Measurement of Neutron Flux in a Medical Compact cyclotron room with Boron-Containing water Self-Shielding

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1. Introduction

In this study, we compared the neutron fluxes in cyclotron rooms with a boron water type self-shield and without a self-shield. The activation of material in a cyclotron room was evaluated, and the decrease of activation with the self-shield was confirmed.

2. Objectives and Methods

2-1 Equipment

We used a CYPRIS HM-18 cyclotron (Sumitomo Heavy Industries, Ltd, Niihama, Japan) and a PETtrace (GE Healthcare, Milwaukee, WI) as cyclotrons without and with self-shields, respectively.

2-2 Measurement of thermal neutrons in the cyclotron room

Gold foils and poly allyl diglycol carbonate (PADC) plastic was used for measurement of neutrons. Fig. 1 and 2 show the arrangements of the HM-18 and PETtrace cyclotron rooms, respectively; their concrete walls were about 1.5 and 0.5 m thick, respectively. Gold foils were arranged from the floor to a height of 1 m and 0 m, respectively (from 1a to 12a and 1b to 12b in Fig1,2).

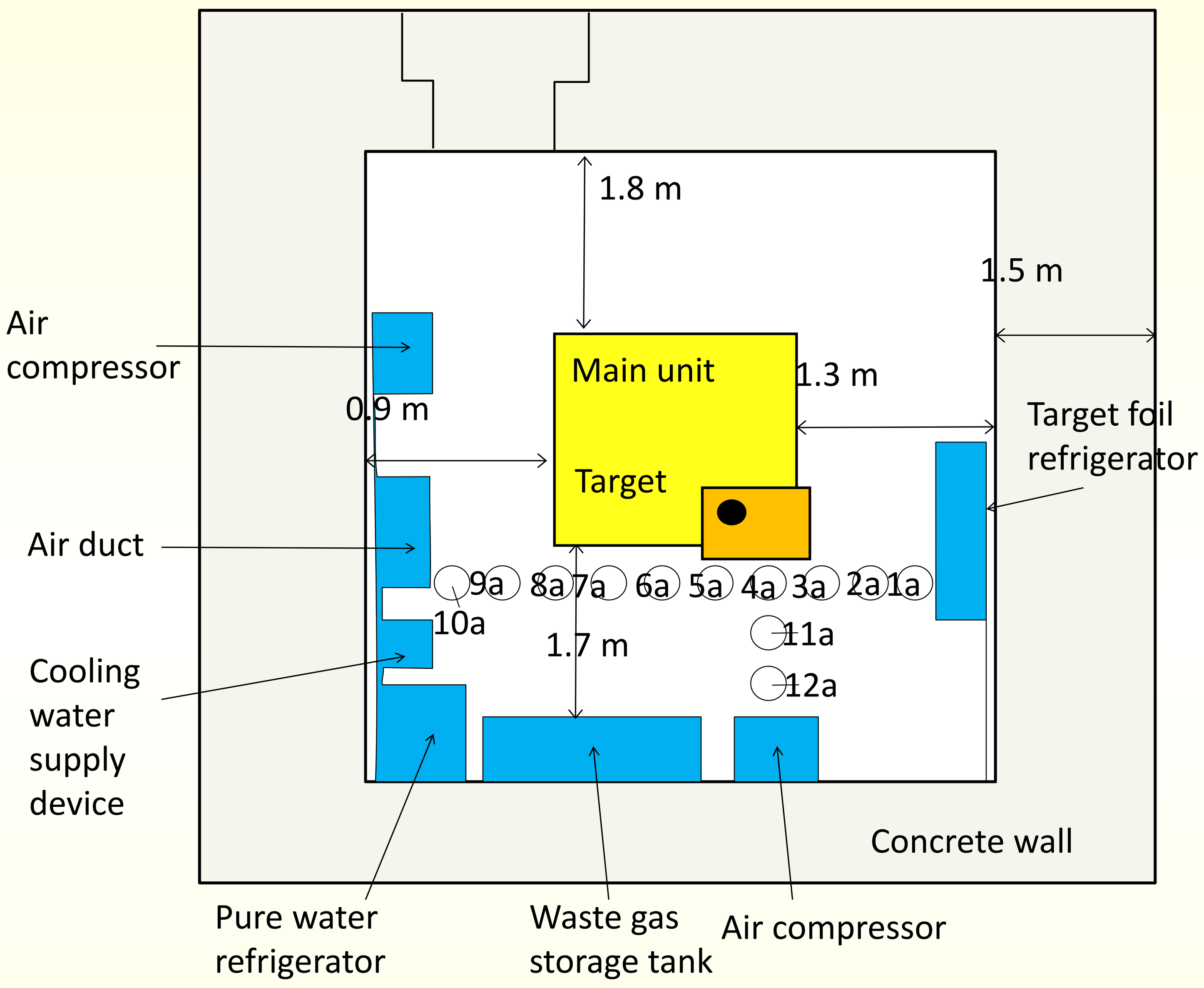

Fig. 1. Arrangement of glass dosimeter and gold foils in the HM-18 cyclotron room.

