Used Fuel Storage Monitoring Using Novel He-4 Scintillation Fast Neutron Detectors and Neutron Energy Discrimination Analysis

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ABSTRACT:

The investigators will build and demonstrate a prototype detector device capable of unambiguously verifying the declared content of dry casks in a non-intrusive manner for the safeguarding and monitoring of used fuel storage installations. This will be achieved through a neutron spectroscopy and imaging system using high-efficiency Helium-4 (^{4}He) gas scintillation fast neutron detectors. This system will prove a valuable tool to identify cask-specific features and maintain a continuity of knowledge about the nuclear material.

Spent nuclear fuel (SNF) will likely be stored in dry storage for an extended period of time in the United States. There is a need for improved methods to verify the content of sealed dry casks; a need for such systems has been expressed by IAEA to restore knowledge in cases where continuity of knowledge has been lost. On average, each of the 104 operating reactors produces 20 metric tons of plutonium per year. On-site SNF pools are filling up, and no centralized repository is available in the near term. The amount of fuel in dry storage increases each year.

This project will address this technology gap by utilizing ^{4}He detector technology, a new tool that has yet to be developed for nuclear security and safeguards applications. It has several advantages over current neutron and gamma detectors used for safeguards, which give it a wide range of potential applications for this purpose. Notably ^{4}He gas is significantly more available than ^{3}He gas and retains energy information of detected neutrons with more fidelity than liquid scintillators. Due to the sheer amount of fissile material in a single stored in a single dry cask, there is a significant neutron fluence emitted whose energy ranges from thermal all the way to uncollided high-energy neutrons suitable for the scope of this project.

The project will (a) Create a neutron spectrometer using ^{4}He detectors (shown at right) through an experimentally validated neutron energy response function and spectral unfolding techniques. (b) Leverage test measurements and a computational spent fuel library enabling the analytical design of a cask-measuring prototype system. (c) Construct a prototype instrument and use it to measure spent fuel casks at a commercial spent fuel storage facility. (d) Use spectral-specific measurement data to show proof of concept for measurable data successfully converted to quantifiable signatures, such as diversion/removal of fuel, and maintenance of fuel and cask integrity of fuel.