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RELAP5-3D Modeling of High Temperature Test Facility (HTTF)

April 2021

Changing the World's Energy Future

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Idaho National Laboratory

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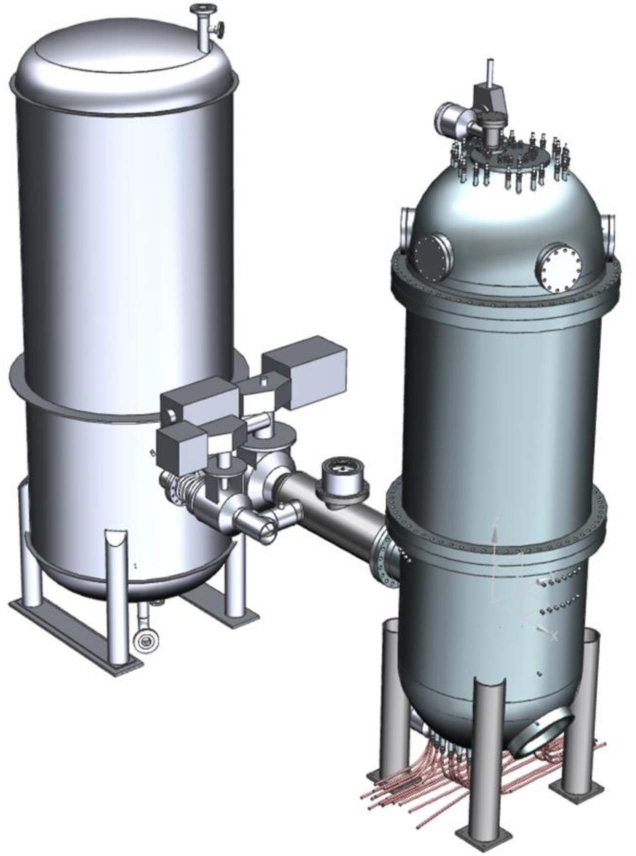
ADVANCED REACTOR TECHNOLOGIES

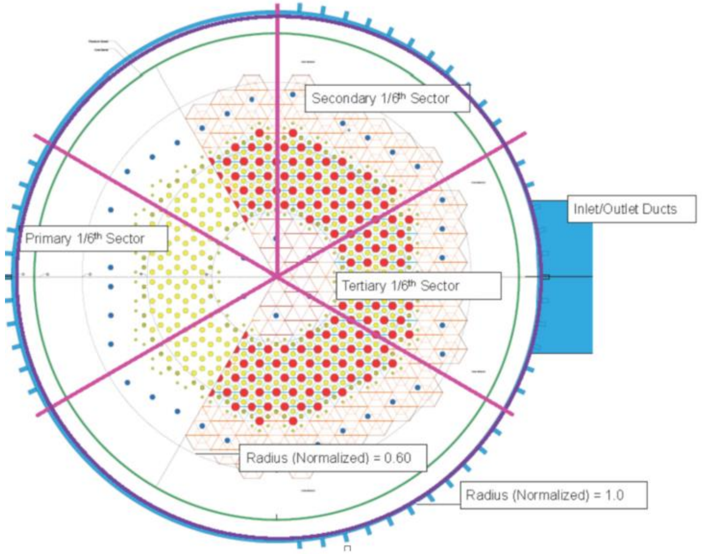
RELAP5-3D Modeling of High Temperature Test Facility (HTTF)

