RELAP5-3D Calculations Supporting HTTF Operation

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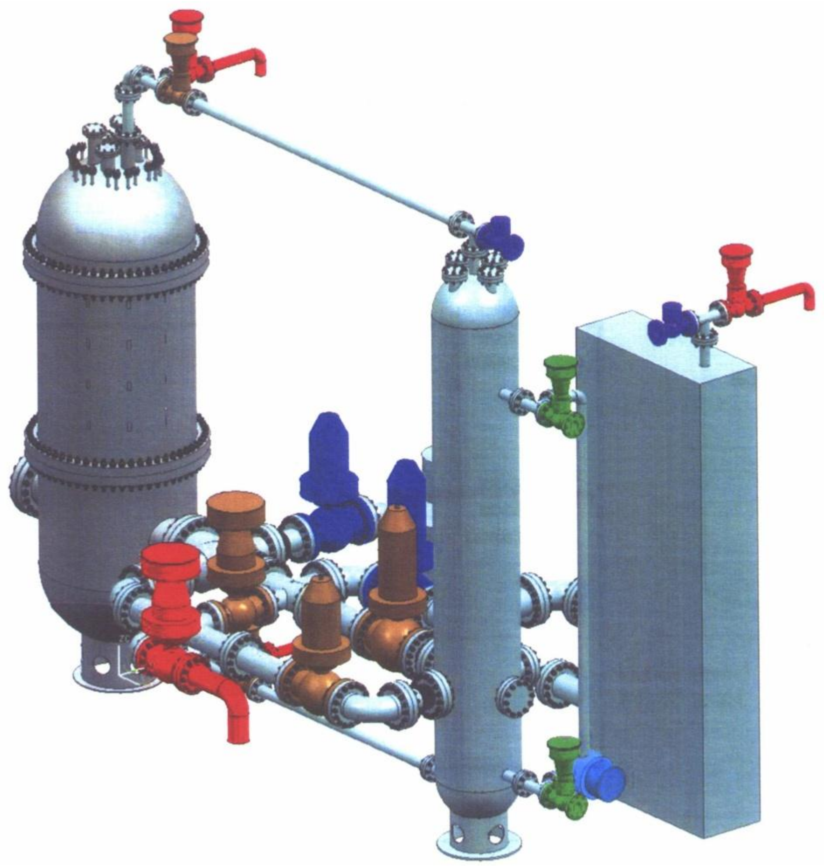
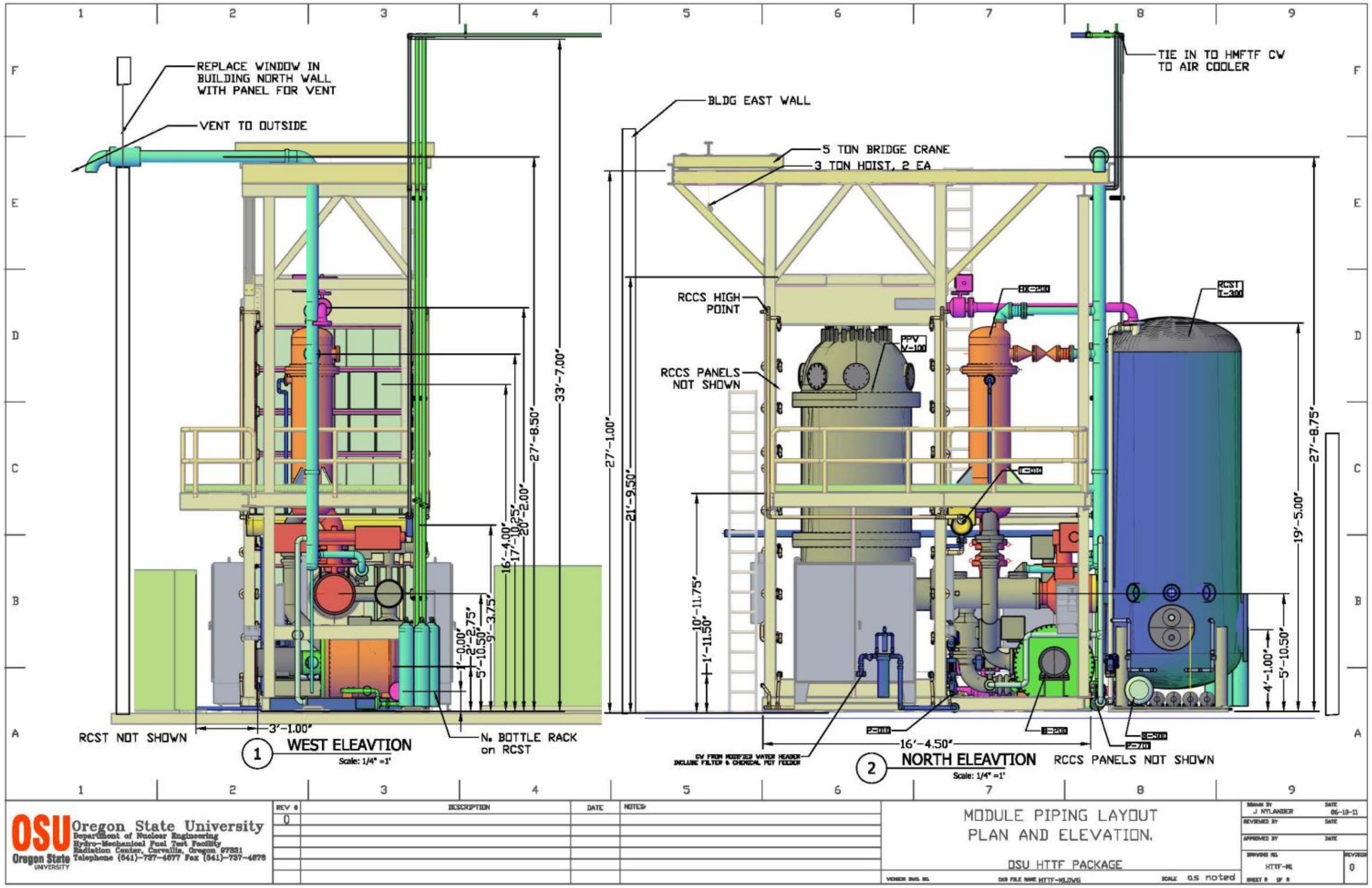
High Temperature Test Facility (HTTF)

- Integral experiment being built at Oregon State University
- Electrically-heated, scaled model of a high temperature gas reactor
  - Reference is the MHTGR (prismatic blocks)
  - Large ceramic block representing core and reflectors
  - ¼ length scale
  - Prototypic coolant inlet (259°C) and outlet (687°C) temperatures
  - Less than scaled power
  - Maximum pressure of ~700 kPa
- Primary focus is on depressurized conduction cooldown transient

