MuCool Absorber Review meeting

FermiLab, Chicago

21 – 22 February 2003

Fluid Flow and Convective Heat Transfer Modelling

by

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Fluid Flow / Heat Transfer Analysis

Two models were built and run:

1) Model 1 with 11 inlet and 15 outlet nozzles;

2) Model 2 with 8 inlet and 12 outlet nozzles

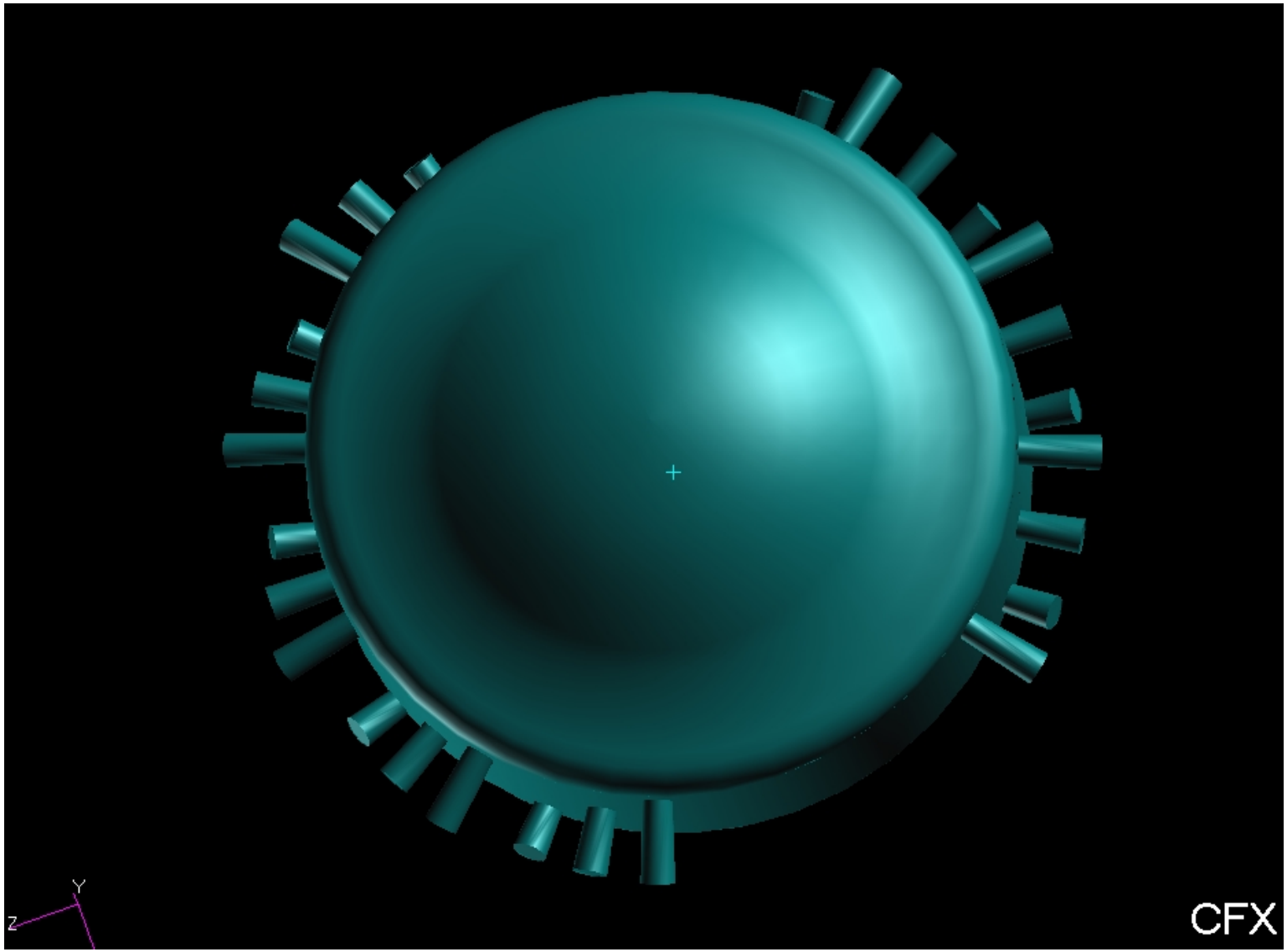
Nozzle sizes are different in each model: Model 1 has nozzle diameter of 0.43", and Model 2 has 0.63" diameter nozzle opening

Fluid flow / thermal interaction analyses were carried out to see if the nozzle arrangement is sufficient for the cooling requirement.

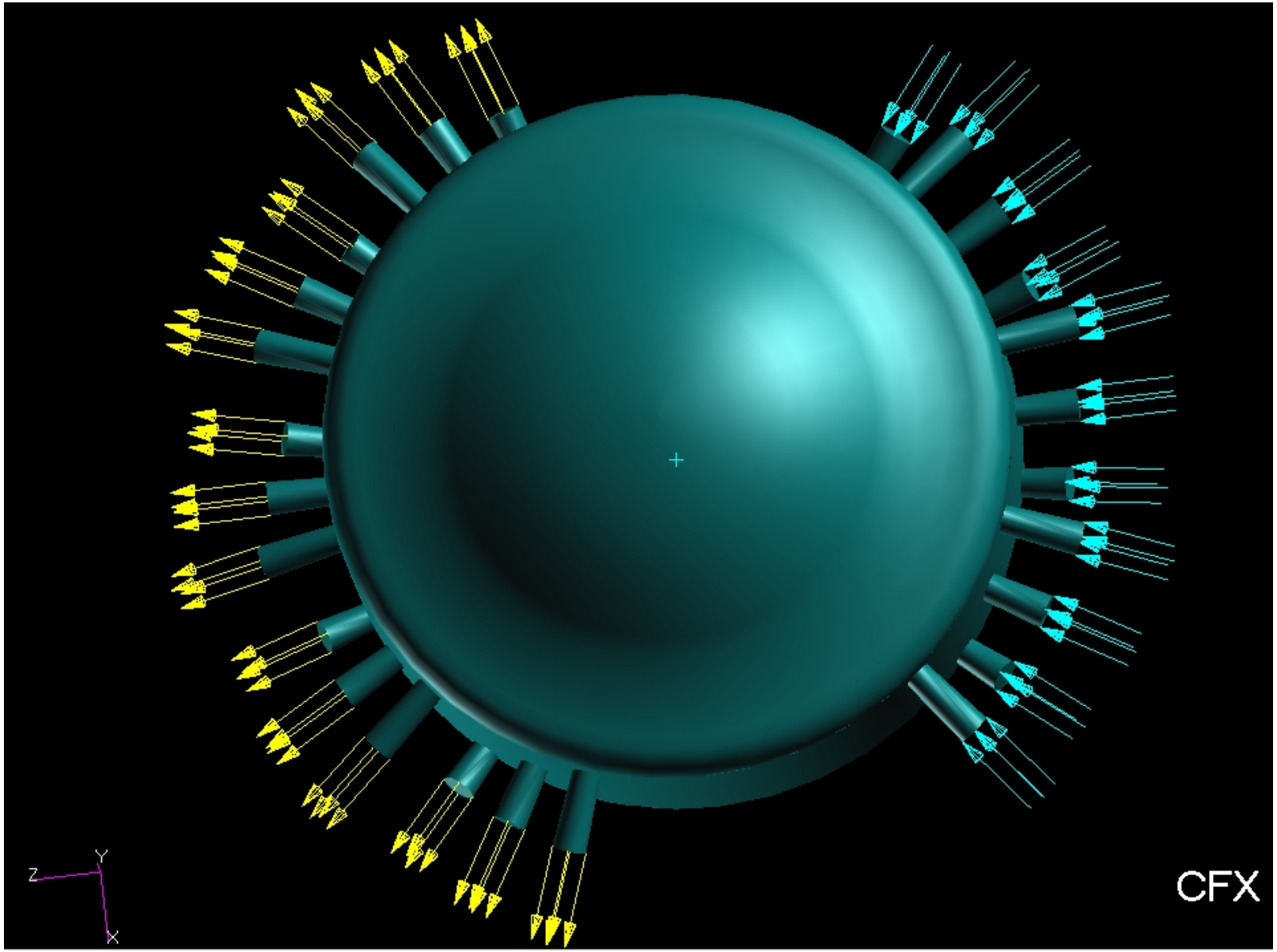
Further analyses were carried out to see if the flow speed could be reduced to minimise the impact on pressure loss within the cryogenic system while maintaining its cooling capacity

All models are based on a 22cm window size

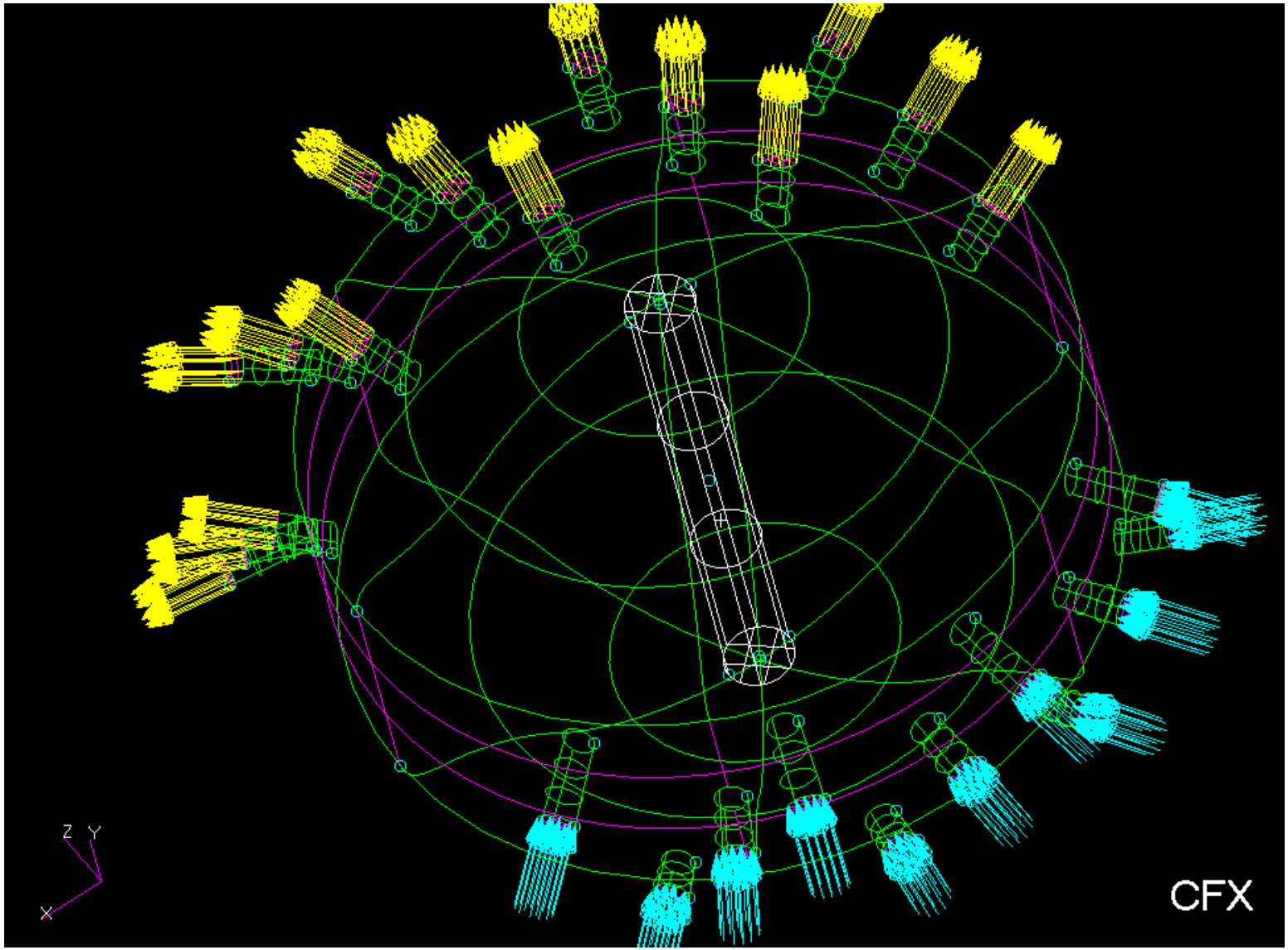
Model 1: with 11 inlet and 15 outlet nozzles



