Tank and Support Structure Design and Analysis

-Saurabh Patil

Vishwakarma Institute of Information Technology (VIIT), India

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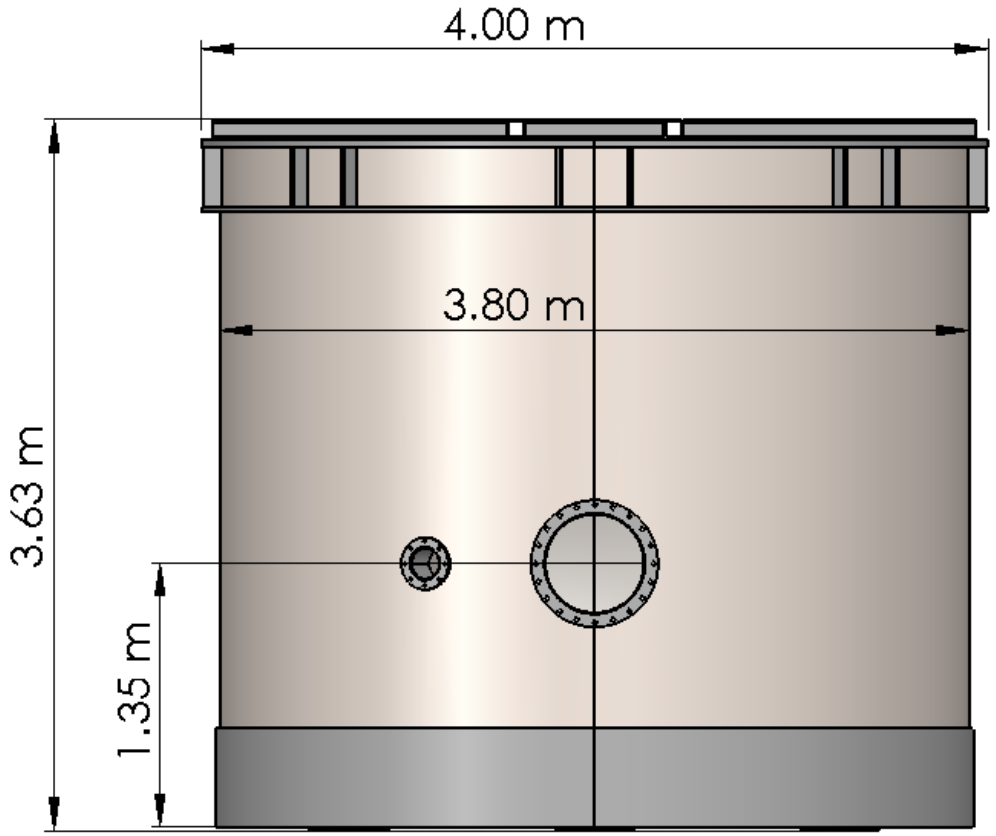
Design Overview

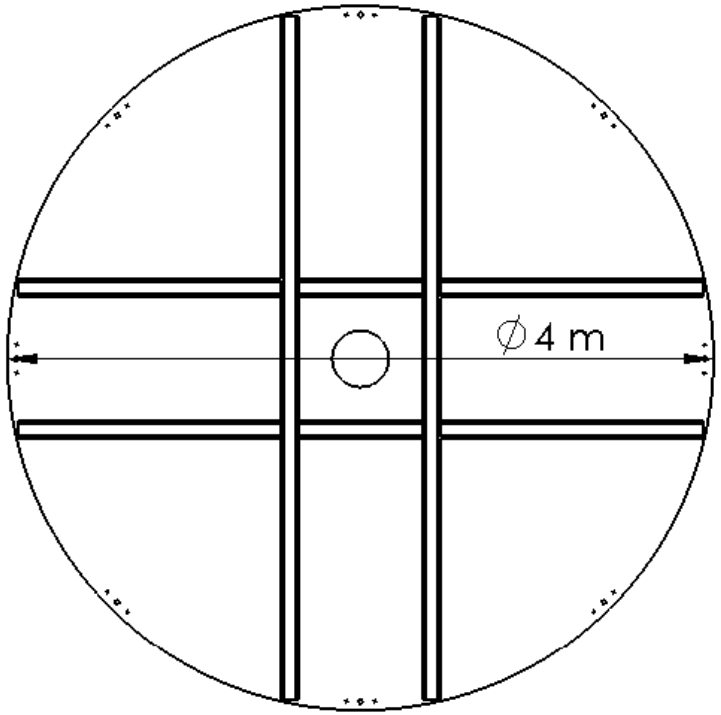
MATERIAL PROPERTIES		
Material	Stainless steel	
Grade	SS 304	
Poisson's ratio	0.31	
Density	7750	kg/m3
Modules of Elasticity	193 X 10^3	M Pa
Design Yield Strength	207	M Pa
Ultimate Tensile Strength	586	M Pa
Thermal Coefficient	1.7 X 10^{-5}	/°C

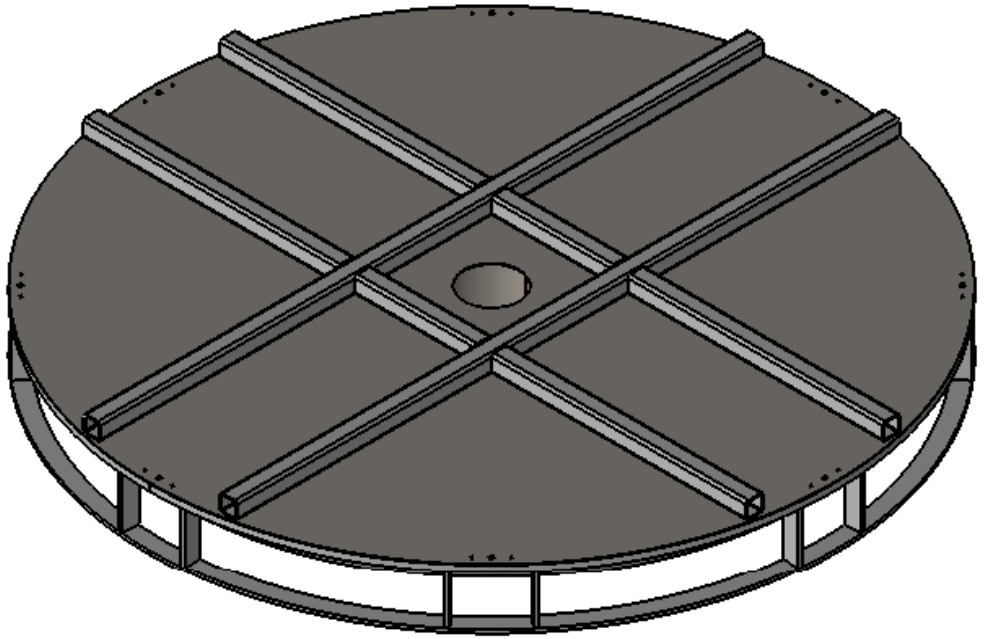
Design Overview

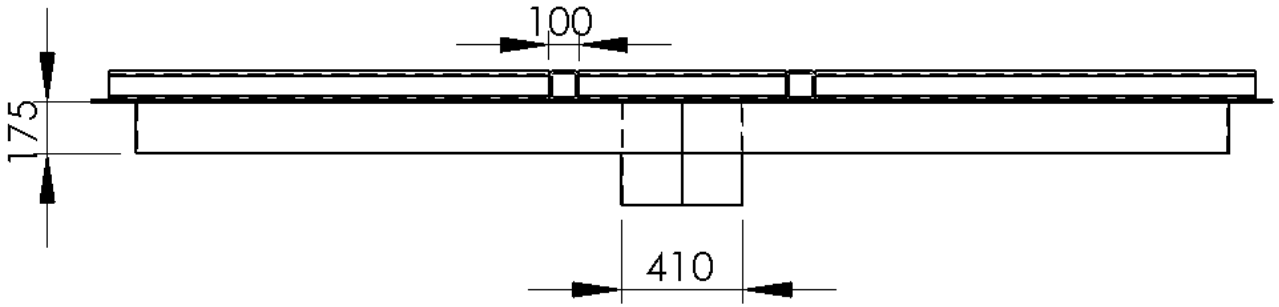
COMPONENT	MASS (TON)
Tank	3.2
Base	2.2
Lid	1.0
Water	38.5
Support Structure +mPMTs	6.0
CDS	0.1
Miscellaneous*	0.2
Total	**~51 TON**

