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Sample Report:
½" Tri-Clamp Flange Connection

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Key Design Engineering is a Canadian engineering firm located in Waterloo, Ontario, that specializes in ASME Code calculations and Canadian Registration Number (CRN) submissions:

- **ASME Code Calculations** per ASME VIII-1 & ASME B31.3 for Pressure Vessels, Fittings, & Piping systems as applicable.
- **Canadian Registration Number (CRN)**: preparation of documentation for submission of pressure vessels, fittings, or pressure piping for registration in one Jurisdiction or Canada-wide.
- **Finite Element Analysis (FEA)** of Pressure Vessels and Fittings in accordance with ASME VIII-2, in compliance with Jurisdictional requirements.

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Executive Summary

Introduction:

This Tri-clamp connection is designed to comply with ASME B31.3-2008. It is an unlisted component because of its shape and must be qualified per 304.7.2, using Finite Element Analysis per ASME VIII-2, Part 5.

Method:

Model:
The valve model has been cut using planes of symmetry to facilitate an analysis using FEA. The software used is Simulation 2010 (formerly known as CosmosWorks), by Dassault Systemes.

Rules:
The Code of construction is ASME B31.3-2008. The results have been interpreted per the rules of ASME VIII-2, Part 5, as permitted by the Code of Construction. The material properties are converted to B31.3 allowable stresses from IID Table U & Y values, as permitted by para 323.1.2.

Scope:
Only the ferrule is included in the current discussion. The Clamp and bolt must be included in the analysis to properly model the joint's behaviour, but are not included in the discussion of the results, since they already have their own CRN number.

Results & Conclusions:

Reaction force:
The reaction force at the boundary balances the force resulting from the system pressure, demonstrating that the loads have been properly applied. The reaction force is acceptable

Displacement:
The displacement plot shows a peak relative displacement of less than 0.001", which does not compromise the seal. The sliding contact between the flange and the clamp has been properly applied, as shown by the difference in colour bands. Displacement is acceptable.

Stress:

- *General:* The highest general stress of 8,859 PSI is less than the Pm limit of 11,666 PSI. General stress is acceptable.

- *Local:* The highest local stress of 14,434 PSI is found on the inside surface of the ferrule and it is acceptable because it is less than the limit for PI+Pb of 17,500 PSI.
- *Linearization:* The PI+Pb through the nozzle neck is 11,821 PSI, which is less than the 1.5*S limit of 17,500 PSI. Stress is acceptable.

Conclusion:
This component has acceptable stresses per ASME VIII-2 for the design condition of 1,200 psig internal pressure at 400F. The requirements of ASME B31.3 are satisfied.

Setup

Code of Construction: ASME B31.3-2008
Design Conditions: 1,200 PSI @ 400°F

Basic Material Allowable Stresses

Description, P/N	Material	Basic Allowable stress (KSI)		Notes
		RT	400F	
Body	A479 316L	16.7	11.66	Converted to B31.3 allowable stresses from IID Table U & Y data.

Material Allowable Strength calculation, ASME B31.3, ver.3.5

Ref: ASME B31.3-2008, 302.3.2

Material type: for Austenitic stainless steels & nickel alloys having similar stress-strain behavior only.

Material:	ASTM A479-316L
Temperature:	400F
Data:	ASME IID Table U & Y

Room Temperature (RT)

Yield =	25,000	psi, Minimum yield strength
Tensile =	70,000	psi, Minimum tensile strength

Elevated Temperature

Yield =	17,500	psi, Minimum yield strength
Tensile =	62,200	psi, Minimum tensile strength

Calculating stress limits: Refer to ASME B31.3, 302.3.2(d)

Room Temperature

From Yield Strength =	2/3*(Yield RT)	=	16666.7 psi
From Tensile Strength =	1/3*Tensile	=	23333.3 psi
	S (lowest value)	=	16,667 psi

Elevated Temperature

From Yield Strength =	90% of Yield	=	15750.0 psi
From RT Yield =	2/3*(Yield RT)	=	11666.7 psi
From Tensile Strength =	1/3*Tensile	=	20733.3 psi
	S (lowest value)	=	11,667 psi

Restrictions on use, per 302.3.2(e)
For material used in flanged joints and other components in which slight deformation can cause leakage or malfunction, additional factors are imposed. *Instead, either 75% of the stress value in Table A-1 or two-thirds of the yield strength at temperature listed in the BPV Code, Section II, Part D, Table Y-1 should be used*.

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Allowable Stress Limits for FEA, per ASME VIII-2, ver.2.3

Ref: ASME VIII-2, 2007, Part 5

Design conditions:	400F	
Material:	A479 316L	
Data:	ASME B31.3	
S =	11,667	psi, Minimum material allowable stress at temperature
k=	1.0	stress intensity factor, per Table AD-150.1

Calculating stress limits:

Refer to ASME VIII-2, 2007, Fig. 5.15

Primary Stress

P_m (General Membrane) = k*S	=	11,667	PSI
P_L (Local Membrane) = 1.5*k*S	=	17,500	PSI
P_L + P_b (Membrane + Bending) = 1.5*k*S	=	17,500	PSI

