Sensitivity Studies on Lead Isotope Compositions and Geometry Effects for a LSDT Spectrometer

Jae Hoon Song, Yong-Deok Lee, Chang Je Park, and Kee Chan Song
Korea Atomic Energy Research Institute, P.O. Box 105, Yuseong, Daejeon, Korea, 305-600
Jh_song@kaeri.re.kr

1. Introduction

A lead slowing-down-time spectrometer has been investigated as a potential nondestructive assay technique for fissile materials in irradiated fuel elements. The correlation of the mean energy of the neutron spectrum and the slowing-down time is very important for a lead slowing-down-time spectrometer operation.[1] It is one of the most important factors to reduce the impurity of the lead used as a spectrometer. This paper focuses on the sensitivity research depending on the isotope composition such as Ag, Cu, As, Sb, Zn, Fe, and Bi in the lead spectrometer. As well as, because the spectrometer consists of several cubical lead bulks, the gap between the bulks provides unexpected results coming from the capture cross section of the hydrogen in the air. Therefore, a geometrical investigation is also performed by the MCNPX simulation code.[2]

2. Neutron Flux for The Isotope Composition

In order to perform a sensitivity study, two candidate models are simulated, "SK" and "J.I.S." The isotope compositions of "SK" and "JIS" are shown in Table I. The test problem consists of a regular hexahedron (180cm x 180cm) filled with Lead and other isotopes as well as the neutron sources to be generated by an electron accelerator are emitted at the center of the cube with an evaporation spectrum. The distance between the source and the imaginary sphere target to be collided with the source neutron is about 20cm.[1] Since the slowing down energy varies with the isotope composition of the lead spectrometer, it is tested to satisfy its requirements.

Table I: Volume fraction of the isotopes for two candidates

	SK (%)	J.I.S. (%)
Pb	99.995	99.990
Ag	0.0002	0.0020
Cu	0.0004	0.0020
As+Sb	0.0001	0.0050
Zn	0.0001	0.0020
Fe	0.0001	0.0020
Bi	0.0010	0.0050

The test problem is performed by varying the Ag composition since its neutron capture cross section is most dominant within a low energy among them. The results are shown in Fig 1. and Fig. 2. In the case of the "SK" model, the neutron spectrum is almost the same with the Ref. (Pb 100%). However, the low energy spectrum below 100eV of the "J.I.S." model is reduced since the Ag is the larger in quantity by about 10 times.

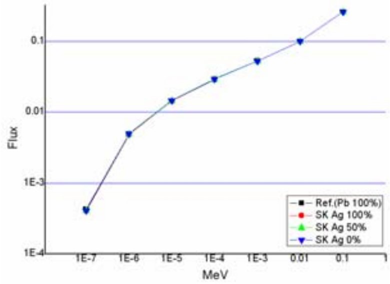

Fig. 1. The neutron spectrum for "SK" model varying with Ag.

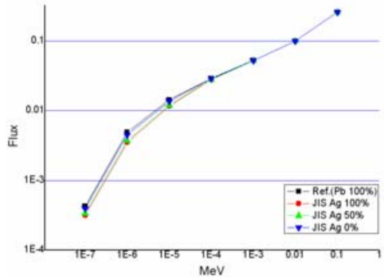

Fig. 2. The neutron spectrum for "J.I.S." model varying with Ag.

3. Investigation for The Geometry Effect of a Lead Spectrometer

During the manufacturing, the lead bulks(10cm x 10cm x 20cm) are piled so that the effects of the gap among the lead bulks are considered. Specially, the air in the gap has hydrogen which has a high capture cross section. Because of that, the correlation of the mean energy of the neutron spectrum and the slowing-down time can be changed. Therefore, it is important to confirm the effects of the gap in the lead spectrometer. The gap is filled with natural air at 20 Celsius and 1 Torr. The isotope compositions of the air are shown in Table II. Case I and case II mean standard dry and wet air, respectively.

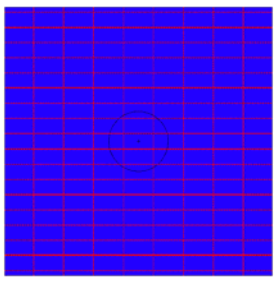

Fig. 3. Schematic geometry for lead spectrometer.

