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RELAP5-3D in the OECD-NEA HTGR Thermal Hydraulics Benchmark

October 2024

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Changing the World's Energy Future

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ANS®
American Nuclear Society

The HTGR T/H Benchmark provides opportunities for code-to-code and code-to-data comparisons

Problem 1: Lower plenum mixing

- Based on HTTF experiment PG-28
- Primarily for CFD modeling
- Code-to-code comparison exercise
- Code-to-data comparison exercise

Problem 2: Depressurized Conduction Cooldown

- Based on HTTF experiment PG-29
- Primarily systems code modeling
- Code-to-code comparison exercise
- Code-to-data comparison exercise
- Error scaling exercise

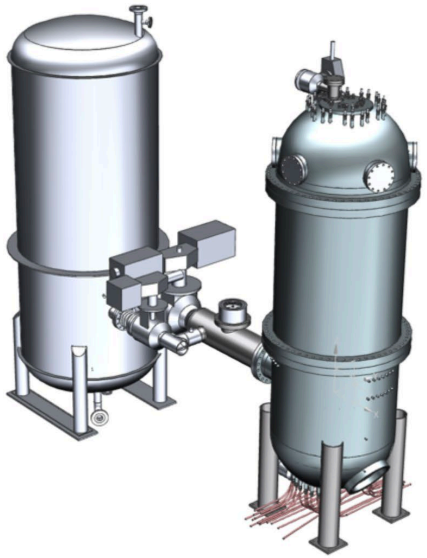
Problem 3: Pressurized Conduction Cooldown

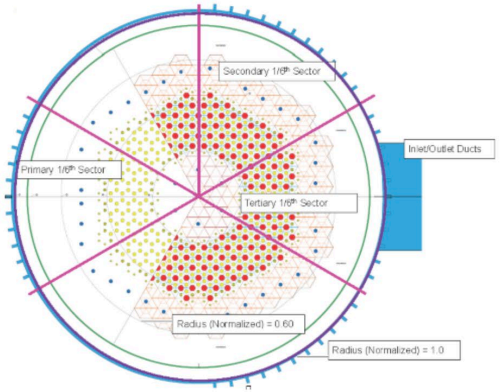
- Based on HTTF experiment PG-27
- Primarily systems code modeling
- Code-to-code comparison exercise
- Code-to-data comparison exercise
- Error scaling exercise

Thermal hydraulic code validation benchmark for high temperature gas-cooled reactors using HTTF data (HTGR T/H)

Ongoing

Benchmark | Reactor physics | Thermal hydraulics | ...





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Benchmark has 16 participants from 9 countries

United States
- Idaho National Laboratory*
- Oregon State University
- Argonne National Laboratory
- Numerical Advisory Solutions

Canada
- Canadian Nuclear Laboratories*
- McMaster University

South Korea
- Korea Atomic Energy Research Institute
- Gachon University

France
- Framatome
- French Alternative Energies and Atomic Energy Commission (CEA)

Netherlands
- Nuclear Research and Consultancy Group (NRG)

Italy
- Nuclear and Industrial Engineering (NINE)

Hungary
- Centre for Energy Research (HUN-REN)

Poland
- National Centre for Nuclear Research (NCBJ)

Belgium
- Tractebel*
- von Karman Institute for Fluid Mechanics (VKI)

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*Indicates RELAP5 used somewhere in workflow

