Assessment of Bulging Severity

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OVERVIEW

- Background
- Plant Experience
- Q&A

BACKGROUND

- Why does bulging occur?
- What are the consequences of bulging?
- Bulging magnitude versus cracking severity
- The Bulging Intensity Factor (BIF)

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Why Does Bulging Occur?

- **Resistance of coke**
  (high nominal stresses)
- **Material / thickness mismatch**
  (mechanical ratchet or progressive distortion)
- **Operation**
  (cycle time, switch temperature, feed rate, ..)
- **Flow patterns inside drums**
  (cold / hot spots)

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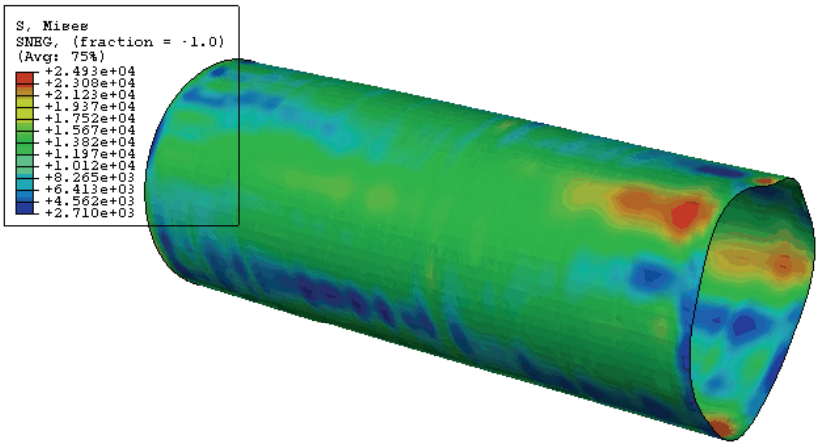
What are the consequences of Bulging?



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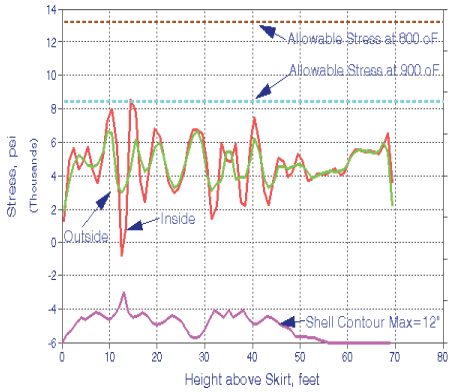
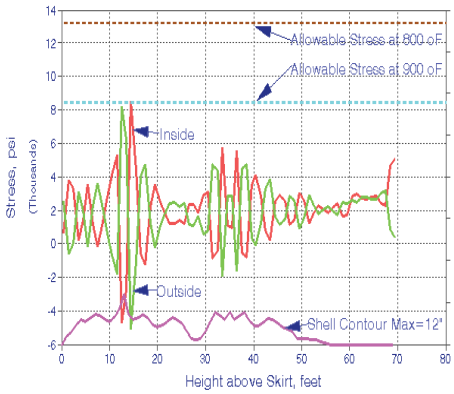
What are the consequences of Bulging?

Hoop Stress For Bulged Drum at 324 deg Profile ('95)
Pressure= 38.4 psi + Hydrostatic



Axial Stress For Bulged Drum at 324 deg Profile ('95)
Pressure= 38.4 psi + Hydrostatic



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What are the consequences of Bulging?

Higher nominal stresses

Accelerated bulging mechanism → Cumulative fatigue damage (cracks and fires)

