PVEng

Pressure Vessel Engineering Ltd.

ASME Calculations - CRN Assistance - Vessel Design - Finite Element Analysis

Design Conditions

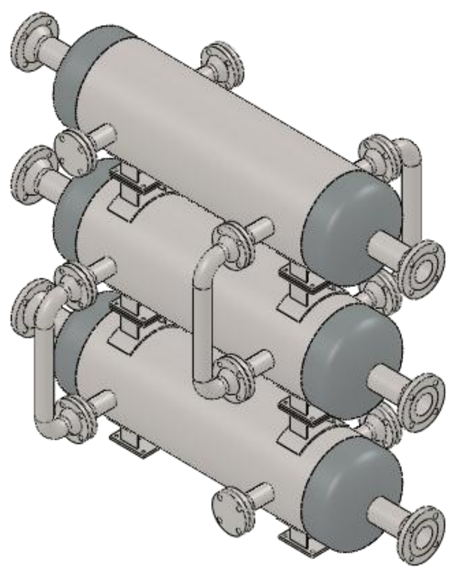
Code:	**ASME VIII-1**	
Year:	**2007**	
Addenda:	**2009**	
MAWP:	**200**	psi
MEAWP:	**0**	psi
Max. Temp.:	**100**	°F
MDMT:	**-20**	°F
MDMT Press.:	**200**	psi
Corrosion Allowance:	**0**	in
Hydrotest:	**260**	psi
Impact Testing:	**None**	
Impact Exemption:	**UG-20(f)**	
Radiography:	**None**	

UG-22 Loadings Considered

Internal Press.:	**Yes**
External Press.:	**No**
Vessel Weight:	**Yes**
Weight of Attachments:	**Yes**
Attachment of Internals:	**No**
Attachment of Externals:	**Yes**
Cyclic or Dynamic Reactions:	**No**
Wind Loading:	**No**
Seismic Loading:	**Yes**
Fluid Impact Shock Reactions:	**No**
Temperature Gradients:	**No**
Differential Thermal Expansion:	**No**
Abnormal Pressures:	**No**
Hydrotest Loads:	**No**

Finite Element Analysis Report - VIII-1

File: **PVEfea-4492.0**
Desc: **Stacked Vessels**
Dwg: **PVEdwg-4492.0**
Date: **September 7, 2010**



Author: Ben Vanderloo
Reviewer: Laurence Brundrett

Conclusion: The vessel has been analyzed to UB-97 using ASME Section IID allowed stress and is acceptable.

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Table of Contents

Revision(s)			
Rev	Description	Date	By
0	Release	7-Sep-10	BTV

Goal:

The stacked vessels will experience seismic conditions for San Francisco California. These condition will be analyzed using finite element analysis and the UB-97 code. ASME section IID allowed stresses will be used with VIII-2 rules to determine the acceptability of the design.

Summary Conclusions:

Materials

Material strength properties used in this report are obtained from ASME IID, Table 1A, and are suitable for VIII-1 components. The rules of ASME VIII-2 are used to set the stress limits.

Model Information

The model used in this report represents the full stacked vessel assembly. A 1/2" tetrahedral solid mesh reduces the reported error to less than 5% for general areas.

Restraints & Loads

The bottom set of saddles are fixed to prevent rigid body motion. All internal surfaces are pressurized and openings have exit pressure forces applied. Theoretical reaction forces closely match actual reaction forces. The model is in balance and can be used for displacement and stress analysis.

Results

Through the FEA we found the displacement to be as expected and the magnitude is acceptable. All stresses are below code allowables. The stacked vessel assembly is acceptable.

Analysis Conclusion:

The stacked vessel assembly PVE-4492 meets ASME VIII-2 design rules using VIII-1 allowed stresses and is acceptable.

Material Stress Limits ver 4.01 ASME VIII-2 Fig 5.1

Material Input Chart:

100 **Temperature** [ºF]

	Material 1	Material 2	Material 3	Material 4
Material =	**SA-516-70**	**SA-105**	**SA-106 B**	**SA-36**
Application =	Shells / Heads	Flanges	Pipe	Supports
Sm [psi] =	20,000	20,000	17,100	16,600
Sy [psi] =				
E1 =	1.0	1.0	1.0	1.0
E2 =	1.0	1.0	1.0	1.0
E [psi] =	29,400,000	29,400,000	29,400,000	29,400,000
v =				
Coef =				
Pm [psi] =	20,000	20,000	17,100	16,600
Pl [psi] =	30,000	30,000	25,650	24,900
Pl+Pb [psi] =	30,000	30,000	25,650	24,900
Pl+Pb+Q [psi] =	60,000	60,000	51,300	49,800

	Material 5	Material 6	Material 7	Material 8
Material =				
Application =				
Sm [psi] =				
Sy [psi] =				
E1 =				
E2 =				
E [psi] =				
v =				
Coef =				
Pm [psi] =				
Pl [psi] =				
Pl+Pb [psi] =				
Pl+Pb+Q [psi] =				

Prop. Sources	ASME Section IID
Comments	

Variable Descriptions: VIII-2 5.13

Sm (basic allowable)
E1 (weld efficiency)
E2 (casting efficiency)
E (modulus of elasticity) - IID Table TM-1
v (Poison's ratio) - IID Table PRD
Coef (coefficient of thermal expansion)

Stress Limit Equations: VIII-2 Figure 5.1

Pm = E1*E2*Sm general primary membrane stress intensity limit

Pl = 1.5*E1*E2*Sm local membrane stress intensity limit

Pl+Pb = 1.5*E1*E2*Sm primary membrane + primary bending stress intensity limit

Pl+Pb+Q = Max(3*E1*E2*Sm,2*E1*E2*Sy) primary + secondary stress intensity

Pl+Pb+Q+F = Use fatigue curves peak stress intensity limit

Comments:

(1) Sy material property is not required, more conservative Pl+Pb+Q limits might be computed without it.
(2) The thermal expansion coefficient is only required for studies including thermal stresses
(3) Refer to VIII-2 5.15 Figure 5.1 and following for the Pm, Pl, Q and F stress limits
(4) Refer to VIII-2 5.14 Table 5.6 for the correct application of the calculated stress limits
(5) Use IID tables 5A and 5B for Sm for VIII-2 studies
(6) Use IID tables 1A and 1B for Sm values (S) for VIII-1 studies
(7) Use B31.1 Table A for Sm values for B31.1 studies
(8) Use B31.3 Table A for Sm values for B31.3 studies

