PENETRATION OF NEUTRONS AND PHOTONS THROUGH SHIELD INJECTED TO PROTON-INDUCED NEUTRONS AND PHOTONS

Yoshitomo Uwamino, Mitsuo Yoshida, Kazuo Shin, Katsumi Hayashi
Department of Nuclear Engineering, Kyoto University

Takashi Nakamura
Institute for Nuclear Study, University of Tokyo

The study on the penetration of several tens-MeV neutrons is required for shielding of high energy accelerators up to a few hundred MeV, since the secondary neutrons of this energy region are dominant. There are several papers on the transmission problem of neutrons higher than 15 MeV, but no papers deal with the spectral measurements. We have performed the spectral measurements of neutrons and photons transmitted through water (80x55x60,100,160 cm^3), graphite (54x90x11.7,23.5,44.9,64.5 cm^3), concrete (75x60x46,69,115 cm^3) and iron (50x52x20,40,60 cm^3) assemblies which are commonly used as beam stopper, accelerator material and shield. The neutron and photon spectra transmitted into the forward direction along the proton beam axis were measured with a NE-213 scintillator by using a source of secondary neutrons and photons produced from 2.145 cm thick carbon target exposed to 52 MeV proton.

The estimation of the room scattering was performed under the experimental arrangement to shut off the leakage radiation from the assembly by setting a 80-cm long paraffin shadow bar between the detector and the assembly. Our experimental data showed that the neutron and photon fluxes obtained with the shadow bar are about one tenth and about 70% of those without it in the worst case, respectively. All the spectra shown below are given with subtracting this background radiation, since the distribution of room scattering is approximated to be uniform in the room.

In order to compare with the experimental results, a Monte Carlo code to calculate the neutron transport in graphite was developed by modifying the O5S code[1]. Our experimental result for 2.145 cm thick carbon target[2] was used as a neutron source of the Monte Carlo calculation. The forward neutron spectrum $\phi_n(E)$ measured with the detector 3.5 m backward from the front face of the assembly is compared with the calculation for 23.5 cm thick graphite assembly in fig. 1 as an example. Figure 1 also includes the uncollided neutron flux $\phi_n^{uncol}(E)$ which is about 20% of total transmitted neutron flux in this thickness. The calculated neutron spectra are in very good agreement with the experimental ones in absolute values for graphite.

Figure 2 shows the forward photon spectrum $\phi_\gamma(E)$ meausred with the detector 3.5 m backward from the front face of 23.5 cm thick graphite assembly as an example. For comparison, fig. 2 includes the uncollided photon flux $\phi_\gamma^{uncol}(E)$. It can be found out that the 4.43 MeV photons from $^{12}C(p,p')^{12}C$ are almost direct component transmitted through the shield without any collision and the photons lower than 4.43 MeV energy include the component scattered in the assembly.

Figures 3 and 4 shows the attenuation of integrated neutron and photon fluxes with the shield thickness. These experimental data are well fitted to the exponential attenuation curve, whose slopes are inversely proportional to the effective atomic numbers of graphite (Z=6), water (Z=7.23), concrete (Z=12) and iron (Z=26). It can be deduced from these results that almost all neutrons leak from the assembly in the forward direction after successive small angle scatterings and that most of leakage photons are those which were generated from the carbon target by a proton beam and penetrated through the assembly without any collision.

References

1) R. E. Textor and V. V. Verbinski, ORNL-4160 (1968).
2) T. Nakamura, M. Yoshida and K. Shin, Nucl. Instr. Methods, in press.

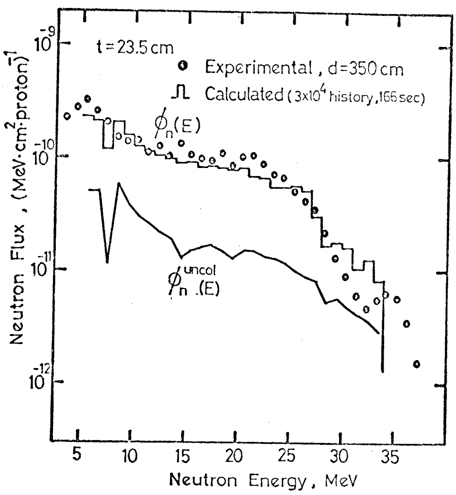

Fig. 1. Forward neutron spectrum through 23.5 cm thick graphite

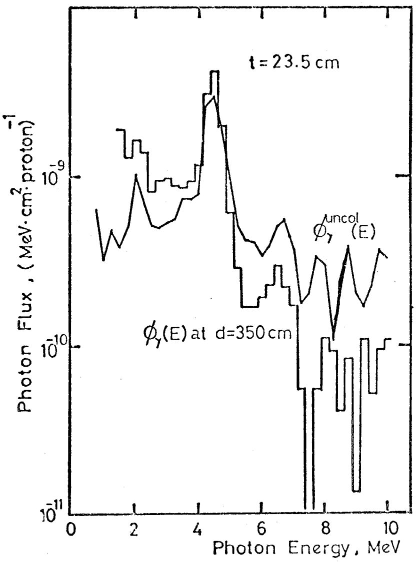

Fig. 2 Forward photon spectrum through 23.5 cm thick graphite

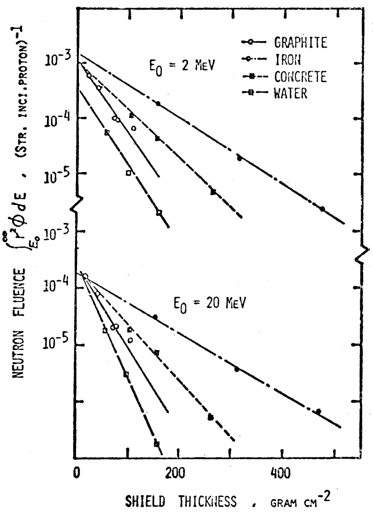

Fig. 3 Attenuation of neutron flux integrated above E_0

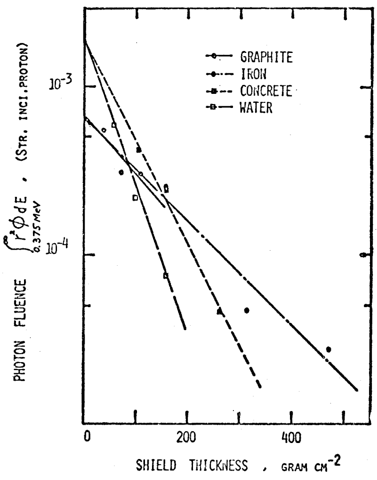

Fig. 4 Attenuation of photon flux integrated above 0.375 MeV