

ASTM B862 / ASME SB862

Standard Specification for Titanium and Titanium Alloy Welded Pipe

This specification covers the requirements for 33 grades of titanium and titanium alloy welded pipe intended for general corrosion resisting and elevated temperature service as follows:

- Grade 1—UNS R50250. Unalloyed titanium, low oxygen,
- Grade 2—UNS R50400. Unalloyed titanium, standard oxygen,
- Grade 2H—UNS R50400. Unalloyed titanium (Grade 2 with 58 ksi (400 MPa) minimum UTS),
- Grade 3—UNS R50550. Unalloyed titanium, medium oxygen,
- Grade 5—UNS R56400. Titanium alloy (6 % aluminum, 4 % vanadium),
- Grade 7—UNS R52400. Unalloyed titanium plus 0.12 to 0.25 % palladium, standard oxygen,
- Grade 7H—UNS R52400. Unalloyed titanium plus 0.12 to 0.25 % palladium (Grade 7 with 58 ksi (400 MPa) minimum UTS),
- Grade 9—UNS R56320. Titanium alloy (3 % aluminum, 2.5 % vanadium),
- Grade 11—UNS R52250. Unalloyed titanium plus 0.12 to 0.25 % palladium, low oxygen,
- Grade 12—UNS R53400. Titanium alloy (0.3 % molybdenum, 0.8 % nickel),
- Grade 13—UNS R5341 3. Titanium alloy (0.5 % nickel, 0.05 % ruthenium), low oxygen,
- Grade 14—UNS R53414. Titanium alloy (0.5 % nickel, 0.05 % ruthenium), standard oxygen,
- Grade 15—UNS R53415. Titanium alloy (0.5 % nickel, 0.05 % ruthenium), medium oxygen,
- Grade 16—UNS R52402. Unalloyed titanium plus 0.04 to 0.08 % palladium, standard oxygen,
- Grade 16H—UNS R52402. Unalloyed titanium plus 0.04 to 0.08 % palladium (Grade 16 with 58 ksi (400 MPa) minimum UTS),
- Grade 17—UNS R52252. Unalloyed titanium plus 0.04 to 0.08 % palladium, low oxygen,
- Grade 18—UNS R56322. Titanium alloy (3 % aluminum, 2.5 % vanadium plus 0.04 to 0.08 % palladium),
- Grade 19—UNS R58640. Titanium alloy (3 % aluminum, 8 % vanadium, 6 % chromium, 4 % zirconium, 4 % molybdenum),
- Grade 20—UNS R58645. Titanium alloy (3 % aluminum, 8 % vanadium, 6 % chromium, 4 % zirconium, 4 % molybdenum) plus 0.04 to 0.08 % palladium,
- Grade 21—UNS R58210. Titanium alloy (15 % molybdenum, 3 % aluminum, 2.7 % niobium, 0.25 % silicon),
- Grade 23—UNS R56407. Titanium alloy (6 % aluminum, 4 % vanadium, extra low interstitial, ELI),
- Grade 24—UNS R56405. Titanium alloy (6 % aluminum, 4 % vanadium) plus 0.04 to 0.08 % palladium,
- Grade 25—UNS R56403. Titanium alloy (6 % aluminum, 4 % vanadium) plus 0.3 to 0.8 % nickel and 0.04 to 0.08 % palladium,
- Grade 26—UNS R52404. Unalloyed titanium plus 0.08 to 0.14 % ruthenium,
- Grade 26H—UNS R52404. Unalloyed titanium plus 0.08 to 0.14 % ruthenium (Grade 26 with 58 ksi (400 MPa) minimum UTS),
- Grade 27—UNS R52254. Unalloyed titanium plus 0.08 to 0.14 % ruthenium,
- Grade 28—UNS R56323. Titanium alloy (3 % aluminum, 2.5 % vanadium) plus 0.08 to 0.14 % ruthenium,
- Grade 29—UNS R56404. Titanium alloy (6 % aluminum, 4 % vanadium with extra low interstitial elements (ELI)) plus 0.08 to 0.14 % ruthenium,
- Grade 33—UNS R53442. Titanium alloy (0.4 % nickel, 0.01 5 % palladium, 0.025 % ruthenium, 0.1 5 % chromium),
- Grade 34—UNS R53445. Titanium alloy (0.4 % nickel, 0.01 5 % palladium, 0.025 % ruthenium, 0.1 5 % chromium),
- Grade 35—UNS R56340. Titanium alloy (4.5 % aluminum, 2 % molybdenum, 1 .6 % vanadium, 0.5 % iron, 0.3 % silicon),
- Grade 37—UNS R52815. Titanium alloy (1 .5 % aluminum),

