ExxonMobil

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Coke Drum Dual Feed Issues

building a bright future together

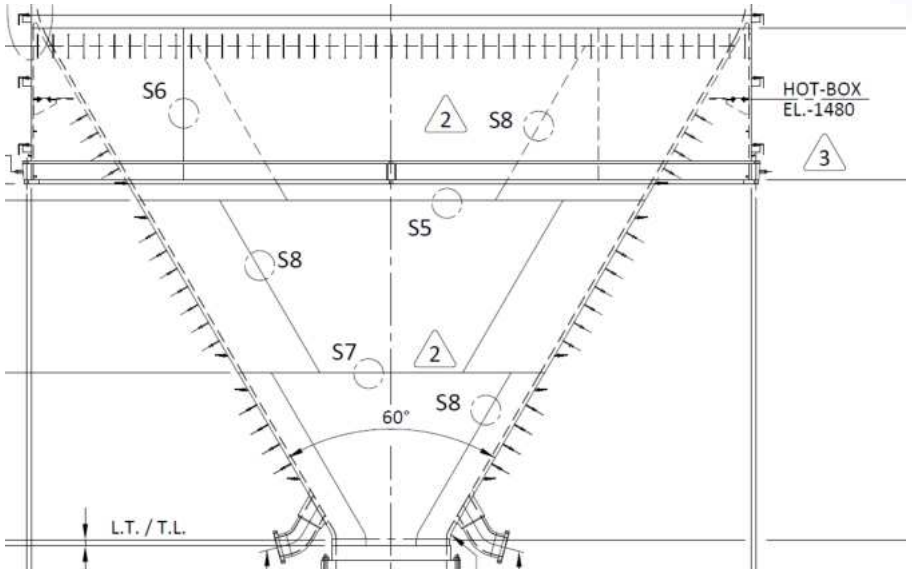
David Gibson – ExxonMobil Manufacturing Principle Engineer

Agenda

- **Drum design**
- **Issues**
- **Operational history**
- **Root cause investigation**
- **Interim management**
- **Long term mitigation**

