Evaluation of Accident Tolerant Fuels Surface Characteristics in Critical Heat Flux Performance

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ABSTRACT:

Enhanced accident tolerant fuels (ATF) are defined as nuclear fuels that can tolerate a severe loss of active cooling in the reactor core for a considerably longer period of time than the current UO2 – zirconium alloy fuel system, while maintaining, or preferably improving, the fuel performance during normal operations and operational transients. DOE-NE initiated in 2012 a variety of research and development activities in the area of ATF to meet the needs of an aggressive Congressional mandate that stipulates that a Lead Test Assembly of ATF be introduced in a commercial LWR by 2022. Several teams across the United States comprising universities, national laboratories and industry are investigating a variety of candidate concepts and technologies for ATF. The Critical Heat Flux (CHF) is one of the key parameters used to evaluate the thermal performance of a fuel product and to establish safety and operational margins. Preliminary studies for the proposed ATF concepts indicate that their cladding surface characteristics (wetting, roughness, porosity, changes in protective oxide layer thickness and characteristics with operating conditions, etc.) are important parameters regarding CHF behavior.

The goal of this proposal is to perform separate-effects and system-wide tests of several of the ATF concepts under consideration to investigate the impact of cladding surface characteristics in CHF under normal and anticipated off-normal conditions. These tests will make use of advanced temperature and fluid measurement instrumentation (optical fibers, ultrasonic Doppler imaging, PIV, high speed camera, magnetic flow sensors and hot wires) to obtain high fidelity qualitative and quantitative measurements for the thermal-hydraulic behavior of the ATF cladding under evaluation. The cladding surfaces of the ATF concepts under study (porosity, roughness, contact angle and wetting characteristics, etc.) will be previously characterized using advanced materials examination techniques such as scanning electron microscopy (SEM), focused ion beam (FIB), atomic force microscopy, X-ray diffraction, etc. The experimental results will be used to develop enhanced models or correlations for the prediction of CHF that will be implemented in suitable subchannel analysis codes.

The involvement of industrial partners AREVA and GE will allow the team to study several of the actual ATF concepts currently under consideration by DOE-NE and will collaborate directly with the teams working on ATF research and development. Our team has experience in the development and licensing of core thermal-hydraulics methodologies, and we expect to be able to leverage this experience to create the enhanced models so that they could be incorporated into licensed codes and used in a relatively short term.