DOE-ID NEPA CX DETERMINATION
Idaho National Laboratory

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SECTION A. Project Title: Pyroprocessing

SECTION B. Project Description and Purpose:

The primary objective of the research and development (R&D) activities described in this Environmental Compliance Permit (ECP) is to obtain fundamental data to support the development of molten salt systems, electrochemical separations, waste form production and development, and other technology development associated with missions and programs at Idaho National Laboratory (INL). These R&D activities are intended to explore and discover original and enhanced methods, techniques, or materials. The following discussion describes this work:

Molten Salt Systems, Pyroprocessing, and Electrochemical Separations

The objective of this program is to obtain fundamental data to support the development of molten salt systems, electrochemical separations, waste form production and development, and other technology development with missions and programs at the Idaho National Laboratory (INL) Materials and Fuels Complex (MFC).

The Pyrochemistry and Molten Salt Systems department performs research and development activities with the specific goals of:

1. Determining fundamental physical and chemical properties of molten salt systems
2. Developing and implementing electrochemical separations
3. Performing chemical and physical measurements of various systems such as: molten salts, metals, ceramics, glasses, and other engineered systems.
4. Designing and conducting experiments on above mentioned systems.
5. Fabricating small-scale test specimens for experimental research.
6. Developing materials, sensors, and instrumentations for molten salt systems.

Research toward the stated objectives is performed in the Hot Fuel Examination Facility (HFEF), and the Water Chemistry Laboratory (MFC-768B) and Engineering Development Laboratory (EDL) at MFC and in the two labs located at the Energy Innovation Laboratory (EIL): Lab B208 and Lab C213, using non-radioactive materials, and in Fuel Conditioning Facility (FCF) for pyrochemistry experiments that involves radioactive materials such as depleted uranium chloride salts. These laboratories or facilities contain chemicals, equipment, and tools used in research activities such as sample preparation, powder preparation, electrochemical experiments, sample characterization, thermal property determination, materials synthesis and fabrication, and general chemistry methods. Some chemicals are sensitive to moisture and oxygen and are handled in inert (argon) atmosphere glove boxes, and all are listed in Form 420.07 for LI-654 and LI-784.

Experimental samples will be prepared, processed, and characterized using equipment that is standard for the industry. This includes using instruments such as an autosiever, balance, cameras, differential scanning calorimeter (DSC), gloveboxes, hand tools, high or slow speed saws, high-temperature furnace, hot plate, impact mortar and pestle, inductively coupled plasma mass spectrometry (ICP-MS), moisture analyzer, laboratory glassware, laboratory oven, laboratory stirrer, micro mill grinder, microscopes, microwave, pH/ion selective electrode meter, potentiostat, pycnometer, sonic sifter, spectroscopic analysis, thermogravimetric analyzer (TGA), vacuum pump, and other similar equipment.

The physical size of the laboratory limits the amount of material that can be used for any specific experiment. Typical samples are under 5 kg for powders or solids. Liquid samples are also small and are typically one liter or less. Most characterization activities utilize smaller samples up to 200 g or 200 ml. Some samples will require heating, and furnace temperatures are typically between 500-650°C but up to 1200°C. Materials are procured, used, and stored in the laboratory. These materials include acids, powders, metals, salts, gases, and hazardous materials (i.e., barium chloride, cadmium, etc.). A glovebox with HEPA filtered exhaust or fume hood with HEPA filtered exhaust is utilized, as necessary. Typically, the process uses simple mixtures to focus on the partitioning of a specific compound. In other experiments, the process uses complex mixtures to imitate conditions expected during treatment of spent nuclear fuel. All materials used in the laboratory are non-radioactive and commercially available. Samples in secondary containers are labeled. Samples will be discarded when no longer needed.

An off-the-shelf lab-scale glass and ceramic melter is in the walk-in-hood in EIL C-213. Operation involves the fabrication of a small-scale glass and ceramic samples for testing and characterization. The materials used in fabrication include $BSiO_4$ and $FePO_4$ glasses, and SiO_4, AlO_4, ZrO_2, TiO_2 ceramics. No hazardous constituents will be included in the formulations and off-gas from the fabrication will include water vapor and the above-mentioned constituents. Closed chiller or house water will be running to and from the furnace for cooling. Different atmosphere hookups will be utilized for furnace operations. These hookups are located with the walk-in hood. The furnace utilizes the ventilation already present within the hood.

