



Designation: **B348-08a** Designation: **B 348 - 09**

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

This standard is issued under the fixed designation B 348; 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 ( $\epsilon$ ) 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<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 to 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),

<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.

Current edition approved Aug. 1, 2008. Published August 2008. June 2009. Originally approved in 1959. Last previous edition approved in 2008 as B 348 - 08a.

<sup>2</sup> For ASME Boiler and Pressure Vessel Code applications see related Specification SB-348 in Section II of that Code.

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

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).

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](#)

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](#)

## 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.

## 4. Ordering Information

4.1 Orders for material under this specification shall include the following information as applicable:

4.1.1 Grade number (Section 1),

4.1.2 Product classification (Section 3),

4.1.3 Chemistry (Table 1),

4.1.4 Mechanical properties (Table 2),

4.1.5 Marking (Section 16),

4.1.6 Finish (Section 8),

4.1.7 Packaging (Section 16),

4.1.8 Required reports (Section 15), and

4.1.9 Disposition of rejected material (Section 14).

## 5. Chemical Composition

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

5.1.1 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.

5.1.1.1 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.

5.1.2 Elements intentionally added to the melt must be identified, analyzed and reported in the chemical analysis.

5.2 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.

<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.





Composition, %

Element	Grade 13	Grade 14	Grade 15	Grade 16	Grade 16H	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
Hydrogen, $B, C$ , max	0.08	0.15	0.05	0.03	0.03	0.015	0.25	2.5-3.5	2.0-3.0
Iron, max	0.08	0.18	0.03	0.015	0.015	0.015	0.015	0.02	0.02
Oxygen, max	0.10	0.15	0.25	0.25	0.25	0.18	0.15	0.12	0.12-0.25
Vanadium	0.08	0.15	0.25	0.03	0.03	0.015	0.30	7.5-8.5	0.17
Titanium	0.04-0.06	0.04-0.06	0.04-0.06	0.015	0.015	0.20	2.0-3.0	7.5-8.5	0.04-0.06
Carbon, max	0.08	0.15	0.03	0.015	0.015	0.30	0.04-0.06	0.04-0.06	0.04-0.06
Chromium	0.08	0.25	0.05	0.015	0.015	0.30	0.04-0.06	0.04-0.06	0.04-0.06
Nickel	0.08	0.25	0.03	0.015	0.015	0.30	0.04-0.06	0.04-0.06	0.04-0.06
Molybdenum	0.08	0.25	0.03	0.015	0.015	0.30	0.04-0.06	0.04-0.06	0.04-0.06
Copper	0.08	0.18	0.03	0.015	0.015	0.30	0.04-0.06	0.04-0.06	0.04-0.06
Zinc	0.08	0.18	0.03	0.015	0.015	0.30	0.04-0.06	0.04-0.06	0.04-0.06
Residuals, $D, E, F$ , max	0.08	0.1	0.1	0.15	0.15	0.15	0.15	0.1	0.1

Composition, %

Element	Grade 23	Grade 24	Grade 25	Grade 26	Grade 26H	Grade 27	Grade 28	Grade 29	Grade 30
Nitrogen, max	0.05	0.12	0.03	0.02	0.30	3.0-4.0	7.5-8.5	0.04-0.08	0.04-0.08
Hydrogen, $B, C$ , max	0.08	0.15	0.03	0.015	0.25	2.5-3.5	2.0-3.0	0.04-0.08	0.04-0.08
Iron, max	0.08	0.15	0.03	0.015	0.25	2.5-3.5	2.0-3.0	0.04-0.08	0.04-0.08
Oxygen, max	0.08	0.15	0.03	0.015	0.25	2.5-3.5	2.0-3.0	0.04-0.08	0.04-0.08
Vanadium	0.08	0.15	0.03	0.015	0.25	2.5-3.5	2.0-3.0	0.04-0.08	0.04-0.08
Titanium	0.08	0.15	0.03	0.015	0.25	2.5-3.5	2.0-3.0	0.04-0.08	0.04-0.08
Carbon, max	0.08	0.15	0.03	0.015	0.25	2.5-3.5	2.0-3.0	0.04-0.08	0.04-0.08
Chromium	0.08	0.15	0.03	0.015	0.25	2.5-3.5	2.0-3.0	0.04-0.08	0.04-0.08
Nickel	0.08	0.15	0.03	0.015	0.25	2.5-3.5	2.0-3.0	0.04-0.08	0.04-0.08
Molybdenum	0.08	0.15	0.03	0.015	0.25	2.5-3.5	2.0-3.0	0.04-0.08	0.04-0.08
Copper	0.08	0.15	0.03	0.015	0.25	2.5-3.5	2.0-3.0	0.04-0.08	0.04-0.08
Zinc	0.08	0.15	0.03	0.015	0.25	2.5-3.5	2.0-3.0	0.04-0.08	0.04-0.08
Residuals, $D, E, F$ , max	0.08	0.1	0.1	0.15	0.15	0.15	0.15	0.1	0.1



Composition, %

Element	Grade 13	Grade 14	Grade 15	Grade 16	Grade 16H	Grade 17	Grade 18	Grade 19	Grade 20
Aluminum	5.5-6.5	5.5-6.75	5.5-6.75	5.5-6.75	5.5-6.75	5.5-6.75	5.5-6.75	5.5-6.75	5.5-6.75
Aluminum, max	6.5	6.75	6.75	6.75	6.75	6.75	6.75	6.75	6.75
Vanadium	0.08	0.08	0.05	0.015	0.040	0.015	0.015	0.040	0.040
Vanadium, max	0.08	0.08	0.05	0.015	0.040	0.015	0.015	0.040	0.040
Tin	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Tin, max	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Ruthenium	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Ruthenium, max	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
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	0.04-0.08	0.04-0.08	0.04-0.08
Palladium, max	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Cobalt	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Chromium	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Chromium, max	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Nickel	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Nickel, max	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Niobium	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Niobium, max	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Zirconium	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Zirconium, max	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Silicon	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Silicon, max	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Residuals, D, E, F, max	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Residuals, D, E, F, max each	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Titanium	0.08-0.14	0.08-0.14	0.08-0.14	0.08-0.14	0.08-0.14	0.08-0.14	0.08-0.14	0.08-0.14	0.08-0.14
Titanium, max	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14

Composition, %

Element	Grade 30.1	Grade 30.8	Grade 340.25	Grade 360.015	Grade 360.015	Grade 370	Grade 38
Nitrogen, max	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Nitrogen, max	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Carbon, max	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Carbon, max	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
Hydrogen, B, C, max	0.015	0.015	0.015	0.015	0.015	0.015	0.015
Iron, max or range	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Iron, max or range	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Oxygen, max or range	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Oxygen, max or range	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Aluminum	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Aluminum, max	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Vanadium	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Vanadium, max	0.08	0.08	0.08	0.08	0.08	0.08	0.08