Assessment of Bulging Severity

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2009 COKING.COM Meeting
Galveston, TX
March 2008

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)

Why Does Bulging Occur?

- **Resistance of coke**

  (high nominal stresses)

- **Material / thickness mismatch**

  (mechanical ratchet or progressive distortion)

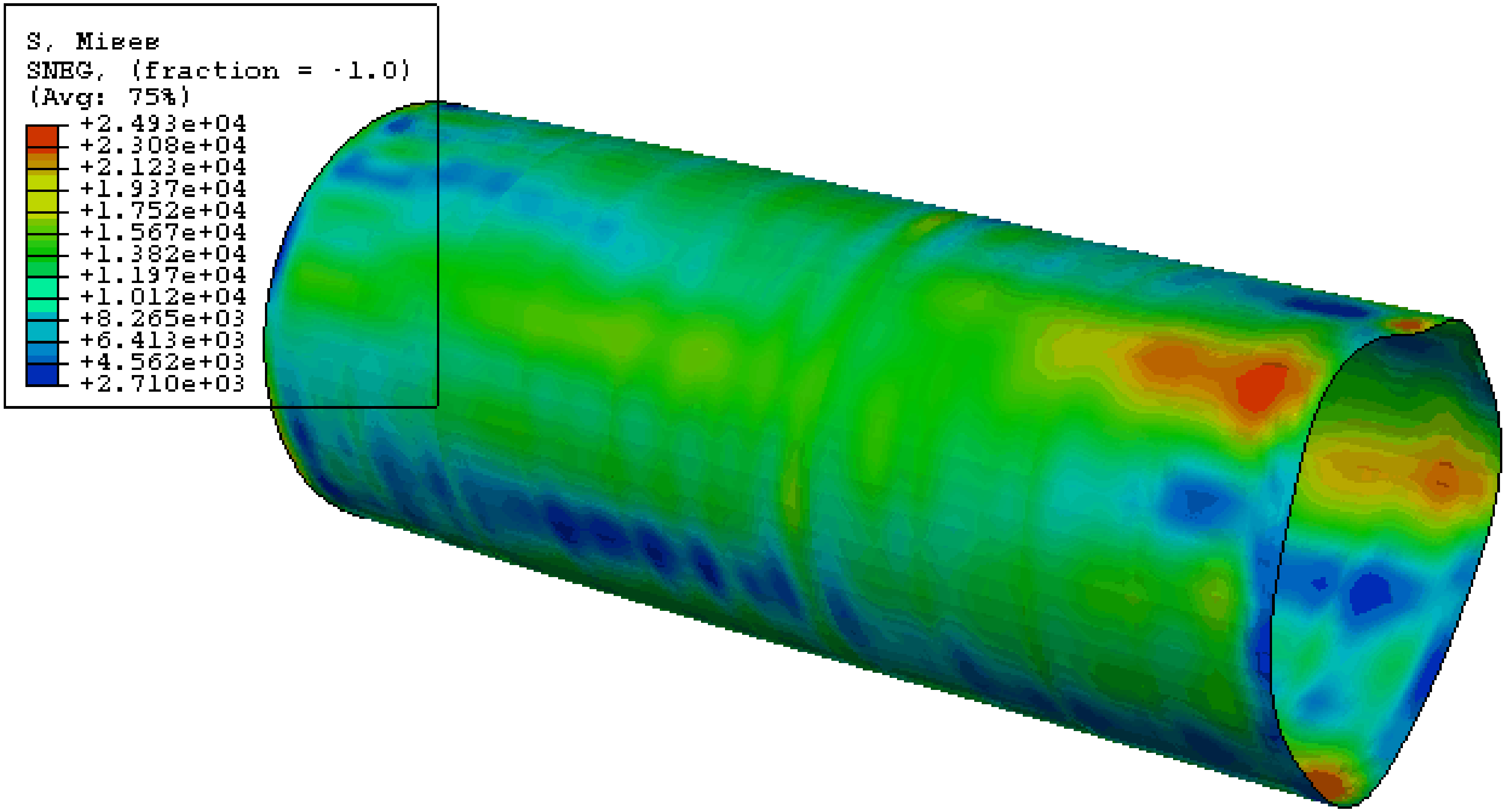
- **Operation**

  (cycle time, switch temperature, feed rate, ..)

- **Flow patterns inside drums**

  (cold / hot spots)

What are the consequences of Bulging?



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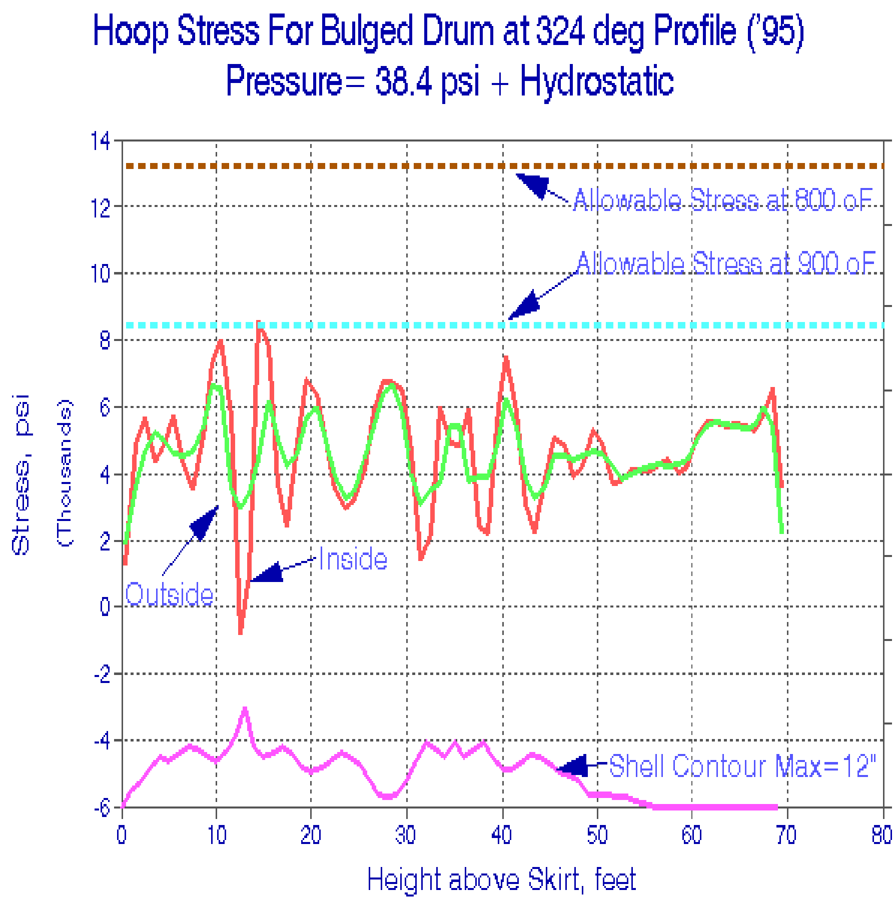
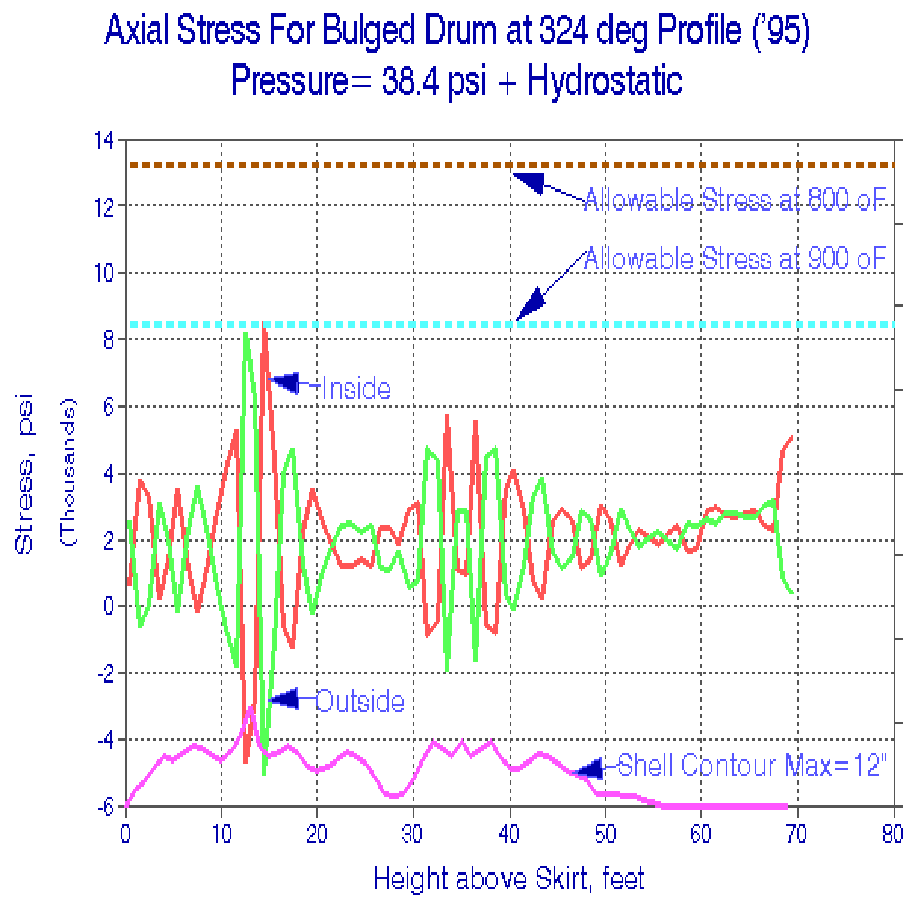
What are the consequences of Bulging?





