

Detecting water in spent nuclear fuel using the prompt neutron capture reaction on hydrogen

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An approach to detect and locate water in spent nuclear fuel (SNF) utilising the neutron capture reaction on hydrogen (to yield deuterium) to exploit the resulting prompt 2.223 MeV γ ray is described. Water present in spent nuclear fuel (SNF) and other fuel element debris (FED) is detrimental to the long-term storage stability of the material due to chemical and structural effects it induces. This research builds on previous efforts to construct a mock AGR fuel element using zinc as a fuel analogue and polyethylene (HDPE) as a water substitute. A series of simulations in Geant4 have been carried out of a modelled fuel element surrounded by reverse electrode germanium (REGe) detectors. Water was added selectively to fuel pins and a γ -ray spectrum from each detector was obtained with both SNF and zinc in the place of fuel material. The features of each spectrum have been processed by a machine learning model allowing for the triangulation of the water-logged fuel pin. Additional randomised water-logged pins will be simulated, and the efficacy of the machine learning model will be tested and optimised. These simulations will be replicated using the physical model and two REGe detectors. Small ²⁵²Cf neutron sources will be placed within select pins in the element so as to emulate the natural production of spontaneous fission neutrons and neutrons from (α , n) reactions. If successful in measuring 2.223 MeV γ rays from the HDPE, machine learning will be applied to the experimental arrangement using spectra from the two REGe's.