INL/CON-24-78083-Revision-0

Initial Development of a new RELAP5-35 Model of HTTF

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Changing the World's Energy Future

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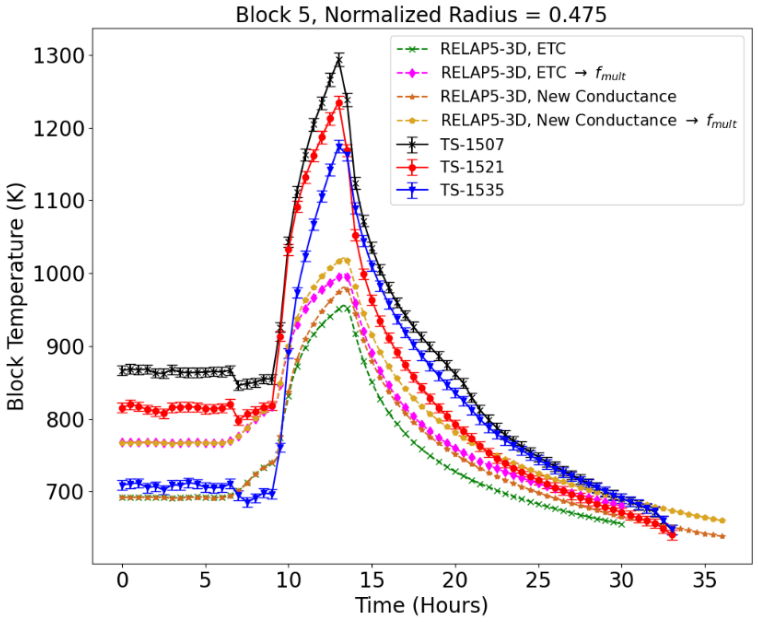
Initial Development of a new RELAP5-3D Model of HTTF

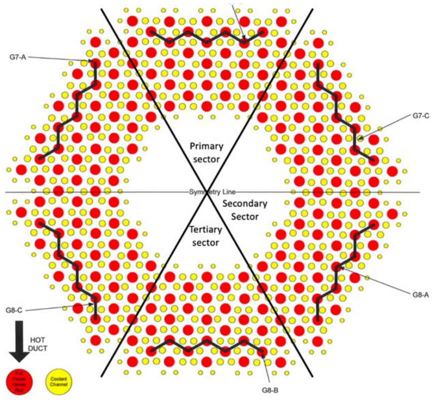
OECD-NEA WPRS Benchmarks Workshop

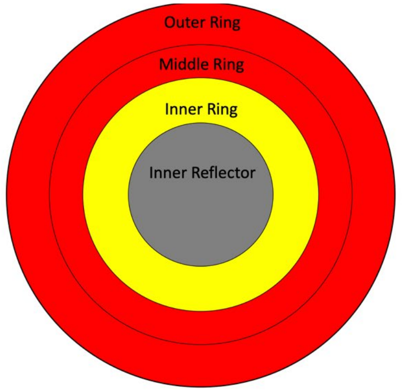
Advanced Reactor Technologies
GAS-COOLED REACTORS

Previous validation studies with RELAP5-3D showed an ability to reproduce trends in measured data but not transient temperatures

- These studies used a RELAP5-3D model described in INL/EXT-18-45579
- Validation studies based on PG-27 showed comparable steady state temperatures, but a temperature rise that was 11-48% too small in the core region
- We hypothesize that this is the result of the relatively coarse nodalization of the model, which lead to heat being generated in 73% of the heater rod volume in the model compared to 20% of the heater rod volume in the experiment
- We have created a new model to test whether a finer nodalization will be able to reproduce transient temperature rise

