



Designation: B 861 – 01

## Standard Specification for Titanium and Titanium Alloy Seamless Pipe<sup>1</sup>

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### 1. Scope

1.1 This specification covers the requirements for 26 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), and

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

1.2 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are for information only.

### 2. Referenced Documents

- 2.1 *ASTM Standards*:
  - A 370 Test Methods and Definitions for Mechanical Testing of Steel Products<sup>2</sup>
  - E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications<sup>3</sup>
  - E 120 Test Methods for Chemical Analysis of Titanium and Titanium Alloys<sup>4</sup>
  - E 1409 Test Method for Determination of Oxygen in Titanium and Titanium Alloys by the Inert Gas Fusion Technique<sup>5</sup>
  - E 1447 Test Method for Determination of Hydrogen in Titanium and Titanium Alloys by the Inert Gas Fusion Thermal Conductivity Method<sup>5</sup>
- 2.2 *ANSI/ASME Standard*:
  - B 36.19M-1985 Stainless Steel Pipe<sup>6</sup>

<sup>1</sup> 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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<sup>2</sup> *Annual Book of ASTM Standards*, Vol 01.03.

<sup>3</sup> *Annual Book of ASTM Standards*, Vol 14.02.

<sup>4</sup> *Annual Book of ASTM Standards*, Vol 03.05.

<sup>5</sup> *Annual Book of ASTM Standards*, Vol 03.06.

<sup>6</sup> Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.



### 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<sup>A</sup>**

Element	Composition, %								
	Grade 1	Grade 2	Grade 3	Grade 5	Grade 7	Grade 9	Grade 11	Grade 12	
Nitrogen, max	0.03	0.03	0.05	0.05	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
Hydrogen, <sup>B,C</sup> max	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	0.30
Oxygen, max	0.18	0.25	0.35	0.20	0.25	0.15	0.18	0.25	0.25
Aluminum	...	...	...	5.5–6.75	...	2.5–3.5	...	...	...
Vanadium	...	...	...	3.5–4.5	...	2.0–3.0	...	...	...
Tin	...	...	...	...	...	...	...	...	...
Ruthenium	...	...	...	...	...	...	...	...	...
Palladium	...	...	...	...	0.12–0.25	...	0.12–0.25	...	...
Molybdenum	...	...	...	...	...	...	...	0.2–0.4	...
Chromium	...	...	...	...	...	...	...	...	...
Nickel	...	...	...	...	...	...	...	0.6–0.9	...
Niobium	...	...	...	...	...	...	...	...	...
Zirconium	...	...	...	...	...	...	...	...	...
Silicon	...	...	...	...	...	...	...	...	...
Residuals, <sup>D,E,F</sup> max each	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Residuals, <sup>D,E,F</sup> max total	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Titanium <sup>G</sup>	balance	balance	balance	balance	balance	balance	balance	balance	balance

  

Element	Composition, %								
	Grade 13	Grade 14	Grade 15	Grade 16	Grade 17	Grade 18	Grade 19	Grade 20	
Nitrogen, max	0.03	0.03	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	0.05	0.05	0.05
Hydrogen, <sup>B,C</sup> max	0.015	0.015	0.015	0.015	0.015	0.015	0.02	0.02	0.02
Iron, max	0.20	0.30	0.30	0.30	0.20	0.25	0.30	0.30	0.30
Oxygen, max	0.10	0.15	0.25	0.25	0.18	0.15	0.12	0.12	0.12
Aluminum	...	...	...	...	...	2.5–3.5	3.0–4.0	3.0–4.0	3.0–4.0
Vanadium	...	...	...	...	...	2.0–3.0	7.5–8.5	7.5–8.5	7.5–8.5
Tin	...	...	...	...	...	...	...	...	...
Ruthenium	0.04–0.06	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	...
Molybdenum	...	...	...	...	...	...	3.5–4.5	3.5–4.5	...
Chromium	...	...	...	...	...	...	5.5–6.5	5.5–6.5	...
Nickel	0.4–0.6	0.4–0.6	0.4–0.6	...	...	...	...	...	...
Niobium	...	...	...	...	...	...	...	...	...
Zirconium	...	...	...	...	...	...	3.5–4.5	3.5–4.5	...
Silicon	...	...	...	...	...	...	...	...	...
Residuals, <sup>D,E,F</sup> max each	0.1	0.1	0.1	0.1	0.1	0.1	0.15	0.15	0.15
Residuals, <sup>D,E,F</sup> max total	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Titanium <sup>G</sup>	balance	balance	balance	balance	balance	balance	balance	balance	balance

  

Element	Composition, %									
	Grade 21	Grade 23	Grade 24	Grade 25	Grade 26	Grade 27	Grade 28	Grade 29	Grade 33	Grade 34
Nitrogen, max	0.03	0.03	0.05	0.05	0.03	0.03	0.03	0.03	0.03	0.05
Carbon, max	0.05	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Hydrogen, <sup>B,C</sup> max	0.015	0.0125	0.015	0.0125	0.015	0.015	0.015	0.015	0.015	0.015
Iron, max	0.40	0.25	0.40	0.40	0.30	0.20	0.25	0.25	0.30	0.30
Oxygen, max	0.17	0.13	0.20	0.20	0.25	0.18	0.15	0.13	0.25	0.35
Aluminum	2.5–3.5	5.5–6.5	5.5–6.75	5.5–6.75	...	...	2.5–3.5	5.5–6.5	...	...
Vanadium	...	3.5–4.5	3.5–4.5	3.5–4.5	...	...	2.0–3.0	3.5	...	...
Tin <sub>4.5</sub>	...	...	...	...	...	...	...	...	...	...
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	0.04–0.08	...	...	...	...	0.01–0.02	0.01–0.02
Molybdenum	14.0–16.0	...	...	...	...	...	...	...	...	...
Chromium	...	...	...	...	...	...	...	...	0.1–0.2	0.1–0.2
Nickel	...	...	...	0.3–0.8	...	...	...	...	0.35–0.55	0.35–0.55



Element	Grade 21	Grade 23	Grade 24	Grade 25	Grade 26	Grade 27	Grade 28	Grade 29	Grade 33	Grade 34
Niobium	2.2–3.2	...	...	...	...	...	...	...	...	...
Zirconium	...	...	...	...	...	...	...	...	...	...
Silicon	0.15–0.25	...	...	...	...	...	...	...	...	...
Residuals, <sup>D,E,F</sup> max each	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Residuals, <sup>D,E,F</sup> max total	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Titanium <sup>G</sup>	balance	balance	balance	balance	balance	balance	balance	balance	Remainder	Remainder

<sup>A</sup>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.

<sup>B</sup>Lower hydrogen may be obtained by negotiation with the supplier.

<sup>C</sup>Final product analysis.

<sup>D</sup>Need not be reported.

<sup>E</sup>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.

<sup>F</sup>The purchaser may, in his written purchase order, request analysis for specific residual elements not listed in this specification.

<sup>G</sup>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, and Grade 29 alloys may be supplied in the following conditions:

5.2.1.1 *Grade 5, Grade 23, Grade 24, Grade 25, or Grade 29—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

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 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/