

April, 2024

Coke Drum Dual Feed Issues



building a bright future
together

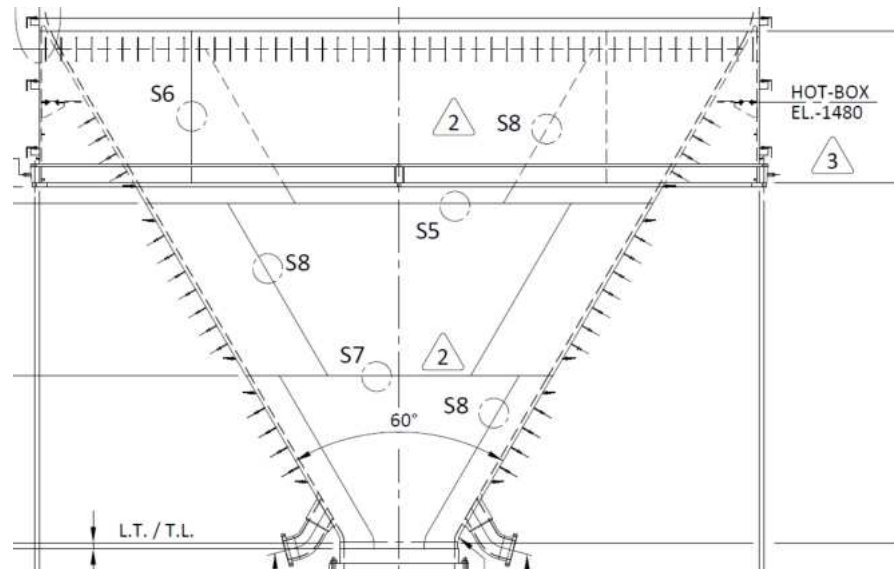
David Gibson – ExxonMobil Manufacturing Principle Engineer

Agenda

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

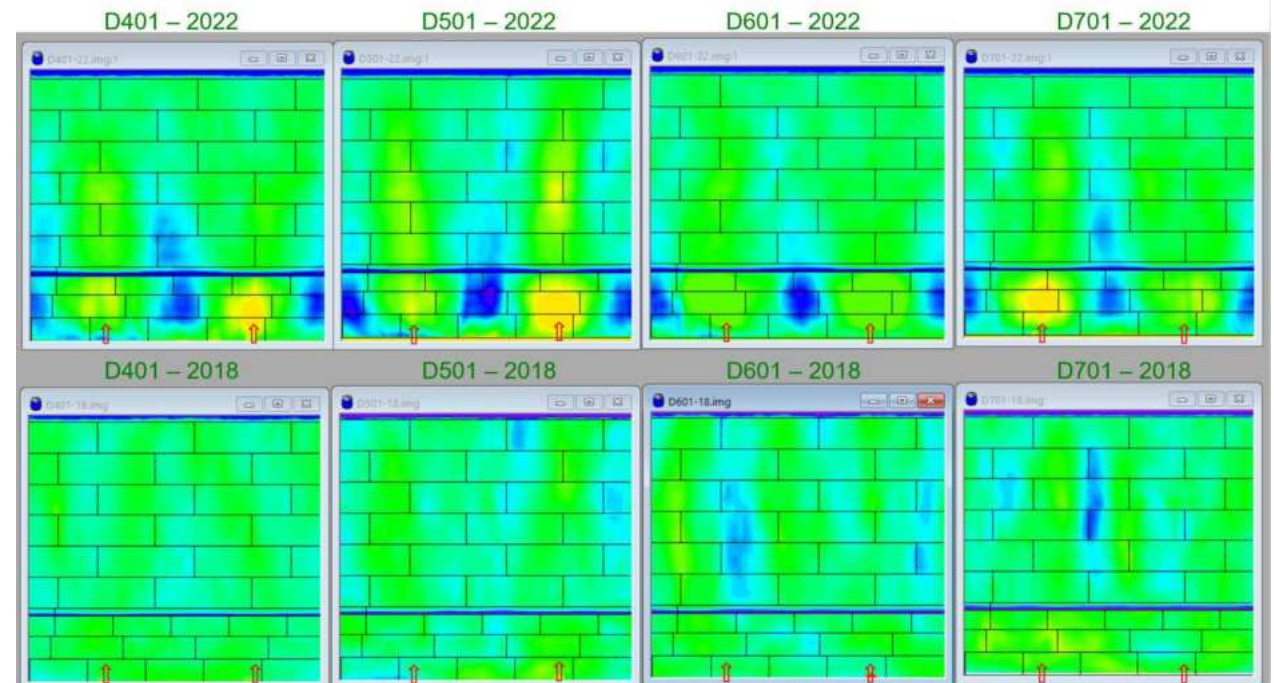
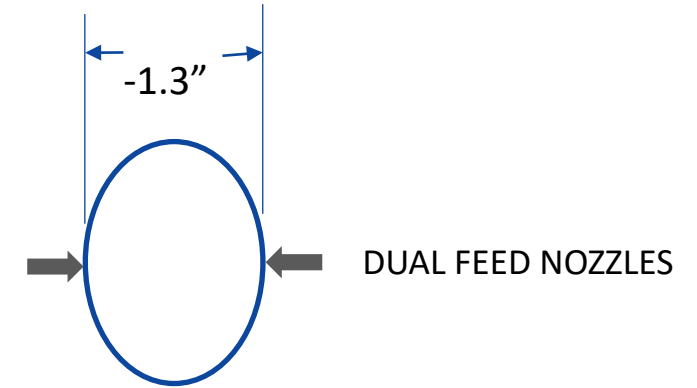
Drum Design