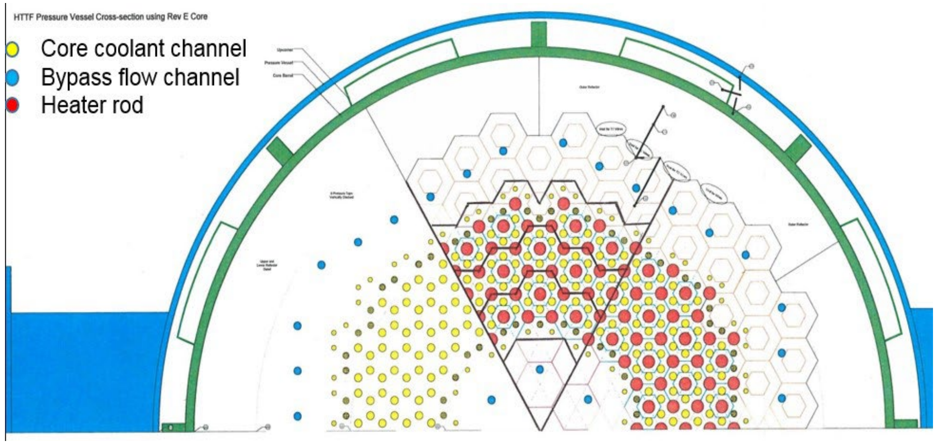




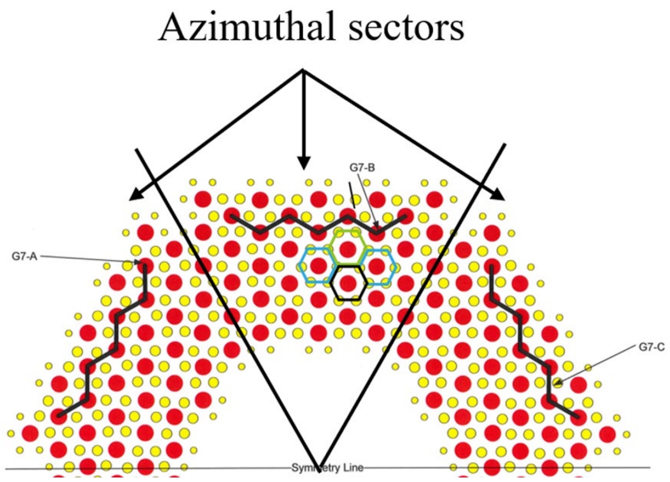


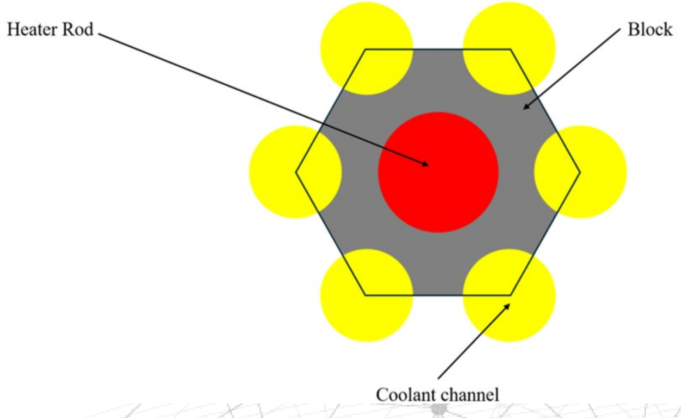
Comparing unit cells

- The old model used a hex block unit cell as shown in the figure on the left
- The new model uses a smaller hex block unit cell as shown in the figure on the right
- The new model also includes separate azimuthal sectors to capture azimuthal asymmetry
- Heater rods used in PG-27 straddle the boundaries of “rings” in the old model
  - Old model was built well before experiments were done, and the location of the active heater rods was not known a priori



