HEAT PIPE HEAT EXCHANGER FOR A MICRO REACTOR: A COMPUTATIONAL FLUID DYNAMICS STUDY

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May 2025

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INTRODUCTION

Research background Problem Statement

- South Africa is experiencing a severe electricity crisis, marked by frequent load shedding and aging infrastructure, and measures must be taken to establish reliable and sustainable power generation systems.

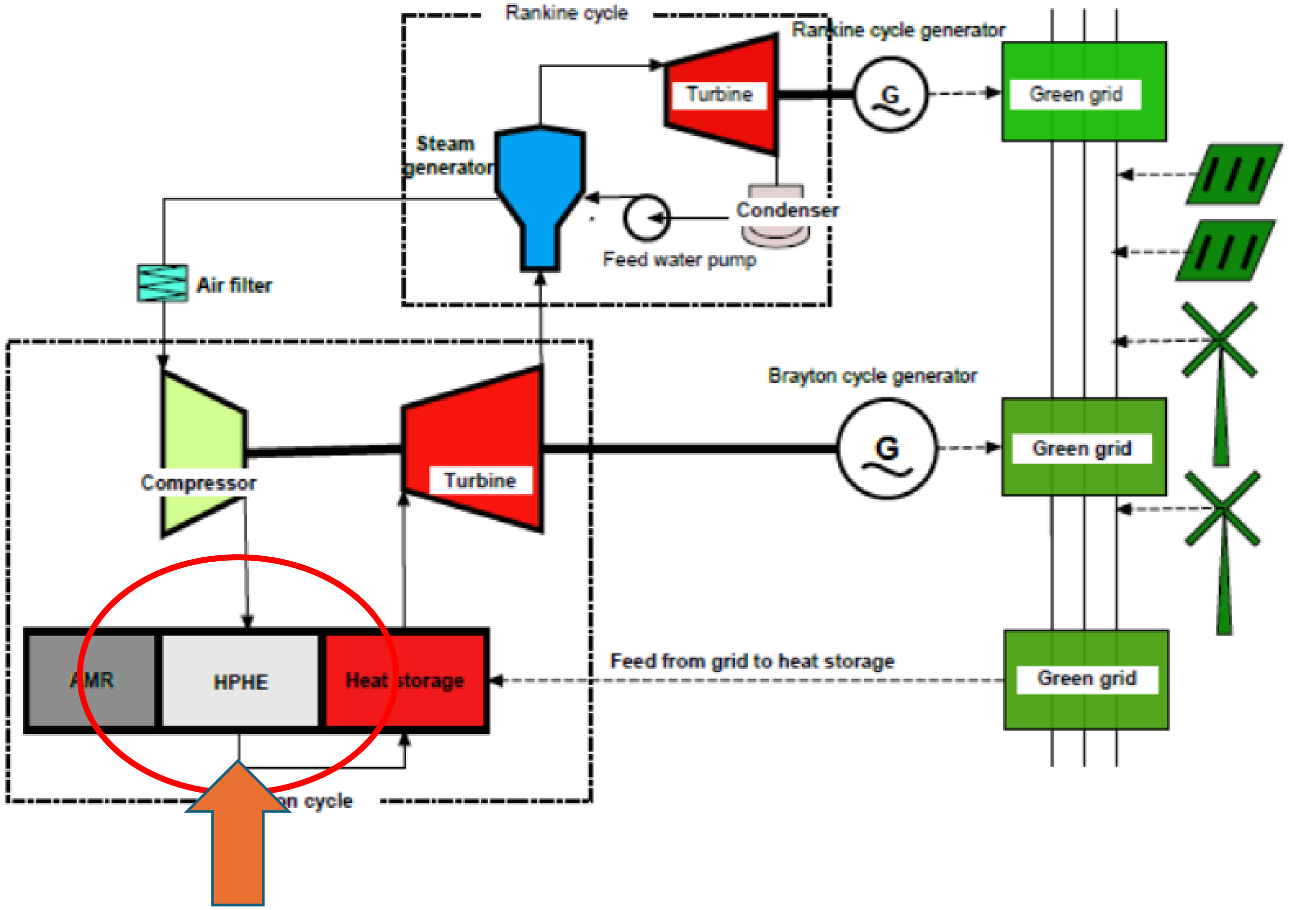
- The country remains heavily dependent on fossil fuels contributing to possibly high carbon footprint, and urgent action is needed to implement “clean carbon-free” energy technologies such as micro nuclear reactors.

