SPECIFICATION FOR TITANIUM AND TITANIUM ALLOY BARS AND BILLETS

SB-348/SB-348M

(Identical with ASTM Specification B348/B348M-19 except that Note A of Table 2 has been revised.)

Specification for Titanium and Titanium Alloy Bars and Billets

1. Scope

1.1 This specification covers annealed titanium and titanium alloy bars and billets as follows:

1.1.1 *Grade 1*—UNS R50250. Unalloyed titanium,

1.1.2 *Grade 2*—UNS R50400. Unalloyed titanium,

1.1.2.1 *Grade 2H*—UNS R50400. Unalloyed titanium (Grade 2 with 58 ksi [400 MPa] minimum UTS),

1.1.3 *Grade 3*—UNS R50550. Unalloyed titanium,

1.1.4 *Grade 4*—UNS R50700. Unalloyed titanium,

1.1.5 *Grade 5*—UNS R56400. Titanium alloy (6 % aluminum, 4 % vanadium),

1.1.6 *Grade 6*—UNS R54520. Titanium alloy (5 % aluminum, 2.5 % tin),

1.1.7 *Grade 7*—UNS R52400. Unalloyed titanium plus 0.12 to 0.25 % palladium,

1.1.7.1 *Grade 7H*—UNS R52400. Unalloyed titanium plus 0.12 to 0.25 % palladium (Grade 7 with 58 ksi [400 MPa] minimum UTS),

1.1.8 *Grade 9*—UNS R56320. Titanium alloy (3 % aluminum, 2.5 % vanadium),

1.1.9 *Grade 11*—UNS R52250. Unalloyed titanium plus 0.12 to 0.25 % palladium,

1.1.10 *Grade 12*—UNS R53400. Titanium alloy (0.3 % molybdenum, 0.8 % nickel),

1.1.11 *Grade 13*—UNS R53413. Titanium alloy (0.5 % nickel, 0.05 % ruthenium),

1.1.12 *Grade 14*—UNS R53414. Titanium alloy (0.5 % nickel, 0.05 % ruthenium),

1.1.13 *Grade 15*—UNS R53415. Titanium alloy (0.5 % nickel, 0.05 % ruthenium),

1.1.14 *Grade 16*—UNS R52402. Unalloyed titanium plus 0.04 to 0.08 % palladium,

1.1.14.1 *Grade 16H*—UNS R52402. Unalloyed titanium plus 0.04 to 0.08 % palladiumm (Grade 16 with 58 ksi [400 MPa] minimum UTS),

1.1.15 *Grade 17*—UNS R52252. Unalloyed titanium plus 0.04 to 0.08 % palladium,

1.1.16 *Grade 18*—UNS R56322. Titanium alloy (3 % aluminum, 2.5 % vanadium) plus 0.04 to 0.08 % palladium,

1.1.17 *Grade 19*—UNS R58640. Titanium alloy (3 % aluminum, 8 % vanadium, 6 % chromium, 4 % zirconium, 4 % molybdenum),

1.1.18 *Grade 20*—UNS R58645. Titanium alloy (3 % aluminum, 8 % vanadium, 6 % chromium, 4 % zirconium, 4 % molybdenum) plus 0.04 %–0.08 % palladium,

1.1.19 *Grade 21*—UNS R58210. Titanium alloy (15 % molybdenum, 3 % aluminum, 2.7 % niobium, 0.25 % silicon),

1.1.20 *Grade 23*—UNS R56407. Titanium alloy (6 % aluminum, 4 % vanadium with extra low interstitial elements, ELI),

1.1.21 *Grade 24*—UNS R56405. Titanium alloy (6 % aluminum, 4 % vanadium) plus 0.04 % to 0.08 % palladium,

1.1.22 *Grade 25*—UNS R56403. 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*—UNS R52404. Unalloyed titanium plus 0.08 to 0.14 % ruthenium,

1.1.23.1 *Grade 26H*—UNS R52404. Unalloyed titanium plus 0.08 to 0.14 % ruthenium (Grade 26 with 58 ksi [400 MPa] minimum UTS),

1.1.24 *Grade 27*—UNS R52254. Unalloyed titanium plus 0.08 to 0.14 % ruthenium,

1.1.25 *Grade 28*—UNS R56323. Titanium alloy (3 % aluminum, 2.5 % vanadium plus 0.08–0.14 % ruthenium),

