STABILITY AND ANGULAR DEPENDENCE OF A HOMEMADE IONIZATION CHAMBER IN ^{60}Co BEAMS

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Abstract: A special cylindrical ionization chamber developed at the Calibration Laboratory of IPEN (LCI) was tested for use in standard gamma radiation beams, radiotherapy level. This homemade ionization chamber was made using only low-cost Brazilian materials. The performance of the ionization chamber was studied in gamma radiation (^{60}Co) beams in relation to its stability and angular dependence. The short- and medium-term stabilities and the angular dependence test achieved results within the international recommendations of the IEC 60731 standard. The results obtained show that this homemade ionization chamber is suitable for gamma radiation measurements.

Key words: ionization chamber, radiotherapy, stability test, angular dependence

1. INTRODUCTION

Radiotherapy is an important therapeutic method which has been widely used. The dose control delivered to patients during radiotherapy procedures is usually based on radiation dosimeters. With the increase of new techniques for radiotherapy treatments, many new types of dosimeters are being applied. In this context, it is possible to enumerate the following types of dosimeters: diodes for in vivo dosimetry, gel dosimetry systems, metal oxide semiconductor field effect transistor (MOSFET) detectors and wireless sensors for remote real-time dose verification [1, 2, 3]. On the other hand, some of the known tools such as termoluminescent dosimeters (TLD), radiochromic films and ionization chambers for dose determinations are still in use in radiotherapy departments, such as hospitals and clinics.

To verify the accuracy of equipments responsible for dose verifications, there are several national and international laboratories. The Calibration Laboratory of IPEN (LCI) provides calibration services of radiation detectors. Annual intercomparisons of the standard systems are offered by the Secondary Standard Dosimetry Laboratory, National Laboratory for Ionizing Radiation Metrology (LNMRI), Rio de Janeiro.

At LCI, the reference standards used in calibration procedures are ionization chambers. These types of radiation detectors are the most practical and important radiation measurement devices, due to their high sensitivity and relatively constant response within a wide range of energies [4].

In this work, a homemade ionization chamber developed at LCI (IPEN) was tested, in relation to the pre-operational characteristics: short- and medium-term stabilities and angular dependence.

2. MATERIALS AND METHODS

The ionization chamber used in the tests was a cylindrical ionization chamber. This chamber was designed and developed at IPEN using only Brazilian low-cost materials. Table 1 shows the technical specifications of the ionization chamber evaluated in this work. A photo of the ionization chamber can be seen in Figure 1.

Tabela 1. Technical specifications of the homemade ionization chamber

Characteristics	Specifications
Electrode material	Aluminum
Wall material	PVC coated with graphite
Electrode thickness	1.2 mm
Chamber inner diameter	6.7 mm
Chamber wall thickness	0.26 mm
Chamber sensitive length	30.00 mm
Chamber sensitive volume	1.06 cm^3

Fig. 1. Homemade ionization chamber developed at IPEN tested in this work

For the stability tests, a ^{90}Sr + ^{90}Y check source, Physikalisch-Technische Werkstätten (PTW; 33 MBq, 1994) and an acrylic holder to achieve reproducible geometric conditions were utilized. This acrylic holder was developed by Maia and Caldas [5]. Figure 2 shows the

acrylic holder (a) and the check source (b) utilized for the stability tests.

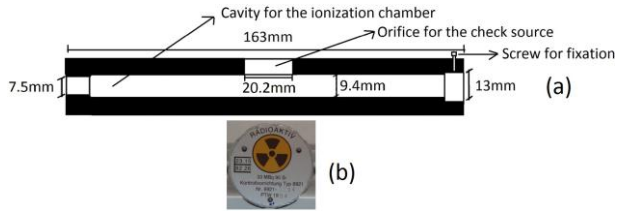

Fig. 2. (a) Acrylic holder for stability tests [5] and (b) check source utilized for stability tests

The irradiation conditions for the angular dependence test were fixed at a reference field of 10 x 10 cm^2 using a Gammatron ^{60}Co irradiator unit, as shown in Figure 3. The air kerma rate was (0.76±0.01) mGy/s, measured using a secondary standard ionization chamber PTW, model TN30002. This ionization chamber has traceability to the Bureau International des Poids et Mesures (BIPM).

