NIPPON STEEL

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Titanium Products
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NIPPON STEEL

Titanium Products

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NIPPON STEEL CORPORATION

Introduction

Titanium, which was found in the 1790s, is the 4th most abundant practical metal existing in the upper crust of the earth. It has taken a long time before an industrial refining process for titanium was reached to completion, and not until 1946 did industrial production of this new metal, titanium begin. The metal was adopted for aerospace applications for the beginning, owing to its specific strength. And then, the demand for titanium, which also has outstanding corrosion resistance, began to increase markedly for such applications as Chemical industries and Electric power generation. Today, titanium is a well-known material for its character from aesthetic and for environmental and biological conformity. Titanium, which has excellent physical properties and is friendly to the environment, meets contemporary needs from the world and has a great potential for an expected growth in the future.

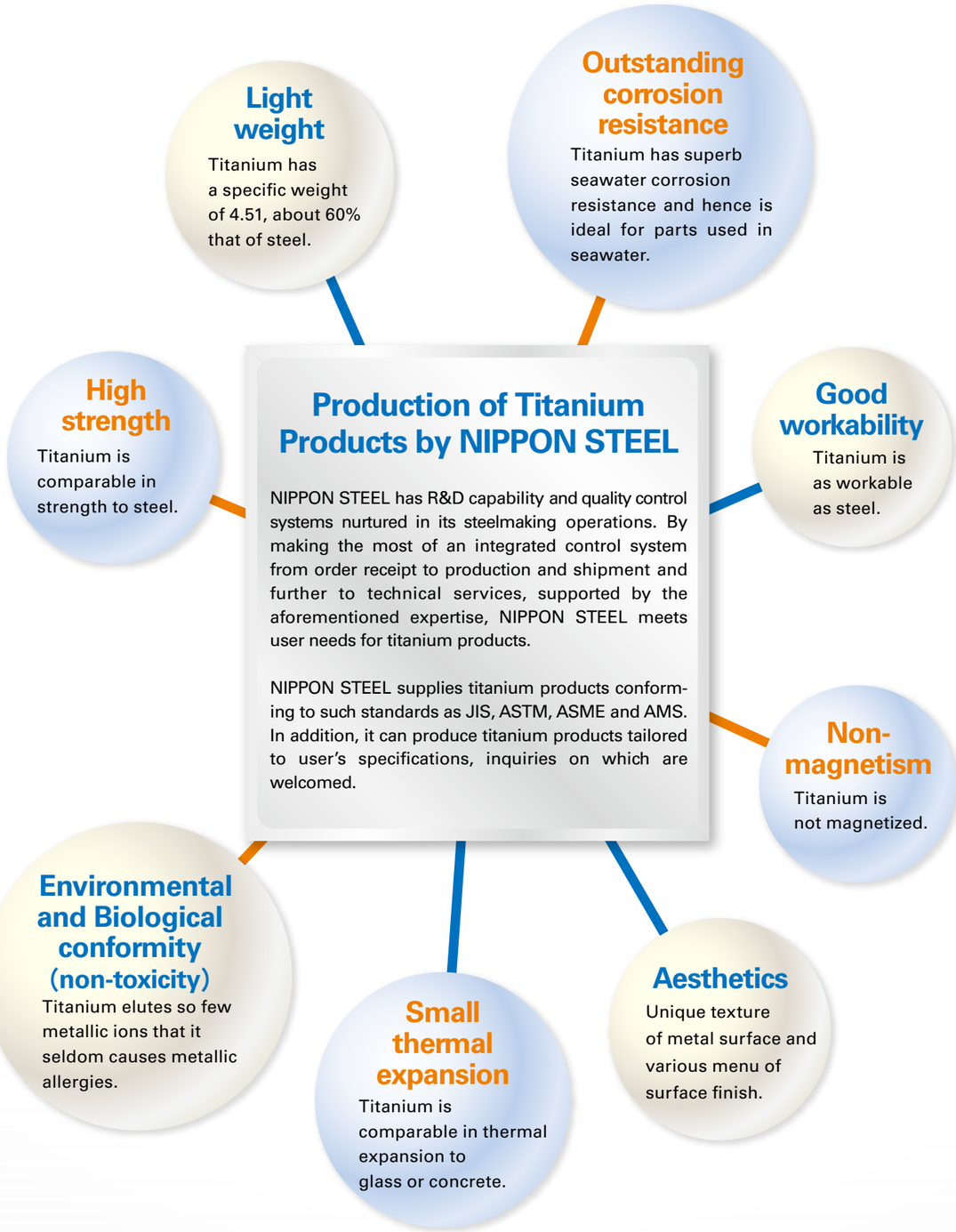
NIPPON STEEL, which was founded in 2012, as a world top-class comprehensive producer of titanium mill products, supplies its high-function, high-quality products and services to the customers by utilizing the best effectiveness of the consolidated management resources of the new corporation and the specialized expertise of the companies.

Based on the results of basic studies of titanium which has been obtained for many decades, with its more strengthened organization and staffs of research and development, we continue R&D for various fields of titanium application, such as Chemical industries, Electric power generation, Seawater desalination, Civil engineering, Architecture, Automotive, Consumer appliances, and Aerospace industries, etc. We are also developing new applications of titanium actively aiming to customers' needs.

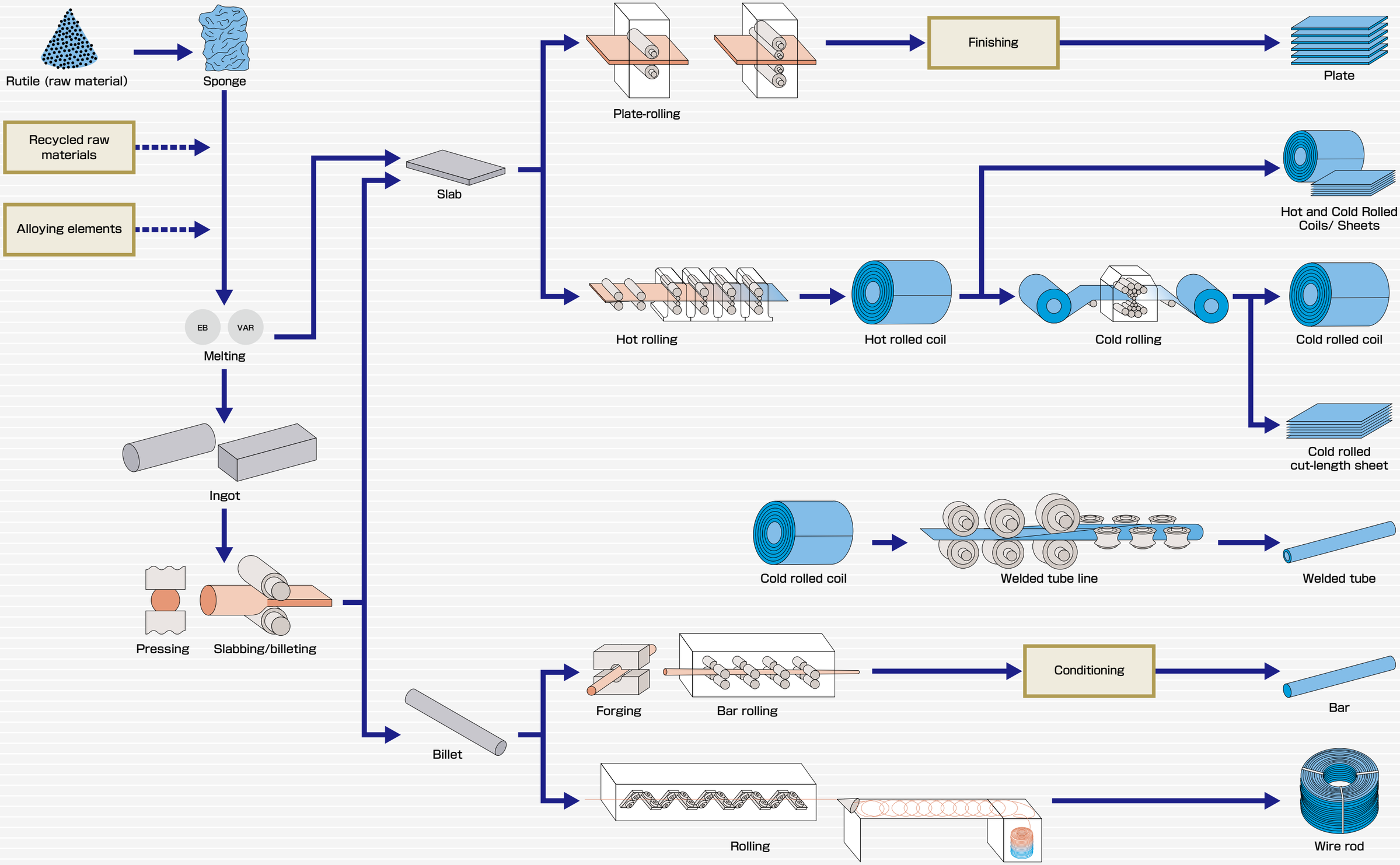
NIPPON STEEL is to pursue the infinite potential of the contemporary metal, "Titanium".

