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The UK HPA Thermoluminescence Dosimetry System

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Abstract

The UK Health Protection Agency's Radiation Protection Division (formerly the National Radiological Protection Board, NRPB) has completed a major modernisation of its TLD service. The new service was launched in November 2006 and is based on Harshaw™ TLD dosemeters, using LiF:Mg,Cu,P, and readers. This paper describes the management and operational aspects of the service.

Keywords: TLD; LiF (Mg,Cu,P); Harshaw

1. Introduction

The UK Health Protection Agency (HPA) was established in 2003 to provide an integrated approach to protecting UK public health. The functions of HPA are to protect the community against infectious diseases and other dangers to health including chemical and radiation hazards. To achieve the last of these, the former UK National Radiological Protection Board (NRPB) joined HPA in 2005 as the Radiation Protection Division (RPD).

In 2000 NRPB had begun to consider the replacement of the TLD system which formed the mainstay of its Personal Dosimetry Service. The service is a moderately large one, covering some 55,000 wearers in the UK and overseas. Employers served represent a wide range of occupational categories, from nuclear site contractors to dental practitioners. Change intervals range from four weeks to three months.

The choice of system was governed by a number of factors including reliability and availability of support. To further promote reliability, non-standard methods were to be avoided far as possible. At least one other dosimetry service (Cassata et al., 2002) was already using Harshaw™ high-sensitivity lithium fluoride, LiF (Mg,Cu,P), and although there was a small risk in following suit, the benefits obtainable in terms of sensitivity and energy dependence of response were felt to outweigh this risk.

The project involved a number of strands including: design of a suitable holder; type testing; development of handling equipment; development of quality systems; and the obtaining of formal approval from the UK regulator, the Health and Safety Executive. The service commenced full operation in 2006 and currently issues an average of 6,500 body dosemeters and 500 extremity dosemeters per week.

2. Dosemeters

The HPA TLD system uses one type of body dosemeter and two types of extremity dosemeter, the finger stall and the ring. All use Harshaw™ high-sensitivity lithium fluoride, LiF:Mg,Cu,P. The body dosemeter (Fig. 1) consists of a two-element card, wrapped in thin plastic and enclosed in a polypropylene holder of HPA design (Eakins et al., 2007, Gilvin et al., 2007A) which incorporates an open window and a thick filter comprised of 4.3 mm PTFE plus 2 mm polypropylene (total mass thickness 1130 mg.cm^{-2}). The TLD element thicknesses are 0.36 mm (behind the thick filter) and 0.25 mm (behind the open window) for measurement of $H_p(10)$ and $H_p(0.07)$ respectively. The wrapper thickness is 8 mg.cm^{-2}.

Fig 1. The HPA body TLD.

Fig 2. The HPA extremity finger stall dosemeter.

Fig 3. The HPA extremity ring dosemeter.

The extremity finger stall (Fig. 2) is of a design developed by UK dosimetry services in conjunction with Thermo Electron (now ThermoFisher Scientific) and a UK manufacturer. The finger stall uses the Harshaw™ EXTRAD TLD element covered by aluminised polyester at 3.2 mg.cm^{-2}. The extremity ring dosemeter (Fig. 3) is of Harshaw design, using the DXTRAD circular TLD element and a thin cap of area density 5 mg.cm^{-2}. All dosemeter types have been thoroughly tested (Gilvin et al., 2007A, Gilvin et al., 2007B, Luo et al., 2002) against international standards.

3. Systems

The service operates three separate control systems, with data transfer by means of text files, automatically processed. The first is the proprietary WinRems™ software which operates the Harshaw™ TLD readers. From this, data is transferred to an in-house visual basic system, TEDI, which controls the physical process of dosemeter issue, governs the movement of dosemeters around the system and performs background dose corrections. In turn, TEDI exchanges dosemeter information with a master database system, DORIS, which manages customer dosemeter requirements, dose reporting and dose record keeping.

Equipment includes three Harshaw TLD™ 8800 Readers, two of which include built-in ^{90}Sr/^{90}Y irradiators for dosemeter calibration, as well as purpose-built machinery for issuing, unwrapping and sorting.

4. Dosimetry

4.1. Reader Calibration

The calibration process characterises the readers in terms of their response to a conventionally-true dose; in other words, the *reader calibration factors* (RCFs, in terms of signal per unit dose) are determined. Traceability to national standards is established if the conventionally-true dose is delivered by a primary or secondary standards laboratory. Uncertainties are minimised if the set of reference (or "calibration") dosemeters used is selected to have physical sensitivities close to the average for the entire population. At HPA, the reference dosemeters are exposed in the HPA secondary standards laboratory either on a suitable phantom (the ISO water-filled slab phantom, 300 mm x 300 mm x 150 mm, for body TLDs) or free-in-air (for extremity dosemeters). A suitable choice of conversion coefficients is made and adequate measures are taken to ensure electronic equilibrium. The calibration source is ^{137}Cs. RCFs for each TLD reader are determined twice a year, for each dosemeter type. See Fig. 4.

