INL/MIS-21-62922-Revision-0

Modeling of HTTF test PG-26 using RELAP5-3D and SAM

June 2021

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Breaking Through to Deployment

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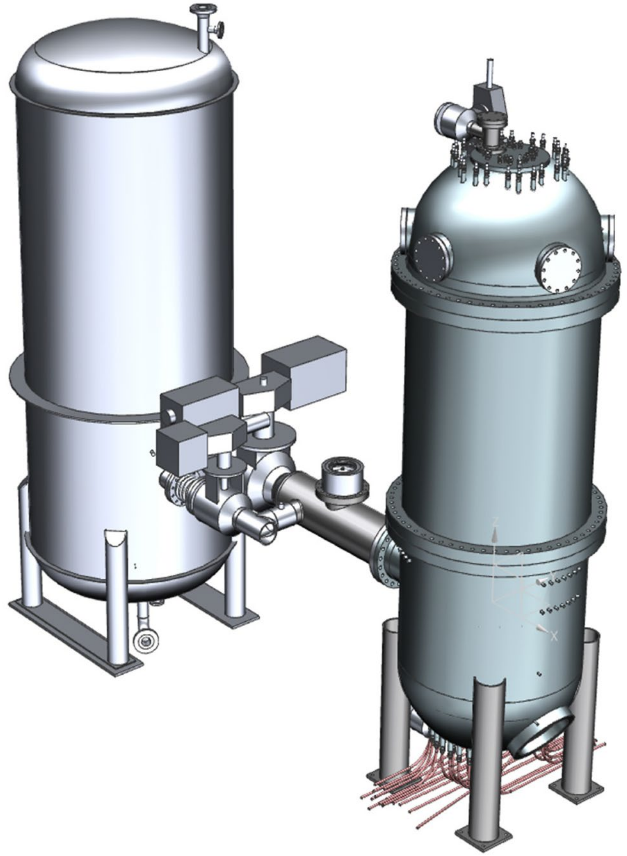
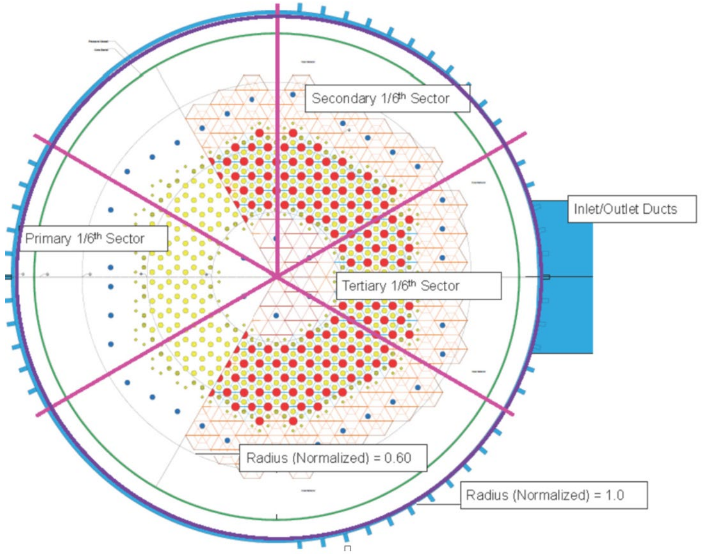
Overview

- HTTF
- PG-26
- REALP5-3D
  - Model
  - Results
- SAM
  - Model
  - Results
- Conclusions

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 (DCC) and pressurized (PCC) conduction cooldown transients

PG-26

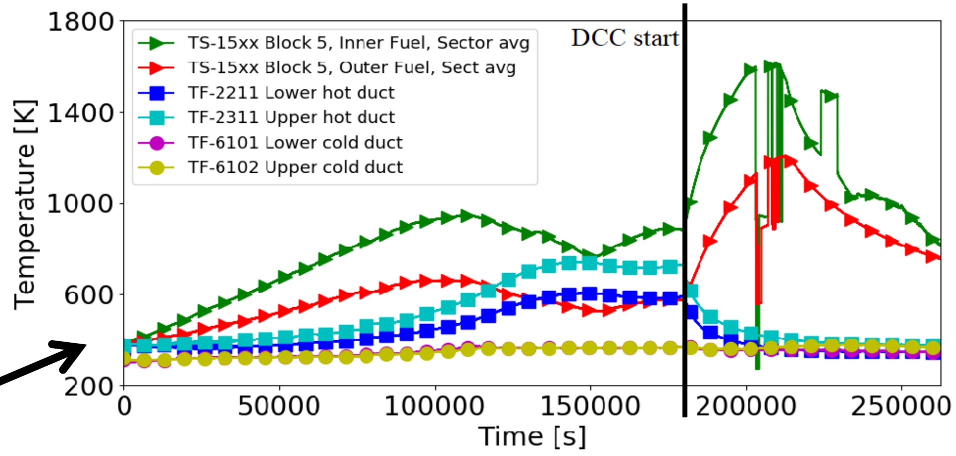
- PG-26: Double Ended Inlet-Outlet Crossover Duct Break
  - **<350kW (two heaters) DCC**
  - Test from 5/30/2019 to 6/03/2019 (**72 hours**)
  - DCC was initiated in the 50th hour of the test
  - Ceramics reached temperatures of near 1400°C

