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Standard Specification for Titanium and Titanium Ingots[1]

This standard is issued under the fixed designation B977; 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.

1. ~~Scope~~ Scope*

1.1 This specification covers titanium and titanium alloy ingots as follows:

1.1.1 *Grade 1*—UNS R50250. Unalloyed titanium,

1.1.2 *Grade 2*—UNS R50400. Unalloyed titanium,

1.1.3 *Grade 3*—UNS R50550. Unalloyed titanium,

1.1.4 *Grade 4*—UNS R50700. Unalloyed titanium,

1.1.5 *Grade 5*—UNS R56400. Titanium alloy (6 % aluminum, 4 % vanadium),

1.1.6 *Grade 6*—UNS R54520. Titanium alloy (5 % aluminum, 2.5 % tin),

1.1.7 *Grade 7*—UNS R52400. Unalloyed titanium plus 0.12 to 0.25 % palladium,

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

1.1.9 *Grade 11*—UNS R52250. Unalloyed titanium plus 0.12 to 0.25 % palladium,

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

1.1.11 *Grade 13*—UNS R53413. Titanium alloy (0.5 % nickel, 0.05 % ruthenium),

1.1.12 *Grade 14*—UNS R53414. Titanium alloy (0.5 % nickel, 0.05 % ruthenium),

1.1.13 *Grade 15*—UNS R53415. Titanium alloy (0.5 % nickel, 0.05 % ruthenium),

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

1.1.15 *Grade 17*—UNS R52252. Unalloyed titanium plus 0.04 to 0.08 % palladium,

1.1.16 *Grade 18*—UNS R56322. Titanium alloy (3 % aluminum, 2.5 % vanadium) plus 0.04 to 0.08 % palladium,

1.1.17 *Grade 19*—UNS R58640. Titanium alloy (3 % aluminum, 8 % vanadium, 6 % chromium, 4 % zirconium, 4 % molybdenum),

1.1.18 *Grade 20*—UNS R58645. Titanium alloy (3 % aluminum, 8 % vanadium, 6 % chromium, 4 % zirconium, 4 % molybdenum) plus 0.04 to 0.08 % palladium,

1.1.19 *Grade 21*—UNS R58210. Titanium alloy (15 % molybdenum, 3 % aluminum, 2.7 % niobium, 0.25 % silicon),

1.1.20 *Grade 23*—UNS R56407. Titanium alloy (6 % aluminum, 4 % vanadium with extra low interstitials, ELI),

1.1.21 *Grade 24*—UNS R56405. Titanium alloy (6 % aluminum, 4 % vanadium) plus 0.4 to 0.8 % palladium,

1.1.22 *Grade 25*—UNS R56403. Titanium alloy (6 % aluminum, 4 % vanadium) plus 0.3 to 0.8 % nickel and 0.04 to 0.08 % palladium,

1.1.23 *Grade 26*—UNS R56404. Unalloyed titanium plus 0.08 to 0.14 % ruthenium,

1.1.24 *Grade 27*—UNS R52254. Unalloyed titanium plus 0.08 to 0.14 % ruthenium,

1.1.25 *Grade 28*—UNS R56323. Titanium alloy (3 % aluminum, 2.5 % vanadium) plus 0.08 to 0.14 % ruthenium,

1.1.26 *Grade 29*—UNS R56404. Titanium alloy (6 % aluminum, 4 % vanadium, extra low interstitial elements, ELI) plus 0.08 to 0.14 % ruthenium,

1.1.27 *Grade 30*—UNS R53530. Titanium alloy (0.3 % cobalt, 0.05 % palladium),

1.1.28 *Grade 31*—UNS R53532. Titanium alloy (0.3 % cobalt, 0.05 % palladium),

1.1.29 *Grade 32*—UNS R55111. Titanium alloy (5 % aluminum, 1 % tin, 1 % zirconium, 1 % vanadium, 0.8 % molybdenum),

1.1.30 *Grade 33*—UNS R53442. Titanium alloy (0.4 % nickel, 0.015 % palladium, 0.025 % ruthenium, 0.15 % chromium),

1.1.31 *Grade 34*—UNS R53445. Titanium alloy (0.4 % nickel, 0.015 % palladium, 0.025 % ruthenium, 0.15 % chromium),

1.1.32 *Grade 35*—UNS R56340. Titanium alloy (4.5 % aluminum, 2 % molybdenum, 1.6 % vanadium, 0.5 % iron, 0.3 % silicon),

1.1.33 *Grade 36*—UNS R58450. Titanium alloy (45 % niobium),

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

1.1.34 *Grade 37*—UNS R52815. Titanium alloy (1.5 % aluminum), and
1.1.35 *Grade 38*—UNS R54250. Titanium alloy (4 % aluminum, 2.5 % vanadium, 1.5 % iron).

