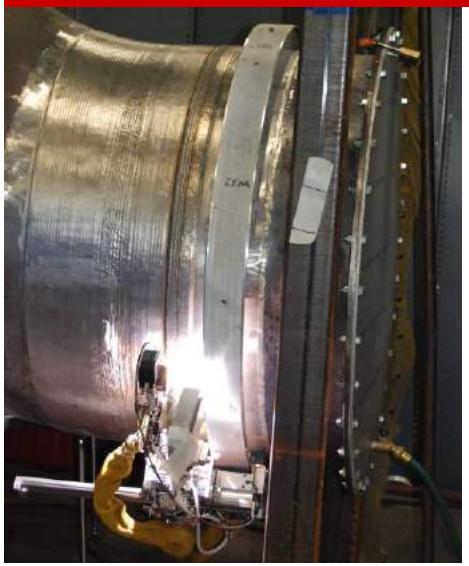


aquilex WSI

Coke Drum Repair

Coking.com®

Calgary Conference
September 14 -17, 2009

AGENDA

- Background on Coke Drum defects
- Locations of defects
- Unique capabilities of Aquilex WSI
- Examples of innovative Repair Methods
  - Repair / Restore Corrosion with Automatice 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

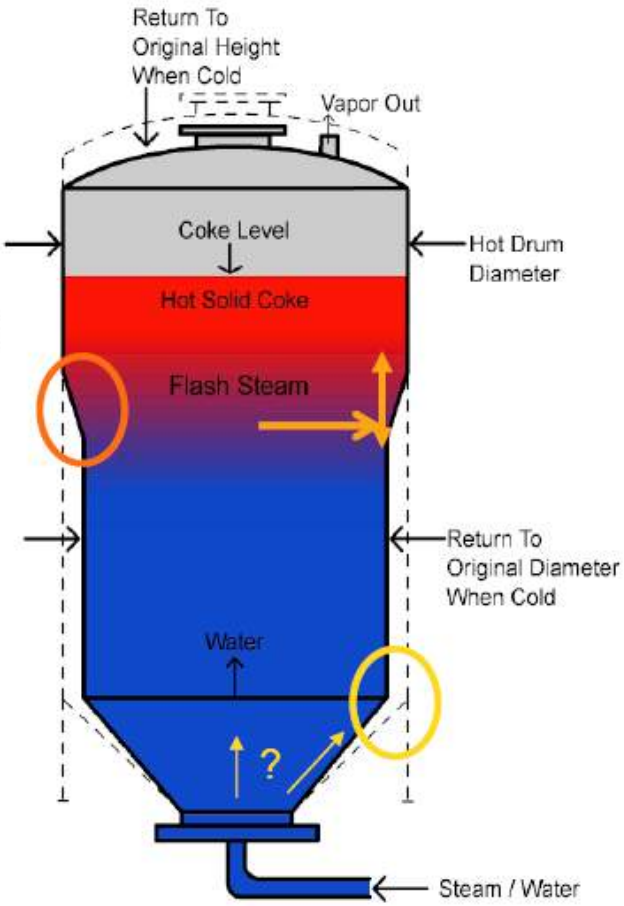
- Cracking
  - Circumferential seam
  - Skirt to Shell welds
  - Shell cracks
- Bulging
  - Circumferential Seams
  - Shell Course
- ID Corrosion
  - Delamination/wear of cladding

Many skirts are cracking within 5 years of operation

Coking Cycle

Some Key Points of the Coking Cycle

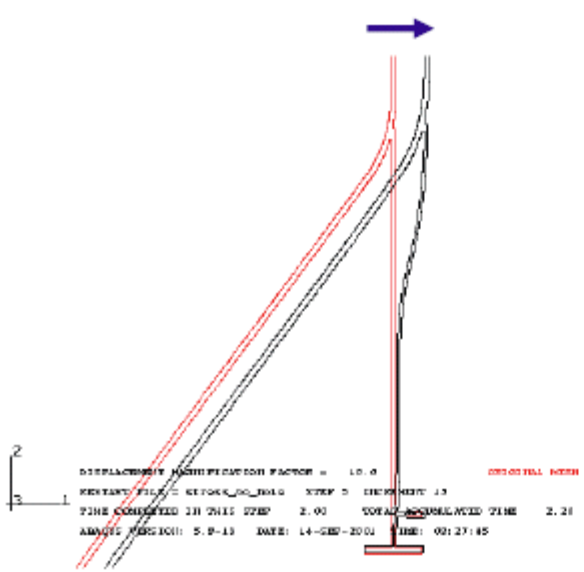
- Hot vapor fills drum, which grows larger
- Hot oil (900F) fills the drum and hardens as it cools, cracks and releases vapor
- Steam is used to remove volatile vapor
- Water enters from bottom to cool the coke bed, becomes steam and flows up the center or outside along the walls
- The coke drum contracts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