HTTF Modeling Meeting

Idaho National Laboratory

HTTF overview

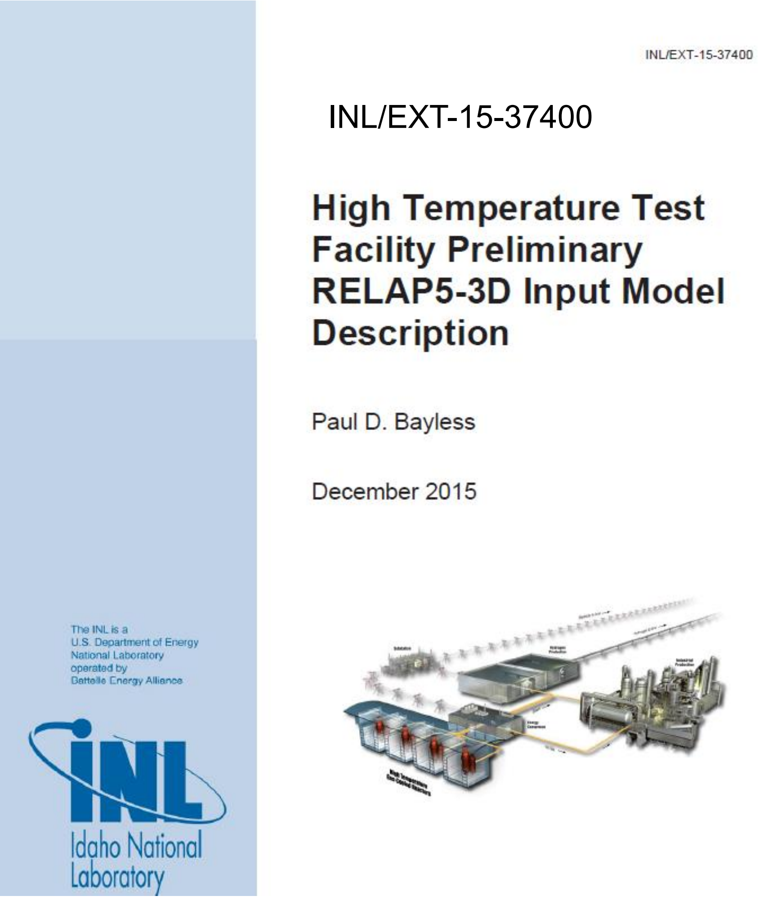




- HTTF at Oregon State University (OSU)
  - Reference: General Atomics' modular high-temperature gas-cooled reactor
    - Helium cooled, electrically heated
    - Prismatic graphite blocks in the core and reflectors
      - Alumina ceramic blocks are used to simulate the core and top and bottom reflectors
  - One-fourth scale in length and diameter
  - Most of the coolant channels in the core are full scale
  - Lower pressure compared to the prototype reactor
  - Over 500 instruments
  - Designed primarily to investigate depressurized conduction cooldown (DCC) transients
- After HTTF restart
  - Quality data for two tests at INL
    - **PG-26** Low power Inlet-Outlet Crossover Duct Break, 2 Heaters
    - **PG-27** Low power Complete Loss Flow, 2 Heaters

RELAP5-3D model

- Paul Bayless’ quality-controlled model used as basis



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High Temperature Test Facility Preliminary RELAP5-3D Input Model Description

Paul D. Bayless

December 2015

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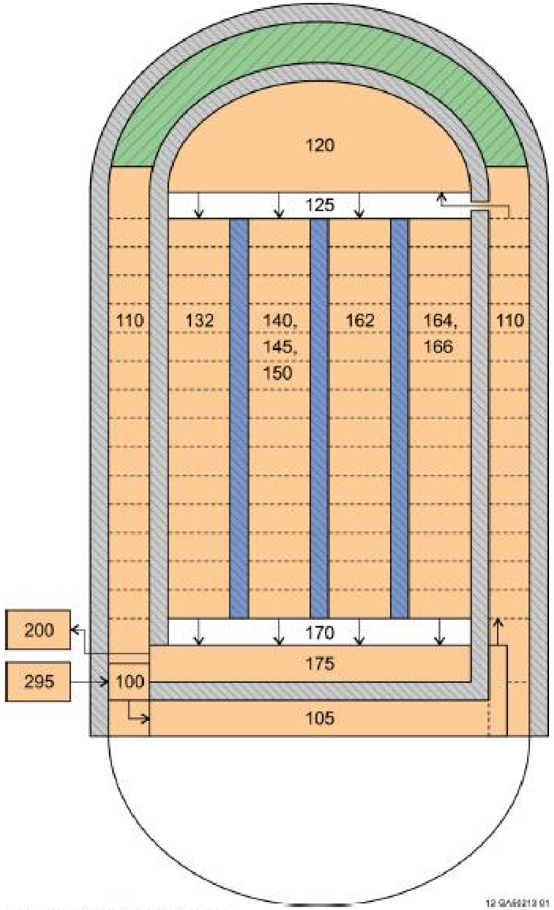


ressure vessel nodalization.

