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A Study on the Dose Estimation Accuracy Using Neutron Source Terms Generated from the Proton-Target Reaction for the Radiation Safety Analysis in RAON ISOL Target Room

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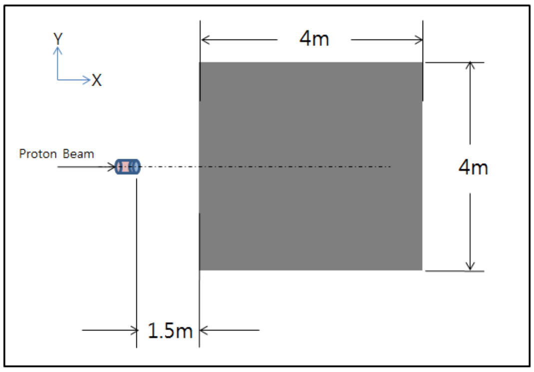
1. Introduction

In RAON ISOL target room, the high energy neutrons are generated by reactions between high energy protons and UCx target nuclides [1]. It is noted that the neutrons are the main radiation for the radiation shielding and safety analysis in the target room. Usually, Monte Carlo approach is used in the facilities, which are required high energy particle analysis such as the accelerator. For increasing efficiency with the Monte Carlo method, the neutron source terms are generated and used for the radiation shielding analysis [2]. Despite the two-step method is widely used, however, there are no certain methodologies or criteria to generate the neutron source term. In this study, the variation of the dose estimation accuracy caused by the source term generation strategy is evaluated and analyzed. Based on the analysis, a guideline of the source term generation is proposed.

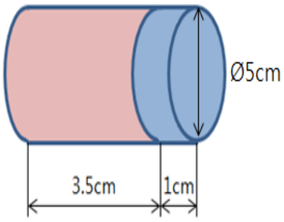
2. Methods and Results

2.1 Production of Source Term

Fig. 1 is the geometrical feature used for the source term analysis. In the ISOL target room, the energy and current of proton beam are 70 MeV and 1 mA, respectively. The proton beam is induced to the cylindrical UC_2 target having a 2.5cm radius and 3.5 cm long. A 1cm long graphite beam dump is located at behind the target. For the source term verification, it is assumed that 400 cm (width) x 400 cm (depth) x 350 cm (height) ordinary concrete shield is placed at 1.5 m distance from the target along the beam direction.



(a) Overview



(b) Target

Fig. 1. Geometrical Configurations for the Source Term Verification

In this study, a procedure to generate the neutron source term is established as following step; (i) an origin point is selected at the front of the target; (ii) spherical surface tally region having 400 cm radius is set; (iii) the tally region is evenly divided into the 1,000 energy sub-regions and 1,024 angular sub-regions; and (iv) the tallied data are reconstructed for the use of the neutron source term.

Overall scale of the target room geometry is much bigger than that of UC_2 target; therefore, the source position can be assumed to be a point source. Therefore, the obtained source term is located at the origin described in Step (i) as a point source.

To study how the source generation strategy affects the dose estimation, several neutron source terms were produced. To observe the effect of direction bins, the angular direction was divided into 512, 256, 128, 64, 32 and 16 with 500 energy bins. As the same way, to find out the effect of energy bin, fixed the number of direction bin to 512, and the energy bin was divided into 500, 333, 200, 100, 50 and 25 respectively. Also, two kinds of energy distributions were adopted that the source generation probabilities in each energy bin are assumed to have histogram and discretized distributions.

Table I: Classification of the Produced Neutron Source Terms

Number of Energy Bin	Number of Energy Bin						Distribution
500	512	256	128	64	32	16	Histogram Discrete
Number of Direction Bin	**Number of Energy Bin**						**Distribution**
512	500	333	200	100	50	25	Histogram Discrete

2.2 Results and Analysis

To analyze the accuracy of the produced source terms, dose results calculated with the generated source terms were compared with the dose result estimated from direct proton induced target reactions. For the dose calculation, the 100 cm (width) x 10 cm (depth) x 100 cm (height) unit tally was used. Dose conversion factor is selected to ICRP Publication 116-AP was used [3]. The calculation was pursued by MCNPX 2.7 code [4] with JENDL/HE 2007 [5] cross section library.