The 3-D model



Model showing the arrangement of the inlet and outlet nozzles

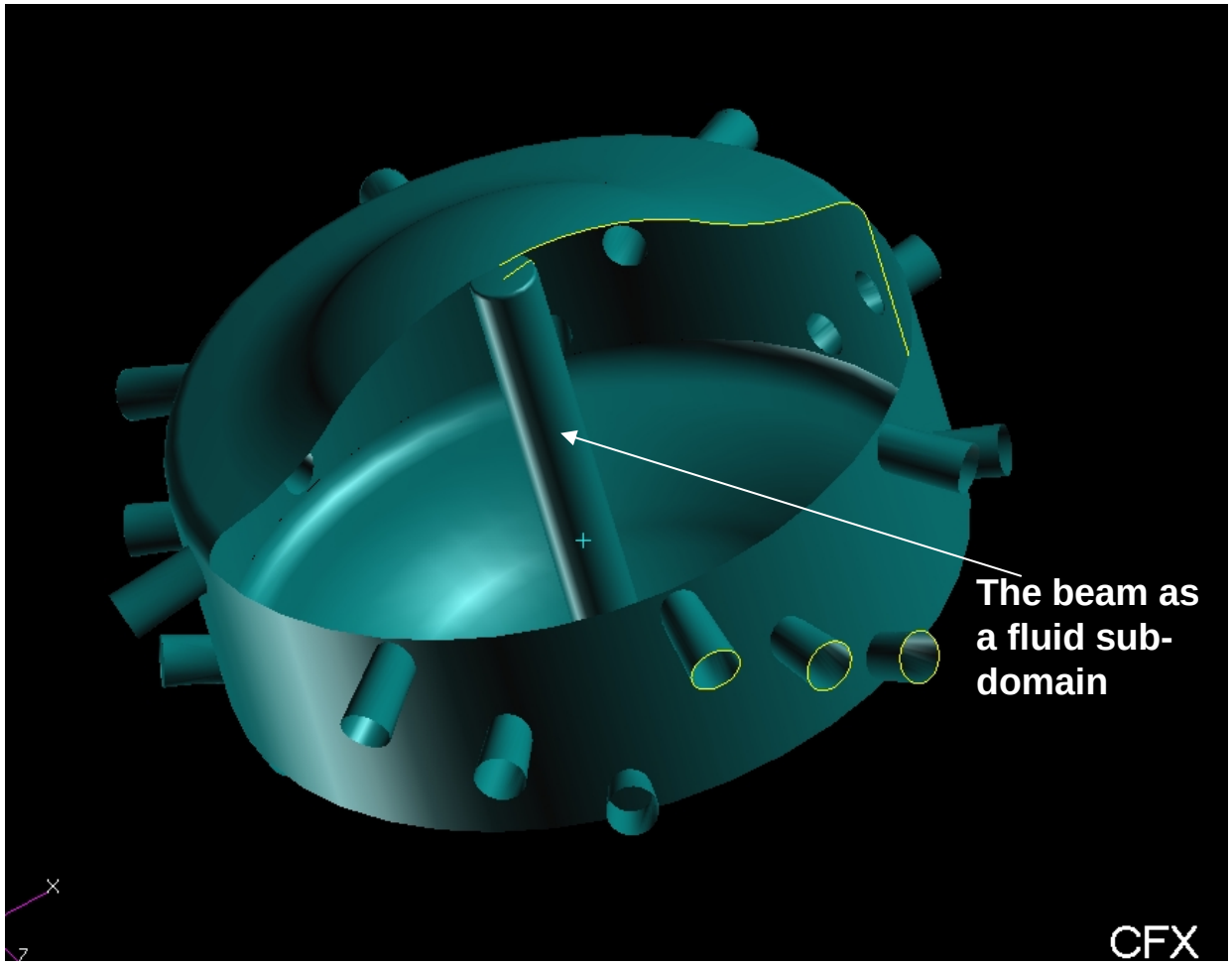


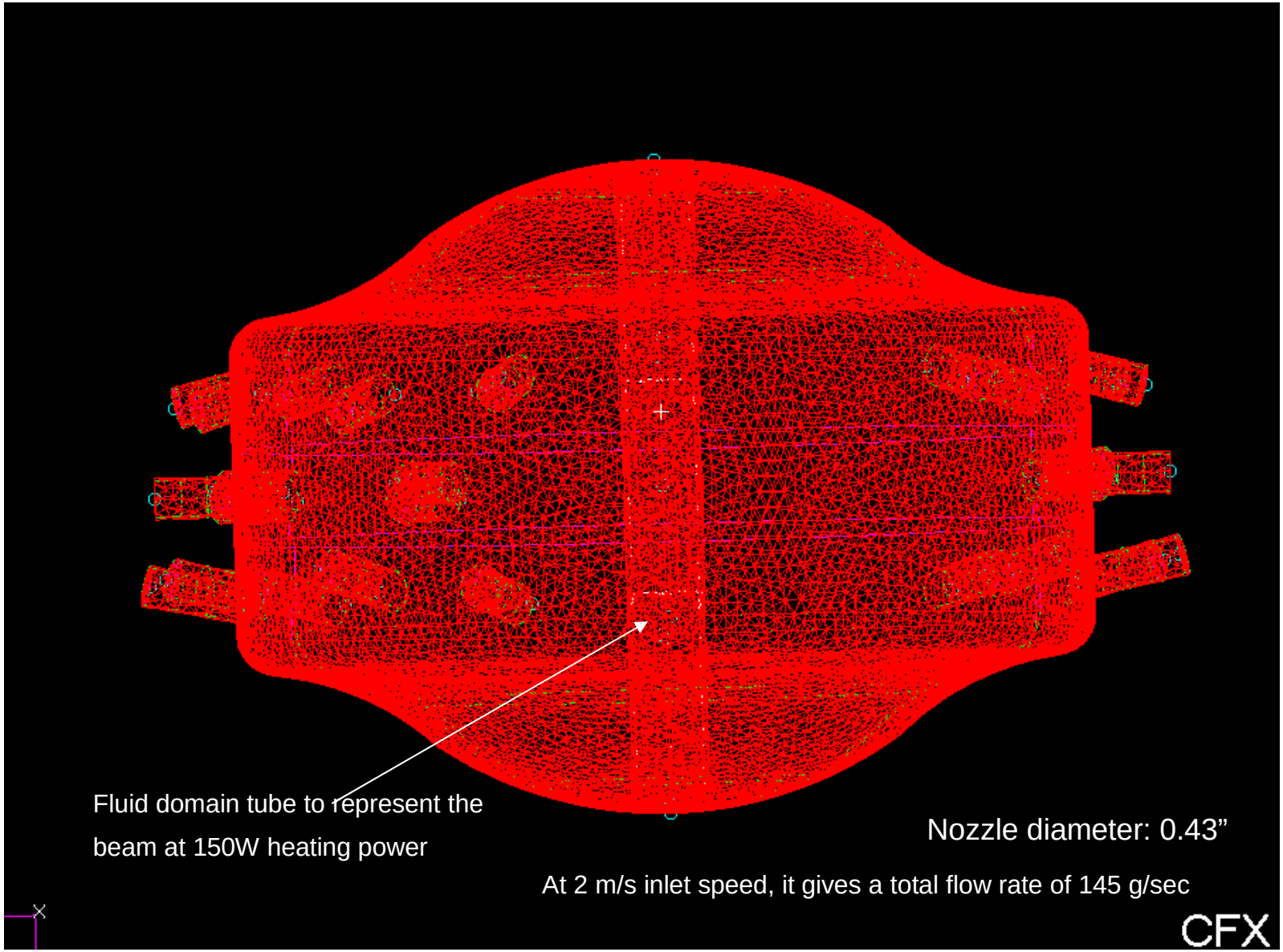
Model showing detail arrangement of the nozzles

For the Heat transfer Analysis:

The Beam is represented by a tube of 10mm radius across the absorber centre from one Window to the other.

Beam Power is assumed to be 150W at steady state.





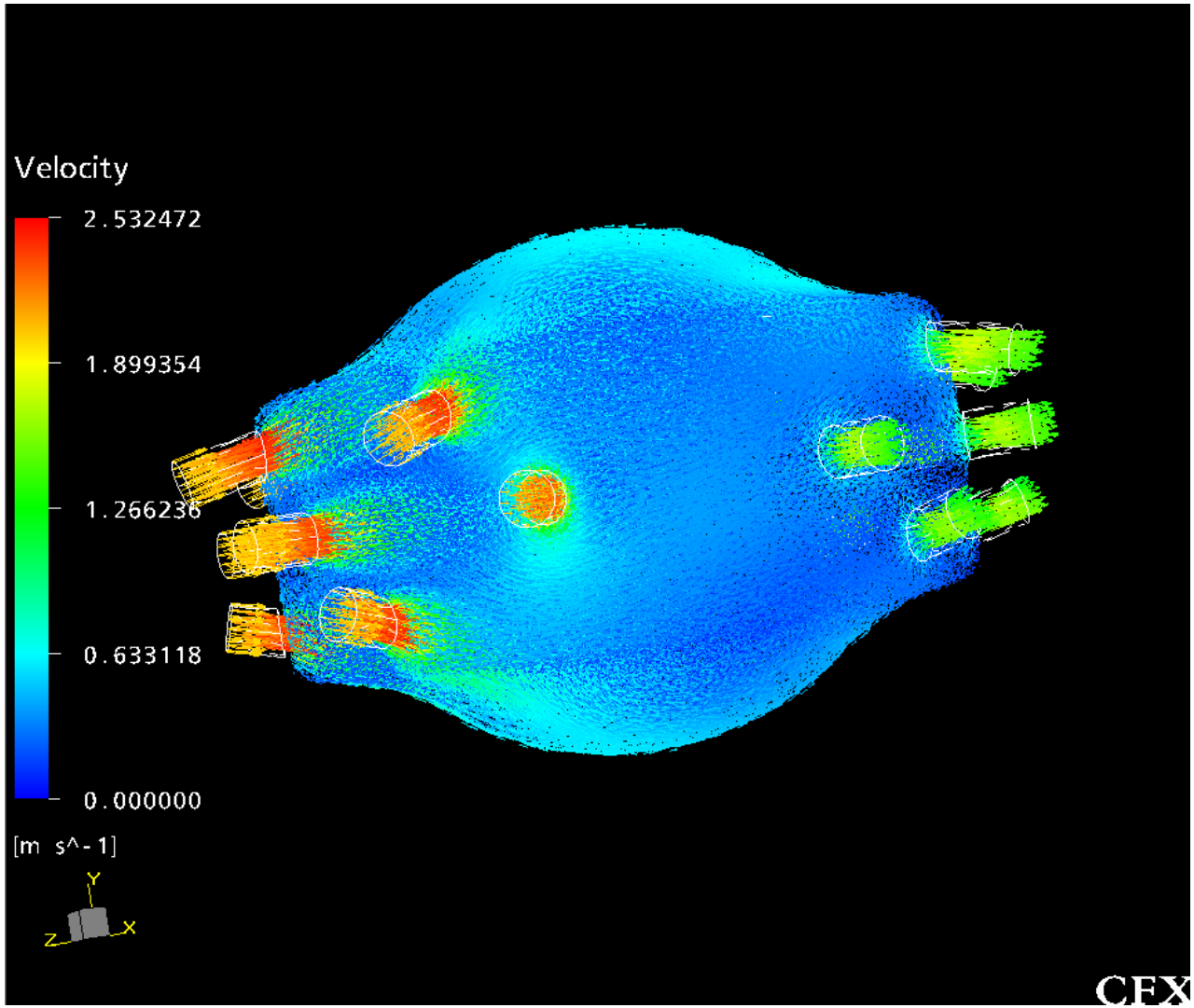
3-D grid of the model

Two inlet flow speeds were run; one at 2m/sec, and the other at 0.5 m/sec.

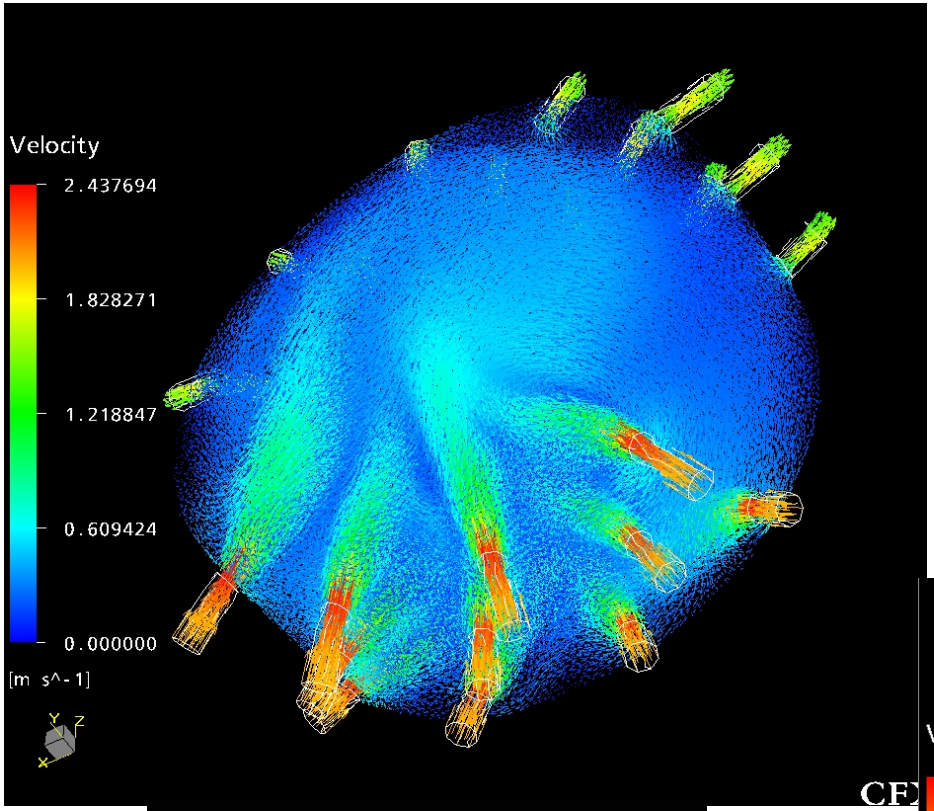
The following is a comparison of results with different flow speeds.

1) Flow speed and Flow Pattern

Does the presence of the "heater" affect the fluid Flow?

