OAK RIDGE National Laboratory | SECOND TARGET STATION

Vessel Systems and Target Station Shielding Thermal Analysis

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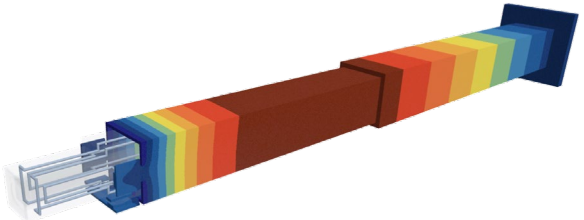
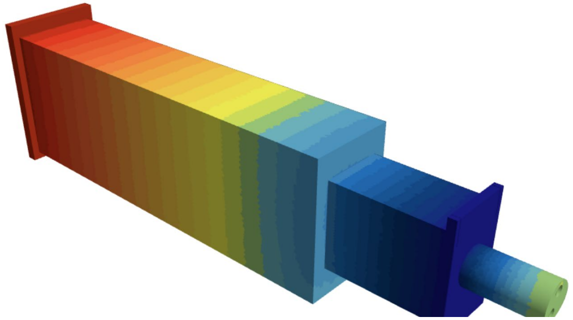
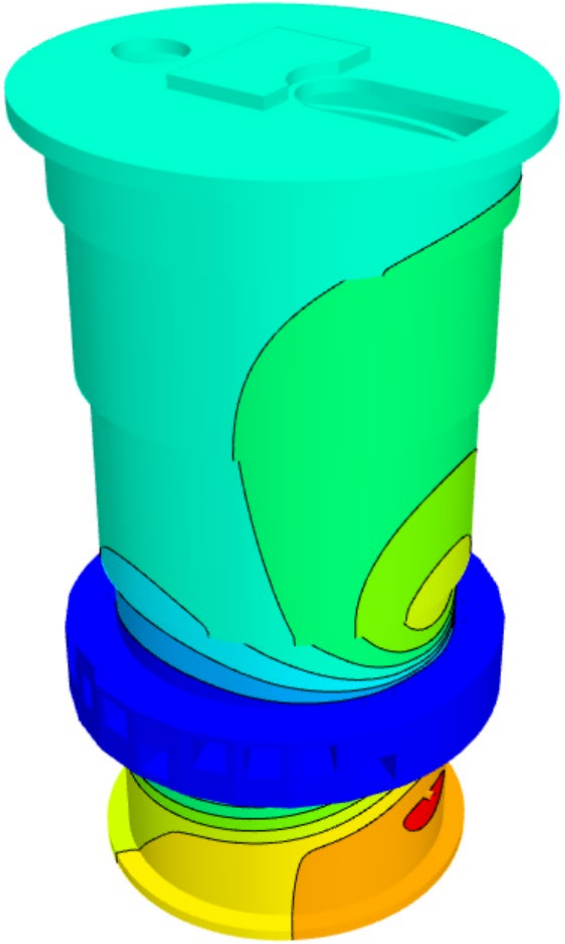
Presentation Outline

Nozzle Extension Analysis

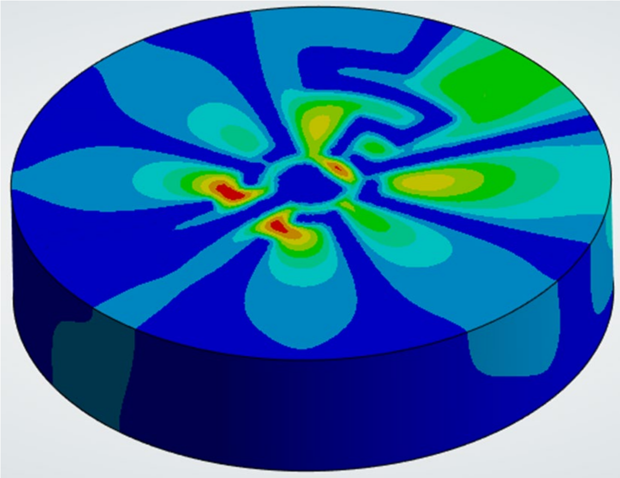


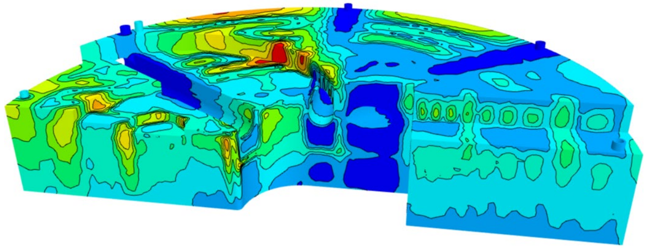


Core Vessel Analysis

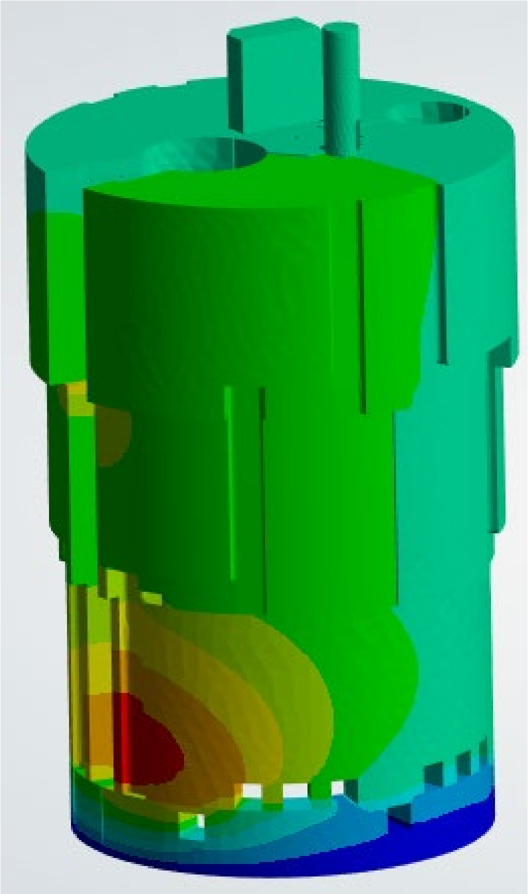


CV Cooled Shielding Analysis

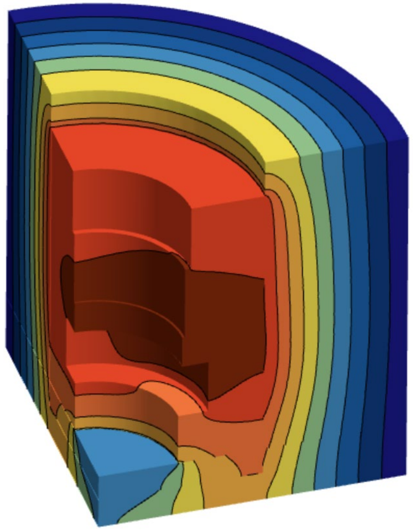




CV Uncooled Shielding Analysis



Target Station Shielding Analysis



OAK RIDGE National Laboratory | SECOND TARGET STATION

Vessel Systems (S.03.06) Core Vessel Thermal Hydraulic Analysis

Min-Tsung Kao

09/06/2023

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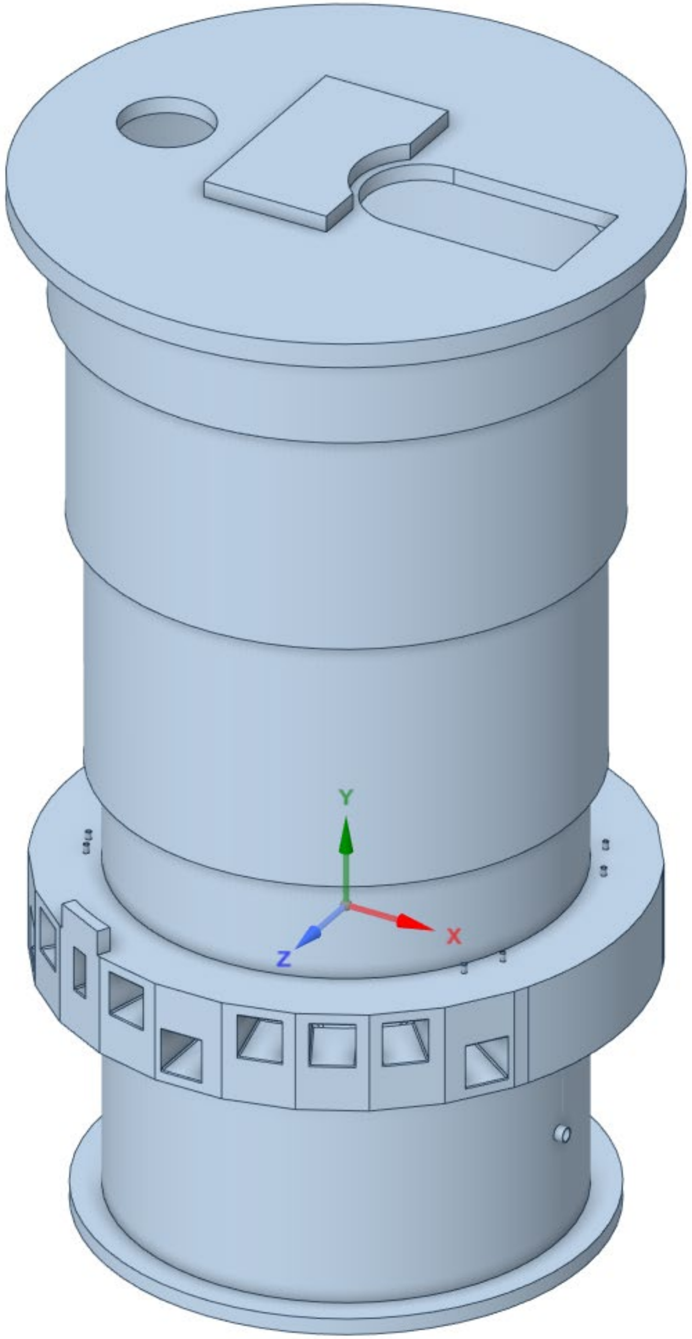
CV Introduction and Requirements

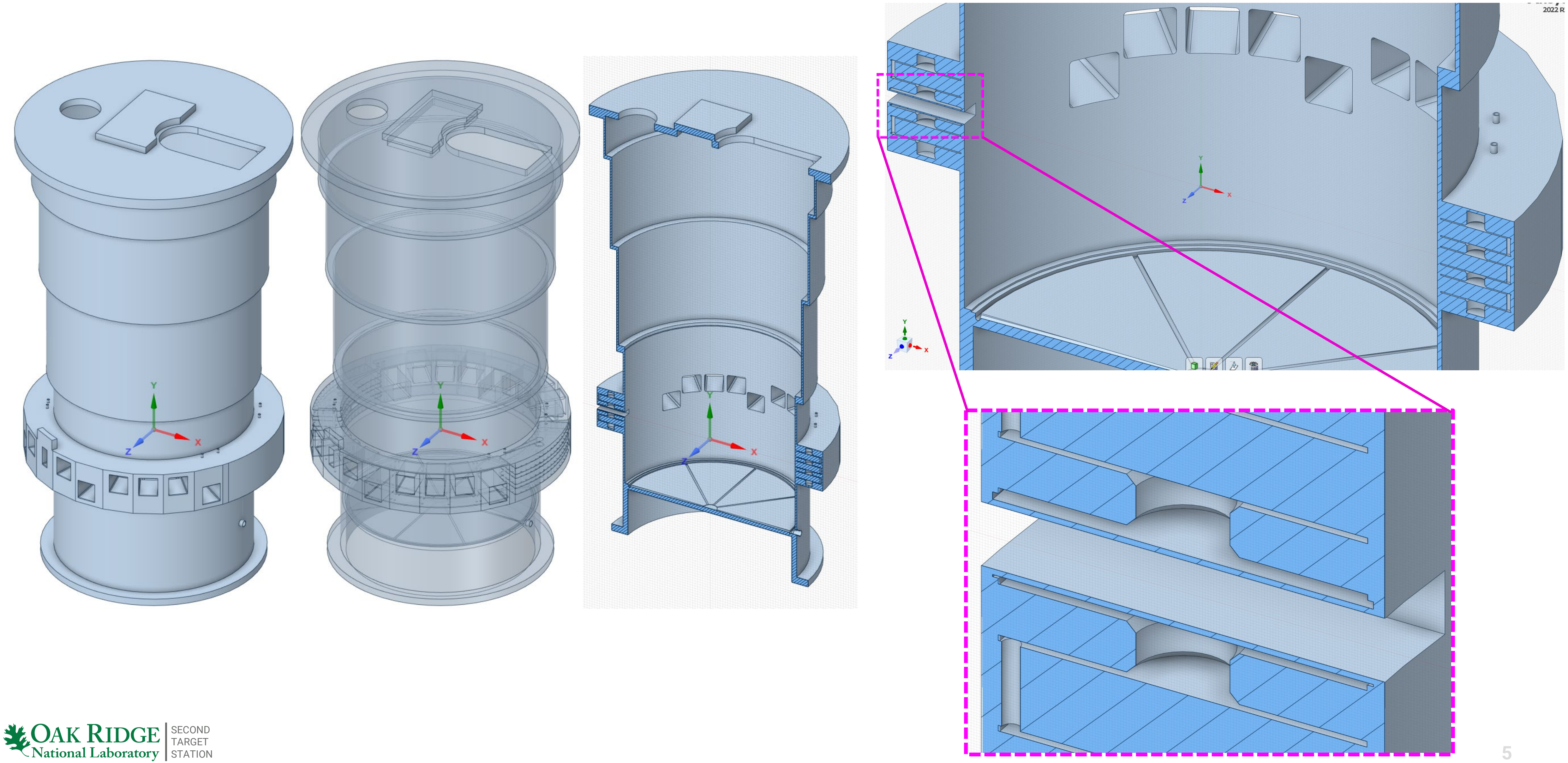
- The position of the following components are impacted by the CV thermal performance:
  - Target Assembly
  - Moderator Reflector Assembly
  - Core Vessel Shielding
  - Monolith Inserts (neutron guide optics)
  - Target Viewing Periscope

Core Vessel Thermal Requirements:

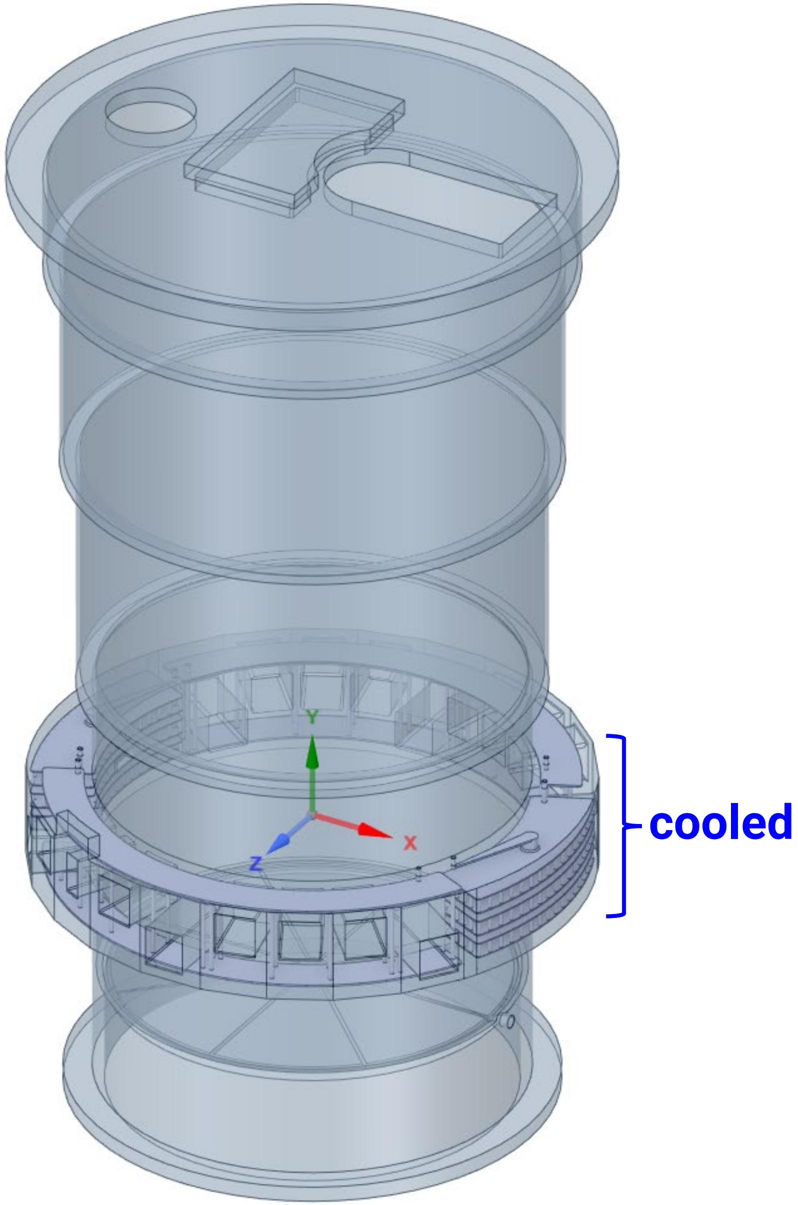
- Maximum stainless steel temperature = 200 C
- Maximum pressure drop = 15 PSI
- Maximum cooling water temperature = 100 C
  - Soft requirement to avoid water boiling within the shielding

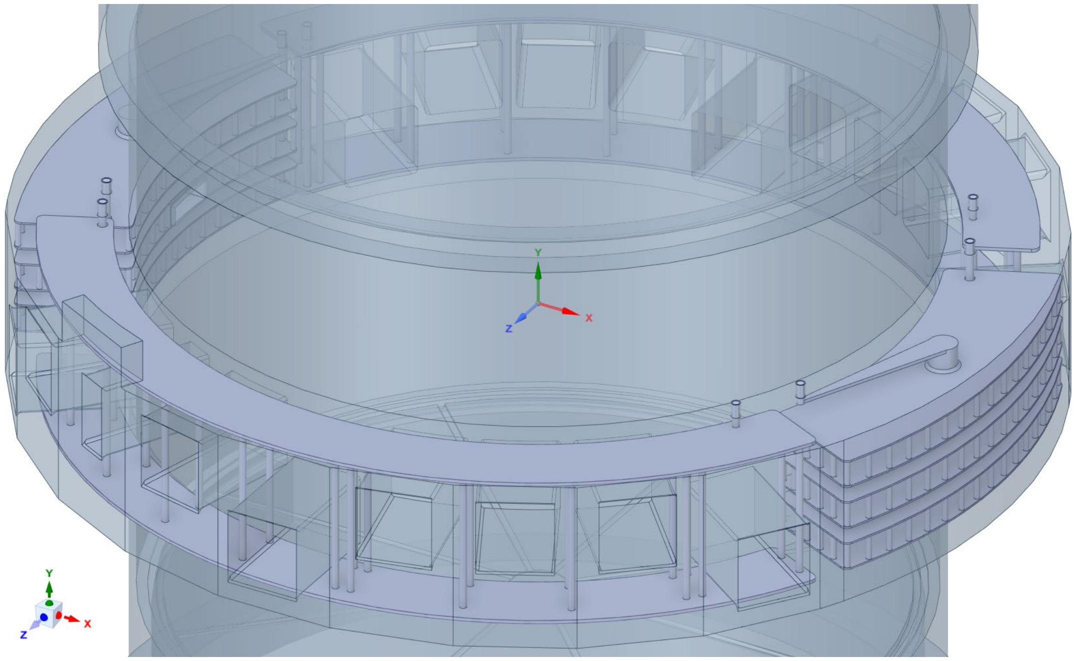


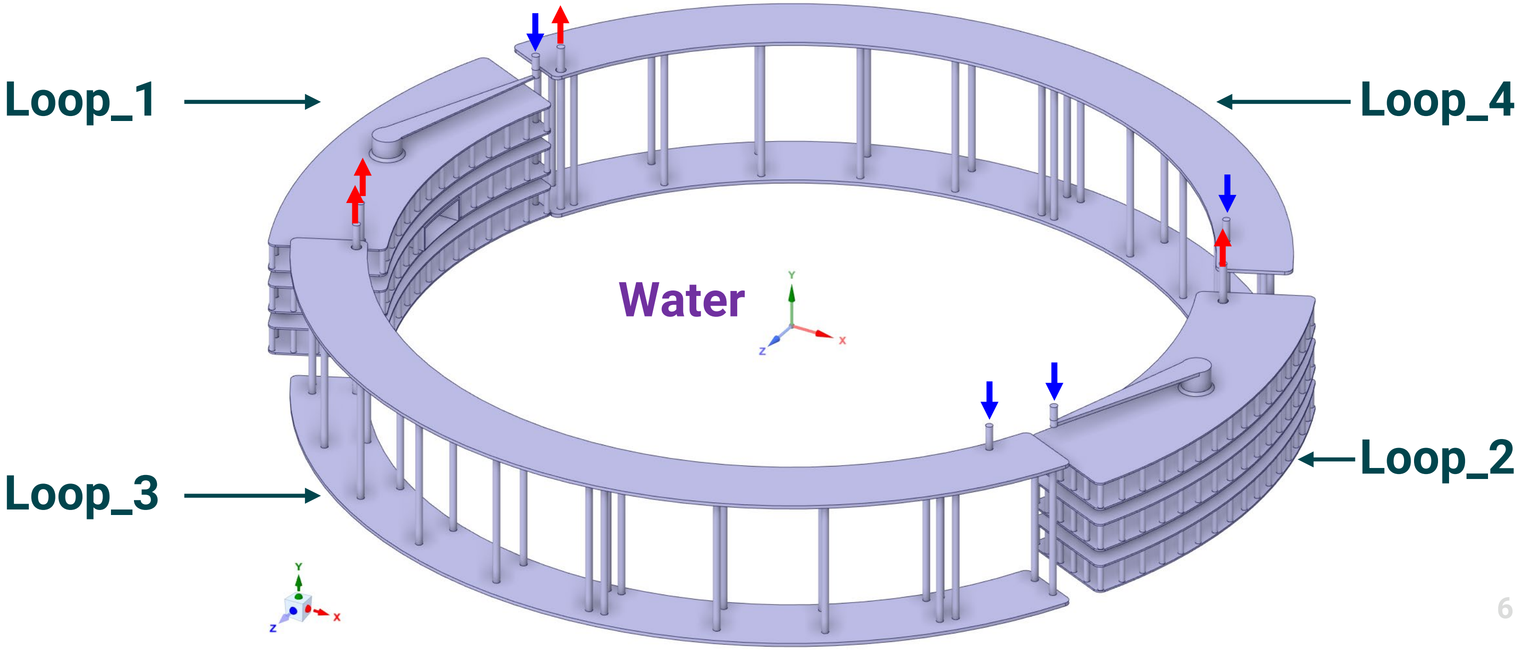
Simplified Core Vessel Model used for thermal analysis



Core Vessel, Cooling Channel



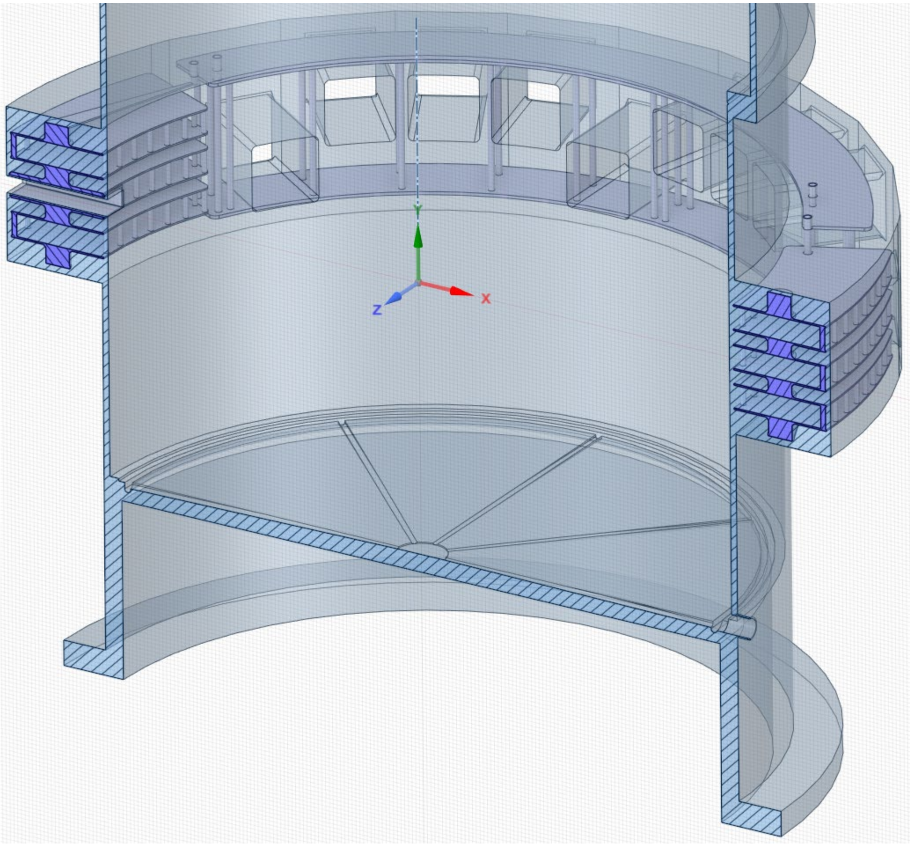


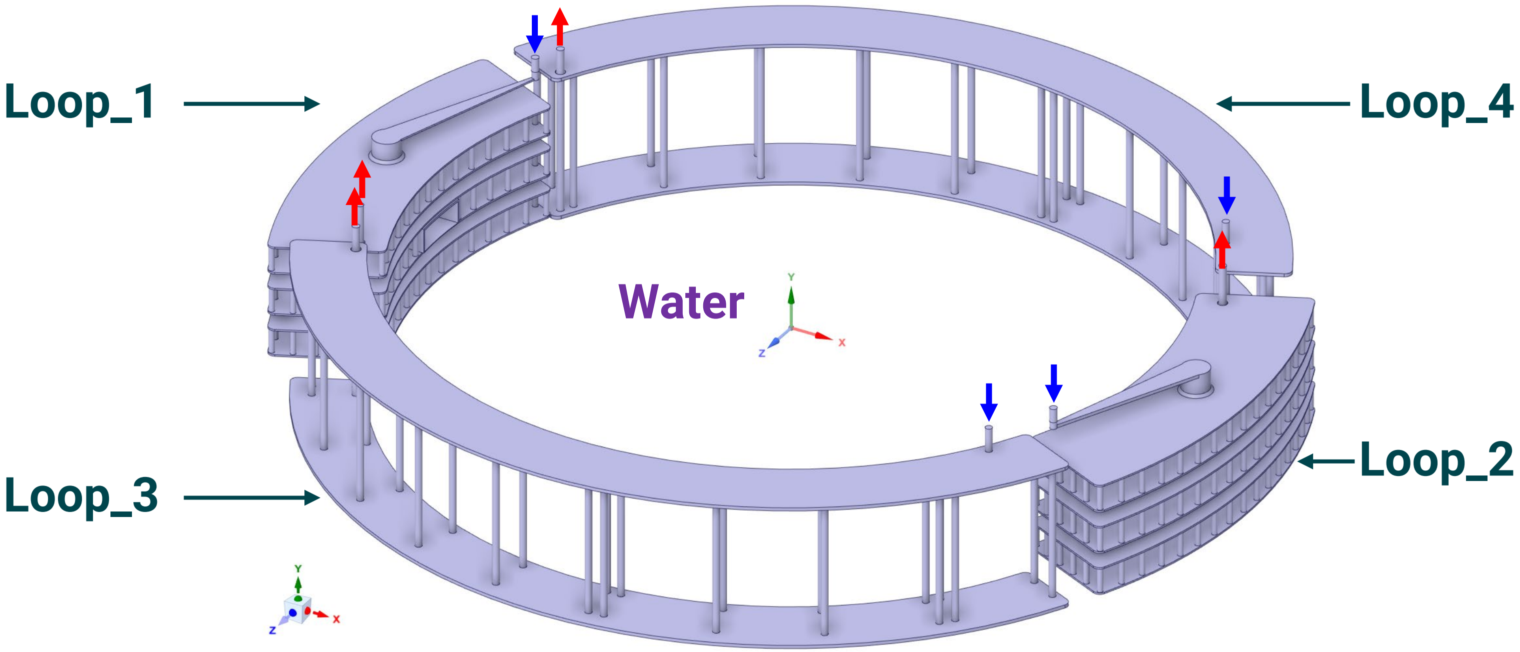


Core Vessel, Cooling Channel

↓ : inlet, 0.5 kg/s (8 GPM) 32.2°C H_2O

↑ : outlet, 45 psia





Material Properties

SS316 Material Properties From Ansys

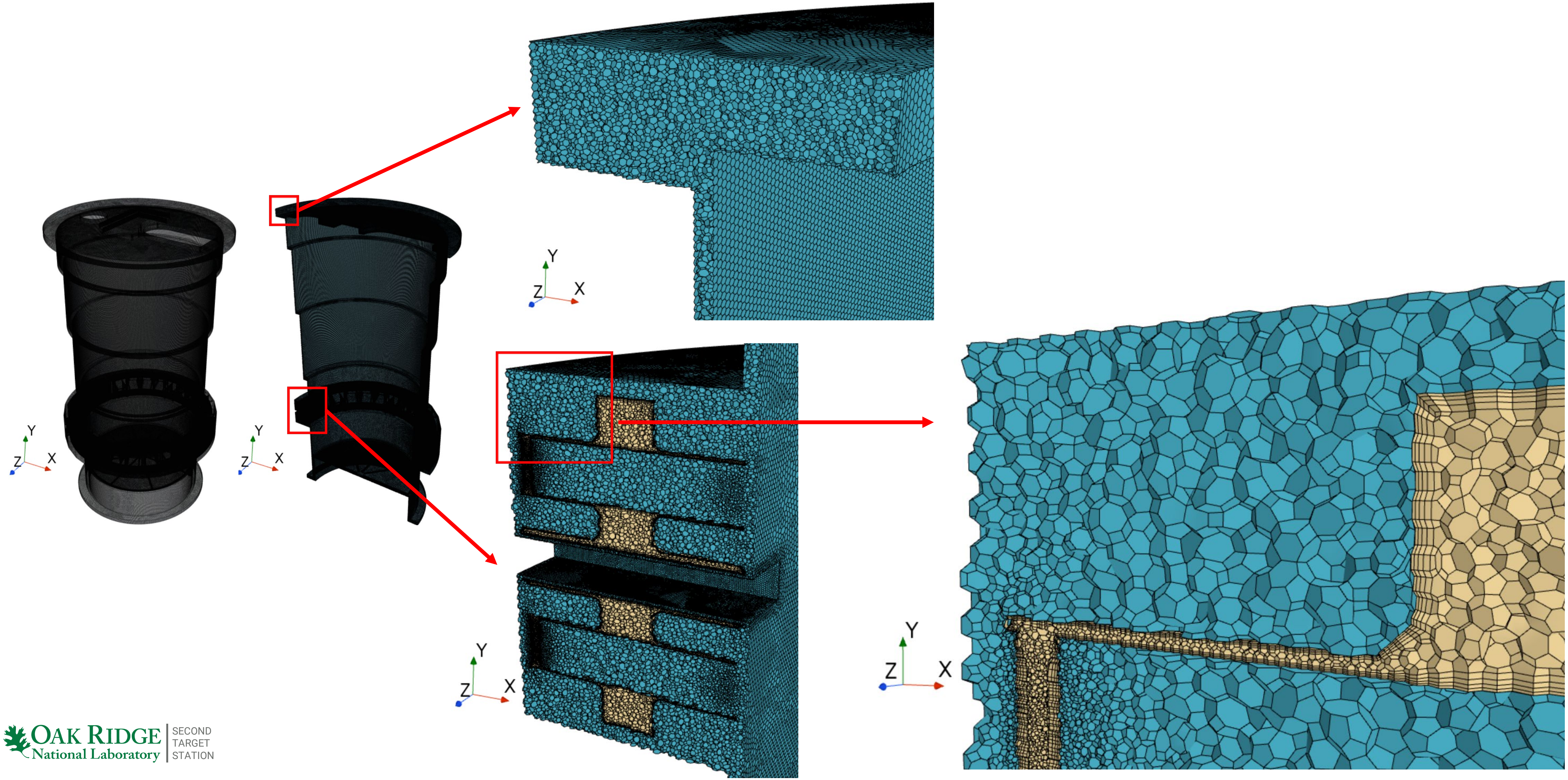
Stainless steel, 316, annealed
Data compiled by Ansys Granta, incorporating various sources including JAHM and MagWeb.

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

Zero Thermal Strain Reference Temperature (°C)	32.2

Core Vessel, Mesh Configuration for CFD Analysis

Polyhedral meshes: 25,375,561



Core Vessel, Heat Source (SS316)

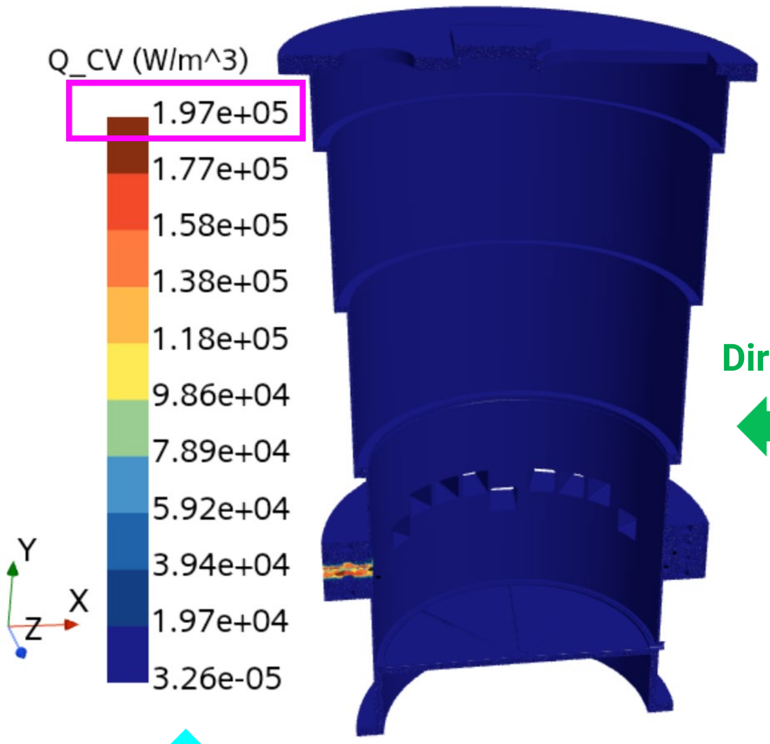
energy deposition from Lukas

Link: https://ornl.sharepoint.com/sites/sts/targetsystems/Shared%20Documents/Forms/AllItems.aspx?csf=1&web=1&e=Ilwgp7&cid=939335e4%2D4ccc%2D4c00%2Da2d2%2D814c53b7125a&FolderCTID=0x01200064187E8E25420543ACAD0BF1C3490EAC&noAuthRedirect=1&id=%2Fsites%2Fsts%2Ftargetsystems%2FShared%20Documents%2FS%2E03%2E02%20Target%20Assembly%2F1%5FCALCULATIONS%2FCALC%2D018%20%2D%20CoreVessel%2FNeutronics&viewid=9be9bc88%2D5a13%2D48c7%2D9fff%2Dd22f94ffdeb5

- o07a_CVBeltDOWN_SS316L.csv
- o07a_CVBeltDOWN_SS316Water.csv
- o08b_CVBeltUP_SS316L.csv
- o08b_CVBeltUP_SS316Water.csv
- o09d_Center_SS316L.csv
- o09d_Center_SS316Water.csv
- o09d_Center_SS316Water_2.csv
- o09f_11_out_Bottom_SS304L.csv
- o09f_11_out_Bottom_SS316L.csv
- o09g_20_out_Top_SS316L.csv
- o09h_22_out_CVTop_above250cm_SS316L.csv

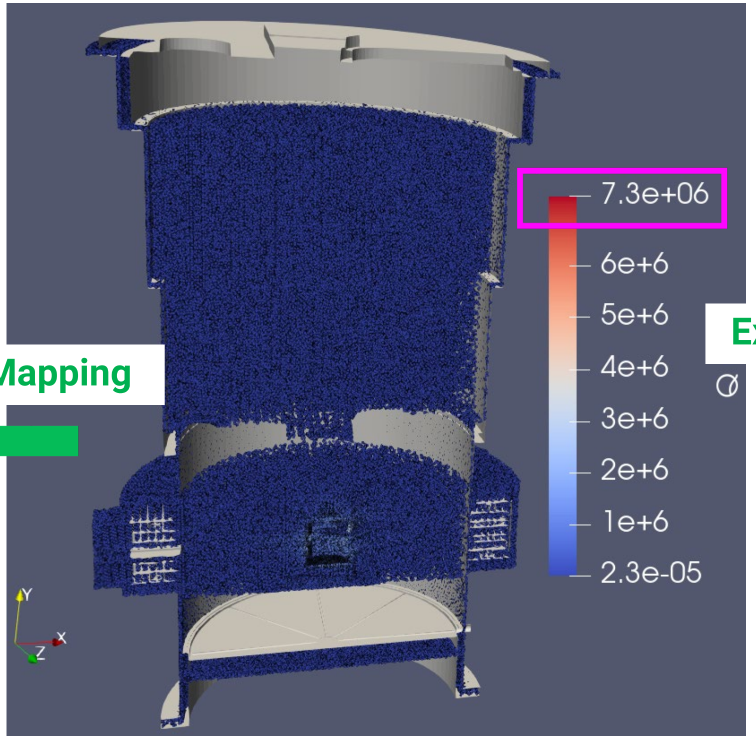
Combined
(unit conversion)

Heat Data Mapped onto CFD Meshes



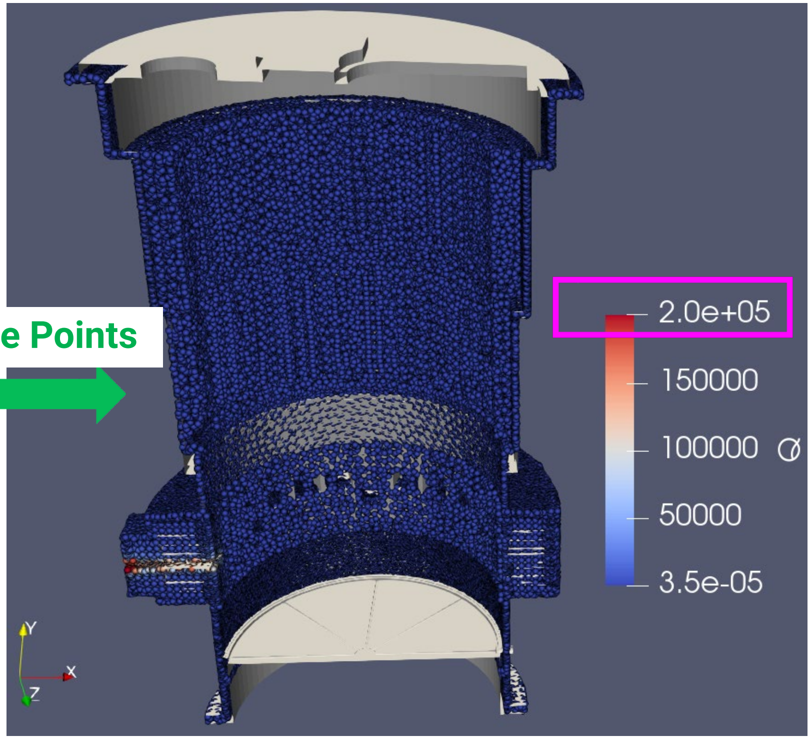
Direct Mapping

Neutronics Heat Data from Lukas



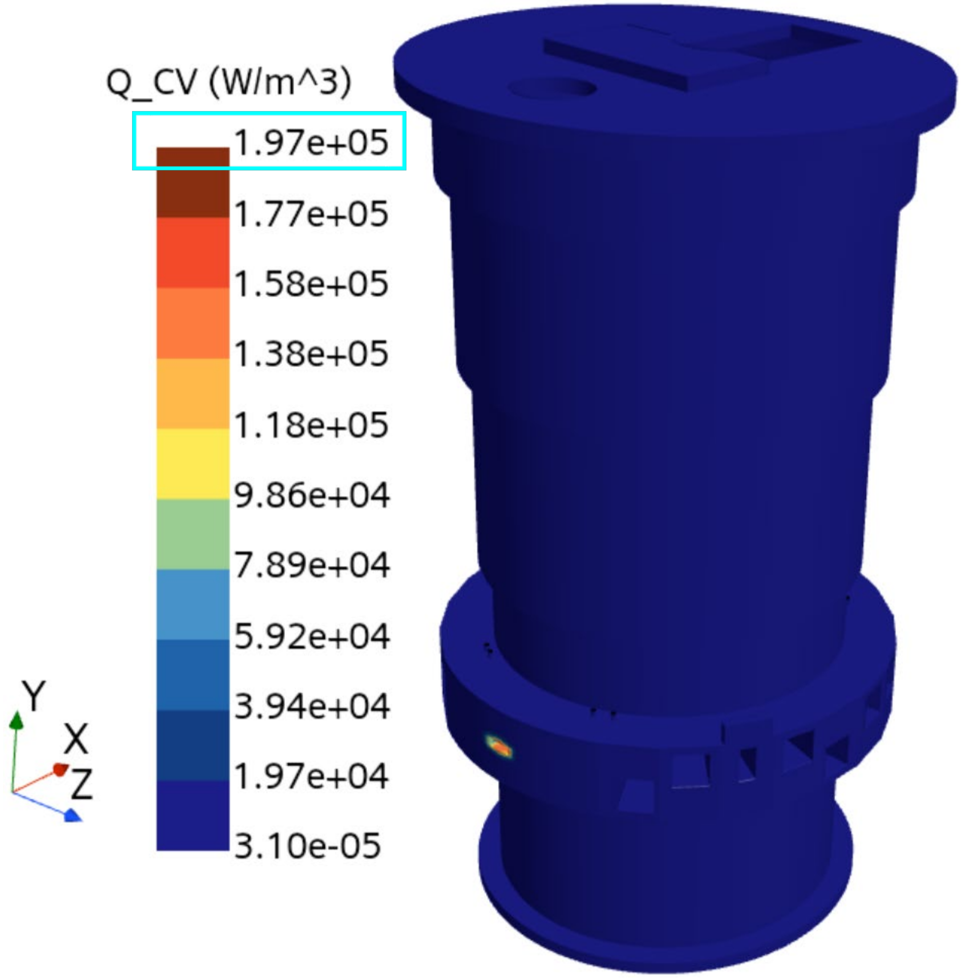
Exclude Points

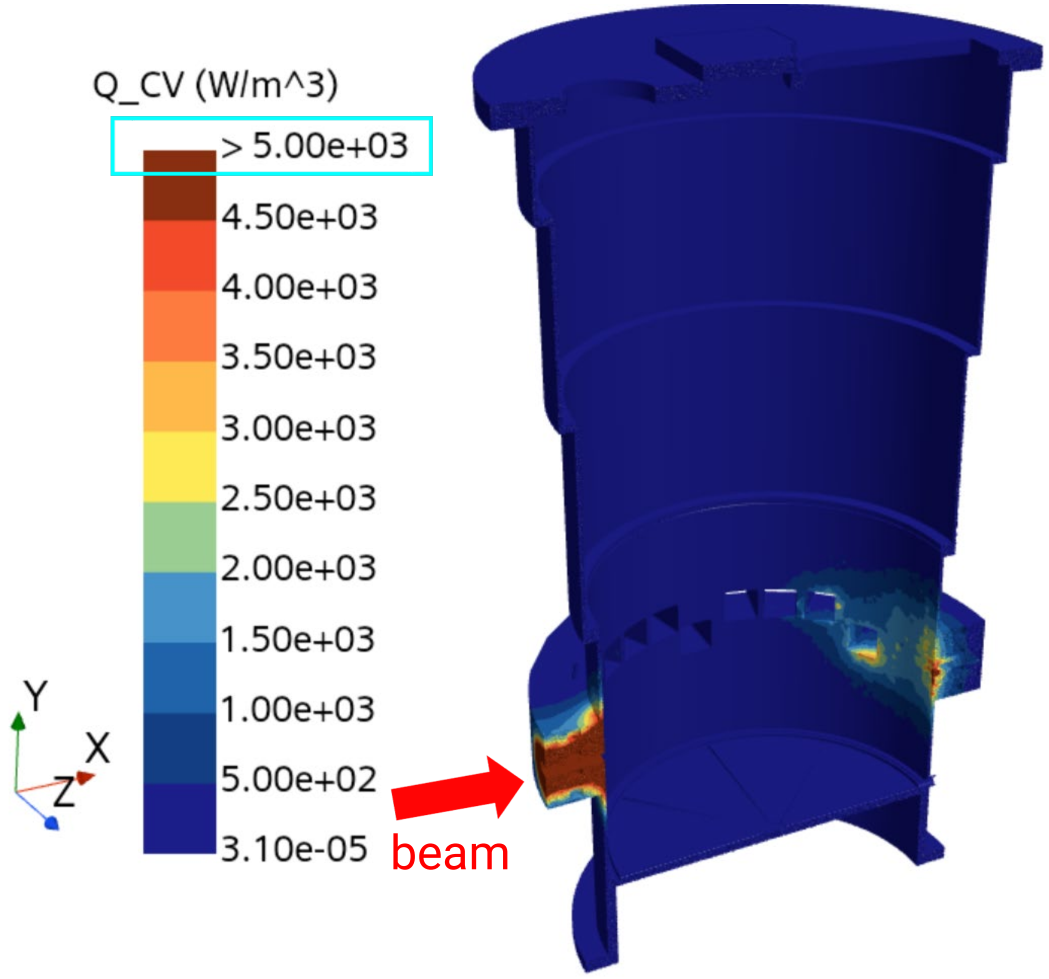
Exclude Neutronics Heat Data Points in Shield Blocks



Core Vessel, Heat Source (SS316)

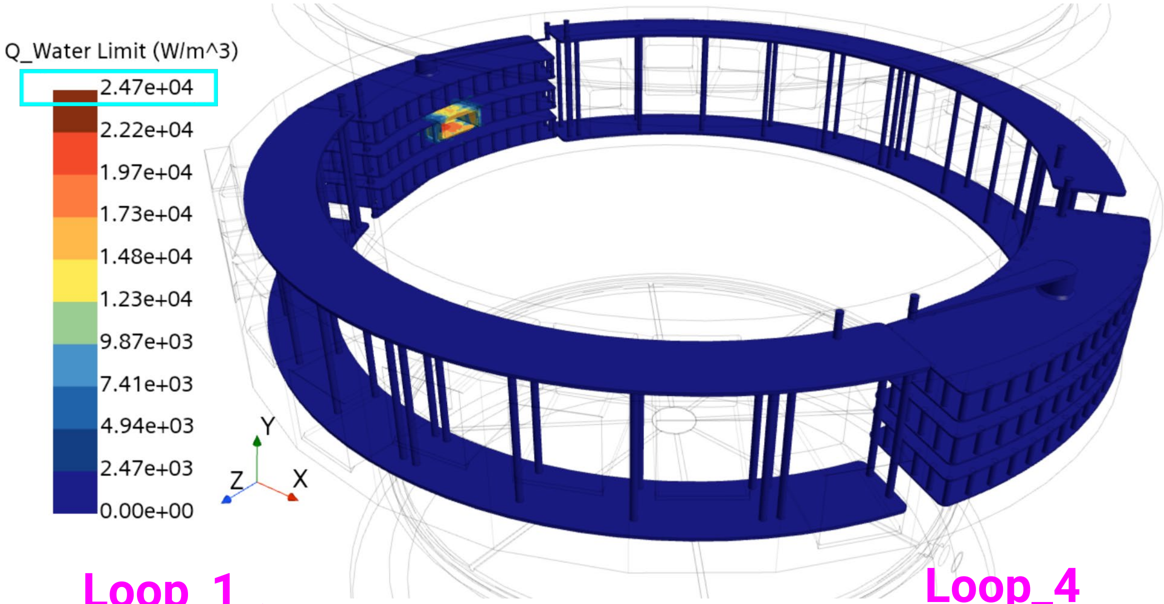
Q_{ss} = 1,868 W





Heat Source in Water

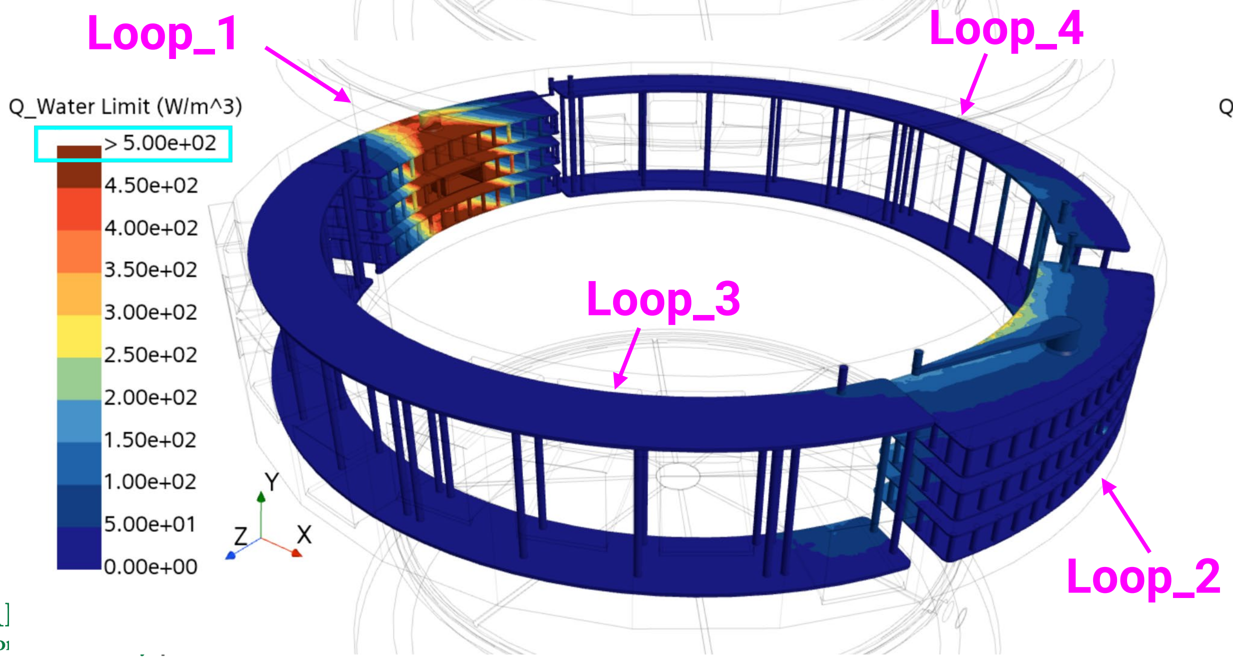
Q_Water approximation: $Q_{water} = QSB_{heat} * \frac{\rho_{water}}{\rho_{SS}}$

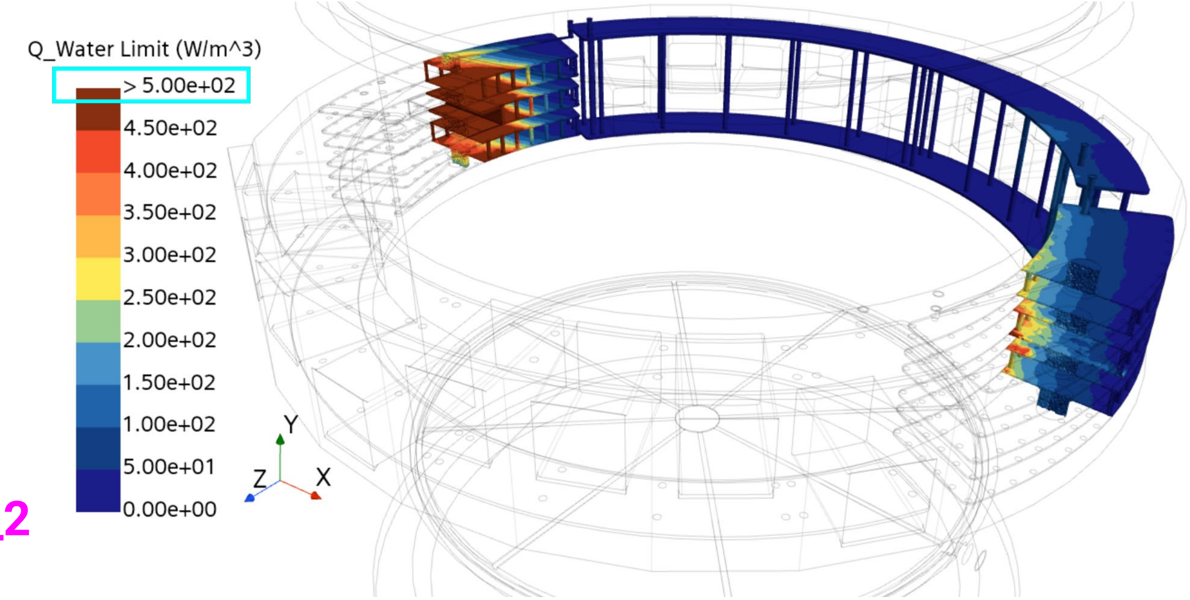


$Q_{water\_Loop\_1}$ = 49.74W

Lower heating
$Q_{water\_Loop\_2}$ = 2.29W
$Q_{water\_Loop\_3}$ = 0.32W
$Q_{water\_Loop\_4}$ = 0.61W

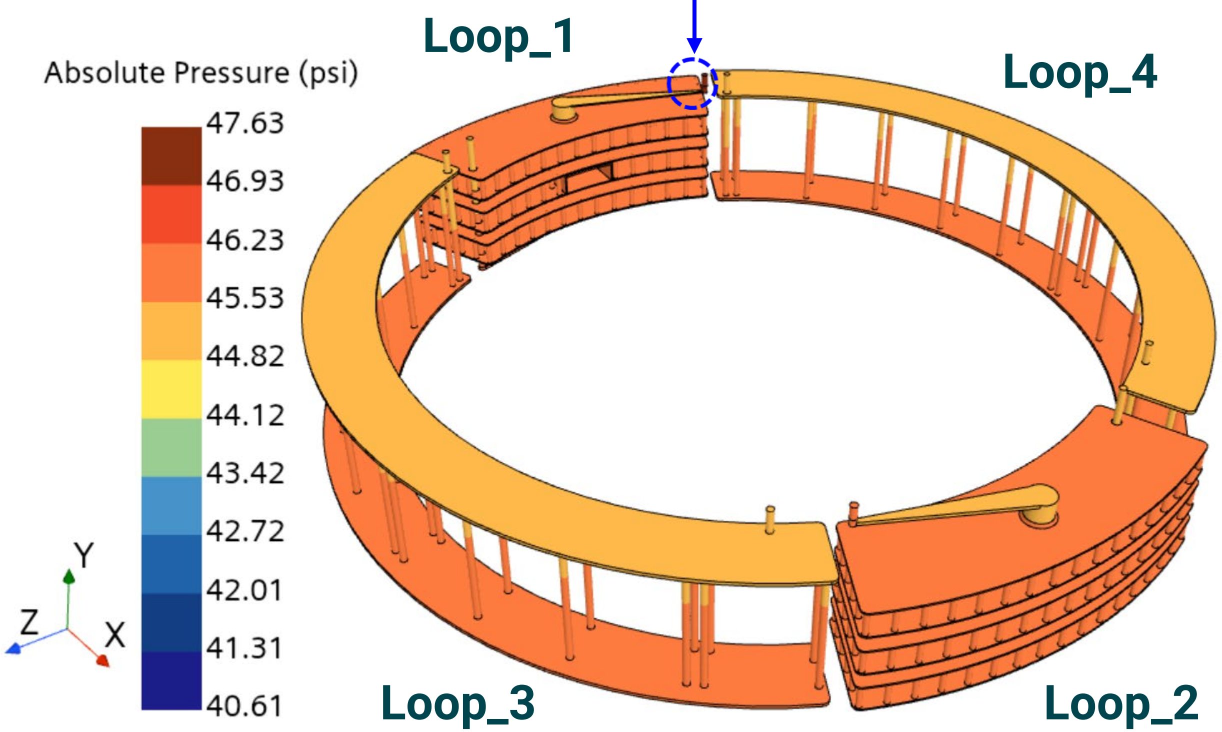
Q_{water_total} **= 52.95W**

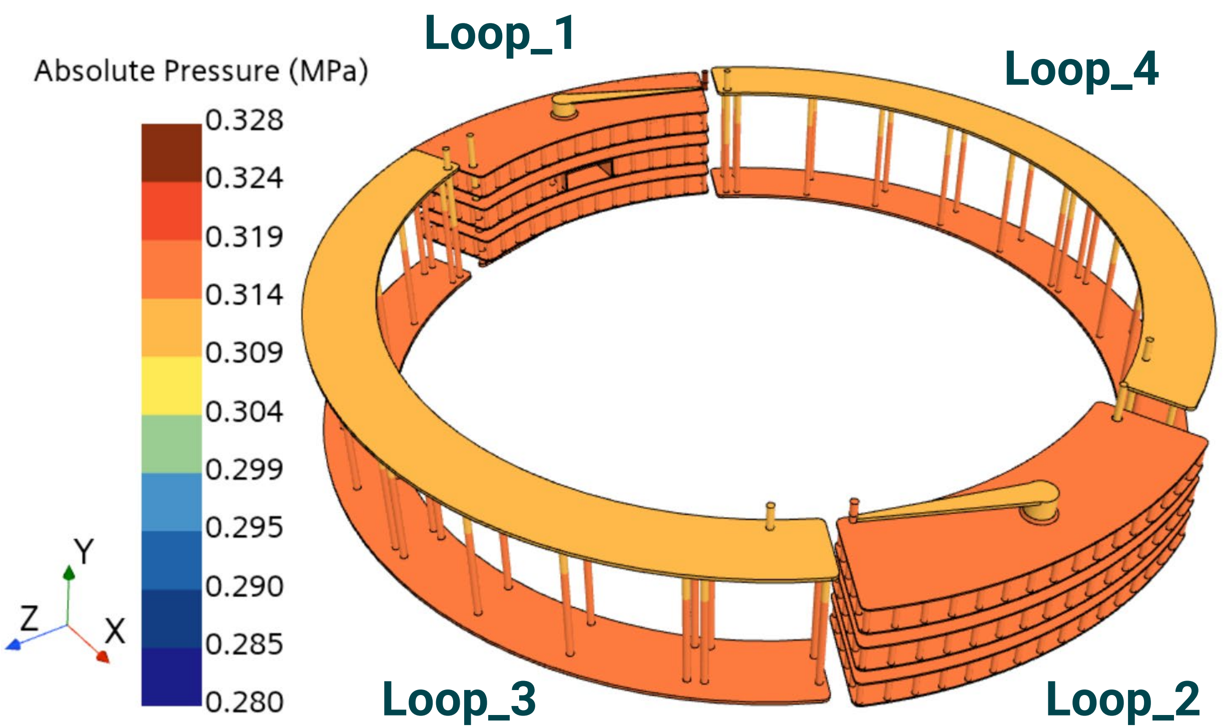




Water Pressure

issue





$\Delta P_{inlet-outlet\_Loop\_1} = 0.17 \text{ bar } (= 17 \text{ kPa} = 2.47 \text{ psi})$