    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

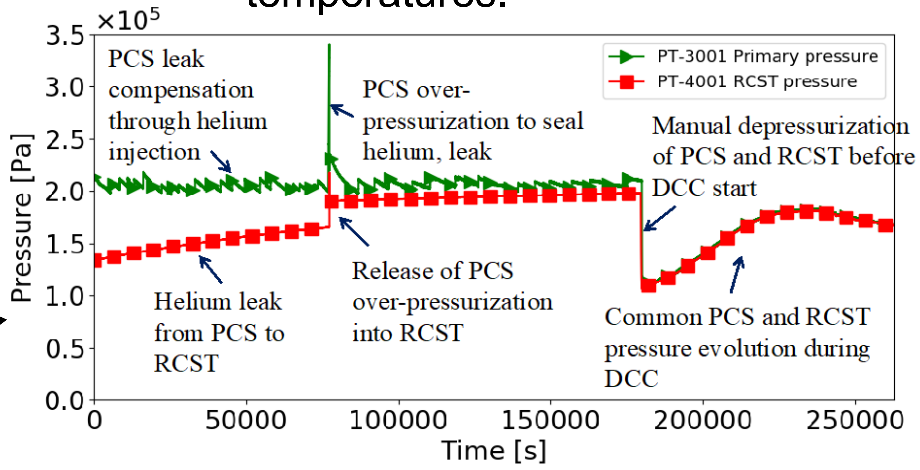
- Figure of Main Interest is:
  - (Depressurized) Core cooling under decay heat conditions
  - Gas mixing phenomena, natural convection, possible flow reversal

PG-26 Modeling Challenges

- No helium mass flow measurements
- No steady state
  - Not before transient, not at time zero
- Limited knowledge of heat flow
  - RCCS
  - Steam generator
  - Thermal stratification
- High uncertainty in thermal properties
- Complex manual operator actions during transient



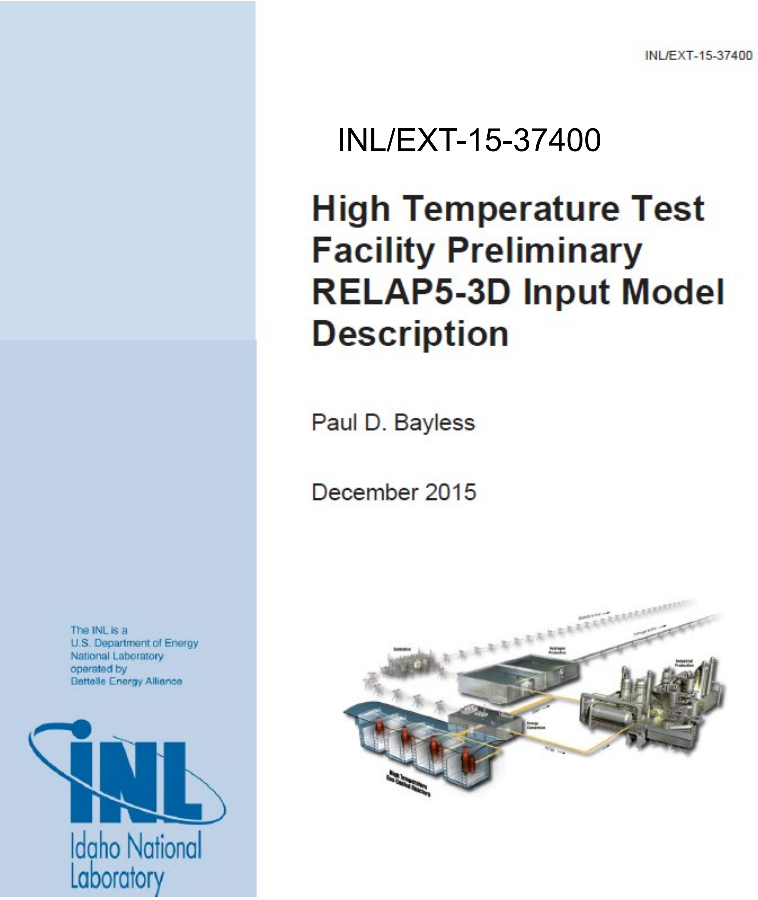
Measured core ceramic (midcore around the inner and outer fuel rings) and helium (in the upper and lower part of the hot and cold ducts) temperatures.



