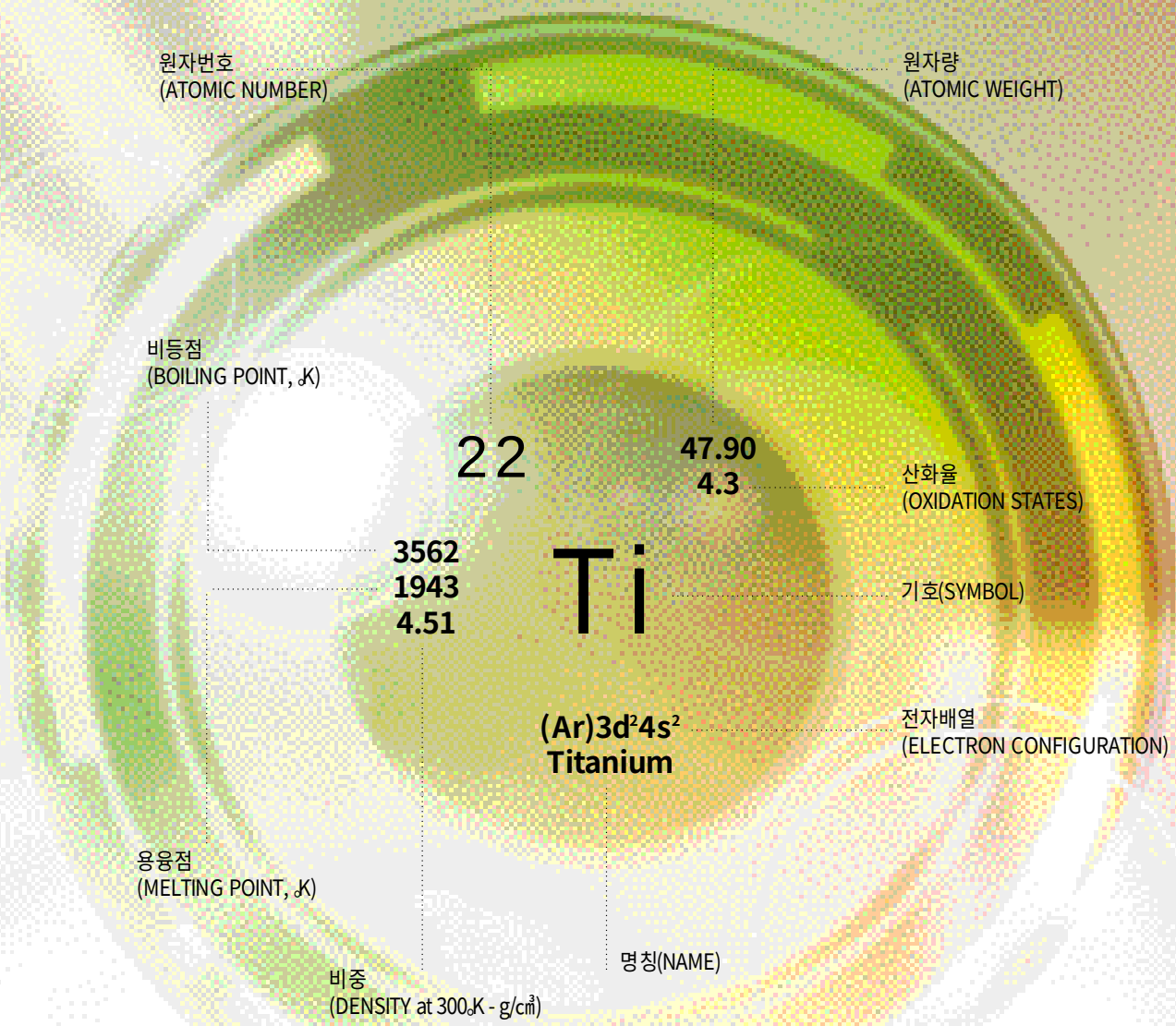
TITANIUM 티타늄



Atomic number	22
Atomic weight	47.90
Atomic volume	10.6 W/D
Boiling point	3260 °C (5900°F)
Coefficient of friction	0.8 at 40 m/min(125 ft/min)
	0.68 at 300 m/min (1000 ft/min)
Coefficient of thermal expansion	8.64 × 10⁻⁶/°C
Color	Dark grey
Covalent Radius	1.32 Å
Density	4.51 g/㎤(0.163 lb/in³)
Electrical conductivity	3% IACS(copper 100%)
Electrical resistivity	47.8 μohm - cm
Electronegativity	1.5 Pauling's
First ionization energy	158k - cal/g - mole
Hardness	HRB 70 to 74
Heat of fusion	440 kJ/kg (eat.)
Heat of vaporization	9.83 MJ/ kg
Machinability rating	40
Magnetic susceptibility	1.25×10⁻⁶ 3.17 emu/g
Melting point	1668°C ± 10°C (3035°F ± 18°F)
Modulus of elasticity	14.9×10⁻⁶psi
Poisson's ratio	0.41
Solidus/llquidus	1275°C (3137°F)
Specific gravity	4.5
Specific heat (at 25°C)	0.518 J/kg K (0.124 BTU/lb °F)
Specific resistance	554 μohm - cm
Tensile strength	35 ksi min
Thermal conductivity	9.0 BTU/hr ft°F
Thermal neutron absorption cross section	
	5.6 barnes/atom
Tensile strength	35 ksi min
Young's modulus of elasticity	116×10⁶ N/m²
	16.8×10⁶ lb f/in.²
	102.7 Gpa

TECHNICAL DATA 기술자료

Titanium Standard (ASTM 기준)