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.3 *The following caveat pertains only to the test method portions of this specification: This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]
E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
E178 Practice for Dealing With Outlying Observations
E539 Test Method for Analysis of Titanium Alloys by X-Ray Fluorescence Spectrometry
E1409 Test Method for Determination of Oxygen and Nitrogen in Titanium and Titanium Alloys by the Inert Gas Fusion Technique
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

3. Terminology

3.1 *Lot Definitions:*
3.2 *ingot, n*—a quantity of metal cast into a shape suitable for subsequent processing to various mill products.

4. Ordering Information

4.1 Orders for material under this specification shall include the following information as required to describe adequately the desired material:
4.1.1 Grade number (1.1),
4.1.2 Nominal weight in the unit system regarded as standard (inch-pound or SI),
4.1.3 Nominal size (width and gauge or diameter, length) in the unit system regarded as standard (inch-pound or SI),
4.1.4 ASTM designation and year of issue.

4.2 Orders for material under this specification may include (at the discretion of the purchaser) the following additional information:
4.2.1 Method of manufacture (5.1),
4.2.2 Surface condition (7.1 and 7.2),
4.2.3 Product analysis (6.2),
4.2.4 Additional chemical analysis (6.1.3),
4.2.5 Requirements for purchaser inspection/witness (11.1), and
4.2.6 Packaging (Section 15).

5. Materials and Manufacture

5.1 Materials covered by this specification are produced by one of the following methods:
5.1.1 double vacuum arc melting,
5.1.2 triple vacuum arc melting,
5.1.3 electron beam cold hearth melting followed by vacuum arc melting,
5.1.4 plasma arc cold hearth melting followed by vacuum arc melting,
5.1.5 electron beam cold hearth melting,
5.1.6 plasma arc cold hearth melting or
5.1.7 other melting process as agreed upon by the purchaser and producer.

5.2 The melting method used to produce the ingot shall be reported to the purchaser on the certification.

[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.

5.3 The melting method shall be at the discretion of the producer, unless specified in the purchase order.

6. Chemical Composition

6.1 The chemistry of titanium and titanium alloy ingot covered by this specification shall conform to the requirements for the specified grade as prescribed in Table 1.

6.1.1 The elements listed for each grade in Table 1 are intentional alloy additions or elements that are inherent to the manufacture of titanium sponge or ingot.

6.1.2 Elements intentionally added to the melt, including additions made via revert additions, must be identified, analyzed and reported in the chemical analysis. Elements not listed in Table 1 for the specified grade shall not be required.

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

6.2 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 other methods acceptable to the purchaser. Alternate techniques are discussed in Guide E2626.

6.3 *Product Check Analysis*—Product check analysis is an analysis made by or for the purchaser for the purpose of verifying the composition of the ingot. The check analysis tolerances reflect the variation between laboratories in the measurement of chemical composition. The permissible variation in the product check analysis from the specified range is as prescribed in Table 2.

7. Condition

7.1 *Surface Finish*—The surface finish shall be at the discretion of the producer, unless specified in the purchase order.

7.2 When specified, the ingots shall be conditioned on the surface to standards agreed upon between the manufacturer and the purchaser.

7.3 Titanium and titanium alloy ingots shall be free of imperfections that would be deemed injurious by the standards of acceptability agreed upon between the purchaser and the manufacturer.

7.3.1 The manufacturer shall be permitted to remove minor surface imperfections. Surface imperfections may be removed up to 1 in. (25 mm) deep from the ingot surface. Areas adjacent to the imperfection shall be blended smoothly into the ingot surface at a slope not less than 3:1.

8. Retest

8.1 If any sample or specimen exhibits obvious contamination, improper preparation, or flaws disqualifying it as a representative sample, it shall be discarded and a new sample or specimen substituted.

8.2 If the results of any test are not in conformance with the requirements of this specification, the original sample from the ingot may be retested or the ingot may be re-sampled and tested.

8.2.1 If the original ingot sample is retested, the frequency of the retest will be at least double the initial number of tests. The retests will be compared to the original value to determine if the original value is an outlier in accordance with Practice E178. If it is an outlier the retest values will be averaged and the averaged retest values reported. If it is not an outlier all the values will be averaged and the averages of all of the tests become the test value reported. If the averaged value reported conforms to the specification, then they become the test values for certification.

