Long-Term Repairs for Bulges

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OVERVIEW

- Is bulging common?
- How bad can bulging be?
- Why do drums bulge?
- So what?
- When should we repair?
- How to repair?
- How long will repairs last?

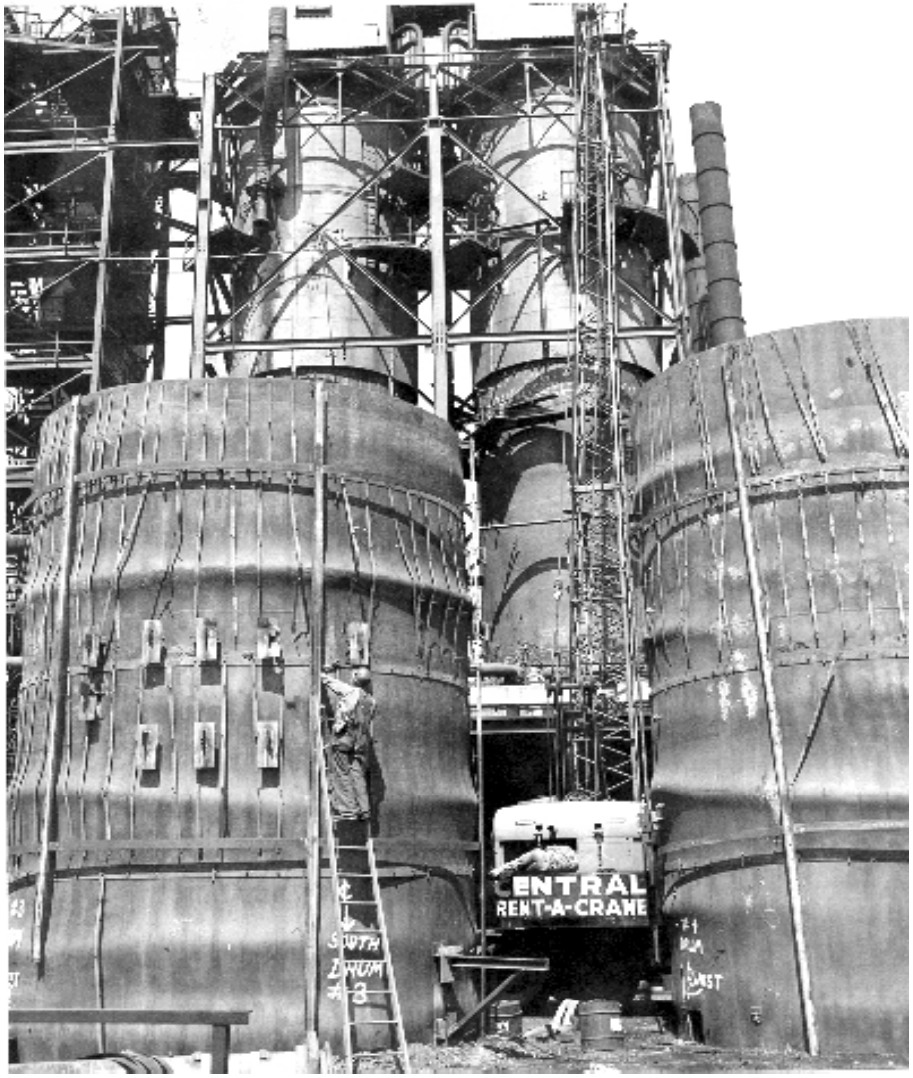
Is bulging common?

Maximum and Average Bulge Results

Question	Maximum Answer Range	Average Answer
Maximum Vertical Length	3” to 620”	65”
Average Vertical Length	2” to 50”	23”
Maximum Circumferential Length	5.5” to 1,074”	547”
Average Circumferential Length	4” to 1,074”	408”
Maximum Radial Bulge	.31” to 6”	3”
Average Radial Bulge	¼” to 6”	2.1”

(1996 API Coke Drum Survey, Final Report, 2003)

How bad can bulging be?



