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Standard Specification for Titanium and Titanium Alloy Forgings¹

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1. Scope

1.1 This specification² covers 31 grades of annealed titanium and titanium alloy forgings as follows:

- 1.1.1 *Grade F-1*—Unalloyed titanium,
- 1.1.2 *Grade F-2*—Unalloyed titanium,
- 1.1.3 *Grade F-3*—Unalloyed titanium,
- 1.1.4 *Grade F-4*—Unalloyed titanium,
- 1.1.5 *Grade F-5*—Titanium alloy (6 % aluminum, 4 % vanadium),
- 1.1.6 *Grade F-6*—Titanium alloy (5 % aluminum, 2.5 % tin),
- 1.1.7 *Grade F-7*—Unalloyed titanium plus 0.12 to 0.25 % palladium,
- 1.1.8 *Grade F-9*—Titanium alloy (3 % aluminum, 2.5 % vanadium),
- 1.1.9 *Grade F-11*—Unalloyed titanium plus 0.12 to 0.25 % palladium,
- 1.1.10 *Grade F-12*—Titanium alloy (0.3 % molybdenum, 0.8 % nickel),
- 1.1.11 *Grade F-13*—Titanium alloy (0.5 % nickel, 0.05 % ruthenium),
- 1.1.12 *Grade F-14*—Titanium alloy (0.5 % nickel, 0.05 % ruthenium),
- 1.1.13 *Grade F-15*—Titanium alloy (0.5 % nickel, 0.05 % ruthenium),
- 1.1.14 *Grade F-16*—Unalloyed titanium plus 0.04 % to 0.08 % palladium,
- 1.1.15 *Grade F-17*—Unalloyed titanium plus 0.04 % to 0.08 % palladium,
- 1.1.16 *Grade F-18*—Titanium alloy (3 % aluminum, 2.5 % vanadium) plus 0.04 % to 0.08 % palladium,
- 1.1.17 *Grade F-19*—Titanium alloy (3 % aluminum, 8 % vanadium, 6 % chromium, 4 % zirconium, 4 % molybdenum),
- 1.1.18 *Grade F-20*—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*—Titanium alloy (3 % aluminum, 2.7 % niobium, 15 % molybdenum, 0.25 % silicon),
- 1.1.20 *Grade F-23*—Titanium alloy (6 % aluminum, 4 % vanadium, extra low interstitials, ELI),
- 1.1.21 *Grade F-24*—Titanium alloy (6 % aluminum, 4 % vanadium) plus 0.04 % to 0.08 % palladium,
- 1.1.22 *Grade F-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 F-26*—Unalloyed titanium plus 0.08 to 0.14 % ruthenium,
- 1.1.24 *Grade F-27*—Unalloyed titanium plus 0.08 to 0.14 % ruthenium,
- 1.1.25 *Grade F-28*—Titanium alloy (3 % aluminum, 2.5 % vanadium plus 0.08–0.14% ruthenium),
- 1.1.26 *Grade F-29*—Titanium alloy (6% aluminum, 4% vanadium, extra low interstitial, ELI plus 0.08–0.14% ruthenium),
- 1.1.27 *Grade F-30*—Titanium alloy (0.3 % cobalt, 0.05 % palladium),
- 1.1.28 *Grade F-31*—Titanium alloy (0.3 % cobalt, 0.05 % palladium),
- 1.1.29 *Grade F-32*—Titanium alloy (5 % aluminum, 1 % vanadium, 1 % tin, 1 % zirconium, 0.8 % molybdenum),
- 1.1.30 *Grade F-33*—Titanium alloy (0.4% nickel, 0.015% palladium, 0.025% ruthenium, 0.15% chromium), and
- 1.1.31 *Grade F-34*—Titanium alloy (0.4% nickel, 0.015% palladium, 0.025% ruthenium, 0.15% chromium).

1.2 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

2. Referenced Documents

2.1 *ASTM Standards:*

- B 348 Specification for Titanium and Titanium Alloy Bars and Billets³
- E 8 Test Methods for Tension Testing of Metallic Materials⁴
- E 29 Practice for Using Significant Digits in Test Data to

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

³ *Annual Book of ASTM Standards*, Vol 02.04.

⁴ *Annual Book of ASTM Standards*, Vol 03.01.



Determine Conformance with Specifications⁵

E 120 Test Methods for Chemical Analysis of Titanium and Titanium Alloys⁶

E 1409 Test Method for the Determination of Oxygen in Titanium and Titanium Alloys by the Inert Gas Fusion Technique⁷

E 1447 Test Method for the Determination of Hydrogen in Titanium and Titanium Alloys by the Inert Gas Fusion Thermal Conductivity Method⁷

3. Terminology

3.1 Definitions of Terms Specific to This Standard:

⁵ Annual Book of ASTM Standards, Vol 14.02.

