

Online Monitoring and Life Extension of Coke Drums



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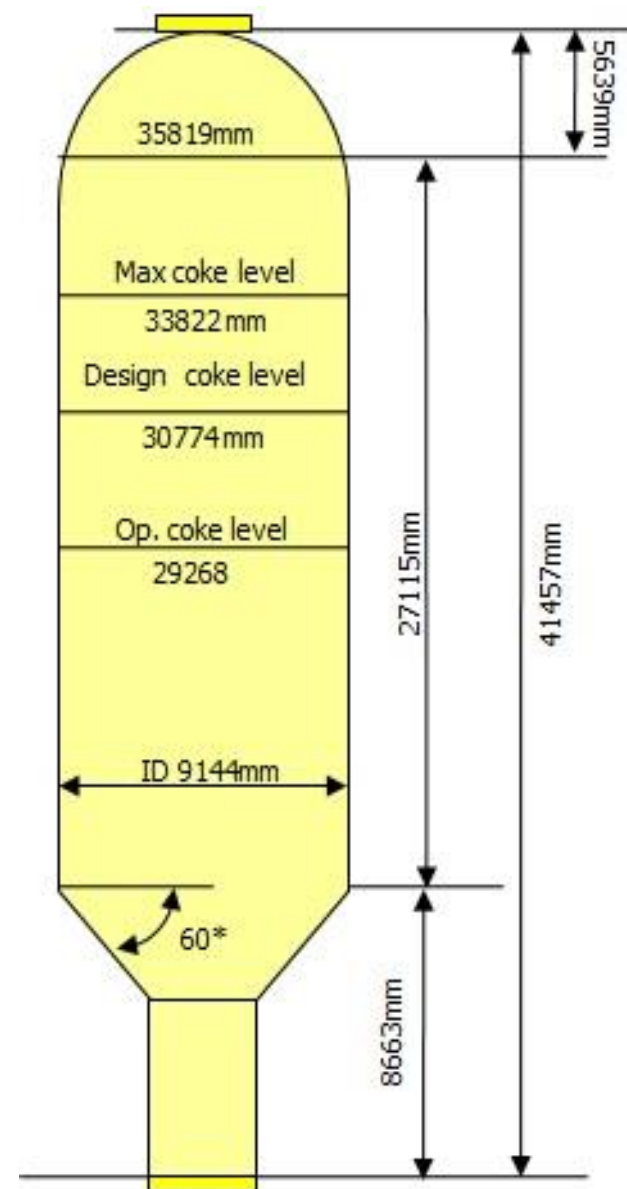
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- Introduction
- Details of Coke drums
- Coking/De-coking cycles
- Failure modes in coke drums & peripherals
- Inspection and monitoring used in MRPL
 - Drum Laser data & severity categorisation
- Strain based engineering analysis observations
- Non-destructive testing (NDT) observations
- Repair methodology and job execution details
- Summary and Conclusion

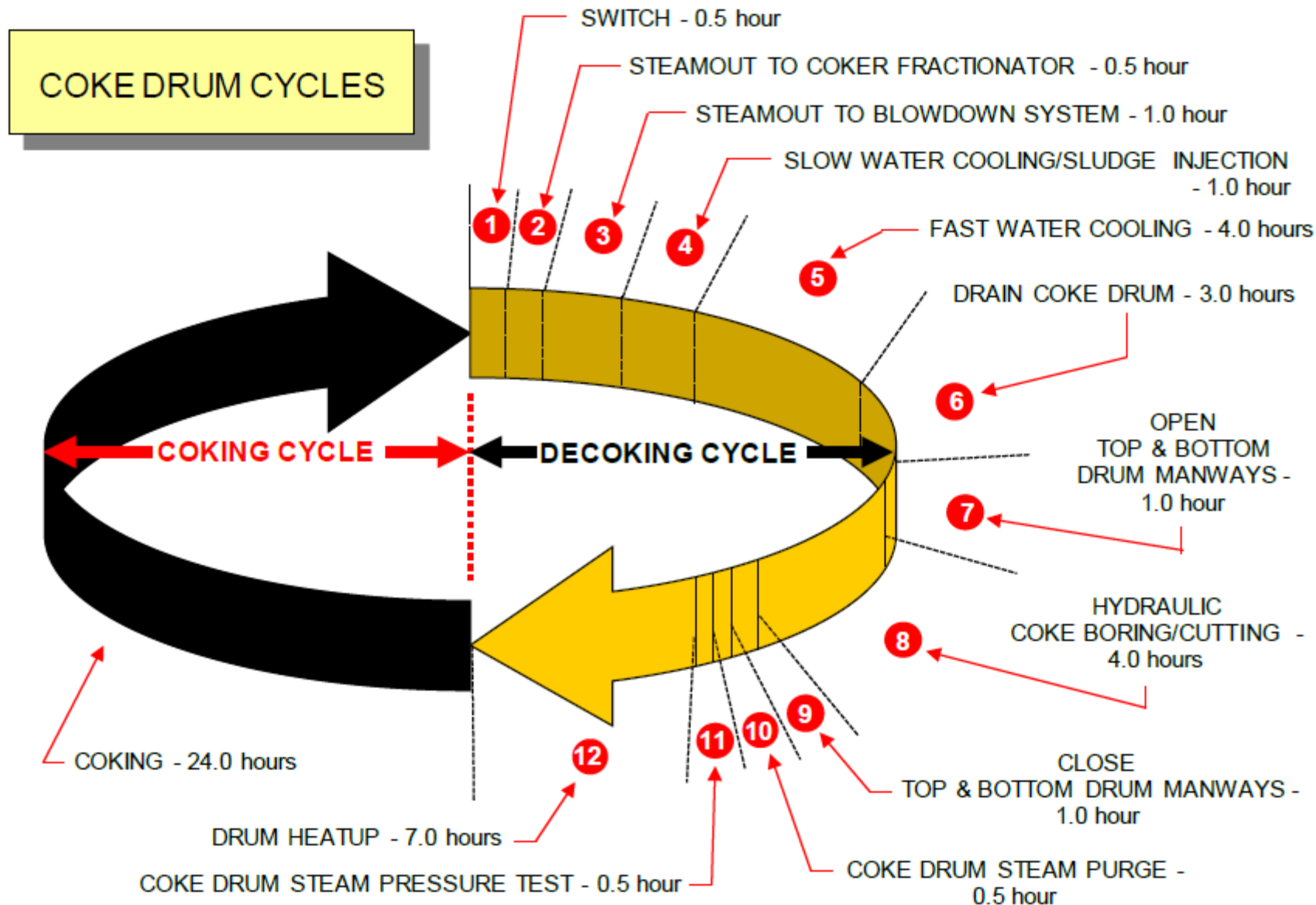
Description	Details
Commissioned in	April 2014
Unit Licensor	M/s Lummus Technology
Capacity	3.0 MMTPA
On-Stream Factor	8000 Hrs/yr (333.33 days)
Turn Down ratio	50%
Design feed TAN	< 0.5
No. of Coke drums	4 nos.
No. of Heaters	2 nos.

