SKIN DOSE ASSESSMENT IN ROUTINE PERSONNEL BETA/GAMMA DOSIMETRY

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1. INTRODUCTION

The International Commission on Radiological Protection (1) recommends a tissue depth of 5-10 mg cm^{-2} as the most appropriate depth for skin dose assessment. An ideal dosemeter for measurement of skin dose should therefore either show a response which is directly a measure of the average dose absorption in a layer of skin at a depth between 5 and 10 mg cm^{-2} or it should be able to give information about type and energy of radiation enough for converting dosemeter response to true skin dose. For penetrating radiation, e.g. gamma photons, the routine monitoring systems practiced today generally measure skin dose with satisfactory precision, e.g. to within $\pm$ 20% for energies ranging from 10 keV to 2 MeV. For more shallowly penetrating radiation, e.g. β-particles, which have ranges that are less than or comparative to the thickness of the dosemeters mostly applied for practical routine dosimetry considerable underestimation of skin dose may occur. Thin dosemeters with high efficiency for beta dosimetry are available (2), however practical difficulties in handling very thin dosemeters combined with a low sensitivity and therefore a high minimum detectable dose make these unattractive for routine dosimetry purposes. New developments in TLD techniques in recent years (3,4,5) have given practical dosemeters with a skin-dose equivalent response to beta exposures over a wide range of energies. These have so far mainly found application for extremity dosimetry.

The present work has studied possible improvements of existing TLD routine monitoring systems for obtaining a satisfactory skin dose assessment without changing the original capabilities of the system. The following three alternatives were studied:

1. Inclusion of a supplementary skin dosemeter in the TLD-badge.
2. Introduction of a second photomultiplier in the read-out chamber to obtain a simultaneous two-side reading of the TL-dosemeter.
3. Application of a boron diffused thermoluminescent surface layer of LiF TL-dosemeters for skin-dose assessment.

2. INCLUSION OF A SUPPLEMENTARY SKIN DOSEMETER IN THE TLD BADGE

The production of skin-dose equivalent, low-transparent, sintered LiF- and $Li_2B_4O_7$:Mn dosemeters by mixing the material with graphite has been reported earlier (3). Table 1 shows dimensions and gamma-response data measured from a recently produced series of $Li_2B_4O_7$:Mn dosemeter with graphite contents from 0 to 20%.

Table 1. Dimensions and ^{60}Co γ-response data of graphite mixed $Li_2B_4O_7$:Mn dosemeters

Graphite Content %	Dimension: Diameter mm	Dimension: Thickness $mg.cm^{-2}$	Relative sensitivity to γ-expos.	Instrument background eqv.mR	Instrument + dosemeter background eqv.mR	Threshold detection limit mR
0	4.45	154	100	3.5	4.0	< 1
4	4.46	163	6.1	58	73	< 200
10	4.46	161	3.0	118	146	< 500
20	4.46	157	1.4	230	288	<1000

The threshold detection limit has been calculated according to ISO standard (6). The measured beta response data of various TL-dosemeters shown in fig. 1 clearly illustrate the amount of underestimation of skin dose, which may occur when standard TL-dosemeters are used to measure dose from low-energy beta particles. It can be seen further that the provision of a personnel badge with an additional graphite mixed (about 5% graphite) $Li_2B_4O_7$:Mn dosemeter, capable of estimating any skin dose with a threshold detection limit of 100-200 mrad will introduce essential improvements for assessment of doses to the skin from low-energy beta emitters.

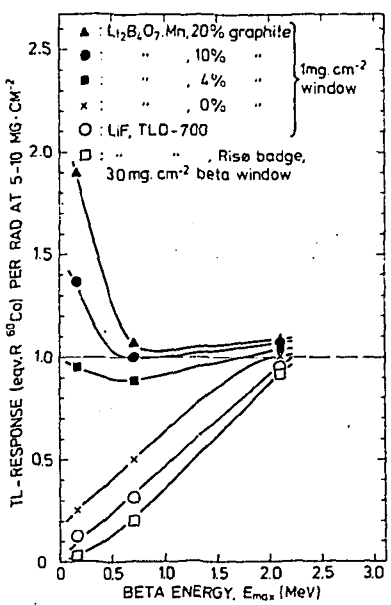

Fig. 1. Beta energy response curves of various TL-dosemeters.

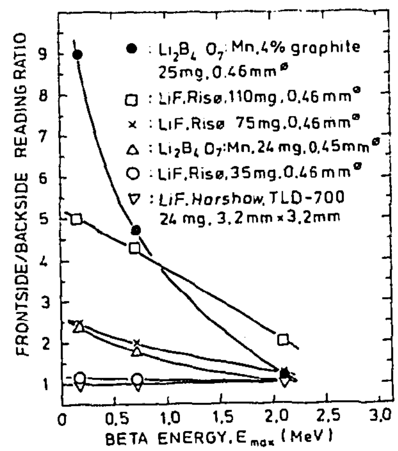

Fig. 2. Frontside/backside reading ratio for various TL-dosemeters as a function of beta energy.