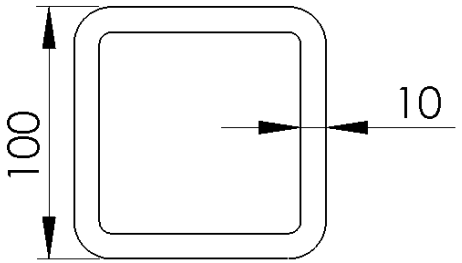


Lid Details

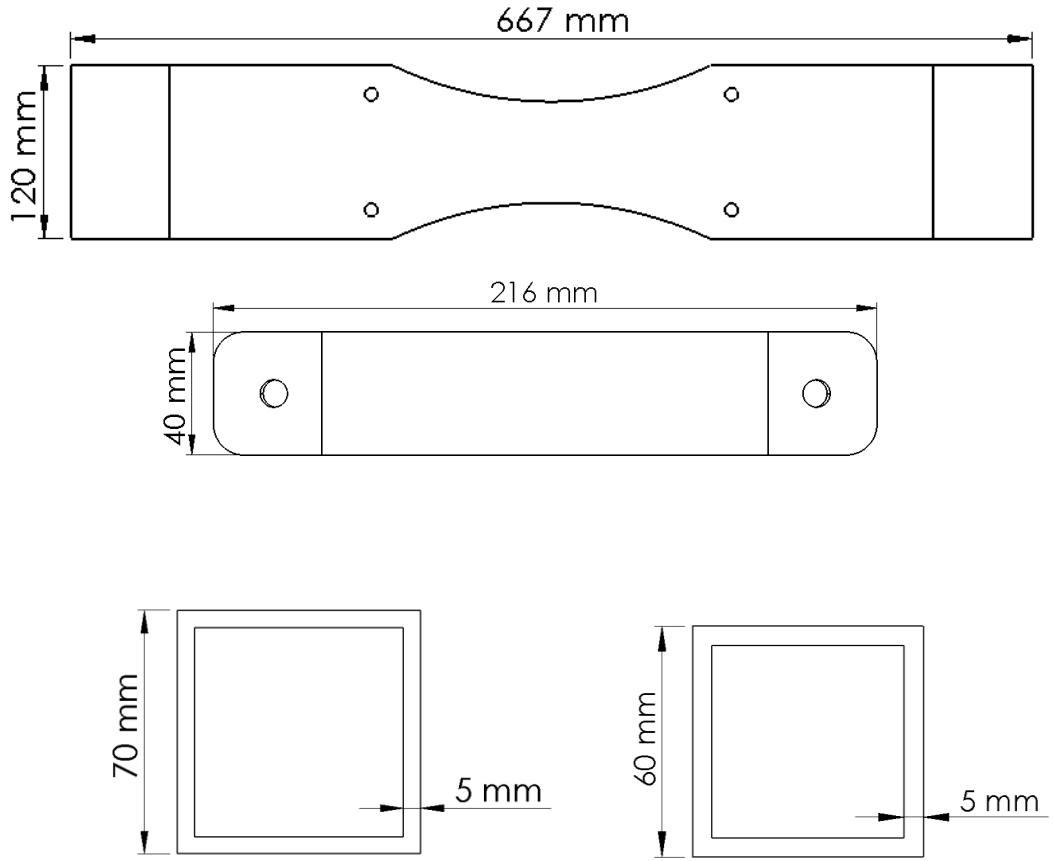


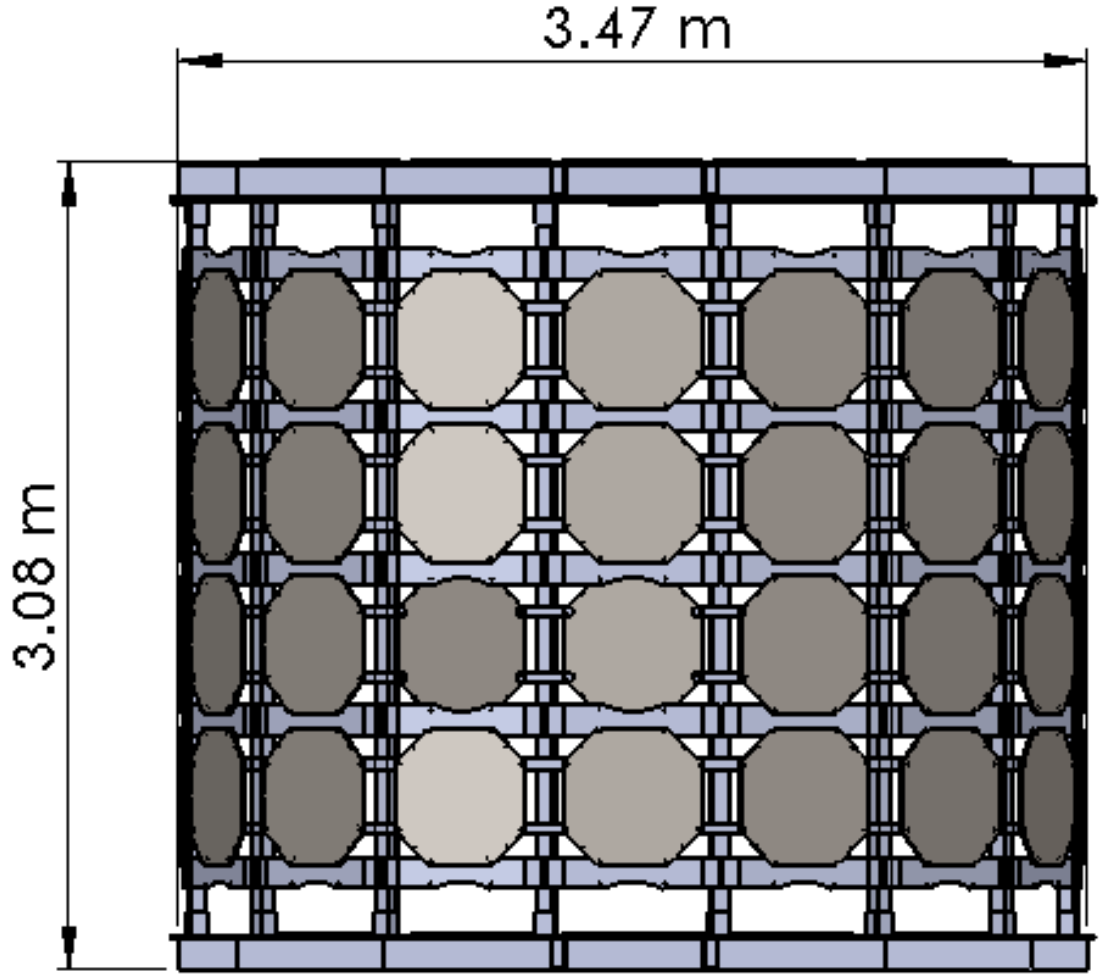




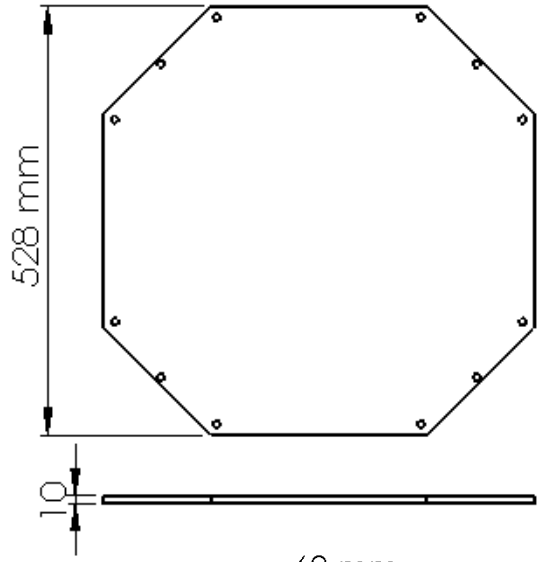


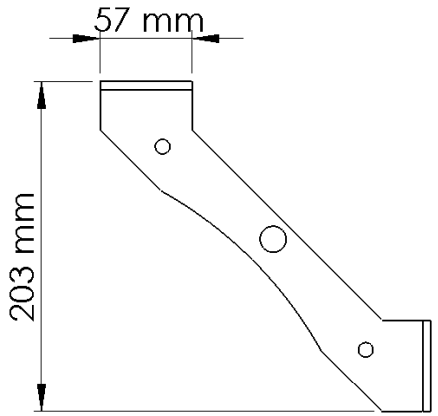
Support Structure Details

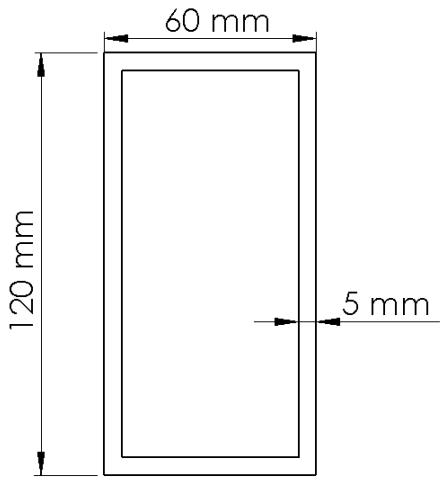


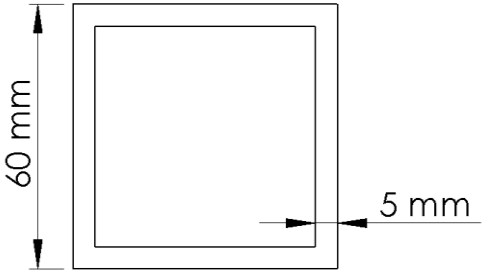


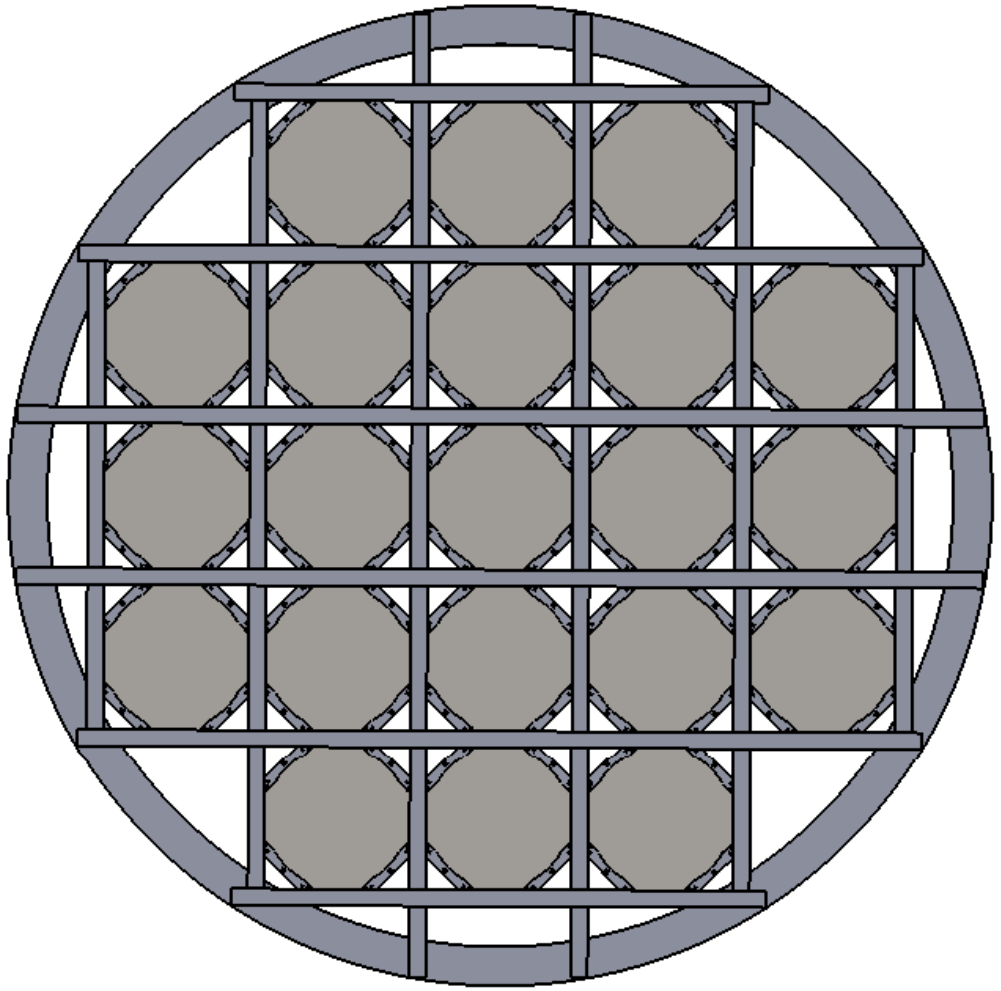
End Cap Details



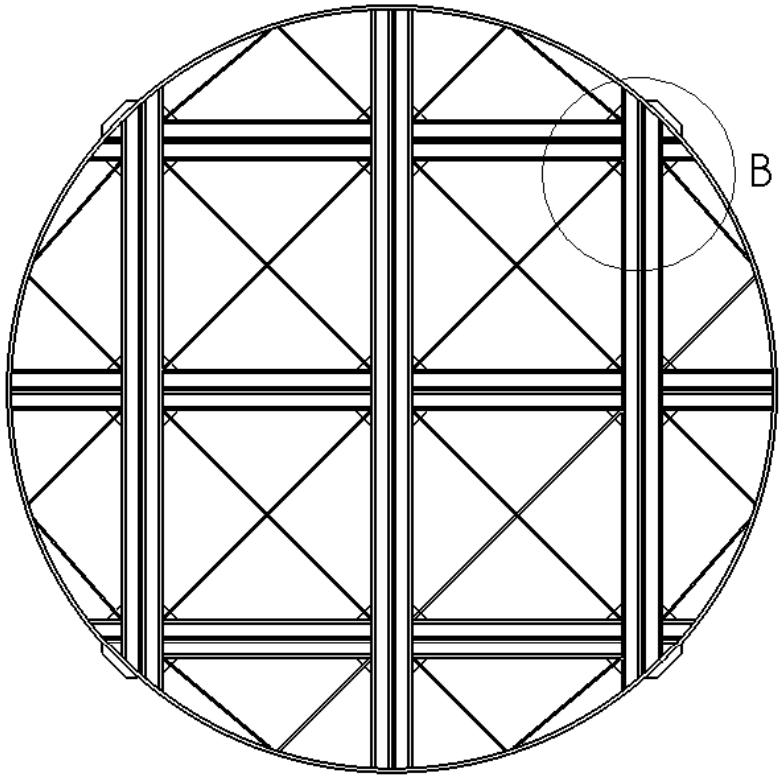


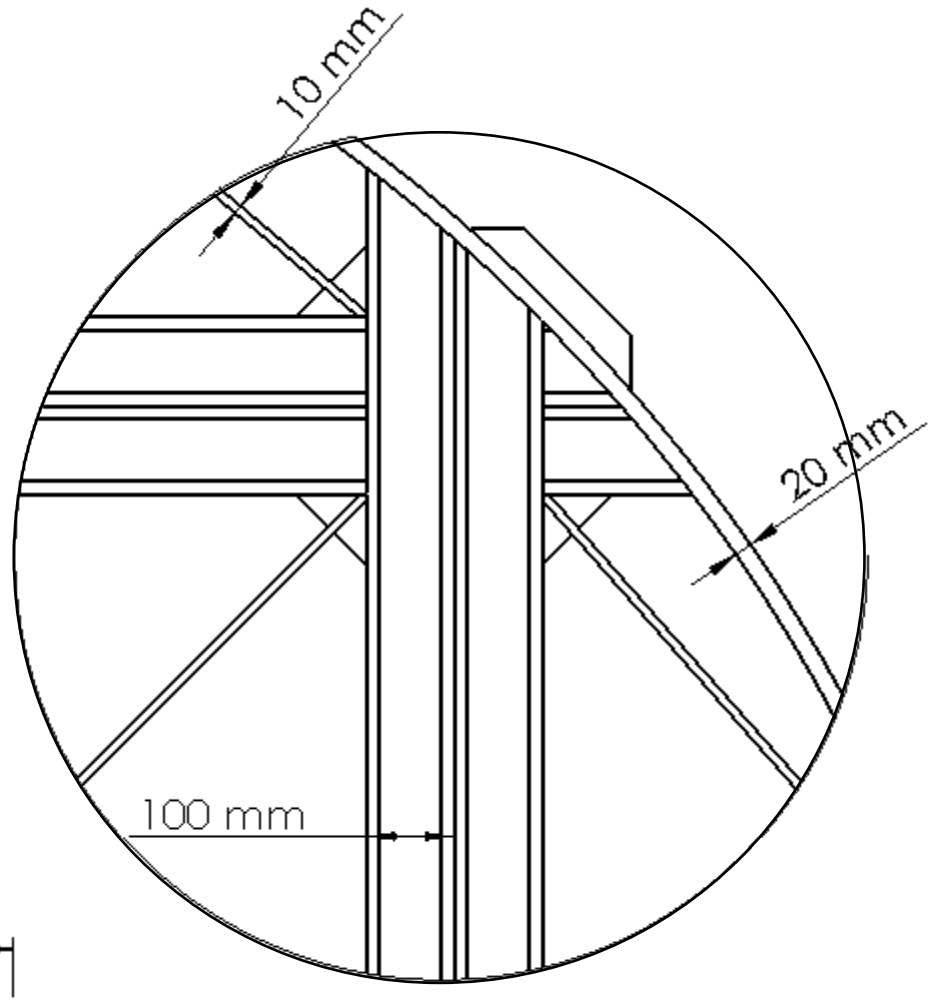




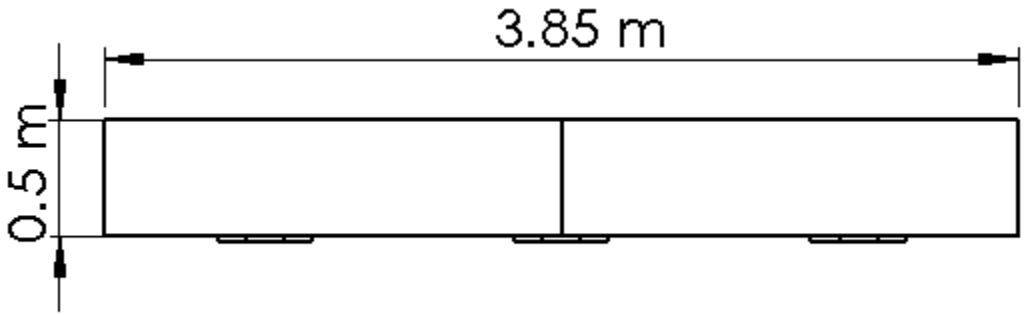


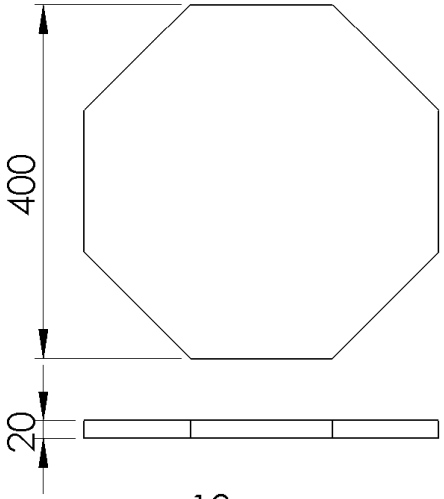
Base Details

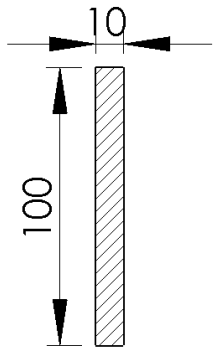


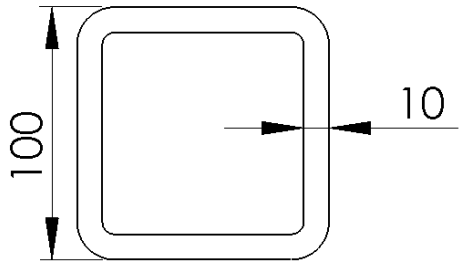


DETAIL B
SCALE 1 : 10



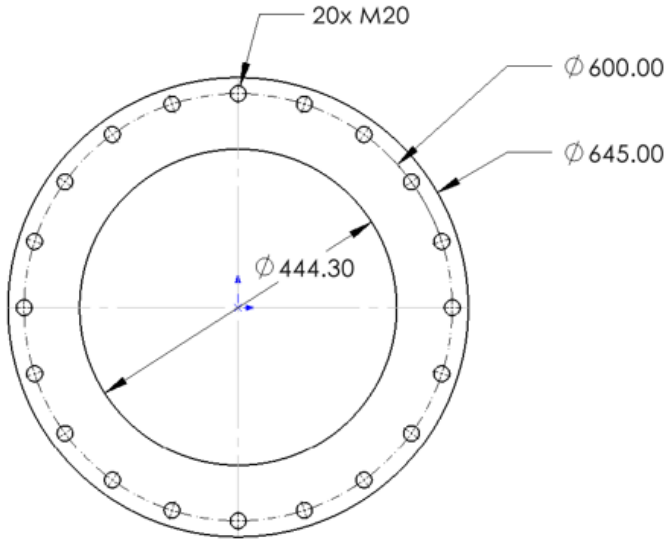


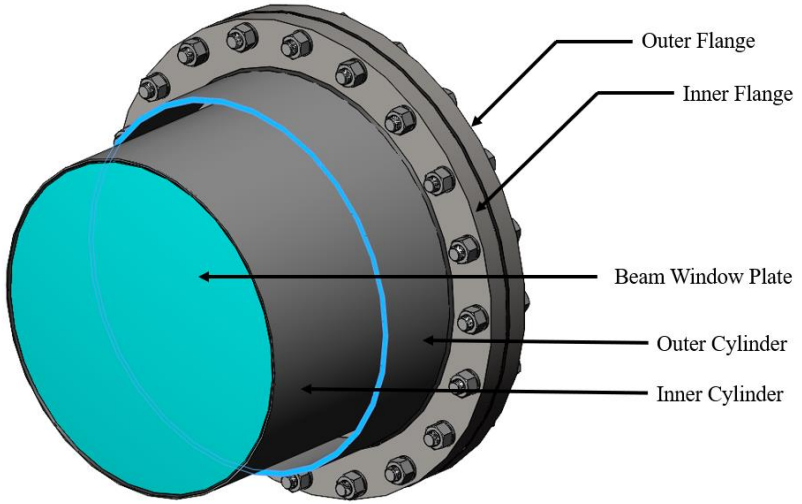


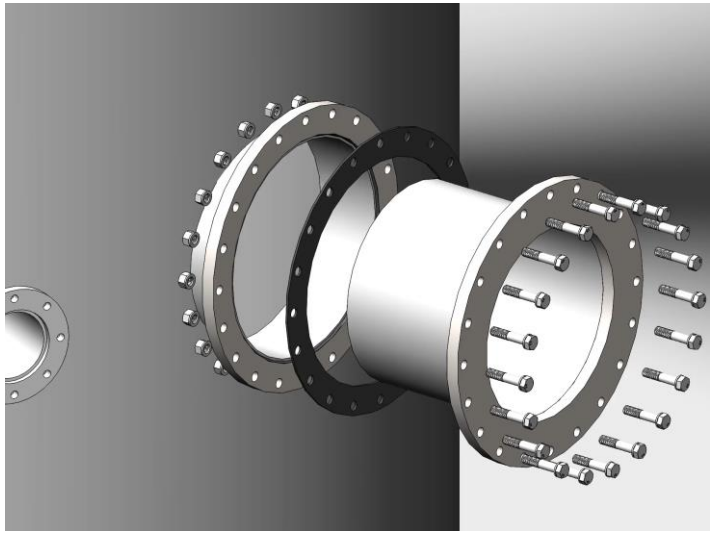


Tertiary Beam Window Details

Part	Standard	Size
Inner Cylinder	Schedule 10	18-inch
Outer Cylinder	Schedule 5s	20-inch
Inner Flange	EN 1092-1	DN 500
Outer Flange	Custom made	
Flange Bolts, Nuts & Washer	M20	