Details of coke drums

Description	Details
Manufacturer	M/s ISGEC Yamunanagar
Total length	41457 mm
Internal Diameter	9144 mm / 180 inches
Design coke level	30774 mm
Metallurgy	SA387 Gr 11 CL1 Base + SA240 410S Clad
Cylindrical Shell	10 nos. shell courses
Thickness of cylindrical shell	26 mm to 41 mm with min. 3 mm Clad
Feed entry nozzle	Side feed



Coking and De-coking cycles



Location of failures	Morphology	Causes
Shell & weld joints	<ul style="list-style-type: none">• Bulging and cracking• Bowing/tilting (banana effect)• Weld cracking at tri-metal joints	<ul style="list-style-type: none">• Cyclic thermo-mechanical loading• Uneven heating/cooling• Different thermal coefficient of expansion.
Skirt and concrete foundation failures	<ul style="list-style-type: none">• Key hole or weld joint Cracks• Bulging / Buckling• Damage to bolts / structural concrete	<ul style="list-style-type: none">• Cyclic thermo-mechanical fatigue• Uneven load distribution• Drum movement /Corrosion/Vibration
Piping failures	<ul style="list-style-type: none">• Cracking	<ul style="list-style-type: none">• Vibration induced mechanical fatigue

Techniques	Occasions/Purpose	Results
Laser Mapping and Remote Visual inspection	<ul style="list-style-type: none">• Initial inspection• August 2017• August 2018	<ul style="list-style-type: none">• No fabrication damage• Localized bulging-2017• Band bulging-2018
Strain based Engineering analysis	<ul style="list-style-type: none">• Strain analysis with August 2017 & 2018 Laser data	<ul style="list-style-type: none">• Identified areas with high propensity of cracking
PAUT/TOFD	<ul style="list-style-type: none">• For identifying bulge induced and weld cracking at higher PSI locations.	<ul style="list-style-type: none">• Confirmed bulge induced and weld cracking
Internal inspection & DPT/MPT	<ul style="list-style-type: none">• April-May 2019	<ul style="list-style-type: none">• Data matched with PAUT/TOFD findings

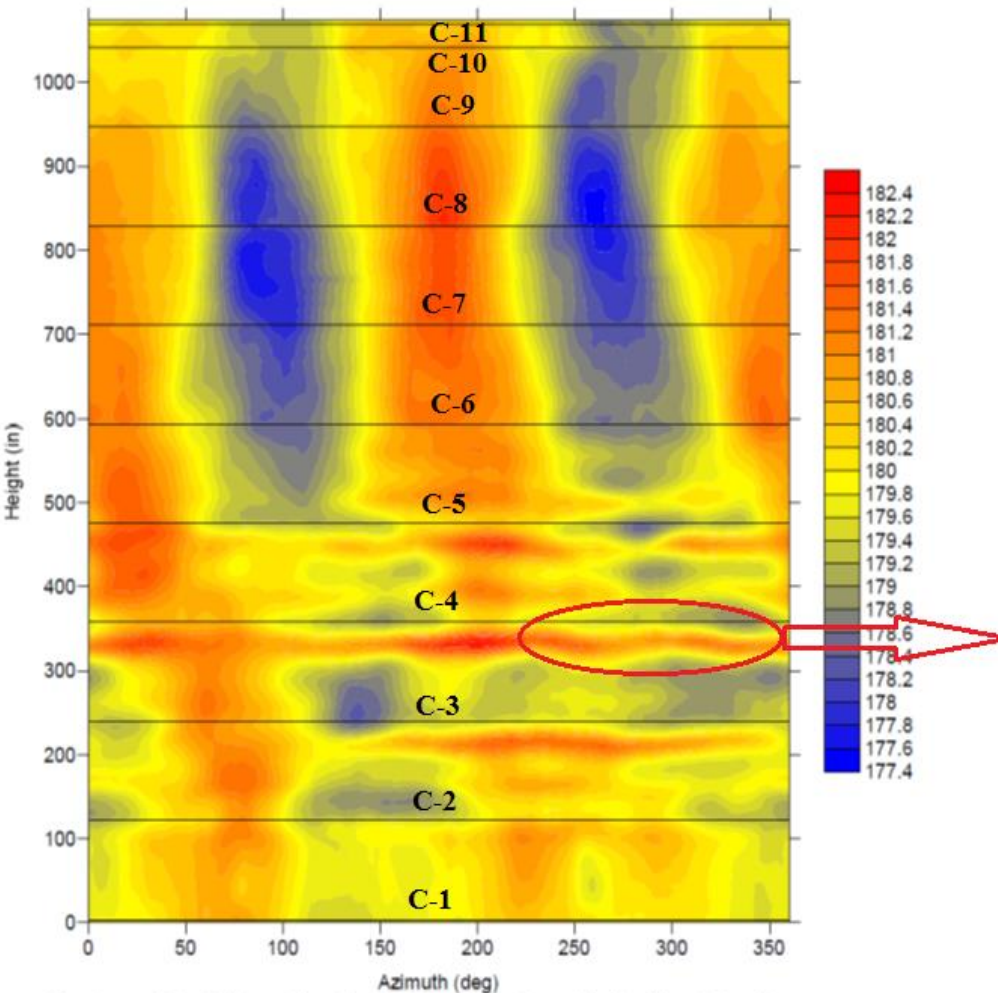
	Drum C	Drum D
Laser data	Radial growth in mm	Radial growth in mm
2017/2018	33 to 60 mm	24 to 78 mm