A water hydrogen torch is a benchtop system that splits an electrolyte solution into hydrogen and oxygen atoms. The torch is used to flame seal quartz tubes and capillaries loaded with salt samples. Operation will include igniting the flame, sealing the tube containing salt and argon, and maintaining the torch including refilling methyl alcohol, flux, and electrolyte solutions. The salts used will include chlorides and fluorides of Li, K, Mg, Zn, Na, Cs, Ca, etc. The sealed tubes may be transferred to a gamma irradiator located at the EIL facility for irradiation of salt samples. The sealed tubes/capillaries will also be shipped to the collaborating labs for characterization including Brookhaven National Lab (BNL), Oak Ridge National Lab (ORNL), and the University of Notre Dame (UND). Once the sealed tubes are shipped outside the INL, they will not be returned to INL. The receiving site will be responsible for disposal. UND manages waste in accordance with Hazardous Waste Procedure ENV02.

Flowing salt properties will be investigated using a natural circulation molten-salt flow loop equipped with instrumentation located within the C-213 glovebox. Specifically, the molten-salt flow loop will be observed to analyze the molten salt flow characteristics (thermal gradients and flow dynamics). The corrosion samples of various metals and alloys will be introduced in the loop through the surge tank. Salt samples will be collected before, during, and after the corrosion tests to monitor the metal alloy corrosion. Various techniques (i.e., ICP analysis, spectroscopy techniques etc.) will be used to analyze the salt samples collected during and after the measurement; and surface characterization techniques (SEM, FIB, optical microscopy etc.) will be used for analysis of metal/alloy surface after the corrosion test. In addition to the corrosion samples, a specimen of stainless steel (SS) 316 pipe will be characterized after the loop operation to evaluate the corrosion during the operation. For salt and metal alloy characterization, the samples will be sent to various facilities including INL Research Center (IRC), Center for Advanced Energy Studies (CAES), and Irradiated Materials Characterization Laboratory (IMCL) at MFC. For some analysis techniques that might not be available at INL sites, X-ray Photoelectron Spectroscopy (XPS) for example, the samples can be shipped to university collaborators listed in this environmental compliance permit (ECP).

Research on molten salt chemistry and corrosion control of chloride salt salts systems will be performed in Engineering Development Laboratory (EDL) at MFC and B208 in EIL, using non-radioactive salts such as NaCl-$MgCl_2$, and in Room 26 of Fuel Conditioning Facility (FCF), using salt mixtures such as NaCl-UCl_3 that contain uranium trichloride (UCl_3) salt. This research will address the knowledge gap in understanding materials corrosion mechanism and salt chemistry control, provide guidance on materials selection for development of molten salt reactors, and develop methodologies for estimating predicted service lifetime of materials based on salt chemistry. Experimental work includes systematically studying the corrosion performance and mechanisms in chloride salts of two typical alloys 316H and Alloy 617 and some binary model alloys, effects of impurities in the salts on corrosion, and salt chemistry control strategies for minimizing the materials corrosion. Typical non-radioactive salts for this study in EDL include NaCl, $MgCl_2$, KCl, LiCl, NH_4Cl, etc. The experiments in Room 26 will mainly use depleted uranium and depleted uranium chloride salts, and the corrosion test temperatures are generally in the range of 600 to 800°C.

Research and development of high entropy alloys (HEAs) for extreme environments will be carried out in Engineering Development Laboratory (EDL). In this work, the HEAs will be fabricated by electro-deoxidation process of oxides in molten salts, which electrolytically reduces a metal oxide to metal. The experimental work in EDL mainly consists of mixing and sintering metal oxide feedstock with HEA compositions (for example TiO_2-Al_2O_3-Nb_2O_5-Cr_2O_3-Ta_2O_5) and electro-deoxidation in molten salts. During the electro-deoxidation process, the oxygen in the sintered oxide pellets (which is cathode) will be removed and oxygen gas is formed in the anode. Typical salts for this study include CaCl2, NaCl, LiCl, etc., and the temperature of the molten salts is generally in the range of 650 to 900°C.

