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Development and Validation of an Improved Optical Fiber-Based Verification System for Spent Fuel Inspection in CANDU Reactors

ABSTRACT

At the Wolsong CANDU (CANada Deuterium Uranium) nuclear power plant in the Republic of Korea, 37-element CANDU fuel assemblies using natural uranium are employed. Due to the short burnup cycle of natural uranium, a relatively large amount of spent nuclear fuel is produced, necessitating safe management and timely verification of spent fuel inventories. To address this need, the Korea Institute of Nuclear nonproliferation And Control (KINAC) developed the Optical Fiber Probe System (OFPS), which is currently used for the Physical Inventory Verification (PIV) of CANDU spent fuel bundles.

In this study, an Improved Optical fiber-based VErification System (IOVES) was developed to enhance the technical capabilities and performance of the OFPS. Radiation profile measurements were conducted using the upgraded system, and Monte Carlo simulations were performed to model the wet storage pool and spent fuel bundles. The simulated radiation profiles were compared with the experimental data to validate the IOVES's performance.

The IOVES consists of a 2.5 × 2.5 × 10 mm^3 p-terphenyl scintillator optically coupled to a photomultiplier tube (H10720-110, Hamamatsu) via a 15-meter-long optical fiber cable. Radiation profiles were measured as the probe moved between spent fuel bundles at a speed of 30 mm/s. The radioactivity of the spent fuel bundles was calculated using the Oak Ridge Isotope GENeration and depletion code (ORIGEN), incorporating actual burnup and cooling time data. The wet storage pool environment was modeled using the GEometry ANd Tracking (GEANT4) toolkit, with the ORIGEN-derived source term.

The comparison between simulated and experimental radiation profiles showed similar patterns, confirming the reliability of the newly developed IOVES. These results suggest that the proposed system can be effectively applied to future PIV activities and contribute to the safe and efficient verification of spent nuclear fuel inventories.

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Workshop topics

Detector systems

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