Coke drum Monitoring & Inspection for Fatigue Life and Safety Improvement

2012 Coking.com, Ft. McMurray, Canada Presentation

Amish B. Jani
Asstt Vice President
(Corrosion & Inspection)

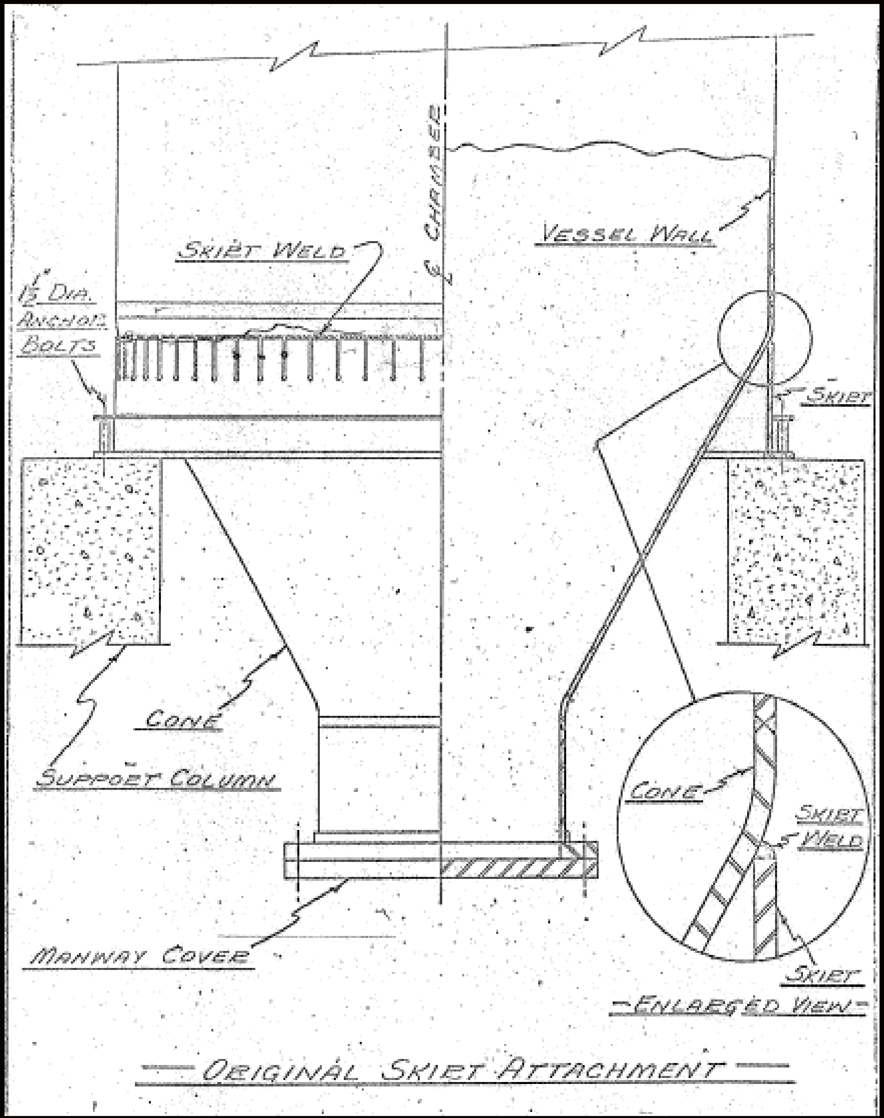
Reliance Industries Limited
Growth is Life

Coking.com®

Tej Chadda
Chief Technology Engineer

FOSTER WHEELER

Safety Moment - Consequences of Monitoring & Routine Inspection



- **Develop plan for Monitoring during Operation and Perform Routine Inspection / Maintenance**

Reliance Industries Limited
Growth is Life

FOSTER WHEELER

Purpose of Monitoring & Inspection Program

- **Coke drums and overhead piping systems (Vapor, PSV, Blowdown) undergo severe temperature changes, thermal cycles and movement, including bowing, on a daily basis. This causes failure due to thermal fatigue.**
- **Inexpensive coke drum monitoring program which plant personnel can use from the start of operation to minimize thermal fatigue damage, pro-actively optimize thermal operation, increase awareness towards safety, and to avoid unplanned shutdown.**

Reliance Industries Limited
Growth is Life

FOSTER WHEELER

Factors Effecting Coke Drum Fatigue Life, Safety and Reliability

- **(1) Mechanical Design**
- **(2) Fabrication**
- **(3) Thermal Operation**
- **(4) Monitoring of TI’s and Thermal Gradient**
- **(5) Inspection of Critical Welds**

Reliance Industries Limited
Growth is Life

FOSTER WHEELER

Coke Drum - Common Damage Modes

- **Cracking of the support skirt weld to drum shell / knuckle junction and / or skirt bulging**
- **Cracking and bulges (distortion) of the drum shell mainly at / near circumferential seams**
- **Overhead nozzle cracking (Vapor, PSV)**
- **Overhead Piping Component failure**

Reliance
Industries Limited
Growth is Life

FOSTER WHEELER

Current Industry Trend/ Thermal Fatigue Considerations

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

Reliance Industries Limited
Growth is Life

FOSTER WHEELER

Outline of Routine Inspection and Monitoring program

(1) Identify critical welds for inspection and provide means for routine visual inspection

(2) Inspect shell bulges and cladding cracks.

(3) Monitor coke drum skin temperature / gradient using (TI) and keep within "design thermal guidelines"

(4) Verify (bowing) "banana" movement of coke drum

(5) Verify "free" unobstructed movement of drum & piping

(6) Monitor Vibration of drum and overhead piping.

Reliance Industries Limited
Growth is Life

FOSTER WHEELER

Routine Inspection and Monitoring Program (cont'd)

#1. Identify critical welds for inspection and provide means for routine visual inspection.

