HTTF Scoping Calculations

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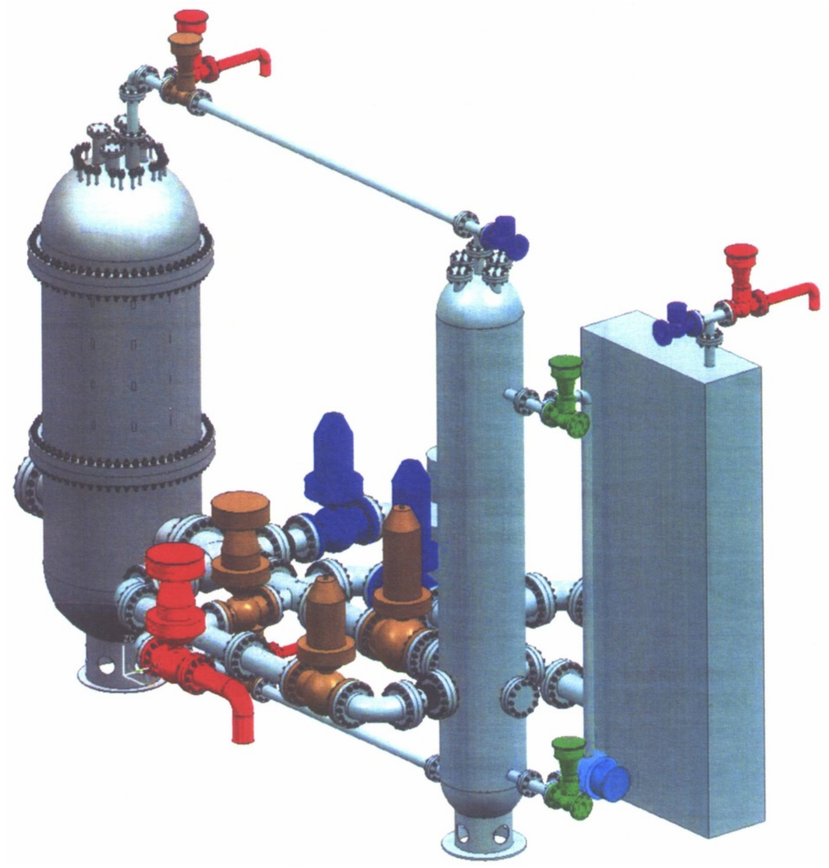
Outline

- Scoping analysis objectives
- HTTF description
- RELAP5-3D input model description
- System heatup simulations
- System cooldown simulations
- System reheat simulations
- Summary

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



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Scoping Analysis Objectives

- Investigate some simple approaches to normal plant operational evolutions
- Determine approximate timing
- Estimate resource requirements
- Get a feel for the overall system response

High Temperature Test Facility (HTTF) RELAP5-3D Input 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

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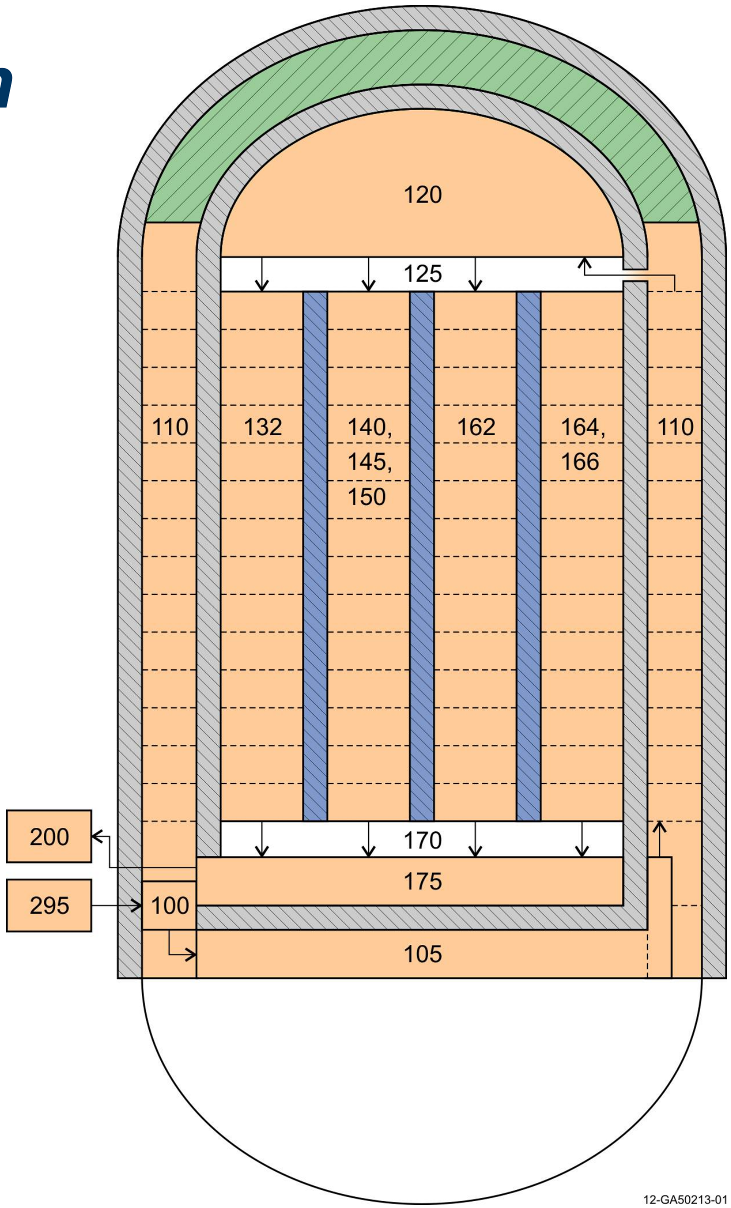
Reactor Vessel Nodalization

