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Preliminary Shielding Assessment for the IFF System in the RAON Heavy-ion Facility

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1. Introduction

A heavy-ion accelerator facility is under a development in Korea to use in the basic science research and various application areas. In this facility, the In-Flight Fragment (IFF) target and isotope separator has been designed to produce various isotopes and transport the interesting isotopes into the experimental rooms. In this work, preliminary radiation shielding assessment was performed for the IFF target room[1].

2. Radiation Source Terms

The radiation source terms were evaluated by using PHITS code[2]. The uranium and xenon beam with the energy range from 200 MeV/u to 400 MeV/u and the bam power of 400 kW were applied as the heavy-ion beam source. The simple graphite targets with various thicknesses were applied as target models. The calculation models of target assembly and beam dump based on the IFF equipment and beam dump design were also considered in the evaluation of the radiation source term. The secondary neutron spectrum in each angle from 0^{o} to 180^{o} was evaluated as the radiation source term for shielding analysis.

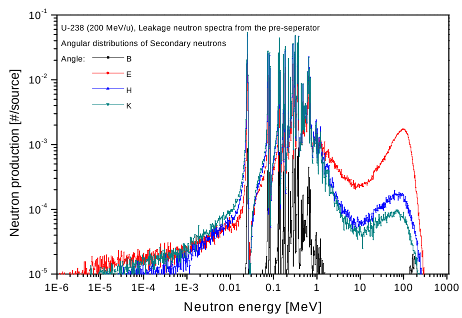

Fig. 1. Energy-angle distributions of secondary neutrons from U-238 beam of 200 MeV/u on pre-separator

3. Evaluation of the Bulk Shield Thickness

The shield thicknesses satisfying the designed dose limit were estimated from the evaluated radiation source term by using MCNPX code[3]. The preliminary target room design was performed based on the estimated shield thickness. Based on the target room design, the dose distribution during an operation was calculated in the target room including beam transport area.

Table I: Bulk shield thickness satisfying the limit of dose rate in the radiation area for workers

Position	Front Wall	Side Wall	Back Wall
Averaged dose rate	580 cm	480 cm	320 cm
Maximum dose rate	700 cm	600 cm	400 cm

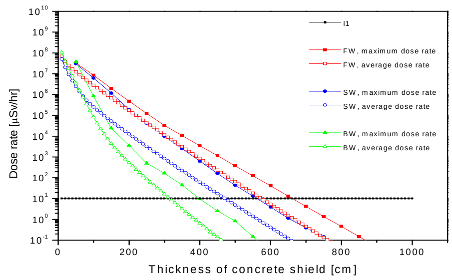

Fig. 2. Distribution of the dose rate behind a concrete shield according to the thickness of the concrete wall

4. Estimation of Dose Distributions after a shutdown

The dose distribution after a shutdown was evaluated based on the activation of the IFF target equipment. Induced activity of the IFF target equipment during an operation was evaluated with the designed heavy-ion beam and the design of the IFF target equipment. From the results of activation calculation, decay gamma-ray spectra produced in each component of IFF target equipment after a shutdown were estimated. The dose distribution inside target room after a shutdown was evaluated with the decay gamma-ray source term and the additional shields around IFF target equipment was considered to reduce the dose level inside target room after a shutdown.

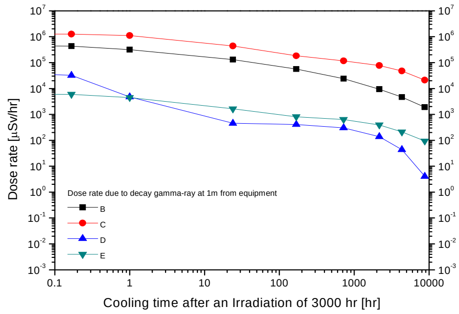

Fig. 3. Dose rate due to decay gamma-rays from the pre-separator according to cooling time after an irradiation during 3000 hours

5. Evaluation of Induced Activities in air and Structural Material

At last, induced activity of the air inside room and concrete wall were estimated. For the air activation analysis, the concentrations of radioactive nuclides produced during an operation were estimated. For the estimation of concrete activation, 30 years of operational history was considered. The production and accumulation of radioactive nuclides in the concrete wall during 30 years was calculated. The normal composition of Portland concrete was applied in the activation calculation and the effect of impurities on the activation was additionally considered.

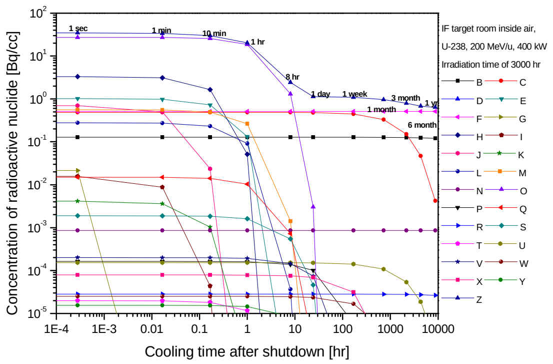

Fig. 4. Induced activities in air inside the pre-separator room according to cooling time after an operation during 300 hours

6. Summary

In this work, preliminary radiation shielding assessment was performed for the IFF target system in RAON heavy-ion accelerator facility. At first, radiation source terms were evaluated with the primary beams and target conditions. Using the evaluated source terms, bulk shield thicknesses were calculated for each radiation area with the limit of dose rate. And dose rates distributed in the room after shutdown were estimated based on the activity analyses for the equipment inside facility. The decay gamma-rays produced after an shutdown is main source for radiation worker's external exposure. Also, induced activity in air was evaluated. Internal exposure is mainly due to radionuclides produced in air. At last, activities in the concrete walls were estimated considering operational histories of the facility. Impurities in the concrete were applied in the activation calculation.

Table II: Impurities considered in the activation calculation for the structural material (concrete)

Parent nuclide	Reaction	Daughter nuclide	Impurity [ppm]
Li-6	n, α	H-3	20.00
Co-59	n, γ	Co-60	10.00
Ni-58	n, p	Co-58	30.00
Cs-133	n, γ	Cs-134	1.20
Eu-151	n, γ	Eu-152	1.00
Eu-153	n, γ	Eu-154	1.00

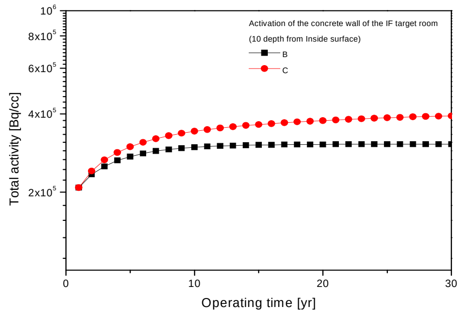

Fig. 5. Induced activities in the concrete wall according to the operational histories during 30 years

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