ANSYS Simulation Results

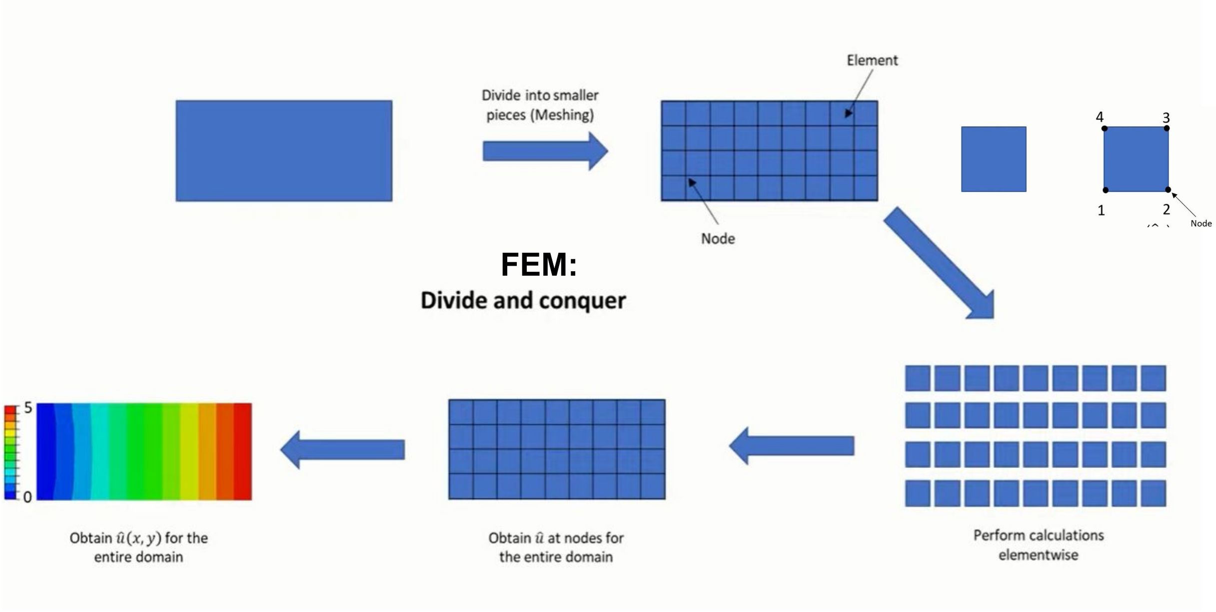
In-Lab Setup and Beampipe Bakeout

By Emma Yeats

Background

Quick Intro to Finite Element Analysis (FEA)

FEA: Utilizes the general Finite Element Method (FEM) to analyze and calculate the solution to boundary value problems on complex 3D geometries.



FEM: obtains an approximate solution to a set of differential equations, boundary conditions by converting the boundary value problem to a system of linear equations.

ANSYS Fluent

General steps:

- ❖ Create your complex geometry in ANSYS's CAD software, SpaceClaim
- ❖ Create a mesh

smaller mesh size ↔ more accurate solution ↔ longer computation

- ❖ State initial conditions, materials and domains
- ❖ Initialize and calculate. Then check out your results!

All simulations were solved using ANSYS Fluent software.

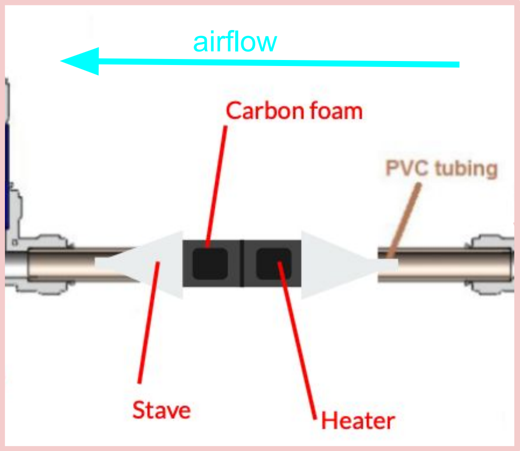
- ❖ Typically used for fluid flow simulations, but we calculated temperature distributions to study the effects of air cooling.

