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Critical Heat Flux Phenomena at High Pressure and Low Mass Fluxes: Tests and Models

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ABSTRACT

The proposed work will examine critical heat flux (CHF) phenomena, both by experiment and modeling, under high-pressure and low mass flux conditions, in a heated rod bundle for prototypic integral reactor core designs. The experimental results will provide important validation data for an updated critical heat flux model for use in thermal-hydraulic computer codes to be used for integral light water reactors (LWRs), which operate under these conditions. The conceptual LWR designs considered as a reference for this study are the NuScale Pressurized Water Reactor Power Plant and the Babcock-Wilcox mPower Reactor Power Plant. There is minimal experimental data at low mass flux conditions and high pressure and not in a rod bundle. Our work will provide data and associated modeling, as well as a better understanding of the CHF process with prototypic flow and pressure ranges in a rod bundle geometry for integral small modular reactor (SMR) designs. These data currently do not exist.

The CHF phenomenon is one of the key physical phenomena that limit the allowable linear power for a nuclear reactor core design under steady-state operating conditions, and can be a limiting condition under transients. The advanced LWR designs being considered for modular reactor plants normally involve core flow rates (either under natural circulation or forced circulation) at mass fluxes far below current LWR conditions. Based on an open literature review, one finds that no data exist for rod bundles and only a sparse database for heated tubes. For these advanced designs to address the needed safety conditions, some fundamental understanding must be obtained for CHF under these conditions.

This proposal will focus on four specific tasks:
1] Perform a scaling analysis for rod bundle geometry that is appropriate for the proposed small modular reactor core designs for a single rod and multiple rod experiments;
2] Design and construct a CHF test facility similar to existing flow loop with scoping tests;
3] Under prototypic controlled flow and pressures conditions, measure flow velocities and pressure drops approaching CHF to determine onset of CHF and flow instabilities. Create a database of experimental CHF data and any associated flow instability conditions;
4] Compare the CHF data with current correlations, if appropriate, and develop a more mechanistic model to increase the reliability of predictions under low flow conditions.