STATE-OF-THE-ART IMPROVEMENTS IN LIFE EXTENSION AND DESIGN PRACTICES

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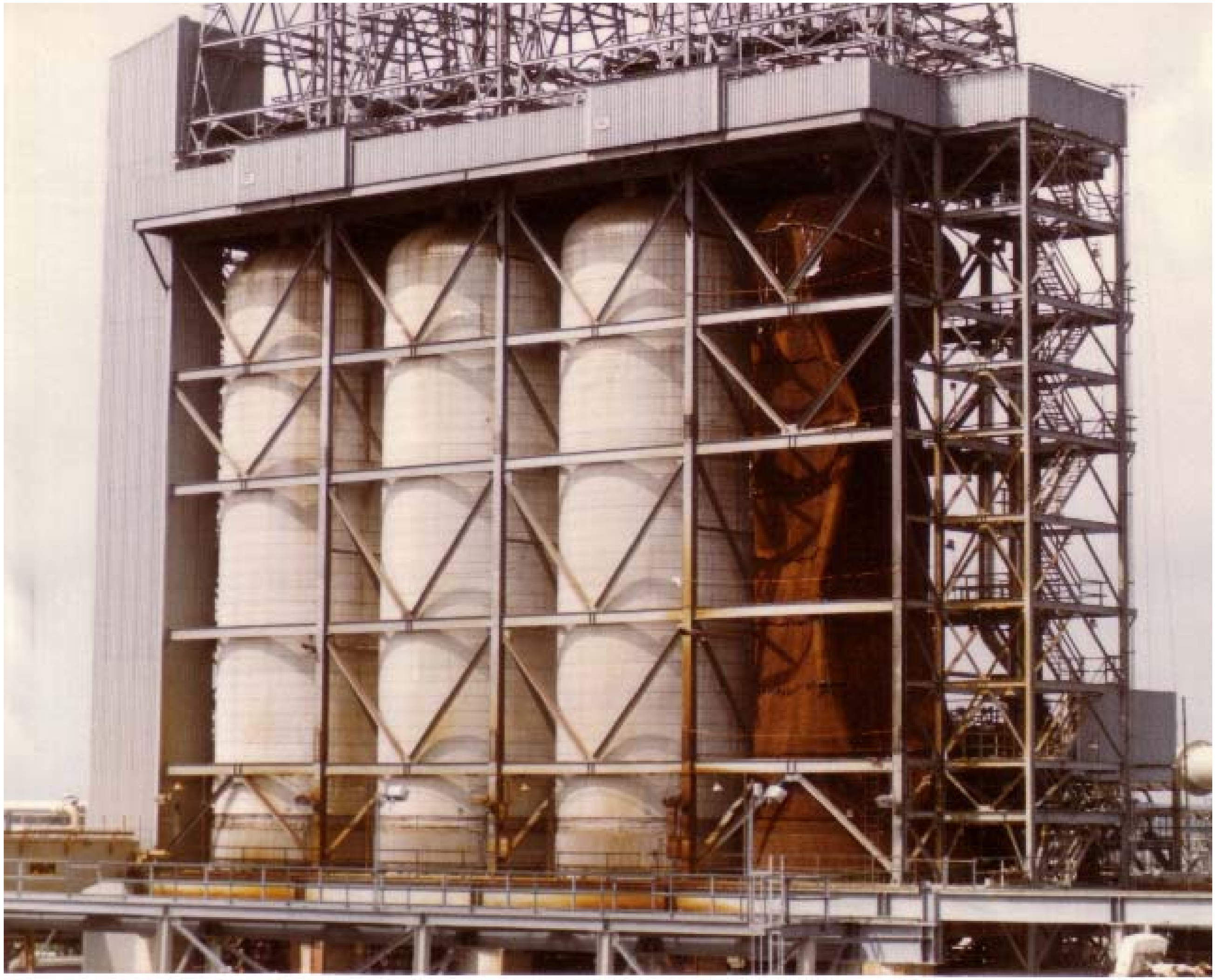
In memory of **Tom Farraro** and his contribution to coke drum technology and his dedication to plant safety

Today's Presentation

- What is a coke drum?
- What causes coke drums to crack?
- Measurement and monitoring of actual coke drum loading and operating conditions?
- Operational Optimization.
- Design considerations for fatigue resistant coke drums using.

Coke Drums



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Some Key Points of the Coking Cycle

Hot vapor fills drum, which grows larger

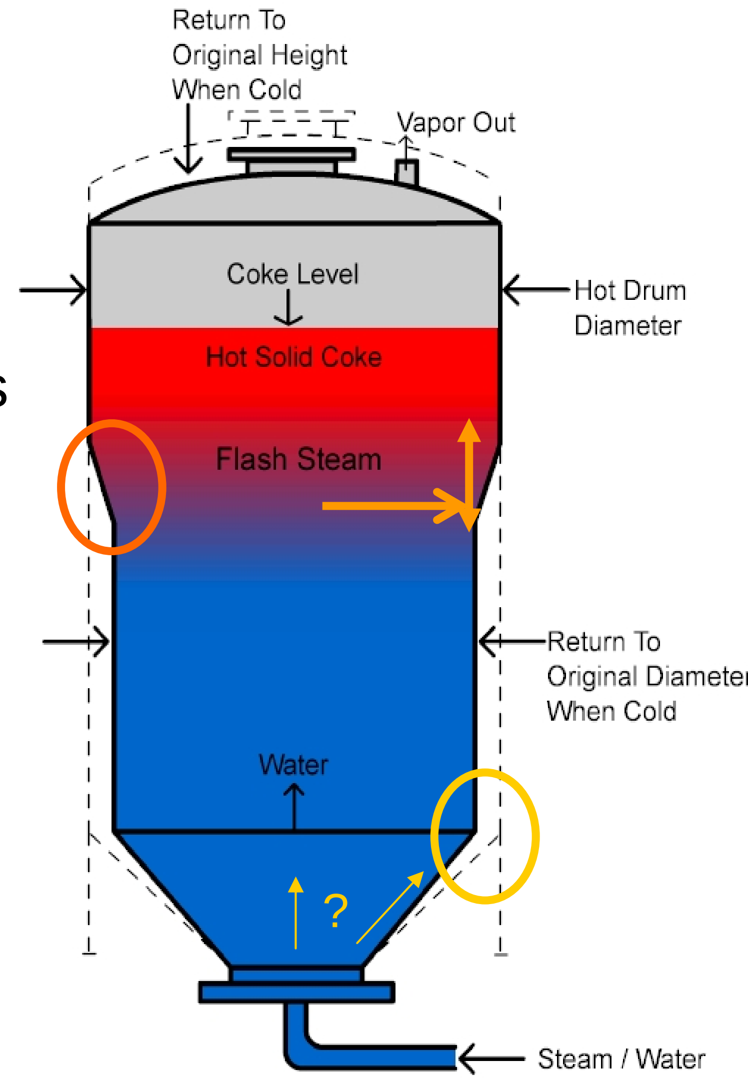
Hot oil (900F) fills the drum and hardens as it cools, cracks and releases vapor

