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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.

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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 (Meghziene 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 cm³, 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

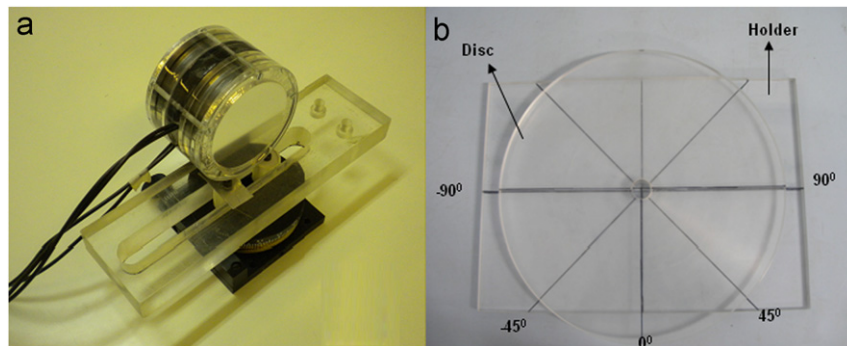


Fig. 1. (a) Double faced ionization chamber placed in the small goniometer that was utilized for small angular displacements and (b) the large goniometer used for large angular displacements.

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 $\pm 3\%$ 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 $\pm 180^\circ$.

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

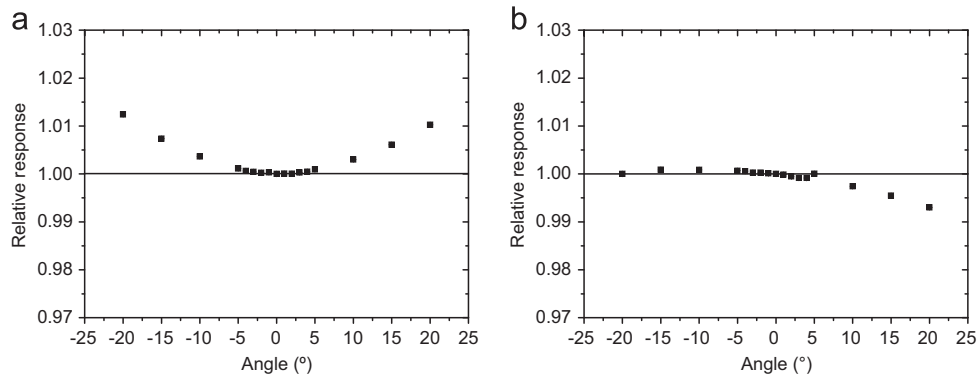


Fig. 2. Angular dependence in the RQR 5 radiation beam of the double faced ionization chamber with (a) the aluminum collecting electrode and (b) the graphite collecting electrode.

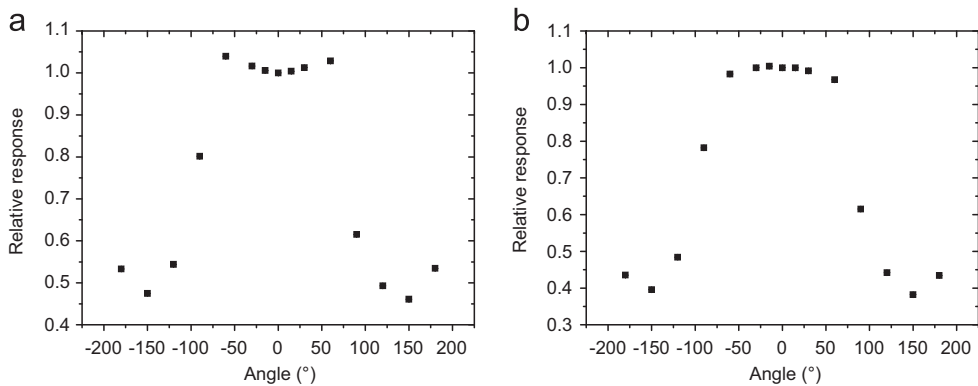


Fig. 3. Angular dependence in the RQT 9 radiation beam of the double faced ionization chamber with (a) the aluminum collecting electrode and (b) the graphite collecting electrode.

