Transactions of the Korean Nuclear Society Autumn Meeting
Jeju, Korea, October 21-22, 2010

A New Target Design with a Beryllium Multiplier for a Lead Slowing Down Time Spectrometer (LSDTS) System

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1. Introduction

In order to quantify fissile isotopes in the spent nuclear fuel or the recycled nuclear material, a lead slowing down time spectrometer (LSDTS) system has been investigated and developed.[1]-[3] Among several components of LSDTS, a highly intense neutron should be produced in the system to overcome the background neutrons from spontaneous fission in the curium isotopes. Thus a thin and plate target is designed using tantalum based on the successive reactions such as a bremmstrahlung conversion (e,γ) and a photoneutron production (γ,n).[4] The beam energy of incident electrons is as high as 35 MeV in LSDTS system, which will decrease in the lead medium after interaction with target. It is known that the higher energy than 5 MeV is enough to produce neutrons for light elements such as beryllium and deuterium.[5] Beryllium is widely used as a reflector due to its good characteristics of neutron scattering. Above all, a neutron multiplier is a good choice for beryllium especially in a fusion facility based on the following chain reaction,

Be-9 + n (>2MeV) -> 2 He-4 + 2n -1.666 MeV

and the cross section is as high as about 580 mb.

Using the above application, a beryllium plate is installed on back side of tantalum target in order to multiply neutrons emitting from the target. Furthermore, some sensitivity tests are carried out by changing the thickness of beryllium plate. As a computing tool, MCNPX-2.5 code[6], a popular Monte Carlo three dimensional code, is taken into consideration.

2. Methods and Results

Several cases are considered in this study in order to estimate the effect of the beryllium multiplier for LSDTS target. Fig. 1 depicts LSDTS target with and without beryllium multiplier. Each thickness of Ta target plate increases from 2 mm to 6 mm with 1 mm increment. The radius of target is also increased from 3 cm to 7 cm. For the target with beryllium multiplier, the thickness is varied from 0.5 cm up to 2.0 cm with 0.5 cm increment. The inner medium is filled with helium gas and the outer medium is covered with lead, which is a main slowing down site of fast neutrons. The neutron flux is scored on the outer surface of a lead cylinder. Incident electron energy is 35 MeV with a forward peaked propagation. Multiple physics mode is used in the MCNPX code to account neutron, photon, and electron simultaneously and initial number of simulation particles is given as 1,000,000 to get enough reliable results.

Table I shows the scored neutron flux for various thicknesses of the beryllium plate. The optimal thickness of beryllium is obtained about 1.5 cm in this geometry and its neutron flux intensity is about 3.4 % higher than that of beryllium multiplier free case. It is also found that the thick beryllium plate does not give a multiplication of neutrons but works as a barrier for the neutron propagation. Fig. 2 displays the neutron spectrum for various beryllium thicknesses. From the results, the neutron spectra with beryllium multiplier are slightly broadened less than 1 MeV but the overall shape is almost the same. Around 5 MeV, the flux with the beryllium plate is slightly higher than that of beryllium free case, which is coincident to the energy range of the beryllium multiplication reaction. Fig. 3 shows the neutron flux spectra for inner and outer surfaces of the lead medium. The inner fluxes without beryllium and with beryllium are estimated as 3.35E-5 n/cm^2, 3.53E-5 n/cm^2, respectively, which results from the multiplication effect of the beryllium plate. However, both inner and outer fluxes are distributed in a smooth slope below 1 MeV and in a steep slope above 1 MeV, which is a general trend of the neutron slowing down. Fig. 4 depicts the flux map for target system using mesh tally function in the MCNPX. The central part of plate target is higher neutron flux than other region due to incident electron beam and produced gamma ray. From the center, the neutron source distributed uniformly over the tantalum target and the lead medium. In the case of the beryllium installed target, more neutrons are observed especially on the upper lead surface because of beryllium multiplier.