8.2.2 The manufacturer may resample the ingot at the non-conforming location(s) in a different area at the same axial location. The frequency of the resample will be at least double the initial number of tests. If the results of the resample conform to the specification, then the resample values become the test values for certification.

8.3 The manufacturer may scalp or crop the ingot to remove nonconforming material then sample the remaining ingot position(s). The ingot shall be acceptable if all results of the tests on the ingot conform to this specification.

9. Sampling

9.1 Samples for chemical analyses shall be representative of the material being tested. The utmost care must be used in sampling titanium for chemical analysis because of its great affinity for elements such as oxygen, nitrogen, and hydrogen. Therefore in cutting samples for analysis, the operation should be carried out insofar as possible in a dust-free atmosphere. Chips should be collected from clean metal and tools should be clean and sharp. Samples for analysis should be stored in suitable containers.

9.2 The ingot shall be sampled at a minimum of two locations; top and bottom. The top sample shall be within 12 in. (300 mm) of the top face. The bottom sample shall be within 12 in. (300 mm) of the bottom face.

10. Significance of Numerical Limits

10.1 For purposes of determining compliance with the specified limits for requirements of the properties listed in Table 1 and Table 2, an observed value or a calculated value shall be rounded as indicated in accordance with the rounding method of Practice E29.

TABLE 1 Chemical Requirements

Grade	C max	O range or max	N max	H max[E]	Fe range or max	Al	V	Pd	Ru	Ni	Mo	Cr	Co	Zr	Nb	Sn	Si	Other Elements max, each	Other Elements max, total
					Chemical Composition (Weight %)[A,B,C,D]														
1	0.08	0.18	0.03	0.003	0.20	...	...	...	...	...	...	...	...	...	...	...	...	0.1	0.4
2	0.08	0.25	0.03	0.003	0.30	...	...	...	...	...	...	...	...	...	...	...	...	0.1	0.4
3	0.08	0.35	0.05	0.003	0.30	...	...	...	...	...	...	...	...	...	...	...	...	0.1	0.4
4	0.08	0.40	0.05	0.003	0.50	...	...	...	...	...	...	...	...	...	...	...	...	0.1	0.4
5	0.08	0.20	0.05	0.003	0.40	5.5-6.75	3.5-4.5	...	...	...	...	...	...	...	...	...	...	0.1	0.4
6	0.08	0.20	0.03	0.003	0.50	4.0-6.0	...	...	...	...	...	...	...	...	...	2.0-3.0	...	0.1	0.4
7	0.08	0.25	0.03	0.003	0.30	...	...	0.12-0.25	...	...	...	...	...	...	...	...	...	0.1	0.4
9	0.08	0.15	0.03	0.003	0.25	2.5-3.5	2.0-3.0	...	...	...	...	...	...	...	...	...	...	0.1	0.4
11	0.08	0.18	0.03	0.003	0.20	...	...	0.12-0.25	...	...	...	...	...	...	...	...	...	0.1	0.4
12	0.08	0.25	0.03	0.003	0.30	...	...	...	...	0.6-0.9	0.2-0.4	...	...	...	...	...	...	0.1	0.4
13	0.08	0.10	0.03	0.003	0.20	...	...	...	0.04-0.06	0.4-0.6	...	...	...	...	...	...	...	0.1	0.4
14	0.08	0.15	0.03	0.003	0.30	...	...	...	0.04-0.06	0.4-0.6	...	...	...	...	...	...	...	0.1	0.4
15	0.08	0.25	0.05	0.003	0.30	...	...	...	0.04-0.06	0.4-0.6	...	...	...	...	...	...	...	0.1	0.4
16	0.08	0.25	0.03	0.003	0.30	...	...	0.04-0.08	...	...	...	...	...	...	...	...	...	0.1	0.4
17	0.08	0.18	0.03	0.003	0.20	...	...	0.04-0.08	...	...	...	...	...	...	...	...	...	0.1	0.4
18	0.08	0.15	0.03	0.003	0.25	2.5-3.5	2.0-3.0	0.04-0.08	...	...	...	...	...	...	...	...	...	0.1	0.4
19	0.05	0.12	0.03	0.003	0.30	3.0-4.0	7.5-8.5	...	...	...	3.5-4.5	5.5-6.5	...	3.5-4.5	...	...	...	0.15	0.4
20	0.05	0.12	0.03	0.003	0.30	3.0-4.0	7.5-8.5	0.04-0.08	...	...	3.5-4.5	5.5-6.5	...	3.5-4.5	...	...	...	0.15	0.4
21	0.05	0.17	0.03	0.003	0.40	2.5-3.5	...	...	...	...	14.0-16.0	...	...	...	2.2-3.2	...	0.15-0.25	0.1	0.4
23	0.08	0.13	0.03	0.003	0.25	5.5-6.5	3.5-4.5	...	...	...	...	...	...	...	...	...	...	0.1	0.4
24	0.08	0.20	0.05	0.003	0.40	5.5-6.75	3.5-4.5	0.04-0.08	...	...	...	...	...	...	...	...	...	0.1	0.4
25	0.08	0.20	0.05	0.003	0.40	5.5-6.75	3.5-4.5	0.04-0.08	...	0.3-0.8	...	...	...	...	...	...	...	0.1	0.4
26	0.08	0.25	0.03	0.003	0.30	...	...	...	0.08-0.14	...	...	...	...	...	...	...	...	0.1	0.4
27	0.08	0.18	0.03	0.003	0.20	...	...	...	0.08-0.14	...	...	...	...	...	...	...	...	0.1	0.4
28	0.08	0.15	0.03	0.003	0.25	2.5-3.5	2.0-3.0	...	0.08-0.14	...	...	...	...	...	...	...	...	0.1	0.4
29	0.08	0.13	0.03	0.003	0.25	5.5-6.5	3.5-4.5	...	0.08-0.14	...	...	...	...	...	...	...	...	0.1	0.4
30	0.08	0.25	0.03	0.003	0.30	...	...	0.04-0.08	...	...	...	...	0.20-0.80	...	...	...	...	0.1	0.4
31	0.08	0.35	0.05	0.003	0.30	...	...	0.04-0.08	...	...	...	...	0.20-0.80	...	...	...	...	0.1	0.4
32	0.08	0.11	0.03	0.003	0.25	4.5-5.5	0.6-1.4	...	...	...	0.6-1.2	...	...	0.6-1.4	...	0.6-1.4	0.06-0.14	0.1	0.4
33	0.08	0.25	0.03	0.003	0.30	...	...	0.01-0.02	0.02-0.04	0.35-0.55	...	0.1-0.2	...	...	...	...	...	0.1	0.4
34	0.08	0.35	0.05	0.003	0.30	...	...	0.01-0.02	0.02-0.04	0.35-0.55	...	0.1-0.2	...	...	...	...	...	0.1	0.4
35	0.08	0.25	0.05	0.003	0.20-0.80	4.0-5.0	1.1-2.1	...	...	...	1.5-2.5	...	...	...	...	...	0.20-0.40	0.1	0.4
36	0.04	0.16	0.03	0.001	0.03	...	...	...	...	...	...	...	...	...	42.0-47.0	...	...	0.1	0.4
37	0.08	0.25	0.03	0.003	0.30	1.0-2.0	...	...	...	...	...	...	...	...	...	...	...	0.1	0.4
38	0.08	0.20-0.30	0.03	0.003	1.2-1.8	3.5-4.5	2.0-3.0	...	...	...	...	...	...	...	...	...	...	0.1	0.4

