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Facility and Code Description

High Temperature Test Facility (HTTF), Oregon State University (OSU):

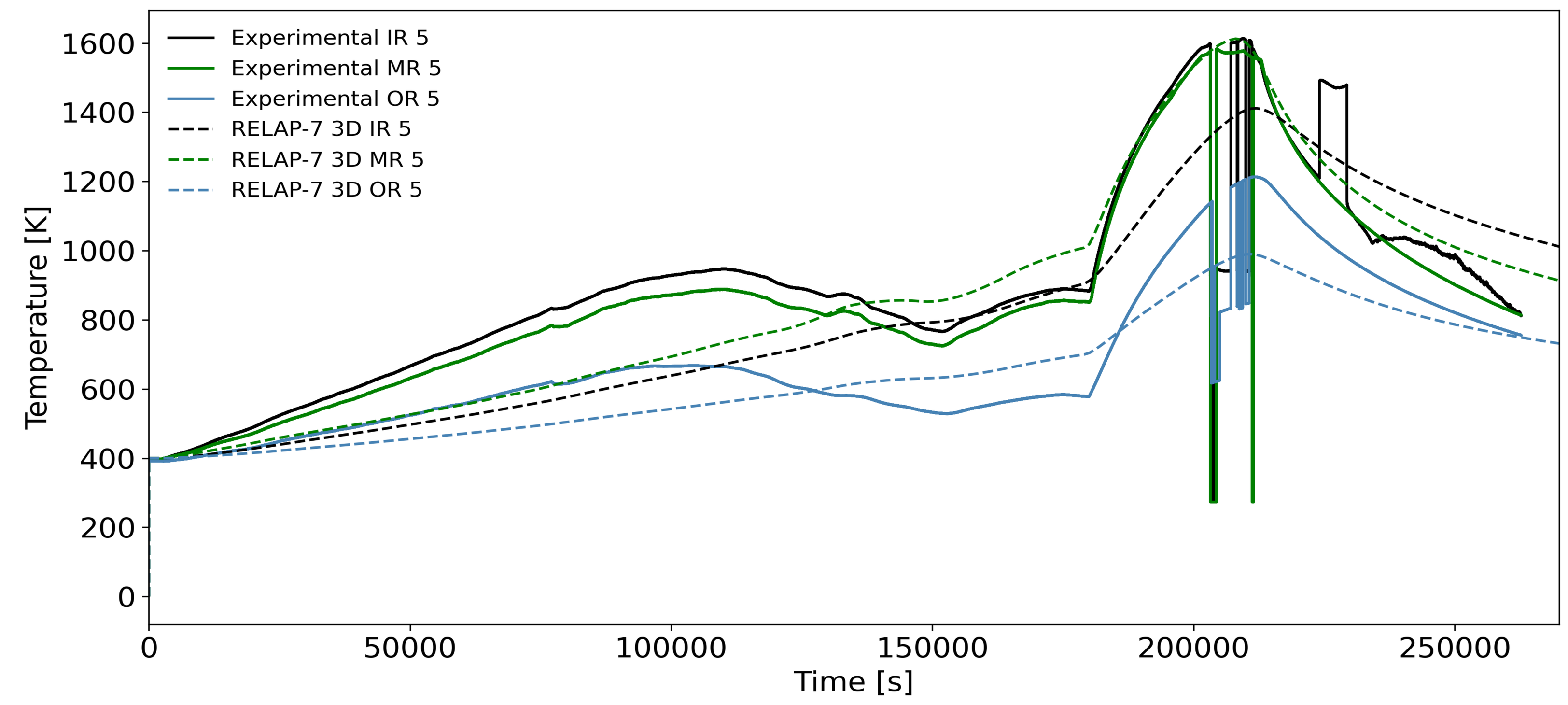
- Prismatic ceramic core with electric heating elements and 558 helium coolant channels.
- Has a ceramic core, outer reflector, core barrel, and reactor pressure vessel (RPV).
- Used to experimentally demonstrate thermal hydraulic conditions expected in advanced gas-cooled nuclear reactors.

