

ASTM B265 / ASME SB265

Standard Specification for Titanium and Titanium Alloy Strip, Sheet, and Plate

This specification covers annealed titanium and titanium alloy strip, sheet, and plate 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 (3.0 % 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 % to 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 to 0.14 % ruthenium,

Grade 29—Titanium alloy (6 % aluminum, 4 % vanadium with extra low interstitial elements, 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 :-

1. The grades of titanium and titanium alloy metal covered by this specification shall conform to the chemical composition requirements 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.	--	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.	--	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	5	--	--	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 for the grade specified.
2. Tension test:
 - i. Tension testing specimens are to be machined and tested in accordance with Test Methods E8.
 - ii. 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.
3. Bend test:
 - i. For sheet and strip, the bend test specimen shall withstand being bent cold through an angle of 105° without fracture in the outside of the bent portion.
 - ii. The width of the bend shall be at least 5 times the thickness.
 - iii. The bend shall be made on a radius equal to that shown in Table 1 for the applicable grade. The bends are to be made in accordance with Test Method E290, using Method 1, Guided Bend Test described in paragraph 3.6.

Table 2

Grade	Tensile Strength, min		Yield Strength, 0.2 % Offset				Elongation in 2 in. or 50 mm, min, %	Bend Test (Radius of Mandrel) ^B	
			min		max			Under 0.070 in. (1.8 mm) in Thickness	0.070 to 0.187 in. (1.8– 4.75 mm) in Thickness
	ksi	MPa	ksi	MPa	ksi	MPa			
1	35	240	20	138	45	310	24	1.5T	2T
2	50	345	40	275	65	450	20	2T	2.5T
2H ^{C,D}	58	400	40	275	65	450	20	2T	2T
3	65	450	55	380	80	550	18	2T	2.5T

4	80	550	70	483	95	655	15	2.5T	3T
5	130	895	120	828	...	...	10 ^E	4.5T	5T
6	120	828	115	793	...	...	10 ^E	4T	4.5T
7	50	345	40	275	65	450	20	2T	2.5T
7H ^{C,D}	58	400	40	275	65	450	20	2T	2T
9	90	620	70	483	...	...	15 ^F	2.5T	3T
11	35	240	20	138	45	310	24	1.5T	2T
12	70	483	50	345	...	...	18	2T	2.5T
13	40	275	25	170	...	...	24	1.5T	2T
14	60	410	40	275	...	...	20	2T	2.5T
15	70	483	55	380	...	...	18	2T	2.5T
16	50	345	40	275	65	450	20	2T	2.5T
16H ^{C,D}	58	400	40	275	65	450	20	2T	2T
17	35	240	20	138	45	310	24	1.5T	2T
18	90	620	70	483	...	...	15 ^F	2.5T	3T
19 ^{G,H}	115	793	110	759	...	...	15	3T	3T
20 ^{G,H}	115	793	110	759	...	...	15	3T	3T
21 ^{G,H}	115	793	110	759	...	...	15	3T	3T
23	120	828	110	759	...	...	10	4.5T	5T
24	130	895	120	828	...	...	10	4.5T	5T
25	130	895	120	828	...	...	10	4.5T	5T
26	50	345	40	275	65	450	20	2T	2.5T
26H ^{C,D}	58	400	40	275	65	450	20	2T	4T
27	35	240	20	138	45	310	24	1.5T	2T
28	90	620	70	483	...	...	15	2.5T	3T
29	120	828	110	759	...	...	10	4.5T	5T
30	50	345	40	275	65	450	20	2T	2.5T
31	65	450	55	380	80	550	18	2T	2.5T
32	100	689	85	586	...	...	10 ^E	3.5T	4.5T
33	50	345	40	275	65	450	20	2T	2.5T

34	65	450	55	380	80	550	18	2T	2.5T
35	130	895	120	828	...	...	5	8T	8T
36	65	450	60	410	95	655	10	4.5T	5T
37	50	345	31	215	65	450	20	2T	2.5T
38	130	895	115	794	...	...	10	4T	4.5T

^A 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.

^B Bend to Radius of Mandrel, 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.

^C 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, 16H, and 26H are intended primarily for pressure vessel use.

^D 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.

^E 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.

^F 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.

^G Properties for material in the solution treated condition.

^H Material is normally purchased in the solution treated condition. Therefore, properties for aged material shall be negotiated between manufacturer and purchaser.

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