Thermal Transient Analyses of Nominal and Bulged Skirts

Prepared by
Julian J. Bedoya, P.E.
Senior Associate
Presented by
Sathish Ramamoorthy Ph.D., P.E.
Associate

Coking.com®
MORE PRODUCTION - LESS RISK!

Coking & CatCracking Conference
New Delhi, India - October, 2013

STRESS ENGINEERING SERVICES INC.
an employee-owned company

Purpose

- Evaluate the effect of thermal loading of skirts with bulges.
  - Choose a coking cycle with typical rates that are aggressive, but not overly aggressive.
- Perform Finite Element Analysis (FEA) on a range of bulged skirts.
  - Nominal: No bulge
  - Bulge of 1.5 inches
  - Bulge of 2.0 inches
- Calculate the cyclic fatigue life based on the stress range during the coking cycle.
  - Cyclic life based on Section VIII, Division 3 procedures.

Model Geometry/Materials

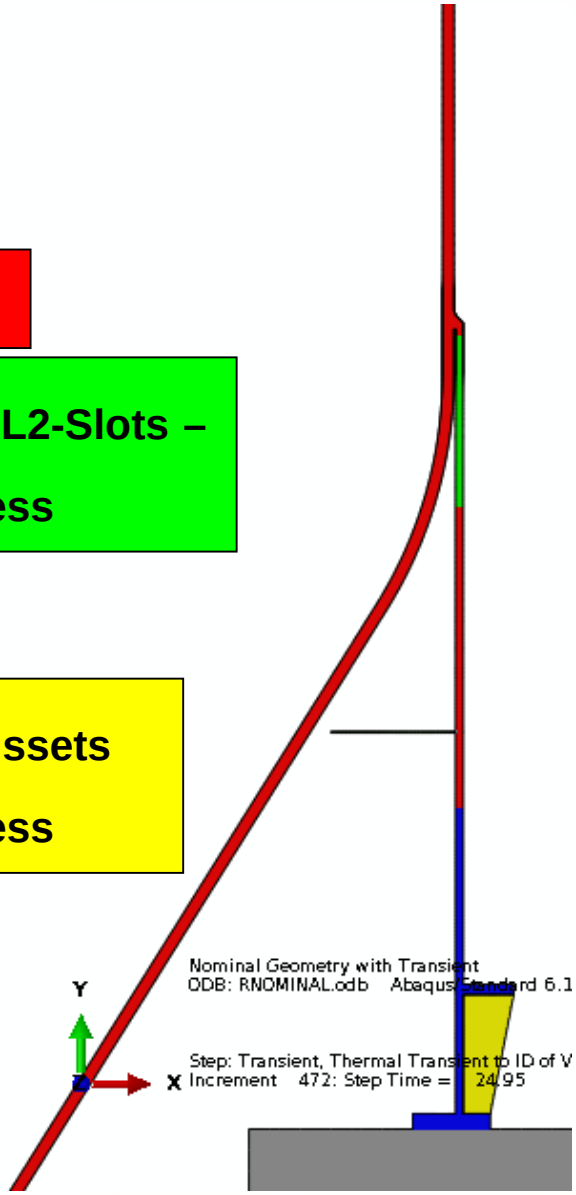
SA-387-GR-11-CL2

SA-387-GR-11CL2-Slots –
No hoop Stiffness

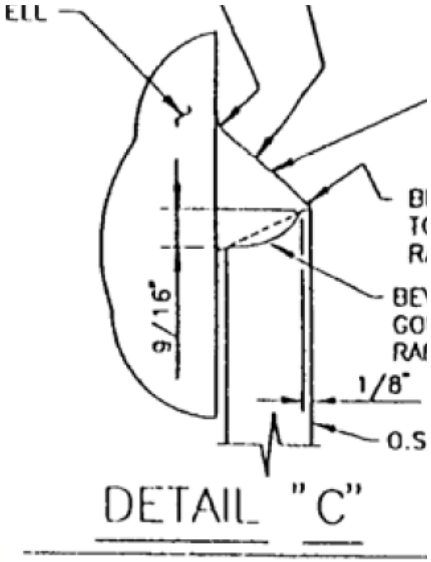
SA-516-70

SA-516-70 – Gussets
No hoop Stiffness

Concrete



- **Drum ID = 27 Feet**
- **Drum Can#1 and Cone W.T. = 1.14”**
- **Skirt ID = 326.75”; Skirt Height = 76.5”**
- **Gap Between Drum and Skirt = 0.125”**



Loads and Boundary Conditions – Mechanical

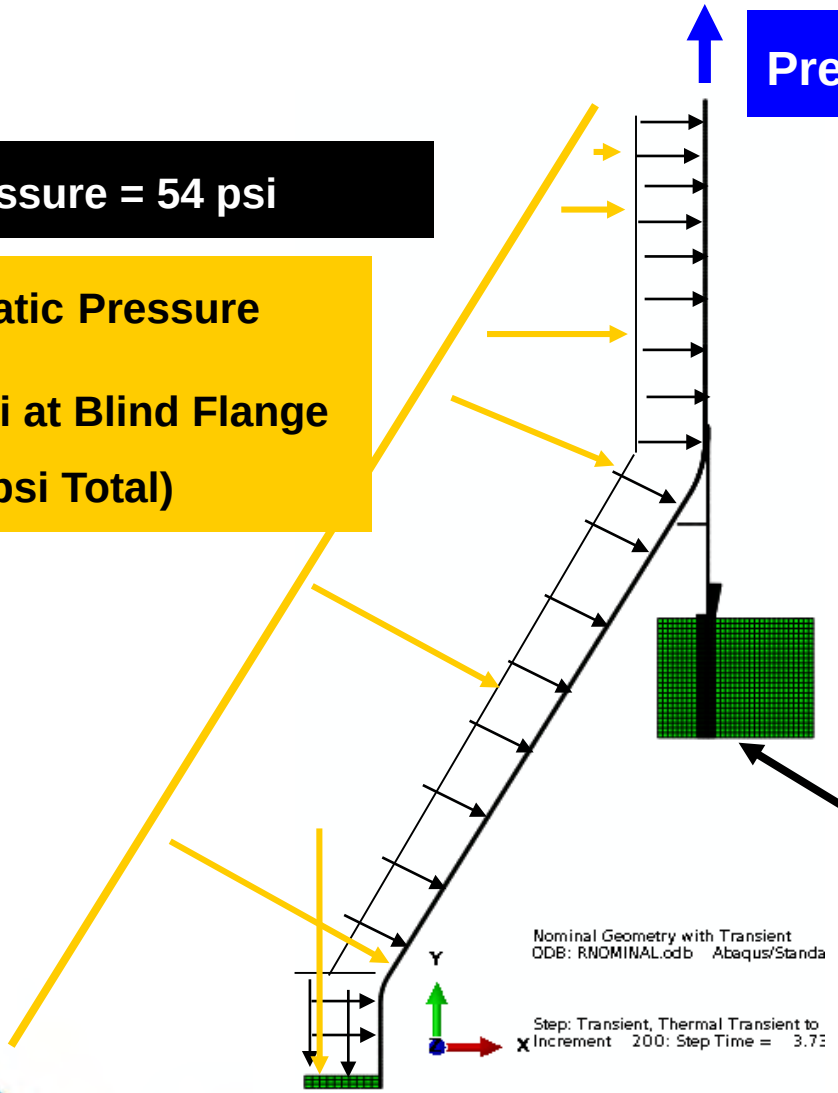
Pressure End Load = PAc

Internal Pressure = 54 psi

Hydrostatic Pressure

69.36 psi at Blind Flange

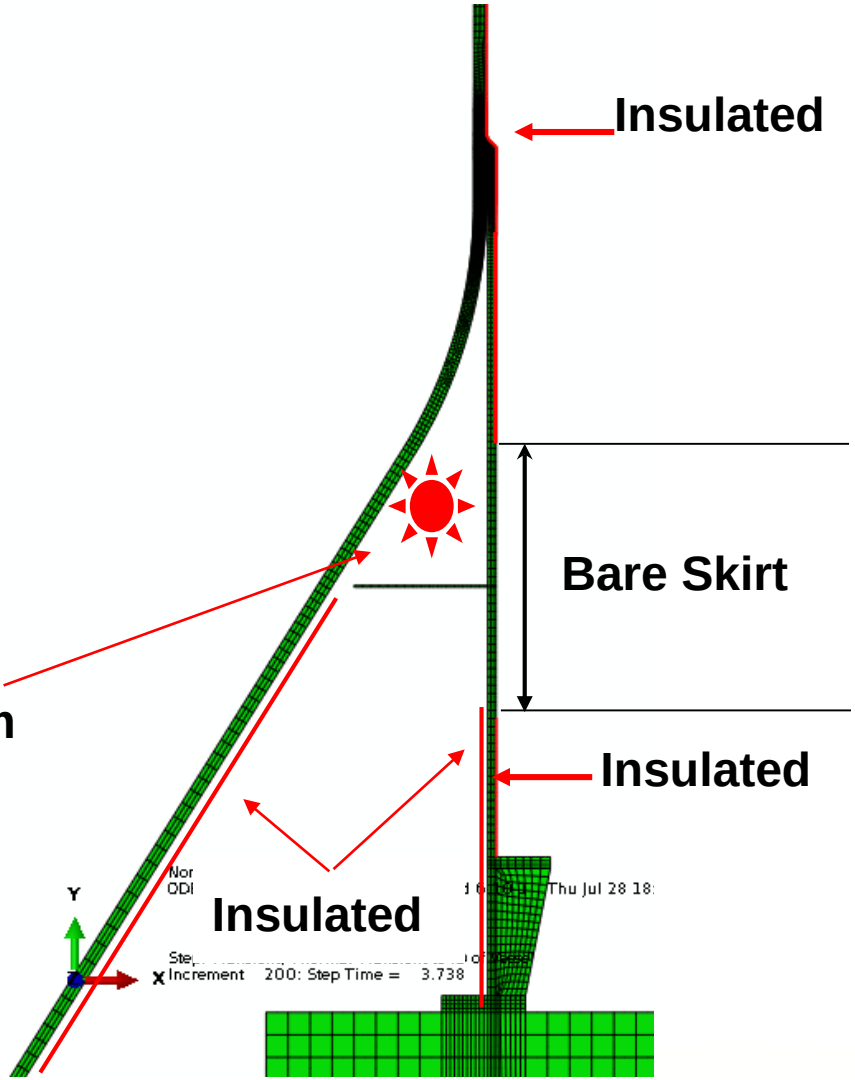
(123.55 psi Total)



