Designation: B862 – 09

StandardSpecification for Titanium and Titanium Alloy Welded Pipe[1]

This standard is issued under the fixed designation B862; 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.

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

1. Scope*

1.1 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:

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

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

1.1.2.1 *Grade 2H*—Unalloyed titanium (Grade 2 with 58 ksi minimum UTS),

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,

1.1.5.1 *Grade 7H*—Unalloyed titanium plus 0.12 to 0.25 % palladium (Grade 7 with 58 ksi minimum UTS),

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,

1.1.12.1 *Grade 16H*—Unalloyed titanium plus 0.04 to 0.08 % palladium (Grade 16 with 58 ksi minimum UTS),

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,

1.1.21.1 *Grade 26H*—Unalloyed titanium plus 0.08 to 0.14 % ruthenium (Grade 26 with 58 ksi minimum UTS),

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),

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

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

1.1.28 *Grade 37*—Titanium alloy (1.5 % aluminum), and

1.1.29 *Grade 38*—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.

The H grades were added in response to a user association request based on its study of over 5200 commercial Grade 2, 7, 16, and 26 test reports, where over 99 % met the 58 ksi minimum UTS.

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

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

Current edition approved May 1, 2009. Published June 2009. Originally approved in 1995. Last previous edition approved in 2008 as B862 – 08a. DOI: 10.1520/B0862-09.

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

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 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.

1.4 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:*[2]

A370 Test Methods and Definitions for Mechanical Testing of Steel Products

B600 Guide for Descaling and Cleaning Titanium and Titanium Alloy Surfaces

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

E1417 Practice for Liquid Penetrant Testing

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 Atomic Emission Plasma Spectrometry

E2626 Guide for Spectrometric Analysis of Reactive and Refractory Metals

2.2 *ANSI/ASME Standards:*[3]

B.1.20.1 Pipe Threads, General Purpose (Inch)

B 36.10 Carbon, Alloy and Stainless Steel Pipes

B 36.19M-1985 Stainless Steel Pipe

ASME Boiler and Pressure Vessel Code Section VIII

2.3 *AWS Standard:*[4]

AWS A5.16/A5.16M-2007 Specification for Titanium and Titanium Alloy Welding Electrodes and Rods

[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.

[3] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

[4] Available from American Welding Society (AWS), 550 NW LeJeune Rd., Miami, FL 33126, http://www.aws.org.

3. Terminology

3.1 *Definitions:*

3.1.1 *lot, n*—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, n*—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),

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 1 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. Filler metal, if used, shall be produced to the latest revision of Specification AWS A5.16/A5.16M-2007 employing the ER Ti-X grade listed in Table 5, unless specified otherwise on the purchase order.

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.

5.2 Pipe shall be furnished as follows unless otherwise specified:

5.2.1 Grades 1, 2, 2H, 7, 7H, 11, 13, 14, 16, 16H, 17, 26H, 33, and 37 shall be furnished as welded or annealed.

5.2.2 Grades 3, 12, 15, and 34 shall be furnished as annealed.

5.2.3 Grade 5, Grade 23, Grade 24, Grade 25, or Grade 35 shall be furnished as annealed, or aged.

5.2.4 Grade 9, Grade 18, or Grade 38 shall be furnished as annealed.

5.2.5 Grade 19, Grade 20, or Grade 21 shall be furnished as solution treated, or solution treated and aged.

6. Chemical Composition

6.1 The grades of titanium and titanium alloy metal covered by this specification shall conform to the requirements of the chemical compositions shown in Table 2.

TABLE 1 Dimensions of Pipe

NOTE 1—Schedule sizes conform to ANSI/ASME B 36.19M-1985 (for "S" sizes) or B 36.10 (for non-S sizes).

NOTE 2—The decimal thickness listed for the respective pipe sizes represent their nominal wall dimensions.