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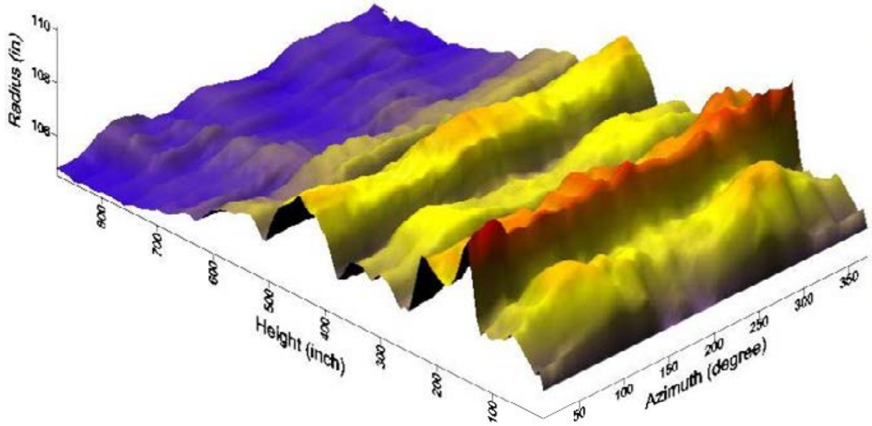
What are the consequences of Bulging?

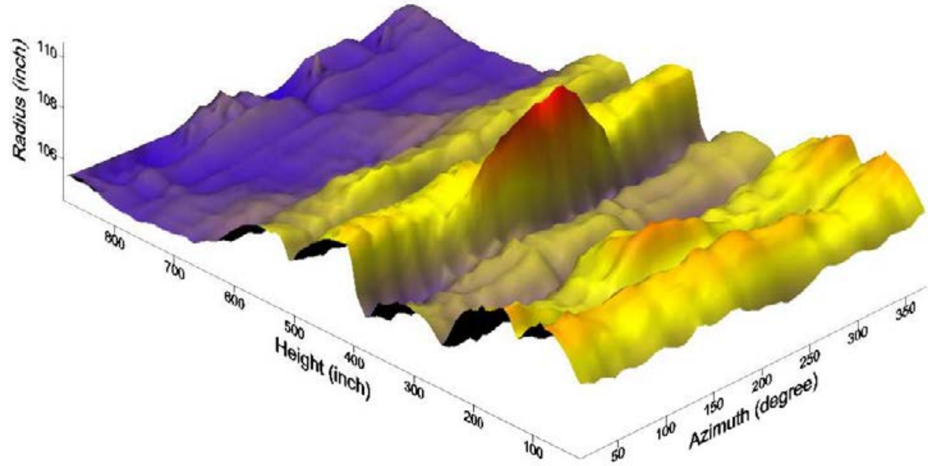
Higher nominal stresses

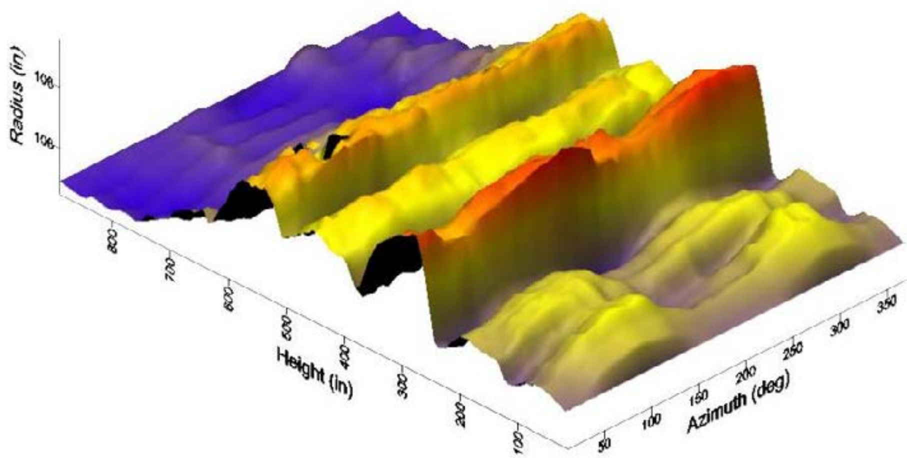
Accelerated bulging mechanism

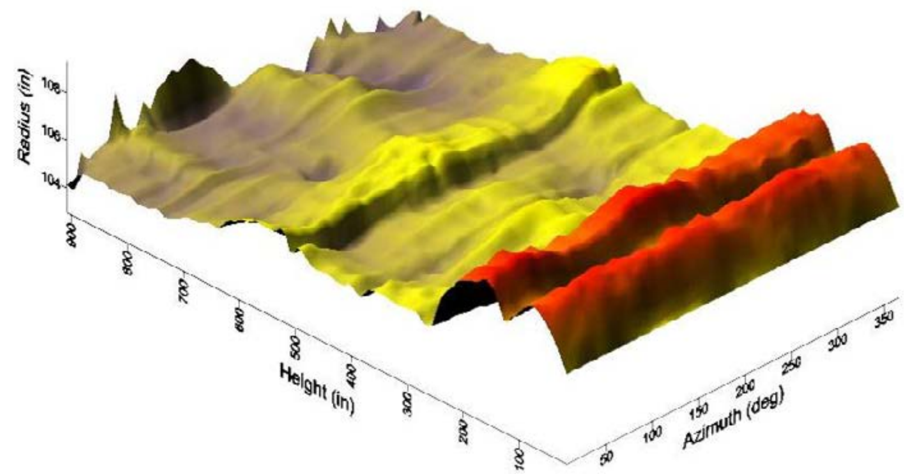
Cumulative fatigue damage (cracks and fires)

Bulging Magnitude vs. Cracking Severity









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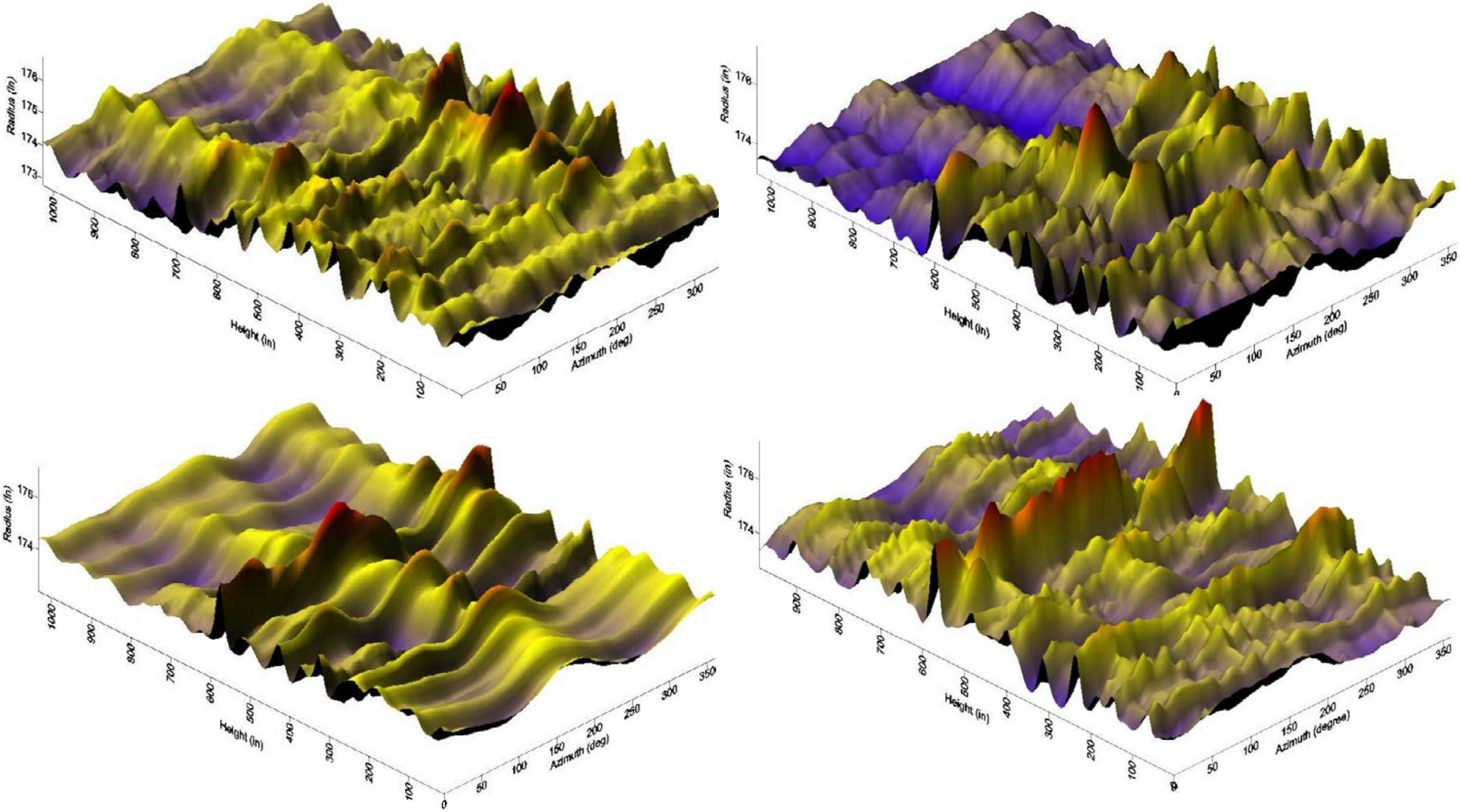
Bulging Magnitude vs. Cracking Severity



