U.S. Department of Energy

Project Title

Advanced Instrumentation for Transient Reactor Testing

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Program: IRP – NE

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ABSTRACT:

Transient testing involves placing fuel or material into the core of specialized materials test reactors that are capable of simulating a range of design basis accidents, including reactivity insertion accidents, that require the reactor produce short bursts of intense high-power neutron flux and gamma radiation. Testing fuel behavior in a prototypic neutron environment under high-power, accident-simulation conditions is a key step in licensing nuclear fuels for use in existing and future nuclear power plants. Transient testing of nuclear fuels is needed to develop and prove the safety basis for advanced reactors and fuels. In addition, modern fuel development and design increasingly relies on modeling and simulation efforts that must be informed and validated using specially designed material performance separate effects studies. These studies will require experimental facilities that are able to support variable scale, highly instrumented tests providing data that have appropriate spatial and temporal resolution. Finally, there are efforts now underway to develop advanced light water reactor (LWR) fuels with enhanced performance and accident tolerance. These advanced reactor designs will also require new fuel types. These new fuels need to be tested in a controlled environment in order to learn how they respond to accident conditions. For these applications, transient reactor testing is needed to help design fuels with improved performance.

In order to maximize the value of transient testing, there is a need for in-situ transient real-time imaging technology (e.g., the neutron detection and imaging system like the hodoscope) to see fuel motion during rapid transient excursions with a higher degree of spatial and temporal resolution and accuracy. There also exists a need for new small, compact local sensors and instrumentation that are capable of collecting data during rapid transient excursions (e.g., local displacements, temperatures, thermal conductivity, neutron flux, etc.). The ability to monitor fuel behavior in real-time will provide information on the time evolution of fuel damage, which is important to develop a thorough understanding of the underlying science of fuel behavior. Such measurements also provide real-time data that can substantially compliment sole reliance on post-irradiation examination (PIE), which only provides data on the final state of fuel rod components.

Our research team proposes to develop and demonstrate specific new and innovative measurement diagnostics for real-time in-situ monitoring to support transient reactor testing. Our proposed objectives has three key program elements:

- Develop innovative concepts that lead to the design of the next generation fuel motion monitoring system to support transient testing, taking advantage of ‘line-of-sight’ core layouts; i.e., advancements in spatial and temporal resolution for hodoscope imaging.
- Develop novel instrumentation to support in-pile transient testing that includes fast response displacement and temperature measurements, thermal conductivity measurements, local fast and thermal neutron flux measurements.
- Demonstrate these novel instrumentation measurement methods in a reactor environment using university TRIGA reactors as well as design for their use in a transient test reactor.

As discussed within our proposal, prior transient testing experience indicates that the sensors and methods identified for investigation within this project are critical for obtaining most of the required key parameters and data from transient tests and for meeting data validation needs identified in Appendix D of this FOA call. It is anticipated that follow-on efforts will be able to meet remaining Appendix D data needs using test fixtures, protocols, and test methods developed from this IRP activity.

This Advanced Instrumentation for Transient Reactor Testing IRP combines the expertise of four universities and a leading national laboratory (and its unique instrumentation laboratory and staff expertise) with an international partner that provides instrumentation and test rigs. The IRP research team will function as a matrixed engineering team that is focused on our five distinct task areas:

Task I: Development of innovations for real-time, ‘line-of-sight’ imaging for a transient test using the current hodoscope concept with advancements in detection and image resolution;

Task II: Development of novel sensors to measure local displacements and temperatures of fuel rod under transient conditions as well as local measurements of neutron fast and thermal flux;

Task III: Out-of-pile testing of these novel sensors under a common test protocol and geometry;

Task IV: In-pile testing of these instruments in a TRIGA reactor to demonstrate the capability to measure these key parameters in a radiation environment under transient conditions;

Task V: Design of Standard Transient Reactor Experiment Test Capsules with Advanced Instrumentation.