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Failure of titanium condenser tube

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ABSTRACT

Failure investigation was carried out on a titanium condenser tube that suffered from a large size perforation. The environment at the shell side is hydrocarbon with low pressure steam, while it is seawater at the tube side. The tube was totally plugged with alkaline scale, consisting of calcium carbonate and calcium sulfate. The investigation revealed that in the initial stages of fouling, the titanium tube suffered from erosion–corrosion damage due to the presence of turbulent flow conditions and suspended solids. On the other hand, when the tube became totally fouled, overheating occurred, leading to growth of the oxide film on the internal tube surface. However, the titanium oxide film cracked due to the pressure exerted by the growing scale inside the tube, leading to thin lip rupture.

1. Introduction

Titanium is widely used in seawater applications such as heat exchangers and condenser tubes due to its immunity to seawater, excellent strength to weight ratio, and biocompatibility. These excellent properties result in trouble-free service and long-term service life. The corrosion resistance to seawater is due to the formation of a very thin oxide film, which mainly consists of TiO_2 [1]. However, this film might suffer breakdown and the tubes experience erosion–corrosion damage under turbulent flow conditions, leading to through-wall leaks. Such turbulent conditions might arise when the tubes become fouled with organic deposits and/or scaled with hardened minerals or when the seawater contains suspended solids [2]. Internal tube fouling might also results in loss of heat transfer and under deposit corrosion [2].

The present paper presents a failure case study carried out on a condenser titanium tube that suffered a large size perforation that was associated with severe precipitation fouling of inorganic minerals. The study revealed that the damage started in the form of erosion–corrosion damage, but with the buildup of the inorganic scale the tube internal surface experienced unusual and unexpected growth of the TiO_2 film, which suffered cracking due to its poor mechanical properties, leading to thinning and rupture of the tube.

2. Background of the failure

After 15 years of service, a condenser tube made of titanium was found suffering from a large size perforation. The titanium bundle was put in service in August 1995 and the failure was observed during a turnaround in December 2010. The tube material is titanium Grade 2 with the dimensions 25.4 mm outside diameter and 1.24 mm thickness. The shell side environment is hydrocarbon with low pressure steam, operating at full vacuum to 40 psig. On the other hand, the tube side environment is seawater operating at 40 psig. The shell side design temperature is 232 °C (450 °F), while the tube side design temperature is 74 °C (165 °F).

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