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)

Why Does Bulging Occur?

- **Resistance of coke**

  (high nominal stresses)

- **Material / thickness mismatch**

  (mechanical ratchet or progressive distortion)

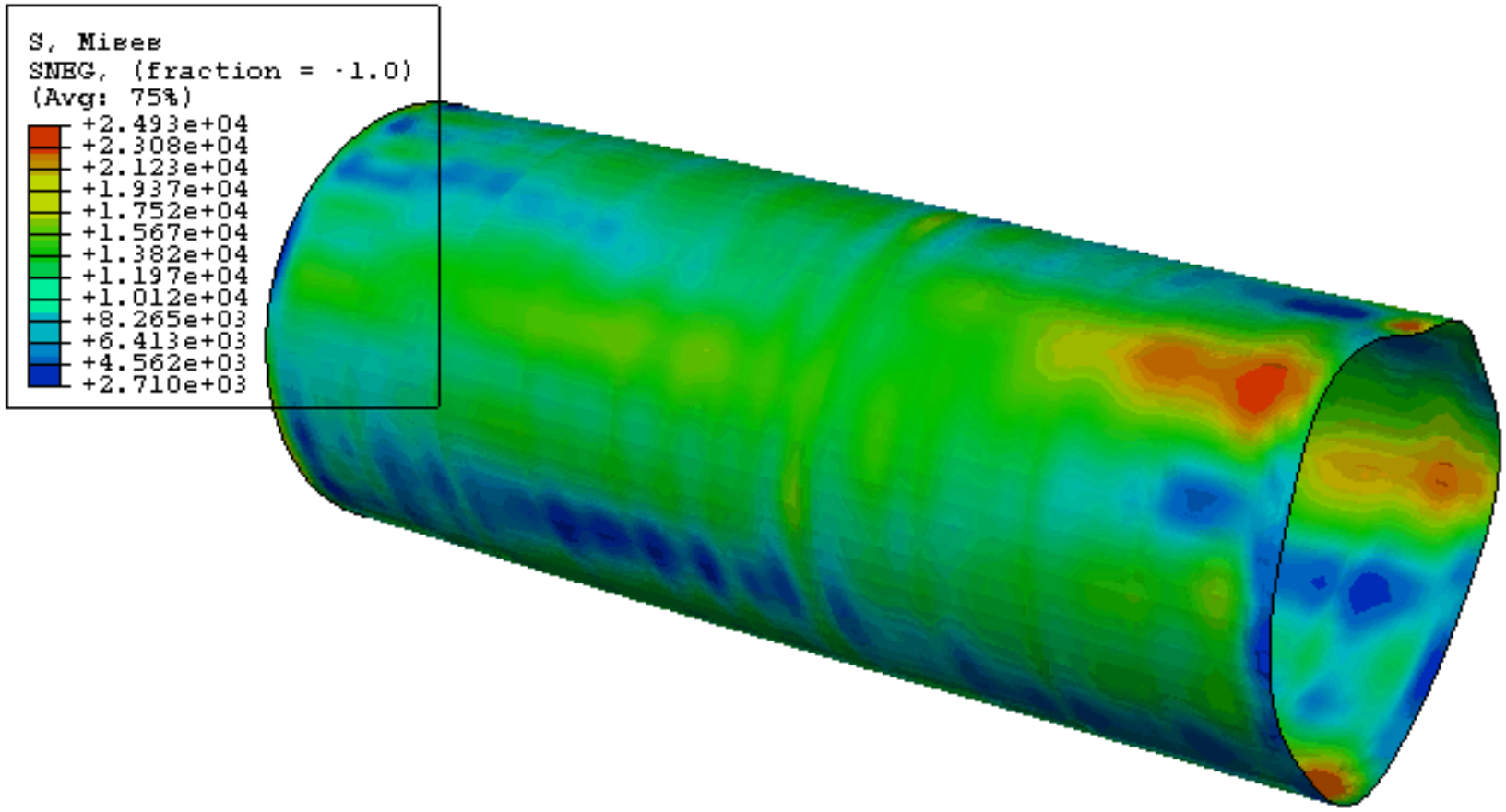
- **Operation**

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

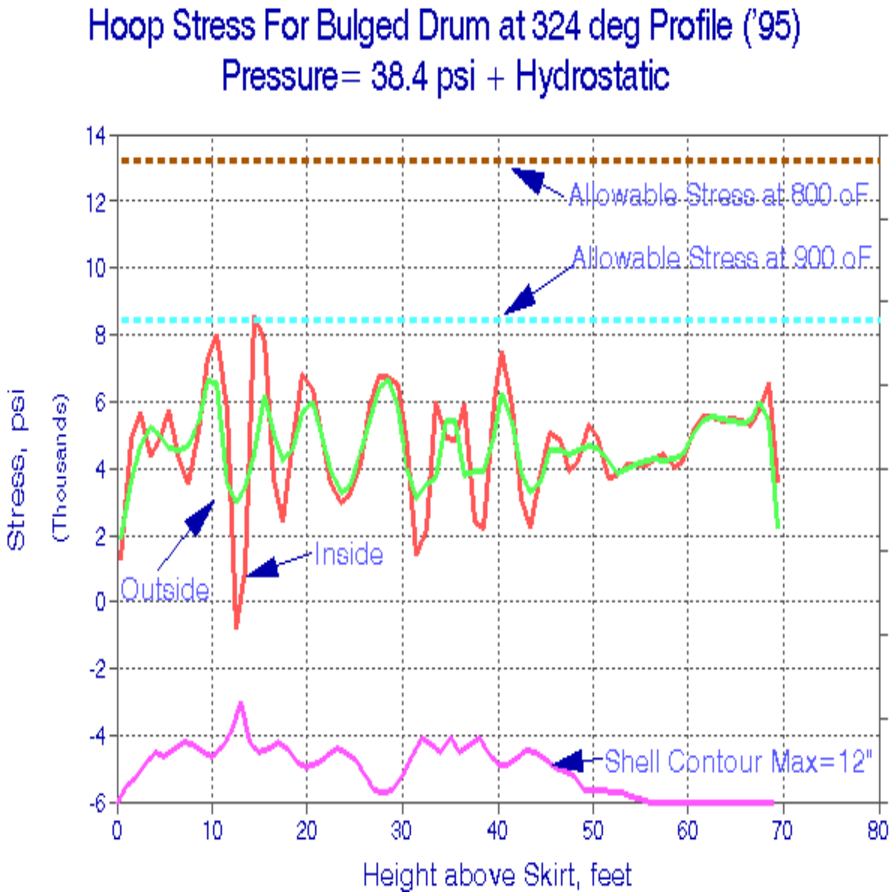
- **Flow patterns inside drums**

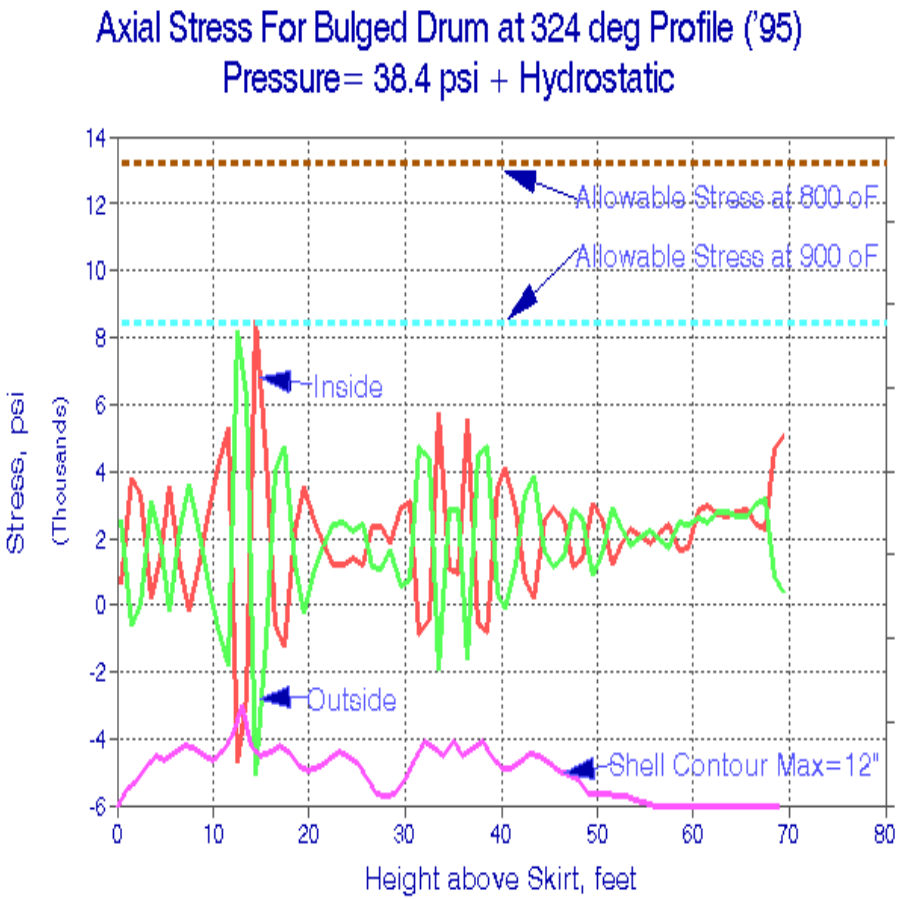
  (cold / hot spots)

What are the consequences of Bulging?



What are the consequences of Bulging?