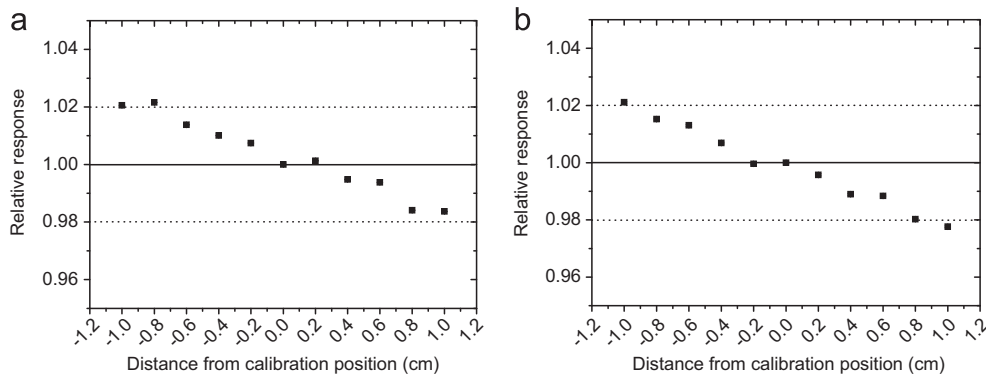


Fig. 4. Results of small displacements from the calibration position of the double faced ionization chamber, in the RQR 5 radiation beam, with (a) the aluminum collecting electrode and (b) the graphite collecting electrode.

was normalized to the one obtained at the reference position. The backward direction was taken as the positive one. The results are presented in Figs. 4 and 5 for the RQR 5 and RQT 9 radiation qualities, respectively.

Figs. 4 and 5 show that there is a change in the relative response within $\pm 2\%$ when the distance from the calibration position varies up to ± 1.0 cm, and for the distance variation within ± 0.4 cm the variation was within $\pm 1\%$. It can be seen that the double faced ionization chamber is sensitive to small displacements from the calibration position.

3.3. Energy dependence test

For the energy dependence test, the double faced ionization chamber was calibrated in the standard RQR, RQA and RQT

radiation quality beams. The chamber was calibrated using the substitution calibration method (IAEA, 2009) against the Radcal RC6 and RC3CT reference ionization chambers. The energy dependence for the double ionization chamber in the studied radiation qualities was expressed in terms of calibration coefficients and correction factors. The correction factors were obtained by the normalization to the reference radiation qualities (RQR 5, RQA 5 and RQT 9) in each energy range. The tandem factors were calculated as the ratios between the calibration coefficients of both faces in all tested energy ranges. Tables 3 and 4 present the calibration and tandem factors for the double faced ionization chamber, in the diagnostic radiology and tomography radiation qualities, respectively.

The results of the energy dependence test of the double faced ionization chamber presented in Table 3 showed that its response

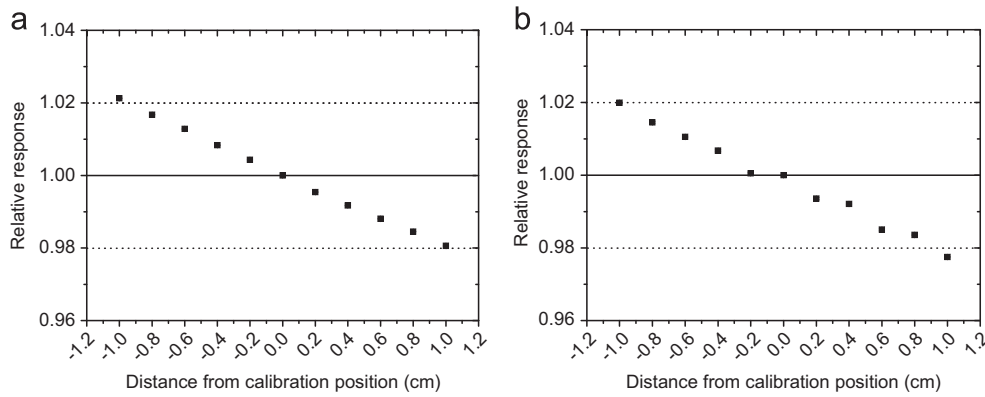


Fig. 5. Results of small displacements from the calibration position of the double faced ionization chamber, in the RQT 9 radiation beam, with (a) the aluminum collecting electrode and (b) the graphite collecting electrode.