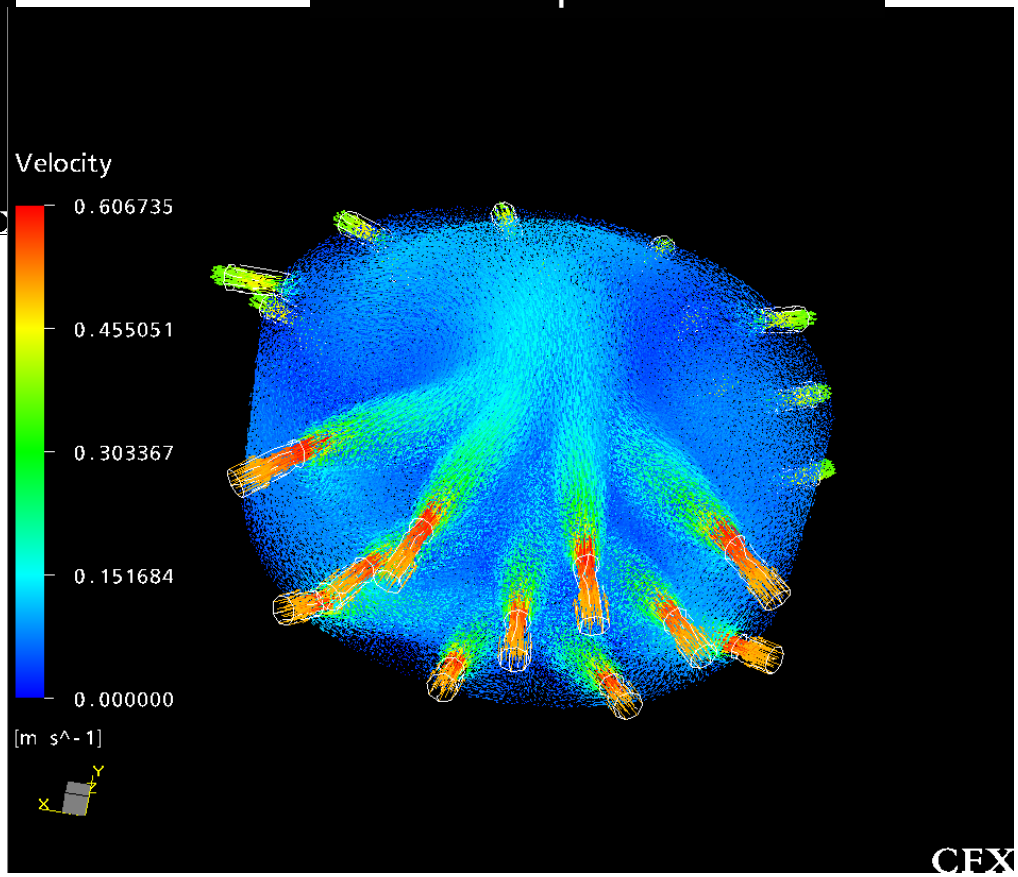


Flow pattern on the combined fluid / heat model – unaffected by the presence of the heat source