- 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

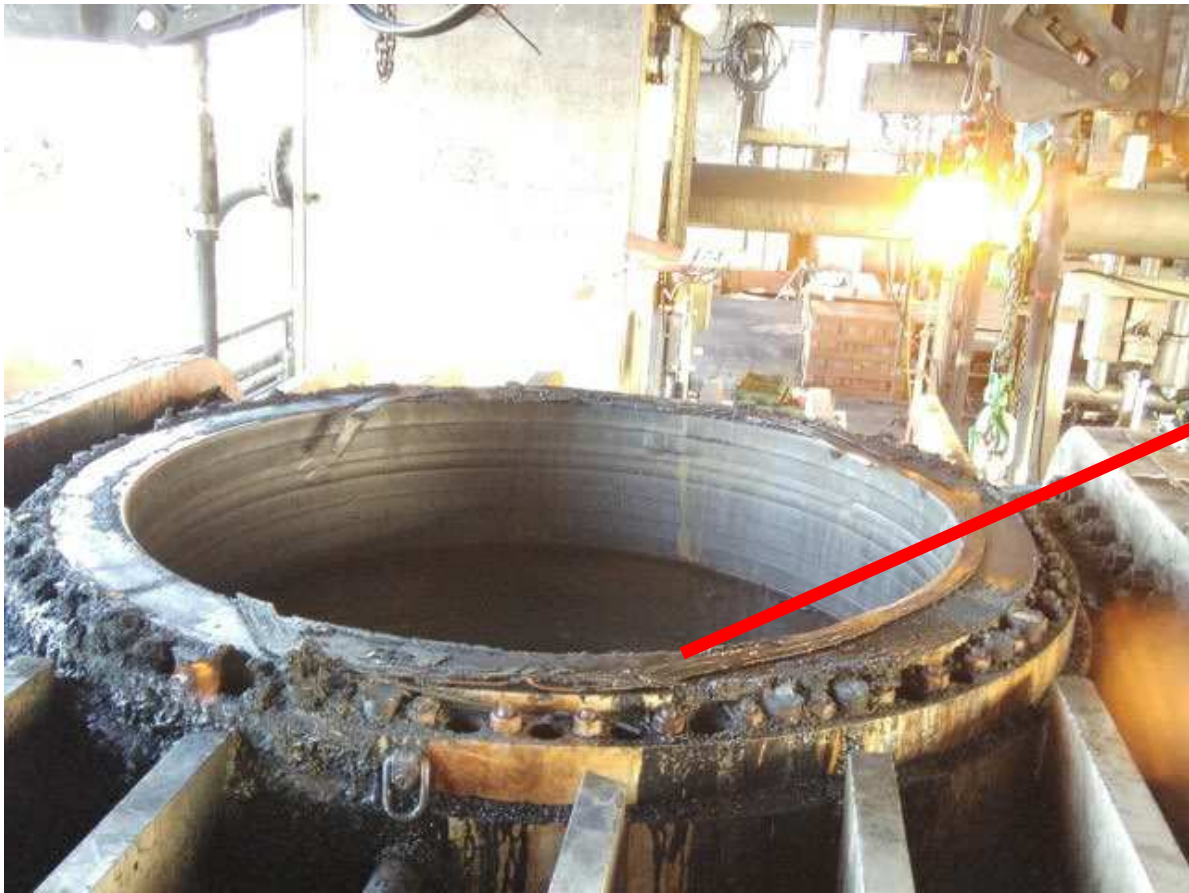


Cone/Flange Distortion Issues

- 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



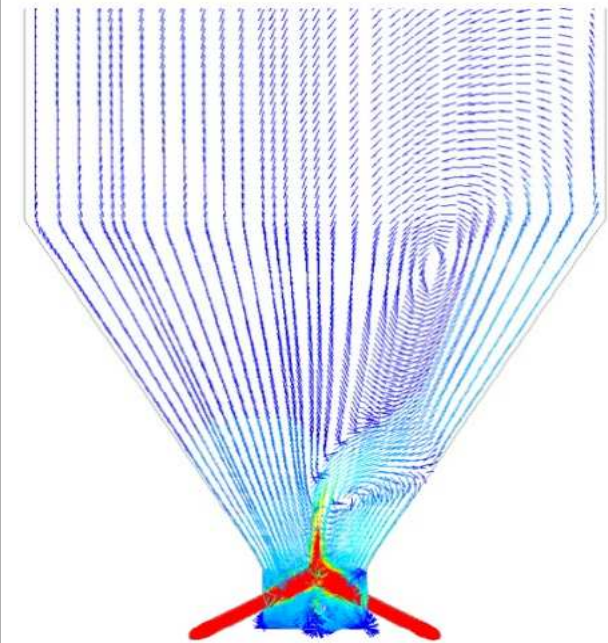
4Q23 Gasket Replacement



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

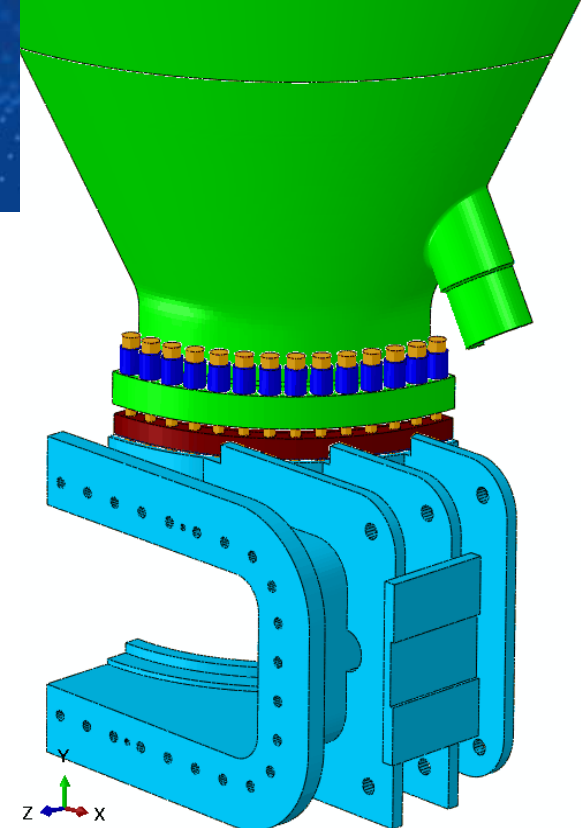
Timeline

Cone Thermal Data

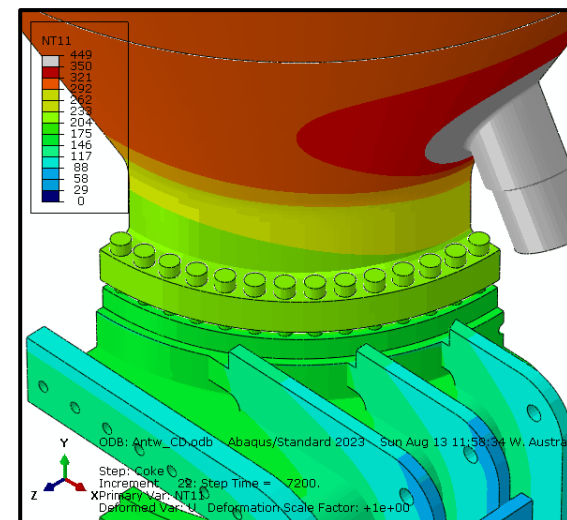


Approach and set up of FEA