1.1.26 *Grade 29*—UNS R56404. Titanium alloy (6 % aluminum, 4 % vanadium, extra low interstitial, ELI plus 0.08 to 0.14 % ruthenium),

1.1.27 *Grade 30*—UNS R53530. Titanium alloy (0.3 % cobalt, 0.05 % palladium),

1.1.28 *Grade 31*—UNS R53532. Titanium alloy (0.3 % cobalt, 0.05 % palladium),

1.1.29 *Grade 32*—UNS R55111. Titanium alloy (5 % aluminum, 1 % tin, 1 % zirconium, 1 % vanadium, 0.8 % molybdenum),

1.1.30 *Grade 33*—UNS R53442. Titanium alloy (0.4 % nickel, 0.015 % palladium, 0.025 % ruthenium, 0.15 % chromium),

1.1.31 *Grade 34*—UNS R53445. Titanium alloy (0.4 % nickel, 0.015 % palladium, 0.025 % ruthenium, 0.15 % chromium),

1.1.32 *Grade 35*—UNS R56340. Titanium alloy (4.5 % aluminum, 2 % molybdenum, 1.6 % vanadium, 0.5 % iron, 0.3 % silicon),

1.1.33 *Grade 36*—UNS R58450. Titanium alloy (45 % niobium),

1.1.34 *Grade 37*—UNS R52815. Titanium alloy (1.5 % aluminum), and

1.1.35 *Grade 38*—UNS R54250. 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.

1.2 The values state in either inch-pound units or SI units are to be regarded separately as standard. The values stated in each system are not exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

1.3 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*

E8/E8M Test Methods for Tension Testing of Metallic Materials

E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

E539 Test Method for Analysis of Titanium Alloys by Wavelength Dispersive X-Ray Fluorescence Spectrometry

E1409 Test Method for Determination of Oxygen and Nitrogen in Titanium and Titanium Alloys by Inert Gas Fusion

E1447 Test Method for Determination of Hydrogen in Titanium and Titanium Alloys by Inert Gas Fusion Thermal Conductivity/Infrared Detection Method

E1941 Test Method for Determination of Carbon in Refractory and Reactive Metals and Their Alloys by Combustion Analysis

E2371 Test Method for Analysis of Titanium and Titanium Alloys by Direct Current Plasma and Inductively Coupled Plasma Atomic Emission Spectrometry (Performance-Based Test Methodology)

E2626 Guide for Spectrometric Analysis of Reactive and Refractory Metals (Withdrawn 2017)

E2994 Test Method for Analysis of Titanium and Titanium Alloys by Spark Atomic Emission Spectrometry and Glow Discharge Atomic Emission Spectrometry (Performance-Based Method)

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *bar, n*—a hot rolled, forged, extruded or cold worked semi-finished solid section product whose cross sectional area is equal to or less than 16 in.^{2} [10 323 mm^2]; 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.

3.1.1.1 *Discussion*—Extruded bar has been approved for use on unalloyed titanium grades 1, 2, 3 and 4 only. Other grades may be produced via the extrusion process with agreement between the producer and the purchaser.

3.1.2 *billet, n*—a solid semi-finished section hot worked or forged from an ingot, with a cross sectional area greater than 16 in.^{2} [10 323 mm^2] whose width is less than five times its thickness.

3.1.3 *heat analysis*—chemical determination based on analysis of ingot or alternate (see Table 1 footnote A, and 9.2); check analysis limits do not apply for Heat Analysis/Producer Ingot Analysis.

3.1.4 *product analysis*—an analysis based on semi-finished or final product; the purchaser may apply check analysis limits to determine compliance with the specification; check analysis limits are not for producer's use at producer ingot acceptance.

3.1.5 *check analysis limits*—Table 3, Permissible Variations in Product Analysis: Percentages above and below those listed in Table 1, when tested on product, by or for the purchaser, or acceptable to purchaser to show compliance with a given specification.

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 Condition required for Grades 9, 18, 20, 21, 23, 28, and 29.