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

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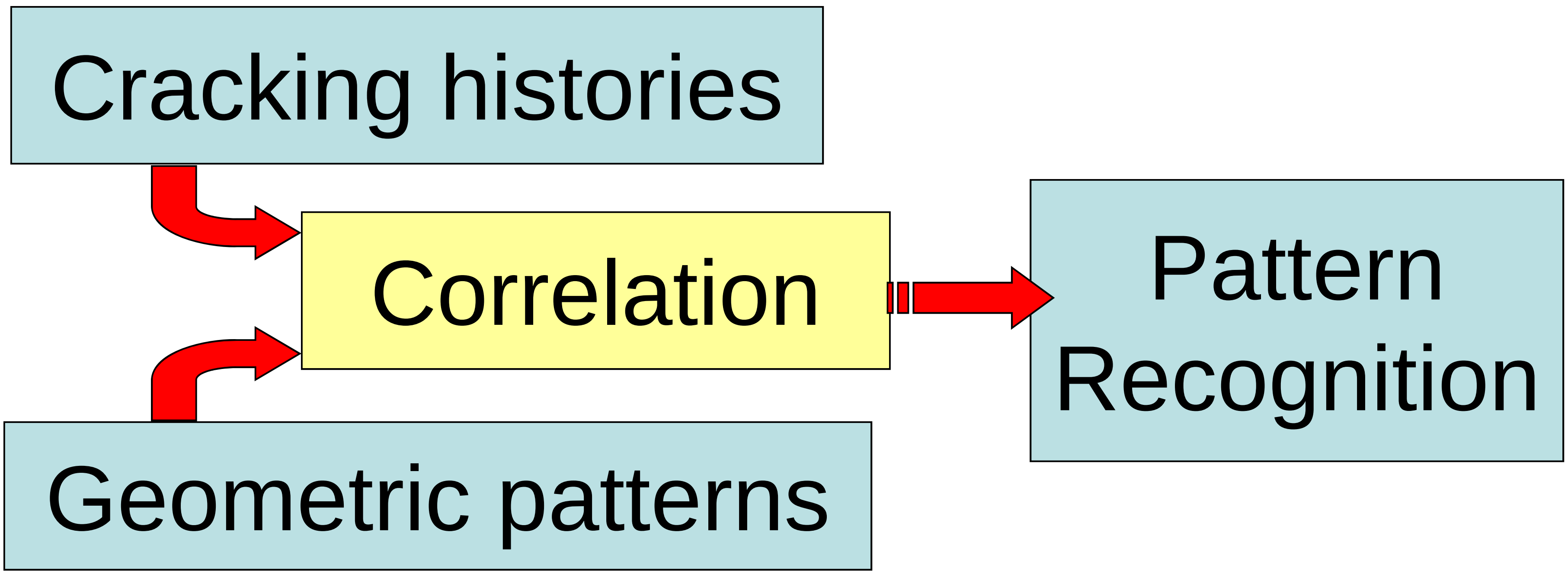
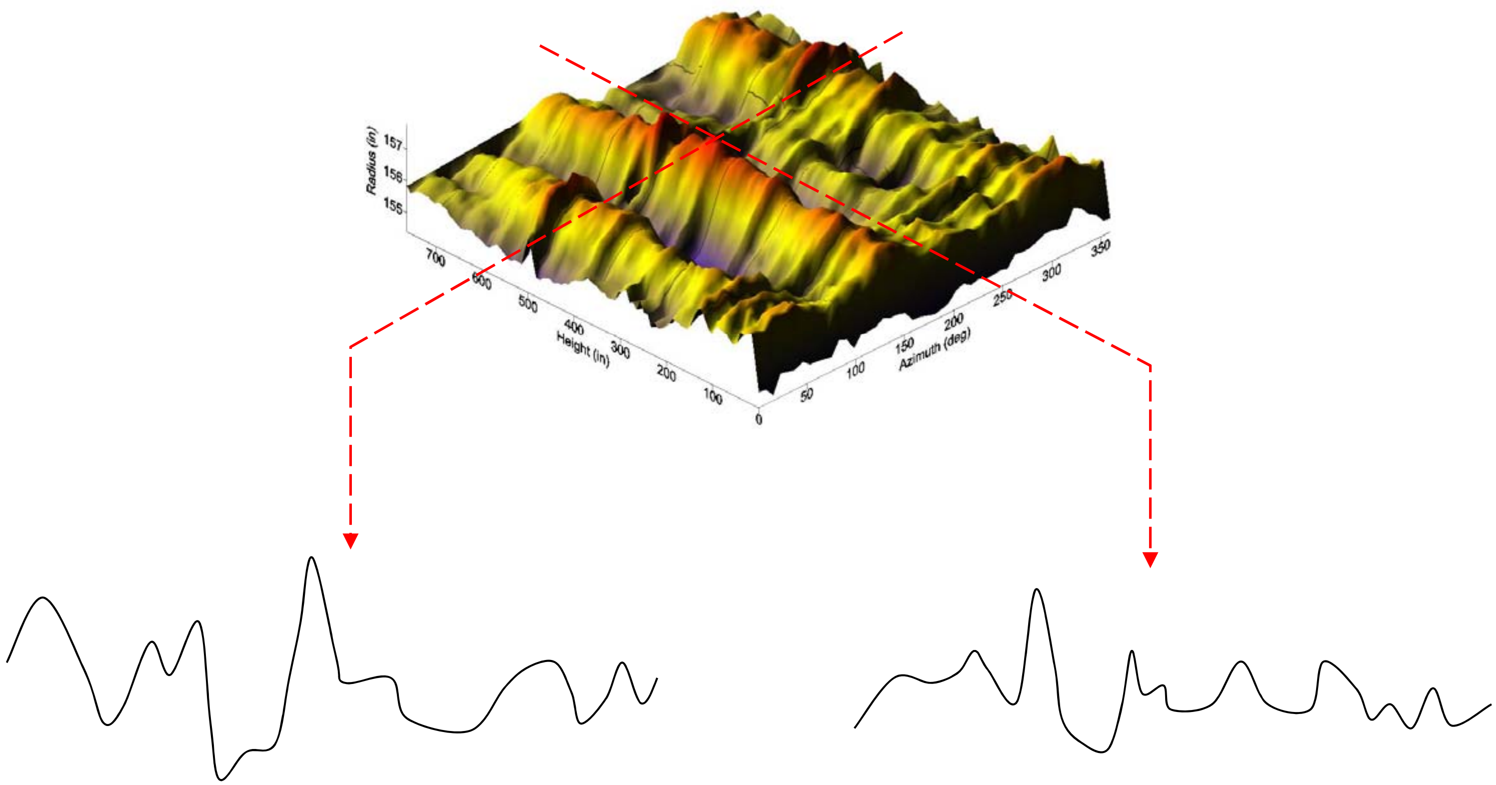
TOOL DEVELOPMENT



Slicing the Bulge

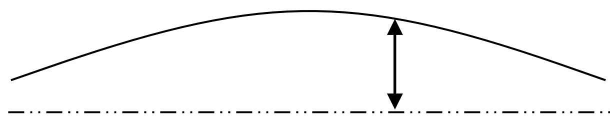


Circumferential profile

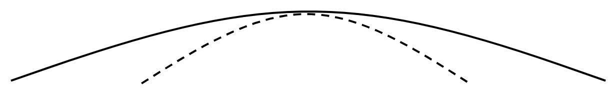
Longitudinal profile

Geometric Parameters

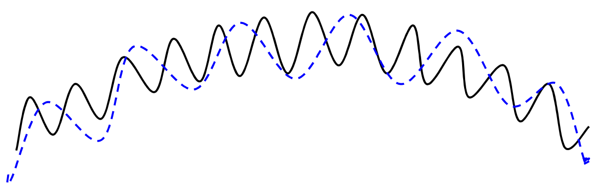
Magnitude



Curvature



Frequency



Circumferential and longitudinal profiles

↓

Cross correlation

↓

BIF

The Bulging Intensity Factor (BIF)

From laser scans:

Identify and Rank

areas most susceptible to cracking

Prioritize & optimize inspections

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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)	

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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)	

BULGING INTENSITY FACTOR (BIF)

