



Standard Specification for Titanium and Titanium Alloy Forgings¹

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1. Scope

1.1 This specification² covers 39 grades of annealed titanium and titanium alloy forgings as follows:

- 1.1.1 *Grade F-1*—UNS R50250. Unalloyed titanium,
- 1.1.2 *Grade F-2*—UNS R50400. Unalloyed titanium,
 - 1.1.2.1 *Grade F-2H*—UNS R50400. Unalloyed titanium (Grade 2 with 58 ksi (400 MPa) minimum UTS),
- 1.1.3 *Grade F-3*—UNS R50550. Unalloyed titanium,
- 1.1.4 *Grade F-4*—UNS R50700. Unalloyed titanium,
- 1.1.5 *Grade F-5*—UNS R56400. Titanium alloy (6 % aluminum, 4 % vanadium),
- 1.1.6 *Grade F-6*—UNS R54520. Titanium alloy (5 % aluminum, 2.5 % tin),
- 1.1.7 *Grade F-7*—UNS R52400. Unalloyed titanium plus 0.12 to 0.25 % palladium,
 - 1.1.7.1 *Grade F-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 F-9*—UNS R56320. Titanium alloy (3 % aluminum, 2.5 % vanadium),
- 1.1.9 *Grade F-11*—UNS R52250. Unalloyed titanium plus 0.12 to 0.25 % palladium,
- 1.1.10 *Grade F-12*—UNS R53400. Titanium alloy (0.3 % molybdenum, 0.8 % nickel),
- 1.1.11 *Grade F-13*—UNS R53413. Titanium alloy (0.5 % nickel, 0.05 % ruthenium),
- 1.1.12 *Grade F-14*—UNS R53414. Titanium alloy (0.5 % nickel, 0.05 % ruthenium),
- 1.1.13 *Grade F-15*—UNS R53415. Titanium alloy (0.5 % nickel, 0.05 % ruthenium),
- 1.1.14 *Grade F-16*—UNS R52402. Unalloyed titanium plus 0.04 to 0.08 % palladium,
 - 1.1.14.1 *Grade F-16H*—UNS R52402. Unalloyed titanium plus 0.04 to 0.08 % palladium (Grade 16 with 58 ksi (400 MPa) minimum UTS),

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² For ASME Boiler and Pressure Vessel Code applications, see related Specification SB-381 in Section II of that Code.

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

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

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

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

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

1.1.20 *Grade F-23*—UNS R56407. Titanium alloy (6 % aluminum, 4 % vanadium, extra low interstitials, ELI),

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

1.1.22 *Grade F-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 F-26*—UNS R52404. Unalloyed titanium plus 0.08 to 0.14 % ruthenium,

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

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

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

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

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

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

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

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

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

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

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

1.1.35 *Grade F-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 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.

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*:³

[B348 Specification for Titanium and Titanium Alloy Bars and Billets](#)

[E8 Test Methods for Tension Testing of Metallic Materials \[Metric\] E0008_E0008M](#)

[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 \(Withdrawn 2017\)](#)⁴

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.

⁴ The last approved version of this historical standard is referenced on www.astm.org.

[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 or cold worked semifinished solid section product whose cross sectional area is less than 16 in.² (10 323 mm²).

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.² (10 323 mm²).

3.1.3 *forging, n*—any product of work on metal formed to a desired shape by impact or pressure in hammers, forging machines, upsetters presses or related forming equipment.

4. Ordering Information

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

4.1.1 Grade number (Section 1),

4.1.2 Tensile properties (Table 1),

4.1.3 Dimensions and tolerances (Section 10),

4.1.4 Sampling, mechanical properties (Section 8),

4.1.5 Methods for chemical analysis if different from those listed in 2.0,

4.1.6 Marking (Section 17),

4.1.7 Packaging (Section 17),

4.1.8 Certification (Section 16),

4.1.9 Disposition of rejected material (Section 14), and

4.1.10 Supplementary requirements (S1).

5. Materials and Manufacture

5.1 Material conforming to the latest revision of Specification [B348](#) shall be used when producing forgings to this specification.

6. Chemical Composition

6.1 The grades of titanium and titanium alloy metal covered by this specification shall conform to the requirements as to chemical composition prescribed in [Table 2](#).

6.1.1 The elements listed in [Table 2](#) are intentional alloy additions or elements which are inherent to the manufacturer of titanium sponge, ingot or mill product.

6.1.1.1 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.

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

6.2 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.

TABLE 1 Tensile Requirements^A

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

^A These properties apply to forgings having a cross section no greater than 3 in.² (1935 mm²). Mechanical properties of forgings having greater cross sections shall be negotiated between the manufacturer and the purchaser.

^B Material is identical to the corresponding numeric grade (that is, Grade F-2H = Grade F-2) except for the higher guaranteed minimum UTS, and may be dual certified with its corresponding numeric grade. Grade F-2H, F-7H, F-16H, and F-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 material in the 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.