CONTENTS

Characteristics of Titanium



Titanium Production Flowchart



Hot and Cold Rolled Coils / Sheets

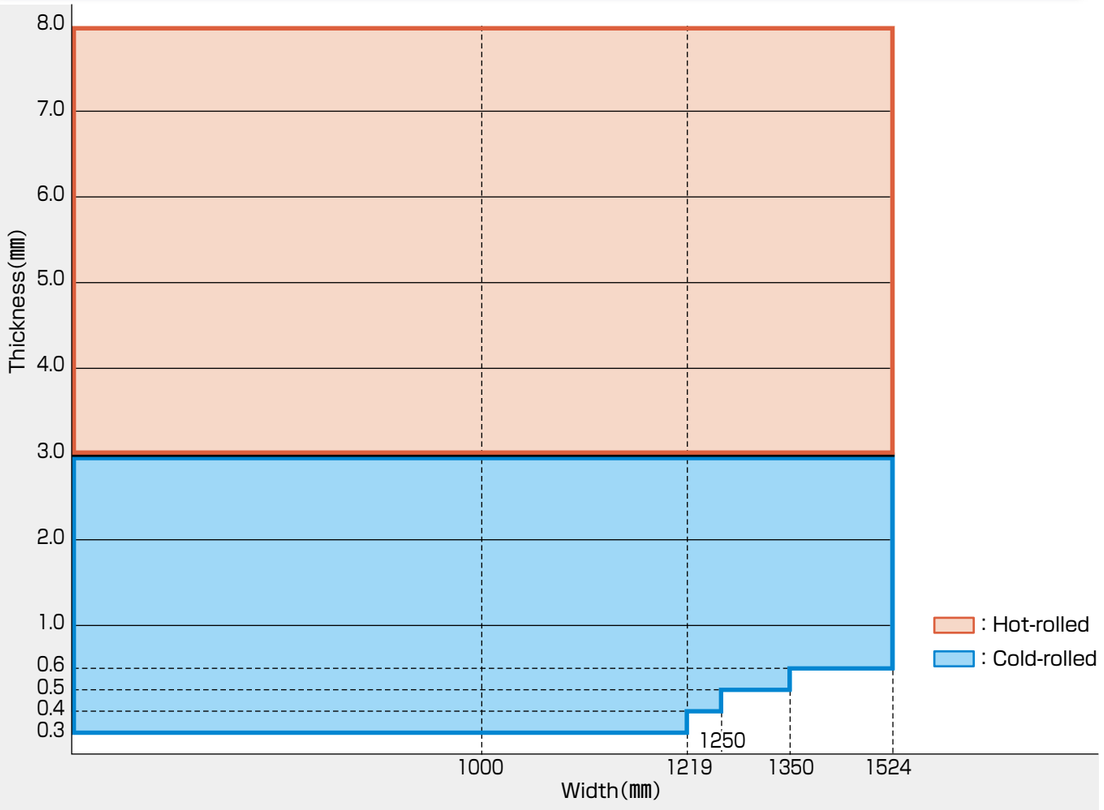
Applicable standards

Standard	Grade
JIS H 4600	Class 1, Class 2, Class 3, Class 4, Class 11, Class 12, Class 13, Class 17, Class 19, Class 20, Class 21, Class 22
ASTM B265	Gr.1, Gr.2, Gr.3, Gr.4, Gr.7, Gr.11, Gr.13, Gr.14, Gr.16, Gr.17, Gr.30, Gr.31
ASME SB 265	Gr.1, Gr.2, Gr.3, Gr.4, Gr.7, Gr.11, Gr.13, Gr.14, Gr.16, Gr.17, Gr.30, Gr.31
AMS	AMS4900, AMS4901, AMS4902
Company specifications	Ti-20V-4Al-1Sn (β alloy), Ti-3Al-5V(α+β alloy) Well-formable grade, Super-TIX™10CU, Super-TIX™10CUNB, Super-TIX™800, Super-TIX™51AF(Hot rolling, α+β alloy)

Surface finish

Vacuum annealing / Annealing & pickling ※ Please consult us for any other surface finish.

Available sizes



(Note 1) For JIS Class 3 (ASTM Gr. 3) or higher grades, please consult us when placing an order.

Titanium Coils / Sheets for Architecture & Design Use

Designing Titanium TranTixxii™

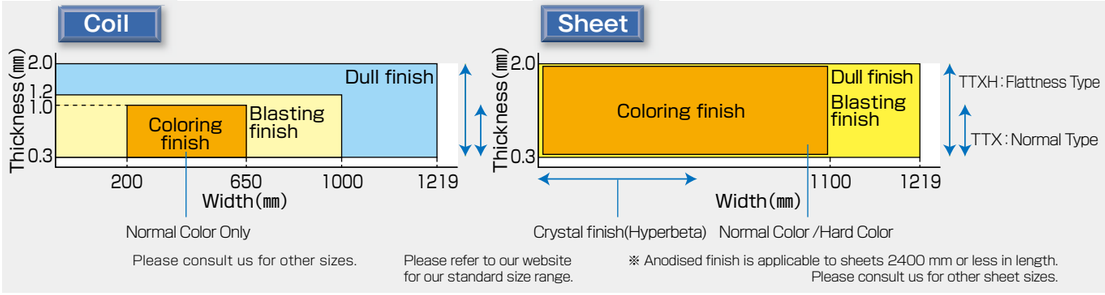
Applicable standard

Standard	Grade
JIS H 4600	Class 1 or Class 1 equivalent (TTX:Normal Type, TTXH:Flattness Type)
ASTM B265	Gr 1 or Gr 1 equivalent (TTX:Normal Type, TTXH:Flattness Type)
ASME SB 265	Gr 1 or Gr 1 or Gr 1 equivalent (TTX:Normal Type, TTXH:Flattness Type)

Surface finish

Texture × Color	Dull finish, Blasting finish, Bright finish, Hairline finish, Crystal finish(Hyperbeta) Coloring finish (Normal Color / Hard Color), IP Coloring finish [*UV Proof/VOC free]
Stable Color	Special Treatment (Less-Subject to Discoloration Technology)

Available sizes



Please consult us for other sizes.

Please refer to our website for our standard size range.

※ Anodised finish is applicable to sheets 2400 mm or less in length. Please consult us for other sheet sizes.

