Assessment of Radiation Dose Rates for Workspace of Pressurizer in Nuclear Power Plant

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1. Introduction

Approximately 80% of the total radiation dose to workers in nuclear power plants occurs during overhaul period [1]. During the overhaul period, the pressurizer maintenance is one of the works performed, and maintenance workers can be exposed to high-energy gamma radiation from the CRUD(Chalk River Unidentified Deposit) deposited inside the pressurizer.

In particular, some maintenance on pressurizer is likely to be performed in the vicinity of the CRUD deposited in the lower part of the pressurizer. As a result, maintenance workers of pressurizer can be exposed to relatively high radiation dose. Therefore, prior to performing work on a pressurizer, the radiation dose should be assessed to determine the level of worker exposure.

The purpose of this study is to assess the radiation dose rates in the workspace around the pressurizer before evaluating the radiation dose to the pressurizer maintenance workers. For this purpose, the following procedures were established: 1) MCNP simulation of the pressurizer, and 2) assessment of the radiation dose rates in workspace.

2. Material and Methods

2.1 Simulation of the pressurizer

Fig. 1 shows the geometric structure of the simulated pressurizer in this study and the source term. The pressurizer was simulated using the MCNP6 computer code. The pressurizer of APR1400, the most recent model of domestic nuclear power plant, was simulated. To simulate the 1) geometric structure and 2) deposited CRUD of the pressurizer, the APR1400 design control documents (DCD) were analyzed [2-3].

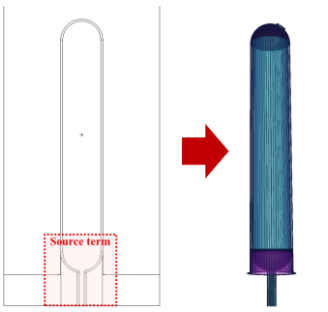

Fig. 1 Geometric structure and source term of simulated pressurizer

In this study, the geometric structure of the pressurizer's surge line, lower head, upper head, and pressurizer body shell were simulated. The nozzles and pipes on the upper part of the pressurizer and the heater on the lower part of the pressurizer were excluded from the simulation because they were considered to have a negligible effect on the radiation dose rates in the workspace. Also, the coolant inside the pressurizer was assumed to be drained.

Table 1 shows the deposited CRUD activities by nuclides in the APR1400 DCD. The CRUD deposited inside the pressurizer was simulated to set up the source term. For this purpose, the CRUD deposition area was set and the gamma ray emissions per unit area was evaluated by CRUD deposition area. The CRUD deposition area was set as the surge line and the lower head. The equilibrium thicknesses of the deposited CRUD for the surge line and the lower head were set to 1.2×10^{-3} and 6.5×10^{-4} g·cm^{-2}, respectively, presented in the APR1400 SAR. To set the gamma ray emissions per unit area from the CRUD, the gamma rays emitted by the six nuclides in the APR1400 DCD were considered. And the gamma ray emissions per unit area derived from the specific activities of each nuclide, the equilibrium thickness of the deposited CRUD, and the gamma ray yield by energy were set as the source term.

Table 1. Deposited CRUD activities by nuclides

Nuclides	Half Life (days)	Activity (Bq/g-CRUD)
Cr-51	27.70	7.31×10^{9}
Mn-54	312.3	1.99×10^{7}
Fe-59	44.50	4.18×10^{7}
Co-58	70.82	1.77×10^{9}
Co-60	5.272	6.22×10^{7}
Zr-95	64.02	4.90×10^{7}

2.2 Assessment of dose rates

The radiation dose rates in the workspace were assessed using a simulated pressurizer. The radiation dose rates in the workspace were assessed using the Mesh tally function of MCNP computer code. The 10 m × 10 m space outside the pressurizer was divided into a grid with 50 cm spacing, and the radiation dose rates at each point were evaluated. The radioactivity of the CRUD utilized in the dose rate assessment was derived from the specific activities by each nuclide presented in

the APR1400 DCD, the equilibrium thickness of the deposited CRUD, and the deposited area.