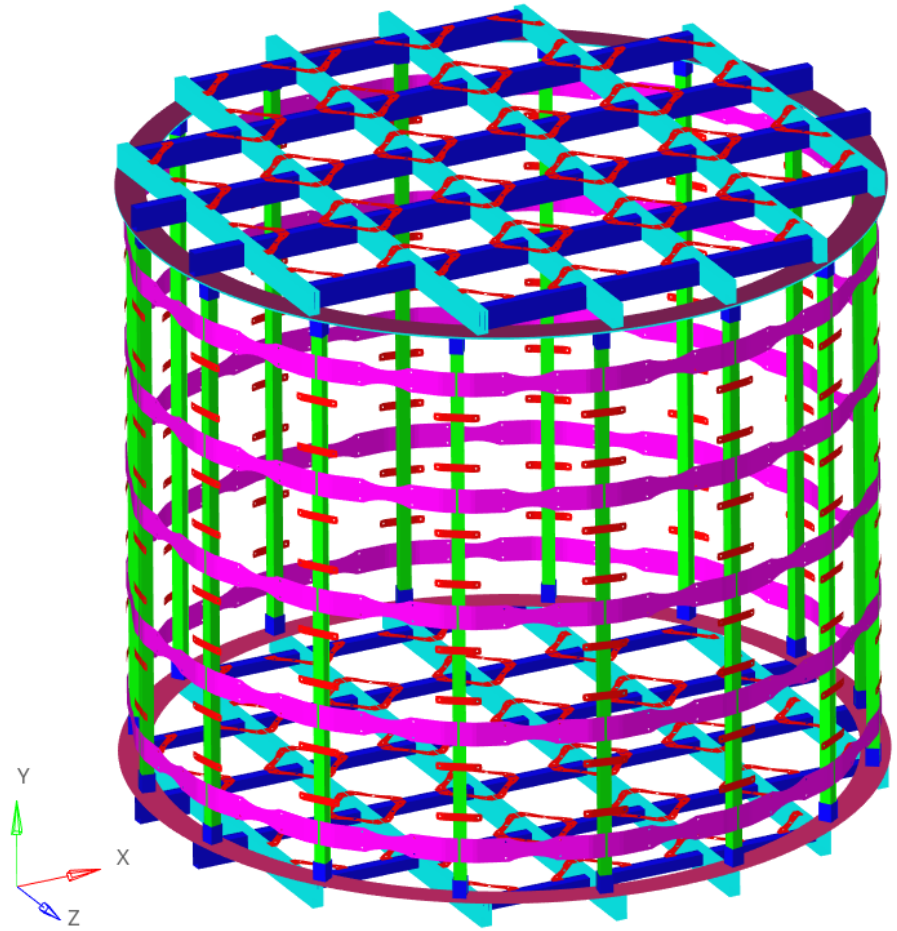
Support Structure Static Analysis

Boundary Condition

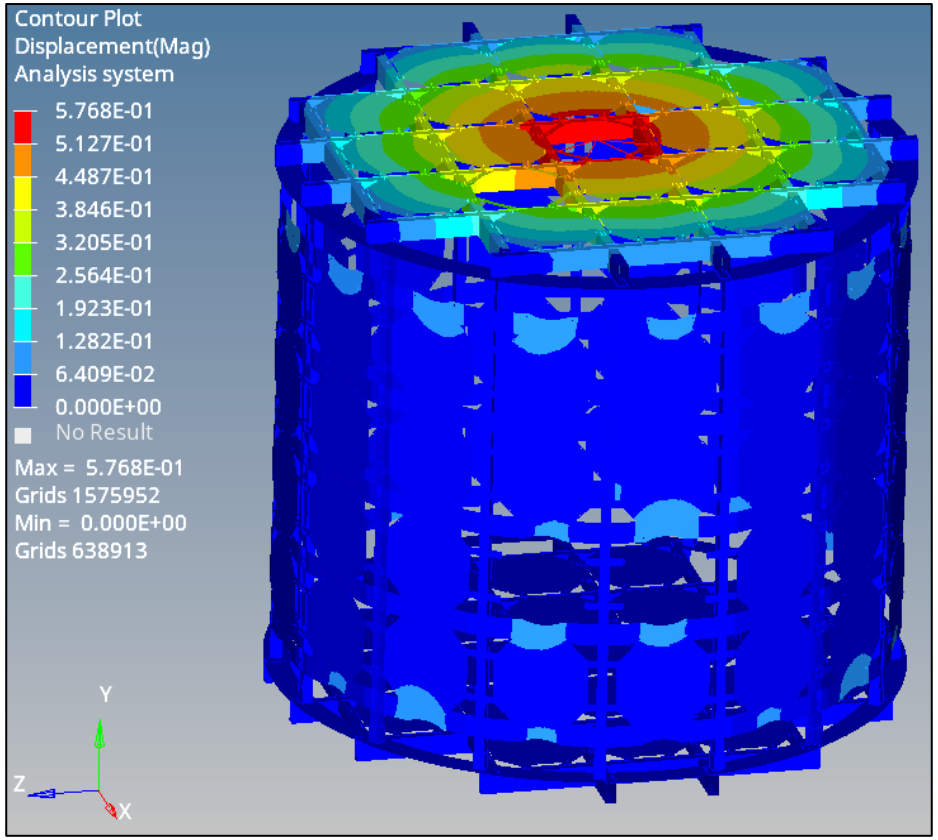
The bottom beams are fixed to all dofs

Loads

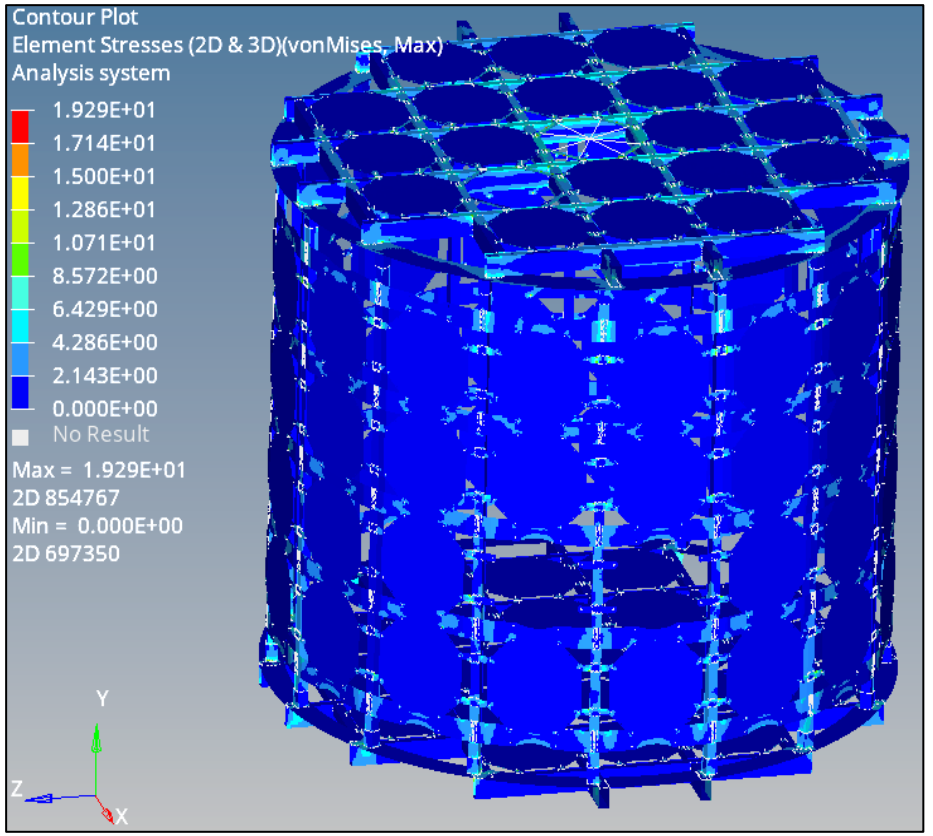
Self wt.(Gravity)+ 102 mPMT wt. 40kgs each



Support Structure Static Analysis



Max. Displacement = 0.58 mm



Max. Stress = 19.30 MPa

Conclusion

1. From the static analysis performed on the two configurations of the support structure, we can infer that the **maximum stress generated is around 20 MPa**.
2. **The FOS is 10**, thus we can conclude that the structure is safe under given loading conditions.

Sr. No.	Top End cap configuration	Displacement (mm) Maximum	vonMises stress (MPa) Maximum	F.O.S
1.	Diagonal mPMT removal	0.58	19.29	10.73

Lid Static Analysis

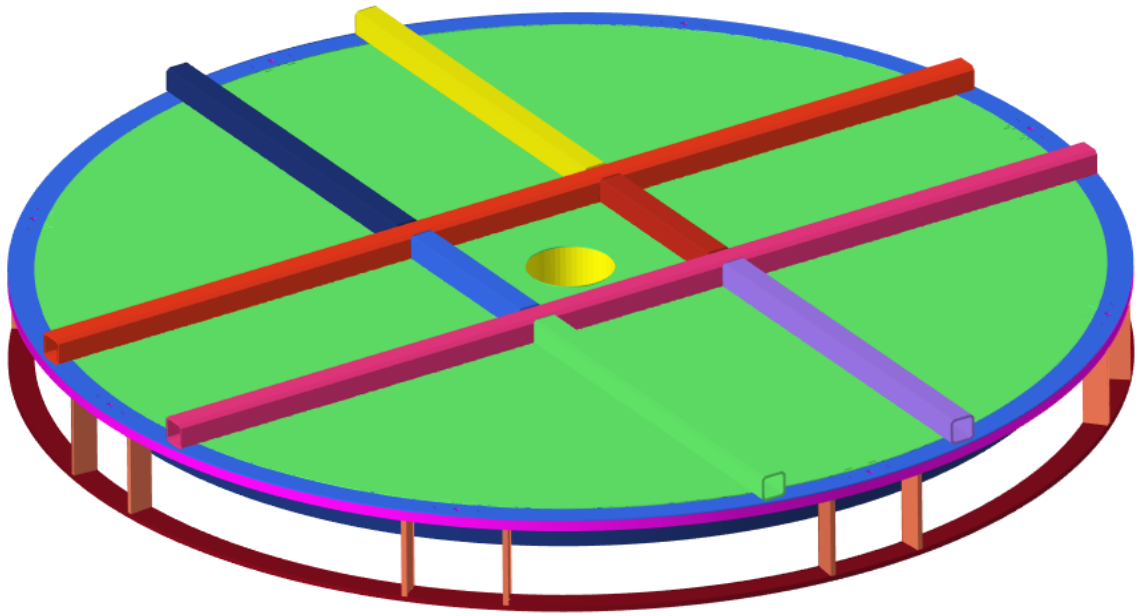
Boundary Condition

Contact between the lid and tank edge is defines.

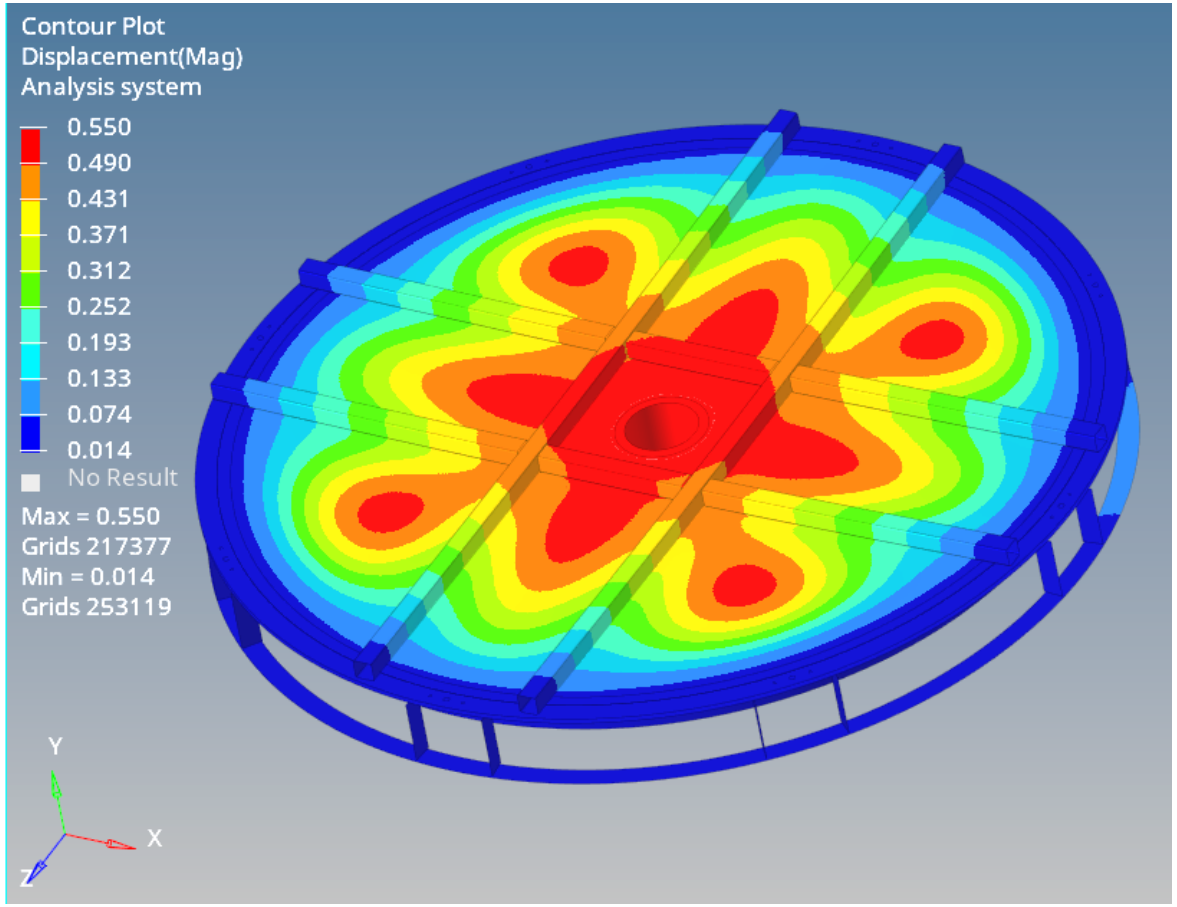
The outer rings and ring connecting members are in contact with the tank surface

