OAK RIDGE National Laboratory

Vessel Systems (S.03.06) Shield Block #1 Thermal and Structural Analysis

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09/04/2024

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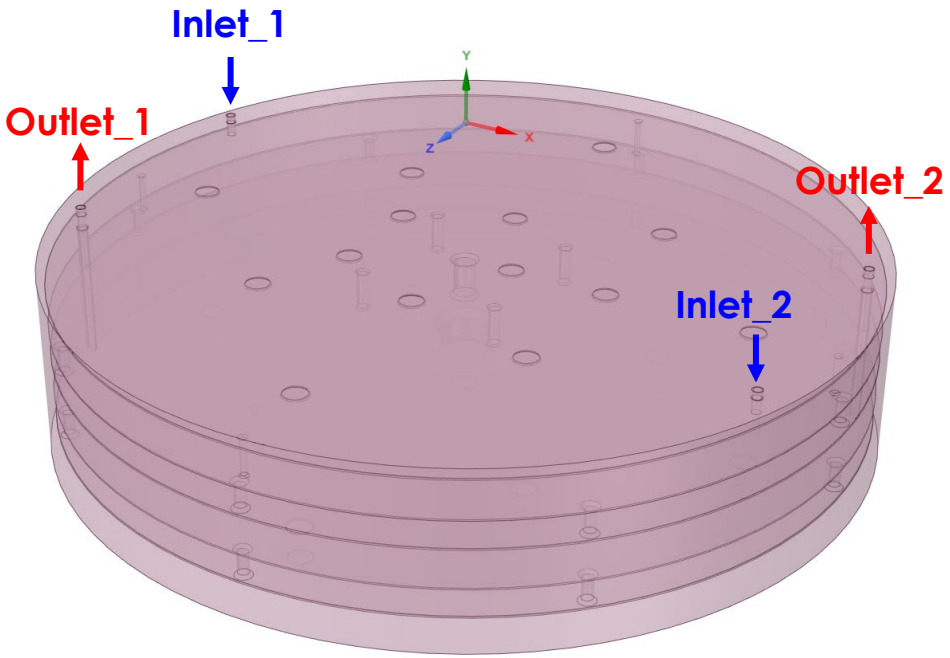
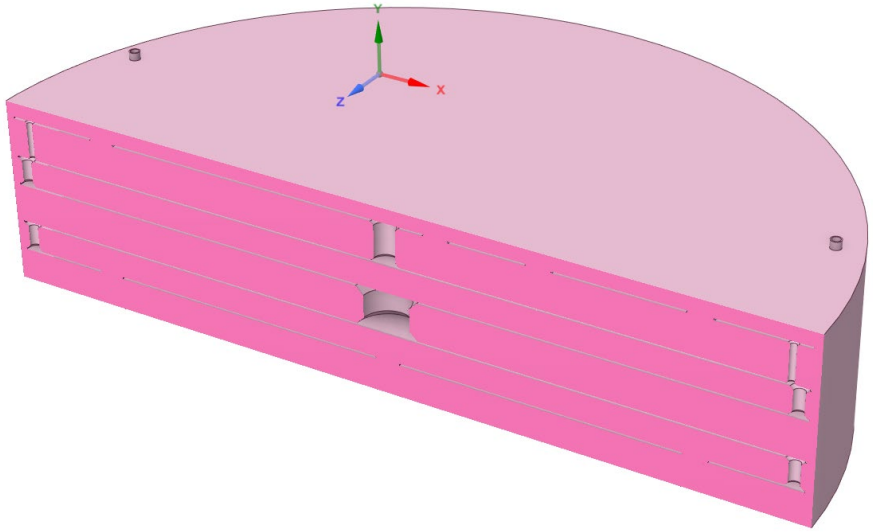
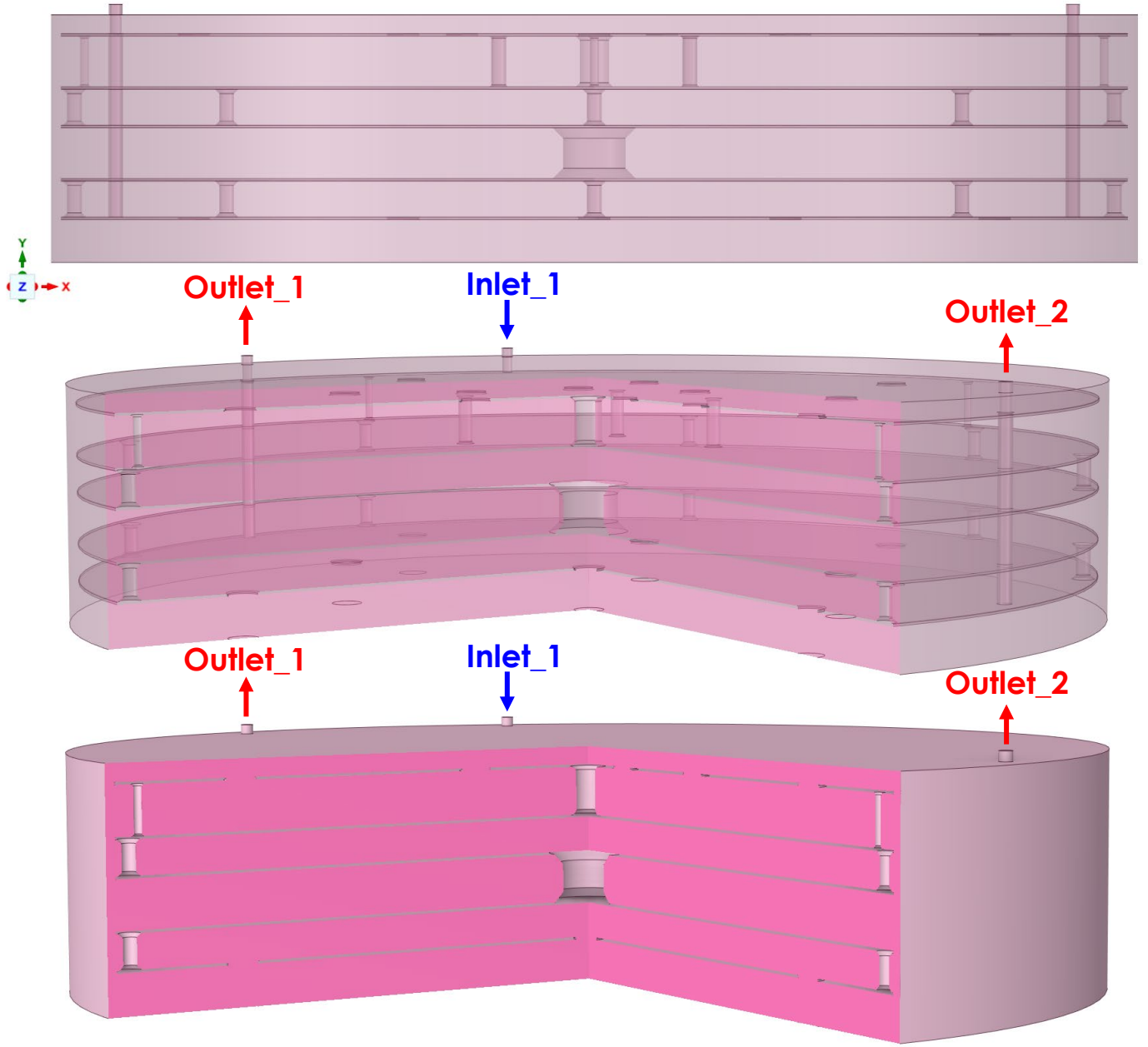
U.S. DEPARTMENT OF ENERGY

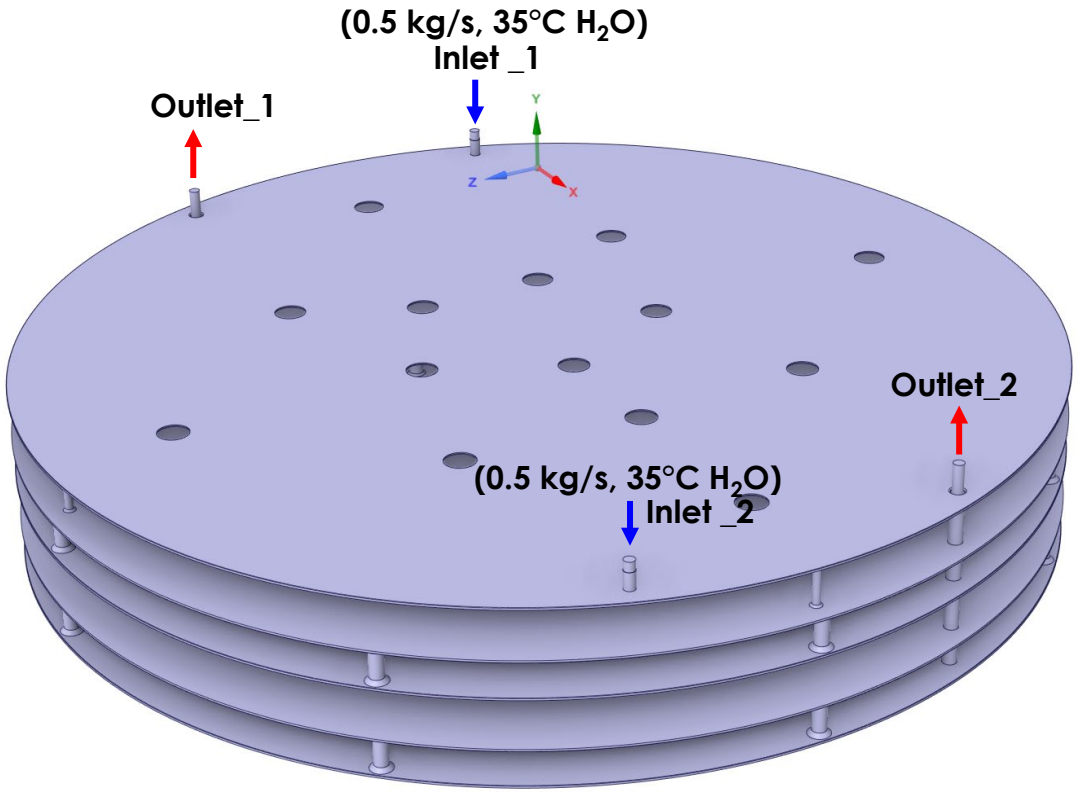
Shield Block # 1(from 02/05/2024), SS316, Solid

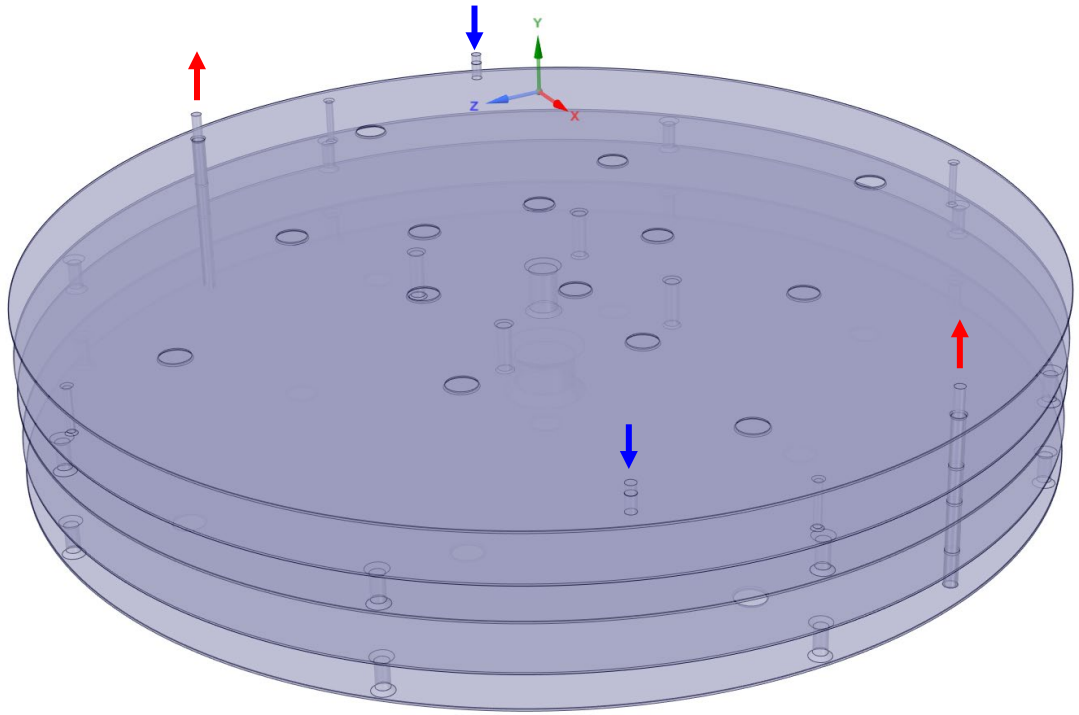


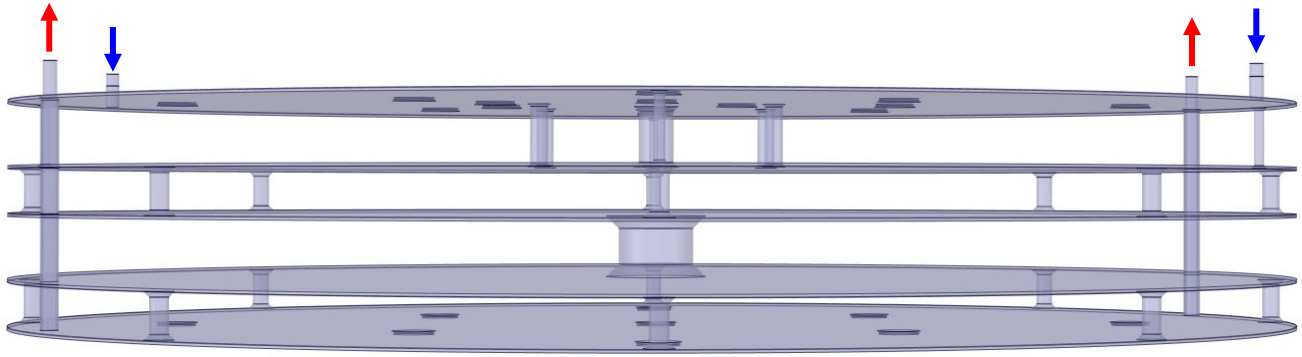




Shield Block # 1(from 02/05/2024), Water







Material Properties

SS316 Material Properties From Ansys

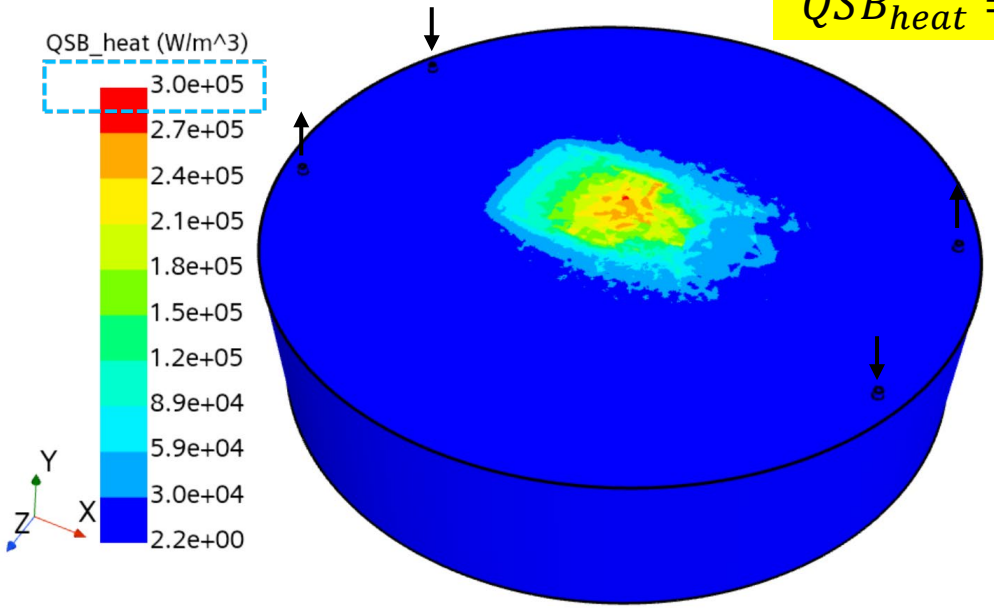
Stainless steel, 316, annealed
Data compiled by Ansys Granta, incorporating various sources including JAHM and MagWeb.

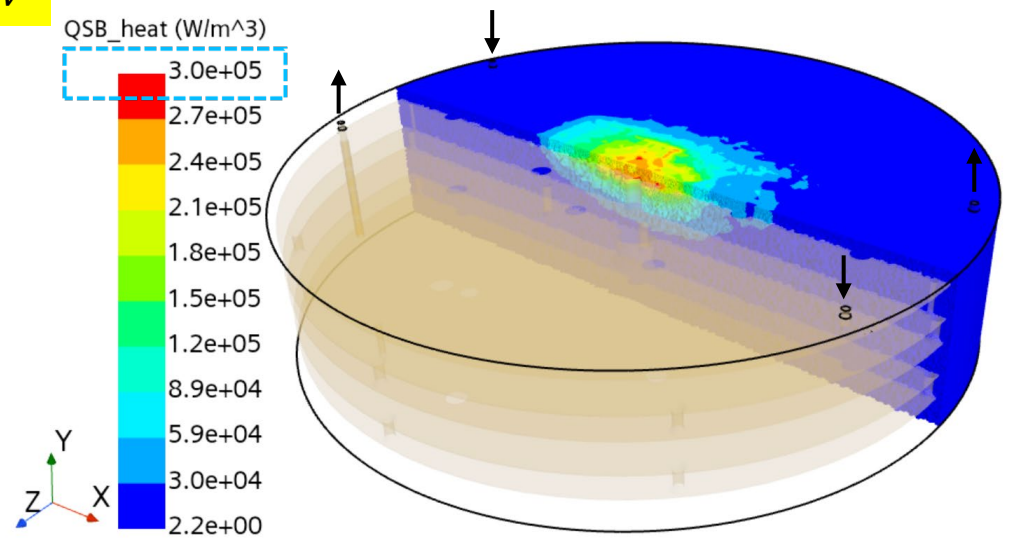
Density (kg/m^3)	**7969**
Coefficient of Thermal Expansion (1/K)	**1.61E-05**
Specific Heat (J/kg-K)	**486.1**
Thermal Conductivity (W/m-K)	**14.58**
Young's Modulus (Pa)	**1.95E+11**
Poisson's Ratio	**0.27**
Bulk Modulus (MPa)	**1.413E5**
Shear Modulus (MPa)	**76772**
Tensile Ultimate Strength (MPa)	**565.1**
Tensile Yield Strength (MPa)	**252.1**

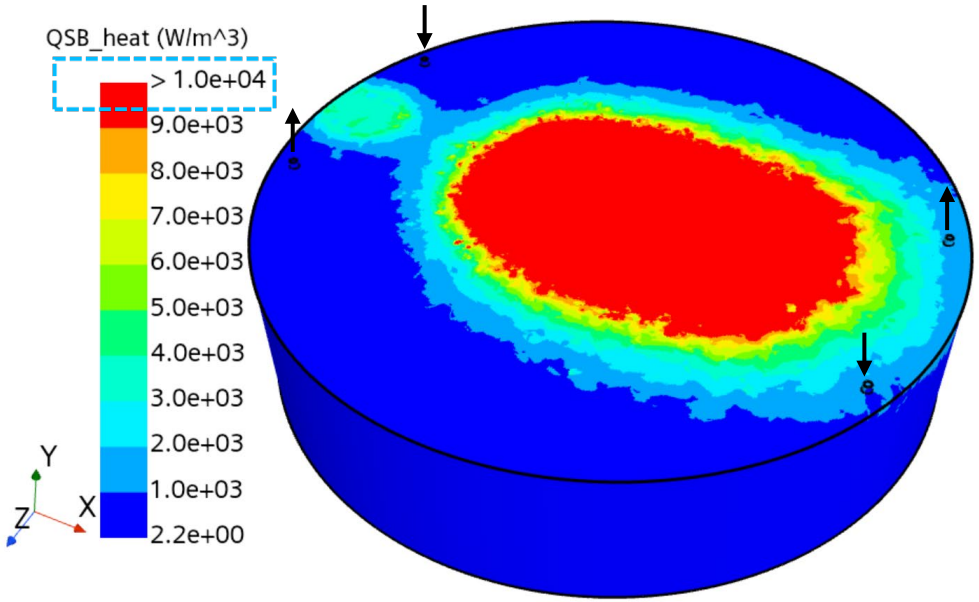
Heat Source and Cooling Channel of Shield Block #1 (SS316)

