



SANDVIK Ti GRADE 2 TUBE AND PIPE, SEAMLESS

DATASHEET

Sandvik Ti Grade 2 is a Commercially Pure (CP) titanium seamless tubing characterized by:

- Excellent resistance to general corrosion in seawater
- Resistant to stress corrosion cracking in chloride and sour gas environments
- Excellent resistance to pitting, crevice, and erosion corrosion
- High heat transfer efficiency
- Good formability and weldability
- Very low thermal expansion
- Moderate strength

STANDARDS

- ASTM: Grade 2
- UNS: R50400

CHEMICAL COMPOSITION (NOMINAL)

Chemical composition (nominal) %

N	H	O	Fe	C
≤0.03	≤0.015	≤0.25	0.30	0.08

APPLICATIONS

Commercially Pure Ti Grade 2 titanium tubing provides excellent service in aggressive chloride-containing environments. The excellent mechanical, physical, and corrosion resistance properties of this grade make it an economical choice for many applications by reducing the product life cycle costs of equipment. Typical applications include:

Oil and gas industry

Chloride environments such as seawater handling and process systems and hydraulic and process fluid tubes in umbilicals.

Seawater cooling

Tubing for heat exchangers and coolers on oil platforms, in refineries, chemical industries, process industries, and other industries using seawater or chlorinated seawater as coolant.

Refineries and petrochemical plants

Heat exchangers and condensers where the process environment contains chlorides, sulfides, organics, organic acids, nitric acid, or wet chlorine.

Geothermal wells

Heat exchangers in geothermal exploitation units, systems exposed to geothermal or high-salinity brines, tubing, and casing for production.

Pulp and paper industry

Tubing for chloride-containing bleaching environments.

Desalination plants

Tube and pipe for seawater transport, heat exchanger tubing, and pressure vessels for reverse osmosis units.

CORROSION RESISTANCE

Titanium should not be used with strong reducing acids, fluoride solutions, pure oxygen, or anhydrous chlorine.

General corrosion

The general corrosion rates for Grade 2 titanium in a variety of media are shown in Table 1. CP titanium exhibits good corrosion resistance to a wide variety of environments including:

- Seawater and brines
- Inorganic salts
- Moist chlorine gas
- Alkaline solutions
- Oxidizing acids
- Organics and organic acids
- Sulfur compounds

Titanium corrosion rate data				C=Concentration % T = Temperature °F (°C) R = Corrosion rate, mpy (mm/year)			
Commercially pure grades							
Media	C	T	R	Media	C	T	R
Acetaldehyde	75	300 (149)	0.02(0.001)	Barium chloride	25	212 (100)	nil
	100	300 (149)	nil	Barium hydroxide	saturated	room	nil
Acetic acid	5 to 99.7	255 (124)	nil	Barium nitrate	10	room	nil
Acetic anhydride	99.5	boiling	0.5 (0.013)	Barium fluoride	saturated	room	nil
Acidic gases	-	100-500 (38-260)	<1.0 (<0.025)	Benzoic acid	saturated	room	nil
containing CO ₂ , H ₂ O, Cl ₂ , SO ₂ , SO ₃ , H ₂ O, O ₂ , NH ₃				Boric acid	saturated	room	nil
Adipic acid	67	450 (232)	nil	Boric acid	10	boiling	nil
Aluminium chloride, aerated	10	212 (100)	0.09 (0.002)*	Bromine	liquid	86 (30)	rapid
Aluminium chloride, aerated	25	212 (100)	124 (3.15)*	Bromine moist vapor	86 (30)	86 (30)	<0.1 (<0.003)
Aluminium fluoride	saturated	room	nil	N-butylric acid	undiluted	room	nil
Aluminium nitrate	saturated	room	nil	Calcium bisulfite	cooking liquor	79 (26)	0.02 (0.001)
Aluminium sulfate	saturated	room	nil	Calcium carbonate	saturated	boiling	nil
Aluminium acid phosphate	10	room	nil	Calcium chloride	5	212 (100)	0.02 (0.005)*
Ammonia anhydrous	100	104 (40)	<5.0 (<0.127)	Calcium chloride	10	212 (100)	0.29 (0.007)*
Ammonium acetate	10	room	nil	Calcium chloride	55	220 (104)	0.02 (0.001)*
Ammonium bicarbonate	50	212 (100)	nil	Calcium hydroxide	saturated	boiling	nil
Ammonium bisulfite pH 2.05	spent pulping liquor	159 (71)	0.6 (0.015)	Calcium hypochlorite	6	212 (100)	0.05 (0.001)
Ammonium chloride	saturated	212 (100)	<0.5 (<0.013)	Calcium hypochlorite	18	70 (21)	nil
Ammonium hydroxide	28	room	0.1 (0.003)	Calcium hypochlorite	saturated	-	nil
Ammonium nitrate	28	boiling	nil	Carbon dioxide	100	-	excellent
Ammonium nitrate+ 1% nitric acid	28	boiling	nil	Carbon tetrachloride	vapor & liquid	boiling	nil
Ammonium sulfate	10	212 (100)	nil	Chlorine gas, wet >0.7 H ₂ O	room	room	nil
Aqua regia	3:1	room	nil	Chlorine gas, wet >1.5 H ₂ O	392 (200)	392 (200)	nil
Aqua regia	3:1	175 (79)	34.8 (0.884)	Chlorine header sludge and wet chlorine	-	207 (97)	0.03 (0.001)
				Chlorine gas, dry <0.5 H ₂ O	room	room	may react
				Chlorine dioxide in steam	5	210 (99)	nil
				Chlorine trifluoride	100	<86 (30)	vigorous reaction Cont.

