Effect of Dual-Inlet Feed on the Integrity of Coker-BUD Joint

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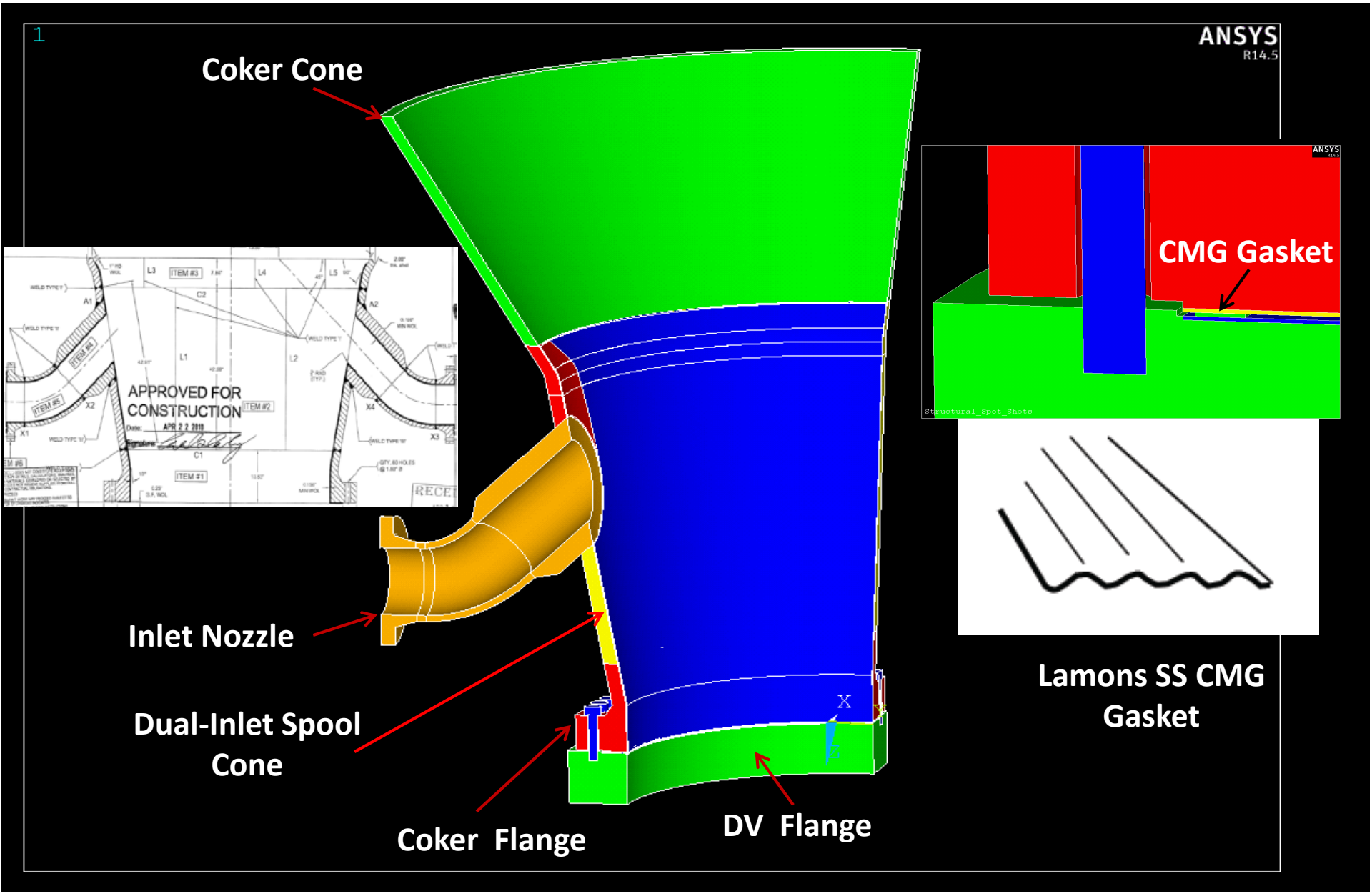
Coking.com

SUNCOR ENERGY

Background

- Three coker sets installed and commissioned in 2001
- Started as a single entry side feed
- Operation ranged 13-14 hour coking Cycles until 2008
- 12 Hour coking cycle Started in 2008
- Banana effect experienced from single side feed triggered installation of dual-inlet feed in 2010
- Started experiencing leakage in 2012 at coker-BUD Joint every 2-3 months
- Leakage discovered at steam test stage
- Shutdown of Coker set for 7-10 days to fix leakage
- Putting new gasket and increasing bolt stress was tried to stop frequent leakage with no success
- This study is part of RCFA for frequent leakage at joint

3-D FEA of Dual-Inlet Feed



Solid Model

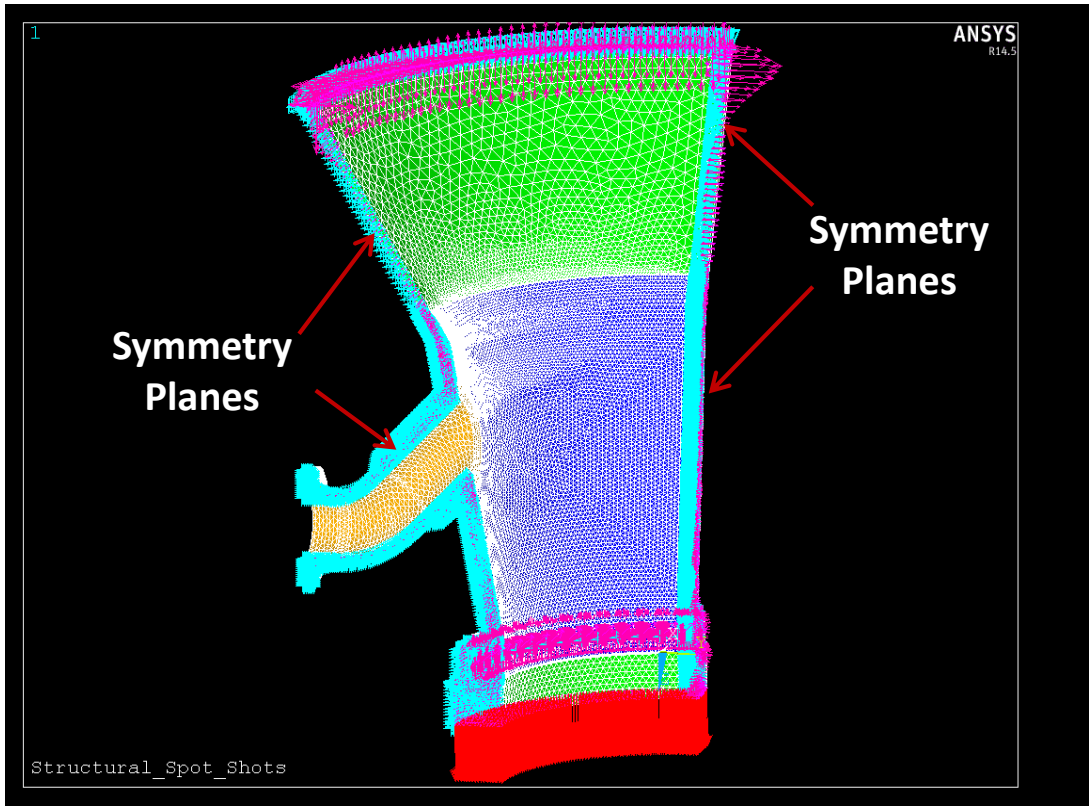
3-D FEA of Dual-Inlet Feed (Continued)

