



Designation: B348 – 13

Standard Specification for Titanium and Titanium Alloy Bars and Billets¹

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

1. Scope*

1.1 This specification² covers annealed titanium and titanium alloy bars and billets as follows:

- 1.1.1 *Grade 1*—UNS R50250. Unalloyed titanium,
- 1.1.2 *Grade 2*—UNS R50400. Unalloyed titanium,
 - 1.1.2.1 *Grade 2H*—UNS R50400. Unalloyed titanium (Grade 2 with 58 ksi (400 MPa) minimum UTS),
- 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,
 - 1.1.7.1 *Grade 7H*—UNS R52400. Unalloyed titanium plus 0.12 to 0.25 % palladium (Grade 7 with 58 ksi (400 MPa) minimum UTS),
- 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,
 - 1.1.14.1 *Grade 16H*—UNS R52402. Unalloyed titanium plus 0.04 to 0.08 % palladium (Grade 16 with 58 (400 MPa) ksi minimum UTS),

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 %–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 interstitial elements, ELI),

1.1.21 *Grade 24*—UNS R56405. Titanium alloy (6 % aluminum, 4 % vanadium) plus 0.04 % to 0.08 % 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 R52404. Unalloyed titanium plus 0.08 to 0.14 % ruthenium,

1.1.23.1 *Grade 26H*—UNS R52404. Unalloyed titanium plus 0.08 to 0.14 % ruthenium (Grade 26 with 58 ksi (400 MPa) minimum UTS),

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 0.08–0.14 % ruthenium),

1.1.26 *Grade 29*—UNS R56404. Titanium alloy (6 % aluminum, 4 % vanadium, extra low interstitial, 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 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 ASME Boiler and Pressure Vessel Code applications see related Specification SB-348 in Section II of that Code.

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

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),

1.1.34 *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).

NOTE 1—H grade material is identical to the corresponding numeric grade (that is, Grade 2H = Grade 2) except for the higher guaranteed minimum UTS, and may always be certified as meeting the requirements of its corresponding numeric grade. Grades 2H, 7H, 16H, and 26H are intended primarily for pressure vessel use.

1.2 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:³

E8 Test Methods for Tension Testing of Metallic Materials

E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

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 Definitions of Terms Specific to This Standard:

3.1.1 *bar, n*—a hot rolled, forged, extruded or cold worked semifinished solid section product whose cross sectional area is equal to or less than 16 in.² (10 323 mm²); rectangular bar must be less than or equal to 10 in. (254 mm) in width and greater than 0.1875 in. (4.8 mm) in thickness.

3.1.1.1 *Discussion*—Extruded bar has been approved for use on unalloyed titanium grades 1, 2, 3 and 4 only. Other grades

may be produced via the extrusion process with agreement between the producer and the purchaser.

3.1.2 *billet, n*—a solid semifinished section hot worked or forged from an ingot, with a cross sectional area greater than 16 in.² (10 323 mm²) whose width is less than five times its thickness.

4. Ordering Information

4.1 Orders for material under this specification shall include the following information as applicable:

4.1.1 Grade number (Section 1),

4.1.2 Product classification (Section 3),

4.1.3 Chemistry (Table 1),

4.1.4 Mechanical properties (Table 2),

4.1.5 Marking (Section 16),

4.1.6 Finish (Section 8),

4.1.7 Packaging (Section 16),

4.1.8 Required reports (Section 15), and

4.1.9 Disposition of rejected material (Section 14).

5. Chemical Composition

5.1 The grades of titanium and titanium alloy metal covered by this specification shall conform to the requirements as to chemical composition prescribed in Table 1.

5.1.1 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.

5.1.1.1 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.

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

5.2 When agreed upon by the producer and 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.

5.3 *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 manufacturer 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 3.

6. Mechanical Properties

6.1 Material supplied under this specification shall conform to the mechanical property requirements given in Table 2, as applicable.

6.2 Tension testing specimens are to be machined and tested in accordance with Test Methods E8. Tensile properties shall be determined using a strain rate of 0.003 to 0.007 in./in./min through the specified yield strength, and then increasing the rate so as to produce failure in approximately one additional minute.

³ 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.