3. Conclusions

It is found that the beryllium plate plays a good role on multiplying slightly moderated neutrons in the target of the LSDTS system. The beryllium plate is installed on the back side of tantalum target and an optimal thickness of beryllium plate is estimated in the proposed target from the sensitivity test. From the analysis, the neutron spectrum does not change significantly not only on the inner side but also on the outer side of lead medium. Thus, by simply installing beryllium plate on the existent target of LSDTS, a preferred neutron yield is obtained without a significant neutron spectrum change. As a future work, a detail application for beryllium multiplier in LSDTS target system shall be performed with some experiments and analyses.

ACKNOWLEDGEMENT

This work has been carried out under the Basic Research Program of Korea Atomic Energy Research Institute.

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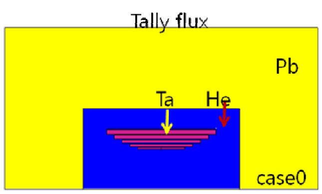
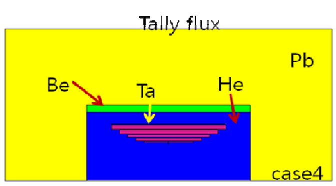


(a) Target without beryllium multiplier



(b) Target with beryllium multiplier

Fig. 1 Configuration of target with and without Be multiplier

Table I. Neutron Flux on the Surface of Lead Medium

Be thickness	0 cm	0.5 cm	1 cm	1.5 cm	2 cm
Neutron flux[1] (n/cm^2)	2.17E-6 (0.058)*	2.19E-6 (0.058)	2.24E-6 (0.058)	2.24E-6 (0.065)	2.18E-6 (0.065)
Neutron flux[2] (n/cm^2)	3.35E-5 (0.020)	3.50E-5 (0.021)	3.48E-5 (0.021)	3.53E-5 (0.022)	3.48E-5 (0.022)

*Relative error = (standard deviation)/(mean), [1] inner, [2] outer

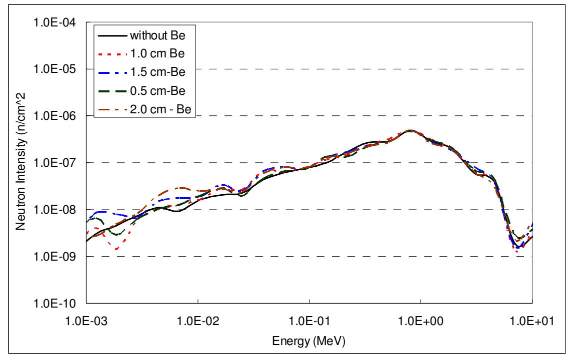


Fig. 2 Neutron spectrum change for various beryllium thicknesses

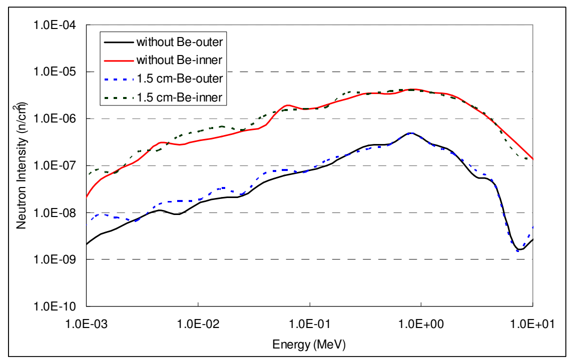
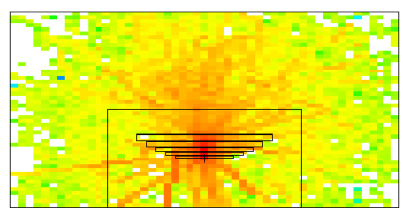
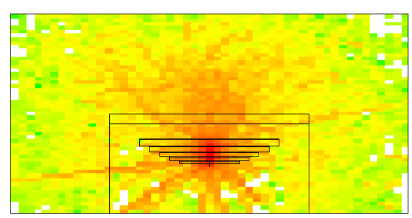


Fig. 3 Neutron spectra for inner and outer lead medium surfaces



(a) Without beryllium



(b) With beryllium

Fig. 4 Neutron flux map of target with and without beryllium multiplier