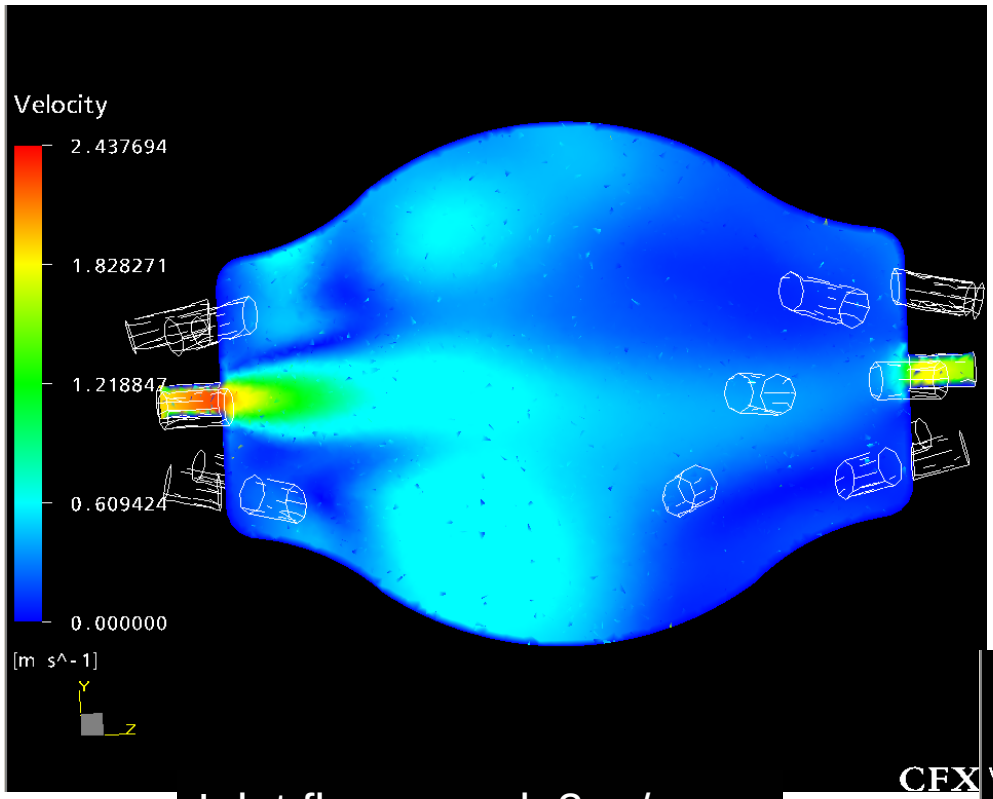


Inlet flow speed: 2m/s

Inlet flow speed: 0.5m/s

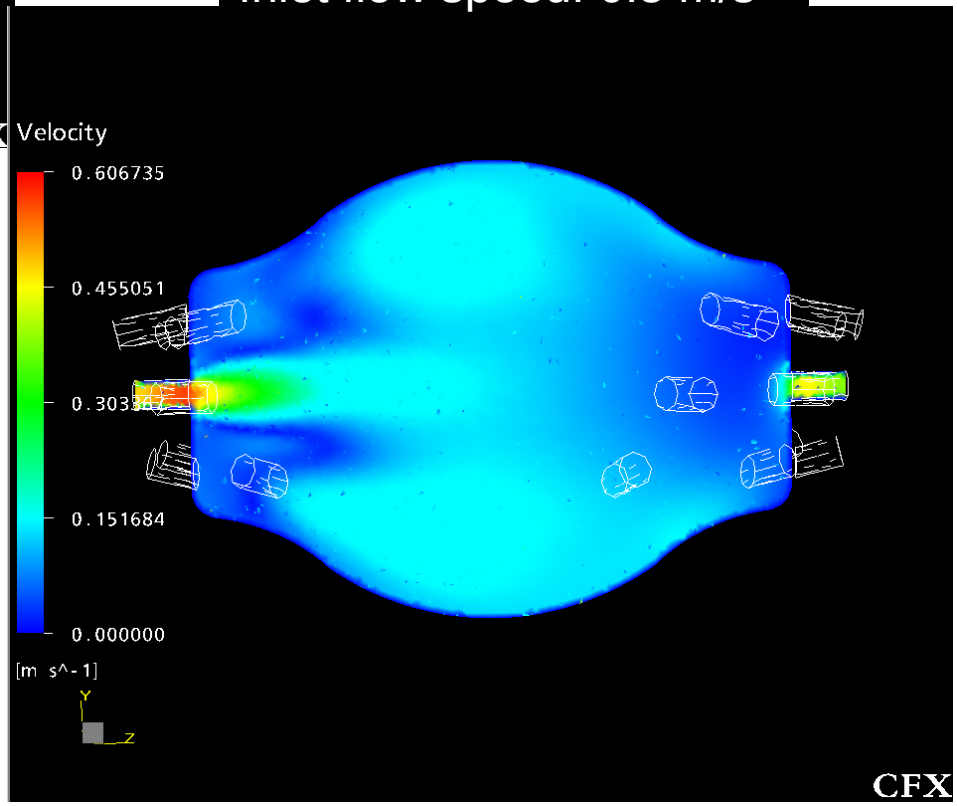


Flow distribution inside the Absorber

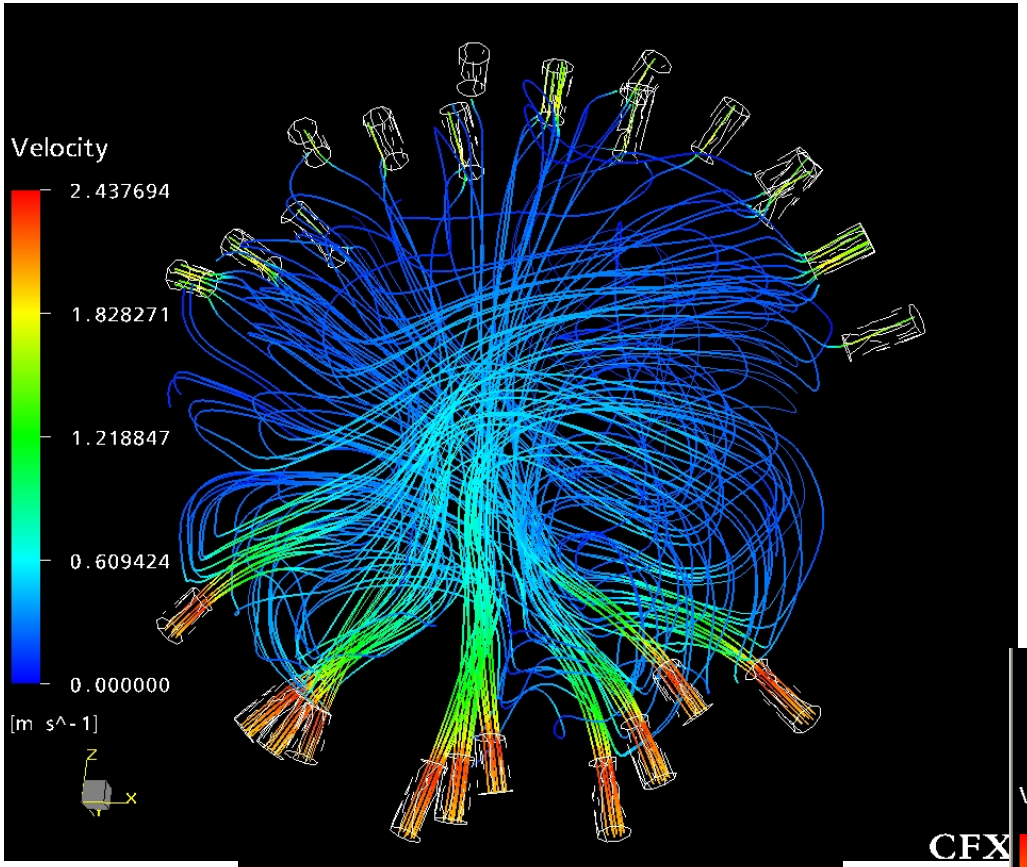


Inlet flow speed: 2 m/s

Inlet flow speed: 0.5 m/s

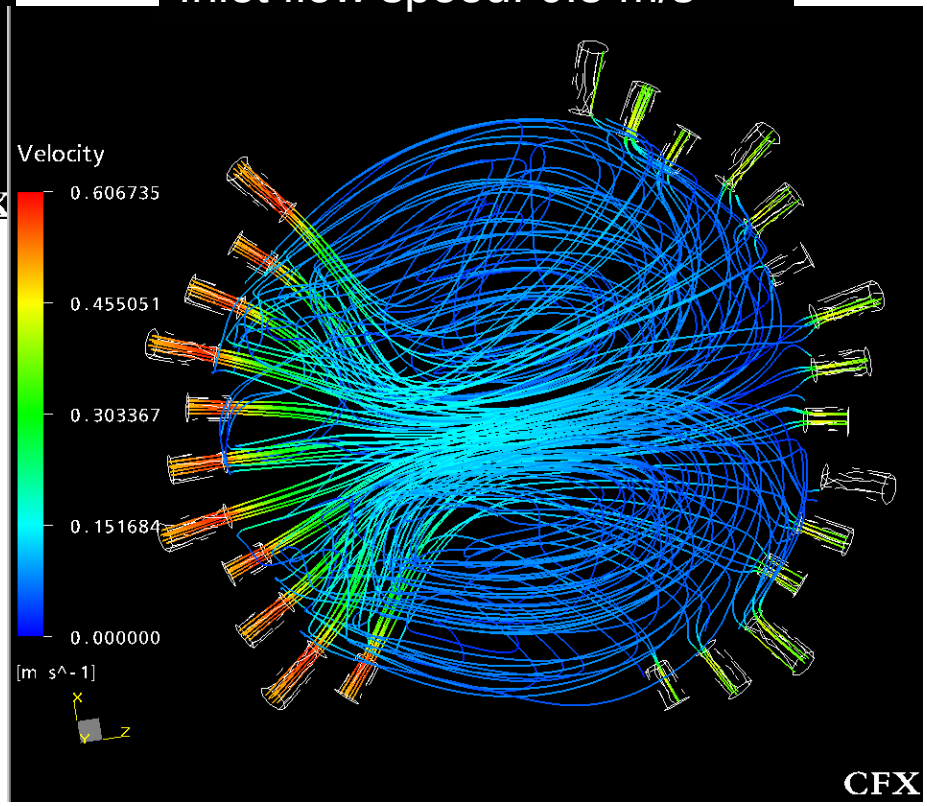


Looking at the flow pattern from a 2-D plane

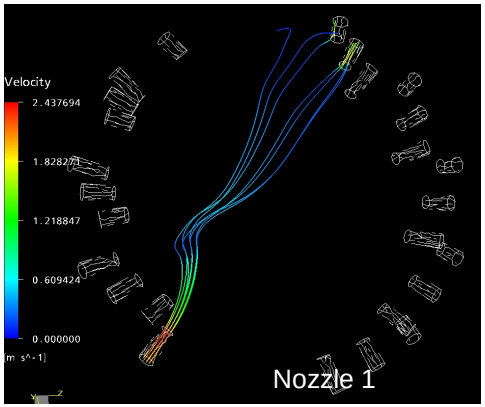


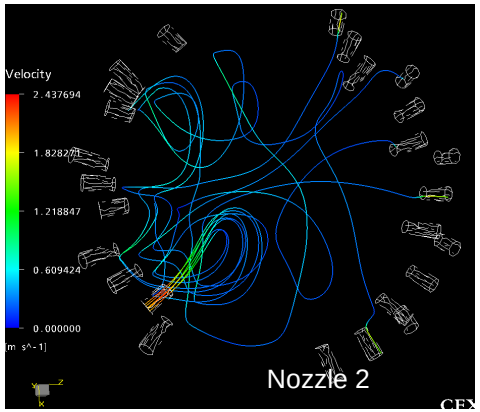
Inlet flow speed: 2 m/s

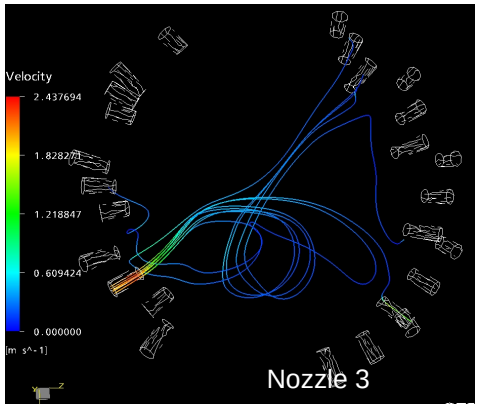
Inlet flow speed: 0.5 m/s

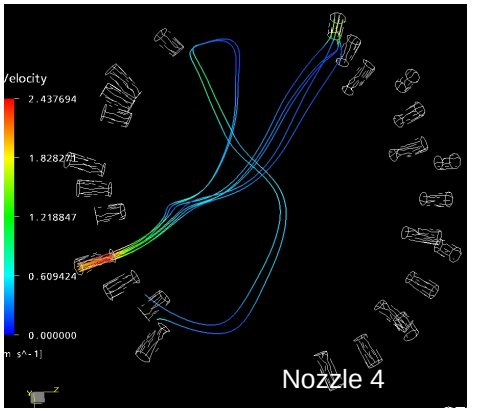


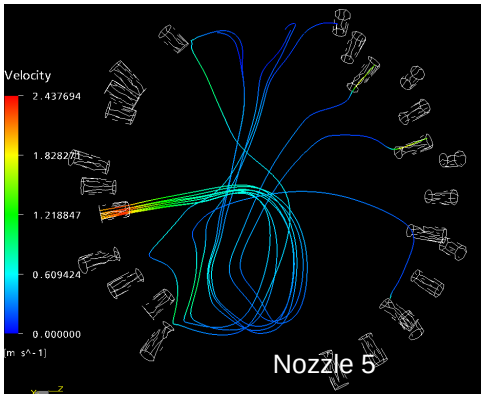
Traces of all the flow paths from the 11 inlet nozzles

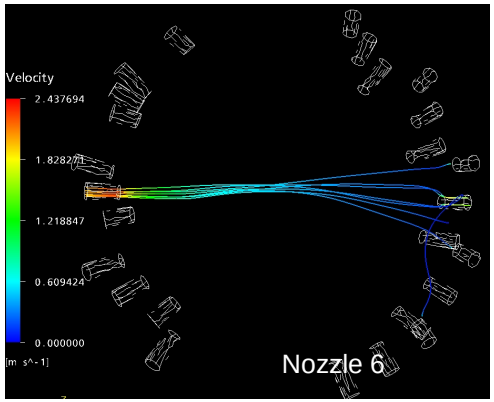


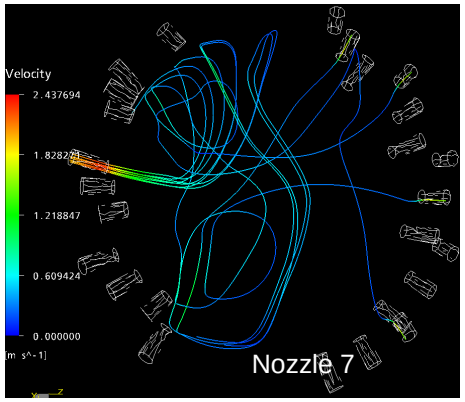


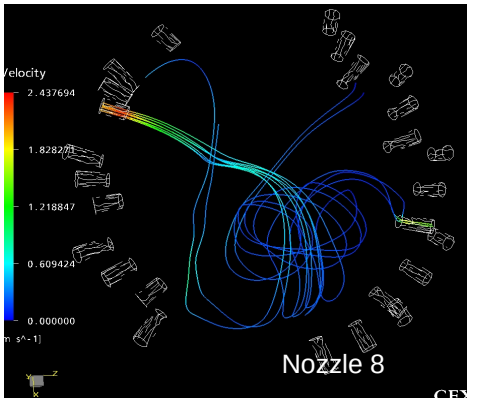


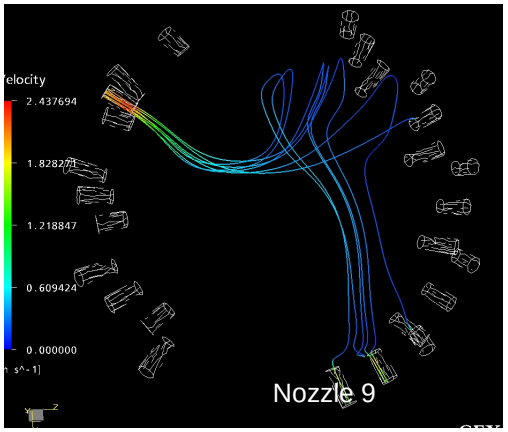


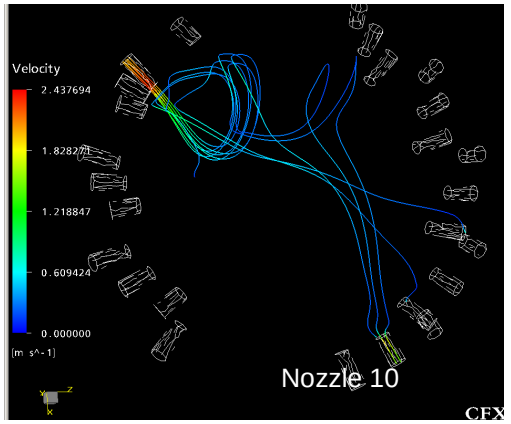


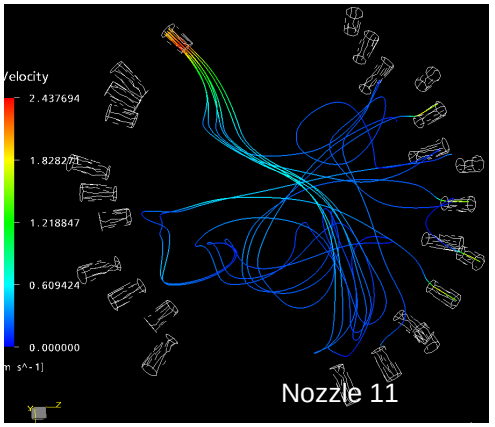








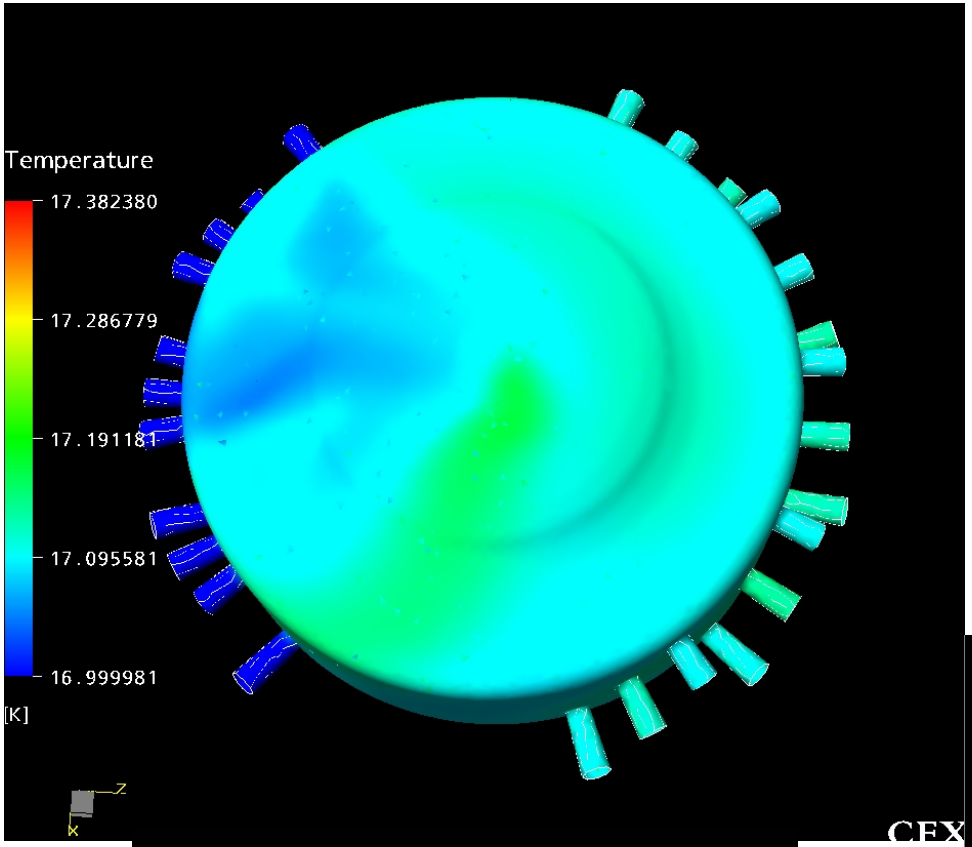




Traces of the individual flow paths from each inlet nozzle for the 2m/s flow model

Results of the Flow analysis:

