

ASTM B381 / ASME SB381

Standard Specification for Titanium and Titanium Alloy Forgings

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

- Grade F-1—Unalloyed titanium,
- Grade F-2—Unalloyed titanium,
- Grade F-2H—Unalloyed titanium (Grade 2 with 58 ksi minimum UTS),
- Grade F-3—Unalloyed titanium,
- Grade F-4—Unalloyed titanium,
- Grade F-5—Titanium alloy (6 % aluminum, 4 % vanadium),
- Grade F-6—Titanium alloy (5 % aluminum, 2.5 % tin),
- Grade F-7—Unalloyed titanium plus 0.12 to 0.25 % palladium,
- Grade F-7H—Unalloyed titanium plus 0.12 to 0.25 % palladium (Grade 7 with 58 ksi minimum UTS),
- Grade F-9—Titanium alloy (3 % aluminum, 2.5 % vanadium),
- Grade F-11—Unalloyed titanium plus 0.12 to 0.25 % palladium,
- Grade F-12—Titanium alloy (0.3 % molybdenum, 0.8 % nickel),
- Grade F-13—Titanium alloy (0.5 % nickel, 0.05 % ruthenium),
- Grade F-14—Titanium alloy (0.5 % nickel, 0.05 % ruthenium),
- Grade F-15—Titanium alloy (0.5 % nickel, 0.05 % ruthenium),
- Grade F-16—Unalloyed titanium plus 0.04 to 0.08 % palladium,
- Grade F-16H—Unalloyed titanium plus 0.04 to 0.08 % palladium (Grade 16 with 58 ksi minimum UTS),
- Grade F-17—Unalloyed titanium plus 0.04 to 0.08 % palladium,
- Grade F-18—Titanium alloy (3 % aluminum, 2.5 % vanadium) plus 0.04 % to 0.08 % palladium,
- Grade F-19—Titanium alloy (3 % aluminum, 8 % vanadium, 6 % chromium, 4 % zirconium, 4 % molybdenum),
- Grade F-20—Titanium alloy (3 % aluminum, 8 % vanadium, 6 % chromium, 4 % zirconium, 4 % molybdenum) plus 0.04 to 0.08 % palladium,
- Grade F-21—Titanium alloy (3 % aluminum, 2.7 % niobium, 15 % molybdenum, 0.25 % silicon),
- Grade F-23—Titanium alloy (6 % aluminum, 4 % vanadium, extra low interstitials, ELI),
- Grade F-24—Titanium alloy (6 % aluminum, 4 % vanadium) plus 0.04 to 0.08 % palladium,
- Grade F-25—Titanium alloy (6 % aluminum, 4 % vanadium) plus 0.3 to 0.8 % nickel and 0.04 to 0.08 % palladium,
- Grade F-26—Unalloyed titanium plus 0.08 to 0.14 % ruthenium,
- Grade F-26H—Unalloyed titanium plus 0.08 to 0.14 % ruthenium (Grade 26 with 58 ksi minimum UTS),
- Grade F-27—Unalloyed titanium plus 0.08 to 0.14 % ruthenium,
- Grade F-28—Titanium alloy (3 % aluminum, 2.5 % vanadium plus 0.08 to 0.14 % ruthenium),

Grade F-29—Titanium alloy (6 % aluminum, 4 % vanadium, extra low interstitial, ELI plus 0.08 to 0.14 % ruthenium),
 Grade F-30—Titanium alloy (0.3 % cobalt, 0.05 % palladium),
 Grade F-31—Titanium alloy (0.3 % cobalt, 0.05 % palladium),
 Grade F-32—Titanium alloy (5 % aluminum, 1 % vanadium, 1 % tin, 1 % zirconium, 0.8 % molybdenum),
 Grade F-33—Titanium alloy (0.4 % nickel, 0.015 % palladium, 0.025 % ruthenium, 0.15 % chromium),
 Grade F-34—Titanium alloy (0.4 % nickel, 0.015 % palladium, 0.025 % ruthenium, 0.15 % chromium),
 Grade F-35—Titanium alloy (4.5 % aluminum, 2 % molybdenum, 1.6 % vanadium, 0.5 % iron, 0.3 % silicon),
 Grade F-36—Titanium alloy (45 % niobium),
 Grade F-37—Titanium alloy (1.5 % aluminum), and
 Grade F-38—Titanium alloy (4 % aluminum, 2.5 % vanadium, 1.5 % iron).