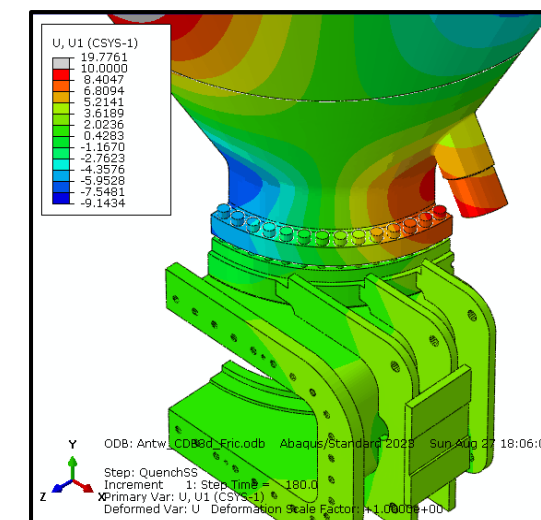
- Analysis Objective
 - Determine if flange deformation and leakage is caused primarily by nonuniform circumferential temperature distribution or asymmetric radial stiffness of the BUD valve.
- Finite element analysis performed through Integrity Engineering
 - 3D model of BUD valve obtained from Z&J.
 - 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

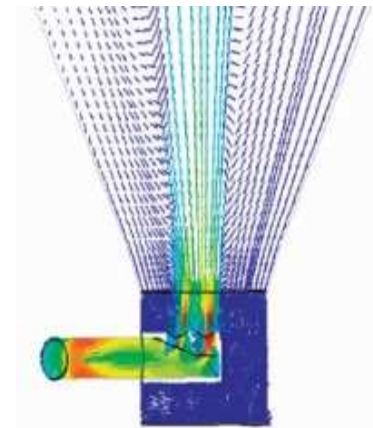
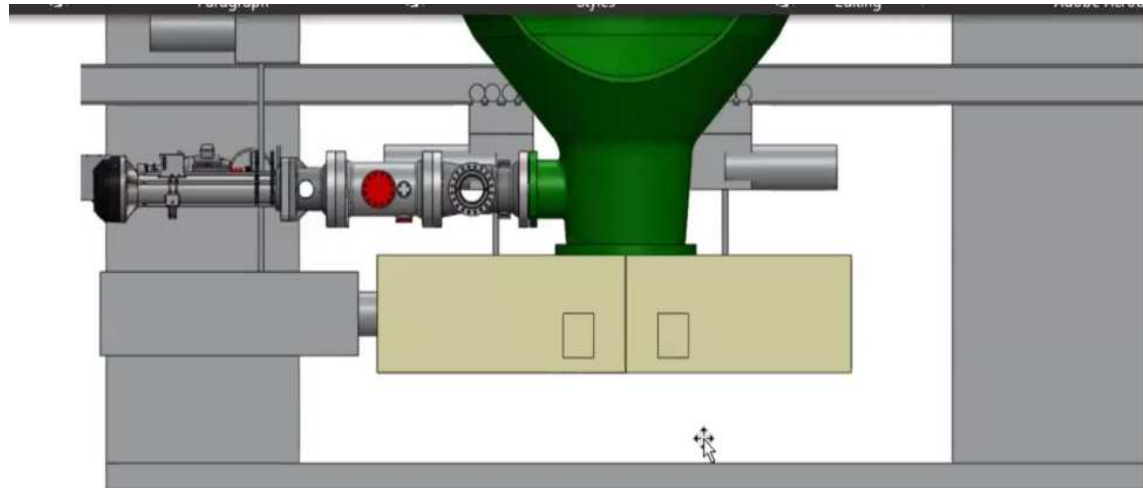


