Coke Drum Monitoring, Inspection, Assessment and Repair for Service Life Improvement

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REFCOMM
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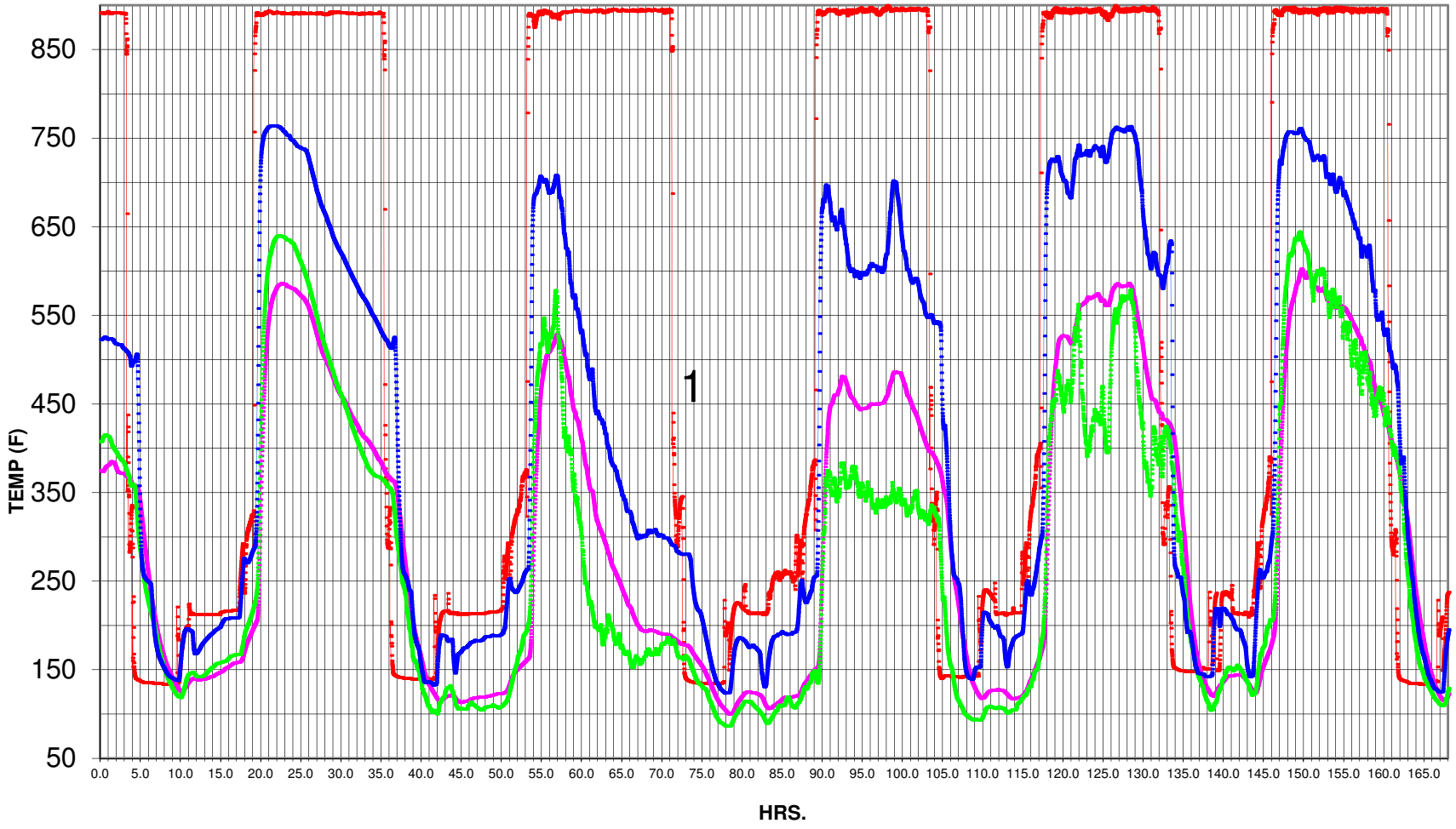
Coke Drum – Transient Temperature Plot @ various cycles & locations



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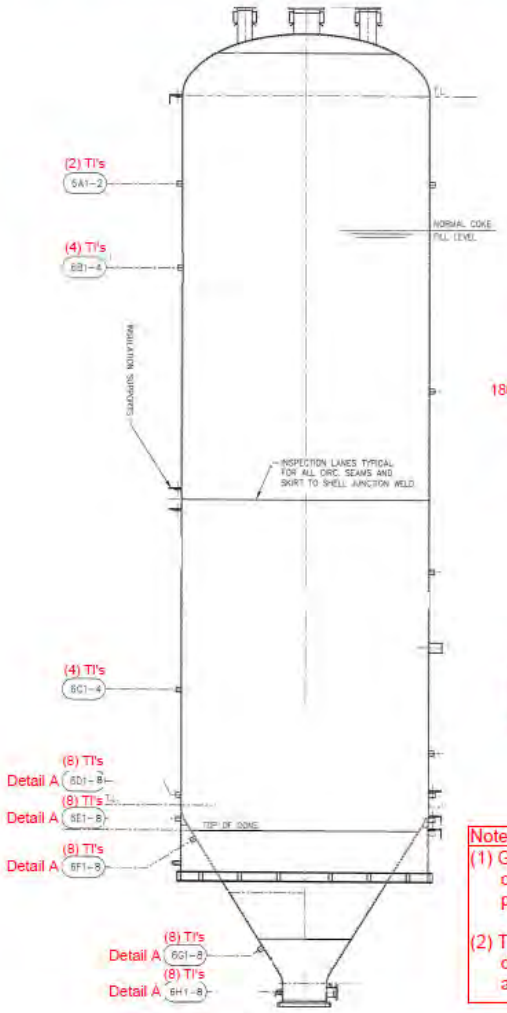
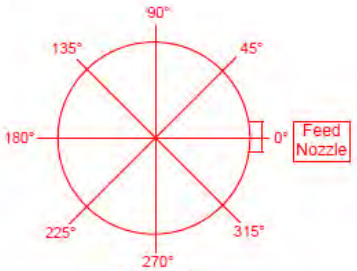
Coke Drum (Monitoring using Skin TI's)

SKIN TI'S LOCATION & THERMAL MONITORING OF COKE DRUM





'Detail A'

Total # of Skin TI's = 50

Notes:
(1) General guidelines to monitor thermal operation of coke drum are provided to plant operation by FWUSAC.

(2) TI data (°F/min) is obtained from field for detailed stress analysis and operational assessment of coke drum by FWUSAC.

