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Standard Specification for Titanium and Titanium Alloy Strip, Sheet, and Plate[1]

This standard is issued under the fixed designation B 265; 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[2] covers annealed titanium and titanium alloy strip, sheet, and plate 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 (3.0 % 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 % to 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 to 0.14 % ruthenium,

1.1.26 *Grade 29*—Titanium alloy (6 % aluminum, 4 % vanadium with extra low interstitial elements, 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, 0.02 5 % 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),

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[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.

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[2] For ASME Boiler and Pressure Vessel Code applications see related Specifications SB-265 in Section II of that Code.

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).

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:*[3]

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
~~E120Test Methods for Chemical Analysis of Titanium and Titanium Alloys~~
~~E~~ 190 Test Method for Guided Bend Test for Ductility of Welds
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 the 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
~~E1409Test Method for Determination of Oxygen and Nitrogen in Titanium and Titanium Alloys by the Inert Gas Fusion Technique~~
~~E1447Test Method for Determination of Hydrogen in Titanium and Titanium Alloys by the Inert Gas Fusion Thermal Conductivity/Infrared Detection Method~~ 2626 Guide for Spectrometric Analysis of Reactive and Refractory Metals

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 Any product 0.187 in. (4.75 mm) and under in thickness and less than 24 in. (610 mm) in width is classified as strip; products 0.187 in. (4.75 mm) and under in thickness and 24 in. (610 mm) or more in width are classified as sheet; any product over 0.187 in. (4.75 mm) in thickness and over 10 in. (254 mm) in width is classified as plate.

4. Ordering Information

4.1 Orders for materials under this specification shall include the following information as applicable:
4.1.1 Grade number (Section 1),
4.1.2 Product limitations (Section 3),
4.1.3 Special mechanical properties (Table 1),
4.1.4 Marking (Section 16),
4.1.5 Finish (Section 8),
4.1.6 Packaging (Section 16),
4.1.7 Required reports (Section 15), and
4.1.8 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 chemical composition requirements prescribed in Table 2.

5.1.1 The elements listed in Table 2 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 2 are deemed to be capable of occurring in the grades listed in Table 2 by and only by way of unregulated or unanalyzed scrap additions to the ingot melt. Therefore, product analysis for elements not listed in Table 2 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.

[3] 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.

TABLE 1 Tensile Requirements[A]

Grade	Tensile Strength, min		Yield Strength, 0.2 % Offset				Elongation in 2 in. or 50 mm, min, %	Bend Test[B]	
			min		max			Under 0.070 in. (1.8 mm) in Thickness	0.070 to 0.187 in. (1.8–4.75 mm) in Thickness
	ksi	MPa	ksi	MPa	ksi	MPa			
1	35	240	20	138	45	310	24	3*T*	4*T*
2	50	345	40	275	65	450	20	4*T*	5*T*
2H[C,D]	58	400	40	275	65	450	20	...	...
3	65	450	55	380	80	550	18	4*T*	5*T*
4	80	550	70	483	95	655	15	5*T*	6*T*
5	130	895	120	828	...	...	10[E]	9*T*	10*T*
6	120	828	115	793	...	...	10[E]	8*T*	9*T*
7	50	345	40	275	65	450	20	4*T*	5*T*
7H[C,D]	58	400	40	275	65	450	20	...	...
9	90	620	70	483	...	...	15[F]	5*T*	6*T*
11	35	240	20	138	45	310	24	3*T*	4*T*
12	70	483	50	345	...	...	18	4*T*	5*T*
13	40	275	25	170	...	...	24	3*T*	4*T*
14	60	410	40	275	...	...	20	4*T*	5*T*
15	70	483	55	380	...	...	18	4*T*	5*T*
16	50	345	40	275	65	450	20	4*T*	5*T*
16H[C,D]	58	400	40	275	65	450	20	...	...
17	35	240	20	138	45	310	24	3*T*	4*T*
18	90	620	70	483	...	...	15[F]	5*T*	6*T*
19[G,H]	115	793	110	759	...	...	15	6*T*	6*T*
20[G,H]	115	793	110	759	...	...	15	6*T*	6*T*
21[G,H]	115	793	110	759	...	...	15	6*T*	6*T*
23[G,H]	120	828	110	759	...	...	10	9*T*	10*T*
24	130	895	120	828	...	...	10	...	...
25	130	895	120	828	...	...	10	...	...
26	50	345	40	275	65	450	20	4*T*	5*T*
26H[C,D]	58	400	40	275	65	450	20	...	...
27	35	240	20	138	45	310	24	3*T*	4*T*
28	90	620	70	483	...	...	15	5*T*	6*T*
29	120	828	110	759	...	...	10	9*T*	10*T*
30	50	345	40	275	65	450	20	4*T*	5*T*
31	65	450	55	380	80	550	18	4*T*	5*T*
32	100	689	85	586	...	...	10[E]	7*T*	9*T*
33	50	345	40	275	65	450	20	4*T*	5*T*
34	65	450	55	380	80	550	18	4*T*	5*T*
35	130	895	120	828	...	...	5	16*T*	16*T*
36	65	450	60	410	95	655	10	[I]	[I]
37	50	345	31	215	65	450	20	4*T*	5*T*
38	130	895	115	794	...	...	10	8*T*	9*T*