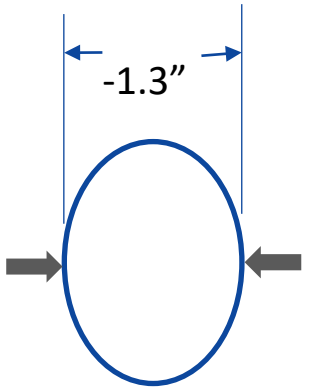
Drum Design

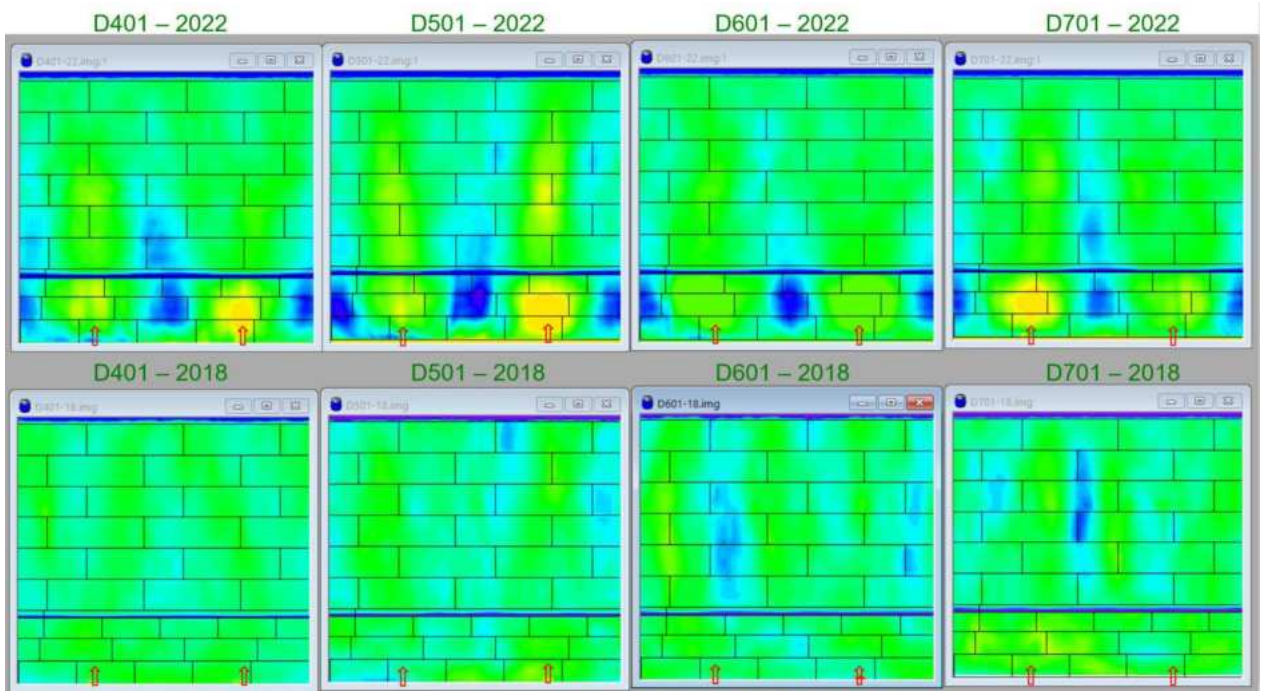
- 32’ diameter drums
- Forged Y ring
- Skirt with keyhole slots
- 2” thick C-1/2 Mo base metal, 410 cladding
- Cone angle of 30° from vertical
- 10” dual feed inlet nozzles, nozzle angle matches cone angle
- 5” thick drum bottom flange
- Z&J un-heading valve
- Startup 4Q2018
- ~23 hour cycle time
- ~450F warm up



Cone/Flange Distortion Issues

- **Severe flange distortion – ovalization**
  - **In plane of dual feed nozzles**
  - **1.3” diametrical flange distortion, varies across 4 drum set**
  - **Worsening over time**
    - **May 2022 (~650 cycles) → 1.1” deformation**
    - **October 2023 (~750 cycles) → 1.38” deformation**
    - **Joint leakage**
    - **Gasket failure**
    - **BUD tapped hole thread damage**
- **Severe cone distortion**
  - **Generally ovalized, >4” difference in diameter**
  - **Localized areas of wrinkles**
- **Beginning to see anchor bolt failure**



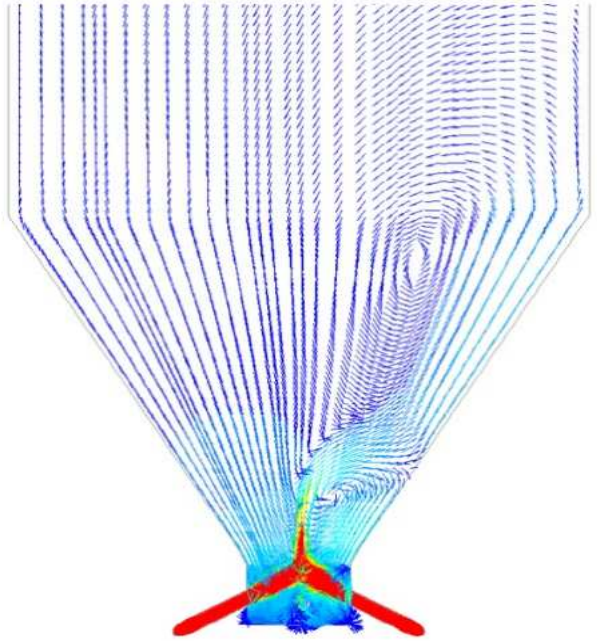


4Q23 Gasket Replacement

Missing gasket section introduces potential for largeer leak vs historical flange leakage experience

