Radiation Shielding Evaluation for Hydraulic Transfer System in Research Reactor

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1. Introduction

The KJRR project has been progressed to secure the supply of key medical and industrial radioisotopes (RIs) and to develop the core technologies of research reactors such as U-Mo fuel and etc. The major facilities to be built through the KJRR project are 1) 15 MW research reactor and building, 2) radioisotopes production facility, 3) fission Mo production facility, 4) radio-waste treatment facility, and 5) neutron irradiation facility [1]. The Hydraulic Transfer System (HTS) among neutron irradiation facilities is designed to be able to transfer the irradiation target by hydraulic power, and neutron irradiation experiment for various materials including Au and Ir can be performed in the HTS hole located inside of the core box. Since neutron irradiation time and specimen mass can be optimized depending on an irradiation material, it is necessary to perform a series of advance neutronics calculations with respect to radiation source and shielding.

In this study, radiation shielding calculations for the candidate HTS target are performed to be used for determining the instrument arrangement, operation parameter, and etc. In particular, the gamma-ray spectrum emitted from the irradiated target are analyzed by using ORIGEN-S [2], and some assumptions are employed to derive the conservative results. The dose rate distribution along to shielding thickness is also evaluated by using QAD-CGGP [3] which is known as a representative point kernel code.

2. Methods and Materials

The nuclear fuel of the KJRR is a typical Material Test Reactor (MTR) type fuel assembly, and two types of Fuel Assembly (FA), standard fuel assembly (SFA) and follower fuel assembly (FFA), are used for the core configuration. A fuel assembly consists of 21 Low Enriched Uranium (LEU) fuel plates (19.75 wt% ^{235}U), and a total of 22 FAs (16 SFAs and 6 FFAs) are loaded in the core (see **Figure 1**). Since the main purpose of the KJRR is to produce the RIs such as Mo-99, I-131, I-125, Ir-192, and etc., the irradiation holes for their production are arranged in between fuel assemblies inside the core. Irradiation holes for NTD are large enough to house a Silicon ingot with a diameter from of 6 inch up to 12 inches. Six NTD holes are provided outside the core, which are surrounded by the reflectors of beryllium and graphite to obtain the required thermal flux level. One HTS and two PTS are located inside and outside of the core box, respectively.

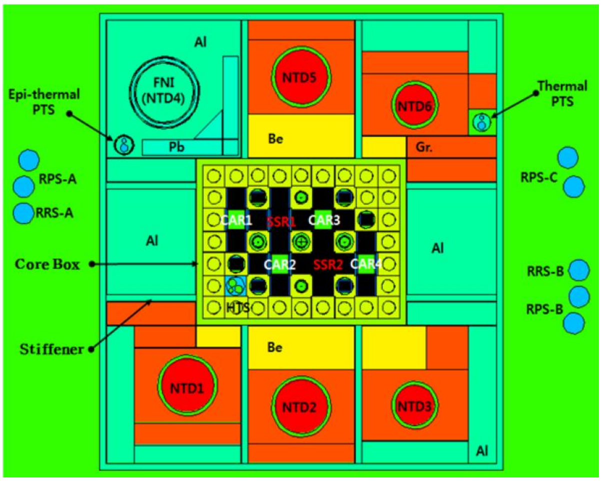

Figure 1. KJRR Core Configuration

In particular, three targets are simultaneously loaded in each loop of HTS, and a target is composed of specimen (Au or Ir), specimen holder, and Inner and Outer Targets. The material and mass of HTS target are presented in **Table 1**, and neutron irradiation time for this target is assumed to be 5 hours based on the total fluence required to produce ^{198}Au and ^{192}Ir isotopes. Regardless of specimen, the specimen holder loading Ir is assumed to derive the conservative results.

Table 1. Material and Mass of HTS Target

	Mass [g]	Material
Specimen	3	Au
	5.6	Ir
Inner Target	22	Al
Outer Target	99	
Specimen Holder	15 (Au) 30 (Ir)	

3. Results and Discussions

The KJRR has two loops to irradiate the HTS target, and six targets can be simultaneously loaded in the core. After neutron irradiation, those targets are moved to the Target Transfer Station (TTS), and it is necessary to analyze the water depth for shielding the gamma-rays emitted from the targets when temporarily being held. **Figure 2** shows the gamma-ray spectrum emitted from six HTS targets. As shown in figure, the radiation strength is gradually decreased along to the decay time, and the percentage of gamma-rays between 1 MeV – 2 MeV is relatively larger than others. The dose rate distribution as a function of water depth is evaluated based on the most conservative gamma-ray spectrum with respect to radiation shielding, which is performed by using QAD-CGGP code. As shown in **Table 2**, the water depth more than 340cm is required to decrease the dose rate less than 5 μSv/hr.

