Thermal & Fluids Analysis Workshop

GSFC · 2015

Thermal Fluid Analysis for Nuclear Thermal Propulsion Radiation Shield

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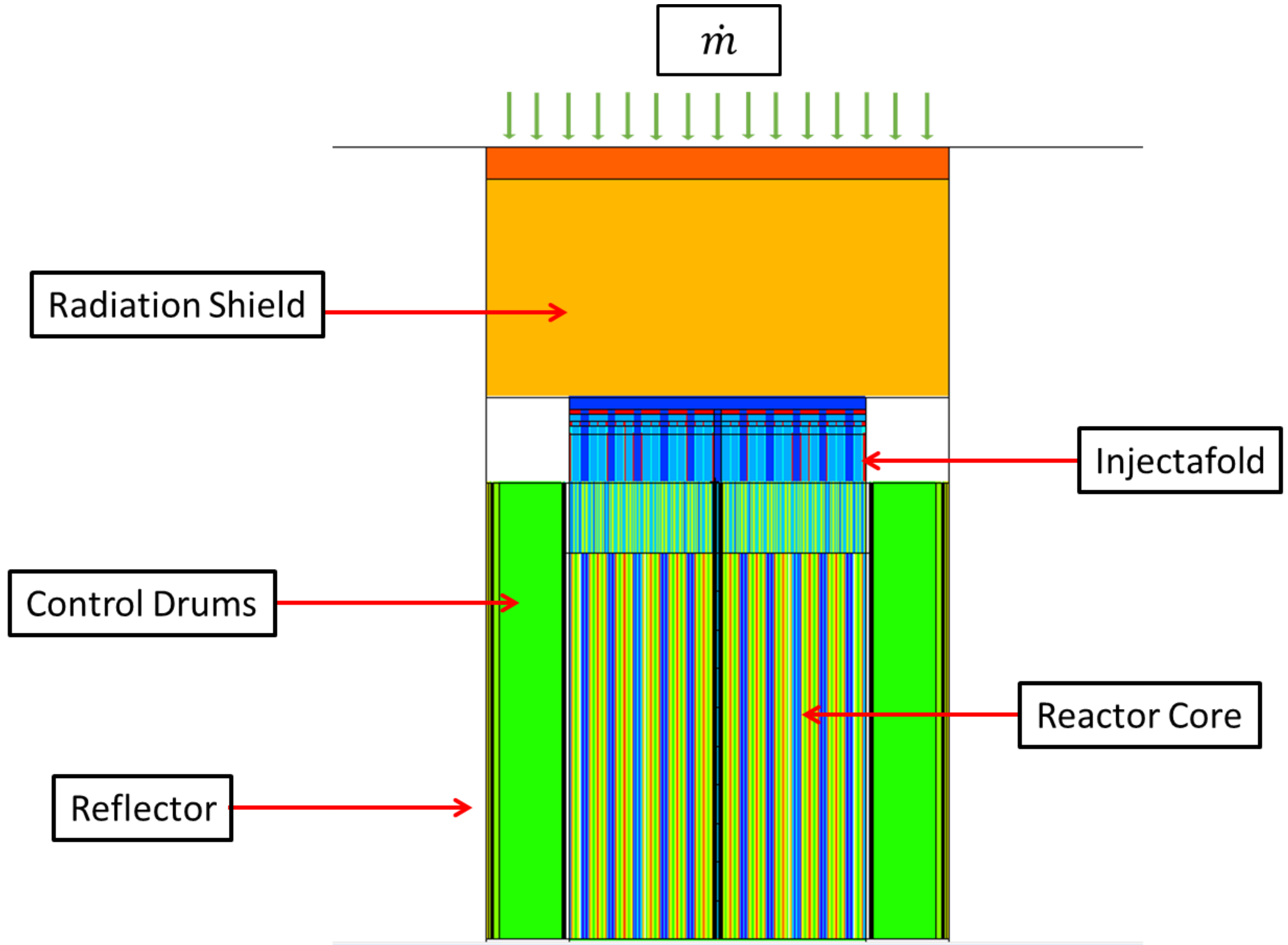
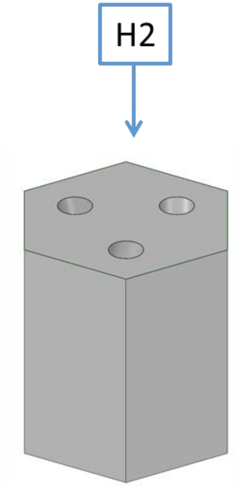
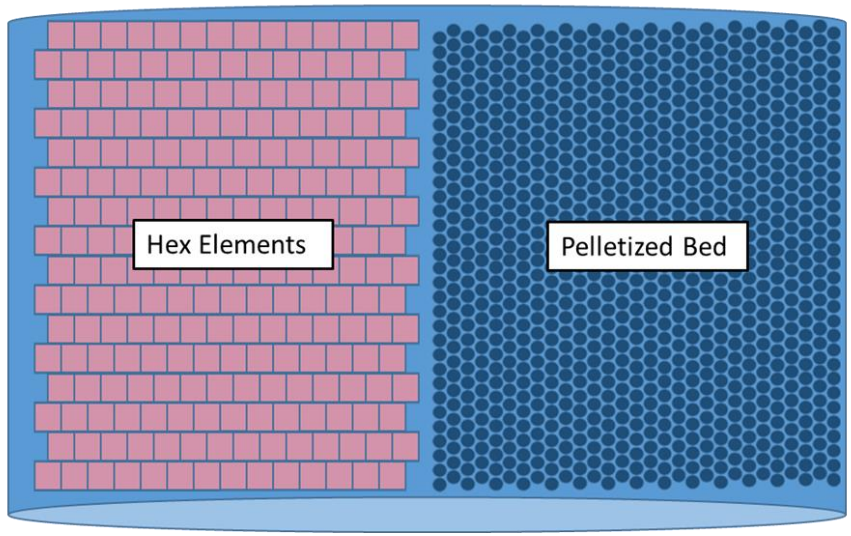
Radiation Shield



