Oak Ridge National Laboratory | SECOND TARGET STATION

MRA Structural Analysis

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8/11/26

U.S. DEPARTMENT OF ENERGY

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Analysis Scope

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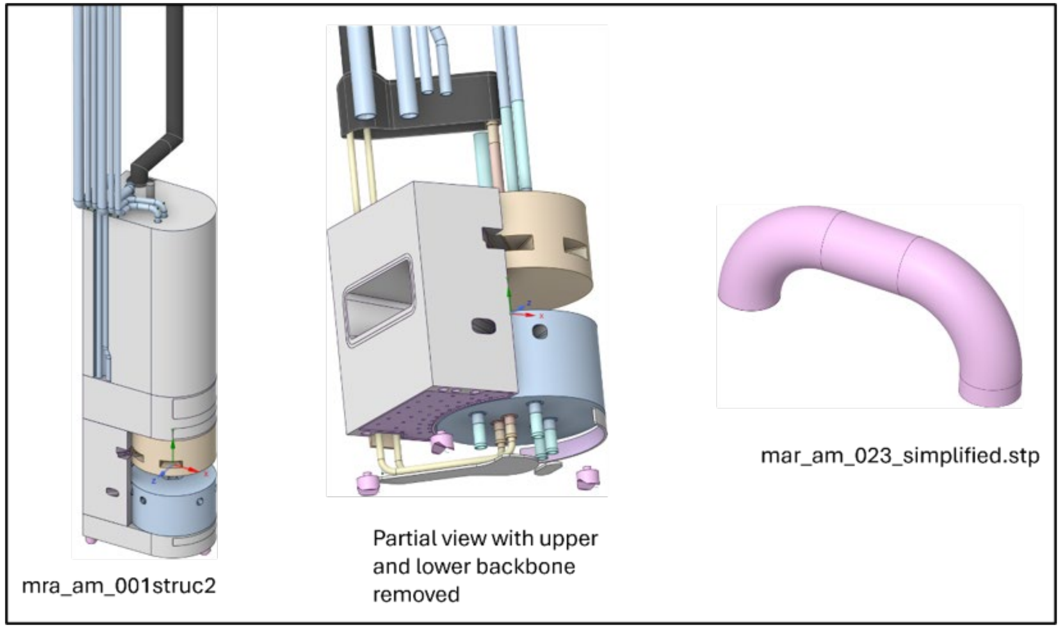
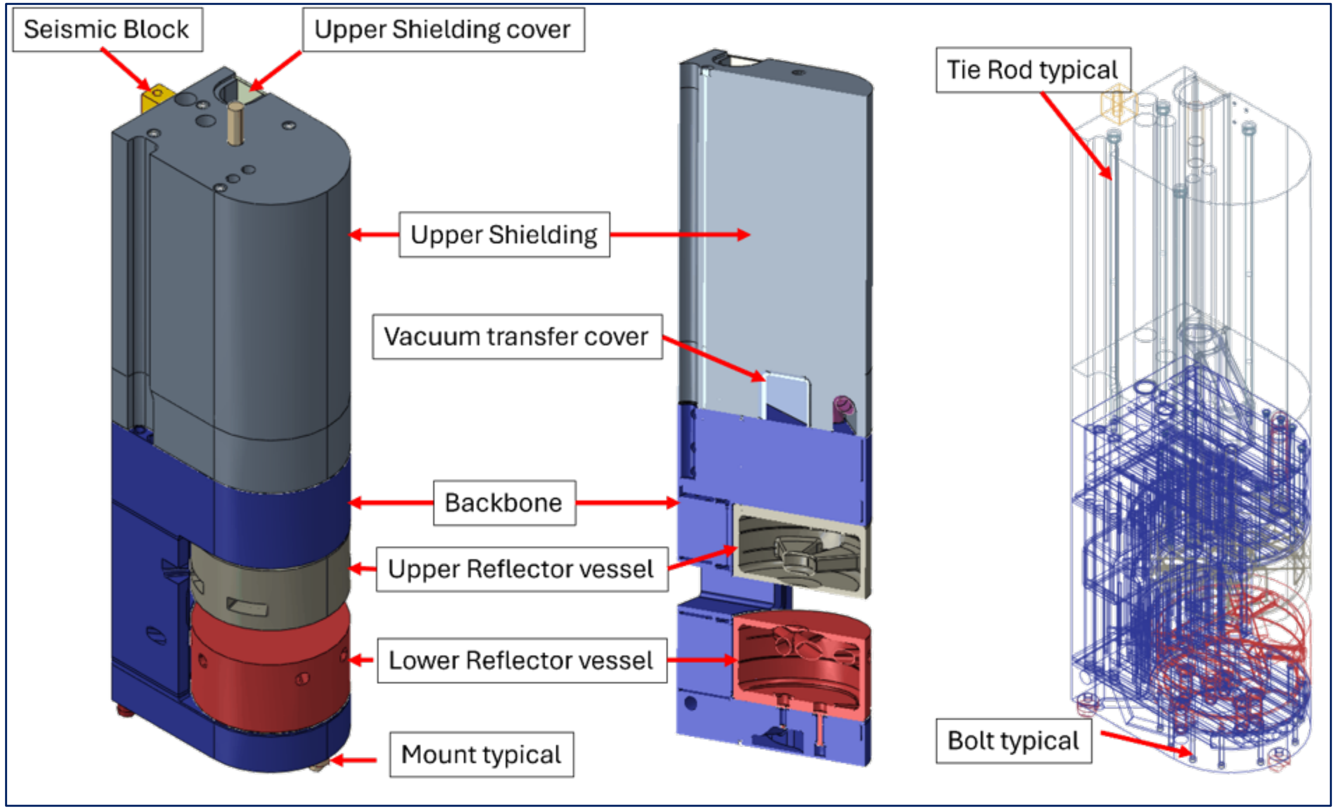
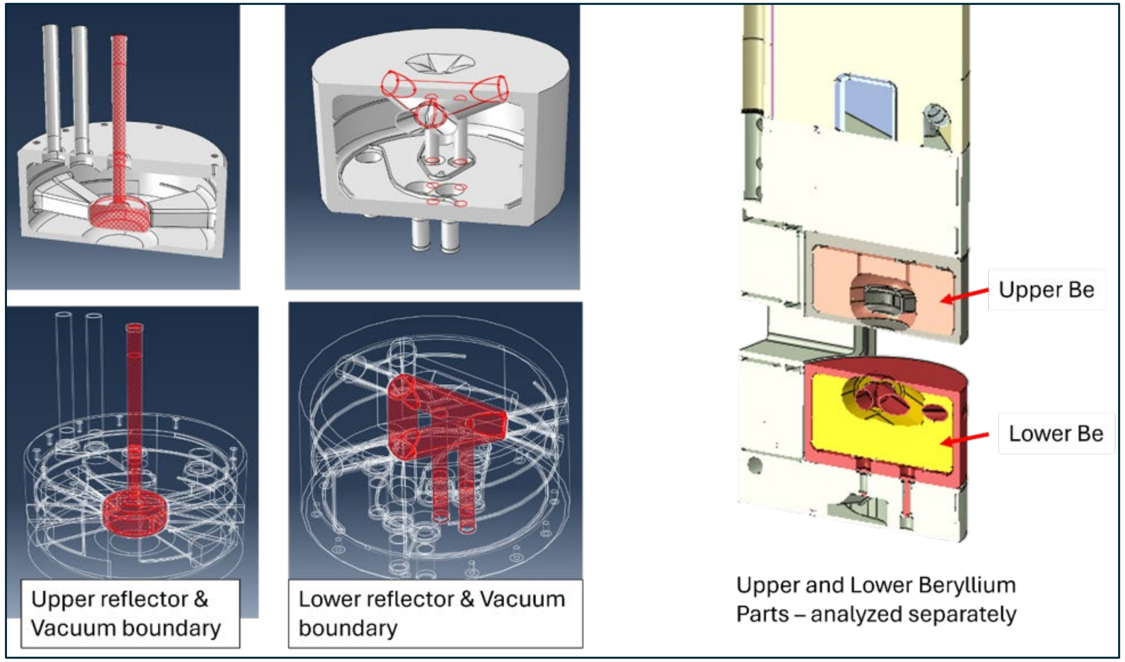
- This structural analysis for the STS Moderator Reflector Assembly components not including the cryogenic moderators and transfer line sections which are cooled to cryogenic temperatures and external piping.
- The analysis evaluates the stresses based on the applicable ASME Boiler and Pressure Vessel Code cases including preloads, gravity, pressures, temperatures and seismic loads.
- Buckling and Thermal fatigue due to beam trips are also included as part of the ASME BPVC analysis.
- Deflections critical for alignment are evaluated.

Step Files

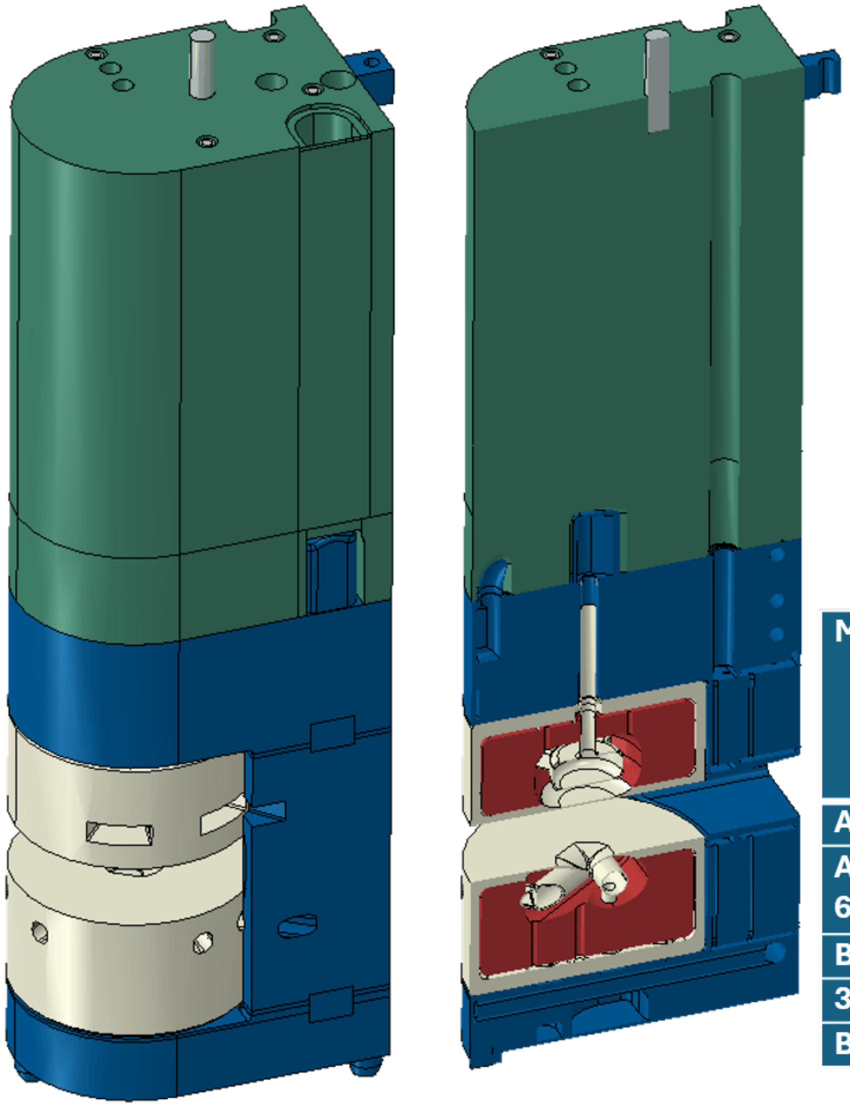


Abaqus Model Assembly Parts





MRA Assembly Materials



Active	Materials	Color
✓	A36	
✓	Al6061	
✓	Beryllilum	
✓	SS316L	
✓	bolt_steel	

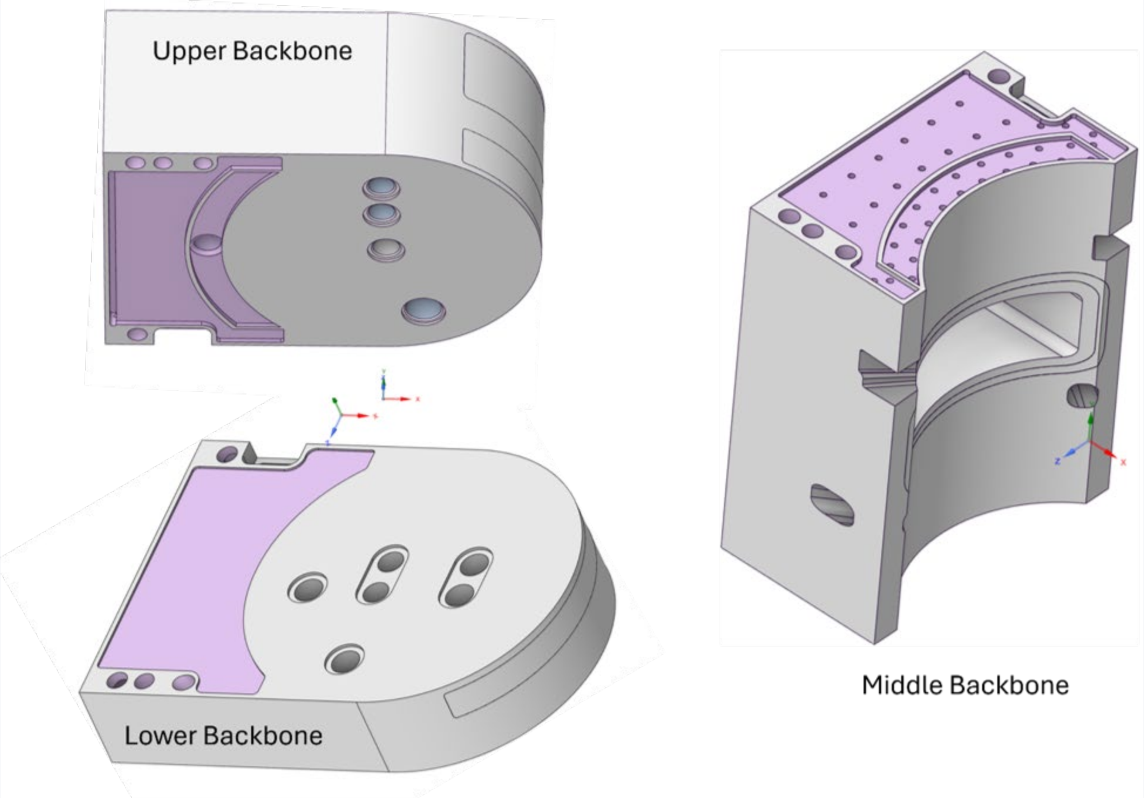
Material	Density (kg/m³)	Young's Modulus (GPa)	Poisson's ratio	Expansion Coefficient (m/K)	Reference Temperature °C
A36 Steel	7850	200	.26	11.7×10^{-6}	20
Aluminum 6061T6	2700	68.9	.33	23.6×10^{-6}	20
Beryllium	2160	303	.24	11.5×10^{-6}	20
316L	7969	195	.27	16.1×10^{-6}	20
Bolt Steel	7969	195	.27	16.1×10^{-6}	20

Requirements per S03040000-SR0001-R02

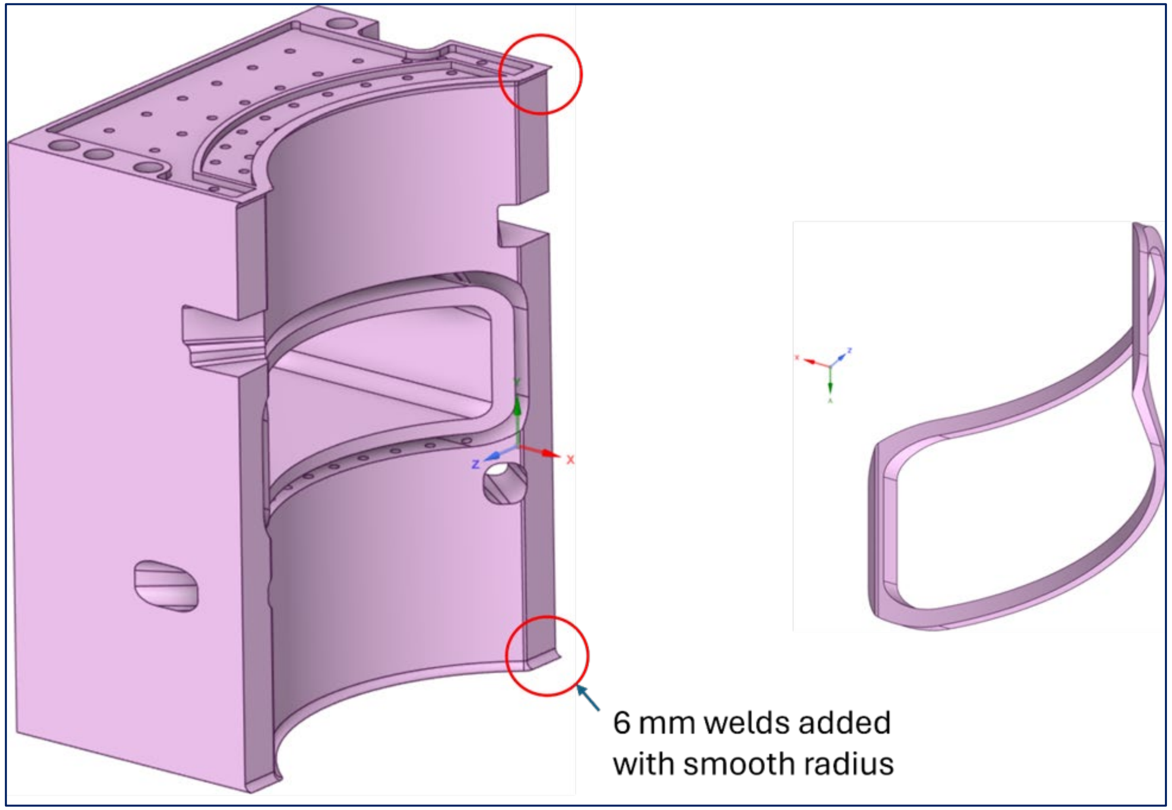
Summary	Description	Item ID
MRA cyclic loading Requirement	The MRA shall be designed for a lifetime of 5 years (25000 hours of 700 kW beam power operation) or more with respect to cyclic loading. The hydrogen boundaries are expected to experience 50 full pressure cycles during commissioning and 10 full pressure cycles per year during operation. Hydrogen pressure is expected to fluctuate 2 bar or less during beam trips and ramps. The water boundaries are expected to experience 20 pump start cycles during commissioning and 4 pump start cycles per year during operation. A pump start cycle is expected to produce an MRA water pressure change of 1 bar or less. No full pressure cycles are expected for the water boundaries. 10000 beam trips are expected to occur each year.	2339
MRA Vacuum Vessel Requirement	The MRA vacuum vessels shall be designed to the intent of the 2023 ASME BPVC. Applied seismic loads shall be derived from the NPH BOD.	2893
MRA Reflector Vessel Requirement	The MRA backbone shall be designed to the intent of the 2023 ASME BPVC. Applied seismic loads shall be derived from the NPH BOD.	2355
MRA Backbone Requirement	The MRA reflector vessels shall be designed to the intent of the 2023 ASME BPVC. Applied seismic loads shall be derived from the NPH BOD.	10921
MRA Vacuum Boundary Pressure Requirement	The MRA vacuum boundary MAWP shall be 2 bara.	2358
MRA Water Boundary Pressure Requirement	The MRA water boundaries shall have a MAWP of 5 bara	2361
MRA Deflection Requirement	The MRA outside surfaces shall not deflect more than +/- ~ 1.5 mm from their installed locations under any expected loading conditions.	2994
MRA Moderator Operational Displacement Requirement	The MRA moderators shall have a displacement of 0.3 mm or less relative to the MRA mounting points from installation to 700 kW operation.	2892

Original Backbone Parts and Modified Middle Backbone

Original Backbone parts

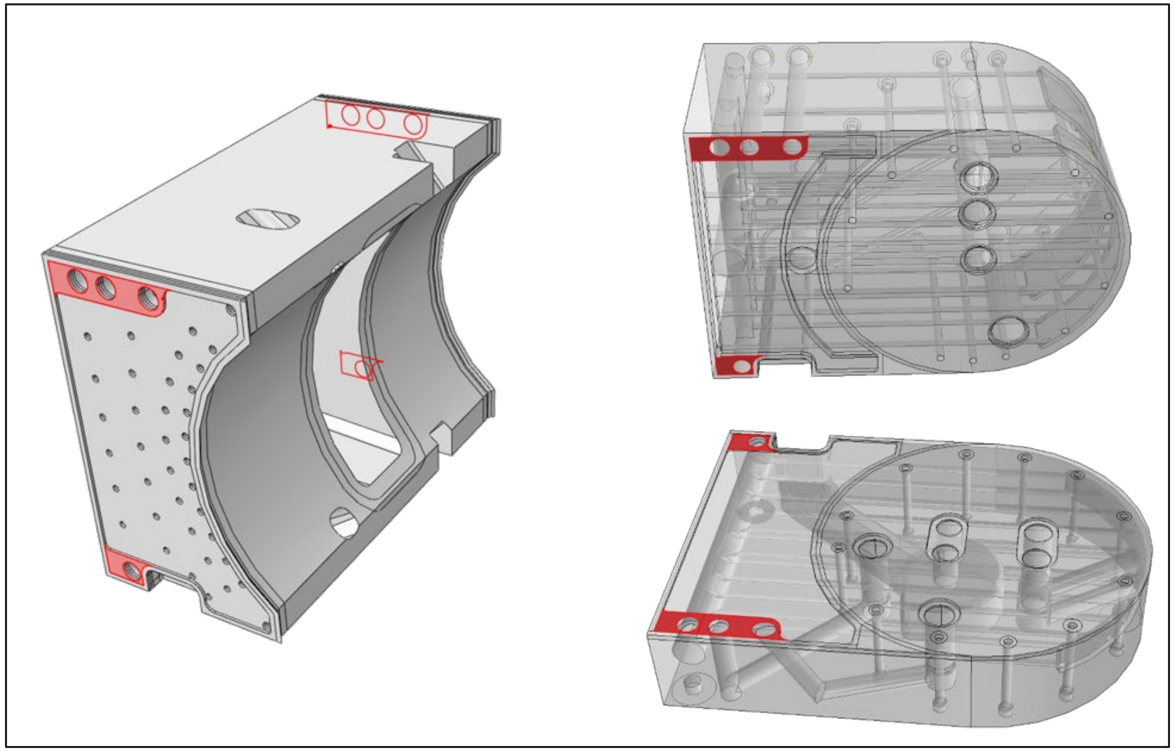


Modified Middle Backbone with smoothed weld



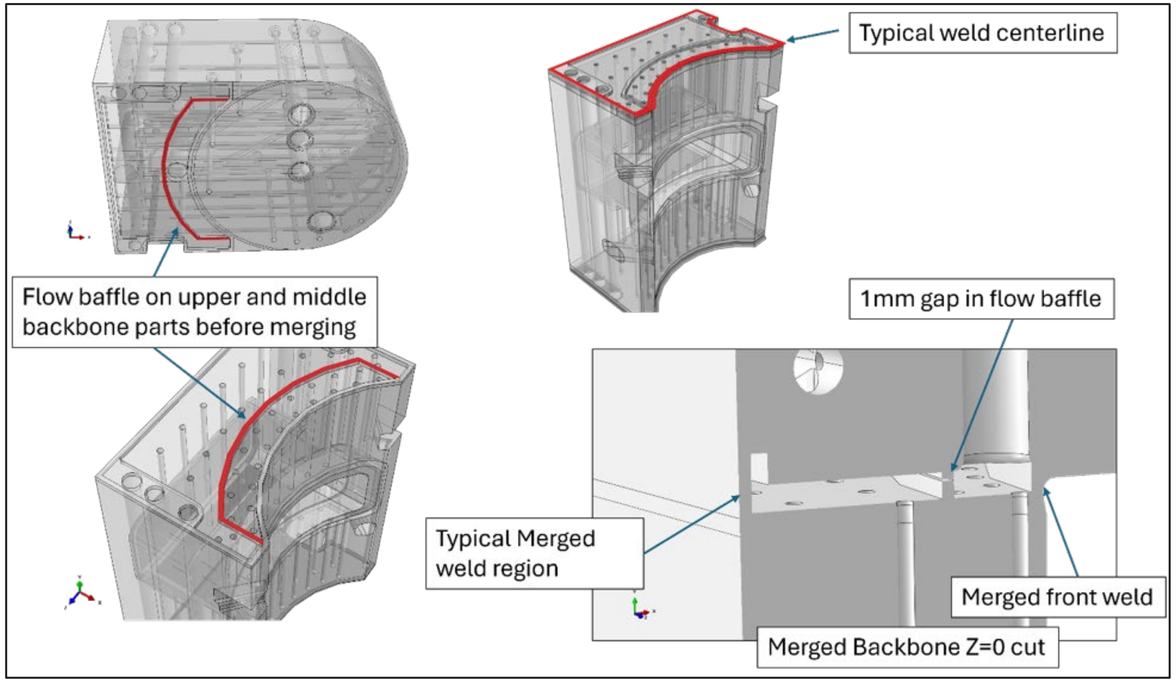
Backbone Modifications and typical weld region after parts merged in Abaqus