Steam is used to remove volatile vapor

Water enters from bottom to cool the coke bed, becomes steam and flows up the center or outside along the walls

The coke drum contracts in diameter and height as it cools and "crushes" the coke

Eventually water can form and fills the drum



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Coker Fire 2005

Why Coke Drums Crack - Review

- Most **not** designed for low cycle fatigue or the compressive strength of coke, unless requested
- Not designed using “Actual” measured thermal transients or stress ranges from daily operation
- Fabrication practices and QA/QC are more critical
- Now operating on shorter cycles (16-10 hr) and MUCH higher stresses for which they are not designed
  - Stresses on drum and surrounding piping and components are much greater at shorter cycles
- Running different feed stocks, i.e. Mayan, which produce harder coke
- Daily operating practices are inconsistent, which can cause significant damage

Why, Where, How, and When do Coke Drums Crack

- **Why ?**
  - Fabrication defects
  - Low Cycle Fatigue from thermal transients
  - Crushing of the coke causes high stresses
  - Thermal Transients are becoming more Severe as cycle time is decreased
  - Design details, materials, and weld procedures not adequate
  - Long term exposure to high temperature : Embrittlement
- **Where ?**
  - Circumference seams in shell
  - Skirt attachments
  - Nozzles (and repads)
  - Miscellaneous attachments (rings, lugs)
  - Bulge Peaks and Valleys

Coke Drum Failed During Quench After Repair

Coke Drum Failed During Fill

Drums are affected by:

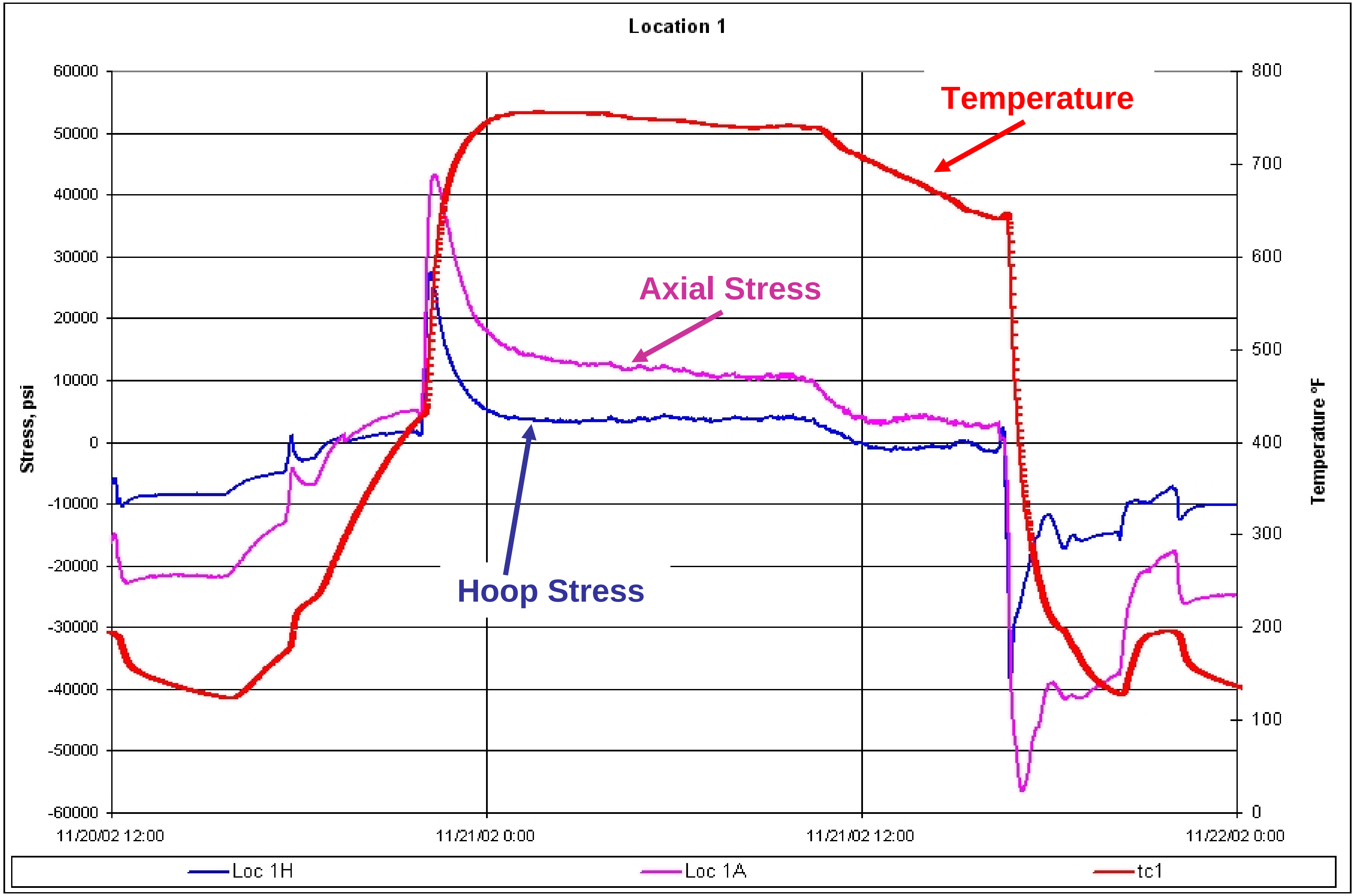
1. Switch temperature (skirt)
2. Quench procedures (shell)
   - Steam and Water amounts and rates
   - From the top or bottom? Top is bad!
   - Anti-foam can act like a quench
   - Bug water
3. Feedstock changes affect coke hardness
4. Cycle time changes, shorter is worse!
5. Consistency of operation
6. Human factors

What is Health Monitoring?

