DOE-ID NEPA CX DETERMINATION
Idaho National Laboratory

CX Posting No.: DOE-ID-INL-21-040

SECTION A. Project Title: Characterizing corrosion mechanisms of structural alloys in actinide-based molten chloride salt

SECTION B. Project Description and Purpose:

Project Overview

The corrosion mechanism of Ni-based alloys in chloride molten salts is not fully understood but necessary to expand understanding of their corrosion mechanisms in chloride salts containing actinide products. The purpose of this project is to answer the following scientific questions:

1) How does the corrosion mechanism of Ni-containing HEAs (multiple principal elements) and conventional Ni-based (one base element) alloys (e.g. Hastelloy, Inconel, etc.) differ in the presence of chloride molten salts with and without actinide products?
2) How does alloy composition dictate the corrosion mechanism and resistance of chloride molten salts with and without actinide products?
3) Do Ni-containing HEAs exhibit superior corrosion resistance compared to conventional Ni-based alloys in chloride molten salts with and without actinide products?

Changes in the redox potential of the molten salt alongside the structural and chemical composition of the exposed Ni-based alloy will be captured employing a combination of electron microscopy techniques, X-ray photoelectron spectroscopy (XPS), spectroelectrochemical, and optical spectroscopy.

Project Logistics

The project will be conducted at the following locations, including the following work activities. A map featuring the location of each building is included.

Fuel Conditioning Facility (FCF) (Building # 765): Generate NaCl molten salt including at least 70% molar percent uranium chloride, either UCl_3, UCl_4, or some combination of the two. Conduct corrosion experiments, exposing Ni-based alloys to NaCl molten salt. Upon completion of corrosion experiments, separate corroded specimens from molten salt, clean specimens of salt residue, and weigh specimens post-corrosion. Both molten salt and specimens will be prepared for transport for storage, sample preparation, and analysis.

Irradiated Materials Characterization Laboratory (IMCL) (Building # 1729) and Electron Microscopy Laboratory (EML) (Building # 774): Conduct sample preparation of corroded specimens exposed to NaCl with and without uranium chloride using cutting, grinding, and polishing methods. Afterwards, characterize exposed Ni-based alloys using electron microscopy techniques, scanning electron microscopy (SEM) and transmission electron microscopy (TEM), including focused ion beam (FIB), secondary ion mass spectroscopy (SIMS), energy dispersive spectroscopy (EDS), electron energy loss spectroscopy (EELS), and electron backscatter diffraction (EBSD).

Research Collaboration Building (RCB) (Building # 1742): Perform additional characterization of corroded Ni-based alloys without uranium chloride using XPS techniques

Energy Innovation Laboratory (EIL) (Building # 688): Characterize changes in redox potential of molten salt using spectroelectrochemical and optical spectroscopy techniques.

Fuels and Applied Sciences Building (FASB) (Building # 787): Store post-experiment molten salt and corroded Ni-based alloy specimens and perform molten salt corrosion experiments when this capability is ready.

Center for Advanced Energy Studies (CAES): Conduct sample preparation of corroded specimens exposed to NaCl without uranium chloride using cutting, grinding, and polishing methods. Afterwards, characterize exposed Ni-based alloys using SEM and TEM techniques, including FIB, EDS and EBSD.

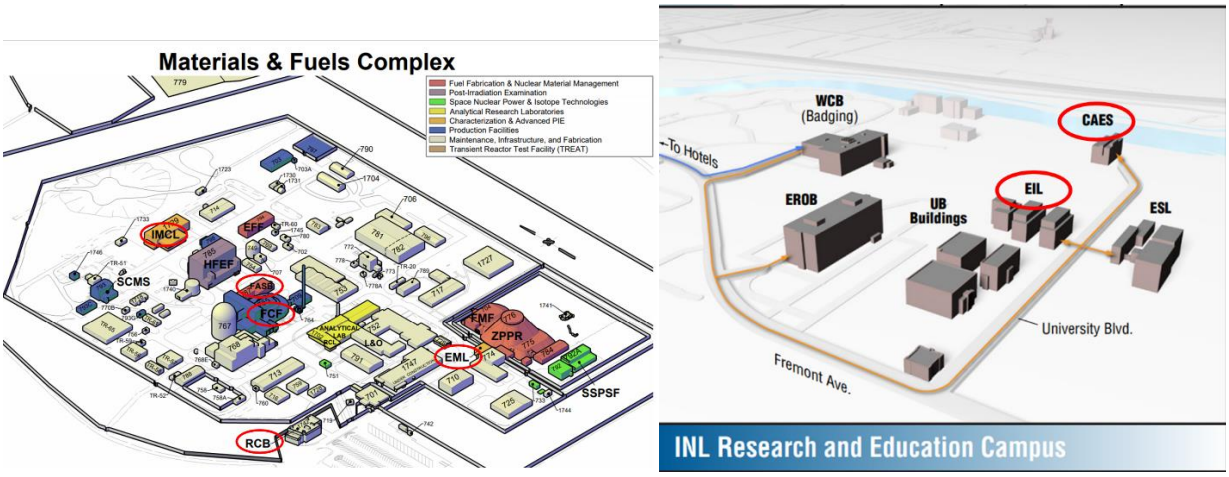

Figure 1: Map featuring the location of all locations at which anticipated work activities will take place in this investigation.

