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PERFORMANCE OF A ROOS IONIZATION CHAMBER IN GAMMA RADIATION BEAMS (^{60}Co)

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ABSTRACT

Among the different types of dosimetry instruments, the ionization chambers are the most practical and important radiation measurement devices due to their high sensitivity and relatively constant response within a wide range of energies. A commercial PTW ionization chamber (Roos electron chamber) usually utilized in X-ray beams, was tested to verify the possibility of its dosimetric application in ^{60}Co beams. The main tests in this work were: short- and long-term stability, saturation, ion collection efficiency, polarity effect, leakage current and angular dependence. The characterization tests were performed using a Gammatron ^{60}Co irradiator and a special goniometer made of PMMA. All results were within international recommendations. The reproducibility test presented results within the recommended limit of ±1%, and all coefficients of variation observed in the repeatability test were lower than ±0.07%. The ion collection efficiency was better than 99.9% for both polarities. For all pairs of polarity evaluated during the saturation test, the polarity effect was lower than the recommended limit. The maximum variation obtained for angular dependence test was only 0.5%. The chamber tested in this work achieved the expected results in the case of all pre-operational tests realized: stability, leakage current, angular dependence, saturation, ion collection and polarity effect. Evaluating the satisfactory results obtained, it is possible to indicate the usefulness of this ionization chamber for dosimetry in ^{60}Co gamma radiation beams.

1. INTRODUCTION

A radiation detector is a device, instrument or system that evaluates, in a direct or indirect way, the quantities exposure, kerma, absorbed dose or equivalent dose, or their derivatives rates [1]. There is a large number of detectors used in radiotherapy, depending on the application conditions. The choice of a radiation dosimeter and its reader must take into account the requirements of the measurement situation. The ionizations chambers are the most widely used type of dosimeter for accurate measurements in radiotherapy procedures. They are also recommended for beam dosimetry as reference radiation detectors [1, 2].

Before clinical use, the dosimeters must be calibrated, that is an important step in the accurate dose deliver to the patient. The Calibration Laboratory of IPEN (LCI) offers calibration services of radiation detectors using X, alpha, beta and gamma radiations. The ^{60}Co sources are used at the LCI mainly for calibration and tests of radiation protection monitors.

The reference standards utilized at LCI in the calibration procedures are ionization chambers that have traceability to primary and secondary standard laboratories. The ionization chambers are recommended as reference dosimeters for photon, electron and other types of radiations [3]. Their use is justified, because they present several advantages: they are robust; and they present easy handling, high precision and stable response within a wide range of energies.

There are many types of ionization chambers depending on their applications. Among the different types of ionization chambers, the plane-parallel type is the most practical one for dose determinations in medical accelerator electron beams and also for the dose determination in the build-up region of photon beams [4, 5]. An example of a plane-parallel ionization is the Roos ionization chamber manufactured for measuring the absolute dose in medical linear accelerator electron beams [4, 5]. Some studies of the Ross ionization chamber in ^{60}Co and kilovoltage X-ray beams were reported by Arbabi *et al.* [4] and Hill *et al*. [6], respectively. Some characteristics of the Roos ionization chamber were studied using a ^{60}Co gamma radiation source [4]. Another application of the Roos ionization chamber already studied was the relative dosimetry of kilovoltage X-ray beams in the energy range of 50-280 kVp [6].

In this work, a Roos chamber, recommended for electron dosimetry in radiotherapy beams, was evaluated to verify its potential use in dosimetry of a ^{60}Co source at LCI.

In order to evaluate the ionization chamber response, some pre-operational tests were undertaken: short- and medium-term stability, leakage current, saturation curve, ion collection efficiency, polarity effect and angular dependence. These important characteristics were investigated in a ^{60}Co radiation beam.

2. MATERIALS AND METHODS

In this work, a Roos commercial ionization chamber from Physikalisch- Technische Werkstätten (PTW) was studied. The technical characteristics and a photo of this chamber are presented in Table 1 and Figure 1.