*May corrode in crevice

"Titanium, The Choice", Titanium Development Association, 1990.

Media	C	T	R	Media	C	T	R
Chloroacetic acid	100	boiling	<5.0(<0.127)	Linseed oil, boiled	-	room	nil
Chlorosulfonic acid	100	room	7.5-12.3 (0.191-0.312)	Lithium chloride	50	300 (149)	nil**
Chloroform	vapor & liquid	boiling	0.01 (0.000)	Magnesium chloride	5-40	boiling	nil*
Chromic acid	10	boiling	0.1 (0.003)	Magnesium hydroxide	saturated	room	nil
Chromic acid	50	180 (82)	1.1 (0.028)	Magnesium sulfate	saturated	room	nil
Chromic acid + 5% nitric acid	5	70 (21)	<0.1 (<0.003)	Manganous chloride	5-20	212 (100)	nil
Citric acid	50	140 (60)	0.01 (0.000)	Maleic acid	18-20	95 (35)	0.6 (0.002)
Citric acid	50	212 (100)	<5.0(<0.127)	Mercuric chloride	saturated	212 (100)	<5 (<0.127)
Citric acid	aerated			Mercuric cyanide	saturated	room	nil
Citric acid	50	boiling	5.50 (0.127-1.27)	Methyl alcohol	91	95 (35)	nil
Cupric chloride	40	boiling	0.2 (0.005)	Nickel chloride	20	212 (100)	0.11 (0.003)
Cupric chloride	55	246 (119) (boiling)	0.1 (0.003)	Nitric acid, aerated	50	room	0.08 (0.002)
Cupric cyanide	saturated	room	nil	Nitric acid, aerated	70	Room	0.18 (0.005)
Cuprous chloride	50	194 (90)	<0.1 (<0.003)	Nitric acid, aerated	10	104 (40)	0.10 (0.003)
Cyclohexane	-	302 (150)	0.1 (0.003)	Nitric acid, aerated	70	158 (70)	1.56 (0.040)
Dichloroacetic acid	100	boiling	0.29 (0.007)	Nitric acid, aerated	40	392 (200)	24 (0.610)
Dichlorobenzene + 4-5% HCl	-	355 (179)	4 (0.102)	Nitric acid, aerated	20	554 (290)	12 (0.305)
Diethylene triamine	100	room	nil	Nitric acid, non-aerated	70	176 (80)	1-3 (0.025-0.076)
Ethyl alcohol	95	boiling	0.5(0.013)	Nitric acid	17	boiling	3-4 (0.076-0.102)
Ethylene dichloride	100	boiling	0.2-5.0 (0.005-0.127)	Nitric acid	35	boiling	5-20 (0.127-0.508)
Ethylene diamine	100	room	nil	Nitric acid	70	boiling	2.5-37 (0.064-0.940)
Ferric chloride	10-20	room	nil	Nitric acid	-	room	0.1 (0.003)
Ferric chloride	10-50	boiling	nil	white fuming		360 (160)	<5.0(<0.127)
Ferric chloride	50	302 (150)	0.1 (0.003)	Nitric acid	<about	room	ignition
Ferric sulfate	10	room	nil	red fuming	2% H ₂ O		sensitive
Fluoboric acid	5-20	elevated	rapid	Nitric acid	>about	room	not ignition