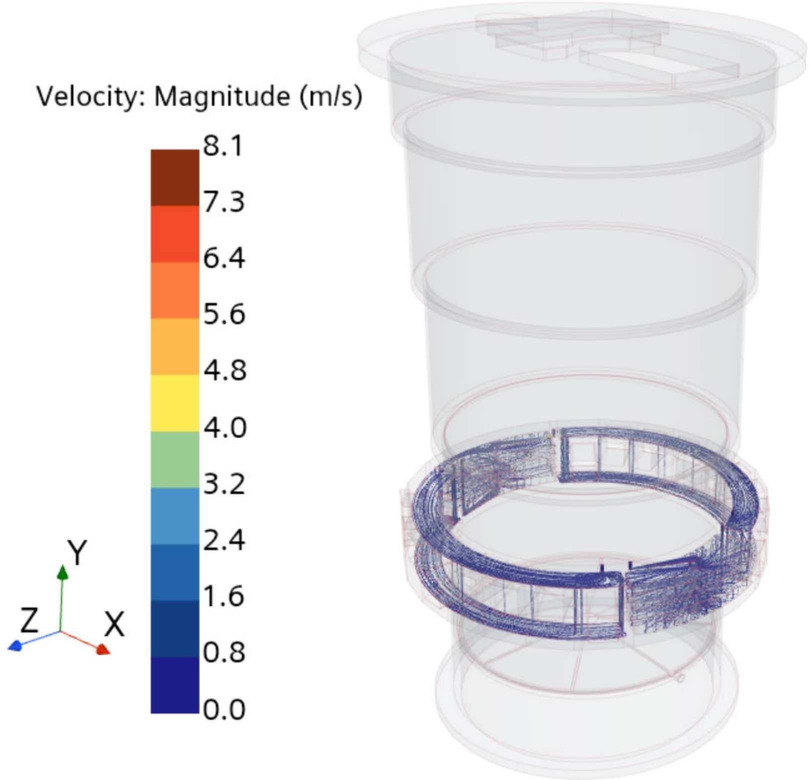
$\Delta P_{inlet-outlet\_Loop\_2} = 0.044 \text{ bar } (= 4.37 \text{ kPa} = 0.63 \text{ psi})$

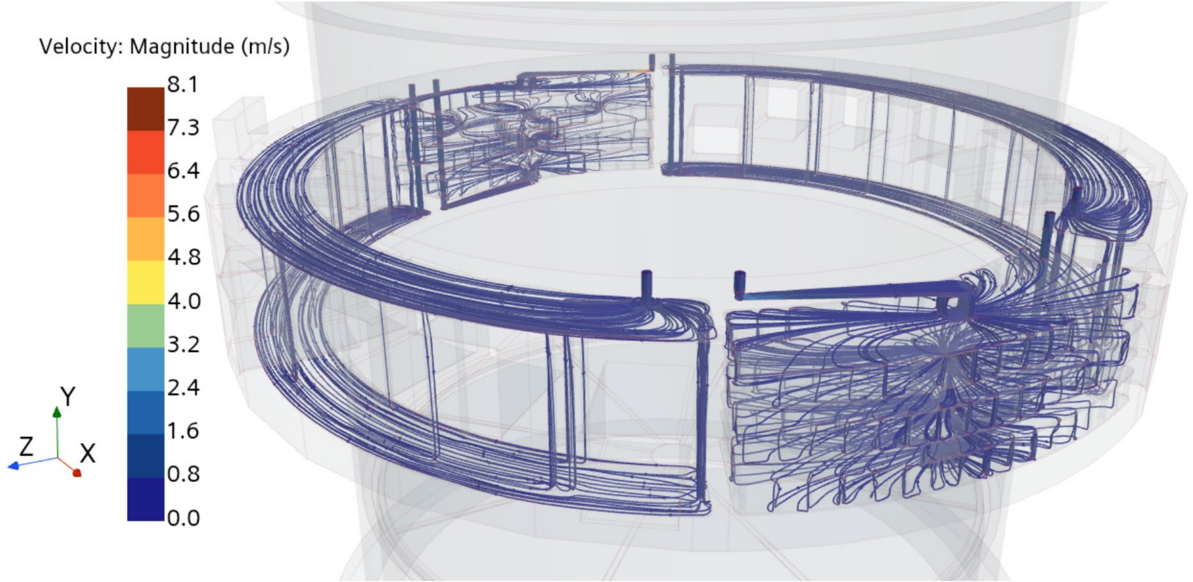
Comparison in next 3 slides

$\Delta P_{inlet-outlet\_Loop\_3} = 0.014 \text{ bar } (= 1.43 \text{ kPa} = 0.21 \text{ psi})$

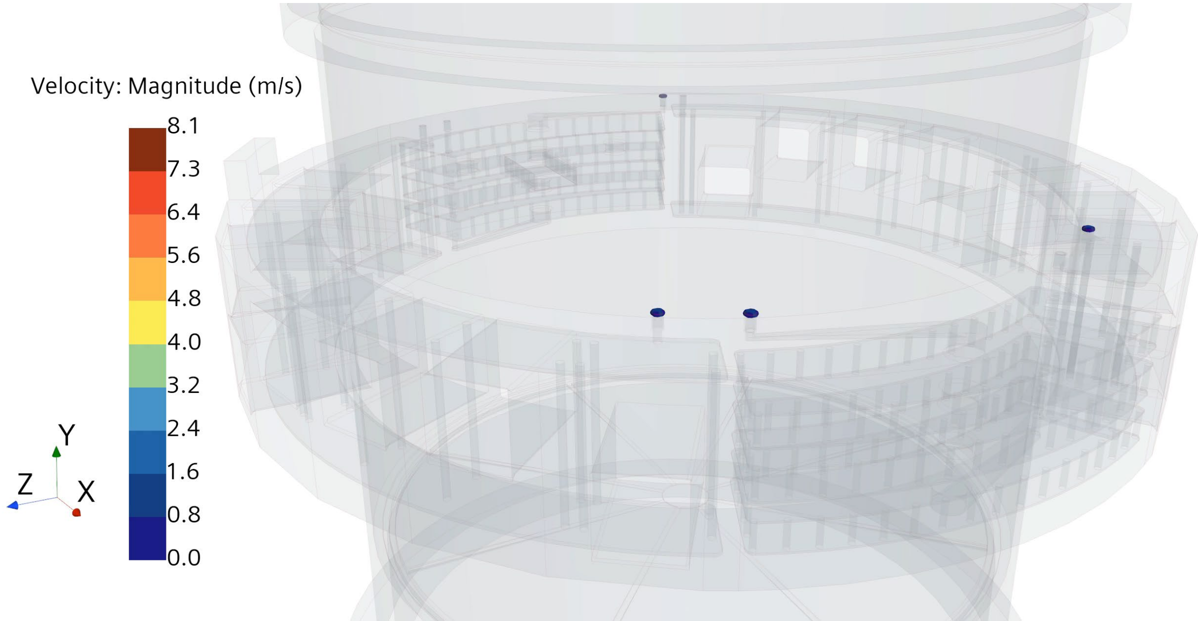
$\Delta P_{inlet-outlet\_Loop\_4} = 0.015 \text{ bar } (= 1.51 \text{ kPa} = 0.22 \text{ psi})$

Core Vessel, Streamlines

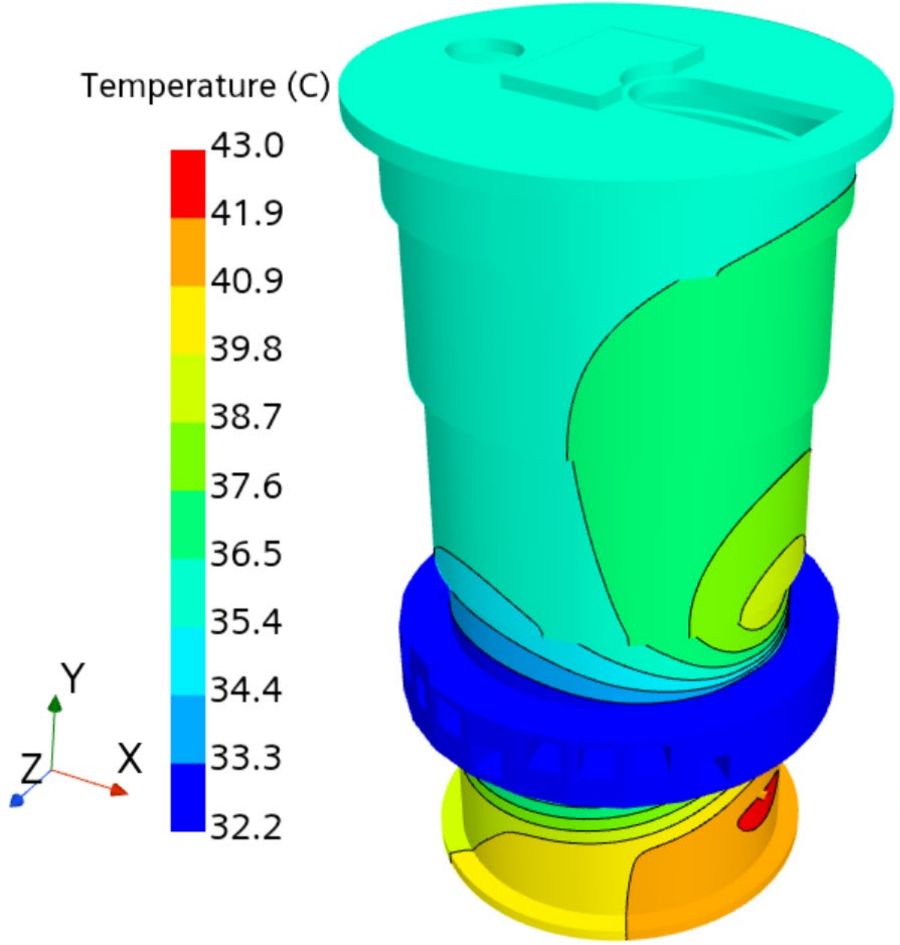




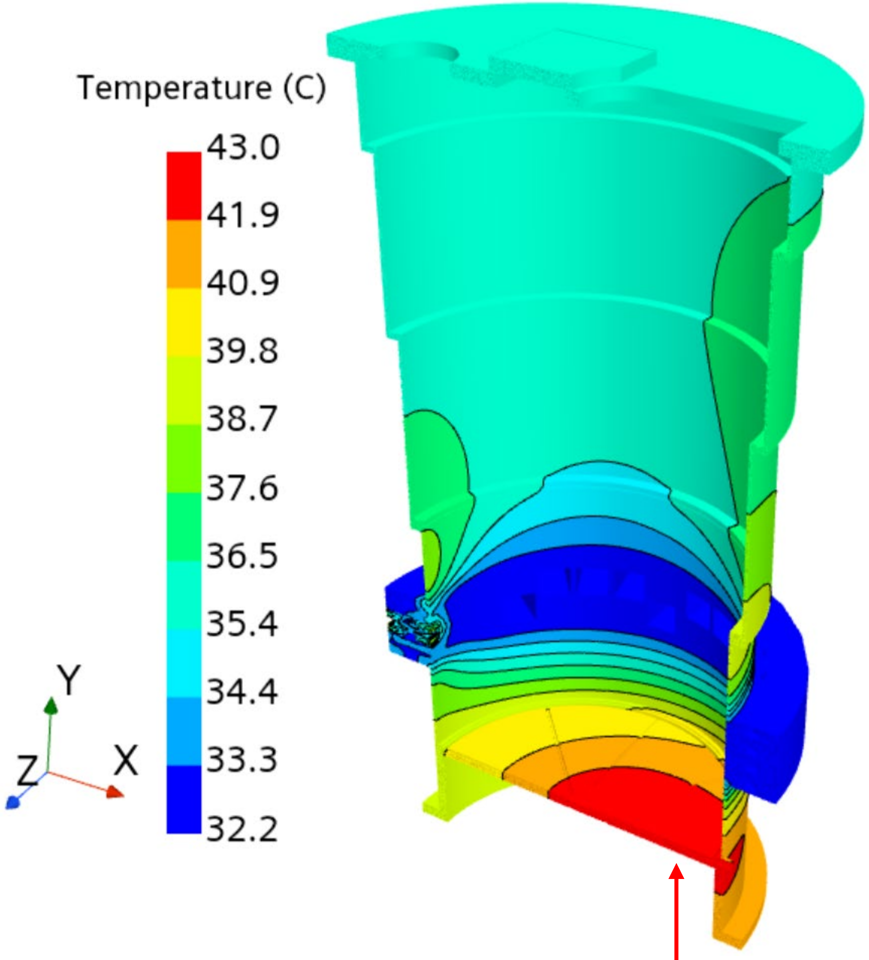
Streamline Animation



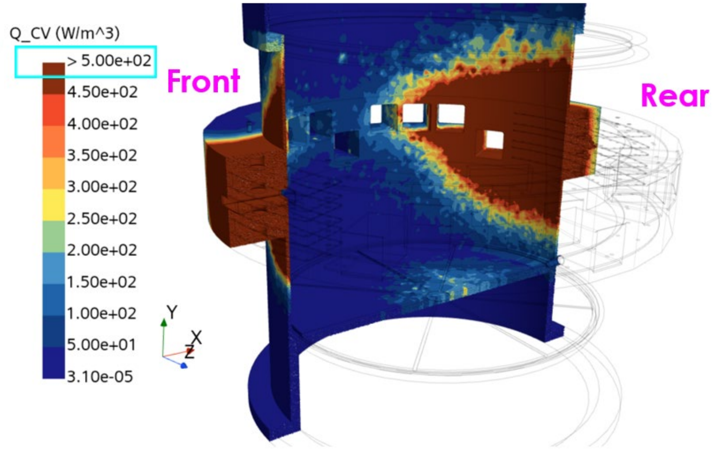
Core Vessel, Stainless Steel Temperature

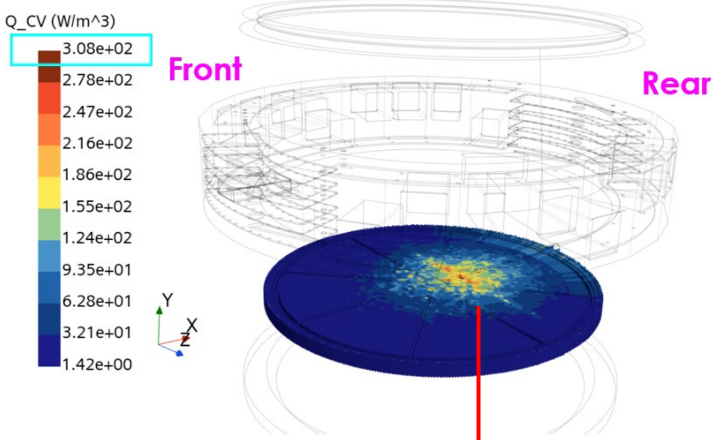


Peak: 43°C



Heat Source

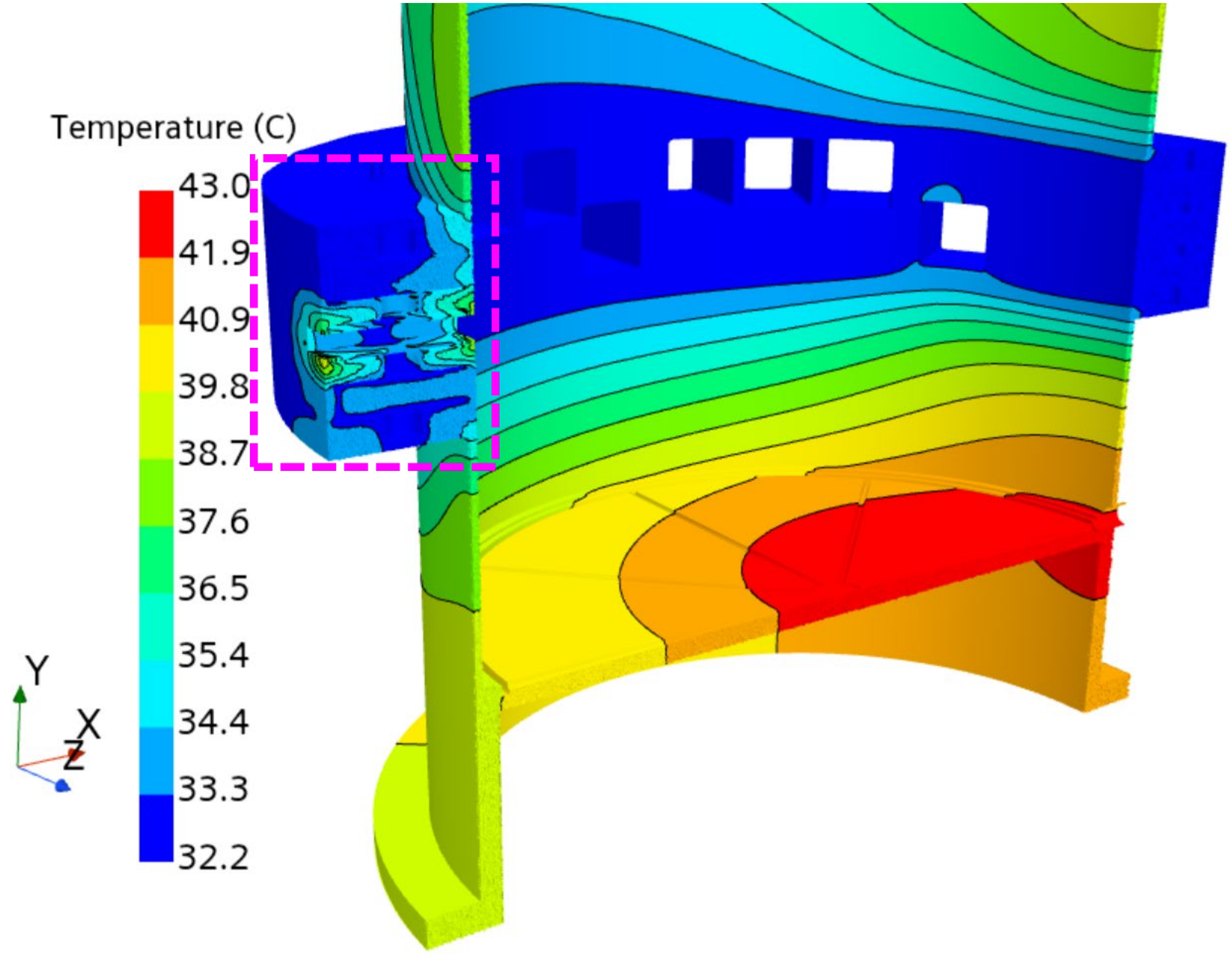


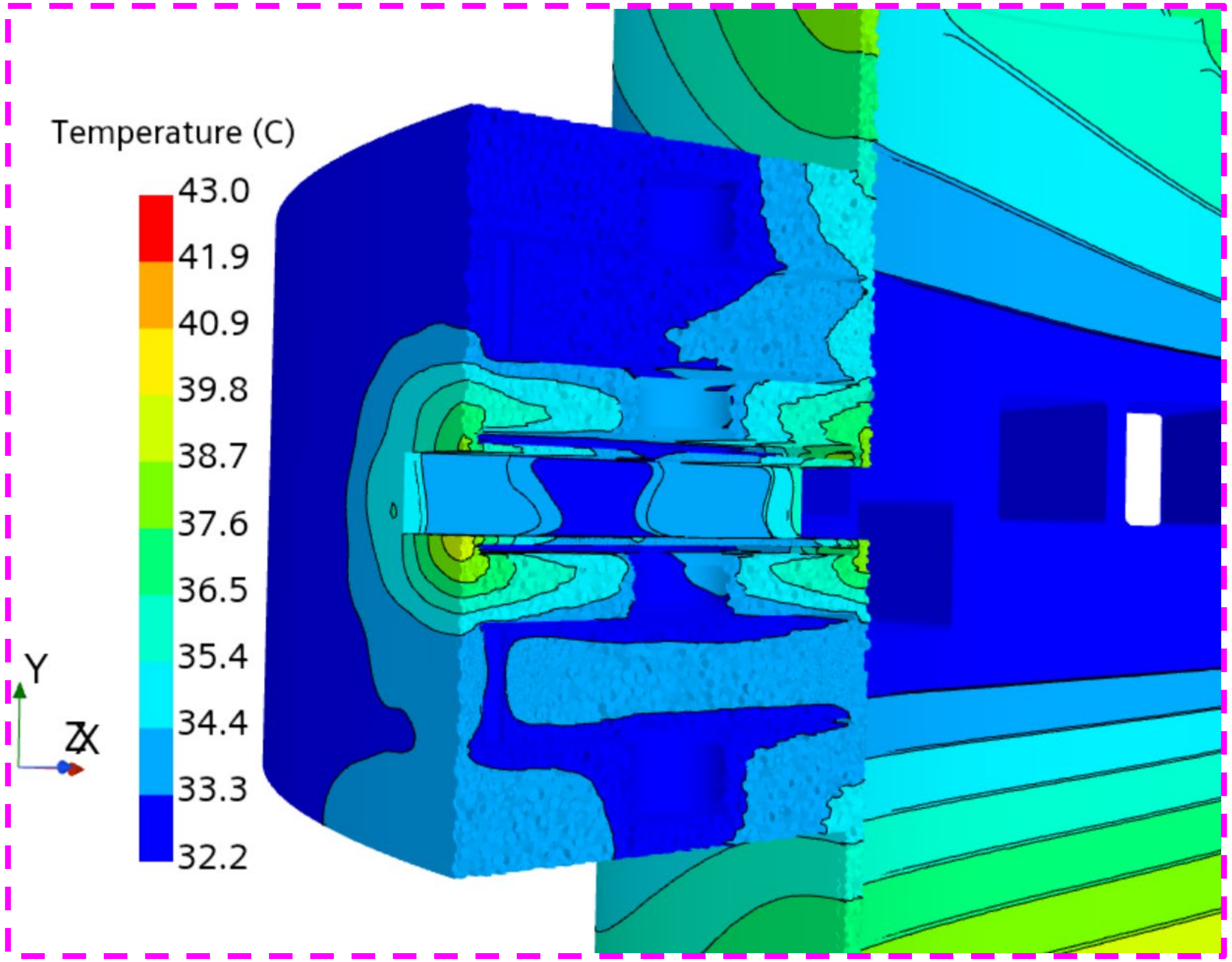


No cooling channel in this plate

Core Vessel, Stainless Steel Temperature

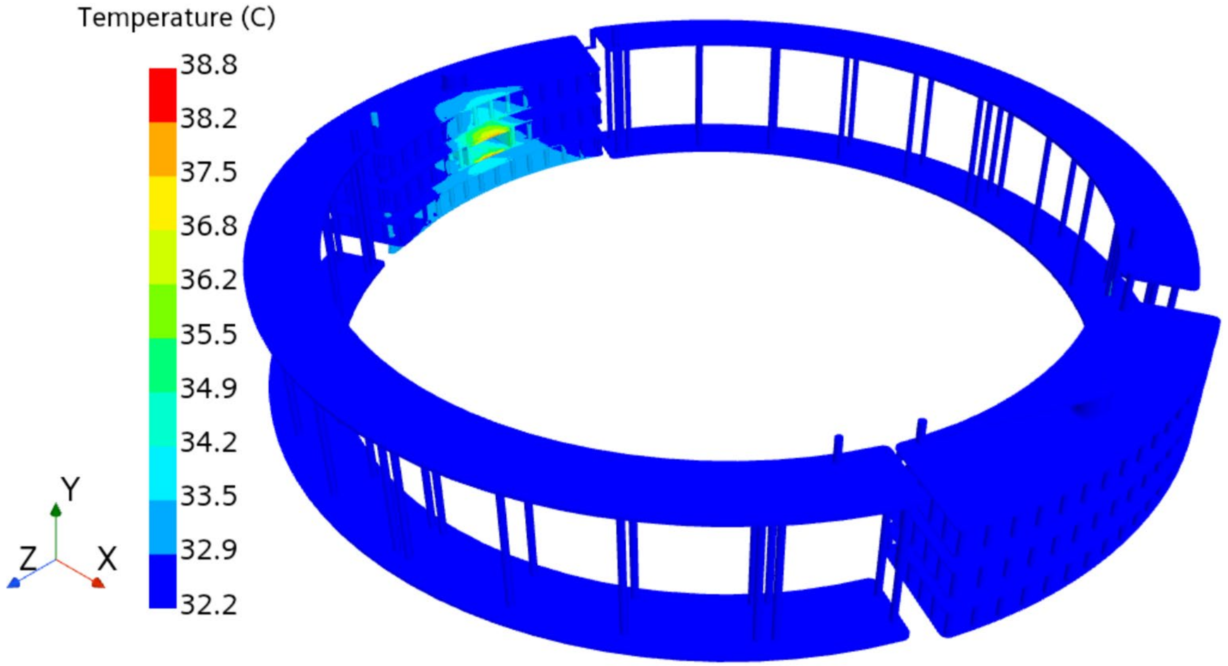
Peak: 43°C

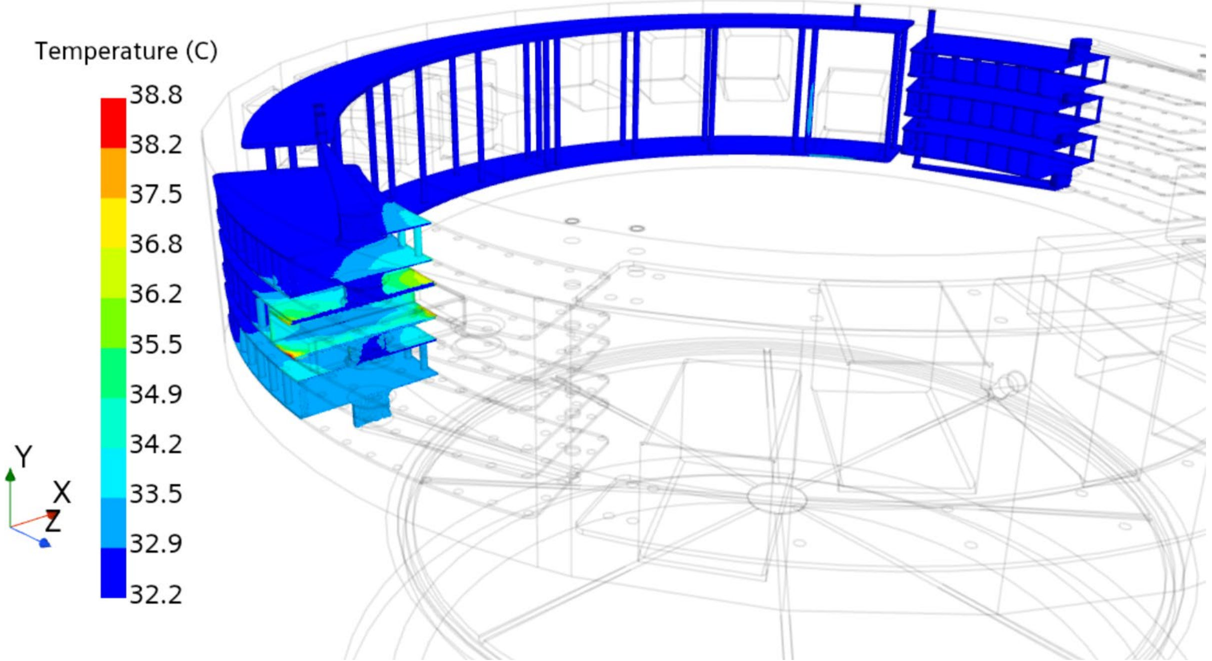




Core Vessel, Water Temperature

Peak: 38.8°C

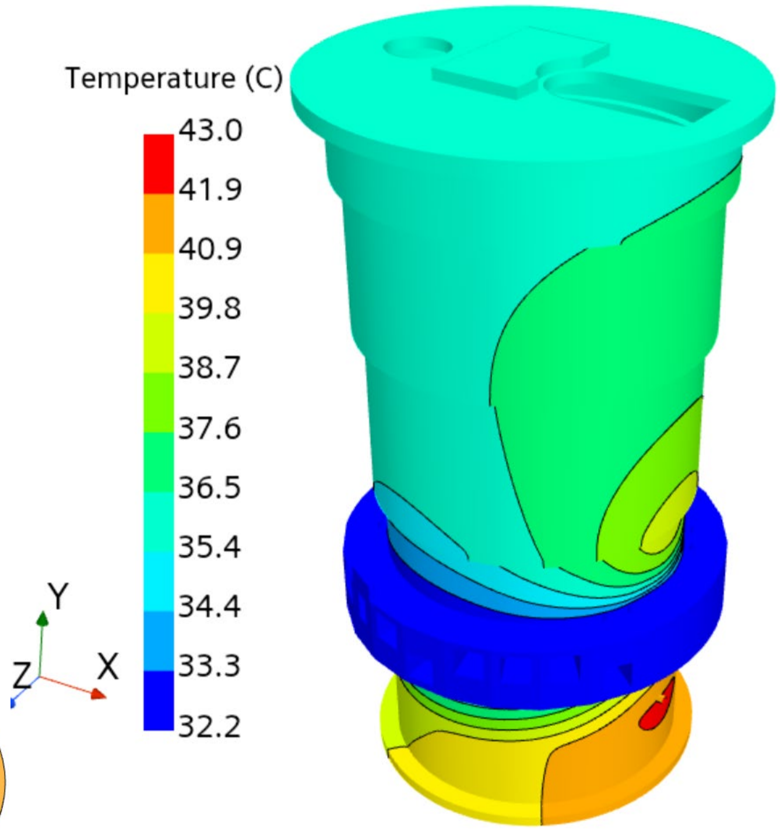


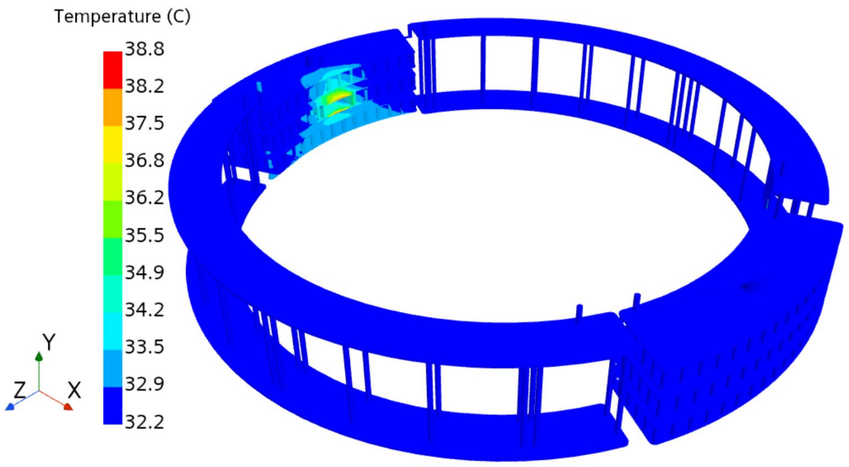


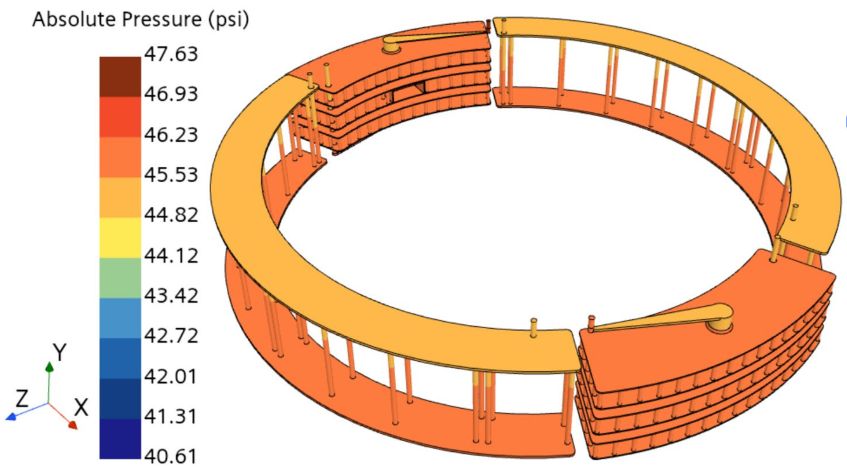
Core Vessel Thermal Analysis Summary

Core Vessel Analysis Results:

- Maximum stainless steel temperature = 200 C
  - ANSYS results: Maximum stainless steel temperature = 43 C → PASS
- Maximum pressure drop = 15 PSI
  - ANSYS results: Maximum water pressure = 2.47 PSI→ PASS
- Maximum water temperature = 100 C
  - ANSYS results: Maximum water temperature = 38.8 C → PASS







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

Min-Tsung Kao

09/04/2024

Shield Block #1 Introduction and Requirements

- The position of the following components are impacted by Shield Block #1 thermal performance:
  - Target Assembly Snubber
  - Moderator Reflector Assembly
  - Core Vessel Shielding
  - Target Viewing Periscope

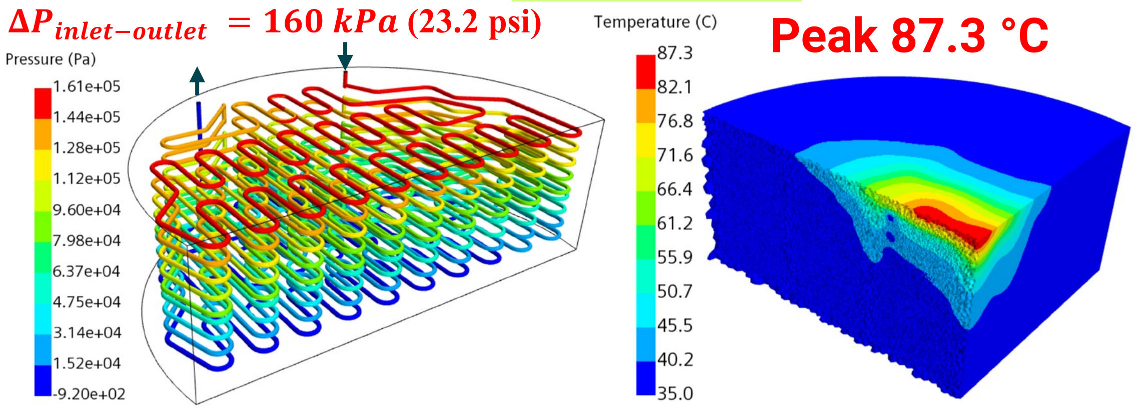
<u>Shield Block #1 thermal requirements:</u>

- Maximum stainless steel temperature = 200 C
- Maximum pressure drop = 15 PSI
- Maximum cooling water temperature = 100 C
  - Soft requirement to avoid water boiling within the shielding

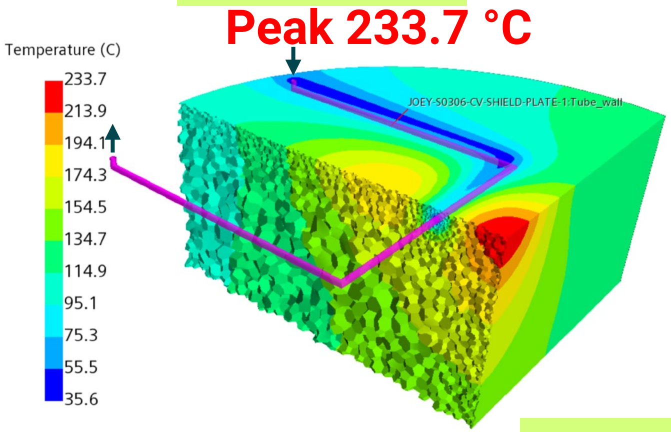
Cooled Block #1

Early Shield Block Designs

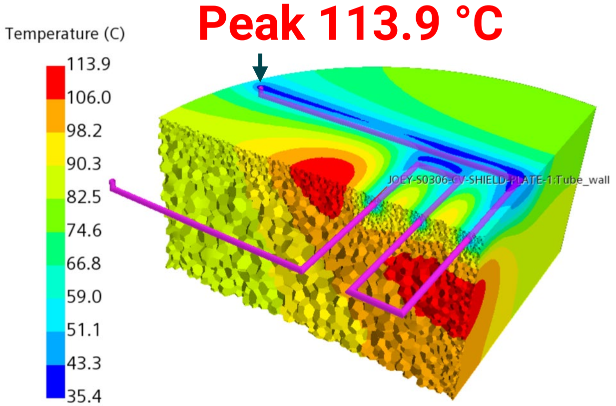
Design_1



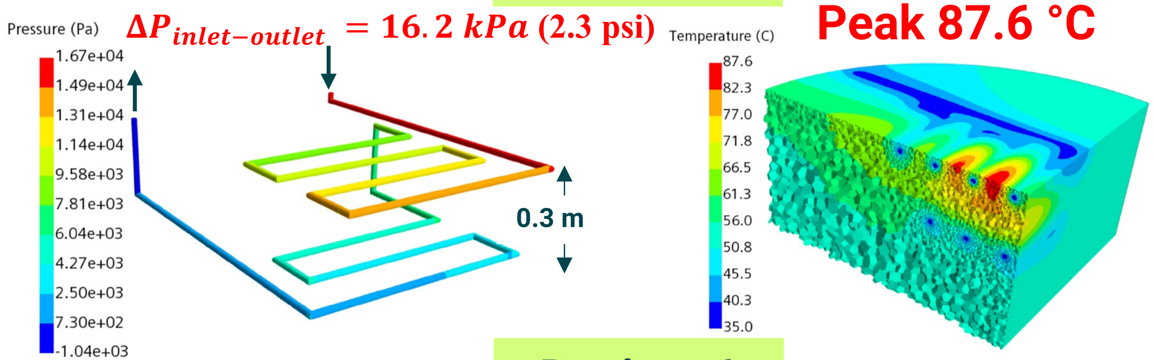
Design_2



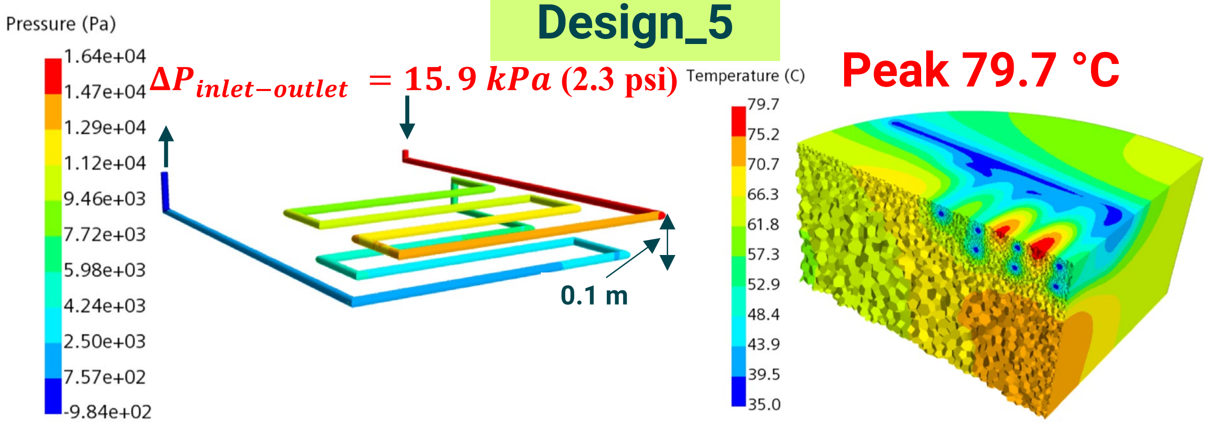
Design_3



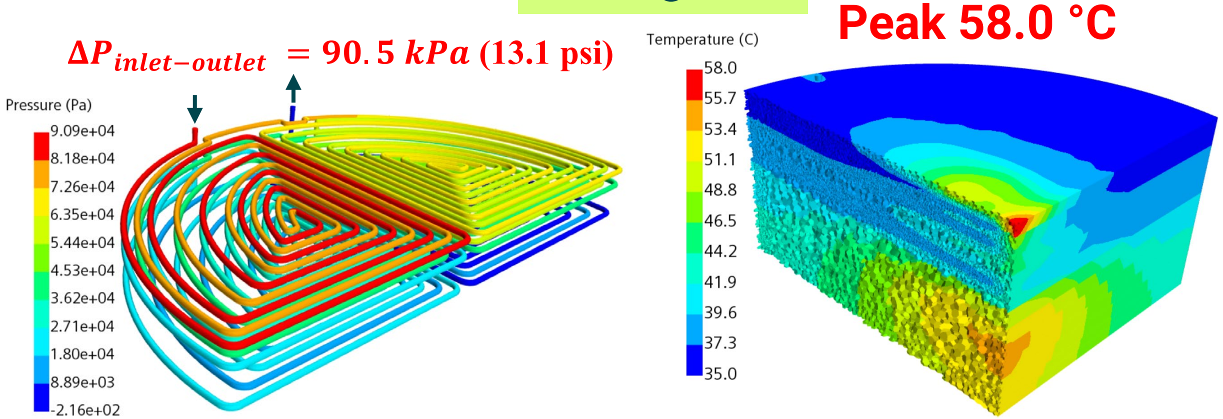
Design_4



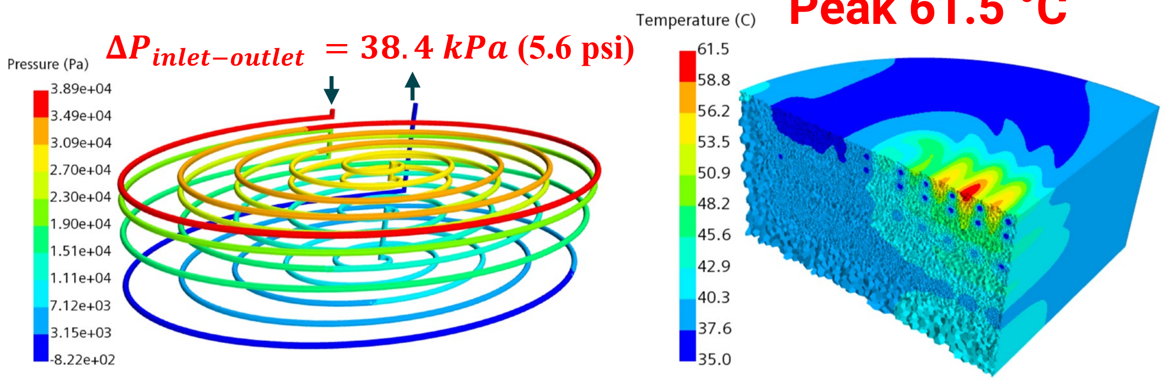
Design_5



Design_6



Design_7

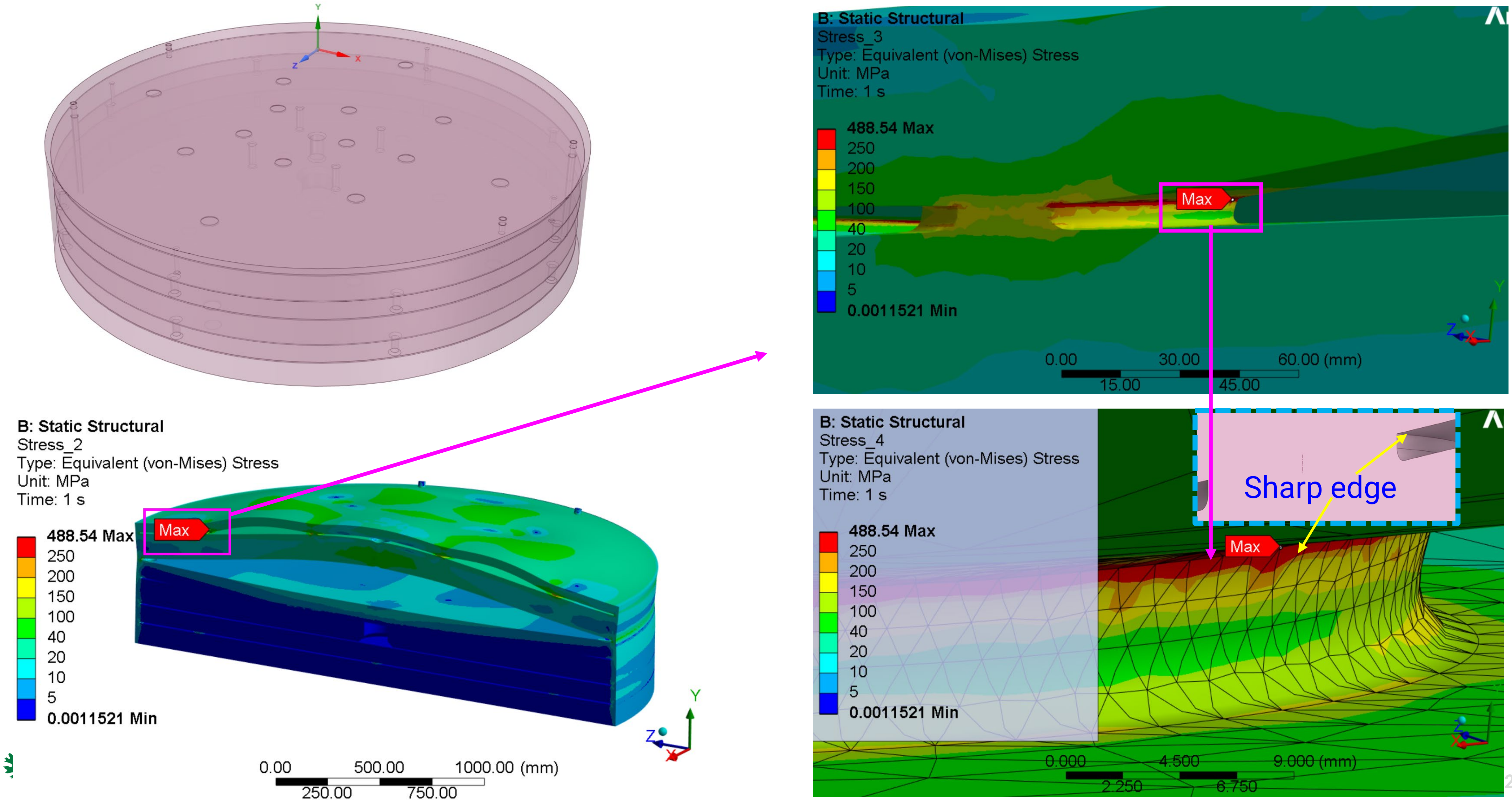


Water pressure + Thermal + Gravity

Stacked Plate Design

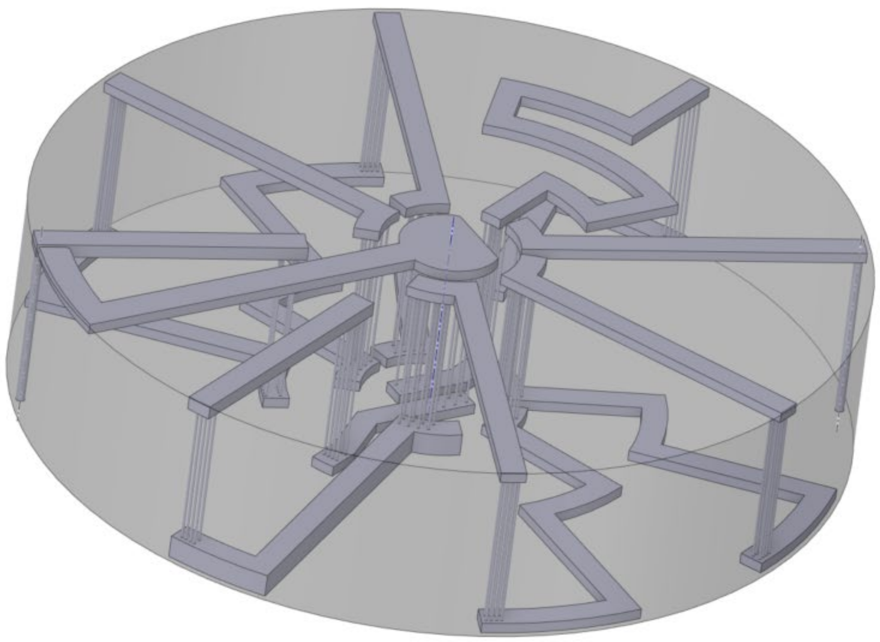
Deformation scale = 180

Peak Stress : 488 MPa
SS316 Yield Strength: 252 MPa

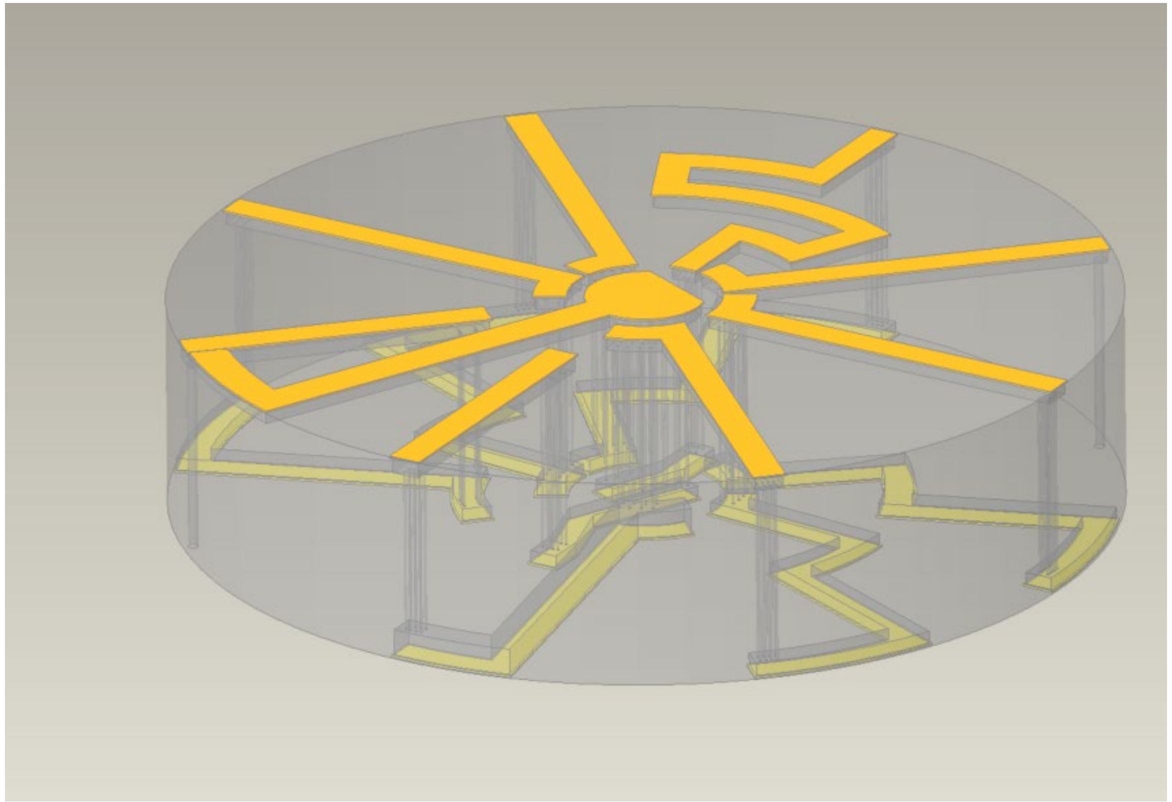


Cooled Block #1 Current Design

Water Volume ~ 20 gallons

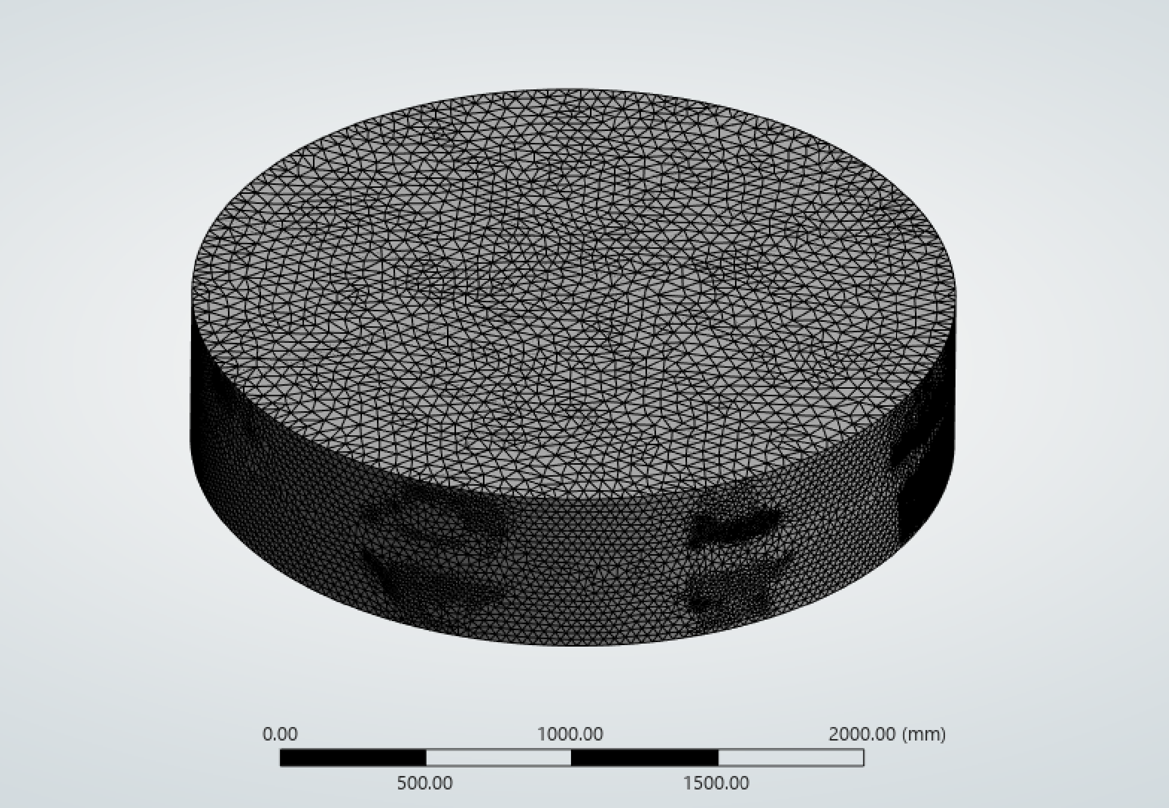


Cover Design



Cooled Block #1 Thermal Analysis

Statistics	
Nodes	1425468
Elements	966921
Show Detailed St...	No



Stainless Steel

Density	7750	kg/m^3

Structural

Isotropic Elasticity		
Derive from	Young's Modulus and Poisson's Ratio	
Young's Modulus	1.93e+11	Pa
Poisson's Ratio	0.31	
Bulk Modulus	1.693e+11	Pa
Shear Modulus	7.3664e+10	Pa
Isotropic Secant Coefficient of Thermal Expansion	1.7e-05	1/°C
Compressive Ultimate Strength	0	Pa
Compressive Yield Strength	2.07e+08	Pa
Tensile Ultimate Strength	5.86e+08	Pa
Tensile Yield Strength	2.07e+08	Pa

