Shielding Design and Radiation Shielding Evaluation for LSDS System Facility

Younggook Kim*, Jeongdong Kim, Yongdeok Lee
Korea Atomic Energy Research Institute(KAERI)
Daedeok-daero, Yuseong-gu, Daejeon, Korea
**Corresponding author: kyg@kaeri.re.kr*

1. Introduction

A Lead Slowing Down time Spectrometry (LSDS) system is under development in the Korea Atomic Energy Research Institute (KAERI). The LSDS is a type of non-destructive assay (NDA) that enables a more accurate and isotopic quantification of the principal fissile materials, e.g., ^{235}U, ^{239}Pu and ^{241}Pu blended in spent nuclear fuel (SNF) assemblies and their reprocessing counterparts throughout the back-end fuel cycle [1,2]. The shielding designs have to satisfy the public dose rates. As the system characteristics, the target in the spectrometer emits approximately 10^{12} neutrons/s. To efficiently shield the neutron, the shielding door designs are proposed for the LSDS system through a comparison of the direct shield and maze designs. Hence, to guarantee the radiation safety for the facility, the door design is a compulsory course of the development of the LSDS system.

To improve the shielding rates, 250∗250 covering structure was added as a subsidiary around the spectrometer.

In this study, the evaluations of the suggested shielding designs were conducted using MCNP code [3].

2. Methods and Results

A shielding door as an absorber should effectively shield neutron from the target to satisfy the limit of the allowable dose rate with a minimal volume increase of the door thickness. An evaluation verifying the shielding efficiency of the door and structures was conducted using the MCNP code.

An evaluation of the 250*250 covering structure for confirming the probability regarding reducing the concrete wall was conducted by using the MCNP code [4].

2.1 Shielding door and covering design

The design condition is used to satisfy the public dose limits (0.1μSv/hr). The significant factors for reducing the dose rates are the structure location, material and thickness. As shown Fig 1, the indoor type consists of a Resin 50 cm door and three structures. The door and structure are located in the LSDS system facility.

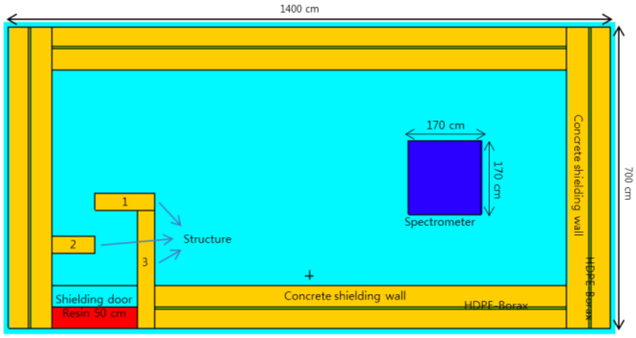

Fig. 1. Actual geometry of Indoor type structure.

The outdoor type consists of a Tungsten 50 cm door and two concrete structures. The shielding door is located in the LSDS system facility and the iron door and structures are located in the general work place outside of the LSDS system facility. Fig 2 shows the outdoor type shielding door design.

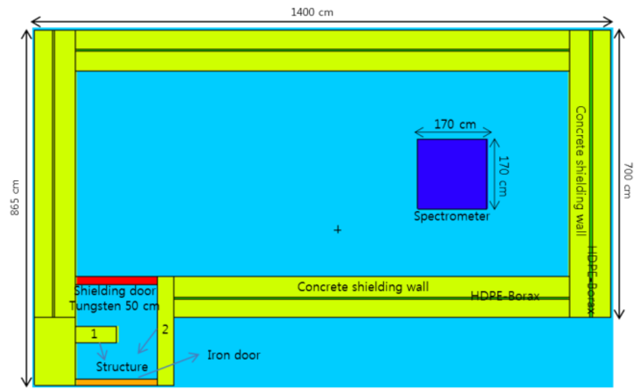

Fig. 2. Actual geometry of Outdoor type structure.

HDPE-Borax, B_4C, Li_2CO_3 and Resin were used for the 250*250 covering structure simulation. The thickness variations were 5 cm and 10 cm. Fig 3 shows the detailed dimension of the covering.

