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An Experimental and Analytical Investigation into Critical Heat Flux (CHF) Implications for Accident Tolerant Fuel (ATF) Concepts

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ABSTRACT:
Following the Fukushima accident, the US Department of Energy Office of Nuclear Energy (DOE-NE) Advanced Fuels Campaign (AFC) is working to develop fuel and cladding candidates with potentially enhanced accident tolerance; 'Accident Tolerant Fuel' (ATF). The AFC is considering a variety of candidate fuel and cladding materials. The most promising cladding concepts include nuclear-grade iron-chromium-aluminum (FeCrAl), fiber-reinforced silicon carbide composite (SiC_f/SiC), and Cr-coated Zircaloy. While ATF R&D to date has been successful in gaining better understanding of the materials performance of proposed candidate cladding and fuels, there has been little evaluation of ATF concepts from a thermal-hydraulics standpoint. Unexplored thermal hydraulics behavior includes boiling curves, Critical Heat Flux (CHF), and friction factors. In particular, the CHF of ATF cladding is key, since it is vital to safety margins during steady-state operation, to the progression of design basis accidents, and to nuclear reactor and fuel design

We will use tightly coupled experiment and modeling to (a) determine any change to CHF attendant upon the use of candidate accident tolerant fuel claddings, and (b) assess the effect of this change on reactor performance and safety characteristics. Experiments will include pool boiling, and low & high pressure flow boiling in steady state and transient conditions. Measurements will include basic physical properties (e.g. contact angles), and 'engineering' quantities, in particular CHF values. An associated modeling program will range from fundamental microscopic, through component-(sub-channel) scale modeling, to system-scale assessments of the influence of changed CHF characteristics on overall plant margins. These assessments will provide best-estimates of safety margins during normal operation and progression of design basis accidents.

Pool and flow boiling experiments will be conducted to help gain mechanistic understanding of ATF CHF, and to generate boiling curves and CHF values for use in systems codes (e.g. RELAP) and subchannel codes (e.g. COBRA-TF). A key outcome of this project will be a holistic best estimate assessment of the potential impact of ATF cladding materials on the progression of key design basis accidents in LWRs, including impacts due to differences in (1) heat transfer characteristics, the boiling curve, and CHF, (2) fuel mass/volume/specific power density, and (3) neutronics effects due to changes in the lattice design or parasitic neutron absorption.