- **Provide "Inspection Lanes" and removable insulation support for frequent inspection of critical weld seams, including the following:**

  (a) Circumferential Welds on Shell

  (b) Skirt to Shell / Knuckle Welds

Routine Inspection and Monitoring Program (cont'd)

Skirt Attachment Welds – Routine Inspection

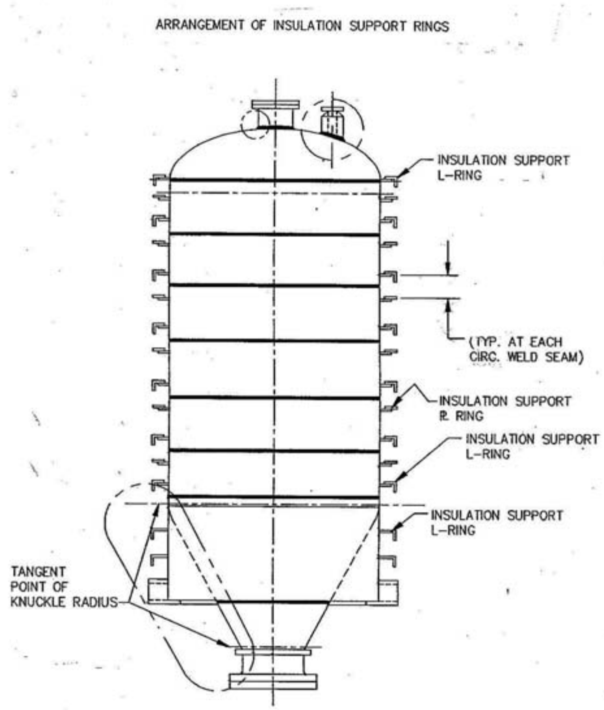
- **Cracking of skirt attachment weld is probably the most widespread maintenance issue. Skirt cracks could compromise the integrity of drum support and / or cause fire if excessive crack length penetrates shell wall.**

- **Skirt to shell welds are the simplest to access and inspect but typically goes unnoticed due to non-leaky cracks covered with insulation.**

Reliance
Industries Limited
Growth is Life

FOSTER WHEELER

Fig #1 – Inspection Lanes at Critical Weld Seam (Removable Insulation)

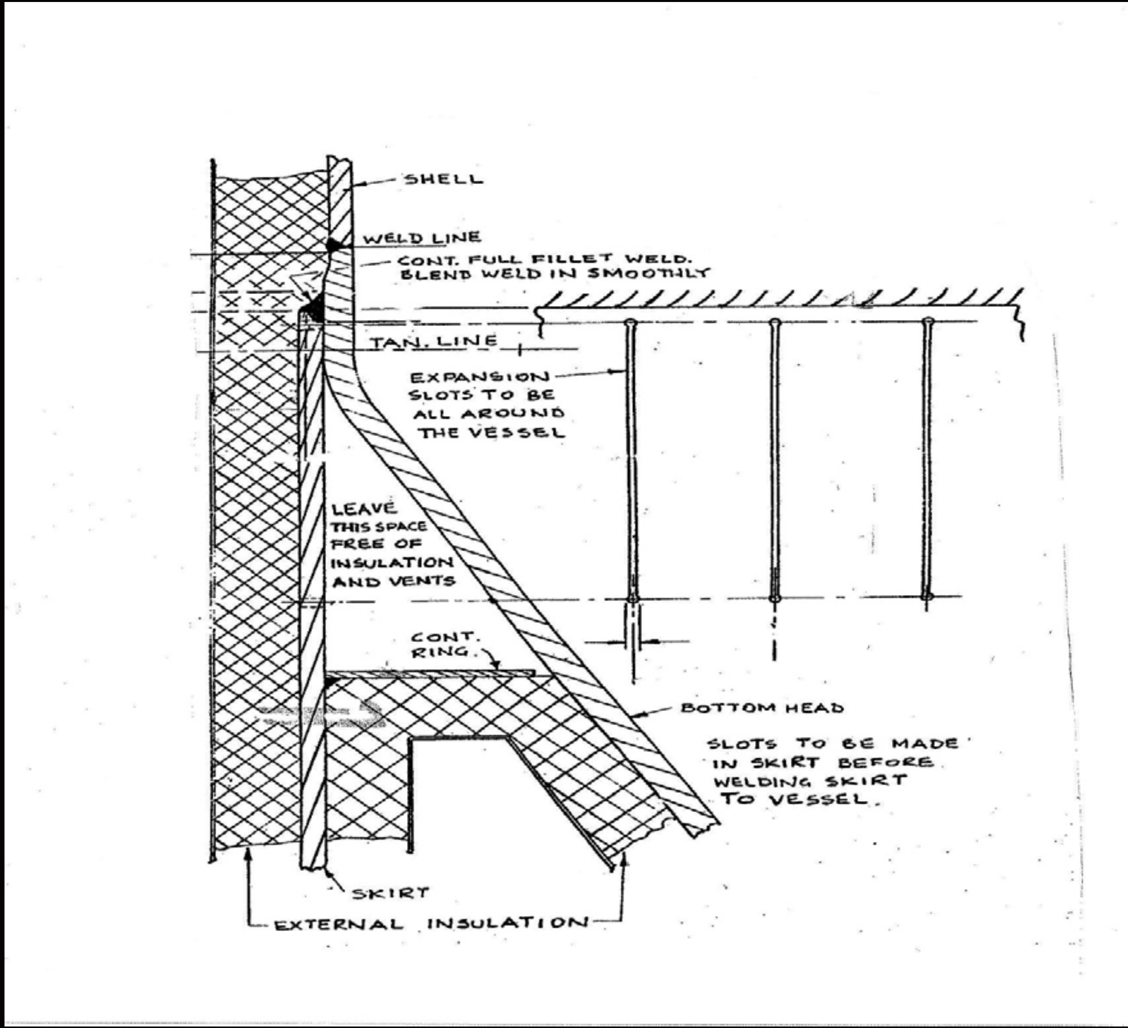


Inspection Lanes at each Circ. Seam
(Including Skirt Attachment Welds Provided with Removable Insulation)

