A THERMOLUMINESCENT NEUTRON DOSIMETER WITH INTERNAL ENERGY - RESPONSE CORRECTION

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INTRODUCTION

During 1976 Mound began a concentrated effort to select a new neutron dosimeter to replace NTA film that had been used for neutron monitoring since 1947. The film has a very low response at the energies where much of the neutron radiation exposure at Mound occurs. In addition, track fading in NTA film further complicated the problem of assessing neutron exposure doses.

Personnel exposures at Mound are to unmoderated and moderated neutrons from (α,n) reactions and to spontaneous fission and neutron induced fissions from ^{238}Pu and ^{252}Cf (an enriched-uranium subcritical assembly). Most of the exposure occurs in shielded glovebox lines used for processing $^{238}PuO_2$. Because the neutrons are of low average energy, it was decided that a thermoluminescent (TL) dosimeter might be a suitable replacement for film.

Some TL dosimeters in use in the U.S.A. were tested along with NTA film. Internal energy calibration was a possibility with one of the TL dosimeters (Fa71) and this dosimeter became the basis for our dosimeter design. Basically, this dosimeter contains two cadmium shielded ^{6}LiF chips with one being shielded on the source side (front shielded) and the other shielded on the wearer side (back shielded). The dosimeter also included a ^{7}LiF chip with each of the ^{6}LiF chips to correct the ^{6}LiF chips for photon response.

DESCRIPTION OF THE MOUND DOSIMETER

The present Mound design incorporates two standard Harshaw TLD cards in a Cycoloc plastic holder which also contains the employe security credential. One card is used for neutron dosimetry and contains two ^{6}LiF chips and one ^{7}LiF chip. This card is placed in a cadmium-tin filter module. Each ^{6}LiF chip is covered on one side with cadmium (0.44 g/cm^2) and on the other with tin (0.39 g/cm^2). The ^{7}LiF chip is covered on both sides with tin. The tin was added to improve the accuracy of neutron dose assessment by filtering out the low energy photons, especially the 60 Kev photons from ^{241}Am. Adding the tin also enabled one ^{7}LiF chip to be used for the photon correction for both ^{6}LiF chips. The other TL card holds two ^{7}LiF chips. When positioned in the filter module, one of the chips is covered on both sides with brass (0.09 g/cm^2) while the other is unfiltered. The brass filter was chosen to approximate a 1 cm deep tissue dose from photons. These two TL chips

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along with the tin covered one constitutes the photon dosimeter. The system was designed for use with a Harshaw automated TLD reader.

CALIBRATION

Calibration of the neutron dosimeter was done by exposing it in a low scattering area to several isotopic neutron sources, both unmoderated and moderated with polyethylene. Neutron spectral information is available for each of these exposures. Additional exposures were made in operating areas where room scattering is significant. For the operating area exposures, a 10" Bonner sphere was used to assess the dose equivalent. A log-log plot of the responses per unit dose for the front-shielded chip (F/H) and the back-shielded chip (B/H) yields the straight line:

$$\ln(F/H) = -(0.48 \pm 0.02) + (0.65 \pm 0.01)\ln(B/H) \qquad \text{Eq. 1}$$

The χ^2 value for this fit is 0.999. Algebraic manipulation of Eq. 1 results in an equation for determining neutron dose H from responses F and B:

$$H = 4.0\, F\, (F/B)^{1.87} \qquad \text{Eq. 2}$$

The range of the ratio F/B for our data is $1.0 < F/B < 2.3$, with the moderated spectra having the lower ratios.

DISCUSSION OF ERRORS

Three sources of error are inherent in the use of Eq. 2. The first is how close any single datum in Figure 1 comes to the calibration line. Even though the data in Figure 1 do closely follow a linear relationship, dose equivalent values from Eq. 2 corresponding to these data may be off by ±15%.

The second source of error is due to the fact that it is the logarithms of the chip responses that are linearly related. If a dosimeter were exposed to two spectra, the TL chip responses would combine linearly (not combine as the logarithms of the responses). The worst error for combining exposures from different spectra is when 80% of the actual dose has a F/B ratio of 1.0 and 20% has a ratio of 2.3. In this case, the dose calculated from using Eq. 2 would be low by 35%.

The third source of error is introduced by the variance of the response for the individual chips. For our data the standard deviation of a single observation at the 1σ level is about ±8% for all exposures greater than about 10 mRem. The propagation of errors in Eq. 2 leads to an uncertainty in H of ±28%.

Others have used the ratio of the responses of the front and back-shielded chips to obtain calibration factors. Two (Pi72 and Cr76) used boron shields instead of cadmium. The use of boron results in a smaller absolute value for the exponent in Eq. 2. We have just begun some measurements using boron shields. Preliminary results indicate a value of -0.5 for the exponent which compares with -0.8 for Pi72 and -0.5 for Cr76. The range of ratios F/B for boron is about 1 to 6 for our spectra whereas for cadmium it is 1 to 2.3. These changes in the exponent and ratio are due to the boron back-shielded chip having a lower response for unmoderated or lightly moderated neutron spectra than a cadmium back-shielded chip and to a reduction in the front-shielded chip response to moderated spectra. This value for the exponent lowers the error of the third type described earlier from 28% to 13%. It lowers the error when combining spectra with the maximum - such error going from 35% to 25%.

Mound is currently using the cadmium-tin filter combination dosimeter for neutron monitoring. Further work is being done to determine how much the boron filters would lower the error in neutron dose calculations. The modular construction of the dosimeter filter packs would enable us to make the change with relative ease should it appear worthwhile.

REFERENCES

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