Measurements of Dose Distribution of Neutrons and γ-Rays in the Beam Transportation Room of a Cyclotron Building with Personnel Monitors

V. 5 Measurements of Dose Distribution of Neutrons and γ-Rays in the Beam Transportation Room of a Cyclotron Building with Personnel Monitors

Yamadera A., Fujita M.* and Izumi Y.**
Cyclotron and Radioisotope Center, Tohoku University
Chiyoda Safety Appliances Co., Ltd.*
Japan Environmental Research Co., Ltd.**

Introduction

The distribution of radiation doses in target rooms or a beam transportation room after stopping the operation of a cyclotron machine has often been measured by many researchers. However, it may also be necessary to know the distribution of doses in the rooms when the cyclotron is being operation, because, in an accidental case that some workers may be left in the room during operation, they have to escape from high radiation areas to lower ones. We measured the distribution of dose equivalents of neutrons and γ-rays during operation of a cyclotron in a beam transportation room.

Measurements

We measured the dose equivalents in the beam transportation room when the beams were transported into the 5th target room (51 course).

Film badges, TLDs and CR-39 plastic track detectors were used to measure the doses of γ-rays, thermal neutrons and fast neutrons. The CR-39 detector is sensitive to fast neutrons and insensitive to γ-rays. We put a number of the sets of these three detectors on the points shown in Fig. 1.

Intensities of neutrons and γ-rays generated depend on the beam currents of protons or deuterons. The beam attenuation conditions are shown in Table 1. Nine tenths of the beam were lost at the analyzer magnet 3 and fifteen sixteenths and thirteen fourteenths of the beam which had passed through the analyzer magnet 3 were lost at S2 chopper in case of protons and deuterons, respectively.

Results

Figures 2-5 show the distributions of dose equivalents of neutrons and γ-rays. The values of γ-ray doses estimated with film badges were larger than those with TLDs but the values of thermal neutron doses showed good agreements. The doses at the bottom of the stairs show lower values than those at the target room. For emergency safety, we can use the bottom of the stairs as a good shelter. The channge of the doses with places of thermal neutrons was not so large as that of fast neutrons, and in the target room, the thermal neutron doses showed almost the same value. β-rays and X-rays

(photon energy <80 keV) were not detected in any points by using film badges (detection limit was 10 mrem).

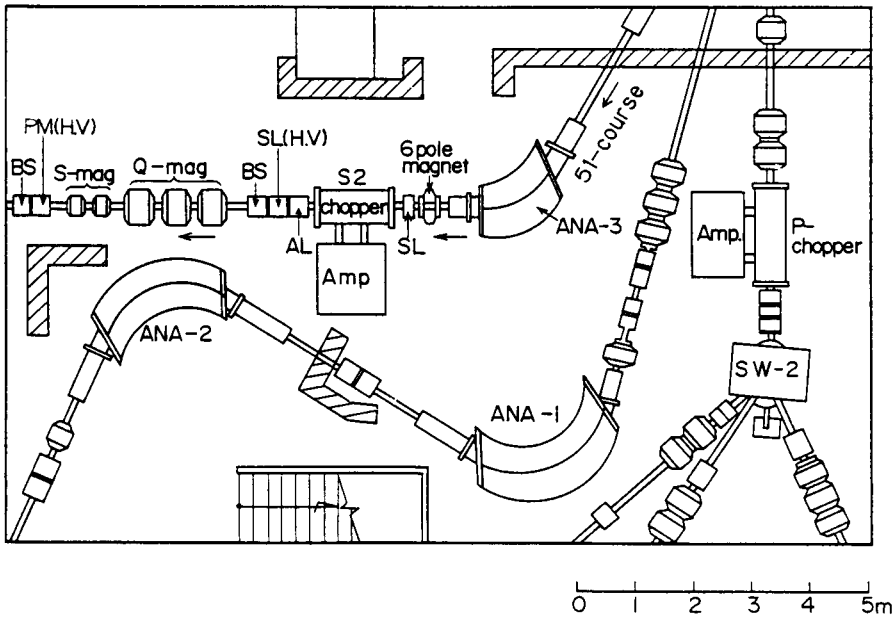
In γ-ray measurement, film badges showed larger values than TLDs. The reasons of this disagreement may be as follows. (1) Energy dependence: The film badge we used were calibrated in doses by using ^{60}Co(γ-ray 1.173, 1.332 MeV) standard sources, but for higher energy γ-rays, film badge we used had higher sensitivity. For example, sensitivity for 3.3 MeV-γ-rays was 1.7 times larger than that for ^{60}Co-γ-rays. (2) Directional dependence: In all directions, except for lateral irradiation, film badge had higher sensitivity than anterior-posterior direction. For example sensitivity in the direction of 135° was 1.2 times higher than in A-P direction. TLDs have no directional dependence for horizontal irradiation, because their shapes are columnar. Perhaps the detectors which we set in the target room were irradiated from all directions with direct radiations and scattered radiations, therefore it is possible that the doses which were measured with film badges were overestimated.