Fluorosilicic	10	room	1870 (47.5)	red fuming	2% H ₂ O		sensitive
Food products	-	ambient	no attack	Nitric acid + 10% Na ₂ CO ₃	40	boiling	4.8-7.4 (0.122-0.188)
Formaldehyde	37	boiling	nil	Nitric acid + 10% Na ₂ CO ₃	40	boiling	0.12-1.40 (0.003-0.036)
Formic acid aerated	25	212 (100)	0.04(0.001)**	Oil well crudes	-	ambient	0.26-23.2 (0.007-0.589)
Formic acid aerated	90	212 (100)	0.05 (0.001)**	Oxalic acid	1	boiling	4247 (107.9)
Formic acid non-aerated	25	212 (100)	96 (2.44)**	Oxalic acid	25	140 (60)	470 (11.9)
Furfural	100	room	nil	Phenol	saturated solution	70 (21)	4.0(0.102)
Glucosic acid	50	room	nil	Phosphoric acid	10-30	room	0.8-2 (0.020-0.051)
Glycerin	-	room	nil	Phosphoric acid	30-80	room	2-30 (0.051-0.762)
Hydrogen chloride	dry gas	ambient	nil	Phosphoric acid	1	boiling	10 (0.254)
Hydrochloric acid	1	boiling	>100 (>2.54)	Phosphoric acid + 3% nitric acid	81	190 (88)	15 (0.381)
Hydrochloric acid chlorine saturated	5	boiling	400 (10.2)	Phosphorous	100	room	0.14 (0.004)
+ 5% HNO ₃	5	200 (93)	1.2(0.030)	Phosphorous trichloride	saturated	room	nil
+ 5% HNO ₃	1	boiling	2.9 (0.074)	Pthalic acid	saturated	room	nil
+ 0.5% CrO ₃	5	200 (93)	1.2 (0.031)	Potassium bromide	saturated	room	nil
+ 1% CrO ₃	5	100 (38)	0.72 (0.018)	Potassium chloride	saturated	room	nil
+ 0.05% CuSO ₄	5	200 (93)	3.6 (0.091)	Potassium ferricyanide	saturated	room	nil
+ 0.5% CuSO ₄	5	200 (93)	2.4 (0.061)	Potassium hydroxide	50	80 (29)	0.4 (0.010)
+ 0.5% CuSO ₄	5	boiling	3.3 (0.084)	Potassium hydroxide	10	boiling	<5.0(<0.127)
Hydrofluoric acid	1.48	room	rapid	Potassium hydroxide	25	boiling	12 (0.305)
Hydrogen peroxide	6	room	<5 (<0.127)	Potassium sulfate	10	room	nil
Hydrogen peroxide	30	room	<12 (<0.305)	Potassium thiosulfate	1	-	nil
Hydrogen sulfide	7.65, moist	200-230 (93-110)	nil	Salicylic acid (Na salt)	saturated	room	nil
Hypochlorous acid + ClO ₂ and Cl ₂	17	100 (38)	0.001 (0.000)	Seawater	-	76 (24)	nil
Iodine in water + Potassium Iodide	-	room	nil	Sebacic acid	-	464 (240)	0.3 (0.008)
Lactic acid	10-85	212 (100)	<5.0(<0.127)	Silver nitrate	50	room	nil
Lead acetate	saturated	room	nil	Sodium acetate	saturated	room	nil

Cont.

