

Titanium in Refineries and CPI



Chuck Young, Tricor Metals, Wooster, OH & Conroe, TX



Overview



Titanium Grades used to prevent or minimize Corrosion

Designing with Titanium

Cost Comparison of Titanium with other CRAs

Anticipated Life Expectancy of Titanium

Applications where Titanium has been used successfully

Titanium Grades

- **Grades 2/2H** **Commercially pure Titanium**
- **Grades 7/7H** **CP Titanium with 0.12- 0.25% Palladium**
- **Grade 9** **Titanium alloy with 3% Al – 2.5% V**
- **Grade 12** **Titanium alloy with 0.3% Mo – 0.8% Ni**
- **Grade 16** **CP Titanium with 0.04-0.08% Palladium**

All are ASTM and ASME approved with UNS numbers in the R5** range**

All have rough density of 0.163 lb/in³ (4.54 g/cm³)

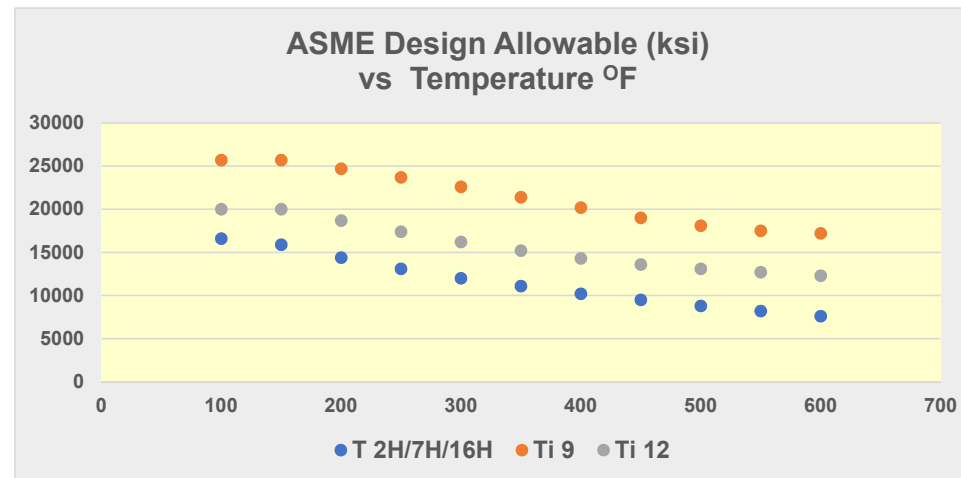
Titanium Mechanical Properties

Grades 2/2H, 7/7H and 16/16H UTS 50 ksi YS 40 ksi min

Grade 12 UTS 70 ksi YS 50 ksi min

Grade 9 UTS 90 ksi YS 75 ksi min

All Titanium Alloys approved by ASME to 600 F



Titanium Corrosion Resistance

Corrosion in Natural or Polluted Seawater

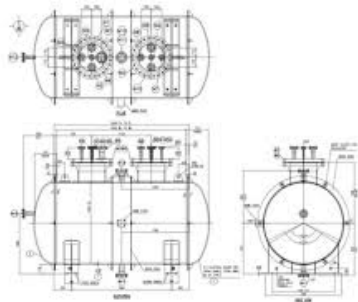
Mode of Corrosion	Cu based Alloys	6 Mo SS & Duplex SS	Titanium Alloys
General Corrosion	Resistant/Susceptible	Resistant	Resistant
Crevice Corrosion	Susceptible	Susceptible (>25 C)	Resistant (<80C) or (up to 200 C)
Pitting Attack	Susceptible	Resistant	Immune
Stress Corrosion	Susceptible	Resistant	Resistant
Corrosion Fatigue	Susceptible	Susceptible	Immune
Galvanic Attack	Susceptible	Resistant	Immune
MIC Corrosion	Susceptible	Susceptible	Immune
Weld/HAZ Corrosion	Susceptible	Susceptible	Resistant
Erosion Corrosion	Susceptible	Resistant	Resistant