Model

- 3-D Structural Nonlinear Finite Element Analysis
- 400K 3-D 10 node solid elements
- Nonlinear contact analysis
- Gasket Material nonlinear behavior Included
- Bolt pre-tensioning
- Only quarter model included due to symmetry BC
- Temperature dependent material properties
- Ramberg-Osgood nonlinear material model as per API 579
- 3 consecutive cycles modeled

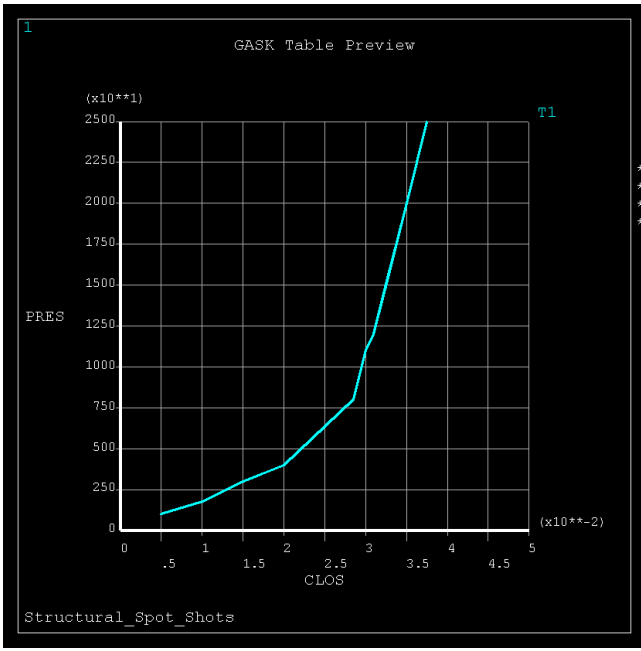
Loading

- 12 Hr. Coker cycle including steam test, vapor heat, 12 hr. charge and quench
- Time Dependent pressure loading
- Temperature body loads from Thermography analysis

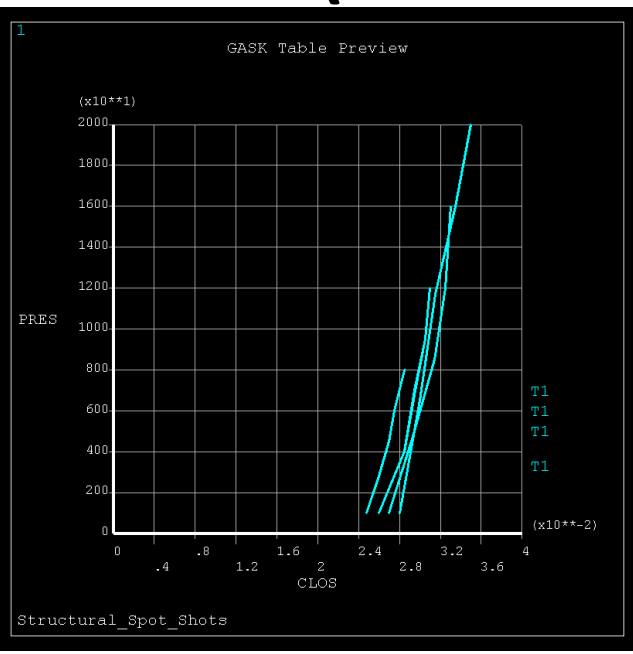


3-D FEA Model

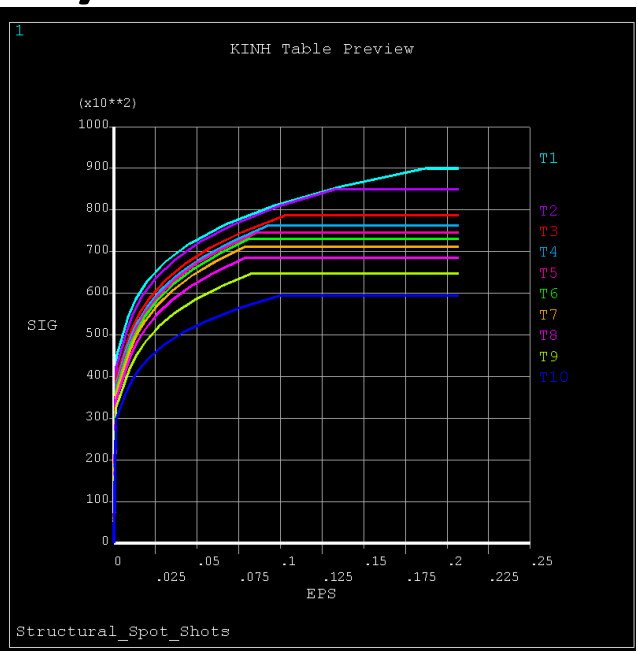
3-D FEA of Dual-Inlet Feed (Continued)