Typical Outline of Coke Drum Cyclic Operation & Fatigue Damage

Unlike any other Pressure Vessel, Coke drums and overhead piping systems undergo severe thermal operation and fatigue damage including the following:

1. Severe Daily temperature changes (> 800 F)
2. Severe Thermal cycles (> 250 cycles per year)
3. Banana (Horizontal) Movement during quench – 4” to 6”
4. Severe Thermal Gradient during quench & coking
5. Vibration during coke cutting, quench & coking

Coke Drum Cyclic Operation & Approach to Extend Fatigue Life

"ROOT CAUSE OF FAILURE"

1. Thermal Gradient after Switch to Coking
2. Thermal Gradient during Water Quench
3. Circumferential Temperature Differential during quench

Pro-Active Approach to Extend Fatigue Life

1. From very beginning, monitor temperature changes
2. Minimize Thermal Gradient / Iterative Process
3. Thermal Operation and Reliability working together

Purpose of Coke Drum & Piping Monitoring, Inspection & Assessment Programs

A. Purpose of Coke Drum & Piping Monitoring

- To extend drum fatigue & service life
- Reduce cost and Improve safety of operation
- Avoid unplanned shutdown
- Raise awareness for Operation & Reliability issue

B. How / When to Implement Monitoring program

- Implement (a) pro-active coke drum thermal monitoring program from start of thermal operation
- Implement (b) pro-active routine inspection program.
- Optimize coke drum operation – Thermal Gradient
- Minimize piping vibration

Coke Drum & Piping Monitoring – Key Items

A. Coke Drum Monitoring:

1. Temperature Gradient during Coking & Quench
2. Circumferential Temperature Differential
3. Banana (Horizontal) Movement
4. Coke drum shell profile / Bulging
5. Vibration during coke cutting, quench & coking
6. Coke drum anchor bolts / concrete

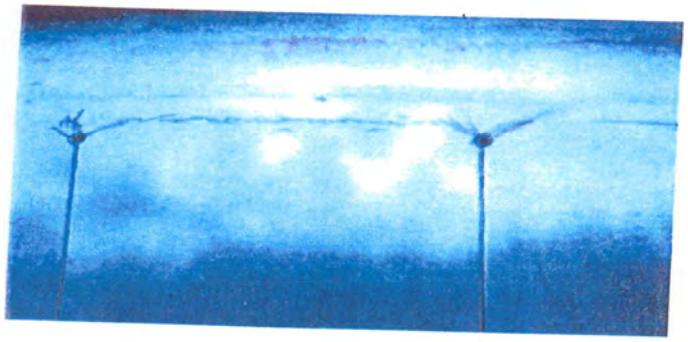
Coke Drum & Piping Monitoring Topics (cont'd)

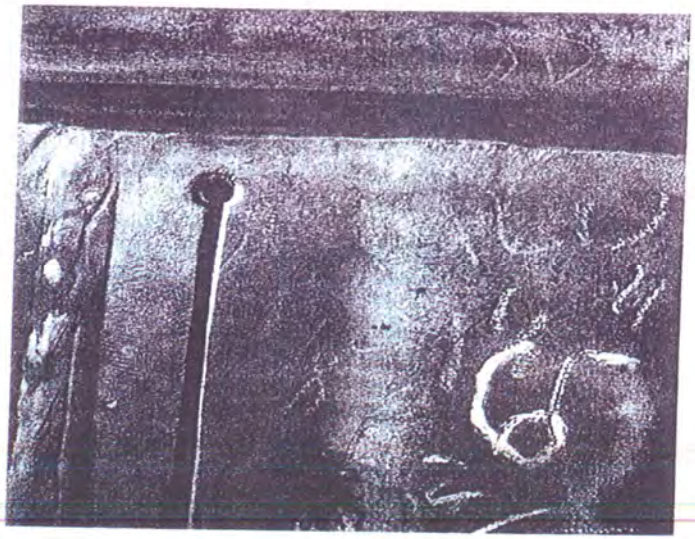
B. Piping Monitoring:

1. "Cold & Hot" clearances for system movement
2. Vibration during coke cutting, quench & coking
3. Banana (Horizontal) Movement
4. Thermal Fatigue & High Stress Nodes
5. Vibration Induced Fatigue & High Stress Nodes

Skirt Crack @ Weld build-Up Junction

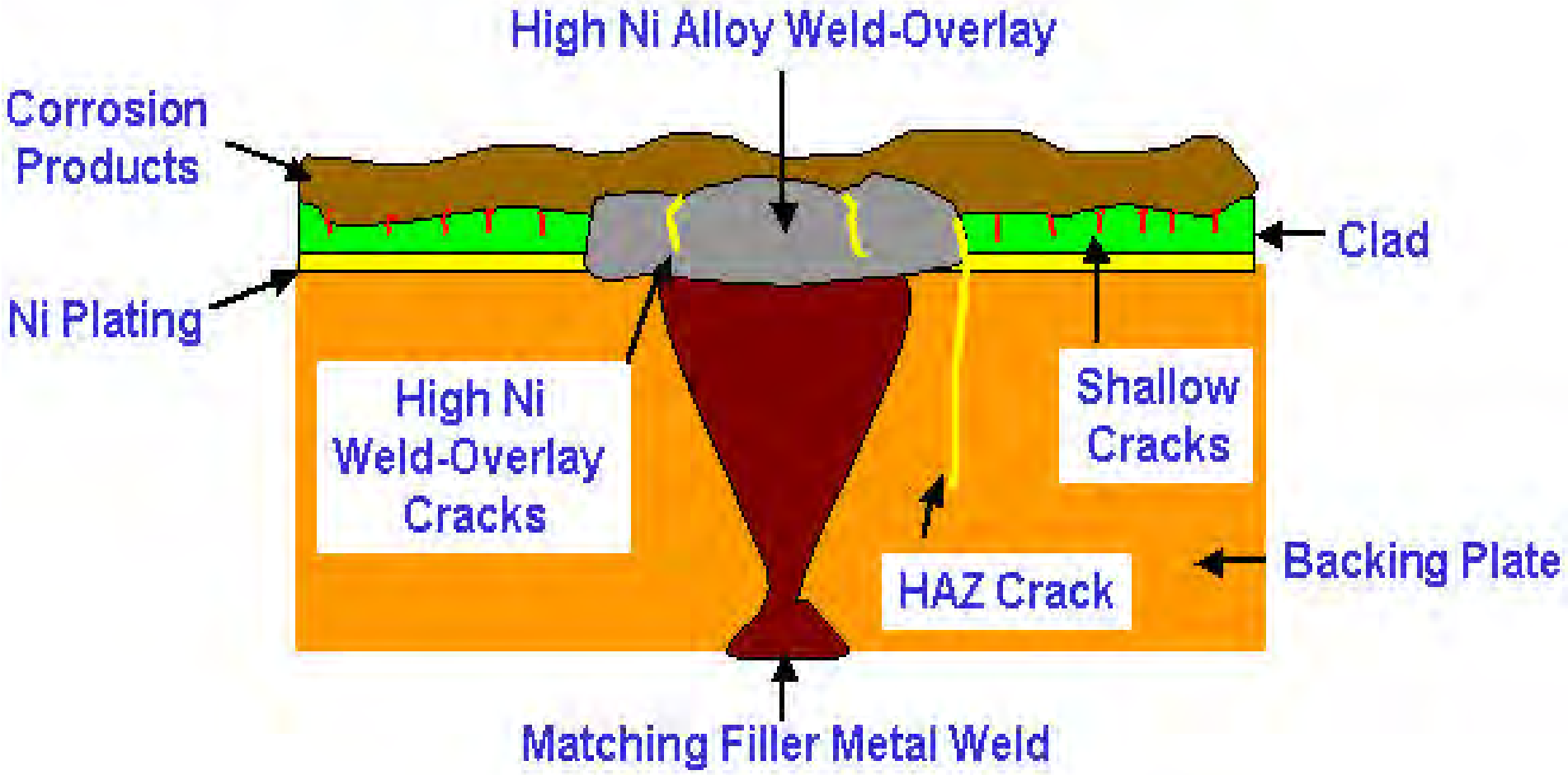
Lap Joint Slotted Skirt Junction Crack (Crack Propagation @ Key Holes)