CHEMICAL COMPOSITION AND MECHANICAL PROPERTIES ACCORDING TO ASTM STANDARDS							
DESIGNATION	GRADE 1	GRADE 2	GRADE 3	GRADE 4	GRADE 5	GRADE 7	GRADE 11
COMPOSITION (%MAX) 화학성분							
Oxygen (O)	0.18	0.25	0.35	0.40	0.20	0.25	0.18
Nitrogen (N)	0.03	0.03	0.05	0.05	0.05	0.03	0.03
Hydrogen (H)	0.015	0.015	0.015	0.015	0.015	0.015	0.015
Carbon (C)	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Iron (Fe)	0.20	0.30	0.30	0.50	0.40	0.30	0.20
Aluminium (Al)	-	-	-	-	5.5 - 6.75	-	-
Vanadium (V)	-	-	-	-	3.5 - 4.5	-	-
Palladium (Pd)	-	-	-	-	-	0.12 - 0.25	0.12 - 0.25
Residual each (total)	0.10(0.4)	0.10(0.4)	0.10(0.4)	0.10(0.4)	0.10(0.4)	0.10(0.4)	0.10(0.4)
MECHANICAL PROPERTIES 기계적성질							
Tensile Strength Mpa min.	240	345	450	550	895	345	240
인장강도(Ksi)	(35)	(50)	(65)	(80)	(130)	(50)	(35)
Yield Strength Mpa	170 - 310	275 - 450	380 - 550	483 - 655	830	275 - 450	170 - 310
항복강도(Ksi)	(25 - 45)	(40 - 65)	(55 - 80)	(70 - 95)	(120)	(40 - 65)	(25 - 45)
Elongation % min.(연신율)	24	20	18	15	10	20	24
Hardness HVtypical (경도)	100 - 150	160 - 200	180 - 220	200 - 280	310 - 350	160 - 200	100 - 150

타금속과의물리적성질비교

소재 MATERIAL	원자번호 Atomic Number	원자량 Atomic Weight	비중 Density (g/cm^3)	용유점 Melting Point (°C)	열팽창계수 Thermal expansion coefficient (/°C)	비열 Specific heat (cal/gr/°C)	열전도율 Thermal conductivity (cal/cm/sec/°C/cm) number	전기비저항 Electrical resistivity (μ Ω – cm)	전기전도율 Electrical conductivity (%IACS)	영율 Young 's conductivity (MPa)	포아손비 Poisson 's ratio
Titanium	22	47.90	4.51	1,668	8.4×10^{-6}	0.124	0.041	55	3.1	106,000	0.34
Ti - 6AI - 4V	-	-	4.4	1,650	8.6×10^{-6}	0.138	0.020	175	0.98	110,000	0.34
Iron	26	55.85	7.86	1,530	12×10^{-6}	0.11	0.15	9.7	18	206,000	0.31
Stainless steel 18 - 8 (AISI 304)	-	-	7.93	from 1,400 to 1,420	17×10^{-6}	0.12	0.039	72	2.4	200,000	0.30
Aluminium	13	26.97	2.7	660	23×10^{-6}	0.21	0.49	2.7	64	69,000	0.33
Aluminium alloy (755 - T6)	-	-	28	from 476 to 638	23×10^{-6}	0.23	0.29	5.8	30	71,600	0.33
Magnesium	12	24.32	1.74	650	25×10^{-6}	0.24	0.38	4.3	40	44,800	0.35
Nickel	28	58.69	8.9	1,456	15×10^{-6}	0.11	0.22	9.5	18	206,000	0.30
Hastelloy®c	-	-	8.9	1,305	11.3×10^{-6}	0.092	0.03	130	1.3	204,600	-
Copper	29	63.57	8.94	1,083	17×10^{-6}	0.092	0.962	1.724	100	108,000	0.34
Zirconium	40	91.22	6.52	1,852	5.8×10^{-6}	0.07	0.040	40.54	3.1	9,110	0.33

Titanium & Titanium Alloys Specifications

AMERICAN CROSS REFERENCED SPECIFICATIONS - TITANIUM & TITANIUM ALLOYS

UNS	SAE/AMS	MILITARY	ASTM	ASME	AWS	BS1	DIN
R50100				SFA - 5.16(ERTi - 1)	A5.16(ERTi - 1)		
R50120				SFA - 5.16(ERTi - 2)	A5.16(ERTi - 2)		
R50125	4951			SFA - 5.16(ERTi - 3)	A5.16(ERTi - 3)		
R50130				SFA - 5.16(ERTi - 4)	A5.16(ERTi - 4)		
R50250		T - 81556	B 265 grade 1	SB - 265 grade 1		TA1	3.7025
		T - 81915	B 337 grade 1	SB - 337 grade 1			
			B 338 grade 1	SB - 338 grade 1			
			B 348 grade 1	SB - 348 grade 1			
			B 381 grade F - 1	SB - 381 grade F - 1			
			F 67 grade 1				
			F 467 alloy Ti 1				
			F 468 alloy Ti 1				
R50400	4902	T - 9046	B 265 grade 2	SB - 265 grade 2		TA2,3,4,5	3.7035
	4941	T - 81556	B 337 grade 2	SB - 337 grade 2			
	4942		B 338 grade 2	SB - 338 grade 2			
			B 348 grade 2	SB - 348 grade 2			
			B 367 grade C - 2	SB - 381 grade F - 2			
			B 381 grade F - 2				
			F 67 grade 2				
			F 467 alloy Ti 2				
			F 468 alloy Ti 2				
R50550	4900	T - 9046	B 265 grade 3				3.7055
		T - 81556	B 337 grade 3				
R50550			B 338 grade 3				
			B 348 grade 3				
			B 367 grade C - 3				
			B 381 grade F - 3				
			F 67 grade 3				
R50700	4901	T - 9046	B 265 grade 4			TA 6,7,8,9	3.7065
		T - 9047	B 348 grade 4				
		F - 83142	B 381 grade F - 4				
			F 67 grade 4				
			F 467 alloy Ti 4				
			F 468 alloy Ti 4				
R52250			B 265 grade 11	SB - 265 grade 11			
			B 337 grade 11				
			B 338 grade 11				
			B 348 grade 11				
			B 381 grade F - 11				
R52400			B 265 grade 7	SB - 265 grade 7			
			B 337 grade 7	SB - 337 grade 7			
			B 338 grade 7	SB - 338 grade 7			
			B 348 grade 7	SB - 348 grade 7			
			B 381 grade F - 7	SB - 381 grade F - 7			
R52401			B 265 grade 7,11	SFA - 5.16(ERTi - 7)	A5.16(ERTi - 7)		
			B 337 grade 7,11				
			B 338 grade 7,11				
			B 348 grade 7,11				
			B 367 grade Ti - Pd7B				
			B 367 grade Ti - Pd8A				
			B 381 grade 7,11				
R52550			B 367 grade C - 2				
			B 367 grade C - 3				
R52700							