Grade 38—UNS R54250. Titanium alloy (4 % aluminum, 2.5 % vanadium, 1 .5 % iron), and
 Grade 39—UNS R53390. Titanium alloy (0.25 % iron, 0.4 % silicon).

A. Heat Treatment :-

1. Welded pipe may be further reduced by cold working or hot working. Cold reduced pipe shall be annealed after cold working at a temperature of not less than 1000°F. Hot worked pipe finished above 1400°F (760°C) need not be further heat treated.
2. Grades 1 , 2, 2H, 7, 7H, 11 , 13, 14, 16, 16H, 17, 26H, 33, 37, and 39 shall be furnished as welded or annealed.
3. Grades 3, 12, 15, and 34 shall be furnished as annealed.
4. Grade 5, Grade 23, Grade 24, Grade 25, or Grade 35 shall be furnished as annealed, or aged.
5. Grade 9, Grade 18, or Grade 38 shall be furnished as annealed.
6. Grade 19, Grade 20, or Grade 21 shall be furnished as solution treated, or solution treated and aged.

B. Chemical Composition :-

The grades of titanium and titanium alloy metal covered by this specification shall conform to the requirements of the chemical compositions shown in Table 1.

Table 1

Grade	UNS Number	Composition, Weight Percent A,B,C,D,E										
		C, max.	O ₂ , max	N, max	H, max	Fe, max	Al	V	Pd	Other Components	Other Elements, max. each	Other Elements, max. total
1	R50250	0.08	0.18	0.03	0.015	0.2	--	--	--		0.1	0.4
2/2H	R50400	0.08	0.25	0.03	0.015	0.3	--	--	--		0.1	0.4
3	R50550	0.08	0.35	0.05	0.015	0.3	--	--	--		--	--
5	R56400	0.08	0.2	0.05	0.015	0.4	5.5-6.75	3.5-4.5	—		0.1	0.4
7/7H	R52400	0.08	0.25	0.03	0.015	0.3	--	--	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	0.2	--	--	0.12-0.25		0.1	0.4
12	R53400	0.08	0.25	0.03	0.015	0.3	--	--	--	Ni (0.6-0.9), Mo (0.2-0.4)	0.1	0.4
13	R53413	0.08	0.1	0.03	0.015	0.2	--	--	--	Ru (0.04-0.06), Ni (0.04-0.06)	0.1	0.4
14	R53414	0.08	0.15	0.03	0.015	0.3	--	--	--	Ru (0.04-0.06), Ni (0.04-0.06)	0.1	0.4
15	R53415	0.08	0.25	0.05	0.015	0.3	--	--	--	Ru (0.04-0.06), Ni (0.04-0.06)	0.1	0.4
16/16H	R52402	0.08	0.25	0.03	0.015	0.3	--	--	0.04-0.08		0.1	0.4
17	R52252	0.08	0.18	0.03	0.015	0.2	--	--	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	0.3	3.0-4.0	7.5-8.5	--	Mo (3.5-4.5), Cr (5.5-6.5), Zr (3.5-4.5)	0.15	0.4
20	R58645	0.05	0.12	0.03	0.02	0.3	3.0-4.0	7.5-8.5	0.04-0.08	Mo (3.5-4.5), Cr (5.5-6.5), Zr (3.5-4.5)	0.15	0.4
21	R58210	0.05	0.17	0.03	0.015	0.4	2.5-3.5	--	--	Mo (14.0-16.0), Cb (2.2-3.2), Si (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	0.2	0.05	0.015	0.4	5.5-6.75	3.5-4.5	0.04-0.08		0.1	0.4
25	R56403	0.08	0.2	0.05	0.015	0.4	5.5-6.75	3.5-4.5	0.04-0.08	Ni (0.3-0.8)	0.1	0.4
26/26H	R52404	0.08	0.25	0.03	0.015	0.3	--	--	--	Ru (0.08-0.14)	0.1	0.4
27	R52254	0.08	0.18	0.03	0.015	0.2	--	--	--	Ru (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	--	Ru (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	--	Ru (0.08-0.14)	0.1	0.4
33	R53442	0.08	0.25	0.03	0.015	0.3	--	--	0.01-0.02	Ru (0.02-0.04), Ni (0.35-0.55), Cr (0.1-0.2)	0.1	0.4
34	R53445	0.08	0.35	0.05	0.015	0.3	--	--	0.01-0.02	Ru (0.02-0.04), Ni (0.35-0.55), Cr (0.1-0.2)	0.1	0.4
35	R56340	0.08	0.25	0.05	0.015	0.2-0.8	4.0-5.0	1.1-2.1	--	Mo (1.5-2.5), Si (0.2-0.4)	0.1	0.4
37	R52815	0.08	0.25	0.03	0.015	0.3	1.0-2.0	--	--		0.1	0.4
38	R54250	0.08	0.2-0.3	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	0.15-0.4	—	—	—	Si (0.3-0.5)	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.

