DOE-ID NEPA CX DETERMINATION
Idaho National Laboratory

CX Posting No.: DOE-ID-INL-21-160

SECTION A. Project Title: Advanced Handling and Safety Enhancement Studies

SECTION B. Project Description and Purpose:

The Idaho National Laboratory (INL) and the Republic of Korea (ROK) Korea Atomic Energy Research Institute (KAERI) both have active research programs in the utilization of civilian nuclear energy and the nuclear fuel cycle. In this proposed collaboration, INL and KAERI will work together to further understand the voloxidation process with a focus on stabilization of damaged used nuclear fuel.

The proposed study between INL and KAERI is four years in duration and is divided into three phases with an overall emphasis and priority on voloxidation technology. All three phases include a range of activities and each phase has an area of emphasis. The phases overlap each other in duration in order to compress the study schedule. Phase A has a planned duration of two years and is focused on demonstration of voloxidation and stabilization on simulated fuel (simfuel) and development of related processes and hardware. Phase B is concurrent in duration with an emphasis on safeguards analysis and the understanding of material-unaccounted-for during key process steps. Phase C is two years in duration and is focused on validation of the previous phases through demonstrations of voloxidation and stabilization with used nuclear fuel in a hot cell facility.

The proposed four-year joint study focuses on exploring advanced technologies, particularly voloxidation, to eliminate safety concerns regarding used fuel management in highly radioactive environments. The collaborative research includes development of technologies for enhancement of safety during handling of damaged used nuclear fuels. Particular focus will be on process development for the initial step in stabilization of damaged used fuels by using a voloxidation process for oxidative decladding as an alternative to mechanical processes. All work will be performed at the Material and Fuels Complex. Expected facility utilization will include the Hot Fuel Examination Facility (HFEF), the Fuels and Applied Sciences Building (FASB), Analytical Laboratory (AL), Engineering Design Laboratory (EDL), Fuel Manufacturing Facility (FMF) and the Experimental Fuels Facility (EFF).

The following subsections describe the proposed activities in detail.

Phase A: Demonstration of Voloxidation on Simulated Fuel

This task covers the development of key processes for damaged used fuel stabilization. The key processes include the following: (1) fuel material recovery, (2) fabrication of stabilized pellets, and (3) fabrication of fuel rods as a final product.

- Fuel material recovery

For a damaged fuel rod, it is difficult to recover UO_2 pellets using existing mechanical decladding methods, and thus an alternative strategy is desired. Simulated damaged fuel rods will be fabricated using depleted uranium and be used for a fuel material recovery test. The operating principle of the fuel material recovery equipment will be based on voloxidation, or oxidative decladding (500°C, oxidizing atmosphere). This process results in oxidation of UO_2 to U_3O_8. An appropriate vibration method will be considered during thermal treatment for detaching fuel from the cladding. After fuel material recovery, oxidation-reduction treatment of recovered powder will be repeatedly carried out to obtain compactable and sinterable UO_2 powder. Milling of oxidation-reduction treated powder will be an optional step to prepare a more compactable and sinterable powder.

- Fabrication of stabilized pellets

This key process deals with mixing the recovered material with lubricants, pressing the powder mixture to produce green pellets, and sintering the green pellets to fabricate stabilized pellets. The lubricants, compacting pressure, and sintering temperature are major factors affecting stability of the final pellets.

- Fabrication of fuel rods

In this key process, fuel rods will be fabricated with the stabilized pellets. Gas tungsten arc welding (GTAW) will be performed to weld fuel rods. The performance of the fabricated fuel rods will be evaluated by helium or pressure decay leak testing and radiography.

Task A1: Performance evaluation of key processes with simfuel

KAERI will investigate the performance of equipment for the fuel material recovery using simulated damaged fuel rods with a length of 10–20 cm. The fuel material recovery tests with the simulated damaged fuel rods will be carried out with an oxidizing atmosphere at 450–500°C in flowing air. In this step, fuel material recovery efficiency can be estimated by measuring weight before and after oxidation and chemical analysis of cladding residues.

For fabrication of stabilized pellets, the compactable and sinterable UO_2 powder will be prepared by repeating oxidation and reduction. In addition, the uranium powders will be mixed with a lubricant (Acrawax powder), and the mixed powder will be pressed into green pellets. Then, the green pellets will be sintered at about 1700°C in an atmosphere of 4%H_2/Ar. The properties of the stabilized pellets will be evaluated by measuring density, compaction strength, and leachability.