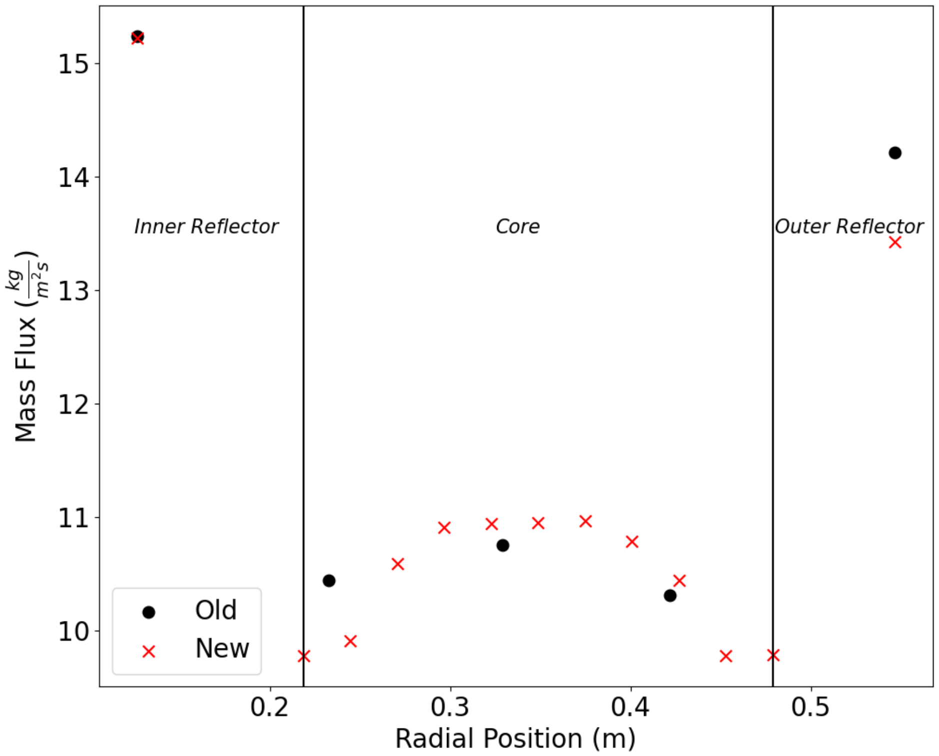
Bayless, P., “RELAP5-3D Input Model for the High Temperature Test Facility,” Idaho National Laboratory, Idaho Falls, ID, INL/EXT-18-45579, 2018.





Comparing mass flow

- Finer radial nodalization better captures the presence of smaller coolant channels at the inner and outer edges of the core
- Smaller coolant channels lead to higher friction and therefore smaller mass flux in the peripheral regions of the core
- Overall, flow distributions are comparable
- Bypass flow through the reflectors is nearly identical

