TITANIUM GRADE 12 – UNS R53400

ALTERNATIVE ALLOY FOR COST REDUCTION AND CORROSION RESISTANCE

CHARLES YOUNG, TRICOR

Titanium Grade 2/2H (UNS R50400) is the workhouse alloy used in the Chemical Processing Industry (CPI) to combat against corrosion and give a long, maintenance-free life. This Grade is essentially pure titanium with a yield strength minimum of 40 ksi and a minimum ultimate tensile strength of 58 ksi for Grade 2H.

When the service becomes too aggressive in terms of corrosion or the pressure and temperature would require a very thick section of Titanium Grade 2/2H, an alternate alloy, Titanium Grade 12 (UNS R53400), can be cost effectively used. Titanium Grade 12 is composed primarily of titanium with additions of molybdenum (0.3%) and nickel (0.8%). It has higher mechanical properties than Grade 2/2H, with a minimum yield strength of 50 ksi and a minimum ultimate tensile strength of 70 ksi.

Figure 1 shows the design allowable stresses (Section VIII, Div 1) for Ti Grade 2H and Ti Grade 12 developed by the ASME (American Society of Mechanical Engineers) for alloys used in the construction of equipment (vessels, exchangers, etc.) for the CPI.

The benefit of the higher strength of Titanium Grade 12 in reducing the thickness of alloy required can be shown at 100 °F (38 °C) and 300 °F (149 °C) in Figures 2 and 3. To withstand 100 psi pressure at 300 °F (149 °C), the thickness of a Ti Grade 2/2H vessel wall would have to be a minimum of 0.55 inches. Since plate only comes in certain thicknesses (unless the

Figure 1 ***ASME Design Allowables***

	R50400	R53400
Temperature Degrees	2H	12
	Psi	Psi
100 °F (38 °C)	16600	20000
150 °F (66 °C)	15900	20000
200 °F (93 °C)	14400	18700
250 °F (121 °C)	13100	17400
300 °F (149 °C)	12000	16200
350 °F (177 °C)	11100	15200
400 °F (204 °C)	10200	14300
450 °F (232 °C)	9500	13600
500 °F (260 °C)	8800	13100
550 °F (288 °C)	8200	12700
600 °F (315 °C)	7600	12300

Titanium Grade 12 Vessel

quantity justifies a special mill run), this would require a plate thickness of 0.625 inches – 5/8 in. nominal thickness. With Ti Grade 12, the thickness required would be 0.41 inches and the actual plate thickness used would be 0.4375 inches – 7/16 in. nominal thickness. Using Ti Grade 12 as an alternative to Ti Grade 2/2H would result in a savings of 30 percent of material.

If the pressure is increased to 300 psi at 300 °F (149 °C), the comparison becomes a plate thickness of 1.53 in. (which would require 1.75 inches – 1 ¾ in. nominal thickness plate) for Ti Grade 2/2H versus a calculated thickness of 1.14 inches (requiring a 1.25 inches – 1 ¾ in. nominal thickness plate) for Ti Grade 12. This again would give a savings of roughly 28 percent for the total weight of plate required.

Currently, costs of Ti Grade 2/2H and Ti Grade 12 are $13.34 per lb. and $15.07 per lb. respectively (a 15 percent difference). Even though Ti Grade 12 is more expensive on a per pound basis, the overall cost of the material for a vessel manufactured in Ti Grade 12 is 21 percent less than if it was fabricated using Ti Grade 2/2H. Considering that the cost of fabrication for Ti Grade 2/2H and Ti Grade 12 is about the same – with similar forming and welding techniques used, this means that vessels fabricated in Titanium Grade 12 can be more cost effective than in Titanium Grade 2/2H in some circumstances.

Titanium Grade 12 also has corrosion resistance superior to Grade 2/2H in most applications and especially gives additional crevice corrosion and under deposit crevice corrosion protection. Figure 4 shows the corrosion resistance of Ti Grade 2/2H versus Ti Grade 12 to crevice corrosion in concentrated brine solution at various temperatures and pH.

> CONTINUED ON PAGE 14

Figure 2 ***Minimum Thickness at 100 psi***

Temperature Degrees	Grade 2H Thickness (inches)	Grade 12 Thickness (inches)
100 °F (38 °C)	0.40	0.33
200 °F (93 °C)	0.46	0.35
300 °F (149 °C)	0.55	0.41
400 °F (204 °C)	0.64	0.46
500 °F (260 °C)	0.74	0.50
600 °F (315 °C)	0.86	0.53

Figure 3 ***Minimum Thickness at 300 psi***

Temperature Degrees	Grade 2H Thickness (inches)	Grade 12 Thickness (inches)
100 °F (38 °C)	1.11	0.93
200 °F (93 °C)	1.28	0.99
300 °F (149 °C)	1.53	1.14
400 °F (204 °C)	1.80	1.29
500 °F (260 °C)	2.08	1.41
600 °F (315 °C)	2.40	1.50