Raised surface removed in modified parts



Raised regions removed to make full penetration welds

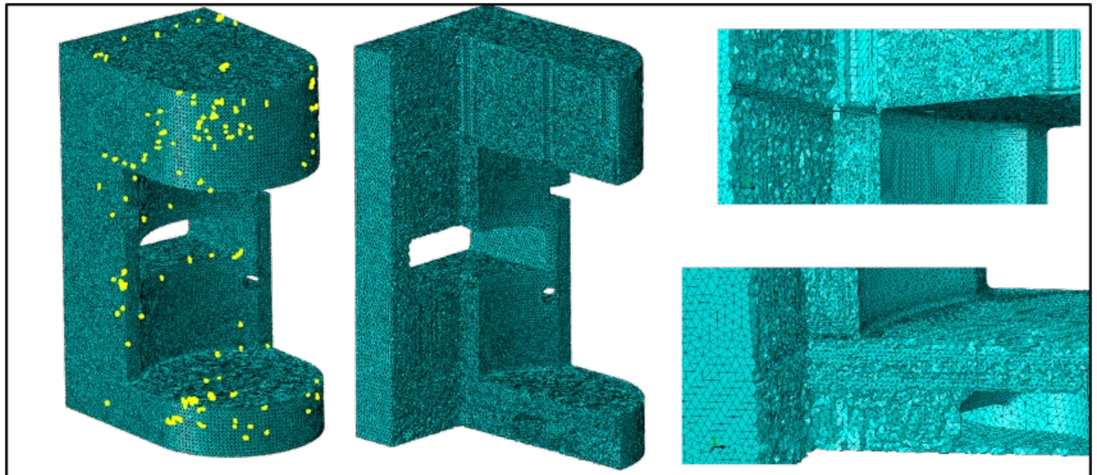
Full Penetration weld centerline and flow baffle



Flow baffles on upper and middle parts not tied

Backbone 316L model

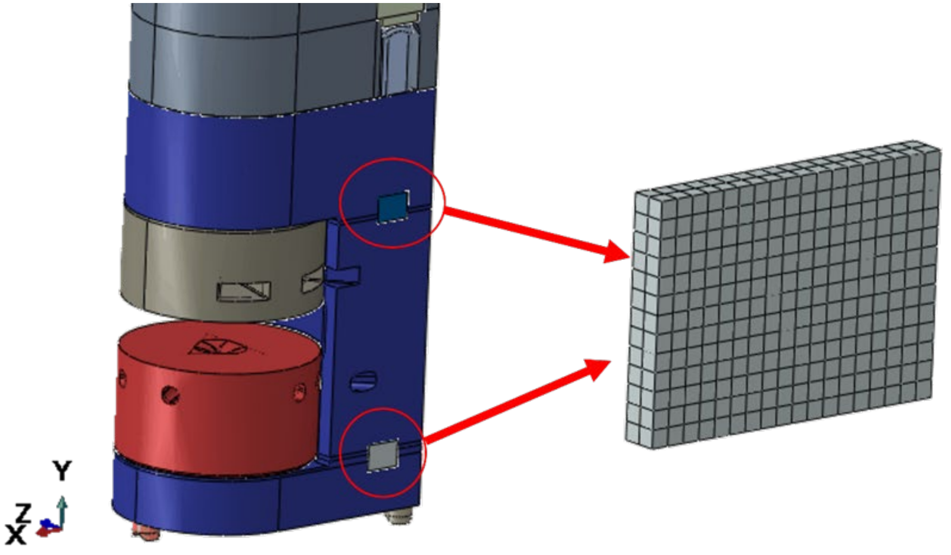
Backbone mesh model after part merged



```
Part: backbone_all
 Tet elements:  4505980
   Min angle on Tri Faces < 5:  62 (0.00137595%)
   Average min angle on tri faces:  38.97,  Worst min angle on tri faces:  0.214
   Max angle on Tri faces > 170:  7 (0.000155349%)
   Average max angle on tri faces:  87.71,  Worst max angle on tri faces:  178.49
   Aspect ratio > 10:  31 (0.000687975%)
   Average aspect ratio:  1.61,  Worst aspect ratio:  80.86
   Shape factor < 0.0001:  8 (0.000177542%)
   Average shape factor:  0.677666,  Worst shape factor:  2.51e-07
  Number of elements :  4505980,   Analysis errors:  0 (0%),  Analysis warnings:  247 (0.0054816%)
```

4,505,980 C3D10 tet elements

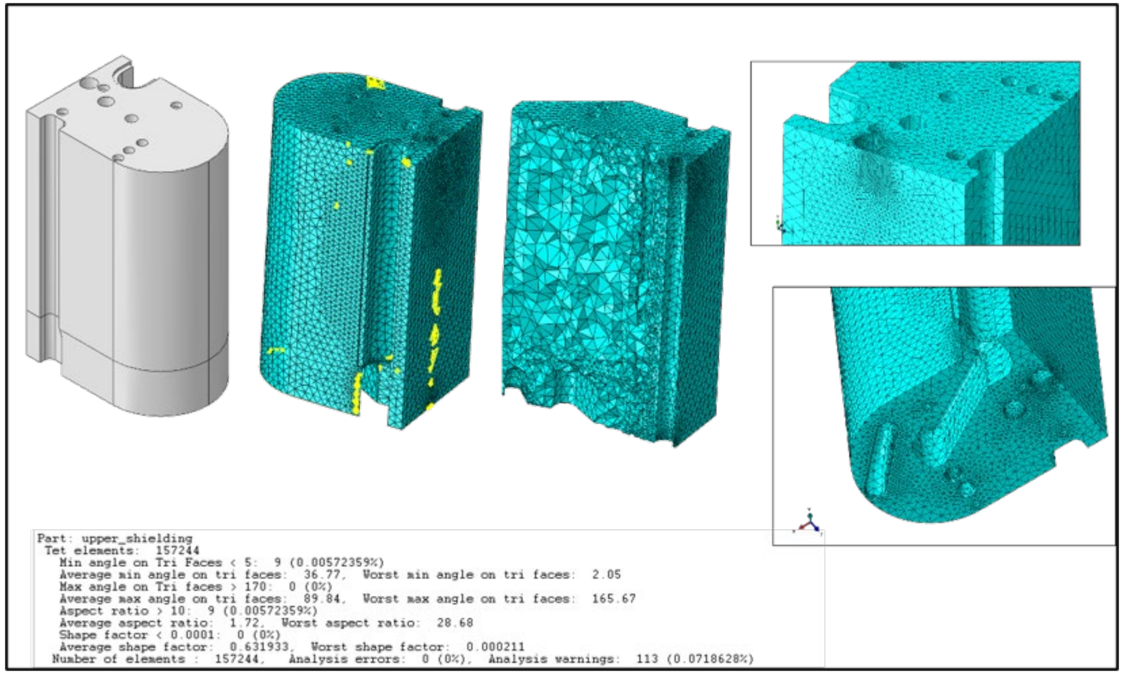
Backbone covers welded after 3 parts welded




```
Part instance:  MRA_AM_010-2-1
 Hex elements:  468
   Aspect ratio > 10:  0 (0%)
   Average aspect ratio:  1.04,  Worst aspect ratio:  1.04
  Number of elements :  468,   Analysis errors:  0 (0%),  Analysis warnings:  0 (0%)
```

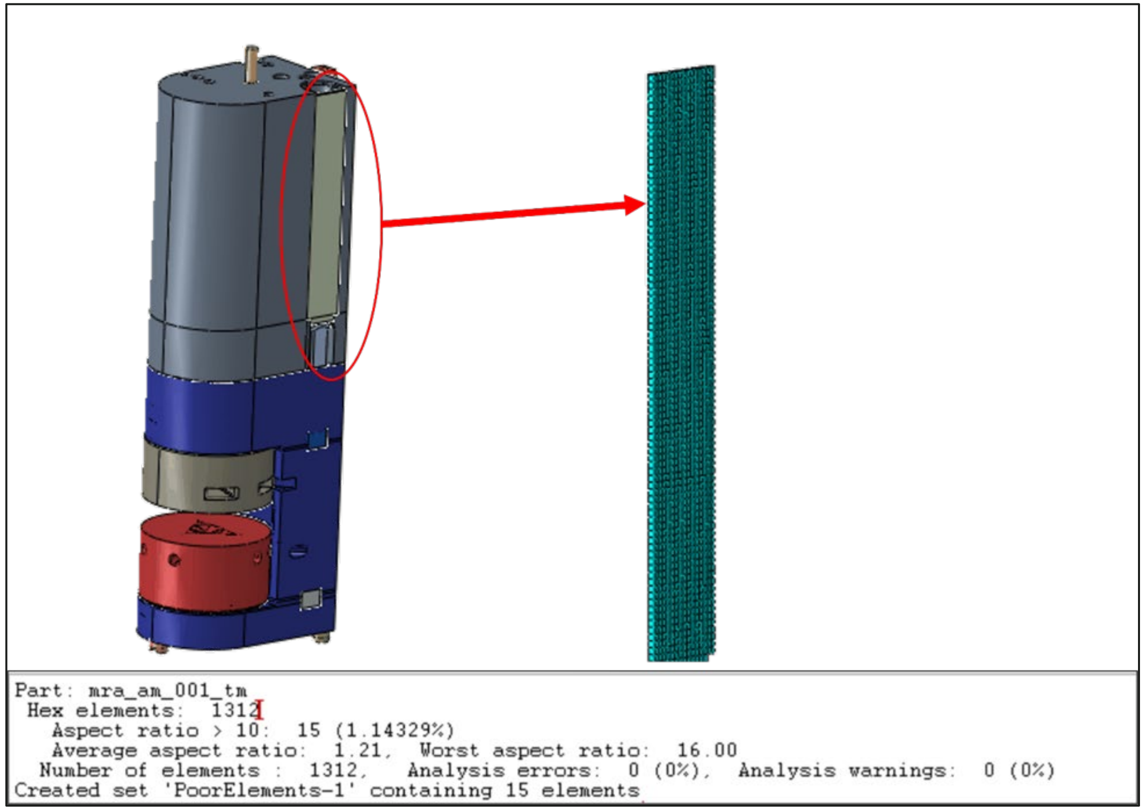
Upper Shielding

A36 Upper Shielding mesh model



157,244 C3D10 tet elements

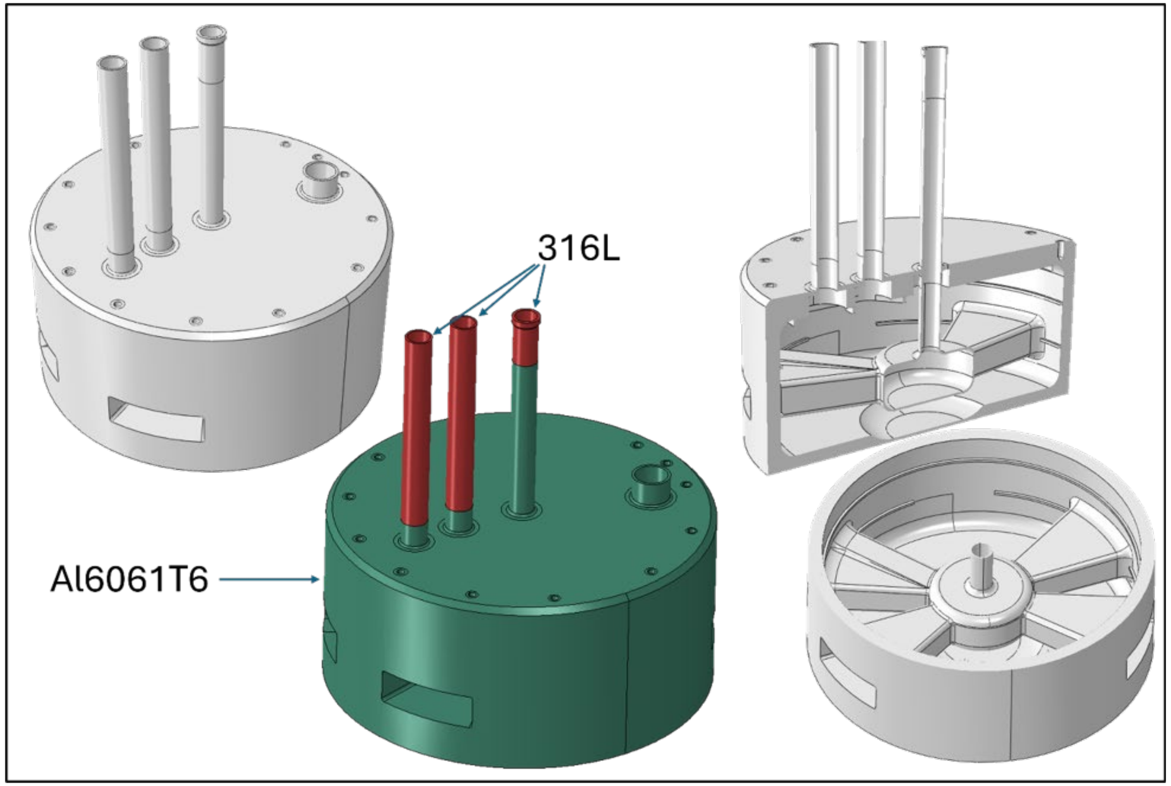
Upper Shielding Vacuum Channel A36 cover plate