Titanium Foils

Applicable standards

Standard	Grade
JIS H 4600	Class 1 equivalent, Class 2 equivalent
ASTM B265	Gr.1 equivalent
ASME SB 265	Gr.1 equivalent

Available sizes

Plates

Applicable standards

● JIS H 4600 ● ASTM B265 ● ASME SB 265

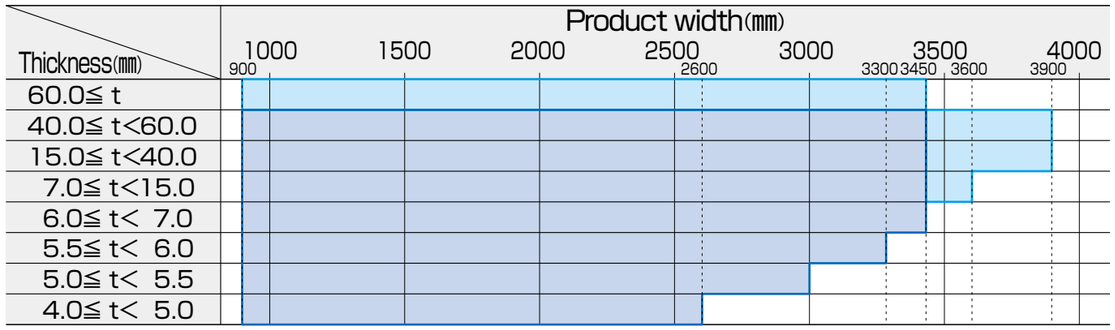
Surface finish

Pickling, Polishing

Available grades and size range

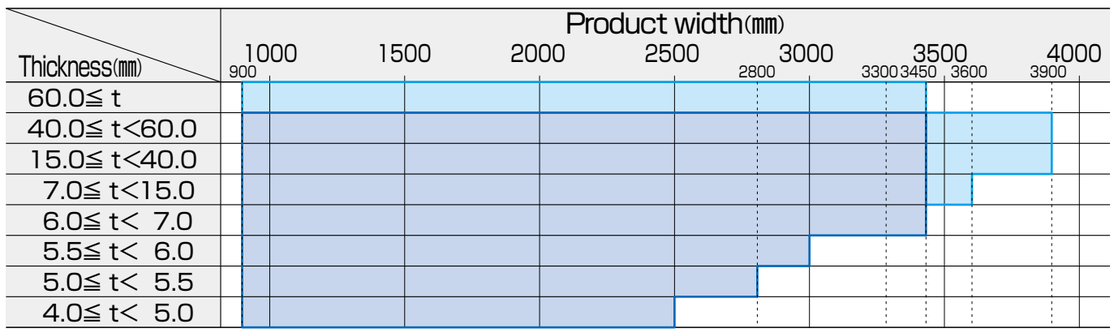
Available grades

● JIS TP270H ● ASTM Gr.1 ● ASME Gr.1
● JIS TP270PdH ● ASTM Gr.11 ● ASME Gr.11
● JIS TP240PdH ● ASTM Gr.17 ● ASME Gr.17



Available grades

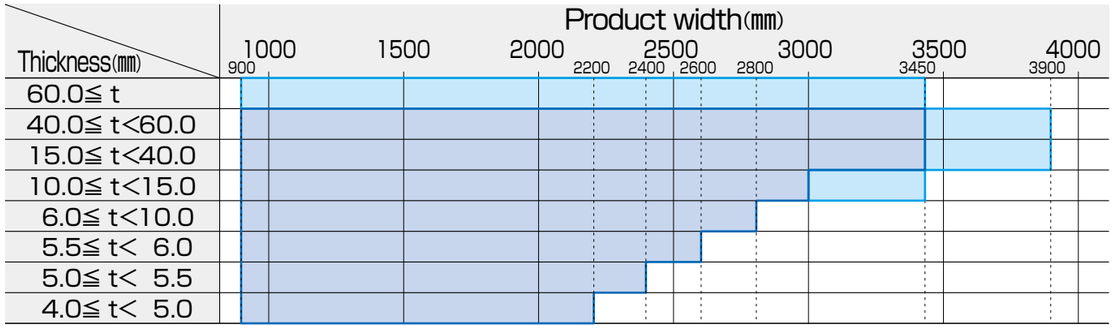
● JIS TP340H ● ASTM Gr.2 ● ASME Gr.2
● JIS TP340PdH ● ASTM Gr.7 ● ASME Gr.7



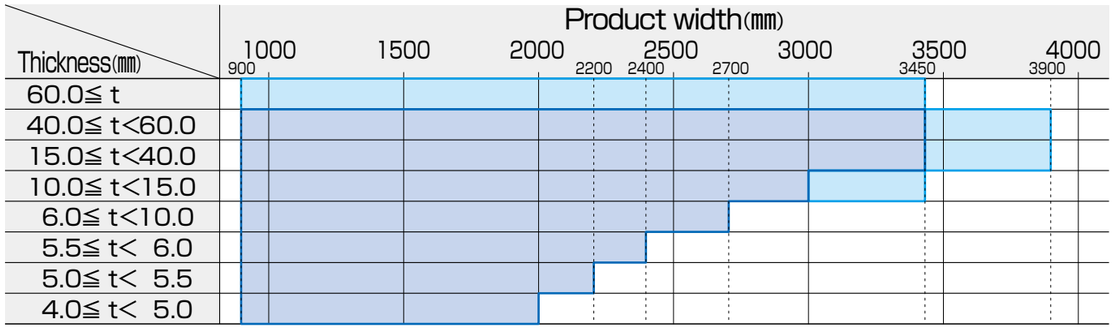
: Available size range : Please consult us when placing an order.

(Note) The maximum product length is 10000 mm (10 m).
Please consult us for products whose length is in the range 10000~14000 mm.

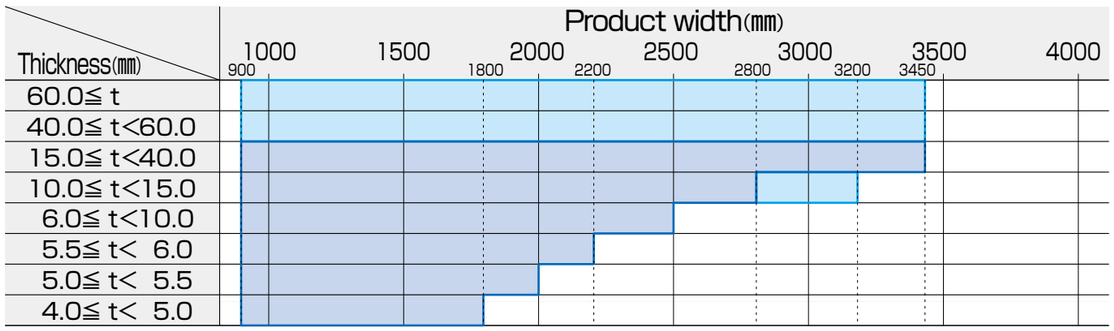
Available grades ● JIS TP480H ● JIS TP480PdH



Available grades ● ASTM Gr.3 ● ASME Gr.3



Available grades ● JIS TP550H ● ASTM Gr.4 ● ASME Gr.4



: Available size range : Please consult us when placing an order.

(Note) The maximum product length is 10000 mm (10 m).
Please consult us for products whose length is in the range 10000~14000 mm.

Welded Tubes and Pipes for Heat Exchanger

Applicable standards

Standard	Grade
JIS H 4631	Class 1, Class 2, Class 3, Class 11, Class12, Class 17, Class 19, Class 21, Class 22
JIS H 4635	Class 1, Class 2, Class 3, Class 11, Class12, Class 17, Class 19, Class 21, Class 22
ASTM B338,B862	Gr.1, Gr.2, Gr.3, Gr.7, Gr.11, Gr.13, Gr.14
ASME SB338,SB862	Gr.1, Gr.2, Gr.3, Gr.7, Gr.11, Gr.13, Gr.14
Company specifications	Super-TIX™10CU, Super-TIX™10CUNB

Available sizes

Outside diameter(㎜) \ Thickness(㎜)	0.4	0.5	0.6	0.7	0.8	1.0	1.2	1.4	1.5	1.6	2.0	3.0
ϕ12.7	●	●	●	●	●	●						
ϕ15.0												
ϕ15.9							●	●	●			
ϕ18.0							●	●	●			
ϕ19.0											●	●
ϕ20.0											●	●
ϕ22.0											●	●
ϕ22.2											●	●
ϕ24.0											●	●
ϕ25.4											●	●
ϕ27.2											●	●
ϕ28.58											●	●
ϕ31.0											●	●
ϕ31.75											●	●
ϕ31.8											●	●
ϕ34.0											●	●
ϕ34.7											●	●
ϕ35.0											●	●
ϕ38.1												
ϕ41.5				●	●							
ϕ42.7				●	●							
ϕ45.0				●	●							
ϕ47.0				●	●							
ϕ48.6				●	●							
ϕ50.8					●							
ϕ56.2												
ϕ60.5												

● : Scope of consultation
Sizes other than those shown above may be made available when requested.
For the available sizes of high-strength products of Class 3 or higher, please consult us.

