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Titanium and Titanium-Alloy Castings, Investment			

RATIONALE

AMS-T-81915A 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 November 2008. It is recommended, therefore, that this specification not be specified for new designs.

"NONCURRENT" refers to those specifications which have previously been widely used and which may be required for production or processing of 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.

Similar but not necessarily identical products are covered in the following specifications. However, this listing is provided for information only and does not constitute authority to substitute these specifications for the "NONCURRENT" specification.

AMS4985	Titanium Alloy, Investment Castings 6Al – 4V, 130 UTS, 120 YS, 6% EL, Hot Isostatically Pressed Anneal Optional or When Specified
AMS4991	Titanium Alloy Castings, Investment 6Al – 4V Hot Isostatic Pressed, Anneal Optional
AMS4992	Castings, Structural Investment, Titanium Alloy 6al 4v Hot Isostatically Pressed

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NOTICE

This document has been taken directly from U.S. Military Specification MIL-T-81915, Amendment 1, and contains only minor editorial and format changes required to bring it into conformance with the publishing requirements of SAE technical standards. The initial release of this document is intended to replace MIL-T-81915, Amendment 1. Any part numbers established by the original specification remain unchanged.

The original Military Specification was adopted as an SAE standard under the provisions of the SAE Technical Standards Board (TSB) Rules and Regulations (TSB 001) pertaining to accelerated adoption of government specifications and standards. TSB rules provide for (a) the publication of portions of unrevised government specifications and standards without consensus voting at the SAE Committee level, and (b) the use of the existing government specification or standard format.

Under Department of Defense policies and procedures, any qualifications requirements and associated qualified products lists are mandatory to DOD contracts. Any requirement relating to qualified products lists (QPL's) has not been adopted by SAE and is not part of this technical report.

1. SCOPE:

1.1 Scope:

This specification prescribes the requirements for Titanium and Titanium-alloy castings produced by the investment casting process.

1.2 Classification:

The titanium and titanium-alloy castings furnished under this specification shall be of the following types, compositions and grades (see 6.2).

1.2.1 Types and composition:

Type I	Commercially pure titanium Composition A (see 3.2)
Type II	Alpha-titanium alloy Composition A - Ti-5Al-2.5Sn
Type III	Alpha-beta titanium alloy Composition A - Ti-6Al-4V Composition B - Ti-6Al-2Sn-4Zr-2Mo

1.2.2 Grades: Castings shall be of Grades A, B and C as shown in Tables II and III, and shall be in accordance with the radiographic reference specified in the tables.

2. APPLICABLE DOCUMENTS:

The following publications of the issue in effect on date of invitation for bids or request for proposal, form a part of this specification to the extent specified herein.

2.1 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
FED-STD-151	Metals; Test Methods
FED-STD-184	Identification Marking of Aluminum, Magnesium and Titanium
MIL-STD-105	Sampling Procedures and Tables for Inspection by Attributes
MIL-STD-129	Marking for Shipment and Storage
MIL-STD-453	Inspection, Radiographic
MIL-STD-2175	Casting, Classification and Inspection of
MIL-STD-6866	Inspection, Liquid Penetrant

2.2 ASTM Publications:

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

ASTM B 660	Packaging/Packing of Aluminum and Magnesium Products, Standard Practice for
ASTM E 8	Tension Testing of Metallic Materials
ASTM E 155	Reference Radiographs for Inspection of Aluminum and Magnesium Castings (Series II)

3. REQUIREMENTS:

3.1 Melting Processes:

The material shall be produced by multiple melting under vacuum or inert atmosphere. Melting processes shall include either singly or in combination, electro-consumable arc, electron beam or other vacuum melting processes suitable for the production of materials meeting the requirements of this specification.

3.2 First Article:

Unless otherwise specified in the contract or order, two castings shall be submitted in advance of production as directed by the procuring activity for examination and written approval. One casting shall be identified as the "dimensional sample," and shall be for dimensional approval. The other casting shall be identified as the "foundry control sample," and shall be for radiography and destructive tests as necessary for approval (see 6.2).