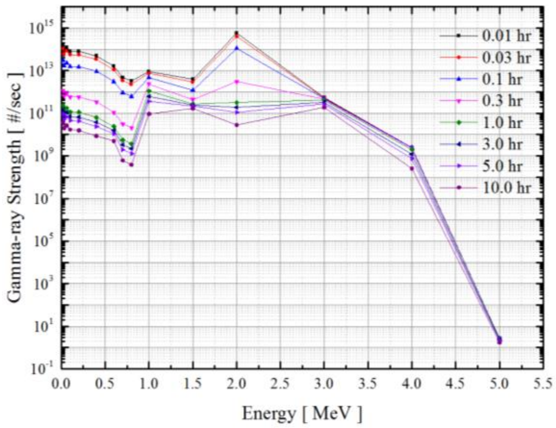

Figure 2. Gamma-ray Spectrum as a Function of Decay Time

Table 2. Dose Rate Distribution Along to Water Depth

Water Depth [cm]	Dose Rate [μSv/hr]	Water Depth [cm]	Dose Rate [μSv/hr]
1.00E+01	6.31E+09	2.20E+02	2.72E+03
2.00E+01	1.46E+09	2.30E+02	1.55E+03
3.00E+01	5.02E+08	2.40E+02	8.80E+02
4.00E+01	2.06E+08	2.50E+02	5.02E+02
5.00E+01	9.26E+07	2.60E+02	2.87E+02
6.00E+01	4.43E+07	2.70E+02	1.64E+02
7.00E+01	2.20E+07	2.80E+02	9.39E+01
8.00E+01	1.13E+07	2.90E+02	5.38E+01
9.00E+01	5.88E+06	3.00E+02	3.09E+01
1.00E+02	3.12E+06	3.10E+02	1.77E+01
1.10E+02	1.68E+06	3.20E+02	1.02E+01
1.20E+02	9.10E+05	3.30E+02	5.87E+00
1.30E+02	4.98E+05	3.40E+02	3.38E+00
1.40E+02	2.75E+05	3.50E+02	1.95E+00
1.50E+02	1.52E+05	3.60E+02	1.12E+00
1.60E+02	8.48E+04	3.70E+02	6.47E-01
1.70E+02	4.74E+04	3.80E+02	3.74E-01
1.80E+02	2.66E+04	3.90E+02	2.16E-01
1.90E+02	1.50E+04	4.00E+02	1.25E-01
2.00E+02	8.47E+03	-	-
2.10E+02	4.79E+03	-	-

** The calculation uncertainty of 30% is included in these results.*

4. Conclusion

The radiation shielding calculations for HTS target are performed to be used for determining the instrument arrangement, operation parameter, and etc., and the ORIGEN-S and QAD-CGGP codes are used for these calculations. Particularly, some assumptions in terms of neutron irradiation time and specimen holder are employed to derive the conservative results. As a result, the gamma-rays emitted from HTS target are mainly concentrated between the energies of 1 MeV and 2 MeV, and the water depth more than 340cm is required to decrease the dose rate less than 5 μSv/hr. It is expected that the above-mentioned results can be sufficiently applied as a reference data in the HTS system design.

ACKNOWLEDGEMENTS

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REFERENCES

[1] Chul-Gyo Seo, Innovative Design Concepts for the Ki-Jang Research Reactor, KNS Spring Meeting, May 30-31, 2013.
[2] B.J. Ade, SCALE/TRITON Primer: A Primer for Light Water Reactor Lattice Physics Calculations, Oak Ridge National Laboratory, ORNL/TM-2011/21, 2012.
[3] Vitisha Suman, D. Datta, P. K. Sarkar, and H. S. Kushwaha, Symbolic Math for Computation of Radiation Shielding, Indian Journal of Pure & Applied Physics, 48, p.787-, 2010.