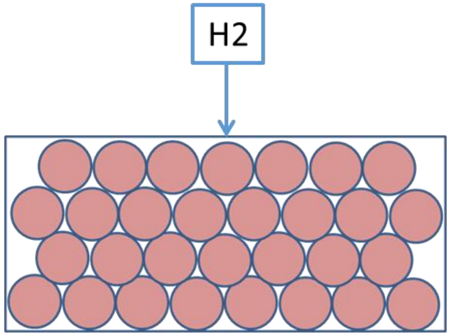
Radiation Shield Concepts

<u>Hex elements stacked</u>
- Cooling using flow channels through each hexagon element

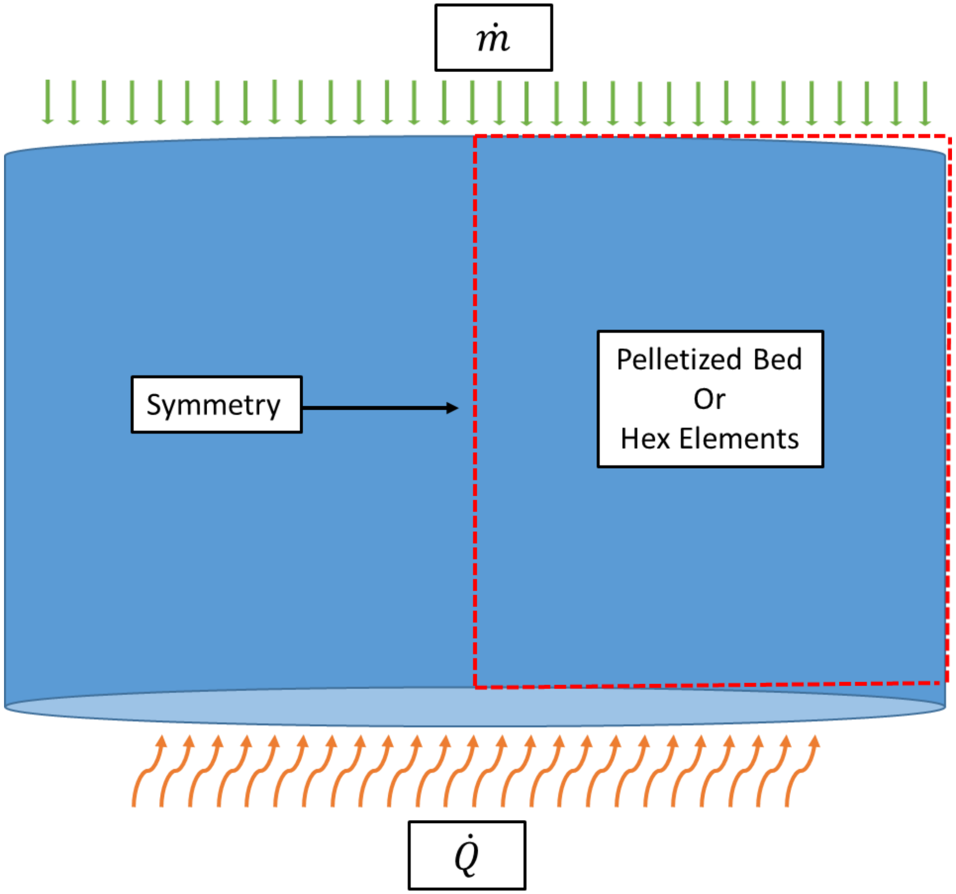




<u>Pelletized bed</u>
- Good flow distribution and increased surface area for cooling



Parameters and Assumptions for Pelletized Bed



Model Parameters

- Mass flow= 13.2 [kg/s]
- Superficial Velocity= 5.4 [m/s]
- Outlet Pressure= 3757 [kPa]
- Inlet Temperature= 306.6 [K]
- Shield Diameter= 1 [m]
- Shield Length = 0.5 [m]
- Void Fraction= 0.4
- Mapped Heat Load
- Allowable DeltaP= 1379[kPa]≈ 200 [psi]

Model Assumptions

- Axisymmetric
- Pellet Diameter= 2 [cm]
- Density is based on ideal gas
- Gas and pellet surface temperature are the same

Pelletized Bed Pressure Drop

The Ergun equation calculates the pressure drop along the length of a pelletized bed given the fluid superficial velocity, pellet size, void fraction, and fluid viscosity and density.