Table 1. Beam attenuation conditions.

particle accelerated	proton	deuteron
energy	35 MeV	25 MeV
electric current		
cyclotron	10∿15 μA	10∿15 μA
after ANA 3*	$(10\sim15)\times\frac{1}{10}$	$(10\sim15)\times\frac{1}{10}$
after S_2 chopper*	$(10\sim15)\times\frac{1}{10}\times\frac{1}{16}$	$(10\sim15)\times\frac{1}{10}\times\frac{1}{14}$
exposure time	3 minutes	5 minutes**

* See Fig. 1.

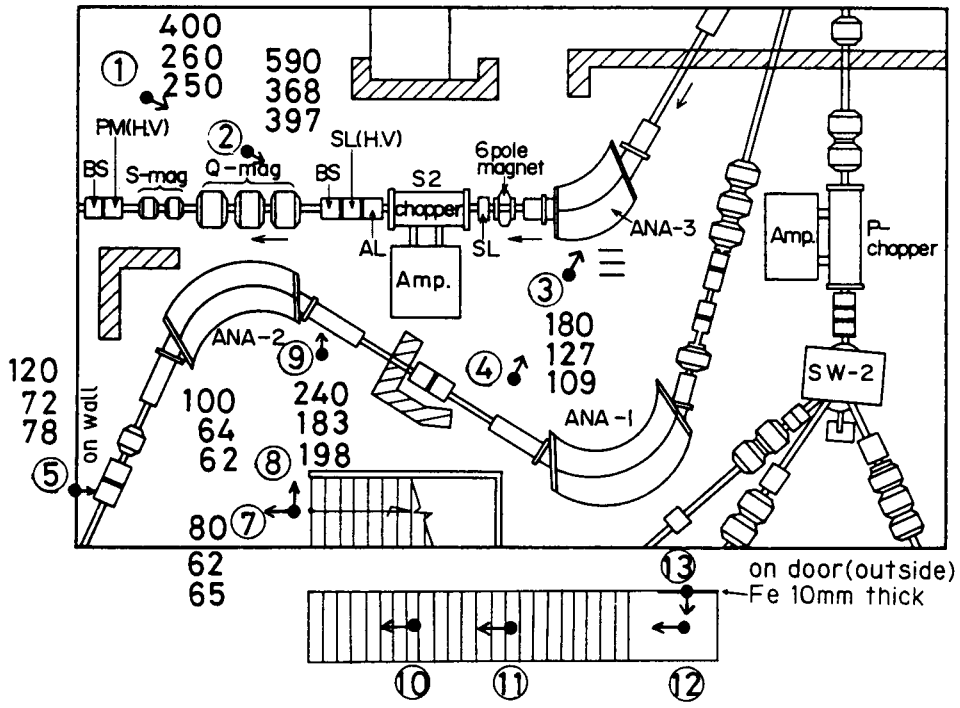
** Except for measuring points 12 and 13, where exposure time was 33 hours.



ANA: analyzer magnet, SL(H.V): slit(horizontal, vertical), SW: switching magnet, BS: beam stopper, S-mag: steering magnet, Q-mag: quadrupole magnet, AL: alumina monitor, PM: profile monitor. Arrows (→) show the direction of beams.

Fig. 1. Arrangement of magnets, beam stoppers, slits, choppers, etc. in the electromagnet room. Protons and deuterons were transported in the upper beam course (51 course).

