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Standard Specification for Titanium and Titanium Alloy Seamless Pipe¹

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^{ε1} NOTE—Tensile strength for Grade 3 in Table 5 was corrected editorially in January 2006.

1. Scope

1.1 This specification covers the requirements for 29 grades of titanium and titanium alloy seamless 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 0.08–0.14 % ruthenium),
 - 1.1.24 *Grade 29*—Titanium alloy (6 % aluminum, 4 % vanadium, extra low interstitial, ELI plus 0.08–0.14 % 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 36*—Titanium alloy (45 % niobium), and
 - 1.1.29 *Grade 37*—Titanium alloy (1.5 % aluminum).
- 1.2

2. Referenced Documents

2.1 ASTM Standards:²

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

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

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 B10.0 on Titanium.

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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.

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 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 Standard:

B 36.19M-1985 Stainless Steel Pipe³

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 *seamless pipe, n*—a hollow tubular product produced with a continuous periphery in all stages of manufacture.

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 1),

TABLE 1 Chemical Requirements^A

Element	Composition, %									
	Grade 1	Grade 2	Grade 3	Grade 5	Grade 7	Grade 9	Grade 11	Grade 12	Grade 13	Grade 14
Nitrogen, max	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
Hydrogen, ^{B,C} max	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	0.40	0.30	0.25	0.20	0.30	0.20	0.30
Oxygen, max	0.18	0.25	0.35	0.20	0.25	0.15	0.18	0.25	0.10	0.15
Aluminum	...	...	...	5.5–6.75	...	2.5–3.5	...	...	...	...
Vanadium	...	...	...	3.5–4.5	...	2.0–3.0	...	...	...	...
Tin	...	...	...	...	...	...	...	...	...	...
Ruthenium	...	...	...	...	...	...	...	...	0.04–0.06	0.04–0.06
Palladium	...	...	...	...	0.12–0.25	...	0.12–0.25	...	...	...
Molybdenum	...	...	...	...	...	...	...	0.2–0.4	...	...
Chromium	...	...	...	...	...	...	...	...	...	...
Nickel	...	...	...	...	...	...	...	0.6–0.9	0.4–0.6	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
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

Element	Composition, %									
	Grade 15	Grade 16	Grade 17	Grade 18	Grade 19	Grade 20	Grade 21	Grade 23	Grade 24	
Nitrogen, max	0.05	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	0.05	0.05	0.05	0.08	0.08	
Hydrogen, ^{B,C} max	0.015	0.015	0.015	0.015	0.02	0.02	0.015	0.0125	0.015	
Iron, max	0.30	0.30	0.20	0.25	0.30	0.30	0.40	0.25	0.40	
Oxygen, max	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	...	...	...	...	...	...	...	...
Palladium	...	0.04–0.08	0.04–0.08	0.04–0.08	...	0.04–0.08	...	...	0.04–0.08
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	...	...	...	...	...	...	...	...
Niobium	...	...	...	...	...	...	2.2–3.2	...	...
Zirconium	...	...	...	...	3.5–4.5	3.5–4.5	...	...	...
Silicon	...	...	...	...	...	...	0.15–0.25	...	...

^A Withdrawn.

³ Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.

Element	Composition, %								
	Grade 15	Grade 16	Grade 17	Grade 18	Grade 19	Grade 20	Grade 21	Grade 23	Grade 24
Residuals, ^{D,E,F} max each	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
Titanium ^a	balance	balance	balance	balance	balance	balance	balance	balance	balance

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TABLE 1 Continued

Element	Composition, %									
	Grade 25	Grade 26	Grade 27	Grade 28	Grade 29	Grade 33	Grade 34	Grade 35	Grade 36	Grade 37
Nitrogen, max	0.05	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	0.04	0.08
Hydrogen, ^{B,C} max	0.0125	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.0035	0.015
Iron, max or range	0.40	0.30	0.20	0.25	0.25	0.30	0.30	0.20–0.80	0.03	0.30
Oxygen, max	0.20	0.25	0.18	0.15	0.13	0.25	0.35	0.25	0.16	0.25
Aluminum	5.5–6.75	...	...	2.5-3.5	5.5-6.5	...	...	4.0–5.0	...	1.0–2.0
Vanadium	3.5–4.5	...	...	2.0-3.0	3.5–4.5	...	...	1.1–2.1	...	...
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	...	...	...	...	0.01-0.02	0.01-0.02	...	...	...
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	...	...	...	...	...	...	...	...	42.0–47.0	...
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
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	Remainder	Remainder	Remainder	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 supplier.