Reliance Industries Limited
Growth is Life

FOSTER WHEELER

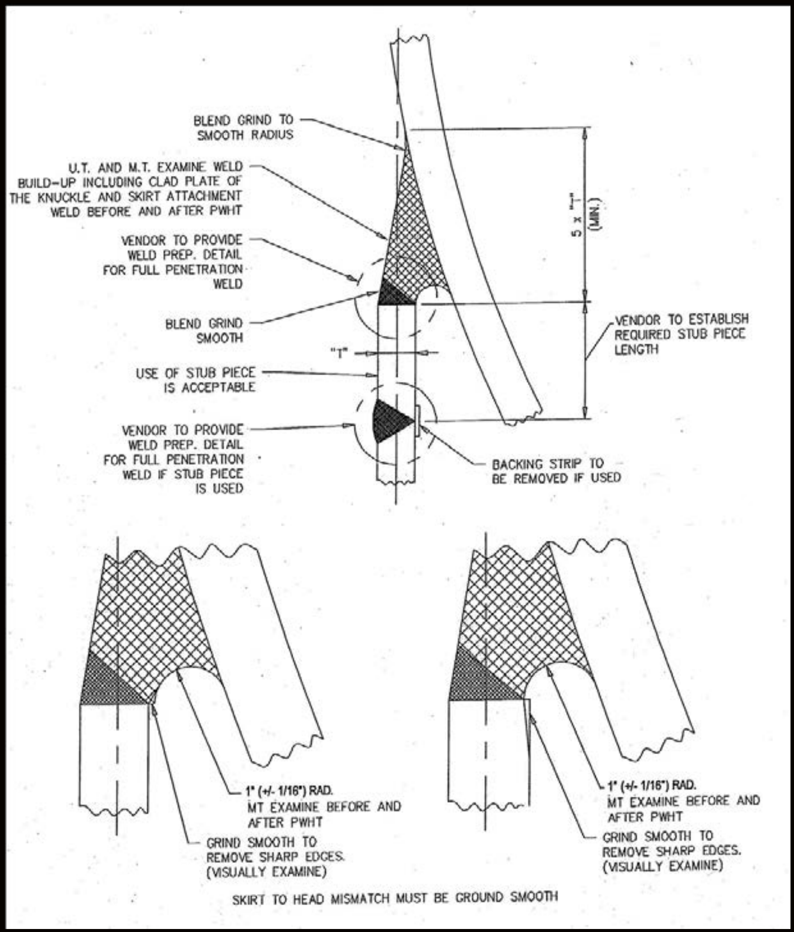
Figure #2 – Lap Joint Slotted Skirt Junction



Reliance Industries Limited
Growth is Life

FOSTER WHEELER

Figure #3 – Coke Drum Skirt to Head Girth Seam Weld



Reliance Industries Limited
Growth is Life

FOSTER WHEELER

Routine Inspection and Monitoring Program (cont'd)