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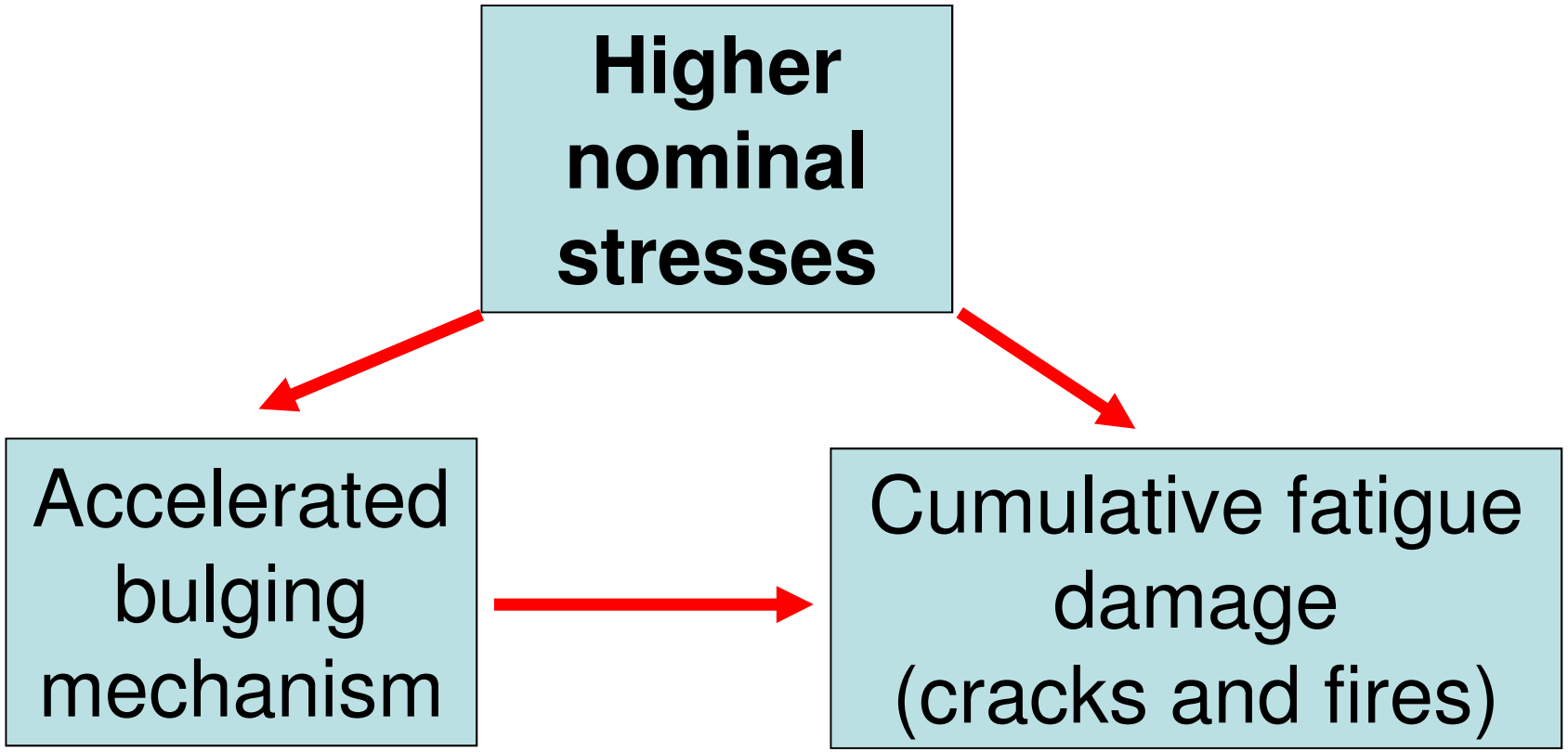
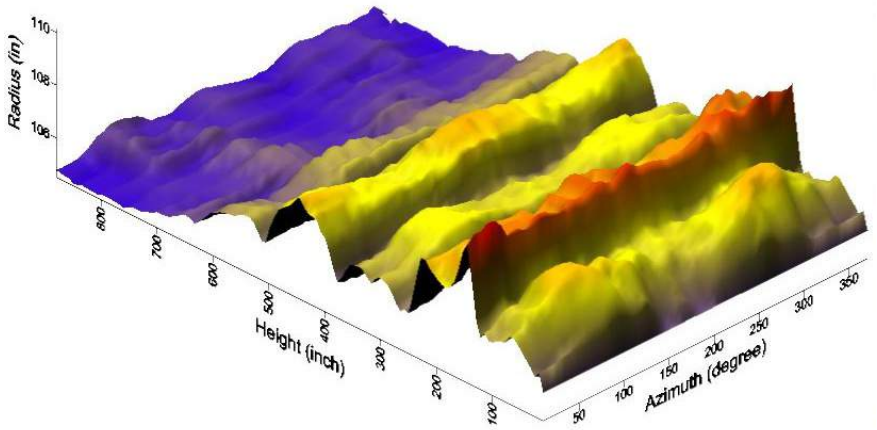
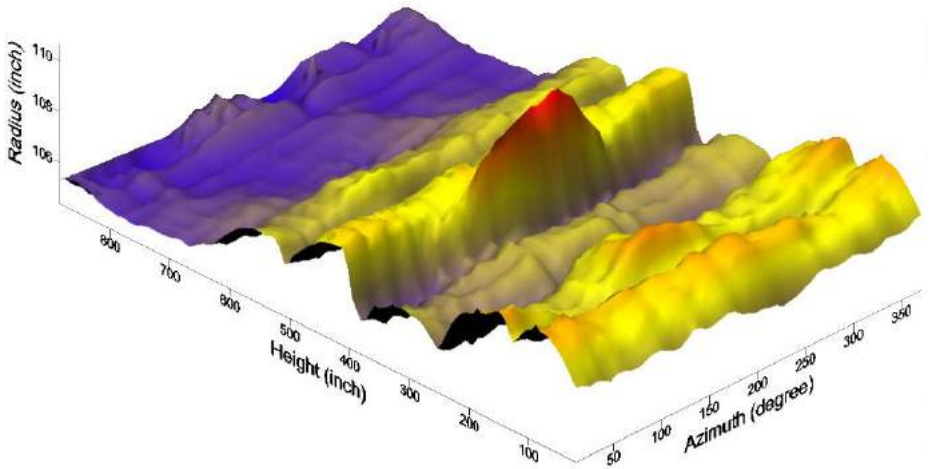
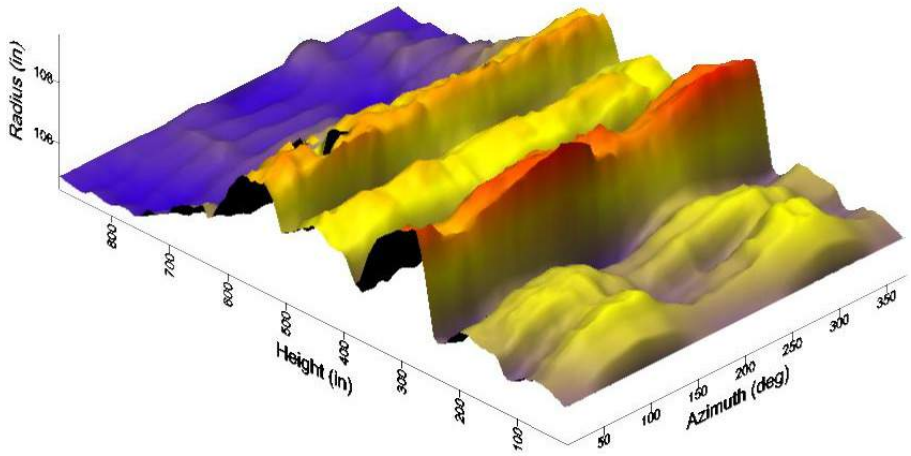
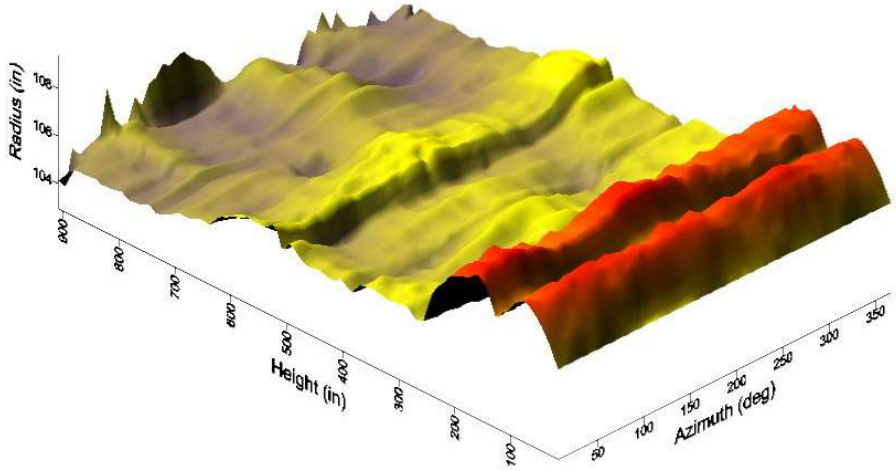


Bulging Magnitude vs. Cracking Severity

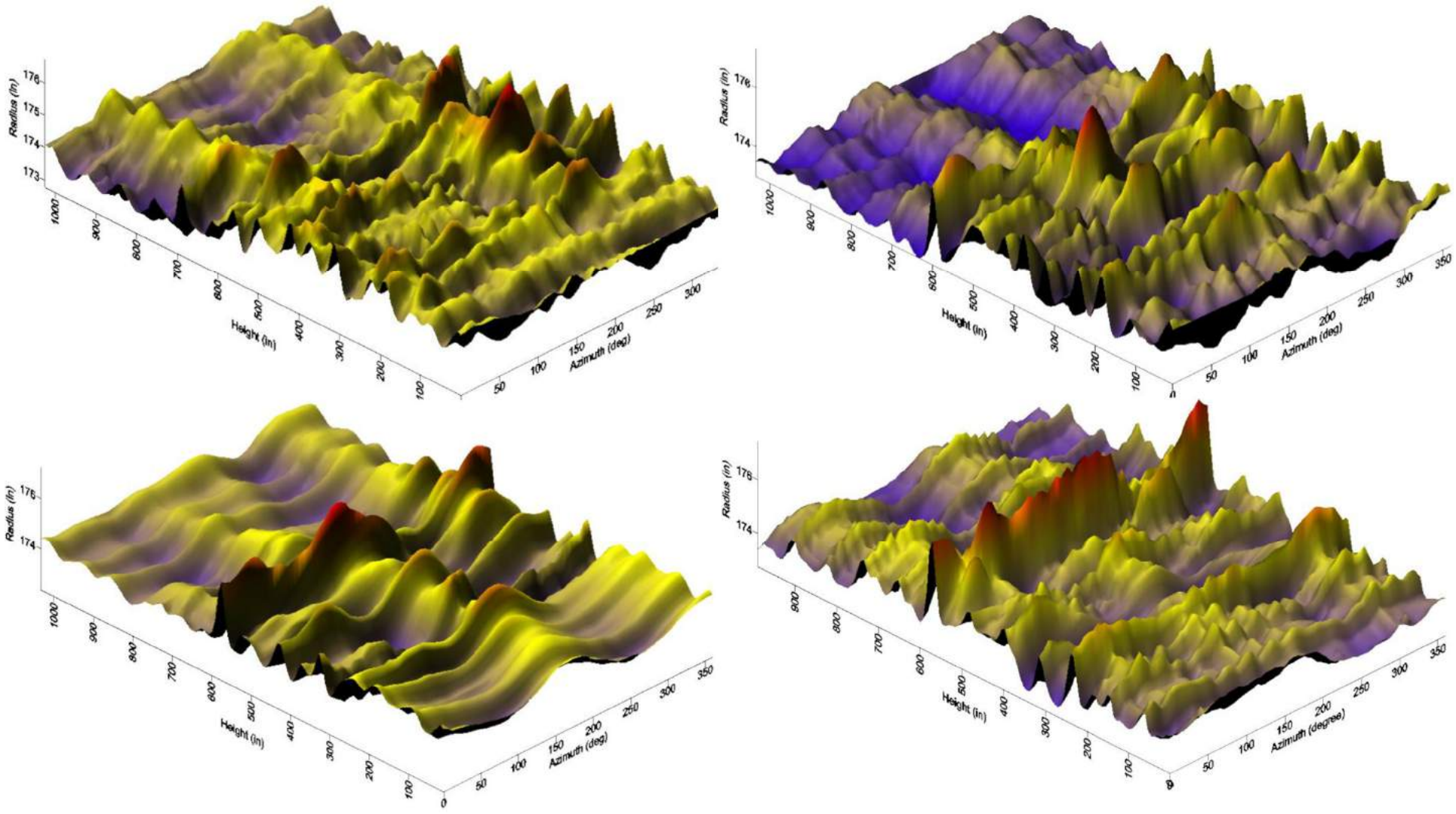








Bulging Magnitude vs. Cracking Severity



Can we use API-579 Assessment?