Model, Mesh & Error

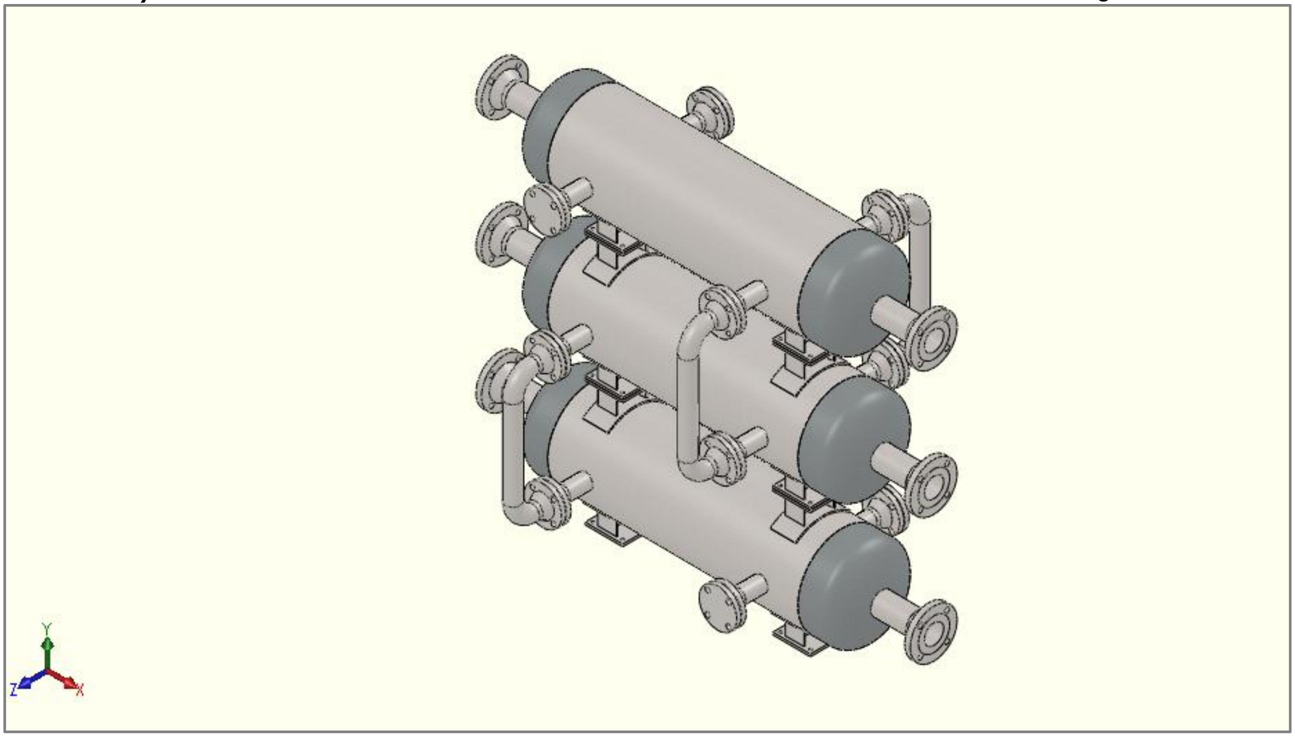


Fig-A A view of the model used in the analysis.
Please refer to PVEdwg-4492.0 for details.

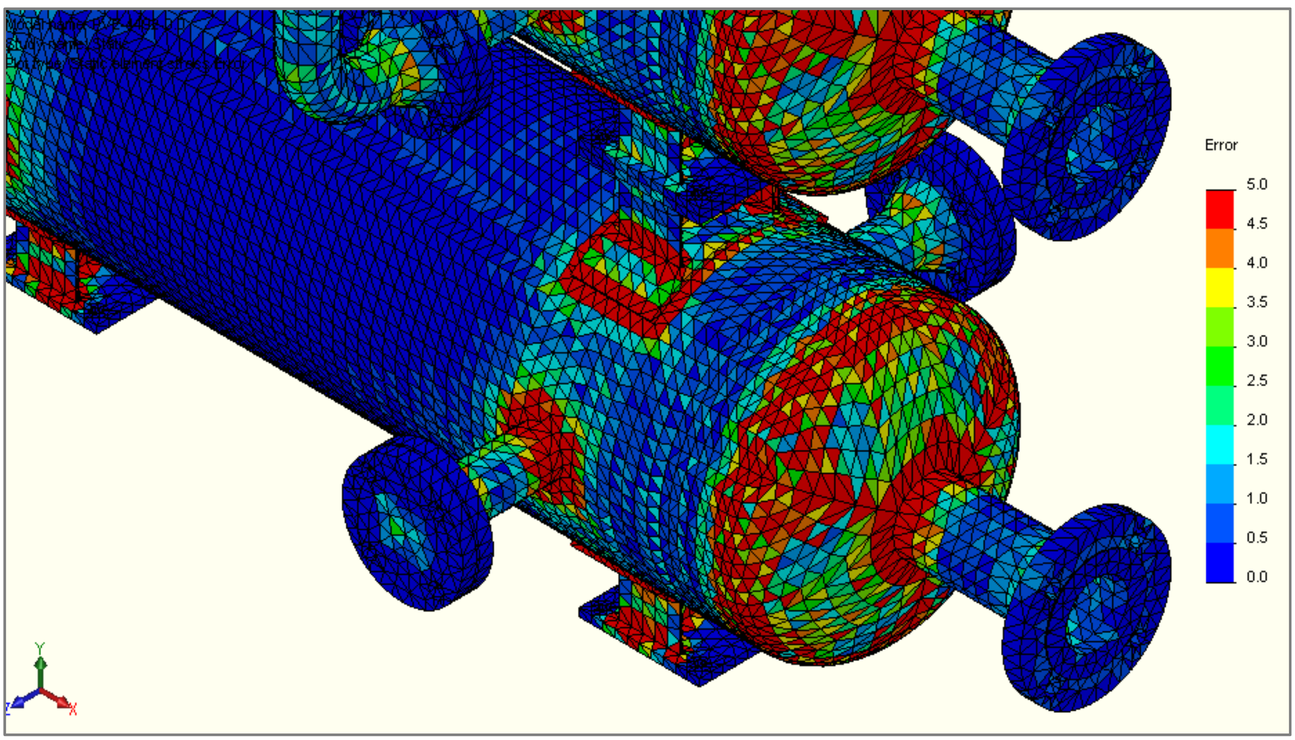


Fig-B A view of the error plot with the mesh overlaid.
A 5/8", second order, tetrahedral, solid mesh was applied globally. No general areas observe error in excess of 5%. The error plot justifies the mesh selected. The model may be used for further analysis.

