THERMOTips

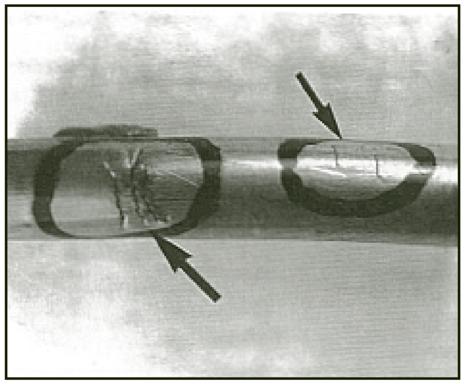
Stress Corrosion Cracking in Tubing Bundles

A recent laboratory summary from a failure of a tube in a tubing bundle concluded that there was a PVC coated wire in direct contact with the 316 stainless steel tubes. Heat from the steam tracer degraded the PVC resulting in chloride deposits on the tube which ultimately lead to tube rupture from chloride ion induced stress corrosion cracking (SCC).

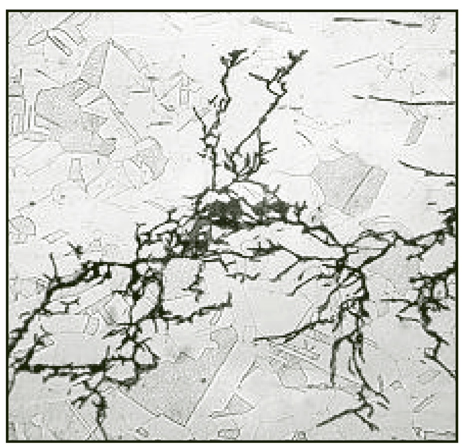
Our experience has been that SCC in tubing bundles has been a rare occurrence. We have only witnessed a few cases in over 20 years of manufacturing these products. Twenty years of tubebundle manufacturing represents millions of feet of tubebundle. The laboratory summaries from these few cases had similar conclusions. In one case PVC tape (electricians tape) was used to seal the bundle ends. The tape melted and deposited a high concentration of chloride ions on the tube. In another case, after installation, seawater was used to flush the tubes. Again a high concentration of chloride deposit resulted in stress corrosion cracking.

Corrosion in the Petrochemical Industry published by The Materials Information Society suggests that SCC require 4 ingredients.

1) An 18-8 austenitic stainless steel
2) The presence of residual or applied surface tensile stresses
3) The presence of chlorides; bromide (BR) and fluoride (F) ions may also be involved
4) The presence of an electrolyte



Chloride ion induced stress corrosion cracking (SCC). Failure initiated from the inside of the tube.



Photograph showing the typical "lightning bolt" cracking pattern associated with SCC.

This list assumes there is heat. SCC usually takes place at elevated temperatures above 140°F (60°C) and below 300°F (149°C). Elevated temperatures cause rapid water evaporation, which concentrates chloride ions. Also, heat speeds up the corrosion reaction rate.

18-8 austenitic stainless steel is most susceptible to SCC. This includes the 300 series stainless steels and the commonly used 316, 316L, 304 and 304L grades. This suggests that other alloys like the 400 series and 800 series would be more resistant. Grades with lower nickel and higher chrome, duplex stainless steel, have been developed specifically to resist SCC. However, at this juncture, the 300 series stainless steels are the most widely used and as a result are chosen because they are readily available and relatively low cost.

"Most mill products, such as sheet, plate, pipe, and tubing contain enough residual tensile stresses from processing to develop cracks without external stresses."[1] Tubing received from the mill already contains enough tensile stress to develop cracks before processing into tubing bundles. Relieving tensile stress after processing is not practical or possible for tubing within tubebundles. Annealing and stress relieving require exposure to temperatures of 1750°F (955°C) or higher. And, stress relieved tubing would be subject to tensile stresses during installation and operation anyway.

Note . . .

1. I. Garverick Linda., Editor, *Corrosion in the Petrochemical Industry,* ASM International, p. 176, 1994

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Stress Corrosion Cracking in Tubing Bundles (continued)

It is has not been determined what concentration of chlorides is necessary to initiate SCC. The average chloride content in rain water is usually in the 75-ppm range according to Mr. John W. Kalis, Jr., a PE and consulting engineer retired from the Dupont Company. He indicates that 75-ppm is not enough to cause SCC. Chlorides are widespread within the environment. Fiberglass insulation used in tubebundle typically contains up to 50 ppm chloride. Because of its widespread occurrence, it is not considered practical to remove or try to eliminate chloride ions.

SCC is an electrochemical reaction and therefore requires an electrolyte. Typically, water penetrates the system. The water carries chloride ions to the metal surface. Heat from the tracer evaporates the water concentrating the chloride ions.

The application and maintenance of a good weather barrier system is critical to the reliability and longevity of a heat tracing application. Water within the thermal insulation effects heat tracing performance and initiates corrosion within the tube. Pre-insulated tubing bundles have a continuous impervious plastic covering preventing water penetration at any point. Special attention only needs to be applied to the end terminations. This fact is why we experience so few failures with both heat tracing and SCC in factory made tubebundle as compared to any kind of field insulated and heat traced system.

Preventive measures may include coating the stainless steel tubing with a corrosion inhibitor like sodium silicate, coating with a barrier of epoxy, or applying cathodic layer over the tube. Protective coatings prevent chloride ions from contacting the tubing. Coatings need to be carefully chosen so as not to create other kinds of corrosion or heat tracing problems. Wrapping the tube with aluminum foil is practical and serves as a cathodic protection anode.

In conclusion, SCC is most prevalent in 18-8 stainless steel at temperatures between 140ºF (60ºC) and 300ºF (149ºC). In most heat tracing applications, the interface between the heat tracer and tube will be within this temperature range. Mill products, such as tubing, contain enough residual tensile stress to develop cracks. Chlorides are prevalent within the environment, therefore, it is not considered practical to eliminate them. Protective coatings and cathodic protection will minimize the occurrence of SCC. But, since SCC is an electrochemical reaction, minimizing or eliminating water from the system seems to be the most practical preventive measure. This is the primary reason we experience so few failures in factory made pre-insulated tubebundles.