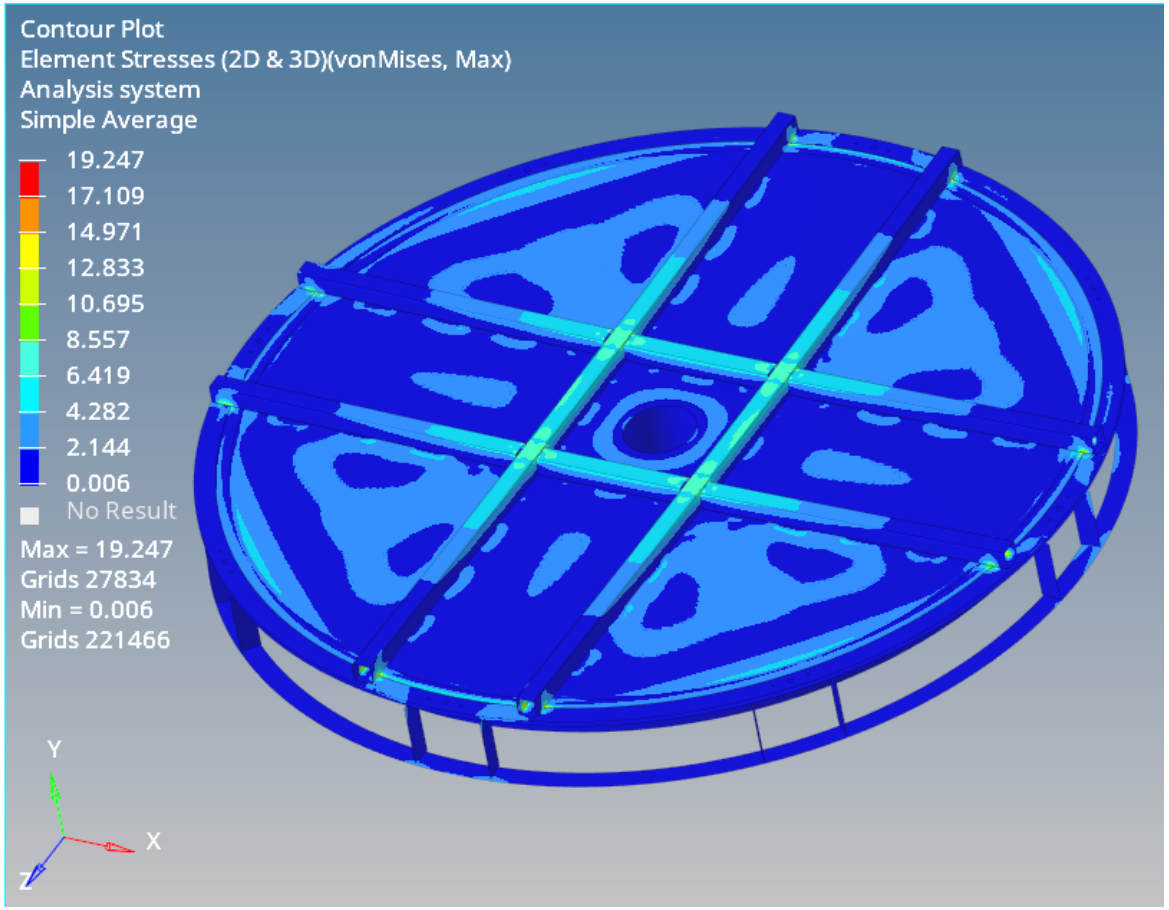
Loads

Self wt.(Gravity)+ 100 kg (CDS) on top rafters



Lid Results

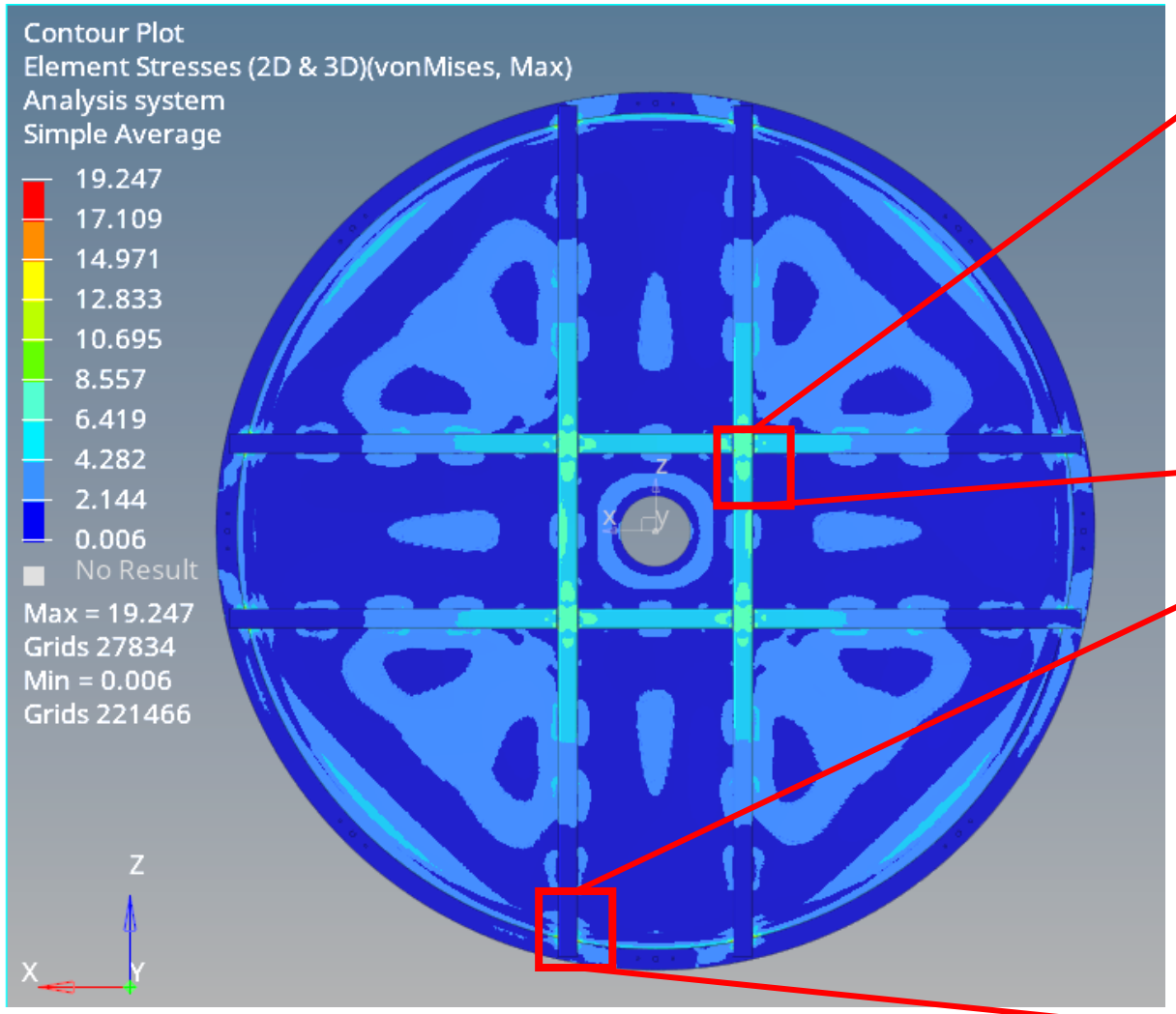


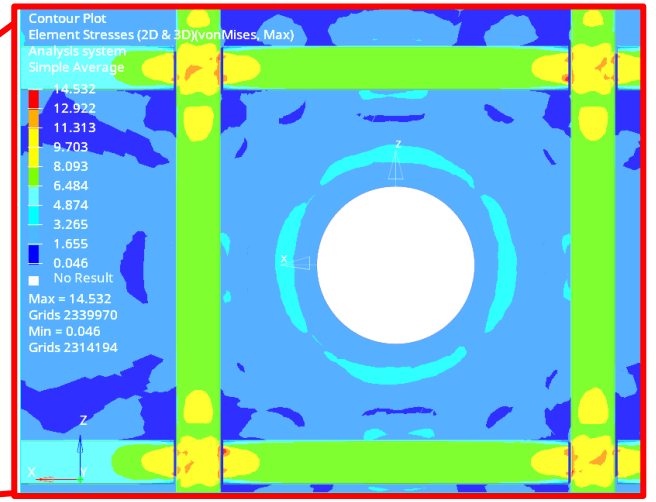


Max. Displacement = 0.55 mm

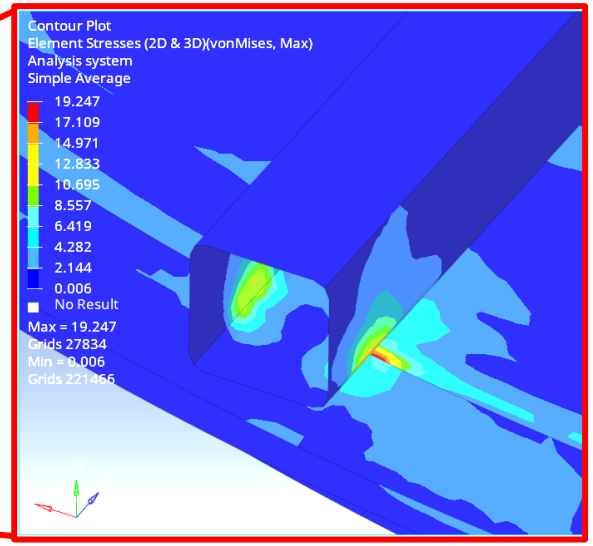
Max. Stress = 19.24 MPa

Lid Results





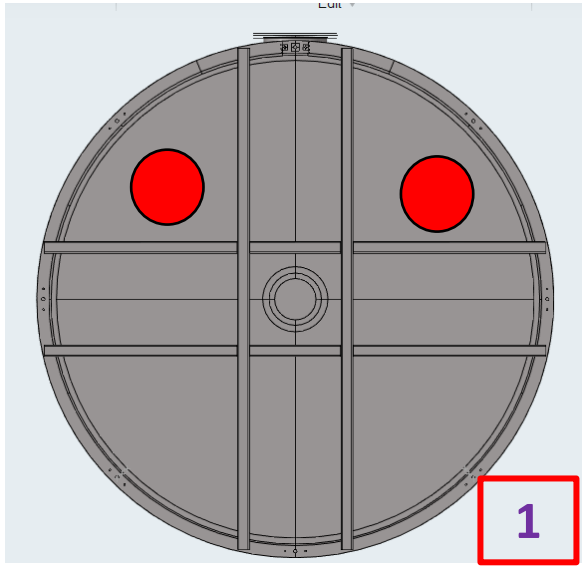
14.24 MPa

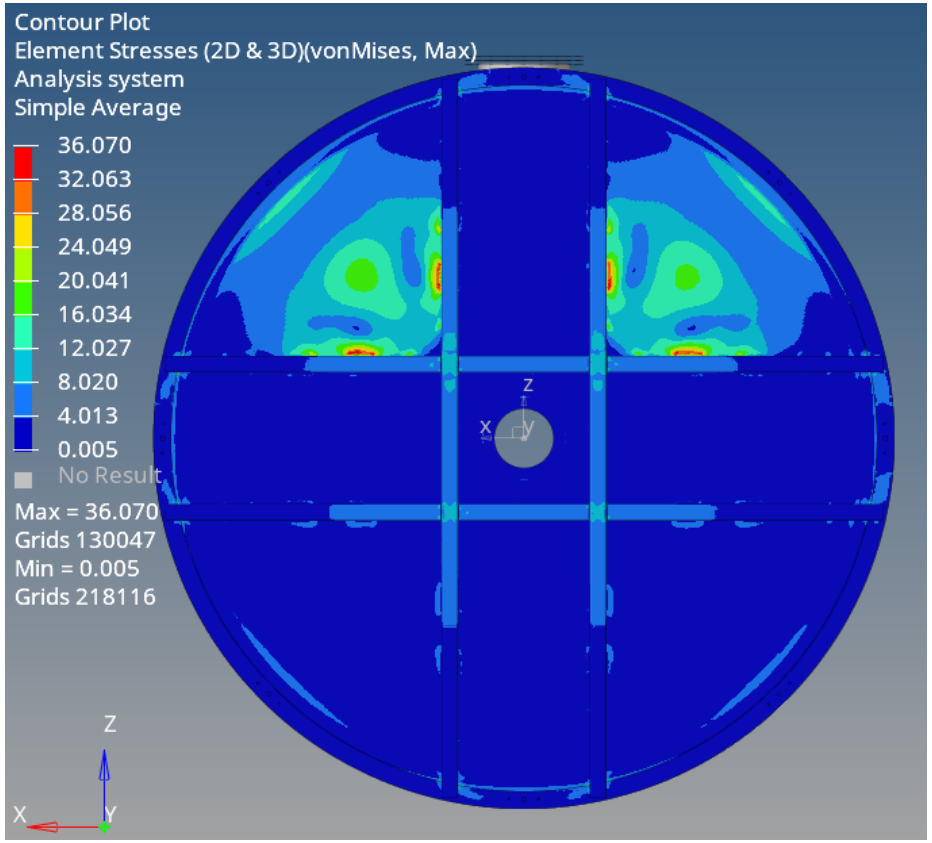


19.24 MPa

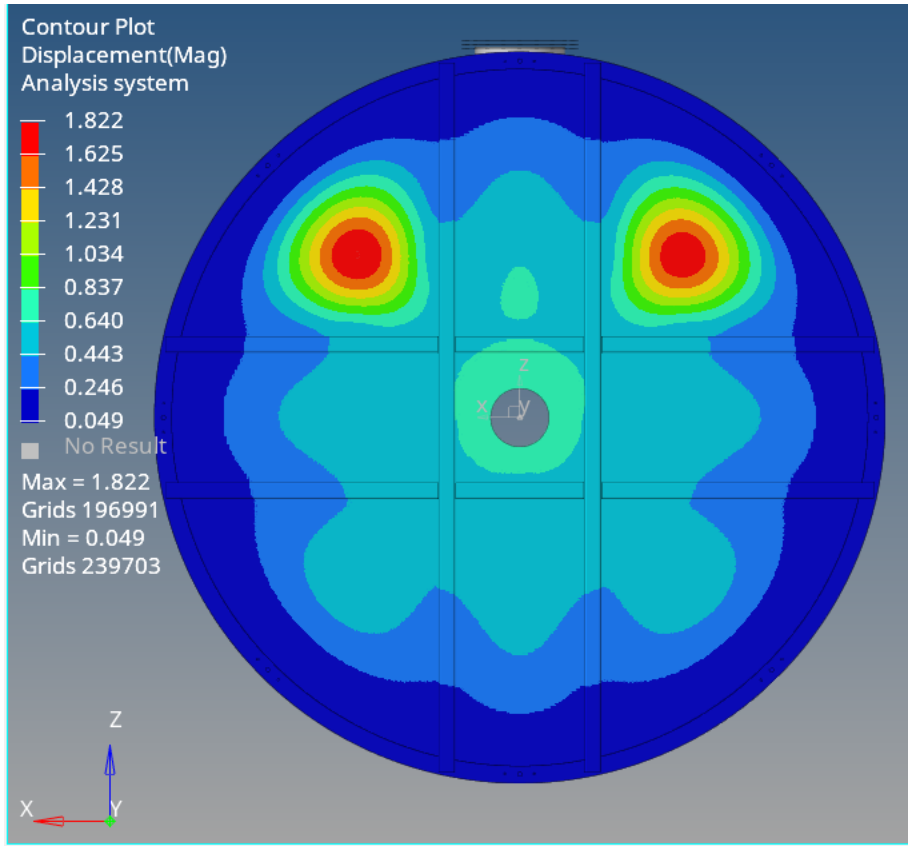
Beam Window

Case 1





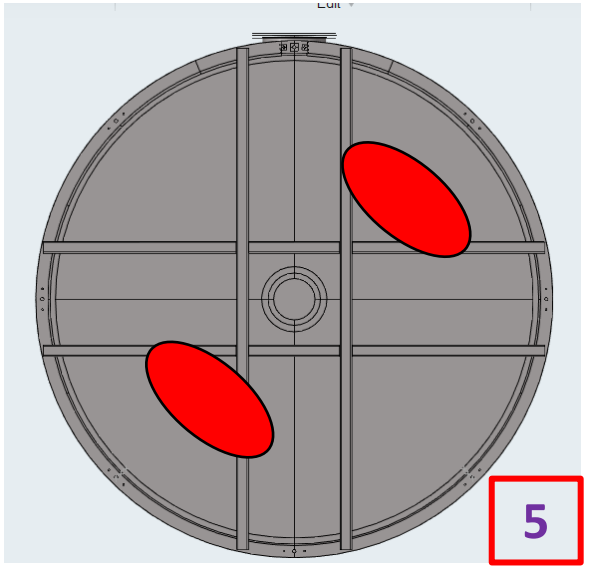
Lid Stress = 36.070 MPa

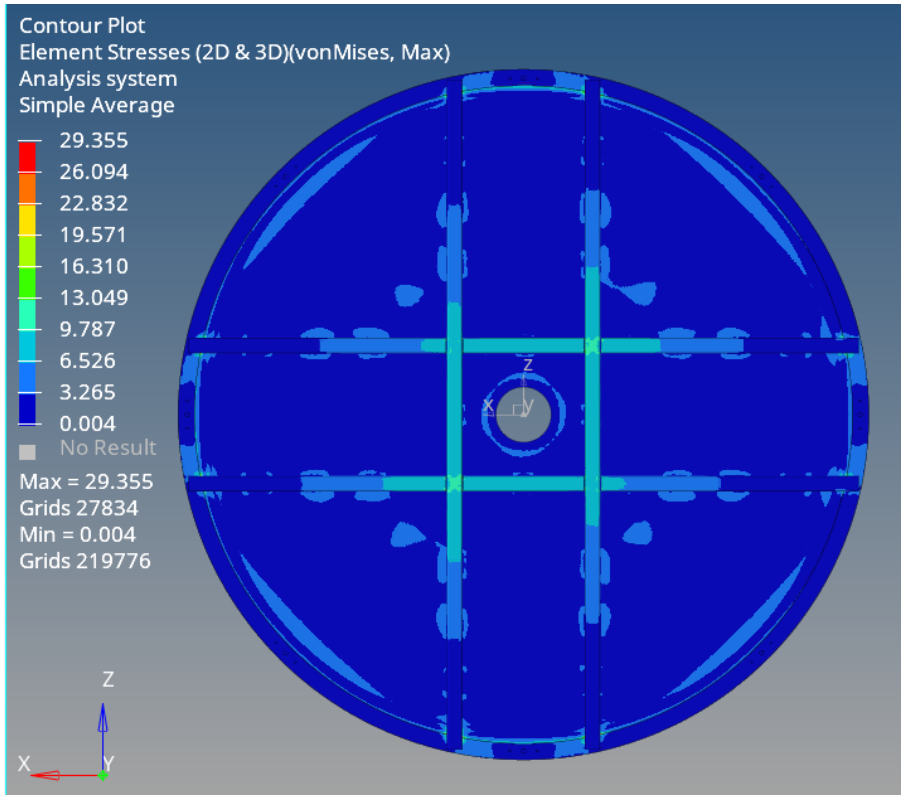


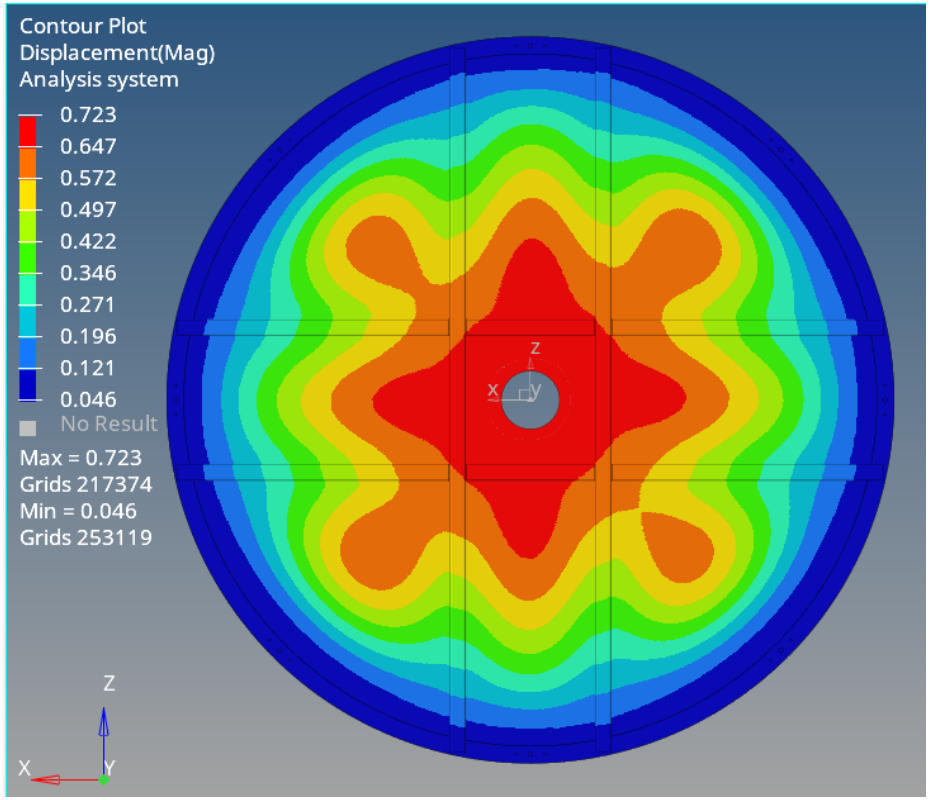
Lid Displacement = 1.822 mm

Beam Window

Case 5







Lid Stress = 29.355 MPa

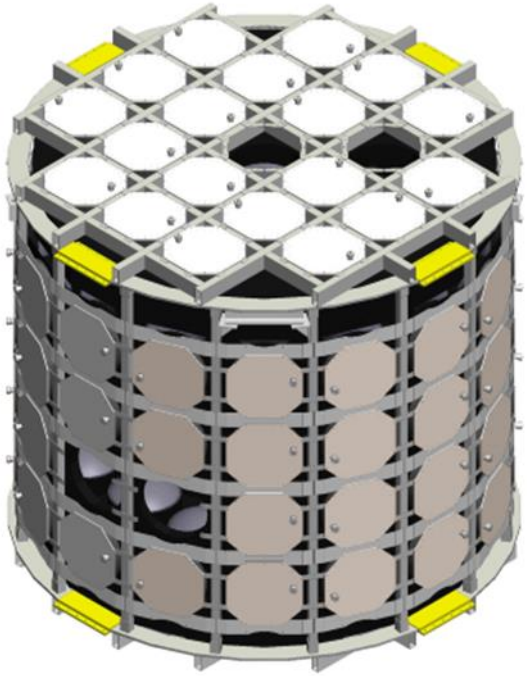
Lid Displacement = 0.723 mm

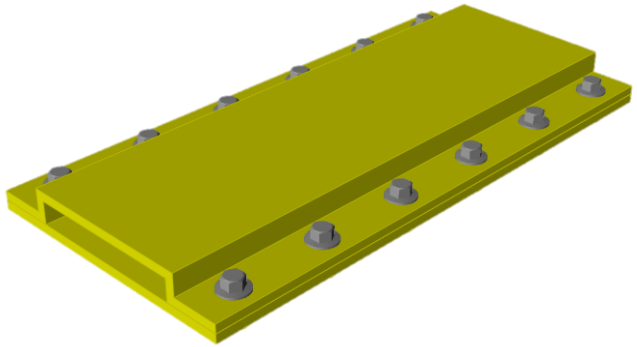
Conclusion

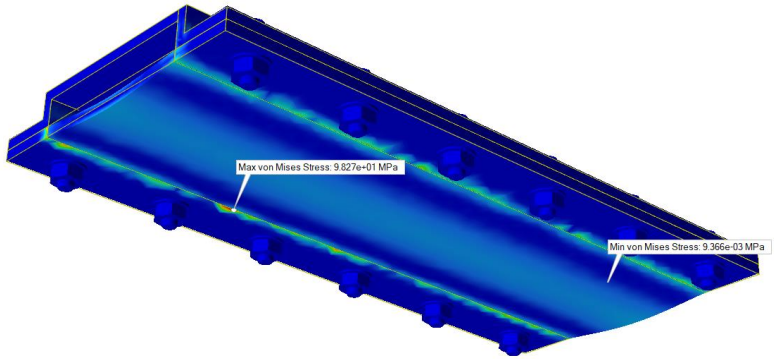
- Under expected loading conditions the maximum stress on the lid is **~ 20 MPa** with a displacement of **0.55 mm.**
- From the Tank Lid Safety studies, we can infer that direct load on lid (Case 1) causes higher stress compared to other cases.
- The minimum factor of safety is **5.7** for the lid.

