Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 17-18, 2018

Preliminary Source Term Assessment on Kori unit 1 Radioactive Bioshield for Decommissioning

Donghyun Lee*, Hee Reyoung Kim
Nuclear Engineering, Ulsan National Institute of Science and Technology, 50, UNIST-gil, Ulsan 44949, Republic of Korea
**Corresponding author: calvinj1@unist.ac.kr*

1. Introduction

Since the decision of Kori unit 1 nuclear power plant decommissioning on June. 2017, the necessity of designing firm and economically efficient D&D project has been emerged. For laying out the project, precise identification on radioactive waste during the process should be preceded on ensuring scenario parameter designation. Especially, since large amount of the radioactive waste consists of concrete, it is crucial to assess the radioactive contamination on bioshield region which surrounds the reactor pressure vessel [1]. Large amount of neutron irradiation on bioshield due to over 30 years of operation, caused high neutron activation on the structure leading to contamination by various radionuclides. Despite of this importance, lack of geometric and material as well as operation history caused little precedent research on source term modeling. From conservative point of modeling on the source term, it is possible to achieve prediction of the amount of the radioactive waste and classification of clearance boundary which leads to analyze recycling possibility and worker safety during the D&D project. The study mainly focused on modeling 3D geometry of the RPV (Reactor Pressure Vessel) and source term, neutron flux distribution and concentration of major targeted radioactive nuclides.

2. Methods and Results

In this section detail physical model on 3D geometry floor plan of the Kori unit 1 RPV and MCNP6 model for designing the source term from neutron flux to activity of each targeted nuclide.

2.1 Physical Model

Kori unit 1 nuclear power plant RPV designing first requires 3D geometry modeling [2]. Normally it is possible to draw the RPV and bioshield into simple cylindrical shape, however precise outline of the structure constructed as cylinder with larger diameter on the down side and relatively smaller diameter on the upper side separated from the middle part of the bioshield. Although the targeted region is bioshield, it is necessary to model whole structure from reactor core to the bioshield for modeling transport of neutron from the core. Table I, shows distance of each part from the core on RPV and Fig. 1. presents 3D view of the whole structure. As well as for MCNP6 modeling for neutron transportation, material property on Table II (density and consisting nuclide) should be identified ahead.

Table I: Kori unit 1 reactor pressure vessel geometry [2]

Cell	Distance from the core (cm)
Core	138
Barrel	142
Bypass	146
Thermal shield	155
Downcomer	167
Pressure vessel	184
Air	316
Concrete (downer part)	530
Concrete (upper part)	500

Table II: Kori unit 1 bioshield material property [2]

Nuclide	Composition (#/barn-cm)
^{1}H	7.41E-03
^{16}O	4.21E-02
^{27}Al	2.28E-03
^{28}Si	1.52E-02
^{56}Fe	2.98E-04
^{23}Na	9.99E-04
^{24}Mg	1.41E-04
^{32}S	5.37E-05
^{39}K	6.61E-04
^{40}Ca	2.78E-03

2.2 MCNP6 Model

Neutron flux transport fluctuation has been modeled with MCNP6, general purpose Monte Carlo N-Particle computing code. 3D geometry and material which discussed on physical model had been in putted on basic structure of the code. For efficiency and accuracy of the neutron flux result, two variance reduction scheme have been applied. First, for accuracy as low relative error, importance management scheme has used. For steady number of inserted particles on each cell, different importance (Core (1), Barrel (2), Bypass (2), Thermal shield (2), Downcormer (2), Pressure vessel (2), Air (2), Concrete (2)) status had applied. Second, for engaging further transport of the particle from reactor core to end of the bioshield, forced collision method has been chosen. On each cell (Core (0.1), Barrel (0.1), Bypass (0.1), Thermal shield (0.1), Downcormer (0.1), Pressure vessel (0.1), Air (0.1), Concrete (0.1))

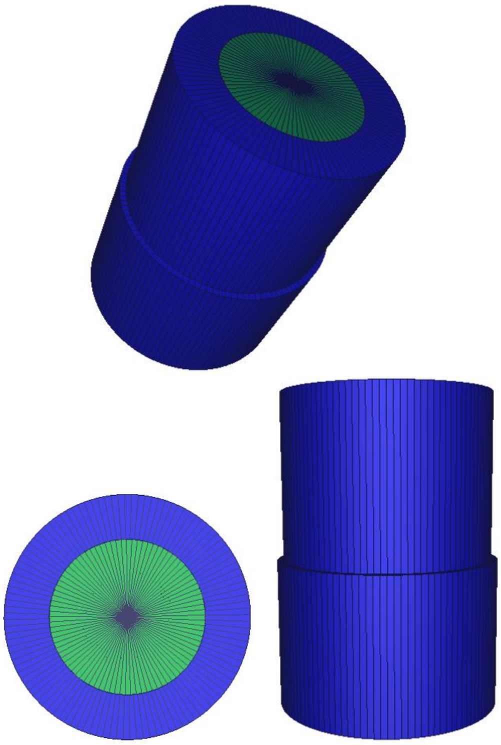

Fig. 1. Kori unit 1 nuclear power plant RPV 3D geometry

2.3 Radioactive contamination

After source term modeling via MCNP6 and neutron transportation, each radioactivity of targeted radio nuclide achieved through time dependent diffusion equation. ^{60}Co, ^{152}Eu and ^{154}Eu have been chosen since they held major percentage among the contamination on reference Trojan nuclear power plant, which has similar aspects as reactor type (PWR), geometric parameters and operation period (30 years of effective full power years) [1,3].