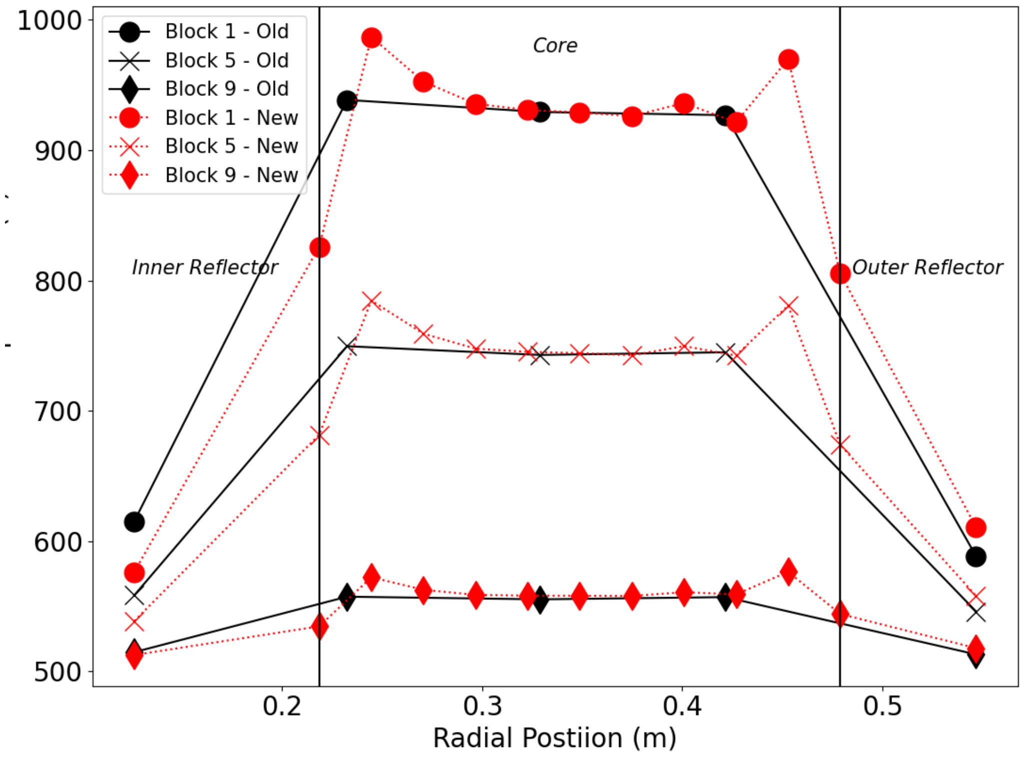


Model	Bypass flow fraction
Old	12.7%
New	12.2%

Type and number of coolant channels in the core

	Small	Medium	Large
Diameter (cm)	0.9525	1.2700	1.5875
#	96	96	324

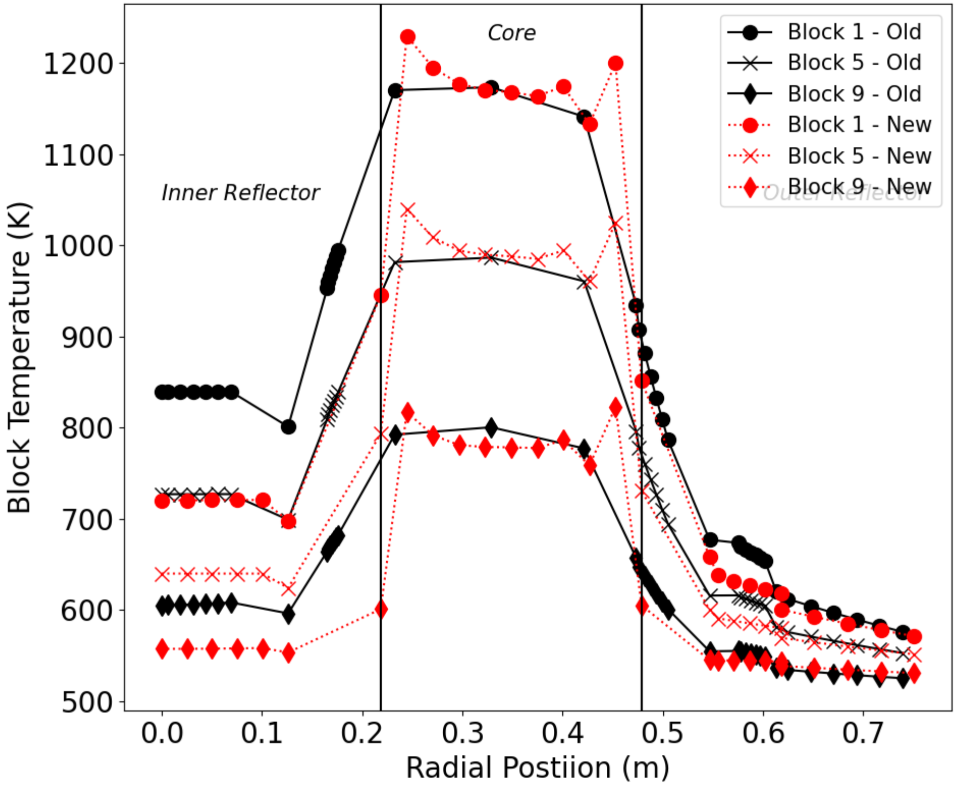
Helium temperature distributions follow mass flux and power distributions



- Inner- and outermost coolant channels in the core have no power, leading to lower temperatures in the new model
- Peaks in helium temperature at the edge of the core are due to higher power-to-flow ratio at the core's edge because of the small and medium coolant channels
- New model is in good agreement with the old model, but shows greater level of detail in results

Block temperature distribution in the core generally follows helium temperature distribution

- Temperatures in the inner reflector are much lower in the new model
  - Revised conduction modeling and inner reflector nodalization lead to increased thermal resistance between core and inner reflector
- Temperatures in the outer reflector are nearly identical
- Core temperatures generally follow helium temperatures, with local variations based on local power-to-flow ratios
- Generally good agreement, but we see differences based on which model is used