4.1.5 Mechanical properties (Table 2),

4.1.6 Marking (Section 16),

4.1.7 Finish (Section 8),

4.1.8 Packaging (Section 16),

4.1.9 Required reports (Section 15), and

4.1.10 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

TABLE 1 Chemical Requirements

		Composition, Weight Percent[A,B,C,D,E]																		
Grade	UNS Number	Carbon, max.	Oxygen range or max.	Nitrogen, max.	Hydrogen, max.	Iron range or max.	Aluminum	Vanadium	Palladium	Ruthenium	Nickel	Molybdenum	Chromium	Cobalt	Zirconium	Niobium	Tin	Silicon	Other Elements, max. each	Other Elements, max. total
1	R50250	0.08	0.18	0.03	0.015	0.20	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	0.1	0.4
2/2H	R50400	0.08	0.25	0.03	0.015	0.30	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	0.1	0.4
3	R50550	0.08	0.35	0.05	0.015	0.30	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	0.1	0.4
4	R50700	0.08	0.40	0.05	0.015	0.50	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	0.1	0.4
5	R56400	0.08	0.20	0.05	0.015	0.40	5.5-6.75	3.5-4.5	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	0.1	0.4
6	R54520	0.08	0.20	0.03	0.015	0.50	4.0-6.0	- -	- -	- -	- -	- -	- -	- -	- -	- -	2.0-3.0	- -	0.1	0.4
7/7H	R52400	0.08	0.25	0.03	0.015	0.30	- -	- -	0.12-0.25	- -	- -	- -	- -	- -	- -	- -	- -	- -	0.1	0.4
9	R56320	0.08	0.15	0.03	0.015	0.25	2.5-3.5	2.0-3.0	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	0.1	0.4
11	R52250	0.08	0.18	0.03	0.015	0.20	- -	- -	0.12-0.25	- -	- -	- -	- -	- -	- -	- -	- -	- -	0.1	0.4
12	R53400	0.08	0.25	0.03	0.015	0.30	- -	- -	- -	- -	0.6-0.9	0.2-0.4	- -	- -	- -	- -	- -	- -	0.1	0.4
13	R53413	0.08	0.10	0.03	0.015	0.20	- -	- -	- -	0.04-0.06	0.4-0.6	- -	- -	- -	- -	- -	- -	- -	0.1	0.4
14	R53414	0.08	0.15	0.03	0.015	0.30	- -	- -	- -	0.04-0.06	0.4-0.6	- -	- -	- -	- -	- -	- -	- -	0.1	0.4
15	R53415	0.08	0.25	0.05	0.015	0.30	- -	- -	- -	0.04-0.06	0.4-0.6	- -	- -	- -	- -	- -	- -	- -	0.1	0.4
16/16H	R52402	0.08	0.25	0.03	0.015	0.30	- -	- -	0.04-0.08	- -	- -	- -	- -	- -	- -	- -	- -	- -	0.1	0.4
17	R52252	0.08	0.18	0.03	0.015	0.20	- -	- -	0.04-0.08	- -	- -	- -	- -	- -	- -	- -	- -	- -	0.1	0.4
18	R56322	0.08	0.15	0.03	0.015	0.25	2.5-3.5	2.0-3.0	0.04-0.08	- -	- -	- -	- -	- -	- -	- -	- -	- -	0.1	0.4
19	R58640	0.05	0.12	0.03	0.02	0.30	3.0-4.0	7.5-8.5	- -	- -	- -	3.5-4.5	5.5-6.5	- -	3.5-4.5	- -	- -	- -	0.15	0.4
20	R58645	0.05	0.12	0.03	0.02	0.30	3.0-4.0	7.5-8.5	0.04-0.08	- -	- -	3.5-4.5	5.5-6.5	- -	3.5-4.5	- -	- -	- -	0.15	0.4
21	R58210	0.05	0.17	0.03	0.015	0.40	2.5-3.5	- -	- -	- -	- -	14.0-16.0	- -	- -	- -	2.2-3.2	- -	0.15-0.25	0.1	0.4
23	R56407	0.08	0.13	0.03	0.0125	0.25	5.5-6.5	3.5-4.5	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	0.1	0.4
24	R56405	0.08	0.20	0.05	0.015	0.40	5.5-6.75	3.5-4.5	0.04-0.08	- -	- -	- -	- -	- -	- -	- -	- -	- -	0.1	0.4
25	R56403	0.08	0.20	0.05	0.015	0.40	5.5-6.75	3.5-4.5	0.04-0.08	- -	0.3-0.8	- -	- -	- -	- -	- -	- -	- -	0.1	0.4
26/26H	R52404	0.08	0.25	0.03	0.015	0.30	- -	- -	- -	0.08-0.14	- -	- -	- -	- -	- -	- -	- -	- -	0.1	0.4
27	R52254	0.08	0.18	0.03	0.015	0.20	- -	- -	- -	0.08-0.14	- -	- -	- -	- -	- -	- -	- -	- -	0.1	0.4
28	R56323	0.08	0.15	0.03	0.015	0.25	2.5-3.5	2.0-3.0	- -	0.08-0.14	- -	- -	- -	- -	- -	- -	- -	- -	0.1	0.4
29	R56404	0.08	0.13	0.03	0.0125	0.25	5.5-6.5	3.5-4.5	- -	0.08-0.14	- -	- -	- -	- -	- -	- -	- -	- -	0.1	0.4
30	R53530	0.08	0.25	0.03	0.015	0.30	- -	- -	0.04-0.08	- -	- -	- -	- -	0.20-0.80	- -	- -	- -	- -	0.1	0.4
31	R53532	0.08	0.35	0.05	0.015	0.30	- -	- -	0.04-0.08	- -	- -	- -	- -	0.20-0.80	- -	- -	- -	- -	0.1	0.4