TABLE 1 Chemical Requirements

Grade	UNS Number	C max	O range or max	N max	H max[E]	Fe range or max	Al	V	Pd	Ru	Ni	Mo	Cr	Co	Zr	Nb	Sn	Si	Other Elements max, each	Other Elements max, total
						Chemical Composition (Weight %)[A,B,C,D]														
1	R50250	0.08	0.18	0.03	0.003	0.20	...	...	...	...	...	...	...	...	...	...	...	...	0.1	0.4
2	R50400	0.08	0.25	0.03	0.003	0.30	...	...	...	...	...	...	...	...	...	...	...	...	0.1	0.4
3	R50550	0.08	0.35	0.05	0.003	0.30	...	...	...	...	...	...	...	...	...	...	...	...	0.1	0.4
4	R50700	0.08	0.40	0.05	0.003	0.50	...	...	...	...	...	...	...	...	...	...	...	...	0.1	0.4
5	R56400	0.08	0.20	0.05	0.003	0.40	5.5-6.75	3.5-4.5	...	...	...	...	...	...	...	...	...	...	0.1	0.4
6	R54520	0.08	0.20	0.03	0.003	0.50	4.0-6.0	...	...	...	...	...	...	...	...	...	2.0-3.0	...	0.1	0.4
7	R52400	0.08	0.25	0.03	0.003	0.30	...	...	0.12-0.25	...	...	...	...	...	...	...	...	...	0.1	0.4
9	R56320	0.08	0.15	0.03	0.003	0.25	2.5-3.5	2.0-3.0	...	...	...	...	...	...	...	...	...	...	0.1	0.4