2) Temperature distribution & Cooling effect

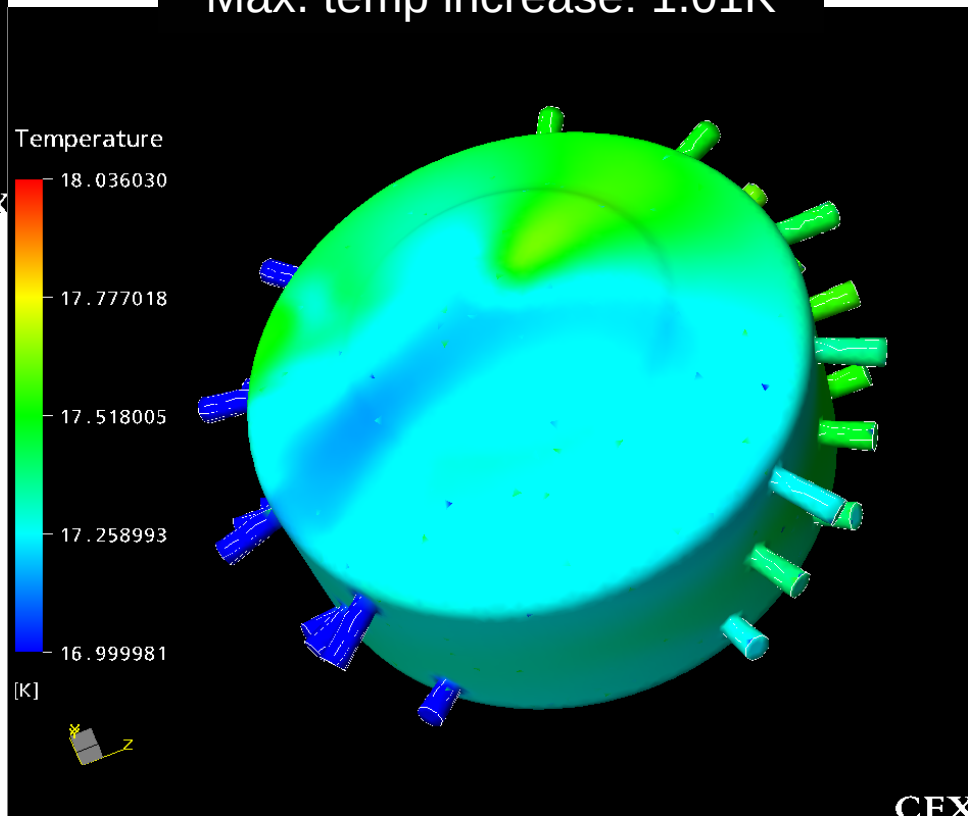


Inlet flow speed: 2 m’s

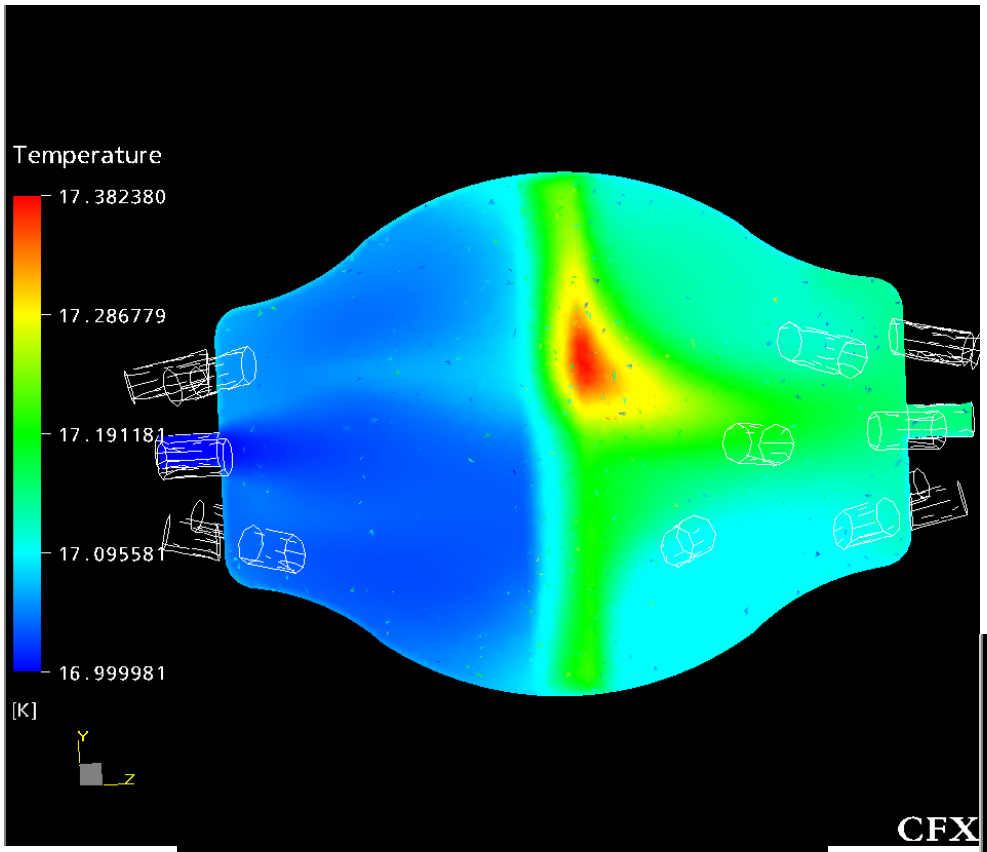
Max. temp. increase: 0.38K

Inlet flow speed: 0.5 m/s

Max. temp increase: 1.01K



An aerial view of the temperature distribution in the Absorber



Inlet flow speed: 2 m/s

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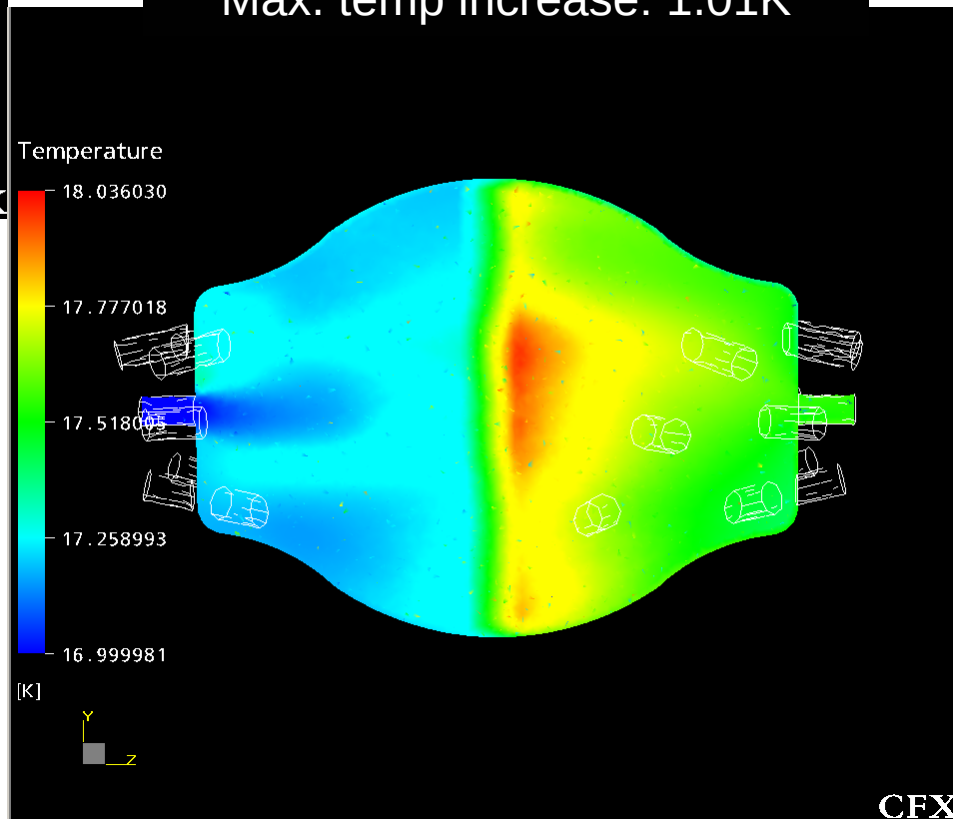
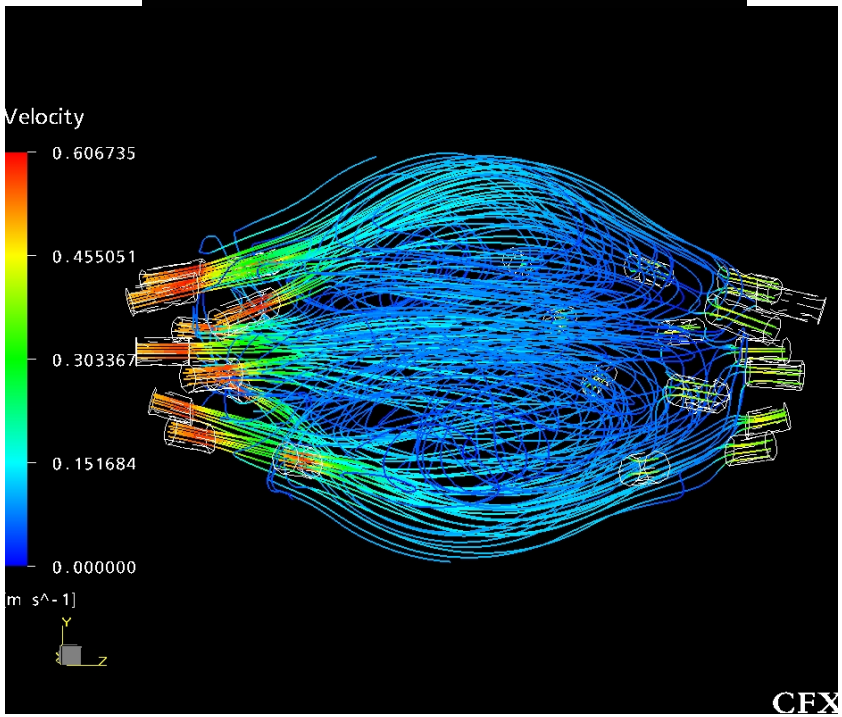
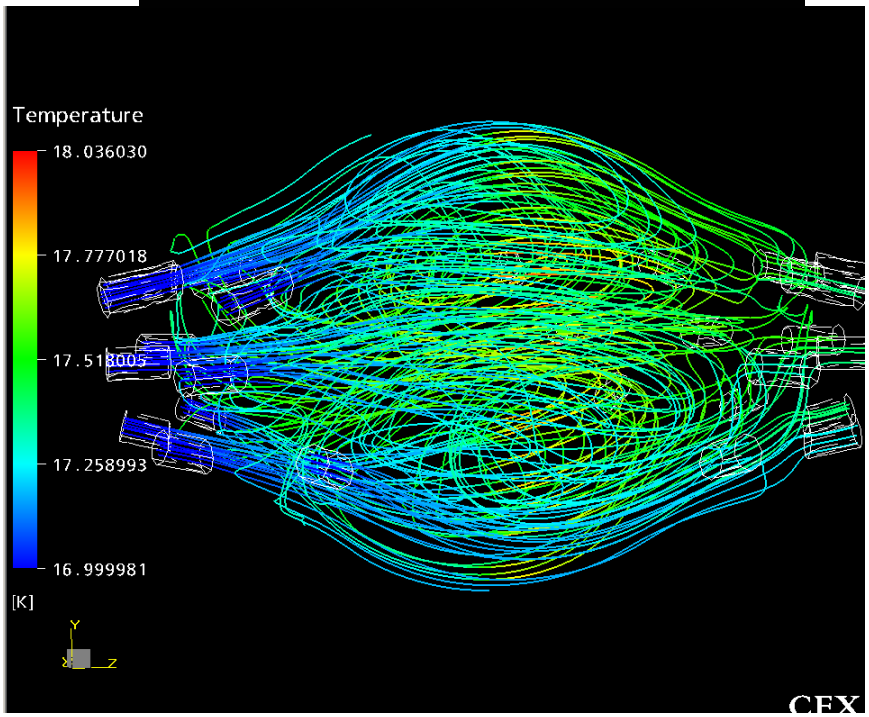


