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Criticality Studies for UREX Processes

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Task 35

Criticality Studies for UREX Processes

D. Beller

BACKGROUND

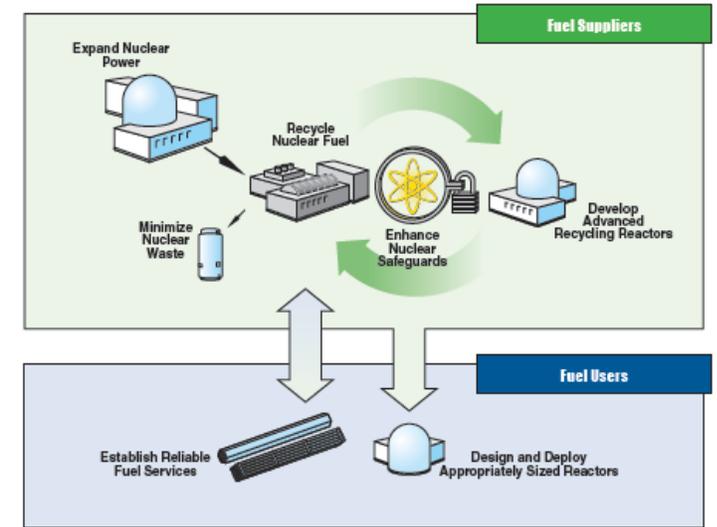
The completion of criticality experiments for mixtures of transuranic actinides (TRU; includes neptunium, plutonium, americium, and curium) that will be created during the separation of used nuclear fuel may be a requirement in order to construct prototype plants for the Global Nuclear Energy Partnership (GNEP). In this program and the Advanced Fuel Cycle Research and Development (AFC R&D) program that supports it, economic and environmental methods are being developed to reduce the impact of waste from commercial nuclear fuel cycles.

Recycling of used fuel by chemically separating it into U, fission products, and TRU would be the first step in this new fuel cycle. Proposed mixtures and concentrations of TRU covering a wide range of conditions must be examined theoretically and experimentally to demonstrate criticality safety in advance of construction of a processing facility. Theoretical studies may be limited because of insufficient nuclear data for the rarer isotopes of Np, Pu, Am, and Cm. These data limitations include reaction cross sections in some energy regimes, thermal feedback coefficients, and delayed neutron fractions.

RESEARCH OBJECTIVES AND METHODS

The completion of criticality experiments for mixtures of transuranic actinides that will be created during the separation of used nuclear fuel may be a requirement to construct prototype plants such as the Engineering-Scale Demonstration (ESD) and the Advanced Fuel Cycle Facility (AFCF) for the Global Nuclear Energy Partnership (see illustration below).

GNEP is a program to develop a worldwide consensus to enable the expanded use of economical, environmentally-friendly nuclear energy to meet growing electricity demand. In this program and the Advanced Fuel Cycle R&D program that supports it, participants are developing economic and environmental methods to reduce the impact of waste from commercial nuclear fuel cycles. Recycling of used fuel by chemically separating it into uranium,



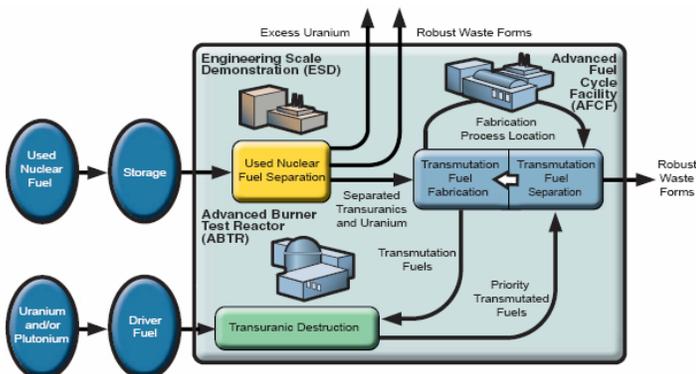
The Global Nuclear Energy Partnership (GNEP) structure.

fission products, and transuranic actinides would be the first step in this new fuel cycle. Proposed mixtures and concentrations of TRU covering a wide range of conditions must be examined theoretically and experimentally to demonstrate criticality safety in advance of construction of a processing facility. Theoretical studies may be limited because of insufficient nuclear data for the rarer isotopes of plutonium, americium, curium, and neptunium. These data limitations include reaction cross sections in some energy regimes, thermal feedback coefficients, and delayed neutron fractions (β).

In collaboration between UNLV, Los Alamos National Laboratory (LANL), Argonne National Laboratory (ANL), and Oak Ridge National Laboratory (ORNL), criticality studies will be conducted to support the development of future fuel cycle facilities.

The first step in determining requirements for criticality studies is an examination of past experiments and criticality and sensitivity studies, as well as available databases. Further sensitivity studies will determine what kinds of experiments should be performed to ensure criticality safety in advanced processes. This information can then be used to formulate an optimum set of experiments that can be analyzed in advance using state-of-the-art radiation transport codes. As these facilities and experiments will include complex geometries, a Monte Carlo N-Particle (MCNP) transport code will be used in these sensitivity, scoping, and design studies.

