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ОРИ

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CALCULATIONAL INVESTIGATION OF NEUTRON DOSE FORMING IN THE SHIELDING LABYRINTHES

Protvino 1992

UDK 539.12.125 M–24

Abstract

Kryuchkov V.P., Sumaneev O.V. Calculational Investigation of Neutron Dose Forming in the Shielding Labyrinthes: IHEP Preprint 92-173. – Protvino, 1992. – p. 7, figs. 10, refs.: 6.

Calculational investigation of the dose equivalent forming in shielding labyrinthes were carried out using the program MOSKIT, which realized the Monte Carlo method for calculating particle (n, p, π, γ) penetration through the matter. The calculational data are shown to be in agreement with experiment. The curves of neutrons and photons dose equivalent in one-, two- and three section labyrinth are presented.

Аннотация

Крючков В.П., Суманеев О.В. Расчетное исследование формирования дозы нейтронов в защитных лабиринтах: Препринт ИФВЭ 92-173. – Протвино, 1992. – 7 с., 10 рис., библиогр.: 6.

С помощью программы MOSKIT, реализующей метод Монте-Карло для расчета переноса частиц (n, p, π, γ) в веществе, проведено расчетное исследование формирования эквивалентной дозы от нейтронов и фотонов в защитных лабиринтах. Показано удовлетворительное согласие расчетных данных с экспериментальными, полученными на изотопном источнике нейтронов. Представлены кривые ослабления дозы от нейтронов и фотонов в одно-, двух- и трехсекционных лабиринтах.

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Расчетное исследование формирования дозы нейтронов в защитных лабиринтах.

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INTRODUCTION

The communication passages (labyrinthes) for personnel, equipment, water, air, electricity are an important part of the radiation shield of nuclear facilities (accelerators, nuclear reactors, etc.). Meanwhile these labyrinthes worsen the efficiency of radiation shield and create additional sources of radiation. Adequate designing of labyrinthes should be based on deep understanding of their shielding efficiency. The results of the calculational investigation of dose forming from neutrons and photons in labyrinthes are presented in this paper.

1. METHOD OF CALCULATION

Calculations were carried out using the code MOSKIT [2]. The peculiarity of this code as compared with analogous known codes is: 1) realization of particle trajectory simulation in 7-dimensional phase space $X, Y, Z, \theta, \Phi, E, I$ (X, Y, Z – coordinates, θ, Φ – polar and asimuth angles, E – energy, I – particle type, where θ, E, I are discrete quantities only; 2) the selection of particle characteristics after scattering is realized by using the matrix of integral distribution of transition probability; 3) the algorithm of particle trajectory simulation, realized in MOSKIT, is universal as far as particle type and its energy. The program MOSKIT is assigned to caculate the transport of neutrons with energy (0.001 eV $< E <$ 10 TeV), protons and pions (10 MeV $< E <$ 10 TeV), photons (1 keV $< E <$ 20 MeV). The constant system for transport calculations of neutron and photons with $E <$ 20 MeV is USCONS [2], for neutrons, protons and pions with $E >$ 20 MeV it is SADKO [3]. There are some angular meshes for various energy regions. The angular mesh of polar angle for energy region $E >$ 20 MeV is uneven and includes 100 angular intervals, for $E <$ 20 MeV it is even and includes 25 agular intervals. The azimuth angle of angular mesh is

even and includes 10 angular intervals. The energy mesh for the calculations in the region 10^{-2} eV – 15 MeV was the same as the multigroup system BNAB 49×15 [4] (49 groups for neutrons and 15-for photons). The knots of the spatial mesh coincide with the bounds of regions where cross sections are constant.

100000 histories were simulated in each variant of task. It took about 15 minutes of computer VAX. Double local estimation was used for calculations of dose equivalent and fluence. It allowed one to obtain the statistics error for this functional less than 6%.

2. DOSE IN ONE-SECTION LABYRINTH

Calculational investigation was carried out for 3 types of labyrinthes. Their schemes are taken from [1] and presented on fig.1.

The geometry of a maze (fig.1a) as the simplest element of the labyrinth is the most important one for investigation of dose forming in the labyrinth. According to [1] we will investigate the function H_s/H_d (H_s – dose from scattered neutrons, H_d – dose from unscattered neutrons of the source), which describes scattered neutron accumulation in a maze. The calculational distribution of H_s/H_d along the maze axis as a function of its width in comparison with experimental data [1] are presented in fig.2. One can see that:

1. Calculational data are in a good agreement with the experiment.

2. There is some irregularity in the behaviour of H_s/H_d for a narrow maze (width < 1 m). It is most obvious for a maze 0.5 m/wide. This irregularity can be explained by the influence of two independent and competing processes: 1) scattering of Am-Be neutrons in the matter of the maze; 2) neutron accumulation in the "source box" and their attenuation in the maze.