Why Do Drums Bulge?

- **Very high stresses**

  (Axial and hoop stresses in the drum may exceed yield during quenching)

- **Material / thickness mismatch**

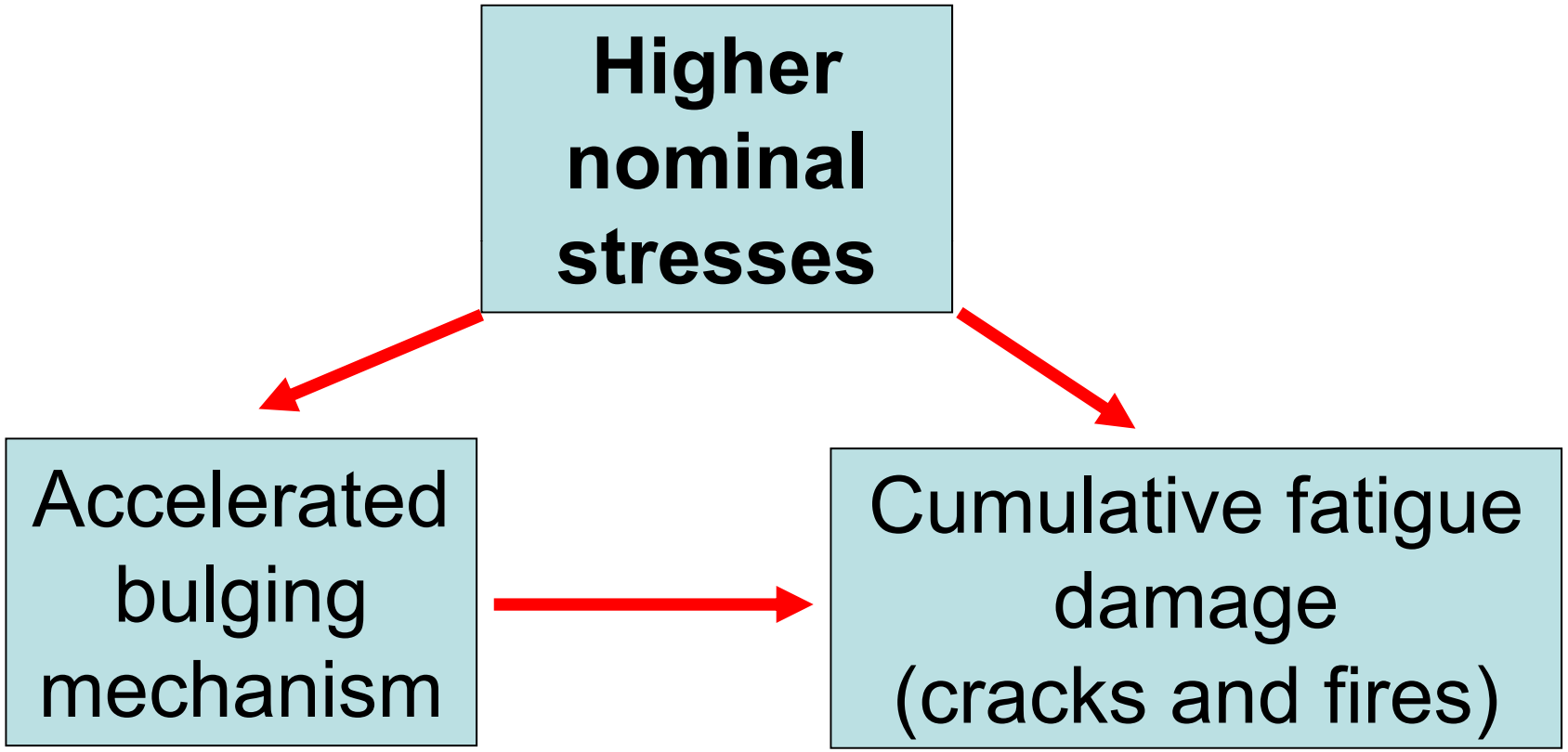
  (mechanical ratchet or progressive distortion)