Secondary Stress

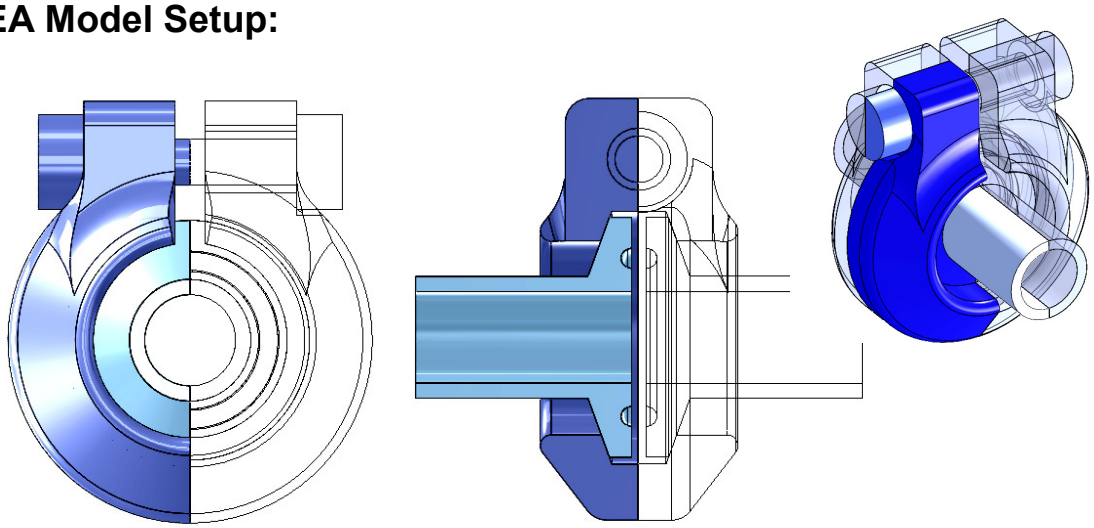
Q (Secondary Membrane+ Bending)= S_{PS}	=	35,001	PSI

where Sps = 3*k*S or 2*Yield, as limited by 5.5.6.1(d)

Peak

F (Increment added to stress concentration)	=	(must use fatigue curves, per Appendix 5)

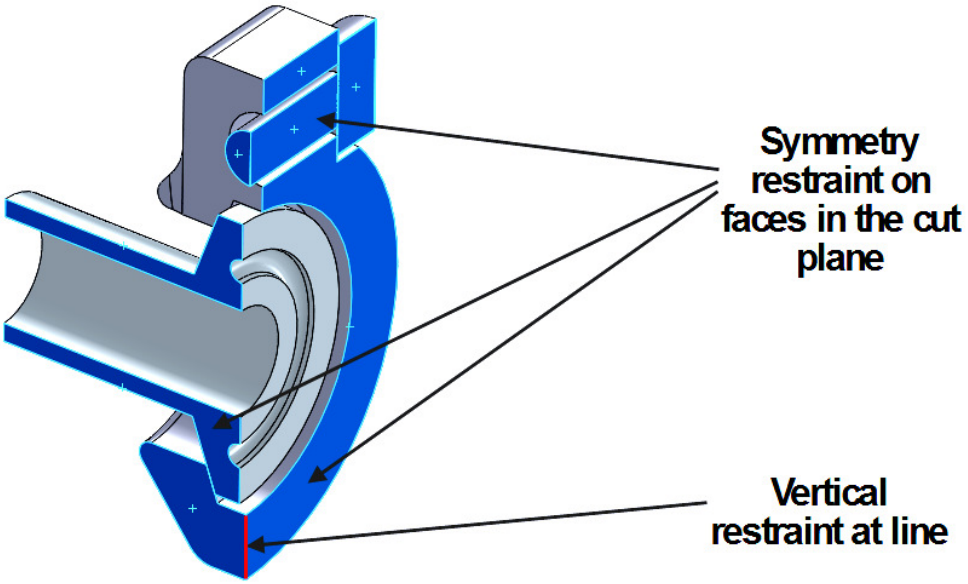
FEA Model Setup:



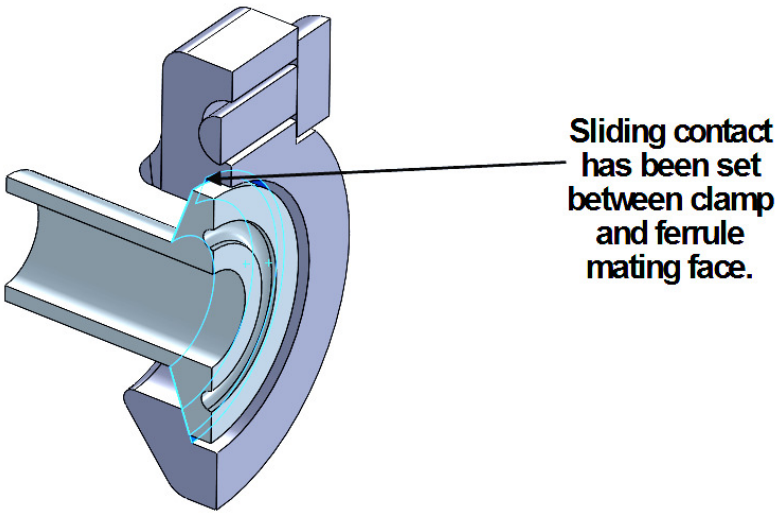
End View Side view

Dimensions: The figure above shows the model used in the Finite Element Analysis. It has been cut along two planes of symmetry, so that only ¼ of the complete model is actually run. The ferrule size is a nominal ½" OD, with 0.0625" thick wall. The bolt size used is ¼-20 UNC with a UNR=0.1894". The bolting material is A 320 B8 Cl.2 for the sake of this sample report, but the clamp itself is excluded from the discussions herein since it already bears its own CRN number.