Cooling of a 150 W beam – red patch shows an area least cooled by the flow

Traces of the flow paths



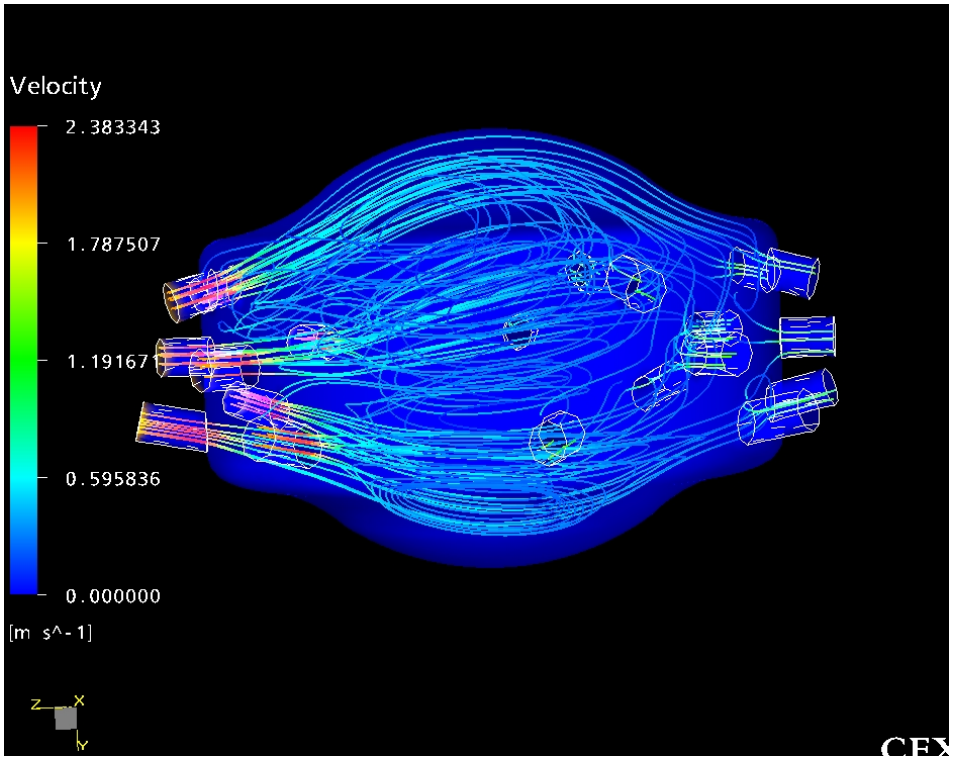
Traces of the heat paths

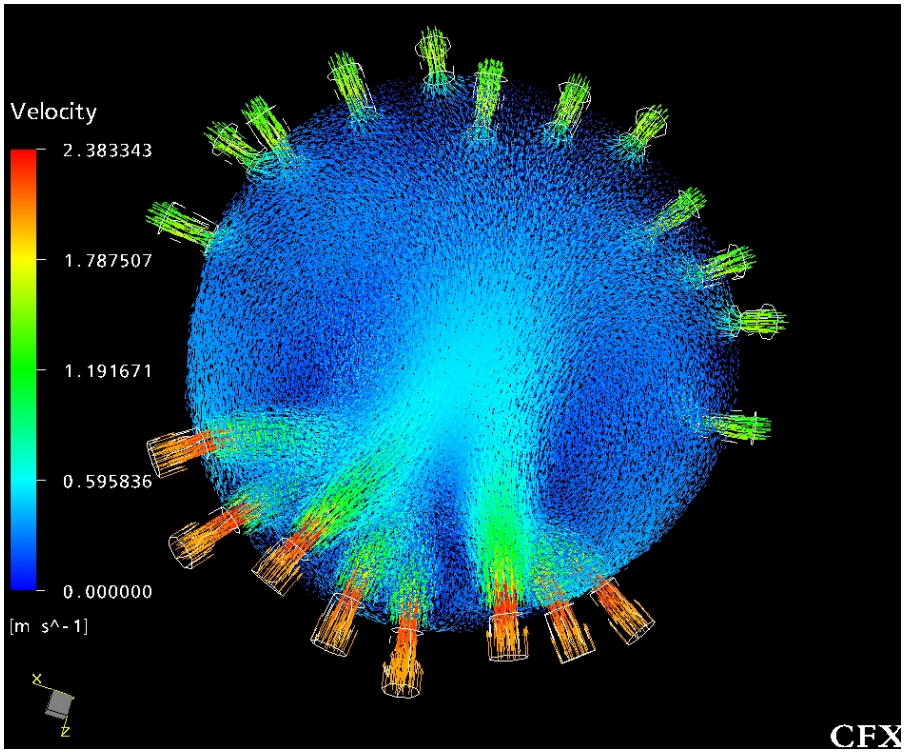


Traces of the individual Flow & Heat paths for the 0.5 m/s flow model

Model 2: with 8 inlet and 12 outlet nozzles

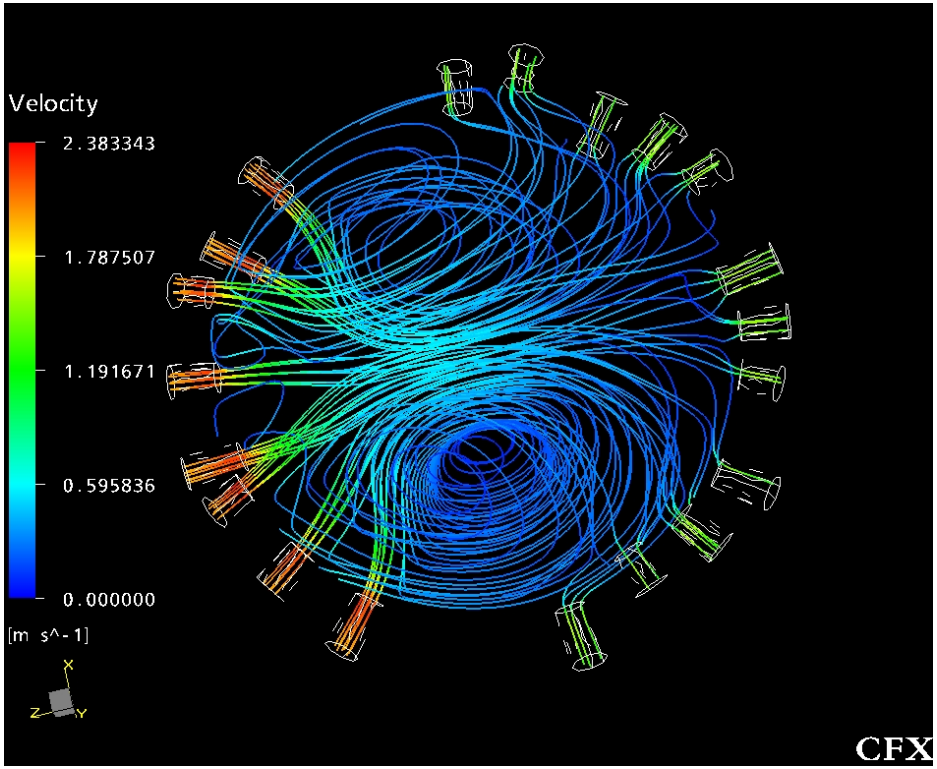
The Flow results

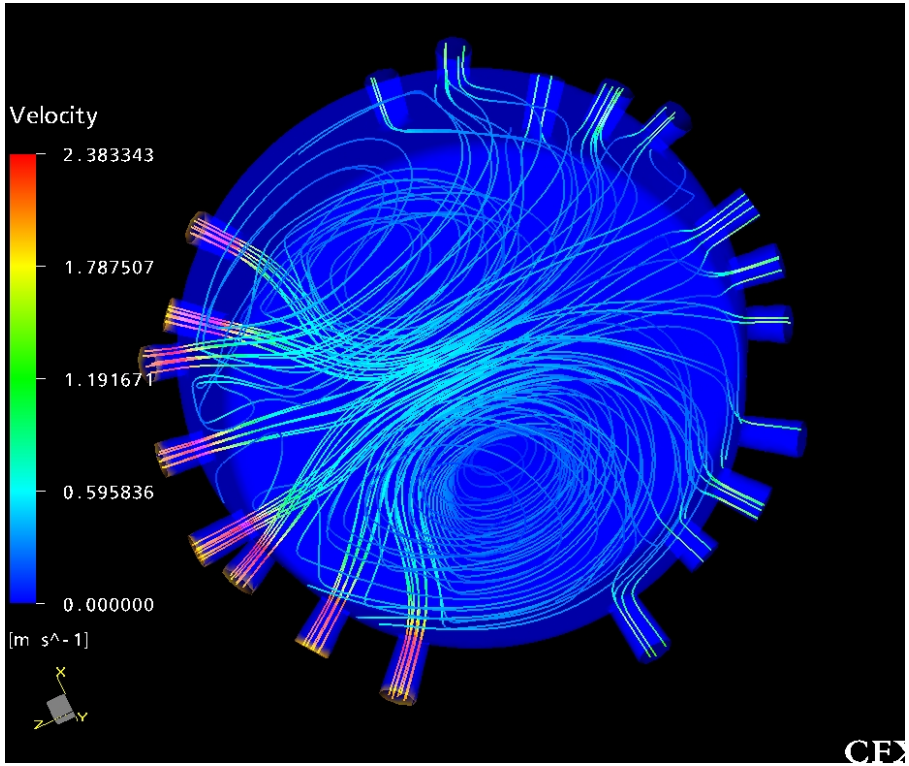




Multi-flow Paths and flow pattern of all nozzles

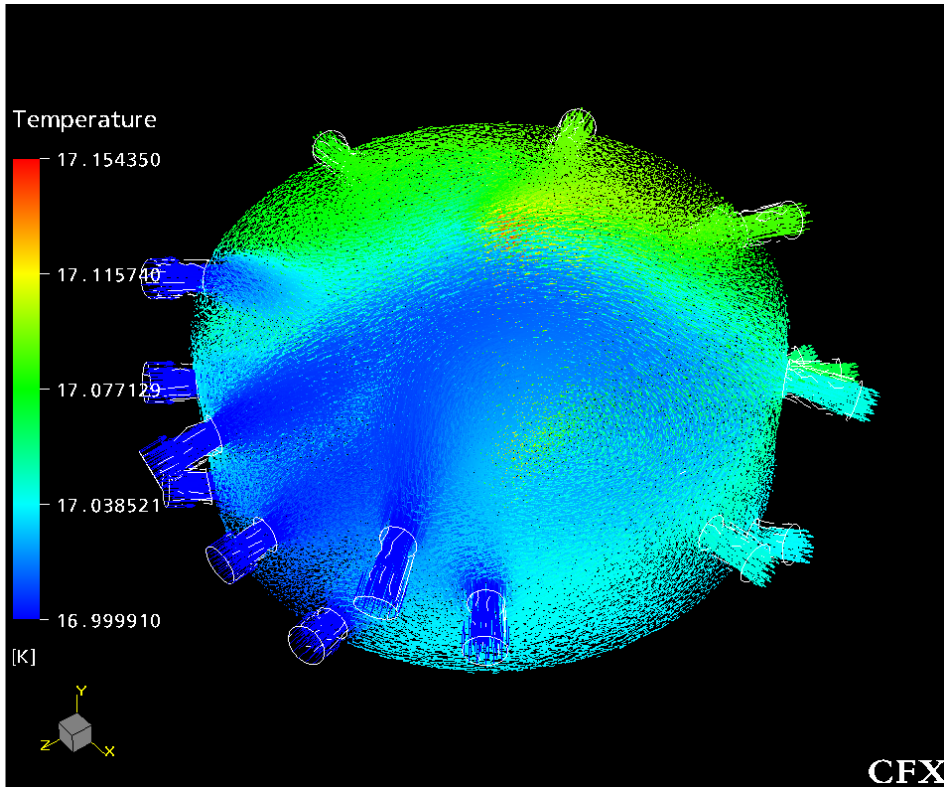
The Flow results

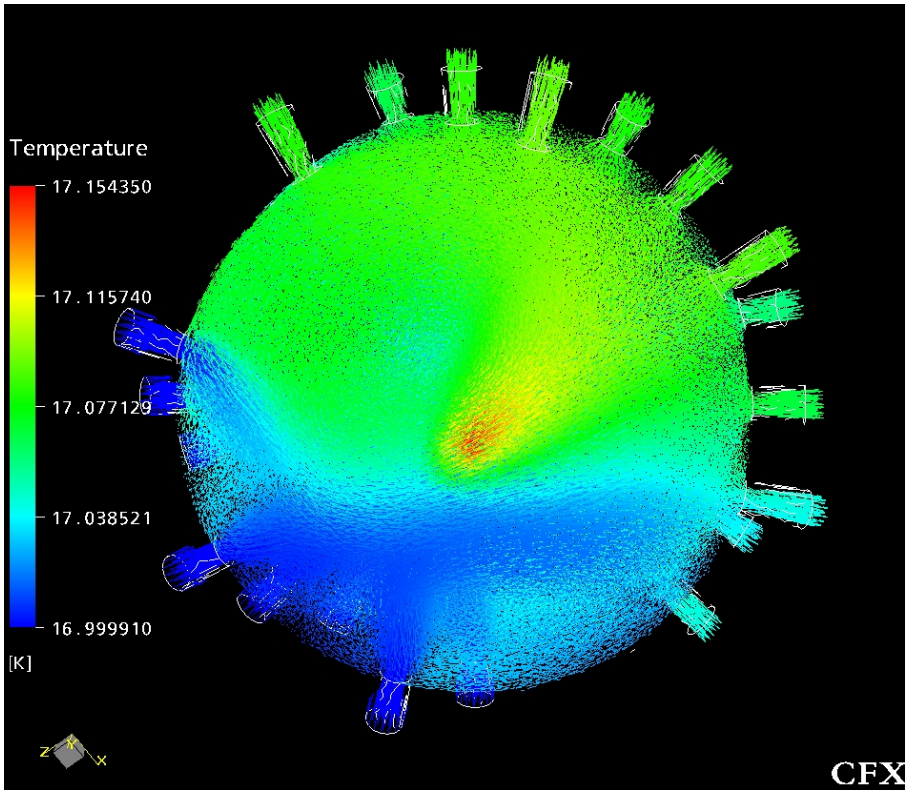




Multi-flow Paths of all nozzles

The temperature results





Temperature distribution inside the Absorber

Max. temp increase: 0.15K

Remarks:

The proposed arrangement of the nozzles seem to provide adequate coverage to both windows;

It is important that the row of inlet nozzles nearest to the window be aiming at centre of that window, and not at the opposite window as the current design implies;

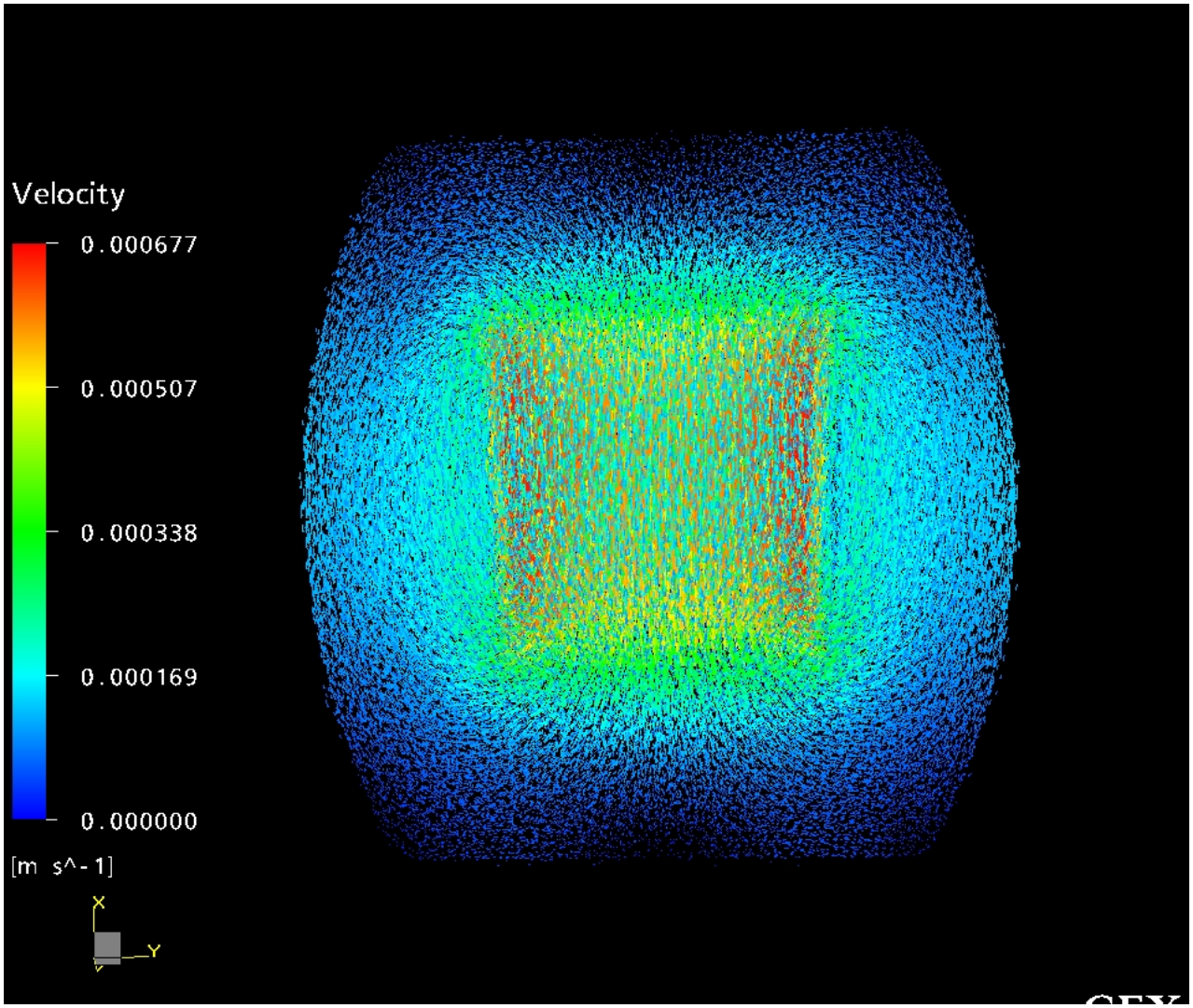
The results show that the Absorber with fewer but larger diameter nozzles seems to provide betting cooling power;

At a low inlet speed of 0.5 m/s, the Absorber with 11 inlet nozzles seems to provide adequate cooling to the 150W beam source. Temperature in the LH2 is only raised by approximately 1 K;

At present we have modelled the beam geometry as a solid tube of 10mm radius. Further analysis is needed to vary the distribution of the beam source to see if it has any effect on the thermal results;

Future analysis will include a metallic window and Absorber body to study the conduction effect. The present model assumes these boundary as an arbitrary adiabatic wall.