High Temperature Test Facility



High Temperature Test Facility

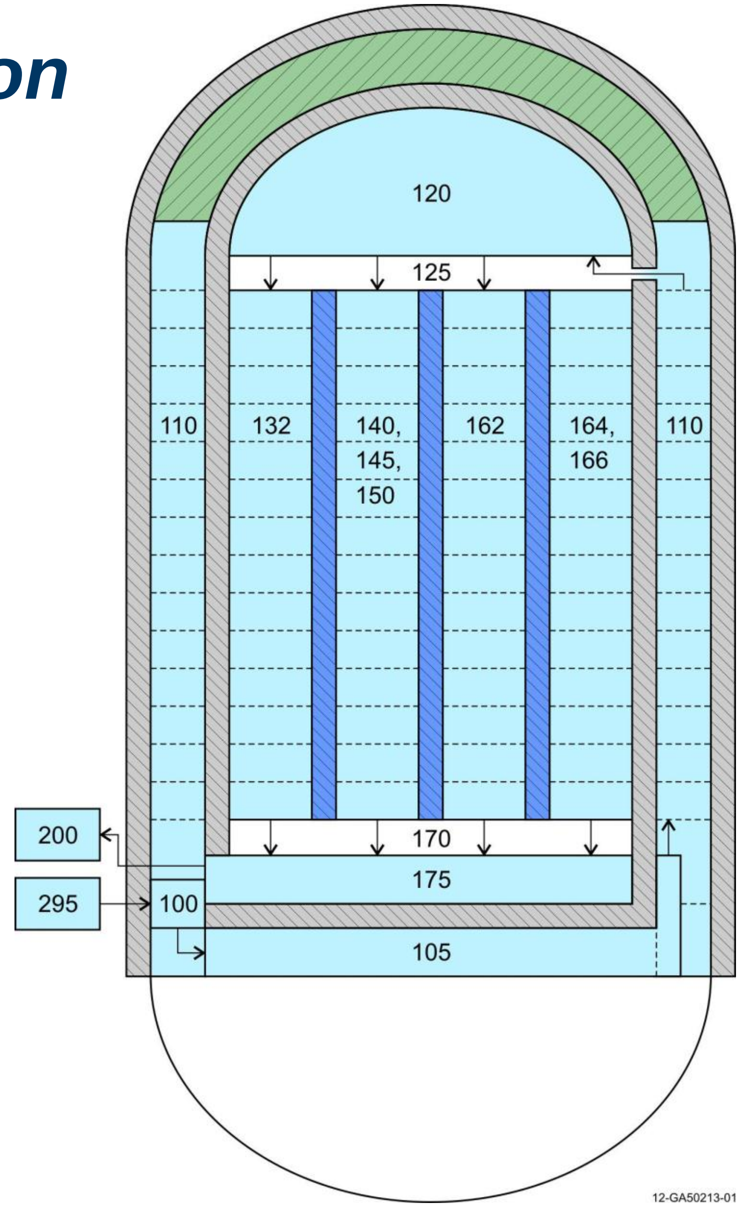


HTTF RELAP5-3D Model Description

- Four systems
  - Primary coolant
  - Secondary coolant
  - Reactor cavity
  - Reactor cavity cooling system (RCCS)
- Central and side reflector regions divided into regions with or without coolant holes
- 2-D (radial/axial) conduction in all vertical heat structures
- Heater block unit cell centered on the coolant channel
- Radial conduction and radiation inside core barrel
- Radiation from core barrel to vessel to RCCS

Reactor Vessel Nodalization

- Multiple flow paths through core
  - Three heated channels
  - Central reflector
  - Side reflector
- Gaps on either side of permanent side reflector not flow-through
- Riser annulus between core barrel and pressure vessel
- No coolant between upper plenum shield and upper head



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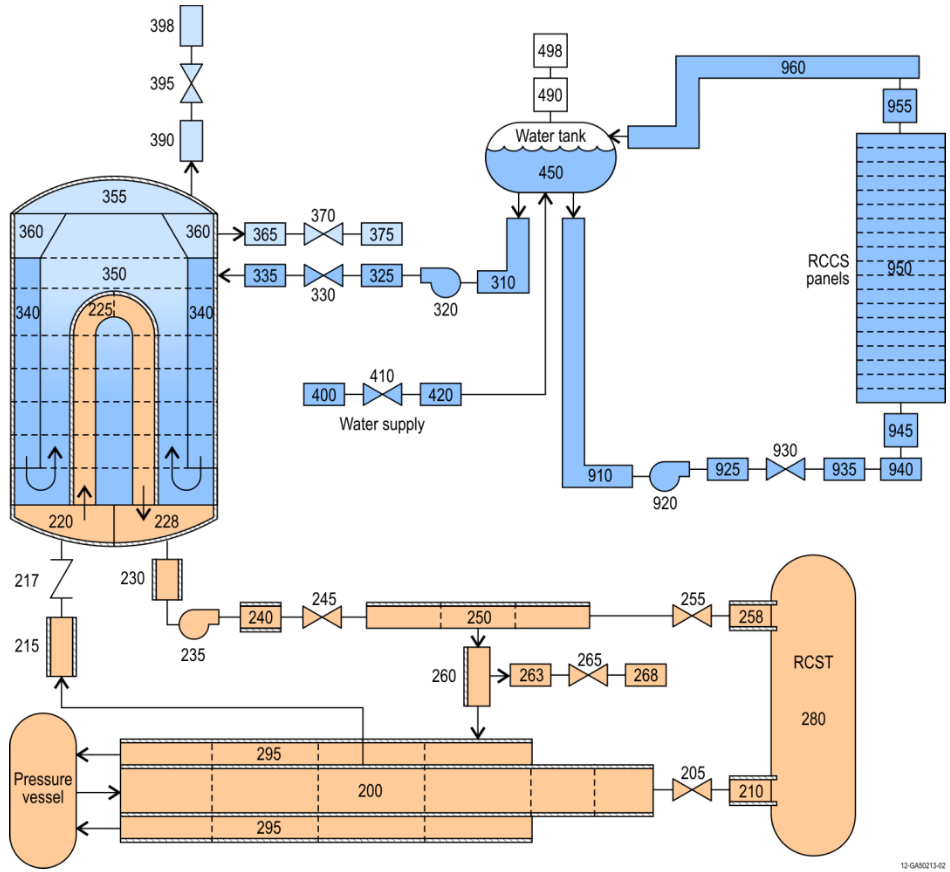
HTTF Ex-vessel Nodalization