2(a)



2 (b)

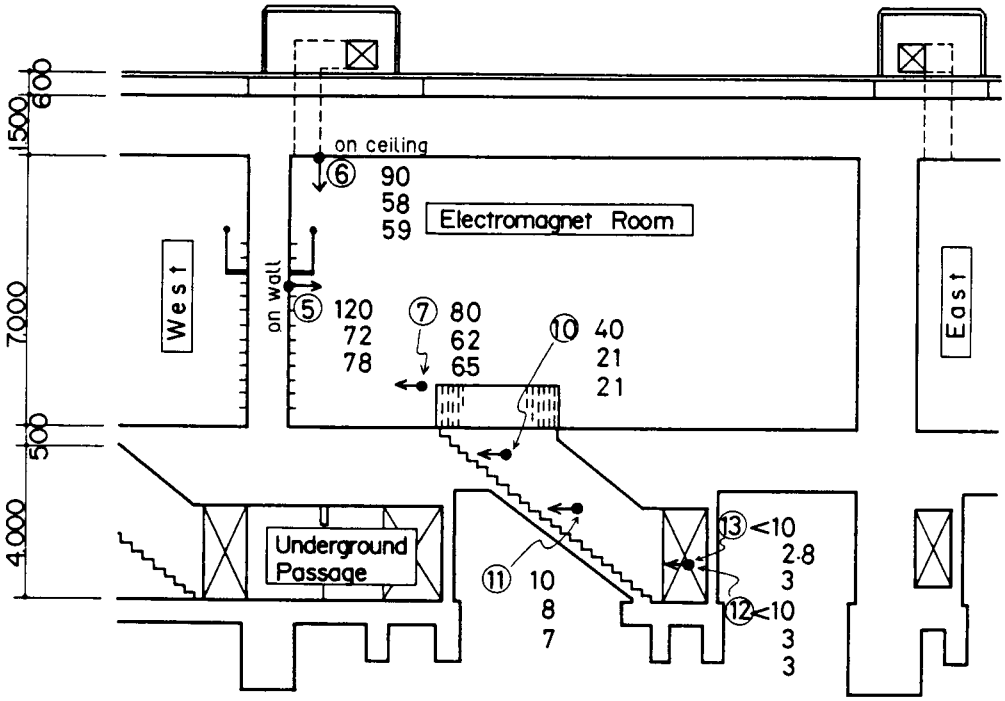
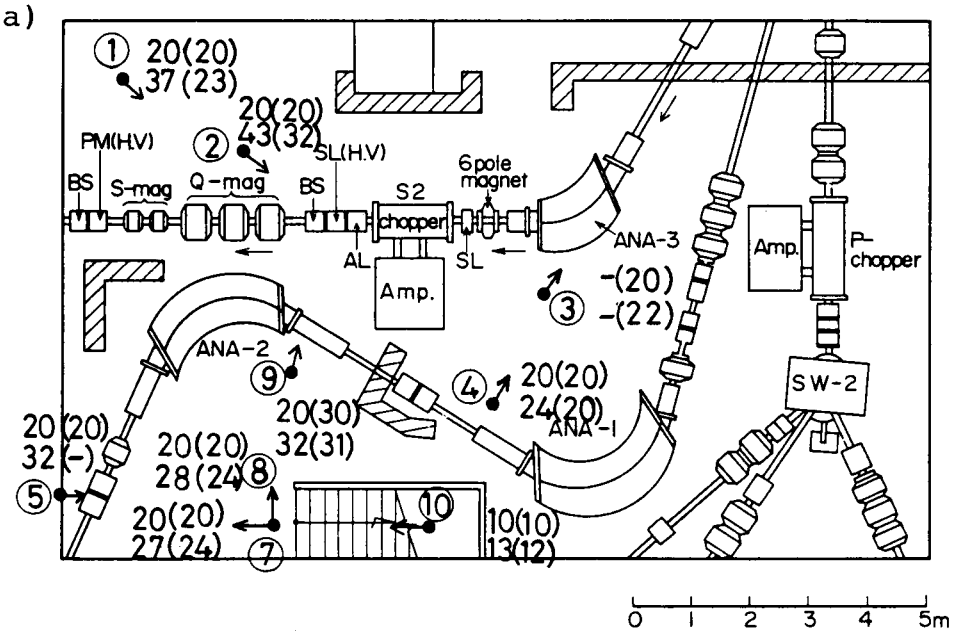


Fig. 2(a,b). Arrangement of detectors and γ-ray doses in mrem in the electromagnetic room (a: plane figure, b: cross sectional view) with 35 MeV protons. Circles (●) show the points measured and arrows (→) attached to the circles the directions of the detectors. Detectors were set at 1 m high except for Nos. 5 and 6. Figures from the upper line to the lower show those obtained with film badges, TLDs (UD-200S) and TLDs (UD-137N), respectively. -: not measured.