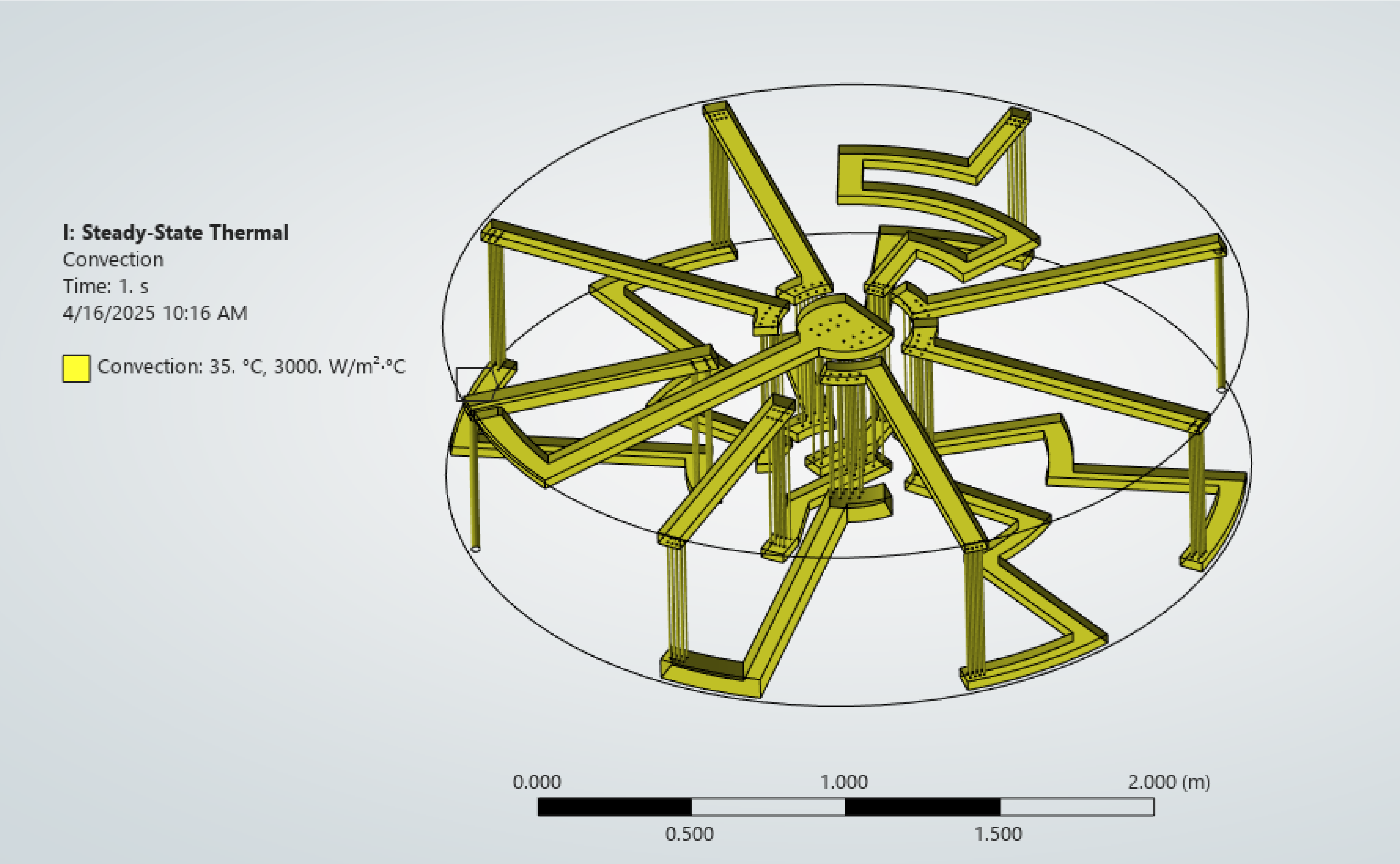
Thermal

Isotropic Thermal Conductivity	15.1	W/m·°C
Specific Heat Constant Pressure	480	J/kg·°C

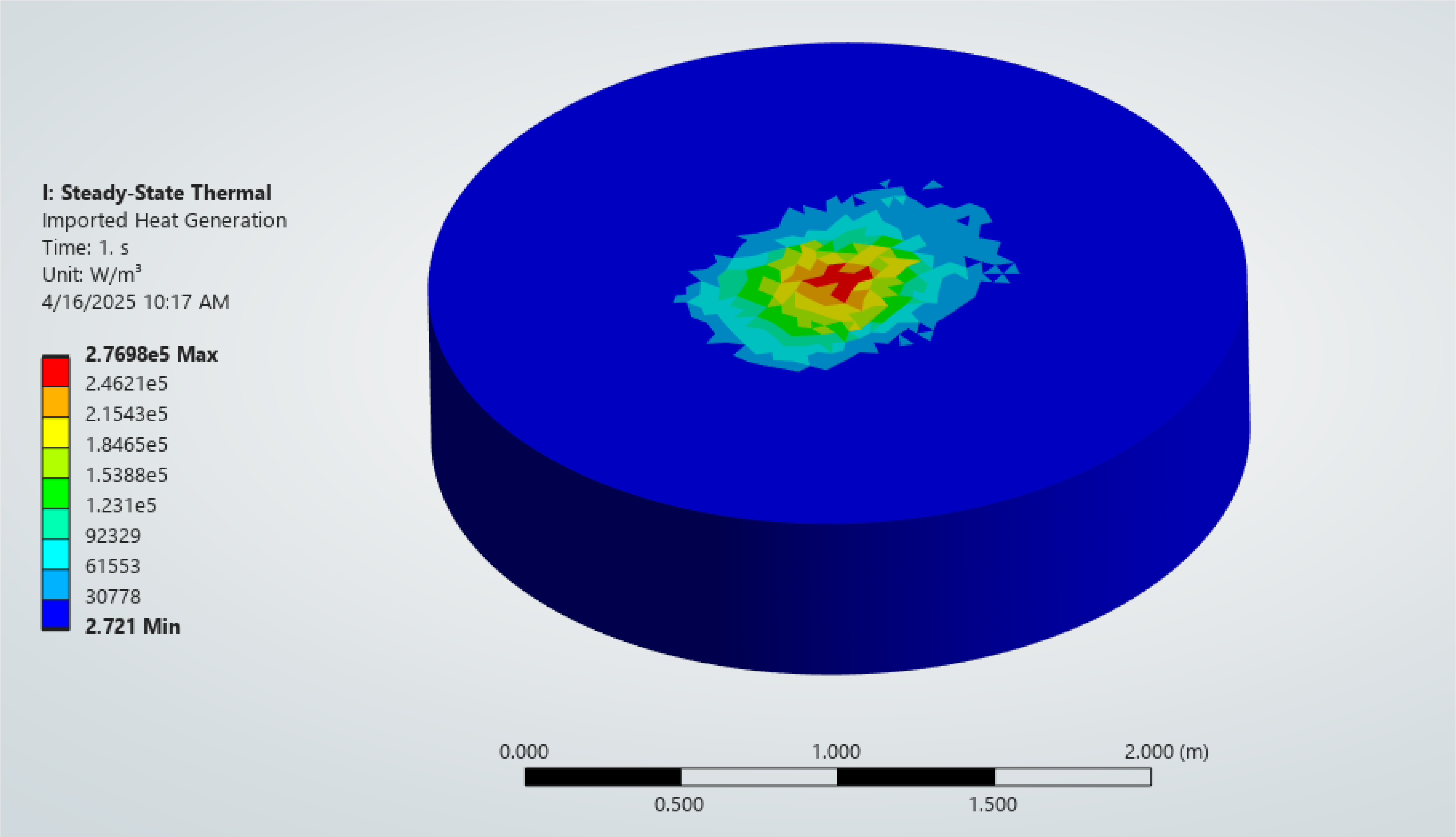
Apply Convection Boundary Condition

Analytical Approach

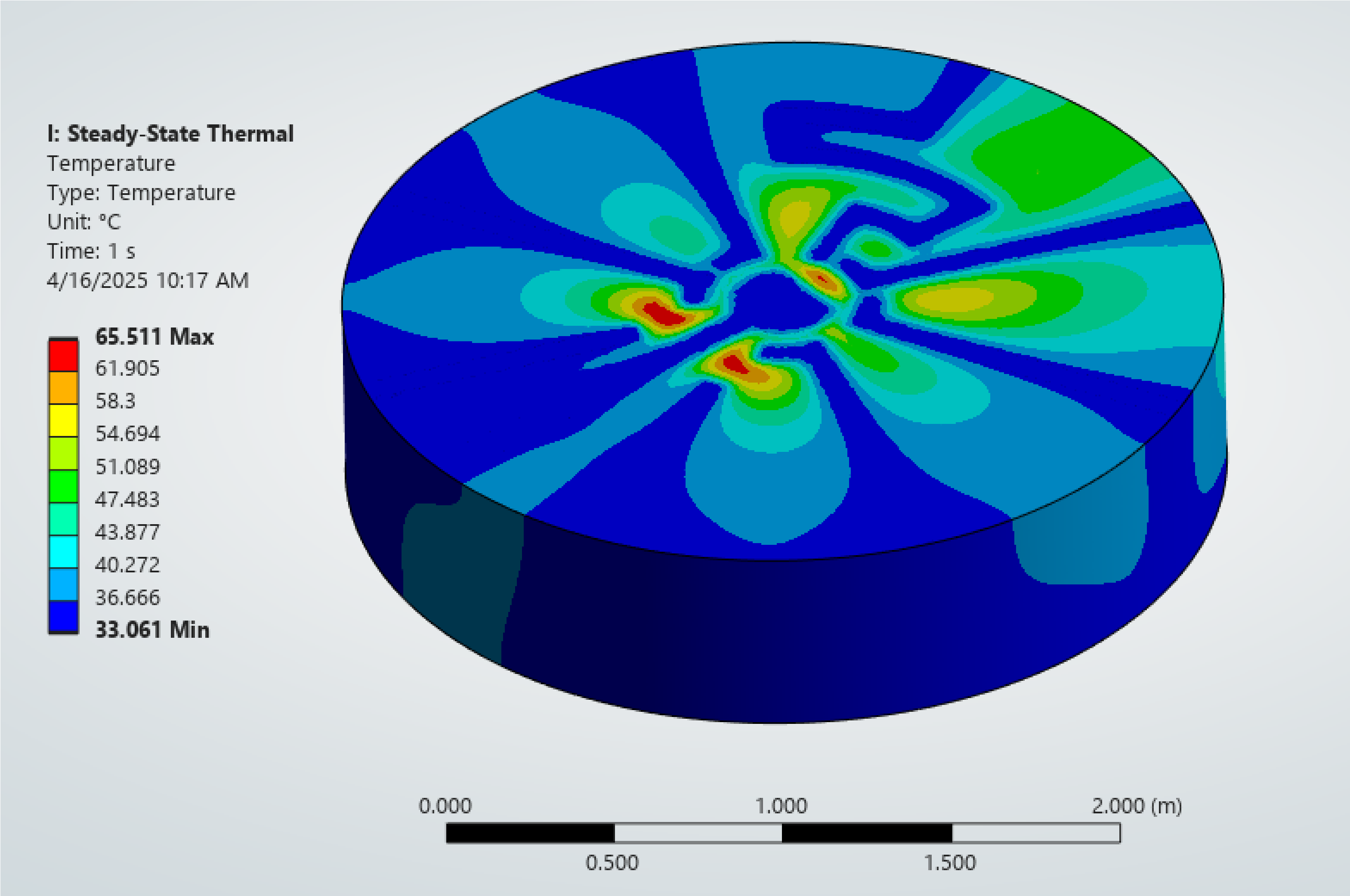
- Steady state thermal analysis with estimated water convection was used
    - Provides a quick method to evaluate cooling geometry
- Convection coefficient calculated using the Dittus-Boelter equation
- A more thorough CFD analysis will be performed during final design



Apply Heat Generation



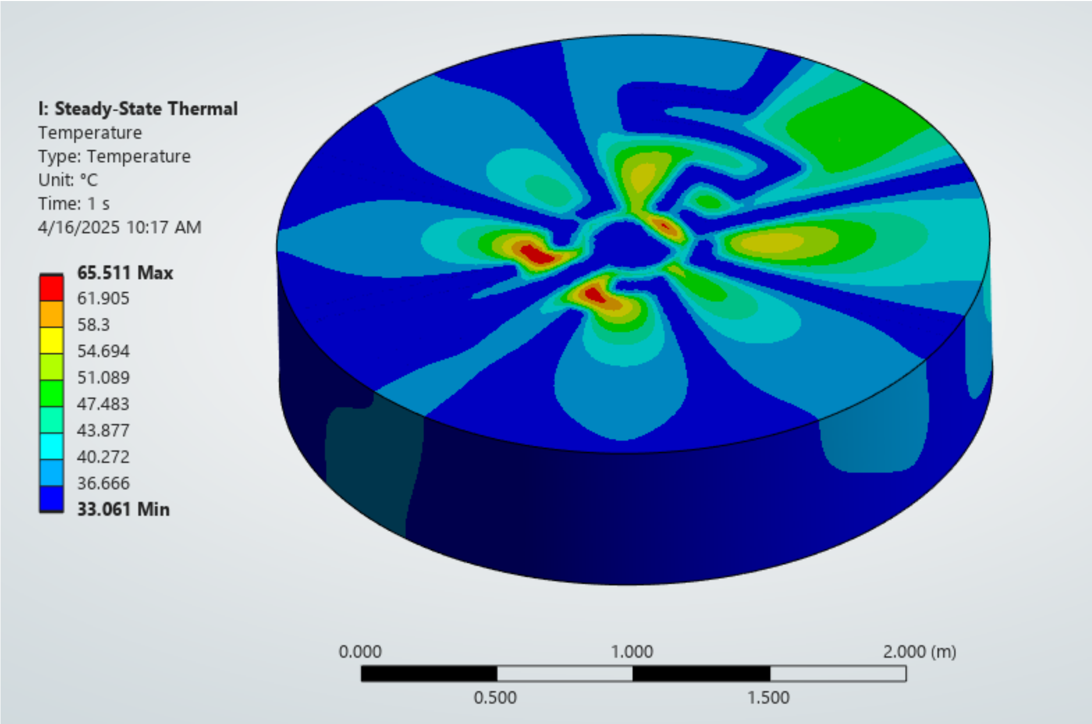
Temperature Results



Shield Block #1 Analysis Summary

Shield Block #1 Analysis Results:

- Maximum stainless steel temperature = 200 C
  - ANSYS results: Maximum stainless steel temperature = 65.5 C → PASS
- Maximum pressure drop = 15 PSI
  - ANSYS results: TBD → Unconfirmed
- Maximum water temperature = 100 C
  - ANSYS results: TBD→ Unconfirmed



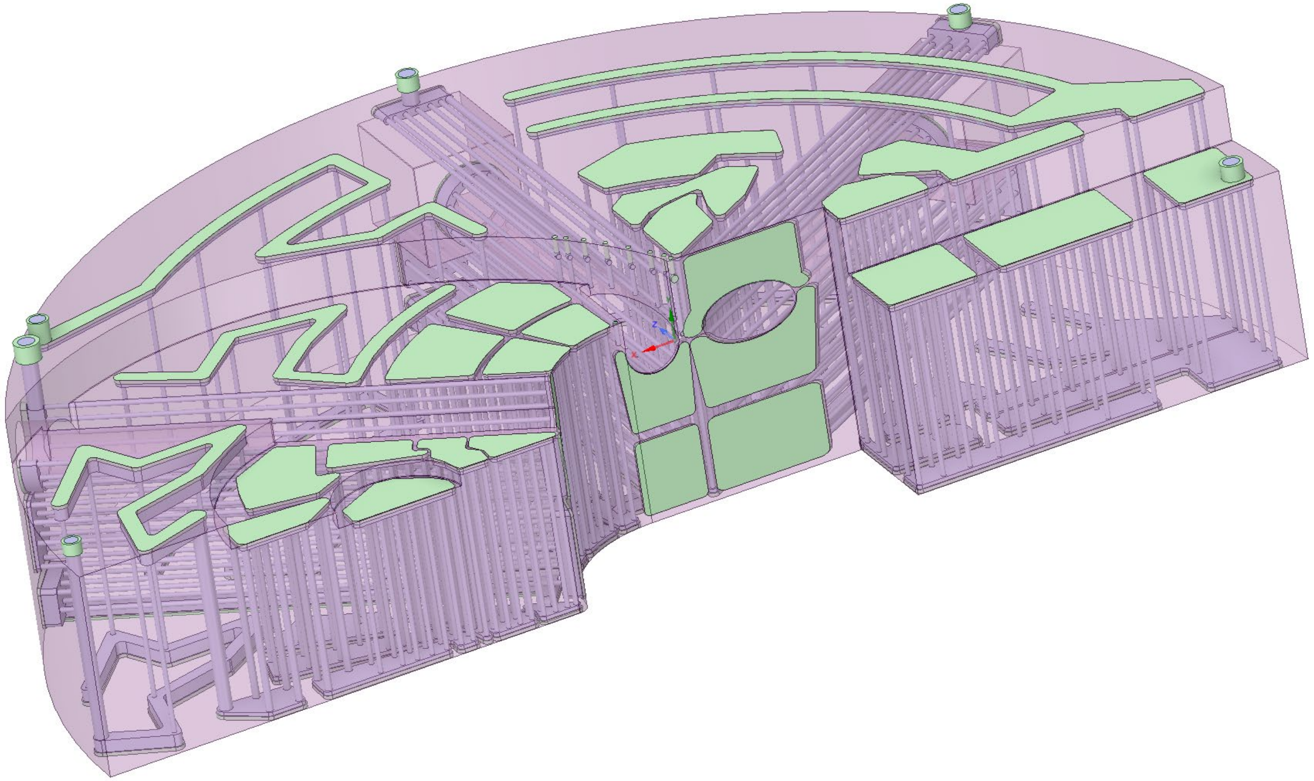
Vessel Systems (S.03.06) Shield Block #3 Thermal and Structural Analysis

Min-Tsung Kao

12/24/2024

Shield Block #3 Introduction and Requirements

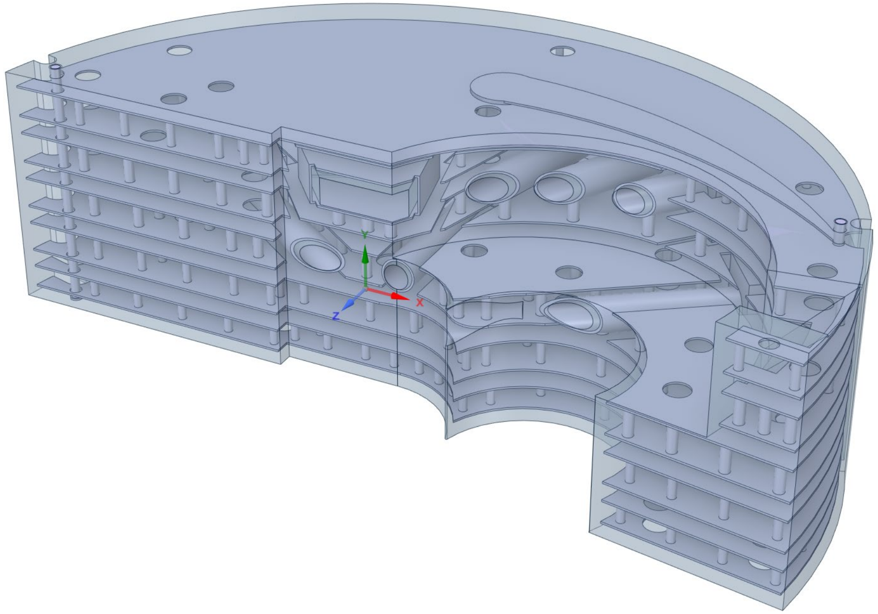
- The position of the following components are impacted by Shield Block #3 thermal performance:
  - Target Assembly Snubber
  - Core Vessel Shielding
  - Target Viewing Periscope

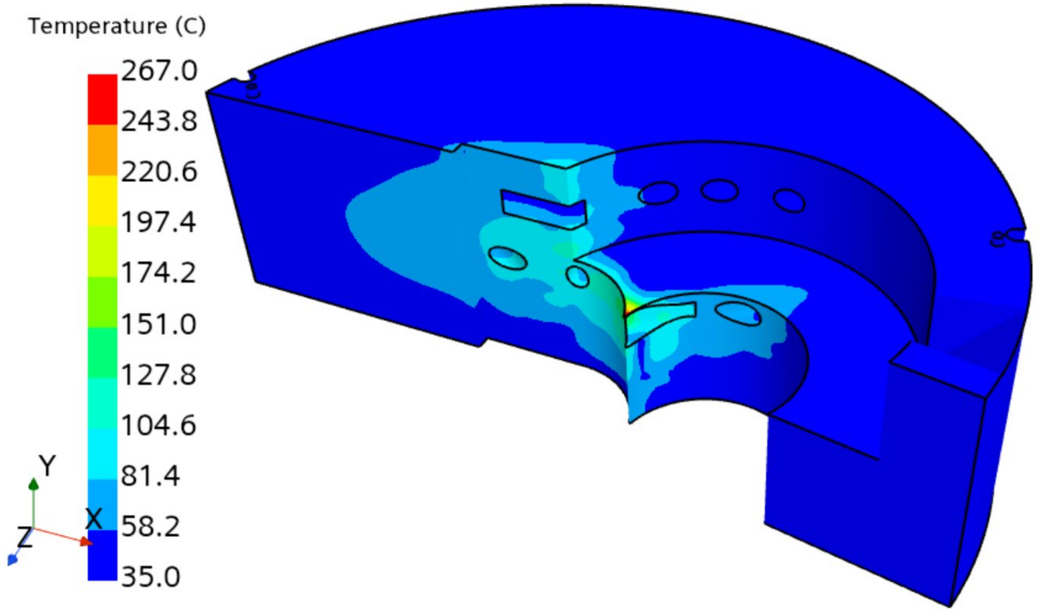


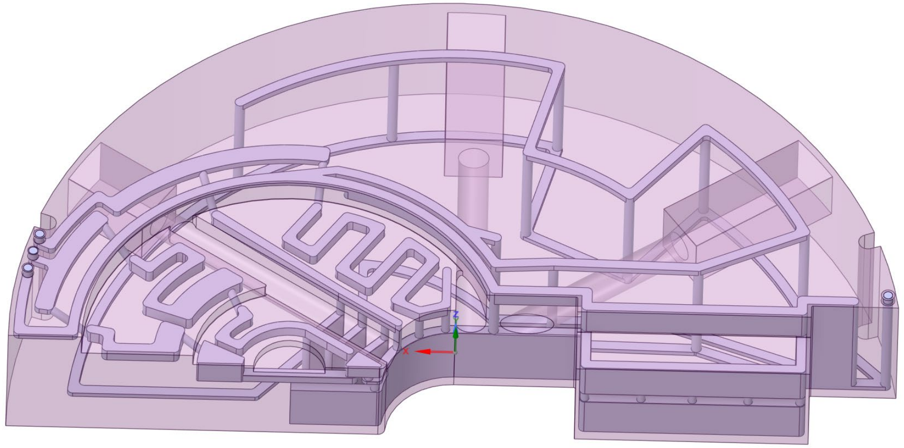
<u>Shield Block #3 thermal requirements:</u>

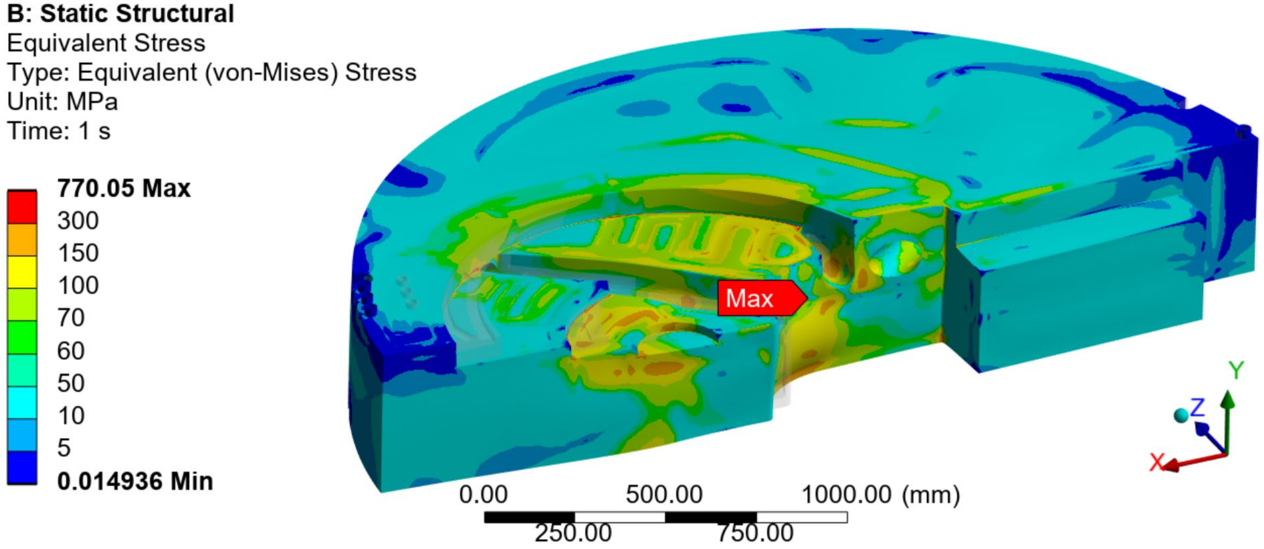
- Maximum stainless steel temperature = 200 C
- Maximum pressure drop = 15 PSI
- Maximum cooling water temperature = 100 C
  - Soft requirement to avoid water boiling within the shielding

Layer 2 cooled shield block history

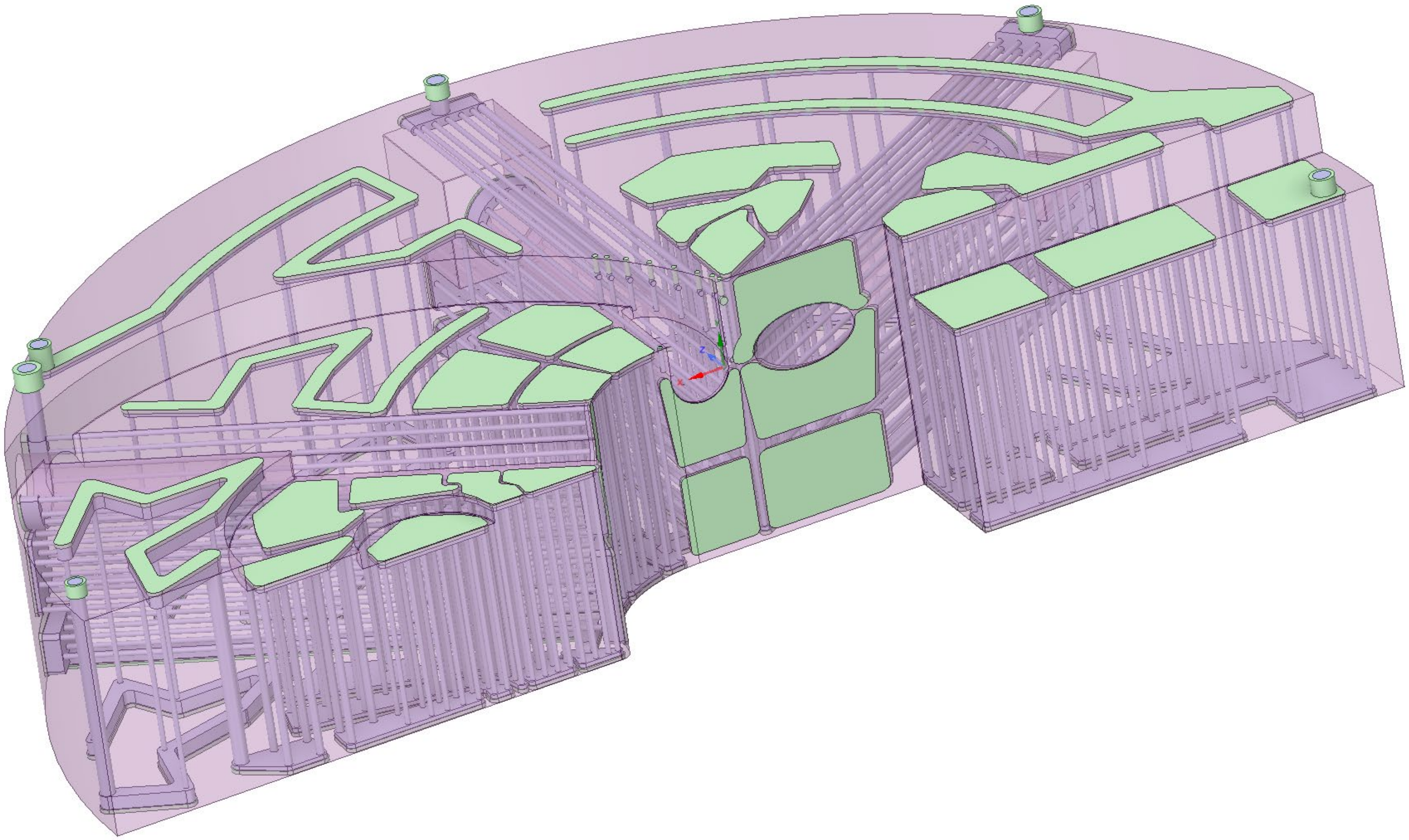




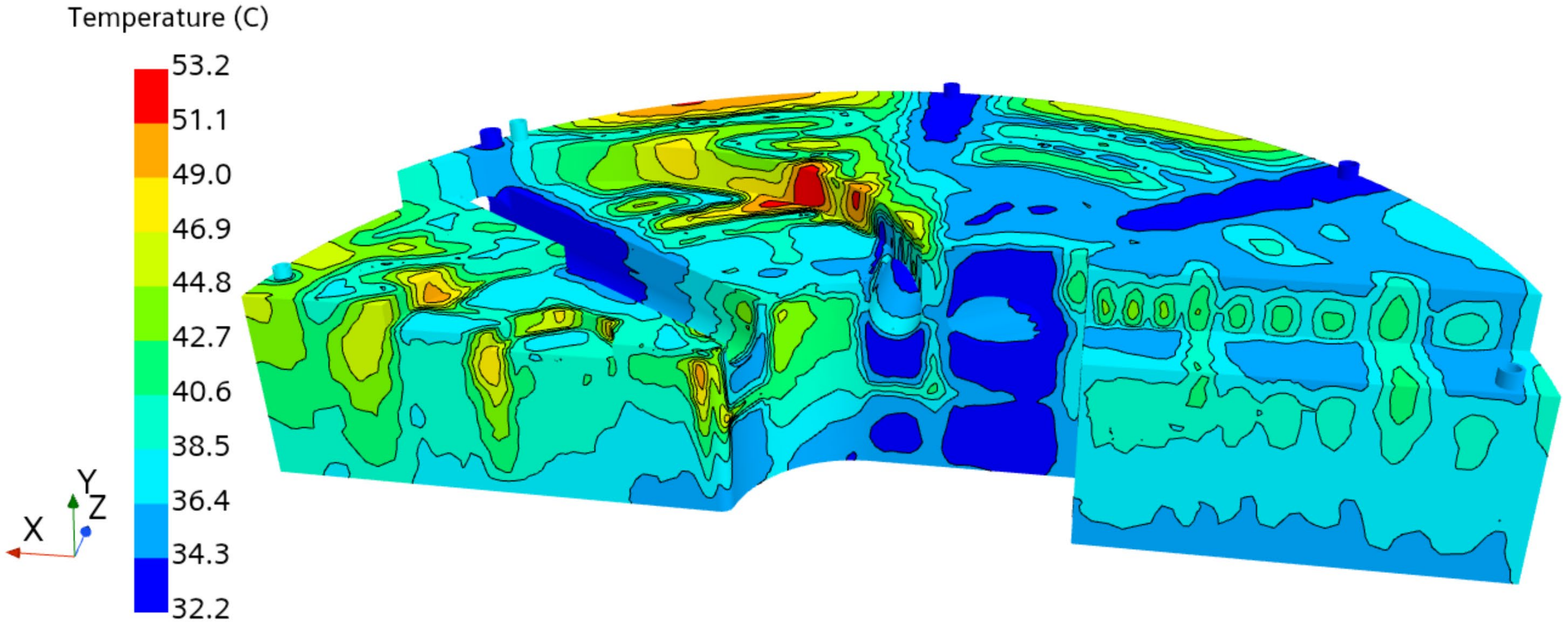


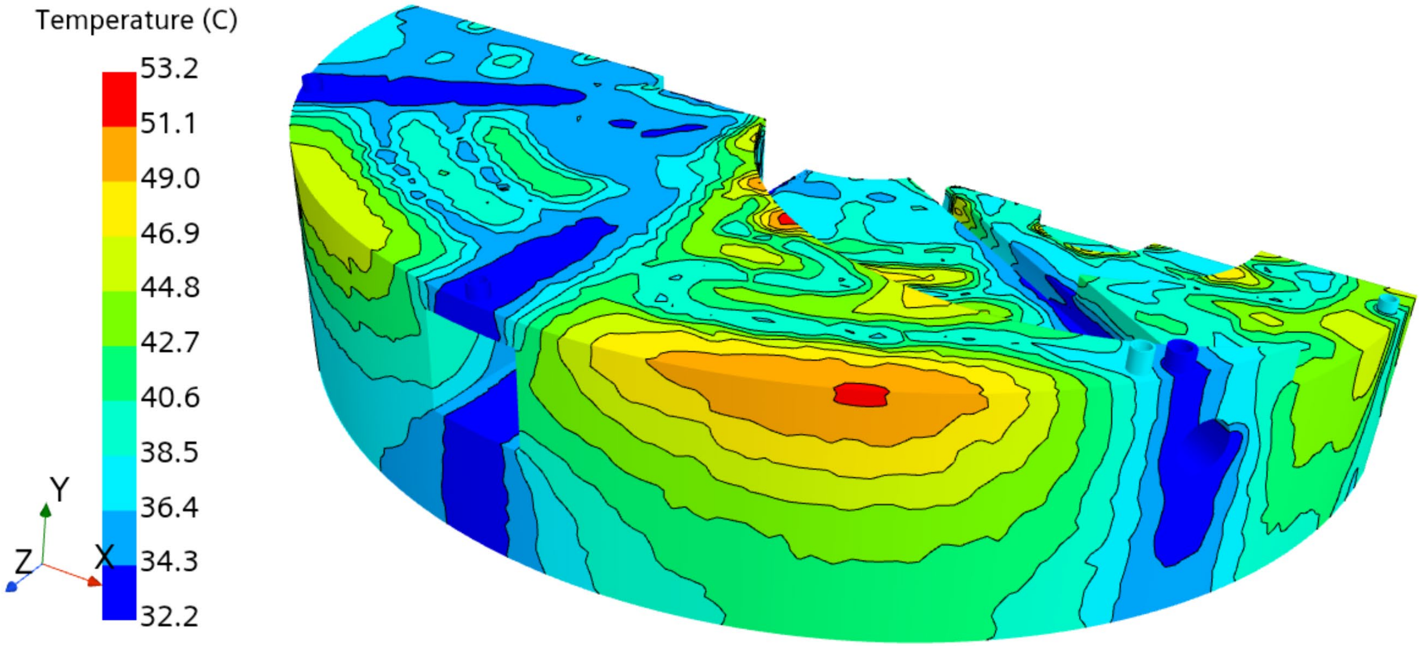


Layer 2 Shield Block Latest Design

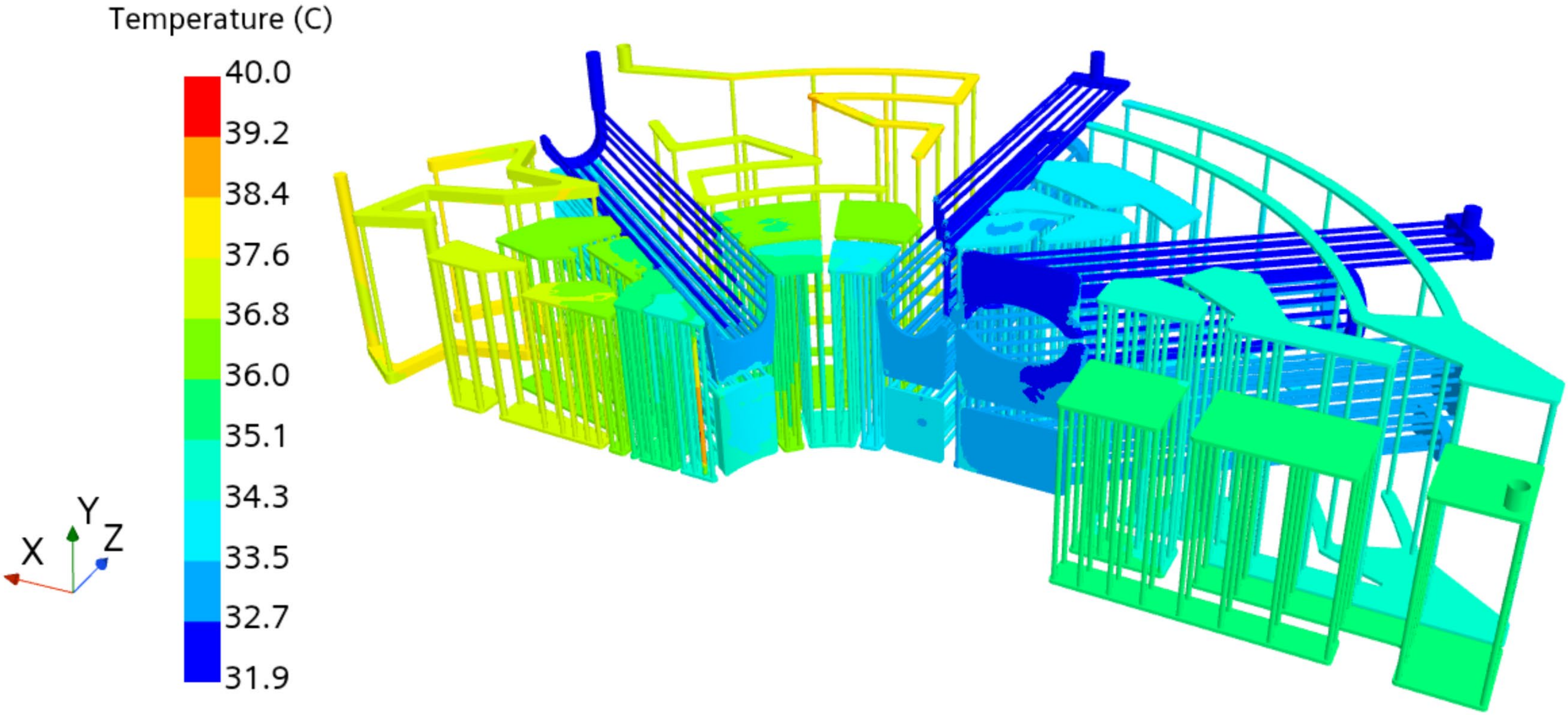


Shield Block #3 (Design_31), SS316 Temperature

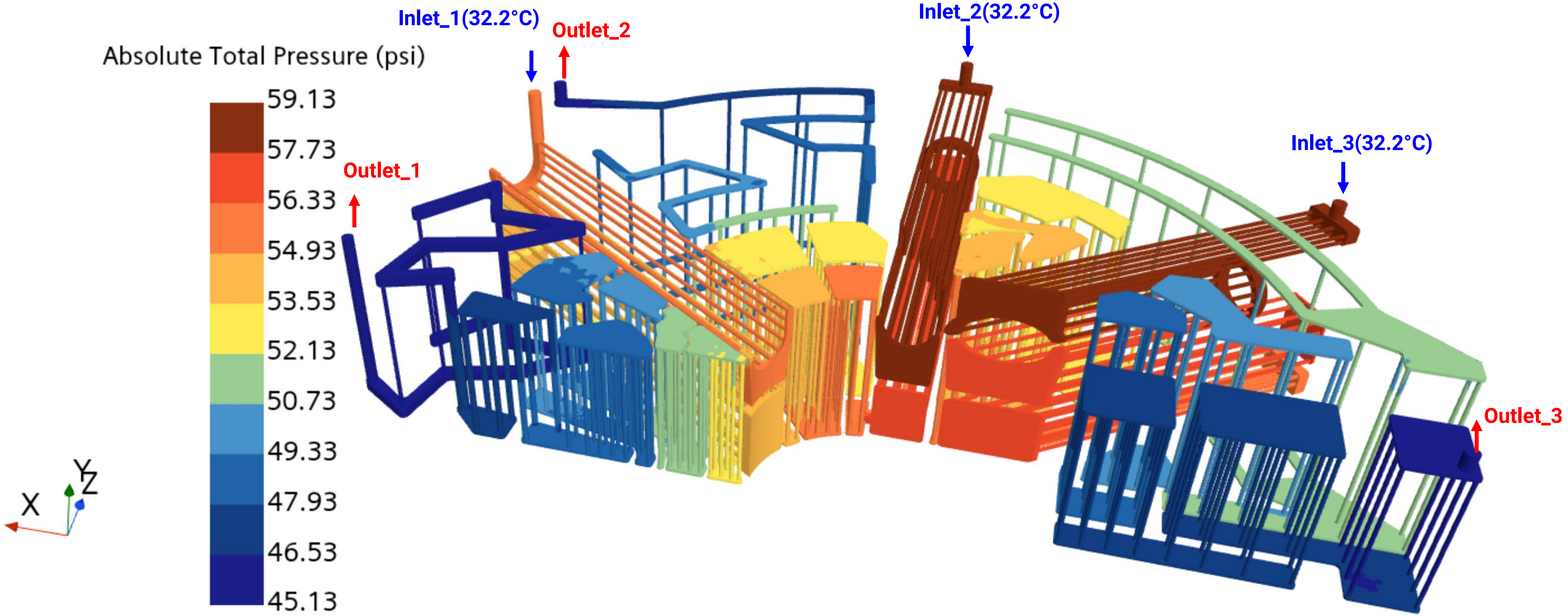




Shield Block #3 (Design_31), Water Temperature



Shield Block #3 (Design_31), Water Pressure



$$\Delta P_{inlet\_1-outlet\_1} = \mathbf{9.5\ psi}\ \text{(8GPM)}$$

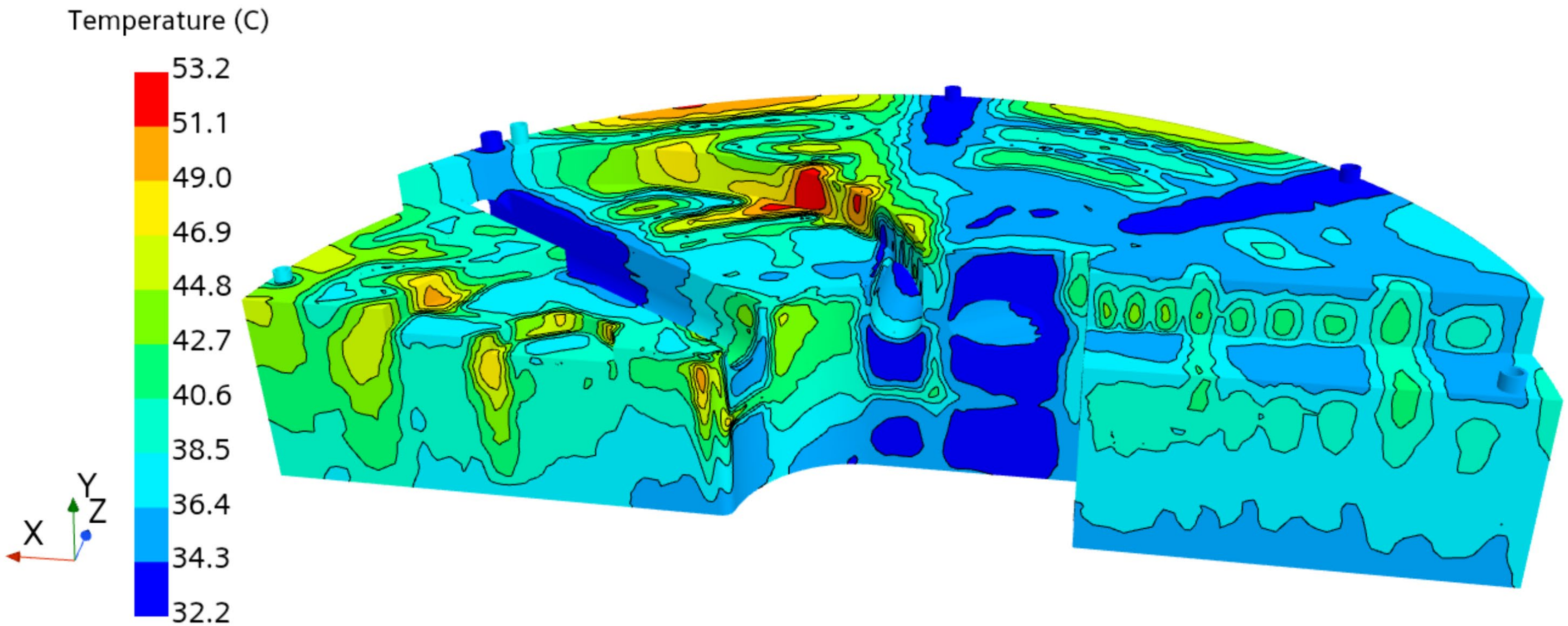
$$\Delta P_{inlet\_2-outlet\_2} = \mathbf{13.2\ psi}\ \text{(8GPM)}$$

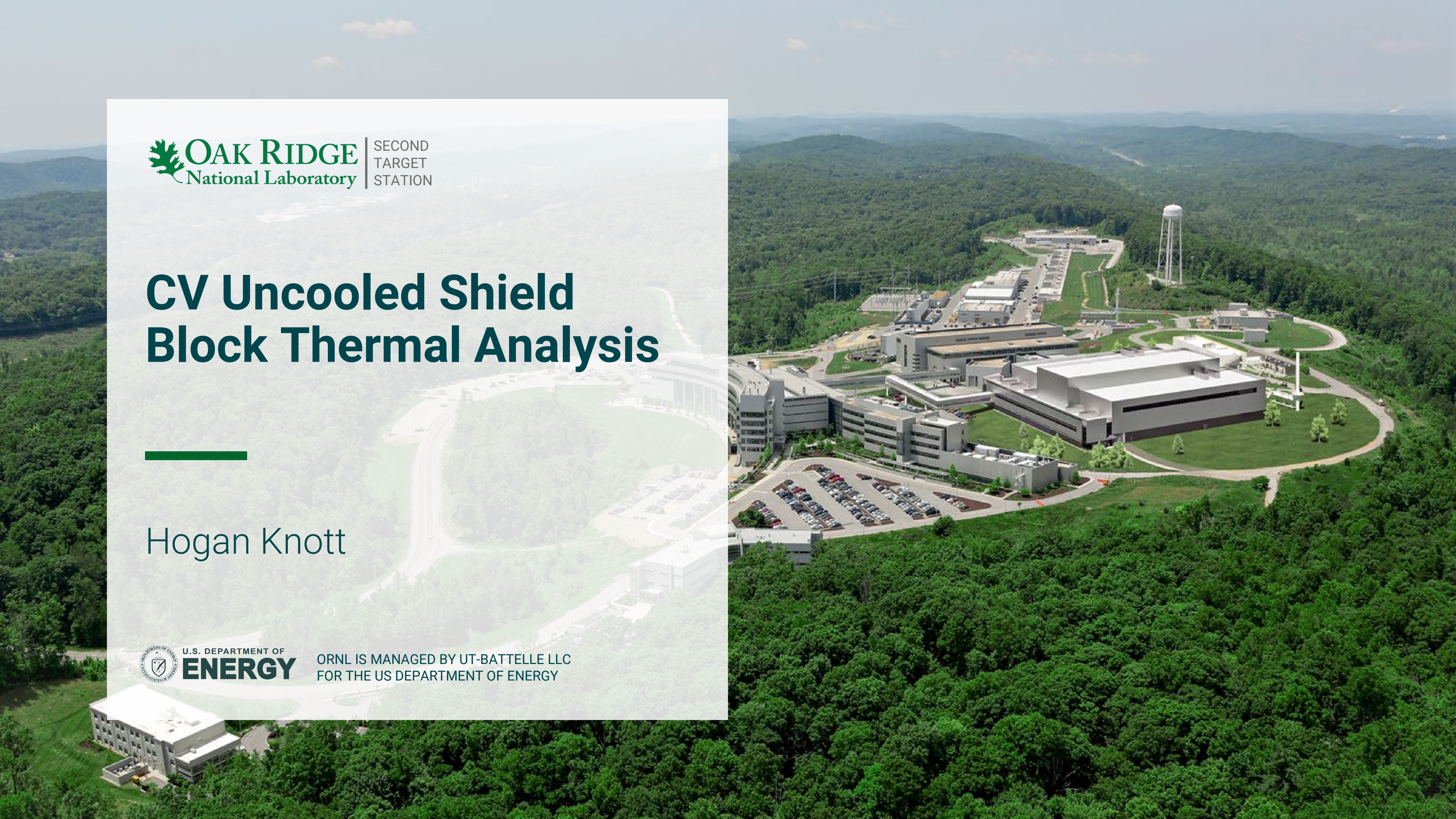
$$\Delta P_{inlet\_3-outlet\_3} = \mathbf{12.9\ psi}\ \text{(8GPM)}$$

Shield Block #3 Analysis Summary

<u>Shield Block #3 Analysis Results:</u>

- Maximum stainless steel temperature = 200 C
  - ANSYS results: Maximum stainless steel temperature = 53.2 C → PASS
- Maximum pressure drop = 15 PSI
  - ANSYS results: Maximum pressure drop = 13.2 → PASS
- Maximum water temperature = 100 C
  - ANSYS results: Maximum water temperature = 40 C → PASS





Oak Ridge National Laboratory | SECOND TARGET STATION

CV Uncooled Shield Block Thermal Analysis

Hogan Knott

U.S. DEPARTMENT OF ENERGY
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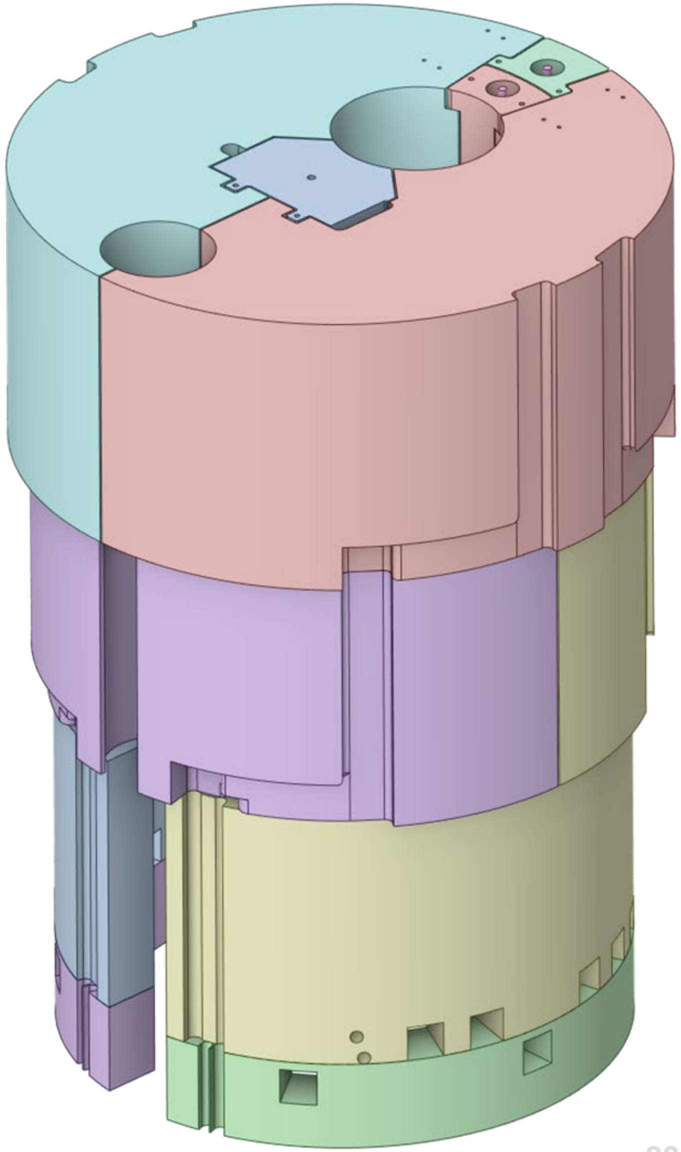
FOR THE US DEPARTMENT OF ENERGY

Uncooled Shielding Introduction and Requirements

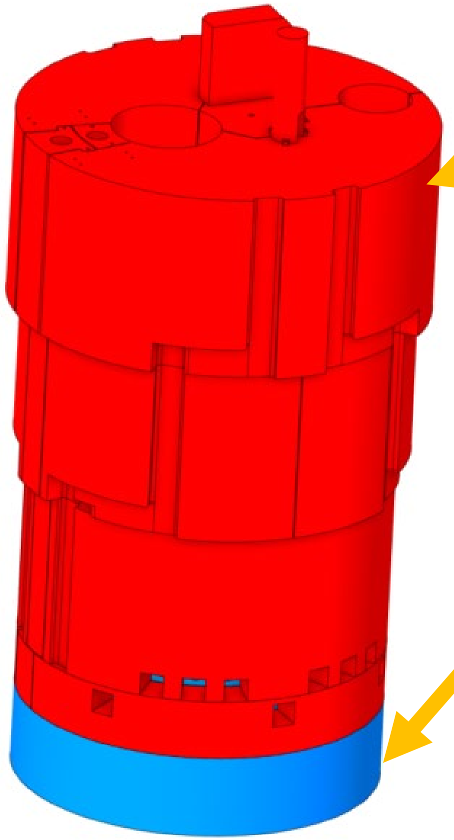
- The position of the following components are impacted by uncooled shielding thermal performance:
  - Target Viewing Periscope

