Designation: B 862 – 99

Standard Specification for Titanium and Titanium Alloy Welded Pipe[1]

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1. Scope

1.1 This specification covers the requirements for 26 grades of titanium and titanium alloy welded pipe intended for general corrosion resisting and elevated temperature service as follows:

1.1.1 *Grade 1*—Unalloyed titanium, low oxygen,

1.1.2 *Grade 2*—Unalloyed titanium, standard oxygen,

1.1.3 *Grade 3*—Unalloyed titanium, medium oxygen,

1.1.4 *Grade 5*—Titanium alloy (6 % aluminum, 4 % vanadium),

1.1.5 *Grade 7*—Unalloyed titanium plus 0.12 % to 0.25 % palladium, standard oxygen,

1.1.6 *Grade 9*—Titanium alloy (3 % aluminum, 2.5 % vanadium),

1.1.7 *Grade 11*—Unalloyed titanium plus 0.12 % to 0.25 % palladium, low oxygen,

1.1.8 *Grade 12*—Titanium alloy (0.3 % molybdenum, 0.8 % nickel),

1.1.9 *Grade 13*—Titanium alloy (0.5 % nickel, 0.05 % ruthenium), low oxygen,

1.1.10 *Grade 14*—Titanium alloy (0.5 % nickel, 0.05 % ruthenium), standard oxygen,

1.1.11 *Grade 15*—Titanium alloy (0.5 % nickel, 0.05 % ruthenium), medium oxygen,

1.1.12 *Grade 16*—Unalloyed titanium plus 0.04 % to 0.08 % palladium, standard oxygen,

1.1.13 *Grade 17*—Unalloyed titanium plus 0.04 % to 0.08 % palladium, low oxygen,

1.1.14 *Grade 18*—Titanium alloy (3 % aluminum, 2.5 % vanadium plus 0.04 % to 0.08 % palladium),

1.1.15 *Grade 19*—Titanium alloy (3 % aluminum, 8 % vanadium, 6 % chromium, 4 % zirconium, 4 % molybdenum),

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

1.1.17 *Grade 21*—Titanium alloy (15 % molybdenum, 3 % aluminum, 2.7 % niobium, 0.25 % silicon),

1.1.18 *Grade 23*—Titanium alloy (6 % aluminum, 4 % vanadium, extra low interstitial, ELI),

1.1.19 *Grade 24*—Titanium alloy (6 % aluminum, 4 % vanadium) plus 0.04 % to 0.08 % palladium,

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

1.1.21 *Grade 26*—Unalloyed titanium plus 0.08 % to 0.14 % ruthenium,

1.1.22 *Grade 27*—Unalloyed titanium plus 0.08 % to 0.14 % ruthenium,

1.1.23 *Grade 28*—Titanium alloy (3 % aluminum, 2.5 % vanadium) plus 0.08 % to 0.14 % ruthenium,

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

1.1.25 *Grade 33*—Titanium alloy (0.4% nickel, 0.015% palladium, 0.025% ruthenium, 0.15% chromium), and

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

1.2 Pipe 8 in. NPS (nominal pipe size) and larger is most frequently custom made for an order. In such cases, the purchaser carefully should consider the applicability of this specification. Since the pipe is custom made, the purchaser may choose a wall thickness other than those in Table 1 to meet specific operating conditions. The purchaser may also be better served to specify only the portions of this specification that are required to meet the operating conditions (for example, annealing, flattening test, chemistry, properties, etc.)

1.3 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are for information only.

1.4 Optional supplementary requirements are provided for pipe where a greater degree of testing is desired. These supplementary requirements may be invoked by the purchaser, when desired, by specifying in the order.

2. Referenced Documents

2.1 *ASTM Standards:*

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products[2]

B 600 Guide for Descaling and Cleaning Titanium and Titanium Alloy Surfaces[3]

E 8 Test Methods for Tension Testing of Metallic Materials[4]

E 29 Practice for Using Significant Digits in Test Data to

[1] This specification is under the jurisdiction of ASTM Committee B-10 on Reactive and Refractory Metals and Alloysand is the direct responsibility of Subcommittee B10.01on Titanium.

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[2] *Annual Book of ASTM Standards*, Vol 01.03.

[3] *Annual Book of ASTM Standards*, Vol 02.04.

[4] *Annual Book of ASTM Standards*, Vol 03.01.

TABLE 1 Dimensions of Pipe

NOTE 1—The following table is a reprint of Table 1 of ANSI B36.19.
NOTE 2—The decimal thicknesses listed for the respective pipe sizes represent their nominal wall dimensions.

