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BUILD-UP PMMA PLATE EFFECT ON CALIBRATION OF TLD READER

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Abstract. *The routine monitoring of the occupationally exposed individuals constitutes an integral part of radiation protection program implemented at the Vinca Institute of Nuclear Sciences (INNV). The Individual monitoring service (IMS) at the INNV, accredited according to quality standard EN ISO/IEC 17025, is using Harshaw 6600 Plus automatic reader and thermoluminescent dosimeters (TLD) from two manufacturers (Harshaw, RadPro international GmbH). Working procedures are implemented according to Technical Recommendations for Monitoring Individuals Occupationally Exposed to External Radiation, RP 160 (European Commission, 2009). Among general consideration, RP 160 is suggesting that routine calibration of dosimetry system should be performed taking into consideration secondary charged particle equilibrium. As TLD system in use at IMS INNV comprises of TLD reader and of TLD cards, this consideration should be applied in both cases: when the reader and the TLD cards are being calibrated. During reader calibration, secondary charged particle equilibrium can be ensured using build-up PMMA plate of certain thickness placed in front of dosimeters.*

In this paper, influence of the build-up plate on reader calibration is being analyzed. This influence is observed through changes in reader calibration factor (RCF). RCF values obtained during reader calibration procedure with and without 2 mm thick build-up plate are presented. Exposures of whole body TLDs placed on slab phantom were done with ^{137}Cs radiation source located at Secondary Standard Dosimetry Laboratory (SSDL) at INNV. TLDs from both manufacturers had 2 detectors for measuring the dose equivalent at the depths of 10 mm and 0.07 mm. TLD reader was calibrated to measure effective dose in terms of Hp(10) and local skin dose in terms of Hp(0.07). RCF values for detectors measuring Hp(10), from both manufacturers, when irradiated without the plate were around 5% higher than RCF values obtained when irradiations were done with the plate. Values of RCFs for detectors measuring Hp(0.07) were around 1% higher when the plate had not been used. As RCF value is inversely proportional to measured dose, reader calibration without build-up plate, in terms of Hp(10), would lead to underestimated dose values. The observed RCF deviation of Hp(0.07) detector is regarded as consequence of exposure conditions uncertainties.

In conclusion, if a constant geometry and constant operational conditions of TLDs are achieved, the only part of the TLD system that is not stable for a long time period is the TLD reader. To avoid inaccurate results, RCF should be orderly checked and reader calibration should be done according to widely accepted standards, currently in effect.

Key words: *TLD, RCF, build-up plate, Hp(10), Hp(0.07)*

1. INTRODUCTION

The routine monitoring of the occupationally exposed individuals constitutes an integral part of radiation protection program implemented at the Vinca Institute of Nuclear Sciences (INNV). The Individual monitoring service (IMS) at the INNV, is accredited according to quality standard EN ISO/IEC 17025 [1]. Working procedures are implemented according to technical recommendation RP 160 [2]. The RP 160 aims at harmonization of individual monitoring practices and is based on internationally accepted standards and documents of relevance [3].

Calibration of the dosimetric systems is not always, completely performed at the IMS. However, it is under its responsibility according [1]. Therefore, IMS is responsible for a proper, reliable and accredited calibration of the dosimetric system in use in the calibration facilities [3].

When calibrating thermoluminescent dosimetry (TLD) reader ratio between average TL output (electric charge) of the calibration Dosimeters ($\overline{Q}$) and the delivered radiation quantity (L) is conveniently expressed in terms of one variable:

$$RCF = \frac{\overline{Q}}{L}. \quad (1)$$

As this variable is only dependant on reader condition it is called Reader Calibration Factor (RCF). Thus, RCF is the main link between TLD response in terms of charge or counts and absorbed dose or dose equivalent in terms of Gray or Sievert, respectively [4].

Once TLD reader is calibrated, the doses from field dosimeters can be obtained from:

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$$D = \frac{ECC * Q}{RCF}, \quad (2)$$

where, D is the measured dose, ECC (element correction coefficient) parameter linked to dosimeter calibration.

