

A NEW USER-FRIENDLY EXTREMITY DOSIMETRY SYSTEM – DESIGN, COMPARISON, AND TESTING

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Abstract: A new extremity TLD system has been developed and tested that provides for user convenience and automated processing while meeting various accreditation requirements. The design is a result of successful collaboration among organisational entities in different countries and included research centres, users, and the manufacturer. The primary consideration was to meet the needs of the medical market, without losing sight of the needs of research laboratories and power plants. This dosimetry system design provides various detector designs based on the need to measure photons or betas. Beyond the fundamental need for accurate dosimetry, the system meets the customers need for a versatile and comfortable ring and provides for both hot and cold sterilisation.

The system represents a unique integration of components comprising the finger ring, dosimeter and dosimeter identification system, and TLD Instruments. The dosimeter identification system in the TLD Reader incorporates a CCD Camera and Machine Vision Technology to interpret the circular bar codes used to quickly and accurately identifies each individual dosimeter. Portability of this dosimetry system has been realised with the adaptation into multiple TLD Instruments.

Keywords: dosimetry, TLD, Ring, dosimeter, dosemeter

1 INTRODUCTION

Personnel monitoring services issuing TLD extremity dosimeters have long been looking for a practical and economic method for automated processing, i.e. identification of the finger ring TLD detectors. Especially for medical users (i.e. surgery) existing detectors are not very suitable, due to their rather large dimensions and the fact that cold sterilisation, required for multiple uses in surgery, is usually impossible. The new technique, described here, is based on circular TLD chips mounted with a Kapton foil on small aluminium discs with a miniaturised circular bar code and corresponding directly readable six digit identification number. These discs are inserted into small disposable plastic finger rings. For readout, up to four discs are inserted into standard TLD reader cards, which can be automatically processed in the HARSHAW 6600 or 8800 readout systems. Identification of the discs is achieved by an internal CCD video camera and special PC software. The whole detection system comprises the following main components described later in detail:

- Dosimeter Ring, Cap and TL-Ringlet
- TLD Card Reader with circular bar code identification system
- PC Workstation with REMS Software
- Carrier Card with Ringlets
- Carrier Card Assembler/ Disassembler
- Ring Assembler/Disassembler
- External Bar Code Reader

2 DOSIMETER RING

Fig. 1 shows the **dosimeter ring** housing the TL detector mounted on a metal disc (ringlet). Due to the variable diameter of the ring between 14 mm and 26 mm it fits any size of finger. The ring itself is made of extruded plastic available in different colours. The material is temperature resistant up to 140°C thus allowing hot gas sterilisation - only before the first use - since elevated temperatures would

change the dose information of the TL-detector. For repeated use special tested disinfection agents can be used. On its flat upper part a circular extension of 9 mm houses the circular **detector ringlet**. It comprises of the **TLD chip** mounted on Kapton foil on an Al disc holding the **bar code** (radial 6 digit ITF) and the corresponding directly readable identification number. A transparent circular cover plate allows to read the ID number on the disc. In addition using an **external bar code reader** automatic identification of the bar code (of the ringlet still in the ring) is possible. A black cover in its centre of the cap protects the TL-chip from light. For the detector readout using a **TL-Reader** the plastic ring is opened by a **Ring Assembler/Disassembler tool** (Fig 3) and the detector ringlet is removed.



Figure 1. a and 1Ring dosimeter (Plastic ring and detector ringlet)

3 CARRIER CARDS

The dose information of the detectors (TLD-chips) were read out in automated processing hot gas TL-Readers (Harshaw Mod. 6600 or 8800) using special detector **carrier cards** (Fig. 2). These cards hold up to four bar coded TLD ringlets by a spring loaded clamping mechanism. The centre of each card contains an additional standard linear bar code for reading the card number if required. The ringlets can be both inserted into and removed from the carrier cards by means of a **Carrier Card Assembler/Disassembler tool** (Fig. 3).



Figure 2. Carriercards for automatic readout of the detector ringlets in an automatic hot gas TL reader



Figure 3. Assembling and Disassembling tools (for Carrier Cards and Rings)

4 VIDEO BAR CODE IDENTIFICATION SYSTEM

The ringlets are automated identified in the read out systems by an integrated video **circular bar code identification system** using a miniaturised standard CCD camera in combination with a frame grabber to capture and analyse a picture of the ringlet. The detection system consists of the following units:

- CCD camera (B/W) with frame grabber
- special lighting unit using power LEDs
- miniaturised PC Card with the analysis software

The processing algorithm first locates the bar codes (4) in the picture calculates the mean brightness along the circumference between the outer and inner radius of the bar code to minimise interference in the tangent direction. Then the grey scale values are determined and the type, width and number of bars identified. After that the bar code is decoded and the ID Number is transmitted to the read out programme for complete chain of custody.