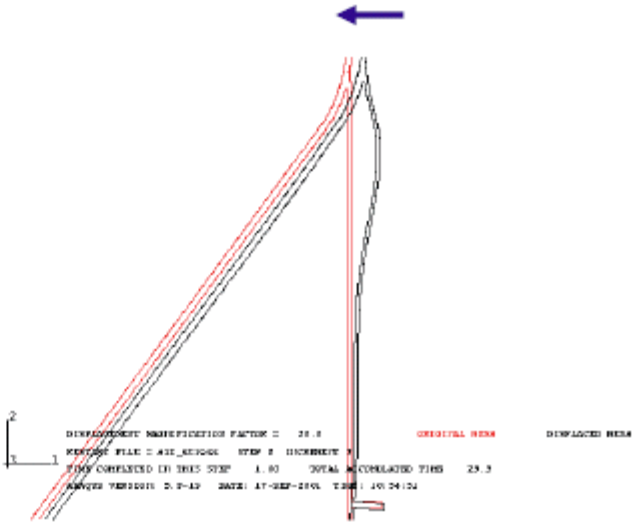


Skirt Cracking

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

DISPLACED SHAPE AT THE END OF FILL





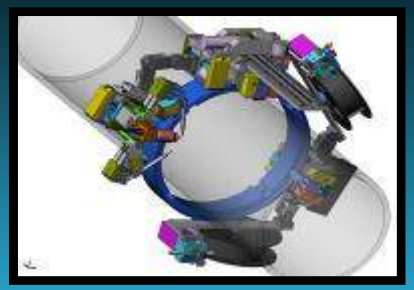
DISPLACED SHAPE 1 HOUR INTO QUENCH

(MAXIMUM STRESS DURING QUENCH OCCURS HERE)

**Courtesy of Stress Engineering*

Global Leading Technology

Tooling Engineering

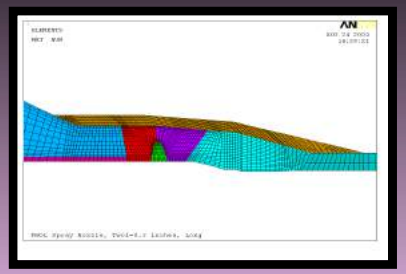


- Mechanical Systems
- High Definition Video
- Controls
- OEM Modifications

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

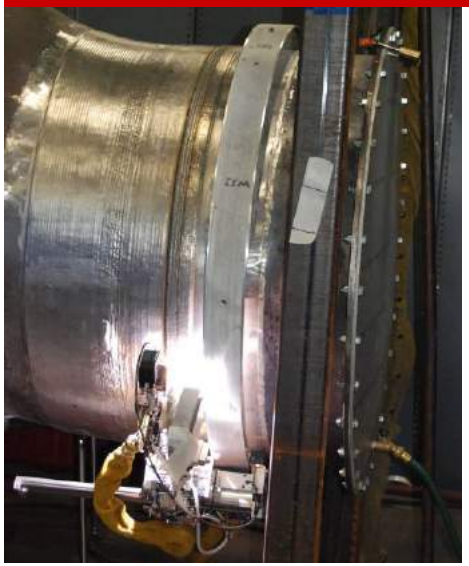
- **FEA Modeling**
- **Integrated 3D CAD**
- **Controls Simulation**