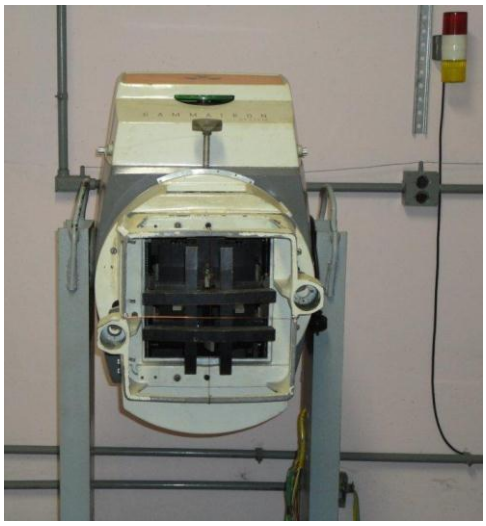

Fig. 3. Gammatron ^{60}Co irradiator unit of the Calibration Laboratory of IPEN

In the angular dependence test, a special holder with a goniometer made of PMMA was also utilized (Figure 4).

All readings were corrected for standard environmental conditions of temperature and pressure [6].

In order to evaluate the results obtained in the angular dependence test, a commercial ionization chamber PTW, Farmer-type (TN 30011-1), was utilized. This ionization chamber has a sensitive volume of 0.6 cm^3, and its wall and electrode material are made of graphite.

During the tests, the homemade and commercial ionization chambers were connected to an electrometer, model UNIDOS E, PTW. During this study, the IEC 60731 [7] recommendations were utilized as reference.

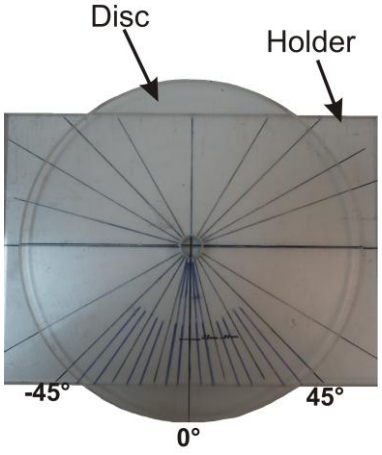

Fig. 4. Goniometer used for the angular dependence test

3. RESULTS AND DISCUSSION

The short-term stability test was performed by taking several measurements with the ionization chamber exposed to the check source under reproducible conditions. According to international recommendations [7], the maximum acceptable coefficient of variation is 0.3%. The highest coefficient of variation obtained was 0.04%, and therefore it is within the recommended limit.

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 5). According to the IEC 60731 [7], the value obtained in each test must not differ from the reference value more than 0.5%. Figure 5 demonstrates that all deviations were within the acceptable limit.

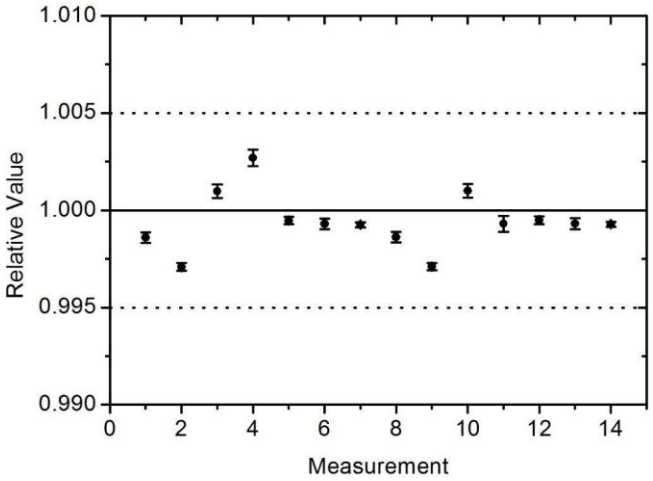

Fig. 5. Medium-term stability of the cylindrical ionization chamber [8]. The dotted lines represent the limits according to IEC 60731[7]

For the angular dependence tests the ionization chamber was placed in the positioning system at a distance of 1.00 m from the ^{60}Co source. The ionization chamber was rotated around its central axis from -40° to +40° in steps of 10°, using the special holder with goniometer (Figure 4). According to the IEC 60731 [7] standard, the value obtained

in each angle must not differ from 0º by more than 1%. The maximum variation obtained was 0.3%, as shown in Figure 6.