Range for ratio of $[(R-R_n)/R_n] \times 100$	Categorization of severity	MRPL drum severity categorisation
0%-1%	Slight	0-45 mm
1%-1.5%	Moderate	45-68 mm
1.5% >=	Severe	69 and above

R- Actual radius measured by Laser mapping

R_n- Nominal radius of drum

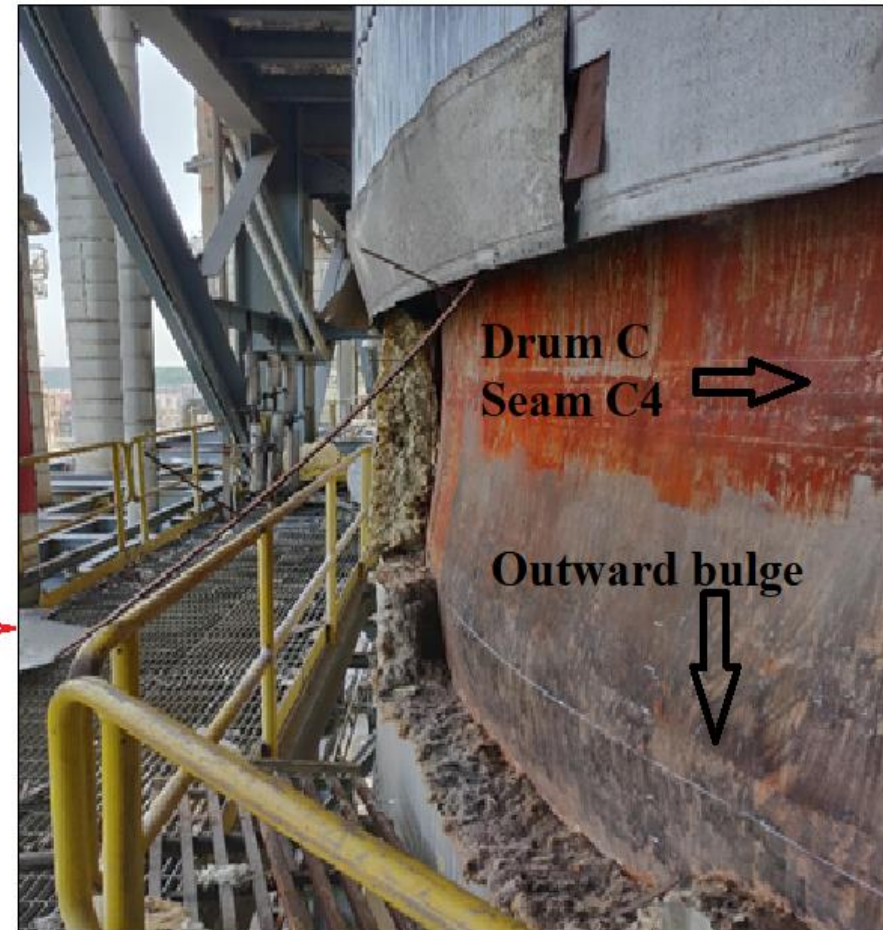
Laser Mapping data of Drum C



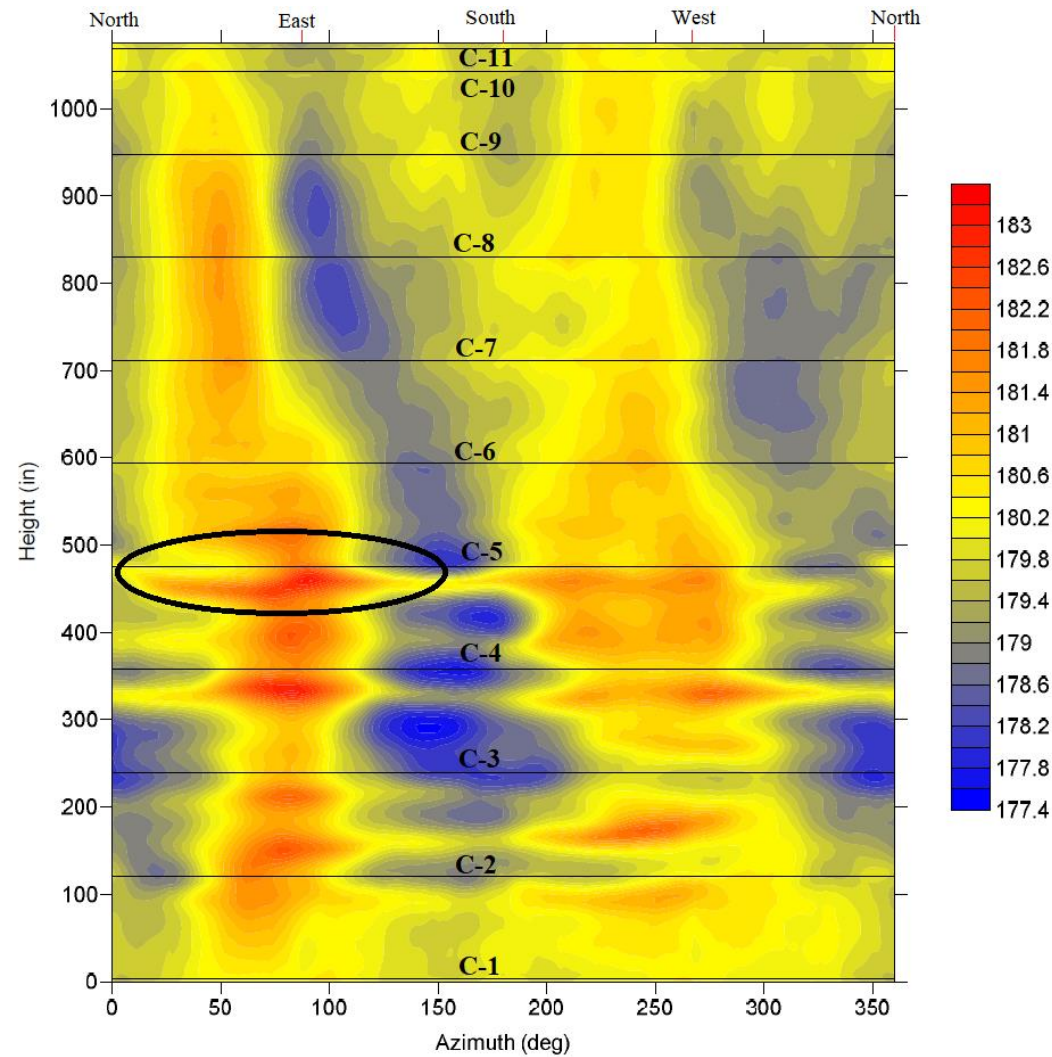
Contour plot of the radius (inches) looking from the inside of the drum