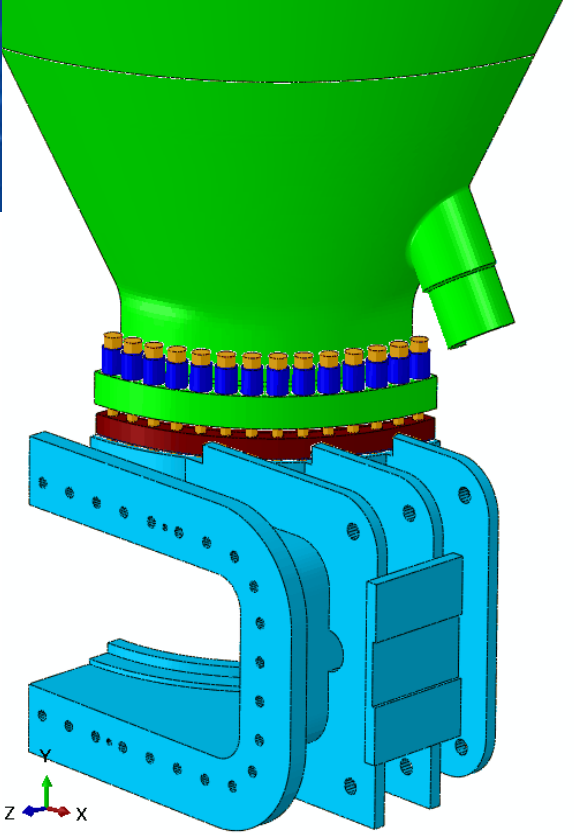
Timeline

Cone Thermal Data

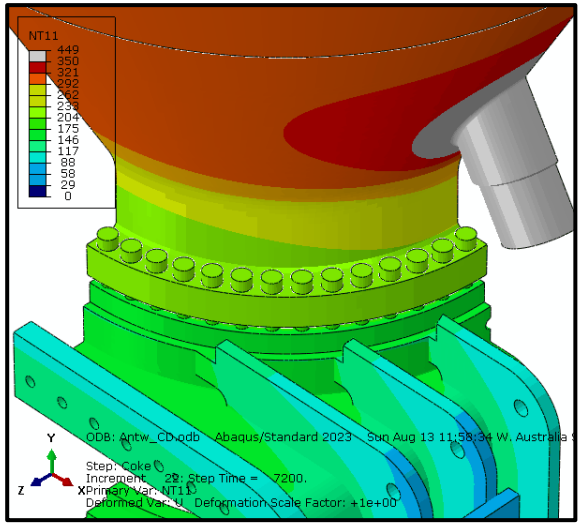


Approach and set up of FEA

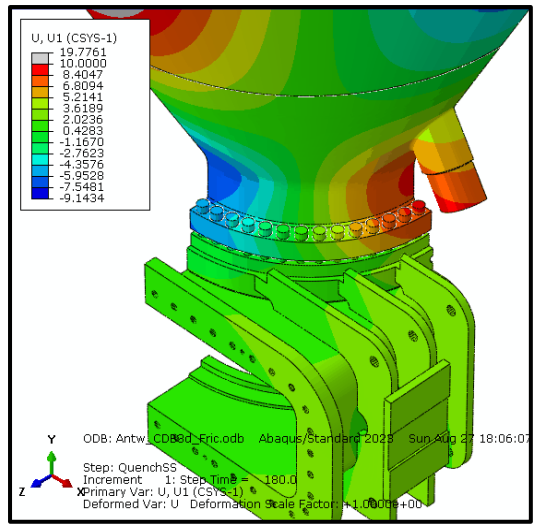
- Analysis Objective
  - Determine if flange deformation and leakage is caused primarily by nonuniform circumferential temperature distribution or asymmetric radial stiffness of the BUD valve.
- Finite element analysis performed through Integrity Engineering
  - 3D model of BUD valve obtained from Z&J.
  - Process data and external temperature measurements used for boundary conditions model calibration.
  - ¼-symmetric, transient, coupled temperature-displacement model.
  - All flange attachment components included in model
    - Bolts including contact between flange bolt holes
    - Belleville washers
    - Gaskets (including non-linear material behavior)



