Moly Does the Job

This case study has been provided by Dave Bennett of M&M Engineering and has been written up by IMOA consultant John Grocki of Advantage Resources Consulting.

Summary

A rendering plant has been using a Type 304L stainless steel (SS) heat exchanger to condense the rendering cooker gases and heat plant water. After two years the unit experienced leaks in both the shell - mostly at the welds - and the tubes. Metallurgical evaluation of the shell plate failure area revealed both pitting and chloride stress corrosion cracking (CSCC). Microbiologically influenced corrosion (MIC) was suspected, but could not be confirmed.

A recommendation was made to replace the Type 304L heat exchanger with a new unit constructed from molybdenum containing 2205 duplex stainless steel (DSS). Because of its significantly increased corrosion resistance, the new unit's life is expected to be many years longer than that of the original unit.

The Process

The vertical, single-pass heat exchanger uses steam/vapor from the rendering cooker inside the tubes to heat plant water on the shell side. The rendering steam enters the exchanger at 300°F [149°C] and cools to 260°F [127°C]. The water supply is softened and chlorinated potable water, entering the unit at around 60° F [16° C], and exiting it at around 200° F [93° C]. The water contains no more than 50 ppm chloride and 1.5 ppm residual chlorine. The unit operates about 18 hours per weekday. During downtime the shell side remains filled with plant water.

The Corrosion

The Type 304L SS heat exchanger developed leaks at weld seams in the shell and in the tubes. The molybdenum free Type 304L SS has inadequate resistance to pitting corrosion in chloride-containing waters above 150°F [66° C], especially at welds and in the heat affected zone. CSCC also is possible at temperatures above 160°F [71° C], even with chloride levels of only a few ppm. While 2% molybdenum-containing Type 316L SS is more resistant to pitting corrosion than 304L SS, it is not much more resistant to CSCC at temperatures above 160°F [71° C].

Inadequate post-weld cleaning and rough grinding marks on the surface accelerated localized corrosion of the shell. However, pitting corrosion also occurred on the hot end of the solution-annealed Type 304L SS tubes. ***Figures 1*** through ***3*** show the corrosion defects.

Figure 1.
View of the horizontal weld piece, showing pitting in the base plate (A) and the weld (B). The surface has a brown stain/deposit.
The dark color band right next to the weld bead indicates inadequate post-weld cleaning.
The coarse grinding marks also lower the pitting resistance.

The Solution

The corrosion problems are being addressed by upgrading the material to a stainless steel with significantly higher resistance to both pitting and CSCC than Type 304L. The selected 2205 DSS resists chloride pitting and CSCC at temperatures up to 220° F [104 °C] in waters with chloride levels up to 2,000 ppm. ***Figures 4*** and ***5*** give pitting and CSCC resistance data for the discussed stainless steels. They show the vastly superior resistance of the 3.1 %

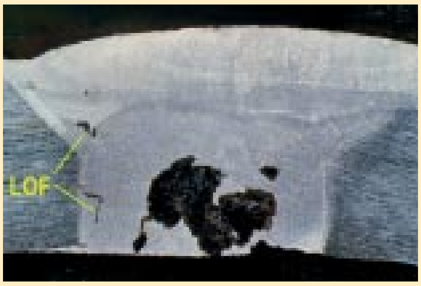

Figure 2.
Cross-section through the deepest cavity in a vertical weld sample: deep pitting corrosion damage and lack of fusion (LOF) in the weld.

Figure 3
Macro-photograph of chloride stress corrosion cracking (CSCC) in the base plate adjacent to the vertical weld, showing classic, branched, intergranular morphology and growth from the internal surface outwards

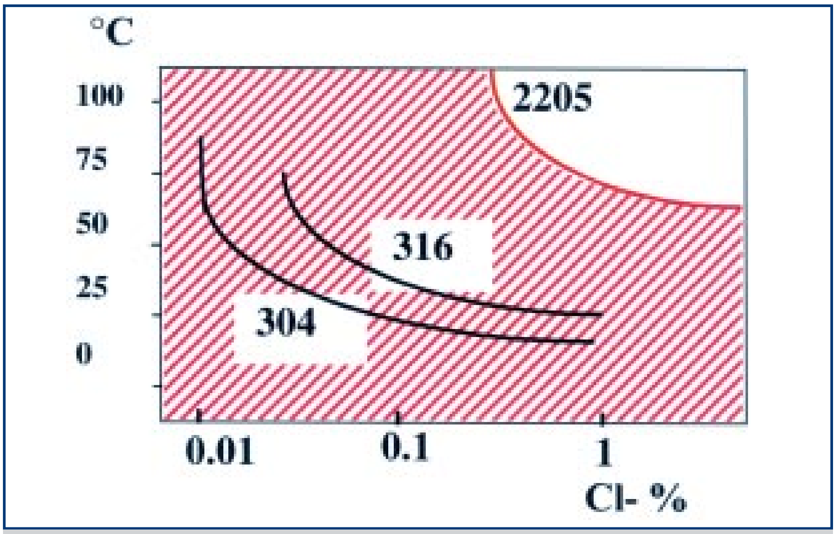

Figure 4.
Pitting corrosion resistance for different stainless steel grades: The effects of temperature and chloride contents are shown. Above the curved line pitting occurs, below it there is no pitting expected.

