Conf-680920--12

The Simultaneous Measurement of X-Ray
Quality and Quantity Using TLD

MASTER

by

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Introduction

A determination of both the quality and quantity of a mono-directional x-ray beam can be made using a modified commercial dosimeter* consisting of a natural CaF_2 phosphor bonded to a metal cylinder (see Fig. 1). Upon exposure of the dosimeter, the dose received by the side toward the x-ray source (anterior side, A) is different than that of the other side (posterior side, P, see Fig. 2) due to attenuation and buildup in the metal cylinder.** Since this effect would be expected to differ with the effective energy of the beam, a measure of the quality of the beam can be obtained if the orientation of the dosimeter during exposure and readout is properly maintained. The thermoluminescent (TL) measurement must be made on a special reader which permits the measurement of the TL from sides A and P separately and simultaneously.

Method and Apparatus

A reproducible orientation of the dosimeter was maintained during exposure and readout by inserting the dosimeter into a standard transistor socket such that the plane of the heating

* Type 080 made by Manufacture Belge de Lampes et de Material Electronique (MBLE) 80 Rue des Deux Gares, Bruxelles 7, Belgium.

** This effect is avoided in the commercial reader by collection of the thermoluminescence from all sides.

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pins was perpendicular to the x-ray beam. The anterior side was marked so that it could be properly positioned during readout.

To measure the thermoluminescence from both sides of the dosimeter simultaneously, a dual photomultiplier tube reader was built (see Fig. 3 and 4). The dosimeter was inserted into a transistor socket located at the bottom of a sliding light-tight drawer. We selected two RCA #6655 photomultiplier (PM) tubes with similar gains which were operated at ~800 volts dc. Photomultiplier tubes, even of the same type, can have different quantum efficiencies as a function of wavelength. This factor is important because the three main glow peaks of natural CaF_2 differ in their spectra; also the spectrum of the standard light source does not exactly match the spectrum from any of the glow peaks. However, we found that these differences were negligible for the two PM tubes we selected.

A common high voltage supply was used for both PM tubes. They were balanced for equal output using a standard light source by reducing the high voltage of the more sensitive PM tube. Effects of blackbody radiation produced by heating during readout were reduced by using blue filters (Corning #5-56) in front of the PM tube cathodes. The heater circuit consisted of a 6 volt ac supply. An adjustable timer, set at 25 seconds, limited the readout time.

The anode current from each PM tube was integrated simultaneously on separate capacitors. The voltage across each capacitor was then measured using a high input impedance volt-

meter (such as Keithley 610B electrometer). To measure the quality of an X-ray beam it is not necessary to know the exact exposure. We found that with exposures of less than 1 R the dark current began to alter the A/P ratio. We found that the A/P ratio was the same ($\pm 5\%$) whether the peak height of any glow peak (Fig. 5) or the total integrated TL was used. When the heating rate was varied from about 50° per second to about 10° per second there was no change in the A/P ratio within the experimental uncertainty.

The standard dosimeter is constructed with a nickel cylinder 50 microns thick which works quite effectively for determining qualities in the diagnostic x-ray range (see Curve B, Fig. 6). The accuracy of the technique varies with the energy, but in the range from ~ 20 to ~ 85 keV effective, the standard deviation of energy determination is ~ 5 keV. In order to extend the useful range to other energies, it was necessary to have the manufacturer construct dosimeters with the following materials: aluminum, silver, tantalum and gold. The various metal cylinders differed in their A/P ratio vs. effective energy (see Fig. 6). The useful ranges of the various types of cylinders is given in Table 1. The gold cylinder dosimeter appears to be the most useful. This dosimeter also offers the interesting possibility of measuring the dose from thermal neutrons. The A/P ratio vs. energy response for the various metal based dosimeters is very similar above 300 keV. An interesting but at present unexplained phenomenon observed with all dosimeters studied is the lower A/P ratio in the energy region of the ^{137}Cs γ -ray.

The commercial TL reader*** measures the height of the third peak whereas our reader integrates the light from Peaks I, II, and III (see Fig. 5). Since Peak I has a relatively short half-life of the order of a few hours, it is necessary to remove this peak in order to obtain an accurate measurement of the quantity of radiation. This can be done by waiting about one day for it to decay, or it is possible to develop a special heating circuit to remove the first peak before the integration. The second and third peaks are stable at room temperatures. The quantity of radiation received by the dosimeter can be determined in the same measurement as the quality, but because of the energy dependence of CaF_2 it is necessary to make a correction.**** The A/P ratio can be used for this correction by calibrating the TL vs. exposure of the anterior and/or posterior side of the dosimeter using a ^{60}Co source. When measuring the exposure at other energies, the integrated TL should be multiplied by the A/P correction factor of the particular dosimeter being used. Figure 7 illustrates the correction factor vs. A/P ratio for the gold cylinder dosimeter.

A particularly useful application for these dosimeters would be to check the effective energy and output of diagnostic and orthovoltage therapy x-ray equipment via mail. The dosimeters can be conveniently inserted into styrofoam blocks and mailed to centers having radiation equipment for evaluation

*** Model PNA 049, M.B.L.E.

**** Model 080 is normally used in a container that has a filter to flatten its energy response.

and intercomparison. This might be of significant value for Public Health Service officers for checking the adequacy of the filtration of medical x-ray machines by mail.

The authors would like to express their appreciation to Mr. C. Brooks of Manufacture Belge de Lampes et de Material Electronique for his cooperation in constructing these dosimeters, and to Mr. Mark Lutz for his help in the construction and preliminary testing of the special reader.

METAL USED FOR CYLINDER	Z	USEFUL EFFECTIVE ENERGY RANGE.
ALUMINUM	13	LESS THAN 30 keV
NICKEL	28	20-85 keV
SILVER	47	20-150 keV
TANTALUM	73	20-300 keV
GOLD	79	20-300 keV
TABLE

M.B.L.E 080 DOSIMETER

Figure 1 Diagram of MBLE dosimeter Model 080.

Figure 2 Diagram of cross section of MBLE dosimeter.

Figure 3 Illustration of dosimeter in open drawer of the reader showing the dual PM tube arrangement.

Figure 4 Block diagram of the TL reader.

Figure 5 CaF_2 glow curve; the temperatures of the peaks are at $\sim 100^\circ\text{C}$, $\sim 175^\circ\text{C}$ and $\sim 260^\circ\text{C}$.

Figure 6 A. Aluminum (Z = 13) cylinder. B. Nickel (Z = 28) cylinder.

Figure 6 C. Silver (Z = 47) cylinder. D. Tantalum (Z = 73) cylinder.

Figure 6 E. Gold (Z = 79) cylinder.

Figure 6 Graphs of the A/P ratio vs. effective energy for various metal cylinders.

Figure 7 Correction factor relative to Co^{60} vs. A/P ratio for the gold cylinder.