Fuel rod fabrication that includes remote end-cap welding technology using GTAW will be performed by INL. Equipment will be prepared for preliminary tests. The performance of equipment will be evaluated by welding of cladding and end caps. Optimum welding conditions will be determined based on microstructure observations and hardness tests on the weldments as funding allows. The fabrication of simfuel rods of 35 cm (~14 inches) in length and between 0.635 cm (0.25 inches) and 1.27 cm (0.5 inches) in diameter will be targeted. In this step, ceria (CeO_2) or depleted uranium dioxide (DUO_2) pellets will be used as stabilized simfuel pellets and loaded into fresh cladding tubes such as Zircaloy-4 or ZIRLO. Unlike commercial nuclear fuel rod fabrication, the fuel rods for the stabilization process do not need components such as plenum springs and axial blankets. The performance criteria for the fabricated fuel rods will be evaluated by helium or pressure leak testing and radiography.

Task A2: Derivation of improvements of key processes using simfuel

The design for improved remote operability of fuel material recovery and pelletizing equipment will be performed by KAERI. For fuel rod fabrication, the design including improved remote operability will be performed by INL.

Task A3: Optimization of operational conditions for key processes using simfuel

The optimized operating conditions for fuel material recovery and stabilized pellet fabrication will be derived by complementary tests. The performance of these processes and characteristic data for the stabilized pellets will be reported by KAERI. For the fuel rod fabrication process implemented at INL, the optimized operating conditions will be derived by complementary tests at INL. The performance of these processes and characteristic data for the fuel rod fabrication will be reported by INL. These optimized conditions will be applied to the verification tests in Task C2 and C3.

Task A4: Design of key process equipment for hot cell test

In this task, key process equipment (which may include fuel material recovery, stabilized pellet fabrication, and fuel rod fabrication) will be designed in a collaboration between INL and KAERI for hot cell operation.

Task A5: Manufacture of key process equipment for hot cell test

Key process equipment (which may include fuel material recovery, stabilized pellet fabrication, and fuel rod fabrication) for HFEF hot cell operation will be manufactured by INL as funding allows. Existing INL hot cell capabilities will be utilized to the maximum extent possible in lieu of newly manufactured equipment.

Phase B: Safeguards Analysis

The Safeguards-By-Design (SBD) concept recommends preemptive consideration for points or regions for safeguards measurement where access is limited such as in a hot cell. It is necessary to minimize Material Unaccounted For (MUF) during these key processes and to evaluate material balances in bulk handing facilities for safeguards effectiveness.

This task will focus on safeguards analysis for the damaged used fuel stabilization process, especially on MUF characteristics and material balances.

During the damaged fuel stabilization process with simfuel, MUF (hold-up and process losses) will be measured and analyzed to investigate the origin of MUF occurrence. This activity can be performed by associating the simfuel test at KAERI with the hot cell tests at INL.

Based on the analysis of the origins of MUF occurrence, plans for MUF analysis and material balance evaluations in the hot cell operations will be established. Safeguards recommendations for damaged fuel stabilization processes will be derived and these will reflect analysis of the hot cell verification test. The safeguards recommendations will contain (1) methods to reduce MUF including equipment design and process procedures, (2) material balance evaluation techniques, and (3) safeguards measures such as in-cell radiation detectors for hold-up verification.

Task B1: Analysis of MUF origins and establishment of hot cell verification plan

A hot cell verification test plan will be established for MUF analysis and material balance evaluation for the stabilization process taking consideration for hot cell conditions by INL. The plan will include radiation measurement activities with in-cell radiation detectors for hold-up verification.

Task B2: Measurement and analysis of MUF in damaged fuel stabilization

Measurement of MUF (hold-up and process losses) will be conducted during the damaged fuel stabilization process in an INL hot cell. Mass of nuclear material in each unit process will be tracked to determine MUF. Taking samples for destructive analysis (DA) and non-destructive analysis (NDA) can be included for material balance evaluation, as well as in-cell radiation detection of the process equipment to verify hold-up and process losses.

Task B3: Overall evaluation of MUF in damaged fuel stabilization process

Task B3 will be focused on evaluation of MUF characteristics and material balance evaluation from the verification test results for the damaged fuel stabilization process. A final evaluation report by INL will include MUF characteristics, material balance evaluations, and safeguards recommendations on the damaged fuel stabilization in terms of Safeguards-By-Design (SBD).