PCS and RCST pressure evolutions

RELAP5-3D Model

- Paul Bayless' quality-controlled model used as basis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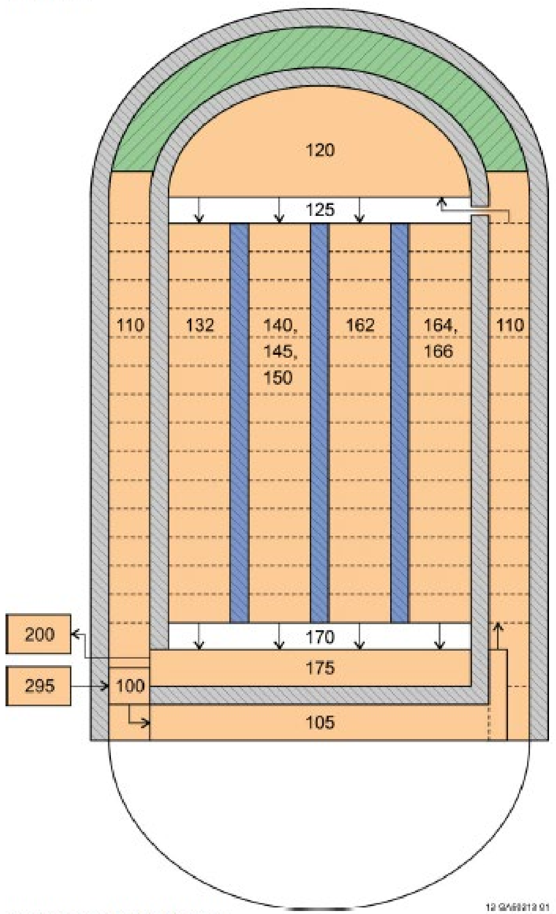
High Temperature Test Facility Preliminary RELAP5-3D Input Model Description

Paul D. Bayless

December 2015

The INL is a U.S. Department of Energy National Laboratory operated by Battelle Energy Alliance



ressure vessel nodalization.