Gasket Loading



Gasket Un-Loading



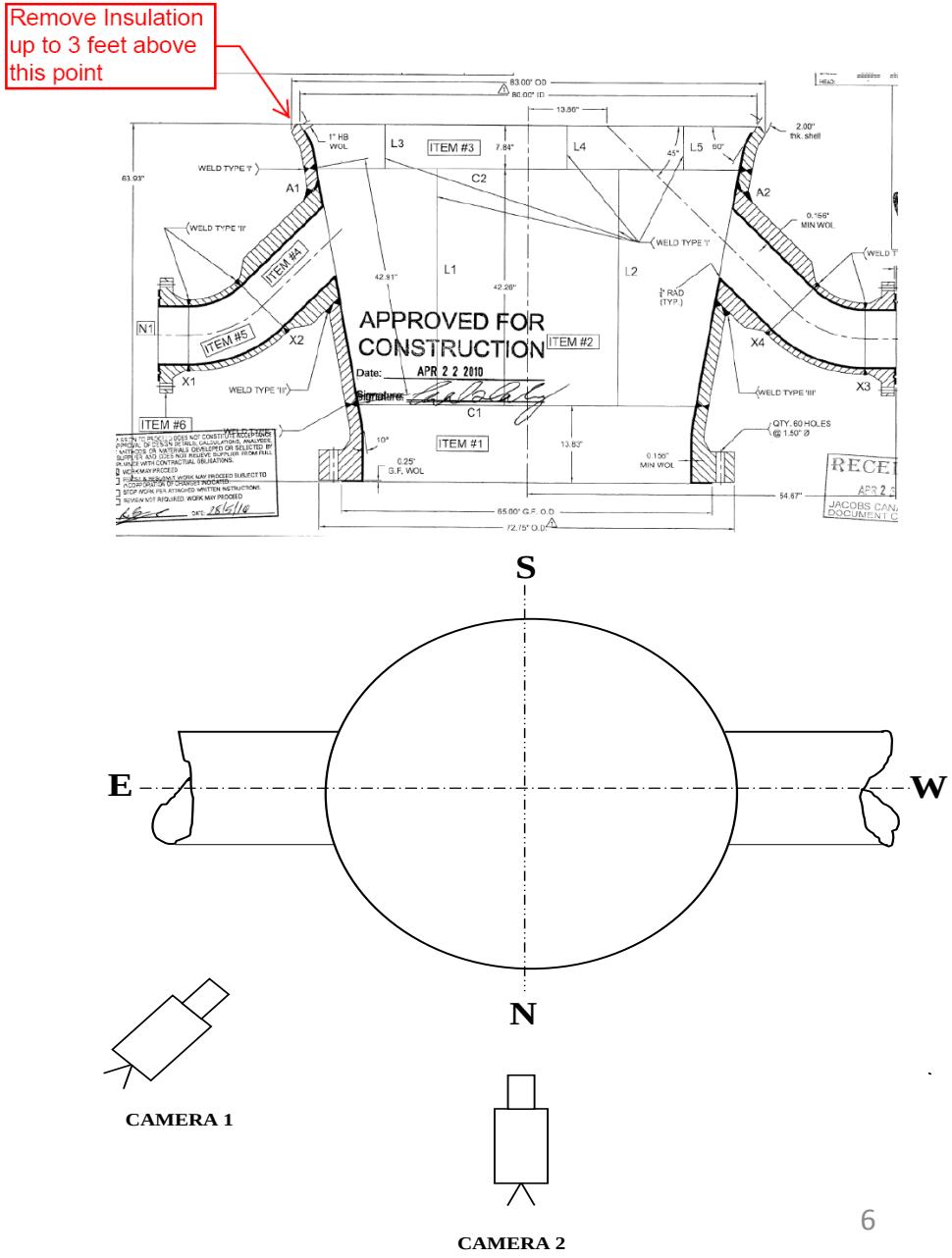
Ramberg-Osgood Material Model

- Gasket loading and unloading curves for CMG SS gasket as provided by manufacturer
- Minimum required gasket seating stress 7600 psi
- Minimum required gasket operating stress 6000 psi
- Gasket crush stress 35000-40000 psi

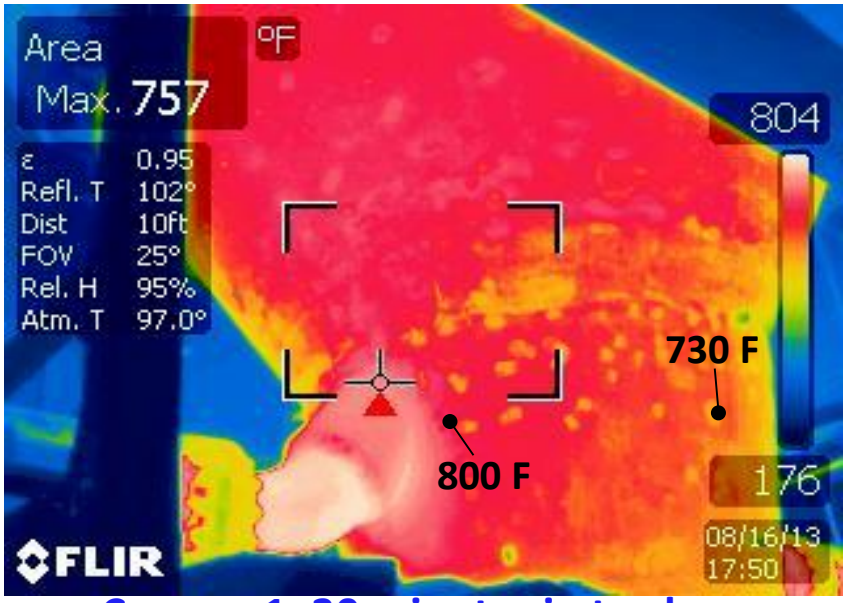
3-D FEA of Dual-Inlet Feed (Continued)

Thermography Scope

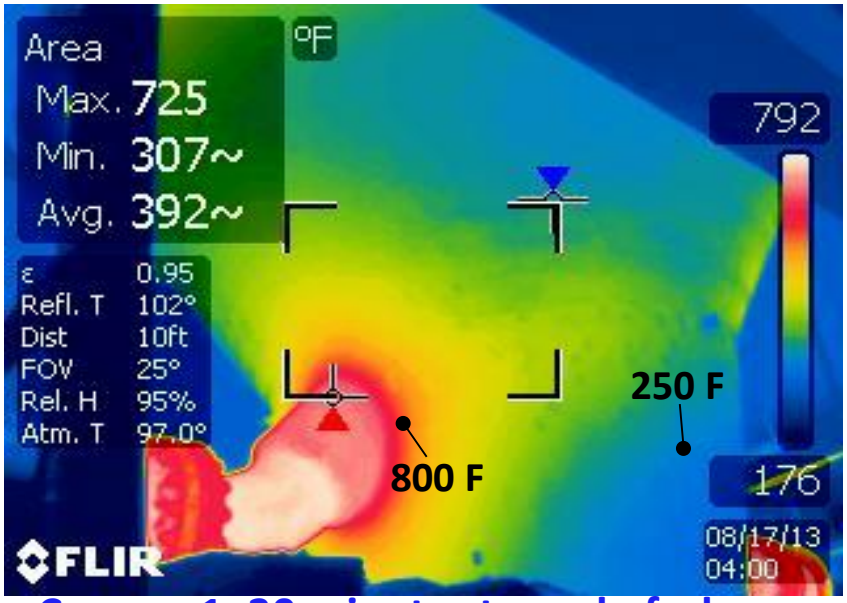
- 2 Cameras
- Steam Test/Vapor heat 1 shot every 10 minutes
- 1hour before and after start of charge 1 shot every minute
- Steady charge 1 shot every 10 minutes
- 1 hour before end of charge till end of water quench, 1 shot every minute