NPS Desig.	Outside Dia.		Nominal Wall Thickness															
			Schedule 5S[A]		Schedule 5[A]		Schedule 10S[A]		Schedule 10[A]		Schedule 40S		Schedule 40		Schedule 80S		Schedule 80	
	in	mm	in	mm	in	mm	in	mm	in	mm	in	mm	in	mm	in	mm	in	mm
⅛	0.405	10.29	x	x	x	x	0.049	1.24	0.049	1.24	0.068	1.73	0.068	1.73	0.095	2.41	0.095	2.41
¼	0.540	13.72	x	x	x	x	0.065	1.65	0.065	1.65	0.088	2.24	0.088	2.24	0.119	3.02	0.119	3.02
⅜	0.675	17.15	x	x	x	x	0.065	1.65	0.065	1.65	0.091	2.31	0.091	2.31	0.126	3.20	0.126	3.20
½	0.840	21.34	0.065	1.65	0.065	1.65	0.083	2.11	0.083	2.11	0.109	2.77	0.109	2.77	0.147	3.73	0.147	3.73
¾	1.050	26.67	0.065	1.65	0.065	1.65	0.083	2.11	0.083	2.11	0.113	2.87	0.113	2.87	0.154	3.91	0.154	3.91
1	1.315	33.40	0.065	1.65	0.065	1.65	0.109	2.77	0.109	2.77	0.133	3.38	0.133	3.38	0.179	4.55	0.179	4.55
1-¼	1.660	42.16	0.065	1.65	0.065	1.65	0.109	2.77	0.109	2.77	0.140	3.56	0.140	3.56	0.191	4.85	0.191	4.85
1-½	1.900	48.26	0.065	1.65	0.065	1.65	0.109	2.77	0.109	2.77	0.145	3.68	0.145	3.68	0.200	5.08	0.200	5.08
2	2.375	60.32	0.065	1.65	0.065	1.65	0.109	2.77	0.109	2.77	0.154	3.91	0.154	3.91	0.218	5.54	0.218	5.54
2-½	2.875	73.02	0.083	2.11	0.083	2.11	0.120	3.05	0.120	3.05	0.203	5.16	0.203	5.16	0.276	7.01	0.276	7.01
3	3.500	88.90	0.083	2.11	0.083	2.11	0.120	3.05	0.120	3.05	0.216	5.49	0.216	5.49	0.300	7.62	0.300	7.62
3-½	4.000	101.60	0.083	2.11	0.083	2.11	0.120	3.05	0.120	3.05	0.226	5.74	0.226	5.74	0.318	8.08	0.318	8.08
4	4.500	114.30	0.083	2.11	0.083	2.11	0.120	3.05	0.120	3.05	0.237	6.02	0.237	6.02	0.337	8.56	0.337	8.56
5	5.563	141.30	0.109	2.77	0.109	2.77	0.134	3.40	0.134	3.40	0.258	6.55	0.258	6.55	0.375	9.53	0.375	9.53
6	6.625	168.27	0.109	2.77	0.109	2.77	0.134	3.40	0.134	3.40	0.280	7.11	0.280	7.11	0.432	10.97	0.432	10.97
8	8.625	219.07	0.109	2.77	0.109	2.77	0.148	3.76	0.148	3.76	0.322	8.18	0.322	8.18	0.500	12.70	0.500	12.70
10	10.75	273.05	0.134	3.40	0.134	3.40	0.165	4.19	0.165	4.19	0.365	9.27	0.365	9.27	0.500	12.70	0.594	15.09
12	12.75	323.85	0.156	3.96	0.156	3.96	0.180	4.57	0.180	4.57	0.375	9.53	0.406	10.31	0.500	12.70	0.688	17.48
14	14.00	355.60	0.156	3.96	0.156	3.96	0.188	4.78	0.250	6.35	x	x	0.438	11.13	x	x	0.750	19.05
16	16.00	406.40	0.165	4.19	0.165	4.19	0.188	4.78	0.250	6.35	x	x	0.500	12.70	x	x	0.844	21.44
18	18.00	457.20	0.165	4.19	0.165	4.19	0.188	4.78	0.250	6.35	x	x	0.562	14.27	x	x	0.938	23.83
20	20.00	508.00	0.188	4.78	0.188	4.78	0.218	5.54	0.250	6.35	x	x	0.594	15.09	x	x	1.031	26.19
22	22.00	558.80	0.188	4.78	0.188	4.78	0.218	5.54	0.250	6.35	x	x	x	x	x	x	1.125	28.58
24	24.00	609.60	0.218	5.54	0.218	5.54	0.250	6.35	0.250	6.35	x	x	0.688	17.48	x	x	1.219	30.96
26	26.00	660.40	x	x	x	x	x	x	0.312	7.92	x	x	x	x	x	x	x	x
28	28.00	711.20	x	x	x	x	x	x	0.312	7.92	x	x	x	x	x	x	x	x
30	30.00	762.00	0.250	6.35	0.250	6.35	0.312	7.92	0.312	7.92	x	x	x	x	x	x	x	x
32	32.00	812.80	x	x	x	x	x	x	0.312	7.92	x	x	0.688	17.48	x	x	x	x
34	34.00	863.60	x	x	x	x	x	x	0.312	7.92	x	x	0.688	17.48	x	x	x	x
36	36.00	914.40	x	x	x	x	x	x	0.312	7.92	x	x	0.750	19.05	x	x	x	x

[A] Threading not permitted in accordance with ANSI B.1.20.1.