- Sure! Level 3 Assessment only

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

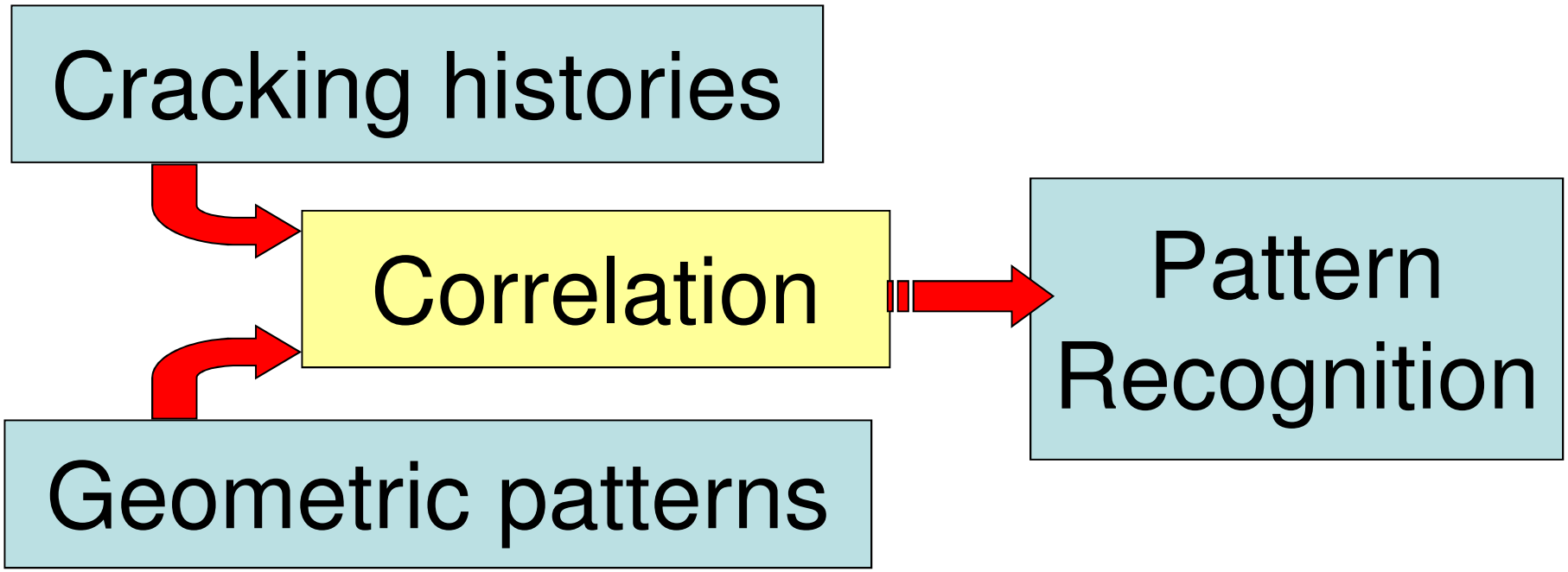
- Requirements

  (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.

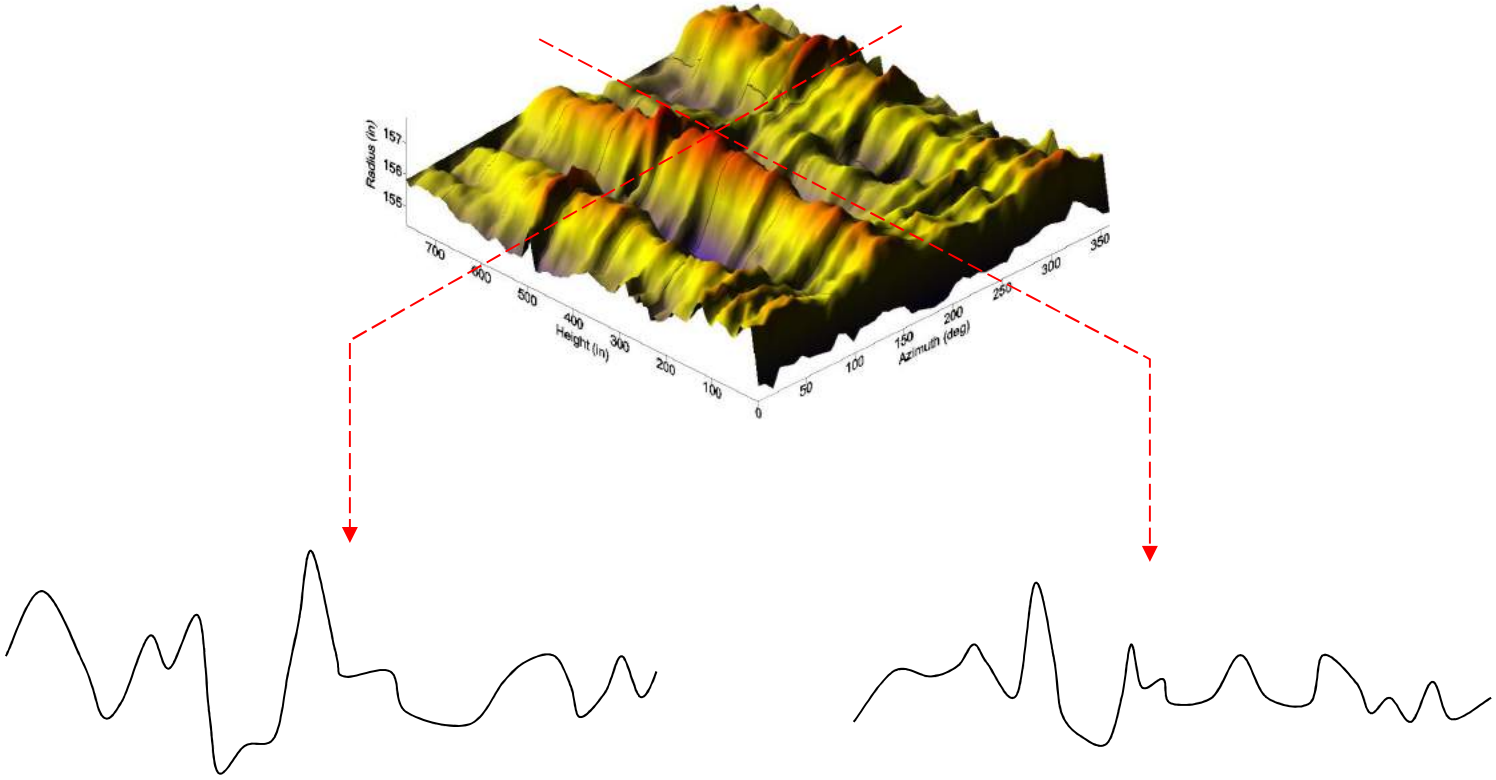
- Problems

  - ✓ 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!

TOOL DEVELOPMENT



Slicing the Bulge



Circumferential profile

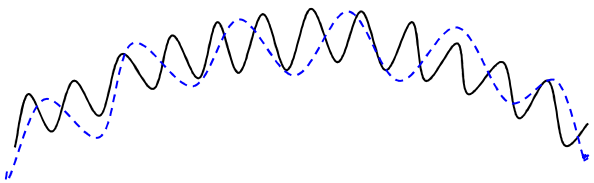
Longitudinal profile

Geometric Parameters

Magnitude

Curvature

Frequency



Circumferential and longitudinal profiles

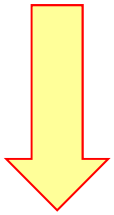
Cross correlation

BIF

The Bulging Intensity Factor (BIF)

From laser scans:

Identify and Rank
areas most susceptible to cracking



Prioritize & optimize inspections

BULGING INTENSITY FACTOR (BIF)