The Engineering Development Laboratory (EDL) at MFC will also support projects related to pyrochemical R&D. It is desired to design equipment (e.g., furnace systems) and develop techniques to separate salt and metal products and then to cast them into usable forms. A small furnace is installed in the MBRaun glovebox in the EIL. The furnace is small enough to fit into the transfer chamber and will support the project adequately. It will also be necessary to produce surrogate dendrites (copper) for feed into these tests using molten salt furnaces. While the research is ultimately interested in application to irradiated uranium, early development phases begin with non-radioactive surrogate metals such as stainless steel or copper and salts containing only stable isotopes of fission product elements. Development activities will involve the melting materials in one or more high temperature furnaces and may involve batches up to 15 kg of LiCl-KCL salts and the melting of up to 20 kg of stainless steel or copper. Some tests will occur inside inert-atmosphere gloveboxes (any tests including salt, which is hygroscopic) and some furnaces set up on worktables. In some tests, up to 1 kg of zinc may be used as a non-hazardous surrogate for cadmium. Other materials in the hot zones of these furnaces will include aluminum oxide-based thermal insulations, zirconium dioxide, graphite, steel, stainless steel, and molybdenum.

Based on the analysis in the 2007 *Final Environmental Assessment for the Consolidation and Expansion of the Idaho National Laboratory Research and Development at a Science and Technology Campus* (DOE/EA-1555) and associated Finding of No Significant Impact (FONSI), DOE consolidated and expanded R&D capabilities for INL at the REC in Idaho Falls. Only programs having minimal potential hazards to workers or the public are performed in Idaho Falls at the REC. INL uses the following limits to define “minimal potential hazard” activities:

1. The dose to the public limit in DOE Order 458.1 is 100 mrem/yr from all sources (direct radiation, air inhalation, food and water consumption, etc.) (See 458.1 CRD 2.b.(1).(a)). Exceeding 25 mrem/year requires calculating dose to the extremities and lenses of the eyes (2.e.(1).(a).3). This 25 mrem/yr limit is also the determinant for including non-DOE sources in environmental ALARA dose assessment to the maximally exposed individual (MEI). Projects approved under this ECP must not exceed this 25 mrem/year limit.
2. For radiological air emissions, the unmitigated radiological emissions from each source or emissions point (i.e., each individual emissions point) must be below 0.1 mrem/yr as described in 40 CFR 61, Subpart H. Projects having unmitigated emissions that exceed the 0.1 mrem/yr limit are required to install stack monitors (40 CFR 61.93.(e). For projects having mitigated emissions resulting in a dose to the public that exceeds 0.1 mrem/yr, an Approval to Construct from EPA must be approved prior to commencement of the project. Projects approved under this ECP must not exceed the 0.1 mrem/yr limit for air emissions.
3. Radioactive material inventory must be below the 40 CFR 302.4 Appendix B reportable quantity levels for LTHC3 facilities where such work is authorized in Tenant Use Agreements (TUAs). For buildings leased under “start clean/stay clean” criteria, no unsealed radiological materials are allowed, except for minor quantities authorized in the Energy Innovation Laboratory (EIL).
4. The dose to public for each building is limited to less than 0.1 mrem/yr and the combined dose to the public from all buildings at the IRC campus must be less than 10 mrem/yr, and the combined dose to the public from the EIL, EROB, and the UB buildings must be less than 10 mrem/yr.
5. Research not involving higher risk organism or materials which require control measures at bio-hazard safety level three (BSL-3) or higher (neither of which are currently allowed at INL). See LWP-14621, Laboratory Biological Experimentation Safety.

Sampling may be periodically performed for information and evaluation purposes on materials. This may include sending samples to the MFC Analytical Laboratory (AL) for detailed analysis.

This project also supports development efforts to increase the technical readiness level of molten salt reactors (MSRs) and builds and tests a molten salt natural circulation flow loop to test the corrosion phenomena, thermal-hydraulic behavior, and redox chemistry control on flowing molten salt systems with temperature differentials. A flow loop will be procured and installed in MFC's EDL building

Chemicals used for this project will include ethanol, isopropyl, and/or acetone for cleaning of parts during assembly. Potential salts used during flow loop operation consist of alkali, alkaline earth, lanthanide, and transition metal chloride of fluoride salts. (LiCl, NaCl, KCl, $MgCl_2$, $CaCl_2$, $CrCl_2$, $CRCl_3$, $MnCl_2$, $FeCl_2$, $FeCl_3$, $CoCl_2$, $NiCl_2$, $LaCl_3$, $CeCl_3$, $PrCl_3$, $NdCl_3$, $SmCl_3$, $EuCl_3$, $GdCl_3$, $TbCl_3$, $DyCl_3$, $HoCl_3$, $ErCl_3$, $TmCl_3$, $YbCl_3$, $LuCl_3$, LiF, NaF, KF). The total mass of salt waste will be approximately 10-20 kg, consisting primarily of alkali or alkaline earth chlorides or fluorides, with trace amounts of other salts listed above. Argon gas will be used to maintain an inert atmosphere inside the flow loop and will be vented to the atmosphere. No emissions of hazardous air pollutants are anticipated. No radionuclides will be used during this project activity.

