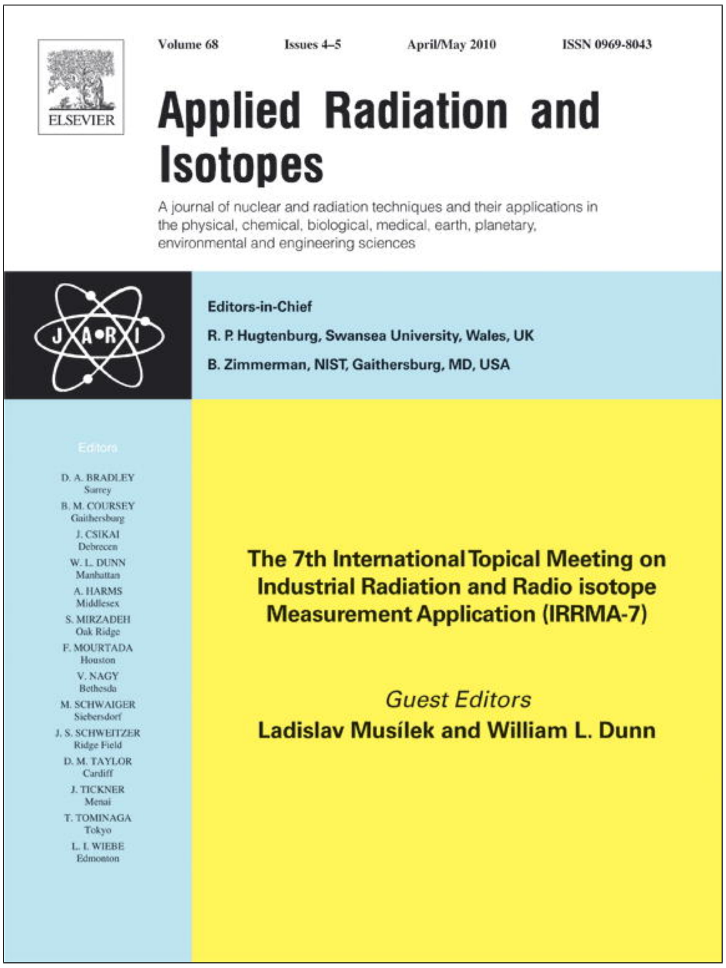

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Preliminary studies of a new monitor ionization chamber

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ABSTRACT

A new monitor ionization chamber was developed at Instituto de Pesquisas Energéticas e Nucleares (IPEN) in order to monitor X-ray beams. The main difference of this monitor ionization chamber in relation to other monitor chambers is its geometry, which consists of a ring-shaped sensitive volume. Because of this geometry, the monitor chamber has a central hole through which the direct radiation beam passes. The operational characteristics of the monitor chamber were evaluated: saturation, ion collection efficiency and polarity effect. Besides these tests, the short- and medium-term stabilities of its response were also evaluated. During the tests the leakage current was always negligible. All results showed values within those recommended internationally (IEC, 1997. Medical electrical equipment—dosimeters with ionization chambers and/or semi-conductor detectors as used in X-ray diagnostic imaging. IEC 61674. International Electrotechnical Commission, Genève).

1. Introduction

Ionization chambers are the most widely used dosimeters for measurements of exposure or absorbed dose. These chambers are available in different designs and they are constructed of different materials depending on their application (Boag, 1987). The ionization chambers are mostly cylindrical, spherical and planar (parallel-plate).

A co-axial transmission ionization chamber is a special type of ionization chamber, used to monitor radiation beams, and is always required when the radiation intensity may vary due to fluctuations of the power supply, for example. A simple parallel-plate chamber was suggested by Attix (1986) to function as a monitor chamber for X-ray beam applications. He suggested that thick Lucite plates coated with graphite be used as the collecting electrode, guard ring and window entrance, all of them electrically insulated. For electron beams and soft X-ray beams the window entrance can be replaced with a stretched foil. An external thimble chamber (Farmer-type chamber) was another suggestion for this purpose (Attix, 1986).

Recently, the International Atomic Energy Agency published a report with recommendations to be used in the dosimetry of diagnostic radiology beams (IAEA, 2007). In this document there are many recommendations on the use of monitor chambers, such as their positioning in the radiation field, performance specifications, and also a calibration method for other chambers, by the substitution method, using the monitor chamber.

According to the same publication (IAEA, 2007), "the monitor chamber should add as little filtration to the beam as possible" and "the performance specifications of the monitor chamber and the associated measuring assembly should be similar to that of the standard instrument."

