~~Designation:B861–08a~~ Designation: B 861 – 09

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 Aug. 1, ~~2008.~~2009. Published August ~~2008.~~2009. Originally approved in 1995. Last previous edition approved in 2008 as B 861 – 08a.

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

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 539 Test Method for X-Ray Fluorescence Spectrometric Analysis of 6Al-4V Titanium Alloy
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 Inert Gas Fusion Thermal Conductivity/Infrared Detection Method
E 1941 Test Method for Determination of Carbon in Refractory and Reactive Metals and Their Alloys
E 2371 Test Method for Analysis of Titanium and Titanium Alloys by Atomic Emission Plasma Spectrometry
E 2626 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

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

[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.

El Grade- ment	Grade 1	G rade 2	Grade 2H	Grade 3	Grade 5	Grade 7	Grade 7H	Grade 9	Grade 11	Grade 12	GMolybde- num	Chromium	Cobadlt	Zirconium	Niobium	Tin	Silicon	Othe 13
Composition, % Weight Percent[A,B,C,D,E]																		
	Car- bon, max.	Oxygen range or max.	Nitrogen, max.	Hydrogen, max.	Iron range or max.	Aluminum	Vanadium	Palladium	Ruthe- nium	Nickel	Molybdenum	Chromium	Cobalt	Zirconium	Niobium	Tin	Silicon	Othe 13
						r Elements, max. each						Other Elements, max. total						
Nitro- gen, max	0.03	0.03	0.03	0.05	0.05	0.03	0.03	0.03	0.03	0.03	0.03							
											0.03							
Car- bon, max Car- bon, max	0.08	0.08	0.08	0.08	0.08	0.08	0.08											
0.08 1	0.08 0.08	0.08 0.18	0.08 0.08															
Hydro- gen,[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							
Hydro- gen,[B,C] max3	0.015	0.20	- -	- -	- -	- -	- -	- -	- -	- -	0.015							
Iron, max	0.20	0.30	0.30	0.30														
Iron, max- -	- -	- -	- -	0.1	0.4													
0.40 2	0.30 0.08	0.30 0.30	0.25 0.25	0.03	0.20 0.015	0.30 0.30	0.20 0.20											
Oxy- gen, max	0.18	0.25	0.25	0.35	0.20	0.25	0.25	0.15	0.18	0.25	- -	0.1	0					
Oxy- gen, max- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	0.1	0.4					
Alumi- num	...	...	...	...	5.5– 6.75	...	...	2.5– 3.5	...	...	...							
2H	0.08	0.25	0.03	0.015	0.30	- -	- -	- -	- -	- -	...							
Vana- dium	...	...	...	...	3.5– 4.5	...	...											
Vanadium- - -	- -	- -	- -	- -	- -	- -	0.1	0.4										
2.0– 3.0	...	...	...															
3	0.08	0.35	0...															
Tin	...	...	...	...	...	...	...	...	...	...	...							
Tin05	0.015	0.30	- -	- -	- -	- -	- -	- -	- -	- -	...							
Ruthe- nium	...	...	...	...														
Ruthenium- - -	- -	- -	- -	0.1	0.4													

Composition, % Weight Percent[A,B,C,D,E]

El- Grade- ment																
...	...	...	...	...	...	0.04–0.06										
4	0.08	0.40	0.05	0.015	0.50	0.04–0.06										
Palladium	...	...	...	...	...	0.12–0.25	0.12–0.25	...	0.12–0.25	...	- -	0.1	0..			
Palladium- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	0.1	0.4			
Molybdenum	...	...	...	...	...	...	...	...	...	0.2–0.4	...					
5	0.08	0.20	0.05	0.015	0.40	5.5-6.75	3.5-4.5	- -	- -	- -	...					
Chromium	...	...	...	...	...	...	...	...4								
Chromium- -	- -	- -	- -	- -	- -	- -	0.1	0.4								
—	...	...	...													
—	—	—	...													
Nickel	...	...	...	...	...	...	...	...	...	0.6–0.9	0.4–0.6					
Nickel—	—	—	—	—	—	—	—	—	—	—	0.4–0.6					
Niobium	...	...	...	...												
Niobium—	—	—	—	—	—											
...	...	...	...	...	...	...	...									
7	0.08	0.25	0.03	0.015	0.30	- -	...									
Zirconium	...	...	...	...	...	...	...	...	...	...	.1	0..				
Zirconium	0.12-0.25	- -	- -	- -	- -	- -	- -	- -	- -	- -	0.1	0.4				
Silicon	...	...	...	...	...	...	...	...	...	...	...					
7H	0.08	0.25	0.03	0.015	0.30	- -	- -	0.12-0.25	- -	- -	...					
Residuals[D,E,F], max each	0.1	0.1	0.1	0.1	0.1	0.1	0.1									
Residuals[D,E,F], max each- -	- -	- -	- -	- -	- -	- -	0.1	0.4								
0.1	0.1	0.1	0.1													
9	0.08	0.15	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	- -	- -	- -	0.1	0.4
Residuals[D,E,F], max total03	0.015	0.25	2.5-3.5	2.0-3.0	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	0.1	0.4
Titanium[G]	balance	balance	balance	balance	balance	balance	balance	balance	balance	balance	balance					