TABLE 1 *Continued*

		Composition, Weight Percent[A,B,C,D,E]																		
Grade	UNS Number	Carbon, max.	Oxygen range or max.	Nitrogen, max.	Hydrogen, max.	Iron range or max.	Aluminum	Vanadium	Palladium	Ruthenium	Nickel	Molybdenum	Chromium	Cobalt	Zirconium	Niobium	Tin	Silicon	Other Elements, max. each	Other Elements, max. total
32	R55111	0.08	0.11	0.03	0.015	0.25	4.5-5.5	0.6-1.4	- -	- -	- -	0.6-1.2	- -	- -	0.6-1.4	- -	0.6-1.4	0.06-0.14	0.1.	0.4
33	R53442	0.08	0.25	0.03	0.015	0.30	- -	- -	0.01-0.02	0.02-0.04	0.35-0.55	- -	0.1-0.2	- -	- -	- -	- -	- -	0.1	0.4
34	R53445	0.08	0.35	0.05	0.015	0.30	- -	- -	0.01-0.02	0.02-0.04	0.35-0.55	- -	0.1-0.2	- -	- -	- -	- -	- -	0.1	0.4
35	R56340	0.08	0.25	0.05	0.015	0.20-0.80	4.0-5.0	1.1-2.1	- -	- -	- -	1.5-2.5	- -	- -	- -	- -	- -	0.20-0.40	0.1	0.4
36	R58450	0.04	0.16	0.03	0.015	0.03	- -	- -	- -	- -	- -	- -	- -	- -	- -	42.0-47.0	- -	- -	0.1	0.4
37	R52815	0.08	0.25	0.03	0.015	0.30	1.0-2.0	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	0.1	0.4
38	R54250	0.08	0.20-0.30	0.03	0.015	1.2-1.8	3.5-4.5	2.0-3.0	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	0.1	0.4

[A] At minimum, the analysis of samples from the top and bottom of the ingot or of the product from the top and bottom of the ingot shall be completed and reported for all elements listed for the respective grade in this table.

[B] Final product hydrogen shall be reported. Ingot hydrogen need not be reported. Lower hydrogen may be obtained by negotiation with the manufacturer.

[C] Single values are maximum. The percentage of titanium is determined by difference.

[D] Other elements need not be reported unless the concentration level is greater than 0.1 % each, or 0.4 % total. Other elements may not be added intentionally. Other elements may be present in titanium or titanium alloys in small quantities and are inherent to the manufacturing process. In titanium these elements typically include aluminum, vanadium, tin, chromium, molybdenum, niobium, zirconium, hafnium, bismuth, ruthenium, palladium, yttrium, copper, silicon, cobalt, tantalum, nickel, boron, manganese, and tungsten.

[E] The purchaser may, in the written purchase order, request analysis for specific elements not listed in this specification.

