U.S. DEPARTMENT OF ENERGY
INTERNATIONAL NUCLEAR ENERGY RESEARCH INITIATIVE
DOE/Canada

ABSTRACT

Development of Inert Matrix Fuels for Plutonium and Minor Actinide Management in Power Reactors

Principal Investigator (U.S.): M.K. Meyer, Argonne National Laboratory (ANL)

Principal Investigator (Canada): P. Boczar, Atomic Energy Canada Ltd. (AECL)

Collaborators: University of Florida, Los Alamos National Laboratory, Idaho National Engineering and Environmental Laboratory, Brookhaven National Laboratory

Project Number: 2004-002-C

Project Start Date: June 2004

Project End Date: May 2007

There is interest in the U.S. and world-wide in the investigation of IMF (inert matrix fuels) for scenarios involving stabilization or burn down of plutonium in the fleet of existing commercial power reactors. IMF offer the potential advantage for more efficient destruction of plutonium and minor actinides (MA) relative to MOX fuel. Greater efficiency in plutonium reduction results in greater flexibility in managing plutonium inventories and in developing strategies for disposition of MA, as well as a potential for fuel cycle cost savings. Because fabrication of plutonium-bearing (and MA-bearing) fuel is expensive relative to UO_2 in terms of both capital and production, cost benefit can be realized through a reduction in the number of plutonium-bearing elements required for a given burn rate. In addition, the choice of matrix material may be manipulated either to facilitate fuel recycling or to make plutonium recovery extremely difficult. In addition to plutonium/actinide management, an inert matrix fuel having high thermal conductivity may have operational and safety benefits; lower fuel temperatures could be used to increase operating and safety margins, uprate reactor power, or a combination of both.

The CANDU reactor offers flexibility in plutonium management and MA burning by virtue of on-line refueling, a simple bundle design, and good neutron economy. A full core of inert matrix fuel containing either plutonium or a plutonium-actinide mix can be utilized, with plutonium destruction efficiencies greater than 90%, and high (>60%) actinide destruction efficiencies. The Advanced CANDU Reactor (ACR) could allow additional possibilities in the design of an IMF bundle, since the tighter lattice pitch and light-water coolant reduce or eliminate the need to suppress coolant void reactivity, allowing the center region of the bundle to include additional fissile material and to improve actinide burning. The ACR would provide flexibility for management of plutonium and MA from the existing LWR fleet, and would be complementary to the AFCI program in the U.S. Many of the fundamental principles concerning the use of IMF are nearly identical in LWRs and the ACR, including fuel/coolant compatibility, fuel fabrication, and fuel irradiation behavior. In addition, the U.S. and Canada both have interest in development of Generation IV SCWR (supercritical water reactor) technology, to which this fuel type would be applicable for plutonium and MA management. An inert matrix fuel with high thermal conductivity would be particularly beneficial to any SCWR concept. Given these similarities, it is proposed that a joint project be conducted within the framework of a U.S.-Canada INERI project on IMF.

2004-002-C (continued)

Goals for IMF development will be established, from which baseline fuel requirements will be derived. IMF candidates will be assessed against this baseline through scoping analyses of core neutronics, fuel performance and coolant compatibility, and accident analysis. As a result of these initial analyses, IMF candidates will be down-selected for further study. Detailed design studies will be conducted for the down-selected fuel types, resulting in fuel and assembly designs. AECL has previously performed assessments of candidate IMF materials, and has selected SiC as the preferred option. This proposal will focus on SiC and similar high-conductivity, refractory matrix fuels, unless the initial analysis identifies a better candidate for CANDU applications. Representative fuel specimens will be fabricated with the aim of developing techniques suitable for fabrication of irradiation test specimens. Measurement of critical material properties will be conducted, or correlations developed in the absence of data. Irradiation testing of fuel specimens will be conducted to moderate burnup using existing irradiation test designs in ATR (U.S.) and NRU (Canada). Irradiation testing will be followed by post-irradiation examinations using established methods. This data is required to provide proof-of-concept for the selected IMF. Benefits of this work include a significant reduction in the uncertainty regarding the use of IMF in power reactor fuel cycles, and the generation of fuel behavior data required for further testing of IMF concepts in proposed future power reactor tests. This work is performed in the U.S. in conjunction with a similar INERI with the EC, leveraging resources for fabrication, irradiation testing, and postirradiation examination; costs are leveraged in the U.S. by utilization of fabrication, transport, and analysis methods developed as part of the AFCI program, and in particular the LWR-2 irradiation test. Conducting this project under an INERI offers further significant cost benefit through the sharing of AECL and DOE resources to accomplish this work scope.

Due to schedule requirements for fabricating Pu bearing fuels, coordinating potential international shipments, and performing irradiation testing, this work scope stretches over four years. Alternatively, the project could end with PIE start at the end of year three and be subject to renewal or extension. The U.S. portion of this work is currently performed under AFCI work packages A0202J61 and Y0201J21.