The equipment to be purchased and used to support this effort is anticipated to be electrical furnaces, heat trace, thermocouples, control cabinets and associated electronics, silicone gaskets and O-rings, an argon cover gas system (including iron/nickel-based alloy or copper piping, pipe fittings, valves, solenoids, oxygen and moisture sensors, gas purification beds, circulation blowers, control electronics), flow loop assembly (including a welded assembly of iron/nickel based structural alloy tubing, pipes, fittings, flanges, valves, plates, and machined parts), electrode assemblies (including ceramic insulating tubes made from $Al2O_3$, Mg2O, CaO-SiO_2, or similar electrodes made from Ni, C, Pt, Ir, Ru, Ag, Mg, Ta, W, Mo, or Zr), corrosion coupons made from iron/nickel based structural alloys, corrosion sample retrieval assemblies (including iron/nickel-based structural alloy tubes, rods, bolts, flanges, and rare-earth magnets), ceramic thermal insulation made from calcium silicate or similar engineered ceramic materials, and an aluminum support frame.

Facility modifications may include electrical upgrades to supply power to the system, argon gas supply tie-ins, and exhaust routing.

HiFunda, in partnership with INL, will design, develop, and demonstrate a high-temperature reference electrodes (HTRE) that uses a near-net shape fluoride ion transport membrane or a controlled porosity membrane with seals engineered for this demanding high-temperature molten salt application. The challenges associated with improving reference electrodes for molten salts applications are 1) to select the membrane and container materials that are chemically and mechanically stable in higher temperature fluoride-based molten salts, and 2) to develop robust HTRE and seal designs that are chemically compatible, can withstand thermal cycling, are cost effective, and are manufacturable (designed for manufacturing and assembly).

Project experiments will be performed inside the argon-atmosphere gloveboxes in MFC-789, a non-radiological facility. No gaseous emissions will be generated during the experiments.

Joint Fuel Cycle Studies (JFCS)

INL is performing an ongoing kilogram-scale test of electrochemical recycling of used nuclear fuel, known as the Integrated Recycling Test (IRT), at MFC to study flowsheet options and the technical and economic feasibility and nonproliferation acceptability of electrochemical recycling of commercial light water reactor (LWR) fuel. The JFCS program includes fuel Procurement, the IRT, critical gap research and development (R&D), and the fuel rodlet fabrication and irradiation.

As part of the JFCS, automation R&D will be performed. This research includes working with robotic systems outside of hot cells and future work on developing radiation-hardened robotic systems. Research involves developing interface requirements with external equipment, using with systems with surrogate materials (sand, ball bearings, dowel pins, metal rods, and metal strips), and using non-powered hand tools.

Fuel Procurement

The JFCS program plans to transfer 4 g of curium-244 oxide from the Fuel Manufacturing Facility (FMF) to the Hot Fuels Examination Facility (HFEF). The material was pure Cm-244 oxide but has decayed and is now 75% Pu-240. A source term document, ECAR-4277, has been issued which describes the material. Due to nuclear safety constraints at HFEF, the powder will be bound in LiCl salt during the breakout process in the Transuranic Breakout Glovebox at FMF. The material will then be loaded into four separate GSAD containers and shipped in the 6M drum to HFEF. At HFEF, the material will be mixed with the spent fuel being received from the Idaho Nuclear Technology and Engineering Center (INTEC) to simulate the presence of Cm-244 seen in high burnup nuclear fuels. The materials will then be processed together through the JFCS recycling equipment in HFEF.

Material will be shipped from INTEC to MFC using the existing 6M package/fissionable material payload/container. The 6M package is a non-DOT approved container designed for transferring radioactive and/or fissionable materials. There are two 6M package sizes that could be used: 55 gallon and 110 gallon. Only one loaded 6M package payload is allowed during each shipment. The payload materials are identified as:

- Fissionable materials (with trace quantities of other radioactive materials)
- Curium

The shipment includes Cm-244, Cm-246, Pu-240, Pu-242, U-238, U-236, Th-234, and Th-232 in quantities less than or equal to those listed in the table below:

Table 1. Radionuclides in proposed shipment

Radionuclide	Moles	Grams
Cm-246	2.02E-03	4.97E-01
Cm-244	1.03E-02	2.53E+00
Pu-242	1.07E-05	2.58E-03

Pu-240	3.06E-02	7.33E+00
U-238	3.50E-10	8.33E-08
U-236	6.87E-05	1.62E-02
Th-234		

The IRT process requires about 45 kilograms of used high-burnup LWR fuel or use as feedstock. This feedstock is not available at INL or other sites in the DOE complex. The original CRADA for the IRT proposed to use 25 individual pressurized water reactor (PWR) rods from the Byron Nuclear Generating Station in Illinois shipped to INL in a Nuclear Assurance Corporation legal-weight truck (NAC-LWT) cask and stored in the Hot Fuels Examination Facility (HFEF) hot cell.