3. Neutron accumulation degree (maximum of H_s/H_d) increases with the maze width.

The degree of dose accumulation in the maze is determined by the albedo of the maze wall matter. The calculation of the dose distribution versus geometry (fig.1a) with steel walls, was performed to confirm this fact. The results of H_s/H_d calculation for a steel maze are presented in fig.3 in comparison with those for a concrete maze. One can see that neutron accumulation in the steel maze exceeds neutron accumulation in the concrete maze by a factor of 2-4. It is related with the ratio of the albedo for steel to that for concrete (A_{fe}/A_c 2-3).

The scattered neutrons spectra F(E) in point 1 (fig.1a) for width 1 and 2 meter are presented in fig.4. One can see that the spectra of scattered neutrons in the concrete maze are smooth enough and slowly change with the increasing

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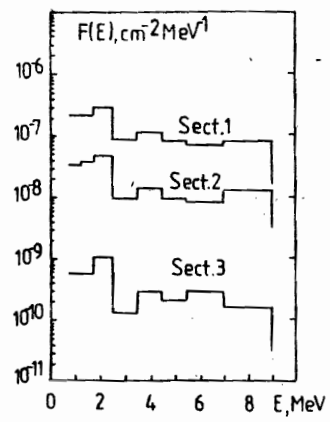

Figure 8. Energy distribution of photons in points 1,2,3 (fig.1c) of a concrete labyrinth with 3 sections.

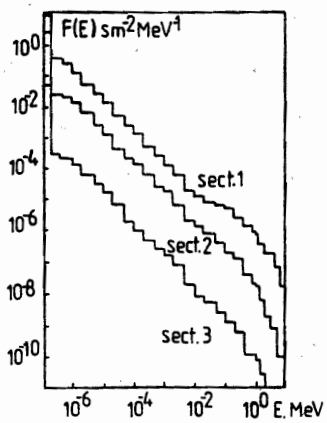

Figure 9. Energy distribution of neutrons in the points 1,2,3 (fig.1c) of a concrete labyrinth with 3 sections.

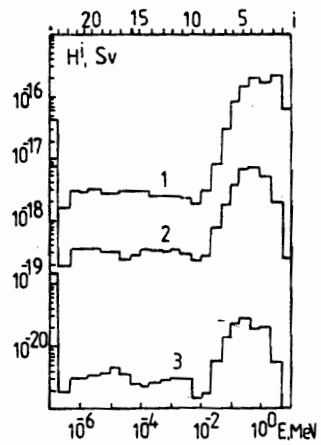

Figure 10. Distribution of group neutron dose Hi (1) in points 1,2,3 (fig.1c) of a concrete labyrinth with 3 sections.

width. The spectrum of neutrons in the steel maze (fig.5), unlike the spectrum in the concrete maze, has typical peaks, which correspond to resonances in the total cross section for Fe.

3. DOSE IN 2- AND 3-SECTIONED LABYRINTH

In fig.6,7 we presented calculational neutron and photon dose equivalent distribution along the axis of the 2d and 3d section labyrinths in arbitrary units. The absolute value of the dose equivalent can be obtained by multiplying the data in fig.6 by the coefficient K=7,2 Sv and K = $7{,}6 \cdot 10^{-15}$ Sv for data in fig.7. These coefficients were calculated by using the fluence-to-dose factors from recommendations [5] with accounting for the factor of 2. Arbitrary values of the dose equivalent in the first and in the second section of the labyrinth are in a good agreeent with the experimental data within 10-20% error. The agreement of calculational data with experimental for the third section is worse (about 20-40%).

Neutrons spectra in points 1,2,3 (fig.1c) in fig.9 show, that the spectrum becomes softer with increasing of the number of bends and the contribution of soft neutrons to the total dose is increasing. This fact is illustrated by fig.10. In fig.9 we presented neutrons group dose equivalent as a function of energy group number.

$$H_i = \int_{E_i}^{E_{i-1}} h(E)F(E)dE,$$

where h is the maximum dose equivalent.

Additionally, fig.10 shows that the dose equivalent from 0,1-5 MeV neutrons and from thermal neutrons are the main contribution in the total dose. An important practical conclusion follows from it: detectors with the sensitivity to neutrons in the energy region indicated above must be chosen for measurement dose equivalent behind the labyrinth.

The authors would like to thank Dr. K.Tesch of DESY for pointing out the need for these calculations.