- Instrumentation much like your process instrumentation but using strain gages and thermocouples to measure and control “actual” drum damage
- Measures “actual” drum response (stress range) to daily cycling, temperatures and strains
- Calculates fatigue damage per cycle
- Calculates time to through wall crack based on actual stress range
- Compare response from one operating scenario versus another so adjustments can be made to reduce high stress events, i.e. optimization
- Used like a speedometer to measure how fast drum life is being used up by cycling

High Temperature Strain Gage Locations at Bulge

A Cycle For In-Line Skirt Response



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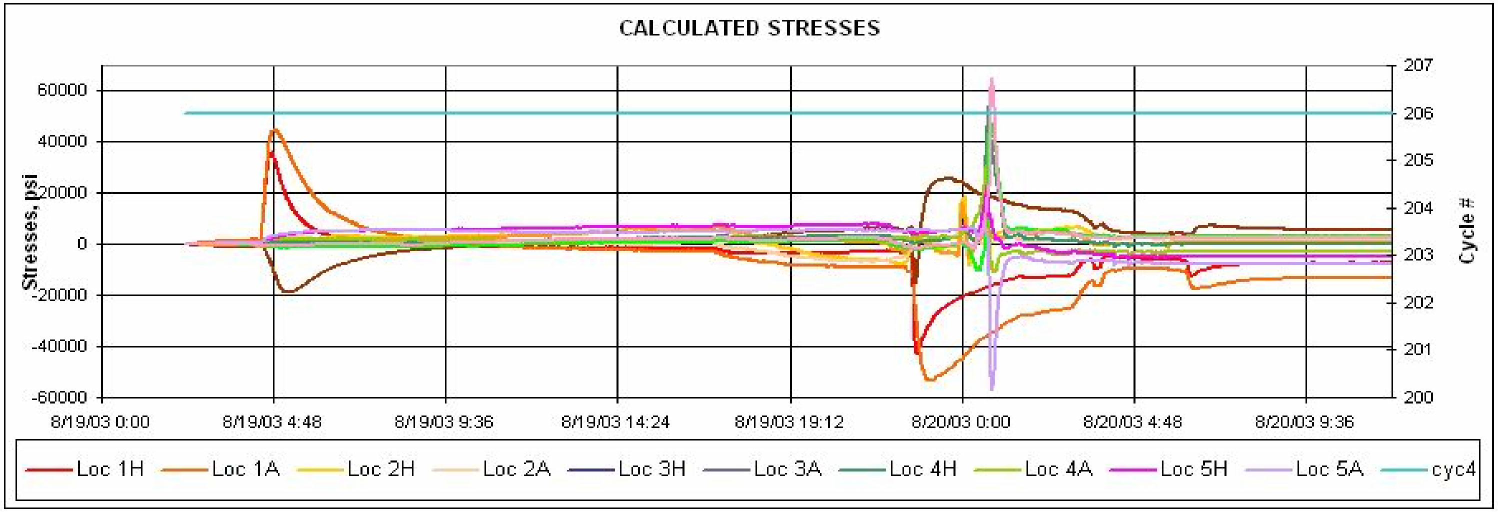
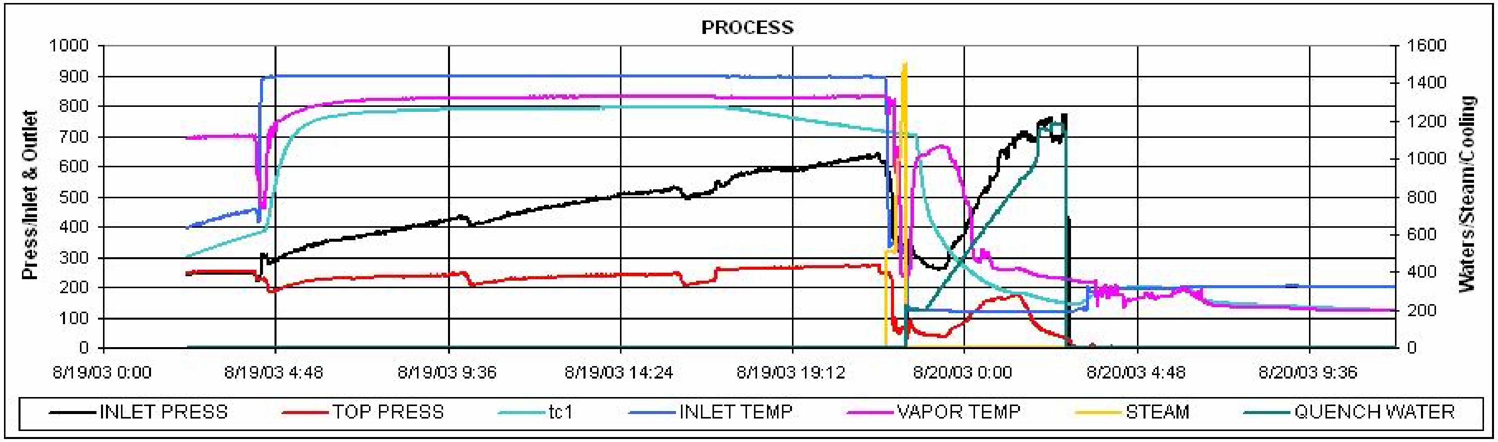
Fill and Quench Transients Overlaid with Process Information





