



Designation: B 265 – 06

## Standard Specification for Titanium and Titanium Alloy Strip, Sheet, and Plate<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 strip, sheet, and plate as follows:

- 1.1.1 *Grade 1*—Unalloyed titanium,
- 1.1.2 *Grade 2*—Unalloyed titanium,
- 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,
- 1.1.8 *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,
- 1.1.15 *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,
- 1.1.24 *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, 0.025 % 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

<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 Specifications SB-265 in Section II of that Code.

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

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

<sup>A</sup> 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.

<sup>B</sup> 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.

<sup>C</sup> 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.

<sup>D</sup> 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.

<sup>E</sup> Properties for material in the solution treated condition.

<sup>F</sup> Material is normally purchased in the solution treated condition. Therefore, properties for aged material shall be negotiated between manufacturer and purchaser.

<sup>G</sup> As agreed upon between purchaser and supplier.

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

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 120** Test Methods for Chemical Analysis of Titanium and Titanium Alloys<sup>4</sup>

**E 190** Test Method for Guided Bend Test for Ductility of Welds

**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 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

<sup>3</sup> 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.

<sup>4</sup> Withdrawn.

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.

**TABLE 2 Chemical Requirements<sup>A</sup>**

| Element                               | Composition, % |         |         |         |          |         |           |         |           |          |           |           |
|---------------------------------------|----------------|---------|---------|---------|----------|---------|-----------|---------|-----------|----------|-----------|-----------|
|                                       | Grade 1        | Grade 2 | Grade 3 | Grade 4 | Grade 5  | Grade 6 | Grade 7   | Grade 9 | Grade 11  | Grade 12 | Grade 13  | Grade 14  |
| Nitrogen, max                         | 0.03           | 0.03    | 0.05    | 0.05    | 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      | 0.08    | 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    | 0.50    | 0.40     | 0.50    | 0.30      | 0.25    | 0.20      | 0.30     | 0.20      | 0.30      |
| Oxygen, max                           | 0.18           | 0.25    | 0.35    | 0.40    | 0.20     | 0.20    | 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 | ...      | ...       | ...       |
| Cobalt                                | ...            | ...     | ...     | ...     | ...      | ...     | ...       | ...     | ...       | ...      | ...       | ...       |
| Molybdenum                            | ...            | ...     | ...     | ...     | ...      | ...     | ...       | ...     | ...       | 0.2–0.4  | ...       | ...       |
| Chromium                              | ...            | ...     | ...     | ...     | ...      | ...     | ...       | ...     | ...       | ...      | ...       | ...       |
| Nickel                                | ...            | ...     | ...     | ...     | ...      | ...     | ...       | ...     | ...       | 0.6–0.9  | 0.4–0.6   | 0.4–0.6   |
| 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 15       | Grade 16  | Grade 17  | Grade 18  | Grade 19 | Grade 20  | Grade 21  | Grade 23 | Grade 24  | Grade 25  | Grade 26  |  |
| Nitrogen, max                         | 0.05           | 0.03      | 0.03      | 0.03      | 0.03     | 0.03      | 0.03      | 0.03     | 0.05      | 0.05      | 0.03      |  |
| Carbon, max                           | 0.08           | 0.08      | 0.08      | 0.08      | 0.05     | 0.05      | 0.05      | 0.08     | 0.08      | 0.08      | 0.08      |  |
| Hydrogen, <sup>B,C</sup> max          | 0.015          | 0.015     | 0.015     | 0.015     | 0.02     | 0.02      | 0.015     | 0.0125   | 0.015     | 0.0125    | 0.015     |  |
| Iron, max                             | 0.30           | 0.30      | 0.20      | 0.25      | 0.30     | 0.30      | 0.40      | 0.25     | 0.40      | 0.40      | 0.30      |  |
| Oxygen, max                           | 0.25           | 0.25      | 0.18      | 0.15      | 0.12     | 0.12      | 0.17      | 0.13     | 0.20      | 0.20      | 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 |  |
| 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 | ...       |  |
| 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, <sup>D,E,F</sup> max each  | 0.1            | 0.1       | 0.1       | 0.1       | 0.15     | 0.15      | 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       |  |
| Titanium <sup>G</sup>                 | balance        | balance   | balance   | balance   | balance  | balance   | balance   | balance  | balance   | balance   | balance   |  |

**TABLE 2** *Continued*

| Element                                  | 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, <sup>B,C</sup> 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     |
| Iron, max<br>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<br>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, <sup>D,E,F</sup><br>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><br>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   | Remainder | Remainder | Remainder | Remainder | Remainder | balance   |

<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 manufacturer.

<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.

† Residual max value for silicon in Grade 25 was corrected editorially.

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.

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.

6.3 For sheet and strip, the bend test specimen shall stand 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