- Blue Inward
- Red Outward

Drum nominal radius is about 180 inches
(4572 mm)



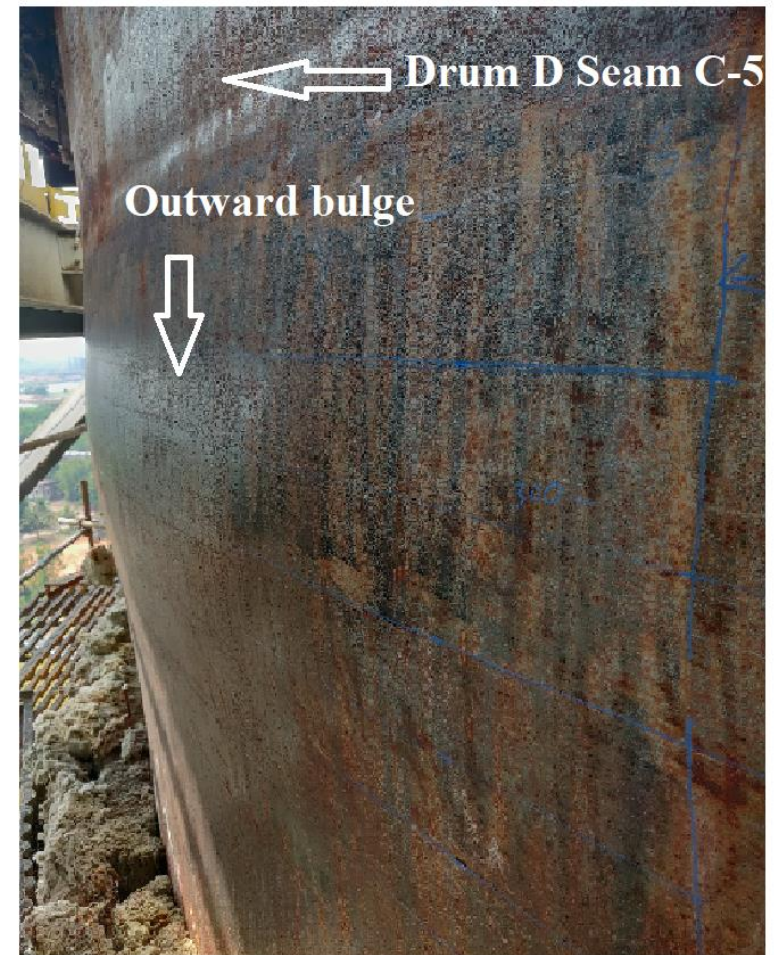
Laser Mapping data of Drum D



**Drum D-2018: Contour plot of radius (inches)
looking from inside of drum**

■ Inward
■ Outward

Drum nominal radius is about 180 inches
(4572 mm)

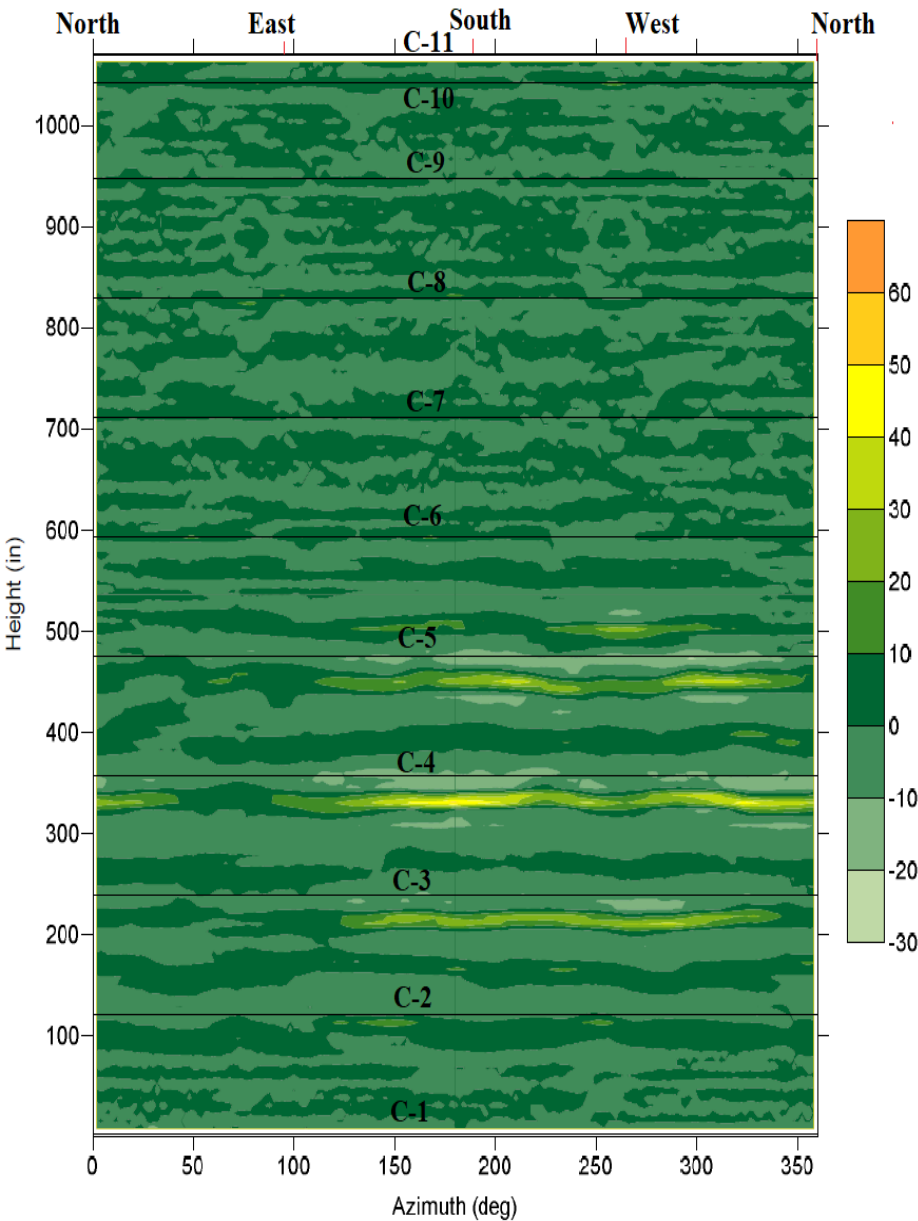


	Drum C		Drum D	
PSI data (%)	Max (+)ve	Max (-)ve	Max (+)ve	Max (-)ve
2017 data	(+)45.9	(-)22.2	(+)47.8	(-)29.7
2018 data	(+)51.7	(-)21.3	(+)47.1	(-)25.9

