NEUP Nuclear Energy University Programs

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Computational and Experimental Benchmarking for Transient Fuel Testing

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Program:
IRP-NE – Transient Fuel Testing

ABSTRACT:
An effort is presently underway to restart the Transient Reactor Test (TREAT) Facility, located at the Idaho National Laboratory (INL) by 2018. The TREAT Facility has historically been utilized to provide empirical data to support the comprehensive characterization of light water reactor fuel and sodium-cooled fast reactor fuel under a variety of conditions. The TREAT Facility is an air cooled, graphite moderated, (presently) highly enriched uranium fueled test reactor that comprises a square lattice configuration of solid fuel assemblies. In the central fuel assembly locations, one may remove select assemblies and insert a fueled-experimental loop in place. Due to the large thermal and reactive mass of the core the TREAT Facility has the ability to operate (and impose) nearly an infinite number of temporal boundary conditions on such an experimental loop and the fuel located in the loop, accordingly. This test reactor provides the capability of significantly expanding upon the existing empirical data available for traditional light water reactor fuel, supporting the accident tolerant fuel program in the U.S., and efforts to license next generation sodium-cooled reactors (such as TerraPower's reactor). The restart of this unique test reactor has pushed the capabilities of historically developed codes, used to provide the safety case for experimental conduct and design. However, significant progress in the development and implementation of mechanistic-based models has been underway in recent years through large integrated programs such as the Department of Energy's (DoE's) Nuclear Energy Advanced Modeling and Simulations (NEAMS) program. In addition to these 'next-generation' computer codes, instrumentation capabilities and experimental hardware design has significantly improved since the shutdown of the TREAT Facility in 1994.

Leveraging such advancements in computational tools, along with new experimental instrumentation and hardware developments, this team proposes a work scope which will lead to the following outcomes: (1) a comprehensive evaluation of existing TREAT Facility neutronics data according to established guidelines per the International Handbook of Evaluated Reactor Physics Benchmark Experiments (IRPhEP Handbook); (2) a complete characterization of existing sodium loop experimental data; (3) a compilation of relevant empirical data of a representative TREAT Facility flow loop; and (4) an integrated instrumentation plan for the TREAT Facility.

This scope has been clearly organized to successfully yield the aforementioned outcomes through three integrated project tasks which are organized congruently with those presented in the funding opportunity announcement, as follows:

1. **<u>Neutronics Benchmarks</u>** – A comprehensive neutronics benchmarking analysis will be conducted using PROTEUS (DoE NEAMS code), PARCS/AGREE (U.S. Nuclear Regulatory Commission [NRC] code) and Open MC (Monte Carlo code). An IRPhEP will result from this comprehensive benchmarking analysis. [Led by the University of Michigan]
   1.1. **Steady-State** – Two steady state condition benchmarking tests will be selected and studied.
   1.2. **Transient** – Two transient condition benchmarking problems will be selected and studied.
2. **<u>Loop Thermal-Hydraulics</u> –** A complete thermal hydraulic study will be conducted that focuses on the experimental loops placed within the TREAT Facility. These include a comprehensive evaluation of historical data collected from previous sodium experiments as well as expansion of existing data through design, development, and utilization of a new experimental loop that is representative of a proposed TREAT water flow loop. [Led by Oregon State University]
   2.1. **Sodium Loop** – Data from historically collected sodium loop calibration experiments will be used in a benchmark study against Nek5000 (DoE NEAMS code) and Star CCM+ (Industry code).
   2.2. **Water Loop** – Empirical data resulting from the new experimental flow loop will be benchmarked against RELAP5-3D (Industry code) and TRACE (U.S. NRC code). The experimental loop will also be used to support operational shake-down issues for a TREAT Facility prototype.
3. **<u>Core Instrumentation</u> –** The result of task 1 and 2, along with the conduct of ongoing experimental efforts underway by the FY14 IRP-NE team, will provide a clear basis for the design and development of a comprehensive TREAT Facility instrumentation plan. [Led by Massachusetts Institute of Technology]
   3.1. **Instrumentation Plan** – A comprehensive instrumentation plan (location and instrument selection) will be conducted.
   3.2. **Initial Benchmark Evaluation** – Testing of instruments that are required for implementation within the TREAT Facility and that have not already been tested will be conducted at the Massachusetts Institute of Technology Reactor II (steady state tests) and the Oregon State TRIGA® Reactor (transient tests).

Our integrated team comes from a wide background and has a multidisciplinary set of skills which embodies the premise of such an integrated research project. These skills and experience are ideally suited to successfully completing all of work scope defined within the proposal as well as actively communicating with the TREAT Fuel Testing Restart effort so as to facilitate the most high impact and relevant outcomes possible.

Additionally, an advisory board (AB) has been assembled to oversee the conduct, direction, and quality of work produced within the proposed work scope. The collective AB has a unique and well-rounded perspective to provide dynamic feedback as necessary and approval to proceed on critical tasks within the proposed work scope. Present AB Members (who have agreed to participate on this team's proposal) include the technical point of contact for FY15 IRP-NE category, Dr. Daniel Wachs as the AB Chair; Dr. David Hill ([formerly] Deputy Laboratory Director, INL), Daniel Jordheim (Manager of Fuel Design Neutronics – America, AREVA), Dr. Steve Bajorek (Senior Technical Advisory for Thermal Hydraulics, NRC), Dr. Michael Corradini (PI FY14 IRP-NE, Professor, University of Wisconsin), Dr. Andrew Klein (Professor, Oregon State University), and François Barré (Safety Research Deputy Director, IRSN).

This project's activities directly aligns with past, present, and proposed future DoE office of Nuclear Energy activities in support of the Transient Fuel Testing Restart effort, Accident Tolerant Fuels Program, and NEAMS program.