Media	C	T	R	Media	C	T	R
Sodium aluminate	25	boiling	3.6 (0.091)	Sulfuric acid, aerated	3	140 (60)	0.5 (0.013)
Sodium bifluoride	saturated	room	rapid		5	140 (60)	190 (4.83)
Sodium bisulfate	saturated	room	nil		3	212 (100)	920 (23.4)
Sodium bisulfate	10	150 (66)	72 (1.83)		concentrated	room	62 (1.57)
Sodium chloride	23	boiling	nil*	Sulfuric acid	1	boiling	700 (17.8)
pH 1.5				Sulfuric acid	5	200 (93)	nil
Sodium chloride	23	boiling	28 (0.711)*	+0.25% CuSO ₄			
pH 1.2				+ 0.25% CuSO ₄	30	100 (38)	2.4(0.061)
Sodium chloride	23	boiling	nil*	+ 0.5% CrO ₃	30	200 (93)	nil
pH 1.2 some dissolved chlorine				+ 1.0% CuSO ₄	30	boiling	65 (1.65)
Sodium citrate	saturated	room	nil	Sulfuric acid vapors	96	150 (66)	nil
Sodium cyanide	saturated	room	nil	Sulfuric acid			
Sodium dichromate	saturated	room	nil	+ 10% HNO ₃	90	room	18 (0.457)
Sodium fluoride	saturated	room	0.3 (0.008)	+ 70% HNO ₃	30	room	4.0(0.102)
Sodium bisulfite	25	boiling	nil	+ 90% HNO ₃	10	room	nil
Sodium carbonate	25	boiling	nil	Sulfuric acid saturated	62	60 (16)	0.07 (0.002)
Sodium chlorate	saturated	room	nil	with chlorine			
Sodium hydroxide	5-30	70 (21)	>0.12 (>0.001)	Sulfuric acid saturated	5	374 (190)	<1 (<0.025)
Sodium hydroxide	10	boiling	0.84 (0.021)	with chlorine			
Sodium hydroxide	40	176 (80)	5.0 (0.127)	Sulfuric acid+	40	212 (100)	passive
Sodium hydroxide	50	135 (57)	0.5(0.127)	4.79 g/l Ti+ ⁴			
Sodium hydroxide	73	265 (129)	7.0(0.178)	Sulfurous acid	6	room	nil
Sodium hydroxide	50-73	370 (188)	>43 (>1.09)	Tannic acid	25	212 (100)	nil
Sodium hypochlorite	6	room	nil	Tartaric acid	10-50	212 (100)	<5(<0.127)
Sodium nitrate	saturated	room	nil	Terephthalic acid	77	425 (218)	nil
Sodium phosphate	saturated	room	nil	Tetrachloroethalene,	100	boiling	0.02 (0.001)
Sodium silicate	25	boiling	nil	liquid and vapor			
Sodium sulfate	10-20	boiling	nil	Tetrachloroethylene +	-	boiling	5(0.127)
Sodium sulfide	saturated	room	nil	H ₂ O			
Sodium sulfite	saturated	boiling	nil	Tetrachloroethylene	100	boiling	nil
Sodium thiosulfate	25	boiling	nil	Titanium tetrachloride	99.8	572 (300)	62 (1.57)
Soils, corrosive	-	ambient	nil	Titanium tetrachloride	concentrated	room	nil
Stannic chloride	24	boiling	1.76 (0.045)	Trichloroacetic acid	100	boiling	573 (14.6)
Stannic chloride	saturated	room	nil	Trichloroethylene	99	boiling	0.1-5
Steam+ air	-	180 (82)	0.01 (0.000)				(0.003-0.127)
Succinic acid	100	365 (185)	nil	Urea + 32% ammonia	28	360 (182)	3.1 (0.079)
Sulfamic acid	3.75 g/l	boiling	nil	+ 20.5% H ₂ O, 19% CO ₂			
Sulfamic acid	7.5 g/l	boiling	108 (2.74)	Water, degassed	-	600 (316)	nil
Sulfamic acid +	7.5 g/l	boiling	1.2 (0.030)	X-ray developer	-	room	nil
.375 g/FeC ₂				solution			
Sulfur dioxide,	near 100	room	0.1 (0.003)	Zinc chloride	20	220 (104)	nil*
water saturated				Zinc chloride	50	302 (150)	nil*
Sulfur dioxide gas +	18	600 (316)	0.2 (0.006)	Zinc chloride	75	392 (200)	24 (0.610)*
small amount SO ₂							
and approx 3% O ₂							

Crevice corrosion

CP titanium exhibits good resistance to crevice corrosion in salt solutions compared to stainless steels. CP titanium will not exhibit crevice corrosion at temperatures under 80 °C (176°F) regardless of pH, even under super chlorinated conditions.

