RADIATION SHIELDING FOR THE RIKEN SSC

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ABSTRACT

Neutron transport calculation has been carried out with the ANISN code for monoenergetic neutrons emitted from a point source which is located at the center of a sphere of shielding materials. Concrete beam dumps have been designed for neutron sources which will be generated by reactions of 200 MeV protons with a thick aluminum target, and 135 MeV/u carbon beams with a thick iron target.

INTRODUCTION

The RIKEN SSC (separated sector cyclotron) will operate in a 200 MeV energy range for protons, and accelerate light heavy ions up to 135 MeV/u, and heavier ions to the lower energy region. In the previous report[1], the design for shielding wall and beam dump was made mainly by using the calculated results of Alsmiller et al.[2] and Roussin et al.[3], because we had not the cross section data available in these energy ranges. Recently the neutron-photon multigroup cross sections in ANISN format for neutron energies from thermal to 400 MeV were obtained, so the estimation for the beam dump has been done again.

NEUTRON SOURCE

The neutron sources to be shielded are assumed to be generated by the reactions of 1) 200 MeV protons with a thick aluminum target[4] and 2) 135 MeV/u carbon ions with a thick iron target. (We abbreviate these reactions to p+Al and C+Fe, respectively.) The beam intensity is assumed to be 6 × 10^{12} ions/sec. The latter energy spectrum was obtained approximately by shifting the spectrum cited in ref.5 (100 MeV/u ^{12}C beams on ^{56}Fe target) 35 MeV to higher energy, because we had no data for 135 MeV/u ^{12}C ions on ^{56}Fe

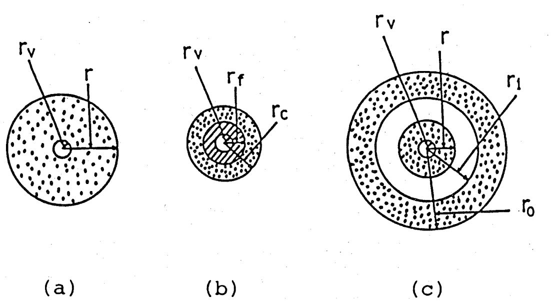


Fig.1. Geometries used in calculation of neutron transport.
(a) Spherical beam dump r_v=0.05 m, r=3-7 m
(b) Complex beam dump r_v=0.05 m, r_f=1 m, r_c=3 m
(c) Spherical shell structure with a spherical beam dump at the inside of a concrete shell r_v=0.05 m, r=2-3 m, r_i=5 m, r_0=7 m

Table 1

Atomic density of concrete and iron used for the calculation.

	Density (atoms/cm³)
Concrete component	
H	5.95×10^{21}
O	4.48×10^{22}
Si	2.00×10^{22}
Ca	1.52×10^{21}
Fe	7.38×10^{20}
Iron	
Fe	7.70×10^{22}

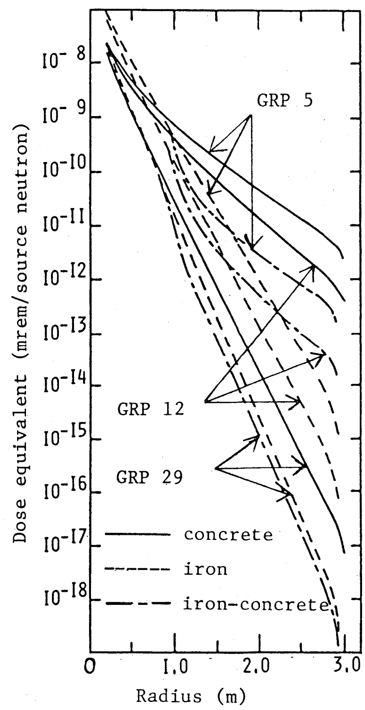


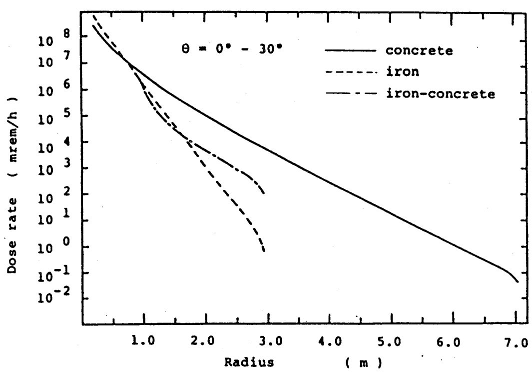
Fig.2. Dose attenuations in spherical beam dumps.
GRP 5,12 and 29 mean the initial neutron energies of 300-275 MeV, 140-120 MeV and 22.5-20.0 MeV, respectively.

target. It will not be so wrong because shape of the energy spectrum does not vary markedly in this incident-energy region.[6]

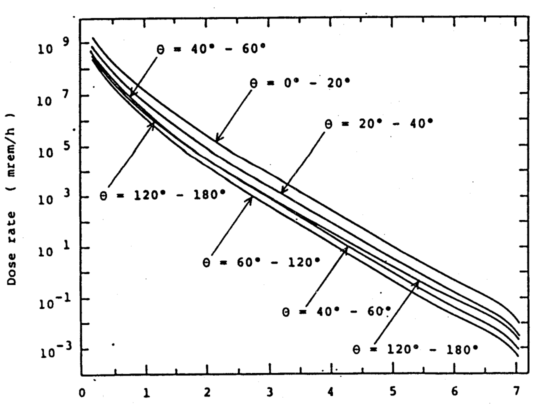
We can also see that the angular distribution of neutrons produced by the reaction of C+Fe is not so remarkably forward peaking as that of the reaction of p+Al.[4,5]

CALCULATED RESULTS

Geometries for calculations with the ANISN code are shown in Fig. 1 and atomic densities of concrete and iron are given in Table 1. Typical results are shown in Figs. 2 and 3, in which dose attenuations of neutrons by concrete, iron, and iron-concrete assembly are given. Figure 2 shows the dose attenuation of one monoenergetic neutron emitted from the center of a sphere of shielding materials. Figures 3-a and b show, respectively, the dose attenuations of neutrons which will be generated by the reactions of the p+Al and the C+Fe, in the shielding spheres.



