

Successful Reversal of Deterioration in an Old Set of Coke Drums

Pierre DuPlessis

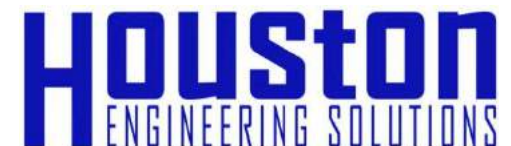
Retired, Suncor Energy

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Overview

- One of the oldest and thinnest sets of coke drums suffered accelerated deterioration, unpredicted cracks, and loss of containment.
- A novel approach to mechanical integrity was successful in transforming drums into a reliable set of vessels.
- As a result, plans to replace drums were canceled and the time between turnarounds is being considered for an increase.
- Results from this set of drums are compared to another set at the same facility that was managed differently.

Equipment Description

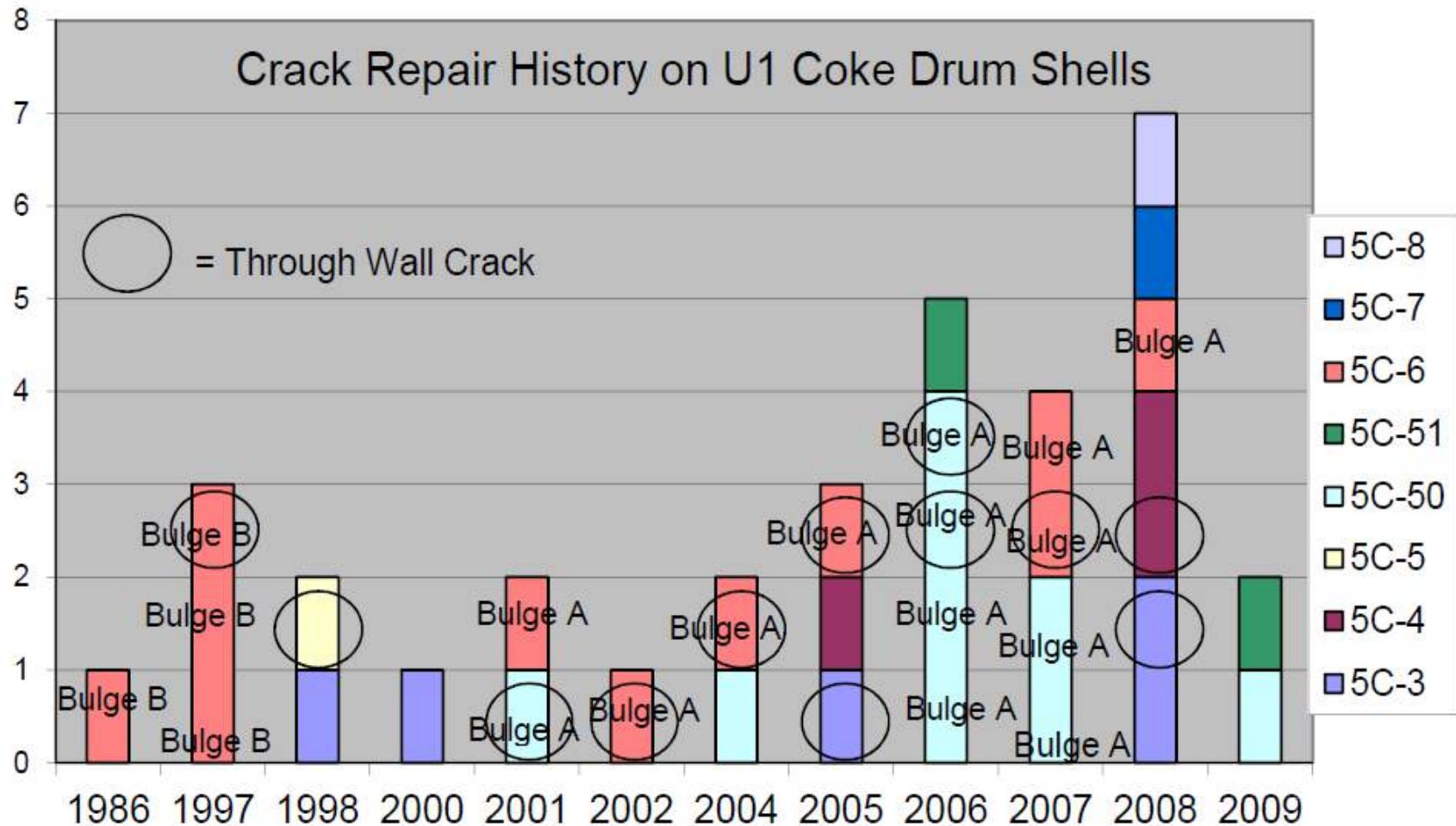
Two upgraders that process oil sand bitumen at the same site in Northern Alberta, Canada.