Convective Heat Transfer Analysis



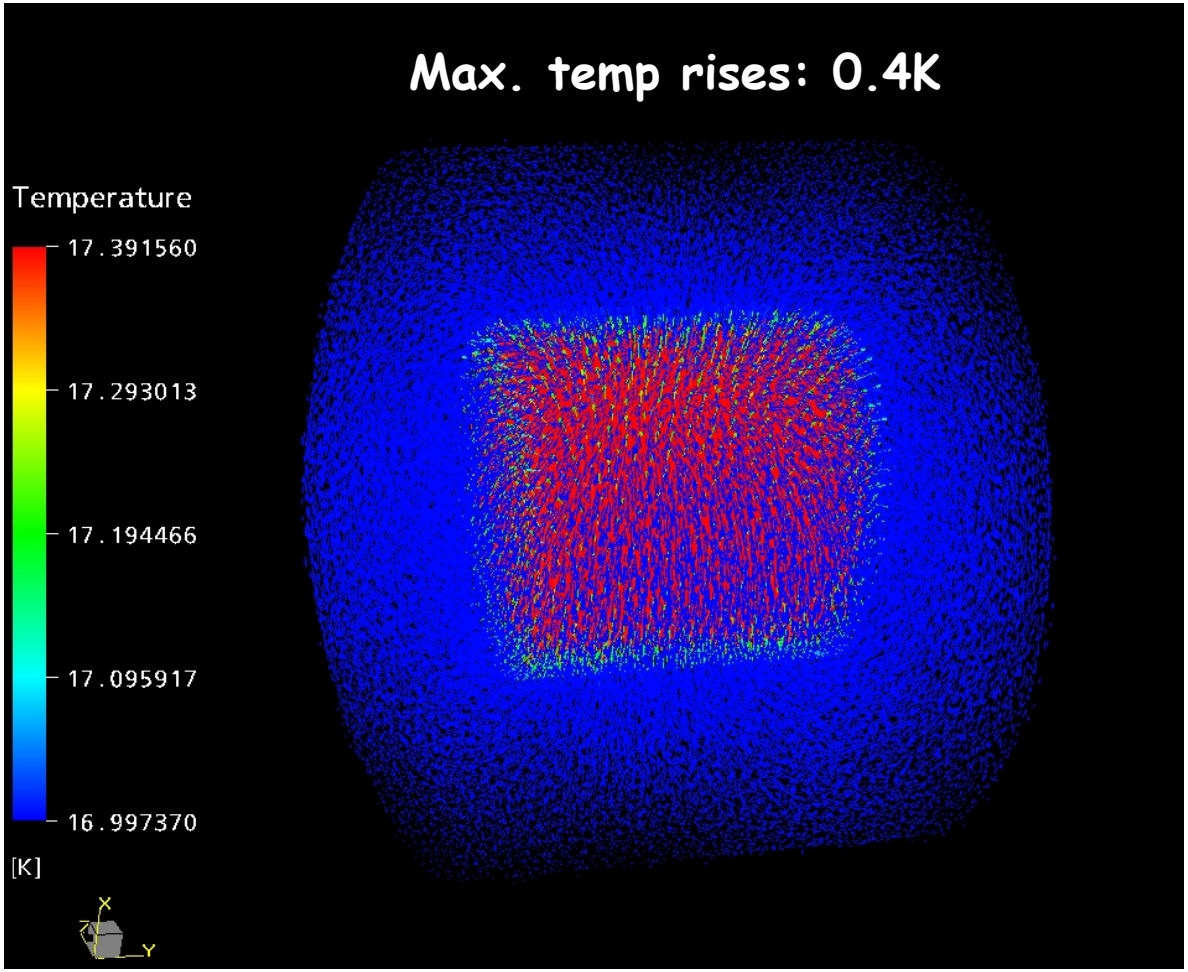
Natural Convection pattern

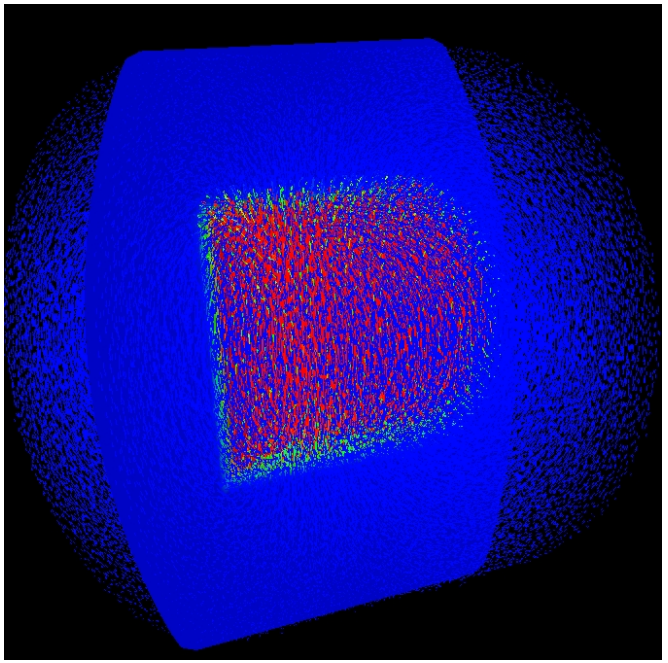
Case 1 study –Convective heat transfer only

Fluid temp: 17K

Heater Power: 60W

Wall temp. 17K constant





Temperature distribution pattern

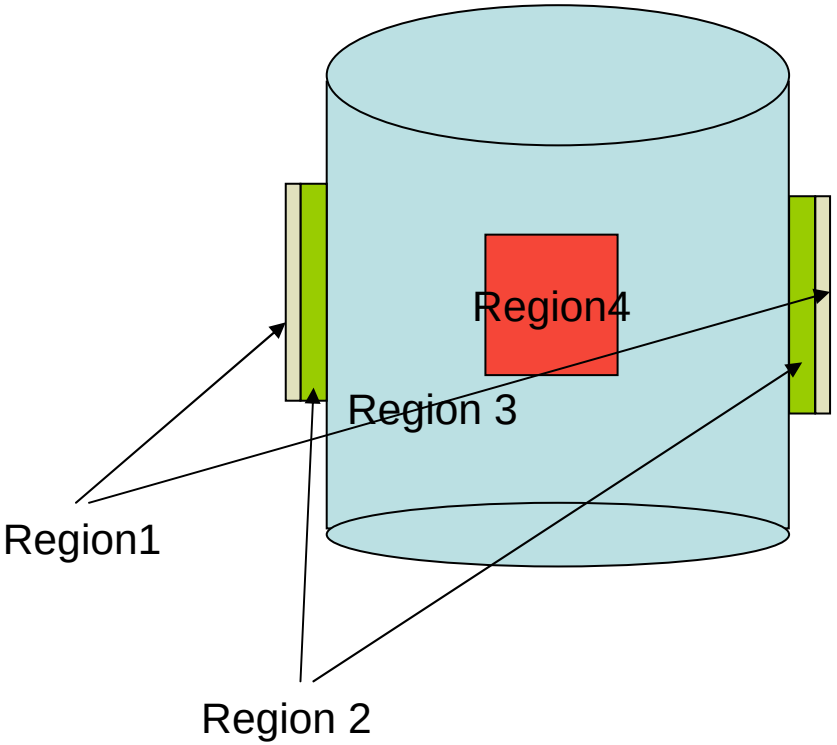
Case 1 study –Convective heat transfer only

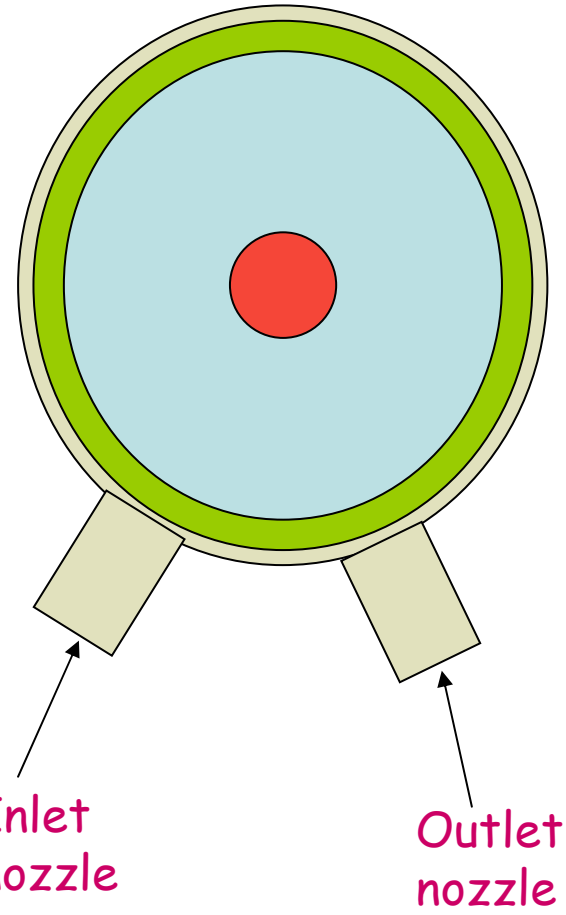
Fluid temp: 17K

Heater Power: 60W

Wall temp. 17K constant

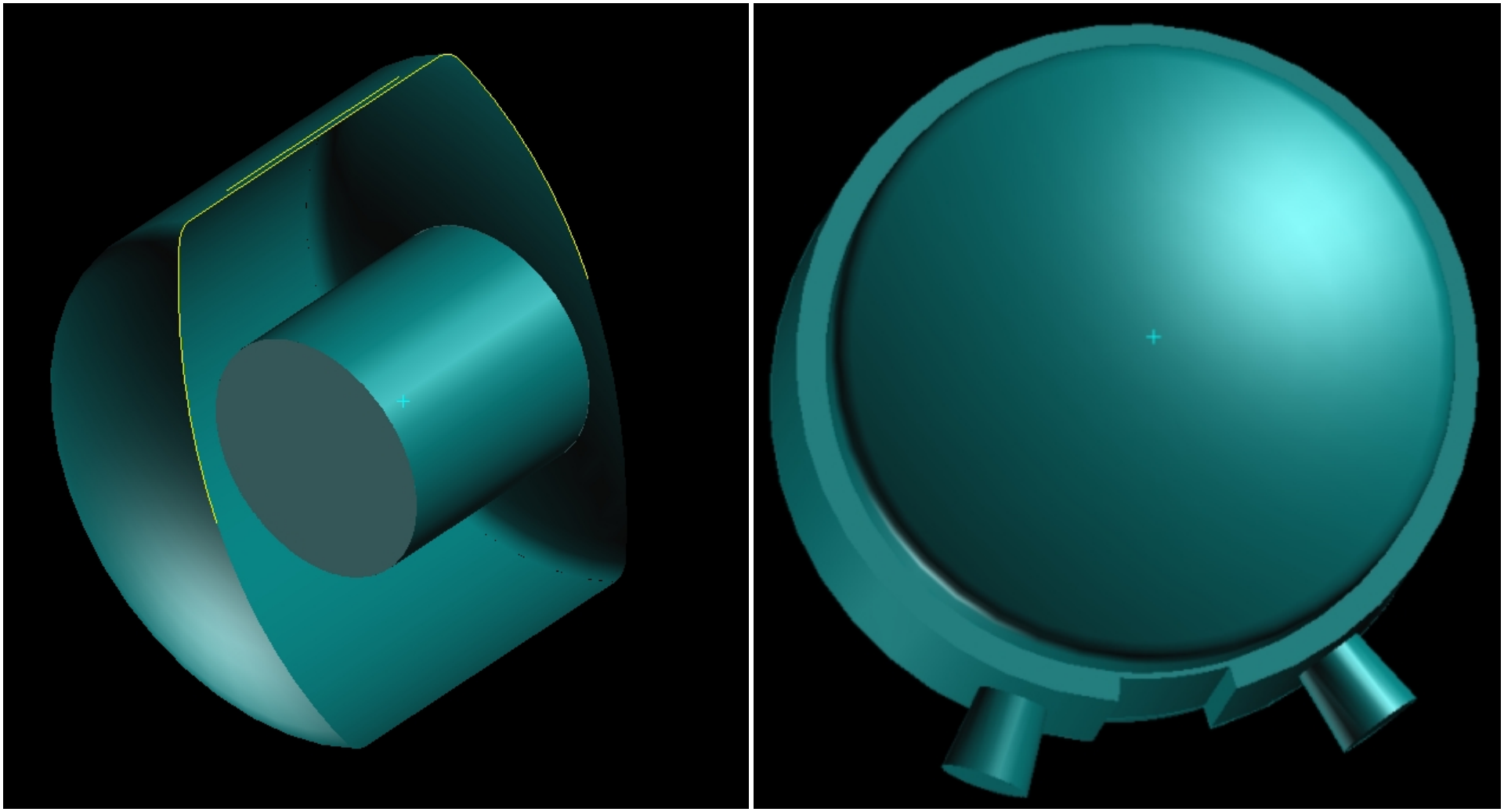
Modelling convective heat transfer with active cooling outside