- **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



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Coker Weld Overlay Project

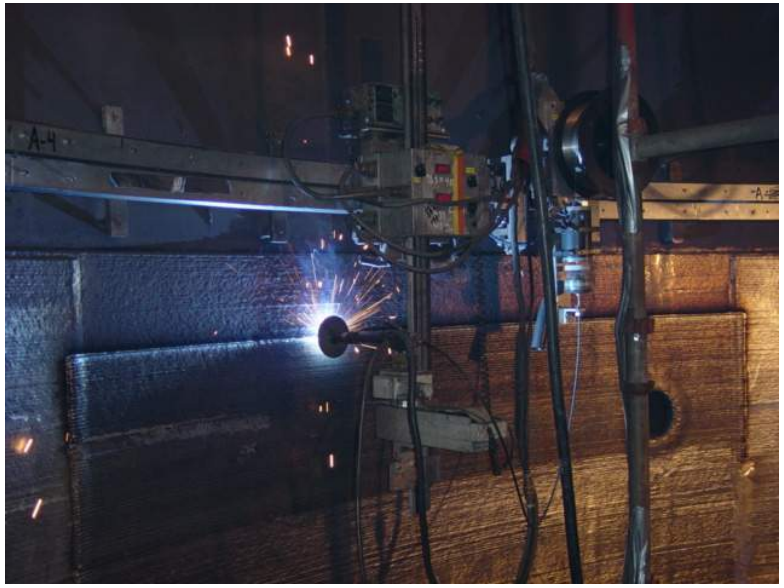
Refinery in Southern California

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



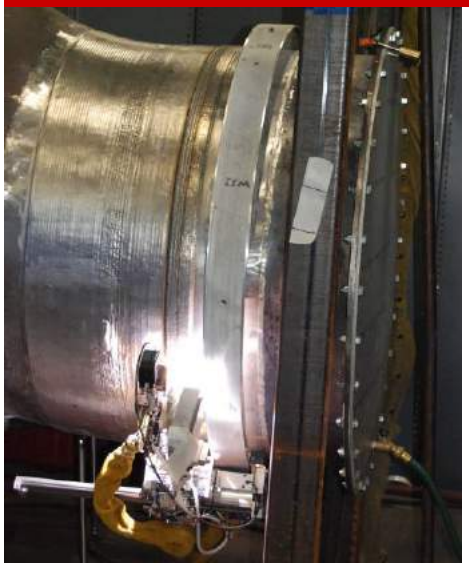
Project Planning

- 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

Unifuse Vessel Overlay

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"

