CSB Investigation: Chevron Refinery Pipe Rupture and Fire
Richmond, California

Southern California Society For Risk Analysis
26th Annual Meeting
May 30, 2013
Chevron Refinery Pipe Rupture and Fire
Richmond, California

Background

Incident Review

Sulfidation Corrosion

Review of Findings and Recommendations
Chevron Richmond Refinery
Line Constructed of Carbon Steel

Process Fluid is Light Gas Oil

Atmospheric Crude Column

8-inch "4-sidecut" line

P = 55 psig
T = 640 °F
Guidelines for Avoiding Sulfidation (Sulfidic) Corrosion Failures in Oil Refineries

API RECOMMENDED PRACTICE 939-C
FIRST EDITION, MAY 2009
Mechanics of Sulfidation Corrosion

Sulfur

Compound

React with

Iron

Corrosion

450 °F – 800 °F

Steel
Sulfidation Rates of Various Alloys

Modified McConomy Curves (0.6 % S content)

Curves can be found in API RP 939-C
Carbon Steel Corrosion Rate Variability

Graph from API RP 939-C
## Inherently Safer Materials of Construction

Thinning resulting from 15 years of operation (Estimated)

<table>
<thead>
<tr>
<th>Material of Construction</th>
<th>Chevron</th>
<th>4-sidecut</th>
<th>9-Chrome</th>
<th>Stainless Steel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low-Silicon Carbon Steel</td>
<td>90 % Wall Loss</td>
<td>65% Wall Loss</td>
<td>9% Wall Loss</td>
<td>&lt; 1% Wall Loss</td>
</tr>
</tbody>
</table>

INHERENTLY SAFER
Corrosion Monitoring of Carbon Steel Piping

Generic Piping Configuration

- Elbow Components
- Straight-Run Components
- Measurement Location
100 Percent Component Inspection Identifies Low-Silicon Components
Inherently Safer Metallurgy Reduces Hazard
Low-Silicon 4-Sidecut Component Not Monitored

- Measurement Location
- Weld
- High-Silicon Elbow Component
- Low-Silicon Pipe Component
Low-Silicon 4-Sidecut Component Not Monitored
Figure 1 - NPS 8 Carbon Steel Piping Failed Due to Sulfidation Corrosion (H₂ Free)

Note the relatively uniform thinning, which resulted in a sizeable rupture
Figure 3 – FCC Fractionator Bottoms piping operating at 150 psig (1 MPa) and 650-700°F (340-370°C). See also sketch in Figure 4. (Courtesy of BP)
8-Inch Schedule 80 Piping Thickness Survey Results

- Overhead Pipe Thickness: 0.309-0.364
- Elbow Thickness: 0.482-0.548
- Flap Thickness: 0.031-0.057"
- Pipe Above the Pup Piece Measured from OD Thickness: 0.357-0.42"
- Remainder of the Failed Pup Piece Thickness: 0.03-0.10"
- Top of Tee Thickness: 0.50-0.56"
- Bottom of Tee Thickness: 0.47-0.56"
- Bottom Near Tee Thickness: 0.20-0.22"
- Bottom Thickness: 0.43-0.45"
Figure 5 - Summary of Reported Failures by Type, Number of Reported Instances, and Percentage of the Total
Many Chevron Recommendations to Inspect or Upgrade 4-Sidecut

Pipe Ruptures

Recommendations to 100 Percent Inspect 4-Sidecut

Recommendations to Upgrade Metallurgy of 4-Sidecut
Process Hazard Analysis

Process Hazard Analysis Required by OSHA PSM Program
  – Enforceable by Cal/OSHA and City of Richmond

PHA team DID evaluate “leak or rupture” of 4-sidecut line

PHA team did not identify 4-sidecut Sulfidation vulnerabilities
  – PHA team not knowledgeable of 4-sidecut corrosion hazards
  – PHA team did not seek out additional corrosion expertise

No PHA recommendations to improve 4-sidecut safeguards
Damage Mechanism Hazard Reviews

These hazard reviews:

- Analyze all process equipment failure mechanisms including:
  - Corrosion
  - Cracking

- Identify potential safeguards to control or eliminate hazard

Not required by regulators or by current Chevron standards

May have prompted PHA team to recommend replacing 4-sidecut line

CSB recommended to Chevron and State of California to require Damage Mechanism Hazard Reviews as part of PHA cycle
Adequacy of PHA Safeguards

Safeguard Evaluation Methodologies; accepted methods include:

- Quantitative, e.g., Quantitative Risk Analysis
- Semi-Quantitative, e.g., Layers of Protection Analysis, and
- Qualitative, e.g., NFPA Fire Codes

Chevron PHAs do not use these safeguard evaluation methodologies

- Reliability of safeguards were not adequately verified
- Rely on PHA team experiences, beliefs, and areas of expertise

CSB recommended to California Regulators to require a fully documented, rigorous analysis of safeguards using established methods such as LOPA
Implementation of Inherently Safer Systems (ISS)

Contra Costa County process facilities are required consider inherently safer design opportunities in PHAs and for new construction.

But many more opportunities exist:

- Management of Change (MOCs)
- Process Unit Rebuilds
- Major Repairs
- Corrective actions from incident investigation recommendations

Chevron did not document the analysis of ISS alternatives.

CSB recommended more rigorous ISS requirements by:

- City of Richmond / Contra Costa County
- State of California
Multi-Agency Regulatory Approach Needed

Program will improve public accountability and process safety performance

Sharing of data and operational coordination will help regulators prevent major incidents

Regulators have cited the need for greater multi-agency cooperation

CSB recommended multi-agency regulatory cooperation
Transparency Drives Process Safety

Transparency is the public disclosure of process safety information.

Minimal transparency exists between refineries, regulators, and the public.

The CSB recommended that the multi-agency group establish procedures for greater transparency between local officials, regulators, the workforce, and the public.
Many Factors Contributed to Incident

Immediate Causes
- Failure caused by sulfidation corrosion in low-silicon carbon steel
- Chevron failed to shut down unit when leak was found

Latent Causes
- Chevron never fully inspected or replaced the 4-sidecut despite many recommendations
- Chevron PHA process failed to identify sulfidation corrosion hazard
Many Factors Contributed to Incident

Regulations did not require rigorous ISS implementation

Regulations did not require damage mechanism hazard review

Regulations did not require evaluation of safeguard effectiveness

Multi-agency cooperation and transparency needed in California
Additional Items Still Under Investigation

California

- Refinery regulatory regime

Chevron

- Safety culture
- Management system
- Mechanical integrity systems
- Emergency planning, notification, and response
- Process safety indicators
CSB Board Members Approve Chevron Richmond Refinery Fire Interim Investigation Report

The interim report was approved at a public meeting in Richmond, California on August 19, 2013
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