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The shielding calculation for the CN guide shielding assembly in HANARO

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1. Introduction

The cold neutron research facility in HANARO is under construction. The area including neutron guides and rotary shutter in the reactor hall should be shielded by the guide shielding assembly which is constructed of heavy concrete blocks and structure. The guide shielding assembly is divided into 2 parts, A and B, as shown in Fig. 1. Part A is about 6.4 meters apart from the reactor biological shield and it is constructed of heavy concrete blocks whose density is above 4.0g/㎤. And part B is a fixed heavy concrete structure whose density is above 3.5g/㎤. The rotary shutter is also made with heavy concrete whose density is above 4.0g/㎤ and includes 5 neutron guides inside. It can block the neutron beam by rotating when CNS is not operating. The dose criterion outside the guide shielding assembly is established as 12.5μSv/hr which is also applied to reactor shielding in HANARO.

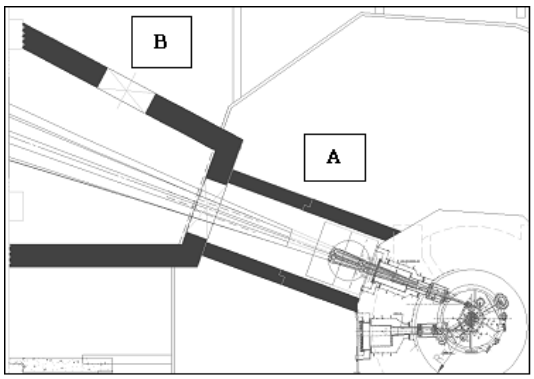

Fig. 1 Conceptual drawing of guide shielding assembly

2. Methods and Results

2.1 Radiation Source

The purpose of guide shielding assembly is to protect the neutrons and gammas from the neutron guides and rotary shutter. For shielding calculation of the guide shielding assembly, the neutron and gamma were used as a primary radiation source which was already evaluated at the boundary between reactor pool and reactor biological shield. The neutron and gamma fluxes and the angular distribution of neutron at the boundary are presented in Table 1 and 2.

Table 1 Neutron and gamma fluxes at the boundary between reactor pool and reactor biological shield

	Flux (#/㎠•s)
Thermal (E<0.625eV)	3.29E+11
Epi-thermal (0.625eV<E<10keV)	1.27E+10
Fast (E>10keV)	4.69E+09
Gamma	1.67E+11

Table 2 Angular distribution of the neutrons at the boundary between reactor pool and reactor biological shield

Polar angle	Angular distribution of radiation	
	fraction	Cumulative fraction
0 ~ 1°	2.35 %	2.35 %
1 ~ 2°	6.92 %	9.27 %
2 ~ 3°	10.66 %	19.93 %
3 ~ 5°	26.09 %	46.02 %
5 ~ 10°	42.67 %	88.69 %
10 ~ 30°	7.86 %	96.55 %
30 ~ 90°	3.45 %	100 %

2.2 Dose rate inside the guide shielding assembly

The shielding calculation of the guide shielding assembly was performed by MCNP-4C code. It was difficult to calculate a reliable dose rate outside the guide shielding assembly by MCNP code because of the calculation time and errors created from the long neutron guides more than 14 meters and the thick heavy concrete shield with several meters. But it was possible to calculate the dose rate inside the guide shielding assembly by describing simply the in-pile plug, CN guides and rotary shutter in the MCNP calculation. Using the simple model of them, the dose rate inside the guide shielding assembly was calculated when the rotary shutter was both opened and closed. But the dose rate when the rotary shutter was closed couldn't be obtained due to the shielding effect by a thick heavy concrete of 4m in thickness. If the dose rate is below the criterion when rotary shutter is opened then the dose rate also will be below the criterion when rotary shutter is closed. The dose rate inside the guide shielding assembly was calculated by MCNP-4C using F4 tally and the dose conversion factor (ANSI/ANS-6.1.1-1977), at the positions which were shown in Fig. 2 and 3.