UNS	SAE/AMS	MILTARY	ASTM	ASME	AWS	BS1	DIN
R53400			B 265 grade 12	SB - 265 grade 12			
			B 337 grade 12	SB - 337 grade 12			
			B 338 grade 12	SB - 338 grade 12			
			B 348 grade 12	SB - 348 grade 12			
			B 381 grade F - 12	SB - 381 grade F - 12			
R53401			B 265 grade 12	SFA - 5.16(ERTi - 12)	A5.16(ERTi - 12)		
			B 337 grade 12				
			B 338 grade 12				
			B 348 grade 12				
			B 381 grade 12				
R54520	4910	T - 9046	B 265 grade 6				
	4926	T - 9047	B 348 grade 6				
	4966	T - 81556	B 367 grade C - 6				
		T - 81915	B 381 grade F - 6				
R54520		F - 83142					
R54521	4909	T - 9046					
	4924	T - 9047					
		T - 81556					
		F - 83142					
R54522	4953			SFA - 5.16(ERTi - 6)	A5.16(ERTi - 6)		
R54523				SFA - 5.16(ERTi - 6ELI)	A5.16(ERTi - 6ELI)		
R54550		F - 83142					
R54560		T - 9046					
		T - 9047					
R54620	4919	T - 9046					
	4952	T - 9047					
	4975	T - 81915					
	4976	T - 83142					
R54621							
R54624			B 265				
			B 337				
			B 338				
R54790	4974	T - 9047					
		F - 83142					
R54810	4915	T - 9046					
	4916	T - 9047					
	4933	T - 81556					
	4955	F - 83142					
R56080	4908	T - 9046					
R56210		T - 9046		SFA - 5.16(ERTi - 15)	A5.16(ERTi - 15)		
		T - 9047					
R56260	4981	T - 9047					
R56320	4943	T - 9046	B 265 grade 9	SFA - 5.16(ERTi - 9)	A5.16(ERTi - 9)		
	4944	T - 9047	B 337 grade 9				
			B 338 grade 9				
			B 348 grade 9				
			B 381 grade F - 9				
R56321				SFA - 5.16(ERTi - 9ELI)	A5.16(ERTi - 9ELI)		
R56400	4905	T - 9046	B 265 grade 5	SFA - 5.16(ERTi - 5)	A - 5.16(ERTi - 5)	TA 10,11,12	3.7165
	4906	T - 9047	B 348 grade 5			TA 28,56,59	
	4911	T - 81556	B 367 grade C - 5				
	4931	T - 81915	B 381 grade F - 5				
	4934	F - 83142					
	4935						
	4954						
	4965						
	4967						

MECHANICAL PROPERTIES OF WROUGHT TITANIUM & TITANIUM ALLOYS

ASTM Standard		Tensile Strength		Yield Strength			
B 348 Grade	B 381 Grade	ksi	MPa	ksi	MPa	% EI	% R[a]
1	F - 1	35	240	25	170	24	30
2	F - 2	50	345	40	275	20	30
3	F - 3	65	450	55	380	18	30
4	F - 4	80	550	70	483	15	25
5	F - 5	130	895	120	825	10	25
6	F - 6	120	825	115	795	10	25
7	F - 7	50	345	40	275	20	30
9	F - 9	90	620	70	483	15	25
11	F - 11	35	240	25	170	24	30
12	F - 12	70	483	50	345	18	25
13	F - 13	40	275	25	170	24	30
14	F - 14	60	410	40	275	20	30
15	F - 15	70	483	55	380	18	25
16	F - 16	50	345	40	275	20	30
17	F - 17	35	240	25	170	24	30
18	F - 18	90	620	70	483	15	25

a. Single values are minimum

MECHANICAL PROPERTIES OF CAST TITANIUM & TITANIUM ALLOYS

Casting Standard			Tensile Strength		Yield Strength			Hardness	
ASTM B 367	AMS 4985	AMS 4991	ksi	MPa	ksi	MPa	% EI	Rockwell max	HB max
C - 2	-	-	50	345	40	275	15	96 HRB[b]	210[b]
C - 3	-	-	65	450	55	380	12	24 HRC[b]	235[b]
C - 5	-	-	130	895	120	825	6	39 HRC[b]	365[b]
C - 6	-	-	115	795	105	725	8	36 HRC[b]	335[b]
Ti - Pd 7B	-	-	50	345	40	275	15	96 HRC[b]	210[b]
Ti - Pd 8A	-	-	65	450	55	380	12	24 HRC[b]	235[b]
-	6Al - 4V[c]	-	130	895	120	825	6	39 HRC	-
-	6Al - 4V[d]	-	130	895	120	825	6	39 HRC	-
-	6Al - 4V[c]	-	125	860	108	745	4.5	39 HRC	-
-	-	6Al - 4V[d]	130	895	120	825	6	39 HRC、	-
-	-	6Al - 4V[e]	127	875	110	760	4.5	39 HRC、	-
-	-	6Al - 4V[c]	130	895	120	825	6	39 HRC、	-

a. Single values are minimum unless otherwise noted.
b. Supplementary requirement applied only when specified by the purchaser. Values are averages of three of three teets. See ASTM B 367 for more details.
c. Separately - cast specimens or specimens cut from attached coupons
d. Specimens cut from casting - designated areas.
e. Specimens cut from casting - non - designated areas.
f. Casting shall not be rejected on the basis of hardness if tensile property requirements of AMS 4991 are met.