- 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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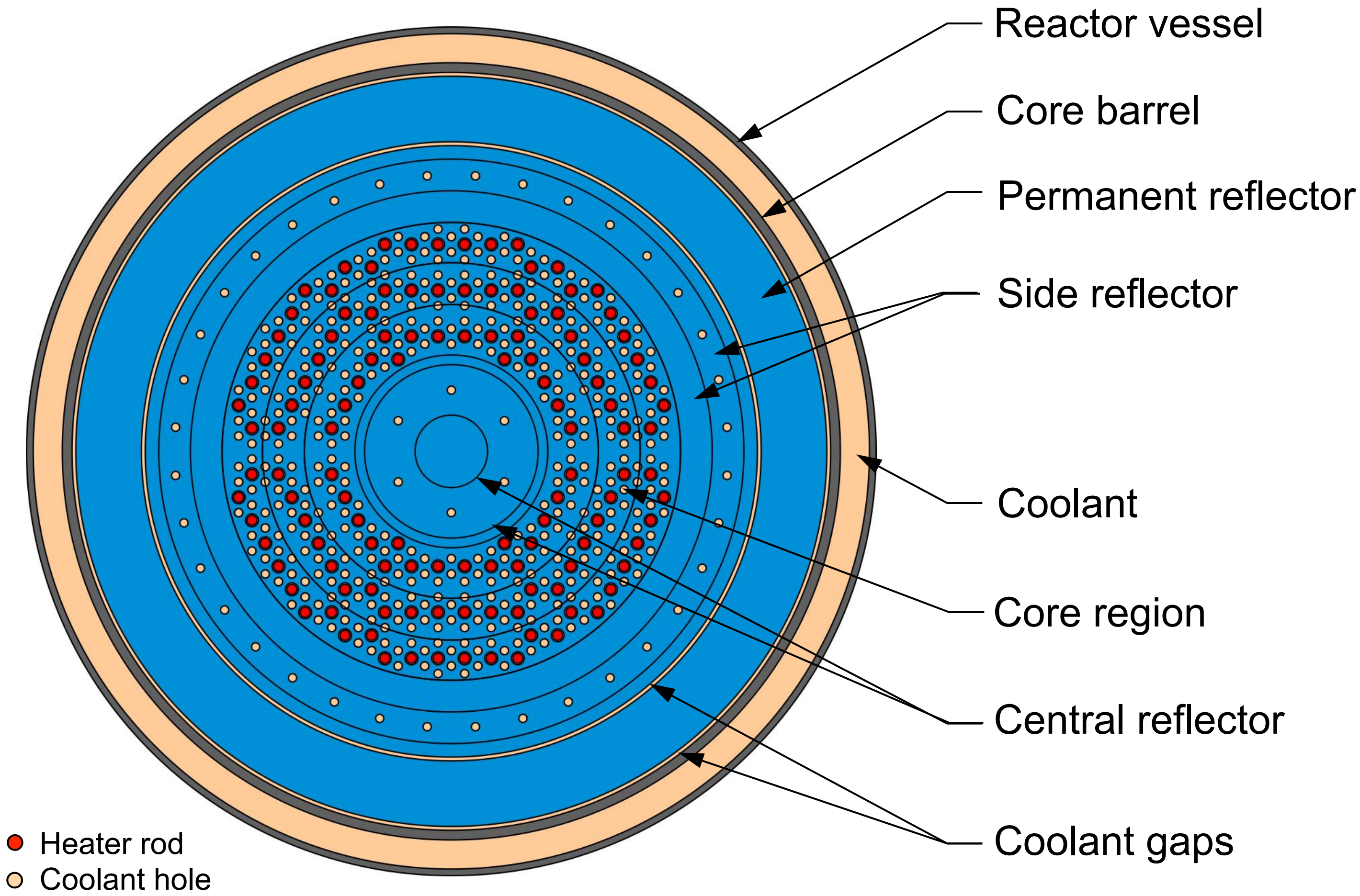
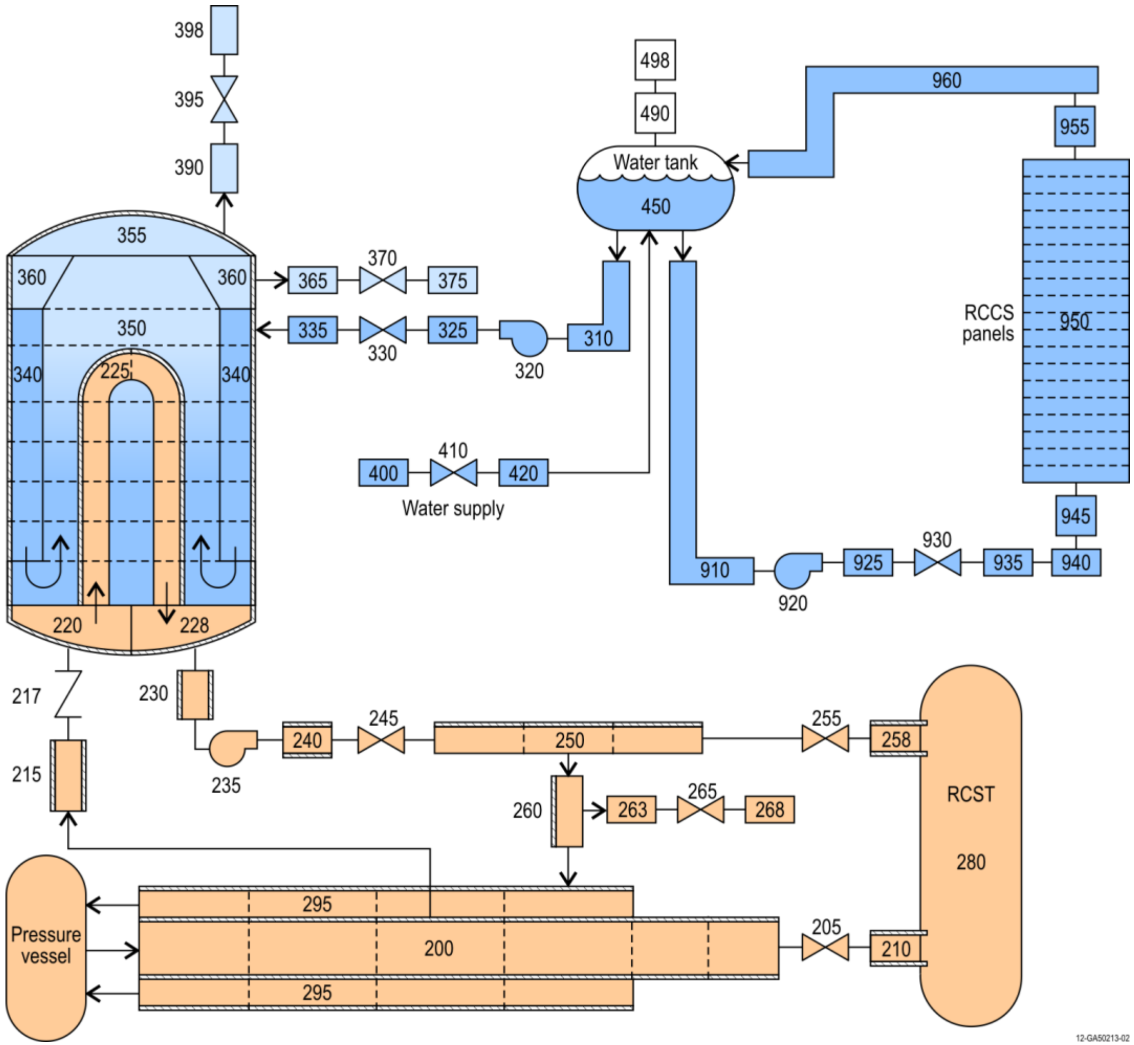
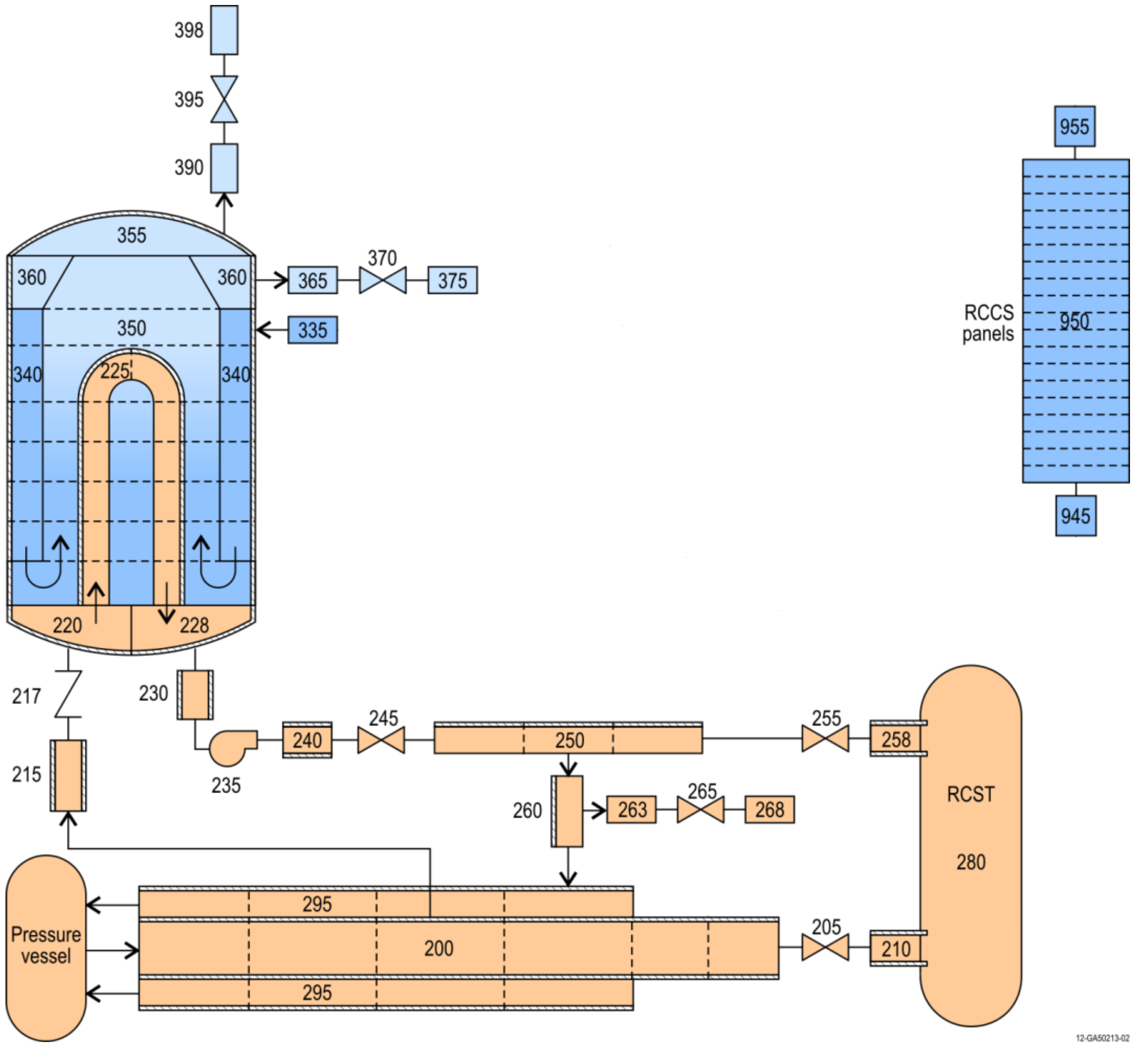
HTTF RELAP5-3D Core Region Radial Nodalization



HTTF Ex-vessel Nodalization (base)



HTTF Ex-vessel Nodalization (modified)



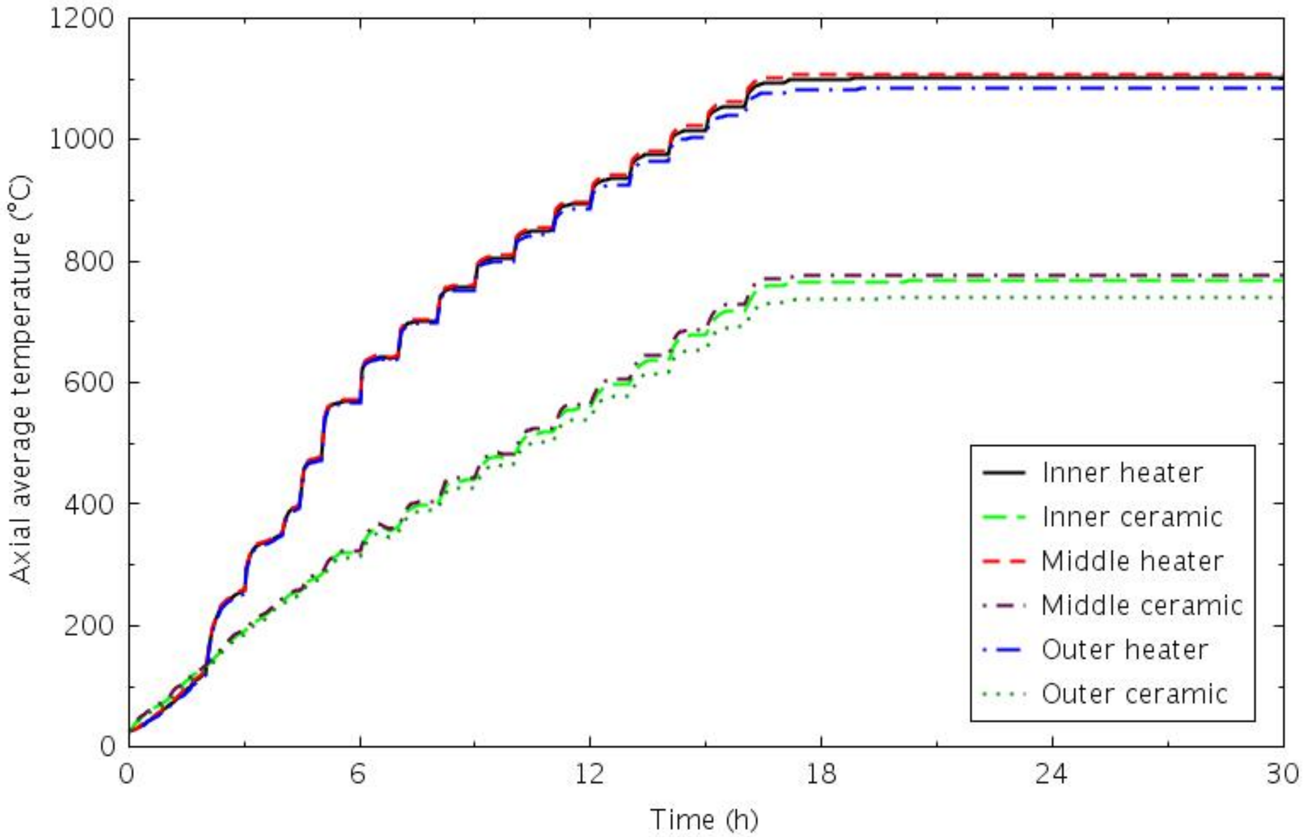
Initial Heatup Calculations

- Entire system at ambient temperature (28°C) and pressure
- Steam generator secondary full of air
- Core ceramic heatup rate limited to 55.6°C/h
- Principal interest is steam generator response
  - Minimize steaming
  - Maintain tube integrity
- Approach
  - Start feedwater flow before tubes reach saturation temperature
  - Use compressor only for initial heatup
  - Maximum allowed heatup rate

