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Shielding Analysis for a Lead Slowing Down Time Spectrometer System

K.Y. Noh[*], C.J. Park, Y.D. Lee, J.W. Lee
Korea Atomic Energy Research Institute, 150 Deokjin-dong, Yuseong-gu, Daejeon, Republic of Korea, 305-353
[*]*Corresponding author: ky-noh@kaeri.re.kr*

1. Introduction

A lead slowing down time spectrometer(LSDTS) system has been designed in order to analyze the contents of the special materials such as U-235, Pu-239, Pu-241[1][2]. However, the target in LSDTS emits a high intensity of neutron and gamma rays when operating. For example, a typical neutron yield of LSDTS is about 1E+12 neutrons/s[3][4]. In this study, a preliminary shielding evaluation was carried out with a simplified model of the LSDTS system in order to protect neutron. The MCNPX code[5], a popular Monte Carlo three dimensional code, was used and a sensitivity study was also performed for the shielding thickness and materials. Additionally, Variance reduction with geometric splitting technique was tried in order to get highly efficient results.

2. Methods and Results

Three materials were considered to evaluate the shielding analysis for LSDTS: polyethylene, B_4C, normal and concentrated concrete. The medium of LSDTS is full of pure lead blocks, which provides an inherent radiation shielding effect.

The geometric splitting card, importance are assigned to each cell in the problem, were used in the MCNPX modeling to get computational efficiency. The point source was assumed to be positioned at the origin in all models. The surface dose rate was converted from surface flux based on the ICRP-21 conversion factor sets.

2.1 Normal B_4C and Concentrated B_4C shielding

The simplified model is depicted in Fig. 1. The shielding material is used for lead, air, polyethylene, B_4C and concrete. The thickness of lead, air, polyethylene, B_4C and concrete are 50 cm, 1 m, 18 cm, 1~20 cm and 50 cm. Dose rate is observed as thickness of B_4C is changing from 1 cm to 20 cm. Many geometry splitting was taken. The initial intensity of neutron was 1E+12 neutrons/s. Therefore, concrete inquires 12 cm and 17 cm when the concentrated B_4C and the normal B_4C are used. For both B_4C shielding cases on the outer surface of concrete, the dose rate was obtained in Fig. 2.

2.2 Heavy concrete and polyethylene shielding

The pure lead, air, polyethylene and heavy concrete were considered for neutron shielding analysis. This model informed of how much the dose rate was changed when the polyethylene was increased.

Fig. 3. shows the results for heavy concrete with various thicknesses. From the analysis, the dose rate is decreased in proportion to the increasing of polyethylene thickness. It was found that more neutrons slowed down after they passed through the polyethylene. The surface dose rate on the outer concrete wall was estimated about 1 mSv/h which is higher than the public dose rate criterion. Therefore, more investigation should be performed to reduce the dose rate to satisfy the criteria.

2.3 Various conditions

With the previous investigation, it was found that B_4C and polyethylene are effective to decrease dose rate. Therefore, various conditions were considered for neutron shielding such as different concrete, polyethylene and B_4C thickness.

Table 1. shows the results for various materials with various thicknesses. It is better when polyethylene and B_4C are thicker. If there is a restriction of facility space, polyethylene is more effective than B_4C. However, it is recommended to use the polyethylene and B_4C in the neutron shielding effectively.

3. Conclusions

It was found that 55 cm, 20 cm, 35 cm and 5 cm concrete are used for each 4 cases as shown Table 1 to find dose rate which is lower than the public dose rate criterion. From the calculation result, it is recommended that polyethylene, B_4C and normal concrete are used at 30 cm, 15 cm and 50 cm to meet the criteria.

Additionally, shielding calculation on beam loss, activation analysis and the distance after hot area will be performed.