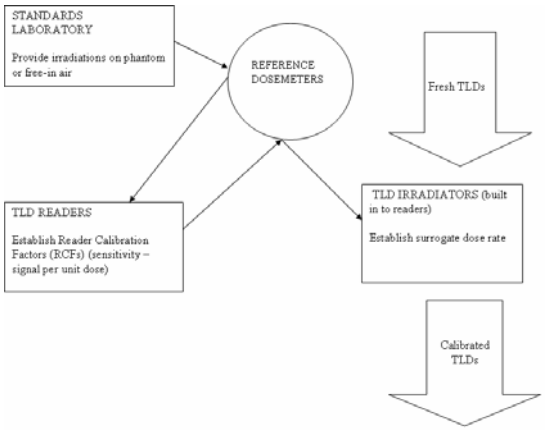

Fig . 4. Summary of traceability and calibration route.

4.2. Dosemeter Calibration

For the bulk calibration of dosemeters, the irradiator units built into the Harshaw™ 8800 readers are used as surrogates for the secondary standards laboratory calibration field. To establish the surrogate dose rates, the same reference cards as used for reader calibration are exposed for a preset duration in the irradiator units, and immediately read. This takes place soon after the routine bi-annual reader calibration, in order to avoid any effects of reader drift. The output of this process answers the question, "how many seconds in the irradiator unit gives the same response as *x* millisieverts conventionally-true dose?" This information is then used in calibrating individual dosemeters.

Dosemeter calibration takes place by loading the dosemeters into the TLD readers and executing an automatic calibration cycle, available under WinRems™. This consists of, consecutively, a clearance anneal, an exposure in the irradiator unit, and a calibration read. The operator then supplies the known surrogate dose value to allow the individual dosemeter calibration factors, known as *element correction coefficients*

(ECC) to be calculated and stored. WinRems™ allows a range of acceptable ECC values to be set; dosemeters whose ECCs lie outside this range are rejected.

Body TLD cards are routinely re-calibrated every five years. However, owing to their construction extremity dosemeters are relatively less protected during use. Hence, in order to reduce the risks of, for example, loss of phosphor from the surface of a dosemeter element, extremity dosemeters are re-calibrated more frequently (annually).

4.3. Energy and Angle Dependence - No Correction Applied

In calibrating the dosemeters and in calculating results, no correction for energy or angle is applied. All results are therefore reported as if for the calibration field (^{137}Cs). This approach is justified in view of the small variation of response of the dosemeters with radiation energy and angle (Gilvin et al., 2007A, Gilvin et al., 2007B, Luo et al., 2002).

4.4. Residual Signal

The material LiF (Mg,Cu,P) exhibits some residual signal following routine reading; in the present system this residue has been found to be about 1% of the primary signal (Gilvin et al., 2007A). This is dealt with by using a feature in WinRems™ which allows dosemeters showing a result above a settable level to be rejected, and hence to be properly annealed before re-issue.

4.5. Background Correction

The background signal is comprised of a small intrinsic component (from the dosemeter itself and from the TLD reader electronics) together with a larger contribution form natural background. The natural background component arises from cosmic and terrestrial gamma radiation, and varies according to location. In the UK the range is from 50 to 110 μSv per month. This is accounted for by the TEDI system, which counts the number of days between the last pre-issue read (or anneal) and the post-issue read. This number is then multiplied by either a site-specific daily dose rate or a default UK national average value, and subtracted from the gross dose.

4.6. Measurement Uncertainty

The measurement uncertainty varies with a number of factors, including the energy and angle distribution of the radiation field. In the HPA service, where many different users encounter a variety of radiation environments, the conservative assumption is made that the radiation energy and angle of incidence are not known, and that the response probability function is therefore rectangular. Other factors to be taken into account include calibration uncertainties, and the dependence of response upon environmental and time effects (ageing and fading).

The measurement uncertainty also depends upon dose. At low doses the uncertainty in natural background becomes significant, and this it is therefore appropriate, when quoting uncertainties, to specify the wearing period (e.g. one month) and to state the uncertainty at different levels of dose.

For the present system an uncertainty analysis has been carried out for the $H_p(10)$ measurement, making conservative assumptions and covering all of the above sources, which show the measurement uncertainties at the 95% confidence level to be approximately:

- 55% at 0.05 mSv
- 12% at 0.5 mSv
- 11% at 5 mSv

for a one-month issue. Meanwhile, whilst the value for the decision threshold L_c found in laboratory conditions is much lower, the practical value for a one-month issue is at least 40 μSv, the difference being attributable to the natural background correction.

5. Processes

*5.1. Transitional Arrangement*s

The new system was launched in November 2006. For operational reasons the switch from issuing old-style to new-style TLDs was made on a specific day, rather than by phasing the change. Parallel processing of both types of dosemeters continued for a period of seven months, after which processing of old-system TLDs was discontinued.

5.2. Despatch, Return & Transit

Dosemeters are despatched together with delivery documentation in high-colour padded envelopes which carry prominent warnings to avoid x-ray scanners. These can be used for return. Clients can also order extra control dosemeters to provide information on transit doses.

