AGENDA

• Background on Coke Drum defects
• Locations of defects
• Unique capabilities of Aquilex WSI
• Examples of innovative Repair Methods
  – Repair / Restore Corrosion with Automatic Weld Overlay
  – Skirt to Shell weld Repair Utilizing Temperbead
  – Bulge Repair with Temperbead
  – Skirt replacement and Shell Repair

• Conclusion
Coke Drums

- API - 80% of all coke drums in operation are experiencing cracking
- Cracking occurs within 5 to 7 years
- Most are Cracking and Bulging
- Why are they cracking and/or bulging
  - Operating on shorter cycles
  - Running different feedstocks
  - Weren’t designed for low cycle fatigue or compressive strength of coke
Typical Coke Drum Failures

- Cracking
  - Circumferential seam
  - Skirt to Shell welds
  - Shell cracks

- Bulging
  - Circumferential Seams
  - Shell Course

- ID Corrosion
  - Delamination/wear of cladding

Many skirts are cracking within 5 years of operation
Coking Cycle

Some Key Points of the Coking Cycle

Hot vapor fills drum, which grows larger
Hot oil (900F) fills the drum and hardens as it cools, cracks and releases vapor
Steam is used to remove volatile vapor
Water enters from bottom to cool the coke bed, becomes steam and flows up the center or outside along the walls
The coke drum contracts in diameter and height as it cools and “crushes” the coke
Eventually water can form and fills the drum
Skirt Cracking

During Quench - Skirt is Pushed and then gets Pulled by Knuckle

*Courtesy of Stress Engineering*
Global Leading Technology

**Tooling Engineering**
- Mechanical Systems
- High Definition Video
- Controls
- OEM Modifications

**Materials & Welding**
- Codes & Standards
- Welding Processes
- Corrosion Coatings
- Metallurgy

**Project Engineering**
- Solution Design
- Application Eng.
- Field Engineering
- Process Procedures

**Operations Support**
- Fleet Maintenance
- Mobilization Staging
- Site Technicians
- System Testing

- FEA Modeling
- Integrated 3D CAD
- Controls Simulation

- Mockup/Training Center
- 300+ Traveler Library
- 1050+ Welder Certifications

- 600+ Procedures
- Temperbead, E/C, etc.
- Level 3 NDE Capability

- 180 Automatic Systems
- 75 Semi-Auto Systems
- 40 Remote Vision Sets

Applied Engineering Excellence
Coker Weld Overlay Project

Refinery in Southern California
Project Overview

• T/A to Retro fit (4) four Coke Drums to accept new Delta Valves

• Coke Drum Material: SA387, Grade C, 1 ¼ Cr ½ Mo, 25mm thick

• Perform repairs to existing 410 explosion bonded cladding by applying over 115sq.m. of Inconel 82 Overlay in cone section above bottom nozzle

• Schedule: 10 days for all four drums total completion
Customer Challenge

• (2) Large projects occurring in Coker (Installing Delta Valve’s and Overlay work)

• Schedule: 10 days

• Reducing Cost

• Improving Quality

• Reducing Safety Instances
Project Planning

- Provided Planner to coordinate schedule and activities with others
- Developed detailed ventilation plan so other contractor personnel can continue to work while WSI performed our scope
- Provided crew of 8 In-direct personnel for entire project and 8 weld operators per coke drum working two shifts
- All work performed under WSI “R” stamp and QA program
WSI Solution

• Utilized 4 **Unifuse** PLC controlled Automated Weld Systems per drum (16 systems)
• Met customer’s 10 day schedule
• Took on additional scope during the T/A
• Safety: Zero lost time accidents
• Customer stated: “WSI was the best company out 22 on this T/A…First Class Crew”
Bulge Repair of Coke Drum
Utilizing Temperbead

Refinery in Canada
Bulging Coke Drum

- 8 Coke Drums
- Material: SA 263 Grade C
- Wall Thickness: 22.3mm
- Diameter: Ranging from 7925mm to 9755mm.
- Size: Ranging from 20m to 29m.
- One of the Cokers was experiencing bulging due to fire in drum
Bulge Severity and Growth

- Customer used Stress Engineering’s BIF to evaluate bulge severity of the drum surface.
- Result were intended as a guide to rank bulges for inspection priority as a function of their likelihood to encourage cracking.
- BIF factor correlates the geometric bulging patterns of past cracking histories, developed from examine other coke drums, to the bulges on the coke drum.

<table>
<thead>
<tr>
<th>BIF</th>
<th>Internal Cracking Likelihood</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; +2</td>
<td>Severe</td>
</tr>
<tr>
<td>+1.5 to +2</td>
<td>Very High</td>
</tr>
<tr>
<td>+1 to +1.5</td>
<td>High</td>
</tr>
<tr>
<td>+0.75 to +1</td>
<td>Medium</td>
</tr>
<tr>
<td>0 to +0.75</td>
<td>Low</td>
</tr>
</tbody>
</table>

- Of the eight drums reviewed, 1 Drum was identified with the most severe bulging at 2 Locations. We name them Bulge A & Bulge B.