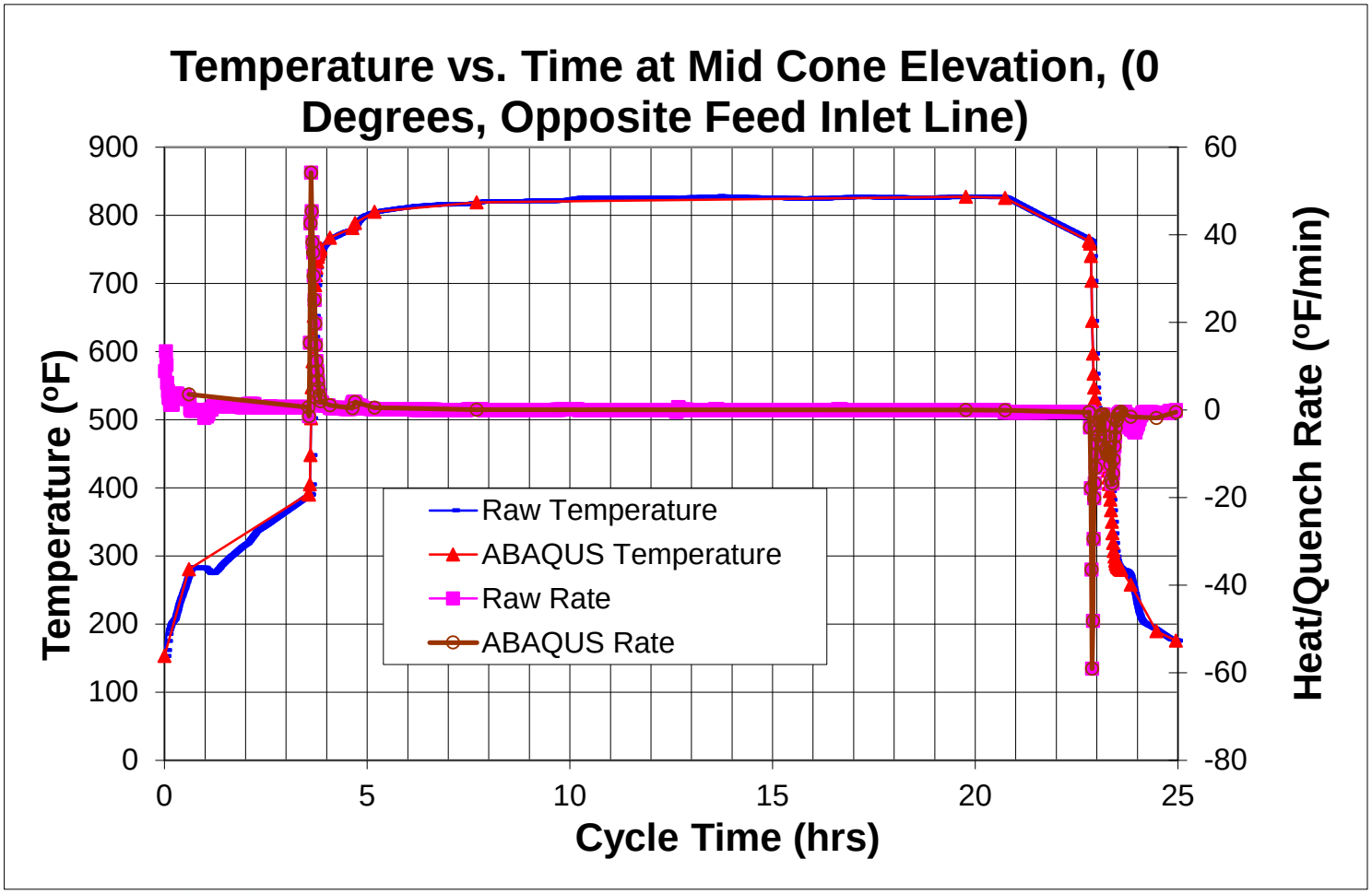
Concrete fixed at bottom

Loads and Boundary Conditions

Radiation Between Cone and Skirt From Hot Box



Transient Thermal Analysis Input Parameters

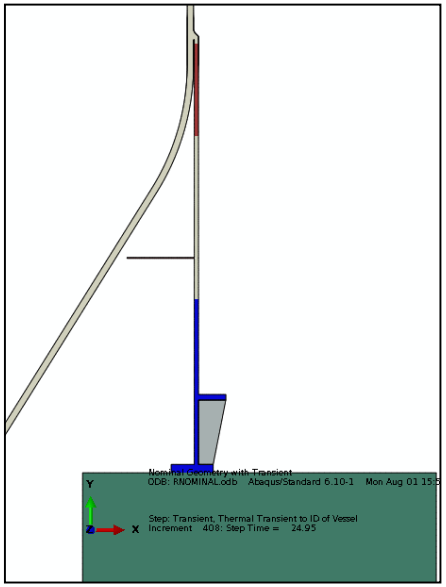


- **Max Fill Rate: 54.2ºF/min**
- **Max Quench Rate: 59.1ºF/min**
- **Switch-In Temperature = 390ºF**
- **Switch-Out Temperature = 758ºF**

