A Preliminary Study on the Shielding Analysis for Lead Slowing Down Time Spectrometer(LSDTS) System

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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, Am-241, etc.[1][2] However this system releases 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 both neutron and gamma ray. 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, multi-step calculation with surface source read and write technique was tried to get highly efficient results.

2. Methods and Results

In this paper, three cases are considered to evaluate shielding analysis for LSDTS: gamma ray shielding, neutron shielding, and sensitivity test.

The medium of LSDTS is full of pure lead blocks, which provides an inherent radiation shielding effect. The surface source read and write (SSR, SSW) cards were used in the MCNPX modeling to get computational efficiency. The numbers of histories are taken 1E+6 for gamma ray shielding analysis and 1E+7 for neutron shielding analysis, respectively. The point source was assumed to be positioned at the origin in all models. The surface dose rate is converted from surface flux based on the ICRP-21 conversion factor sets.

2.1 Gamma ray shielding

The simplified model is depicted in Fig. 1. The radius of inner lead sphere is given as 50 cm and it is surrounded by 1m cubic which is filled with air. The outer shielding material is a normal concrete of which thickness is 50 cm. And total 3 step geometry splitting was taken. The initial intensity of gamma rays was 1E+12 photons/s. On the outer surface of concrete shielding material, the surface dose rate was obtained 2.30 E-15 μSv/h. This surface dose rate is sufficiently small due to inner lead medium and it is expected that there is no shielding concern about gamma rays for LSDTS system.

2.2 Neutron shielding

With the previous gamma ray shielding model, a neutron shielding calculation performed with 2 step geometry splitting technique. Fig. 2 shows neutron spectrum behavior after each calculation step. It is found that more neutrons slowed down after they passed through the concrete wall. The surface dose rate on the outer concrete wall was estimated about 1.13E-05 mSv/h which is lower than the public dose rate criterion, 1.0E-04 mSv/h. However, more investigation has been performed in this study for neutron shielding analysis with various shielding material and thickness.

2.3 Sensitivity analysis

Two materials were considered for neutron shielding analysis such as concrete and polyethylene. Table 2 shows the results for normal and heavy concrete with various thickness. From the analysis 20 cm and 24 cm thicknesses are required at least for normal and heavy concretes, respectively. There is a slight improvement when the heavy concrete was used instead of normal concrete. Table 3 shows the sensitivity results for polyethylene and concrete. In this test, the polyethylene was located inside of the normal concrete. When 2 cm thick polyethylene was added, about 4 cm thickness gain of concrete was obtained. Furthermore 5 cm polyethylene was positioned inside part of the outer concrete, it was revealed that 10 cm reducing effect of concrete shielding material.

3. Conclusions

It was found that the gamma ray effect on LSDTS system was almost negligible and neutron effect is quite dominant due to high intensity of target materials. And heavy concrete provides a slight advantage as a shielding medium of LSDTS system. Polyethylene also gives a good alternative to reduce the thickness of outer concrete shielding material. A further investigation will be performed for the detail shielding analysis for the LSDTS system including an acceleration system for neutron production.

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REFERENCES

[1] Y.D. Lee, N.M. Abdurrahman, R.C. Block, D.R. Harris, and R.E. Slovacek, "Design of a Spent-Fuel Assay Device Using a Lead Spectrometer," Nucl. Sci. Eng., 131, 45 (1999).
[2] D. Rochman, R.C. Haight, J.M. O'Donnel, A. Michaudon, S.A. Wender, D.J. Vieira, E.M. Bond, T.A. Bredeweg, A. Kronenberg, J.B. Wilhelmy, T. Ethvignot, T. Granier, M. Petit, and Y. Danon, "Characteristics of a Lead Slowing-Down Spectrometer Coupled to the LANSCE Accelerator," Nuclear Instruments and Methods in Physical Research A, 550, 397 (2005).
[3] H. Krinninger, E. Ruppert, and H. Siefkes, "Operational Experience With the Automatic Lead-Spectrometer Facility for Nuclear Safeguards," Nucl. Instr. Methods, 117, 61 (1974).
[4] N. Baltateanu, M. Jurba, V. Calian, G. Stoenescu, "Optimal Fast Neutron Sources Using Linear Electron Accelerators," Proceedings of EPAC 2000, pp.2591-2593,Vienna, Austria (2000).
[5] D.B. Pelowitz, ed., MCNPX User's Manual, LA-CP-05-0369, Los Alamos National Laboratory, 2005.

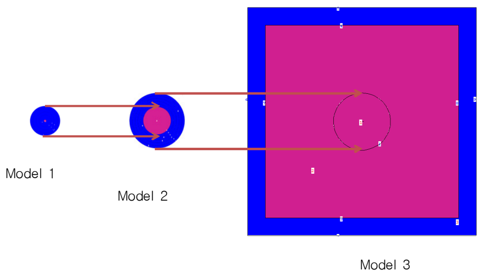
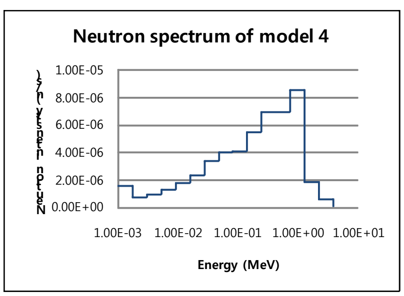
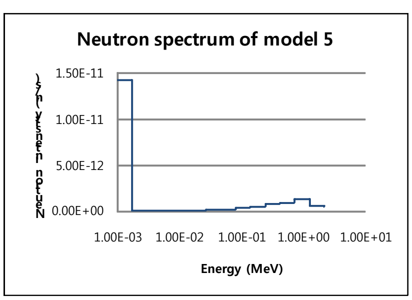


Fig. 1 Configuration of gamma ray shielding problem



(a) on the surface of lead medium



(b) on the surface of concrete medium

Fig. 2 Neutron spectrum change on the surface of shielding materials

Table 1. Dose Rate for Normal and Heavy Concretes

Thickness (cm)	Normal Concrete		Heavy Concrete	
	Dose Rate (mSv/h)	Standard deviation (mSv/h)	Dose Rate (mSv/h)	Standard deviation (mSv/h)
18	-	-	1.471E-04	3.794E-06
19	-	-	1.172E-04	3.281E-06
20	1.736E-04	3.680E-06	9.350E-05	2.683E-06
21	1.480E-04	3.921E-06	7.685E-05	2.513E-06
22	1.188E-04	2.887E-06	6.170E-05	2.419E-06
23	1.034E-04	2.946E-06	5.312E-05	2.608E-06
24	8.402E-05	2.588E-06	-	-
25	6.926E-05	2.140E-06	-	-

Table 2. Dose Rate of Polyethylene and Normal Concrete

Normal concrete thickness (cm)	Dose Rate (mSv/h)		
	0 cm P.E.	2 cm P.E.	5 cm P.E.
13	-	-	1.23E-04
14	-	-	1.03E-04
15	-	-	8.54E-05
16	-	-	7.05E-05
17	-	1.60E-04	5.77E-05
18	-	1.35E-04	4.80E-05
19	-	1.11E-04	3.80E-05
20	1.86E-04	9.23E-05	3.14E-05
21	1.63E-04	7.42E-05	2.67E-05
22	1.33E-04	6.38E-05	2.21E-05
23	1.05E-04	5.01E-05	1.74E-05
24	8.85E-05	4.28E-05	1.44E-05
25	7.01E-05	3.52E-05	1.27E-05