Restraints & Loads

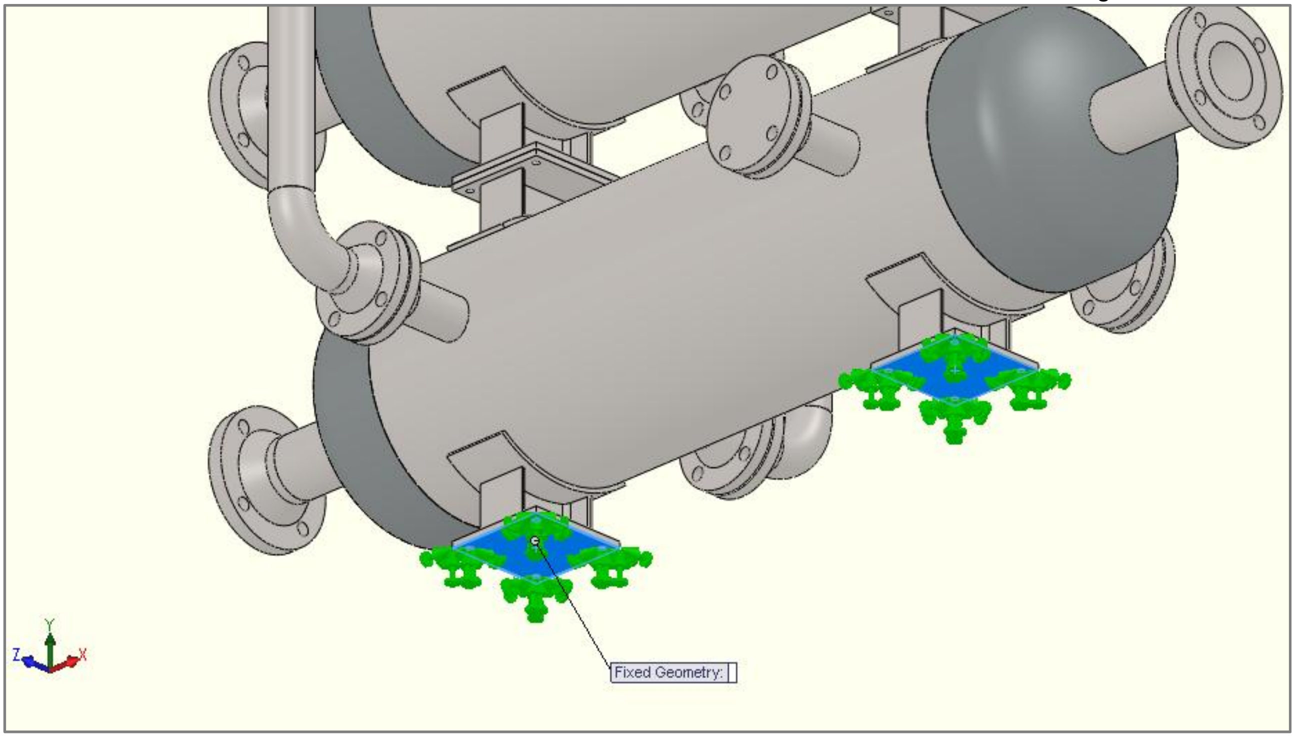


Fig-A A view of the fixed restraint applied to supports.
This restraint prevents ridged body motion in all directions while allowing the model to displace as it would in reality.