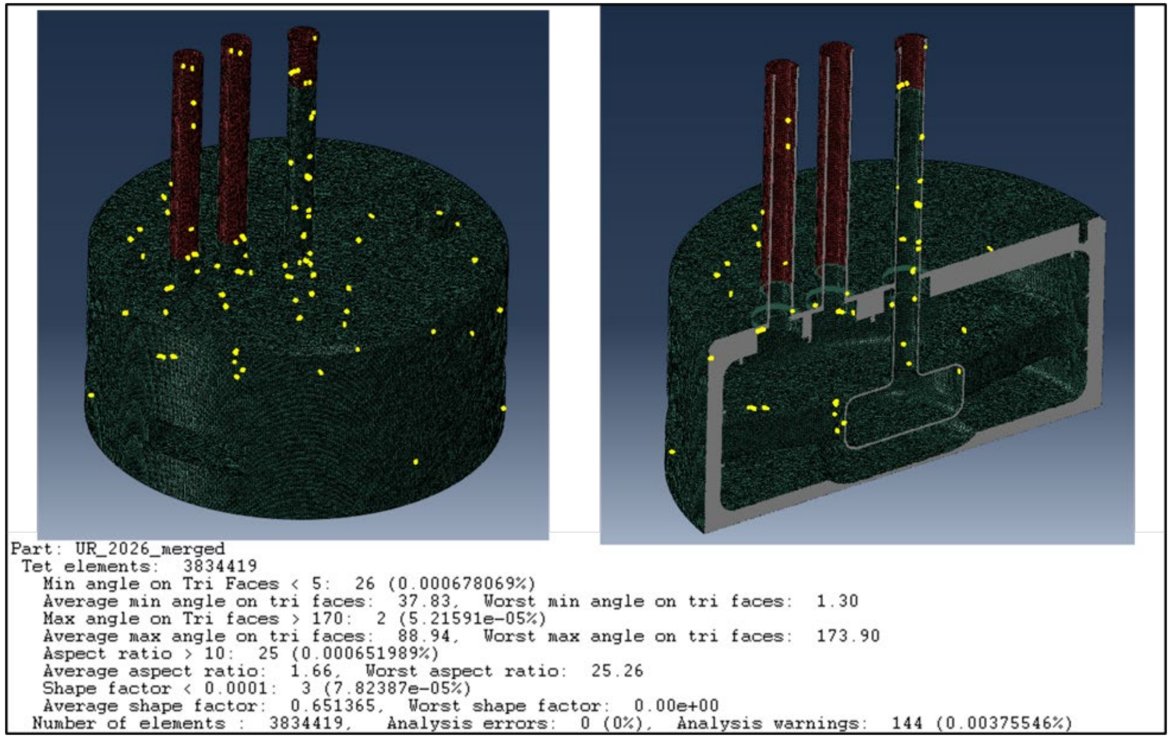
1,312 C3D8 Hex elements

Upper Reflector Vessel with merged bimetallic tubes

Vessel with materials shown

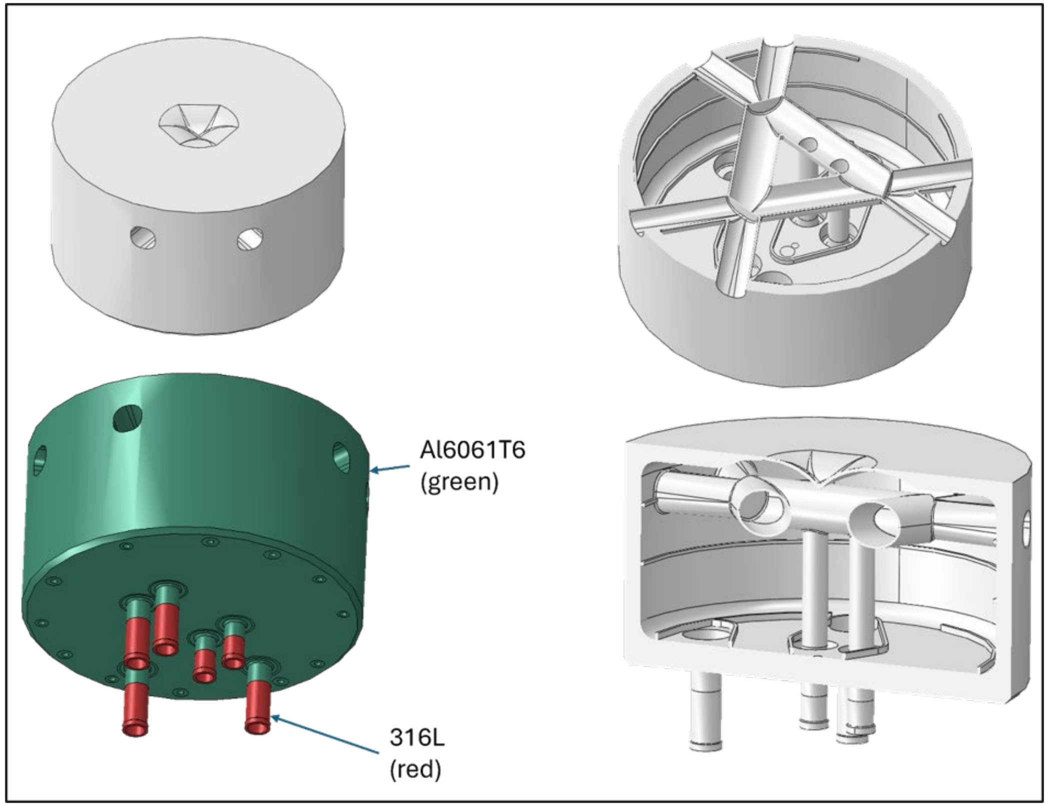


Mesh model – 3.8e6 C3D10 elements

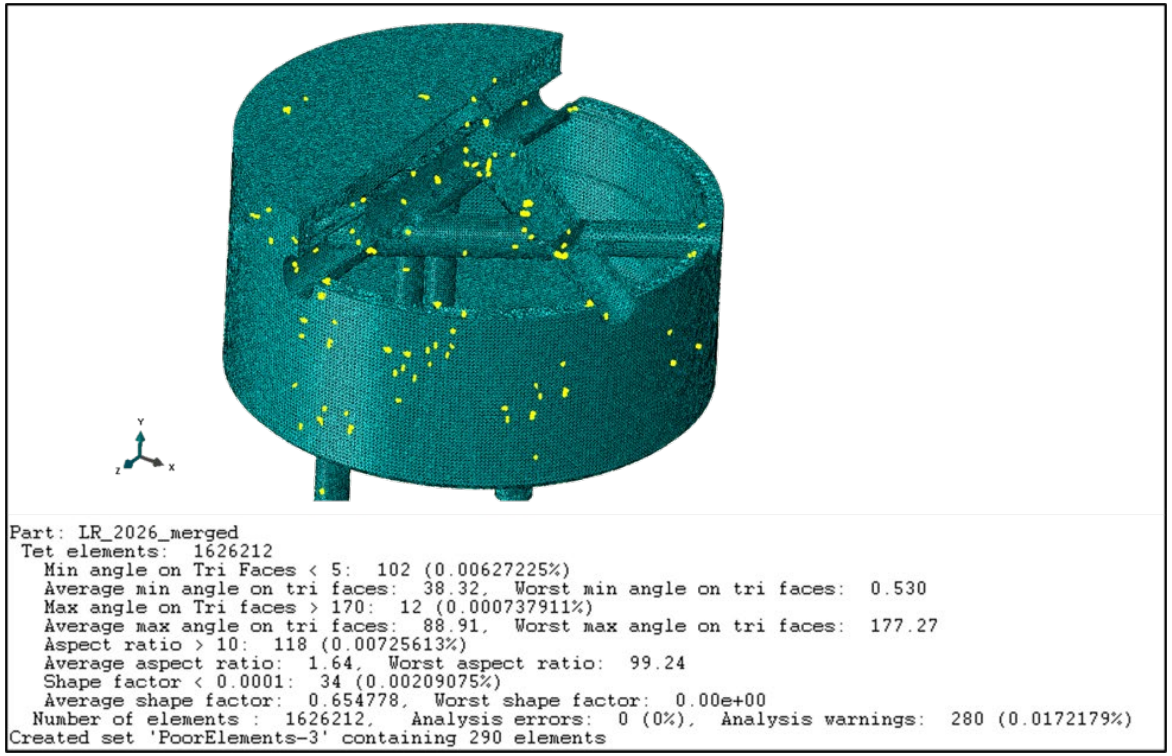


Lower Reflector vessel with merged Bi-metallic tubes

Vessel with view cuts and materials

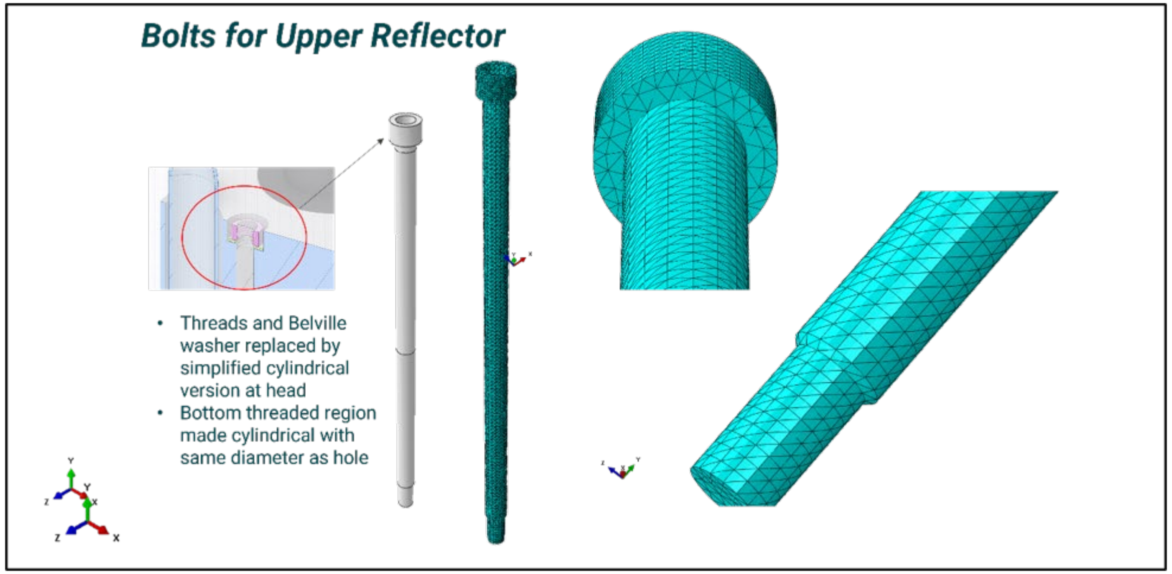


Mesh model 1.6e6 C3D10 tet elements



Bolts and tie rod models

Typical upper bolt with simplified thread region

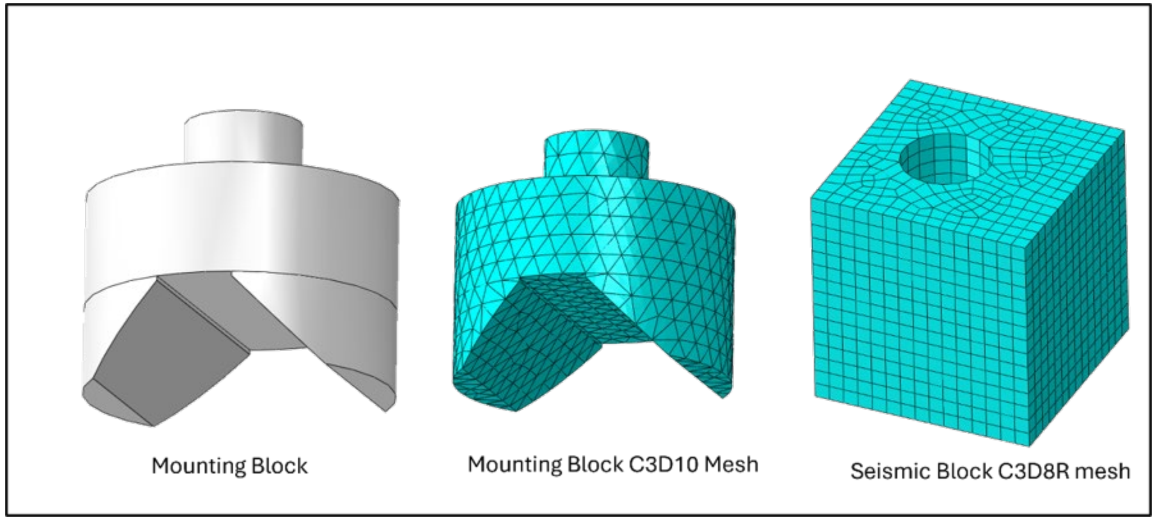


12 upper vessel bolts and 12 lower vessel bolts- similar but shorter – approximately 2e4 C3D10 elements for each bolt

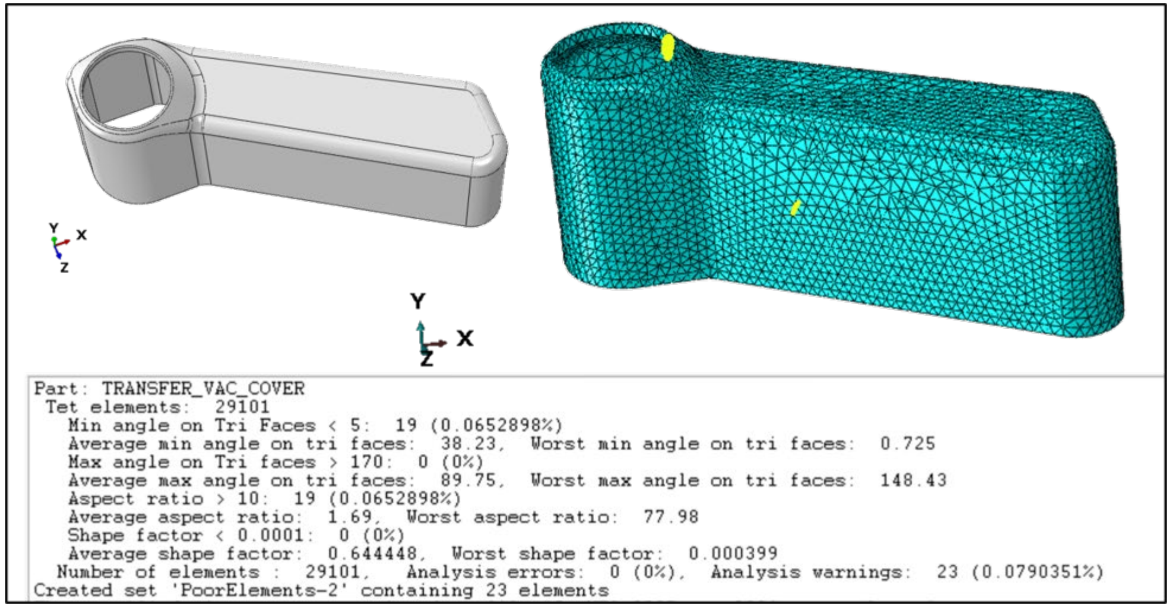
Typical Tie Rod with simplified thread region

Mounting block and vacuum cover shell models

Mounting block and seismic block

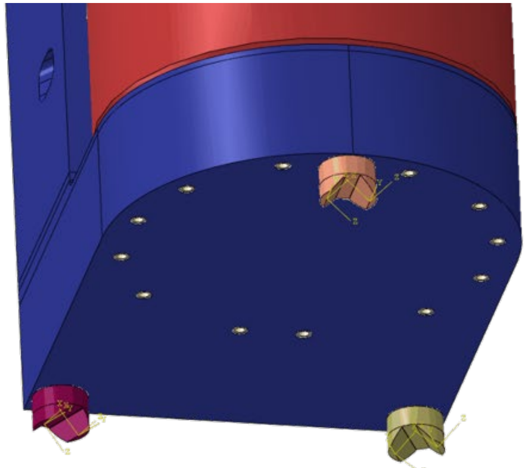


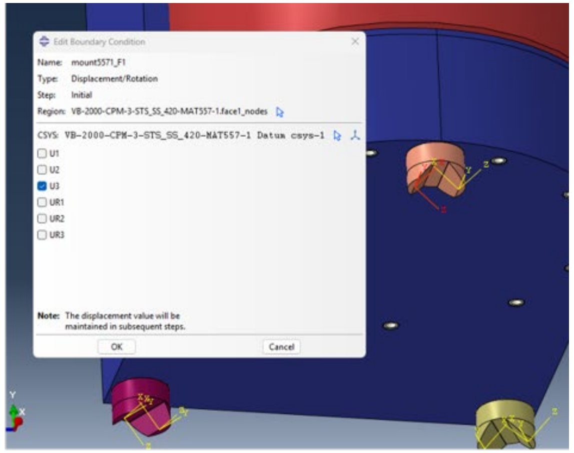
Vacuum cover shell



Boundary Conditions

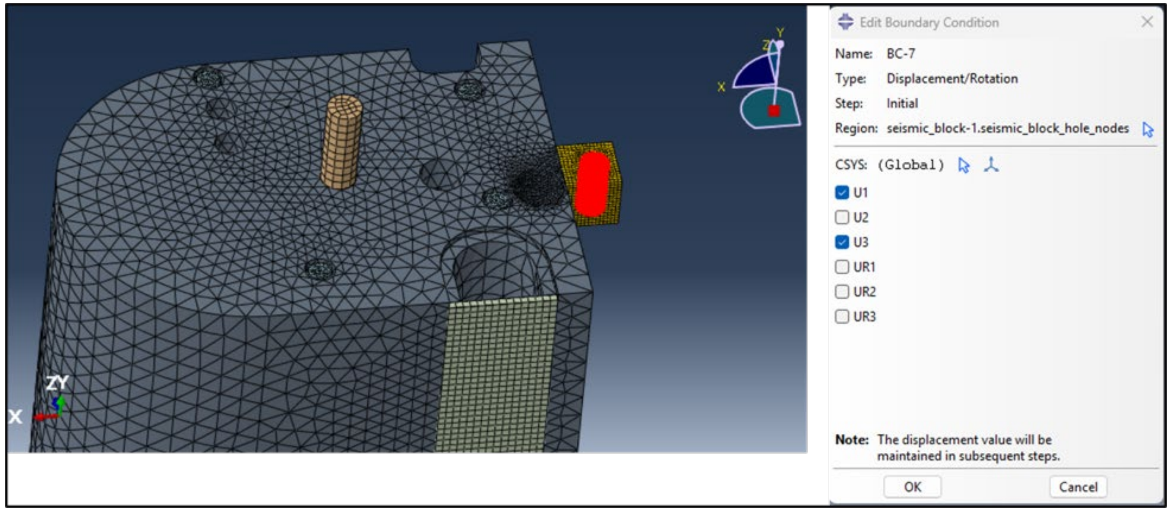
Mounting blocks





Displacement normal to angled surfaces fixed surfaces point to center axis so net displacements are radial

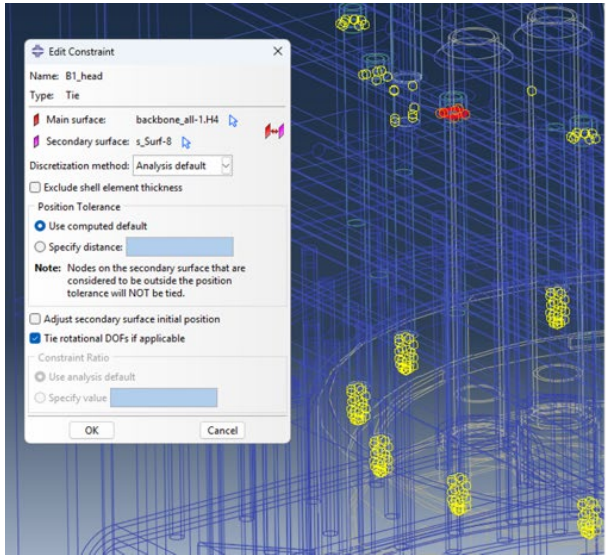
Seismic block restrant

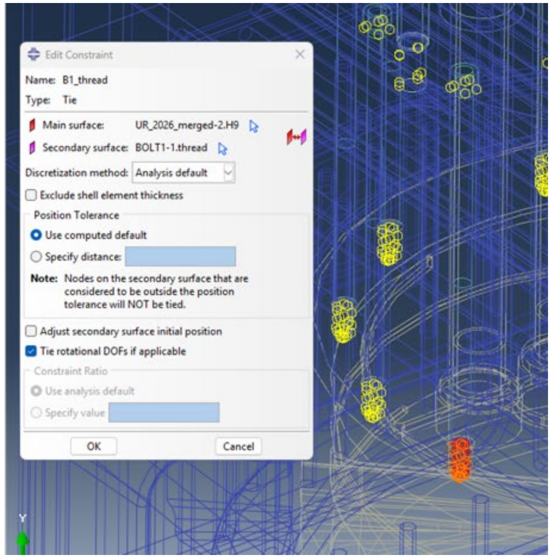


Hole surface nodes restrained to only allow vertical displacement

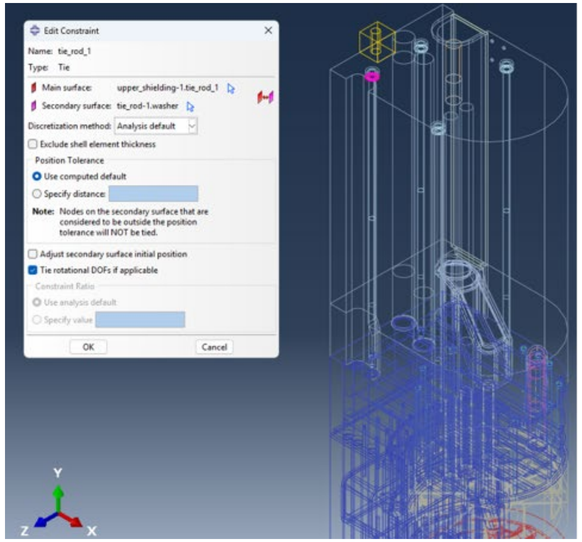
Typical bolt and tie rod head and threaded region contraints

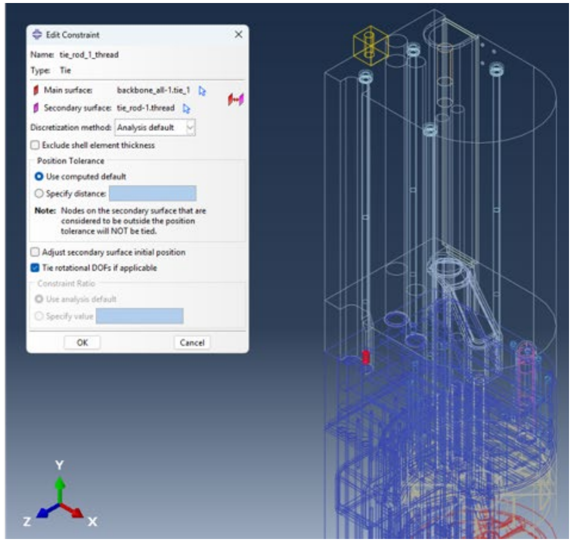
Upper Bolt 1 head and thread tie constraint





Tie rod 1 head and threaded region tie constraint

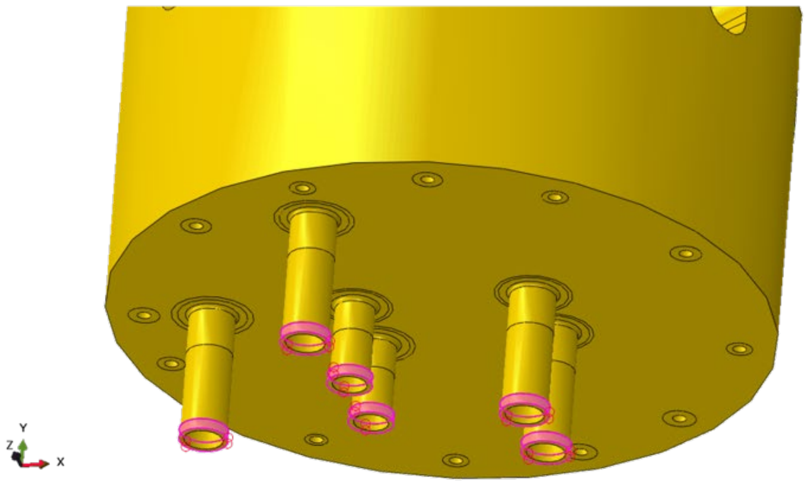




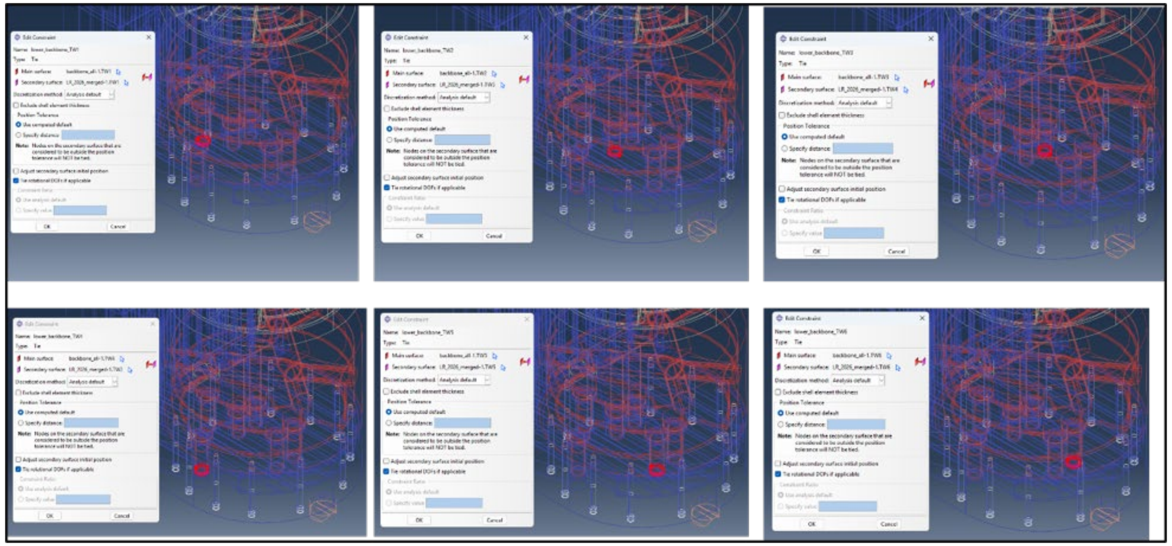
Lower Reflector Vessel 316L weld surfaces

