Performance of a Ring-Shaped Monitor Ionization Chamber in Standard Radiotherapy Beams

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***Abstract*— Monitoring the X-ray intensity is very important in order to obtain an accurate dose delivery to patients. This accuracy is one of the most important points for the success of a radiotherapy treatment. Therefore, a ring-shaped ionization chamber was developed at Instituto de Pesquisas Energéticas e Nucleares to be used as a monitor chamber for X-radiation beams. This monitor ionization chamber is composed by a PMMA body, collecting electrode and guard ring made of graphite, and an entrance window of thin aluminized polyester foils. It has a central hole for the radiation beam. The main advantage of this kind of ionization chamber in relation to commercial monitor chambers is the changeless characteristics of the beam, since the radiation is not intersected directly by the chamber, due to its central hole. As characterization tests have been performed with satisfactory results using diagnostic radiology X-ray beam qualities, in this work the chamber was studied using radiotherapy qualities.**

Keywords—**monitor chamber, X- radiation, graphite chamber**

I. INTRODUCTION

Radiation therapy is one of three main treatment modalities used in malignant diseases such as cancer, including surgery and chemotherapy. The success of a radiotherapy treatment depends on the correct dose delivery, among other factors. Therefore, a quality control program is very important.

In radiotherapy, the recommended limits for the performance of instruments are more restricted, since the treatment results are closely related to the dose delivered to the target volume and surrounding healthy tissues.

The most widely dosimeters utilized are the ionization chambers. Their operation is based on the collection of all charges created by direct ionization of the gas by applying an electronic field [1].

Monitor chambers are a particular type of ionization chamber. They are used with the purpose of monitoring any variation on radiation intensity mostly due to variations of power supply to the radiation generator. In radiotherapy, these monitor chambers are utilized to guarantee the accurate patient exposure while in calibration laboratories they are used to correct any fluctuations in the standard beam intensity during a calibration procedure [2].

A ring-shaped monitor chamber was developed at the Calibration Laboratory of Instituto de Pesquisas Energéticas e Nucleares (IPEN) by Yoshizumi [3], it concerns a chamber specially designed for monitoring of X-ray beams.

In 2009, Yoshizumi and Caldas obtained good responses to all pre-operational tests performed with the ring-shaped ionization chamber: saturation curve, ion collection efficiency, polarity effect, response linearity and response stability [4].

Given the importance of calibration of radiation measurement instruments and the knowledge of their characteristics in this work, the monitor chamber was tested using radiotherapy beam qualities, although it was specially designed to be used in diagnostic radiology radiation beams.

II. MATERIALS AND METHODS

In this work a ring-shaped graphite monitor ionization chamber was used. This ionization chamber has the body structure of PMMA, entrance window of aluminized polyester with surface density equal to 1,87mg.cm^{-2} and a collecting electrode made of graphite coated PMMA plates; it presents a diameter of the central hole of 7 cm, sensitive volume of 160 cm^3, and it measures only the radiation penumbra. In order to measure the ionization currents from ring-shaped ionization chamber, it was connected to an electrometer Physikalisch-Technische Werksstätten (PTW), Germany, model UNIDOS, which also allows to vary the voltage to the chamber, reversing its polarity. The ionization chamber (Fig. 1) was connected by co-axial cables to the electrometer.

The reference ionization chamber was a plane-parallel ionization chamber, PTW, model M23344.

Fig. 1 Ring-shaped graphite monitor chamber

An X-ray equipment, Pantak/Seifert, model ISOVOLT 160HS, operating up to 160kV, was used. In this equipment many radiation beam qualities were established: radiotherapy, conventional radiology, mammography and radiation protection, in accordance to international recommendations. Five X-radiation beam qualities of low energy, radiotherapy level, were implanted in the Laboratory of Calibration, using as reference beams those recommended by Bureau International des Poids et Mesures (BIPM) [5]. The characteristics of these beam qualities are described in Table 1.

Table 1 Characteristics of standard X-radiation beam, radiotherapy level, implemented at the Pantak/Seifert, according to BIPM [5]

Radiation Quality	Generating Potential (kV)	Half-value Layer (mmAl)	Additional Filtration (mmAl)	Air Kerma Rate (mGy.min^{-1})
T-10	10	0.043	-	3.229 ± 0.003
T-25	25	0.279	0.372	2.753 ± 0.002
T-30	30	0.185	0.208	9.492 ± 0.005
T-50(a)	50	2.411	3.989	0.834 ± 0.002
T-50(b)	50	1.079	1.008	3.878 ± 0.002

III. Results and Discussion

In this work, the ring-shaped ionization chamber was tested using radiotherapy beam qualities. The energy dependence was determined and correction factors were obtained. Moreover, the correction factors for reproducibility were verified.

For all tests performed, the ring-shaped ionization chamber was positioned at the distance of 30 cm, as recommended by the IEC 61267 standard [6] for diagnostic radiology beams. These conditions were maintained due to the experimental arrangement. All measurements were corrected for the normal conditions of temperature and pressure.

A. Energy dependence

To determine the energy dependence of the monitor chamber, the standard ionization chamber was positioned at the distance of 50 cm and both chambers were irradiated simultaneously. This procedure was utilized to determine the calibration coefficients of the ring-shaped chamber. These calibration coefficients were normalized to the T-30 beam quality, and the correction factors were determined.

