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Application of Monte Carlo Method to Test Fingerprinting System for Dry Storage Canister

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1. Introduction

From 1992, dry storage canisters have been used for long-term disposition of the CANDU spent fuel bundles at Wolsong. Periodic inspection of the dual seals is currently the only measure that exists to verify that the contents have not been altered. So, verification for spent nuclear fuel in the dry storage is one of the important safeguarding tasks because the spent fuel contains significant quantities of fissile material.

Although traditional non-destructive analysis and assay techniques to verify contents are ineffective due to shielding of spent fuel and canister wall, straggling position of detector, etc., Manual measurement of the radiation levels present in the reverification tubes that run along the length of the canister to enable the radiation profile within the canister is presently the most reliable method for ensuring that the stored materials are still present. So, gamma-ray fingerprinting method has been used after a canister is sealed in Korea to provide a continuity of knowledge that canister contents remain as loaded.

The present study aims at test of current fingerprinting system using the MCNPX that is a well-known and widely-used Monte Carlo radiation transport code [1], which may be useful in the verification measures of the spent fuel subject with final disposal guidance criterion(4kg of Pu, 0.5 SQ)[2].

2. Methods and Results

2.1 CANDU Dry Storage

The canister is a cylindrical type silo that is 6.5 m of height with a 3.0 m of outside diameter. Two reverification tubes are placed on opposite at a distances of 71.02 cm from the central axis of the canister. A canister can contain as many as nine fuel baskets with 60 fuel bundles in each basket. Each bundle contains approximately 19.2 kg of UO_2 including 70g of Pu. Therefore, there is approximately 10.37 metric tons of uranium including 37.8kg of Pu in a single storage canister.

2.2 Source Term

The material composition and photon production spectrum of the CANDU spent fuel were evaluated using the fuel depletion code ORIGEN-ARP[3] with following assumptions: (a) All bundles are the same as CANDU reactor's spent fuel of 7500 MWd/MTIHM burnup and 10 years of cooling time. The photon production spectrum (Ph/s) per bundle is shown in Fig. 1. The integrated gamma ray intensity is 2.305×10^{13} ph/s per bundle. So the total integrated intensity was estimated to be 1.245×10^{16} ph/s.

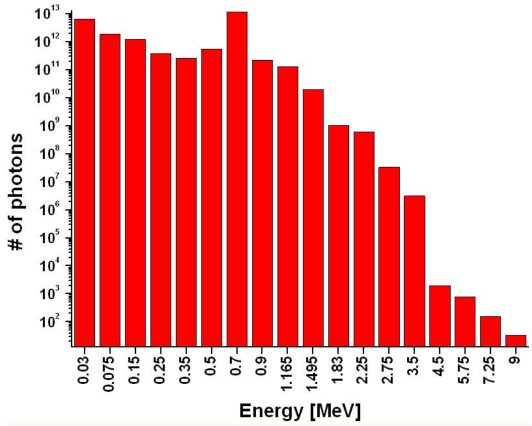

Fig. 1. Photon source spectrum per bundle for CANDU spent fuel of 7500 MWd/MTIHM burnup and 10 years of cooling time calculated by ORIGEN-ARP.

2.3 Simulation

Doses at the detector position were calculated using the Monte Carlo code system MCNPX^{TM}, version 2.5 with the energy deposition tally F6. Three possible cases, real spent fuel, dummy, and no material in the midst of basket, were simulated to evaluate the potentialities. The dimensions and materials of the canister provided by the manufacturer were inserted with following assumptions: (a) The individual bundles were a homogenized mixture containing approximately 24.2 kg of spent fuel element, air, and cladding material, (b) The total length of the CdZnTe detector was 232 cm divided by 307 equal parts with 2.38 cm of radius for reducing relative error, (c) The dummy bundles are made of stainless steel. The detailed model was constructed consisting of 540 fuel bundles, 9 fuel baskets, the concrete structure of the storage canister, and a detector placed in a reverification tube. The radius of the bundles is 5.125 cm and the length is 49.53 cm. These bundles were placed in the basket.

Figure 2 shows the vertical profile corresponding to the detection of gamma rays in each case. It can be seen that the doses of the detector were decreased to ~95% of the detector's base measurement for dummy and empty. Based on this result, it was found that current fingerprinting system have adequate performance to meet the guidance requirements for reverification.

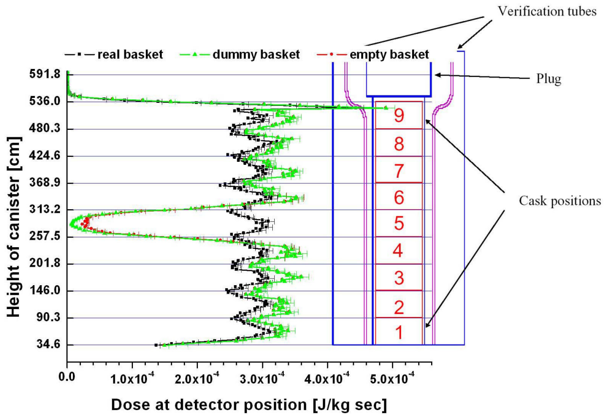

Fig. 2. Calculated gamma-ray fingerprinting response using CdZnTe with real, dummy, and empty basket.

3. Conclusion

In this study, ORIGEN-ARP and MCNPX calculations were performed to establish the expected gamma-ray source term from the CANDU spent fuel and to test the current fingerprinting system for reverification, respectively. It can be seen that the doses of the detector were decreased to ~95% of the detector's base measurement for dummy and empty. Based on this result, it was found that current fingerprinting system can be used to verify one basket. To verify the partial defect, however, further work is required.

REFERENCES

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