OAK RIDGE National Laboratory

MELCOR Model Development for BlueCRAB and FATE Microreactor Code Comparisons

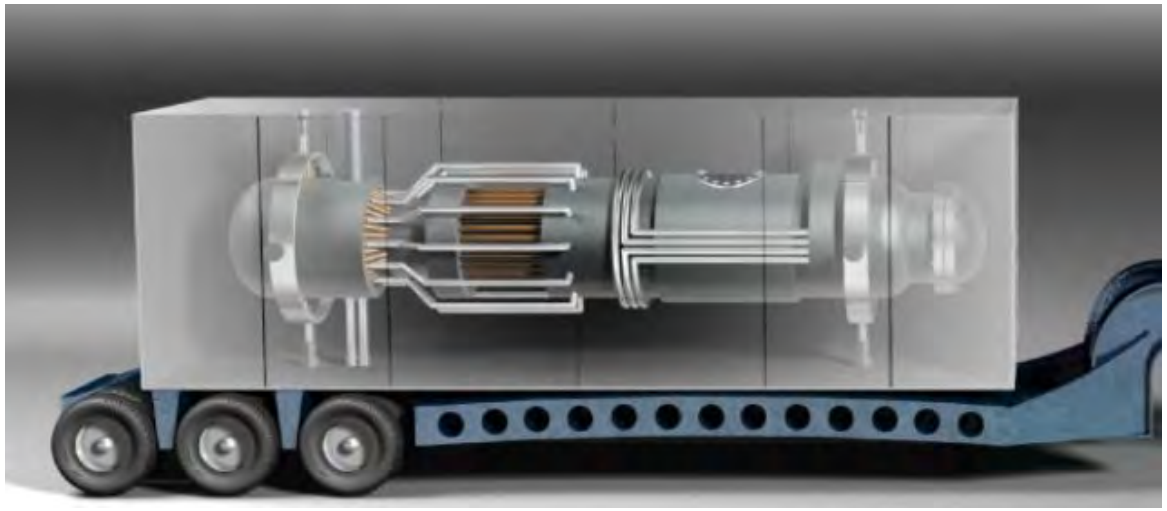
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Background

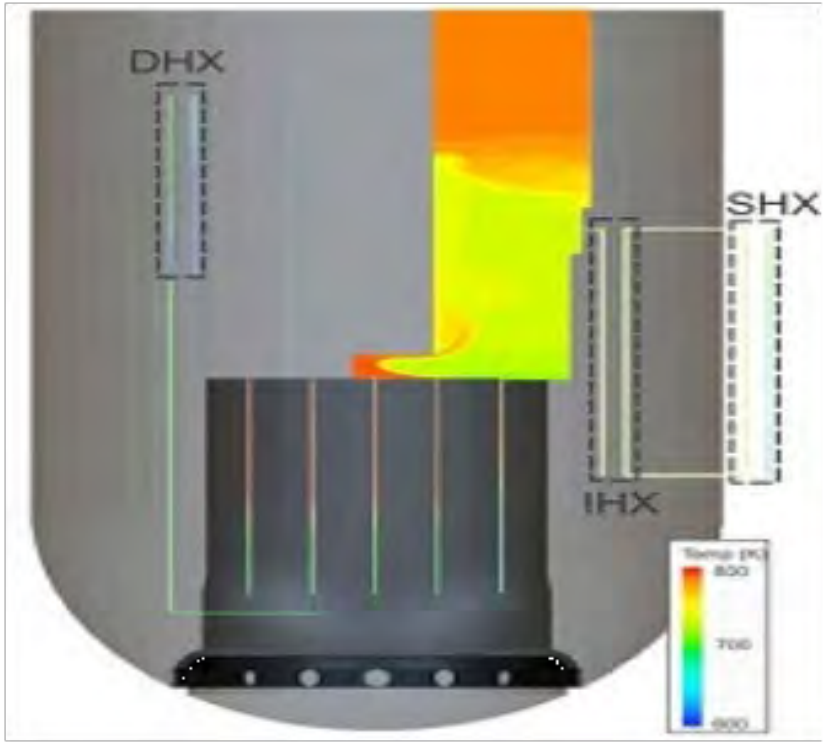
- Microreactors are typically reactors with a power under 50 MWt
- Unique characteristics include novel operation, modular, compact, and fuel form and technology
- Qualified tools are required by both the industry and US NRC for license applications and confirmatory assessments
- Advanced reactor analysis and design tools have been developed to support the licensing of microreactors



