PENETRATION OF FAST NEUTRONS THROUGH AN AXISYMMETRIC SHIELD

A. N. Kozhevnikov, V. A. Khodakov, and A. V. Khrustalev

Analytical and numerical methods of solving the equation for the transport of radiation through a shield of complex configuration involve the familiar difficulties of many-dimensional geometry and the necessity of taking account of the energy dependence of the cross sections and the anisotropy of scattering processes in matter. In many cases the Monte Carlo method surmounts these difficulties by simulating particle trajectories directly, but it is not free of faults either, the main one being the necessity of simulating improbable events. This is the case in the calculation of deep penetrations of radiation, but the calculations can

Fig. 1. Attenuation of neutrons with energies E ≥ 1 MeV as a function of shield thickness h: O) experimental data [4] (total flux); ●) experimental data [4] (unscattered flux); —) Monte Carlo calculation; ---) calculation using total cross section.

Fig. 2. Fast neutron spectra for various shield thicknesses (Monte Carlo calculation).
be speeded up appreciably by using splitting and Russian roulette. Optimal splitting factors are obtained in [1] for a given arrangement of splitting surfaces, but so far as we know the general problem of choosing the number and locations of the splitting surfaces which ensure the greatest efficiency remains unsolved.

V. A. Khodakov solved this problem exactly for the simplest physical model of the transport of radiation through an infinite slab shield. The optimum parameters of the statistical model (attenuation in the layers, splitting factors) depend on the probability characteristics of the interaction of the radiation with the shield material, but the absolute minimum calculation time for a given statistical error in the cases of practical interest is nearly achieved by dividing the shield into arbitrary layers with repeated attenuation of the particle current and appropriate smoothing in the depth of the shield.

This result is used in the ANKON program written in FORTRAN for a digital computer. The calculation is based on the stochastic simulation of the "wandering" of a particle in phase space with appropriate transition probabilities. Splitting and Russian roulette are accomplished in this program by the lexicographic processing of trees of trajectories [2]. Preliminary calculations show that Russian roulette is ineffective in estimating the current of fast neutrons behind a shield of hydrogenous material, and therefore neutrons backscattered toward the source can be neglected.

The ANKON program permits the calculation of integrated fluxes and spectral-angular distributions of neutrons with energies from 0.1 to 14 MeV both inside and outside finite lithium hydride shields. Plane sources are considered with various angular and spatial distributions.

Simulation of the deep penetration of radiation requires very accurate data on the interaction of radiation with matter. Analysis showed that for neutrons in the 0.1–14 MeV energy range lithium hydride can be regarded as consisting of H and Li atoms in taking account of the following interaction processes: elastic scattering by hydrogen, elastic scattering by lithium, inelastic scattering by lithium, and absorption. In choosing the ranges and scattering processes the program uses data obtained by linear interpolation in the tables in the cross section library [3]. In order to ensure the correctness of the set of interaction constants the calculated results were compared with the corresponding experimental data.

Figure 1 shows the calculated and experimental dependence of the attenuation of the neutron flux \( (E \geq 1 \text{ MeV}) \) on the thickness of a lithium hydride \( (\rho = 0.5 \text{ g/cm}^3) \) shield for a plane monodirectional source having a fission spectrum [4]. Here the calculations and experiments are for good geometry. A certain divergence at large thicknesses can be explained by the fact that the spectrum of incident neutrons in the experiment was harder than the fission spectrum above 1 MeV. Figure 2 shows histograms of fast neutron spectra for lithium hydride shields of various thicknesses. The figure illustrates the tendency of the spectrum to harden with increasing thickness of a hydrogenous shield.