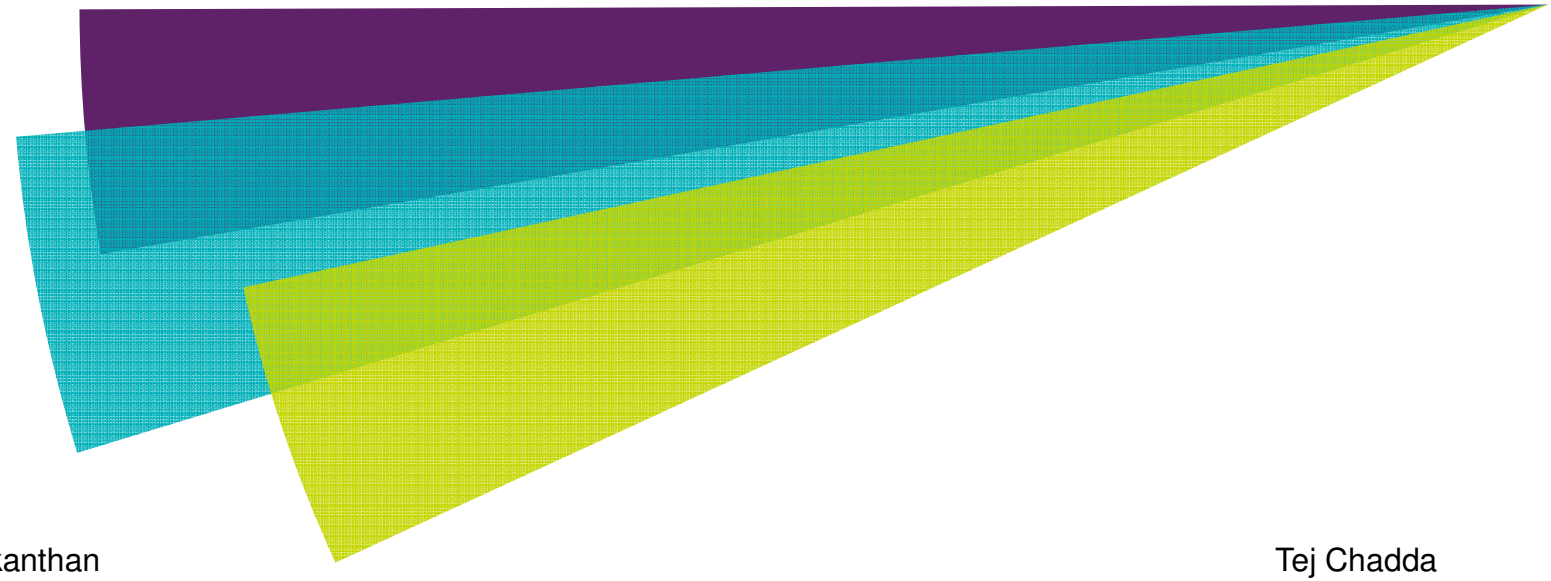
Fatigue Life & Reliability Consideration During Field Repair of Coke Drum & Piping

2017 Refcomm Presentation at Galveston, Texas

May 8-12, 2017



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REFCOMM GALVESTON MAY 8-12 2017

Fatigue Life and Reliability Considerations during Field Repair of Coke Drum & Piping

OVERVIEW

- Introduction to RIL DCU & (16)-Coke drum / Piping System
- Repair Consideration
- Fatigue Life & Reliability Consideration
- Field Repair Execution (Solid Skirt ; Vapor Line)
- Routine Inspection & Monitoring
- Thermal Operation & Gradient Optimization
- Q & A

Introduction to RIL DCU & (16)-Coke drum / Piping System

AmecFW DCU Process Licensor and DEC

Coker # 1

- Coker # 1 with (8)-coke drums / bottom feed / started in year ’99
- Basis of original process design – 24 hr coking cycle
- Coking cycle reduced to 14 hrs few years after commissioning

Coker # 2

- Coker # 2 with (8)- drums / single side feed / started in year ’09
- (4) coke drums modified to dual feed inlet in year ’13
- Basis of original process design – 13 hr coking cycle
- Coke drum design “duplicate” of Coker # 1 except “uniform” wall

Introduction to RIL DCU & (16)-Coke drum / Piping System (cont'd)

- Skirt Junction weld cracks continued to be monitored and repaired "on-line"
- Vapor line weld cracks continued to be monitored and repaired
- Thermal Gradient and operation optimization performed by plant operators in year 2007 with assistance from AmecFW
- Routine Inspection and monitoring programs for coke drum & piping welds implemented by RIL reliability team per recommendation and assistance from AmecFW
- Current goal is field repair of coke drum / piping considering also fatigue life and reliability improvement
- Current modification to coke drums include the use of Center Feed Injection Device

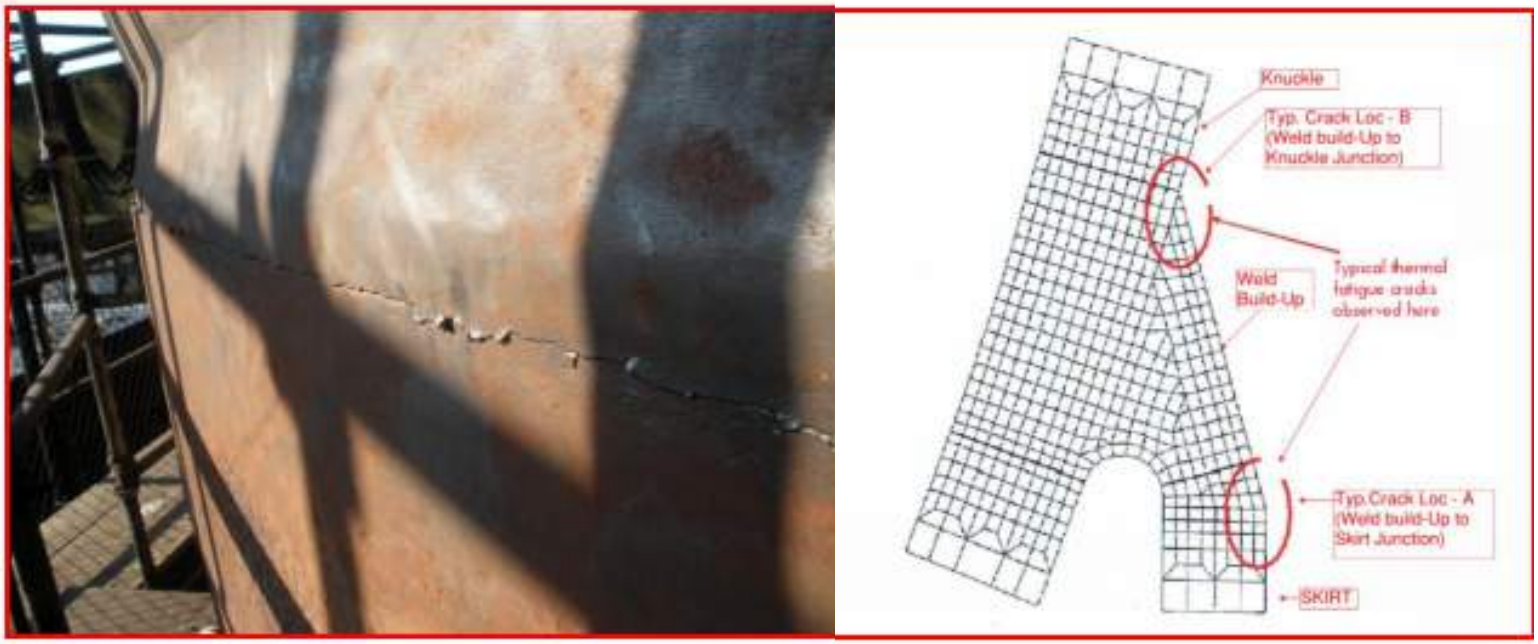
(Operational results will be shared in future)

