Fast quench problems and how they damage coke drums

Coke Drum Reliability Workshop

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Classic Drum Deformation For Low Alloy Drums

Weil and Murphy (Kellogg 1960, ASME)

- Permanent deformation pattern of vessels in cyclic service
- Skirt is attached to the cylinder by welding

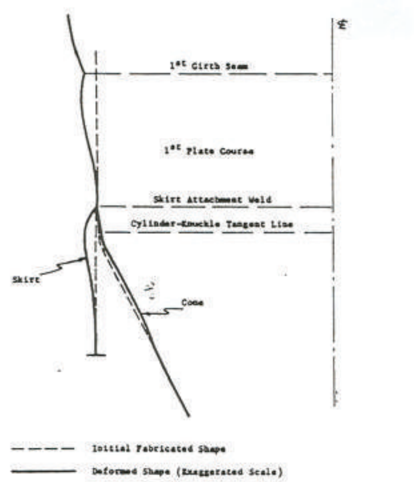


Fig. 7 Deformation pattern of vessels in heavily cyclic service

Typical* Butt Weld Detail

- Welds fail from Low Cycle Fatigue
- Crack initiates often at edges of weld cap interface to clad
- Crack grows through base metal to leak hot oil in Circ crack

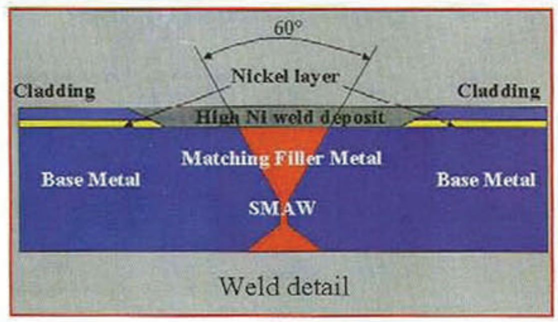
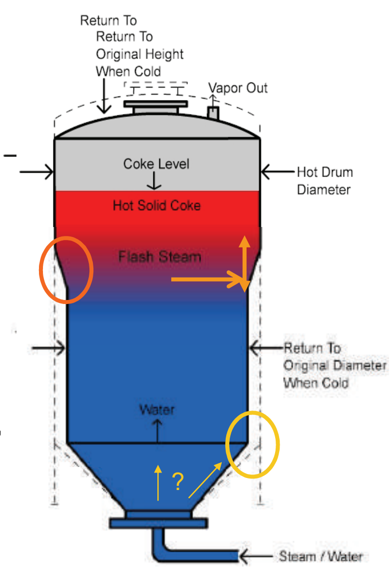


Fig. 3 — A typical weld detail.

*** Joint detail may vary**

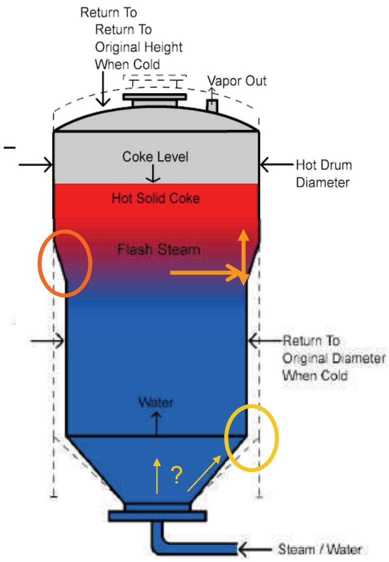
Some Key Points of the Coking Cycle

- The drum grows larger and taller when it is hot
- It is filled with a lot of hard material as the hydrocarbon cracks and releases vapor
- Some cokes will bond to the wall, and flow channels develop within the coke bed
- Hot oil is stopped (diverted to other drum)
- 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 shrinks in diameter and height as it cools
- Eventually water can form and fills the drum
- *Which way does the water go?*



Discussion of the Flows during the Coking Cycle

- Traditional Analysis methods assume a uniform average flow of water upwards to remove heat from coke bed and shell at same time
- Coke bed formation determines path of least resistance for water flow
  - Flow channel area and friction
    - Plugging and channel collapse
  - Permeability
  - Porosity
  - Collapse strength of coke matrix
- Temperature measurements suggest fast quench with flow near wall is common
- This creates greater stress in **shell/cladding bond** and **skirt weld**
- This increases likelihood that hot zones remain in coke after quench