RELAP-7:

- System analysis code developed by The Idaho National Laboratory (INL).
- Developed utilizing the Multiphysics Object-Oriented Simulation Environment (MOOSE).
- Capable of being coupled to other MOOSE applications modeling the varying physics of nuclear reactors.

Objectives

- Model the PG-26 transient conducted at the HTTF using the MOOSE multi-app approach to couple heat conduction in the ceramic core and fluid low.
- Model 3-D heat conduction within the HTTF core, side reflector, core barrel, and RPV with MOOSE heat conduction capabilities.
- Use RELAP-7 to model 1-D fluid flow through the 558 helium coolant channels.
- Validate the method of coupling 3-D heat conduction results with 1-D fluid flow results.



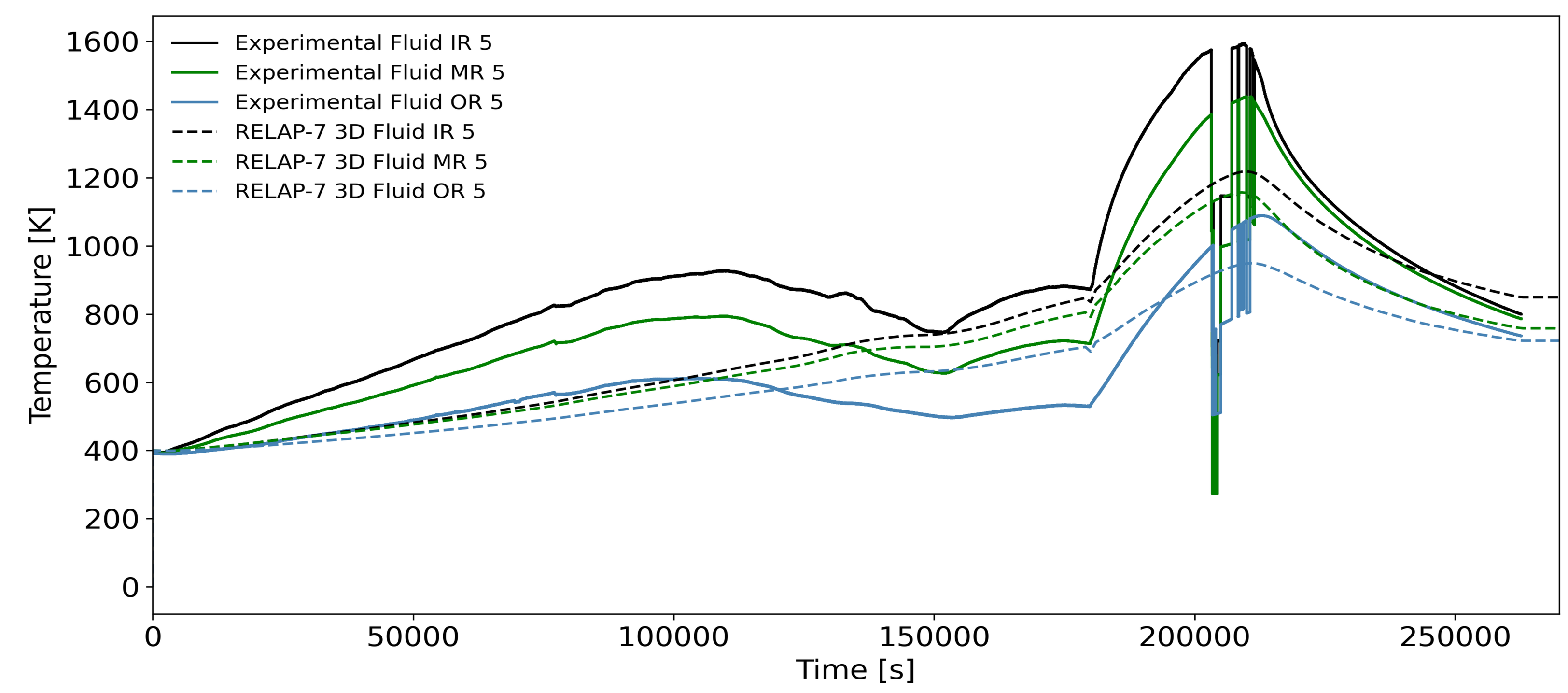


Figure 3: TOP Comparison of 3-D RELAP-7 results to solid core temperatures recorded at the HTTF during the PG-26 transient. Temperatures were recorded in core block 5, the middle axial plane, in the inner (IR), middle (MR), and outer (OR) radial rings. Vertical variations in experimental data were due to temporary failure of thermocouples during the experiment.

BOTTOM Comparison of 3-D RELAP-7 results to helium coolant temperatures recorded in core block 5, the middle axial plane, in the inner (IR), middle (MR), and outer (OR) radial rings. Vertical variations in experimental data were due to temporary failure of thermocouples during the experiment.