- **Flow patterns inside drums**

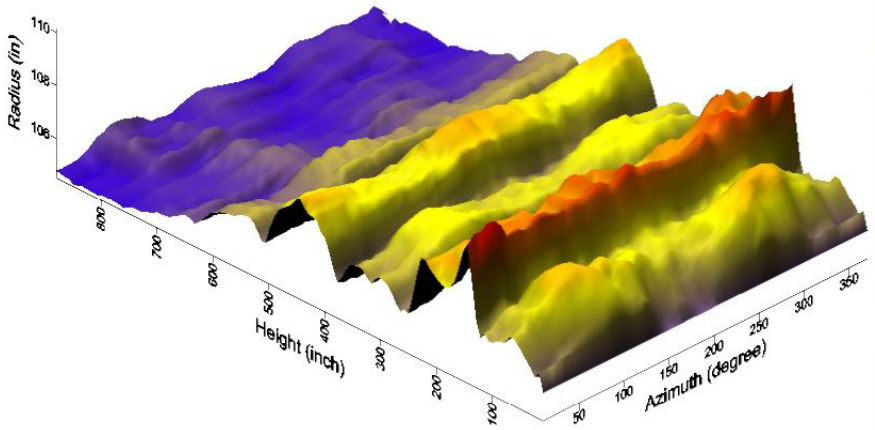
  (cold / hot spots)

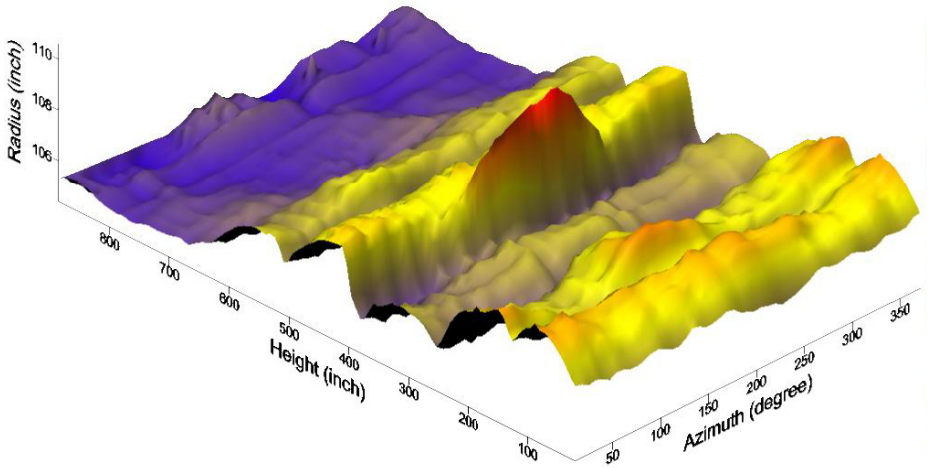
- **Imperfections**

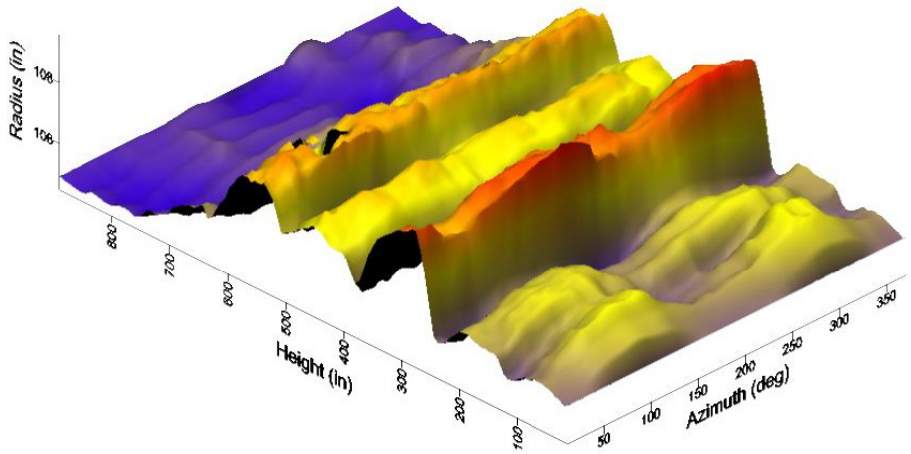
So what?