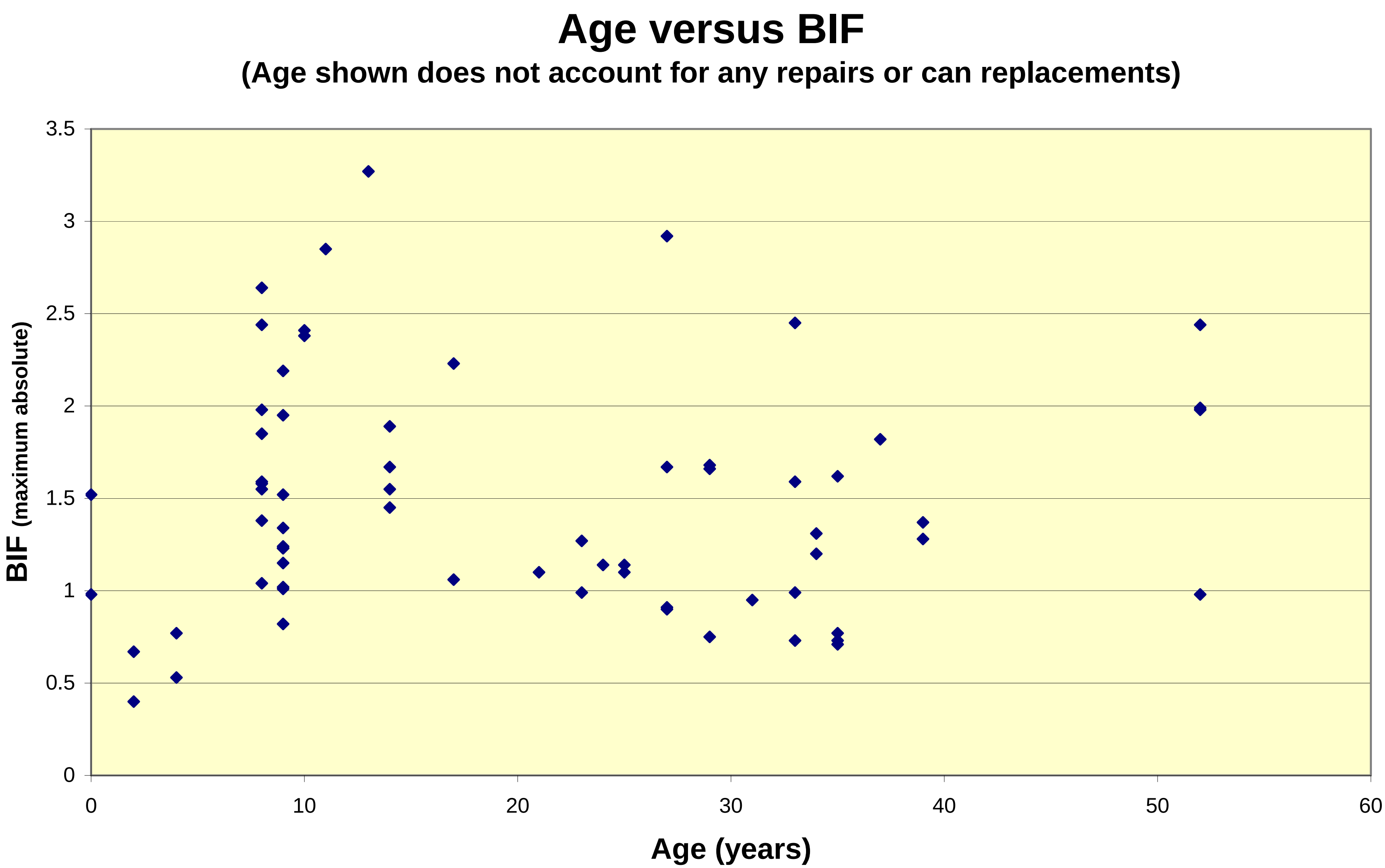
SEVERITY IMPLICATIONS

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

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.

DATABASE



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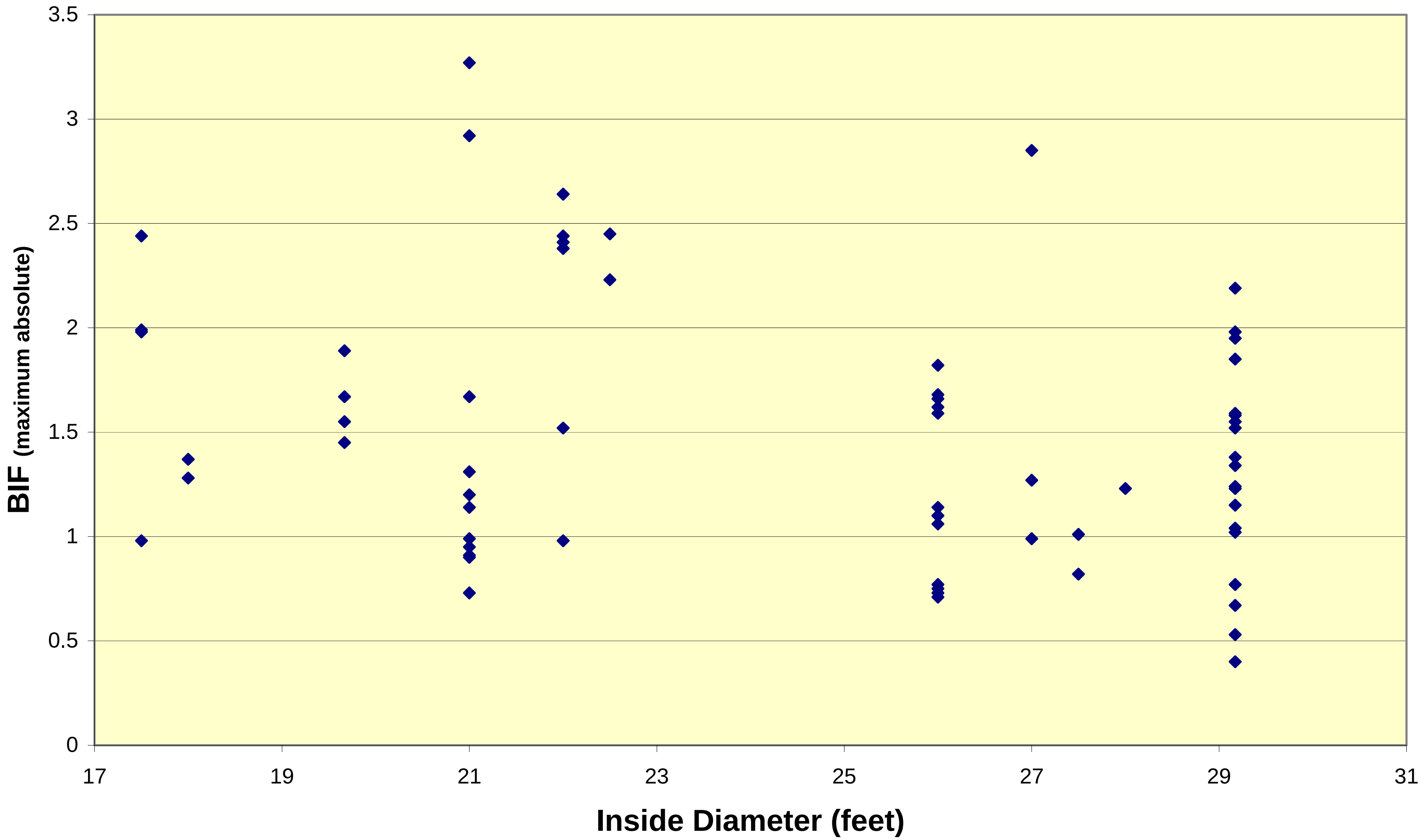
DATABASE

Diameter versus BIF



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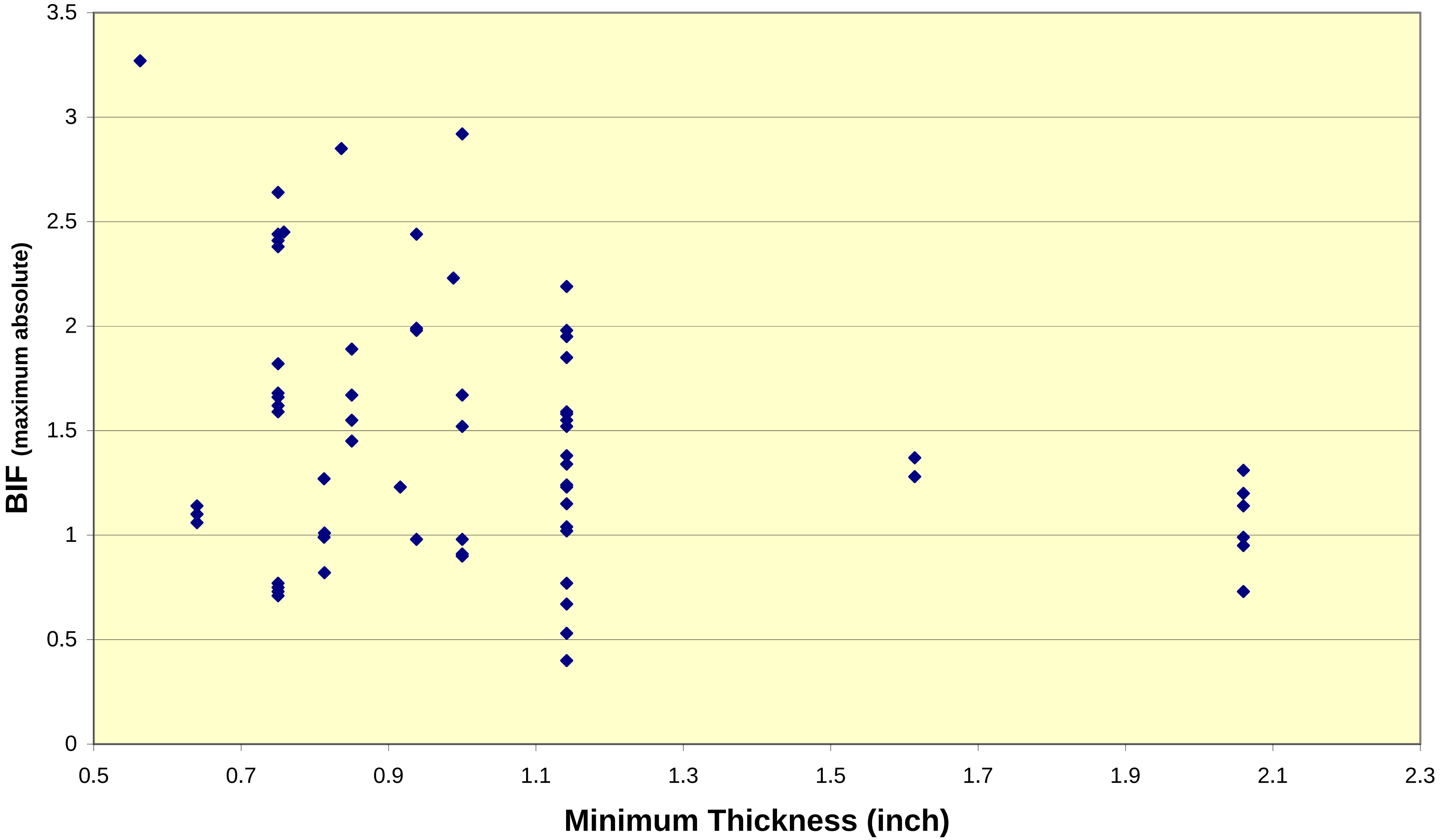
DATABASE