Model Boundary Conditions:

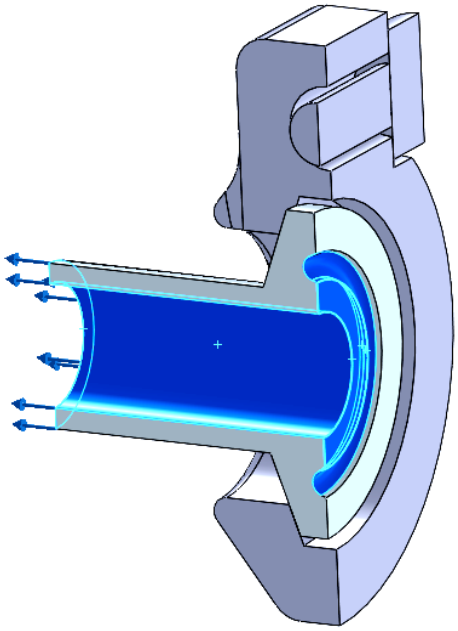


Restraints: The figure above shows the restraints that were used on the model. A symmetry constraint has been applied to the faces in the two cut-planes. A vertical restraint has been applied where shown.

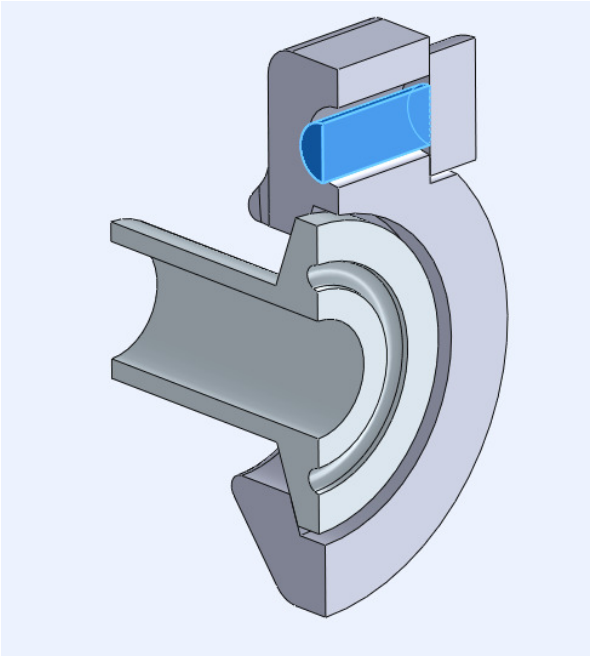


Sliding Surface: A sliding surface condition was applied at the touching surfaces of the clamp with the ferrule's flange.

Application of Loads:

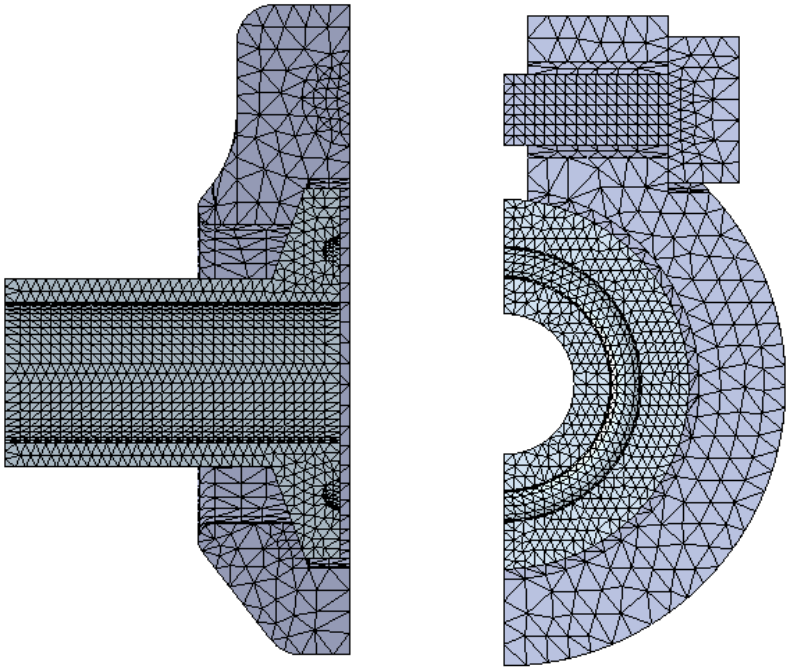


System Pressure: As shown above, a system pressure of 1,200 PSI was applied to all applicable internal faces. A pressure-equivalent force was applied to the end of the tube, as shown.



Bolting Preload: As shown in the figure to the left, the bolt was preloaded by application of a negative temperature differential to the shaft only. The actual preload is a factor of the assembly stiffness and contact condition between the clamp and the flanges. The calculated preload force in the bolt is 319 lbf, and thus the preload stress is **11,251 PSI.** The bolting connector feature could have been used if the clamp had been oriented in a different direction. The sliding contact introduces a non-linear effect that is best covered by a solid bolt.