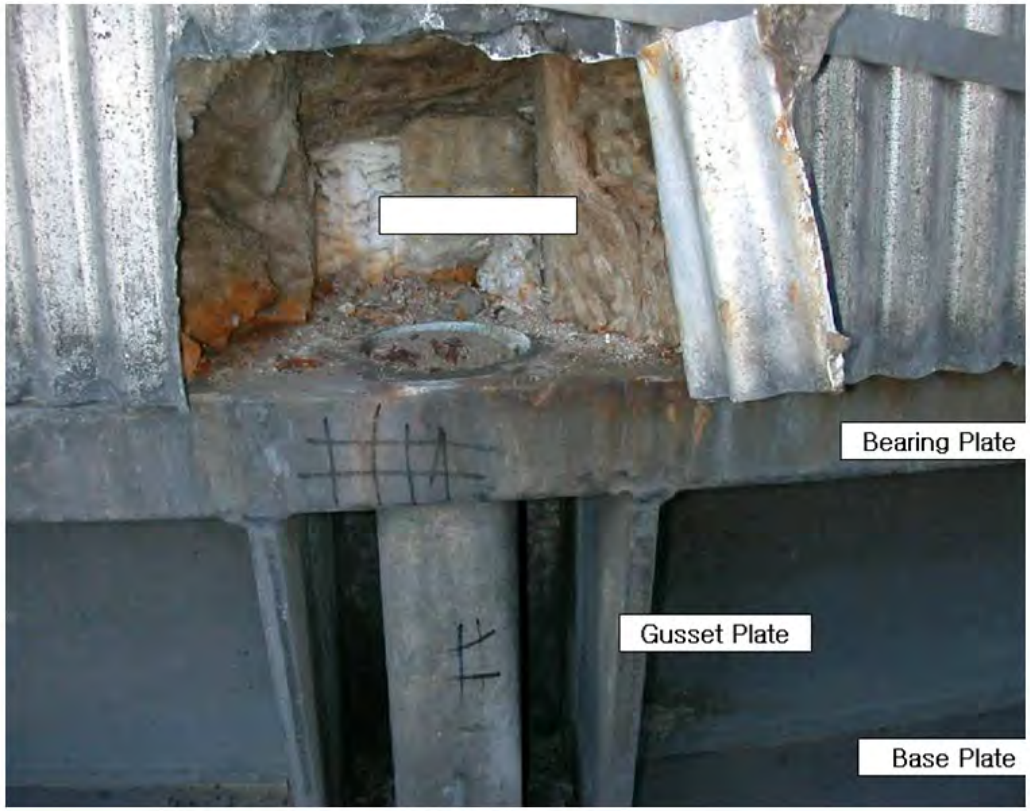
Coke Drum – Shell Bulging

Critical Weld Junction (Circumferential Seam)



Coke Drum - Anchor Bolt Issue

- Broken Anchor Bolt of DCU Coke Drum



Broken Anchor Bolt W/2 Nuts

Factors Affecting Coke Drum Fatigue Life, Safety and Reliability

1. Mechanical Design / Stress Riser
2. Fabrication / Stress Riser
3. Thermal Operation / Thermal Gradient
4. Monitoring Temperature using Skin TI's
5. Inspection of Shell / Cone and Critical Welds
6. Pro-active assessment to Optimize coke drum thermal operation

Assessment / Repair of Coke Drum – Critical Areas

Coke Drum

1. Skirt Junction – Crack / Repair
2. Shell - Bulging / Crack / Repair
3. Circumferential Weld Crack & Clad Restoration
4. Anchor Bolts – Necking, Crack / Repair
5. Concrete - Crack
6. Nozzle – Crack / Repair

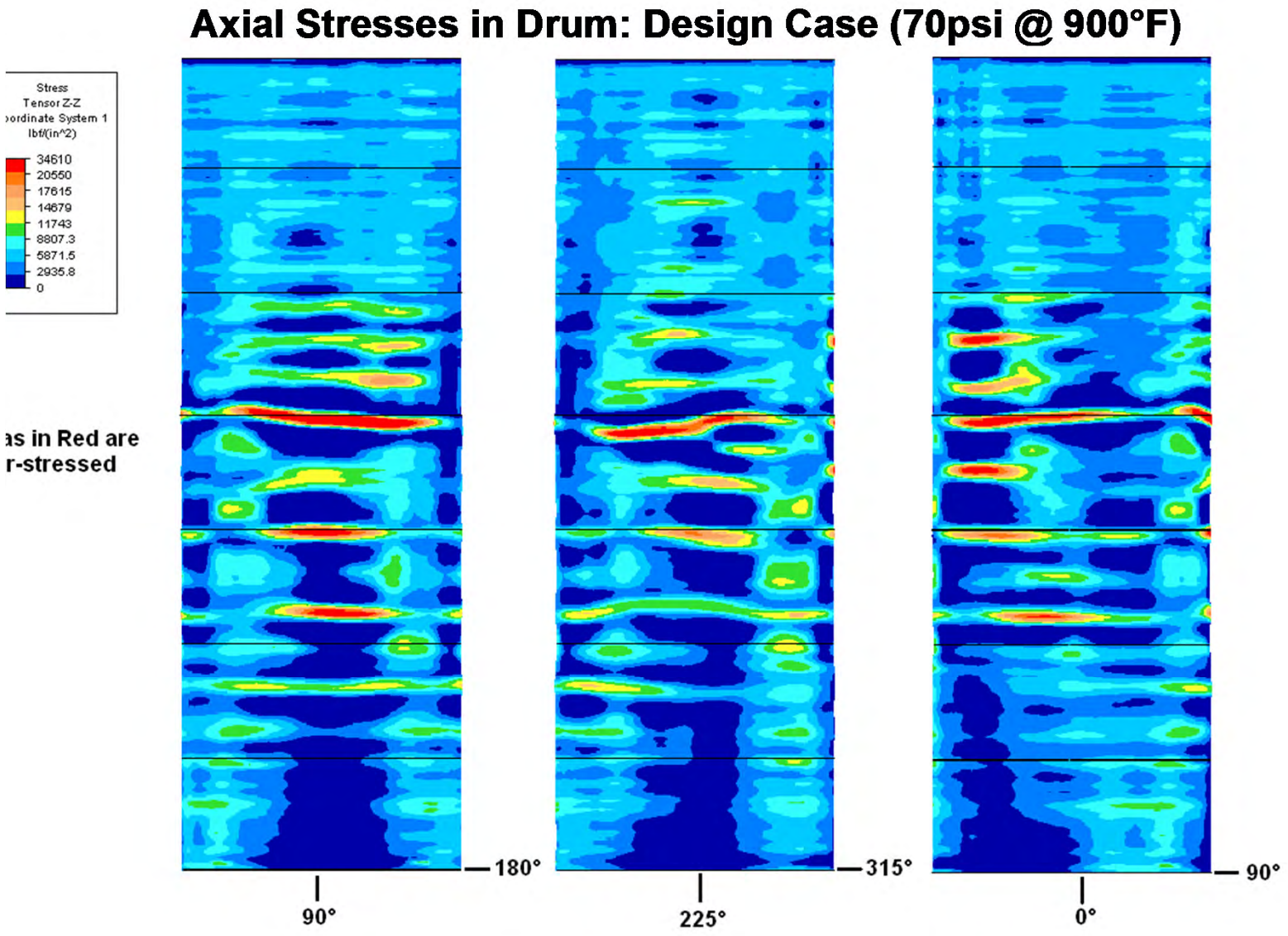
Coke Drum - Common Damage Modes, Assessment and Repair