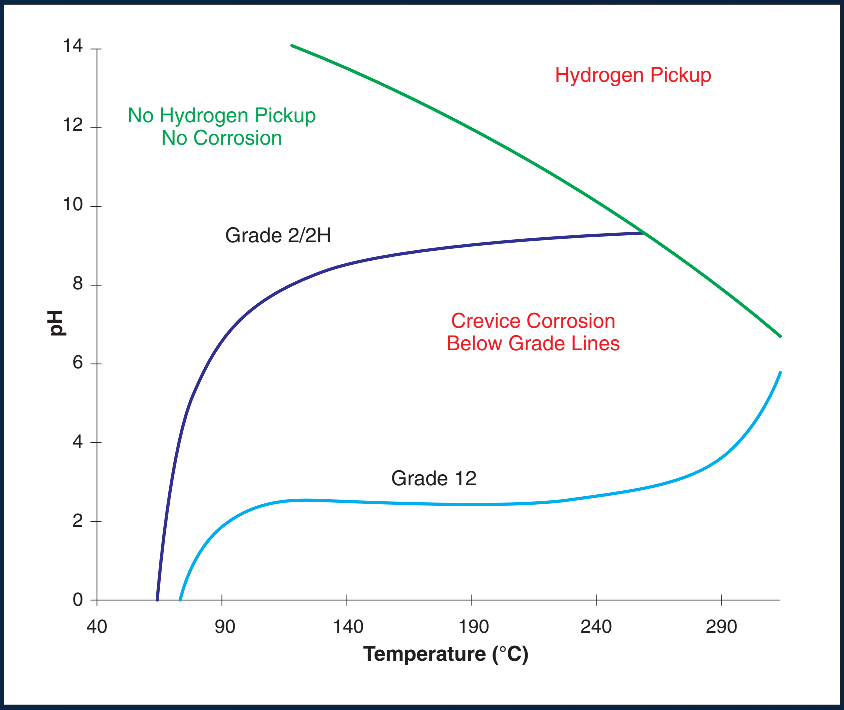
Titanium Grade 12 Piping

Above a pH of 2, Ti Grade 12 can be used up to a temperature of 464 °F (240 °C) where Ti Grade 2/2H, even at a pH of 2, can be vulnerable to crevice corrosion. Neither Titanium Grade is subject to hydrogen pickup in this corrosive environment, except at high pH levels, and Grade 2/2H is regularly used in chloride service where crevice corrosion, or under deposit corrosion, are not an issue.

Ti Grade 12 offers superior service in boiling HCl up to a pH of about 2 as shown in Figure 5. Ti Grade 2/2H is good only up to about 0.1 pH and is almost never used in HCl service. In other corrosive chemical environments the difference in corrosion resistance is much the same, with Ti Grade 12 showing better overall corrosion resistance and superior resistance to crevice and under deposit corrosion.

There are many other chemicals where Ti Grade 12 offers better

Figure 4 ***Crevice Corrosion in Saturated Brine***

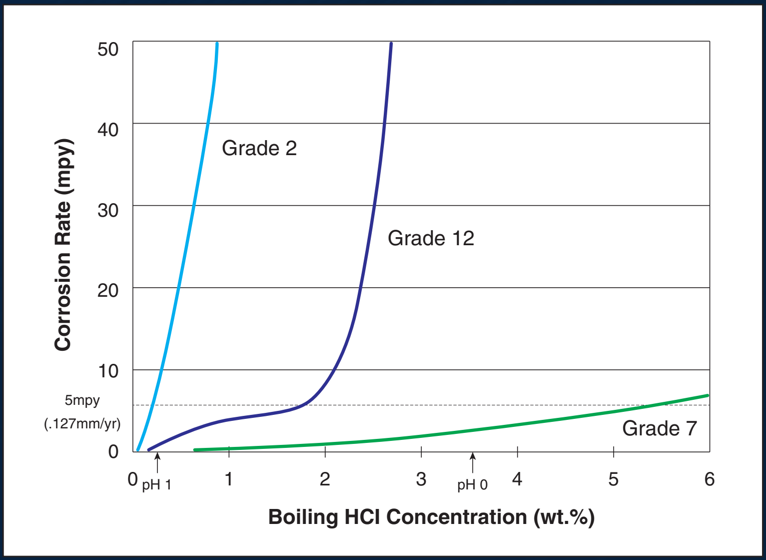


corrosion resistance than Ti Grade 2H and can offer the possibility of using thinner sections to reduce the cost of the overall project. You can find more corrosion data on all of the titanium Grades in a number of publications on the internet from titanium producers and other organizations like MTI, NACE, ANNA, API and the Chlorine Institute. If you don't find applicable data, it may be wise to perform some preliminary corrosion tests in your exact environment. Samples of all titanium Grades, as well as other alloys, are also available from Tricor Metals – as well as assistance in evaluating which alloy may be best for your application.

While most applications of titanium in the CPI are in static service, there may be some where vibration comes into play (e.g., heat exchangers and piping, agitators, etc.) and knowledge of the fatigue strength or endurance limit of the titanium alloy may be helpful in determining which alloy to use. The fatigue strength of Ti Grade 2 was investigated by Wardlaw & Hall and reported in ASTM STP728 -1981 and found to be at least 45 ksi at 107 cycles at room temperature. Analysis further indicated that Ti Grade 2 is also tolerant of reasonable surface defect severities for fatigue loading with maximum stresses within ASME Code specifications. Research into the fatigue endurance limits of other titanium alloys (including Ti Grade 12) has also shown similar results – with the endurance limit well above 50 percent of the ultimate tensile strength. In addition, it has been noted that finer grain size and slightly higher oxygen contents slightly increase the endurance limit while welding, when performed correctly, and has no effect on the fatigue characteristics of titanium alloys.

In conclusion, Ti Grade 12 offers some significant advantages in strength and corrosion resistance over Ti Grade 2H, while providing similar fatigue limits for applications in the Chemical Process Industry. It would be worthwhile to evaluate Ti Grade 12 to reduce the cost of a titanium project and to gain valuable corrosion resistance. ▪

Figure 5 ***Ti Grades in Boiling Hydrochloric Acid***



...vessels fabricated in Titanium Grade 12 can be more cost effective than in Titanium Grade 2/2H in some circumstances.