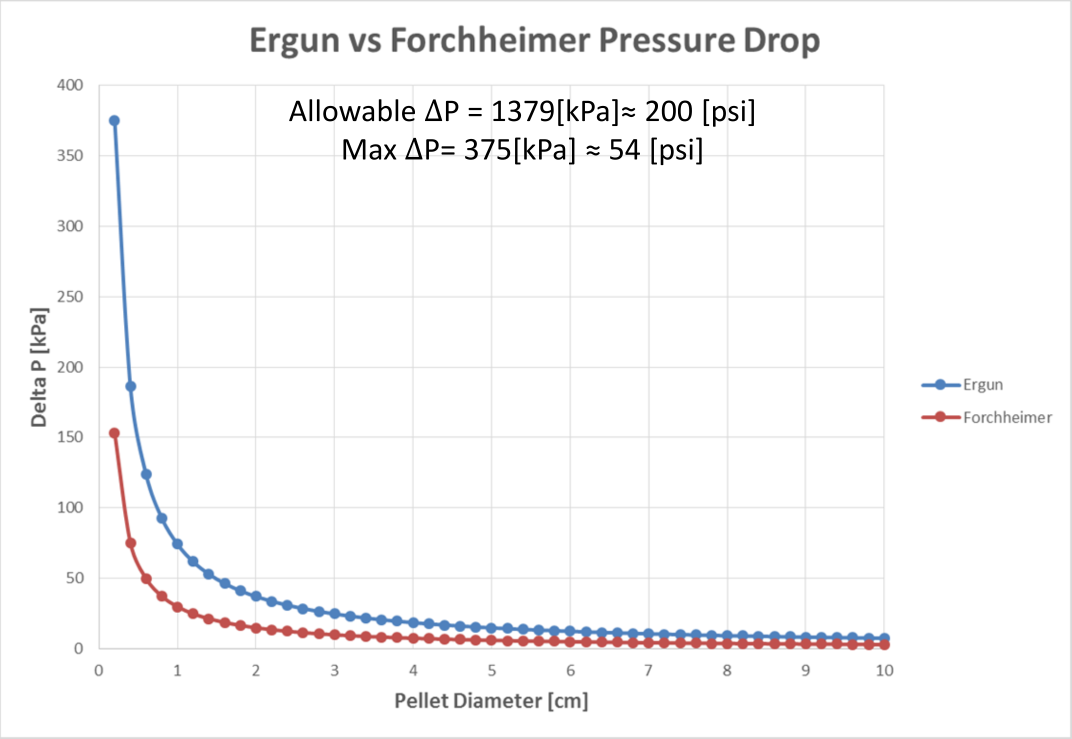
Ergun

$$\Delta P = \frac{150\mu V_s L}{D^2}\frac{(1-\varepsilon)^2}{\varepsilon^2} + \frac{1.75\rho