The calibration coefficients and the correction factors are shown in Table 2.

The energy dependence of the monitor ionization chamber is presented in Fig. 2.

Table 2 Calibration coefficients and correction factors of the ring-shaped ionization chamber using radiotherapy beam qualities

Radiation Quality	Half-value Layer (mmAl)	Calibration Coefficient (mGy/nC)	Correction Factor
T-10	0.043	146.16 ± 0.35	1.584 ± 0.005
T-25	0.279	67.55 ± 0.28	0.732 ± 0.003
T-30	0.185	92.27 ± 0.22	1.000 ± 0.003
T-50(a)	2.411	18.59 ± 0.19	0.201 ± 0.002
T-50(b)	1.079	28.81 ± 0.14	0.312 ± 0.002

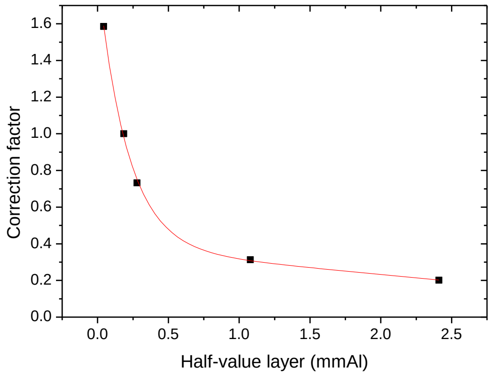

Fig. 2 Energy dependence of ring-shaped graphite ionization chamber, at radiotherapy X- ray beam qualities. The uncertainties of the measurements are lower than 1% and they are not visible

As can be seen in Table 2 and Fig. 2, the ring-shaped ionization chamber presents high energy dependence. This fact is not important once this dependence is known and this ionization chamber is not a reference system. The most important characteristic of a monitor chamber is its response stability to conserve the calibration coefficients values.

B. Response stability

For the response stability determination, two tests were performed: the short-term and the medium-term stability tests.

Ten consecutive measurements were taken for the short-term stability test. According to the IEC 61674 standard [7], the maximum standard deviation of these measurements must be less than ±3%. The maximum variation obtained was 0.56%, thus within the recommended limit.

For each radiation beam quality, the short-term stability test data were used to determine the medium-term stability. The performance of this test was possible because the X-ray equipment Pantak/Seifert is a highly stable generator. The mean value of each set of ten measurements from the short-term stability test was evaluated, and the medium-term stability was obtained. Table 3 shows the maximum variation obtained for the medium-term stability test for all radiation beam qualities. In Fig. 3, the medium-term stability results obtained for the T-30 beam quality is illustrated. The other beam qualities presented the same behavior.

Table 3 Maximum variation of the constancy of the calibration coefficients for different radiation qualities

Radiation Quality	Maximum Variation (%)
T-10	1.12
T-25	1.03
T-30	0.87
T-50(a)	0.55
T-50(b)	0.38

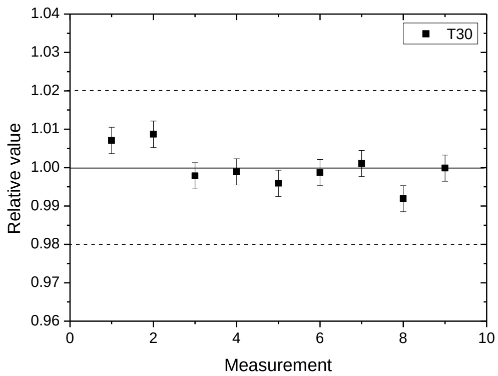

Fig. 3 Medium-term stability test of the ring-shaped ionization chamber using radiotherapy beam qualities. The dashed lines represent the recommended limits of ± 2% [7]

Comparing the results from Tables 2 and 3, the maximum variation in calibration coefficients decrease as the tube voltage increases, according expected.

The results showed in Table 3 and Figure 3 are within the recommended limit of ±2% [7].

IV. Conclusions

The ring-shaped ionization chamber presented good constancy of the calibration coefficients in the radiotherapy level. Therefore the ionization chamber presents usefulness as monitor chamber in low energy X-radiation beams.

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References

1. Knoll G F (1999) Radiation detection and measurement. John Wiley & Sons, New York
2. International Atomic Energy Agency (2000) Absorbed dose determination in external beam radiotherapy TRS 398. Viena
3. Yoshizumi M T (2010) Design, construction and characterization of special ionization chamber for X radiation beams monitoring. Universidade de São Paulo, São Paulo (In Portuguese)
4. Yoshizumi M T, Caldas L V E (2009) A new ring-shaped graphite monitor ionization chamber. Nucl Instrum Meth Phys Res A 619(2010):207-210
5. Bureau International des Poids et Mesures (2004) Measuring condition used for the calibration of ionization chambers at the BIPM. Sèvres
6. IEC (2005) Medical diagnostic X-ray equipment - Radiation conditions for use in the determination of characteristics. IEC 61267, Genève
7. IEC (1997) Medical electrical equipment - Dosimeters with ionization chambers and/or semi-conductor detectors as used in X-ray diagnostic imaging. IEC 61674, Genève

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