Corrosion in Other Media

Appendix A A Guide to Aqueous Corrosion - Resistance	316 Stainless Steel	6 M O Stainless Steel	Monel 400	Incoloy 825	Inconel 625	Hastelloy C-276	Titanium
Organic Acids	A	A	B	A	A	A	A
Alkalines & Salts	B	B	A	B	A	A	A
Seawater	B	A	A	A	A	A	A
Sulfuric Acid	B	B	B	A	A	A	C
Hydrochloric Acid	D	B	C	B	A	A	D
Hydrofluoric Acid	D	C	A	B	B	A	D
Phosphoric Acid	C	C	D	B	A	A	C
Nitric Acid	C	C	D	A	B	C	B
Chlorine (wet)	D	D	B	C	B	A	A
	A = Excellent			C = Acceptable			
	B = Good			D = Not recommended			

Design Considerations

From Design to Quality Product
Mechanical design – Div 1 vs Div 2
Thermal design – don't overdesign
Reputable experienced Fabricator
Welding – clean, purged
Quality assurance – design in
Final Inspection



Heat Exchanger Specification Sheet									
1	Company								
2	Location								
3	Service of Unit: INTERCOOLER Our Reference								
4	Item No. MCH-1-INTERCOOLER Your Reference								
5	Date Rev No. 0 Job No.								
6	Size	1000-4000	mm	Type	HEX	Hor	Connected	0 parallel	1 series
7	Fluid inlet	286.5	mm	Fluid outlet	286.5	mm	Fluid inlet	286.5	mm
8	PERFORMANCE OF ONE UNIT								
9	Fluid description	Shell Side			Tube Side				
10	Fluid name	PROCESS GAS			WATER				
11	Fluid quantity, Total	kg/h			245180				
12	Inlet temp	kg/h			30/31				
13	Outlet	kg/h			0				
14	Noncondensable	kg/h			0				
15		kg/h			0				
16	Temperature In/Out	°C			34 33 28 32				
17	Over. Safety point	°C							
18	Capacity	kg/hr			335 / 434 / 807.5 / 806.88				
19	Pressure	kg			0.010 / 0.009 / 0.004 / 0.004				
20	Maximum wt. %	kg			30.95 30.95				
21	Maximum wt. %	kg							
22	Specific heat	kcal/kg °C			0.4716 / 0.4705 / 1.001 / 1.000				
23	Thermal conductivity	kcal/m °C			0.009 / 0.009 / 0.009 / 0.009				
24	Latent heat	kcal/kg							
25	Pressure drop	kg			3.003 3.048 5.099 4.711				
26	Pressure drop	kg			13.17 1.4				
27	Pressure drop, shell side	kg			0.014 0.007 0.01 0.008				
28	Pressure drop, tube side	kg			0.009 0.009 0.009 0.009				
29	Pressure drop, total	kg			0.009 0.009 0.009 0.009				
30	Heat exchanger	kg			30.463 30.463 30.463 30.463				
31	CONSTRUCTION OF ONE SHELL								
32		Shell Side			Tube Side				
33	Design/heat pressure	kg/cm²			4.07 MPa / 6.11 MPa /				
34	Design temperature	°C			130 10				
35	Number passes per shell				1 4				
36	Current thickness	mm			3.18 3.18				
37	Corrosion	mm			456.4 / 1 300.2 /				
38	Corrosion	mm			456.4 / 1 300.2 /				
39	Corrosion	mm			456.4 / 1 300.2 /				
40	Tube No.	M45/16			11.11 mm Length 4000 mm Pitch 40 mm				
41	Tube Type	mm			Material Carbon Steel Tube pattern 30				
42	Shell	Carbon Steel			ID 1600 OD 1626 mm Shell material Carbon Steel				
43	Channel or baffle	Carbon Steel			Channel material Carbon Steel				
44	Channelhead flange	Carbon Steel			Channelhead flange Carbon Steel				
45	Flangehead cover				Flangehead cover Flangehead cover				
46	Flangehead cover				Flangehead cover Flangehead cover				
47	Flangehead cover				Flangehead cover Flangehead cover				
48	Flangehead cover				Flangehead cover Flangehead cover				
49	Flangehead cover				Flangehead cover Flangehead cover				
50	Flangehead cover				Flangehead cover Flangehead cover				
51	Flangehead cover				Flangehead cover Flangehead cover				
52	Flangehead cover				Flangehead cover Flangehead cover				
53	Flangehead cover				Flangehead cover Flangehead cover				
54	Flangehead cover				Flangehead cover Flangehead cover				
55	Flangehead cover				Flangehead cover Flangehead cover				
56	Flangehead cover				Flangehead cover Flangehead cover				
57	Flangehead cover				Flangehead cover Flangehead cover				
58	Flangehead cover				Flangehead cover Flangehead cover				
59	Flangehead cover				Flangehead cover Flangehead cover				
60	Flangehead cover				Flangehead cover Flangehead cover				
61	Flangehead cover				Flangehead cover Flangehead cover				
62	Flangehead cover				Flangehead cover Flangehead cover				
63	Flangehead cover				Flangehead cover Flangehead cover				
64	Flangehead cover				Flangehead cover Flangehead cover				
65	Flangehead cover				Flangehead cover Flangehead cover				
66	Flangehead cover				Flangehead cover Flangehead cover				
67	Flangehead cover				Flangehead cover Flangehead cover				
68	Flangehead cover				Flangehead cover Flangehead cover				
69	Flangehead cover				Flangehead cover Flangehead cover				
70	Flangehead cover				Flangehead cover Flangehead cover				
71	Flangehead cover				Flangehead cover Flangehead cover				
72	Flangehead cover				Flangehead cover Flangehead cover				
73	Flangehead cover				Flangehead cover Flangehead cover				
74	Flangehead cover				Flangehead cover Flangehead cover				
75	Flangehead cover				Flangehead cover Flangehead cover				
76	Flangehead cover				Flangehead cover Flangehead cover				
77	Flangehead cover				Flangehead cover Flangehead cover				
78	Flangehead cover				Flangehead cover Flangehead cover				
79	Flangehead cover				Flangehead cover Flangehead cover				
80	Flangehead cover				Flangehead cover Flangehead cover				
81	Flangehead cover				Flangehead cover Flangehead cover				
82	Flangehead cover				Flangehead cover Flangehead cover				
83	Flangehead cover				Flangehead cover Flangehead cover				
84	Flangehead cover				Flangehead cover Flangehead cover				
85	Flangehead cover				Flangehead cover Flangehead cover				
86	Flangehead cover				Flangehead cover Flangehead cover				
87	Flangehead cover				Flangehead cover Flangehead cover				
88	Flangehead cover				Flangehead cover Flangehead cover				
89	Flangehead cover				Flangehead cover Flangehead cover				
90	Flangehead cover				Flangehead cover Flangehead cover				
91	Flangehead cover				Flangehead cover Flangehead cover				
92	Flangehead cover				Flangehead cover Flangehead cover				
93	Flangehead cover				Flangehead cover Flangehead cover				
94	Flangehead cover				Flangehead cover Flangehead cover				
95	Flangehead cover				Flangehead cover Flangehead cover				
96	Flangehead cover				Flangehead cover Flangehead cover				
97	Flangehead cover				Flangehead cover Flangehead cover				
98	Flangehead cover				Flangehead cover Flangehead cover				
99	Flangehead cover				Flangehead cover Flangehead cover				
100	Flangehead cover				Flangehead cover Flangehead cover				