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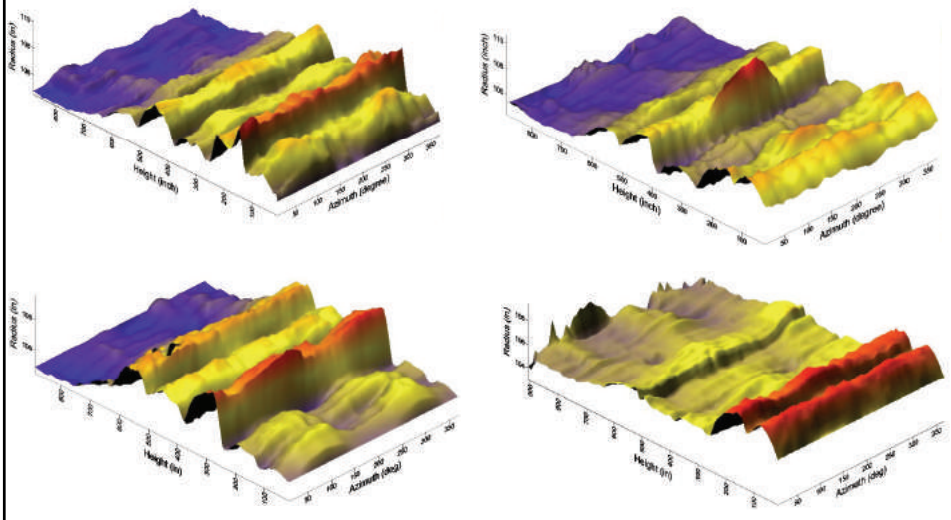
Bulging Magnitude vs. Cracking Severity



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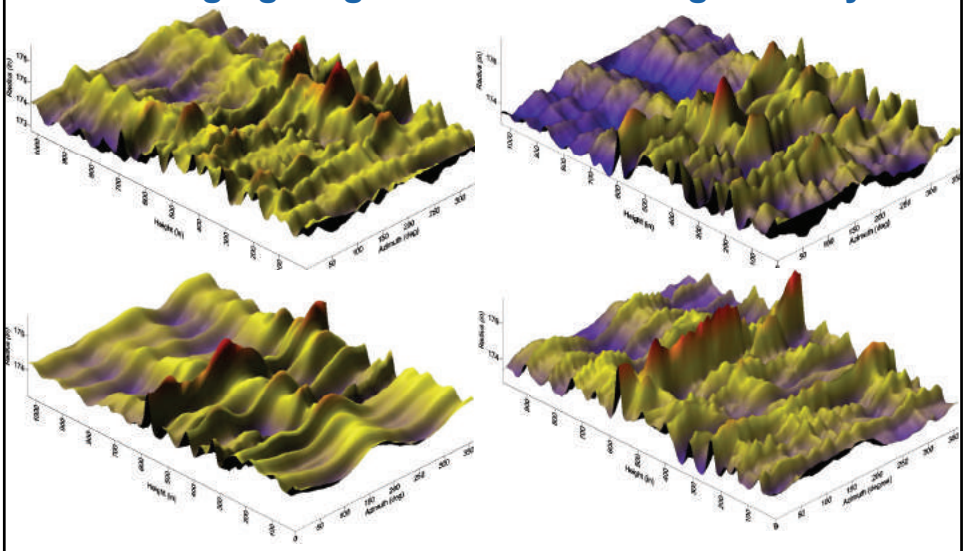
Bulging Magnitude vs. Cracking Severity



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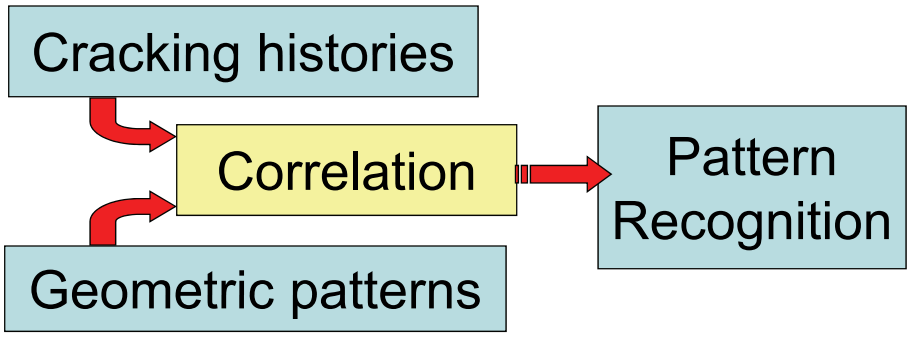
TOOL DEVELOPMENT