<u>Uncooled Shielding Thermal Requirements:</u>

- Maximum carbon steel temperature = 200 C

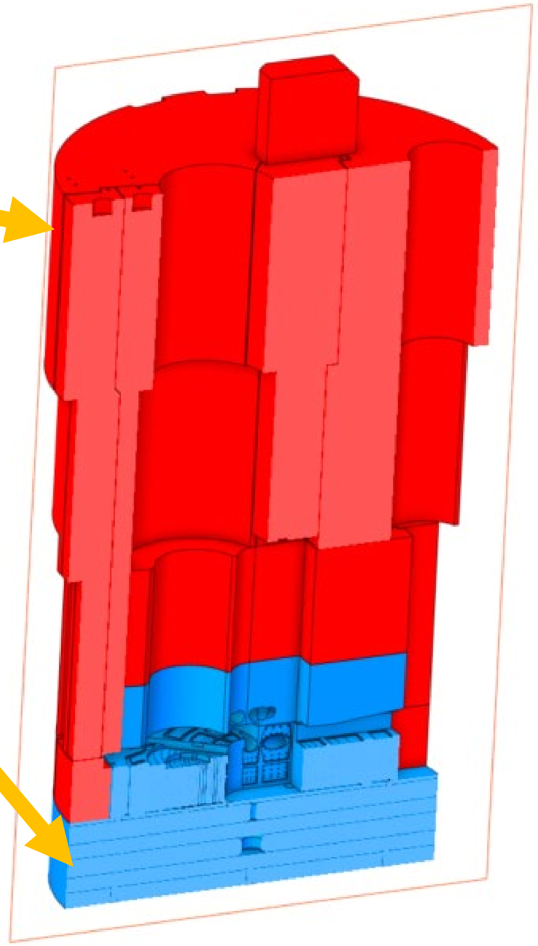


Vessel Shielding Area Definition



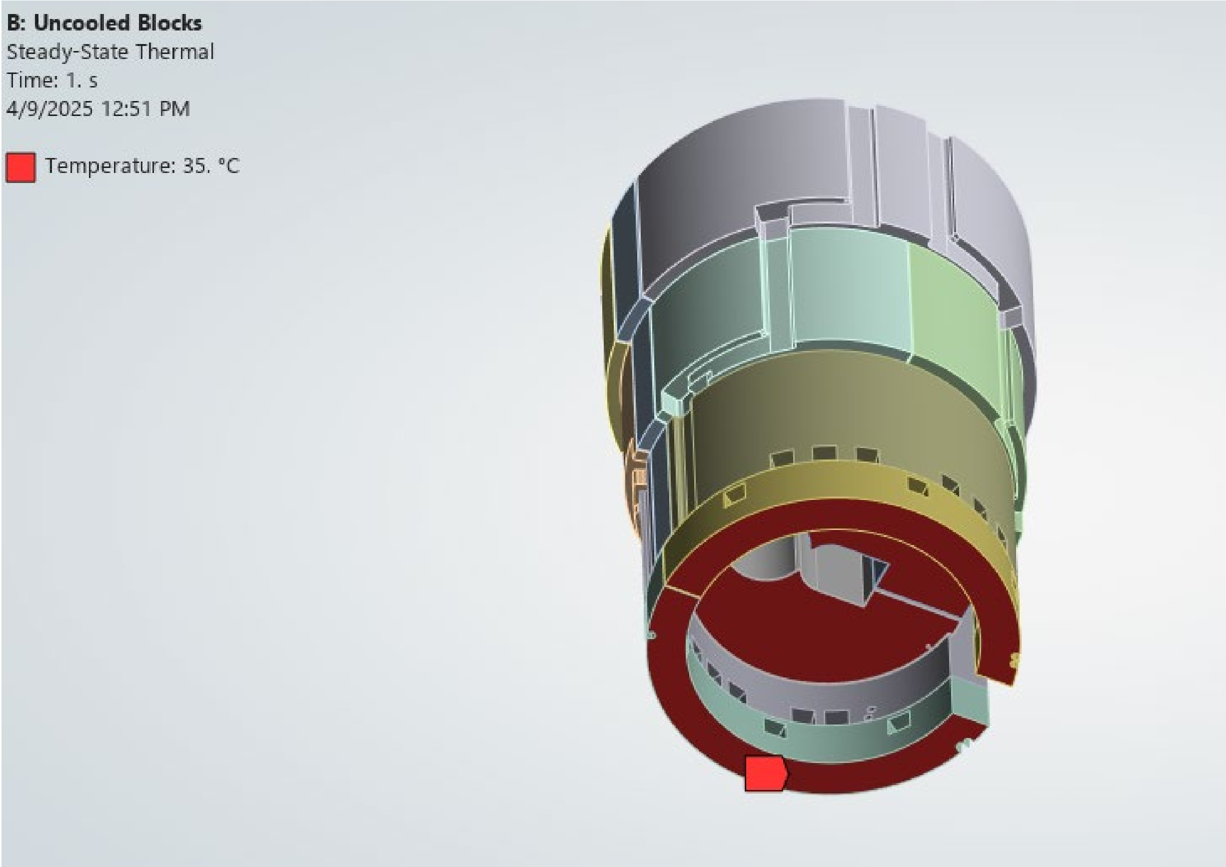
Uncooled Shielding: A36 Steel

Water Cooled Shielding: Stainless Steel 316/316L



Thermal Model Boundary Conditions

Assume surfaces contacting stainless steel are maintained at 35°C

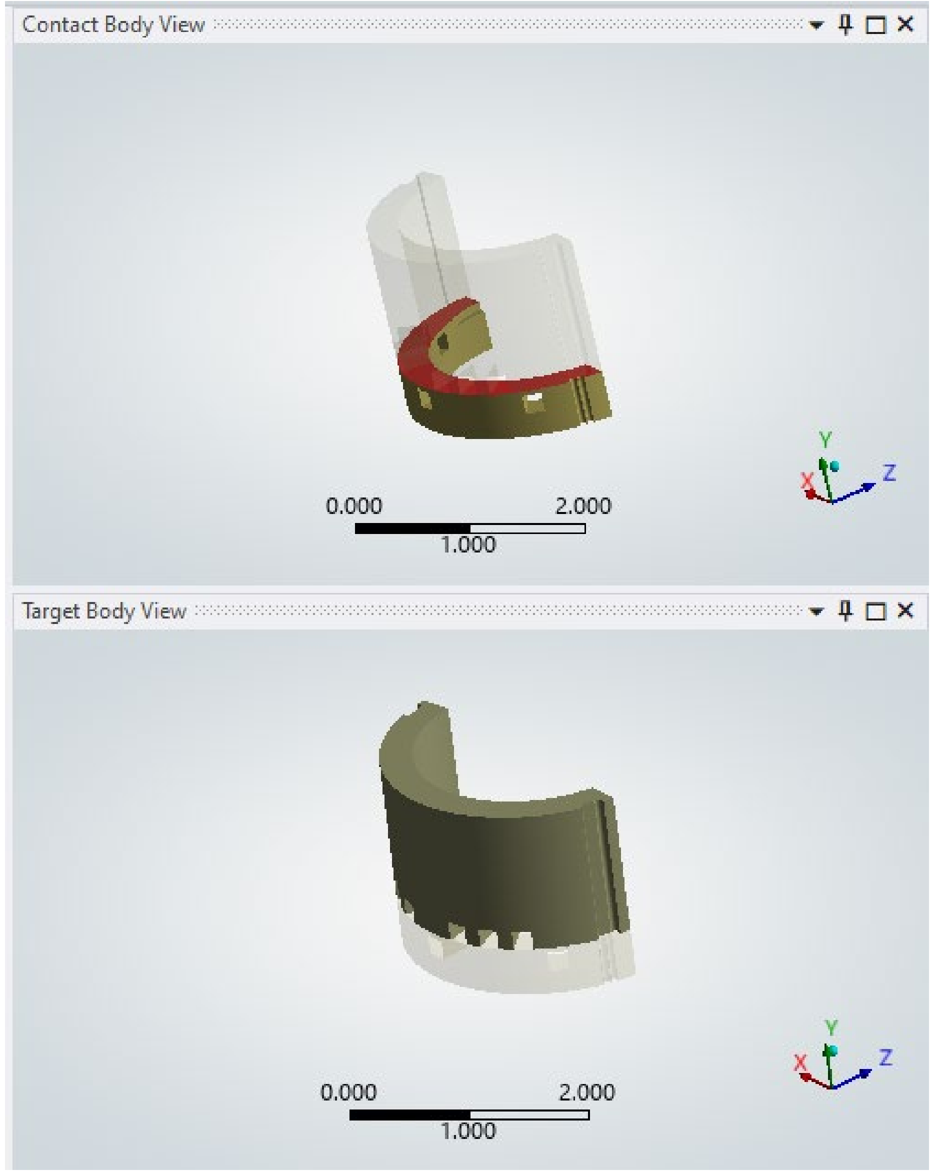


Thermal Model Boundary Conditions

Assume thermal contact resistance of $R''_{t,c}$ = 0.0025 m^2*K/W between all contacting resting surfaces [1]

Conservative assumption for stainless steel contact under vacuum conditions

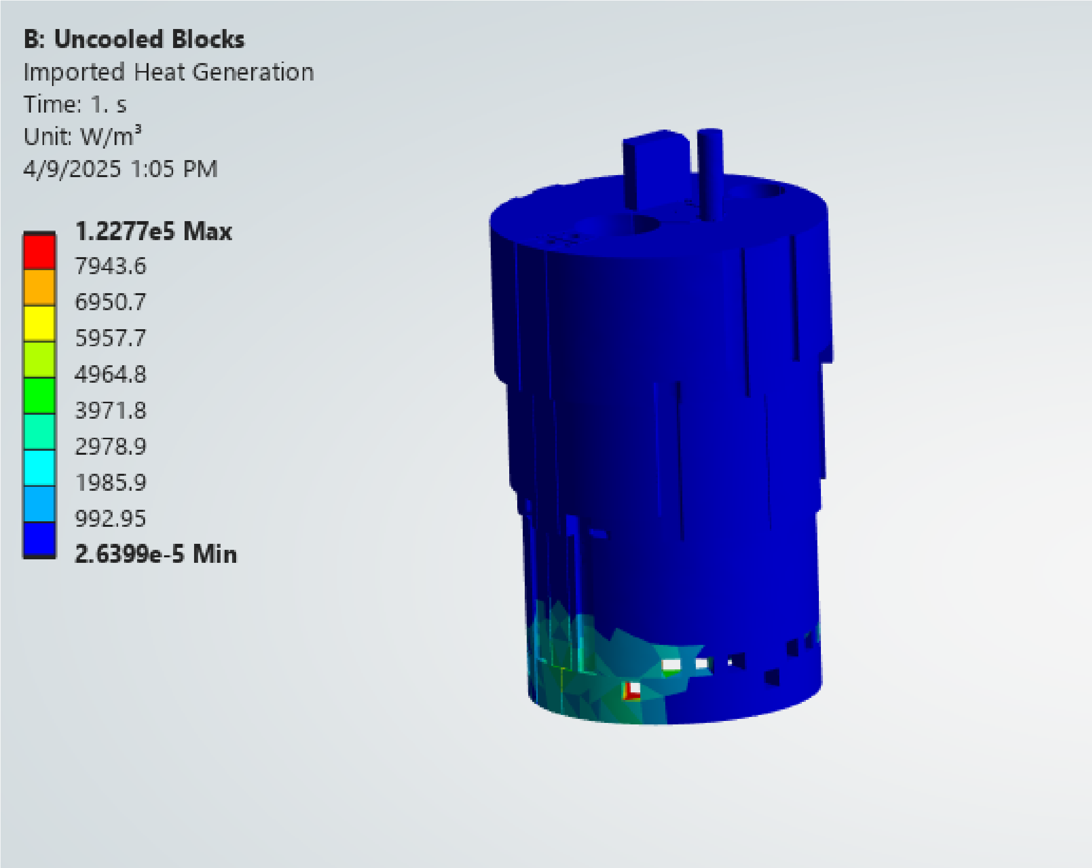
No convective or radiative effects applied

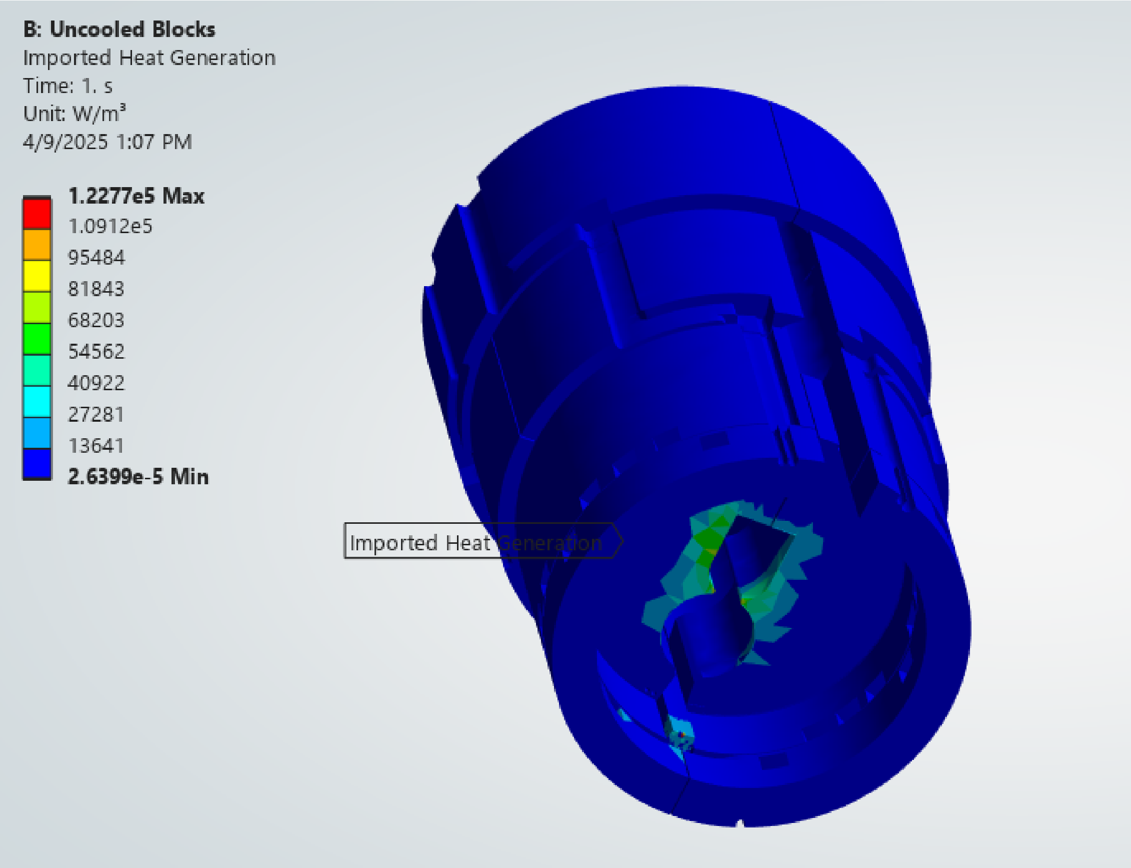


Apply Heat Generation Plot

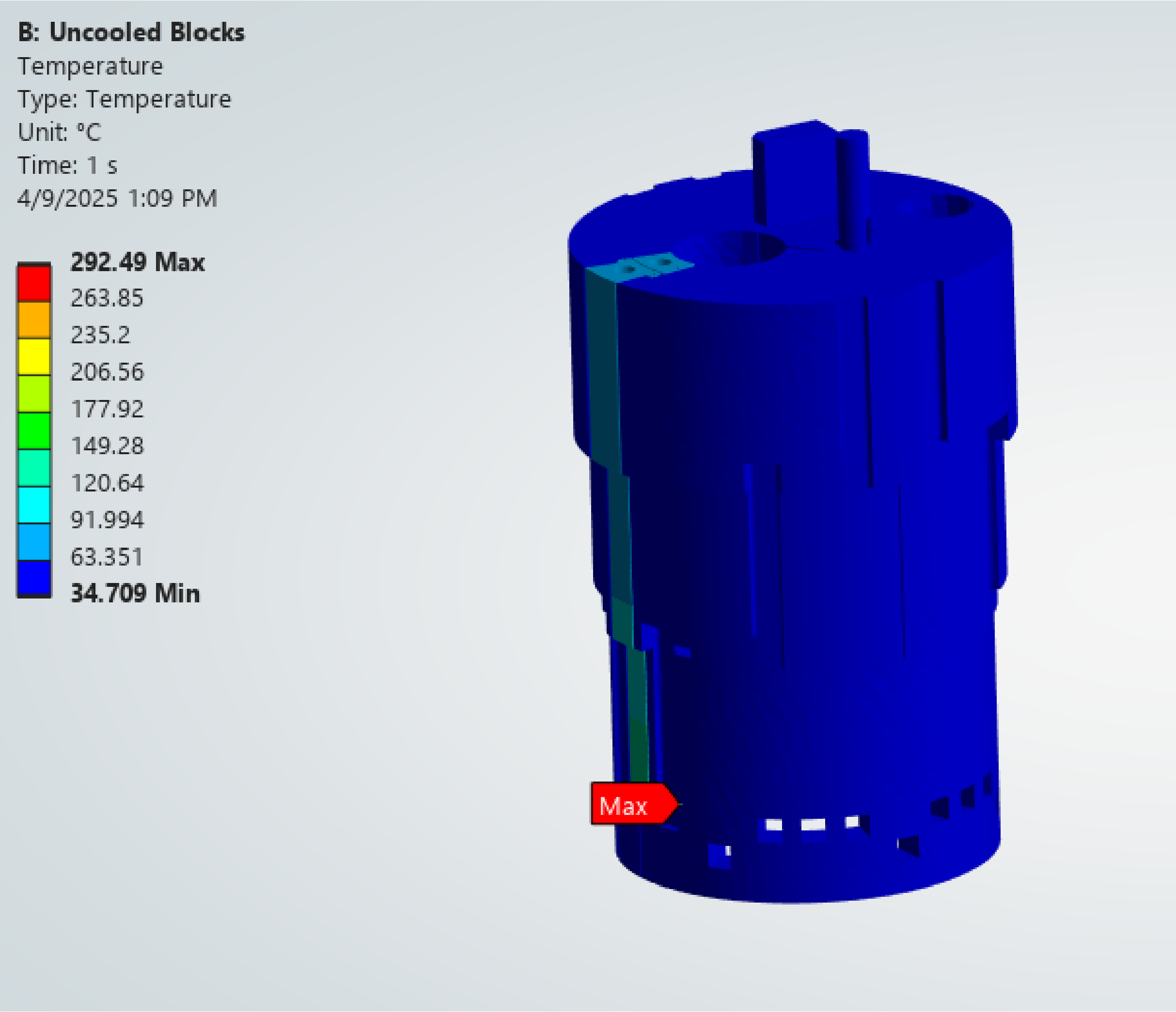
Results:

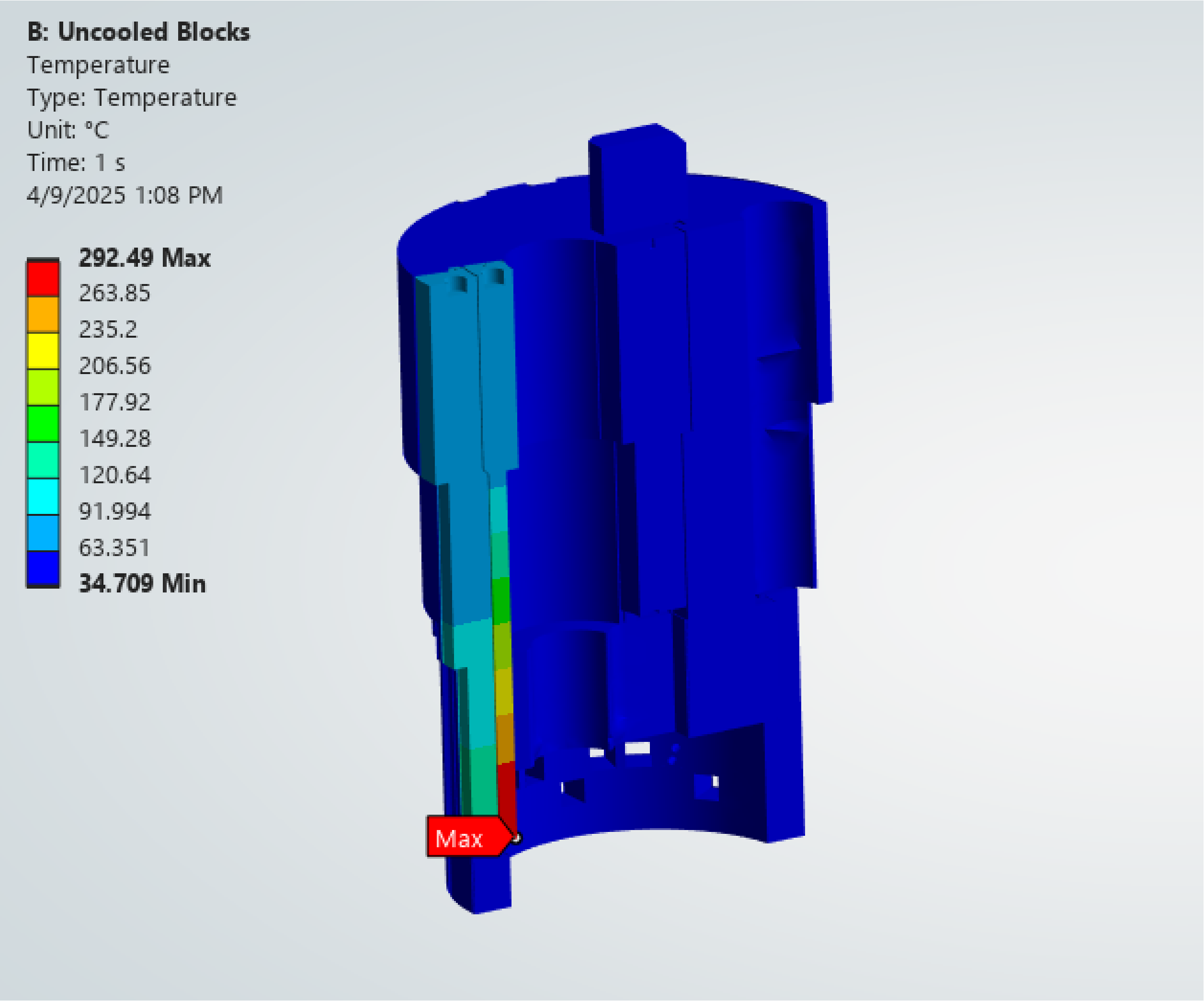
Row	Target
	Total Heat Rate (W)
1	5844.8



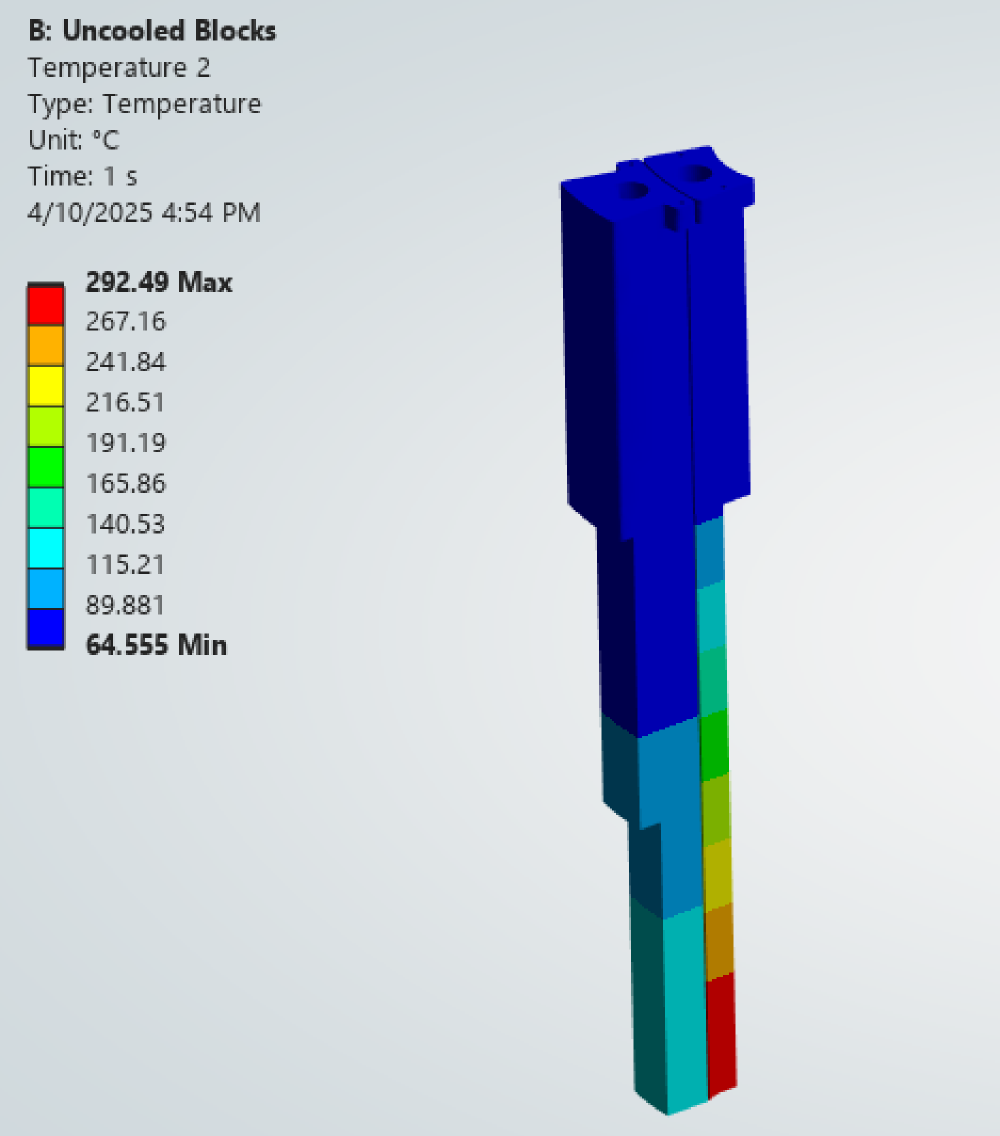


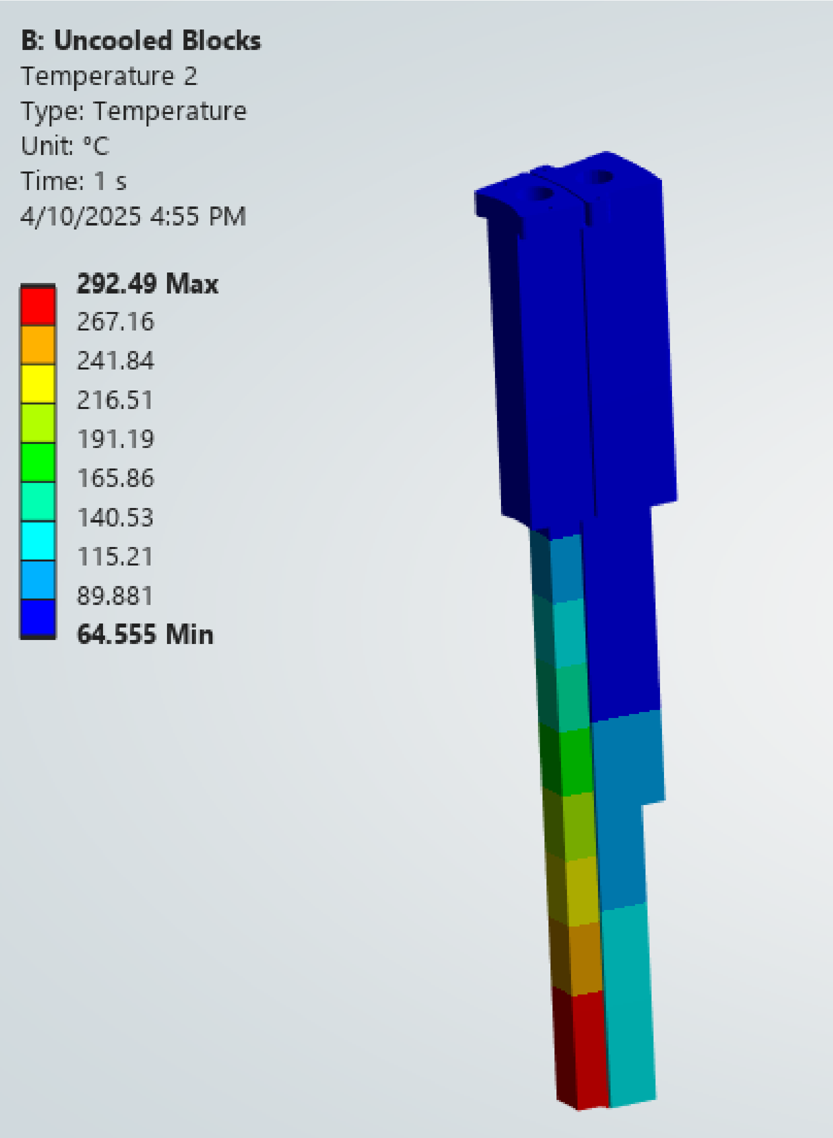
Temperature Results



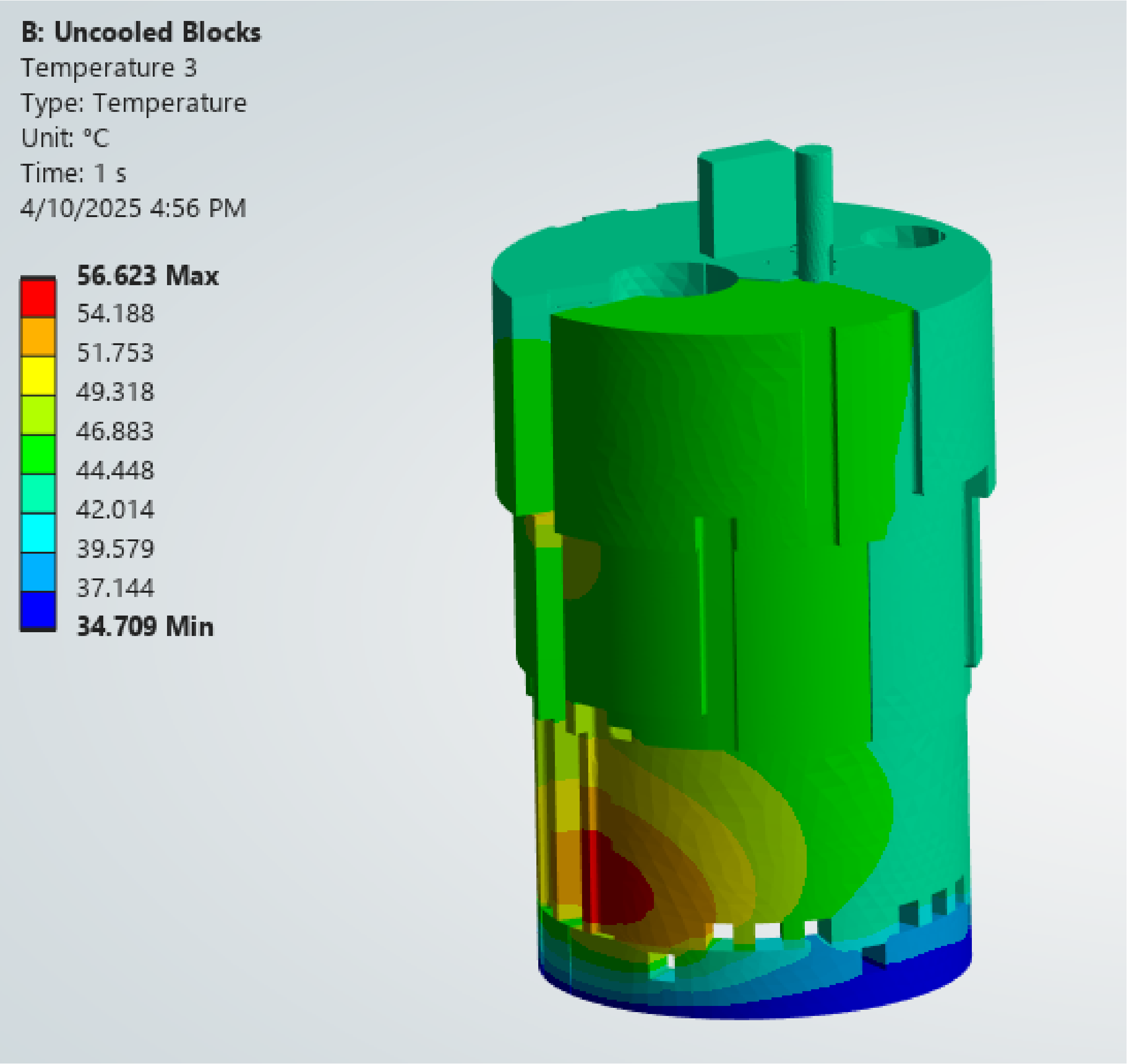


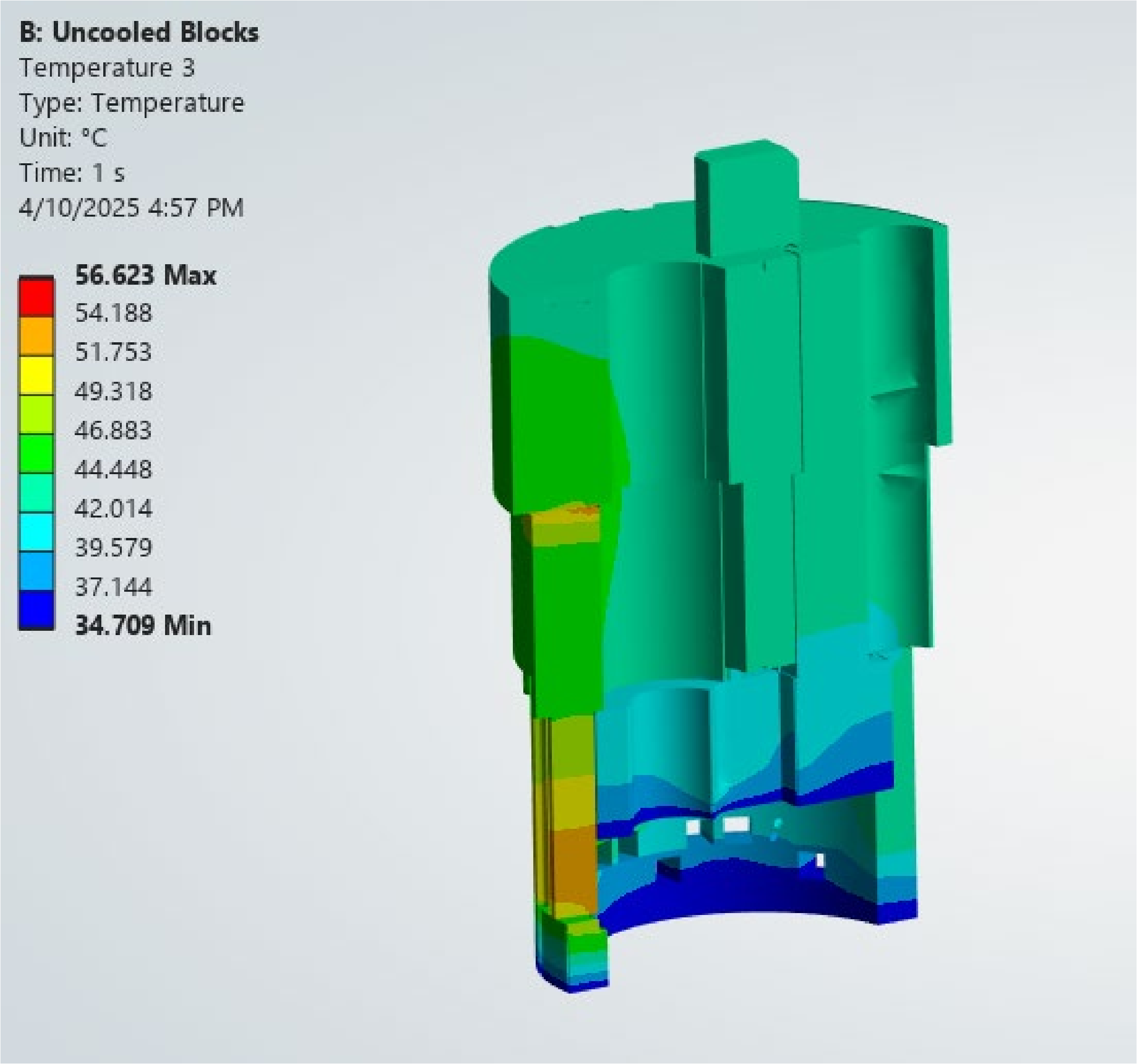
Temperature Results Removable Blocks





Temperature Results Stationary Blocks

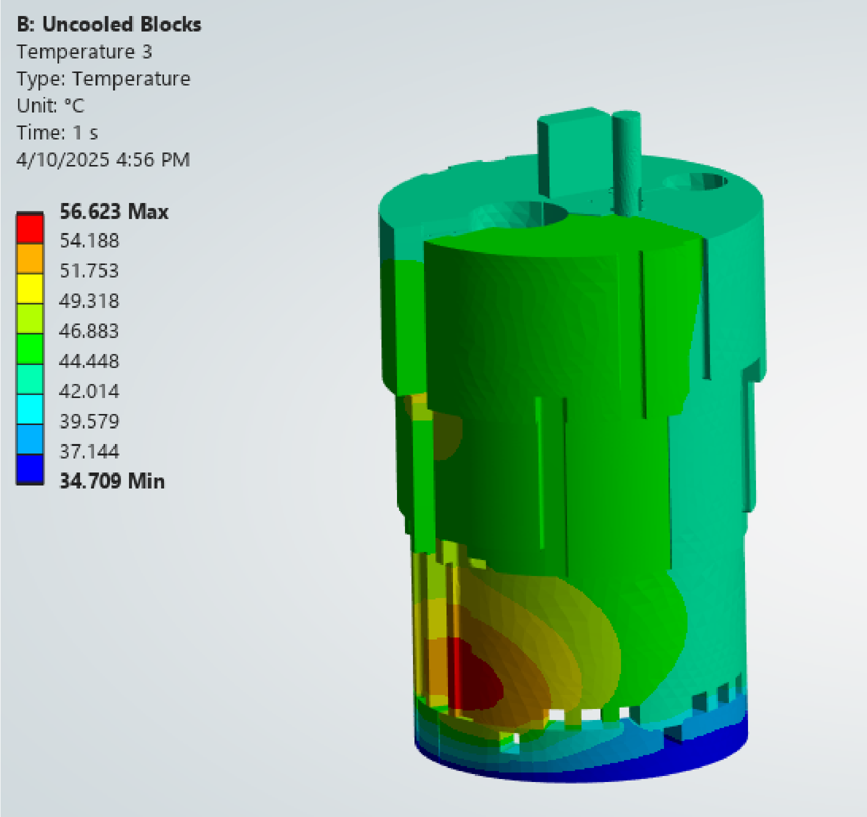


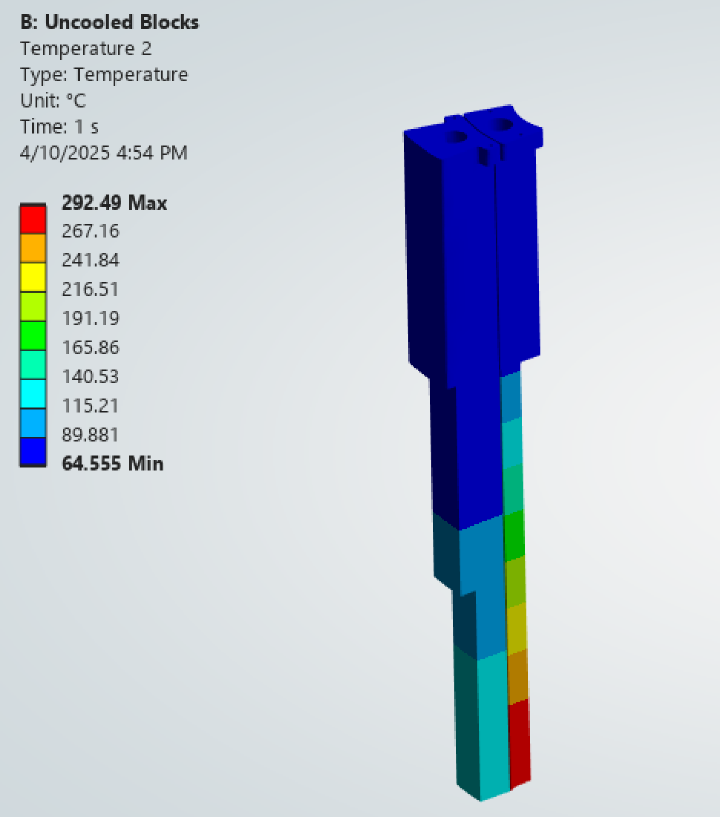


Uncooled Shielding Analysis Summary

Uncooled Shielding Analysis Results:

- Maximum stationary shielding stainless steel temperature = 200 C
  - ANSYS results: Maximum stainless steel temperature = 56.6 C → PASS
- Maximum removable shielding stainless steel temperature = 200 C
  - ANSYS results: Maximum stainless steel temperature = 292.5 C → FAIL





SECOND TARGET STATION

CV Nozzle Extension Thermal Analysis

Min-Tsung Kao

U.S. DEPARTMENT OF ENERGY

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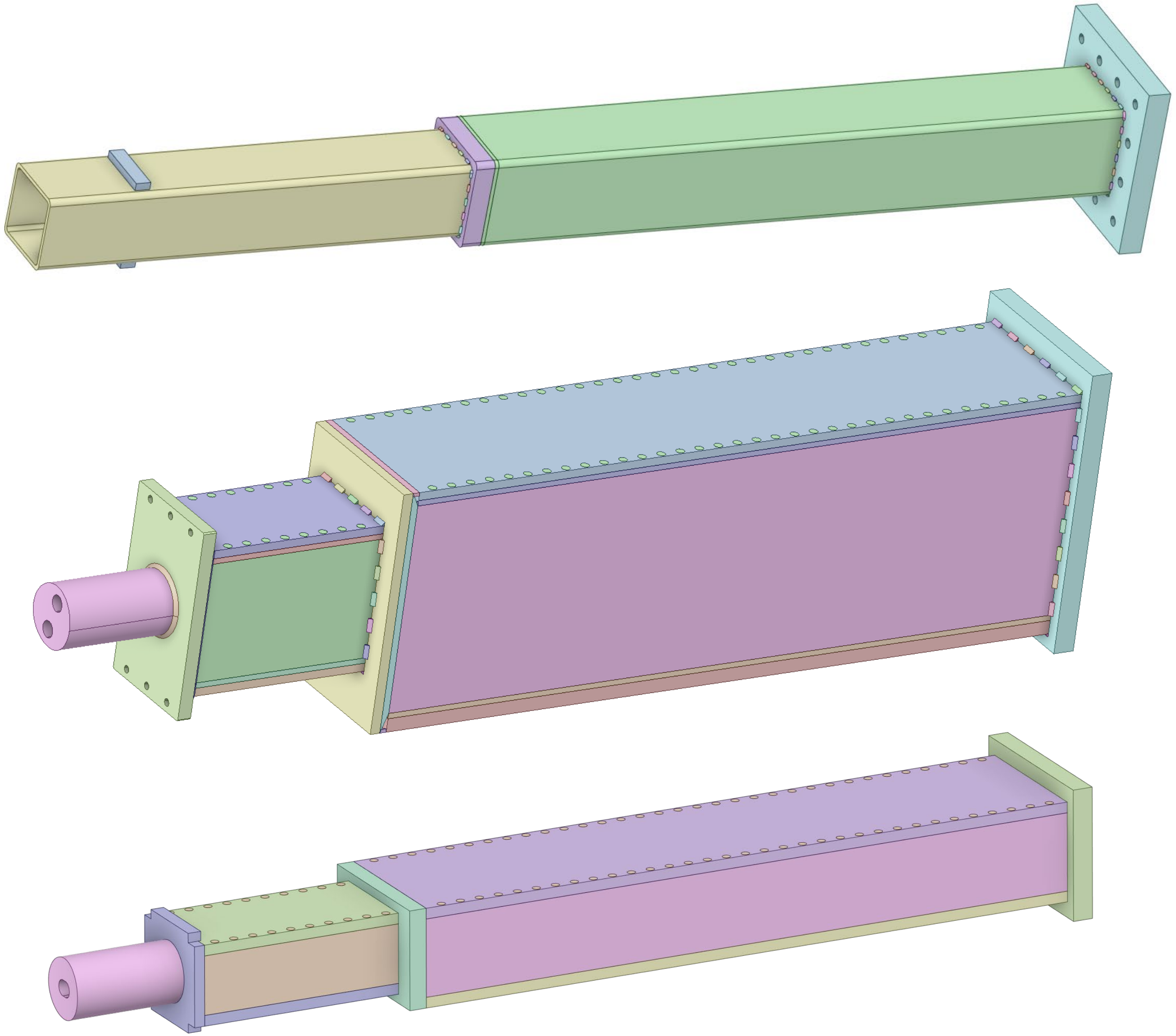
Nozzle Extensions Introduction and Requirements

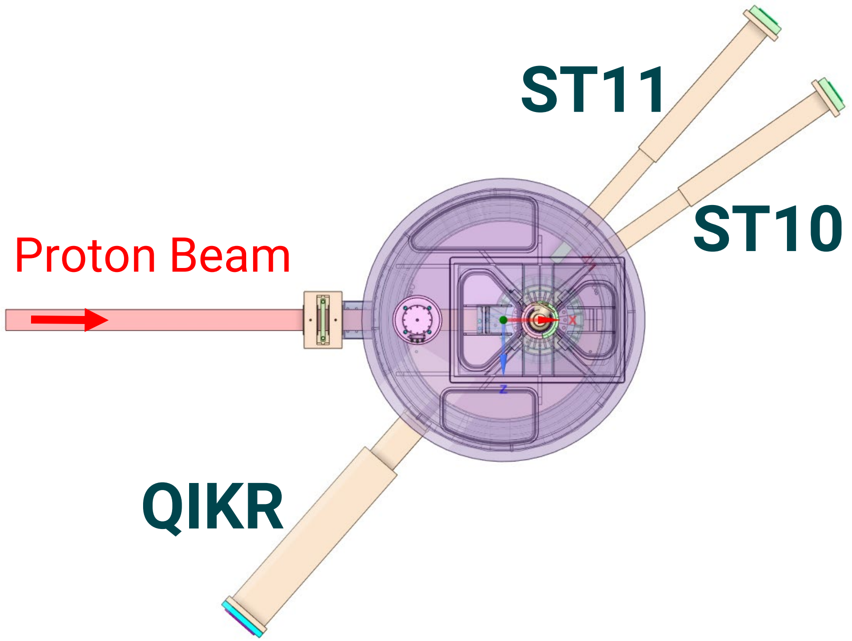
- The position of the following components are impacted by nozzle extension thermal performance:
  - Monolith Inserts (with guide optics)

<u>Nozzle Extensions Thermal Requirements:</u>

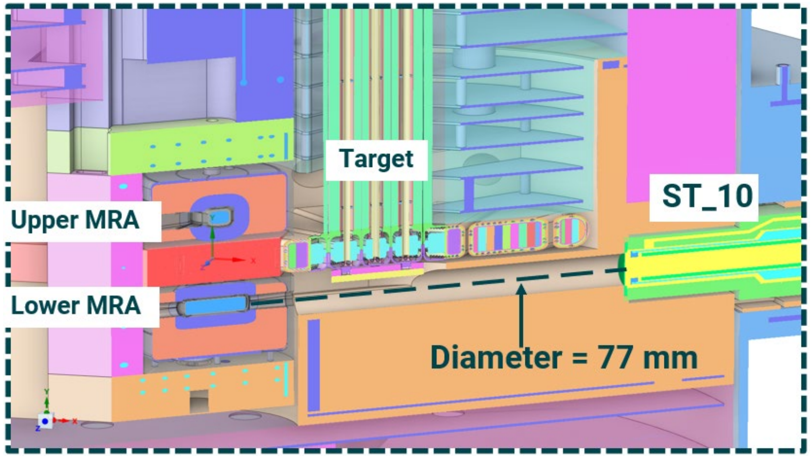
- Maximum stainless steel temperature = 200 C



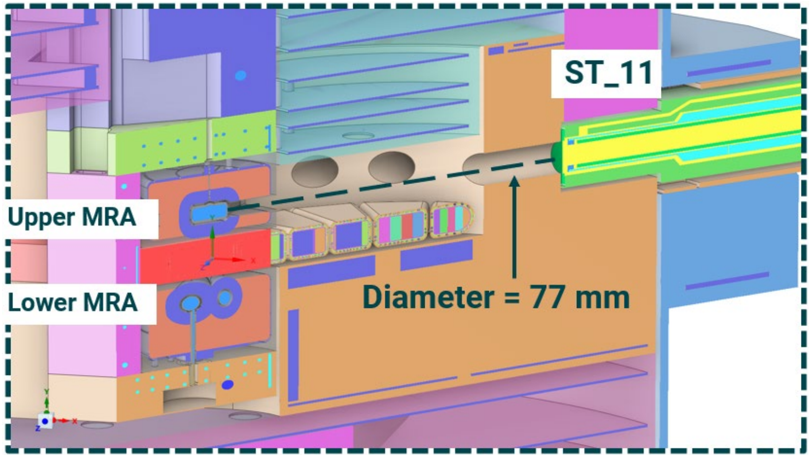
CV Nozzle Extensions Analyzed in This Presentation



ST10: facing lower MRA



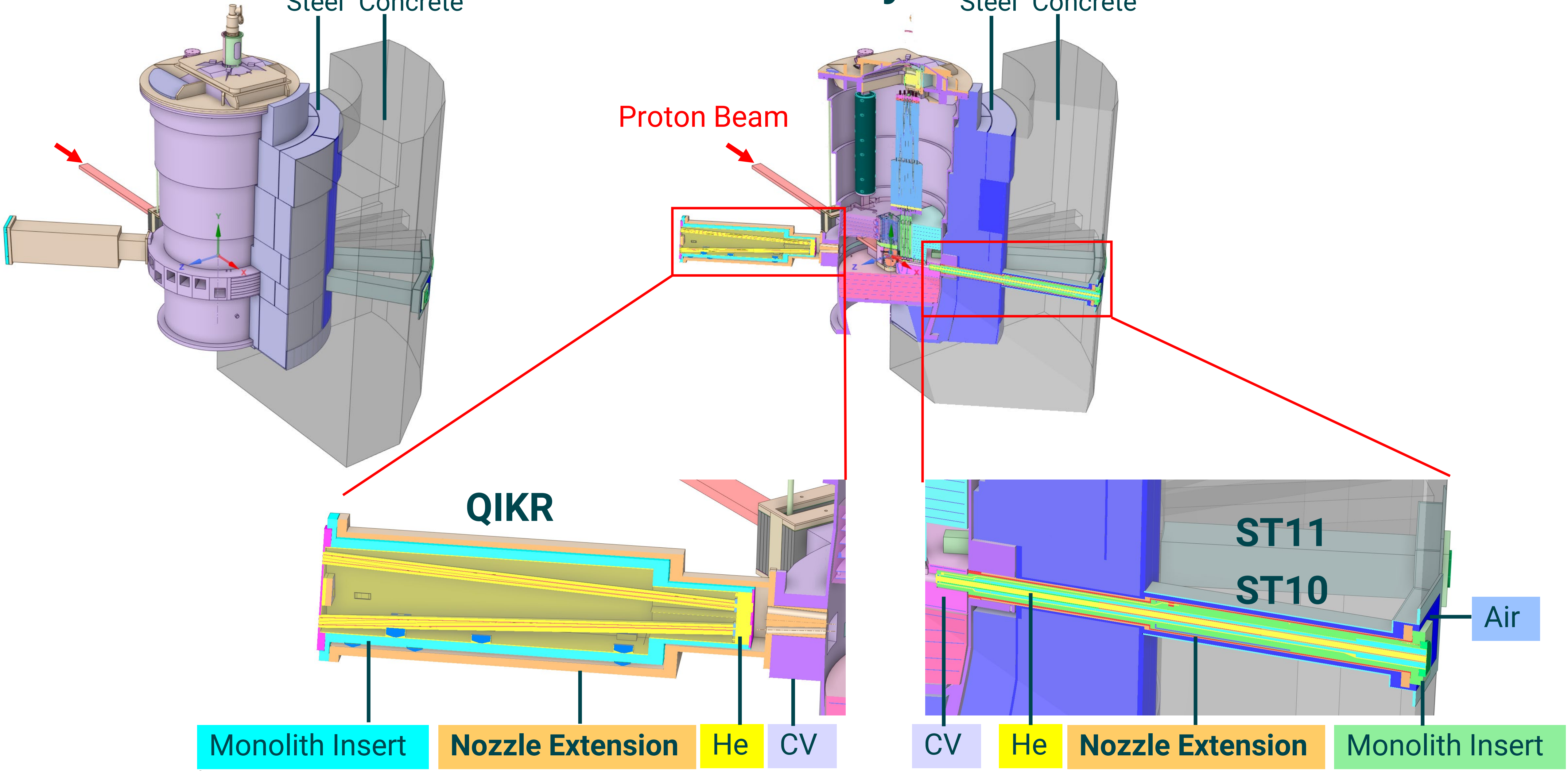
ST11: facing upper MRA



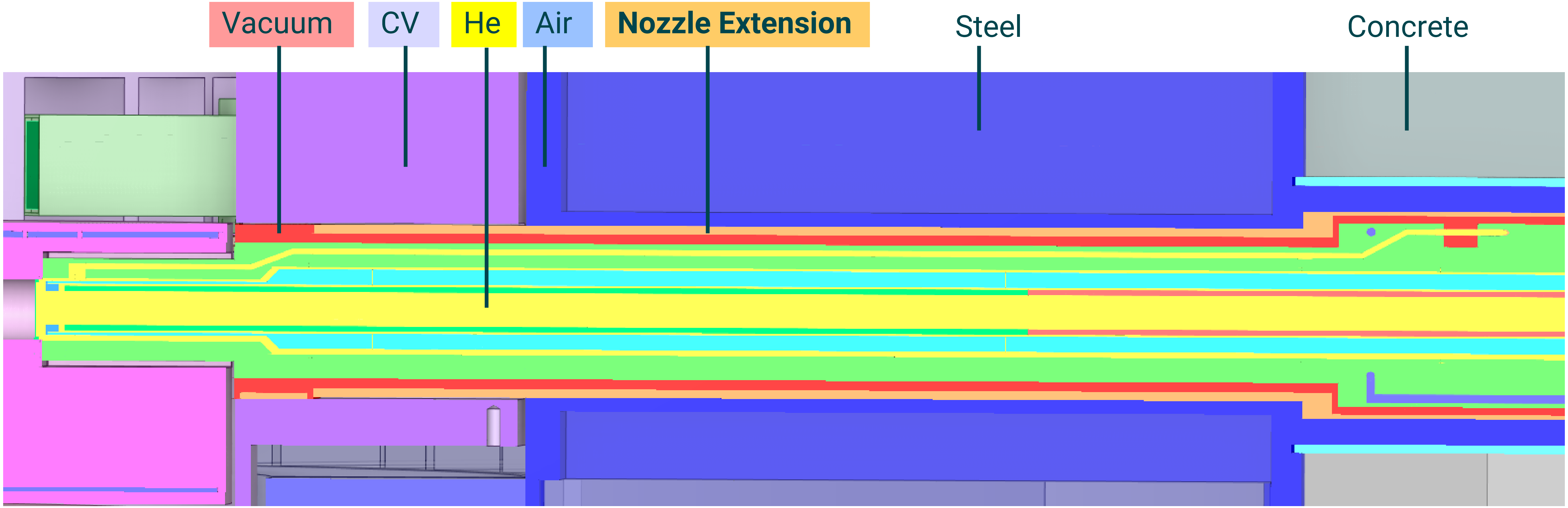
The **nozzle extensions** at **QIKR**, **ST10**, and **ST11** are chosen for the thermal analysis because:

- **ST10**: facing the **lower** MRA (**~1 m**), **forward** direction of proton beam, **higher** energy deposition, **active cooling**
- **ST11**: facing the **upper** MRA (**~1 m**), **forward** direction of proton beam, **higher** energy deposition, **active cooling**
- **QIKR**: **farther** away from MRA (**~1.9m**), **backward** direction of proton beam, **lower** energy deposition, **passively cooled**

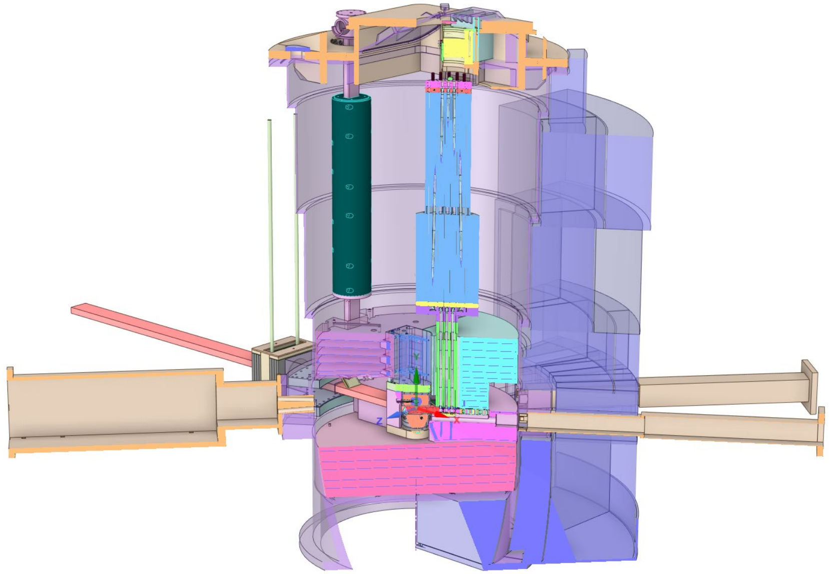
Geometry

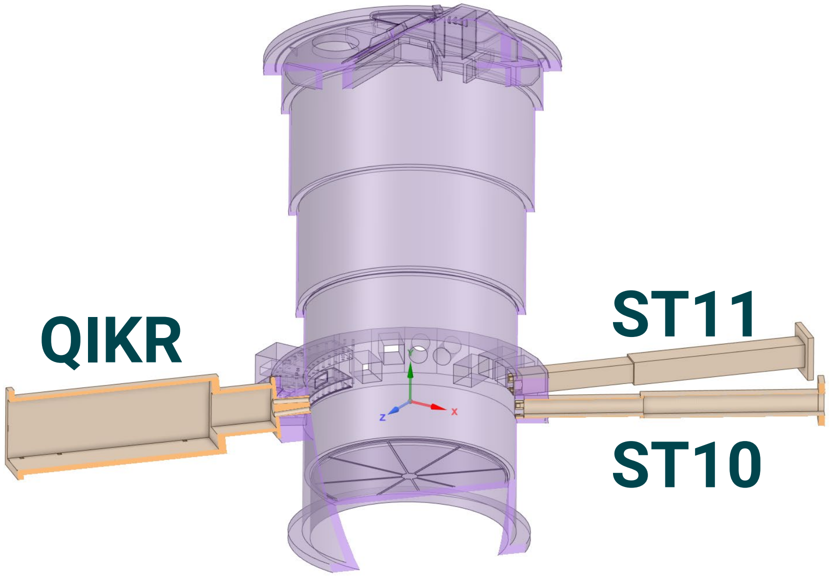

Steel
Concrete
Proton Beam
Steel
Concrete
QIKR
Monolith Insert
Nozzle Extension
He
CV
ST11
ST10
Air
CV
He
Nozzle Extension
Monolith Insert

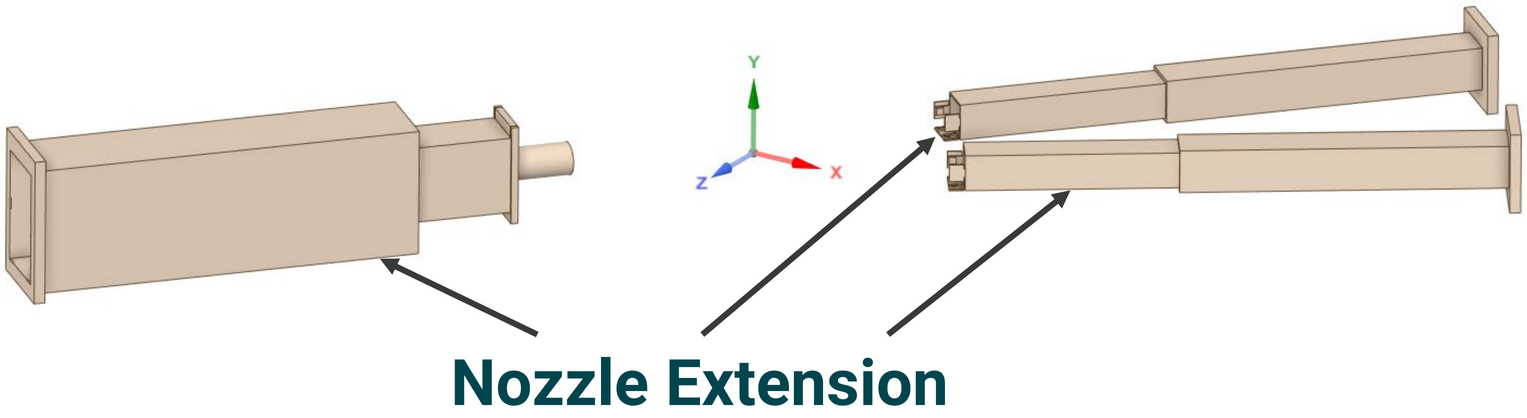
Geometry (ST10)



Geometry, Nozzle Extension @ ST10, ST11, and QIKR

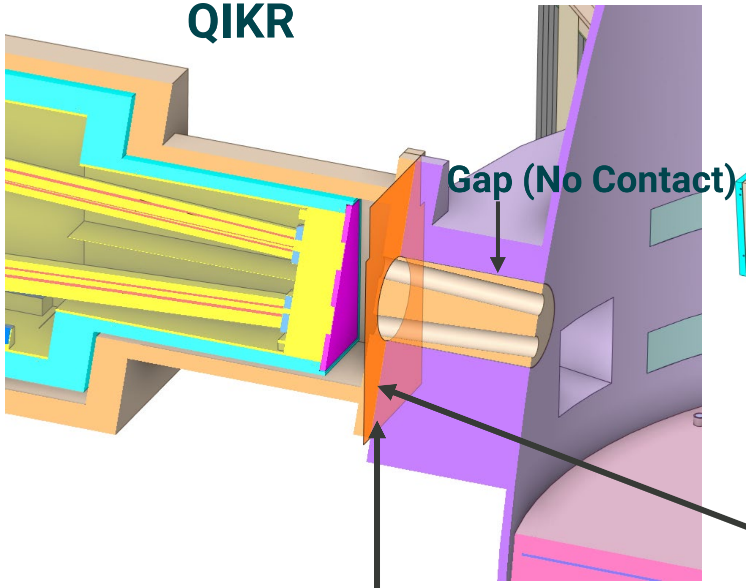


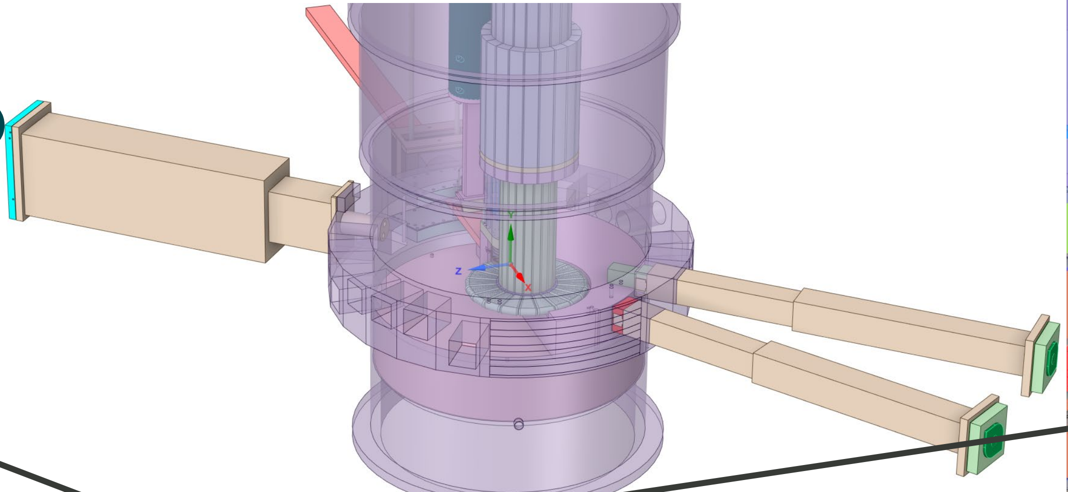


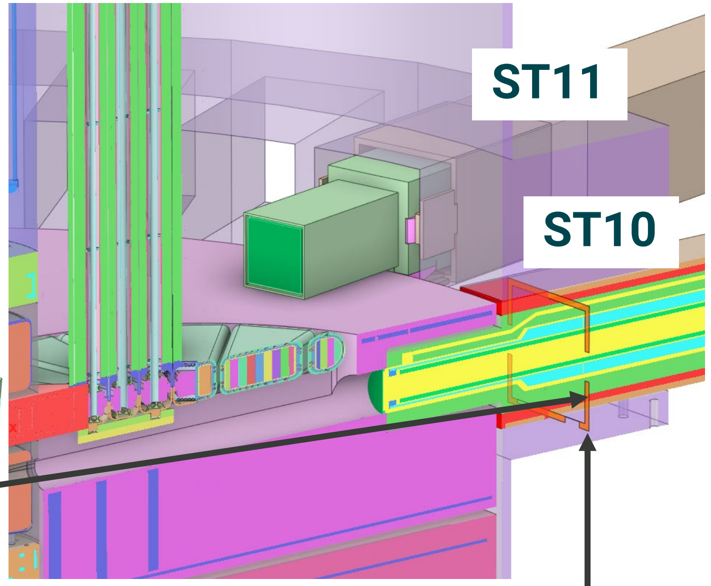


- This presentation discusses the **temperature profile** of nozzle extensions.
- The results in this presentation are extracted from the thermal analyses done for the QIKR and Monolith Insert Modules at ST10 and ST11. More details can be found : Monlith_Insert_PDR_CFD_Analysis_06_25_2024.pptx
  MTK_QIKR_Heat_Transfer_Analysis_2025_03_07_Updated.pptx
- The front surface of the nozzle extension is welded to the well-cooled core vessel beltline (active cooling).
- A separate CFD analysis was done for the core vessel beltline, and the obtained temperature profile was used to set the boundary condition for the nozzle extension.