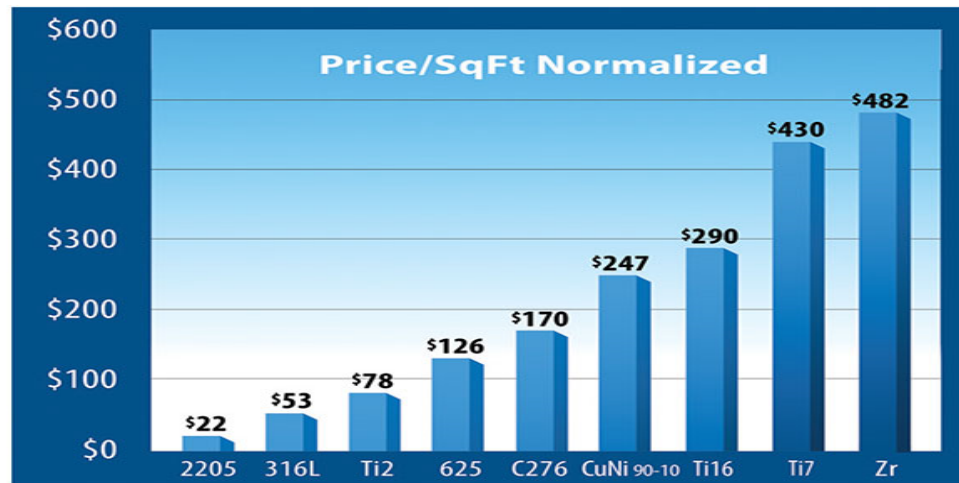
Design Review

- **Accurately determine design condition**
- **Consider material stress values at operating conditions**
avoid overdesign - use stiffener rings
and carbon steel supports
- **Corrosion resistance must be evaluated**
Proper selection of Titanium grade.
No corrosion allowance should be required.
True for pressure vessels but also equally applies to towers,
columns, heat exchangers and piping systems as well.



