Stainless Steels in a Waste-Heat Boiler

Components manufactured of stainless steel Type 321 failed due to carburization at high temperatures, but those made from Type 310, exposed to the same conditions, showed no signs of degradation.

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Our experience with Type 321 stainless used as a shroud in a high temperature pressure vessel has proved unsatisfactory. This shroud, installed in a waste-heat boiler following a secondary reformer in a 600 ton/day ammonia plant, consists of 1/4 in. rolled plate about 4 ft. in dia. which serves as protection for insulation in the primary waste-heat boiler. The shroud is constructed in about 4 ft. sections which are individually supported from the vessel wall. There is a vapor barrier in each section behind the shroud to prevent gas channelling in the insulation, and allowance is made for thermal expansion by the use of slip joints. A bayonet tube heat exchanger bundle extends into the shroud from the top of the vessel and ends about 10 ft. from the bottom.

Hot secondary reformer effluent gas enters the vessel near the bottom at about 1,750- to 1,800°F. During operating upsets it is possible that the temperature may be about 200°F higher than this temperature for short periods of time. The composition of the gas is about 37.5% steam, 35% hydrogen, 14% nitrogen, 8% carbon monoxide, 5% carbon dioxide, and 5% methane, argon, and helium.

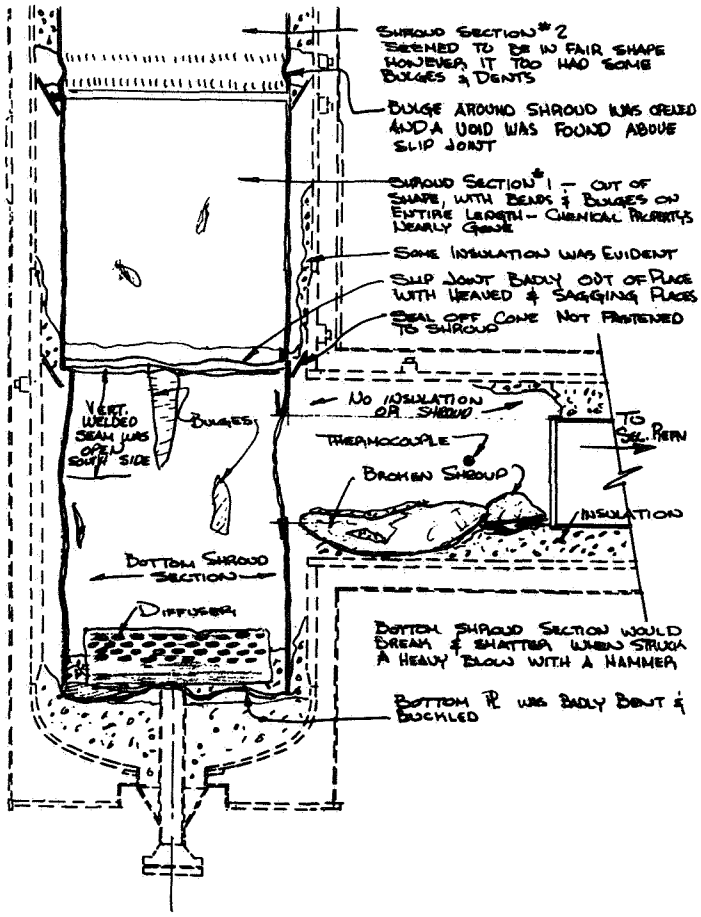

Figure 1. Damaged shroud section.

Shroud failure

The first shroud failure occurred in January 1969, after about 2 years of operation. Approximately 10 ft. of the shroud in the bottom section of the vessel was found to be in poor condition and was replaced. Replacement was made with ASTM Type 321 material since this was the only material that was available at the time.

In January 1971, the vessel and the shroud were inspected and the lower section found to be in poor condition. Figure 1 shows the condition of the shroud at that time. The bottom section of the shroud near the hot gas inlet nozzle was found to be severely warped and distorted. The metal had lost all of its metallic properties in that it was brittle and had properties similar to pottery. Sections could be broken out of the shroud in some areas with a ball-peen hammer. The section above this had also deteriorated to a considerable degree, but was not as bad as the lower section. Higher up in the vessel the shroud was found to be in good condition indicating that deteriorating was a function of operating temperature. At temperatures below about 100°F, the shroud appeared to be satisfactory. The section of the transfer line shroud from the secondary reformer to the waste heat exchanger was disintegrated, and lay in the bottom of the transfer line duct.

Metallographic examination of a section of the shroud in the lower section of the vessel showed that failure was due to carburization at high temperature. Substantial amounts of carbon were introduced into the metal, which caused it to become very brittle. Micro-photographs showed islands of carbides in the deteriorated metal matrix. A high concentration of carbides existed at the surface of the remaining metal which decreased towards the center of the specimen. Operating temperature variations then caused fractures and cracks in the carburized metal which resulted in scaling and thinning of the metal surface.

It was noted during the vessel inspection that the shroud in the secondary reformer outlet duct, and the diffuser pipe which was installed at the end of the transfer duct, were in

good physical condition. This is also shown on the figure, but is not immediately apparent at first glance. Notice that the transfer line upstream of the failed section is in good condition, and that the diffuser is in relatively good condition. These two items had been made out of ASTM Type 310 material which is a 25-20 material. It had been in service for over 4 yr. under the same operating conditions. No apparent metal degradation had taken place during this time. Based on this experience, the shroud in the low section of the vessel was repaired with Type 310 material.

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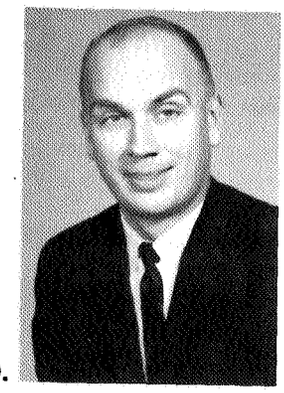

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