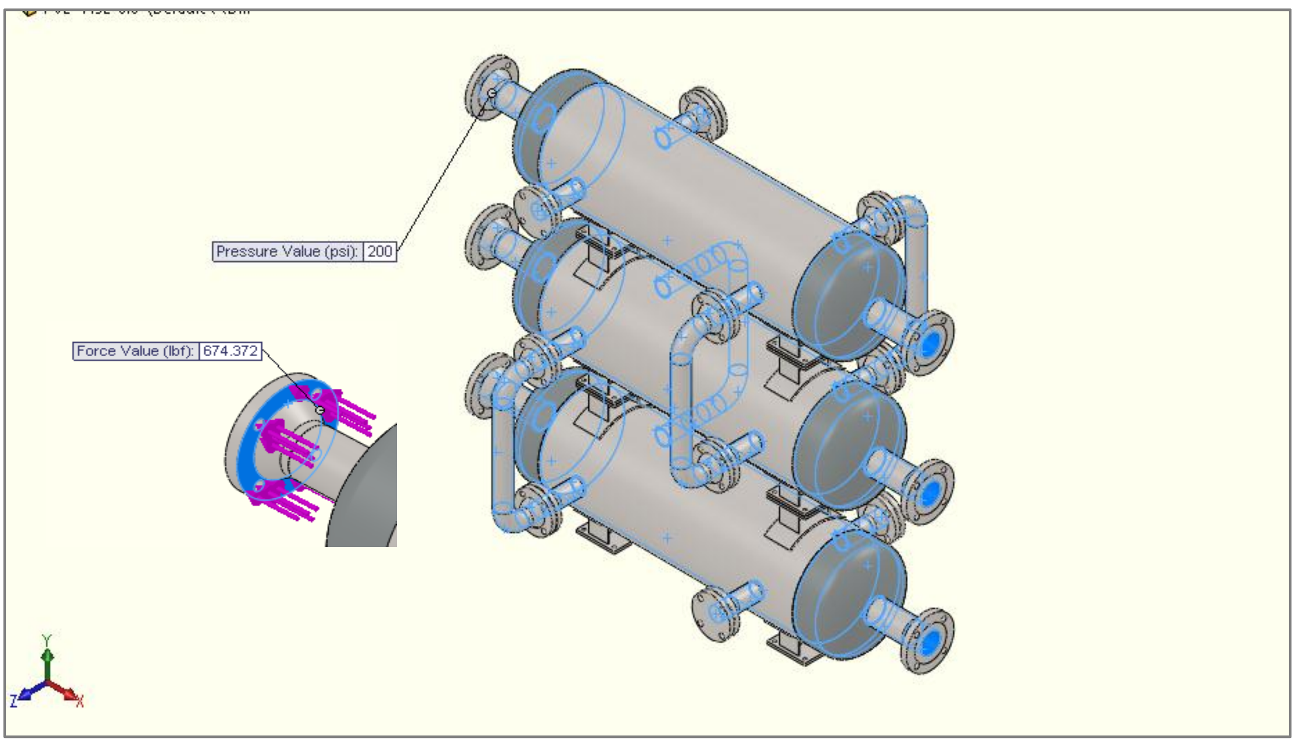


Fig-B A view of 200 psi applied up to the pressure boundary. Exit pressure forces are applied to openings. Opening Area = 7.392 in^2, Force = 674.372 lb

Loads & Frequency

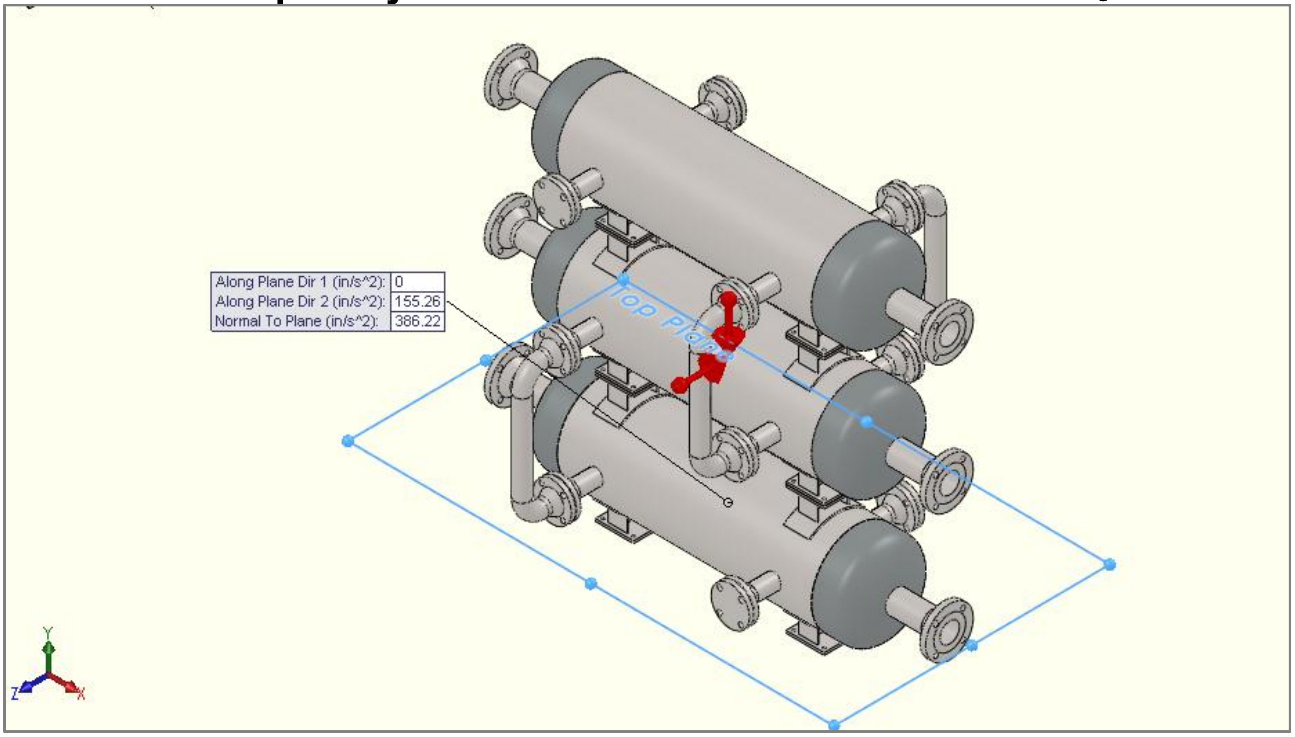


Fig-A A view the vertical 1 g (386.22 in/s^2) and horizontal 0.402 g (155.26 in/s^2) accelerations applied to the model. The horizontal acceleration is used to simulate seismic loads. See next page for details.