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Codes

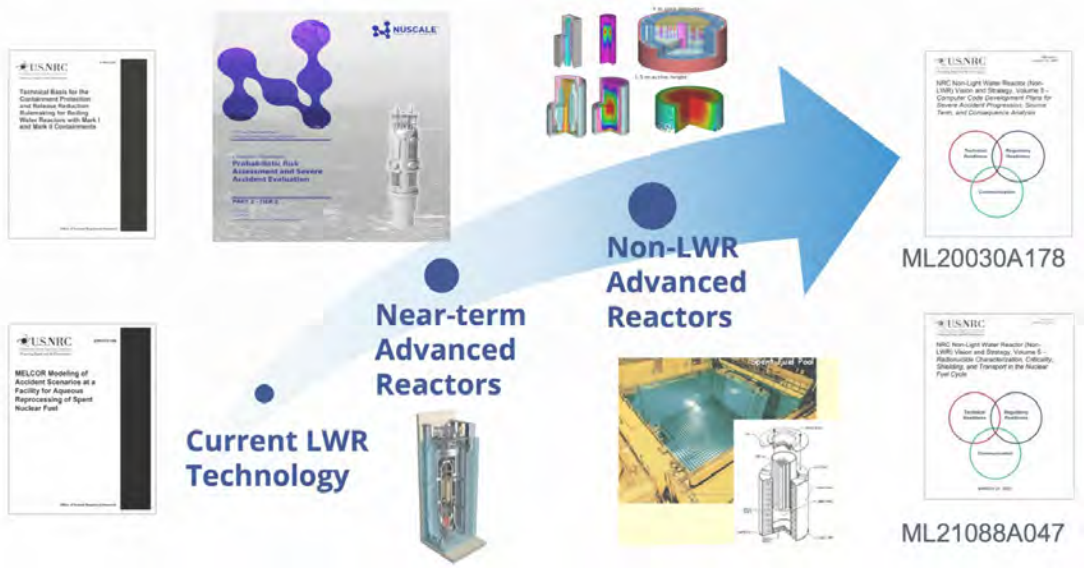
- MELCOR: Methods of Estimation of Leakages and Consequences of Releases
  - Consequence analyses: estimates release source terms
- BlueCRAB: Federal version of Comprehensive Reactor Analysis Bundle (CRAB)
  - Multiphysics calculations (neutronics, fuel performance, thermalhydraulics, transient)
- FATE: Facility Flow, Aerosol, Thermal, and Explosion
  - Facility response: simulates engineering processes



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MELCOR

- Enhancements are underway for modelling diverse designs, including the Westinghouse's eVinci microreactor
- These updates include
  - Modelling uranium oxycarbide as fuel
  - Modelling TRISO particle-based fuel for a heat pipe reactor
  - Modelling heat pipes in horizontal orientation
  - Modelling both TRISO particle-based fuel and liquid metal coolant



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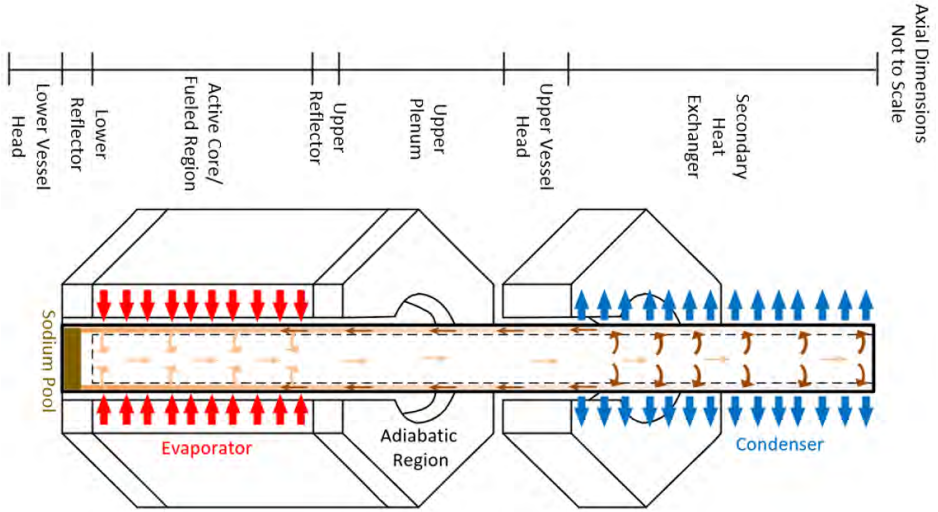
Objective

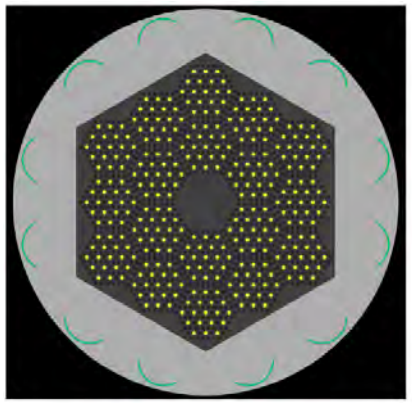
- Develop and assess a realistic heat pipe microreactor (rHPMR) using MELCOR
  - For comparisons with BlueCRAB and FATE codes

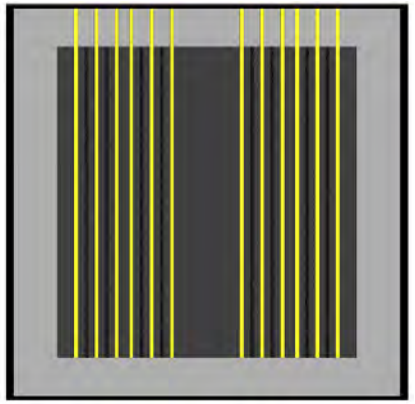
eVinci Design

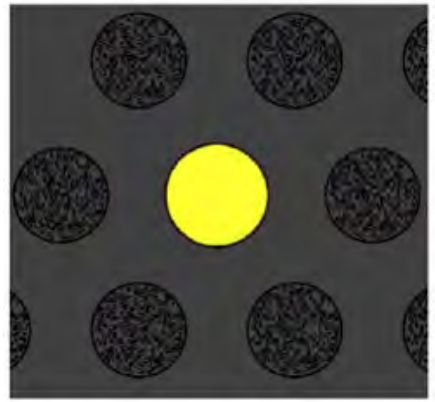
- A horizontal, prismatic block, heat pipe-cooled, TRISO-fueled 5 MWt microreactor
- Core consists of a graphite monolith with cylindrical channels for TRISO compacts and sodium heat pipes