Composition, % Weight Percent[A,B,C,D,E]

El Grade- ment											
11	0.08	0.18	0.03	0.015	0.20	- -	- -	0.12-0.25	- -	- -	balance

Element	Composition, %													
	Grade 14 - -	Grade 15 - -	Grade 16 - -	Grade 16H - -	Grade 17 - -	Grade 18 - -	Grade 19 - -	Grade 20.1	0.4					
Grade 21	Grade 23	Grade 24												
12	0.08	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			
0.25	0.03	0.015	0.30	- -	- -	- -	- -	0.6-0.9	0.2-0.4	- -	0.05			
Carbon, max	0.08	0.08	0.08	0.08	0.08									
Carbon, max- -	- -	- -	- -	- -	0.1	0.4								
	0.08	0.05	0.05	0.05	0.08	0.08								
13	0.08	0.10	0.03	0.015	0.20	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		
Hydrogen,[B,C] max- -	- -	- -	0.04-0.06	0.4-0.6	- -	- -	- -	- -	- -	- -	- -	0.1	0.4	
Iron, max	0.30	0.30	0.03	0.015	0.30	0.30	0.20	0.25	0.30	0.30	0.40	0.25	—	—
14	0.08	0.15	0.03	0.015	0.30	- -	- -	- -	0.04-0.06	0.4-0.6	- -	- -	-	- - -
Oxygen, max	0.15	0.25	0.25	0.25	0.18	0.15	0.12	0.12	0.17	0.13	0.20			
15	0.08	0.25	0.05	0.015	0.30	- -	- -	- -	0.04-0.06	0.4-0.6	0.20			
Aluminum	...	...	...	...	...	2.5–3.5	3.0–4.0							
Aluminum- -	- -	- -	- -	- -	- -	- -	0.1	0.4						
3.0–4.0	2.5–3.5	5.5–6.5	5.5–6.75											
16	0.08	0.25	0.5–6.75											
Vanadium	...	...	...	...	...	2.0–3.0	7.5–8.5	7.5–8.5	...	3.5–4.5	3- -			
Vanadium03	0.015	0.30	- -	- -	0.04-0.08	- -	- -	- -	- -	- -	- -			
Tin	...	...	...	...	...	...	...	...	...	...	—			
16H	0.08	0.25	0.03	0.015	0.30	- -	- -	0.04-0.08	- -	- -	- -			
Ruthenium	0.04–0.06	0.04–0.06	...	...	...	...	...	...	...	...	...			
17	0.08	0.18	0.03	0.015	0.20	- -	- -	0.04-0.08	- -	- -	...			
Palladium	...	...	0.04–0.08	0.04–0.08	0.04–0.08	0.04–0.08	...							
Palladium- -	- -	- -	- -	- -	- -	- -	0.1	0.4						
0.04–18	0.08	...	0.03	0.015	...	0.04–0.08								
18	0.08	0.15	0.03	0.015	0.25	0.04–0.08								
Molybdenum	...	...	...	...	...	...	3.5–4.5	3.5–4.5	14.0–16.0	...	- -	0.1	0..	
2.5-3.5	2.0-3.0	0.04-0.08	- -	- -	- -	- -	- -	- -	- -	- -	- -	0.1	0.4	
Chromium	...	...	...	...	...	...	5.5–6.5	5.5–6.5	...	...	...			
19	0.05	0.12	0.03	0.02	0.30	3.0-4.0	7.5-8.5	- -	- -	- -	3.5-4.-			
Nickel	0.4–0.6	0.4–0.6	...	...	...	...	...	..4						
Nickel5	5.5-6.5	- -	3.5-4.5	- -	- -	- -	0.15	0.4						
20	...	...	...											
20	0.05	0.12	0.-											
Niobium	...	...	...	...	...	...	...	...	2.2–3.2	...	..5	- -	- - -	