MECHANICAL PROPERTIES OF SURGICAL IMPLANT TITANIUM & TITANIUM ALLOYS

ASTM Standard			Tensile Strength		Yield Strength				Bend Test[e]	
F 67	F 136	F 620	ksi	MPa	ksi	MPa	% EI	% RA	Under 0.070 in. in thickness	0.070 to 0.187 in. in thickness
Grade 1	-	-	35	240	25 - 45	170 - 310	24	-	3T	4T
Grade 2	-	-	50	345	40 - 65	275 - 450	20	-	4T	5T
Grade 3	-	-	65	450	55 - 80	380 - 550	18	-	4T	5T
Grade 4	-	-	80	550	70 - 95	483 - 635	15	-	5T	6T
-	6Al - 4V	-	120[b]	825	110[c]	760[c]	8	15 - 20	9T	10T
-	6Al - 4V	-	125[b]	860	115[b]	795[b]	10	25	9T	10T
-	-	6Al - 4V	-	-	-	-	-	-	-	-

a. Single values are minimum unless otherwise noted.
b. Applies to under 1.75 in. (44.45㎜) thickness or diameter.
c. Applies to 1.75 in. (44.45㎜) to 4.0 in. (101.60㎜) inclusive.
d. When specified by the implant manufacturer, the mechanical properties shall be tested and confirmed by the forger, upon completion of forgings, to comply with the minimum mechanical properties as specified by the implant manufacturer. See ASTM F 620 for more details.
e. T equals the thickness of the bend test specimen.

ASTM SPECIFICATIONS - TITANIUM & TITANIUM ALLOYS

ASTM	TITLE
B 265	Standard Specification for Titanium and Titanium Alloy Strip, Sheet, and Plate
B 299	Standard Specification for Titanium Sponge
B 337	Standard Specification for Seamless and Welded Titanium and Titanium Alloy Pipe
B 338	Standard Specification for Seamless and Welded Titanium and Titanium Alloy Tubes for Condensers and Heat Exchangers
B 348	Standard Specification for Titanium and Titanium Alloy Bars and Billets
B 363	Standard Specification for Seamless and Welded Unalloyed Titanium and Titanium Alloy Welding Fittings
B 367	Standard Specification for Titanium and Titanium Alloy Castings
B 381	Standard Specification for Titanium and Titanium Alloy Forgings
B 481	Standard Practice for Preparation of Titanium and Titanium Alloys for Electroplating
B 600	Standard Guide for Descaling and Cleaning Titanium and Titanium Alloy Surfaces
B 817	Standard Specification for Powder Metallurgy (PM) Titanium Alloy Structural Components
B 801	Standard Specification for Titanium and Titanium Alloy Seamless Pipe
B 862	Standard Specification for Titanium and Titanium Alloy Welded Pipe
B 863	Standard Specification for Titanium and Titanium Alloy Wire

ASTM TESTING STANDARDS - TITANIUM & TITANIUM ALLOYS

ASTM	TITLE
E 120	Standard Test Methods for Chemical Analysis of Titanium and Titanium Alloys
E 539	Standard Test Method for X - Ray Emission Spectrometric Analysis of 6AI - 4V Titanium Alloy
E 1320	Standard Reference Radiographs for Titanium Castings
E 1409	Standard Test Methods for Determination of Oxygen in Titanium and Titanium Alloys by the Inert Gas Fusion Technique
E 1447	Standard Test Method for Determination of Hydrogen in Titanium Alloys by the Inert Gas Fusion Thermal Conductivity Method
F 945	Standard Test Method for Stress - Corrosion of Titanium Alloys by Aircraft Engine Cleaning Materials
G 41	Standard Practice for Determining Cracking Susceptibility of Metals Exposed Under Stress to a Hot Salt Environment

SURGICAL IMPLANT INTERNATIONAL SPECIFICATIONS - TITANIUM & TITANIUM ALLOYS

Standard	TITLE
ASTM F 67	Standard Specification for Unalloyed Titanium for Surgical Implant Applications
ASTM F 136	Standard Specification for Wrought Titanium 6AI - 4V ELI Alloy for Surgical Implant Applications
ASTM F 620	Standard Specification for Titanium 6AI - 4V ELI Alloy Forgings for Surgical Implants
ASTM F 1295	Standard Specification for Wrought Titanium - 6 Aluminium - 7 Niobium Alloy for Surgical Implant Applications
AS 2320.2	Metals for the Manufacture of Surgical Implants - Part 2: Unalloyed Titanium
AS 2320.3	Metals for the Manufacture of Surgical Implants - Part 3: Wrought Titanium 6 - Aluminium 4 - Vanadium Alloy
CAN3 - Z310.1 - 78	Titanium Alloy (6% Aluminium and 4% Vanadium) for Surgical Implants
CAN/CSA - Z310.7	Orthopaedic Implants Standards
BS 7252: Part 2	Metallic Materials for Surgical Implants Part 2: Unalloyed Titanium
BS 7252: Part 3	Metallic Materials for Surgical Implants Part 3: Wrought Titanium 6 - Aluminium 4 - Vanadium Alloy
BS 7254: Section 6.2	Orthopaedic Implants Part 6: Forgings Section 6.2: Method for Specifying
DIN 5832 Part 2	Implants for Surgery - Metalic Materials - Part 2: Unalloyed Titanium
DIN 5832 Part 3	Implants for Surgery - Metalic Materials - Part 3: Wrought Titanium 6 - Aluminium 4 - Vanadium Alloy