Fatigue Life & Reliability Consideration during field repair (Coke drum & OVHD Piping)

Field Repair & Fatigue Life / Reliability Improvement Consideration

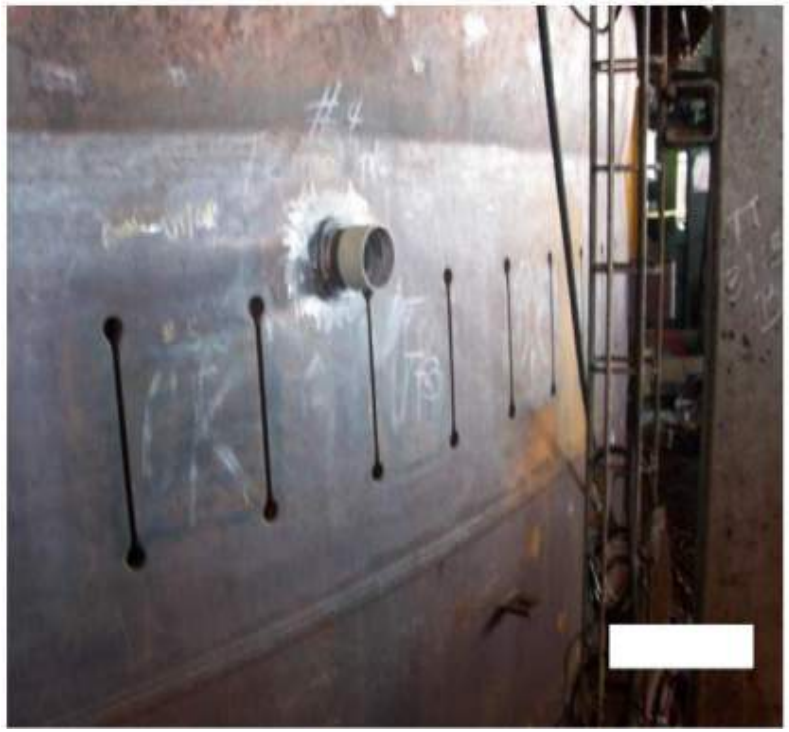
- Can existing design be upgraded to be fatigue resistant ?
- Can existing fabrication practice be upgraded to be fatigue resistant
- Can existing thermal operation be further optimized to reduce thermal gradient after switch to coking and during water quench ?
- Can Delta T between drum / Vapor line be reduced during quench ?

Fatigue Life & Reliability Consideration (cont'd)



Weld build-up skirt junction crack, typical Locations & Fatigue Resistant Consideration:
Can thermal B.M. / Stress be reduced at skirt crotch area by redesign ?

Fatigue Life & Reliability Consideration (cont'd)
(Modification of coke drum solid skirt to slotted skirt)



Fatigue resistant design change during field repair to reduce moment / stress. Repair performed during shutdown using shop fabricated slotted skirt panel, field welding & PWHT

Fatigue Life & Reliability Consideration (cont'd)
(During coke drum field repair)

Key Factors to be considered during the field repair of aging coke drum:

- The original design, fatigue life basis, stress riser and fatigue resistance of the coke drums.
- The original fabrication and stress risers of coke drum.
- Coke drum temperature monitoring data using skin TI's, Thermal gradient and Thermal Operation history of coke drum
- Coking cycle history
- Operating thermal operation parameters including preheat, drum temperature at switch to coking, switch operation and water quench.
- Past inspections and repair history of shell / cone and critical welds, crack, bulge and detailed mechanical integrity assessments
- Stress riser and the quality of corner intersections (chamfering / radiused) between slots and keyholes especially at the upper keyhole

Fatigue Life & Reliability Consideration (cont'd)
(Modification of coke drum solid skirt to slotted skirt)

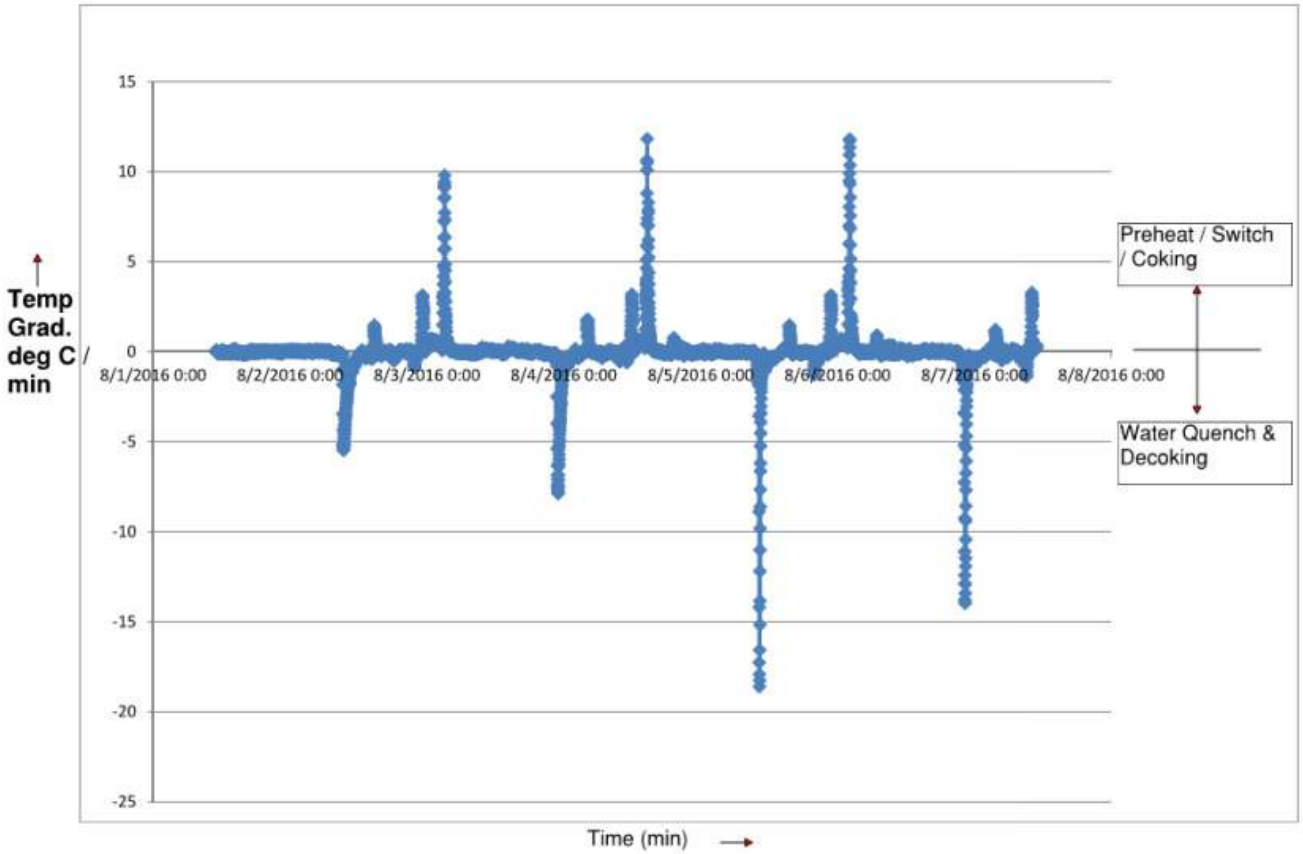
FEA of solid and slotted skirt, thermal gradient & estimated fatigue life

A comparative stress study of skirt modification was performed.