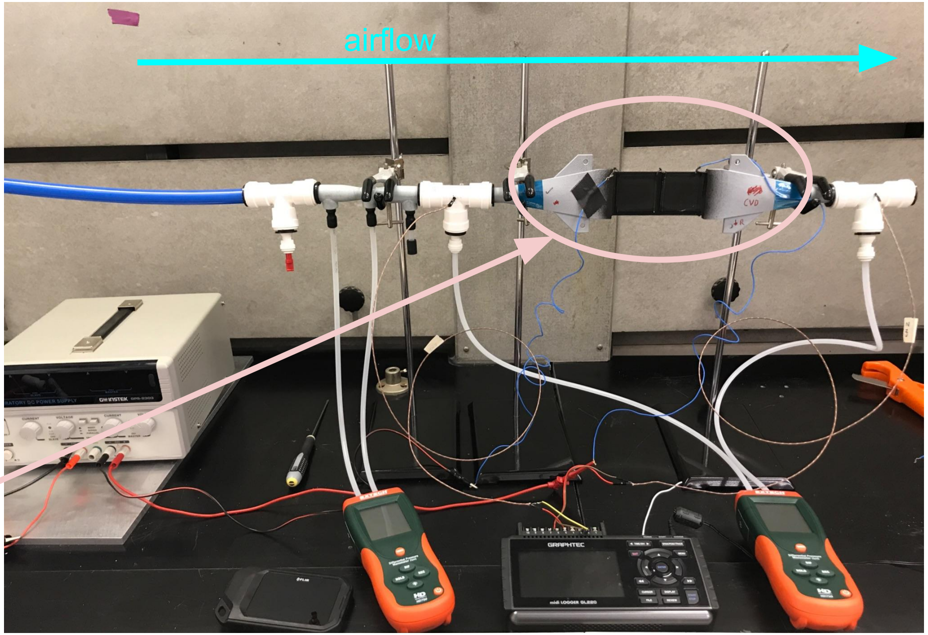
In-Lab Stave Setup

Thermal Simulation

In-Lab Stave Setup

In-lab setup flows air of varying temperature through carbon foam interior to the stave to cool the heater.