Welded Tubes and Pipes for Plumbing

Applicable standards

Standard	Grade
JIS H 4631	Class 1, Class 2, Class 3, Class 11, Class12, Class 17, Class 19, Class 21, Class 22
JIS H 4635	Class 1, Class 2, Class 3, Class 11, Class12, Class 17, Class 19, Class 21, Class 22
ASTM B338,B862	Gr.1, Gr.2, Gr.3, Gr.7, Gr.11, Gr.13, Gr.14
ASME SB338,SB862	Gr.1, Gr.2, Gr.3, Gr.7, Gr.11, Gr.13, Gr.14
Company specifications	Super-TIX™10CU, Super-TIX™10CUNB

Available sizes

Outside diameter(㎜) \ Thickness(㎜)	1.0	1.2	1.5	2.0	3.0	4.0	5.0	6.0	8.0	10.0	12.0	14.0	16.0	18.0	20.0	24.0	28.0
ϕ13.8																	
ϕ17.3																	
ϕ19.0																	
ϕ21.7																	
ϕ25.4																	
ϕ27.2																	
ϕ34.0						●											
ϕ38.1						●											
ϕ41.5						●											
ϕ42.7						●											
ϕ45.0						●											
ϕ47.0						●											
ϕ48.6						●	●										
ϕ56.2						●	●										
ϕ60.5																	
ϕ76.3																	
ϕ89.1																	
ϕ101.6																	
ϕ114.3																	
ϕ139.8																	
ϕ165.2																	
ϕ216.3																	
ϕ267.4																	
ϕ318.5																	
ϕ355.6																	
ϕ406.4																	
ϕ457.2																	
ϕ508.0																	
ϕ558.8																	
ϕ609.6																	
ϕ660.4																	
ϕ711.2																	
ϕ762.2																	
ϕ812.8																	
ϕ914.4																	
ϕ1016.0																	

● : Scope of consultation
Sizes other than those shown above may be made available when requested.
For the available sizes of high-strength products of Class 3 or higher, please consult us.

Wire Rods and Bars

Applicable standards

	Standard	Grade
Wire rods	Equivalent of JIS H 4650·H4670	Class 1, Class 2, Class 3, Class 4, Class 11, Class 12, Class 13, Class 61
	Equivalent of ASTM B348·B863	Gr.1, Gr.2, Gr.3, Gr.4, Gr.7, Gr.9(Ti-3Al-2.5V), Gr.19(Ti-3Al-8V-6Cr-4Mo-4Zr)
	Company specifications	Super-TIX™800, Super-TIX™51AF, Super-TIX™523AFM, 15-3-3-3 equivalent
Bars	JIS H 4650	Class 1, Class 2, Class 3, Class 4
	ASTM B348	Gr.1, Gr.2, Gr.3, Gr.4, Gr.5
	ASTM F136, AMS4928	
	Company specifications	Super-TIX™800, Super-TIX™51AF, Super-TIX™523AFM, SSAT™-2041CF

(Please consult us for any other materials to be applied to Bars.)

Surface finishes

Wire rods SF(Super Finish※), SF + Annealing, SF + Annealing + Pickling ※Special peeling finish.

Bars Peeling, Pickling
(Please consult us for any other surface finish.)

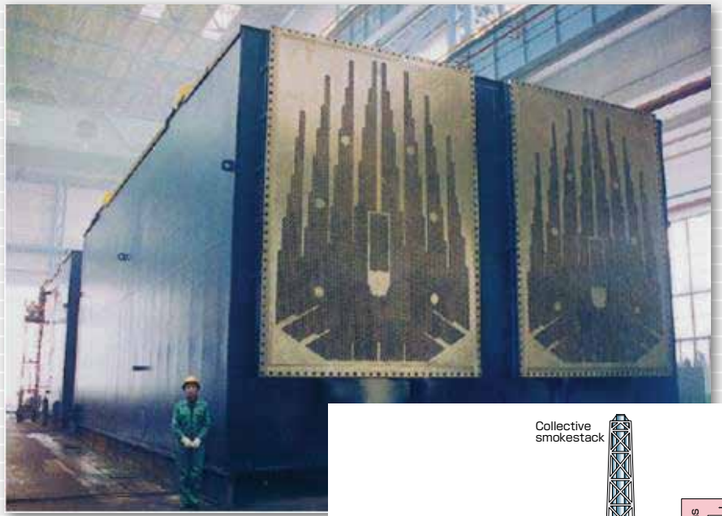
Available sizes

Wire rods φ6.0, φ6.5, φ7.0, φ7.5, φ9.5, φ12.0, φ15.0, φ15.5 (mm)
(Please consult us for any other product size.)

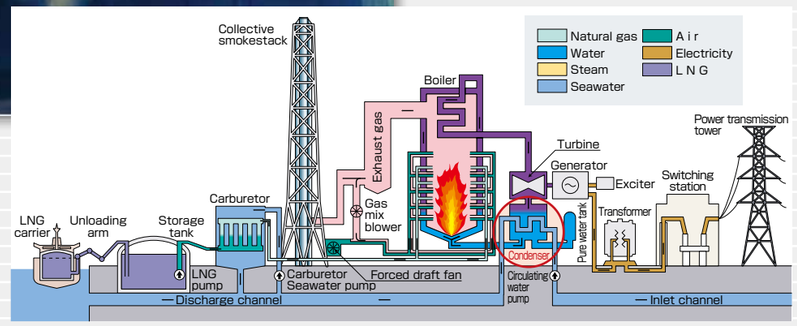
Bars φ8～φ350 (mm)
(Please consult us for any other product size.)

Examples of Applications of Titanium

Electric Power, Energy and Seawater Desalination



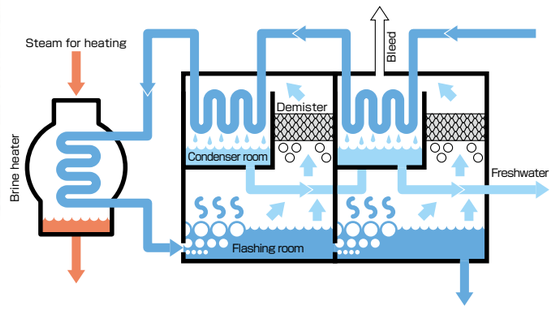
Ordinary thermal power generation (using LNG)



Ras Az Zawr Phase-1 Package "D"

Seawater Desalination Plant (MSF)

Principle of operation of multi-stage flash (MSF) distillation process

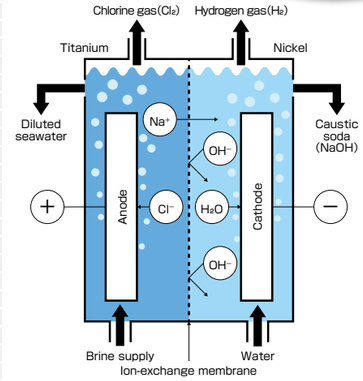


Examples of Applications of Titanium

Chemical Plants and Electrolysis

General view of soda electrolytic tank

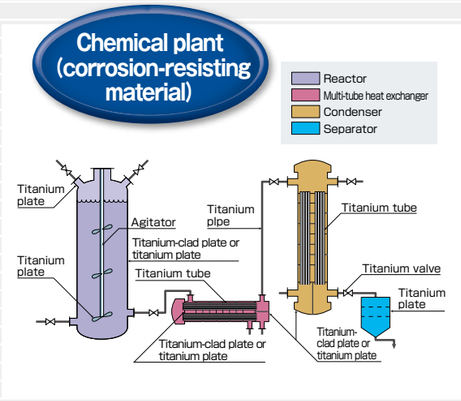
Conceptual diagram of electrolytic tank with ion exchange membrane



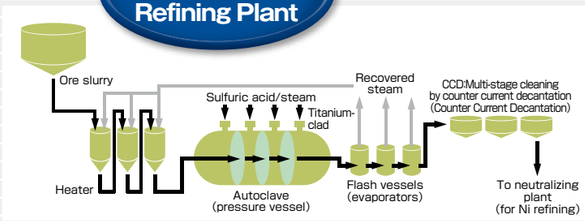
Multi-tube heat exchanger for chemical use