Minimum thickness versus BIF



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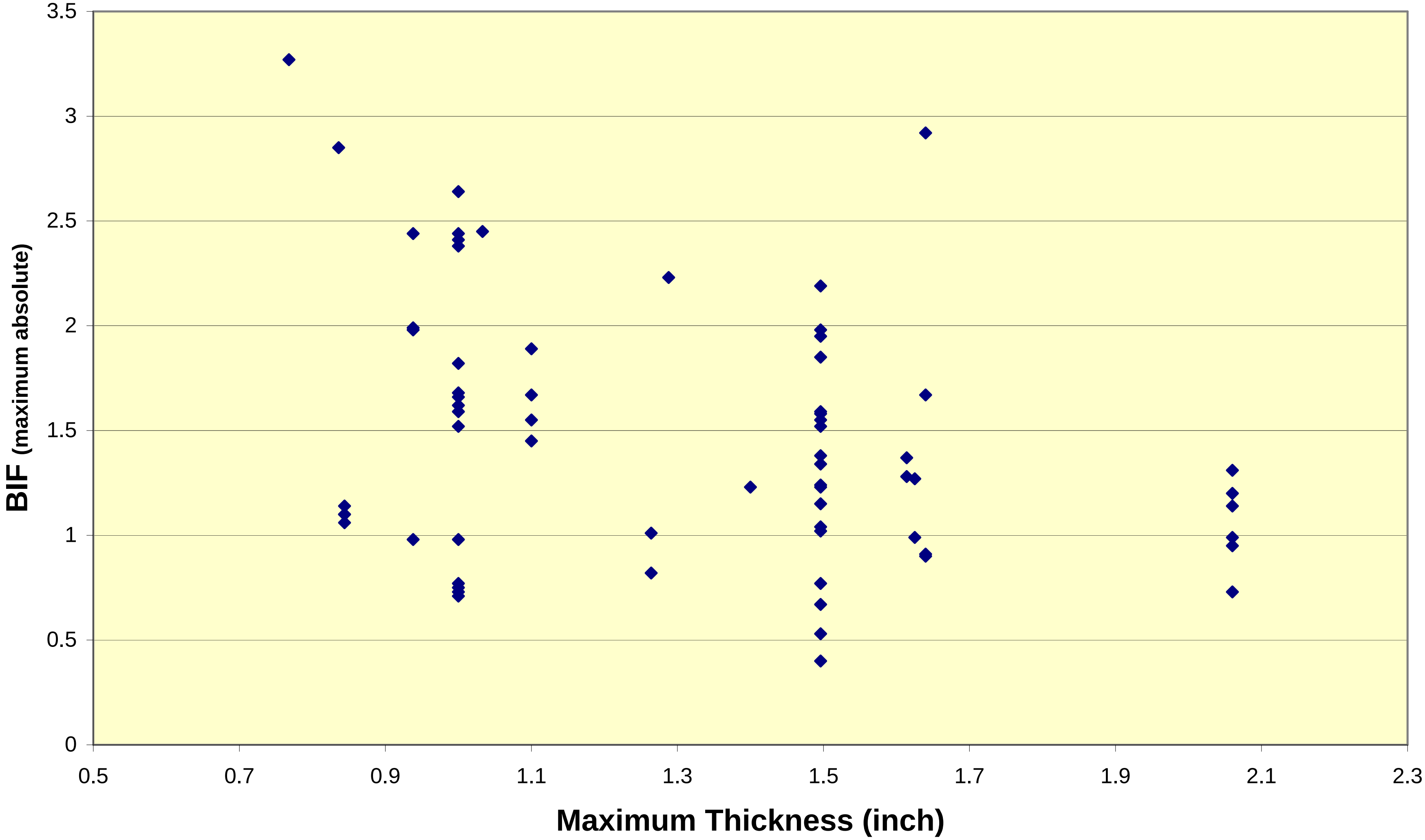
DATABASE

Maximum thickness versus BIF



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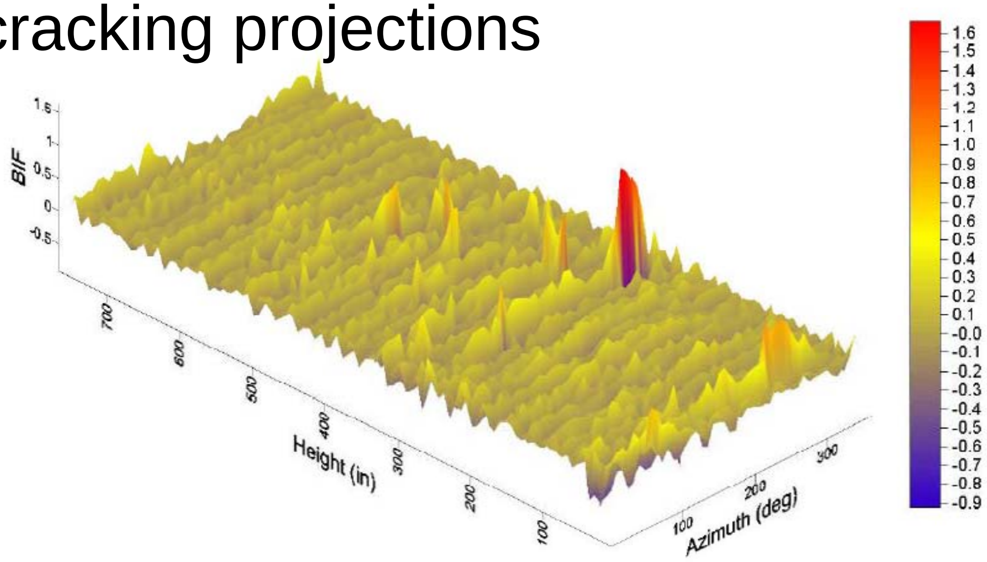
BIF Output

- 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




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 ?

