~~Designation:B861–06a~~ Designation: B 861 – 08

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

This standard is issued under the fixed designation B 861; 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 34 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,
1.1.2.1 *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, extra low interstitial, 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 36*—Titanium alloy (45 % niobium),
1.1.29 *Grade 37*—Titanium alloy (1.5 % aluminum), and
1.1.30 *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.

Current edition approved ~~June 1, 2006.~~May 15, 2008. Published June ~~2006.~~2008. Originally approved in 1995. Last previous edition approved in 2006 as B 861 – 06a.

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 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]

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

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 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

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),

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, Grade 36, and Grade 38 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, Grade 28, or Grade 38*—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

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.

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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.

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

TABLE 1 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	...	...
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	0.04–0.08	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	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 36	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	0.03
Carbon, max	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.04	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	0.0035	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	0.03	0.30	1.2–1.8

TABLE 1 *Continued*

Element	Composition, %											
	Grade 25	Grade 26	Grade 26H	Grade 27	Grade 28	Grade 29	Grade 33	Grade 34	Grade 35	Grade 36	Grade 37	Grade 38
Oxygen, max or range	0.20	0.25	0.25	0.18	0.15	0.13	0.25	0.35	0.25	0.16	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	0.8–0.14	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	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	0.4
Titanium[G]	balance	balance	balance	balance	balance	balance	Remainder	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 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.

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 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.

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 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 3 Permissible Variations in Diameter

Nominal Outside Diameter (NPS)[A]	Permissible Variations in Outside Diameter	
	Over	Under
⅛ in. to 1½ in. (3.2 mm to 38 mm)	1/64 in. (0.397 mm)	1/32 in. (0.794 mm)
over 1½ in. to 4 in. (38 mm to 102 mm)	1/32 in. (0.794 mm)	1/32 in. (0.794 mm)
over 4 in. to 8 in. (102 mm to 203 mm)	1/16 in. (1.588 mm)	1/32 in. (0.794 mm)
over 8 in. to 18 in. (203 mm to 432 mm)	3/32 in. (2.382 mm)	1/32 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
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
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.

9.2 *Diameter*—Variations in outside diameter shall not exceed those prescribed in Table 3.

9.3 *Thickness*—The variation in thickness at any point shall not be more than ±12.5 % of the nominal wall thickness specified.

9.4 *Length*—Pipe shall be furnished in lengths as specified in the purchase order. No pipe shall be under the specified length and not more than ¼ in. (6.4 mm) over that specified.

9.5 *Straightness*— The pipe shall be free of kinks and bends and the maximum bow of lengths up to 10 ft (3 m) shall not exceed 1:500. For lengths greater than 10 ft, the maximum bow shall not exceed 1:400.

10. Finish

10.1 The finished pipe shall have smooth ends, be free of burrs, and shall be free of injurious external and internal imperfections of a nature that will interfere with the purpose for which it is intended. Minor defects may be removed providing the dimensional tolerances of Section 9 are not exceeded. Unless otherwise specified, the pipe shall be furnished free of scale.

11. Number of Tests

11.1 Samples for test shall be taken from one pipe for each 1000 ft (300 m), but in no case shall less than one pipe be tested, selected at random, from each lot. Results of the following tests shall be reported to the purchaser or his representative.

11.1.1 One tension test from each pipe selected.

11.1.2 The flattening test specified in 15.1.

11.1.3 The bend test, required by 14.1, when specified by the purchaser.

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