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A double faced ionization chamber for quality control in diagnostic radiology beams

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ABSTRACT

The development of new radiation detectors of low cost but with adequate materials is a very important task for countries that have to import ionization chambers such as Brazil. A special double faced ionization chamber was developed for use in conventional diagnostic radiology beams and computed tomography energy ranges. The results show that this new chamber present applicability in conventional diagnostic radiology and computed tomography quality control programs.

1. Introduction

Diagnostic radiology with X-ray beams is the major contribution of human exposure to ionizing radiation, in all its modalities (UNSCEAR, 2010). However, in the case of conventional radiation diagnosis and computed tomography (CT) diagnosis the overall dose is not sufficient to cause deterministic effects, but stochastic effects may be present (Meghzifene et al., 2010). The dosimetry in diagnostic radiology plays an important role to provide the compromise between the radiation protection of the patient and staff and the image quality for a correct diagnosis. The ionization chamber is the recommended device to verify the dose levels in this practice. For accurate dosimetry, the ionization chamber must be calibrated against a reference chamber, in a calibration laboratory.

An important task for a calibration laboratory is to provide calibration services for user of diagnostic radiology level dosimeters. The accuracy of the calibration procedures is associated with the correct estimative of the X-ray beam quality (IAEA, 2007). It is accomplished by means of the beam half-value layer (HVL) measurements with an ionization chamber. In clinical practice the HVL verification is a time consuming procedure and alternative ways must be found to verify the X-ray beam quality periodically (Costa et al., 2008).

In this work, a homemade ionization chamber is proposed to be used in diagnostic radiology and computed tomography quality control programs. This ionization chamber is double faced, and can be used in measurements of air kerma and air kerma rates of X-radiation fields (Costa and Caldas, 2003; Silva and Caldas, 2011). The objective of this work was to evaluate the double faced ionization chamber in terms of angular and energy dependence, and the influence of small displacements from the calibration positions. This kind of ionization chamber allows the determination/confirmation of conventional diagnostic radiology and CT radiation qualities through tandem curves obtained previously in standard radiation qualities.

2. Materials and methods

The double faced ionization chamber has two faces with different collecting electrode materials: aluminum and graphite. It has a sensitive volume of 6.0 cm^3, on each side, suitable for conventional diagnostic radiology energy ranges. The entrance windows of both faces are made of aluminized polyester with a superficial density of 1.87 mg cm^{-2}. A PTW UNIDOS-E electrometer was utilized to measure the charge from the double faced ionization chamber. This electrometer has traceability to the Brazilian Secondary Standard Dosimetry Laboratory. A Radcal RC6 and RC3CT reference ionization chambers were used to obtain the calibration factors for the new chamber developed.

The irradiations were performed at the Calibration Laboratory of IPEN (LCI) and the irradiation system utilized in this work was a Pantak Seifert Isovolt 160HS X-ray equipment with a tungsten target that operates from 5 to 160 kV (the tube current has a range of 0.1 to 45 mA). The Pantak system has an inherent filtration of 0.8 mmBe. The double faced ionization chamber was submitted to IEC RQR and RQA conventional diagnostic radiation qualities and IEC RQT computed tomography radiation qualities. These qualities are presented in Tables 1 and 2.

Two goniometers were utilized in this work to evaluate the double faced ionization chamber angular dependence in conventional diagnostic radiology and computed tomography radiation qualities. The angles were changed in clockwise and counterclockwise senses.

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Table 1
IEC conventional diagnostic radiation qualities established at LCI (IEC, 2005).

Radiation quality	High voltage (kV)	Tube current (mA)	Additional filtration (mmAl)	Half-value layer (mmAl)	Air kerma rate (mGy/min)
RQR 3	50	10	2.4	1.78	21.71
RQR 5	70	10	2.8	2.58	37.49
RQR 8	100	10	3.2	3.97	68.01
RQR 10	150	10	4.2	6.57	118.08
RQA 3	50	20	12.4	3.8	3.83
RQA 5	70	20	23.8	6.8	3.60
RQA 8	100	20	37.2	10.1	5.67
RQA 10	150	20	49.2	13.3	12.33

Table 2
IEC computed tomography radiation qualities established at LCI (IEC, 2005).