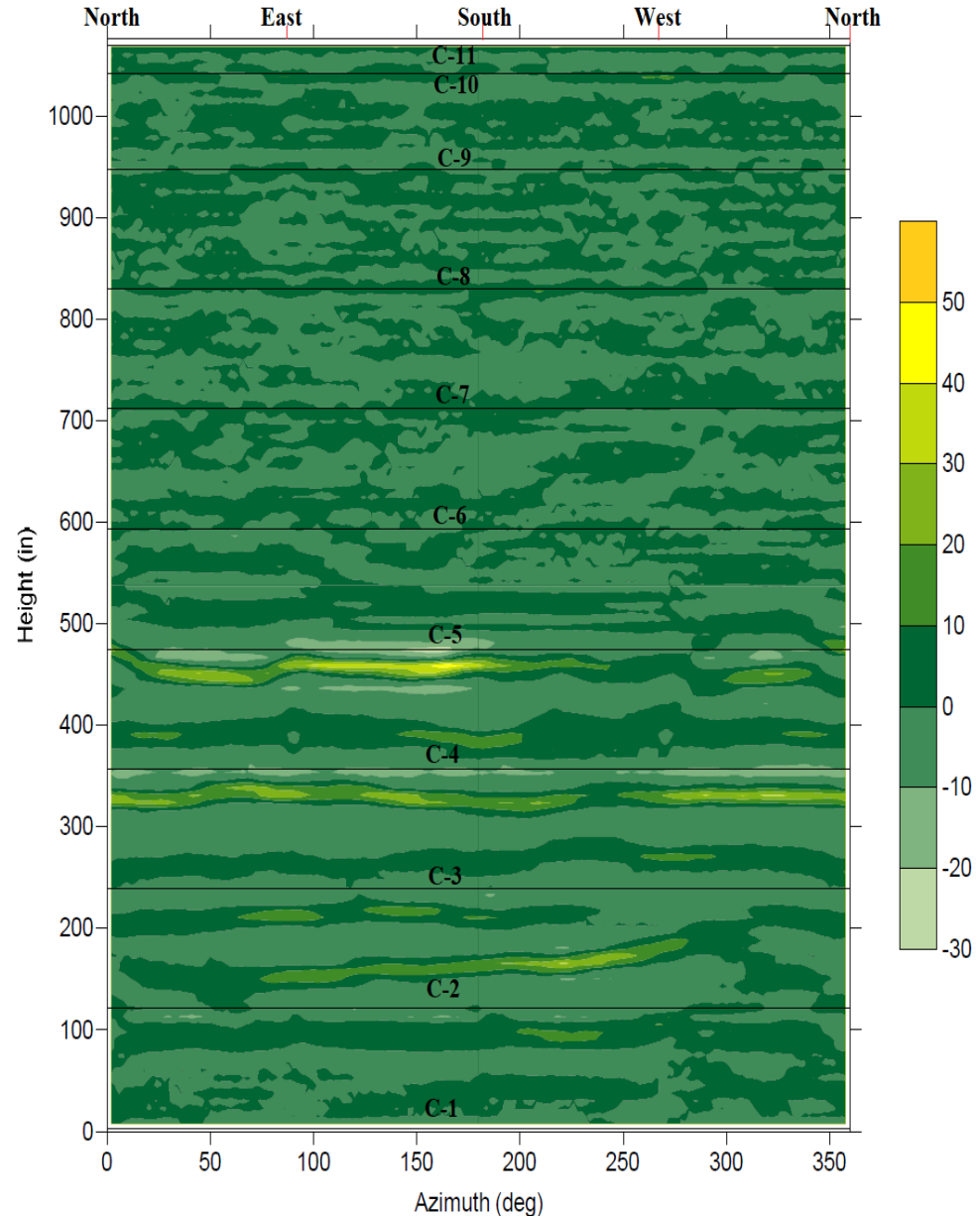
PSI magnitude	Severity Grade	Likelihood of Bulging-Related Cracks	Recommended Frequency of Laser Scanning
80% to 100%	Failure	Likely	6 months to 1 year
60% to 80%	Danger	Probable	1 year
40% to 60%	Concern	Possible	1 to 2 years
0 to 40%	Design	Unlikely	2 to 3 years

Plastic Strain Index (PSI) values	Failure initiation location
Positive (+ve)	Inner surface of drums
Negative (-ve)	Outer surface of drums

