Reliability of an x-ray system for calibrating and testing personal radiation dosimeters

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Abstract: Metrology laboratories are expected to maintain standardized radiation beams and traceable standard dosimeters to provide reliable calibrations or testing of detectors. Results of the characterization of an x-ray system for performing calibration and testing of radiation dosimeters used for individual monitoring are shown in this work.

Keywords: personal dose equivalent, personal radiation dosimeters, X-ray calibration system.

1. INTRODUCTION

X and gamma reference radiations were internationally established for calibrating and determining the energy dependence of dosimeters that are used for radiation protection purpose [1]. Dosimetry of the reference radiations in terms of air kerma in air requires reliable and traceable standard dosimeters. Reliable dosimetry is the basis of a system to derive the operational quantity for individual monitoring, the personal dose equivalent in 10 mm depth, Hp(10) [2].

In Brazil, electronic dosimeters (EPD) based on diodes or semiconductor detectors have widely been used for task-related personal monitoring, however their reliability is based only on calibrating them in a standard ^{137}Cs gamma beam.

Preliminary studies stressed the need of performing additional checks before using EPD to verify if they comply with specific requirements [3].

The aim of this work was to verify the reliability of the x-ray calibration system of the Dosimeter Calibration Laboratory, Centro de Desenvolvimento da Tecnologia Nuclear, LCD/CDTN, for performing calibration and testing of radiation dosimeters used for individual monitoring in terms of air kerma in air and Hp(10).

2. METHODS AND RESULTS

The stability of a 600cc NE 2575 standard ionization chamber was studied based on its response from a ^{90}Sr/^{90}Y radiation source-chamber fixed geometry. Results from 2013 to 2016 showed that its repeatability (the variation coefficient of many cycles of ten measurements) varied from 0.04% to 0.21%. In the same time interval, its reproducibility represented by its relative response varied within ±1.0%. Both results are acceptable values for a standard chamber.

The traceability of the NE 2575 standard ionization chamber was verified by calibrating it against a similar chamber that is the national standard of the Brazilian Laboratory of Ionizing

Radiation Metrology, Instituto de Radioproteção e Dosimetria, LNMRI/IRD.

Air kerma rates in air were measured by both chambers by substitution method in N60, N80, N100 and W60, W80 e W110, narrow and wide ISO spectrum series, respectively (Fig. 1).

Figure 1 – LCD/CDTN x-ray calibration set-up for calibrating the 2575NE chamber against the LNMRI/IRD national standard.

Calibration coefficients of the LCD/CDTN chamber (Table 1) showed that its energy dependence was about 2% in the energy range; this is a typical value for a standard chamber.

Table 1 – Calibration coefficients of the LCD/CDTN 2575NE ionization chamber.

Reference radiation	Calibration coefficient (10^4 Gy.C^{-1})	Expanded uncertainty, k=2 (%)
N60	4.30	2.28
N80	4.27	2.28
N100	4.22	2.28
W60	4.34	2.25
W80	4.31	2.25
W110	4.25	2.25

The reliability of the LCD/CDTN calibration procedure in terms of air kerma in air was verified through a cross-comparison with the LNMRI/IRD by calibrating a TK30 model EXRADIN travelling ionization chamber in both Laboratories (Fig.2)

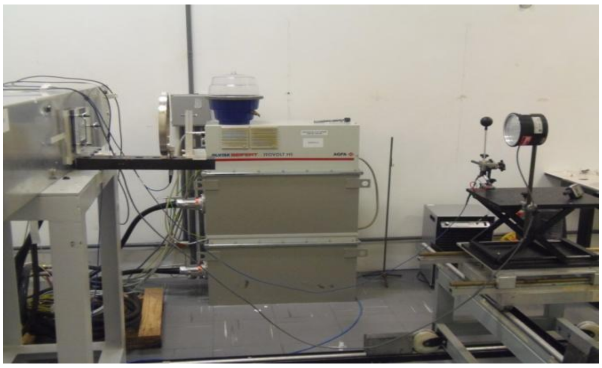

Figure 2 – X-ray set-up for calibrating the TK30 travelling chamber against the CDTN standard chamber.

