Evaluation of Dose Equivalent Using a Tissue-Equivalent Ionization Chamber and a Geiger-Müller Dosimeter*

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Summary. When detailed neutron energy spectrum data are lacking for a mixed field of neutrons and photons, it is permissible when estimating the dose equivalent to assume that the quality factor for the neutrons is 10. With this assumption, it is shown that the responses of a tissue-equivalent ionization chamber and a Geiger-Müller dosimeter can be used to obtain an acceptable approximation of the dose equivalent in the mixed field without requiring precise knowledge of the relative neutron sensitivity of the Geiger-Müller dosimeter.

Introduction

In a mixed field of neutrons and gamma rays the dose equivalent, $H$, may be computed as

$$H = D_G + \int Q(E_N)D_N(E_N)dE_N,$$

where $D_G$ is the gamma-ray absorbed dose in tissue, $Q(E_N)$ is the quality factor as a function of neutron energy, $E_N$ (see [4]), $D_N(E_N)$ is the neutron absorbed dose in tissue as a function of $E_N$, and the integration extends over the entire spectrum of neutron energies present.

Detailed neutron energy spectrum data are often lacking. It is then permissible to assume that $Q$ is 10 [5]. This practice will usually overestimate the dose equivalent as the maximum $Q$ for neutrons is 11 at 0.5 MeV [4] and neutrons of most energies have values of $Q$ less than 10. This simplification gives the approximation

$$H = D_G + 10 D_N.$$

$D_N$ and $D_G$ may be estimated using a homogeneous tissue-equivalent ionization chamber in combination with a dosimeter having a low relative neutron sensitivity,

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In a previous report [3] this second dosimeter was assumed to be a nonhydrogenous ionization chamber, that is, a carbon dioxide or argon gas cavity surrounded by walls of teflon, graphite or aluminum. For such chambers $k_U$ may be as low as 0.01 for neutron energies of a few hundred keV and as high as about 0.3 for 15 MeV neutrons [6]. An analysis based on Eq. (2) showed that use of the constant value $k_U = 0.15$ results in errors for $H$ of less than 20% even if the appropriate value of $k_U$ is as small as zero or as large as 0.3.

The present report is a reanalysis of this measurement technique using for the second dosimeter a photon energy-compensated Geiger-Müller (GM) counter [8, 1, 7, 2, 6]. Instrumentation for the practical application of this GM dosimeter is straightforward and its high sensitivity to gamma rays, nominally $5 \times 10^4$ counts per mGy (5000 counts per mrad) in tissue, make it suitable for radiation protection measurements. The relative neutron sensitivity of such a device is not known precisely; however, Wagner and Hurst [8] calculated $k_U < 0.0015$ for a neutron energy of 5 MeV at which the neutron sensitivity, due mainly to inelastic collisions in the gamma-ray energy correction screen, should be a maximum. Their measurements indicated that $k_U < 0.005$ for neutrons in the energy range from 0.68 to 4.2 MeV. It has also been determined experimentally [2] that $k_U$ for this GM dosimeter does not exceed 0.005 for 15 MeV neutrons. The uncertainty of the precise value of this very low relative neutron sensitivity will be shown to result in estimates of $H$ from Eq. (2) having negligible error.

**Analysis**

The response of a dosimeter is here considered to be the quantity observed as the reaction of the dosimeter to a given radiation field, for example, meter deflection. For a given type of radiation, dosimeter sensitivity is taken to be the quotient of the response by the absorbed dose in the material of interest which results in the response. In a mixed field of neutrons and gamma rays the quotient of the response of the tissue-equivalent ionization chamber by its sensitivity to the gamma rays used for calibration, $R_T$, is given by

$$R_T = k_T D_N + h_T D_G,$$

and for the GM dosimeter the quotient of its response in the same mixed field by its sensitivity to the gamma rays used for calibration, $R_U$, is given by

$$R_U = k_U D_N + h_U D_G.$$  \hspace{1cm} (4)

The relative neutron sensitivities $k_T$ and $k_U$ are the ratios of the sensitivities of each dosimeter to neutrons to its sensitivity to the gamma rays used for calibration, and the relative photon sensitivities $h_T$ and $h_U$ are the ratios of the sensitivities of each dosimeter to the photons in the mixed field to its sensitivity to the gamma rays used for calibration.

The ratios $h_T$, $h_U$, and $k_T$ are usually close to unity. To simplify the analysis of the affect of uncertainty in $k_U$ on the estimation of $H$ from Eq. (2), it will be assumed...