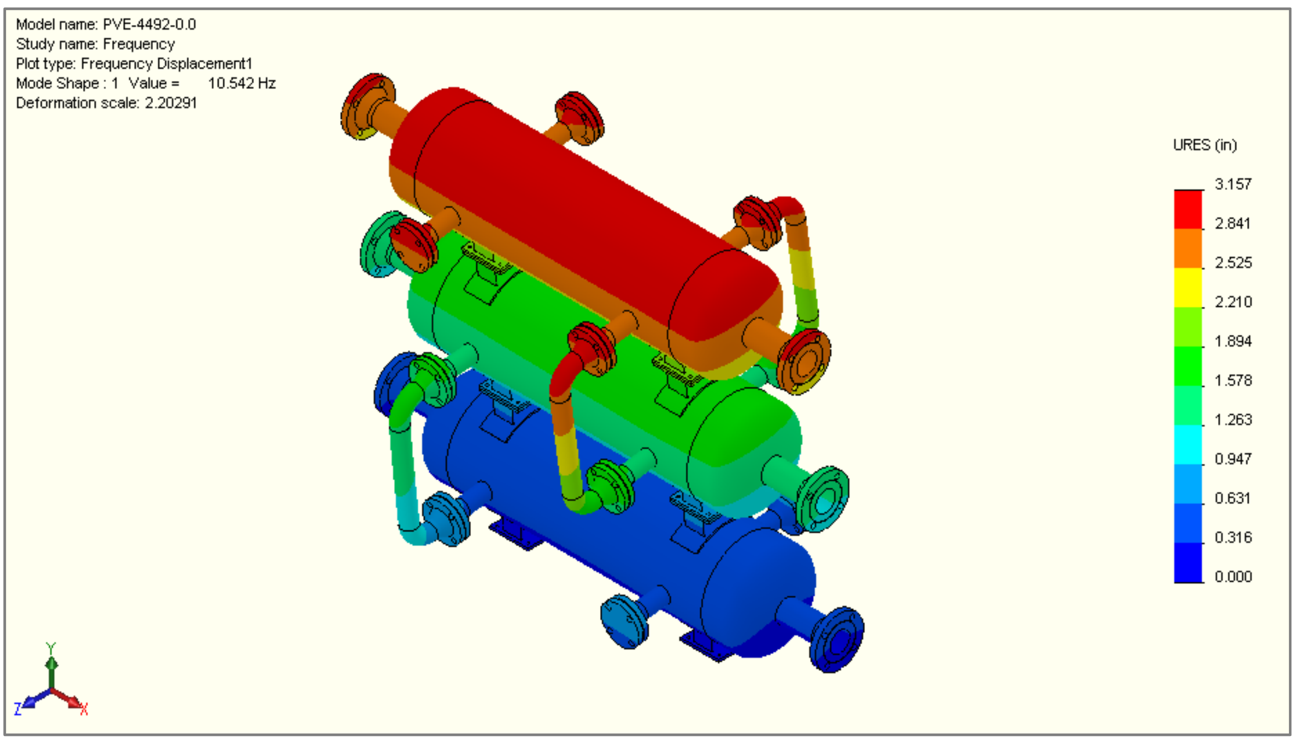


Fig-B A view of the first critical frequency mode. This mode produces a 10.542 Hz frequency used to calculate the base shear and base acceleration. See next page for details.

FEA UB-97 Base Shear (Zone 4) ver 1.00

The Seismic Design Handbook, Second Edition Frazad Naeim Page 250-255

Conditions:

	Seismic Base Shear **Load** Case
0.095	**T** [s] - Period of vibration
1,104	**W** [lb] - Weight of vessel
2.80	**R** [] - Structural System Coeficient
1.25	**I** [] - Importance Factor (1.0 or 1.25)
C	**S** [] - Seismic Source Type (A, B or C)
>= 15	**D** [km] Distance from source
0.96	**CvM** Velocity Coefficient
1.0	**Nv** [] - Near Source Factor (Based on S)
0.36	**CaM** Acceleration Coefficient
1.0	**Na** [] - Near Source Factor (Based on S)
0.4	**Z** [] - Seismic zone factore

Seismic Constants:

Cv [] = CvM*Nv — 0.96*1 = **0.960**

Ca [] = CaM*Na — 0.36*1 = **0.360**

Ts [s] = Cv/(2.5*Ca) — Transition period between Vmax and T control of base shear

0.96/(2.5*0.36) = **1.067**

Tmin [s] = (Cv*I*W)/(R*Vmin) — Transition period between Vmin and T control of base shear

(0.96*1.25*1104)/(2.8*158) = **3.000**

Base Shear:

V1 [lbs] = ((Cv*I)/(R*T))*W — ((0.96*1.25)/(2.8*0.095))*1104 = **4,990**

Vmax [lbs] = (2.5*Ca*I/R)*W — (2.5*0.36*1.25/2.8)*1104 = **444**

Vmin1 [lbs] = 0.11*Ca*I*W — 0.11*0.36*1.25*1104 = **55**

Vmin2 [lbs] = (0.8*Z*Nv*I/R)*W — (0.8*0.4*1*1.25/2.8)*1104 = **158**

Vmin [lbs] = Max(Vmin1,Vmin2) — MAX(55,158) = **158**

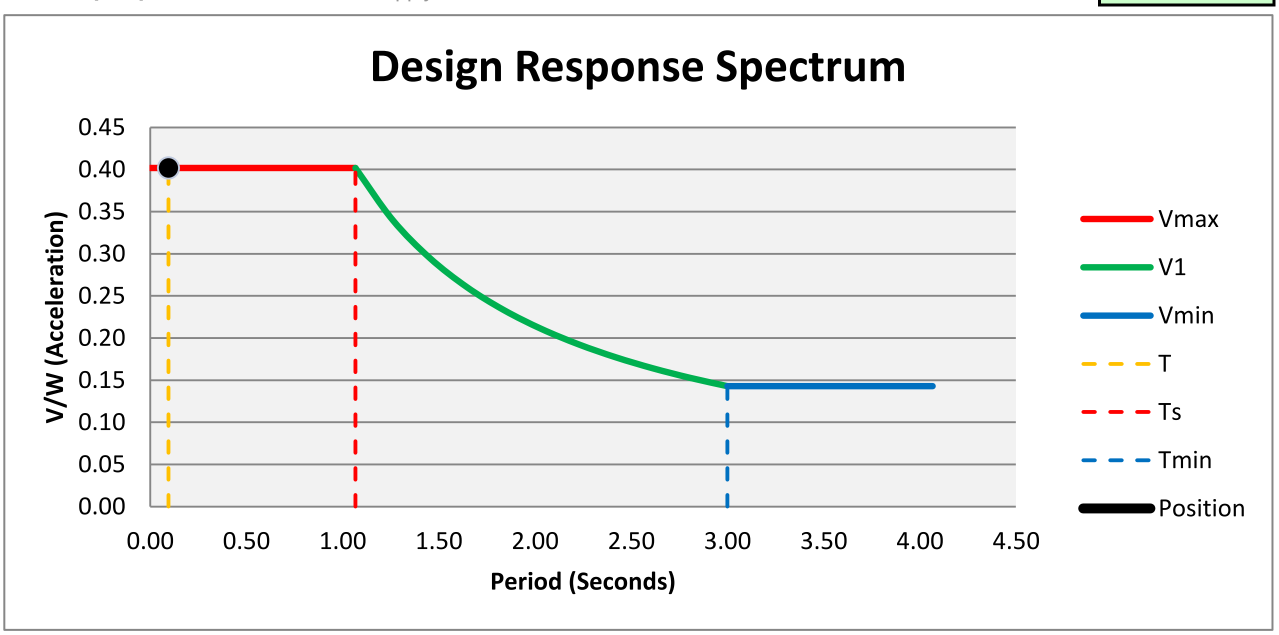
V [lbs] = Max(Min(V1,Vmax),Vmin) — MAX(MIN(4990,444),158) = **444**