NPS Designator	Outside Diameter		Nominal Wall Thickness							
	in.	mm	Schedule 5S[A]		Schedule 10S[A]		Schedule 40S		Schedule 80S	
			in.	mm	in.	mm	in.	mm	in.	mm
⅛	0.405	10.29	...	...	0.049	1.24	0.068	1.73	0.095	2.41
¼	0.540	13.72	...	...	0.065	1.65	0.088	2.24	0.119	3.02
⅜	0.675	17.15	...	...	0.065	1.65	0.091	2.31	0.126	3.20
½	0.840	21.34	0.065	1.65	0.083	2.11	0.109	2.77	0.147	3.73
¾	1.050	26.67	0.065	1.65	0.083	2.11	0.113	2.87	0.154	3.91
1.0	1.315	33.40	0.065	1.65	0.109	2.77	0.133	3.38	0.179	4.55
1¼	1.660	42.16	0.065	1.65	0.109	2.77	0.140	3.56	0.191	4.85
1½	1.900	48.26	0.065	1.65	0.109	2.77	0.145	3.68	0.200	5.08
2	2.375	60.33	0.065	1.65	0.109	2.77	0.154	3.91	0.218	5.54
2½	2.875	73.03	0.083	2.11	0.120	3.05	0.203	5.16	0.276	7.01
3	3.500	88.90	0.083	2.11	0.120	3.05	0.216	5.49	0.300	7.62
3½	4.000	101.60	0.083	2.11	0.120	3.05	0.226	5.74	0.318	8.08
4	4.500	114.30	0.083	2.11	0.120	3.05	0.237	6.02	0.337	8.56
5	5.563	141.30	0.109	2.77	0.134	3.40	0.258	6.55	0.375	9.52
6	6.625	168.28	0.109	2.77	0.134	3.40	0.280	7.11	0.432	10.97
8	8.625	219.08	0.109	2.77	0.148	3.76	0.322	8.18	0.500	12.70
10	10.750	273.05	0.134	3.40	0.165	4.19	0.365	9.27	0.500[B]	12.70[B]
12	12.750	323.85	0.156	3.96	0.180	4.57	0.375[B]	9.52[B]	0.500[B]	12.70[B]
14	14.000	355.60	0.156	3.96	0.188[B]	4.78[B]	...	...	...	...
16	16.000	406.40	0.165	4.19	0.188[B]	4.78[B]	...	...	...	...
18	18.000	457.20	0.165	4.19	0.188[B]	4.78[B]	...	...	...	...
20	20.000	508.00	0.188	4.78	0.218[B]	5.54[B]	...	...	...	...
22	22.000	558.80	0.188	4.78	0.218[B]	5.54[B]	...	...	...	...
24	24.000	609.60	0.218	5.54	0.250	6.35	...	...	...	...
30	30.000	762.00	0.250	6.35	0.312	7.92	...	...	...	...

[A] Schedules 5S and 10S wall thicknesses do not permit threading in accordance with ANSI B1.20.1.
[B] These do not conform to ANSI B36.10.

Determine Conformance with Specifications[5]

E 120 Test Methods for Chemical Analysis of Titanium and Titanium Alloys[6]

E 1409 Test Method for Determination of Oxygen in Titanium and Titanium Alloys by the Inert Gas Fusion Technique[6]

E 1417 Practice for Liquid Penetrant Examination[7]

E 1447 Test Method for Determination of Hydrogen in Titanium and Titanium Alloys by the Inert Gas Fusion Thermal Conductivity Method[8]

2.2 *ANSI/ASME Standards:*

B 36.19M-1985 Stainless Steel Pipe[9]

ASME Boiler and Pressure Vessel Code, Section VIII

3. Terminology

3.1 *Definitions:*

3.1.1 *lot*—a number of pieces of pipe of the same nominal size and wall thickness manufactured by the same process from a single heat of titanium or titanium alloy and heat treated by the same furnace parameters in the same furnace.

3.1.2 *welded pipe*—a hollow tubular product produced by forming flat-rolled product and seam welding to make a right circular cylinder.