[A] Minimum and maximum limits apply to tests taken both longitudinal and transverse to the direction of rolling. Mechanical properties for conditions other than annealed or plate thickness over 1 in. (25 mm) may be established by agreement between the manufacturer and the purchaser.
[B] *T* equals the thickness of the bend test specimen. Bend tests are not applicable to material over 0.187 in. (4.75 mm) in thickness.
[C] 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.
[D] 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.
[E] For Grades 5, 6 and 32 the elongation on materials under 0.025 in. (0.635 mm) in thickness may be obtained only by negotiation.
[F] Elongation for continuous rolled and annealed (strip product from coil) for Grade 9 and Grade 18 shall be 12 % minimum in the longitudinal direction and 8 % minimum in the transverse direction.
[G] Properties for material in the solution treated condition.
[H] Material is normally purchased in the solution treated condition. Therefore, properties for aged material shall be negotiated between manufacturer and purchaser.
[I] As agreed upon between purchaser and supplier.

5.2 When agreed upon by 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 manufacturer shall not ship material that is outside the limits specified in Table 2 for the applicable grade. Product analysis limits shall be as specified in Table 3.

5.4 At least two samples for chemical analysis shall be tested to determine chemical composition. Samples shall be taken from the ingot or the extremes of the product to be analyzed.

6. Mechanical Properties

6.1 Material supplied under this specification shall conform to the mechanical property requirements given in Table 1 for the grade specified.

6.2 Tension testing specimens are to be machined and tested in accordance with Test Methods E 8. 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.

TABLE 2 Chemical Requirements[A]

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	Grade 13	Grade 14
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	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	0.08	0.08
Hydrogen,[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	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	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	0.10	0.15
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	...	...	...	...	...	...	...	...	...	...	...	...	0.04–0.06	0.04–0.06
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	0.4–0.6	0.4–0.6
Niobium	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Zirconium	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Silicon	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Residuals,[D,E,F] 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	0.1	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	0.4	0.4	0.4	0.4
Titanium[G]	balance	balance	balance	balance	balance	balance	balance	balance	balance	balance	balance	balance	balance	balance

Element	Composition, %												
	Grade 15	Grade 16	Grade 16H	Grade 17	Grade 18	Grade 19	Grade 20	Grade 21	Grade 23	Grade 24	Grade 25	Grade 26	Grade 26H
Nitrogen, max	0.05	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.05	0.05	0.03	0.03
Carbon, max	0.08	0.08	0.08	0.08	0.08	0.05	0.05	0.05	0.08	0.08	0.08	0.08	0.08
Hydrogen,[B,C] max	0.015	0.015	0.015	0.015	0.015	0.02	0.02	0.015	0.0125	0.015	0.0125	0.015	0.015
Iron, max	0.30	0.30	0.30	0.20	0.25	0.30	0.30	0.40	0.25	0.40	0.40	0.30	0.30
Oxygen, max	0.25	0.25	0.25	0.18	0.15	0.12	0.12	0.17	0.13	0.20	0.20	0.25	0.25
Aluminum	...	...	...	...	2.5–3.5	3.0–4.0	3.0–4.0	2.5–3.5	5.5–6.5	5.5–6.75	5.6–6.75	...	...
Vanadium	...	...	...	...	2.0–3.0	7.5–8.5	7.5–8.5	...	3.5–4.5	3.5–4.5	3.5–4.5	...	...
Tin	...	...	...	...	...	...	...	...	...	...	...	...	...
Ruthenium	0.04–0.06	...	...	...	...	...	...	...	...	...	...	0.08-0.14	0.08–0.14
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	...	...
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	...	...	...	...	...	...	...	...	...	0.3–0.8	...	...
Niobium	...	...	...	...	...	...	...	2.2–3.2	...	...	...	...	...
Zirconium	...	...	...	...	...	3.5–4.5	3.5–4.5	...	...	...	...	...	...
Silicon	...	...	...	...	...	...	...	0.15–0.25	...	...	...	...	...
Residuals,[D,E,F] max each	0.1	0.1	0.1	0.1	0.1	0.15	0.15	0.1	0.1	0.1	0.1 †	0.1	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	0.4	0.4	0.4
Titanium[G]	balance	balance	balance	balance	balance	balance	balance	balance	balance	balance	balance	balance	balance

Element	Composition, %											
	Grade 27	Grade 28	Grade 29	Grade 30	Grade 31	Grade 32	Grade 33	Grade 34	Grade 35	Grade 36	Grade 37	Grade 38
Nitrogen, max	0.03	0.03	0.03	0.03	0.05	0.03	0.03	0.05	0.05	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	0.04	0.08	0.08
Hydrogen,[B,C] max	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.0035	0.015	0.015

