Preliminary Assessment of the Concrete Bioshield Radioactive Contamination for Decommissioning the Kori NPP unit 1

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

1. Introduction

Since the Kori unit 1 nuclear power plant reactor has been settled for decommissioning on June. 2017, it is necessary on radioactive contamination assessment for the facilities in order to design adequate D&D project breakdown process. Especially, due to relatively high absorption of neutron along reactor bioshield region, the radiological contamination concentration on the structure is comparatively higher than that of other components of the power plant. Therefore, it is necessary to assess the radioactive contamination on bioshield region. However, the study of the subject has been weak from the lack of geometrical information and the operation data library of the facility. In order to insure safety of the workers and economic efficiency of the D&D project, it is required to analyze the radioactive contamination through modeling the reactor area and analytic source-term approach. In the study, the neutron flux distribution and radioactivity concentration are analyzed using 3-dimensioanl geometric design parameters on the concrete structure for contamination assessment of the bioshield region.

2. Methods

In this section, physical model for facility modeling, mathematical model on source term design and numerical model with radioactive nuclei concentration calculation are described.

2.1 Physical Model

MCNP6 general purpose Monte Carlo N-Particle computing code is used for geometry design of the Kori unit 1 reactor vessel structure and nuclei concentration of each regional space. Although the main research object is to assess the bioshield structure, in order to design the source term physical model with neutron transport module, the defining of the entire space from reactor core to bioshield.

For designing the neutron flux distribution, first 3D geometry of the Kori unit 1 has to be defined [1]. The targeted regions are lined as reactor core (baffle), barrel (stainless steel), bypass (H_2O), thermal shield (stainless steel), downcorner (H_2O), pressure vessel (carbon steel), air and bioshield (concrete). For MCNP6 geometry model, the mechanical property of each regional structures should be inputted [1].

Second, the nuclei concentration on each structures should be added for transporting the neutron from reactor core to bioshield [1]. Each concentration converted into density on the region and later to radioactive nucleus radioactivity through diffusion equation from target nucleus.

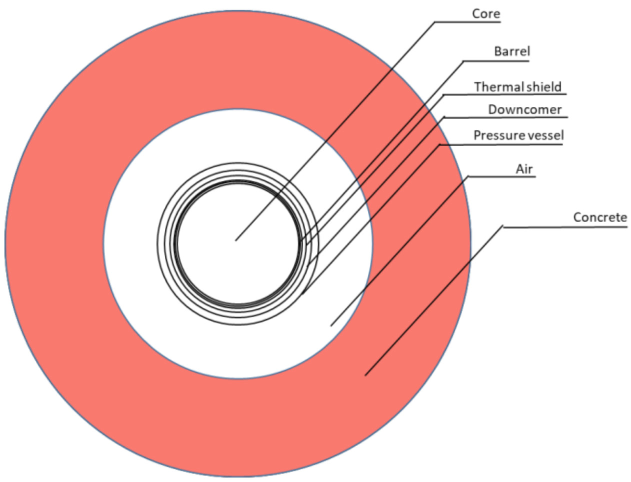

Fig. 1. Kori unit 1 reactor vessel 3D geometry (Top view)

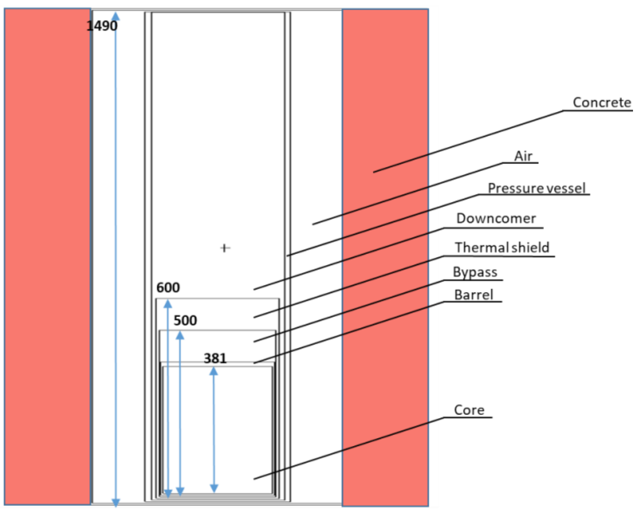

Fig. 2. Kori unit 1 reactor vessel 3D geometry (Side view, cm)

Table I: Kori unit 1 reactor vessel 3D geometry (top view)

Cell	Distance from the core (cm)
Core	138
Barrel	142
Bypass	146
Thermal shield	155
Down comer	167
Pressure vessel	184
Air	316
Concrete	530

Table II: Kori unit 1 reactor vessel bioshield nuclei concentration

Region		Concrete	
Nuclide	Mass number	Number	Weight
H	1	0.00741	1.23E-26
O	16	0.0421	1.12E-24
Al	27	0.00228	1.02E-25
Si	28	0.01524	7.09E-25
Fe	56	0.000298	2.77E-26
Na	23	0.001	3.82E-26
Mg	24	0.000142	5.65E-27
S	32	5.38E-05	2.86E-27
K	39	0.000661	4.28E-26
Ca	40	0.002782	1.85E-25
Total		0.071967	2.24E-24
Density			2.24

2.2 Mathematical Model

Radioactive contamination could be calculated from the diffusion equation using MATLAB and MS-EXCELL based on concentration of the targeted radioactive nucleus [2]. The diffusion equation is consisted of production term and diffusion term which is able from the result of neutron flux distribution on MCNP6 analysis.

