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DOSE RATE FROM HIGH-ENERGY ELECTRONS AND PHOTONS*

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Abstract

Electron-photon cascade calculations have been carried out, and energy deposition as a function of depth has been obtained for monoenergetic electrons (0.1 to 20 GeV) and photons (0.01 to 20 GeV) normally incident on a semi-infinite slab of water 30-cm thick. The calculated results are in approximate agreement with experimental data for the case of 5.2-GeV incident electrons.

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1. Introduction

For radiation protection purposes around high-energy electron accelerators, it is of interest to know the dose rate which results from a flux density of high-energy electrons and photons[1]. An IBM code for the study of the lateral and longitudinal development of electromagnetic cascades induced in matter by high-energy electrons and photons has previously been written by C. D. Zerby and H. S. Moran[2-4]. In this paper results obtained with this code on energy deposition in water slabs by high-energy normally incident electrons and photons are presented.

2. Calculational details and results

The electron-photon cascade code has been described in detail elsewhere[2-4] and will not be discussed here. Calculations have been carried out for incident electrons of energy 0.1, 0.2, 0.5, 1, 5.2, 10, and 20 GeV, and for incident photons of energy 0.01, 0.02, 0.05, 0.1, 0.2, 0.5, 1, 5.2, 10, and 20 GeV. The geometry considered is that of a broad beam of monoenergetic particles normally incident on semi-infinite slabs of water of specified thickness. Calculations have been carried out using slab thicknesses of 7.5, 15, 22.5, and 30 cm, and it has been assumed that the energy deposited in a slab of thickness x is the same as that which would be deposited in thickness x of a slab of thickness y (>x). This is, of course, only approximately true since there is some backscattering, but in the results presented here the error is not thought to be appreciable. In carrying out the calculations, photons were transported until their energy fell below 0.01 MeV, and charged particles (electrons and positrons) were transported until their energy fell below 2 MeV. Photons and charged particles with energies of less than these cutoff values were assumed to deposit their energy locally. K. Tesch[1]) has measured the energy deposited in tissue-equivalent material by 5.2-GeV incident electrons. The calculated results are compared with these experimental measurements in Fig. 1. In the figure the solid histogram represents the calculations while the plotted points represent the experimental data. The calculated values are slightly lower than the experimental values at almost all depths.

The results of all of the calculations for incident electrons and photons are given in Tables 1 and 2, respectively. The values given in the tables are in all cases averaged over depth intervals of 7.5 cm. Strictly speaking, the values in the tables are for the absorbed dose (rad) since no quality factor was used in the calculations. In the present instance, however, a quality factor of unity is very reasonable, so the values in the tables can be taken to represent the dose equivalent (rem). In considering the values in the tables, it must be remembered that the calculations are statistical, and therefore the results contain statistical fluctuations. Furthermore, the code of Zerby and Moran was primarily intended for use at high energy, and the approximations used are not equally valid over the entire energy range considered. In general, the results for the lower incident energies must be considered more approximate than those for the higher incident energies, and, in particular, the results for the low-energy incident photons must be considered to be very approximate.

For radiation protection purposes, it is convenient to have the incident flux density of particles such that the maximum dose rate at any depth in the slab does not exceed the tolerance dose rate of 2.5 millirem per hour. By drawing smooth curves through the histogram values given in Tables 1 and 2, the maximum dose rate per unit incident flux density at any

