A UNIVERSAL AUTOMATIC TLD-READER FOR LARGE-SCALE RADIATION DOSIMETRY

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Abstract

A universal automatic TLD-reader has been developed that can accept most of the present and probably many future types of solid TL-detectors. Perfect temperature contact, low background signal, high sensitivity, short cycle-times (about 18 sec., sample changing included) and good reproducibility are secured by heating the detectors with jets of hot nitrogen gas. A special manipulating device enables the reader to accept TLD's as offered by any sample changer (e.g. rotating disc or conveyor belt), making the instrument applicable in large scale personnel monitoring, environmental control, radiation therapy etc. The automatic selection of dosimeters with uniform sensitivity is one of the features of this instrument.

Introduction

Although the daily practice of handling TLD in routine radiation dosimetry is not yet completely without problems, the advantages of this technique are clear enough. Especially in personnel monitoring TLD has in many cases proved to be more reliable than film dosimetry. For this and several other reasons, such as the need for automation, many institutes and dosimetry services are considering the possibility of using TLD in radiation protection, or have adopted this technique already. Unfortunately, most of the TLD-readers now commercially available are intended for manual operation. The few automatic systems developed so far suffer from the drawback that they are completely closed systems, since they are adapted to special types of personnel dosimeters and hence are not necessarily compatible with other types of TL-detectors.

TNO, also anticipating the use of TLD in personnel monitoring (for about 10,000 people on a bi-weekly base) therefore developed an automatic and versatile TLD-reader that leaves complete freedom in the design of a future, automatically processable, dosimetry system. The instrument accepts most of the present (and probably many future) types of solid TL-detectors.

After an experimental set-up had been tested in the laboratory of the Radiological Service Unit TNO with satisfactory results, a more sophisticated prototype (Fig.1) has recently been developed in cooperation with one of the other institutes*) of the Organisation for Scientific Research TNO. This instrument might be the basis for serial production by some commercial manufacturer.

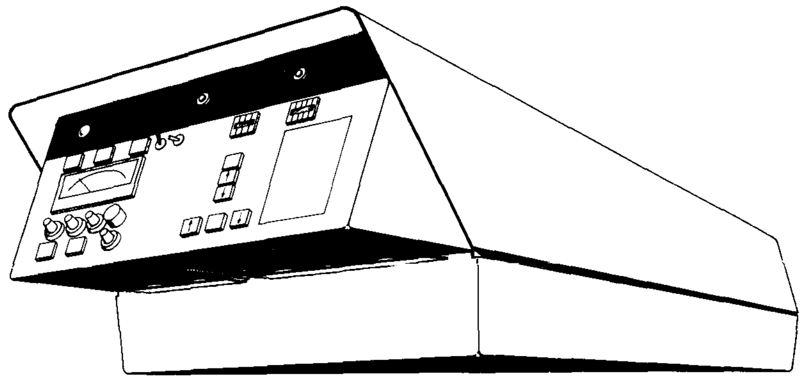

Fig.1.
Automatic TLD-reader (prototype).

The reader

Thermo-optical part. We use hot nitrogen gas as the heating agent - as has previously been described by Petrock and Jones[1] and is now being used by some others[2] - because of the well known advantages of this method: perfect temperature contact between heating medium and detector independent of its shape, low background signal, constant starting conditions and short cycle times (200 dosimeters can be read per hour).

The TL-detector, fixed on top of a thin suction needle (see below) is exposed to three hot-gas jets which are placed under angles of 120^0 (see Fig.2). The heating cavity has been designed to accept TLD's up to a diameter of 13 mm (teflondiscs). As a consequence the nitrogen consumption is relativily high (4 to 5 liter N_2 per minute per jet, i.e. ± 1 ¢ per reading). The gas temperature can be varied and stabilized within a wide range to meet the requirements for different detector materials.

Except for the three gas in- and outlets, the heating cavity is completely closed during readout, so that no spurious light can interfere with the TL-signal and the gas be kept free from impurities.

The TL-light is measured with a cooled and temperature stabilized PM-tube. An ellipsoidal mirror (Fig.3) is used to avoid thermal contact between heating cavity and PM-housing. In the lightpass a diaphragm is placed, to shield light emitted by other sources than the TLD itself.