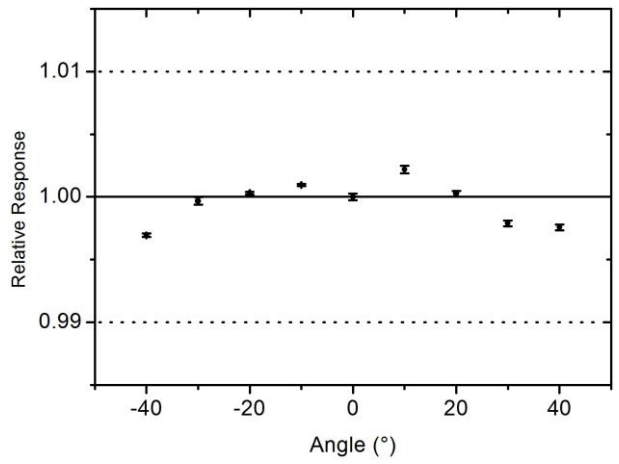

Fig. 6. Angular dependence test of the cylindrical chamber developed at IPEN. Normalization of the chamber response was performed in relation to 0º. The dotted lines represent the limits according to IEC 60731[7]

The results for angular dependence tests obtained with the homemade ionization chamber were compared with the results obtained with the PTW Farmer-type ionization chamber (TN 30011-1). The dependence angular results for the commercial ionization chamber are shown in Figure 7. The angular dependence test for the commercial ionization chamber followed the same procedure: rotation of the ionization chamber around its central axis from -40° to +40° in steps of 10°. The maximum variation obtained in this test was 0.4%. It is possible to observe that the angular dependence results obtained with the ionization chambers are in good agreement.

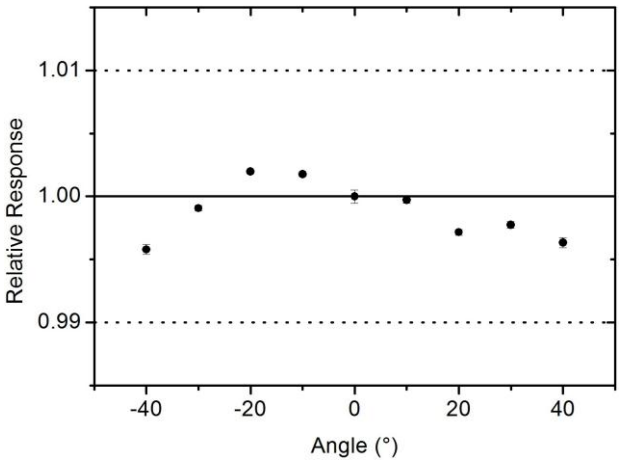

Fig. 7. Angular dependence test of the commercial ionization chamber. Normalization of the chamber response was performed in relation to 0º. The dotted lines represent the limits according to IEC 60731[7]

The angular dependence of the homemade ionization chamber was evaluated, considering the possibility of small variations in the radiation incidence angle due to possible imprecision in the chamber positioning. It may be observed that the response variation caused by this small variation in the radiation beam incident angle did not result in significant measurement variations.

4. CONCLUSIONS

The cylindrical ionization chamber presented good performance in the tests proposed in this work. The main objective of its construction was achieved, because it presents a potential use in radiotherapy dosimetry. The results obtained in the tests of stability and angular dependence were satisfactory, when compared with the international recommended limits. Moreover, the construction of this chamber shows the feasibility of producing radiation detectors with materials available at the Brazilian market and with excellent performance, which makes it accessible for use at hospitals and radiation metrology laboratories.

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