THE LARGEST COKE DRUM BULGE REPAIRS IN INDUSTRY HISTORY

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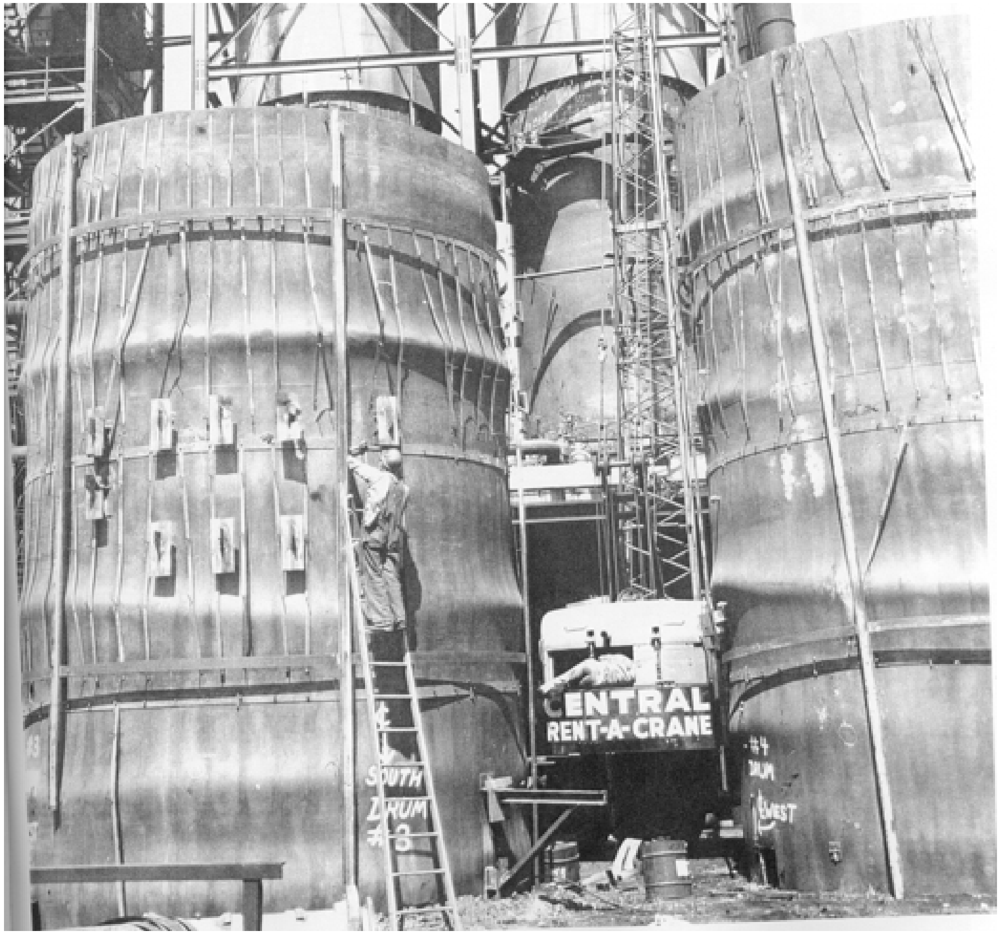
Overview

- Technical Background.
- Repair implementation.

Technical Background

History of Shell Bulging & Cracking

- Major problem for decades.
- Despite design improvements, still a problem- perhaps more severe today.



Courtesy of CB&I

API Surveys

- 1968 Survey:
  - Carbon steel drums bulged far more extensively than C-Mo drums before giving through-wall cracks.
- 1996 Survey:
  - 97% said cracks were primarily circumferential.
  - 57% reported shell bulging. <u>Of the drums that bulged, 87% cracked</u>.

Bulging Types

There are different types of bulges that are created by different mechanisms and should be treated differently:

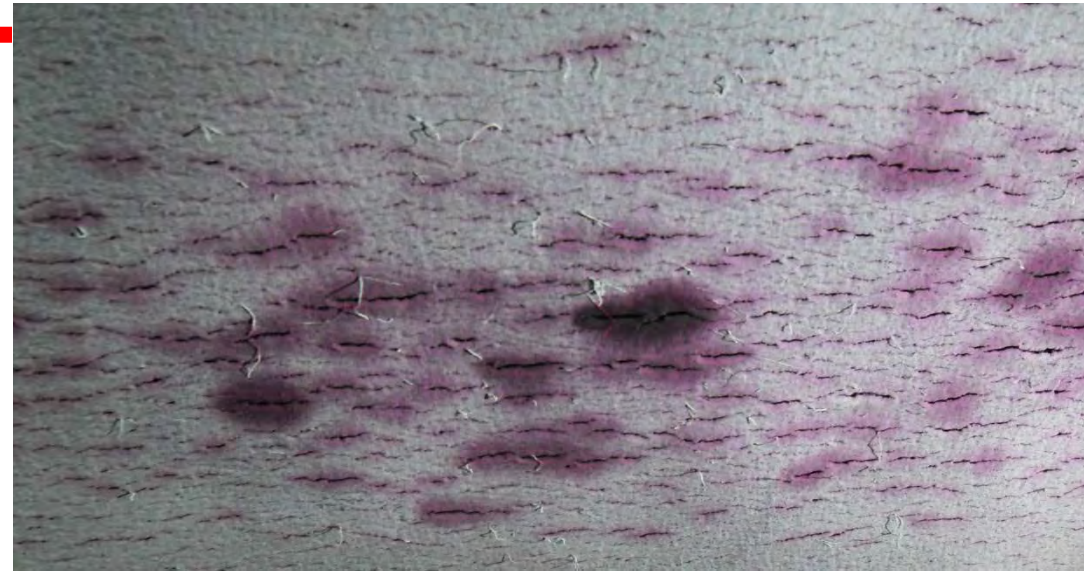
- Circumferential welds (especially w/ thickness change)
- Middle of drum
- In plates away from welds

