Wireless Multifunctional Ultrasonic Arrays with Interdigital and Airborne Transducers for Monitoring Leakage and Corrosion Conditions of Welded Dry Storage Canisters

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Program: Spent Fuel and Waste Disposition: Storage & Transportation (FC-4.2)

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ABSTRACT:

Welded dry storage canisters (DSC) are critical structures for the storage of spent nuclear fuels. To provide assurance that the safety functions of DSC continue to be met, DOE is interested in developing innovative methods to interrogate DSC conditions, such as canister leakage indicators (internal pressure, temperature, and helium/air mixture) and conditions related to canister corrosion (free and/or vapor water). However, because of the harsh temperature/radiation that sensors could be subjected to, limited accessible sensing areas, thick canister walls, and high complexity of DSC, it is extremely difficult to achieve wireless, quantitative, on-demand interrogation and continuous monitoring of those conditions by using only external sensors.

In response to the program *Spent Fuel and Waste Disposition: Storage & Transportation* (*FC-4.2*), this proposed research aims to develop innovative, wireless, multifunctional, ultrasonic sensor arrays that enable on-demand, quantitative interrogation and monitoring of both the canister leakage indicators (helium, helium/air mixture, internal pressure, and temperature) and corrosion conditions (free and/or vapor water). To achieve this overall objective, three specific Tasks are proposed.
In Task 1, we will develop on-chip, small-size, wirelessly sensors by fusing the merits of various configurations of optimized interdigital transducers on piezoelectric chips, ultrasonic Bragg reflectors, ultrasonic delay lines, and phononic crystals, in order to enable key functionalities such as quantitative integration and monitoring of multiple DSC conditions including internal pressure, temperature, free water, and vapor water. We will also develop airborne ultrasonic arrays to enable key functionalities such as detecting helium leakage as well as quantitative evaluation and monitoring of the helium/air volume ratio based on the change of effective wave speed. In Task 2, we will further improve and characterize our ultrasonic sensor arrays by investigating the effects of combined DSC conditions on our sensors through fundamental theoretical studies and multi-physics modeling, decoupling combined effects, testing the sensor survivability, and performing characterization tests on a small-scale canister mockup. In Task 3, we will develop a fully integrated prototype based on our sensing method and validate the prototype through onsite experiments on both the ORNL full-scale vertical canister mockup and the Orano NUHOMS horizontal system.

By accomplishing all the Tasks, we expect to better understand the effects of complex DSC conditions on ultrasonic waves and achieve an innovative, wireless, ultrasonic technology for on-demand quantitative evaluation and real-time monitoring of DSC conditions. With these capabilities, our research will lead to innovative DSC monitoring technologies that have the potential to significantly exceed current standards and address unmet needs. We expect that our ultrasonic sensing technology will be of tremendous value to the nuclear industry and the monitoring of spent fuel storage and transportation systems.