Figure 4. Hot gas TL Reader (Modell 6600) with internal circular bar code identification system

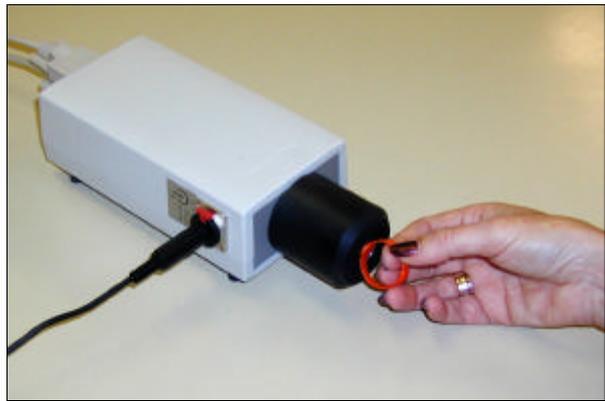


Figure 5. External bar code reader for automatic identification of the bar code (of the ringlet still in the ring)

5 TL READ OUT SYSTEMS

The detectors in the carrier cards can be read out in different standard **TL-Readers** – Fig. 4 (Harshaw Model 6600, or 8800) providing the following features:

- Fully automated instrument for thermoluminescence dosimetry capable of doing not only extremity but whole body, environmental and neutron dosimetry with the same unit.
- The extremity dosimeters may be constructed of not only LiF:Mg,Ti as discussed in this paper but also the new LiF:Mg, Cu, P high sensitivity material in chip or powder forms to increase low energy performance.
- Non contact heating systems using hot nitrogen and linear closed loop heating profiles with $\pm 1^\circ\text{C}$ repeatability.
- High capacity and throughput (800 extremity readings automatically evaluated at the rate of 280 per hour in one loading of the Model 6600 and 7 times that capacity and increased speed for the Model 8800.
- Each reader has built in diagnostics and quality control functions to ensure the highest quality dosimetry.
- The REMS software has built in reader and dosimeter calibration functions.

These systems consists of the TL-card reader and the REMS (Radiation Evaluation and Management System) software resident on a controlling PC.

6 DOSIMETRIC PROPERTIES AND TYPE TESTING

The ring dosimeter was tested in different laboratories for its dosimetric properties. It was designed to measure “extremity dose” in different dose quantities depending on local requirements. International documents (ICRU [1], ICRP[2], EU Directive [3], ISO standard [4]) recommend to use the quantity **personal dose equivalent $H_p(0,07)$** for the measurement of extremity dose. In addition, other quantities such as H_s as defined by ANSI N13.32 are used in the United States.

Enhanced **low energy beta response** has been achieved using a thin (about 7 mg/cm²) LiF: Mg, Cu, P high sensitivity powder and a thin entrance window of about 5 mg/cm². Test results of this new beta dosimeter will be discussed in a future paper.

Independent type tests were carried out at the PTB (Germany) and the BEV/ARCS (Austria) for different measuring quantities. The dosimeter meets both the requirement PTB-A-23.2 (Dec. 1992) for the measuring quantity **photon dose equivalent H_x** and the ÖNORM-S5237-1 [5] for the measuring quantity **personal dose equivalent H_p(0,07)**.

Within the scope of these type testing, the influence of various quantities which are not subject of the measurement – so called influence quantities - were investigated. According to the requirements these influences must not exceed stated limits. Fig 6 shows the energy dependence of the dosimeter for different dose quantities. The different results (PTB/BEV) are caused by the different measuring quantities requiring different irradiation conditions (free in air and on a phantom) and by the different stated reference energies.

As a result of these type tests the dosimeter was approved for the following measuring and energy ranges (Tab. 1):

Table 1. Approved measuring and energy ranges of the dosimeter for photon measurements

Org./Country	Standard	Measuring quantity	Measuring range	Energy range
PTB/Germany	PTB-A-23.2 (92)	H _x	1mSv – 10 Sv	10 keV – 1400 keV
BEV/Austria	ÖNORM S5237-2 (99)	H _p (0,07)	0,5 mSv – 10 Sv	15 keV – 1340 keV