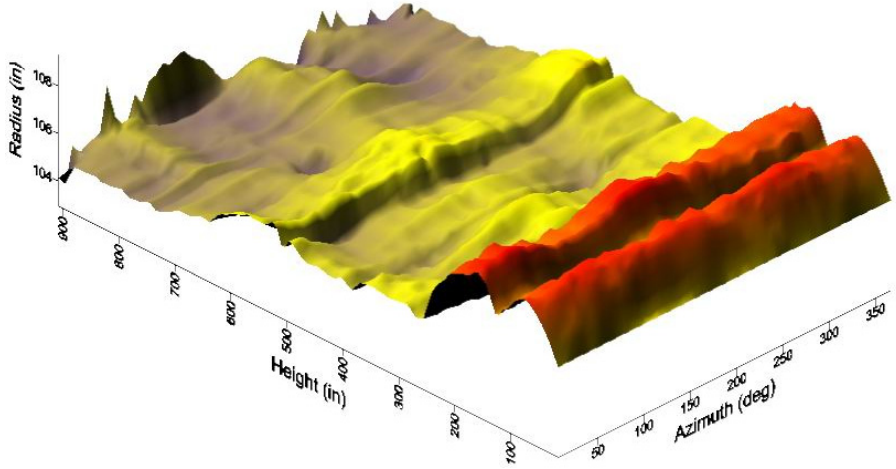

Higher nominal stresses
Accelerated bulging mechanism
Cumulative fatigue damage (cracks and fires)

When should we repair?









Assessment Techniques

- API 579/ ASME FFS
- Bulging Intensity Factor (BIF)

Can we use API-579 Assessment?

- Sure! Level 3 Assessment only

  (plastic collapse, local failure, buckling, and fatigue analyses)

- Requirements

  (1) quantify both mechanical and thermal loads,
  (2) simulate how these bulges were formed to account for residual stresses and plastic deformation in bulges (nonlinear model),
  (3) use continuum elements to capture stress fields at sharp bulges,
  (4) evaluate crack stability or growth if any exist or likely to form, and
  (5) incorporate creep damage effects for Carbon steel drums.

- Problems

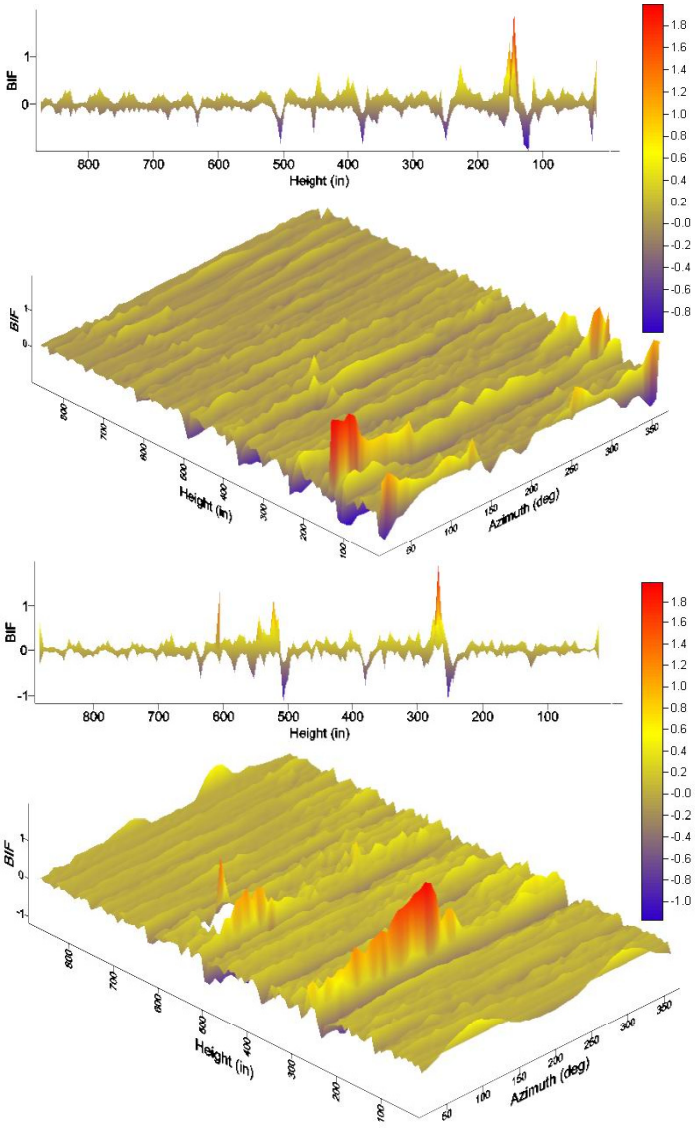
  - ✓ Cost: A strain-gage monitoring system, a nonlinear continuum model, and a LOT of labor and computer time can cost $ ½ to 1 M
  - ✓ Feasibility: Requirement (2) above may not be achievable!