General view of wet-type Nickel Refining Plant

Chemical plant (corrosion-resisting material)

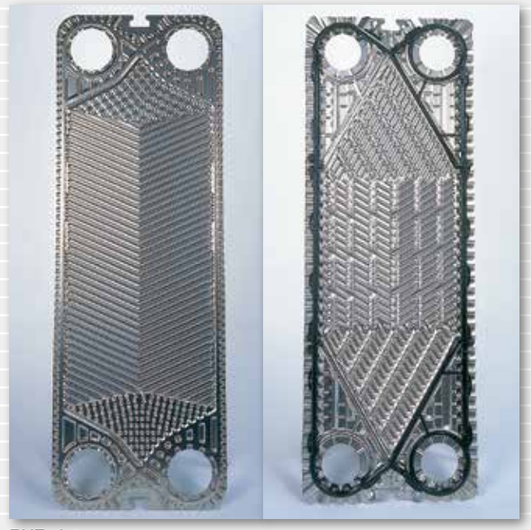


Conceptual diagram of Nickel Refining Plant



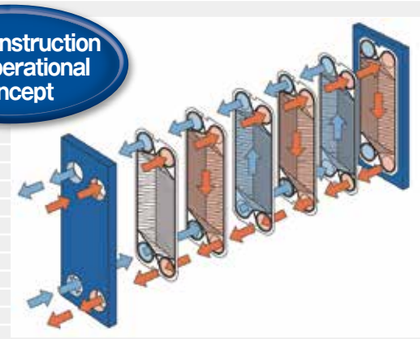
PHE, Aircraft and Jet Engines

PHE equipment



PHE plate

PHE construction and operational concept



Airbus A380

Examples of Applications of Titanium

Automobiles, Consumer Appliances, Sports and Medical Care

Amuse GT-R and its exhaust system

YAMAHA YZF-R1

CASIO OCEANUS

DUNLOP XXIO7

SNOWPEAK tableware made of titanium

Artificial bone made of titanium

Titanium flame of glasses

Civil Engineering and Architectural Materials

Main hall of Kinryuzan Sensoji Temple

Kyushu National Museum

Grand National Theater in Beijing, China

Grand Theater in Hangzhou

Marques de Riscal Winery Hotel

Tokyo International Airport D-runway pier

Standards of Titanium Products [Commercially-Pure Titanium/Corrosion-Resistant Titanium Alloys]

Classification	Standard	Chemical composition [mass%]										Tensile properties		
		C	H	O	N	Fe	Pd	Co	Ru	Ni	Ti	0.2%proof stress [MPa]	Tensile strength [MPa]	Elongation [%]
Commercially-Pure titanium	Well-formable grade	≦0.08	≦0.013	≦0.15	≦0.03	≦0.20					rem.	≧120	≧250	≧40
	JIS Class 1	≦0.08	≦0.013	≦0.15	≦0.03	≦0.20	–	–			rem.	≧165	270–410	≧27
	JIS Class 2	≦0.08	≦0.013	≦0.20	≦0.03	≦0.25	–	–			rem.	≧215	340–510	≧23
	JIS Class 3	≦0.08	≦0.013	≦0.30	≦0.05	≦0.30	–	–			rem.	≧345	480–620	≧18
	JIS Class 4	≦0.08	≦0.013	≦0.40	≦0.05	≦0.50	–	–			rem.	≧485	550–750	≧15
	ASTM/ASME Grade1	≦0.08	≦0.015	≦0.18	≦0.03	≦0.20	–	–			rem.	138–310	≧240	≧24
	ASTM/ASME Grade2	≦0.08	≦0.015	≦0.25	≦0.03	≦0.30	–	–			rem.	275–450	≧345	≧20
	ASTM/ASME Grade3	≦0.08	≦0.015	≦0.35	≦0.05	≦0.30	–	–			rem.	380–550	≧450	≧18
	ASTM/ASME Grade4	≦0.08	≦0.015	≦0.40	≦0.05	≦0.50	–	–			rem.	483–655	≧550	≧15
Corrosion-resistant titanium alloys	JIS Class 17	≦0.08	≦0.015	≦0.18	≦0.03	≦0.20	0.04–0.08	–			rem.	≧170	240–380	≧24
	JIS Class 19	≦0.08	≦0.015	≦0.25	≦0.03	≦0.30	0.04–0.08	0.20–0.80			rem.	≧275	345–515	≧20
	JIS Class 20	≦0.08	≦0.015	≦0.35	≦0.05	≦0.30	0.04–0.08	0.20–0.80			rem.	≧380	450–590	≧18
	ASTM/ASME Gr.17	≦0.08	≦0.015	≦0.18	≦0.03	≦0.20	0.04–0.08	–			rem.	138–310	≧240	≧24
	ASTM/ASME Gr.30	≦0.08	≦0.015	≦0.25	≦0.03	≦0.30	0.04–0.08	0.20–0.80			rem.	275–450	≧345	≧20
	ASTM/ASME Gr.31	≦0.08	≦0.015	≦0.35	≦0.05	≦0.30	0.04–0.08	0.20–0.80			rem.	380–550	≧450	≧18
	JIS Class 11	≦0.08	≦0.013	≦0.15	≦0.03	≦0.20	0.12–0.25	–			rem.	≧165	270–410	≧27
	JIS Class 12	≦0.08	≦0.013	≦0.20	≦0.03	≦0.25	0.12–0.25	–			rem.	≧215	340–510	≧23
	JIS Class 13	≦0.08	≦0.013	≦0.30	≦0.05	≦0.30	0.12–0.25	–			rem.	≧345	480–620	≧18
	ASTM/ASME Grade11	≦0.08	≦0.015	≦0.18	≦0.03	≦0.20	0.12–0.25	–			rem.	138–310	≧240	≧24
	ASTM/ASME Grade7	≦0.08	≦0.015	≦0.25	≦0.03	≦0.30	0.12–0.25	–			rem.	275–450	≧345	≧20
	JIS Class 21	≦0.08	≦0.015	≦0.10	≦0.03	≦0.20			0.04–0.06	0.40–0.60	rem.	≧170	275–450	≧24
	JIS Class 22	≦0.08	≦0.015	≦0.15	≦0.03	≦0.30			0.04–0.06	0.40–0.60	rem.	≧275	410–530	≧20
	ASTM/ASME Grade13	≦0.08	≦0.015	≦0.10	≦0.03	≦0.20			0.04–0.06	0.4–0.6	rem.	≧170	≧275	≧24
	ASTM/ASME Grade14	≦0.08	≦0.015	≦0.15	≦0.03	≦0.30			0.04–0.06	0.4–0.6	rem.	≧275	≧410	≧20

Standards of Titanium Products [Titanium Alloys]