The results are tabulated below

Skirt Description	Skirt Slot	Thermal Gradient	Estimated Fatigue Life (Inner Crotch)	Estimated Fatigue Life (Upper Keyhole)
Original / Solid	None	8H@500F/ 10Q	2100	N/A
Original / Solid	None	12H@500F /20Q	1200	N/A
Modified/ Slotted	WITH SLOTS	8H@500F /10Q	>7000	>7000
Modified/ Slotted	WITH SLOTS	12H@500F /20Q	4800	8900

Fatigue Life & Reliability Consideration (cont'd)
Operating thermal gradient review & optimization



Thermal Gradient Review of Skirt Junction and Optimization of Coke drum Thermal Operation

Fatigue Life & Reliability Assessment (cont'd)
Thermal Gradient Review and Optimization

Optimization of thermal Operation & gradients:

Key operational parameters depending on the design and fatigue life basis:

- Pre-heat temperature of coke drum prior to switch to coking
- (290 deg C is preferred but should be a minimum of 260 deg C)
- The duration of the switch to coking to avoid thermal shock (generally a 2-step switch targeting a 15 minute interval).
- The transient thermal gradients after switch to coking (generally in the target range of 4 – 7 deg C/min)
- The transient thermal gradients during water quenching (generally in the target range of 8 – 12 deg C/min)
- Optimize the quench rate and schedule to accomplish the above targets and guidelines

Fatigue Life & Reliability Consideration (cont'd)
Critical High Stress Piping Weld, Crack & Repair

Overhead Piping Critical High Stress Weld, Crack & Repair Consideration

- Thermal Fatigue & Vibration Induced Fatigue Consideration
- Original design, whether fatigue resistant
- Weld quality impacts on fatigue life and Fatigue Strength Reduction Factor consideration
- Components for which ASME B31.3 Code does not provide equation to calculate Stress Intensification Factor (SIF)
- SIF for Pipe or Pipe Fitting to Pipe Thickness mismatch
- SIF for pipe to reducer
- SIF for pipe to flange
- SIF of the above weld junctions require detailed FEA for further use

Fatigue Life & Reliability Consideration (cont'd)
Enhanced fabrication and NDE of piping welds during repair

Enhanced fabrication, examination and inspection in addition to the typical welding and NDE procedures, specifically:

- The final weld pass on the ID and OD is to be ground smooth and flush to remove any weld cap.
- Any offset between thicknesses to be ground to 10:1 taper or use thickness transition spool.
- 100% visual inspection of both OD and ID is required.
- For carbon and low alloy steel materials, perform 100% inspection of the root pass and final pass (ID as well as OD) after grinding smooth and flush.
- 100% RT of the final weld.
- Acceptance criteria for welds per B31.3 Table 341.3.2 for severe cyclic service

Fatigue Life & Reliability Consideration (cont'd)
Effect of banana movement, BE & piping stress

Coke Drum Banana Movement Estimate

- Consider temperature difference between the hot side and the cold side of coke drum shell during operation, especially during quench
- Estimate the banana movement, (BE), of the coke drum

$$BE = 1.2\,(R+0.5D)\,(1-\cos(\alpha))$$

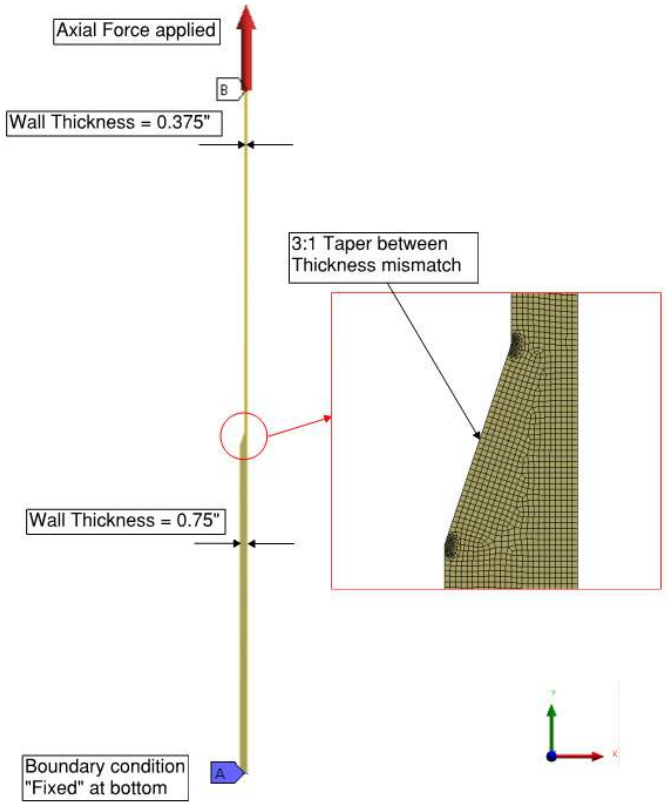
$$\text{Where } \alpha = 57.2956\,\gamma\,(Th-Tc)\,(1+\gamma x Tc)\pi\,/(180D)$$

- Perform overhead piping system stress analysis
- Perform repair assessment considering cyclic thermal stress level:

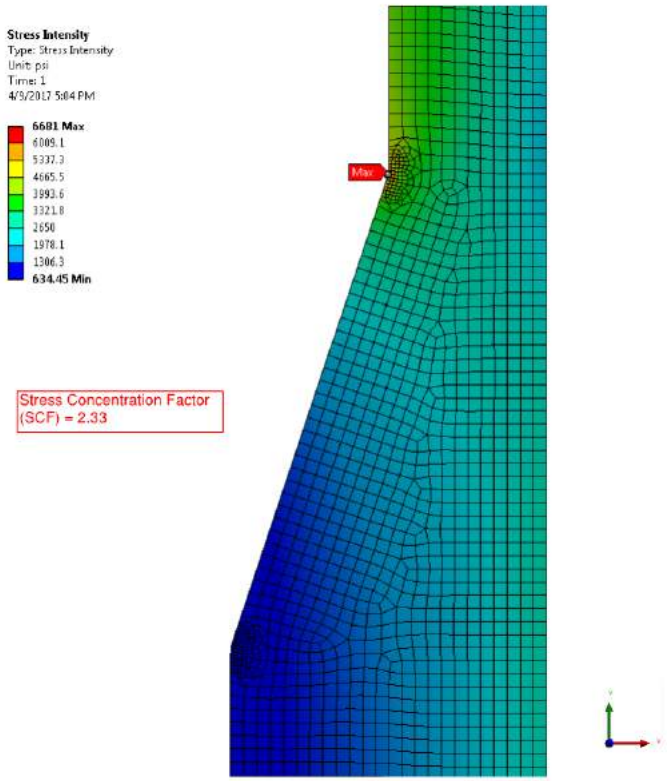
Legend

D	Coke drum nominal diameter
L	Coke Drum Height, Bottom Tangent Line to Top Tangent Line
Th	Shell Hot Side Temperature
Tc	Shell Cold Side Temperature
γ	Coefficient of thermal expansion

Fatigue Life & Reliability Consideration (cont'd)
Calculation of SCF at thickness mismatch using FEA