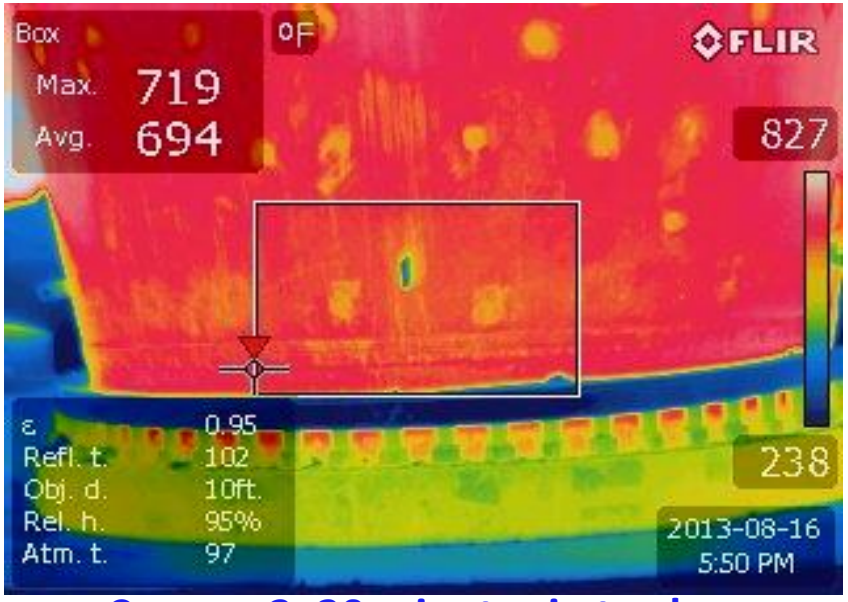
3-D FEA of Dual-Inlet Feed (Continued)