Stress corrosion cracking

Grade 2 titanium shows excellent resistance to stress corrosion (SCC) cracking in hot chloride solutions and is immune to sec in seawater.

Erosion corrosion

Titanium shows excellent resistance to erosion in flowing seawater with velocities up to 130 ft/sec (40 m/sec) showing negligible effect on the material. The presence of abrasive particles, such as sand, has only a small effect on corrosion.

Hydrogen embrittlement

There is no significant absorption of hydrogen into titanium exposed to seawater, even at higher temperatures. Normally hydrogen absorption occurs only when the three following conditions are met:

1. pH is < 3 or > 12
2. Temperature is above 176F (80C)

3. A mechanism exists for hydrogen generation such as a galvanic couple or impressed current.

Bio-corrosion

Titanium alloys have demonstrated a unique immunity to all forms of microbiologically influenced corrosion. Since titanium alloys do not display any toxicity toward marine organisms, biofouling can occur in seawater. This can be minimized by chlorination or by increasing the water velocity through the heat exchanger.

Corrosion fatigue

Titanium, unlike many other materials, does not show a decrease in fatigue performance in the presence of seawater. Both fatigue endurance limits and fatigue crack growth rates are the same whether tested in air or seawater.

Galvanic corrosion

In the galvanic series, titanium is towards the noble end near stainless steels, and will normally act as the cathode when coupled with other metals. The titanium will therefore not be affected by galvanic corrosion but can accelerate corrosion of the other metal. Coupling of titanium with more noble metals, such as graphite, only enhances titanium's passivity.

FABRICATION

Bending

Titanium tubing can be bent at room temperature using standard bend tooling and techniques. When bending thin walled tubing or if a tight bend radius is needed, a mandrel should be used for adequate support of the ID. The mandrel should be well lubricated in order to prevent galling of the ID surface. Due to the moderate strength and low modulus of this alloy, springback is about twice that of stainless steel and must be taken into account.

Roller expansion

Titanium tubing can be roller expanded into tube sheets similar to other tubing materials. The suggested wall reduction for titanium is 10% to provide optimum pull out strength.

Machining and cutting

Machining and cutting titanium tubing is routine when the following procedures are used:

- Use low cutting speeds and high feed rates
- Use large volumes of coolant
- Use sharp tools and replace as soon as worn
- Never stop feeding while tool is in contact with workpiece

TUBING AND PIPE SPECIFICATIONS

ASTM B337: Seamless and welded pipe

ASTM B338: Seamless and welded tubing

ASME SB338: Seamless and welded tubing

AMS 4943: Aerospace hydraulic tubing, annealed

AMS 4944/4945: Aerospace hydraulic tubing, cold worked and stress relieved

DIN/VD/TUV 230/2: Seamless tube and pipe

Approved by the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, Section VIII, Div. 1, Case 2081

SIZES AND SURFACE CONDITIONS

Tube and pipe are supplied in the cold reduced or cold reduced and annealed condition. Tubing can be delivered in the following surface conditions: as cold pilgered, acid etched, or belt polished. The principal size range for seamless products is shown as the white area in figure 1.