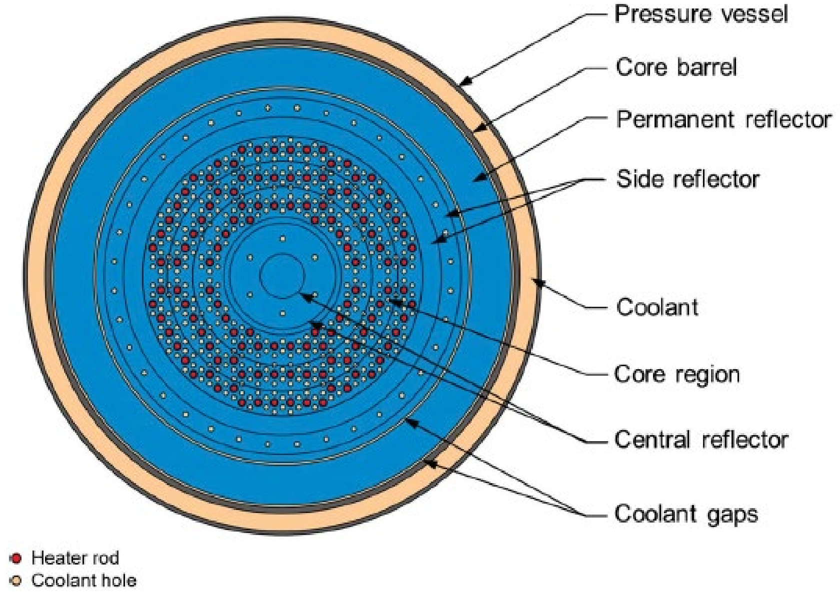
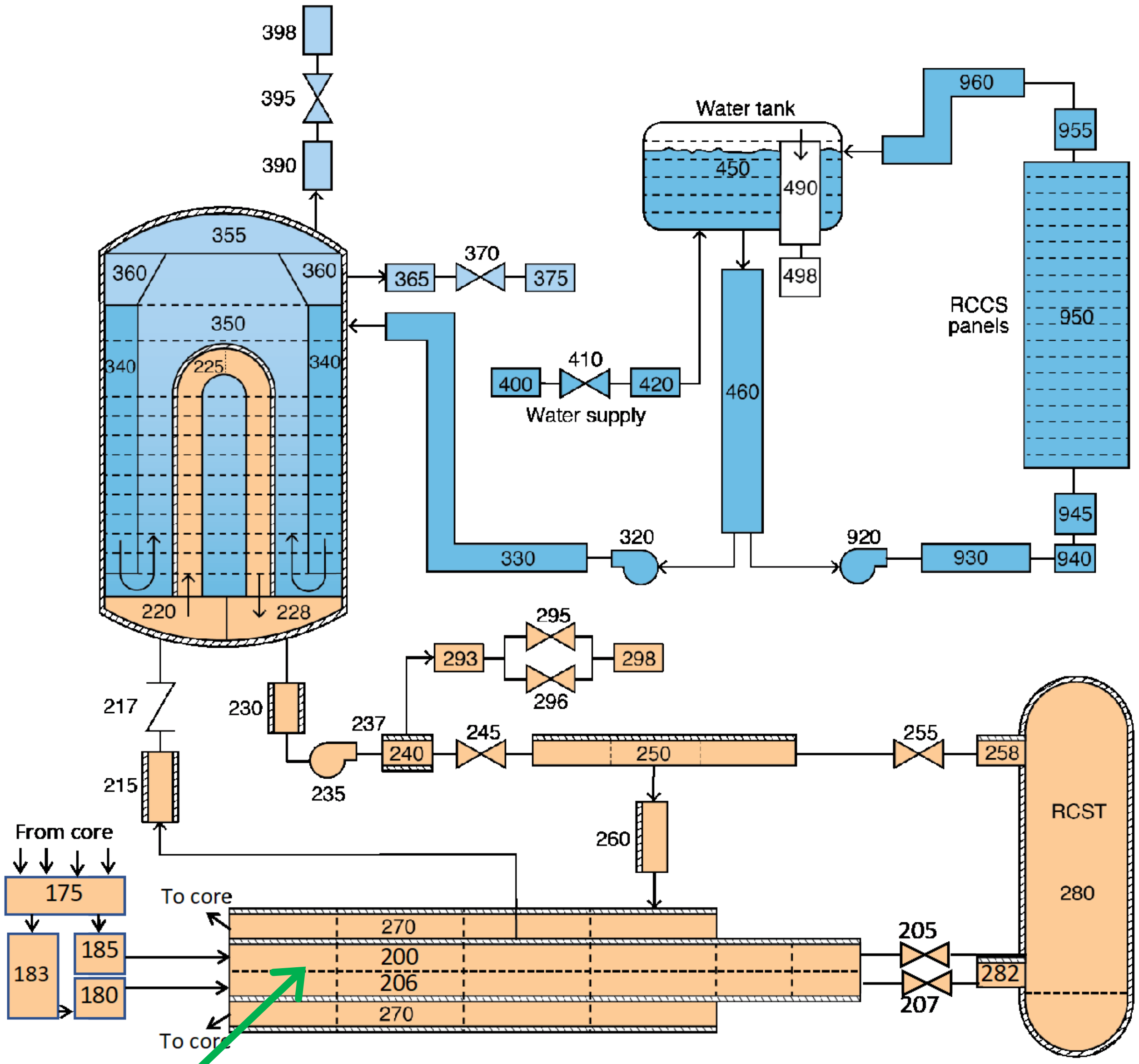


Figure 2. Primary pressure vessel radial nodalization.

RELAP5-3D Model

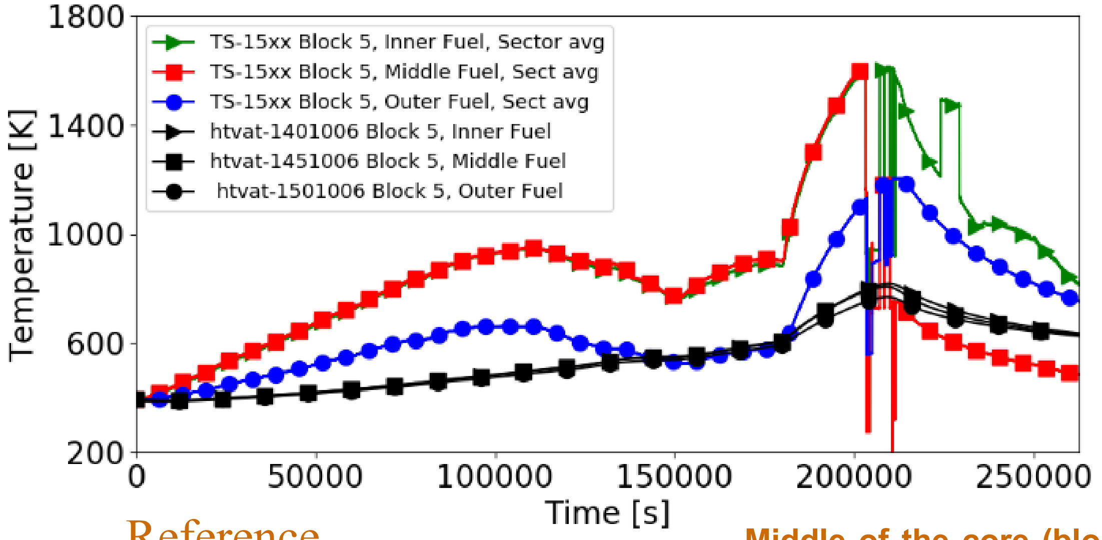
- Changes to Paul's base model
  - Replaced hot duct with "split" hot duct
    - Hope to see countercurrent single-phase flow
  - Primary helium blower BC replaced with circulator model