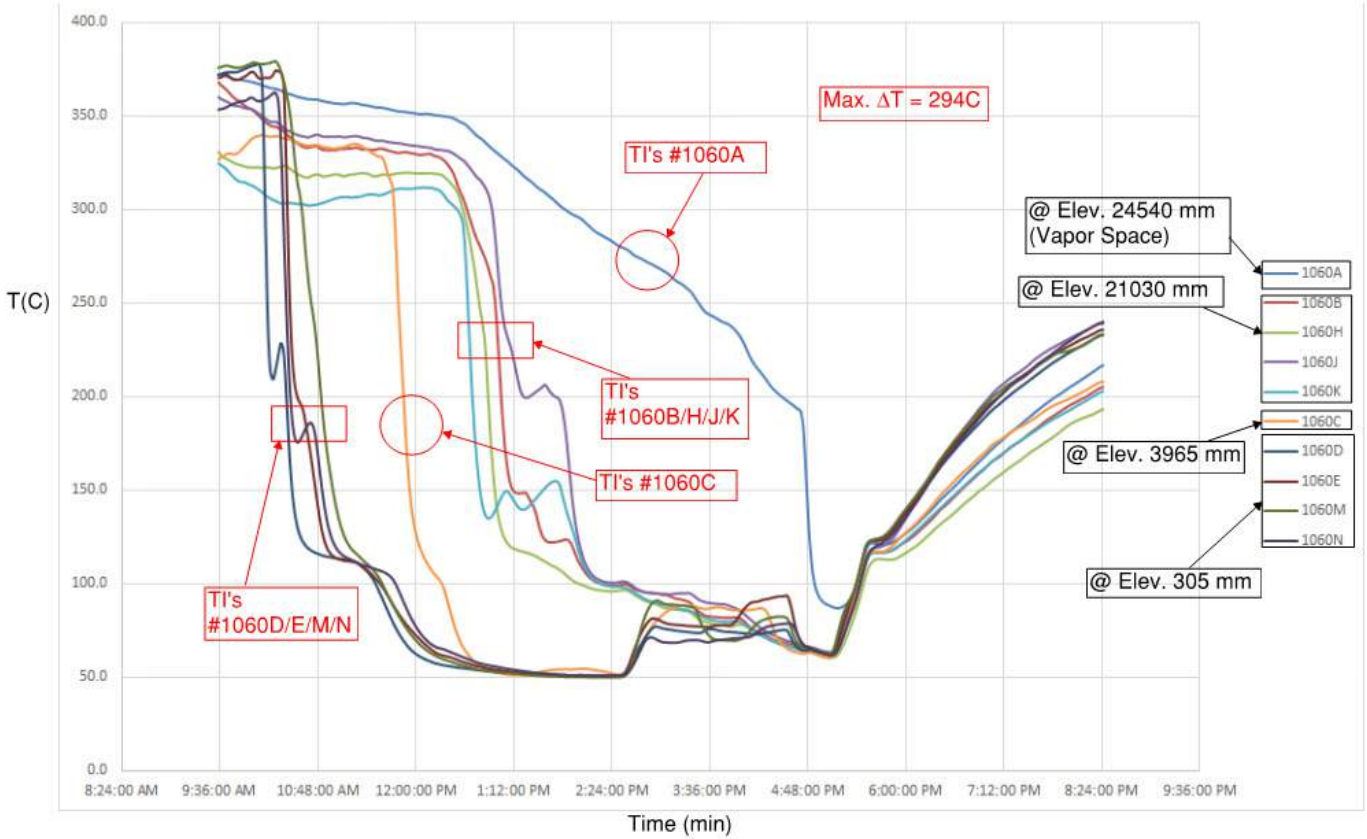


FEA MODEL - 2D AXISYMMETRIC
@ Pipe / Fitting Wall Thickness Mismatch



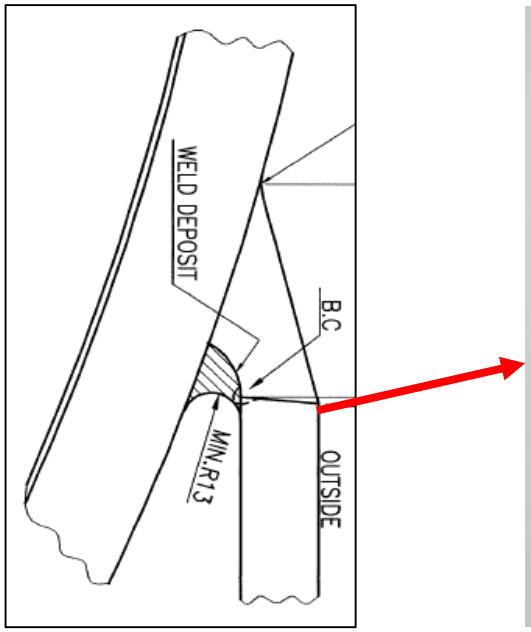
FEA STRESS RESULTS & SCF

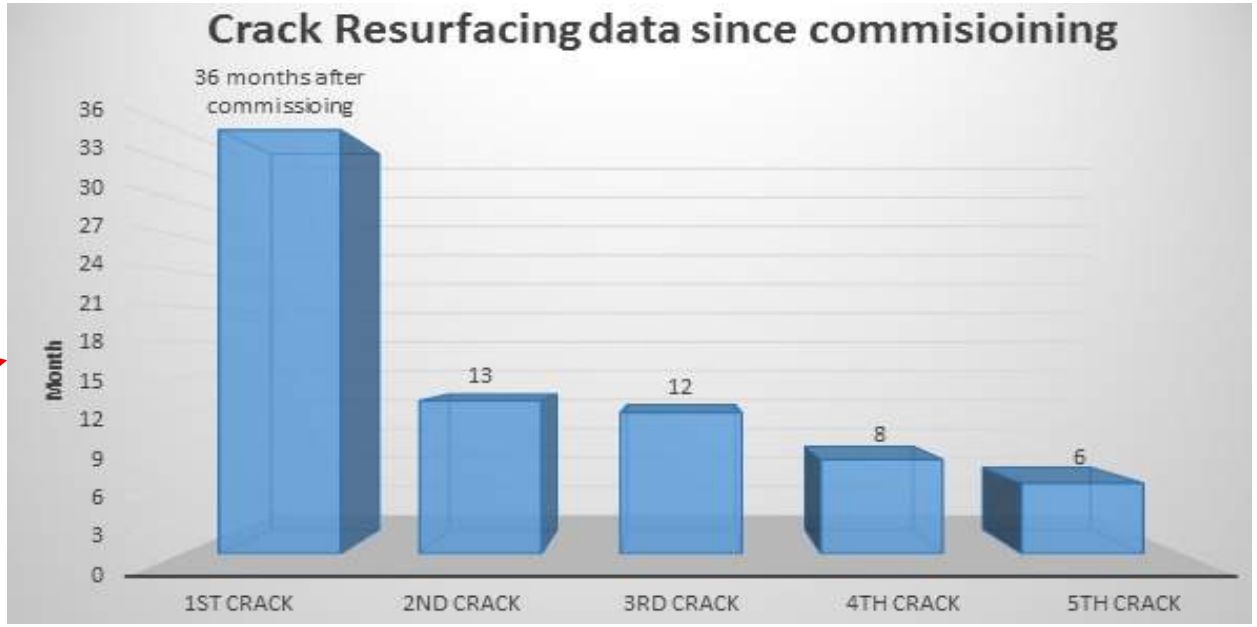
Fatigue Life & Reliability Consideration (cont'd)
Calculation of "Delta T" between Coke drum & OVHD line



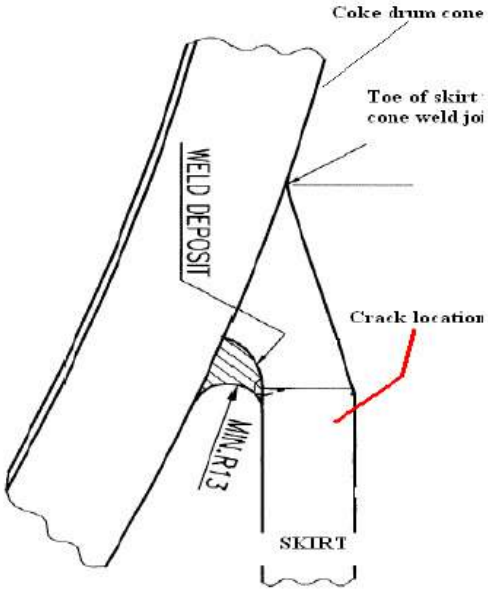
Temperature Profile for TI's @ Various elevations of coke drum (DFI)