In April 1995, DOE completed the *Programmatic Spent Nuclear Fuel Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs Final Environmental Impact Statement* (DOE/EIS-0203) (hereafter, 1995 EIS) (DOE 1995a). The 1995 EIS contains an analysis of the potential environmental impacts associated with managing DOE's complex-wide Spent Nuclear Fuel (SNF) Program from 1995 until 2035 and includes an analysis of a broad spectrum of fuel element designs. In the June 1995 Record of Decision (ROD) for the 1995 PEIS, DOE selected Alternative 4a (Regionalization by Fuel Type) and decided to transport 165 Metric Tons of Heavy Metal (MTHM) in 1,940 planned shipments of SNF (including 575 Navy shipments) to the INL Site through the year 2035 [60 Federal Register (FR) 28680, June 1, 1995]. DOE issued an amended ROD in June 1996 for the 1995 PEIS, which lowered the number of planned shipments of SNF to the INL Site to 1,133 (575 shipments for the Navy and 558 planned shipments for DOE) (61 FR 9441, March 8, 1996).

At present, INL cannot accept irradiated fuel subject to the Idaho Settlement Agreement. It is anticipated that noncompliance issues will be resolved before this project begins, and INL will be able to accept the irradiated materials. Prior to receiving the Byron shipment, DOE will complete a supplemental analysis (SA) to the *Programmatic Spent Nuclear Fuel Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs Final Environmental Impact Statement* (DOE/EIS-0203). If INL cannot accept the irradiated materials, the JFCS program proposes to complete project activities using about 35 kg of DOE-owned LWR fuel in dry storage at the Irradiated Fuel Storage Facility at Chemical Processing Plant (CPP) building 603 (CPP-603). The LWR fuel is low to intermediate burnup and does not meet the full requirements of the JFCS collaboration. Fluor Idaho will retrieve the fuel from storage and ship the material to MFC in the Nuclear Assurance Corporation (NAC) legal-weight truck (LWT) (NAC-LWT) cask using the Multi-purpose Haul Road on the INL Site. Shipments will not use public transportation routes. Table 2 describes the fuels proposed for shipment from CPP-603 to MFC.

Table 2. Summary of interim LWR fuel from CPP-603.

Current Container ID	Old Container ID	LWR Fuel Description	Burnup	Discharge Date	Enrichment
CAN-GSF-106-23	A-7	7 Saxton MAPI fuel rods	5 GWd/MT	1972	5.7%
		3 Saxton fuel rods	16.8, 15.6, 10.4 GWd/MT	1972	12.5%
CAN-GSF-106-19	I-1	16 Dresden rod sections from approx. 5 fuel rods	28 GWd/MT	1994	3.1%
CAN-GSF-107-29	I-8	3 Saxton MAPI fuel rods	5 GWd/MT	1972	5.7%
		2 Saxton fuel rods	16.0, 18.5 GWd/MT	1972	12.5%
CAN-GSF-107-21	J-4	15 Dresden rod sections from approx. 5 fuel rods	28 GWd/MT	1994	3.1%
CAGSF-106-13	J-7	4 Saxton fuel rods	16.7, 17.4, 16.7, 17.6 GWd/MT	1972	12.5%
CAN-GSF-107-03	K-4	2 HB Robinson fuel rods sectioned	28 GWd/MT	1974	3.1%
		2 Peach Bottom fuel rods sectioned	11.9 GWd/MT	1976	2.5%

Integrated Recycling Test

Modular Workstations

Modular workstations in the HFEF Argon Cell support equipment for the IRT. Two large workstations and a smaller intermediate table furnish operating space and power and instrumentation connections for replaceable equipment. Bins below the workstation operating surfaces supply storage for equipment not in use. Each workstation includes one integrated balance for mass tracking purposes.