TABLE 2 Chemical Requirements

Grade	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
					Composition, Weight Percent[A,B,C,D,E]														
																	- -	0.1	0.4
1	0.08	0.18	0.03	0.015	0.20	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	0.1	0.4
2	0.08	0.25	0.03	0.015	0.30	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	0.1	0.4
2H	0.08	0.25	0.03	0.015	0.30	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	0.1	0.4
3	0.08	0.35	0.05	0.015	0.30	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.1	0.4
5	0.08	0.20	0.05	0.015	0.40	5.5-6.75	3.5-4.5	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.1	0.4
7	0.08	0.25	0.03	0.015	0.30	- -	- -	0.12-0.25	- -	- -	- -	- -	- -	- -	- -	- -	- -	0.1	0.4
7H	0.08	0.25	0.03	0.015	0.30	- -	- -	0.12-0.25	- -	- -	- -	- -	- -	- -	- -	- -	- -	0.1	0.4
9	0.08	0.15	0.03	0.015	0.25	2.5-3.5	2.0-3.0	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	0.1	0.4
11	0.08	0.18	0.03	0.015	0.20	- -	- -	0.12-0.25	- -	- -	- -	- -	- -	- -	- -	- -	- -	0.1	0.4
12	0.08	0.25	0.03	0.015	0.30	- -	- -	- -	- -	0.6-0.9	0.2-0.4	- -	- -	- -	- -	- -	- -	0.1	0.4
13	0.08	0.10	0.03	0.015	0.20	- -	- -	- -	0.04-0.06	0.4-0.6	- -	- -	- -	- -	- -	- -	- -	0.1	0.4
14	0.08	0.15	0.03	0.015	0.30	- -	- -	- -	0.04-0.06	0.4-0.6	- -	- -	- -	- -	- -	- -	- -	0.1	0.4
15	0.08	0.25	0.05	0.015	0.30	- -	- -	- -	0.04-0.06	0.4-0.6	- -	- -	- -	- -	- -	- -	- -	0.1	0.4
16	0.08	0.25	0.03	0.015	0.30	- -	- -	0.04-0.08	- -	- -	- -	- -	- -	- -	- -	- -	- -	0.1	0.4
16H	0.08	0.25	0.03	0.015	0.30	- -	- -	0.04-0.08	- -	- -	- -	- -	- -	- -	- -	- -	- -	0.1	0.4
17	0.08	0.18	0.03	0.015	0.20	- -	- -	0.04-0.08	- -	- -	- -	- -	- -	- -	- -	- -	- -	0.1	0.4
18	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	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	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	0.05	0.17	0.03	0.015	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	0.0125	0.25	5.5-6.5	3.5-4.5	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	0.1	0.4
24	0.08	0.20	0.05	0.015	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	0.015	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	0.015	0.30	- -	- -	- -	0.08-0.14	- -	- -	- -	- -	- -	- -	- -	- -	0.1	0.4
26H	0.08	0.25	0.03	0.015	0.30	- -	- -	- -	0.08-0.14	- -	- -	- -	- -	- -	- -	- -	- -	0.1	0.4
27	0.08	0.18	0.03	0.015	0.20	- -	- -	- -	0.08-0.14	- -	- -	- -	- -	- -	- -	- -	- -	0.1	0.4
28	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	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
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33	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	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	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
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37	0.08	0.25	0.03	0.015	0.30	1.0-2.0	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	0.1	0.4
38	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.

TABLE 3 Permissible Variations in Product Analysis

Element	Product Analysis Limits, Max or Range, %	Permissible Variation in Product Analysis
Aluminum	0.5 to 2.5	±0.20
Aluminum	2.5 to 6.75	±0.40
Carbon	0.10	+0.02
Chromium	0.1 to 0.2	±0.02
Chromium	5.5 to 6.5	±0.30
Hydrogen	0.02	+0.002
Iron	0.80	+0.15
Iron	1.2 to 1.8	±0.20
Molybdenum	0.2 to 0.4	±0.03
Molybdenum	1.5 to 4.5	±0.20
Molybdenum	14.0 to 16.0	±0.50
Nickel	0.3 to 0.9	±0.05
Niobium	2.2 to 3.2	±0.15
Nitrogen	0.05	+0.02
Oxygen	0.30	+0.03
Oxygen	0.31 to 0.40	±0.04
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	0.06 to 0.40	±0.02
Vanadium	2.0 to 4.5	±0.15
Vanadium	7.5 to 8.5	±0.40
Zirconium	3.5 to 4.5	±0.20
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.

6.1.1 The elements listed in Table 2 are intentional alloy additions or elements that are inherent to the manufacture of titanium sponge, ingot, or mill product.