- Microreactors rely on efficient thermal regulation to function safely, and the Heat Pipe Heat Exchanger (HPHE) is a key component for transferring and managing heat during operation.

- There is a growing emphasis on using computational fluid dynamics (CFD) to design HPHE systems that can enhance heat transfer, improve safety, and increase the overall efficiency of microreactors under different operational conditions.”

INTRODUCTION

Research Background and Problem Statement



Focus of this presentation

Flow Chart of a Power Cell

- The reactor transfers heat to a secondary air circuit through a HPHE, enabling efficient thermal energy exchange without direct fluid contact.

- The HPHE separates the helium coolant from the air loop, preventing tritium contamination.

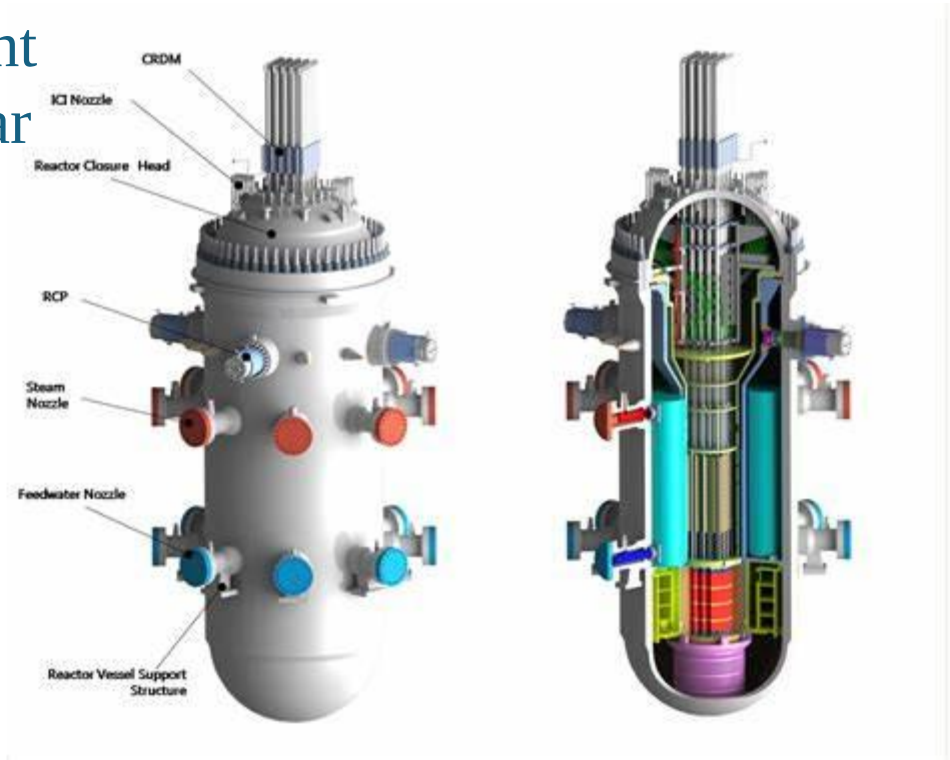
INTRODUCTION

The Micro Reactor (MR)

- A micro reactor is a compact, factory-fabricated nuclear reactor designed to generate a limited amount of electrical power or heat through controlled nuclear fission.

- **The reactor design must fully align with the four primary objectives outlined in the Generation IV roadmap:**

➢ ensure enhanced safety
➢ reduce the production of radioactive waste
➢ strengthen resistance to the proliferation of nuclear weapons materials
➢ promote the long-term sustainability of power generation.

