



Designation: B 348 – 06a

## Standard Specification for Titanium and Titanium Alloy Bars and Billets<sup>1</sup>

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*This standard has been approved for use by agencies of the Department of Defense.*

### 1. Scope

1.1 This specification<sup>2</sup> covers annealed titanium and titanium alloy bars and billets as follows:

- 1.1.1 *Grade 1*—Unalloyed titanium,
- 1.1.2 *Grade 2*—Unalloyed titanium,
  - 1.1.2.1 *Grade 2H*—Unalloyed titanium (Grade 2 with 58 ksi minimum UTS),
- 1.1.3 *Grade 3*—Unalloyed titanium,
- 1.1.4 *Grade 4*—Unalloyed titanium,
- 1.1.5 *Grade 5*—Titanium alloy (6 % aluminum, 4 % vanadium),
- 1.1.6 *Grade 6*—Titanium alloy (5 % aluminum, 2.5 % tin),
- 1.1.7 *Grade 7*—Unalloyed titanium plus 0.12 to 0.25 % palladium,
  - 1.1.7.1 *Grade 7H*—Unalloyed titanium plus 0.12 to 0.25 % palladium (Grade 7 with 58 ksi minimum UTS),
- 1.1.8 *Grade 9*—Titanium alloy (3 % aluminum, 2.5 % vanadium),
- 1.1.9 *Grade 11*—Unalloyed titanium plus 0.12 to 0.25 % palladium,
- 1.1.10 *Grade 12*—Titanium alloy (0.3 % molybdenum, 0.8 % nickel),
- 1.1.11 *Grade 13*—Titanium alloy (0.5 % nickel, 0.05 % ruthenium),
- 1.1.12 *Grade 14*—Titanium alloy (0.5 % nickel, 0.05 % ruthenium),
- 1.1.13 *Grade 15*—Titanium alloy (0.5 % nickel, 0.05 % ruthenium),
- 1.1.14 *Grade 16*—Unalloyed titanium plus 0.04 to 0.08 % palladium,
  - 1.1.14.1 *Grade 16H*—Unalloyed titanium plus 0.04 to 0.08 % palladium (Grade 16 with 58 ksi minimum UTS),
- 1.1.15 *Grade 17*—Unalloyed titanium plus 0.04 to 0.08 % palladium,
- 1.1.16 *Grade 18*—Titanium alloy (3 % aluminum, 2.5 % vanadium) plus 0.04 to 0.08 % palladium,

1.1.17 *Grade 19*—Titanium alloy (3 % aluminum, 8 % vanadium, 6 % chromium, 4 % zirconium, 4 % molybdenum),

1.1.18 *Grade 20*—Titanium alloy (3 % aluminum, 8 % vanadium, 6 % chromium, 4 % zirconium, 4 % molybdenum) plus 0.04 %–0.08 % palladium,

1.1.19 *Grade 21*—Titanium alloy (15 % molybdenum, 3 % aluminum, 2.7 % niobium, 0.25 % silicon),

1.1.20 *Grade 23*—Titanium alloy (6 % aluminum, 4 % vanadium with extra low interstitial elements, ELI),

1.1.21 *Grade 24*—Titanium alloy (6 % aluminum, 4 % vanadium) plus 0.04 % to 0.08 % palladium,

1.1.22 *Grade 25*—Titanium alloy (6 % aluminum, 4 % vanadium) plus 0.3 % to 0.8 % nickel and 0.04 % to 0.08 % palladium,

1.1.23 *Grade 26*—Unalloyed titanium plus 0.08 to 0.14 % ruthenium,

1.1.23.1 *Grade 26H*—Unalloyed titanium plus 0.08 to 0.14 % ruthenium (Grade 26 with 58 ksi minimum UTS),

1.1.24 *Grade 27*—Unalloyed titanium plus 0.08 to 0.14 % ruthenium,

1.1.25 *Grade 28*—Titanium alloy (3 % aluminum, 2.5 % vanadium plus 0.08–0.14 % ruthenium),

1.1.26 *Grade 29*—Titanium alloy (6 % aluminum, 4 % vanadium, extra low interstitial, ELI plus 0.08–0.14 % ruthenium),