3(a)



3(b)

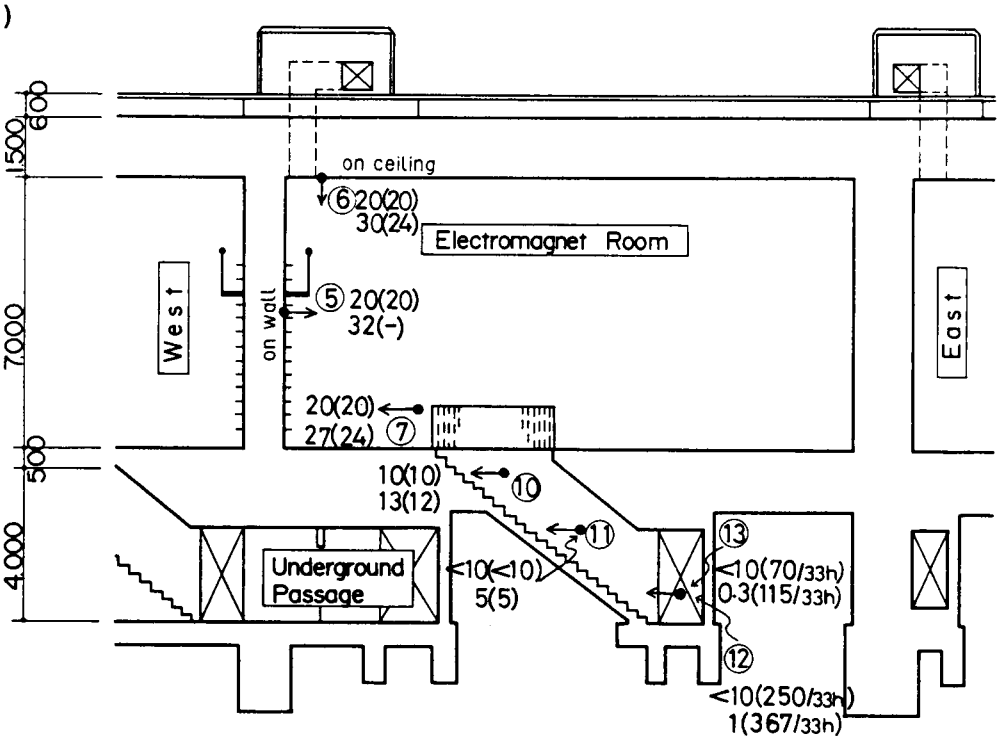
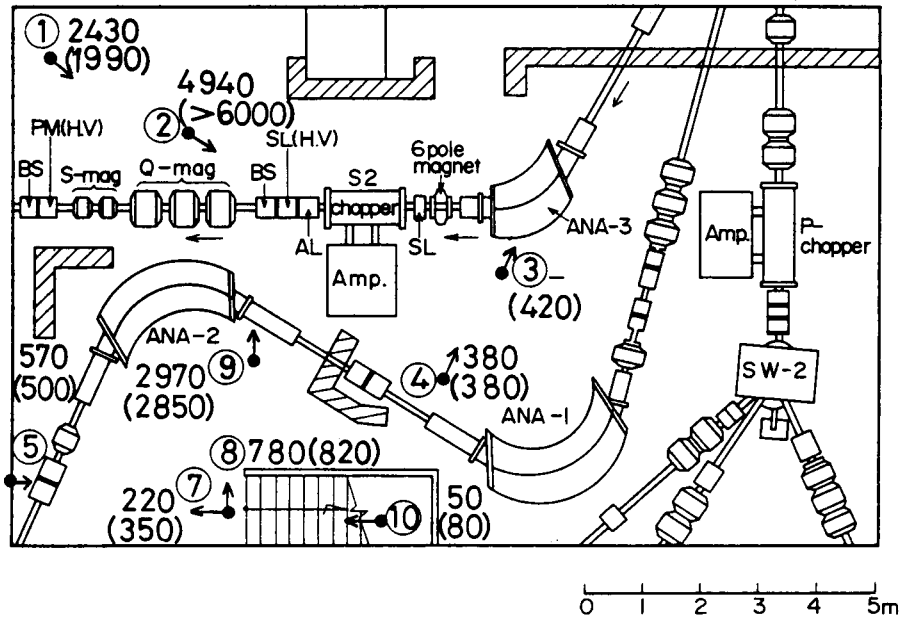