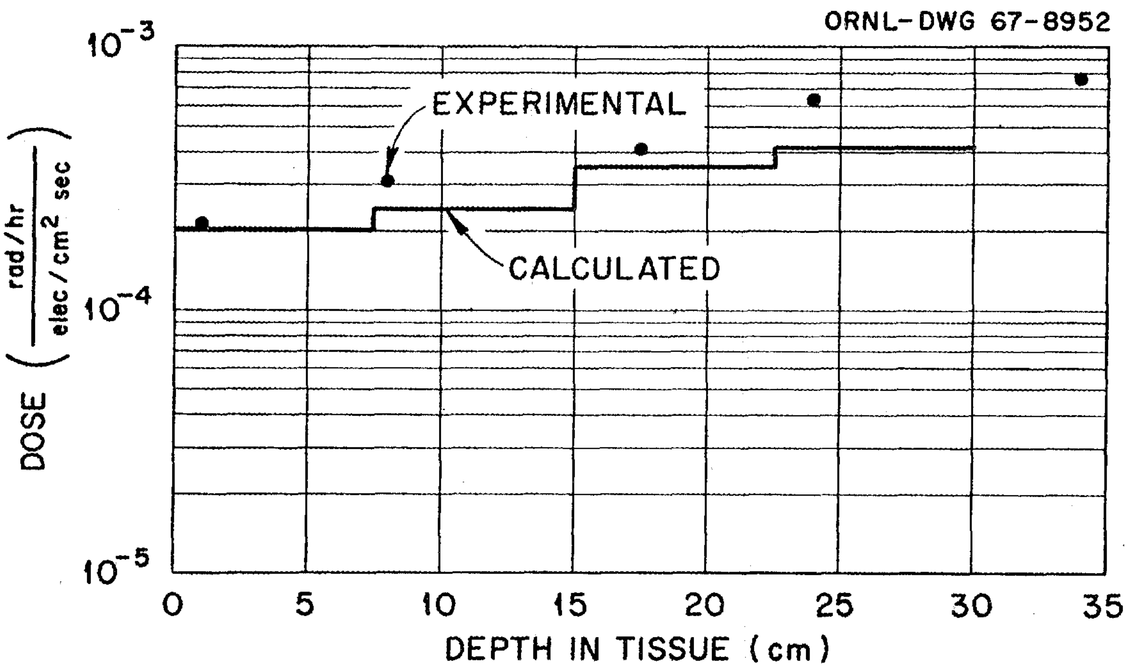

Fig. 1. Dose from 5.2-GeV electrons vs depth in tissue.

Table 1

Dose rate from incident electrons

Incident Electron Energy	Dose rate Averaged over indicated depth interval 10^{-4} (rad/h)/(electron/cm^2 sec)			
(GeV)	0-7.5 cm	7.5-15.0 cm	15.0-22.5 cm	22.5-30.0 cm
0.100	1.6	1.6	1.4	1.0
0.200	1.6	1.8	1.9	1.8
0.500	1.8	2.0	2.2	2.5
1.00	1.8	2.1	2.5	3.2
5.20	2.0	2.5	3.6	4.2
10.0	2.1	2.7	3.7	4.9
20.0	2.2	2.8	4.3	5.7

Table 2

Dose rate from incident photons

Incident Photon Energy	Dose rate Averaged over indicated depth interval 10^{-4} (rad/h)/(photon/cm^2 sec)			
(GeV)	0-7.5 cm	7.5-15.0 cm	15.0-22.5 cm	22.5-30.0 cm
0.010	0.07	0.09	0.07	0.07
0.020	0.10	0.15	0.12	0.13
0.050	0.13	0.30	0.32	0.28
0.100	0.16	0.42	0.51	0.65
0.200	0.19	0.49	0.77	0.95
0.500	0.21	0.62	0.92	1.4
1.00	0.23	0.63	1.2	1.6
5.20	0.26	0.81	1.4	2.2
10.0	0.29	0.88	1.6	2.4
20.0	0.30	1.0	1.5	2.6

depth in the slab has been estimated, and the maximum incident flux density of electrons and photons such that the maximum dose rate does not exceed the tolerance dose rate has been obtained. These maximum permissible incident flux densities are shown as a function of incident energy in Fig. 2. Also shown in the figure for comparison purposes are the estimates previously given by Tesch[1]).