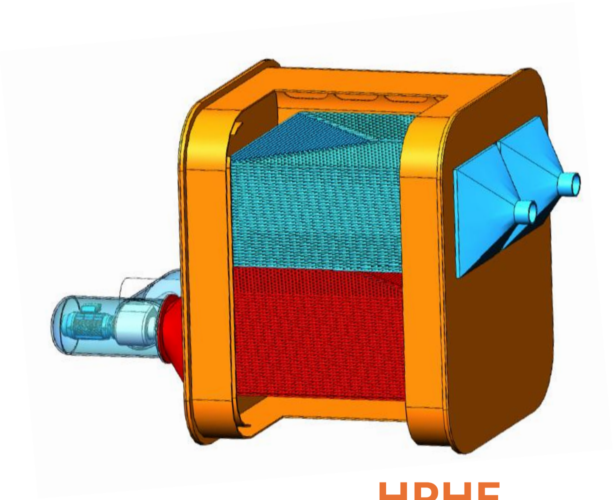


Small modular Reactor

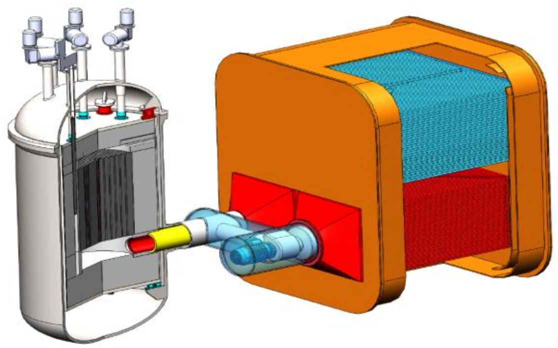
INTRODUCTION

Heat Pipe Heat Exchanger

- HPHE is a thermal management system designed to efficiently transfer heat from the reactor core to a secondary power conversion loop.
- It uses heat pipes as passive components to move thermal energy from the high-temperature source (reactor core) to a cooler working fluid,



HPHE



HPHE coupled to the PowerCell Modular Reactor (PCMR)

INTRODUCTION

Heat Pipe Heat Exchanger

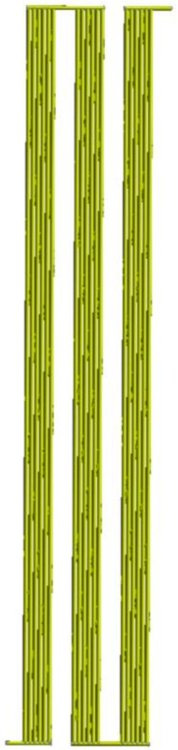
- A heat exchanger is an important part of A reactor. It helps move and control the heat made during nuclear fission

- **Steam Generation**: It helps generate more steam to be stored or passed out to the turbines.
- **Safety and Containment**: Heat exchangers help to contain and manage radioactive materials.
- **Temperature Regulation**: Heat exchangers assist in maintaining optimal operating temperatures within the reactor core.
- **Pressure Drop**: Lead Bismuth Eutectic (LBE) is put at atmospheric pressure to avoid leakages

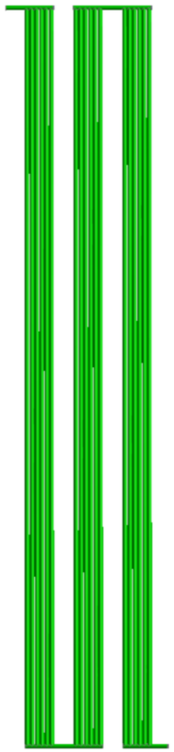
- The aim is to design a heat exchanger that keeps heat moving well in the reactor
- Computational fluid dynamics will be used to model a HPHE for a nuclear reactor.

