Evaluation of linearity of response and angular dependence of an ionization chamber for dosimetry in computed tomography

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Abstract. In this paper a pencil-type ionization chamber designed and manufactured at Instituto de Pesquisas Energéticas e Nucleares was evaluated for dosimetric applications in computed tomography beams. To evaluate the performance of this chamber two tests were undertaken: linearity of response and angular dependence. The results obtained in these tests showed good results, within the international recommendations. Moreover, this homemade ionization chamber is easy to manufacture, of low cost and efficient.

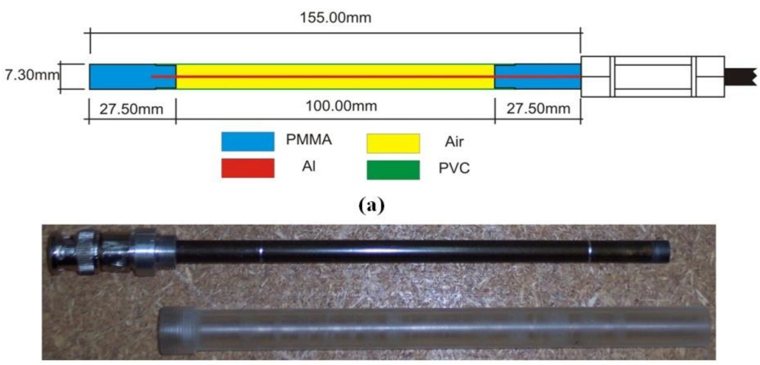
1 Introduction

The fact that computed tomography (CT) is a diagnostic procedure that delivers significant exposure is well known. In the past it was seen as acceptable in areas of its greatest applications, such as for investigation of malignancies; its diagnostic value was greater than its inherent risk. However, CT is now utilized extensively in diagnostic of benign diseases and in the care of children and young people where the cumulative dose considerations are of utmost importance. This issue about radiation doses from CT procedure has received much attention in both the popular media and scientific investigation, due in part to the fact that the dose levels from CT typically exceed those from conventional radiography, and that the use of CT continues to grow [1]. The dosimetry in CT medical equipments differs from the conventional diagnostic radiology dosimetry mainly because of the tube rotation around the patient. A special ionization chamber, named pencil ionization chamber, is commercially available for CT dosimetric measurements [2]. Externally, the pencil ionization chamber is similar to a thimble chamber, except that it is longer and thinner. The sensitive length of a typical pencil ionization chamber is 10 to 15 cm; its external diameter is about 9 mm; and its volume is approximately 3 cm^3 [3].

This work completes an initial study in order to characterize a new pencil ionization chamber for use in dosimetry of computed tomography beams. The preliminary results about short- and medium–term stabilities, saturation curve, ion collection efficiency, polarity effect, stabilization time and leakage current, were already reported [4]. In this paper, the performance of a pencil ionization chamber developed at IPEN/CNEN-SP was analyzed in two tests: linearity of response and angular dependence. The linearity of response tests evaluated the behavior of the ionization chamber in relation to the air kerma rate, and the angular dependence tests verified the response of the ionization chamber in relation to small angulations along the vertical and axial axes. These tests were made using the available diagnostic radiology quality beams at the Calibration Laboratory of IPEN.

2 Materials and Methods

The pencil ionization chamber utilized in this work was manufactured using polymethyl methacrylate (PMMA), graphite coated polyvinyl chloride (PVC), aluminum plates and co-axial cables. The diagram and photo of this ionization chamber are shown in Figures 1(a) and (b), respectively.



(a)

(b)

Fig. 1. Diagram (a) and photo (b) of the pencil ionization chamber with its protection cap

The wall material of the ionization chamber is PVC coated with graphite and its electrode material is made of aluminum with a thickness of 1.2 mm. The internal diameter is 6.7 mm and the wall thickness and the sensitive length of the chamber are 0.26 mm and 100.0 mm, respectively.

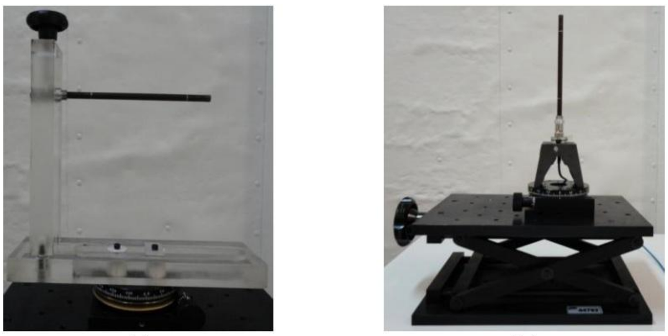
During the tests the pencil ionization chamber was connected to an electrometer, model UNIDOS E, Physikalisch- Technische Werkstätten (PTW) Freiburg, Germany.

An industrial X-ray unit, Pantak Seifert, model ISOVOLT 160HS, that operates from 5 to 160 kV, was also utilized. The tests were made using the diagnostic radiology quality beam RQT 9, as defined by the International Electrotechnical Commission [5]. To establish this quality, and other radiation qualities utilized at LCI, a parallel plate ionization chamber with 1.0 cm^3 of sensitive volume, PTW, model 77334, was utilized. This chamber has traceability to the German primary standard laboratory Physikalisch-Technische Bundesanstalt (PTB).

All measurements obtained in this work were corrected for standard environmental conditions [6].

For the linearity test, the chamber was positioned at 1.00 m from the X-ray tube, and the tube current was varied from 2 mA to 25 mA, for a fixed voltage of 120 kV and additional filtration of 3.5 mmAl + 0.35 mmCu. The irradiation time was 15 s. The air kerma rate was determined using a Radcal ionization chamber, type RC3CT, serial number 8769, using the same parameters already mentioned. This ionization chamber was calibrated at PTB.