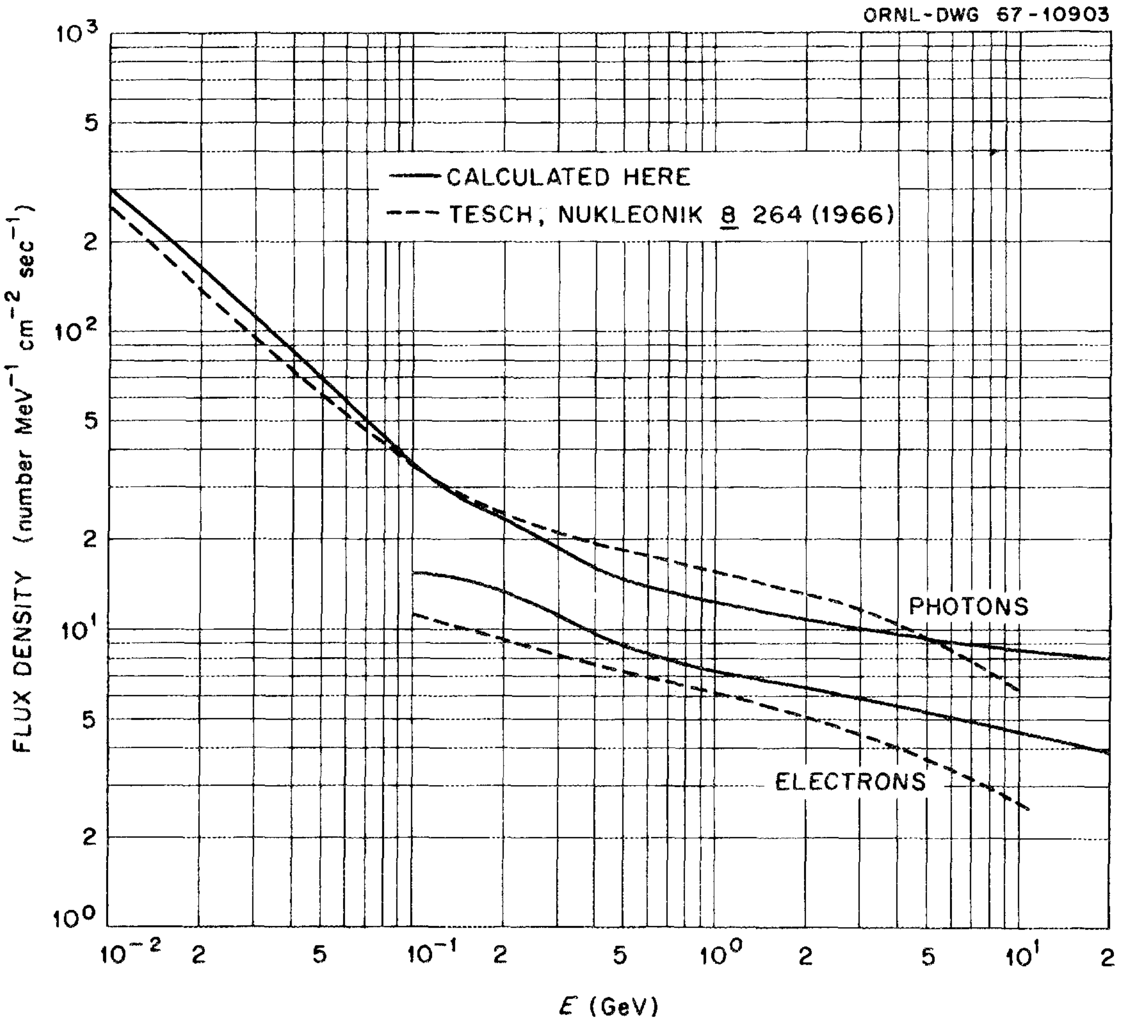

Fig. 2. Flux density to produce a maximum dose rate of $2.5 \cdot 10^{-3}$ rem/hr.

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