As the h_{K} - conversion coefficients from air kerma to dose equivalent quantity of ISO 4037-3, are valid only under conditions of secondary electron equilibrium, calibration of a TLD reader has to be performed taking into consideration secondary charged particle equilibrium [5]. Only then we can say that

$$H_p(d) = h_K * K_{air}, \quad (3)$$

where, $H_p(d)$ is dose equivalent at depth d, K_{air} is air kerma.

By placing a layer in front of the detector which, together with the wall material and the cover of the detector, gives a combined layer of a thickness larger than the range of the most energetic secondary electrons, reproducible results can be obtained. According to [6] no additional layers are required for photon energies below 250 keV; a 1.5 mm thick layer of polymethyl methacrylate (PMMA) is sufficient up to 0.66 MeV. For energies up to 1.33 MeV, a 4 mm PMMA layer is sufficient.

The influence of the PMMA plate on the photon field by scattering and attenuation is taken into account by a correction factor k_{PMMA}. The plate should be positioned immediately in front of the detector but in real condition it is hardly achievable. Thus, [5] recommends to locate the plate a certain distance away from the detector in the direction of the radiation source to allow a rotation of the dosemeter or of the combination of dosemeter and phantom. This arrangement also secures complete build-up for angles of rotation around 90° and it requires only one value of k_{PMMA} for all angles of rotation. Now, instead (3), dose equivalent is calculated according to:

$$H_p(d) = k_{PMMA} * h_K * K_{air}, \quad (4)$$

During TLD reader calibration, secondary charged particle equilibrium was ensured using 2 mm build-up PMMA plate placed between dosimeters and ^{137}Cs (662 keV) source [5]. k_{PMMA} value for ^{137}Cs is 1 [5].

Here presented is influence of the PMMA plate on TLD reader RCF.

2. Method

The IMS at INNV is using Harshaw 6600 Plus automatic reader and TLD cards from two manufacturers (Harshaw, RadPro international GmbH).

In this paper two calibration procedures for Harshaw TLD reader will be addressed. For both procedures two sets of ten calibration dosimeters were placed on ISO slab phantom (dimensions: 30 cm × 30 cm × 15 cm). One set was produced by Harshaw and the other by RadPro international GmbH.

The positions of TLDs are shown in Fig. 1.

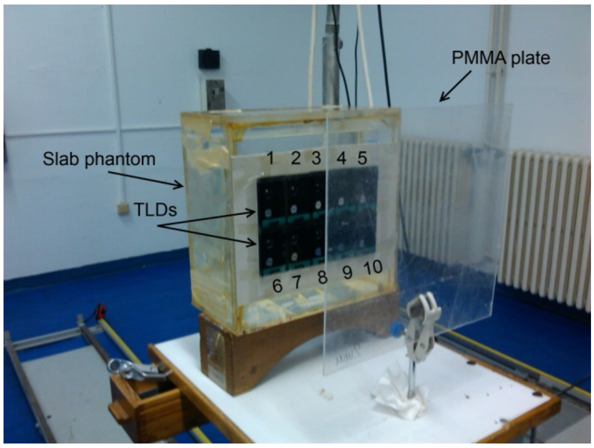

Fig. 1. Dosimeters' position during calibration

Each dosimeter had two thermoluminescent (TL) chips made of LiF: Mg, Ti. One TL chip was behind filter 1 (ABS plastic + PTFE), and the other was behind filter 2 (Aluminized mylar) [4]. The TL chip that has filter 1 in front is used for measuring personal dose equivalent at the depth of 10 mm, Hp(10), and the other is use for measuring personal dose equivalent at the depth of 0.07 mm, Hp(0.07).

Harshaw dosimeters were irradiated with the dose of 1 mSv, 3 m from the ^{137}Cs (662 keV) source, and without PMMA screening plate. The dose rate was 16.482 μGy/min. This was repeated also for Radpro dosimeters.

In second case, exposition parameters were kept exactly the same as during first calibration. The only difference was that PMMA plate, 30 cm x 30 cm x 2 mm, was positioned 15 cm in front of dosimeters (see Fig. 1).