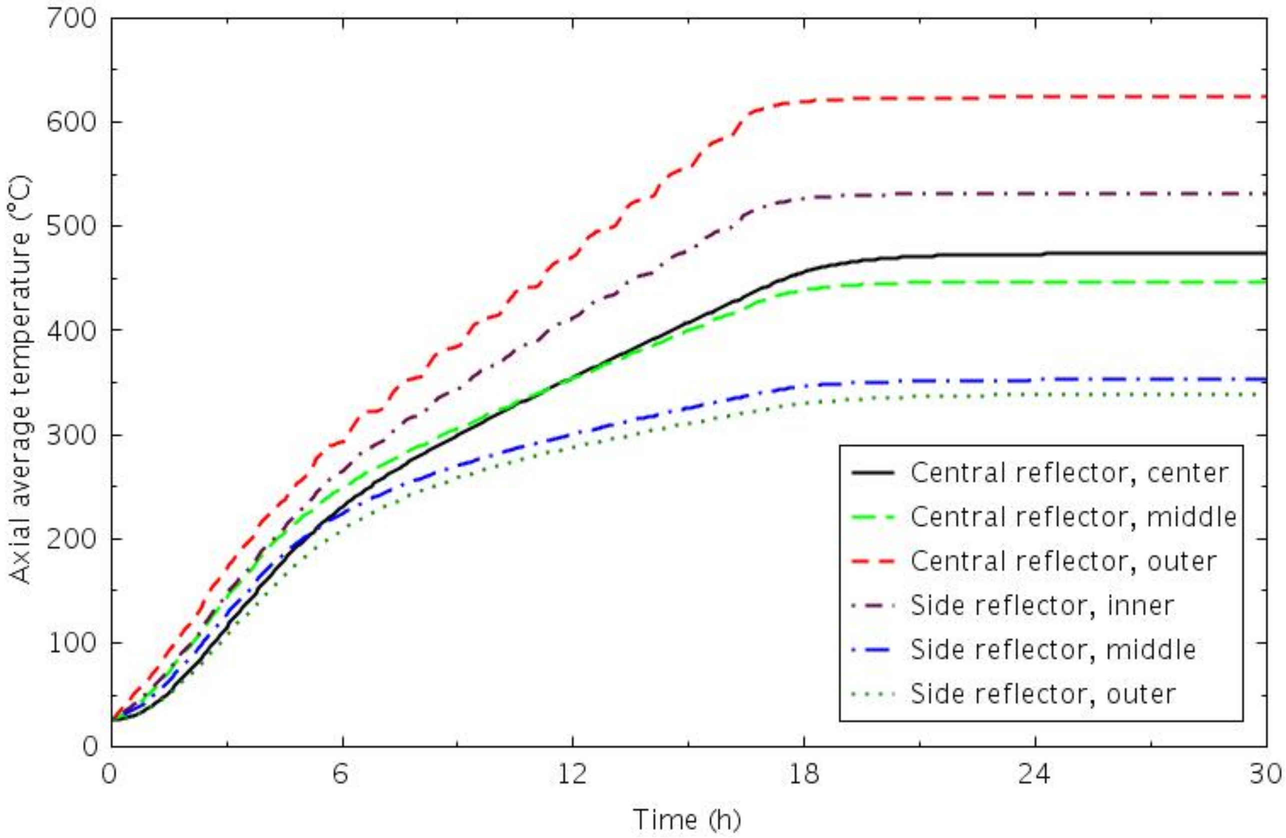
Initial Heatup Boundary Conditions

- Primary helium flow of 1.0 kg/s
- Feedwater flow
  - 0.01 kg/s starting when tubes approach saturation temperature
  - Controlled to maintain vessel inlet temperature of 258.6°C
- Constant RCCS flow of 0.5 kg/s of 17°C water
- Ambient heat loss only modeled on back side of RCCS panels

Initial Heatup Core Temperatures



Initial Heatup Reflector Temperatures



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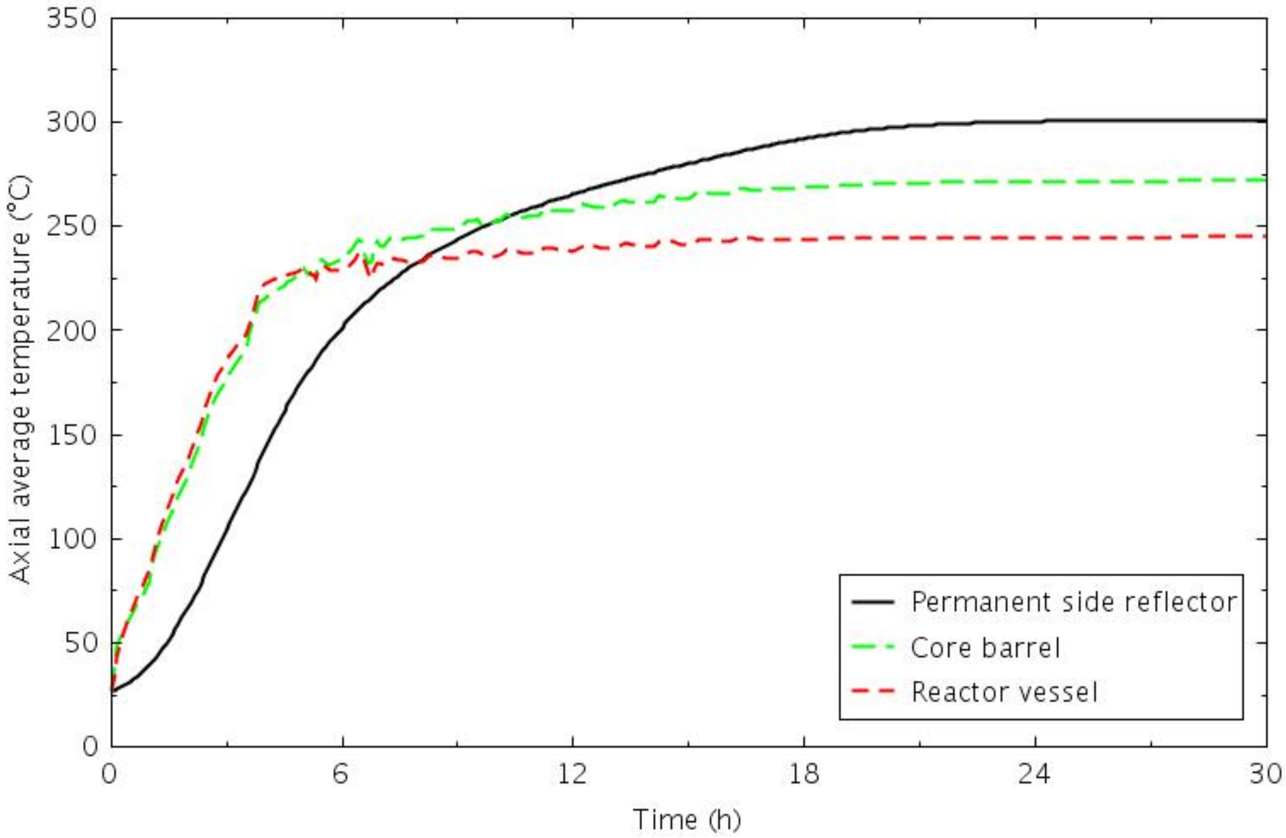
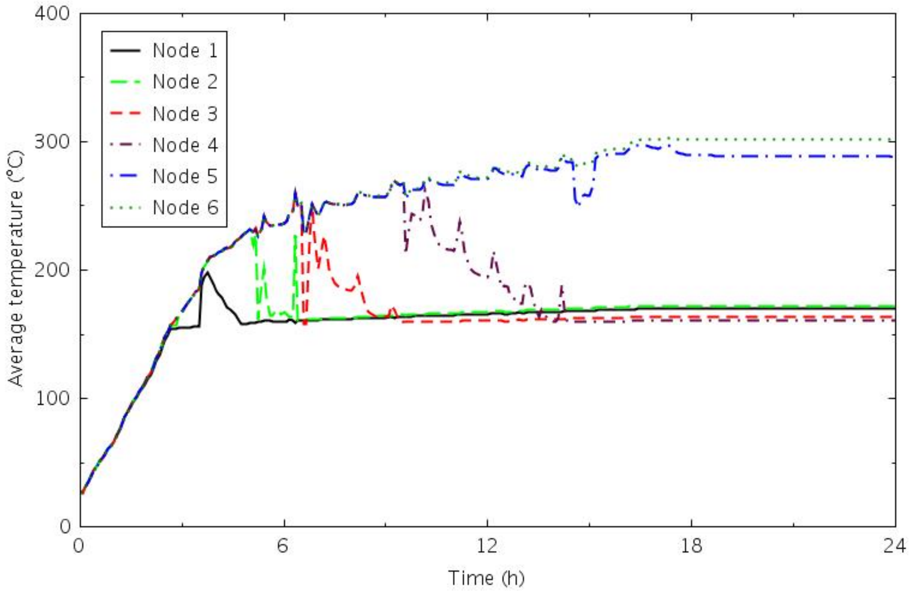
Initial Heatup Outer Structure Temperatures