Temperature (°C) Profile During Coking



Radial Displacement (mm) During Quench

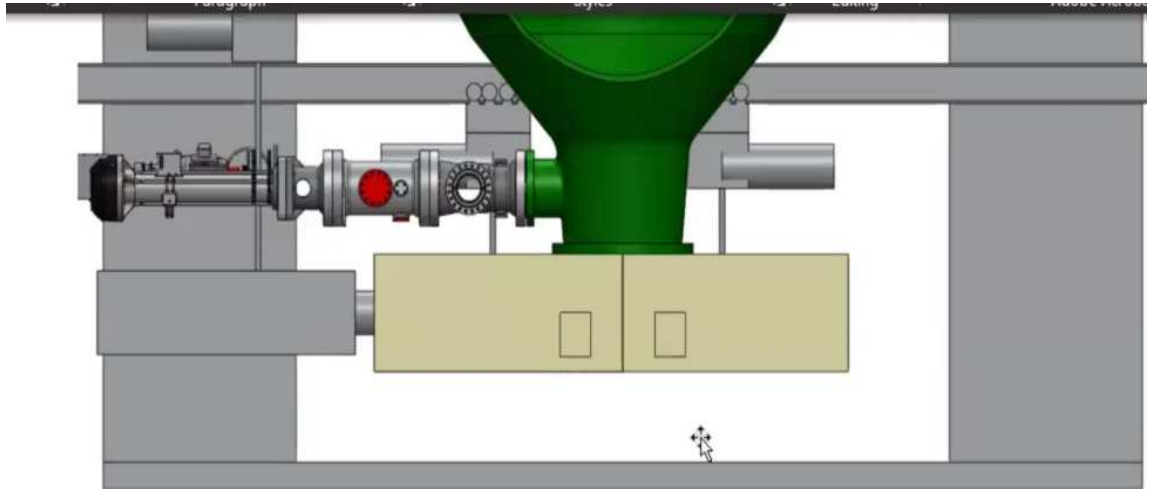


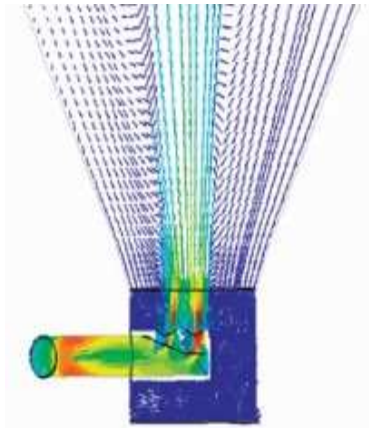
Main conclusions FEA analysis – Integrity Engineering Solutions

- Root cause of distortion - Thermal gradients created by the dual feed nozzles
- Valve stiffness does not appear to be a significant contributor to the ovalization.
- Insulating the flange neck to the back of the flange produces slightly less flange deformation and gasket stress variation.
- The flange bolts exceed yield during coke drum operation (bending) → thread damage in valve, extraction difficulty
- Gasket performance during operation is very sensitive to variation in bolt load.