TABLE 2 Tensile Requirements[A]

Grade	Tensile Strength, min		Yield Strength (0.2 % Offset) min or range		Elongation in 4*D*, 4 W or 2 inch min, %	Reduction of Area, min %
	ksi	MPa	ksi	MPa		
1	35	240	20	138	24	30
2	50	345	40	275	20	30
2H[B,C]	58	400	40	275	20	30
3	65	450	55	380	18	30
4	80	550	70	483	15	25
5	130	895	120	828	10	25
6	120	828	115	795	10	25
7	50	345	40	275	20	30
7H[B,C]	58	400	40	275	20	30
9	90	620	70	483	15	25
9[D]	90	620	70	483	12	25
11	35	240	20	138	24	30
12	70	483	50	345	18	25
13	40	275	25	170	24	30
14	60	410	40	275	20	30
15	70	483	55	380	18	25
16	50	345	40	275	20	30
16H[B,C]	58	400	40	275	20	30
17	35	240	20	138	24	30
18	90	620	70	483	15	25
18[D]	90	620	70	483	12	20
19[E]	115	793	110	759	15	25
19[F]	135	930	130 to 159	897 to 1096	10	20
19[G]	165	1138	160 to 185	1104 to 1276	5	20
20[E]	115	793	110	759	15	25
20[F]	135	930	130 to 159	897 to 1096	10	20
20[G]	165	1138	160 to 185	1104 to 1276	5	20
21[E]	115	793	110	759	15	35
21[F]	140	966	130 to 159	897 to 1096	10	30
21[G]	170	1172	160 to 185	1104 to 1276	8	20
23	120	828	110	759	10	25
23[D]	120	828	110	759	7.5[H], 6.0[I]	15
24	130	895	120	828	10	25
25	130	895	120	828	10	25
26	50	345	40	275	20	30
26H[B,C]	58	400	40	275	20	30
27	35	240	20	138	24	30
28	90	620	70	483	15	25
28[D]	90	620	70	483	12	20
29	120	828	110	759	10	25
29[D]	120	828	110	759	7.5[H], 6.0[I]	15
30	50	345	40	275	20	30
31	65	450	55	380	18	30
32	100	689	85	586	10	25
33	50	345	40	275	20	30
34	65	450	55	380	18	30
35	130	895	120	828	5	20
36	65	450	60 to 95	410 to 655	10	...
37	50	345	31	215	20	30
38	130	895	115	794	10	25

[A] These properties apply to longitudinal sections up to 3 in. [76 mm] in thickness with a maximum of 10 in.^{2} [64.5 cm^2].
[B] 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. Grade 2H, 7H, 16H, and 26H are intended primarily for pressure vessel use.
[C] 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.
[D] Properties for material in transformed-beta condition.
[E] Properties for solution treated condition.
[F] Properties for solution treated and aged condition–Moderate strength (determined by aging temperature).
[G] Properties for solution treated and aged condition–High strength (determined by aging temperature).
[H] For product section or wall thickness values <1.0 in.
[I] For product section or wall thickness values ≥ 1.0 in.

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.

TABLE 3 Permissible Variations in Product Analysis

Element	Product Analysis Limits, max or Range, %	Permissible Variation 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
Cobalt	0.2 to 0.8	±0.05
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	0.6 to 1.2	±0.15
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
Tin	0.62.0 to 3.0	±0.15
Vanadium	0.6 to 4.5	±0.15
Vanadium	7.5 to 8.5	±0.40
Zirconium	0.6 to 1.4	±0.15
Residuals[A] (each)	0.15	+0.02

[A] A residual is an element present in a metal or alloy in small quantities and is inherent to the manufacturing process but not added intentionally. In titanium these elements include aluminum, vanadium, tin, iron, chromium, molybdenum, niobium, zirconium, hafnium, bismuth, ruthenium, palladium, yttrium, copper, silicon, cobalt, tantalum, nickel, boron, manganese, and tungsten.

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.

5.3 *Product Analysis*—Product analysis tolerances do not broaden the specified heat analysis requirements, but cover variations between laboratories in the measurement of chemical content. The ingot manufacturer shall not ship material which is outside the limits specified in Table 1 for the applicable grade. Product analysis limits shall be as specified in Table 3.

6. Mechanical Properties

6.1 Material supplied under this specification shall conform to the mechanical property requirements given in Table 2, as applicable.

6.2 Tension testing specimens are to be machined and tested in accordance with Test Methods E8/E8M. Tensile properties shall be determined using a strain rate of 0.003 to 0.007 in./in./min through the specified yield strength, and then increasing the rate so as to produce failure in approximately one additional minute.

7. Dimensions, Weight, and Permissible Variations

7.1 *Size*—Tolerances on titanium and titanium alloy material covered by this specification shall be as specified in Tables 4-11, as applicable.