Bulging-Induced Cracks

- Bulging-only
- Combination of bulging and weld defect
- Combination of bulging and weld-base mismatch

Bulging-Induced Cracks

INTERIOR



EXTERIOR

Consequences of Bulging

- PRIMARY: Excessive <u>strain</u>
  - Local failure
  - Initiation of bulging cracks
  - Strain age embrittlement.
- SECONDARY: Increase in nominal <u>stress</u>
  - More fatigue damage
  - Accelerated propagation of cracks
- Leaks and fires

Bulging Assessment per API-579 / ASME-FFS

- Level 1: N/A to coke drums
- Level 2: Does not exist
- Level 3: Infeasible and costly process

Industry Practice

- Stress analysis (1st generation)
- Geometric analysis (2nd generation)
- Strain analysis (3rd generation)

Strain Analysis

- Plastic Strain Index (PSI)™
- Based on failure limit of industry standard API 579/ ASME FFS
- Focuses on primary mode of failure.
- Excellent correlation with bulging cracks.

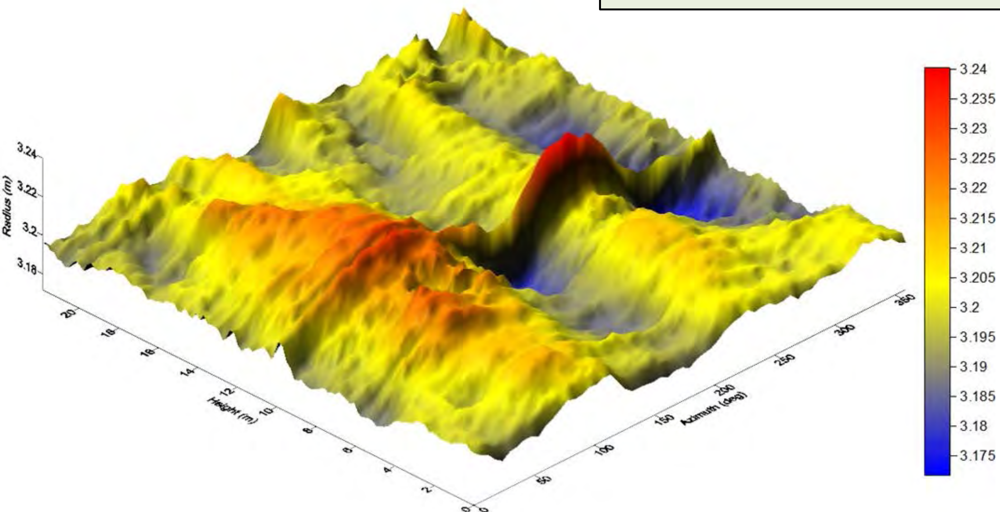
PSI Analysis

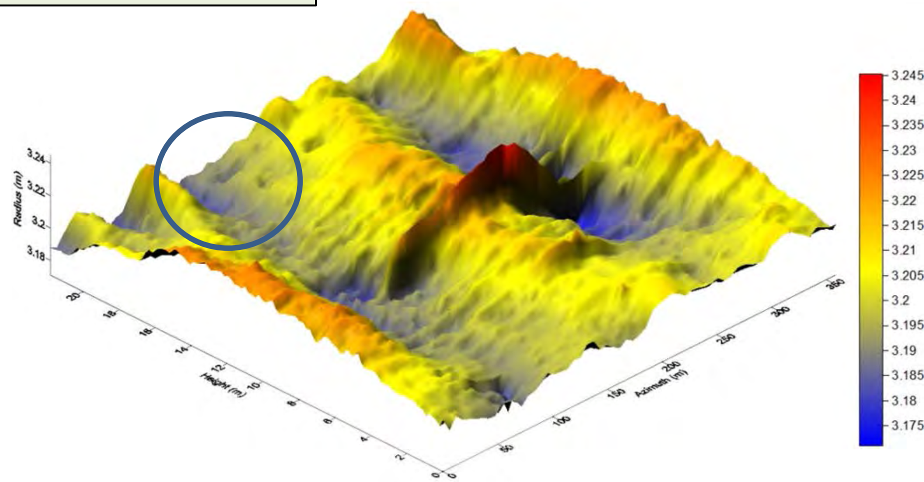
- Four-tier severity system: Design, Concern, Danger, and Failure.
- Used to determine likelihood of bulging-induced cracking and frequency of laser scanning.
- Can be used for other pressure vessels with bulges of similar failure modes.