Main conclusions FEA analysis – Integrity Engineering Solutions

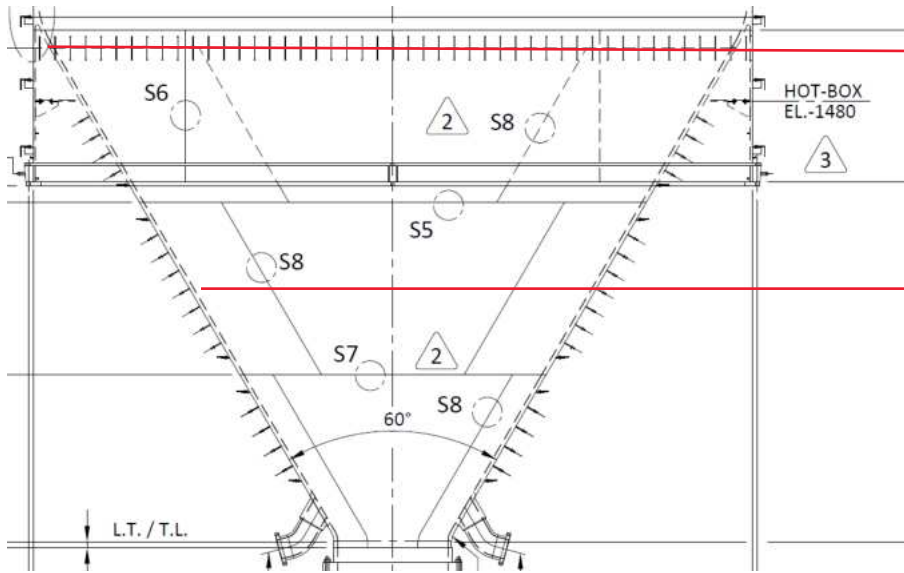
- Root cause of distortion - Thermal gradients created by the dual feed nozzles
- Valve stiffness does not appear to be a significant contributor to the ovalization.
- Insulating the flange neck to the back of the flange produces slightly less flange deformation and gasket stress variation.
- The flange 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

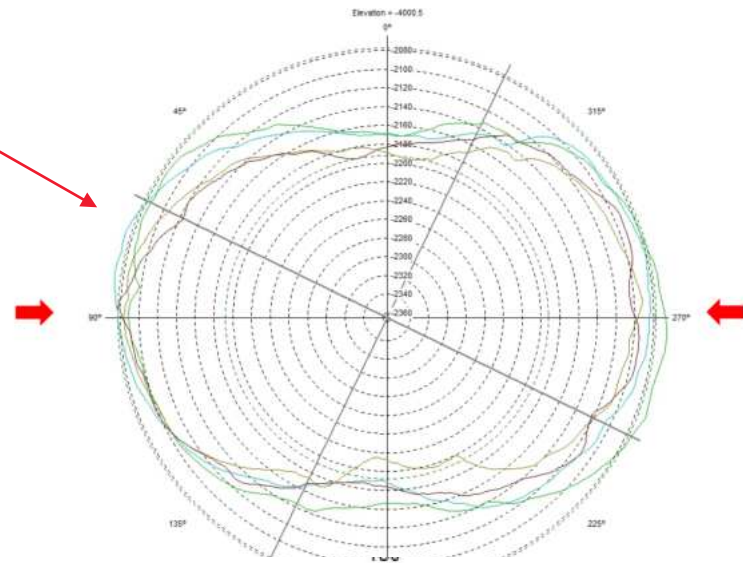
- **Install Center Feed Devices (CFD) on all 4 drums** to eliminate temperature gradients.
 - Requires lower cone replacement
 - Challenging fit-up due to cone distortion
- **Flange replacement** is an interim repair, but **not recommended**.
 - Cone distortion and fatigue life consumption will continue 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