BULGING INTENSITY FACTOR (BIF)

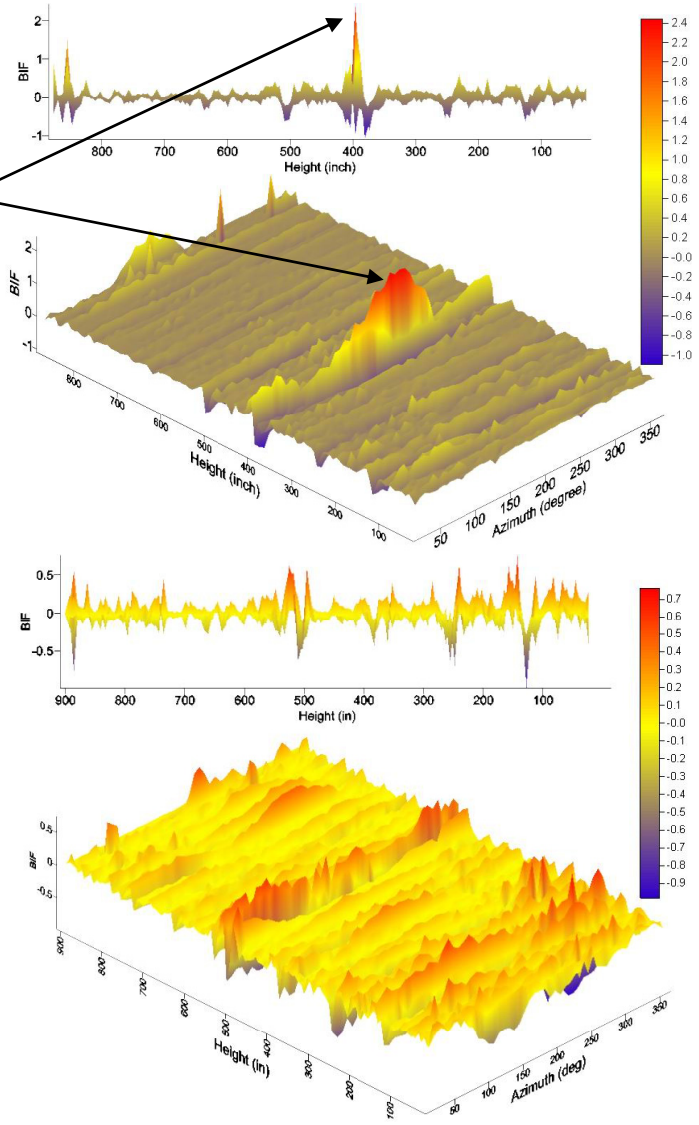
Converts laser scans to severity maps
based on a database of cracking history