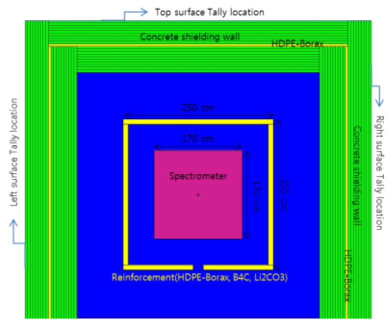

Fig. 3. 250∗250 covering structure.

2.2 Radiation shielding evaluations.

Along the door height, the evaluation results of the indoor and outdoor designs were satisfied within the public dose limits. Fig 4 shows the results of the shielding door evaluations.

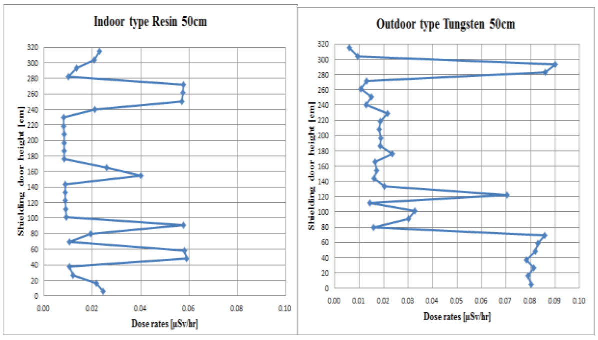

Fig. 4. Dose rates for two different types of shielding door.

At the outside of the shielding wall, the evaluation results of the 250*250 covering were satisfied within the public dose limits. Table 1 shows the shielding rates (%) according to the thickness (no shielding, HDPE-Borax of 5 cm and 10 cm). Based on the Left wall dose rates data, in case of comparing No shielding with the 5 cm HDPE-Borax for covering, about 70.5% shielding rates is performed than No shielding. Along the increasing thickness 10 cm, shielding rates are more effective about 18.8% improved than 5 cm.

Table I: Shielding rate for each 5 cm, 10 cm thickness

Material and thickness	Dose rate(μSv/h)			Shielding rates(%)		
	Left	Right	Top			
No shielding	4.48E-02	3.49E-02	4.18E-02	-	-	-
HDPE-Borax (5cm)	1.32E-02	1.11E-02	1.08E-02	70.5	68.2	74.2.
HDPE-Borax(10cm)	5.04E-03	5.80E-03	4.86E-03	88.8	83.4	88.4

Fig 5 shows the dose rates along the changing covering materials. In case of using B_4C, dose rates are about 0.01 μ Sv/h that is the lowest. Resin and HDPE-Borax show the almost same dose rates.

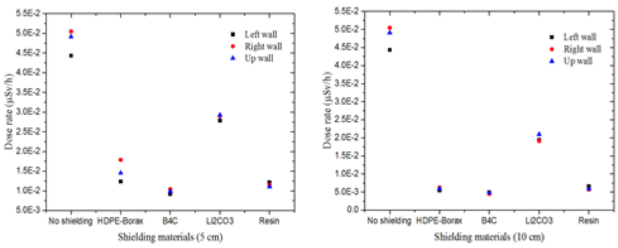

Fig. 5. Dose rates for varying materials of covering.

3. Conclusions

The suggested door design and covering structures can shield the neutron efficiently, thus all evaluations of all conditions are satisfied within the public dose limits.

From the Monte Carlo code simulation, Resin(Indoor type) and Tungsten(Outdoor type) were selected as the shielding door materials. From a comparative evaluation of the door thickness, In & Out door thickness was selected 50 cm.

Considering the affordability and outstanding performance in terms of the superior neutron shielding capability, HDPE-borax, Li_2CO_3 and B_4C are compared for the covering material. B_4C is the best material for the 250*250 covering. The covering thickness is an important design parameters for the LSDS system. The optimized shielding door design and covering structure in this study can be referred to as a reference of importance for a future LSDS system facility construction to secure radiation safety.

4. ACKNOWLEDGMENTS

This work was supported by the Nuclear Research Foundation of Korea (NRF) grant funded by the Ministry of Science, ICT and future Planning (MSIP) of Korea under project No. 2014030151.

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