6.1.1.1 Elements other than those listed in Table 2 are deemed to be capable of occurring in the grades listed in Table 2 by and only by way of unregulated or unanalyzed scrap additions to the ingot melt. Therefore, product analysis for elements not listed in Table 2 shall not be required unless specified and shall be considered to be in excess of the intent of this specification.

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

6.3 At least two samples for chemical analysis shall be tested to determine chemical composition. Samples shall be taken from the ingot or the opposite extremes of the product to be analyzed.

7. Product Analysis

7.1 When requested by the purchaser and stated in the purchase order, an analysis of chemical composition shall be made on the finished product.

7.2 The product analysis tolerances listed in Table 3 do not broaden the specified analysis requirements but cover variations between different laboratories in the measurement of chemical content. The manufacturer shall not ship finished product outside of the limits specified in Table 2 for the applicable grade.

8. Tensile Requirements

8.1 The tensile properties of the pipe, in the condition specified, shall conform to the room temperature requirements of Table 4. Mechanical properties for other conditions may be established by written agreement between the manufacturer and the purchaser.

9. Permissible Variations in Dimensions

9.1 A system of standard pipe sizes approved by ANSI as American National Standard for Stainless Steel Pipe (ANSI/ASME B 36.19M-1985) reproduced as Table 1 shall apply.

9.2 Permissible variations in dimensions at any point in the length of the pipe shall conform to the following:

9.2.1 Variations in outside diameter, unless otherwise specified, shall not exceed the limits prescribed in Table 6. For diameters greater than 30 in., the diameter shall not exceed ± 0.5 % of the specified outside diameter. The tolerances on the outside diameter include ovality except as provided for in 9.2.2 and 9.2.3.

9.2.2 Thin-wall pipe usually develops significant ovality (out-of-roundness) during final annealing, straightening, or both. Thin-wall pipe are defined as having a wall thickness of 3 % or less of the outside diameter.

9.2.3 The diameter tolerances of Table 6 are not sufficient to provide for additional ovality expected in thin-wall pipe and are applicable only to the mean of the extreme (maximum and minimum) outside diameter readings in any one cross section. However, for thin-wall pipe the difference in extreme outside diameter readings (ovality) in any one cross section shall not exceed 1.5 % of the specified outside diameter.

9.2.4 Straightness shall be determined by using a 10 ft (3 m) straight edge placed so that both ends of the straight edge are in contact with the pipe. The separation between the straight edge and the pipe shall not exceed 0.250 in. at any point.

9.2.5 Thickness of the wall shall be measured by any appropriate means. The variation in thickness at any point shall not be more than ±12.5 % of the nominal wall thickness specified, unless otherwise agreed upon between the purchaser and manufacturer at the time of the order. Maximum reinforcement of the weld shall conform to the values prescribed in Table 7.

9.2.6 *Length*—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 ¼ in. (6.4 mm) minus zero. Random lengths of pipe and lengths of pipe over 24 ft may be ordered and the maximum and minimum lengths supplied shall be specified in a purchase order.

10. Finish

10.1 The finished pipe shall be straight and shall have smooth ends, be free of burrs, and shall be free of injurious external and internal imperfections. Minor defects may be removed, providing the dimensional tolerances of 9.2.5 are not exceeded. Unless otherwise specified, the pipe shall be furnished free of scale.

TABLE 4 Tensile Requirements[A]

Grade	Tensile Strength, min		Yield Strength (0.2 % Offset)				Elongation 2 in. or 50 mm, gauge length, min %
			min		max		
	ksi	(MPa)	ksi	(MPa)	ksi	(MPa)	
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

[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, 16H, 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, 16, 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.

† Tensile strength for Grade 3 was corrected editorially.
† Tensile strength for Grade 5 was corrected editorially.

11. Number of Tests

11.1 Tests shall be made as follows on 2 % of the process length pipes selected at random, from each lot, but in no case shall less than one pipe be tested. Results of the following tests shall be reported to the purchaser or their representative.

11.1.1 One tension test from each pipe selected.

11.1.2 The guided bend test or flattening test specified in 14.1 and 14.2.

11.2 If any test specimen shows defective machining or develops flaws due to the preparation, the specimen may be discarded and another substituted.

11.3 If the percentage of elongation of any tension test specimen is less than that specified in 8.1, and any part of the fracture is more than ¾ in. (19 mm) from the center of the gauge length as indicated by scratches marked on the specimen before testing, the specimen may be discarded and another substituted.

11.4 Each length of pipe shall be subjected to the hydrostatic test specified in 15.1 and 15.2.

12. Retests

12.1 If the chemical or mechanical test results of any lot are not in conformance with the requirements of this specification, the lot may be retested at the option of the manufacturer. The frequency of the retest will be double the initial number of tests. If the results of the retest conform to the specification, then the retest values will become the test values for certification. Only original conforming test results or conforming retest