Fig. 3(a,b). Thermal neutron doses in mrem with 35 MeV protons and 25 MeV deuterons. The upper line figures show the data with Film-badges, and lower those with TLDs. Figures in parentheses show those on deuterons. -: not measured.

4 (a)



4 (b)

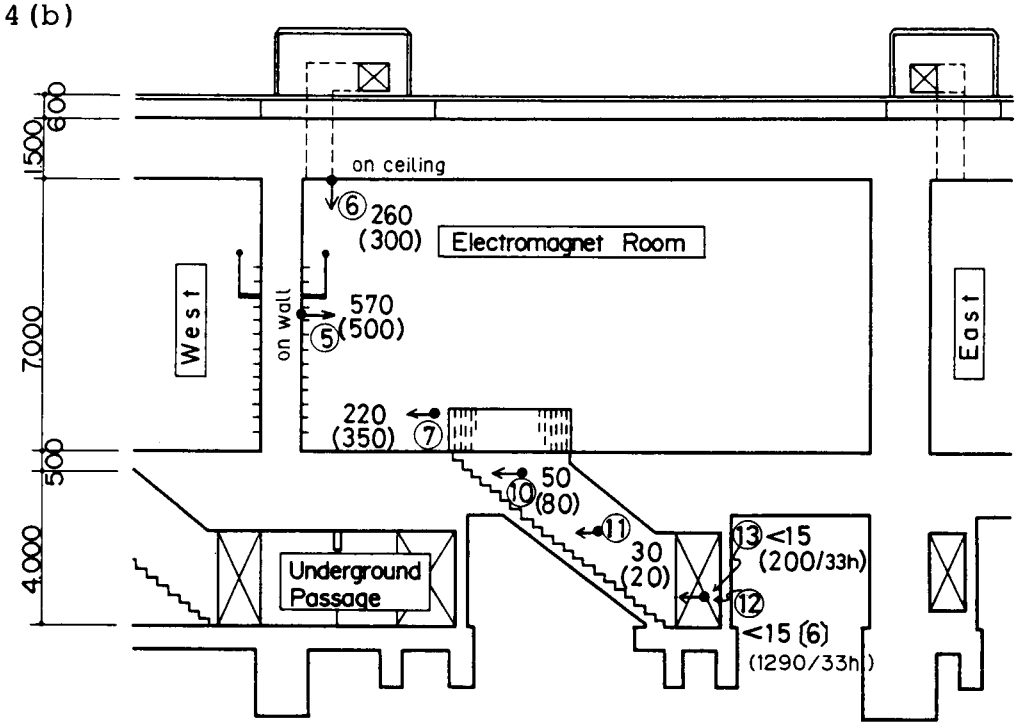
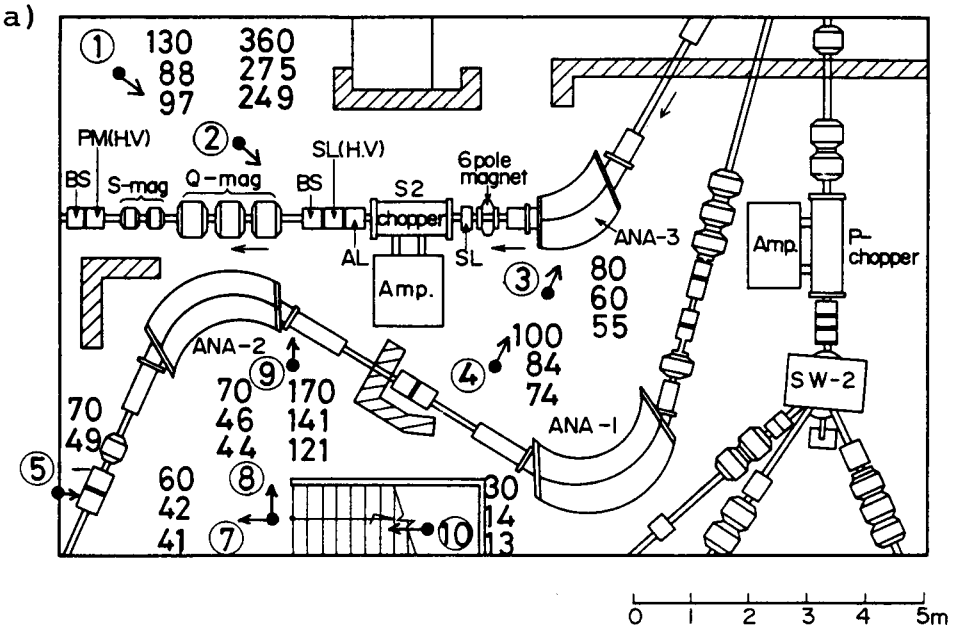