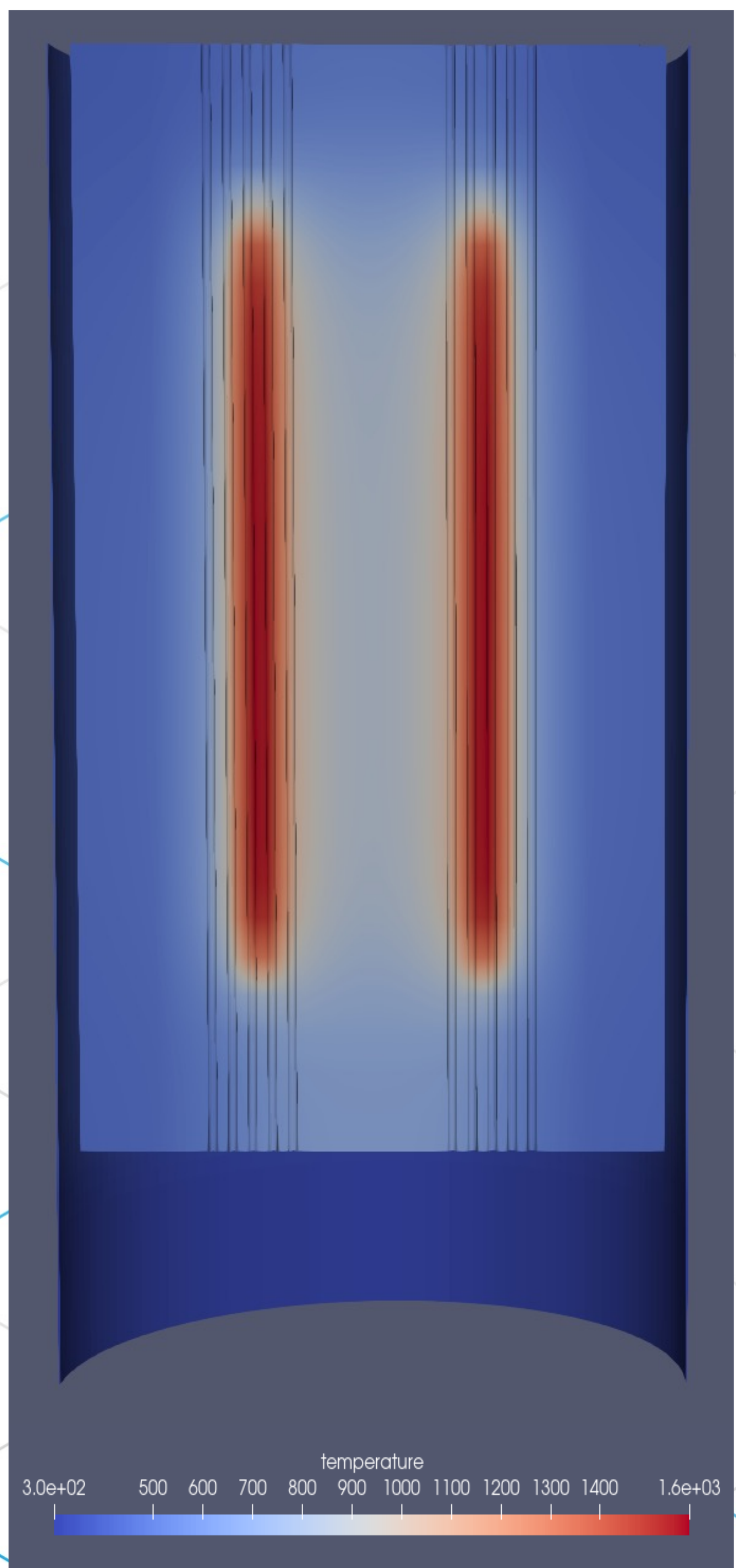
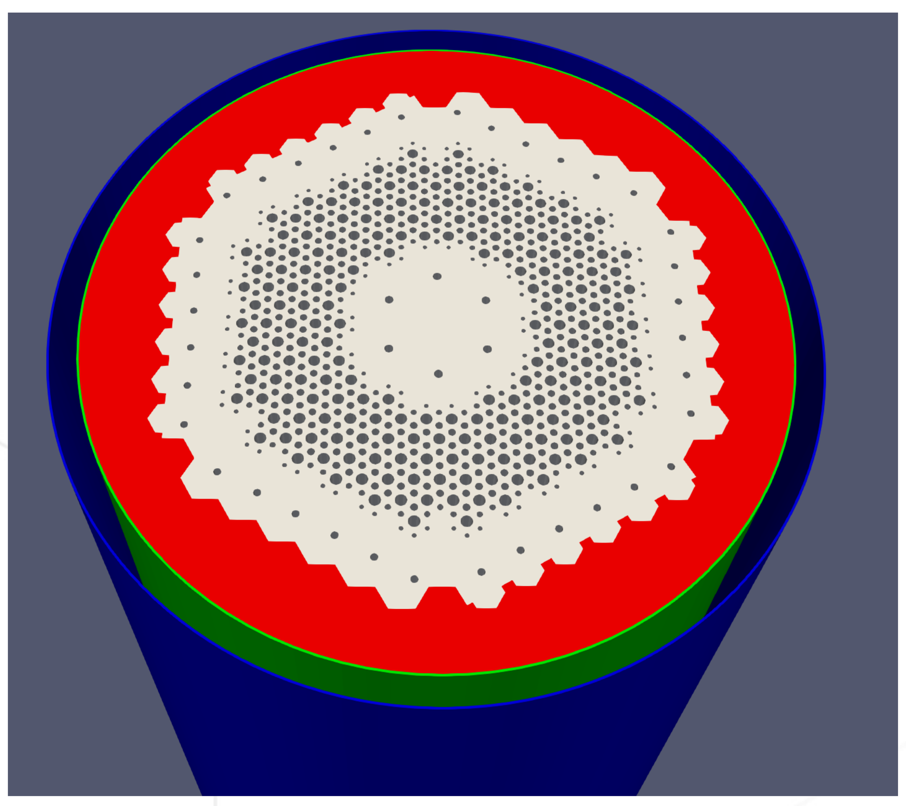


Figure 1: Vertical cut away of the HTTF core showing the temperature profile during the hottest point of the PG-26 transient.