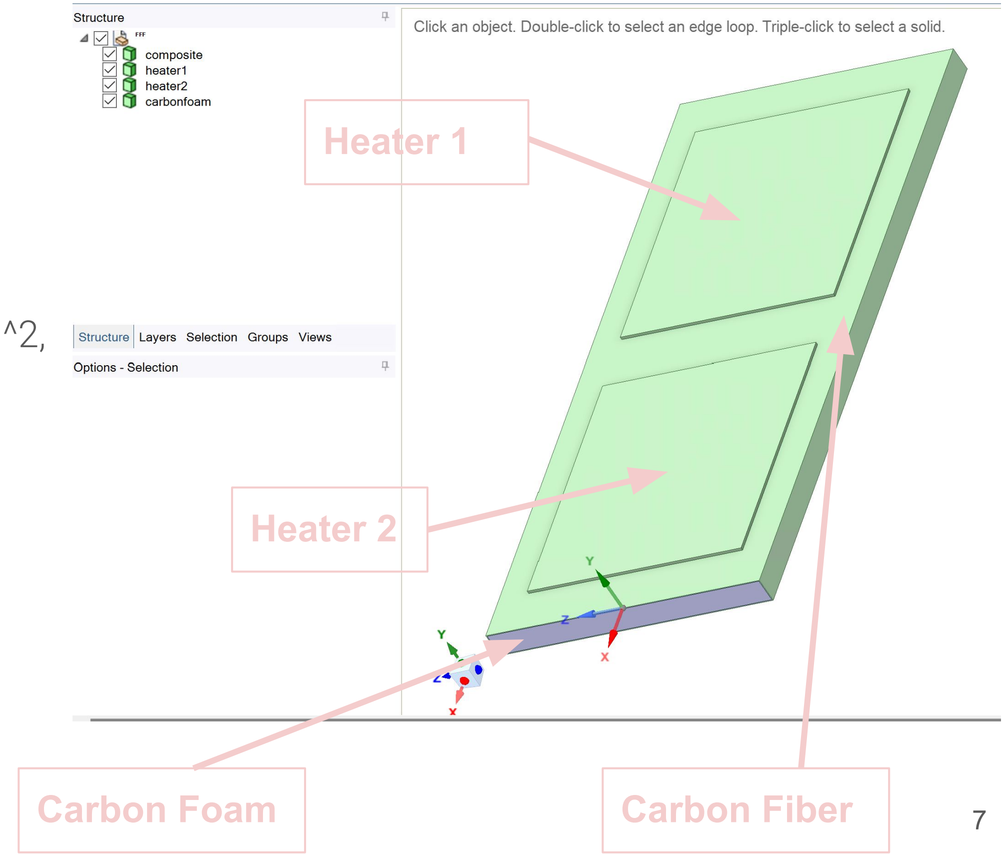




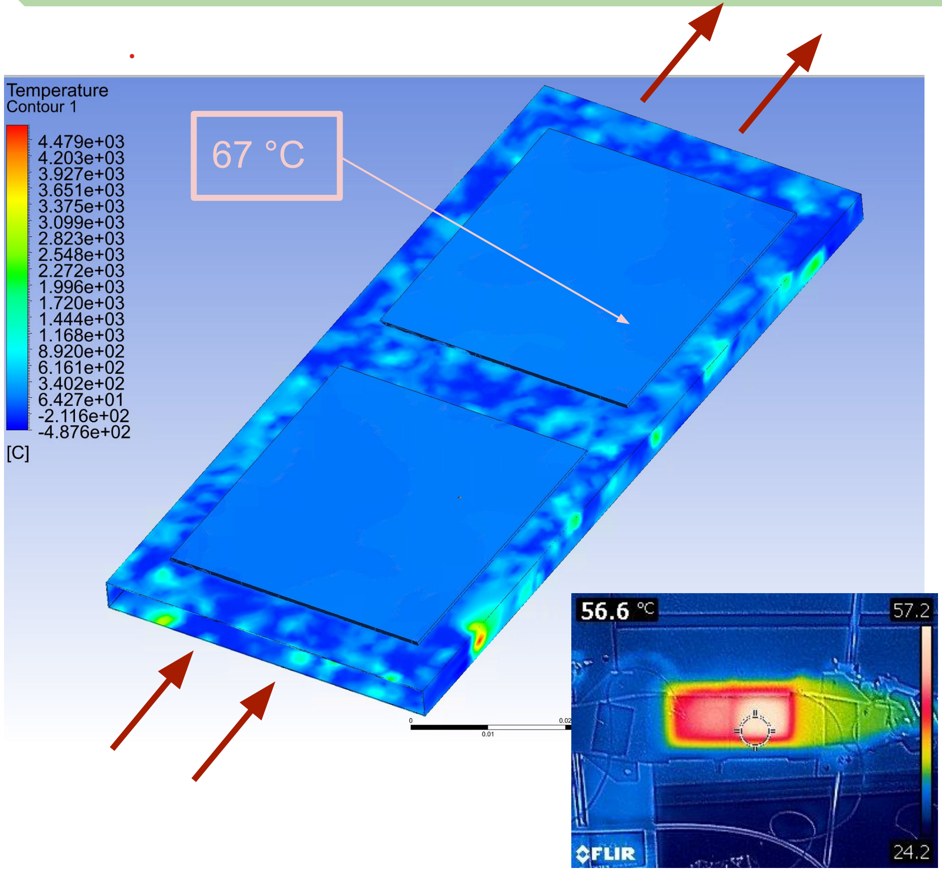
ANSYS Setup

- Initial Conditions
  - Heat Output 3000 W/m^2
  - Incoming airflow velocity 5 m/s
  - Incoming airflow temperature 300 K
  - Porous fluid domain with viscous resistance coefficients K=.4462e+8 m^2, c=.15

- Materials
  - Carbon foam (porous zone)
  - Carbon fiber
  - Pure silicon



Simulation Results



- ❖ Results are close to matching the data found by the in-lab setup.
  - ➢ Center of first heater ~325 K (51°C)
  - ➢ Center of second heater ~338 K (65°C)
- ❖ Porous medium coefficients may need to be adjusted
- ❖ Overall, provides a nice benchmark to continue with more air cooling simulations