In comparison to the values obtained in the LNMRI/IRD, the calibration coefficients of the TK30 chamber determined in the LCD/CDTN showed very small differences in all four reference radiations (Table 2). The highest difference of 0.82% was probably due to the very small ionization current produced the highly-filtered radiation and the uncorrected influence of the leakage current. Considering that the E_n number [4] were lower than 1.0, the results confirmed the metrological coherence between both laboratories and, consequently, the reliability of the LCD/CDTN calibration procedure.

The metrological ability of the LCD/CDTN to irradiate dosimeters in terms of Hp(10) was compared with two others Brazilian metrology laboratories. A set of five thermoluminescent (TL) dosimeters was irradiated on the ISO standard slab phantom; they were provided and evaluated by an independent dosimetry laboratory in terms of Hp(10).

Table 3 shows that the highest difference between the LCD/CDTN and another laboratory was lower than the ISO recommended uncertainty of ±10%.

Table 2 – Cross-comparison between the calibration procedures of the TK30 ionization chamber in terms of air kerma in air in the LCD/CDTN and LNMRI/IRD.

Reference radiation	Calibration coefficient (10^6 Gy.C^{-1}) LCD/CDTN	LNMRI/IRD	Difference (%)	E_n number [4]
N60	1.023 (2.30%)*	1.022 (2.28%)*	+0.13	0.03
N80	1.035 (2.30%)	1.039 (2.28%)	-0.43	0.12
N100	1.036 (2.30%)	1.028 (2.28%)	+0.82	0.24
W110	1.037 (2.30%)	1.040 (2.25%)	-0.26	0.09

** Expanded uncertainty (k=2).*

Table 3 – Comparison between the LCD/CDTN and two other metrology laboratories on the ability to irradiate dosimeters in terms of Hp(10).

Reference radiation	Personal dose equivalent, Hp(10) (mSv)			Difference (%)	
	LCD/CDTN	Lab. 2	Lab. 3	Lab. 2	Lab.3
N60	2.77 ± 0.14*	2.94 ± 0.16*	2.62 ± 0.12*	-5.8	+5.7
N80	2.39 ± 0.14	2.33 ± 0.16	2.33 ± 0.15	+2.6	+2.6
N100	2.11 ± 0.13	2.33 ± 0.11	2.04 ± 0.09	-9.4	+3.4
W110	2.18 ± 0.13	2.30 ± 0.16	2.02 ± 0.10	-5.2	+7.9

** Expanded uncertainty, k=2.*

3. CONCLUSION

Since all metrological tests showed acceptable results, one can state that the reliability of the LCD/CDTN x-ray system to calibrate and test personal dosimeters in terms of Hp(10) was proved.

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4. REFERENCES

[1] International Organization for Standardization, ISO, 1996. *X and gamma reference radiations for calibrating dosemeters and doserate meters and for determining their response as a function of photon energy - Part 1 -Radiation characteristics and production methods*. International Standard 4037, Geneva.

[2] International Organization for Standardization, ISO, 2012, 2015. *Reference radiation fields for radiation protection — Definitions and fundamental concepts*. International Standard 29661:2012 +A1:2015, Geneva.

[3] Guimarães, M.C.; Silva, C.R.E.; Oliveira, P.M.C.O.; Da Silva, T.A. – *On the response of electronic personal dosimeters on constant potential and pulsed x-ray beams*. J. Phys. Conf. Ser. 733 012094, p. 1-5, doi:10.1088/1742 -6596/733/1/012094 (2016).

[4] British Standard, BS, 2010. *Conformity assessment – General requirements for proficiency testing*. ISO/IEC 17043.