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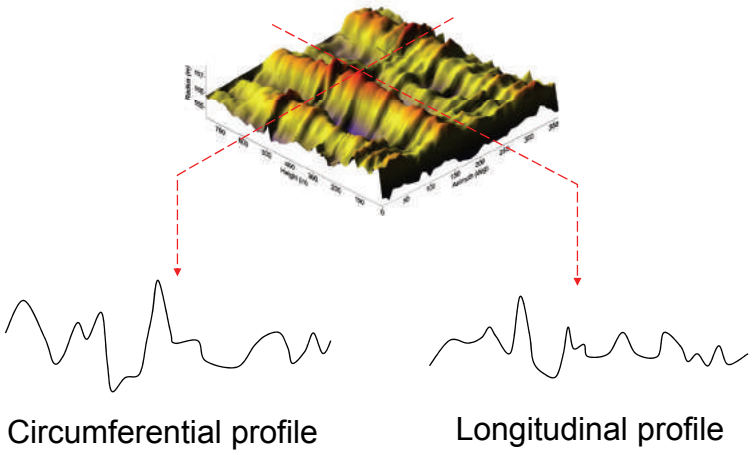
Slicing the Bulge



Circumferential profile

Longitudinal profile

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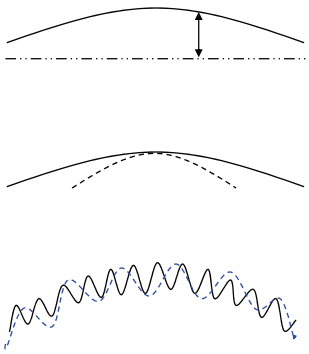
Geometric Parameters

Magnitude

Curvature

Frequency



Circumferential and longitudinal profiles

↓

Cross correlation

↓

BIF

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The Bulging Intensity Factor (BIF)

From laser scans:

Identify and Rank
areas most susceptible to cracking

Prioritize & optimize inspections

BULGING INTENSITY FACTOR (BIF)

Chrome Alloy Drums

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

BULGING INTENSITY FACTOR (BIF)

Carbon steel and C-1/2 Mo Drums

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

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BULGING INTENSITY FACTOR (BIF)

SEVERITY IMPLICATIONS

Severity Grade	Cracking Pattern Related to Bulging	Recommended Laser Scanning Frequency
Low	Rare	Every 3 years
Medium	Seldom	Every 2 years
High	Occasional	Every 1 year
Very High	Repeated	Every 1 year
SEVERE	Too frequent to operate economically	Consider partial or full shell replacement

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DATABASE

- Calibration data base: 11 drums with known cracking histories.
- Application data base: 70+ scans.
- Carbon steel, Carbon-1/2Mo and 1 to 1¼ Chrome drums.

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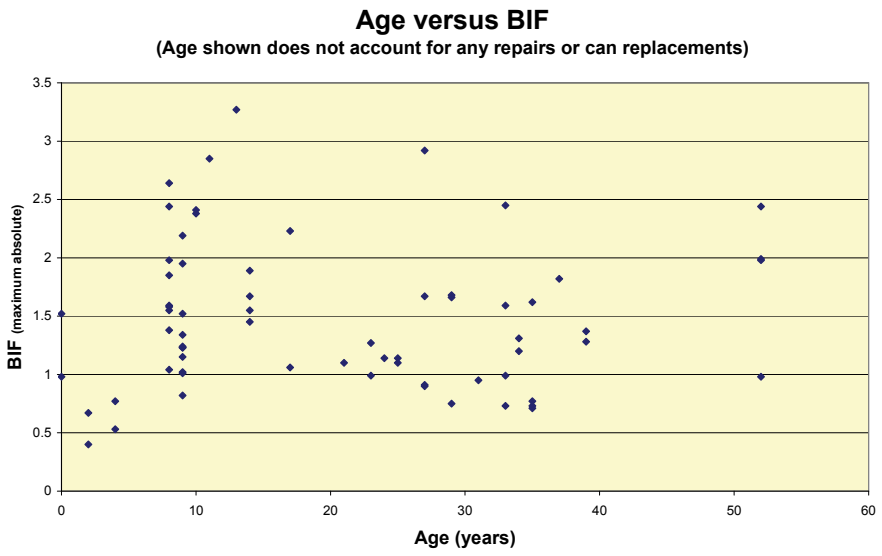
DATABASE