- Cracking and bulges of the drum shell mainly at / near circumferential seams. Assessment for high stress, future crack location and shell can replacement etc.
- Thermal fatigue cracking of skirt weld to drum shell / knuckle junction. Stability & Stress assessment during skirt crack repair (shutdown or on-line) & for LPWHT.
- Anchor Bolts Failure and / or Concrete Crack and assessment to modify by using disk springs
- Overhead nozzle and Piping Component failure cracking (Vapor, PSV) and assessment for thermal fatigue, vibration induced fatigue, NDE, weld finish etc

Shell Bulge assessment for Coke Drum Routine Inspection, Safety and Life Improvement

- Perform Stress Assessment (FFS) of “Bulged” drums per Code and modify inspection programs
  - Determine “critical stress locations” based on ASME Code and identify potential future crack locations for routine monitoring and inspection program
  - Perform Stress Assessment per Code considering P/T for all Operating and Design cases
  - De-rate Pressure / Temperature, as required
  - Perform Structural buckling and stability study in per Code and FW guideline considering all operating cases including seismic

Coke Drum - Shell Bulge assessment (FFS)



Membrane + Bending Stress (Inside Surface)

Outline of FW's Pro-Active Thermal Monitoring, Routine Inspection & Assessment Programs

1. Monitor coke drum skin temperature / gradient using (TI) and keep within "design thermal guidelines"
2. Inspect shell bulges and cladding cracks.
3. Inspect critical welds of coke drum and piping. Provide means for routine visual inspection
4. Verify (bowing) "banana" movement of coke drum
5. Verify "free" unobstructed movement of drum & piping
6. Monitor Vibration of drum and overhead piping.
7. Perform Stress assessment / Optimize thermal operation

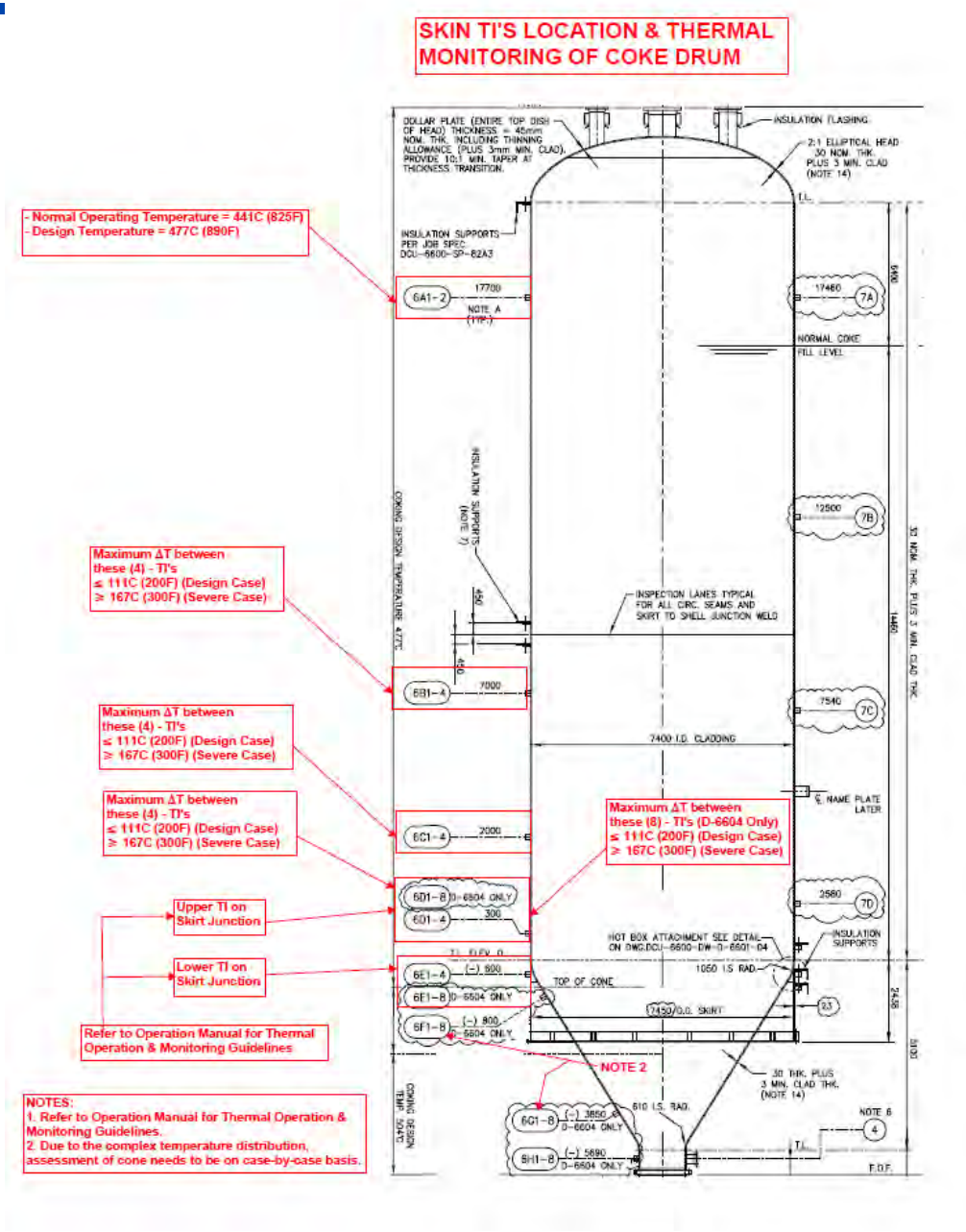
For details of CD Monitoring, Inspection and life improvement at Reliance since year 2007,