PSI magnitude	**Severity Grade**	**Likelihood of Bulging-Induced Cracks**	**Recommended Frequency of Laser Scanning**
80% to 100%	Failure	Likely	6 months to 1 year
60% to 80%	Danger	Probable	1 year
40% to 60%	Concern	Possible	1 to 2 years
0 to 40%	Design	Unlikely	2 to 3 years

Radius Map

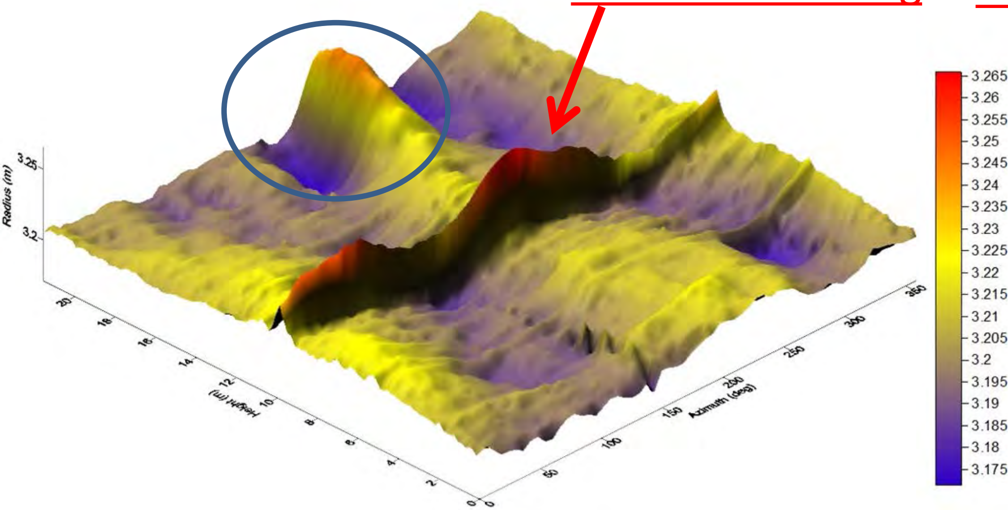