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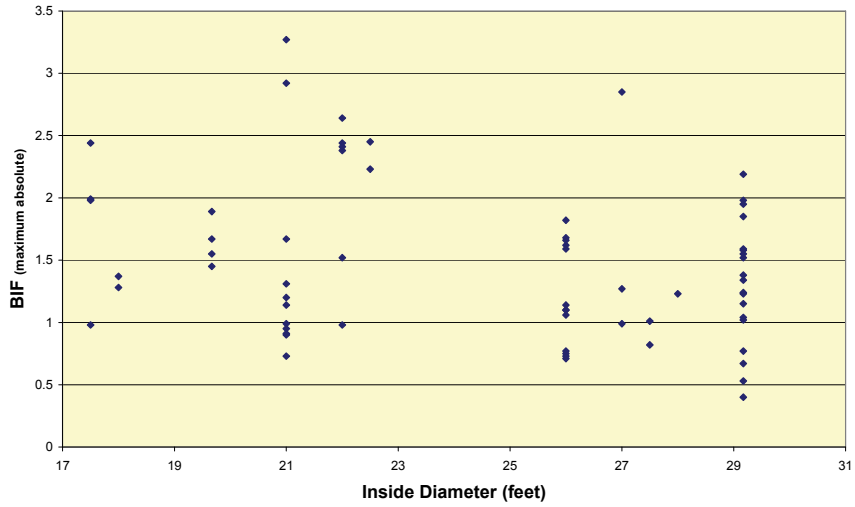
DATABASE

Diameter versus BIF



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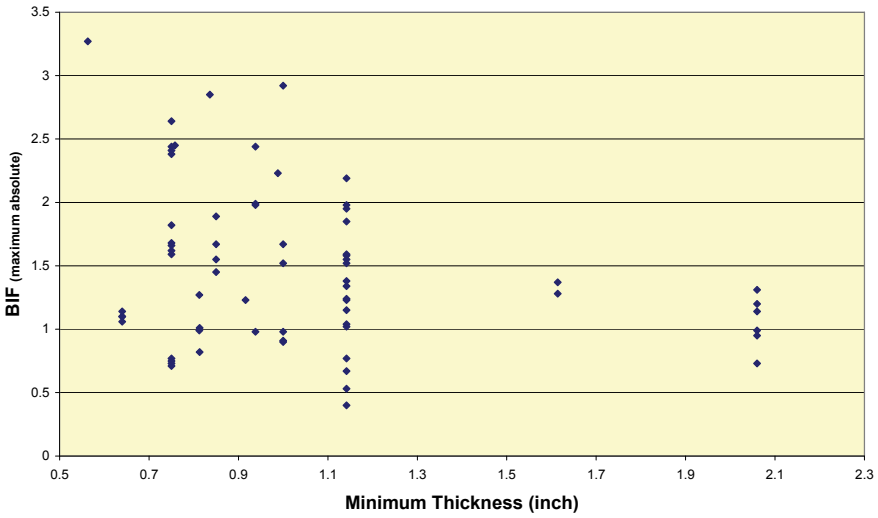
DATABASE