Phase C: Validation Tests with Used Nuclear Fuel

In this task, using LWR used fuel, stabilized pellets and fuel rods as the final products of a stabilization effort will be fabricated in an INL hot cell. The performance data of at least one of three key processes and the characteristics of any stabilized products will be evaluated.

Task C1: Qualification tests for the manufactured equipment

The qualification tests for key process equipment (which may include fuel material recovery, stabilized pellet fabrication, and fuel rod fabrication) will be carried out at INL to demonstrate fabricated equipment readiness to be operated in a hot cell environment. A management self-assessment (MSA) may be required following the qualification tests if mandated by the nuclear facility.

Task C2: Recovery verification test with used fuel

After completion of the qualification testing and/or MSA, the verification test with the hot cell process equipment will be implemented with used fuel stored at the INL. The fuel material recovery (voloxidation) will be verified using the optimized operational conditions. The fuel material recovery efficiency will be analyzed by measuring weight and chemical analysis of cladding residues.

Task C3: Fabrication of stabilized pellets and fuel rods using spent fuel

This task requires the completion of Task C2 since the product of Task C2 becomes feed material for the fabrication of stabilized pellets. The voloxidation step will be prioritized for design, fabrication, and hot cell testing. If demonstrated, the stability of fabricated pellets will be evaluated by measuring the density of the pellet and the compaction strength at INL. Moreover, the leachability of the fabricated pellet will be measured, and it will be compared to that of used fuel pellets.

If funding allows for fuel rod fabrication, the fuel rod fabrication process will be verified at INL using the stabilized fuel pellets under optimized operating conditions. The prototype fuel rods will be of ~35 cm (~14 inches) in length and between 0.635 cm (0.25 inches) and 1.27 cm (0.5 inches) in diameter. The performance of the fabricated fuel rod will be evaluated by measuring helium or pressure leak rate and radiography, if radiography is feasible based on radiation levels.

Task C4: Evaluation of verification tests and derivation of improvements in damaged fuel stabilization

Based on the results of Task C2 and C3, improvements for the equipment and associated operating conditions will be reported for future use by INL.

At this time the only expected equipment purchases are welders and ancillary hardware for existing furnaces.

SECTION C. Environmental Aspects or Potential Sources of Impact:

Air Emissions

Experiment irradiation and PIE will be performed at the ATR and MFC facilities. Air emissions would include minor amounts of radionuclides and toxic air pollutants. The irradiation in the ATR is not a modification in accordance with Idaho Administrative Procedures Act (IDAPA) 58.01.01.201 and 40 Code of Federal Regulation (CFR) 61 Subpart H. ATR radionuclide emissions are sampled and reported in accordance with Laboratory Wide Procedure (LWP)-8000 and 40 CFR 61 Subpart H.

The irradiated specimens will be delivered to the MFC HFEF for disassembly and then undergo routine PIE before being sent to the AL for analysis. The PIE examination in HFEF and the analysis completed in the Analytical Lab is not a modification in accordance with Idaho Administrative Procedures Act (IDAPA) 58.01.01.201 and 40 Code of Federal Regulation (CFR) 61 Subpart H.

Packaging in HFEF is not a modification in accordance with Idaho Administrative Procedures Act (IDAPA) 58.01.01.201 and 40 Code of Federal Regulation (CFR) 61 Subpart H.

Releases of radioactive airborne contaminants from the proposed action are not expected to increase to the annual dose to the Maximum Exposed Individual (MEI).

Discharging to Surface-, Storm-, or Ground Water

N/A

Disturbing Cultural or Biological Resources

N/A

Generating and Managing Waste

Total project transuranic waste volume is projected to be less than 1 ft3. Experiment disassembly creates relatively small amounts of LLW radioactive waste for disposal. Cutting, slicing, grinding, and polishing activities create small volumes of remote handled LLW. Some industrial waste will be generated during lab studies.

Releasing Contaminants

Although not anticipated, there is a potential for spills when using chemicals.

Using, Reusing, and Conserving Natural Resources

All materials will be reused and recycled where economically practicable. All applicable material will be diverted from disposal in the landfill where conditions allow.

SECTION D. Determine Recommended Level of Environmental Review, Identify Reference(s), and State Justification: Identify the applicable categorical exclusion from 10 Code of Federal Regulation (CFR) 1021, Appendix B, give the appropriate justification, and the approval date.