All irradiations were done in secondary standard laboratory (SSDL) at Vinca Institute of Nuclear Sciences.

When 24 hours after exposure passed, the dosimeters were read on Harshaw TLD reader, while Reader calibration mode was enabled. The output signal of this mode is the electric charge produced by light emitted from stimulated TL chips. After acquiring the electric charge from each chip, nominal dose of 1 mSv was manually put into the Reader. This enabled calculation of the RCF according to (1).

3. Results

The results of calibration procedures with PMMA and without PMMA plate are shown in fig. 2-5. The output signal from TLDs in the form of electric charge was collected per each TL chip, and presented.

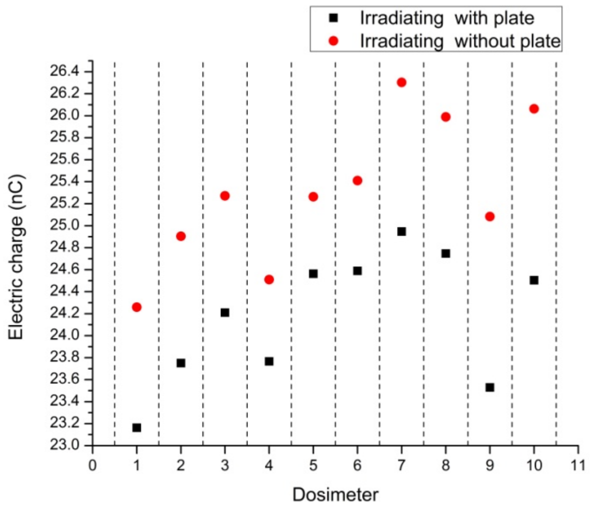

Fig. 2. Output signal from Harshaw TLD measuring Hp(10)

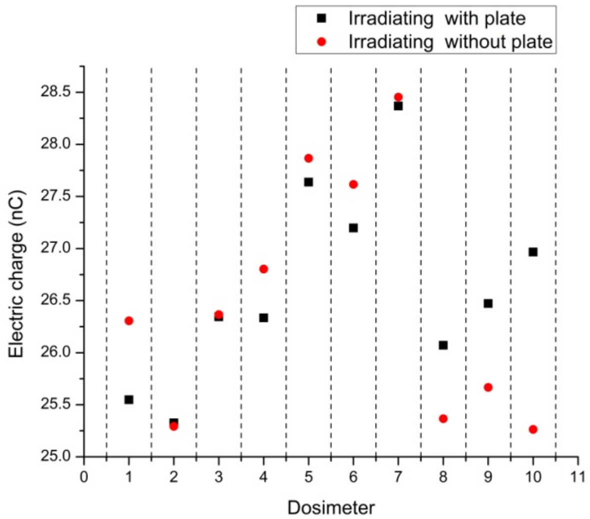

Fig. 3. Output signal from RadPro TLD measuring Hp(10)

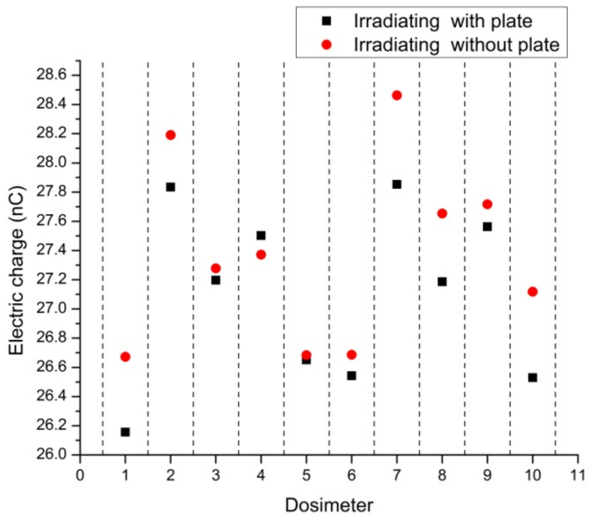

Fig. 4. Output signal from Harshaw TLD measuring Hp(0.07)