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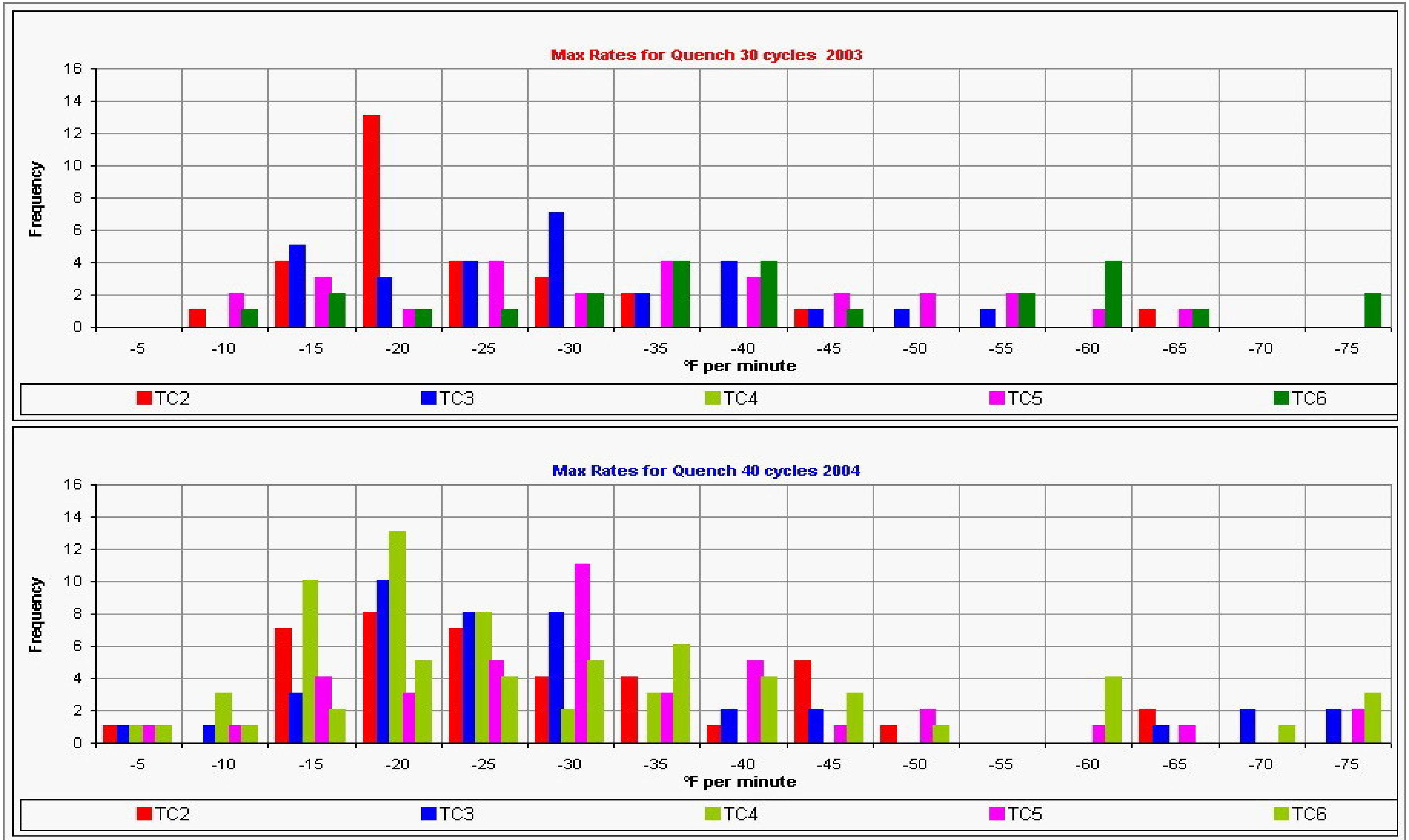
Histogram of Heating and Cooling Rates



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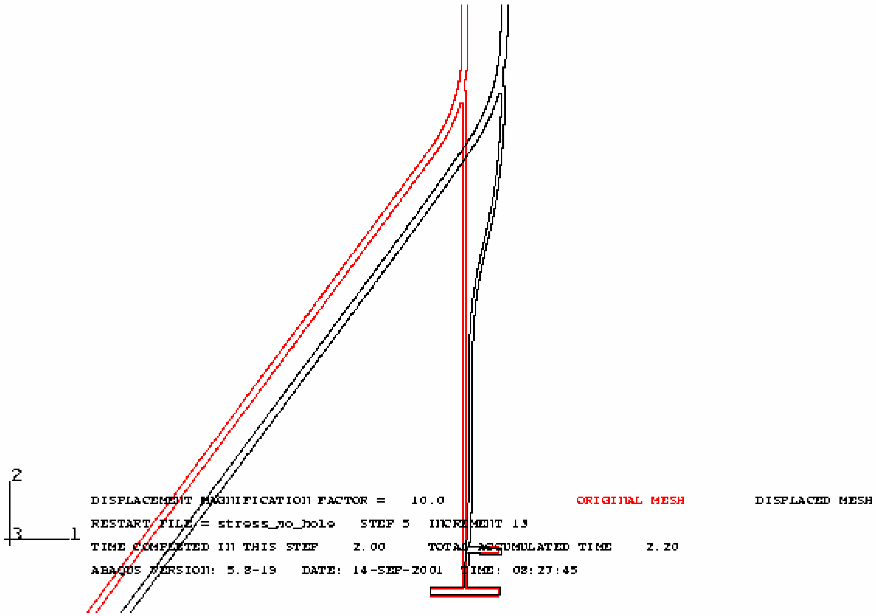
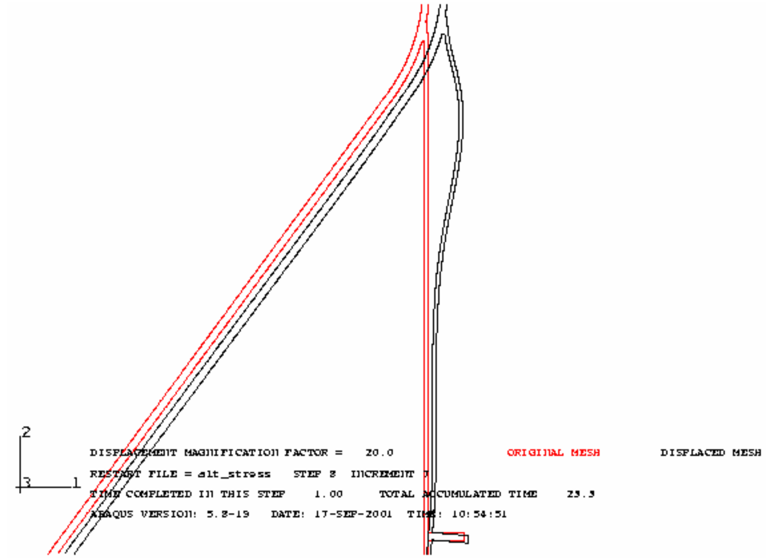
Skirt is Pushed and then gets Pulled by Knuckle