ASME SPECIFICATIONS - TITANIUM & TITANIUM ALLOYS

ASTM	TITLE
SB - 265	Specification for Titanium and Titanium Alloy Strip, Sheet, and Plate
SB - 337	Specification for Seamless and Welded Titanium and Titanium Alloy Pipe
SB - 338	Specification for Seamless and Welded Titanium and Titanium Alloy Tubes for Condensers and Heat Exchangers
SB - 348	Specification for Titanium and Titanium Alloy Bars and Billets
SB - 363	Specification for Seamless and Welded Unalloyed Titanium and Titanium Alloy Welding Fittings
SB - 367	Specification for Titanium and Titanium Alloy Castings
SB - 381	Specification for Titanium and Titanium Alloy Forgings

AWS SPECIFICATIONS - TITANIUM & TITANIUM ALLOYS

AWS	TITLE
A5.16	Specification for Titanium and Titanium Alloy Welding Electrodes and Rods
D10.6	Recommended Practices for Gas Tungsten Arc Welding of Titanium Pipe and Tubing

JAPANESE JIS SPECIFICATIONS

JIS	TITLE
G 3603	Titanium Clad Steels
H 0511	Testing Methods for Brinell Hardness of Titanium Sponge
H 4605	Titanium - Palladium Alloy Sheet, Plates and Strips
H 4607	Sheets and Plates of Titanium Alloys
H 4630	Titanium Pipes and Tubes for Ordinary Piping
H 4631	Titanium Tubes for Hest Exchangers
H 4635	Titanium - Palladium Alloy Pipes and Tubes for Ordinary Piping
H 4636	Titanium - Palladium Alloy Pipes and Tubes for Heat Exchangers
H 4650	Titanium Rods and Bars
H 4655	Titanium - Palladium Alloy Rods and Bars
H 4657	Rods, Bars and Forgings of Titanium Alloys
H 4670	Titanium Wires
H 4675	Titanium - Palladium Alloy Wires
H 7001	Glossary of Terms used in Shape Memory Alloys
H 7101	Methods for Determining the Transformation Temperatures of Shape Memory Alloys
H 7103	Methods of Fixed Temperature Tensile Test for Wires of Ti - Ni Shape Memory Alloys
Z 3107	Methods of Radiographic Test and Classification of Radiographs for Titanium welds
Z 3331	Titanium and Titanium Alloy Rods Wires for Inert Gas Shielded Arc Welding