Various degrees of ovality circled

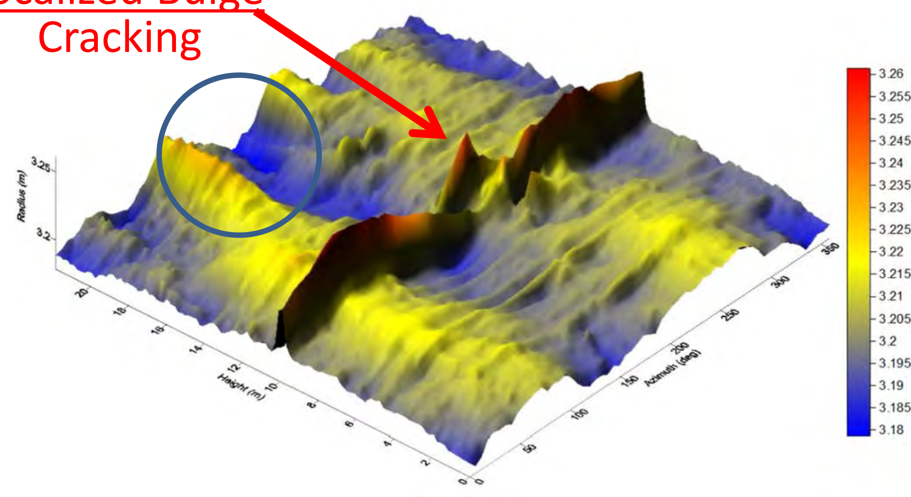




Excessive cracking

Localized Bulge Cracking





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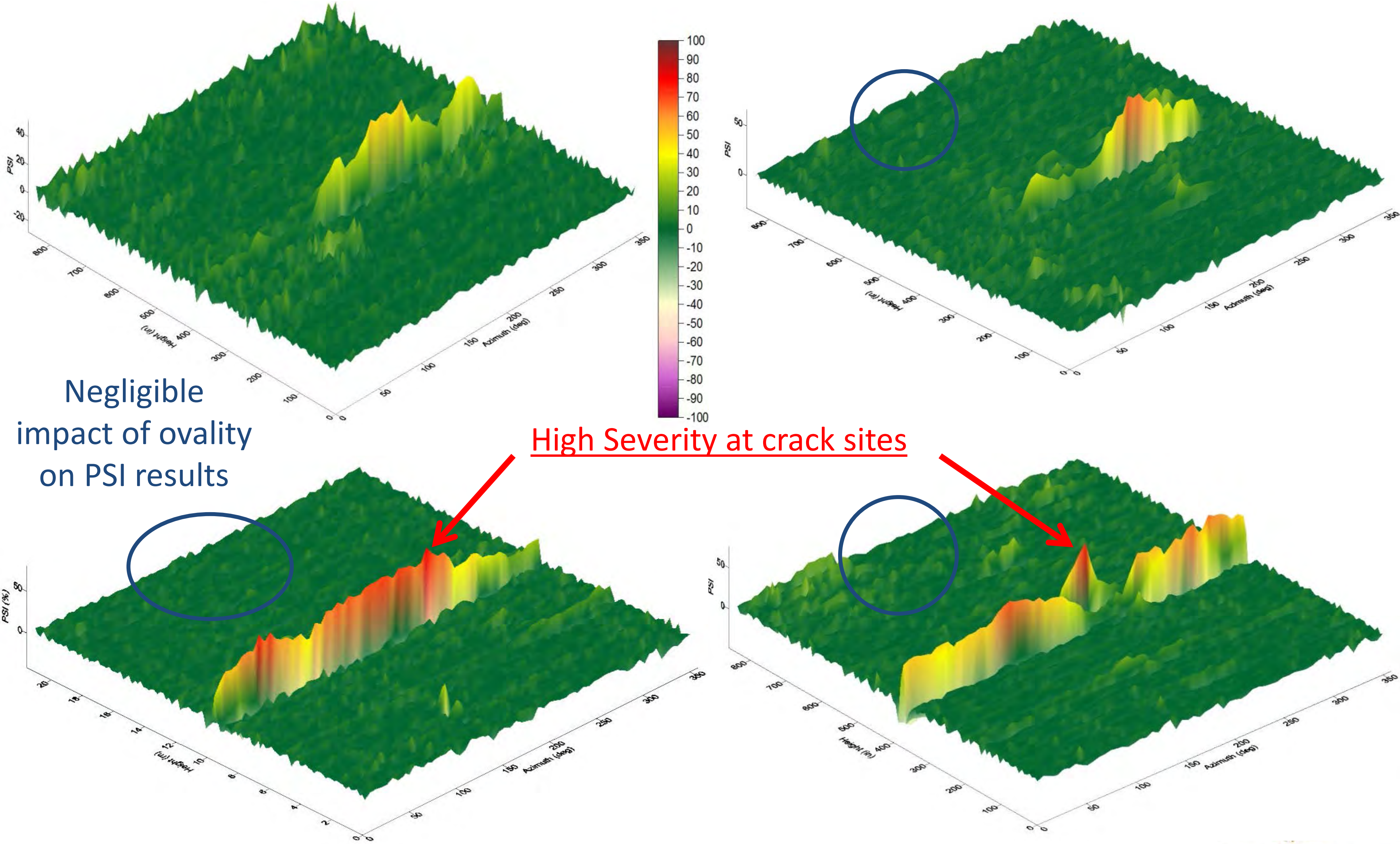
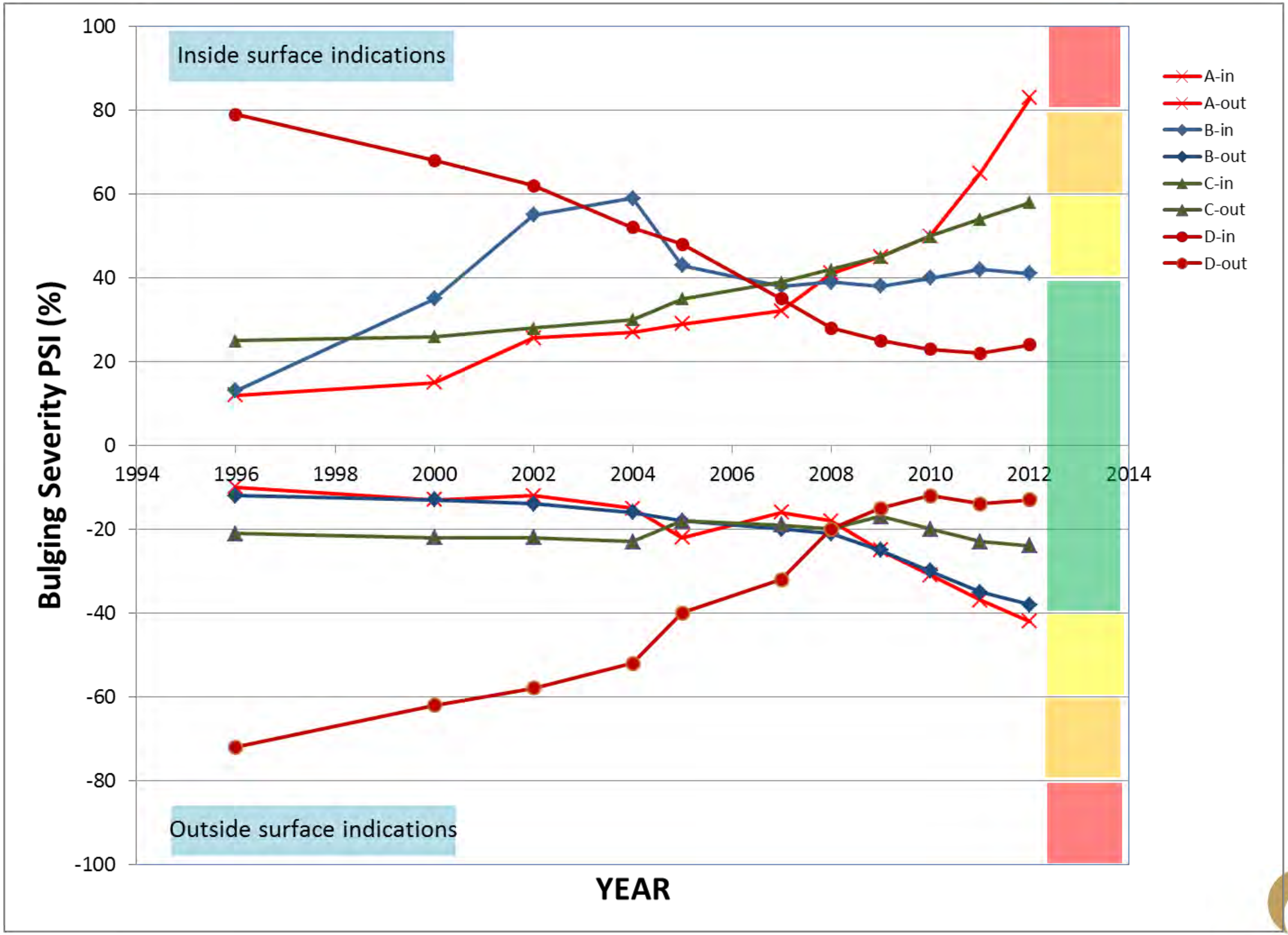
Plastic Strain Index (PSI)