Ref: FW / Reliance Joint Presentation in 2013 Coking.com conference

Current Industry Trend/ Thermal Fatigue Considerations

- Shorter coking cycle
- Larger coke drums
- Severe thermal gradients during heat-up / switch to coking and during “Quench”

Coke Drum (TI's & Monitoring)

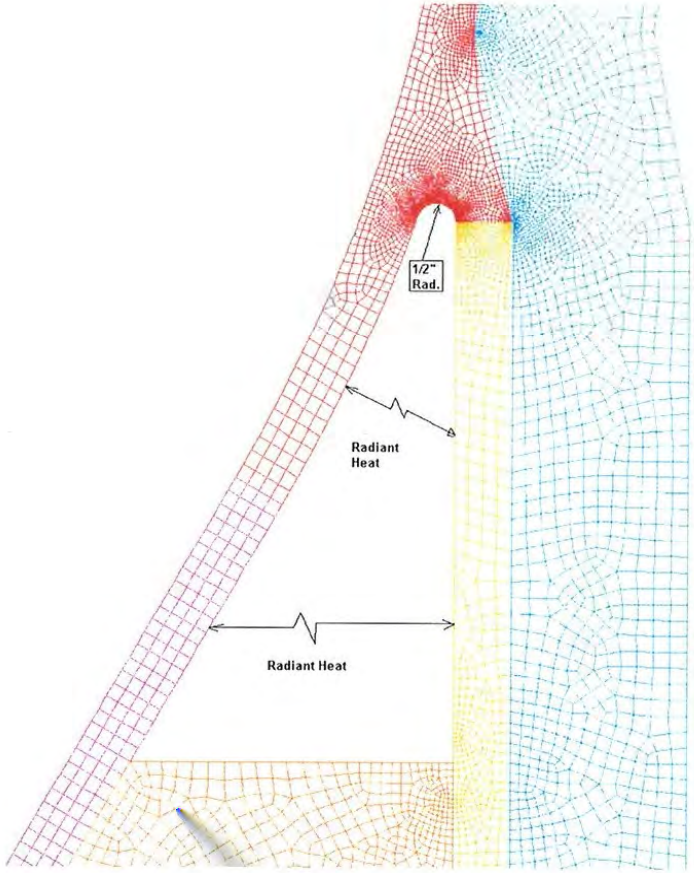


Operational assessment & Thermal Gradient Optimization program for Coke Drum Life Improvement

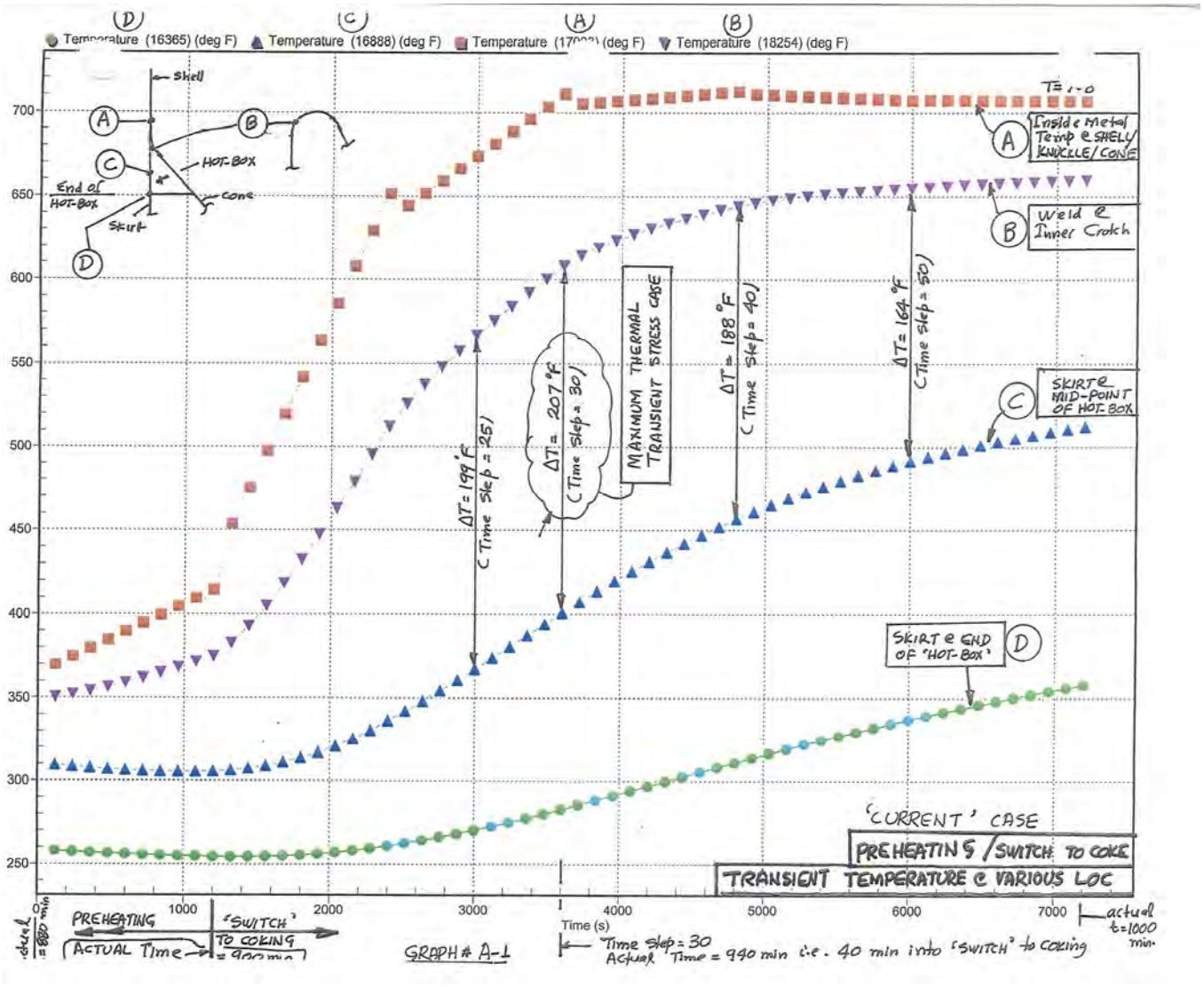
- Assess Thermal Operation and Optimize Thermal Gradients (ramps) to address the following key parameters:
  - Pre-Heat temperature prior to switch to coking
  - Duration of switch to coking
  - Transient thermal ramp during ‘Heat-Up’ cycle
  - Transient ramp during ‘Quench’ cycle
  - Optimize quench rate and schedule