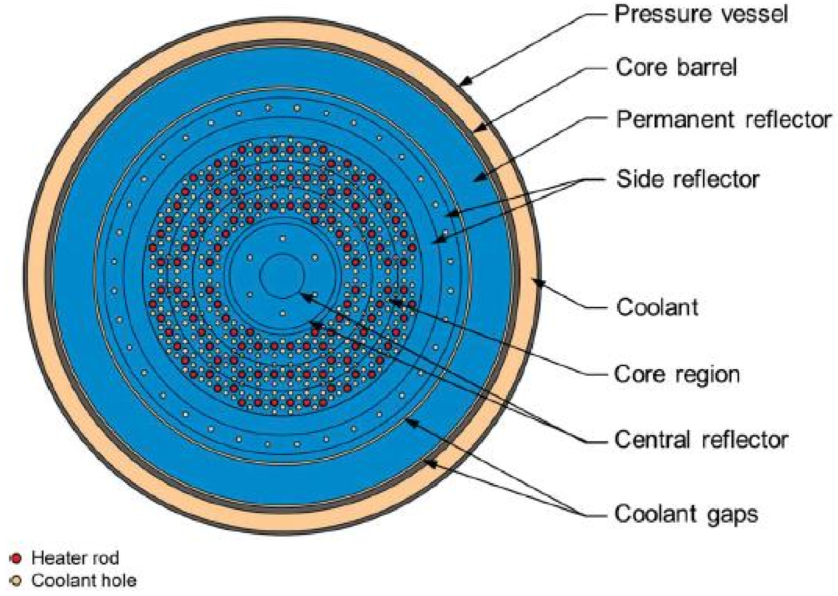
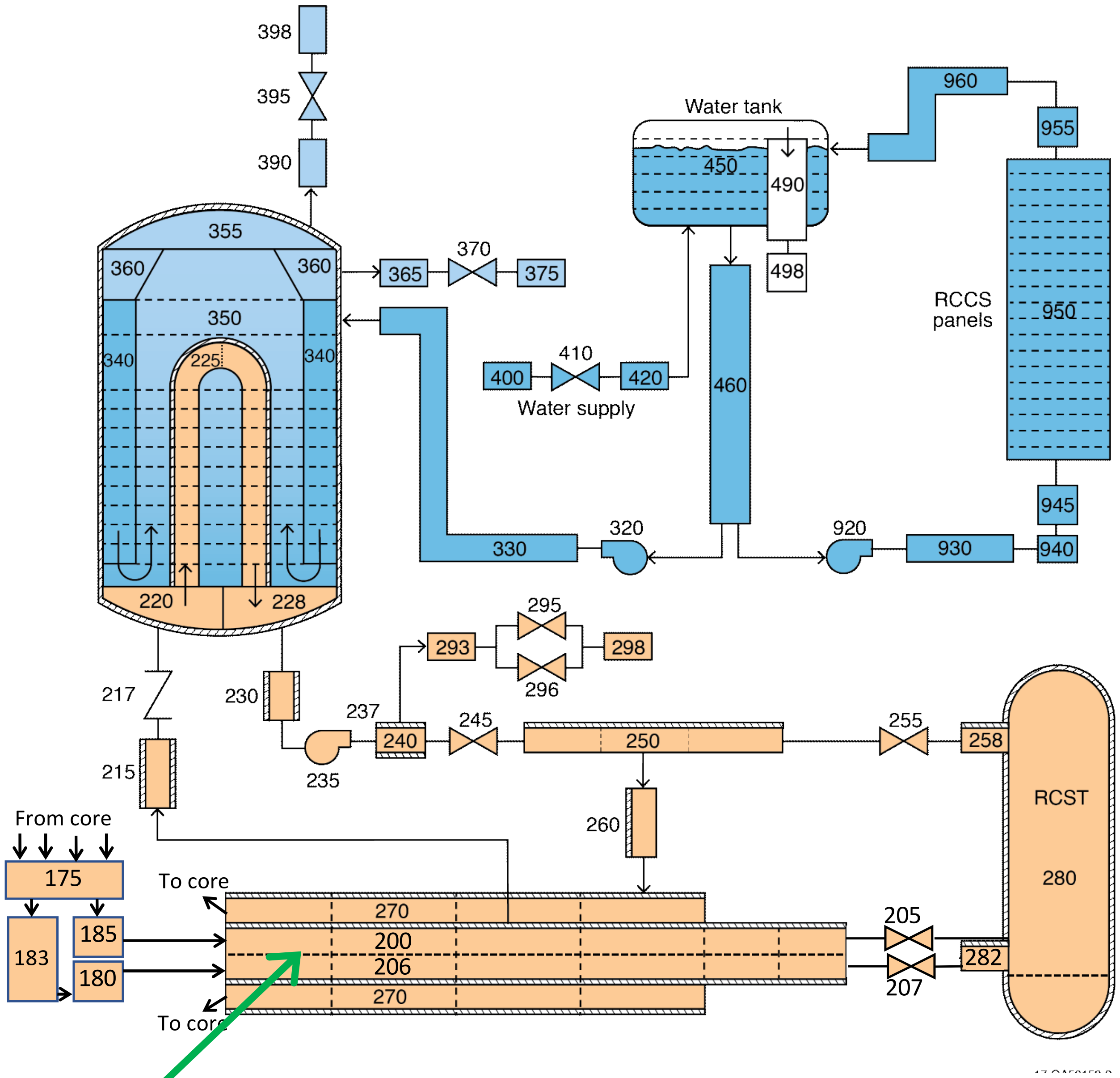