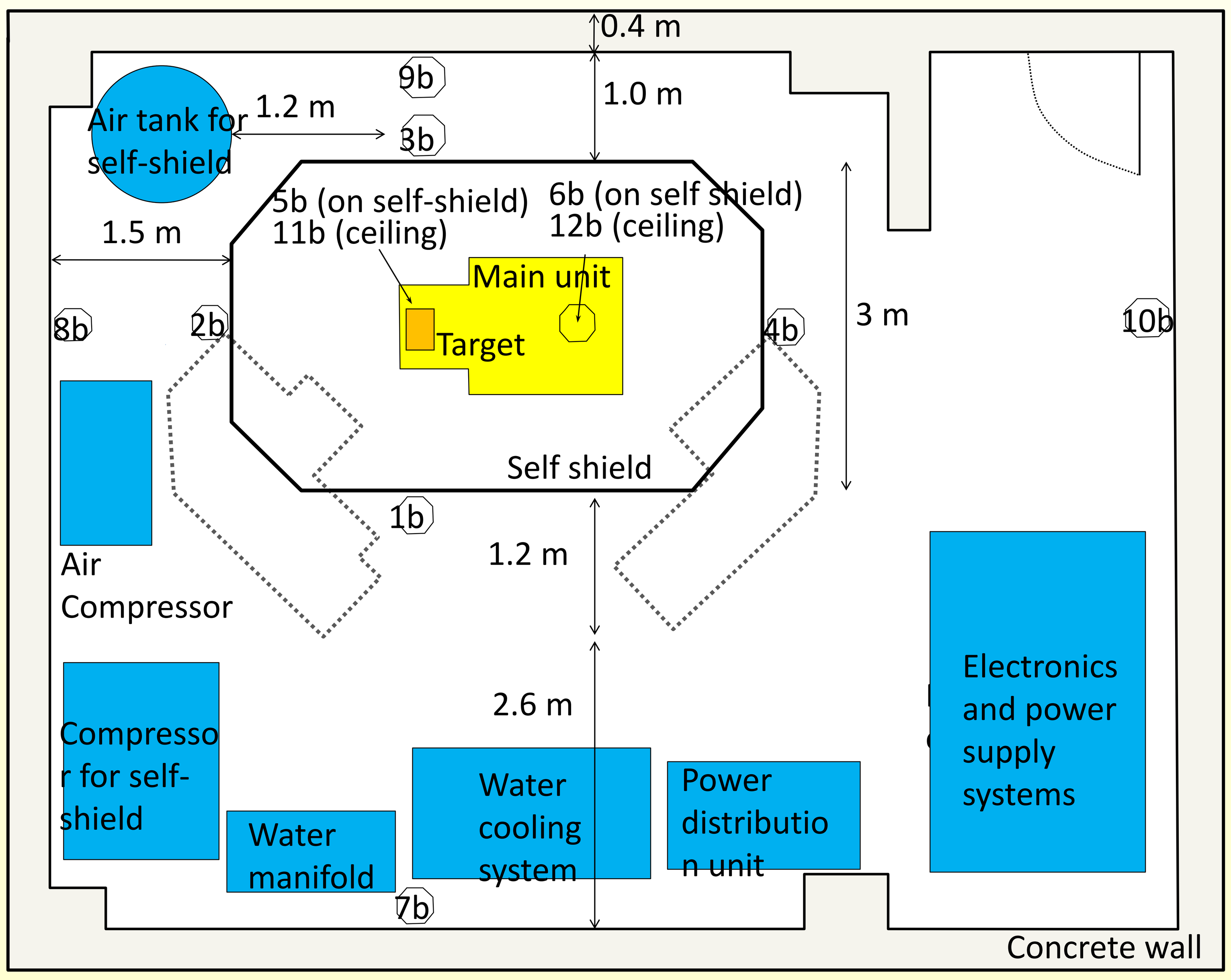

Fig.2. Arrangement of glass dosimeter and gold foils in the PETtrace cyclotron room.

3. Results

3-1 Measurement of thermal neutrons on the floor of the cyclotron room

Table 1 lists the thermal neutron fluxes and the Cd ratios in the cyclotron rooms. The measurements gave average thermal neutron fluxes of about 10^5 and 10^2 cm^{-2} s^{-1} for HM-18 and PETtrace, respectively. The thermal neutron flux had decreased by three digits outside the self-shield.