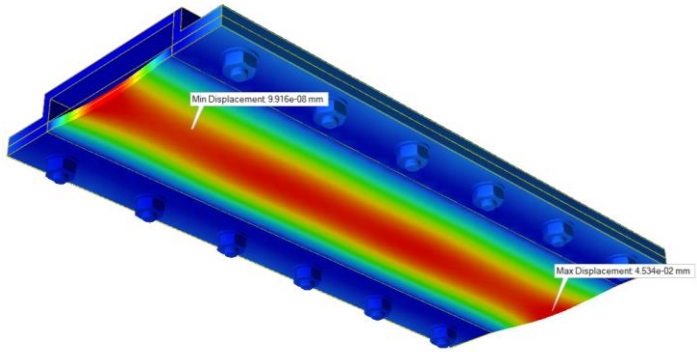
Lid Case Study			
Case	Max. VonMises stress (MPa)	Max. Displacement (mm)	FOS
1	36.070	1.822	5.7
5	29.355	0.723	7.0

Support Ring Clamps Static Analysis









Max. Stress = 98 MPa

Max. Displacement = 0.05 mm

Hydrostatic Analysis

Boundary Condition

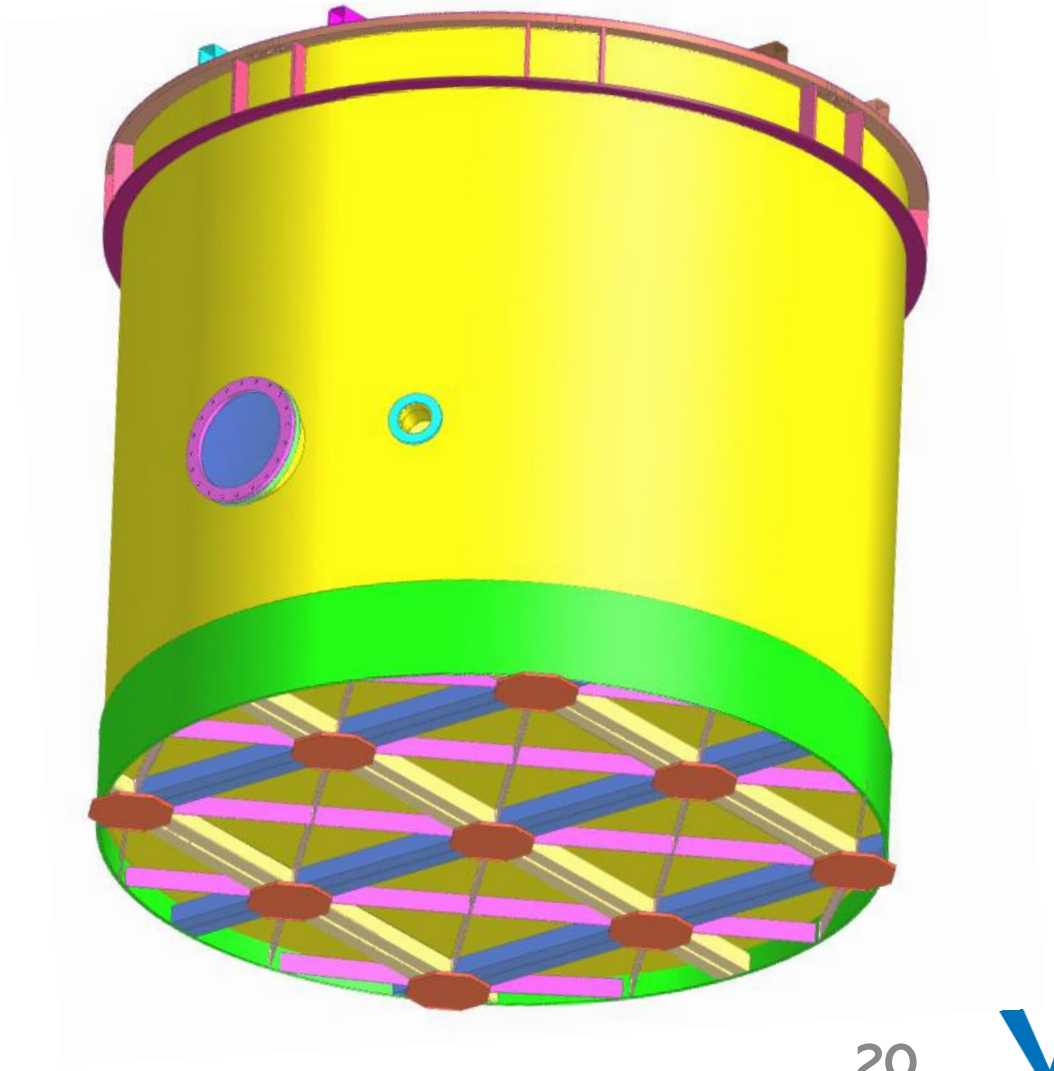
The bottom plates are restricted to all dofs.

Loads

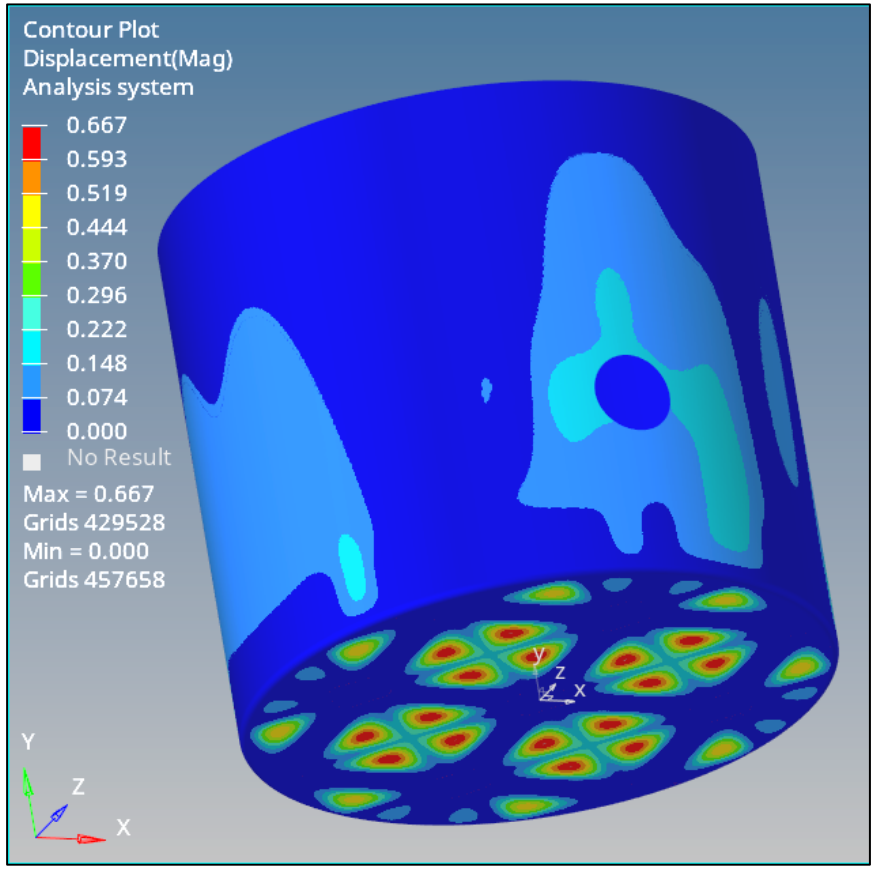
Self wt.(Gravity)+ Hydrostatic Pressure on tank walls

(ht. of water =3.4m) +500 kg (CDS) on top rafters

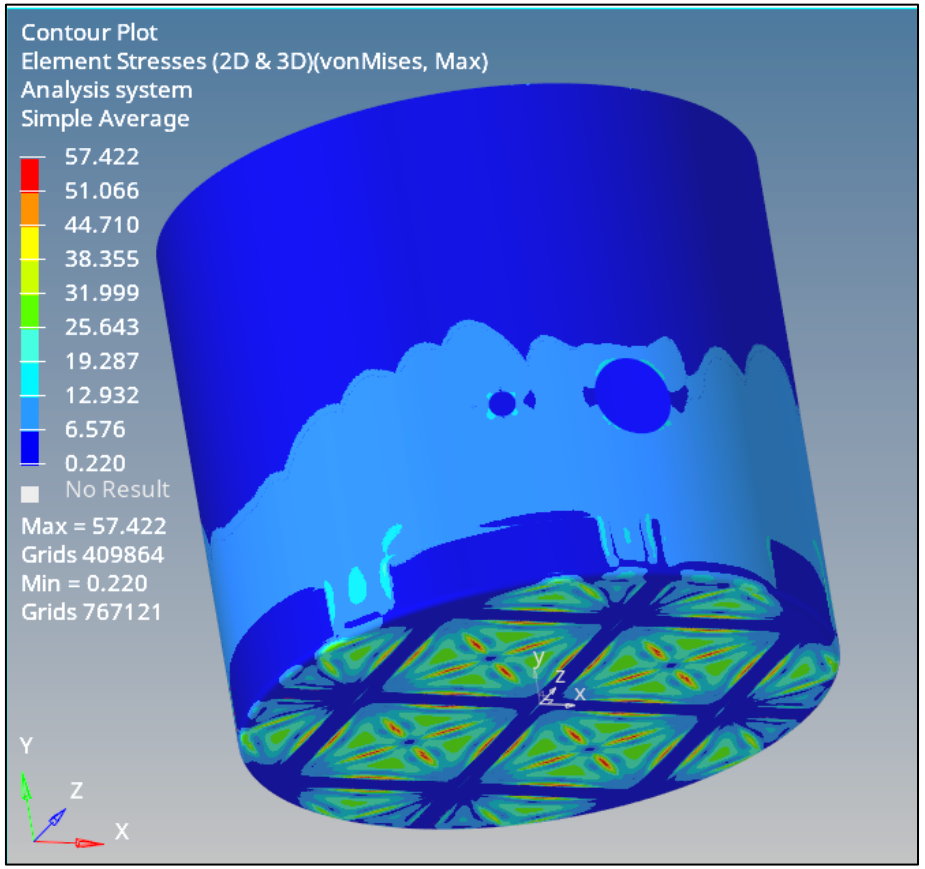
- Wt. of Water = 38.50 tons
- Ht. of Water level = 3400mm
- Tank Wall Thickness = 6mm