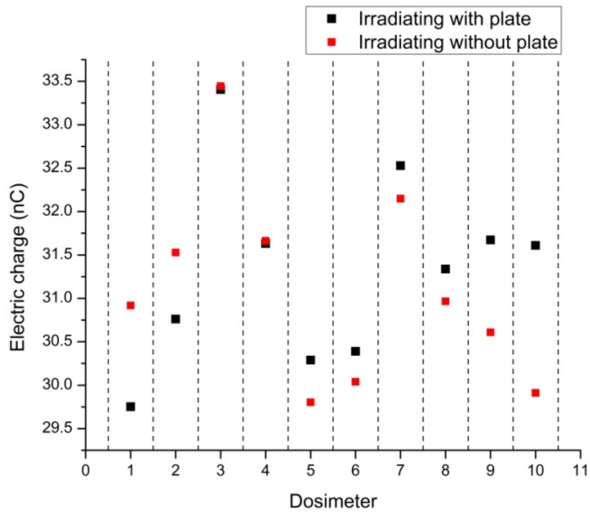

Fig. 5. Output signal from RadPro TLD measuring Hp(0.07)

Values of calculated RCFs for measuring personal dose equivalent Hp(10), Hp(0.07) obtained by calibration with and without PMMA plate are shown in Fig. 6.

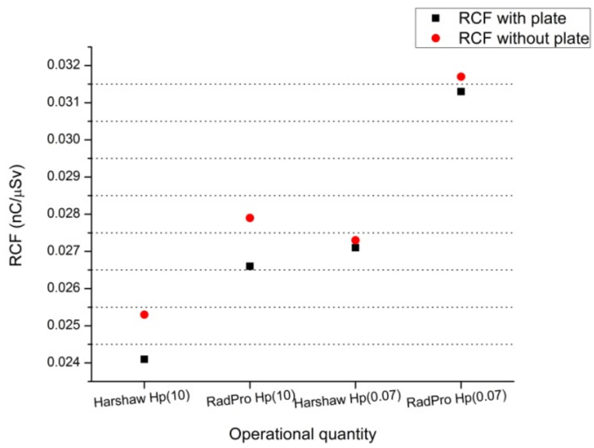

Fig. 6. RCF values for Harshaw 6600 Plus Automated TLD Reader

4. Discussion

TLD reader is one part of the TLD system that can become unstable over time [4] and it is important to regularly calibrate it. This paper presents influence of build-up PMMA plate on calibration of TLD reader. For this purposes dosimeters from two manufacturers were used. When PMMA plate was used, in both cases, the chip measuring deep dose irradiated less light and less electric charge was collected (see Fig 2-3). This led to smaller RCF (see Fig. 6). In fact, RCF calculated when PMMA plate was present during calibration, was nearly 5 % smaller. According to (2) dose is inversely proportional to RCF, and overestimated RCF would lead to underestimated dose.

Analyses of chip response under filter 2 showed that for the dosimeters from both manufacturers utilization of build-up PMMA plate has no meaning (see Fig. 4-5). This is in accordance to standard [5]. The observed RCF deviation of Hp(0.07) detector of nearly 1 % (see Fig. 6) is regarded as consequence of exposure conditions uncertainties.

Uncertainties of *L* and *Q* parameter in (1) influence the results in this paper. The L and Q uncertainties are 4.4% and 1.4%, respectively with coverage factor k=2. The calculated uncertainty calculated as combined is 4.7%. This suggests that more measurements are needed to confirm that 5% difference is consequence of PMMA plate, and not of measurement uncertainty.

5. Conclusions

PMMA build-up plate, used while a radiation detector calibration is performed, assures that in the absence of the PMMA plate, the instrument correctly measures in photon fields, under conditions of electronic equilibrium which is nearly always met during TLD monitoring of occupationally exposed workers.

Calibration of Harshaw 6600 Plus TLD reader was analyzed in this paper. Influence of 2 mm PMMA build-up plate was studied. The results showed that this plate should be used when reader is to be calibrated for measuring Hp(10). Considering Hp(0.07), PMMA plate has insignificant influence on calibration.

Further studies are being planned for investigation the relation between RCF and the distance between PMMA plate and dosimeters.

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