Boundary Conditions

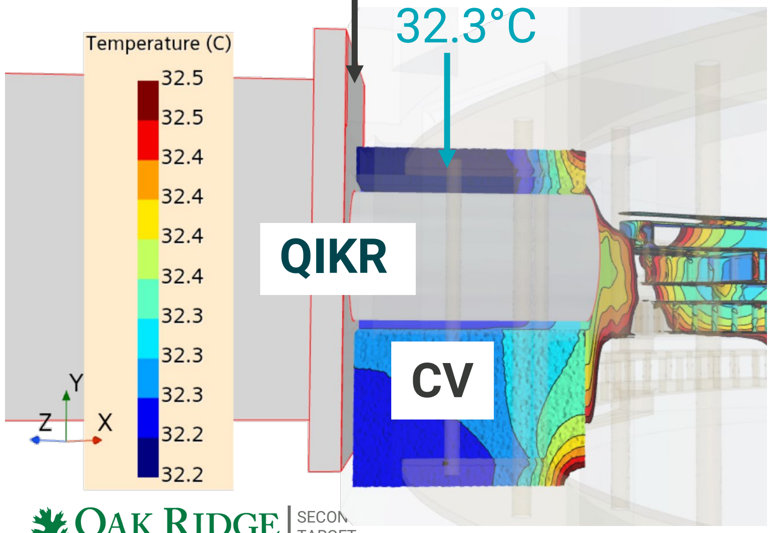






Assume @ 35°C (conservative)

Contact Surface



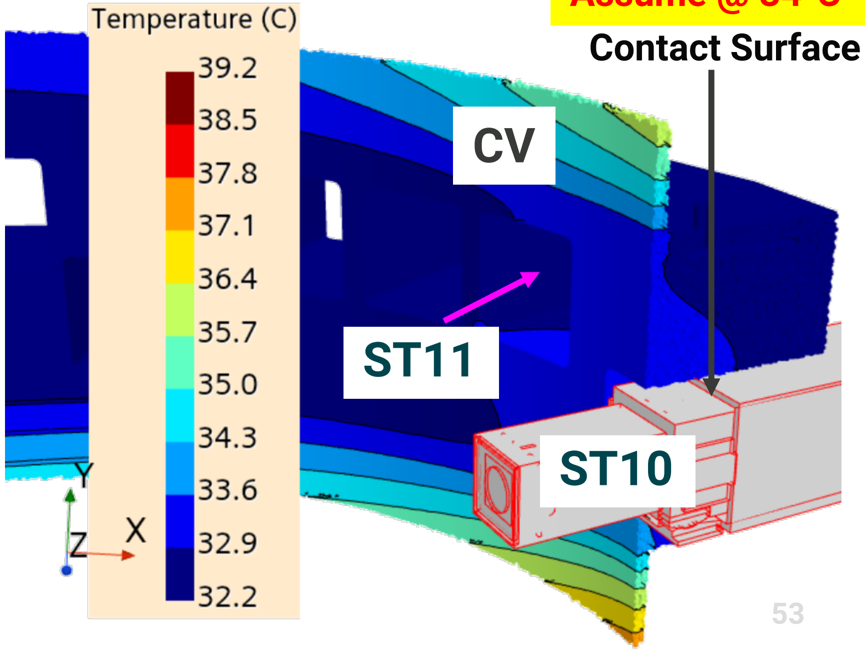
- **Front surface** is **welded** to the core vessel beltline.
- **ST10** & **ST11** have **active cooling** circuits.
- **QIKR** is only **passively cooled** through the contact with CV; therefore, its front surface is assumed at a higher temperature (35°C, conservative assumption).

Boundary Conditions:

- front surface of ST10 & ST11: **34°C**
- front surface of QIKR: **35°C**

Assume @ 34°C

Contact Surface

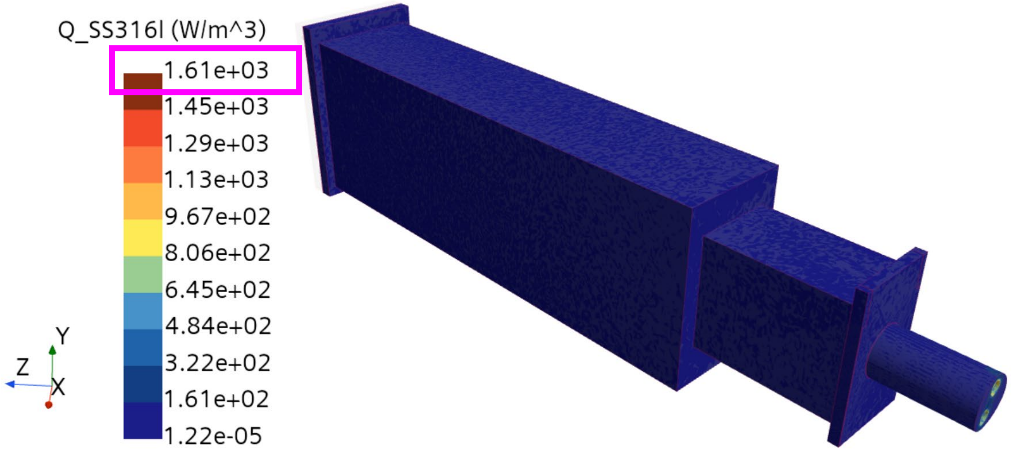


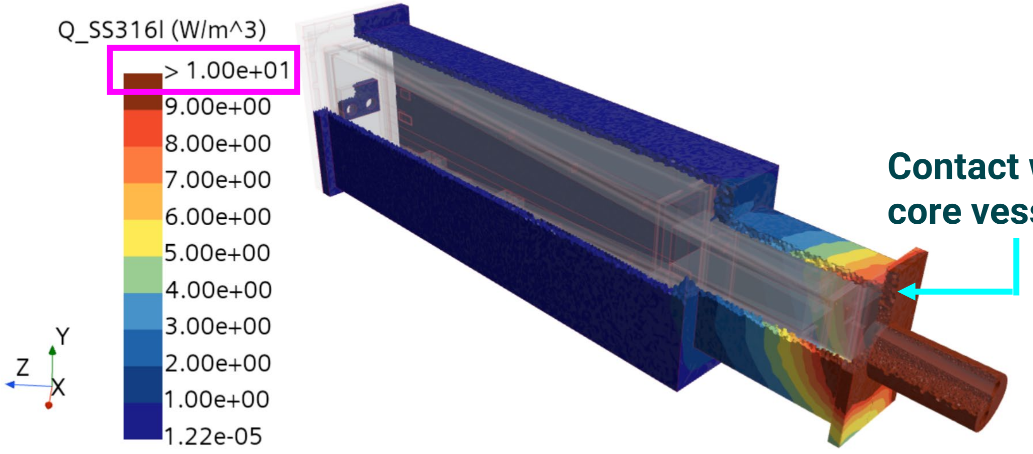
Heat Source, Nozzle Extension of QIKR

- Energy deposition of QIKR from Kristel Ghoos

1 kW/m^3 = 1 mW/cc

Total Heat: 1.77 W

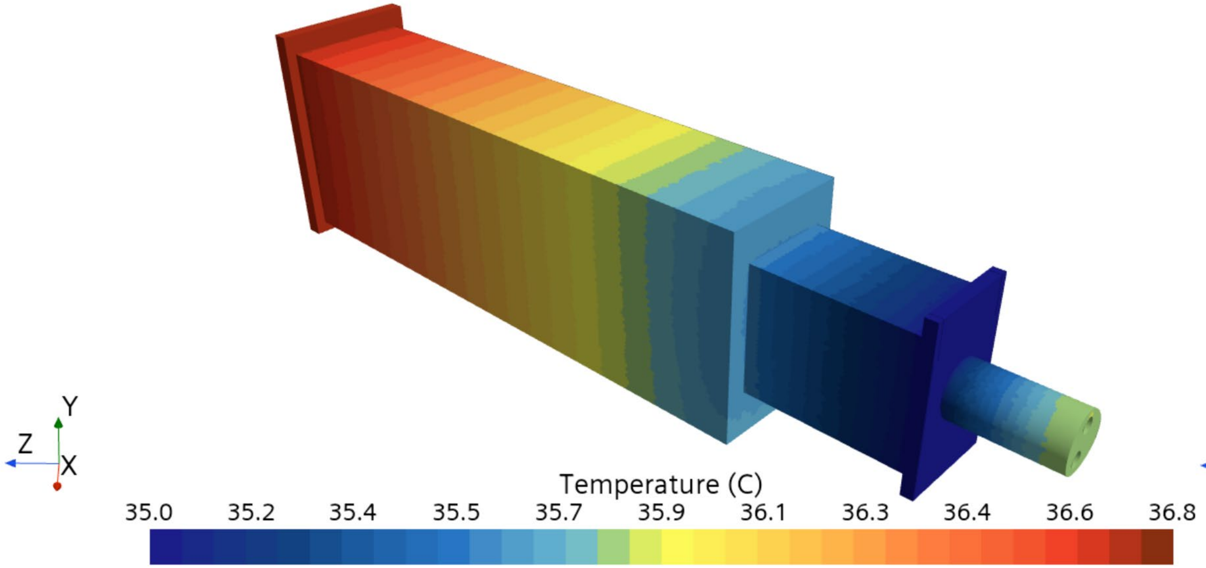


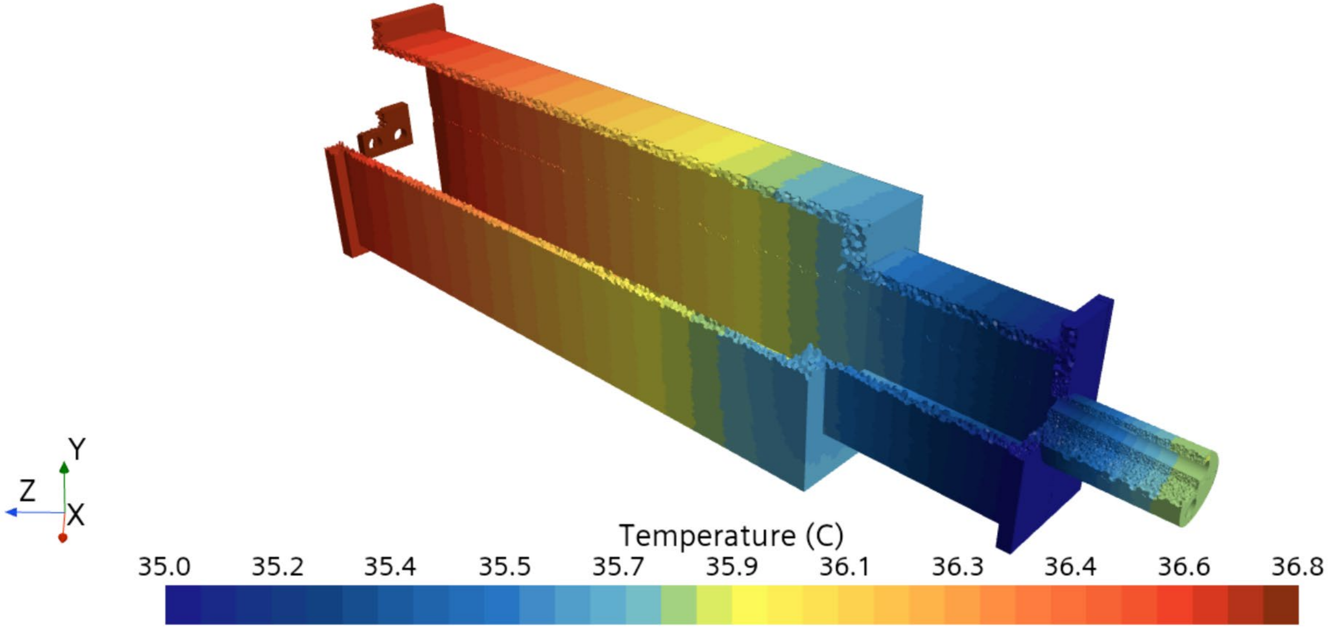


Contact with well-cooled core vessel beltline

Temperature, Nozzle Extension of QIKR

Peak: 36.8°C





Heat Source, Nozzle Extensions of ST10 & ST11

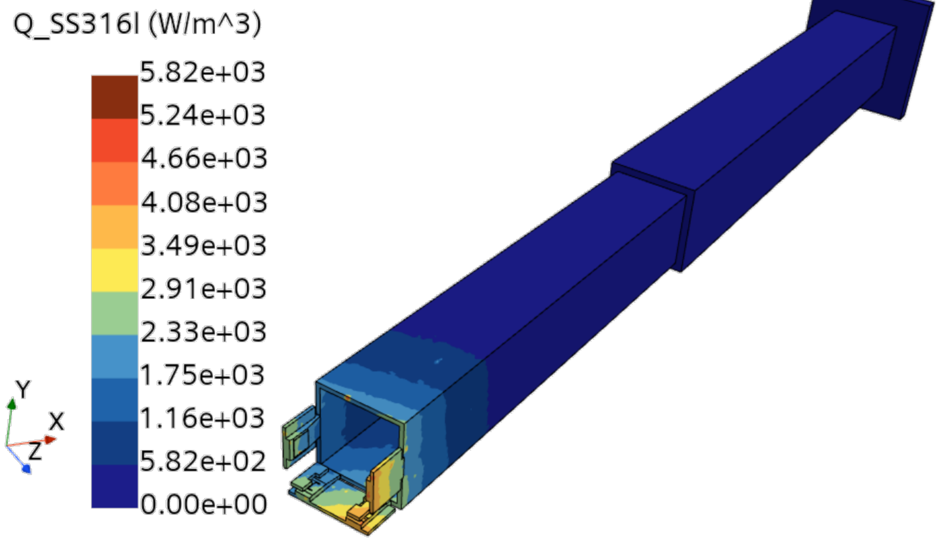
- Energy deposition of ST10 & ST11 from Thomas Miller

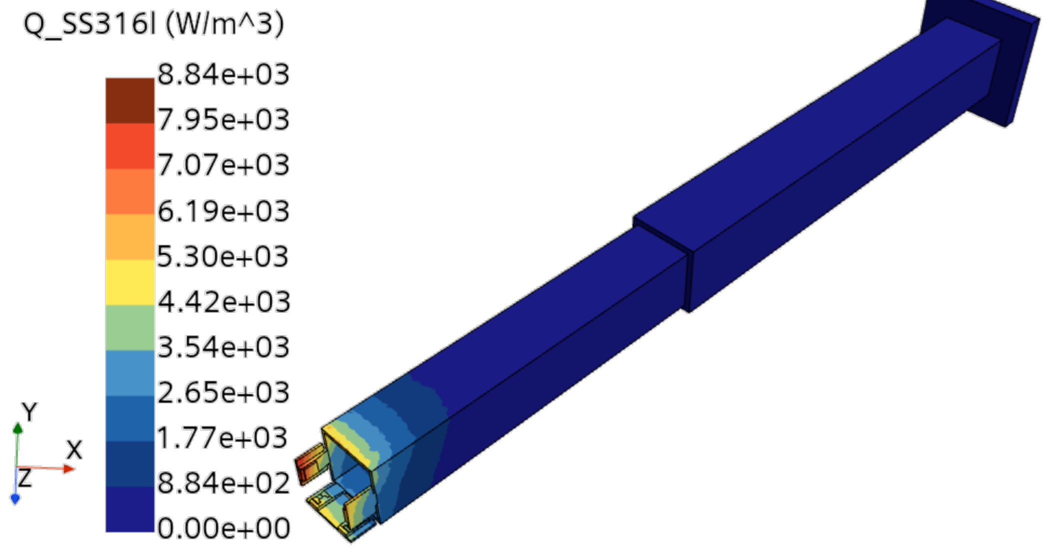
ST10

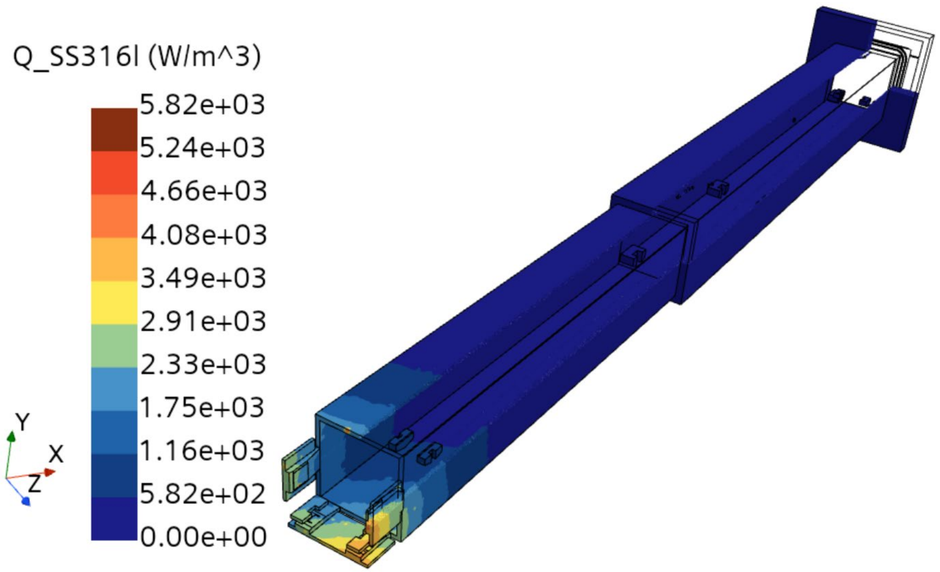
Total Heat: 8.5 W

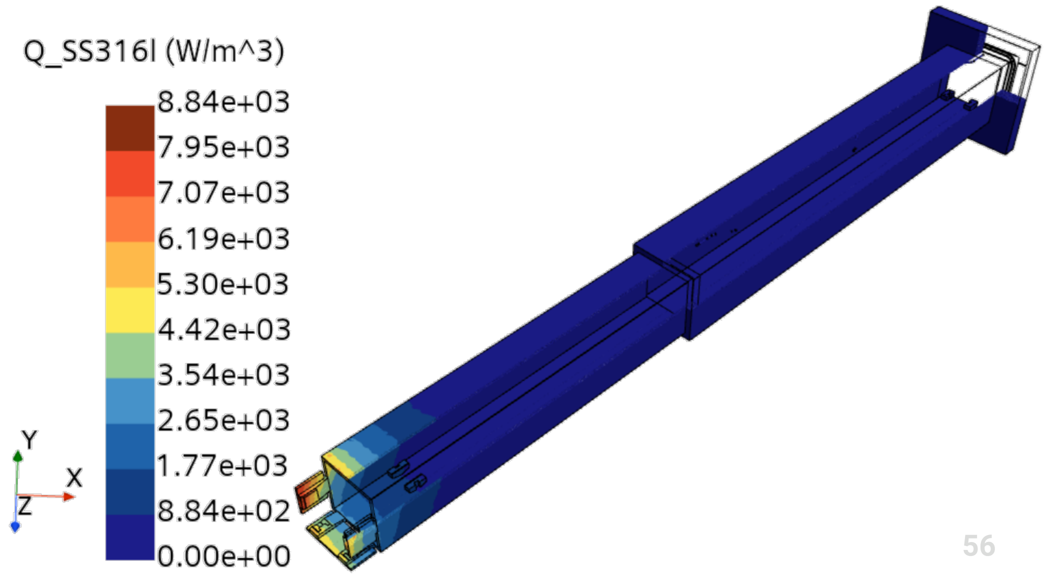
ST11

Total Heat: 12.6 W









Temperature, Nozzle Extensions of ST10 & ST11

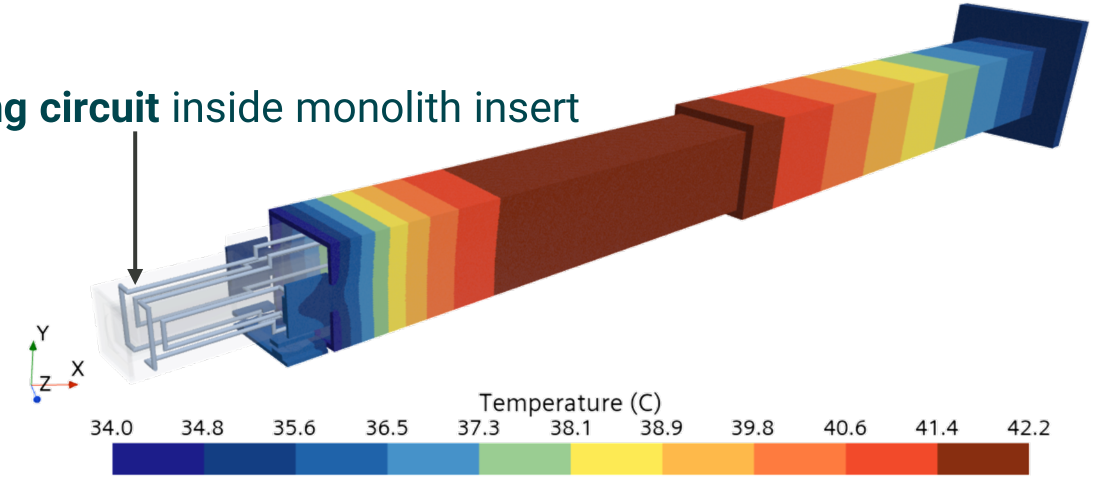
ST10

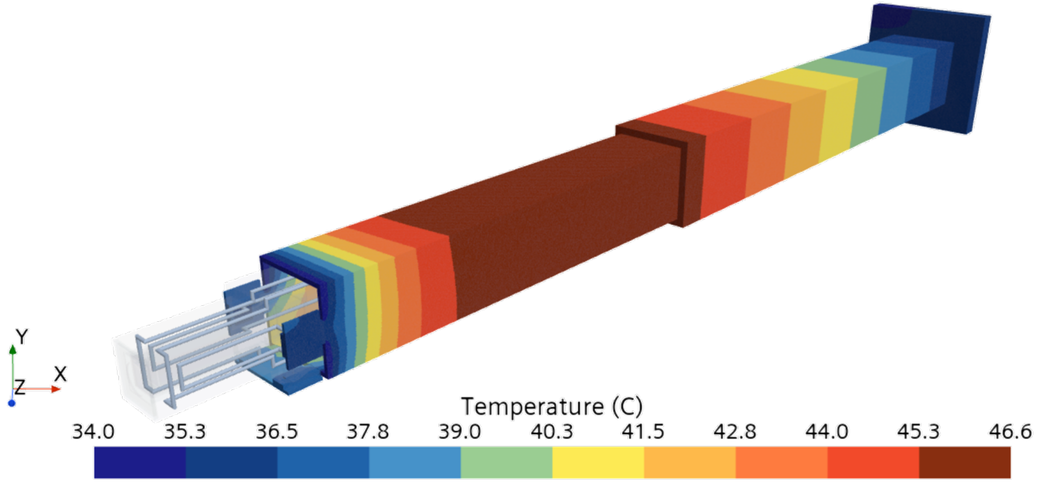
Peak: 42.2°C

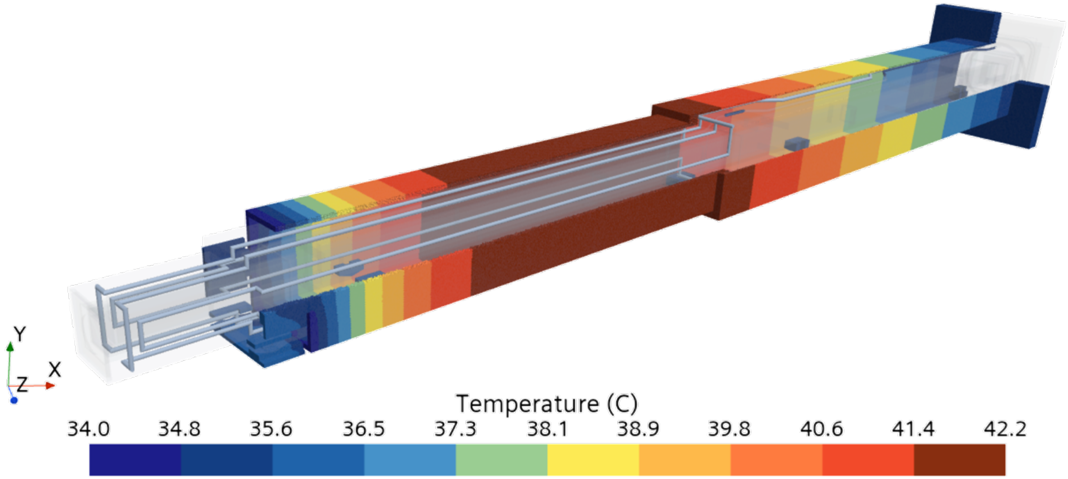
ST11

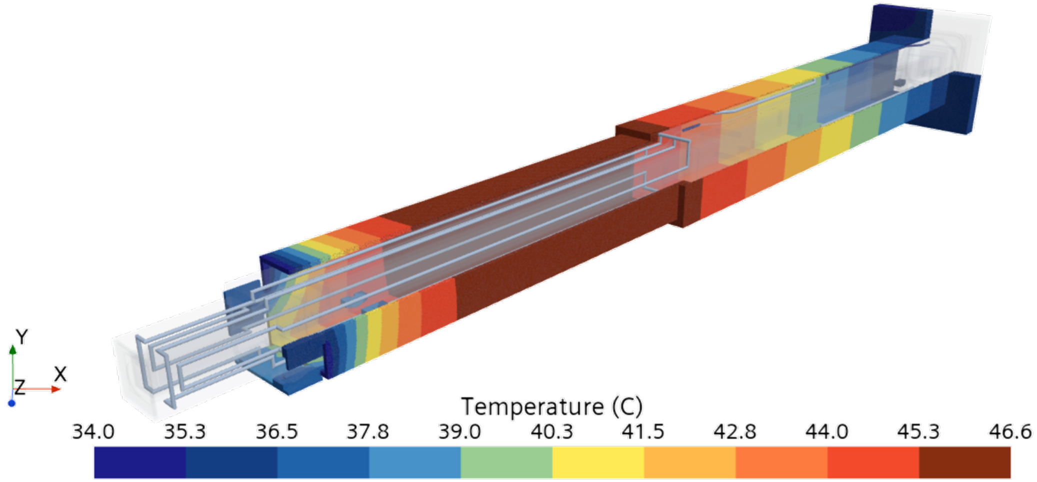
Peak: 46.6°C

Cooling circuit inside monolith insert





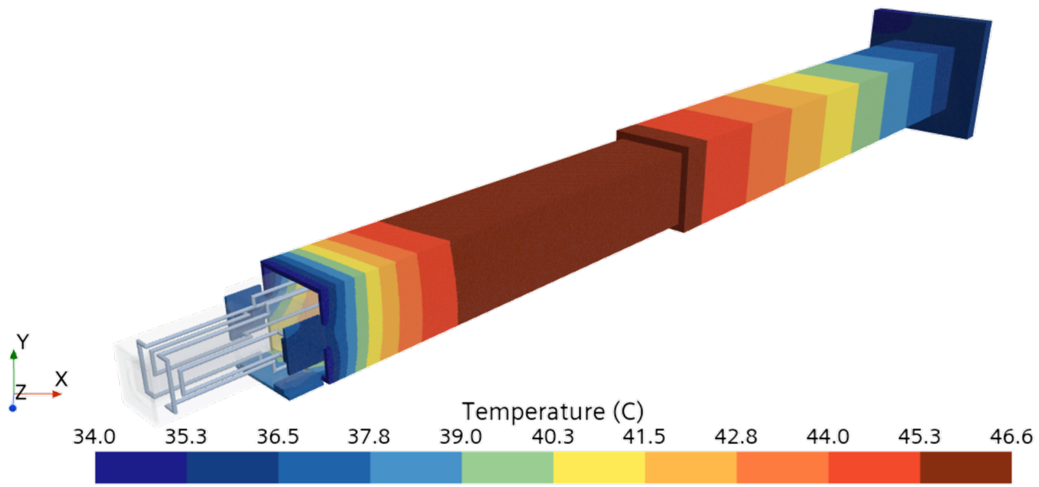


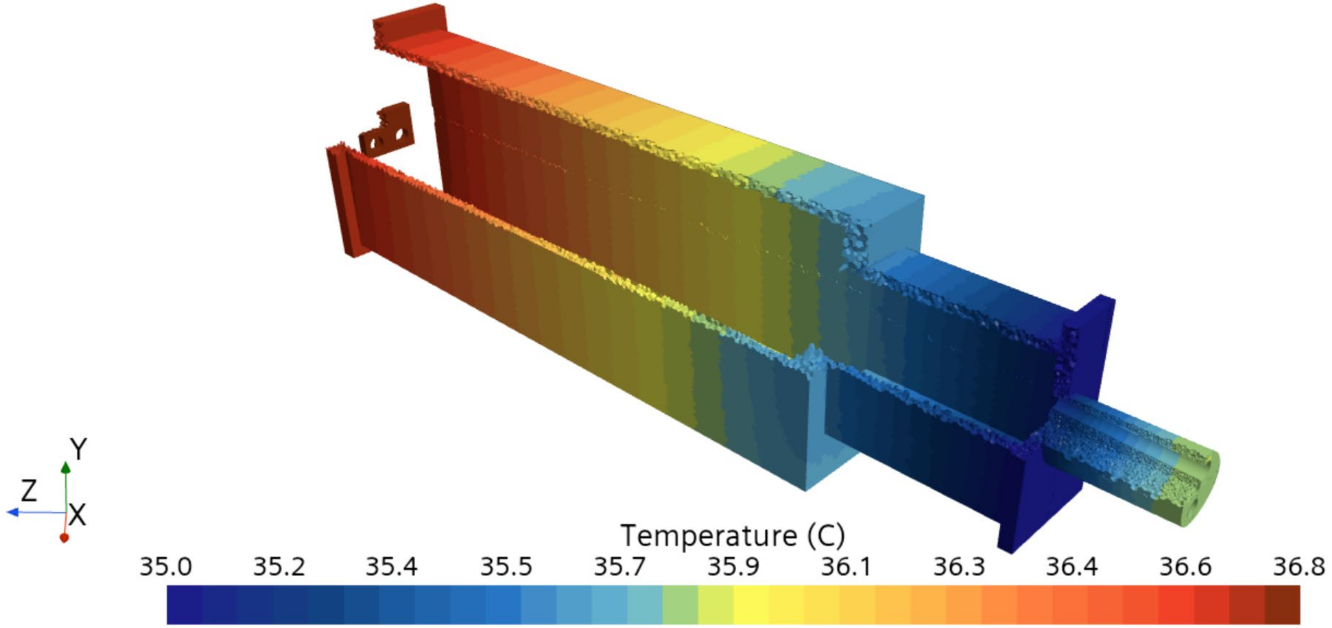


Nozzle Extension Analysis Summary

<u>Uncooled Shielding Analysis Results:</u>

- Maximum standard nozzle extension stainless steel temperature = 200 C
    - ANSYS results: Maximum stainless steel temperature = 46.6 C → PASS
- Maximum QIKR Nozzle Extension stainless steel temperature = 200 C
    - ANSYS results: Maximum stainless steel temperature = 36.8 C → PASS
- Maximum Dual Channel Nozzle Extension stainless steel temperature = 200 C
    - ANSYS results: TBD → Unconfirmed





OAK RIDGE National Laboratory | SECOND TARGET STATION

CV & TSS PDR Neutronics Contributions: Monolith Heating

Thomas M Miller, Min-Tsung Kao, Kumar Mohindroo

March 27, 2025

U.S. DEPARTMENT OF ENERGY
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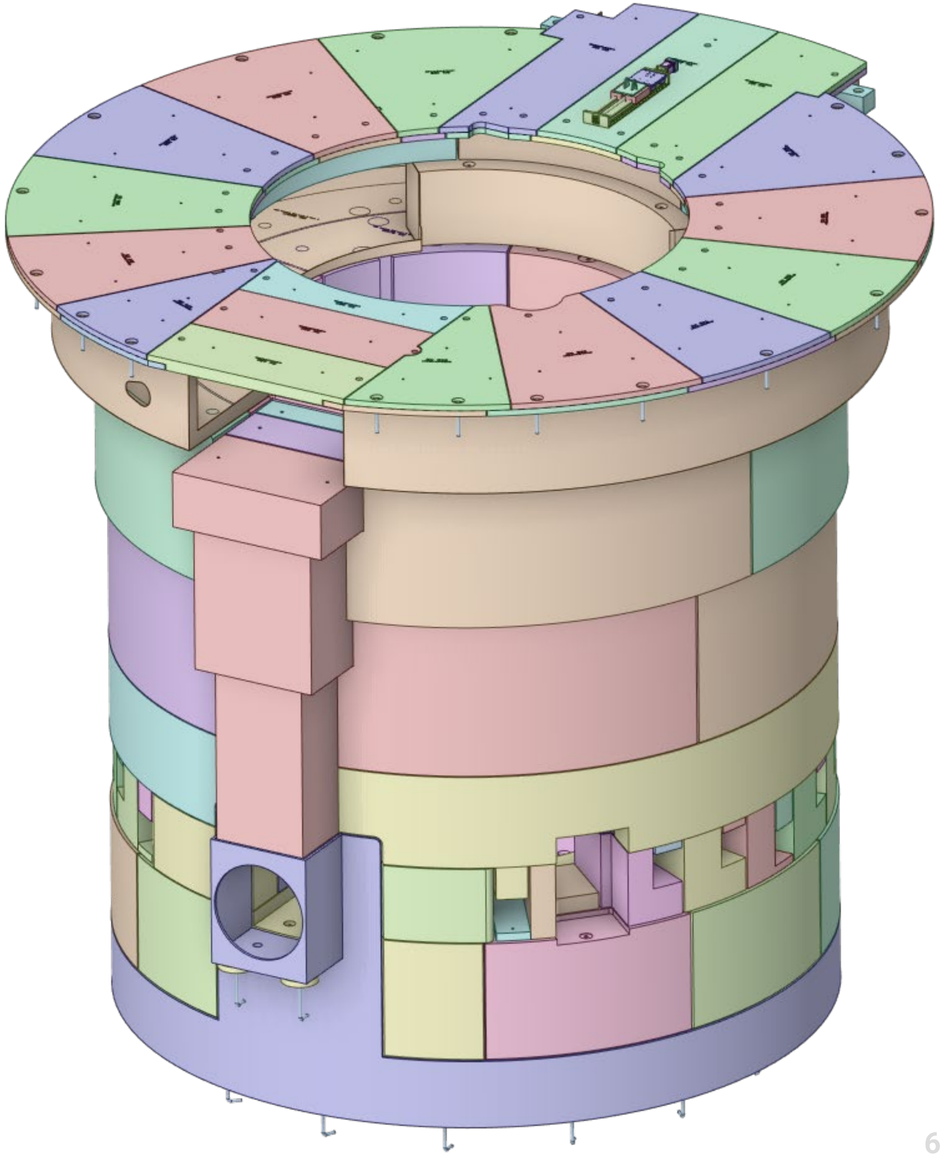
Target Station Shielding Introduction and Requirements

- The target station shielding provides significant radiation shielding to the monolith
- The target station shielding also provides thermal protection for the monolith concrete, reducing the amount of neutronic heating is seen in the concrete

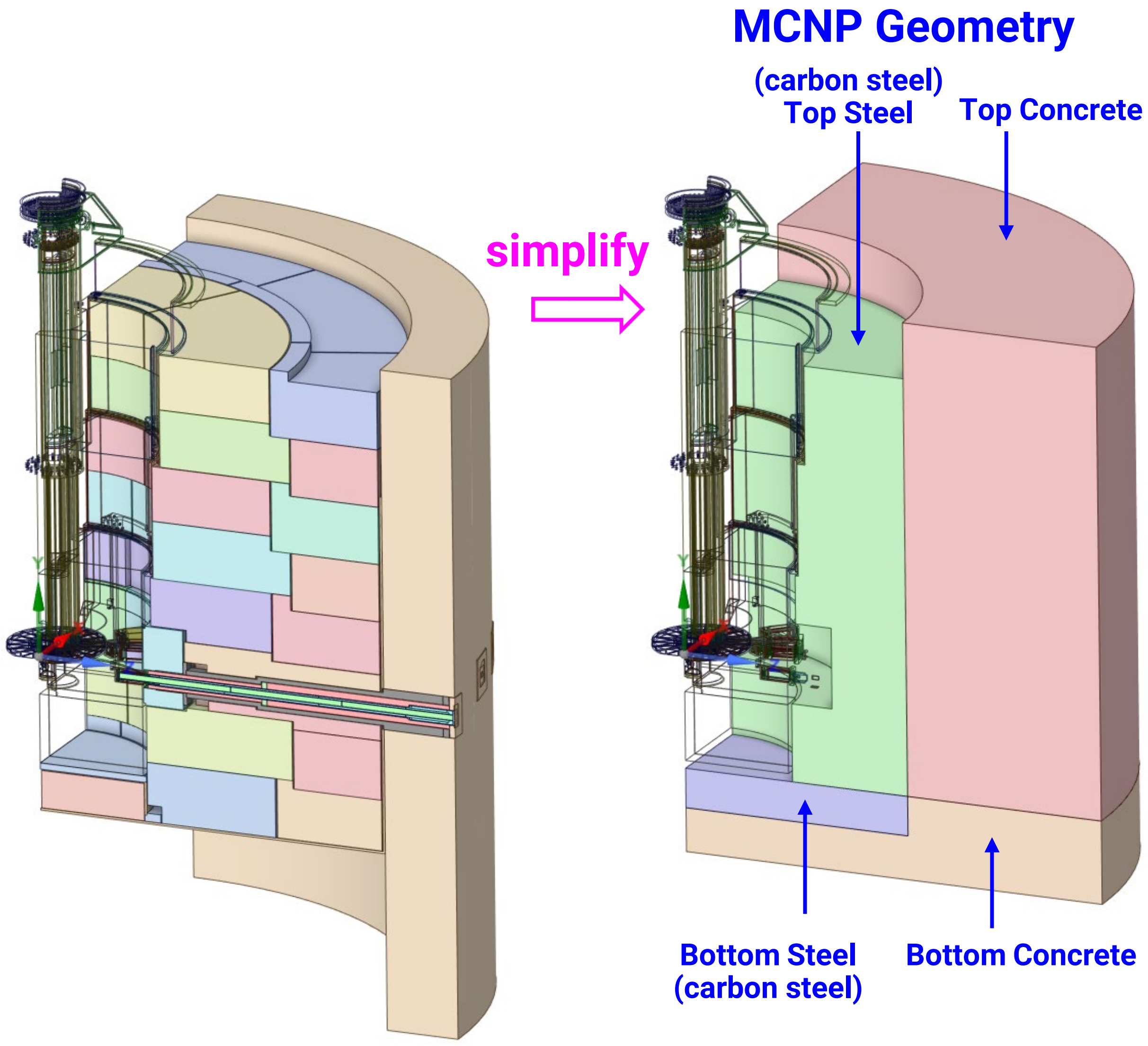
<u>**Target Station Shielding Thermal Requirements:**</u>

- Maximum carbon steel temperature = 200 C
- Maximum concrete temperature = 65 C

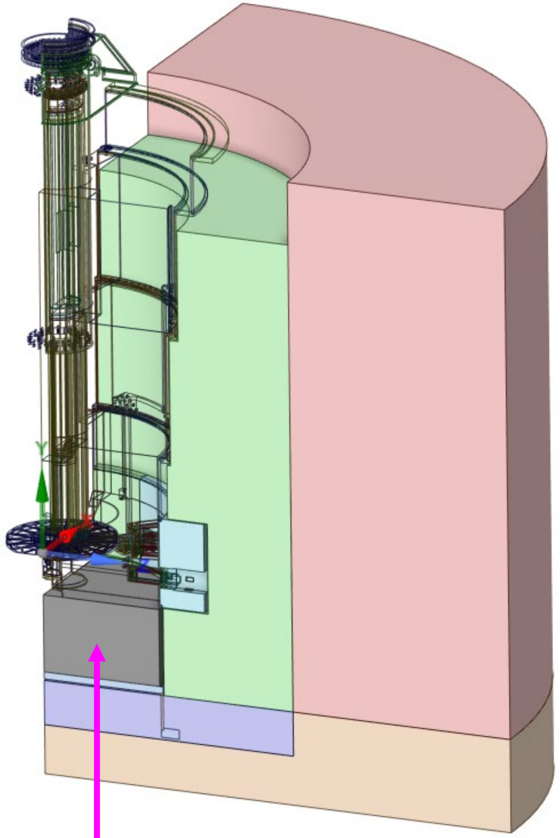


Monolith Shielding Heating and Thermal Analysis

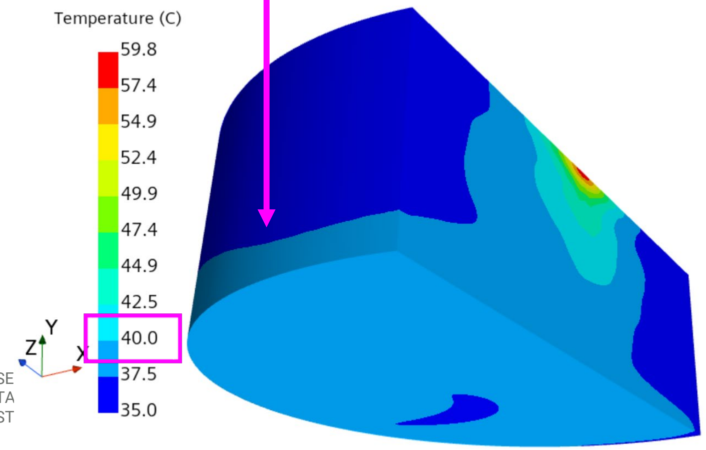
- Objective is to ensure the concrete temperature is below 65°C
- A greatly simplified geometry was analyzed for preliminary design

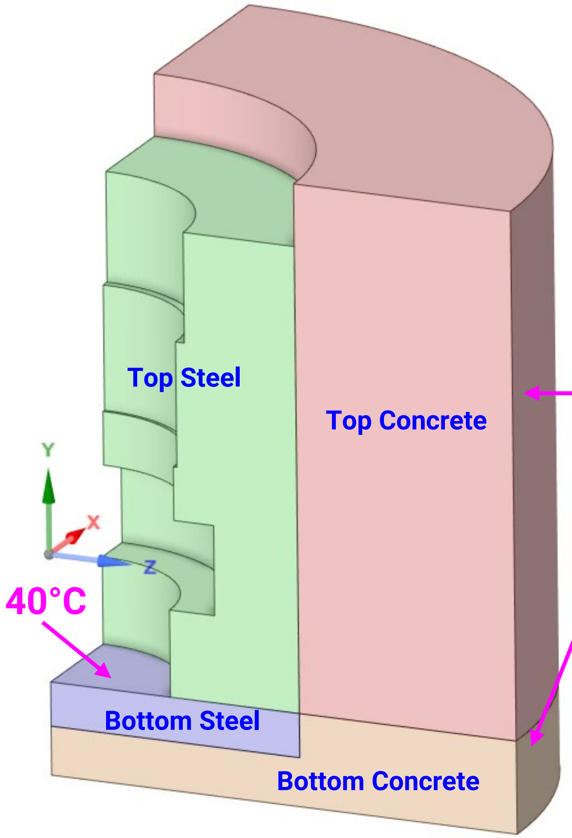


Monolith Shielding Heating and Thermal Analysis



Bottom shield block is well cooled.
Heating data provided by L. Zavorka





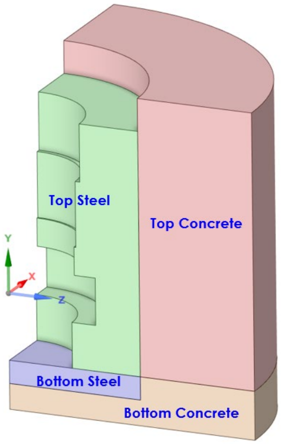
Concrete outer surface temperature will change the heat transfer coefficient, h. Therefore, the value of h for each case in this presentation is slightly different.

- Heat transfer coefficient, h = 1.38 W/m^2-K
- Environment temperature, $T_\infty = 35°C$

- Adiabatic boundary condition for the rest surfaces (top, bottom, and inner surfaces).

- **Perfect contact** for **radial interface** between **steel** and **concrete** (to maximize heat transfer to concrete)
- **Thermal contact resistance** for the **horizonal** interfaces

Monolith Shielding Heating and Thermal Analysis

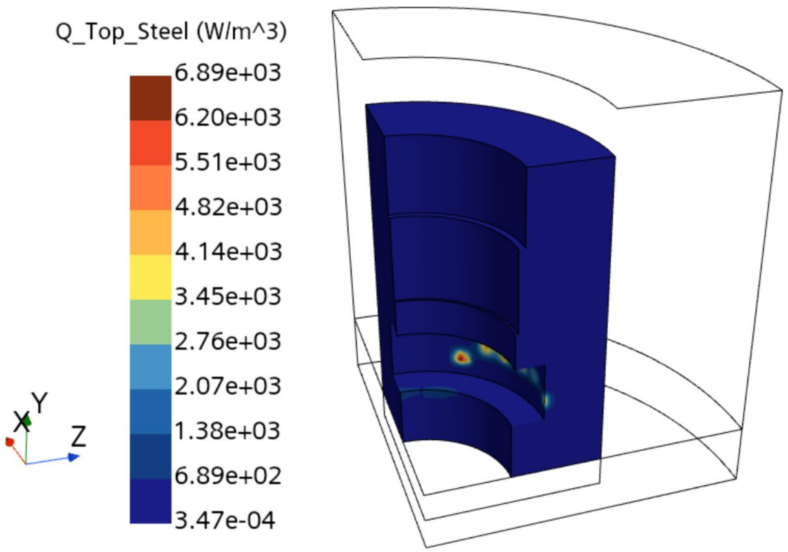


Volumetric Heat Sources from Thomas Miller

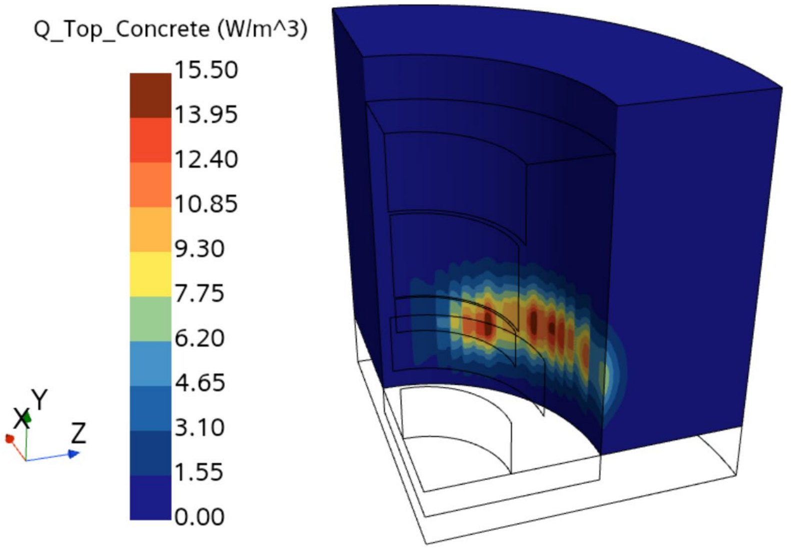
- The volumetric heat sources were calculated from MCNP with **rectangular** meshes, which did not exactly capture the geometry boundaries.
- The volumetric heat source of the top steel in this thermal analysis was multiplied by a factor of 1.232 to match to total heat from MCNP calculation.

Q_Total = 546 W

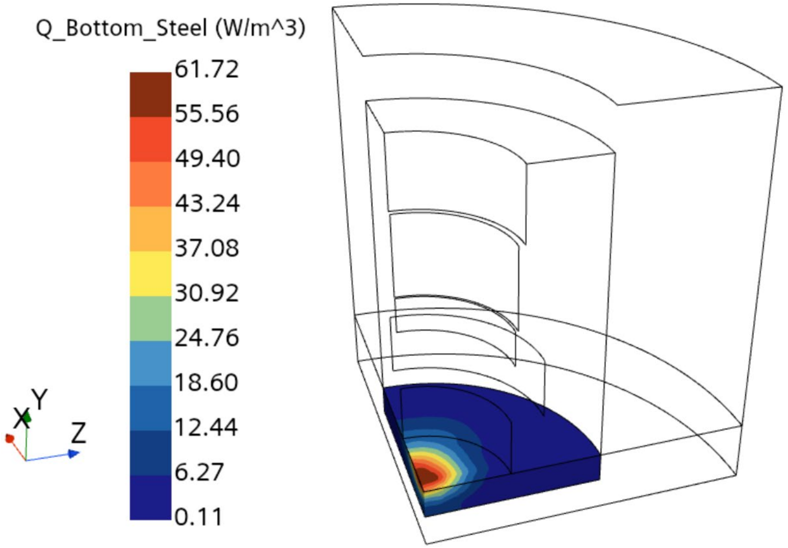
$Q\_Top\_Steel = 519W$



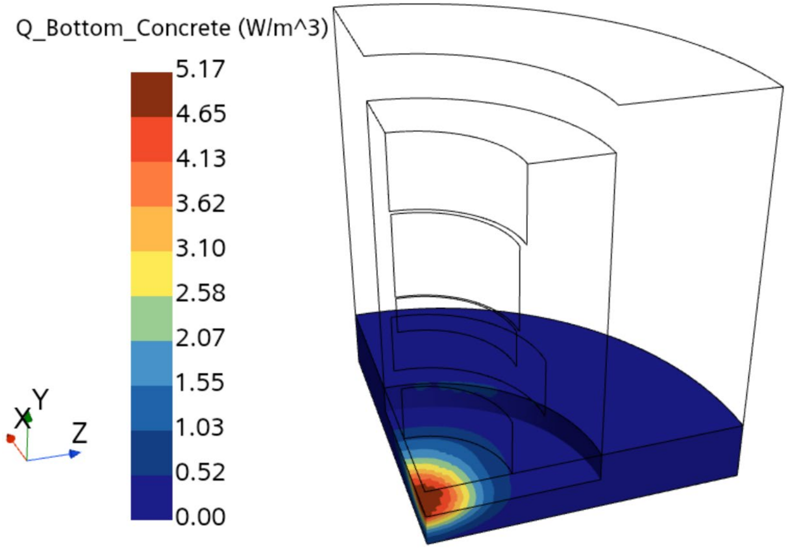
$Q\_Top\_Concrete = 12.7W$



$Q\_Bottom\_Steel = 12.3W$



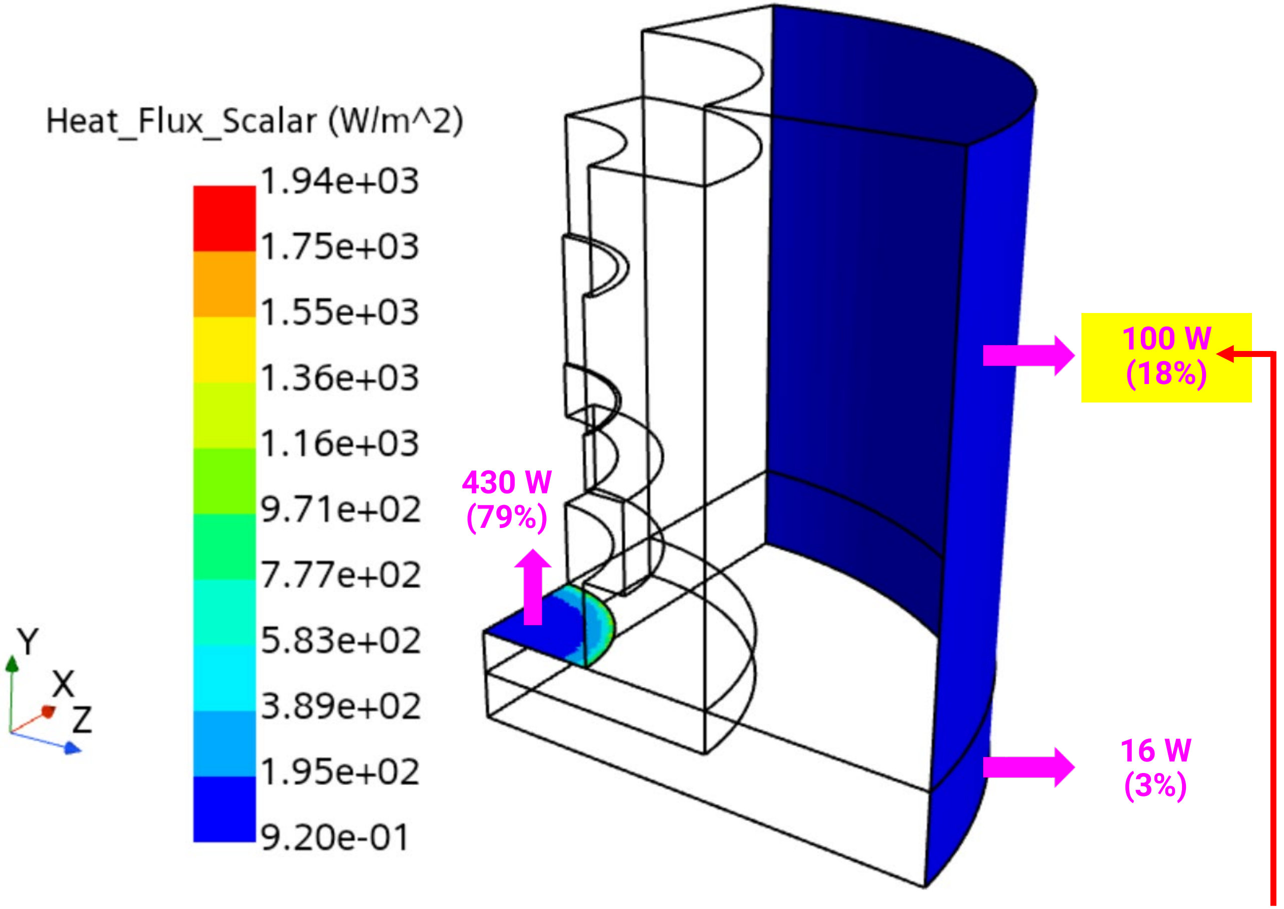
$Q\_Bottom\_Concrete = 2W$



Monolith Shielding Heating and Thermal Analysis

Heat Removal on Boundaries

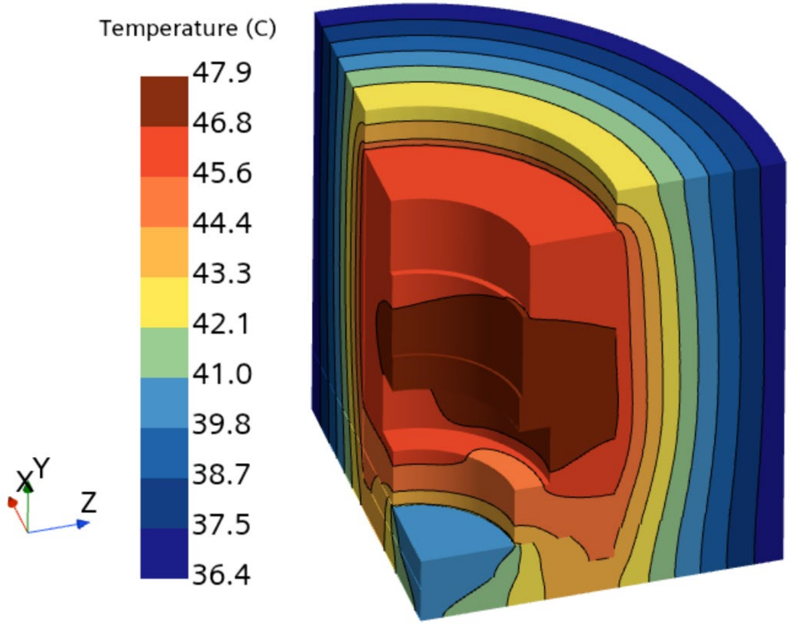
Portion of the 519 W in **top steel** and the heat in **top concrete** flow **outwards** to the **concrete outer surface**. Therefore, it is ok to assume perfect contact radially between concrete and steel because the top concrete is mainly cooled by the 35°C environment, not by the 40°C cooled surface.