Vmax acceleration limit controls the base shear

Pressure and Gravity To Apply:

aH [in/s^2] = V/W*386.22 — acc. to apply in fea — 444/1104*386.22 = **155.178**

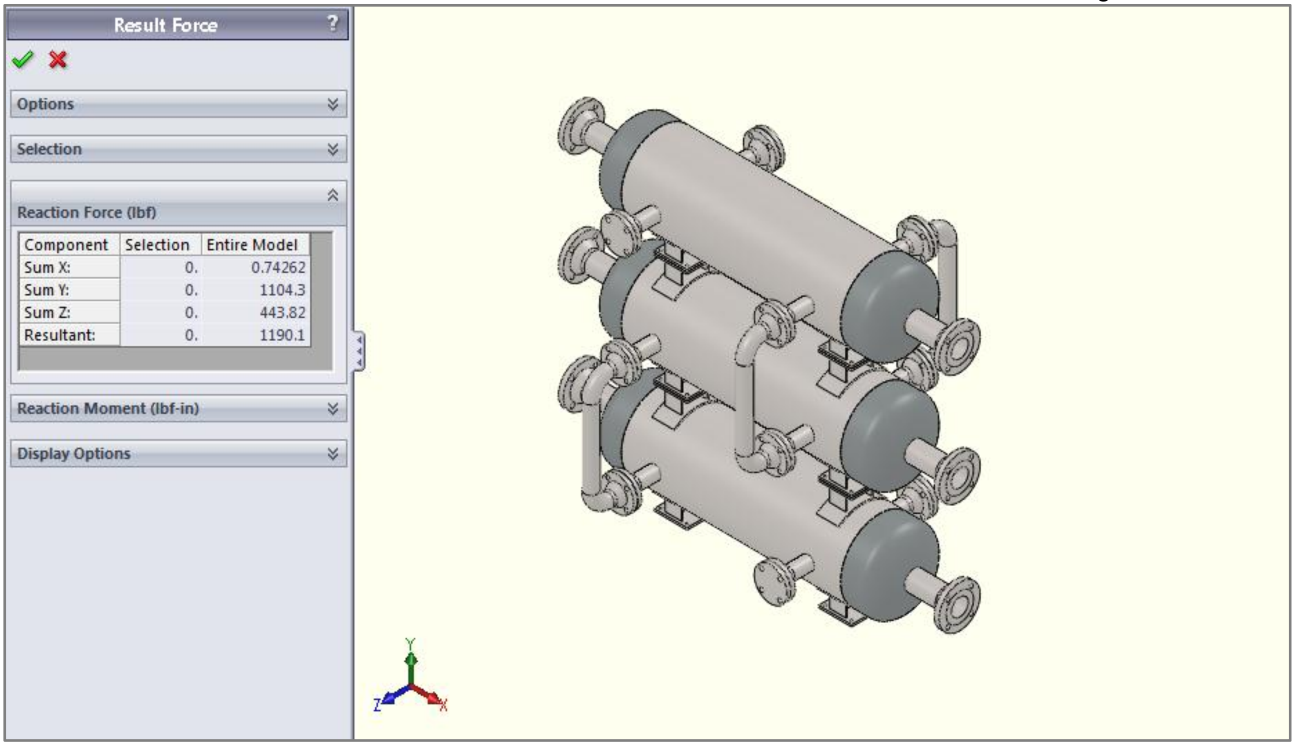
aV [in/s^2] = 1*368.22 — acc. to apply in fea — 1*368.22 = **368.220**



Seismic Code Requirements (Presentation), John W. Wallace, University of California

http://www.scribd.com/doc/19713104/Seismic-Code-Requirements

Reaction Forces ver 4.08



View showing Global Reaction Forces from analysis.
Calculated Reaction Forces = Analysis Reaction Forces within 0.0%
Model is balanced, results are valid.

X Axis: reaction forces on the YZ plane caused by loads in the X direction

0.00	**XArea** [in2] - Pressurized area on YZ plane
200	**P** [psi] - Pressure
0	**XForce** [lbs] - Added force in the X direction
0.7	**XReaction** [lbs] - Reaction force in X direction reported by FEA program

TReactionX [lbs] = XArea*P+XForce Theoretical X reation force 0*200+0 = **0**

Y Axis: reaction forces on the XZ plane caused by loads in the Y direction

0	**YArea** [in2] - Pressurized area on XZ plane
1,104	**YForce** [lbs] - Added force in the Y direction
1,104.30	**YReaction** [lbs] - Reaction force in Y direction reported by FEA program

TReactionY [lbs] = YArea*P+YForce Theoretical Y reation force 0*200+1104 = **1,104**

Z Axis: reaction forces on the XY plane caused by loads in the Z direction

0	**ZArea** [in2] - Pressurized area on XY plane
444	**ZForce** [lbs] - Added force in the Z direction
443.82	**ZReaction** [lbs] - Reaction force in Z direction reported by FEA program

TReactionZ [lbs] = ZArea*P+ZForce Theoretical Z reation force 0*200+444 = **444**

Resultant of reaction forces in X, Y and Z:

TResultant [lbs] = sqrt(TReactionX^2+TReactionY^2+TReactionZ^2) Theoretical resultant
SQRT(0^2+1104^2+444^2) = **1,190**

Resultant [lbs] = sqrt(XReaction^2+YReaction^2+ZReaction^2) Actual resultant
SQRT(1^2+1104^2+444^2) = **1,190**