Property	Value	Property	Value
Fuel radius	1.0 cm	Arc width for poison strip	120.0
TRISO packing fraction	36%	Gap around control drums	0.05 cm
Fuel compact gap	0.05 cm	Reactor external radius	112.0 cm
Heat pipe external radius	1.1 cm	Active zone height	160.0 cm
Heat pipe gap	0.05 cm	Top reflector thickness	20.0 cm
Pin pitch	3.4 cm	Bottom reflector thickness	20.0 cm
Assembly pitch	32.0 cm	TRISO kernel thickness	250.0 µm
Monolith apothem	75.0 cm	TRISO buffer thickness	100.0 µm
Gap around monolith	0.05 cm	TRISO IPyC thickness	40.0 µm
Distance of drums from core center	95.0 cm	TRISO SiC thickness	35.0 µm
Poison strip internal radius	14.0 cm	TRISO OPyC thickness	40.0 µm
Control drum external radius	15.0 cm		





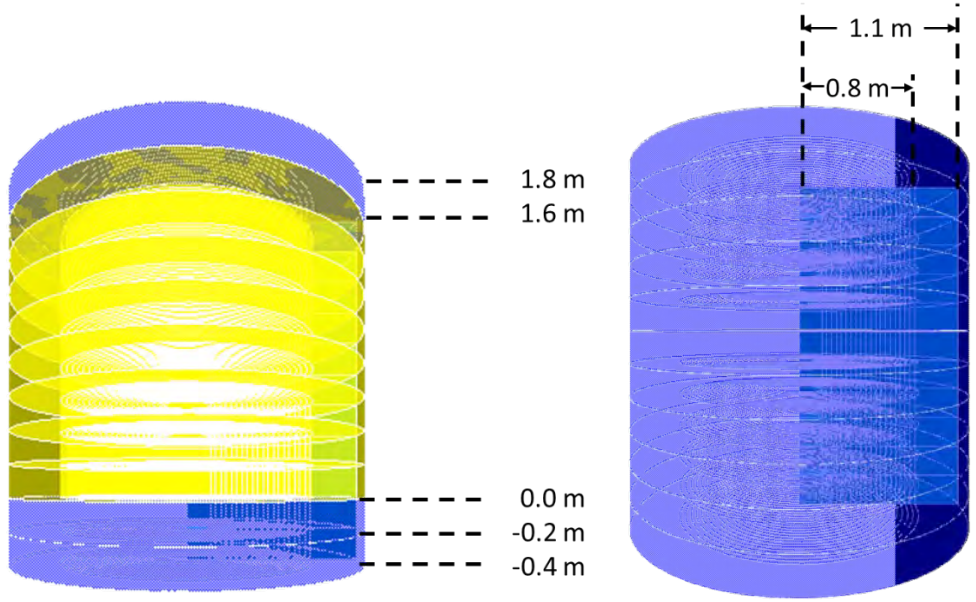


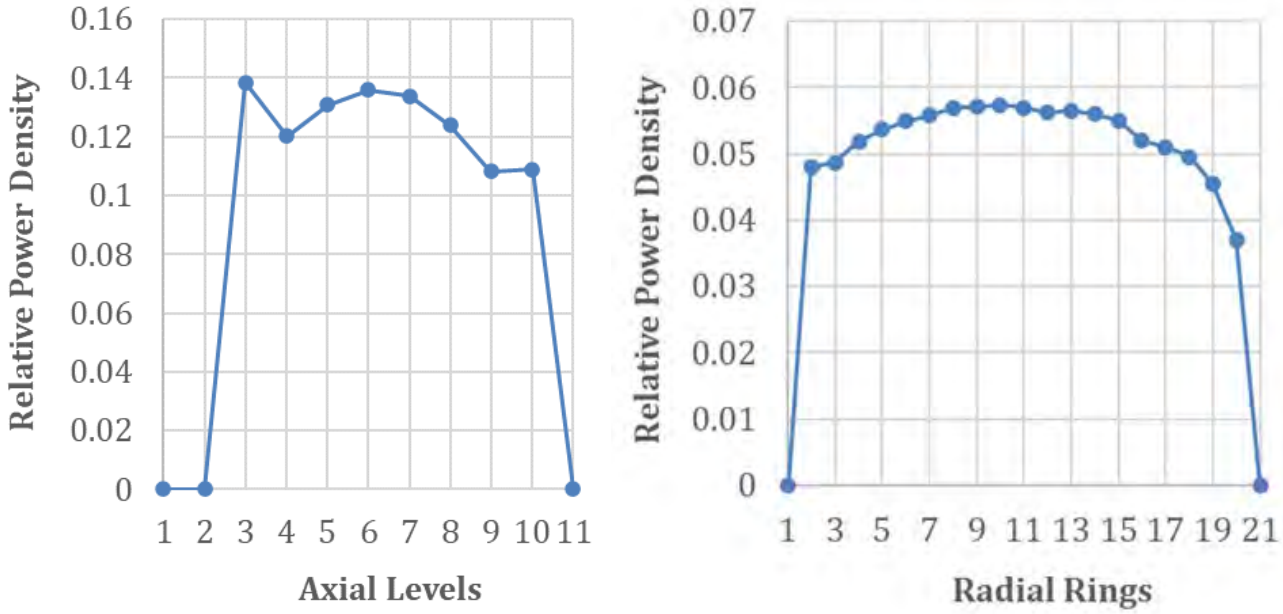


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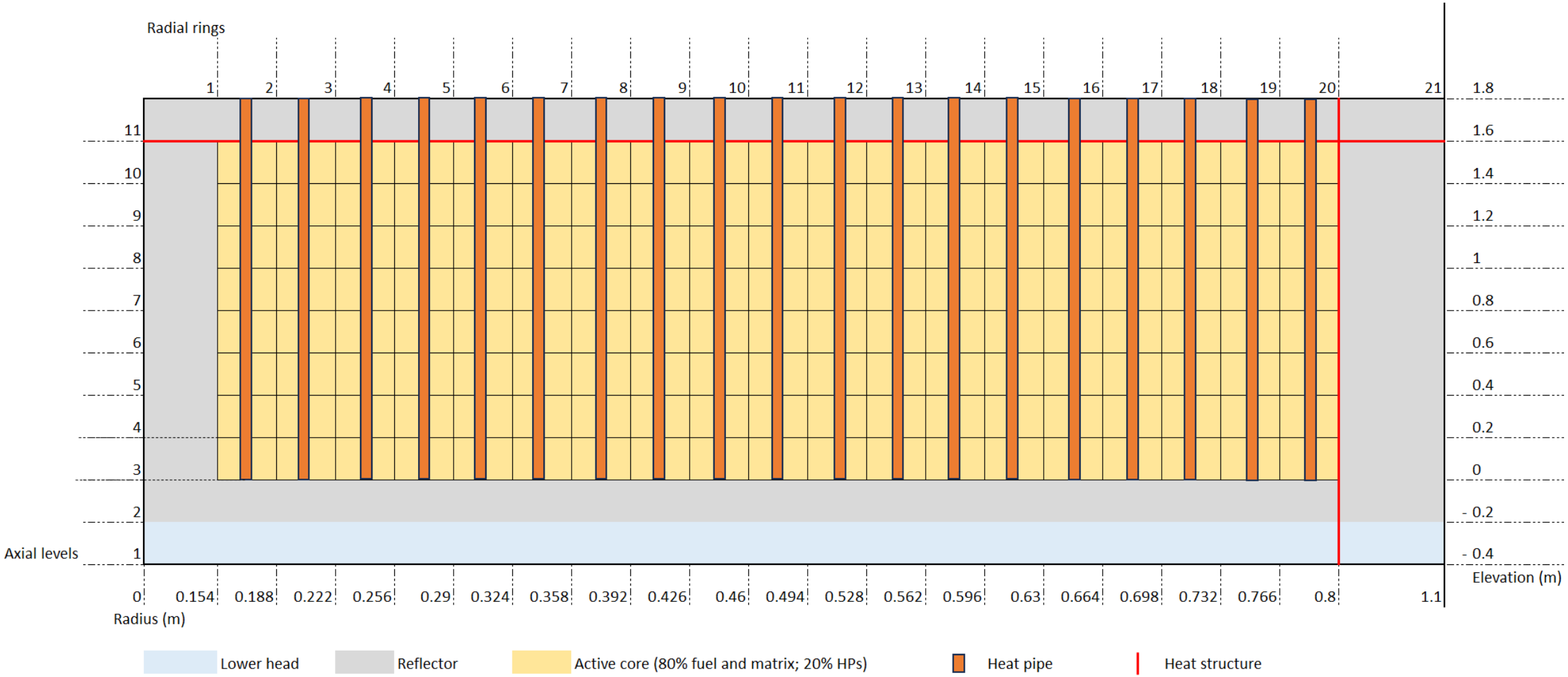
rHPMR Model

- Core nodalization
  - 11 axial levels (−0.4 to 1.8 m)
  - 21 radial rings (outer radius of 1.1 m)
  - The active core is represented by axial levels 3–10 and radial rings 2–20
- Relative power density across 11 axial levels and 21 radial rings
  - the active core cells contribute to the power (i.e., nonzero power fraction)
- Each core cell is assumed to consist of 80% fuel and graphite matrix, and the remaining 20% is occupied by a heat pipe