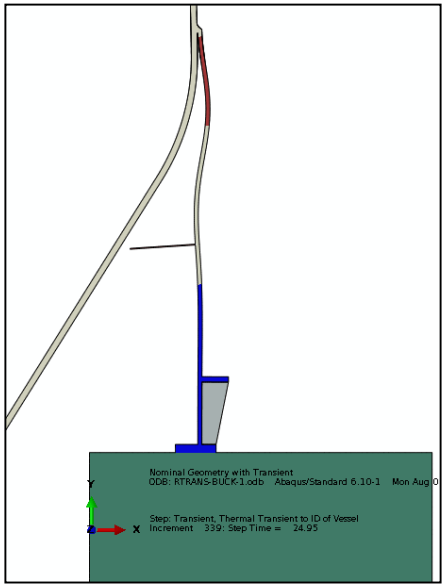
Geometries Analyzed

- **Three different geometries were analyzed:**

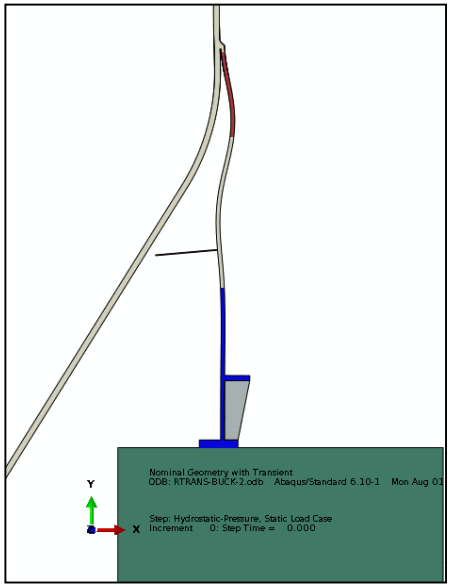
Nominal Skirt Geometry



Skirt with a 1.5” Bulge



Skirt with a 2.0” Bulge

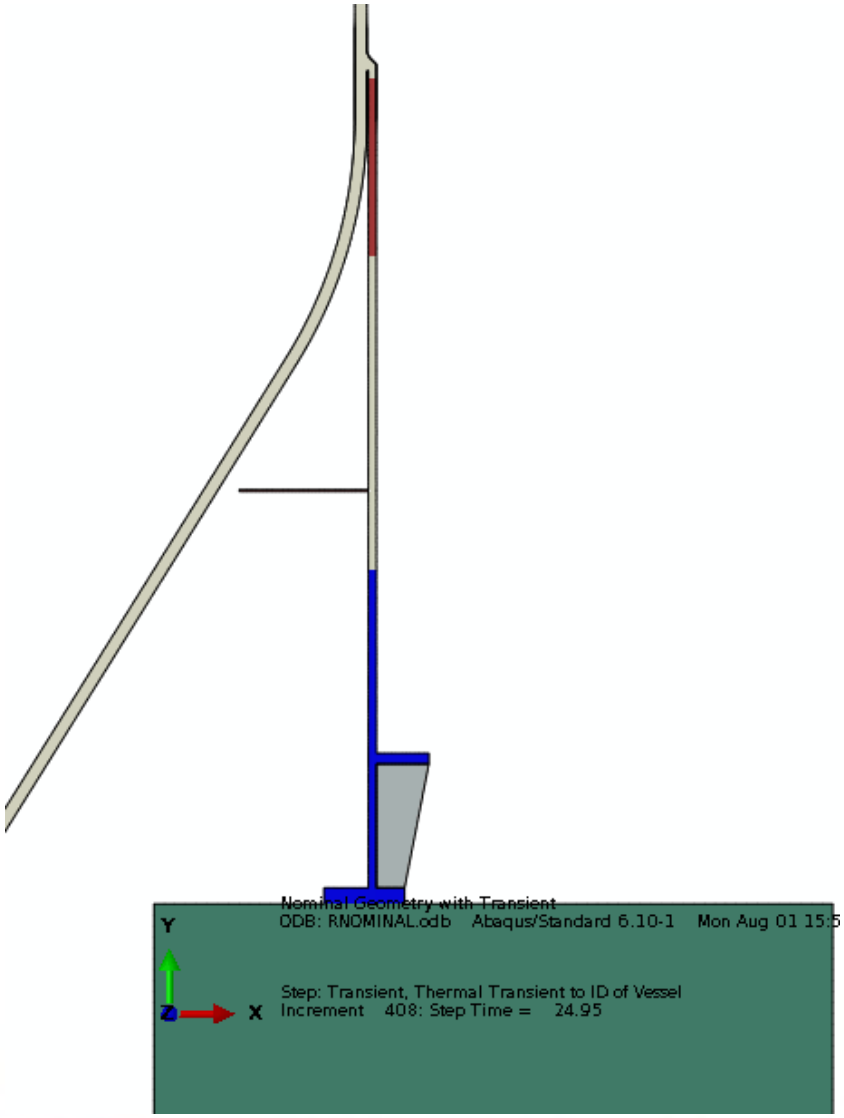


Results For Nominal Geometry

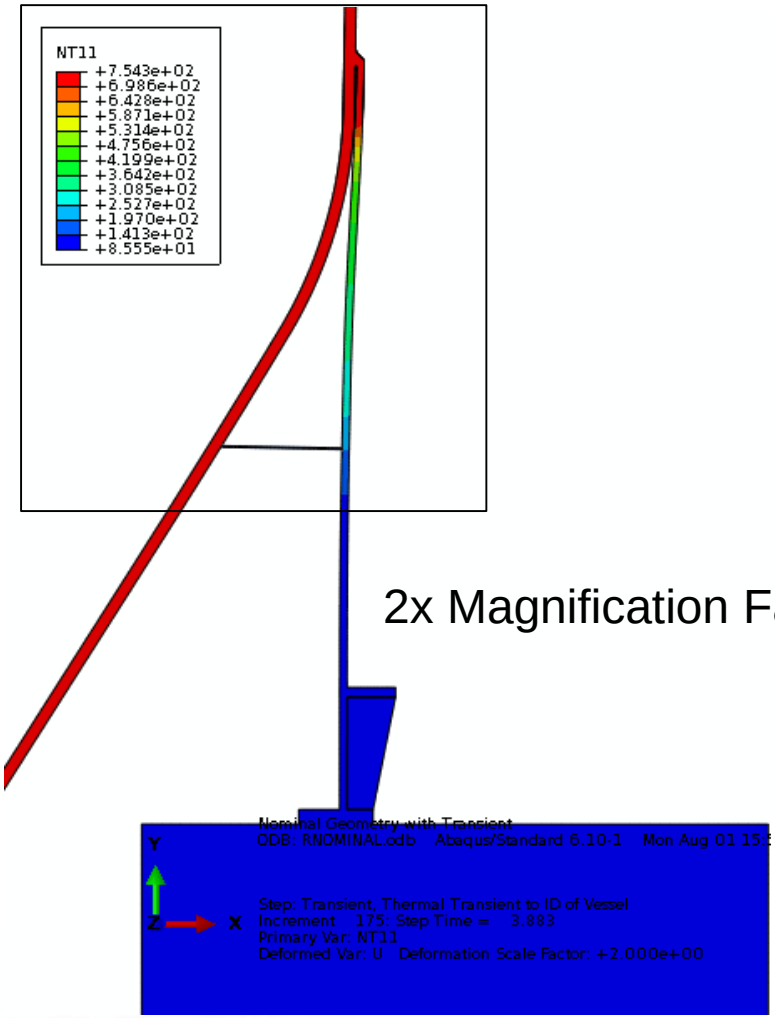
Undeformed

Nominal Skirt

Geometry

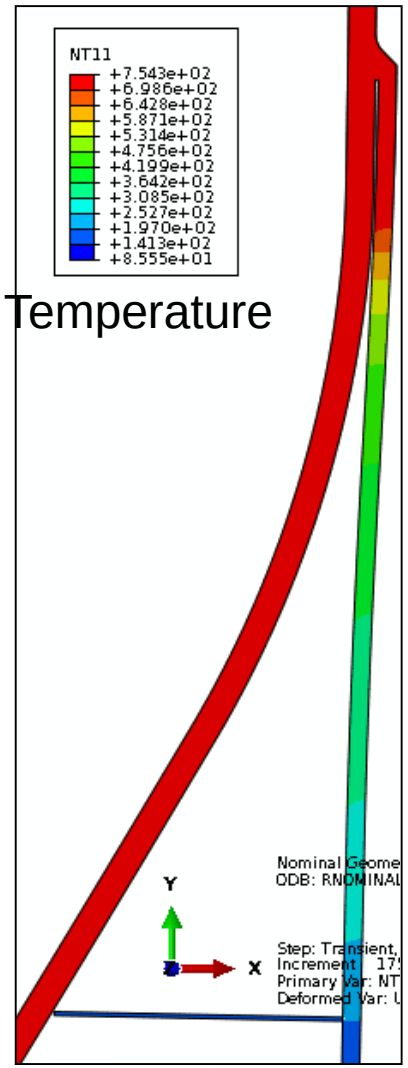


Temperature During the Fill Transient
3.88 hrs – Nominal

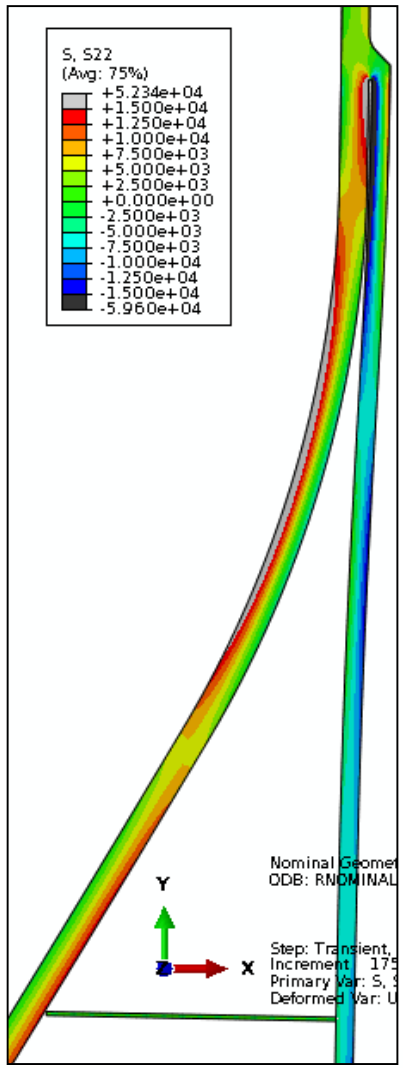


2x Magnification Factor

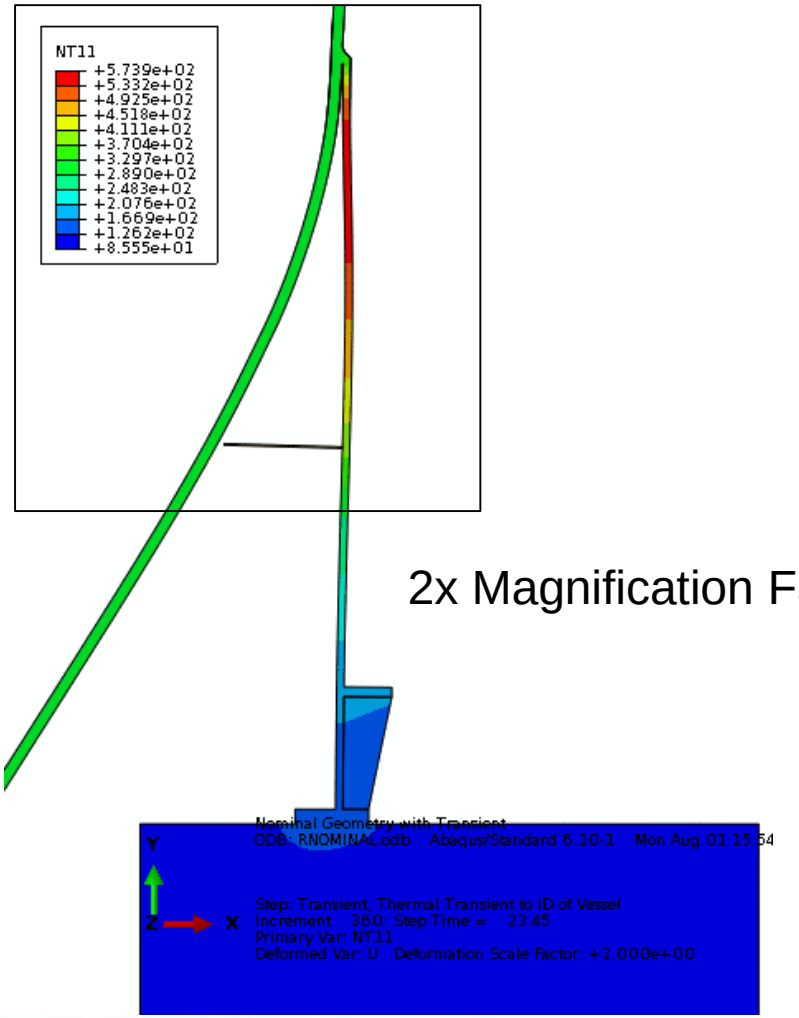
Temperature



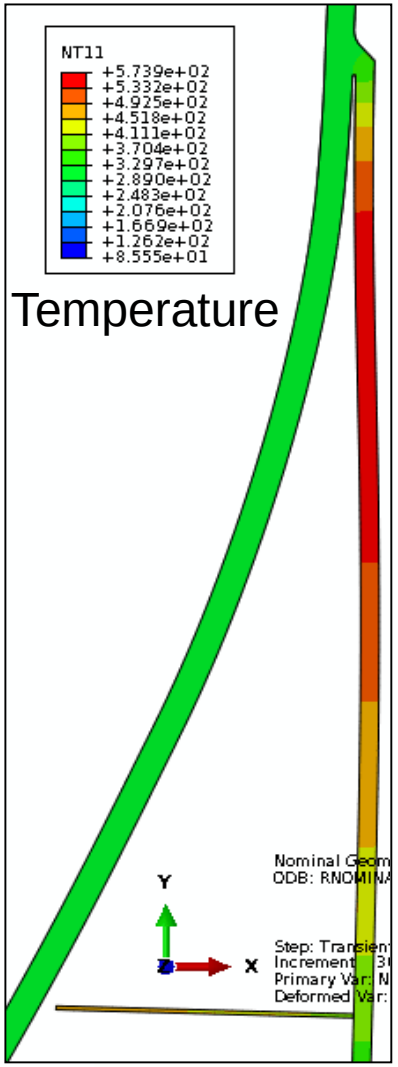
Axial Stress



Temperature During the Quench Transient
23.45 hrs – Nominal

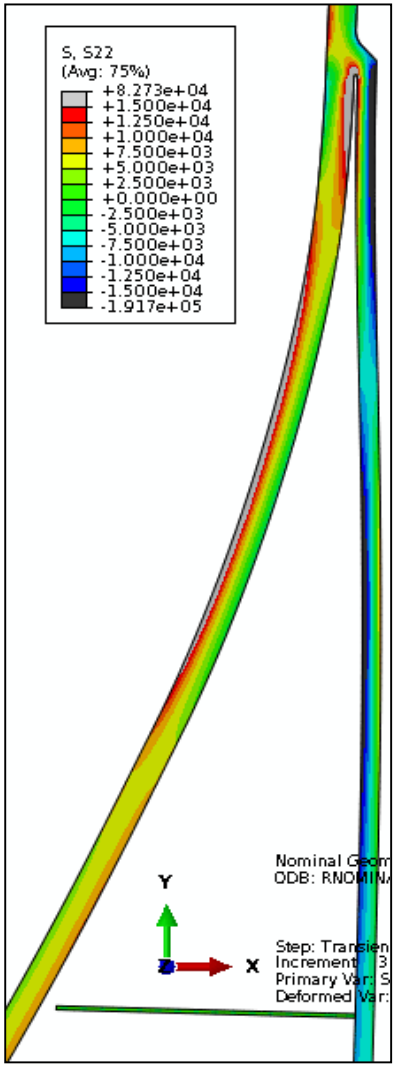


2x Magnification Factor



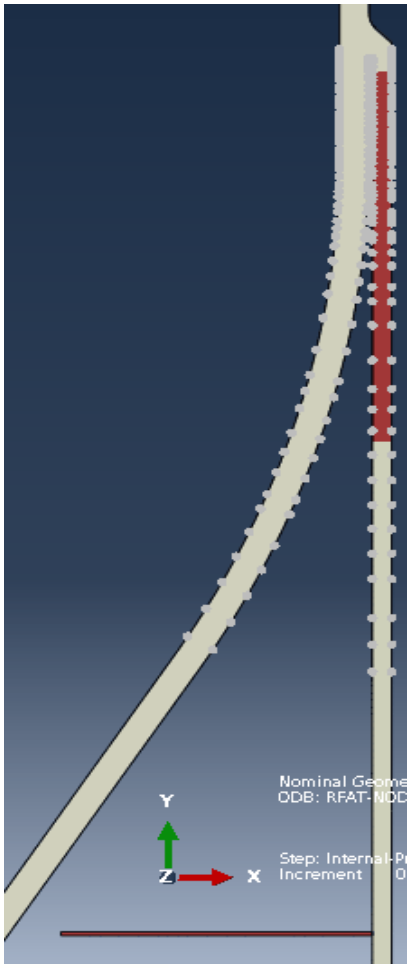
Temperature

Axial Stress



