ENERGY DEPENDENCE OF A HOMEMADE IONIZATION CHAMBER DESIGNED FOR X RADIATION FIELD MAPPING

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Abstract: This work presents the energy dependence tests of a homemade cylindrical ionization chamber, with a sensitive volume of 0.34 cm^3. This ionization chamber was designed and constructed for X radiation field mapping at the Calibration Laboratory of IPEN (LCI). The tests of energy dependence were made using an industrial X-ray system. The performance of this ionization chamber was satisfactory for the tested standard diagnostic radiology (conventional and tomography) qualities.

Key words: ionization chamber; energy dependence; radiation field mapping.

1. INTRODUCTION

Calibration procedures include the constancy check of radiation beam mapping. This is an important step to assure a reliable calibration procedure, and it is necessary to detect if there is any irregularity in the radiation field caused, for example, by setup changes of the irradiation system.

At the Calibration Laboratory (LCI) of the Instituto de Pesquisas Energéticas e Nucleares (IPEN/CNEN-SP) some ionization chambers have been developed for clinical and scientific metrological applications [1 - 3].

Recently, a cylindrical ionization chamber was designed and manufactured at IPEN. Because of its small volume, this ionization chamber was used for radiation field mapping [4].

In order to complete the characterization of this ionization chamber, the objective of this work was to study its energy dependence. This test was carried out in standard diagnostic radiology quality beams (direct and attenuated) and in standard tomography beams, for the homemade ionization chamber and also for a commercial pencil-type ionization chamber Victoreen. The results for the homemade and commercial ionization chambers were compared.

2. MATERIALS AND METHODS

The ionization chamber tested in this work was a homemade ionization chamber made of PVC and PMMA with a collecting electrode of aluminum (Figure 1). The sensitive volume is made of PVC coated with graphite, with an internal diameter of 6.70 mm, and wall thickness of 0.26 mm. The sensitive volume length is 1.00 cm. This ionization chamber was connected to an electrometer, Physikalisch-Technische Werkstätten (PTW), model UNIDOS E Freiburg, Germany.

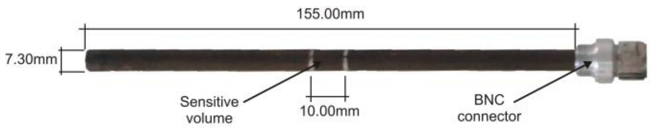

Fig. 1. Cylindrical ionization chamber developed at IPEN

In order to compare the results obtained with the homemade ionization chamber, the same measurements were made with a commercial pencil ionization chamber Victoreen, model 660-6. This ionization chamber is not sealed and presents 3.2 cm^3 of sensitive volume and 10 cm of sensitive length.

The irradiations were carried out using an industrial X-ray system, Pantak/Seifert, model ISOVOLT 160HS. This equipment operates from 5 to 160 kV. The diagnostic radiology qualities defined by the International Electrotechnical Commission [5], established in this system, are presented in Table 1 with their parameters.

The reference system for these diagnostic radiology qualities was a parallel plate ionization chamber with 1.0cm^3 of sensitive volume, PTW, model 77334, with traceability to the German primary standard laboratory Physikalisch-Technische Bundesanstalt (PTB). The reference system used to establish the tomography qualities was a RADCAL pencil ionization chamber, model RC3CT. This ionization chamber was calibrated by the German primary standard laboratory PTB. Therefore it is a secondary standard system.

The uncertainties presented in this work are expanded uncertainties, and they were computed by combining the type A and type B uncertainties, as recommended by ISO [6], using a coverage factor of 2.

Table 1. Characteristics of the standard radiation qualities utilized in this work, based on IEC 61267 [5].

Radiation Quality	Voltage (kV)	Half-value layer (mmAl)	Air kerma rate (mGy/min)
Direct beams			
RQR3	50	1.78	21.60 ± 0.18
RQR5	70	2.58	37.88 ± 0.32
RQR8	100	3.97	67.45 ± 0.54
RQR10	150	6.57	120.01 ± 1.02
Attenuated beams			
RQA3	50	12.40	3.46 ± 0.08
RQA5	70	23.80	3.45 ± 0.01
RQA8	100	37.20	5.93 ± 0.02
RQA10	150	49.20	13.48 ± 0.03
Tomography beams			
RQT8	100	6.90	22.0 ± 0.33
RQT9	120	8.40	34.0 ± 0.51
RQT10	150	10.1	57.0 ± 0.86

3. RESULTS AND DISCUSSION

For the energy dependence test, the ionization chamber was calibrated in the beam qualities described in Table 1. Figures 2 and 3 show the energy dependence curves, for the direct and attenuated beams of the standard diagnostic radiology qualities, for both the homemade ionization chamber and the Victoreen ionization chamber. The results for the energy dependence curves, utilizing the RQT standard tomography beam, are shown in Figure 4.

Initially the calibration coefficients were divided by the air kerma rates and then these ratios were normalized to the values obtained in RQR5 (direct), RQA5 (attenuated) and RQT9 (tomography) beams. The energy dependence (taking into account the highest and the lowest calibration coefficients in percentage) obtained in the RQR standard diagnostic quality beams was 3.0% for the homemade ionization chamber, and 2.1% for the Victoreen ionization chamber. In the attenuated beams, the energy dependence was 23.0% and 13.6% for the homemade and the Victoreen chambers, respectively. When utilizing the RQT standard diagnostic quality beam, the energy dependence was 1.2% for the homemade chamber and 1.3% for the Victoreen chamber. This homemade chamber was initially designed for use in tomography beams, therefore these good results.