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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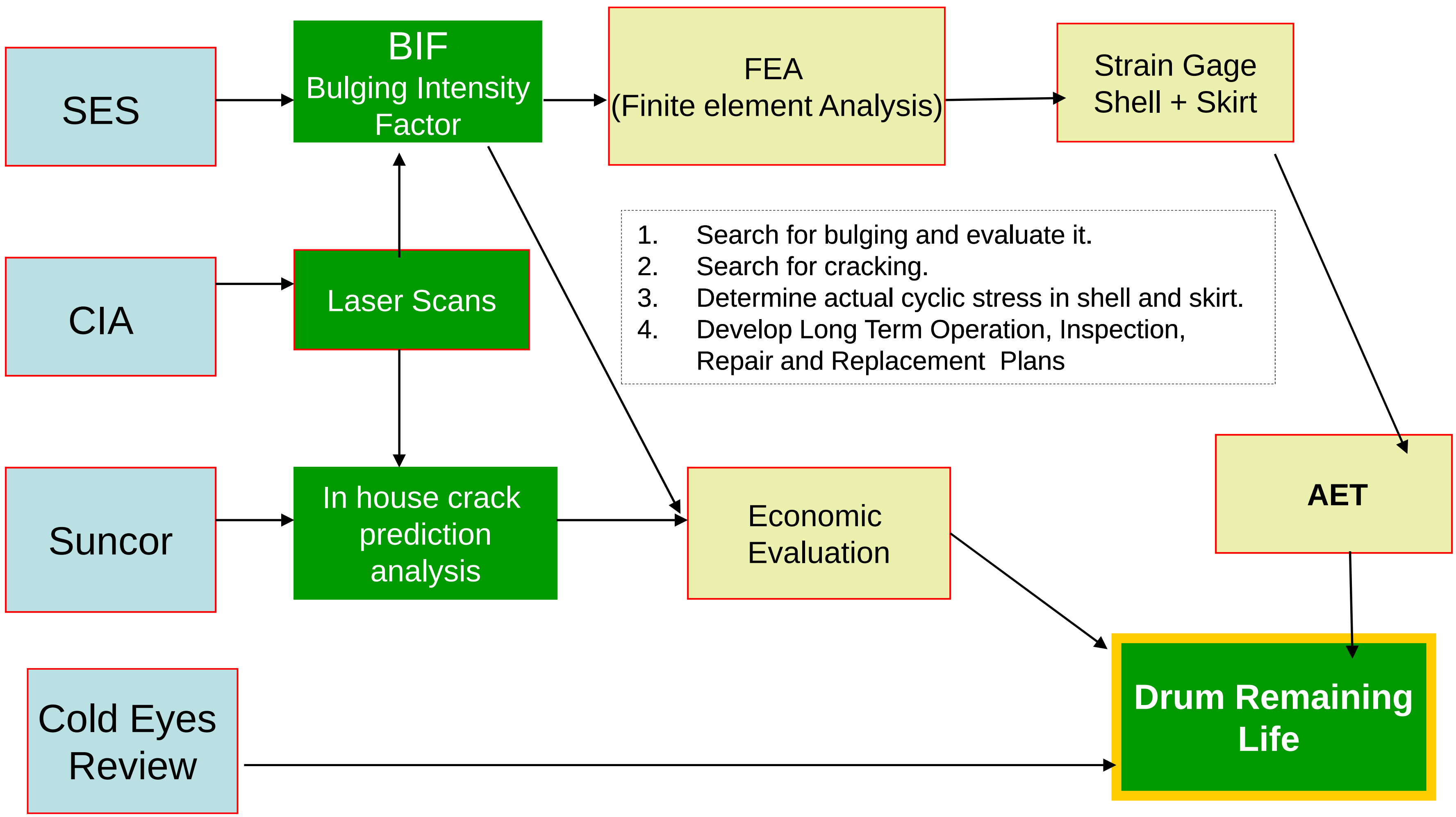
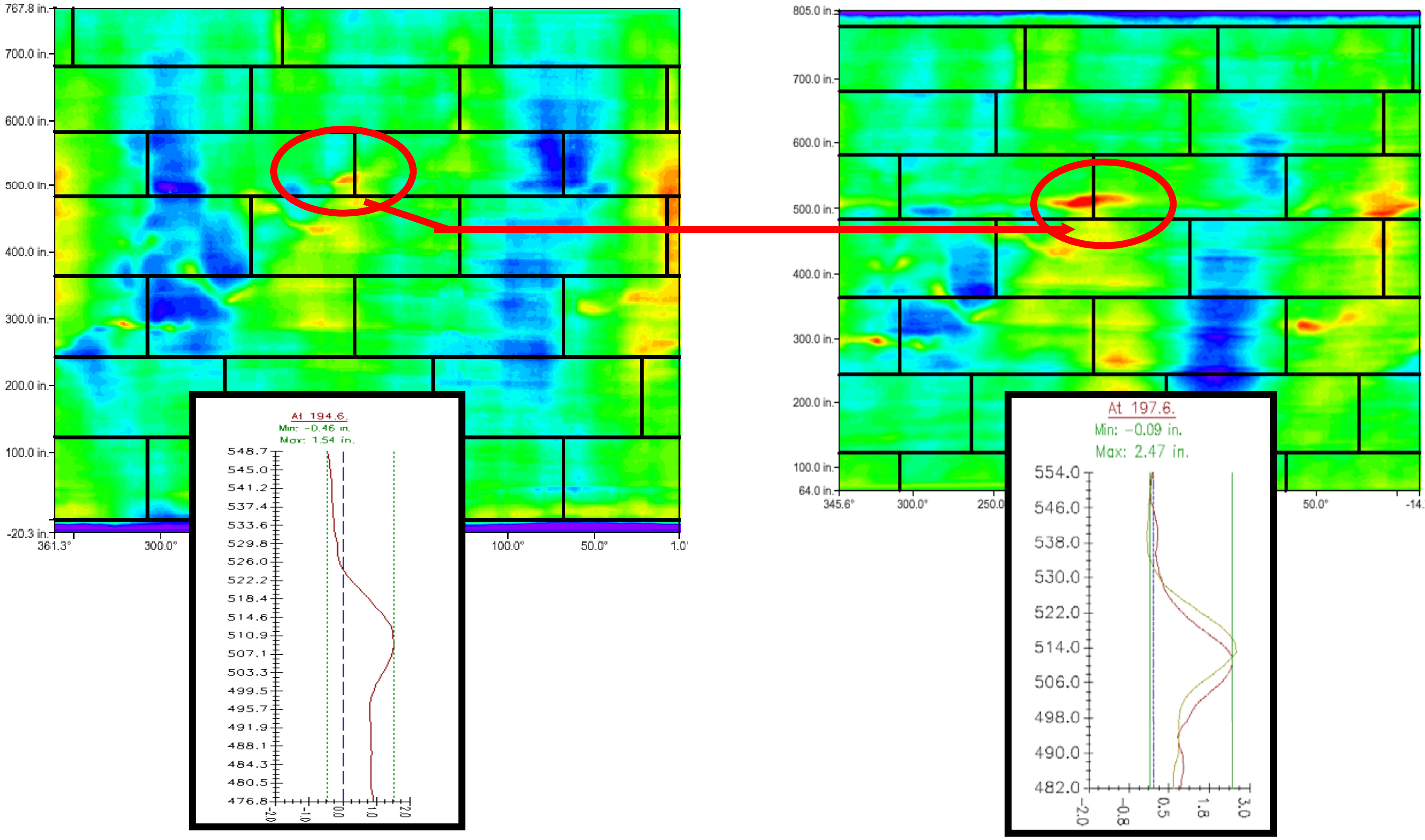
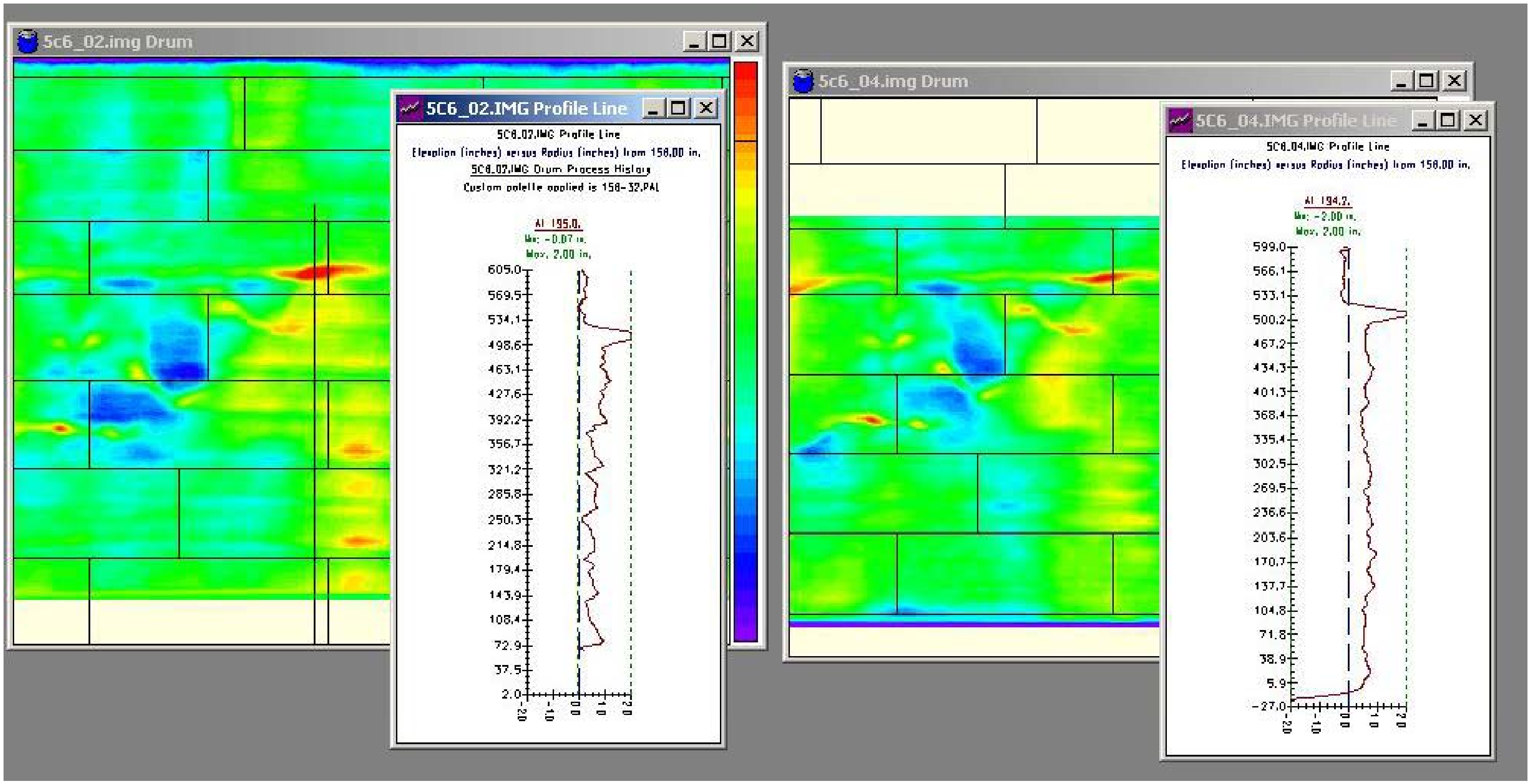
Approach for Remaining Life