Figure 2. Primary pressure vessel radial nodalization.

RELAP5-3D model

- Changes to Paul's base model
  - Replaced hot duct with "split" hot duct
    - Hope to see countercurrent single-phase flow
  - Primary helium blower BC replaced with circulator model



"Split" hot duct

PG-26

- PG-26: Double Ended Inlet-Outlet Crossover Duct Break
  - **<350kW (two heaters) DCC**
  - Test from 5/30/2019 to 6/03/2019 (**72 hours**)
  - DCC was initiated in the 50th hour of the test
  - Ceramics reached temperatures of near 1400°C

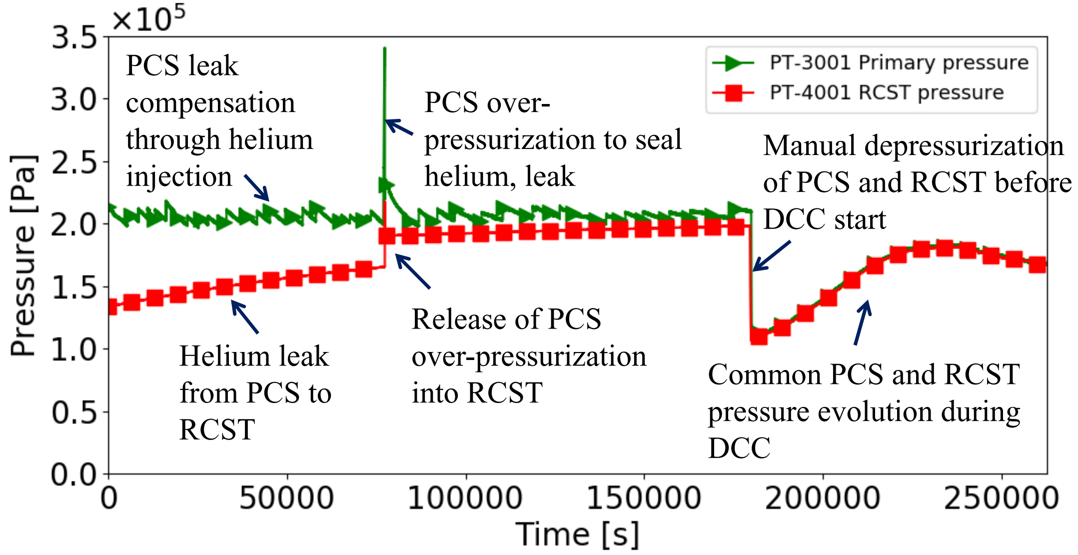
  and thermocouples began failing
    - Heater power was reduced
    - In the 59th hour heater 110 quit operation
    - The other heater, 104, was secured
  - Cool down data collected until the 72nd hour