Consideration for Skirt Repair / Modification

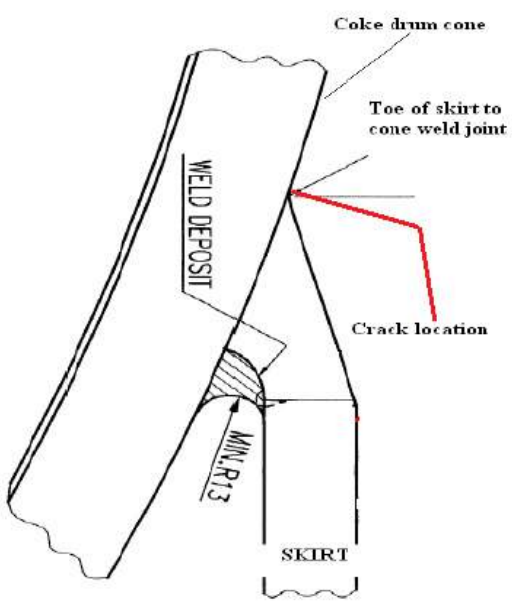




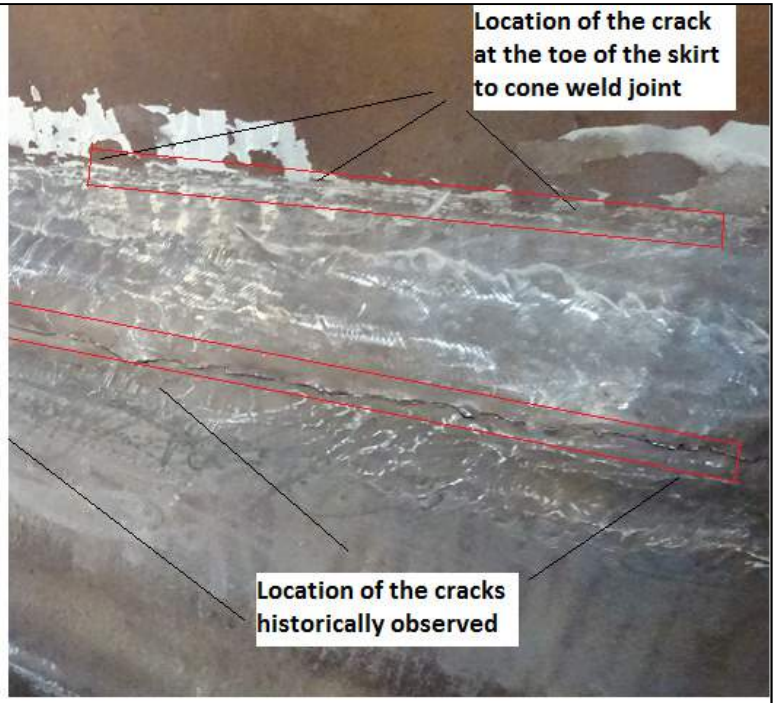
Consideration for Skirt Repair / Modification



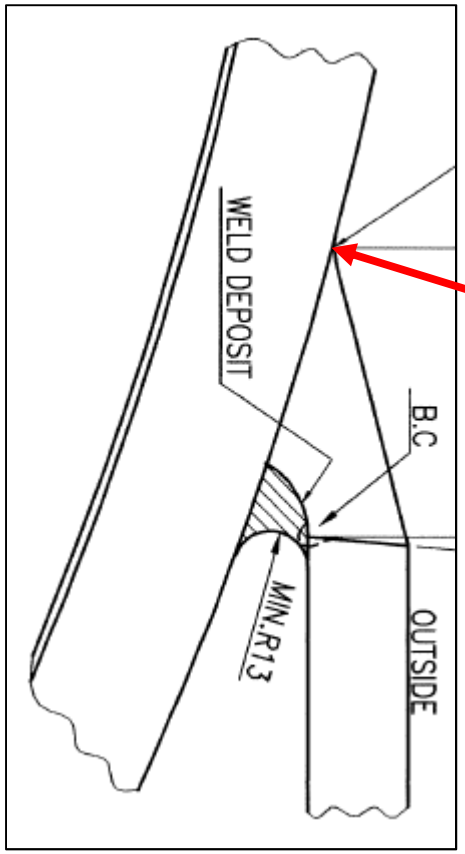
Historically, crack has been observed at this location.



First instance where the crack has propogated at the toe of the weld



Consideration for Skirt Repair / Modification



Field Repair Execution: Case # 1
(Solid Skirt Modification to Slotted Skirt)

"On-Line" fabrication Of Mock-up Sample. New Methodology for Skirt Slot & Keyhole cutting & Chamfering with radiused & smooth corner finish (both Inside & Outside Surfaces)

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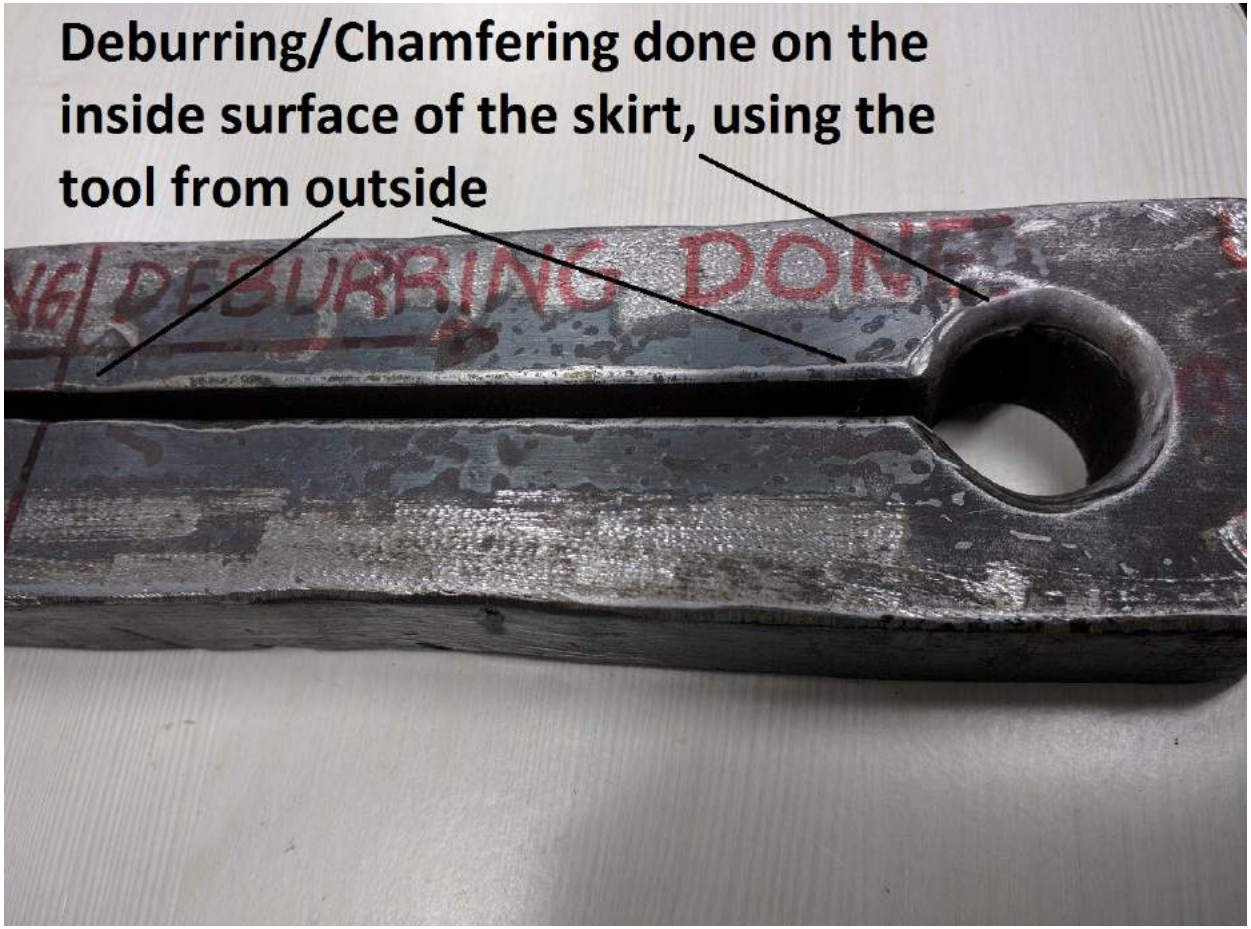
Field Repair Execution: Case # 1 (cont'd)
Mock-Up Sample Preparation of Slotted Skirt with Keyhole