TABLE 1 Chemical Requirements

Composition, Weight Percent^{A,B,C,D,E}

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
1	R50250	0.08	0.18	0.03	0.015	0.20	--	--	--	--	--	--	--	--	--	--	--	--	0.1	0.4
2/2H	R50400	0.08	0.25	0.03	0.015	0.30	--	--	--	--	--	--	--	--	--	--	--	--	0.1	0.4
3	R50550	0.08	0.35	0.05	0.015	0.30	--	--	--	--	--	--	--	--	--	--	--	--	0.1	0.4
4	R50700	0.08	0.40	0.05	0.015	0.50	--	--	--	--	--	--	--	--	--	--	--	--	0.1	0.4
5	R56400	0.08	0.20	0.05	0.015	0.40	5.5-6.75	3.5-4.5	--	--	--	--	--	--	--	--	--	--	0.1	0.4
6	R54520	0.08	0.20	0.03	0.015	0.50	4.0-6.0	--	--	--	--	--	--	--	--	2.0-3.0	--	--	0.1	0.4
7/7H	R52400	0.08	0.25	0.03	0.015	0.30	--	--	0.12-0.25	--	--	--	--	--	--	--	--	--	0.1	0.4
9	R56320	0.08	0.15	0.03	0.015	0.25	2.5-3.5	2.0-3.0	--	--	--	--	--	--	--	--	--	--	0.1	0.4
11	R52250	0.08	0.18	0.03	0.015	0.20	--	--	0.12-0.25	--	--	--	--	--	--	--	--	--	0.1	0.4
12	R53400	0.08	0.25	0.03	0.015	0.30	--	--	--	--	0.6-0.9	0.2-0.4	--	--	--	--	--	--	0.1	0.4
13	R53413	0.08	0.10	0.03	0.015	0.20	--	--	--	0.04-0.06	0.4-0.6	--	--	--	--	--	--	--	0.1	0.4
14	R53414	0.08	0.15	0.03	0.015	0.30	--	--	--	0.04-0.06	0.4-0.6	--	--	--	--	--	--	--	0.1	0.4
15	R53415	0.08	0.25	0.05	0.015	0.30	--	--	--	0.04-0.06	0.4-0.6	--	--	--	--	--	--	--	0.1	0.4
16/16H	R52402	0.08	0.25	0.03	0.015	0.30	--	--	0.04-0.08	--	--	--	--	--	--	--	--	--	0.1	0.4
17	R52252	0.08	0.18	0.03	0.015	0.20	--	--	0.04-0.08	--	--	--	--	--	--	--	--	--	0.1	0.4
18	R56322	0.08	0.15	0.03	0.015	0.25	2.5-3.5	2.0-3.0	0.04-0.08	--	--	--	--	--	--	--	--	--	0.1	0.4
19	R58640	0.05	0.12	0.03	0.02	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	R58645	0.05	0.12	0.03	0.02	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	R58210	0.05	0.17	0.03	0.015	0.40	2.5-3.5	2.5-3.5	--	--	--	14.0-16.0	--	--	2.2-3.2	--	0.15-0.25	--	0.1	0.4
23	R56407	0.08	0.13	0.03	0.0125	0.25	5.5-6.5	3.5-4.5	--	--	--	--	--	--	--	--	--	--	0.1	0.4
24	R56405	0.08	0.20	0.05	0.015	0.40	6.5-6.75	4.5-5.5	0.04-0.08	--	--	--	--	--	--	--	--	--	0.1	0.4
25	R56403	0.08	0.20	0.05	0.015	0.40	6.75-6.75	3.5-4.5	0.04-0.08	--	0.3-0.8	--	--	--	--	--	--	--	0.1	0.4
26/26H	R52404	0.08	0.25	0.03	0.015	0.30	--	--	--	0.08-0.14	--	--	--	--	--	--	--	--	0.1	0.4
27	R52254	0.08	0.18	0.03	0.015	0.20	--	--	--	0.08-0.14	--	--	--	--	--	--	--	--	0.1	0.4
28	R56323	0.08	0.15	0.03	0.015	0.25	2.5-3.5	2.0-3.0	--	0.08-0.14	--	--	--	--	--	--	--	--	0.1	0.4
29	R56404	0.08	0.13	0.03	0.0125	0.25	5.5-6.5	3.5-4.5	--	0.08-0.14	--	--	--	--	--	--	--	--	0.1	0.4
30	R53530	0.08	0.25	0.03	0.015	0.30	--	--	0.04-0.08	--	--	--	--	0.20-0.80	--	--	--	--	0.1	0.4
31	R53532	0.08	0.35	0.05	0.015	0.30	--	--	0.04-0.08	--	--	--	--	0.20-0.80	--	--	--	--	0.1	0.4

TABLE 1 Continued

 Composition, Weight Percent^{A,B,C,D,E}

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
32	R55111	0.08	0.11	0.03	0.015	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	R53442	0.08	0.25	0.03	0.015	0.30	--	--	0.01-0.02	0.02-0.04	0.35-0.55	--	0.1-0.2	--	--	--	--	--	0.1	0.4
34	R53445	0.08	0.35	0.05	0.015	0.30	--	--	0.01-0.02	0.02-0.04	0.35-0.55	--	0.1-0.2	--	--	--	--	--	0.1	0.4
35	R56340	0.08	0.25	0.05	0.015	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	R58450	0.04	0.16	0.03	0.015	0.03	--	--	--	--	--	--	--	--	--	42.0-47.0	--	--	0.1	0.4
37	R52815	0.08	0.25	0.03	0.015	0.30	1.0-2.0	--	--	--	--	--	--	--	--	--	--	--	0.1	0.4
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, the analysis of samples from the top and bottom of the ingot shall be completed and reported for all elements listed for the respective grade in this table.

^B Final product hydrogen shall be reported. Ingot hydrogen need not be reported. 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.