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Standard Specification for Titanium and Titanium Alloy Castings¹

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1. Scope

1.1 This specification covers titanium and titanium alloy castings intended for general corrosion resistant and industrial applications.

1.2 This specification is intended for use of purchasers and/or producers of reactive metal castings for defining the requirements and assuring the properties of castings for unique corrosion-resistant applications, that is, not for commodity items which must meet all potential purchasers' requirements.

1.2.1 Users are advised to use the specification as a basis for obtaining castings which will meet minimum acceptance requirements established and revised by consensus of the members of the committee.

1.2.2 User requirements considered more stringent may be met by the addition to the purchase order of one or more supplementary requirements, which may include, but are not limited to, those listed in Sections S1 through S8.

1.3 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

2. Referenced Documents

2.1 ASTM Standards:²

A 802/A 802M Practice for Steel Castings, Surface Acceptance Standards, Visual Examination

E 8 Test Methods for Tension Testing of Metallic Materials

E 10 Test Method for Brinell Hardness of Metallic Materials

E 18 Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

E 94 Guide for Radiographic Testing

E 120 Test Methods for Chemical Analysis of Titanium and Titanium Alloys³

E 142 Test Method for Controlling Quality of Radiographic Testing³

E 165 Test Method for Liquid Penetrant Examination

E 446 Reference Radiographs for Steel Castings Up to 2 in. (51 mm) in Thickness

E 1409 Test Method for Determination of Oxygen in Titanium and Titanium Alloys by the Inert Gas Fusion Technique

E 1447 Test Method for Determination of Hydrogen in Titanium and Titanium Alloys by the Inert Gas Fusion Thermal Conductivity Method

3. Terminology

3.1 Definitions of Terms Specific to This Standard:

3.1.1 ~~lot~~ *lot, n*—shall consist of all castings of the same design produced from the same pour.

3.1.2 ~~pour~~ *pour, n*—shall consist of all material melted and cast at one time.

4. Ordering Information

4.1 Orders for castings to this specification shall include the following as required, to describe the requirements adequately:

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²This specification is under the jurisdiction of ASTM Committee B10 on Reactive and Refractory Metals and Alloys and is the direct responsibility of Subcommittee B10.01 on Titanium.

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³For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* Vol 01-02, volume information, refer to the standard's Document Summary page on the ASTM website.

⁴Annual Book of ASTM Standards, Vol 03.01.

⁵Withdrawn.

4.1.1 Description of the castings by pattern number or drawing. Dimensional tolerances shall be included on the casting drawing,

4.1.2 Quantity,

4.1.3 Grade designation (see Table 1),

4.1.4 Options in the specification, and

4.1.5 Supplementary requirements desired, including the standards of acceptance.

5. Materials and Manufacture

5.1 Materials for this specification shall be melted by conventional processes used for reactive metals. Typical methods include the consumable electrode and induction-slag, plasma arc, induction-skull, and electron beam melting processes.

6. Chemical Composition

6.1 *Pour Analysis*—An analysis of each pour shall be made by the producer from a sample such as a casting or test bar that is representative of the pour. The chemical composition determined shall conform to the requirements specified for the relevant grade in Table 1.

6.1.1 The elements listed in Table 1 are intentional alloy additions or elements which are inherent to the manufacture of titanium sponge, ingot or mill product.

6.1.1.1 Elements other than those listed in Table 1 are deemed to be capable of occurring in the grades listed in Table 1 by and only by way of unregulated or unanalyzed scrap additions to the ingot melt. Therefore product analysis for elements not listed in Table 1 shall not be required unless specified and shall be considered to be in excess of the intent of this specification.

6.1.2 Elements intentionally added to the melt must be identified, analyzed, and reported in the chemical analysis.

6.2 When agreed upon by the producer and the purchaser and requested by the purchaser in his written purchase order, chemical analysis shall be completed for specific residual elements not listed in this specification.

6.3 *Product Analysis*—Product analysis tolerances do not broaden the specified heat analysis requirements, but cover variations between laboratories in the measurement of chemical content. The producer shall not ship material which is outside the limits specified in Table 1 for the applicable grade. Product analysis limits shall be as specified in Table 2.

6.4 *Sampling*—Samples for chemical analysis may be made by the purchaser on a representative casting from any lot. Due to the possibility of oxygen or other interstitial contamination, samples for oxygen, carbon, hydrogen, and nitrogen analysis shall be taken no closer than ¼ in. (6.3 mm) to a cast surface except that castings too thin for this shall be analyzed on representative material. The chemical composition determined shall conform to the analysis in Table 1 within the check analysis variations shown in Table 2 or shall be subject to rejection by the purchaser.

6.5 *Referee Analysis*—In the event of disagreement between the producer and purchaser concerning the analysis of any casting, Test Methods E 120 shall be used as a referee chemical analysis method.

7. Heat Treatment

7.1 Unless otherwise specified in the contract, all castings will be supplied in the as-cast condition except when post-weld heat treatment is required.