Routine Inspection & Monitoring (cont'd)
Coke Drum Skirt Junction

TYPICAL INSPECTION/MONITORING FOR KNUCKLE/SKIRT

Jan 2012 : Scheduled Monthly External Visual Inspection of Skirt/Knuckle weld joints

Coke Drum	Date	Location	Inspection peep windows (Counting CW, 0°N as reference: N-->E-->S-->W)															
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
R01	07.01.2012	*Skirt joint*	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	NA
		Knuckle joint	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	NA
R02	05.01.2012	*Skirt joint*	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	NA	NA
		Knuckle joint	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	NA	NA
R03	05.01.2012	*Skirt joint*	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
		Knuckle joint	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
R04	06.01.2012	*Skirt joint*	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
		Knuckle joint	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
R05	09.01.2012	*Skirt joint*	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	NA	NA
		Knuckle joint	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	NA	NA
R06	05.01.2012	*Skirt joint*	OK	OK	OK	NI	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	NA
		Knuckle joint	OK	OK	OK	NI	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	NA
R07	09.01.2012	*Skirt joint*	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	NA
		Knuckle joint	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	NA
R08	05.01.2012	*Skirt joint*	OK	OK	OK	NI	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	NA
		Knuckle joint	OK	NI	OK	NI	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	NA

Legends

OK:	No visual indication of any crack
HLC:	Hair line cracklike indication visible.
NI:	Not inspected this time due to improper cutting of glass wool/ obstruction of alt drain line or scaffolding pipe.
NA:	Not available.
	Indications "as is" wrt last inspection.
	Indications increased wrt last inspection.
	New indications observed this time.

CD summary	Skirt	no. of drums	Knuckle	no. of drums
indications "as-is" wrt last inspection	-	-	-	-
indications increased	-	-	-	-
new indications	-	-	-	-
Total drums with HLC visible	NIL	NIL	NIL	NIL

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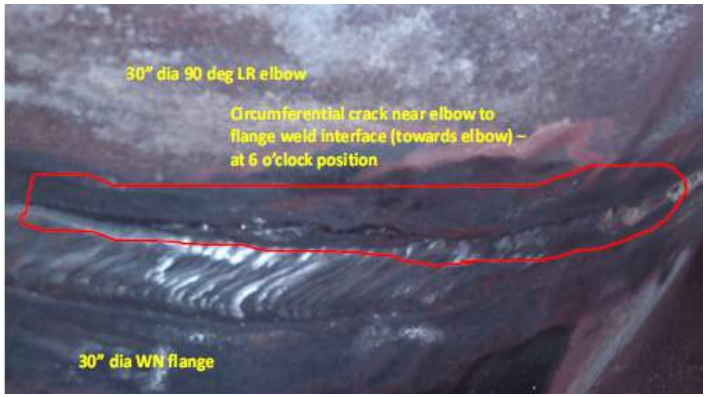
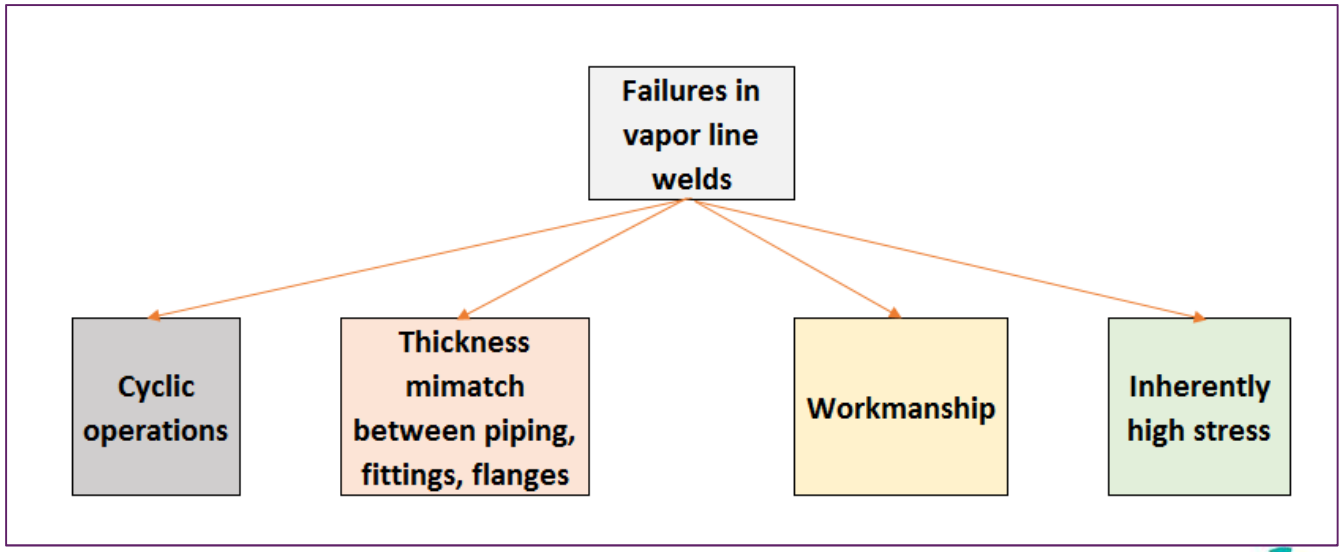
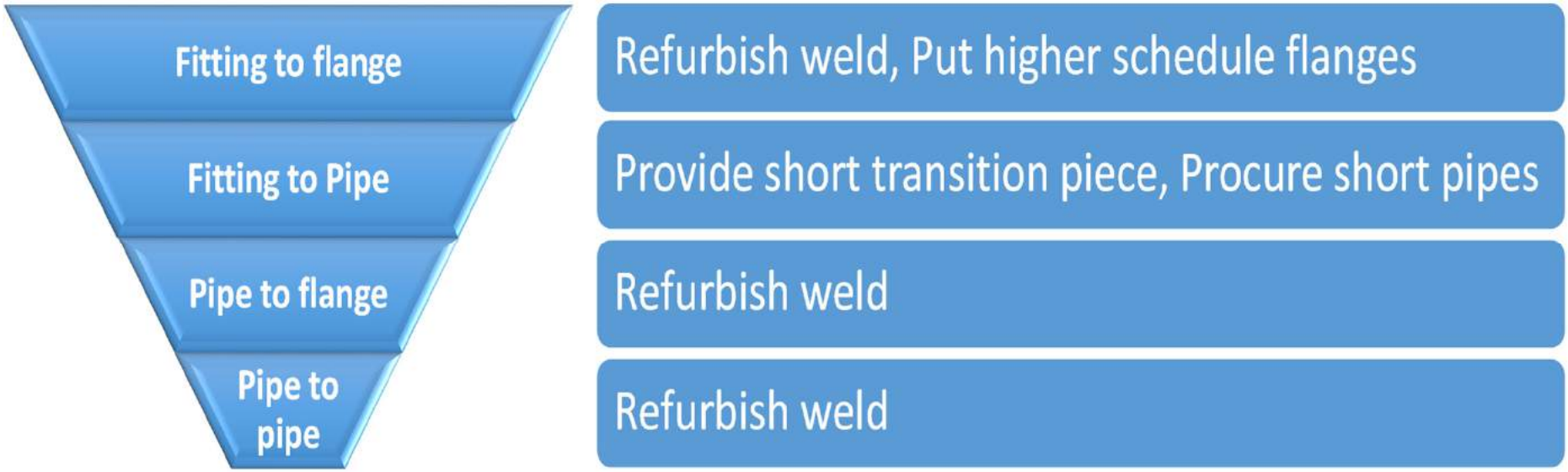
FIELD REPAIR CASE # 2: Vapor Line Weld Crack at Thickness Mismatch (Fitting to Pipe)