PSI Trend => Repair Need



Common Types of Bulge Repairs

- Window replacement
- Can replacement
- Weld overlays
  - Internal
  - External
  - Sandwich

Window Replacement

- Advantages
  - Simplest
  - Least expensive
- Disadvantages
  - Fit-up stresses
  - Two-way material mismatch
  - Short-term repair

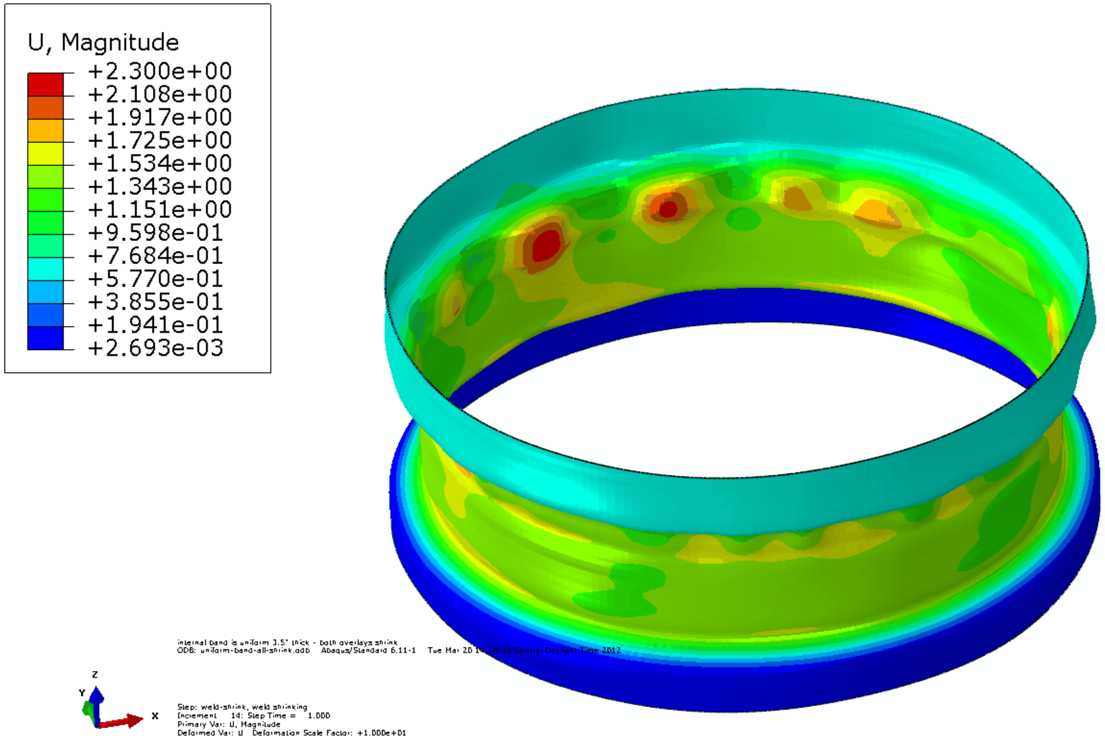
Can Replacement

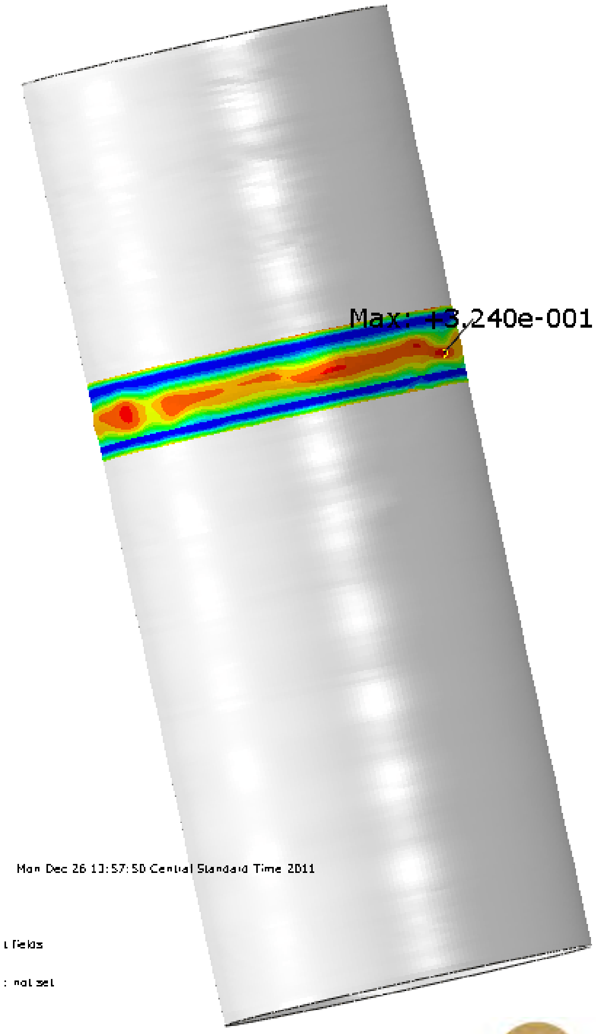
- Advantages
  - Better than window replacement
  - Effective solution for
    - Diagonal bulging
    - Extensive widespread cracking
    - Remote locations
- Disadvantages
  - Fit-up stresses
  - One-way material mismatch
  - Medium-term repair