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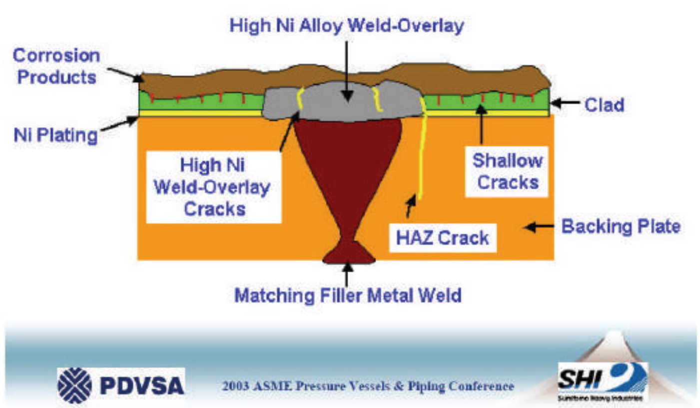
Problem Circ Weld Seam* Cracking Is Common

4. Crack Initiation and Propagation



* Joint detail may vary

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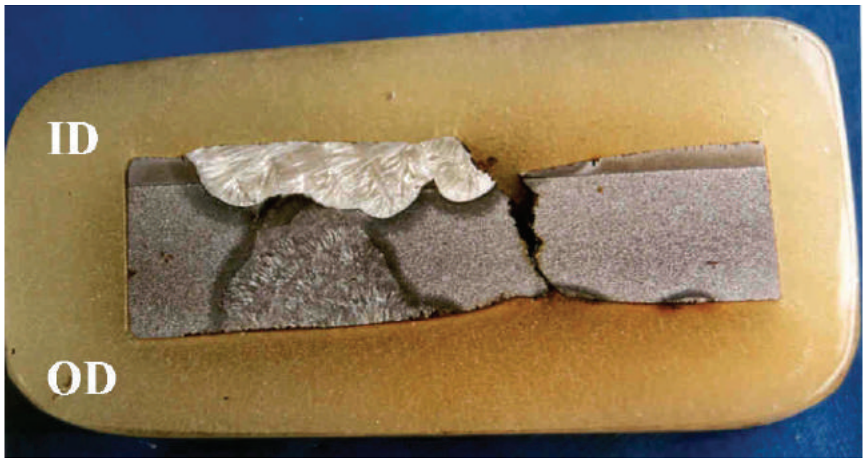
Cracking from ID at Weld Cap to Clad Junction



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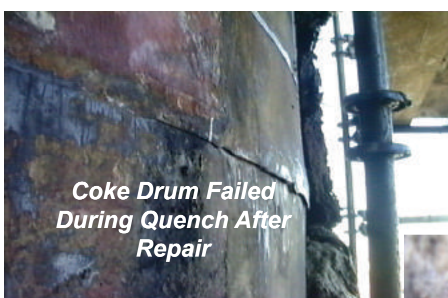
Drum Cracking Examples



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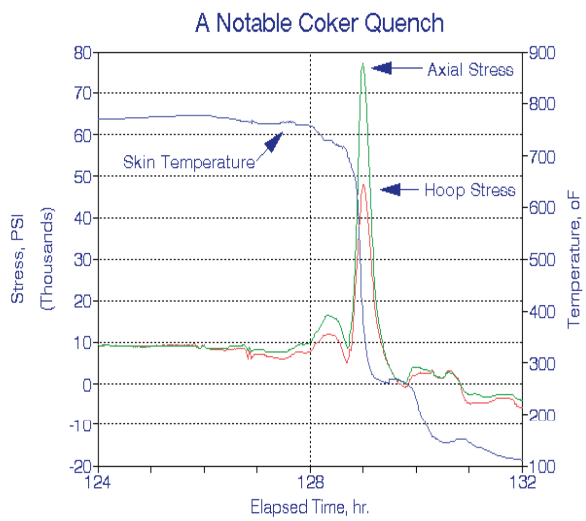
A NOTABLE QUENCH STRESS MEASURED ON SHELL O.D.



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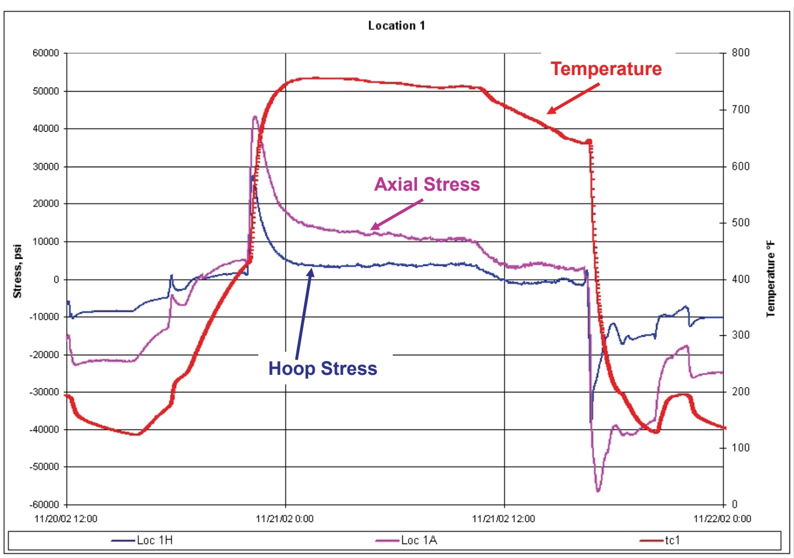
A Measured Cycle For In-Line Skirt Stress Response (OD)