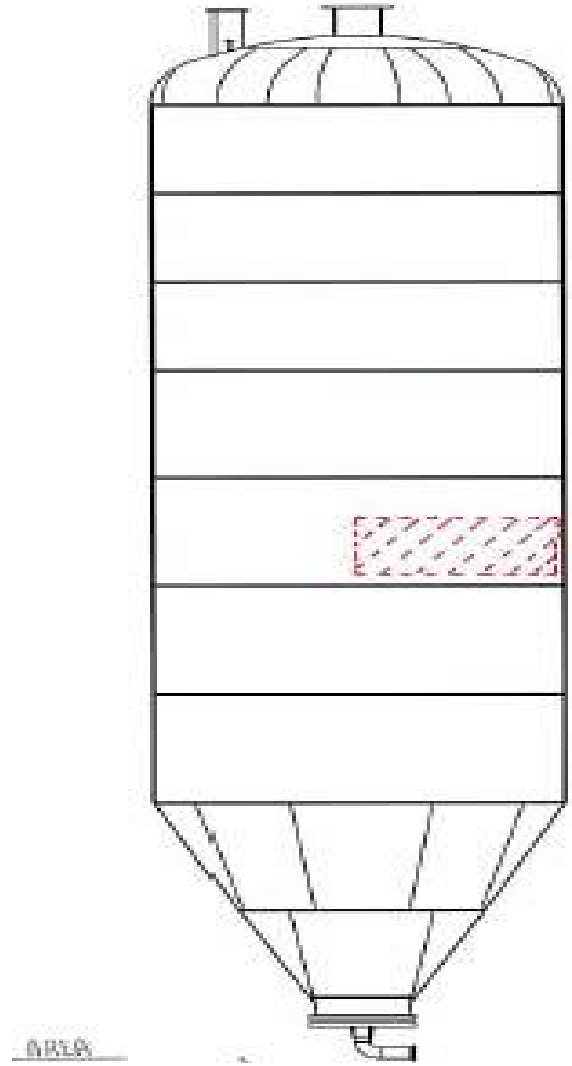


Bulge Repair of Coke Drum Utilizing Temperbead

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

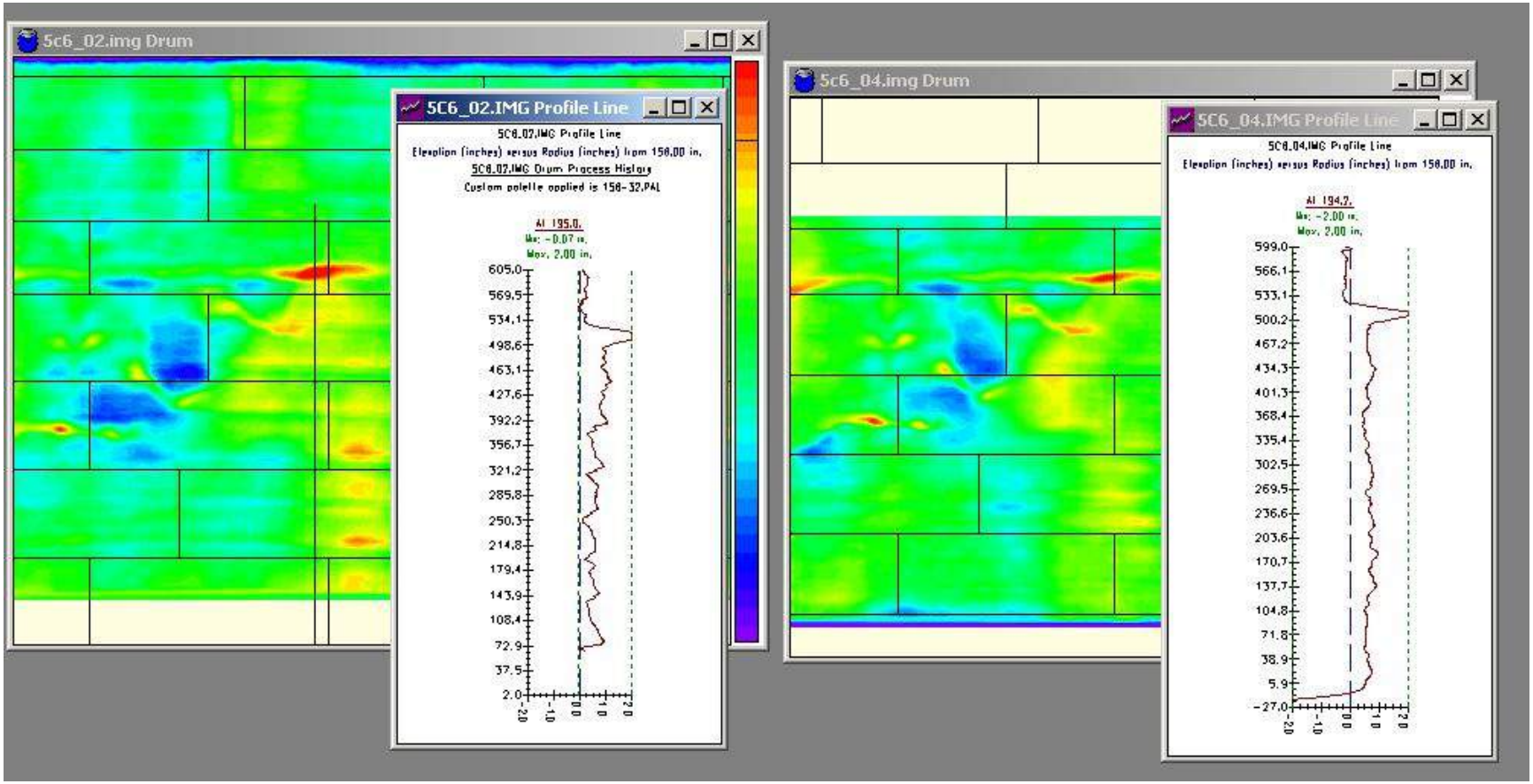
- Customer used Stress Engineering's BIF to **evaluate bulge severity** of the drum surface.
- Result were intended as a guide to **rank bulges** for inspection priority as a function of their likelihood to encourage cracking.
- BIF factor **correlates** the geometric bulging patterns of past cracking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