Alloy	Carbon Steel	External Cracking Likelihood	Internal Cracking Likelihood
≥+2	≥+2.5	SEVERE (End of Economic Life)	
+1.5 to +2	+2 to +2.5		Very High
+1 to +1.5	+1.5 to +2		High
+0.75 to +1	+1 to +1.5		Medium
0 to +0.75	0 to +1		Low
0 to -0.75	0 to -1	Low	
-0.75 to -1	-1 to -1.5	Medium	
-1 to -1.5	-1.5 to -2	High	
-1.5 to -2	-2 to -2.5	Very High	
≤-2	≤-2.5	SEVERE (End of Economic Life)	

BIF Severity Maps



“V. HIGH - SEVERE”
Almost through-wall crack



How to repair?

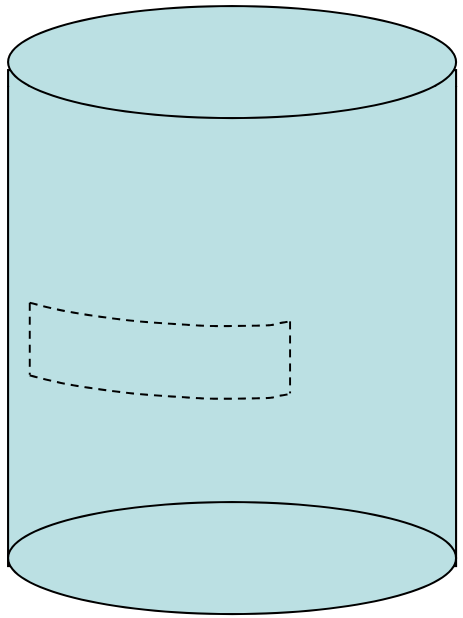
- **Short term**

  Gouge cracks and re-weld

- **Long term**
  - Window replacement
  - Can replacement
  - Weld overlay repair

