Alleima® Ti Grade 2

Tube and pipe, seamless

Datasheet

Alleima® 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

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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

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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

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Titanium corrosion rate data

Commercially pure grades

C=Concentration %
T = Temperature °F (°C)
R = Corrosion rate, mpy (mm/year)

Media	C	T	R
Acetaldehyde	75	300 (149)	0.02(0.001)
	100	300 (149)	nil
Acetic acid	5 to 99.7	255 (124)	nil
Acetic anhydride	99.5	boiling	0.5 (0.013)
Acidic gases containing CO_2, H_2O,Cl_2, SO_2, SO_3, H_2O,O_2, NH_3	–	100-500 (38-260)	<1.0 (<0.025)
Adipic acid	67	450 (232)	nil
Aluminium chloride, aerated	10	212 (100)	0.09 (0.002)*
Aluminium chloride, aerated	25	212 (100)	124 (3.15)*
Aluminium fluoride	saturated	room	nil
Aluminium nitrate	saturated	room	nil
Aluminium sulfate	saturated	room	nil
Aluminium acid phosphate	10	room	nil
Ammonia anhydrous	100	104 (40)	<5.0(<0.127)
Ammonium acetate	10	room	nil
Ammonium bicarbonate	50	212 (100)	nil
Ammonium bisulfite pH 2.05	spent pulping liquor	159 (71)	0.6 (0.015)
Ammonium chloride	saturated	212 (100)	<0.5 (<0.013)
Ammonium hydroxide	28	room	0.1 (0.003)
Ammonium nitrate	28	boiling	nil
Ammonium nitrate+ 1% nitric acid	28	boiling	nil
Ammonium sulfate	10	212 (100)	nil
Aqua regia	3:1	room	nil
Aqua regia	3:1	175 (79)	34.8 (0.884)
Barium chloride	25	212 (100)	nil
Barium hydroxide	saturated	room	nil
Barium nitrate	10	room	nil
Barium fluoride	saturated	room	nil
Benzoic acid	saturated	room	nil
Boric acid	saturated	room	nil
Boric acid	10	boiling	nil
Bomine	liquid	86 (30)	rapid)
Bromine moist	vapor	86 (30)	<0.1 (<0.003)
N-butyric acid	undiluted	room	nil
Calcium bisulfite	cooking liquor	79 (26)	0.02 (0.001)
Calcium carbonate	saturated	boiling	nil
Calcium chloride	5	212 (100)	0.02 (0.005)*
Calcium chloride	10	212 (100)	0.29 (0.007)*
Calcium chloride	55	220 (104)	0.02 (0.001)*
Calcium hydroxide	saturated	boiling	nil
Calcium hypochlorite	6	212 (100)	0.05 (0.001)
Calcium hypochlorite	18	70 (21)	nil
Calcium hypochlorite	saturated slurry	–	nil
Carbon dioxide	100	–	excellent
Carbon tetrachloride	vapor & liquid	boiling	nil
Chlorine gas, wet	>0.7 H_2O	room	nil
Chlorine gas, wet	>1.5 H_2O	392 (200)	nil
Chlorine header sludge and wet chlorine	–	207 (97)	0.03 (0.001)
Chlorine gas, dry	<0.5 H_2O	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
Chloracetic acid	100	boiling	<5.0(<0.127)
Chlorosulfonic acid	100	room	7.5-12.3 (0.191-0.312)
Chloroform	vapor & liquid	boiling	0.01 (0.000)
Chromic acid	10	boiling	0.1 (0.003)
Chromic acid	50	180 (82)	1.1 (0.028)
Chromic acid + 5% nitric acid	5	70 (21)	<0.1 (<0.003)
Citric acid	50	140 (60)	0.01 (0.000)
Citric acid	50 aerated	212 (100)	<5.0(<0.127)
Citric acid	50	boiling	5.50 (0.127-1.27)
Cupric chloride	40	boiling	0.2 (0.005)
Cupric chloride	55	246 (119) (boiling)	0.1 (0.003)
Cupric cyanide	saturated	room	nil
Cuprous chloride	50	194 (90)	<0.1 (<0.003)
Cyclohexane	–	302 (150)	0.1 (0.003)
Dichloroacetic acid	100	boiling	0.29 (0.007)
Dichlorobenzene + 4-5% HCl	–	355 (179)	4 (0.102)
Diethylene triamine	100	room	nil
Ethyl alcohol	95	boiling	0.5(0.013)
Ethylene dichloride	100	boiling	0.2-5.0 (0.005-0.127)
Ethylene diamine	100	room	nil
Ferric chloride	10-20	room	nil
Ferric chloride	10-50	boiling	nil
Ferric chloride	50	302 (150)	0.1 (0.003)
Ferric sulfate	10	room	nil
Fluoboric acid	5-20	elevated	rapid
Fluorosilicic	10	room	1870 (47.5)
Food products	–	ambient	no attack
Formaldehyde	37	boiling	nil
Formic acid aerated	25	212 (100)	0.04(0.001)**
Formic acid aerated	90	212 (100)	0.05 (0.001)**
Formic acid non-aerated	25	212 (100)	96 (2.44)**
	90	212 (100)	118 (3.00)**
Furfural	100	room	nil
Linseed oil, boiled	–	room	nil
Lithium chloride	50	300 (149)	nil*
Magnesium chlride	5-40	boiling	nil*
Magnesium hydroxide	saturated	room nil	
Magnesium sulfate	saturated	room	nil
Maganous chloride	5-20	212 (100)	nil
Maleic acid	18-20	95 (35)	0.6 (0.002)
Mercuric chloride	saturated	212 (100)	<5 (<0.127)
Mercuric cyanide	saturated	room	nil
Methyl alcohol	91	95 (35)	nil
Nickel chloride	20	212 (100)	0.11 (0.003)
Nitric acid, aerated	50	room	0.08 (0.002)
Nitric acid, aerated	70	Room	0.18 (0.005)
Nitric acid, aerated	10	104 (40)	0.10 (0.003)
Nitric acid, aerated	70	158 (70)	1.56 (0.040)
Nitric acid, aerated	40	392 (200)	24 (0.610)
Nitric acid, aerated	20	554 (290)	12 (0.305)
Nitric acid, non-aerated	70	176 (80)	1-3 (0.025-0.076)
Nitric acid	17	boiling	3-4 (0.076-0.102)
Nitric acid	35	boiling	5-20 (0.127-0.508)
Nitric acid	70	boiling	2.5-37 (0.064-0.940)
Nitric acid white fuming	–	room 360 (160)	0.1 (0.003) <5.0(<0.127)
Nitric acid red fuming	<about 2% H_2O	room	ignition sensitive
Nitric acid red fuming	>about 2% H_2O	room	not ignition sensitive
Nitric acid + 10% $FeCl_3$	40	boiling	4.8-7.4 (0.122-0.188)
Nitric acid + 10% NaClO	40	boiling	0.12-1.40 (0.003-0.036)
Oil well crudes	–	ambient	0.26-23.2 (0.007-0.589)
Oxalic acid	1	boiling	4247 (107.9)
Oxalic acid	25	140 (60)	470 (11.9)
Phenol	saturated	70 (21)	4.0(0.102)