C. Tensile Requirements :-

The tensile properties of the pipe, in the condition specified, shall conform to the room temperature requirements of Table 2.

Table 2

Grade	Tensile Strength, min, ksi (MPa)	Yield Strength (0.2 % Offset), ksi (MPa)		Elongation 2 in. or 50 mm, gauge Grade length, min %
		min	max	
1	35 (240)	20 (138)	45 (310)	24
2	50 (345)	40 (275)	65 (450)	20
2H ^{B,C}	58 (400)	40 (275)	65 (450)	20
3	65 (450)	55 (380)	80 (550)	18
5	130 (895)	120 (828)	...	10
5 ^D	160 (1103)	150 (1034)	...	6
7	50 (345)	40 (275)	65 (450)	20
7H ^{B,C}	58 (400)	40 (275)	65 (450)	20
9	90 (620)	70 (483)	...	15
11	35 (240)	20 (138)	45 (310)	24
12	70 (483)	50 (345)	...	18
13	40 (275)	25 (170)	...	24
14	60 (410)	40 (275)	...	20
15	70 (483)	55 (380)	...	18
16	50 (345)	40 (275)	65 (450)	20
16H ^{B,C}	58 (400)	40 (275)	65 (450)	20
17	35 (240)	20 (138)	45 (310)	24
18	90 (620)	70 (483)	...	15
19 ^E	115 (793)	110 (759)	...	15
19 ^D	135 (930)	130 (897)	159 (1096)	10
19 ^D	165 (1138)	160 (1103)	185 (1276)	5
20 ^E	115 (793)	110 (759)	...	15
20 ^D	135 (930)	130 (897)	159 (1096)	10
20 ^D	165 (1138)	160 (1103)	185 (1276)	5

21 ^E	115 (793)	110 (759)	...	15
21 ^D	140 (966)	130 (897)	159 (1096)	15
21 ^D	170 (1172)	160 (1104)	185 (1276)	8
23	120 (828)	110 (759)	...	10
24	130 (895)	120 (828)	...	10
25	130 (895)	120 (828)	...	10
26	50 (345)	40 (275)	65 (450)	20
26H ^{B,C}	58 (400)	40 (275)	65 (450)	20
27	35 (240)	20 (138)	45 (310)	24
28	90 (620)	70 (483)	...	15
29	120 (828)	110 (759)	...	10
33	50 (345)	40 (275)	65 (450)	20
34	65 (450)	55 (380)	80 (550)	18
35	130 (895)	120 (828)	...	5
37	50 (345)	31 (215)	65 (450)	20
38	130 (895)	115 (794)	...	10
39	75 (515)	60 (410)	90 (620)	20

^A Properties for as welded or annealed condition except as noted.

^B 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. Grade 2H, 7H, 1 6H, and 26H are intended primarily for pressure vessel use.

^C The H grades were added in response to a user association request based on its study of over 5200 commercial Grade 2, 7, 1 6, and 26 test reports, where over 99 % met the 58 ksi minimum UTS.

^D Properties for material in the solution treated and aged condition.

^E Properties for material in the solution treated condition.

