DOE-ID NEPA CX DETERMINATION
Idaho National Laboratory

CX Posting No.: DOE-ID-INL-23-002 R1

SECTION A. Project Title: Process Development and Demonstration for Curio Solutions Fuel Recycling Process

SECTION B. Project Description and Purpose:

Revision 1.

A GAIN voucher was awarded to expand the project scope by adding facilities (MFC-704, Fuel Manufacturing Facility and MFC-752, INL Analytical Laboratory) and additional experiments.

The first experiment will focus on two lanthanide fluorides of interest (LaF3 and NdF3). Electrochemical experiments will be performed with the lanthanide fluorides in the base LiF-NaF-KF (FLiNaK) molten salt at three concentrations and temperatures of interest in a furnace in a non-radiological facility. At each concentration and temperature, these electrochemical measurements will be performed at both a solid (e.g., Ta, W) and liquid (e.g., Bi, Cd) working electrode. Salt samples will be taken at each composition for elemental analysis. It is estimated that this task will last from week 1 to 18.

The following experiment, spanning weeks 13 to 26, will use uranium fluoride and thorium fluoride to perform the same electrochemical measurements as in the first task in a matching molten salt furnace within a radiological facility. Some work has been previously performed on uranium fluoride electrochemistry by the proposed partner researchers in this facility. While thorium is not a part of LWR UNF, the Gibbs free energy of ThF4 is close to that of CmF3.

Therefore, the reduction potential of thorium is expected to be relatively close to curium. Hence, readily available thorium serves as an excellent proxy and provides a lower bound for the reduction potential of curium which is not expected to be available for use. For these experiments, the same compositions, temperatures, and working electrode materials will be targeted as the first task. Salt samples will again be taken at each composition for elemental analysis.

For third experiment, expected from week 23 to week 38, synthesis of PuF4, NpF4, and AmF3 will be performed either in a Fuel Manufacturing Facility (FMF) transuranic glovebox, or the Hot Fuel Examination Facility (HFEF) hot cell using ammonium fluoride or another fluorinating agent (e.g., bismuth fluoride). Initial tests may be performed with lanthanides in a non-radiological facility to confirm success of the chemical synthesis method. Electrochemical measurements will be performed with the synthesized actinide fluorides in FLiNaK in the Hot Fuel Dissolution Apparatus (HFDA) located in the HFEF hot cell during weeks 35 to 50. The same electrochemical techniques will be performed as with the previous measurements with lanthanides and uranium, targeting the same compositions, temperatures, and working electrode materials. Salt samples will be analyzed at the INL Analytical Laboratory.

The final experiment, spanning about four weeks, will be to compile, document, and report all the work performed and results from the preceding four tasks. Ultimately, data leading to the comparison of reduction potentials of the species of interest at different working electrodes is the desired outcome of the proposed work. Curio will use the data generated throughout the study to design pilot-scale equipment and devise a kinetic model to simulate process scale-up.

Original ECP

Curio is pursuing applied research and experimental demonstrations to reduce risks and uncertainties, incorporate safeguards-by-design, and minimize waste streams in its proprietary NuCycle™ process. The proposed collaboration will be conducted between Curio and Idaho National Laboratory (INL). The primary goal of the proposed effort is recycling nuclear fuel while proving >96% reduction in high-level waste (HLW), perpetuation of impure plutonium streams in the entire process, >99.9% transuranic coextraction, and targeted cost metrics.

The main deliverable of the 3-year collaboration is a laboratory-scale demonstration of NuCycle's integrated unit operations using actual used nuclear fuel (UNF). Additionally, online monitoring and safeguards-by-design will be incorporated into the process flowsheet to track actinide inventory to within 1% uncertainty while maintaining cost Effectiveness. Finally, a techno-economic analysis will study scaleup of the modular, integrated, and compact NuCycle process by conducting a systems analysis and developing a digital representation that incorporates kinetics models acquired from the experimental work. The expected outcomes are a demonstration of feasibility, proof of process scalability, safeguards implementation, and increased confidence in process integration.

Drawing upon lessons learned from non-nuclear experiments, INL will setup an integrated lab-scale demonstration. INL has committed 1.5kg of irradiated LWR fuel from the H.B. Robinson plant (Westinghouse 3-loop PWR) with 30GWd/MT and 50-yr cooling time (currently in HFEF hot cells) to this project. UNF with higher burnups and shorter cooling time may become available during the project term and will be used if the option arises. In preparation for the demonstration, INL will adapt existing HCl gas delivery and scrubber systems for use with NF3 (and possibly HF) and deployed for testing with the molten salt furnaces in the radiological and hot cell facilities. Lab-scale testing will include the following considerations: (1) In existing apparatus, DEOX will be performed at ~500C with maximum 8-in rod segments to acquire U3O8. Off-gases will be captured for analysis. (2) The U3O8 will be fluorinated with NF3 in a salt bath to separate UF6 from other fuel constituents which will be collected in a condenser for analysis. This effort will utilize the NF3 delivery and scrubber system and involve a new headplate for the HFDA. Voltammetry will be utilized to observe reduction progress and salt and metal product samples will be obtained for analysis. Project activities will take place in MFC-787, Fuels and Applied Science Building (FASB); MFC-785, Hot Fuel Examination Facility (HFEF); and MFC-789, Engineering Development Laboratory (EDL).

No modifications will be required for any of these facilities to accommodate this project. Furnace inserts will be fabricated off-site by a subcontractor for the existing furnaces in EDL, FASB, and HFEF.

This project will be performed under a CRADA and is part of an ARPA-E CURIE award. The directorate performing the work is NS&T; however, all work will be performed at existing MFC facilities.

SECTION C. Environmental Aspects or Potential Sources of Impact:

Air Emissions

Project activities will generate chemical and radionuclide emissions during operations. The emissions from FASB have been addressed in APAD INL-18-008 Rev1. Emissions from EDL have been addressed in APAD INL-14-003 Rev1. Emissions from FMF are addressed in PER-152, INL Air Quality Permit to Construct. Furthermore, these emissions are not expected to increase above historical levels released by any of these facilities and therefore would not constitute a new source or modification.

Discharging to Surface-, Storm-, or Ground Water

Not applicable

Disturbing Cultural or Biological Resources

Cultural: Pursuant to the 2023 Programmatic Agreement, this federal undertaking does not trigger Section 106 review as the proposed activity has no potential to cause effects to historic properties. This applies to Revision 1, only.

Generating and Managing Waste

Project activities will generate industrial, radioactive, RCRA hazardous, and mixed waste. It is estimated that less than 1 cubic foot of industrial waste, less than 1 cubic foot of RH-TRU waste, and less than 1 cubic foot of RH-LLW waste will be generated. Project personnel will work with WGS to characterize and properly disposition waste.

Releasing Contaminants

When chemicals are used, there is the potential for spills.

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:

B3.6 "Small-scale research and development, laboratory operations, and pilot projects"

Justification:

B3.6 Small-scale research and development, laboratory operations, and pilot projects. 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); and 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 or developed 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.

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: 5/22/2023.