A. Chemical Composition :-

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.

Table 1
Composition, Weight Percent^{A,B,C,D,E}

Grade	C, max.	O ₂ max.	N, max.	H, max.	Fe max.	Al	V	Pd	Ru	Ni	Mo	Cr	Co	Zr	Cb	Sn	Si	Other Elements, max. each	Other Elements, max. total
F-1	0.08	0.18	0.03	0.015	0.2	--	--	--	--	--	--	--	--	--	--	--	--	0.1	0.4
F-2	0.08	0.25	0.03	0.015	0.3	--	--	--	--	--	--	--	--	--	--	--	--	0.1	0.4
F-2H	0.08	0.25	0.03	0.015	0.3	--	--	--	--	--	--	--	--	--	--	--	--	0.1	0.4
F-3	0.08	0.35	0.05	0.015	0.3	--	--	--	--	--	--	--	--	--	--	--	--	0.1	0.4
F-4	0.08	0.4	0.05	0.015	0.5	--	--	--	--	--	--	--	--	--	--	--	--	0.1	0.4
F-5	0.08	0.2	0.05	0.015	0.4	5.5-6.75	3.5-4.5	--	--	--	--	--	--	--	--	--	--	0.1	0.4
F-6	0.08	0.2	0.03	0.015	0.5	4.0-6.0	--	--	--	--	--	--	--	--	--	2.0-3.0	--	0.1	0.4
F-7	0.08	0.25	0.03	0.015	0.3	--	--	0.12-0.25	--	--	--	--	--	--	--	--	--	0.1	0.4
F-7H	0.08	0.25	0.03	0.015	0.3	--	--	0.12-0.25	--	--	--	--	--	--	--	--	--	0.1	0.4
F-9	0.08	0.15	0.03	0.015	0.25	2.5-3.5	2.0-3.0	--	--	--	--	--	--	--	--	--	--	0.1	0.4

F-29	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	0.08	0.25	0.03	0.015	0.3	--	--	0.04-0.08	--	--	--	--	0.20-0.80	--	--	--	--	0.1	0.4
F-31	0.08	0.35	0.05	0.015	0.3	--	--	0.04-0.08	--	--	--	--	0.20-0.80	--	--	--	--	0.1	0.4
F-32	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	0.08	0.25	0.03	0.015	0.3	--	--	0.01-0.02	0.02-0.04	0.35-0.55	--	0.1-0.2	--	--	--	--	--	0.1	0.4
F-34	0.08	0.35	0.05	0.015	0.3	--	--	0.01-0.02	0.02-0.04	0.35-0.55	--	0.1-0.2	--	--	--	--	--	0.1	0.4
F-35	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
F-36	0.04	0.16	0.03	0.015	0.03	--	--	--	--	--	--	--	--	--	42.0-47.0	--	--	0.1	0.4
F-37	0.08	0.25	0.03	0.015	0.3	1.0-2.0	--	--	--	--	--	--	--	--	--	--	--	0.1	0.4
F-38	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 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 residual elements not listed in this specification.

B. Mechanical Properties :-

1. Forgings supplied under this specification shall conform to the requirements as to mechanical properties specified in Table 2, as applicable.
2. Specimens for tension tests shall be machined and tested in accordance with Test Methods E8.
3. Tensile properties shall be determined using a strain rate of 0.003 to 0.007 in./in.·min through the specified yield strength.

Table 2^A

Grade	Tensile Strength, min ksi (MPa)	Yield Strength (0.2 % Offset), min or Range ksi (MPa)	Elongation in 4D, min, %	Reduction of Area, min, %
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 (1 935 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-1 6H, 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, 1 6, 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.

¹For product section or wall thickness values ≥ 1.0 in.

C. Non-destructive Tests :-

1. Non-destructive test requirements such as ultrasonic test, X ray, or surface inspection shall be specified by the purchaser, if required.

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