- Figure of main interest are:
  - (Depressurized) Core cooling under decay heat conditions
  - Gas mixing phenomena, natural convection, possible flow reversal

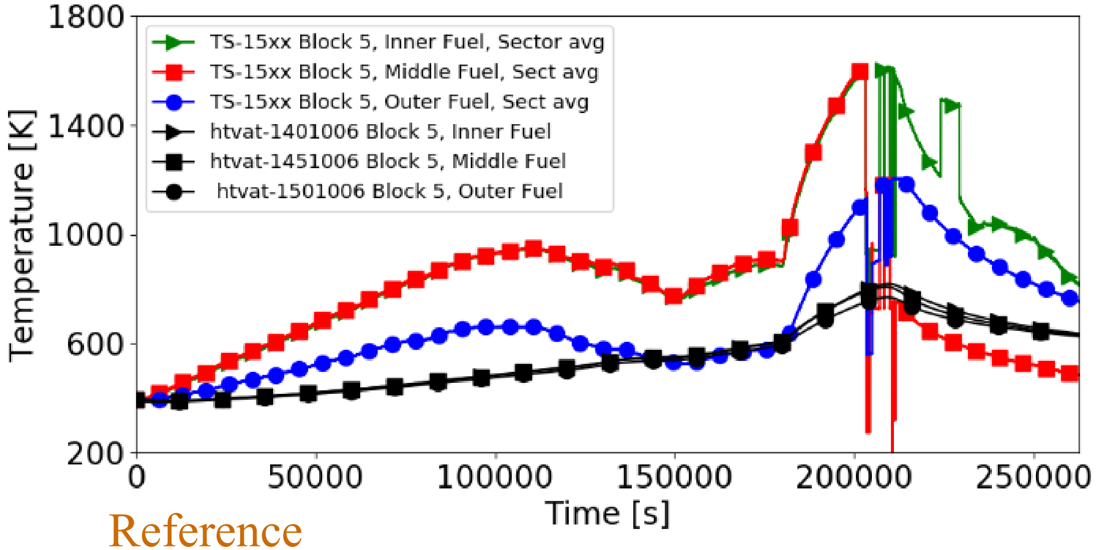
- Different possible model approaches using RELAP5-3D:
  - Model the facility state right before the DCC starts as RELAP5-3D steady-state and only the DCC as RELAP5-3D transient
    - Goal: Get a well-defined facility state modeled before the transient of interest starts
    - Difficulties: Difficult to characterize the steady state before the DCC starts.
  - Model the whole transient including the heat-up phase as RELAP5-3D transient
    - Goal: “Better” facility state before transient starts, better known initial conditions at time zero
    - Difficulties: More difficult to model, need HTTF boundary conditions (stem generator behavior, etc.) during the heat-up.
  - Main modeling concern: No primary helium mass flows measured

