Model Validation using novel CFD-grade experimental database for NGNP Reactor Cavity Cooling Systems with Water and Air

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ABSTRACT:

The Reactor Cavity Cooling System (RCCS) is a key safety system for the Next Generation Nuclear Plant (NGNP) gas-cooled thermal reactor to reliably transfers the core decay heat to the environment under all accident situations. Both a water-cooled and an air-cooled design have been proposed for the RCCS. Both RCCS design options consist of a set of pipes/ducts built into the reactor cavity and facing the reactor pressure vessel (RPV). Coolant (water or air, depending on the design option) flowing into the RCCS pipes removes the heat from the RPV by radiation and/or convection. The RCCS is designed to provide long term cooling of the RPV and protect the cavity structure from overheating. Both air-cooled and water-cooled RCCS are designed to operate in a passive mode during accidents, providing heat removal from the RPV and the reactor cavity using natural circulation. Several of the fundamental modeling challenges associated with the RCCS are common with the passive safety systems of Gen-III+ LWRs and integral small modular reactors (SMRs). For example, three-dimensional mixing dominated by buoyancy in the air-cooled RCCS plena and flashing-induced flow instabilities in the water-cooled RCCS risers are fundamental modeling issues common to most passive decay heat removal systems with small to modest driving pressure differences.

We propose to use advanced innovative instrumentation to build a high-resolution experimental database and to use the novel experimental data to assess and further develop the predictive capabilities of both 1D thermal-hydraulic system codes and computational fluid dynamics (CFD) computer codes. We plan to investigate specific thermal-hydraulic issues, which will ensure that the RCCS is able to successfully accomplish its safety functions under all conditions, and will result in improved computational methodologies for the prediction of the RCCS behavior. The improved models proposed here will also have the direct benefit of improving the predictive capability of the passive systems of Gen-III+ LWRs and SMRs passive systems.

The project objectives are to (a) provide an improved understanding of the behavior of the water-cooled RCCS during two-phase flow natural circulation operation, leveraging an existing RCCS experimental facility operated at University of Wisconsin-Madison; (b) provide improved physical insight of the mixing and stratification in the upper plena of the air-cooled RCCS through the design and operation of a new scaled test facility at the University of Michigan, equipped with advanced instrumentation and aimed at providing a novel detailed CFD-grade experimental database; (c) use the high resolved experimental data to advance the computational methodologies (both CFD and best-estimate thermal-hydraulic system codes) for the prediction of the RCCS behavior. The CFD-grade experimental database will be made available to the community through the NE-KAMS database currently being developed under the lead of Idaho National Laboratory (INL). The project will also support the expected operation of the RCCS.