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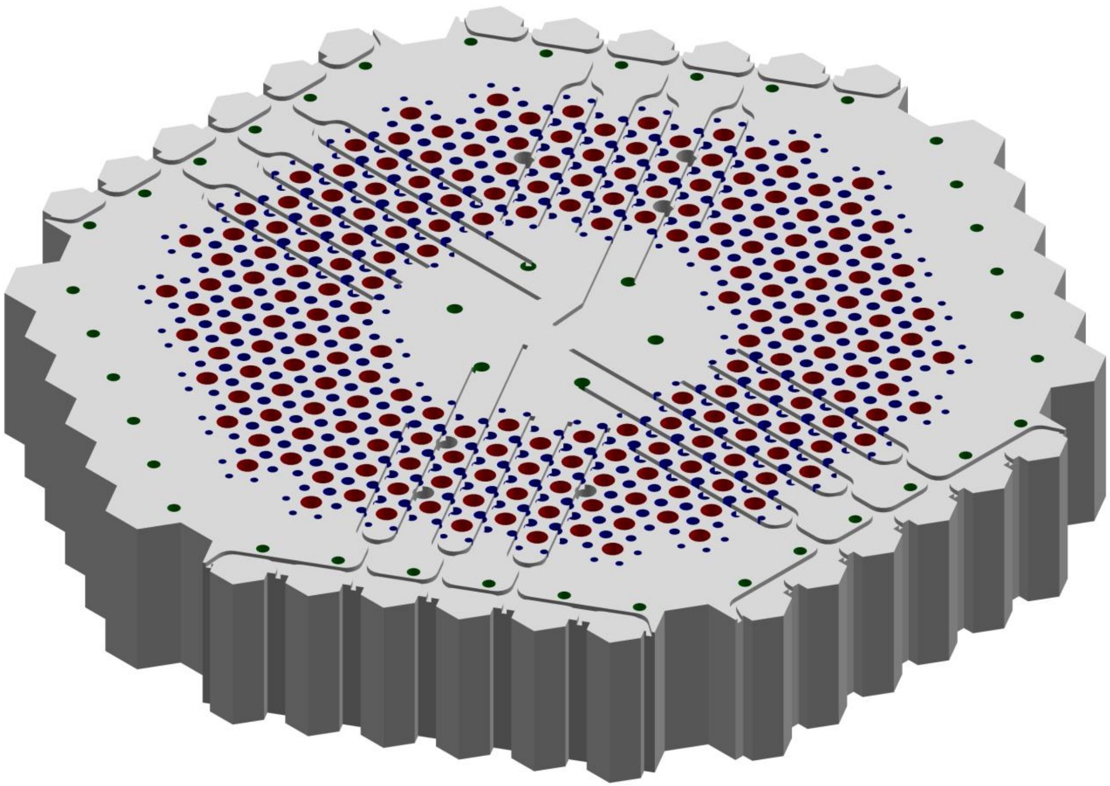
Core Block Design



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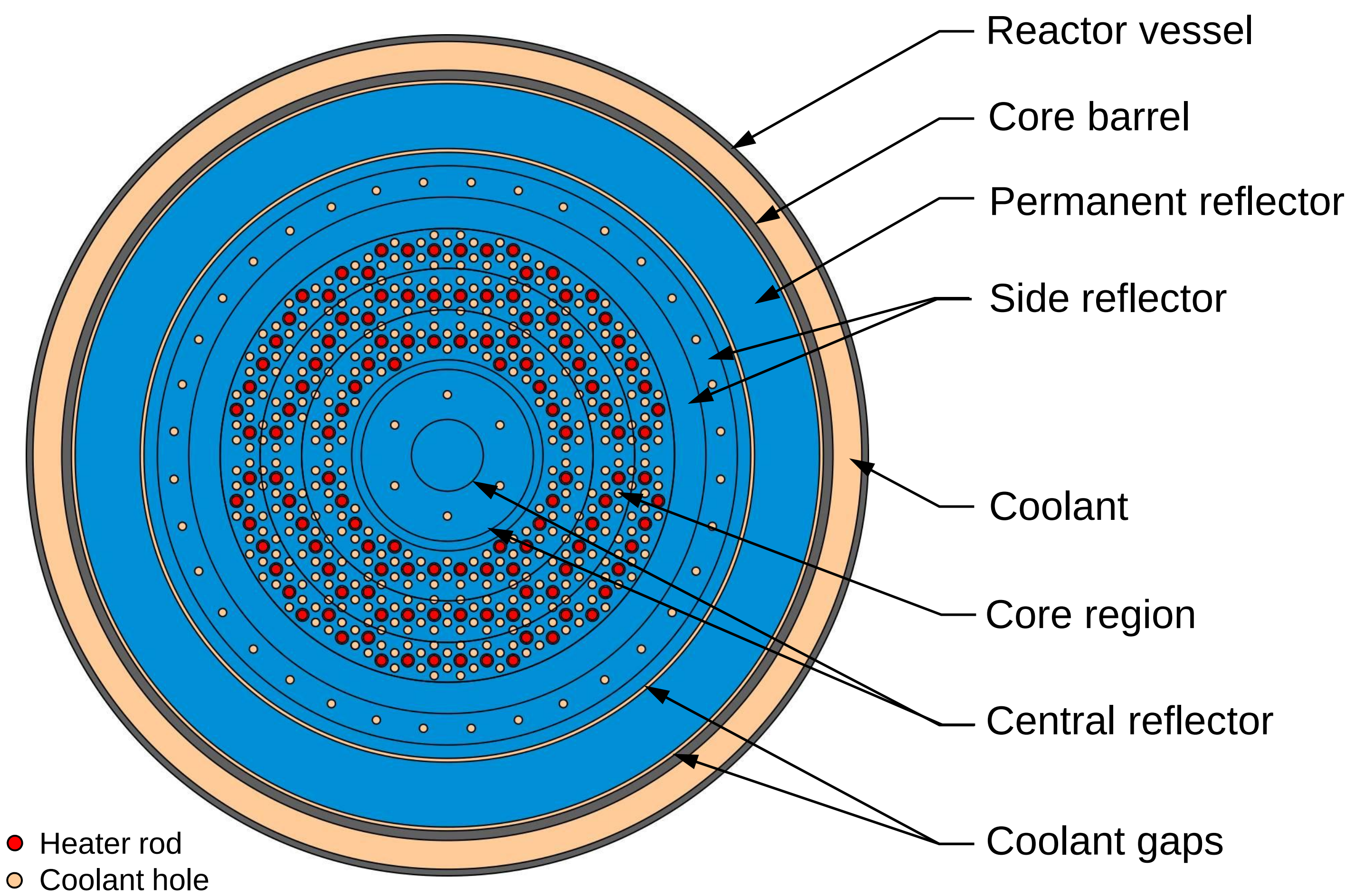
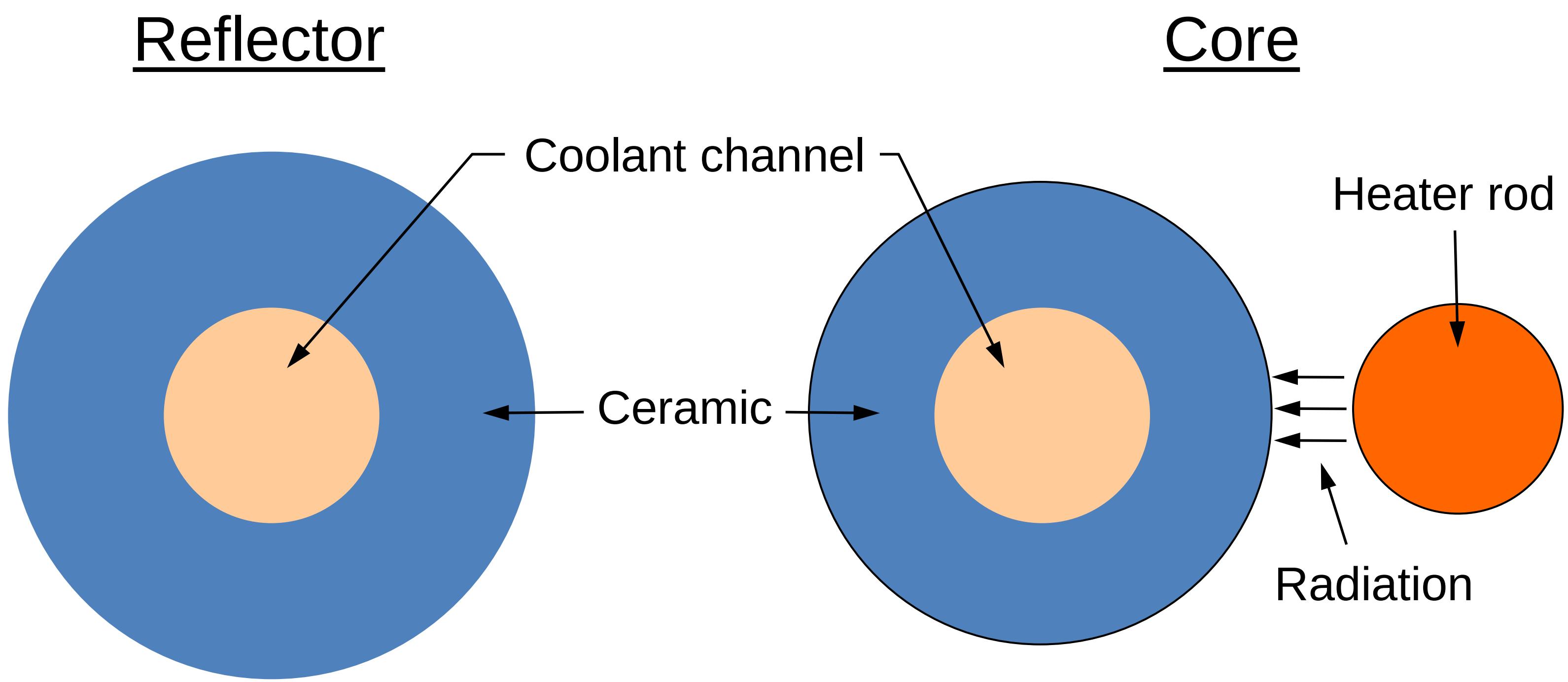
HTTF RELAP5-3D Core Region Radial Nodalization