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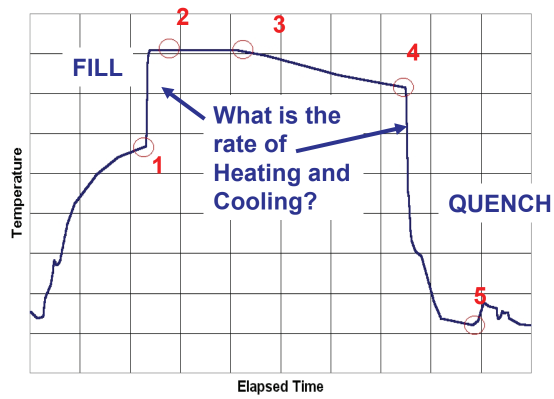
Skirt FE Analysis based on Measured Transients

Some Key points to describe the transient

1. Switch-In after Prewarm
2. Max temperature during Filling
3. Begin to cool from Coke Insulation Build-up
4. Begin Quench after Switch-Out and Steam Purge
5. Open drum, remove water and begin drilling



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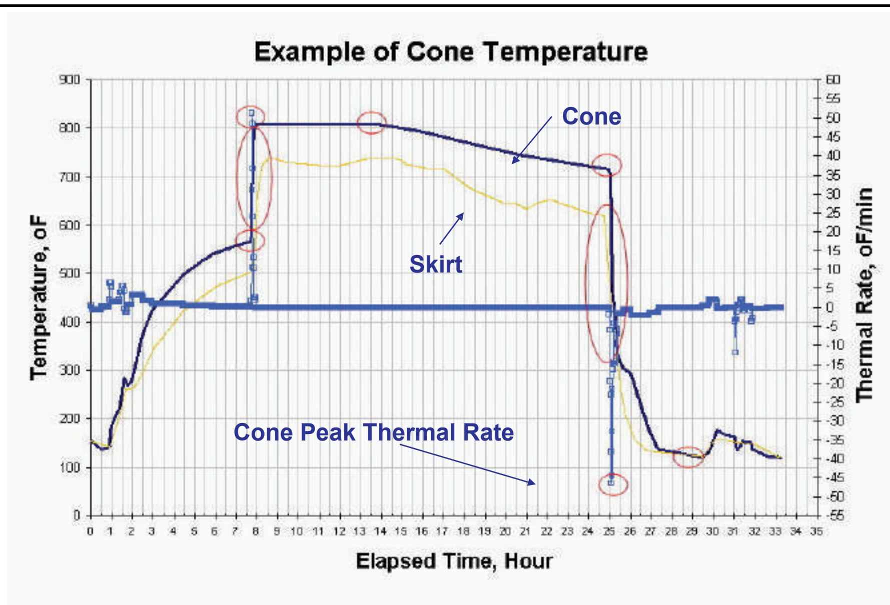