Tank Results

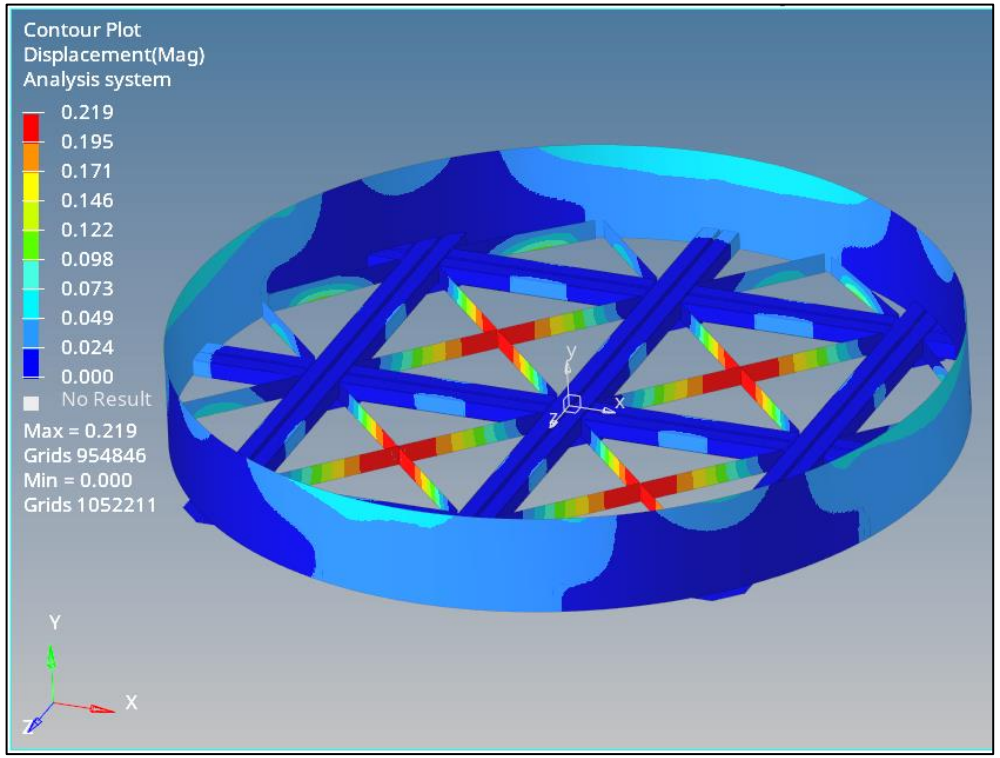


Max. Displacement = 0.67 mm

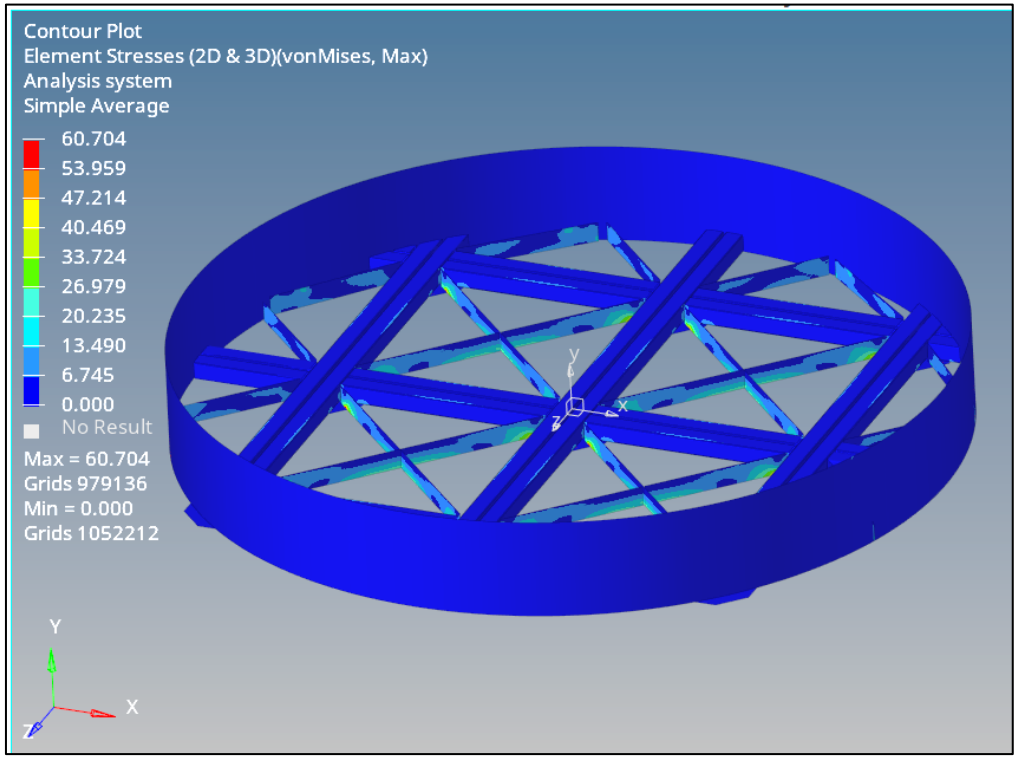


Max. Stress = 57.42 MPa

Base Support Results

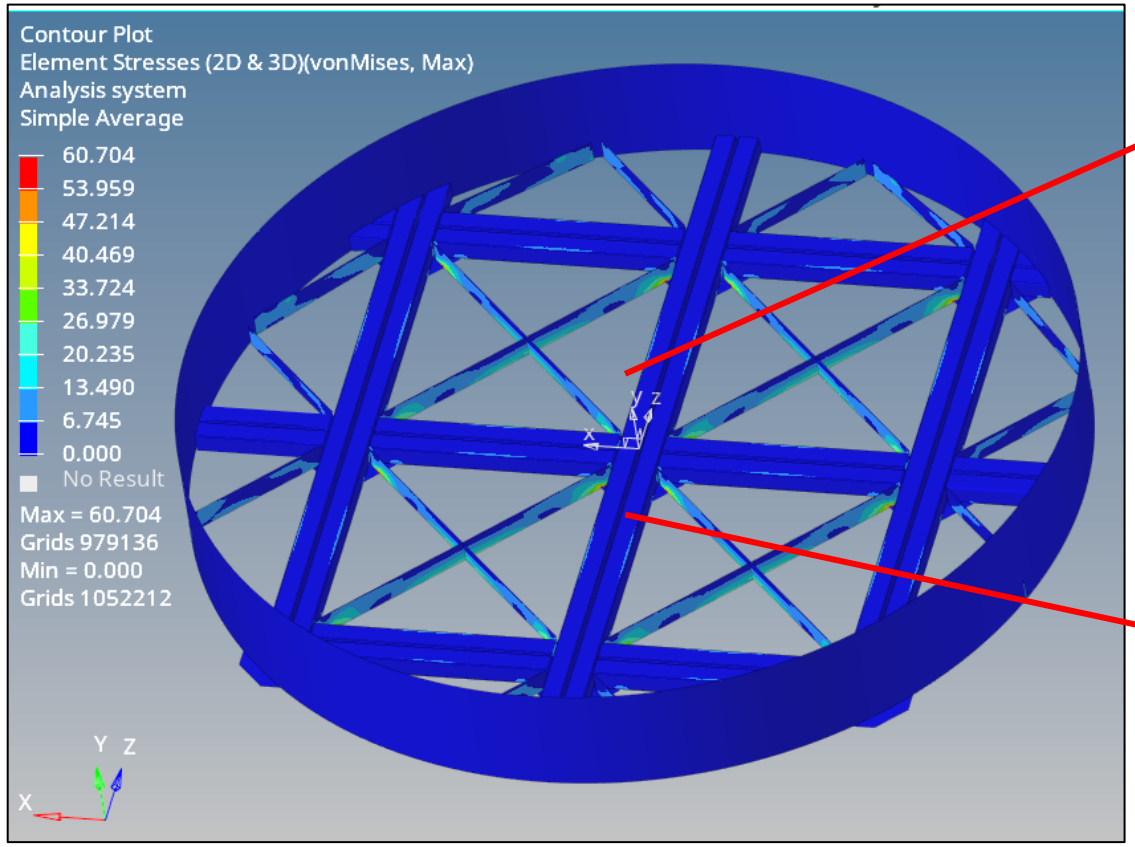


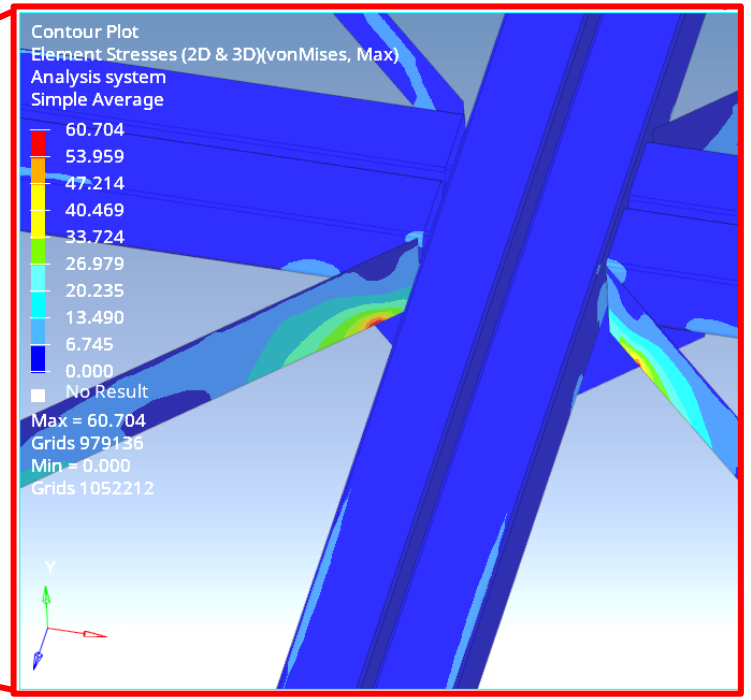
Max. Displacement = 0.22 mm



Max. Stress = 60.70 MPa

Base Support Results



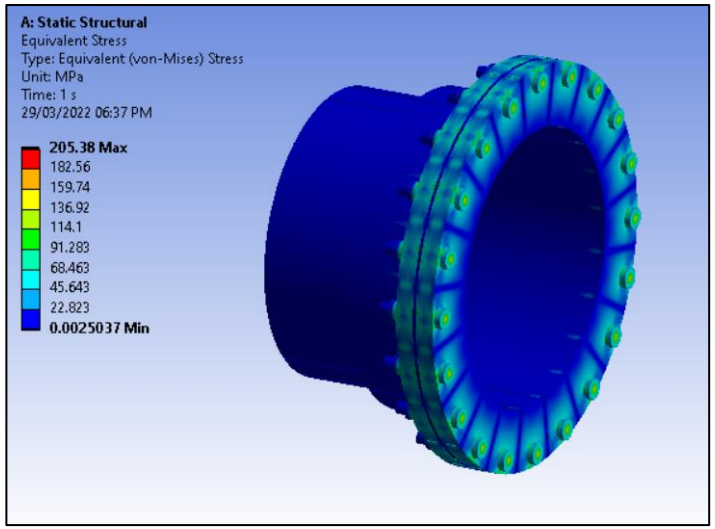


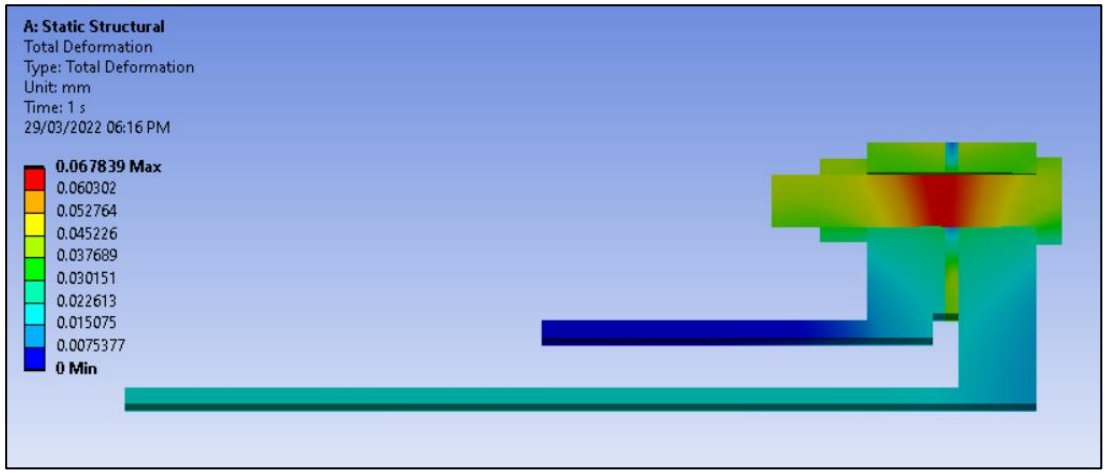
Max. Stress = 60.70 MPa

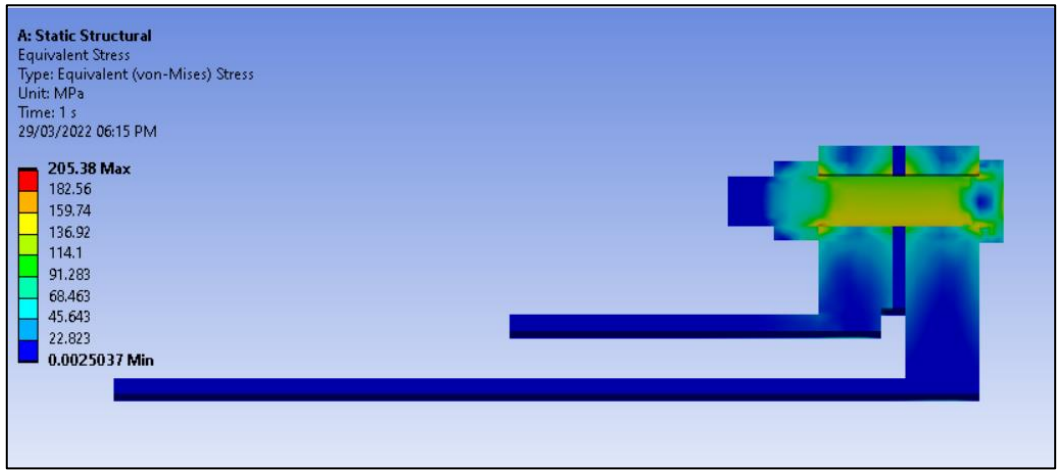
Tertiary Beam Window Results

- Overall, the max, stress is in bolt due to preload of about 150 MPa.
- The stress on Flanges is about 50 MPa and on cylinder is 40 MPa.

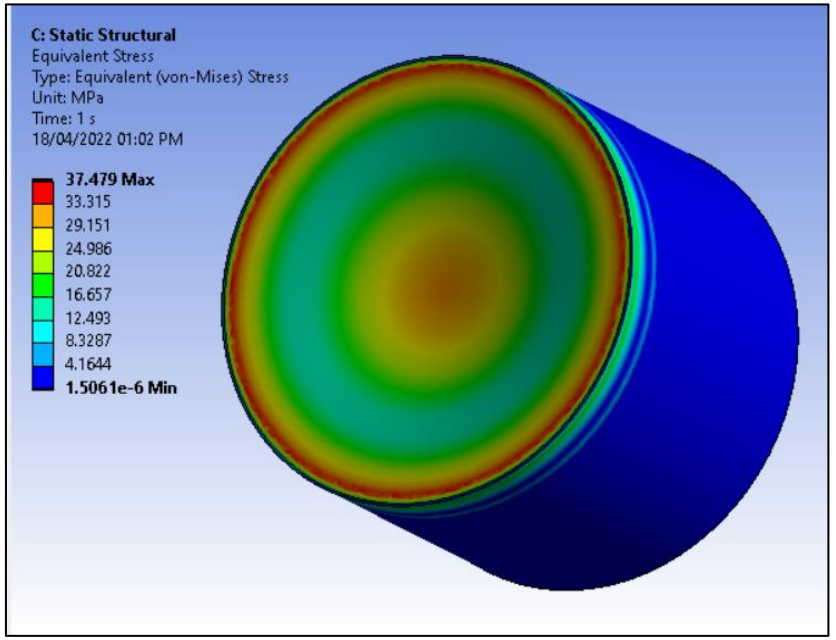
The Design seems to be safe in this FEA Study.



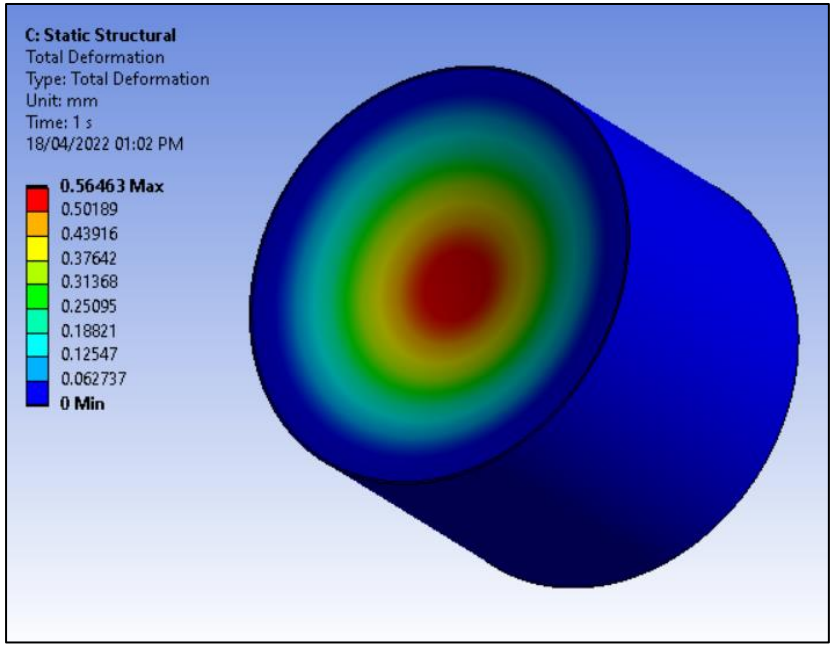




Tertiary Beam Window Results



Max. Stress = 38 MPa



Max. Displacement = 0.57 mm

Conclusion

1. From the results we can infer that
2. The maximum stress and displacement due to Hydrostatic Pressure on the Tank assembly occurs on the Tank base of **60.70 MPa** .
3. The maximum displacement is obtained on the tertiary beam i.e., **0.50mm**
4. In the study, the model appears to be safe by the **factor of safety 3.46** (w.r.t to yield stress of 207 MPa)

Tank		Tertiary Beam Window		Base Mesh		Factor of Safety
Max. VonMises stress (MPa)	Max. Displacement (mm)	Max. VonMises stress (MPa)	Max. Displacement (mm)	Max. VonMises stress (MPa)	Max. Displacement (mm)	
57.42	0.67	45.20	0.50	60.70	0.22	3.46

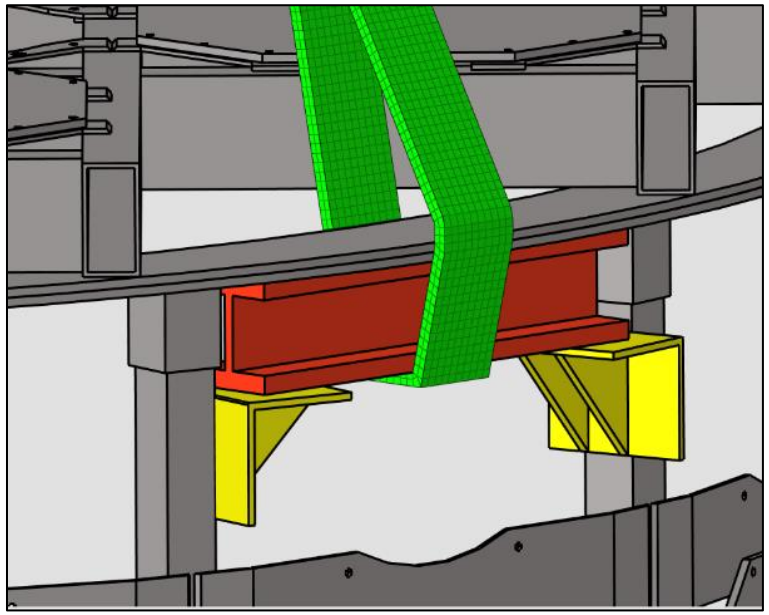
Support Structure Lifting Analysis

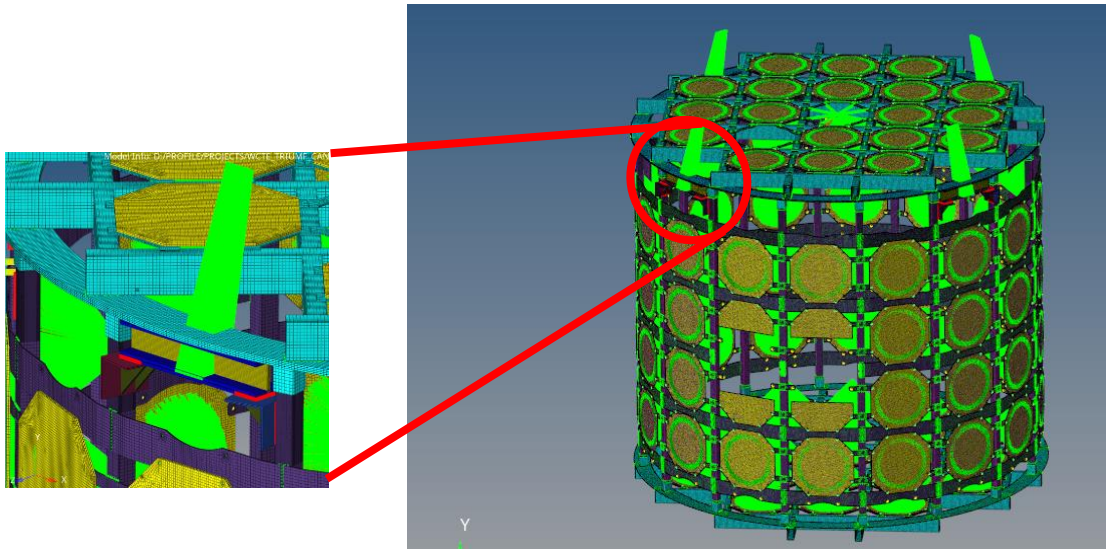
Boundary Condition

The Bottom End of the Beam Fixed

Loads

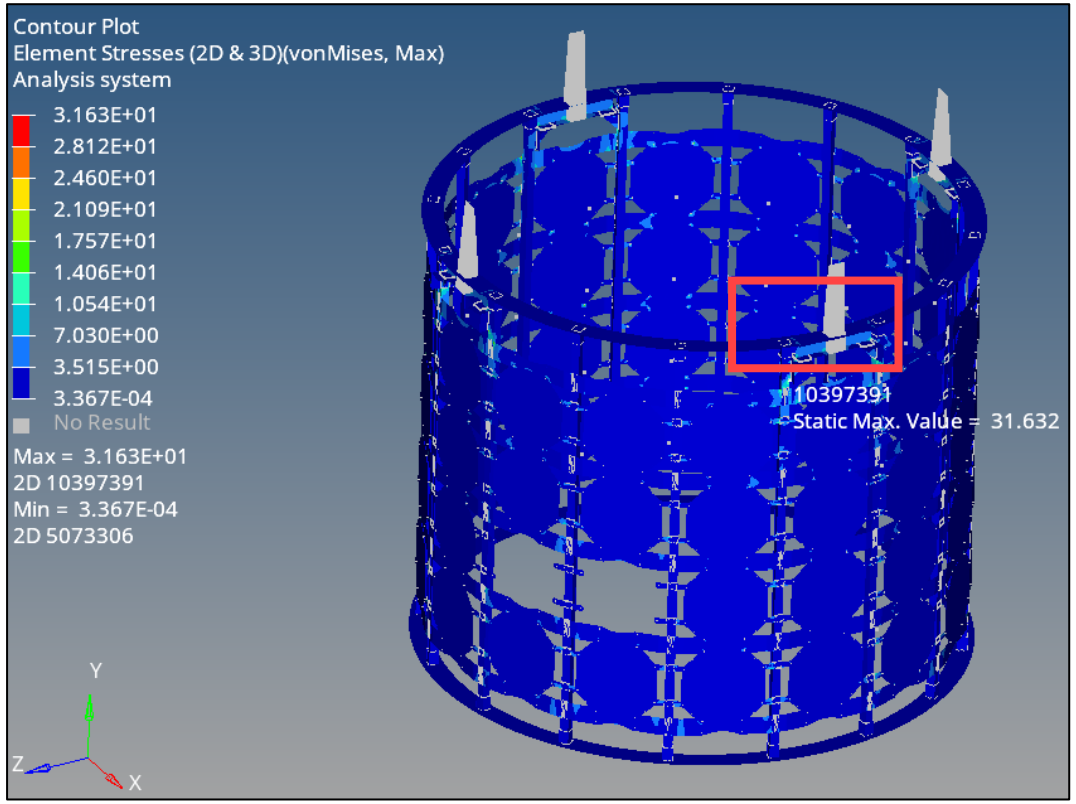
Self wt.(Gravity)+ 102 mPMT wt. 40kgs each