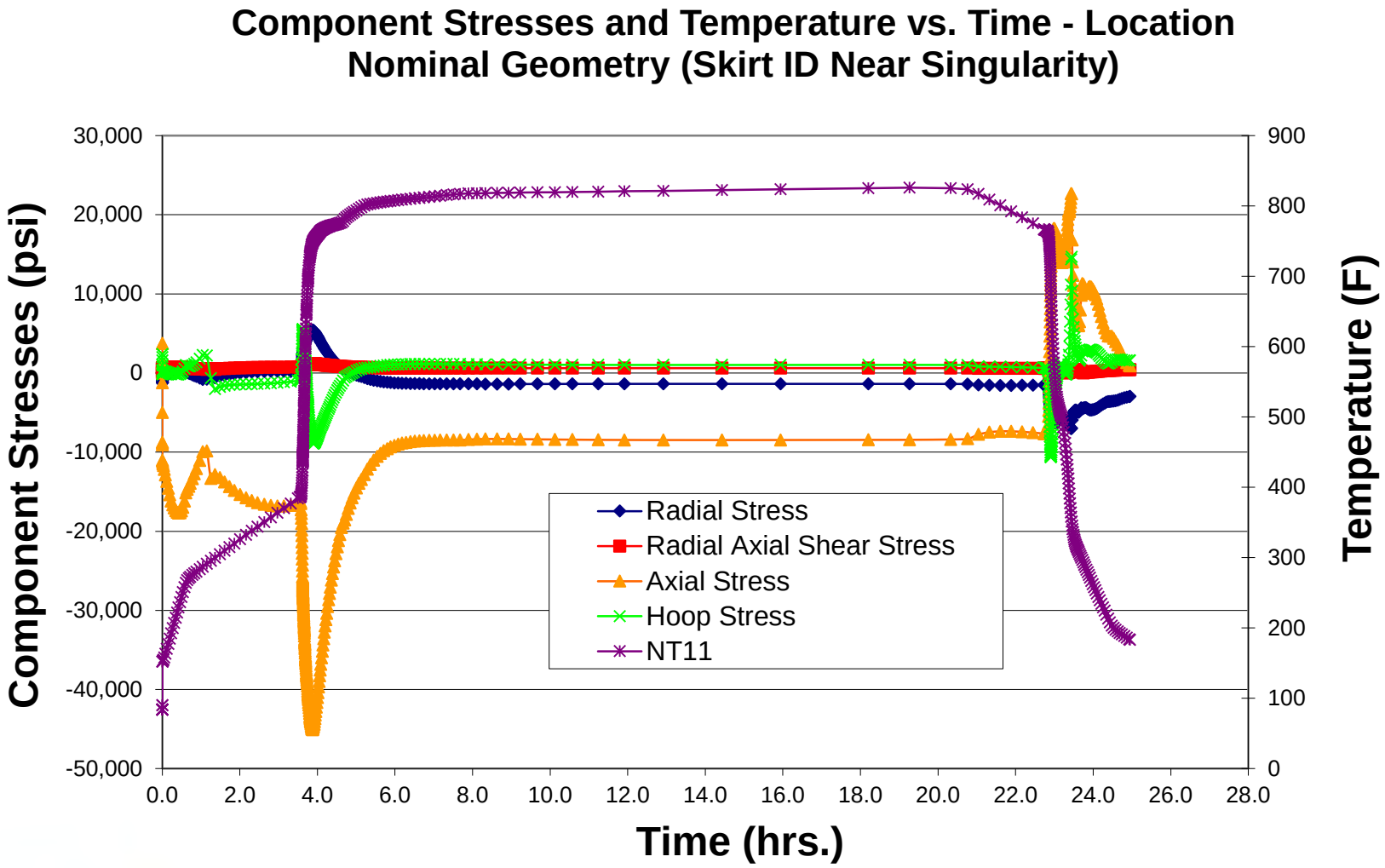
Model Results

Nodal Locations Analyzed For Fatigue



- Presented in terms of component stress differences:
- Extreme points in the cycle for each location analyzed is identified and a stress difference is calculated.
- Fatigue life is then calculated based upon the stress intensity range at the time-average transient temperature using KD320.2 in ASME VIII Div. 3 (2004)

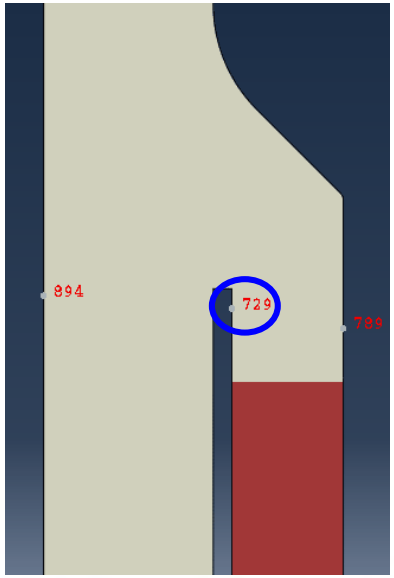
Component Stresses – Nominal Geometry



Fatigue Calculation Results
Skirt ID Near Singularity

- **Analysis reported at ~0.125” away From Singularity**
- Stress range = 80.2 ksi
- Alternating stress = 40.1 ksi
- Adjusted Alternating stress (560F) = 44.4 ksi
- Minimum Fatigue life (@ 560F) = **6,409** cycles

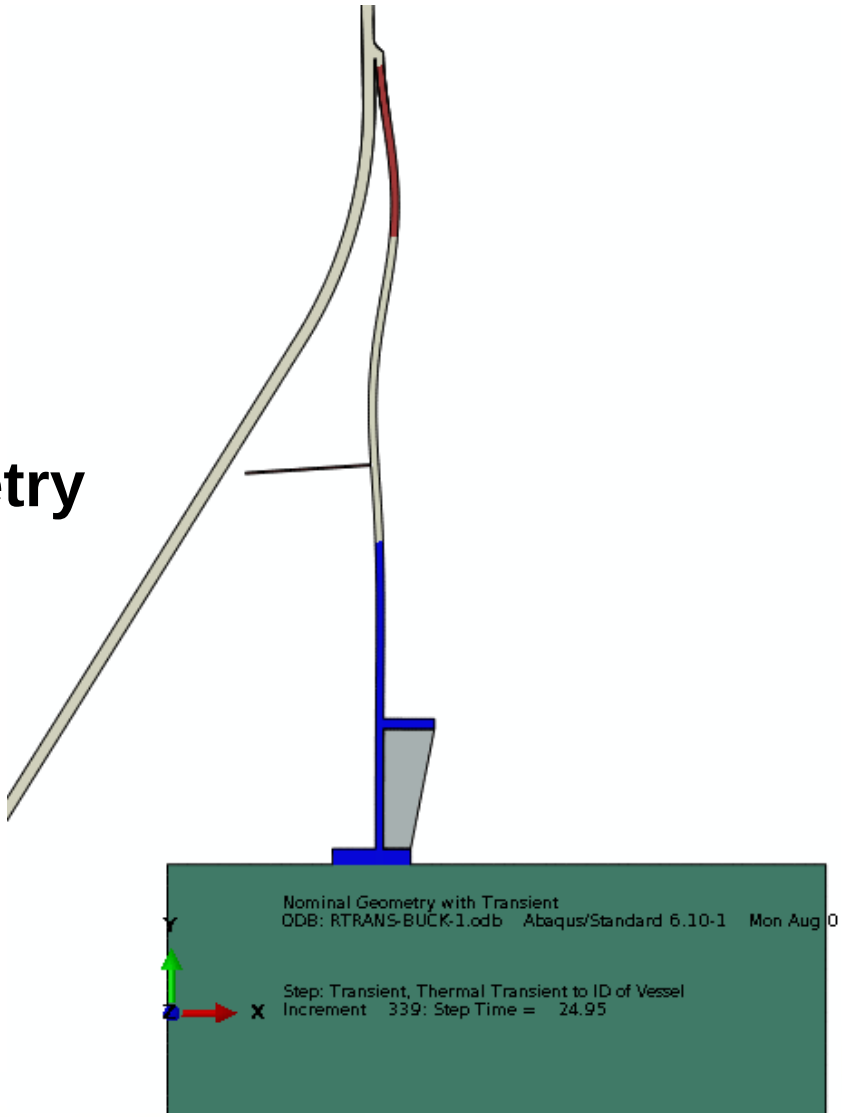
Per ASME VIII Div. 3 Fatigue Equations for Welded Construction KD 320.2



