Penetration through Shielding Materials of Secondary Neutrons and Phtons Generated by 52-MeV Protons

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Attenuation of neutrons and photons transmitted through graphite, iron, water and ordinary concrete assemblies were studied. Energy spectra of neutrons ($E \gtrsim 2$ MeV) and photons ($E \gtrsim 0.4$ MeV) were measured using an NE-213 organic scintillation detector with an n-γ discrimination technique, and thermal and fast neutron flux distributions in an assembly were measured with gold and iron activation foils, respectively. Source neutrons and photons were produced by 52-MeV proton bombardment of a 21.4-mm-thick graphite target placed in front of the assembly. The distributions of the light output from the scintillator were unfolded by the revised FERDO code using neutron and photon response functions calculated by the Monte Carlo codes. These experimental results were used as benchmark data on neutron and photon penetration by neutrons of energy above 15 MeV. Multigroup Monte Carlo, one-dimensional ANISN and two-dimensional DOT-3.5 transport calculations were performed with the DLC-58/HELLO group cross sections to compare with the measurement and to evaluate the cross sections. Source neutrons of energy below the lower limit of the measurement (2 MeV) were estimated by the evaporation model.

Figure 1 shows the absolute comparison of measured and calculated forward neutron spectra transmitted through ordinary concrete shield, as an example[1]. The results of the ANISN calculation of neutrons in slab geometry and the three-dimensional Monte Carlo calculation agreed with the experimental values. The attenuations of neutron fluxes integrated above 2 MeV are shown in Fig. 2. The agreement of ANISN and Monte Carlo calculations is well within the accuracy of 7% in the measured attenuation coefficients for graphite, iron and water, and less than 10% for concrete. As shown in Fig. 3, the DOT-3.5 calculation in cylindrical geometry is in good agreement with thermal neutron flux distribution in a 44.5-cm-thick graphite assembly measured with gold activation foils. Fig. 4 shows the attenuation profile of the photon flux integrated above 0.4 MeV. The ANISN calculation gave more than 20% overestimation of the photon attenuation coefficients in the case of deep penetration through the medium for which the photon mean-free-path is shorter than that of neutrons, such as in iron and concrete. The secondary photons produced by the neutron-nucleus reactions are dominant compared with the primary photons, but otherwise the ANISN calculations gave good results. As an example, Fig. 5 shows the absolute comparison of measured and calculated forward photon spectra transmitted through concrete. This difference may be explained by that the photons produced by neutron-nucleus nonelastic collisions of energies of higher than 14.9 MeV are neglected in DLC-58, and that the photons scattered by the walls and the ceiling make a noticeable contribution compared with strongly attenuated photons through these thick shields.

Reference

1) Y. Uwamino, T. Nakamura and K. Shin
Nucl. Sci. Eng., 80, 360 (1982).

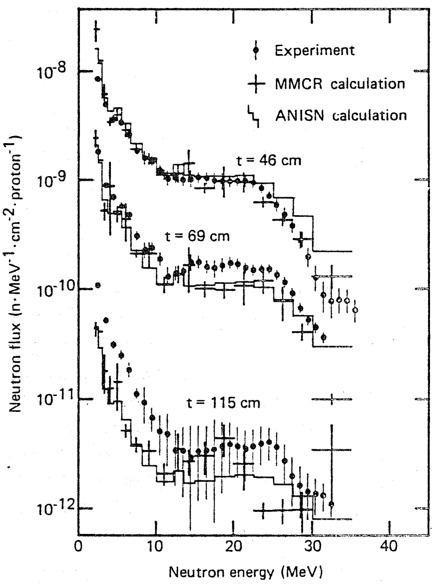

Fig. 1. Comparisons of absolute values of measured and calculated forward neutron spectra transmitted through ordinary concrete assemblies.

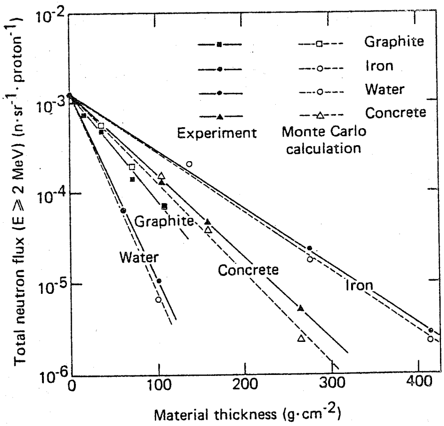

Fig. 2. Measured and calculated attenuation profiles of the neutron fluxes integrated above 2 MeV. The calculations shown here were obtained by the Monte Carlo code.

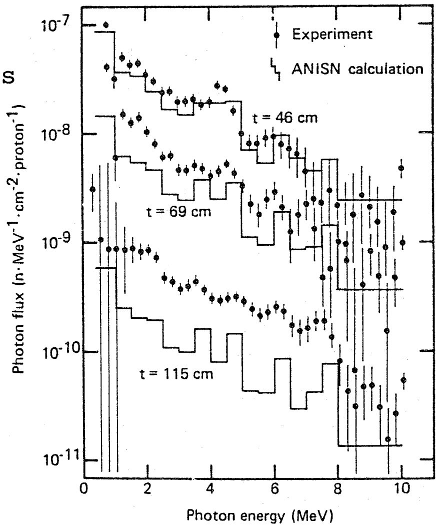

Fig. 5. Comparisons in absolute value of measured and calculated forward photon spectra transmitted through ordinary concrete assemblies.

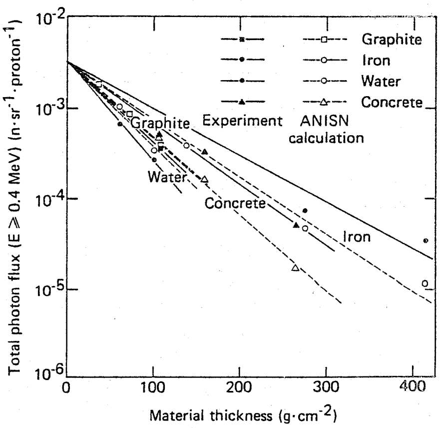

Fig. 4. Measured and calculated attenuation profiles of the photon fluxes integrated above 0.4 MeV.