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

Neutron shielding design for a neutron generator

Jeong-Tae Jin*, Byung-Hoon Oh, Seok-Kwan Lee, Dae-Sik Chang, Sung-Ryul Huh, Bong-Ki Jung, Sang-Jin Lee**
Korea Atomic Energy Research Institute, 111 Daedeok-daero 989, Yuseong-gu, Daejeon, Korea
***Institute for Basic Science, 70 Yuseong-daero 1689-gil, Yuseong-gu, Daejeon, Korea*
**Corresponding author: jtjin@kaeri.re.kr*

1. Introduction

Neutron generators can be excellent tools for materials analysis, explosive material detection, nuclear weapon detection, and high quality radiography [1]. Recently, a high-flux movable D-D neutron generator with an output flux of 1 x 10^{10} n/s is being developed at Korea Atomic Energy Research Institute.

To test the characteristics of the neutron generator, we designed a neutron shielding system to shield the neutrons generated by it. The shielding system constitutes a primary shielding system of polyethylene of 500 mm thickness and a secondary shielding system of concrete of 800 mm thickness. In consideration of sufficient safety, Monte Carlo simulation was performed assuming that the neutron source of 10^{11} n/s, and the dose outside the secondary shield system was evaluated as 0.0048 uSv/h.

On the other hand, in the neutron generator, Bremsstrahlung X-rays are also generated, but detailed shielding design for this will be omitted in this presentation. However, according to the evaluation, it was found that the X-ray shielding was possible with lead of 5 mm thick.

2. Neutron shielding design

2.1 Neutron shielding system

The shielding system was designed based on the neutron maximum flux 1 x 10^{11} n/s and dose evaluation was carried out. As shown in Figure 1, the shielding system consists of a primary and a secondary system made of polyethylene and concrete, respectively. Figure 2 shows a Monte Carlo simulation model for neutron shielding evaluation. The primary shielding result was the dose of point 1 and the result of the secondary shielding was evaluated by point 2 ~ point 5.

2.2 Dose evaluation by Monte Carlo simulation and configurations of primary shielding system

Figure 3 shows the dose outside of the shielding system when the neutron source is 1 x 10^{10} n/s and there is only a secondary shield system of concrete of 800 mm thickness. So in the case of only the secondary concrete shielding system, when the neutron flux is 1 x 10^{10} n/s or more, since the dose from the outside of the shielding system exceeds the safety value, an additional shielding is necessary.

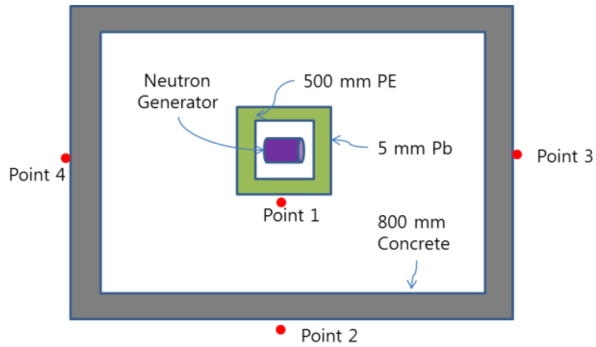

Fig. 1. Configuration of the shielding system.

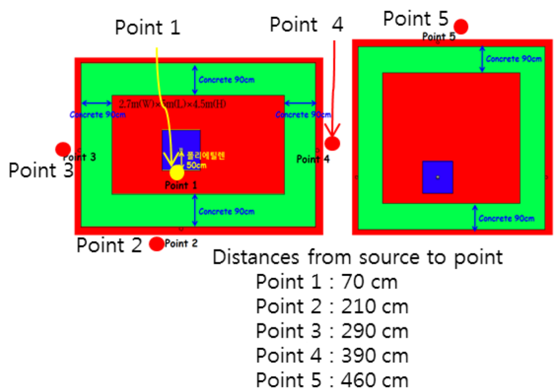

Fig. 2. A Monte Carlo simulation model for neutron shielding evaluation;
(Concrete: 2.7m(W)x5m(L)x4.5m(H)).

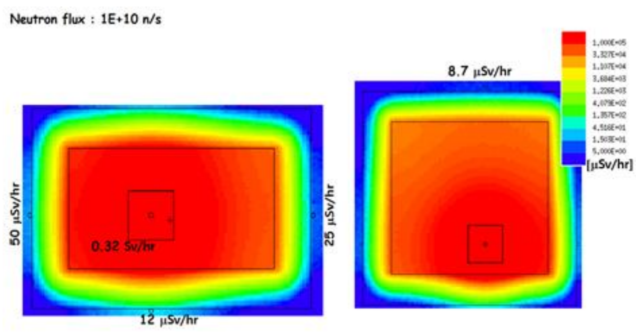

Fig. 3. Dose outside of the shielding system when the flux of the neutron source is 1 x 10^{10} n/s and there is only a secondary shielding system of concrete of 800 mm thickness.

Figure 4, 5, and 6 show the dose at the outside of the primary shielding system and at the outside of the secondary shielding system when the neutron fluxes are 1 x 10^{10} n/s, 5 x 10^{10} n/s, and 1 x 10^{11} n/s, respectively. As shown in the evaluation results, when primary and secondary shielding systems are provided, even when neutron flux is 1 x 10^{11} n/s, the dose outside of the secondary shielding system can be found to be below the safety value.