7.2 If post-weld heat treatment is required, it shall consist of a stress relief performed at $1075 \pm 25^\circ\text{F}$ ($580 \pm 14^\circ\text{C}$) for Grades C-2, C-3 Ti-Pd7B, Ti-Pd8A, Ti-Pd16 and Ti-Pd17, and $1200 \pm 25^\circ\text{F}$ ($650 \pm 14^\circ\text{C}$) for Grades C-5, C-6, and Ti-Pd18. Time at temperature shall be a minimum of ½ h plus an additional ½ h at temperature per inch of thickness for section sizes greater than

TABLE 1 Chemical Requirements

Element	Composition, Weight %								
	Grade C-2	Grade C-3	Grade C-5	Grade C-6	Grade Ti-Pd7B	Grade Ti-Pd8A	Grade Ti-Pd16	Grade Ti-Pd17	Grade Ti-Pd18
Nitrogen, max	0.05	0.05	0.05	0.05	0.05	0.05	0.03	0.03	0.05
Carbon, max	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Hydrogen, max	0.015	0.015	0.015	0.015	0.015	0.015	0.0150	0.0150	0.0150
Iron, max	0.20	0.25	0.40	0.50	0.20	0.25	0.30	0.20	0.25
Oxygen, max	0.40	0.40	0.25	0.20	0.40	0.40	0.18	0.25	0.15
Aluminum	...	...	5.5–6.75	4.00–6.00	...	...	...	...	2.5–3.5
Vanadium	...	...	3.5–4.5	...	...	...	...	...	2.0–3.0
Tin	...	...	...	2.0–3.0	...	...	...	...	...
Palladium	...	...	...	...	0.12 min	0.12 min	0.04–0.08 ^A	0.04–0.08 ^A	0.04–0.08 ^B
Other elements (each), max ^C	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Other elements (total), max ^C	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40

^AGrade TiPd16 and TiPd17—Unalloyed titanium with reduced palladium content to enhance corrosion properties are similar to Grade TiPd, 7B and 8A.

^BGrade 18—Palladium added to titanium alloy 3Al-2.5V to enhance corrosion properties.

^CNeed not be reported. By agreement between producer and purchaser, analysis may be required and limits established for elements or compounds not specified in this table.

TABLE 2 Check Analysis Tolerances

Element	Maximum or Range, Weight%	Permissible Variation in Check Analysis
Nitrogen	0.05	+0.02
Carbon	0.10	+0.02
Hydrogen	0.015	+0.003
Iron	0.50	+0.15
	0.40	+0.08
	0.25	+0.05
	0.20	+0.04
Oxygen	0.40	+0.08
	0.25	+ 0.05
	0.20	+ 0.04
Aluminum	2.5–6.75	±0.40
Vanadium	2.0–4.5	±0.15
Tin	2.0–3.0	±0.15
Palladium	0.04–0.25	±0.02
Other (each)	0.10	+0.02

1 in. (25 mm). After heat treatment, the castings should be cooled in air or in the furnace to ambient temperature unless otherwise agreed upon between the purchaser and producer.

8. Workmanship, Finish, and Appearance

8.1 All castings shall be made in a workman-like manner and shall conform to the dimensions in drawings furnished by the purchaser before manufacturing is started. If the pattern is supplied by the purchaser, the dimensions of the casting shall be as predicted by the pattern.

8.2 The surface of the casting shall be free of adhering mold material, scale, cracks, and hot tears as determined by visual examination. Other surface discontinuities shall meet the visual acceptance standards specified in the order. Practice A 802/A 802M or other visual standards may be used to define acceptable surface discontinuities and finish. Unacceptable surface discontinuities shall be removed and their removal verified by visual examination of the resultant cavities.

9. Repair by Welding

9.1 If repairs are required, these shall be made using a welding procedure and operators certified to quality requirements established by the producer. The procedures developed shall be consistent with standard practices recommended for reactive metal alloys. The producer shall maintain documentation on procedure and welder qualifications. Procedure modifications or special arrangements shall be as agreed upon between the producer and the purchaser.

9.2 The composition of the deposited weld metal shall be within the chemical requirements for each grade established in Table 1.

9.2.1 Unalloyed titanium Grades C-2 and C-3, and low-alloy Grades Ti-Pd7B, Ti-Pd8A, Ti-Pd16, and Ti-Pd17 castings shall be stress-relieved if the repair is considered capable of adding stresses that will interfere with the purpose for which the castings are intended. The decision for stress relieving shall be made by the producer, unless otherwise agreed upon. The stress-relief cycle shall be in accordance with 7.2 followed by air or furnace cooling to room temperature, or as agreed upon between the purchaser and the producer.

9.2.2 Grade C-5 (Ti-6Al-4V), Grade C-6 (Ti-5Al-2.5Sn) and Grade Ti-Pd 18 castings shall be stress-relieved after weld repair, if the weld defect or excavation is through a wall or exceeds 1 in.³ (16 000 mm³) of deposited metal. The stress-relief cycle shall be in accordance with 7.2.

9.2.3 Hot isostatic pressing (HIP) may be substituted for required thermal treatment provided all requirements for that treatment are met, and temperatures detrimental to the material properties are not reached.

10. Inspection

10.1 The producer shall afford the purchaser's inspector all reasonable facilities necessary to satisfy him that the material is being produced and furnished in accordance with this specification. Foundry inspection by the purchaser shall not interfere unnecessarily with the producer's operations.

10.2 If the results of any chemical or mechanical property test lot are not in conformance with the requirements of this specification, the lot may be retested at the option of the producer. The frequency of the retest will double the initial number of tests. If the results of the retest conform to the specification, then the retest values will become the test values for certification. Only original conforming test results or the conforming retest results shall be reported to the purchaser. If the results for the retest fail to conform to the specification, the material will be rejected in accordance with Section 11.

10.3 For purposes of determining conformance with the specifications contained herein, an observed or a calculated value shall be rounded off to the nearest unit in the last right-hand significant digit used in expressing the limiting value. This is in accordance with the round-off method of Practice E 29.