Minimum thickness versus BIF



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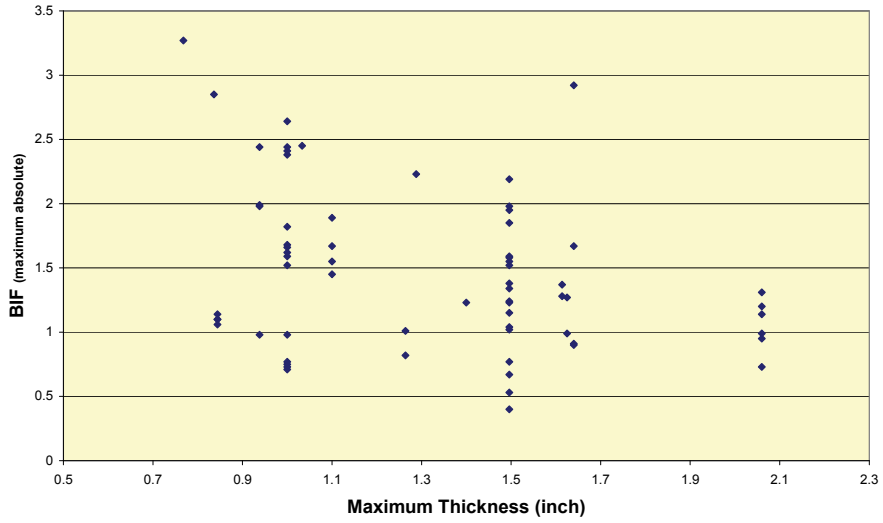
DATABASE

Maximum thickness versus BIF



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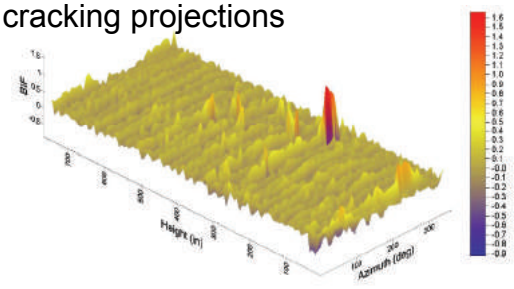
BIF Output

- Two-dimensional color contour plots
- Three-dimensional surface maps
- Ranking of most severe locations
- Multiple scans:
  - Statistical analysis
  - Growth rate analysis
  - Future cracking projections



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SUNCOR COKE DRUMS

- 6 of C- /2 Mo Drums
- ID = 26', T-T = 66'
- Built 1966
- Completed 8200 Cycles

- 2 of 1Cr - 1/2 Mo Drums
- ID = 26', T-T = 66'
- built 1979
- Completed 5,500 Cycles

- 4 of 1Cr- 1/2 Mo
- ID = 29', T-T = 94'
- Built 2001
- Completed 1800 Cycles

- Upcoming Cokers
- 2 of 30' dia – 1Cr--1/2MO (Installed)
- 6 of 32' dia – 1Cr- 1/2MO

Suncor Portion of this presentation is compiled with the contributions received from Projects, Reliability, Process and Operations Group.
Special Thanks to : Vrajesh Shah- Sustainable Projects, Charles Stephens & Aaron Johnson - Reliability Engineering

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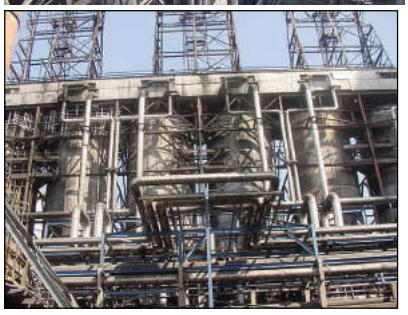

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OBJECTIVES

- How severe is the Bulging in the Drums ?
- How should we prioritize the drum inspection needs?
- When will the bulging result in Cracking ?
- When should we replace the coke drums?
- How soon do we need to rescan the drum ?
- How to minimize unplanned outages ?
- What will be the total crack repair cost 5 to 10 years from now ?

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Evaluation Techniques

- Laser scans
- Bulge Severity and Growth Analysis using Bulge Inspection Factor (BIF)
- JIP CokerCola software analysis
- Finite Element Analysis
- Probabilistic Crack Propagation calculations
- Strain Gage Measurements
- AET (Acoustic Emission Testing)