PSI plots of Drum C & D



**Drum C-2018 : Contour plot of the Plastic Strain Index (%)
looking from the inside of the drum**



**Drum D-2018 : Contour plot of the Plastic Strain Index (%)
looking from the inside of the drum**

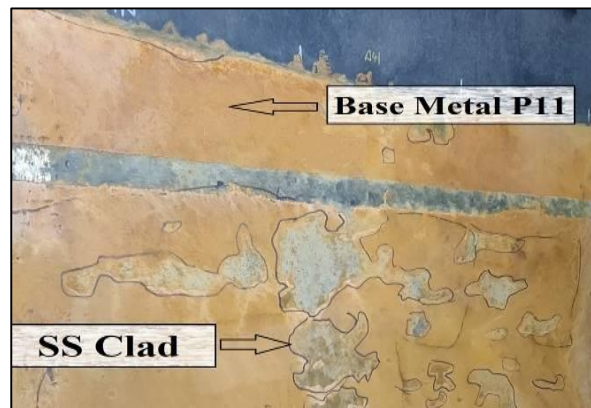
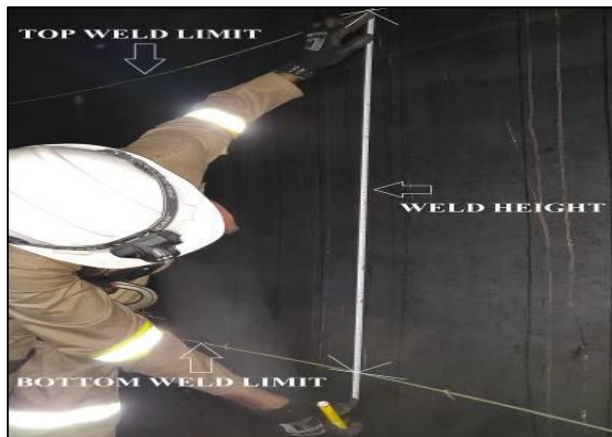
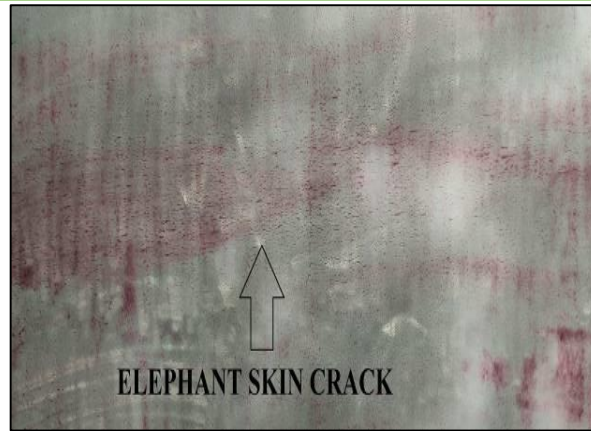
- Faster deterioration in SA-387 Gr 11 Class 1 drums is attributed to lower strength than Class 2 material typically used in industry.
- Inspection of identified bulging zones from inside and outside surface using Visual, DPT, UT.
- If cracks observed, design and implement high-quality weld overlay repairs at first shutdown.
- Annual laser scanning and strain analysis for bulge assessment

- Inspection performed during de-coking cycles from outside surface
- PAUT using angle shear beam (for locating ID cracks) and zero deg longitudinal beam (for locating clad disbonding) performed.
- PAUT and TOFD performed for circumferential weld seam examination.
- Weld cracking observed at the interface of tri-metal joint.
- Multiple crack like indications observed in shell plate bulge area scanning, in line with PSI analysis data.
- Circ. length of defect 6-760 mm & depth 1.3-8 mm (from drum ID).
- Three category of defects:
 - 1) up to 50% of clad
 - 2) > 50% and within clad
 - 3) Depth more than clad thickness and penetrating into base metal

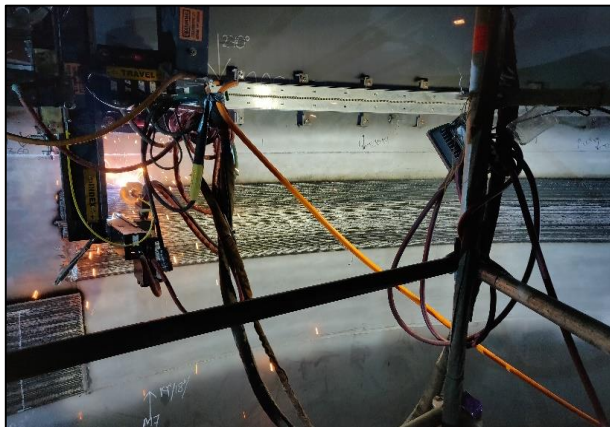
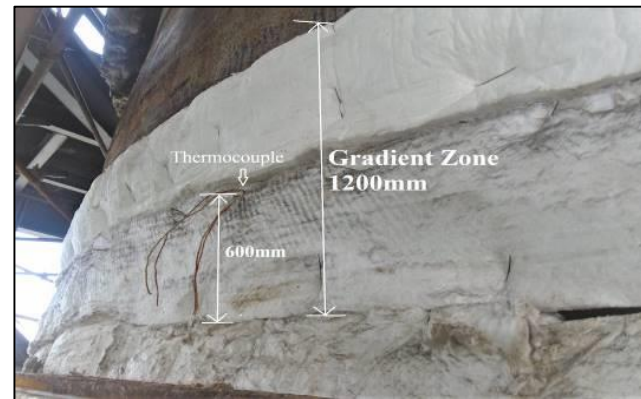
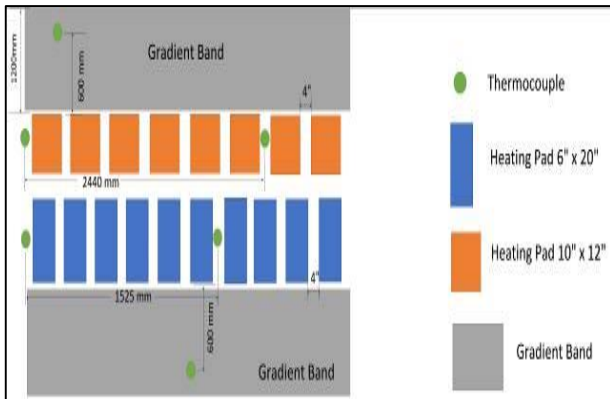
- Initial inspection, repair area defect confirmation and marking
- Recording of initial data
 - 1) Grid thickness-for overlay thickness check
 - 2) Dimensional check-for distortion check
 - 3) Hardness check
 - 4) MPI of outside surface for ruling out OD defects.
- Clad removal by arc gouging without pre-heating & finish grinding
- CuSO₄ check, PMI and DPT of the finished surface.
- Grit blasting prior to welding to meet SA-3 & primer application
- Fixing of Pre-heating/Post heating pads on drum outer surface, AWO track fixing and machine sequencing.
- Preheating, sealing of clad interface and 1st layer AWO welding

- Visual inspection of finished 1st layer, switching off preheating and data collection
- Visual inspection of finished 2nd layer (final layer), including taper at the interface.
- DPT of the interface and post heating.
- Visual inspection and DPT after post heating.
- Removal of AWO tracks and DPT of tack welds after grinding on inner and outer surface (for thermocouple locations)
- PAUT from outer surface of bulge area and PAUT and TOFD for weld seam area.
- Visual inspection and DPT of the insulation support cleats and outer surface of the drums.