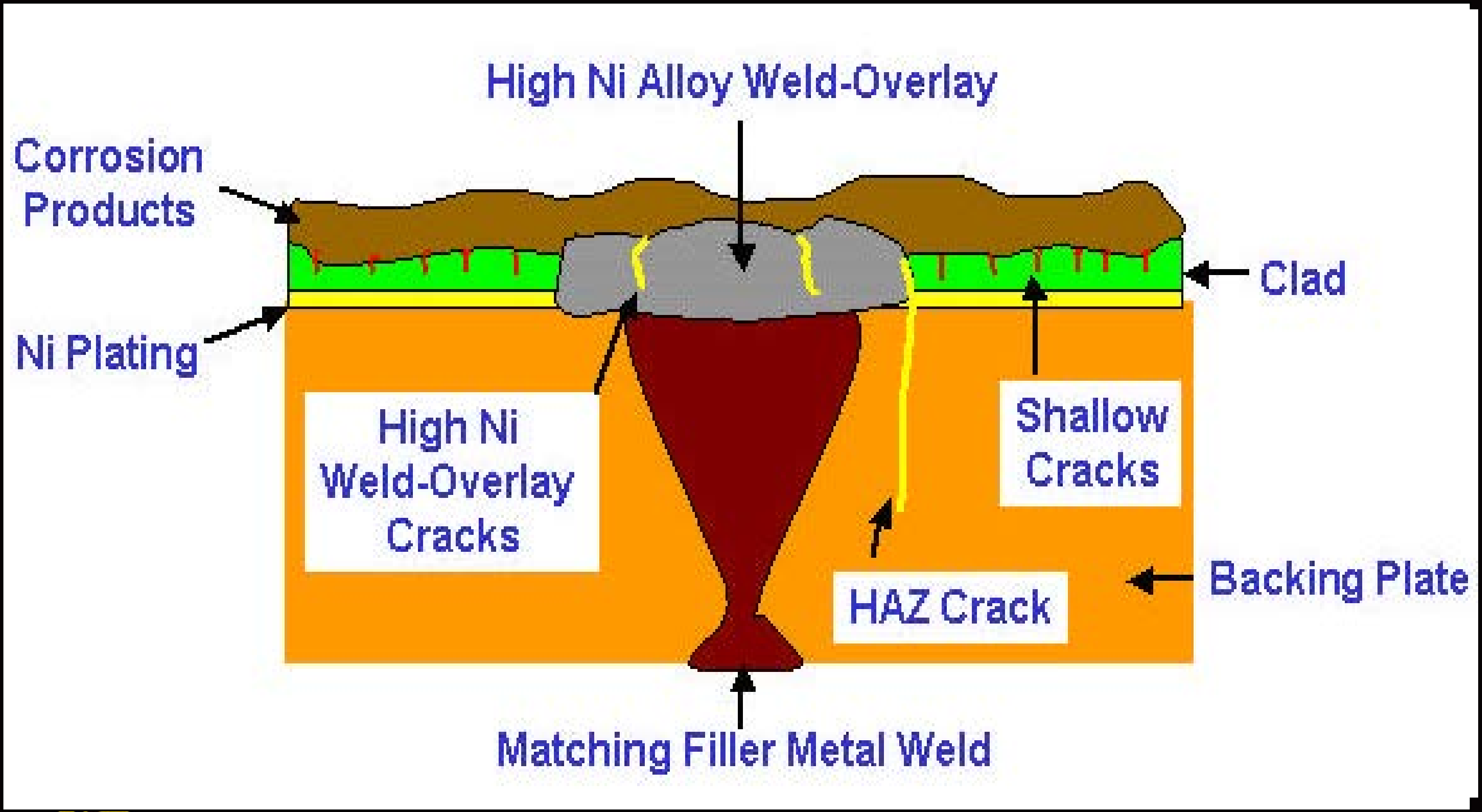
2. Shell Bulges and Cladding Cracks

- Inspect and monitor all shell bulged areas and circ. seams with disbonded or cracked cladding. These are most likely locations for future thru-wall damage sites.
- Cracking of circumferential seams with thickness transition especially in mid-section of drum.
- Bulge formation and cladding cracks are the result of severe quench and causes thermal or corrosion fatigue.

Reliance Industries Limited
Growth is Life

FOSTER WHEELER

Fig # 4 : Critical Weld Junction (Circ Seam)



Reliance Industries Limited
Growth is Life

FOSTER WHEELER

Outline of Routine Inspection and Monitoring program (cont'd)

3. Monitor coke drum skin temperature / gradient using (TI's) and keep within "design thermal guidelines"

(a) Using TI's provided on shell immediately above bottom tangent line and on skirt, verify temperature ramps during heat-up and quench cycles.

(b) Severe transients during heat-up lead to skirt failure. Severe transients during "Quench" lead to shell bulges.

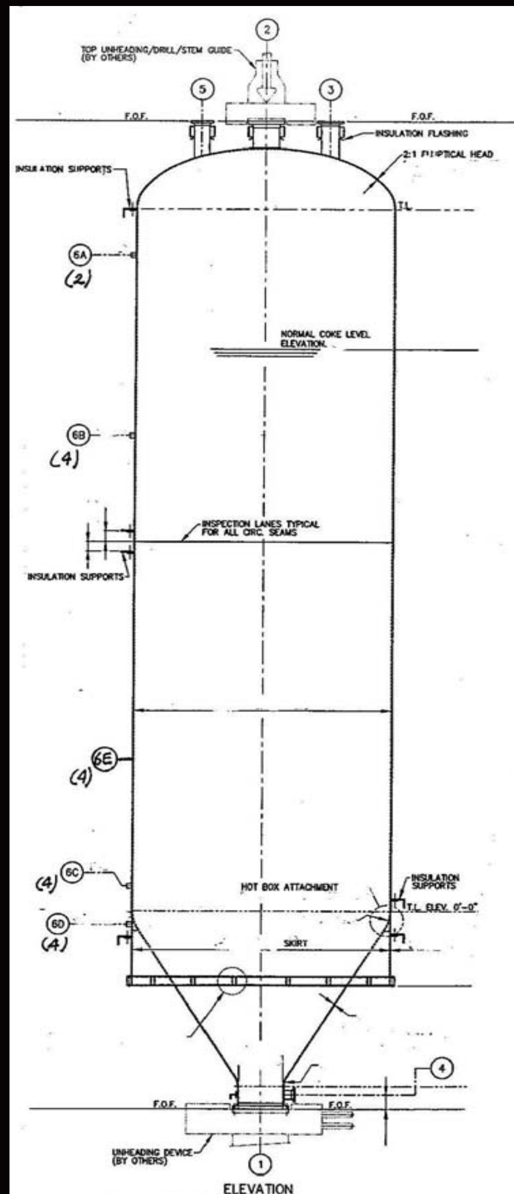
(c) Verify circumferential temperature differential on shell.

(d) If thermal guidelines are not met, consider operational changes / optimization and / or frequent inspection.

Reliance Industries Limited
Growth is Life

FOSTER WHEELER

Figure #5 – Coke Drum (TI's & Monitoring)

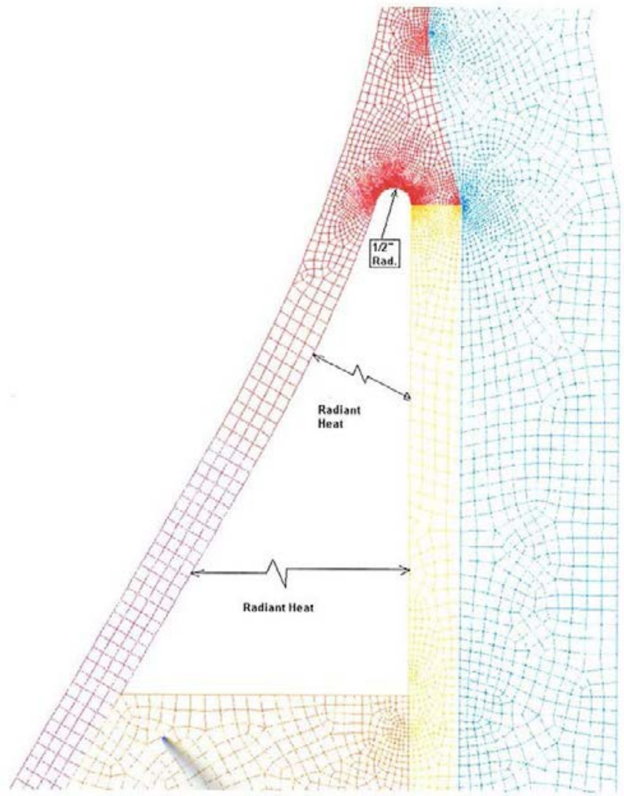


Reliance
Industries Limited
Growth is Life

FOSTER WHEELER

Figure #6 – Finite Element Analysis

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



Reliance Industries Limited
Growth is Life

FOSTER WHEELER

Outline of Routine Inspection and Monitoring Program (cont'd)

#4. Verify (bowing) "banana" movement

- (a) Banana movement is caused by uneven cooling of opposite walls of drum, especially during quenching.