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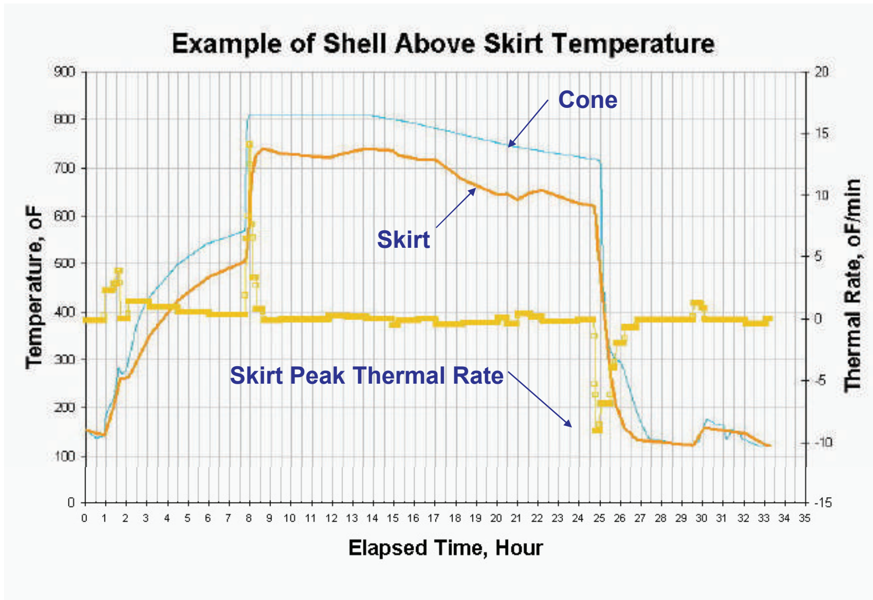
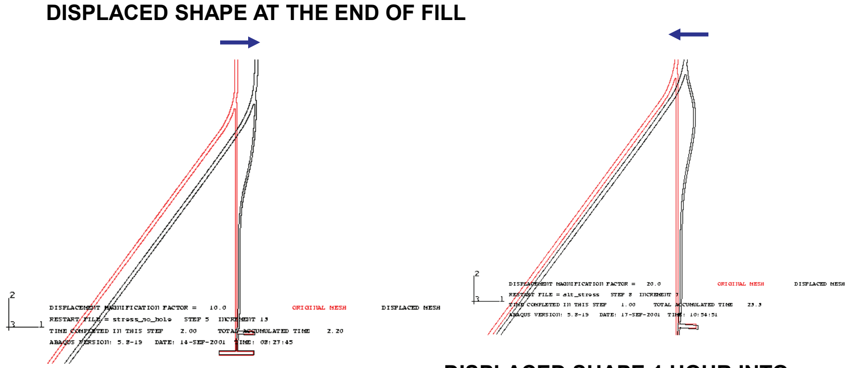


During Quench - Skirt is Pushed and then gets Pulled by Knuckle

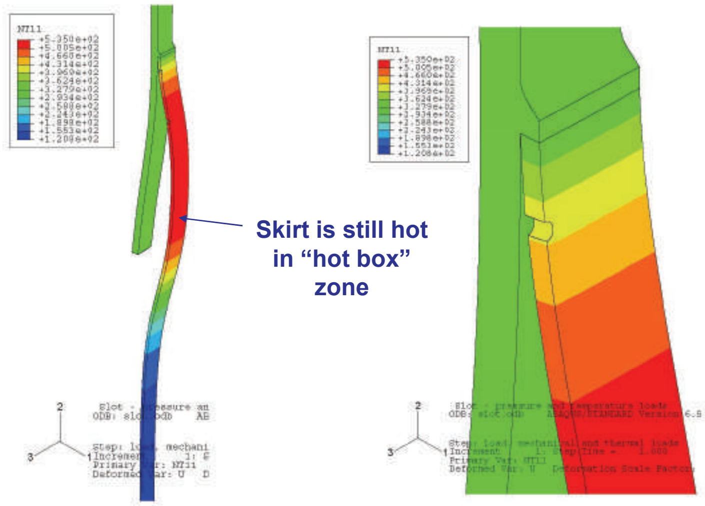
DISPLACED SHAPE AT THE END OF FILL



DISPLACED SHAPE 1 HOUR INTO QUENCH

(MAXIMUM STRESS DURING QUENCH OCCURS HERE)

Example Temperature Distribution During Quench



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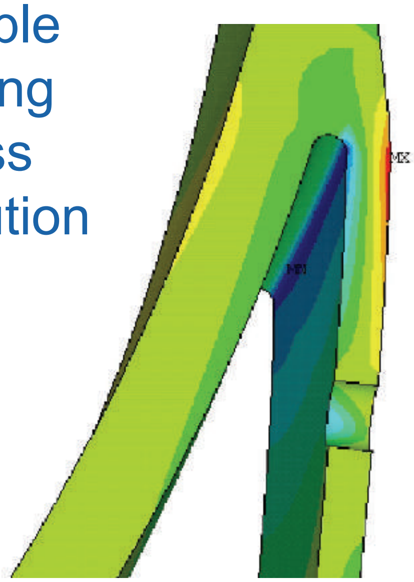
Example Bending Stress Distribution