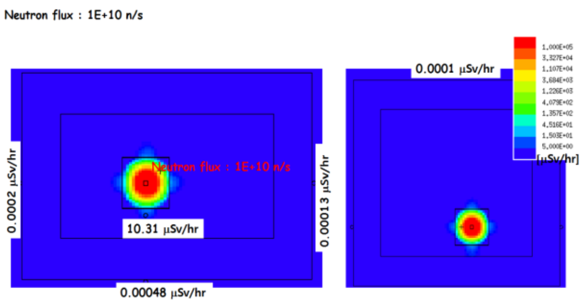

Fig. 4. Dose at the outside of the primary shielding system (10.31 uSv/h) and at the outside of the secondary shielding system (0.00048 uSv/h) when the neutron flux is 1 x 10^{10} n/s.

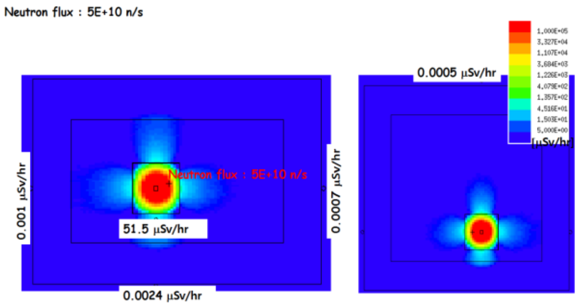

Fig. 5. Dose at the outside of the primary shielding system (51.5 uSv/h) and at the outside of the secondary shielding system (0.0024 uSv/h) when the neutron flux is 5 x 10^{10} n/s.

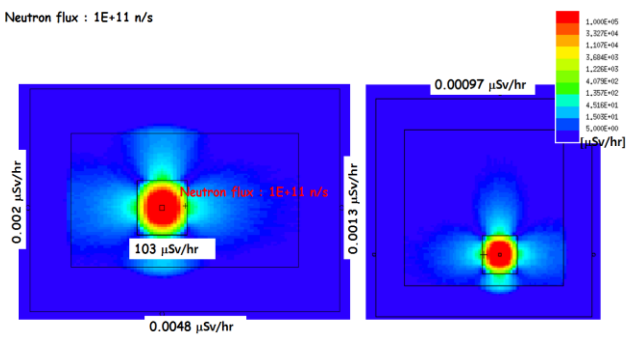

Fig. 6. Dose at the outside of the primary shielding system (103 uSv/h) and at the outside of the secondary shielding system (0.0048 uSv/h) when the neutron flux is 1 x 10^{11} n/s.

Figure 7 shows the basic configuration of a primary shielding system consisting of 5 layers of 100 mm thick polypropylene. The step-like structure between the plate and plate minimizes the neutron leakage. Figure 8 is a configuration that considers the access space of power cables, bellows for vacuum exhaust, etc. [2, 3].

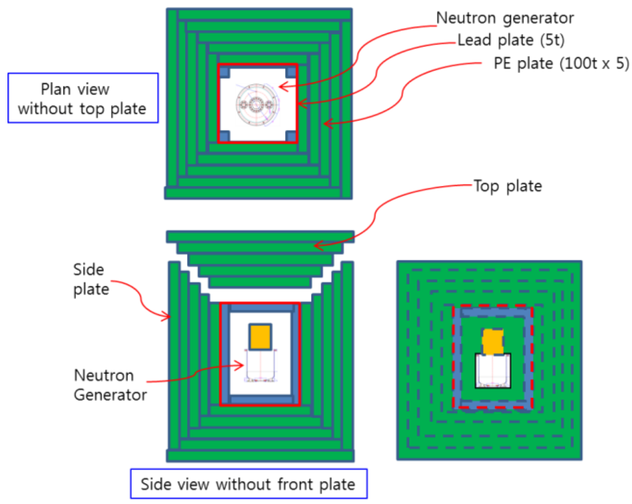

Fig. 7. Basic configuration of a primary shielding system.

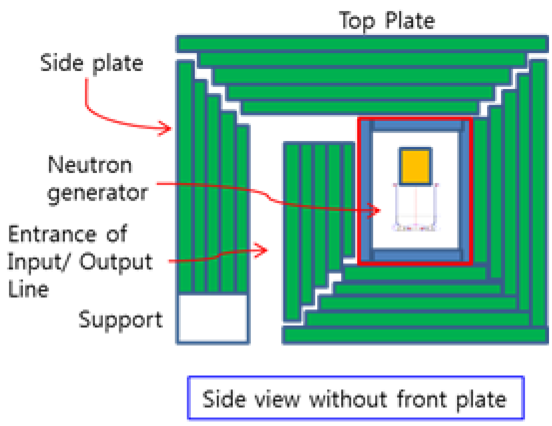

Fig. 8. A configuration that considers the entrance of input and output lines for the neutron generator.

3. Conclusions

A shielding system was designed to shield the neutrons generated by the neutron generator with an output flux more than 1 x 10^{10} n/s. It constitutes a primary shielding system of polyethylene of 500 mm thickness and a secondary shielding system of concrete of 800 mm thickness.

Monte Carlo simulation was performed assuming that the neutron source of 10^{11} n/s, and the dose outside of the secondary shielding system was evaluated as 0.0048 uSv/h, indicating that the neutron shielding is sufficient.

The primary shielding system consists of 5 layers of 100 mm thick polypropylene and have a step-like structure between the plate and plate to minimize the neutron leakage.

REFERENCES

[1] Ian S. Anderson, Robert L. McGreevy, Hassina Z. Bilheux, "Neutron Imaging and Applications", Springer.

[2] National Council on Radiation Protection and Measurements, "Structural shielding design and evaluation for medical use of X rays and gamma rays of energies up to 10 MeV", NCRP report No. 49. 2009.

[3] Korean Agency for Technology and Standards, " Nuclear facilities-Ventilation penetrations for shielded enclosures" KS A ISO 15080, 2012.