Mesh:

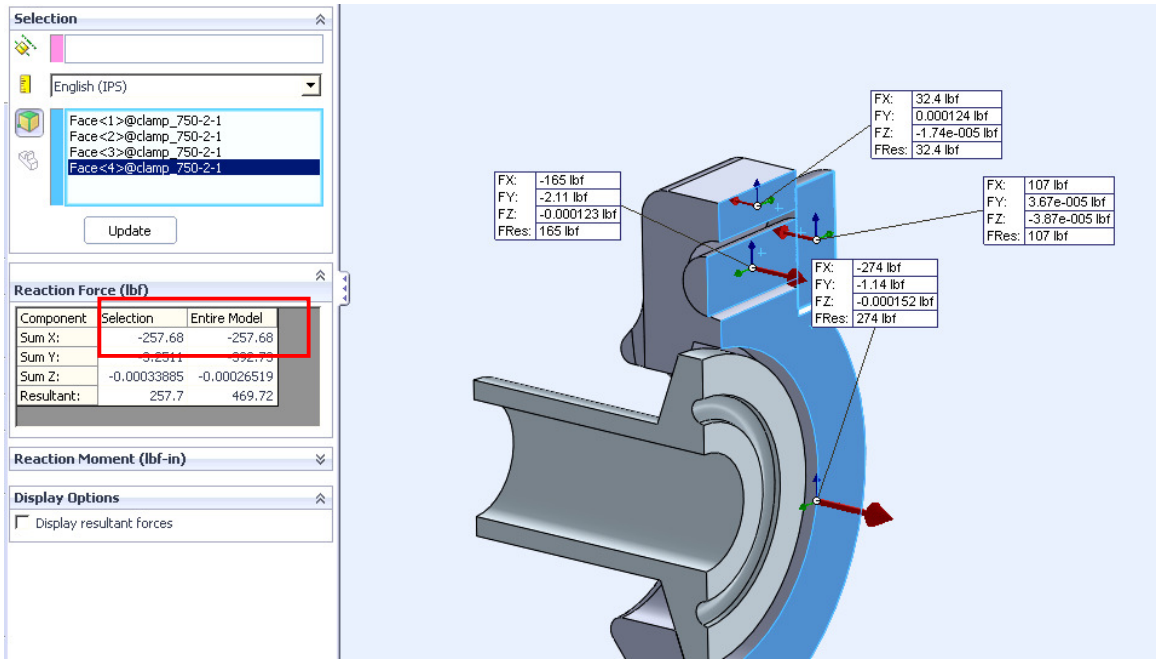


The figures above show the mesh sizes used. The Mesh characteristics are:

- Mesh type: Solid - Tetrahedron
- Mesh Quality: High quality, with mid-side nodes, greater than 2nd order integration.
- Mesh size:
  Global mesh size is 0.06”, as shown.
  Mesh refinement is 0.0277”, in the ferrule and the bolt

The mesh sizes have been selected so as to keep the error to less than 5% in all the critical areas.

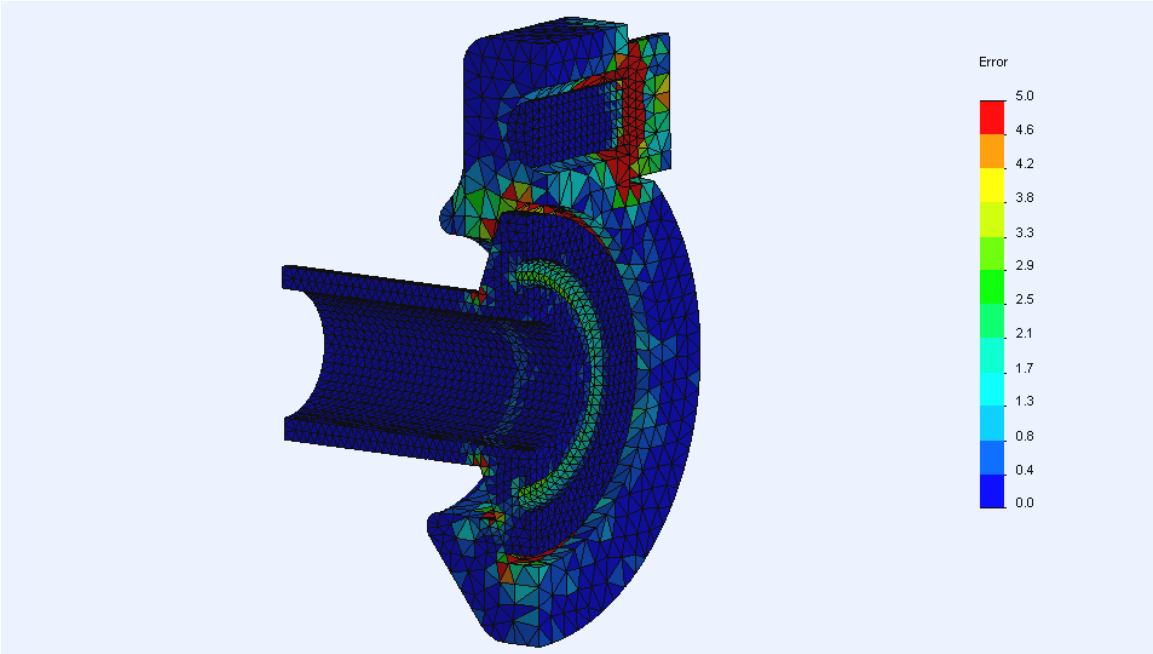
Reaction Forces:



Reaction force: The figure above shows the reaction force for the entire model. The projected area for pressure application on the end is 0.205sq.in, and the expected reaction force is 246 lbf. The model's actual reaction load in the axial direction is 257 lbf, because of an additional effect incorporated by the preloaded bolt. Overall, the difference is 4.2%, which is acceptable because of the effect caused by the temperature-induced preloaded bolt.