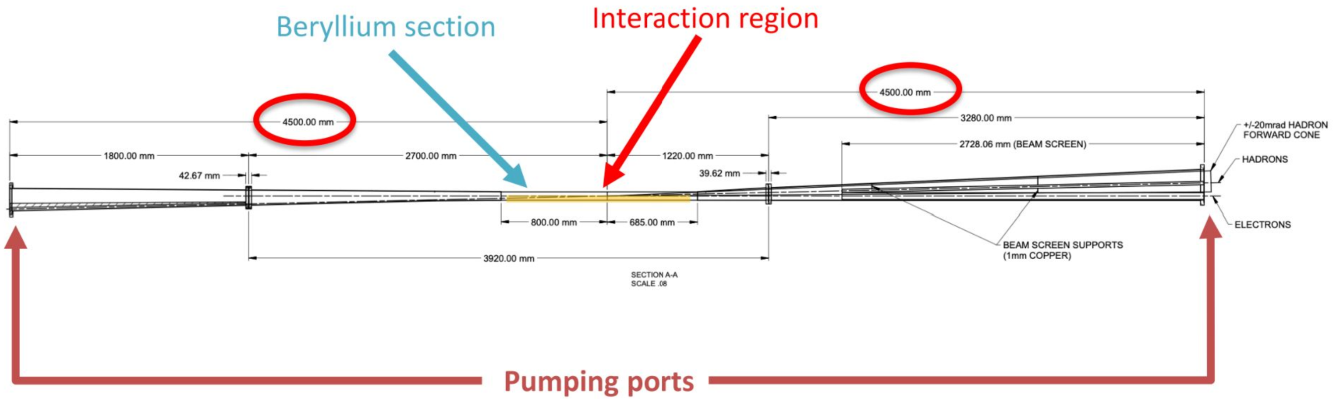
Beampipe Bakeout

Thermal Simulation

Bakeout Problem

- We need to remove water molecules and other contaminants from the interior section of the beampipe (beryllium/interaction region).
  - Pump hot gas in, at ≥100°C, to break water molecule bonds

- A previous ANSYS study found the minimum distance between Layer1 and the beampipe, ~5mm, in order to keep Layer 1 around 30°C but the study neglected the effects of air cooling on the beampipe