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

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

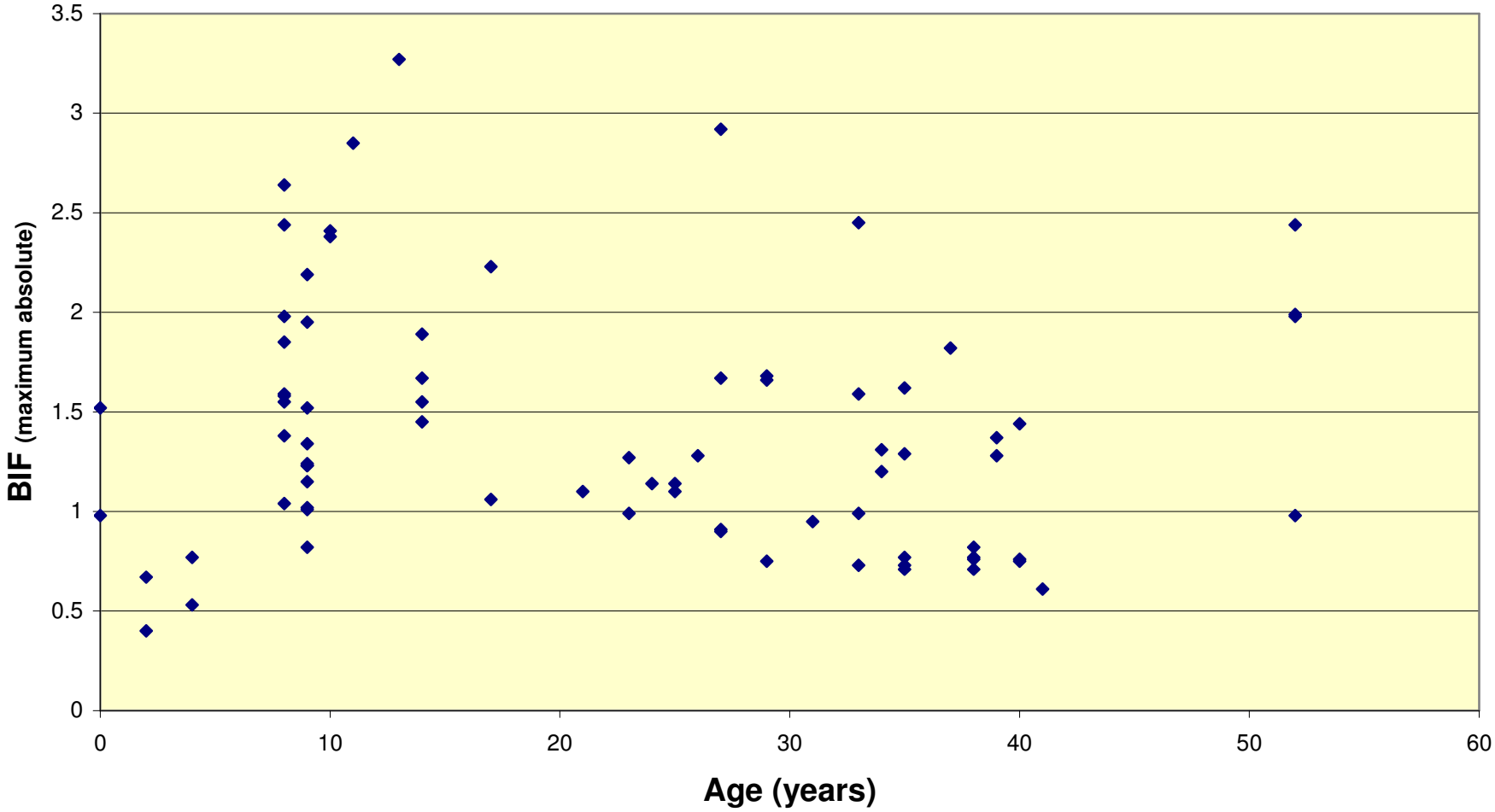
DATABASE

- Calibration data base: 11 drums with known cracking histories.
- Total data base: 80+ scans.
- Carbon steel, Carbon-1/2Mo and 1 to 1¼ Chrome drums.

DATABASE

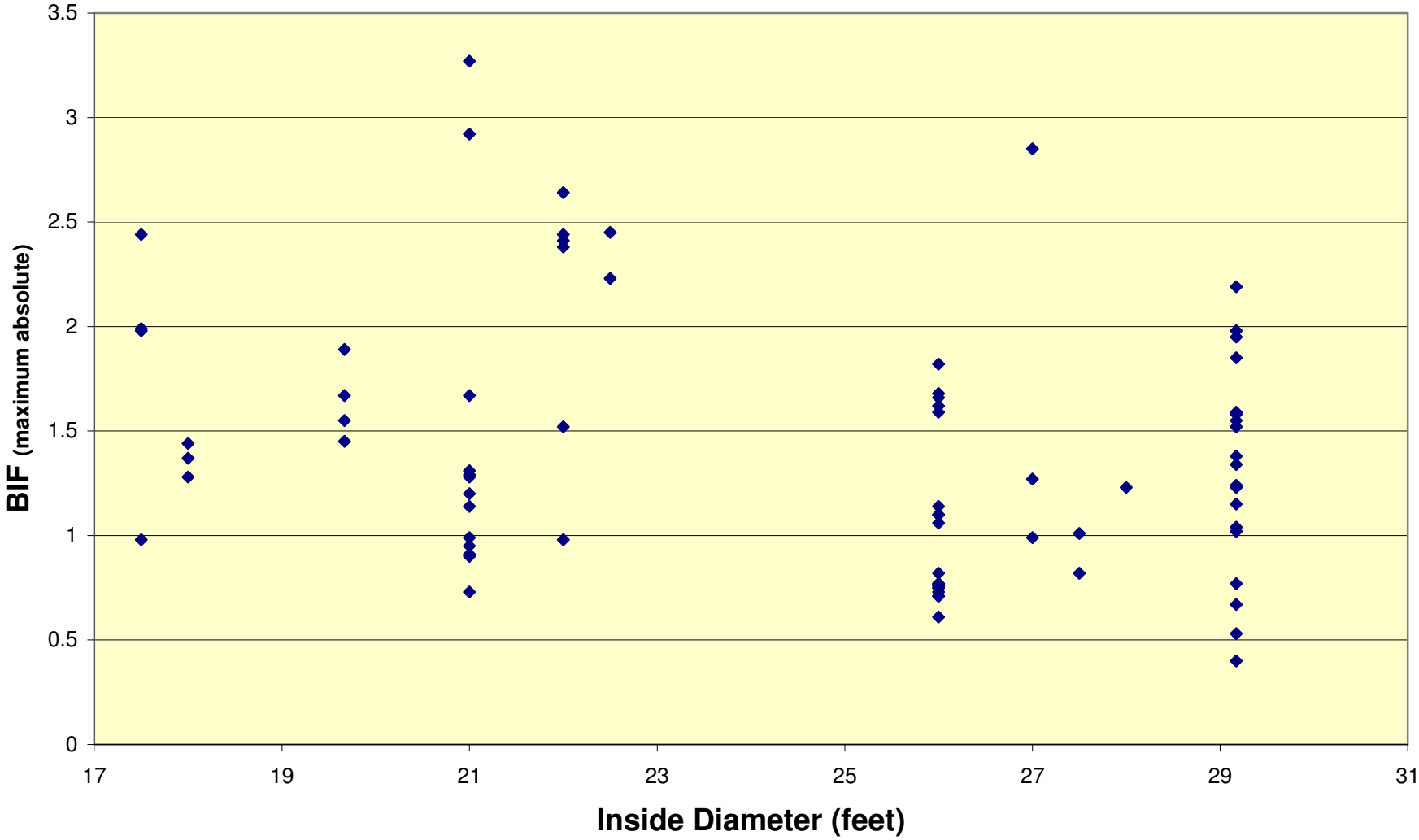
Age versus BIF

(Age shown does not account for any repairs or can replacements)



