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Experimental investigation and development of models and correlations for cladding-to-coolant heat transfer phenomena in transient conditions in support of TREAT and the LWR fleet.

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ABSTRACT:

Cladding-to-coolant heat transfer in transient conditions is a critical area of uncertainty in nuclear reactor safety. This uncertainty manifests itself in the use of extremely conservative models that widely bound the onset and duration of thermal-hydraulics phenomena, particularly CHF and post-CHF, and significantly impacts predictions of both accident progression and fuel performance behavior. Improved understanding and predictive models to describe the transitions to film boiling and its duration could meaningfully improve fuel development and safety and design margins in LWRs and will be of invaluable support to the TREAT program.

This proposal addresses this critical knowledge gap. We will take advantage of the high-resolution experimental techniques developed by the investigators (i.e., high-speed infrared thermometry and phase detection, and high-speed optical fibers thermometry) to perform carefully controlled, first-of-a-kind separate effect experiments of transient heat transfer.

The objective of these experiments is to:

1. Elucidate heat transfer phenomena between the fuel cladding and the coolant in transient conditions
   a. Focusing on CHF and post-CHF conditions;
   b. Considering
      i. Exponential power escalations and rapid power pulses, representative of reactivity initiated accidents (RIA), up to PWR pressures and at several flow rates and subcooling degrees,
      ii. Anticipated Operational Occurrence, such as BWR power pulses following a turbine trip,
      iii. Reflooding scenarios (e.g., LOCA scenarios),
      iv. post-CHF heat transfer at ambient pressure and PWR conditions;
   c. Considering conventional Zircaloy claddings and ATF concepts, with a focus on Cr-coated Zircaloy.
2. Generate a comprehensive database to critically evaluate existing models and correlations, and benchmark modeling tools developed by NEAMS and/or in use by the nuclear community, including thermal-hydraulics codes (e.g., CTF and RELAP5) and fuel performance codes (e.g., BISON).
3. Verify fundamental hypothesis and develop physical models and correlation to model these phenomena with the aforesaid computational tools.
4. Support the LWR fleet and the TREAT research programs with new understanding, targeted experimental results, and modeling with new and representative physical models and correlations.

This project brings together a team with decades of experience in experimental two phase flow and heat transfer and fuel performance analyses, and leverages unique developments made possible through previous research including projects funded through the NEUP program. 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 engage under-represented minorities.