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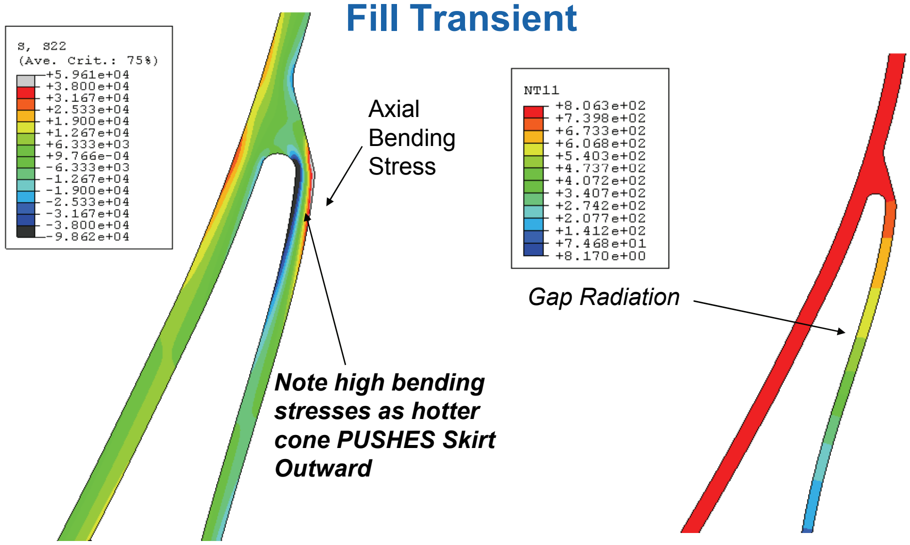
Example In-Line Skirt Axial Stress During the Fill Transient



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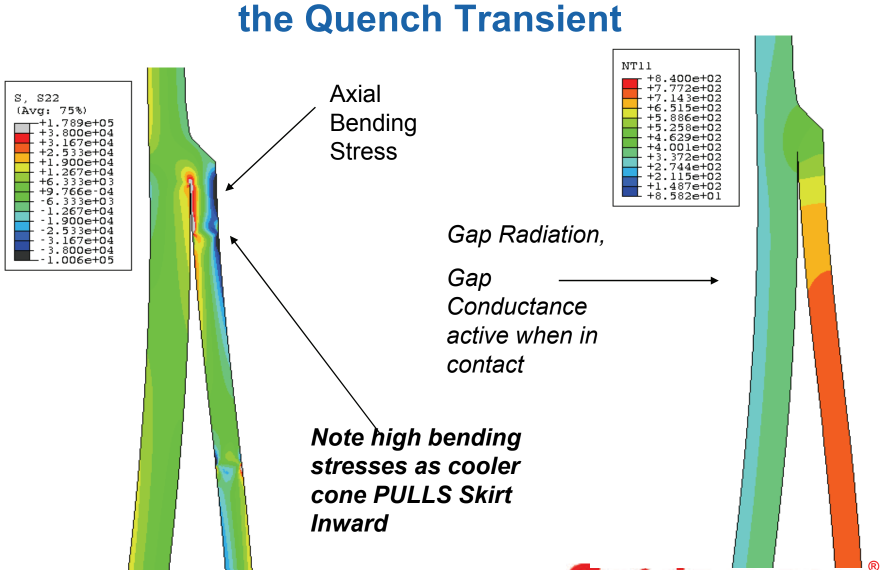
Example Tangent Mount Axial Stress During the Quench Transient



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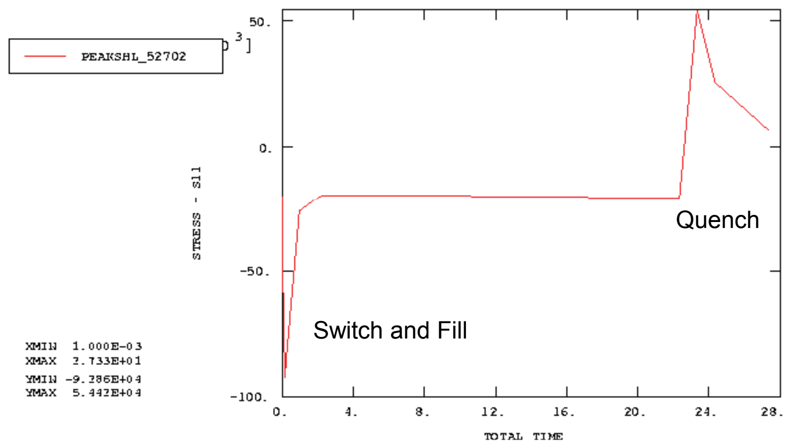

FEA : Axial Stress transient at the top of the skirt ID is function of SCF at inside radius

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FATIGUE LIFE CALCULATION FOR A SKIRT IS MORE ACCURATE USING MEASURED THERMAL TRANSIENT

- •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.