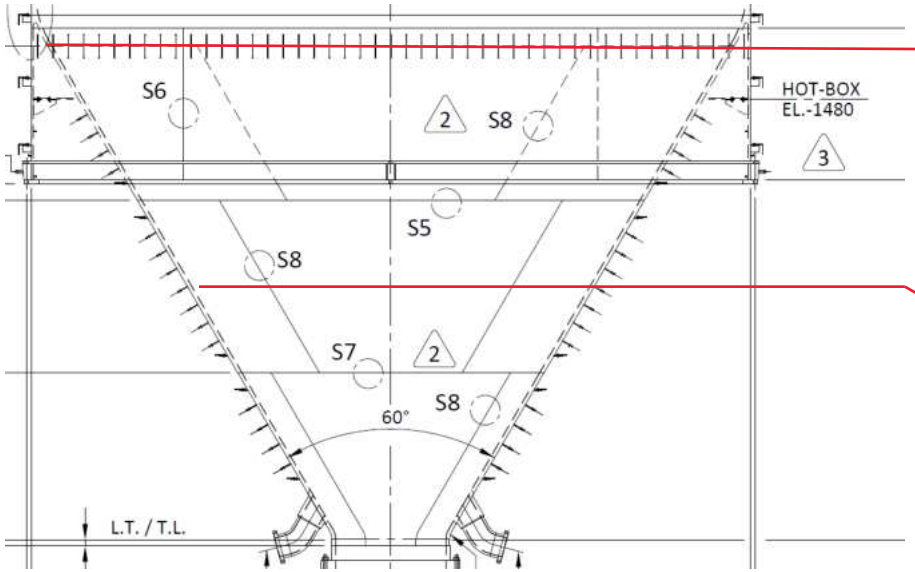
Recommendation - Center Feed Device

- **Install Center Feed Devices (CFD) on all 4 drums** to eliminate temperature gradients.
  - Requires lower cone replacement
  - Challenging fit-up due to cone distortion
- **Flange replacement** is an interim repair, but **not recommended**.
  - Cone distortion and fatigue life consumption will continue leading to pressure boundary cracking.
  - Fitting the new cone later will become more challenging. Poor fit-up will result in future cracking
  - Flange leakage and anchor bolt issues will continue



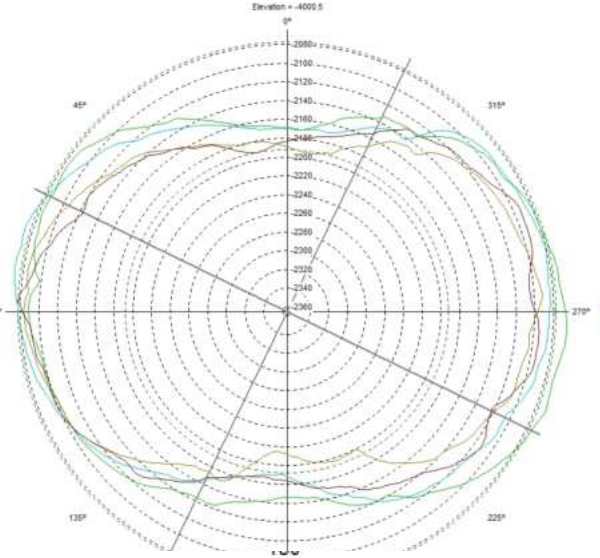


Cone Laser Scans



All Four (4) Drum Polar Plots:

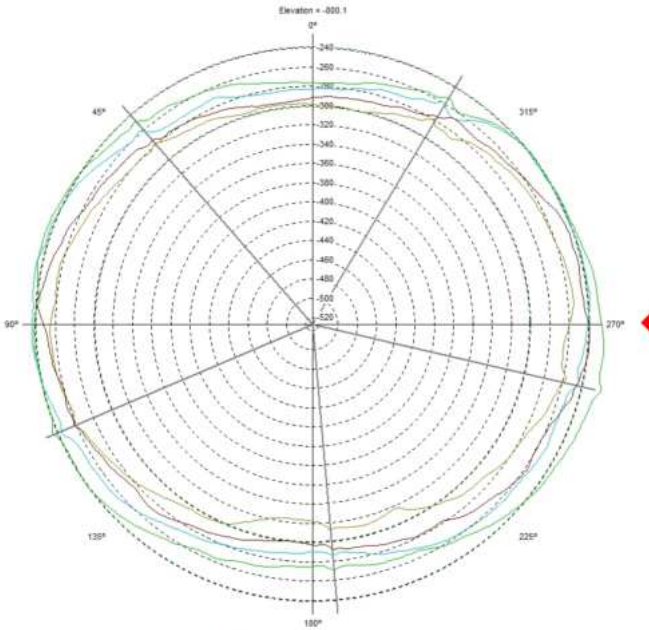
Elevation -4000mm



Drum	Min	Max	Diff	Change
D401-22	-2192	-2077	+115	-17
D501-22	-2215	-2084	+132	+26
D701-22	-2171	-2066	+105	-16
D601-22	-2191	-2070	+121	-