TABLE 2 Chemical Requirements

 Composition, Weight Percent^{A,B,C}

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
F-1	R50250	0.08	0.18	0.03	0.015	0.20	--	--	--	--	--	--	--	--	--	--	--	--	0.1	0.4
F-2/ F-2H	R50400	0.08	0.25	0.03	0.015	0.30	--	--	--	--	--	--	--	--	--	--	--	--	0.1	0.4
F-3	R50550	0.08	0.35	0.05	0.015	0.30	--	--	--	--	--	--	--	--	--	--	--	--	0.1	0.4
F-4	R50700	0.08	0.40	0.05	0.015	0.50	--	--	--	--	--	--	--	--	--	--	--	--	0.1	0.4
F-5	R56400	0.08	0.20	0.05	0.015	0.40	5.5- 6.75	3.5- 4.5	--	--	--	--	--	--	--	--	--	--	0.1	0.4
F-6	R54520	0.08	0.20	0.03	0.015	0.50	4.0- 6.0	--	--	--	--	--	--	--	--	2.0- 3.0	--	--	0.1	0.4
F-7/ F-7H	R52400	0.08	0.25	0.03	0.015	0.30	0.12- 0.25	--	--	--	--	--	--	--	--	--	--	--	0.1	0.4
F-9	R56320	0.08	0.15	0.03	0.015	0.25	2.5- 3.5	2.0- 3.0	--	--	--	--	--	--	--	--	--	--	0.1	0.4
F-11	R52250	0.08	0.18	0.03	0.015	0.20	0.12- 0.25	--	--	--	--	--	--	--	--	--	--	--	0.1	0.4
F-12	R53400	0.08	0.25	0.03	0.015	0.30	--	--	--	--	0.6- 0.9	0.2- 0.4	--	--	--	--	--	--	0.1	0.4
F-13	R53413	0.08	0.10	0.03	0.015	0.20	0.04- 0.06	--	--	--	0.4- 0.6	--	--	--	--	--	--	--	0.1	0.4
F-14	R53414	0.08	0.15	0.03	0.015	0.30	0.04- 0.06	--	--	--	0.4- 0.6	--	--	--	--	--	--	--	0.1	0.4
F-15	R53415	0.08	0.25	0.05	0.015	0.30	0.04- 0.06	--	--	--	0.4- 0.6	--	--	--	--	--	--	--	0.1	0.4
F-16/ F-16H	R52402	0.08	0.25	0.03	0.015	0.30	0.04- 0.08	--	--	--	--	--	--	--	--	--	--	--	0.1	0.4
F-17	R52252	0.08	0.18	0.03	0.015	0.20	0.04- 0.08	--	--	--	--	--	--	--	--	--	--	--	0.1	0.4
F-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
F-19	R58640	0.05	0.12	0.03	0.02	0.30	3.5- 4.0	3.0- 4.0	0.08	--	--	3.5- 4.5	5.5- 6.5	--	3.5- 4.5	--	--	--	0.15	0.4
F-20	R58645	0.05	0.12	0.03	0.02	0.30	4.0- 4.0	8.5- 8.5	0.04- 0.08	--	--	3.5- 4.5	5.5- 6.5	--	3.5- 4.5	--	--	--	0.15	0.4
F-21	R58210	0.05	0.17	0.03	0.015	0.40	2.5- 3.5	3.0- 4.0	0.04- 0.08	--	--	14.0- 16.0	--	--	2.2- 3.2	--	0.15- 0.25	--	0.1	0.4
F-23	R56407	0.08	0.13	0.03	0.0125	0.25	5.5- 6.5	3.5- 4.5	--	--	--	--	--	--	--	--	--	--	0.1	0.4
F-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
F-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
F-26/ F-16H	R52404	0.08	0.25	0.03	0.015	0.30	--	--	--	0.08- 0.14	--	--	--	--	--	--	--	--	0.1	0.4
F-27	R52254	0.08	0.18	0.03	0.015	0.20	0.08- 0.14	--	--	0.08- 0.14	--	--	--	--	--	--	--	--	0.1	0.4
F-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
F-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
F-30	R53530	0.08	0.25	0.03	0.015	0.30	0.04- 0.08	--	0.04- 0.08	--	--	--	--	0.20- 0.80	--	--	--	--	0.1	0.4

TABLE 2 Continued

UNS Grade	Composition, Weight Percent ^{A,B,C}																		
	Carbon, max.	Oxygen, range	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
F-31	R53532	0.08	0.35	0.05	0.015	0.30	--	--	0.04-0.08	--	--	--	0.20-0.80	--	--	--	--	0.1	0.4
F-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
F-33	R53442	0.08	0.25	0.03	0.015	0.30	--	--	0.01-0.04	0.35-0.55	--	0.1-0.2	--	--	--	--	--	0.1	0.4
F-34	R53445	0.08	0.35	0.05	0.015	0.30	--	--	0.01-0.02	0.35-0.55	--	0.1-0.2	--	--	--	--	--	0.1	0.4
F-35	R56340	0.08	0.25	0.05	0.015	0.20-0.80	4.0-5.0	1.1-2.1	0.01-0.02	--	1.5-2.5	--	--	--	--	--	0.20-0.40	0.1	0.4
F-36	R58450	0.04	0.16	0.03	0.015	0.03	--	--	--	--	--	--	--	--	42.0-47.0	--	--	0.1	0.4
F-37	R52815	0.08	0.25	0.03	0.015	0.30	1.0-2.0	--	--	--	--	--	--	--	--	--	--	0.1	0.4
F-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 Final product hydrogen shall be reported. Ingot hydrogen need not be reported. Lower hydrogen may be obtained by negotiation with the manufacturer.

^B 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, niobium, zirconium, hafnium, bismuth, ruthenium, palladium, yttrium, copper, silicon, cobalt, tantalum, nickel, boron, manganese, and tungsten.

^C The purchaser may, in the written purchase order, request analysis for specific residual elements not listed in this specification.