Fuel Decladding Equipment

INL processes used nuclear fuel rods as feedstock for the IRT. Processing requires used nuclear fuel rod storage, handling, sectioning, and de-cladding. The de-clad fuel is sieved to remove fines, and some fines are manipulated to demonstrate and test processing methods. Some higher burnup cladding sections will be processed to demonstrate methods to reduce fuel holdup.

Oxide Reduction System

The project electrochemically reduces de-clad used fuel to metallic form in the oxide reduction system. The reduction process tests the ‘universal’ basket concept, i.e., a loaded basket is processed through the oxide reduction, distillation, and electrorefining systems without unloading. The reduction system is designed to allow testing of scalability features such as multiple electrodes and variations in basket thickness or electrode spacing. The anode system has the flexibility to test materials, geometries, immersion depths, and off-gas capture settings. An oxide reduction system has been designed, constructed, tested, and installed, and operates as a part of the (IRT).

Electrorefining System

The project electro-refines processed fuel from the oxide reduction system to recover purified low-enriched uranium (LEU). Transuranic elements accumulate in the electrorefining salt, and a liquid cadmium cathode (LCC) extracts a uranium/transuranic/rare earth product to acquire feedstock to manufacture fuel rodlets. The electrorefining vessel also allows the project to test features important to scalability.

Distillation Systems

After oxide reduction and electrorefining, INL separates salts from metallic products and cadmium and salt from the uranium/transuranic/rare earth products via vacuum distillation. HFEF has two remote distillation systems to maintain the IRT processing schedule.

Sampling/Casting Furnace

Casting transuranic fuel slugs is an objective of the IRT, and a variety of metallic products require sampling. Material losses, remote reliability, and scalability are important for long-term success of electrochemical recycling processes. The project samples and casts fuels in HFEF and fabricates fuel in a glovebox at the Fuel Manufacturing Facility (FMF).

Critical Gap Research and Development

Head End Processes

The method for processing used fuel is important to subsequent processes. Critical gap studies evaluate and select fuel preparation methods used in the IRT and include design development, testing, cutting methods, and handling fuel pieces. Potential measurement methods to determine input accountancy are important to determine nonproliferation acceptability. R&D includes additional studies for processing fuel fines, such as agglomeration or sintering, or the examination of off gasses produced from processing. Prior research indicates high burnup fuels may display increasing fuel hold up in the cladding. Proposed research also evaluates methods to reduce fuel hold-up.

Current technology for electrolytic reduction utilizes platinum anodes, but other materials, such as iridium or conductive ceramics, have the potential to deliver cost and durability advantages. Anode material testing focuses on the performance of iridium electrodes in surrogate salt systems.

Experiments support system design and troubleshoot oxide reduction system operations in the IRT. This research evaluates construction materials and system behavior and characteristics during different operating scenarios. Testing uses non-radioactive surrogates and depleted uranium (DU).

Electrorefining & Liquid Cadmium Cathode Operations

This activity tests a scaled-up prototype electrorefining system with molten salt and uranium dendrites. This allows challenges and performance limitations to be identified before remote equipment fabrication and installation and allows troubleshooting of remote process operations. Testing includes evaluating the impact of process parameters, system design, and construction materials. Testing uses non-radioactive surrogates and DU.

The LCC approach recovers a product combined of uranium, transuranic, and residual rare earth materials during the IRT. Ongoing studies explore the impact of process parameters, system design, and construction materials. Studies use non-radioactive surrogates, DU, and transuranic (TRU) elements and utilize equipment and materials already on-Site at MFC. Studies also analyze anode residue.

Product Conditioning

In the recovery of the uranium/TRU/rare earth product via LCC technology, the rare earth contamination may be higher than the desired concentration in the metal fuel. Ongoing, jointly planned experiments explore the feasibility of ways to reduce the concentration of rare earths in uranium/TRU/rare earth products. Studies use non-radioactive surrogates, depleted uranium, and TRU elements and utilize equipment and materials at MFC.

The IRT requires four distillation operations. Distillation system design issues require confirmation, including evaluating the performance of stainless steel for the pressure boundary for distillation up to 1200°C. Ongoing investigations confirm the design and materials for the distillation system and test the performance of advanced crucible materials for distillation operations. Initial screening uses uranium, and final testing uses uranium/transuranic/rare earth products.

A high-temperature distillation furnace separates salt and consolidates the dendritic uranium product into an ingot. Initial scoping experiments have been successful at separating salt and metals at atmospheric pressure by a porous bed, with a short residence time. These characteristics and system compactness have the potential to improve product purity, process monitoring, and safeguards opportunities. These tests use non-radioactive surrogates and DU.