3-2Long term neutron measurement by use of PADC in a cyclotron room

The neutron dose measured by PADC in the PETtrace cyclotron room is shown Table 2. The doses of the thermal neutron were low compared with these of the fast neutrons.

Table 1 Thermal neutron fluxes and Cd ratios of cyclotron room measured by gold foils

HM-18			PETtrace			
Point (Fig. 1)	Cd ratio	Thermal neutron flux ($\times 10^5$ $cm^{-2}s^{-1}$)	Point (Fig.2)	Height from floor (m)	Cd ratio	Thermal neutron flux ($\times 10^1$ $cm^{-2}s^{-1}$)
1a	2.7	5.7 ± 1.3	1b	1	1.2	3.5 ± 0.8
2a	2.3	8.0 ± 1.8		0.1	1.1	4.6 ± 1.0
3a	2.6	11.7 ± 2.5	2b	1	1	3.5 ± 0.7
4a	2.3	16.6 ± 3.7		0.1	1.3	3.7 ± 0.8
5a	2.2	14.9 ± 3.3	3b	1	1.1	4.1 ±0.9
6a	2.7	11.4 ± 2.5		0.1	1.2	4.7 ± 1.0
7a	2.5	6.1 ± 1.3	4b	1	1.5	3.1 ± 0.7
8a	1.7	0.9 ± 0.2		0.1	1.4	4.8 ± 1.1
9a	1.9	1.0 ± 0.2	5b	on self-shield	1	16.0 ± 3.5
10a	2.2	0.5 ± 0.1	6b	on self-shield	1	1.9 ± 0.4
11a	3.1	1.8 ± 0.4	7b	1	1.1	1.6 ± 0.4
12a	2.1	1.4 ± 0.3		0.1	1	4.4 ± 1.0
			8b	1	1.2	6.7 ± 1.5
				0.1	1.3	7.8 ± 1.7
			9b	1	1.2	2.3 ± 0.5
				0.1	1.2	4.1 ± 0.9
			10b	1	1.1	9.6 ± 2.1
				0.1	1	7.8 ± 1.7
			11b	Ceiling	1.1	8.9 ± 2.0
			12b	Ceiling	1.1	6.6 ± 1.5

Table 2Neutron dose for 1 month in cyclotron room using PADC.

Point	Height from floor (m)	Thermal neutrons (mSv)	Fast neutrons (mSv)
1b	1	0.001	0.010
	0	0.002	0.050
2b	1	0.001	0.060
	0	0.003	0.040
3b	1	0.000	0.000
	0	0.001	0.000
4b	1	0.000	0.000
	0	0.002	0.000
5b	On self-shield	0.002	0.070
6b	On self-shield	0.001	0.000
7b	1	0.000	0.000
	0	0.000	0.010
8b	1	0.002	0.020
	0	0.022	0.080
9b	1	0.001	0.010
	0	0.000	0.010
10b	1	0.003	0.000
	0	0.001	0.000
11b	Ceiling	0.006	0.090
12b	Ceiling	0.000	0.000

4.Discussion

Table 1 shows that the thermal neutron flux was reduced by three orders of magnitude lower when a self-shield was installed. A similar tendency was observed in other studies. The clearance level (RS-G-1.7) is 0.1 Bq/g for ^{60}Co, ^{152}Eu, and ^{134}Cs. The neutron fluxes for ^{60}Co, ^{134}Cs, and ^{152}Eu (which are the principal activation nuclides generated in concrete) are such that $\Sigma D/C$ becomes unity for typical cyclotron usage (1 h per day for 30 years). The composition of concrete was calculated and the neutron flux was found to be about $2.7 \times 10^3 cm^{-2}s^{-1}$. The neutron flux attenuated behind the self-shield and was about $10^2 cm^{-2}s^{-1}$ when the cyclotron was operating. Therefore, the radiation level of the walls was sufficiently below the clearance level. However, the self-shield contains holes that connect with the exterior, and neutrons may pass through them. It is thus necessary to monitor the neutron leakage at each facility. It is essential to stop any leakage as soon as it occurs. Moreover, the floor should be corresponding as a no-self-shield type.

5.Conclusions

The neutron flux in a cyclotron laboratory with a self-shield was evaluated. The thermal neutron flux outside the self-shield was about 10^2 cm^{-2} s^{-1}, and the radioactivity of the wall of a self-shield cyclotron was below the clearance level. Due to the increasing public awareness of the problem, safe management of radioactive waste is critical for successful operation and decommissioning of accelerator facilities.