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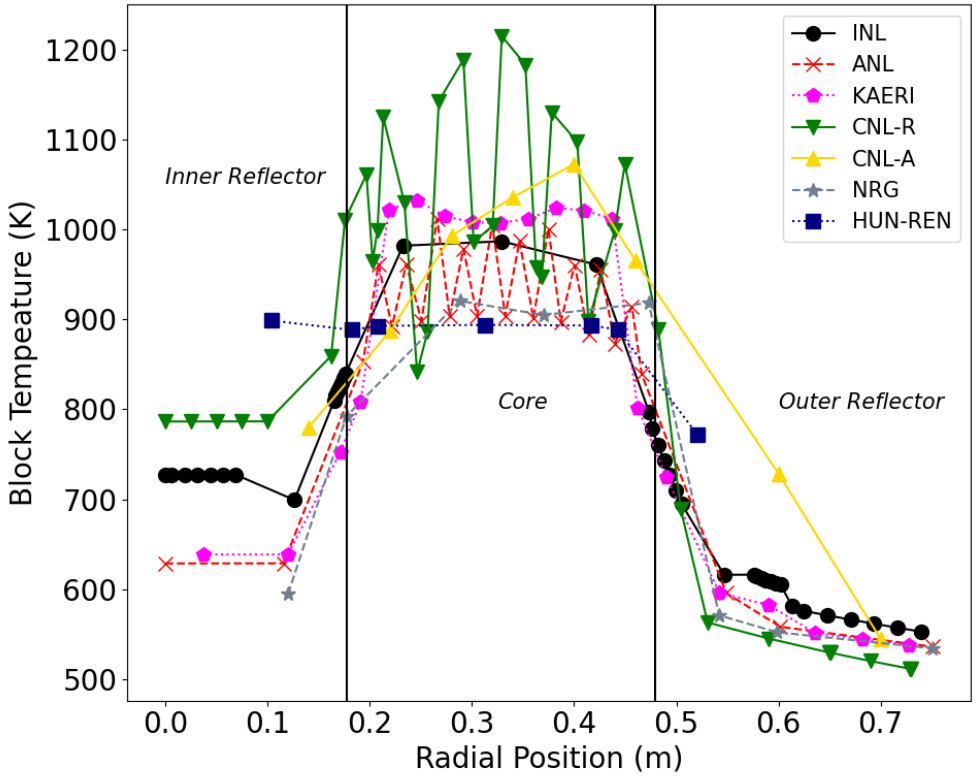
Code-to-code comparisons in the benchmark have shown RELAP5-3D provides comparable predictions to several other codes

- Code-to-code comparisons provide an opportunity for insight into the impacts of modeling assumptions and model nodalization
- We see significant differences in predictions of inner reflector temperatures here, but similar behavior for temperatures in the core region



Block temperature comparison at the core midplane during a 2.2 MW steady state

Figure from: Kile et al., "Code Benchmark of a Depressurized Conduction Cooldown Transient in the High Temperature Test Facility," *Proceedings of Advances in Thermal Hydraulics*, Orlando, FL, November 17-20, 2024

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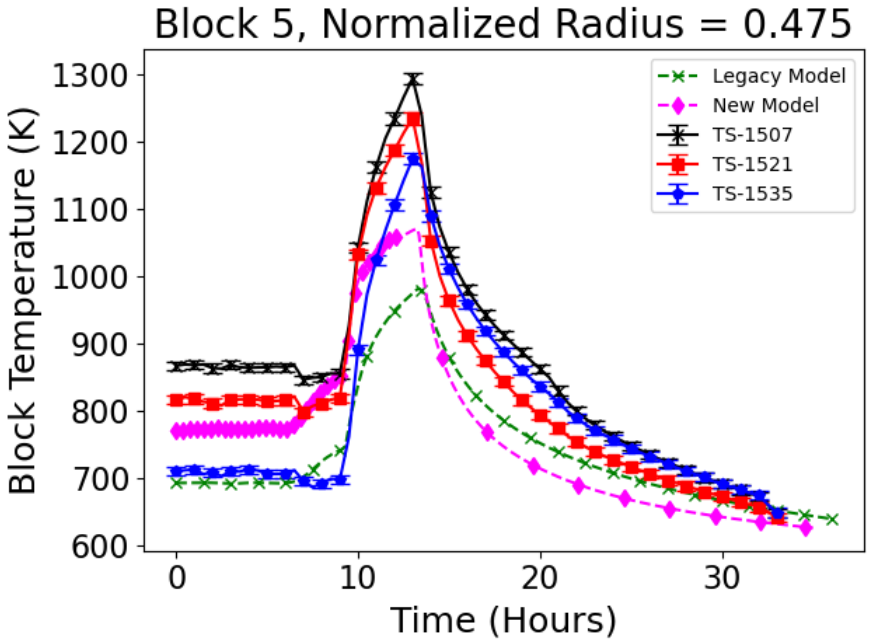
We want to validate RELAP5-3D for prismatic HTGR analysis

- RELAP5-3D has been used for analysis of several prismatic HTGRs, but these applications lie outside the code's validation basis
- INL has developed 2 RELAP5-3D models of HTTF and used them during this benchmark
- First model has been used extensively and is described in depth in INL/EXT-18-45579



- RELAP5-3D models have generally shown an ability to predict trends in HTTF data but not to reproduce measured values within their uncertainty