"Split" hot duct

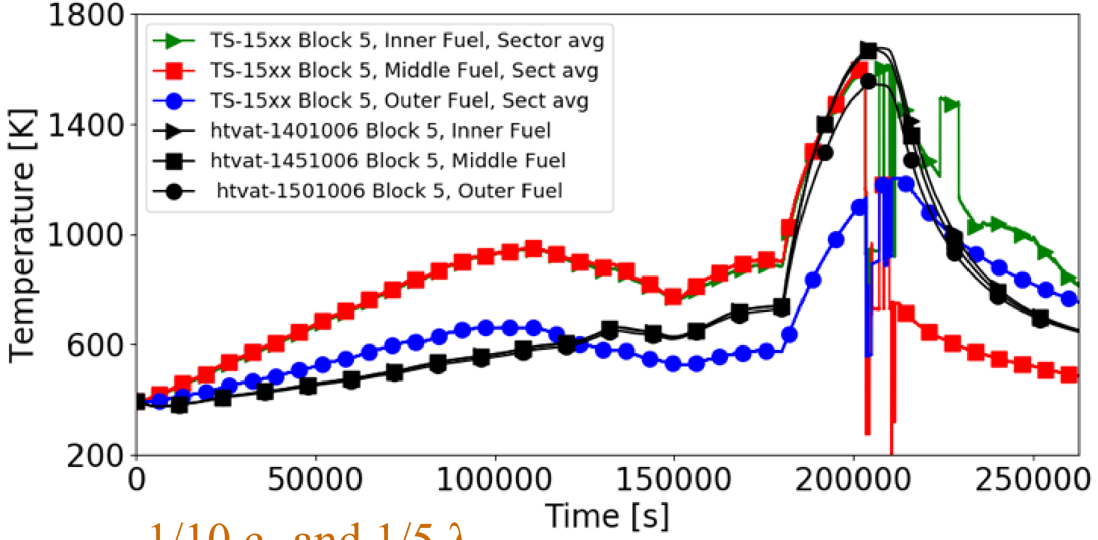
RELAP5-3D PG-26 Results

- Different possible model approaches using RELAP5-3D:
  - Model the facility state before the DCC starts as steady-state and only the DCC as transient
  - Model the whole transient including the heat-up phase as RELAP5-3D transient
- Reference
  - Best value for helium mas flow rate (15g/s)
- Sensitivity
  - 1/10 cp and 1/5 thermal conductivity
- Friction in the primary loop might be underestimated
  - Natural convection flow paths in RELAP5-3D (not observed in experiment)
    - lower (outlet) plenum → upper hot duct → RCST → lower hot duct → lower outlet plenum
    - RCST → Cold duct → Core → Hot duct → RCST
  - Sensitivity to friction shows:
    - Disappearance of natural convection
    - Natural convection and heat loss through the vessel walls are not a major contributor to the core temperature distribution



Reference

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



1/10 c_p and 1/5 λ.

- SAM portion of work
- Please also add your logos to the first slide and the slide master

Conclusions

- System codes **RELAP5-3D and SAM** have **successfully** been used to model the HTTF test PG-26.
- **RELAP5-3D**:
  - The general tendency is to underpredict the ceramic and helium temperatures.
  - Many of the assessment findings being in minimal agreement with the data.
  - Discrepancies between measured data and RELAP5-3D reflect limitations in boundary condition and thermal property knowledge (not code deficiencies).
- **SAM**:
  - SAM conclusions
- RELAP5-3D and SAM calculations provide some insights and point to missing or uncertain data
- The principal conclusion is that the PG-26 test data are insufficient for a system code assessment.