TLD-manipulator. The problem of puting a TL-detector from any holder or sample changer into the heating cavity has been solved by developing a special manipulating device. This TLD-manupulator may roughly be described as follows (Fig.3): In a cubical piece of metal a rotatable drum is fitted. The drum has a radial bore in which a hollow piston can be moved up and down. The bottom of the piston is closed, the other end is provided with a removable cap in the centre of which a hollow needle is mounted. When the piston is retracted within the drum, the latter can be rotated freely. With the drum in vertical position the needle may protrude either through a hole in the top or through a hole in the bottom of the

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cube. If, in the latter position, the piston is evacuated through a duct in the cube, the suction needle can pick up a TLD. The TLD may now be brought into the heating cavity by successivily: retracting the piston into the drum, rotating the drum over 180^0, and moving the piston outwards again. After readout the TLD can be brought back into the position it came frome but, if desired, the TLD may be dropped at another site by using a third opening ("emergency exit") in the cube, at which the drum can be stopped. This feature may be used if the detector has to be removed from the series for some reason (see the description of the electronics).

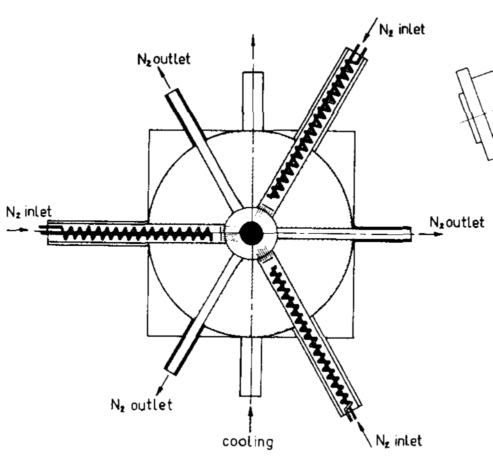
The construction of the TLD-manipulator indeed leaves the user complete freedom as to the way of offering a TLD to the reader. For this purpose any simple sample changer will do, such as a rotating disc or a conveyor belt. This means that there are essentially no restrictions in the way a TLD-batch is designed, except in that the detectors must be presented freely to be picked up after the holder was opened.

Electronics. The TL-signal is handled in a conventional way. The PM current is digitalized by means of a current-to-frequency converter (for which in the prototype a set-up as proposed by Shapiro[3] is used). Light output is integrated during the readout time. In principle a dose-range of about seven decades can be covered without range-switching. To get sufficient accuracy at low doses and to avoid saturation of the converter, the range will in practice be limited to six decades by setting the sensitivity, for example from 5 mR to 5000 R.

Because the temperature to time relationship is not linear - the gas temperature being constant - the response curve (Fig.4)has no direct scientific significance, but still it can be used as an indication for proper working of the instrument. The readout process can be followed on a logarithmic rate meter, or compared with a standard curve as stored in a computer memory.

The reader can be used as well in automatic as in semi-automatic (only cycle) and in manual mode. The instrument is

Fig.2. TLD (teflon disc) in centre of heating cavity, exposed to three jets of hot nitrogen gas.



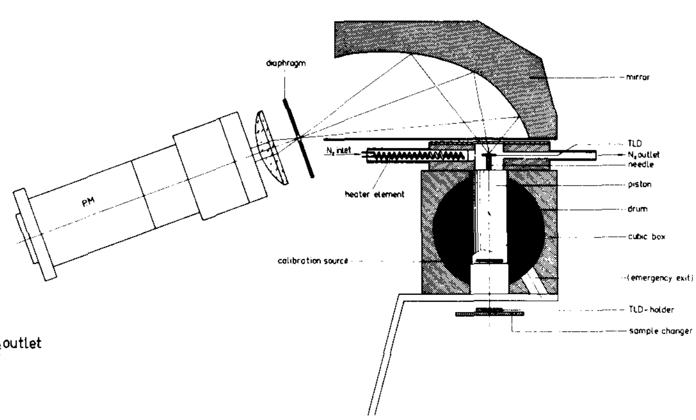


Fig.3. Diagram of the principle parts of the reader.

designed as a fail-safe system. This is of great importance in TL-dosimetry, where the dose-information is essentially lost by the readout procedure. Therefore checks are continuously performed for nitrogen flow, gas temperature, false release of the TLD from the needle, etc. Before each cycle the optical and electronic parts can be checked by means of a radioactive (^{14}C) lightsource fixed at the bottom of the piston.

The rear panel is provided with in- and output connectors, so that additional modules of conventional nuclear electronics and even a programmable processor (such as the PDP/8) for external control and data handling can be used. Nevertheless, to make the system as selfsupporting as possible, several features have been built into the prototype, such as timers, display, sample changer control, etc.