  (b) Using the nozzles on top of Coke drum and 2-reference points at 90 degrees apart, the horizontal movement of coke drum can be measured during entire operating cycle including water quench.

  (c) Excessive banana movement is an indication of severe quench and channeling leading to shell bulge. This causes clearance and nozzle loading problems.

Reliance Industries Limited
Growth is Life

FOSTER WHEELER

Outline of Routine Inspection and Monitoring program (cont'd)

#5. <u>Verify "free" unobstructed movement of overhead Vapor line, PSV system and for Coke Drum</u>:

(a) The movements should include bowing (banana) effect and thermal effect considering coke drum and line.

(b) Prior to start-up and after the line and coke drum are insulated, verify structural clearances between lines and columns, beams / floor penetrations etc.

(c) Verify structural clearances during operation specially during water quench.

Reliance Industries Limited
Growth is Life

FOSTER WHEELER

Outline of Routine Inspection and Monitoring program (cont'd)

#6. Verify magnitude of Vibration of coke drum and overhead piping system

Verify if the vibration is significant during water quench, coking and coke cutting. Measure displacement at top of drum and on the line at significant locations.

Reliance Industries Limited
Growth is Life

FOSTER WHEELER

‘Operational Guidelines’ for Coke Drum Life Improvement

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**

Reliance
Industries Limited
Growth is Life

FOSTER WHEELER

Coke Drum Monitoring Program – *Fatigue Life / Safety Improvement* (cont'd)

PLANT OPERATION

COKE DRUM LIFE EXTENSION, RELIABILITY AND SAFETY

FW / STRESS ANALYSIS, FEA

FW / PROCESS & OPERATION

Reliance Industries Limited
Growth is Life

FOSTER WHEELER

RIL's TYPICAL PRO-ACTIVE INSPECTION AND MONITORING PROGRAM FOR COKE DRUMS

	On-line/Routine	Offline (e.g. during pigging/shutdowns)
Skirt	16-window inspection lanes: Visual *(monthly)*	Visual, MPI, PA-UT *(every pigging)*
	Anchor bolts: Visual, UFD *(2yrs)*	Anchor bolts: Visual, UFD
	TXI data review (*Six monthly)*	
Shell	Banana movement (*Six monthly)*	Ext PAUT @ strategic circ welds *(every pigging)*
	Laser Scans/Bulge mapping *(condition based)*	Ext PAUT @Nozzles *(every shutdown)*
Piping	Bulge assessment *(condition based)*	Hardness surveys of clad/welds *(every shutdown)*
	Supports: Visual (3-5yrs)	High Stress Nodes

Reliance
Industries Limited
Growth is Life

FOSTER WHEELER

TYPICAL INSPECTION / MONITORING FOR KNUCKLE / SKIRT

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

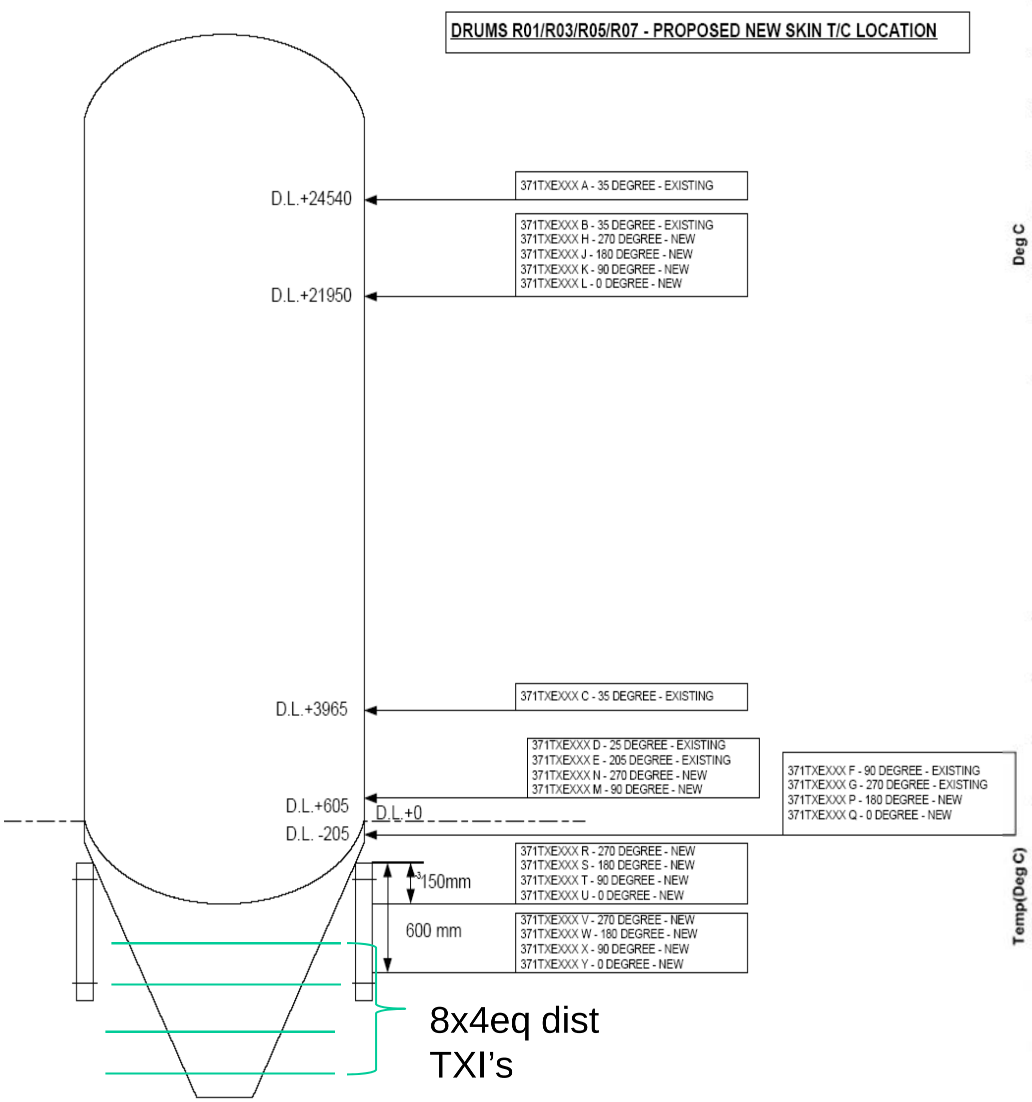
Coke Drum	Date	Location	Inspection peep windows (Counting CW, 0°N as reference: N-->E-->S-->W)															
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
R01	07.01.2012	*Skirt joint*	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	NA
		Knuckle joint	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	NA
R02	05.01.2012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