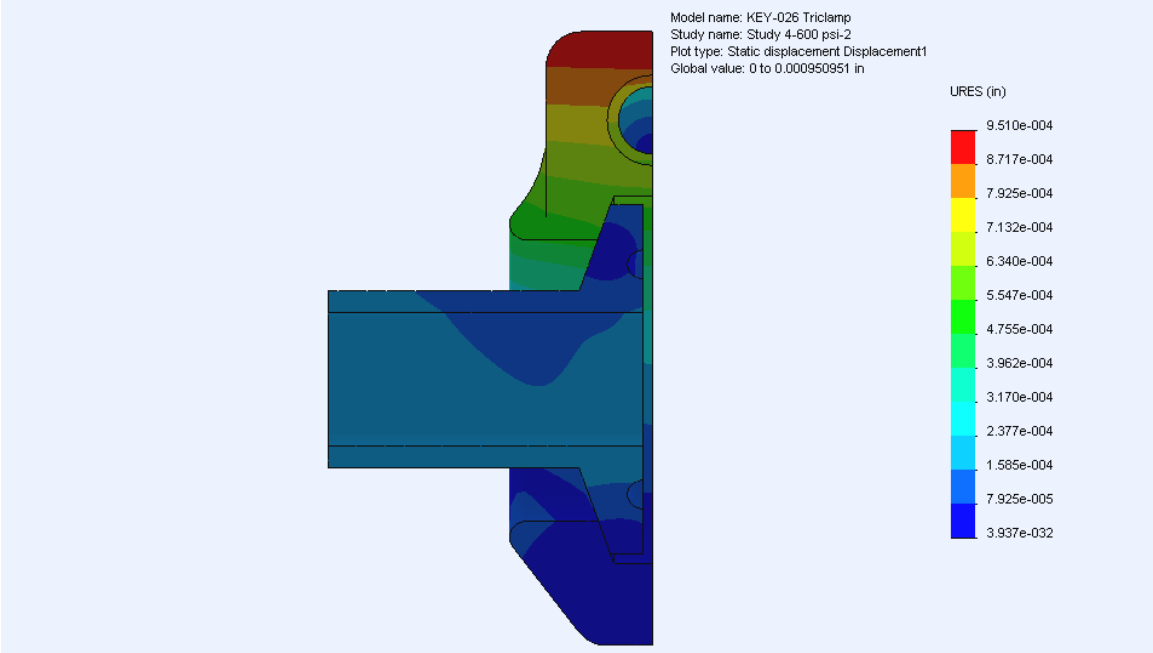
Results and discussion:

Error Plot:

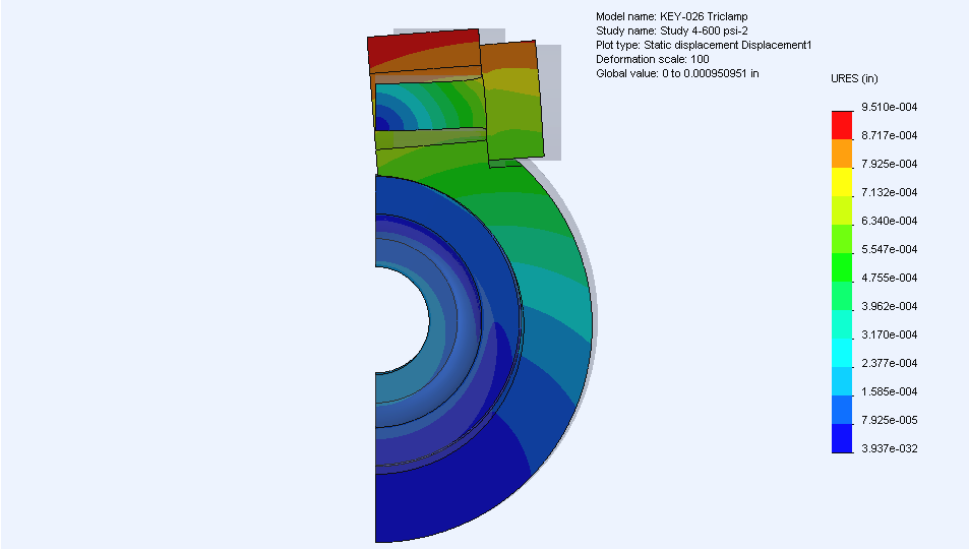


Overall Error Plot: The figure above shows that the error is <5% in all critical general areas of the Tri-Clamp ferrule. Areas with error over 5% are directly at the discontinuity and no more than one element away from it. Error plot is acceptable.