Alloy classification	Nominal composition or company standard	Product form				Chemical composition (mass%)													Examples of Tensile properties at room temperature (minimum values)				Advantageous features	Main related standards, etc.
		Plate	Sheet	Welded tube	Bar/ wire rod	Al	V	Mo	Cr	Zr	Sn	Si	Cu	Nb	Fe	O	N	C	Heat treatment *	0.2%proof stress min.(MPa)	Tensile strength min.(MPa)	Elongation min. (%)		
α + β alloy	Ti-3Al-2.5V		○*	○*	○	2.5–3.5	2.0–3.0								≦0.25	≦0.15	≦0.03	≦0.08	Annealing	485	620	15	Good cold formability	JIS Class 61
																				483	620	15		ASTM Gr.9
	Ti-6Al-4V				○	5.50–6.75	3.50–4.50								≦0.30	≦0.20	≦0.05	≦0.08	Annealing	827	895	10	Versatility	AMS4928 AMS6930, 6931(AMS-T-9047)
																			STA	1070	1140	10		
						5.5–6.75	3.5–4.5								≦0.40	≦0.20	≦0.05	≦0.08	Annealing	825	895	10		JIS Class 60
																				828	895	10		ASTM Gr.5
	Ti-6Al-4V ELI				○	5.5–6.5	3.5–4.5								≦0.25	≦0.13	≦0.03	≦0.08	Annealing	755	825	10	Good low-temperature toughness	JIS Class 60E
																								ASTM Gr.23, ASTM F136
	Ti-6Al-6V-2Sn				○	5.00–6.00	5.00–6.00				1.50–2.50		0.35–1.00		0.35–1.00	≦0.20	≦0.04	≦0.05	Annealing	965	1035	10	Good hardenability	AMS4971, 6935, 6936
																			STA	1105	1205	8		
	Ti-6Al-2Sn-4Zr-2Mo-0.08Si				○	5.50–6.50		1.80–2.20		3.60–4.40	1.80–2.20	0.06–0.10			≦0.10	≦0.15	≦0.05	≦0.05	Annealing	825	895	10	Good heat resistance	AMS4975, 4976
																			STA	860	930	10		
	Ti-6Al-2Sn-4Zr-6Mo				○	5.50–6.50		5.50–6.50		3.60–4.40	1.75–2.25				≦0.15	≦0.15	≦0.04	≦0.04	STA	1105	1170	10	Good creep resistance	AMS4981, 6906
β alloy	Ti-3Al-8V-6Cr-4Mo-4Zr				○	3.0–4.0	7.5–8.5	3.5–4.5	5.5–6.5	3.5–4.5					≦0.30	≦0.14	≦0.03	≦0.05	ST	759	793	15	Good cold formability Good age hardenability	AMS4957, 4958, 6920, 6921
																≦0.12			STA	1100	1170	4		ASTM Gr.19, β-C
	Ti-10V-2Fe-3Al				○*	2.6–3.4	9.0–11.0								1.6-2.2	≦0.13	≦0.05	≦0.05	STA	1103	1193	4	High strength and high toughness High fatigue strength Good hardenability	AMS4983, 4984, 4986, 4987
	Ti-15V-3Cr-3Sn-3Al		○*		○	2.5–3.5	14.0–16.0		2.5–3.5		2.5–3.5				≦0.25	≦0.13	≦0.05	≦0.05	ST	689	703	12	Good Cold formability Good age hardenability	AMS4914* JIS 1736
																			STA	965	1100	7		
Company standard product	Super-TIX™800		○		○										0.50–1.50	0.25–0.45	≦0.02	≦0.08	Annealing	550	700	10	High strength between Class 61 (Gr. 9) and Class 60 (Gr. 5)	Original
	Super-TIX™800N	○													0.50–1.50	0.20–0.40	0.02–0.05	≦0.08	Annealing	550	700	10	High strength between Class 61 (Gr. 9) and Class 60 (Gr. 5)	Original
	Super-TIX™51AF(Ti-5Al-1Fe)		○		○	4.50–5.50									0.50–1.50	≦0.25	≦0.05	≦0.08	Annealing	700	800	10	High strength comparable to Class 60 (Gr. 5)	Original
	Super-TIX®523AFM(Ti-5Al-2Fe-3Mo)				○	4.50–5.50		2.5–3.5							1.50–2.50	≦0.25	≦0.05	≦0.08	Annealing	870	950	10	Strength superior to Class 60 (Gr. 5)	Original
	Super-TIX™05CU(Ti-0.5Cu)	○											0.40–0.70		≦0.20	≦0.18	≦0.03	≦0.08	Annealing	165	270	27	Homogeneous structure	Original
	Super-TIX™10CU(Ti-1Cu)		○	○									0.80–1.20		≦0.20	≦0.15	≦0.03	≦0.08	Annealing	270	360	35	Good heat resistance	Original
	Super-TIX™10CUNB(Ti-1Cu-0.5Nb)		○	○									0.80–1.20	0.40–0.60	≦0.20	≦0.15	≦0.03	≦0.08	Annealing	270	360	35	Good heat resistance	Original
	Super-TIX™10CSSN(Ti-1Cu-1Sn-0.35Si-0.25Nb)		○	○							0.90–1.20	0.10–0.50	0.80–1.20	0.20–0.50	≦0.20	≦0.15	≦0.03	≦0.08	Annealing	270	395	20	Good heat resistance	Original
	Ti-3Al-5V		○	○*		2.50–3.50	4.50–5.50								≦0.20	≦0.12	≦0.05	≦0.08	Annealing	670	810	10	Good cold formability	Original
	Ti-20V-4Al-1Sn		○		○	3.0–3.6	19.0–22.5				0.80–1.20				≦0.20	≦0.20	≦0.05	≦0.08	ST	600	630	15	Good cold formability	Original
																			STA	950	1050	10		

*: Please consult us when placing an order.

*ST : Solution treatment STA : Solution treatment + aging

Technical Data

Physical Properties

The advantageous physical properties of pure titanium are as follows.

①Light weight 【Specific gravity】(60% of specific gravity of steel and about 1.7 times that of aluminum)
②Low thermal expansion 【Hermal expansion coefficient】(ne-half that of 18-8 stainless steel and one-third that of aluminum)
③Low hear conductivity 【Heat conductivity】(nearly the same as 18-8 stainless steel)
④Low electric conductivity 【Electric conductivity】(about 3% of copper)
⑤High flexibility 【Longitudinal elastic modulus】(one-half of iron or stainless steel and the same as copper)
⑥6 Non-magnetism 【Magnetic permeability】(non-magnetic material; magnetic permeability = 1.0001)

Comparison of physical properties between titanium and other metallic materials

Item	Atomic number	Atomic weight	Specific gravity	Melting point (℃)	Linear expansion coefficient (/K)	Specific heat (KJ/Kg·K)	Thermal conductivity (w/m·K)	Specific resistivity (μΩ·m)	Electric conductivity (% ratio to copper)	Young's modulus (GPa)
Titanium	22	47.90	4.51	1668	8.4×10^{-6}	0.519	17	0.55	3.1	106.3
titanium alloy Ti-6Al-4V	—	—	4.43	1650	8.8×10^{-6}	0.610	7.5	1.71	1.1	110
Iron	26	55.85	7.9	1530	12×10^{-6}	0.460	63	0.097	18	205.8
18-8stainless steel (SUS 304)	—	—	7.9	1400 ~1420	17×10^{-6}	0.502	16	0.72	2.4	199.9
Aluminum	13	26.97	2.7	650	23×10^{-6}	0.879	205	0.027	64	69.1
Aluminum alloy (7075)	—	—	2.8	476 ~638	23×10^{-6}	0.962	121	0.058	30	71.5
Magnesium	12	24.32	1.7	650	25×10^{-6}	1.004	159	0.043	40	44.8
Nickel	28	58.69	8.9	1453	15×10^{-6}	0.460	92	0.095	18	205.8
Hastelloy C	—	—	8.9	1305	11.3×10^{-6}	0.385	13	1.3	1.3	204.4
Copper	29	63.57	8.9	1,083	17×10^{-6}	0.385	385	0.017	100	107.8

Note) 18-8 stainless steel : Cr(18%)-Ni(8%)-Fe(R)
Aluminum alloy 7075 : Super-super duralumin
[Cu(1.6%)-Mg(2.5%)-Cr(2.3%-Zn(5.6%)-Al(R) subjected to solution heat treatment and aging)
Hastelloy C : 54Ni-17Mo-15Cr-5Fe-4W

■ Properties other than those shown above
Crystal structure
α titanium (885℃ or lower) : Close-packed hexagonal lattice
β titanium (above 885℃) : Body-centered cubic lattice
Latent heat of fusion : 60.7 J/g, relative magnetic permeability : 1.0001 (Source: Japan Titanium Society)