Advantages of Weld Overlay Repair

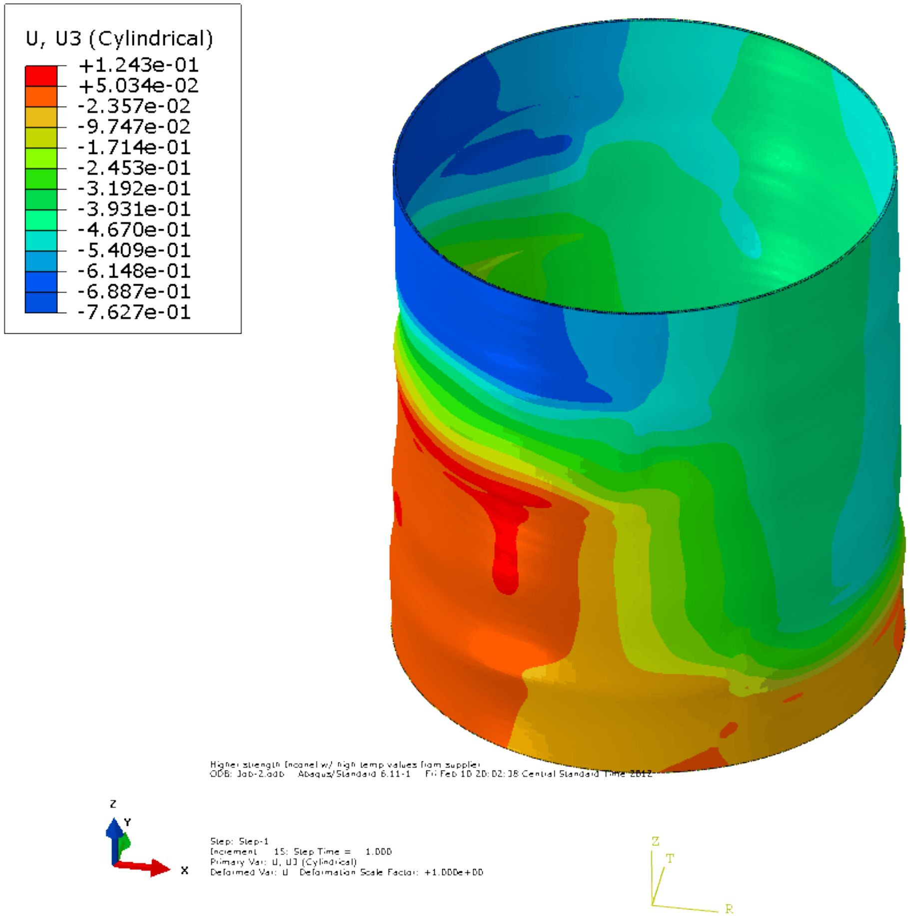
- Advantages:
  - Lower nominal stresses under mechanical loads.
  - Favorable residual stresses on application surface.
  - Possible reduction of bulging severity.
  - Most effective and longest-lasting repair, if designed and applied properly.
- Disadvantages:
  - Need good automated procedure.
  - Unfavorable low tensile residual stresses.
  - Need proper engineering to handle potential for:
    - Instability / buckling
    - Excessive distortion.
    - Impact of transition stress riser on fatigue life.
    - Excessive thermal expansion stresses from repaired zone expanding differently from rest of wall.
    - Ratcheting in thinner wall that could result in generation of new bulges.