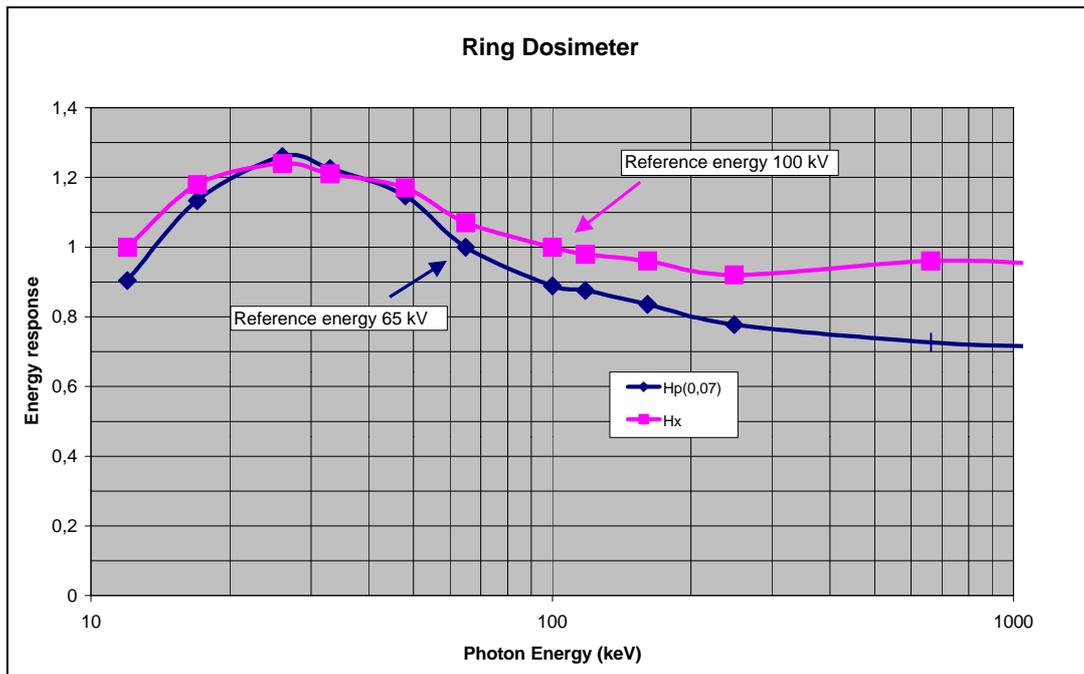


Figure 6. Energy response of the dosimeter measured for different measuring units (photon dose equivalent H_x, and personal dose equivalent H_p(0,07). and for different reference energies (100 keV and 65 keV)

7 FURTHER DEVELOPMENTS

Based on the successful concept of the described **ring dosimeter** a new type of a **wrist dosimeter** is in preparation. A prototype (Fig. 7.) for it already exists and the optimisation of the design considering dosimetric properties, user conveniences and special needs of customers, are carried out at the moment.

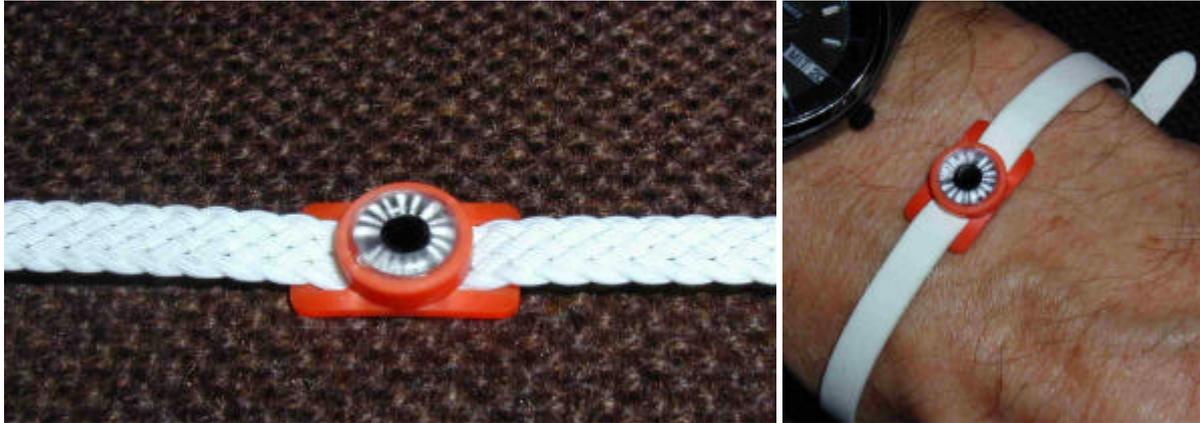


Figure 7. a and b Wrist dosimeter (Plastic housing and detector ringlet)

8 CONCLUSION

The new finger ring dosimetry system described is a fairly simple and economic solution for automated processing of extremity dosimeters, particularly if used for medical applications requiring small and conveniently wearable rings suitable for cold sterilisation. The dosimetric properties are in accordance with national standards guaranteeing correct estimation of the radiation burden of occupationally exposed persons.

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