^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 2),

4.1.4 Diameter tolerance (Table 3),

4.1.5 Length tolerance (see 9.3),

4.1.6 Method of manufacture and finish (Sections 5 and 10),

4.1.7 Product analysis, if required (Sections 6 and 7; Table 1 and Table 4),

4.1.8 Mechanical properties, (Sections 8, 14, 15, and 16 and Table 5),

4.1.9 Packaging (Section 23),

4.1.10 Inspection and test reports (Sections 19, 20 and 21), and

4.1.11 Product marking (Section 22).

5. Manufacture

5.1 Seamless pipe may be manufactured by any method that will yield a product meeting the requirements of this specification.

5.2 Unless specified, cold worked pipe shall be heat treated at a temperature of not less than 1000°F (538°C). Hot worked pipe finishing above 1400°F (760°C) need not be further heat treated. The minimum heat treat conditions for Grade 9, 18, and 28 pipe delivered in the stress relieved condition shall be 600°F (316°C) for at least 30 min.

5.2.1 Grade 5, Grade 9, Grade 18, Grade 19, Grade 20, Grade 21, Grade 23, Grade 24, Grade 25, Grade 28, Grade 29, Grade 35, and Grade 36 alloys may be supplied in the following conditions:

5.2.1.1 Grade 5, Grade 23, Grade 24, Grade 25, Grade 29, Grade 35, or Grade 36—annealed or aged condition,

5.2.1.2 Grade 9, Grade 18, or Grade 28—cold-worked and stress-relieved or annealed,

5.2.1.3 Grade 9, Grade 18, Grade 23, Grade 28, or Grade 29—transformed-beta condition, and

5.2.1.4 Grade 19, Grade 20, or Grade 21—solution-treated or solution-treated and aged.

~~6. Chemical Requirements~~ Chemical Requirements

6. Chemical Requirements

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

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

6.1.1.1 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 the ingot melt. Therefore, product analysis for elements not listed in

TABLE 2 Dimensions of Pipe

NOTE 1—Schedule sizes conform to ANSI/ASME B36.19 (for “S” sizes) or B36.10 (for non-S sizes).