Work Activity

Task 1: Procurement of sodium chloride molten salt

INL has established an operating procedure for procuring sodium chloride molten salt containing uranium chloride in the Fuel Cycle Glovebox (FCG) in FCF. Generally, synthesis entails mixing uranium metal powder, uranium hydride powder, or uranium metal dendrites with chloride salt, which in this case would be sodium chloride, and heating the mixture between 500 to 1000 °C for a period of several days, including leaving the furnace unattended overnight.

Task 2: Molten Salt corrosion studies on nickel-based alloys

Corrosion studies are also conducted with the FCG and in FASB. An example of the experimental design for a corrosion study is illustrated in Figure 2. Specimens are attached to a designated sample holder and lowered in the preheated salt, usually heated between 500 and 900 °C. Upon the completion of the experiment, samples are removed and transferred to a fume hood, where they are rinsed with water. After cleaning, the samples are transferred back into the FCG for weighing.

Task 3: Sample preparation of exposed nickel-based alloys for characterization

Samples are transported to EML or CAES for microscopy sample preparation, which incorporates sectioning, grinding, and polishing of specimens in preparation for analysis using SEM and TEM facilities.

Task 4: Multi-modal characterization of nickel-based alloys and NaCl molten salt

Additional SEM and TEM analysis will be conducted at IMCL or CAES, alongside XPS. Specimens will also be transported to EIL for spectroelectrochemical and optical spectroscopy analysis. Upon completion of analysis, specimens will be stored at FASB.

The proposed actions will not modify buildings.

Waste Management

Waste generated from molten salt synthesis and the rinsing of corroded specimens is anticipated to generate hazardous waste, removal of which will be reported to Waste Generator Services (WGS) to identify an appropriate disposal method.

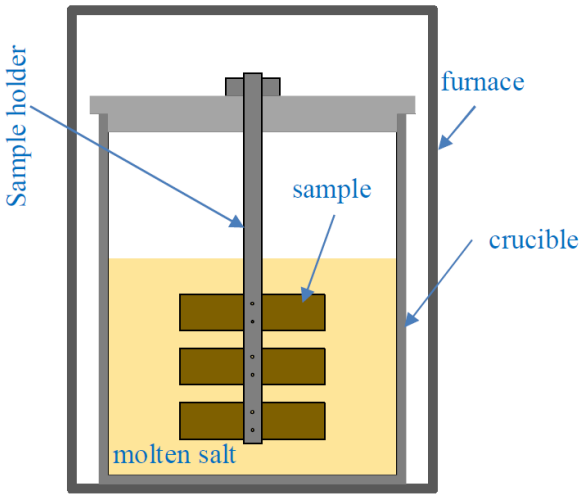

Figure 2: Schematic illustrating the general setup for molten salt corrosion testing (Image reproduced from FCF-NOP-9167D)

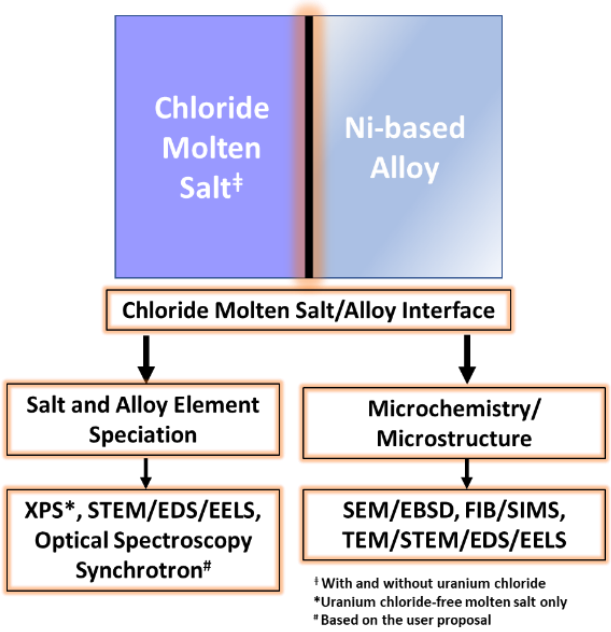

Figure 3: Schematic illustrating the proposed multi-modal characterization approach for analyzing corrosion mechanisms of Ni-based alloys in chloride molten salts

SECTION C. Environmental Aspects or Potential Sources of Impact:

Air Emissions

This activity may emit negligible amounts of radionuclides and toxic air pollutants. These emissions would be considered routine, and work would be covered by existing Permits to Construct or APADs. No new APAD would be required.

Discharging to Surface-, Storm-, or Ground Water

N/A

Disturbing Cultural or Biological Resources

The EML, FASB, and FCF are eligible for the National Register of Historic Place (NHRP). As a result, any proposed modifications to these facilities for this project requires a review by the Cultural Resource Management Office (CRMO).

Generating and Managing Waste

This work is expected to generate small amounts of Low-Level Radioactive Waste (LLW). All Waste will be managed by Waste Generator Services (WGS).

Releasing Contaminants

When chemicals are used during the project there is the potential for spills that could impact the environment.

Using, Reusing, and Conserving Natural Resources

Waste will be diverted from the landfill to the extent possible.

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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:
This EC references the Categorical Exclusion B3.6 "Small research and development, laboratory operations, and pilot projects."

Justification:
Project activities in this EC are consistent with 10 CFR 1021 Appendix B to Subpart D, Categorical Exclusion 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 two 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 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 Anderson, DOE-ID NEPA Compliance Officer on: 04/26/2021