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

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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.

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

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:* [2]

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

B 600 Guide for Descaling and Cleaning Titanium and Titanium Alloy Surfaces

E 8 Test Methods for Tension Testing of Metallic Materials

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

E 120 Test Methods for Chemical Analysis of Titanium and Titanium Alloys

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

E 1417 Practice for Liquid Penetrant Testing

E 1447 Test Method for Determination of Hydrogen in Titanium and Titanium Alloys by the Inert Gas Fusion Thermal Conductivity/Infrared Detection Method

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-2004 Specification for Titanium and Titanium Alloy Welding Electrodes and Rods

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

[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.

[4] Available from American Welding Society (AWS), 550 NW LeJeune Rd., Miami, FL 33126.

TABLE 1 Dimensions of Pipe

NOTE 1—Schedule sizes conform to ANSI/ASME B 36.19 (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[A]

Element	Composition, %										
	Grade 1	Grade 2	Grade 2H	Grade 3	Grade 5	Grade 7	Grade 7H	Grade 9	Grade 11	Grade 12	Grade 13
Nitrogen, max	0.03	0.03	0.03	0.05	0.05	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	0.08	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	0.015	0.015	0.015
Iron, max	0.20	0.30	0.30	0.30	0.40	0.30	0.30	0.25	0.20	0.30	0.20
Oxygen, max	0.18	0.25	0.25	0.35	0.20	0.25	0.25	0.15	0.18	0.25	0.10
Aluminum	...	...	...	...	5.5–6.75	...	...	2.5–3.5	...	...	...
Vanadium	...	...	...	...	3.5–4.5	...	...	2.0–3.0	...	...	...
Tin	...	...	...	...	...	...	...	...	...	...	...
Ruthenium	...	...	...	...	...	...	...	...	...	...	0.04–0.06
Palladium	...	...	...	...	...	0.12–0.25	0.12–0.25	...	0.12–0.25	...	...
Cobalt	...	...	...	...	...	...	...	...	...	...	...
Molybdenum	...	...	...	...	...	...	...	...	...	0.2–0.4	...
Chromium	...	...	...	...	...	...	...	...	...	...	...
Nickel	...	...	...	...	...	...	...	...	...	0.6–0.9	0.4–0.6
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	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	0.4	0.4	0.4
Titanium[G]	balance	balance	balance	balance	balance	balance	balance	balance	balance	balance	balance

Element	Composition, %										
	Grade 14	Grade 15	Grade 16	Grade 16H	Grade 17	Grade 18	Grade 19	Grade 20	Grade 21	Grade 23	Grade 24
Nitrogen, max	0.03	0.05	0.03	0.03	0.03	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	0.05	0.05	0.05	0.08	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	0.015
Iron, max	0.30	0.30	0.30	0.30	0.20	0.25	0.30	0.30	0.40	0.25	0.40
Oxygen, max	0.15	0.25	0.25	0.25	0.18	0.15	0.12	0.12	0.17	0.13	0.20
Aluminum	...	...	...	...	...	2.5–3.5	3.0–4.0	3.0–4.0	2.5–3.5	5.5–6.5	5.5–6.75
Vanadium	...	...	...	...	...	2.0–3.0	7.5–8.5	7.5–8.5	...	3.5–4.5	3.5–4.5
Tin	...	...	...	...	...	...	...	...	...	...	...
Ruthenium	0.04–0.06	0.04–0.06	...	...	...	...	...	...	...	...	...
Palladium	...	...	0.04–0.08	0.4–0.08	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	0.4–0.6	0.4–0.6	...	...	...	...	...	...	...	...	...
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	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	0.4
Titanium[G]	balance	balance	balance	balance	balance	balance	balance	balance	balance	balance	balance

Element	Composition, %										
	Grade 25	Grade 26	Grade 26H	Grade 27	Grade 28	Grade 29	Grade 33	Grade 34	Grade 35	Grade 37	Grade 38
Nitrogen, max	0.05	0.03	0.03	0.03	0.03	0.03	0.03	0.05	0.05	0.03	0.03
Carbon, max	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Hydrogen,[B,C] max	0.0125	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015
Iron, max or range	0.40	0.30	0.30	0.20	0.25	0.25	0.30	0.30	0.20–0.80	0.30	1.2–1.8
Oxygen, max or range	0.20	0.25	0.25	0.18	0.15	0.13	0.25	0.35	0.25	0.25	0.20–0.30
Aluminum	5.5–6.75	...	...	...	2.5–3.5	5.5–6.5	...	...	4.0–5.0	1.0–2.0	3.5–4.5
Vanadium	3.5–4.5	...	...	...	2.0–3.0	3.5–4.5	...	...	1.1–2.1	...	2.0–3.0
Tin	...	...	...	...	...	...	...	...	...	...	...
Ruthenium	...	0.08–0.14	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	...	...	...	...	...	0.01-0.02	0.01-0.02	...	...	...
Cobalt	...	...	...	...	...	...	...	...	...	...	...
Molybdenum	...	...	...	...	...	...	...	...	1.5–2.5	...	...
Chromium	...	...	...	...	...	...	0.1-0.2	0.1-0.2	...	...	...
Nickel	0.3–0.8	...	...	...	...	...	0.35-0.55	0.35-0.55	...	...	...
Niobium	...	...	...	...	...	...	...	...	...	...	...

TABLE 2 *Continued*

Element	Composition, %										
	Grade 25	Grade 26	Grade 26H	Grade 27	Grade 28	Grade 29	Grade 33	Grade 34	Grade 35	Grade 37	Grade 38
Zirconium	...	...	...	...	...	...	...	...	...	...	...
Silicon	...	...	...	...	...	...	...	...	0.20–0.40	...	...
Residuals,[D,E,F] max each	0.1	0.1	0.1	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	0.4	0.4	0.4
Titanium[G]	balance	balance	balance	balance	balance	balance	Remainder	Remainder	Remainder	Remainder	balance

[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.

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.

requirements of this specification. ~~As~~Filler metal, if used, shall be of the grade 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, 2H, 7H, 9, 11, 12, 13, 16H, 18, 19, 20, 21, 23, 24, 25, or 26H 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.

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.

TABLE 4 Tensile Requirements[A]

Grade	Tensile Strength, min ksi	Tensile Strength, min (MPa)	Yield Strength (0.2 % Offset) min ksi	Yield Strength min (MPa)	Yield Strength max ksi	Yield Strength max (MPa)	Elongation 2 in. or 50 mm, gauge length, min %
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]	60	(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.
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.

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.

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.