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

NPS Design.	Outside Dia.		Nominal Wall Thickness																
	in	mm	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
1/8	0.405	10.29	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	0.095	2.41
1/4	0.540	13.72	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	0.119	3.02
3/8	0.675	17.15	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	0.126	3.20
1/2	0.840	21.34	0.065	1.65	0.065	1.65	2.11	0.083	2.11	0.109	2.77	0.109	2.77	0.147	3.73	0.147	3.73	0.147	3.73
3/4	1.050	26.67	0.065	1.65	0.065	1.65	2.11	0.083	2.11	0.113	2.87	0.113	2.87	0.154	3.91	0.154	3.91	0.154	3.91
1	1.315	33.40	0.065	1.65	0.065	1.65	2.77	0.109	2.77	0.133	3.38	0.133	3.38	0.179	4.55	0.179	4.55	0.179	4.55
1-1/4	1.660	42.16	0.065	1.65	0.065	1.65	2.77	0.109	2.77	0.140	3.56	0.140	3.56	0.191	4.85	0.191	4.85	0.191	4.85
1-1/2	1.900	48.26	0.065	1.65	0.065	1.65	2.77	0.109	2.77	0.145	3.68	0.145	3.68	0.200	5.08	0.200	5.08	0.200	5.08
2	2.375	60.32	0.065	1.65	0.065	1.65	2.77	0.109	2.77	0.154	3.91	0.154	3.91	0.218	5.54	0.218	5.54	0.218	5.54
2-1/2	2.875	73.02	0.083	2.11	0.083	2.11	3.05	0.120	3.05	0.203	5.16	0.203	5.16	0.276	7.01	0.276	7.01	0.276	7.01
3	3.500	88.90	0.083	2.11	0.083	2.11	3.05	0.120	3.05	0.216	5.49	0.216	5.49	0.300	7.62	0.300	7.62	0.300	7.62
3-1/2	4.000	101.60	0.083	2.11	0.083	2.11	3.05	0.120	3.05	0.226	5.74	0.226	5.74	0.318	8.08	0.318	8.08	0.318	8.08
4	4.500	114.30	0.083	2.11	0.083	2.11	3.05	0.120	3.05	0.237	6.02	0.237	6.02	0.337	8.56	0.337	8.56	0.337	8.56
5	5.563	141.30	0.109	2.77	0.109	2.77	3.40	0.134	3.40	0.258	6.55	0.258	6.55	0.375	9.53	0.375	9.53	0.375	9.53
6	6.625	168.27	0.109	2.77	0.109	2.77	3.40	0.134	3.40	0.280	7.11	0.280	7.11	0.432	10.97	0.432	10.97	0.432	10.97
8	8.625	219.07	0.109	2.77	0.109	2.77	3.76	0.148	3.76	0.322	8.18	0.322	8.18	0.500	12.70	0.500	12.70	0.500	12.70
10	10.75	273.05	0.134	3.40	0.134	3.40	4.19	0.165	4.19	0.365	9.27	0.365	9.27	0.500	12.70	0.500	12.70	0.500	12.70
12	12.75	323.85	0.156	3.96	0.156	3.96	4.57	0.180	4.57	0.375	9.53	0.375	9.53	0.500	12.70	0.500	12.70	0.500	12.70
14	14.00	355.60	0.156	3.96	0.156	3.96	4.78	0.188	4.78	x	x	x	x	x	x	x	x	x	x
16	16.00	406.40	0.165	4.19	0.165	4.19	4.78	0.188	4.78	x	x	x	x	x	x	x	x	x	x
18	18.00	457.20	0.165	4.19	0.165	4.19	4.78	0.188	4.78	x	x	x	x	x	x	x	x	x	x
20	20.00	508.00	0.188	4.78	0.188	4.78	5.54	0.218	5.54	x	x	x	x	x	x	x	x	x	x
22	22.00	558.80	0.188	4.78	0.188	4.78	5.54	0.218	5.54	x	x	x	x	x	x	x	x	x	x
24	24.00	609.60	0.218	5.54	0.218	5.54	6.35	0.250	6.35	x	x	x	x	x	x	x	x	x	x
26	26.00	660.40	x	x	x	x	x	0.312	7.92	x	x	x	x	x	x	x	x	x	x
28	28.00	711.20	x	x	x	x	x	0.312	7.92	x	x	x	x	x	x	x	x	x	x
30	30.00	762.00	0.250	6.35	0.250	6.35	7.92	0.312	7.92	x	x	x	x	x	x	x	x	x	x
32	32.00	812.80	x	x	x	x	x	0.312	7.92	x	x	x	x	x	x	x	x	x	x
34	34.00	863.60	x	x	x	x	x	0.312	7.92	x	x	x	x	x	x	x	x	x	x
36	36.00	914.40	x	x	x	x	x	0.312	7.92	x	x	x	x	x	x	x	x	x	x

^A Threading not permitted in accordance with ANSI B.1.20.1

TABLE 3 Permissible Variations in Diameter

Nominal Outside Diameter (NPS) ^A	Permissible Variations in Outside Diameter	
	Over	Under
½ in. to 1½ in. (3.2 mm to 38 mm)	¼ in. (0.397 mm)	½ in. (0.794 mm)
over 1½ in. to 4 in. (38 mm to 102 mm)	½ in. (0.794 mm)	½ in. (0.794 mm)
over 4 in. to 8 in. (102 mm to 203 mm)	¼ in. (1.588 mm)	½ in. (0.794 mm)
over 8 in. to 18 in. (203 mm to 432 mm)	¾ in. (2.382 mm)	½ in. (0.794 mm)

^A NPS = nominal pipe size.

TABLE 4 Permissible Variations in Product Analysis

Element	Product Analysis Limits, Permissible Variation	
	max or Range, %	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
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
Niobium	>30	±0.50
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.

Table 1 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 his 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 4 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 1 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 5. 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 B36.19M-1985) reproduced as Table 2 shall apply.