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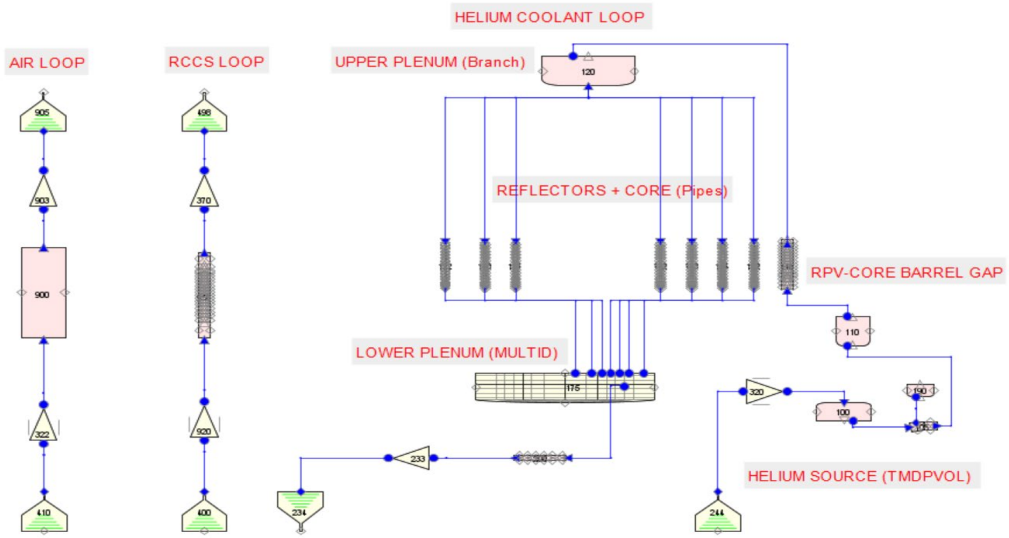
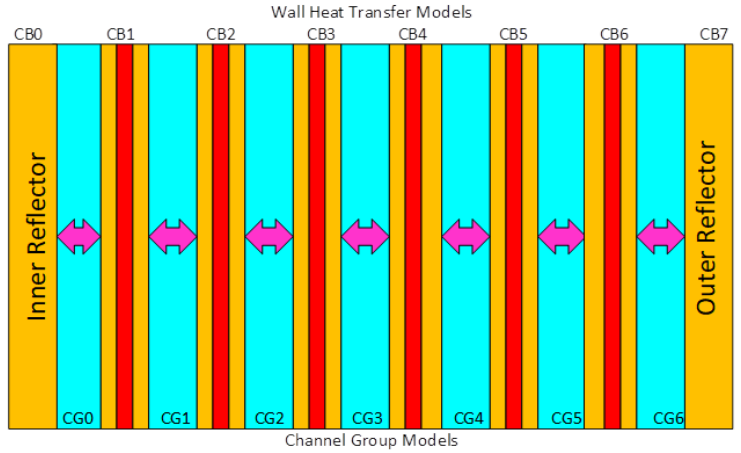
Canadian Nuclear Laboratories are also using RELAP5-3D to model HTTF

- CNL originated the idea of a six-sector RELAP5-3D model
- CNL analyses have been published in the following:
  - Podila et al., “Coupled simulations for prismatic gas-cooled reactor,” *Nuclear Engineering and Design*, vol. 395 (2022).
  - Kile et al., “Code Benchmark of a Depressurized Conduction Cooldown Transient in the High Temperature Test Facility,” *Proceedings of Advances in Thermal Hydraulics*, Orlando, FL, November 17-20, 2024.
- CNL includes heater rods and blocks as regions in the same heat structure whereas INL uses separate heat structures and radiation enclosures to connect the two





Figures from: Kile et al., “Code Benchmark of a Depressurized Conduction Cooldown Transient in the High Temperature Test Facility,” *Proceedings of Advances in Thermal Hydraulics*, Orlando, FL, November 17-20, 2024

