DOSEMETER FOR MEASURING PARTIAL BODY DOSE AND FOR ADDITIONALLY DETERMINING THE TYPE OF RADIATION

M. Heinzelmann, M. Pagenkemper
Nuclear Research Centre Jülich
Department of Safety and Radiation Protection

While handling unshielded, radioactive substances the radiation dose to the nand frequently has to be measured. Close to the radiation source the greatest fraction of the dose may originate from weakly penetrating β-radiation. However, part of the dose also originates from strongly penetrating radiation. In general, the skin is the critical organ and a dosemeter which can measure the individual dose equivalent, superficial, is sufficient to fulfil the legal regulations. However, information about the type of radiation is additionally required in order to evaluate the working conditions and radiation hazards. This is particularly important in evaluating possible radiation injuries after an accident. If the radiation type is known then the dose can be more accurately determined from the dosemeter reading with the aid of appropriate correction factors.

PREVIOUS EXTREMITY DOSEMETER

A few years ago, an extremity dosemeter was developed at the Nuclear Research Centre Jülich (KFA) enabling a precise determination of the skin dose to be made (1). This dosemeter also provides additional information about the radiation quality. The dosemeter contains three thin TLD's of LiF in Teflon arranged in series and covered with a very thin, aluminized plastic foil of 0.9 mg/cm² mass per area. The first TLD measures the directional dose equivalent H'(0.07) approximately independent of energy. The second and third TLD's in the dosemeter provide information about the depth dose distribution and thus about the radiation quality.

The dosemeter is excellently suited for the determination of H'(0.07). This was demonstrated during participation in the 1986 international intercomparison programme of the Commission of the European Communities. In this intercomparison programme 36 dosemeters from each participant were irradiated with β-radiation of various energies from E_{max} = 0.23 MeV to E_{max} = 2.2 MeV, with Cs-137 γ-radiation and with β-γ mixed radiation. Irrespective of the radiation type, radiation energy and direction of incidence, the results of the KFA extremity dosemeter were in agreement with the reference values within ±23 % for all 36 dosemeters (2).

However, a disadvantage of this dosemeter is that the very thin window in front of the TLD is not sturdy enough and is occasionally destroyed.

MODIFIED EXTREMITY DOSEMETER

Since the previous dosemeter was not sturdy enough attempts were made to develop a more suitable extremity dosemeter. The new dosemeter should be more sturdy and moreover provide even more information about the radiation field. The new dosemeter should also be able to differentiate between high-energy and low-energy γ-radiation (3).

In the modified extremity dosemeter (Fig. 1), three TLD's are arranged one behind the other in a finger-ring and the three TLD's are enclosed by a heat-shrinkable sleeve. Two ultra-thin TLD's of $CaSO_4$ in Teflon are used, between which a 0.4 mm thick TLD of LiF in Teflon is arranged. The thinnest opaque heat-shrinkable foil on the market is used with an unshrunk thickness of 0.05 mm.

Different radiation fields can be distinguished using the readings of the three TLD's in the dosemeter:

In the case of high-energy β-radiation and γ-radiation, all three TLD's show the same value which is equivalent to the value of the skin dose.

For low-energy β-radiation, the first, ultra-thin TLD gives a high value. The other TLD's show considerably lower values.

For low-energy γ-radiation, the first and third TLD's show the same, too high values. The dose is determined from the reading of the middle TLD. The presence of low-energy γ-radiation and thus the oversensitivity of the $CaSO_4$ detectors may be recognized by the fact that the first and third detectors show the same reading and that in addition both readings are higher than that of the middle TLD. The energy of the γ-radiation can be assessed from the ratio of the reading of the first TLD to the reading of the second TLD.

The response R of the first TLD and the ratio of the readings of the three TLD's are given for β-radiation in Table 1. The response is too low for low-energy β-radiation. It can be seen from the ratios $D_1:D_2$, the reading of the first TLD to the reading of the second TLD, and $D_1:D_3$, the reading of the first TLD to the reading of the third TLD, that the dosemeter was irradiated by low-energy β-radiation. It is then possible to correct the too low response of the dosemeter.

Fig. 2 shows the response for γ-radiation.

The lower detection limit is equal to 0.3 mSv for the reading of the first and third TLD's and equal to 0.8 mSv for the reading of the second TLD.

The readings of the dosemeter in mixed β-γ-radiation fields were calculated from the response of the three TLD's to β-radiation and γ-radiation of various energies. The calculations were carried out for over 400 different radiation fields. It was established that the dose may be determined precisely in the vast majority of cases. However, there are radiation fields in which the dose is incorrectly determined by up to a factor of two. These are radiation fields with low-energy β-radiation (Pm-147) and γ-radiation. Apart from radiation fields with low energy β-radiation, the dose may be determined with an accuracy of ± 25 % in all other radiation fields.

