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Innovative Approach to SCC Inspection and Evaluation of Canister in Dry Storage

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ABSTRACT:

Lifetime extension of dry storage canisters requires the ability to accurately predict and monitor material degradation so that corrective maintenance actions can be taken. Monitoring and inspection of dry storage facilities in combination with material property prediction capabilities are necessary. Chloride-initiated stress corrosion cracking (CISCC) of a spent fuel canister (primarily in welds or heat affected zones) is one of the safety concerns during the dry storage of used nuclear fuel at an Independent Spent Fuel Storage Installations (ISFSIs). Deterioration by CISCC can lead to canister penetration, potentially releasing helium and radioactive gases, and permitting air ingress which could pose a threat to fuel rod integrity. This study will result in enhanced understanding of conditions which could be conducive to CISCC initiation (such as pitting) or CISCC propagation rate, and will develop methods that could be used to identify the occurrence of CISCC in its early stages in the field. The model and methodology developed in the proposed project with quantified uncertainty can be used to inform recommendations for periodic NDE examinations to monitor the extent of any cracking.

The general objectives project are:

Database development

- Literature review of the current understanding of chloride SCC, and creation of database on CISCC.
- Assess monitoring techniques of temperature, moisture content, and chloride concentration in marine atmosphere and polluted industrial areas.
- Identify environmental and metallurgical factors that have an impact on CISCC. This information will be used to develop the appropriate laboratory testing methodologies for SCC initiation and growth.

Laboratory CISCC Studies

Testing to quantify the effect of environmental and metallurgical factors that have an impact on SCC initiation and growth rate, such as salt concentrations, temperature, most susceptible heat affected zone microstructure, metal stresses, pH, and relative humidity.

- Experimental testing to determine the most susceptible zone within the weld heat affected zones.
- Controlled and instrumented pitting initiation and crack propagation rate studies with specimens representing the most susceptible microstructure, varying environmental parameters and specimen tensile stress conditions to cover the range expected on the canister surfaces.

- Utilize these data to develop the technical understanding, with associated uncertainties, for prediction of crack initiation and crack growth rates, and ultimately, canister penetration lifetimes.

<u>Development of a NDE method for CISCC</u>

- Assess a range of canister surface inspection nondestructive evaluation (NDE) methods and their suitability and probability to detect the presence of CISCC on the canister surface in the field. Two inspection methods have been selected for testing for in-situ CISCC detection.
- Assess the radiation tolerance and temperature on NDE materials sensors (temperature and energy deposition, radiation), and NDE deployment options.
- Develop and test a NDE inspection method in the laboratory
- Build a partial mockup for NDE testing and verify that the method can be deployed in the field.
- If possible, utilize the developed NDE CISCC detection technology at an ISFSI location, for industry application.

The proposed quantitative study of CISCC, will provide the following benefits:

1) Reduce the risk of canister failure due to CISCC thus reducing risk to site personnel, the public, and the environment due of fission product gas release.
2) Increase confidence in the long term performance of dry storage systems.
3) Provide a cost-effective and reliable NDE diagnostic technique for a high radiation environment, allowing in situ inspection of canisters and reducing the likelihood and expense of requiring canister replacement.
4) Reduce the gaps of our understanding in CISCC initiation and crack growth rates and aid in development of better theoretical models.
5) Enlarge the operating space of ISFSIs by reducing uncertainties and reducing the cost of ISFSI operation.
6) Improve prediction of CISCC impact on canister integrity at higher fuel burnups and longer periods of extended storage.

The project includes three universities and three national laboratories, and the industry partner Chicago Bridge and Iron industry (CB&I) with extensive experience in spent nuclear fuel dry storage facilities design and NDE. Colorado School of Mines will be the primary contractor and will oversee all aspects of the project; including the fabrication of the simulated welded specimens, material, mechanical, and thermal properties of Types 304 and 304L stainless steel, and crack initiation study. North Carolina State University, University of South Carolina, and Argonne National Laboratory, will lead the work on crack propagation rate measurement. The national laboratories, Sandia and Los Alamos, are funded by the DOE for related work. Their collaboration with this project will largely be to integrate existing DOE efforts with the IRP team, this leveraging funding for both efforts. Specifically, Sandia National Laboratories will provide the data on characterization of weld and heat-affected zones (HAZ) and characterization of environment on the canister surface, and aid in defining representative corrosion test conditions. Los Alamos National Laboratory will develop an innovative detection system based on ultrasound for crack initiation and propagation rate, and will utilize IRP resources (e.g. the canister mockup) for testing that method. CB&I will interface with utilities that operate ISFSIs to a conduct field demonstration of the crack inspection system, and will evaluate the impact of project results on the ISFSI licensing process and industry. This project team proposes to not only produce models capable of predicting the CISCC impacts on canister lifetimes over a wide range of environmental conditions, canister thermal loads, and tensile stresses, but also to benchmark and validate existing models used in evaluating CISCC of dry storage canisters. In addition, the uncertainty quantification will be built in from the beginning of the project.