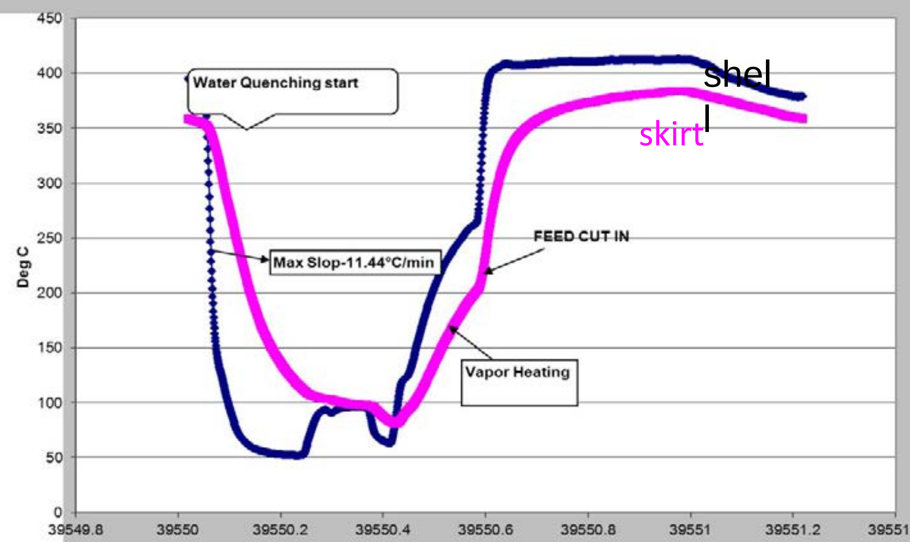
Legends

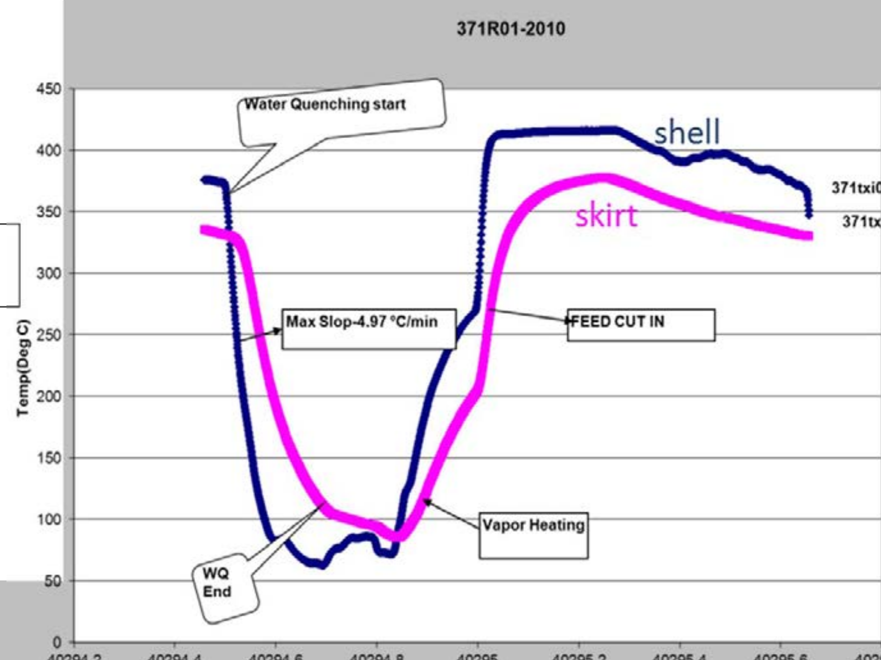
OK:	No visual indication of any crack
HLC:	Hair line cracklike indication visible.
NI:	Not inspected this time due to improper cutting of glass wool/ obstruction of alt drain line or scaffolding pipe.
NA:	Not available.
(light yellow)	Indications "as is" wrt last inspection.
(yellow)	Indications increased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

TYPICAL SKIN TXI LOCATIONS, MONITORING







TYPICAL CRACK MAPPING FOR SHELL AND KNUCKLE / SKIRT

Nomenclature

Knuckle

(mapping on outside of the drum circle)