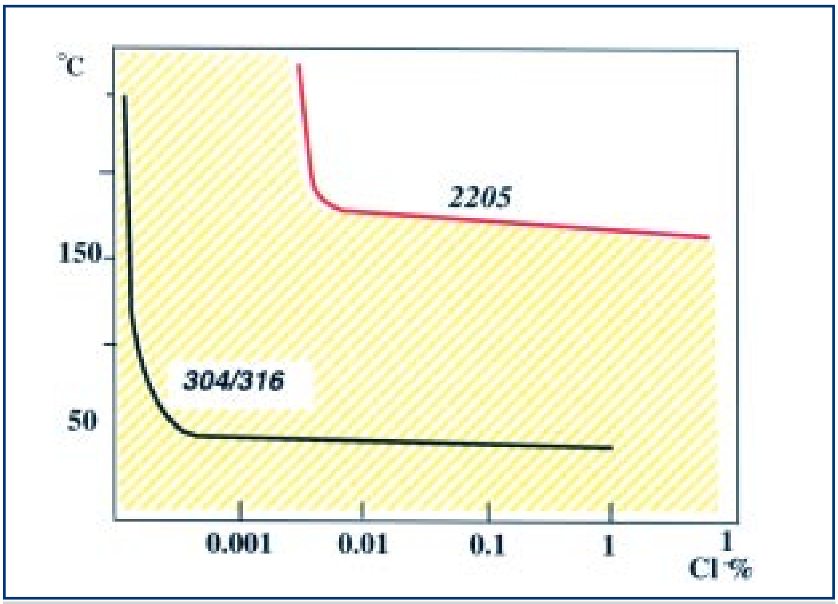

Figure 5.
CSCC resistance in neutral, aerated aqueous solutions for different stainless steels. No CSCC is expected to the left below the curves.

molybdenum-containing, duplex alloy 2205 compared to both Type 304 and 316 austenitic SS.
The nominal chemical compositions for 2205 DSS and Types 304L and 316L SS are shown in **Table 1.**

The Cost Savings

Table 2. provides the relative costs of the materials and the fabricated heat exchanger in three different stainless steels, Types 304L, 316L and 2205 if no design changes are made.
The moderately higher material and fabrication costs for 2205 DSS could be partially offset by redesigning the unit, using its two times higher yield strength to decrease the wall thickness and therefore the weight of the shell and the tubes. As the 2205 DSS should provide at least times longer service life than the 304L SS

unit, the life cycle cost savings become significant. The rough life cycle cost calculations shown in **Table 2** do not even include inflation adjustments, cost of labor to install a replacement unit, or cost of downtime because of an unexpected leak. The estimations only include the direct cost of purchasing a new Type 304L unit every two years or a Type 316L unit every four years at today's prices.

Grade	UNS Number	**Molybdenum**	Chromium	Nickel	Nitrogen	Carbon Max.
304L	S30403	**-**	18	9	-	0.03
316L	S31603	**2**	17	11	-	0.03
2205	S32205	**3.1**	22.1	5.6	0.16	0.02

Table 1. Typical chemical compositions of stainless steel grades.

Grade	Relative Material Cost	Relative Fabricated Unit Cost	Relative Life Cycle Cost
304L	1.00	1.00	1.00
316L	1.25	1.22	0.61
2205	1.33	1.30	**0.27**

Table 2. Relative material cost, fabricated unit cost and life cycle costs under the assumption that Type 316L would last twice as long and 2205 five times as long as Type 304L. Significant cost savings can be achieved over the assumed minimum life cycle of ten years with a 2205 heat exchanger as compared to a Type 304L or 316L exchanger.

The Indian Stainless Steel Development Association is organising the

"2nd International Conference Stainless 2002 – Markets and Applications" –in Mumbai on 6-7 December, 2002.

This conference is being called at a time when a distinct change in the end-use applications of stainless steel is emerging in India.

The objective of the conference is to up-date the audience about the new developments and trends in the markets and applications for stainless steel in India and in different parts of the world. The conference will lay special emphasis on two areas, Architecture, Building and Construction and the Transportation sectors with presentations aimed at the end-use sector personnel. Through these presentations and exposure to new products and applications, the conference hopes to give additional momentum to the developments taking place in India.

Online registration for Stainless 2002 is available at the ISSDA website www.stainlessindia.org