Monolith Shielding Heating and Thermal Analysis

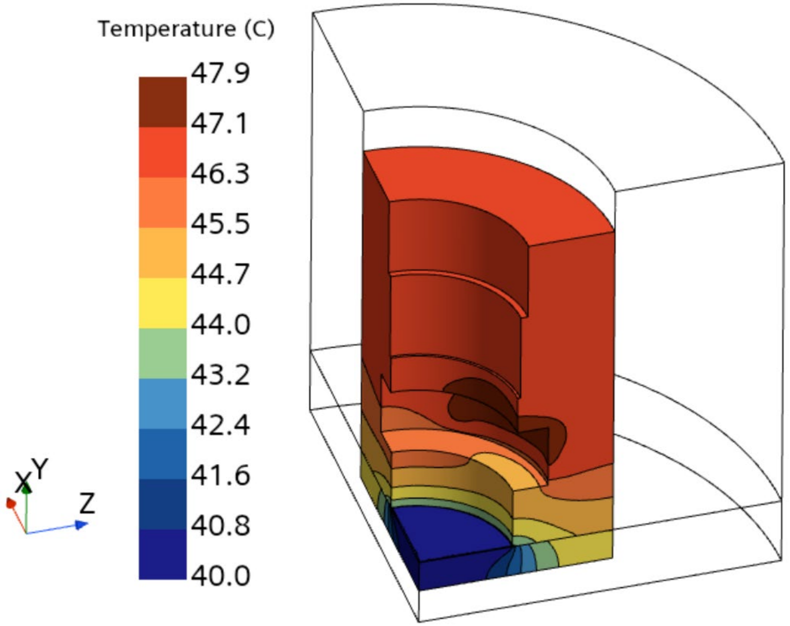
- **Heat transfer coefficient, h = 1.38 W/m^2-K**

Steel + Concrete Temperature



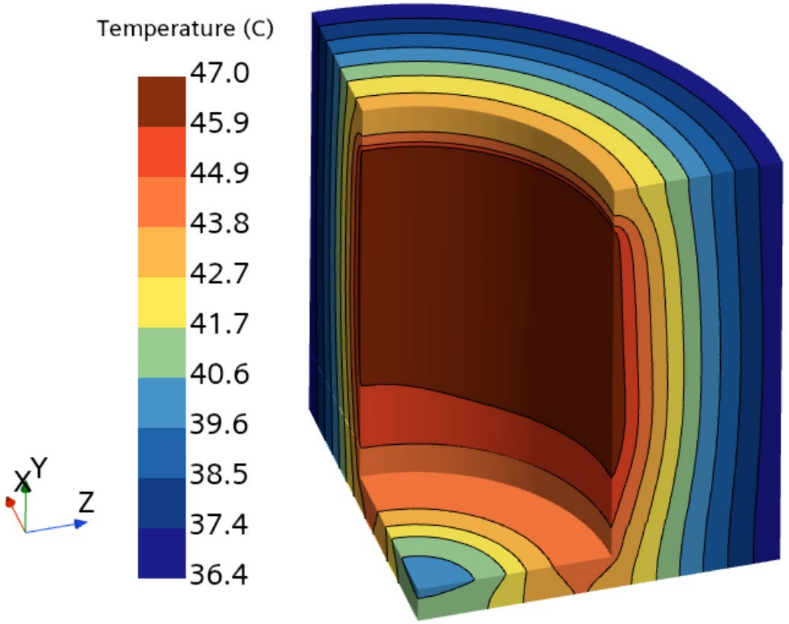
Steel Temperature

Peak: 47.9°C



Concrete Temperature

Peak: 47.0°C



Average outer surface temperature is 36.5°C.

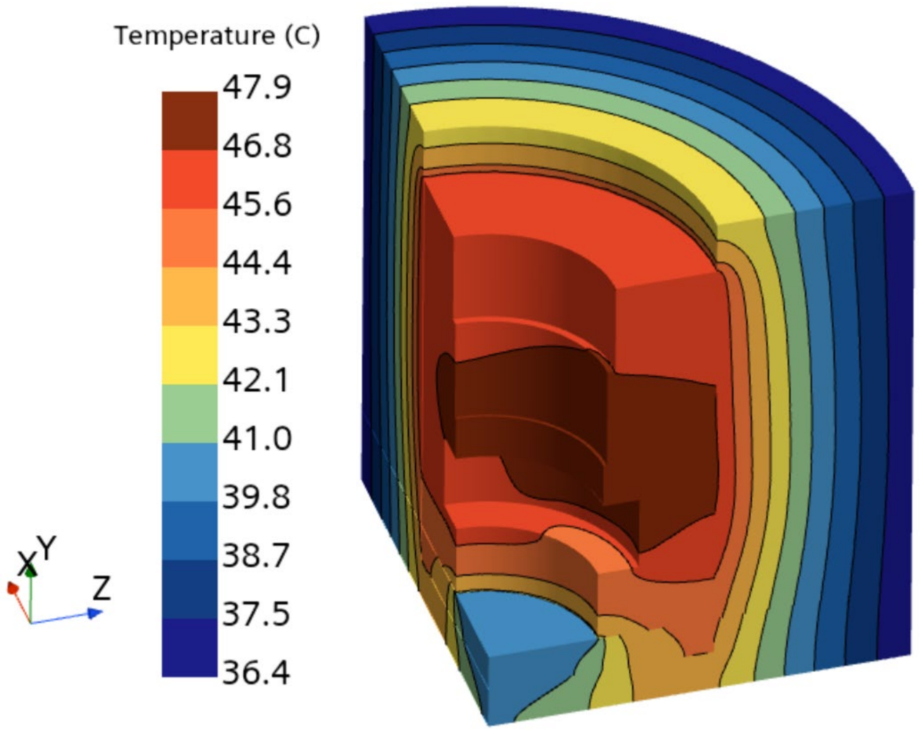
⇩

This value was used to evaluate heat transfer coefficient.

Target Station Shielding Analysis Summary

Uncooled Shielding Analysis Results:

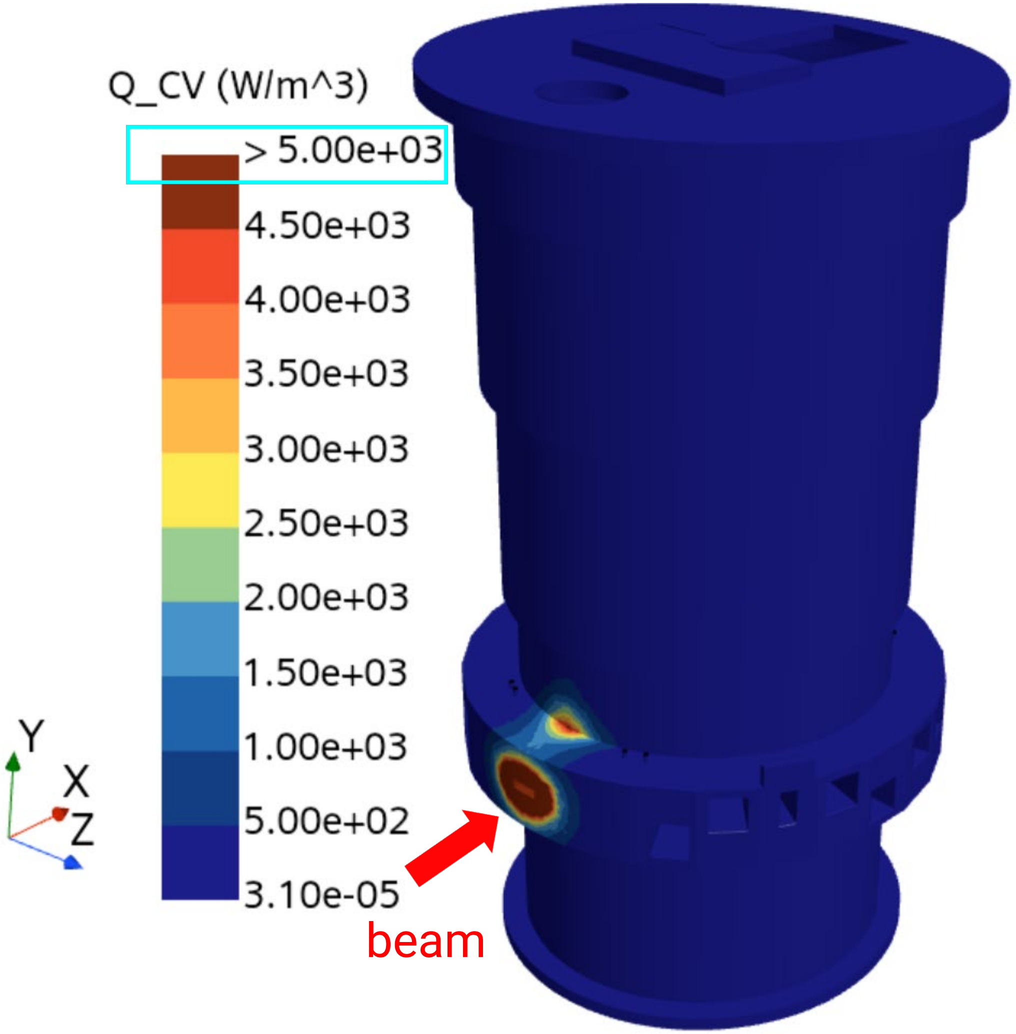
- Maximum carbon steel temperature = 200 C
  - ANSYS results: Maximum stainless steel temperature = 47.9 C → PASS
- Maximum concrete temperature = 65 C
  - ANSYS results: Maximum concrete temperature = 44 C → PASS



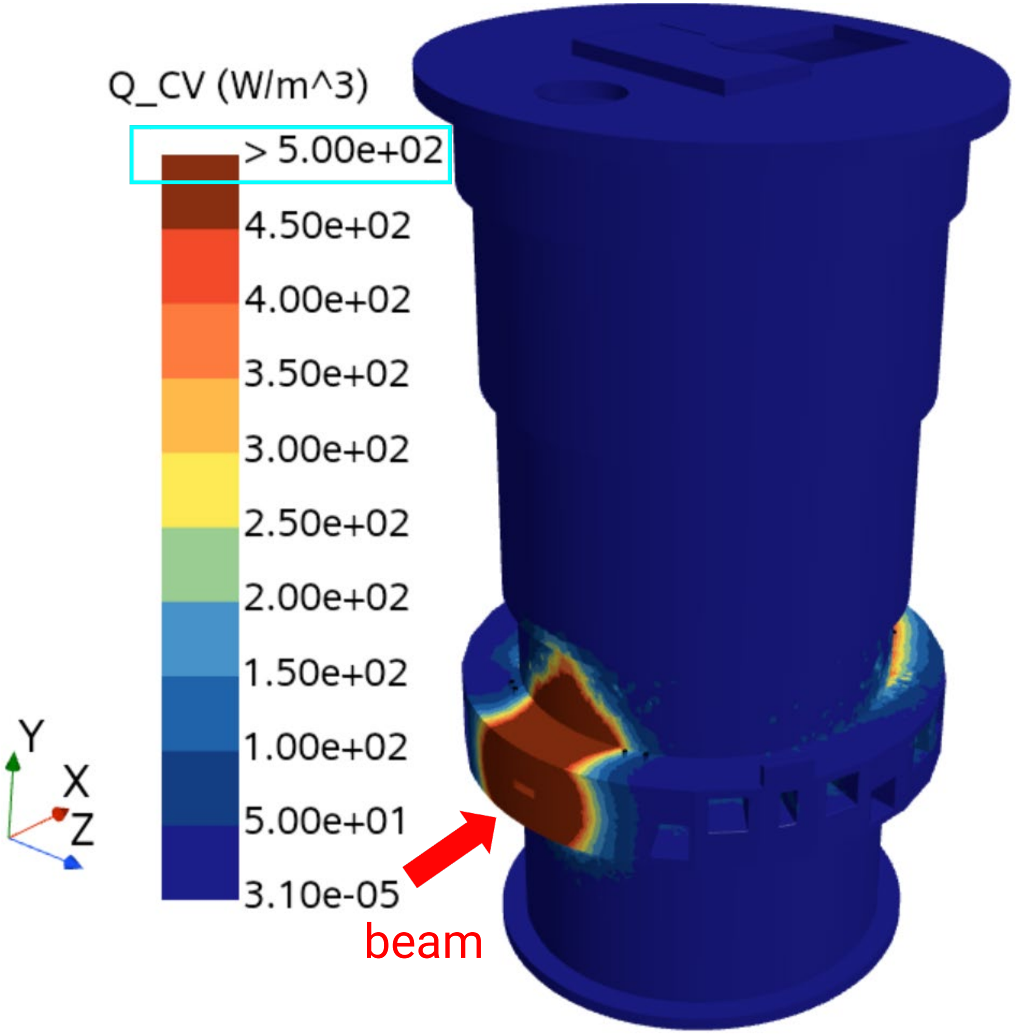
Backup Slides

Core Vessel, Heat Source (SS316)

Q_{ss} = 1,868 W



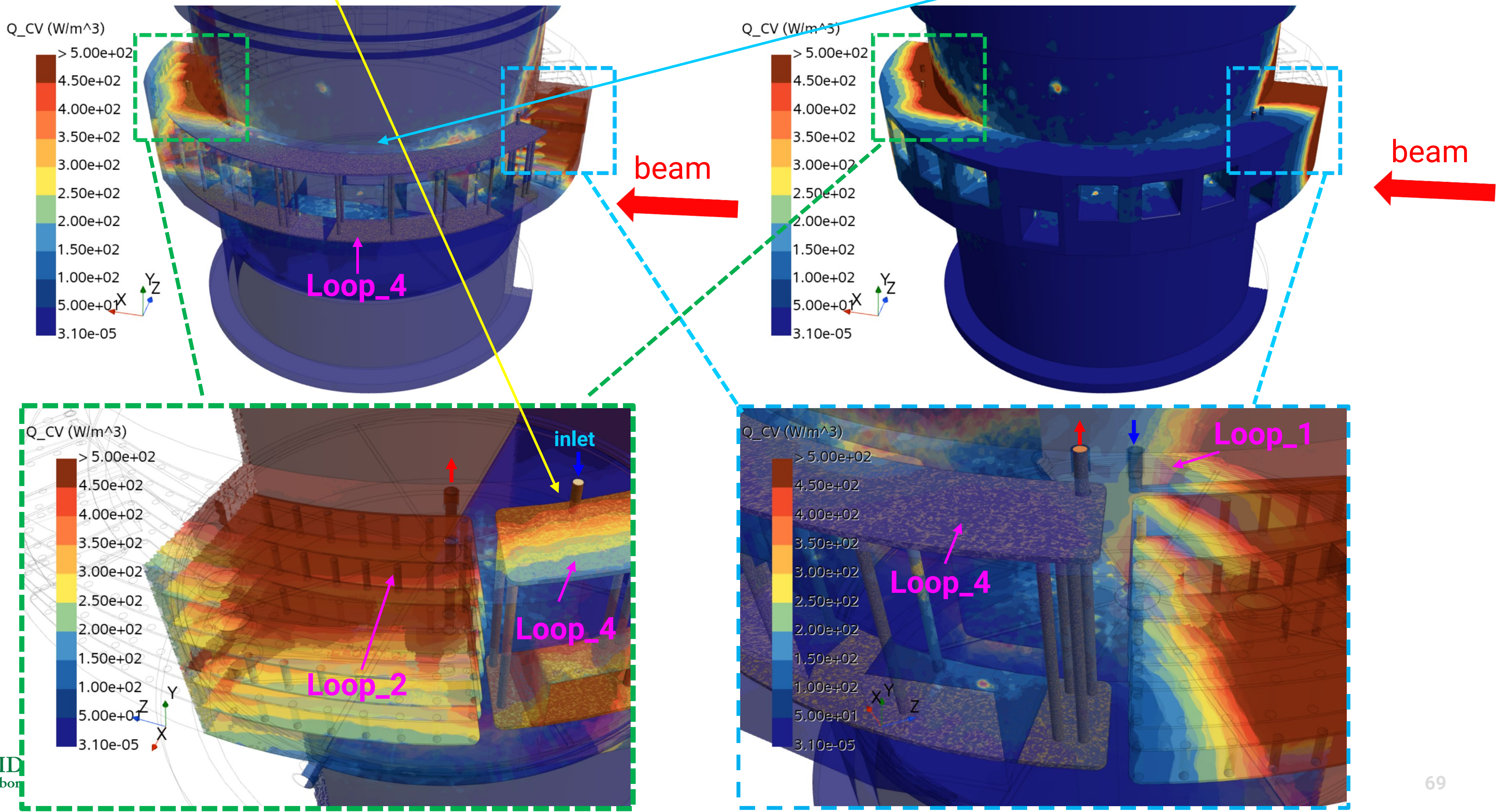
Front View



Front View

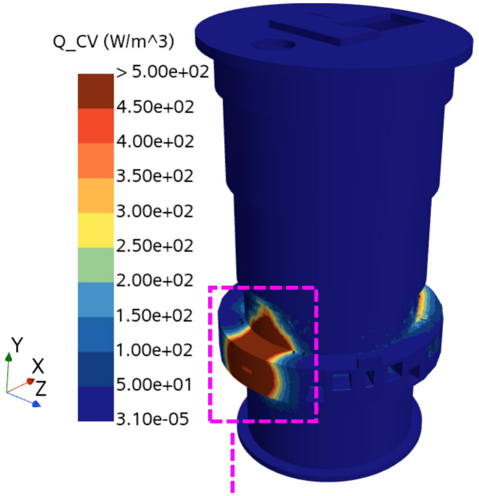
Heat Source (SS316) of Core Vessel and Cooling Channel

Only the region near the **inlet of Loop_4** has **higher heating**. The heating rate for the **rest of Loop_4** is **low** (**Loop_3** is similar).

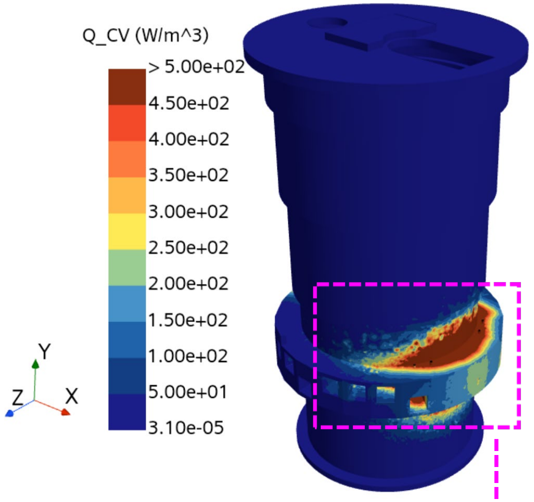


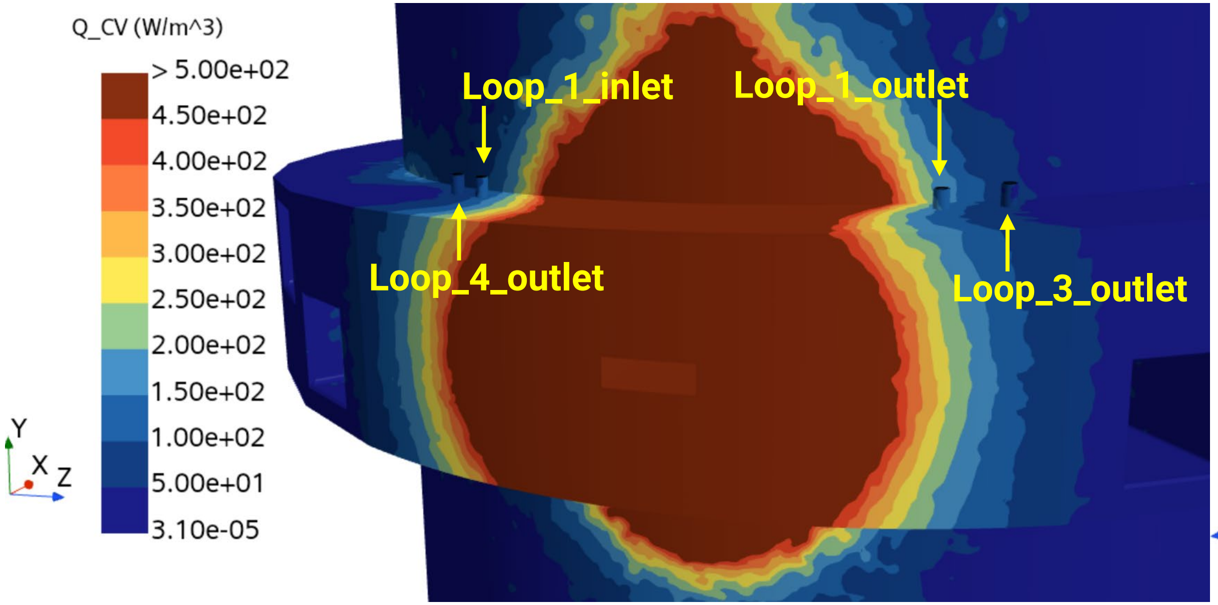
Core Vessel, Heat Source (SS316)

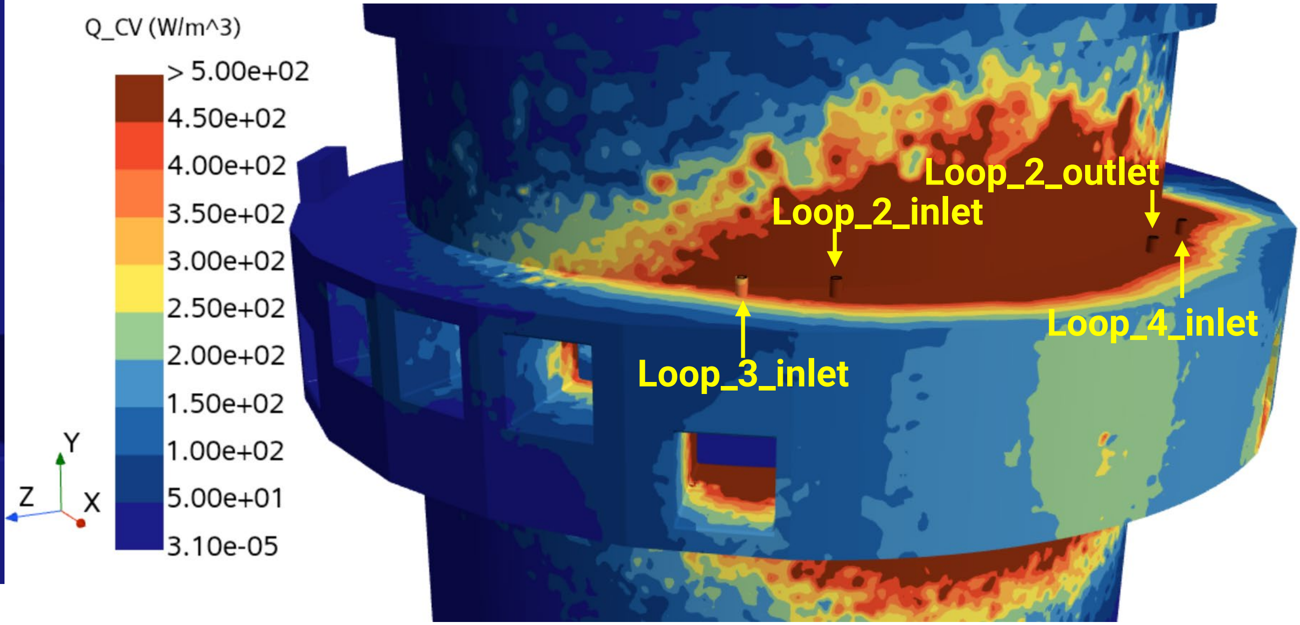
Front View



Rear View

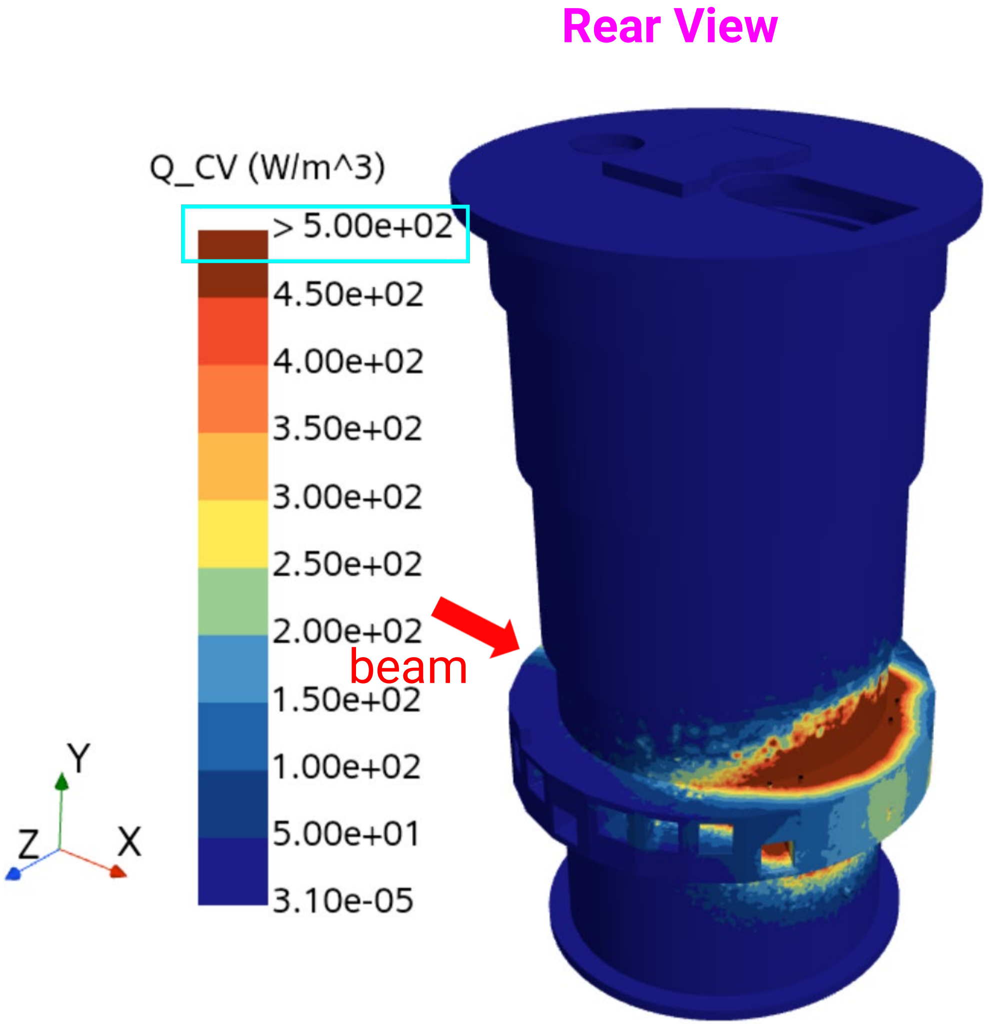


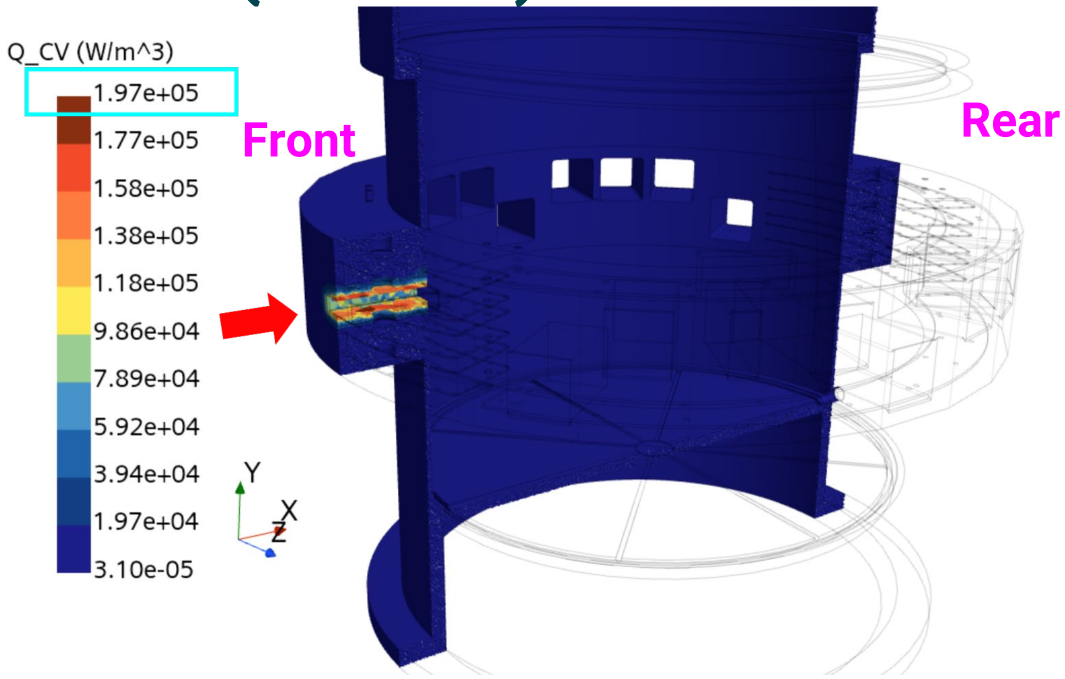


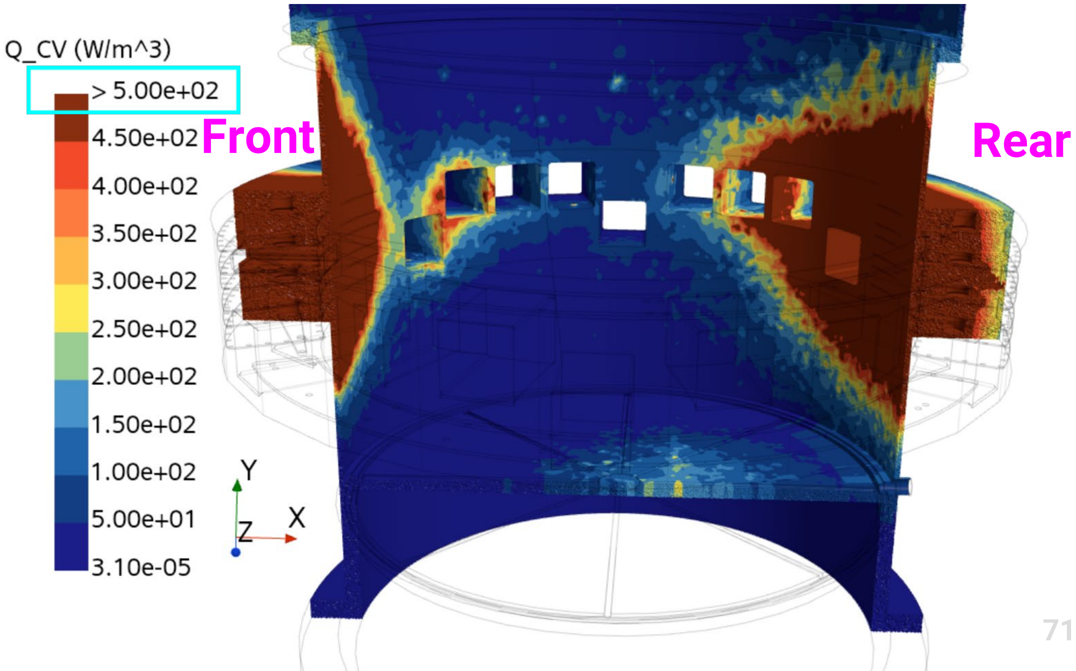


Core Vessel, Heat Source (SS316)

Q_{ss} = 1,868 W



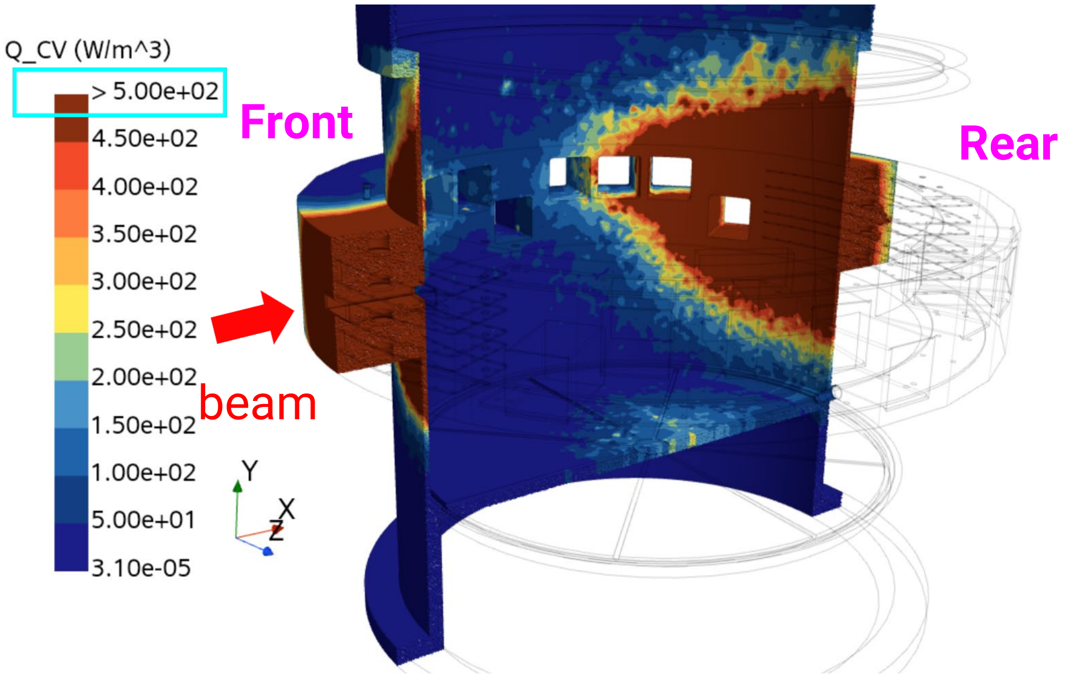




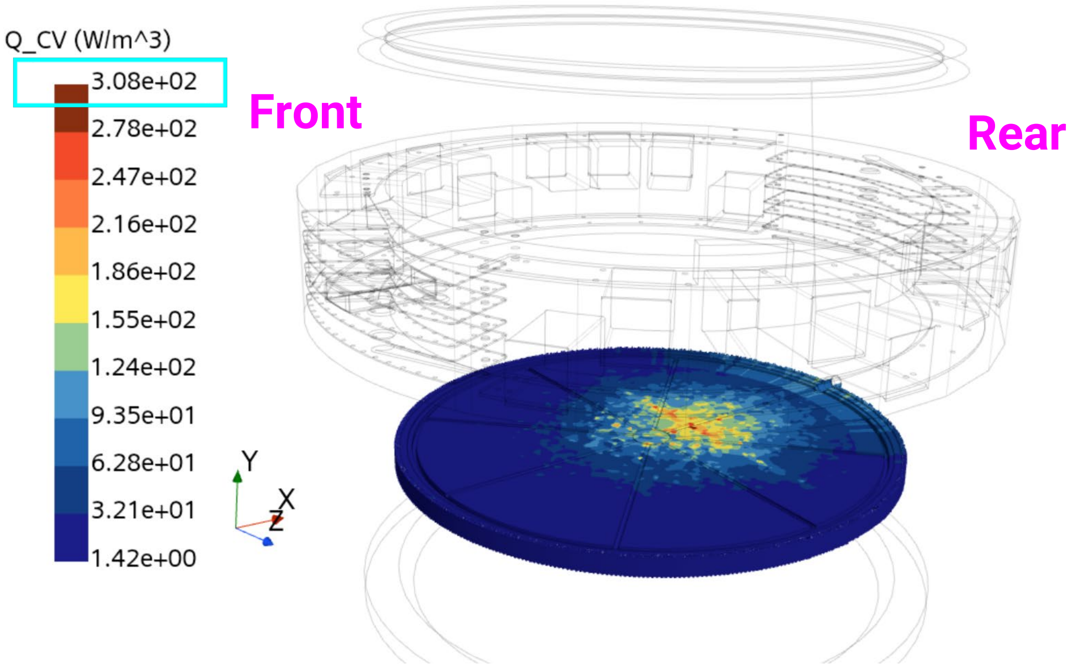
OAK RIDGE National Laboratory | SECOND TARGET STATION

Core Vessel, Heat Source (SS316)

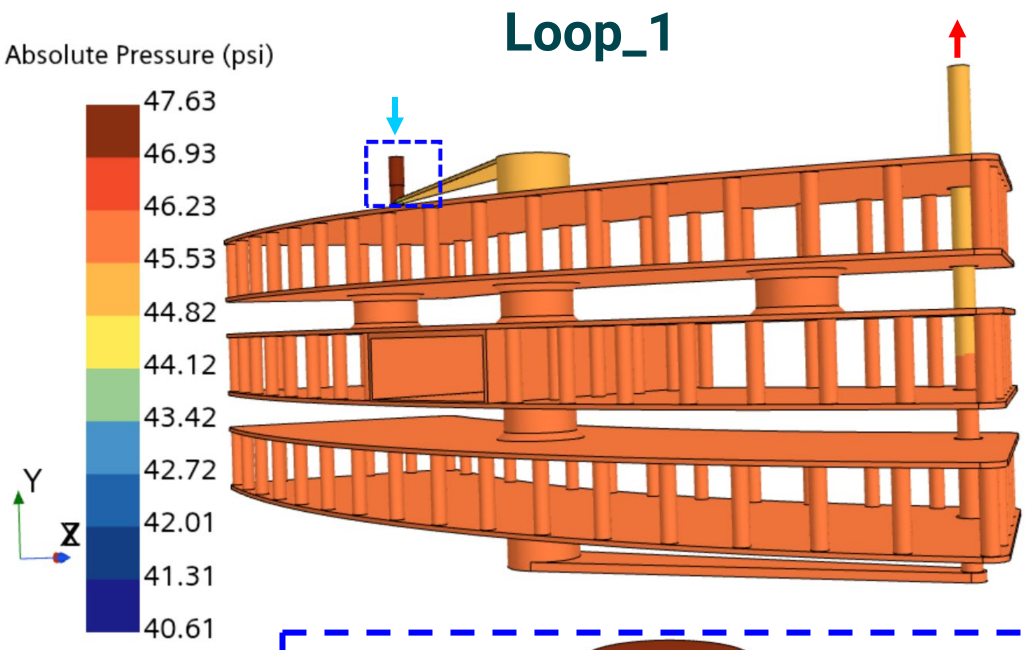
Q_{ss} = 1,868 W

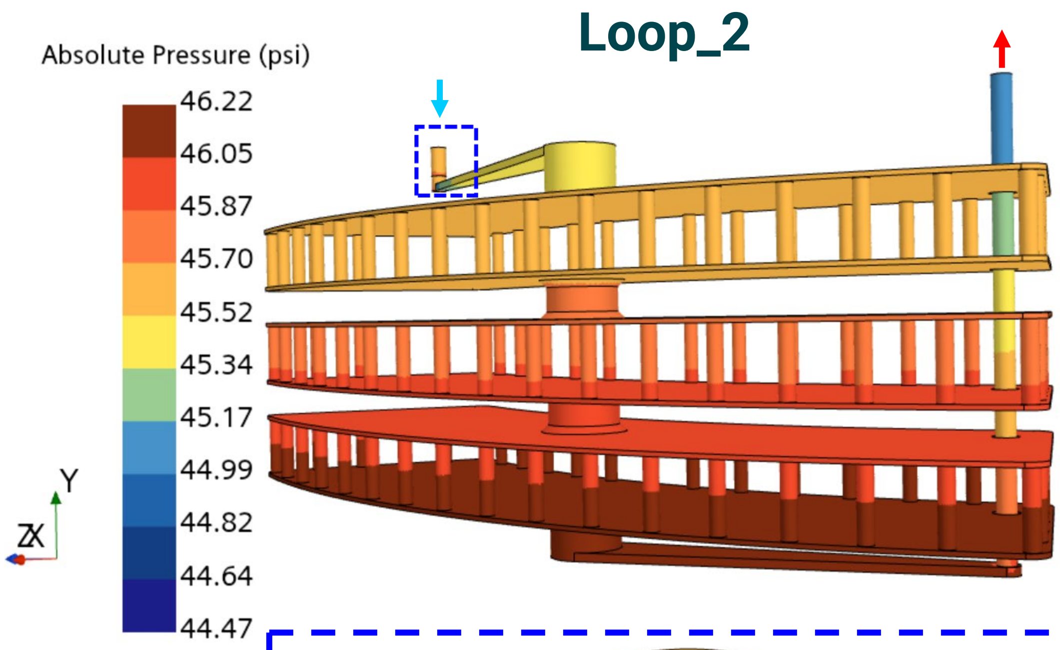


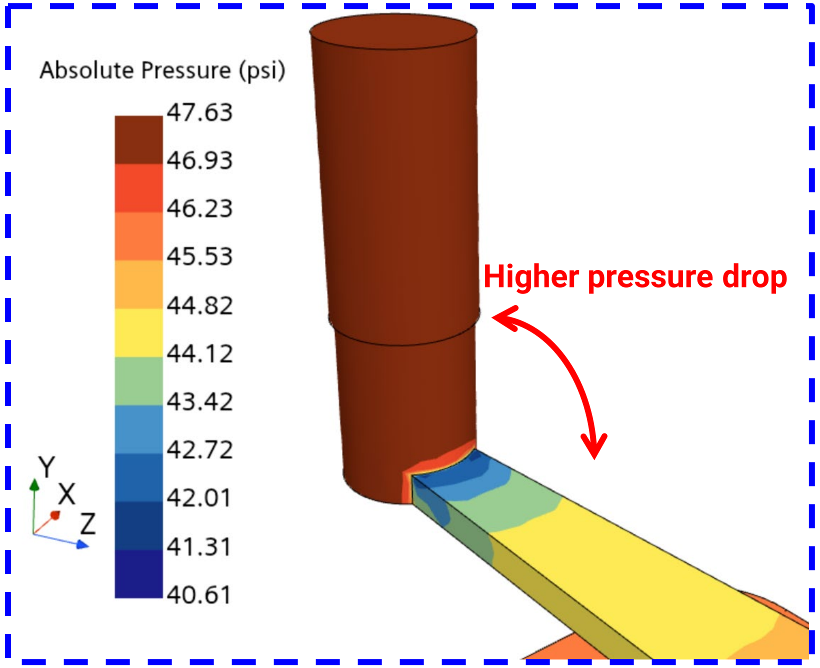
Bottom Plate

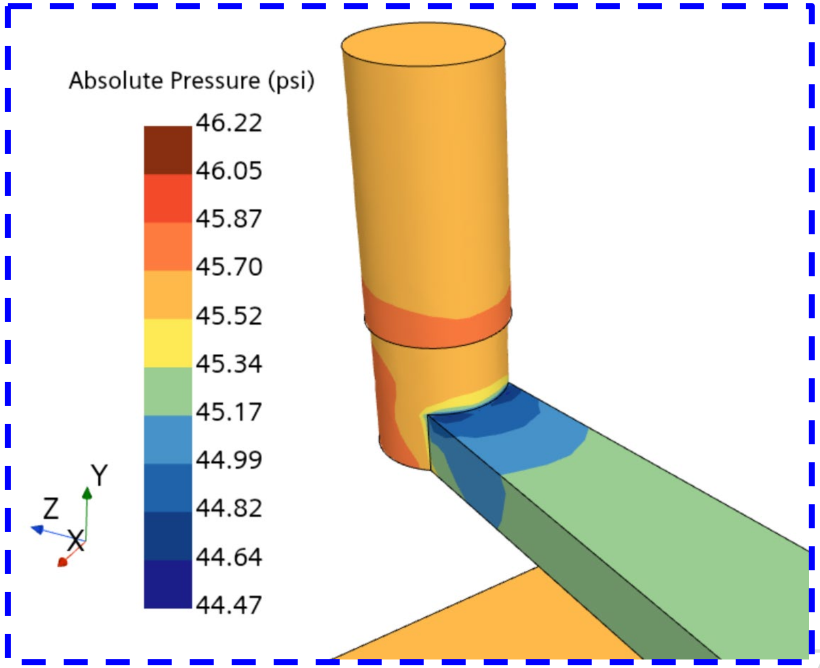


Water Pressure Loop_1 & Loop_2







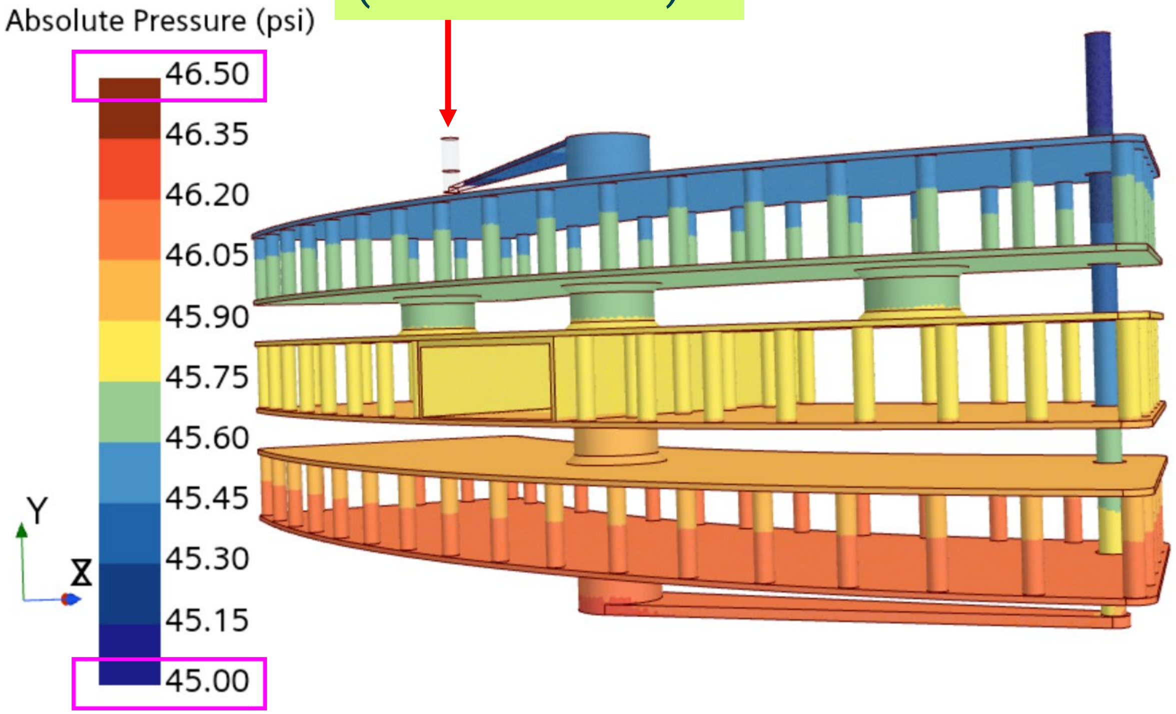


Water Pressure Loop_1 & Loop_2

Loop_1

Show the pressure distribution 45 psi ~ 46.5 psi

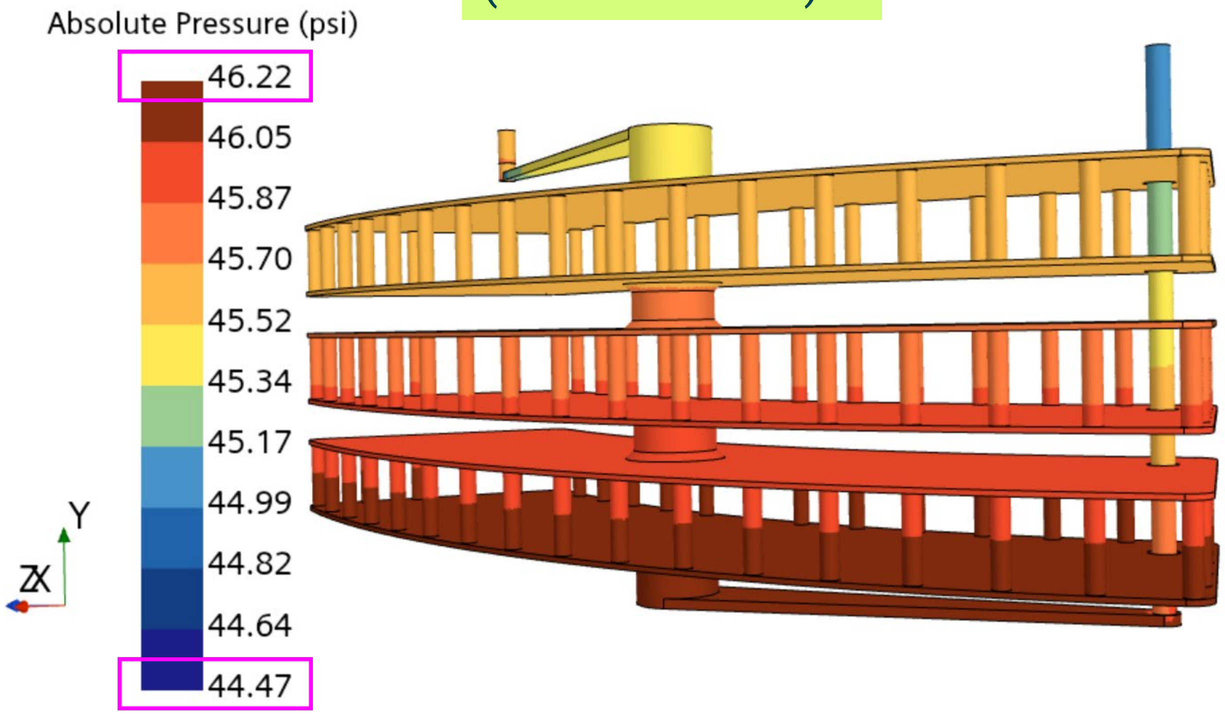
(inlet excluded)



Loop_2

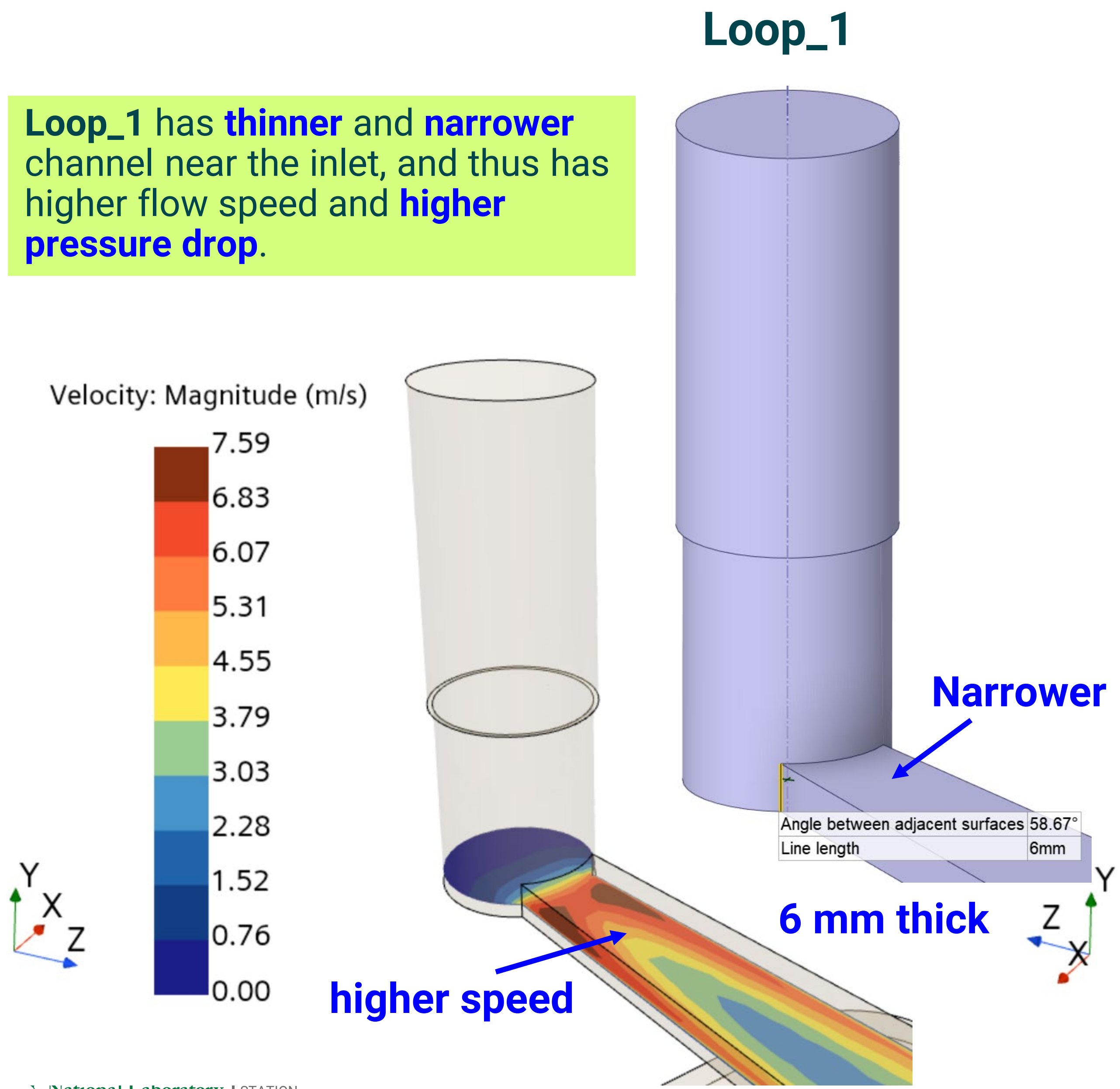
Show the pressure distribution 44.47 psi ~ 46.22 psi

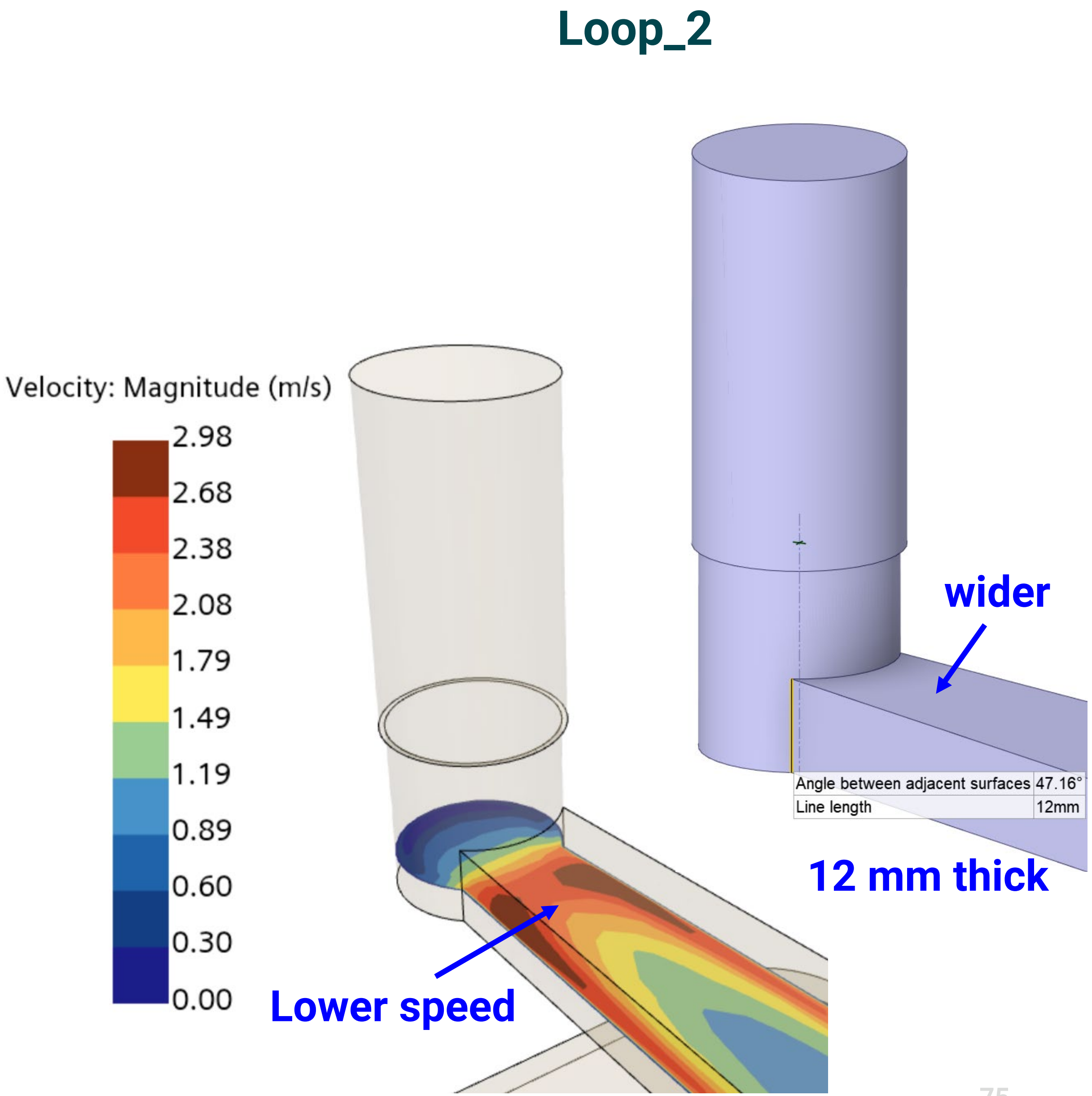
(Whole domain)



Velocity Loop_1 & Loop_2

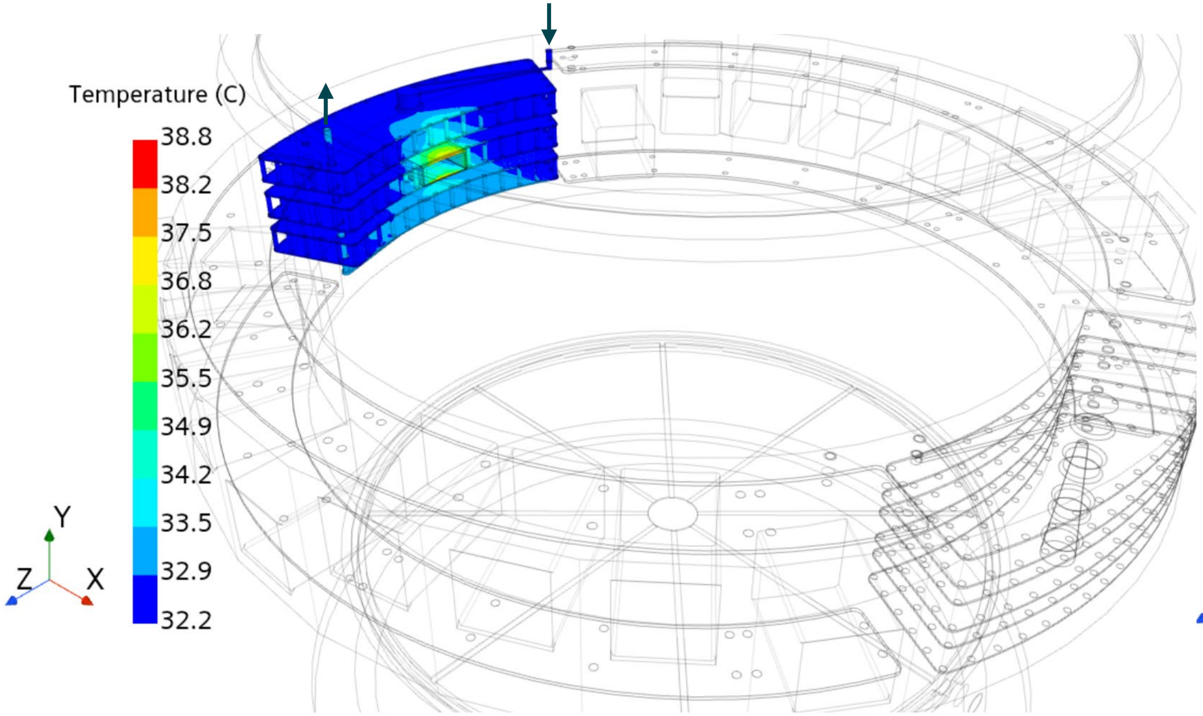
Loop_1 has **thinner** and **narrower** channel near the inlet, and thus has higher flow speed and **higher pressure drop**.