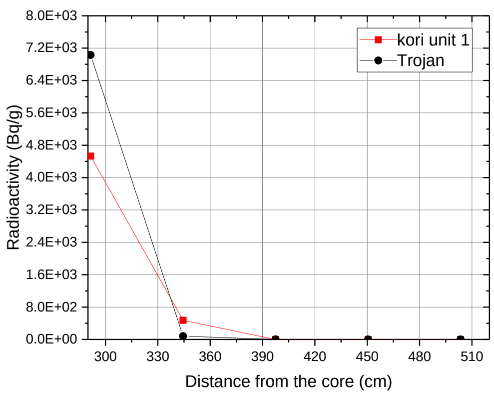

Fig. 2. ^{60}Co radioactivity on bioshield (Bq/g)

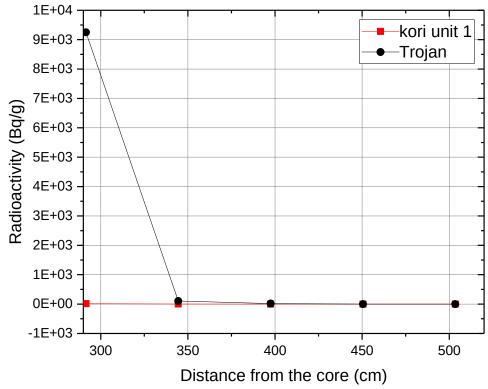

Fig. 3. ^{152}Eu radioactivity on bioshield (Bq/g)

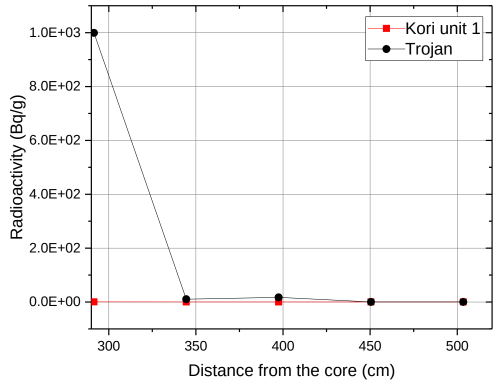

Fig. 4. ^{154}Eu radioactivity on bioshield (Bq/g)

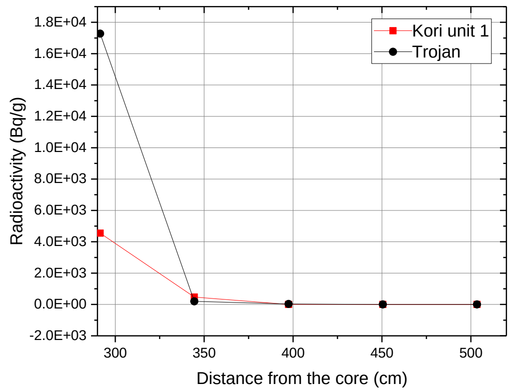

Fig. 5. Total radioactivity on bioshield (Bq/g)

In Fig. 2. Shows radioactivity of ^{60}Co for maximum 4.53E+03 Bq/g and minimum 7.86E-08 Bq/g. Fig. 3. Shows radioactivity of ^{152}Eu for maximum 1.42E+01 Bq/g and minimum 2.46E-10 Bq/g. Fig. 4. Shows radioactivity of ^{154}Eu for maximum 4.86E-01 Bq/g and minimum 8.43E-12 Bq/g. On Fig. 5, total radioactive contamination shows maximum 4.55E+03 Bq/g and minimum 7.88E-08 Bq/g. All data showed exponentially reducing trend as distance from the reactor core increases.

3. Conclusions

From Fig. 5, the total radioactivity positioned under 0.1Bq/g at 397cm region, which is clearance boundary followed by Nuclear Safety and Security Commission on Republic of. Although the actual license release should be assessed based on whole radionuclide, however based on related foreign nuclear power plant cases, Co and Eu hold most effects on contamination. Since the clearance boundary depends on total amount of radioactive nuclide existed further adding of nuclide with using ORIGEN could be enhance the conservativism of the result. In addition advance modeling of bioshield structural characteristic such as steel rebar could achieve more integrated result and trends for real contamination situation on the structure.

REFERENCES

[1] Radiological Characterization of Shut Down Nuclear Reactors for Decommissioning Purpose, International Atomic Energy Agency, Technical Reports Series No. 389, Vienna (1998)
[2] K. J. Lee, H. S. Kim, S. W. Shin, M. J, Song, and Y. K. Lee, Preliminary Estimation of Activation Products Inventory in reactor Components for Kori unit 1 decommissioning, J. Korea Asso. Radiat. Prot. Vol. 28 No.
[3] Republic of Korea Nuclear Safety and Security Commission, notice No.2014-003, Article 2, 2014.9.16