Courtesy of Stress Engineering Services Inc.
Compare 2002 and 2004 Bulges

Courtesy of Stress Engineering Services Inc.
FEA Performed

- Stress Engineering performed FEA to validate overlay as “fix” for the problem

- Weld overlay reduces the stress on the bulge
  - Bulge peak hoop stress was reduced by 43% and 49% respectively on weld ID and OD
  - Bulge peak axial stress was reduced by 43% and 49% respectively on weld ID and OD

- The life of the repaired bulge is controlled by the hoop stress at the taper

- Increased Life Expectancy of Coke Drum by over 3X
Bulge Overlay

• Bulged area overlaid: 6.5m x 2m

• Applied Alloy 625, 955mm thick (2 layers), overlay utilizing temperbead utilizing (2) PLC controlled Unifuse Weld Systems

• Temperbead eliminated the need for PWHT

• Post Soak of 450º F (233C) for 2 hours to eliminate any potential for hydrogen
Temperbead Welding

HAZ created by 1\textsuperscript{st} weld layer

HAZ is tempered by deposition of successive layers
Conclusion

• Assessment by Stress Engineering quantified remaining life of bulge, and validated overlay process
• Overlay extended life of drum (bulged area) by 3X
• Unifuse® Overlay controls enabled temperbead application and increased productivity
Skirt to Shell Weld Repair with Temperbead Process

Refinery in California
Skirt Cracking

- 2 - Coke Drums
- Tower details:
  - SA-387-Grade 11 material
  - 31.7m tall
  - 8m ID
  - Original wall thickness 31.75mm
- Turnaround inspection:
  - 2003 T/A repaired weld seams in Coker # 2
  - May 2006 found many indications approximately 5mm deep, 25mm long, throughout the entire circumference of the weld seam in both drums
Customer Challenge

Client options:

- **Stick Welding:**
  - Already had contracted with local general contractor to gouge and re-weld, and it was going to take 3 outages to complete.
  - 3 Outages x 5 days = 15 Days required

- **Automated Welding:**
  - Utilize Temper bead technique
  - Work on both Coke Drums simultaneously
  - Eliminate PWHT
WSI Approach

Engineered Repair Design:

- Utilizing 8 Automated Weld Systems
- Machined and Re-Welded Circ Seam using Temperbead WPS
- Post Soak used, eliminated PWHT
- UT Shear Wave acceptable
- 5 day Schedule for the welding of both Coke Drums
- Savings $$$
  - Customer avoided 10 days of Downtime
- Recently inspected after 1000 cycles - no cracks reported
Schedule

• Schedule was developed with the integrated team: Operations, Maintenance, Safety, Engineering, and Corporate Executives.
• Project Team reviewed and approved the entire plan…Repair and Safety
• This was an emergent project completely mobilized within 2 weeks of notification
Skirt Replacement and Shell Cracking Repair

Refinery in California
Customer’s Challenge

- 12 Drums
- Material: SA 387-12-CL2
- Drum Thickness: 1.377”
- Height: 90’ Tan - Tan
- Diameter: 18’5” ID

- Customer was experiencing cracking below skirt to shell weld. Changed the skirt design (key hole slot) to reduce stress on skirt to shell weld.
Cutting Out the Skirt Windows

• Set up torch to cut out window sections
• Windows were set up to be cut in 3 sections; Total of 9 windows – 3 stages
• The windows were cut approximately 10’ apart from each other.
Cutting Skirt Windows.

- Track guided torch in action.
- The torch cut a slice 90 degree in to the skirt.
- Then the bevels were cut after the window was removed.
Shell Crack Removal

• The crack was excavated with the carbon arc gouge process.
• The cracks ranged in depth from approximately 0.188” to 0.75”
• The cracks were removed to a minimum of 0.380” to ensure an acceptable weld repair geometry.
• If the crack still existed at 0.380” then more excavation was done.
• MT was performed to ensure cracks removed
Shell Crack Removal
Shell Crack Repairs

• 1\textsuperscript{st} and 2\textsuperscript{nd} layer of temper bead welded then in process MT performed
• After all of the welding and the 2 hour heat soak was completed a UT shear wave was done to check the area for flaws.
• If no flaws were found the area set for 24 hours to look for delayed cracking. After the 24 hour wait, another UTSW was done.
• If this UTSW was good then the window repairs started in this section of the skirt.
Fitting the windows
Welding Skirt Window

- GMAW and SMAW Temperbead procedures for P4
- Geometry dictated process
- Butter layer applied over 1 ½” backing strap
- Subsequent passes applied
- Post Weld Heat Soak 550 degrees for 2 Hours
- UT Shear Wave performed for Final Inspection
Finish ground window
Conclusion

Keys to Innovative Repair of Coke Drums
- Pre-Planning / Optimized Coordination
- Utilize Depth of Resources
- Applied Technology / Innovation

Value these keys provide:
- Safety Improvement
- Reduced Schedule Risk and Duration
- Lower Cost
- Improved Quality/Longevity
Questions……

Thanks…. Michael Welch
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