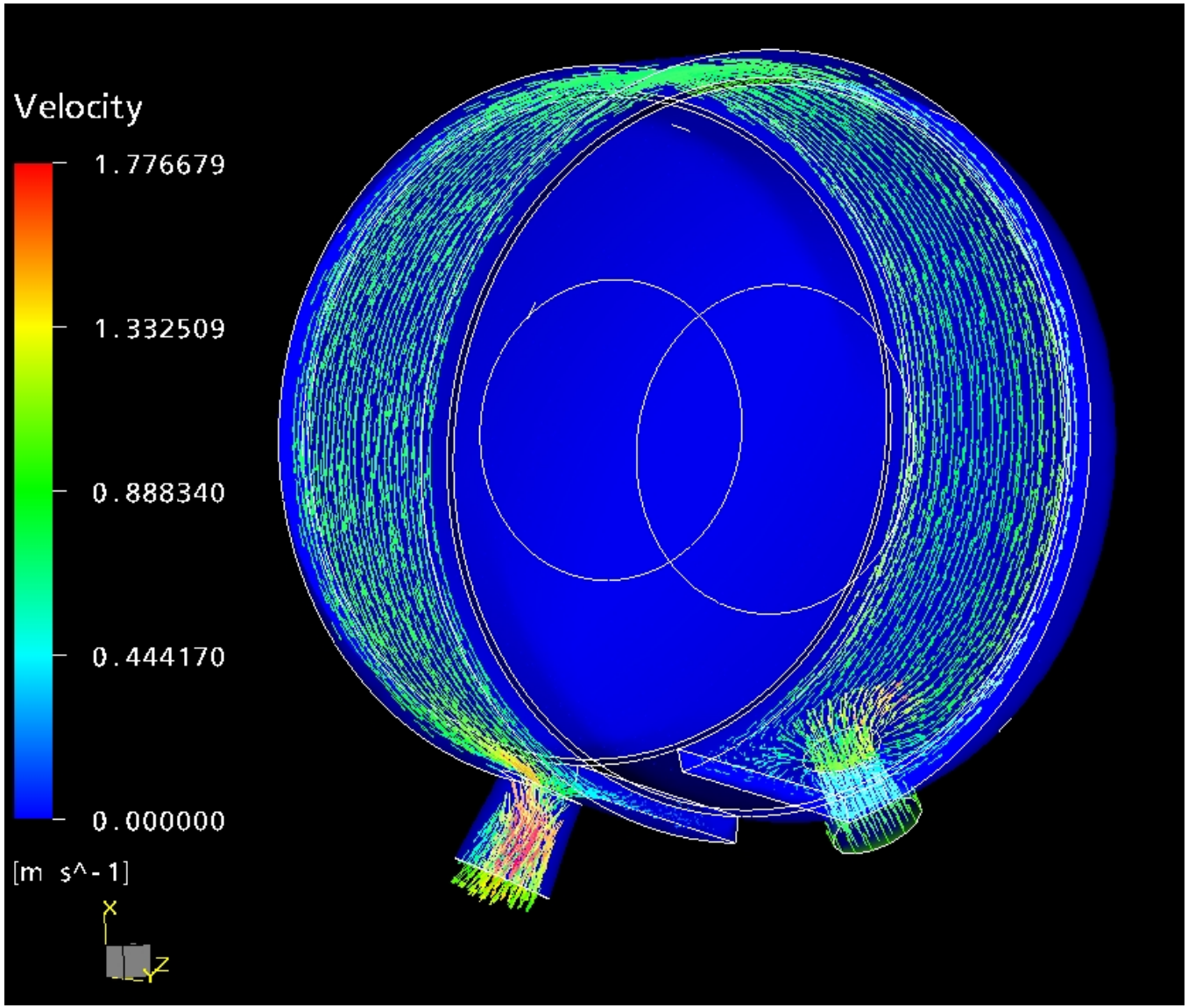


Region 1 – flow compartment
Region 2 – dividing wall
Region 3 – Convective chamber
Region 4 -- Heater

Top view of the model



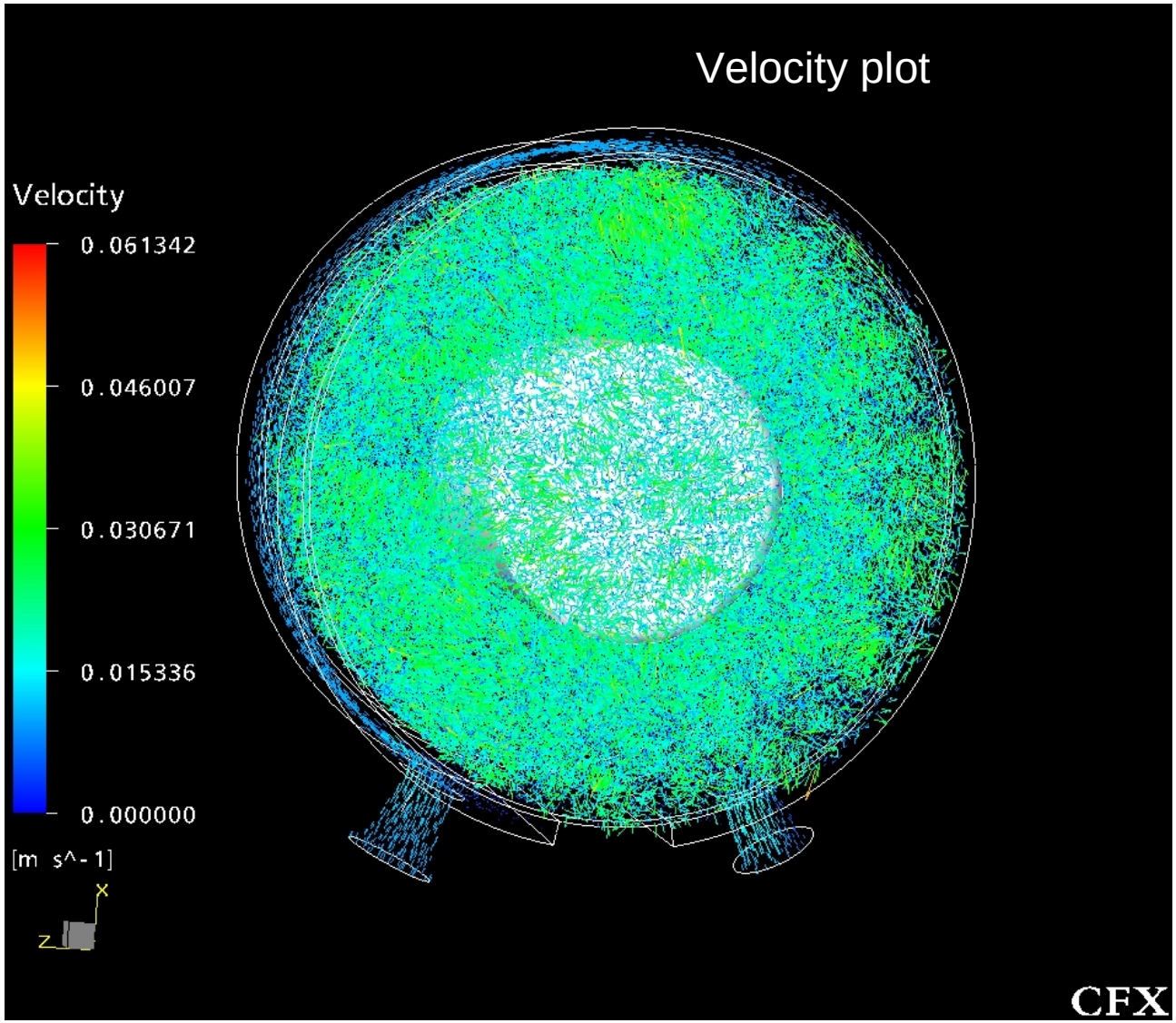
The 3-D model of the Convective Absorber



Case 2 –

Coolant inlet velocity: 1m/s
Temp: 4K
Heater Power: 60W

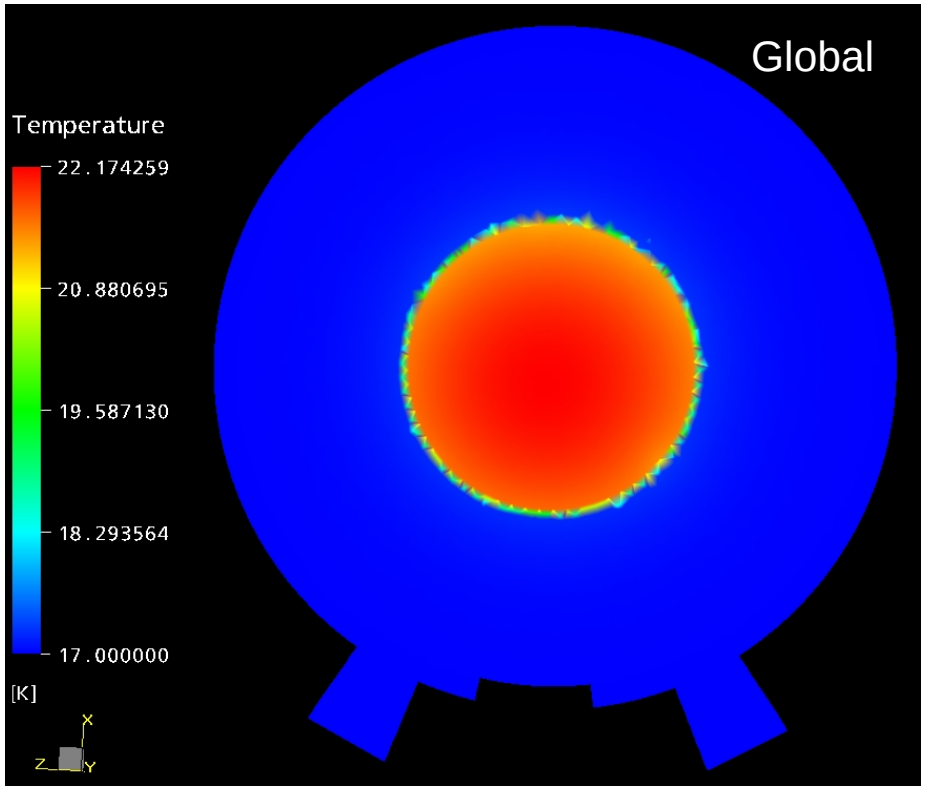
Plot showing Coolant flow pattern

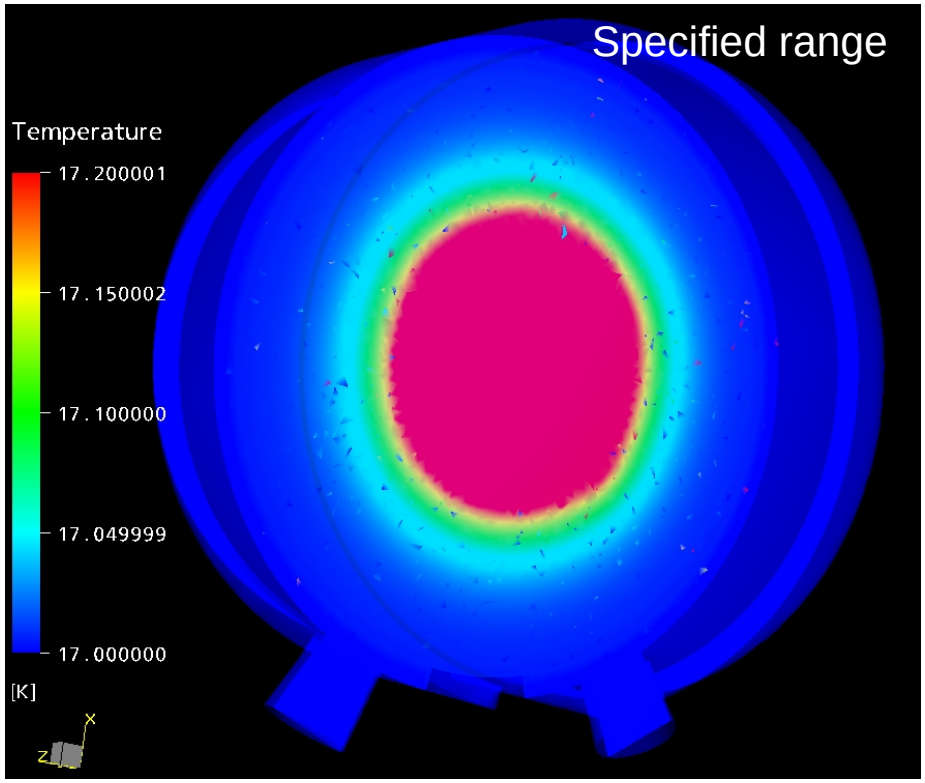


Case 3 –

Coolant inlet velocity: 0.01m/s
Temp: 17K
Heater Power: 60W

temp. plots





Case 3 –

Coolant inlet velocity: 0.01m/s

Temp: 17K

Heater Power: 60W