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TANDEM STUDY WITH THERMOLUMINESCENT MATERIALS IN STANDARD DIAGNOSTIC BEAMS

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ABSTRACT

Tandem systems formed with different thermoluminescent dosemeters were evaluated in standard diagnostic radiation beams. The utilized materials are commercially available, and the aim of this study was to carry out a performance comparison. The results show that the energy dependence of the materials, except TLD-100, were very high. Therefore, there are several possibilities of pair combinations forming a tandem system, but all of them using TLD-100 with a high energy dependent TL material. For all pair combinations evaluated in this study, the differences in the measurement ratios of subsequent energy values were always higher than 14%. The main differences among these tandem systems were in the dose sensitivity. The more advantageous TLD pair, among all evaluated, was TLD-100 and TLD-200, but several other combinations were also very efficient.

1. INTRODUCTION

The utilization of thermoluminescent dosimeters (TLDs) with different energy dependence characteristics, composing a tandem system, is a common practice in several kinds of radiation beams [1,2,3,4]. The radiation metrology group of the Instituto de Pesquisas Energéticas e Nucleares (IPEN) developed also other kinds of tandem systems using ionization chambers [5,6,7,8,9].

The advantage of the tandem system is to allow the determination of the incident beam effective energy, during dosimetric procedures. Therefore, tandem systems are very useful for beam energy determinations, using high energy dependent dosimeters.

The objective of this study was to propose and characterize tandem systems composed by TLDs in diagnostic radiology standard beams. Several types of TLDs were utilized, and the tandem curves were analyzed.

2. MATERIALS AND METHODS

Six types of TL materials were tested in this study: three types of $CaSO_4$:Dy pellets (conventional $CaSO_4$:Dy pellets, thin $CaSO_4$:Dy pellets, and thin $CaSO_4$:Dy+10%C pellets), LiF:Mg,Ti (Harshaw TLD-100), CaF_2:Dy (Harshaw TLD-200) and CaF_2:Mn (Harshaw TLD-400). The three types of $CaSO_4$:Dy pellets were produced at IPEN. The conventional $CaSO_4$:Dy pellet has 6.0 mm in diameter and 0.8 mm in thickness, and the thin $CaSO_4$:Dy types have the same diameter and 0.2 mm in thickness [10,11,12,13]. The Harshaw pellets have the dimensions of 3 mm x 3 mm x 0.9 mm.

For the TL measurements a Harshaw Nuclear System, model 2000A/B, was utilized. All TLDs were evaluated with a linear heating rate of 10°C/s, using a constant flow of high purity nitrogen of 5.0 liters/min.

The thermal treatment applied to $CaSO_4$:Dy pellets, prior irradiation, was 300°C for 3 hours. For all the Harshaw TLDs, the thermal treatment, prior irradiation, was 400°C for 1 hour[14]. In the case of TLD-200, a post-irradiation thermal treatment at 115°C for 10 minutes was also applied.

The TLDs were evaluated in diagnostic radiology standard beams (International Electrotechnical Commission-IEC), established at an industrial X-ray system Pantak/Seifert, model ISOVOLT 160HS. Their parameters are listed in Table 1. The reference system utilized for these qualities was a parallel-plate ionization chamber with 1 cm^3 of sensitive volume, PTW, model 77334, with a PTW electrometer, model UNIDOS 10001. This chamber was calibrated by the German primary standard laboratory Physikalisch-Technische Bundesanstalt (PTB).

Table 1. Characteristics of diagnostic radiology qualities at the Pantak/Seifert X-ray equipment, model ISOVOLT 160HS.

Radiation Quality	Voltage (kV)	Half-Value Layer (mmAl)	Effective Energy (keV)	Air Kerma Rate (mGy/min)
RQA3	50	3.91	37.30	3.39
RQA6	80	8.13	54.75	3.99
RQA8	100	10.09	63.95	5.76
RQA9	120	11.39	71.15	7.93
RQA10	150	13.02	82.10	13.28

3. RESULTS

The energy dependence of the TL materials response was studied in standard diagnostic X-rays beams. The dependence energy curves, obtained for each type of TLD, are presented in Figure 1. The TL responses were normalized by the values obtained for the RQA8 quality.

At Figure 1, the general behaviour of the commercial TLDs (already well known) is showed: the TLD-100 has a very flat energy dependence, while the other materials present a very high energy dependence. However, it is also known that the TL sensitivity of the TLD-100 samples is lower than the TL sensitivity of the other materials. So, the tandem system can be created by associating the TLD-100 with any of the other materials. These tandem systems have the advantage of combining the flat energy dependence of the TLD-100 with the high sensitivity of the other materials.