BIF	Internal Cracking Likelihood
≥ +2	Severe
+1.5 to +2	Very High
+1 to +1.5	High
+0.75 to +1	Medium
0 to +0.75	Low

- 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

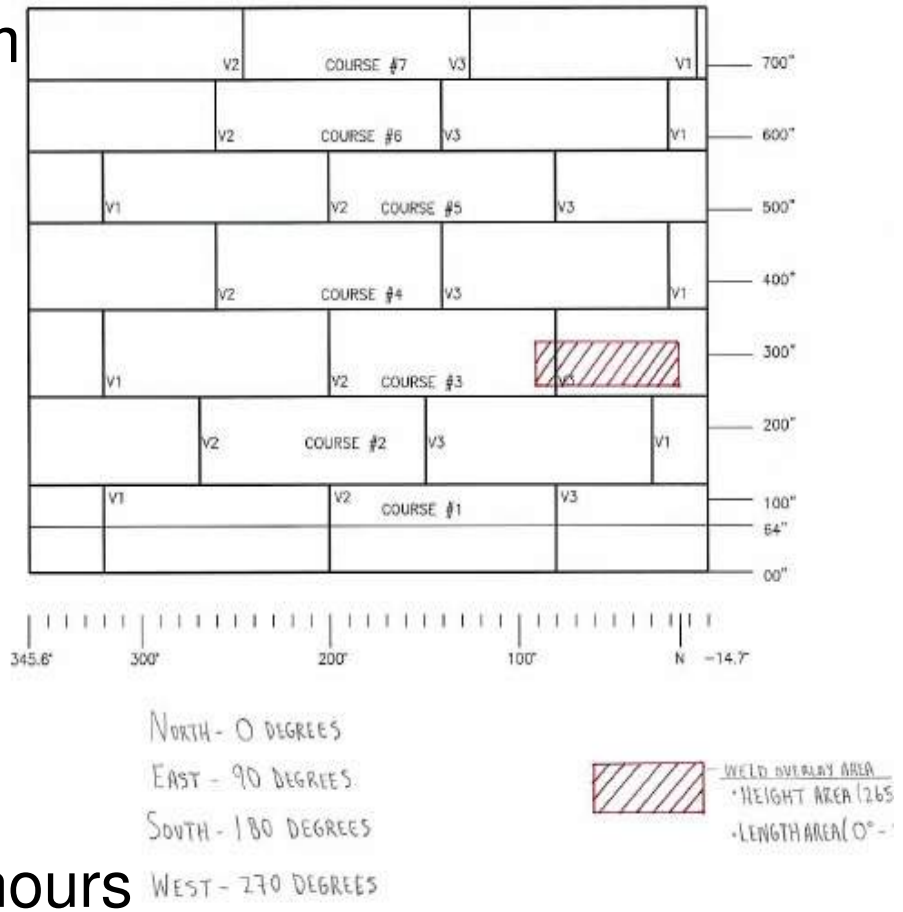
- Weld overlay reduces the stress on the bulge
  - Bulge peak hoop stress was reduced by 43% and 49% respectively on weld ID and OD
  - Bulge peak axial stress was reduced by 43% and 49% respectively on weld ID and OD
- The life of the repaired bulge is controlled by the hoop stress at the taper

- Increased Life Expectancy of Coke Drum by over 3X

Bulge Overlay

- Bulged area overlaid: 6.5m x 2m

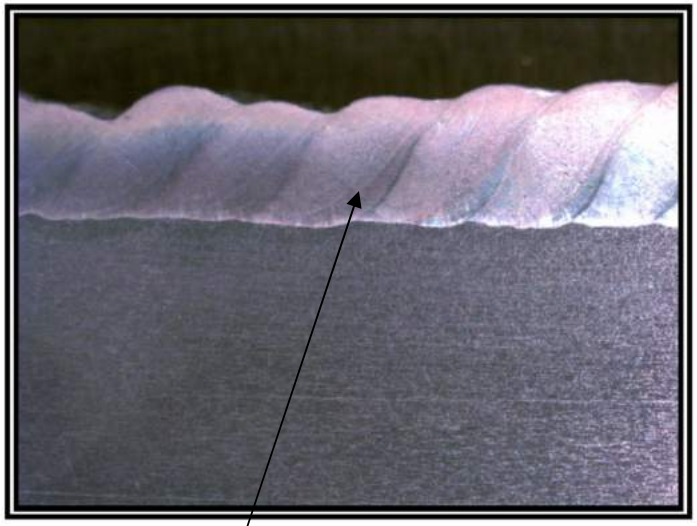
- Applied Alloy 625, 955mm thick (2 layers), overlay utilizing temperbead utilizing (2) PLC controlled Unifuse Weld Systems