Finite Element Model vs Reality

After 5 years (~1369 cycles) cracks were discovered in all 4 drum skirts (no slots) prior to T/A

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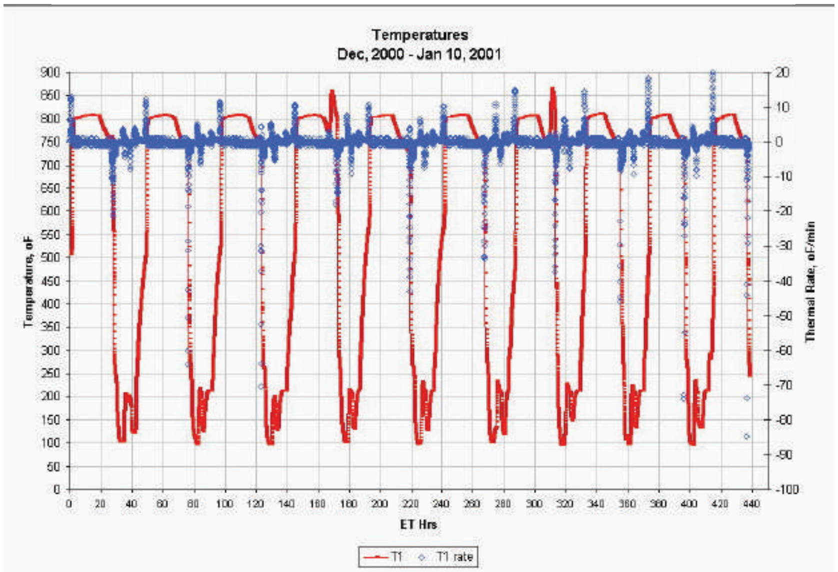
Thermal Cycles and Rates for Cone



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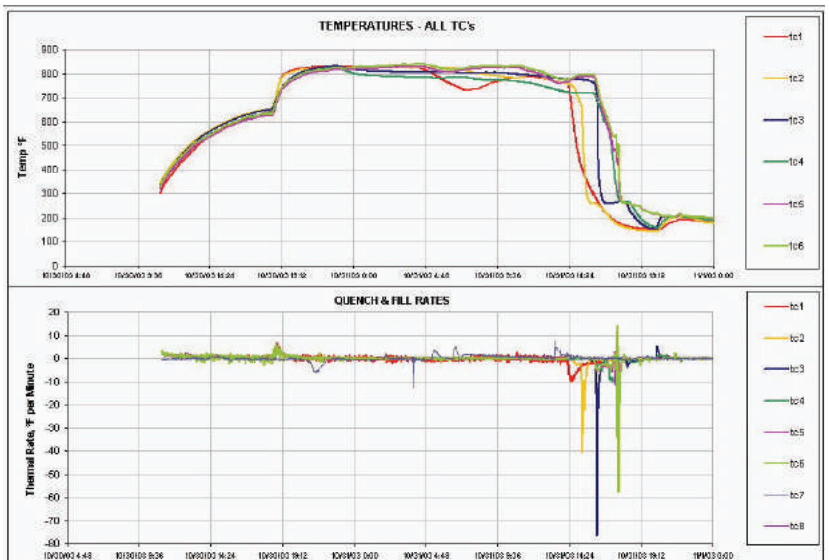
Thermal Cycles and Rates for Skirt and Shell