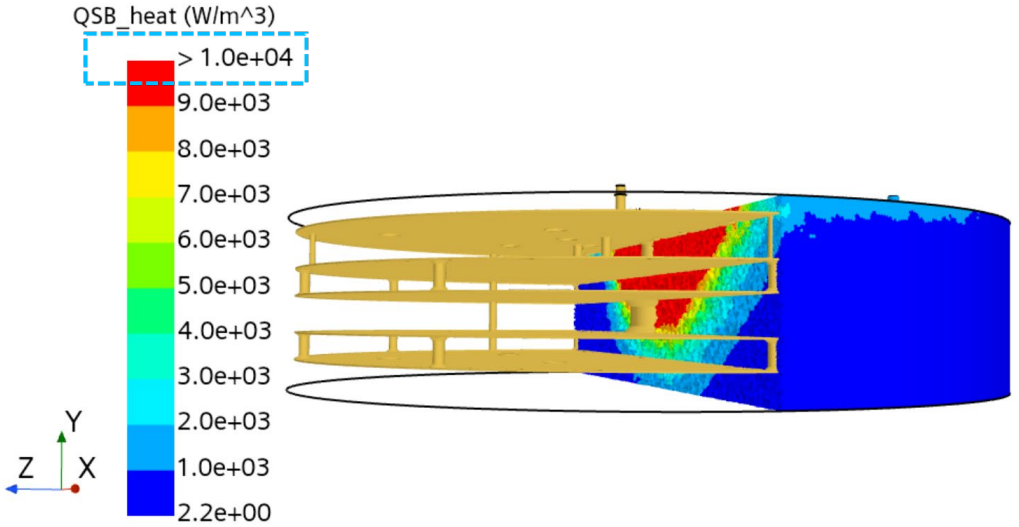
Neutronics Heating from Lukas (2023) Link https://ornl.sharepoint.com/sites/sts/targetsystems/Shared%20Documents/Forms/AllItems.aspx?csf=1&web=1&e=llwgp7&cid=939335e4%2D4ccc%2D4c00%2Da2d2%2D814c53b7125a&FolderCTID=0x01200064187E8E25420543ACAD0BF1C3490EAC&noAuthRedirect=1&id=%2Fsites%2Fts%2Ftargetsystems%2FShared%20Documents%2FS%2E03%2E02%20Target%20Assembly%2F1%5FCALCULATIONS%2FCALC%2D018%20%2D%20CoreVessel%2FNeutronics&viewid=9be9bc88%2D5a13%2D48c7%2D9fff%2Dd22f94ffdeb5

$$QSB_{heat} = 12.56\ kw$$





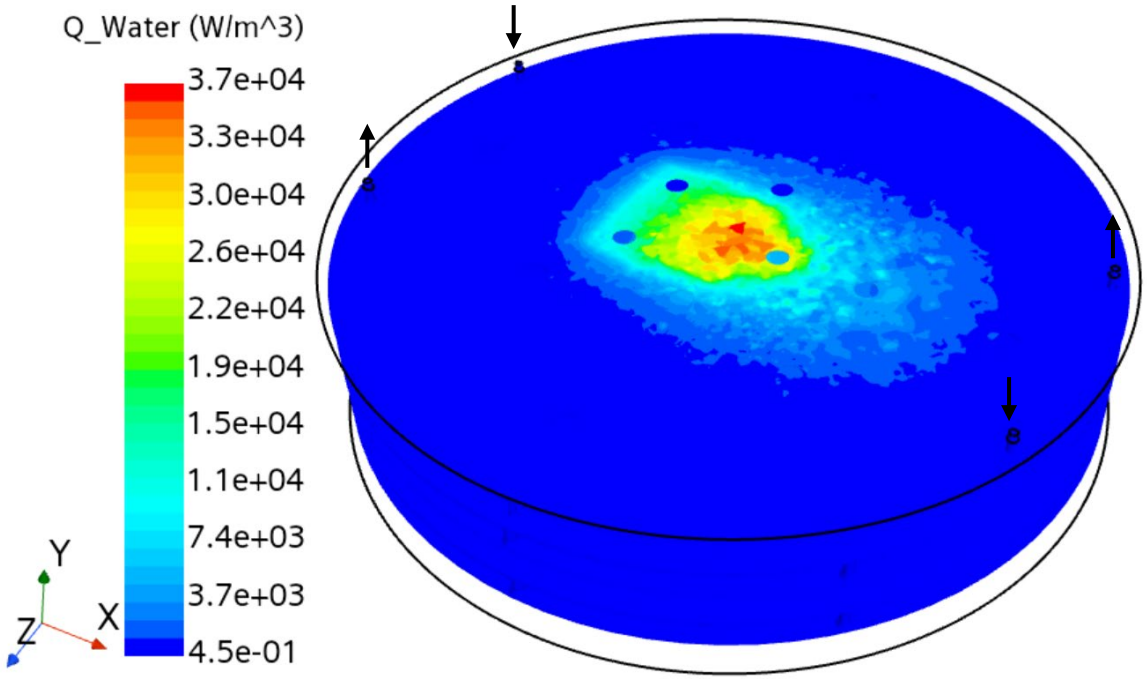


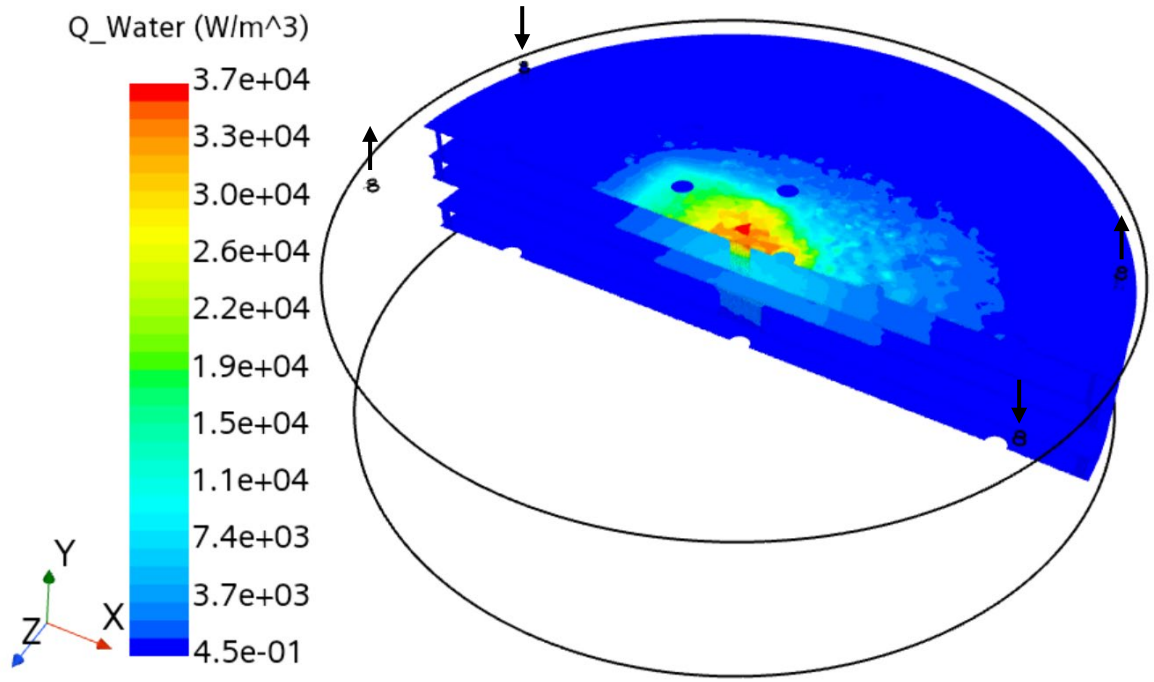


Heat Source in Water

Q_Water approximation: $Q_{water} = QSB_{heat} * \frac{\rho_{water}}{\rho_{SS}}$

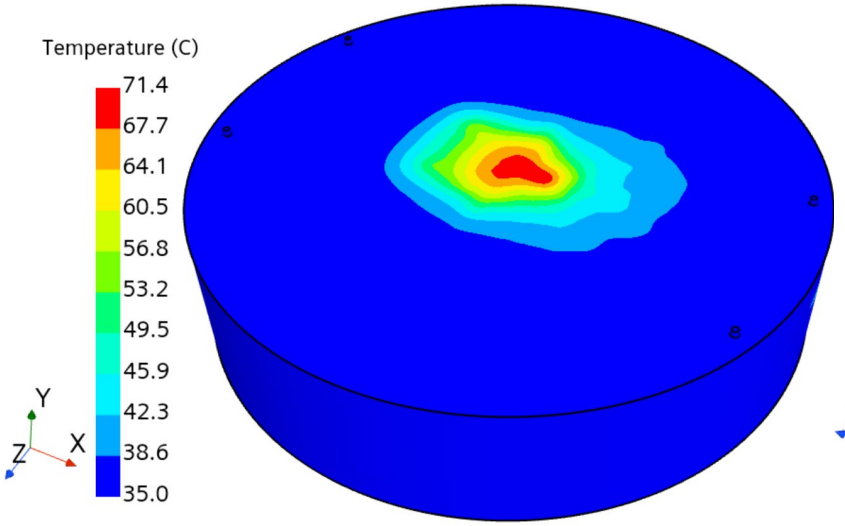
Q_{water} = 109W

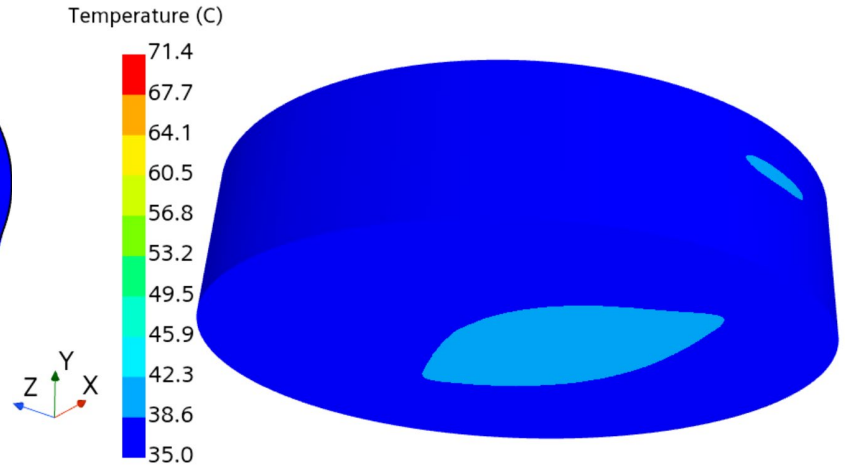


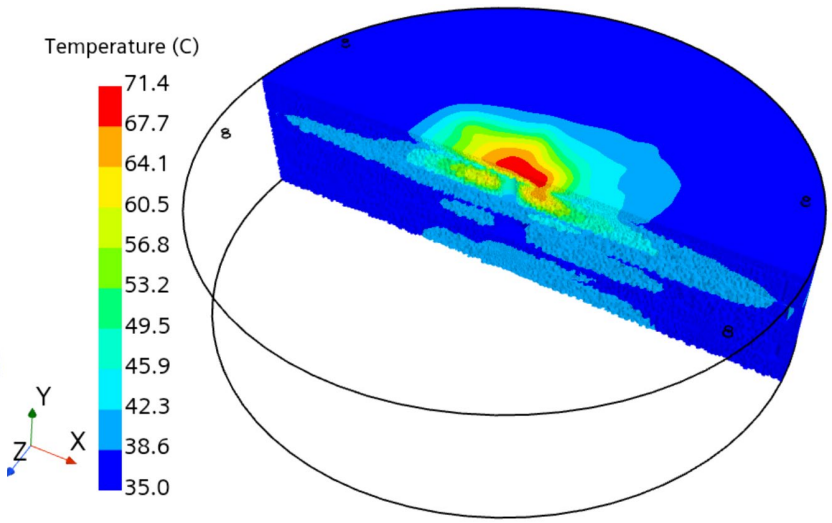


Shield Block #1, Stainless Steel Temperature

Peak: 71.4°C







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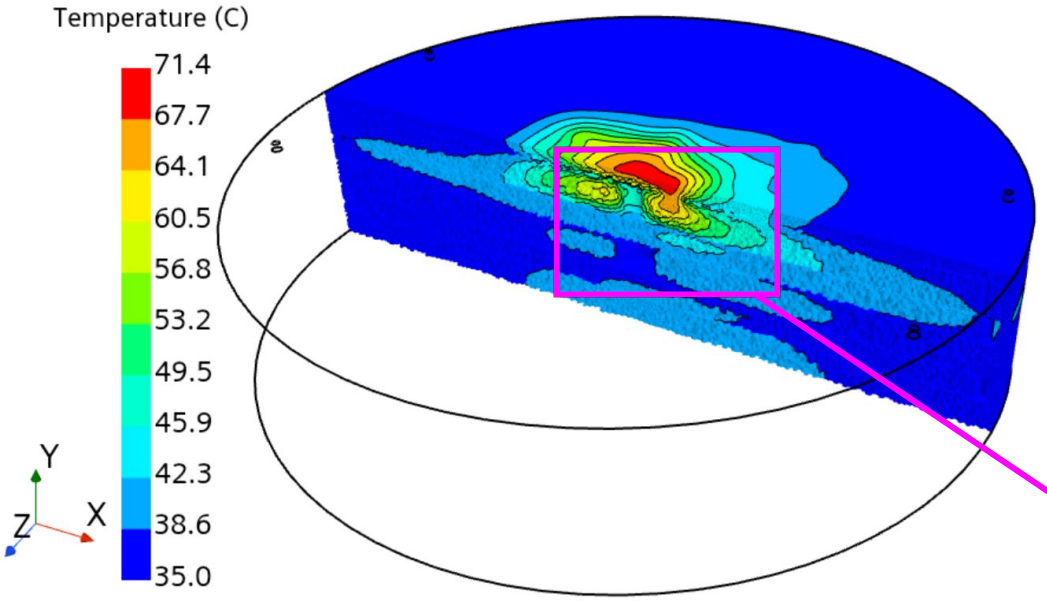
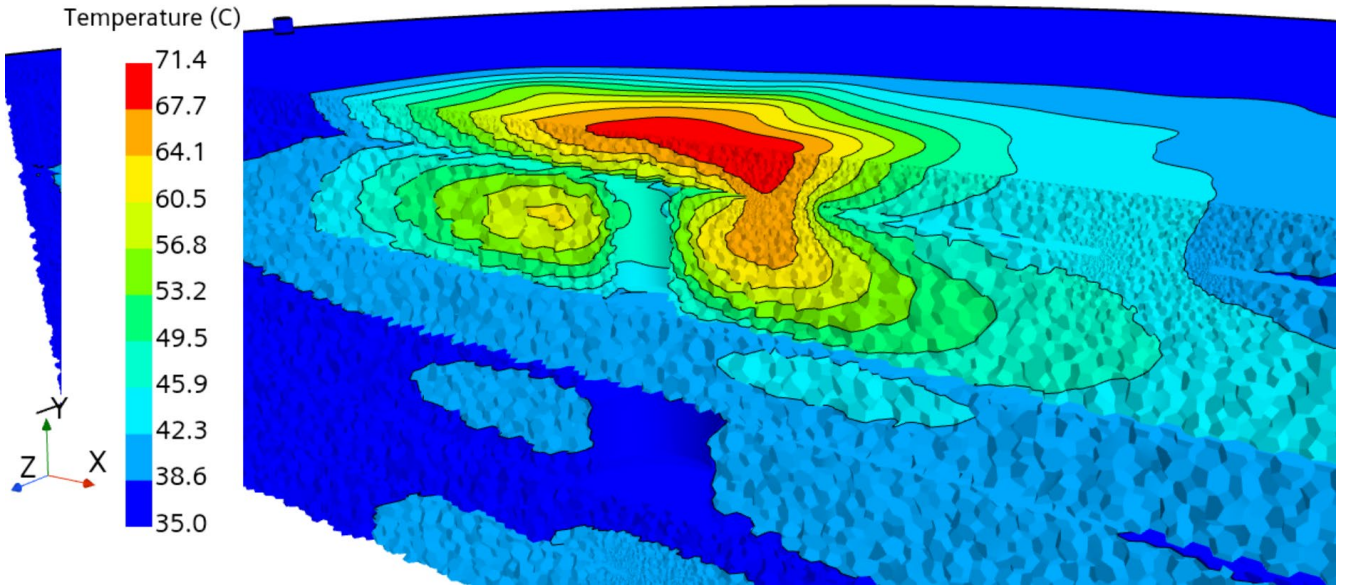
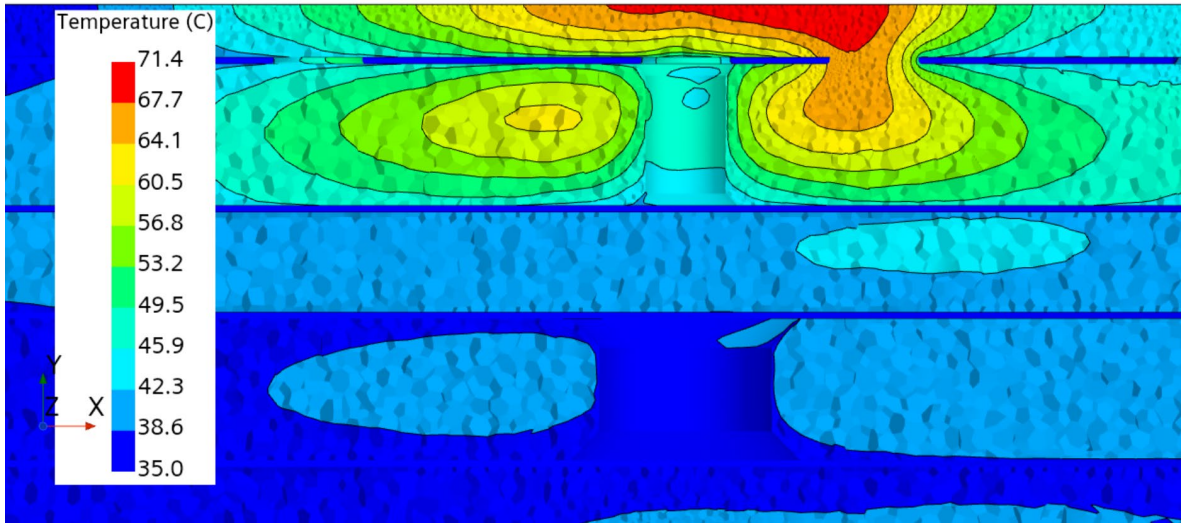
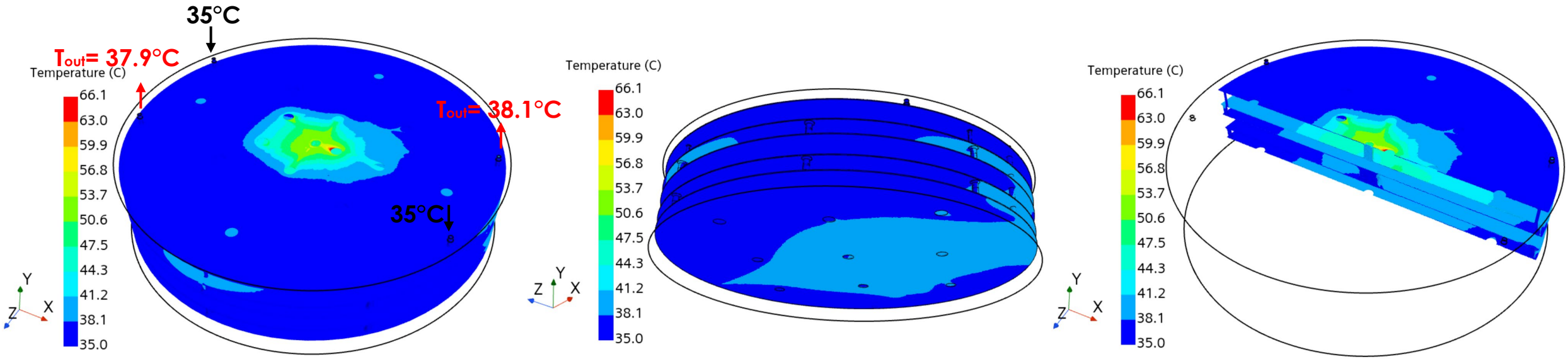