7.2 *Weight*—Quantity extras are applicable to individual items of a grade, thickness, width, and length ordered at one time for shipment at one time to one destination. Different lengths of the same size and grade may be combined for quantity extra. The shipping weight of any item of an ordered size in any finish may exceed the theoretical weight by as much as 10 %.

8. Workmanship, Finish, and Appearance

8.1 Titanium and titanium alloy bar and billet shall be free of injurious external and internal imperfections of a nature that will interfere with the purpose for which it is intended. Annealed material may be furnished as descaled, sandblasted, ground, or rough turned. The manufacturer shall be permitted to remove minor surface imperfections by spot grinding if such grinding does not reduce the thickness of the material below the minimum permitted by the tolerance for the thickness ordered.

9. Sampling

9.1 Samples for chemical analyses shall be representative of the material being tested. The utmost care must be used in

TABLE 4 Permissible Variations in Size for Titanium Bars—Hot-Worked Rounds and Squares

Specified Size, in. [mm]	Size Variations, in. [mm]	Out-of-Round[A] or Out-of-Square,[B] in. [mm]
¼ to 5⁄16 [6.35 to 7.94], incl	±0.005 [0.13]	0.008 [0.20]
Over 5⁄16 to 7⁄16 [7.94 to 11.11], incl	±0.006 [0.15]	0.009 [0.23]
Over 7⁄16 to 5⁄8 [11.11 to 15.88], incl	±0.007 [0.18]	0.010 [0.25]
Over 5⁄8 to 7⁄8 [15.88 to 22.22], incl	±0.008 [0.20]	0.012 [0.30]
Over 7⁄8 to 1 [22.22 to 25.40], incl	±0.009 [0.23]	0.013 [0.33]
Over 1 to 1⅛ [25.40 to 28.58], incl	±0.010 [0.25]	0.015 [0.38]
Over 1⅛ to 1¼ [28.58 to 31.75], incl	±0.011 [0.28]	0.016 [0.41]
Over 1¼ to 1⅜ [31.75 to 34.92], incl	±0.012 [0.30]	0.018 [0.46]
Over 1⅜ to 1½ [34.92 to 38.10], incl	±0.014 [0.36]	0.021 [0.53]
Over 1½ to 2 [38.10 to 50.80], incl	±1⁄64 [0.40]	0.023 [0.58]
Over 2 to 2½ [50.80 to 63.50], incl	+1⁄32, −0 [0.79]	0.023 [0.58]
Over 2½ to 3½ [63.50 to 88.90], incl	+3⁄64, −0 [1.19]	0.035 [0.89]
Over 3½ to 4½ [88.90 to 114.30], incl	+1⁄16, −0 [1.59]	0.046 [1.17]

[A] Out-of-round is the difference between the maximum and minimum diameters of the bar, measured at the same cross section.
[B] Out-of-square section is the difference in the two dimensions at the same cross section of a square bar, each dimension being the distance between opposite faces.

TABLE 5 Permissible Variations in Size for Titanium Bars—Hot-Worked Hexagons and Octagons

Specified Sizes Between Opposite Sides, in. [mm]	Size Variation, in. [mm]	Maximum Difference, 3 Measurements, in. [mm]
¼ to ½ [6.35 to 12.70], incl	±0.007 [0.18]	0.011 [0.28]
Over ½ to 1 [12.70 to 25.40], incl	±0.010 [0.25]	0.015 [0.38]
Over 1 to 1½ [25.40 to 38.10], incl	±0.021 [0.53]	0.025 [0.64]
Over 1½ to 2 [38.10 to 50.80], incl	±1/32 [0.79]	1/32 [0.79]
Over 2 to 2½ [50.80 to 63.50], incl	±3/64 [1.19]	3/64 [1.19]
Over 2½ to 3½ [63.50 to 88.90], incl	±1/16 [1.59]	1/16 [1.59]