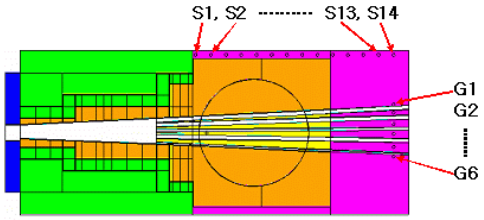

Fig. 2 Horizontal tally positions in MCNP calculation

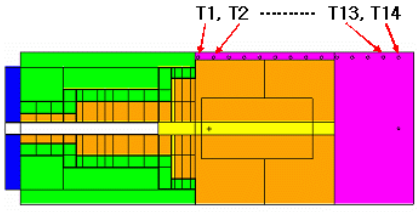

Fig. 3 Axial tally positions in MCNP calculation

As the result of MCNP calculation when rotary shutter is opened, the maximum dose rates by neutrons and gammas were evaluated about 1.36E-03 Sv/hr and 2.93E-04 Sv/hr, respectively. The total dose rate inside the guide shielding assembly was evaluated less than 1.65E-03 Sv/hr.

2.3 Attenuation in the heavy concrete shield

The dose rate outside the guide shielding assembly was evaluated by using the maximum dose rate inside the guide shielding assembly and the dose attenuation rate of neutron and gamma in the heavy concrete. The dose attenuation rate of neutron and gamma in the heavy concrete was evaluated with a conservative assumption that the neutron and gamma sources are mono-directional. Fig. 4 shows the calculation model.

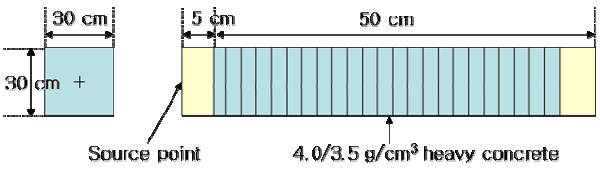

Fig. 4 MCNP calculation model for the dose attenuation rate

2.4 Dose rate outside the guide shielding assembly

From the calculation results of the dose attenuation rate for neutron, the 1/10 attenuation thickness for dose rate was evaluated as 18cm and 21cm, respectively when the densities of heavy concrete are 4.0g/㎤ and 3.5g/㎤. In case of gamma, the 1/10 attenuation thickness was evaluated as 25cm and 27cm, respectively when the densities of heavy concrete are 4.0g/㎤ and 3.5g/㎤. Therefore, the results of dose rate outside the guide shielding assembly using the 1/10 attenuation thicknesses of neutron and gamma in heavy concrete are calculated as follows.

1) Neutron dose rate outside of the guide shielding assembly
a. 4.0g/㎤ heavy concrete(50cm) : 2.27 μSv/hr
b. 3.5g/㎤ heavy concrete(80cm) : 0.21 μSv/hr

2) Gamma dose rate outside of the guide shielding assembly
a. 4.0g/㎤ heavy concrete(50cm) : 2.93 μSv/hr
b. 3.5g/㎤ heavy concrete(80cm) : 0.32 μSv/hr

Therefore the total dose rates outside the guide shielding assembly are evaluated 5.2μSv/hr and 0.53μSv/hr respectively for part A with 4.0g/㎤ and part B with 3.5g/㎤, heavy concrete. The total dose rates outside the guide shielding assembly are satisfying the design criteria.

3. Conclusion

The dose rate outside the guide shielding assembly was evaluated using the neutron and gamma sources at the boundary between reactor pool and reactor biological shield. The dose rate inside the guide shielding assembly was calculated using the MCNP code with the simple calculation model of the in-pile plug, CN guides and rotary shutter. And then the dose rate outside the guide shielding assembly was calculated using the 1/10 attenuation thickness of neutron and gamma in heavy concrete. The total dose rate outside the guide shielding assembly was evaluated as less than 5.2 μSv/hr which is satisfying the shielding design criteria, 12.5 μSv/hr.

Acknowledgement

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