Fig. 2 is the result estimated from the use of the direct proton source. To analyze the accuracy of the source term, the results calculated with the source term were compared with that given in Fig. 2. The results with the number of energy bin are given in Fig. 3. In case of histogram distribution, all source terms excepting 25 bins give a good agreement within 5 % relative difference compared with that of the direct proton source. In case of discrete distribution in Fig. 3(b), it shows entirely different tendencies compared with the results in Fig. 3 (a). In this case, the dose rates generally were evaluated higher value than that using the direct proton source. Also, it shows that the difference is decreased as the number of energy bin is increased.

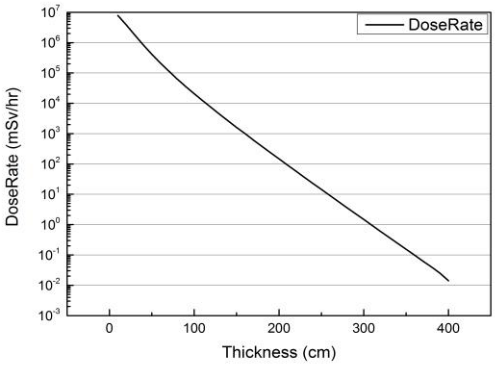
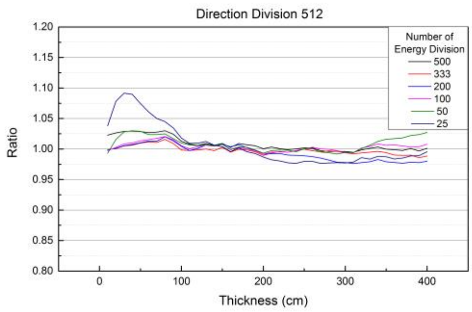
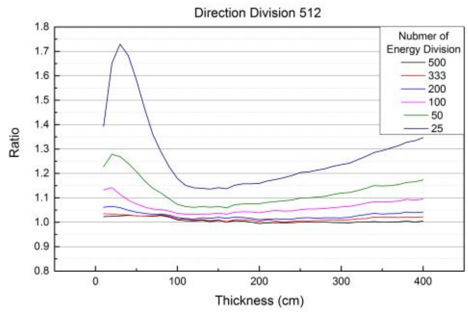


Fig. 2. Result of Dose Calculation Using Direct Proton Source



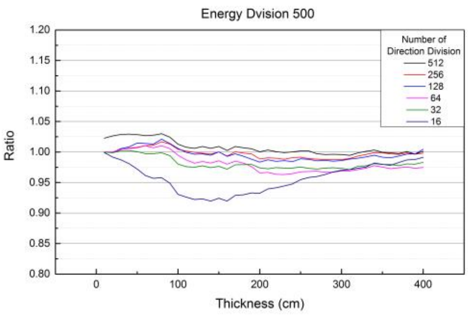
(a) Histogram



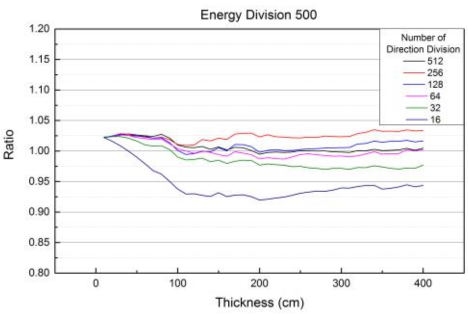
(b) Discrete Distribution

Fig. 3. Dose Rate of Neutron Source Term According to the Number of Energy Bins

Fig. 4 shows the dose ratio as the strategy of angular bin. In case of histogram distribution, the neutron source terms excepting 16 bins give good agreements within 5 % relative difference. In case of discrete distribution, dose rate of all the neutron source terms has difference within 5 % except 16 divided source term.



(a) Histogram



(b) Discrete Distribution

Fig. 4. Dose Rate of Neutron Source Term According to Number of Direction Bin in (a) Histogram and in (b) Discrete Distribution at 500 Energy Bin

3. Conclusion

In this study, to give a guideline of the neutron source term, the source term generation scheme and dose estimation were performed in RAON ISOL facility. The dose calculations were pursued with the number of the energy-angular bins and they are compared with the results calculated by the direct proton source. The analysis shows a good agreement in the case of which the energy and direction bins of neutron source term are divided into 50 and 128 sub-bins, respectively. Also, it shows that the use of discrete energy source term at the upper bin boundaries give conservative dose results. This study can contribute to the increase of the estimation accuracy for the high energy radiation shielding analysis.

4. Acknowledgement

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