Shield Block #1, Water Temperature

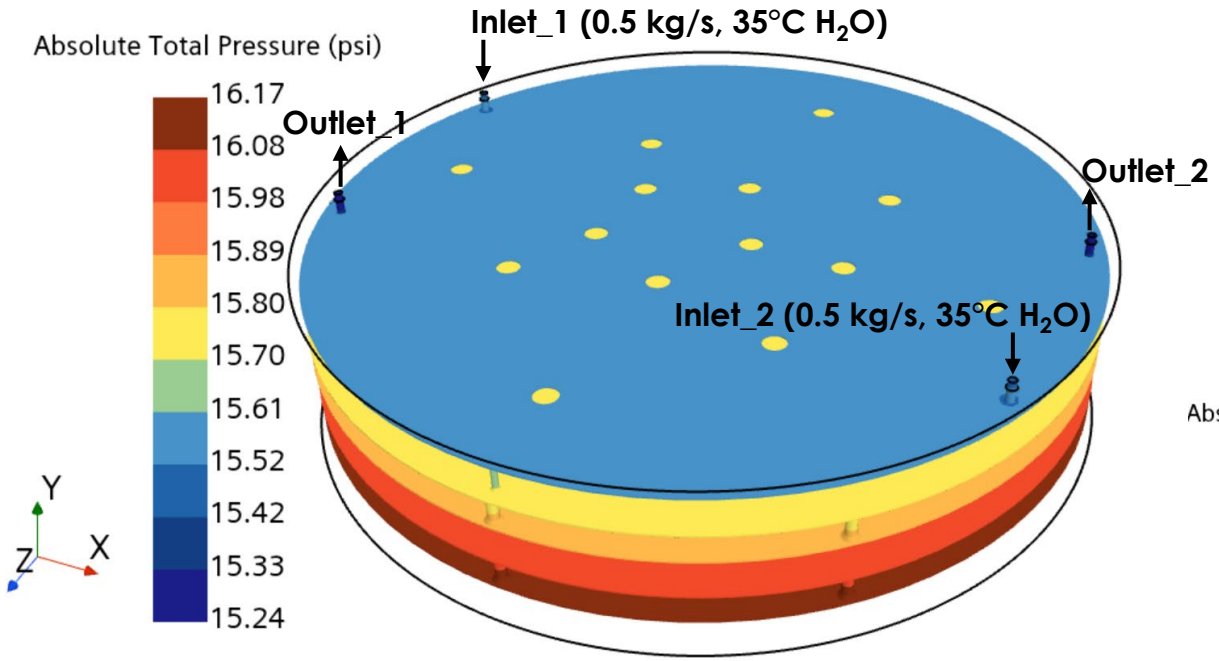
Peak: 66.1°C

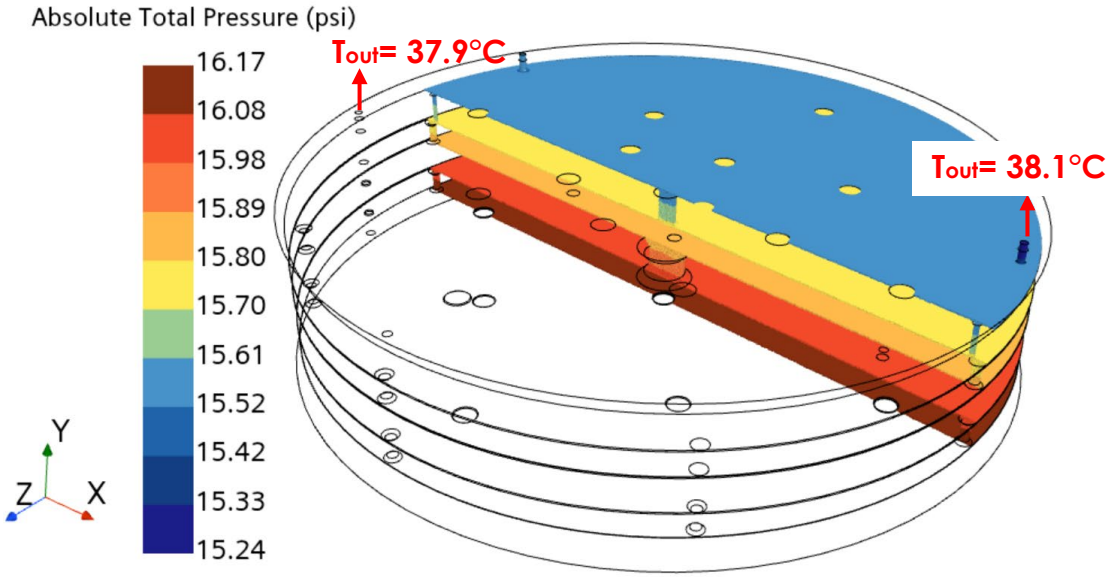


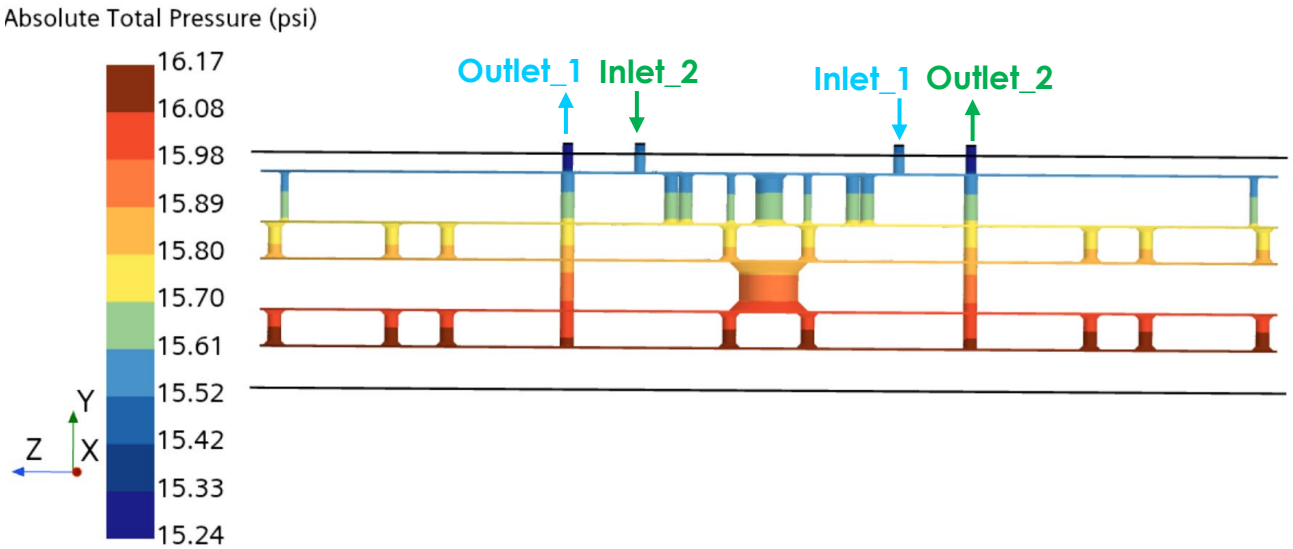
Shield Block #1, Pressure

$$\Delta P_{inlet\_1-outlet\_1} = 0.0172 \text{ bar } (= 1.72 \text{ kPa} = 0.25\ psi = 0.017\ atm)$$

$$\Delta P_{inlet\_2-outlet\_2} = 0.0172 \text{ bar } (= 1.72 \text{ kPa} = 0.25\ psi = 0.017\ atm)$$

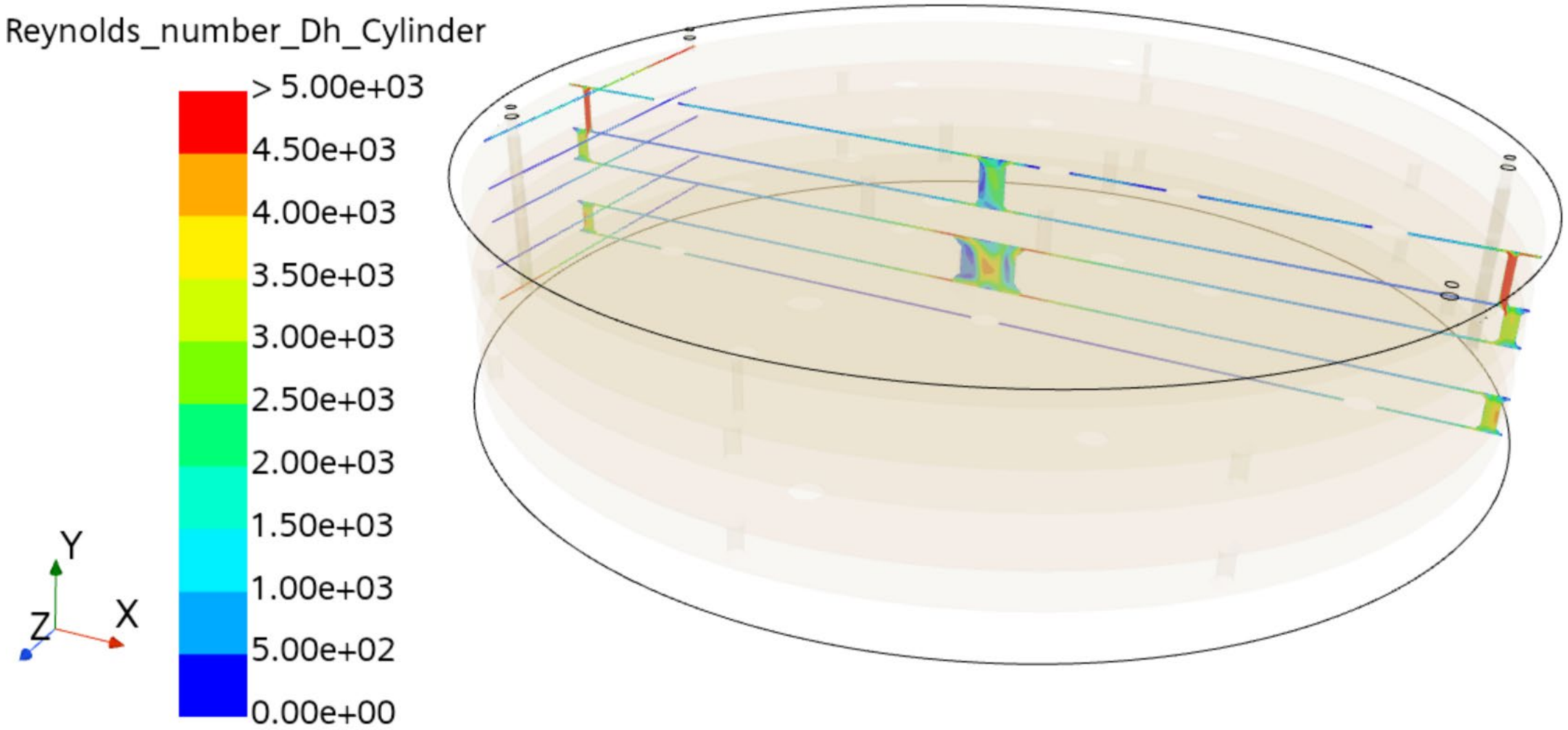




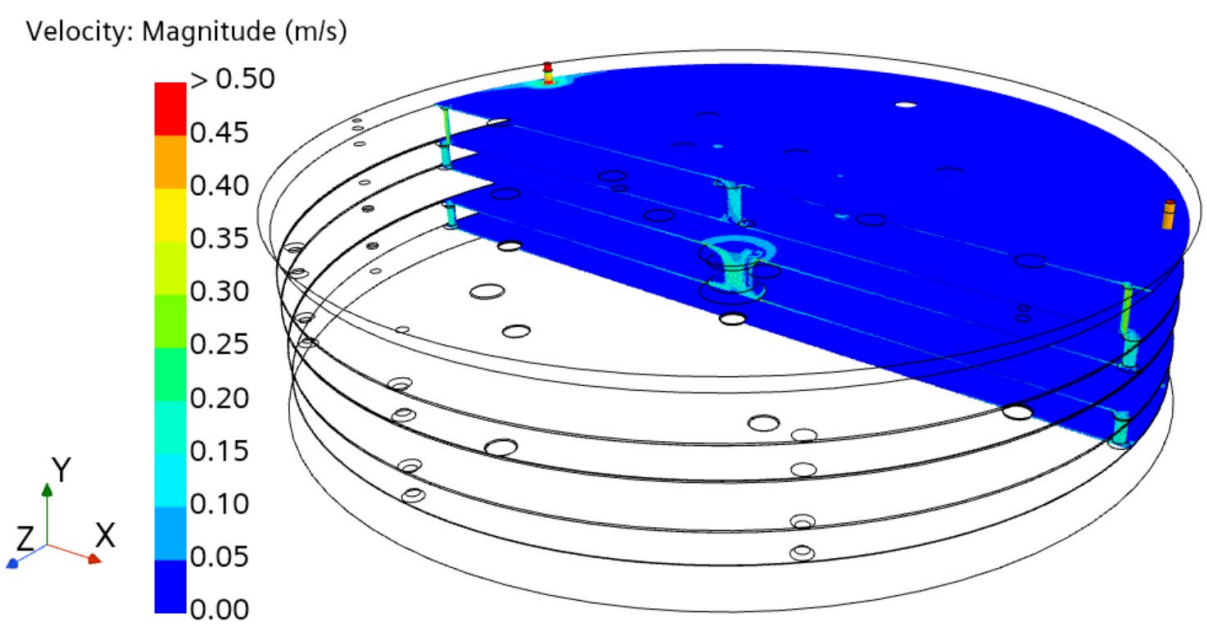


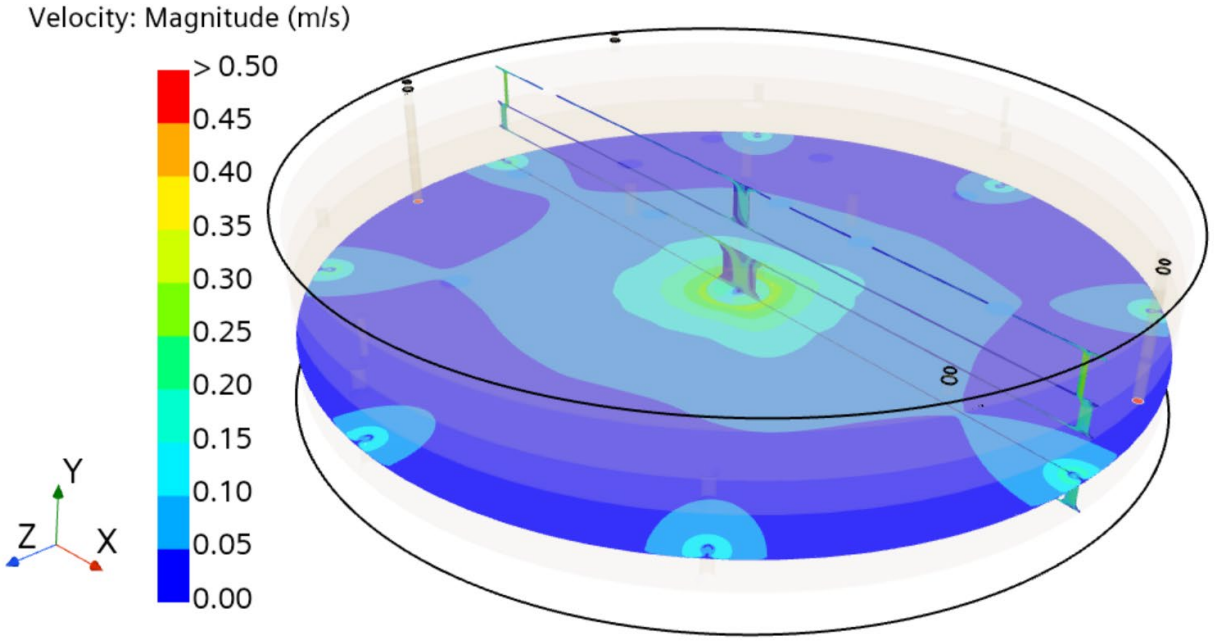
Shield Block #1, Reynolds Number

Turbulent Flow (Realizable k-ε model used)