COMPARE 1996 AND 2000 BULGES



COMPARE 2002 AND 2004 BULGES



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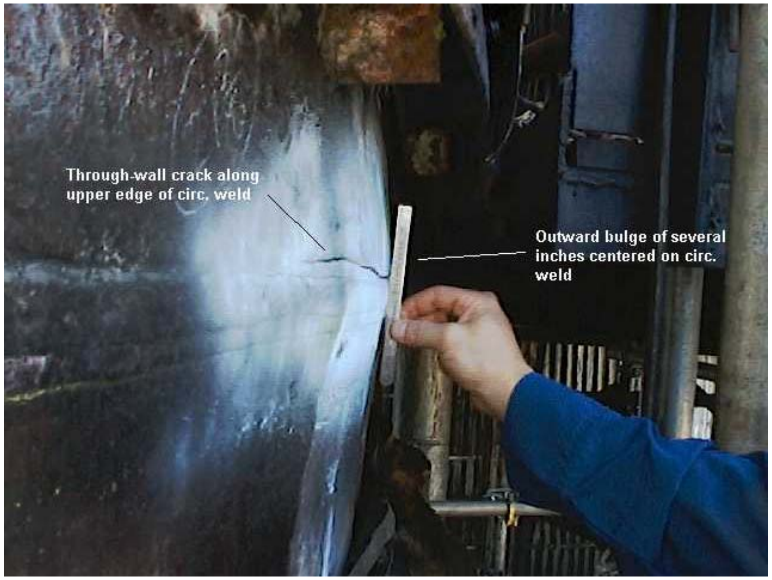
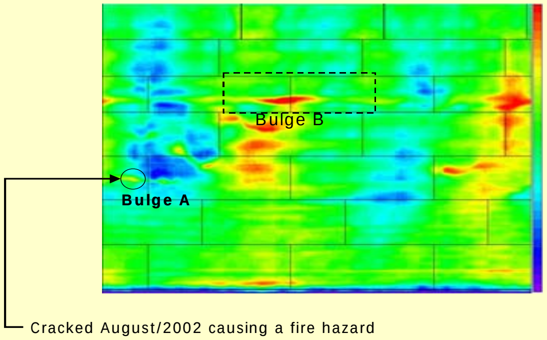
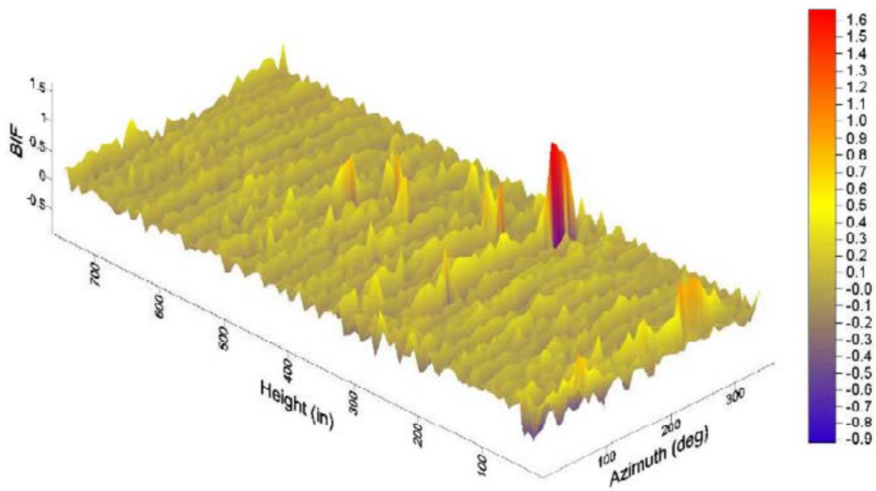
CRACK HISTORY – All DRUMS

<u>1967</u>: 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)
<u>1981</u>: 5C-50/51 started up
1 Crack in 5C50
June 1998
3/4/7/8 never cracked



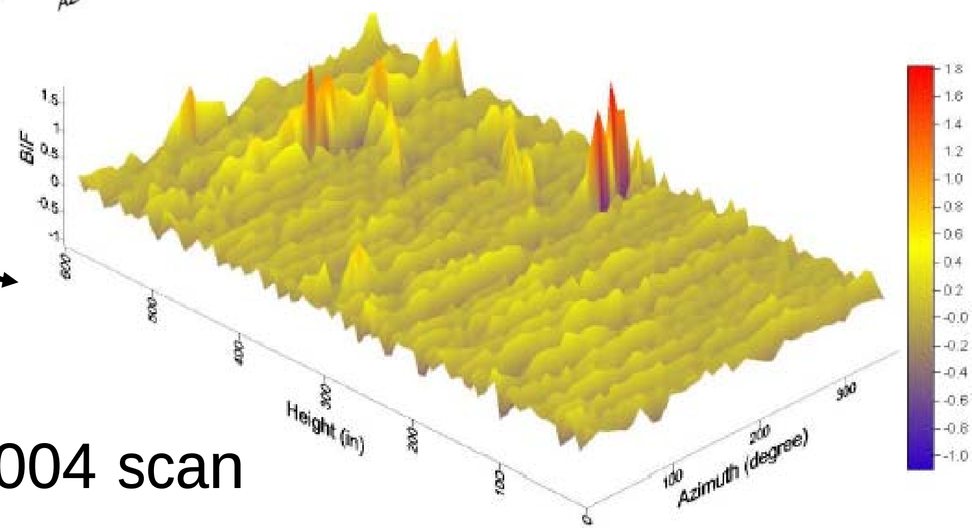


Bulges change over time



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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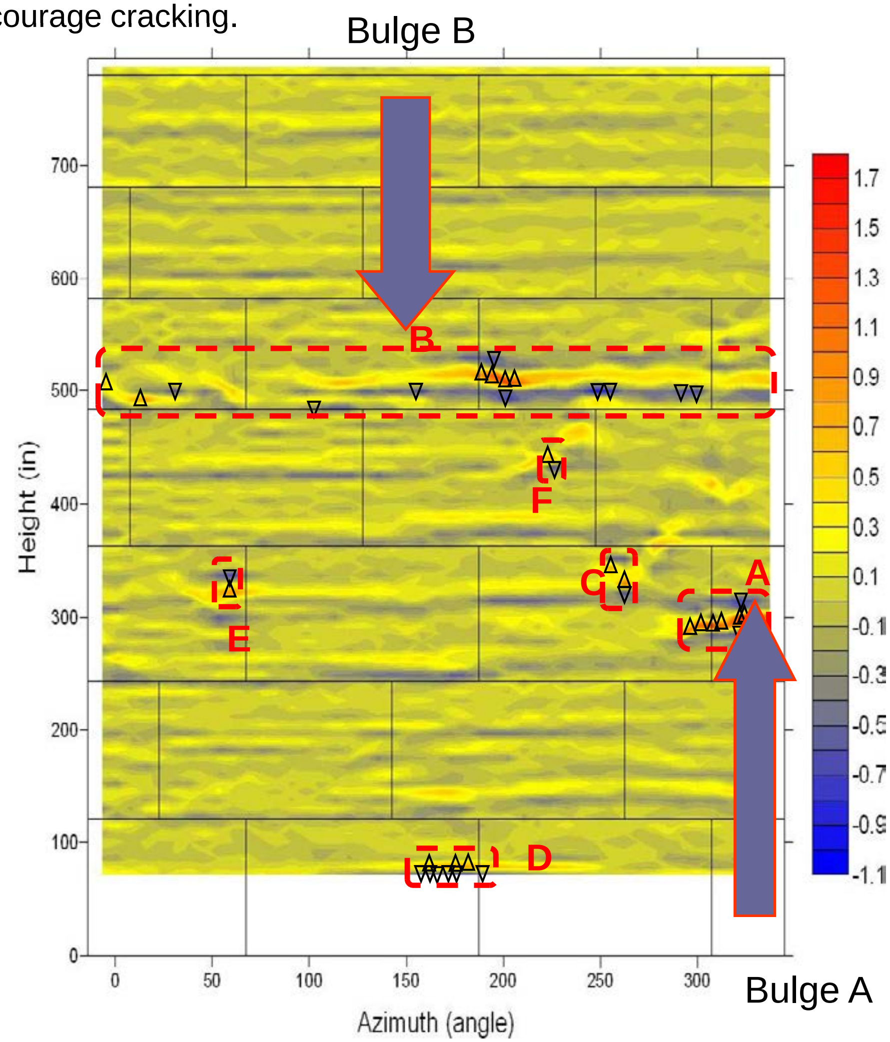
BIF Results

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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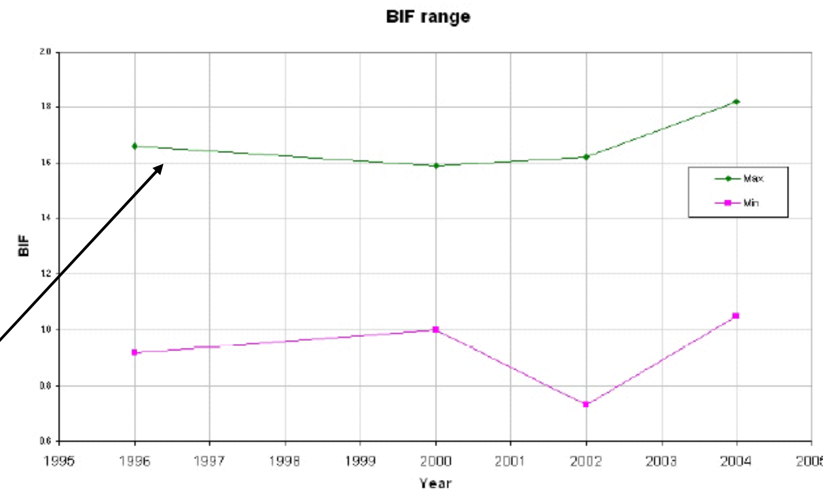
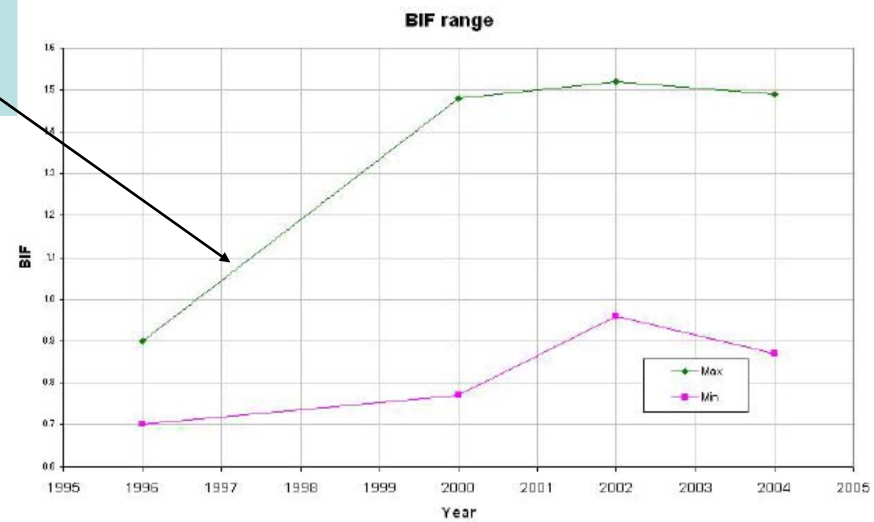
Changes in BIF for Bugle A and Bulge B



Changes in BIF Bugle A

Increase in the BIF over the years.