V^2}{D}\frac{(1-\varepsilon)}{\varepsilon^3}$$

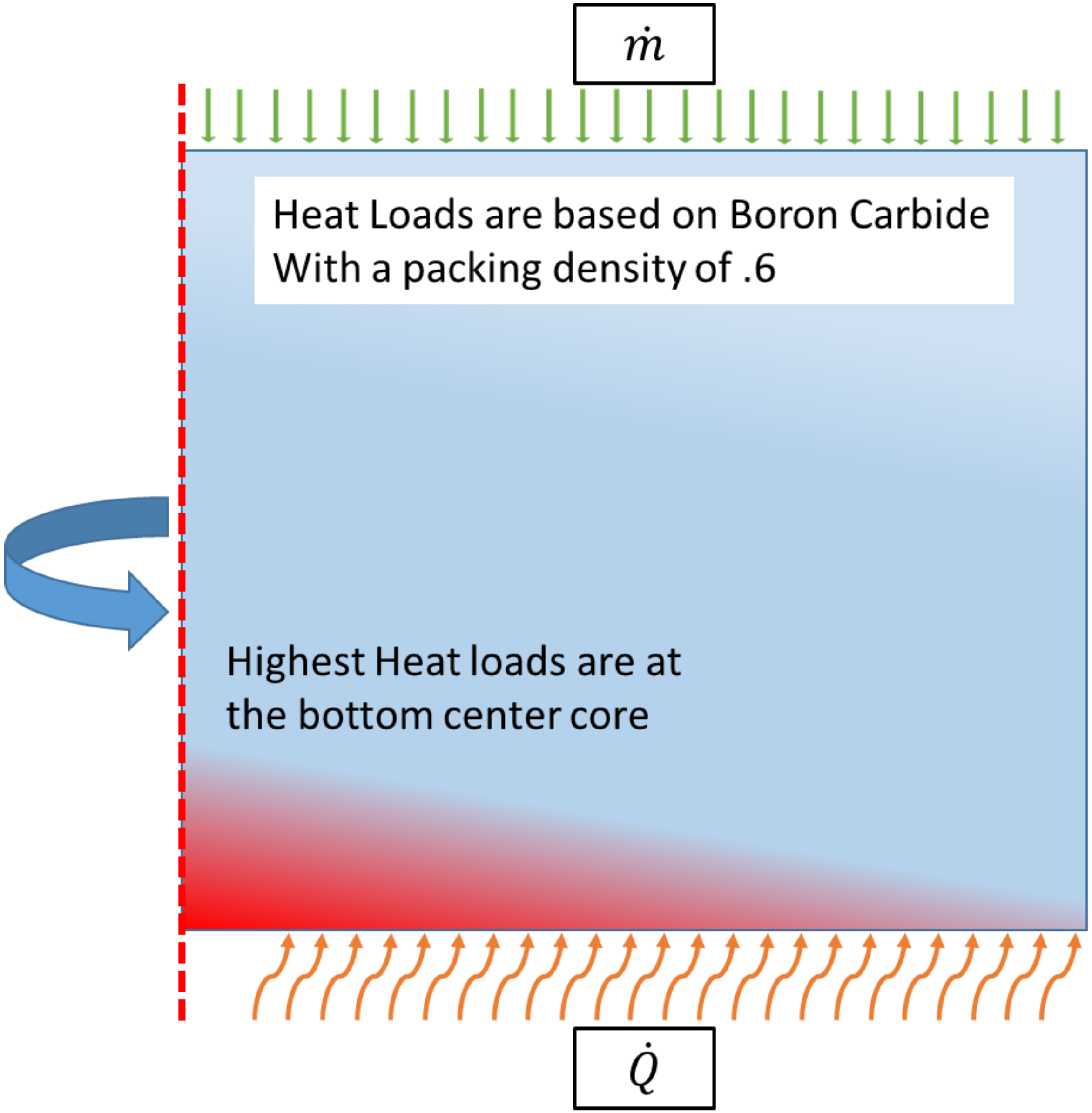
Permeability $k = \frac{D^2\varepsilon^2}{150(1-\varepsilon)^2}$