The reader can be used for automatic selection of dosimeters of uniform sensitivity out of a batch of equally exposed TLD's, by using a lower- and an upper count (dose-)level. If these levels are set, for example, according to $\bar{x} - 2\sigma$ and $\bar{x} + 2\sigma$ respectively (assuming that the average response $\bar{x}$ is known), then dosimeters showing a sensitivity within the chosen range are repositioned (thus collected), while detectors responding outside this range are ejected through the above mentioned "emergency exit" (thus separated from the others).

During normal automatic readout, the lower level can, if desired, be used to cause a prolonged, adjustable, heating time (post-read anneal) after a relatively high dose has been measured. In this mode, doses above the upper limit will cause the TLD to leave the reader by the "emergency exit", to be annealed in an oven.

Experiments

Up to now , experiments have been carried out in some detail for LiF hot-pressed ribbons (Harshaw, $^{1}/_{8}$ x $^{1}/_{8}$ x 0.035 inch, 25 mg) and LiF teflon-discs (Teledyne Isotopes, 12.7 mm dia., 30 mg),

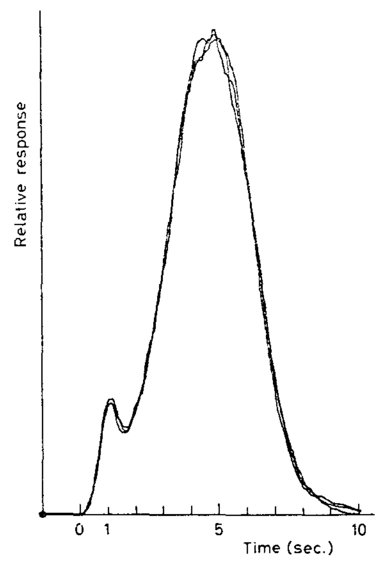


Fig.4. Successively recorded glow curves of 3 LiF-ribbons (Harshaw, 25 mg) exposed to 0,5 R ^{60}Co gamma radiation.

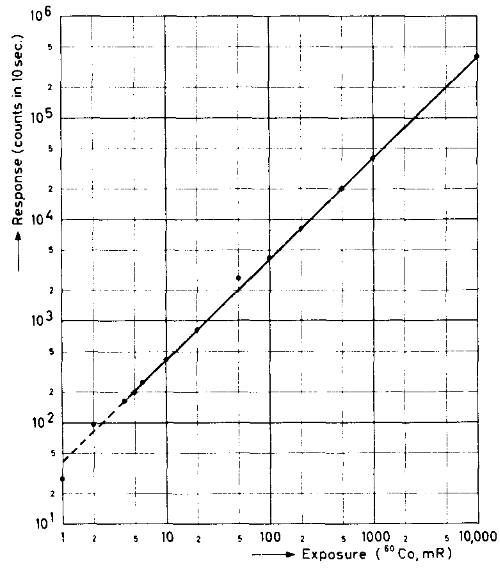


Fig.5. Dose-response curve of hot-pressed ribbons (Harshaw TLD-100, 25 mg) read in automatic reader.

because these detector materials are possibly used in a future TLD-batch. Fig. 5 shows the dose-response curve for the Harshaw, LiF-chips. The data points represent the averages of eight TLD's. For this experiment - in which non-selected TLD's from one manufacturing batch were used - standard deviations appeared to be 9% at 5 mR and 2-4% above 20 mR.

The sensitivity of the instrument would make it possible to detect doses far below 1 mR, but unfortunately we did not succeed in finding the proper annealing procedure to make the signal of non-irradiated TLD's sufficiently low and constant. This was especially true for the 12.7 mm diameter teflon discs which, moreover, show substantial light-sensitivity. These phenomena were responsible for the fact that, for this material, the detection threshold was as high as about 5 mR, although these dosimeters were found to be roughly twice as sensitive as the hot-pressed ribbons.

The dosimeters are almost completely emptied, as can be proved by a second readout, which gives a response corresponding to less than 0.1% of the original dose, If desired, this remaining signal may be used to prove the significance of an unexpected high dose.

Conclusion

Our experience with the experimental version of the TLD-reader as described above, proved that the apparatus satisfies our requirements as to fast evaluation of different types of TLD's, although it was not supplied with the features as available in the more elaborate prototype that has just been finished. This universal automatic TLD-reader being available now, the way is open to us (as it is, in principle, to anyone) to design an automatically processable personnel TL-dosimeter for large-scale radiation protection measurements.

Irrespective of the fact whether this is a good thing or not, in practice most institutions prefer to have their own input in the dosimetry system used, as far as philosophy and choice of the applied TL-materials are concerned. Up to now this was impossible without designing all parts of the equipment. We think that this universal instrument will help to overcome the hesitations to use TLD on a large scale and will make this attractive technique more a tool than a toy.

References

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