Table 3

Calibration coefficients of the double faced ionization chamber for the IEC conventional diagnostic radiology radiation qualities. The tandem factors were obtained by the quotients between the response of the chamber with graphite collecting electrode and the response of the chamber with the aluminum collecting electrode.

Radiation quality	Graphite collecting electrode		Aluminum collecting electrode		Tandem factor
	Calibration coefficient (Gy/μC)	Correction factor	Calibration coefficient (Gy/μC)	Correction factor	
<i>Direct beams</i>					
RQR 3	4.824 ± 0.038	1.035 ± 0.011	1.845 ± 0.014	1.026 ± 0.011	2.615 ± 0.029
RQR 5	4.661 ± 0.036	1.000 ± 0.011	1.798 ± 0.014	1.000 ± 0.011	2.592 ± 0.028
RQR 8	4.424 ± 0.034	0.949 ± 0.011	1.848 ± 0.014	1.027 ± 0.011	2.394 ± 0.026
RQR 10	4.095 ± 0.032	0.879 ± 0.010	2.004 ± 0.015	1.114 ± 0.012	2.044 ± 0.022
<i>Attenuated beams</i>					
RQA 3	4.822 ± 0.045	1.128 ± 0.015	1.684 ± 0.014	0.934 ± 0.012	2.864 ± 0.036
RQA 5	4.276 ± 0.039	1.000 ± 0.013	1.802 ± 0.016	1.000 ± 0.013	2.373 ± 0.030
RQA 8	3.993 ± 0.034	0.937 ± 0.012	2.157 ± 0.017	1.197 ± 0.014	1.851 ± 0.022
RQA 10	3.773 ± 0.030	0.882 ± 0.011	2.657 ± 0.021	1.475 ± 0.017	1.420 ± 0.016

Table 4

Calibration coefficients of the double faced ionization chamber for the IEC computed tomography radiation qualities. The tandem factors were obtained by the quotients between the responses of the chamber with graphite collecting electrode and the response of the chamber with the aluminum collecting electrode.

Radiation quality	Graphite collecting electrode		Aluminum collecting electrode		Tandem factor
	Calibration coefficient (Gy/μC)	Correction factor	Calibration coefficient (Gy/μC)	Correction factor	
RQT 8	39.697 ± 0.598	1.039 ± 0.022	19.059 ± 0.287	0.932 ± 0.011	2.083 ± 0.044
RQT 9	38.190 ± 0.573	1.000 ± 0.021	20.450 ± 0.308	1.000 ± 0.021	1.867 ± 0.040
RQT 10	37.293 ± 0.560	0.977 ± 0.021	22.150 ± 0.333	1.083 ± 0.023	1.684 ± 0.036

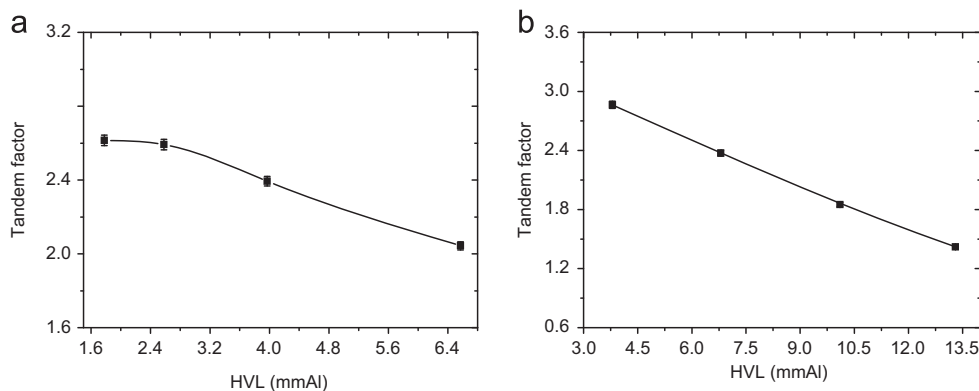


Fig. 6. Tandem curves for (a) RQR radiation qualities and (b) RQA radiation qualities.

variation with energy is within ±5% as recommended in IEC 61674 (IEC, 1997) for RQR 3, RQR 5 and RQR 8 radiation qualities. For the RQR 10 radiation quality both faces presented values over ±5%. In this case, the energy dependence presented a maximum

of 13% for the graphite collecting electrode face. For the RQA radiation qualities, the results of the energy dependence of both ionization chamber faces energy dependence results exceeded the limits of variation.