Set	Age	Inlet	Diameter	Length	Thickness	Material
U1	6 from 1967 and 2 from 1981	bottom	26'	66.5'	0.64" - 1"	C- 1/2Mo, 1Cr
U2	4 from 2001 and 2 from 2008	side - dual	32'	91'	1.41" - 1.89"	1Cr

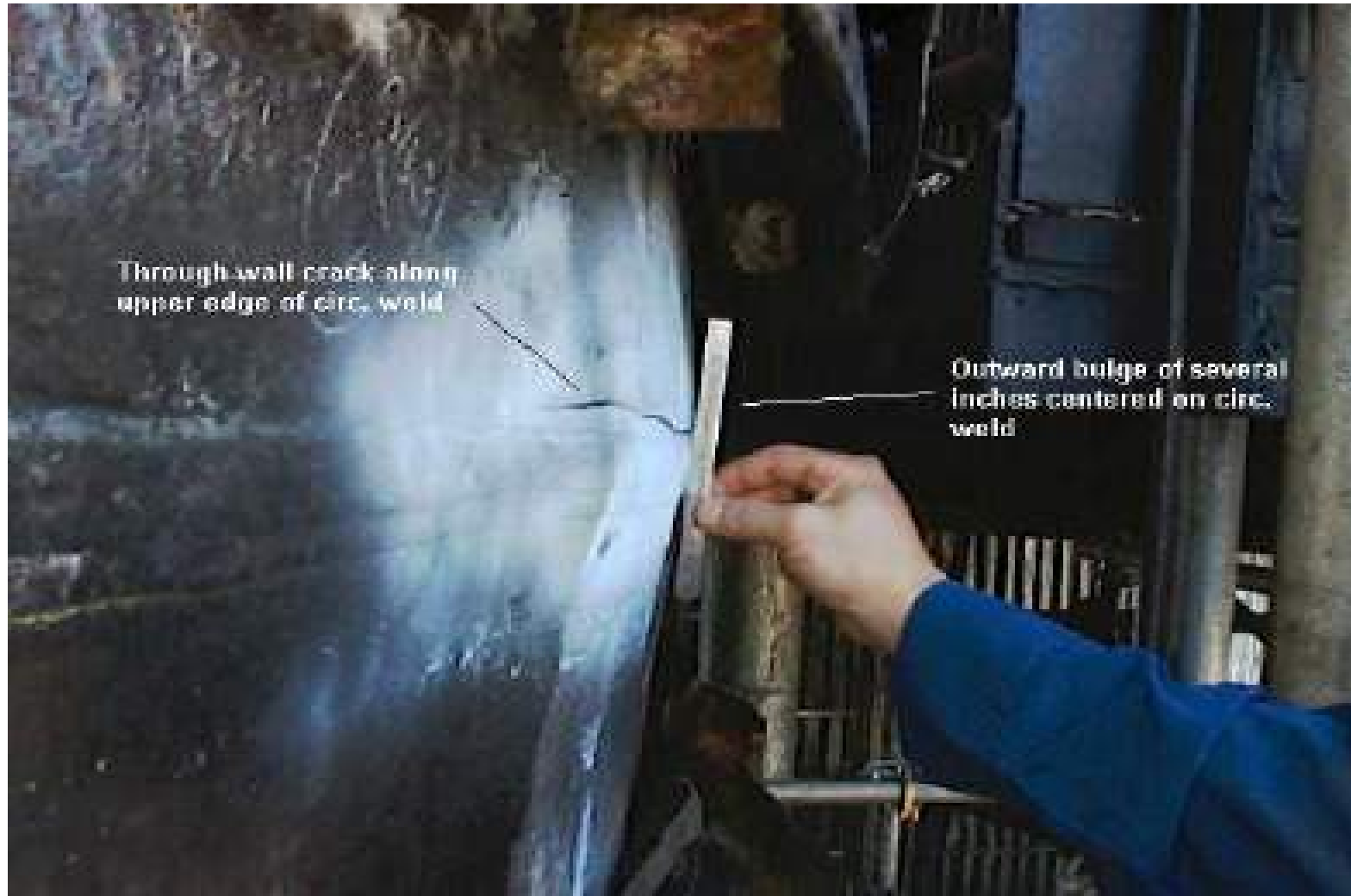
U1 Cokers



Crack Repair History in U1



A Bulge and Through-Wall Crack



Typical Elephant Skin Cracks



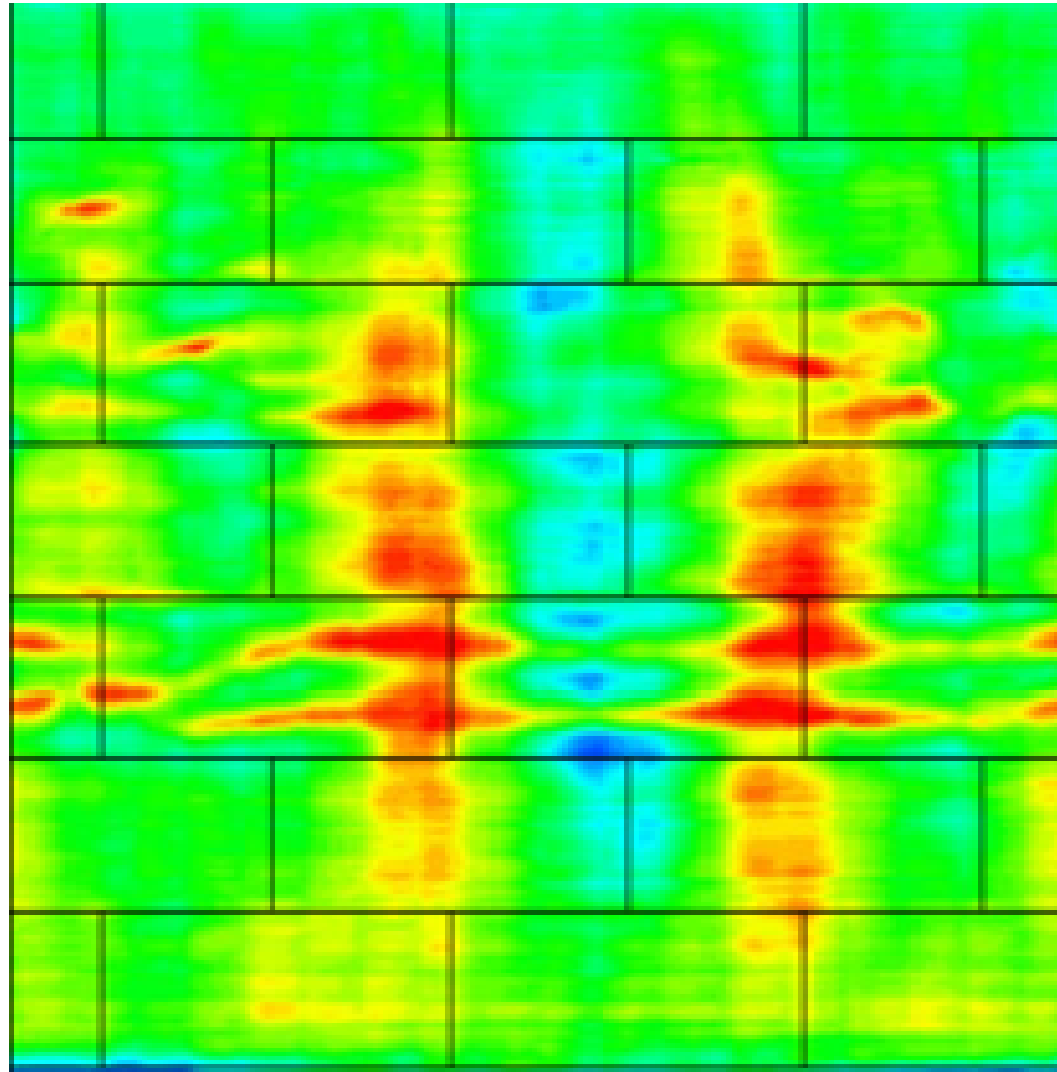
A Leak During Quench



Management Strategy

- The core of new strategy is the understanding that bulging and cracking in coke drums are inevitable and that with the right inspection, assessment, and repair tools, a **systematic proactive** integrity program can extend their economic life virtually indefinitely.
- Every three years, during T/A, all or most drums receive thorough inspections followed by bulging assessment and long-term repairs of areas susceptible to bulging-induced or stress-riser cracking.
- Methods and extent of inspections and repairs are a function of bulging severity and inspection history for each drum.
- A comprehensive mechanical and fatigue test program demonstrated effectiveness of long-term repairs.