3. Results and Discussion

3.1 Results in simulation of the pressurizer

Fig. 2 shows the radiation field inside the pressurizer simulated in this study. As a result of the computational simulation of the pressurizer, the radiation dose rates due to the CRUD deposited inside the pressurizer were higher in the lower part of the pressurizer. And the center of the pressurizer showed a relatively higher radiation dose rates than the periphery. This is because the equilibrium thickness of the CRUD deposited in the surge line is about twice that of the CRUD deposited in the lower head. As a result, the gamma ray emissions per unit area from the surge line located in the center of the pressurizer are relatively high, leading to a higher radiation dose rates in the center of the pressurizer.

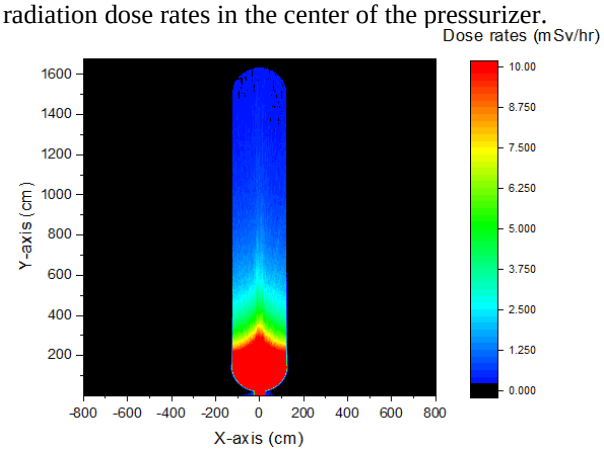

Fig. 2 Radiation field inside the pressurizer

3.2 Results in assessment of dose rates

Fig 3. Shows the radiation dose rates of the workspace around the pressurizer assessed in this study. Excluding the assessment points inside the pressurizer, a total of 376 points were assessed. The results showed that the dose rates ranged from about 8.06×10^{-4} to 1.78×10^{-2} mSv·hr^{-1} for the entire workspace. The radioactivity of the source term set for the dose rate assessment in this study was derived based on the specific activity presented in the APR1400 DCD. The specific activity of the CRUD in the APR1400 DCD were found to be a conservative value evaluated using conservative factors [3]. Therefore, the results of the dose rate assessment of the workspace around the pressurizer are also considered to be somewhat conservative.

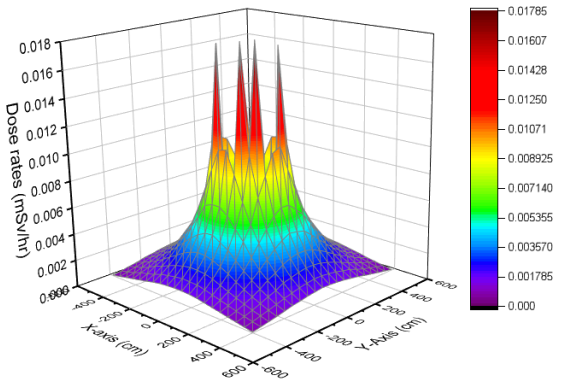

Fig. 3 Radiation dose rates of the workspace

4. Conclusions

In this study, a radiation dose rate assessment was conducted for the workspace around the pressurizer in the nuclear power plant. To evaluate the radiation dose rate in the workspace, the study was conducted in the following procedures: 1) MCNP simulation of the pressurizer, and 2) assessment of the radiation dose rate in the workspace.

The results of the workspace radiation dose rate evaluation showed that the radiation dose rates ranged from 8.06×10^{-4} to 1.78×10^{-2} mSv·hr^{-1} for the entire workspace. Since the specific activities by nuclide used in this study to assess the radiation dose rates are somewhat conservatively evaluated, the radiation dose rates of the workspace are also considered to be conservatively derived.

The results of this study can be used as a basis for the dose assessment of pressurizer maintenance workers during overhaul period.

ACKNOWLEDGEMENTS

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