Shielding Design for Fast Neutron Radiography Facility

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1. Introduction

Recently utilization of fast neutron is being increased. The inspection method using neutron is similar to that of using x-ray in its principle, but the manner of interaction with matter is fundamentally different. Therefore the variety of information can be obtained when neutron is used. Moreover, in case of using fast neutron, inspection against high-Z materials or thick object becomes easy.

In this study, GENIE16C, D-T reaction based neutron generator, made by SODERN in France was used as neutron source for fast neutron radiography(FNR). The maximum neutron generation rate of GENIE16C is about $2x10^8$ n/sec and the neutron energy generated by D-T reaction is 14 MeV.[1] The difficulties for shielding are caused by this high neutron energy. In this study, the shielding design was conducted against people in a limited space within the existing building, and scattering effect due to the shield was assessed in the detector.

2. Method and Results

Shielding calculation was performed by using MCNP4C code which is able to solve the coupling transport problem for neutron and gamma. Upon calculation, neutron source having isotropy of 14 MeV was delineated, and number of history was determined to maintain relative error of calculation results within 10 %. The dose conversion factor(DCF) from ICRP74 was applied to convert flux of neutron and gamma ray.

In fast neutron generated by D-T reaction, there were difficulties such that neutron absorber material could not be used for shielding differently from the case of thermal neutron. Therefore, it should be almost depends upon energy slowing down due to collision with shielding material. In the previous study, TiH2 and ZrH2 were evaluated to be effective materials for fast neutron shielding.[2] However since these materials are expensive and can not obtain commercially, shielding structure was designed using concrete and general polyethylene(PE). And SUS304 was used as material comprising structure.
Shielding design was performed based on following restrictions.

① The operating time is less than 40 hours per week and the limited dose rate value announced by MOST is 10.0 mrem per week.

② The irradiation room and operating room should be constructed within the limited space(5.5m(W) x 7.5 m(D) x 3.2 m(H)) and the irradiation room should be designed to maintain over 4.0 m to depth according to Korean Standard.

③ The sinking of ground should be considered to determine thickness of shielding wall.

2.1 Results of Shielding Calculation

Figure 1 and 2 present the designed shielding structure.

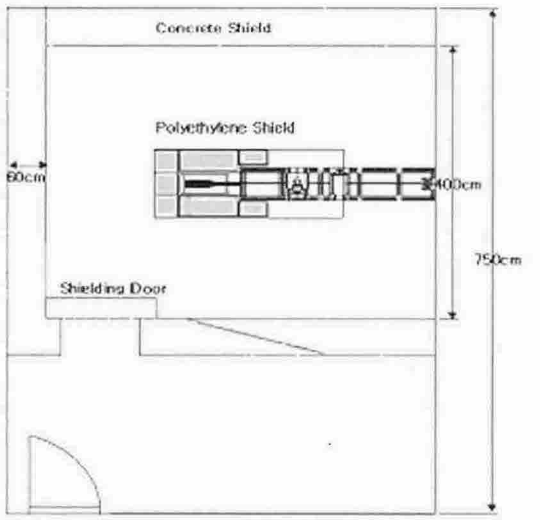

Fig 1. Plan view of shielding structure including exposure room and operating room.

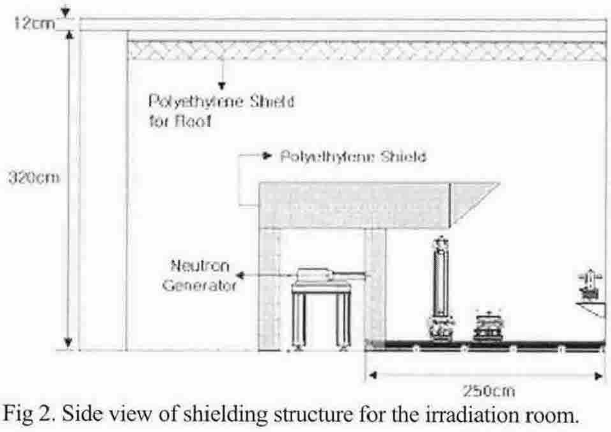

Fig 2. Side view of shielding structure for the irradiation room.