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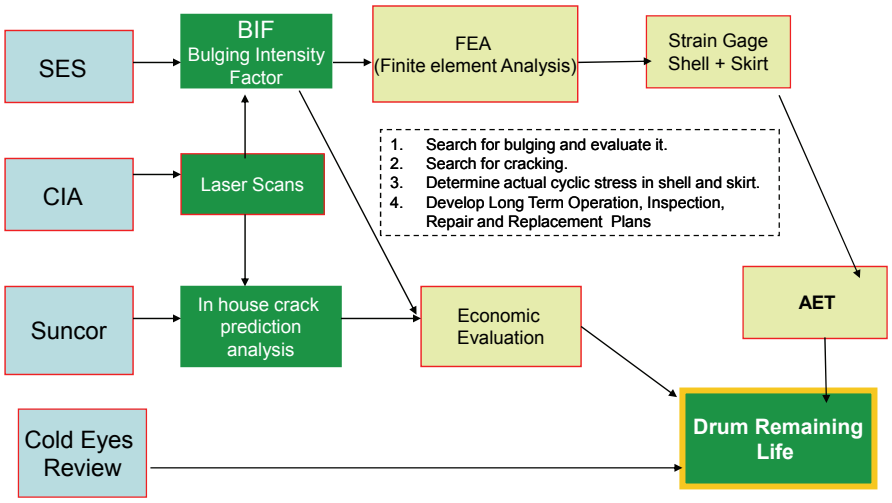
Approach for Remaining Life



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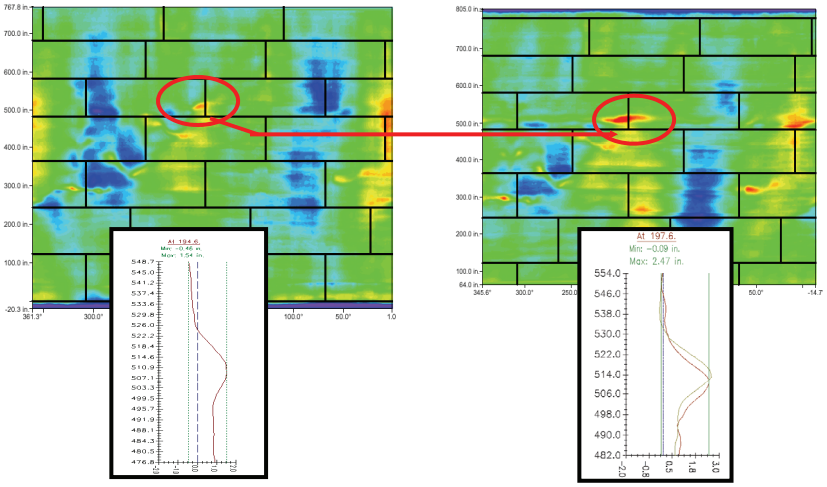
COMPARE 1996 AND 2000 BULGES



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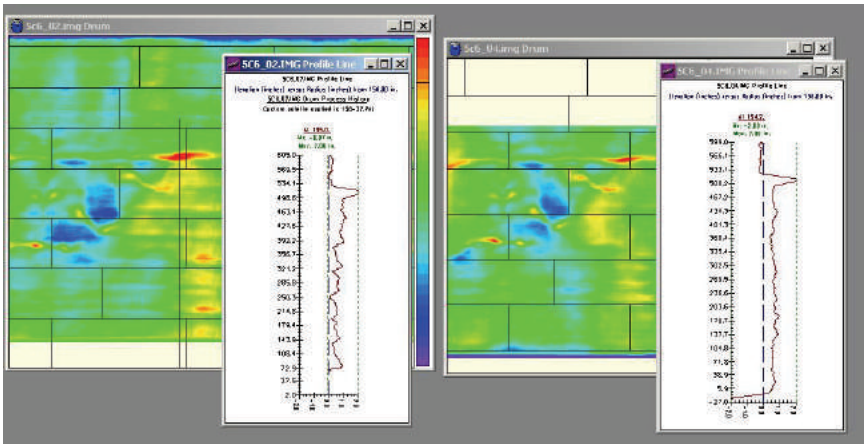
COMPARE 2002 AND 2004 BULGES



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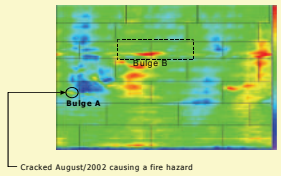
CRACK HISTORY – All DRUMS

