European Site #9 - Sulphur Recovery Unit (SRU) Waste Heat Boiler Tube Failure

Safety Impact			Environmental Impact		Production Impact		Damage
Fatalities	Injuries	First Aid	Leak Volume	Reportable	Days	Cost	Cost
0	0	0	Small	No	27	$$	$

The Incident

A Sulphur Recovery Unit (SRU) suffered an unplanned shutdown triggered by flame failure following an internal leakage in a reaction furnace waste heat boiler (WHB). The resulting loss of SRU capacity forced a shutdown of one gas oil hydrotreater and reduced throughput at two more gas oil hydrotreaters. If another of the SRUs had been off-line for maintenance at the time of this incident, production losses would have been significantly higher.

Background

The purpose of the reaction furnace (thermal reactor) is to burn off ammonia (NH_3) and destroy hydrocarbons contained in the acid gas from the Amine Treatment Unit (ATU) and sour gas from the Sour Water Stripper (SWS). The reaction furnace incorporates a high intensity burner and firing of the burner is controlled to maintain the furnace temperature above 1250 ºC (2282 ºF) to ensure ammonia is destroyed but below 1500 ºC (2732 ºF) to avoid refractory damage. In practice, the furnace is typically run at temperatures approaching the upper end of this temperature range in order to achieve the desired conversion of hydrogen sulphide (H_2S) to elemental sulphur (S).

Exhaust gas from the reaction furnace is cooled in the waste heat boiler by heat exchange with boiler feedwater (BFW). The WHB tubesheet forms the rear wall of the reaction furnace. The WHB tubes and tubesheet are fabricated from carbon steel and are protected from overheating by direct radiation from the burner and from accelerated corrosion by means of hexagonal-head ceramic ferrules inserted into the tube ends. The hexagonal-heads fit together to completely cover the tubesheet in the tube field area. Ceramic fibre paper is inserted between the hexagonal-heads to fill any gaps and castable refractory is applied outside the tube fields to protect the outer edges of the tubesheet. The problems began from start of run (SOR) during natural gas commissioning. Poor instrumentation and very limited feedback on temperatures led to the furnace being heated to around 2000 ºC (3632 ºF). Old flame eyes were only looking at the infrared spectrum and did not work well in natural gas mode. Performance was further limited when using modulating steam or nitrogen to the burner. Consequently, the flame eyes were being run in by-pass mode for long periods. The LumaSense E^2T optical pyrometer devices were compromised by sooting of the viewport, caused by starting up in a very low ratio of gas to air and not checking for excess O2 at any time. The unit ran for about 3 weeks before shutdown.

Causes

The immediate cause of the SRU shutdown was flame failure. A critical factor was a tube leak caused by overheating and accelerated corrosion of the tube to tubesheet weld (the leak got progressively worse and eventually blew back through that tube, pushing ferrules out around the tube end of the leaking tube). The root cause was inadequate control.

Lessons

An integrity operating window (IOW) limit should be set to limit the fraction of natural gas fired in order to avoid exceeding overheating the reaction furnace and waste heat boiler. Nitrogen should be available to quench the reaction furnace temperature. A dual function infrared thermometer (pyrometer) capable of simultaneous gas and refractory temperature measurement is the preferred method of temperature measurement as the pyrometer can be taken out of service for calibration with the furnace on-line and it requires only a single viewport. However, care is required to ensure the viewport remains clear of sulphur and soot deposits which compromise the performance of the pyrometer.