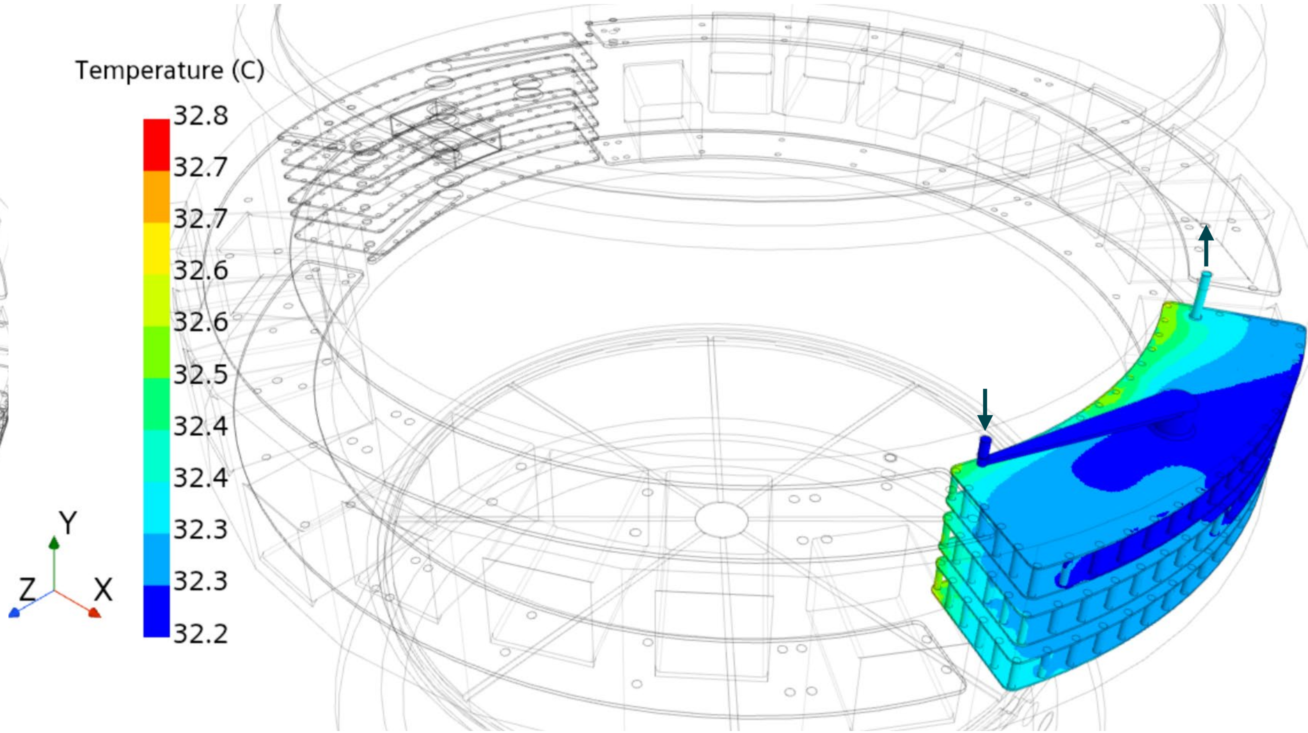
Core Vessel, Water Temperature

Loop_1



Inlet Temperature : 32.20°C
Outlet Temperature : 32.89°C

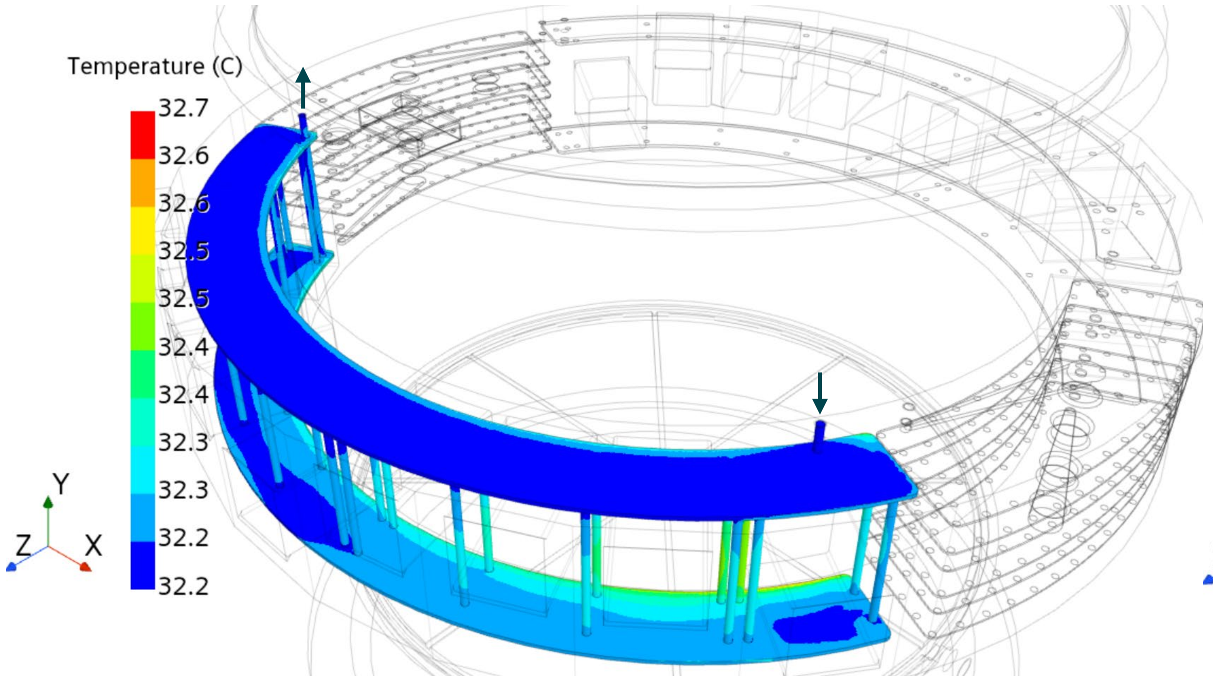
Loop_2



Inlet Temperature : 32.20°C
Outlet Temperature : 32.33°C

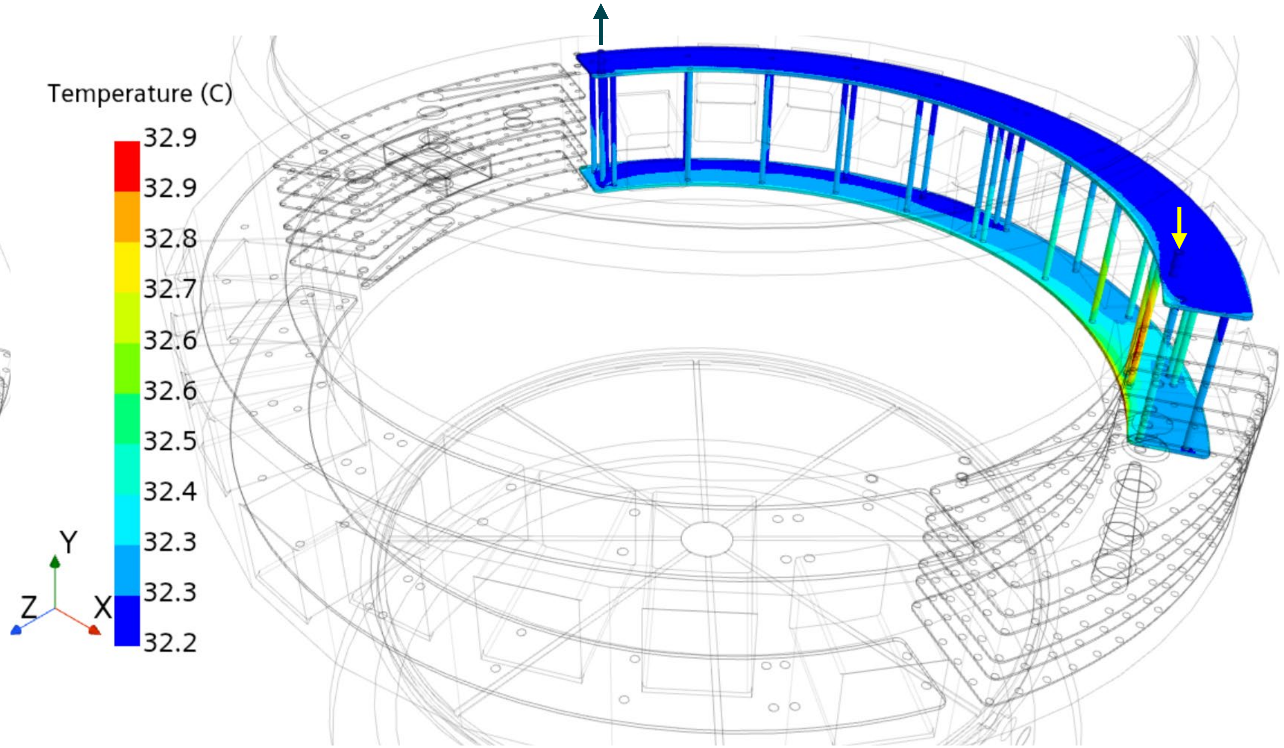
Core Vessel, Water Temperature

Loop_3



Inlet Temperature : 32.20°C
Outlet Temperature : 32.24°C

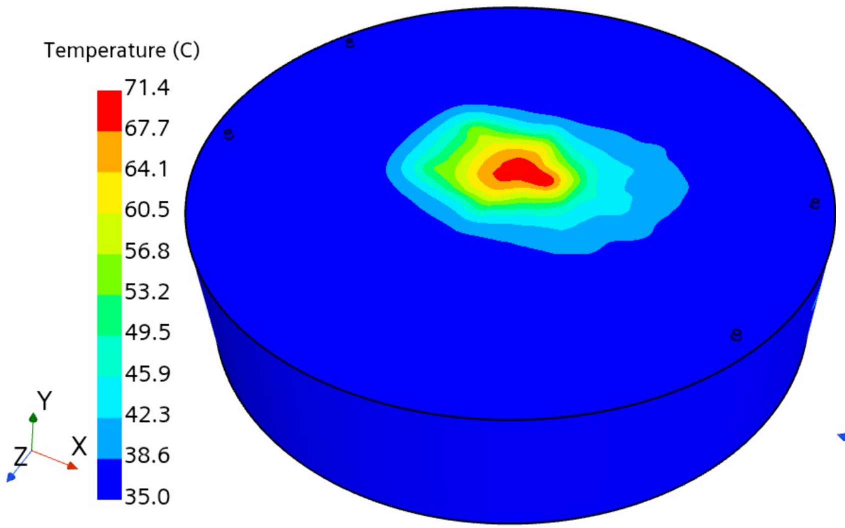
Loop_4

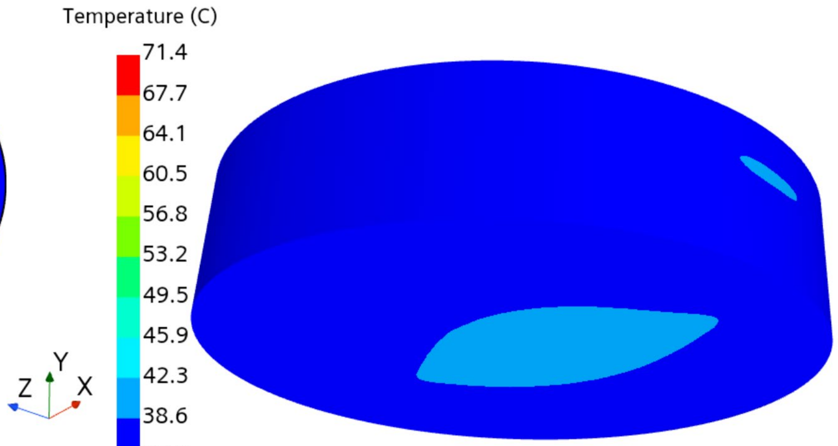


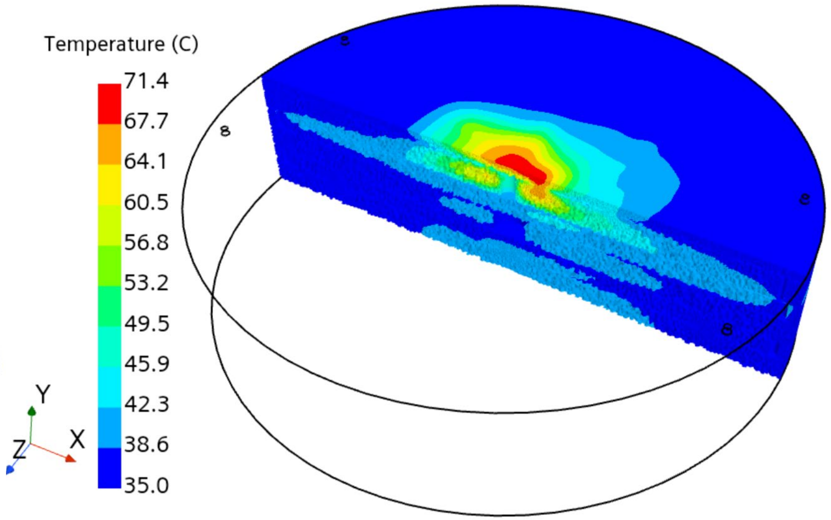
Inlet Temperature : 32.20°C
Outlet Temperature : 32.26°C

Shield Block #1, Stainless Steel Temperature

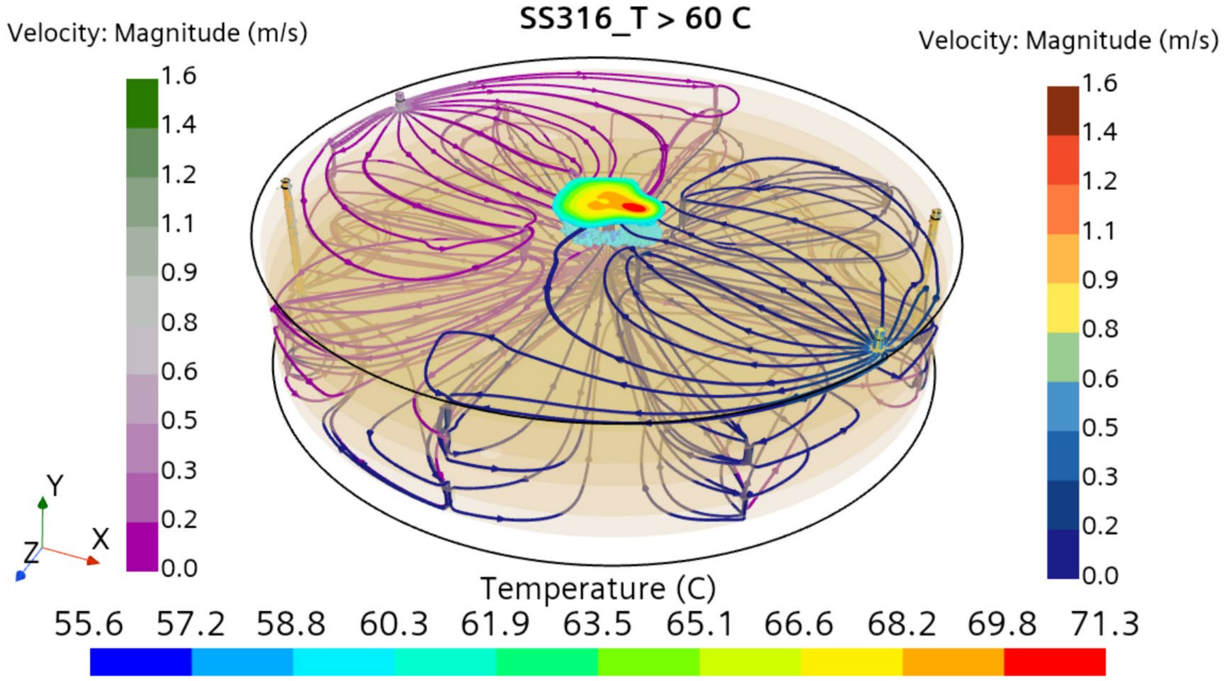
Peak: 71.4°C



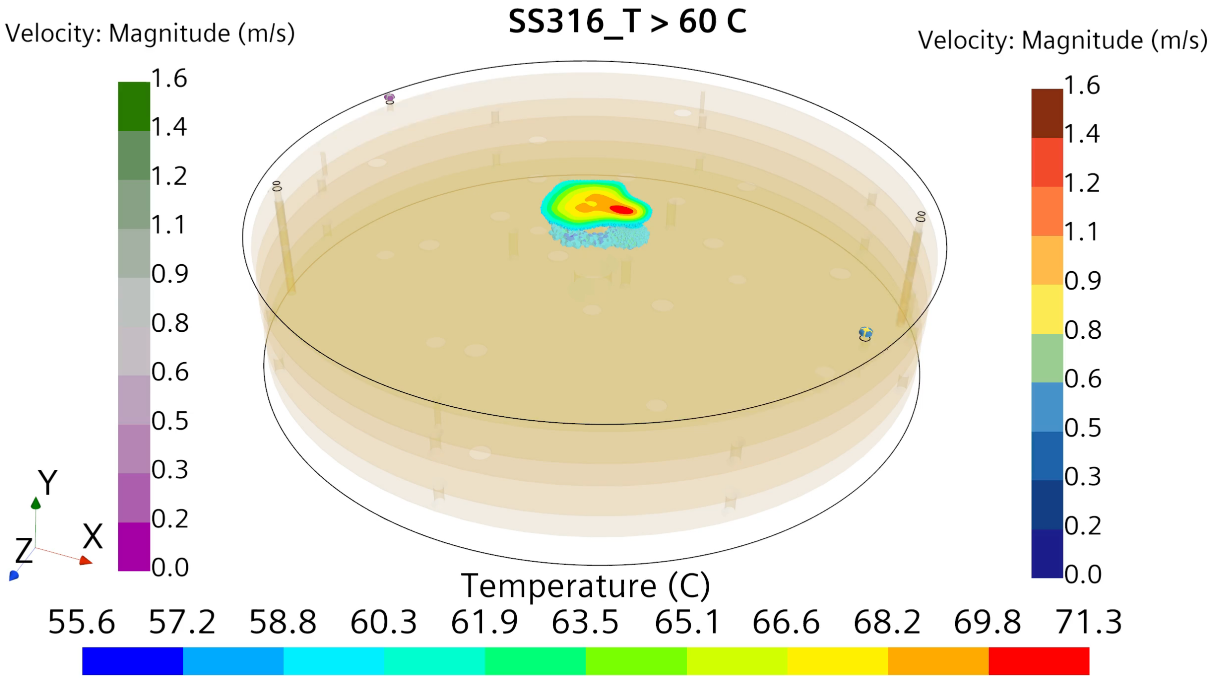




Shield Block #1, Streamlines

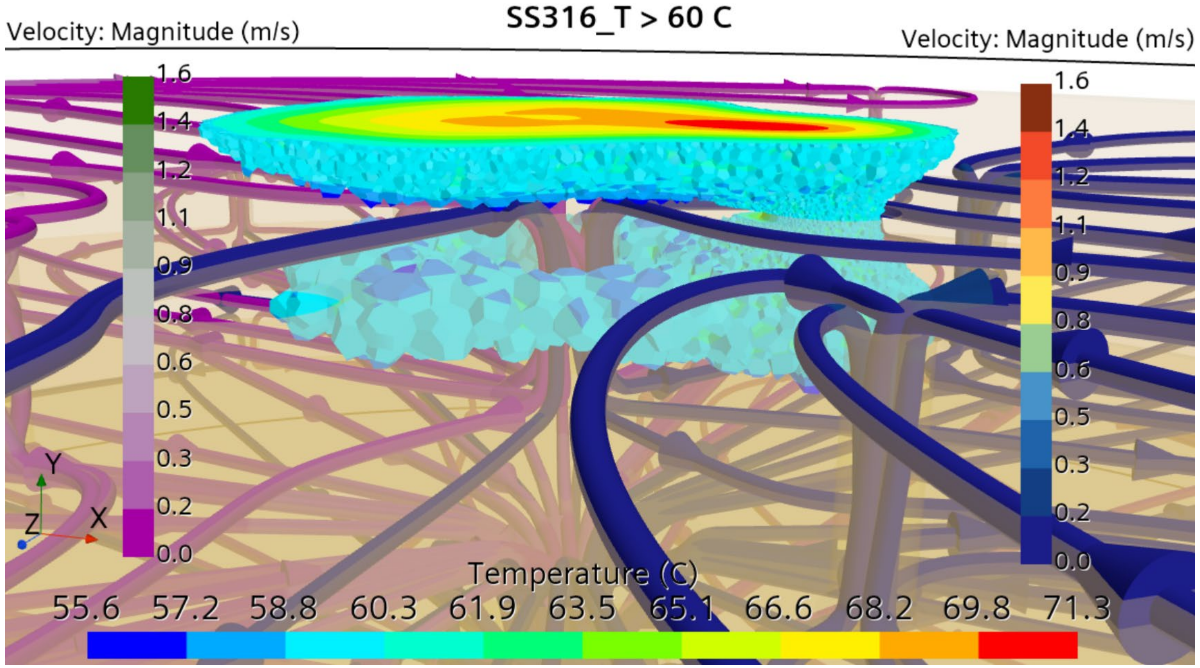


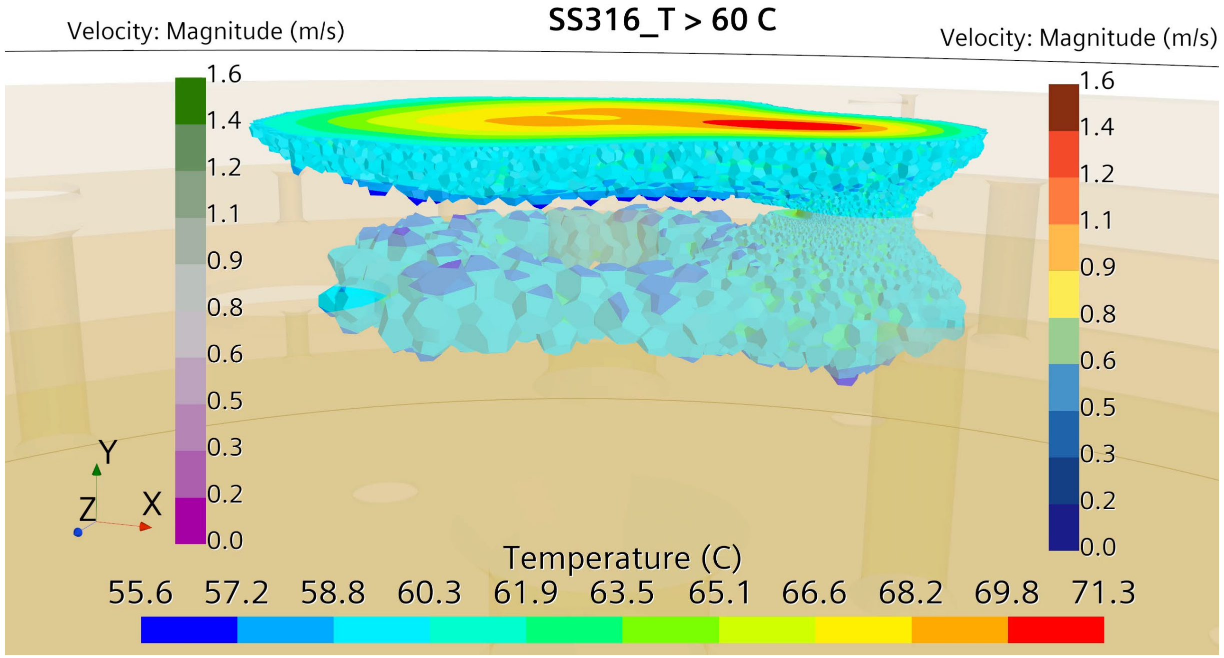
Animation



Shield Block #1, Streamlines

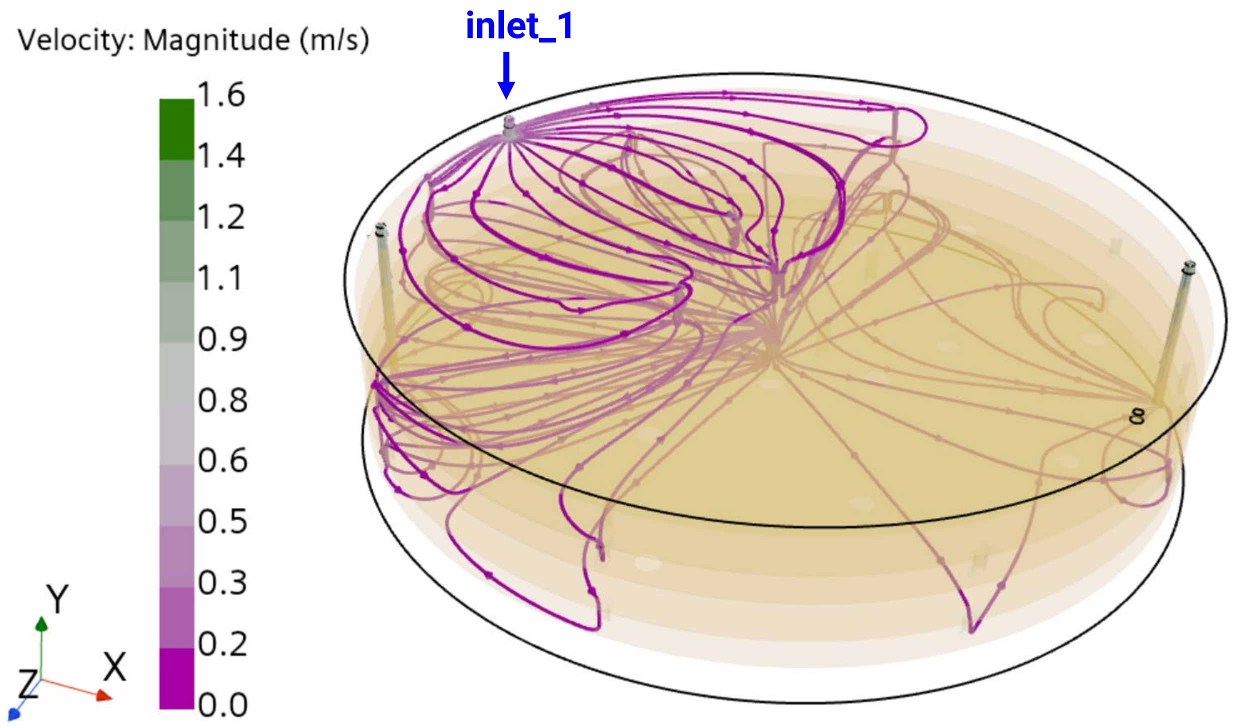
Animation



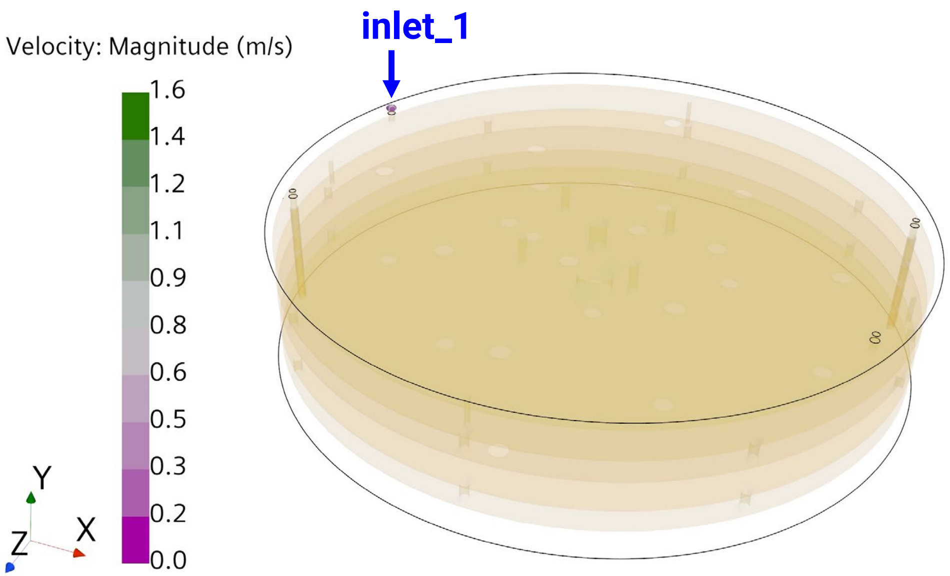


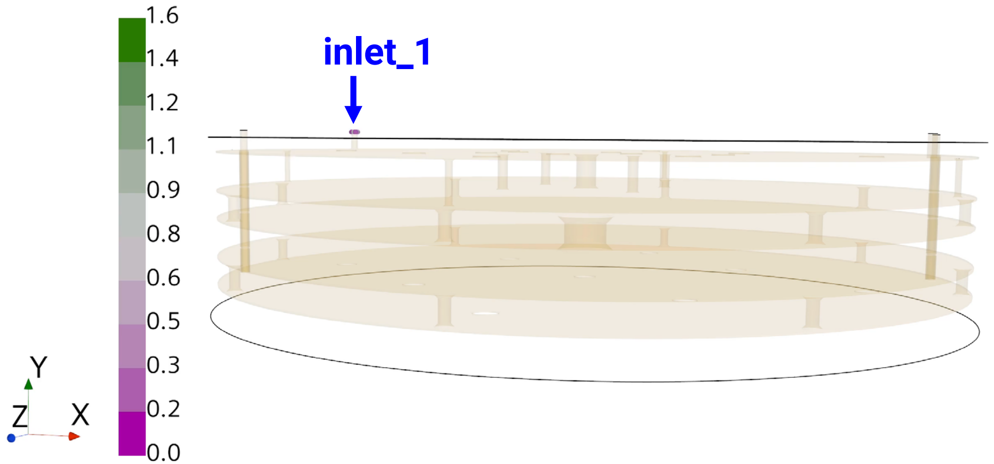
Shield Block #1, Streamlines

Streamlines from **inlet_1**



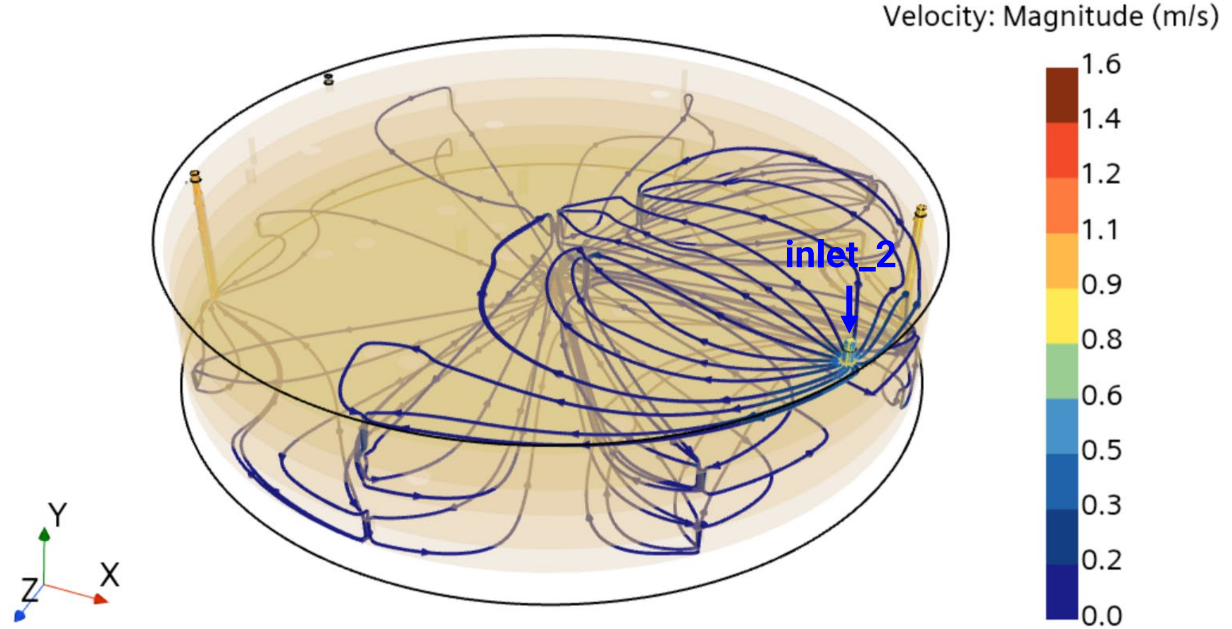
Animation



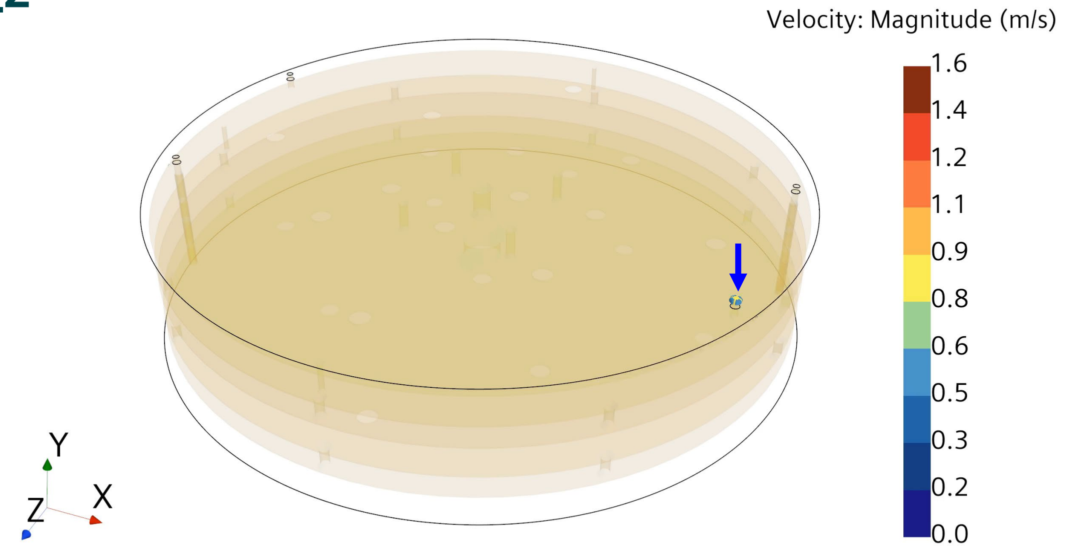


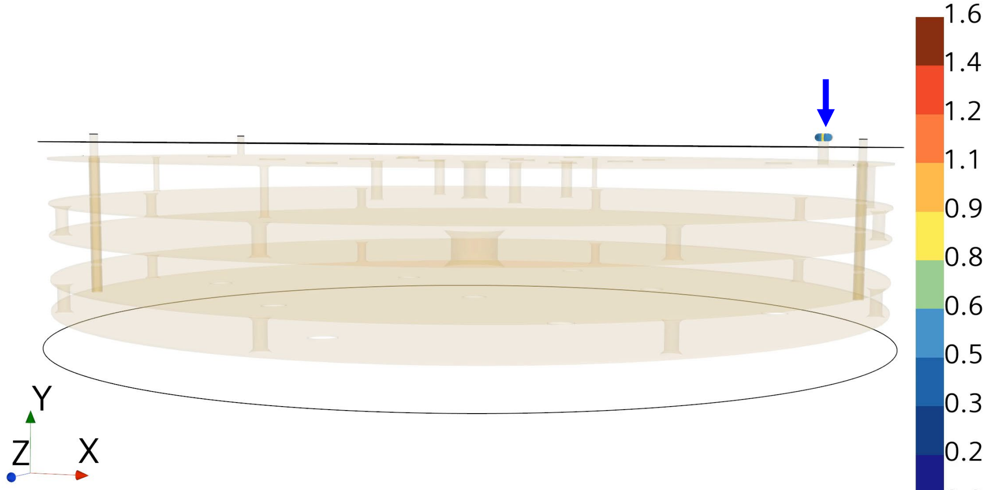
Shield Block #1, Streamlines

Streamlines from **inlet_2**

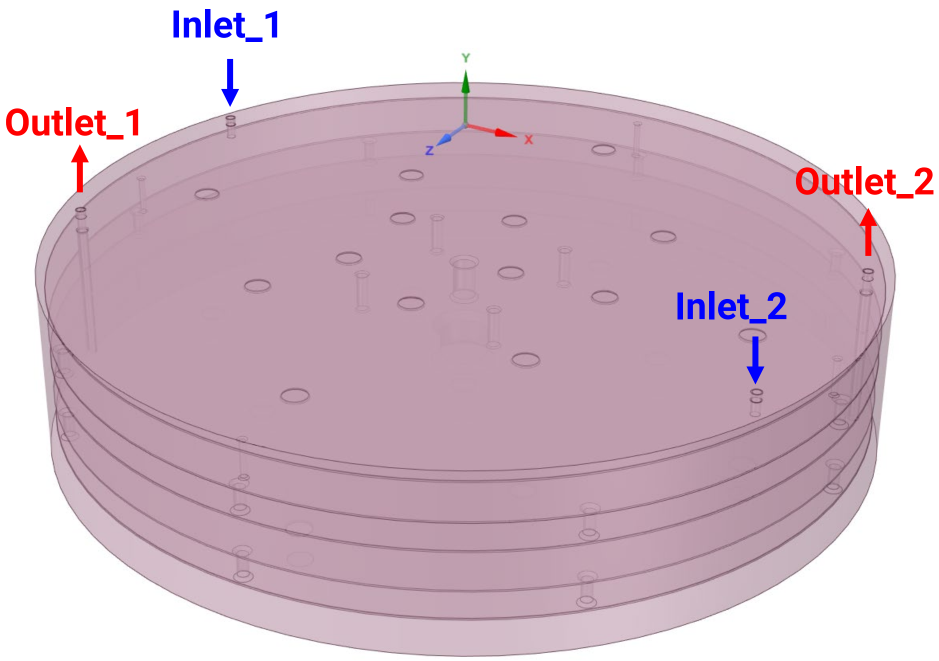


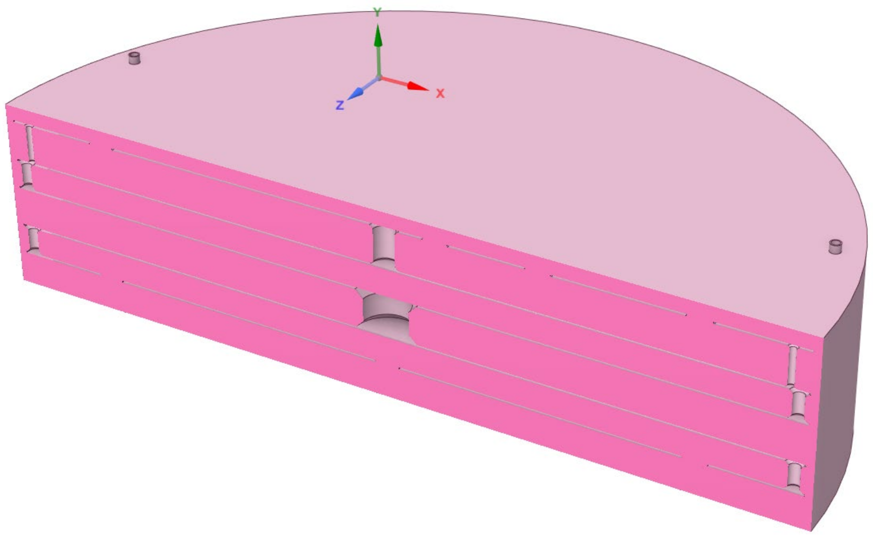
Animation

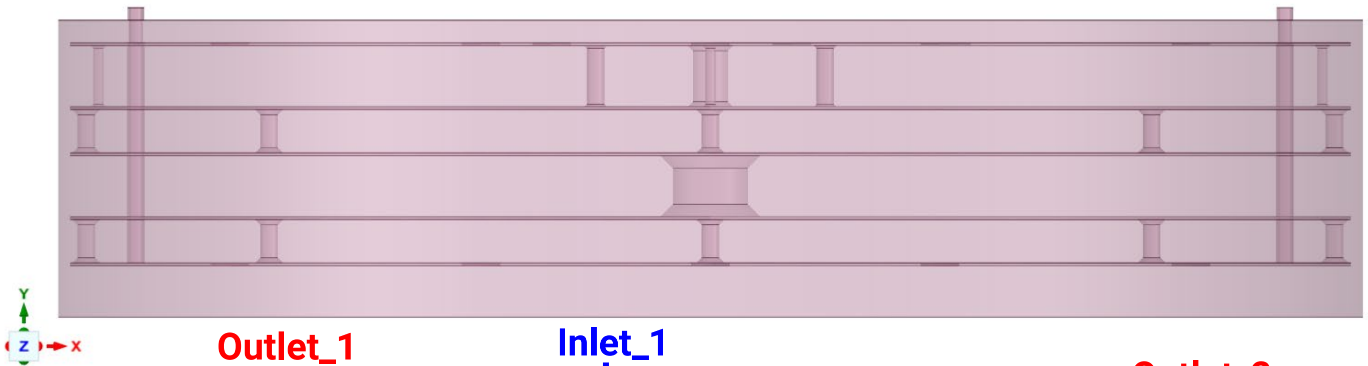


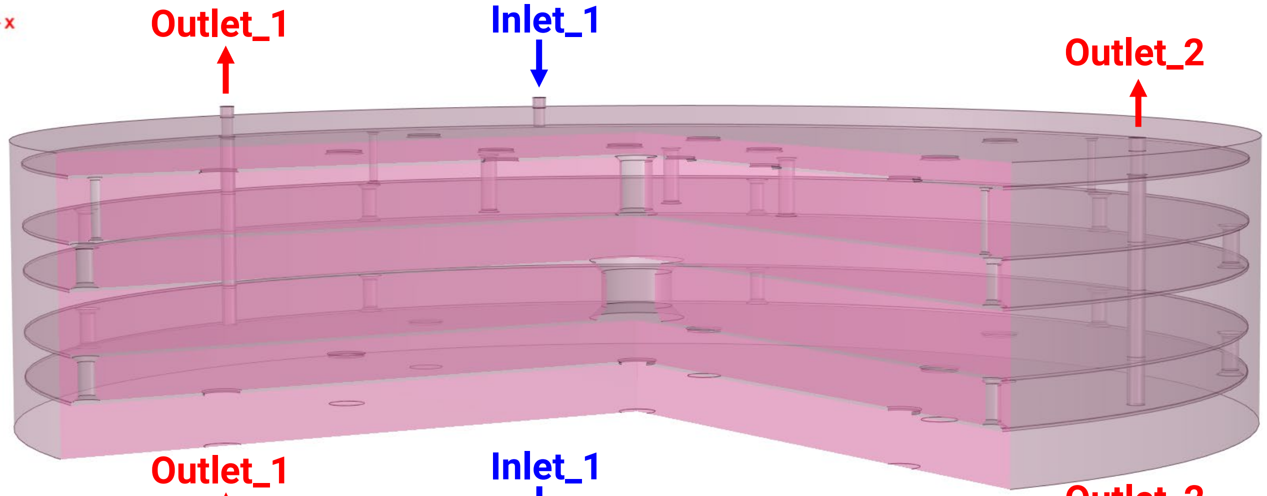


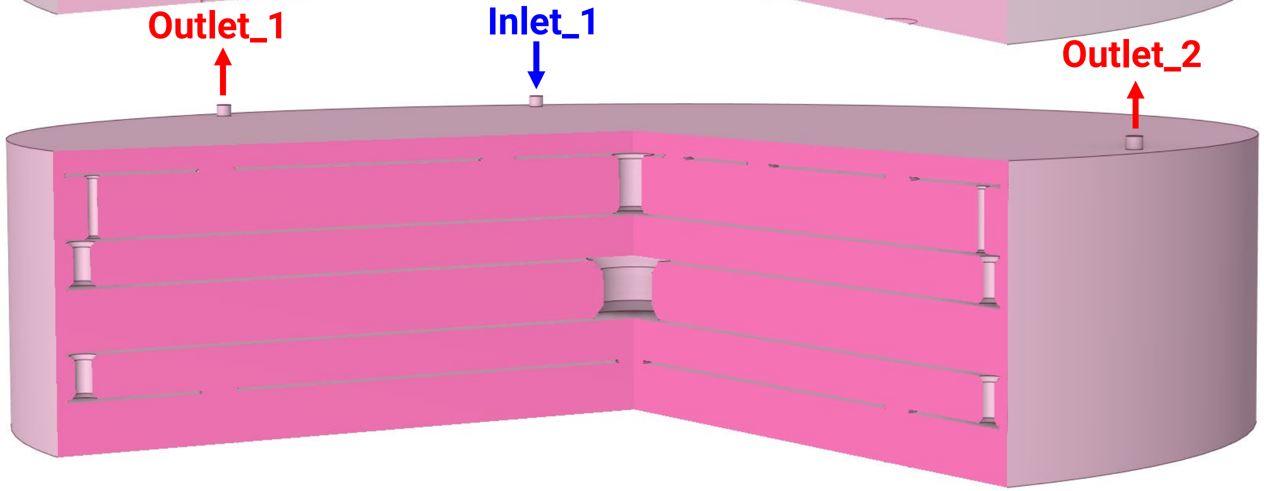
Shield Block # 1(from 02/05/2024), SS316, Solid







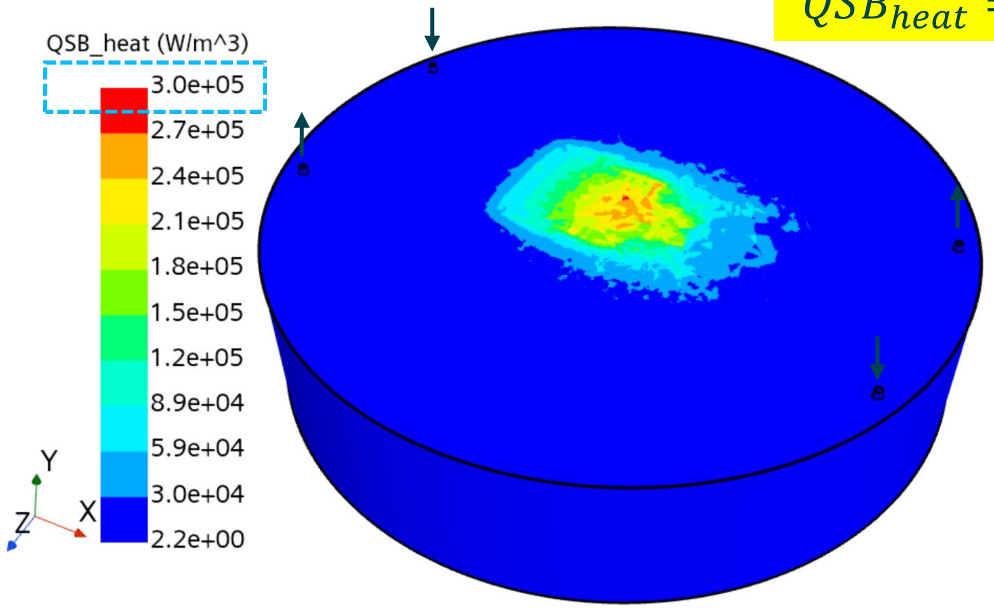


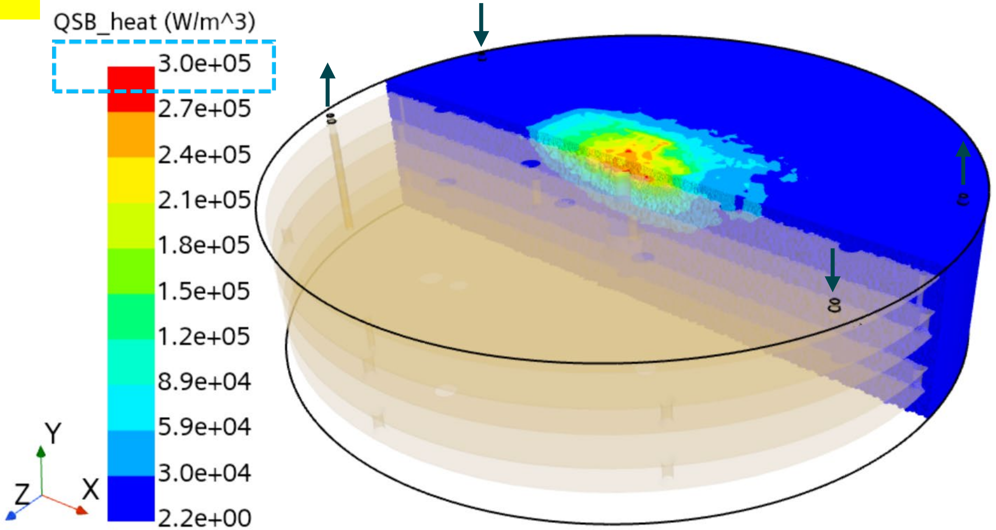


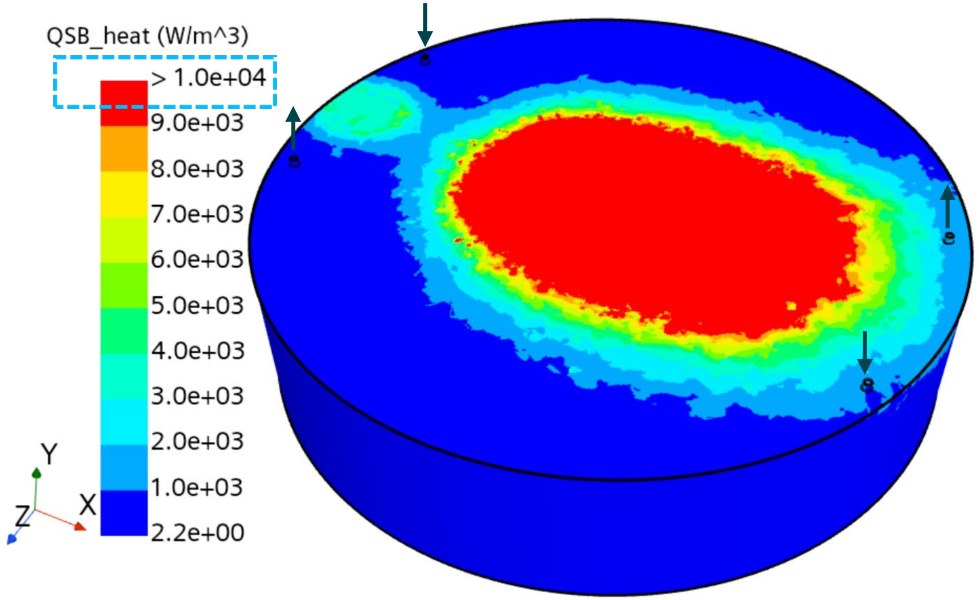
Heat Source and Cooling Channel of Shield Block #1 (SS316)