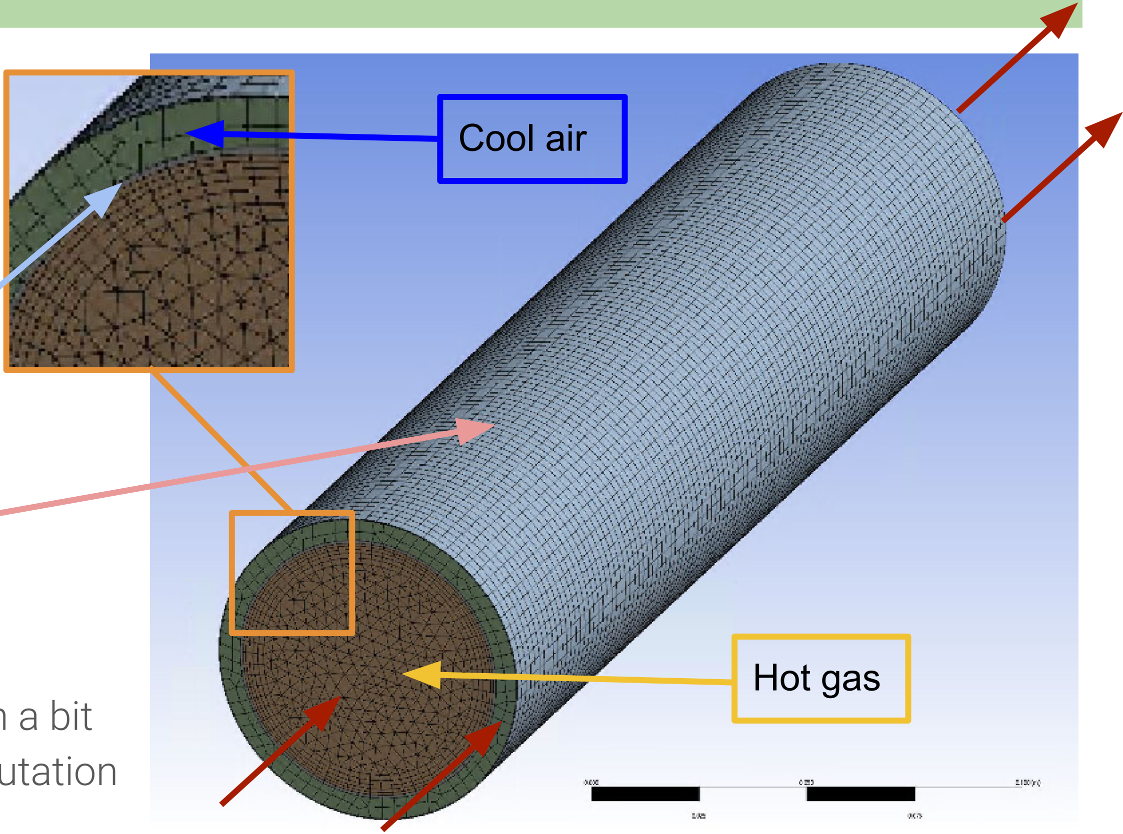


A recent experimental setup had difficulty achieving a gas temperature ≥100° C

Setup

- Initial Conditions at Inlet
  - Cool air temperature 298 K
  - Cool air velocity 5 m/s
  - Hot gas velocity 5 m/s

- Materials
  - Beryllium Alloy
  - Pure silicon

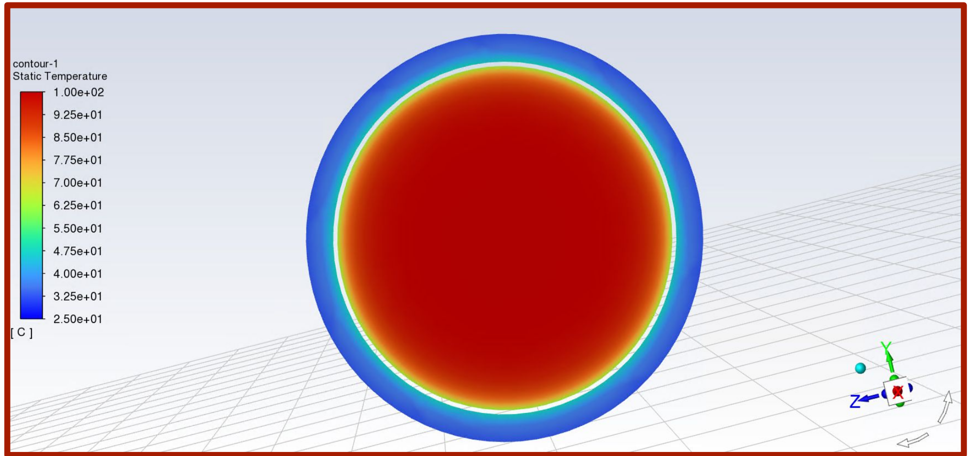


Note: had to make the width of the silicon a bit larger due to limitation in meshing/computation

Simulation Results

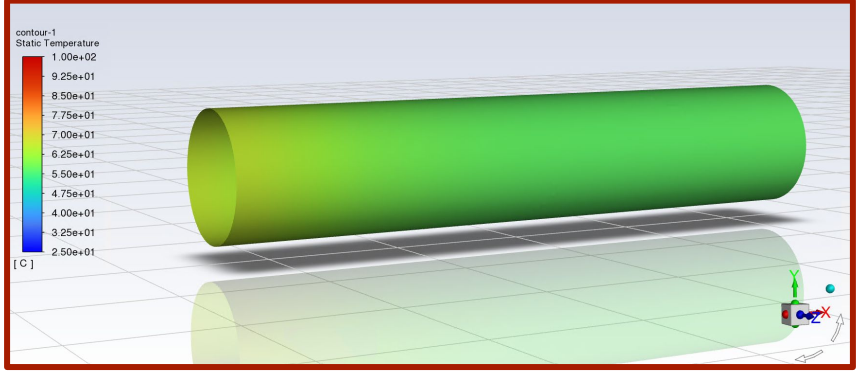
Inner edge cools significantly (60-70°C)

Not great!



