Pre-evaluation of an ionization chamber for clinical radiotherapy dosimetry

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Abstract. This work presents some pre-operational tests for characterization of a new homemade ionization chamber developed at the Calibration Laboratory of Instituto de Pesquisas Energéticas e Nucleares (IPEN/CNEN). This chamber was designed for use in radiotherapy dosimetry. To study the utilization of this chamber in radiotherapy, some tests were undertaken: short- and medium-term stabilities, saturation curve, recombination loss, polarity effect and leakage current. All results obtained in these tests were within the international recommendations.

1 Introduction

At the Calibration Laboratory (LCI) of the Instituto de Pesquisas Energéticas e Nucleares (IPEN/CNEN), several ionization chambers were developed as working metrological standards, and for clinical and scientific purposes. The main motivation to develop these kinds of ionization chambers is to obtain accurate measurements of radiation doses of applied dosimetry. These ionization chambers were constructed to be used mainly in diagnostic radiology and radiotherapy energy ranges [1 - 4]. There are several types of commercial ionization chambers that are robust and precise; however, they are quite expensive equipments. With the aim to develop new dosimeters attending international recommendations and of low cost, this work presents the initial evaluation of a homemade cylindrical ionization chamber developed at LCI for routine use in radiotherapy dosimetry.

The main differences of this ionization chamber, in relation to commercial ionization chambers are its constituent materials and geometry. In this project, just low-cost Brazilian materials were utilized, and the ionization chamber is a pencil-type with 1.06 cm^3 of sensitive volume. The objective of this work was to pre-evaluate this ionization chamber, through some important tests: polarity effect, saturation curve, ion collection efficiency, short- and medium-term stabilities and leakage current.

2 Materials and Methods

The special cylindrical ionization chamber developed at LCI is made of Polyvinyl chloride (PVC) and Poly(methyl methacrylate) (PMMA). The wall material of the ionization chamber is made of PVC coated with graphite, and its collecting electrode material is made of aluminum, with a thickness of 1.20 mm. The chamber internal diameter is 6.70 mm, and its wall thickness and sensitive length are 0.26 mm and 30.00 mm, respectively, as shown in Figure 1. The sensitive volume is 1.06 cm^3.

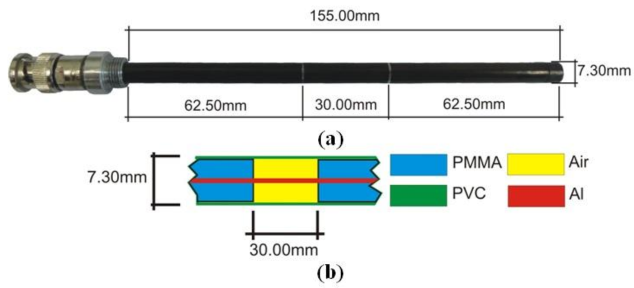

Fig. 1. (a) Ionization chamber developed at LCI, and (b) schematic representation of the sensitive volume

During the tests, the ionization chamber was connected to an electrometer, model UNIDOS E, Physikalisch-Technische Werkstätten (PTW) Freiburg, Germany. For the pre-operational tests of polarity effect, saturation curve and ion collection efficiency, an industrial X-ray unit, Pantak Seifert, model ISOVOLT 160HS, that operates from 5 to 160 kV, with the T radiation quality beams [5] was utilized. In this work, the qualities used were T-50(a) and T-50(b), with the parameters described in Table 1.

Table 1. Standard therapy radiation qualities implemented at the Pantak/Seifert X-ray system

Radiation quality	Voltage (V)	Additional filtration (mmAl)	Half-value layer (mmAl)	Air kerma rate (mGy/min)
T-50(a)	50	3.989	2.411	0.8208±0.0036
T-50(b)	50	1.008	1.079	4.027±0.016

In this study, the IEC 60731 [6] recommendations, specific for ionization chambers used in radiotherapy, were utilized as reference for all tests.

The ion collection efficiency in a continuous radiation beam can be calculated by the two voltage method [7], according to:

$$K_s = \frac{(V_1/V_2)^2 - 1}{(V_1/V_2)^2 - (M_1/M_2)} \quad . \tag{1}$$

where M_x is the collected charge at a V_x voltage, and $V_1/V_2 = 2$, for V_1=100 V and V_2=200 V.

The irradiation conditions for all measurements were fixed at a collimated field, measuring 3.0 cm in length and 3.5 cm in height, in order to irradiate just the sensitive volume of the ionization chamber. This technique allows analyzing only the response of the ionization chamber, avoiding the interference of the body of PMMA. The distance from the focal spot was fixed at 50.0 cm, and the tube current was 20.0 mA. All readings were corrected for environmental conditions [8].

A $^{90}Sr + ^{90}Y$ check source device, PTW, model 8921 (33MBq, 1994), was utilized for the stability tests. In these tests an acrylic support was utilized to obtain reproducible measurements.