Temperature Conversion Tables

To °C	To °F	To °C	To °F	To °C	To °F	To °C	To °F	To °C	To °F	To °C	To °F	To °C	To °F	To °C	To °F
-17.8	0 32.0	10.0	50 122.0	38	100 212	260	500 932	538	1000 1832	816	1500 2732	1093	2000 3632	1371	2500 4532
-17.2	1 33.8	10.6	51 123.8	43	110 230	266	510 950	543	1010 1850	821	1510 2750	1099	2010 3650	1377	2510 4550
-16.7	2 35.6	11.1	52 125.6	49	120 248	271	520 968	549	1020 1868	827	1520 2768	1104	2020 3668	1382	2520 4568
-16.1	3 37.4	11.7	53 127.4	54	130 266	277	530 986	554	1030 1886	832	1530 2786	1110	2030 3686	1388	2530 4586
-15.6	4 39.2	12.2	54 129.2	60	140 284	282	540 1004	560	1040 1904	838	1540 2804	1116	2040 3704	1393	2540 4604
-15.0	5 41.0	12.8	55 131.0	66	150 302	288	550 1022	566	1050 1922	843	1550 2822	1121	2050 3722	1399	2550 4622
-14.4	6 42.8	13.3	56 132.8	71	160 320	293	560 1040	571	1060 1940	849	1560 2840	1127	2060 3740	1404	2560 4640
-13.9	7 44.6	13.9	57 134.6	77	170 338	299	570 1058	577	1070 1958	854	1570 2858	1132	2070 3758	1410	2570 4658
-13.3	8 46.4	14.4	58 136.4	82	180 356	304	580 1076	582	1080 1976	860	1580 2876	1138	2080 3776	1416	2580 4676
-12.8	9 48.2	15.0	59 138.2	88	190 374	310	590 1094	588	1090 1994	866	1590 2894	1143	2090 3794	1421	2590 4694
-12.2	10 50.0	15.6	60 140.0	93	200 392	316	600 1112	593	1100 2012	871	1600 2912	1149	2100 3812	1427	2600 4712
-11.7	11 51.8	16.1	61 141.8	99	210 410	321	610 1130	599	1110 2030	877	1610 2930	1154	2110 3830	1432	2610 1730
-11.1	12 53.6	16.7	62 143.6	100	212 413	327	620 1148	604	1120 2048	882	1620 2948	1160	2120 3848	1438	2620 4748
-10.6	13 55.4	17.2	63 145.4	104	220 428	332	630 1166	610	1130 2066	888	1630 2966	1166	2130 3866	1443	2630 4766
-10.0	14 57.2	17.8	64 147.2	110	230 446	338	640 1184	616	1140 2084	893	1640 2984	1171	2140 3884	1449	2640 4784
-9.44	15 59.0	18.3	65 149.0	116	240 464	343	650 1202	621	1150 2102	899	1650 3002	1177	2150 3902	1454	2650 4802
-8.89	16 60.8	18.9	66 150.8	121	250 482	349	660 1220	627	1160 2120	904	1660 3020	1182	2160 3920	1460	2660 4820
-8.33	17 62.6	19.4	67 152.6	127	260 500	354	670 1238	632	1170 2138	910	1670 3038	1188	2170 3938	1466	2670 4838
-7.78	18 64.6	20.0	68 154.4	132	270 518	360	680 1256	638	1180 2156	916	1680 3056	1193	2180 3956	1471	2680 4856
-7.22	19 66.2	20.6	69 156.2	138	280 536	366	690 1274	643	1190 2174	921	1690 3074	1199	2190 3974	1477	2690 4874
-6.67	20 68.0	21.1	70 158.0	143	290 554	371	700 1292	649	1200 2192	927	1700 3092	1204	2200 3992	1482	2700 4892
-6.11	21 69.8	21.7	71 159.8	149	300 572	377	710 1310	654	1210 2210	932	1710 3110	1210	2210 4010	1488	2710 4910
-5.56	22 71.6	22.2	72 161.6	154	310 590	382	720 1328	660	1220 2228	938	1720 3128	1216	2220 4028	1493	2720 4928
-5.00	23 73.4	22.8	73 163.4	160	320 608	388	730 1346	666	1230 2246	943	1730 3146	1221	2230 4046	1499	2730 4946
-4.44	24 75.2	23.3	74 165.2	166	330 626	393	740 1364	671	1240 2264	949	1740 3164	1227	2240 4064	1504	2740 4964
-3.89	25 77.0	23.9	75 167.0	171	340 644	399	750 1382	677	1250 2282	954	1750 3182	1232	2250 4082	1510	2750 4982
-3.33	26 78.8	24.4	76 168.8	177	350 662	404	760 1400	682	1260 2300	960	1760 3200	1238	2260 4100	1516	2760 5000
-2.78	27 80.6	25.0	77 170.6	182	360 680	410	770 1418	688	1270 2318	966	1770 3218	1243	2270 4118	1521	2770 5018
-2.22	28 82.4	25.6	78 172.4	188	370 698	416	780 1436	693	1280 2336	971	1780 3236	1249	2280 4136	1527	2780 5036
-1.67	29 84.2	26.1	79 174.2	193	380 716	421	790 1454	699	1290 2354	977	1790 3254	1254	2290 4154	1532	2790 5054
-1.11	30 86.0	26.7	80 176.0	199	390 734	427	800 1472	704	1300 2372	982	1800 3272	1260	2300 4172	1538	2800 5072
-0.56	31 87.8	27.2	81 177.8	204	400 752	432	810 1490	710	1310 2390	988	1810 3290	1266	2310 4190	1543	2810 5090
0	32 89.6	27.8	82 179.6	210	410 770	438	820 1508	716	1320 2408	993	1820 3308	1271	2320 4208	1549	2820 5108
0.56	33 91.4	28.3	83 181.4	216	420 788	443	830 1526	721	1330 2426	999	1830 3326	1277	2330 4226	1554	2830 5126
1.11	34 93.2	28.9	84 183.2	221	430 806	449	840 1544	727	1340 2444	1004	1840 3344	1282	2340 4244	1560	2840 5144
1.67	35 95.0	29.4	85 185.0	227	440 824	454	850 1562	732	1350 2462	1010	1850 3362	1288	2350 4262	1566	2850 5162
2.22	36 96.8	30.0	86 186.8	232	450 842	460	860 1580	738	1360 2480	1016	1860 3380	1293	2360 4280	1571	2860 5180
2.78	37 98.6	30.6	87 188.6	238	460 860	466	870 1598	743	1370 2498	1021	1870 3398	1299	2370 4298	1577	2870 5198
3.33	38 100.4	31.1	88 190.4	243	470 878	471	880 1616	749	1380 2516	1027	1880 3416	1304	2380 4316	1582	2880 5216
3.89	39 102.2	31.7	89 192.2	249	480 896	477	890 1634	754	1390 2534	1032	1890 3434	1310	2390 4334	1588	2890 5234
4.44	40 104.0	32.2	90 194.0	254	490 914	482	900 1652	760	1400 2552	1038	1900 3452	1316	2400 4352	1593	2900 5252
5.00	41 105.8	32.8	91 195.8			488	910 1670	766	1410 2570	1043	1910 3470	1321	2410 4370	1599	2910 5270
5.56	42 107.6	33.3	92 197.6			493	920 1688	771	1420 2588	1049	1920 3488	1327	2420 4388	1604	2920 5288
6.11	43 109.4	33.9	93 199.4			499	930 1706	777	1430 2606	1054	1930 3506	1332	2430 4406	1610	2930 5306
6.67	44 111.2	34.3	94 201.2			504	940 1724	782	1440 2624	1060	1940 3524	1338	2440 4424	1616	2940 5324
7.22	45 113.0	35.0	95 203.0			510	950 1742	788	1450 2642	1066	1950 3542	1343	2450 4442	1621	2950 5342
7.78	46 114.8	35.6	96 204.8			516	960 1760	793	1460 2660	1071	1960 3560	1349	2460 4460	1627	2960 5360
8.33	47 116.6	36.1	97 206.6			521	970 1778	799	1470 2678	1077	1970 3578	1354	2470 4478	1632	2970 5378
8.89	48 118.4	36.7	98 208.4			527	980 1796	804	1480 2696	1082	1980 3596	1360	2480 4496	1638	2980 5396
9.44	49 120.2	37.2	99 210.2			532	990 1814	810	1490 2714	1088	1990 3614	1366	2490 4514	1643	2990 5414
		37.8	100 212.0			538	1000 1832			1093	2000 3632			1649	3000 5432

CONVERSION FORMULA °C= 5/9 (°F - 32) °F= 9/5 (°C)+32

내식성비교 (Corrosion Rates of Titanium and Other Metallic Alloys)