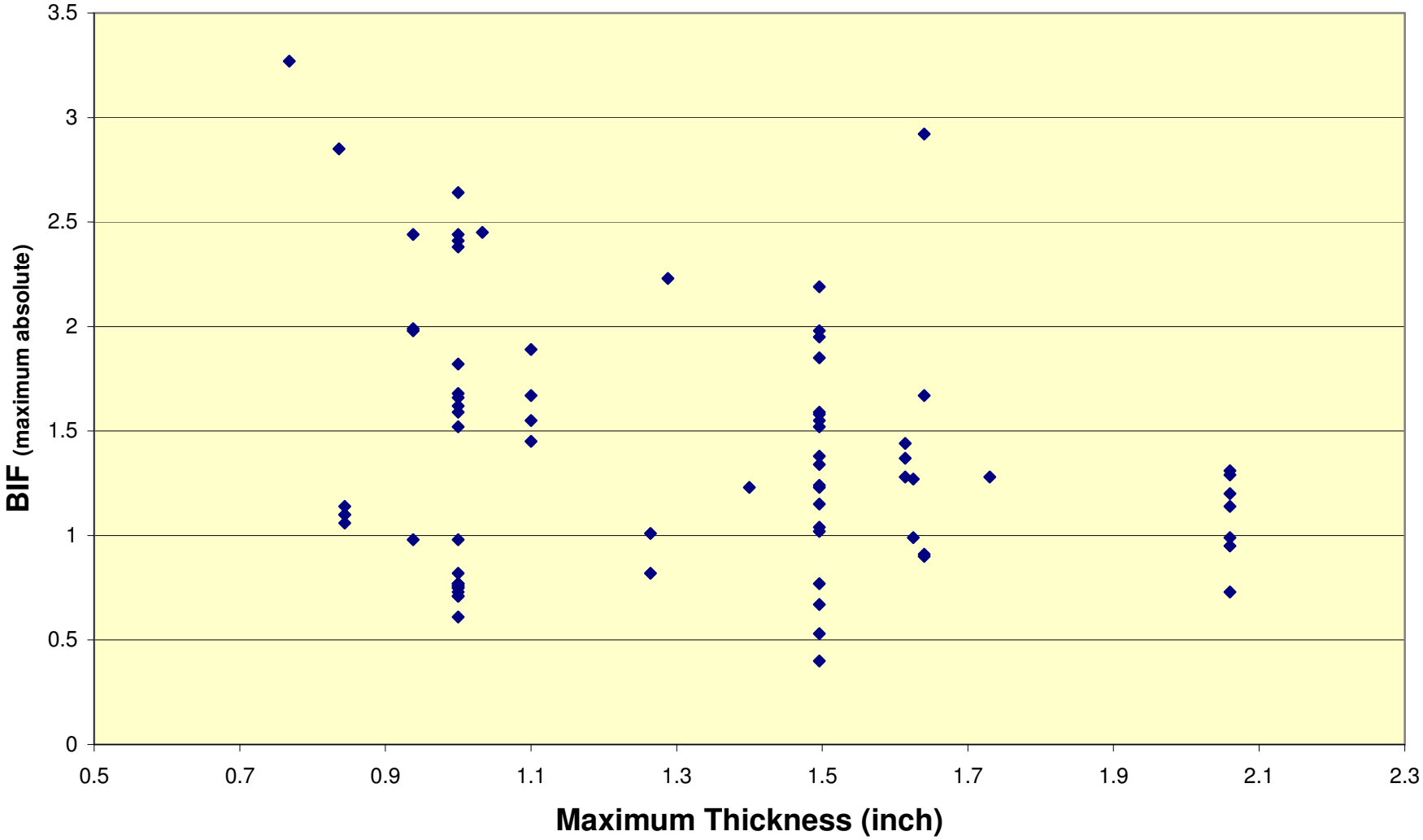
DATABASE

Diameter versus BIF



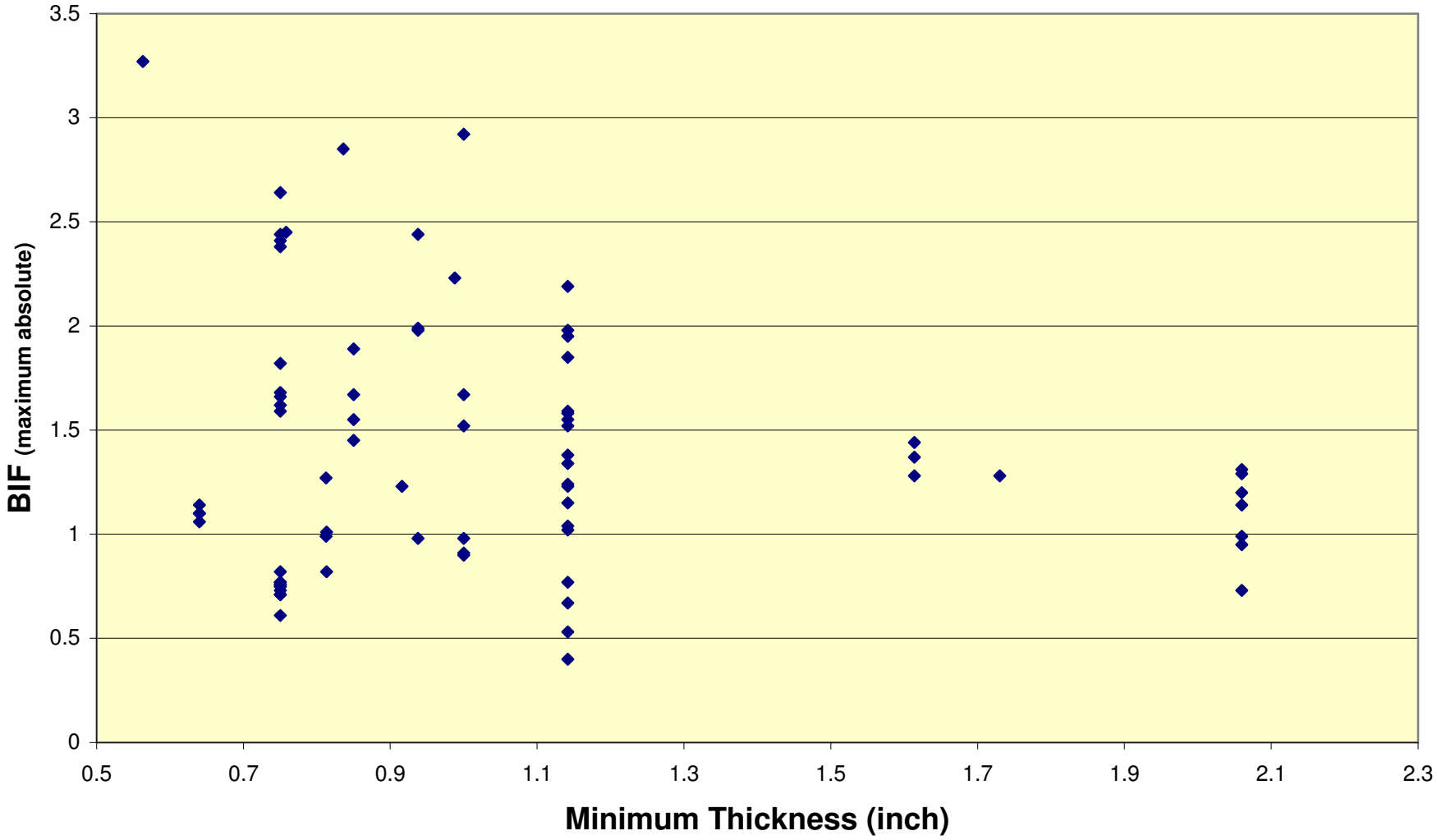
DATABASE

Maximum thickness versus BIF



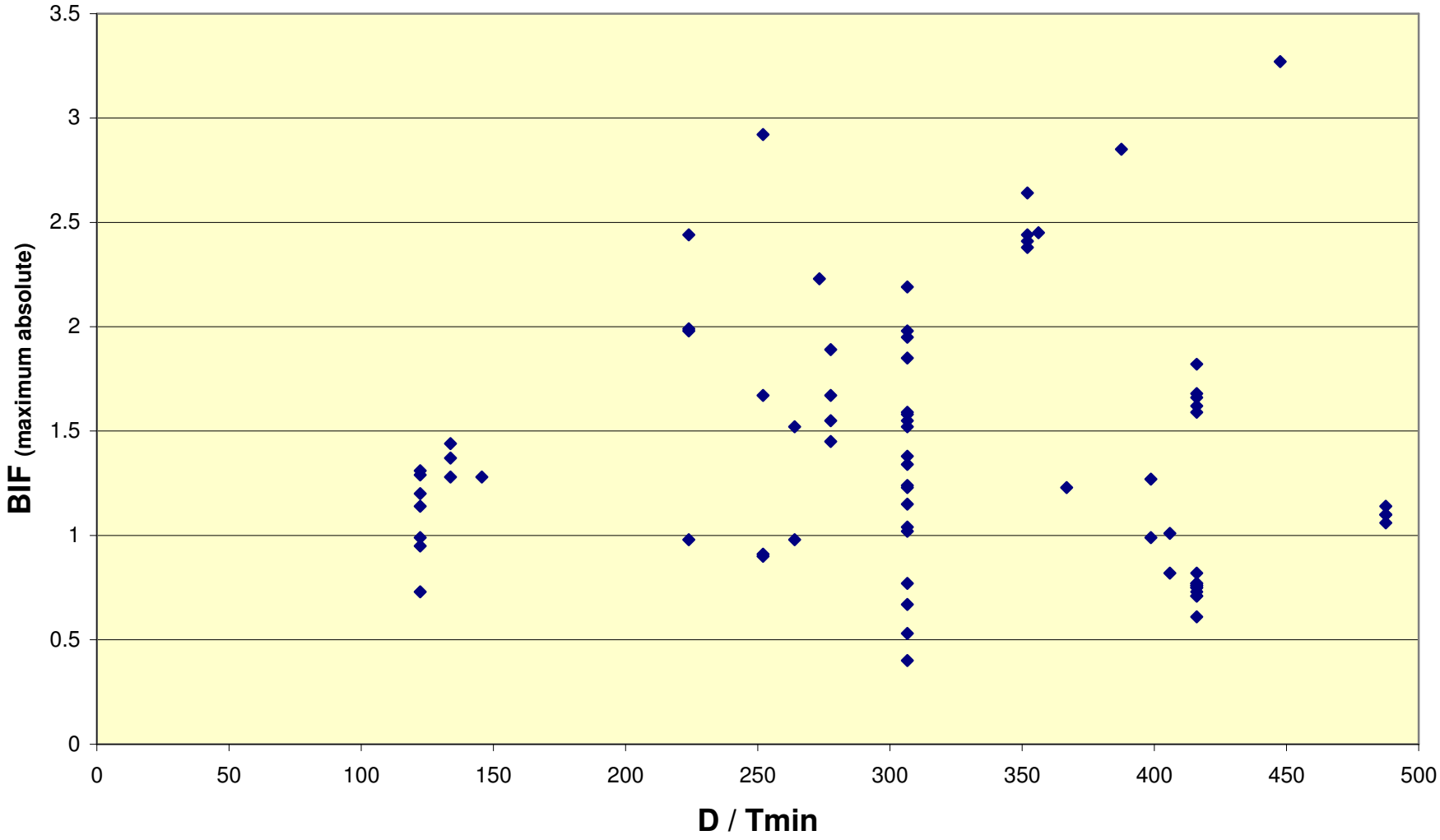
DATABASE

Minimum thickness versus BIF



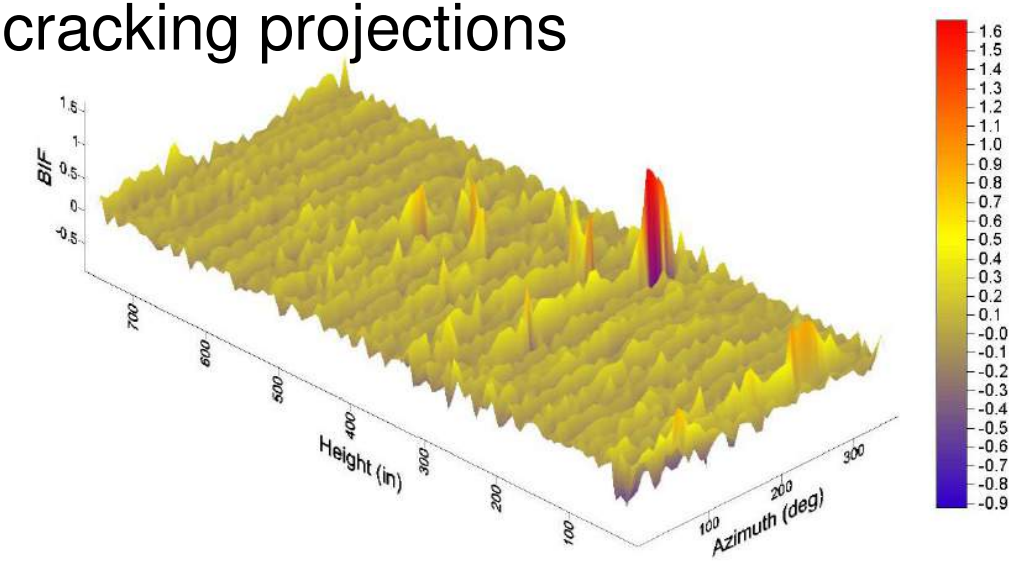
DATABASE

Diameter over Minimum Thickness versus BIF

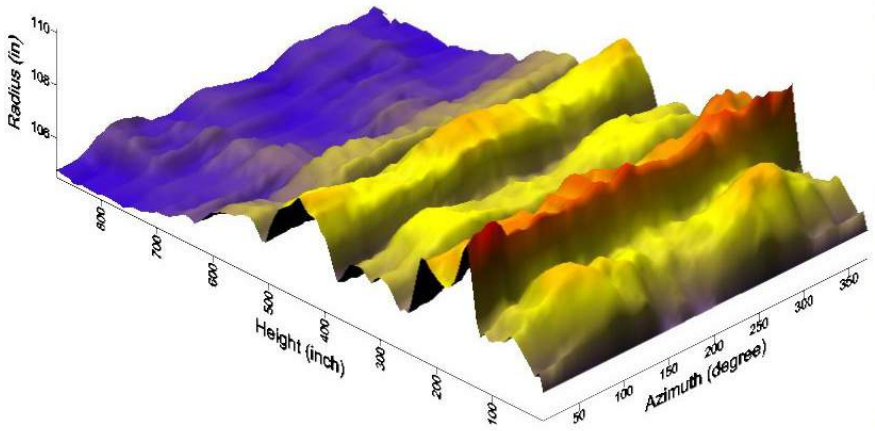


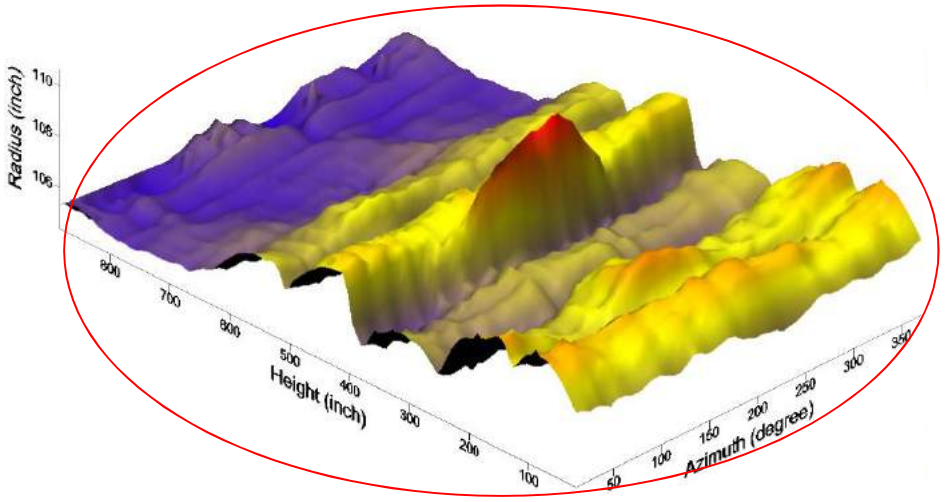
BIF Output

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



Case Study (1)


