THE ATTENUATION OF NEUTRONS IN A LABYRINTH AT AN ACCELERATOR

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ABSTRACT

Using Cf-252 source, attenuation of neutrons in rectangular and curved labyrinths were studied. To measure neutrons, Andersson-Braun type neutron dose equivalent meter and moderated BF_3 counters were used. Measured dose equivalent in the 2nd leg was compared with the results by K. Tesch.

INTRODUCTION

There are many concrete labyrinths in the access ways for accelerators and the experimental data are needed on attenuation of accelerator produced radiation . Many studies were done about duct streaming of neutrons at nuclear reacters, but usually the diameter of ducts are much smaller compared with that of the access ways at accelerators. At some accelerator laboratories, the attenuation of neutrons in labyrinths was studied experimentally[1], but those geometrical conditions were limited.

Recently, however, attenuation of neutrons in labyrinths with rectangular bends were systematically studied at DESY by K. Tesch and the fit of his experimental data gave simple formulae to estimate attenuation of neutron dose equivalent in multi-legged rectangular labyrinths[2].

Then in this work Cf-252 fission neutron source was set in accelerator multi-legged mazes at KEK 12 GeV proton synchrotron and neutrons were measured using neutron rem-counters and BF_3 counters. And the experimental results were compared with the calculated ones using the above formulae because these labyrinths are much longer than those studied by K. Tesch. And neutrons were also measured in curved mazes.

EXPERIMENTAL PROCEDURE

Cf-252, 0.79 microgram, was used as isotropic fission neutron source. To measure neutron dose equivalent, Andersson-Braun type rem-counter, Studsvik 2202D, were used [3]. BF_3 counters, bare, cadmium coverd and polyethylene 4 cm thick covered, were also used to know neutron spectra.

There are multi-legged rectangular labyrinths between KEK 12 GeV PS and M2 local controll room. The inside width is 1.8 m, the height 2.0 m and the total length is about 50 m. These walls of mazes are made of ordinary concrete more than 80 cm thick and the concrete mazes are covered with thick earth shield. So the neutron background due to cosmic rays was low and usually less than 0.5 nSv/h. The neutron source and detectors were set at the center of cross section of the mazes, that is 1.0 m high above the floor.

There is another curved maze, 11.5 m radius, at M3 controll room. Its cross section is 3.0 m wide and 2.5 m high and the total length is about 27 m. In this case the neutron source was also put at 1.0 m high above the floor.

RESULTS AND DISCUSSION

First the typical experimental results in rectangular labyrinths are shown in Fig. 1. In this case the first leg is 8.8 m long and second one 16.9 m. Count rates of the rem-counter, bare and polyethylene moderated BF_3 counters are shown as a function of distance from the source. The bare BF_3 counter is very sensitive to low energy neutrons and response of moderated one is rather flat compared with the former. So in the second leg neutron spectra are much softer than in the first leg as shown in Fig. 1 but spectra are almost in equilibrium when the length of the second leg is longer than 4 m.

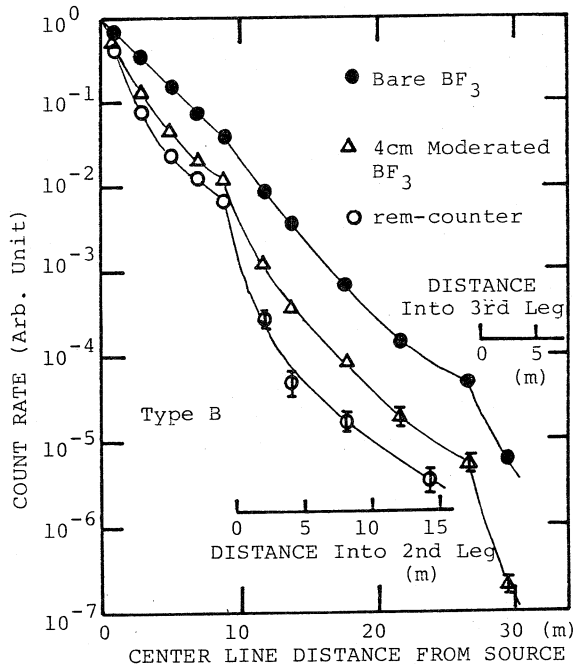

Fig. 1 Attenuation of neutrons in three-legged labyrinth measured by rem-counter, bare BF_3 and 4 cm thick polyethylene moderated BF_3 counters.