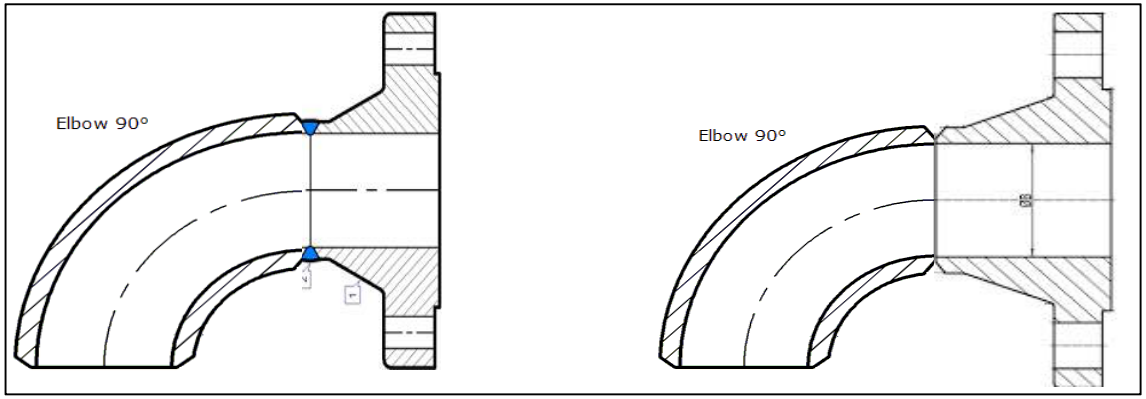
FIELD REPAIR CASE # 2: Vapor Line Weld Crack at Thickness Mismatch (Fitting to Pipe)

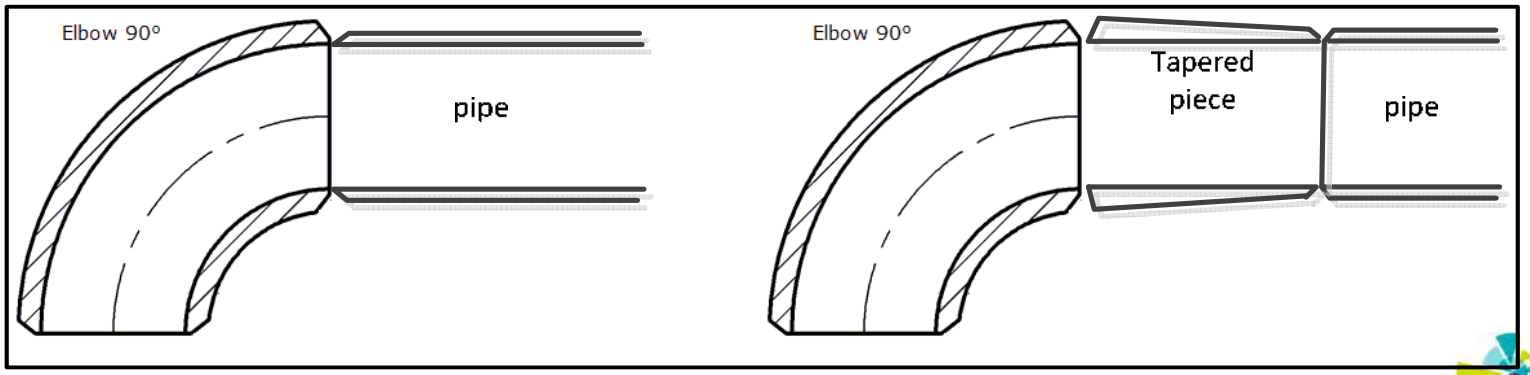


FIELD REPAIR CASE # 2: Vapor Line Weld Crack at Thickness Mismatch (Fitting to Pipe)

New methodology of vapor line weld crack repair

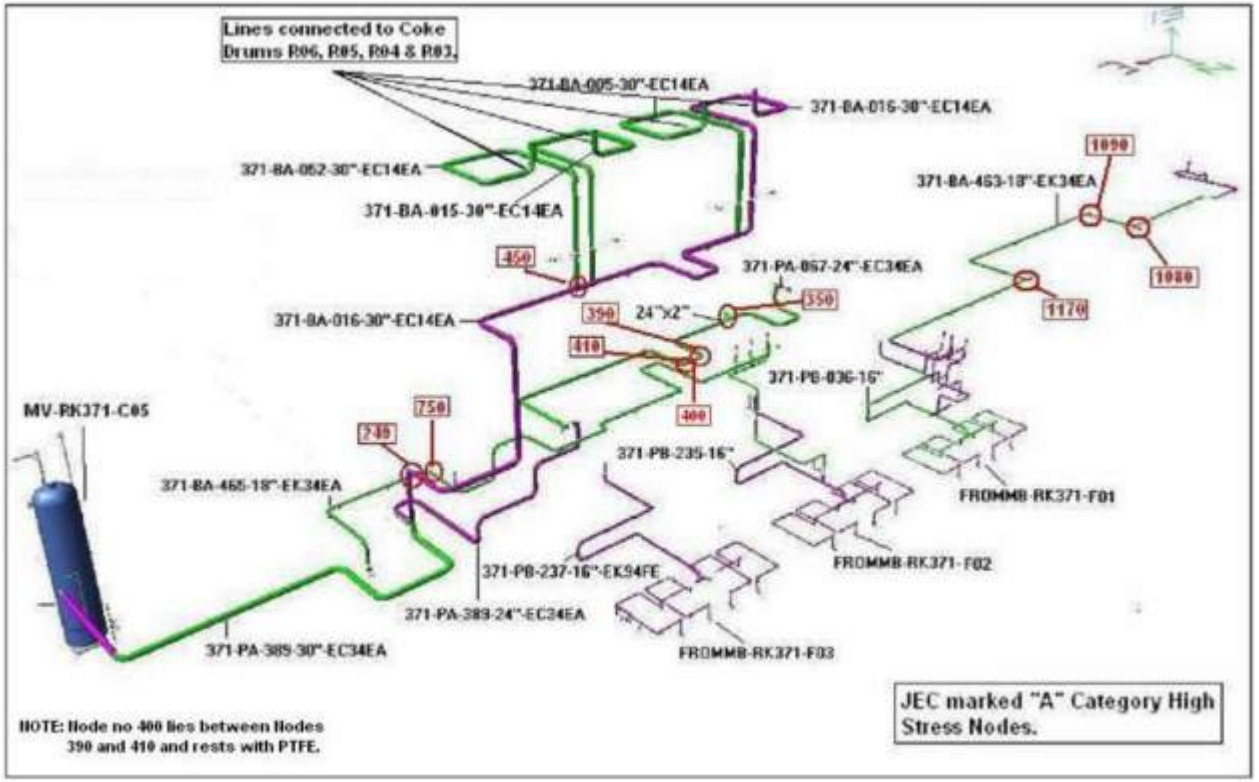
using taper thickness transition spool to minimize stress riser





