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A Study on the Effect of Major Corrosion Products on Gamma Dose Rates during Preventive Maintenance Period of Yonggwang Nuclear Power Plant Unit 3

Wi-Ho HA*,a Jae Cheon KIM,a Soon Young KIM,b and Jong Kyung KIM,a
a Dept. of Nuclear Engr, Hanyang Univ., 17 Haengdang, Seongdong, Seoul,133-791, Korea
b Innovative Technology Center for Radiation Safety, Hanyang Univ.,17 Haengdang, Seongdong, Seoul, 133-791, Korea

1. Introduction

Information on radiation dose distribution inside the containment building (CB) of nuclear power plant (NPP) can be effectively used to decide evacuation route and time schedule for the workers [1]. Inspection and repairing works of major components are mainly performed during preventive maintenance period after reactor shutdown. During that period, most of gamma doses are induced by the major corrosion products in reactor coolant system (RCS).

In this study, activity levels of the major corrosion products presented in FSAR for Yonggwang NPP Unit 3 [2] were evaluated to accurately assess gamma dose during the preventive maintenance period. And, gamma dose contribution of the corrosion products other than cobalt isotopes which are the most significant sources of gamma exposure was quantified at the main working area inside the CB of the NPP.

2. Methodology

2.1. Evaluation of the Major Corrosion Products

Activity concentrations of major corrosion products in RCS during preventive maintenance period were evaluated by using CRUDSIM code [3] which is a computational code to predict the amount of the corrosion products and their radioactivity originated from RCS. It is known that CRUDSIM code gives the activity of only cobalt isotopes in the circulating crud inside RCS and the deposited crud at the surfaces of steam generator (S/G) and reactor core, individually. Even though the major corrosion products of concern are ^{58}Co and ^{60}Co in CRUDSIM code, some long-lived radionuclides as well as the cobalt isotopes were considered in this study to investigate the effect of the corrosion products other than cobalt on gamma dose rates. To do so, CRUDSIM code was modified by adding a new calculation module developed to calculate the activity levels of other corrosion products into the original CRUDSIM code.

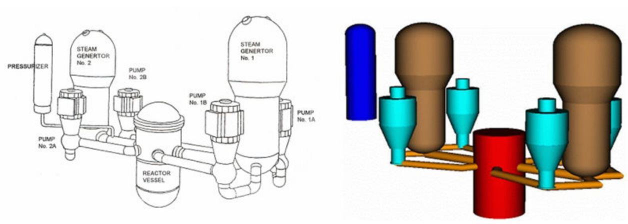
Activities of corrosion products depend on the several operating parameters. On the basis of Nuclear Design Report (NDR) [4] and FSAR for Yonggwang NPP Unit 3, both the geometrical condition of the RCS and chemical condition of coolant were employed as input data of the modified CRUDSIM code. Table 1 shows the activities of the major corrosion products calculated by the modified CRUDSIM code.

Table 1. Calculation Results of Activities of the Corrosion Products by Using Modified CRUDSIM code

CRUD	Coolant (μCi/cm^3)	Reactor Core (μCi/cm^2)	S/G (μCi/cm^2)
^{60}Co	3.004×10^{-4}	1.833×10^{2}	4.786×10^{-1}
^{58}Co	8.642×10^{-4}	5.454×10^{2}	1.374×10^{0}
^{54}Mn	8.798×10^{-5}	5.504×10^{1}	1.403×10^{-1}
^{51}Cr	5.651×10^{-4}	3.697×10^{2}	8.877×10^{-1}
^{59}Fe	5.785×10^{-5}	3.698×10^{1}	9.158×10^{-2}

2.2. MCNP Geometry Modeling

Prior to the calculation of gamma dose rates, modeling of the CB was performed by using MCNPX code[4]. Geometry modeling was based on the actual design for the CB of Yonggwang NPP Unit 3. The principal interests of MCNP modeling are the structures affecting the radiation field distribution at the main working area. Therefore, major components such as reactor core, S/G, and reactor coolant pump (RCP) were modeled in this study. Their geometry is identically modeled, and their material composition is homogenized on the basis of the actual design. The shielding walls inside the CB are mostly composed of concrete, and floor layers of them are located at the height levels of 100, 122, and 142 ft. Figure 1 shows the actual design and MCNP modeling result of the major components.



A. Actual Design B. MCNP Modeling
Figure 1. Actual Design and MCNP Modeling Result of the Major Components

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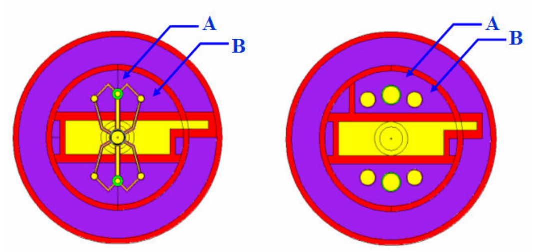
* Present Address: National Radiation Emergency Medical Center, Korea Institute of Radiological & Medical Science, Seoul, Korea

3. Results

Activities of the major corrosion products in RCS calculated by using the modified CRUDSIM code were employed as gamma sources during preventive maintenance period inside the CB. It is assumed that the circulating crud exists inside the primary coolants passing through RCS, S/G, RCP, and refueling pool. Deposited crud was employed only at the surfaces of reactor core and S/G. The ambient dose equivalent was calculated by using Mesh Tally option of MCNPX code [5, 6].

The gamma dose rates were analyzed at the main working area. Also, gamma dose contribution of each radionuclide was evaluated, respectively. Figure 2 shows the calculation points at the main working area. Table 2 presents the calculation results of gamma dose rates and the gamma dose contribution of cobalt isotopes and other corrosion products employed in this study at the height levels of 100 and 122 ft.



A. 100 ft B. 122 ft

Figure 2. Calculation Points at the Main Working Area

Table 2. Calculation Results of the Gamma Dose Rates and the Gamma Dose Contribution at the Main Working Area inside the CB

Height Level \ Calculation Point	A (μSv/hr)		B (μSv/hr)	
	Cobalt (%)	Others (%)	Cobalt (%)	Others (%)
100 ft	941		131	
	91.1	8.9	90.8	9.2
122 ft	63.0		16.1	
	91.0	9.0	90.1	9.9

It is noted that the average fraction of gamma dose contribution of cobalt isotopes and other corrosion products were found to be 90.7% and 9.3%, respectively. From the results, gamma dose evaluated by original CRUDSIM code can be underestimated by about 10%. The statistical errors of gamma dose rates calculated by MCNPX code were within 3% at all points.

4. Conclusions

In this study, gamma dose contributions of cobalt isotopes and other corrosion products in RCS were quantified during preventive maintenance period of Yonggwang NPP Unit 3. As the results, it is noted that gamma dose contribution of other corrosion products approaches up to about 10% of total gamma dose. Therefore, in the evaluation of gamma dose in CB of NPP, some corrosion products other than cobalt isotopes such as Mn, Cr, and Fe need to be considered for more accurate calculation of gamma dose in CB.

Acknowledgement

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