface contamination, determined by metallographic examination of cross sections at not lower than 200X magnification.

3.8 Casting Classification and Inspection:

Purchaser shall specify applicable inspection methods, the required minimum frequency of inspection (casting class) and acceptance standards (casting grade). Purchaser may zone different areas of the casting with different classifications or grades (See 8.1.9).

3.8.1 Castings shall be produced under radiographic control. This control shall consist of radiographic examination of each casting until process controls in accordance with 4.4.2 have been established to ensure production of acceptable castings. The frequency of subsequent radiographic inspection shall be in accordance with the frequency required by purchaser.

3.8.1.1 AMS-STD-2175 may be used to specify radiographic test frequency.

3.8.1.2 Radiographic inspection shall be in accordance with ASTM E 1742.

3.8.1.3 If the reference radiographs of ASTM E 1320 are used, purchaser shall specify the maximum acceptable plate size allowed for each discontinuity type.

3.8.2 Fluorescent penetrant inspection shall be performed in accordance with ASTM E 1417.

3.8.2.1 Where acceptance limits are not specified, limits shall conform to the maximum allowable discontinuity size and distribution for fluorescent penetrant inspection of AMS-STD-2175, Grade B.

3.9 Quality:

3.9.1 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.

3.9.1.1 Castings shall be free of cracks, laps, tears, and cold shuts.

3.9.1.2 Castings shall be free of scale, excessive roughness, and other process induced surface contamination which could obscure defects.

3.9.1.3 Discrete Positive Material: Unless otherwise specified, isolated, well-rounded, and smoothly-adhered positives are permitted as follows:

3.9.1.3.1 As-Cast Surfaces: An unlimited quantity equal to or less than 0.005 inch (0.13 mm) in height are allowed, with unlimited positives up to 0.020 inch (0.51 mm) in height and 0.04 inch (1.0 mm) in diameter allowed in a 1 inch (25 mm) square area.

3.9.1.3.2 Subsequently Machined Areas: An unlimited quantity equal to or less than 0.06 inch (1.5 mm) are allowed.

3.9.1.3.3 Other Positive Material: Unless otherwise specified, evidence of parting lines, masking lines, wax welds, in-process weld witness, and gate witness is permitted as follows:

3.9.1.3.3.1 As-Cast Surfaces: Shall be equal to or less than unlimited positions up to 0.020 inch (0.51 mm) in height.

3.9.1.3.3.2 Subsequently Machined Surfaces: Shall be equal to or less than 0.06 inch (1.5 mm) in height.

3.9.1.4 Unless otherwise specified, discrete surface pits and depressions shall have well-rounded and smooth bottoms, shall not exceed 10% of the wall thickness of the casting or 0.03 inches (0.75 mm) in depth, whichever is less, shall not exceed 0.06 inches (1.5 mm) in diameter, and shall be separated by at least two times the diameter of the largest such discontinuity.

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

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

3.9.2.2 Purchaser may define areas of the casting where welding is not permitted.

3.9.2.3 After welding, castings shall be annealed by heating to 1550 °F ± 25 (843 °C ± 14) for not less than two hours in a vacuum, or shall be hot isostatically pressed in accordance with 3.5. Pyrometry for annealing heat treatment and instruments/thermocouples shall be in accordance with AMS 2750.

3.10 Processing:

3.10.1 Castings shall not be exposed to halogenated solvents.

3.10.2 Castings shall not be exposed to organic halogen-bearing compounds unless such compounds are promptly and completely removed by subsequent cleaning using procedures acceptable to purchaser.

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 witness vendor tests, to sample, and to perform any confirmatory testing deemed necessary to ensure that the castings conform to specified requirements.

4.2 Classification of Tests:

4.2.1 Acceptance Tests: Composition (3.1), tensile properties (3.6), surface contamination (3.7) and inspection of castings (3.8), except as specified in 4.2.2, are acceptance tests and shall be performed on each lot.

4.2.2 Periodic Tests: Radiographic inspection (3.8.1) is a periodic test when performed at a sampling frequency specified in accordance with AMS-STD-2175.

4.2.3 Preproduction Tests: All technical requirements are preproduction tests and shall be performed on sample casting prior to or on the initial shipment of castings to a purchaser, when a change in control factors occurs (See 4.4.2), and when purchaser deems confirmatory testing to be required.

4.3 Sampling and Testing:

The minimum testing performed by vendor shall be in accordance with the following:

4.3.1 One chemical analysis specimen (See 3.4.1) shall be taken from each master heat or casting lot as applicable and tested for conformance with Table 1. Oxygen, nitrogen, and hydrogen determinations shall be obtained on a casting lot basis (See 8.1.4) after processing.

4.3.2 One or more preproduction sample castings shall be tested to requirements of the casting drawing and to all technical requirements of this specification. Purchaser may specify the quantity of preproduction sample castings tested.

4.3.3 Tensile Specimens: When casting size and section thickness permit tensile specimens to be extracted from the casting, one casting of the lowest radiographic quality shall be selected from each lot and tested for conformance to 3.6.

4.3.3.1 For determining conformance to 3.6, when specimen locations are not shown on the drawing, not less than three tensile specimens in accordance with 3.4.2 shall be removed and tested. Once established and approved (See 4.4.2), test specimen locations may be changed only as agreed upon by purchaser and vendor.

4.3.3.2 When casting size or section thickness do not permit the removal of standard test specimens in accordance with ASTM E 8 or ASTM E 8M, sampling and testing for tensile properties shall be as agreed upon by purchaser and vendor.

4.3.4 All castings shall be fluorescent penetrant inspected.

4.3.5 Minimum radiographic inspection frequency shall be in accordance with the frequency of non-destructive inspection specified by purchaser (See 4.2.2).

4.4 Approval:

4.4.1 Sample casting(s) from new or reworked master patterns produced under the casting procedure of 4.4.2 shall be approved by purchaser before castings for production use are supplied, unless such approval be 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 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. If necessary to make any change to these parameters, vendor shall submit a statement of the proposed changes for purchaser's reapproval. When requested, vendor shall also submit test specimens, sample castings, or both, to purchaser for reapproval.

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