Titanium Cost Comparison

Titanium - **Affordable & Available** Updated 2nd Quarter 2019



Metal	Density (Lbs/In ³)	Yield Strength	Price/lb	Price/Sq Ft	Price/Sq Ft Normalized
2205	0.29	65,000	\$3.48	\$36	\$22
316L	0.29	25,000	\$3.18	\$33	\$53
Ti2	0.163	40,000	\$13.34	\$78	\$78
625	0.305	55,000	\$15.74	\$173	\$126
C276	0.32	41,000	\$15.17	\$175	\$170
CuNi 90-10	0.323	15,000	\$7.98	\$93	\$247
Ti16	0.163	40,000	\$49.35	\$290	\$290
Ti7	0.163	40,000	\$73.35	\$430	\$430
Zr	0.234	30,000	\$42.94	\$362	\$482

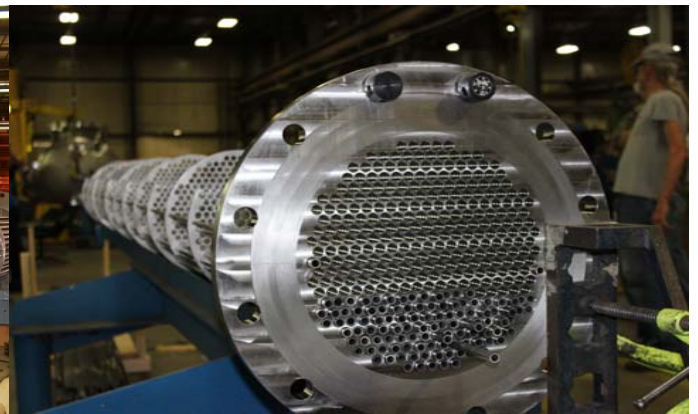
Life Expectancy for Titanium

Titanium

Nuclear Surface Condensers	>50 yr life
Reaction Vessel Terephthalic Acid	>50 yr life
Overhead Crude Exchgrs(no erosion)	>20 years
Sour Water Strippers	20-30 years
Crude Distillation Columns	>25 years
pH control to 250F	
Grade 12 Crude Overhead Condensers	
to 340F	>20 years

Titanium Applications

Titanium vessels, tanks and heat exchangers in various designs are used in the Chemical Process Industry



Titanium Applications



**Titanium Grade 2 tank in
Central US refinery**

**Replaced rubber-lined tank
due to high maintenance**

**3 section tank 100%
Titanium**

**Corrosives – Ferric Chloride
/Asphaltenes**

**In service for over 7 yrs with
no maintenance issues**

**Expect to last 30 years or
more**

Titanium Applications



**Titanium Condenser with
Grade 9 tubes**

**Tubes were $\frac{3}{4}$ x 0.095" wall
High pressure application in
Terephthalic acid plant**

**In service now for over 6
years with no issues**

Titanium Applications



**Dual Titanium Exchangers
with 2 exchanger bundles in
series**

**Titanium Grade 2 tubes
Dichloromethane Chemical
service**

**In service over 11 years with
no maintenance issues**

Titanium Applications



**Titanium Grade 2 Piping in
Southeast US**

**Terephthalic Acid plant
Expansion**

Piping from 2" to 60"

**Original plant had used
Titanium for over 30 years
Expansion in service for over
6 years with no issues**

Thank you for listening.



Charles Young

Tricor Metals

Wooster, OH & Conroe, TX

www.tricormetals.com

Metallurgist & Business Development Mgr.

chuck@tricormetals.com

330-264-3299 x 2500





TITANIUM • TANTALUM • ZIRCONIUM • HASTELLOY • DUPLEX STAINLESS STEEL