1Q 2017

• Plan was to run ~30kbpd of a crude

• Acidic properties caused Ops to cut rate to maintain 5.5pH in brine water, achieved ~20kbpd

• Led to significant rate cuts and lost profit

• Alternative crude sourcing to fill gap was not feasible

• <20ppm NH3 in Wash Water, 7.5pH
Multiple crudes from this producer show pH depression
- Drops could be sudden and severe, violating integrity limits
- Acid loading varies between cargos, even for the same crude
- Makes planning rates difficult

Producer verified acidic additive used intermittently at the well head

Crudes from this producer have since been banned by Process Engineering
pH Limit Background

• Desalter brine Integrity limit is set at 5.5pH

• Mechanical is concerned low pH is causing corrosion in:
  - Preheat Train
  - Desalter
  - Brine Effluent piping
Troubleshooting

• Pulled iron samples from brine water in attempt to estimate corrosion rate

• Made pH vs. Iron (ppm) curve to see if process changes impacted dissolved iron

• Process changes made to reduce corrosion
  - Base-lined data – no filmer, 100% water to front of cold train
  - Added chemical vendor filmer to 1st Stg Desalter
  - Removed 1st Stg water from front of crude train, routed it just upstream of mix valve
Troubleshooting

Desalter pH - Iron Relationship

- No Filmer
- Filmer
- 4-10 Shift
- Dry Cold Train
- 2nd Stg

y = 62.216e^{-0.558x}
R² = 0.5961

y = 59.132e^{0.63x}
R² = 0.642

y = 38.958e^{0.461x}
R² = 0.6329

y = 57.448e^{-0.539x}
R² = 0.8766

Iron in Brine (ppm)

pH

Andeavor

Acidic Crude

October 5, 2017
Observations

• Iron did vary with pH
• 2\textsuperscript{nd} stage consistently showed 0ppm iron. 1\textsuperscript{st} Stg showed some iron at lower pH
• Filmer had no impact
• Change in water mix point had no impact on iron. Did see spike in Vac Overhead chlorides.
Observations

- Crude has iron in it, detected using xray.
- Ran acidic water through crude, no iron detected in effluent water
- Chem Vendor – refineries using brine acidification desalter don’t monitor iron, use UT
- Solids/sediments in desalter may contain iron

Process Conclusions
- No cold train corrosion occurring
- Desalter may be corroding
- May be leaching iron from desalter sludge
- Iron content is not a good way to measure corrosion at the desalter

Mechanical concerned about damage from campagin
Risk - Desalter

Assumptions:

• All iron came from desalter wall, water section
• Life based only corrosion allowance - vessel wall still intact, pH was corrected before significant damage or a hole-through occurred
• 100% corrosion allowance available
• Low failure risk

### Desalter Vessel Equipment Life Calc - Assuming Corrosion is all in vessel

<table>
<thead>
<tr>
<th>Water</th>
<th>Iron, Mass Lost</th>
<th>Desalter Wall Loss</th>
<th>Vessel Life</th>
<th>Life Span Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>bph Water</td>
<td>gph</td>
<td>lb/hr</td>
<td>ppm Iron</td>
</tr>
<tr>
<td>360</td>
<td>15,120</td>
<td>125,496</td>
<td>6</td>
<td>0.75</td>
</tr>
<tr>
<td>360</td>
<td>15,120</td>
<td>125,496</td>
<td>5</td>
<td>0.63</td>
</tr>
<tr>
<td>360</td>
<td>15,120</td>
<td>125,496</td>
<td>4</td>
<td>0.50</td>
</tr>
<tr>
<td>360</td>
<td>15,120</td>
<td>125,496</td>
<td>3</td>
<td>0.38</td>
</tr>
<tr>
<td>360</td>
<td>15,120</td>
<td>125,496</td>
<td>2</td>
<td>0.25</td>
</tr>
<tr>
<td>360</td>
<td>15,120</td>
<td>125,496</td>
<td>1</td>
<td>0.13</td>
</tr>
</tbody>
</table>
Risk: Bundles w/ even corrosion

