Lessons Learned Database
Individual Incident Summary Report

IChemE
Safety & Loss Prevention
Special Interest Group

Incident Title	**Hydrofluoric Acid Alkylation Unit Multiple Explosions**		
Incident Type	Fire and Explosion		
Date	21st June 2019		
Country	USA		
Location	Girard Point, PA		
Fatalities	**Injuries**	**Cost**	
0	6	US$ 342 m (2021) – Ref. 3	

Incident Description

Credit: US Chemical Safety Board

A pipe elbow in the discharge line of the standby depropaniser reflux pump of the hydrofluoric acid alkylation (HFA) unit ruptured catastrophically. The elbow was installed in 1973 and fabricated from carbon steel (CS) to the relevant pipe fitting design code (ASTM A234 – 1965). The line contained approx. 94.7 wt% propane (C3), 2.5 wt% hydrofluoric acid (HF) and 2.8 wt% other hydrocarbons (HC). The escaping liquid flashed and formed a ground-hugging, highly flammable vapour cloud which ignited ~ 2 mins later.

Approx. 30 secs after ignition, the control board operator activated the Rapid Acid Deinventory (RAD) system which dumped the bulk HF inventory from the acid settler to the RAD drum and activated the acid section "safe park" system which shut down acid service pumps and closed remote-operated block valves. The HF vapour release mitigation system was also activated, but remote-control circuitry to the water pumps had been damaged by fire so they did not start. Two explosions occurred ~ 13 and 17 mins later. A boiling liquid expanding vapour explosion (BLEVE) occurred ~ 3 mins later when the feed surge drum containing mainly butylene (C4=) and butanes (iC_4 and nC_4) ruptured violently, propelling large pieces of the vessel up to 0.64 km (0.4 miles) away. Fortunately, no-one was killed and the flying projectiles missed the RAD drum and adjacent units containing large inventories of hazardous chemicals. The shift supervisor put on firefighter protective gear and manually started the water pumps for the HF mitigation system ~ 17 mins later.

Incident Analysis

Basic cause was rupture of a pipe elbow in the depropaniser reflux pump discharge line due to localised accelerated HF corrosion.

Critical factors included: 1) The elbow had a much higher nickel (Ni) and copper (Cu) content than the straight CS pipe on either side, making it more susceptible to accelerated HF corrosion, 2) Flame impingement on the feed surge drum, 3) Absence of remote-operated Emergency Block Valves (EBVs) downstream of leak location (to isolate large hydrocarbon inventories in downstream towers), 4) Fire damage to the elevated HF mitigation water spray system (delayed start limited capture of HF released during the incident).

Root causes included: 1) Inadequate design standard (ASTM A234 did not specify safe limits for Ni and Cu content of CS pipe fittings in HFA service), 2) Inadequate inspection (industry guidance recommended positive material identification and thickness checks be conducted on all CS piping components), 3) Inadequate safeguards (too few remote-operated EBVs).

Lessons Learned

1) All individual CS piping components and welds in identified HFA corrosion zones should be inspected to identify areas of accelerated HF corrosion, 2) Active safeguards (e.g. HF vapour mitigation water sprays, RAD system) can fail in major incidents involving fire or explosion, 3) Inherently safer alkylation technologies (e.g. those using ionic liquid or solid acid catalysts) should be evaluated as potentially viable alternatives to conventional HFA processes.

More Information

1) "Fire and Explosions at Philadelphia Energy Solutions Refinery Hydrofluoric Acid Alkylation Unit", US Chemical Safety and Hazard Investigation Board, Report No. 2019-04-I-P (2022).
2) "Specification for Carbon Steel Materials for Hydrofluoric Acid Alkylation Units", National Association of Corrosion Engineers, Paper No. 03651 (2003).
3) "100 Largest Losses in The Hydrocarbon Industry 1974 – 2019", Marsh Property Risk Consulting Practice, 27th Edition (2022).

Industry Sector	Process Type	Incident Type
Oil & Gas	Alkylation (HF)	Explosion & Fire
Equipment Category	**Equipment Class**	**Equipment Type**
Mechanical	Piping	Fittings (Elbow)

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