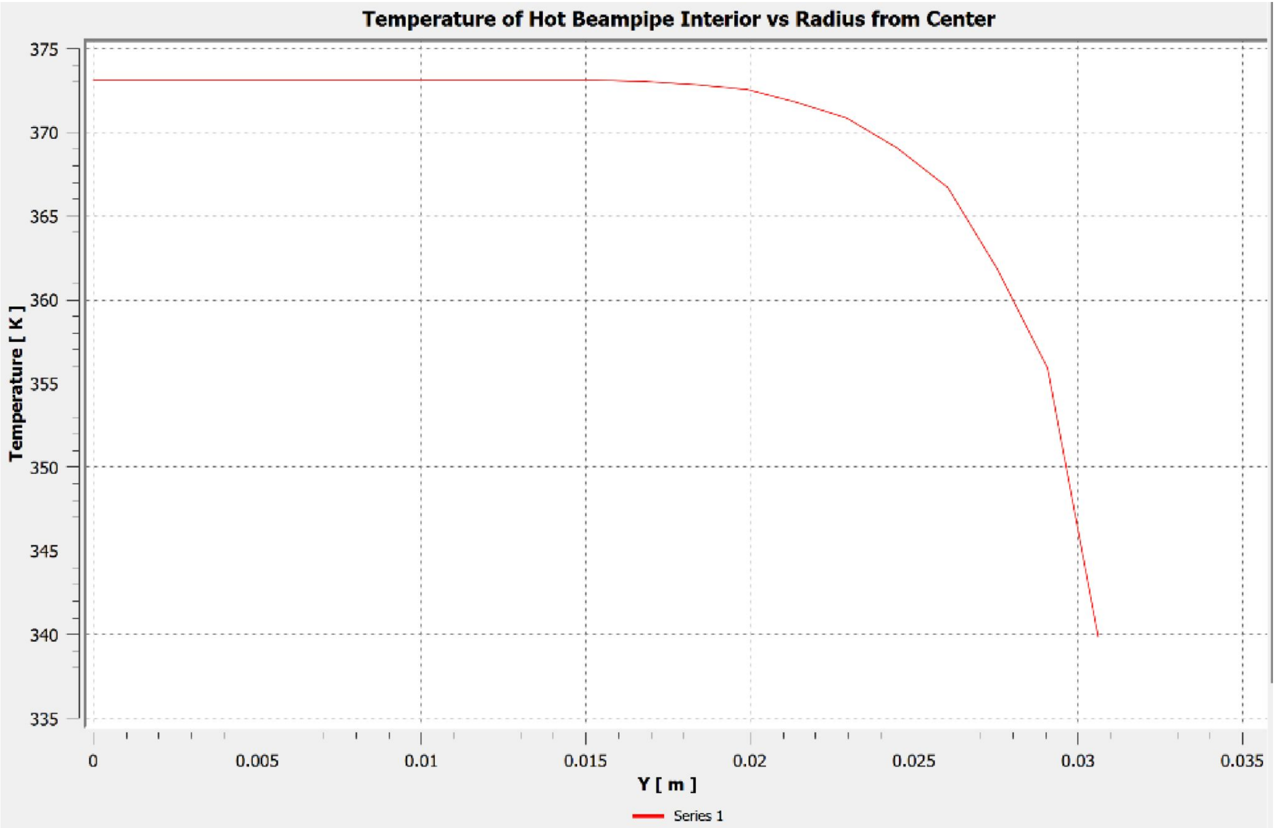
Beampipe Outlet

Inner Surface of Beampipe



Likely need to reoptimize a few parameters, like cooling air velocity, temperature, and hot gas temperature

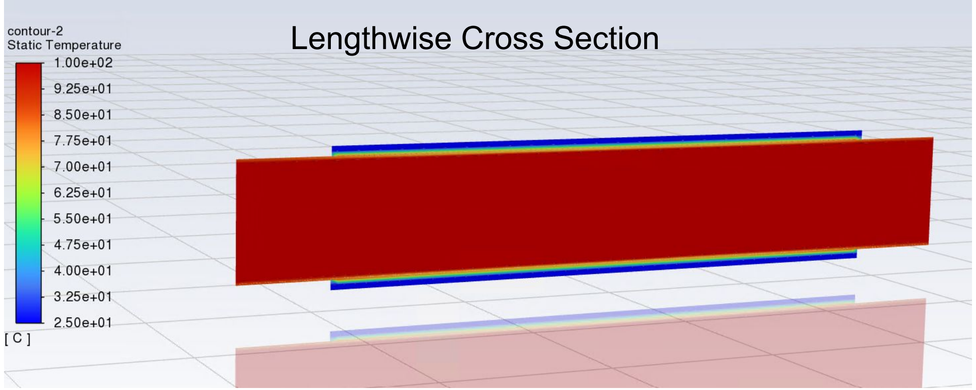
Simulation Results



Sudden drop at edge of beampipe interior (at the outlet).