6 Bi-metallic tube weld surfaces

Lower Reflector showing locations of 6 fitting ties

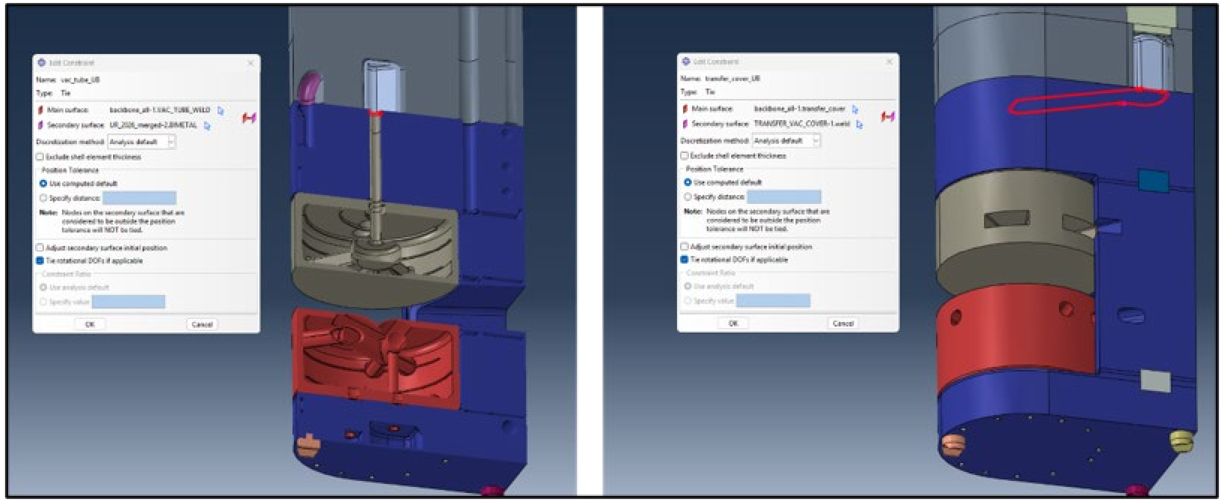


Tie Constraints

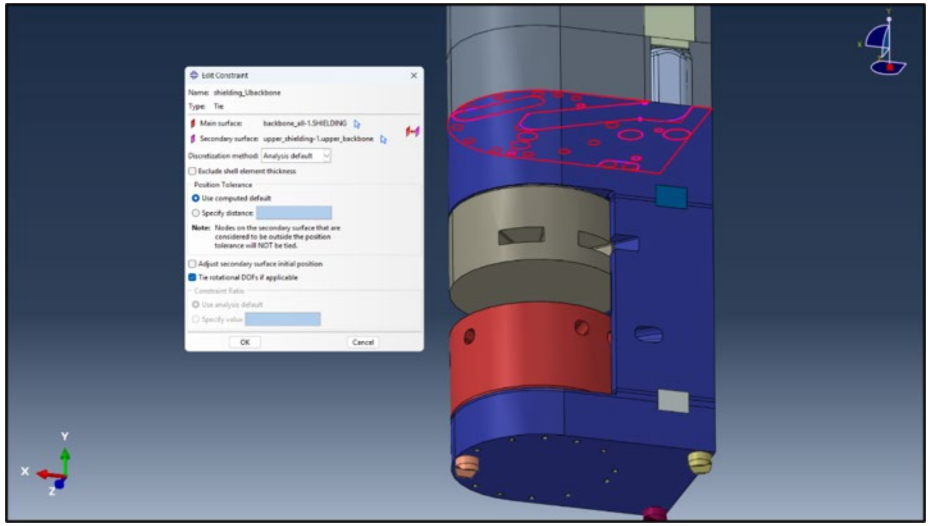


Vacuum boundary welds and upper shielding to backbone tie

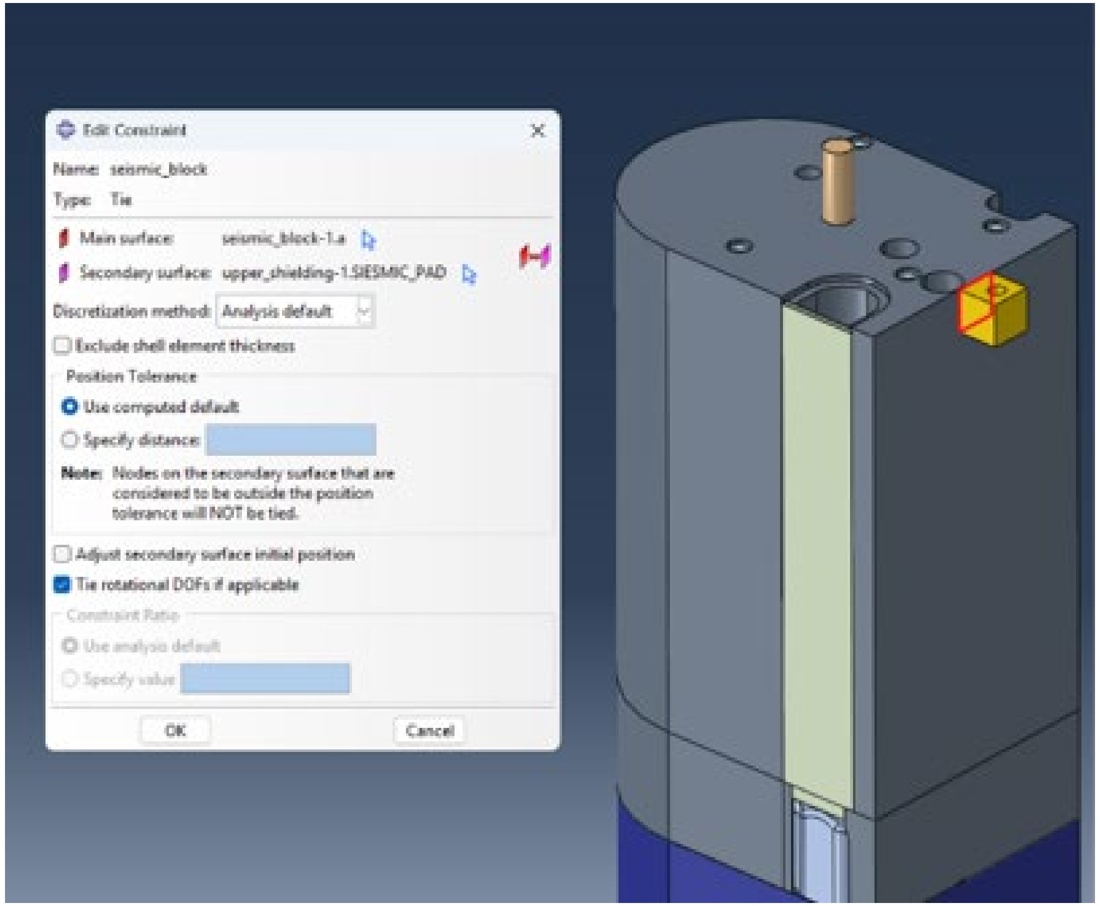
Vacuum boundary welds

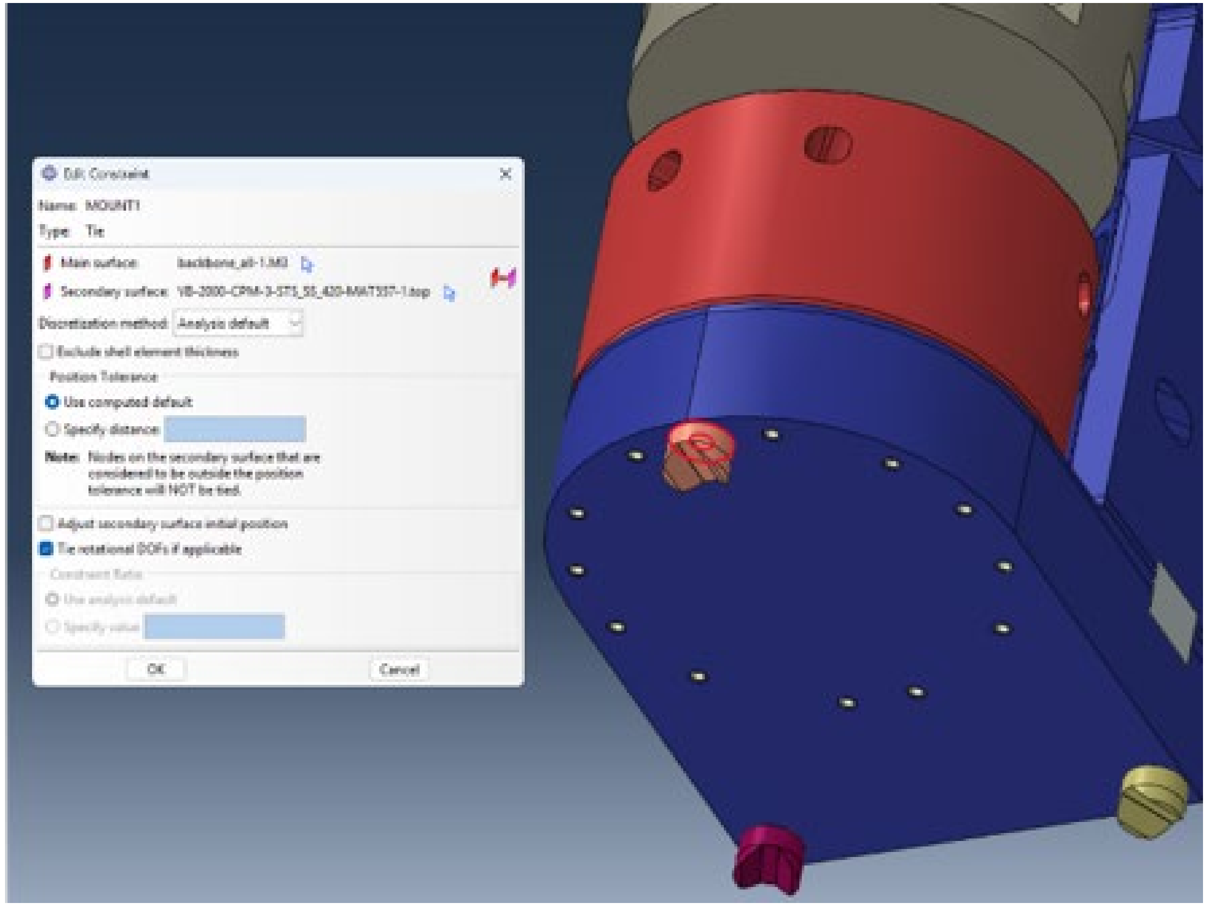


Upper shielding tie to backbone

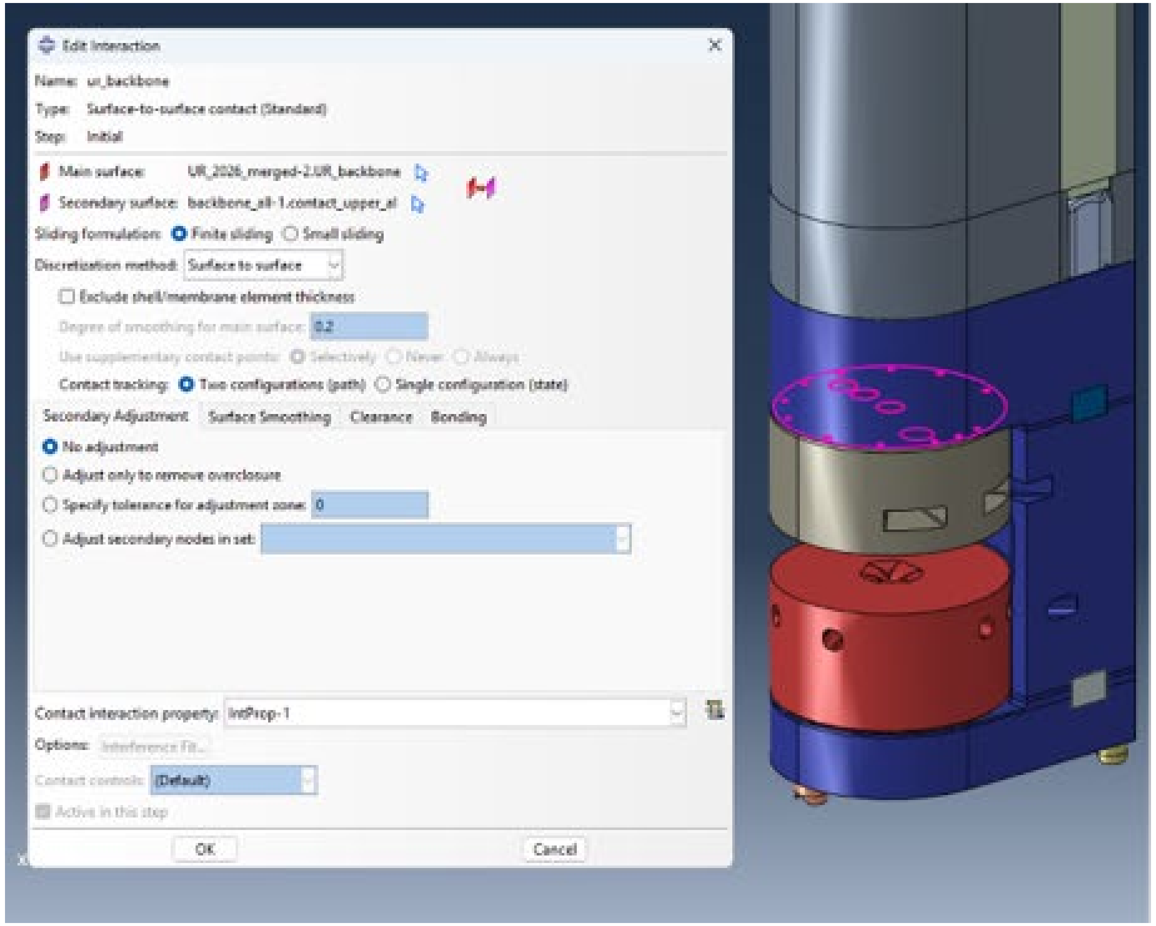


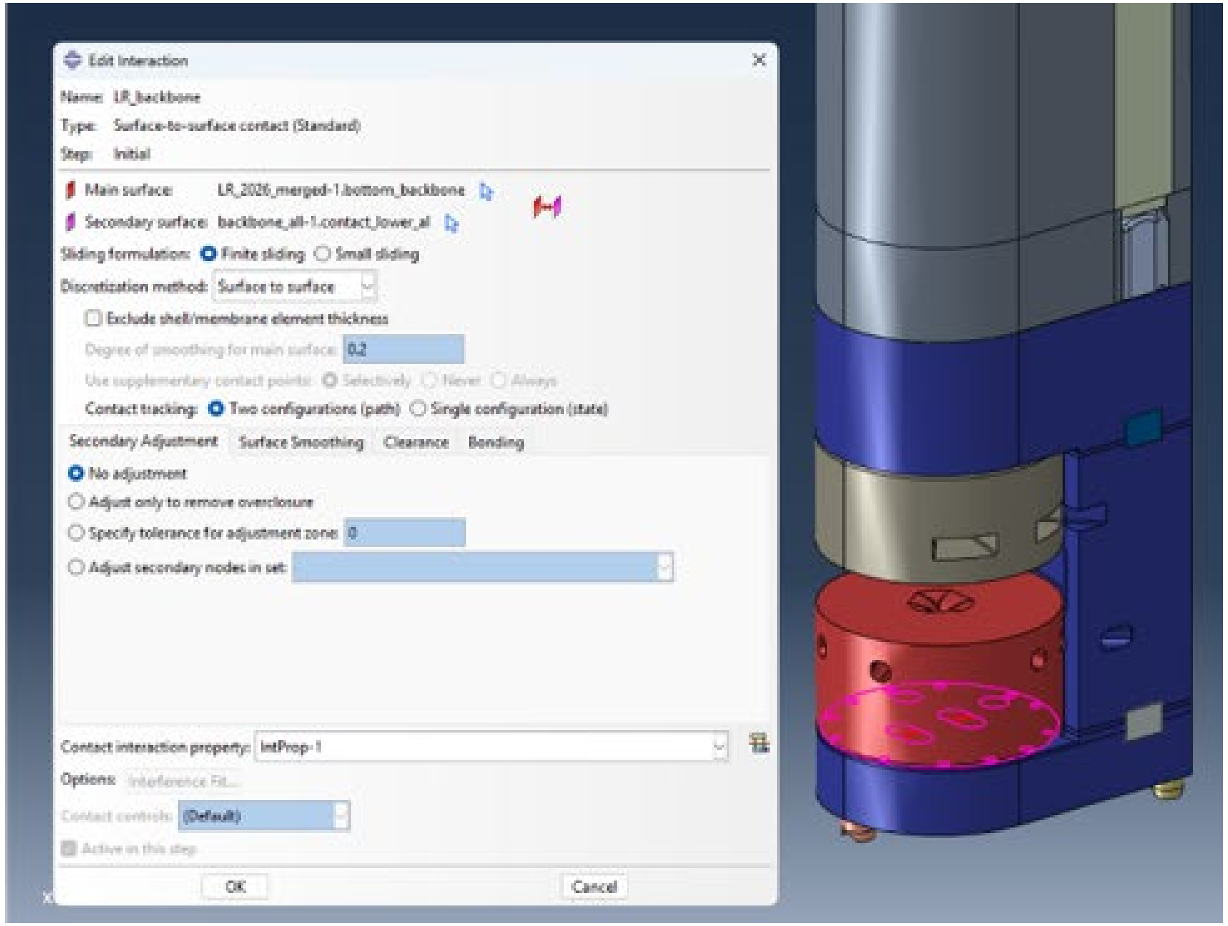
Seismic block and lower mount typical tie constraints





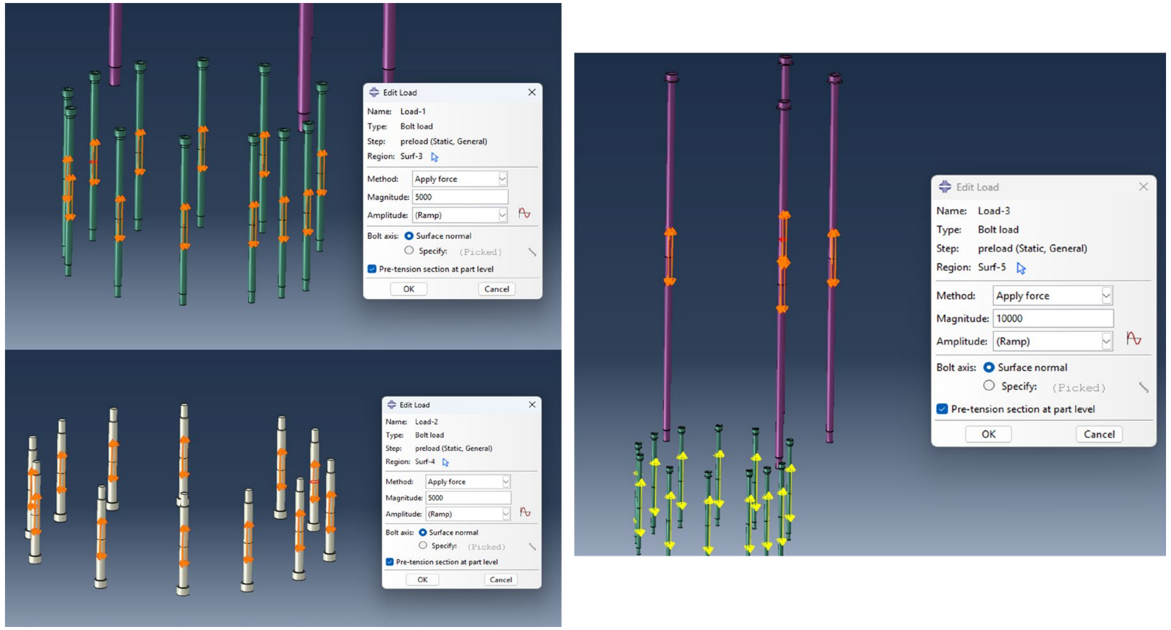
Upper and Lower Reflector Vessel Surface to Surface hard frictionless Interactions to backbone



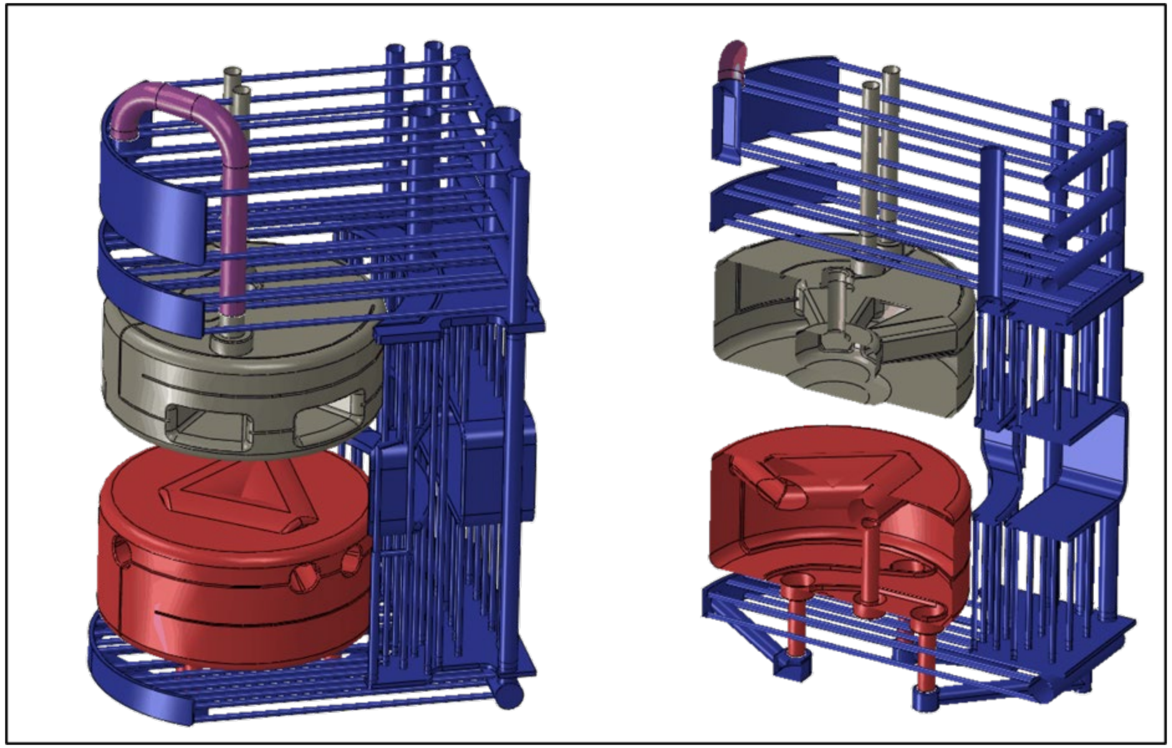


Loads

Preloads 5kN bolts 10 kN tie rods

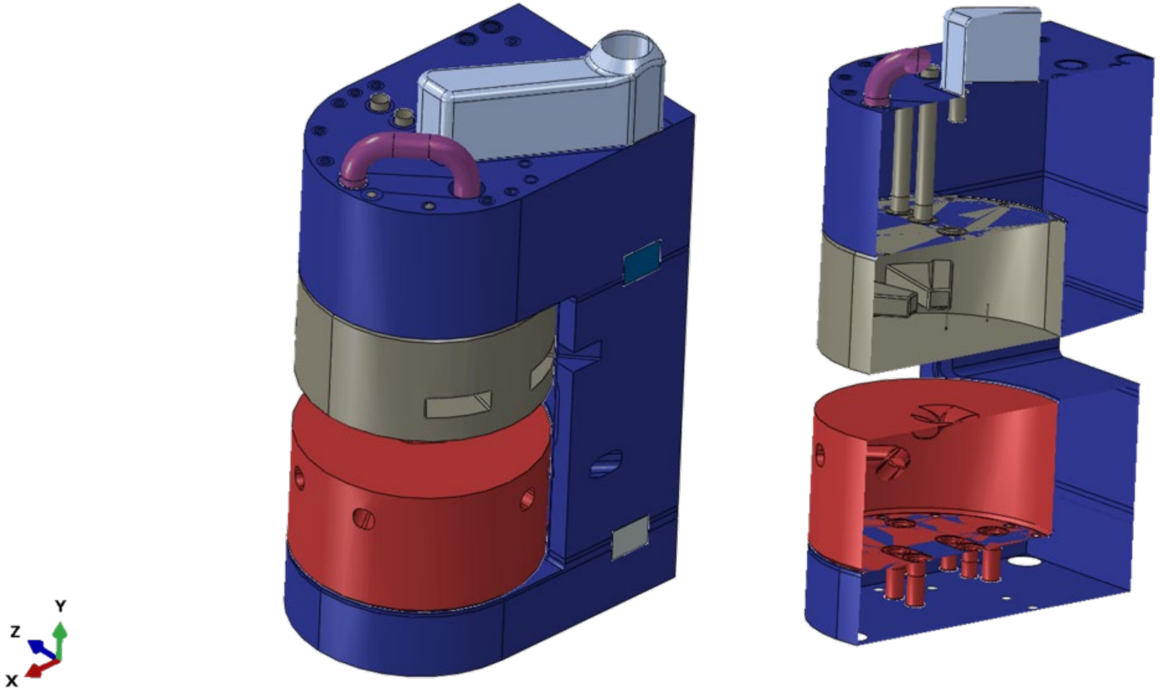


Water Pressure – 3, 5 and 5.75 bar



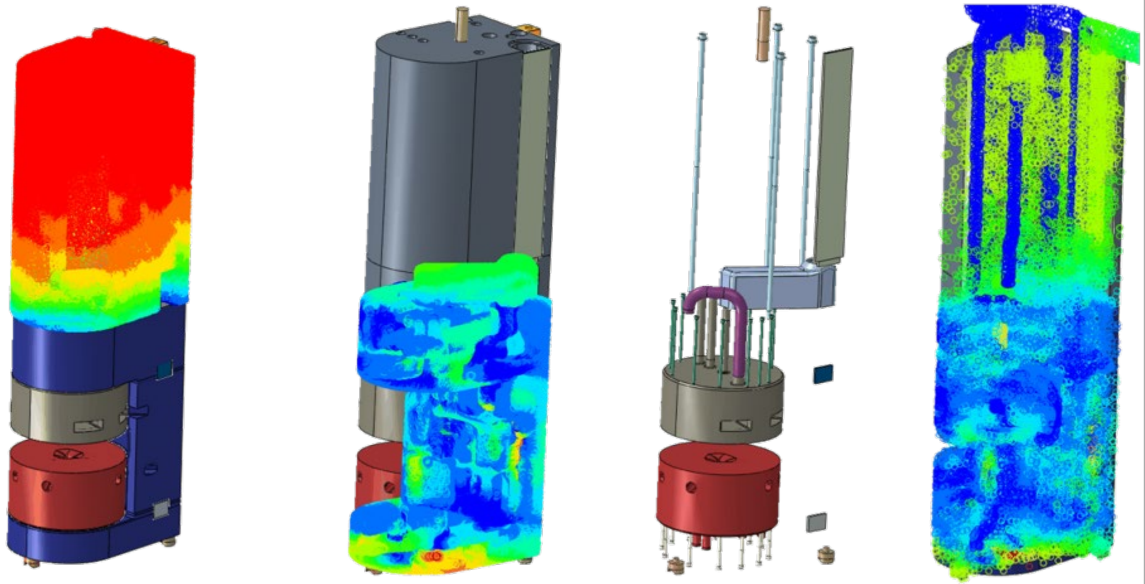
Vacuum boundary – 0 or 2 bar

Core vessel atmosphere – 0 or 1 bar



Thermal and Seismic loads

Imported Temperature Fields



A36-2 upper shielding | Backbone merged | Parts mapped with Temperature all | Temperature all