The new extremity dosemeter is sturdy and is particularly suitable for dose determination in pure β- and γ-radiation. The dosemeter is also suitable for mixed β-γ-radiation fields if no low-energy β-radiation is present. The dose may be incorrectly determined by up to a factor of two in mixed radiation fields with low-energy β-radiation.

REFERENCES

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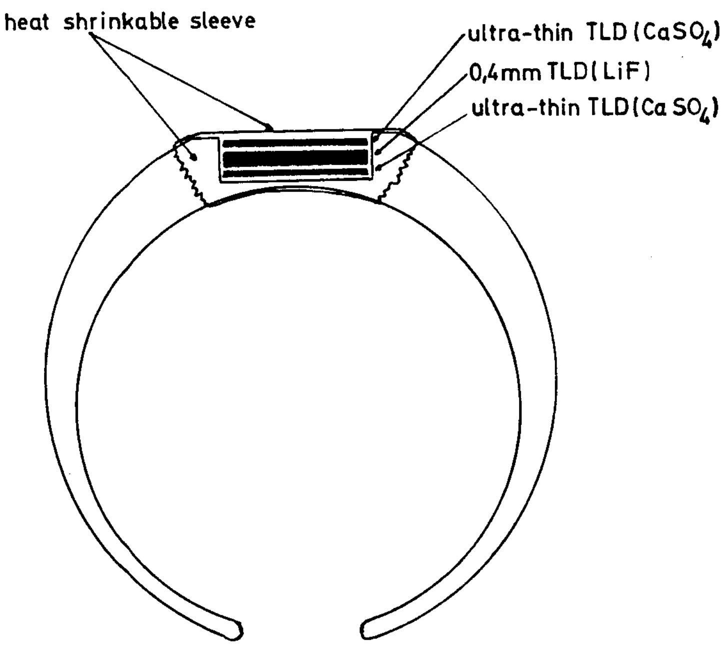

Fig. 1: Diagram of the modified extremity dosemeter

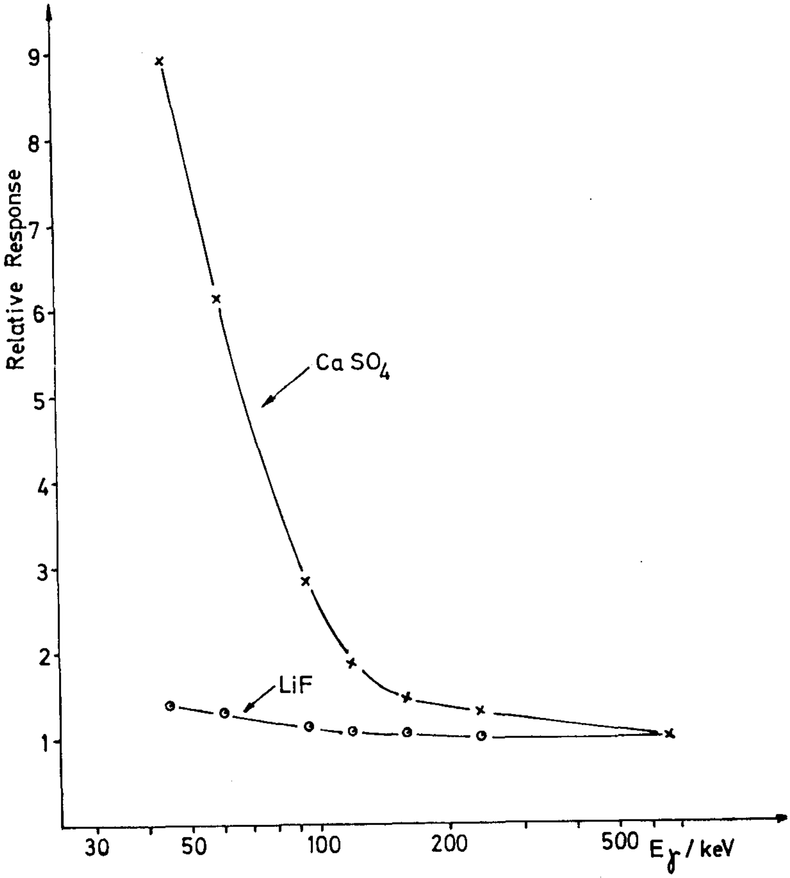

Fig. 2: Energy dependence of the response for γ-radiation of the first TLD ($CaSO_4$) and the second TLD (LiF) of the dosemeter

Table 1: Response, R, of the first TLD, the ratio $D_1:D_2$ of the reading of the first TLD to the reading of the second TLD and $D_1:D_3$ of the reading of the first TLD to the reading of the third TLD for irradiation with the PTB secondary standard

Nuclide	R	$D_1 : D_2$	$D_1 : D_3$
Pm-147	0.55	≈ 15	3.3
Tl-204	0.92	1.8	6.5
Sr-90/Y-90	0.98	1.0	1.1