[illegible]	[illegible]	[illegible]	[illegible]
Gluconic acid	50	room	nil
Glycerin	–	room	nil
Hydrogen chloride	dry gas	ambient	nil
Hydrochloric acid	1	boiling	>100 (>2.54)
Hydrochloric acid	5	boiling	400 (10.2)
chlorine saturated	5	374 (190)	<1 (<0.025)
	10	374 (190)	>1120 (>28.5)
+ 5% HNO_3	5	200 (93)	1.2(0.030)
+ 5% HNO_3	1	boiling	2.9 (0.074)
+0.5% CrO_3	5	200 (93)	1.2 (0.031)
+ 1% CrO_3	5	100 (38)	0.72 (0.018)
+ 0.05% $CuSO_4$	5	200 (93)	3.6 (0.091)
+0.5% $CuSO_4$	5	200 (93)	2.4 (0.061)
+0.5% $CuSO_4$	5	boiling	3.3 (0.084)
Hydrofluoric acid	1.48	room	rapid
Hydrogen peroxide	6	room	<5 (<0.127)
Hydrogen peroxide	30	room	<12 (<0.305)
Hydrogen sulfide	7.65, moist	200-230 (93-110)	nil
Hypochlorous acid + ClO_2 and Cl_2	17	100 (38)	0.001 (0.000)
Iodine in water + Potassium Iodide	–	room	nil
Lactic acid	10-85	212 (100)	<5.0(<0.127)
Lead acetate	saturated	room	nil
[illegible]	[illegible] solution	[illegible]	[illegible]
Phosphoric acid	10-30	room	0.8-2 (0.020-0.051)
Phosphoric acid	30-80	room	2-30 (0.051-0.762)
Phosphoric acid	1	boiling	10 (0.254)
Phosphoric acid+ 3% nitric acid	81	190 (88)	15 (0.381)
Phosphorous oxychoride	100	room	0.14 (0.004)
Phosphorous trichloride	saturated	room	nil
Pthalic acid	saturated	room	nil
Potassium bromide	saturated	room	nil
Potassium chloride	saturated	room	nil
Potassium ferricyanide	saturated	room	nil
Potassium hydroxide	50	80 (29)	0.4 (0.010)
Potassium hydroxide	10	boiling	<5.0(<0.127)
Potassium hydroxide	25	boiling	12 (0.305)
Potassium sulfate	10	room	nil
Potassium thiosulfate	1	–	nil
Salicylic acid (Na salt)	saturated	room	nil
Seawater	–	76 (24)	nil
Sebacic acid	–	464 (240)	0.3 (0.008)
Silver nitrate	50	room	nil
Sodium acetate	saturated	room	nil