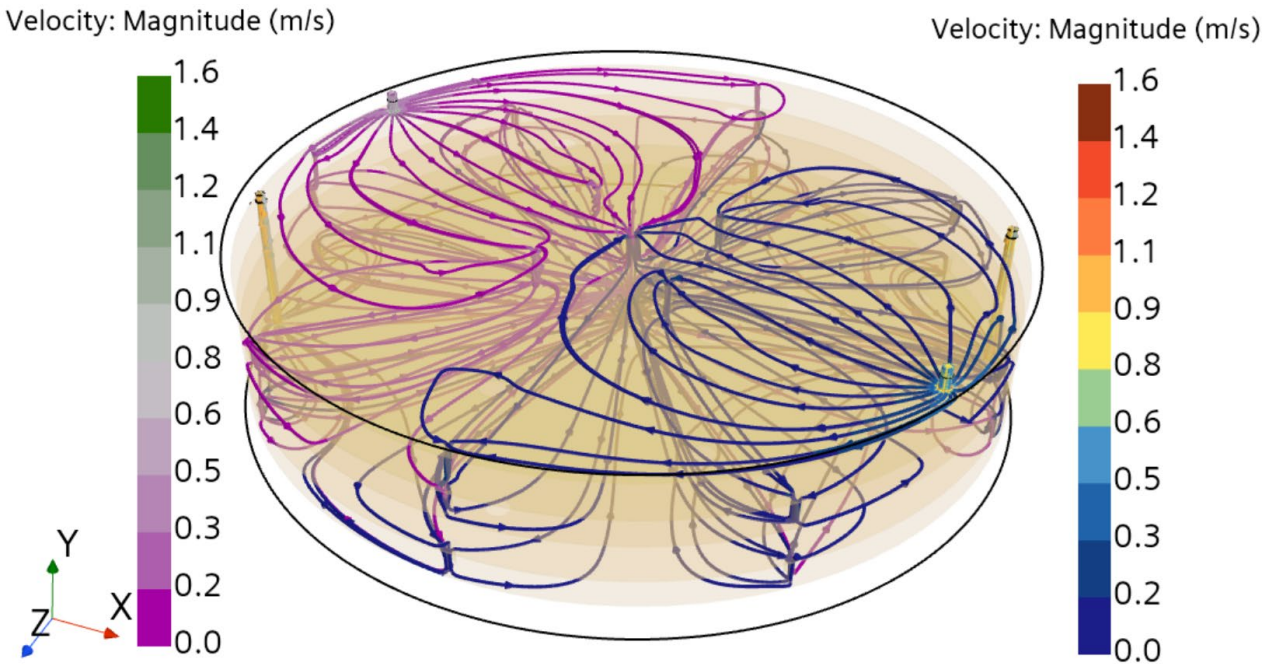


Shield Block #1, Velocity

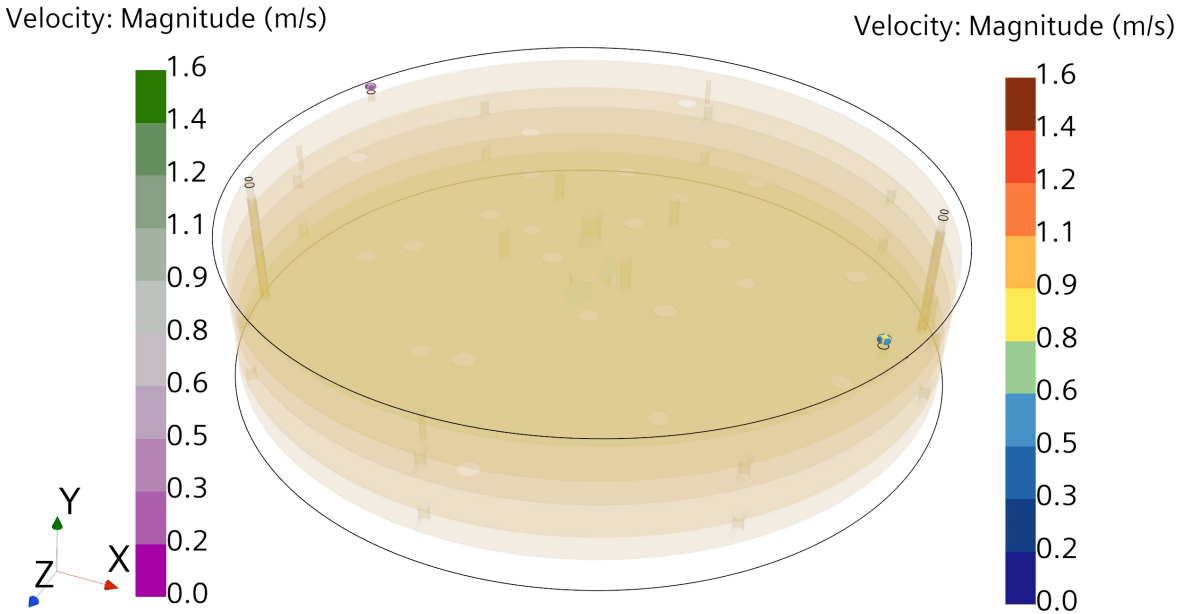




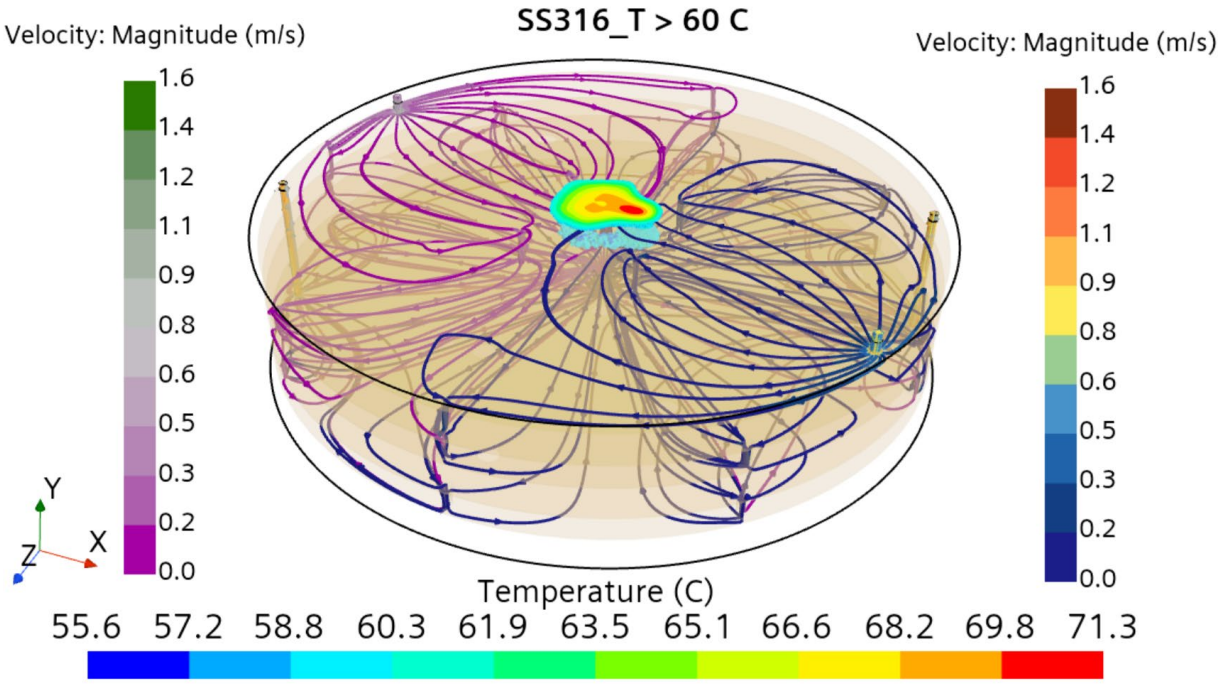
Shield Block #1, Streamlines



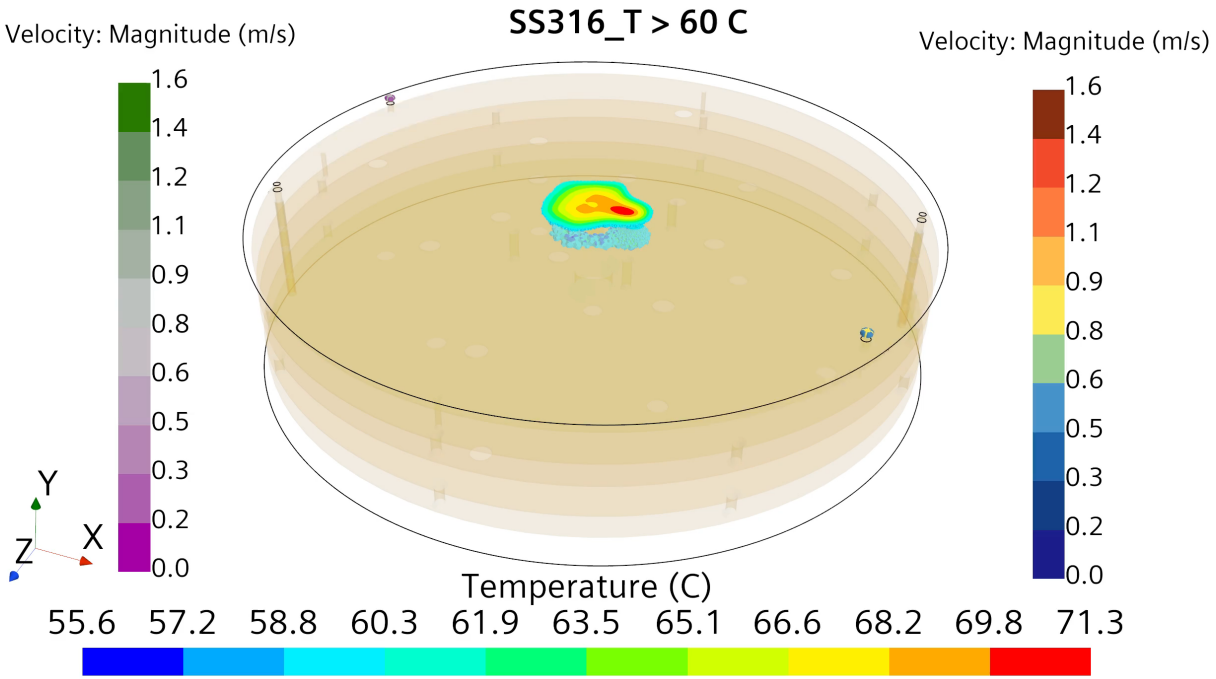
Animation



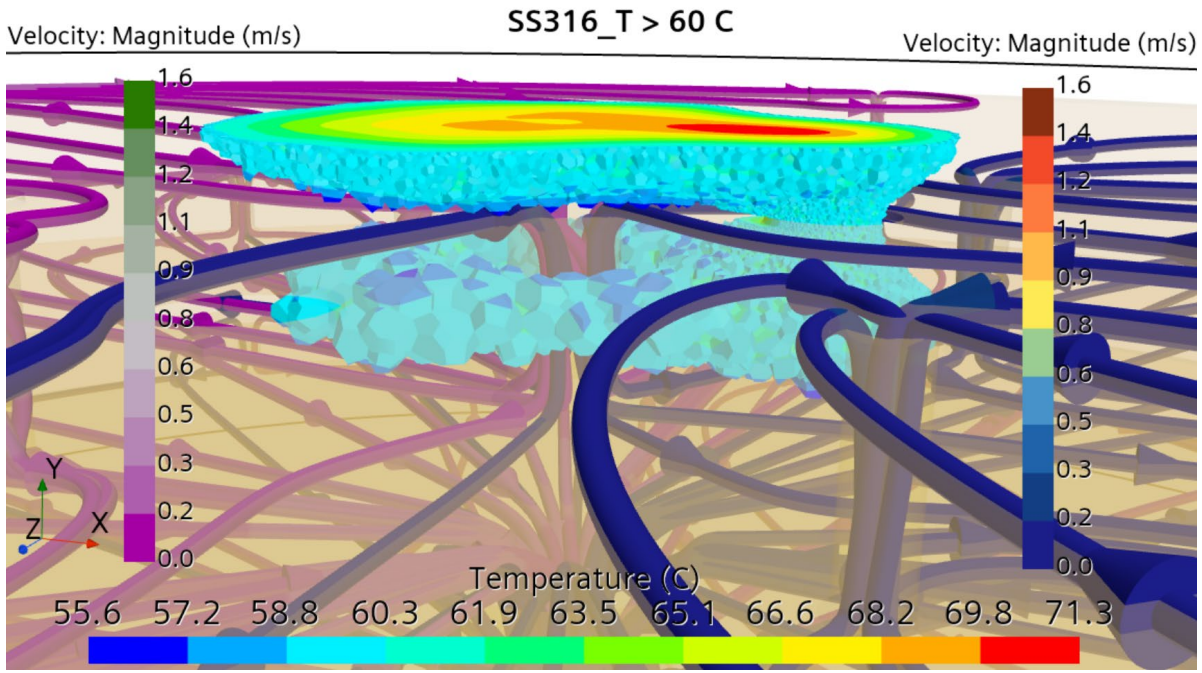
Shield Block #1, Streamlines



Animation



Shield Block #1, Streamlines



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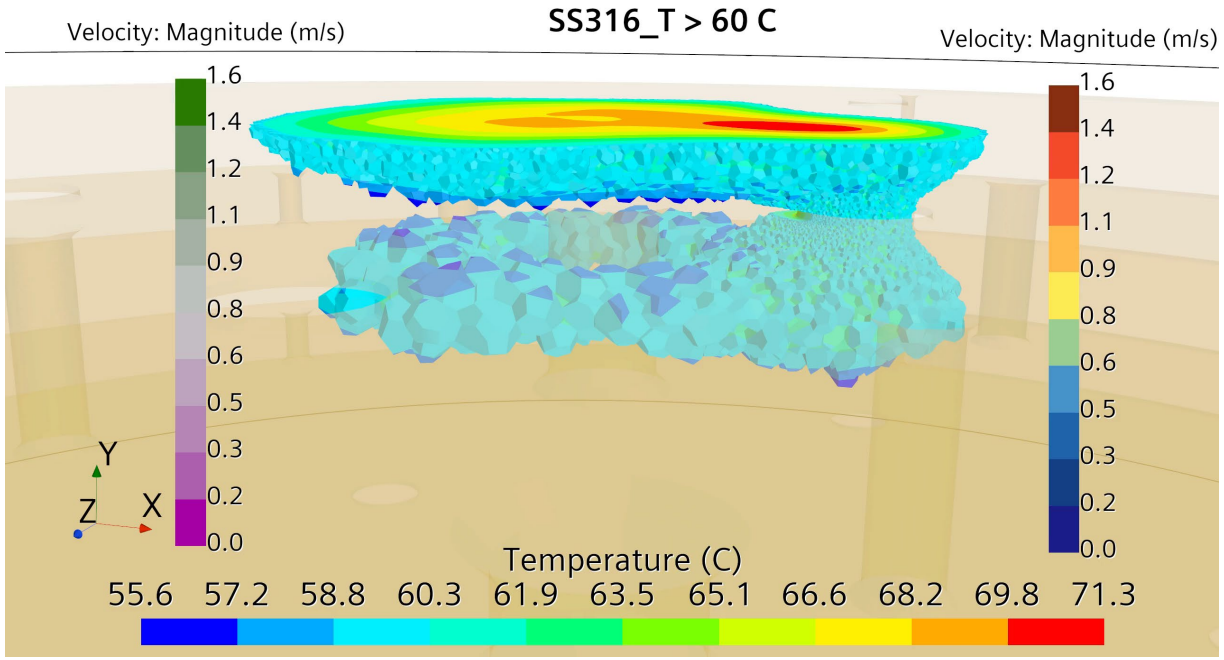
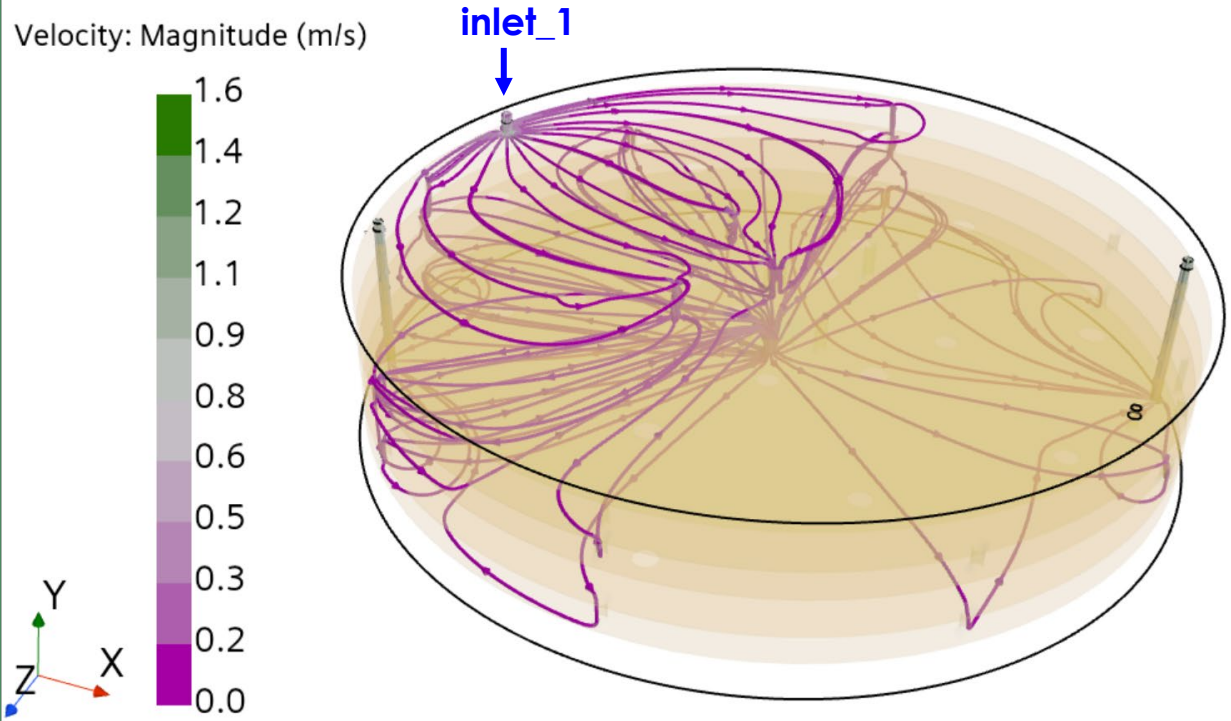
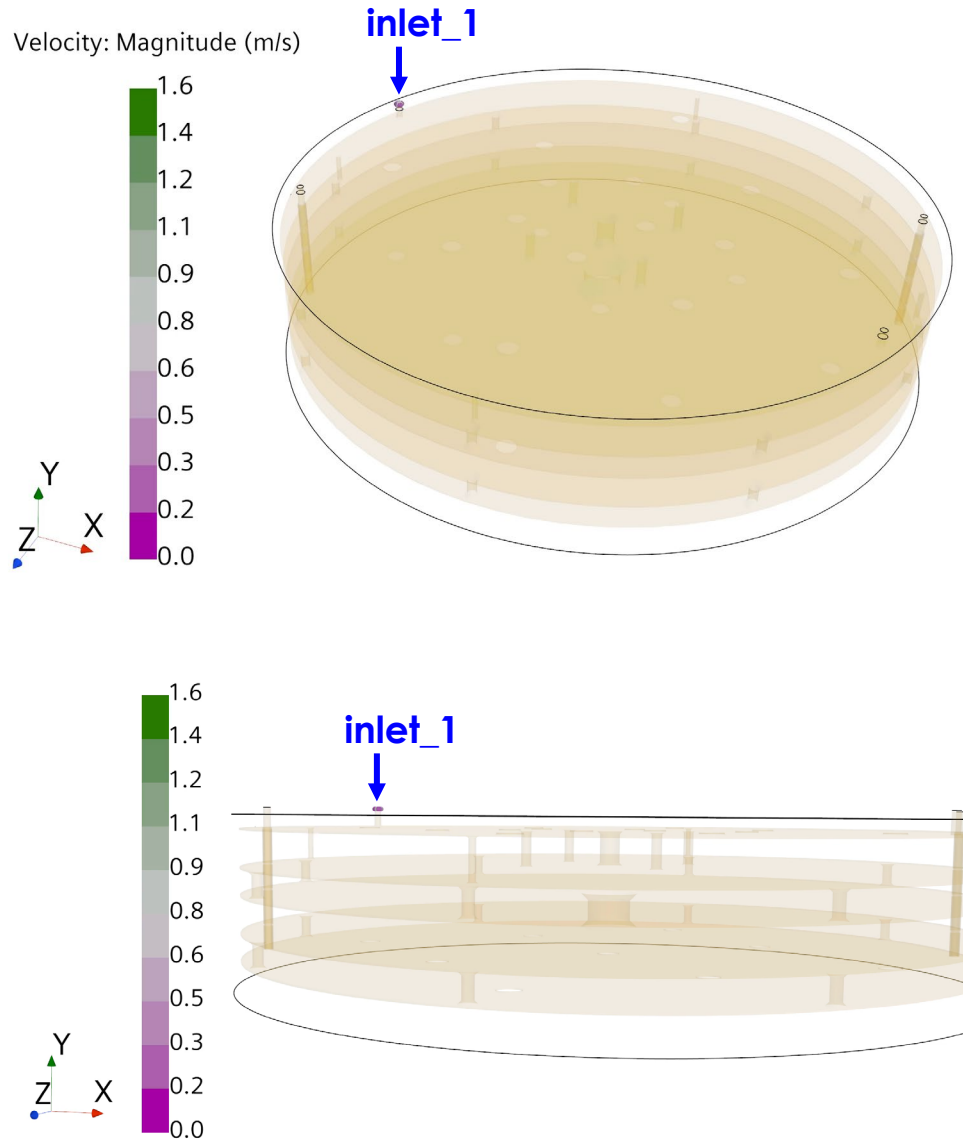