DISPLACED SHAPE AT THE END OF FILL

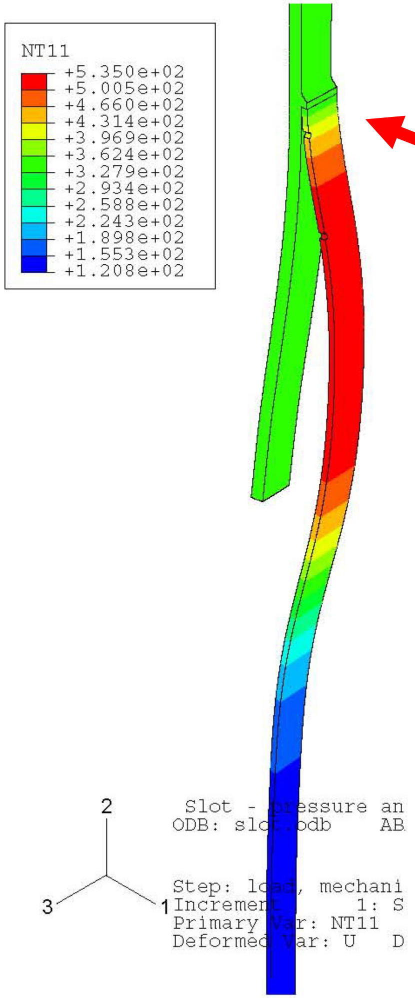




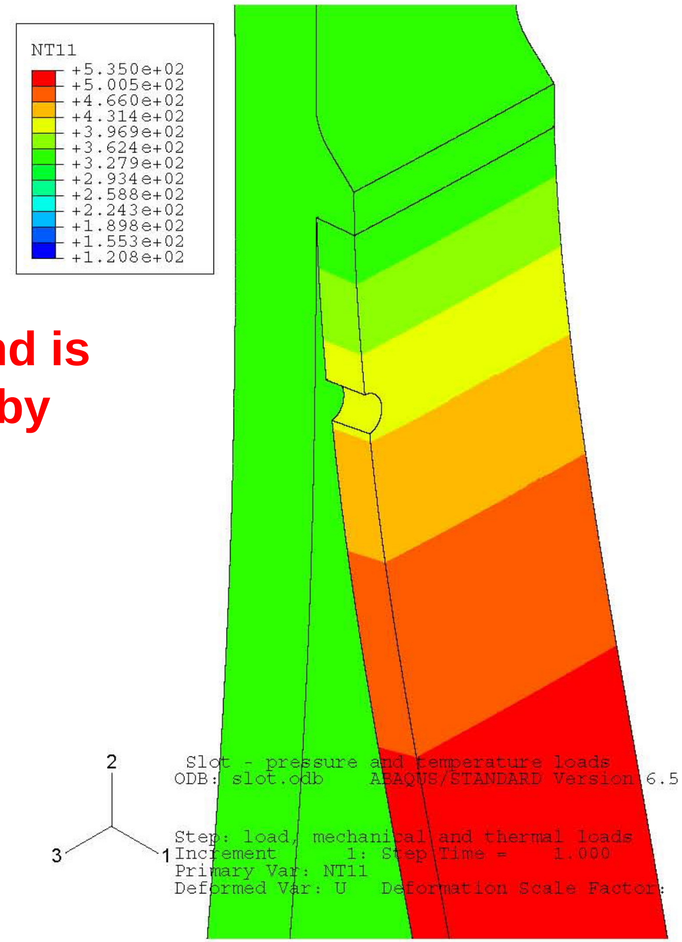
DISPLACED SHAPE 1 HOUR INTO QUENCH

(MAXIMUM STRESS DURING QUENCH OCCURS HERE)

