

ASTM B348 / ASME SB348

Standard Specification for Titanium and Titanium Alloy Bars and Billets

This specification covers annealed titanium and titanium alloy bars and billets as follows:

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

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

Grade	Composition, Weight Percent ^{A,B,C,D,E}																		
	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
1	0.08	0.18	0.03	0.015	0.2	--	--	--	--	--	--	--	--	--	--	--	--	0.1	0.4
2	0.08	0.25	0.03	0.015	0.3	--	--	--	--	--	--	--	--	--	--	--	--	0.1	0.4
2H	0.08	0.25	0.03	0.015	0.3	--	--	--	--	--	--	--	--	--	--	--	--	0.1	0.4
3	0.08	0.35	0.05	0.015	0.3	--	--	--	--	--	--	--	--	--	--	--	--	0.1	0.4
4	0.08	0.4	0.05	0.015	0.5	--	--	--	--	--	--	--	--	--	--	--	--	0.1	0.4
5	0.08	0.2	0.05	0.015	0.4	5.5- 6.75	3.5- 4.5	--	--	--	--	--	--	--	--	--	--	0.1	0.4
6	0.08	0.2	0.03	0.015	0.5	4.0- 6.0	--	--	--	--	--	--	--	--	--	2.0- 3.0	--	0.1	0.4
7	0.08	0.25	0.03	0.015	0.3	--	--	0.12- 0.25	--	--	--	--	--	--	--	--	--	0.1	0.4
7H	0.08	0.25	0.03	0.015	0.3	--	--	0.12- 0.25	--	--	--	--	--	--	--	--	--	0.1	0.4
9	0.08	0.15	0.03	0.015	0.25	2.5- 3.5	2.0- 3.0	--	--	--	--	--	--	--	--	--	--	0.1	0.4

11	0.08	0.18	0.03	0.015	0.2	--	--	0.12-0.25	--	--	--	--	--	--	--	--	--	0.1	0.4
12	0.08	0.25	0.03	0.015	0.3	--	--	--	--	0.6-0.9	0.2-0.4	--	--	--	--	--	--	0.1	0.4
13	0.08	0.1	0.03	0.015	0.2	--	--	--	0.04-0.06	0.4-0.6	--	--	--	--	--	--	--	0.1	0.4
14	0.08	0.15	0.03	0.015	0.3	--	--	--	0.04-0.06	0.4-0.6	--	--	--	--	--	--	--	0.1	0.4
15	0.08	0.25	0.05	0.015	0.3	--	--	--	0.04-0.06	0.4-0.6	--	--	--	--	--	--	--	0.1	0.4
16	0.08	0.25	0.03	0.015	0.3	--	--	0.04-0.08	--	--	--	--	--	--	--	--	--	0.1	0.4
16H	0.08	0.25	0.03	0.015	0.3	--	--	0.04-0.08	--	--	--	--	--	--	--	--	--	0.1	0.4
17	0.08	0.18	0.03	0.015	0.2	--	--	0.04-0.08	--	--	--	--	--	--	--	--	--	0.1	0.4
18	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
19	0.05	0.12	0.03	0.02	0.3	3.0-4.0	7.5-8.5	--	--	--	3.5-4.5	5.5-6.5	--	3.5-4.5	--	--	--	0.15	0.4
20	0.05	0.12	0.03	0.02	0.3	3.0-4.0	7.5-8.5	0.04-0.08	--	--	3.5-4.5	5.5-6.5	--	3.5-4.5	--	--	--	0.15	0.4
21	0.05	0.17	0.03	0.015	0.4	2.5-3.5	--	--	--	--	14.0-16.0	--	--	--	2.2-3.2	--	0.15-0.25	0.1	0.4
23	0.08	0.13	0.03	0.0125	0.25	5.5-6.5	3.5-4.5	--	--	--	--	--	--	--	--	--	--	0.1	0.4
24	0.08	0.2	0.05	0.015	0.4	5.5-6.75	3.5-4.5	0.04-0.08	--	--	--	--	--	--	--	--	--	0.1	0.4
25	0.08	0.2	0.05	0.015	0.4	5.5-6.75	3.5-4.5	0.04-0.08	--	0.3-0.8	--	--	--	--	--	--	--	0.1	0.4
26	0.08	0.25	0.03	0.015	0.3	--	--	--	0.08-0.14	--	--	--	--	--	--	--	--	0.1	0.4
26H	0.08	0.25	0.03	0.015	0.3	--	--	--	0.08-0.14	--	--	--	--	--	--	--	--	0.1	0.4
27	0.08	0.18	0.03	0.015	0.2	--	--	--	0.08-0.14	--	--	--	--	--	--	--	--	0.1	0.4
28	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

