Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 23-24, 2019

Activation Property of HANARO Spent Fuel in Dense Storage Rack

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1. Introduction

Research reactor is used to produce medical and industrial isotope and to perform the experiment on developing semi-conductor, components, and nuclear fuel, which contributes to national welfare and health and nuclear industry or extra component industries. The storage capacity of the spent fuel is important not only for nuclear power plant, but also for research reactor. Before the amount of spent fuel reach its storing capacity, it is necessary to prepare the management measure of spent fuel and as it must not stop being operated up until the end of full lifespan.

HANARO spent fuel pool has enough space for the spent fuel to be generated for the future. However, it is necessary to make a long-term plan to prepare for the saturation of the storage. In this study, the safety of the storage was evaluated in terms of the dose rate distribution when the storage rack was replaced with a dense storage rack. Gamma-ray energy spectrum and dose rate are calculated at different distances from the spent fuel by using TRITON, ORIGEN-S, MCNP and QAD-CGGP.

2. Methods and Results

2.1 Characteristic of HANARO Fuel

HANARO uses standard and reduced fuel elements having a core diameter of 6.35 and 5.49 mm, respectively. Fuel meat consists of low enriched U_3Si dispersed in the aluminum matrix. There are two types of fuel assemblies. 36-rods fuel assembly (FA) is a hexagonal shape which is arranged in two inner hexagonal arrays with the standard elements and outermost array with the reduced ones. 18-rods fuel assembly is a cylindrical shape with the 18 standard elements. Initial enrichment of U-235 is 19.75 wt%. Major impurity nuclides in the fuel meat are B, Mg, Si, Cr, Mn and Fe. The amounts of uranium in the 36-rods and 18-rods fuel assemblies are 2.2 and 1.2 kg, respectively [1].

2.2 Generation of Nuclear Library

To estimate activity and dose rate of the spent fuels, source term calculated using nuclear reaction library for the HANARO core should be defined. The nuclear reaction library for the HANARO spent fuel was generated using the TRITON module in the SCALE-6.2 package code system [2]. Figure 1 shows the models of 36-rods and 18-rods fuel assemblies for the TRITON calculations. In the TRITON calculations, a burnup-specific nuclear library was generated for the initial enrichment of 0.5, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19 and 19.75 wt% of U-235. For the burnup of fuel, it is considered up to 120,000 MWD/MTU for 24 burnup points at 5,000 MWD/MTU intervals. In the calculation process, ENDF/B-VII.0 238-group neutron library was used for default library.

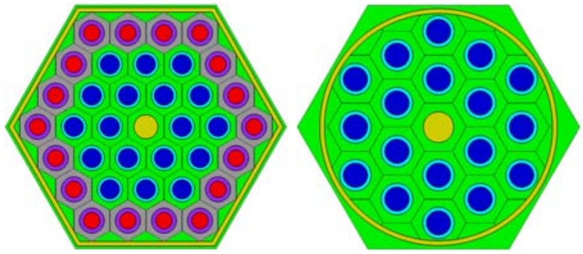

Fig. 1. Calculation models of 36-rods and 18-rods spent fuel assemblies for TRITON

2.3 Gamma-ray Spectrum

Decay gamma rays are main source of dose rate of the spent fuels. The gamma-ray energy spectrum was estimated by using the ORIGEN-S module in the SCALE-6.2 package code system. Burnup and decay time were considered, and the following conservative assumptions were applied for the estimation.

· Fuel is withdrawn after 8 operation cycles. Each operation cycle is composed of 28 days for operation and 14 days for cooling.
· Three 36-rods and two 18-rods fuel assemblies are withdrawn at each operation cycle.
· Average powers of the 36-rods and 18-rods fuel assemblies are 1.1166 MW/FA and 0.639 MW/FA, respectively.
· 30% of the relative uncertainty is considered for the calculation of gamma-ray spectrum.
· Numbers of bundles for the 36-rods and 18-rods spent fuel assemblies are 864 and 660, respectively.
· Decay time of the spent fuel assemblies are from 1 day to 3000 days.

Gamma-ray energy spectra for 36-rods fuel assembly by decay time are shown in Figure 2. As the decay time increases, the intensity of the gamma rays decreases, particularly, the intensity of low energy gamma rays decreases significantly.

