R&M Technology
Unexpected Hazard of Switching into a Close Drum Isolation Valve

Mike Kimbrell – BP Coking Advisor

Refining & Logistics
Summary of Incident

- Switched into a closed inlet isolation valve (SP-6)
  - Coupling between valve actuator and valve failed
  - Interlock was based on position indication of actuator
- Heater transfer line pressured up and flange at switch valve began to leak
  - This leak caught fire immediately
  - Many of the flanges in the transfer line between the heater and the switch valve leaked
- Loss of hydrocarbon flow tripped the burners off
- High pressure on the transfer line prevented the switch valve from moving to bypass position
Incident Summary - continued

- Drain line between switch valve and inlet isolation was used to depressurize line to the blow down system
  - As pressure decreased the leaks stopped
  - Once the pressure was down the switch valve could be moved to the bypass position
- As the pressure decreased, the velocity media (BFW in this case) began to flow
- During the incident the heater feed pump was shut down remotely. The discharge block valve was shut remotely a short time later
- System had been blocked in for approximately 35 minutes
- There were no injuries associated with this event
Sketch of Heater Feed System
Events leading up to the Incident

- Initial start-up of this unit was Feb 2009
- Inlet isolation valve involved in incident required more torque to turn starting May 2010, one year prior to the incident
  - Site had been in contact with valve manufacturer. Had increased the available torque from the actuator to move valve
  - In Aug 2010, a pneumatic assist was used to get the valve to close as the actuator was not always able to close the valve. Limited the air pressure to 70 psig.
  - March 2011 the actuator had the gears replaced as they were severely worn due to the excessive force required to close the valve
- Steam purges for this valve came from steam generated on site from the HCGO steam generator
Actuator gear wear
Plot of Transfer Line Pressure at the Switch Valve

Presión (Kg/cm²g)

41P004 Presión aguas arriba switch-valve (Kg/cm²g)

09/05/2011
18/05/2011
Plot of coke drum inlet temperature

41T020 Temperatura entrada D-4102 (°C)

Temperature (°C)
Photos of Coke in the Inlet Isolation Valve
Pressures at Feed Pump and Heater Pass Inlet – Unexpected pressures

Heater feed pump shut off
Pressure is 58.5 kg/cm² (832 Psig)

Pressure at heater feed pump exceeded 84 kg/cm² (1195 psig)

Pressure at the heater pass inlet exceeded 60 kg/cm². Transmitters were at the maximum range
Standard methods of protecting the heater transfer line

- Two primary methods have been used to protect the heater transfer line from over pressurization.
  - Relief valve on the heater outlet routed to the bottom of the fractionator
    - Concern with relief valve or nozzle plugging. Have experienced this at multiple sites
  - Designing heater transfer line for blocked discharge pressure
    - Heater tubes designed for pump shut-off pressure at 1300°F using the elastic limit and not creep-rupture limit
    - Low flow on the heater passes trips burners. Should prevent tubes from rupturing. Heater pass will coke from heat stored in firebox
    - ASME B31.3 allows 33% over design pressure for 10 hr per incident and no more than 100 hrs per yr
Allowable stress curve for 9% Cr – 1% Mo Heater tubes – API Std. 530
Transfer line design conditions

- To cover the blocked discharge case, the heater transfer line was designed for the following:
  - 66.2 kg/cm² (942 psig) at 513°C (955°F)
  - Line class used 600# flanges and valves. These conditions are within the allowable using the 33% excess pressure of B31.3
- Heater outlet flanges are 900# class. The rest of the transfer line is 600# class.
  - None of the 900# class flanges leaked. Using the same 33% excess pressure at the design temperature calculates to 101.6 bar-g.
Flange ratings by class from ASME B16.5

By interpolation, the Allowable pressure for These 9% Cr – 1% Mo Flanges is 67.8 bar-g

