A Preliminary Study on the Radiation Shielding Analysis for the C-12 Ion Beam in the RAON Bio-medical Laboratory

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1. Introduction

RAON is a heavy ion accelerator which is under development in Korea, and both ISOL and IF systems are used for the heavy ion generations. The bio-medical laboratory is a facility of RAON to generate some specific heavy ions such as C-11 and C-9 using C-12 ion beam. From the reactions between C-12 beam and target nuclides, lots of prompt radiations are generated; therefore, the radiation shielding and safety should be properly estimated for the operation period of the accelerator.

In this study, as a preliminary study on the radiation safety of the bio-medical laboratory facility, the radiation characteristics in the laboratory were analyzed and evaluated.

2. Methods and Results

In this study, exposure doses to the public are evaluated outside the hypothetical shielding wall for the bio-medical laboratory by using MCNPX ver. 2.7 [1], Monte Carlo N-Particle transport code. Instead of using one-step calculation, calculation of source terms from the reaction between C-12 beam and target is carried out firstly, and then dose calculation is done using the pre-calculated source term. The JENDL-HE was employed as the cross-section library and ICRP-116 flux-to-dose conversion factors [2] of AP (Antero-Posterior) type for the gamma and the neutron were used in the calculations.

2.2 Source term calculation

Radiation source of this study is extracted from the reaction between C-12 beam and Be target installed in the linear accelerator. Energy of C-12 beam is 310 MeV/nucleon having intensity of 6.25E+13 particles/s (beam current of 0.01 mA). C-12 beam is assumed to be generated at a point and is incident normal to the target surface. Be target is a pure beryllium with cylinder shape and its thickness and radius are 2.6 cm and 5 cm, respectively.

In the course of source term calculation, heavy ion, neutron, and gamma source generated from the reaction were obtained as the function of solid angle at collision point. As the result, it is found that a particle of C-12 generates 0.84 heavy ions and 0.89 neutrons, and the heavy ions more than 99.999% are distributed within an angle of 5 degree from the initial source direction, on the other hand about 15 % of neutrons generated within 0 ~ 5 degree as shown in Fig. 1. It is, therefore, found that heavy ion source from C-12 beam is highly forward directed.

The number of gamma particle from a C-12 ion, meanwhile, is 0.02, which shows nearly a constant flux for the all solid angle.

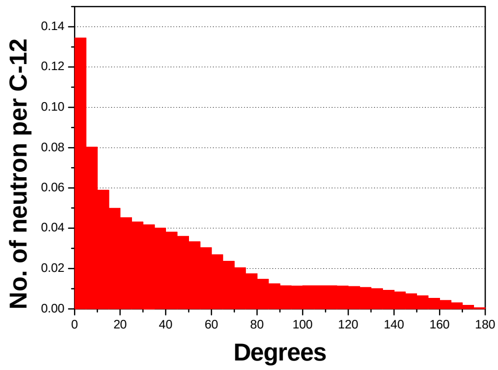
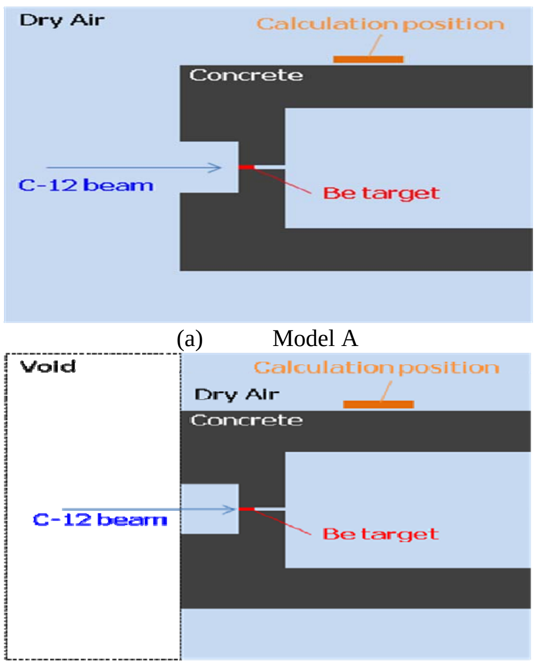


Fig. 1. Yield of the neutron for the solid angle from the initial C-12 particle direction

2.3 Bio-medical Laboratory Model



(a) Model A

(b) Model B

Fig. 2. Calculation Models

The model of the radiation shielding calculation for the bio-medical laboratory is shown in Fig. 2. The model A is consisted of beryllium target, concrete wall, and dry air for the inner and outer region of the bio-medical laboratory (Figure 2-(a)). The model B is the same as the model A, except that the left side of the Fig. is set to void. (Figure 2-(b)).

The details of the model and the materials of the buildings are shown in Table I.

Table I: Construction details of the bio-medical laboratory

Materials	Density (g/cm^3)	Chemical composition (wt%)	
Dry Air	0.001205	Hydrogen Oxygen	24 76
Concrete	2.30	Hydrogen Oxygen Sodium Aluminum Silicon Carbon Iron	1.0 53.2 2.9 3.4 33.7 4.4 1.4
Be target	1.86	Beryllium	100

In this study, dose rates at the calculation position as shown in Fig. 2 were estimated in order to find the effect of dry air in the region of incident C-12 beam through the comparison of the results from the two models.

2.4 Results

Table II shows the dose rates calculated at the calculation position in the model A with the wall thickness of 4, 5 and 6 meters and the model B with 4 m. The dose rates are calculated at some specific points and compared each other.

Table II: Neutron and gamma dose rates according to model type and wall thickness

Model/ thickness of the wall	Neutron		gamma	
	Dose rate (mSv/h)	R.E* (%)	Dose rate (mSv/h)	R.E (%)
Model A/ 4m	4.55e+00	12.7	6.49e-02	16.1
Model A/ 5m	5.38e+00	12.5	5.35e-02	15.1
Model A/ 6m	4.97e+00	16.7	5.32e-02	21.4
Model B/ 4m	1.37e-03	26.6	4.21e-06	52.0

*R.E is relative error: standard deviation /average

For the model A, neutron dose rates were ranged from 4.55 to 5.38 mSv/h, and gamma dose rates from 0.05 to 0.06 mSv/h. Considering the relative error level, the results are seemed to be constant without reference to wall thickness. On the other hand, the dose rates were calculated to be 1.37e-03 mSv/h for neutron, and 4.21e-06 mSv/h for gamma in the case of model B. This means that the absence of dry air in the model B give rise to very low dose rate.

3. Conclusions

Radiation characteristics for the bio-medical laboratory of RAON were analyzed and evaluated from the viewpoint of radiation safety using the two models constructed in this work.

It is noted that the dose rate outside the concrete wall is mainly affected by the reaction between neutron/gamma with dry air in the region of incident beam. Therefore, it is recommended that the radiation shielding analysis in the incident beam region should be carefully made and evaluated for the accurate analysis from the viewpoint of the radiation safety in the bio-medical laboratory.

Acknowledgement

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