Ergun with Forcheimer Drag term

$$\Delta P = \frac{\mu V_s L}{k} + \frac{1.75\rho V^2 L}{\sqrt{k}}\frac{\varepsilon}{\sqrt{150\varepsilon^3}}$$



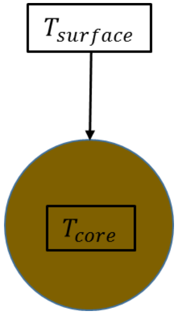
Heat Load Distribution

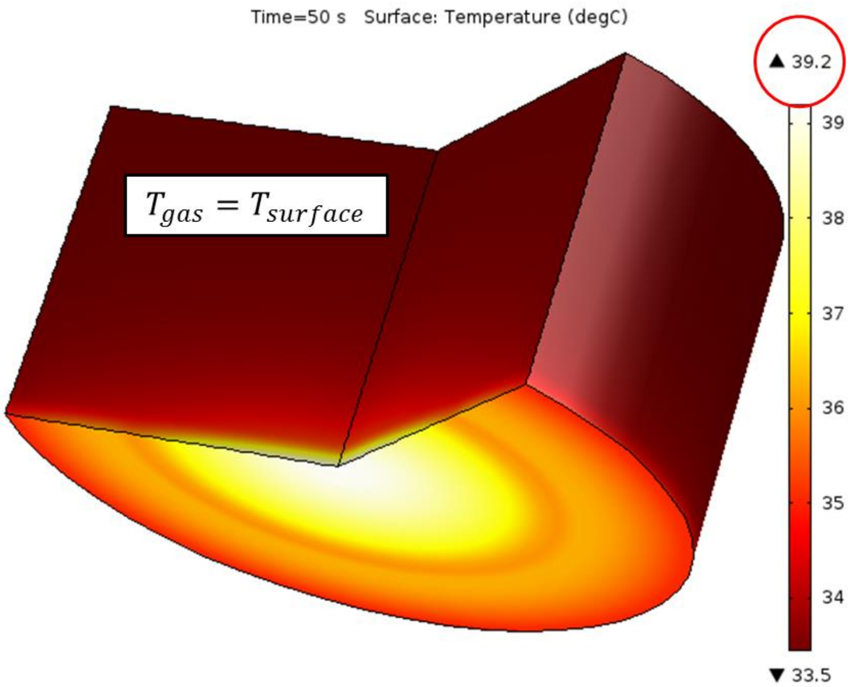


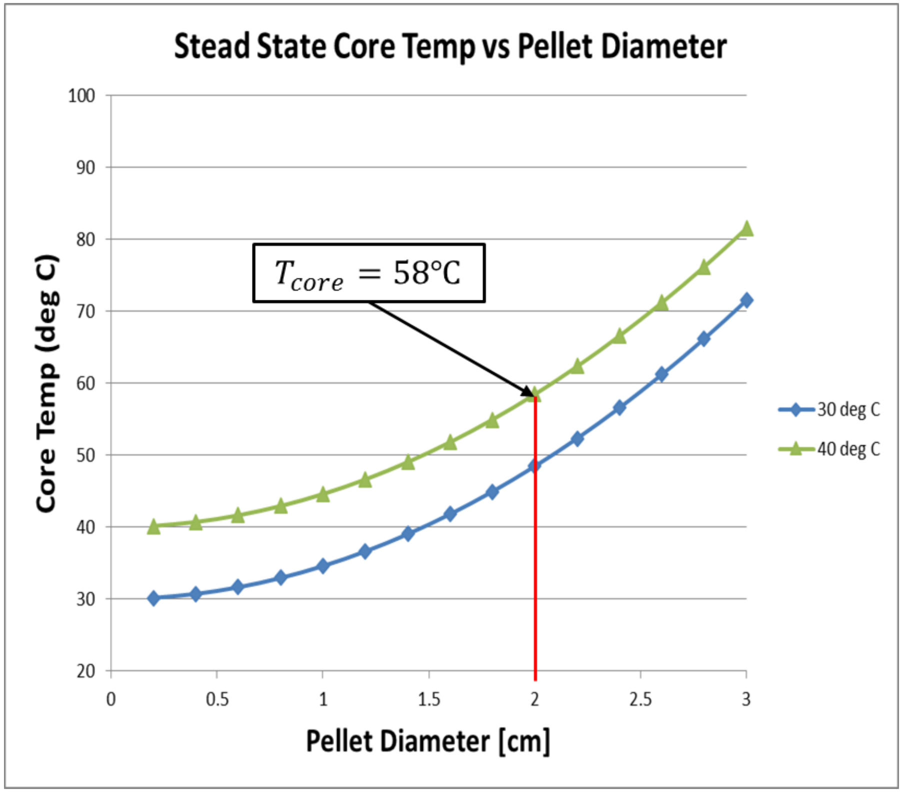
Temperature Distribution

Pellet Surface Temp Assuming:

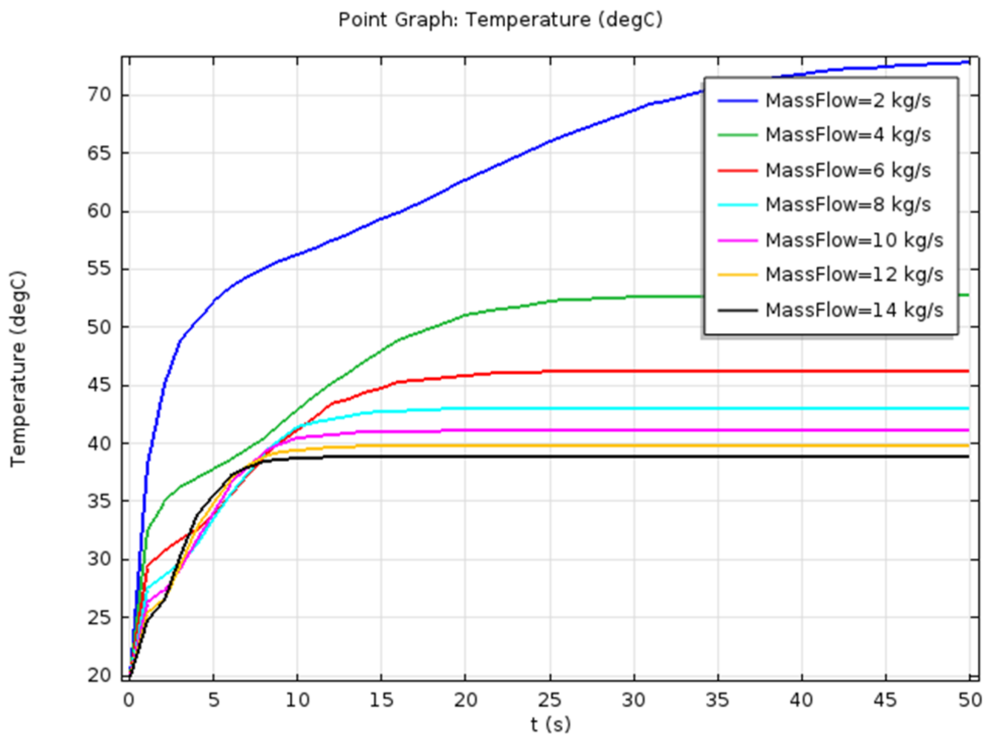
- Mass flow= 13.2 [kg/s]
- Superficial Velocity= 5.36 [m/s]
- Pellet Diameter= 2 [cm]

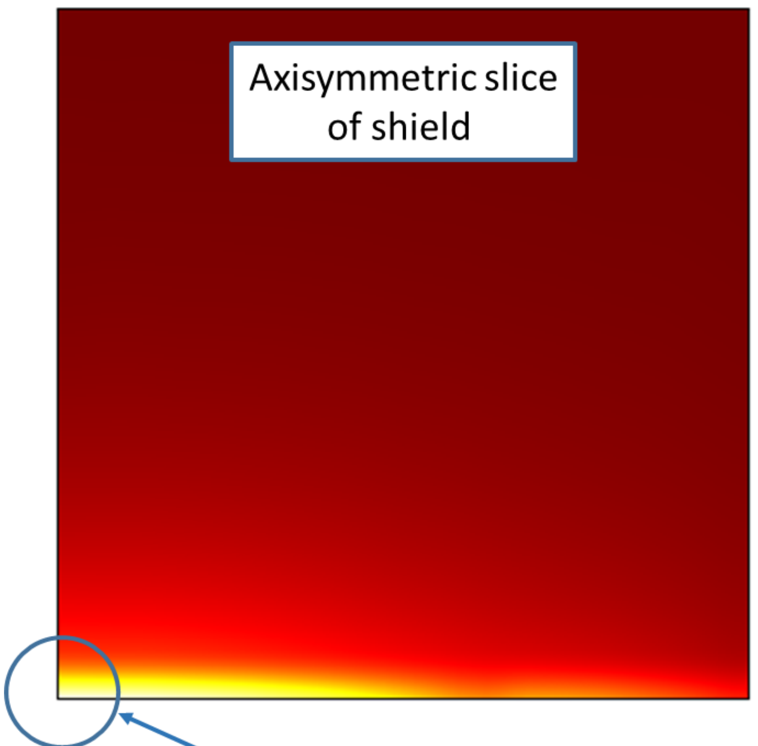






Shield Temperature with Lower Mass flows





Note: These temperature profiles are only for a pelletized bed

Mass Flow was varied and temperatures Profiles were taken from this point.

Potential Future Work

- Consider alternate hybrid shield combining
- Pelletized bed
- Hex layers
- Cylinder stacks
- Multiple materials

- If pelletized shield temperatures are acceptable, flow rates can be diverted elsewhere if needed