Radius (in)
Height (inch)
Azimuth (degree)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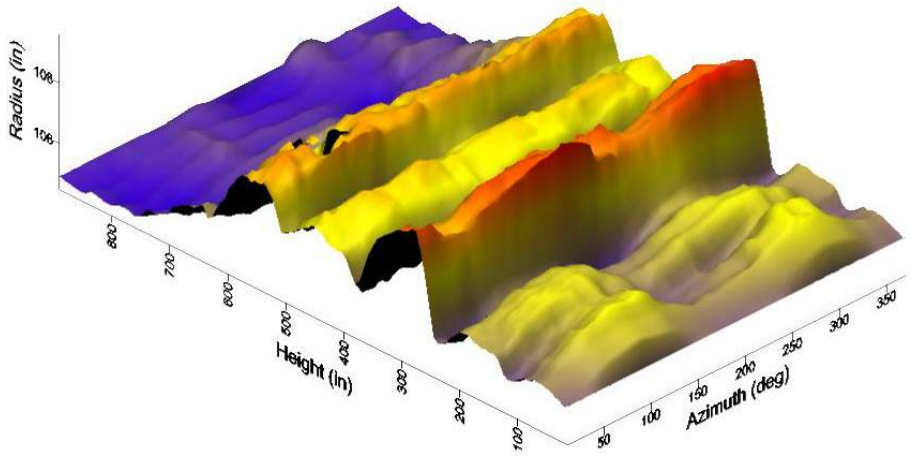
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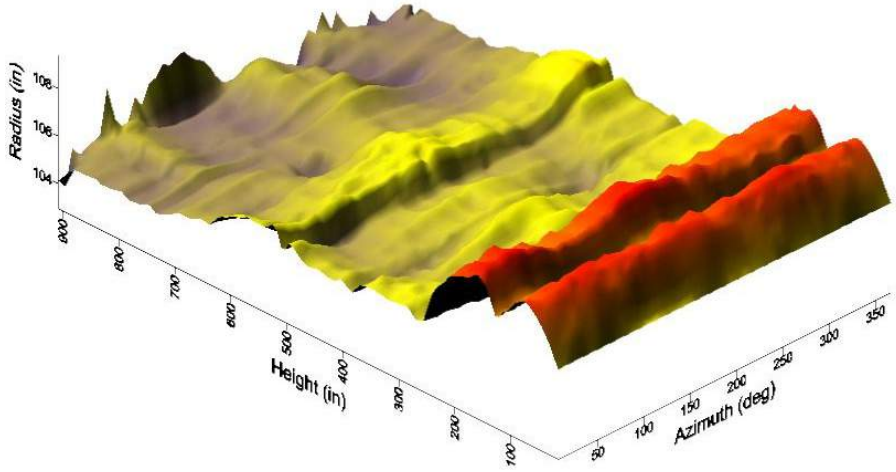
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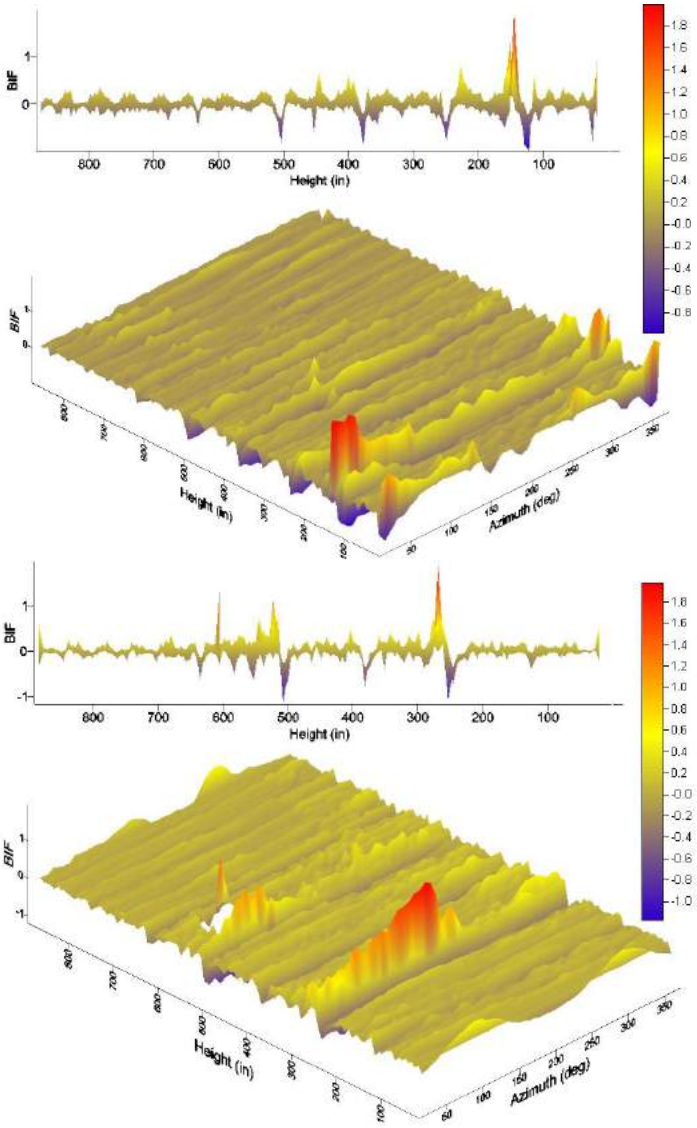
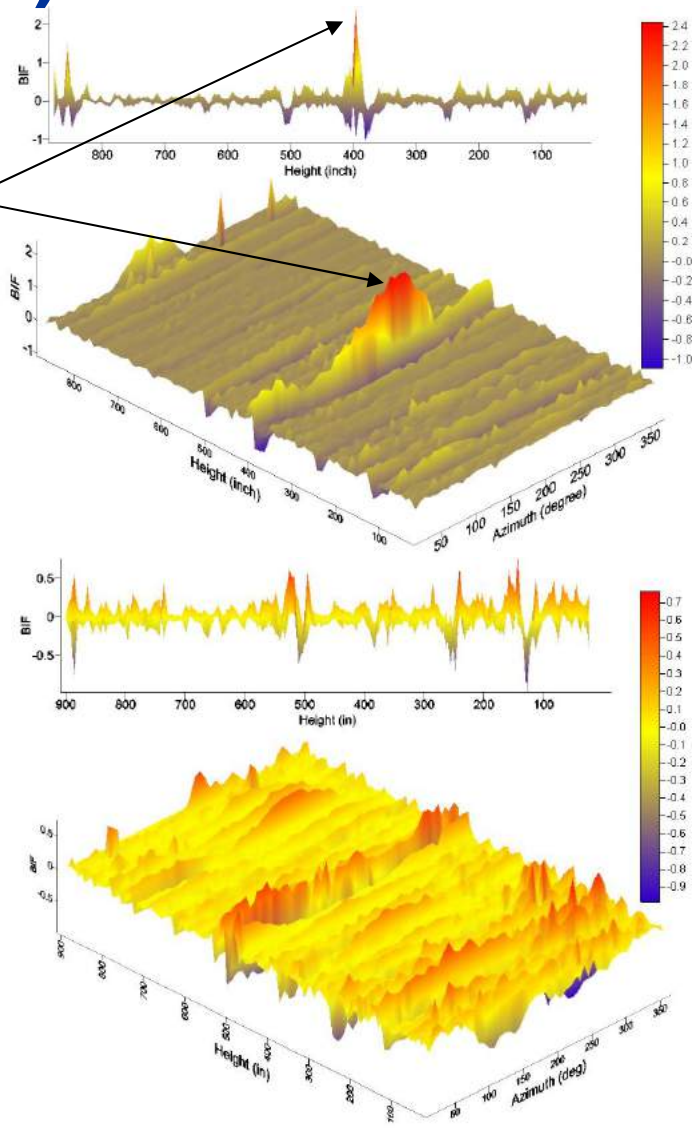
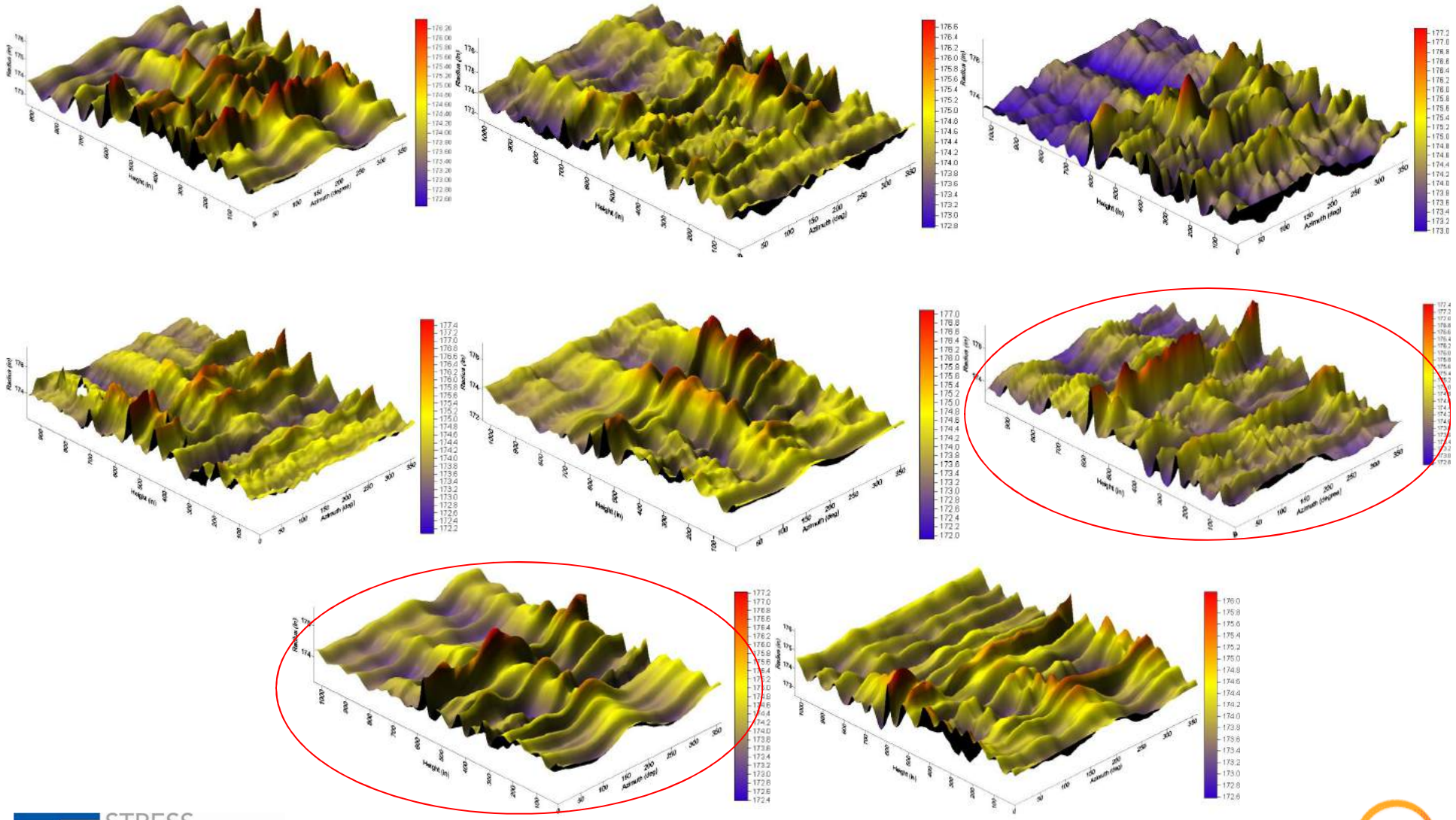