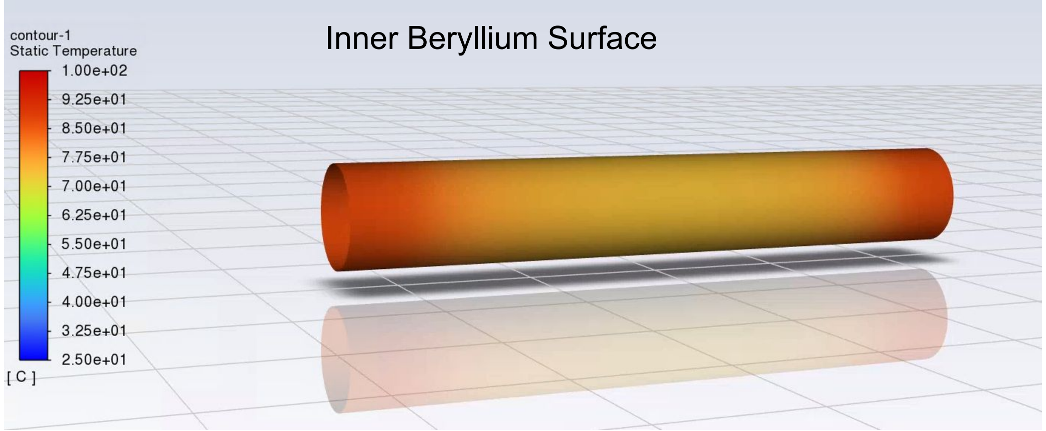
Lowest Temperature is 340 K, or ~67°C

Back to Basics



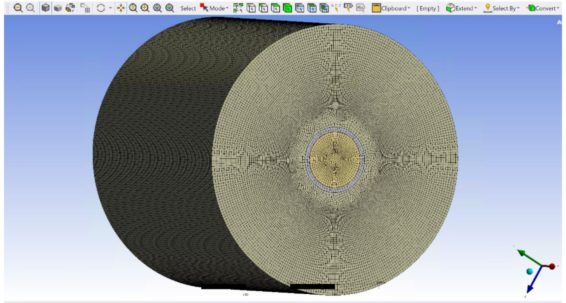
In light of previous results, we wanted to study what would happen if the hot gas was held at constant temperature (100°C) paired with no airflow.

If we can find the minimum hot gas temperature needed to give the beryllium a temperature of 100°C, then our results should mirror JLab's (future work)



Summary + Future Work

- ❖ Verified simulation results with experimental data (in-lab setup)
- ❖ Began study of beampipe bakeout and working towards a more optimized setup
- ❖ What’s next?
  - ➢ Generally, refine mesh and run more iterations (possible new computer?)
  - ➢ Check resistance coefficients for porous medium (carbon foam)
  - ➢ Apply air cooling simulation to the barrel and disk components of EIC tracker
  - ➢ Include a more accurate geometry of the entire beryllium section of the beampipe
  - ➢ Verify type of hot gas used inside
  - ➢ Test out different hot gas temperatures
  - ➢ Test out different airflow velocities and temperatures



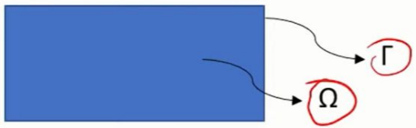
Special Thanks to Youtube Teachers/References

Big shoutout to Ming Zhao on youtube because he's awesome

- Singularity Engineering
- CFD Ninja
- Solid Mechanics Classroom
- Ansys-Tutor
- *Thermal and Mechanical Analysis of Carbon Foam* by Mihnea S. Anghelescu
- *EIC –Thermal Analysis of Beryllium Section of Beampipe* by Pablo Campero

Backup

Mathematical treatment



- Poisson's equation:

$$\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} = \phi$$

(+ Boundary conditions)

- If $u^e(x,y)$ is an exact solution, then
  - $\frac{\partial^2 u^e}{\partial x^2} + \frac{\partial^2 u^e}{\partial y^2} - \phi = 0$
- Let $\hat{u}$ is an approximate solution,
  - $\frac{\partial^2 \hat{u}}{\partial x^2} + \frac{\partial^2 \hat{u}}{\partial y^2} - \phi \neq 0$
  - Residual $R = \frac{\partial^2 \hat{u}}{\partial x^2} + \frac{\partial^2 \hat{u}}{\partial y^2} - \phi$

- Now the objective is to find an approximate solution $\hat{u}$ such that R is close to zero at each point within our domain Ω