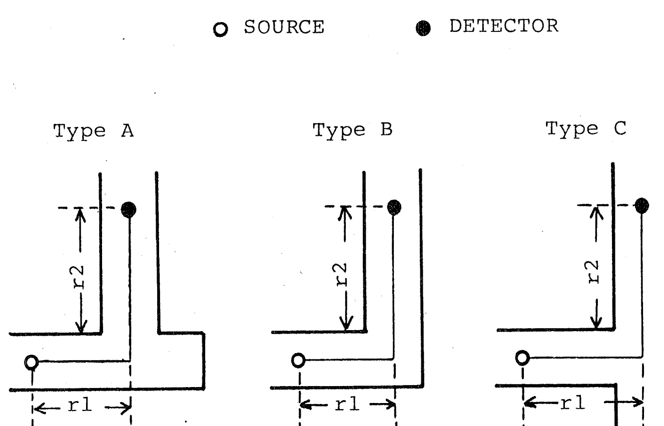

Fig. 2 Three types of labyrinths with and without "neutron traps" at the entrance of the 2nd leg

Then attenuation of neutrons in the second leg was systematically studied in three kinds of geometries as shown in Fig. 2. In type A, there is a "neutron trap" at the end of the first leg and type B without a "trap" , then in type C it is on the opposit side of the second leg. The neutron source was set at several positions in the first leg, that is 1.5, 3.0, 5.0 and 8.8 m distant from the corner. Measured neutron dose equivalent rates are shown in Fig. 3 as a function of length in the second leg. Each lenth was measured as in Fig. 2. Dose equivalent rates for three types of geometries are in good agreement with each other within each statistical error as shown in Fig. 3. So both neutron traps, type A and C, are useless.

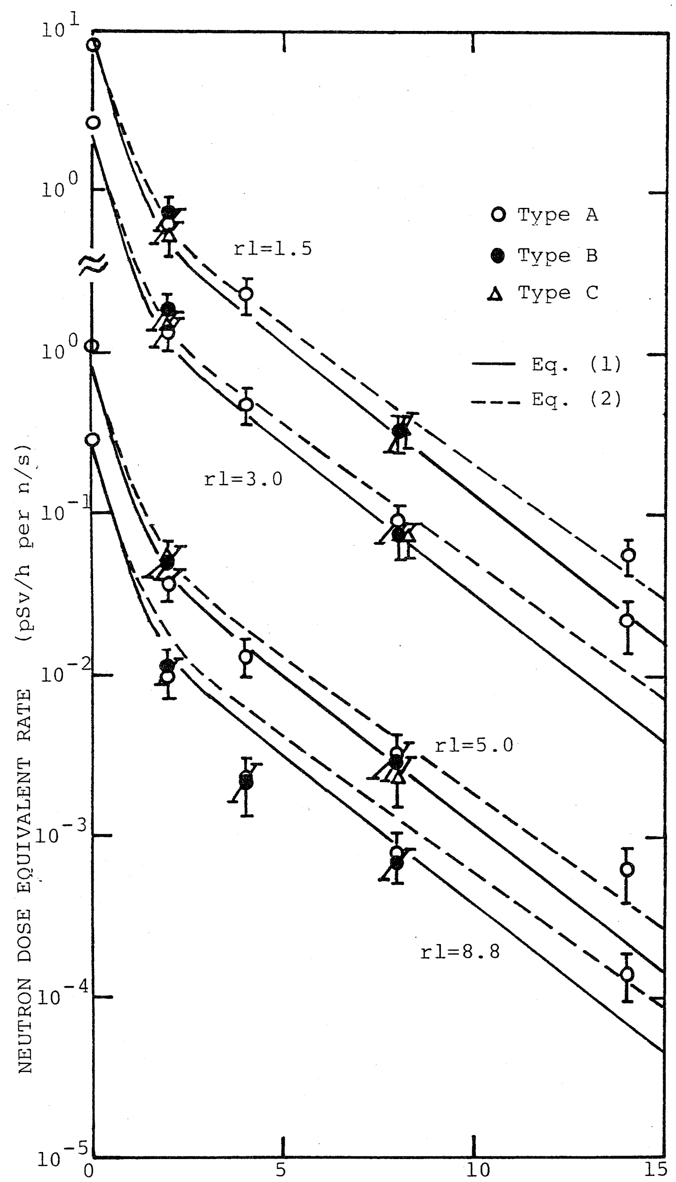

Fig. 3 Attenuation of neutron dose equivalent in the 2nd leg. Length of the each 1st leg is 1.5, 3.0, 5.0 and 8.8 m.