The reactor core source is defined with using watt fission spectrum, power density, and volumetric neutron source equation since it has a cylindrical geometry [3]. The neutron flux (1)

$$\phi = \frac{Se^{-\frac{r}{L}}}{4\pi D r} \quad (1)$$

could be converted into concentration of targeted nuclei through radioactive decay equation with production linked with time dependence (2).

$$\frac{dn(t)}{dt} = \sum \phi C - \lambda n(t) \quad (2)$$

2.3 Numerical Model

^{60}Co is the target nuclei for assessing the concentration [3]. Since it is one of the major long term gamma radiation nucleus and its relatively simple decay chain enables efficient yet adequate analysis reliability.

3. Results

The neutron flux distribution on bioshield region assessed from maximum 4.26E+07 #/cm^{2}sec to minimum 6.54E-45 #/cm^{2}sec, and showed reduced corresponding along height and radius from the core. Followed by the neutron flux, ^{60}Co activity distribution showed from maximum 7.11E+04 Bq/g to minimum 1.01E-47 Bq/g. For confirming the reliability of the data the result has been compared with similar boundary conditioned previous assessed Trojan nuclear power plant (30 EFPY) data [3].

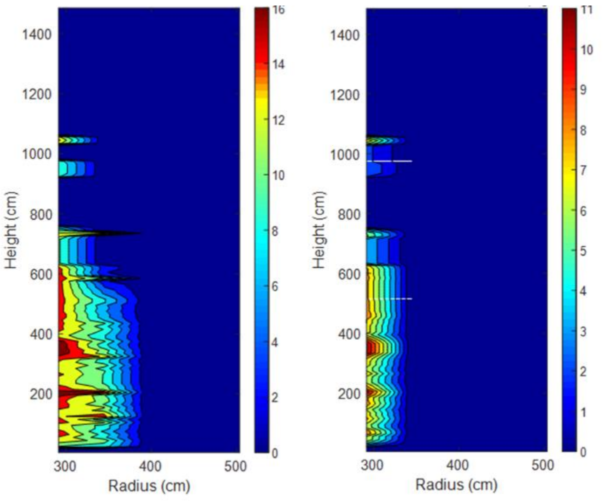

Fig. 3. Kori unit 1 bioshield average neutron flux distribution #/cm^{2}sec (left), ^{60}Co radioactivity Bq/g (right)

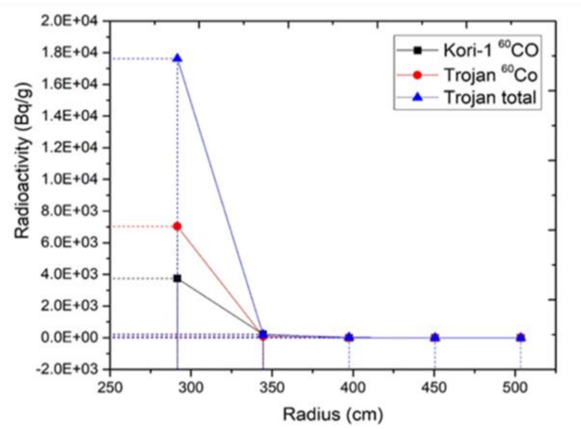

Fig. 4. Kori unit 1 bioshield average ^{60}Co radioactivity comparing with Trojan nuclear power plant

4. Conclusions

^{60}Co activity result on Kori unit 1 showed similar tendency on reducing in bioshield region. Especially after approximately 395cm from the reactor core the difference between Trojan case and assessed Kori unit 1 is negligible [4]. For encouraging on project reliability and assessment accuracy, not only ^{60}Co but also several other radioactive nuclei as ^{152}Eu should be considered further. In case of additional nuclei considered on the assessment, the clearance radius would be relatively further drifted apart from the reactor core. Despite of the significance of the subject, the radioactive containment on Kori unit 1 has been restricted only on 2D assessment. \However the result on 3D point view provided that not only radius but also height from the reactor core of the bioshield should be considered on designing D&D project of the unit.

REFERENCES

[1] 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. 2 : 109 – 116, 2003

[2] Accidental Safety Analysis Methodology Development in Decommission of the Nuclear Facility, KINS/ HR-445, 2002

[3] Radiological Characterization of Shut Down Nuclear Reactors for Decommissioning Purpose, International Atomic Energy Agency, Technical Reports Series No. 389, Vienna, 1998

[4] A state of the Art on the Technology for Reduction and Reuse of the Decommissioning Concrete Wastes, KAERI/ AR-800, 2008