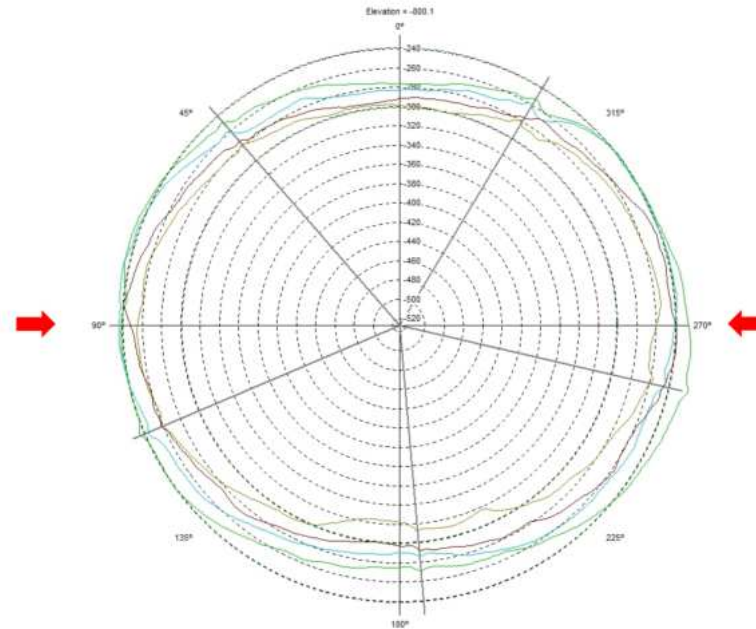


All Four (4) Drum Polar Plots:
Elevation -4000mm



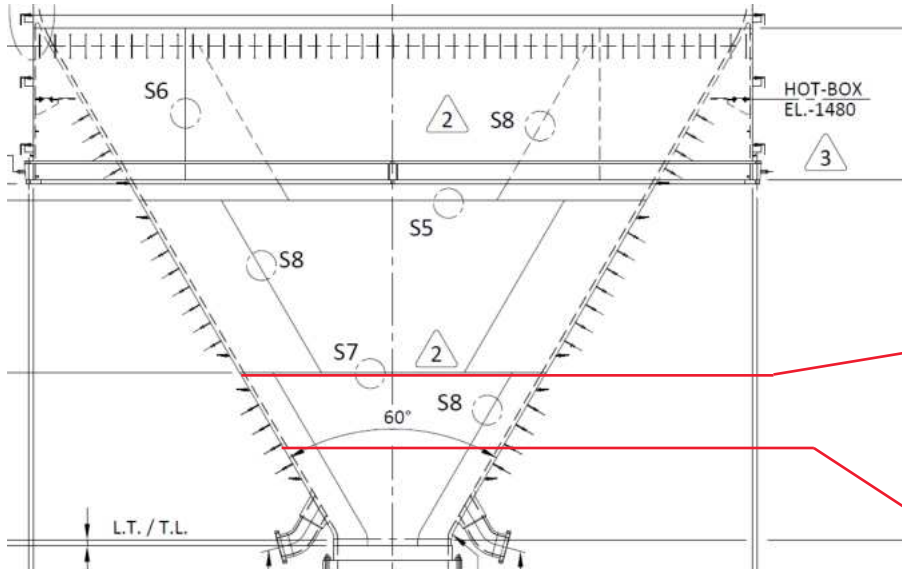
Drum	Min	Max	Diff	Change
D401-22	-2192	-2077	+115	-17
D501-22	-2215	-2084	+132	+26
D701-22	-2171	-2066	+105	-16
D601-22	-2191	-2070	+121	-