Assumptions:
• Iron is evenly removed from all bundles
• 50% wall loss allowable

Desalter Vessel Equipment Life Calc - Assuming Corrosion is all in vessel

<table>
<thead>
<tr>
<th>Water</th>
<th>gph</th>
<th>lb/hr</th>
<th>ppm Iron</th>
<th>lb-Fe/hr</th>
<th>lb-Fe/day</th>
<th>cuin/day</th>
<th>in lost/day</th>
<th>in/year</th>
<th>mil/year</th>
<th>Vessel Life</th>
<th>Life Span Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>bph Water</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>90 Day Run</td>
</tr>
<tr>
<td>360</td>
<td>15,120</td>
<td>125,496</td>
<td>6</td>
<td>0.75</td>
<td>18.1</td>
<td>5.06</td>
<td>2.39E-05</td>
<td>0.0087</td>
<td>8.73</td>
<td>28.6</td>
<td>0.86%</td>
</tr>
<tr>
<td>360</td>
<td>15,120</td>
<td>125,496</td>
<td>5</td>
<td>0.63</td>
<td>15.1</td>
<td>4.22</td>
<td>1.99E-05</td>
<td>0.0073</td>
<td>7.28</td>
<td>34.3</td>
<td>0.72%</td>
</tr>
<tr>
<td>360</td>
<td>15,120</td>
<td>125,496</td>
<td>4</td>
<td>0.50</td>
<td>12.0</td>
<td>3.37</td>
<td>1.59E-05</td>
<td>0.0058</td>
<td>5.82</td>
<td>42.9</td>
<td>0.57%</td>
</tr>
<tr>
<td>360</td>
<td>15,120</td>
<td>125,496</td>
<td>3</td>
<td>0.38</td>
<td>9.0</td>
<td>2.53</td>
<td>1.19E-05</td>
<td>0.0044</td>
<td>4.36</td>
<td>57.2</td>
<td>0.43%</td>
</tr>
<tr>
<td>360</td>
<td>15,120</td>
<td>125,496</td>
<td>2</td>
<td>0.25</td>
<td>6.0</td>
<td>1.69</td>
<td>7.97E-06</td>
<td>0.0029</td>
<td>2.91</td>
<td>85.8</td>
<td>0.29%</td>
</tr>
<tr>
<td>360</td>
<td>15,120</td>
<td>125,496</td>
<td>1</td>
<td>0.13</td>
<td>3.0</td>
<td>0.84</td>
<td>3.98E-06</td>
<td>0.0015</td>
<td>1.45</td>
<td>171.7</td>
<td>0.14%</td>
</tr>
</tbody>
</table>
Risk: Bundles-focused corrosion

Assumptions:
- All measured iron came from 1 bundle stack
- 50% wall loss allowable
- Stove, Diesel have least available metal – but lowest velocities
- HGO, TCSS have most metal – but highest velocities
- All stacks have bypasses to enable pulling – if valves hold

<table>
<thead>
<tr>
<th>Water</th>
<th>Iron, Mass Lost</th>
<th>Individual HX Stack Life with 100% Corrosion in only the list stack</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>bph gph lb/hr</td>
<td>HGO (lb-Fe/hr) lb-Fe/day Life (years) % Reduction (90 days)</td>
</tr>
<tr>
<td></td>
<td>ppm Iron lb-Fe/hr lb-Fe/day Life (years) % Reduction (90 days)</td>
<td></td>
</tr>
<tr>
<td>Life</td>
<td>% Life</td>
<td>Reduction</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>pH 4, not possible, introduces wet H2S cracking</th>
<th>pH 5~2.5ppm</th>
<th>Andeavor</th>
</tr>
</thead>
<tbody>
<tr>
<td>360 15,120 125,496 6 0.75 18.1 2.0 12.3% 0.9 27.4% 1.1 21.5%</td>
<td>360 15,120 125,496 5 0.63 15.1 2.4 10.2% 3.8 6.5% 1.1 22.9% 1.4 18.0%</td>
<td>360 15,120 125,496 4 0.50 12.0 3.0 8.2% 4.8 5.2% 1.3 18.3% 1.7 14.4%</td>
</tr>
<tr>
<td>360 15,120 125,496 3 0.38 9.0 4.0 6.1% 6.4 3.9% 1.8 13.7% 2.3 10.8%</td>
<td>360 15,120 125,496 2 0.25 6.0 6.0 4.1% 9.6 2.6% 2.7 9.1% 3.4 7.2%</td>
<td>360 15,120 125,496 1 0.13 3.0 12.1 2.0% 19.1 1.3% 5.4 4.6% 6.9 3.6%</td>
</tr>
</tbody>
</table>

Bundle Life - Assuming all corrosion is targeted at the specified stack
Conclusion

• Presence of acidic compounds limits crude throughput
• Variability in cargoes prevents accurate planning
• Iron data showed corrosion rates increased but could potentially be manageable for one off cargos
• Additional UT or other corrosion monitoring needed to better understand risks and possible adjustments to pH Integrity Limit
• Process group has banned acidic crudes, and all crudes from this producer