Seismic Loads

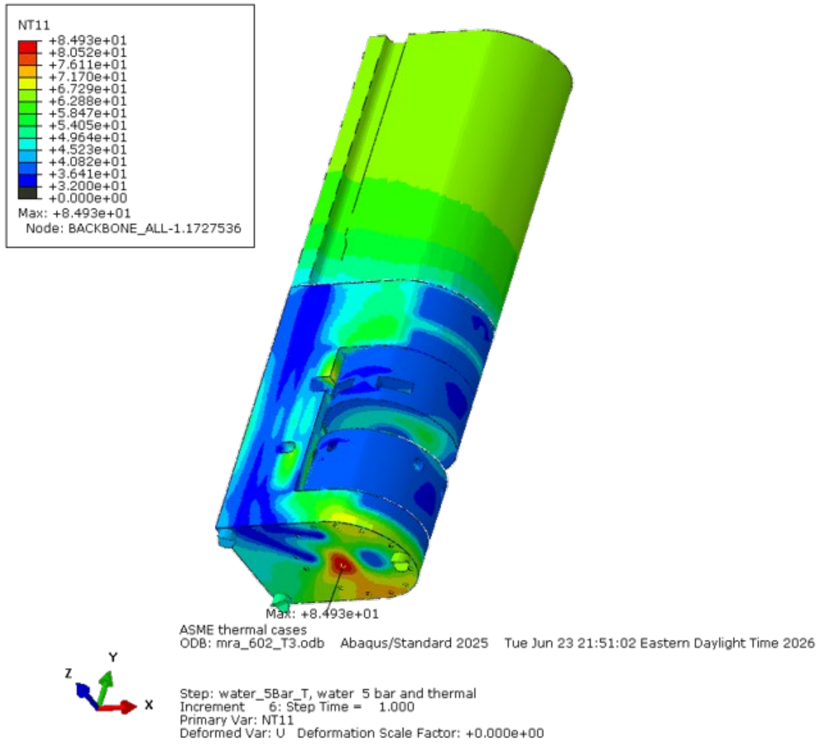
Table 1: STS SSCs using ASCE-7-16 Chap. 13 - Seismic Requirements for Nonstructural Components (Equivalent Static Method)

SSC	F_p/W_p (Eq.13.3-1)	F_p/W_p max (Eq.13.3-2)	F_p/W_p min (Eq.13.3-3)	E_v (Eq.13.3.1.2)
Moderator Reflector Assembly (Conservative Attachment Height)	0.308	1.16	0.22	0.10

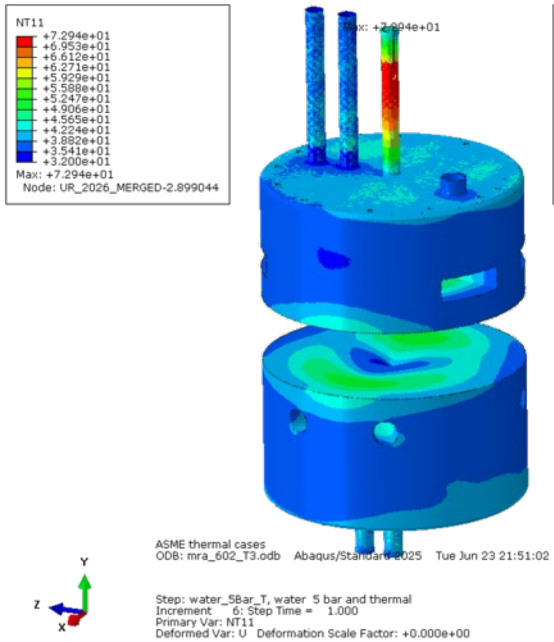
Horizontal force Fp =.308 Wp and the vertical Ev = 0.1 Wp. The accelerations to be applied for Abaqus cases in the horizontal plane (X,Z) are 0.7Fp or 2.11 N/m2. In the vertical plane it would be .69 N/m2.

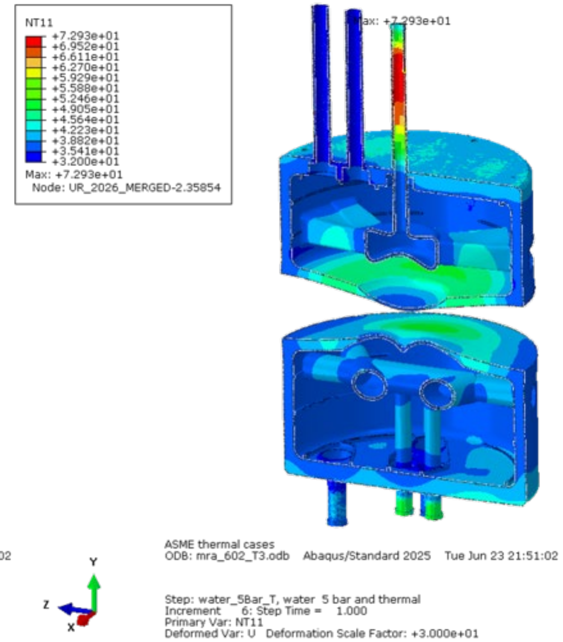
Temperatures as Mapped by Abaqus from imported data fields

Assembly - peak 85 °C at backbone bottom



Aluminum peak 73 C on Upper Vessel vacuum tube





ASME BPVC Code Cases and Abaqus Analysis cases

ASME Case	Abaqus case	Water Pressure (P bar)	Core Vessel pressure(bar)	Weight (D)	Vacuum Space Pressure (bar)	Seismic load (E)	Thermal T
1	1	5	0	D			
1	3	3	0	D	2	0	
3	10	3	1	D	0	0	T
3	8	5	0	D	0	0	T
5	7	3	0	.6D	0	.7E overturn	
6	4	3	0	D	0	.7 Ex	
6	5	3	0	D	0	.7Ez	
6	6	3	0	D	0	.7Ey	
9	9	3	0	D	0	0	T
18	2	5.75	0	D	0	0	
	11	3	0	D	2	0	T

Abaqus Analysis done with two input files – non-thermal and with thermal

Load Manager for non-thermal cases

Load Manager

	Name	preload	gravity	Step-3	Step-4	Step-5	Step-6	Step-7	Step-8	Step-9
✔	EX						Created	Deactivated		
✔	EY								Created	Deactivated
✔	EZ							Created	Deactivated	
✔	Eoverturning									Created
✔	Load-1	Created	Modified	Propagated	Propagated	Propagated	Propagated	Propagated	Propagated	Propagated
✔	Load-2	Created	Modified	Propagated	Propagated	Propagated	Propagated	Propagated	Propagated	Propagated
✔	Load-3	Created	Modified	Propagated	Propagated	Propagated	Propagated	Propagated	Propagated	Propagated
✔	Load-6		Created	Propagated	Propagated	Propagated	Propagated	Propagated	Propagated	Deactivated
✔	vac 2bar					Created	Deactivated			
✔	water_3bar					Created	Propagated	Propagated	Propagated	Propagated
✔	water_5_75_ba				Created	Deactivated				
✔	water_5_bar			Created	Deactivated					

Edit... Move Left Move Right Activate Deactivate

Step procedure: Static, General
Load type: Gravity
Load status:

Create... Copy... Rename... Delete... Dismiss

Preload and gravity steps the same for both input files

Load Manager for thermal cases

Load Manager

	Name	preload	gravity	water_3bar_	water_5Bar_T	water_3bar_T	water_3bar_CV 1bar	water_3bar_vac_2bar
✔	CV1bar						Created	Deactivated
✔	Load-1	Created	Modified	Propagated	Propagated	Propagated	Propagated	Propagated
✔	Load-2	Created	Modified	Propagated	Propagated	Propagated	Propagated	Propagated
✔	Load-3	Created	Modified	Propagated	Propagated	Propagated	Propagated	Propagated
✔	Load-6		Created	Propagated	Propagated	Propagated	Propagated	Propagated
✔	P3			Created	Deactivated			
✔	P3water					Created	Propagated	Propagated
✔	P5				Created	Deactivated		
✔	Vac_2bar							Created

Edit... Move Left Move Right Activate Deactivate

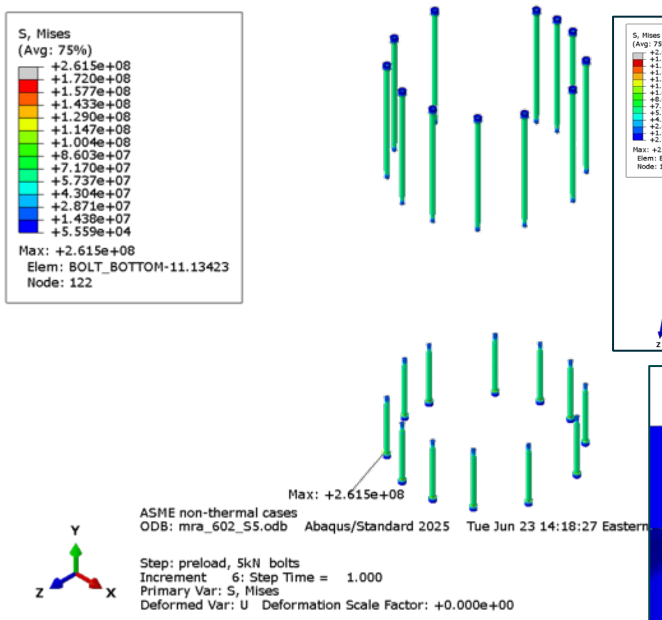
Step procedure: Static, General
Load type: Pressure
Load status:

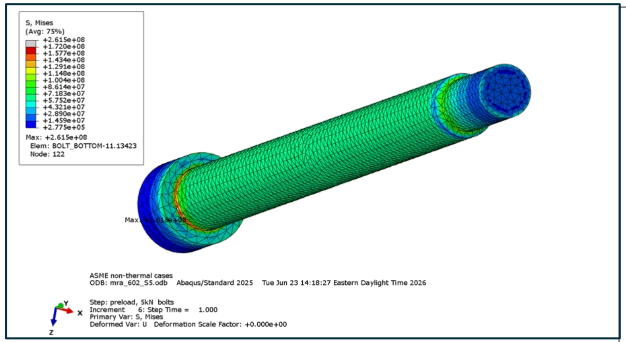
Create... Copy... Rename... Delete... Dismiss

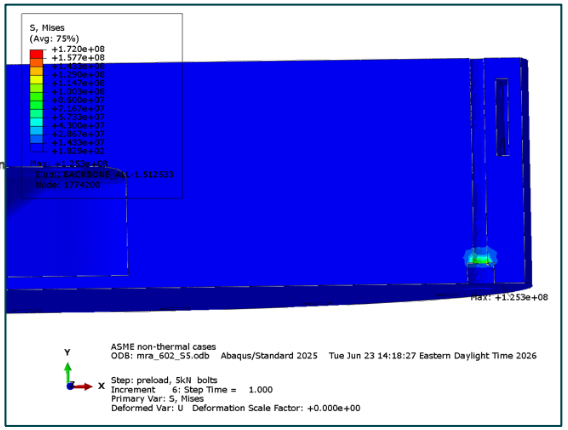
- A step with 3 bar water pressure and all nodes at 32 °C included for beam trip thermal fatigue stress analysis
- Normal operating temperatures applied for all following steps

Preloads gave predicted Axial loads with peaks at mesh singularities and at backbone contact regions

Bolt peak at singularity – Backbone peak 125 MPa

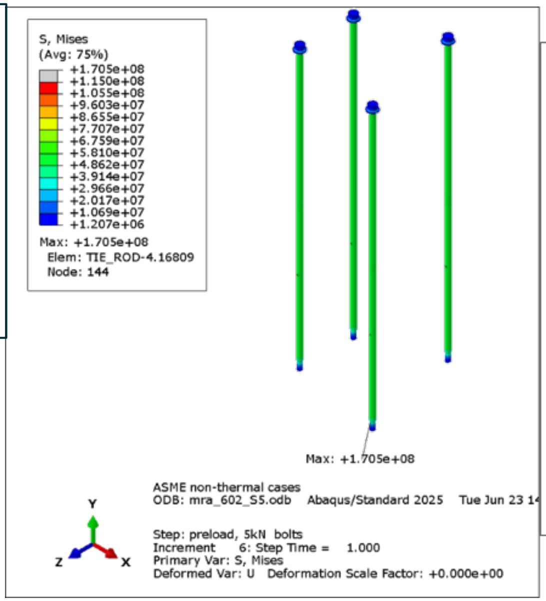


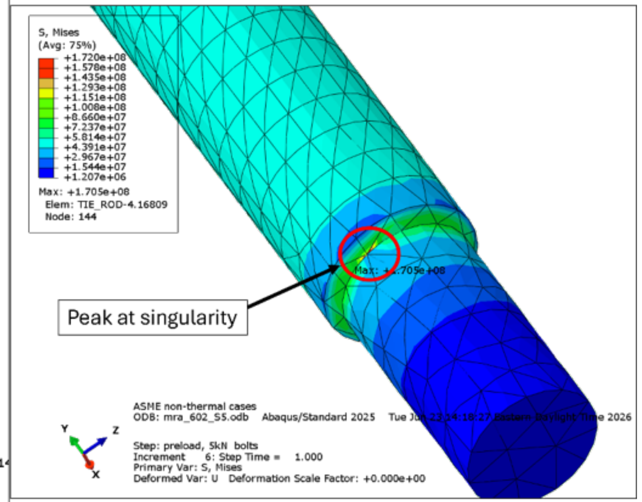




Axial bolt stress 70 MPa

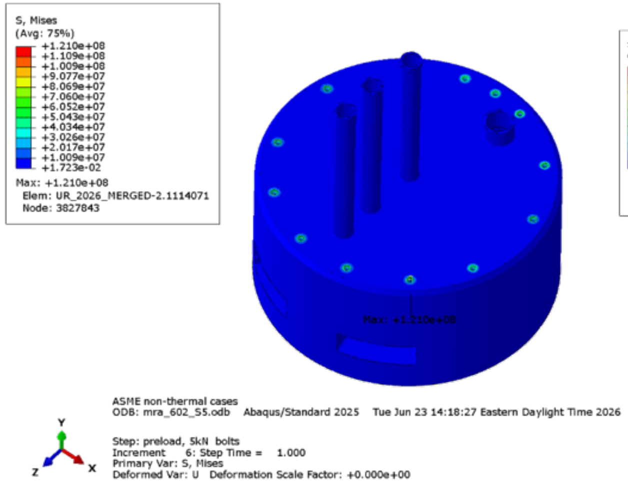
Tie rod stresses – axial miplane 50 MPa

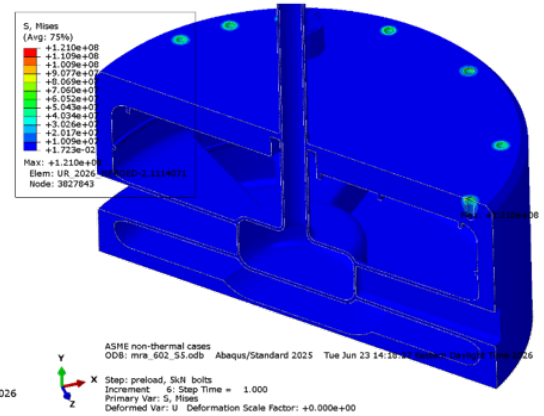




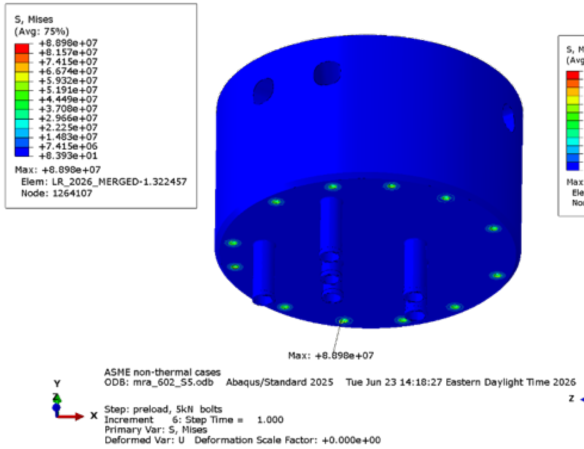
Preload stress on Reflector Vessels

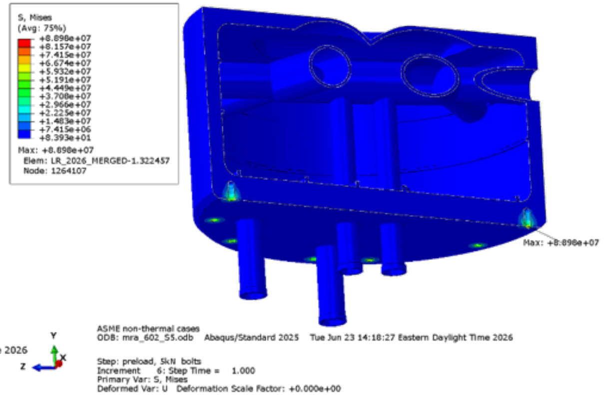
Upper Reflector vessel peak 121 MPa



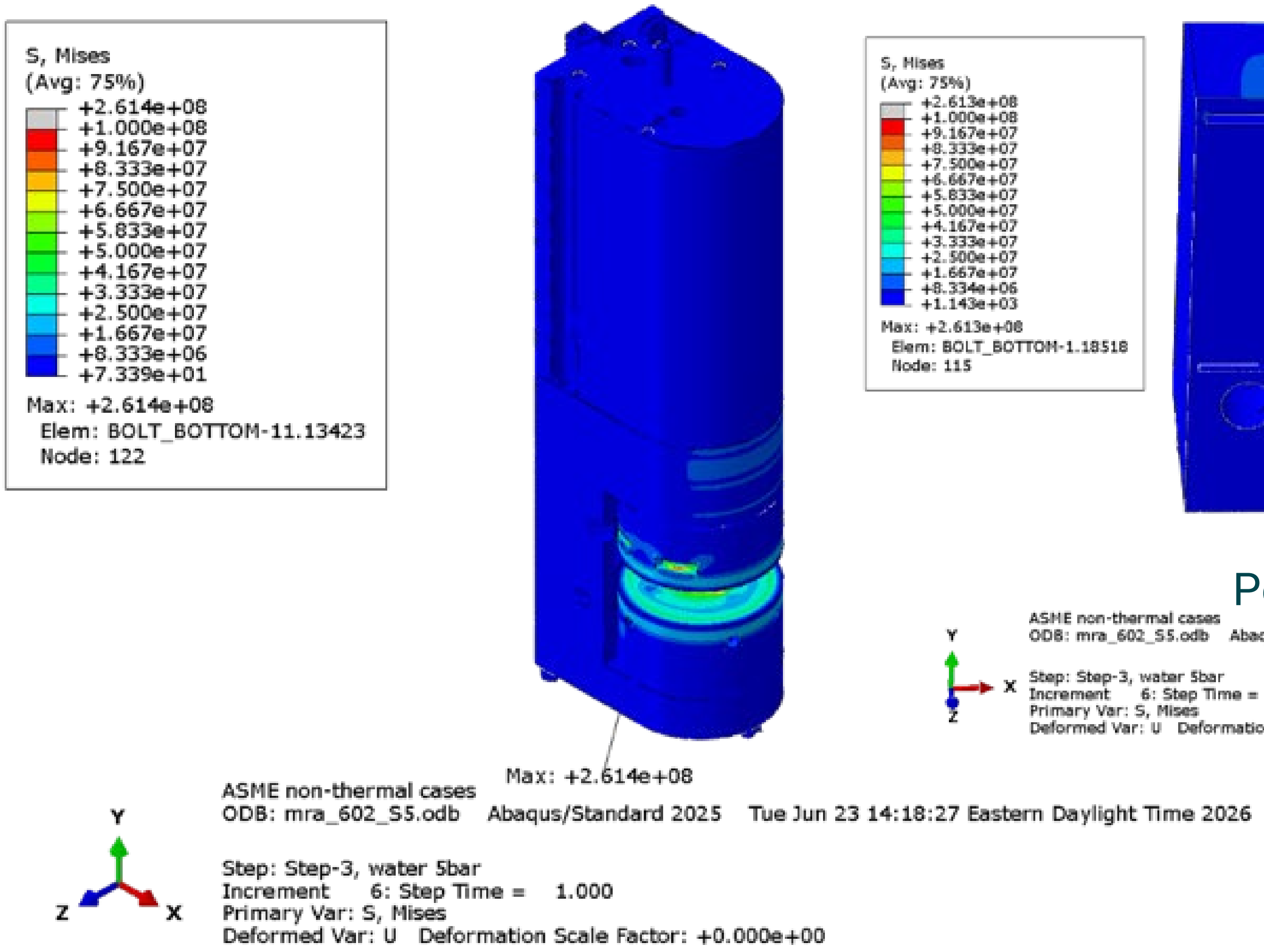


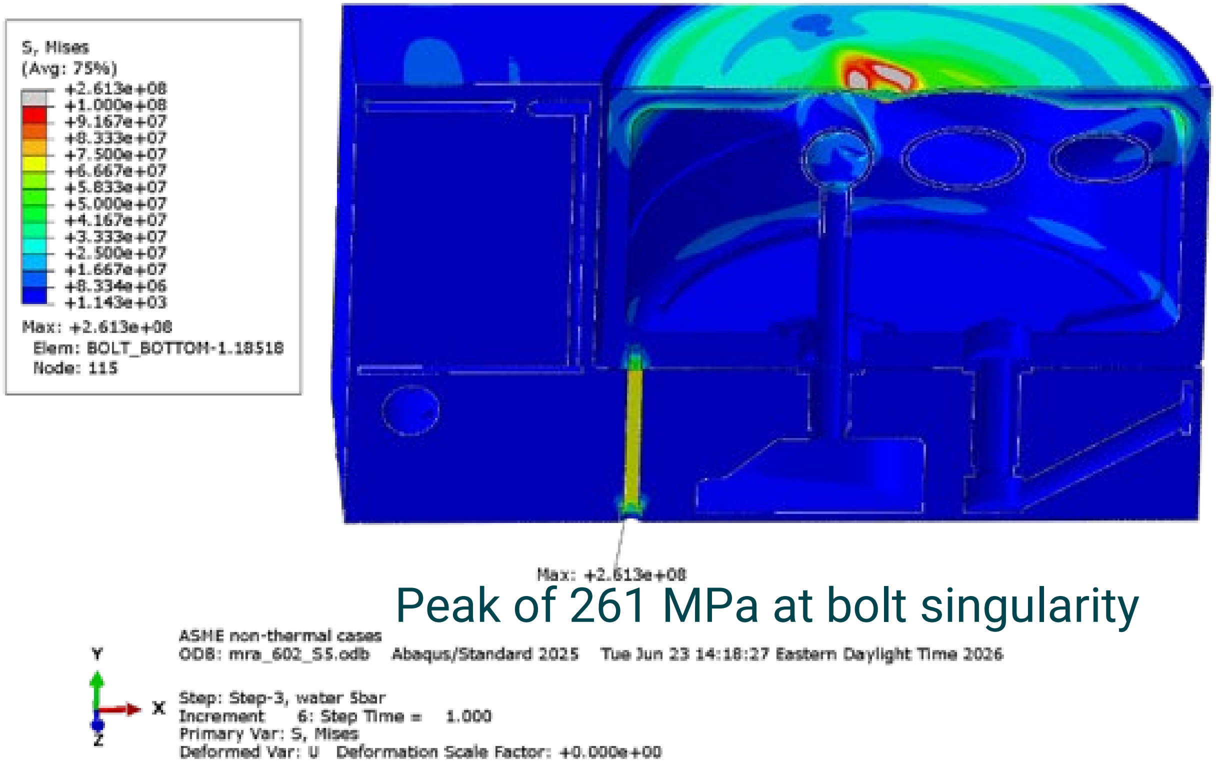
Lower Reflector vessel peak 89 MPa





Preload, Gravity and 5 bar water (Abaqus case 1)

