Designation: ~~B367 – 13 (Reapproved 2017)~~ B367 – 22

Standard Specification for Titanium and Titanium Alloy Castings[1]

This standard is issued under the fixed designation B367; 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 U.S. Department of Defense.

1. ~~Scope~~ Scope*

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

1.1.1 *Grade C-2*—UNS R52550. Unalloyed titanium,

1.1.2 *Grade C-3*—UNS ~~R52550.~~R52551. Unalloyed titanium,

1.1.3 *Grade C-5*—UNS ~~R56400.~~R56409. Titanium alloy (6 % aluminum, 4 % vanadium),

1.1.4 *Grade C-7*—UNS R52700. Unalloyed titanium plus 0.12 to 0.25 % palladium,

1.1.5 *Grade C-8*—UNS ~~R52700.~~R52703. Unalloyed titanium plus 0.12 to 0.25 % palladium,

1.1.6 *Grade C-9*—UNS R56320. Titanium alloy (3 % aluminum, 2.5 % vanadium),

1.1.7 *Grade C-12*—UNS R53400. Titanium alloy (0.3 % molybdenum, 0.8 % nickel),

1.1.8 *Grade C-16*—UNS R52402. Unalloyed titanium plus 0.04 to 0.08 % palladium,

1.1.9 *Grade C-17*—UNS ~~R52252.~~R52702. Unalloyed titanium plus 0.04 to 0.08 % palladium, and

1.1.10 *Grade C-38*—UNS R54250. Titanium alloy (4 % aluminum, 2.5 % vanadium, 1.5 % iron).

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] 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.

Current edition approved ~~Nov. 1, 2017~~April 1, 2022. Published ~~November 2017~~April 2022. Originally approved in 1961. Last previous edition approved in ~~2013~~2017 as ~~B367 – 13~~.B367 – 13 (2017). DOI: ~~10.1520/B0367-13R17~~.10.1520/B0367-22.

***A Summary of Changes section appears at the end of this standard**

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.

1.4 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

~~A802/A802M~~A802 Practice for Steel Castings, Surface Acceptance Standards, Visual Examination
~~E8~~E8/E8M Test Methods for Tension Testing of Metallic Materials ~~[Metric] E0008_E0008M~~
E10 Test Method for Brinell Hardness of Metallic Materials
E18 Test Methods for Rockwell Hardness of Metallic Materials
E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
~~E94~~E94/E94M Guide for Radiographic Examination Using Industrial Radiographic Film
~~E142 Method for Controlling Quality of Radiographic Testing (Withdrawn 2000)~~[3]
~~E165~~E165/E165M Practice for Liquid Penetrant Testing for General Industry
E446 Reference Radiographs for Steel Castings Up to 2 in. (50.8 mm) in Thickness
~~E539 Test Method for Analysis of Titanium Alloys by Wavelength Dispersive X-Ray Fluorescence Spectrometry~~
~~E1409 Test Method for Determination of Oxygen and Nitrogen in Titanium and Titanium Alloys by Inert Gas Fusion~~
~~E1447 Test Method for Determination of Hydrogen in Titanium and Titanium Alloys by Inert Gas Fusion Thermal Conductivity/Infrared Detection Method~~
~~E1941 Test Method for Determination of Carbon in Refractory and Reactive Metals and Their Alloys by Combustion Analysis~~
~~E2371 Test Method for Analysis of Titanium and Titanium Alloys by Direct Current Plasma and Inductively Coupled Plasma Atomic Emission Spectrometry (Performance-Based Test Methodology)~~
E2626 Guide for Spectrometric Analysis of Reactive and Refractory Metals (Withdrawn 2017)[3]

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.

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.

[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] The last approved version of this historical standard is referenced on www.astm.org.

TABLE 1 Chemical Requirements

Grade	UNS Number	Carbon, max.	Oxygen range or max.	Nitrogen, max.	Hydrogen, max.	Iron range or max.	Aluminum	Vanadium	Palladium	Ruthenium	Nickel	Molybdenum	Chromium	Cobalt	Zirconium	Niobium	Tin	Silicon	Other Elements, max. each	Other Elements, max. total
		Composition, Weight Percent[A,B,C,D,E]																		
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C-2	R52550	0.10	0.40	0.05	0.015	0.20	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	0.1	0.4
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~~C-3~~	~~R52550~~	~~0.10~~	~~0.40~~	~~0.05~~	~~0.015~~	~~0.25~~	—	—	—	—	—	—	—	—	—	—	—	—	~~0.1~~	~~0.4~~
C-3	R52551	0.10	0.40	0.05	0.015	0.25	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	0.1	0.4
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~~C-5~~	~~R56400~~	~~0.10~~	~~0.25~~	~~0.05~~	~~0.015~~	~~0.40~~	~~5.5-6.75~~	~~3.5-4.5~~	—	—	—	—	—	—	—	—	—	—	~~0.1~~	~~0.4~~
C-5	R56409	0.10	0.25	0.05	0.015	0.40	5.5-6.75	3.5-4.5	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	0.1	0.4
C-6	R54520	0.10	0.20	0.05	0.015	0.50	4.0-6.0	- -	- -	- -	- -	- -	- -	- -	- -	- -	2.0-3.0	- -	0.1	0.4
C-7	R52700	0.10	0.40	0.05	0.015	0.20	- -	- -	0.12-0.25	- -	- -	- -	- -	- -	- -	- -	- -	- -	0.1	0.4
~~C-8~~	~~R52700~~	~~0.10~~	~~0.40~~	~~0.05~~	~~0.015~~	~~0.25~~	—	—	~~0.12-0.25~~	—	—	—	—	—	—	—	—	—	—	—
C-8	R52703	0.10	0.40	0.05	0.015	0.25	- -	- -	0.12-0.25	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
C-9	R56320	0.10	0.20	0.05	0.015	0.25	2.5-3.5	2.0-3.0	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
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C-12	R53400	0.10	0.25	0.05	0.015	0.30	- -	- -	- -	- -	0.6-0.9	0.2-0.4	- -	- -	- -	- -	- -	- -	0.1	0.4
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C-16	R52402	0.10	0.18	0.03	0.015	0.30	- -	- -	0.04-0.08	- -	- -	- -	- -	- -	- -	- -	- -	- -	0.1	0.4
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~~C-17~~	~~R52252~~	~~0.10~~	~~0.20~~	~~0.03~~	~~0.015~~	~~0.25~~	—	—	~~0.04-0.08~~	—	—	—	—	—	—	—	—	—	~~0.1~~	~~0.4~~
C-17	R52702	0.10	0.20	0.03	0.015	0.25	- -	- -	0.04-0.08	- -	- -	- -	- -	- -	- -	- -	- -	- -	0.1	0.4
C-18	R58465	0.08	0.20	0.03	0.015	0.25	2.5-3.5	2.0-3.0	0.04-0.08	- -	- -	- -	- -	- -	- -	- -	- -	- -	0.1	0.4
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C-38	R54250	0.08	0.20-0.30	0.03	0.015	1.2-1.8	3.5-4.5	2.0-3.0	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	0.1	0.4