Shield Block #1, Streamlines

Streamlines from **inlet_1**



Animation



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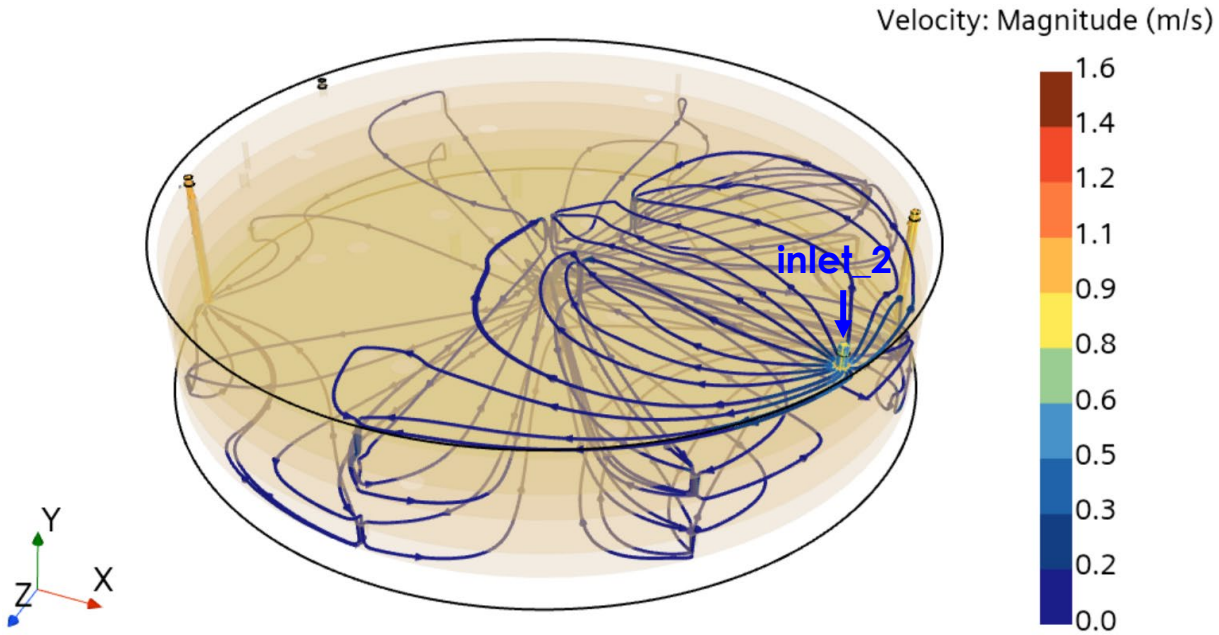
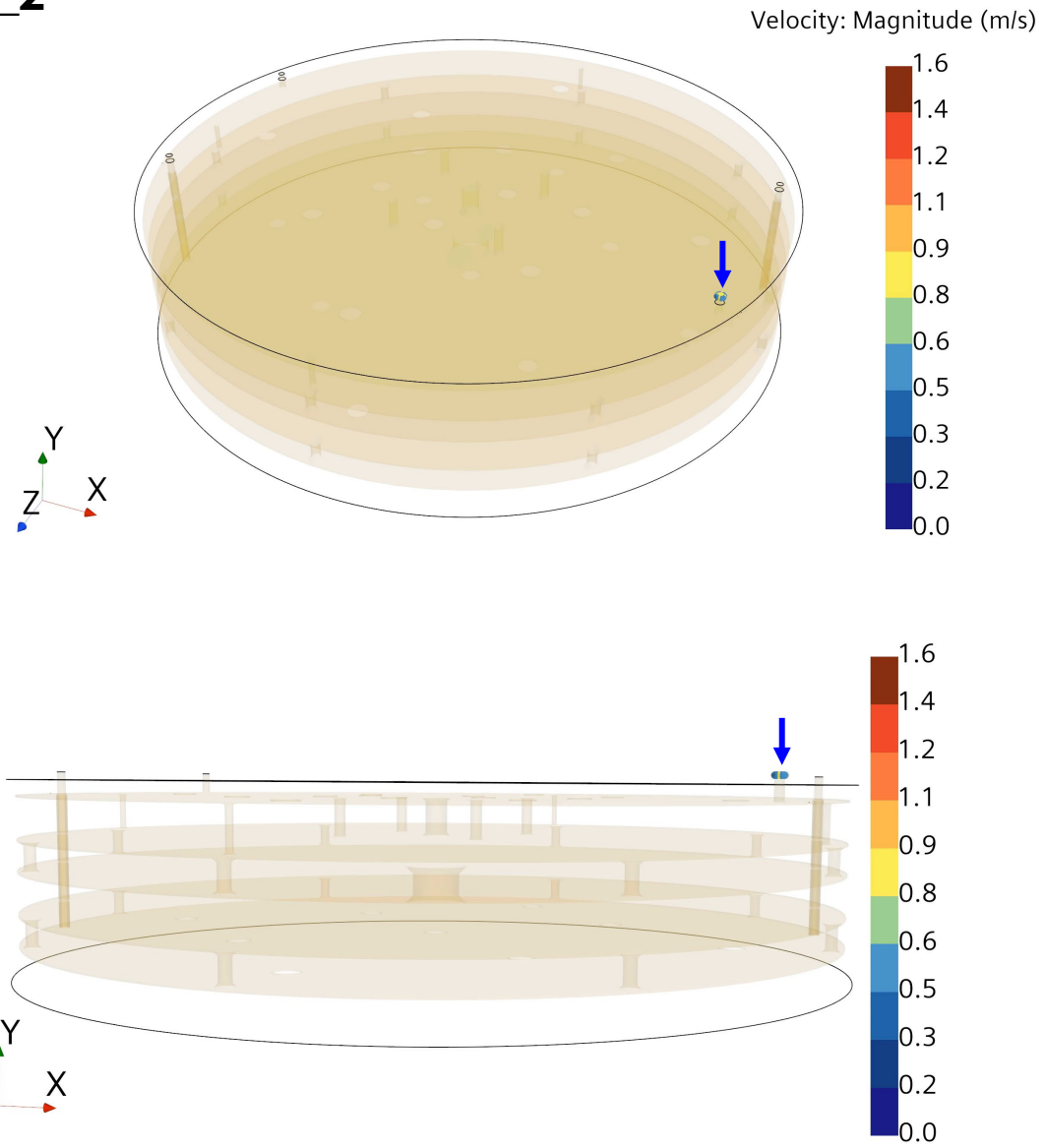
Shield Block #1, Streamlines

Streamlines from **inlet_2**

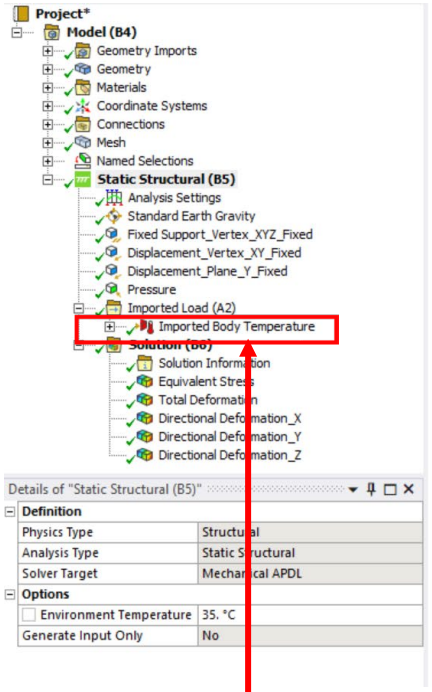


Animation

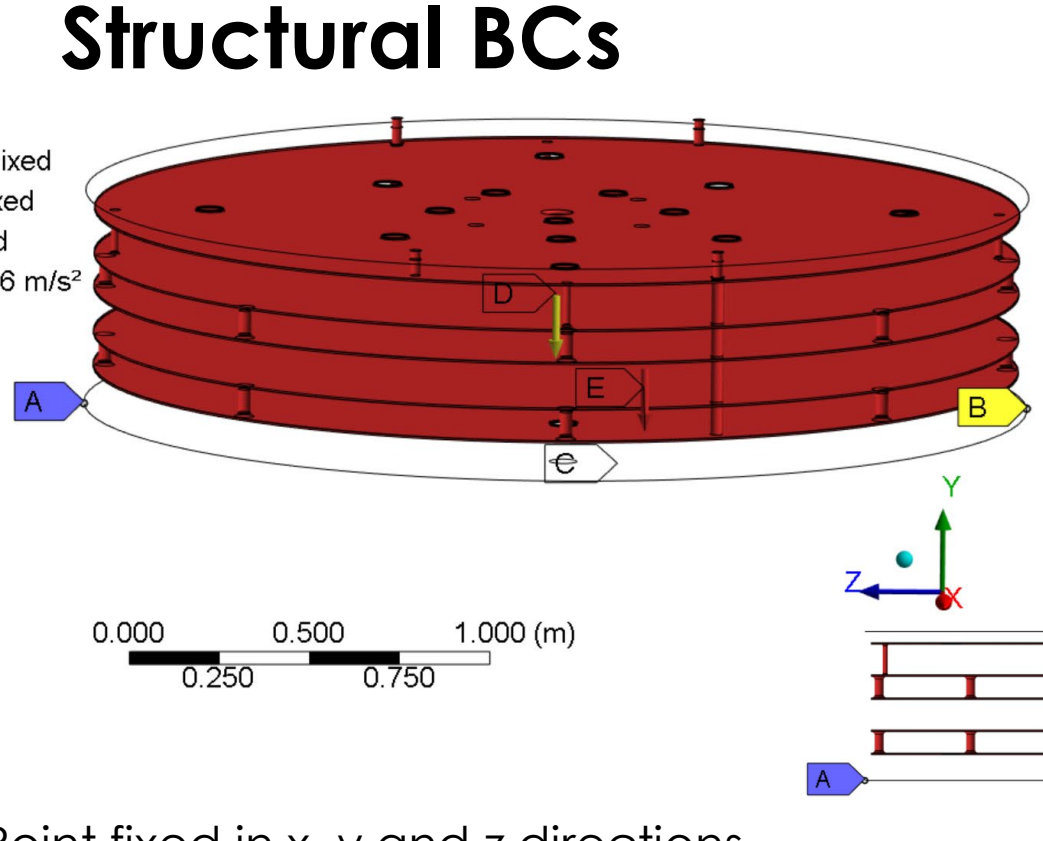


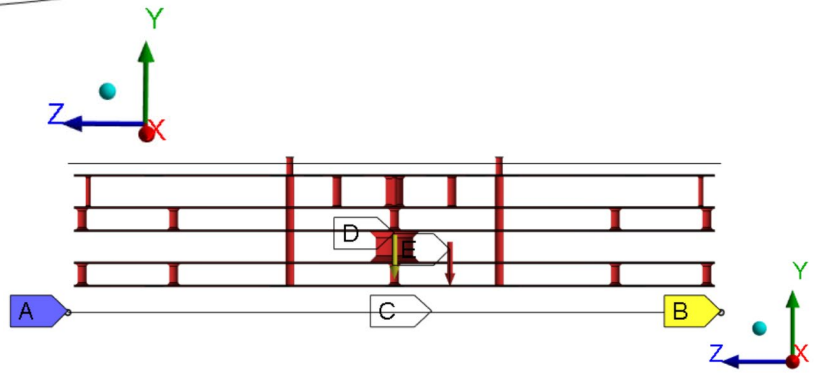
Shield Block #1 Structural Analysis

Shield Block #1, SS316 (Design_16)
Structural BCs



temperature profile from **CFD** (STARCCM+)





- BC-A: Point fixed in x, y and z directions
  - ➢ Reference point
- BC-B: point can only move in z direction
  - ➢ Fixed in y : Block rests on flat surface
  - ➢ Fixed in x : symmetric, no rotation
- BC-C: Plane fixed in y
  - ➢ Block rests on flat surface
- BC-D: Gravity (-y direction)
- **BC-E: Uniform Pressure of 5 bar (= 0.5 MPA)**

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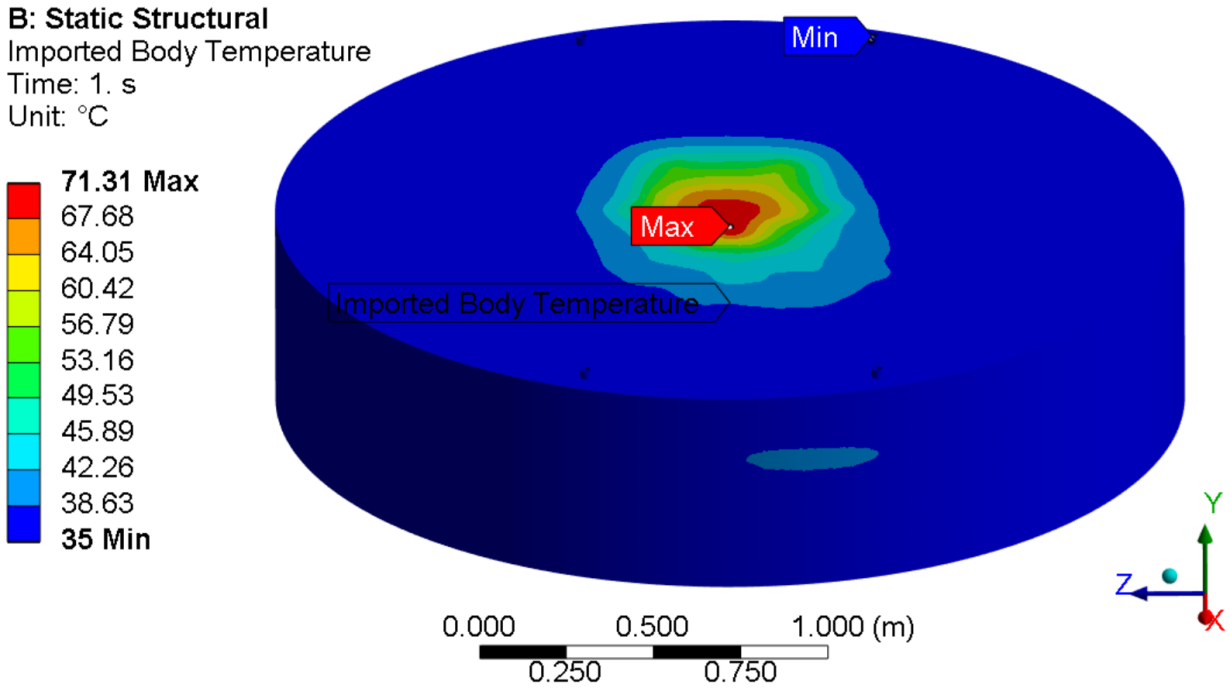
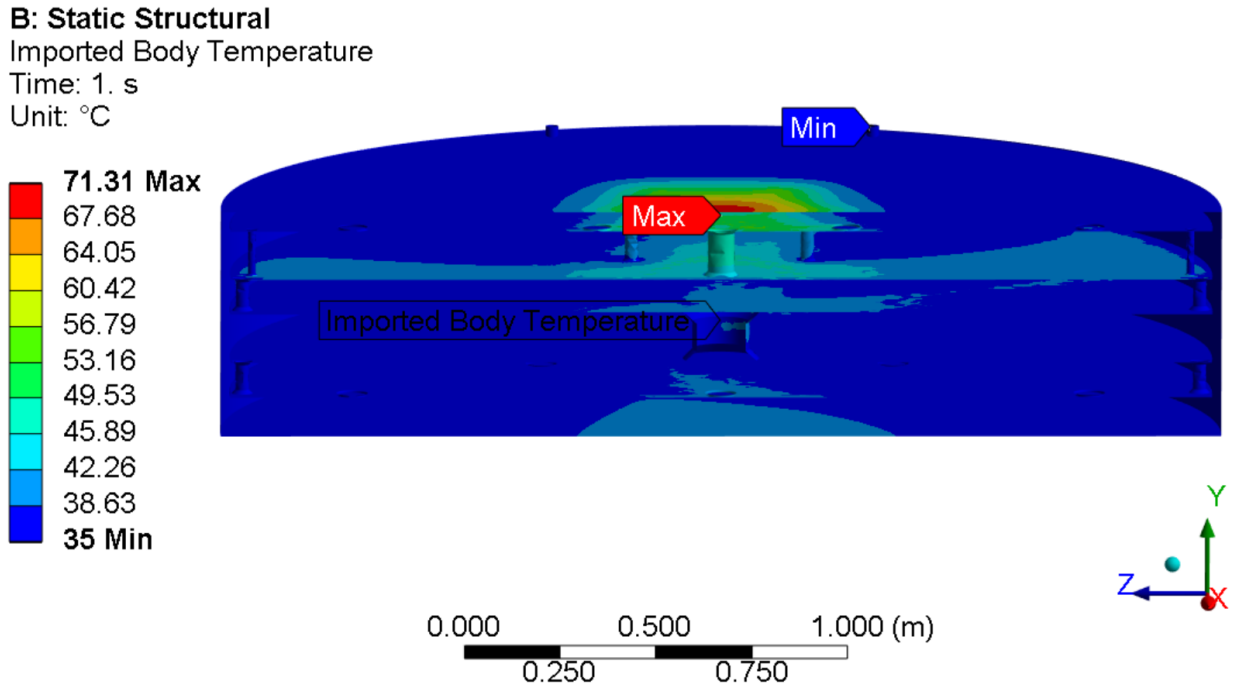
Temperature Profile from CFD (STARCCM+)