Finite Element Analysis of Skirt Junction

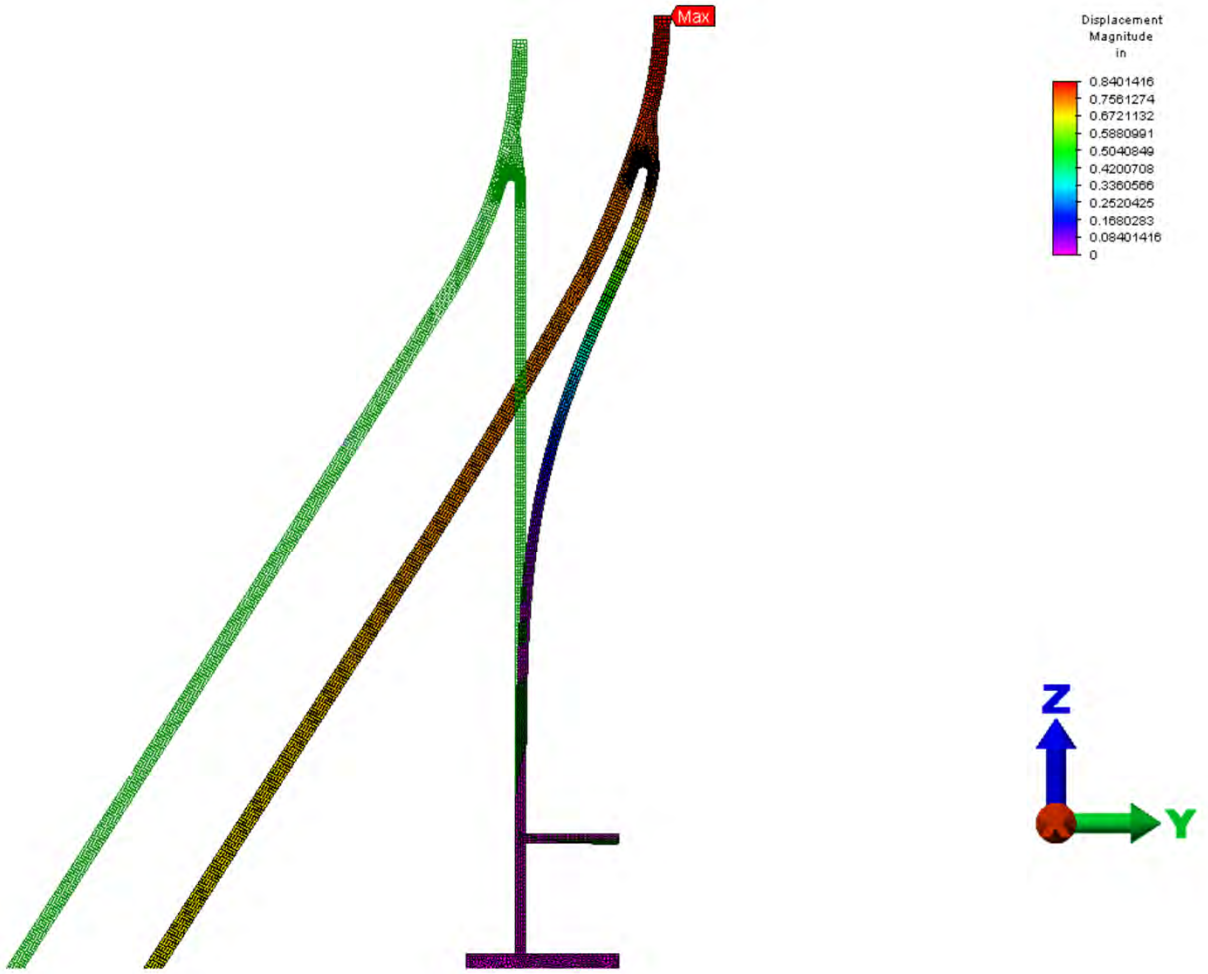
Fatigue Life Evaluation of
Coke Drum Support Skirt / Shell Junction
Using Transient Thermal Stress Analysis



Transient Temperature during Heat-Up / Switch to Coking (at Skirt Junction)



