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Standard Specification for Titanium and Titanium Alloy Castings[1]

This standard is issued under the fixed designation B 367; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

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 standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

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 of Metallic Materials
E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
E 94 Guide for Radiographic Examination
~~E120Test Methods for Chemical Analysis of Titanium and Titanium Alloys~~
~~E~~ 142 Test Method for Controlling Quality of Radiographic Testing[3]
E 165 Test Method for Liquid Penetrant Examination
E 446~~Reference Radiographs for Steel Castings Up to 2 in. [51 mm] in Thickness~~ Reference Radiographs for Steel Castings Up to 2 in. [51 mm] in Thickness
E 539 Test Method for X-Ray Fluorescence Spectrometric Analysis of 6Al-4V Titanium Alloy
E 1409 Test Method for Determination of Oxygen and Nitrogen 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/Infrared Detection Method
E 1941 Test Method for Determination of Carbon in Refractory and Reactive Metals and Their Alloys
E 2371 Test Method for Analysis of Titanium and Titanium Alloys by Atomic Emission Plasma Spectrometry
E 2626 Guide for Spectrometric Analysis of Reactive and Refractory Metals

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

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

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[1] This 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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[2] For 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* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Withdrawn.

3.1.2 *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:

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.

TABLE 1 Chemical Requirements

Element	Composition, Weight %										
	Grade C-2	Grade C-3	Grade C-5	Grade C-6	Grade C-12	Grade Ti-Pd7[A]	Grade Ti-Pd8[B]	Grade Ti-Pd16	Grade Ti-Pd17	Grade Ti-Pd18	Grade C-38
Nitrogen, max	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.03	0.03	0.05	0.03
Carbon, max	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.08
Hydrogen, max	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.0150	0.0150	0.0150	0.015
Iron, max or range	0.20	0.25	0.40	0.50	0.30	0.20	0.25	0.30	0.20	0.25	1.2–1.8
Oxygen, max or range	0.40	0.40	0.25	0.20	0.25	0.40	0.40	0.25†	0.18†	0.15	0.20–0.30
Aluminum	...	...	5.5–6.75	4.00–6.00	...	...	...	...	...	2.5–3.5	3.5–4.5
Vanadium	...	...	3.5–4.5	...	...	...	...	...	...	2.0–3.0	2.0–3.0
Tin	...	...	...	2.0–3.0	...	...	...	...	...	...	...
Ruthenium	...	...	...	...	...	...	...	...	...	...	...
Palladium	...	...	...	...	...	0.12 min	0.12 min	0.04–0.08[B]	0.04–0.08[B]	0.04–0.08[A]	...
Cobalt	...	...	...	...	...	...	...	...	...	...	...
Molybdenum	...	...	...	...	0.2–0.4	...	...	...	...	...	
Chromium	...	...	...	...	...	...	...	...	...	...	...
Nickel	...	...	...	...	0.6–0.9	...	...	...	...	...	...
Niobium	...	...	...	...	...	...	...	...	...	...	...
Zirconium	...	...	...	...	...	...	...	...	...	...	...
Silicon	...	...	...	...	...	...	...	...	...	...	...
Residuals,[C,D,E] max each	...	...	...	...	...	...	...	...	...	...	0.1
Residuals,[C,D,E] max total	...	...	...	...	...	...	...	...	...	...	0.4
Titanium[F]	...	...	...	...	...	...	...	...	...	...	balance
Other elements (each), max[G]	0.10	0.10	0.10	0.10	0.1	0.10	0.10	0.10	0.10	0.10	...
Other elements (total), max[G]	0.40	0.40	0.40	0.40	0.4	0.40	0.40	0.40	0.40	0.40	...

[A] *Grade 18*—Palladium added to titanium alloy 3Al-2.5V to enhance corrosion properties.

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

[C] Need not be reported.

[D] A residual is an element present in a metal or an alloy in small quantities and is inherent to the manufacturing process but not added intentionally. In titanium these elements include aluminum, vanadium, tin, chromium, molybdenum, niobium, zirconium, hafnium, bismuth, ruthenium, palladium, yttrium, copper, silicon, cobalt, tantalum, nickel, boron, manganese, and tungsten.

[E] The purchaser may, in his written purchase order, request analysis for specific residual elements not listed in this specification.

[F] The percentage of titanium is determined by difference.

[G] Need 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.

† Corrected editorially.

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 E120 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 ± 25°F (580 ± 14°C) for Grades C-2, C-3, C-12, Ti-Pd7B, Ti-Pd8A, Ti-Pd16 and Ti-Pd17, and 1200 ± 25°F (650 ± 14°C) for Grades C-5, C-6, Ti-Pd18, and C-38. 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 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~~

~~8.1All 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.~~

~~8.2The 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 A802/A802M~~ Methods of Chemical Analysis

8.1 The chemical analysis shall normally be conducted using the ASTM standard test methods referenced in 2.1. Other industry standard methods may be used where the ASTM test methods in 2.1 do not adequately cover the elements in the material or by agreement between the producer and purchaser. Alternate techniques are discussed in Guide E 2626.

9. Workmanship, Finish, and Appearance

9.1 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.

9.2 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.

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	1.2–1.8	±0.20
Iron	0.50	+0.15
	0.40	+0.08
	0.25	+0.05
	0.20	+0.04
Oxygen	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
Molybdenum	0.2–0.4	±0.04
Nickel	0.3–0.9	±0.05
Other (each)	0.10	+0.02