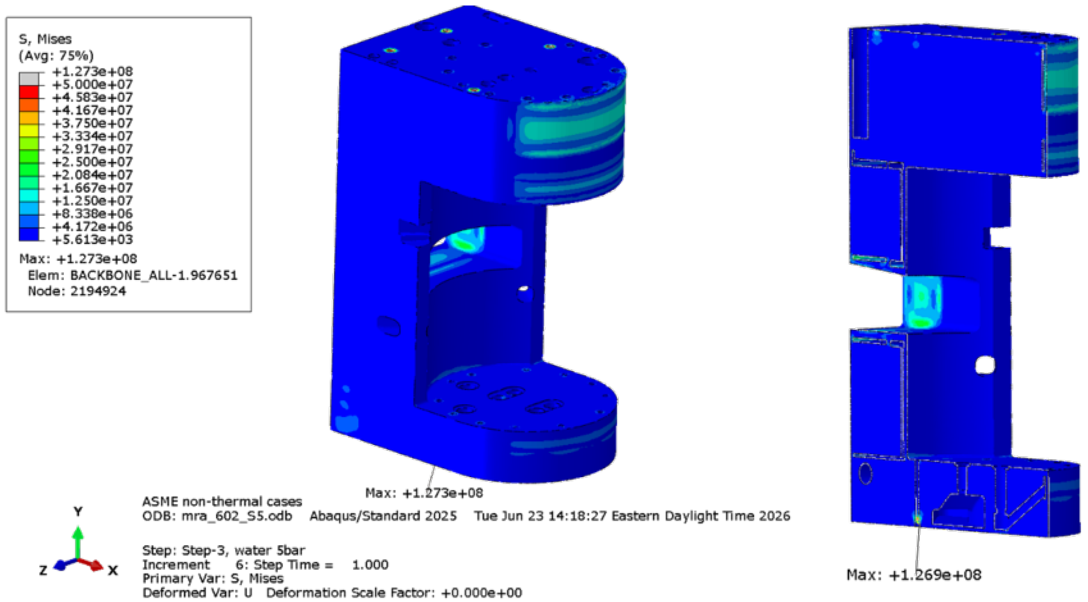




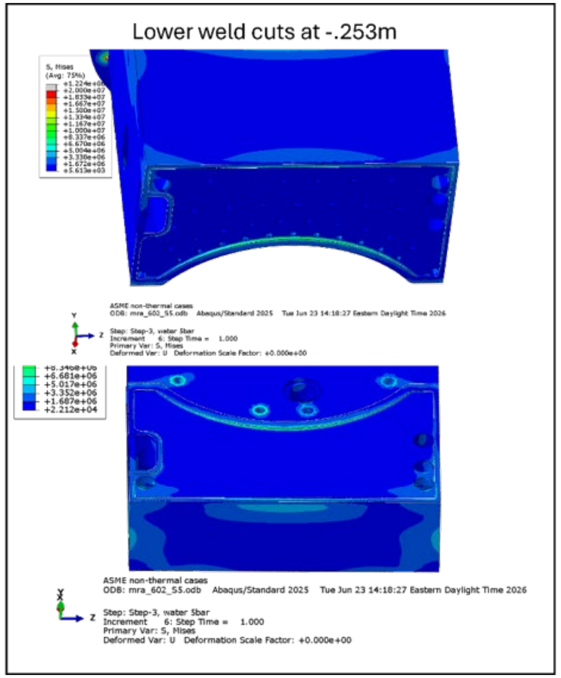
Peak of 261 MPa at bolt singularity

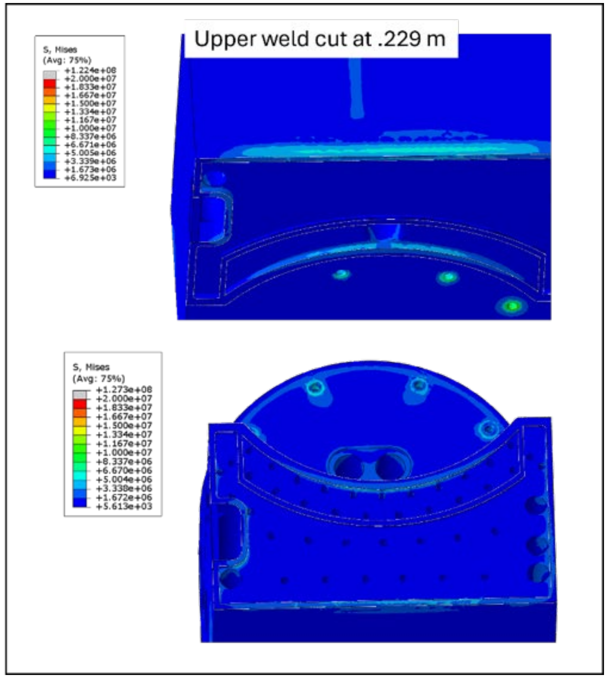
Abaqus case 1 backbone Stress

Peak 127 MPa near bolt head contact



weld stress low - 20 MPa scale maximum

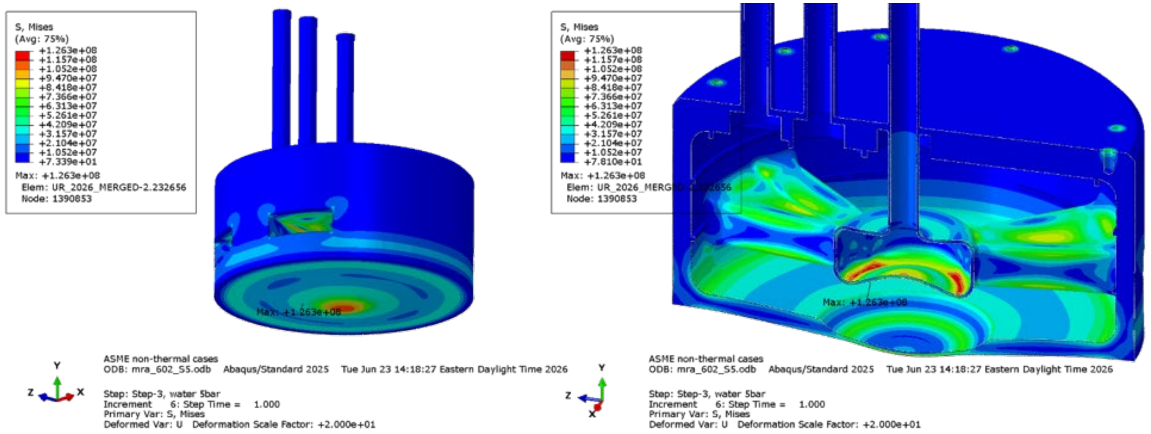


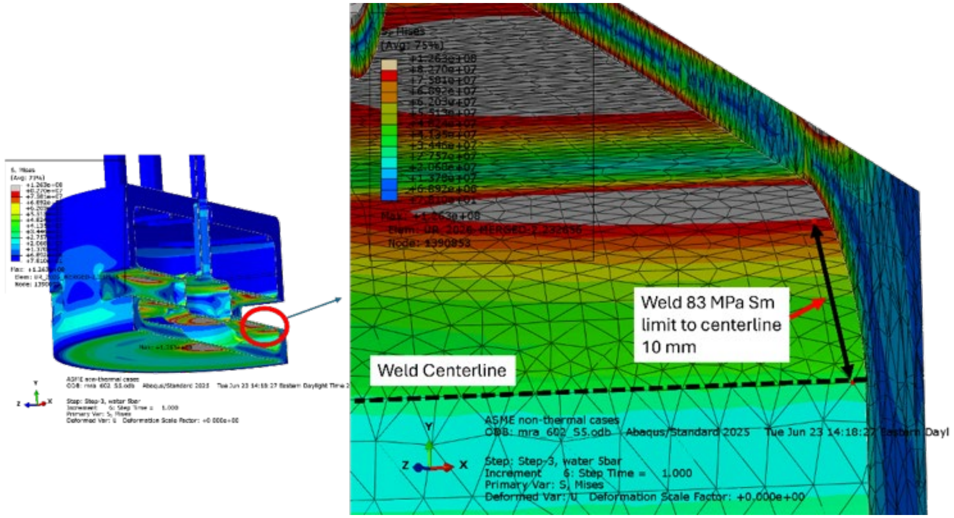


Abaqus case 1 Upper Reflector Vessel Stress

Peak 126.3 MPa – below 127 MPa 1.5S_m limit

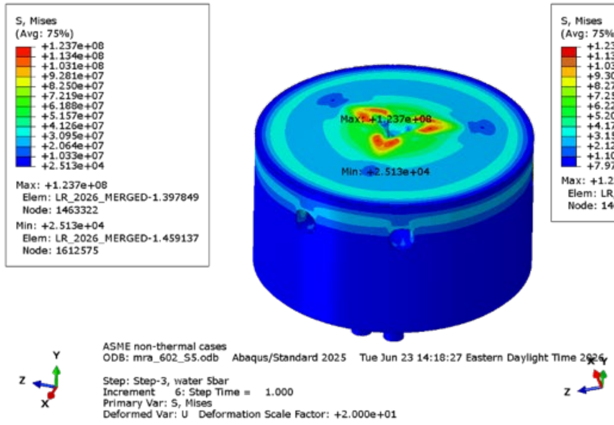
Minimum 10 mm distance from weld centerline to 83 MPa stress weld Sm limit - exceeds 5 mm HAZ

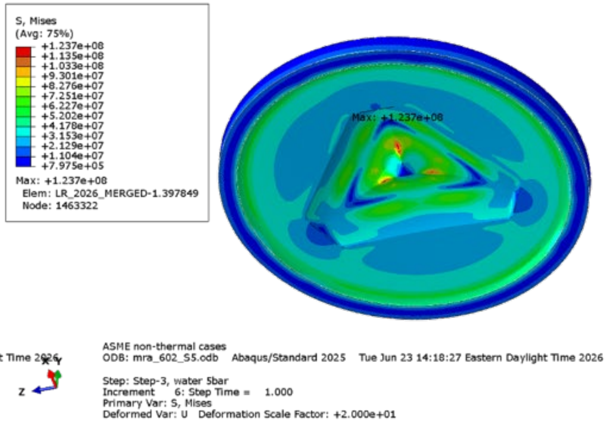




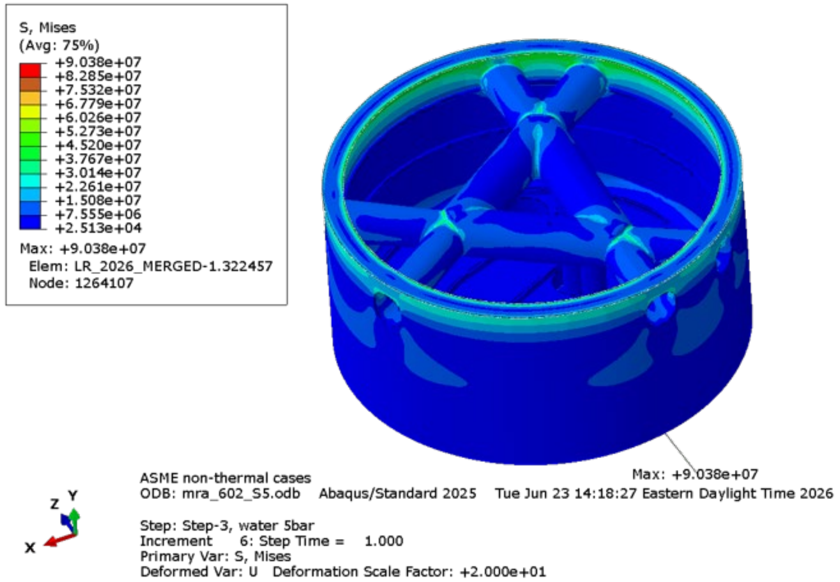
Abaqus case 1 Lower Reflector Vessel Stress

Mises Stress peak 123.7 MPa on lid inside surface





Mises Stress showing weld zones below 83 MPa

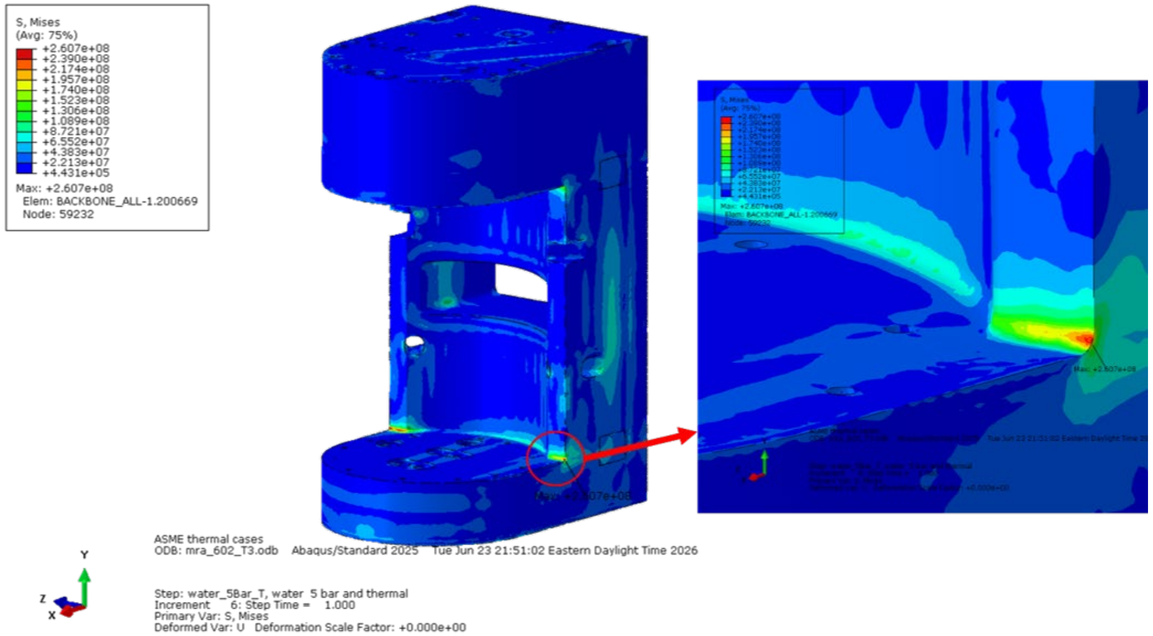


Load Cases and peak stress and displacement results

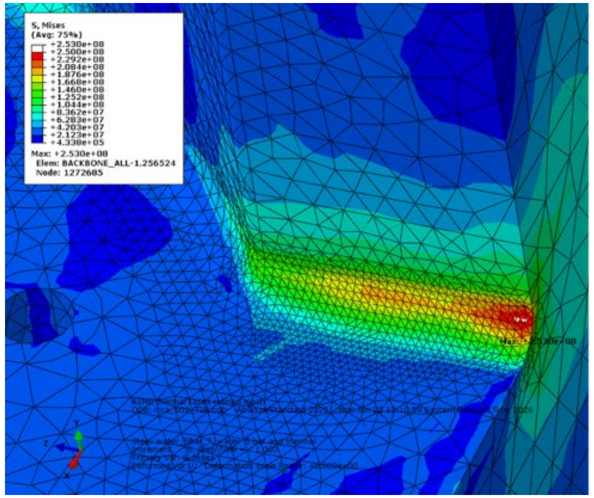
ASME Case	Abaqus case	Water Pressure (bar)	Core Vessel (bar)	Weight	Vac (bar)	Seismic load	Thermal	SS S max (MPa)	Al S max (MPa)	U Max (mm)
1	1	5	0	D				127	126	0.99
1	3	3	0	D	2			126	121	0.61
3	10	3	1	D			T	258	113	0.84
3	8	5	0	D			T	261	139	1.11
5	7	3	0	.6D		.7E overturn		126	122	0.61
6	4	3	0	D		.7 Ex		126	124	0,61
6	5	3	0	D		.7Ez		126	120	0.61
6	6	3	0	D		.7Ey		126	121	0.61
9	9	3	0	D			T	259	114	0.85
18	2	5.75	0	D				128	145.5	1.13
	11	3	0	D	2		T	259	114	0.85

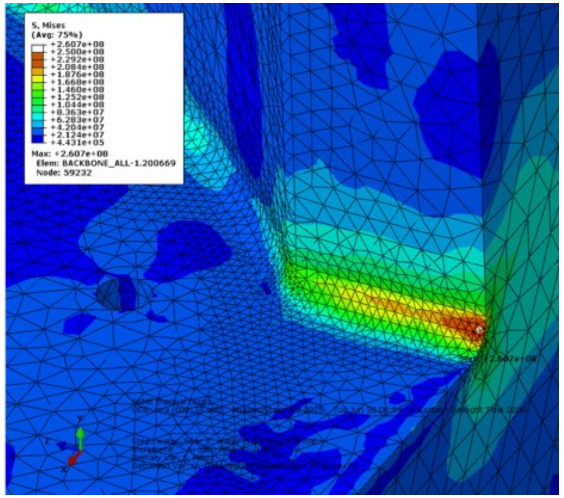
Abaqus Case 8 - 5 bar water pressure and thermal