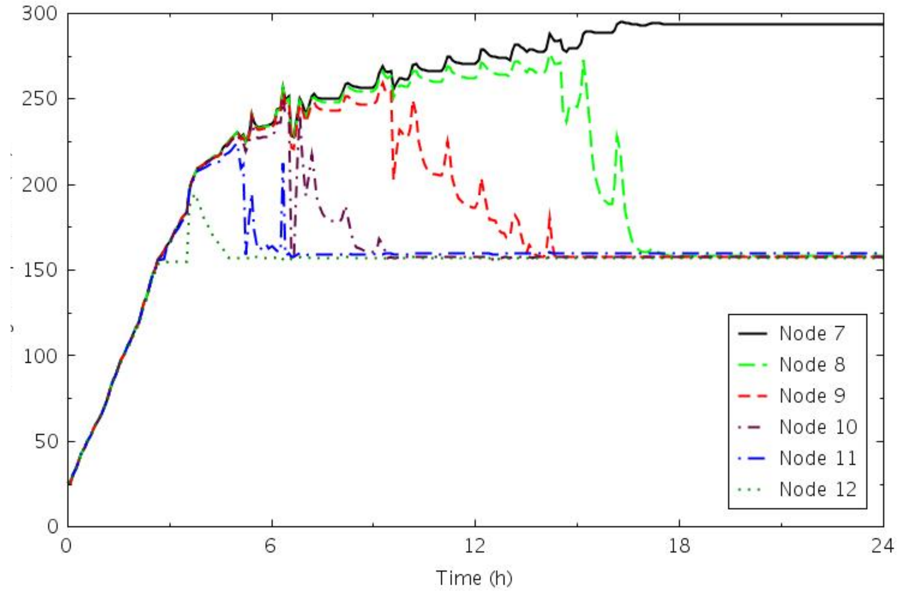


Initial Heatup Steam Generator Tube Temperatures

Upflow side



Downflow side



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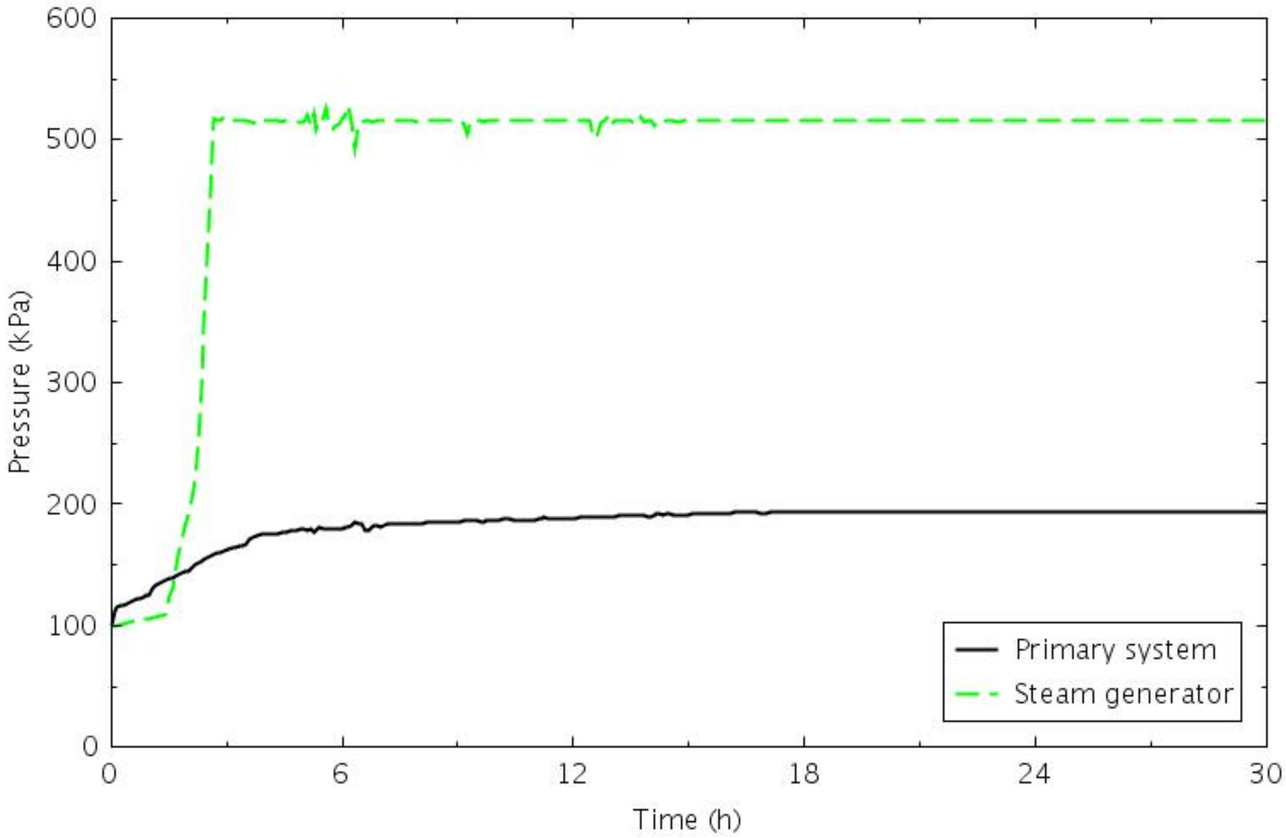
Initial Heatup System Pressures



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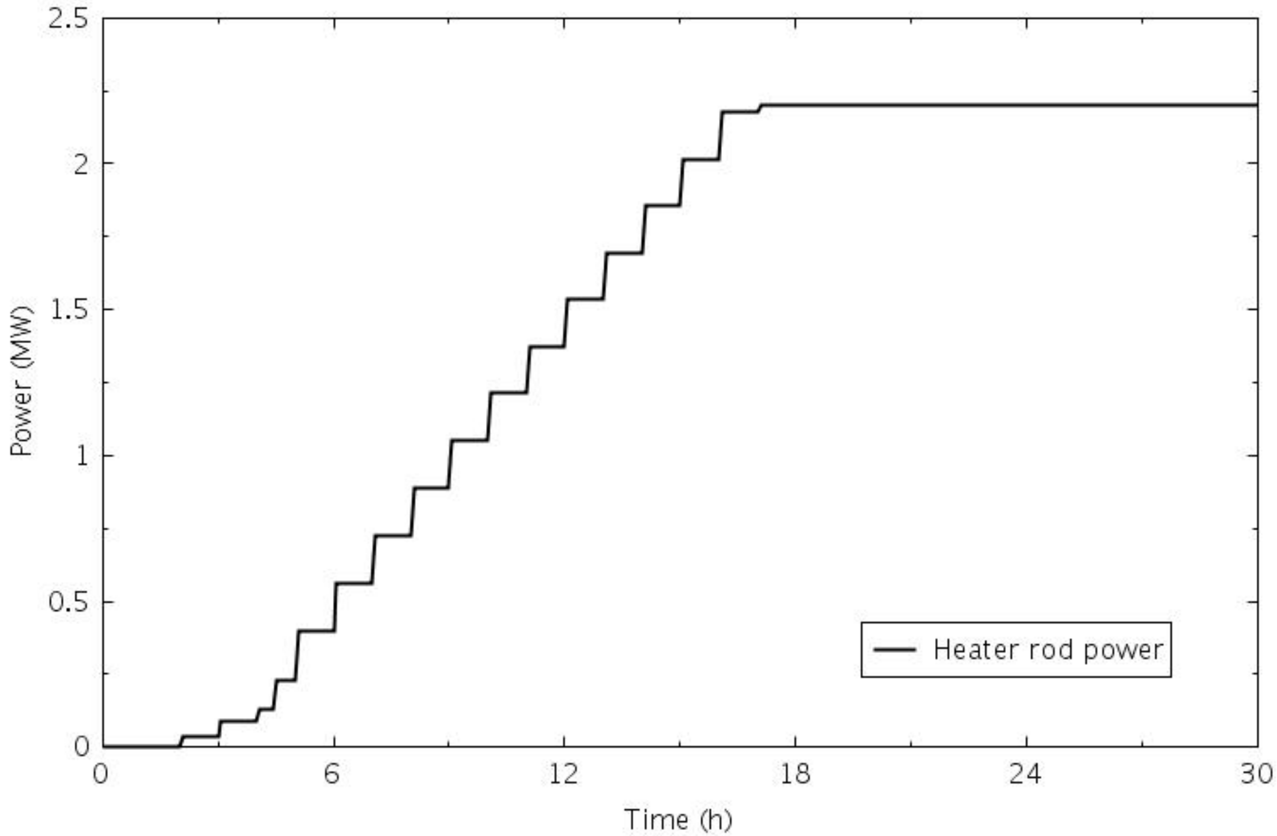
Initial Heatup Heater Rod Power