For the results obtained with the attenuated beams it is necessary to consider the fact that this new ionization chamber has a small sensitive volume, and the air kerma rates of the attenuated beams are very low.

Besides that, the difference obtained between the RQR and RQA radiation qualities was also observed with other ionization chamber developed at LCI. The results obtained for an extended-length parallel-plate ionization chamber, with 3.2cm^3 of sensitive volume, presented an energy dependence of 2.6% [2]. In this test, the authors utilized the radiations qualities RQR2 to RQR10, with half-value layers between 1.44 and 4.73 mmAl.

Considering the RQA standard diagnostic radiation quality, another ionization chamber developed at IPEN [1] presented a behavior similar to the ionization chamber tested in this work. This ionization chamber is a special parallel plate, with a double face, a tandem chamber, with 0.6cm^3 of sensitive volume. The energy dependence tests were performed at a Rigaku-Denki X-ray system, with the half-value layer varying from 0.25 to 0.89 mmAl. The authors obtained an energy dependence of approximately 20.0%.

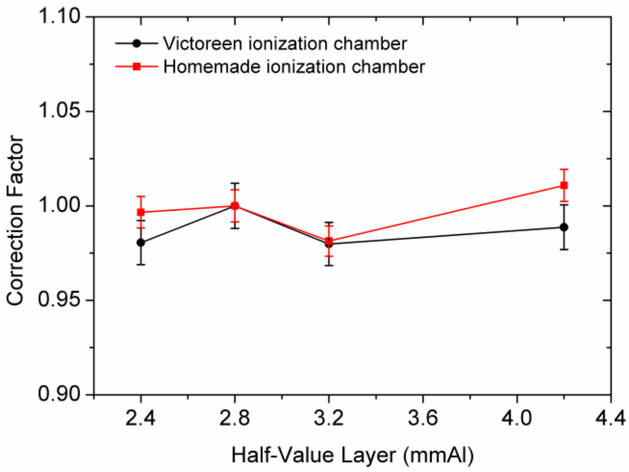

Fig. 2. Energy dependence curve of the cylindrical ionization chambers in diagnostic radiology quality direct beams. The calibration coefficients were normalized to the RQR5 quality

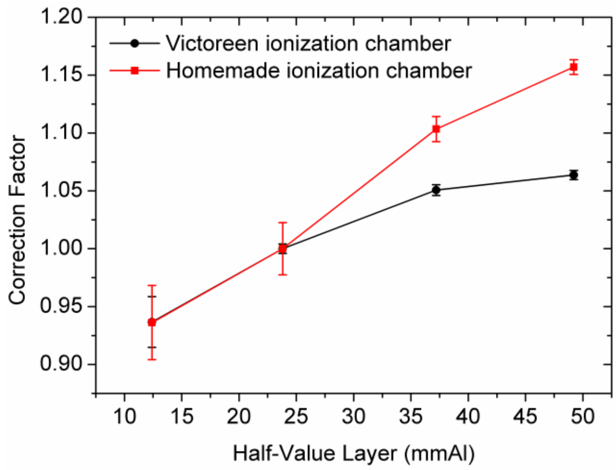

Fig. 3. Energy dependence curve of the cylindrical ionization chambers in diagnostic radiology quality attenuated beams. The calibration coefficients were normalized to the RQA5 quality

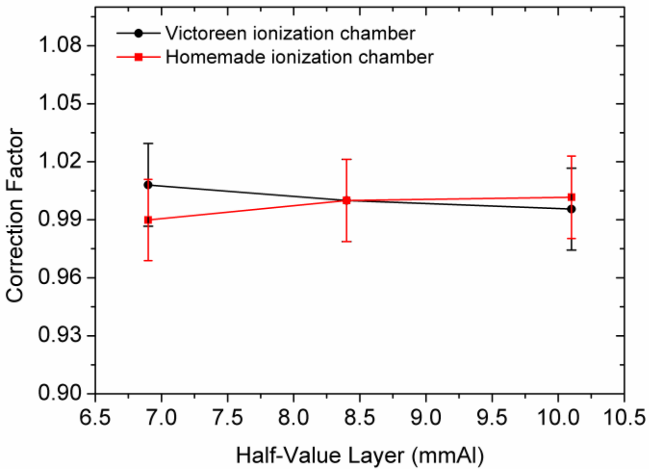

Fig. 4. Energy dependence curve of the cylindrical ionization chambers in tomography quality beams. The calibration coefficients were normalized to the RQT9 quality

3. CONCLUSION

The energy dependence curves obtained for a new homemade cylindrical ionization chamber showed results in agreement with those of a commercial pencil ionization chamber Victoreen. Besides that, the difference between the results for the RQR and RQA standard diagnostic radiation qualities was similar to previous results, for other ionization chambers also developed at IPEN. These results, and those from other tests previously obtained: short- and medium term stabilities, saturation curve, ion collection efficiency, polarity effect, stabilization time, leakage current, angular dependence, linearity of response and the mapping of the standard X-ray radiation field [4], demonstrate the possibility of the application of this chamber in X radiation field mapping, because of its good performance and small sensitive volume. The construction of this homemade chamber corroborates the feasibility of producing radiation detectors with materials available at the Brazilian market.

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