Electroanalytical Sensors for Liquid Fueled Fluoride Molten Salt Reactor

Final CRADA Report

Chemical and Fuel Cycle Technologies

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Participants: ThorCon US, Inc.

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Non Proprietary Final CRADA Report

For the Office of Scientific and Technical Information (OSTI)

CRADA Number: 2018-18134

CRADA Title: Electroanalytical Sensors for Liquid Fueled Fluoride Molten Salt Reactor

CRADA Start Date 3/15/2019 – End Date 11/30/2020

DOE Program or Other Government Support

Program office: Department of Energy, Office of Nuclear Energy, Gateway for Accelerated Innovation in Nuclear

Program manager name: Dr. John H. Jackson

Program manager phone or email: john.jackson@inl.gov

Participant(s)

Participant 1 name: Mr. Lars Jorgensen

Complete address: ThorCon US, Inc., 142 Lyons Road, Stevenson, WA 98648

Participant 2 name: Click or tap here to enter text.

Complete address: Click or tap here to enter text.

Participant 3 name: Click or tap here to enter text.

Complete address: Click or tap here to enter text.

Argonne National Laboratory

Argonne PI(s): Elizabeth A. Stricker, Nathaniel C. Hoyt

Funding Table

To add rows, right-click in bottom row and select "Insert" "rows above".

	Planned Funding	Actual Funding	In-Kind
Government	400,000.00\$	400,000.00\$	
ThorCon US, INC	\$	\$	100,000.00\$
Enter Participant 2 here	\$	\$	\$
Enter Participant 3 here	\$	\$	\$
Total	400,000.00\$	400,000.00\$	100,000.00\$

Nature of Work

Describe the research (summary of Scope of Work and principal objectives of the CRADA):

ThorCon is developing a thermal thorium / uranium molten salt fueled reactor that uses a fuel salt consisting of NaF - BeF₂ - ThF₄ - UF₄ - UF₃, which uses 19.75% enriched uranium. It is not a breeder reactor but requires regular additions of fissile material. On-site fuel processing is limited to adding make-up fuel, and adding beryllium to maintain redox balance in the fuel salt. The fluoride salt is an excellent flux that will strip the protective oxygen away from all metal surfaces it contacts. In order to protect the metal surfaces in the primary loop, no free fluorine is allowed. Maintaining a ratio of UF₄ to UF₃ provides a chemical buffer that can absorb any free fluorine released during the fission process before it can harm the structure. Periodic additions of metallic beryllium to the fuel salt will react with UF₄ to form BeF₂ and UF₃, which will maintain the desired UF₄/UF₃ ratio. A means to measure the UF₄/UF₃ ratio is important to maintain the fuel salt in a non-corrosive state and could also provide additional insight into the corrosion behavior and chemical constitution of the system. A promising measurement technique is based on electrochemistry.

DOE mission area(s):

Energy and Environmental Science and Technology

Choose an item.

Choose an item.

Conclusions drawn from this CRADA; include any major accomplishments:

This document serves as a summary report for the work conducted under GAIN Voucher CRADA 2018-18134 between Argonne National Laboratory and ThorCon US, Inc. The overall goal for the project was to develop electrochemical sensor technologies to enable the in situ monitoring of the liquid fuel salt proposed for use in the ThorCon molten salt reactor. The specific project goals included in situ measurements of the redox potential, uranium concentration, and plutonium concentration in the salt.

ThorCon's fuel salt has a number of unique attributes that make these types of measurements challenging. ThorCon's salt is a $\text{BeF}_2\text{-NaF}$ salt that contains high weight-loadings of UF_4 and ThF_4 . The high weight-loadings make the use of electrodeposition peaks, which are typically used for electroanalytical measurements in nuclear-relevant molten salts, problematic due to the increase in electrode area that occurs when metals are deposited onto the sensor's electrodes. ThorCon's fluoride-based salt creates additional challenges due to its ability to dissolve oxide species into the salt, which causes issues for the selection, cleaning, and conditioning of long-lasting sensor components such as the electrodes.

Argonne overcame these challenges and was able to develop analytical techniques and select materials that enable electrochemical measurements of the ThorCon fuel salt. Argonne tested a variety of candidate electrode materials, and ultimately selected platinum electrodes as the best option to achieve high-fidelity measurements in the ThorCon fuel salt. Using these electrodes, Argonne was able to demonstrate measurements of the salt potential and of the concentration of uranium in the salt through characterization of the $\text{U}^{4+}/\text{U}^{5+}$ reaction. This work represents the first electrochemical description of this reaction along with its first use for quantitative electroanalytical measurements. Testing on a single electrode for 67 days of near-continuous electroanalytical measurements indicated minimal material degradation, suggesting that the electrodes can achieve stable measurements over long durations.

The plutonium peak that was planned to be used for quantification of the plutonium concentration in the salt was not able to be detected using the sensor, and measurements could not be achieved. Although sufficient plutonium tetrafluoride was added to the salt to be measured, the current hypothesis is that the oxide concentration in the salt was too high to support the presence of the $\text{Pu}^{3+}/\text{Pu}^{4+}$ couple.

This work represents the first demonstration of long-duration monitoring of a realistic MSR fuel salt formulation. Ultimately, a multi-electrode array composed of platinum electrodes will be able to measure uranium and plutonium content, and salt redox potential in ThorCon's fuel salt across a full range of operational temperatures for durations sufficiently long to support real-world deployment.

Technology Transfer-Intellectual Property**Argonne National Laboratory background IP:**

N/A

Participant(s) background IP:

N/A

Identify any new Subject Inventions as a result of this CRADA:

N/A

Summary of technology transfer benefits to industry and, if applicable, path forward/anticipated next steps towards commercialization:

A multi-electrode array composed of platinum electrodes will be able to measure uranium and plutonium content, and salt redox potential in ThorCon's fuel salt across a full range of operational temperatures for durations sufficiently long to support real-world deployment.

Other information/results (papers, inventions, software, etc.):

N/A

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