Laser Scanning



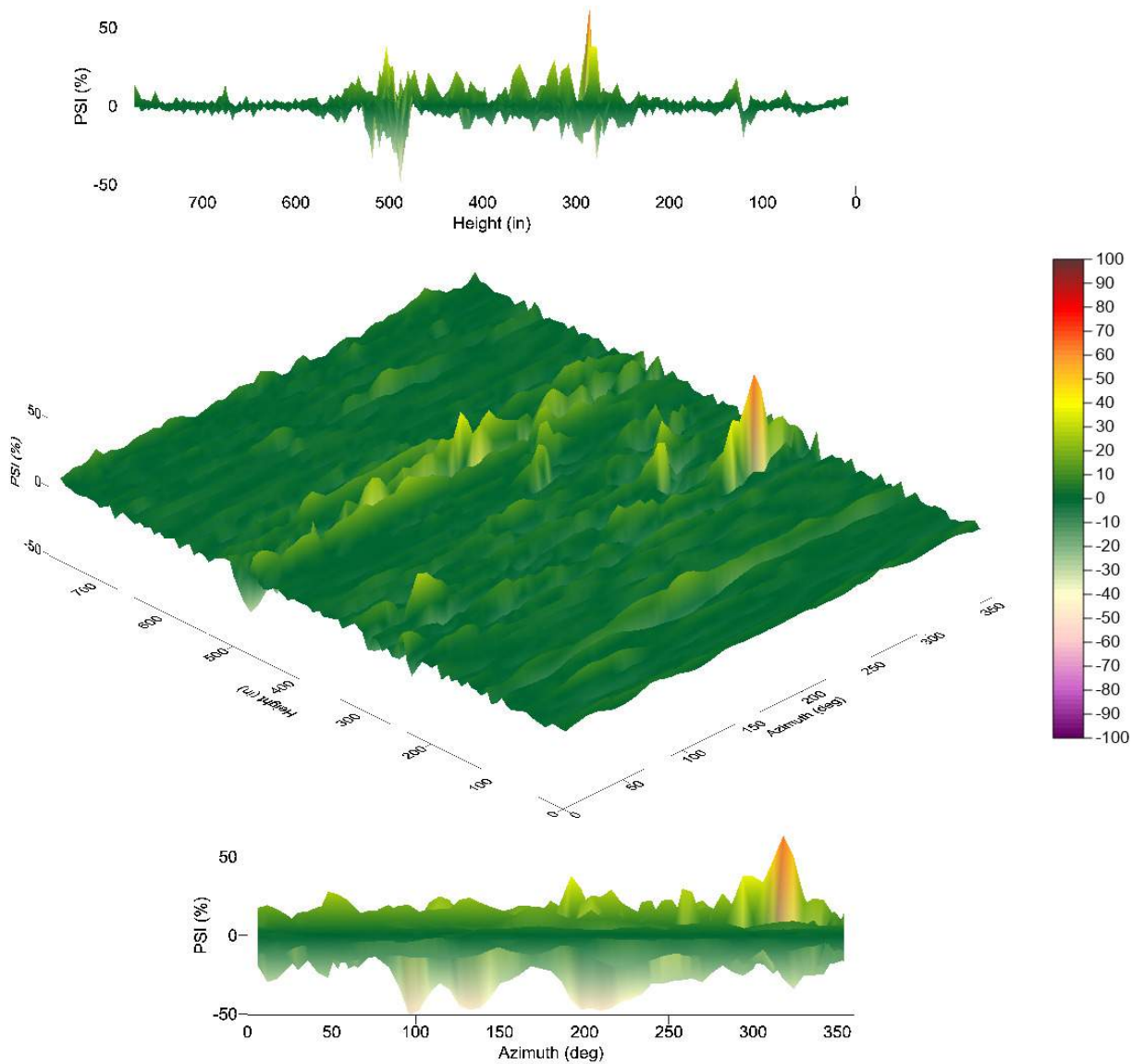
Bulging Assessment

Plastic Strain Index (PSI)TM:

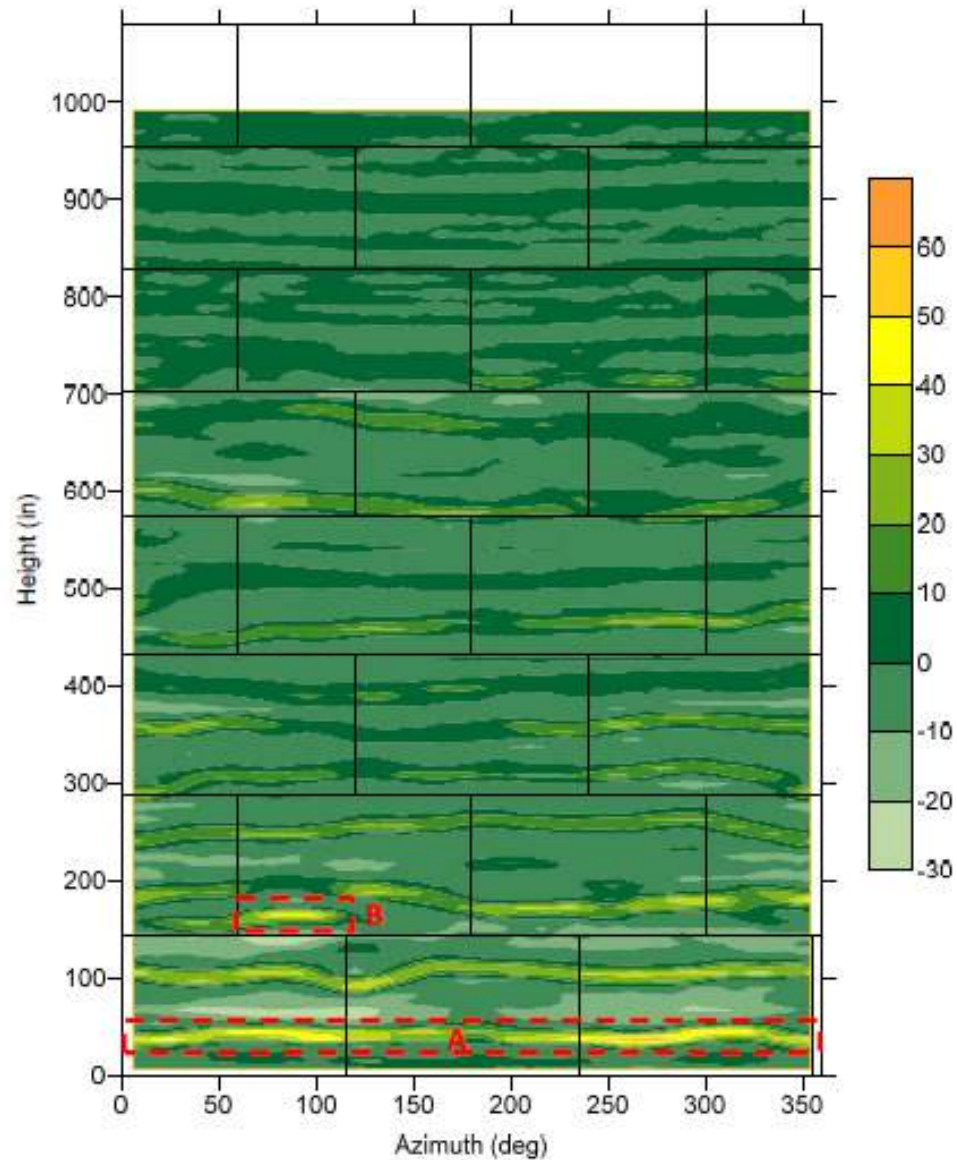
- Ratio of effective plastic strain to failure limit of API 579/ ASME FFS Standard.
- Focuses on primary mode of failure.
- Correlates with observed bulging cracks.