PG-26 results

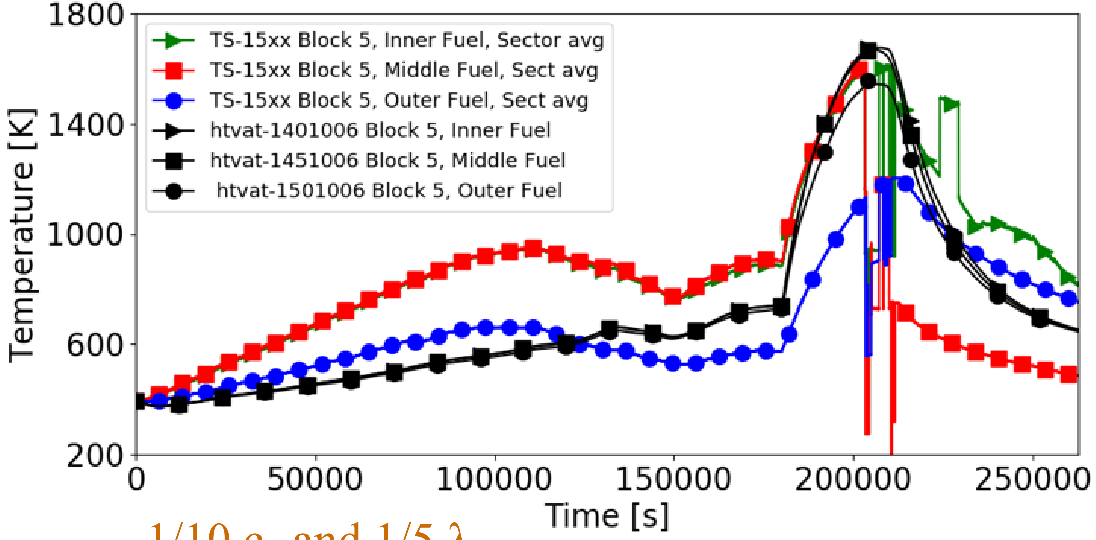
- Challenges
  - No helium mass flow measurements
  - No steady state
  - Limited knowledge of heat flow
  - High uncertainty in thermal properties
  - Complex manual operator actions during transient



Middle of the core (block 5) ceramic temperatures in the fuel region.



Reference

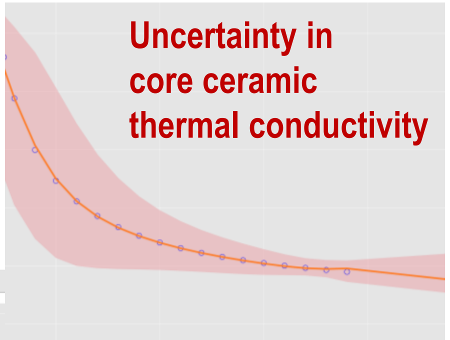


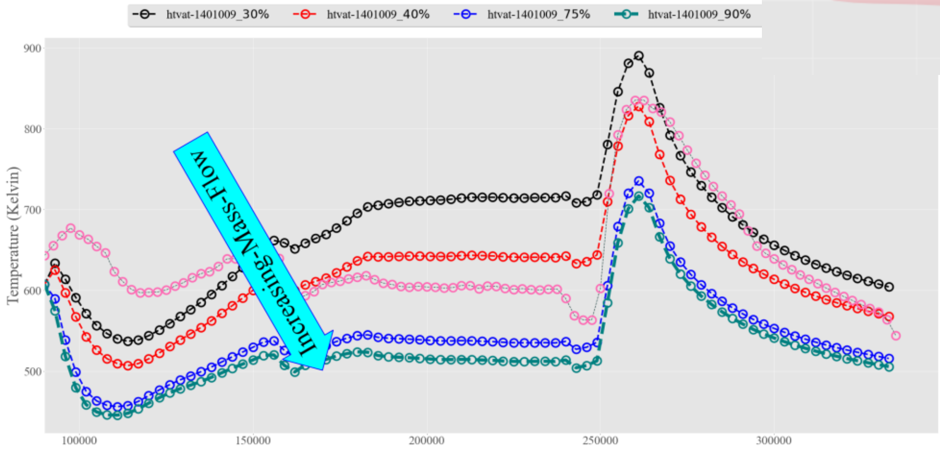
1/10 c_p and 1/5 λ.