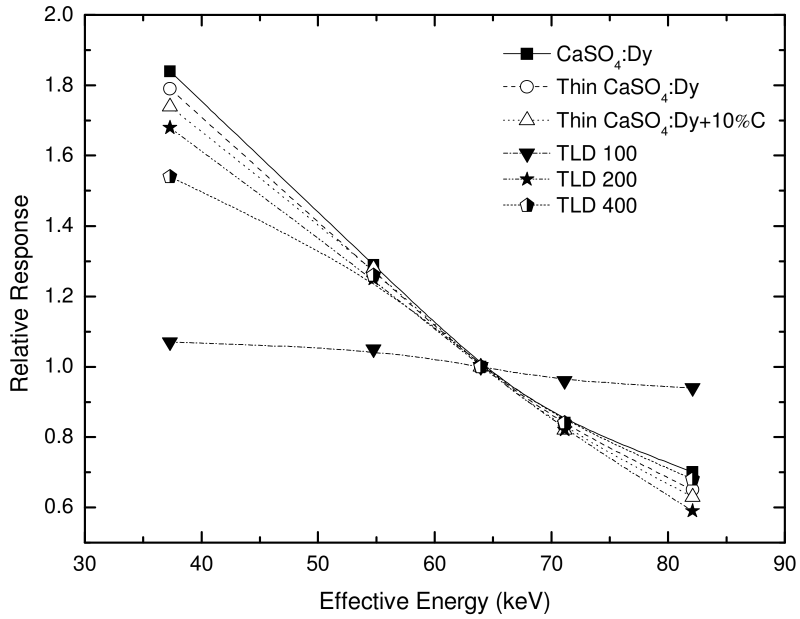

Figure 1. Energy dependence of the TL response of various commercial TLDs in diagnostic radiology standard beams. To allow comparisons, the measurements were normalized for the RQA8 quality.

The obtained tandem curves for the pairs of materials are presented in Figure 2. These curves are not absolute: to allow the comparison among the curves, once the materials present elevated differences in their TL sensitivity, the ratios were normalized in relation to the RQA8 radiation quality result.

A tandem curve shall have preferentially a high inclination to allow energy determination of the radiation beams. The tandem curves obtained in this work were very similar, and they presented adequate inclinations. The differences in the measurement ratios of subsequent energy values were always higher than 14%, which is much more than necessary to precisely determine the effective energy of radiation beams.

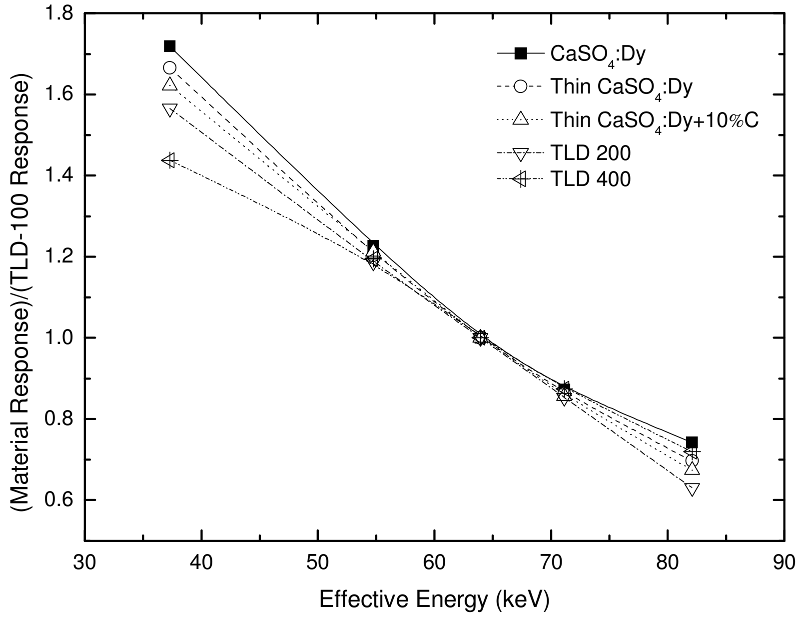

Figure 2. Tandem curves obtained by the ratios of the measurements performed using different TLDs and the measurements obtained with TLD-100, in diagnostic radiology qualities, at the Pantak/Seifert X-ray equipment. To allow comparisons, the ratios were normalized for the RQA8 radiation quality.

The main difference among the TLDs pair combinations evaluated in this work is the dose sensitivity. The TLD-100 is not very sensitive. So, the second material in the pair should be as sensitive as possible. Table 2 presents the relative sensitivity of these TLDs in the RQA6 quality. Considering the results of the relative sensitivity, the pair TLD-100 and TLD-200 is the most advantageous for composing a tandem system.

Table 2. Relative TL sensitivity of different TLDs, in a diagnostic standard beam (RQA6).

TL Pellets	Relative Sensitivity
$CaSO_4$:Dy	61.8
Thin $CaSO_4$:Dy	32.3
Thin $CaSO_4$:Dy + 10% C	1.5
TLD-100	1.0
TLD-200	179.7
TLD-400	42.4

The overall uncertainties in all realized tests were estimated following the ISO-GUM recommendations [15]. The expanded uncertainty obtained, considering a coverage factor of 2, was estimated from 7.0% (for the TLD-400) to 10.0% (for the conventional CaSO4:Dy pellets).

4. CONCLUSIONS

This paper presents a comparative study among some possible TLD tandem systems. The study was performed in diagnostic radiology standard beams, and the several pair combinations presented the adequate characteristic for tandem systems. Considering the energy dependence, the evaluated systems did not exhibit great differences. However, each pair combination could be easily differentiated by the variations in the relative TL sensitivity of the materials. Therefore, the pair TLD-100 and TLD-200 was analyzed as the most advantageous.

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