4. Ordering Information

4.1 Orders for materials under this specification shall include the following information as required:

4.1.1 Quantity,

4.1.2 Grade number (Section 1 and Table 2),

[5] *Annual Book of ASTM Standards*, Vol 14.02.
[6] *Annual Book of ASTM Standards*, Vol 03.05.
[7] *Annual Book of ASTM Standards*, Vol 03.03.
[8] *Annual Book of ASTM Standards*, Vol 03.06

[9] Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

TABLE 2 Chemical Requirements[A]

Element	Composition, %							
	Grade 1	Grade 2	Grade 3	Grade 5	Grade 7	Grade 9	Grade 11	Grade 12
Nitrogen, max	0.03	0.03	0.05	0.05	0.03	0.03	0.03	0.03
Carbon, max	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Hydrogen,[B,C] max	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015
Iron, max	0.20	0.30	0.30	0.40	0.30	0.25	0.20	0.30
Oxygen, max	0.18	0.25	0.35	0.20	0.25	0.15	0.18	0.25
Aluminum	...	...	...	5.5–6.75	...	2.5–3.5	...	...
Vanadium	...	...	...	3.5–4.5	...	2.0–3.0	...	...
Tin	...	...	...	...	...	...	...	...
Ruthenium	...	...	...	...	...	...	...	...
Palladium	...	...	...	...	0.12–0.25	...	0.12–0.25	...
Cobalt	...	...	...	...	...	...	...	...
Molybdenum	...	...	...	...	...	...	...	0.2–0.4
Chromium	...	...	...	...	...	...	...	...
Nickel	...	...	...	...	...	...	...	0.6–0.9
Niobium	...	...	...	...	...	...	...	...
Zirconium	...	...	...	...	...	...	...	...
Silicon	...	...	...	...	...	...	...	...
Residuals,[D,E,F] max each	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Residuals,[D,E,F] max total	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Titanium[G]	balance	balance	balance	balance	balance	balance	balance	balance

Element	Composition, %									
	Grade 13	Grade 14	Grade 15	Grade 16	Grade 17	Grade 18	Grade 19	Grade 20	Grade 21	Grade 23
Nitrogen, max	0.03	0.03	0.05	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Carbon, max	0.08	0.08	0.08	0.08	0.08	0.08	0.05	0.05	0.05	0.08
Hydrogen,[B,C] max	0.015	0.015	0.015	0.015	0.015	0.015	0.02	0.02	0.015	0.0125
Iron, max	0.20	0.30	0.30	0.30	0.20	0.25	0.30	0.30	0.40	0.25
Oxygen, max	0.10	0.15	0.25	0.25	0.18	0.15	0.12	0.12	0.17	0.13
Aluminum	...	...	...	...	...	2.5–3.5	3.0–4.0	3.0–4.0	2.5–3.5	5.5–6.5
Vanadium	...	...	...	...	...	2.0–3.0	7.5–8.5	7.5–8.5	...	3.5–4.5
Tin	...	...	...	...	...	...	...	...	...	...
Ruthenium	0.04–0.06	0.04–0.06	0.04–0.06	...	...	...	...	...	...	...
Palladium	...	...	...	0.04–0.08	0.04–0.08	0.04–0.08	...	0.04–0.08	...	...
Cobalt	...	...	...	...	...	...	...	...	...	...
Molybdenum	...	...	...	...	...	...	3.5–4.5	3.5–4.5	14.0–16.0	...
Chromium	...	...	...	...	...	...	5.5–6.5	5.5–6.5	...	...
Nickel	0.04–0.06	0.04–0.06	0.04–0.06	...	...	...	...	...	...	...
Niobium	...	...	...	...	...	...	...	...	2.2–3.2	...
Zirconium	...	...	...	...	...	...	3.5–4.5	3.5–4.5	...	...
Silicon	...	...	...	...	...	...	...	...	0.15–0.25	...
Residuals,[D,E,F] max each	0.1	0.1	0.1	0.1	0.1	0.1	0.15	0.15	0.1	0.1
Residuals,[D,E,F] max total	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Titanium[G]	balance	balance	balance	balance	balance	balance	balance	balance	balance	balance

TABLE 2 *Continued*

Element	Composition, %							
	Grade 24	Grade 25	Grade 26	Grade 27	Grade 28	Grade 29	Grade 33	Grade 34
Nitrogen, max	0.05	0.05	0.03	0.03	0.03	0.03	0.03	0.05
Carbon, max	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Hydrogen,[B,C] max	0.015	0.0125	0.015	0.015	0.015	0.015	0.015	0.015
Iron, max	0.40	0.40	0.30	0.20	0.25	0.25	0.30	0.30
Oxygen, max	0.20	0.20	0.25	0.18	0.15	0.13	0.25	0.35
Aluminum	5.5–6.75	5.5–6.75	...	...	2.5–3.5	5.5–6.5	...	...
Vanadium	3.5–4.5	3.5–4.5	...	...	2.0–3.0	3.5–4.5	...	...
Tin	...	...	...	...	...	...	...	...
Ruthenium	...	...	0.08–0.14	0.08–0.14	0.08–0.14	0.08–0.14	0.02-0.04	0.02-0.04
Palladium	0.04–0.08	0.04–0.08	...	...	...	...	0.01-0.02	0.01-0.02
Cobalt	...	...	...	...	...	...	...	...
Molybdenum	...	...	...	...	...	...	...	...
Chromium	...	...	...	...	...	...	0.1-0.2	0.1-0.2
Nickel	...	0.3–0.8	...	...	...	...	0.35-0.55	0.35-0.55
Niobium	...	...	...	...	...	...	...	...
Zirconium	...	...	...	...	...	...	...	...
Silicon	...	...	...	...	...	...	...	...
Residuals,[D,E,F] max each	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Residuals,[D,E,F] max total	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Titanium[G]	balance	balance	balance	balance	balance	balance	Remainder	Remainder