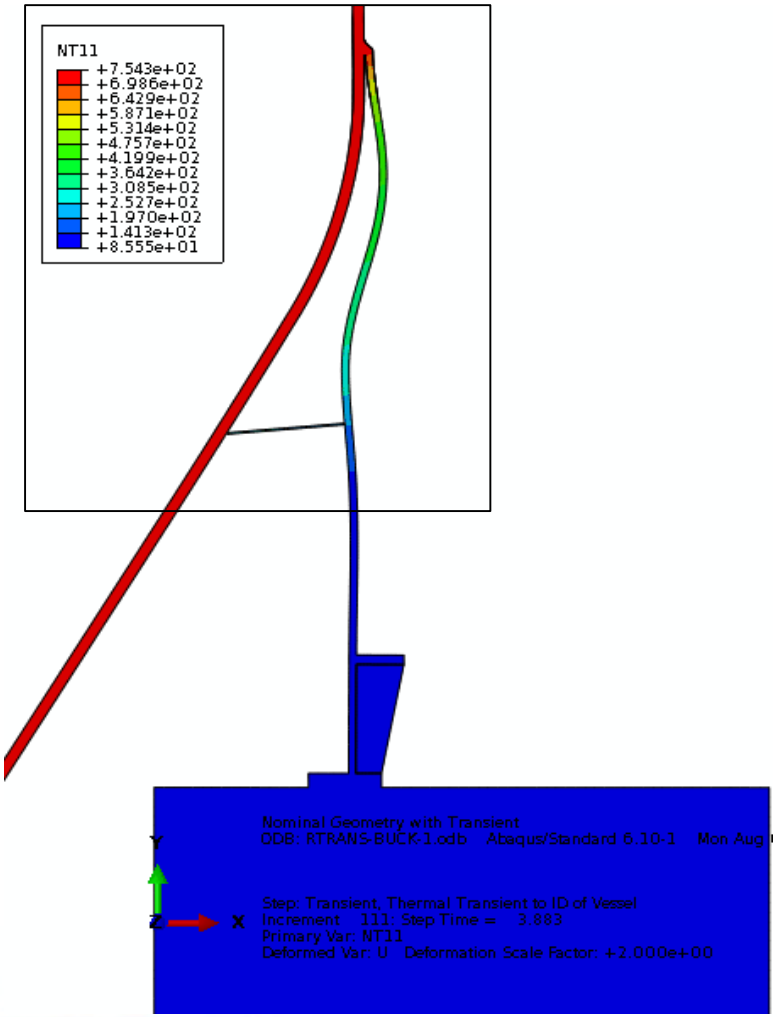
Results For 1.50” Bulge Geometry

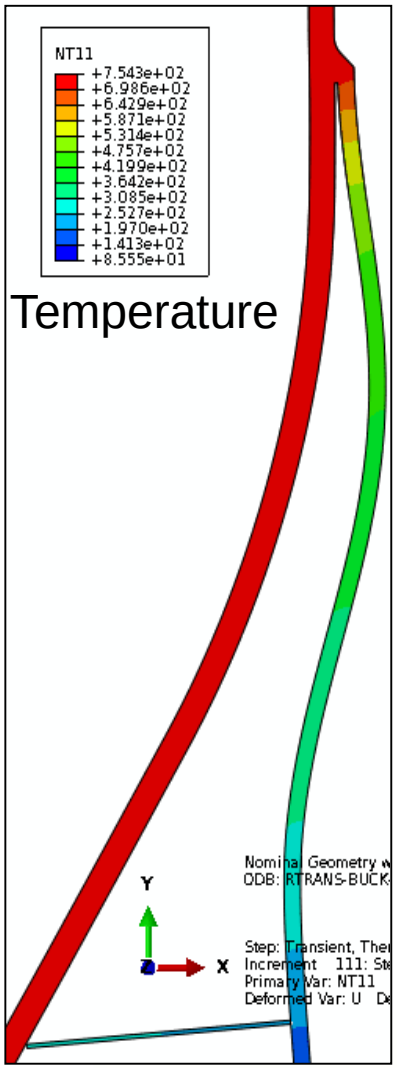
Undeformed 1.50”

Bulge Skirt Geometry



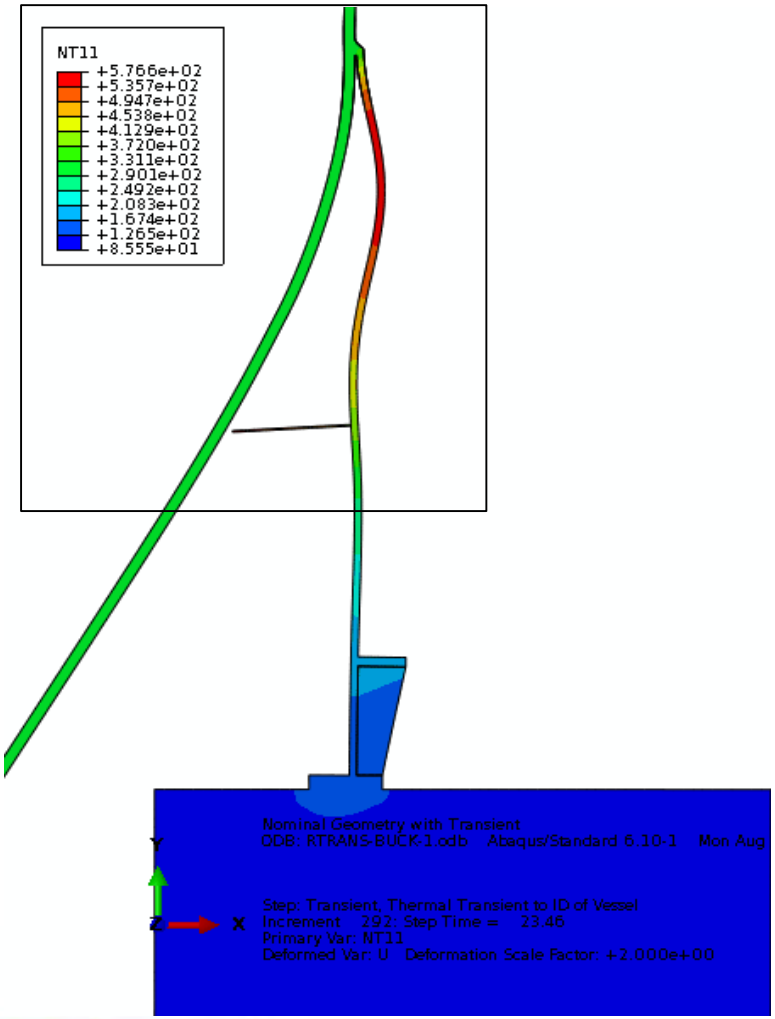
Temperature During the Fill Transient
3.88 hrs – 1.50” Bulge

