INDUSTRIAL SOLUTIONS LABORATORY

Company Information

Company Name	*Orano Federal Services LLC*	**Date Submitted**	*11/15/2024*
Project Title	*Thermal Modeling of Surface Temperatures of a Dry Storage Canister for Spent Nuclear Fuel (ORANO_TEMP)*	**Planned Starting Semester**	*Spring 2025*

Senior Design Project Description

Personnel

Typical teams will have 4-6 students, with engineering disciplines assigned based on the anticipated Scope of the Project.

Please provide your estimate of staffing in the below table. The Senior Design Committee will adjust as appropriate based on scope and discipline skills.

Discipline	Number	Discipline	Number
Mechanical	4	Electrical	1
Computer	1	Industrial/Systems	

Company and Project Overview:

Headquartered in Washington, D.C., Orano USA is a leading technology and services provider for decommissioning shutdown nuclear energy facilities, used fuel management for existing and advanced reactors, federal site cleanup and closure, and the sale of uranium, conversion, and enrichment services to the U.S. commercial and federal markets. With its parent company Orano, Orano USA has more than 30 years' experience in decontaminating and dismantling nuclear facilities, and more than 50 years' experience securely transporting and storing used nuclear fuel (UNF).

The Orano Federal Services business combines the capabilities, technologies and resources from multiple Orano companies to serve the U.S. Department of Energy (DOE) and its subcontractors in all phases of the nuclear fuel cycle. Orano Federal Services provides key services as an active member in various projects that support DOE's five strategic services: Environmental Management (EM), Nuclear Energy (NE), Office of Science (SC), Office of Energy Efficiency & Renewable Energy (EERE), and National Nuclear Security Administration (NNSA). Orano Federal Services currently is a contract team member of the following significant projects: the High Burnup (HBU) Demonstration Project; the enrichment for high assay low enriched uranium (HALEU); the deconversion of enriched HALEU; support to multiple advanced reactors designated by DOE for support under various programs such as the Advanced Reactor Deployment Program; et al.

Due to the Federal governments defunding of the U.S. repository program for the disposal of spent nuclear fuel (SNF) at Yucca Mountain, SNF is now residing in dry storage canisters (DSC) found in concrete overpacks/modules for indefinite periods of extended interim storage. Although this storage system safely and securely stores SNF from nuclear reactors, there is a hypothetical concern that DSCs are susceptible to chloride-induced stress corrosion cracking (CISCC). For CISCC to occur, three conditions need to exist: a susceptible material needs to exist, a tensile stress needs to be present, and a corrosive environment needs to exist. For DSCs, the stainless steel (particular in the heat affected zones around the welds where the welding has created areas with less chromium present) is considered to be susceptible to SCC and tensile stress exists as the metal has been bent from a flat sheet to create the cylinder of the DSC. A corrosive environment may also exist if the DSC is stored near a body of water where chlorides can be made airborne and subsequently deposit on a DSC surface. However, when the DSC surface is above a certain temperature, the airborne chlorides are not likely to deliquesce on the DSC surface and hence not create a corrosive environment. In this project, the objective is to develop a thermal model for the surface temperatures of a DSC containing spent nuclear fuel to examine at what age the temperature of the spent nuclear fuel drops to a level where the DSC surface temperature along the longitudinal weld allows for deliquescence of chlorides. This model should also be modified to examine the impact to the surface temperature if a coating is applied across the top of the welds.

To verify the thermal model, some testing should be performed using the full-scale DSC located at UNC Charlotte. This testing would involve placing a heat source inside a portion of the DSC and measuring the surface temperature and comparing this to the computational model. In addition, a coating could also be placed on the DSC external surface along the heat affected zone of the weld and a similar heating and measurement test performed to examine the insular impact of the coating to the surface temperature.

The objective of this project should be to determine the surface temperature at which deliquescence occurs along the heat affected zone of a longitudinal weld. In addition, once the thermal model is confirmed, the model should be updated to include convective heat transfer cooling of the surface with natural air circulation. This updated model can then be exercised to determine if ceasing the convective flow across the surface of the DSC keeps the temperature sufficiently hot to prevent deliquescence.

Project Requirements:

Develop a computational thermal model for the conductive heat transfer for heat from the internal portion of a DSC to the surface of the DSC and establish the DSC surface temperatures.

Examine the impact to the thermal model as a result of adding a coating to the surface of the DSC. Perform some benchmarking of the thermal model using the DSC stored at UNC Charlotte by EPRI. Once benchmarked, add a convective cooling model to the DSC surface temperature thermal model to examine the impact of natural convection flow on the surface of the DSC. Determine the temperatures at which deliquescence cannot occur on the surface of the DSC, especially around the heat affected zone associated with the longitudinal welds for a canister.

Project objectives (expected):

1. Develop a computation model for the thermal behavior of the surface temperatures of a DSC from a heat source internal to a DSC.
2. Benchmark this model through the placement of heater inside the DSC stored at UNC Charlotte and measuring surface temperatures, especially along the heat affected zones of longitudinal welds of the DSC.
3. Determine the heat input needed to ensure the DSC surface temperatures are above the temperature at which salt deliquescence occurs.
4. Modify the DSC thermal model to examine the impact of a coating to the surface of the DSC to the DSC surface temperature distribution.
5. Benchmark the impact of this coating.
6. Determine the heat input needed to ensure the DSC surface temperatures are above the temperature at which salt deliquescence occurs with the DSC coating (partial/full coating).
7. Modify the DSC thermal model to examine the impact of convective cooling from naturally circulated air across the surface of the DSC.
8. Determine if a benchmark test is possible to verify the model.
9. Determine the heat input needed to ensure the DSC surface temperatures are above the temperature at which salt deliquescence occurs with the DSC coating (partial/full coating) and convective cooling.
10. Using this updated model exercise it to determine if ceasing the convective flow across the surface of the DSC keeps the temperature sufficiently hot to prevent deliquescence.

Expected Deliverables/Results:

- Thermal model of DSC surface temperatures considering a heat source internal to the DSC (representative of spent nuclear fuel heat) with conductive heat transfer through the DSC wall and convective cooling of the DSC surface by natural circulating air

- Compiled recommendations of how to prevent deliquescence on the surface of a DSC, especially in the heat affected zones of longitudinal welds of the DSC

- Benchmarks of the thermal model using the DSC stored at UNC Charlotte with an internal heat source

Disposition of Deliverables at the End of the Project:

Students are graded based on their display and presentation of their team's work product. It is mandatory that they exhibit at the Expo, so if the work product was tested at the supporter's location, it must be returned to campus for the Expo. After the expo, the team and supporter should arrange the handover of the work product to the industry supporter. This handover must be concluded within 7 days of the Expo.

List here any specific skills, requirements, specific courses, knowledge needed or suggested (If none please state none):

-heat transfer course work,
-computational modeling skills,
-hands-on-skills