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

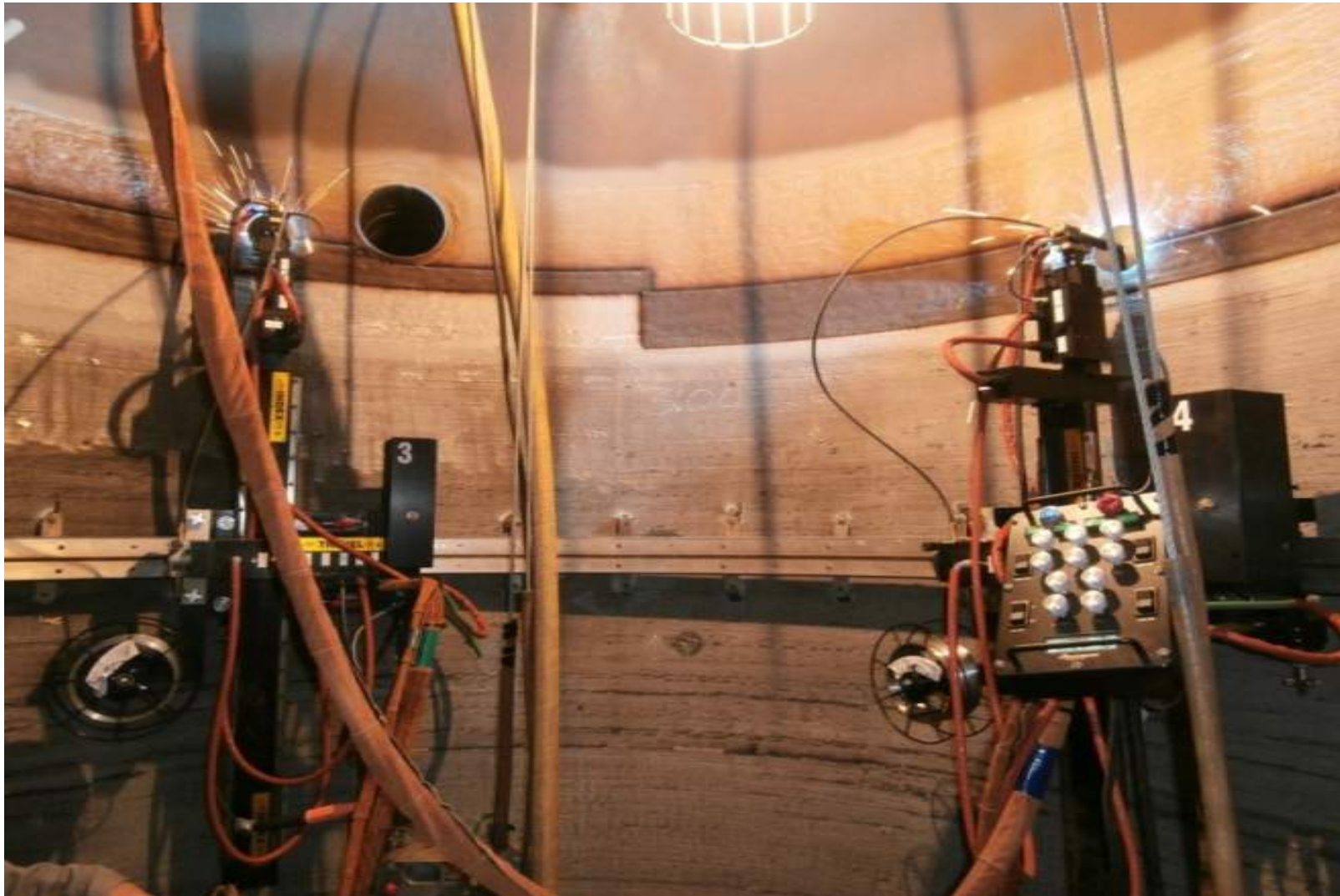
An Example PSI map



Long-Term Repairs



Automated Weld Overlay in Progress

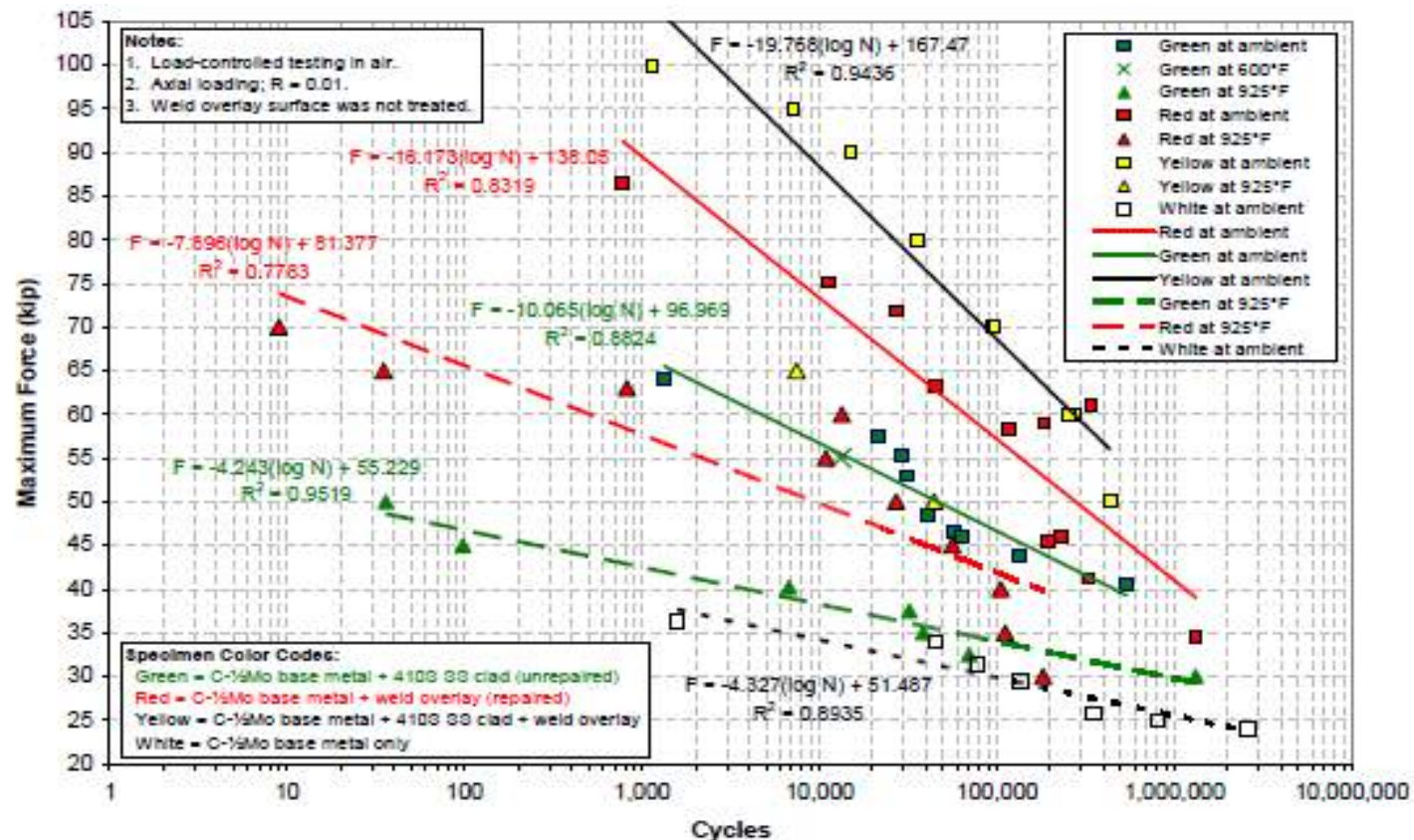


Test Program

- In 2008, a test program was initiated to assess and optimize the performance of engineered weld overlays for long-term repairs of coke drums.
- Utilized a C-1/2Mo plate that was recovered from a retired drum that was in operation for 20 years and Inconel 625 weld overlay.
- Mechanical testing, metallurgical examinations, nondestructive evaluations, and load-controlled fatigue isothermal tests were conducted on:
 - base material + clad (unrepaired condition)
 - base material + weld overlay (repaired condition)
 - base material + clad + weld overlay (proposed unconventional overlay on clad)
 - as-welded overlay
 - retired base metal
- Some key findings:
 - Valuable unpublished properties were obtained for in-service base metal and as-welded Inconel 625 overlay.
 - Impact of weld overlay on fatigue life of test coupons quantified.