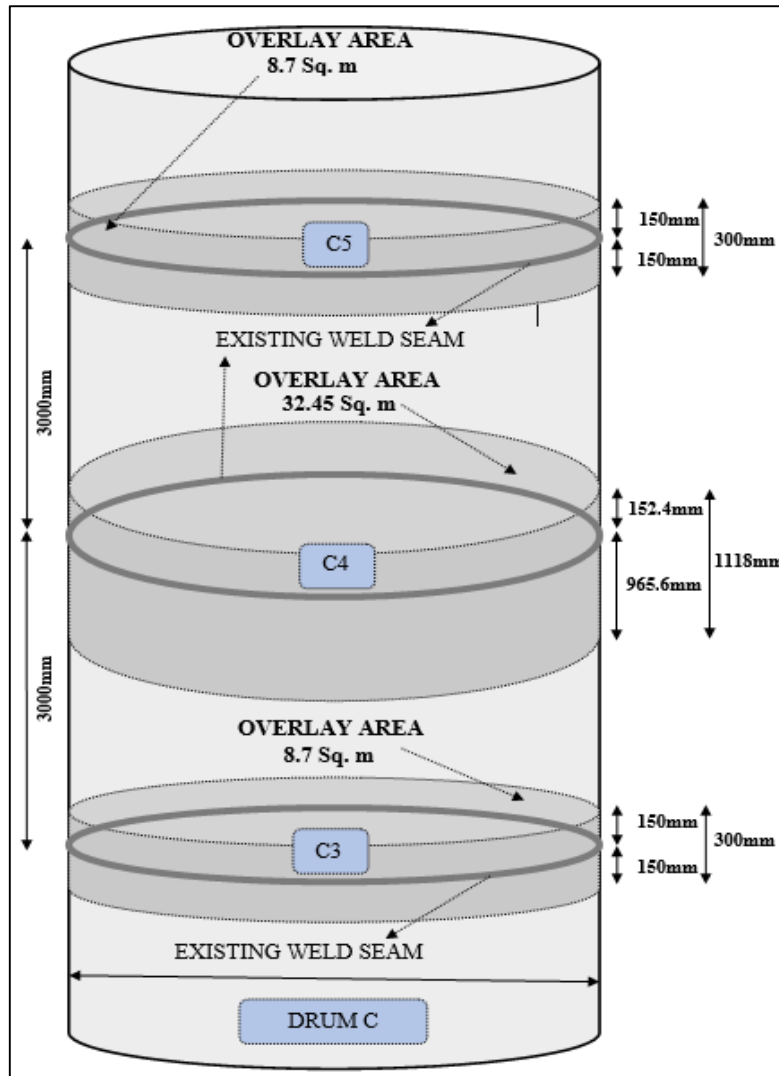
Details of job execution



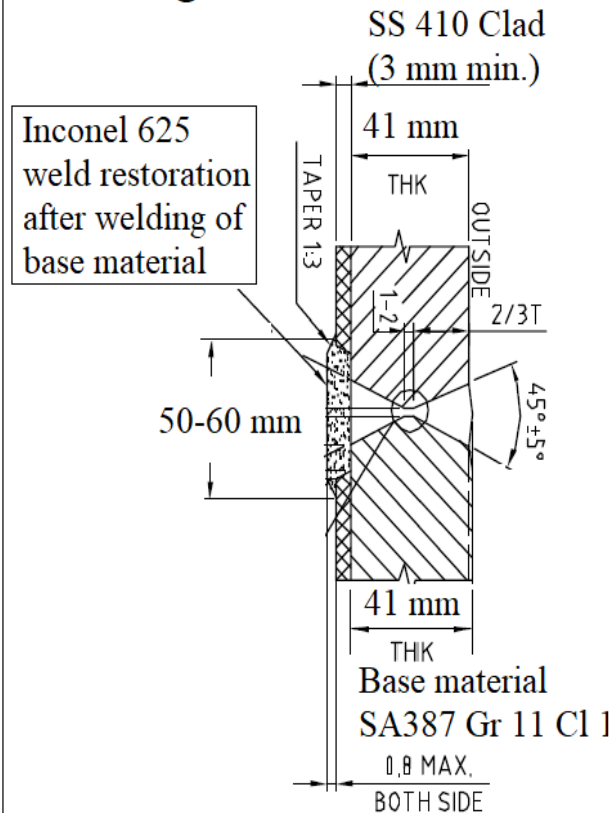
Details of job execution



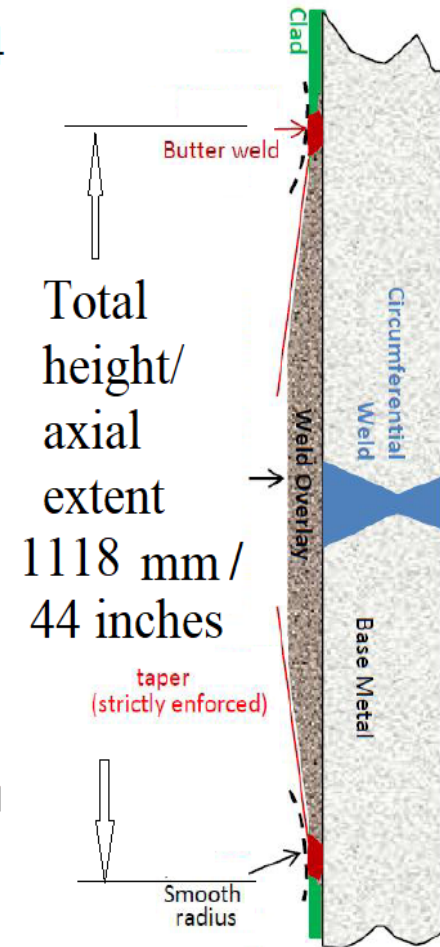
Drum C overlay extent



Welding Cross-section at C4

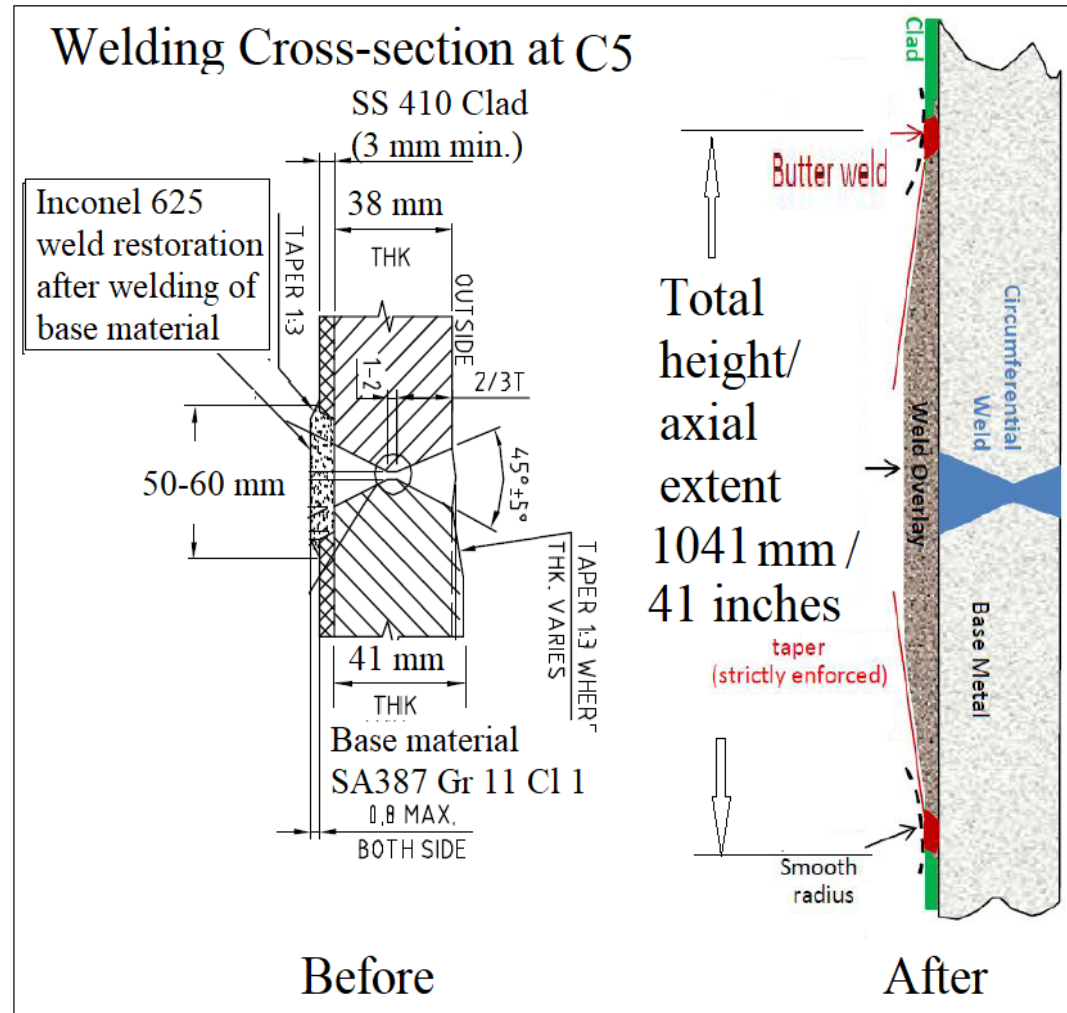
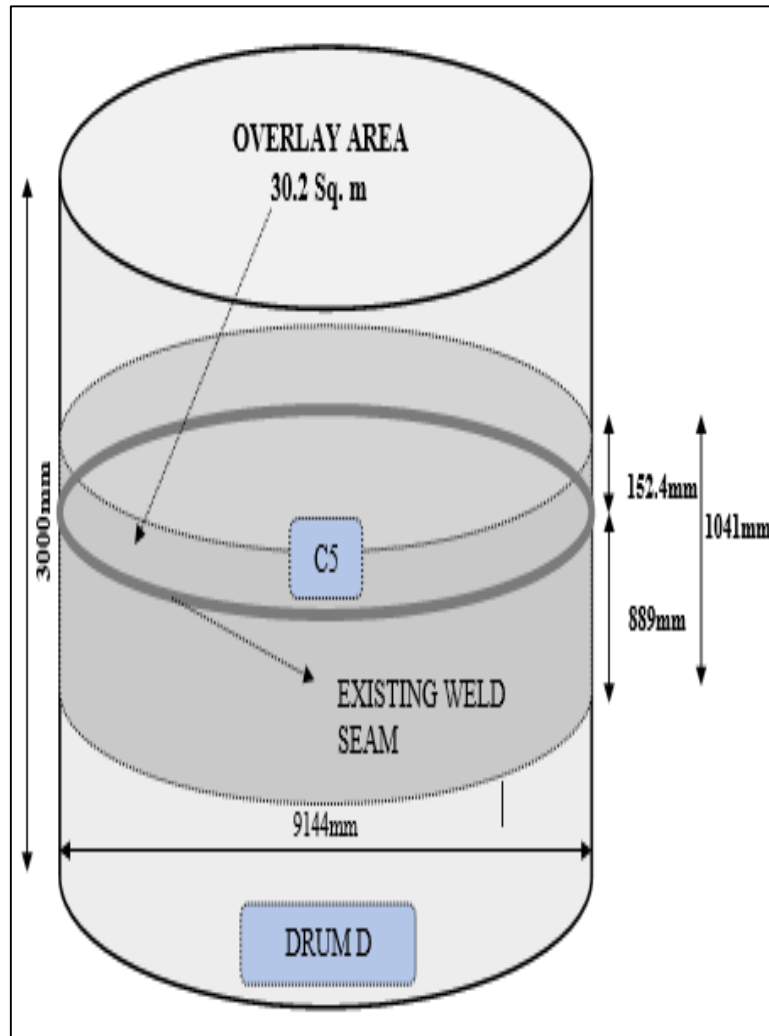


Before



After

Drum D overlay extent



- Due to cyclic service of the drums, regular monitoring is essential
- Laser mapping is the starting point, followed by engineering analysis based on bulge severity
- Results of engineering analysis to be confirmed by further NDT to decide on need for repair action
- Full circumferential band repair using AWO is recommended over patch repair of bulges
- Multiple elevation repairs requires planned sequencing of jobs
- Inspection of outer surface of drums is highly recommended post AWO



Thank You

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