1.1.27 *Grade 30*—Titanium alloy (0.3 % cobalt, 0.05 % palladium),

1.1.28 *Grade 31*—Titanium alloy (0.3 % cobalt, 0.05 % palladium),

1.1.29 *Grade 32*—Titanium alloy (5 % aluminum, 1 % tin, 1 % zirconium, 1 % vanadium, 0.8 % molybdenum),

1.1.30 *Grade 33*—Titanium alloy (0.4 % nickel, 0.015 % palladium, 0.025 % ruthenium, 0.15 % chromium),

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

1.1.32 *Grade 35*—Titanium alloy (4.5 % aluminum, 2 % molybdenum, 1.6 % vanadium, 0.5 % iron, 0.3 % silicon),

1.1.33 *Grade 36*—Titanium alloy (45 % niobium),

1.1.34 *Grade 37*—Titanium alloy (1.5 % aluminum), and

1.1.35 *Grade 38*—Titanium alloy (4 % aluminum, 2.5 % vanadium, 1.5 % iron).

<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> For ASME Boiler and Pressure Vessel Code applications see related Specification SB-348 in Section II of that Code.

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.

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:<sup>3</sup>

**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

<sup>3</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto: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<sup>4</sup>

**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

## 3. Terminology

### 3.1 Definitions of Terms Specific to This Standard:

3.1.1 *bar, n*—a hot rolled, forged, or cold worked semifinished solid section product whose cross sectional area is equal to or less than 16 in.<sup>2</sup>(10 323 mm<sup>2</sup>); rectangular bar must be less than or equal to 10 in. (254 mm) in width and greater than 0.1875 in. (4.8 mm) in thickness.

3.1.2 *billet, n*—a solid semifinished section hot rolled or forged from an ingot, with a cross sectional area greater than 16 in.<sup>2</sup>(10 323 mm<sup>2</sup>) whose width is less than five times its thickness.

<sup>4</sup> Withdrawn.

**TABLE 1 Chemical Requirements<sup>A</sup>**

Element	Composition, %											
	Grade 1	Grade 2	Grade 2H	Grade 3	Grade 4	Grade 5	Grade 6	Grade 7	Grade 7H	Grade 9	Grade 11	Grade 12
Nitrogen, max	0.03	0.03	0.03	0.05	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	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	0.015	0.015	0.015
Iron, max	0.20	0.30	0.30	0.30	0.50	0.40	0.50	0.30	0.30	0.25	0.20	0.30
Oxygen, max	0.18	0.25	0.25	0.35	0.40	0.20	0.20	0.25	0.25	0.15	0.18	0.25
Aluminum	...	...	...	...	...	5.5–6.75	4.0–6.0	...	...	2.5–3.5	...	...
Vanadium	...	...	...	...	...	3.5–4.5	...	...	...	2.0–3.0	...	...
Tin	...	...	...	...	...	...	2.0–3.0	...	...	...	...	...
Ruthenium	...	...	...	...	...	...	...	...	...	...	...	...
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
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	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	0.4	0.4
Titanium <sup>G</sup>	balance	balance	balance	balance	balance	balance	balance	balance	balance	balance	balance	balance

Element	Composition, %										
	Grade 13	Grade 14	Grade 15	Grade 16	Grade 16H	Grade 17	Grade 18	Grade 19	Grade 20	Grade 21	
Nitrogen, max	0.03	0.03	0.05	0.03	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	0.05	0.05	0.05	
Hydrogen, <sup>B,C</sup> max	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.02	0.02	0.015	
Iron, max	0.20	0.30	0.30	0.30	0.30	0.20	0.25	0.30	0.30	0.40	
Oxygen, max	0.10	0.15	0.25	0.25	0.25	0.18	0.15	0.12	0.12	0.17	
Aluminum	...	...	...	...	...	...	2.5–3.5	3.0–4.0	3.0–4.0	2.5–3.5	
Vanadium	...	...	...	...	...	...	2.0–3.0	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	...	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	0.4–0.6	...	...	...	...	...	...	...	