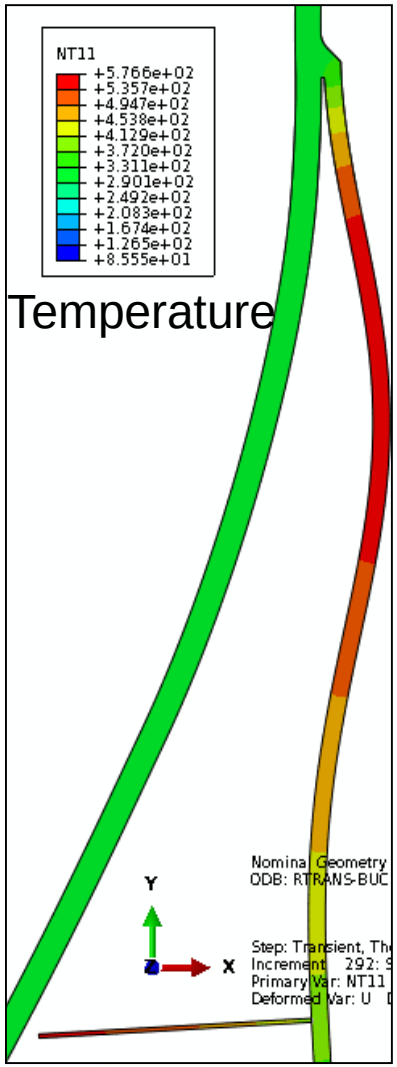




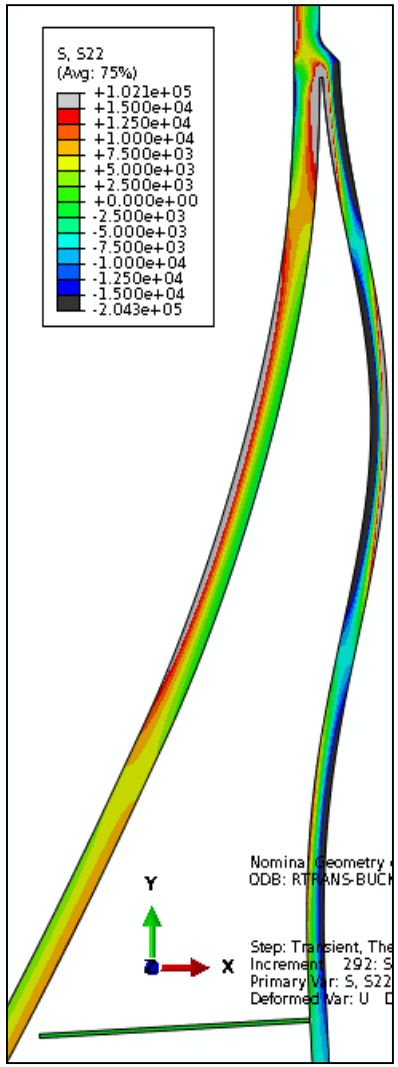
Axial Stress

Temperature During the Quench Transient
23.46 hrs – 1.50” Bulge





Axial Stress

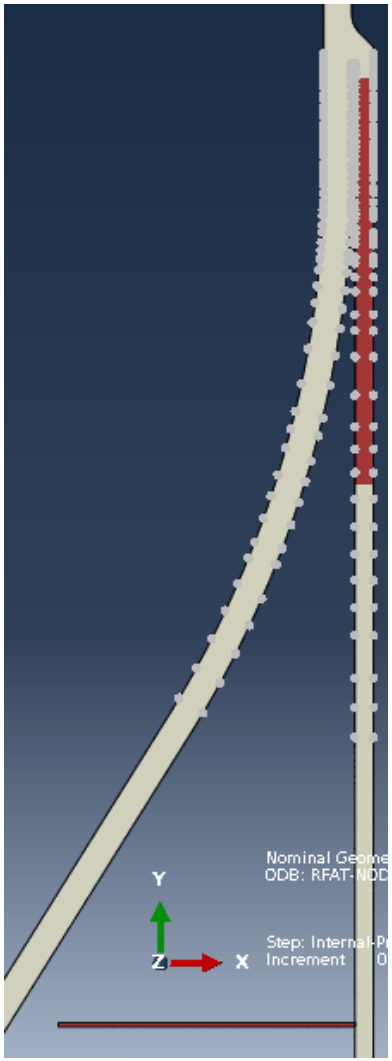


Model Results

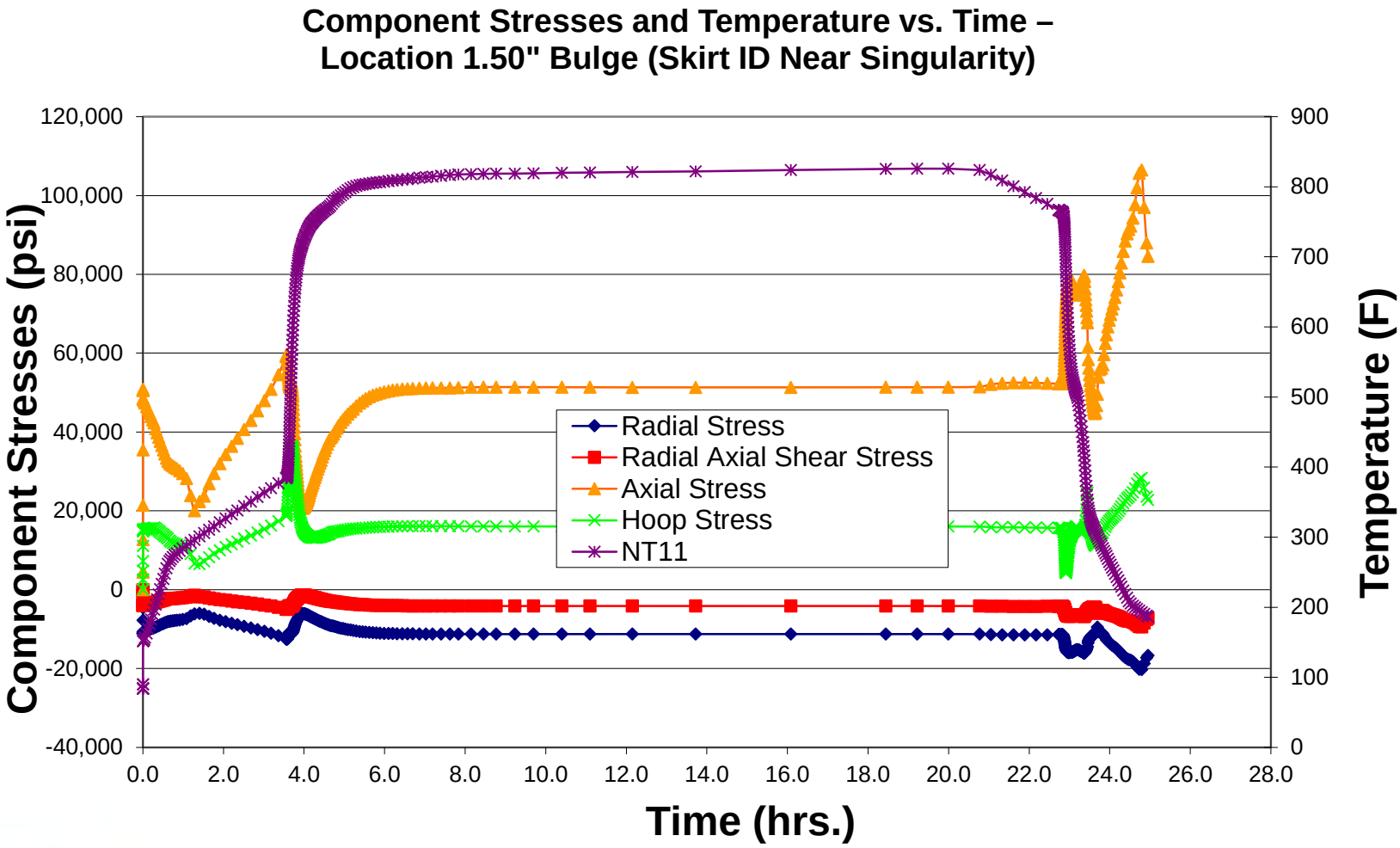
The same presentation and format as for the nominal geometry

- Presented in terms of component stress differences:
- Extreme points in the cycle for each location analyzed is identified and a stress difference is calculated.
- Fatigue life is then calculated based upon the stress intensity range at the time-average transient temperature using KD320.2 in ASME VIII Div. 3 (2004)

The exact same nodal locations as for the nominal geometry are reported



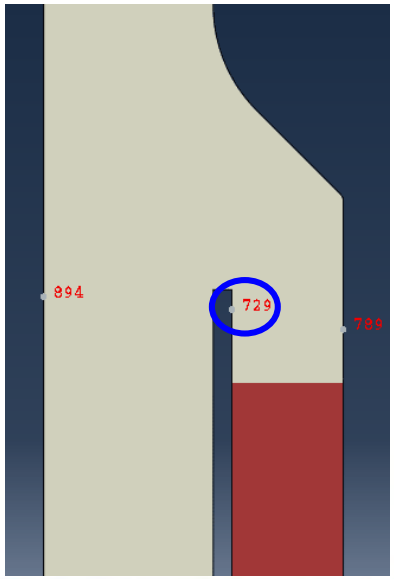
Component Stresses – 1.50” Bulge



Fatigue Calculation Results
Skirt ID Near Singularity – 1.50” Bulge

- **Analysis reported at ~0.125” away From Singularity**
- Stress range = 128.1 ksi
- Alternating stress = 64.1 ksi
- Adjusted Alternating stress (560F) = 70.9 ksi
- Minimum Fatigue life (@ 560F) = **1,497** cycles

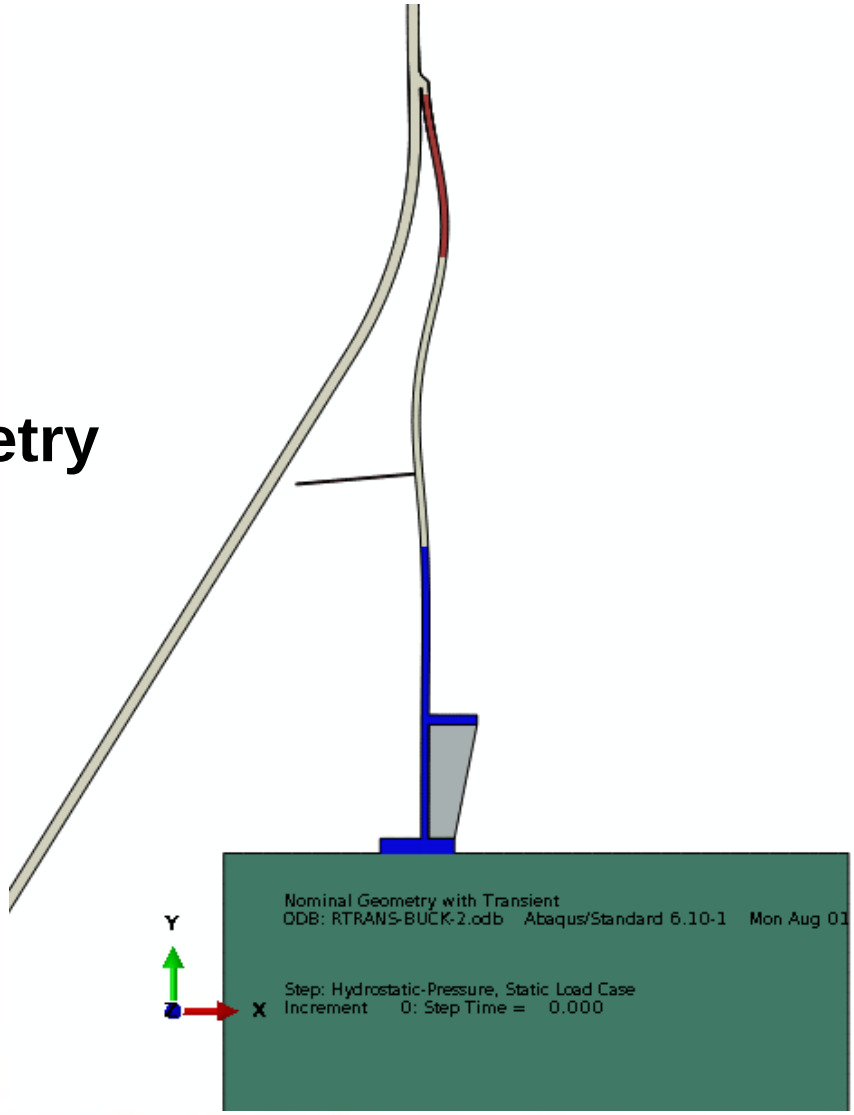
Per ASME VIII Div. 3 Fatigue Equations for Welded Construction KD 320.2



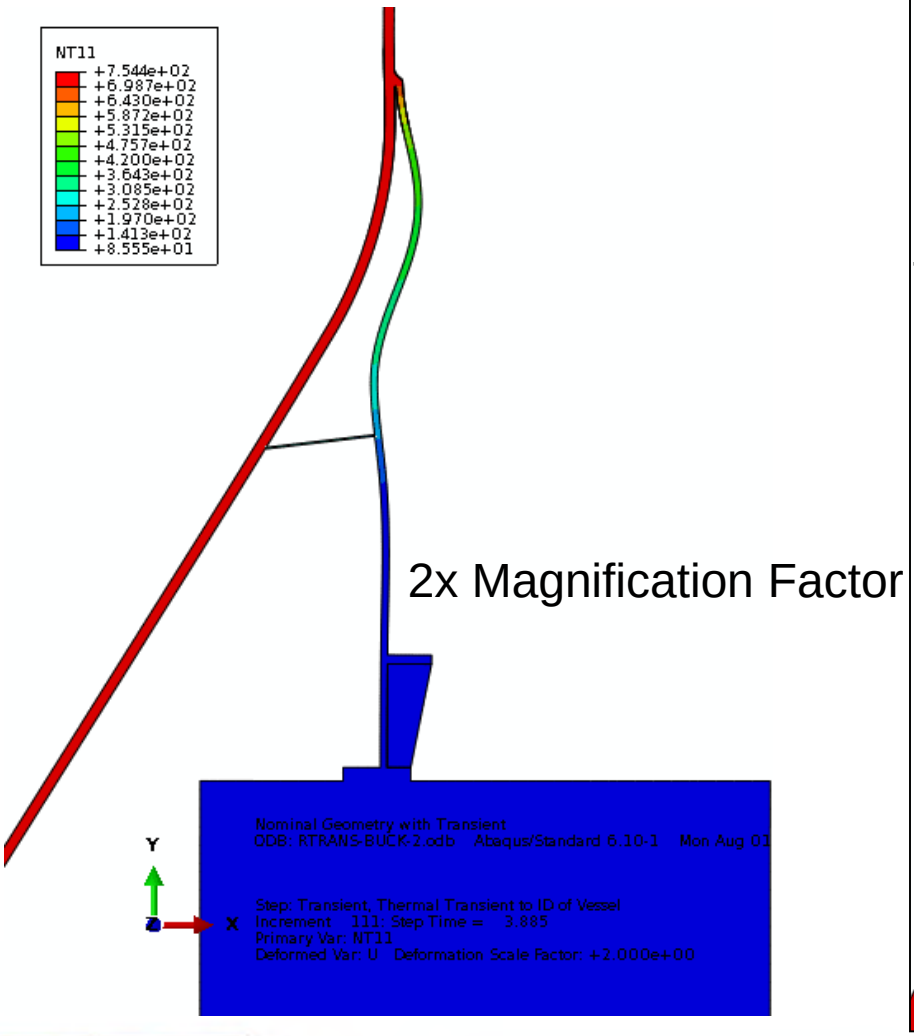
Results For 2.00” Bulge Geometry

Undeformed 2.00”

