Improved Understanding of Zircaloy-2 Hydrogen Pickup Mechanism in BWRs

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ABSTRACT:

Zr-based alloys are used in light water reactors (LWRs) as fuel cladding and fuel structural materials such as channels, water rods and spacers. Zircaloy-2 material is mainly used in boiling water reactors (BWRs) and Zircaloy-4 is used in both BWRs and pressurized water reactors (PWRs). In high temperature reactor coolant environment, Zr-based alloys form a uniform corrosion and also pickup hydrogen as part of the corrosion process. Hydrogen in Zr-based alloys form Zirconium hydrides and cause degredation of mechanical properties of the material under neutron irradiation. Zircaloy-2 material in BWRs show high hydrogen pickup and variability at high burnup. Hydrogen pickup mechanism of Zr-based alloys is a complex phenomenon and not understood clearly. An improved understanding of hydrogen pickup in Zr-based alloy has a strong impetus, especially the high hydrogen pickup at high burnup conditions in BWRs. Such an improved understanding is important to the nuclear industry. Ongoing Nuclear Regulatory Commission (NRC) loss of coolant accident (LOCA) rulemaking and new reactivity insertion accident (RIA) acceptance criteria both have limiting metrics that are tied to the hydrogen content of the fuel cladding and highlight the need for predicting fuel cladding hydrogen content at the end of life. Knowledge on the reasons responsible for the high hydrogen pickup and variability at high burnup would greatly enhance the industry's ability to predict hydrogen pickup. *This proposal will pursue a multi-institutional joint research to understand why Zircaloy-2 material exhibit high hydrogen pickup and a large variability in BWR environments by investigating a correlation between the irradiated Zircaloy-2 oxide layer resistivity and hydrogen pickup*.

The work scope includes testing and post-irradiation examination (PIE) of irradiated Zircaloy-2 materials in commercial BWRs. The work will be carried out in cooperation with Electric Power Research Institute's Nuclear Fuel Industry Research (EPRI's NFIR) Program, which will provide pre-irradiated channel and water rod materials manufactured by AREVA NP Inc. and Global Nuclear Fuel (GNF) and irradiated in several commercial BWRs. Selected samples for this project scope will be offered to the NSUF Sample Library in case of interest from other researchers. *The main scope will include in-situ electrochemical impedance spectroscopy (EIS) measurements on pre-irradiated channel and water rod samples as well as post-irradiation characterization of same materials using Transmission Electron Microscopy and Scanning Electron Microscopy at Pacific Northwest National Laboratory (PNNL).* Full execution of the proposed work will take three (3) years. Investigation will be focused on determining if the irradiated Zircaloy-2 oxide layer resistivity is correlated to the hydrogen pickup. To compliment the electrochemistry measurements, detailed oxide microstructure of the tested materials such as cracks and porosity will be determined. The list of major deliverables are as follows:

- Results of the baseline characterization, shipment and sample selection (protocols, procedures).
- Results of the baseline characterization and EIS measurements.
- Final report.