Several ionization chambers have been developed at the Calibration Laboratory of IPEN for use in the diagnostic radiology and radiotherapy energy ranges (Albuquerque and Caldas, 1989; Dias and Caldas, 1998; Costa and Caldas, 2003; Maia and Caldas, 2005; Oliveira and Caldas, 2007).

In this work a new monitor ionization chamber was developed for use in monitoring of X-ray radiation beams in the diagnostic radiology energy range. This ionization chamber was designed to be simple and of low cost. The main difference between this chamber and commercial monitor transmission chambers is its ring shaped sensitive volume. There is a central hole in the ionization chamber through which the radiation beam passes. The aim of this central hole is to avoid interference of the ionization chamber with the direct radiation beams, thus maintaining their original spectra.

2. Materials and methods

The new monitor ionization chamber was connected to an electrometer (Model UNIDOS 10474, Physikalisch-Technische Werkstätten (PTW), Freiburg, Germany). All measurements were corrected to the environmental reference conditions (20 °C and 101.3 kPa).

For the pre-operational tests, an industrial X-ray unit, Pantak/Seifert, model ISOVOLT 160HS, that operates from 5 to 160 kV, was

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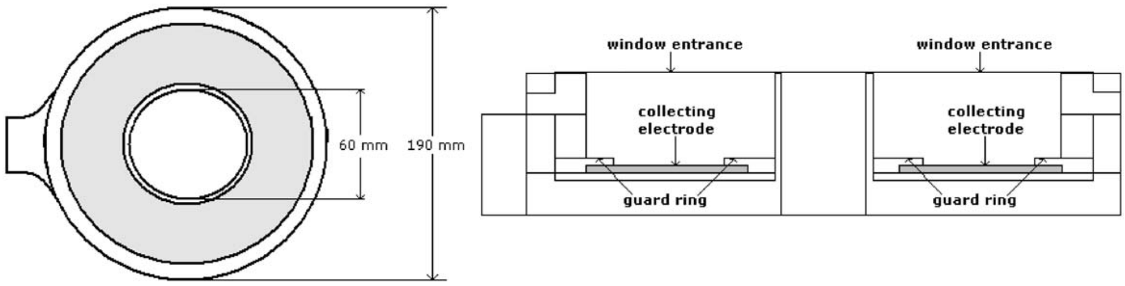

Fig. 1. Diagram of the monitor chamber developed at IPEN.

utilized. These tests were performed using the diagnostic quality beam RQR 5 defined by the International Electrotechnical Commission, IEC 1267 (1994). The reference system for the established diagnostic radiology qualities in this equipment is a parallel-plate ionization chamber PTW, model 77334, with a 1 cm^3 sensitive volume, traceable to the German primary standard laboratory Physikalisch-Technische Bundesanstalt (PTB).

The stability tests were performed using a $^{90}Sr+^{90}Y$ check source device, PTW, model 8921, with nominal activity of 33 MBq, 1994.

3. Results and discussion

The new ionization chamber is shown in Fig. 1. This is a parallel-plate ionization chamber with a central hole. The chamber body is made of PMMA that provides electrical insulation and mechanical rigidity. The collecting electrode is made of a ring-shaped aluminum plate and the outer electrode (entrance window) is an aluminized polyester foil. The collecting electrode is surrounded by PMMA disks spray-coated with graphite, which operate as guard rings (one surrounding the total sensitive volume and the other surrounding the central hole). The guard rings are necessary to keep the electric field constant on both sides of the collecting electrode. The outer diameter of the ionization chamber is 190 mm, the central hole has 60 mm of diameter and the total sensitive volume is about 200 cm^3. The ionization chamber has its symmetry axis coinciding with the beam cone axis. The final ionization chamber is shown in Fig. 2.

The pre-operational tests of the monitor chamber studied were: saturation curve, ion collection efficiency and polarity effect. The short- and medium-term stability measurements of the chamber response were taken over a period of one month. During this period, the leakage current was always negligible.

3.1. Saturation, ion collection efficiency and polarity effect

The saturation test was performed to determine the optimal applied voltage for the ionization chamber. A saturation curve was obtained from measurements of the chamber response by varying the X-ray tube voltage from −400 V to +400 V, in steps of ±50 V (Fig. 3). The ionization chamber was positioned at 30 cm from the focal spot; at this distance the air kerma rate was 544.2 mGy/min. As shown in Fig. 3, the ionization chamber response reached saturation. The chosen applied voltage for the monitor chamber was −400 V.