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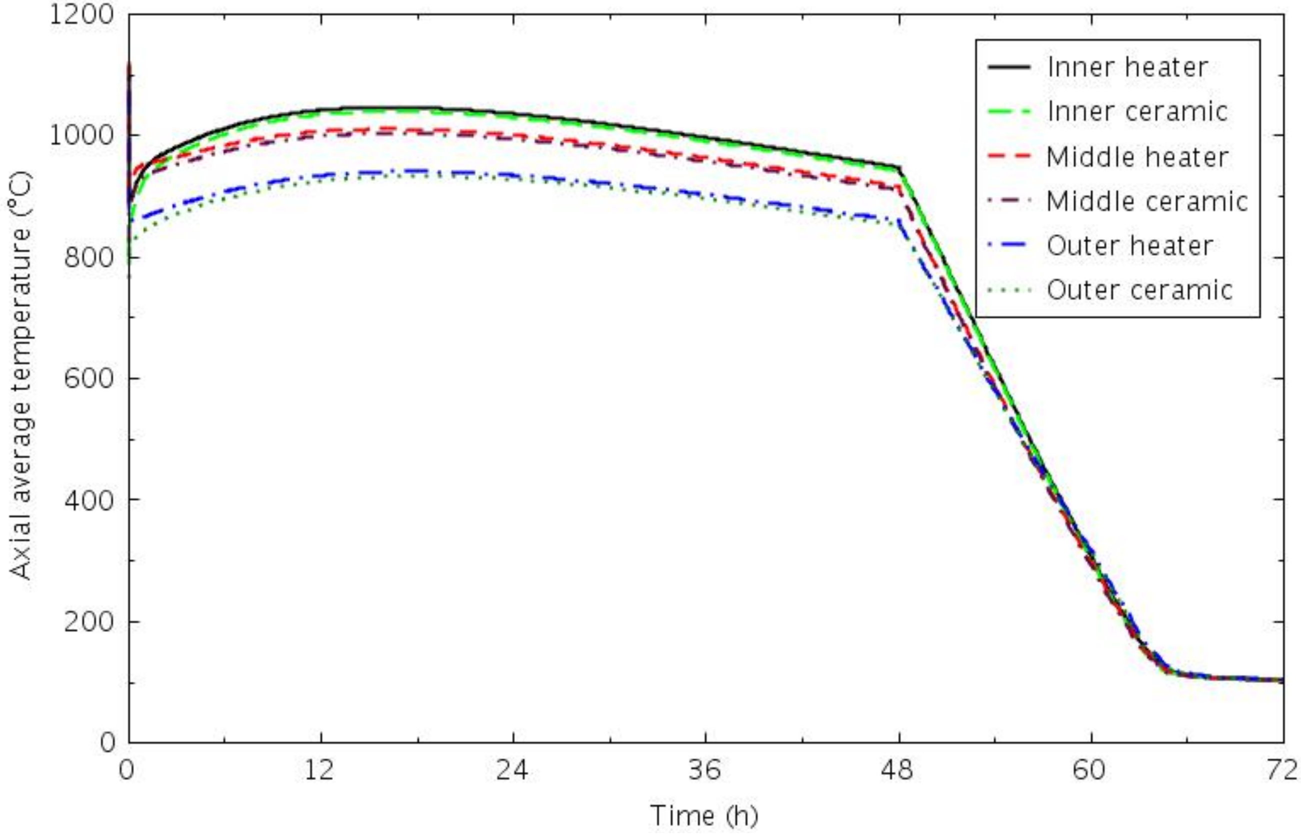
System Heatup Observations

- Heater rods reach full power in 17 hours
- Full heatup will take about 24 hours
- Temperatures may be close enough after 21 hours
- Portions of the steam generator tubes are uncovered
- Steam generator uses about 35,000 kg (9,300 gal) of water
- Heater rods require about 25,000 kWh
- More helium needed to reach operating pressure

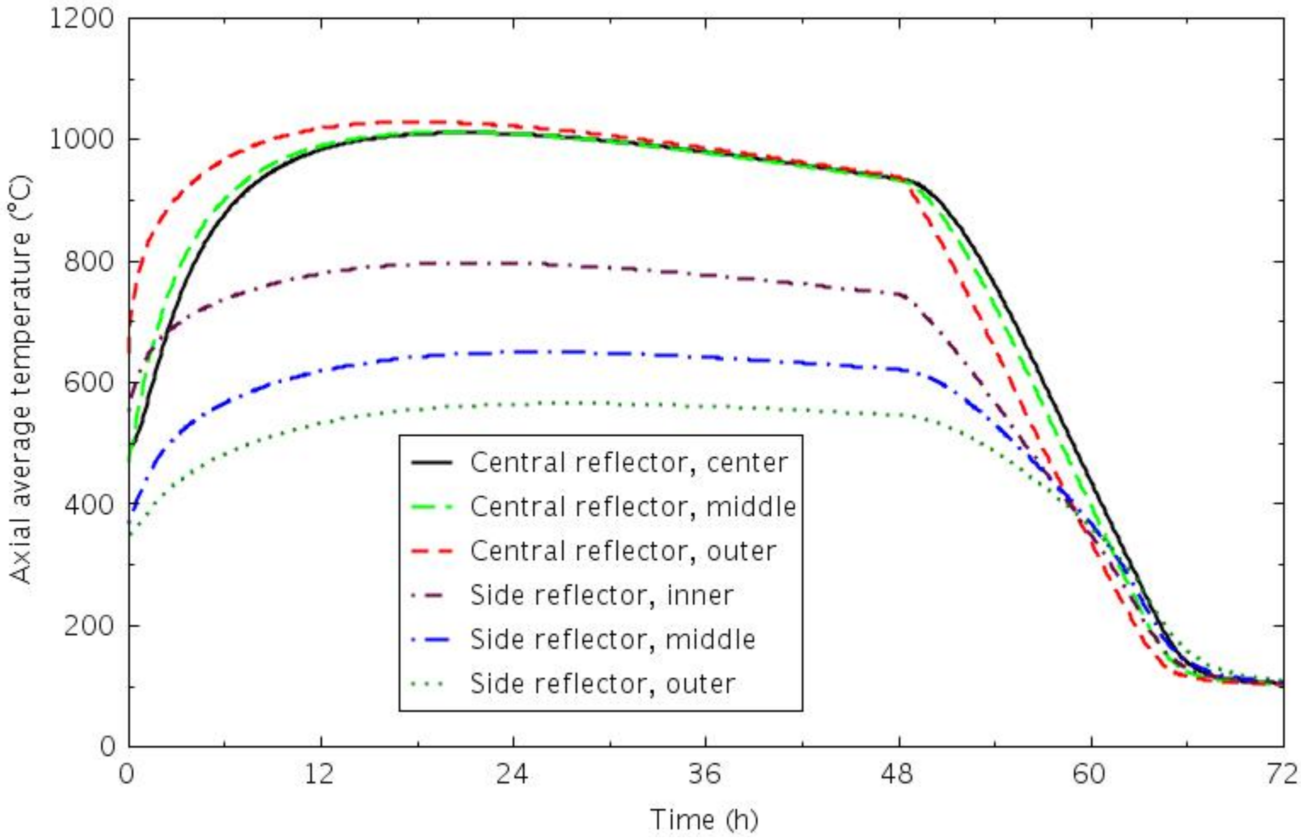
System Cooldown Calculations

- Begins after a 2-day depressurized conduction cooldown (DCC) test
  - Turn power off, close break valves, open loop isolation valve
- Controlled cooldown
  - 55.6°C/h maximum ceramic cooldown rate
  - Primary control through primary coolant flow rate
- Walk-away
  - Break valves stay open
  - No feedwater or RCCS flow
- Maximum cooldown
  - Ignores cooldown rate limitation