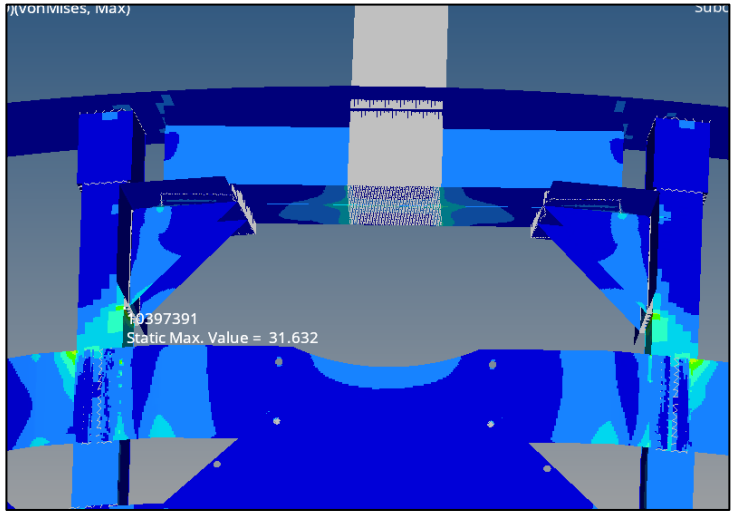




Support Structure Lifting Analysis

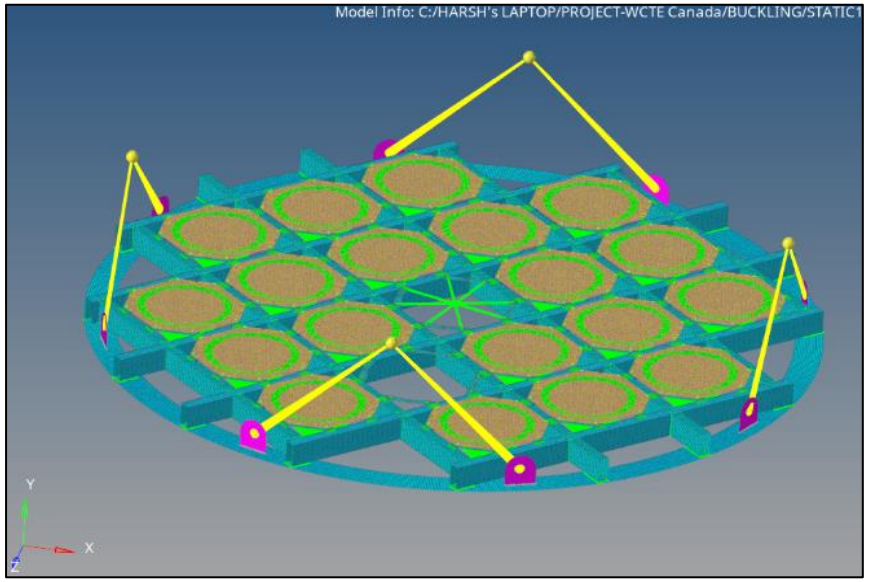
Support Structure Lifting Results

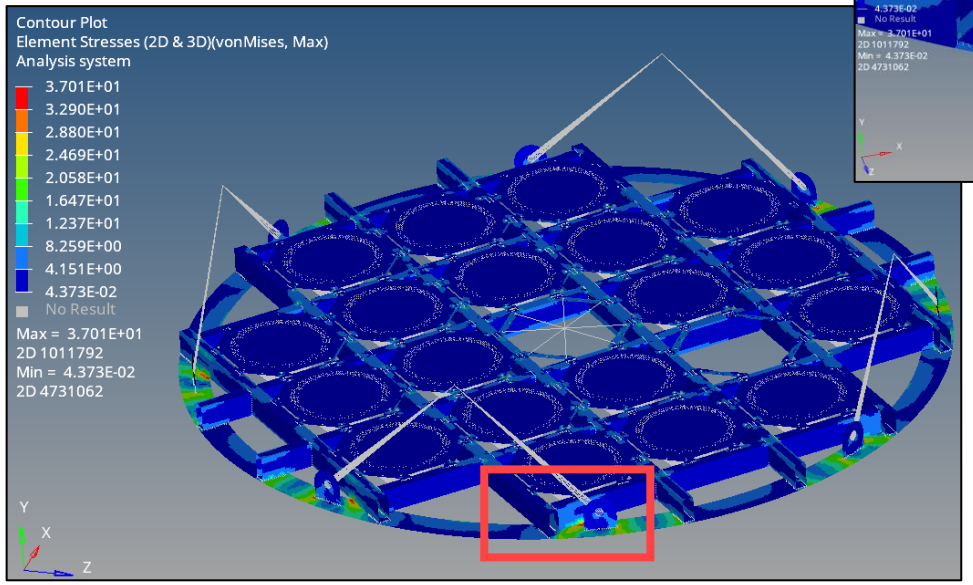


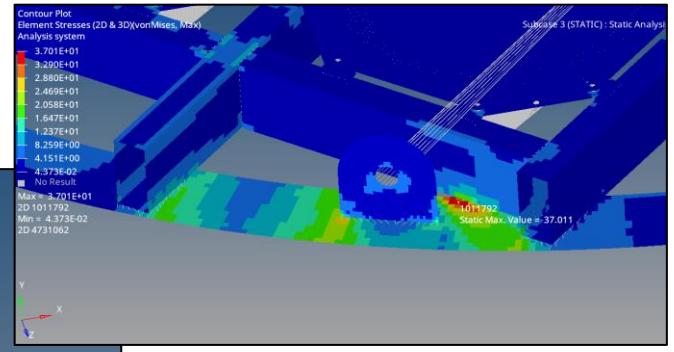


Max. Stress = 32 MPa

End Cap Lifting Analysis







Max. Stress = 37 MPa

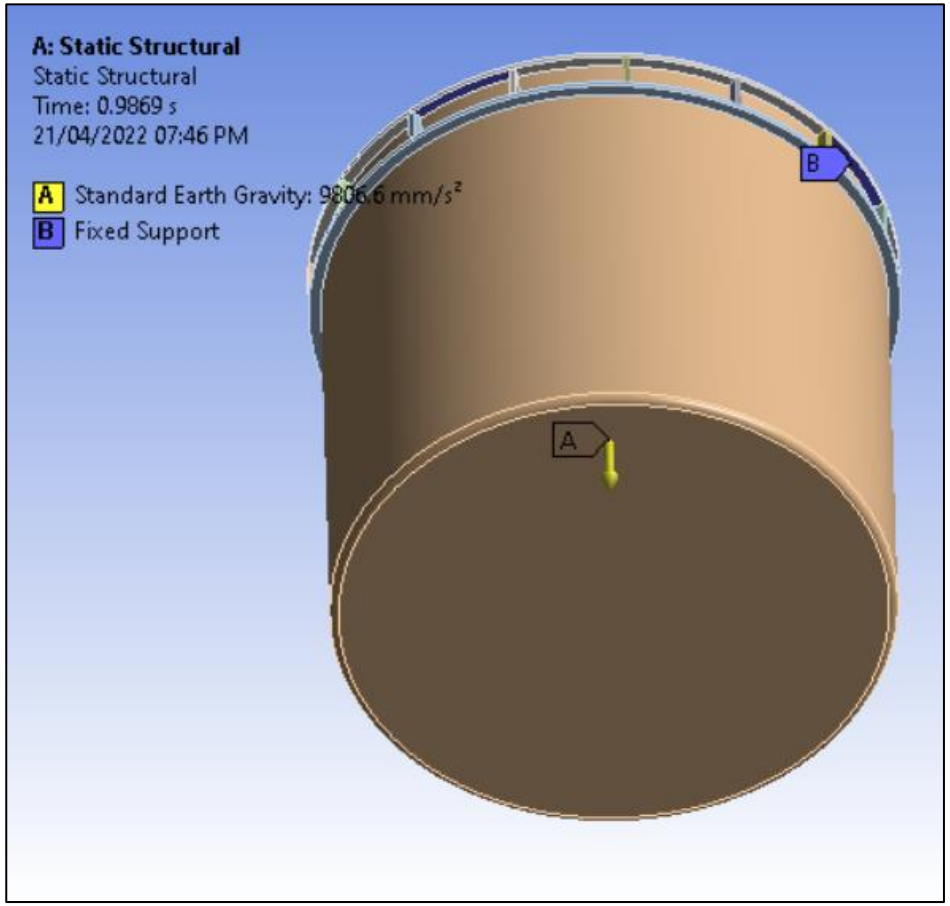
Tank Lifting Analysis

Boundary Condition

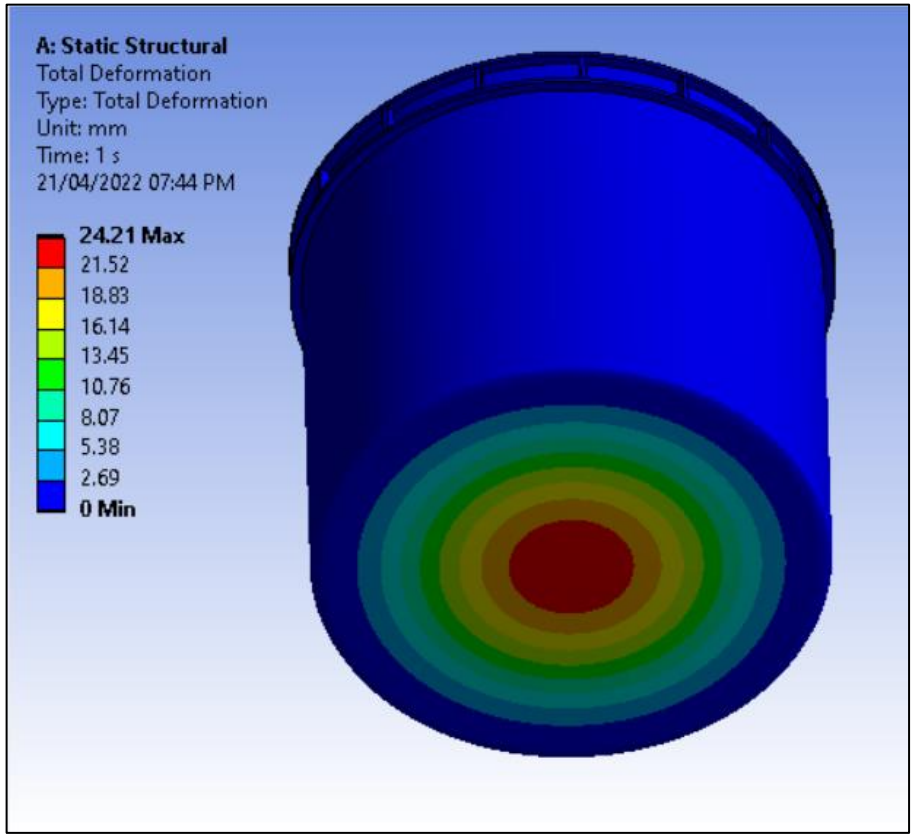
Top Ring Constrained

Loads

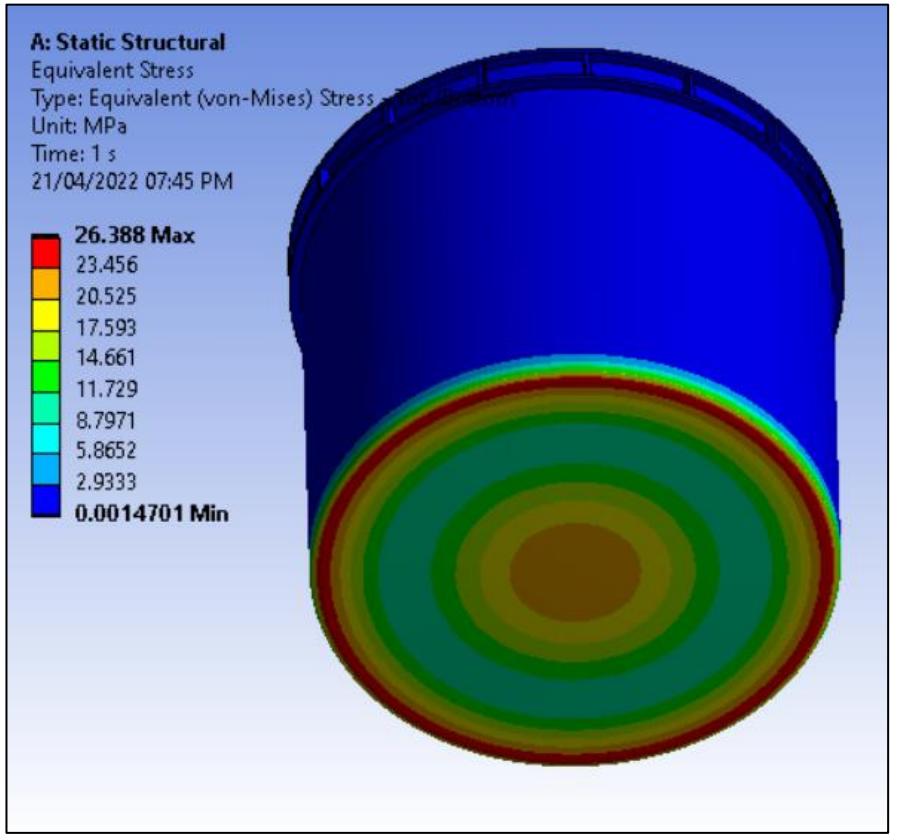
Self wt.(Gravity)



Tank Lifting Analysis Results



Max. Displacement = 24 mm



Max. Stress = 27 MPa

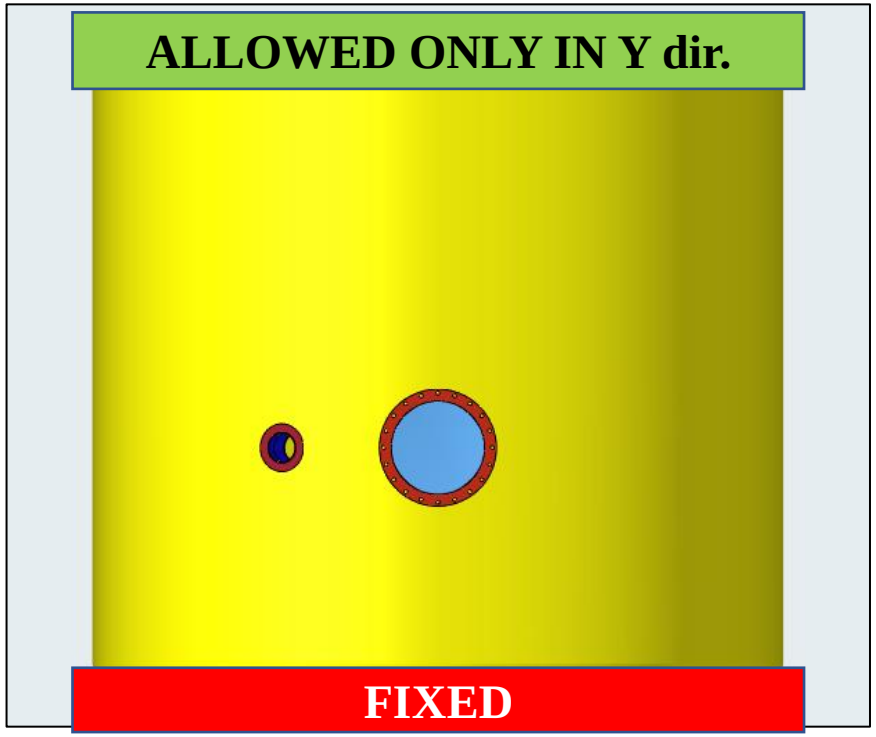
Buckling Analysis

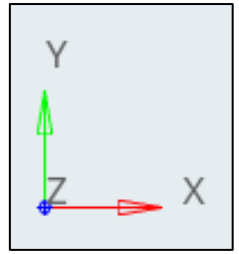
Boundary Condition

- The base are restricted to all dofs.
- Top edge is only allowed in axial dir. (Y-dir.)