Element	Composition, %											
	Grade 27	Grade 28	Grade 29	Grade 30	Grade 31	Grade 32	Grade 33	Grade 34	Grade 35	Grade 36	Grade 37	Grade 38
Iron, max or range	0.20	0.25	0.25	0.30	0.30	0.25	0.30	0.30	0.20-0.80	0.03	0.30	1.2–1.8
Oxygen, max or range	0.18	0.15	0.13	0.25	0.35	0.11	0.25	0.35	0.25	0.16	0.25	0.20–0.30
Aluminum	...	2.5-3.5	5.5-6.5	...	...	4.5-5.5	...	...	4.0-5.0	...	1.0-2.0	3.5–4.5
Vanadium	...	2.0-3.0	3.5-4.5	...	...	0.6-1.4	...	...	1.1-2.1	...	...	2.0–3.0
Tin	...	...	...	...	...	0.6-1.4	...	...	...	...	...	...
Ruthenium	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	...	...	...	...
Cobalt	...	...	...	0.20–0.80	0.20–0.80	...	...	...	...	...	...	...
Molybdenum	...	...	...	...	...	0.6-1.2	...	...	1.5-2.5	...	...	...
Chromium	...	...	...	...	...	...	0.1-0.2	0.1-0.2	...	...	...	...
Nickel	...	...	...	...	...	...	0.35-0.55	0.35-0.55	...	...	...	...
Niobium	...	...	...	...	...	...	...	...	...	42.0-47.0	...	...
Zirconium	...	...	...	...	...	0.6-1.4	...	...	...	...	...	...
Silicon	...	...	...	...	...	0.06-0.14	...	...	0.20-0.40	...	...	...
Residuals,[D,E,F] 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,[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	0.4	0.4
Titanium[G]	balance	balance	balance	balance	balance	balance	Remainder	Remainder	Remainder	Remainder	Remainder	balance

[A] 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.
[B] Lower hydrogen may be obtained by negotiation with the manufacturer.
[C] Final product analysis.
[D] Need not be reported.
[E] 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.
[F] The purchaser may, in his written purchase order, request analysis for specific residual elements not listed in this specification.
[G] The percentage of titanium is determined by difference.
† Residual max value for silicon in Grade 25 was corrected editorially.

6.3 For sheet and strip, the bend test specimen shall withstand being bent cold through an angle of 105° without fracture in the outside of the bent portion. The bend shall be made on a diameter equal to that shown in Table 1 for the applicable grade.

7. Permissible Variations in Dimensions

7.1 Dimensional tolerances on titanium and titanium alloy material covered by this specification shall be as specified in Tables 4-13, as applicable.

8. Finish

8.1 Titanium and titanium alloy sheet, strip, and plate 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, as sandblasted, or as ground, or both sandblasted and ground. If shipped as descaled, sandblasted, or ground, 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 for Chemical Analysis

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

10. ~~Methods of Chemical Analysis~~

~~10.1The chemical analysis shall be conducted by the standard techniques normally utilized by the manufacturer and purchaser.~~

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	0.6 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.

TABLE 4 Permissible Variations in Thickness of Titanium Sheet

Specified Thickness, in. (mm)	Permissible Variations in Thickness, plus and minus, in. (mm)
0.146 to 0.1875 (3.71 to 4.76), excl	0.014 (0.36)
0.131 to 0.145 (3.33 to 3.68)	0.012 (0.31)
0.115 to 0.130 (2.92 to 3.30)	0.010 (0.25)
0.099 to 0.114 (2.51 to 2.90)	0.009 (0.23)
0.084 to 0.098 (2.13 to 2.49)	0.008 (0.20)
0.073 to 0.083 (1.85 to 2.11)	0.007 (0.18)
0.059 to 0.072 (1.50 to 1.83)	0.006 (0.15)
0.041 to 0.058 (1.04 to 1.47)	0.005 (0.13)
0.027 to 0.040 (0.69 to 1.02)	0.004 (0.10)
0.017 to 0.026 (0.43 to 0.66)	0.003 (0.08)
0.008 to 0.016 (0.20 to 0.41)	0.002 (0.05)
0.006 to 0.007 (0.15 to 0.18)	0.0015 (0.04)
0.005 (0.13)	0.001 (0.03)

TABLE 5 Permissible Variations in Width and Length of Titanium Sheet

Specified Width, in. (mm), for Thicknesses Under 3⁄16 in.	Permissible Variations in Width, in. (mm)
24 to 48 (610 to 1220), excl	+1⁄16 (+1.60), –0
48 (1220) and over	+1⁄8 (+3.20), –0
Specified Length, ft (m)	**Permissible Variations in Length, in. (mm)**
Up to 10 (3)	+1⁄4 (+6.35), –0
Over 10 to 20 (3 to 6)	+1⁄2 (+12.7), –0

~~In case of disagreement Test Methods E120 shall be used as the referee method except for carbon, oxygen, and hydrogen which are not covered in Test Methods E120. Test Method E1409 shall be used as a referee method for oxygen and Test Method E1447~~