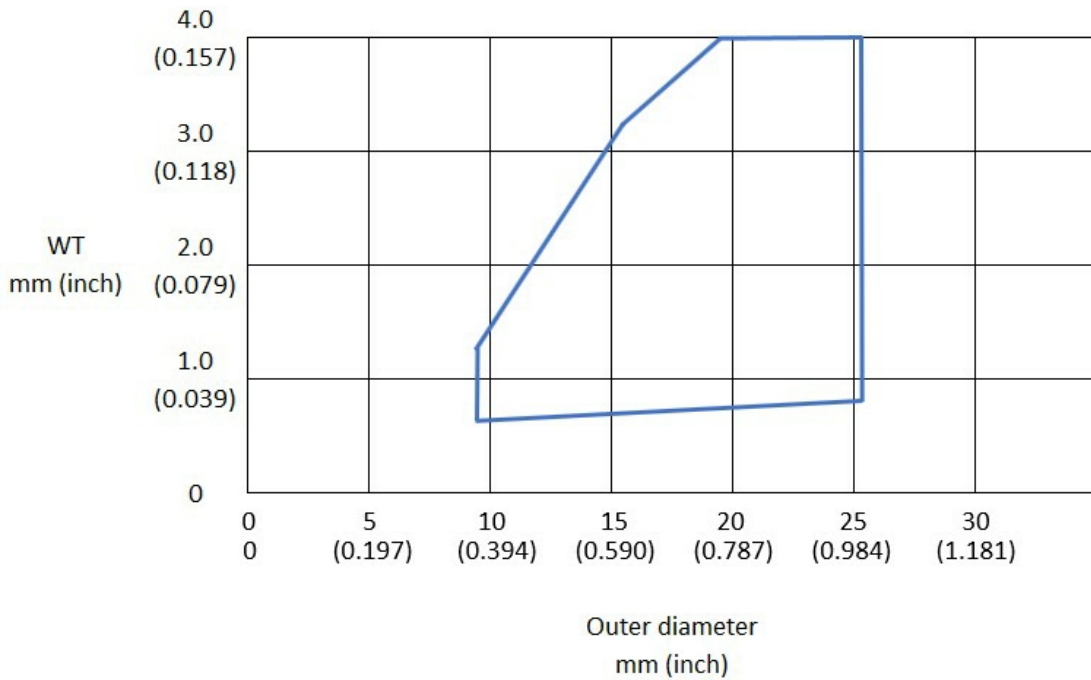


Figure 1 Principal size range for seamless tube and pipe.

OD	WT	L
9.50 - 24.4 mm	.07 - 4 mm	up to 17 m

Other dimensions can be quoted for special projects.

MECHANICAL PROPERTIES

Tensile properties for Grade 2 titanium, as specified by ASTM B338, shown below:

	Ultimate Strength		Yield strength		Elongation 2"
	ksi	MPa	ksi	MPa	%
Min	50	345	40	275	20
Max			65	450	10
Typical data		530		380	39

A comparison of the yield strength of CP Titanium Grade 2 with other corrosion resistant tubing alloys is shown in figure 3. *Min. 400 MPa for Titanium 2H

Hardness

92 HRB max.

PHYSICAL PROPERTIES

Density 0.162 lbs/in³, 4.51 g/cm³

CP titanium tubing is lighter than comparable steel products, as its density is 45% less than ferrous alloys. Light weight and moderate strength give this product advantages where a strength-to-weight ratio better than stainless steel or CuNi alloys is required.

Melting point

3020°F (1660°C)

Beta transus

1675F (913C)

Thermal Conductivity22 W/m°C (12.7 BTU) för RT
(Timet: 12,6 resp. 21,8. BPVC: 22-19.9 RT-200°C.)**Elastic modulus**

The elastic modulus of Cp titanium, as shown below, is roughly one-half that of steel alloys.

	psi	GPa
Tension (E)	15.0 x 10 ⁶	103

FATIGUE PERFORMANCE

Titanium, unlike many other materials, does not show a decrease in fatigue performance in the presence of seawater. Both fatigue endurance limits and fatigue crack growth rates are the same whether tested in air or seawater.

WELDABILITY

The weldability of CP titanium tubing is very good as long as the necessary precautions are taken. Due to the reactive nature of titanium inert gas shielding must be in place on both the OD and ID of the tubes. The material must be also free from any grease or oil contamination.

Manual or automatic TIG welding is regularly used to weld titanium tubing either with or without filler wire. A low heat input should be used to minimize the size of the heat-affected zone. No post-weld heat treatment is normally performed on titanium tubing.

Disclaimer: Recommendations are for guidance only, and the suitability of a material for a specific application can be confirmed only when we know the actual service conditions. Continuous development may necessitate changes in technical data without notice. This datasheet is only valid for Sandvik materials.