[A] At minimum, one pour analysis shall be completed and reported for all elements listed for the respective grade in this table.
[B] If the casting is subjected to thermal or chemical processing following the pour, final product hydrogen shall be reported in lieu of pour hydrogen. Lower hydrogen may be obtained by negotiation with the manufacturer.
[C] Single values are maximum. The percentage of titanium is determined by difference.
[D] Other elements need not be reported unless the concentration level is greater than 0.1 % each, or 0.4 % total. Other elements may not be added intentionally. Other elements may be present in titanium or titanium alloys in small quantities and are inherent to the manufacturing process. In titanium these elements typically 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 the written purchase order, request analysis for specific elements not listed in this specification.

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.

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~~25 °F (580 ± ~~14°C~~)14 °C) for Grades C-2, C-3, C-7, C-8, C-12, C-16 and C-17, and 1200 ± ~~25°F~~25 °F (650 ± ~~14°C~~)14 °C) for Grades C-5, C-6, C-9, C-18, 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.

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

8. 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 E2626.

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 ~~A802/A802M~~A802 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.

10. Repair by Welding

10.1 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.

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

10.2.1 Unalloyed titanium Grades C-2 and C-3, and low-alloy Grades C-12, C-7, C-8, C-16, and C-17 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.

10.2.2 Grade C-5 (Ti-6Al-4V), Grade C-6 (Ti-5Al-2.5Sn), Grade C-9, Grade C-18, and C-38 castings shall be stress-relieved after weld repair, if the weld defect or excavation is through a wall or exceeds 1 in.^{3} (16.4 cm^3) of deposited metal. All welds on Grade C-12 (Ti-.3Mo-.8Ni) castings shall be stress-relieved after weld repair. The stress-relief cycle shall be in accordance with 7.2.

10.2.3 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.

11. Referee Test and Analysis

11.1 In the event of disagreement between the manufacturer and the purchaser on the conformance of the material to the requirements of this specification, a mutually acceptable referee shall perform the tests in question using the ASTM standard methods in 2.1. The referee's testing shall be used in determining conformance of the material to this specification.

12. Inspection

12.1 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.

12.2 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 13.

12.3 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 E29.

13. Rejection

13.1 Any rejection based on test reports shall be reported to the producer within 60 days from the receipt of the test reports by the purchaser.

13.2 Material that shows unacceptable discontinuities as determined by the acceptance standards specified on the order, subsequent to acceptance at the producer's works, may be rejected, and the producer shall be notified within 60 days, or as otherwise agreed upon.

13.3 In the event of disagreement between the producer and the purchaser on the conformance of the material to the requirements of this specification, a mutually acceptable referee shall perform the tests in question. The referee's testing shall be used in determining the conformance of the material to this specification.

14. Certification

14.1 The manufacturer shall supply at least one copy of the report certifying that the material supplied has been manufactured, inspected, sampled, and tested in accordance with the requirements of this specification and that the results of chemical analysis, tensile, and other tests meet the requirements of this specification for the grade specified. The report shall include results of all chemical analysis, tensile tests, and all other tests required by the specification.

15. Product Marking

15.1 Unless otherwise specified, the following shall apply.

15.1.1 Castings shall be marked for material identification with the ASTM designation number (Specification B367) and grade symbol, that is, C-2, C-3, C-5, C-6, C-7, C-8, C-9, C-12, C-16, C-17, C-18, or C-38 if size permits. Marking shall be in such position as not to impair the function of the casting.

15.1.2 The producer's name or identification mark and the pattern number shall be cast or stamped using low stress stamps on all castings. Small size castings may be such that marking must be limited consistent with the available area.

15.1.3 The marking of lot numbers on individual castings shall be agreed upon by the producer and the purchaser.

15.1.4 Marking shall be in such a position as not to injure the usefulness of the casting.

16. Keywords

16.1 castings; corrosion resistant; titanium; titanium alloys