3.2.1 The submitted castings shall be fully representative of the foundry practice that will be used in production. If temporary gating was used to develop suitable foundry practice, the submitted casting shall be made after the permanent gating has been installed. All critical melting and pouring parameters shall be recorded.

3.2.2 Molds: The mold materials should be essentially nonreactive, as shall the atmospheres in the molds at the time of pouring.

3.2.3 Surface contamination: The surfaces of castings shall be free from surface contamination by oxygen, nitrogen or carbon. Pickling or chemical milling may be used to remove contaminated zones from as-cast surfaces. The surface roughness shall not exceed RHR 80 when the casting is submitted to the purchaser.

3.3 Material:

The material shall be such as to produce investment castings in full compliance with the requirements specified herein.

3.4 Chemical composition:

The chemical analysis of castings shall comply with the limits specified in Table I.

TABLE 1. CHEMICAL COMPOSITION, PERCENT BY WEIGHT ^{1/}

COMPOSITION	ELEMENTS										
	Al	Sn	Mo	V	Zr	Fe	C	N	H ^{2/}	O	Ti Total Other Elements
TYPE I - COMMERCIALLY PURE TITANIUM											
A	-	-	-	-	-	0.20	0.08	0.05	0.015	0.20	Bal 0.60
TYPE II - ALPHA TITANIUM ALLOY											
A (5Al-2.5Sn)	4.50- 5.75	2.0- 3.0	-	-	-	0.50	0.08	0.05	0.020	0.20	Bal 0.40
TYPE III - ALPHA-BETA TITANIUM ALLOY											
A (6Al-4V)	5.5- 6.75	-	-	3.5- 4.5	-	0.30	0.08	0.05	0.015	0.20	Bal 0.40
B (6Al-2Sn-4Zr -2Mo)	5.5 6.5	1.5 2.5	1.5 2.5	-	3.6 4.4	0.35	0.08	0.05	0.015	0.12	Bal 0.40

- ^{1/} Percent maximum, except where indicated as a range.
- ^{2/} Hydrogen shall be determined on each lot of the product as shipped.

3.5 Foundry control:

Castings shall be produced under foundry control approved by the procuring activity. Foundry control shall consist of examination of castings by radiographic methods for determining internal defects until the gating and other foundry practices have been established to produce castings meeting the quality standards furnished by the procuring activity or agreed upon by the procuring activity and contractor. When foundry practices have been so established, the production method shall not be changed until the procuring activity is satisfied that the change does not adversely affect the quality of the castings.

3.6 Soundness:

When specified (see 6.2), the soundness of castings shall conform to standards furnished or approved by the procuring activity. The extent of porosity and other defects in the castings shall not exceed those shown by the standard, and such defects shall be absent in designated areas. The standards supplied or approved by the procuring activity for determining conformance with soundness requirements may consist of sectioned castings or photographs thereof or radiographs of at least the important sections of the castings. When specified (see 6.1), the minimum weight of each casting shall be controlled.

3.7 Identification marking:

Each casting shall be identified with the part number by use of raised numerals in a location indicated on the drawing. When no location is shown on the drawing, the number shall be located so as not to be machined off in finishing to the required dimensions. Castings on which it is impracticable to provide raised numerals shall be so marked as to be properly identified at the point of delivery.

3.8 Surface imperfections:

The casting surface shall not contain cracks, laps, cold shuts or inclusions (see 4.4.2.3).

3.9 Radiographic requirements:

After the foundry control methods of 3.5 have been established, the castings shall be radiographically inspected as specified in 4.5.2.

3.10 Mechanical properties:

The mechanical properties shall conform to the requirements of Table IV. The strength requirements of the casting, tested in full size, shall be as specified on the drawing for the part concerned or in other purchase information (see 6.2).