Corrosion Resistance

Comparison of corrosion resistance between titanium and other metallic materials

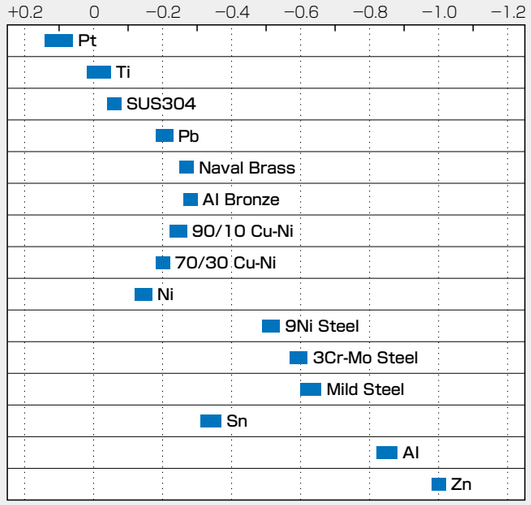
Corroding medium	Composition (%)	Temperature (℃)	Corrosion resistance: Titanium	18-8 stainless steel	Hastelloy C
Hydrochloric acid	10	24	○	×	◎
	30	24	×	×	◎
	10	80	×	–	○
	30	80	×	–	△
Sulfuric acid	10	24	△	–	◎
	50	24	×	×	◎
	10	100	×	–	◎
	50	100	×	–	◎
Nitric acid	10	24	◎	◎	◎
	50	24	◎	◎	–
	10	100	◎	◎	△
	50	100	◎	○	–
Aqua regia	$HCl{:}HNO_3$ 3 : 1	24	◎	×	△
		100	○	–	–
Chromic acid	5	24	◎	–	◎
Hydrogen fluoride	5	30	×	×	△
Phosphoric acid	10(with aeration)	24	○	◎	◎
	50(with aeration)	24	△	◎	◎
	10(with aeration)	100	×	◎	◎
	50(with aeration)	100	×	○	◎
Ferric chloride	10	24	◎	×	◎
	30	24	◎	×	◎
	10	100	◎	–	×
	30	100	◎	–	×
Cupric chloride	10	24	○	×	○
	30	24	○	×	○
	10	100	○	–	–
	30	100	○	–	–
Sodium chloride	10	24	◎	○	○
	40	24	◎	○	○
	10	100	◎*	○*	○
	40	100	◎*	○*	○
Calcium chloride	10	24	◎	◎	◎
	50	24	◎	○	◎
	10	100	◎*	–	◎
	50	100	◎*	×	◎
Ammonium chloride	10	24	◎	△	◎
	40	24	◎	–	◎
	10	100	◎*	–	◎
	40	100	◎*	–	◎
Magnesium chloride	10	24	◎	△	◎
	40	24	◎	○	◎
	10	100	◎*	△*	◎
	40	100	◎*	–	◎
Ferrous sulfate	10	24	◎	○	○
	50	24	◎	○	○
	10	100	◎	○	○
	50	100	◎	–	○

Corroding medium	Composition (%)	Temperature (℃)	Corrosion resistance: Titanium	18-8 stainless steel	Hastelloy C
Ammonia	10	24	◎	◎	◎
	30	24	◎	◎	◎
	10	80	◎	○	○
	30	80	◎	○	◎
Caustic soda	10	24	◎	◎	◎
	50	24	◎	◎	–
	10	100	◎	◎	◎
	50	100	○	○	◎
Carbonic soda	10	24	◎	◎	◎
	30	24	–	–	–
	10	100	◎	◎	◎
	30	100	◎	◎	◎
Hydrogen sulfide	Dry gas	24	◎	△	◎
	Wet gas	24	◎	○	○
Chlorine	Dry gas	24	×	–	◎
	Wet gas	24	◎	–	△
	Dry gas	100	–	◎	○
	Wet gas	90	◎	–	△
Sulfur dioxide	Dry gas	30~60	◎	–	–
	Wet gas	30~90	◎	–	–
Seawater	Rapidly flowing water	24	◎	–	–
	Still water	100	◎*	–	◎
Acetic acid	10	24	◎	◎	◎
	60	24	◎	◎	◎
	10	100	◎	◎	◎
	60	100	◎	○	◎
Formic acid	10	24	○	○	◎
	50	24	○	○	◎
	10	100	○	×	◎
	30	100	×	×	◎
Lactic acid	10	24	◎	○	○
	50	24	◎	○	◎
	10	100	◎	○	○
	50	100	◎	×	○
Oxalic acid	10	24	○	○	○
	20	52	×	–	○
	50	24	–	○	○
	10	100	–	–	○
	50	100	–	×	○
Citric acid	10	24	◎	○	◎
	50	24	◎	○	◎
	10	100	◎	○	◎
	50	100	×	×	◎

Note) *There are cases in which pitting or other local corrosion occurs with the material.
Corrosion rate ◎ : <0.127 ○ : <0.127~0.508
△ : 0.508~1.27 × : >1.27mm/year
(Source: Japan Titanium Society)

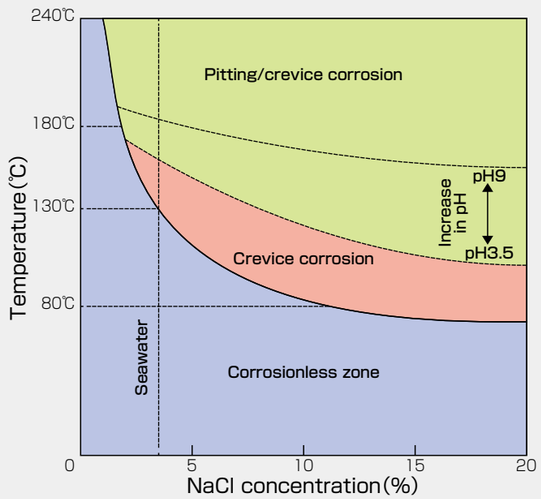
Corrosion Resistance in Seawater

Corrosion potential in seawater (flowing water)



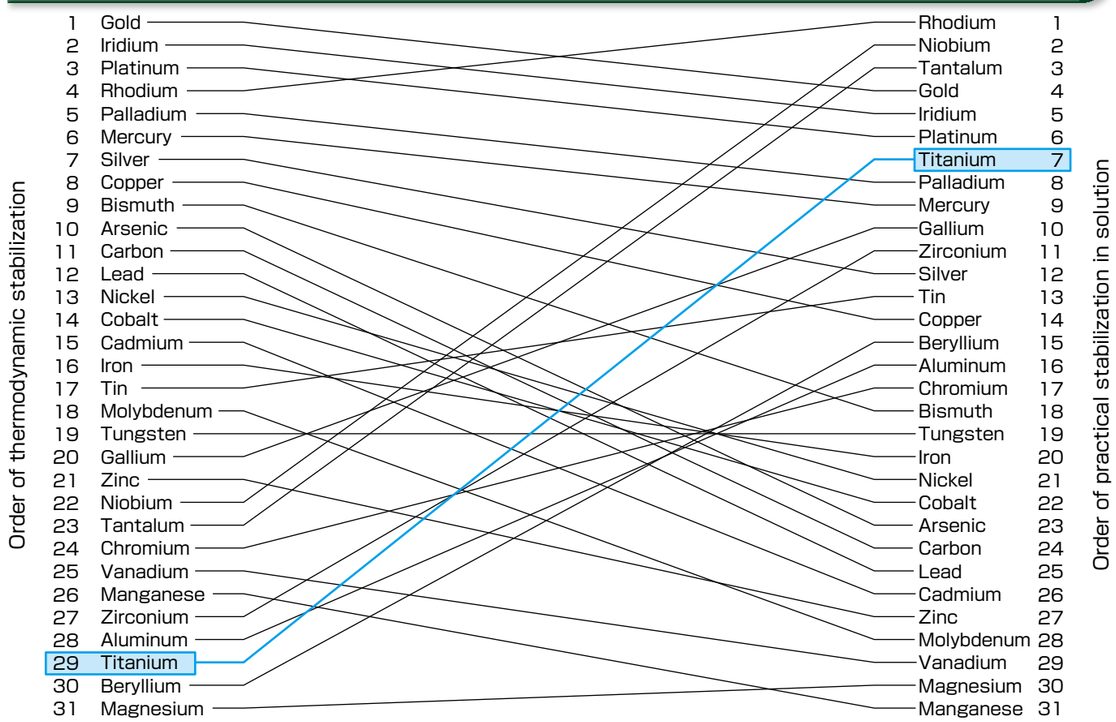
Use of Sumitomo Metal's brochure : Since 2007

Influences of temperature, concentration and pH on pitting/crevice corrosion of commercially pure titanium in salty water