Table II: Volume fraction of the isotopes for the air in test problem

	Case I (%)	Case II (%)
N2	78.084000	74.960064
O2	20.946000	20.108160
Ar	0.9340000	0.8966400
CO2	0.0383000	0.0367680
Ne	0.0018180	0.0017453
He	0.0005240	0.0005030
CH4	0.0001745	0.0001675
Kr	0.0001140	0.0001094
H2	0.0000550	0.0000528
H2O	0.0(dry)	0.0040000

The results for case I are shown in Fig. 4. and Fig. 5. The effect of the dry air in the gap is negligible in the case of the "SK" model since it has a smaller amount of isotopes than that of the "J.I.S." model by about 0.1 times. However, in the case of "J.I.S." the effects of the air in the gap should be considered in view of the correlation for the mean energy of the neutron spectrum and the slowing-down time.

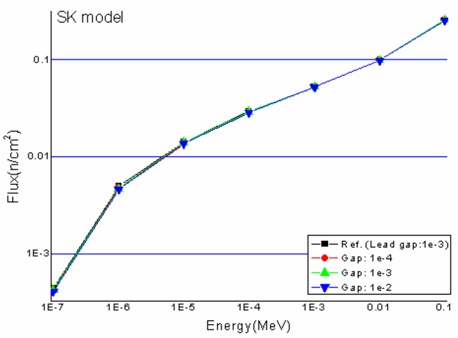

Fig. 4. The neutron spectrum for the gap effect in the case I with "SK" model.

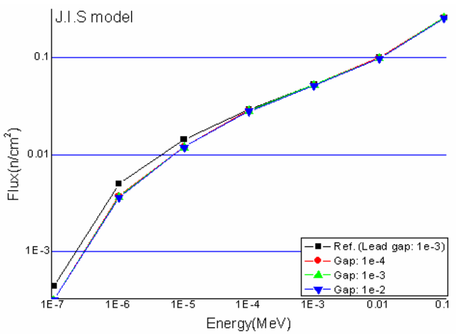

Fig. 5. The neutron spectrum for the gap effect in the case I with "J.I.S." model.

Fig. 6 shows the results for case II with 4% water vapor in air. The hydrogen mass fraction of case II is larger than that of case I by about 10^3 times so that the neutron is easily captured within the range of a low energy level even though the Argon has a large capture cross section. Therefore, it is required that in order to use the "J.I.S." as a lead spectrometer the air is enough to be dehydrated.

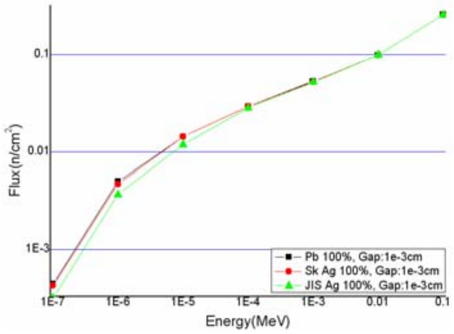

Fig. 6. The comparison of neutron flux distribution for case II.

4. Summary and conclusions

Sensitivity studies were performed depending on different isotope compositions and geometries. Two candidates for a lead spectrometer, "SK" and "J.IS.", models were chosen. Since the amount of impurities especially for Ag which has a large capture cross section within the range of a low energy is larger than that of "SK", the amplitude of the neutron spectrum in a low energy is decreased in the "J.I.S." model. Therefore, to use "J.I.S." as a lead spectrometer, it is required to sufficiently reduce a material having large capture cross section such as Ag. On the other hand, the first sensitivity study for a gap in which a slowing-down is generated due to a neutron capture by hydrogen in air is performed with increasing gap width. The "J.I.S." model shows that when the gap width is increased, the neutron flux is decreased in the range of a low energy level due to a large amount of hydrogen. However, the neutron flux within a low energy level is almost the same as the Ref.(filled with pure lead) in the "SK" model. The reason is that even if the "SK" model has hydrogen within the gap, the amount of impurity in the lead bulks is smaller than that of the "J.I.S." model. In the second sensitivity study, the air contains water vapor by about 4% which is the same with the quantity near the surface of the earth. The neutron flux in the range of a low energy level is reduced. As a conclusion, when designing a LSDT spectrometer, it is recommended to investigate the amounts of Ag as well as the hydrogen effect coming from the gap.

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.B. Pelowitz, ed., MCNPX User's Manual, LA-CP-05-0369, Los Alamos National Laboratory, 2005.