5.3. Process Cycle

In addition to the reading, annealing and limited sorting function performed by the TLD readers, other laboratory operations are carried out as follows. Following reading, the dosemeters are sorted to separate out those which are due for re-calibration and those which are to be rejected for some reason (see below). The remaining dosemeters can be re-issued. Upon return from the user (radiation employer), dosemeters are checked in and monitored for contamination, removed from their wrapper or other housing, and read.

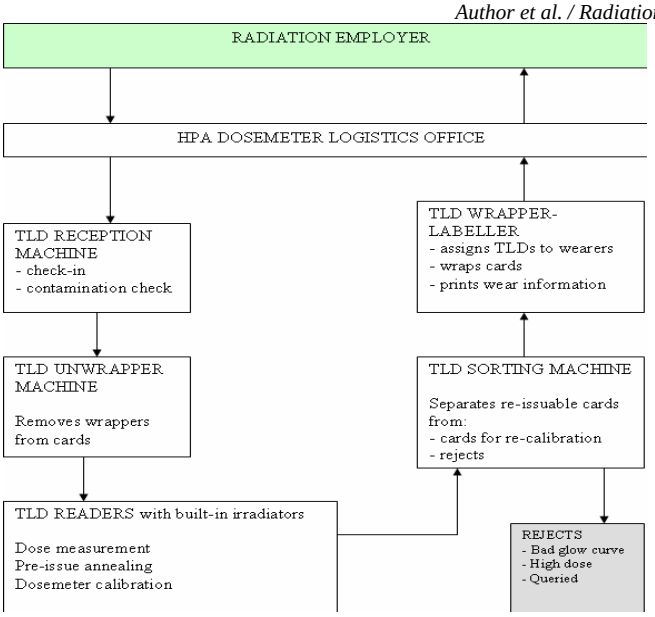

Fig. 5. Flow of body TLD cards in the HPA system.

For extremity dosemeters, these handling processes are largely manual, but for body TLD cards the following specialist equipment is used:

- wrapper/ labeller (Autowrappers, Norwich, UK)
- sorter (Martech, Weymouth, UK)
- reception machine (Gemini Technology, Reading, UK)
- unwrapping machine (also Gemini Technology).

The process cycle for body TLD cards is summarised in Fig. 5, where the re-calibration sub-cycle is omitted for simplicity.

5.3. Heating Cycle

For reading and annealing, the manufacturer's recommended time-temperature profiles are used in all cases. See Table 1.

Table 1. Time-Temperature Profiles

	Body TLD	*Extremity TLD*
Preheat T, °C	165	165
Preheat t, sec	20	10
Acquire Rate, °C/sec	15	15
Acquire T, °C	260	255
Acquire t, sec	13.3	13.3
Anneal T, °C	260	255
Anneal t, sec	10	10

5.4. Exceptions

Alerts are produced by the TEDI system for the following reasons. In each case, service staff take action to inform clients as appropriate.

- high dose (>15 mSv)
- dose exceeds customer investigation level
- transit control dosemeter shows non-zero dose.

Similarly, dosemeters or results may be rejected from the system for a number of reasons:

- glow curve has failed QA test (see below)
- high dose (dosemeter may be needed in investigation and will not be re-issued)
- queried by previous user (dosemeter may need to be physically examined)
- calibration failure (ECC out of range).

6. Quality Assurance

A number of quality assurance measures are taken in the routine service. Those having an influence on dosimetry include the following.

6.1. Quality Control Checks

The WinRems™ system allows for the regular checking of reader performance. The photomultiplier tube system noise, and its response to the reference light sources built into the Harshaw™ 8800 readers, is checked at intervals of *n* cards, and whenever a reading session is begun. At HPA, *n* is set to 10.

Additionally, a set of dedicated cards is used to check the response of each reader. Some of the cards are given a known reference dose and the remainder are left unexposed. At HPA, at least five cards of each type are read on each reader each day.

WinRems™ immediately halts the TLD reader if the results for any of the above checks lie outside pre-set limits. On a monthly basis, the laboratory supervisor analyses the QC results and checks for trends.

6.2. Glow Curve Checks

WinRems™ stores the glow curve for every read or anneal which takes place, and these can be recalled for later investigation. The software can also be configured to split the integration region into up to four regions of interest (ROI). At HPA, the ROI information is used by TEDI to highlight glow curves which have an unusual shape or dose ratio. These results are diverted for a supervisor's attention before being released. The minimum retention period for glow curves is five years.

6.3. Dummy Customer Subscription

Dosemeters of each type are issued on a quarterly basis to a member of HPA staff with QA responsibilities, who gives the dosemeters a certain exposure. The dosemeters are returned for processing exactly as for customer dosemeters, and the final results compared with those expected.

6.4. External Dosimetry Tests

In order to retain HSE Approval, the service is subject to routine performance testing in accordance with HSE protocols (HSE, 1996A, HSE 1996B) at least every eighteen months. The service also participates in intercomparisons wherever possible.

7. Summary

The Radiation Protection Division of the UK Health Protection Agency has launched a new TLD service based on Harshaw™ LiF (Mg,Cu,P). The service possesses a number of features which provide a high level of reliability and a reasonable level of accuracy.

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