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-SP). 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-SP), 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 to international recommendations and of low cost, this work presents the initial evaluation of a homemade cylindrical ionization chamber for routine use in ^{60}Co beams, developed at LCI.

The main difference of this ionization chamber, from other commercial ionization chambers is its constituent materials. In this project, just low-cost Brazilian materials were utilized. The objective of this work was to characterize this ionization chamber, through some important tests about the 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.

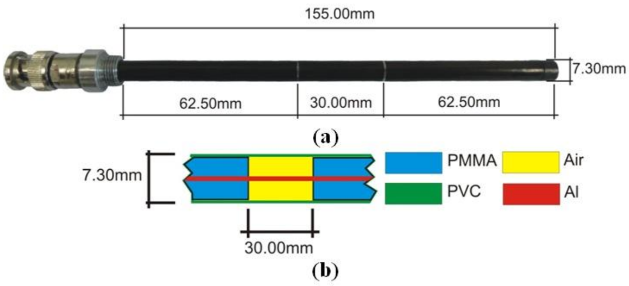

Fig. 1. (a) Ionization chamber developed at LCI, and (b) schematic representation of the sensitive volume

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, a Gammatron equipment with a ^{60}Co gamma radiation source was utilized.

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.

The irradiation conditions for all measurements were fixed at a reference field of 10 x 10 cm^2 using a ^{60}Co unit at the LCI for 15 s. All readings were corrected for environmental conditions [5].

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.

3 Results and Discussions

3.1 Short- and medium-term stabilities

The chamber response was tested in relation to its stability (short-and medium-term stabilities). 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 obtained by taking the medium value of the ten measurements of the short-term stability tests during a period of one month (Figure 3). According to IEC 60731 [6], the value obtained in each test must not differ from the reference value by more than 0.5%. As Figure 3 demonstrates, all deviations were within the acceptable range.

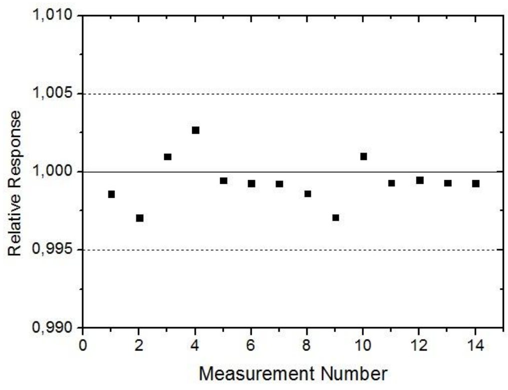

Fig. 3. Medium-term stability test for the new homemade ionization chamber using a ^{90}Sr+^{90}Y check source device. The dashed lines represent the recommended limits (0.5%) according to IEC 60731 [6]. The uncertainties associated to the measurements are negligible, and they do not appear in the graph

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 was determined using a ^{60}Co gamma radiation source. A saturation curve (Figure 4) was obtained 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 entire tested voltage interval. The chosen applied voltage for the ionization chamber was +100 V.

The saturation curve test determines the optimal voltage for the chamber operation. Using the saturation curve two other tests could be analyzed: the polarity effect and collection efficiency.

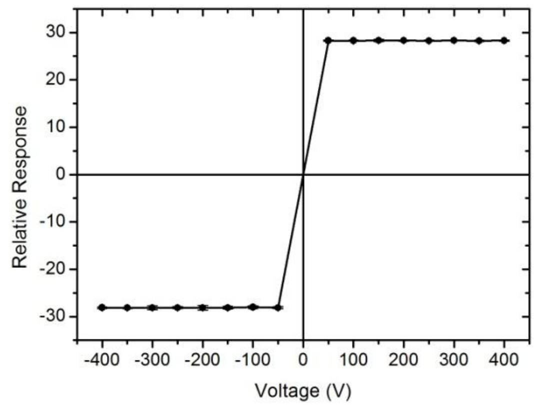

Fig. 4. Saturation curve for the new homemade ionization chamber using with a ^{60}Co gamma radiation source. The uncertainties associated to the measurements are negligible, and they do not appear in the graph

Evaluation of the polarity effect was determined by comparing the collected charges at similar voltages of opposite signal. The highest value obtained in this test was 0.48%. 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.

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 were very satisfactory when compared with international recommended limits. Observing these results it is possible to verify the possibility of the use of this homemade chamber in clinical and metrological applications. Moreover, the construction of this chamber corroborates the feasibility of producing radiation detectors with materials available at the Brazilian market and with excellent performance.

Acknowledgements

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