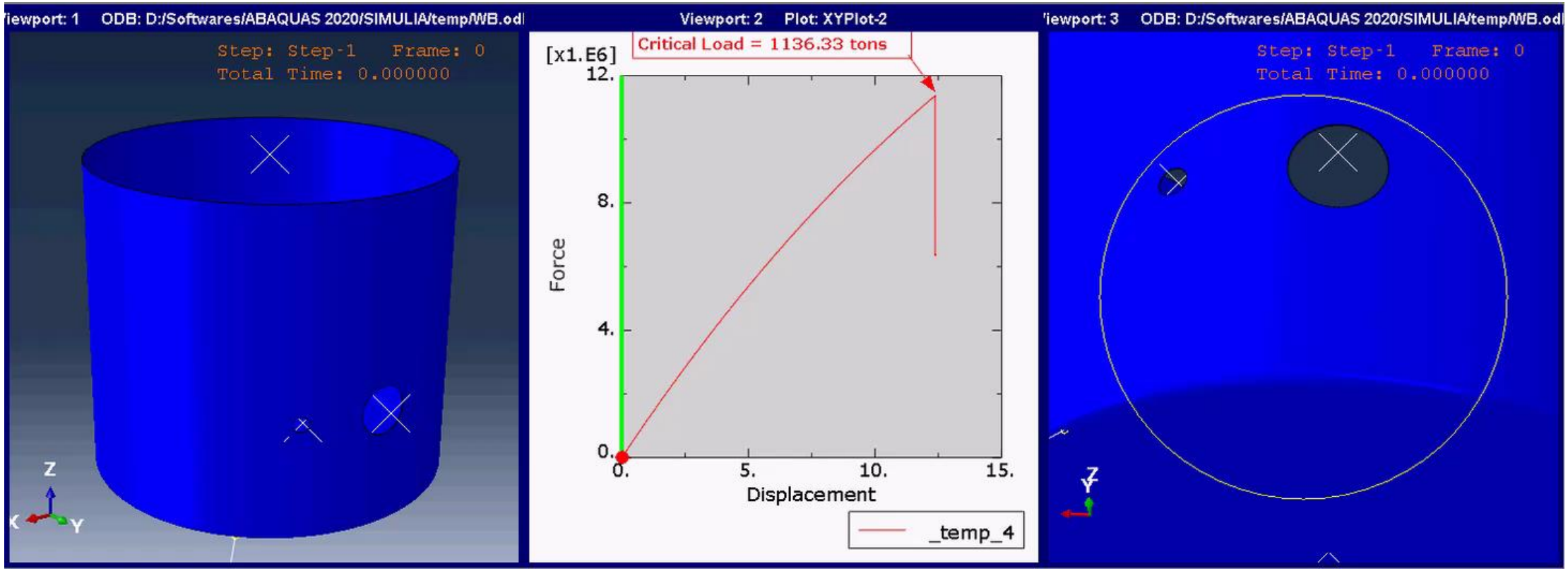
Tank properties

- Thickness= 6mm
- Length= 3400mm
- Diameter= 3800mm





Nonlinear Buckling Analysis



Deformation

Force – Displacement response graph

Non-Linear Buckling Critical Load = 1136 ton. Actual load is 2 tons. Hence Safe

Conclusion

- The critical buckling load of the Tank in Non-Linear Buckling analysis under axial compression is **1136 tons** .

- Since the **self weight (2 tons) is less than calculated critical buckling load**, the Tank is safe to buckling.

Analysis	Critical Load
Linear Buckling	2633 tons
Nonlinear Buckling	1136 tons

Modal Analysis

Boundary Condition

The bottom plates are restricted to all dofs.

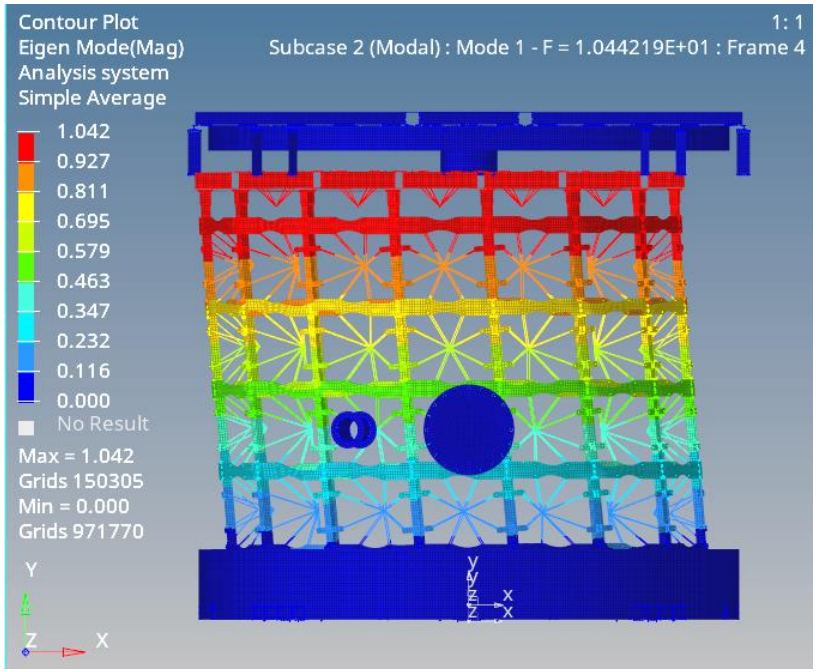
Loads

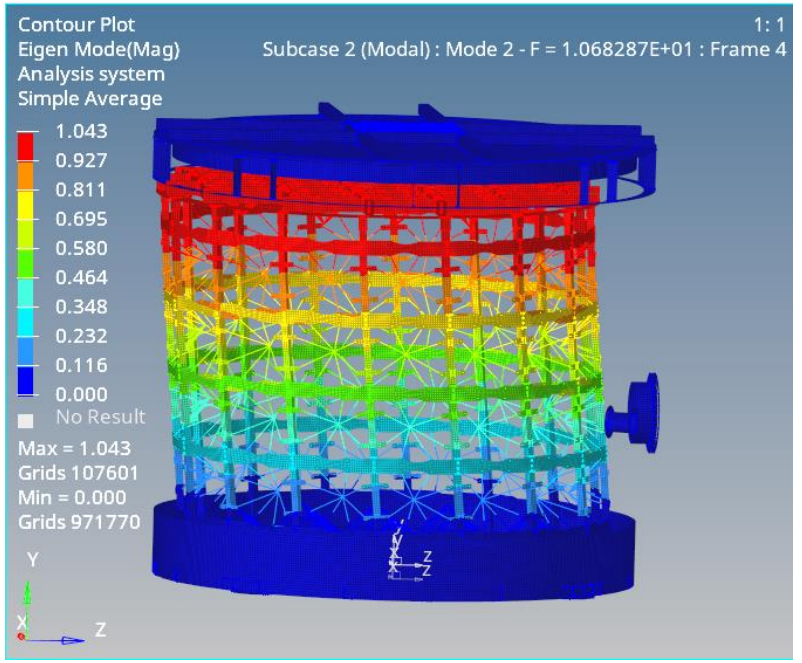
Self wt.(Gravity)+ Hydrostatic Pressure on tank walls

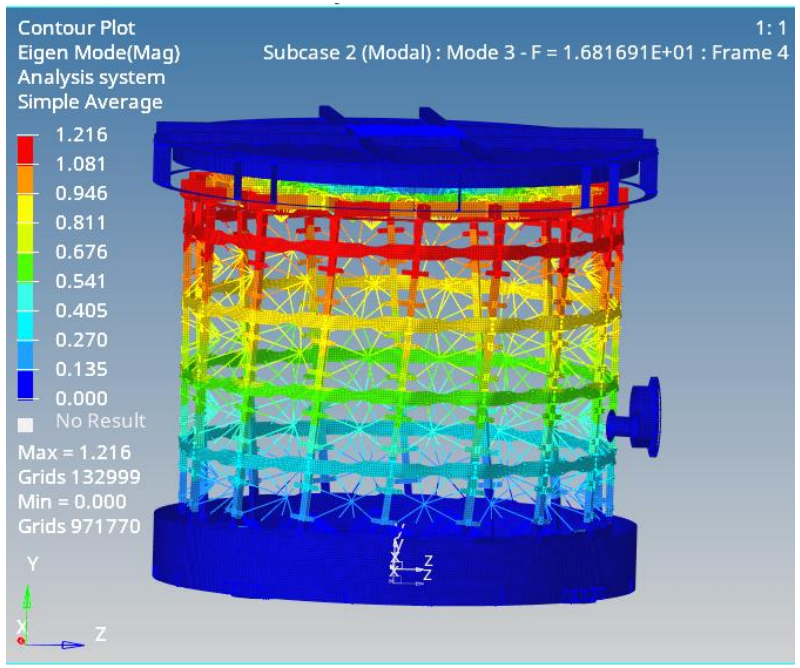
(free surface ht. =3.4m) +100 kg (CDS) on top rafters

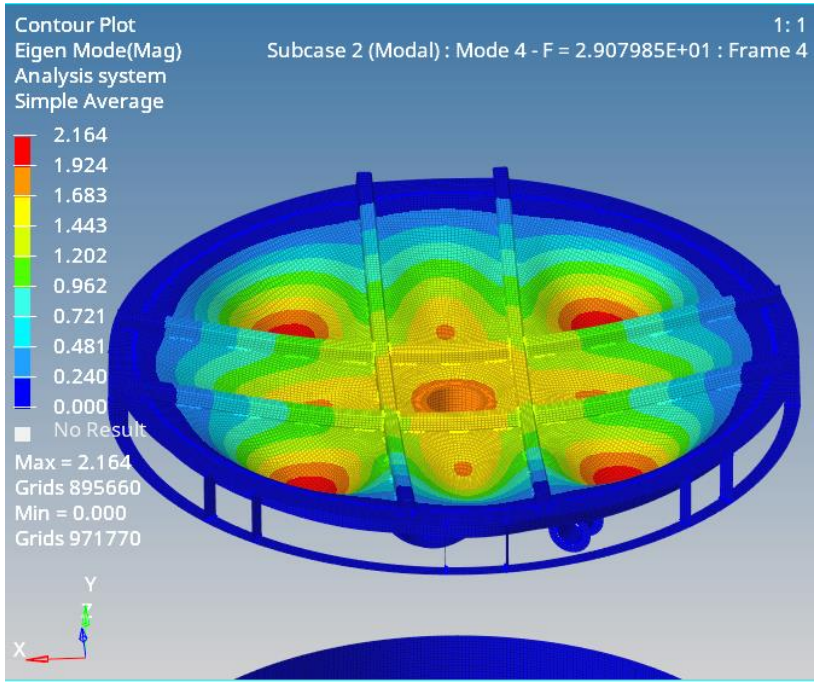
Analysis up to 50 Natural Modes

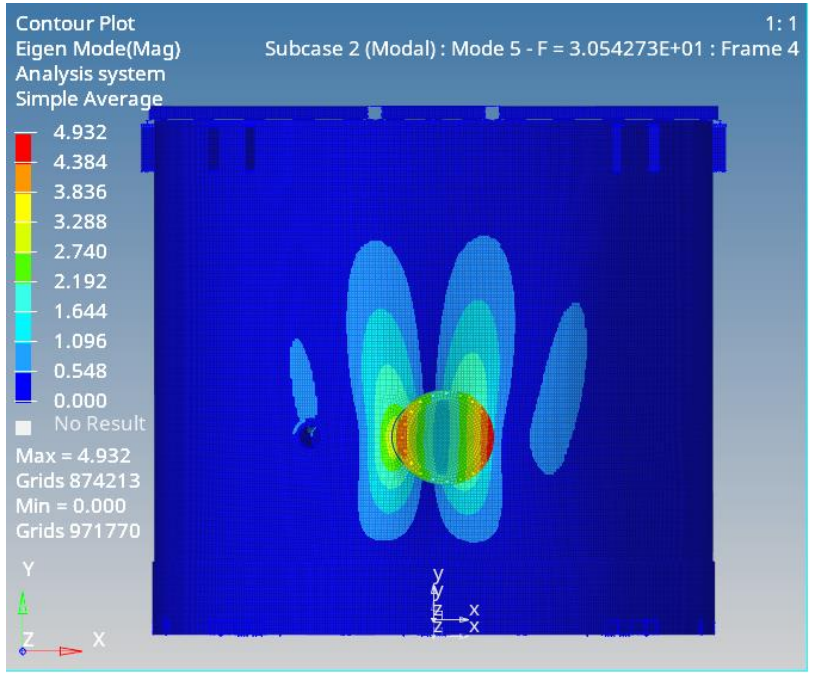
Structure and Tank are not coupled in this Study

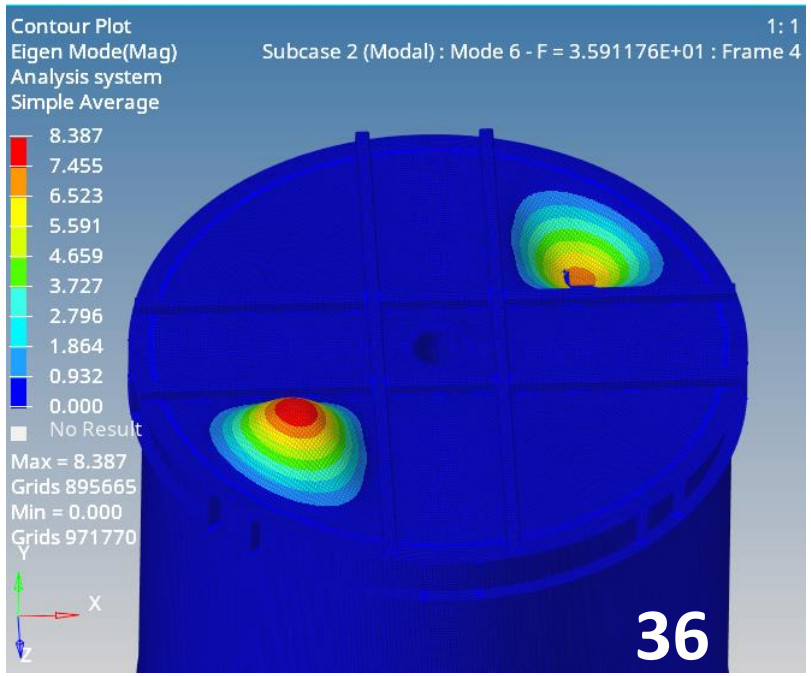

Contour Plot
Eigen Mode(Mag)
Analysis system
Simple Average
1: 1
Subcase 2 (Modal) : Mode 1 - F = 1.044219E+01 : Frame 4
1.042
0.927
0.811
0.695
0.579
0.463
0.347
0.232
0.116
0.000
No Result
Max = 1.042
Grids 150305
Min = 0.000
Grids 971770


Contour Plot
Eigen Mode(Mag)
Analysis system
Simple Average
1: 1
Subcase 2 (Modal) : Mode 2 - F = 1.068287E+01 : Frame 4
1.043
0.927
0.811
0.695
0.580
0.464
0.348
0.232
0.116
0.000
No Result
Max = 1.043
Grids 107601
Min = 0.000
Grids 971770


Contour Plot
Eigen Mode(Mag)
Analysis system
Simple Average
1: 1
Subcase 2 (Modal) : Mode 3 - F = 1.681691E+01 : Frame 4
1.216
1.081
0.946
0.811
0.676
0.541
0.405
0.270
0.135
0.000
No Result
Max = 1.216
Grids 132999
Min = 0.000
Grids 971770


Contour Plot
Eigen Mode(Mag)
Analysis system
Simple Average
1: 1
Subcase 2 (Modal) : Mode 4 - F = 2.907985E+01 : Frame 4
2.164
1.924
1.683
1.443
1.202
0.962
0.721
0.481
0.240
0.000
No Result
Max = 2.164
Grids 895660
Min = 0.000
Grids 971770


Contour Plot
Eigen Mode(Mag)
Analysis system
Simple Average
1: 1
Subcase 2 (Modal) : Mode 5 - F = 3.054273E+01 : Frame 4
4.932
4.384
3.836
3.288
2.740
2.192
1.644
1.096
0.548
0.000
No Result
Max = 4.932
Grids 874213
Min = 0.000
Grids 971770


Contour Plot
Eigen Mode(Mag)
Analysis system
Simple Average
1: 1
Subcase 2 (Modal) : Mode 6 - F = 3.591176E+01 : Frame 4
8.387
7.455
6.523
5.591
4.659
3.727
2.796
1.864
0.932
0.000
No Result
Max = 8.387
Grids 895665
Min = 0.000
Grids 971770

Results

MODAL PARTICIPATION FACTORS FOR SUBCASE 3

RIGID BODY MODES BASED ON REFERENCE POINT AT ORIGIN OF BASIC COORDINATE SYSTEM

Mode	Frequency	X-TRANS	Y-TRANS	Z-TRANS	X-ROTAT	Y-ROTAT	Z-ROTAT
1	1.044E+01	-1.077E+00	3.128E-07	5.367E-02	1.464E+02	1.731E-01	2.888E+03
2	1.068E+01	-5.391E-02	9.424E-05	-1.068E+00	-2.878E+03	-1.190E-01	1.463E+02
3	1.682E+01	7.458E-05	2.006E-03	-4.195E-05	-1.119E-01	1.656E+03	-2.466E-01
4	2.872E+01	-9.483E-02	-3.873E-02	3.779E-02	5.492E+01	-2.873E+02	5.444E+01
5	2.908E+01	5.511E-03	-8.250E-01	9.631E-03	2.172E+01	1.516E+01	-3.505E+00
6	3.505E+01	2.656E-02	-1.340E-02	2.890E-01	6.916E+02	1.880E+01	-5.038E+01
7	3.591E+01	-2.413E-02	2.247E-03	4.619E-04	2.521E+02	-1.622E+00	3.417E+02
8	3.607E+01	1.763E-02	3.327E-04	1.722E-03	2.932E+02	-3.510E-01	-2.911E+02
9	3.613E+01	-5.311E-03	-4.411E-03	-3.133E-04	7.264E-01	-8.039E-01	7.323E+01
10	3.669E+01	1.778E-03	-3.551E-03	-3.214E-04	4.105E-01	-1.148E+01	-8.333E-02

Critical frequency of tank with structure is:

- X dir. = 10.44 Hz
- Y dir. = 29.08 Hz
- Z dir. = 10.68 Hz

Thank You