All Four (4) Drum Polar Plots:
Elevation -800mm



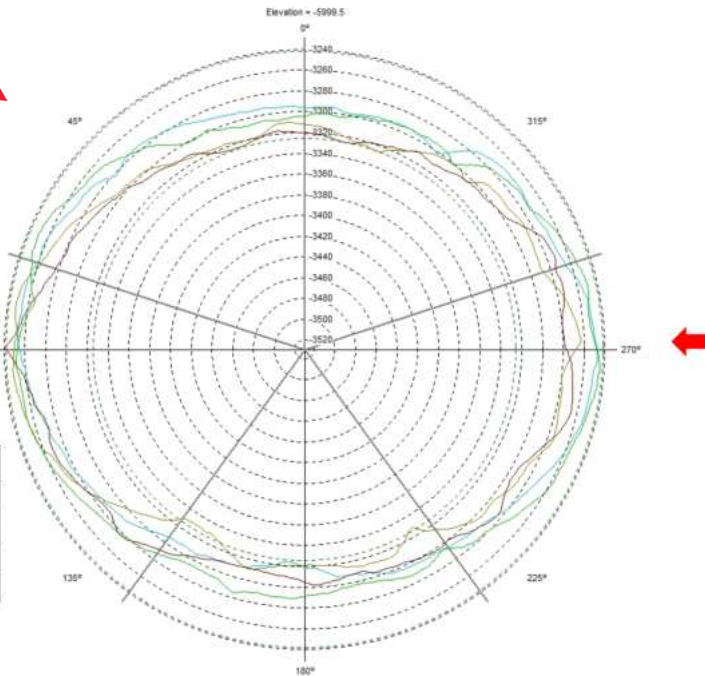
Drum	Min	Max	Diff	Change
D401-22	-301	-239	+62	-8
D501-22	-325	-255	+70	+13
D701-22	-277	-220	+57	-2
D601-22	-292	-234	+58	-