- Weighted-Residual (WR) statement
  - $\int W(x,y)(\frac{\partial^2 \hat{u}}{\partial x^2} + \frac{\partial^2 \hat{u}}{\partial y^2} - \phi)\, d\Omega = 0$ (or)
  - $\int W(x,y)(\nabla^2 \hat{u} - \phi)\, d\Omega = 0$

Integrate by parts

- Weak form of the WR statement
  - $\int W\, \nabla\hat{u}.\hat{n}\, d\Gamma - \int \nabla W . \nabla\hat{u} d\Omega - \int W\, \phi\, d\Omega = 0$

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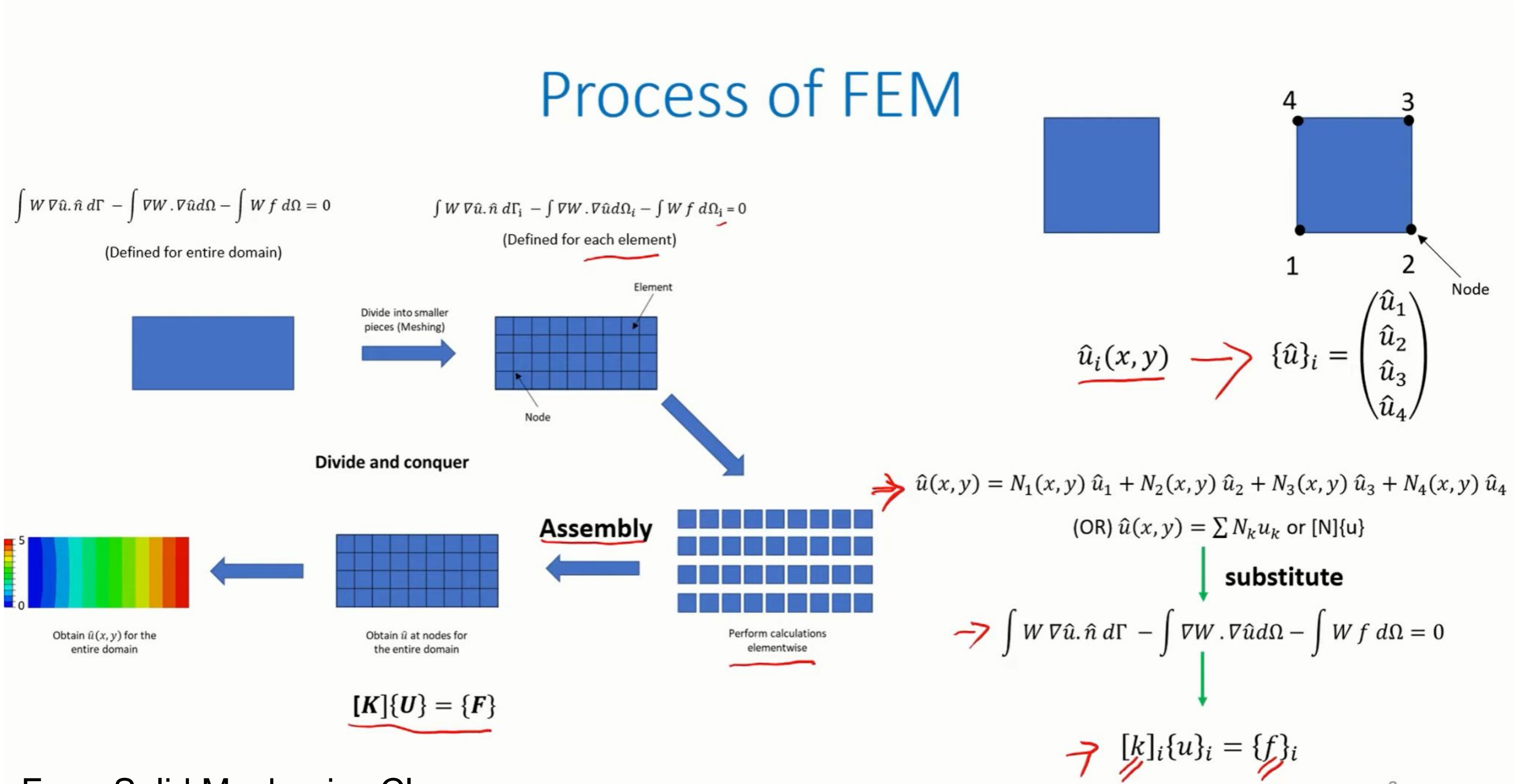
Backup



From Solid Mechanics Classroom