ACKNOWLEDGEMENT

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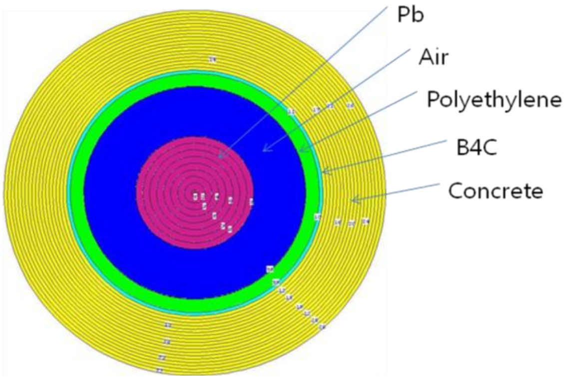

Fig.1. Configuration of neutron shielding problem.

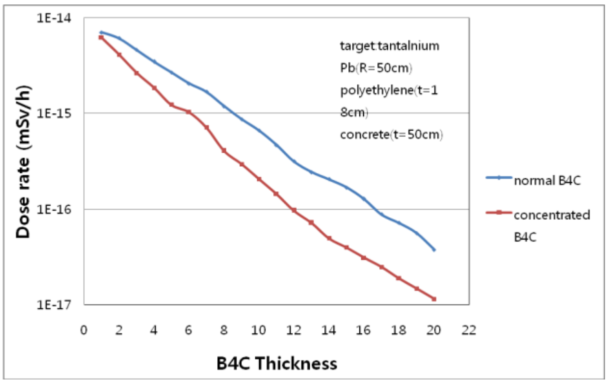

Fig. 2. Dose rate at concrete outer surface by B_4C thickness change.

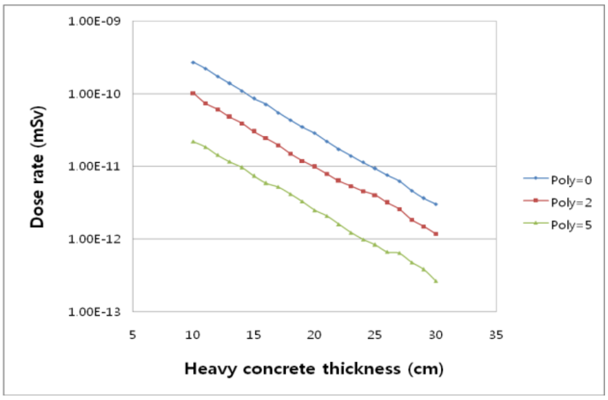

Fig. 3. Dose rate at concrete outer surface by heavy concrete and polyethylene thickness change.

Table 1. Dose rate at concrete outer surface by various conditions

Concrete thickness (cm)	**Dose rate (mSv)**			
	poly=20, b4c=5	poly=30, b4c=5	poly=20, b4c=15	poly=30, b4c=15
5	2.35E-14	6.21E-16	1.74E-15	6.97E-17
10	1.15E-14	2.79E-16	8.46E-16	2.89E-17
15	5.72E-15	1.20E-16	4.87E-16	1.19E-17
20	2.70E-15	7.86E-17	3.20E-16	5.32E-18
25	1.61E-15	4.64E-17	1.41E-16	5.48E-18
30	9.35E-16	2.09E-17	8.40E-17	1.55E-18
35	5.00E-16	1.08E-17	4.41E-17	9.83E-19
40	3.19E-16	4.98E-18	2.59E-17	6.92E-19
45	1.81E-16	3.52E-18	1.91E-17	3.37E-19
50	1.05E-16	1.83E-18	1.32E-17	2.27E-19
55	6.74E-17	1.09E-18	5.22E-18	1.36E-19
60	4.20E-17	8.90E-19	3.31E-18	6.65E-20
65	3.04E-17	5.12E-19	1.55E-18	3.85E-20
70	1.63E-17	1.99E-19	9.00E-19	2.74E-20
75	8.43E-18	1.54E-19	5.17E-19	9.56E-21
80	1.69E-18	6.81E-20	3.81E-20	2.80E-21
85	8.25E-19	5.77E-20	2.01E-20	1.61E-21
90	1.30E-19	1.60E-21	7.60E-21	3.78E-22