3.11 Heat-treatment:

Heat-treatment shall be performed on a whole casting and never on a portion only. Heat treatment shall be conducted as detailed in MIL-H-81200.

- 3.11.1 Hot isostatic pressing: Hot isostatic pressing may be used provided that all thermal treatment requirements are met subsequent to hipping and that the resulting material meets all the requirements contained herein.

3.12 Dimensions:

The dimensions of the castings shall be within the dimensions and tolerances specified on the applicable drawings.

3.13 Workmanship:

Castings shall be uniform in quality and condition, sound, clean, and substantially free from foreign materials.

- 3.13.1 Castings shall not be repaired by plugging, welding, or other methods without written permission from the procuring activity. Castings shall not be mechanically straightened after heat-treatment without written permission from the procuring activity.

4. QUALITY ASSURANCE PROVISIONS:

4.1 Responsibility for inspection:

Unless otherwise specified in the contract or purchase order, the supplier is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified in the contract or order, the supplier may use his own or any other facilities suitable for the performance of the inspection requirements specified herein, unless disapproved by the Government. The Government reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to ensure that supplies and services conform to prescribed requirements.

- 4.1.1 Responsibility for compliance: All items shall meet all requirements of sections 3 and 5. The inspection set forth in this specification shall become a part of the contractor's overall inspection system or quality program. The absence of any inspection requirements in the specification shall not relieve the contractor of the responsibility of ensuring that all products or supplies submitted to the Government for acceptance comply with all requirements of the contract. Sampling inspection, as part of manufacturing operations, is an acceptable practice to ascertain conformance to requirements, however, this does not authorize submission of known defective material, either indicated or actual, nor does it commit the Government to accept defective material.

- 4.1.2 Foundry control approval: Production of a given casting shall not begin until the foundry is approved, unless such approval be waived in writing by the procuring activity. Foundry control samples shall be submitted as directed by the procuring activity. The manufacturer shall use the same foundry practices and the same heat-treating procedures for production castings as for approved sample castings. If necessary to make any change, the foundry shall notify the procuring activity before the first shipment of castings incorporating such a change, and shall submit sample castings produced by the changed procedure for approval in accordance with 3.5.
- 4.1.2.1 Radiographic acceptance procedure: Acceptance shall be made by comparison with a standard set of radiographs contained in ASTM E 155. Radiographic indications shall be identified in terms of the defects listed in Table II. Acceptance shall be made in accordance with one of three grades specified in the engineering drawing (see 6.3). When no grade is specified, Grade C shall apply.
- 4.2 Classification of tests:
- The inspection and testing of castings shall be classified as follows:
- a. First Article inspection (see 4.3)
 - b. Quality conformance inspection (see 4.4).
- 4.3 First Article:
- 4.3.1 First Article inspection: First article inspection of the titanium-alloy castings shall consist of all tests described under Test Methods for all the requirements specified in Section 3 (see 4.5).
- 4.3.2 First article sample: The first two castings produced under each contract or order shall be the first article test samples (see 3.1). The samples shall be forwarded to a testing activity designated by the procuring activity. The manufacturer shall supply a certified statement of composition and prior tests which shows that the castings comply with the requirements of this specification (see 3.5). Samples shall be identified as required by the procuring activity for acceptance procedure.
- 4.4 Quality conformance inspection:
- Quality conformance inspection shall consist of all tests as described under 4.5.
- 4.4.1 Lot: Unless otherwise specified in the contract or order, a lot shall consist of not more than 2000 pounds of casting of the same part number produced in a pouring period not exceeding eight hours with metal from a single heat which is heat-treated in one furnace load.
- 4.4.2 Sampling for quality conformance inspection: Unless otherwise specified on the drawing or other purchase information and where applicable, sampling plans and procedures in the determination of the acceptability of products submitted by a supplier shall be in accordance with MIL-STD-105.

