Validation of RELAP-7 for forced convection and natural circulation reactor flows

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ABSTRACT:

Nuclear reactor systems present a significant challenge to computational simulation due to the wide range of system conditions and associated physics. Furthermore, the regulatory demands to increase safety margin and justify safe operation and shutdown adds a daunting challenge for complete system understanding. Together these requirements result in the need for large amounts of validation data under varying conditions and configurations. The degree of reliance on computational tools for nuclear power plant regulation and design can only be justified by extensive code validation with experimental data. Therefore, this work aims to generate a large database for forced convective and natural circulation reactor flows. Through the synthesis of existing data from past experimental efforts and generation of new data from an existing well-scaled facility, a database providing a logical path to system code validation can be created.

The experimental data will be used to validate the new RELAP-7 thermal-hydraulics code under conditions critical to analysis of current and future Light Water Reactor (LWR) systems. The experiments follow a sequential hierarchy validation path (pyramid), which starts with forced convective flows based on well-established benchmark data spanning prototypic LWR operational and accident conditions. The validation is then extended to the newly generated natural circulation data. Due to the coupling of pressure drop, flow rate and heat transfer through the void fraction, accident mitigation strategies relying on natural circulation present significant challenges for system codes. Such a path allows for a consistent delineating of phenomenological contributions and quantifying uncertainties of different physics phenomena.

A key component of the proposed validation strategy is the development and implementation of state-of-the-art uncertainty characterization (UC) algorithms in the form of a toolkit that can be readily accessible by the various models used to analyze the experiments proposed in this project. Despite the importance of uncertainties, nuclear simulation codes have always lacked an integrated framework for their characterization. This project will combine well-established techniques with recently developed UC algorithms to ensure a comprehensive treatment and understanding of all uncertainty sources that can be efficiently computed. These algorithms will provide a rigorous manner by which the credibility of the model can be established.

Close collaboration between experimental, modeling, and computational experts will provide an expansive study of reactor flows from inception of data through validation and model uncertainty quantification. The outcomes of the work include: synthesis of existing experimental data for thermal-hydraulic system code validation spanning the full range of prototypic system pressures under forced convection two-phase flow; a new experimental database from an existing well-scaled facility under natural circulation conditions; validation and uncertainty quantification of RELAP-7 under forced convection and natural circulation reactor conditions.