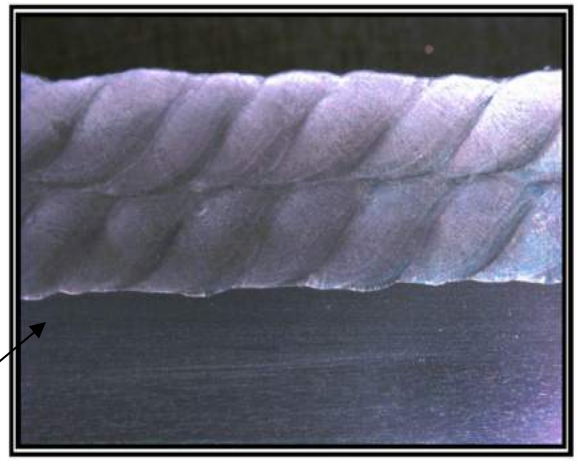
- Temperbead eliminated the need for PWHT

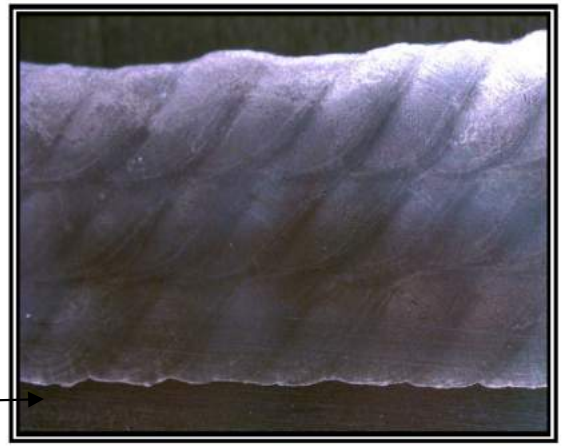
- Post Soak of 450º F(233C)for 2 hours to eliminate any potential for hydrogen