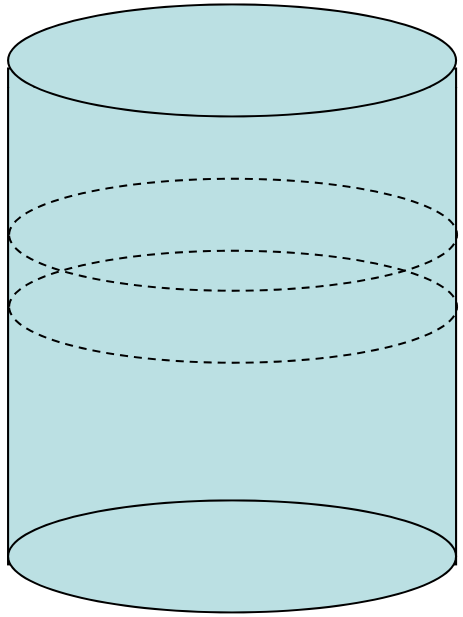
Window Replacement

Pros and cons

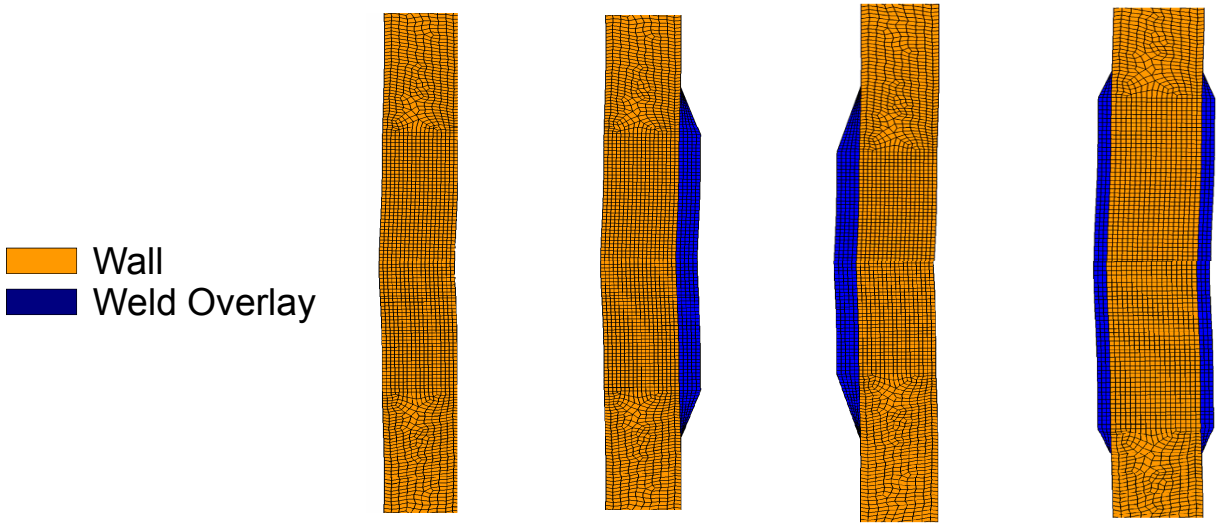


Can Replacement

Pros and cons



Weld Overlay Repair



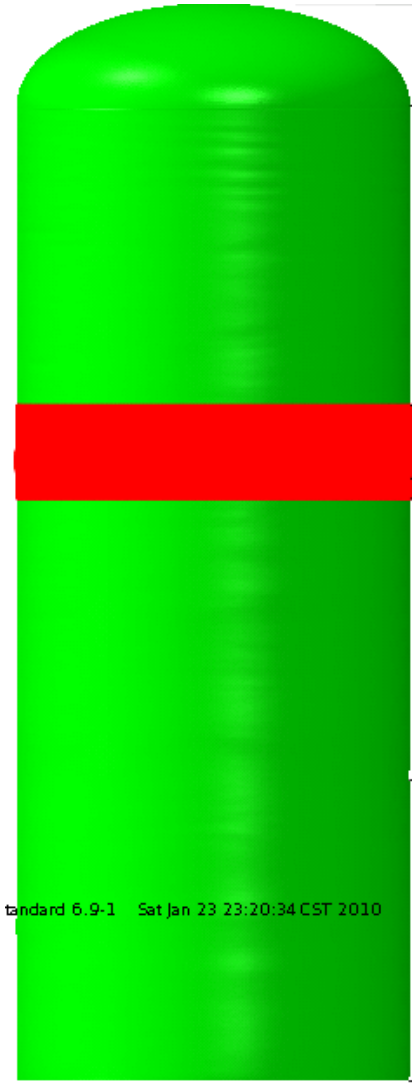
Proper design

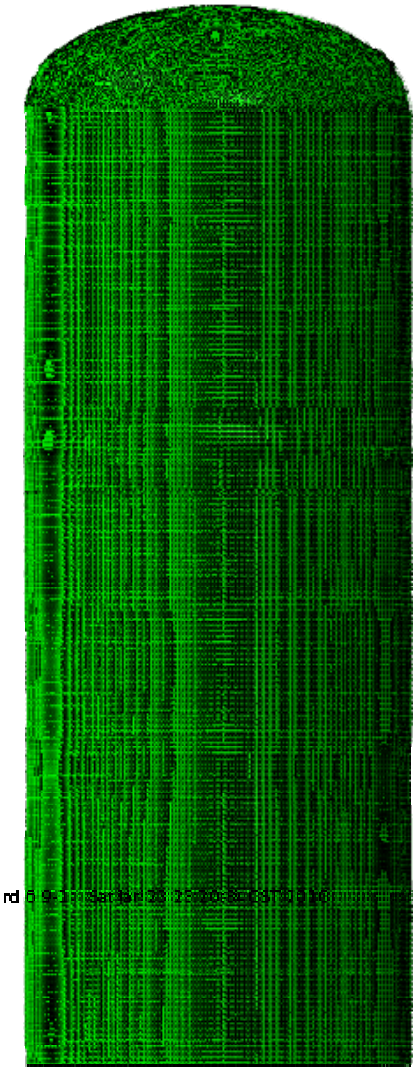
- Thickness Increase
- Favorable residual stresses
- Severity reduction