Fig. 4(a,b). Fast neutron doses in mrem with CR-39. Figures outside and in parentheses show the data obtained with 35 MeV protons and 25 MeV deuterons, respectively. Datum in square bracket was obtained with a rem counter. -: not measured.

5 (a)



5 (b)

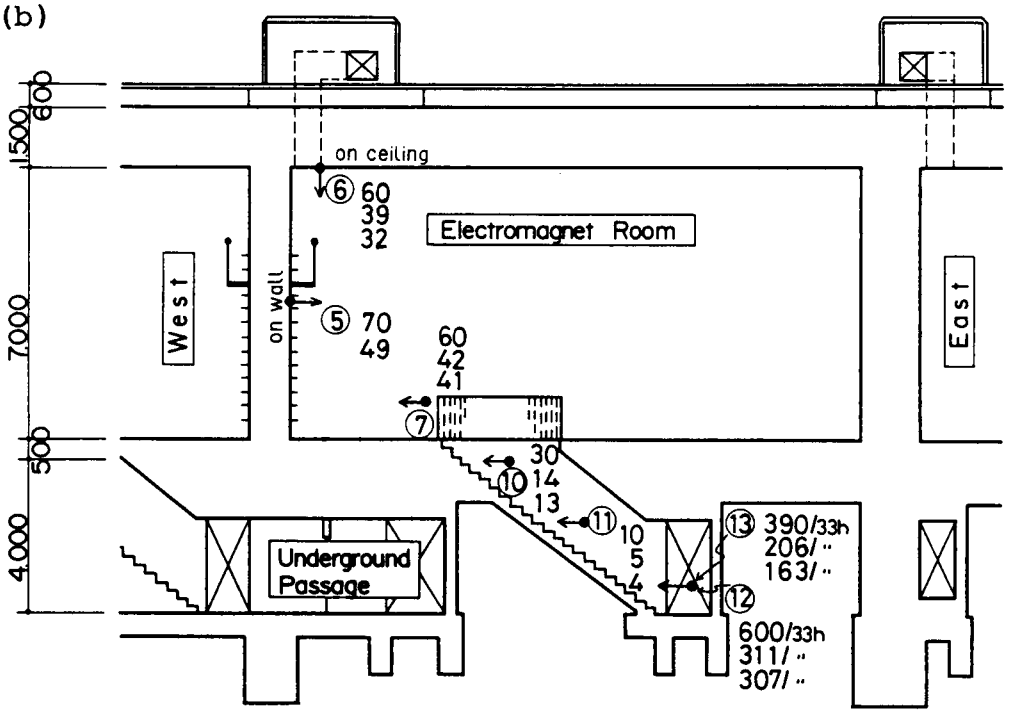


Fig. 5(a,b). Gamma-ray doses in mrem with 25 MeV deuterons. Figures from the upper line to the lower show those with film badges, TLDs (UD-200S), TLDs (UD-137N) respectively. -: not measured.