TABLE II

**MINIMUM SOUNDNESS FOR TITANIUM-ALLOY CASTINGS SUBMITTED
FOR FOUNDRY CONTROL APPROVAL (MAXIMUM PERMISSIBLE
RADIOGRAPH IN ACCORDANCE WITH ASTM E 155)**

Imperfection (ASTM E 155)	Radiograph Reference	Grade A	Grade B	Grade C
Porosity (round)	1.21	None	None	1
Porosity (elongated)	1.22	None	None	2
Shrinkage cavity	2.1	None	1	1
Foreign material (less dense)	3.11	None	None	1
Foreign material (more dense)	3.12	None	1	1
Cracks	-	None	None	None
Cold shuts	-	None	None	None
Laps	-	None	None	None

4.4.2.1 Sampling for visual and dimension examination: A random sample shall be selected from each lot in accordance with MIL-STD-105, Inspection Level II, Acceptable Quality Level (AQL) 2.5 percent defective for the test of 4.5.5.

4.4.2.2 Sampling for chemical composition: A random sample shall be selected from each lot in accordance with MIL-STD-105, Inspection Level S-1, acceptance number of zero for the test of 4.5.1. Preparation of sample specimens for the chemical analysis shall be in accordance with Methods 111.1 or 112.1 of FED-STD-151.

4.4.2.3 Sampling for radiographic and penetrant inspection: The frequency of sampling of each lot for radiographic and penetrant inspection for the tests of 4.5.2 and 4.5.3 shall be in accordance with MIL-STD-2175 and MIL-STD-6866.

4.4.2.4 Sampling for mechanical properties: Castings shall be selected at random from each lot in accordance with MIL-STD-105, Inspection Level S-2, acceptance number zero for test of 4.5.4.

4.4.2.4.1 Unless otherwise specified in the contract or drawing, tension test specimens shall be cut from locations shown on the drawing according to the sampling specified in 4.4.2 or on the drawing. If no location is shown, three specimens shall be taken from a thick, medium, and thin section of each casting selected at random, as close as practicable to cover thickness variations.

4.5 Test methods:

- 4.5.1 Chemical analysis: Analysis shall be spectrographic or chemical; Methods 111.1 or 112.1 of FED-STD-151. In case of dispute, the chemical analysis by wet chemical methods shall be the basis for acceptance.
- 4.5.2 Radiographic inspection: This examination shall be conducted in accordance with MIL-STD-453. Unless otherwise noted, the limits of X-ray indications shall be as specified in Table III. Additional radiographic inspection may be specified by the procuring activity.

TABLE III.

**MAXIMUM ACCEPTANCE DEFECTS IN TITANIUM-ALLOY
CASTINGS (MAXIMUM PERMISSIBLE RADIOGRAPH IN
ACCORDANCE WITH ASTM E 155) 1/, 2/, 3/, 4/**

Defects (ASTM E 155)	Radiograph Reference	Grade A	Grade B	Grade C
		Thickness (inch) <u>1/4</u> <u>3/4</u>	Thickness (inch) <u>1/4</u> <u>3/4</u>	Thickness (inch) <u>1/4</u> <u>3/4</u>
Porosity (round)	1.21	None	1 1	3 3
Porosity (elongated)	1.22	None	1 2	3 4
Shrinkage cavity	2.1	None	1 NA	2 NA
Foreign material (less dense)	3.11	None	1 1	2 2
Foreign material (more dense)	3.12	None	1 1	2 1
Cracks	-	None	None	None
Cold shuts	-	None	None	None
Laps	-	None	None	None

- 1/ When two or more types of defects are present to an extent equal to or not significantly better than the acceptance standards for respective defects, the parts shall be rejected.
- 2/ When two or more types of defects are present and the predominating defect is not significantly better than the acceptance standard, the part shall be considered borderline.
- 3/ Borderline castings shall be reviewed for acceptance or rejection by competent engineering personnel and Government quality assurance representative(s).
- 4/ Porosity and inclusions allowed by this table shall be cause for rejection when closer than twice their maximum dimension to an edge or extremity of a casting.