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For Categorical Exclusions (CXs), the proposed action must not: (1) threaten a violation of applicable statutory, regulatory, or permit requirements for environmental, safety, and health, or similar requirements of Department of Energy (DOE) or Executive Orders; (2) require siting and construction or major expansion of waste storage, disposal, recovery, or treatment or facilities; (3) disturb hazardous substances, pollutants, contaminants, or Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)-excluded petroleum and natural gas products that pre-exist in the environment such that there would be uncontrolled or unpermitted releases; (4) have the potential to cause significant impacts on environmentally sensitive resources (see 10 CFR 1021). In addition, no extraordinary circumstances related to the proposal exist that would affect the significance of the action. In addition, the action is not "connected" to other action actions (40 CFR 1508.25(a)(1) and is not related to other actions with individually insignificant but cumulatively significant impacts (40 CFR 1608.27(b)(7)).

References: 10 CFR 1021, Appendix B to subpart D, items B3.6, "Small-scale research and development, laboratory operations, and pilot projects"

Programmatic Spent Nuclear Fuel Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs Final Environmental Impact Statement and Record of Decision (DOE/EIS-0203, 1995) and supplemental analyses (DOE/EIS-0203-SA-01 and DOE/EIS- 0203-SA-02) and the Amended Record of Decision (1996)

Final Environmental Impact Statement for the Waste Isolation Pilot Plant (DOE/EIS-0026, October 1980) and Final Supplement Environmental Impact Statement for the Waste Isolation Pilot Plant (SEIS-I) (DOE/EIS-0026-FS, January 1990)

Final Waste Management Programmatic Environmental Impact Statement [WM PEIS] (DOE/EIS-0200-F, May 1997) and Waste Isolation Plant Disposal Phase Supplemental EIS (SEIS-II) (DOE/EIS-0026-S-2, September 1997)

Final Site-Wide Environmental Impact Statement for the Continued Operation of the Department of Energy/National Nuclear Security Administration Nevada National Security Site and Off-Site Locations in the State of Nevada (DOE/EIS-0426, December 2014).

Justification: The proposed R&D activities are consistent with CX B3.6 "Siting, construction, modification, operation, and decommissioning of facilities for small-scale research and development projects; conventional laboratory operations (such as preparation of chemical standards and sample analysis); small-scale pilot projects (generally less than 2 years) frequently conducted to verify a concept before demonstration actions, provided that construction or modification would be within or contiguous to a previously disturbed area (where active utilities and currently used roads are readily accessible). Not included in this category are demonstration actions, meaning actions that are undertaken at a scale to show whether a technology would be viable on a larger scale and suitable for commercial deployment."

NEPA coverage for the transportation and disposal of waste to WIPP are found in the Final Waste Management Programmatic Environmental Impact Statement [WM PEIS] (DOE/EIS-0200-F, May 1997) and Waste Isolation Plant Disposal Phase Supplemental EIS (SEIS-II) (DOE/EIS-0026-S-2, Sept. 1997), respectively. The 1990 ROD also stated that a more detailed analysis of the impacts of processing and handling TRU waste at the generator-storage facilities would be conducted. The Department has analyzed TRU waste management activities in the Final Waste Management Programmatic Environmental Impact Statement (WM PEIS) (DOE /EIS-200-F, May 1997). The WM PEIS analyzes environmental impacts at the potential locations of treatment and storage sites for TRU waste; SEIS-II addresses impacts associated with alternative treatment methods, the disposal of TRU waste at WIPP and alternatives to that disposal, and the transportation to WIPP.

The environmental impacts of transferring LLW from the INL Site to the Nevada National Security Site were analyzed in the 2014 Final Site-Wide Environmental Impact Statement for the Continued Operation of the Department of Energy/National Nuclear Security Administration Nevada National Security Site and Off-Site Locations in the State of Nevada (DOE/EIS-0426) and DOE's Waste Management Programmatic EIS (DOE/EIS-200). The fourth Record of Decision (ROD) (65 FR 10061, February 25, 2000) for DOE's Waste Management Programmatic EIS established the Nevada National Security Site as one of two regional LLW and MLLW disposal sites.

Is the project funded by the American Recovery and Reinvestment Act of 2009 (Recovery Act) ☐ Yes ☒ No

Approved by Jason L. Anderson, DOE-ID NEPA Compliance Officer on: 12/15/2021