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#6-206 Differential Die Away and Delayed Neutron Temporal Analysis to Determine Fissile Mass and Isotopes in Uranium Samples

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Special nuclear material is often identified and quantified through gamma-ray spectroscopy or characteristic neutron signatures. However, the passive gamma signature of ^{235}U can be easily shielded, and its passive neutron signature is negligible. To address this challenge, we propose using a neutron generator to probe uranium and induce fission, from which the prompt and delayed neutrons can be used to quantify the isotopic content. In this work, a ^{4}He-based fast neutron detector was used to perform differential die away (DDA) analysis while the delayed neutron emission time profile was simultaneously measured with moderated ^{3}He detectors. High-pressure ^{4}He scintillators were chosen for this application due to their ability to record the fast neutron spectrum and their intrinsic insensitivity to gamma rays when a ~300 keV energy deposition threshold is applied. The detectors and neutron generators were housed in a custom well-like cubic structure that comprised inner layers of ordinary high-density polyethylene (HDPE) and an outer layer of borated high-density polyethylene (B-HDPE) to eliminate room-return neutrons. The intensity of the measured DDA signal is related to the fissile mass of the sample, such that this signal can be used to quantify fissile mass. The delayed neutron time profile provides information on the fissile material composition in the sample. When these two measurements are combined, both the fissile mass and isotopic composition of the sample can be determined. Experiments with uranium were conducted at the National Criticality Experiments Research Center at the Nevada National Security Site. Two MC-15s, consisting of 15 moderated ^{3}He tubes each, were used to measure delayed neutrons, and an Arktis S670 ^{4}He detector was used to measure prompt neutrons. Four uranium source configurations were measured: a 3.7 cm highly enriched uranium (HEU) sphere, the same 3.7 cm HEU sphere surrounded by 1.2 cm of depleted uranium (DU), a 3.8 cm DU sphere, and a 3.8 cm DU sphere surrounded by 1.3 cm of HEU. A Thermo-Fisher P211 D-T neutron generator emitting ~10 µs pulses with ~10^{6} neutrons per pulse at 100 Hz, served as the interrogating source. The detectors were surrounded with HPDE and B-HDPE in a box configuration with open space in the center. A large amount of polyethylene was used to provide a consistent and intense thermal neutron environment to drive the DDA signature. The source was placed in the center of the box, and the D-T generator was placed at the bottom of the box. The generator was operated in one-minute on, three-minutes off cycles. The DDA time profiles were measured between pulses, while the delayed neutron time profiles were observed in the three minutes following generator shutoff. Since ^{235}U and ^{238}U have different delayed neutron group yields, analysis of the measured delayed neutron time is used to reconstruct the isotope's relative abundance while the DDA signal is used to determine the fissile mass.

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