"V. HIGH - SEVERE"
Almost through-wall crack

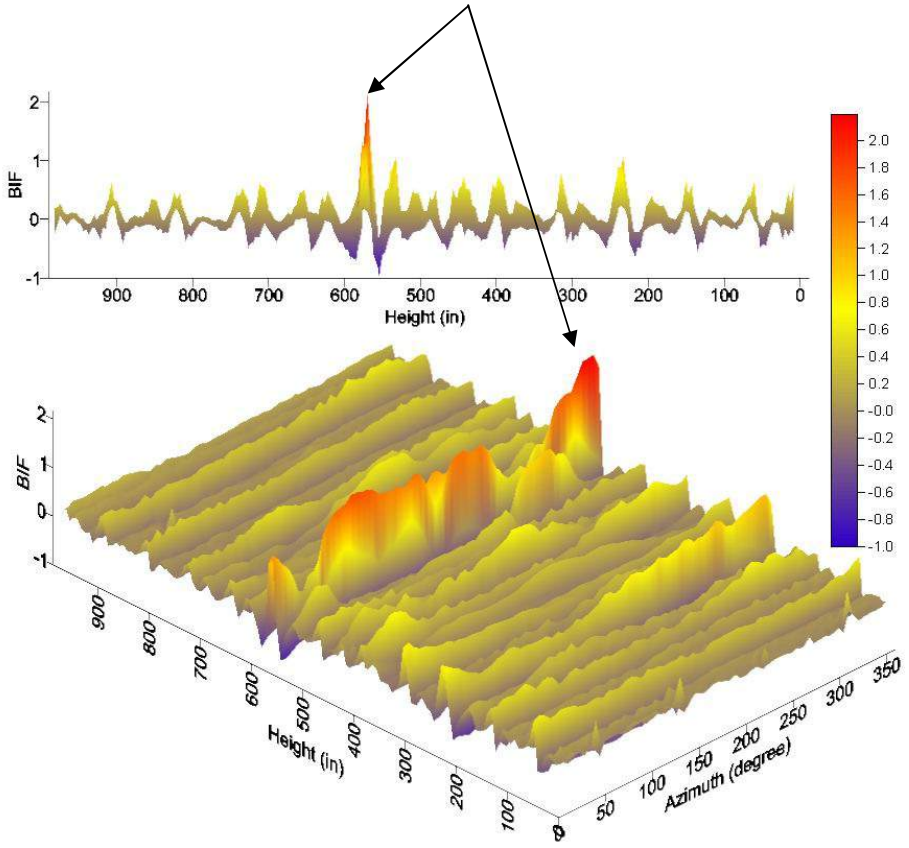


Case Study (2)

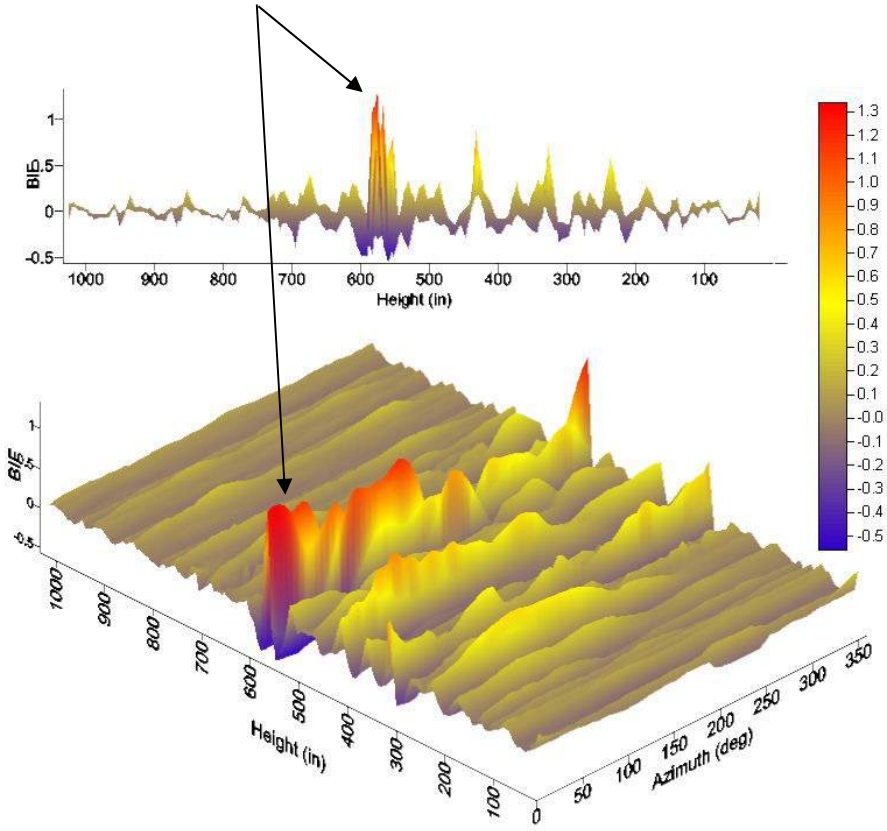


Case Study (2)

"SEVERE"
Multiple cracks: total 21 ft long



"HIGH"
2 cracks: 2.5 ft and 3 ft long



Summary

- The Bulging Intensity Factor (BIF) is a geometry-based technique for assessing the severity of coke drum bulges
- The method is designed to help in:
  - Planning maintenance outages, repairs, and replacement
  - Determining the frequency of laser scans
  - Quantifying the risk of failure
  - Prioritizing inspections and optimizing resource allocations
- So far, predictions seem to correlate well with cracking history

SUNCOR COKE DRUMS (14)

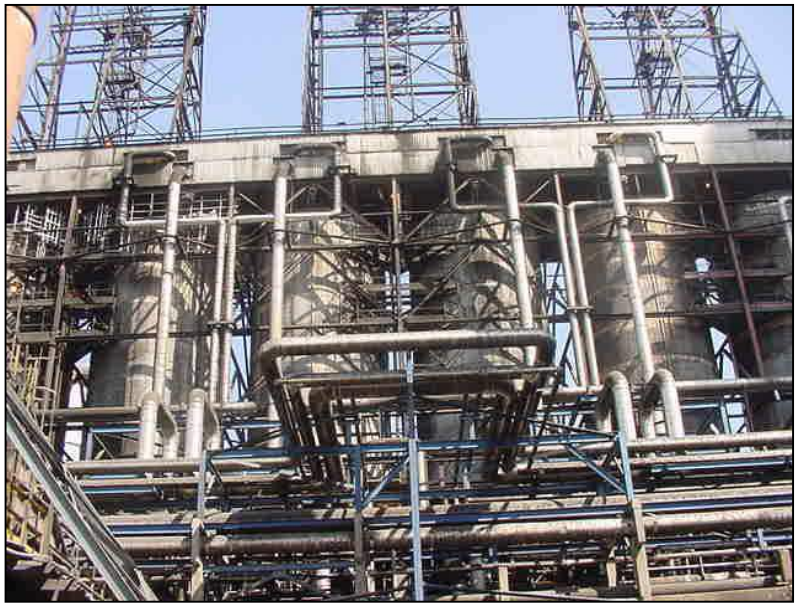
- 6 of C- 1/2 Mo Drums
- ID = 26’, T-T = 66’
- Built 1966
- Completed 8200 Cycles

- 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

- 2 of 30’ dia – 1Cr-1/2 Mo
- Built 2007
- 6 of 32’ dia – 1Cr- ½ Mo (future)