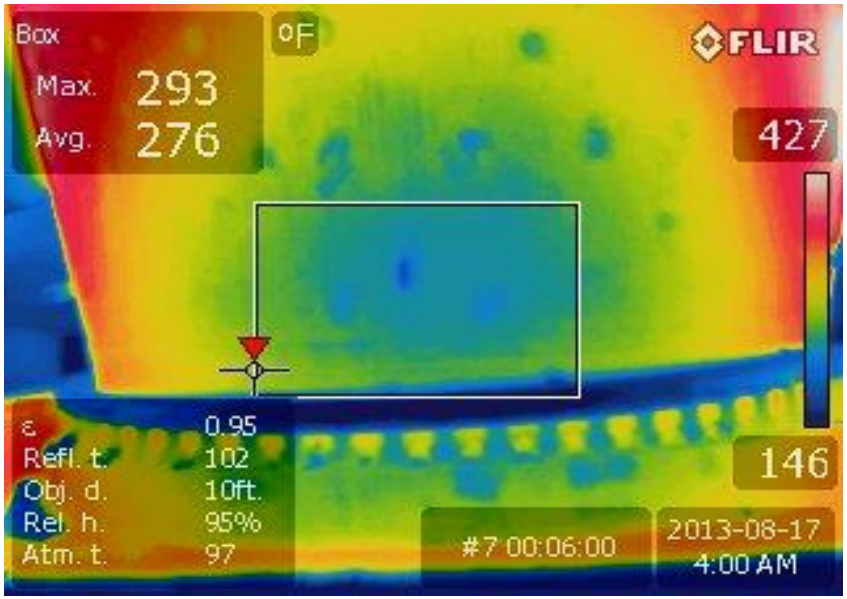
Camera 1. 30 minutes in to charge



Camera 1. 30 minutes to end of charge

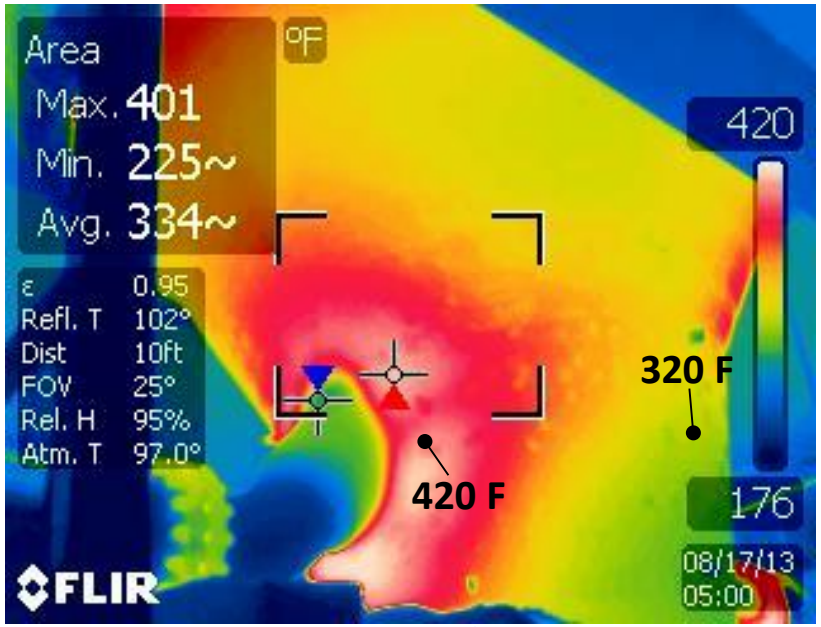


Camera 2. 30 minutes in to charge

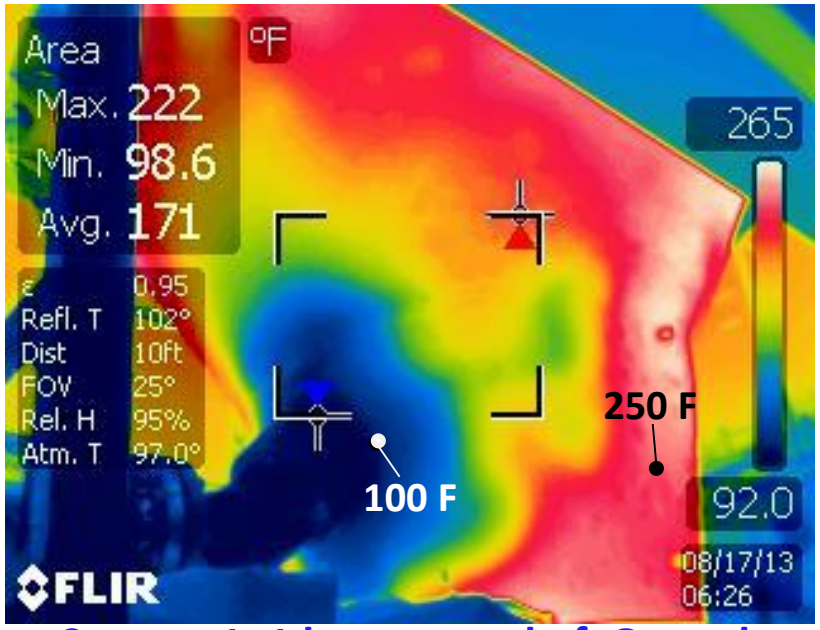


Camera 2. 30 minutes to end of charge

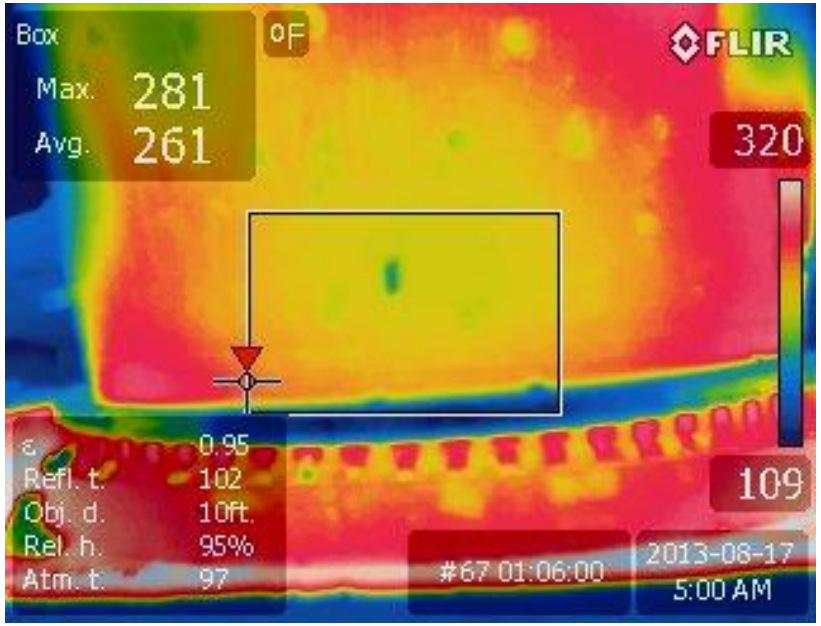
3-D FEA of Dual-Inlet Feed (Continued)