1967: 5C-3~8 started up
4 Thru wall cracks in Drum 6
(Sept 1997, Aug 2002, June 2004, Aug 2005)
1 crack in Drum 5
(April 2001)
1981: 5C-50/51 started up
1 Crack in 5C50
June 1998
3/4/7/8 never cracked



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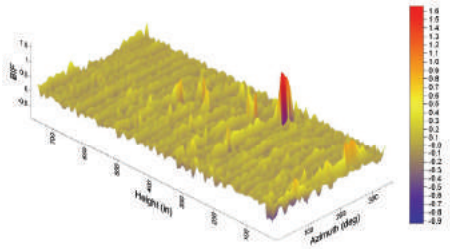
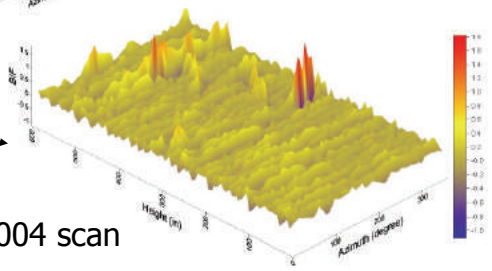
Bulges change over time



BIF map of 1996 scan

Suncor tracks the progress of the BIF of a certain bulge and predict when it may reach a critical value (BIF > 1.5)



BIF map of 2004 scan

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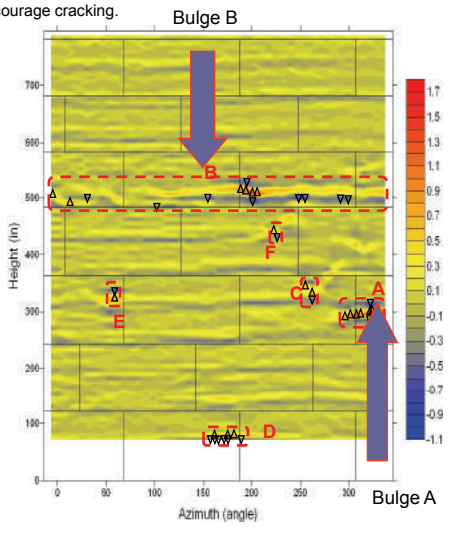
BIF Results

Suncor used SES'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.

Rank	BIF	Zone	severity
1	1.82	A	very high
2	1.54	A	very high
3	1.49	B	high
4	1.23	A	high
5	1.19	A	high
6	1.12	A	high
7	1.10	B	high
8	1.06	B	high
9	1.03	A	high
10	0.94	B	medium
11	0.93	E	medium
12	0.91	B	medium
13	0.85	B	medium
14	0.84	C	medium
15	0.83	B	medium
16	0.83	C	medium
17	0.80	D	medium
18	0.79	B	medium
19	0.78	B	medium
20	0.76	B	medium



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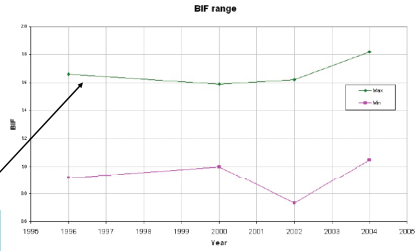
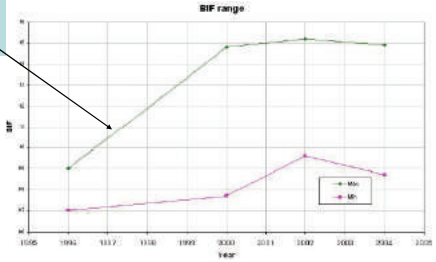
Changes in BIF for Bugle A and Bulge B

Increase in the BIF over the years.



