Introduction

• Coke Drums are batch operated, the reliability and profitability are heavily influenced by how they are operated every day.

• US coker operation today is heavily influenced by “opportunity” crudes and running 10-16 hour cycles

• Industry needs:
  – an approach for ranking and optimization of process & operations versus reliability and profits
  – a tool to allow better planning for maintenance, TAR and capital spending at the refinery and across many different sites.
Approach

1. SME’s - process, operation, inspection, mechanical for site review
2. Present operating & process practices condition
3. “Actionable” plan for inspection, maintenance and repairs
4. Measure local stresses and temperature gradients - HMS
5. Proactive planning maintenance and capital spending
6. Reliability “score” ranking provides guidance on damage
7. Optimize daily operations versus drum damage
Why Coke Drum Reliability Matters
Approach - Critical Factors

- Estimated drum life is set by a combination of critical factors, specific for each drum.
- Critical factors are needed for different drum regions:
  - Shell - girth seams
  - Skirt-to-shell junction
  - Skirt proper
- Factors:
  - Temperatures / strains / stresses: Measure “actual” local stresses and thermal gradients with Health Monitoring System.
  - Type of coke produced.
  - Other critical factors: Design, maintenance and inspection.
- Critical factors drive the assessment that predicts the current and future condition of drums.
Critical Factors Cracking and Bulging

Shell - Bulging

Bulging

Bulging Shell - Bulging
Axial Strain: Skirt-to-Shell Junction, 0 deg

Thermocouple and Strain Gage Locations
Critical Factors - Process and Operations

- Operating review is not just about data – it is an opportunity to **Optimize Process and Improve Daily Operation**
- Steam and water flow rates are reviewed and optimized for both operation / process efficiency and to reduce damage, cracking, and bulging.
  - Allow better conversion of feed, minimize hot spots
  - Improve consistency through better understanding
    - Inconsistent switch and quench procedures can cause significant stress and fatigue damage in shell and skirt.
- Measuring “actual” drum thermal gradients and strain gauges is imperative.
  - Accurately measure local drum response, linked to operation.
  - Evaluate effect of inlet types: side, dual, bottom, center.
  - Relate operations to stresses & damage.
- Closing the loop by teaching and training “inexperienced” operators.
Coke Drum Reliability Study Data Form – Process and Operating Information

<table>
<thead>
<tr>
<th>Site</th>
<th>[Saved to this PC]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date information is reported</td>
<td></td>
</tr>
<tr>
<td>Drum tag number</td>
<td></td>
</tr>
</tbody>
</table>

**Product Information**
Please enter complete sets of information for different periods/durations of operation (e.g. “condition 1”, “condition 2”, etc.):

<table>
<thead>
<tr>
<th>Condition Duration (years and cycles)</th>
<th>Condition 1</th>
<th>Condition 2</th>
<th>Condition 3</th>
<th>Condition 4</th>
<th>Condition 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of Coke Produced (shot, sponge, transition, needle)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Typical Coke Hardness</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coke Hardness Range</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal drum outage, ft</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anti-foam injection start</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Operating Data**

<table>
<thead>
<tr>
<th>Drum overhead temperature, °F</th>
<th>Before quench</th>
<th>Downstream of quench</th>
<th>Drum overhead pressure, psig</th>
<th>Cycle Length (hours)</th>
<th>Cycle length components, hr</th>
</tr>
</thead>
</table>
Critical Factors – Switch Temperature

Preheat/Switch Temperature Effect

Temperature vs. Time

Stress vs. Time
Thermal Gradients

[Diagrams showing thermal gradient distributions on June 9th, 10th, 12th, and 19th at various times with temperature scales and height and circumference axes.]
Critical Factors – Improved Quench

(from PDVSA)
Critical Factors - Operating Data

- Temperature at Start of Fill: Average Cycle = 458.4°F
- Quench Rate: Average Cycle = -26.8°F/min
- Cycle Time: Average Cycle = 16.7 Hours
Pulling It Together