Next these experimental results were compared with the calculated ones using Tesch's formulae. These formulae are as follows, dose equivalent in the first leg is approximately two times as large as the direct contribution from the source because of scattered neutrons and in the second leg it is shown using the next equation if normalized to unity at the entrance of the second leg.

$$f2(r2)=[\exp(-r2/0.45) + 0.022*A^{1.3}*\exp(-r2/2.35)] / [1 + 0.022*A^{1.3}] \quad (1)$$

r2: distance into the second leg (m)
A : cross sectional area of labyrinth (m)

And dose equivalent due to Cf-252 neutron is 1.26 micro Sv/h per n/cm^2/sec, as calculated using ICRP-21. These calculated results are also shown in Fig. 3 (Full line). As a whole they are in good agreement with our experimental results within a facter 4. Agreement is especially good when lengths of both the first and the second legs are shorter than about 10 m. Results obtained from Eq. (1) noticeably underestimate dose equivalent rates if the second leg is longer than 10 m. So we revised the above formula as follows using least-squares fitting[4];

$$f2(r2)=[\exp(-r2/0.51) + 0.024*A^{1.3}*\exp(-r2/2.57)] / [1 + 0.024*A^{1.3}] \quad (2)$$

and the calculated results using Eq. (2) are shown in Fig. 3 (Dashed line). In this case agreement is better when r2 is larger than 10 m.

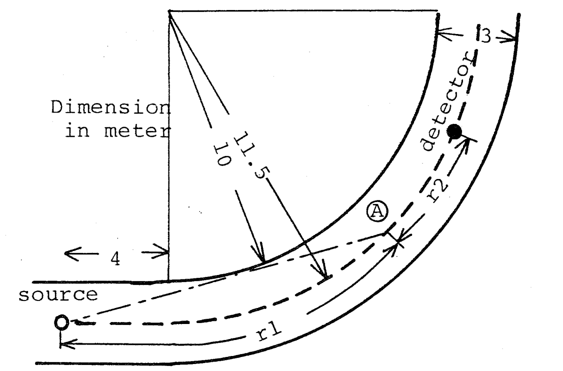

Fig. 4 Curved maze. The source disappears at Ⓐ.

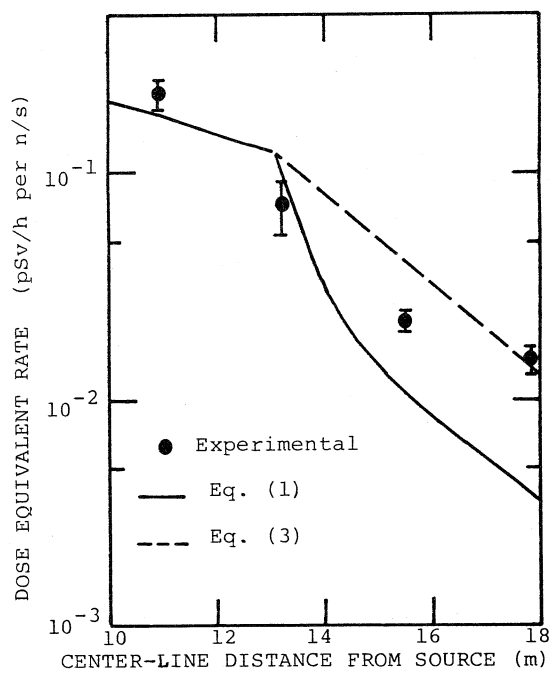

Fig. 5 Dose equivalent rate in curved maze.

In the case of the curved maze shown in Fig. 4, measured dose equivalent rates are shown in Fig. 5 as a function of distance from the source along the center line of the maze. It is not adequate to use Eq. (1) in this case. But to compare these results with those at rectangular mazes, calculated ones using Eq. (1) are also shown in Fig. 5 (Full line). To stretch Eq. (1) for curved mazes, it is assumed that r2 is the distance along the center line from the detector to the point where the source disappears (point A in Fig. 4). As shown in Fig. 5, curved mazes are not so effective as rectangular ones. There is not a simple and assured formula to astimate curved labyrinths but in curved tunnels it is suggested that[5]

$$f2(r2)=\exp(-\ r2/0.7/R^{0.5}) \quad (3)$$

R: tunnel radius (m)

and this result is shown in Fig. 5 (Dashed line). It was normalized at point A in Fig. 4. It is rather in good agreement with the experimental results within a facter 2.

CONCLUSION

Neutron spectra become much softer in the 2nd leg than in the 1st one but they are in equilibrium when the 2nd leg is longer than 4 m. To reduce neutron dose equivalent, "neutron traps" at the entrance of the 2nd leg are useless. Calculated dose equivalent rates using Tesch's formulae are in good agreement with our experimental results within a facter 4. But they are too low when the 2nd leg is longer than 10 m so these formulae were revised.

Curved mazes are not so effective as rectangular ones and attenuation of neutron dose equivalent in these mazes are rather well estimated using Eq. (3).

REFERENCES

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