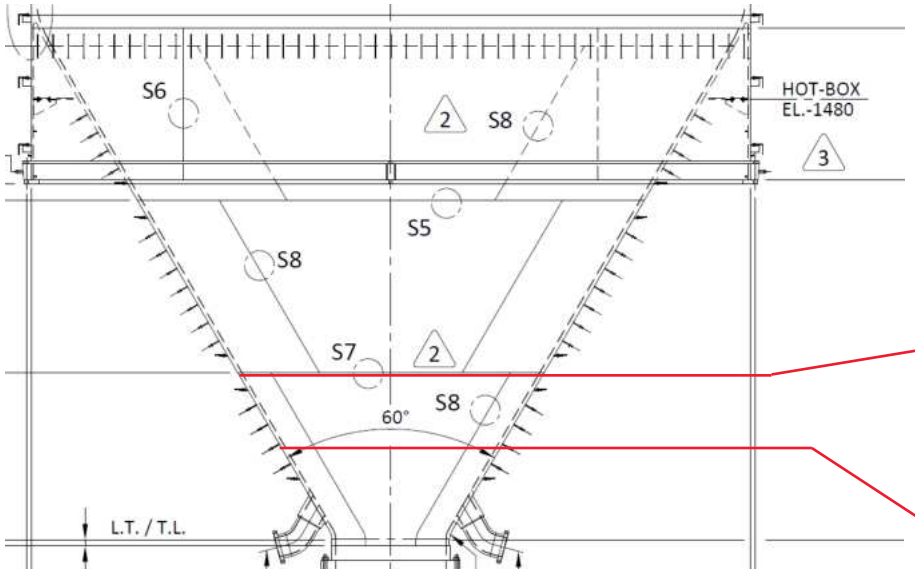
All Four (4) Drum Polar Plots:

Elevation -800mm



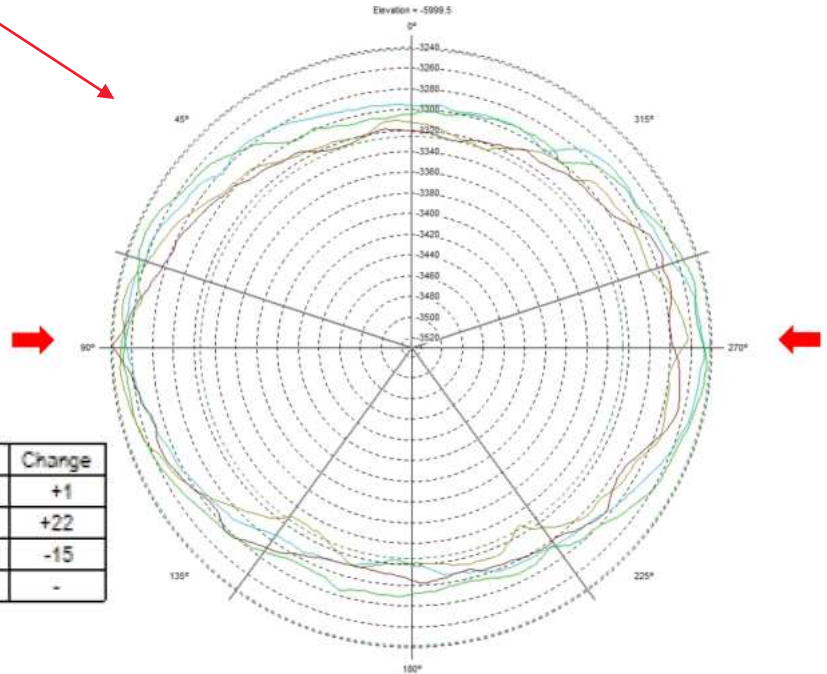
Drum	Min	Max	Diff	Change
D401-22	-301	-239	+62	-8
D501-22	-325	-255	+70	+13
D701-22	-277	-220	+57	-2
D601-22	-292	-234	+58	-