TABLE 6 Permissible Variations in Size for Titanium Bars—Hot-Worked Flats

Specified Widths, in. [mm]	Thickness Variation from Specified Thickness, in. [mm]			
	⅛ to ½ in. [3.18 to 12.70 mm], incl	Over ½ to 1 in. [12.70 to 25.40 mm], incl	Over 1 to 2 in. [25.40 to 50.80 mm], incl	Width Variation, in. [mm]
To 1 [25.40], incl	±0.008 [0.20]	±0.010 [0.25]	...	+1/64, −1/64 [+0.40, −0.40]
Over 1 to 2 [25.40 to 50.80], incl	±0.012 [0.30]	±0.015 [0.38]	±1/32 [0.79]	+1/32, −1/32 [+0.79, −0.79]
Over 2 to 4 [50.80 to 101.60], incl	±0.015 [0.38]	±0.020 [0.51]	±1/32 [0.79]	+1/16, −1/32 [+1.59, −0.79]
Over 4 to 6 [101.60 to 152.40], incl	±0.015 [0.38]	±0.020 [0.51]	±1/32 [0.79]	+3/32, −1/16 [+2.38, −1.59]
Over 6 to 8 [152.40 to 203.20], incl	±0.016 [0.41]	±0.025 [0.64]	±1/32 [0.79]	+⅛, −5/32 [+3.18, −3.97]
Over 8 to 10 [203.20 to 254.0], incl	±0.021 [0.53]	±0.031 [0.79]	±1/32 [0.79]	+5/32, −3/16 [+3.97,−4.76]

TABLE 7 Permissible Variations in Size for Titanium Bars—Cold-Finished Rounds

Specified Size, in. [mm]	Size Variation,[A] in. [mm]
Over ½ to 1 [12.70 to 25.40], excl	±0.002 [0.05]
1 to 1½ [25.40 to 38.10], excl	±0.0025 [0.06]
1½ to 4 [38.10 to 101.60], incl	±0.003 [0.08]

[A] When it is necessary to heat treat or heat treat and pickle after cold finishing, because of special hardness or mechanical property requirements, tolerances are commonly double those shown in this table.

TABLE 8 Permissible Variations in Size for Titanium Bars—Cold-Finished Hexagons, Octagons, and Squares

Specified Size, in. [mm]	Size Variation,[A] in. [mm]
Over ½ to 1 [12.70 to 25.40], incl	+ 0, – 0.004 [–0.10]
Over 1 to 2 [25.40 to 50.80], incl	+ 0, – 0.006 [–0.16]
Over 2 to 3 [50.80 to 76.20], incl	+ 0, – 0.008 [–0.20]
Over 3 [76.20]	+ 0, – 0.010 [–0.25]

[A] When it is necessary to heat treat or heat treat and pickle after cold finishing, because of special hardness or mechanical property requirements, tolerances are commonly double those shown in this table.

sampling titanium for chemical analysis because of its great affinity for elements such as oxygen, nitrogen, and hydrogen. Therefore, in cutting samples for analysis, the operation should be carried out insofar as possible in a dust-free atmosphere. Chips should be collected from clean metal and tools should be clean and sharp. Samples for analysis should be stored in suitable containers.

9.2 At least two samples for chemical analysis shall be tested to determine chemical composition. Samples shall be taken from top and bottom ingot locations, or from product representative of the top and bottom of the ingot or from the opposite extremes of the product to be analyzed.

10. Methods of Chemical Analysis

10.1 The chemical analysis shall normally be conducted using the ASTM standard test methods referenced in 2.1. Other industry standard methods may be used where the ASTM test methods in 2.1 do not adequately cover the elements in the material or by agreement between the producer and the purchaser. Alternate techniques are discussed in Guide E2626.

11. Retests

11.1 If the results of any chemical or mechanical property test lot are not in conformance with the requirements of this specification, the lot may be retested at the option of the manufacturer. The frequency of the retest will double the initial number of tests. If the results of the retest conform to the specification, then the retest values will become the test values for certification. Only original conforming test results or the conforming retest results shall be reported to the purchaser. If the results for the retest fail to conform to the specification, the material will be rejected in accordance with Section 14.

12. Referee Test and Analysis

12.1 In the event of disagreement between the manufacturer and the purchaser on the conformance of the material to the requirements of this specification, a mutually acceptable referee shall perform the tests in question using the ASTM standard test methods in 2.1. The referee's testing shall be used in determining conformance of the material to this specification. Check analysis limits apply.

13. Rounding-Off Procedure

13.1 For purposes of determining conformance with the specifications contained herein, an observed or a calculated value shall be rounded off to the nearest "unit" in the last right-hand significant digit used in expressing the limiting value. This is in accordance with the round-off method of Practice E29.

14. Rejection

14.1 Material not conforming to this specification or to authorized modifications shall be subject to rejection. Unless otherwise specified, rejected material may be returned to the manufacturer at the manufacturer's expense, unless the purchaser receives, within three weeks of notice of rejection, other instructions for disposition.