Temperbead Welding



HAZ created by 1st weld layer

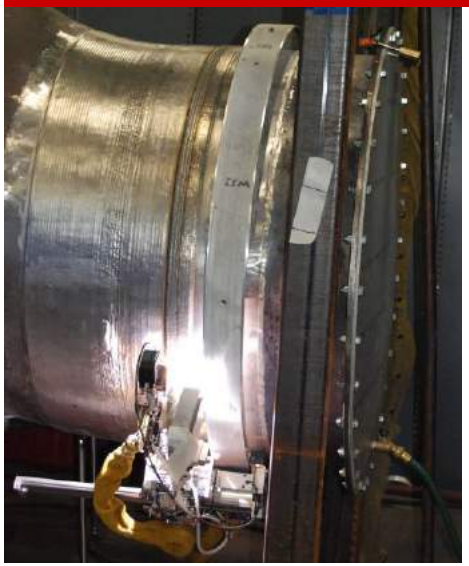




HAZ is tempered by deposition of successive layers

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

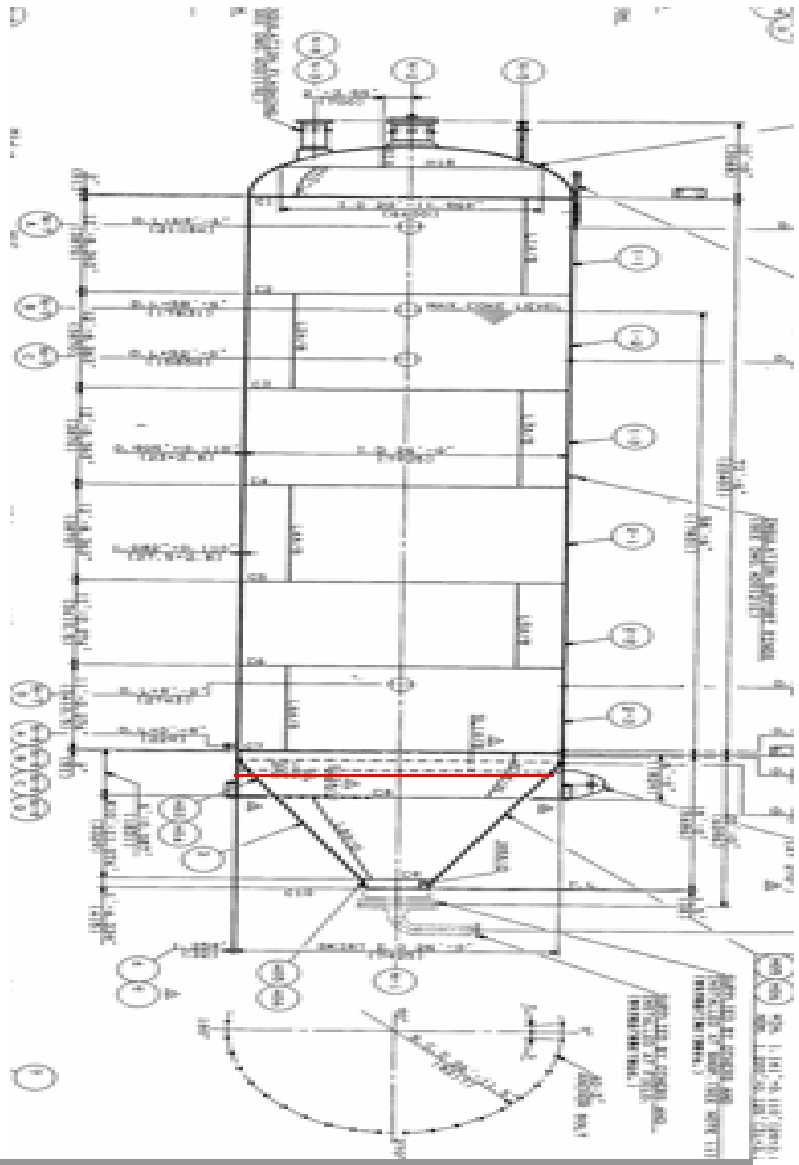


Skirt to Shell Weld Repair with Temperbead Process

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

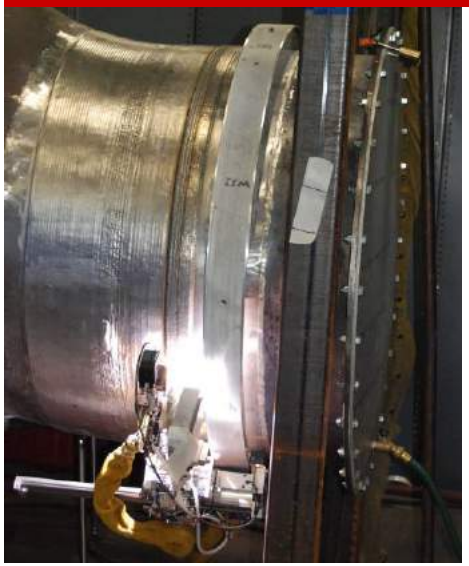
WSI Approach

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



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Skirt Replacement and Shell Cracking Repair

