Multifunctional Laser Processing for Repair and Mitigation of Pitting and Cracks in Welded Stainless Steel Dry Storage Canisters

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ABSTRACT:

Because of the uncertain status of the Yucca Mountain Nuclear Waste Repository, the nation faces the prospect of extended long-term storage (i.e., > 120 years) of spent nuclear fuel in dry storage canister (DSC) systems at independent spent-fuel storage facilities (ISFSIs). Moreover, many DSCs are located at operating or decommissioned nuclear power plant sites with marine environments, which are known to be corrosive as a result of both high humidity and the deposition of chloride-containing salts from on-shore winds, surf, and fog. The aggressive environment may lead to pitting and stress corrosion cracking (SCC) in the stainless steel welds, which increases the risks for extended long-term storage. As the old DSCs filled in the last century reach the end of their design lifetime, licensing extension will have to be granted, which requires a method of inspecting and enhancing the corrosion resistance for these old DSCs when necessary. To our knowledge, no DSC venders currently have a full re-licensing/re-certification program yet, but it will become urgent within the next 10 years.

The proposed project aims to create a strategic solution that combines laser cleaning and laser peening for removal of surface contamination and mitigation of pitting and SCC in welded stainless steels, and protection from further corrosion. Laser cleaning will be used to remove surface contamination (e.g., chloride containing salts and rust) and mitigate pitting on DSC stainless steels. Laser peening will be performed on DSC stainless steels for mitigation of SCC and enhancement of corrosion resistance. Due to the ability to use fiber optics for laser beam generation and delivery, the technologies developed will be easily integrated with any loaded system for in-service inspection and repair. A prototype robotic system with high internal degrees of freedom will be adopted and integrated with fiber optics to perform a variety of locomotion laser processing activities in the limited space between DSC surface and its concrete module. To achieve the project aims, we will seek completion of five objectives: ***Objective 1)*** develop a laser processing system for cleaning and peening of the welded stainless steel of DSCs; ***Objective 2)*** develop a laser cleaning process to remove surface salts and rust, and mitigate pitting from welded stainless steels; ***Objective 3)*** Develop a laser peening process to mitigate SCC, preventing DSCs from further corrosion; ***Objective 4)*** Conduct performance tests on the DSC steels treated by multifunctional laser processes to confirm the improved corrosion resistance; and ***Objective 5)*** Integrate fiber optics with a prototype robotic system for DSC surface repair.

The benefits of the laser processes include the portability of the laser system for easy field deployment, safe operation (with negligible heat input and without spark or hydrogen gas generation), reliability (without external mechanical force), cleanliness (without chemicals), accessibility (fiber optics with flexibility for use in difficult-to-access locations and geometry), remote operation (laser system placed at up to 50 m away from DSC), precise control, and accuracy. The system is also suitable to repair the canisters on site if there is a plan to take them out of the concrete overpack for relocation, which will inhibit the initiation and growth of pits and cracks without sending the filled canisters back to factory. Thus, the proposed solution will meet the ultimate goal described for the FC-4.2 program to mitigate SCC for long-term storage of the DSCs.