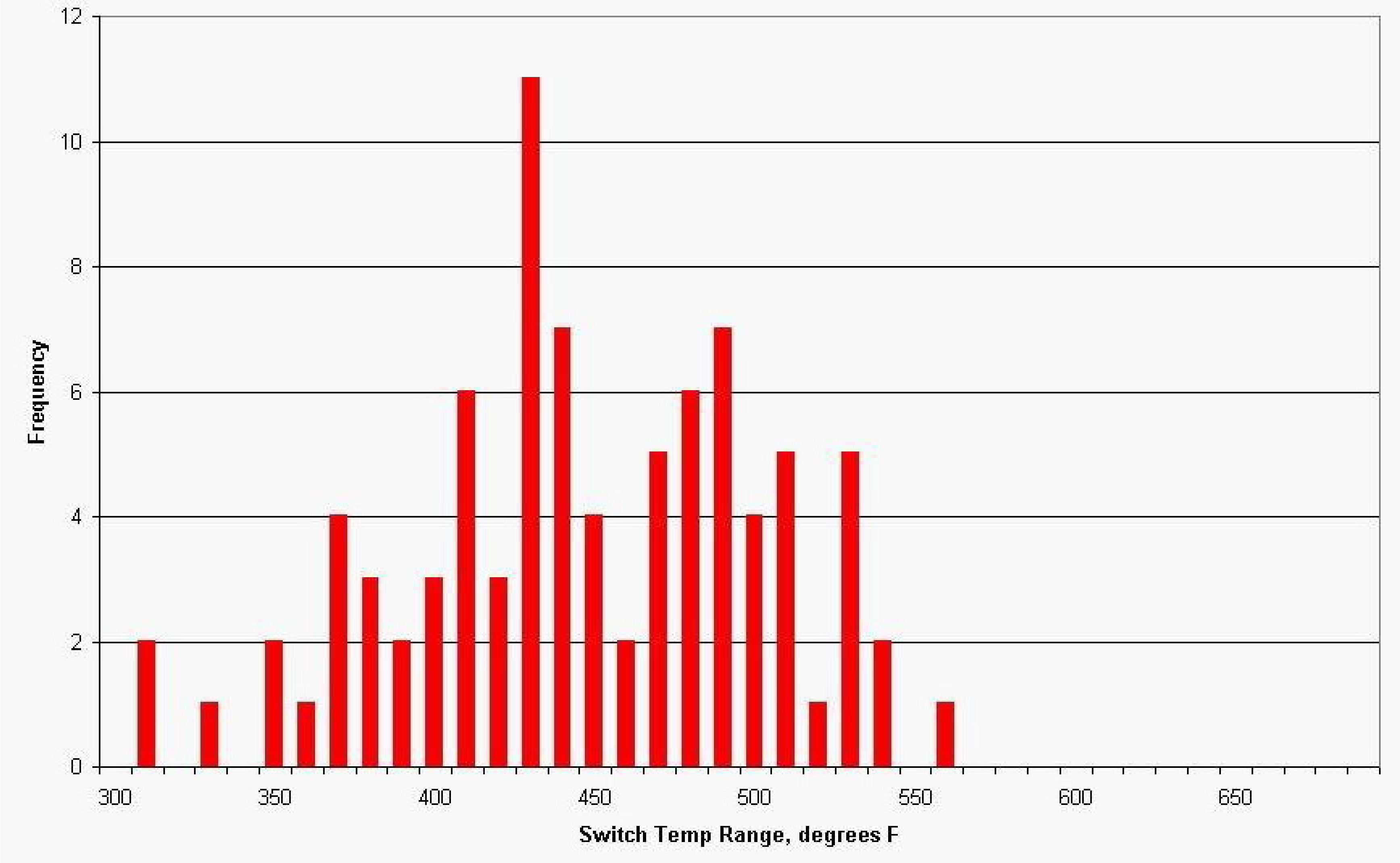
3D Model Temperature During Quench



Hot Ring is Thermally Expanded and is Pulled Back by Skirt



Histogram of Skirt Switch Temperatures



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Cracked Skirt to Shell weld 4 Drums– 1369 Cycles or about 5 Years (SES Predicted 1228 Cycles)

- •Design (by others) predicted 152 years
- •SES Transient analysis performed prior to T/A
- •Maximum stress intensity range during transient = 143,430 psi
- • Using ASME code Section VIII Division 2 fatigue design Table 5-110.1, UTS < 80 ksi, a fatigue life of 1228 cycles was obtained.

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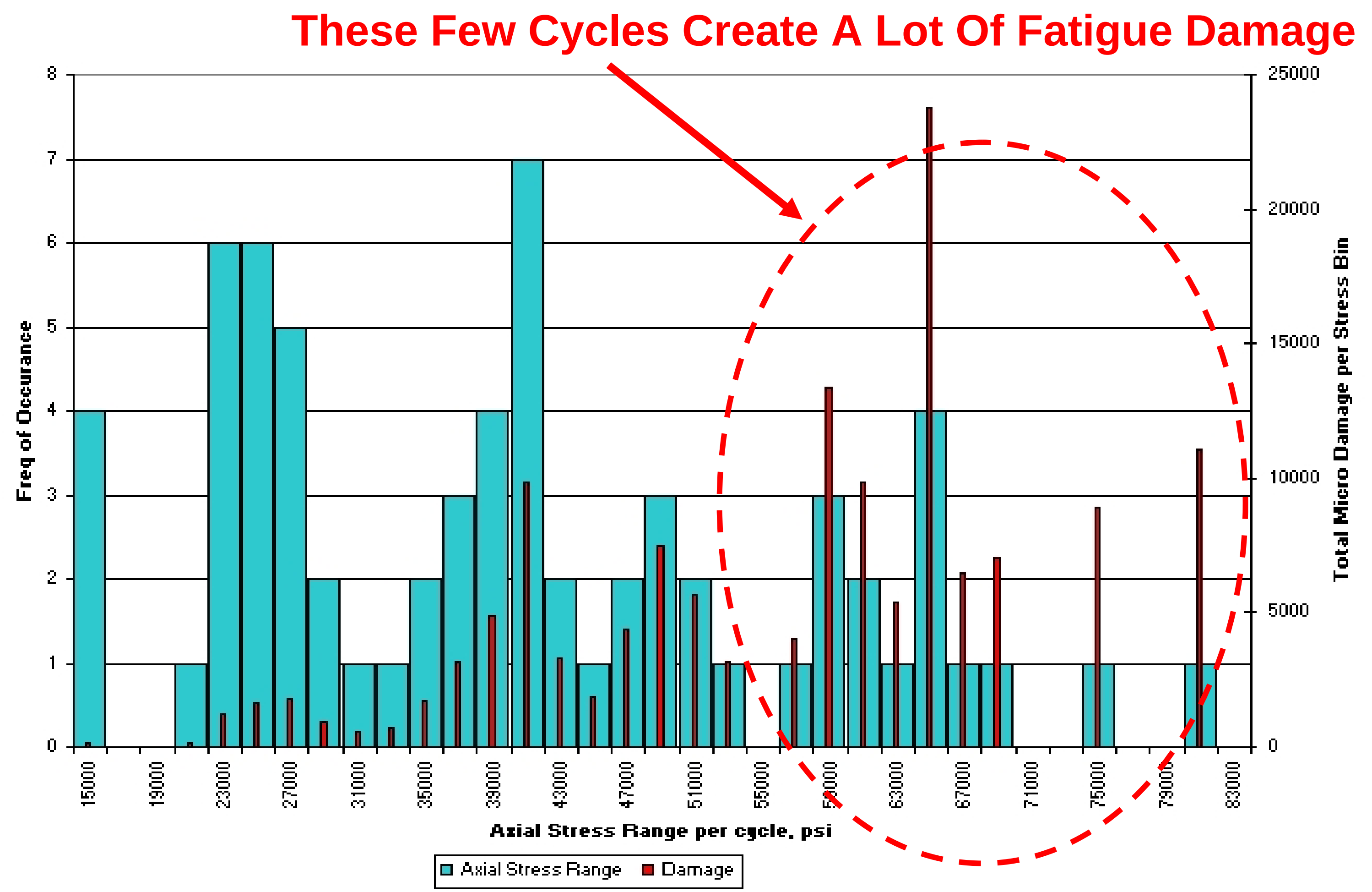
Histogram of Stress Ranges and Fatigue Damage