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

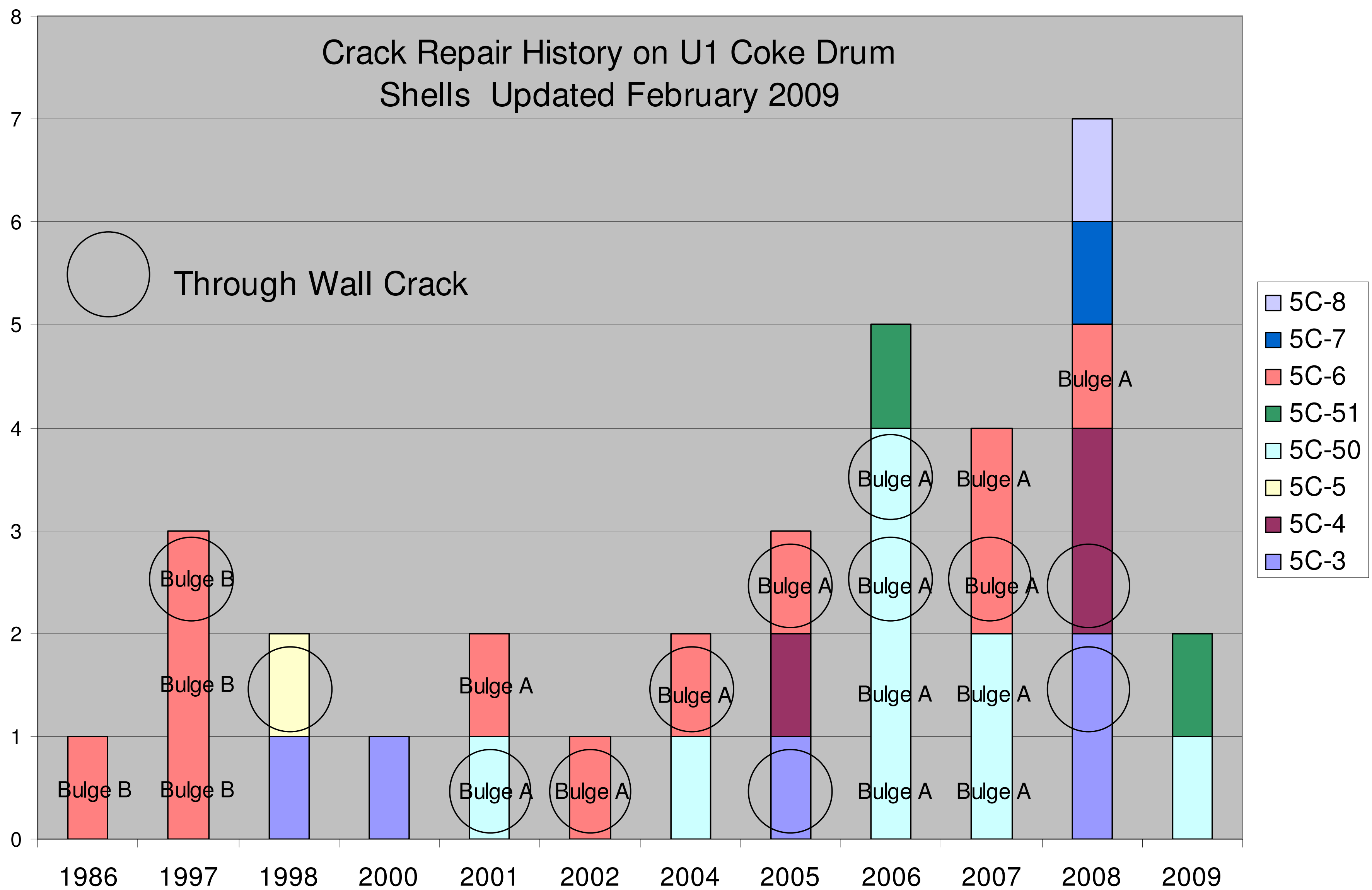
- How severe is the Bulging in the Drums ?
- How should we prioritize the drum inspection needs?
- When will the bulging result in Cracking ?
- When should we replace the coke drums?
- How soon do we need to rescan the drum ?
- How to minimize unplanned outages ?
- What will be the total crack repair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

Evaluation Techniques

- Laser scans
- Bulge Severity and Growth Analysis using Bulging Intensity Factor (BIF)
- Software analysis – in house
- Finite Element Analysis
- Probabilistic Crack Propagation calculations
- Strain Gage & temperature Measurements
- AET (Acoustic Emission Testing)
- Shear wave UT

BIF RESULTS – ALL DRUMS

DRUM	Maximum BIF and severity ranking							Severity of last scan	Deterioration speed	Notable areas
	1996	2000	2002	2004	2005	2007	2008			
5C3			0.66 ~0.73			0.76~ 0.66		Marginally Medium	Slow	South side of the fifth can
5C4			0.58 ~0.71		0.76 ~0.76		0.61 ~0.56	Low	None	South side of the fourth can
5C5			0.77 ~0.61					Medium	Mild	Circumferential weld between the fourth and fifth cans and south side of the fifth can
5C6	1.66 ~0.92	1.59 ~1.0	1.62 ~1.08	1.82 ~1.10				Very high	Fast	Northeast side of the middle of the third can and the bottom of the fifth can
5C7	0.68 ~0.75				0.46 ~0.71			Low	None	None
5C8	0.68 ~0.89				0.77 ~0.60	0.75 ~0.64		Marginally Medium	None	North side of sixth can
5C50	1.06 ~0.64	1.10 ~0.67		1.14 ~0.69				High	Mild	Bottom of the fifth can
5C51				1.10 ~0.73				High	N/A	Bottom of the fifth can



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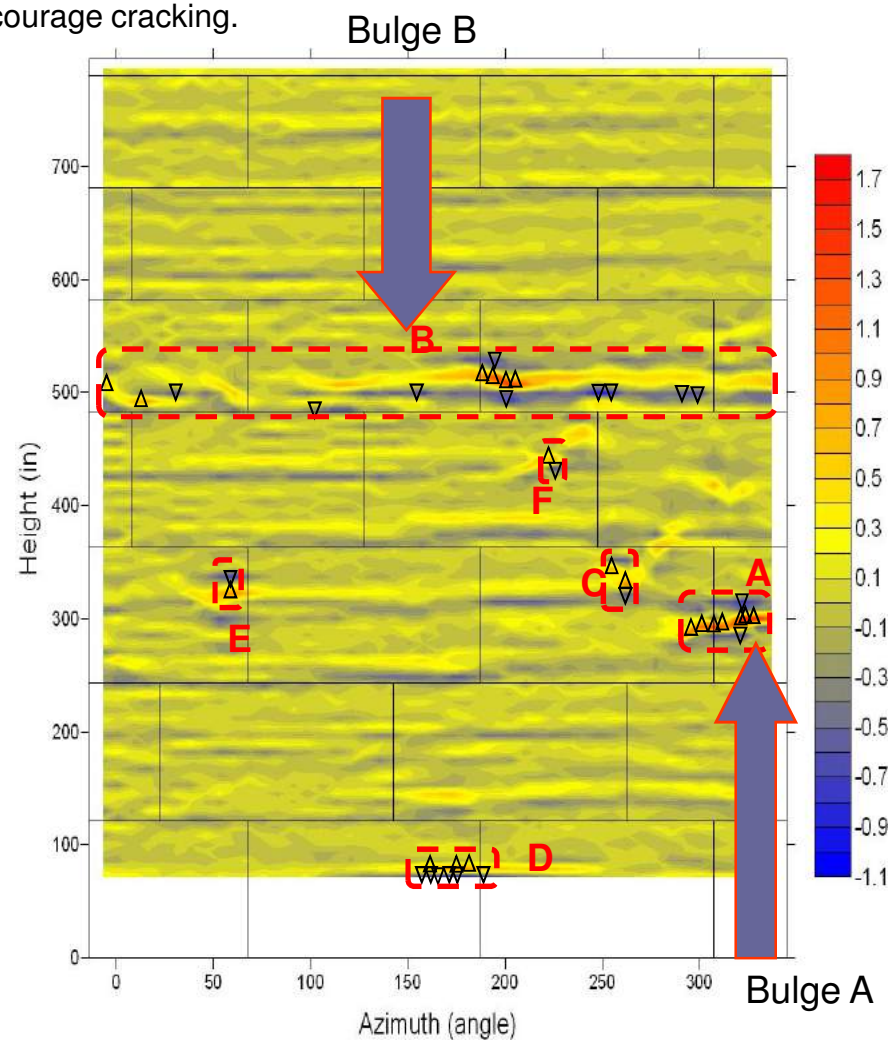
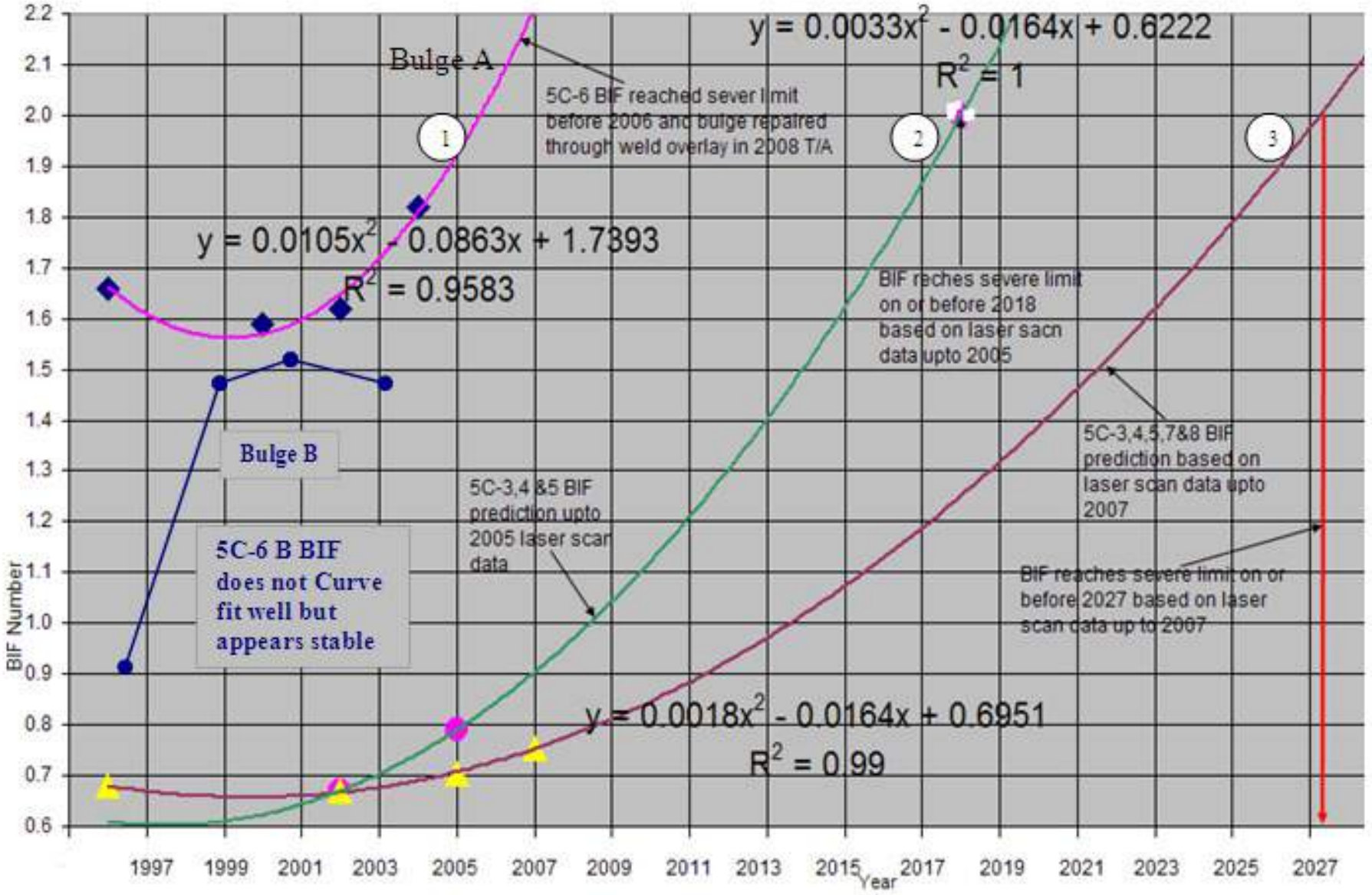
BIF Results

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



BIF Bulge Severity Prediction for likelihood of Cracking



CONCLUSIONS

- Suncor used this technique along with other available tools to make future predictions of drum inspection needs and projected life

- The BIF is used for identifying and ranking the most severe locations on a drum and finding cracks before they go through wall

- Suncor's experience shows that the BIF correlates well with actual cracking history

Questions?

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