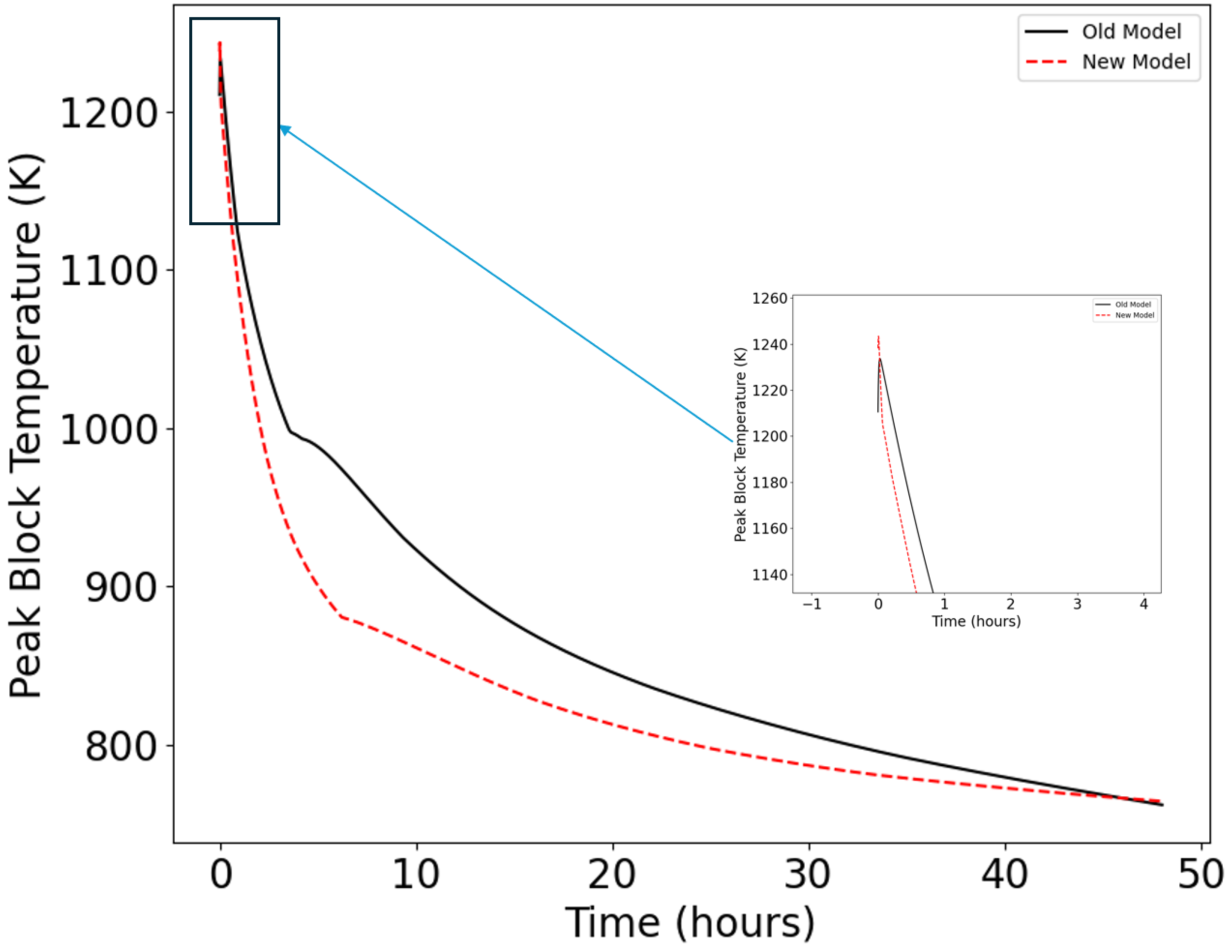


Energy Balance

- Steady-state energy balance is nearly identical between the two models
- This provides further confidence in the models
- The old model included radiation pathways between the top grid plate and the top head as well as between the bottom of the lower reflector and the lower plenum support structures. These pathways are missing in the new model
- Missing radiation pathways lead to greater heat removed by convection in the helium, but not much greater heat removal (an increase of 0.07%)