Peak Stress 261 MPa



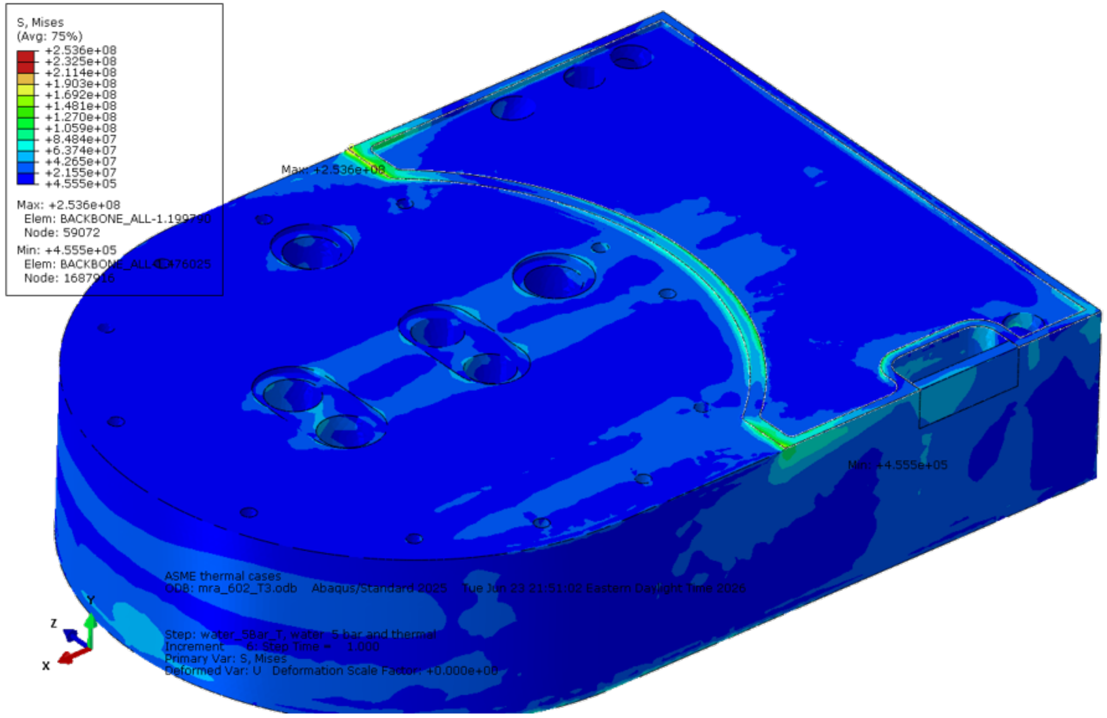
Peak with mesh refinement 253 MPa



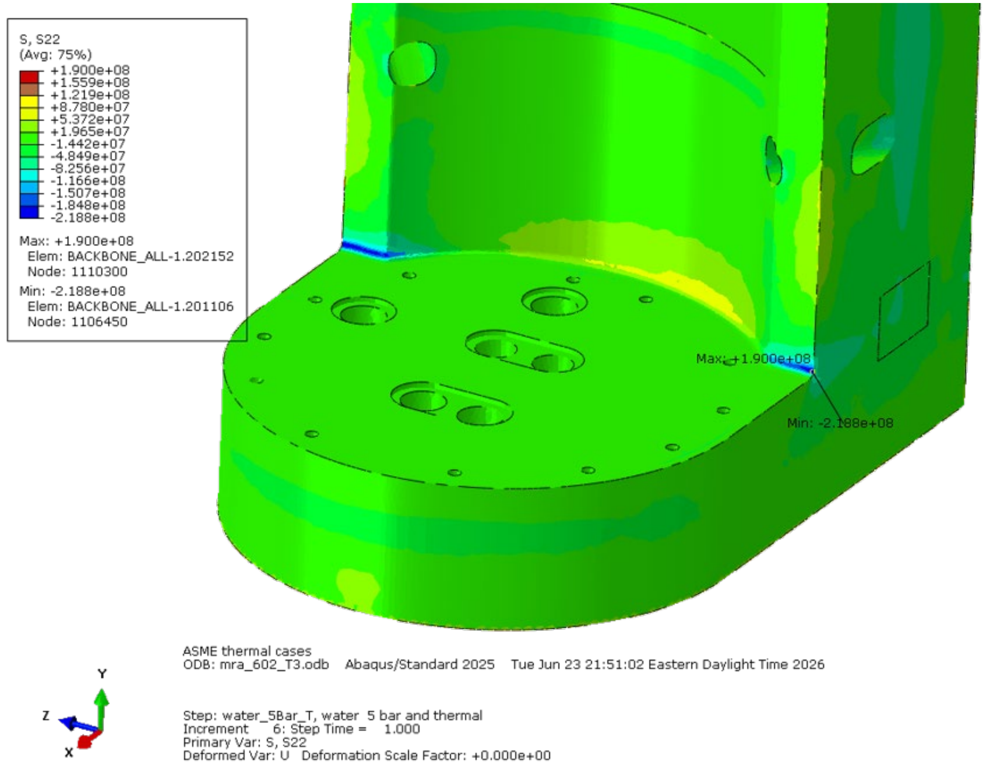


Abaqus Case 8 - 5 bar water pressure and thermal

Middle backbone to lower backbone weld stress

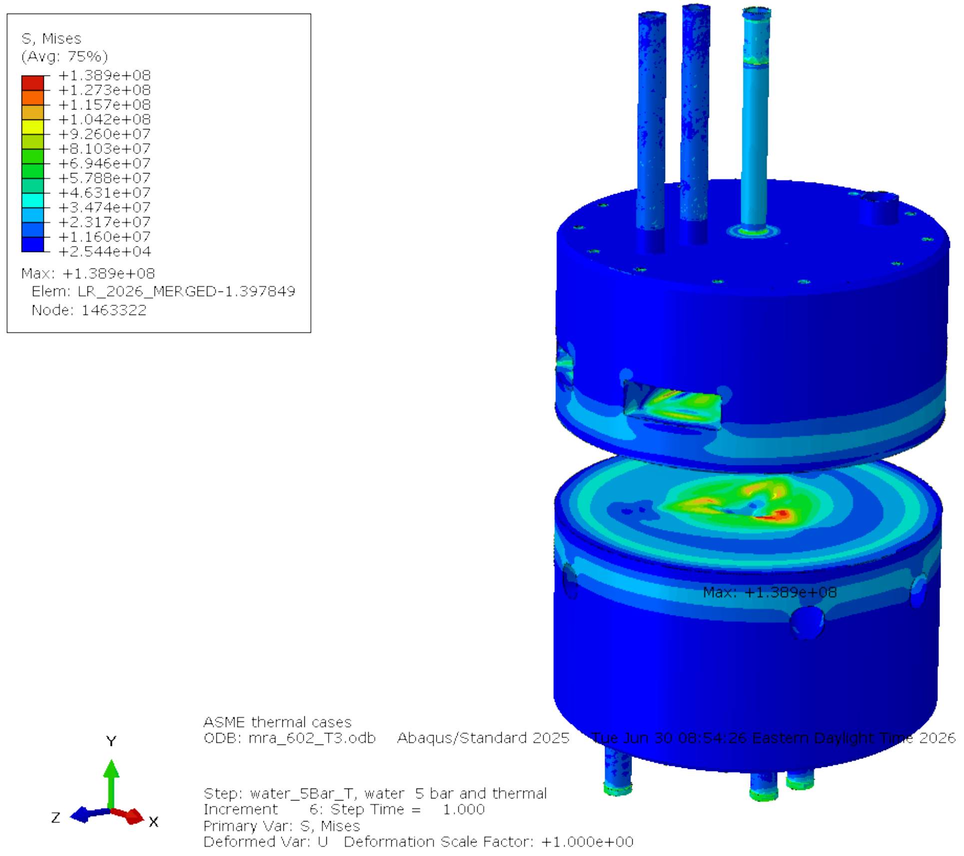


Vertical stress showing compression at peak location

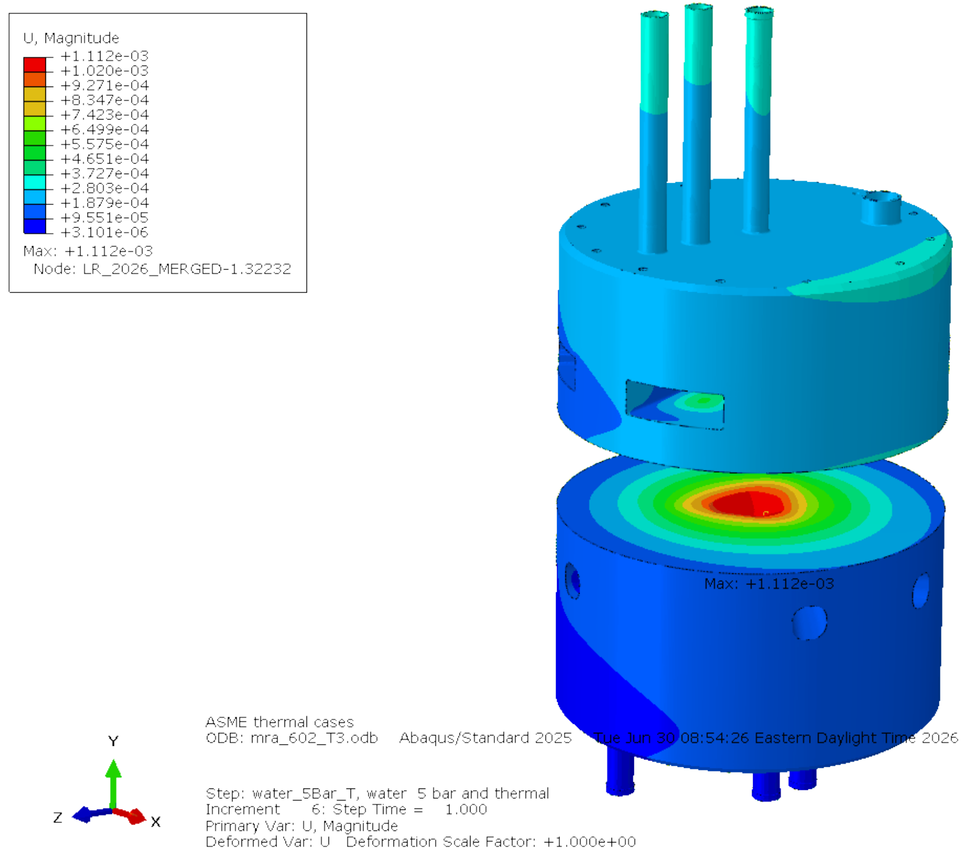


Abaqus Case 8 - 5 bar water pressure and thermal- Reflector Vessel stress and displacement

Peak 139 MPa – below 3Sm limit of 254 MPa

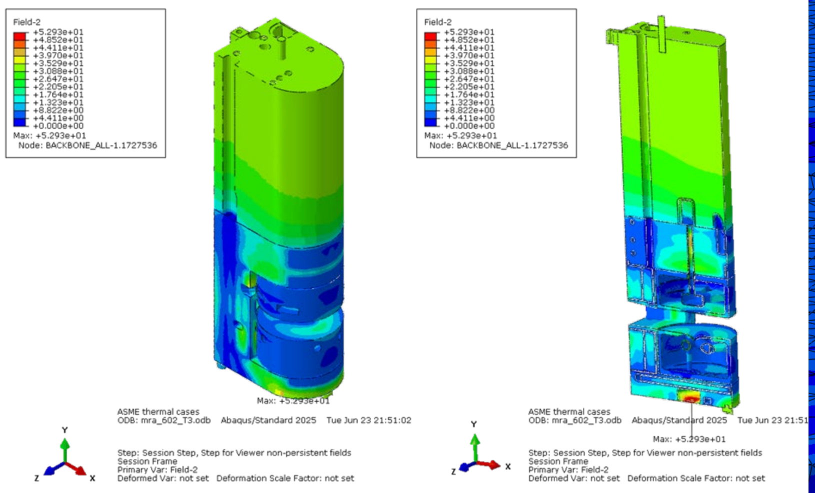


Peak Displacement 1.1 mm below 1.5 mm limit

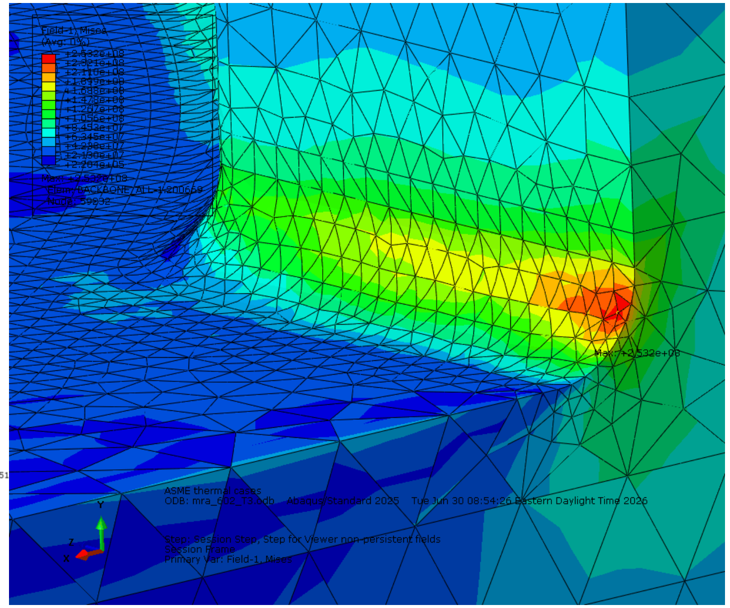


Abaqus case 9 Normal operation 3 bar water and thermal fatigue evaluation

Temperature change after beam trip – 53 °C max



Backbone peak 0 % averaging 253 MPa at peak location

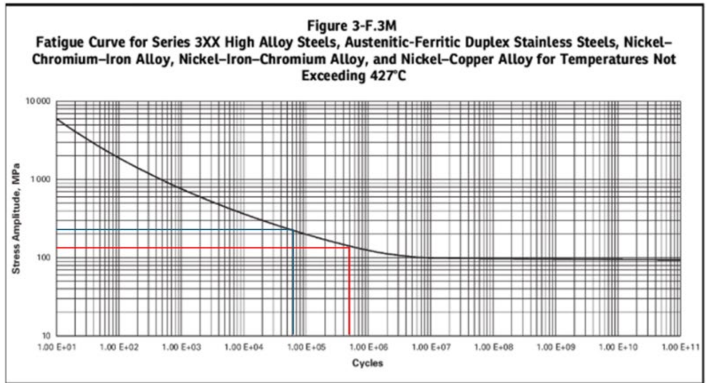


Fatigue life 50 years

316L Peak
253 MPa
Sa= 126.5 MPa

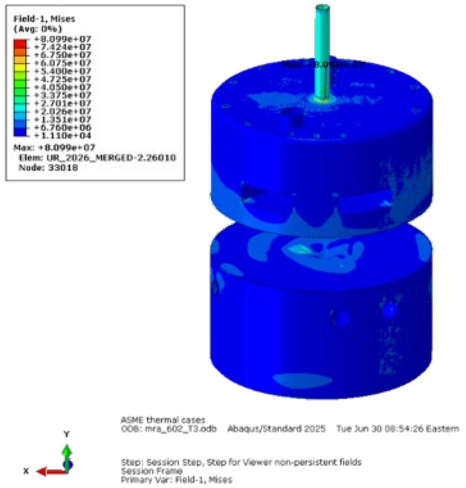
Life ~5x 10^5 cycles
Life ~ 50 years

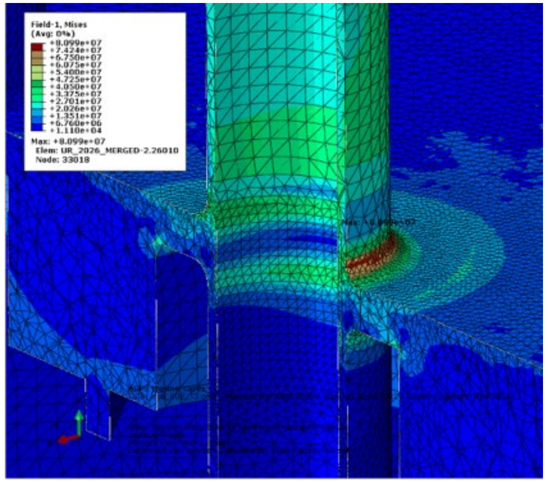
6e4 cycles ~
6 years
Sa ~210MPa
S~420 MPa



Abaqus case 9 Normal operation 3 bar water and thermal fatigue evaluation

Reflector Vessel – thermal fatigue peak stress 80.9 MPa in upper vessel



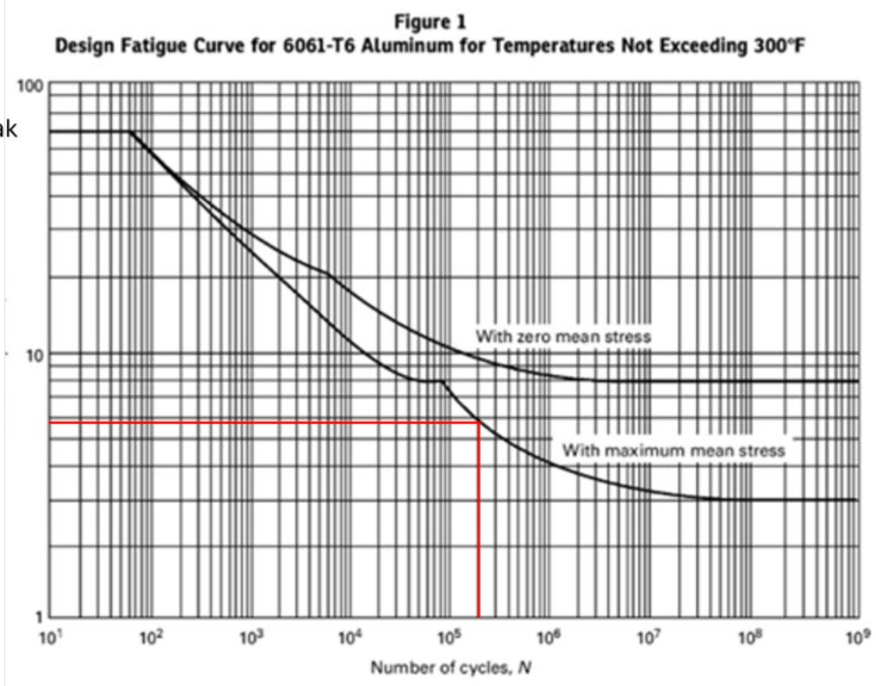


Al6061T6 fatigue life minimum 20 years

Upper Reflector Peak
80.9 MPa
11.7 ksi
Sa= 5.87 ksi

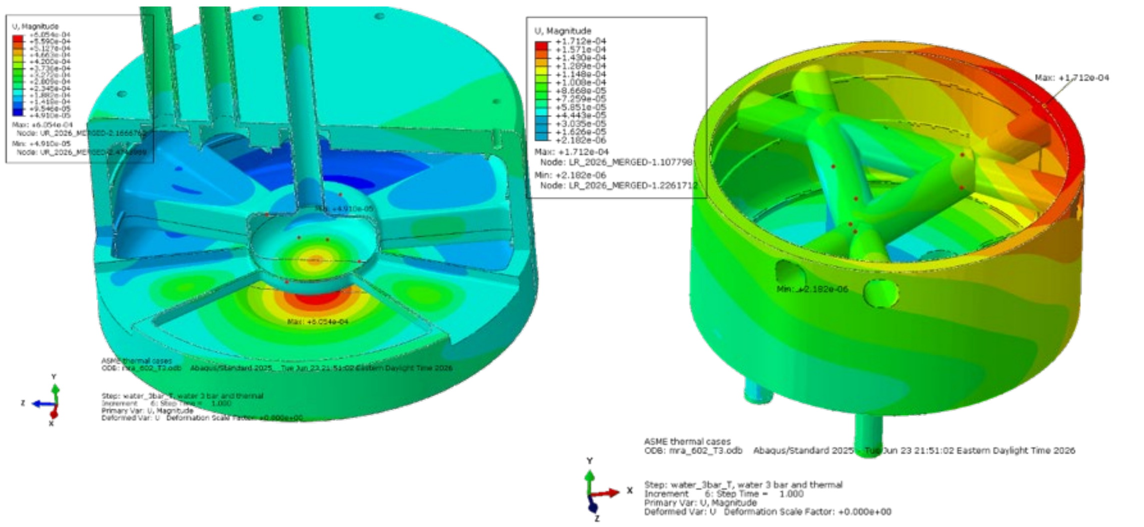
Life ~ 2 x 10^5 cycles
Life ~ 20 years

Lower Reflector Peak
68 MPa
9.9 ksi
Sa 4.9ksi
Life~ 3 x 10^5 cycles
Life ~ 30 years



Normal operation hydrogen vessel 6 support point locations and displacements for upper and lower reflector vessels

Displacement (m) and attachment points in red



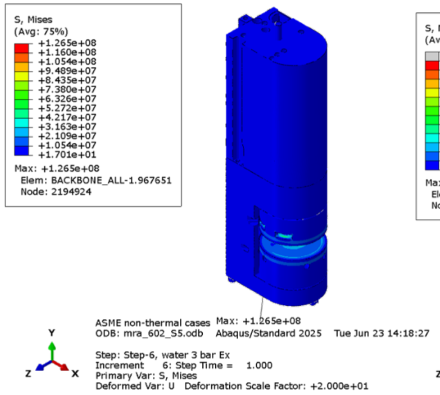
Attachment point closest node displacements

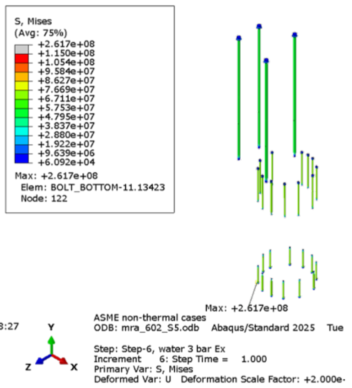
		Node base location (mm)			Node displacements (mm)			
	NODE #	X	Y	Z	magnitude	ux	uy	uz
Upper								
U1	1387493	-0.497	85.700	-38.733	0.230	0.161	0.165	-0.008
U2	60962	-33.081	85.700	19.796	0.234	0.136	0.189	0.018
U3	1368983	33.787	85.700	19.796	0.246	0.178	0.168	0.023
U4	1158278	-0.290	132.280	38.964	0.192	0.166	0.091	0.033
U5	1604049	-34.048	132.280	-19.700	0.187	0.155	0.105	0.004
U6	1493301	34.048	132.280	-19.654	0.206	0.186	0.090	0.009
Lower								
L1	2010272	72.728	-81.651	0.039	0.111	0.011	0.110	0.015
L2	151810	-43.697	-81.508	54.408	0.078	-0.029	0.066	0.028
L3	151761	-43.697	-81.508	-54.408	0.078	-0.022	0.074	-0.015
L4	2157730	72.727	-121.349	-0.039	0.091	0.026	0.086	0.012
L5	153775	-43.697	-121.492	54.408	0.054	-0.021	0.041	0.028
L6	152931	-43.697	-121.492	-54.408	0.055	-0.014	0.048	-0.022

Abaqus case 4 -Seismic Ex load in beam direction example

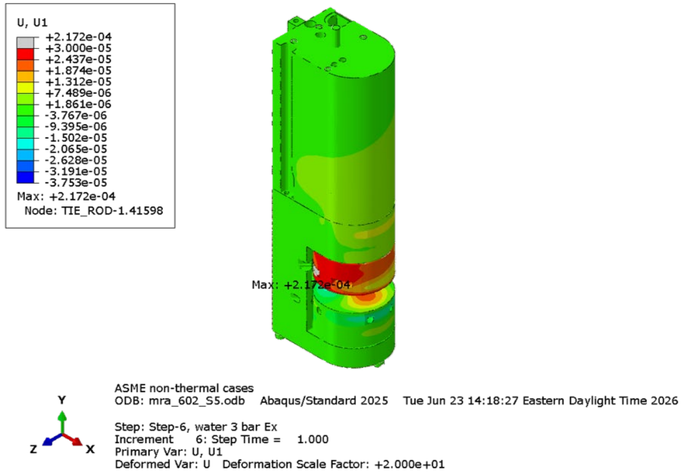
Peak assembly stress without bolts and tie rods - 126 Mpa

Bolt and tie rod axial stress < 115 MPa





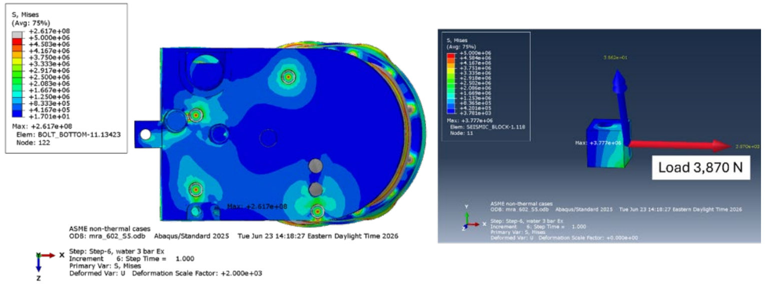
Displacement toward target center (m) – peak .22 mm



Stress (Pa)

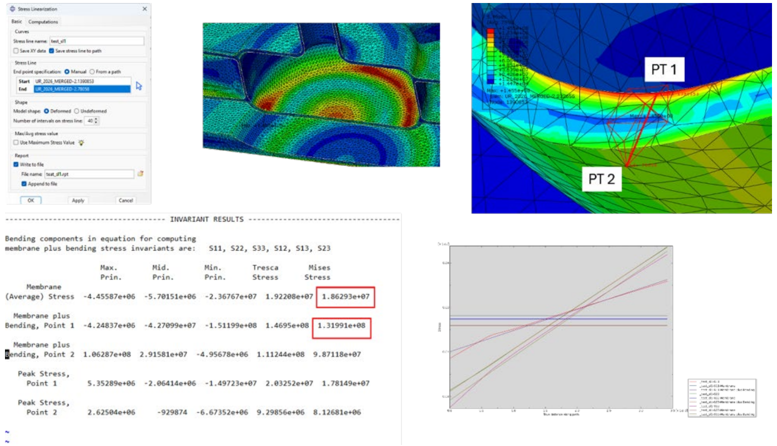
Displacement x 2000

Seismic block load 3,870 N



Abaqus case 2 Test pressure

Upper Vessel



INVARIANT RESULTS

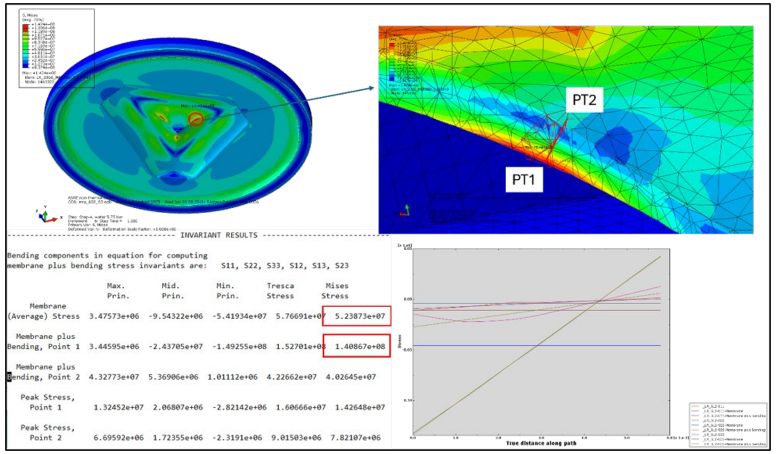
Bending components in equation for computing membrane plus bending stress invariants are: S11, S22, S33, S12, S13, S23

	Max. Prin.	Mid. Prin.	Min. Prin.	Tresca Stress	Mises Stress
Membrane (Average) Stress	-4.45587e+06	-5.70151e+06	-2.36767e+07	1.92208e+07	1.86293e+07
Membrane plus Bending, Point 1	-4.24837e+06	-4.27099e+07	-1.51199e+08	1.4695e+08	1.31991e+08
Membrane plus Bending, Point 2	1.06287e+08	2.91581e+07	-4.95678e+06	1.11244e+08	9.87118e+07
Peak Stress, Point 1	5.35289e+06	-2.06414e+06	-1.49723e+07	2.03252e+07	1.78149e+07
Peak Stress, Point 2	2.62504e+06	-929874	-6.67352e+06	9.29856e+06	8.12681e+06

P_m=18.7 MPa

P_m+P_b=131MPa

Lower Vessel



INVARIANT RESULTS

Bending components in equation for computing membrane plus bending stress invariants are: S11, S22, S33, S12, S13, S23

	Max. Prin.	Mid. Prin.	Min. Prin.	Tresca Stress	Mises Stress
Membrane (Average) Stress	3.47573e+06	-9.54322e+06	-5.41934e+07	5.76691e+07	5.23873e+07
Membrane plus Bending, Point 1	3.44595e+06	-2.43705e+07	-1.49255e+08	1.52701e+08	1.40867e+08
Membrane plus Bending, Point 2	4.32773e+07	5.36906e+06	1.01112e+06	4.22662e+07	4.02645e+07
Peak Stress, Point 1	1.32452e+07	2.06807e+06	-2.82142e+06	1.60666e+07	1.42648e+07
Peak Stress, Point 2	6.69592e+06	1.72355e+06	-2.3191e+06	9.01503e+06	7.82107e+06

P_m=52 MPa

P_m+P_b=141MPa

Criteria evaluation

The elastic stresses in the upper reflector vessel for the test pressure case were evaluated against the criteria in ASME case 4.1.6.2 Test Conditions. The shell with the peak stress is Al6061T6 with a yield stress (Sy) of 227.5 MPa (33 ksi). The membrane stress as shown in Figure 82 is 18.6 MPa which is less than Sy/1.5 so the acceptance criteria is

$P_m+P_b < \gamma_{min}Sy$

Where

γ_{min} = 1.5 β_γ and β_γ =.8 for pneumatic testing and $\gamma_{min}Sy$ = 273 MPa

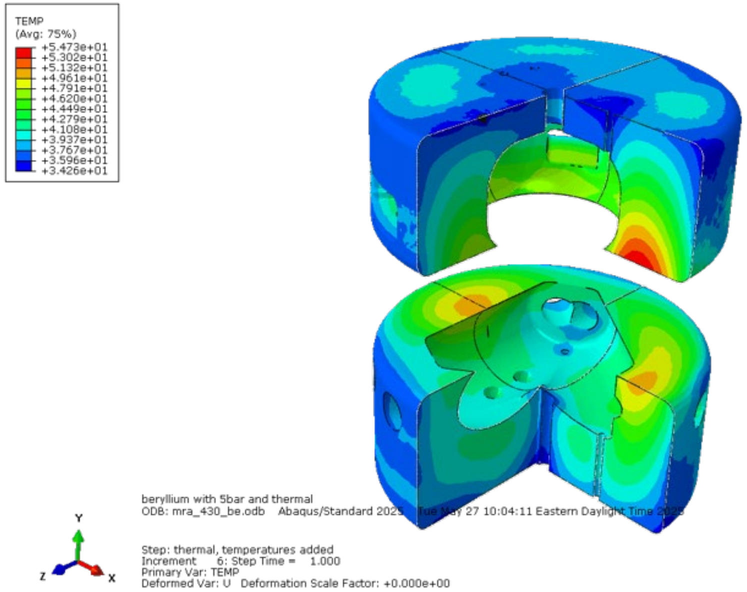
For this case P_m+P_b = 131 MPa at point 1 which is less than $\gamma_{min}Sy$

A similar analysis for the lower vessel was done. Stress linearization point 1 was the high stress node at 142 MPa. The membrane stress was 52 MPa and membrane plus bending was 141 MPa would show the elastic test condition criteria of <273 MPa is met.