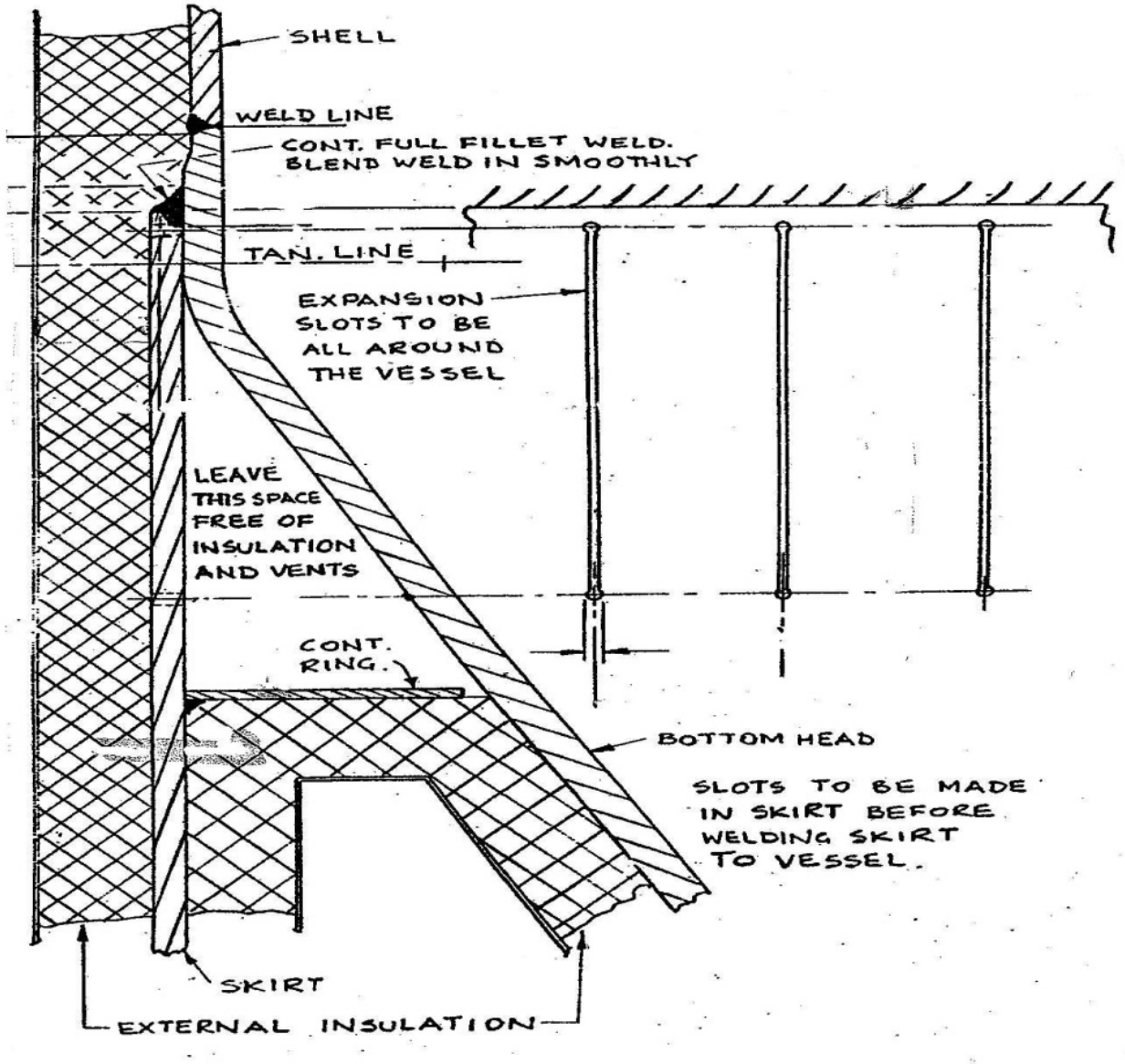
Skirt Displacement during Heat-up



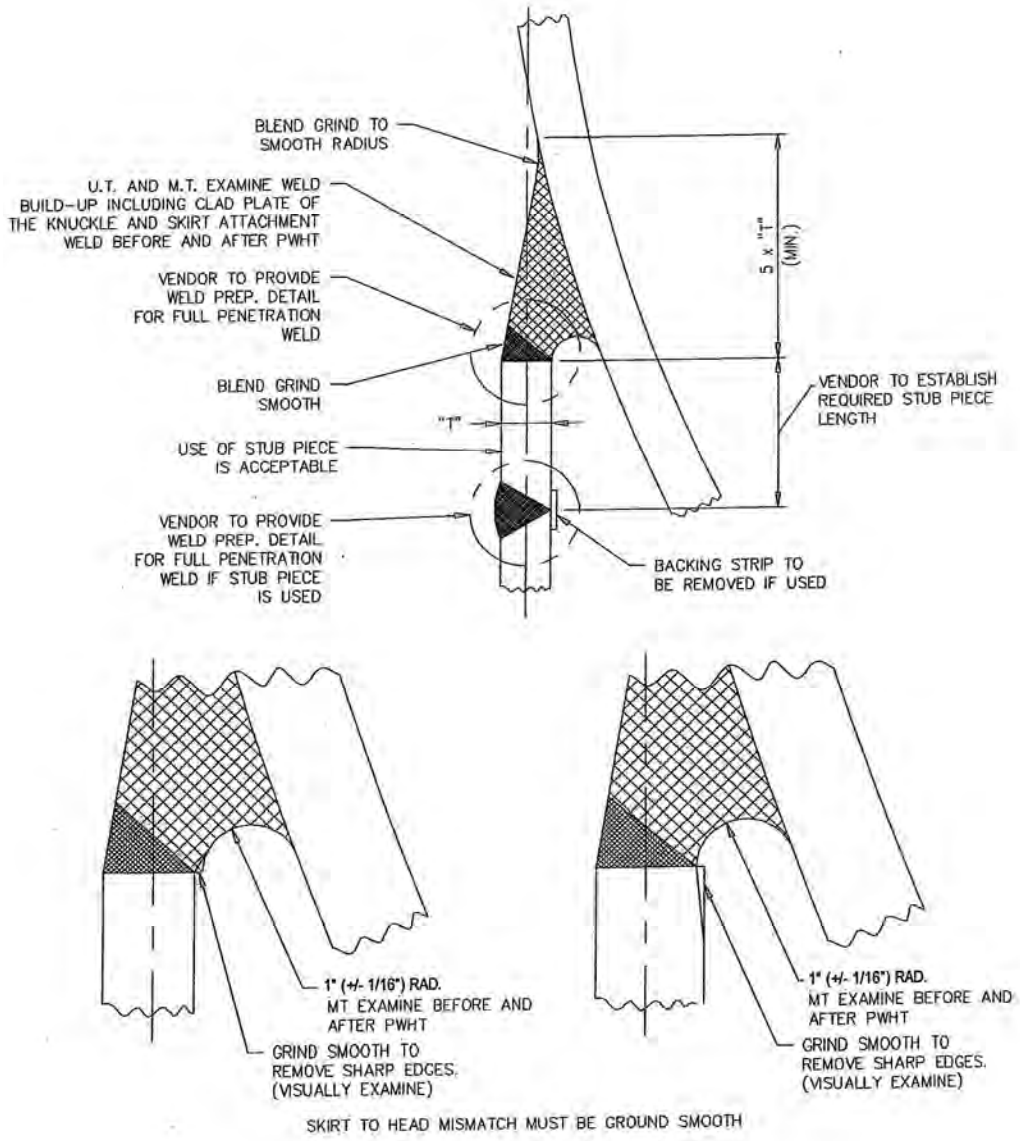
Time Step 77 After Switch to Coking

SKIRT Thermal Displacement During Heat-Up

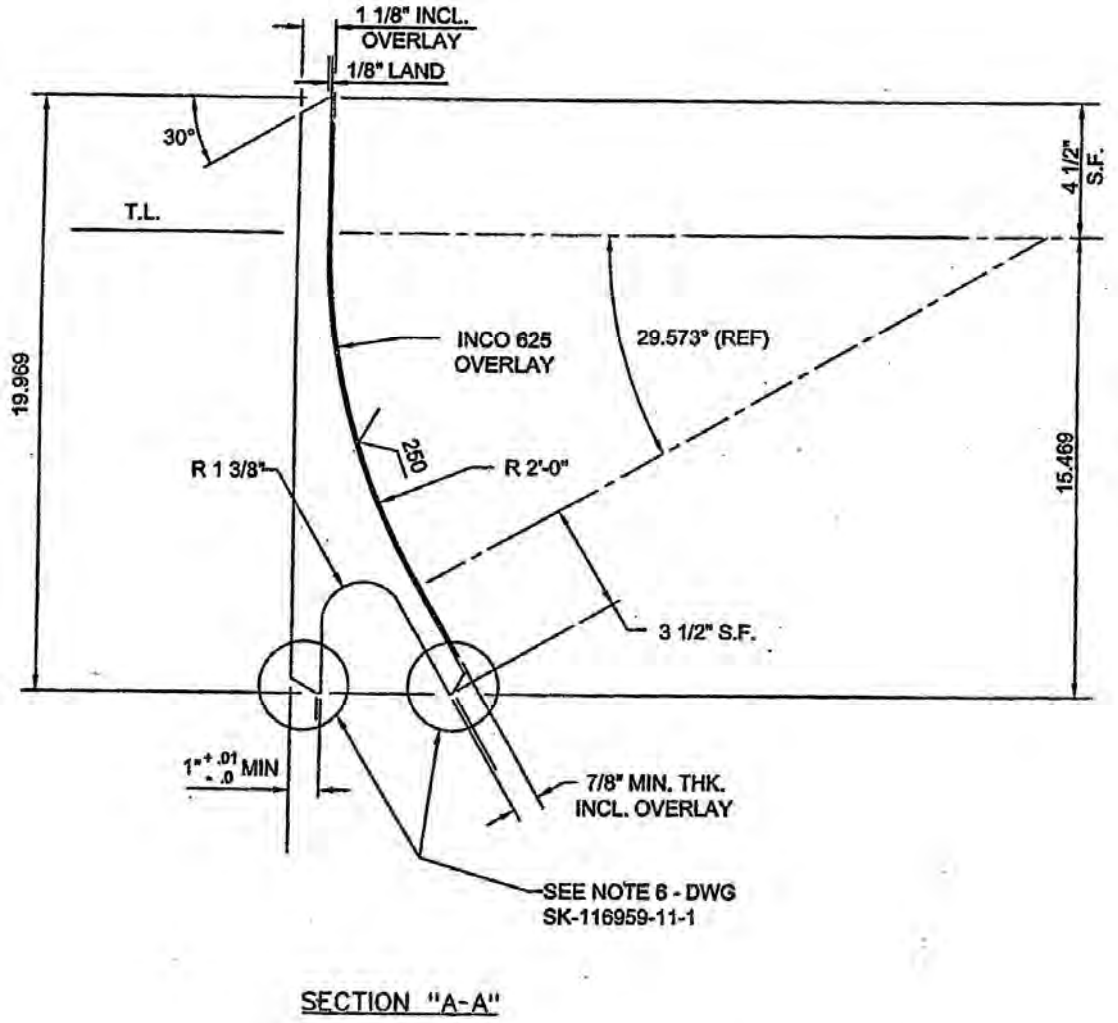
Lap Joint Slotted Skirt Junction



Coke Drum Skirt / Weld Build-up / Cone Junction

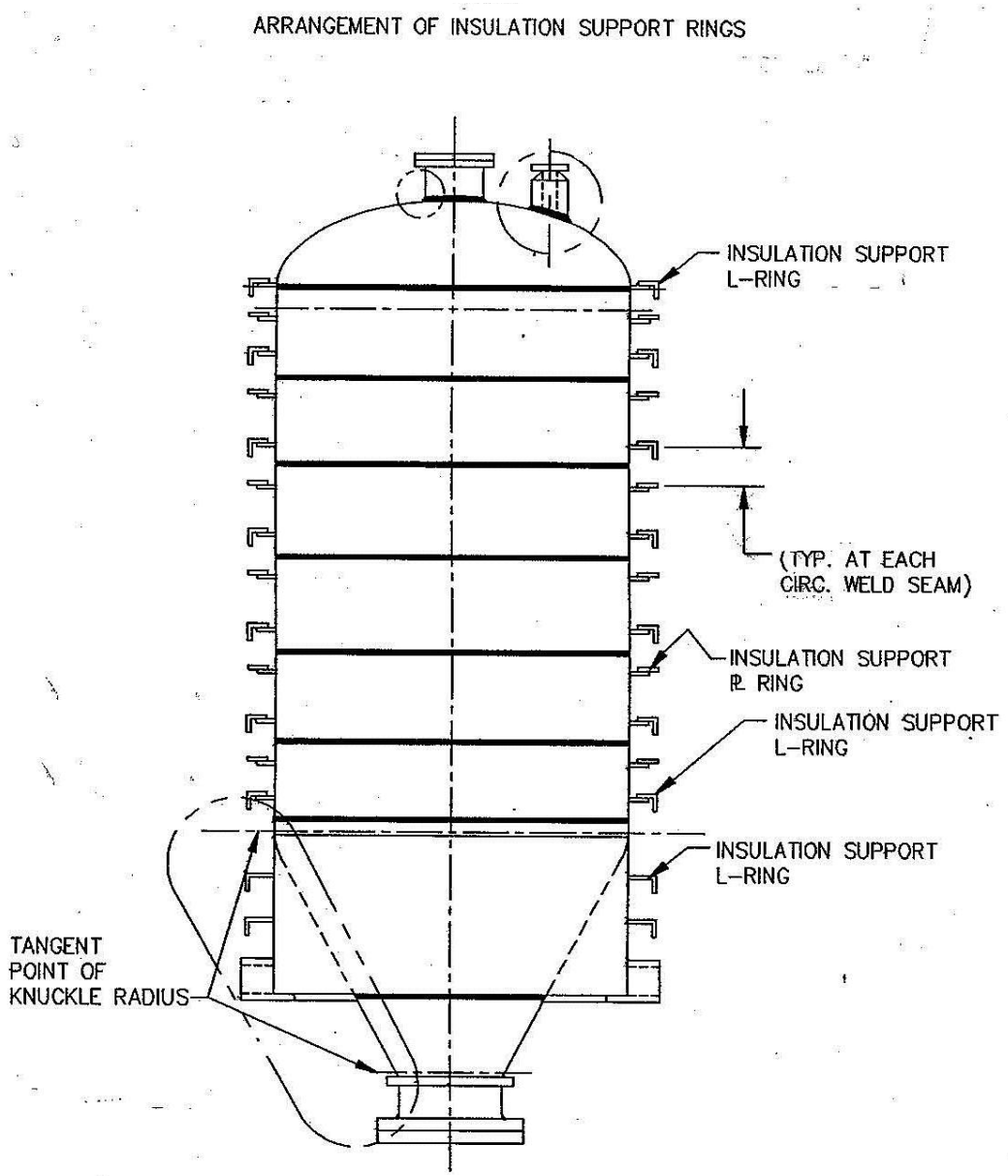


Forged Y-Ring Skirt



SECTION "A-A"

Inspection Lanes at Critical Weld Seam (Removable Insulation)



FW's Programs for Coke Drums Life / Safety Improvement by Thermal Monitoring, Routine Inspection and Assessment

	On-line/Routine	Offline / Shutdown
Skirt	Critical Welds including @ Inspection lanes	Critical Welds including @ inspection lanes
	Anchor bolts and concrete crack	Anchor bolts and concrete crack
	TXI data review: stress & thermal operation assessment (Thermal Gradient)	
Shell	Banana Movement	Critical Welds including @ Inspection Lanes
	Critical Welds @ Inspection Lanes	Hardness surveys of clad/welds
	Laser Scans/Bulge mapping: Assessment for FFS and future "crack" location.	Nozzles / Shell / Top Head Intersection
Piping	High Stress Nodes / Piping Vibration / Critical Welds subject to Thermal Fatigue and / or Vibration induced fatigue	High Stress Nodes and Critical Welds
	Critical Supports	Critical Supports

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Coke Drum: FW's Thermal Monitoring, Routine Inspection and Assessment Programs (cont'd)