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Determination of Critical Heat Flux and Leidenfrost Temperature on Candidate Accident Tolerant Fuel Materials

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Program: FC-2.3, Critical Heat Flux for Accident Tolerant Fuels (ATF)

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ABSTRACT:

Since the 2011 Fukushima accident, significant research has been devoted to developing accident-tolerant fuel (ATF) cladding materials. These investigations have mostly focused on the ability of potential ATF materials to resist runaway steam oxidation and retain their mechanical strength and structural integrity under thermal shocks. However, knowledge is relatively lacking for the thermal-hydraulic properties of these materials, particularly under light water reactor (LWR) operating conditions. In particular, two properties that determine safety margins for normal and off-normal conditions, the critical heat flux (CHF) and Leidenfrost point (LFP) temperature, have not been investigated thoroughly for ATF materials.

The primary objective of the proposed work is to measure CHF on three candidate ATF materials under normal and off-normal LWR conditions, and compare the results with those for a control zircaloy surface. Materials to be investigated include silicon carbide (SiC), FeCrAl-coated zircaloy, Cr-coated zircaloy, and bare zircaloy as a control. We will also measure the roughness, wettability, and wickability of these materials and examine how these parameters change for fresh, steam-oxidized (not irradiated), and in-pile coupons (which are subject to oxidation, chemical attack, and irradiation). Crucially, for each material we will measure how wettability and wickability change with pressure and temperature, ranging from atmospheric to PWR conditions. We will then conduct CHF tests using actual fuel claddings at pressures ranging from atmospheric to PWR levels. We will also consider transient boiling conditions, e.g. Loss-of-Flow-Accidents and particularly Reactivity Initiated Accidents, in support of upcoming national efforts to study transient ATF fuel behavior in the Transient Reactor Test (TREAT) at Idaho National Laboratory. Specific parameters to be varied include system pressure, inlet flow quality, inlet subcooling, mass flow rate, and (for transient tests) width and shape of the power pulse. Since deposition of CRUD changes surface properties, which may affect CHF, tests will also be performed to assess the effect of CRUD deposition on CHF on selected ATF candidate materials. The LFP temperature determines safety margins during post-loss of coolant accident (LOCA) scenarios, in which reflooding (PWR) and spray quenching (BWR) are employed. Thus, although this is by no means the main focus of this project, the LFP temperature for each material will also be measured.

This work will yield material-specific models and/or correlations for CHF and quenching that can be readily implemented in state-of-the-art simulation tools developed with the support of DOE in the frame of the IRP project 15-8843 or the Nuclear Energy Advanced Modeling and Simulation (NEAMS) program. In addition, the results of this work will inform upcoming lead test rod/lead test assembly (LTA/LTR) irradiations by providing safe operating limits for each material.