Imported Temperature



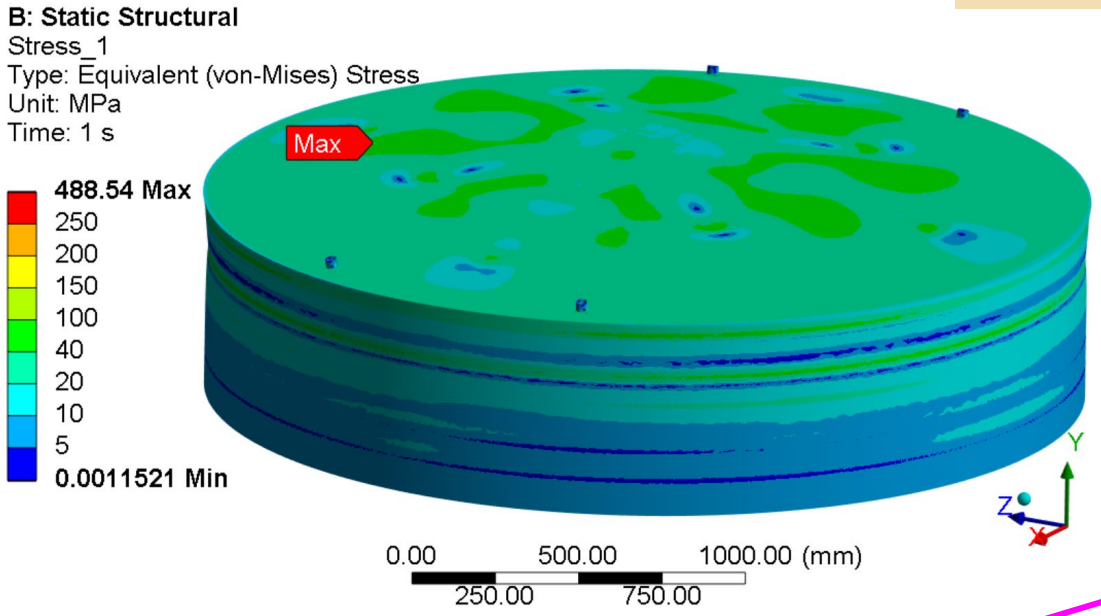


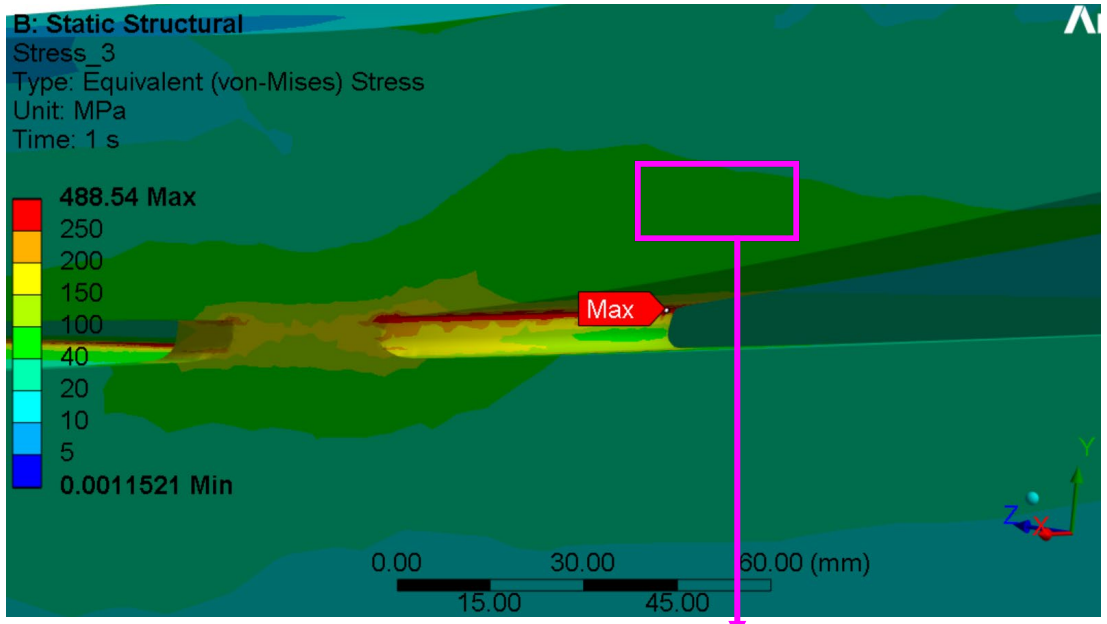
Water pressure + Thermal + Gravity

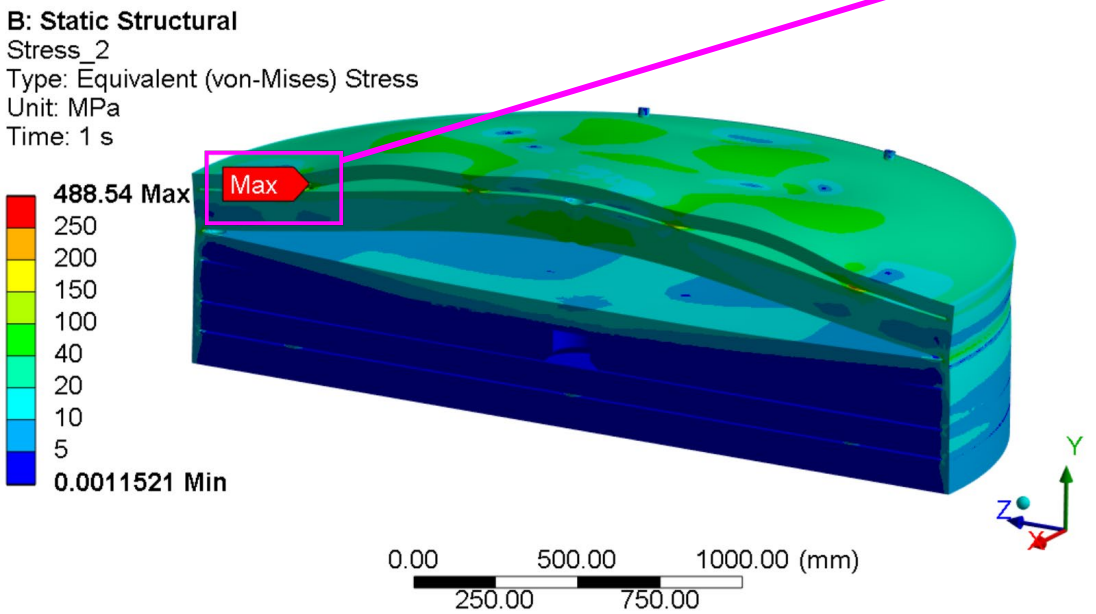
Von-Mises Stress

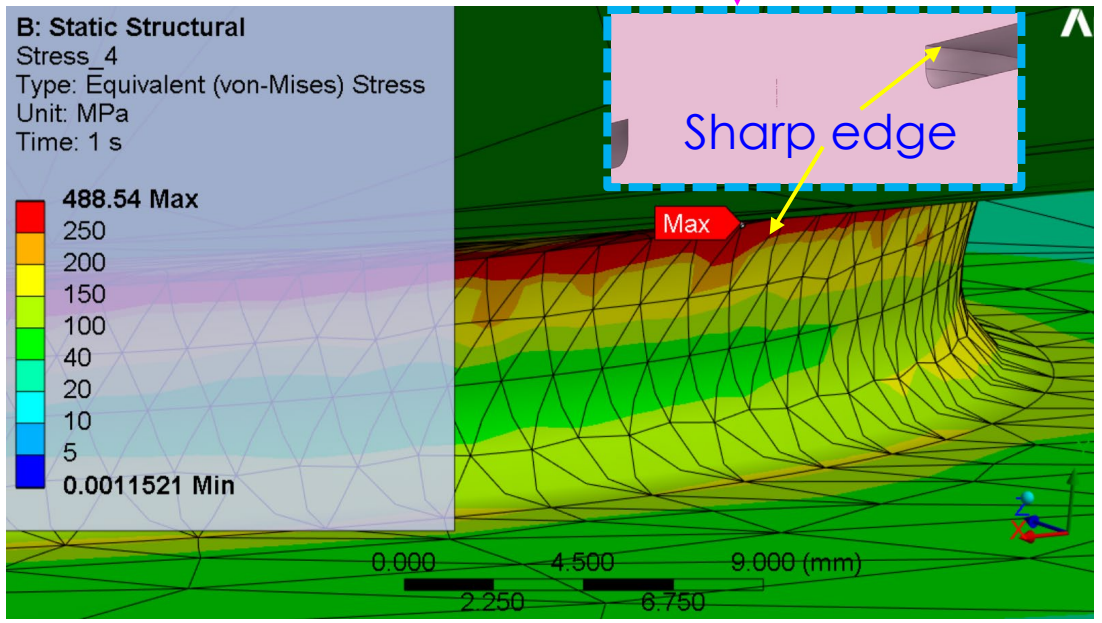
Deformation scale = 180

Peak Stress : 488 MPa
SS316 Yield Strength: 252 MPa





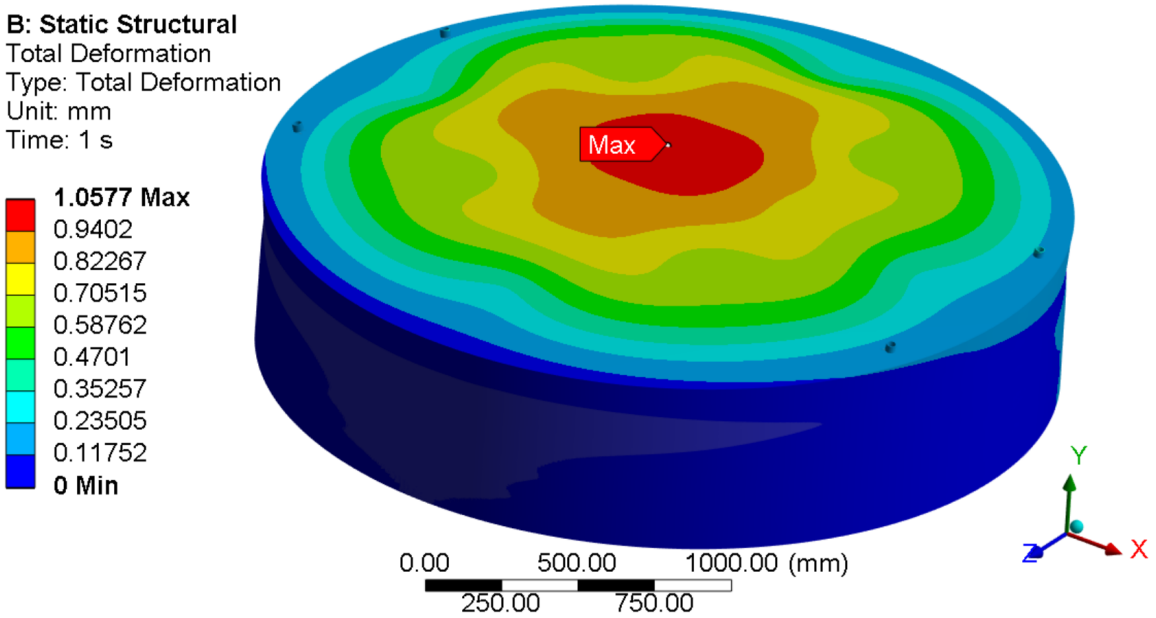


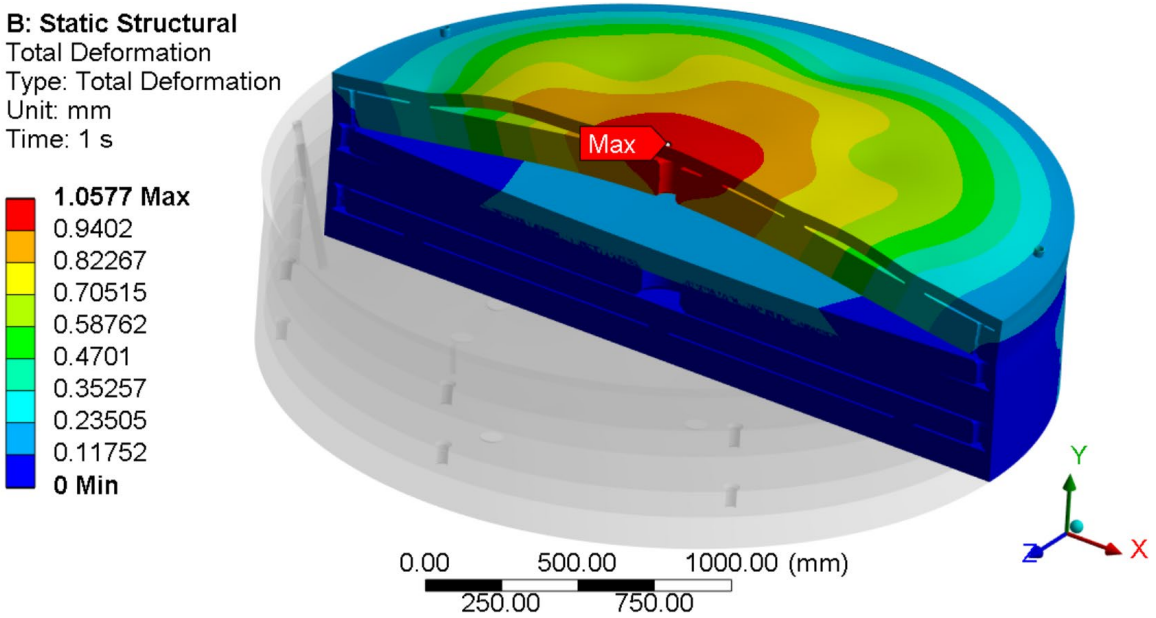


Water pressure + Thermal + Gravity

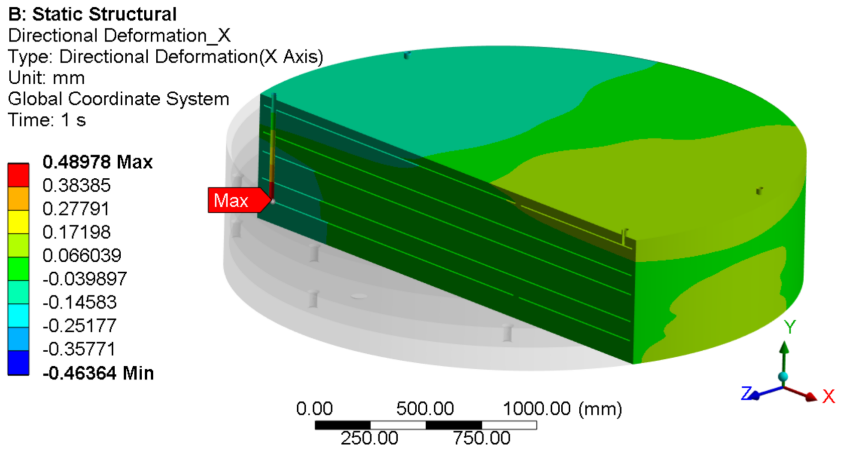
Displacement

Total Deformation

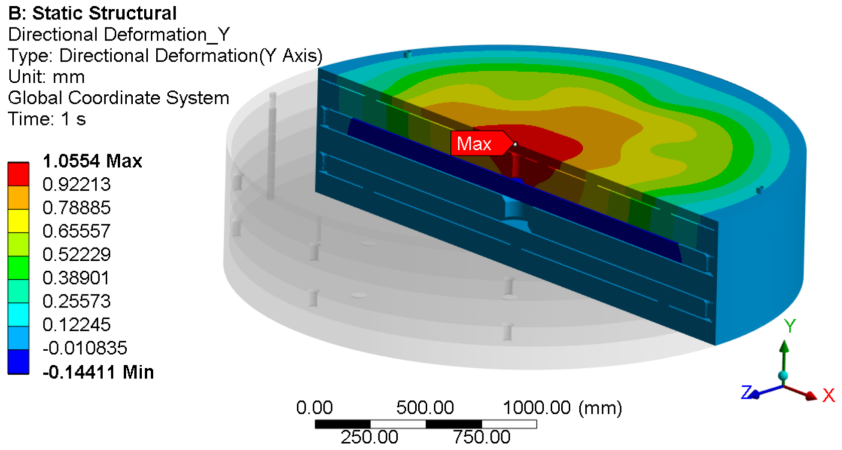




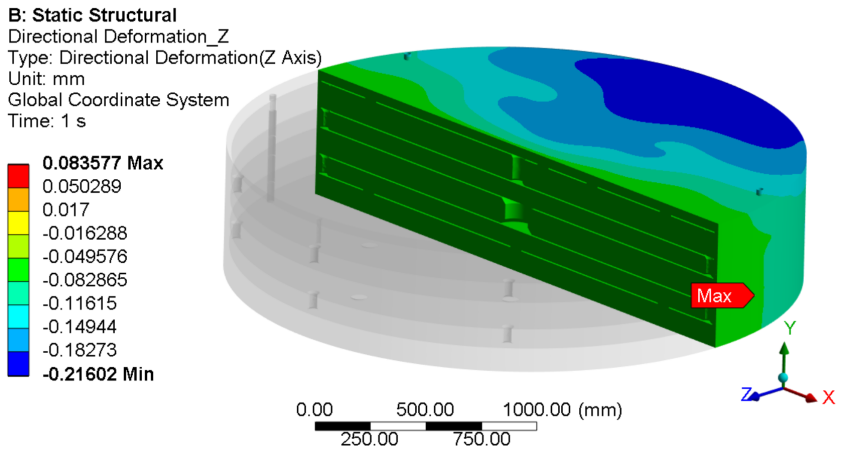
X - Deformation



Y - Deformation



Z - Deformation

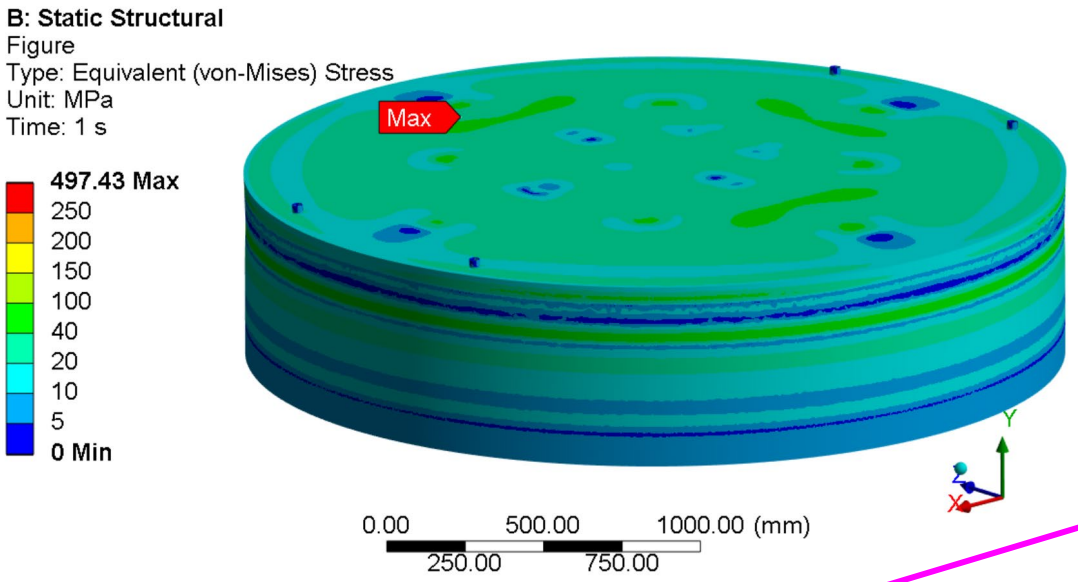


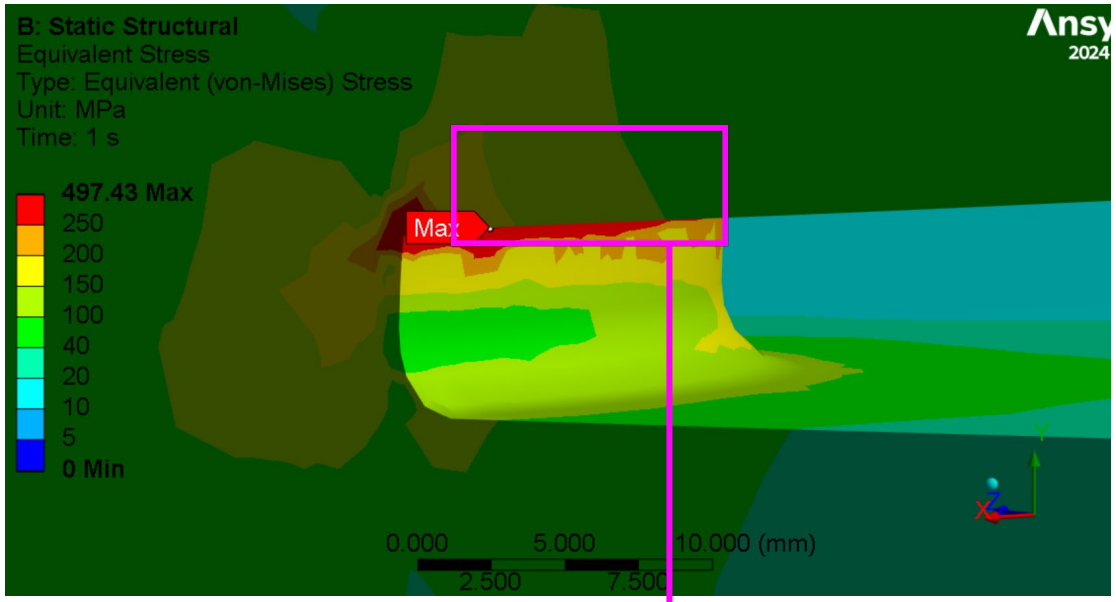
Water Pressure 5 bar

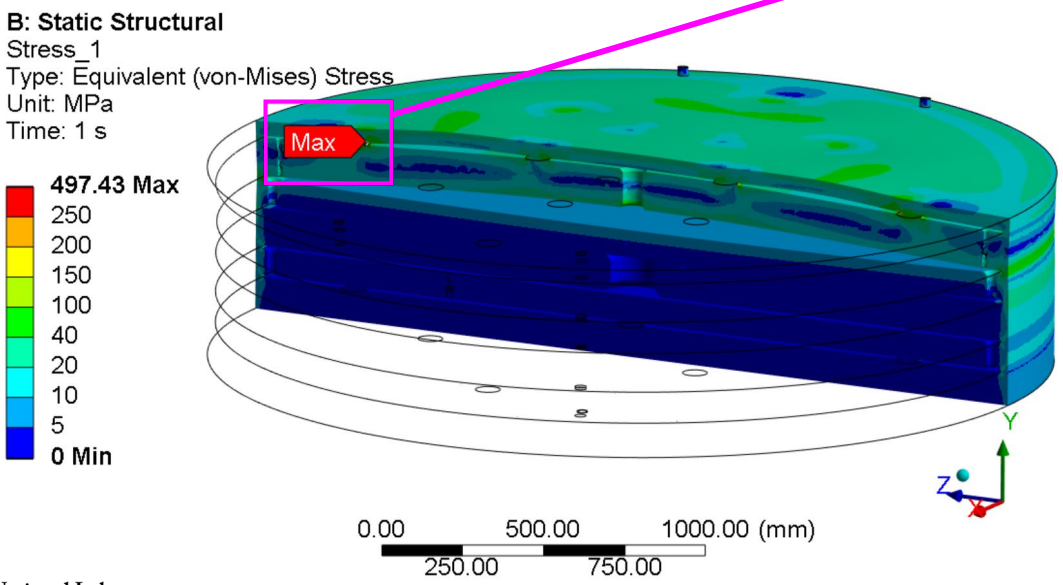
Von-Mises Stress

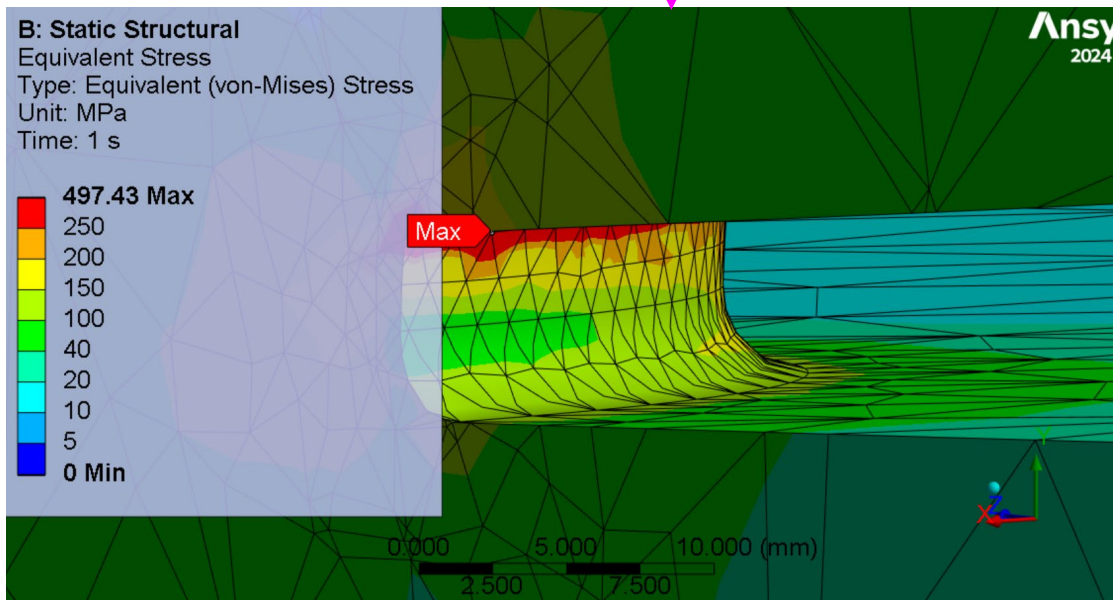