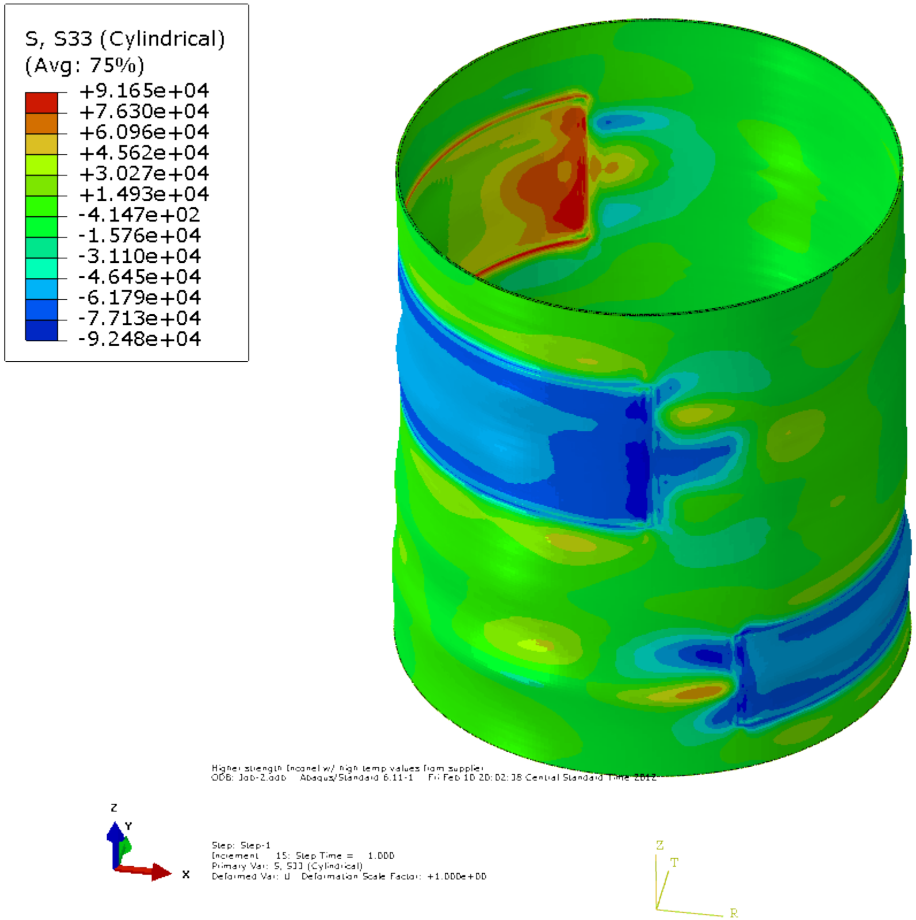
Buckling / Local Failure





Non-symmetric Distortion





Repair Implementation

Time History

- 08 coke drums commissioned in 1998
- Drums are 1.25Cr0.5Mo/SS410 clad

- Shell bulges monitoring since 2001
- Bulges >3” since 2007
- First shell crack: Apr2009 (2500cycles)
- First throughwall crack: Feb2010 (2740cycles)
- BOL repairs started: June2010
- Approx cycles:3650 Oct13

Scope of Repairs

- Total repairs with Controlled-Deposition Welding (CDW, without PWHT)

- Total Surface Area BOL repairs: 3350sqft

- Max size single location BOL repairs: 663sqft (2.2m x 28m)

Inspection requirements

Preparatory

- Repair specific PQR: Hardness, Toughness, Microstructure
- Mock-up with approved WPS/PQR: I, V, S

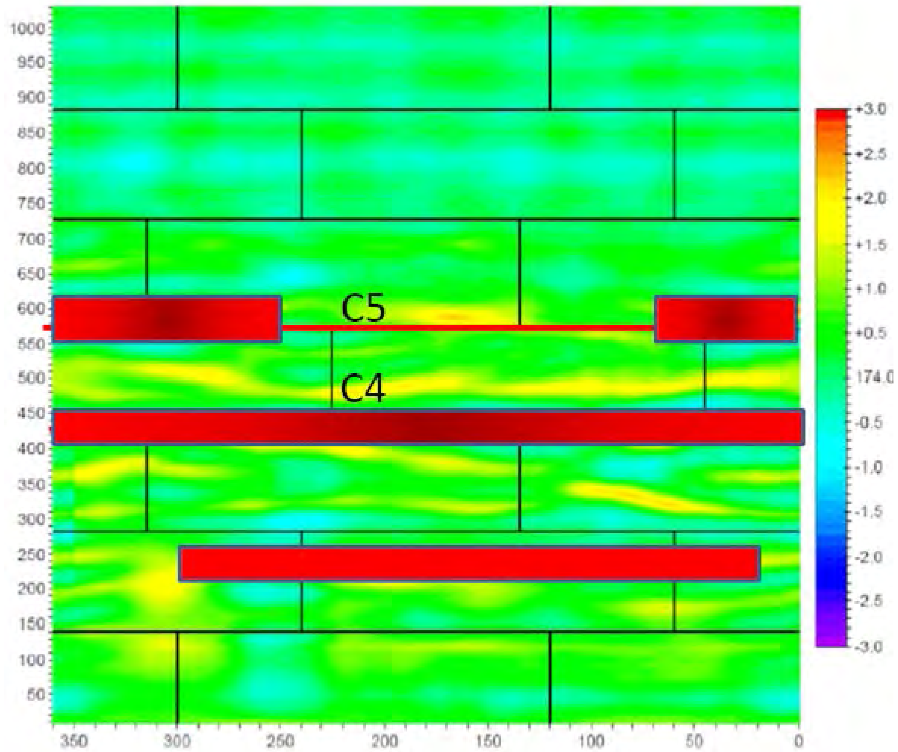
Site execution

- Mapping+Marking
- Clad layer removal – Cu Sulfate test (A380)
- Thickness check, Base line diameter measurements
- BOL as per approved WPS: Surface finish at edges/interface, PMI, Thk, Fluorescent DPT, Distortion measurements, Taper edges 10:1, hardness limits for overlay/interface/HAZ