For the angular dependence tests, the chamber was positioned at 1.00 m from the X-ray tube and it was rotated in the horizontal and axial directions. The ionization chamber was fixed at a special support made of acrylic, designed to allow the repeatability of the measurements. The positioning system was fixed at a goniometer, OPTRON, model GN1 200. In Figure 2 (a) the positioning system is shown for the horizontal angular dependence test and in Figure 2 (b) for the axial angular dependence test.



(a) (b)

Fig. 2. Positioning system utilized in the horizontal (a) and axial (b) angular dependence tests

For the horizontal angular dependence tests, the chamber was placed in the positioning system at a distance of 1.00 m from the X-ray tube. The ionization chamber was rotated around its horizontal central axis from -50º to +50º in steps of 10º.

In the axial angular dependence tests, the chamber was positioned at 1.00 m from the X-ray tube, and it was rotated around its central axis from -180º to +180º in steps of 30º.

3 Results and Discussion

3.1 Linearity of response test

In this case the pencil ionization chamber was exposed to several air kerma rates. This test was realized at the Pantak X-ray system. In order to provide the air kerma rate variation, the nominal currents were varied between 2 and 25 mA, at the fixed potential of 120 kV. The air kerma rates were determined using the reference system calibrated for the RQT 9 quality beam. Figure 3 shows the chamber response variation, normalized for the reading using a current of 2 mA, in function of the air kerma rate. A linear fit was obtained, and the uncertainty in the angular coefficient was only 0.01%, with a correlation coefficient R^2 of 0.99999.

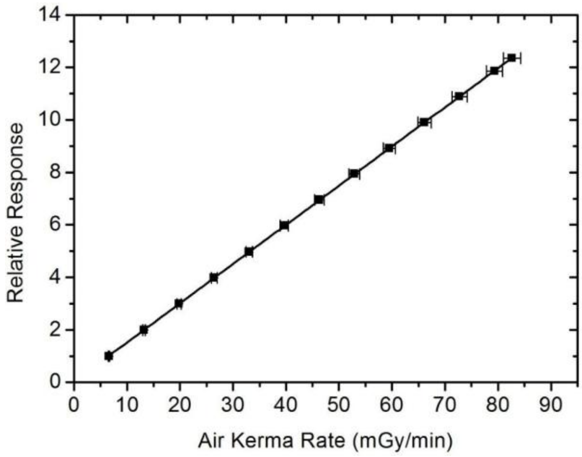


Fig. 3. Linearity of response test of the pencil ionization chamber developed at IPEN/CNEN-SP

3.2 Angular dependence tests

For the angular dependence tests the pencil ionization chamber was also exposed to the same standard beam (RQT 9). For the horizontal angular dependence test, the maximum variation obtained was 1.03%, as shown in Figure 4. In the axial angular dependence test, the maximum variation obtained was 1.90%, as shown in Figure 5.

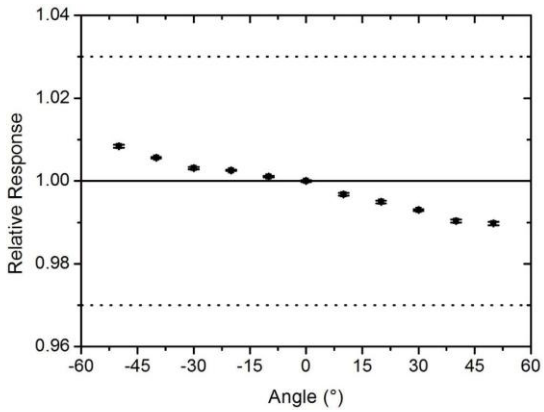


Fig. 4. Horizontal angular dependence test of the chamber developed at IPEN/CNEN-SP. Normalization of the chamber response was performed in relation to 0º, and the dotted lines represent the limits according to IEC 61674 [7]

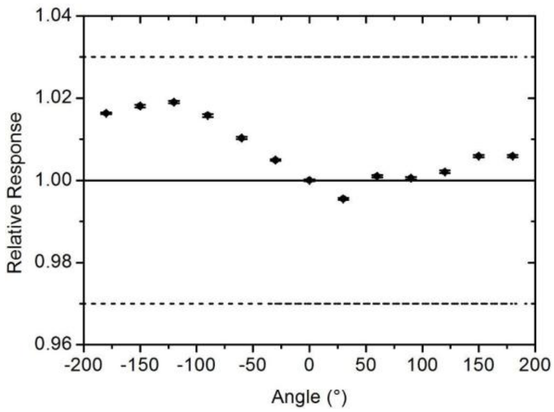


Fig. 5. Axial angular dependence test of the chamber developed at IPEN/CNEN-SP. Normalization of the chamber response was performed in relation to 0º, and the dotted lines represent the limits according to IEC 61674 [7]

By the IEC 61674 [7] recommendations, the value obtained in each angle must not differ from 0º by more than 3%. Therefore, the results obtained in the angular dependence tests show that the pencil ionization chamber produced at IPEN/CNEN-SP presents results within the recommended international limits [7].

4 Conclusions

Some operational characteristics of a homemade ionization chamber, specially designed for dose measurement in computed tomography, were evaluated. The motivation for the development of this chamber was its easy and low-cost construction, because only low-cost Brazilian materials were utilized. The linearity of response and angular dependence tests showed satisfactory results in comparison with international recommended limits. The good results obtained in this work and the results reported elsewhere [4] represent a good possibility of use of this ionization chamber at laboratories and hospitals.

Acknowledgements

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