Cone Laser Scans – cont'd



All Four (4) Drum Polar Plots:

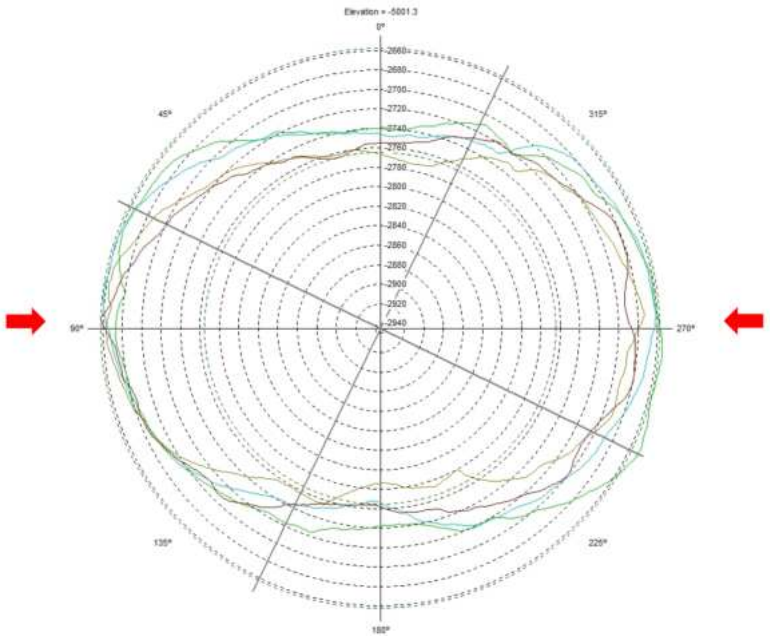
Elevation -6000mm



Drum	Min	Max	Diff	Change
D401-22	-3326	-3242	+84	+1
D501-22	-3331	-3248	+83	+22
D701-22	-3307	-3245	+62	-15
D601-22	-3325	-3248	+77	-

All Four (4) Drum Polar Plots:

Elevation -5000mm



Drum	Min	Max	Diff	Change
D401-22	-2765	-2658	+107	-17
D501-22	-2787	-2663	+124	+31
D701-22	-2744	-2651	+93	-17
D601-22	-2769	-2659	+110	-

Interim Management and Final Mitigation

3Q18 SU

- Retorque post TA
- Flange leakage during run
- Smoldering insulation
- No routine retorque
- CMGC gaskets

1Q22 TA

- Flange distortion interfering with valve studs
- Severe gasket walk
- Thread damage in BUD
- 10-30mm flange ovalization
- 4/5 valve inductive heating to re-assemble
- 6/7 valve over bored flange bolt holes to re-assemble
- Thread repairs
- Laser scan – severe cone deformation
- Corrukamm gasket, non bolt captured

2023

- Frequent flange leaks 6/7 drums
- Re-torque 5/6/7 drums
- Small fire due to saturated insulation drum 7

4Q23 VALVES 6/7

- Lower valves to replace gasket, repair threads, re-torque
- Severe gasket damage, 1/5 of gasket missing
- 16 of 56
  26 of 56 threads repaired
- Flange ovalization increased
  22 → 28mm &
  28 → 35mm

General Conclusions

- Larger diameter drums with dual feed inlet nozzles susceptible to cone/flange distortion
- Root cause - thermal mal-distribution induced by dual feed nozzles
- Worsening cone/flange distortion over time
  - Accelerated fatigue life consumption → cone cracking
- Potential for anchor bolt issues
- Temporary mitigations
  - Over size flange bolt holes → easier assembly/disassembly, increased gasket walk, long term gasket integrity concerns
  - Inductive heating to assemble/disassemble joint → less gasket walk, increased valve thread damage, challenged assembly/disassembly
  - Flange replacement → short term mitigation 1-3 years, cone deformation continues, drum life implications
- **Long term mitigation**
  - Convert from dual feed to retractable center feed device prior to cone life consumption