Changes in BIF Bugle A



Changes in BIF for Bulge B

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BIF RESULTS - ALL DRUMS

Drum	Maximum BIF and severity ranking						Rate of deterioration	Areas of Concern
	1968	1981	1996	2000	2002	2004		
3					0.73 low			Fifth can and the south side of the lower four circumferential welds
4					0.71 low			
5					0.77 Medium			Circumferential weld between the fourth and fifth cans
6	0		1.66 v. high	1.59 v. high	1.62 v. high	1.82 v. high	High	Northeast side of the middle of the third can and the bottom of the fifth can
7								
8								
50		0	1.06 high	1.1 high		1.14 high	Mild	Bottom of the fifth can
51						1.1 high		Bottom of the fifth can

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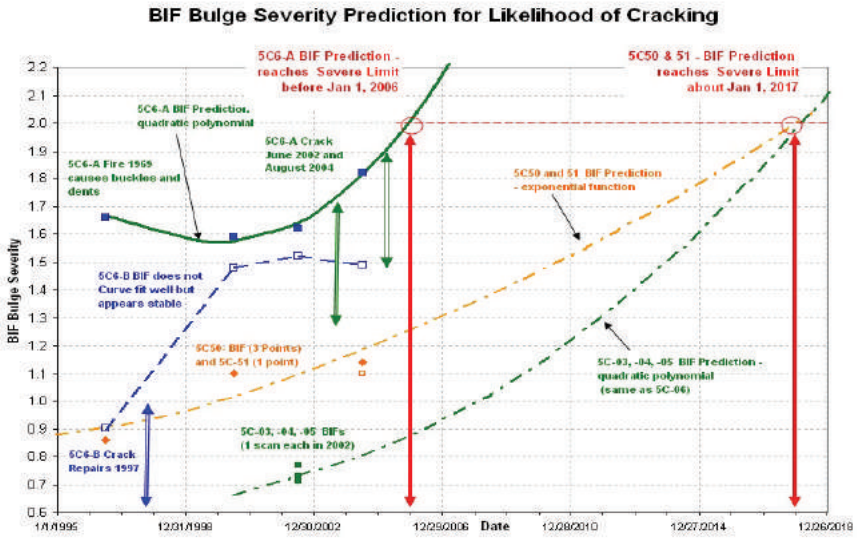

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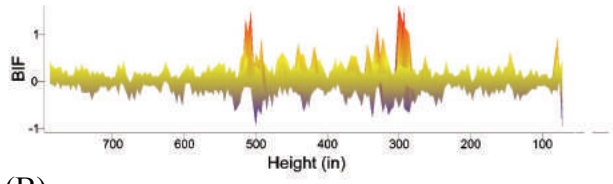
Plant Experience

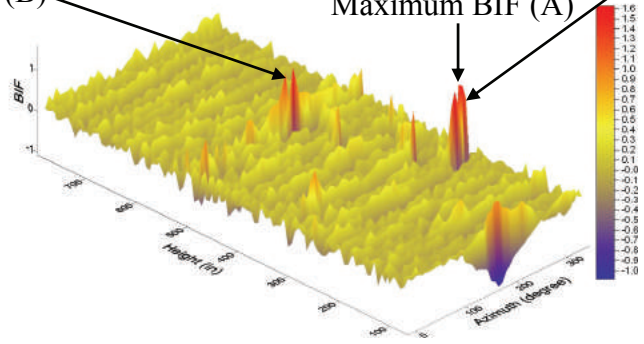


Crack away from weld (BIF=1.82)

THROUGH WALL CRACK August 2005

(B)

Maximum BIF (A)



Bulge A is expected to have a "severe" likelihood of cracking between May/2005 and June/2006

Bulge B- The bulges in shell course #5, is expected to remain stable at the "very high" likelihood of cracking for the next few years

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CONCUSIONS

- The BIF is a valid method for evaluating the severity of bulging in coke drums
- The BIF is used for identifying and ranking the most severe locations on a drum and finding cracks before they go through wall
- Suncor used this technique along with other available tools to make future predictions of drum inspection needs and projected life
- Suncor's experience shows that the BIF correlates well with actual cracking history

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Summary of Benefits

- **Operators:** planned maintenance outages
- **Owners:** quantify the risk of failure and plan drum repairs and replacement
- **Inspectors:** prioritize work and optimize the allocation of resources

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