Computational Method

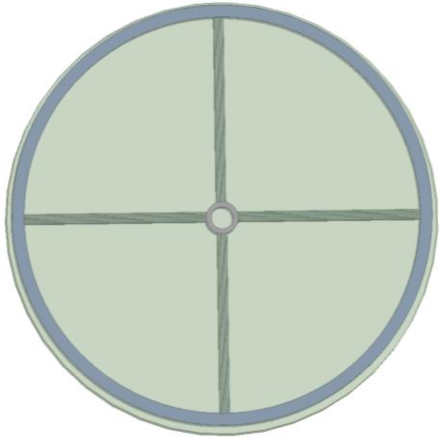
Geometry



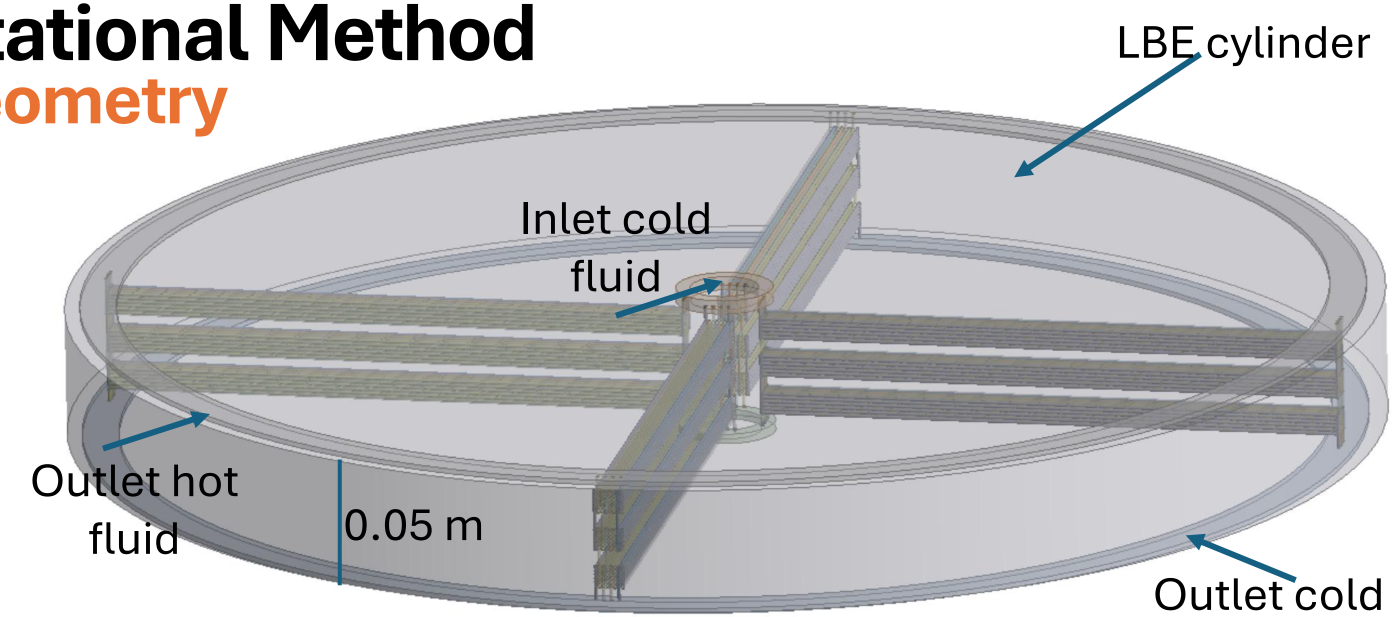
Cold fluid pipe



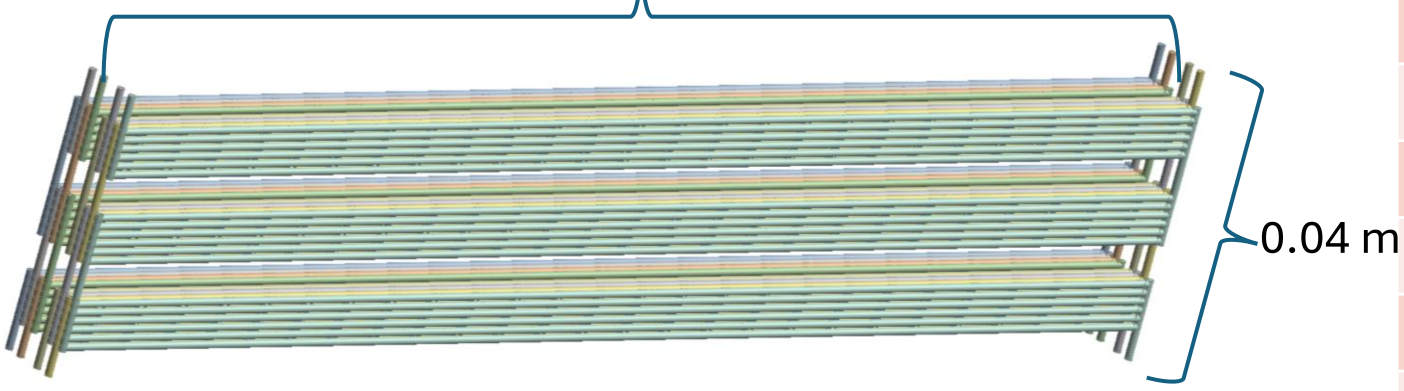
Hot fluid pipe



Top view of the HPHE



Full view of the HPHE

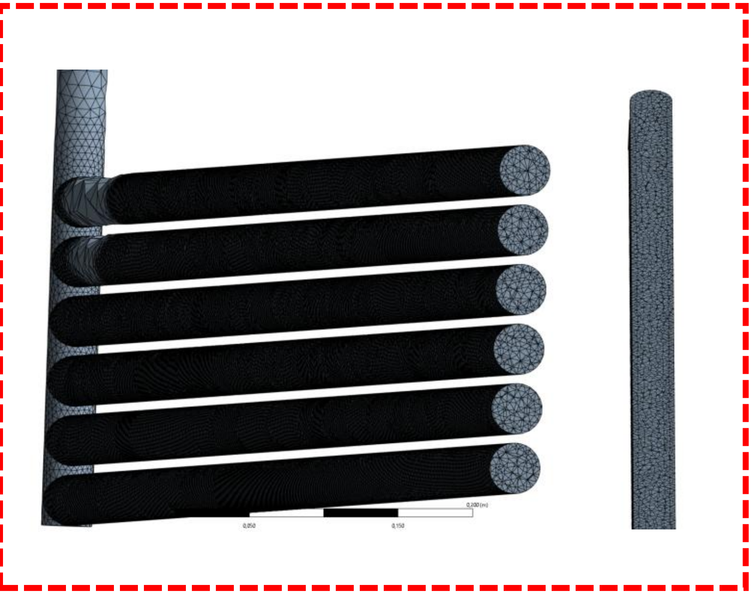


Part	Diameter (m)
Inner pipe	0.00152
Outer pipe	0.0034
Cylinder	13.50
Outlet (o)	13.15
Outlet (i)	12.40
Inlet (o)	1 .00
Inlet (i)	0.70

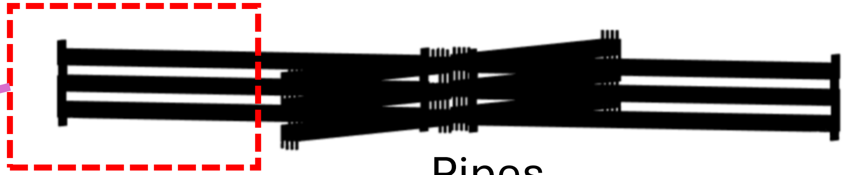
- Total number of pipes 32
- 6 m each of 18 sub pipes in a single serpentine pipe

Computational Method

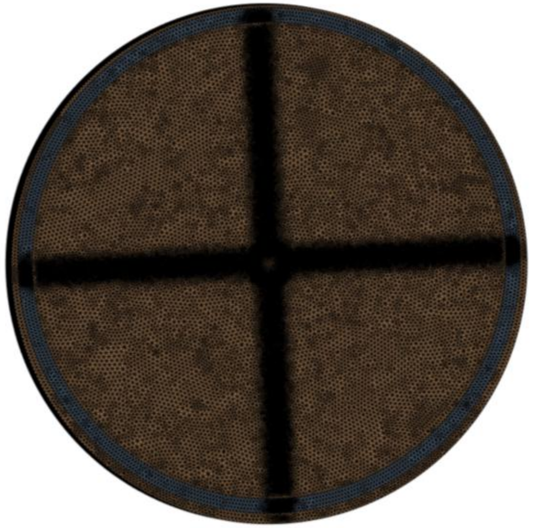
Meshing



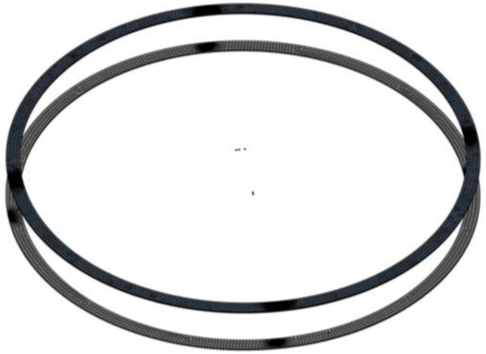
Inner part of the pipe



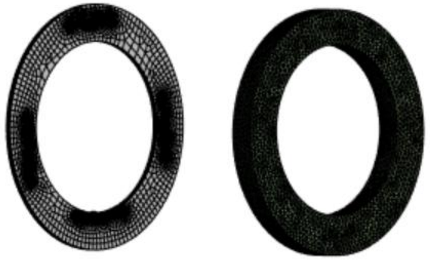
Pipes



Meshed HPHE



Hot and cold fluids outlets



Hot and cold fluids inlets

- The geometry is discretized using the Finite Volume Method, which breaks the domain into small control volumes for numerical analysis.
- performed to ensure that simulation results remain consistent regardless of mesh density.

Nodes	56902625
Elements	340858196

Future Work

Results ,Discussion and Conclusion

the next steps typically include:

1.Set up and run simulations : Application of boundary conditions, material properties, and run the solver to perform the calculations.

2.Post-processing and results :Analyze the simulation output, such as temperature, pressure, or velocity distributions.

3.Discussion : Interpretation of the results, explaining trends, and comparing with expectations or previous studies.

4.Conclusion :Summarizing key findings and their significance.

Any Questions