3. TWO SIDE READING OF TL-DOSEMETER

A simultaneous separate reading of the TL-emission from each side of an irradiated dosemeter offers some possibility for registrating the attenuation of the radiation when passing through the dosemeter mass and thus to get some information about the amount of low-energy radiation contributing to the dose. A two-side reader, based on hot nitrogen gas heating and provided with two photomultipliers looking at each side of the dosemeter during read-out has been described earlier (3). The ratio between front- and backside reading is a complex function of dosemeter thickness and optical transparancy, type and energy composition of radiation and light reflection characteristics of read-out chamber. Fig. 2 shows measured data from dosemeters with varying thickness and optical transparancy. By correlating the data from fig. 2 with corresponding measured dose/dosemeter response conversion factors one can evaluate expressions which convert the front/backside reading ratios, R(Emax), to dose/dosemeter response conversion factors. An example of this, using data from $Li_2B_4O_7$:Mn, is given in fig. 3, which shows that the expression $R(Emax))^{0.65 \cdot R(Emax)}$ is an extremely good estimate of the corresponding dose/dosemeter response conversion factor. It is obvious that the highest accuracy of dose estimation by this method is obtained when only a single beta emitter is involved. For mixed energies the method underestimates doses from low-energy radiation f.example a skin dose received 90% from ^{147}Pm and 10% from ^{90}Y will be underestimated by 35%.

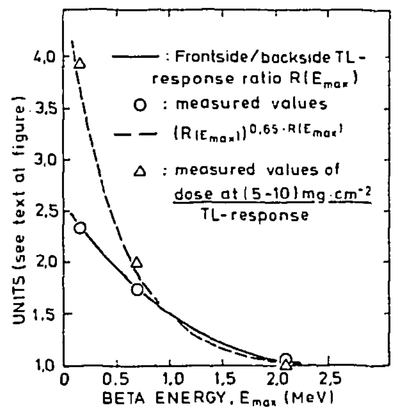

Fig. 3. Relationship between frontside/backside reading ratio R(Emax) and dose/dosemeter response conversion factor for $Li_2B_4O_7$:Mn

4. BORON DIFFUSED THERMOLUMINESCENT SURFACE LAYER OF LIF TL-DOSEMETERS

A new high temperature glow peak produced only in a thin surface layer of LiF TLD-100 chips by diffusion of boron into the LiF material has been applied recently for dosimetry of electrons of energies from 0.1 to 30 keV (7). Experiments with diffusion of boron into sintered LiF dosemeters produced in our laboratory have given diffused surface layers with a new glow peak at 340°C and with a thickness sufficientfor application for personnel beta dosimetry. The heigth of the 340°C surface layer glow peak compared to that of the original 240°C peak representing the total dosemeter thickness is a measure of dose contribution from low-energy radiation. Fig. 4 illustrates the build-up of the new glow peak relative to the original peak 5 and fig. 5 shows the variation of the peak heigth ratio of the two peaks with beta energy. The threshold detection limit of the 340°C peak for application for skin-dose measurements is approx.

100 mrad.

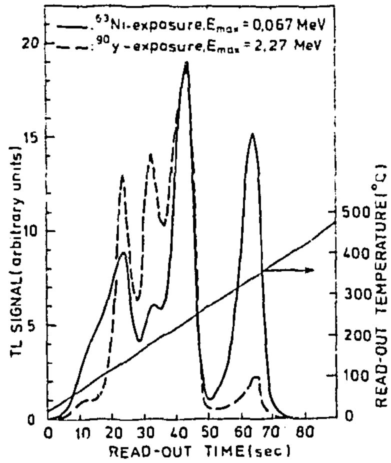

Fig. 4. Glow curves of boron diffused LiF from exposures to a low- and a high energy beta emitter.

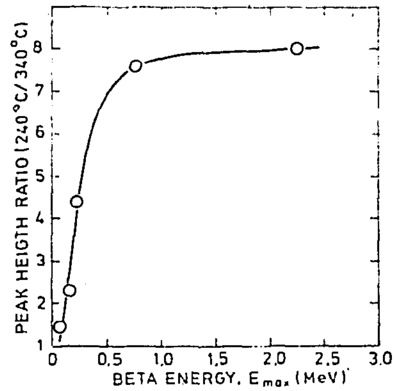

Fig. 5. Ratio of 240°C/340°C peakheigth as a function of beta energy.

5. CONCLUSION

The present work outlines three alternative methods by which substantial improvements of the capabilities of existing routine monitoring systems for skin dose assessment can be obtained. The introduction of a suplementary skin dosemeter may be an attractive method for systems with badges that have a capability for an additional dosemeter already built-in. The two-side reading method has limited possibilities because of reduced accuracy for mixed radiation and technical difficulties in using it for TLD systems with planchet heating. The use of a boron diffused LiF layer for skin dose assessment seems to be most attractive method since the only modification needed here is replacement of a dosemeter. However the study of this method is so far only in a preliminary stage and further investigations are needed to prove its practical applicability.

6. REFERENCES

1. ICRP, Publication 26, Pergamon, Oxford (1977).
2. Marshall, M., Docherty, J., Phys. Med. Biol., 16, 503-510, (1971).
3. Koczynski, A. et al. 1974, in Proc. 4th Int. Conf. on Luminescence Dosimetry, Krakow, Poland (Institute of Nuclear Physics, Krakow, Poland) p. 641.
4. Pradhan, A.S. and Bhatt, R.C., Phys. Med. Biol., 1977, 22, 873-879.
5. Charles, M.V. and Khan, Z.U., Intern. Symp. on Advances in Radiation Protection Monitoring, IAEA, Stockholm, 1978, (SM-229/24).
6. Personal and Environmental Thermoluminescence Dosemeters, ISO/TC85/SC2/WG7 24E, 5. draft.
7. Lasky, J.B., 1978, COO-1105-256.