Deformation scale = 50

Peak Stress : 497 MPa
SS316 Yield Strength: 252 MPa









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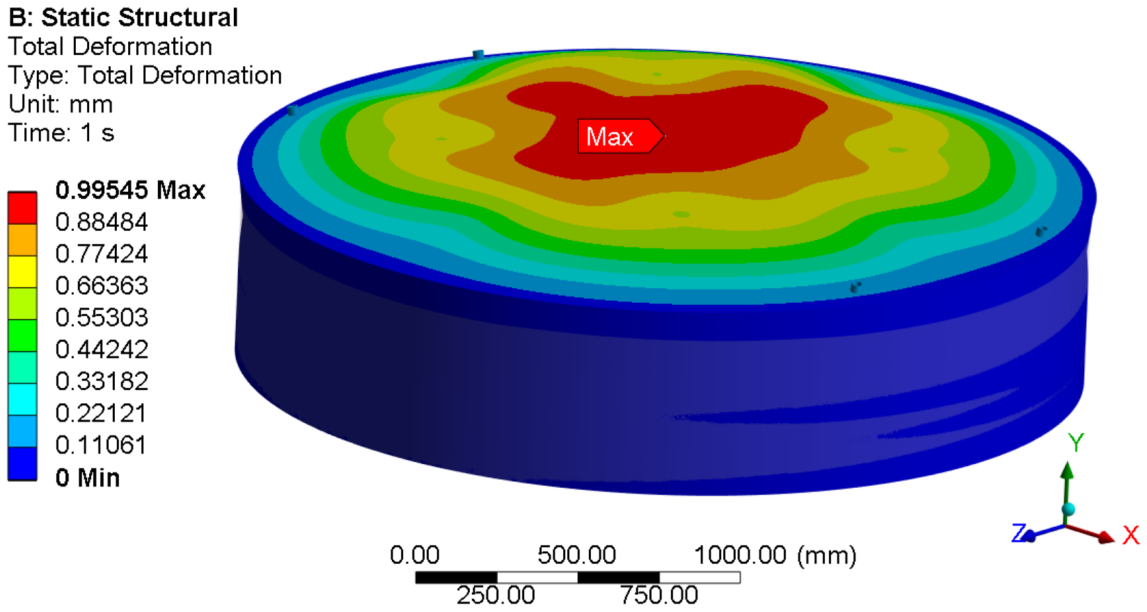
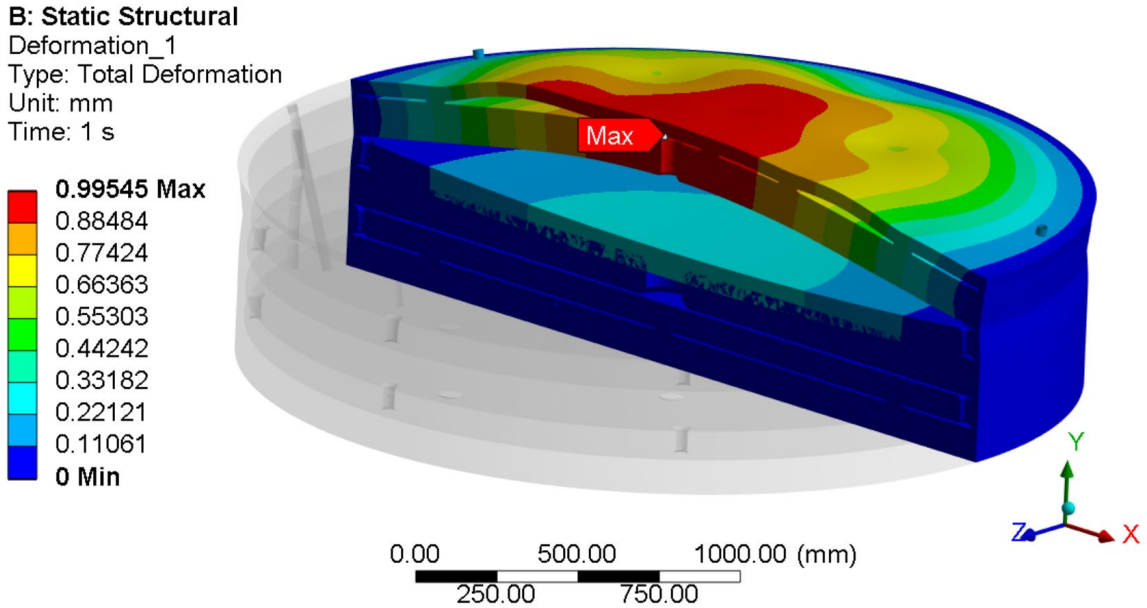
Water Pressure 5 bar

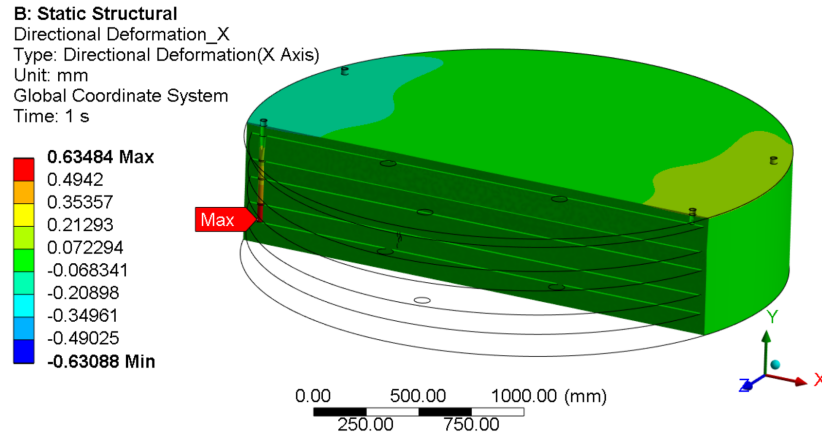
Displacement

Total Deformation

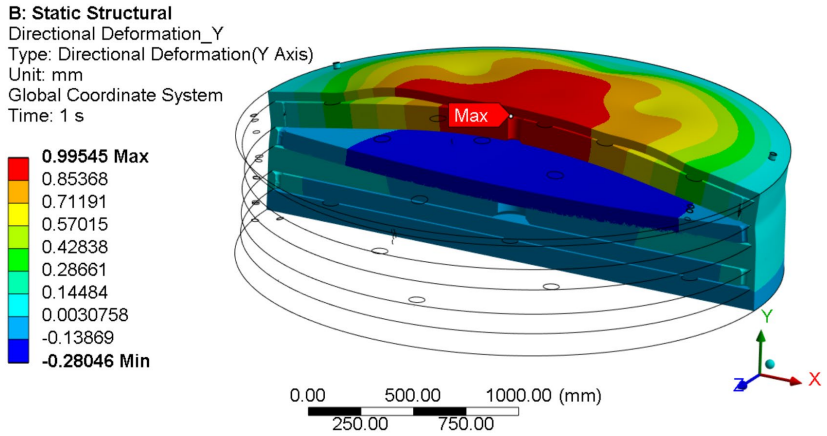




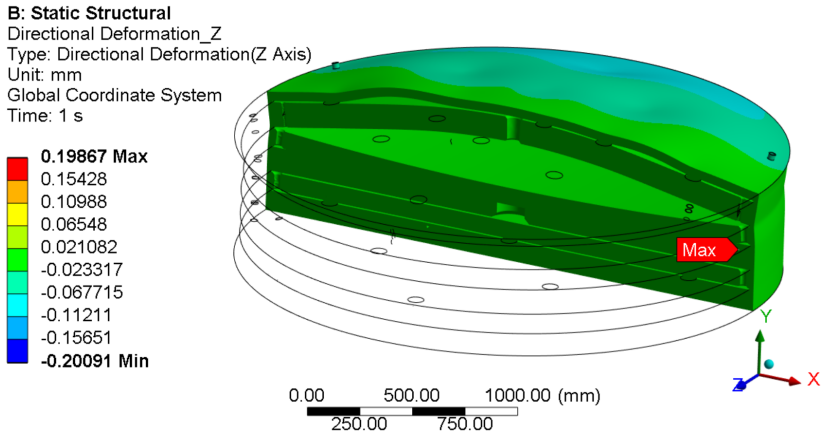
X - Deformation



Y - Deformation



Z - Deformation

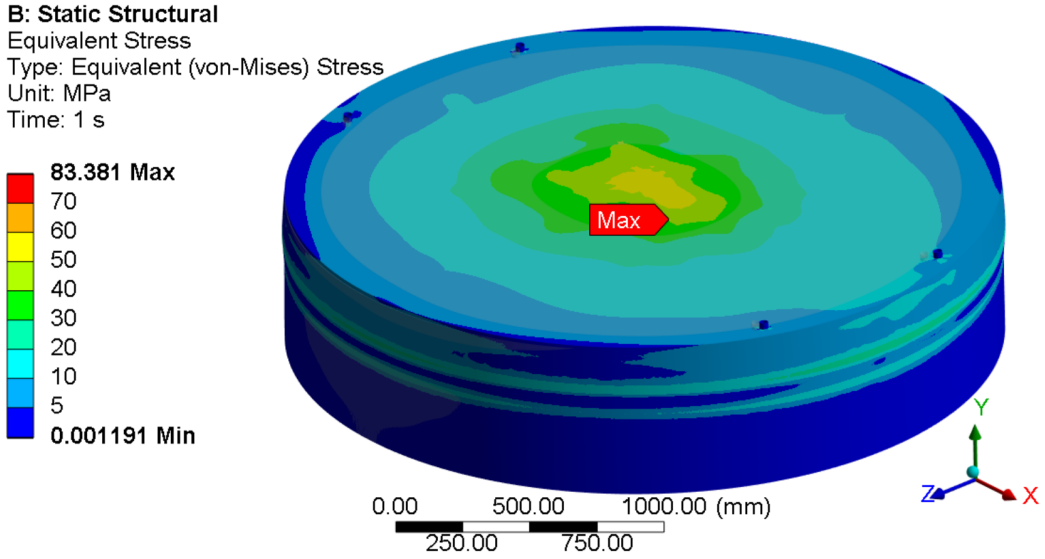


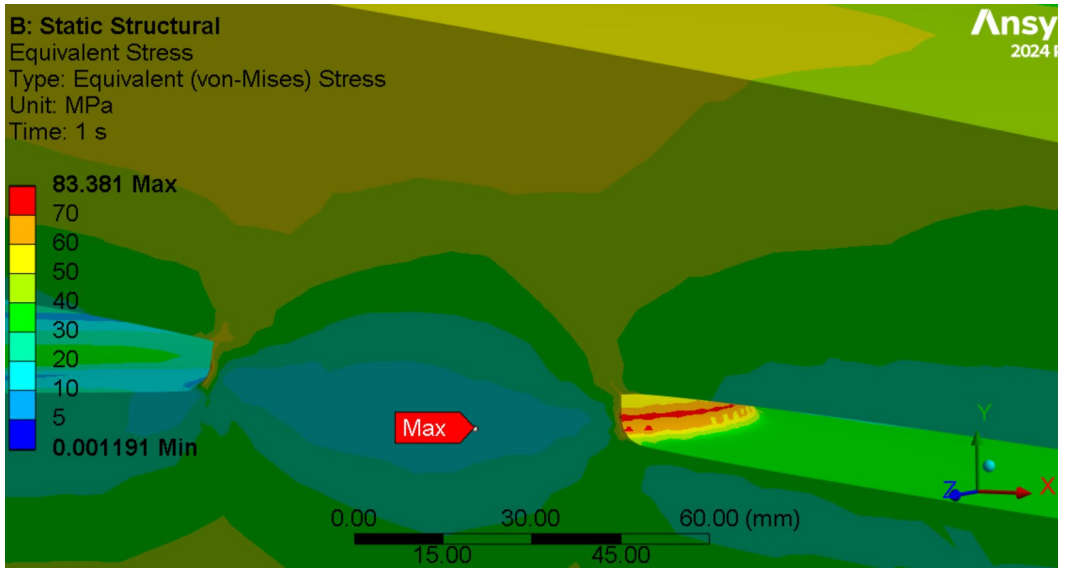
Thermal Only

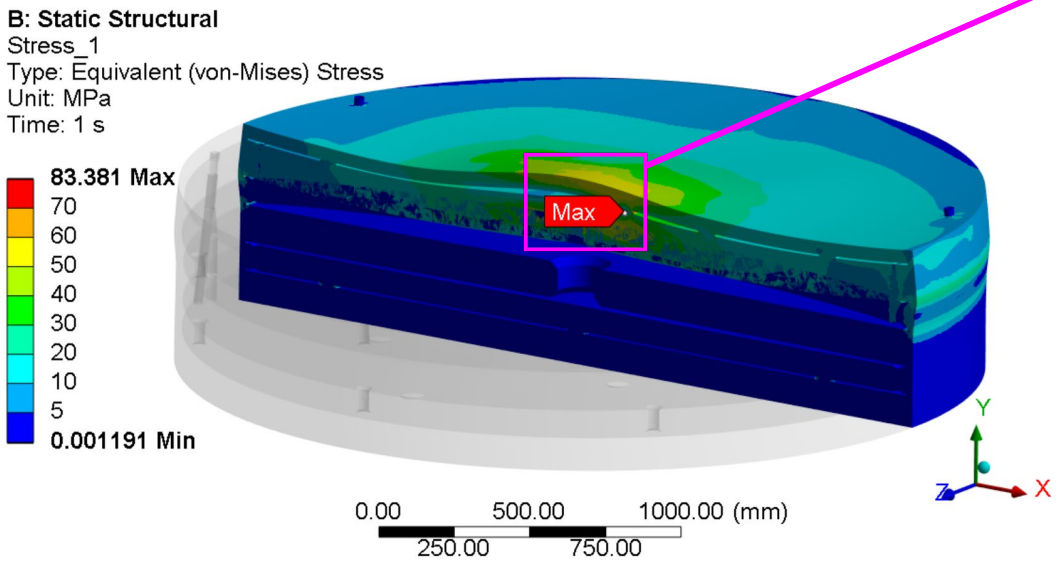
Von-Mises Stress

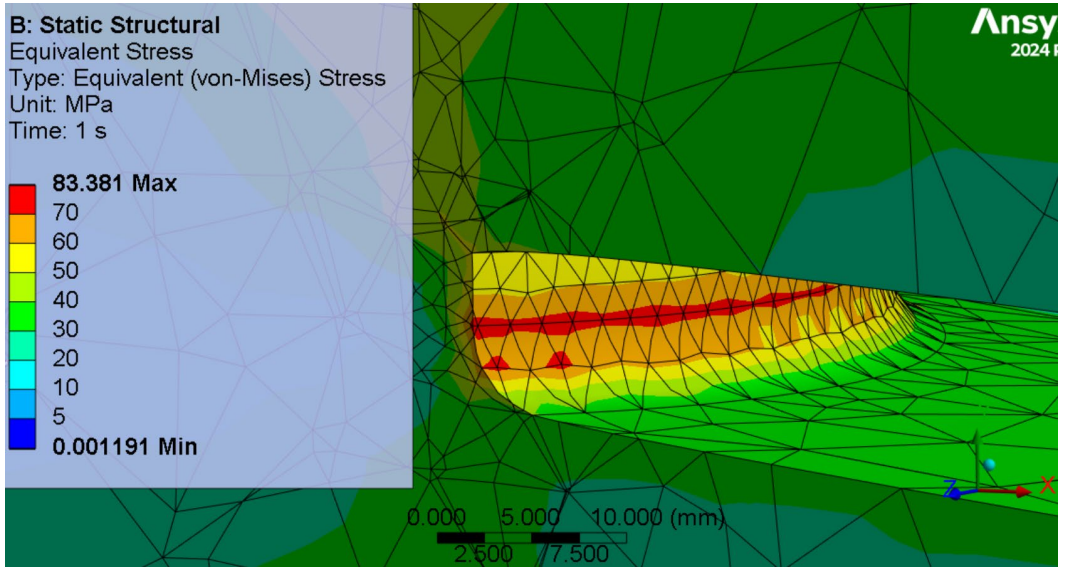
Deformation scale = 500

Peak Stress : 83 MPa
SS316 Yield Strength: 252 MPa









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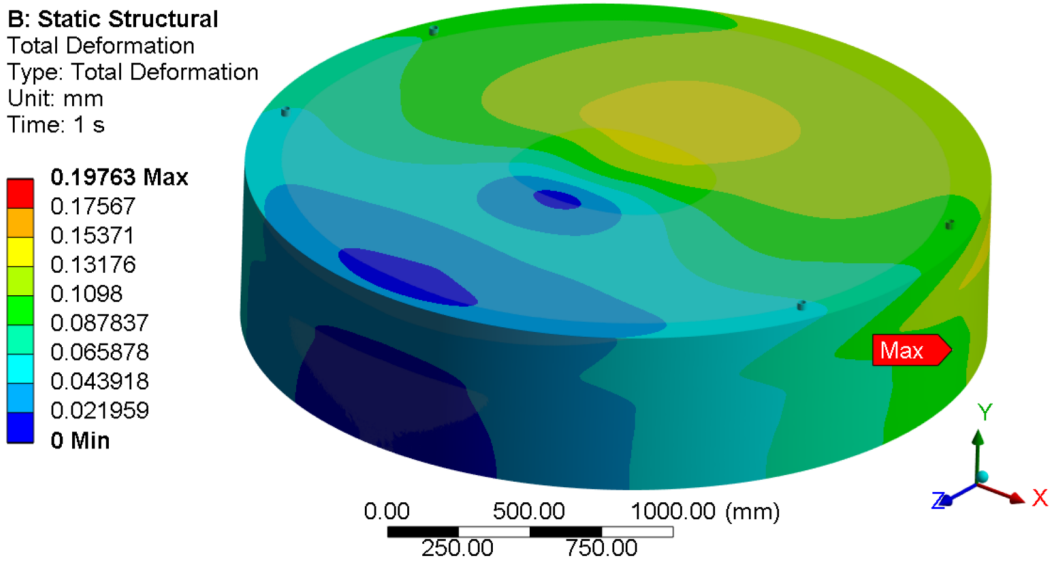
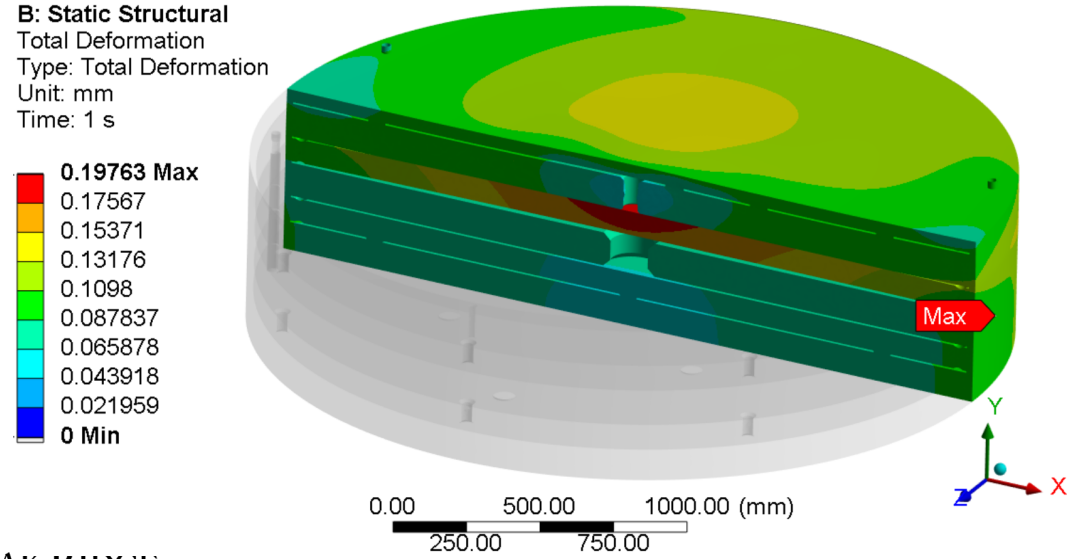
Thermal Only