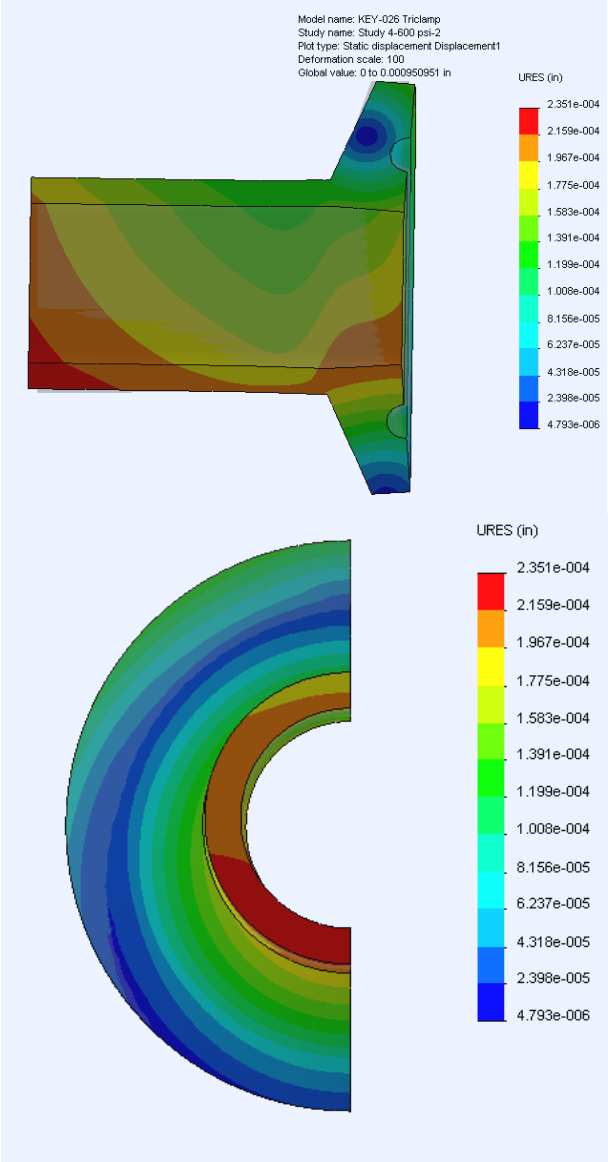
Displacement:



Overall Displacement: The figures above and below show the overall relative displacement as viewed from the inside and end, respectively. The peak relative displacement is 0.00095” as shown at the top of the clamp. The displacement in the flange is 0.00023”. Color band differences between the flanges and clamp show that the sliding contact was properly applied. Displacement is Acceptable.



Displacement, cont'd:



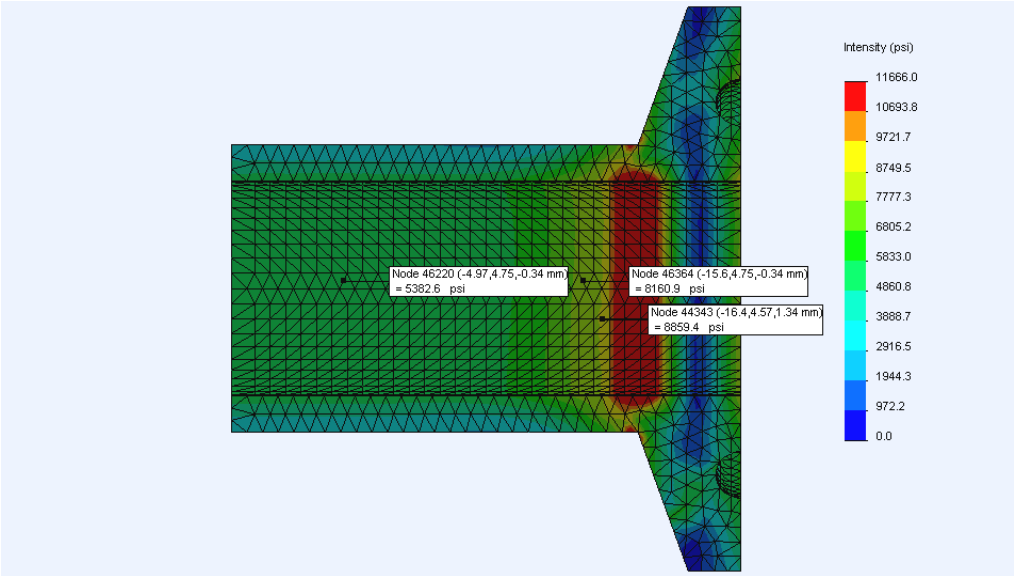
The resultant ferrule displacement is displayed in the figures to the left. The display has been capped at 2.351E-4 in, so that the colour bands could be differentiated. The clamp has been hidden both for clarity and because it is excluded from this analysis as it is already CRN approved.

Upper Figure: The top flange shows rotation about the blue centre, while the lower flange shows rotation about the lower edge.

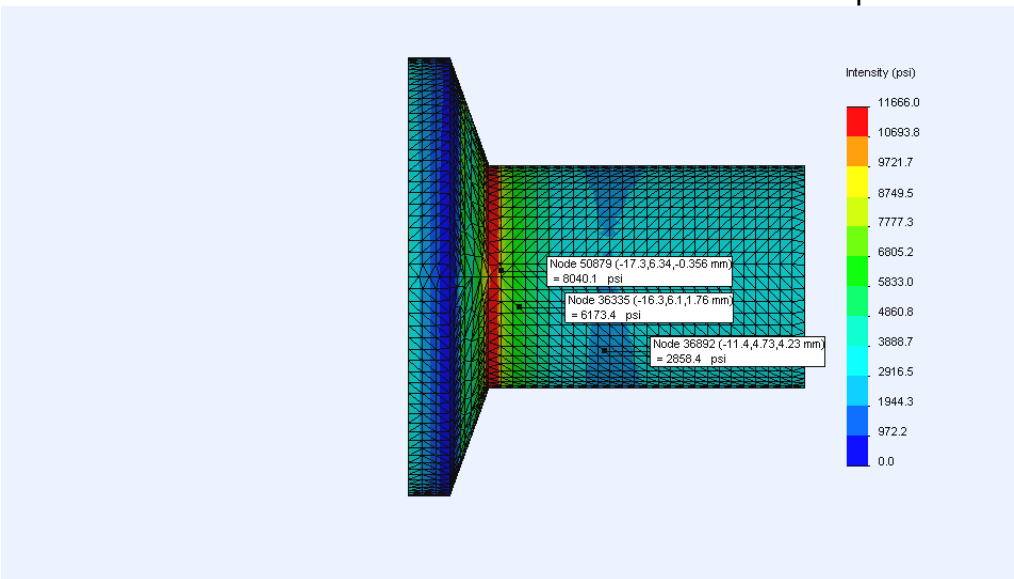
Lower Figure: The pattern noticed above is consistent with the lower figure, which shows a view from the back of the flange. The blue band, indicating resultant "zero" displacement travels from the centre of the upper flange down to the bottom edge of the lower part of the flange.

