FLARE LINE FAILURE CASE, WHAT HAVE WE LEARNED?

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Overview

- Background
- Flare System Overview
- Event Sequence
- Root Causes / Corrective Actions
- Brittle Fracture Discussion
- Other Follow Up Actions
- Learning / Conclusions
Background

- The Westlake Petro 1 plant is a “demethanizer first” ethane cracker with a back end acetylene converter

- An off-spec event on 1/4/02 at the acetylene converter led to flaring of liquid ethylene product via the unit cold flare drum

- Through a sequence of events, the cold flare drum overhead line fell to below its minimum design metallurgy temperature

- On 1/5/02, the cold temperatures led to brittle fracture of the cold flare drum overhead line, loss of hydrocarbon containment, and ultimately an explosion and fire
Westlake Petro 1 Flare Drum System Overview

- The cold flare drum contents are vaporized and superheated with a closed loop propanol system

- Heat is supplied to the propanol system with 70# steam (~270 F)

- The vaporizer and superheater heats the cold flare drum material from cryogenic temperatures to above the minimum design metal temperature of the cold flare drum carbon steel overhead piping @ -10 F
Westlake Petro 1 Flare Drum System Overview

Original System

150# Carbon Steel Piping, MDMT= -10 F

Cold Flare Superheater

Cold Vapor Header

Cold Liquid Header

Cold Flare Drum

Cold Flare Vaporizer

Propanol Vaporizer

Warm Flare Drum

70# steam

70# steam condensate

Key

- CS process piping
- SS process piping
- Propanol
- 70# steam/condensate
Event Sequence

• The Westlake Petro 1 ethylene product went off spec on acetylene, initiating flaring of liquid ethylene product

• Acetylene converter outlet analyzer was in error which allowed the ethylene splitter inventory to be contaminated with acetylene prior to corrective action being taken

• A portion of the off spec liquid ethylene product was consumed by internal Westlake customers, with the balance being flared via the cold flare drum

• Malfunction of the cold flare drum vaporizer and superheater allowed the cold flare drum overhead line temperature to fall sharply
Event Sequence, Cont...

- A low temperature alarm sounded as the overhead line temperature fell to 0 F, and the thermocouple “went bad” at a value of -13 F

- With the cold flare drum overhead line running below its minimum design temperature of -10 F, the pipe ruptured, resulting in loss of hydrocarbon containment

- The hydrocarbon released found an ignition source, resulting in an explosion and fire
Cold Flare Drum Overhead Line Fire

- Superheater
- Warm flare drum
- Cold flare drum
Root Causes of the Fire

• Vaporizer/superheater exchanger fouling had reduced heat transfer capacity of the cold flare system

• Once flaring began, the cold flare drum overhead line experienced low temperature

• Brittle fracture of cold flare drum overhead piping due to operation below the minimum design temperature of the carbon steel line
Root Cause #1: Vaporizer/Superheater Malfunction

- After the event, it was determined that fouling had compromised the operation of the vaporizer and superheater exchangers

Corrective Actions:
- 2 LI’s installed on cold flare drum w/ DCS hi alarms @ 10%
- Heavy oil pull down system installed to allow removal of heavy oil from the cold flare drum
- Cold flare drum superheater replaced with 50% larger exchanger and propanol piping was replaced to handle higher throughput
Root Cause #2: Cold Safety Awareness/Management

• Once flaring began, the cold flare drum overhead line low temperature was not recognized

Corrective Action:
• Plant wide training conducted to re-emphasize cold safety awareness, including root causes and corrective actions for cold flare line event
Root Cause #3: Brittle Fracture

- The “final stress” that ultimately caused the brittle fracture of the piping has not been identified, but could have been any number of internal or external stresses
- External stress - Hard rain that came at the time of event?
- Internal stress - Contraction of the cold flare line due to temperature gradient?

Corrective Actions:
- Carbon steel flare system piping replaced with stainless steel, ~100' downstream of warm/cold flare drum tie-point
- Thermocouple installed on new stainless steel piping upstream of SS to CS transition
- Stress analysis on the new flare line, FEA on flare drum
- See “Flare Drum System Modifications” diagram
Overhead Line Brittle Fracture

30" cold flare drum overhead line failure due to brittle fracture
Carbon Steel Brittle Fracture Discussion

• Carbon steel piping is typically used in services w/ temperatures above -10 to -20 F
  – Impact testing can certify the use of carbon steel piping in services as cold as -55 F (i.e. “killed carbon steel”)

• At temperatures below -10 to -20 F normal carbon steel loses ductility and strength
  – The metal becomes brittle and can be susceptible to brittle fracture

• Three main factors influence the onset of brittle fracture:
  – Temperature
  – Flaw size (notches, scratches, etc…)
  – Stress
Impact Energy vs. Temperature for Carbon and Stainless Steel

Stainless Steel --
Retains strength and ductility at relatively low temperatures

Low-Medium Carbon Steel --
Loses strength and ductility at low temperatures

Temperature
Impact Energy
Initial fracture believed to have occurred on elbow section of cold flare drum overhead line.

Charpy impact testing determined that the elbow section of the line was below the standard specification for impact tested carbon steel at -20 F.
Other Follow Up Actions

• Study conducted to identify and replace carbon steel components in cryogenic service
  – Bimetallic demethanizer tower upgraded to stainless steel during 2003 T/A
  – Demethanizer tower reboiler piping upgraded from killed carbon steel to stainless steel during 2003 T/A
  – Ethylene splitter bottoms piping upgraded from killed carbon steel to stainless steel during 2003 T/A

• Install new cold flare line overhead thermocouple with a minimum range to -200 F
Westlake Petro 1 Flare Drum System Modifications

New reorganized TI, min range = -200 °F

New Cold Flare Superheater

New Cold Flare Drum

Cold Vapor Header

Cold Liquid Header

New Cold Flare Drum System Modifications

LI
TI

Old Facilities in Blue

Heavy Oil Pulldown System

2 new LI's

New 150# Stainless Steel Piping

To Elevated Flare

Propanol Vaporizer

70# steam

70# steam condensate

Warm Flare Drum

Key

New Facilities in Black

Old Facilities in Blue

Propanol

70# steam/condensate
Safety/Environmental Impact

- The state police, the Local Emergency Planning Commission (LEPC), and the National Response Center (NRC) were notified of the event.
- No first aid or recordable injuries
- The fire was contained within a few hours, but it was not completely extinguished for 1 week
- The plant was shut down for 1 month while repairs were made to the unit
Key Learnings

• Event specific
  – Heavy liquid introduced to the cold flare drum should be removed in a timely manner
  – Cyclopentadiene (CPD) and other components in deethanizer bottoms streams can polymerize to foul cold flare heat exchangers
  – Cold flare system fouling may not be readily identified due to infrequency of use

• General
  – Unit upsets will tend to find the “weak link” in management systems, facilities, and personnel
  – Cold safety should remain a focus for all ethylene plants