Controlled Cooldown Core Temperatures



Controlled Cooldown Reflector Temperatures



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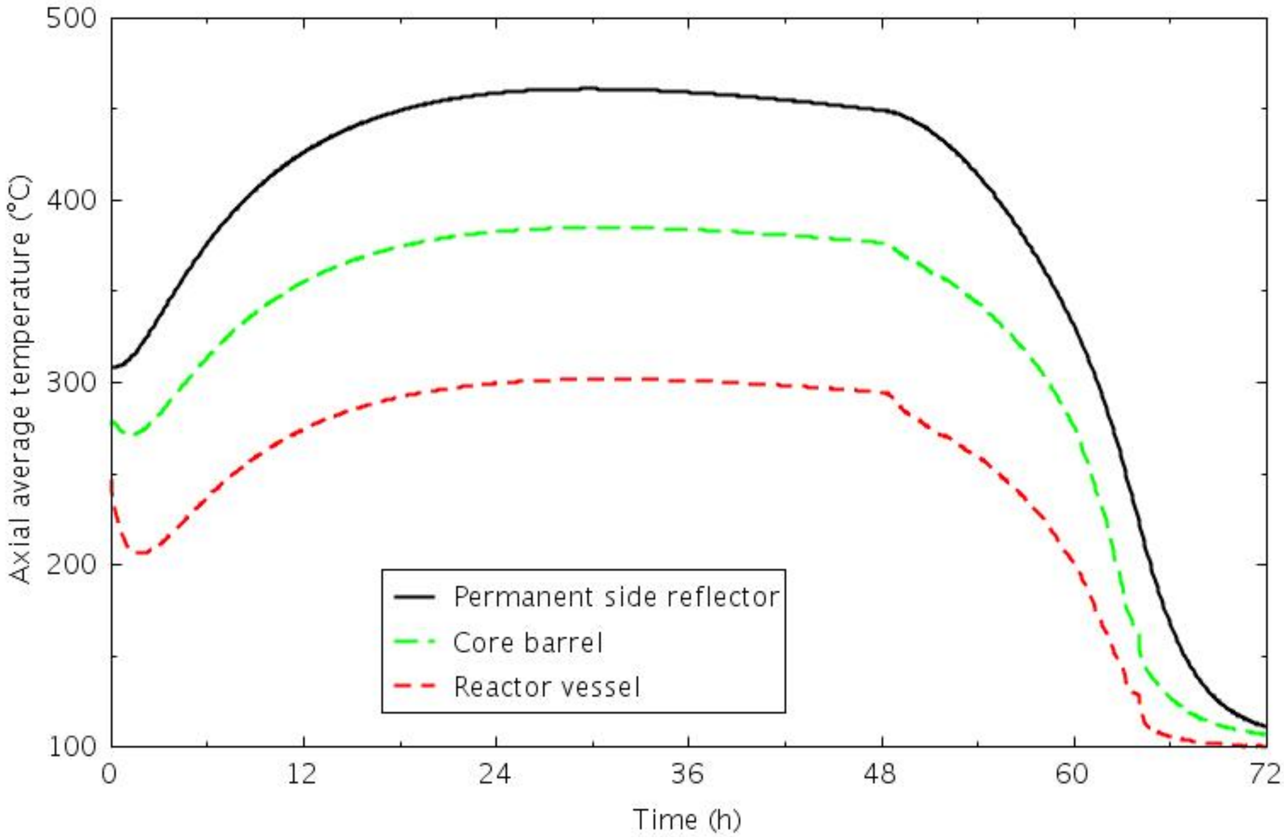
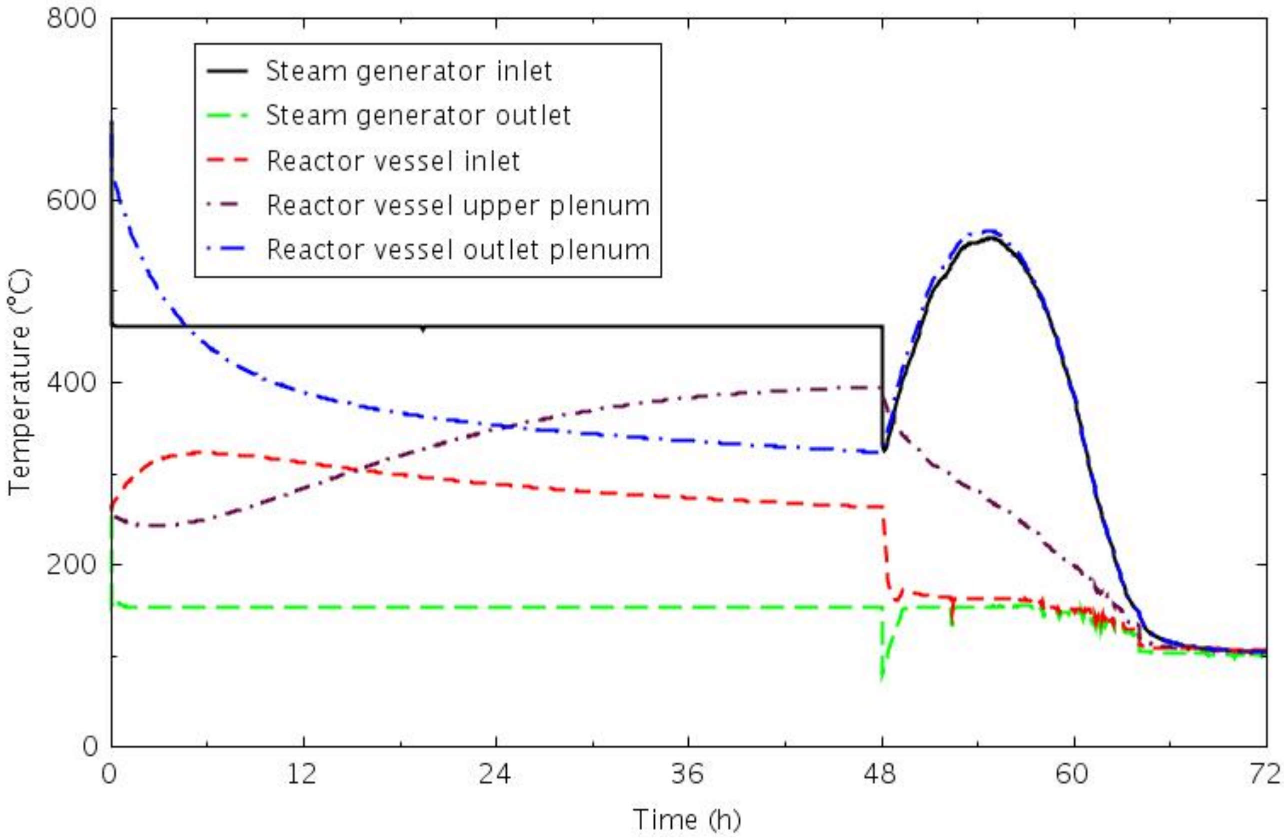
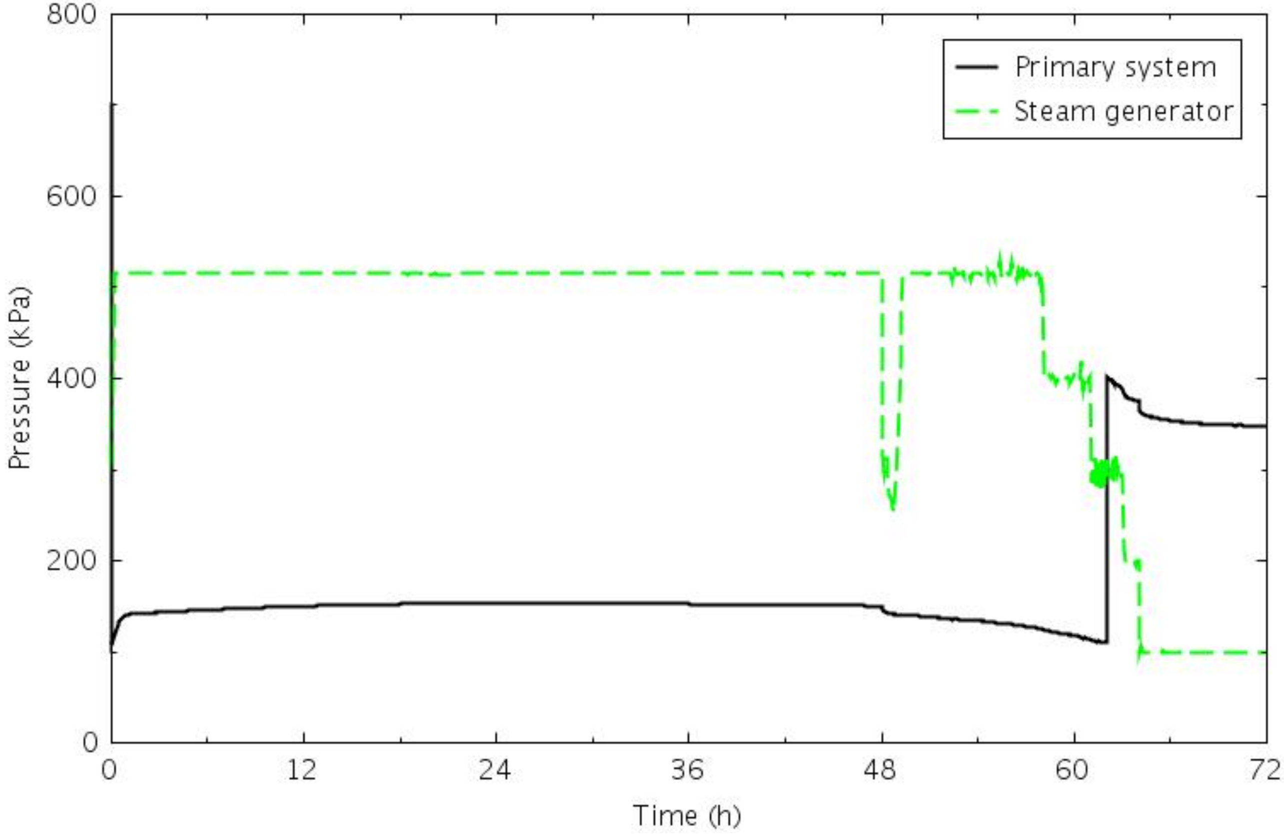
Controlled Cooldown Outer Structure Temperatures



Controlled Cooldown Helium Temperatures



Controlled Cooldown System Pressures



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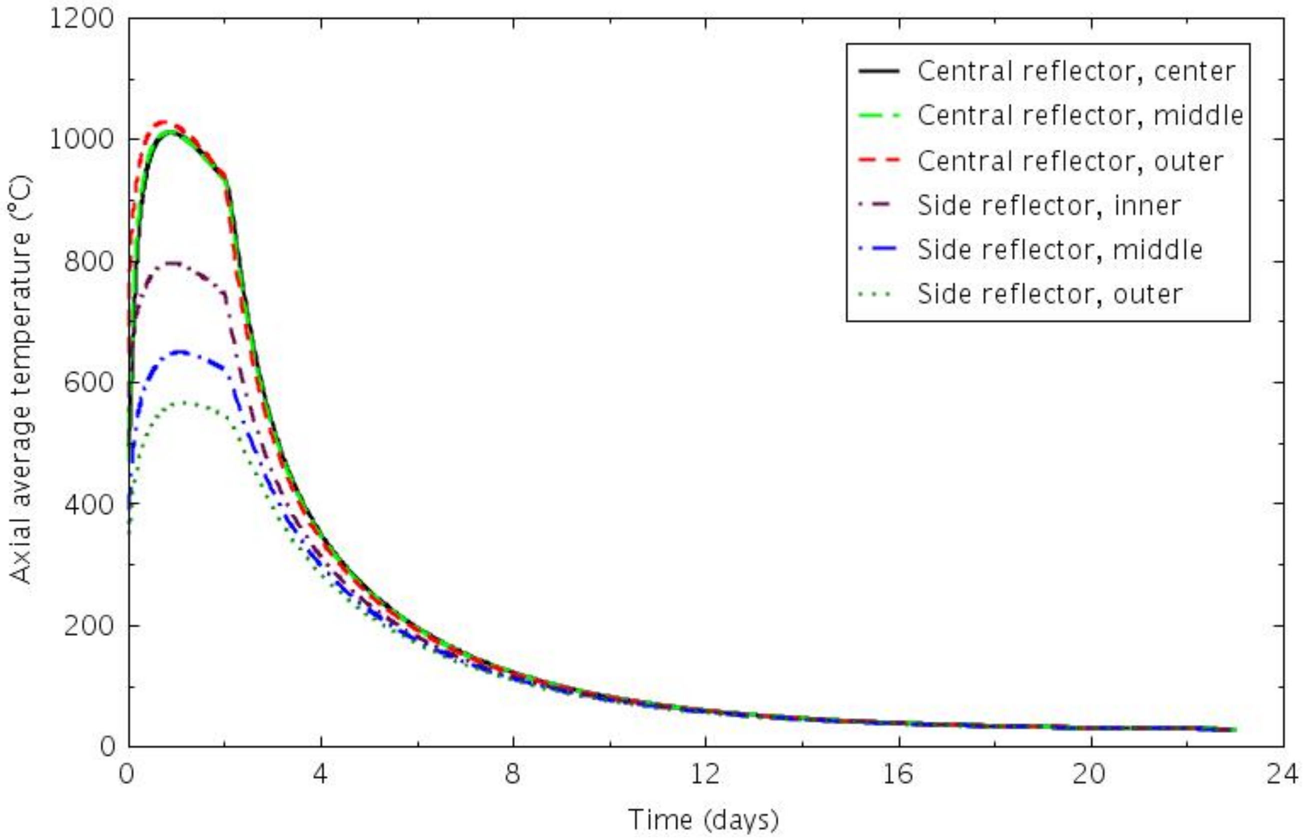
Walk-away Cooldown Reflector Temperatures