Fatigue Test Results

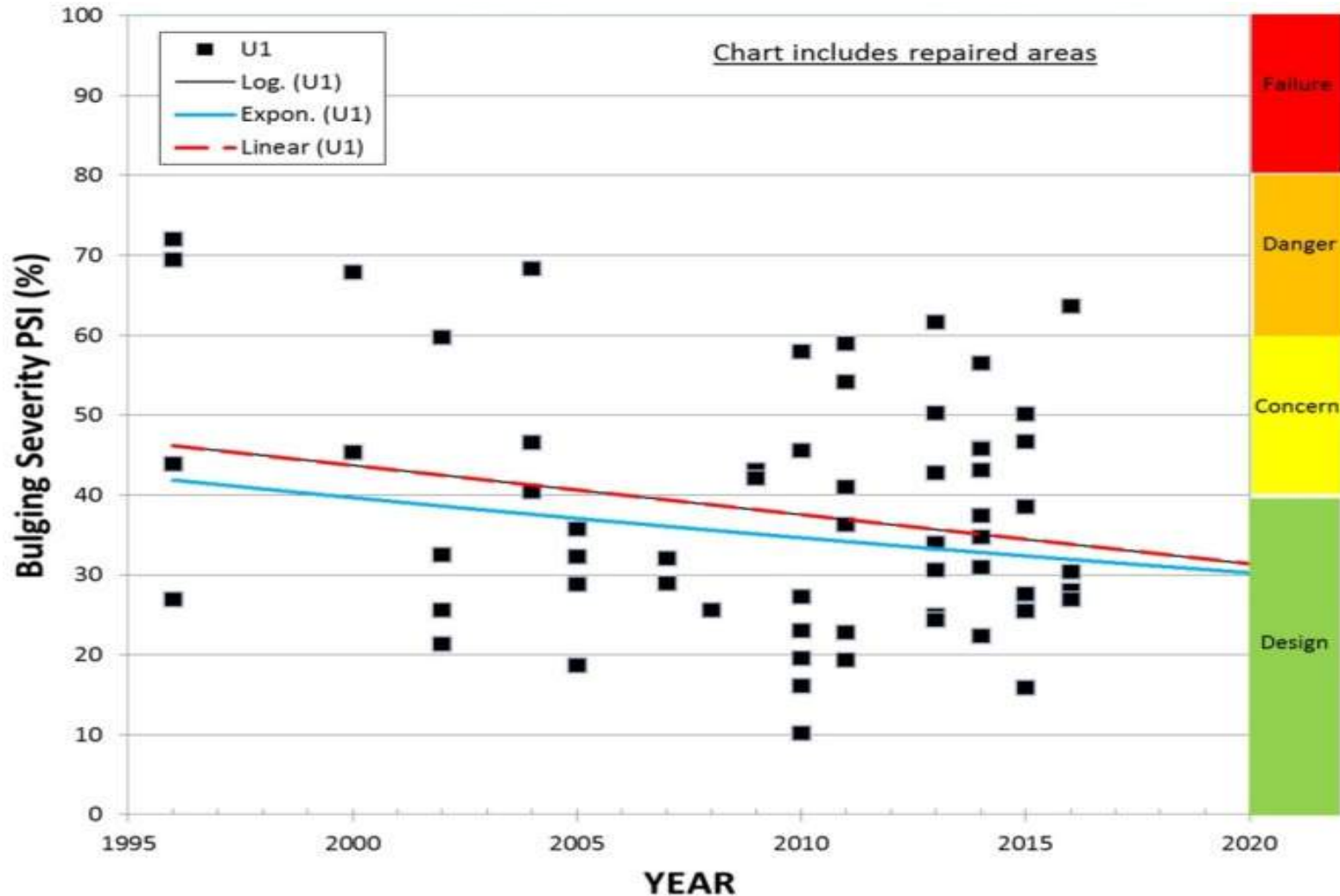
- At constant temperature, standard weld overlay (overlay on base metal) increased fatigue life of test coupons by an order of magnitude.
- Unconventional weld overlay on clad improved fatigue performance even more but, since tests were isothermal, effect of thermal cycling was not examined.



Results of Management Strategy

- Bulging severity in U1 drums has not only stabilized but decreased which is dramatic and unique in industry. Trend for U2 drums, which did not use the same strategy, showed a significant increase in bulging severity over time.
- No cracks in unpredicted areas were found in U1 drums. The few cracks found were mostly non-bulging induced at circumferential seam welds.
- None of the bulges that had been weld-overlaid experienced through-wall cracking.
- Extension of inspection intervals of U1 drums from three to four years is being considered. Combined savings are estimated at \$30 million per year for the four sets of drums.
- Project to replace U1 coke drums was cancelled in 2011.