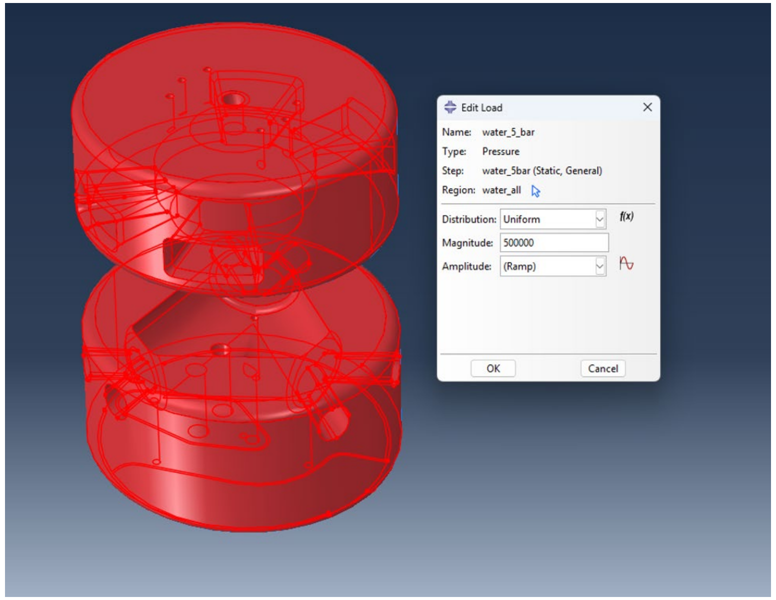
Beryllium stress analysis and Reflector Vessel Buckling analysis

Beryllium analyzed separately with 5 bar pressure and imported temperature profile

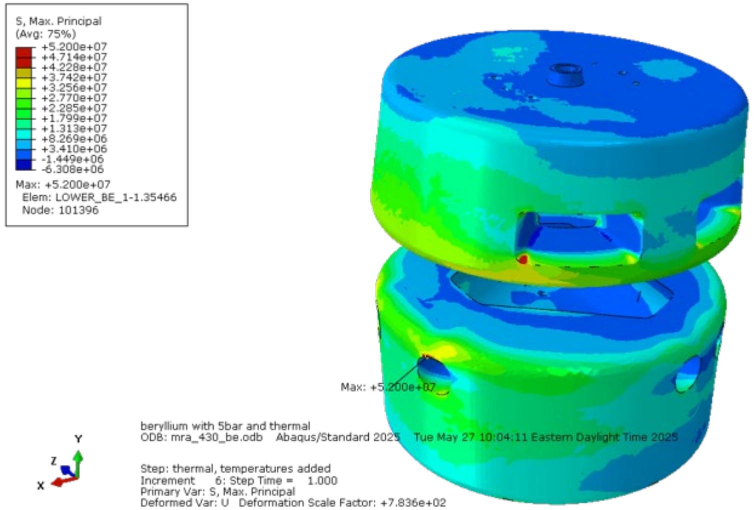
Temperatures



5 bar Pressure



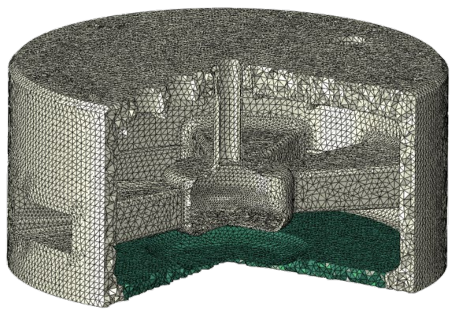
Max Principal stress 52 MPa

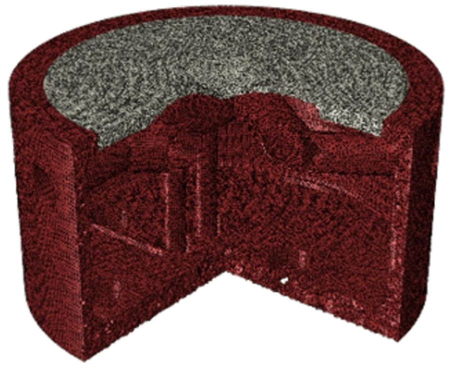


Stresses well below yield of 241 MPa (35 ksi) and ultimate strength of 324 MPa (47 ksi).

Buckling analysis per ASME Method B Section 5.4.3 with elastic-plastic properties

Materials - T6 – green upper, tan lower

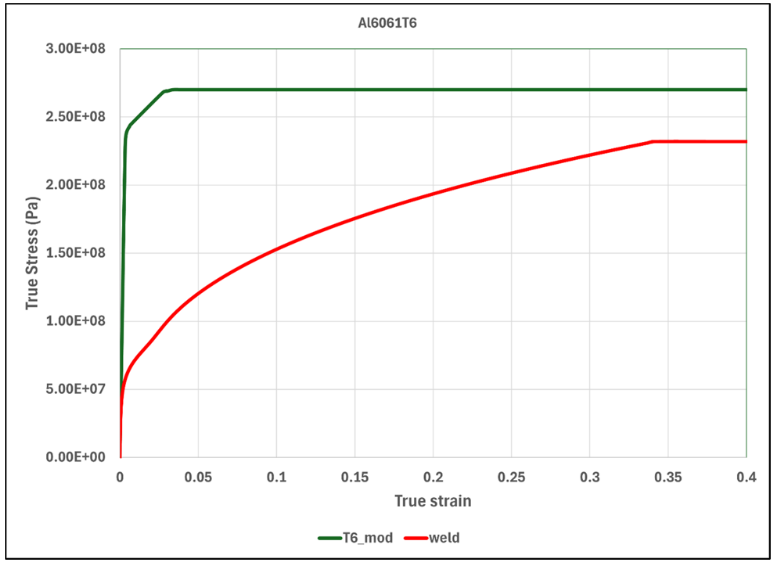




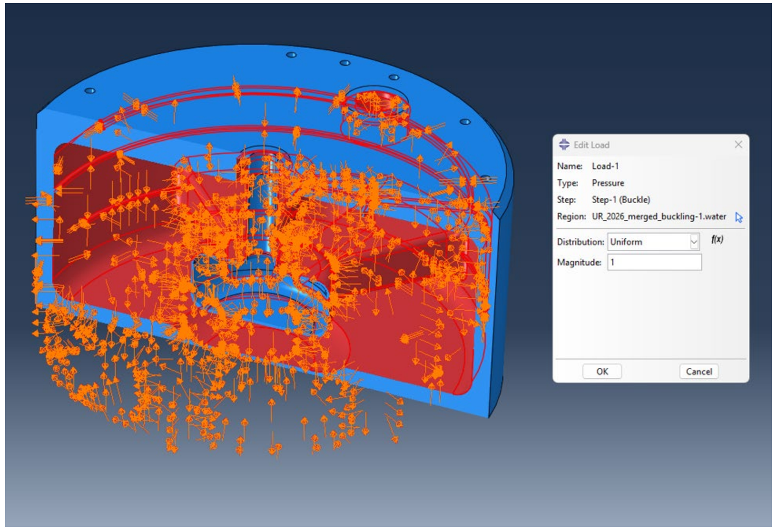
Analysis cases

ASME Case	Abaqus Step	Water Pressure (P bar)	Core Vessel pressure(bar)	Weight (D)	Vacuum Space Pressure (bar)	Seismic load (E)	Thermal T
1	1	8.35		1.67 *D			
5	2	7.348		1.47 *D		1.186 Ex	
5	3	7.348		1.47 *D		1.186 Ez	
5	4	7.348		1.47 *D		1.186 Ey	
2	5	7.348		1.47 *D			T with 1.47*CTE

Elastic- plastic properties



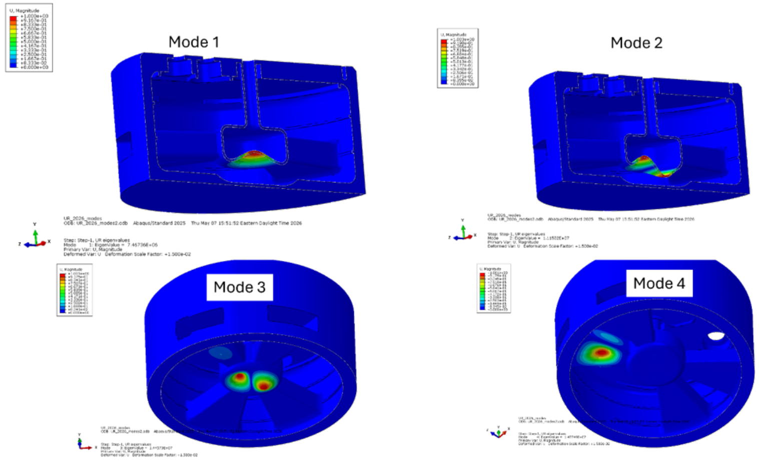
Upper Vessel Eigenvalue analysis



Eigenvalues

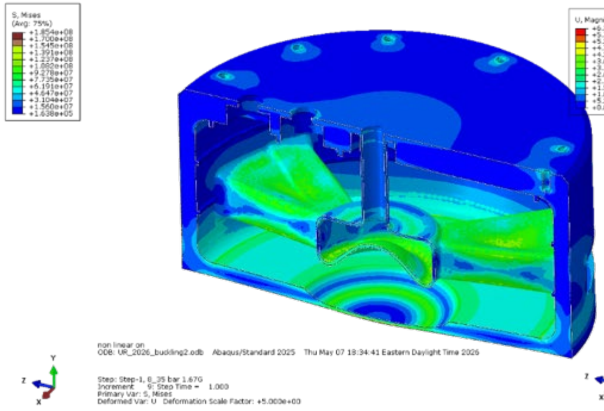
Mode	Eigenvalue	FOS 5 bar
1	7.46736E+06	14.9
2	1.11582E+07	22.3
3	1.44570E+07	28.9
4	1.47749E+07	29.5
5	1.74690E+07	34.9
6	1.79560E+07	35.9
7	1.80531E+07	36.1
8	1.93045E+07	38.6
9	1.94791E+07	39.0
10	2.00320E+07	40.1

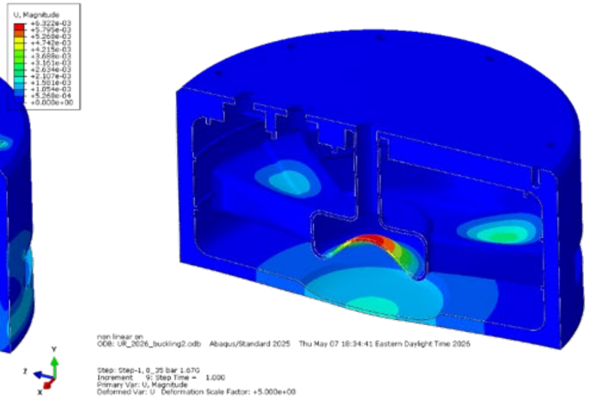
Mode Shapes



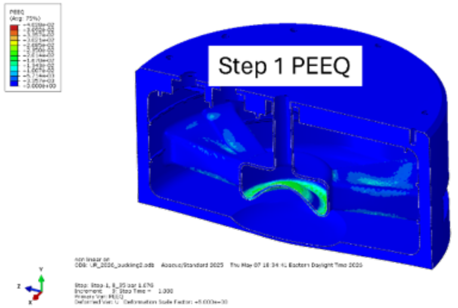
Buckling analysis with .25mm initial deformed shape from mode 1

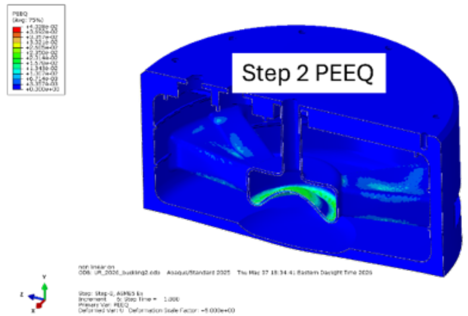
Upper Vessel Step 1 Stress and displacement

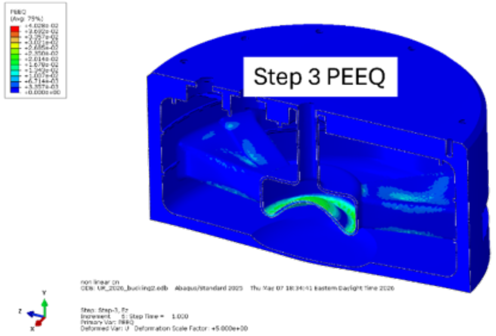


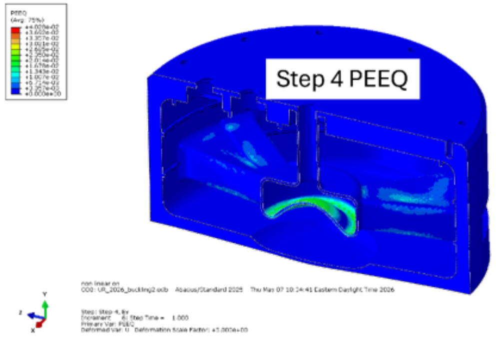


Step 1-4 PEEQ – all converged showing stable



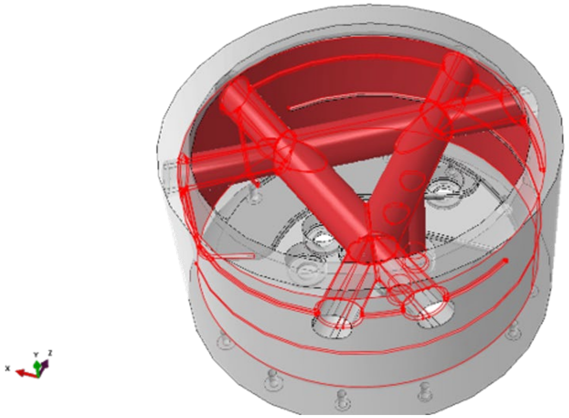




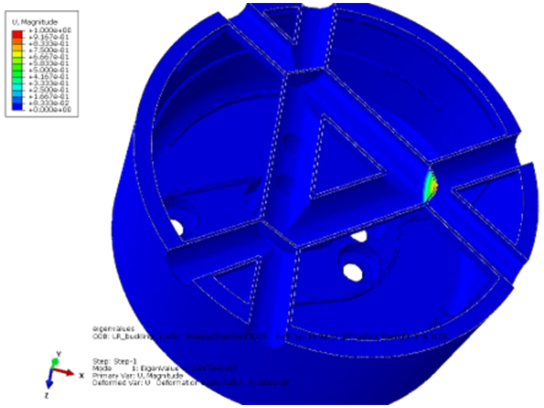


Lower Reflector vessel pressure load surfaces and eigenvalue evaluation with mode shapes

Pressure on surface subject to buckling

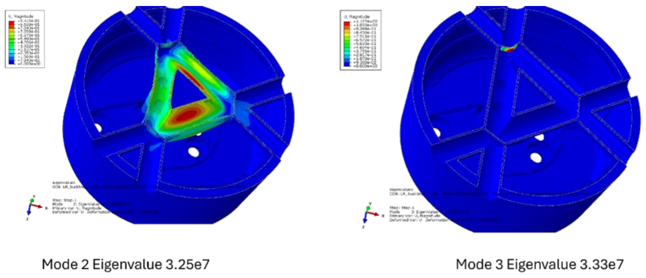


Mode 1 shape



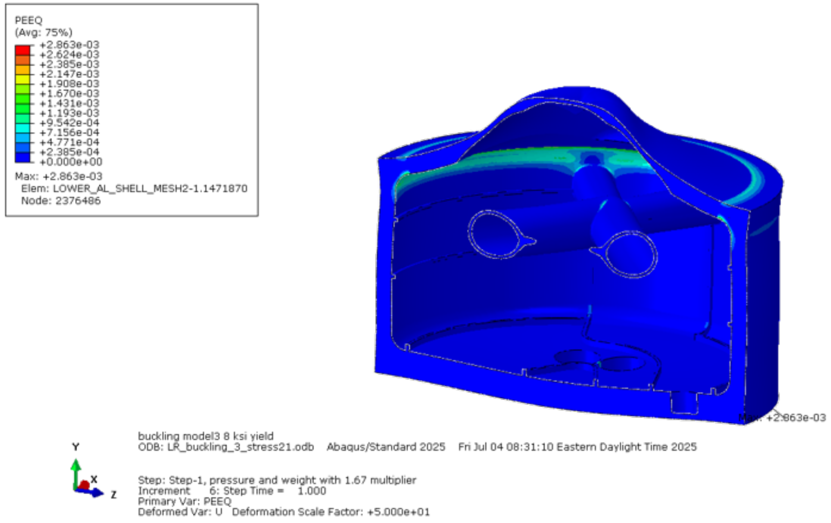
Mode 1 Eigenvalue 2.92e7

Modes 2 and 3

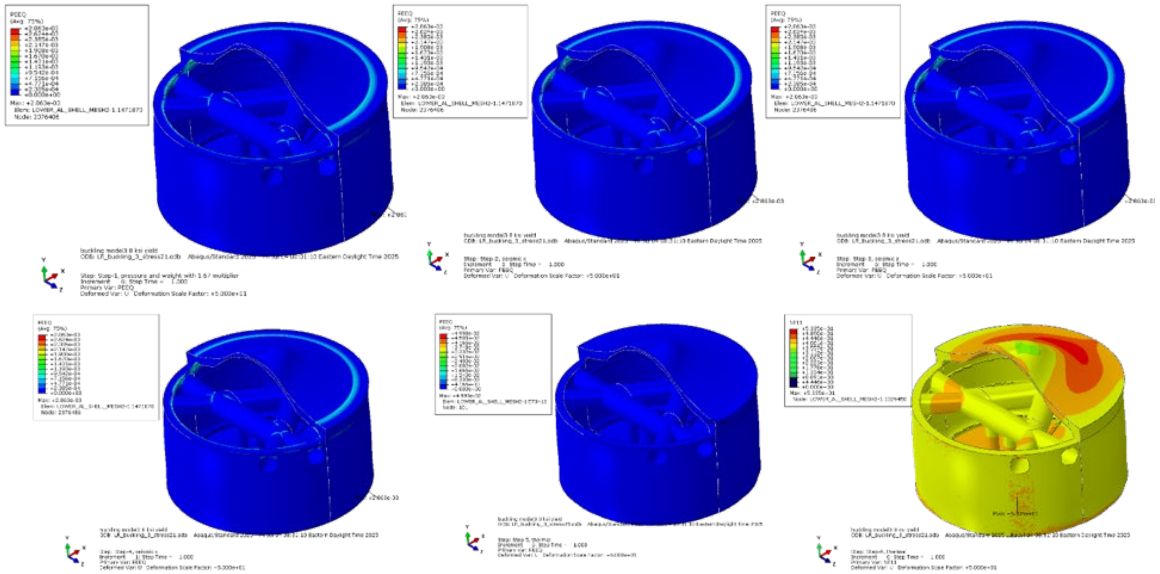


Buckling analysis with .25mm initial deformed shape from mode 1

Mode 1 PEEQ converged



All modes converged showing stable



Conclusions – requirements met

Summary	Description	Results
MRA cyclic loading Requirement	The MRA shall be designed for a lifetime of 5 years (25000 hours of 700 kW beam power operation) or more with respect to cyclic loading. The hydrogen boundaries are expected to experience 50 full pressure cycles during commissioning and 10 full pressure cycles per year during operation. Hydrogen pressure is expected to fluctuate 2 bar or less during beam trips and ramps. The water boundaries are expected to experience 20 pump start cycles during commissioning and 4 pump start cycles per year during operation. A pump start cycle is expected to produce an MRA water pressure change of 1 bar or less. No full pressure cycles are expected for the water boundaries. 10000 beam trips are expected to occur each year.	2339 Pass – 50 year life backbone 20 year upper reflector and 30 year lower reflector
MRA Vacuum Vessel Requirement	The MRA vacuum vessels shall be designed to the intent of the 2023 ASME BPVC. Applied seismic loads shall be derived from the NPH BOD.	2893 Pass
MRA Reflector Vessel Requirement	The MRA backbone shall be designed to the intent of the 2023 ASME BPVC. Applied seismic loads shall be derived from the NPH BOD.	2355 Pass
MRA Backbone Requirement	The MRA reflector vessels shall be designed to the intent of the 2023 ASME BPVC. Applied seismic loads shall be derived from the NPH BOD.	10921 Pass
MRA Vacuum Boundary Pressure Requirement	The MRA vacuum boundary MAWP shall be 2 bara.	2358 Pass
MRA Water Boundary Pressure Requirement	The MRA water boundaries shall have a MAWP of 5 bara	2361 Pass
MRA Deflection Requirement	The MRA outside surfaces shall not deflect more than +/- ~ 1.5 mm from their installed locations under any expected loading conditions.	2994 Pass Peak 1.1 mm
MRA Moderator Operational Displacement Requirement	The MRA moderators shall have a displacement of 0.3 mm or less relative to the MRA mounting points from installation to 700 kW operation.	2892 Pass peak .25mm