Error [%] = 100*(TResultant-Resultant)/Resultant 100*(1190-1190)/1190 = **0.0**

CheckError = abs(Error)<2 Error should be less than 2% ABS(0)<2 = **Acceptable**

Displacement

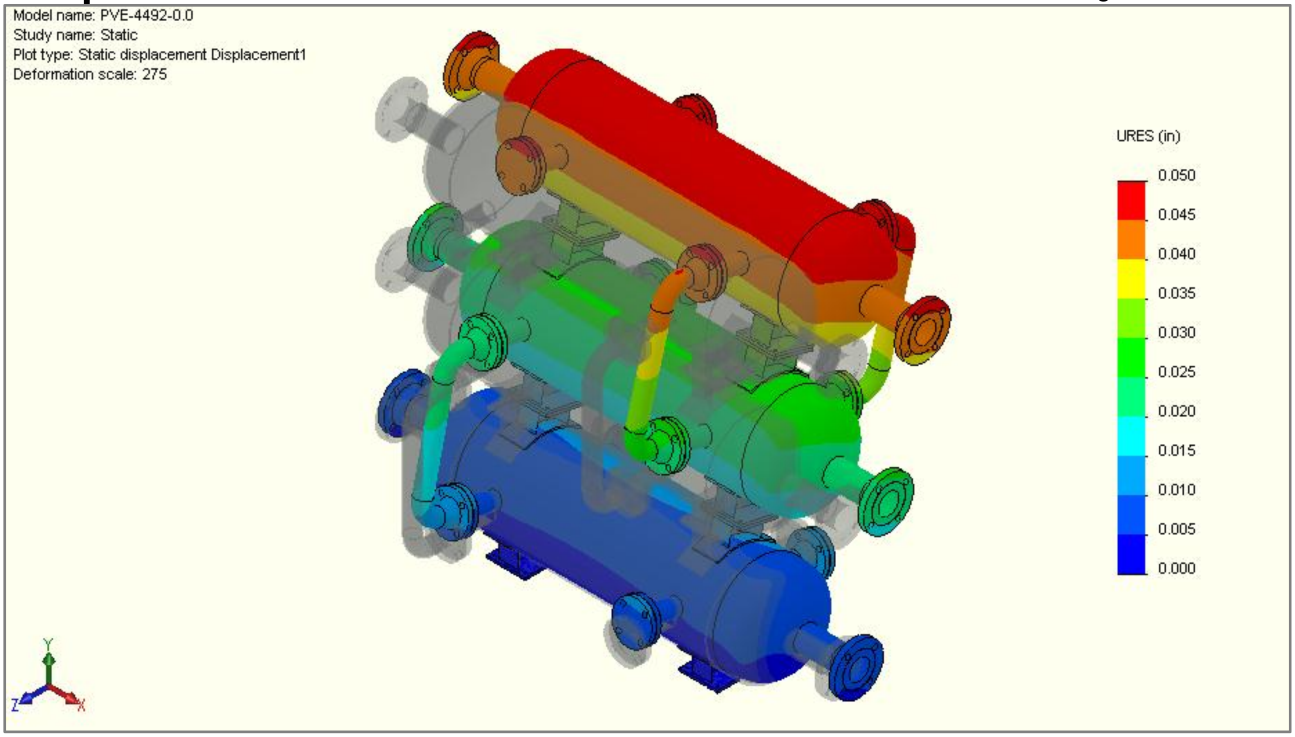


Fig-A A view of the displacement plot with superimposed original geometry, results are magnified 275 times. The direction of displacement is as expected. The magnitude of displacement is acceptable.

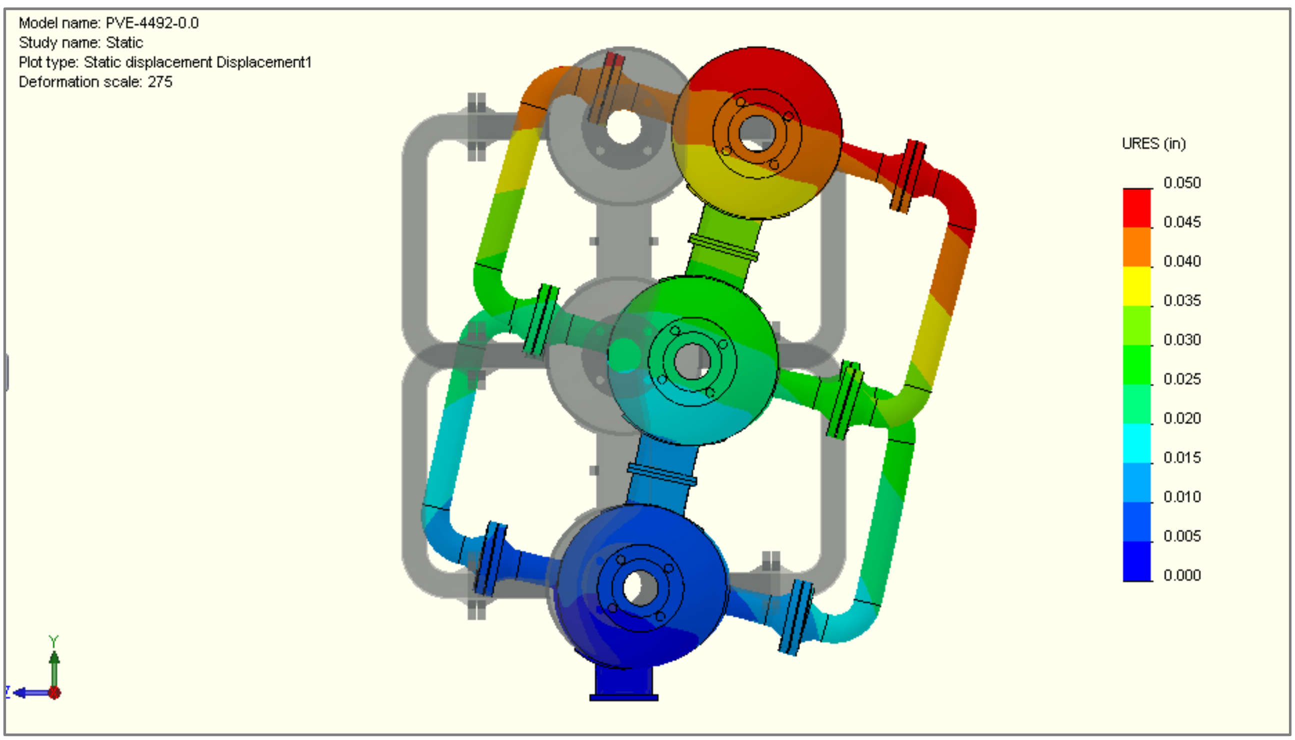


Fig-B An alternative view of Fig-A.