(a)



(b)

Fig.3. Dose rates as a function of radius for neutron sources generated by reactions of a) the p+Al and b) the C+Fe.
Beam intensity is 6 × 10^{12} ions/sec. In (a) only the calculated results in angular interval 0° - 30° are given.

By using Figs. 3-a and b we can determine the radial size of the beam dump, in the various directions with respct to the beam, which yield a tolerance dose at the shield surface. The tolerance dose rate at the just outsize of the wall around the target area is established to be less than 0.6 mrem/h[7]. Generally the beam dump will be set up in contact with the wall of the target area (3 m thickness in our case). Therefore the allowable dose at the surface of a concrete beam dump, and its radial size in the angular width of 0° - 30° are, respectively, 2.5 × 10^3 mrem/h and 3.25 m for the neutron source of the p+Al case. Thus an iso-dose contour can be drawn for a concrete beam dump as shown in Fig. 4. In the figure, a similar curve for the neutron source of the C+Fe case is also given.

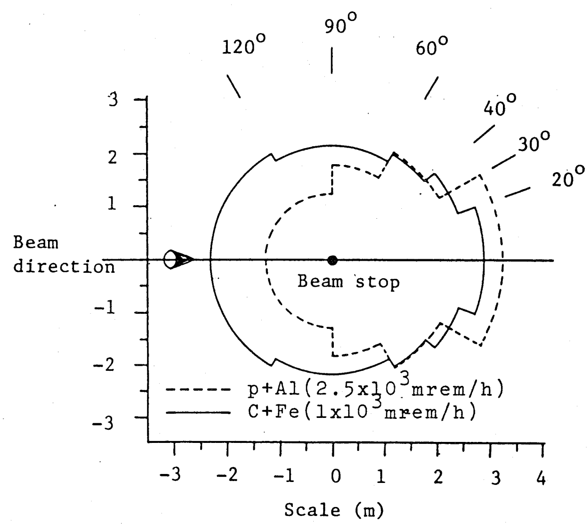


Fig.4. Iso-dose contours for the sources of p+Al and C+Fe.
Beam intensity is assumed to be 6 × 10^{12} ions/sec. The numerical values in the figure correspond to the dose rates at the surface of the beam dump, when the dose rate at the outer surface of the wall around a target area reduce to 0.6 mrem/h.

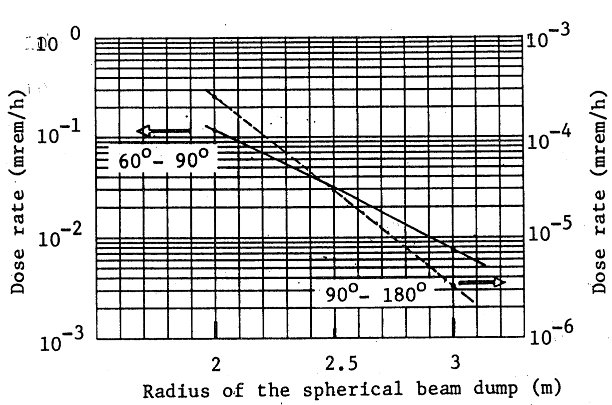


Fig.5. Dose rate at the outer surface of a concrete spherical shell as a function of the radius of a concrete beam dump for the p+Al.
Beam intensity is assumed to be 6 × 10^{12} ions/h.

When the beam dump is set up adequately apart from a ceiling, the room will be considered to have a geometry shown in Fig. 1 - c. The dose rate is shown in Fig. 5 as a function of radius of the spherical beam dump. The distance from a beam stop to the ceiling is 5 m and the thickness is 2 m. Figure 5 is used to determine the radial size of the beam dump, which is estimated for the dose not to exceed the allowable radiation level at the surface of the floor of an upper room. If the radiation level at the floor is kept less than 0.1 mrem/h which is much lower than the allowable level, the radial size should be more than 2.1 m for the neutron source of the p+Al case.

The radial dependence of the calculated dose given in Figs. 2 and 3 contains a component attributed to the neutrons backscattered. They may amount to a few tens percent. We plan to calculate the transport of neutrons for several other materials intending to design a more satisfactory beam dump which meets demands with reference to size, residual activities etc. Moreover, it is an important problem to minimize the leakage neutrons through the entrance of the beam dump in order to minimize not only the health hazard but also the radiation background in measuring systems for experiments.

CONCLUDING REMARKS

Calculation of neutron transport has been done with the ANISN code for beam dumps of concrete, iron, and iron-concrete assembly, assuming a monoenergetic point source at the center of the sphere. Using calculated results, the relation between the dose rate and the radius of a spherical beam dump was obtained in various directions for the neutron sources of the p+Al and the C+Fe. The usableness of the diagram for the design of neutron shielding was examined. We are now proceeding the design of the beam dump more extensively.

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