For example,

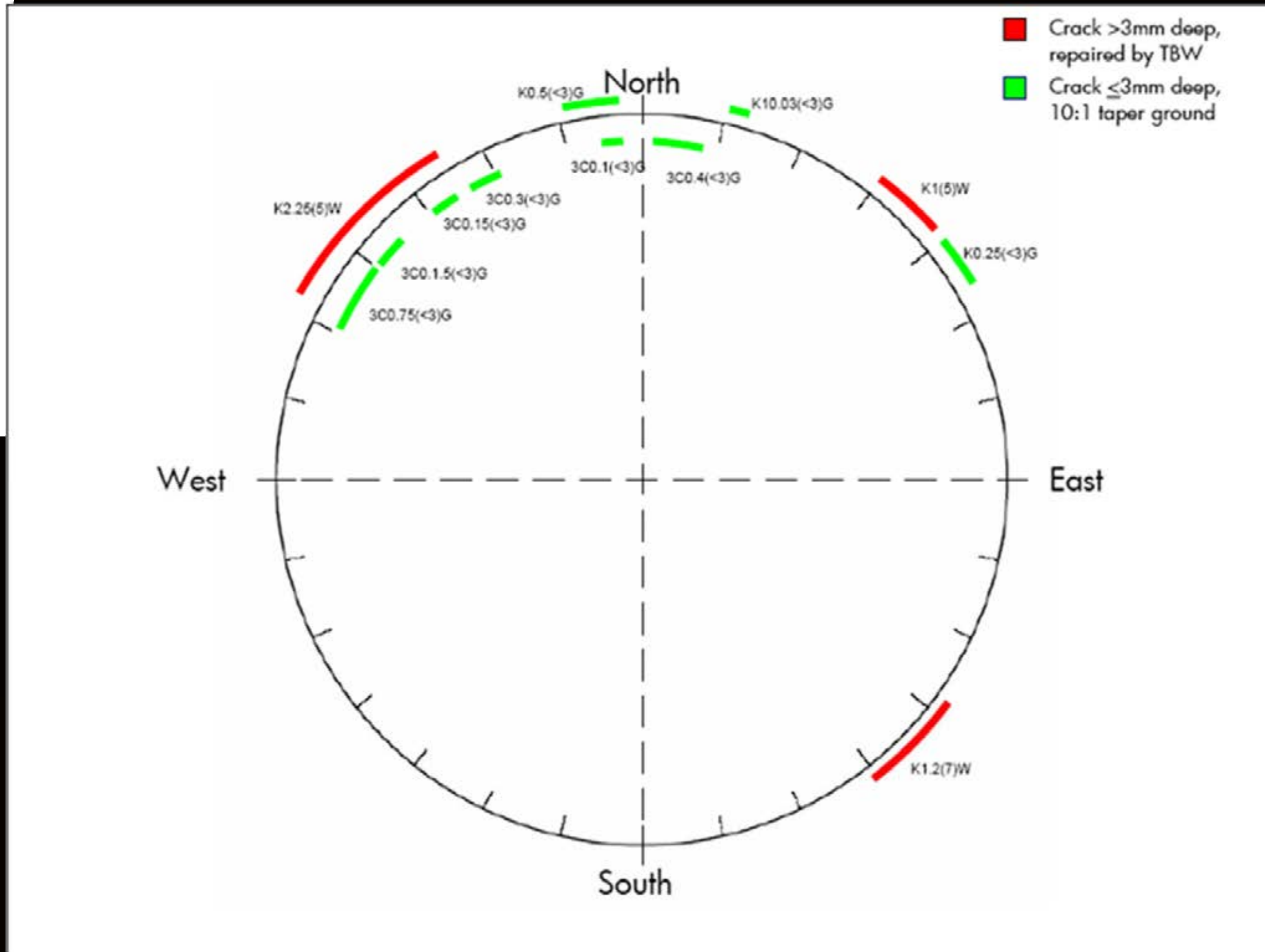
K1.5(7)W

Where,

K=knuckle

1.5=length of crack in m

(7)=max depth of crack in mm



Shell

(mapping on inside of the drum circle)