The thickness of concrete shielding wall was determined as 60 cm, according the restriction 2 & 3. Because this concrete wall could not satisfy the limiting dose rate value, additional shield composed with PE is needed. The PE thickness in the side part was designed to have 30.0 ~ 35.0 cm, and the one in the top part to have 55.0 cm.

In the ceiling part, as concrete thickness is 12.0 cm, shielding is very weak. Therefore, PE of 22.0 cm thick was installed additionally in whole ceiling of irradiation room.

Assessment of dose rate was conducted by finely dividing exterior wall face of the shield into the node of 10cm x 10cm size. In Figure 3, dose rate distribution assessed at the wall face of the operator room is shown. The maximum value of 0.205 mrem/hr was exhibited at the shielding door of which thickness of shield is relatively thin. It indicate that the limit value was not exceeded in spite of considering maximum value of 95% confidence region.

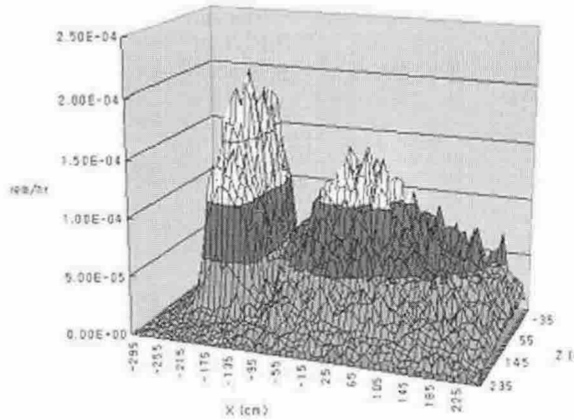

Fig 3. Dose rate distribution at shielding wall surface of operating room.

And also maximum values assessed in the wall face of other direction exihibited very low values than the limit value respectively as 0.137 mrem/hr, 0.145 mrem/hr and 0.168 mrem/hr.

2.2 Analysis of Scattering Effects at Detector due to Shielding Structure

Since dose rate cannot be satisfied only with concrete shielding wall due to insufficient room space, method to enclose the PE structure was taken. Scattered neutron with shielding structures is able to cause noises in detector system. The following four cases were evaluated for neutron scattering effects and the distance between neutron source and object was assumed to be 1.0 m.

① Case 1 : all shielding structures were considered,
② Case 2 : only concrete wall was considered,
③ Case 3 : there is no shielding structure, and
④ Case 4 : detector is covered with PE shield.

In table 1, the ratio of incident neutron without scattering to all of incident neutron for 4 cases is compared at the detector location. As the structure of shield becomes complicated, more noise may occur due to scattered neutron. And, in the scattered neutron energy spectrum, most of neutrons were distributed near 0.1 MeV. This means that use of neutron absorber material is not effective to shield for this system.

Table 1. The ratio of incident neutrons without scattering with shielding structures.

	Neutrons without scattering / all of incident neutrons (at detector location)
Model 1	46.00 %
Model 2	62.00 %
Model 3	100.0 %
Model 4	32.00 %

Although, the noises by scattering effects could be partly reduced by positioning of devices, that is not effective method.[3] To increase the reaction rate of detector material with fast neutron(14 MeV) without scattering and to decrease the scattered neutron flux at detector location are more effective methods. Therefore, it is important to select detector material and to design collimator.

3. Conclusion

In this paper, shielding design was performed under the conservative conditions that GENIE16C is operated with maximum power during working time and occupancy factor for residents is 100 %. From the calculation results, the highest dose rate is 8.2 mrem/week, this was not exceed the limit value. Therefore, it can be said that proposed shielding structure was designed safely in the irradiation aspects of operator and residents. However, because the shielding structure cause noises to imaging process, the further R&D is needed to design collimator and to develop detector material.

REFERENCES

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