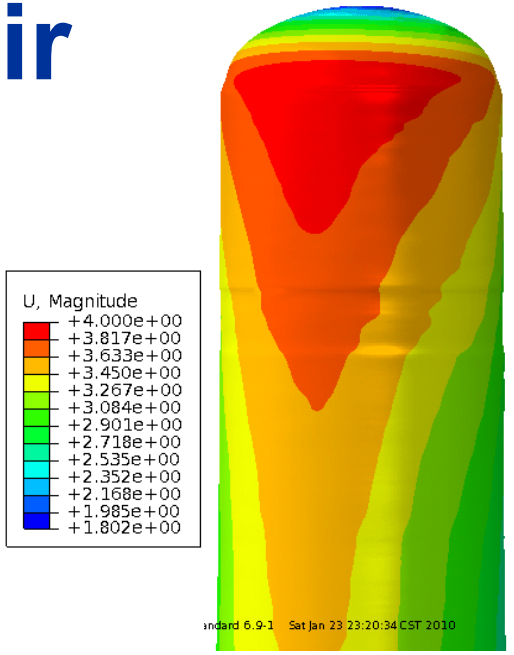
Improper design

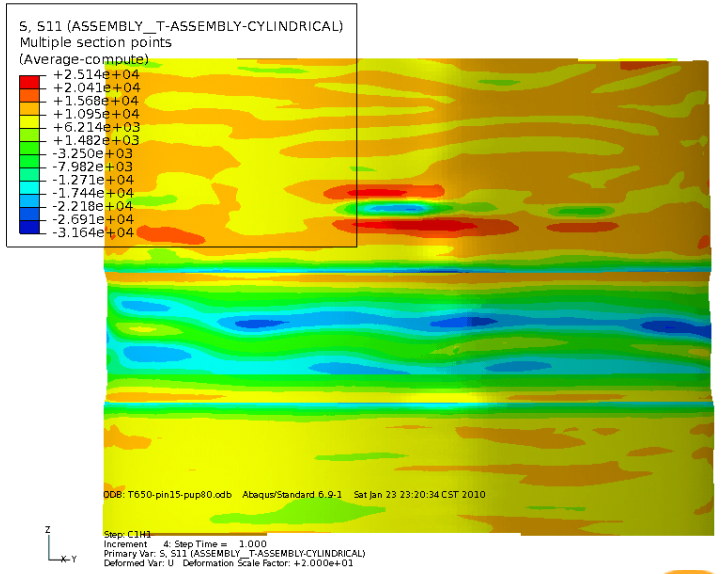
- Excessive distortion/ buckling
- Ineffectiveness
- Weld-related cracks/ defects

Analysis of Repair









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SUNCOR ENERGY

UNKNOWNS

- Properties of as-welded overlay
- Interaction between overlay material and drum wall (base metal, clad, and seam weld)
- Magnitude of extension of remaining life

INFORMAL JOINT INDUSTRY PROGRAM

- Scope tailored to specific needs and budget of each company
- Results are exchanged at the end, if mutually agreed to by parties
- Testing: Isothermal (high temperature and ambient) and Thermo-mechanical fatigue
- Base Metals: C-½Mo, 1¼Cr-½Mo, others pending
- Overlay: Inconel 625

SUNCOR EXPERIENCE

- Suncor uses the BIF to assess bulging severity and determine the need and extent of repairs.
- Weld overlay repair was used as a long-term solution for one drum and is pending for another.
- Weld repair analysis was conducted using finite element analysis to assess the distortion and estimate the fatigue life.
- A fatigue test program for examining the durability of weld overlay repair and optimizing its application is underway. Phase 1 has been completed and Phase 2 is pending.

Questions?

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