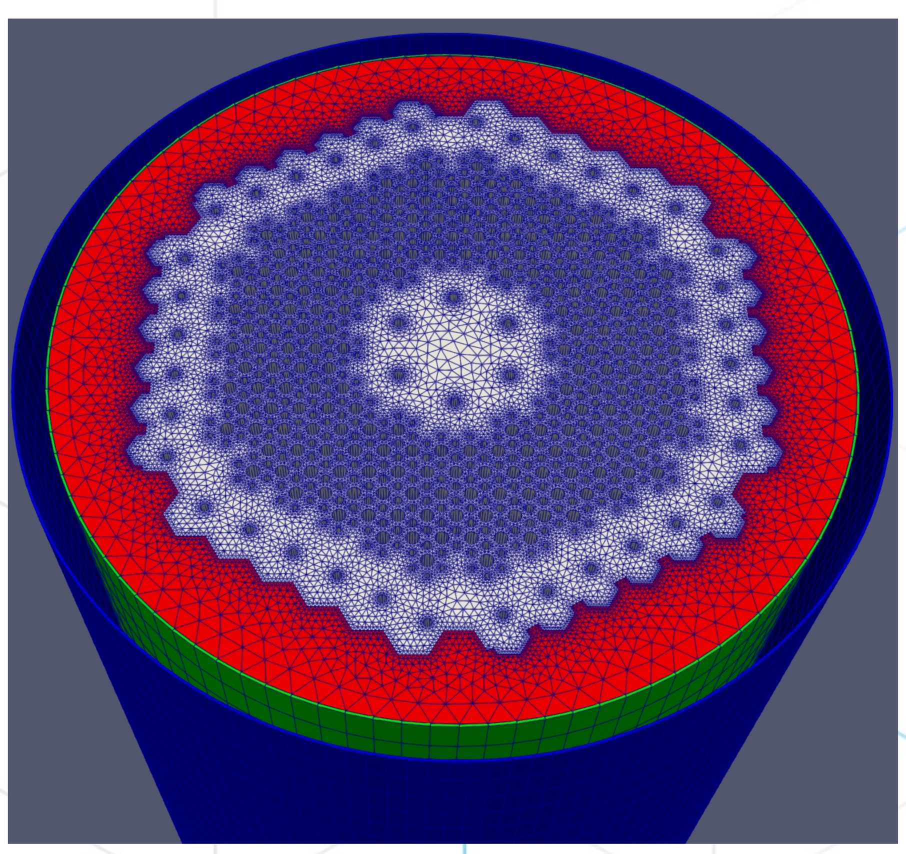


Figure 2: TOP 3-D model of the HTTF showing the core (white), outer reflector (red), core barrel (green), and RPV (blue).

BOTTOM 3-D model of the HTTF core with the overlayed finite element mesh shown in blue.

PG-26 Transient and RELAP-7 Model Description

PG-26 Transient:

- Heat-up period lasting approximately 180,000 s
- After 180,000 seconds, system depressurization occurred in the primary and secondary loops
- The gas circulator was turned off and the electrical heat power output was increased
- Electric heater power was slowly decreased to simulate decay curve of a nuclear reactor

MOOSE/RELAP-7:

- Combined 3-D model of the HTTF core, outer reflector, core barrel, and RPV was generated using CAD software.
- Mesh was generated using MOOSE mesh generation tools and Cubit.
- Power output from the heaters was applied to the surfaces of the HTTF core where the heaters are located.
- Radiative heat transfer between the core barrel outer surface and the inner surface of the RPV
- The MOOSE multi-app execution process is used to couple the flow through the cooling channels and the heat conduction in the ceramic blocks with convective boundary conditions.
- Measured temperature is applied at the upcomer inlet, and the measured system pressure is applied at the core outlet.

Results

- Accurately predicted peak ceramic temperatures experienced within the HTTF core during the PG-26 transient.
- Underpredicted coolant temperatures throughout the core.
- Unable to accurately predict core and coolant temperatures experienced during initial heat-up period due to uncertainties of the PG-26 transient (coolant leak occurred, unknown mass flow rate through the core, unknown amount of added coolant to account for leak, unknown temperature of makeup coolant added to system).
- Successfully demonstrated the multi-app capabilities of MOOSE and RELAP-7 to model high temperature gas-cooled systems.
- 3-D modeling approach allowed for direct comparison between simulation results and data recorded by instrumentation throughout the HTTF core.
- 3-D core model can be extended in RELAP-7 to model rest of the HTTF thermodynamic system.