N. American Site #2 - Vacuum Distillation Unit (VDU) Vacuum Residue Recirculation Line Rupture

Safety Impact			Environmental Impact		Production Impact		Damage
Fatalities	Injuries	First Aid	Leak Volume	Reportable	Days	Cost	Cost
0	0	0	Large	Yes	~78	$$$$$	$$$$

The Incident

An emergency shutdown of the vacuum distillation unit (VDU) and the adjacent crude distillation unit (CDU) was manually initiated following rupture of a section of the vacuum residue recirculation line. The rupture resulted in a release of hot vacuum residue under pressure and above its auto-ignition temperature. A major fire erupted, causing damage to adjacent process equipment, piping and instrument cabling. The last flames were finally extinguished after approximately 1 hour and 43 minutes. Fortunately, there were no injuries but the CDU/VDU and several other units remained shut down for approximately 11 weeks while the necessary repairs were completed.

Background

The main purpose of the recirculation line is to enable the unit to be placed on circulation in case of emergency, but it is also used occasionally during periods of low throughput and for startups and shutdowns. The line connects the vacuum residue rundown to the vacuum charge heater inlet and incorporates a single block valve. The inlet end is open to process and ties in to the rundown line via a top-entry branch in an elevated piperack. The outlet end ties in to the heater inlet line at the heater coil manifold located near grade and is block valved closed (no normal flow).

The recirculation line is fabricated from DN 150 (6" NS) 9 Cr/1 Mo pipe (ASTM A335 Gr. P9) and is electrically heat traced and insulated. The rupture occurred close to the inlet end at the top of the pipe in a horizontal, straight section above a pipe shoe. The release continued to feed the fire for 36 minutes; initially from the vacuum residue pump (until the vacuum tower level control valve closed, isolating the pump discharge) and then by reverse flow from the coker (until the leak source had been identified and isolated). Inspection of the ruptured pipe section revealed much greater thinning on top of the pipe than the bottom and a smooth transition in wall thickness from top to bottom with no discontinuities or pitting. Computational fluid dynamics (CFD) revealed the presence of a natural thermosyphon action in the line. The tracing was triple-wrapped at the rupture location due to the pipe shoe (two cables on top and one below). The tracing temperature set point was 190 ^{o}C (374 ^{o}F) but the sensor was located at a low point in the line.

Causes

The immediate cause of the fire was loss of primary containment (LOPC) due to rupture of the vacuum residue recirculation line as a result of thinning caused by high temperature sulphidation corrosion (HTSC). Critical factors included backflow of vacuum residue from the coker (extended duration of fire), thermosyphon action at the open-to-process end of the recirculation line (maintained high enough temperature to enable thermal cracking and replenished sulphur supply) and localised overheating (triple-wrapped heat tracing at rupture location and remote location of tracing temperature sensor). Root causes included inadequate job knowledge (potential for thermal cracking was not realised so thickness measurement locations were not specified where high temperature vapour may accumulate), inadequate procedures (shutdown procedure did not isolate feeds entering the unit from other units or tankage) and inadequate design (absence of emergency shutdown system and remote-operated battery limit isolation valves).

Lessons

Sulphidation corrosion (also known as sulphidic corrosion) is a result of naturally occurring sulphur compounds found in crude oils. In the absence of hydrogen, the rate of sulphidation corrosion depends on many factors such as the concentration and type of sulphur compounds present and the fluid temperature and flow rate. Hydrogen sulphide (H_2S) is the most active sulphur species from a corrosion perspective and sulphidation corrosion rates increase rapidly above 260 ^{o}C (500 ^{o}F). The HTSC rate can be up to 6 times faster in the vapour phase than the liquid phase.