HTTF RELAP5-3D Model Unit Cells



Analyses Supporting Facility Operation

- Initial facility heatup
- Recovery following depressurized conduction cooldown test
  - Reheat
  - Cooldown

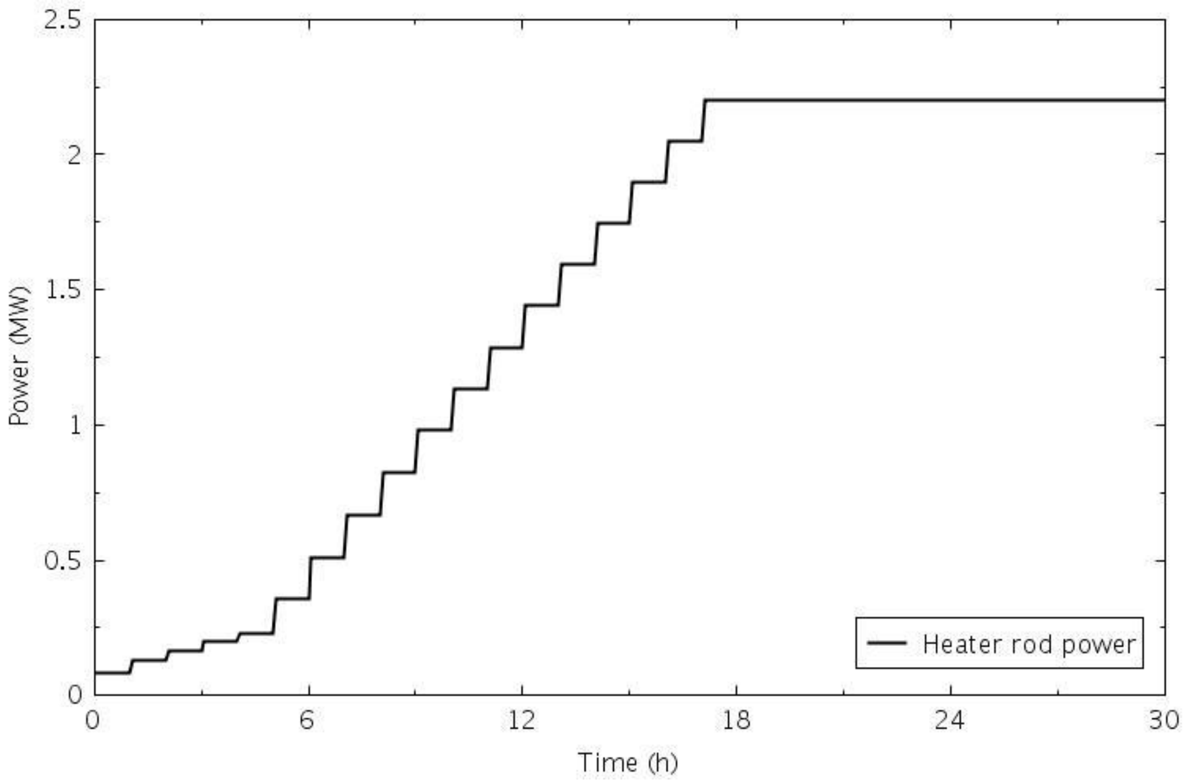
Possible Approaches to Initial Heatup

- Heat up with just in-vessel natural circulation
  - Minimizes heat loss
  - High stress on heater rods (low heat transfer rate)
  - Would likely require a very slow heatup
- Heat up with primary coolant flow but dry steam generator
  - Faster, controlled heatup rate possible
  - Reduces heat loss
  - All piping and primary system components at high temperature
  - Introducing cold feedwater to hot tubes
- Initial heatup with dry steam generator, then start steaming
  - Some heat loss
  - When to start feedwater?