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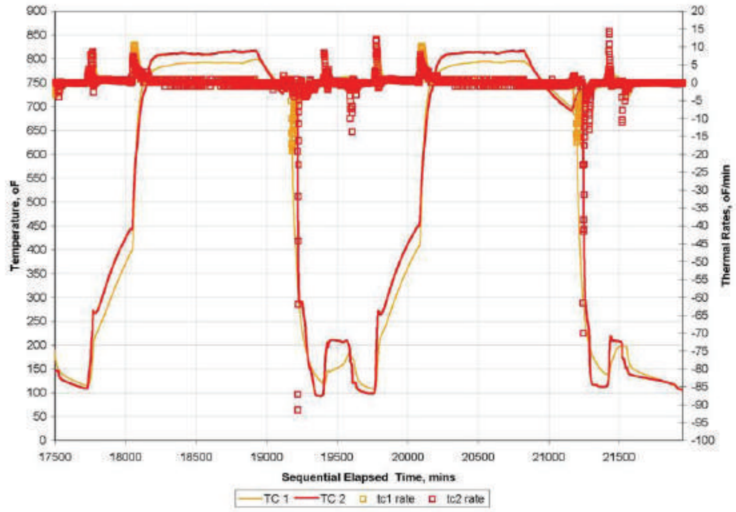
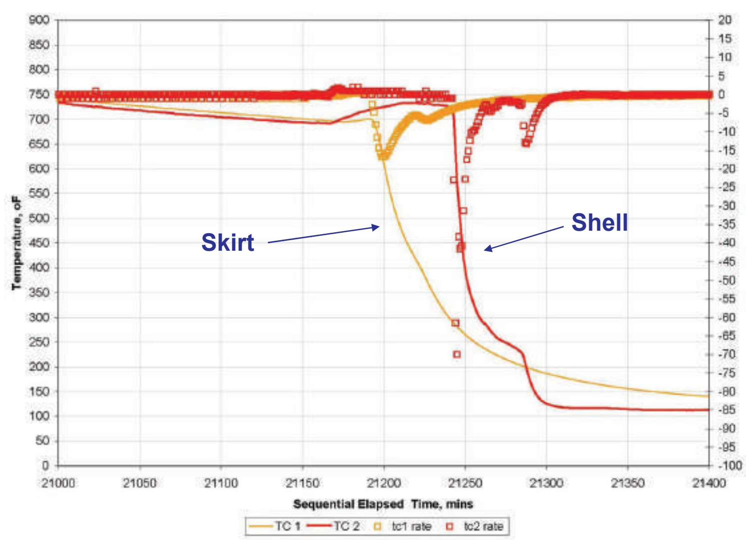
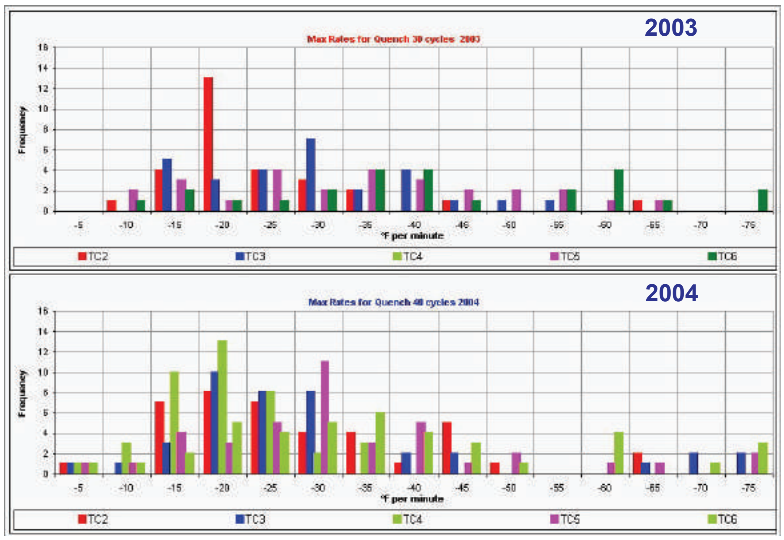
Thermal Cycles and Rates for Skirt and Shell



Thermal Quench and Rates for Skirt and Shell



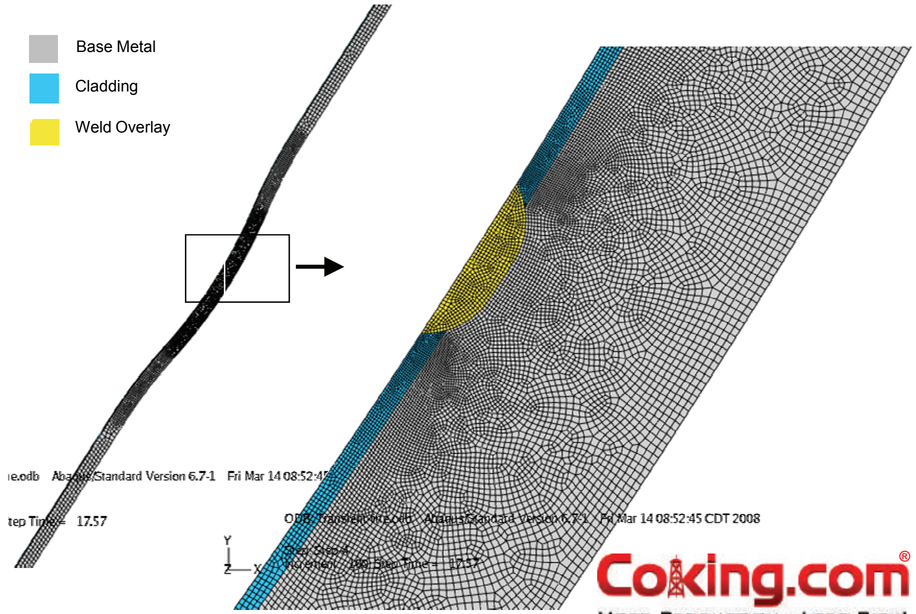
Thermal Rate Histogram for Shell



Does Fast Quench Shorten Cyclic Life ?