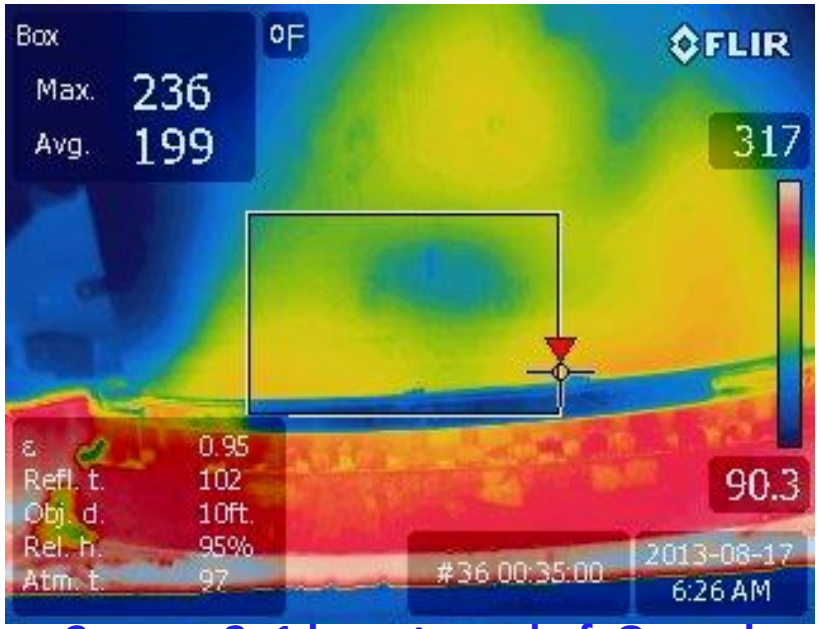
Camera 1. Start of Quench



Camera 1. 1 hour to end of Quench

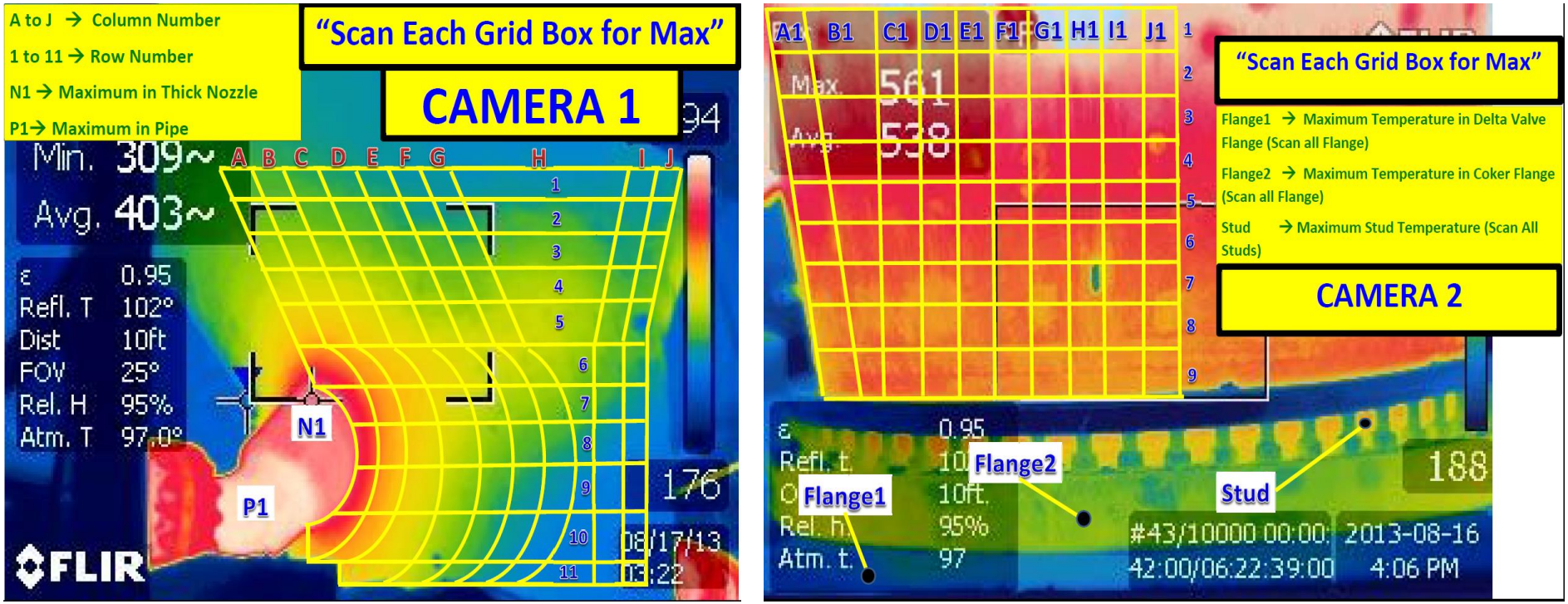


Camera 2. Start of Quench



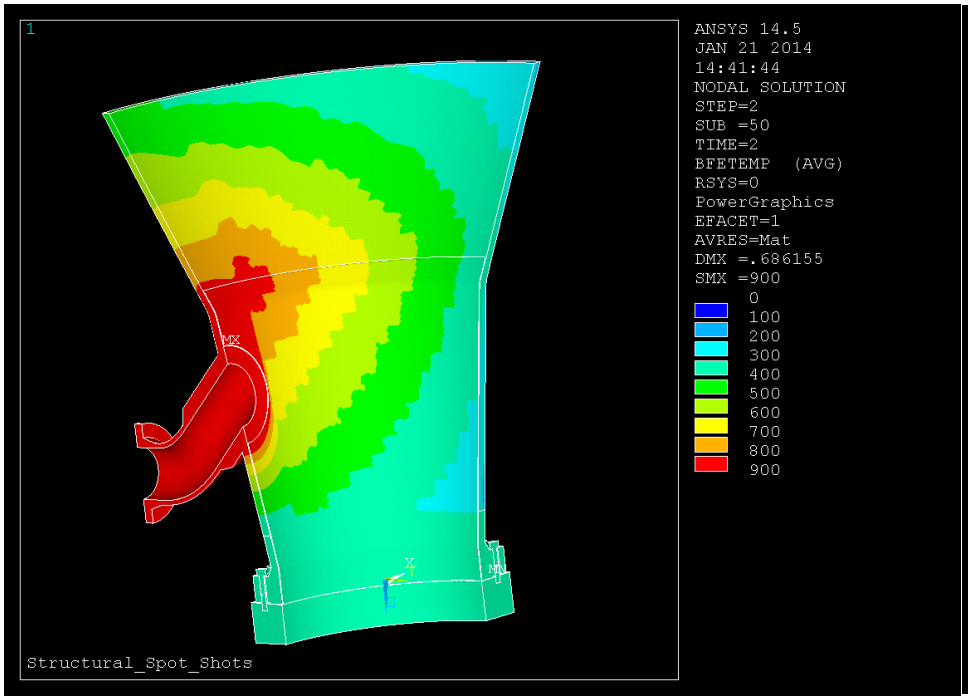
Camera 2. 1 hour to end of Quench

3-D FEA of Dual-Inlet Feed (Continued)

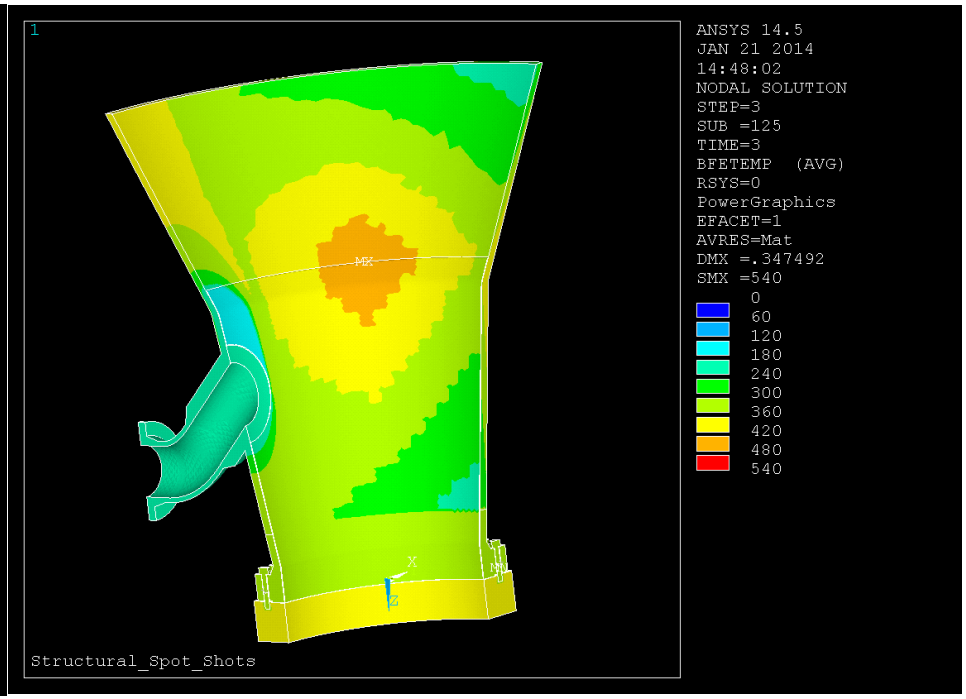


Thermography Grid

3-D FEA of Dual-Inlet Feed (Continued)