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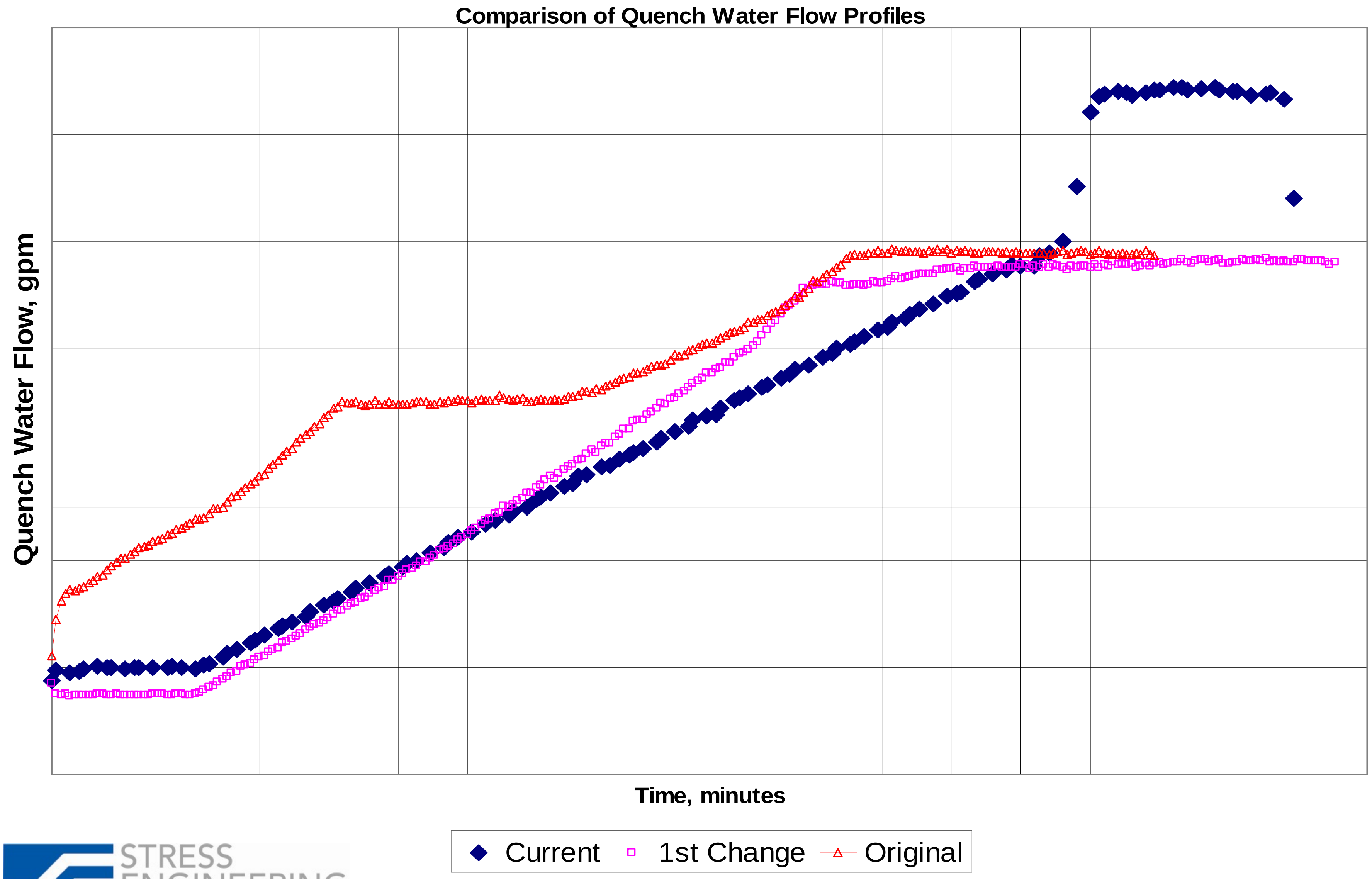
Drum Quenching Modifications Example



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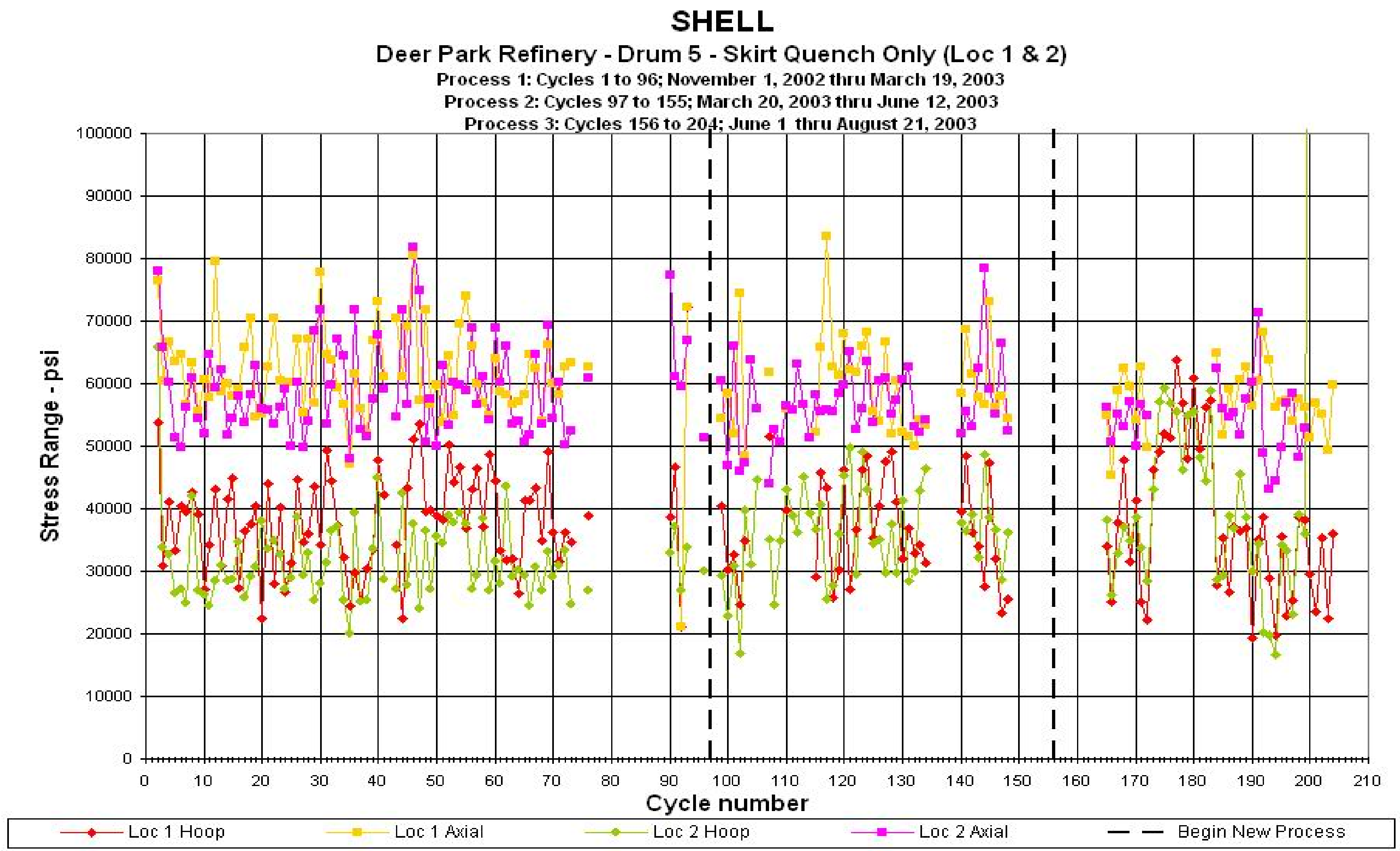