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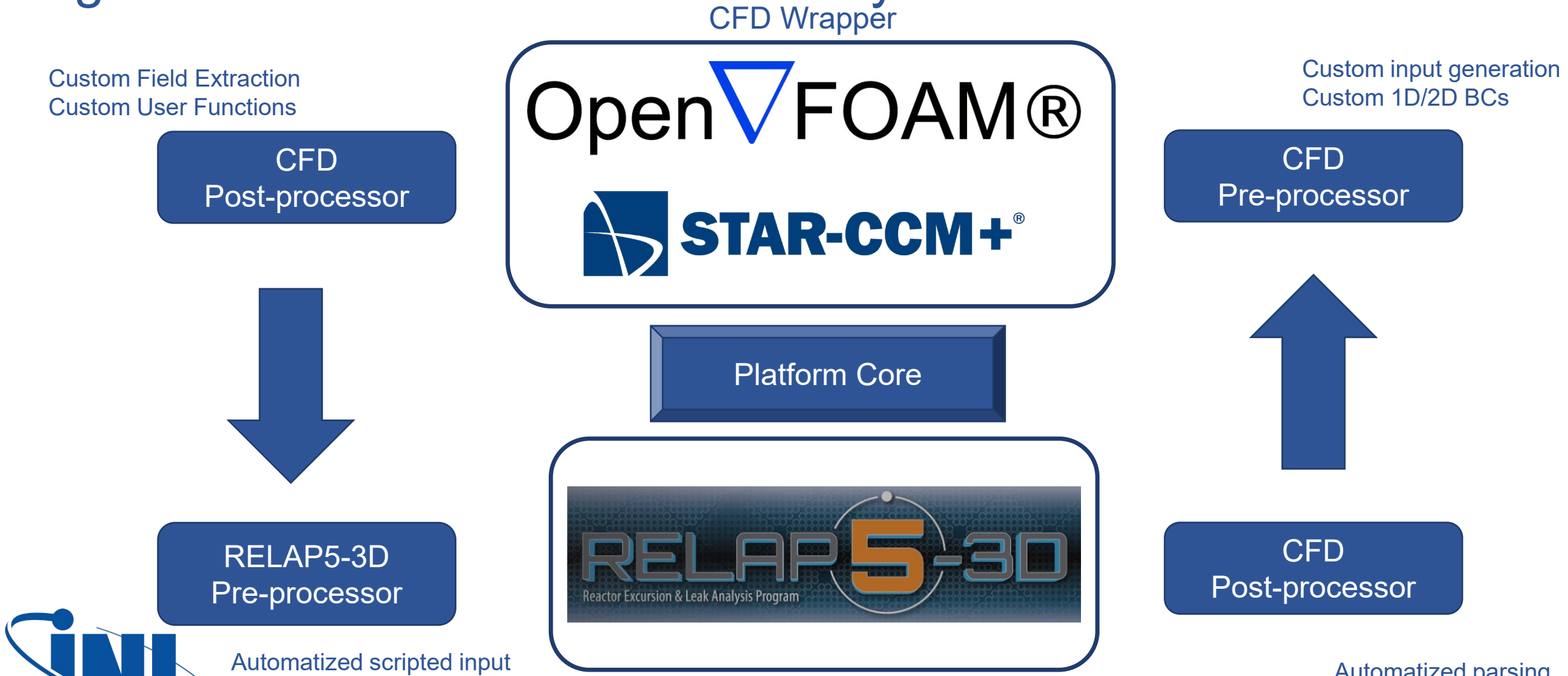
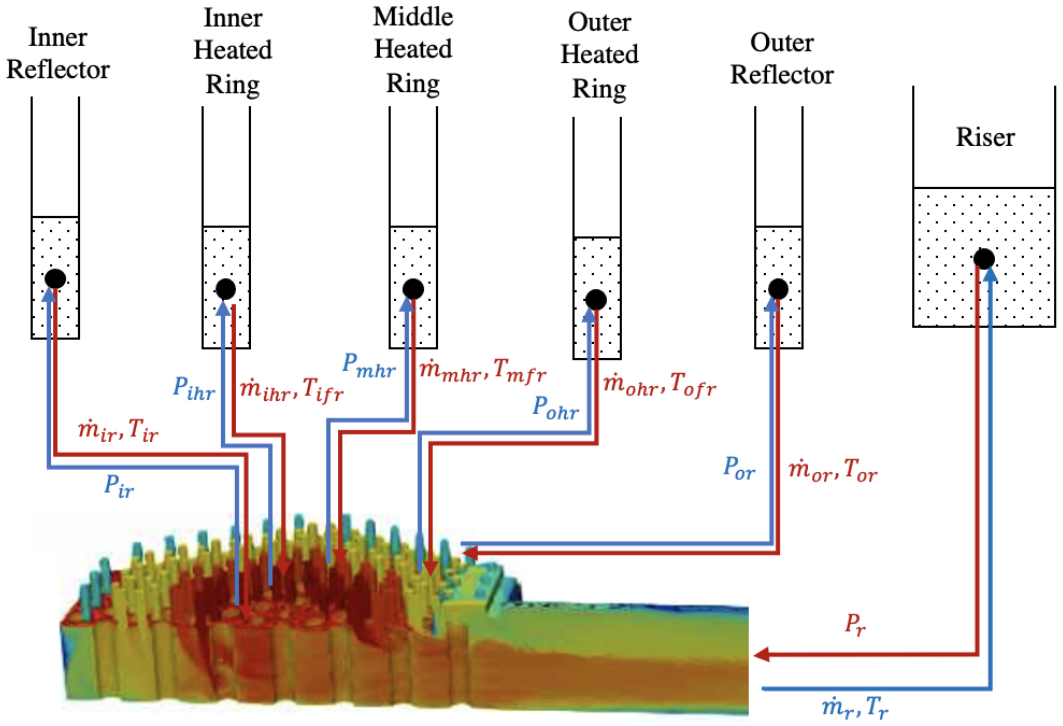
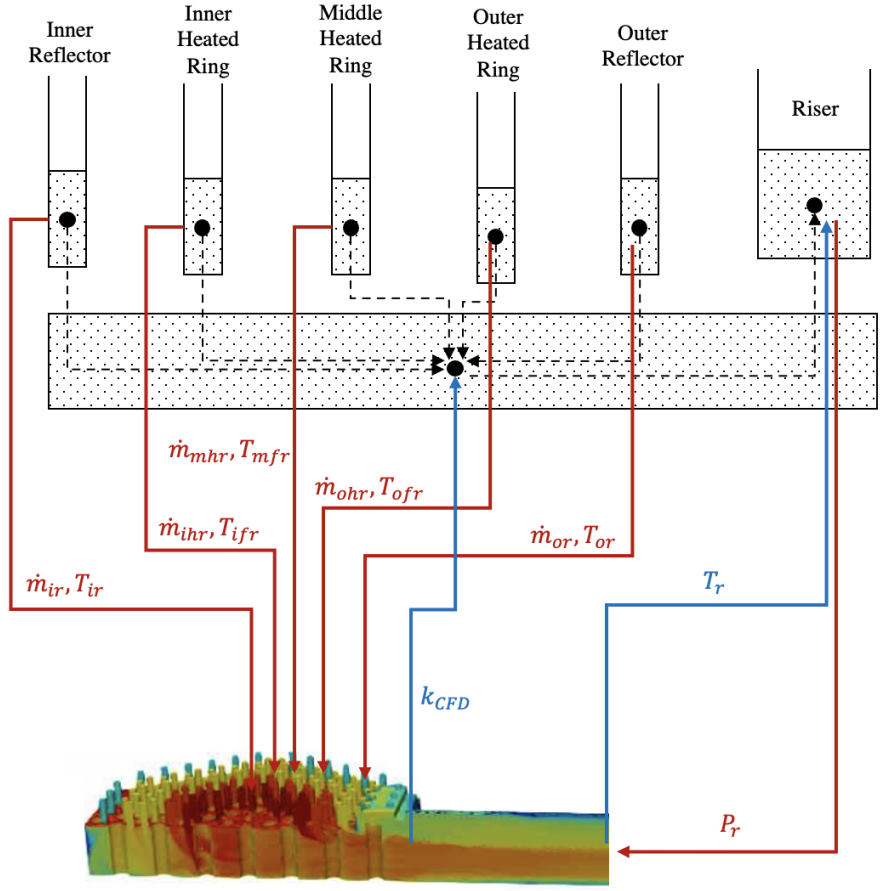
For lower plenum modeling, RELAP5-3D can be used to generate inlet and outlet boundary conditions



Two approaches: Domain segregated and domain overlapping





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Wrapping up

- RELAP5-3D is a key part of the HTGR Thermal Hydraulics Benchmark
- Predicting temperatures in the core has been difficult, but trends are well captured
- Using RELAP5-3D to generate boundary conditions for CFD models of the lower plenum shows great promise, with the domain segregated approach leading to errors as low as 6.3%, and 5.2% for the domain overlapping approach
- This benchmark is ongoing, and the final report is scheduled for release in December of 2025

Acknowledgements

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- Thanks to Tariq Jafri, Geoff Waddington, and Xianmin Huang at CNL for providing a description of their model
- Thanks to Mauricio Tano Retamales at INL for developing the CFD coupling approach with RELAP5-3D
- Thanks to all organizers of this benchmark for all their hard work

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