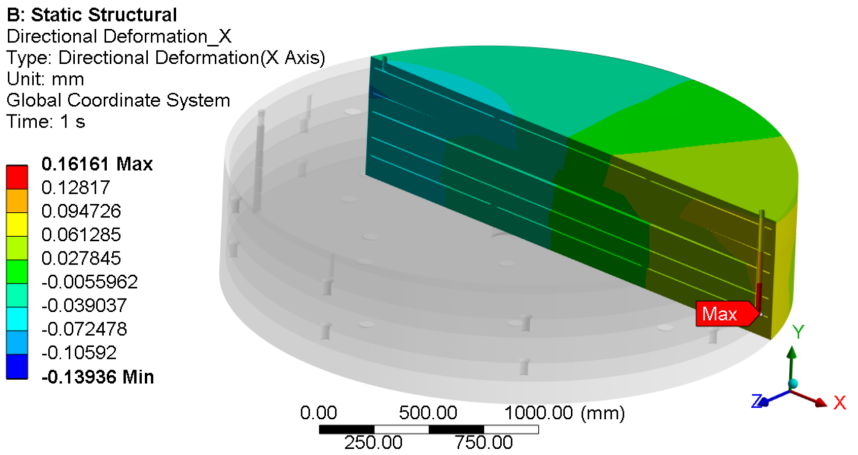
Displacement

Total Deformation

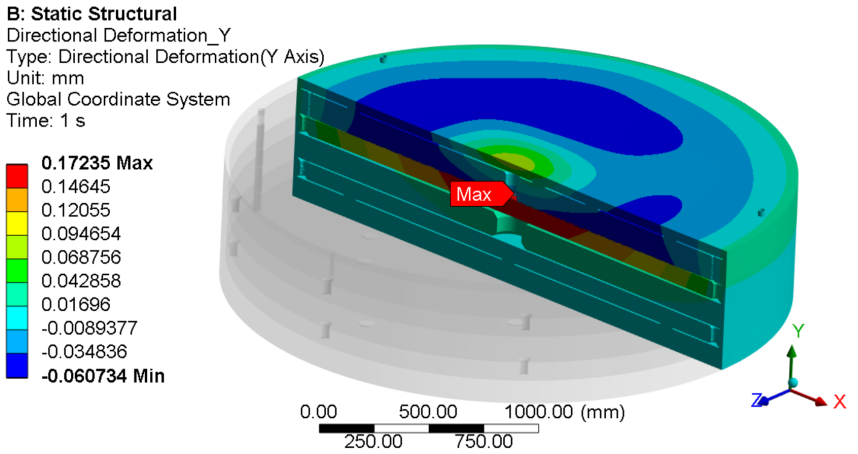




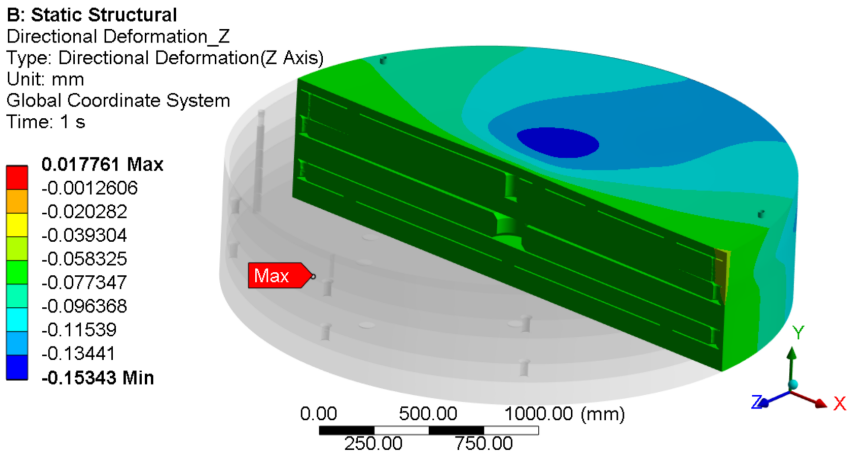
X - Deformation



Y - Deformation



Z - Deformation



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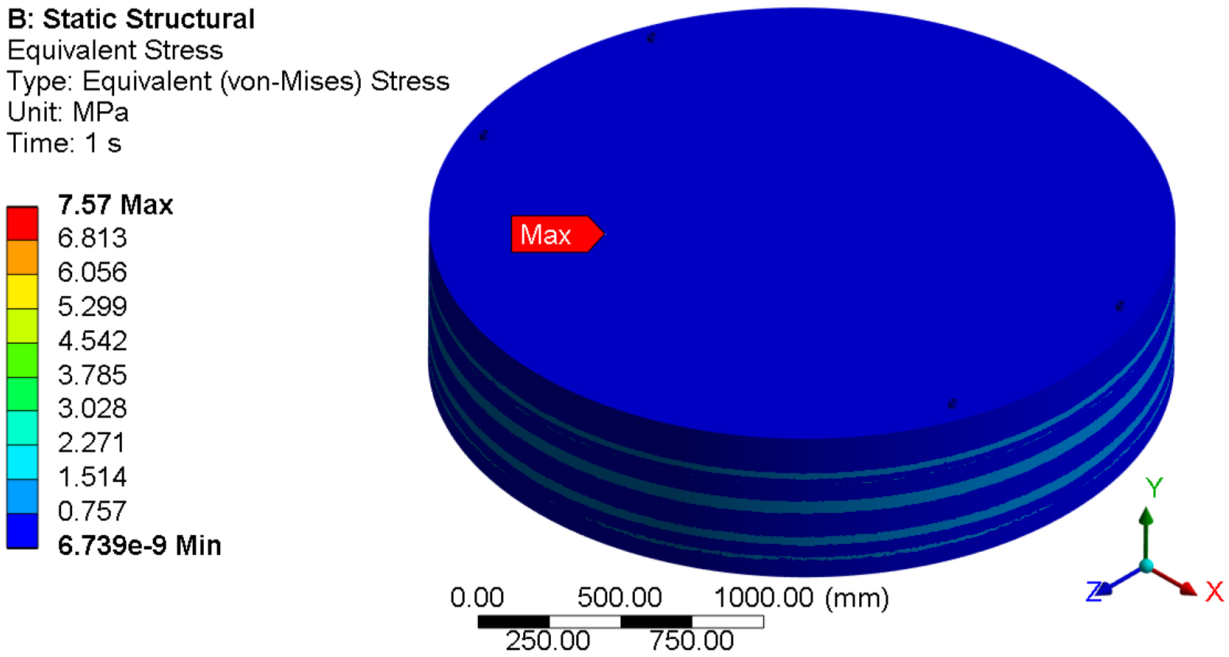
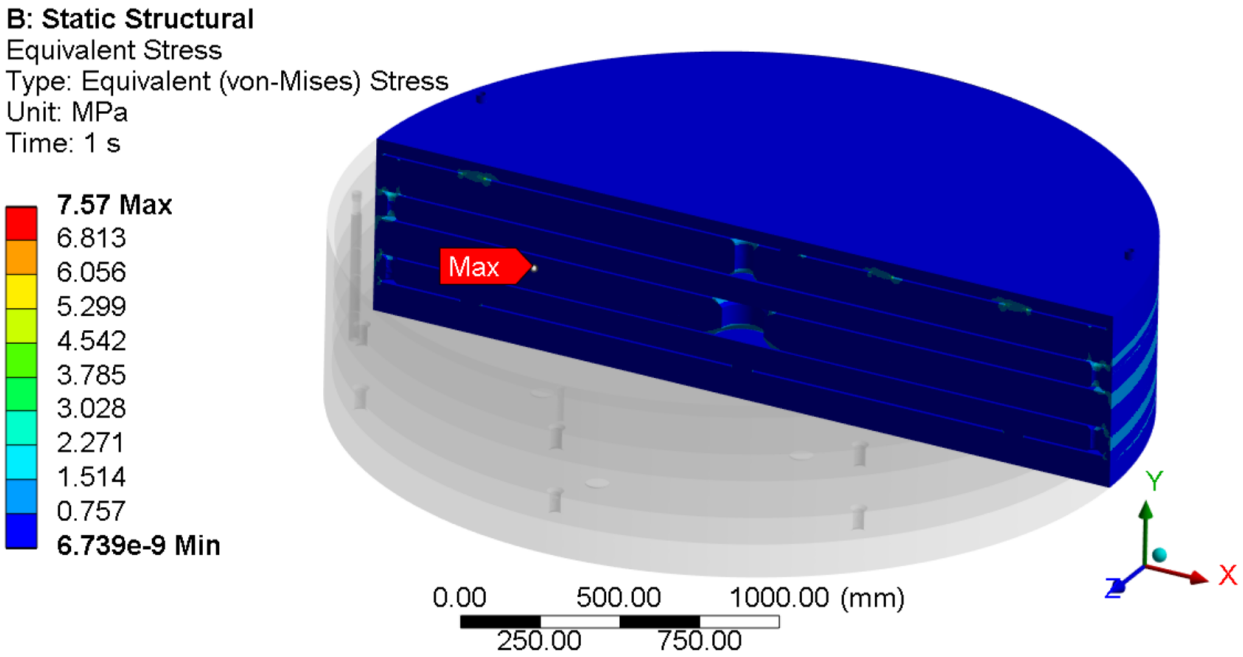
Gravity Only

Von-Mises Stress

Deformation scale = 100

Peak Stress : 13 MPa
SS316 Yield Strength: 252 MPa





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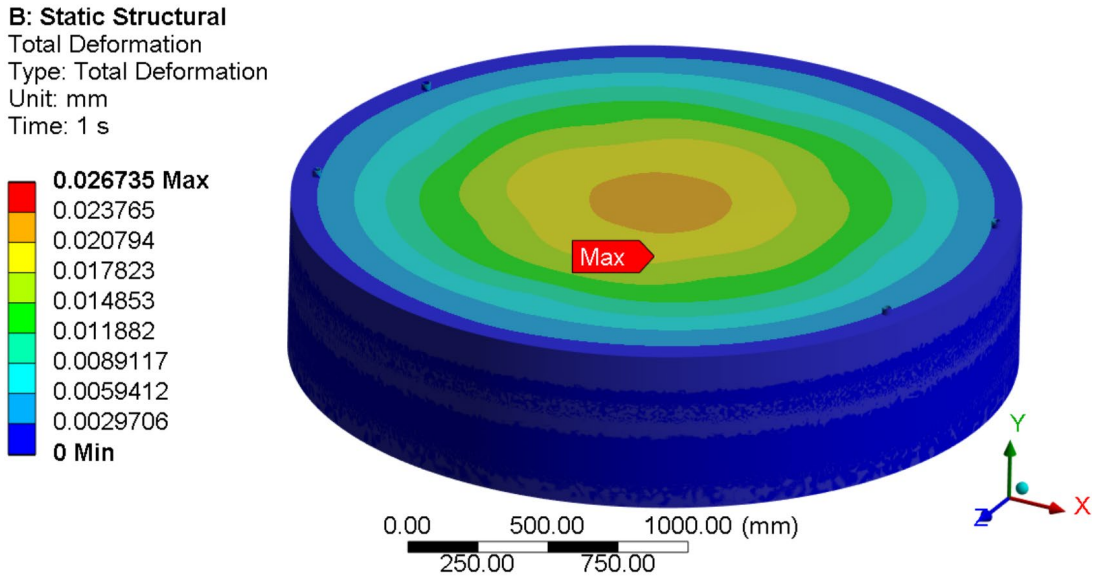
Gravity Only

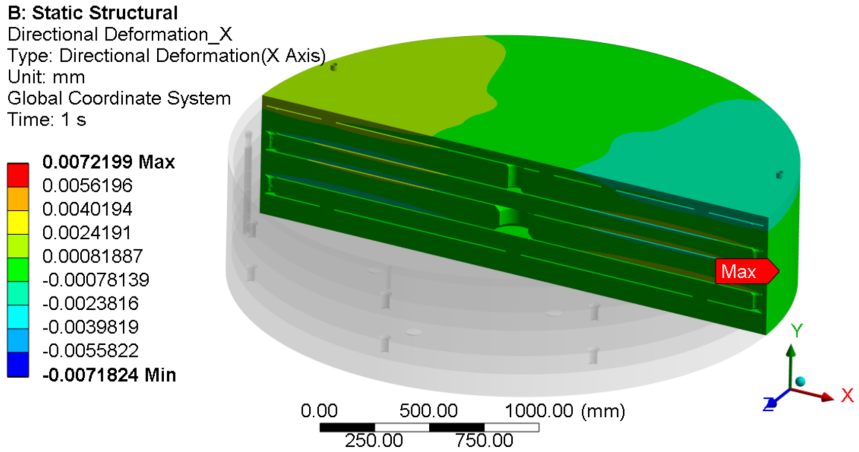
Displacement

Total Deformation

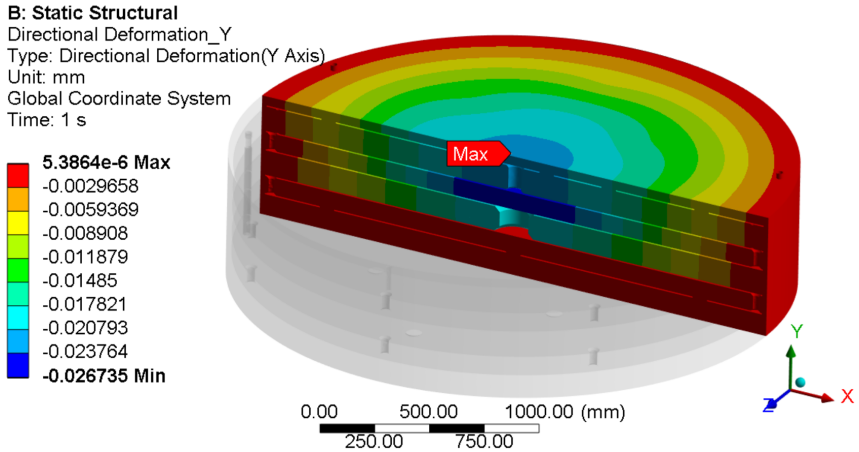
Deformation scale = 100

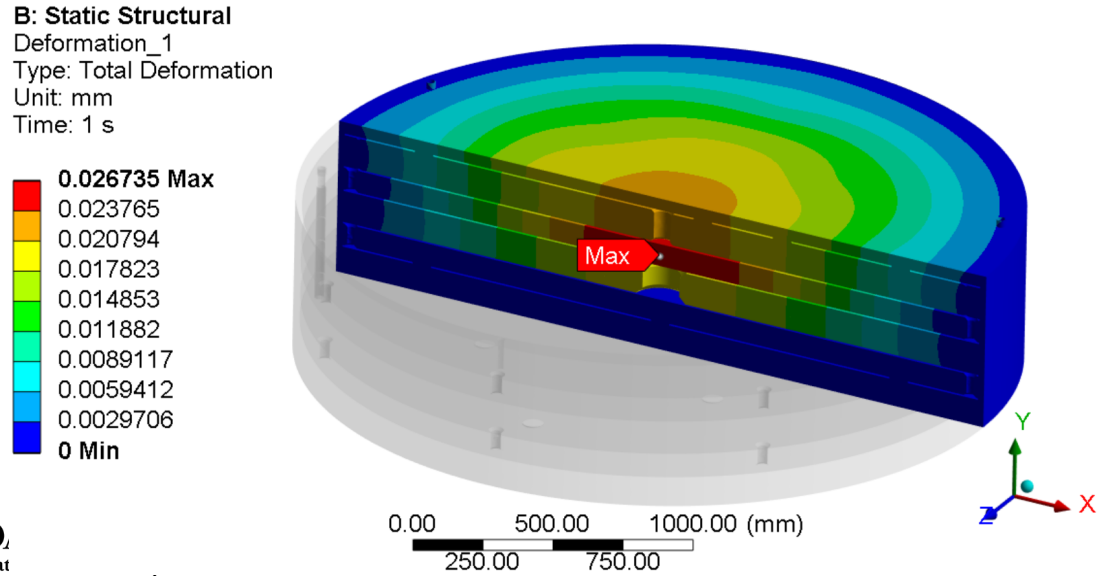


X - Deformation

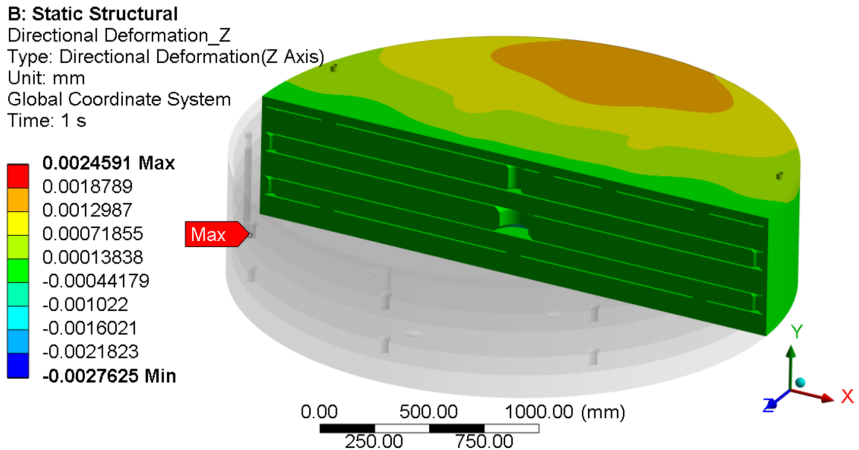


Y - Deformation





Z - Deformation



Summary

Current Model

Absolute value for **deformation**

Bottom Shield Block (Design 16), Uniform Water Pressure of 5 bar
SS316 Tensile Yield Strength: 252.1 MPa ; SS316 Tensile Ultimate Strength: 565.1 MPa

	Max. Von-Mises Stress (MPa)	Max. Total Deformation (mm)	Max. Y Deformation (mm)	Max. X Deformation (mm)	Max. Z Deformation (mm)
Water Pressure **5 bar** Only	497	0.995	0.995	0.63	0.2
Thermal Effect Only	83	0.198	0.17	0.16	0.15
Gravity Effect Only	7.6	0.027	5.4E-06	7.2E-03	2.7E-03
Water Pressure+Thermal+Gravity	**488**	**1.06**	**1.06**	**0.49**	**0.22**

Previous Model

Bottom Shield Block (Design 14), Water Pressure from Normal Operation
SS316 Tensile Yield Strength: 252.1 MPa ; SS316 Tensile Ultimate Strength: 565.1 MPa

	Max. Von-Mises Stress (MPa)	Max. Total Deformation (mm)	Max. Y Deformation (mm)	Max. X Deformation (mm)	Max. Z Deformation (mm)
Water Pressure Effect Only	171	0.22	0.22	0.03	0.02
Thermal Effect Only	859	0.18	0.16	0.11	0.15
Gravity Effect Only	13	0.03	2.76E-06	2.50E-03	2.20E-03
Water Pressure+Thermal+Gravity	**833**	**0.36**	**0.36**	**0.11**	**0.15**