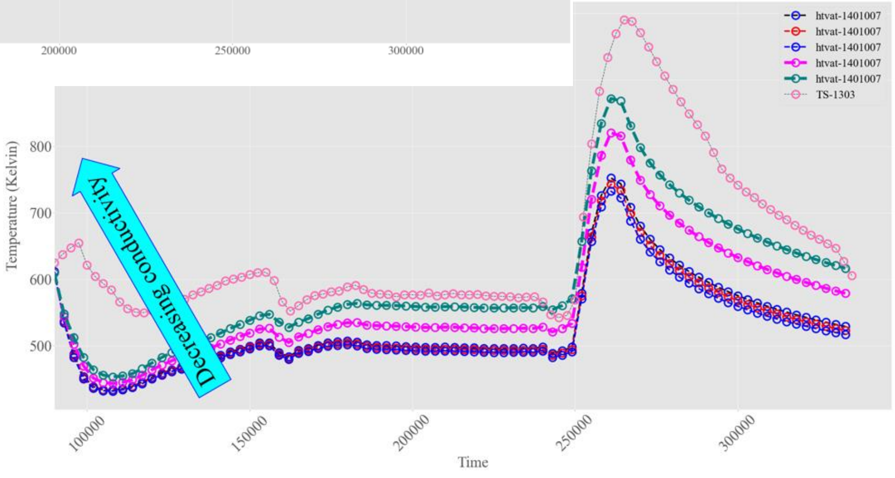
PG-27 results

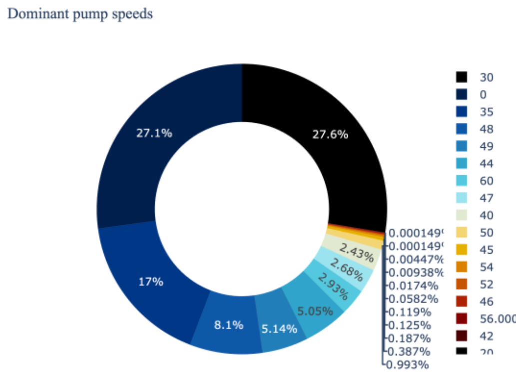
- Like PG-26, but PCC
- Similar modeling challenges
- E.g. frequent blower speed changes
  - Inlet pressure and blower speed not consistent

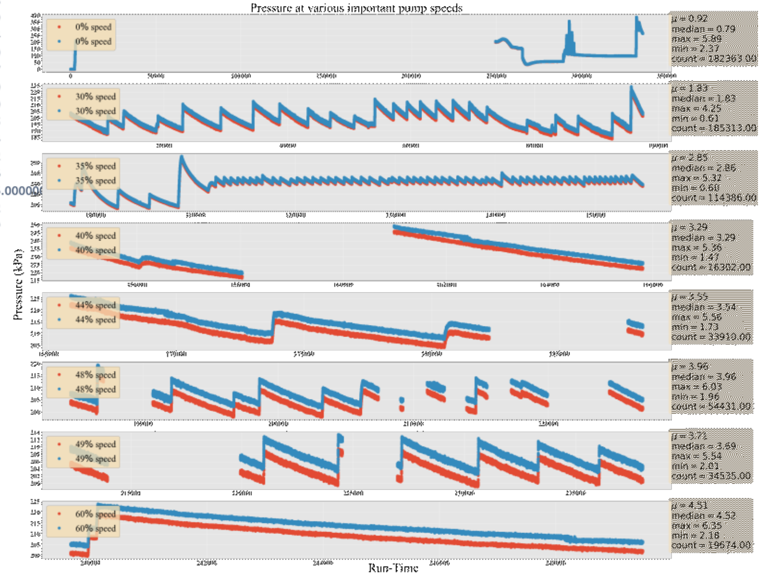
PG-27 core ceramic temperature sensitivities











Recent Publications

- Harvesting PG-26 analysis
  - Submitted journal paper draft on HTTF PG-26 using RELAP5-3D to Annals of Nuclear Energy.
    => Currently under review.
  - Joined INL/ANL ANS summary (ANS annual meeting 2021) on HTTF PG-26 modeling using RELAP5-3D (INL) and SAM (ANL).

- FY21
  - PCC test PG-27 analyzed with RELAP5-3D.
  - Submitted NURETH abstract on HTTF PG-27 using REALP5-3D.
    => Abstract accepted for full paper.