Element	Composition, %												
	Grade 14- -	Grade 15- -	Grade 16- -	Grade 16H- -	Grade 17- -	Grade 18- -	Grade 19- -	Grade 20.1	0.4				
Niobium03 Zirconium	0.02 ...	0.30 ...	3.0-4.0 ...	7.5-8.5 ...	0.04-0.08 ...	- - ...	- - 3.5–4.5	3.5-4.5 3.5–4.5	5.5-6.5 ...	- - ...	3.5-4.5 ...	- -	- - -
21 Silicon Silicon0 23 23	0.05 ... - - 0.08 0.08	0.17 ... - - 0.13 0.13	0.03 ... - - 0.03 0.03	0.015 ... 2.2-3.2 0.0125– 0.0125	0.40 ... - - 0.25 0.25	2.5-3.5 ... 0.15-0.25 ... 5.5-6.5	- - ... 0.1 ... 3.5-4.-	- - ...4 0.4	- -	- -	14.0-16.-		
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	0.1Re-siduals-[D,E,F], max total	0.4	
Residuals,[D,E,F] max each5	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	0.1	0.4	
24 24	0.4 0.08	0.4 0.20	0.4 0.05	0.4 0.015	0.4 0.40	0.4 5.5-6.75	0.4 3.5-4.5	0.4 0.04-0.08	0.4 - -	0.4 0.4			
Titanium[G] Titanium[G]- -	balance - -	balance - -	balance - -	balance - -	balance - -	balance - -	balance - -	balance 0.1	balance0.4 0.4				
25 25	balance 0.08	balance balance											

Element	Composition, %												
	Grade0.250	Grade 260.05	Grade 26H0.015	Grade 270.40	Grade 285.5-6.75	Grade 293.5-4.5	Grade 330.04-0.08	Grade 34- -	Grade0.35-0.8	Grade 36- -	Grade 37- -	Grade 38- -	- -- -- -0.1
Nitrogen, max	0.05	0.03	0.03	0.03	0.03	0.03	0.03	0.05	0.05	0.03	0.03	—	——
26	0.08	0.25	0.03	0.015	0.30	- -	- -	- -	0.08-0.14	- -	- -	- -	- -- --
Carbon, max	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.04	0.08	—	——
26H	0.08	0.25	0.03	0.015	0.30	- -	- -	- -	0.08-0.14	- -	- -	- -	- -- --
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	—	——
27	0.08	0.18	0.03	0.015	0.20	- -	- -	- -	0.08-0.14	- -	- -	- -	- -- --
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	
28	0.08	0.15	0.03	0.015	0.25	2.5-3.5	2.0-3.0	- -	0.08-0.14	- -	- -	1.2–1.8	
Oxygen, max or range	0.20	0.25	0.25	0.18	0.15	0.13	0.4						
Oxygen, max or range- -	- -	- -	- -	- -	- -	0.1	0.4						
25	0.35	0.25	0.16	0.015	0.25	0.20–0.30							
29	0.08	0.13	0.03	0.015	0.25	5.5-6.30							
Aluminum	5.5–6.75	...	...	...	2.5- 3.5	5.5- 6.5	...	...	4.0–5.0	...	1.0–2.0	3.5–41	0.5
Aluminum5 Vanadium	3.5-4.5 3.5–4.5	- - ...	0.08-0.14 ...	- - ...	- - 2.0–3.0	- - 3.5–4.5	- - ...	- - ...	- - 1.1–2.1	- - ...	- - ...	0.1 2.0–3.0	0.4
—	—	—	—	—	—	—	—	—	—	—	—	2.0–3.0	
Tin 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	...	...	...	...—	— —