The ion collection efficiency was obtained by the two-voltage method, given by the equation (IAEA, 2001):

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

Fig. 2. Photograph of the new monitor chamber.

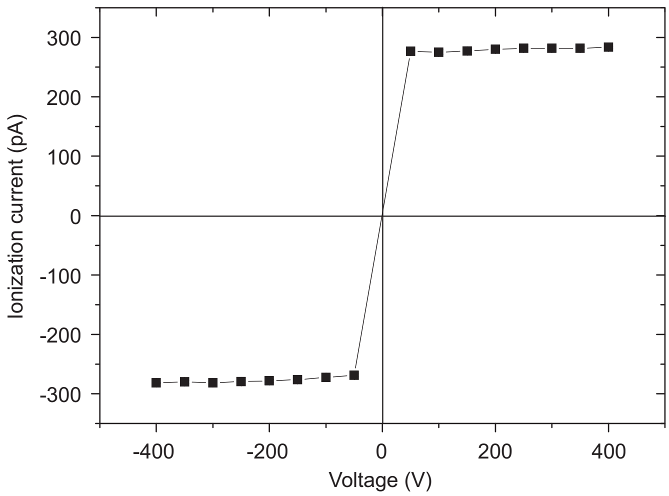

Fig. 3. Saturation curve of the monitor chamber using a diagnostic radiology quality beam (RQR 5).

where M_i is the collected charge at the polarizing voltages V_i (operational polarizing voltage) and $V_1/V_2=2$. The ion collection efficiency was better than 99.9% for both polarities. This result is in accordance with the value of 5% of ionic recombination losses, recommended by IEC (1997).

The polarity effect was determined by the ratio of the collected charges for similar voltages of opposite polarity. In Table 1 the results for all pairs of voltages are presented.

Table 1
Polarity effect of the new monitor ionization chamber.

Voltage (V)	Collected charge (nC)	Ratio
+50/−50	2.77/2.69	1.03
+100/−100	2.75/2.72	1.01
+150/−150	2.77/2.76	1.00
+200/−200	2.80/2.78	1.01
+250/−250	2.81/2.79	1.01
+300/−300	2.82/2.82	1.00
+350/−350	2.82/2.80	1.01
+400/−400	2.84/2.82	1.01

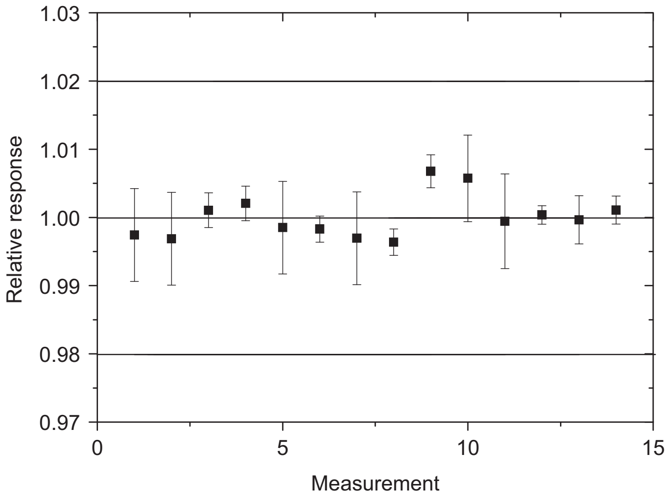

Fig. 4. Medium-term stability of the monitor ionization chamber.

3.2. Leakage current

The leakage current was determined by measuring the chamber response for 20 min, before and after irradiation. For both cases, the leakage current was only 0.25% of the ionization current produced at the minimum air kerma rate used in this work. This value is within the limit recommended internationally (IEC, 1997).

3.3. Short- and medium-term stability

For the short-term stability test, the monitor chamber was exposed to the check source, and 10 consecutive measurements were taken, under reproducible conditions. The maximum variation of the monitor chamber response was $<0.4\%$, and therefore it is within the recommended limit of 3% (IEC, 1997).

The medium-term stability test was obtained by taking the medium value of the 10 measurements of the short-term stability during a period of one month (Fig. 4). The maximum variation obtained was 0.7%, thus within the 2% value recommended limit (IEC, 1997).

4. Conclusions

The new monitor ionization chamber developed at IPEN and presented in this work achieved the expected results in the case of all pre-operational tests realized: saturation, ion collection efficiency and polarity effect. During these tests the chamber response stability showed an adequate performance, satisfying the international recommendations. This monitor chamber is a good alternative for use in any laboratory or hospital, because of its simple design and low-cost materials used.

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