TABLE 9 Permissible Variations in Size for Titanium Bars—Cold-Finished Flats

Size Width or Thickness, in. [mm]	Width Variations[A] from Specified Thicknesses, in. [mm]		Thickness Variation,[A] in. [mm]
	¼ in. [6.35 mm] and under	Over ¼ in. [6.35 mm]	
Over ⅜ to 1 [9.54 to 25.40], incl	±0.004 [0.10]	±0.002 [0.05]	±0.002 [0.05]
Over 1 to 2 [25.40 to 50.80], incl	±0.006 [0.15]	±0.003 [0.08]	±0.003 [0.08]
Over 2 to 3 [50.80 to 76.20], incl	±0.008 [0.20]	±0.004 [0.10]	±0.004 [0.10]
Over 3 to 4½ [76.20 to 114.30], incl	±0.010 [0.25]	±0.005 [0.13]	±0.005 [0.13]

[A] When it is necessary to heat treat or heat treat and pickle after cold finishing, because of special hardness or mechanical property requirements, tolerances are commonly double those shown in this table.

TABLE 10 Permissible Variations in Length for Titanium Bars—Hot Worked and Cold Finished

Specified Sizes, all Shapes, in. [mm]	Length Variations, in. [mm]	
	To 12 ft [3.66 m], incl	Over 12 to 25 ft [3.66 to 7.62 m], incl
To 2 [50.80], incl	+½, –0 [+12.70]	+¾, –0 [+19.05]
Over 2 to 4 [50.80 to 101.60], incl	+¾, –0 [+19.05]	+1, –0 [+25.40]
Over 4 to 6 [101.60 to 152.40], incl	+1, –0 [+25.40]	+1¼, –0 [+31.75]
Over 6 to 9 [152.40 to 228.60], incl	+1¼, –0 [+31.75]	+1½, –0 [+38.10]
Over 9 to 12 [228.60 to 304.80], incl	+1½, –0 [+38.10]	+2, –0 [+50.80]
Machine Cut After Machine Straightening		
To 3 [76.20], incl	+⅛, –0 [+3.18]	+3⁄16, –0 [+4.76]
Over 3 to 6 [76.20 to 152.40], incl	+ 3⁄16, –0 [+4.76]	+¼, –0 [+6.35]
Over 6 to 9 [152.40 to 228.60], incl	+¼, –0 [+6.35]	+5⁄16, –0 [+7.94]
Over 9 to 12 [228.60 to 304.80], incl	+½, –0 [+12.70]	+½, –0 [+12.70]

TABLE 11 Camber for Hot-Worked and Cold-Finished Titanium Bars for Machining

NOTE 1—Camber is the greatest deviation of a side from a straight line. Measurement is taken on the concave side of the bar with a straightedge. Unless otherwise specified, hot-worked and cold-finished bars for machining purposes are furnished machine straightened to the tolerances specified in this table.

	Tolerance
Hot worked	⅛ in. [3.18 mm] in any 5 ft [1524 mm], but may not exceed ⅛ × No. of ft in length / 5
Cold finished	1⁄16 in. [1.59 mm] in any 5 ft [1524 mm], but may not exceed 1⁄16 × No. of ft in length / 5

15. Certification

15.1 The manufacturer shall supply at least one copy of the report certifying that the material supplied has been manufactured, inspected, sampled, and tested in accordance with the requirements of this specification and that the results of chemical analysis, tensile, and other tests meet the requirements of this specification for the grade specified. The report shall include results of all chemical analysis, tensile tests, and all other tests required by the specification. The report shall include the manufacturing method (hot rolled, forged, extruded or cold worked).

16. Packaging and Package Marking

16.1 *Marking*—Unless otherwise specified, individual pieces or bundles shall have attached a metal tag stamped with the purchase order number, the specification number, the nominal size and manufacturer's heat number, or shall be boxed and the box marked with the same information. In addition to the above identification, bars 1 in. [25.4 mm] and over in diameter or distance between parallel sides shall be stamped with the heat number within 2 in. [50.8 mm] of one end.

16.2 *Packaging*—Unless otherwise specified, material purchased under this specification may be packaged for shipment either by boxing, crating, single boarding, burlapping, or with no protection in accordance with the manufacturer's standard practice.

17. Keywords

17.1 bar; billet; titanium; titanium alloy