For example,

5C1.5(7)W

Where,

5C=5th Circ weld (from btm cone) on shell

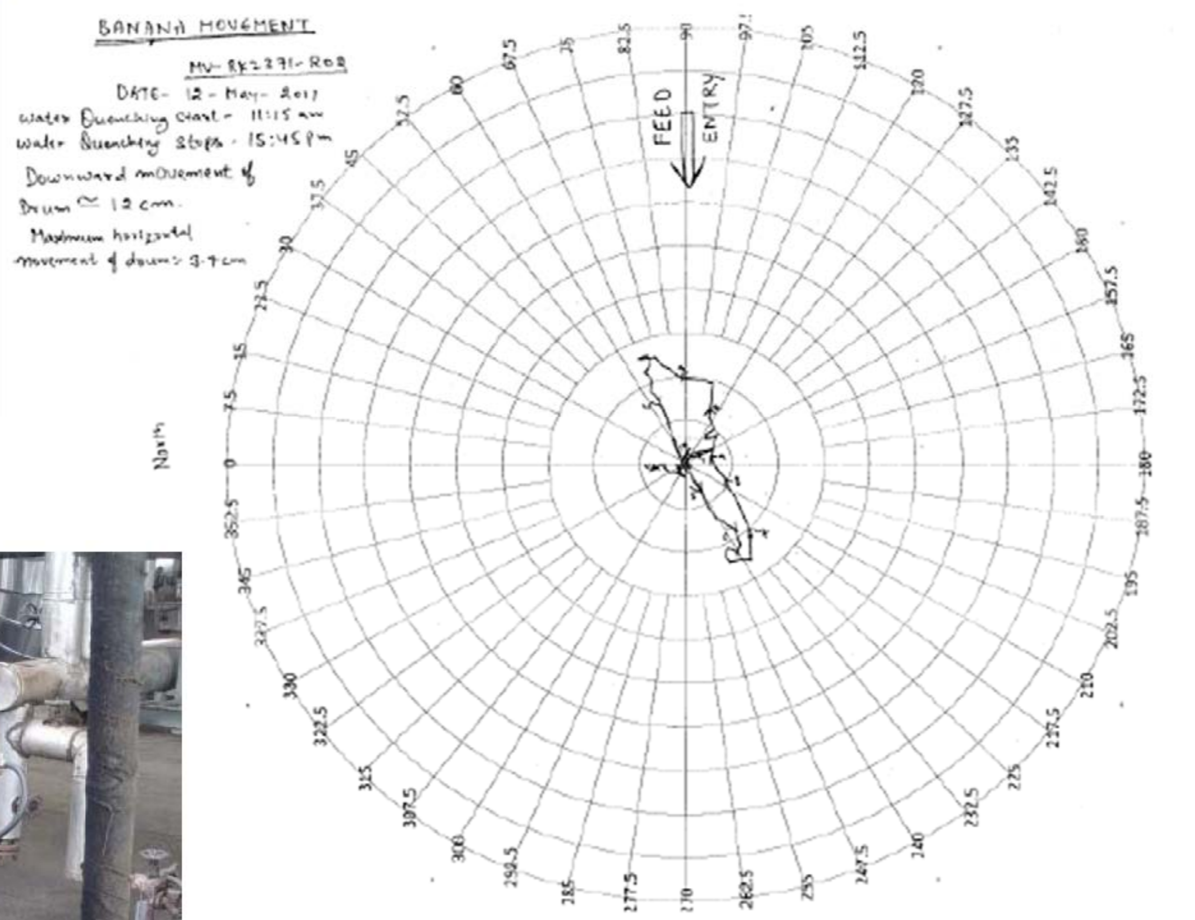
1.5=length of crack in m

(7)=max depth of crack in mm

BANANA MOVEMENT

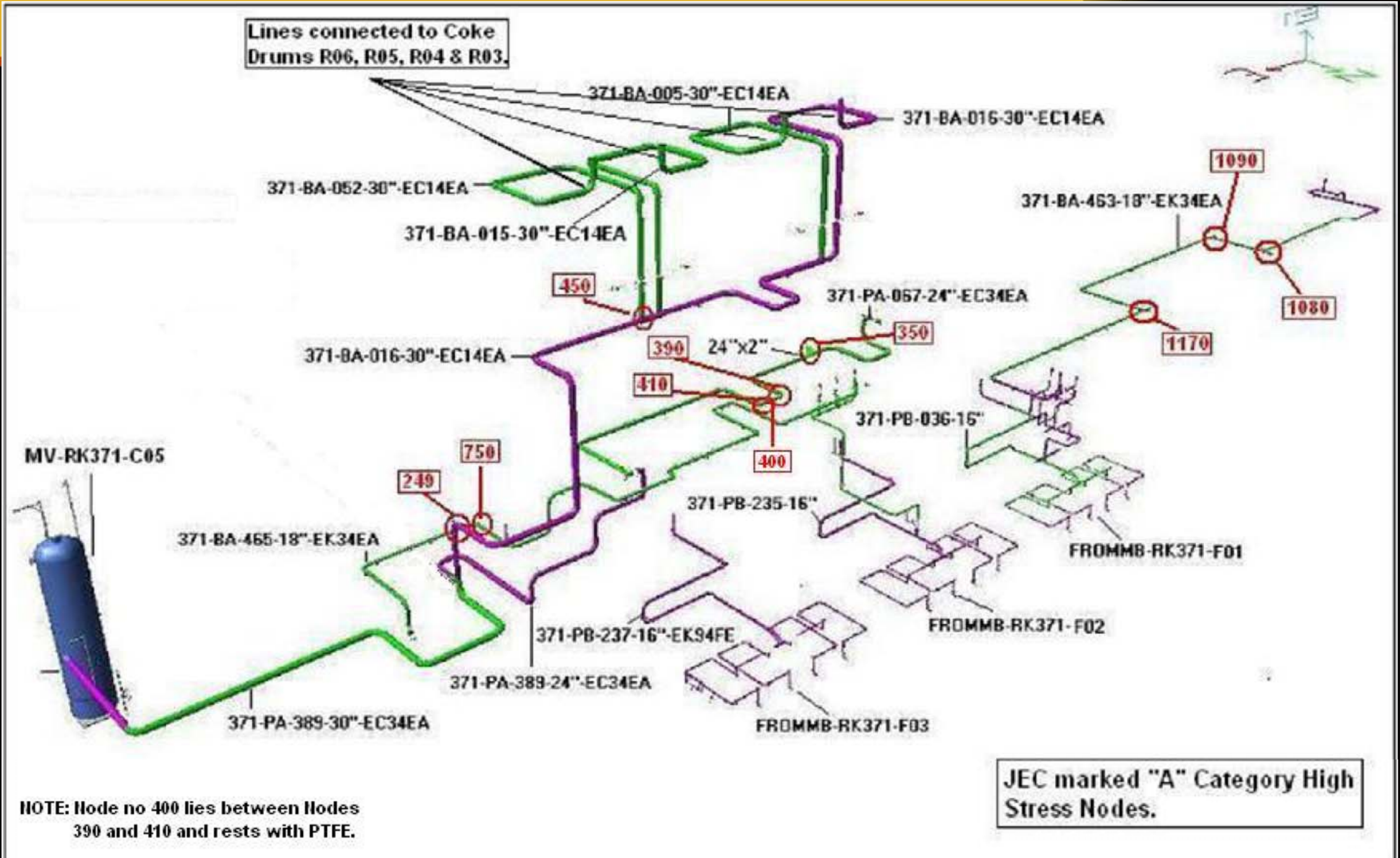
Measurements taken by attaching pointer to “TUD” and plotting the “Poler” plots

A Sample Banana Movement During Quench Cycle-01



FOSTER WHEELER

HIGH STRESS NODES



Reliance
Industries Limited
Growth is Life

Critical stressed locations mapping and criticality ranking

Periodic inspection at frequencies based on criticality

FOSTER WHEELER

SUPPORT MODIFICATIONS CARRIED OUT TO REDUCE VIBRATIONS

Thank You