Cone Laser Scans – cont'd

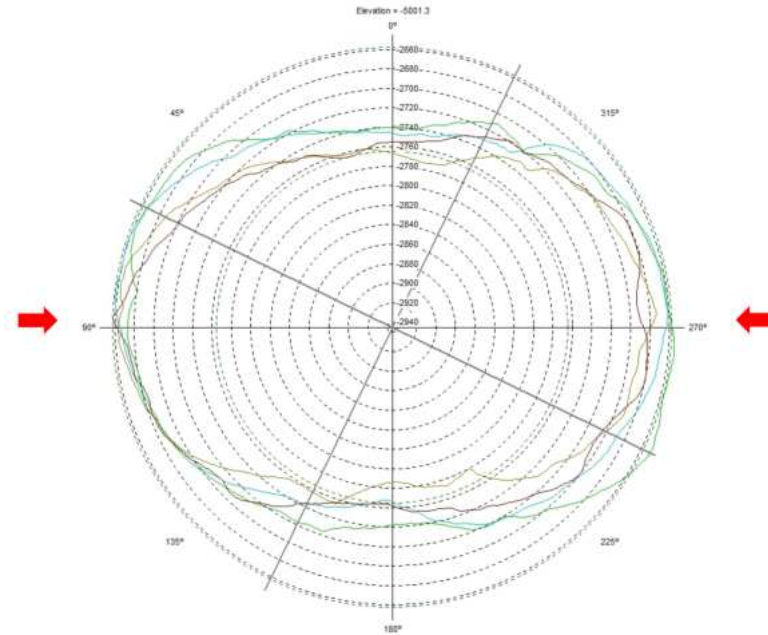


All Four (4) Drum Polar Plots:
Elevation -6000mm

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	-

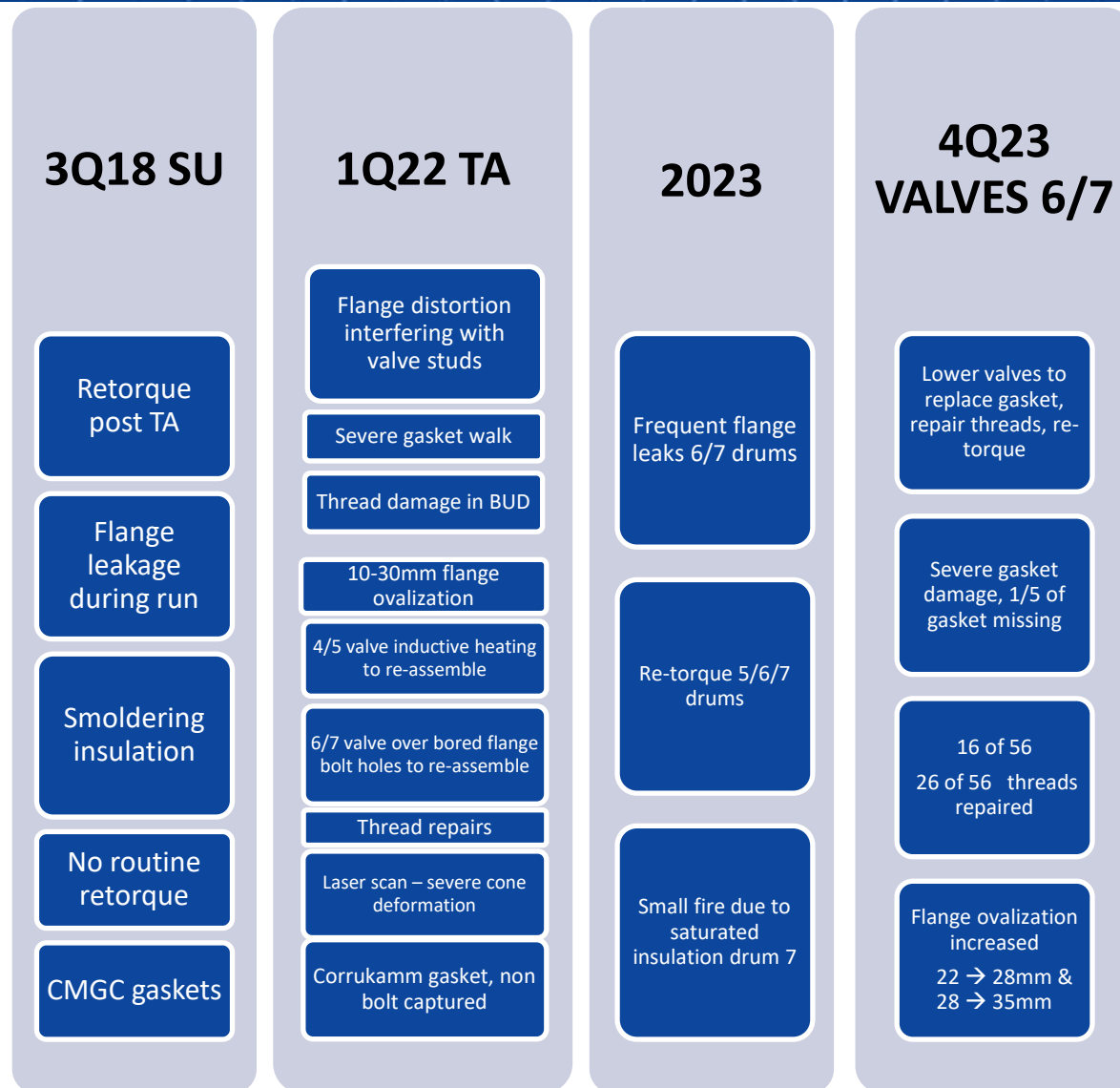


All Four (4) Drum Polar Plots:
Elevation -5000mm



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



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

©2024 ExxonMobil. ExxonMobil, the ExxonMobil logo, the interlocking “X” device and other product or service names used herein are trademarks of ExxonMobil, unless indicated otherwise. This document may not be distributed, displayed, copied or altered without ExxonMobil's prior written authorization. To the extent ExxonMobil authorizes distributing, displaying and/or copying of this document, the user may do so only if the document is unaltered and complete, including all of its headers, footers, disclaimers and other information. You may not copy this document to or reproduce it in whole or in part on a website. ExxonMobil does not guarantee the typical (or other) values. Any data included herein is based upon analysis of representative samples and not the actual product shipped. The information in this document relates only to the named product or materials when not in combination with any other product or materials. We based the information on data believed to be reliable on the date compiled, but we do not represent, warrant, or otherwise guarantee, expressly or impliedly, the merchantability, fitness for a particular purpose, freedom from patent infringement, suitability, accuracy, reliability, or completeness of this information or the products, materials or processes described. The user is solely responsible for all determinations regarding any use of material or product and any process in its territories of interest. We expressly disclaim liability for any loss, damage or injury directly or indirectly suffered or incurred as a result of or related to anyone using or relying on any of the information in this document. This document is not an endorsement of any non-ExxonMobil product or process, and we expressly disclaim any contrary implication. The terms “we,” “our,” “ExxonMobil Technology and Engineering Company” and “ExxonMobil” are each used for convenience, and may include any one or more of ExxonMobil Technology and Engineering Company, Exxon Mobil Corporation, or any affiliate either directly or indirectly stewarded.