Cont.

Media	C	T	R
Sodium aluminate	25	boiling	3.6 (0.091)
Sodium bifluoride	saturated	room	rapid
Sodium bisulfate	saturated	room	nil
Sodium bisulfate	10	150 (66)	72 (1.83)
Sodium chloride pH 1.5	23	boiling	nil*
Sodium chloride pH 1.2	23	boiling	28 (0.711)*
Sodium chloride pH 1.2 some dissolved chlorine	23	boiling	nil*
Sodium citrate	saturated	room	nil
Sodium cyanide	saturated	room	nil
Sodium dichromate	saturated	room	nil
Sodium fluoride	saturated	room	0.3 (0.008)
Sodium bisulfite	25	boiling	nil
Sodium carbonate	25	boiling	nil
Sodium chlorate	saturated	room	nil
Sodium hydroxide	5-30	70 (21)	>0.12 (>0.001)
Sodium hydroxide	10	boiling	0.84 (0.021)
Sodium hydroxide	40	176 (80)	5.0 (0.127)
Sodium hydroxide	50	135 (57)	0.5(0.127)
Sodium hydroxide	73	265 (129)	7.0(0.178)
Sodium hydroxide	50-73	370 (188)	>43 (>1.09)
Sodium hypochlorite	6	room	nil
Sodium nitrate	saturated	room	nil
Sodium phosphate	saturated	room	nil
Sodium silicate	25	boiling	nil
Sodium sulfate	10-20	boiling	nil
Sodium sulfide	saturated	room	nil
Sodium sulfite	saturated	boiling	nil
Sodium thiosulfate	25	boiling	nil
Soils, corrosive	–	ambient	nil
Stannic chloride	24	boiling	1.76 (0.045)
Stannic chloride	saturated	room	nil
Steam+ air	–	180 (82)	0.01 (0.000)
Succinic acid	100	365 (185)	nil
Sulfamic acid	3.75 g/l	boiling	nil
Sulfamic acid	7.5 g/l	boiling	108 (2.74)
Sulfamic acid + .375 g/FeC_3	7.5 g/l	boiling	1.2 (0.030)
Sulfur dioxide, water saturated	near 100	room	0.1 (0.003)
Sulfur dioxide gas + small amount SO_3 and approx 3% O_2	18	600 (316)	0.2 (0.006)
Sulfuric acid, aerated	3	140 (60)	0.5 (0.013)
	5	140 (60)	190 (4.83)
	3	212 (100)	920 (23.4)
	concentrated	room	62 (1.57)
Sulfuric acid	1	boiling	700 (17.8)
Sulfuric acid +0.25% $CuSO_4$	5	200 (93)	nil
+ 0.25% $CuSO_4$	30	100 (38)	2.4(0.061)
+0.5% CrO_3	30	200 (93)	nil
+ 1.0% $CuSO_4$	30	boiling	65 (1.65)
Sulfuric acid vapors	96	150 (66)	nil
Sulfuric acid			
+ 10% HNO_3	90	room	18 (0.457)
+ 70% HNO_3	30	room	4.0(0.102)
+ 90% HNO_3	10	room	nil
Sulfuric acid saturated with chlorine	62	60 (16)	0.07 (0.002)
Sulfuric acid saturated with chlorine	5	374 (190)	<1 (<0.025)
Sulfuric acid+ 4.79 g/l Ti^{+4}	40	212 (100)	passive
Sulfurous acid	6	room	nil
Tannic acid	25	212 (100)	nil
Tartaric acid	10-50	212 (100)	<5(<0.127)
Terepthalic acid	77	425 (218)	nil
Tetrachloroethalene, liquid and vapor	100	boiling	0.02 (0.001)
Tetrachloroethylene + H_2O	--	boiling	5(0.127)
Tetrachloroethylene	100	boiling	nil
Titanium tetrachloride	99.8	572 (300)	62 (1.57)
Titanium tetrachloride	concentrated	room	nil
Trichloracetic acid	100	boiling	573 (14.6)
Trichloroethylene	99	boiling	0.1-5 (0.003-0.127)
Urea + 32% ammonia + 20.5% H_2O, 19% CO_2	28	360 (182)	3.1 (0.079)
Water, degassed	–	600 (316)	nil
X-ray developer solution	–	room	nil
Zinc chloride	20	220 (104)	nil*
Zinc chloride	50	302 (150)	nil*
Zinc chloride	75	392 (200)	24 (0.610)*