The work may also require generation of new cross section libraries and thermal scattering coefficient databases. Future criticality studies may include cross section sensitivity studies and design of critical experiments including dilute mixtures of Pu, mixed higher actinides in solution, and fuels.



The Global Nuclear Energy Partnership research facilities.

RESEARCH ACCOMPLISHMENTS

Progress implementing NJOY for cross section processing continued with the assistance of LANL and ORNL specialists. NJOY was successfully implemented and is now used to produce temperature-broadened point-wise cross section libraries from eight isotopes of higher actinides for sensitivity studies. Benchmarking of libraries and criticality studies is underway; a benchmark analysis of the Jezebel critical assembly with two temperature-broadened libraries was completed to validate variational and criticality methods.

Processing cross-sections in NJOY99.259 was completed and a review of criticality benchmark experiments was initiated for establishing the range of applicability of physical and spectral parameters. Modeling of criticality sensitivity testing with minor actinides in the UNM AGN-201 reactor continued. A review of criticality safety benchmark experiments was completed for the established range of applicability of physical and spectral parameters and reactivity sensitivity studies began on higher actinides. Fast spectrum reactivity sensitivity studies were completed on eight higher actinide isotopes at six different temperatures. Void and replacement reactivity changes were calculated with three fast benchmark experiments.

The SHEBA liquid-core critical assembly was modeled in preparation for sensitivity studies. Reactivity sensitivity studies of the SHEBA liquid-core critical assembly was completed and modeling detectors for determining ability to measure reactivity changes was initiated. A californium source was added opposite a neutron detector to model neutron transport through the liquid-core SHEBA for reactivity sensitivity studies.

Other Accomplishments

Dr. Charlotta Sanders joined the UNLV research faculty and this project as a co-investigator. Her expertise is in radiation transport, criticality, and shielding analyses, with substantial experience with investigations related to used nuclear fuel. She is advising students and developing new research projects for continuation of MPAC research.

Funding was approved for a contract with Professor Robert Busch of the University of New Mexico (UNM) to investigate the use of UNM's AGN-201 reactor for criticality sensitivity experiments with higher actinides. A MCNP model of AGN-201 reactor was

ACADEMIC YEAR HIGHLIGHTS

- ◆ Lawrence Lakeotes, M.S. thesis, Department of Mechanical Engineering, "Neutron Cross-Section Sensitivity Studies in Higher Actinides for Criticality Safety in Reprocessing," University of Nevada, Las Vegas, NV, April 2008.
- ◆ L. Lakeotes, "Neutron Cross-Section Sensitivity Studies in Higher Actinides for Criticality Safety in Reprocessing," oral presentation, 2008 American Nuclear Society Student Conference, College Station, TX, March 1, 2008.
- ◆ Timothy Beller graduated with an M.S. in Materials and Nuclear Engineering, December 2007.
- ◆ Ryan LeCounte graduated with an M.S. in Materials and Nuclear Engineering, December 2007.
- ◆ Lawrence Lakeotes graduated with an M.S. in Materials and Nuclear Engineering, May 2008.
- Sandra De La Cruz graduated with a B.S.M.E. (nuclear option), May 2008.
- UNLV submitted a closely related, multi-year proposal to the Nuclear Energy Research Initiative for Consortium (NERI-C) with Georgia Tech and UNM as consortium members for computational and experimental examination of actinide cross sections and criticality experiments.
- ◆ Dr. Charlotta Sanders joined the UNLV research faculty and this project as a co-investigator.

obtained from UNM, some programming errors were corrected, and successful criticality runs were conducted in preparation for sensitivity studies.

These studies have begun by modeling small quantities of higher actinides in the reactor hole to determine reactivity sensitivity for potential experiments. Using this funding to prepare for future work, UNLV and UNM conducted a Reactor Experimentation Laboratory Course at UNM using the AGN 201M reactor. In addition, a research proposal was submitted to DOE/NE for collaboration with UNM and Georgia Tech for criticality studies using the UNM AGN reactor.

FUTURE WORK

During the following year the SCALE and MCNP/MCNPX will be used to investigate cross section sensitivity of UREX process and conceptual integral experiments.

Research Staff

Denis Beller, Principal Investigator, Research Professor, Mechanical Engineering Department
Charlotta Sanders, Research Professor, Mechanical Engineering Department

Students

Ryan LeCounte, Lawrence Lakeotes and Timothy Beller, Graduate Students, Mechanical Engineering Department
Tanya Sloma and Sandra De La Cruz, Undergraduate Students, Mechanical Engineering Department

Collaborators

Robert Busch, Professor, Nuclear Engineering Department, University of New Mexico
Richard McKnight, Argonne National Laboratory
Michael Dunn, Nuclear Data Division, Oak Ridge National Laboratory
David Hayes, Los Alamos National Laboratory
Thomas Ward, UNLV Russian Collaboration Science Adviser, TechSource, Inc.