Unraveling how mixing vane spacers affect cladding-to-coolant heat transfer phenomena in light water reactors.

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ABSTRACT:

Cladding-to-coolant heat transfer is a critical area of uncertainty in nuclear reactor safety. This uncertainty manifests itself in the use of extremely conservative models that widely bound thermal hydraulics phenomena, particularly the departure from nucleate boiling. The CASL-delivered models have shown the potential of the M-CFD approach to alleviate this issue. However, the introduction of heather rod geometries with grid spacers has demonstrated an increase in bias error. The effect of mixing vane spacer is not clearly understood, let alone accurately modeled.

This proposal addresses this critical knowledge and technical gap. We will take advantage of the high-resolution experimental techniques developed by the PI and the advanced modeling framework developed by the co-PI:

1. To reveal how mixing vane spacers affect the cladding-to-coolant heat transfer
    a. by running single-phase forced convection and subcooled flow boiling experiments and without mixing vanes spacers in prototypical nuclear reactor conditions.
    b. by using non-intrusive infrared diagnostics that allow measuring the time-dependent temperature and heat flux distributions on the heating surface, simultaneously with non-intrusive phased-detection diagnostics that allow tracking the distribution of vapor (i.e., bubbles) and liquid on the heating surface.
    c. by deploying advanced image processing algorithm to analyze infrared and phase detection videos and measure space-dependent (i.e., as a function of the position on the heating surface with respect to the mixing vane) boiling parameters (e.g., nucleation site density, bubble growth time and wait time, and bubble footprint size distribution), together with space dependent and time-averaged wall temperature, heat flux, and heat transfer coefficient.
2. To advance the development and validation of Multiphase Computational Fluid Dynamics (M-CFD) tools to flows in presence of mixing vane spacers
    a. against our single-phase forced convection experiments, and
    b. against our subcooled nucleate boiling experiments, including CHF, by updating and validating subgrid boiling models based on the GEN II heat flux partitioning formulation developed by the CASL consortium,

    in order to support industrial and DOE/NE efforts aiming at improving the prediction of DNB margin in nuclear reactors.
3. To generate a comprehensive experimental database that can be used by the nuclear community:
    a. to critically evaluate existing models and correlations.
    b. to benchmark modeling tools used for the design and safety analysis of nuclear systems.

This project brings together a team with decades of experience in experimental two-phase flow and heat transfer, and leverages unique developments made possible through previous research including projects funded through DOE programs. To tackle the challenges of this project, the research team will involve graduate and undergraduate research assistants, who will benefit from both theoretical and hands-on experience offered by this study, with a firm commitment to enhance diversity and inclusion.