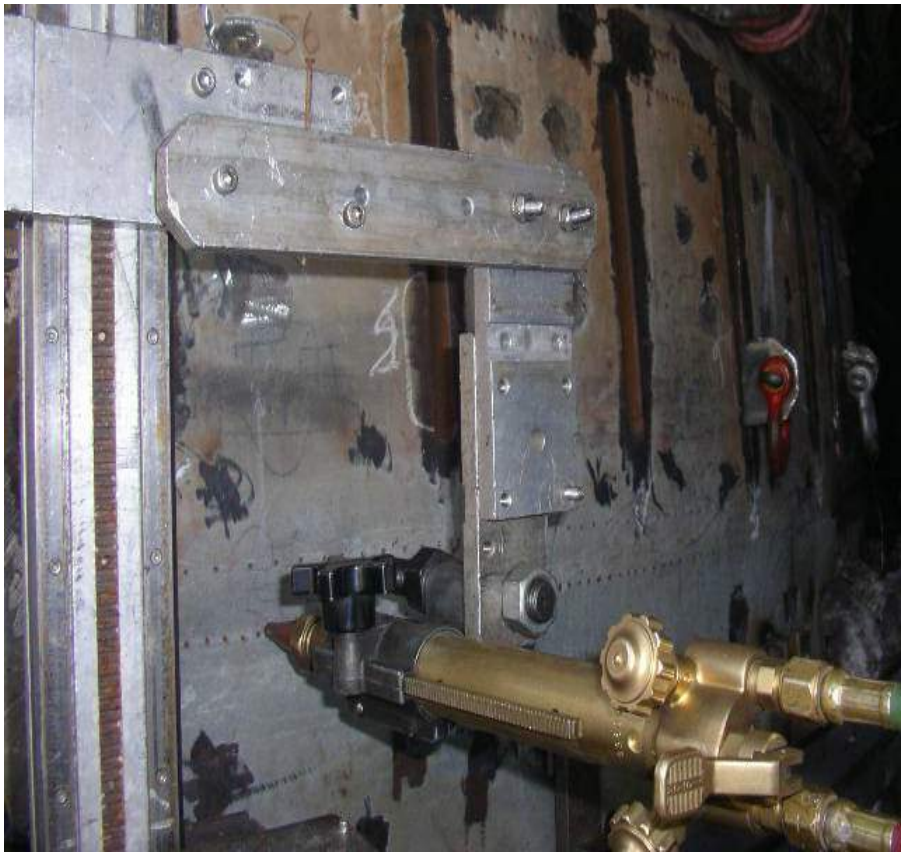
Refinery in California

Customer's Challenge

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

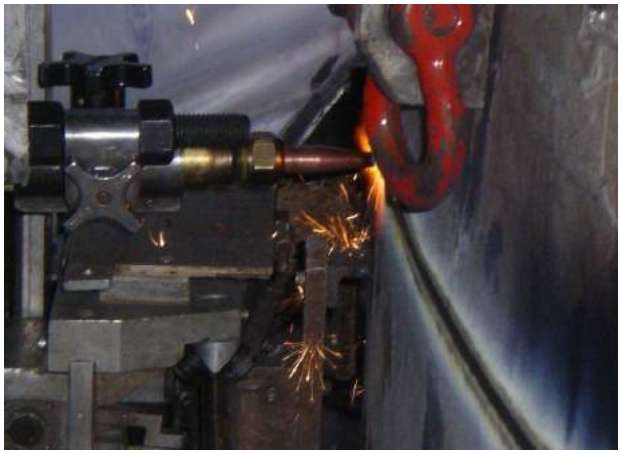
- Customer was experiencing cracking below skirt to shell weld. Changed the skirt design (key hole slot) to reduce stress on skirt to shell weld.

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

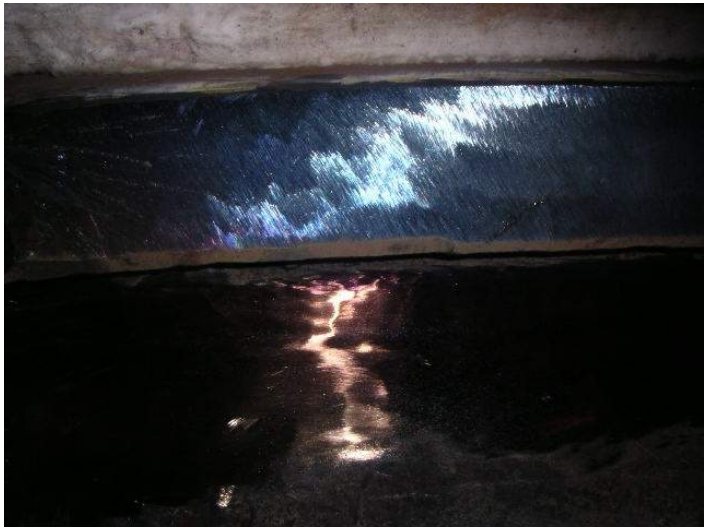
- The crack was excavated with the carbon arc gouge process.
- The cracks ranged in depth from approximately 0.188” to 0.75”
- The cracks were removed to a minimum of 0.380” to ensure an acceptable weld repair geometry.
- If the crack still existed at 0.380” then more excavation was done.
- MT was performed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

Shell Crack Removal

Shell Crack Repairs

- 1st and 2nd 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….

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