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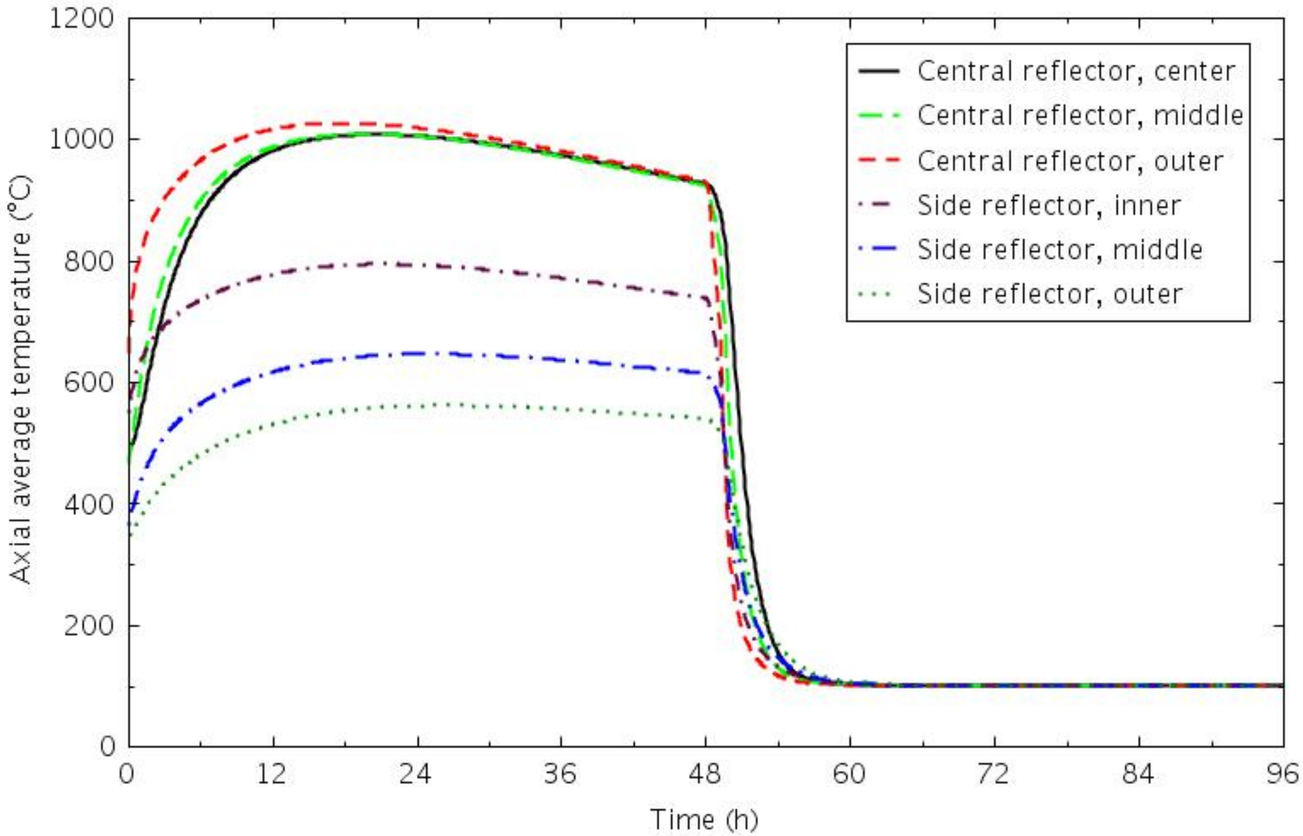
Maximum Cooldown Reflector Temperatures



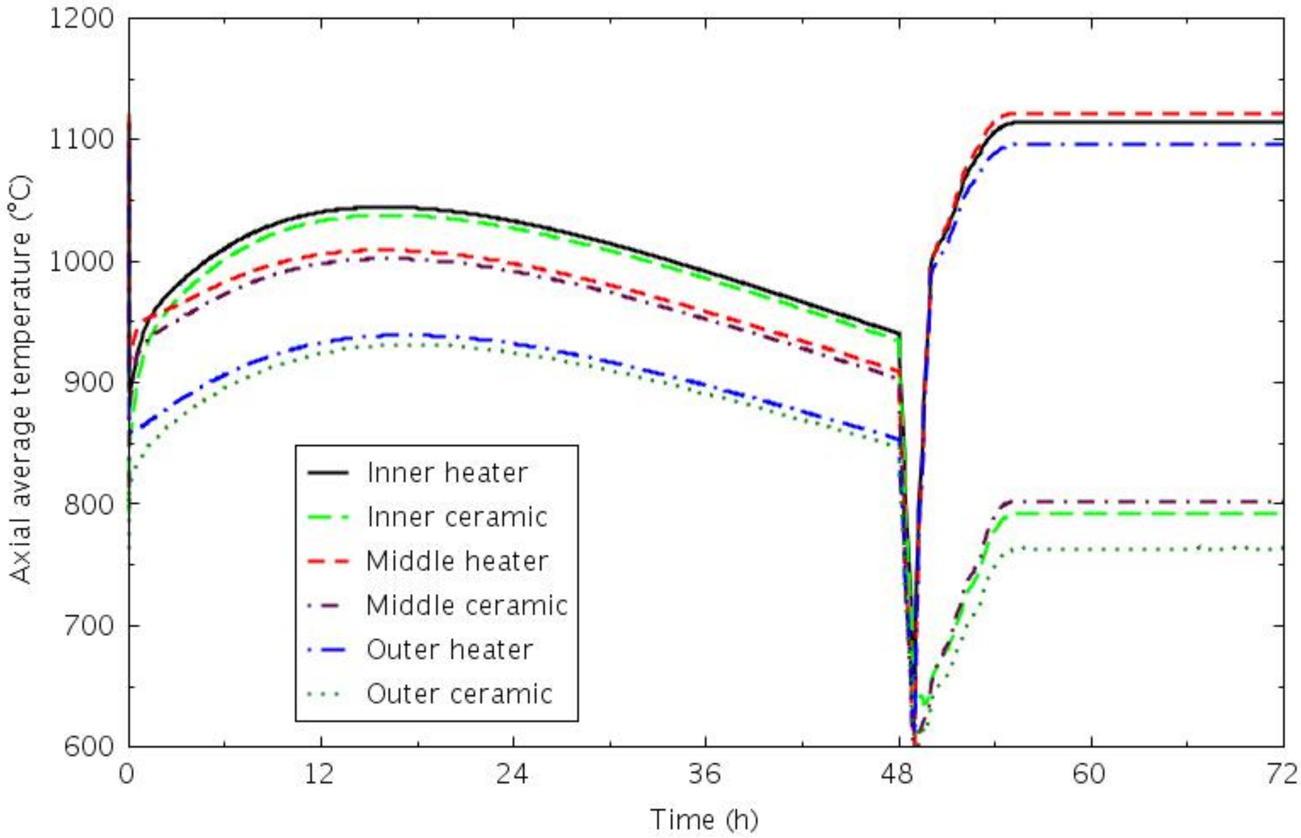
System Cooldown Observations

- Cooldown at the maximum rate will take about 24 hours, using about 11,000 kg (2,800 gal) of water
- Cooling down by turning the power off and walking away will take about 3 weeks
- At full primary coolant flow, cooldown would take about 12 hours, using about 9,300 kg (2,500 gal) of water
- For forced flow cooldown cases, the steam generator secondary limits the ultimate temperature