Table 1. Technical specifications of the Roos ionization chamber (as stated by the manufacturer)

Characteristics	Specifications
Entrance window	1 mm PMMA, 1.19 g/cm^3 0.02 mm graphite, 0.82 g/cm^3 0.1 mm varnish, 1.19 g/cm^3
Sensitive volume	Radius 7.5 mm Depth 2 mm
Guard ring width	4 mm
Nominal sensitive volume	0.35 cm^3

Figure 1. Photo of the Roos chamber utilized in this work.

For the measurements, the Roos chamber was connected to an electrometer PTW, model UNIDOS E. During all irradiations, a build-up cap, made of acrylic, with 4 mm thickness was utilized.

An irradiator Gammatron/Siemens, with a ^{60}Co source was utilized. The air kerma rate was (0.765±0.019) mGy/s determined by the use of the PTW reference ionization chamber, model TN 30002. The irradiation conditions were a reference field of 10 x 10 cm^2, and a fixed distance of 1.0 m between the ionization chamber and the source. The measurements obtained were corrected for the standard environmental conditions of temperature and pressure [7].

In the angular dependence test a goniometer was utilized, shown in Figure 2.

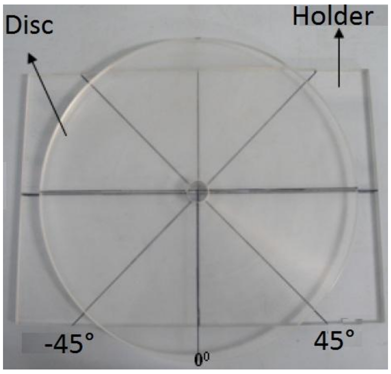

Figure 2. Goniometer utililized for the angular dependence test.

3. RESULTS AND DISCUSSION

3.1. Short- and medium-term stability

Initially, the Roos ionization chamber was tested in relation to its short-term stability. It was obtained by ten readings of charge, during a time interval of 15s, under reproducible conditions in the ^{60}Co beam. The highest variation coefficient obtained was 0.07%. According to recommended international limits, the maximum variation acceptable is 0.5%.

The medium–term stability was obtained by taking the mean values of 10 measurements during a period of one month under reproducible conditions. Figure 3 shows that the maximum variation coefficient is within the recommended limit of 1% [8].

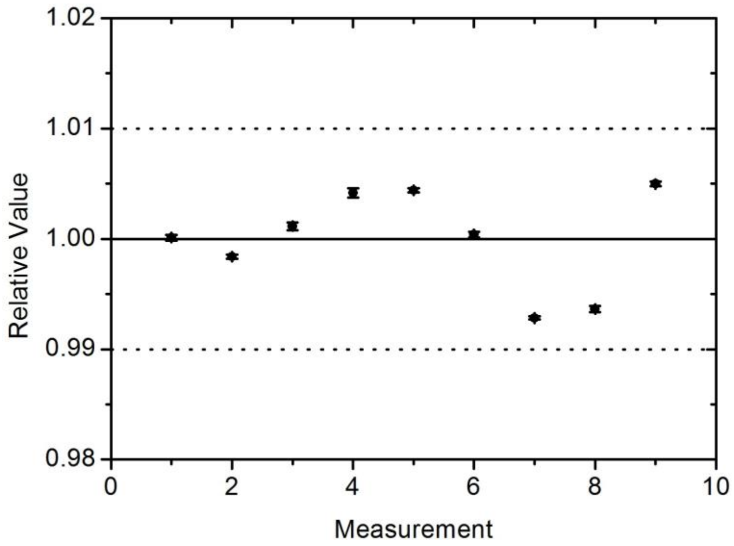

Figure 3. Medium-term stability of the Roos ionization chamber in ^{60}Co beams. The dotted lines represent the limits according to IEC 60731 [8].

3.2. Saturation, ion collection efficiency and polarity effect

In order to obtain the best polarity voltage to be applied to the ionization chamber, the saturation curve was achieved. To obtain the saturation curve the voltage was varied from -400 V to +400 V, in steps of 50 V.

The mean value in module of the ionization chamber was 10.33 pA, and the maximum variation coefficient obtained was 0.60%. The saturation was already achieved at 100 V; the chosen voltage to operate this chamber was 100 V, as already recommended by the manufacturer. Figure 4 shows the saturation chamber of the Roos chamber.