Fuel Fabrication

Engineering-scale fuel fabrication is critical to commercialization of electrochemical recycling. Weld inspection is a challenging technology that must be perfected for remote application. The project tests ultrasonic and laser weld inspection systems and evaluates alternative approaches to qualify the welding process based on statistical analysis of process parameters. These tests utilize only non-radioactive materials.

The properties of some metal fuel alloys need to be characterized. The project performs fuel alloy fabrication and analysis in the MFC Casting Laboratory. Casting studies use several fuel variations to evaluate potential products in the IRT. These studies use non-radioactive surrogates, DU, and TRU elements and use equipment and materials at MFC. Cast fuel sample characterization methods include dilatometry, differential scanning calorimetry, and laser flash thermal diffusivity.

Studies also evaluate in-reactor cladding performance. Metal fuel integrity could be limited by the interaction of fuel constituents and fission products with the cladding, commonly described as fuel cladding chemical interaction (FCCI). Studies are needed to verify the performance of barrier materials that mitigate FCC, especially in the case of TRU and rare-earth-bearing metal fuel. The project produces, irradiates, and evaluates barrier cladding samples.

Fundamental Properties and Waste Forms

Activities to increase fundamental knowledge of molten salt systems include studies to evaluate 1) electrochemical or thermophysical characteristics of molten solutions and 2) technology to monitor process conditions inside molten salt electrochemical systems. These studies use non-radioactive surrogates, DU, and TRU elements and equipment and materials at MFC. Identification and demonstration of waste forms is critical to the feasibility of electrochemical recycling. The IRT evaluates the most feasible and cost-effective options for fission product concentration and immobilization from the electrochemical recycling of used LWR fuel. These evaluations involve waste experts from INL, KAERI, Pacific Northwest National Laboratory (PNNL), and Argonne National Laboratory (ANL). Once processes have been defined, laboratory-scale waste forms may be fabricated, if necessary, from fission product streams for characterization and testing. Fission product concentration and waste form processes would be optimized for application to the IRT.

In the IRT, some iodine enters the oxide reduction vessel with used fuel. Experiments have shown that I_2 has the potential to be released with O_2 during the reduction process. Improved understanding of how to capture this iodine, either as a gas or by capture within the molten salt, is critical to understanding the mass balance of fission product in a real process. Studies evaluate methods to better understand I_2 release during the reduction process and quantitatively capture the iodine from the off-gas stream in a surrogate salt system. The project also examines methods to extract iodine and tellurium from the molten salt. The feasibility of getter materials to selectively absorb reactive fission products will be tested in a surrogate salt system.

Argonne National Laboratory Activities

Argonne National Laboratory (ANL) in Illinois performs supporting research on fundamental properties and waste forms and head-end processes, with similar work scope to that described above. These activities use only non-radioactive surrogates, DU or very limited amounts of TRU materials in authorized radiological facilities at ANL. These activities will be conducted with materials already located at ANL and will not involve shipment of any materials between ANL and INL.

Fuel Rodlet Fabrication and Irradiation

Fuel rodlet fabrication and irradiation activities focus on the production of one or more transuranic-bearing fuel rodlets, irradiation in the Advanced Test Reactor (ATR), and post-irradiation examination (PIE) at MFC. After PIE at INL, the irradiated sample segments and PIE remnants would be stored with other similar DOE-owned irradiated materials and experiments at MFC, most likely in HFEF or the Radioactive Scrap and Waste Facility (RSWF) in accordance with DOE's *Programmatic Spent Nuclear Fuel (SNF) Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs Final Environmental Impact Statement (FEIS) and ROD* (DOE/EIS-0203, 1995) and supplemental analyses (DOE/EIS-0203-SA-01 and DOE/EIS-0203-SA-02) and the Amended Record of Decision (February 1996). Ultimate disposal of the irradiated sample segments and PIE remnants would be along with similar DOE-owned irradiated materials and experiments currently at MFC.

Packaging, repackaging, transportation, receiving, and storing used nuclear fuel and research and development for used nuclear fuel management is within the scope of DOE's *Programmatic Spent Nuclear Fuel (SNF) 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 (February 1996). The analysis includes those impacts related to transportation to, storage of, and research and development related to used nuclear fuel at the INL (see Tables 3.1 of the SNF Record of Decision (May 30, 1995) and Table 1.1 of the Amended Record of Decision [February 1996].