	Power Removed by Helium (kW)	Power Removed by Cavity Air (kW)	Power Removed by RCCS (kW)	Helium Outlet Temperature (K)	RCCS Outlet Temperature (K)
Old Model	2185.2	1.5	12.4	921.2	316.2
New Model	2186.8	1.5	12.5	921.7	316.2

Transient Comparison

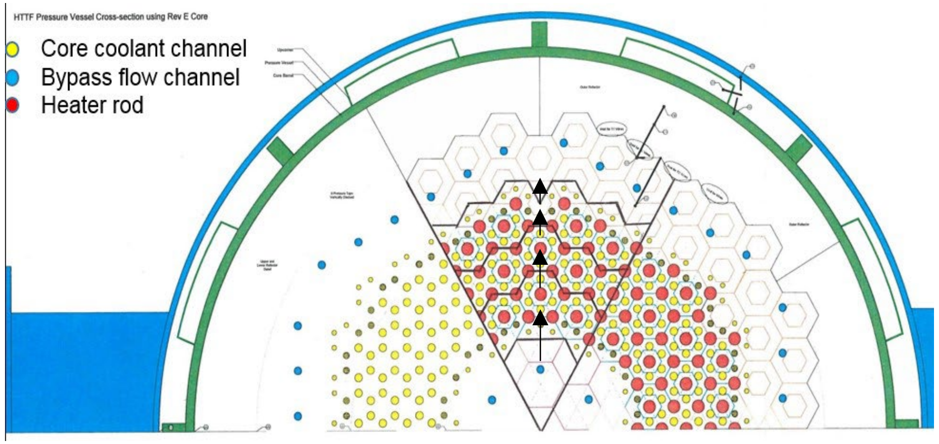


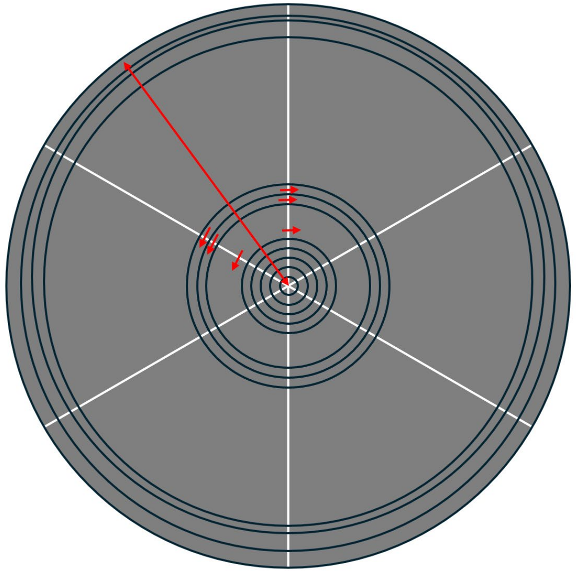
- Transient is a pressurized conduction cooldown
  - Flow goes from 1.0 kg/s to 0.0 kg/s linearly over 1 second
  - ANS-94 decay heat standard
- Note that while the boundary conditions used here are from P3Ex1B, the results are not P3Ex1B results
- Difference in peak block temperature is just 3 K
- Temperature rise in old model is higher than new
- Differences from ~0.25-45 hours arise due to increased thermal resistance in new model between core and inner reflector

Model	Peak Block Temperature (K)
Old	1233.7
New	1236.7

Comparison of conduction pathways

- Old model could not capture azimuthal asymmetry
- New, sectorized model can capture azimuthal asymmetry and allows azimuthal conduction
- All analysis done so far has used symmetric heating and all heater rods active
- Biggest value statement for the new model is in situations such as PG-28 and PG-29 experiments where heating is both radially non-uniform and azimuthally asymmetric





Conclusions and Future Work

- New and old RELAP5-3D models of HTTF provide comparable results in full-power steady state, but new model provides greater resolution
- Energy balance shows excellent agreement between the two models
- New model has higher thermal resistance between the core and the inner reflector
- The maximum block temperature achieved during PCC differs by 3 K between the two models
- Long-term, the new model predicts lower temperatures due to higher thermal resistance between the core and inner reflector
- Future work includes modeling of radially non-uniform and azimuthally asymmetric conditions to demonstrate greater differences between new and old models