Stress

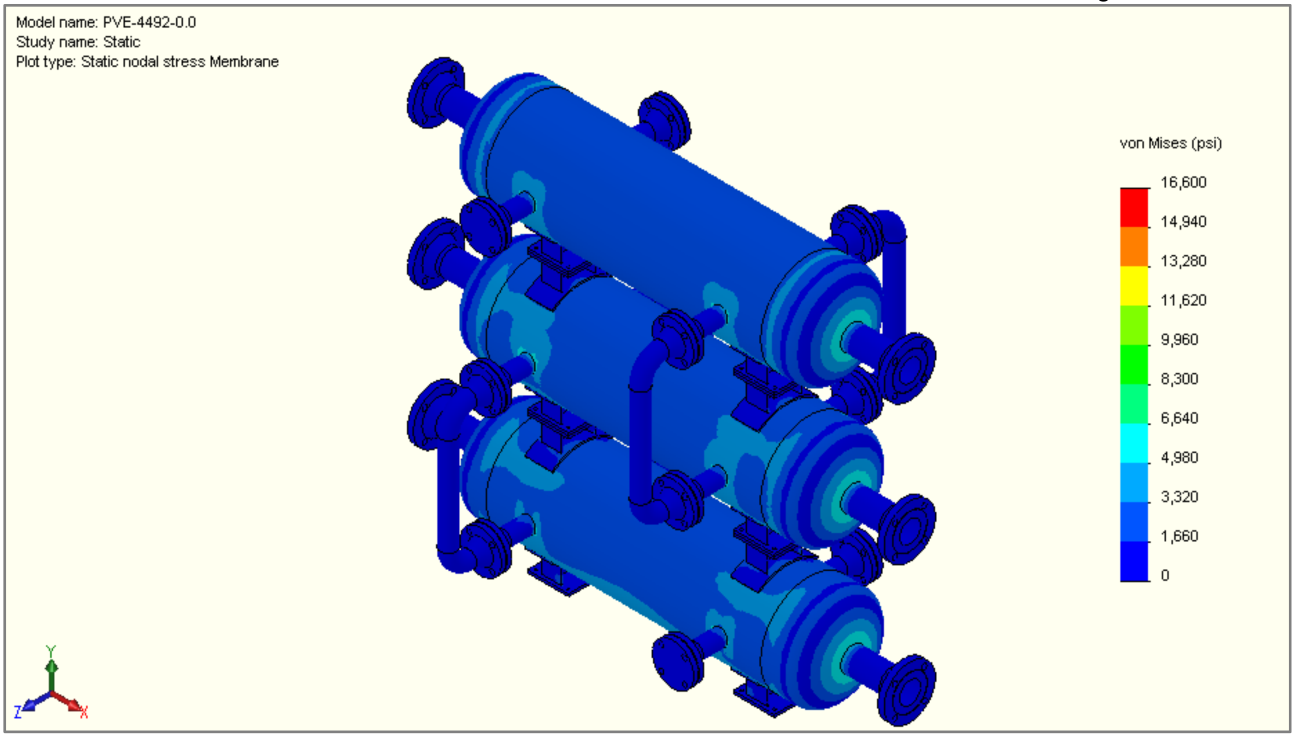


Fig-A A view of the stress plot (von Mises) capped at the primary general membrane allowable of 16,600 psi for the supports.

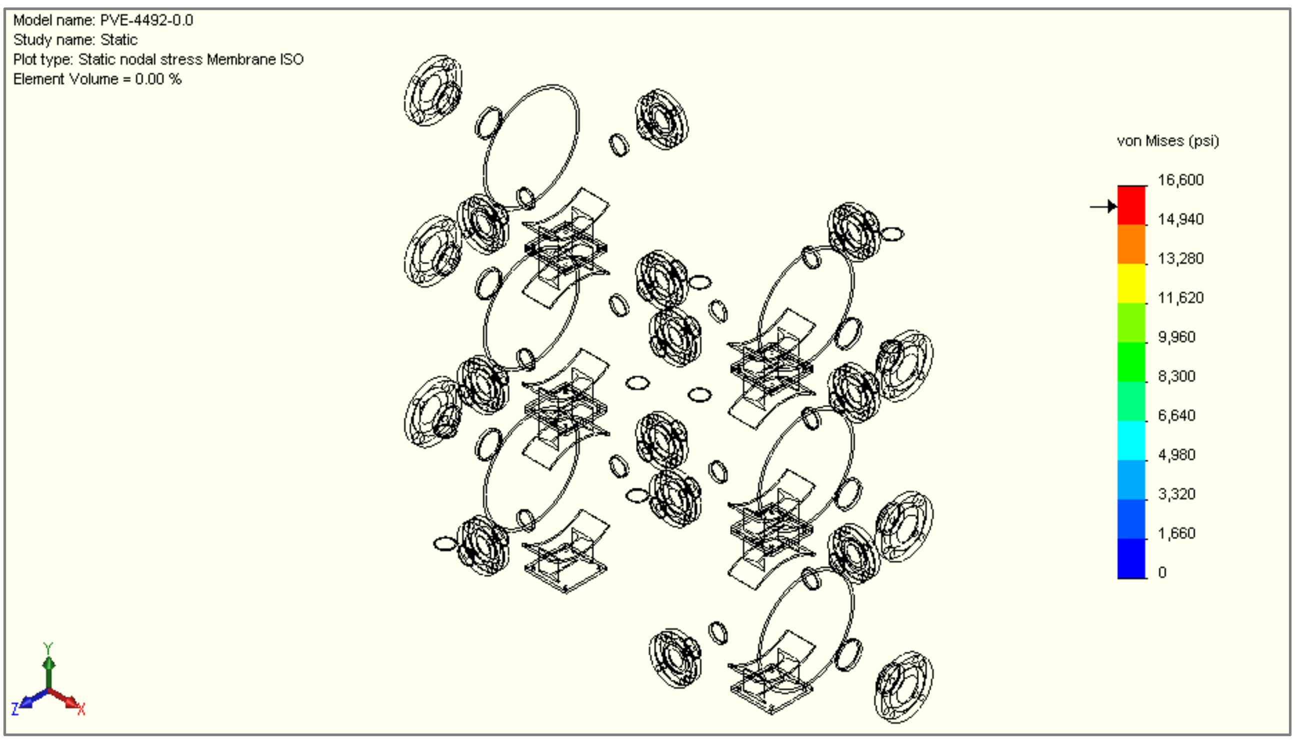


Fig-B An "ISO clipped" view of Fig-A.
No stresses in excess of the primary general membrane allowable are observed.
Results are acceptable.