This movement is consistent with the overall clamp deformation. Because of the bolted upper connection, the clamp's rotation is observed relative to the solid section at the bottom, as seen on the previous page.

General Stress:

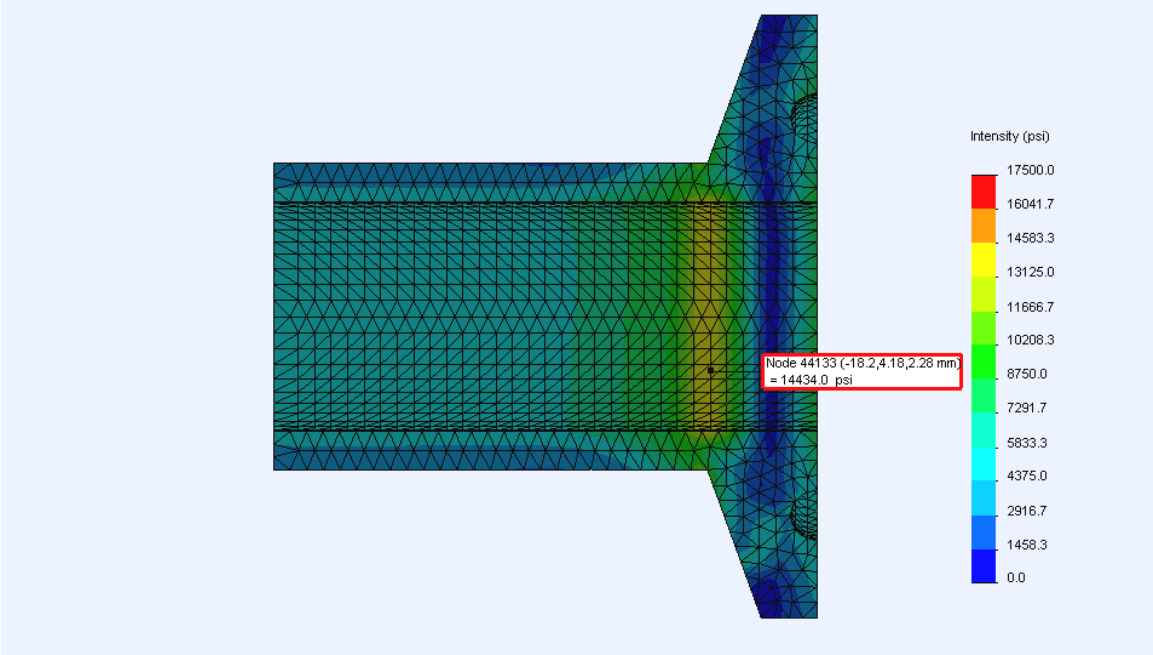


Inside General stress: The stress display has been capped off at the Primary Membrane allowable stress of 11,666 PSI. The highest general stress on the inside face is shown above to be 8,859 PSI, which is acceptable because it is less than the Pm limit noted above. Inside General Stress is acceptable