- Where Does Fast Quench Hurt?
  - Skirt Attachment Weld
  - Shell Circ Seams
  - Cone Circ Seams
- Why Does Fast Quench Hurt?
  - Constraint created by components at different temperatures (i.e. thermal expansions)
  - Different Material Properties (Yield, Expansion, Conductivity, Diffusivity)

FEA Transient Analysis for ID Circ Seam



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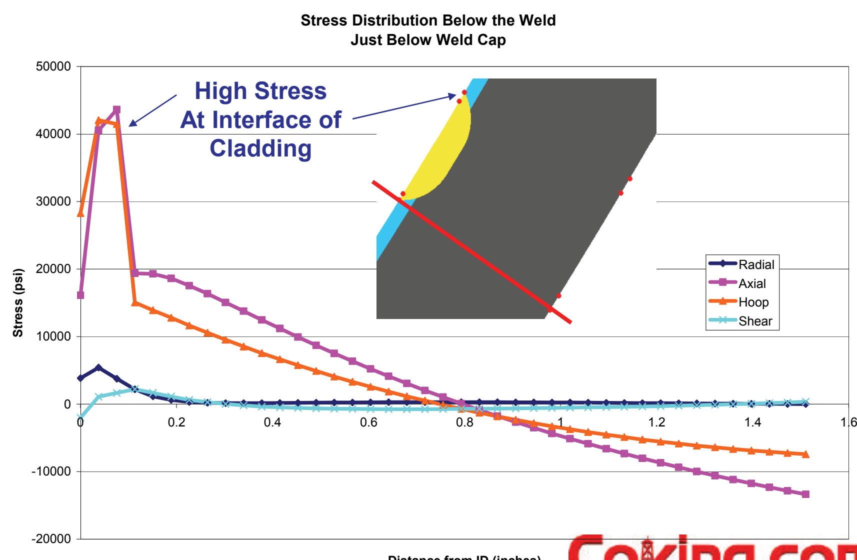
Stress Distribution Across Weld During Quench for Linear Elastic Fracture Mechanics Evaluation



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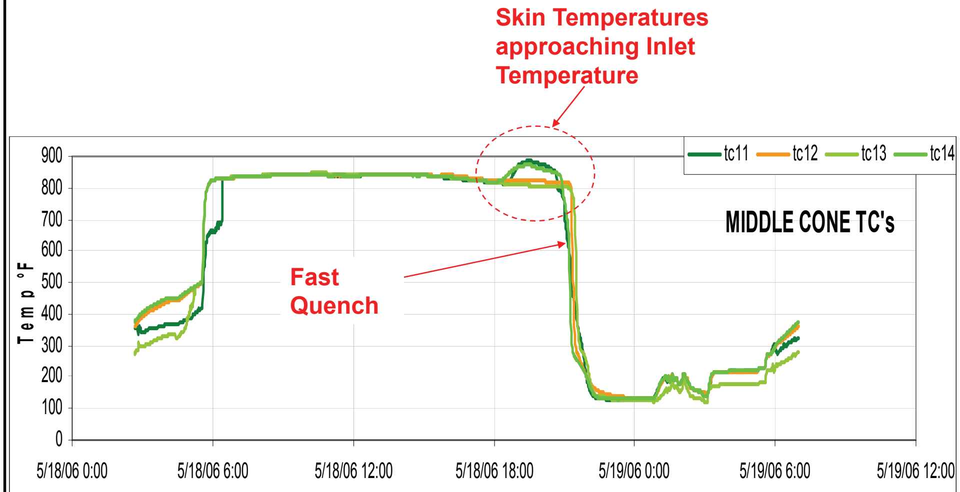
Example of Measured Cone Temperatures



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Fast Quench Issues

- ***Traditional Analysis*** methods assume a ***uniform average flow*** of water upwards to remove heat from coke bed and shell at same time, or ***up thru central primary flow channel***.
- Coke bed formation determines path of least resistance for water flow
  - Flow channel area and friction
    - Plugging and channel collapse creates new flow paths
  - Permeability
  - Porosity
  - Collapse strength of coke matrix
- Temperature measurements suggest fast quench with flow near wall is common
  - **Generally random and not necessarily aligned with Inlet Nozzle**
- This creates greater stress in **shell/cladding bond** and **skirt weld**
  - **Creates greater stress at circ seams tri-metal junction**
- This increases likelihood that **hot zones remain** in coke bed after quench

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What to do about Fast Quench ?

- Change the way you do it
- Use Sensor Measurements (TC and HTSG) to guide you
- Use your Process Technology experts to address the possible procedures and maintain production
- Change the way drums are made
- Or, be prepared for continued problems….

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