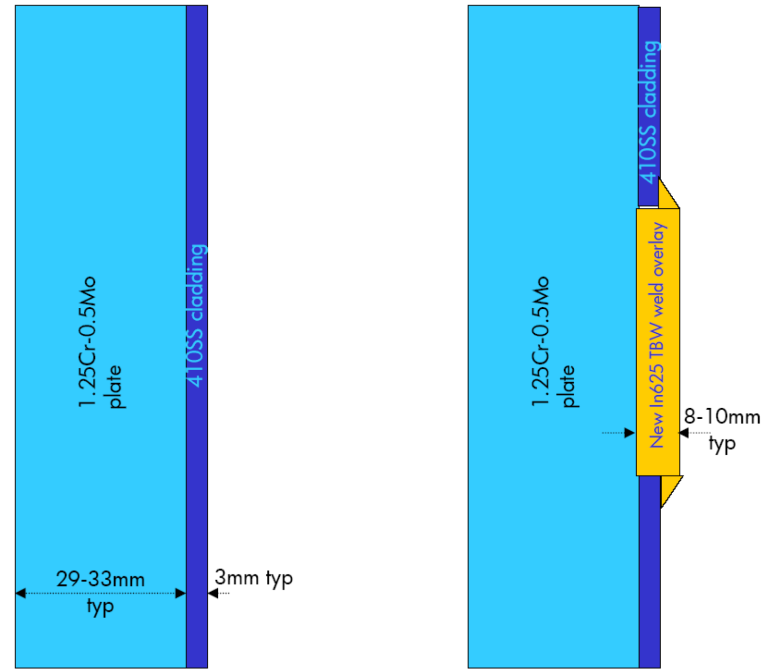
Challenges

- Overall process safety, Planning and scheduling for drum-pair repairs, with other drums in line.
- WPS/PQR: CDW with 3layers min, hardness control
- Quality welders/operators specific to CDW requirements
- Working crew within one single confined space
- Simultaneous repairs for multiple locations in a drum
- Mapping/marking on drum wall
- Distortion measurements
- Controlling WPS parameters during execution at site
- Prediction of subsequent bulge growth
- Residual stress control
- Expected life post repairs, esp due to shake-down effect

Photographs

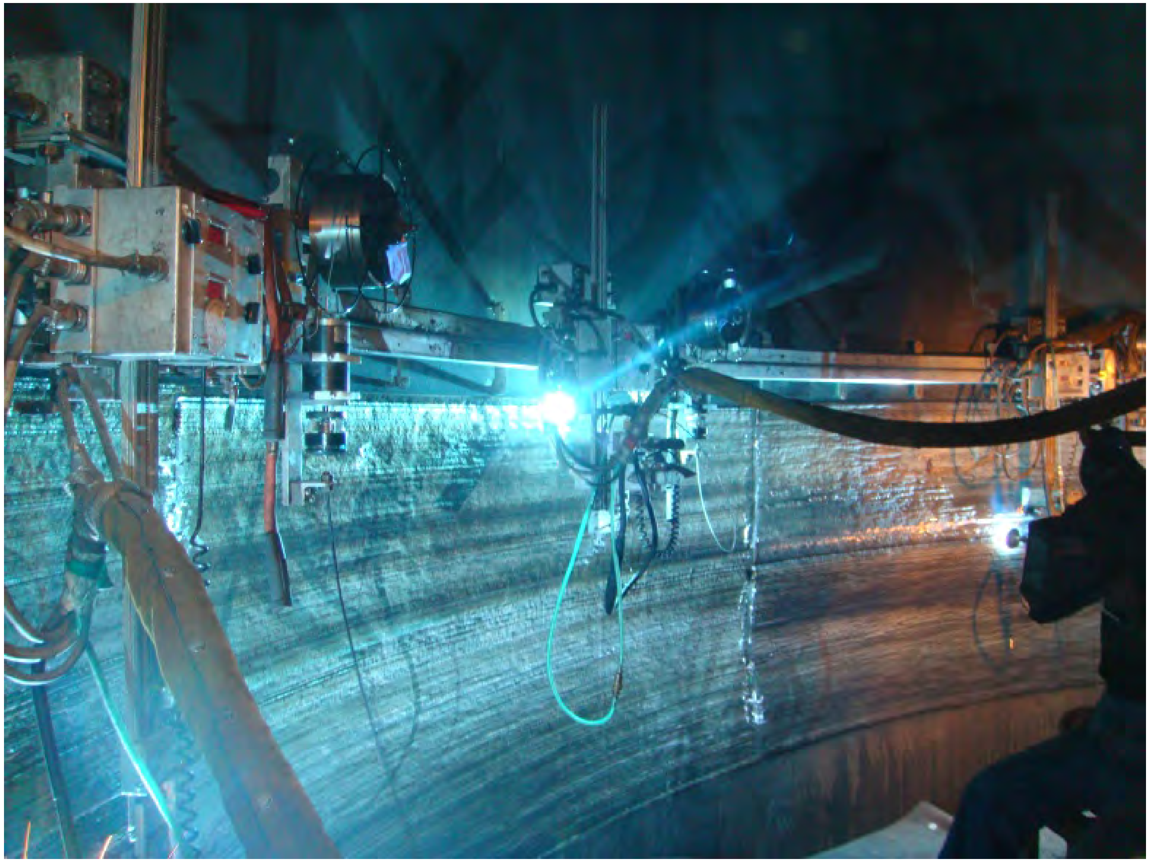


Typical Shell Map with repair areas on shell courses



Typical Shell cross section: as-is/post-repairs

Photographs



Typical bulge overlay repairs inside of the coke drum

Performance

- Bulge growth under control, steady.