Changes in BIF for Bulge B

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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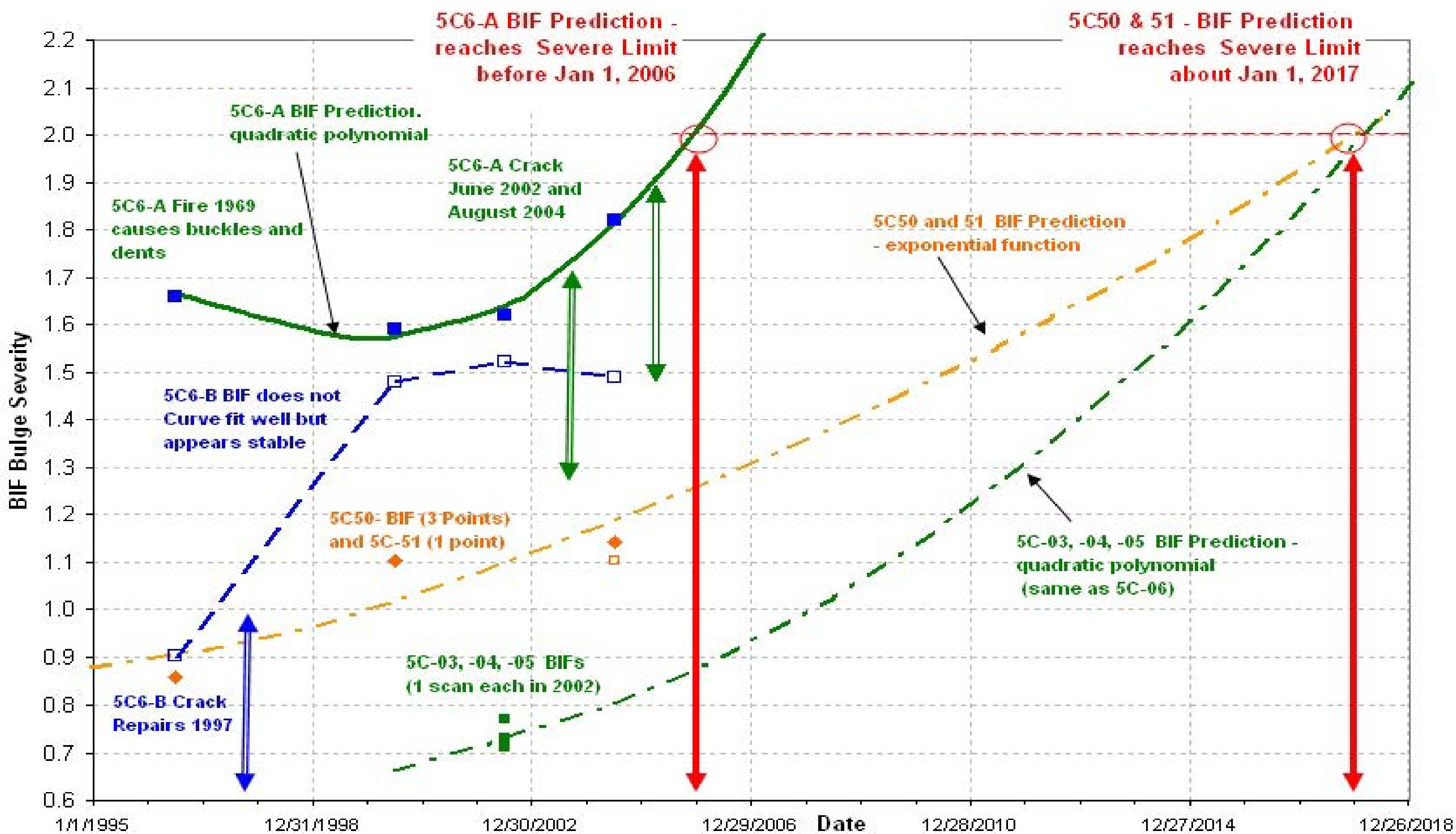
BIF Bulge Severity Prediction for Likelihood of Cracking



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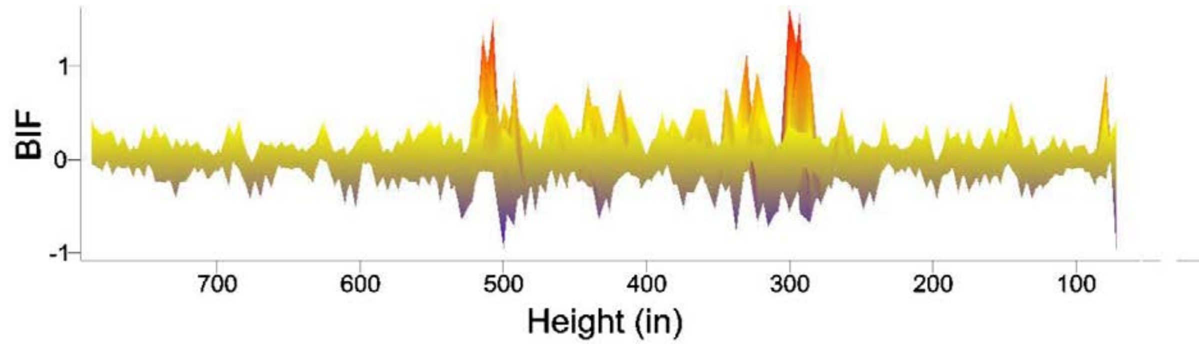
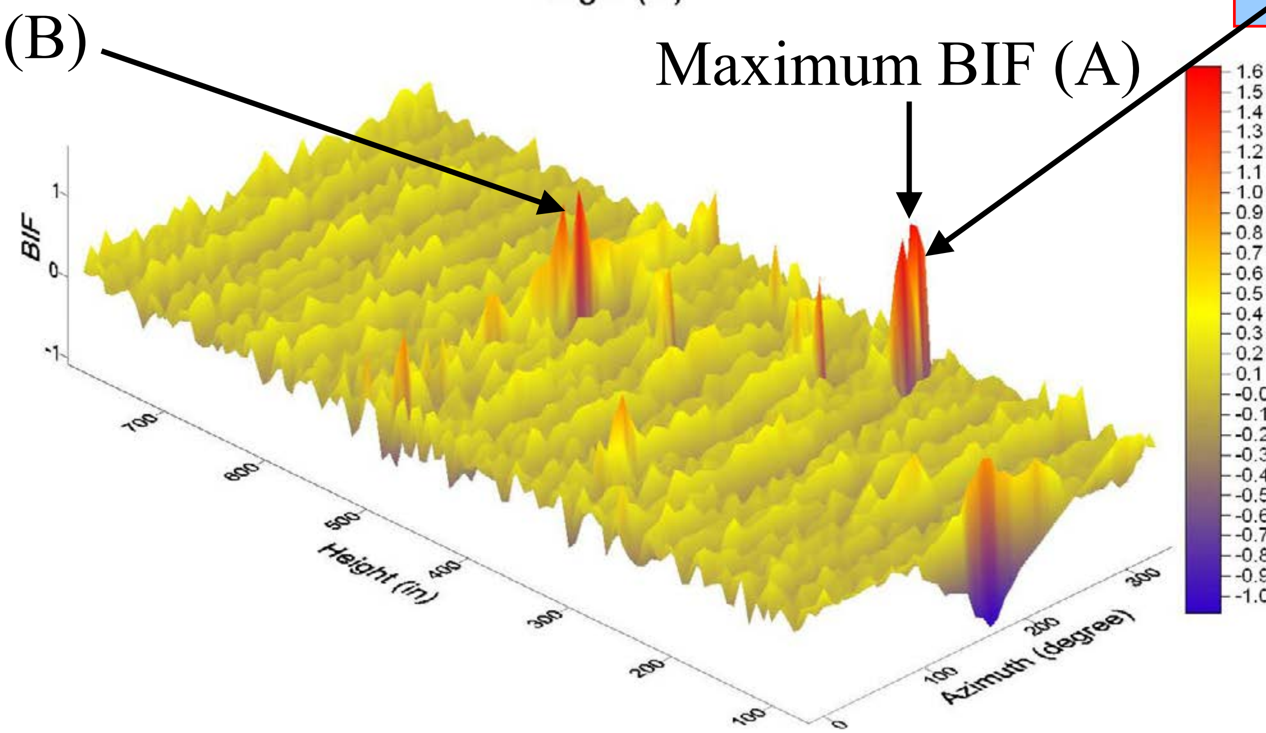
Plant Experience



Crack away from weld (BIF=1.82)

THROUGH WALL CRACK August 2005



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

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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