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Multi-modal Surface Acoustic Wave Sensing System for Pressure and Temperature monitoring of Spent Fuel Canisters

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ABSTRACT:

With the defunding of the proposed Yucca Mountain nuclear waste repository, there is no clear pathway for spent nuclear fuel (SNF) disposition, and dry cask storage at ISFSI (Independent spent fuel storage installation) for an extended period is now necessary. In the majority of DCSSs, the spent fuel is housed in a stainless-steel canister which is then placed in a concrete overpack. Monitoring temperature, pressure, radiation, humidity, helium gas leakage, etc., inside these enclosed vessels is crucial to ensure the fuel security. However, the enclosed configuration of the canisters presents significant challenges to sensing and instrumentation needed to monitor quantities such as temperature, pressure, radiation, humidity, and helium gas leakage, all of which are crucial to ensure safety and security. Wiring through holes in the canister vessel walls is expensive, undesirable and largely defeats the purpose of the sealed canister. Placing sensors inside the canister vessel is challenging because of high radiation dose and temperature up to 400°C.

We propose a novel, viable and economic sensing technology to address the aforementioned challenges for long-term monitoring of internal conditions in SNF dry storage canisters. The objective of this proposal is to develop a multi-modal wireless passive SAW (Surface Acoustic Wave) sensor array, which can be deployed on the outside surface of the canister, to monitor the strain of the canister and thus determine the internal pressure. In addition, the SAW sensor could also measure the surface temperature and potentially monitor helium gas leaks.

The research team will first design the multimodal surface acoustic wave strain/temperature sensor based on the theory of piezoelectricity. Langasite (LGS) will be used as the piezoelectric substrate for the SAW sensor, given its tolerance to temperature and moderate radiation doses. The team will fabricate the sensors on LGS in a state-of-the-art manufacturing facility in NETL. Subsequently, the sensor will be tested for accuracy and sensitivity, with design iterations as necessary to optimize sensor performance. Algorithms for quantifying the canister strain and temperature from the data, as well as mapping these quantities over the canister using an array of sensors, will also be developed. A final test and demonstration of the sensor system will be performed using a scaled canister setup at ORNL.

Deliverables include a functional requirements document for canister monitoring, numerical results of high temperature LGS SAW strain sensor based on applicable theory and finite element analysis, a prototype of the multi-modal LGS SAW sensor for high temperature simultaneous strain and temperature sensing; sensor data processing algorithms and 3D sensor array mapping; and documentation of results from the integrated sensing system tests;

If successful, our sensing system will enable the monitoring of the canister internal pressure from a strain sensor deployed outside of the canister, and thus avoid the complexity and difficulty of placing sensors inside the canister; Future associated electronics and energy storage system could also be placed outside of the canister to avoid high cost and long lead times needed to develop high temperature electronics and energy storage systems. The proposed sensing array could also be used to detect helium gas leaks through monitoring the local temperature change caused by the high thermal conductivity of helium.