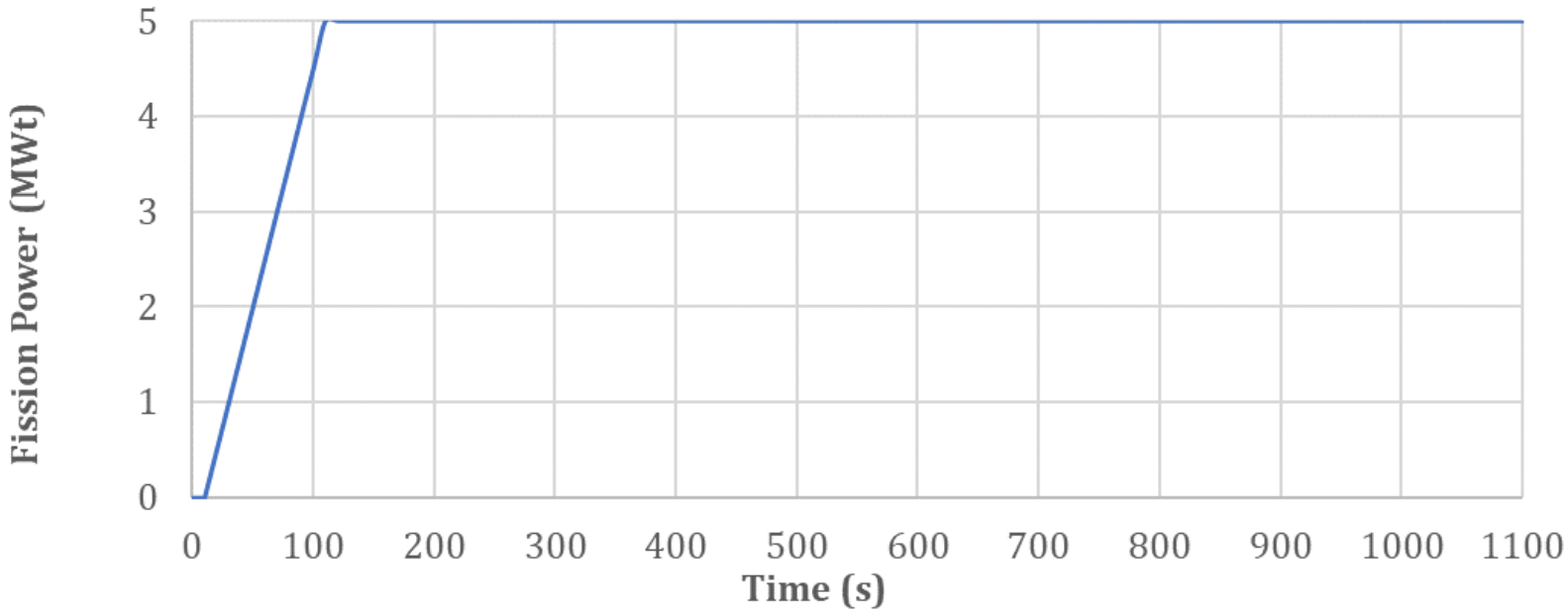
rHPMR Schematic



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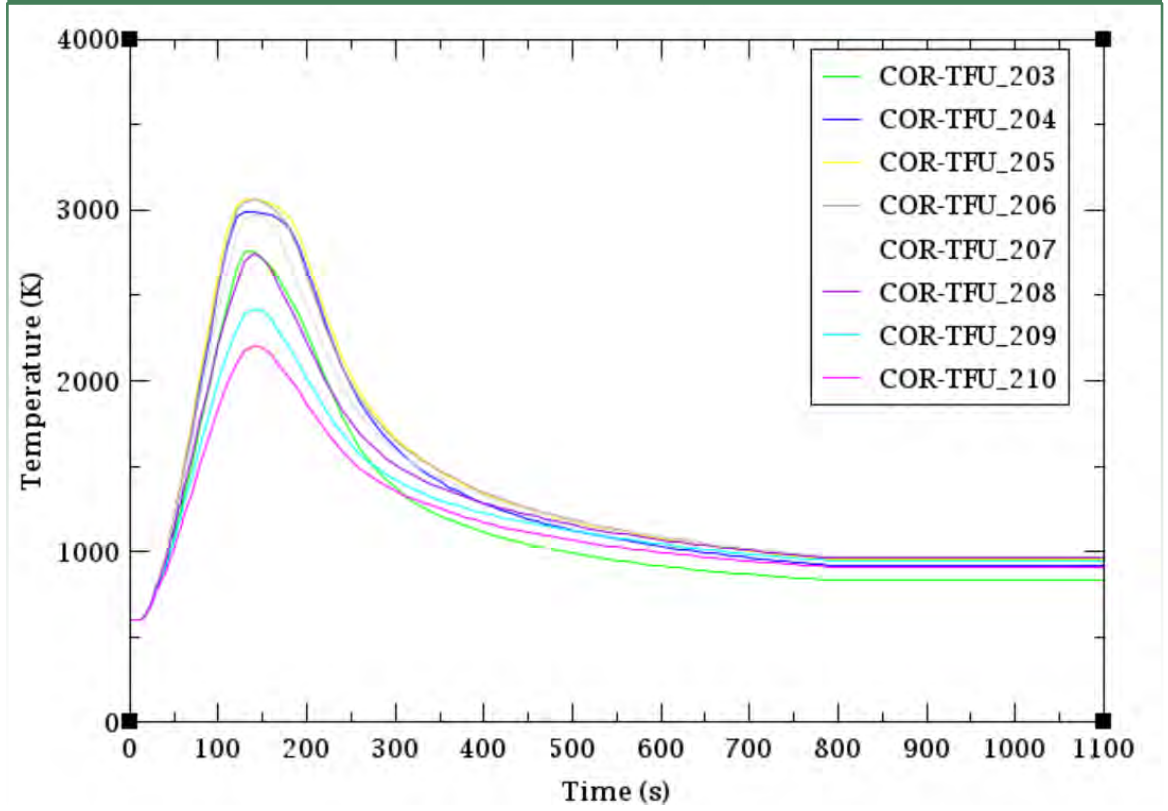
rHPMR Simulation

- Steady-state simulation for 1,100 s
- Thermal power ramping up to 5 MW under 2 min, after a delay of 10 s

