DEPTH DISTRIBUTION OF THE ABSORBED ENERGY AND DOSE IN VARIOUS MATERIALS IRRADIATED BY BREMSSTRAHLUNG AT A MAXIMUM ENERGY OF UP TO 1000 MeV

A. A. Vorob'ev, V. A. Vorob'ev, and A. V. Pushkin

The transmission and absorption of high-energy bremsstrahlung through materials was studied by a photographic method. The dependences of the depth distribution of absorbed dose (DDAD) and of the absorbed energy (DDAE) on the maximum bremsstrahlung energy, the atomic number of the absorber, and the irradiation conditions are reported and discussed. On the basis of the results, a method is proposed for constructing the DDAD and DDAE curves for atomic numbers and maximum bremsstrahlung energies in the ranges studied. A systematic experimental check of this method for constructing the DDAD and DDAE curves for iron shows the method to be highly accurate.

The experimental use of electron accelerators requires knowledge of the spatial distribution of the energy absorbed in absorbers [7-12]. There have been only relatively few experimental studies [1-5] of the spatial distribution of energy absorbed from bremsstrahlung having a maximum energy above 100 MeV. Furthermore, these experiments have been carried out under different irradiation conditions and using various methods to measure the absorbed-energy distribution. For this reason it is quite difficult to compare the results or to draw conclusions regarding the distribution of absorbed energy.

We used a photographic method [6] to study the spatial distribution of the absorbed energy at maximum bremsstrahlung energies in the range 250-1000 MeV in semiinfinite absorbers of graphite, aluminum, copper, lead, iron, and several alkali halide crystals: potassium chloride, bromide, and iodide. The bremsstrahlung source was the Sirius Synchrotron at Tomsk Polytechnical Institute.

The spatial distribution of the absorbed dose is described by the depth distribution along the beam axis and by a family of curves showing the radial distribution of the absorbed dose.

In Fig. 1a the depth distributions of the absorbed dose (DDAD) in lead are shown for four maximum bremsstrahlung energies, and in Fig. 1b the DDAD curves found at a maximum bremsstrahlung energy of 1000 MeV in graphite, aluminum, copper, and lead are shown. Here the abscissa shows the absorber depth, while the ordinate shows the relative absorbed dose at the beam axis; the absorbed dose per elementary volume at the maximum of the DDAD curve is assigned a value of 100%. The irradiation field is 20 mm in diameter.

We see from Fig. 1a, b that the shape of the DDAD curves is reminiscent of that of cascade curves for monoenergetic photons; i.e., the curve begins at some initial value of $D_{ini}$, increases, reaches a maximum value $D_{max}$ at a depth $L_{max}$, and then decreases with increasing absorber thickness. The path of the curves depends on the bremsstrahlung energy and the atomic number of the absorber.

For all the materials, the position of the DDAD maximum depends on the bremsstrahlung energy in the same manner [6, 8-11] (Fig. 1c). At first, the depth at which the maximum occurs increases rapidly with increasing bremsstrahlung energy; then the rate at which this depth increases falls off. Over the range of
maximum bremsstrahlung energies studied, up to 1000 MeV, the depth at which the maximum occurs is nearly a linear function of the bremsstrahlung energy, and there is some tendency for saturation [9-12]. An increase in the atomic number of the absorber shifts the depth at which the maximum occurs toward the front surface (Fig. 1d). The dependence of the dose absorbed in the surface layer on the bremsstrahlung energy is shown in Fig. 1e.

We see that $D_{\text{ini}}$ decreases with increasing bremsstrahlung energy and decreasing atomic number, since it is due to back scattering. The relative number of back-scattered particles is known to increase with increasing atomic number and with decreasing energy of the incident photons. We thus find a plausible explanation for the shape of these curves.

The decay of the DDAD curves also depends on the bremsstrahlung energy and the atomic number of the absorber. Analysis of the decay of these curves shows that at absorbed doses of 40-50% or below this decay is described by

$$\frac{1}{a + bt} e^{-at}$$