			Concentration (%)	Temperature (%)	Titanium	Zirconium	St.steel AISI 304	St.steel AISI 316	Hastelloy®C
Inorganic acids (무기산)	Hydrochloric acid (HCl)	염산	1	25	◎	◎	○	◎	◎
				boiling	□	◎	□	□	△
			10	25	○	◎	□	□	◎
				boiling	□	◎	□	□	□
	Sulfuric acid (H_2SO_4)	황산	1	25	◎	◎	◎	◎	◎
				boiling	□	◎	□	△	○
			10	25	○	◎	○	○	◎
				boiling	□	◎	□	□	○
	Nitric acid (NHO_3)	질산	10	25	◎	◎	◎	◎	◎
				boiling	◎	◎	◎	◎	○
			65	25	◎	◎	◎	◎	○
				boiling	◎	◎	○	○	□
Organic acids (유기산)	Acetic acid (CH_3COOH)	초산 (아세트산)	10	boiling	◎	◎	◎	◎	◎
			60	boiling	◎	◎	○	○	◎
	Formic acid (HCOOH)	의산	10	25	◎	◎	△	○	◎
			30	boiling	□	◎	□	□	◎
	Ossalic acid ($(COOH)_2$)	수산	10	25	○	◎	○	○	○
			25	60	□	◎	□	□	○
	Lactic acid ($CH_3CH(OH)COOH$)	젖산 (유산)	10	boiling	◎	◎	○	○	○
			85	boiling	◎	◎	□	□	○
Alkali (알카리)	Sodium hydroxide (NaOH)	가성소다	10	100	◎	◎	◎	◎	◎
			40	boiling	□	○	○	○	○
	Potassium carbonate (K_2CO_3)	탄산칼슘	5	boiling	◎	◎	◎	◎	◎
			20	boiling	◎	◎	◎	◎	◎
Inoganic chlorides (무기염화물)	Sodium chloride (NaCl)	염화나트륨 (소금)	25	25	◎	◎	○	○	○
				boiling	◎	○	○	○	◎
	Ammonium chloride (NH_4Cl)	염화암모늄	40	25	◎	◎	○	○	◎
				boiling	◎	◎	△	○	◎
	Zinc chloride ($ZnCl_2$)	염화아연	20	boiling	◎	◎	□	□	□
			50	boiling	◎	◎	□	□	□
	Magnesium chloride ($MgCl_2$)	염화마그네슘	42	25	◎	◎	◎	◎	◎
				boiling	◎	◎	◎	◎	◎
	Iron chloride ($FeCl_3$)	염화제2철	30	25	◎	□	□	□	△
				boiling	◎	□	□	□	□
Inorganic salts (무기염류)	Sodium sulphate (Na_2SO_4)	황산나트륨	20	25	◎	◎	◎	◎	◎
				boiling	◎	◎	◎	◎	◎
	Sodium sulfide (Na_2S)	황화나트륨	10	25	◎	◎	◎	◎	◎
		boiling			◎	◎	○	○	◎
(NaOCl)	Sodium chlorite (NaOCl)	차아염소나트륨	5	25	◎	◎	△	△	△
			15	25	◎	◎	△	△	△
	Sodium carbonate (Na_2CO_3)	탄산나트륨	30	25	◎	◎	◎	◎	◎
				boiling	◎	◎	◎	◎	◎
Organic compounds (유기화합물)	Methlyl alcohol (CHOH)		95	25	◎	◎	◎	◎	◎
	Carbon tetrachloride (CCl)		100	boiling	◎	◎	○	○	○
	Phenol (C_6H_5OH)	훼놀	포화	25	◎	◎	◎	◎	○
	Formaldehyde (HCHO)		37	boiling	◎	◎	◎	◎	○
Gas (가스)	Chlorine (Cl_2)	염소	dry	25	□	◎	◎	◎	◎
			wet	25	◎	□	□	□	□
	Hydrogen sulfide (H_2S)	황화수소	dry	25	◎	◎	△	○	◎
			wet	25	◎	◎	○	◎	○
	Ammonium (NH_3)	암모니아	100	40	◎	◎	◎	◎	◎
			100	100	◎	◎	◎	◎	◎
Others (기타)	Sea water	해수	-	25	◎	◎	◎	◎	◎
				100	◎	◎	○	○	◎
	Naptha	납사	-	80	◎	◎	◎	◎	◎
				180	◎	◎	◎	◎	◎

※부식율(Corrosion rates): ◎ 0.125㎜/년이하 ○ 0.125~0.5㎜/년 △ 0.5~1.25㎜/년 □ 1.25㎜/년이상

니켈 합금표(Nickel Alloys)