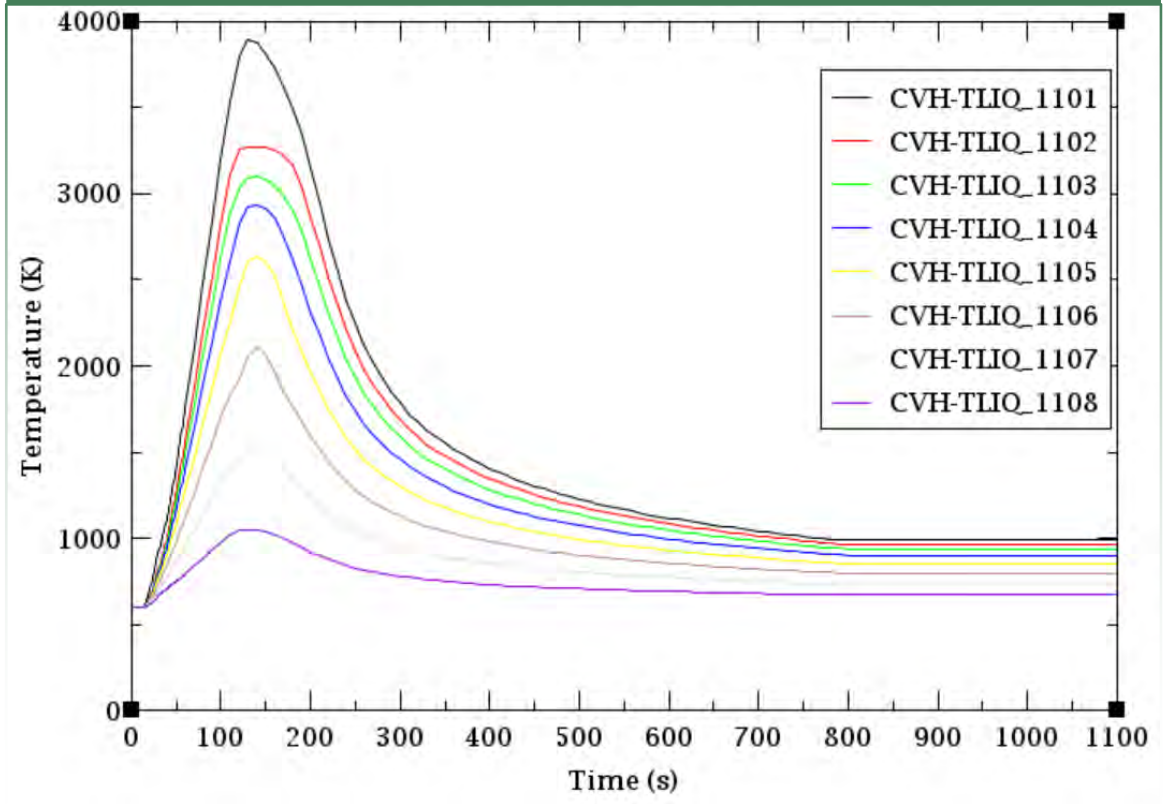


Steady-State Results: Ring 2

Fuel Temperature

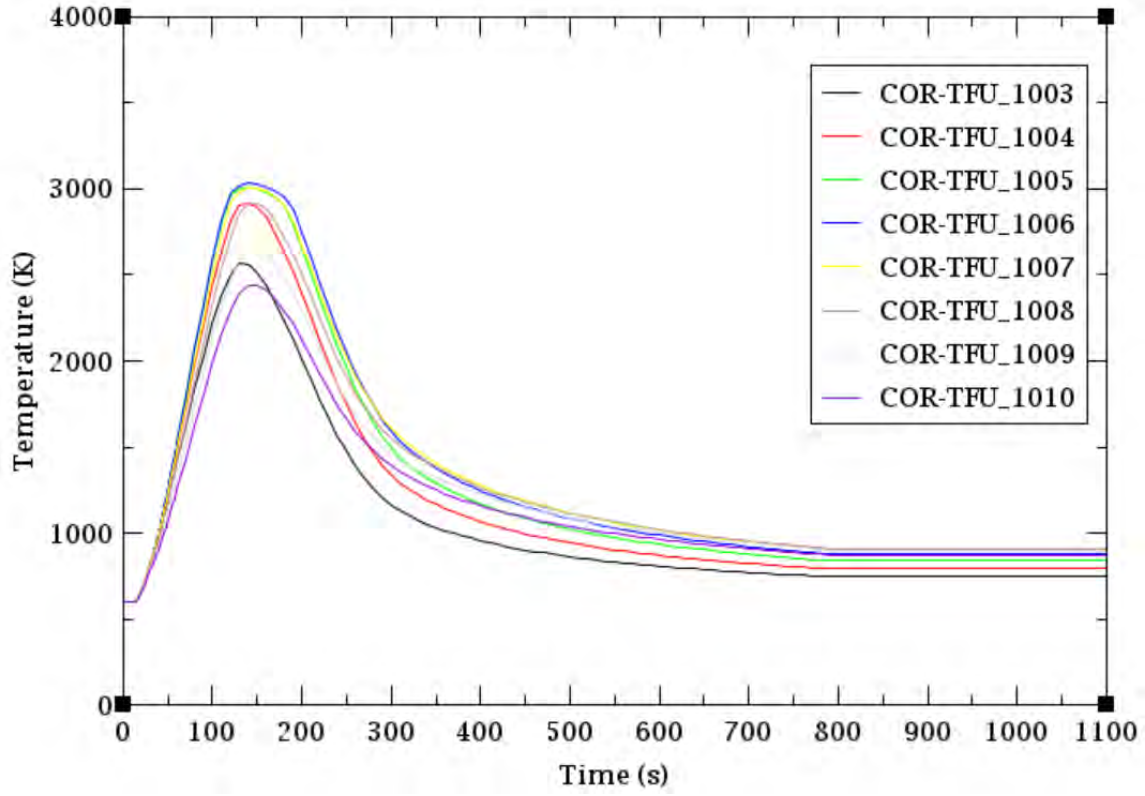


Coolant Temperature

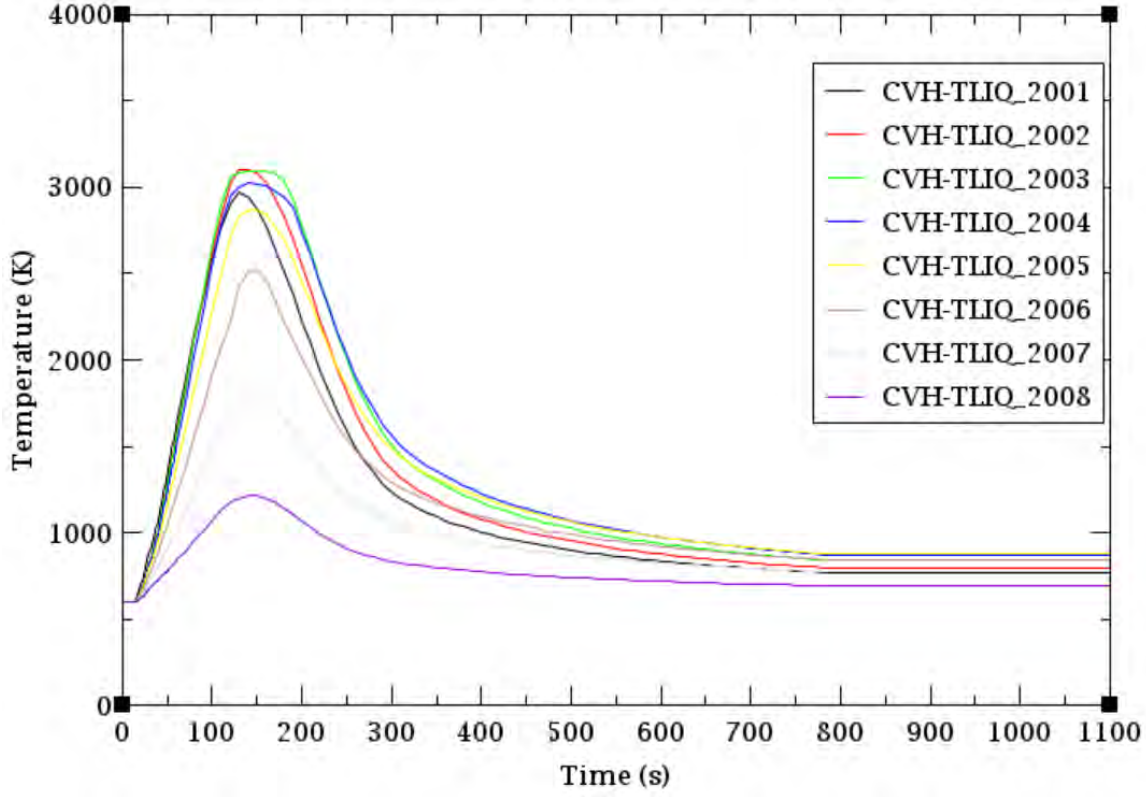


Steady-State Results: Ring 10

Fuel Temperature

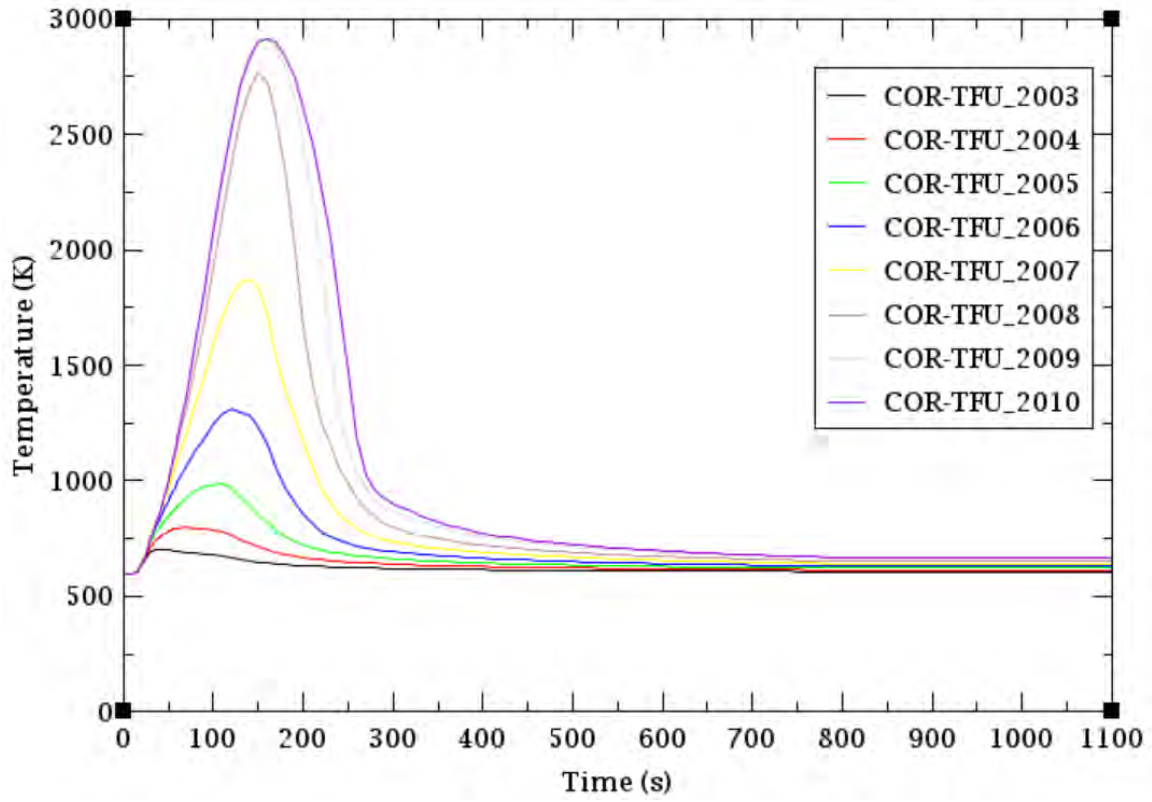


Coolant Temperature

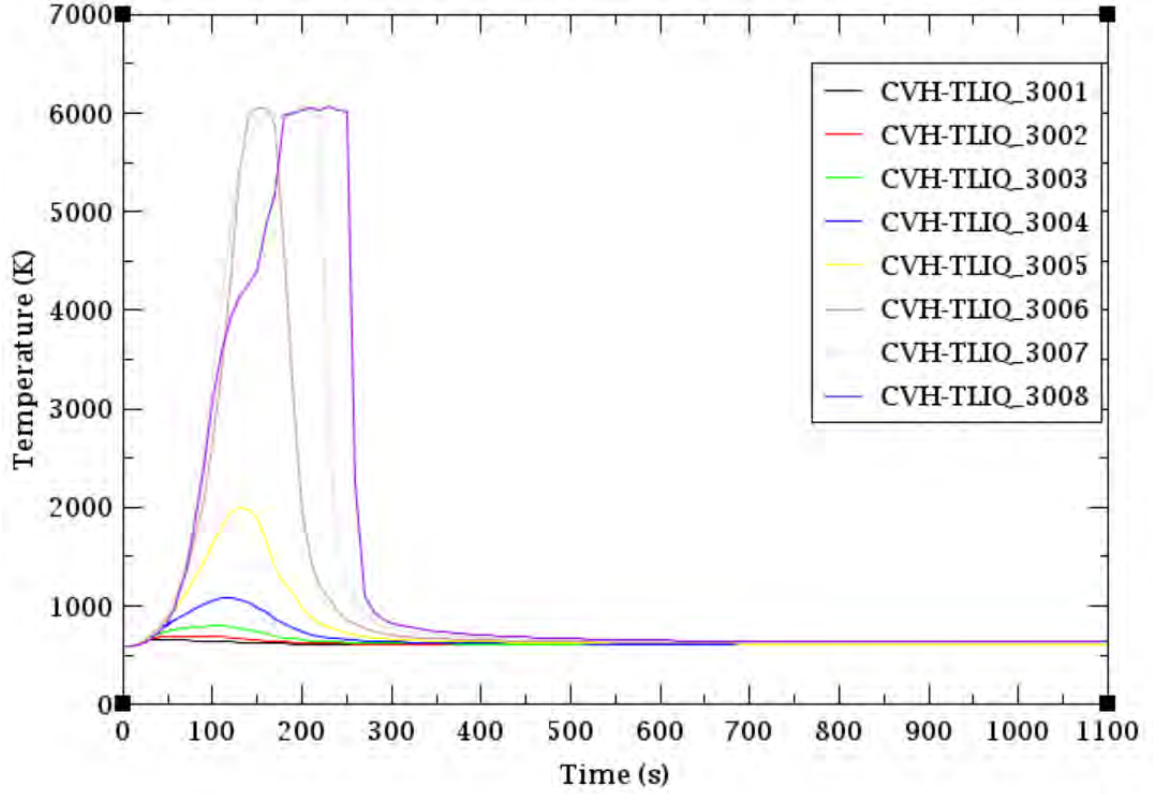


Steady-State Results: Ring 20

Fuel Temperature

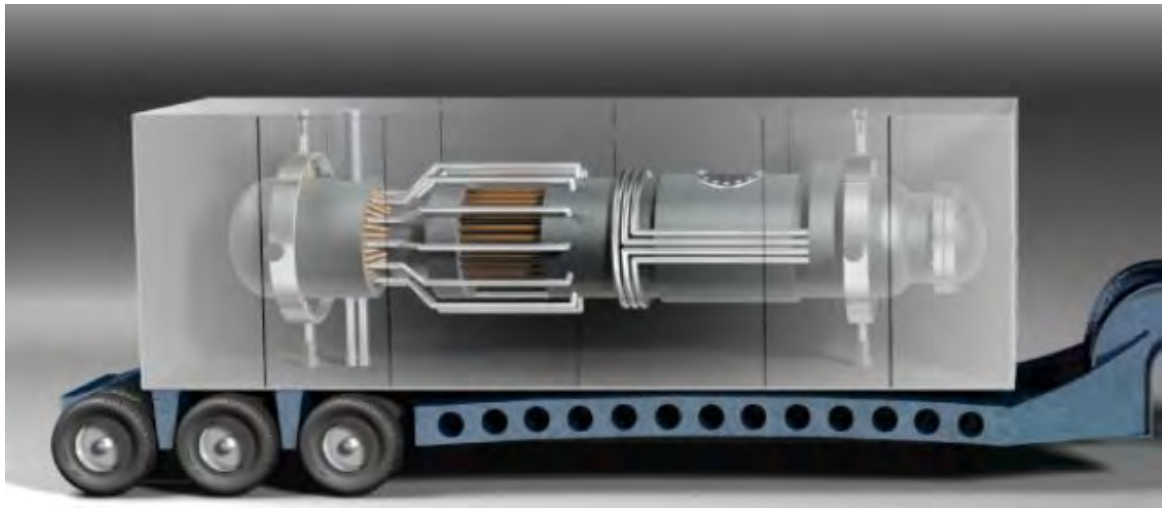


Coolant Temperature



Next rHPMR Model Iteration

- Fuel will be represented by TRISO compacts
- Sodium coolant will be modelled, along with a heat exchanger
  - Radial flow paths connecting active core cells and the reflector are defined to simulate heat transfer to helium.
  - These radial flow paths may not be required when helium is replaced with sodium as coolant in the model



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Summary

- With the existing modelling limitations, a full assessment of the rHPMR was restricted
  - Heat pipes in a vertical orientation
  - TRISO fuel and heat pipes cannot be modelled simultaneously
- Alternative approach was explored to address constraints
  - Heat pipes as control volumes
  - Helium as coolant
- With the approximations, results lack the sufficient quality for a suitable comparison against other codes
- As MELCOR's capabilities expanded and improved, this model will be updated in future

References

1. https://inl.gov/trending-topics/microreactors/
2. https://neams.inl.gov/code-descriptions/
3. https://www.sandia.gov/MELCOR/#:~:text=MELCOR%20is%20our%20flagship%20computer,safety%20technology%20of%20global%20significance
4. N. Choi et al., “Advancements in Multiphysics Microdepletion Analysis of an eVinciTM-like Microreactor Leveraging OpenMC-CRAB Workflow,” Idaho National Laboratory, Idaho Falls, Idaho, USA, INL/RPT-24-77346 Rev:000, 2024.

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Q&A



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