D. Length :-

1. Pipe shall be furnished in lengths as specified in the purchase order. The length tolerance for pipe ordered in specified lengths of 24 ft or less shall be plus 1/4 in. (6.4 mm) minus zero.

E. Test Specimens and Methods of Testing :-

1. The test specimens and the tests required by this specification shall conform to those described in Test Methods and Definitions A370.

F. Pipe Weld Quality Tests :-

1. Assessment of pipe weld quality shall be performed by either the flattening test or the guided bend test.
2. Guided Bend Test—

- i. For Grades 1 , 2, 2H, 7, 7H, 11 , 13, 14, 16, 16H, 17, 26H, 33, and 39 a longitudinal or transverse guided bend test of the weld shall be performed in accordance with the method outlined in the ASME Boiler and Pressure Vessel Code, Section VIII, Paragraph UNF-95.
 - ii. For Grades 3, 5, 9, 12, 15, 18, 19, 20, 21, 23, 24, 25, 34, 35, 37, and 38 the requirements for the guided bend test shall be negotiated between the manufacturer and the purchaser.
3. Flattening Test—
- i. Welded pipe in the final condition shall be capable of withstanding, without cracking, flattening under a load applied gradually at room temperature until the distance between the load platens is H inches. The weld shall be positioned at either 90° or 270° to the direction of the applied load. H is calculated as follows:

$$H, \text{ in. (mm)} = [(1+e) t] / [e + (t/D)] \quad \dots\dots\dots (1)$$
 where: H = minimum flattened height, in. (mm),
 t = nominal wall thickness, in. (mm),
 D = nominal pipe outside diameter, in. (mm) (not pipe size), and
 For Grades 1 , 2, 2H, 3, 7, 7H, 11 , 13, 14, 16, 16H, 17, 26H, and 39:
 e = 0.04 through 1 in. pipe size, and
 e = 0.06 over 1 in. pipe size.
 - ii. For grades not shown above, the requirements for the flattening test shall be negotiated between the manufacturer and purchaser.

G. Hydrostatic Test :-

- 1. Each length of pipe shall withstand, without showing bulges, leaks, or other defects, an internal hydrostatic pressure that will produce in the pipe wall a stress of 50 % of the minimum specified yield strength at room temperature. This pressure shall be determined by the equation:

$$P = SEt / (Ro - 0.4t) \quad \dots\dots\dots (2)$$
 where: P = minimum hydrostatic test pressure, psi (MPa),
 S = allowable fiber stress of one-half the minimum yield strength, psi (MPa),
 t = wall thickness, in. (mm),
 Ro = outside tube radius, in. (mm), and
 E = 0.85 for welded pipe.
- 2. The maximum hydrostatic test pressure shall not exceed 2500 psi (17.2 MPa) for sizes 3 in. (76 mm) and under, or 2800 psi (19.3 MPa) for sizes over 3 in. (76 mm). Hydrostatic pressure shall be maintained for not less than 5 s.
- 3. When requested by the purchaser and so stated in the order, pipe in sizes 14 in. (356 mm) in diameter and smaller, shall be tested to one and one-half times the specified working pressure.
- 4. When one and one-half times the working pressure exceeds 2800 psi (19.3 MPa), the hydrostatic test pressure shall be as agreed upon between the manufacturer and the purchaser.

H. Supplementary Requirements :-

- 1. Pipe Requiring Special Consideration
 - i. Liquid Penetrant Inspection:
 - a. Liquid penetrant inspection shall be performed on all weld surfaces on the outside diameter and a length up to 1.5 times the nominal diameter on the inside diameter weld.

- ii. Radiographic Examination:
 - a. The entire length of weld in each welded pipe shall be examined radiographically, using x-radiation, in accordance with Paragraph UW-51 of Section VIII, Division 1 of the ASME Boiler and Pressure Vessel Code.
 - b. Pipe welds shall be spot radiographed, using x-radiation, in accordance with Paragraph UW-52 of Section VIII, Division 1 of the ASME Boiler and Pressure Vessel Code.
- iii. Stress Relief Heat Treatment:
 - a. The stress relieving heat treatment shall consist of holding the pipe at a minimum temperature of 1100°F for not less than 0.5 h/in. of wall thickness. Minimum time at temperature shall be 20 min.

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