Charge

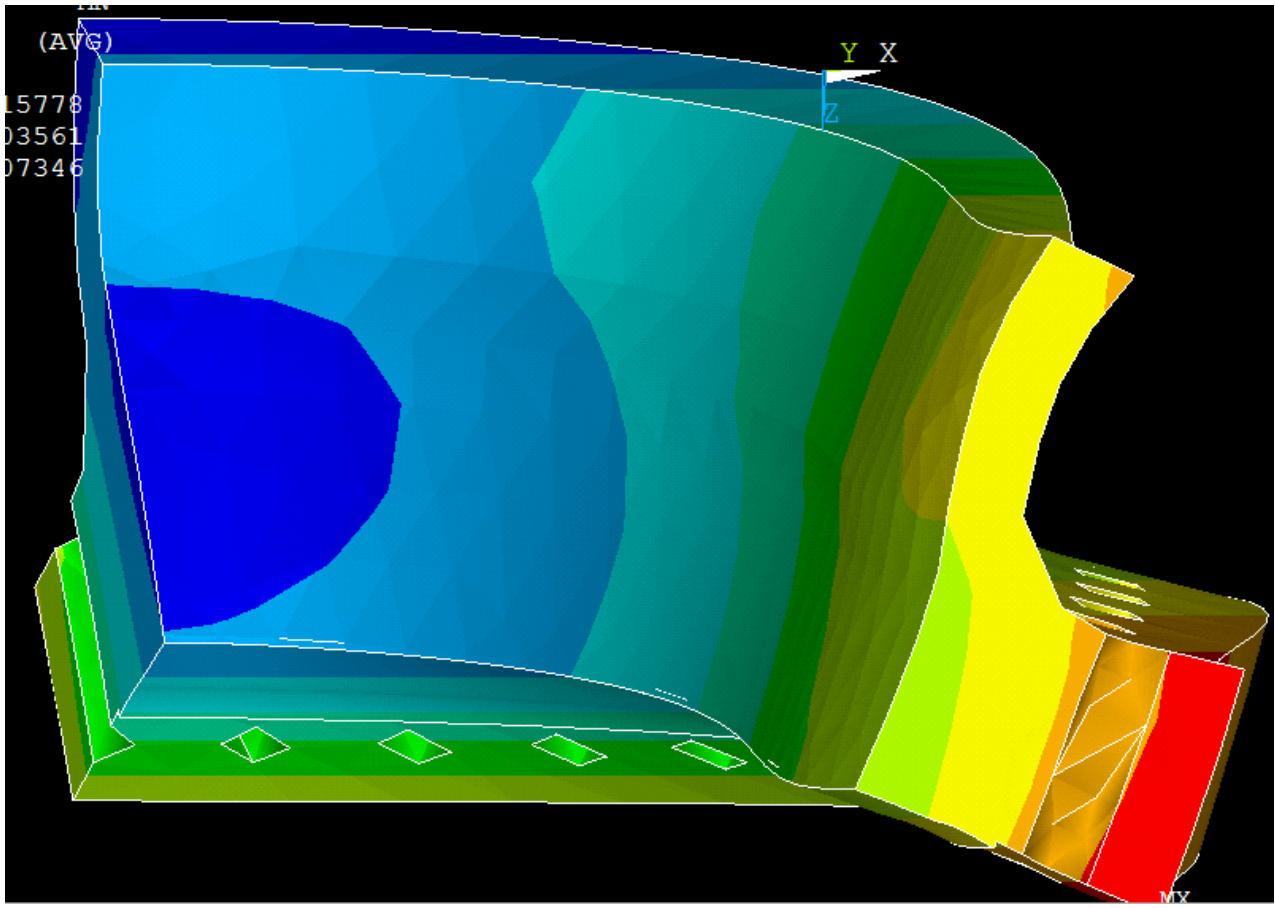


Quench

Temperature Body Loads from Thermography Grid Data

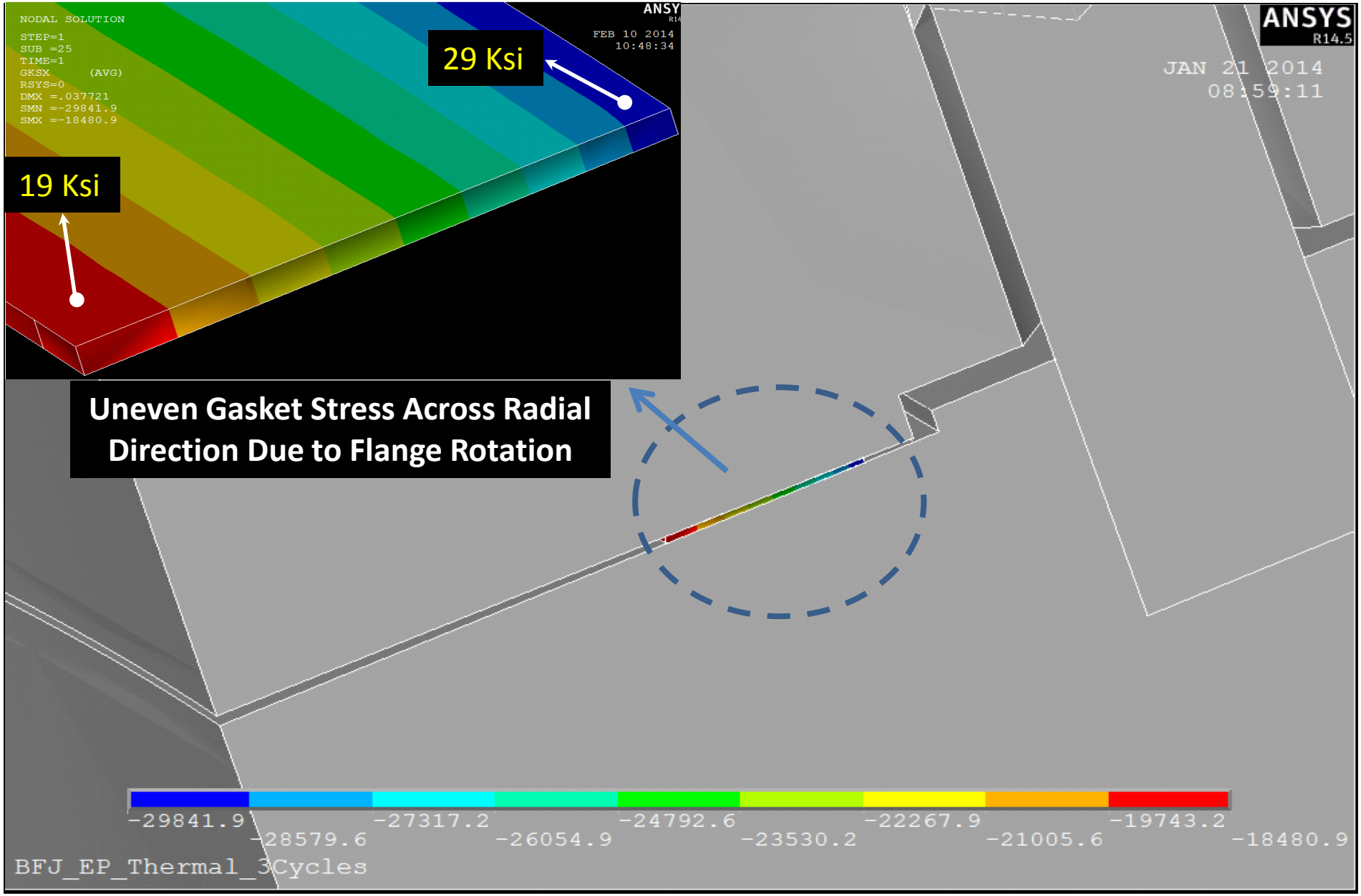
Results

- Coker flange permanent deformation after 3 cycles and releasing all loads including bolt stress
- Deformation on gasket seating surface shows 0.00012” /cycle out of flatness across circumference (~0.44” per year)
- Cowboy hat effect expected to increase with consecutive cycles
- ASME PCC1 recommend maximum 0.01” out of flatness across circumference



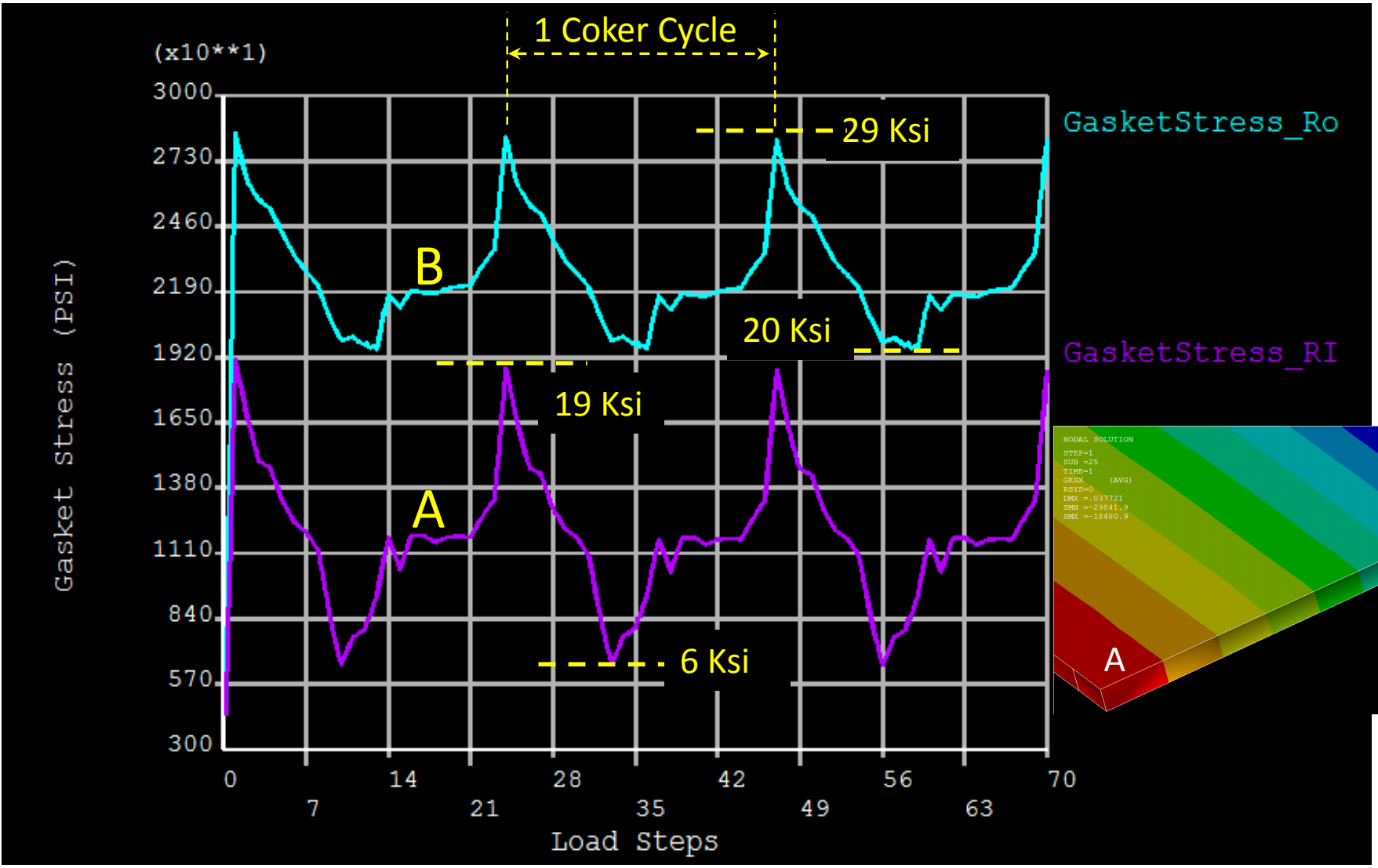
Cowboy Hat Effect on Coker Flange Due to Temperature Gradient Across Circumference- Exaggerated 2000 Times (Only ¼ of Flange Shown)

