



Designation: B338 – 14

Standard Specification for Seamless and Welded Titanium and Titanium Alloy Tubes for Condensers and Heat Exchangers¹

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

1. Scope*

1.1 This specification² covers the requirements for 28 grades of titanium and titanium alloy tubing intended for surface condensers, evaporators, and heat exchangers, 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 7*—UNS R52400. Unalloyed titanium plus 0.12 to 0.25 % palladium,
 - 1.1.4.1 *Grade 7H*—UNS R52400. Unalloyed titanium plus 0.12 to 0.25 % palladium (Grade 7 with 58 ksi (400 MPa) minimum UTS),
- 1.1.5 *Grade 9*—UNS R56320. Titanium alloy (3 % aluminum, 2.5 % vanadium),
- 1.1.6 *Grade 11*—UNS R52250. Unalloyed titanium plus 0.12 to 0.25 % palladium,
- 1.1.7 *Grade 12*—UNS R53400. Titanium alloy (0.3 % molybdenum, 0.8 % nickel),
- 1.1.8 *Grade 13*—UNS R53413. Titanium alloy (0.5 % nickel, 0.05 % ruthenium),
- 1.1.9 *Grade 14*—UNS R53414. Titanium alloy (0.5 % nickel, 0.05 % ruthenium),
- 1.1.10 *Grade 15*—UNS R53415. Titanium alloy (0.5 % nickel, 0.05 % ruthenium),
- 1.1.11 *Grade 16*—UNS R52402. Unalloyed titanium plus 0.04 to 0.08 % palladium,
 - 1.1.11.1 *Grade 16H*—UNS R52402. Unalloyed titanium plus 0.04 to 0.08 % palladium (Grade 16 with 58 ksi (400 MPa) minimum UTS),

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

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

1.1.14 *Grade 26*—UNS R52404. Unalloyed titanium plus 0.08 to 0.14 % ruthenium,

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

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

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

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

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

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

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

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

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

1.1.23 *Grade 37*—UNS R52815. Titanium alloy (1.5 % aluminum),

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

1.1.25 *Grade 39*—UNS R53390. Titanium alloy (0.25 % iron, 0.4 % silicon).

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-338 in Section II of that Code.

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

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

conversions to SI units that are provided for information only and are not considered standard.

2. Referenced Documents

2.1 ASTM Standards:³

A370 Test Methods and Definitions for Mechanical Testing of Steel Products

E8 Test Methods for Tension Testing of Metallic Materials

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

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

3. Terminology

3.1 Lot Definitions:

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

3.1.2 *ingot, n*—no definition required.

3.1.3 *rounds, flats, tubes, and wrought powder metallurgical products (single definition, common to nuclear and non-nuclear standards), n*—a lot shall consist of a material of the same size, shape, condition, and finish produced from the same ingot or powder blend by the same reduction schedule and the same heat treatment parameters. Unless otherwise agreed between manufacturer and purchaser, a lot shall be limited to the product of an 8 h period for final continuous anneal, or to a single furnace load for final batch anneal.

3.1.4 *sponge, n*—a lot shall consist of a single blend produced at one time.

3.1.5 *weld fittings, n*—definition is to be mutually agreed upon between manufacturer and the purchaser.

4. Ordering Information

4.1 Orders for material to this specification shall include the following information, as required:

4.1.1 Quantity,

4.1.2 Grade number (Section 1),

4.1.3 Diameter and wall thickness (Note 2) (Section 12),

4.1.4 Length (Section 12),

4.1.5 Method of manufacture and finish (Sections 5 and 13),

4.1.6 Restrictive chemistry, if desired (Section 6 and Table 1),

4.1.7 Product analysis, if desired (Section 7 and Table 2),

4.1.8 Special mechanical properties, if desired (Section 8 and Table 3),

4.1.9 Nondestructive tests (Section 11),

4.1.10 Packaging (Section 23),

4.1.11 Inspection (Section 17), and

4.1.12 Certification (Section 21).

NOTE 2—Tube is available to specified outside diameter and wall thickness. Average OD and wall are the standard. Maximum or minimum OD or wall should be stated.

5. Materials and Manufacture

5.1 Seamless tube shall be made from hollow billet by any cold reducing or cold drawing process that will yield a product meeting the requirements of this specification. Seamless tube is produced with a continuous periphery in all stages of manufacturing operations.

5.2 Welded tube shall be made from annealed, flat-rolled product by an automatic arc-welding process or other method of welding that will yield a product meeting the tensile requirements found in Table 3 of this specification. Welded tubing shall be heat treated by at least a stress relief after forming and welding. Use of filler material is not permitted.

5.3 Welded/cold worked tube (WCS) shall be made from welded tube manufactured as specified in 5.2. The welded tube shall be sufficiently cold worked to final size in order to transform the cast weld microstructure into a typical equiaxed microstructure in the weld upon subsequent heat treatment. The product shall meet the requirements for seamless tube of this specification.

5.4 Grades 9, 18 and 28, which, at the option of the purchaser, can be furnished in either the annealed or the cold worked and stress relieved condition, defined as at a minimum temperature of 600°F (316°C) for not less than 30 min.

6. Chemical Requirements

6.1 The titanium shall conform to the chemical requirements prescribed in Table 1.

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

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 the written purchase order, chemical analysis shall be completed for specific residual elements not listed in this specification.

7. Product Analysis

7.1 When requested by the purchaser and stated in the purchase order, product analysis for any elements listed in Table 1 shall be made on the completed product.

7.1.1 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

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
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
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	—	—	—	—	—	—	—	—	—	—	—	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	0.04-0.08	—	—	—	—	—	—	—	—	—	—	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	—	0.08-0.14	—	—	—	—	—	—	—	—	—	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
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
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	—	—	—	1.5-2.5	—	—	—	—	—	—	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

TABLE 1 Continued

Grade	UNS Number	Composition, Weight Percent ^{A,B,C,D,E}																		
		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
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
39	R53390	0.08	0.15	0.03	0.015	0.15-0.40	--	--	--	--	--	--	--	--	--	--	0.30-0.50	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.