Initial Facility Heatup Scoping Calculation

- Only the reactor vessel is modeled
- Entire system starts at ambient temperature
- 1.0 kg/s steady state flow rate established
- Power increased step-wise to maintain a 100°F/h maximum heatup rate in the ceramic
- Reactor vessel inlet temperature set to the lower of the
  - Vessel outlet temperature
  - Full power steady-state inlet temperature

Initial Heatup Heater Rod Power



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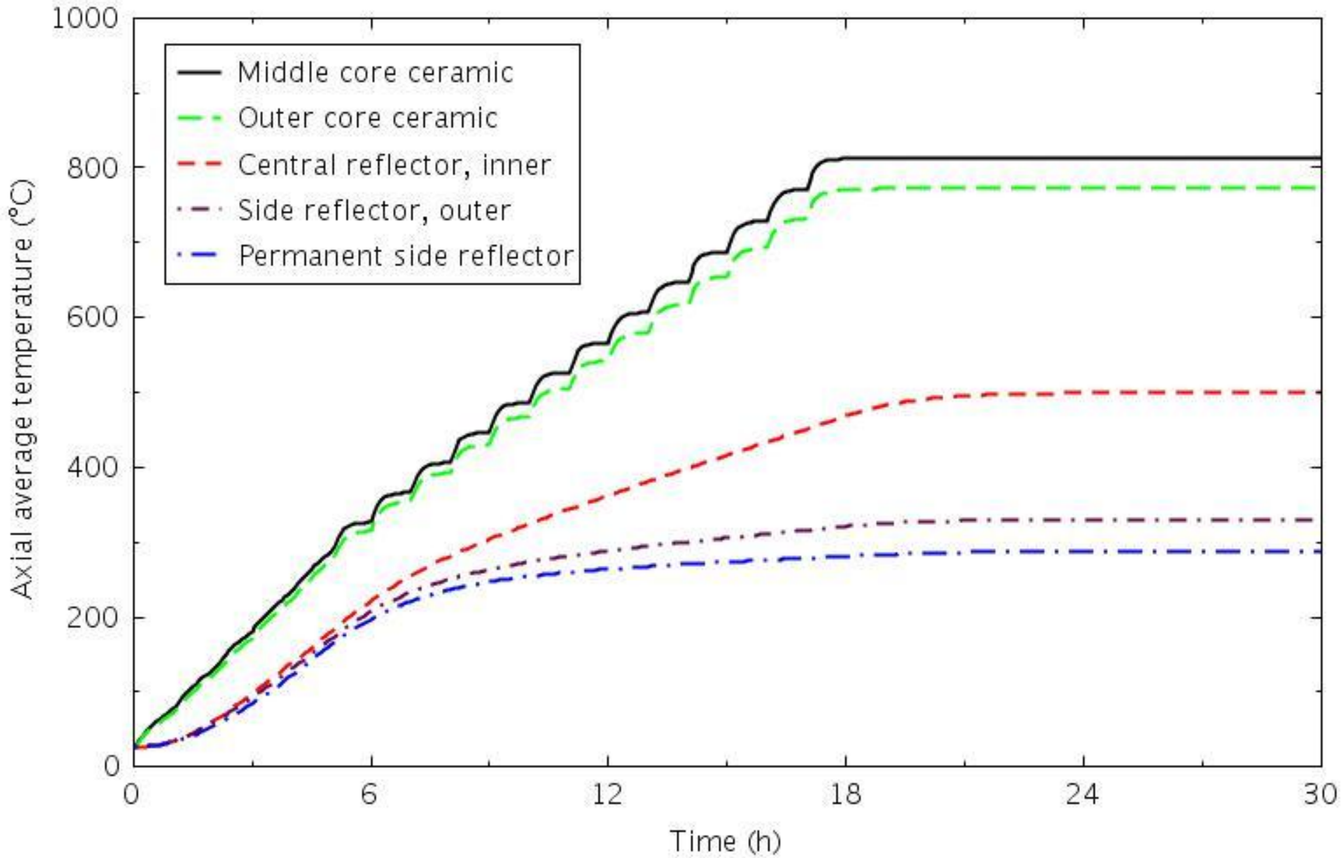
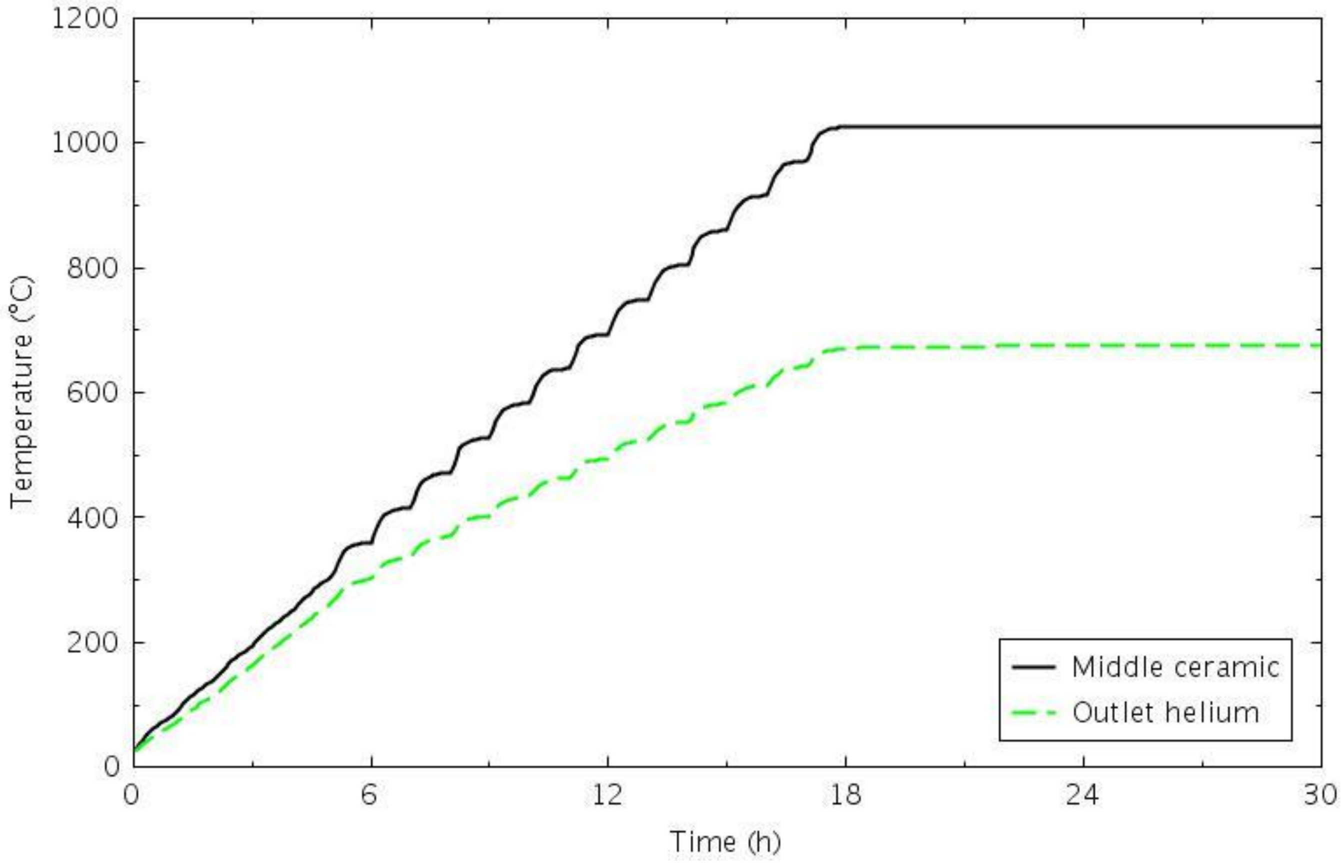
Initial Heatup Average Temperatures