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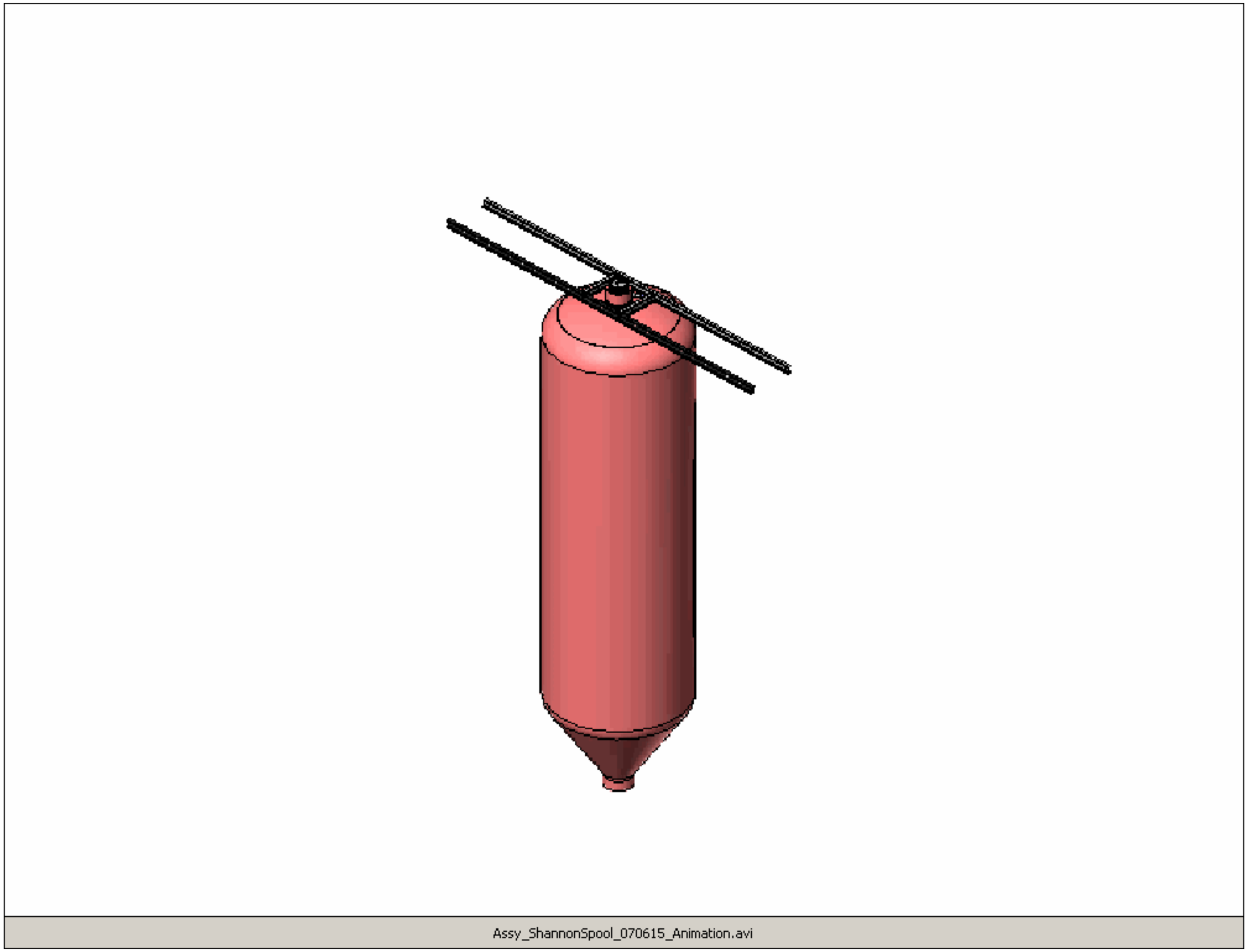
Lessons Learned from recent SES Optimization projects

- Monitoring and optimizing early in drum life gives a better opportunity to increase life
- Severe quenching will increase drum damage
- Inconsistent quenching will increase drum damage
- Higher heater outlet temperatures may mean harder coke and higher damage
- Feedstock will influence type of coke produced and hardness, thus damage to drums
- Reductions in in cycle time by 2 hours has increased fatigue damage by more than 30%

SES Coke Drum Experience

- SES has installed 20+ “HMS” on > 50 drums since 1999 and monitored more than 5000 cycles
- SES has carried out Acoustic Emission tests, new and in-service, for > 60 coke drums
- Fatigue analysis of several DeltaValve installations
- Assessment of structures and piping systems
- Monitoring and analysis of blow-down lines
- Bulge Assessment using “BIF” to prioritize which bulges will crack first
- **SES is presently designing more than 30 coke drums using our fatigue resistant design approach**


Assy_ShannonSpool_070615_Animation.avi

Why are there more problems now?

- Drum cycles are shorter (24 down to 12 hour cycles)
  - Lower switch in temperature
  - Heat and cool faster high thermal transients
  - Production value is greater = expensive outage
- Fabrication practices and defects
- Cladding can initiate cracks in base metal
- 1 1/4 Cr alloys become brittle with age
- Feedstock changes more often, quality and hardness issues
- Graduated wall thickness drums crack within 4-7 years
- Thinner drums bulge more and crack more

Economic Comparison of Shell Design Options

Design	Typical Time Through	To First Wall Crack	Total Life Cycle Cost (25 yrs.)
	Cycles	Years	
Classic Design	2000-3000	**5 - 8**	$9MM – $14MM
Fatigue Resistant Design	7000-9000	**20 - 25**	$6MM - $7MM

Summary How to Improve Your Drum Design

- Request a Fatigue Resistant Design
  - *Ask for it*

- Use Actual Transient Loads for Design Loading Calculations
- High Yield Strength Plate Material (2 ¼ Chrome is stronger and less brittle as it ages)
  - Slows down bulge formation
- High Quality Welding in Shell and Skirt
  - No Defects
  - No Weld Caps
- Uniform Plate Thickness Top to Bottom
  - No Transitions
  - No Stress Concentrations
- Fatigue Resistant Skirt Design

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