합금명 (UNS NO)	주성분 (%)	밀도 (g/㎤)	기계적성질(상온)				특징
			상태	인장강도 1000PSI (Mpa)	항복강도 1000PSI (Mpa)at 0.2% offset	경도 Brinekk (ROCKWELL)	
HASTELLOY B - 2 (N10665)	Ni BAL, Cr 1.0, Mo 28, Mn 1.0 Fe Fe 2.0, Si 0.10, Co 1.0, C 0.01	9.22	Annealed	132.5 (914)	57.5 (396)	228 (B - 98)	용접열영향부의내식성향상
HASTELLOY C - 276 (N10276)	Ni BAL, W 4, Mo 28, Co 2.5 Cr 15.5, Mn 1.0, Fe 3.0, C 0.01	8.89	Annealed	114.9 (792)	51.6 (356)	184 (B - 90)	용접열영향부의내식성향상
HASTELLOY C - 4 (N06455)	Ni BAL, Co 2.0, Cr 16, Mn 1.0 Mo 15.5, Ti 0.7, Fe 3.0, C 0.01	8.64	Annealed	116.2 (801)	61.0 (421)	194 (B - 92)	고온안전성향상
HASTELLOY C - 22 (N06022)	Ni BAL, Cr20 - 22.5, Mo 12.5 - 14.5 W 2.5 - 3.5, Co 2.5, C 0.01	8.69	Annealed	116.3 (802)	58.5 (403)	184 (B - 90)	C - 276보다산화성환경에서의 내식성및내국부부식성우수
HASTELLOY G (N06007)	Ni BAL, Co 0.25, Cr 22, Nb+Ta2 Fe 195, Cu 2, Mo 6.5, Mn 1.5 W 1, Si 1	8.30	Annealed	102.0 (730)	46.2 (319)	161 (B - 84)	고온의황산이나인산에우수한내식성
HASTELLOY G - 3 (N06985)	Ni BAL, Co 5, Cr 21 - 23.5, Cul 5 - 2.5 Fe 18 - 21, W 1.5, Mo 6 - 8, Si 1 Mn 1, C 0.015	8.30	Annealed	99.0 (683)	44.0 (303)	158 (B - 83)	고온의황산이나인산에우수한내식성
HASTELLOY G - 30 (N06030))	Ni BAL, Mo 5.0, Cr 29.5, W 2.5 Fe 15, Mn 2.0, Ca 1.7, Co 5.0 Si 1.0	8.22	Annealed	100 (690)	47 (324)	176 (B - 88)	공업용인산이나강산화성산에 우수한내식성
HASTELLOY X (N06002)	Ni BAL, Co 1.5, Cr 22, Si 1 Fe 18.5, Mn 1, Mo 9, W 0.6 Co 1, Al 0.5, Ti 0.15	8.22	Annealed	109.5 (755)	55.9 (385)	194 (B - 92)	높은고온강도와우수한내식성
ALLOY 20 (N08020)	Ni 35, Mo 2.5, Fe 37 Cr 20, Cu 3.5	8.0	Annealed	90 (620)	45 (310)	183 (B - 90)	산화성및환원성환경에우수한내식성
NICKEL 200 (N02200)	Ni 99.6 C 0.15 MAX	8.89	Annealed	55 - 80 (380 - 550)	15 - 30 (100 - 210)	90 - 120	순수니켈로양호한기계적성질과 우수한내식성
NICKEL 201 (N02201)	Ni 99.6 C 0.02 MAX	8.89	Annealed	55 - 80 (380 - 550)	15 - 30 (100 - 210)	90 - 120	Nickel 200과같은성질이나탄소가 낮아300°C이상의용도로적합
MONEL 400 (N04400)	Ni 99.6 Cu 31.5	8.83	Annealed	70 - 90 (480 - 620)	25 - 50 (170 - 340)	110 - 149	강도가있고용접성이좋아광범위한 적용이가능한고내식합금
MONEL R - 405 (N04405)	Ni 66.5 Cu 31.5 S 0.04	8.83	Annealed	70 - 85 (480 - 590)	25 - 40 (170 - 280)	110 - 140	Monel 400에비해우수한기계가공성
MONEL 450 (CT1500)	Cu 68 Ni 30 Fe 0.7		Annealed	56 (385)	24 (165)	90	용접성과내식성우수
MONEL K - 500 (N05500)	Ni 65.5 Cu 29.5 Al 2.7, Ti 0.6	8.46	Aged	140 - 190 (970 - 1310)	110 - 150 (760 - 1030)	265 - 346	Monel 400과같은성질의시효경화형 합금으로뛰어난고강도
INCONEL 600 (N06600)	Ni 76, Cr 15.5 Fe 8	8.42	Annealed	80 - 100 (550 - 690)	30 - 50 (210 - 340)	120 - 170	고니켈,고크롬합금으로산화성및 환원성분위기고온내식성우수
INCONEL 601 (N06601)	Ni 60.5, Cr 23 Fe 14, Al 1.4	8.06	Annealed	80 - 115 (550 - 690)	30 - 60 (210 - 340)	110 - 150	고온, 내산화성우수
INCONEL 617 (N06617)	Ni 52, Mo 9, C 22 Al 1.2, Co 12.5	8.36	Annealed	110 (760)	51 (350)	173	고온, 내산화성우수
INCONEL 625 (N06625)	Ni 61, Cr 21.5 Mo 9, Nb+Ta 3.6	8.44	Annealed	135 (930)	75 (520)	180	극저온도에서980°C의고온까지높은강도와 인성, 내산화성피로강도를갖는내식성우수
INCONEL 690 (N06690)	Ni 60, Cr 30, Fe 9.5	8.19	Annealed	100 (690)	55 (375)	184	산화성의화학약품과유황함유 가스에우수한내식성
INCONEL 718 (N07718)	Ni 52.5, Mo 3, Cr 19 Fe 18.5,Nb+Ta 1.0	8.19	Aged	196 (1350)	171 (1180)	382	-250°C의저온에서700°C의고온까지우수한강도로 시효상태에서의용접가능(980°C까지내산화성우수)
INCONEL X - 750 (N07750)	Ni 73, Ti 2.5, Cr 15.5 Al 0.8, Fe 7, Nb+Ta 1.0	8.25	Aged	162 - 193 (1120 - 1330)	115 - 142 (790 - 980)	300 - 390	내식성과내산화성이우수한 시효경화형의합금
INCOLOY 800 (N08800)	Ni 32.5, Fe 46, Cr 21	7.95	Annealed	75 - 100 (520 - 690)	30 - 60 (210 - 410)	120 - 184	고온강도가우수
INCOLOY 800 HT (N08811)	Ni 32.5, C 0.08, Fe 46 Cr 21, Al+Ta 1.0	7.95	Annealed	65 - 95 (450 - 660)	20 - 50 (140 - 340)	100 - 184	고온강도가우수
INCOLOY 825 (N08825)	Ni 42, Cu 2.2, Fe 30 Cr 21.5, Mo 3	8.14	Annealed	85 - 105 (590 - 720)	35 - 65 (240 - 450)	120 - 180	광범위한분야에서내식성이풍부하고특히 입계부식, 환원성산에대해양호한성질