Initial Heatup Temperature Increases



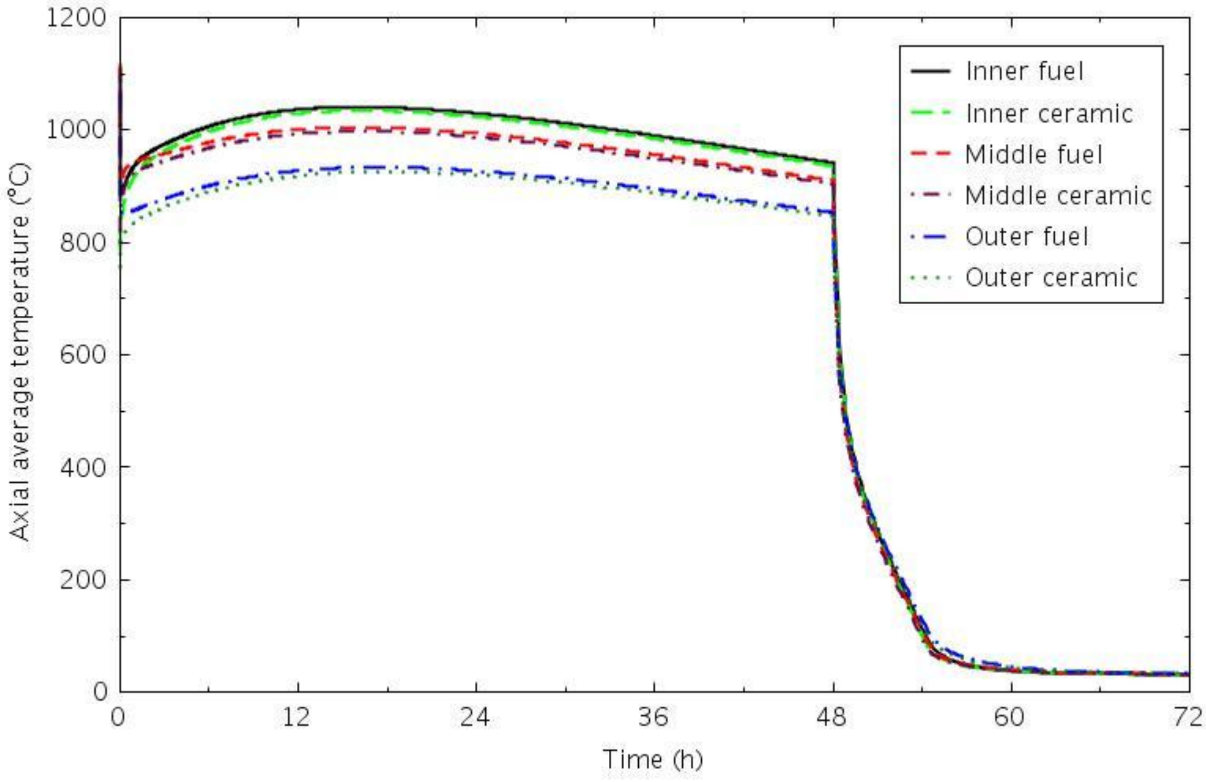
Initial Heatup Calculation Observations

- Core heats up much faster than the reflectors
- Heatup of the permanent side reflector is limiting
  - No adjacent flow for convective heat transfer
  - Must heat up via conduction and radiation
  - Ceramic has low thermal conductivity
- Large thermal inertia suggests that it may be desirable to run experiments in sequence, without cooling down in between

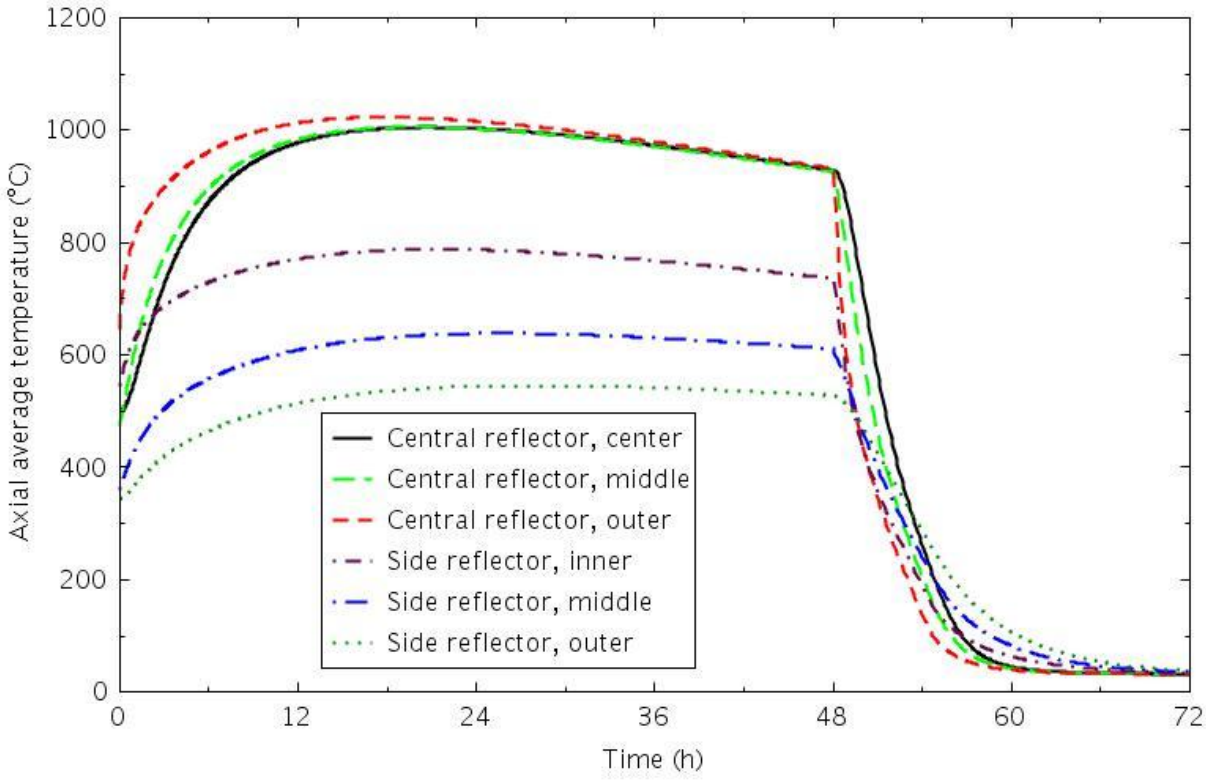
Experiment Recovery Investigations

- Evolutions follow a 48-hr depressurized conduction cooldown (DCC) test
- Cool down facility to ambient temperature
  - 10-s power down
  - 30-s flow increase to ~50% steady state value
  - Assumed 100°C temperature decrease through steam generator
- Reheat for next experiment
  - 30-s flow and pressure increase
  - 60-s constant power followed by 60-s power increase to 2.2 MW
  - Assumed 258.6°C vessel inlet temperature