Same calculation for the 900# class flanges results in 101.6 bar-g

<table>
<thead>
<tr>
<th>Nominal Designation</th>
<th>Forgings</th>
<th>Castings</th>
<th>Plates</th>
</tr>
</thead>
<tbody>
<tr>
<td>9Cr–1Mo</td>
<td>A 182 Gr. F9</td>
<td>A 217 Gr. C12 (1)</td>
<td></td>
</tr>
<tr>
<td>Class Temp., °C</td>
<td>150</td>
<td>300</td>
<td>400</td>
</tr>
<tr>
<td>-29 to 38</td>
<td>20.0</td>
<td>51.7</td>
<td>68.9</td>
</tr>
<tr>
<td>50</td>
<td>19.5</td>
<td>51.7</td>
<td>68.9</td>
</tr>
<tr>
<td>100</td>
<td>17.7</td>
<td>51.5</td>
<td>68.7</td>
</tr>
<tr>
<td>150</td>
<td>15.8</td>
<td>50.3</td>
<td>66.8</td>
</tr>
<tr>
<td>200</td>
<td>13.8</td>
<td>48.6</td>
<td>64.8</td>
</tr>
<tr>
<td>250</td>
<td>12.1</td>
<td>46.3</td>
<td>61.7</td>
</tr>
<tr>
<td>300</td>
<td>10.2</td>
<td>42.9</td>
<td>57.0</td>
</tr>
<tr>
<td>325</td>
<td>9.3</td>
<td>41.4</td>
<td>55.0</td>
</tr>
<tr>
<td>350</td>
<td>8.4</td>
<td>40.3</td>
<td>53.6</td>
</tr>
<tr>
<td>375</td>
<td>7.4</td>
<td>38.9</td>
<td>51.6</td>
</tr>
<tr>
<td>400</td>
<td>6.5</td>
<td>36.5</td>
<td>48.9</td>
</tr>
<tr>
<td>425</td>
<td>5.5</td>
<td>35.2</td>
<td>46.5</td>
</tr>
<tr>
<td>450</td>
<td>4.6</td>
<td>33.7</td>
<td>45.1</td>
</tr>
<tr>
<td>475</td>
<td>3.7</td>
<td>31.7</td>
<td>42.3</td>
</tr>
<tr>
<td>500</td>
<td>2.8</td>
<td>28.2</td>
<td>37.6</td>
</tr>
<tr>
<td>538</td>
<td>1.4</td>
<td>17.5</td>
<td>23.3</td>
</tr>
<tr>
<td>550</td>
<td>...</td>
<td>15.0</td>
<td>20.0</td>
</tr>
<tr>
<td>575</td>
<td>...</td>
<td>10.5</td>
<td>13.9</td>
</tr>
<tr>
<td>600</td>
<td>...</td>
<td>7.2</td>
<td>9.6</td>
</tr>
<tr>
<td>625</td>
<td>...</td>
<td>5.0</td>
<td>6.6</td>
</tr>
<tr>
<td>650</td>
<td>...</td>
<td>3.5</td>
<td>4.7</td>
</tr>
</tbody>
</table>
Potential sources of excess pressure

- Two potential causes were identified by the incident investigation team
  - Liquid water from the velocity BFW or from the emergency BFW entered the heater and vaporized, pressurizing the heater feed circuit
  - The hydrocarbon in the heater transfer line continued to react, similar to a soaker drum on a Visbreaker. The increased number of moles of material due to thermal cracking caused the pressure to increase.
Conclusions

- The rate of pressure increase was faster than what could be justified by thermal cracking
- Heater feed temperature at the point of velocity BFW injection is 300°C (572°F)
  - Vapor pressure of water at this temperature is 87.6 kg/cm² absolute (1246 psia)
  - Required heater feed temperature to reach 101.6 bar-g is 313°C (595°F)
- Most likely cause was liquid water used as velocity media entering the heater and vaporizing with the heater feed pump isolation valve closed.
Recommendations and Mitigations

- Resize restriction orifices on steam purge to hot valves
  - Need to be sized on minimum differential between steam header pressure and process pressure
- Modify interlock logic to monitor drum inlet temperature and not allow switch to be completed if inlet temperature does not increase
- Monitor torque required to move valves. Repair or replace valve when torque value exceeds pre-set limit
- Monitor purge steam flow rates. Ensure purges are flowing when needed
- Reduce the time from loss of flow to burner trip from 20 seconds to 10 seconds