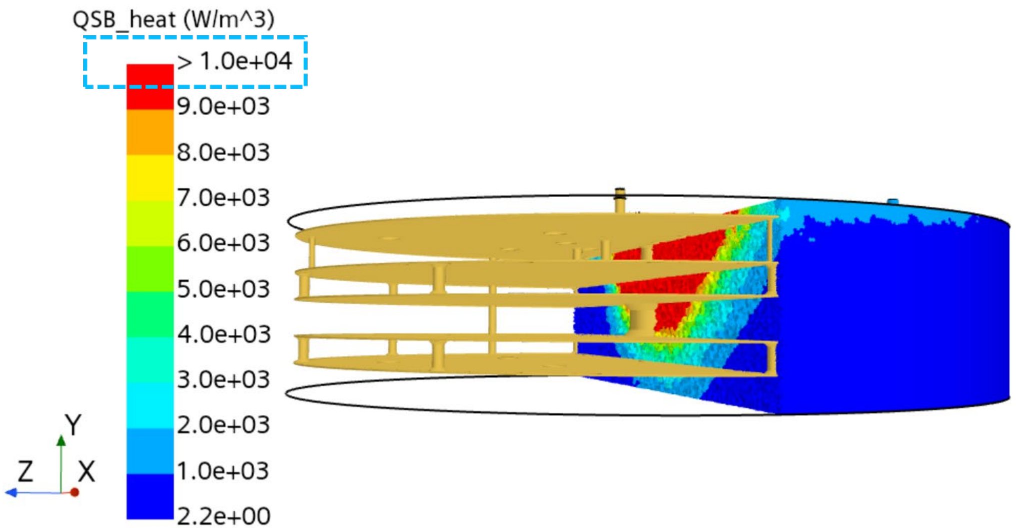
Neutronics Heating from Lukas (2023) Link https://ornl.sharepoint.com/sites/sts/targetsystems/Shared%20Documents/Forms/AllItems.aspx?csf=1&web=1&e=Ilwgp7&cid=939335e4%2D4ccc%2D4c00%2Da2d2%2D814c53b7125a&FolderCTID=0x01200064187E8E25420543ACAD0BF1C3490EAC&noAuthRedirect=1&id=%2Fsites%2Fsts%2Ftargetsys s%2FShared%20Documents%2FS%2E03%2E02%20Target%20Assembly%2F1%5FCALCULATIONS%2FCALC%2D018%20%2D%20CoreVessel%2FNeutronics&viewid=9be9bc88%2D5a13%2D48c7%2D9fff%2Dd22f94ffdeb5

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



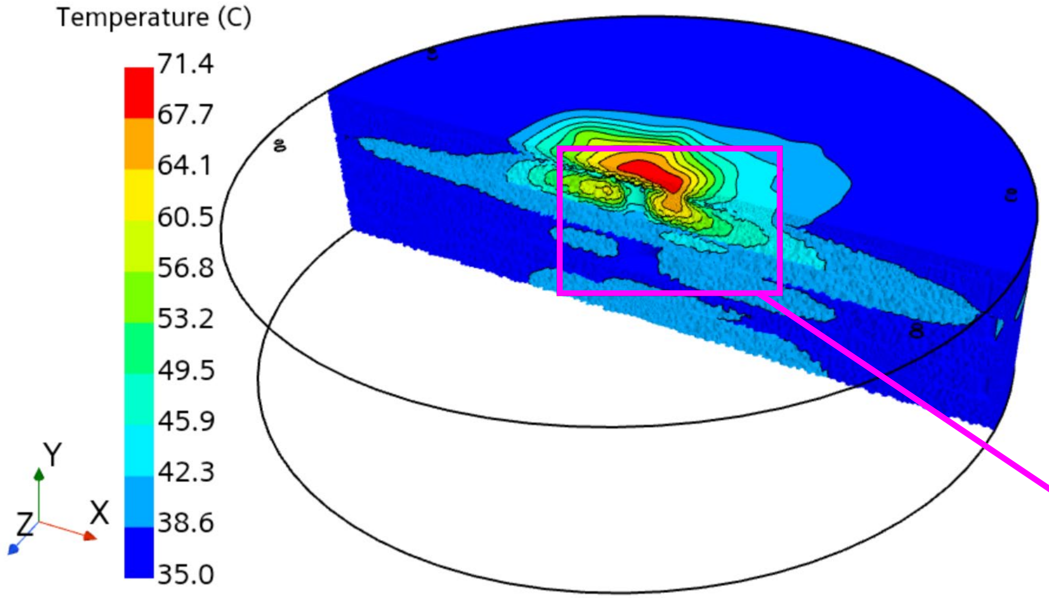


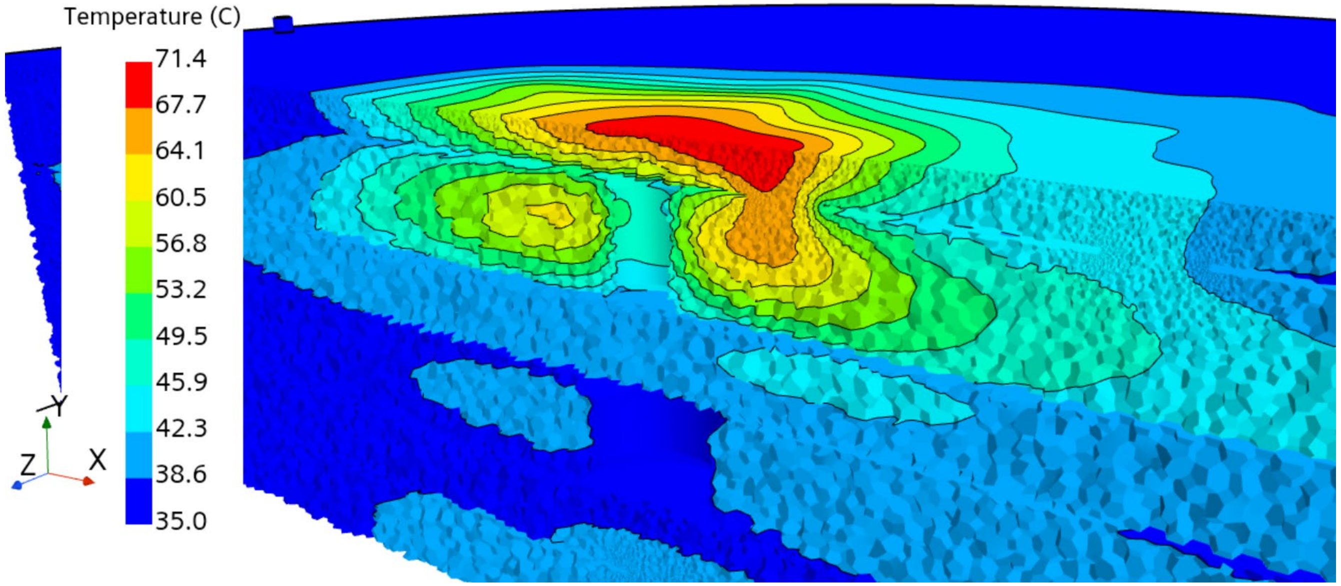


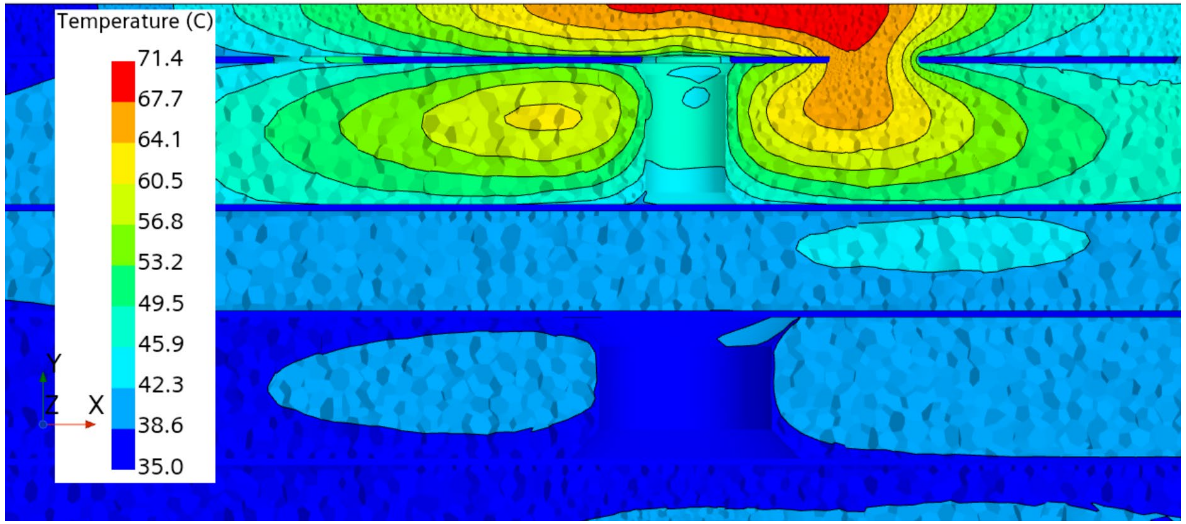


Shield Block #1, Stainless Steel Temperature

Peak: 71.4°C





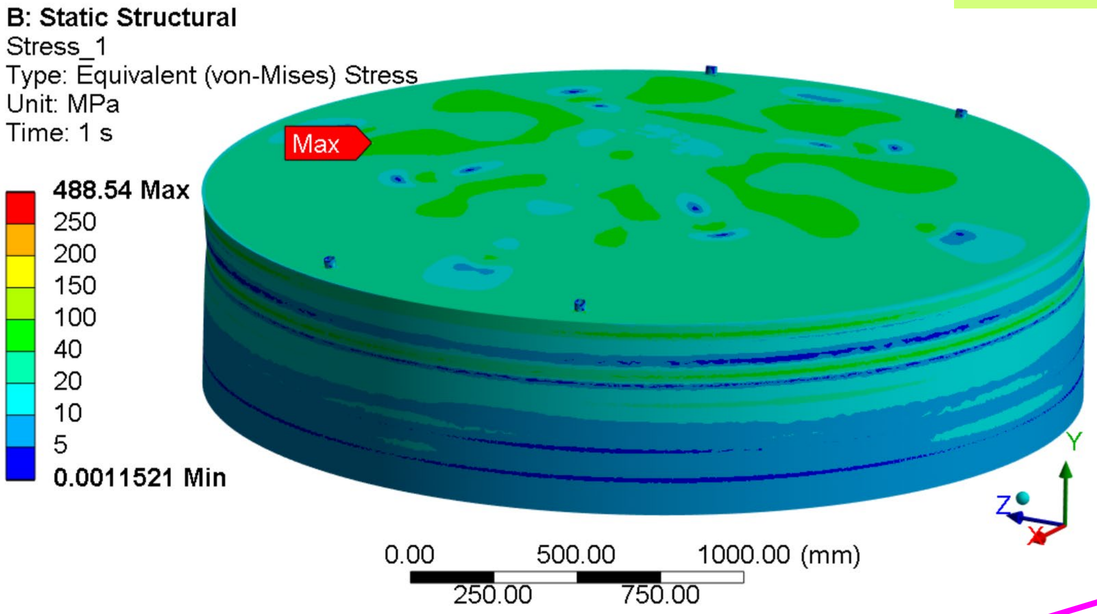


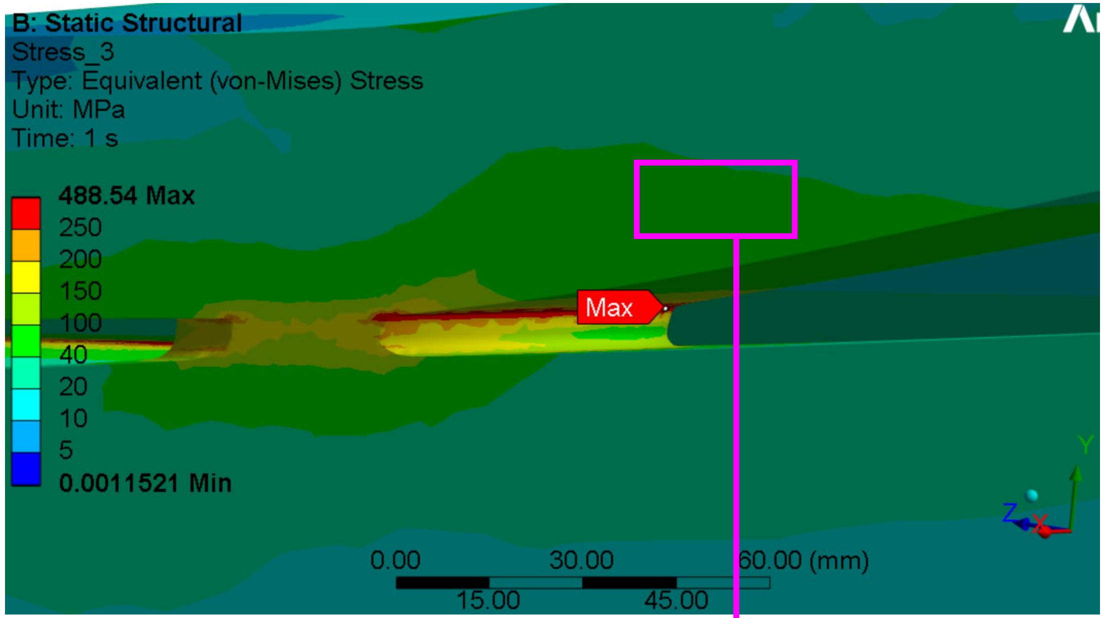
Water pressure + Thermal + Gravity

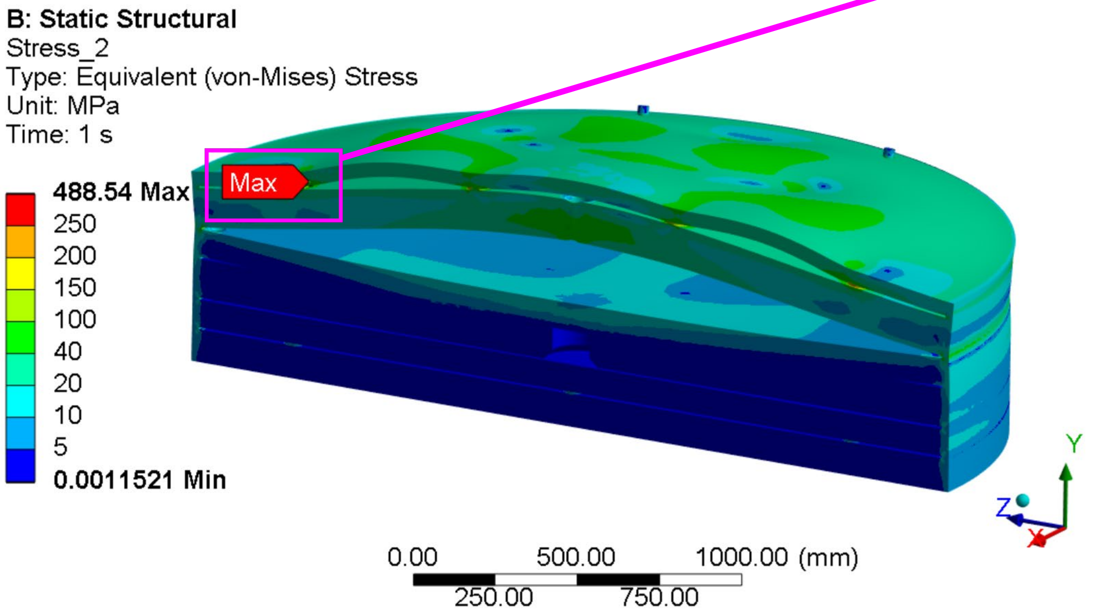
Von-Mises Stress

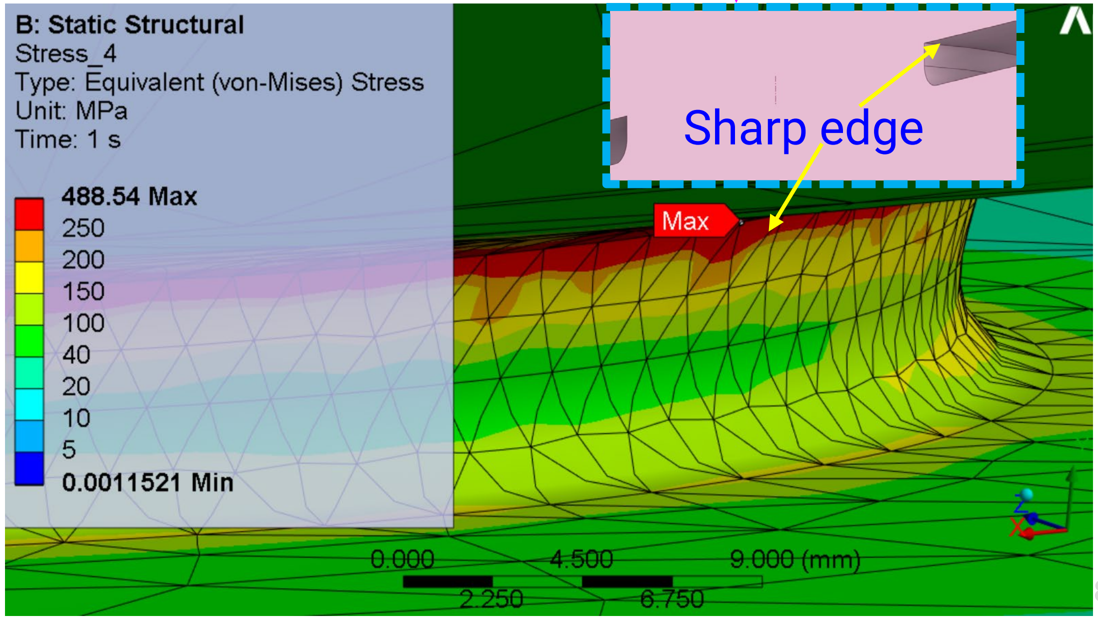
Deformation scale = 180

Peak Stress : 488 MPa
SS316 Yield Strength: 252 MPa





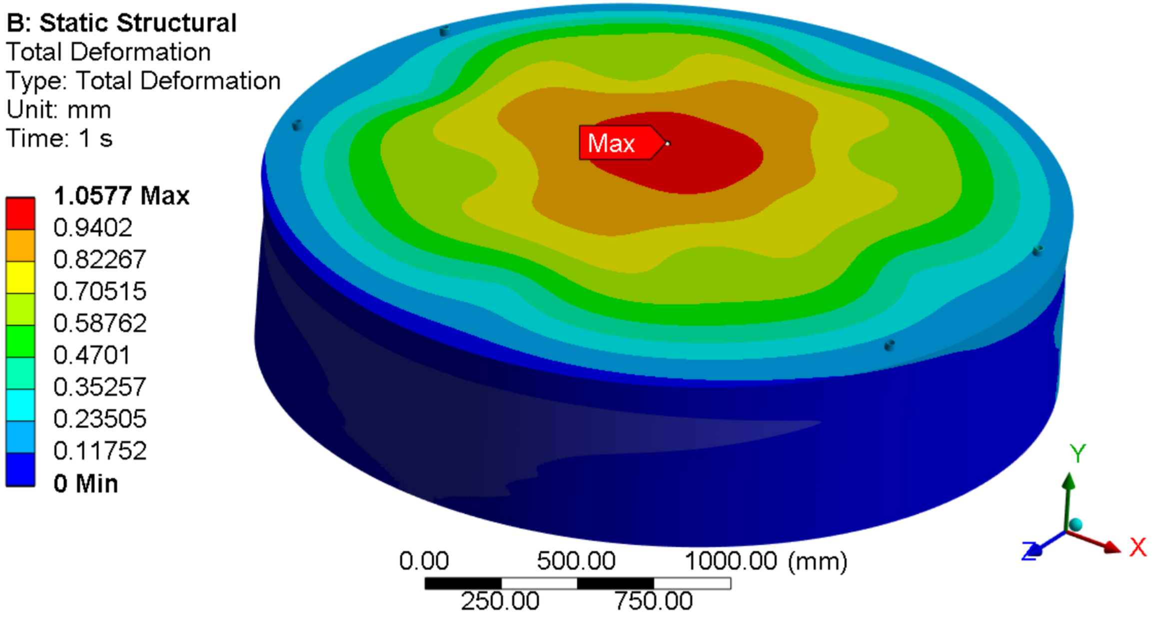


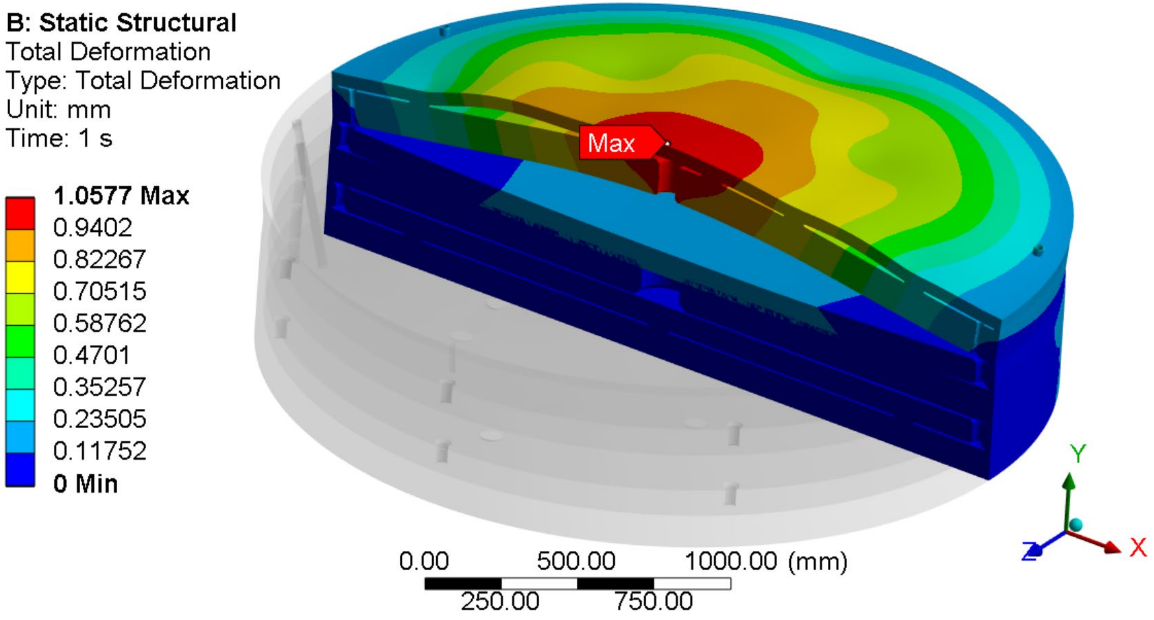


Water pressure + Thermal + Gravity

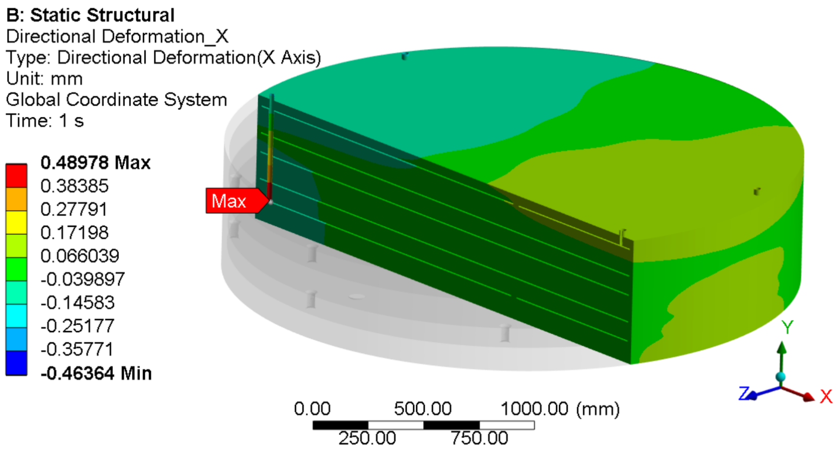
Displacement

Total Deformation

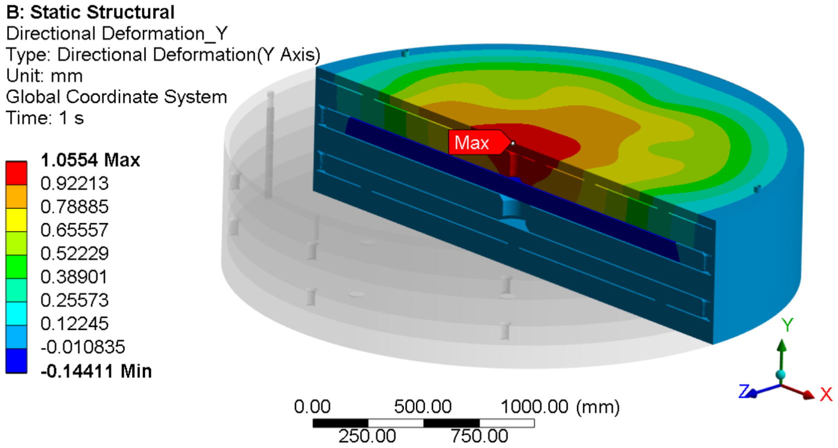




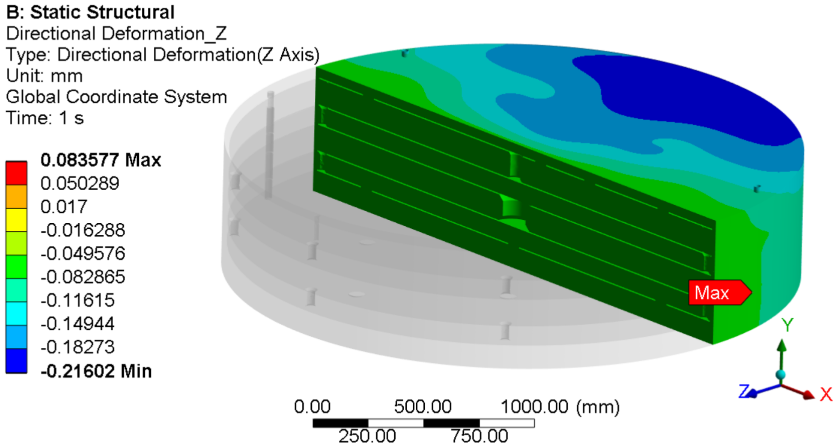
X - Deformation



Y - Deformation



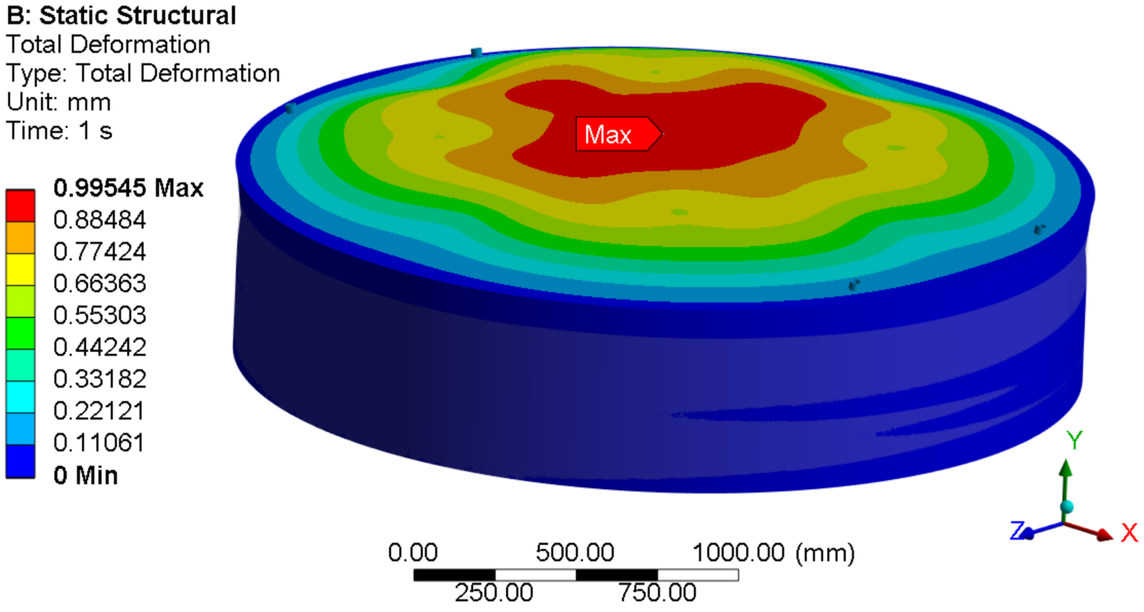
Z - Deformation

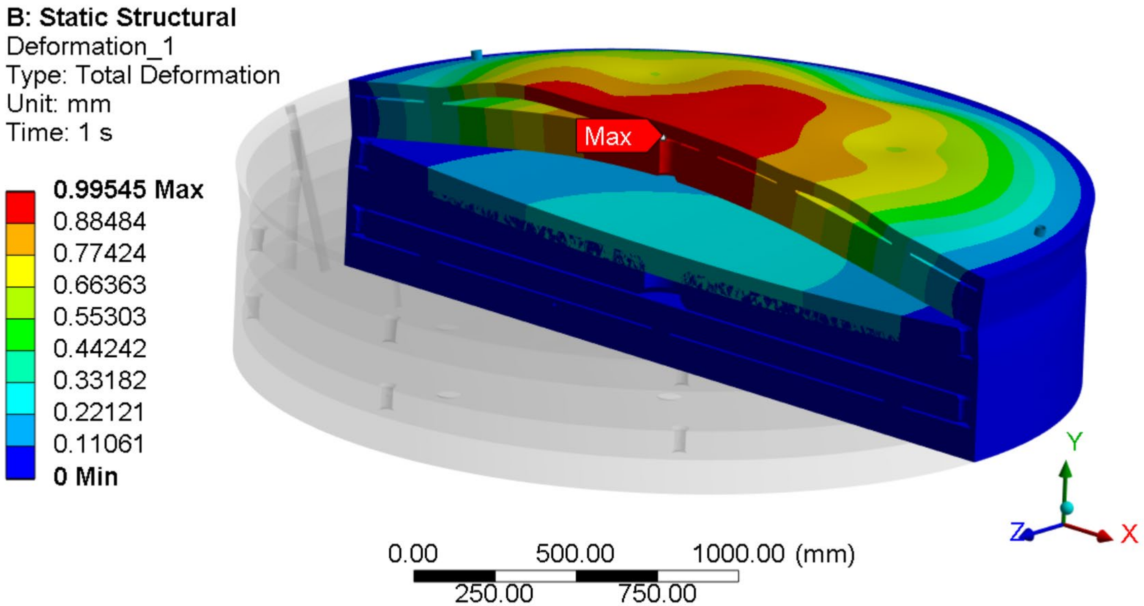


Water Pressure 5 bar

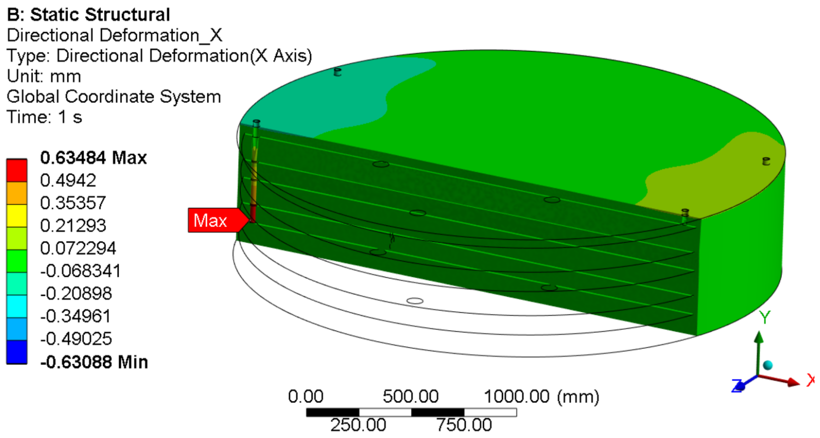
Displacement

Total Deformation

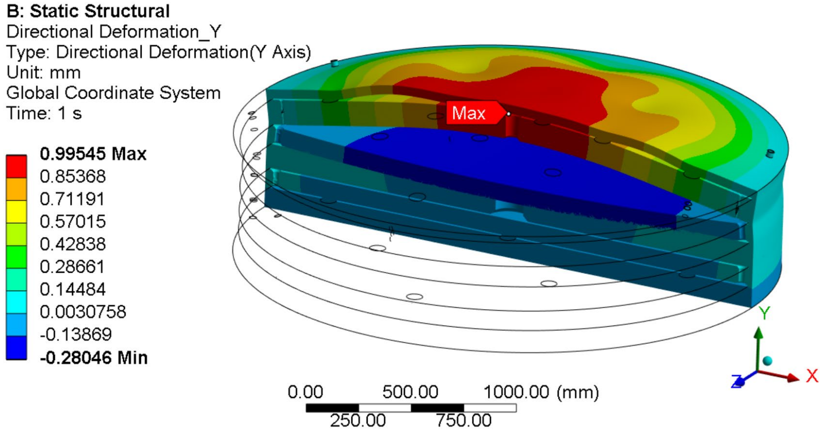




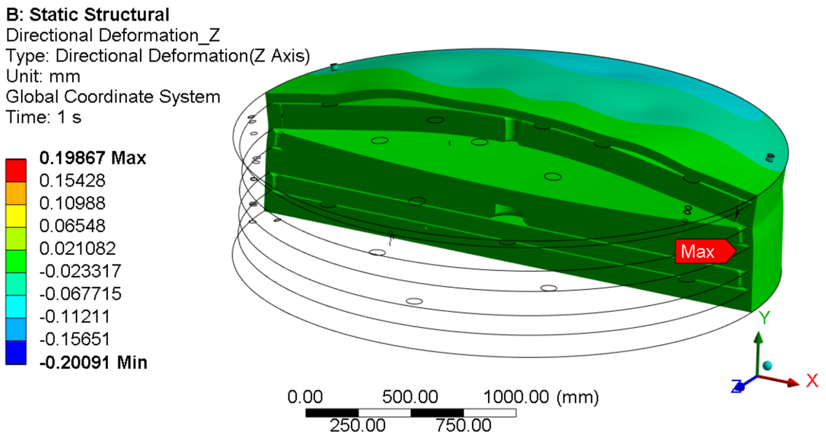
X - Deformation



Y - Deformation



Z - Deformation

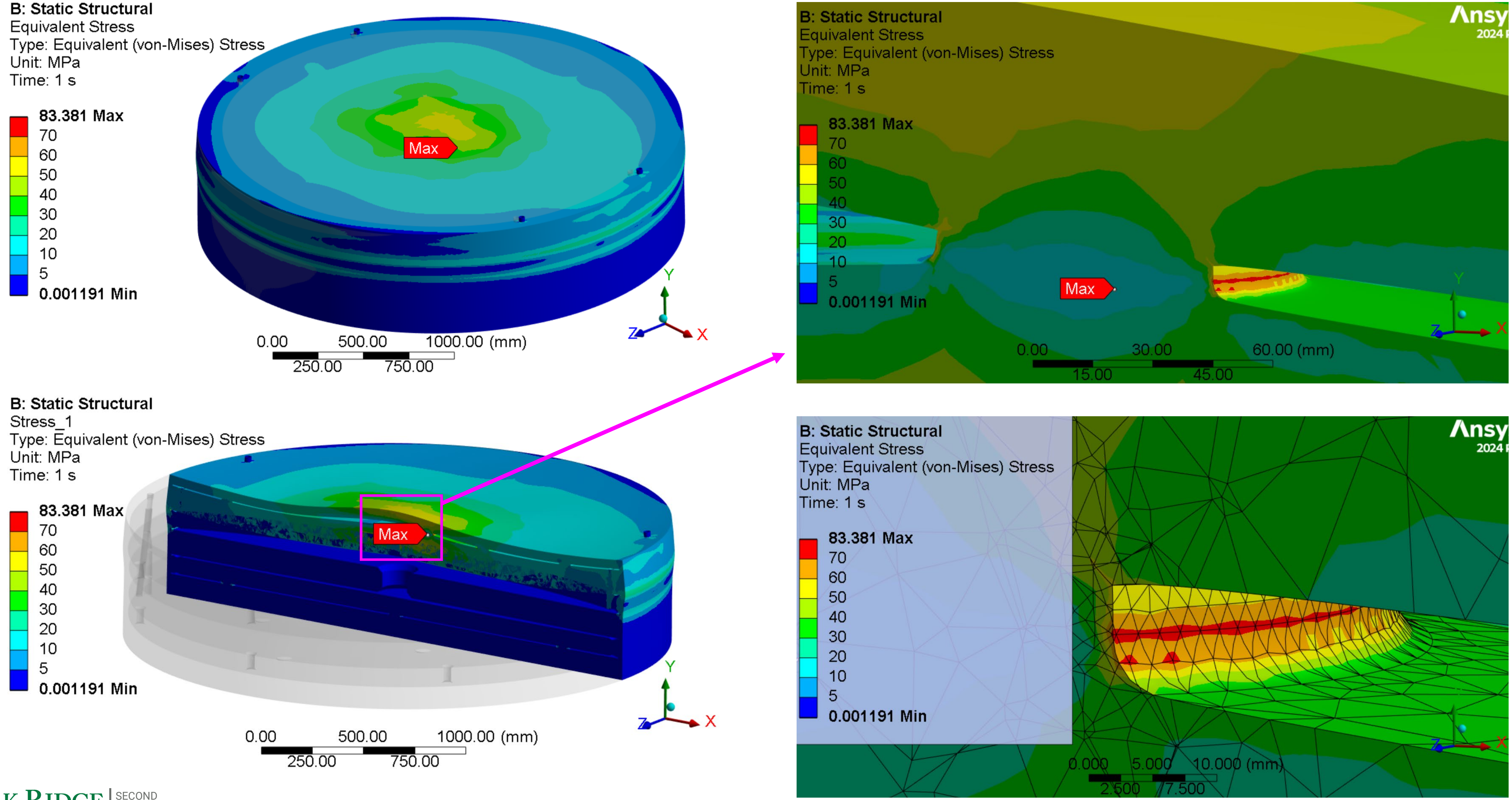


Thermal Only

Von-Mises Stress

Deformation scale = 500

Peak Stress : 83 MPa
SS316 Yield Strength: 252 MPa



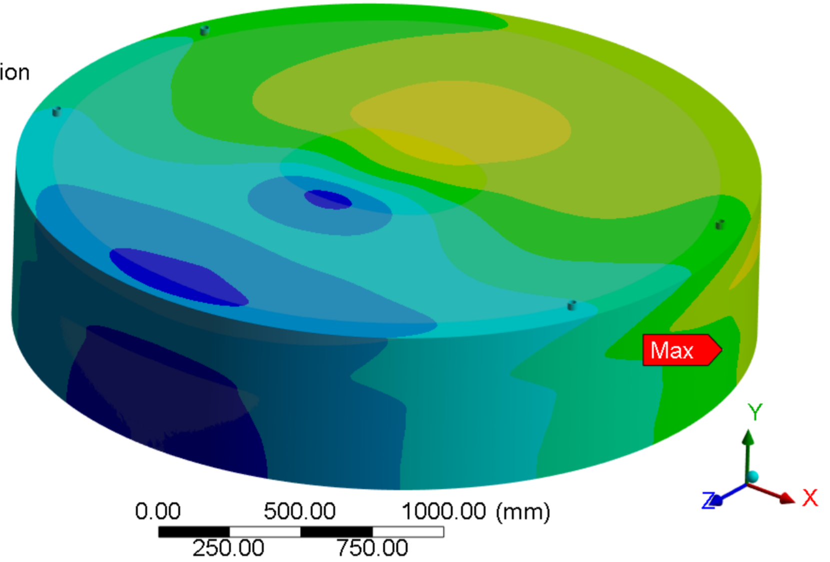
Thermal Only

Displacement

Total Deformation

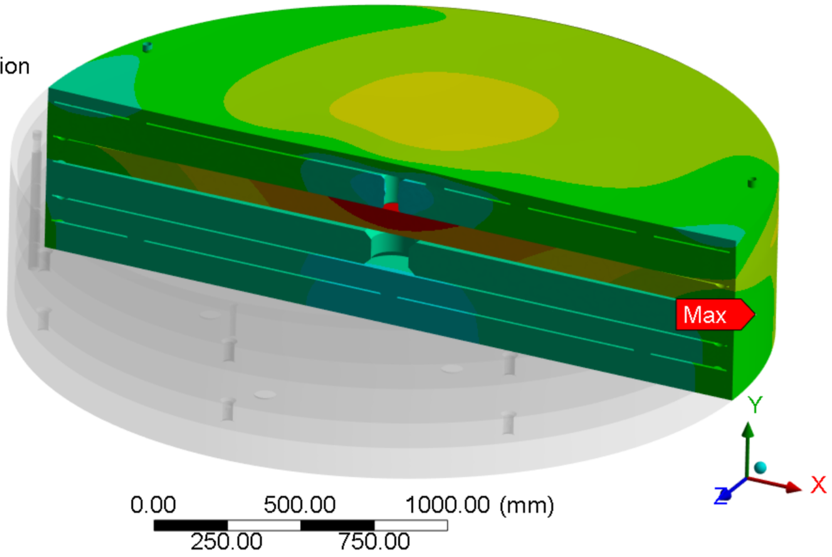
B: Static Structural
Total Deformation
Type: Total Deformation
Unit: mm
Time: 1 s

0.19763 Max
0.17567
0.15371
0.13176
0.1098
0.087837
0.065878
0.043918
0.021959
0 Min



B: Static Structural
Total Deformation
Type: Total Deformation
Unit: mm
Time: 1 s

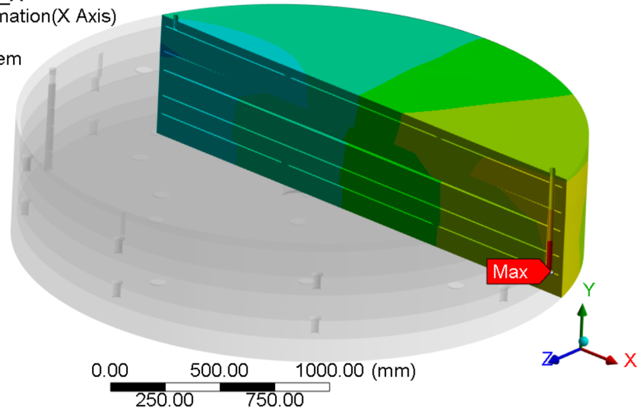
0.19763 Max
0.17567
0.15371
0.13176
0.1098
0.087837
0.065878
0.043918
0.021959
0 Min



X - Deformation

B: Static Structural
Directional Deformation_X
Type: Directional Deformation(X Axis)
Unit: mm
Global Coordinate System
Time: 1 s

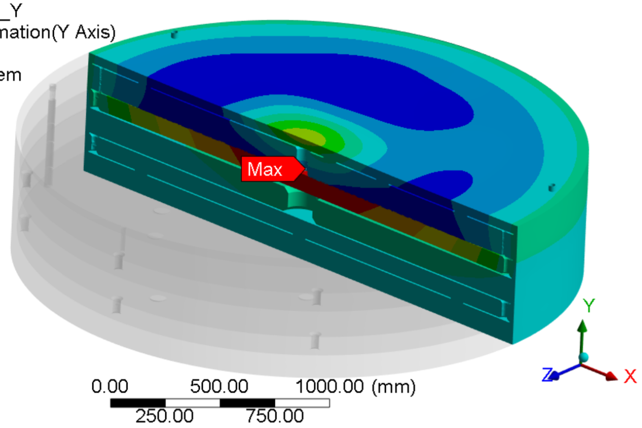
0.16161 Max
0.12817
0.094726
0.061285
0.027845
-0.0055962
-0.039037
-0.072478
-0.10592
-0.13936 Min



Y - Deformation

B: Static Structural
Directional Deformation_Y
Type: Directional Deformation(Y Axis)
Unit: mm
Global Coordinate System
Time: 1 s

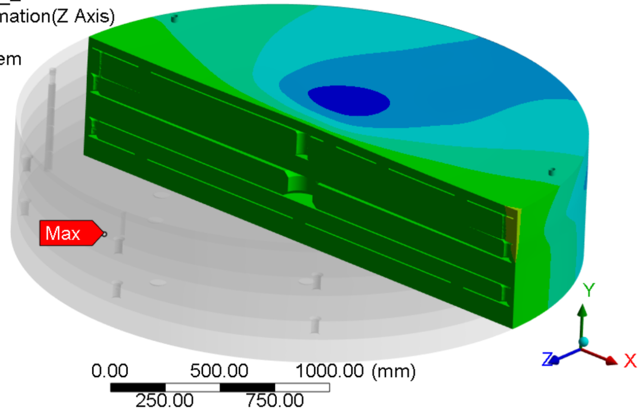
0.17235 Max
0.14645
0.12055
0.094654
0.068756
0.042858
0.01696
-0.0089377
-0.034836
-0.060734 Min



Z - Deformation

B: Static Structural
Directional Deformation_Z
Type: Directional Deformation(Z Axis)
Unit: mm
Global Coordinate System
Time: 1 s

0.017761 Max
-0.0012606
-0.020282
-0.039304
-0.058325
-0.077347
-0.096368
-0.11539
-0.13441
-0.15343 Min

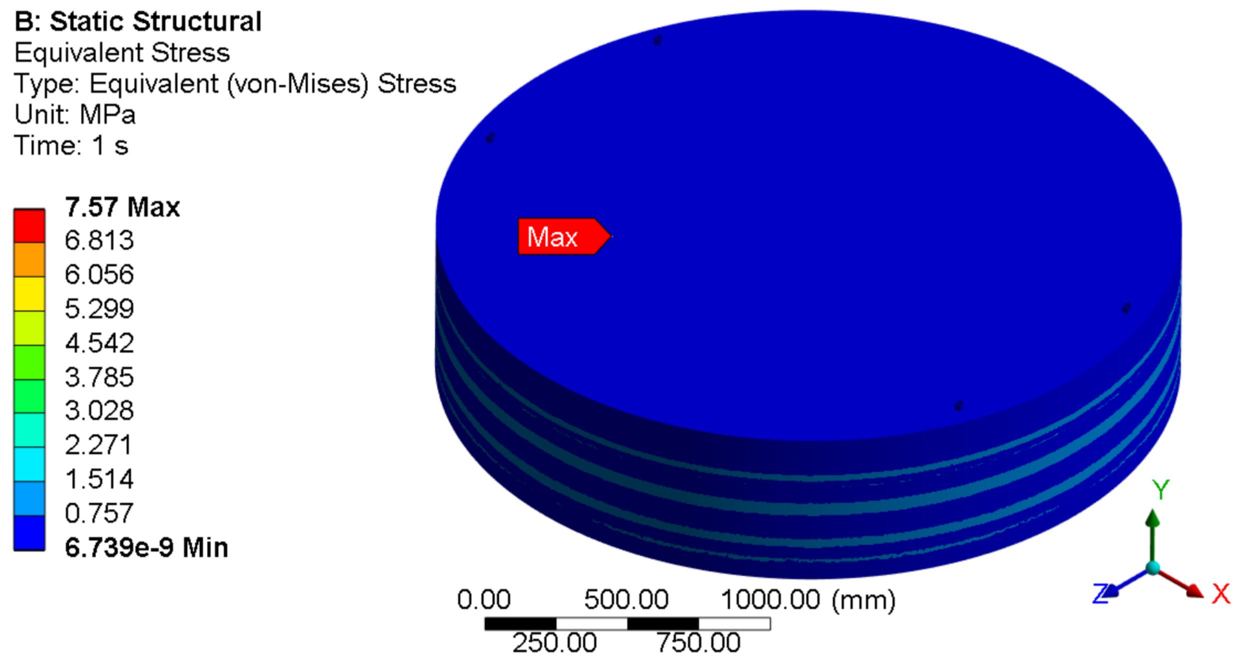


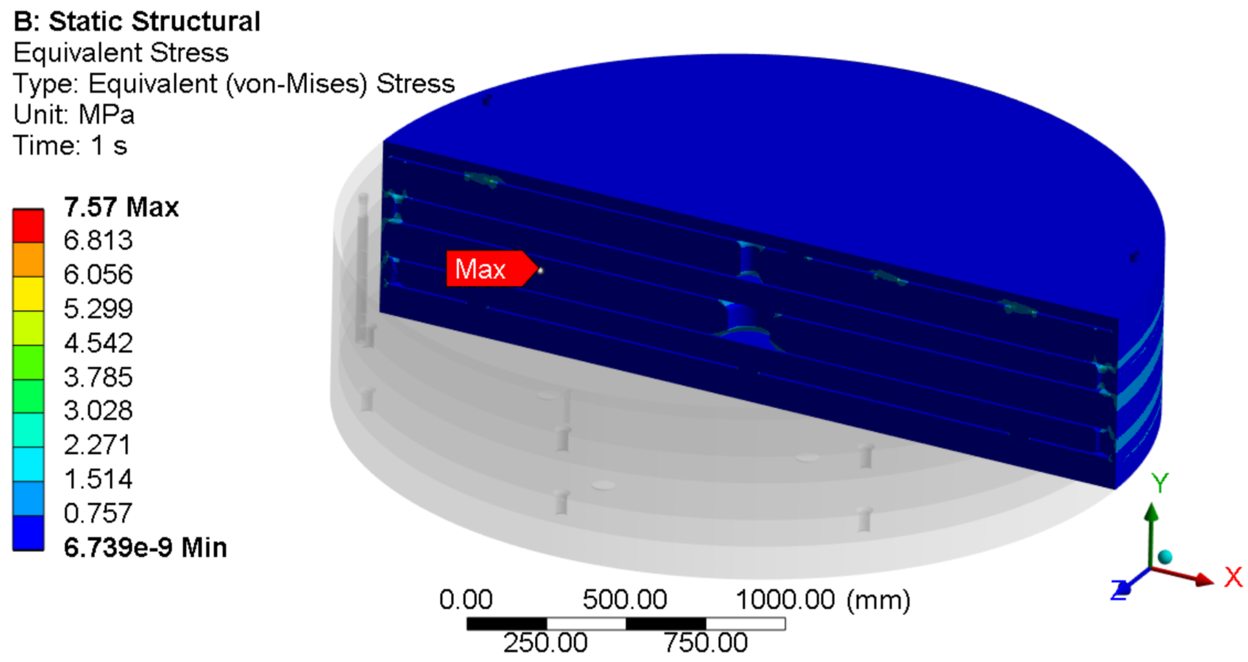
Gravity Only

Von-Mises Stress

Deformation scale = 100

Peak Stress : 13 MPa
SS316 Yield Strength: 252 MPa



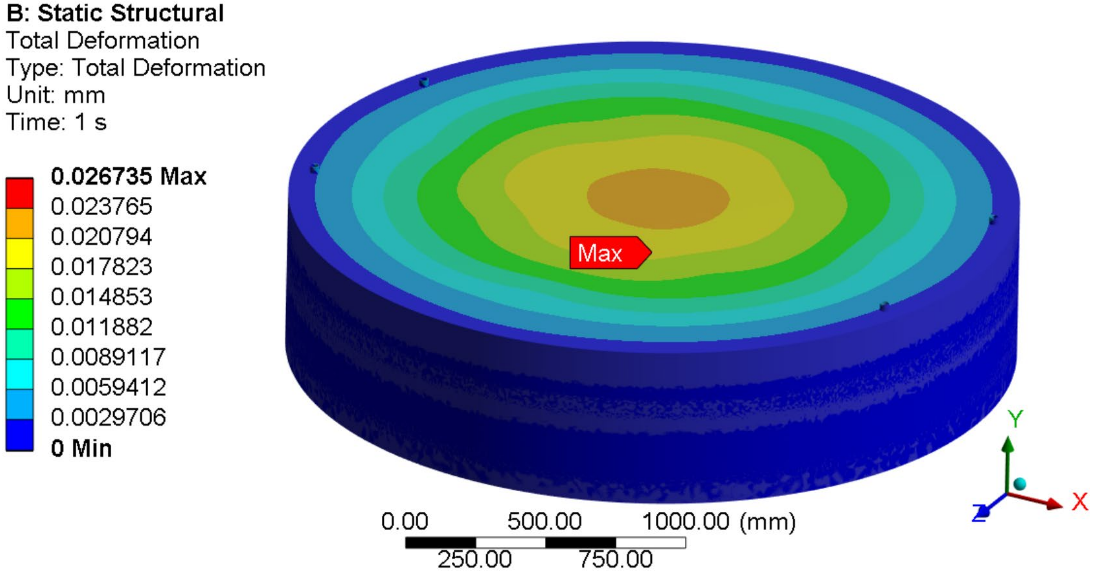


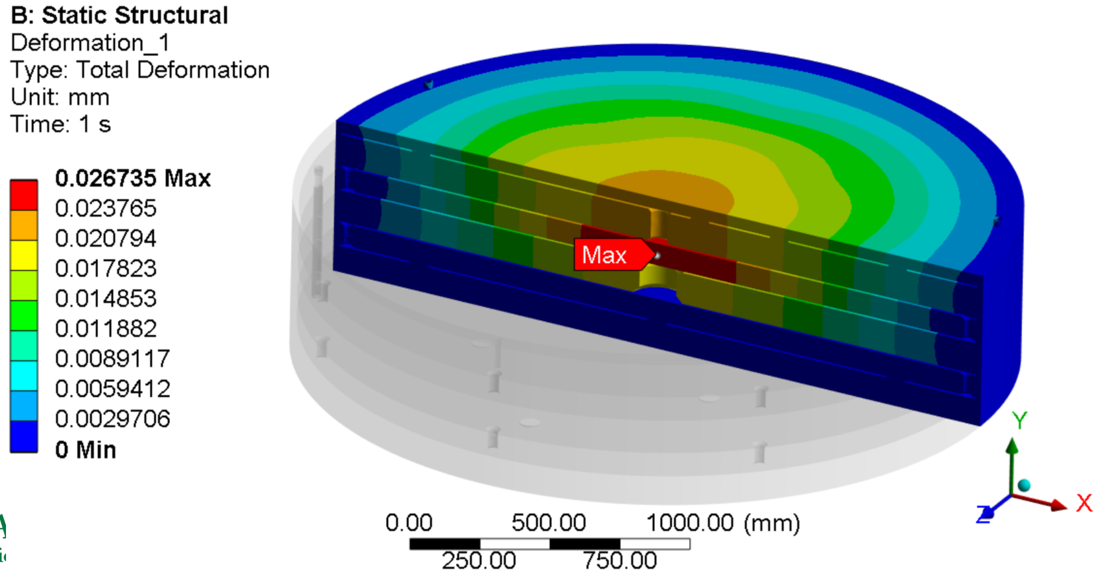
Displacement

Gravity Only

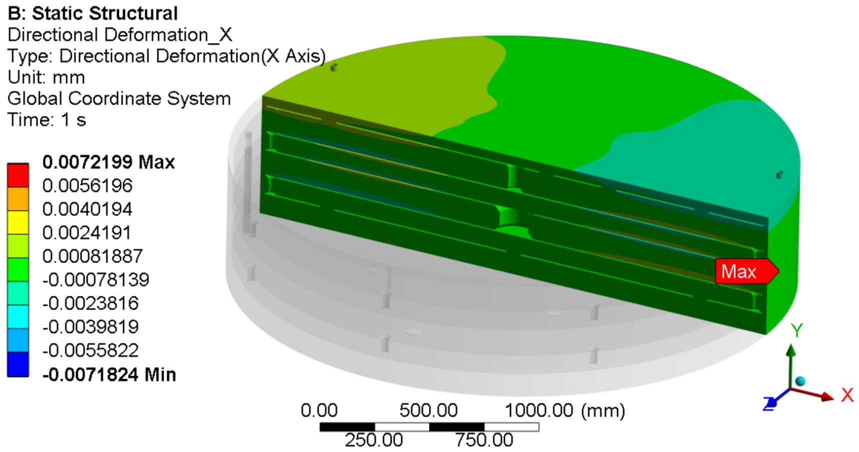
Total Deformation

Deformation scale = 100

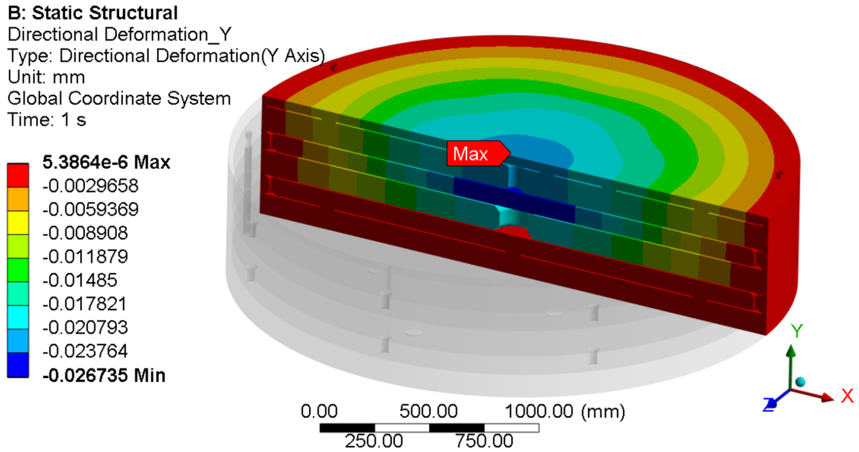




X - Deformation



Y - Deformation



Z - Deformation