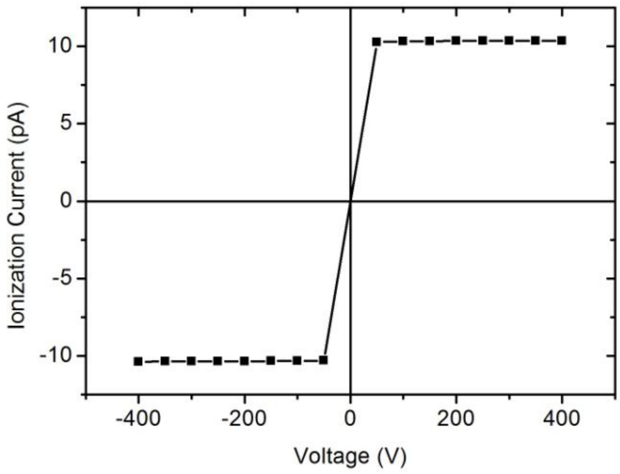

Figure 4. Saturation curve for the Roos ionization chamber, using a ^{60}Co source. The maximum standard deviation of the measurements was lower than 0.1 %.

The saturation curve can also be utilized to determine the polarity effect and the ion collection efficiency.

Under identical irradiation conditions, the use of applied voltages of opposite polarities at an ionization chamber may produce different readings; this phenomenon is the polarity effect. It was obtained in this work, by comparing the collected charges at similar voltages of opposite signals. For all pairs of voltage values utilized in the saturation test, the polarity effect did not exceed the limit of 1.0% recommended by IEC 60731[8].

In order to obtain the ion collection efficiency the following formulae was utilized [9]:

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

where M_x is the collected charge at a V_x voltage, and $V_1/V_2 = 2$. For V_1=300V (or -300V) and V_2=150V (or -150V), the ion collection efficiency was better than 99.9% for both polarities.

3.3. Leakage current

The leakage current was measured 20 min after the irradiation, and the maximum value obtained in this test was 0.04%. This value is within the recommended limit (0.5%), established in the IEC 60731 standard [8].

3.4. Angular dependence test

This test measured the variation in response of the Roos ionization chamber with the angle of incident radiation. Usually the ionization chambers exhibit angular dependence, due to their manufacture and geometrical details, and to the incident radiation energy.

The ionization chamber was moved around its central axis between -60° and +60°, in steps of 10°. According to the IEC 60731 standard [8], the value obtained in each angle must not differ from 0° by more than 1%. The maximum variation obtained with the Roos ionization chamber was 0.6%, as can be seen in Figure 5.

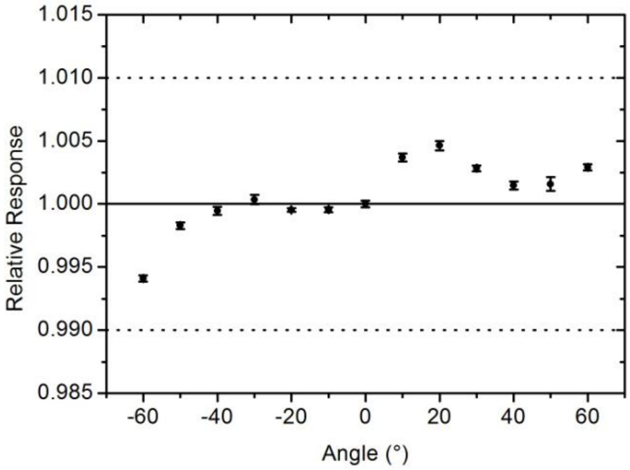

Figure 5. Angular dependence test of the Roos ionization chamber, using a ^{60}Co source. The dotted lines represent the limits according to IEC 60731 [8].

4. CONCLUSIONS

In this work, a PTW Roos 34001 plane-parallel ionization chamber was characterized in ^{60}Co beams. Some operational tests were undertaken: short- and medium-term stability, saturation curve, polarity effect, ion collection efficiency, leakage current and angular dependence. In all tests the ionization chamber achieved results within international recommended limits. Therefore, the Roos ionization chamber tested in this work presents potential use for beam dosimetry of ^{60}Co sources.

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