PSI Trend of U1 Drums



PSI Trend of U2 Drums

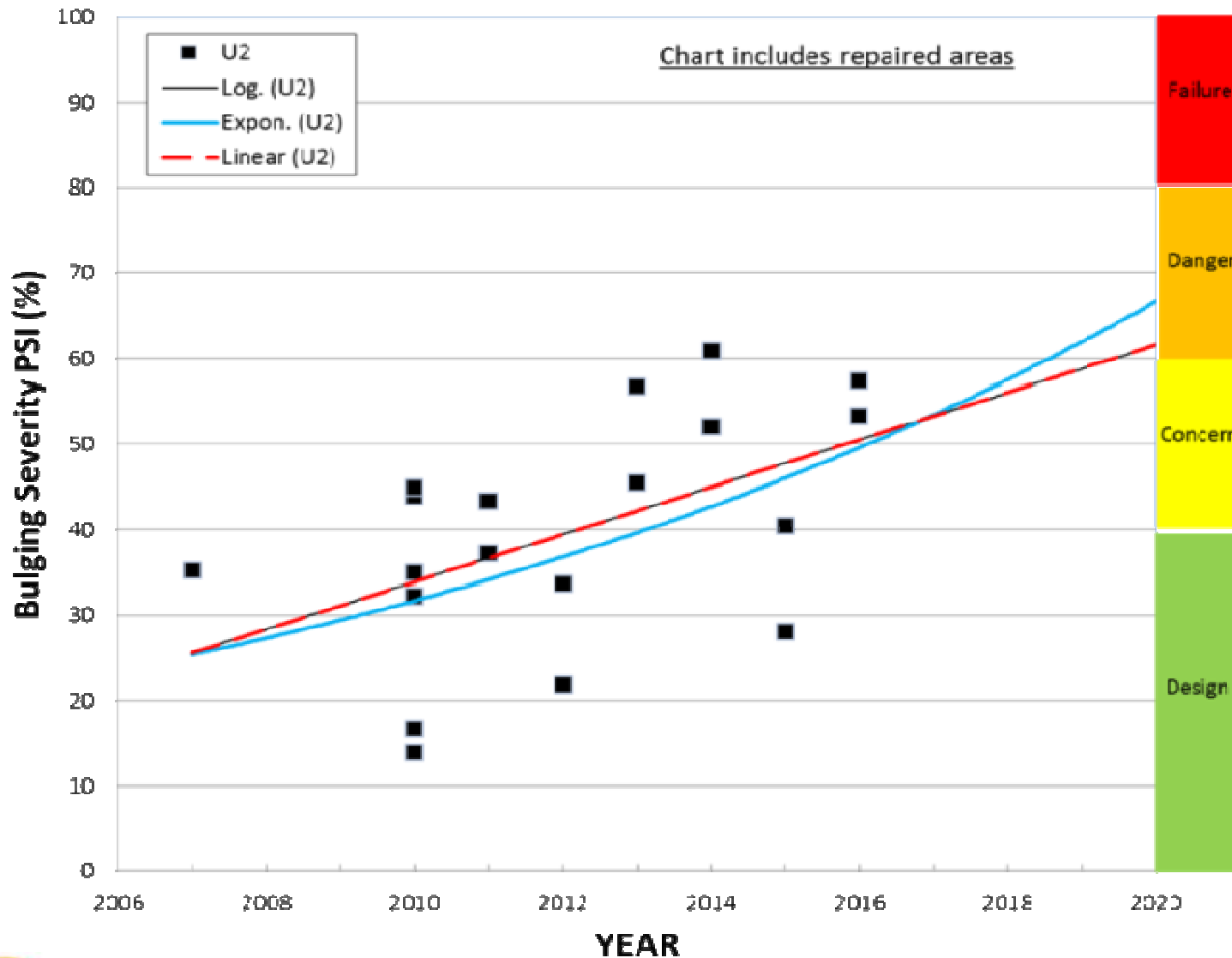


Chart Data Scatter

Data have significant scatter because of the following:

- Not all drums in each set were laser-scanned every time. Initially, only suspected bad actors were scanned. Under the new strategy, all drums are scanned, if possible.
- Not all bulges in all drums were repaired using weld overlay.
- Not all repairs were made at the same time.
- The condition of drums significantly varied. While some drums experienced repeated bulging-induced through-wall cracks, others had none.
- The amount of noise in laser data is dependent on the technology and the inside condition of inspected drum.

Chart Comparison

Comparison between the two drum sets can only be made in a directional manner because of design differences:

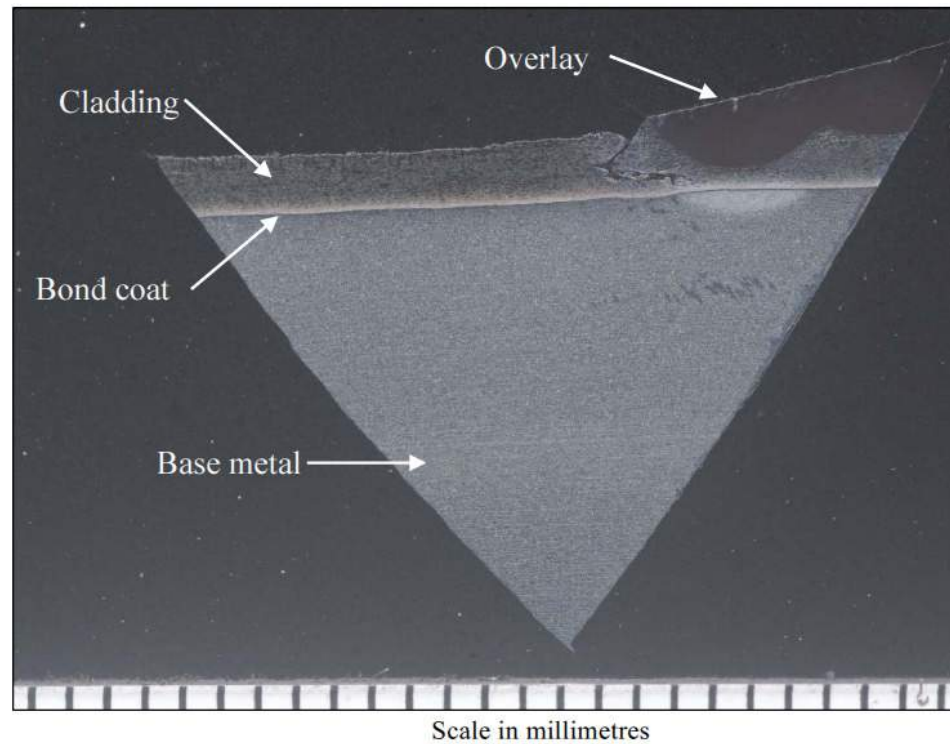
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Implementation Challenges

An uncommon but significant implementation-related challenge have been reported:

- Cracks at poorly-finished toes of weld perimeter.

Efforts to improve the procedures and inspection methods of perimeter transition details and weld surface finish are underway.



Summary

- One of the oldest and thinnest sets of coke drums suffered accelerated deterioration, unpredicted cracks, and loss of containment.
- A new mechanical integrity program was implemented. The core of new strategy is the understanding that bulging and cracking in coke drums are inevitable and that with the right inspection, assessment, and repair tools, a systematic proactive integrity program can extend their economic life virtually indefinitely.
- Every three years, all or most drums receive thorough inspections followed by bulging assessment and long-term repairs of areas susceptible to bulging-induced or stress-riser cracking.
- As a result of the new strategy:
 - Bulging severity has decreased which is dramatic and unique in industry.
 - No cracks in unpredicted areas were found.
 - None of the bulges that had been weld-overlaid experienced through-wall cracking.
 - Extension of inspection intervals from three to four years is being considered.
 - Project to replace these coke drums was cancelled