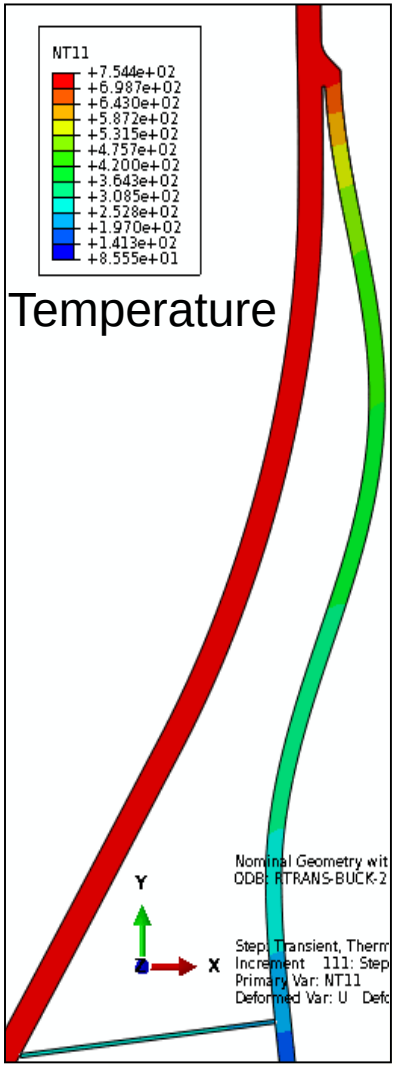
Bulge Skirt Geometry



Temperature During the Fill Transient
3.88 hrs – 2.00” Bulge

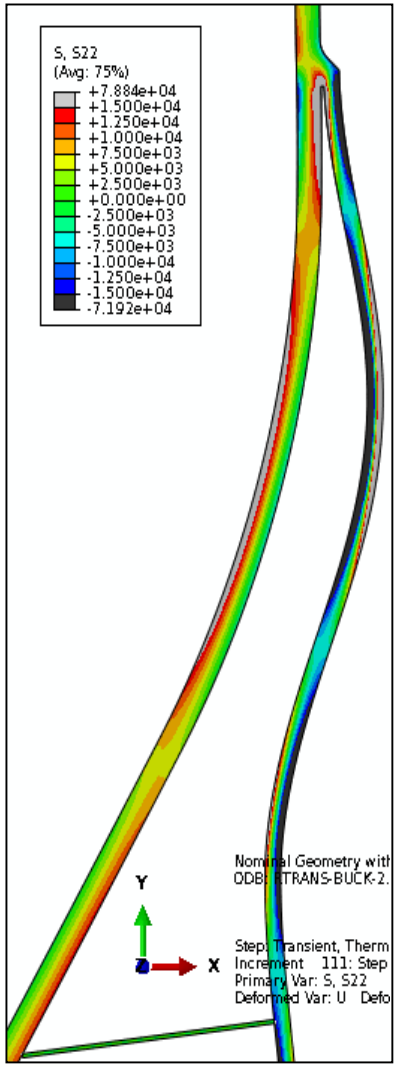


2x Magnification Factor

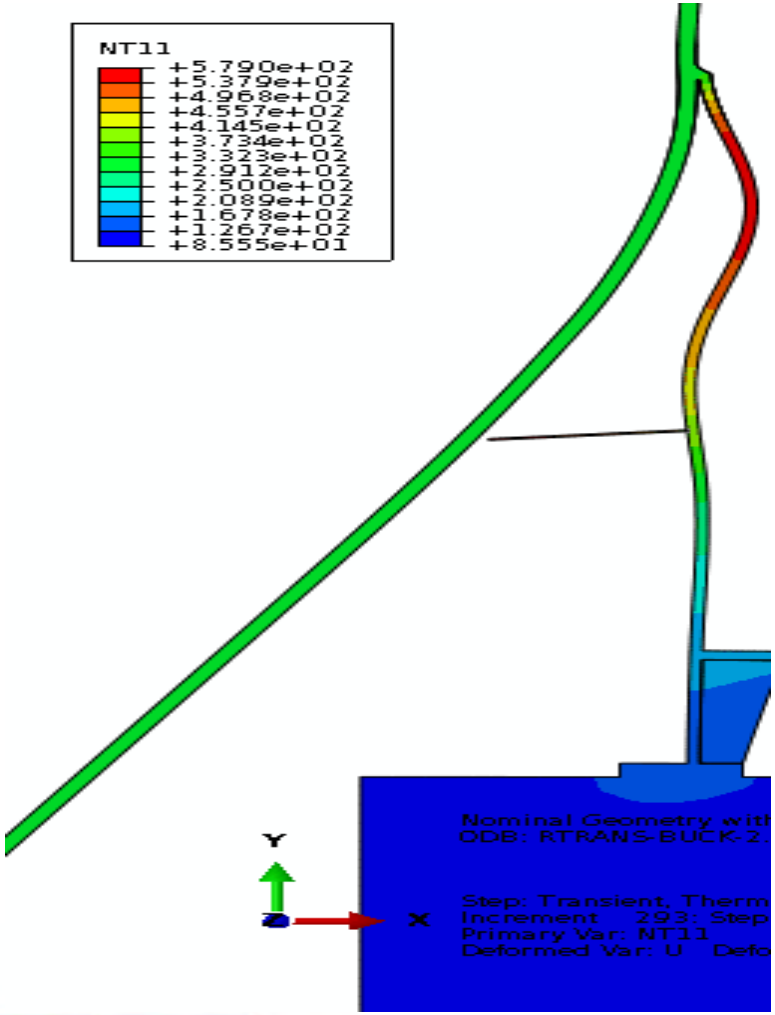


Temperature

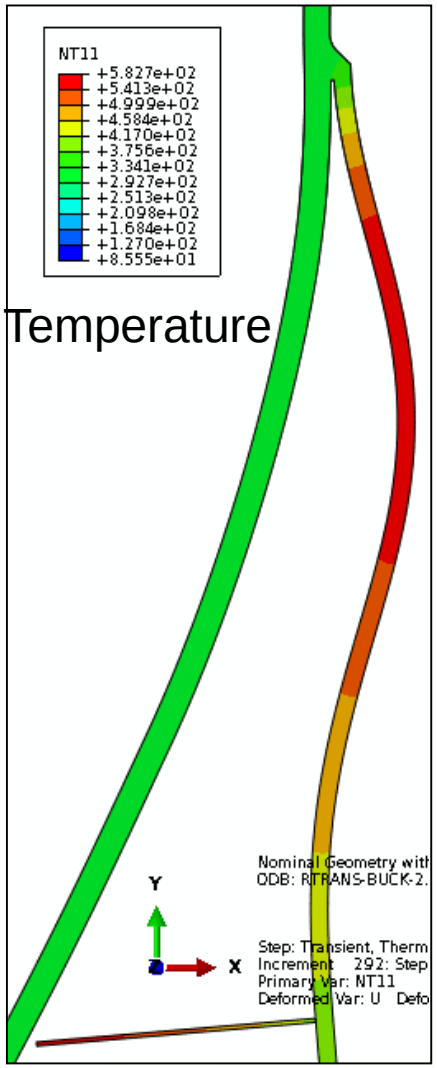
Axial Stress



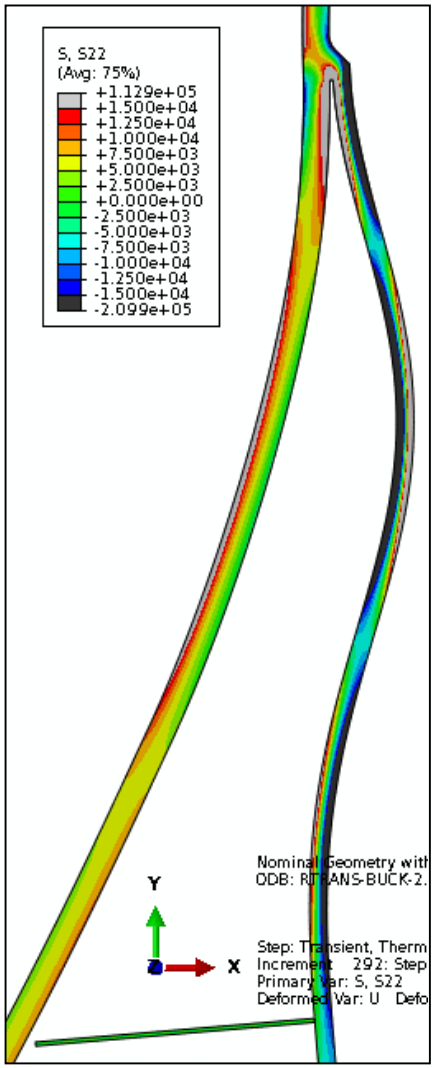
During the Quench Transient
23.46 hrs – 2.00” Bulge