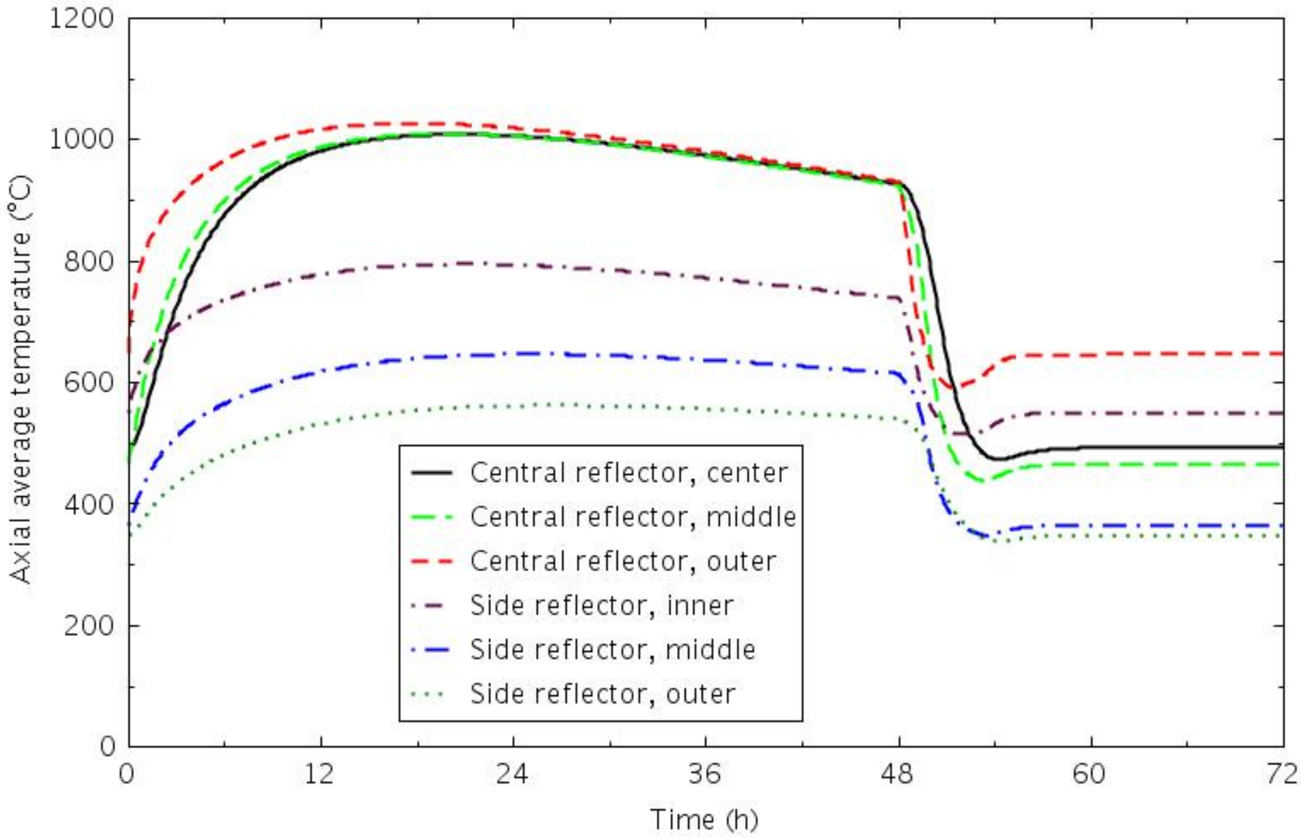
System Reheat Calculations

- Begins after a 2-day DCC test
  - Turn power off, close break valves, open loop isolation valve
- One-hour cooldown to re-introduce hot helium to steam generator tubes
- Reheat at 55.6°C/h in the core ceramic
- Feedwater controlled to maintain nominal vessel inlet helium temperature
- Helium added to repressurize primary system

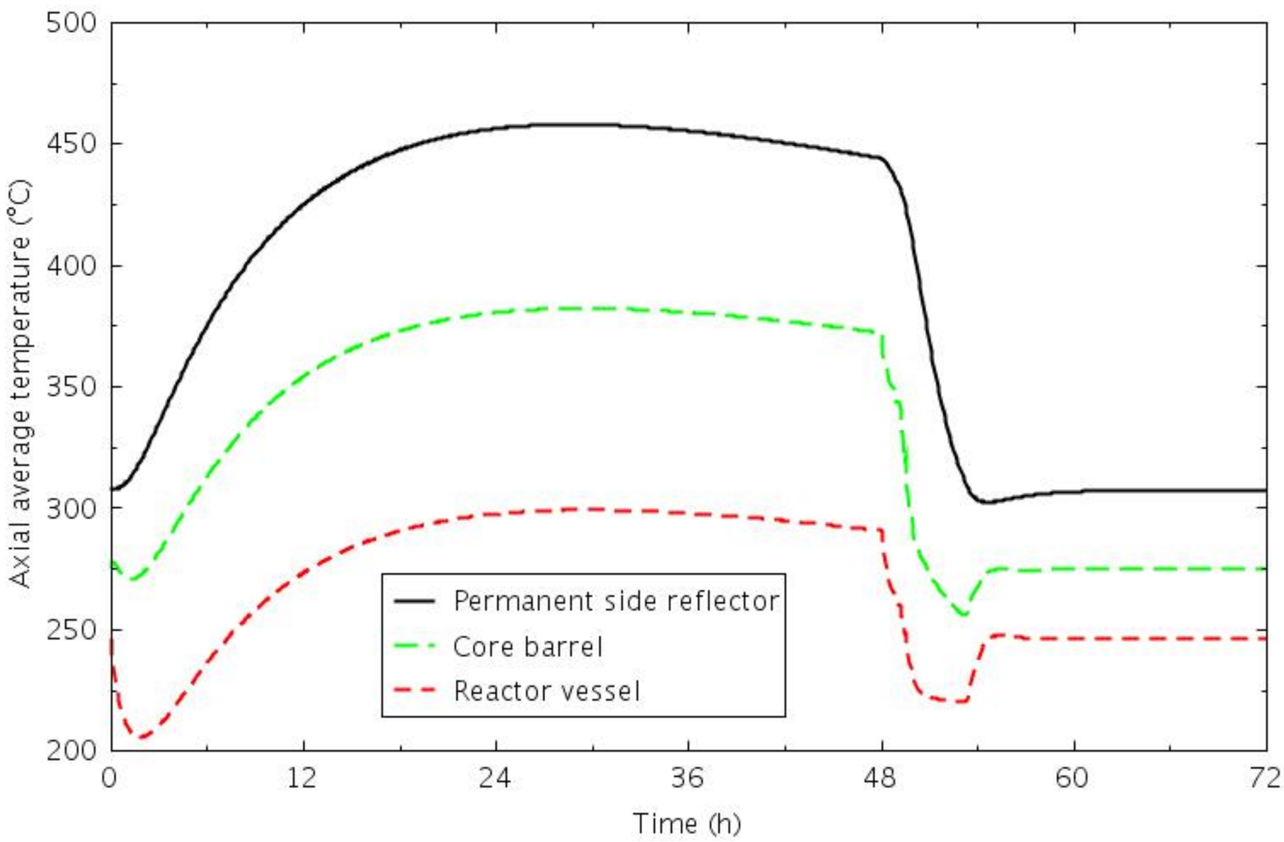
System Reheat Core Temperatures



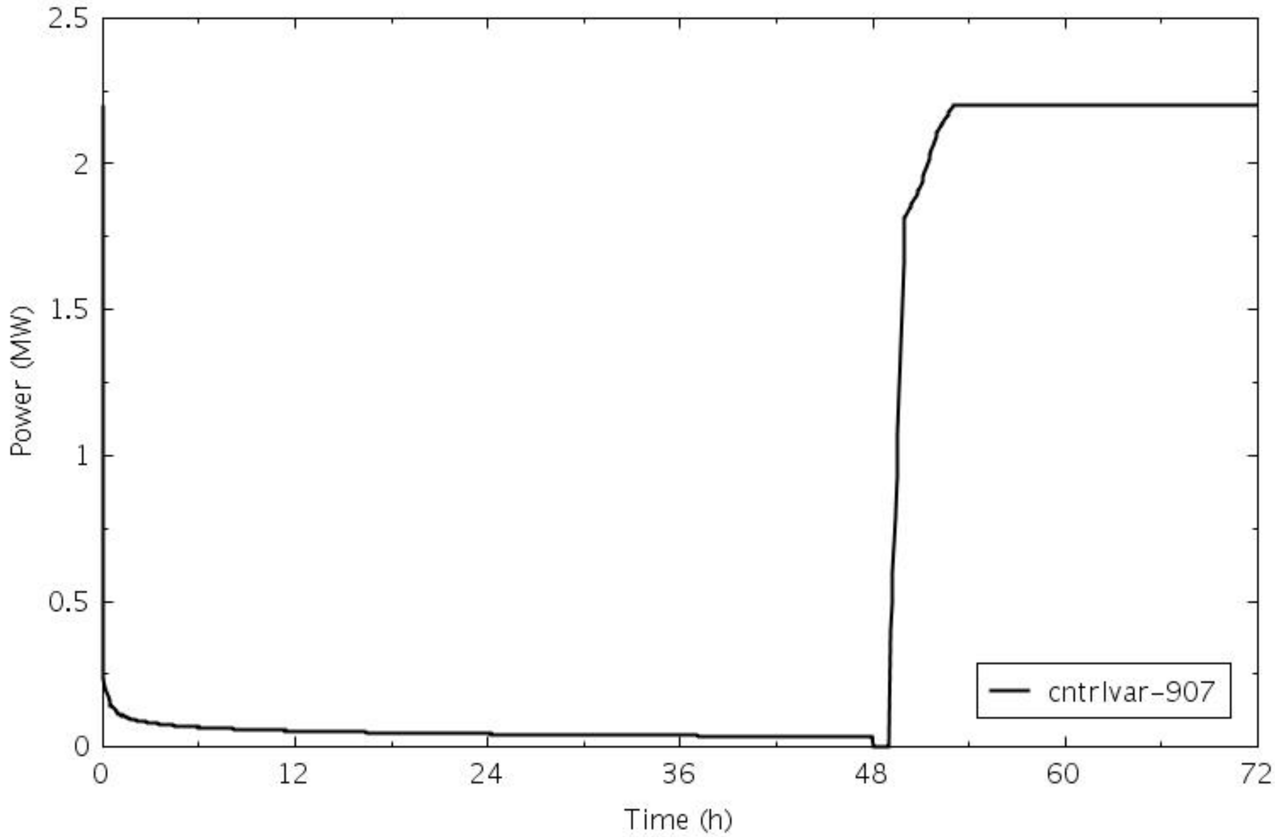
System Reheat Reflector Temperatures



System Reheat Outer Structure Temperatures



System Reheat Heater Rod Power



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System Reheat Observations

- Initial need is to cool the system
- There may be a window in which the system can be recovered relatively quickly

Summary

- Simulations of plant operational evolutions have been performed
- Evolutions were not optimized
- Initial system heatup
  - Takes about 1 day
  - Steam generator tubes are partially uncovered
- System cooldown
  - Takes about 1 day at the maximum cooldown rate
  - Takes about 3 weeks if left alone
  - Might be cooled down in about 12 hours in an emergency
- System reheat
  - Might be able to be accomplished in 12 hours or less