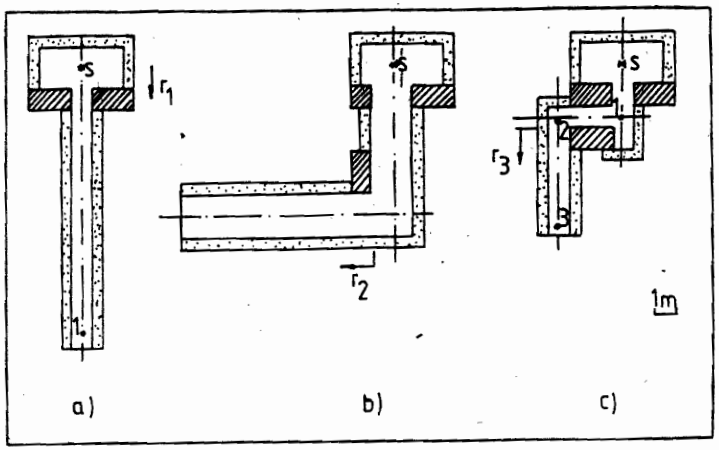

Figure 1. Schematic view of labyrinths used for Monte Carlo simulation.

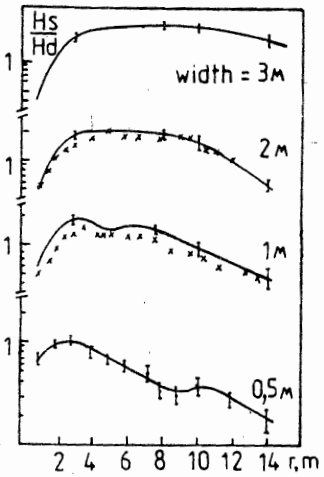

Figure 2. The ratio of the scattered neutron dose equivalent to dose equivalent due to direct neutrons as a function of distance (from the source) inside the first section of a maze (fig.1). — – calculation by MOSKIT; x – experiment [1].

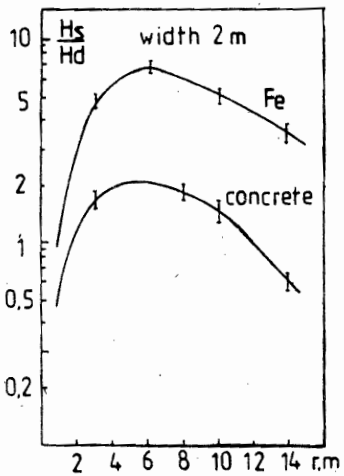

Figure 3. The ratio of the scattered neutron dose equivalent to dose equivalent due to direct neutrons as a function of distance (from the source) inside the first section of a concrete and iron maze (fig.1).

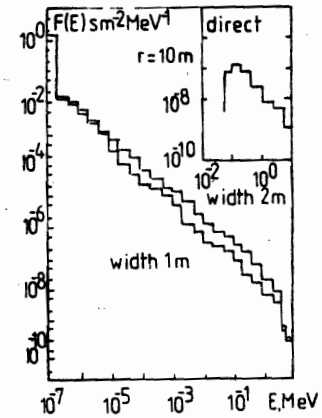

Figure 4. Energy distribution of neutrons in point 1 (fig.1a) of a concrete maze. Distance from the source is 10 m.

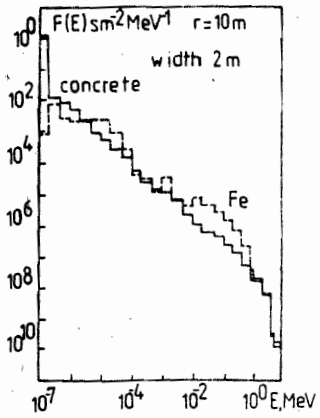

Figure 5. Energy distribution of neutrons in the point 1 (fig.1a) of concrete and iron maze. Distance from the source – 10 m.

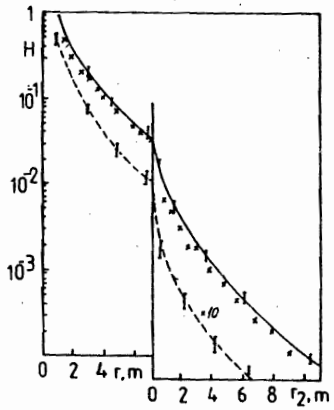

Figure 6. The attenuation of the neutron and photon dose equivalent in a labyrinth with 2 sections. The width is 2 m. — – neutron dose equivalent, MOSKIT calculation; - - - – photon dose equivalent, MOSKIT calculation; x - neutron dose equivalent, experiment [5].

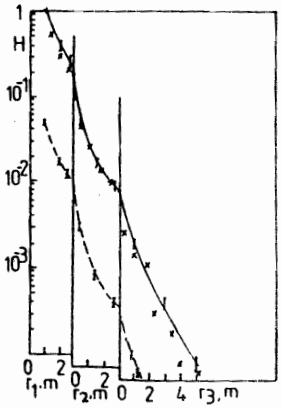

Figure 7. The attenuation of the neutron and photon dose equivalent in a labyrinth with 3 sections. The width is 1 m. — – neutron dose equivalent, MOSKIT calculation; - - - – photon dose equivalent MOSKIT calculation; x - neutron dose equivalent, experiment [5].