• Critical factors are combined to give overall fatigue life

• The combination is based on calibration to numerous case histories
  – Time to initial cracking and bulging
  – Time to first through-wall crack
  – Incomplete data (e.g. no cracking yet) also incorporated for validation

• Provide near, mid, and long-term recommendations for TAR(s) to maximize the reliability of the drums and minimize the lost opportunities to stay on line
Case History - Drum Assessment Tool

1. Idea is that there are defined stages of coke drum life
2. Analysis tested/ultimately calibrated against industry and Becht data
3. Critical Factors: Shell, cone and skirt, welds, switch and quench, cracking, bulging, cycle length, coke type, inlet nozzle type, thickness etc.

- **Stage I:** Minor Problems
  - Proactive maintenance
  - Baseline and routine inspection
- **Stage II:** Predictable Crack Growth
  - More inspection
  - Planned repairs
  - Additional shutdown time required
- **Stage III:** Maintenance Intensive
  - More frequent shutdowns
  - Higher risk of unplanned outages

Goal Planned Spending versus unplanned
Case History - Girth Seam Results

- Results are provided as “quantitative”
- But goal is **forward-looking** 1-2 TARs out

<table>
<thead>
<tr>
<th>Year</th>
<th>Accumulated Cycles</th>
<th>Retirement Life Fraction Consumed*</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0.00</td>
<td>Current state</td>
</tr>
<tr>
<td>11</td>
<td>2275</td>
<td>0.39</td>
<td>TAR</td>
</tr>
<tr>
<td>15</td>
<td>3103</td>
<td>0.53</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>3723</td>
<td>0.64</td>
<td>Reduce run length to help ensure no through-wall cracking</td>
</tr>
<tr>
<td>21</td>
<td>4344</td>
<td>0.75</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>4964</td>
<td>0.85</td>
<td>Plan for replacement</td>
</tr>
<tr>
<td>27</td>
<td>5585</td>
<td>0.96</td>
<td>Likely replacement</td>
</tr>
</tbody>
</table>

* Based on retirement cycle life estimate of 5,830 cycles corresponding to no supplemental PAUT/TOFD inspection.
Program Benefits

- **Optimization** of drum performance to meet production, reliability and profitability goals
- Can **improve fatigue** life by over 30% (~3-5 years)
- **Brings people together – Best Practices**
  Integration of inspection, maintenance, process and operations personnel for better decisions
- **HMS** findings must be continually incorporated
- **Proactive** planning for **maintenance, TAR and capital spending** across one or multiple sites based on risk
- **Improved Reliability will improve Safety and Profitability**
Special Thanks – Coker Key Personnel

- **Mike Kimbrell**
  - 40 years experience – Becht Coker Process SME
  - *Formerly BP* - Process and Operations SME Coking worldwide

- **Mitch Maloney**
  - 40 years experience – Becht Coker Process SME
  - *Formerly ExxonMobil* – Process and Operations SME Coking Worldwide

- **Dave Dewees, PE**
  - 18 years experience - Becht Mechanical SME
  - Fatigue, high temperatures, thermal-stress analysis, crack growth

- **Bob Brown, PE**
  - 30 Years experience – Senior Fellow - Becht Mechanical SME and FFS Specialist
  - Fatigue, high temperatures, thermal-stress analysis, crack growth

- **Ranjan Nadarajah, PhD, PE**
  - 30 years experience - Becht Delayed Coking SME
  - *Formerly ExxonMobil* Mechanical coke drum SME

- **Clay White**
  - 36 years experience - Becht Materials and Corrosion SME
  - *Formerly Phillips 66* - Director Pressure Equipment Mechanical Integrity

- **Chuck Becht V, PE**
  - 15 years experience – VP Engineering
  - Fatigue, high temperatures, thermal-stress analysis, crack growth

- **Bobby Wright, PE**
  - 39 years experience – Becht Manager Refinery Services
  - Formerly Tosco and 29 years coke drum reliability
THANK YOU

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