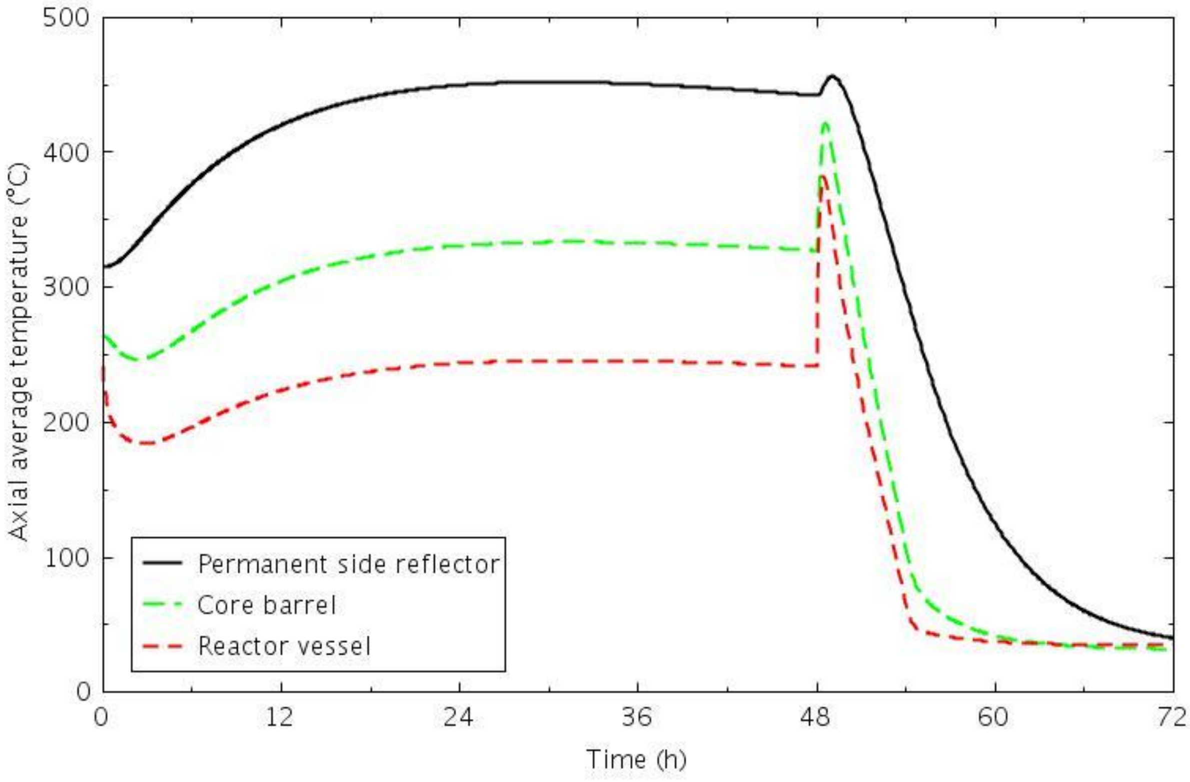
Cooldown Transient Core Temperatures



Cooldown Transient Reflector Temperatures



Cooldown Transient Peripheral Structure Temperatures



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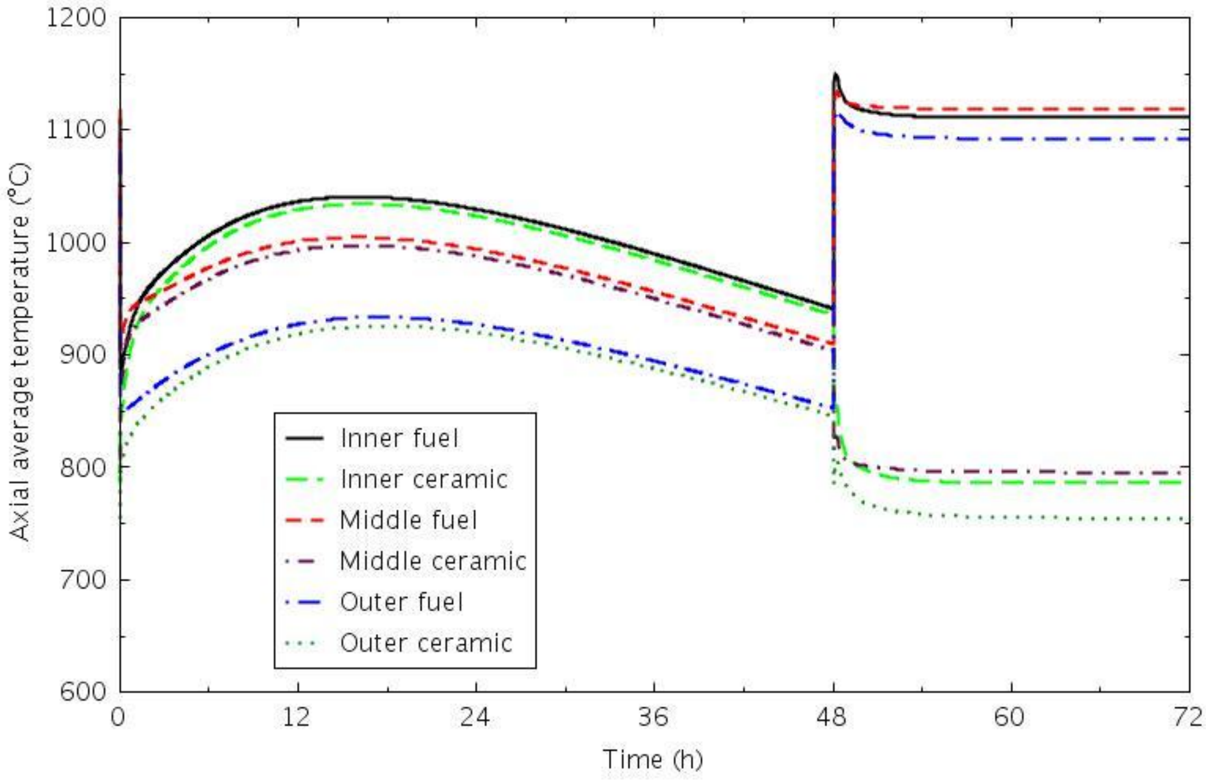
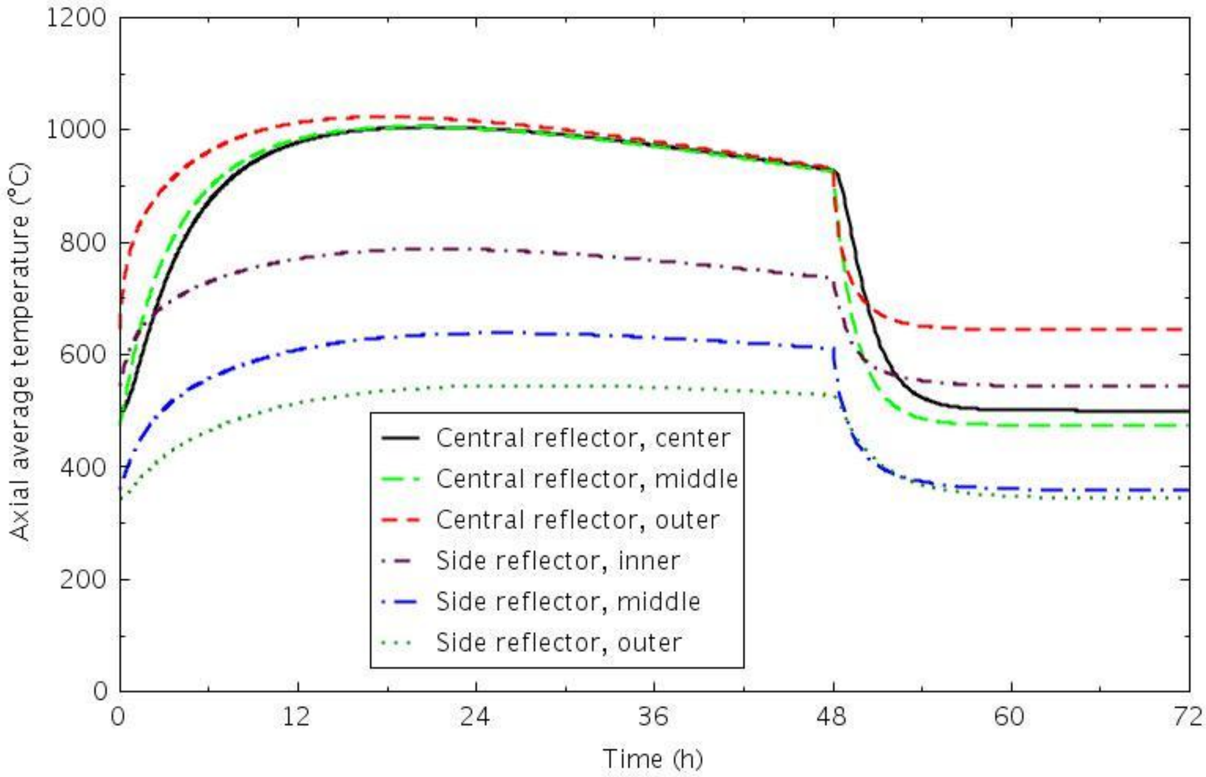
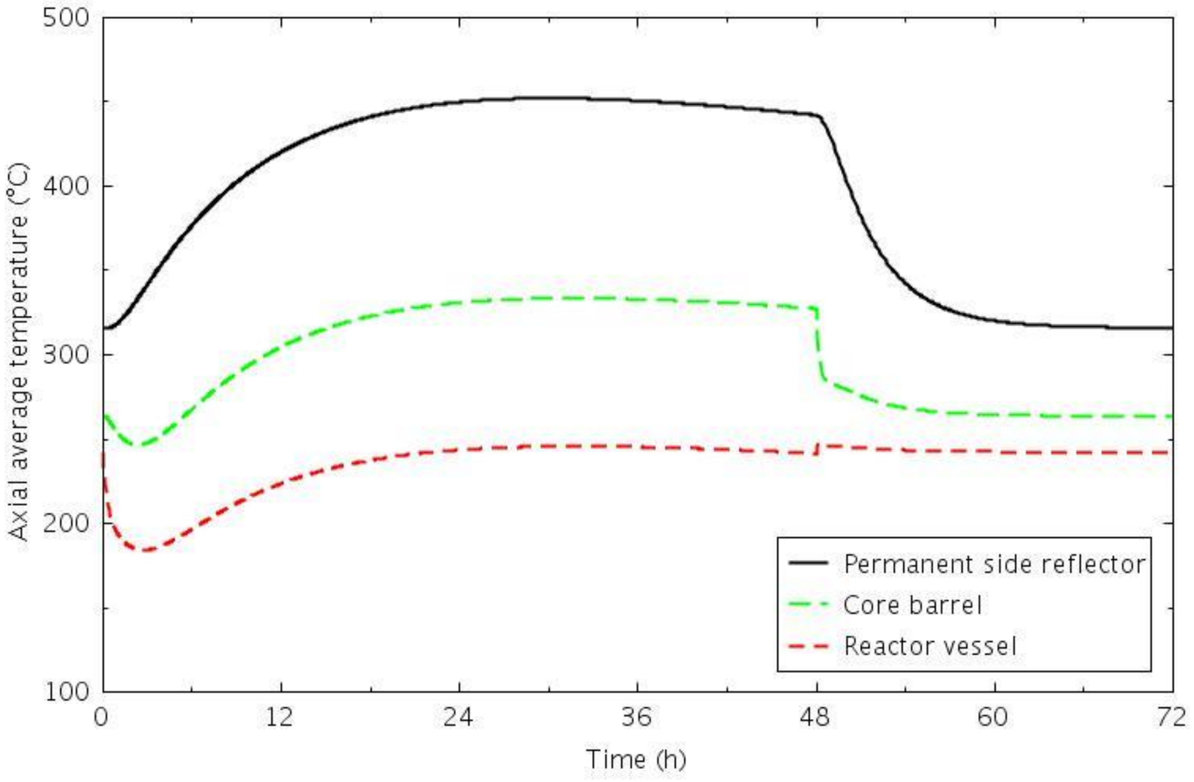
Reheat Transient Core Temperatures



Reheat Transient Reflector Temperatures



Reheat Transient Peripheral Structure Temperatures



Experiment Recovery Observations

- Permanent side reflector is the limiting structure
- Core region responds quickly
- Most structures are above their steady state temperatures at the end of the DCC transient
- For the reheat evolution, it may be desirable to cool down for a while before turning the power back on
- A complication with the reheat evolution is that the vessel coolant may be above piping design temperatures

Summary

- Code calculations have been performed to support the operation of the HTTF
- Facility heatup and cooldown are long evolutions
- How to accelerate cooldown following a test is an open issue
- Additional studies are needed to optimize experiment sequencing