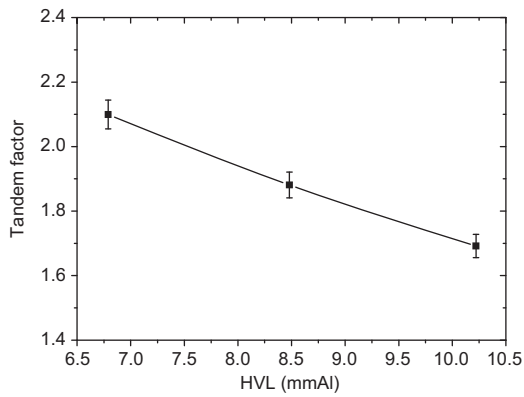


Fig. 7. Tandem curves for RQT radiation qualities.

For the RQT radiation qualities, the chamber with the graphite collecting electrode presented results within the limits of $\pm 5\%$. All results for RQT energy dependence test were over the limit stated at IEC 61674 (IEC, 1997). These results are also presented in Table 4.

In Figs. 6 and 7 are presented the tandem curves obtained for the double faced ionization chamber.

It can be observed from Figs. 5 and 6 that the tandem curves present an adequate slope for its use in quality control programs of the conventional diagnostic radiology energy range (Silva and Caldas, 2011).

4. Conclusions

The double faced ionization chamber was tested in standard conventional diagnostic and computed tomography radiation fields established at LCI. The double faced ionization chamber showed adequate response in terms of angular dependence for the RQR 5 reference radiation quality. Due to its geometry, the double faced ionization chamber presented an angular dependence variation higher than the IEC 61674 recommendations for computed tomography detectors. The double faced ionization chamber was sensitive for small displacements from the calibration position.

A difference in response was observed for each chamber, due to the different materials in their collecting electrodes. From the energy dependence curves, it was possible to obtain tandem curves, which may be used for confirmation/determination of the half-value layers of the radiation beams in quality control programs. Therefore, it can be concluded that the double faced ionization chamber can be used to verify the radiation qualities of the diagnostic radiology beams established at LCI.

Acknowledgments

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References

- Costa, A.M., Caldas, L.V.E., 2003. A special ionisation chamber for quality control of diagnostic and mammography X ray equipment. *Radiat. Prot. Dosim.* 104 (1), 41–45.
- Costa, A.M., Badin, R.S., Leite, M.S., Caldas, L.V.E., 2008. Constancy check of beam quality in conventional diagnostic X-ray equipment. *Appl. Rad. Isot.* 66 (10), 1403–1405.
- IAEA (International Atomic Energy Agency), 2007. *Dosimetry In Diagnostic Radiology: An International Code of Practice*. Technical Report Series no. 457. IAEA, Vienna.
- IAEA (International Atomic Energy Agency), 2009. *Calibration of Reference Dosimeters for External Beam Radiotherapy*. Technical Report Series no. 469. IAEA, Vienna.
- IEC (International Electrotechnical Commission), 1997. *Medical electrical equipment—dosimeters with ionization chambers and/or semi-conductor detectors as used in X-ray diagnostic imaging*. Standard IEC 61674. IEC, Geneva.
- IEC (International Electrotechnical Commission), 2005. *Medical diagnostic X-ray equipment—radiation conditions for use in the determination of characteristics*. Standard IEC 61267. IEC, Geneva.
- Meghzifene, A., Dance, D.R., McLean, D., Kramer, H.-M., 2010. Dosimetry in diagnostic radiology. *Eur. Jour. Radiol.* 76 (1), 11–14.
- Silva, J.O., Caldas, L.V.E., 2011. A tandem system performance for quality control in radiodiagnostic range. *Rev. Bras. Fis. Med.* 4 (3), 27–30 In Portuguese.
- UNSCEAR (United Nations Scientific Committee on the Effects of Atomic Radiation), 2010. *Sources and Effect of Ionizing Radiation*. UNSCEAR 2008 Report, vol. I. United Nations, New York.