[A] Analysis shall be completed for all elements listed in this table for each grade. The analysis results for the elements not quantified in the table need not be reported unless the concentration level is greater than 0.1 % each or 0.4 % total.
[B] Lower hydrogen may be obtained by negotiation with the manufacturer.
[C] Final product analysis.
[D] Need not be reported.
[E] A residual is an element present in a metal or an alloy in small quantities and is inherent to the manufacturing process but not added intentionally. In titanium these elements include aluminum, vanadium, tin, chromium, molybdenum, niobium, zirconium, hafnium, bismuth, ruthenium, palladium, yttrium, copper, silicon, cobalt, tantalum, nickel, boron, manganese, and tungsten.
[F] The purchaser may, in his written purchase order, request analysis for specific residual elements not listed in this specification.
[G] The percentage of titanium is determined by difference.

4.1.3 Nominal pipe size and schedule (Table 1),
4.1.4 Diameter tolerance (see 9.2),
4.1.5 Method of manufacture and finish (Sections 5 and 10),
4.1.6 Product analysis, if required (Sections 6 and 7; Table 2 and Table 3),
4.1.7 Mechanical properties, (Sections 8, 11, 13, 14, and 15, and Table 4),
4.1.8 Packaging (Section 22),
4.1.9 Inspection and test reports (Sections 18, 19 and 20), and
4.1.10 Supplementary requirements.

5. Manufacture

5.1 Welded pipe shall be made from annealed flat-rolled products by a welding process that will yield a product meeting the requirements of this specification. As shown in Table 5, filler metal, if used, shall be of the same grade as the base metal, or the next lower strength grade of similar composition for welding Grades 2, 3, 5, 7, 14, or 15. For welding Grades 1, 9, 11, 12, 13, 18, 19, 20, 21, 23, 24, or 25 the filler metal, if used, shall be the same as the grade specified. For Grade 16, filler metal of Grades 7, 11, 16, or 17 shall be used. For Grade 17, filler metal of Grade 11 or 17 shall be used.

5.1.1 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.

TABLE 3 Permissible Variations in Product Analysis

Element	Product Analysis Limits, Max or Range, %	Permissible Variation in Product Analysis
Nitrogen	0.05	+ 0.02
Carbon	0.10	+ 0.02
Hydrogen	0.02	+ 0.002
Iron	0.50	+ 0.15
Oxygen	0.30	+ 0.03
Oxygen	0.31 to 0.40	±0.04
Aluminum	2.5 to 6.75	±0.40
Vanadium	2.0 to 4.5	±0.15
Vanadium	7.5 to 8.5	±0.40
Palladium	0.01 to 0.02	±0.002
Palladium	0.04 to 0.08	±0.005
Palladium	0.12 to 0.25	±0.02
Ruthenium	0.02 to 0.04	±0.005
Ruthenium	0.04 to 0.06	±0.005
Ruthenium	0.08 to 0.14	±0.01
Silicon	0.15 to 0.25	±0.02
Zirconium	3.5 to 4.5	±0.20
Chromium	0.1 to 0.2	±0.02
Chromium	5.5 to 6.5	±0.30
Niobium	2.2 to 3.2	±0.15
Molybdenum	0.2 to 0.4	±0.03
Molybdenum	3.5 to 4.5	±0.20
Molybdenum	14.0 to 16.0	±0.50
Nickel	0.3 to 0.9	±0.05
Residuals[A] (each)	0.15	+ 0.02

[A] A residual is an element in a metal or alloy in small quantities inherent to the manufacturing process but not added intentionally.

5.2 Pipe shall be furnished as follows unless otherwise specified:
5.2.1 Grades 1, 2, 7, 11, 13, 14, 16, 17, and 33 shall be