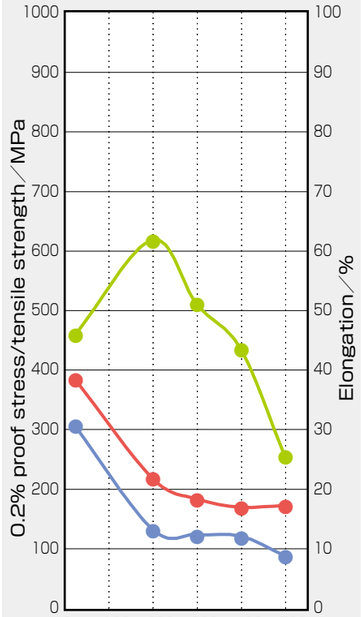
Use of Sumitomo Metal's brochure : Since 2007

Orders of Stabilization of Metals

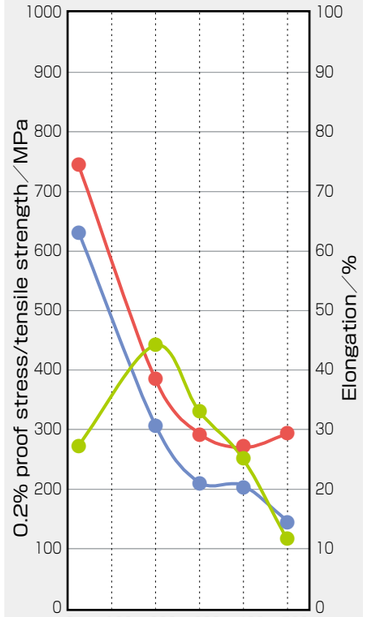


Tensile Properties in High Temperature

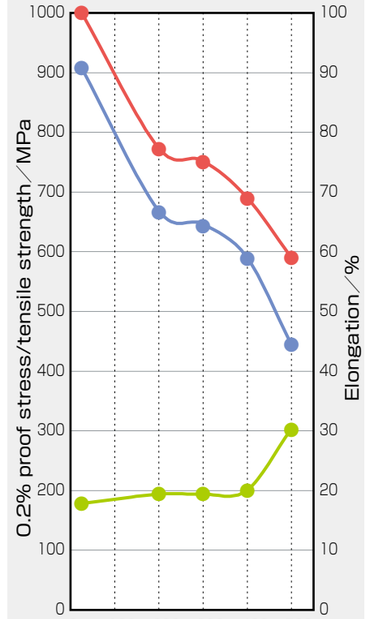
Commercially pure titanium Class 2



Commercially pure titanium Class 4



Ti-6Al-4V Titanium Alloy



0.2% proof stress　Tensile strength　Elongation

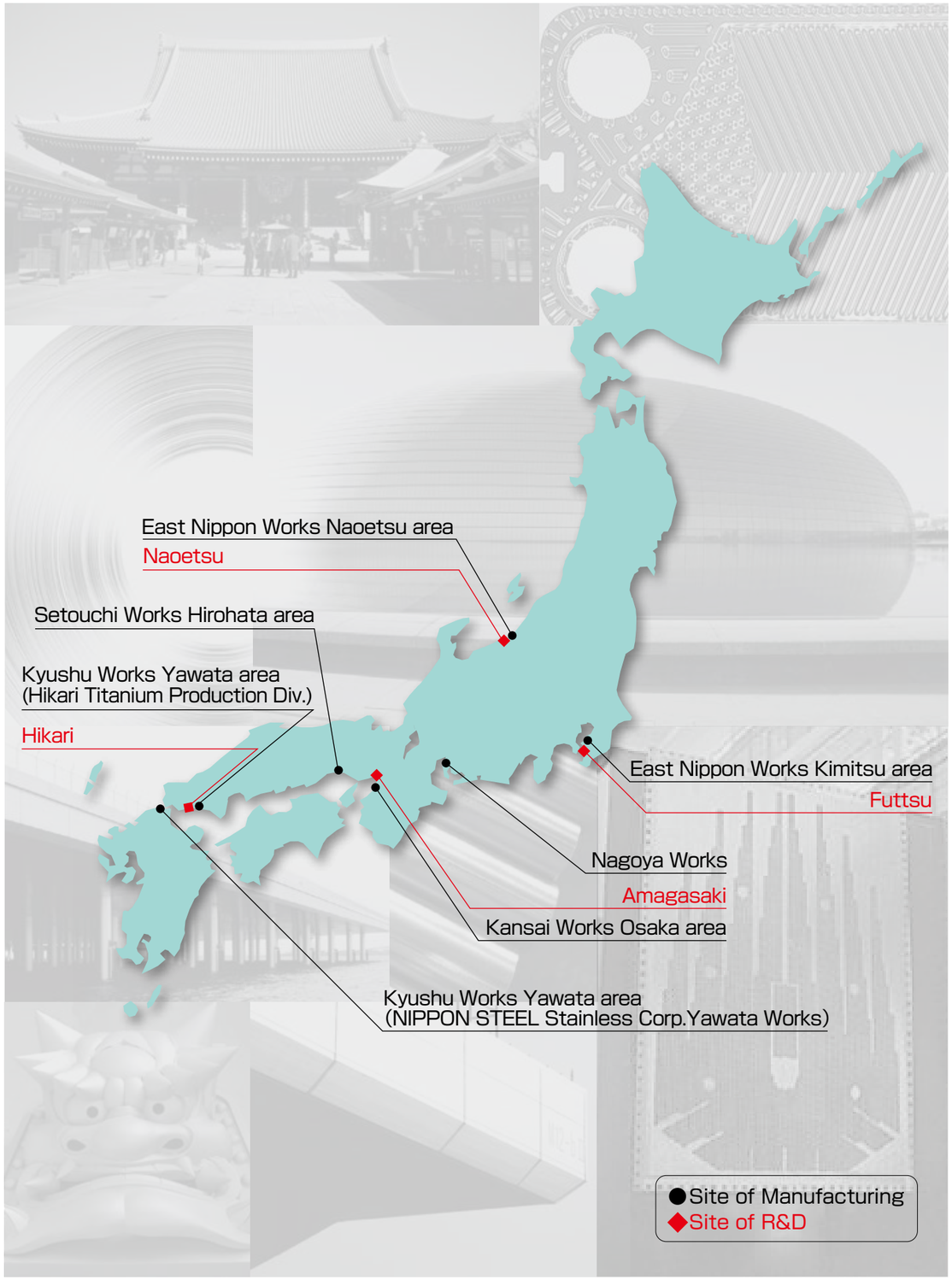
Clarke Number (Note)

Rank	Element		Proportion of existence(%)	Cumulative total
1	Oxygen	O	49.50	49.5
2	Silicon	Si	25.80	75.3
3	Aluminum	Al	7.56	82.9
4	Iron	Fe	4.70	87.6
5	Calcium	Ca	3.39	91.0
6	Sodium	Na	2.63	93.6
7	Potassium	K	2.40	96.0
8	Magnesium	Mg	1.93	97.9
9	Hydrogen	H	0.87	98.8
10	Titanium	Ti	0.46	99.2
11	Chlorine	Cl	0.19	99.4
12	Manganese	Mn	0.09	99.5
13	Phosphorus	P	0.08	99.6
14	Carbon	C	0.08	99.7
15	Sulfur	S	0.06	99.7

Rank	Element		Proportion of existence(%)	Cumulative total
16	Nitrogen	N	0.03	99.8
17	Fluorine	F	0.03	99.8
18	Rubidium	Rb	0.03	99.8
19	Barium	Ba	0.02	99.9
20	Zirconium	Zr	0.02	
21	Chromium	Cr	0.02	
22	Strontium	Sr	0.02	
23	Vanadium	V	0.015	
24	Nickel	Ni	0.010	
25	Copper	Cu	0.010	
26	Tungsten	W	0.006	
27	Lithium	Li	0.006	
28	Cerium	Ce	0.005	
29	Cobalt	Co	0.004	
30	Tin	Sn	0.004	

Note) Clarke Number is defined as orders in composition of element to be existing in upper crust of the earth. (Source: Kagaku Daijiten(Chemical Encyclopedia))
Titanium is the 4th most abundant of practical metals existing in upper crust of the earth, following Aluminum, Iron and Magnesium.

Sites of Manufacturing and Researching



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