Temperature



Axial Stress



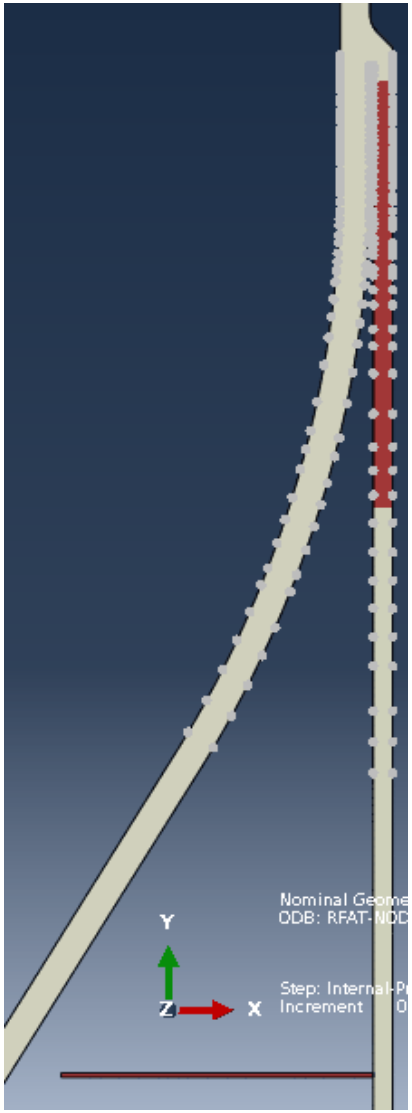
2x Magnification Factor

Model Results

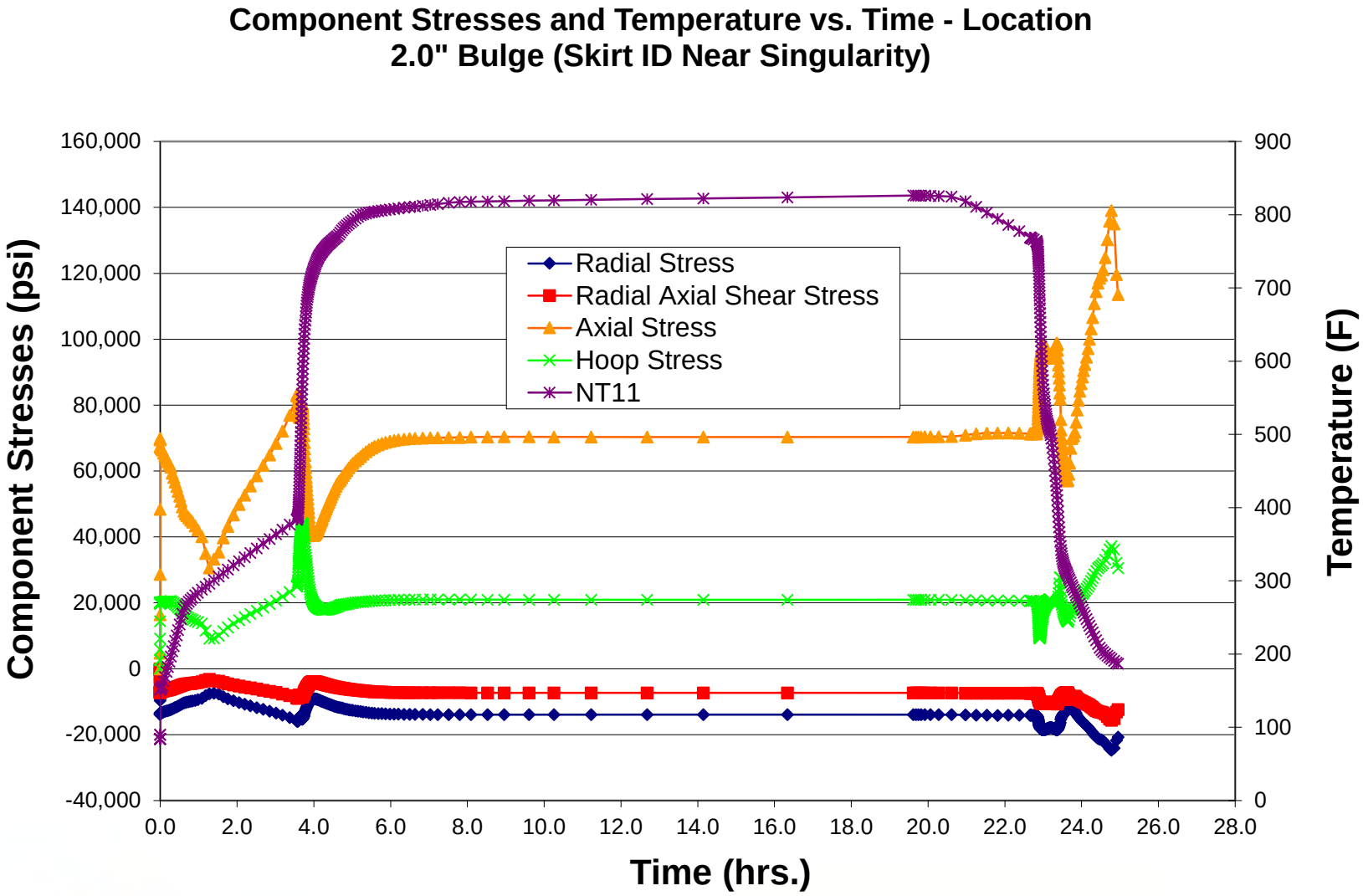
The same presentation and format as for the nominal geometry

- Extreme points in the cycle for each location analyzed are identified and a stress difference is calculated.
- Fatigue life is then calculated based upon the stress intensity range at the time-average transient temperature using KD320.2 in ASME VIII Div. 3 (2004)

The exact same nodal locations as for the nominal geometry are reported.



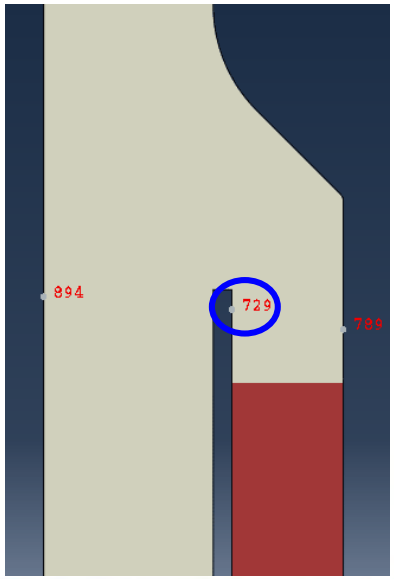
Component Stresses – 2.00” Bulge



Fatigue Calculation Results
Skirt ID Near Singularity – 2.00” Bulge

- **Analysis reported at ~0.125” away From Singularity**
- Stress range = 166.7 ksi
- Alternating stress = 83.4 ksi
- Adjusted Alternating stress (560F) = 92.3 ksi
- Minimum Fatigue life (@ 560F) = **725** cycles

Per ASME VIII Div. 3 Fatigue Equations for Welded Construction KD 320.2



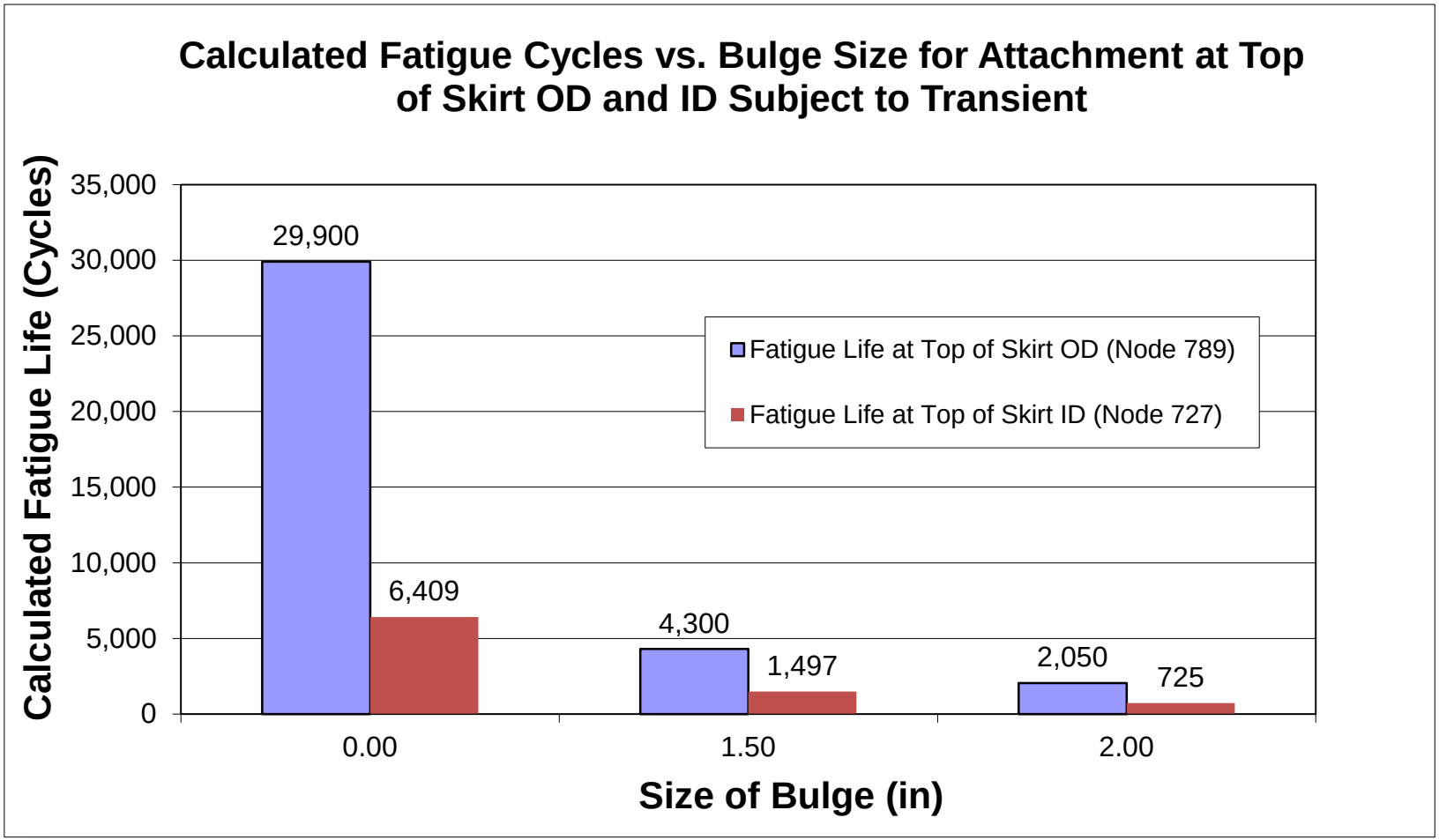
Summary Of Solutions at Skirt ID, ~0.125” Below Singularity (Node 727)

Analysis Iteration	Transient	Stress Range (ksi)	Calculated Fatigue Life (Cycles)
Nominal Geometry	Cycle 3	80.1	6,409
1.5” Bulge	Cycle 3	128.1	1,497
2.0” Bulge	Cycle 3	166.7	725

Summary Of Solutions at Skirt OD, (Node 789)

Analysis Iteration	Transient	Stress Range (ksi)	Calculated Fatigue Life (Cycles)
Nominal Geometry	Cycle 3	50.14	29,900
1.5” Bulge	Cycle 3	90.83	4,300
2.0” Bulge	Cycle 3	114.7	2,050

Discussion



Discussion

- Cycle 3 was selected due to it being a transient with typical rates (not overly aggressive) and having a typical temperature vs. time profile.
- The presence of the bulge significantly affects the fatigue performance of the skirt and drum in all regions considered
  - On the skirt ID near the singularity, life was decreased by 77% by having a 1.5” bulge, and nearly 90% by having a 2” bulge (Node 727)
  - On the skirt OD, at the singularity elevation, life was decreased by 85% with the 1.5” bulge, and 93% by having a 2” bulge (Node 789)
  - Previous damage from operations are not included in this comparative study; i.e., the model does not consider previously accumulated cycles
  - The secondary stresses exceed the allowable limit, thus ratcheting is possible, and the predicted lives would be lower than what is calculated since the bulge could continue to grow

Questions?

Thanks!

Julian J. Bedoya, P.E.
Senior Associate
Stress Engineering Services, Inc.
Julian.Bedoya@stress.com
(281) 955-2900

Sathish Ramamoorthy, PhD., P.E.
Associate
Stress Engineering Services, Inc.
Sathish.Ramamoorthy@stress.com
(281) 955-2900