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
30	0.08	0.25	0.03	0.015	0.3	--	--	0.04-0.08	--	--	--	--	0.20-0.80	--	--	--	--	0.1	0.4
31	0.08	0.35	0.05	0.015	0.3	--	--	0.04-0.08	--	--	--	--	0.20-0.80	--	--	--	--	0.1	0.4
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
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
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
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
36	0.04	0.16	0.03	0.015	0.03	--	--	--	--	--	--	--	--	--	42.0-47.0	--	--	0.1	0.4
37	0.08	0.25	0.03	0.015	0.3	1.0-2.0	--	--	--	--	--	--	--	--	--	--	--	0.1	0.4
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 elements not listed in this specification.

B. Mechanical Properties :-

1. Material supplied under this specification shall conform to the mechanical property requirements given in Table 2, as applicable.
2. Tension testing specimens are to be machined and tested in accordance with Test Methods E8. 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

Grade	Tensile Strength, min		Yield Strength (0.2 % Offset) min or range		Elongation in 4D, min, %	Reduction of Area, min %
	ksi	MPa	ksi	MPa		
1	35	240	20	138	24	30
2	50	345	40	275	20	30
2H ^{B,C}	58	400	40	275	20	30
3	65	450	55	380	18	30
4	80	550	70	483	15	25
5	130	895	120	828	10	25
6	120	828	115	795	10	25
7	50	345	40	275	20	30
7H ^{B,C}	58	400	40	275	20	30
9	90	620	70	483	15	25
9 ^D	90	620	70	483	12	25
11	35	240	20	138	24	30
12	70	483	50	345	18	25
13	40	275	25	170	24	30
14	60	410	40	275	20	30
15	70	483	55	380	18	25
16	50	345	40	275	20	30
16H ^{B,C}	58	400	40	275	20	30
17	35	240	20	138	24	30
18	90	620	70	483	15	25
18 ^D	90	620	70	483	12	20
19 ^E	115	793	110	759	15	25
19 ^F	135	930	130 to 159	897 to 1096	10	20
19 ^G	165	1138	160 to 185	1104 to 1276	5	20
20 ^E	115	793	110	759	15	25
20 ^F	135	930	130 to 159	897 to 1096	10	20
20 ^G	165	1138	160 to 185	1104 to 1276	5	20
21 ^E	115	793	110	759	15	35

21 ^F	140	966	130 to 159	897 to 1096	10	30
21 ^G	170	1172	160 to 185	1104 to 1276	8	20
23	120	828	110	759	10	15
23 ^D	120	828	110	759	7.5 ^H , 6.0 ^I	25
24	130	895	120	828	10	25
25	130	895	120	828	10	25
26	50	345	40	275	20	30
26H ^{B,C}	58	400	40	275	20	30
27	35	240	20	138	24	30
28	90	620	70	483	15	25
28 ^D	90	620	70	483	12	20
29	120	828	110	759	10	25
29 ^D	120	828	110	759	7.5 ^H , 6.0 ^I	15
30	50	345	40	275	20	30
31	65	450	55	380	18	30
32	100	689	85	586	10	25
33	50	345	40	275	20	30
34	65	450	55	380	18	30
35	130	895	120	828	5	20
36	65	450	60 to 95	410 to 655	10	...
37	50	345	31	215	20	30
38	130	895	115	794	10	25

^A These properties apply to longitudinal sections up to 3 in. (76 mm) in thickness with a maximum of 1 0 in.2 (64.5 cm2). Mechanical properties of larger sections shall be negotiated between the manufacturer and purchaser.

^B 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, 1 6H, and 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 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 $\geq 1 .0$ in.

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