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 I 76F (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.

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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

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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.

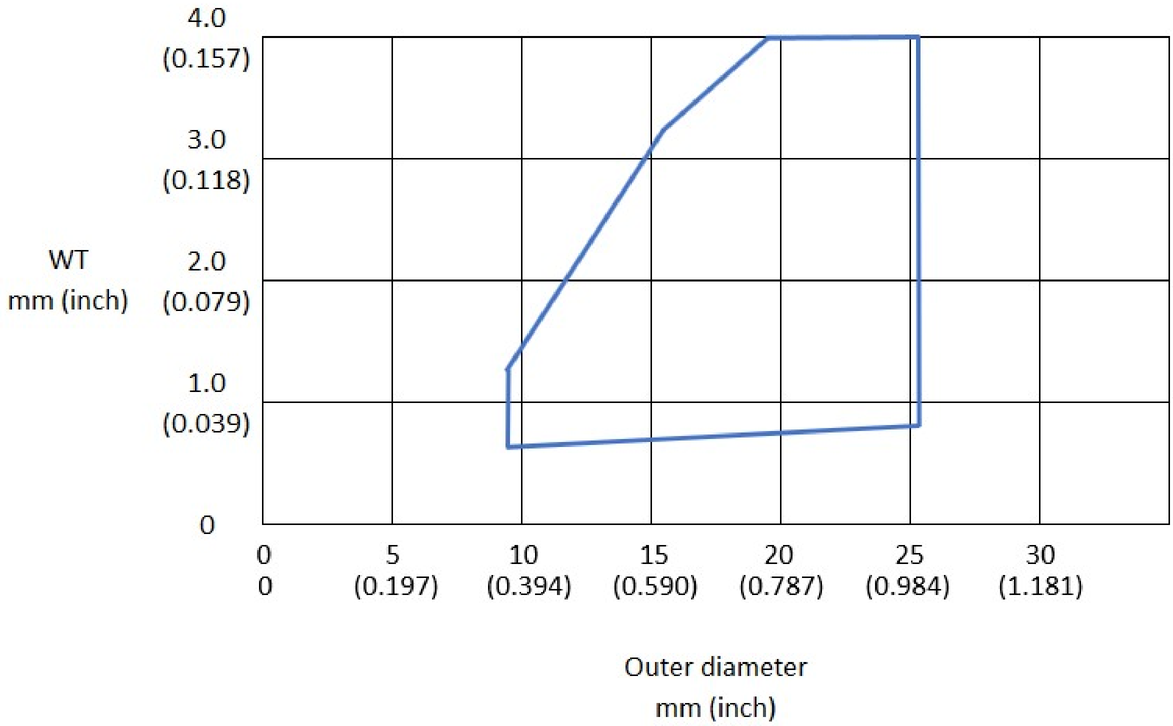

Figure 1 Principal size range for seamless tube and pipe.

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/in^3, 4.51 g/cm^3

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 (I 660°C)

Beta transus

1675F (913C)

Thermal Conductivity

22 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)	15.0×10^6	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.

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