⁶ Annual Book of ASTM Standards, Vol 03.05.

⁷ Annual Book of ASTM Standards, Vol 03.06.

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 9),

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)	25	(170)	24	30
F-2	50	(345)	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-9	120	(828)	110	(759)	10	25
F-9 ^B	90	(620)	70	(483)	15	25
F-11	35	(240)	25	(170)	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-17	35	(240)	25	(170)	24	30
F-18	90	(620)	70	(483)	15	25
F-18 ^B	90	(620)	70	(483)	12	20
F-19 ^C	115	(793)	110	(759)	15	25
F-19 ^D	135	(930)	130 to 159	(897) to (1096)	10	20
F-19 ^E	165	(1138)	160 to 185	(1104) to (1276)	5	20
F-20 ^C	115	(793)	110	(759)	15	25
F-20 ^D	135	(930)	130 to 159	(897) to (1096)	10	20
F-20 ^E	165	(1138)	160 to 185	(1104) to (1276)	5	20
F-21 ^C	115	(793)	110	(759)	15	35
F-21 ^D	140	(966)	130 to 159	(897) to (1096)	10	30
F-21 ^E	170	(1172)	160 to 185	(1104) to (1276)	8	20
F-23	120	(828)	110	(759)	10	25
F-23 ^B	120	(828)	110	(759)	7.5, ^F 6.0 ^G	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-27	35	(240)	25	(170)	24	30
F-28	90	(620)	70	(483)	15	25
F-28 ^B	90	(620)	70	(483)	12	20
F-29	120	(828)	110	(759)	10	25
F-29 ^B	120	(828)	110	(759)	7.5, ^F 6.0 ^G	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

^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 Properties for material in transformed-beta condition.

^C Properties for material in the solution treated condition.

^D Properties for solution treated and aged condition-Moderate strength (determined by aging temperature).

^E Properties for solution treated and aged condition-High Strength (determined by aging temperature).

^F For product section or wall thickness values <1.0 in.

^G For product section or wall thickness values ≤1.0 in.



- 4.1.4 Sampling, mechanical properties (Section 7),
- 4.1.5 Methods for chemical analysis (Section 6),
- 4.1.6 Marking (Section 16),
- 4.1.7 Packaging (Section 16),
- 4.1.8 Certification (Section 15),
- 4.1.9 Disposition of rejected material (Section 13), and
- 4.1.10 Supplementary requirements (S1).

5. Materials and Manufacture

5.1 Material conforming to the latest revision of Specification B 348 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 2 Chemical Requirements^A

Element	Composition, %									
	F-1	F-2	F-3	F-4	F-5	F-6	F-7	F-9	F-11	F-12
Nitrogen, max	0.03	0.03	0.05	0.05	0.05	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
Hydrogen, ^{B,C} max	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
Oxygen, max	0.18	0.25	0.35	0.40	0.20	0.20	0.25	0.15	0.18	0.25
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	...	...	...	...	...	...	...	...	...	...
Palladium	...	...	...	...	...	...	0.12–0.25	...	0.12–0.25	...
Cobalt	...	...	...	...	...	...	...	...	...	...
Molybdenum	...	...	...	...	...	...	...	...	...	0.2–0.4
Chromium	...	...	...	...	...	...	...	...	...	...
Nickel	...	...	...	...	...	...	...	...	...	0.6–0.9
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
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
Titanium ^G	balance	balance	balance	balance	balance	balance	balance	balance	balance	balance

Element	Composition, %									
	F-13	F-14	F-15	F-16	F-17	F-18	F-19	F-20	F-21	F-23
Nitrogen, max	0.03	0.03	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	0.05	0.05	0.05	0.08
Hydrogen, ^{B,C} max	0.015	0.015	0.015	0.015	0.015	0.015	0.02	0.02	0.015	0.0125
Iron, max	0.20	0.30	0.30	0.30	0.20	0.25	0.30	0.30	0.40	0.25
Oxygen, max	0.10	0.15	0.25	0.25	0.18	0.15	0.12	0.12	0.17	0.13
Aluminum	...	...	...	...	...	2.5–3.5	3.0–4.0	3.0–4.0	2.5–3.5	5.5–6.5
Vanadium	...	...	...	...	...	2.0–3.0	7.5–8.5	7.5–8.5	...	3.5–4.5
Tin	...	...	...	...	...	...	...	...	...	...
Ruthenium	0.04–0.06	0.04–0.06	0.04–0.06	...	...	...	...	...	...	...
Palladium	...	...	...	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	0.04–0.06	0.04–0.06	0.04–0.06	...	...	...	...	...	...	...
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	0.1	0.15	0.15	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