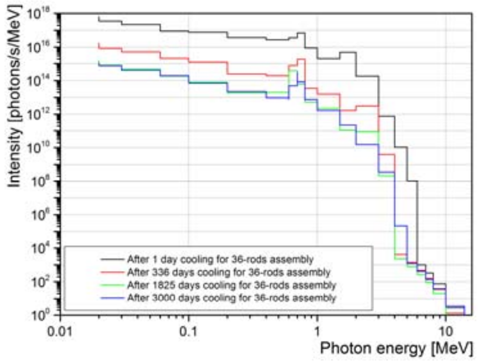

Fig. 2. Gamma-ray energy spectra for 36-rods spent fuel assembly by decay time

2.4 Dose Rate Distribution

Dose rate distribution around the dense storage rack was calculated by using the source term of the spent fuel assemblies. Dimension of the storage pool is 4 (W) × 4 (D) × 13.4 (H) m. The storage rack is immersed in a 12.2 m deep water pool. The storage pool structure which provides biological shielding is built using SUS-304 and heavy weight concrete with thickness of 9 mm and 1.5 m, respectively.

MCNP6.1, QAD-CGGP codes [3] and ICRP74 dose conversion factor were utilized for the calculation. For the calculation of dose rate along the lateral direction of the pool, all spent fuel assemblies were assumed to be located closest to the wall. On the other hand, all spent fuel assemblies were assumed to be located at the highest position of the storage rack for the calculation of dose rate along the upper direction of the pool water.

The resultant dose rate distributions are shown in Figures 3 and 4, respectively. In the Figure 3, the dose rate of the total spent fuel is 10 μSv/hr at the 172 cm from the spent fuel assembly which is surface of the concrete wall. Similarly, in the Figure 4, the dose rate decrease as the distance from the spent fuel assembly increases. The dose rate is 8.75E-7 μSv/hr at the 10 cm away from the surface of the water.

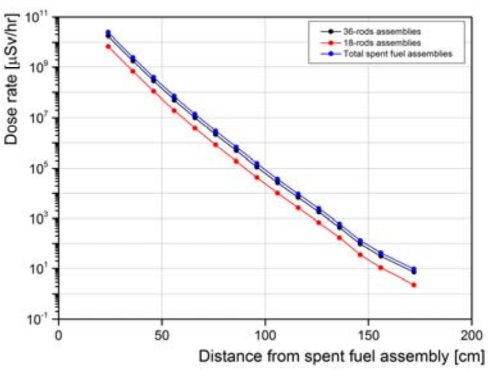

Fig. 3. Dose rate distribution along the lateral direction of the pool by distance from the spent fuel assembly

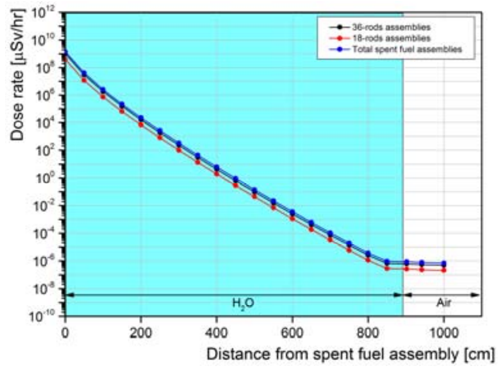

Fig. 4. Dose rate distribution along the upper direction of the pool water by distance from the spent fuel assembly

3. Conclusions

Activation property of HANARO spent fuel for dense storage rack was estimated by using the fuel burnup calculation code, the Monte Carlo neutron transport code and the point kernel shielding code. Gamma-ray energy spectrum and dose rate depend on the burnup and decay time of the spent fuel assemblies. From the calculation results of the dose rate around the spent fuel assemblies, it was confirmed that the dose rates on the surface of wall and on the surface of the concrete wall are significantly lower than the design basis value. In conclusion, the new dense storage rack is safe enough in current spent fuel pool in terms of radiation shielding.

REFERENCES

[1] HANARO Safety Analysis Report, KAERI/TR-710/96 (1996)

[2] U.S.NRC, SCALE/TRITON Primer: A Primer for Light Water Reactor Lattice Physics Calculations, NUREG/CR-7041, ORNL/TM-2011/21, 2012

[3] QAD-CGGP-A: Point Kernel Code System for Neutron and Gamma-Ray Shielding Calculations Using the GP Buildup Factor, RSICC-CCC-645, (1995).