Results (Continued)



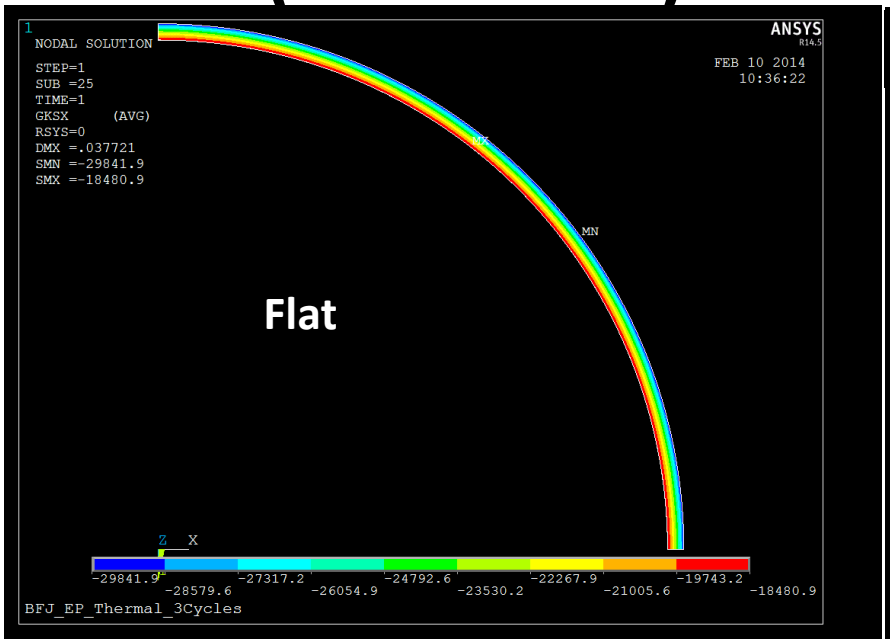
Gasket Stress Post Stud Tensioning

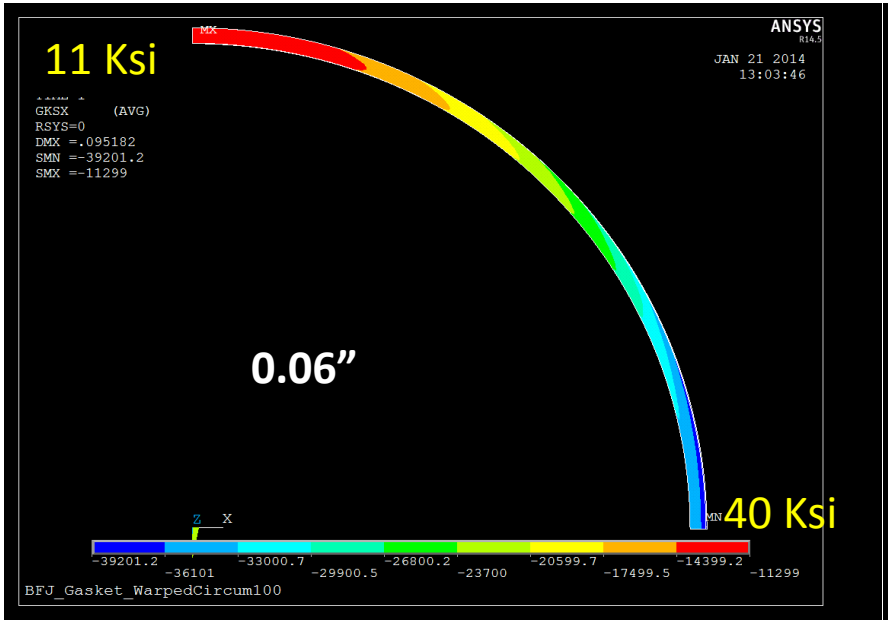
Results (Continued)



Gasket Stress Variation During Coker Cycle on Outer and Inner Radius-3 Cycles (Perfectly Flat Gasket Seating Face)

Results (Continued)





Effect of Gasket Seating Surface Out of Flatness on Gasket Stress

Conclusions

- Cokers equipped with dual inlet feed have been reported to leak frequently at the joint connection with the Bottom Un heading Device (BUD)
- In this study a 3D non-linear structural (FEA) model was developed to investigate the root cause of the connection failure.
- Thermography was conducted on the dual inlet cone and joint connection for the full 12 hour coking cycle.
- Temperature data from the thermography was used as an input load to the FEA model.

Conclusions (Continued)

- Modeling three full coker cycles proves that hot spots generated from the dual inlet feed and the temperature gradient across the dual inlet cone circumference are the main contributors to the flange warpage leading to the connection failure due to the uneven gasket stress distribution.
- Out of flatness across circumference of Gasket seating surface reaches 0.00012” per full coker cycle (0.44”/year)
- Different scenarios for gasket face out of flatness were modeled in the range of 0.02”-0.2” across gasket seating surface circumference
- The model predicts that leakage will start showing when out of flatness reaches ~ 0.14”, which conforms with field measurements at time of leakage

Conclusions (Continued)

- Criterion of 0.02” for gasket face machining at Coker annual was proven to be sufficient to run the coker free of leakage to next planned outage.
- The developed criterion exceeds ASME PCC-1 recommended machining criterion of 0.01”
- Current mitigation include more frequent re-tensioning to avoid expected stud relaxation from out of flatness accumulation through cycles and using Inconel 625 gaskets
- Future mitigation would include new design or stiffening the flange

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