To complete proposed work activities, it is necessary for the project to use the HFEF hot cell which contains both defense and nondefense related materials and contamination. Project materials will come into contact with defense related materials. It is impractical to clean out defense related contamination, and therefore, waste associated with project activities is eligible for disposal at the Waste Isolation Pilot Plant (WIPP). National Environmental Policy Act (NEPA) coverage for the transportation and disposal of waste to WIPP are found in *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 transuranic (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.

There is the potential to generate low level waste (LLW). 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.

The impacts of transporting spent fuel, special nuclear materials, and research fuels between MFC and other INL Site facilities using the Multi-Purpose Haul Road were analyzed Final Environmental Assessment for the Multipurpose Haul Road Within the Idaho National Laboratory Site (DOE/EA-1772).

The JFCS project involves research and development work to test and refine various aspects of separations process activities. Research from the project would be used to support the development of processes to separate and recover materials such as plutonium and uranium. The project does not call for the separation of plutonium or uranium isotopes for production purposes. Because the project is for research and development of separations processes rather than for production purposes, the project does not constitute reprocessing.

Project personnel verify with the program environmental lead (PEL) that the scope, environmental aspects, and work activities are bounded by the environmental impacts analysis of this environmental checklist (EC), and revise this EC, as necessary.

SECTION C. Environmental Aspects or Potential Sources of Impact:

Air Emissions

The proposed action has the potential to generate radiological and chemical emissions. Air emissions are anticipated to be minor, and concentrations are not anticipated to exceed the current monitored/calculated air emissions from these facilities.

The proposed activities could result in an increase in radioactive air emissions from the FCF main stack. The INL Site FEC-PTC (PER-152) must be revised or an APAD must be completed to determine if this modification will require an approval to construct as defined in 40 CFR 61.96 or if PER-152 will need to be revised. All radiological emissions from the FCF are passed through two stages of HEPA filters prior to being emitted to the atmosphere through the MFC Main Stack which is equipped with a continuous stack monitoring system.

The ATR irradiation activities are not modifications 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. All experiments will be evaluated by Environmental Support and Services staff. All radionuclide release data (isotope specific in curies) directly associated with this proposal will be calculated and provided to the Environmental Support organization.

The irradiated specimens will be delivered to the MFC HFEF for disassembly and then undergo routine PIE at (Analytical Laboratory, EML, and IMCL). All radionuclide release data at HFEF will be recorded as part of the HFEF continuous stack monitor. Emissions from the PIE examination at Analytical Laboratory, EML, and IMCL would be tracked and in accordance with 40 CFR 61, Subpart H. These activities are considered routine and 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.

In 2019, the effective dose equivalent to the offsite maximally exposed individual (MEI) from all operations at the INL Site was calculated as 5.59 E-02 mrem/yr, which is 0.56% of the 10-mrem/yr federal standard and was calculated using all sources that emitted radionuclides to the environment from the INL site. The emissions are bounded by the analysis in the 1995 EIS, which estimated the annual cumulative doses to the maximally exposed worker, offsite maximally exposed individual (MEI), and the collective population from DOE's decision to implement the preferred alternative (DOE/EIS-0203). The potential air emissions and human health impacts associated with the proposed action would be smaller than and are bounded by the impacts presented in the 1995 EIS by the impacts presented in the 1995 PEIS.

Discharging to Surface-, Storm-, or Ground Water

N/A

Disturbing Cultural or Biological Resources

Modifications to buildings proposed modifications to facilities eligible for nomination to the National Register of Historic Places (e.g., ATR, EML, FASB, FCF, HFEF) has the potential to impact historic resources. Alterations to these facilities requires a review by the Cultural Resource Management Office (CRMO).

Generating and Managing Waste

Project activities have the potential to generate remote-handled (RH) low-level waste, RH transuranic waste, and miscellaneous hazardous waste. Total project waste volume from this research and development is projected to be less than 1 m3. Waste Generator Services (WGS) staff would be consulted for characterization and disposition pathways determination prior to generating waste.

Releasing Contaminants

When chemicals are used during the project there is the potential for spills that could impact the environment (air, water, and soil)

Using, Reusing, and Conserving Natural Resources

All materials will be reused and recycled where economically practicable. All applicable waste 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.

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 Assessment for the Consolidation and Expansion of the Idaho National Laboratory Research and Development at a Science and Technology Campus (DOE/EA-1555, March 2007)

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).

Final Environmental Assessment for the Multipurpose Haul Road Within the Idaho National Laboratory Site (DOE/EA-1772, August 2010)

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.

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

Approved by Jason Anderson, DOE-ID NEPA Compliance Officer on: 06/14/2021