Routine Inspection & Monitoring (cont'd)
Coke Drum Critical Piping Welds

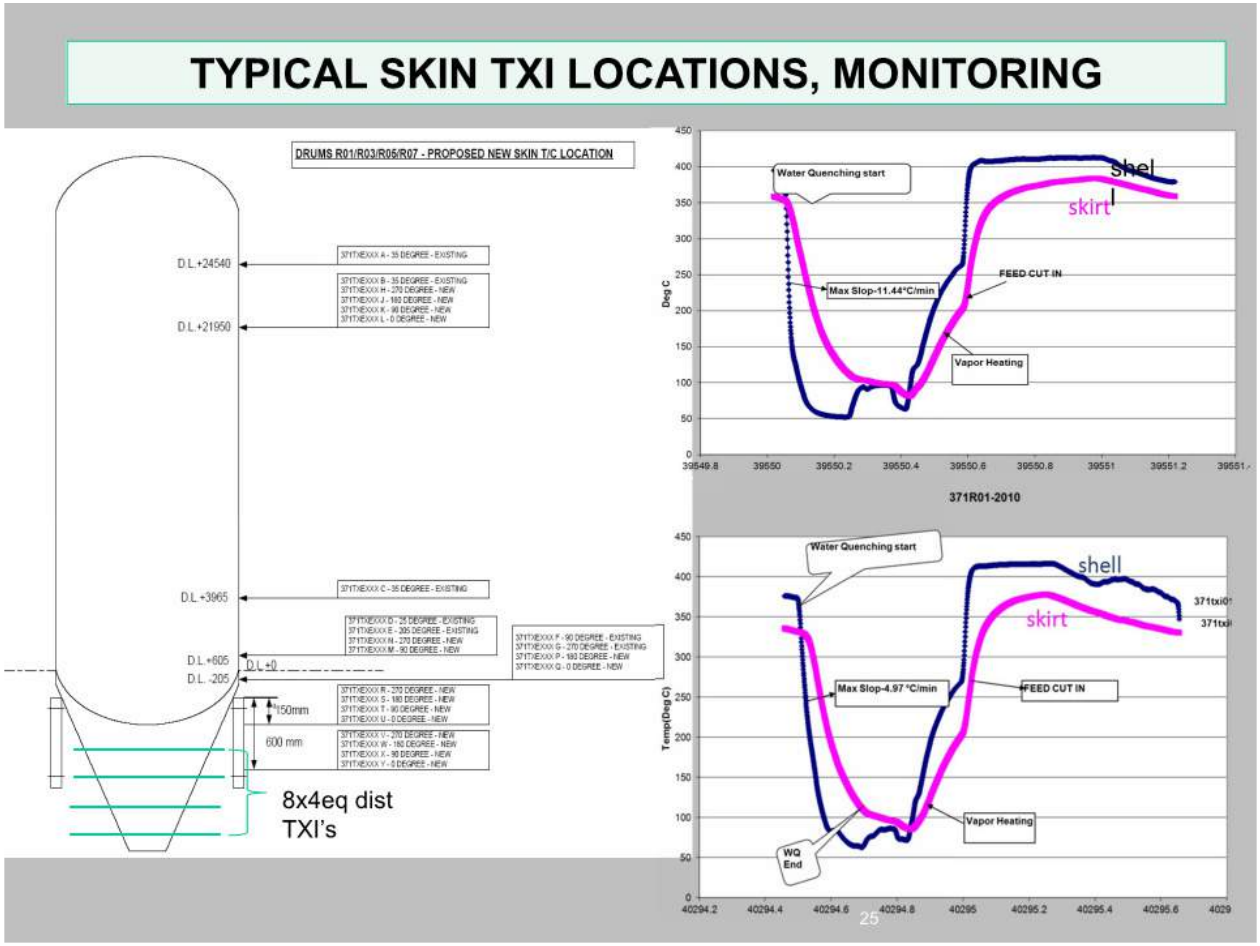
High Stress Welds and Nodes



Coke Drum & Piping
Routine Inspection & Monitoring

	On line	Off line
Skirt	16 window inspection lanes (Visual monthly inspection)	Visual / MPI / PA UT (during pigging)
	Anchor bolts (Visual, UFD once in 2 years)	
	Temperature data monitoring (six monthly)	
Shell	Banana movment	Ext PAUT @ strategic circ welds (every pigging)
	LASER scans / Bulge mapping / Bulge assessment (condition based)	Ext PAUT @Nozzles (every shutdown)
		Hardness surveys of clad/welds (every shutdown)
Piping	Supports (visual 3 - 5 years)	High Stress Nodes

Coke Drum Thermal Operation / Thermal Gradient Optimization



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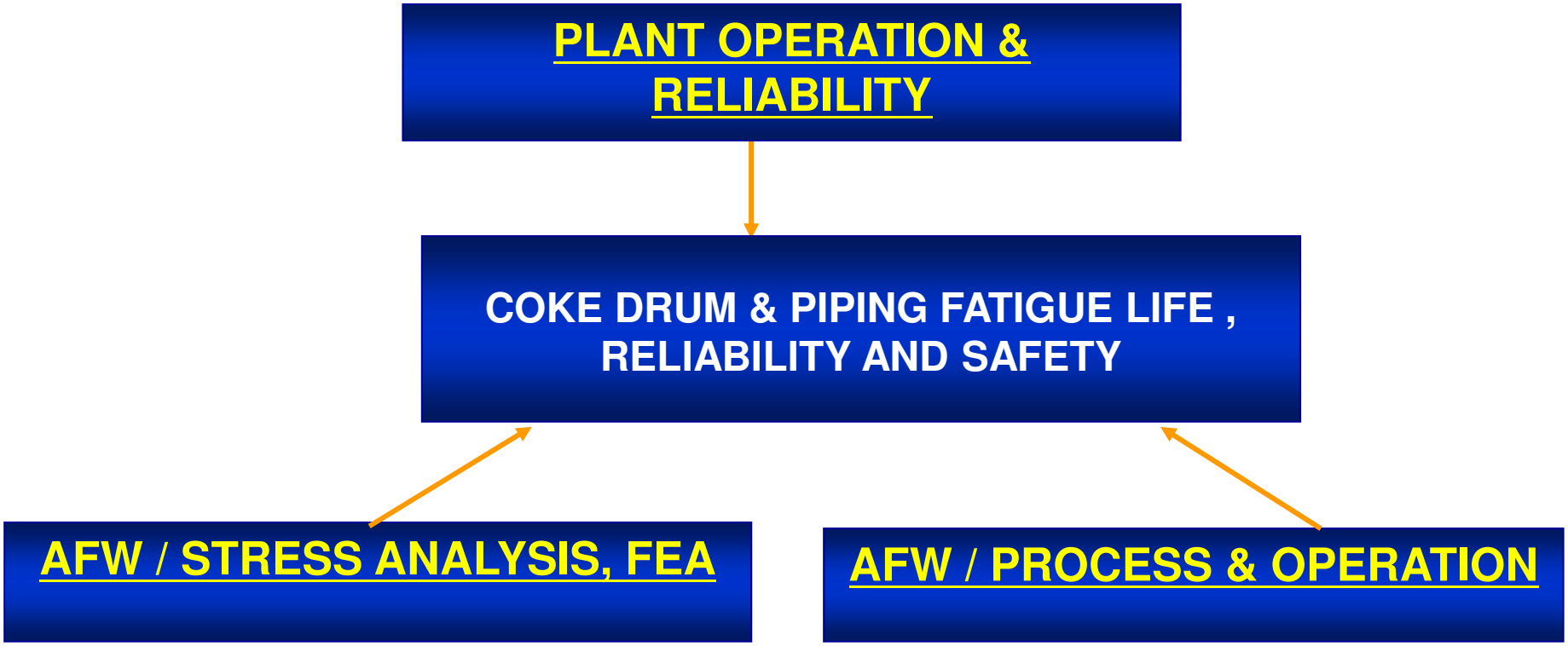
Coke Drum & Piping Monitoring, Assessment, Repair for Fatigue Life and Safety Improvement



Thank you