Radiation quality	High voltage (kV)	Tube current (mA)	Additional filtration		Half-value layer (mmAl)	Air kerma rate (mGy/min)
			(mmCu)	(mmAl)		
RQT 8	100	10	0.30	3.2	6.9	21.79
RQT 9	120	10	0.35	3.5	8.4	33.05
RQT 10	150	10	0.35	4.2	10.1	56.13

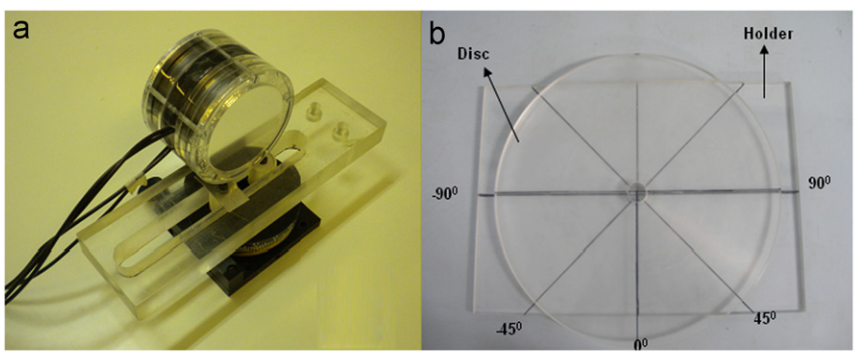

Fig. 1. (a) Double faced ionization chamber placed in the small goniometer that was utilized for small angular displacements and (b) the large goniometer used for large angular displacements.

The counterclockwise was considered as the positive one. In Fig. 1 both goniometers are presented. As the double faced ionization chamber is unsealed, its measurements were corrected for the standard room temperature and pressure. For the measurements of the ambient temperature and pressure a Hart Scientific thermometer, 1529 model, and a GE Druck barometer, DPI 142 model were utilized. The relative humidity varied between 50% and 60%, and it was controlled using dehumidifiers.

3. Results and discussion

3.1. Angular dependence test

The angular dependence of the double faced ionization chamber was evaluated for the reference radiation qualities RQR 5 and RQT 9 as stated in Tables 1 and 2. The small goniometer was utilized for the angular dependence test using RQR 5, and the incident radiation angle was varied in steps of 1° from 0° to 5°, and in steps of 5° from 5° to 20° in both directions.

The large goniometer was utilized for the angular dependence test using the RQT 9, and the incident radiation angle was varied in steps of 15° from 0° to 30° and in steps of 30° from 30° to 180° in both directions. The mean values of ten measurements were taken for each angular position and were normalized to the reference angle (0°). In Figs. 2 and 3 the results for RQR 5 and RQT 9 reference radiation qualities are presented.

It can be observed from Fig. 2 that the double faced ionization chamber angular dependence test result is within the limits of variation of ±3% as stated in the IEC 61674 (IEC, 1997) for non-computed tomography detectors. On the other hand, the double faced ionization chamber angular dependence test for the computed tomography radiation quality presented limits of variation outside the recommendations in the IEC 61674 (IEC, 1997) for computed tomography detectors, as shown in Fig. 3. This fact occurred because of the chamber geometry in relation to the angle of radiation incidence that should change from ±180°.

3.2. Test of small displacements from the calibration position

The double faced ionization chamber was studied in relation to small displacements from the calibration position in RQR 5 and RQT 9 radiation qualities as stated in Tables 1 and 2. The reference position was the calibration position, at 100 cm from the X-ray tube focal spot. For the small displacements from the calibration position, the double faced ionization chamber was moved in steps of 0.2 cm until 1.0 cm in the backward and forward directions. For each position, ten measurements were taken, and the mean value