3 Results and Discussions

3.1 Short- and medium-term stabilities

The chamber response was tested in relation to its stability (short-and medium-terms). The cylindrical chamber was repeatedly exposed to a check source under reproducible conditions. The $^{90}Sr + ^{90}Y$ check source was utilized, and it was positioned at the acrylic support, as shown in Figure 2.

Fig. 2. Ionization chamber inside the positioning device during the stability tests

The short-term stability test was obtained by ten readings of charge, during time intervals of 60 s and using a voltage of +100 V, under reproducible conditions. The highest variation coefficient obtained was 0.04%. According to the international recommendations IEC 60731 [6], the maximum acceptable coefficient of variation is 0.3% for ionization chambers used in radiotherapy.

The medium-term stability test was performed taking the medium values of the short-term stability tests. As shown in Figure 3, all values obtained are within the recommended limits of ±0.5% [6].

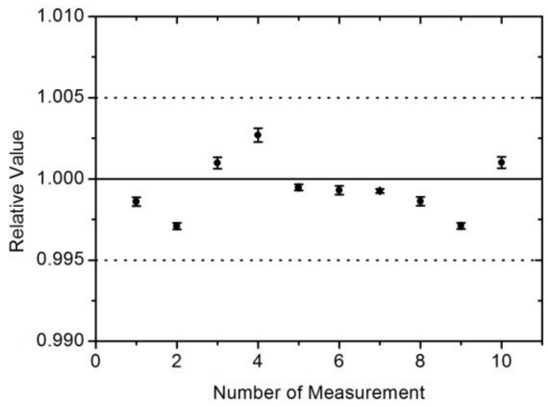

Fig. 3. Medium-term stability test for the new homemade ionization chamber using a $^{90}Sr+^{90}Y$ check source device. The dashed lines represent the recommended limits (0.5%) according to IEC 60731 [6].

3.2 Leakage Current

The leakage current was measured in time intervals of 20 minutes, before and after the irradiation, and the maximum value obtained was 0.01% of the ionization current produced at the minimum air kerma rate produced in this work. This value is within the limit recommended internationally (0.5%) [6].

3.3 Saturation, ion collection efficiency and polarity effect

The saturation curve test determines the optimal voltage for the chamber operation. In this work, the saturation curve was determined using the T-50(a) and T-50(b) radiation qualities. A saturation curve (Figure 4) was obtained, for each radiation quality, varying the voltage from -400 to +400 V, in steps of 50 V, using the charge collecting time of 15 s. For all voltage values applied, no significant changes in the collected charge were observed, indicating that the chamber saturation was achieved in the whole tested voltage interval. The chosen applied voltage for the ionization chamber was +100 V.

Using the saturation curve, two other tests could be analyzed: the polarity effect and ion collection efficiency.

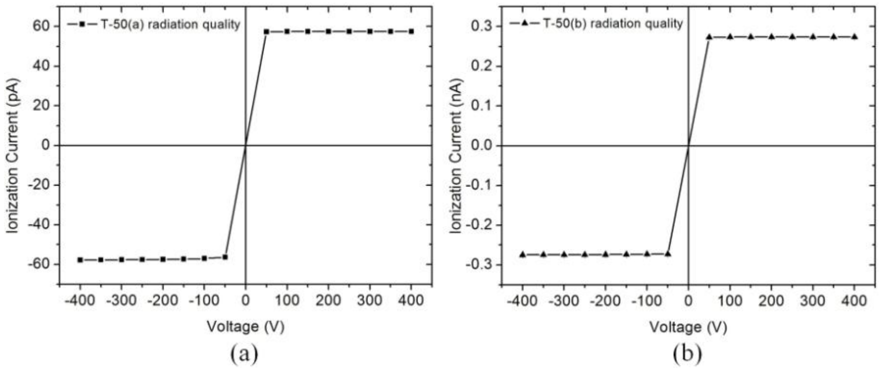

Fig. 4. Saturation curves for the new homemade ionization chamber using (a) T-50(a) radiation quality and (b) T-50(b) radiation quality. The uncertainties associated to the measurements are negligible, and they do not appear in the graphs

The evaluation of the polarity effect was determined by comparing the collected charges at similar voltages of opposite signal. The highest values obtained in this test were 0.8% and 0.2% for the radiation qualities T-50(a) and T-50(b), respectively. According to international recommendations, the values shall not exceed the recommended limit of 1% [6]. The ion collection efficiency was better than 99.9% for both polarities and qualities.

4 Conclusions

The cylindrical ionization chamber developed at IPEN/CNEN-SP presented a good performance in all tests made in this work. The results obtained in this pre-evaluation were satisfactory when compared to the international recommended limits. Observing these results it is possible to verify the possibility of the use of this ionization chamber in clinical and metrological applications. Moreover, the construction technique and geometry of this chamber corroborates the feasibility of producing radiation detectors with materials available at the Brazilian market and with excellent performance.

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