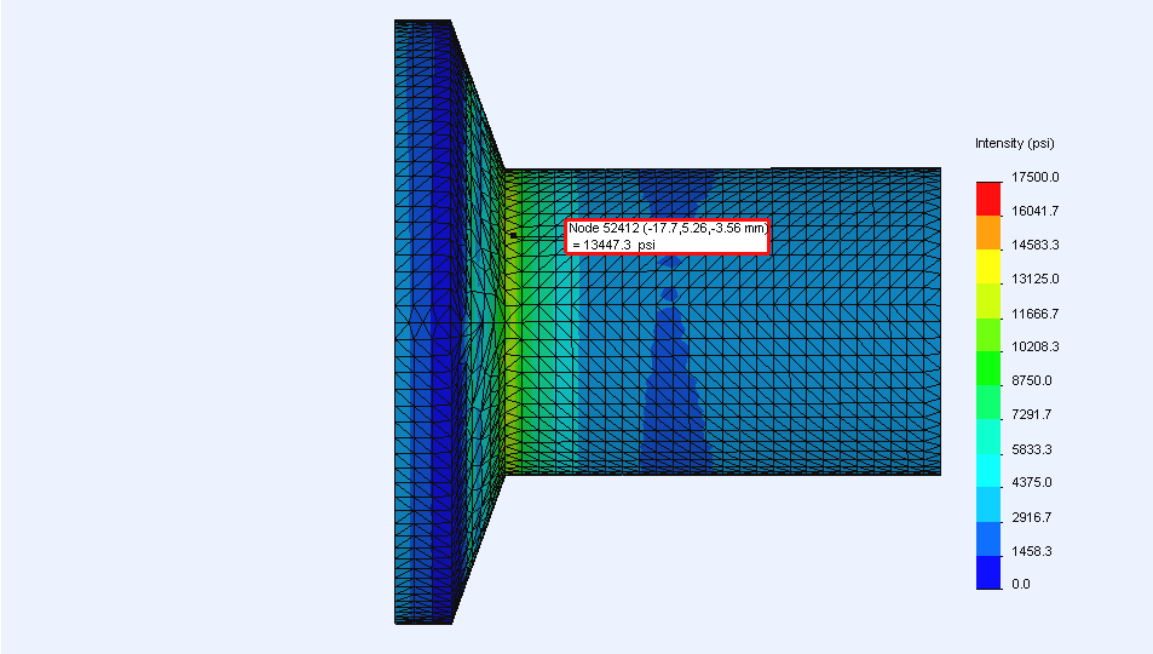


Outside General Stress: The figure above shows the Outside General Stress, with the display capped at the Pm limit. The highest general Primary stress is 8,040 PSI, as shown above. It is acceptable because it is less than Pm=11,666 PSI. General Outside Stress is Acceptable.

Local Stress:

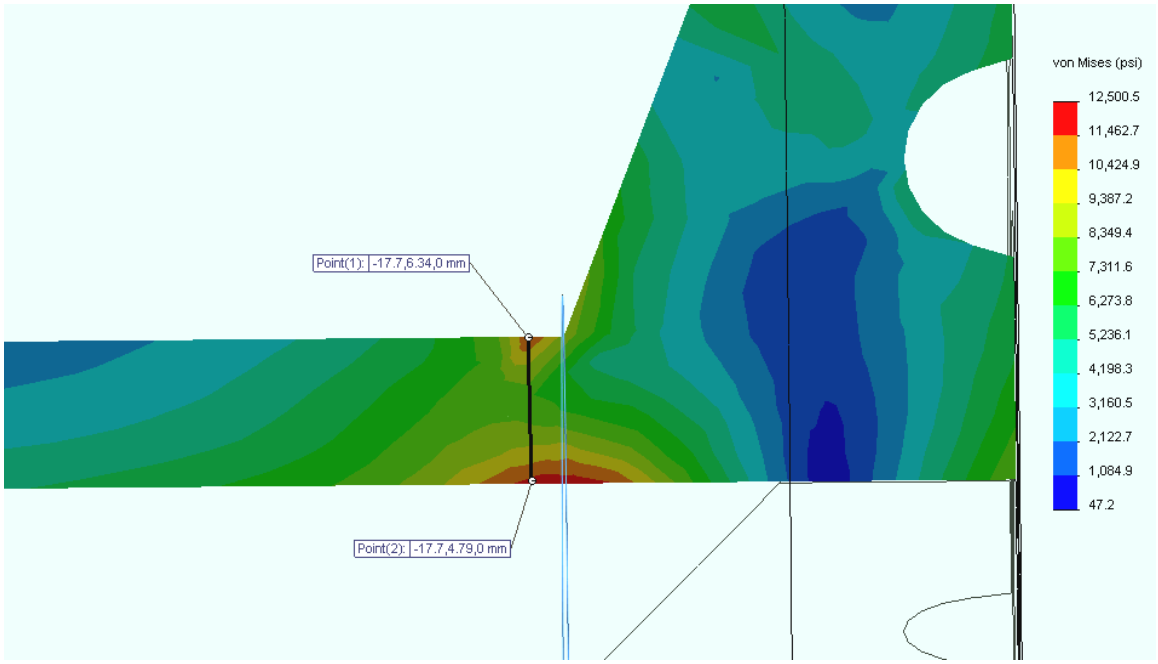


Inside Local stress: The stress display has been capped off at the Local Membrane+ Bending (Pl+Pb) allowable stress of 17,500 PSI. The highest Local Stress on the inside face is shown above to be 14,434 PSI, which is acceptable because it is less than the Pl+Pb limit noted above. Inside Local Stress is acceptable



Outside Local Stress: The figure above shows the Outside LocalStress, with the display capped at the Pl+Pb limit. The highest stress is 13,447 PSI, as shown above. It is acceptable because it is less than Pl+Pb=17,500 PSI. Outside Local Stress is Acceptable.

Stress Linearization:



Linearization: For the cross-sectional area shown above, the membrane stress is 7,694 PSI, which is acceptable because it is less than the allowable Pm stress of 11,666 PSI. The highest Pl+Pb (Local Membrane + Bending) stress is 11,821 PSI, which is less than the 1.5*kS limit of 17,500 PSI. Stress is acceptable.

Quantity, Units: psi	Normal X	Normal Y	Normal Z	Shear XY	Shear XZ	Shear YZ	von Mises
Membrane Stress	1228.7	1054.2	8143.6	-1837.2	55.262	-58.143	7694.1
Bending (Point 1)	8139.2	2266.7	1494.8	-1364	55.793	-18.837	6723.7
Membrane Stress + Bending (Point 1)	9367.9	3320.8	9638.4	-3201.2	111.05	-76.98	8311.1
Bending (Point 2)	-8139.2	-2266.7	-1494.8	1364	-55.793	18.837	6723.7
Membrane Stress + Bending (Point 2)	-6910.5	-1212.5	6648.8	-473.14	-0.5302	-39.306	11821

Please note that Stress Linearization is not required for this level of stress, but it has been included here for demonstration purposes only. The SCL (Stress Classification Line) has been taken a small distance away from the structural discontinuity, at location of highest stress on the back of the flange hub.