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Dosimetric tests of an extrapolation chamber in standard computed tomography beams

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ABSTRACT

Computed tomography (CT) diagnostic exams are responsible for the highest dose values to the patients. Therefore, the radiation doses in this procedure must be accurate. For the dosimetry of CT beams, the radiation detector is usually a pencil-type ionization chamber. This type of dosimeter presents a uniform response to the incident radiation beam from all angles, which makes it suitable for such equipment since the X-ray tube executes a circular movement around the table during irradiation. However, there is no primary standard system for this kind of radiation beam yet. In order to search for a CT primary standard, an extrapolation chamber built at the Calibration Laboratory (LCI) of the Instituto de Pesquisas Energéticas e Nucleares (IPEN) was tested. An extrapolation chamber is a parallel-plate ionization chamber that allows the variation of its sensitive air volume. This chamber was used previously for low-energy radiation beams and showed results within the international recommended limits. The aim of this work is to perform some characterization tests (saturation curve, polarity effect, ion collection efficiency and linearity of response) considering the chamber depth of 1.25 mm in the radiation qualities for computed tomography beams at the LCI. The results showed to be within the international recommended limits.

Keywords: **Extrapolation chamber, computed tomography, dosimetry.**

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1. INTRODUCTION

The use of computed tomography (CT) has increased in diagnostic tests; due to technological advances of this equipment as the process of obtaining images became faster [1]. This caused a concern about the dose received by the patients to undergo this kind of imaging procedure.

A pencil-type ionization chamber is used as radiation detector for computed tomography beams. This dosimeter presents a uniform response to the incident radiation beam from all angles; the commercial chamber used to perform the quality control testing of the equipment has usually a 10 cm length of the sensitive volume [2].

For this kind of radiation beam there is no primary standard system yet. So, it was decided to use an extrapolation chamber, built at the Calibration Laboratory (LCI) of the Instituto de Pesquisas Energéticas e Nucleares (IPEN), for its preliminary evaluation on the establishment of a CT primary standard [3,4]. An extrapolation chamber is a parallel-plate ionization chamber that allows to vary its sensitive volume. This chamber was already used for low-energy radiation beams too, and it showed results within the international recommended limits [4-5].

The aim of this work was to perform some characterization tests (saturation curve, polarity effect, ion collection efficiency and linearity of response) with a specific chamber depth of 1.25mm. These tests are very important, because in the future the collecting electrode will be changed by an aluminum one, and the results obtained will show the usefulness of the extrapolation chamber as a primary standard for CT beams.

2. MATERIALS AND METHODS

The extrapolation ionization chamber tested in this work was developed by Dias and Caldas [3]; it presents a collecting electrode of 30 mm in diameter, the entrance window was made of aluminized polyethylene terephthalate with density of 0.84 mg/cm², and the guard ring and the collecting electrode were made of graphite.

In this study some characterization tests were performed: saturation curve, polarity effect, ion collection efficiency and linearity of response. The chamber depth used was 1.25 mm in the reference radiation quality (RQT 9) for computed tomography beams at the LCI. For these tests, an X-ray system Pantak/Seifert (ISOVOLT model 160HS) was utilized, and it operates up to 160 kV. Table 1 presents the CT radiation qualities at the LCI.

Table 1: Characteristics of the CT standard X radiation qualities at the LCI, based on the Report IEC 61267 [8].

Radiation Quality	Tube Voltage (kV)	Tube Current (mA)	HVL (mmAl)	Air Kerma Rate (mGy/min)
RQT 8	100	10	6.9	22.0
RQT 9 †	120	10	8.4	34.0
RQT 10	150	10	10.1	57.0

† Reference CT radiation quality at LCI/IPEN

HVL: Half-Value Layer

For each test ten consecutive measurements were taken; all of them were corrected for the reference environmental conditions too. The polarity effect and the ion collection efficiency were obtained through the saturation curve.

For the polarity effect test, the ratio of the ionization currents obtained for positive and negative polarities must not exceed 1 % [7], therefore, the results should be in the range 0.99 - 1.01. Using Equation 1, it was possible to calculate the ion collection efficiency of the extrapolation chamber, where the standard deviation must not exceed 95 % [7].

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

where: M_1 and M_2 are the measures obtained with the voltages V_1 = + 100 V and V_2 = + 50 V, respectively.

The linearity of response of the extrapolation chamber must present a linear curve, so the correlation factor needs to be close of 1.0 (R^2= 1.00). The uncertainties of type A and type B were determined, with the combined uncertainty of a coverage factor k = 2 when necessary.

3. RESULTS AND DISCUSSION

Initially are presented the results obtained of the saturation curve, polarity effect and ion collection efficiencies for the extrapolation chamber. Figure 1 shows the saturation curve, while Table 2 shows the results for the polarity effect, and Table 3 shows the results for the ion collection efficiency.

Figure 1: *Saturation curves of the extrapolation chamber for the three radiation qualities for CT. The maximum measurement uncertainty was 0.03%.*

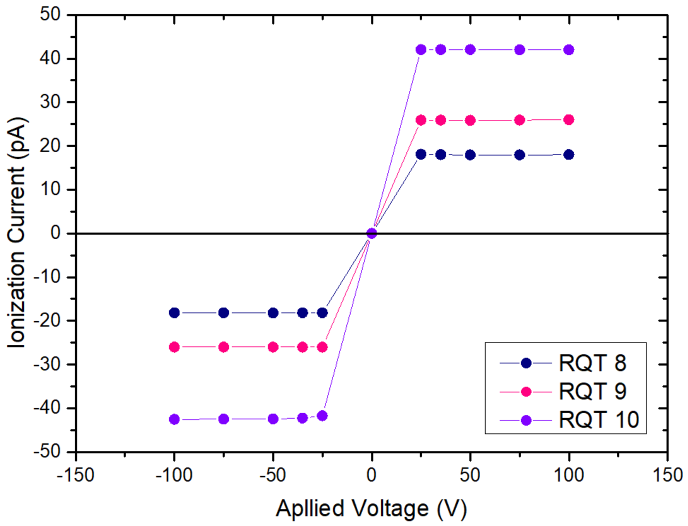

Table 2: Polarity effect of the extrapolation chamber.

Voltage (V)	Polarity Effect		
	RQT 8	**RQT 9**	**RQT 10**
25	0.996	0.996	1.009
35	0.993	0.997	0.995
50	0.987	0.995	0.991
75	0.989	0.996	0.988
100	0.993	1.000	0.987

Table 3: Ion collection efficiency of the extrapolation chamber.

Radiation Quality	Ion Collection Efficiency (%)
RQT 8	99.5
RQT 9	99.3
RQT 10	99.9

The results obtained for the polarity effect and the ion collection efficiency of the extrapolation chamber response are within the recommended limits [7].

For the linearity of response, the results obtained for all three radiation qualities for computed tomography beams can be seen in Figure 2. The results for R2 are shown in Table 4.

Figure 2: *Linearity of response curve of the extrapolation chamber in all radiation qualities for computed tomography beams. The maximum measurement uncertainty was 0.04 %.*

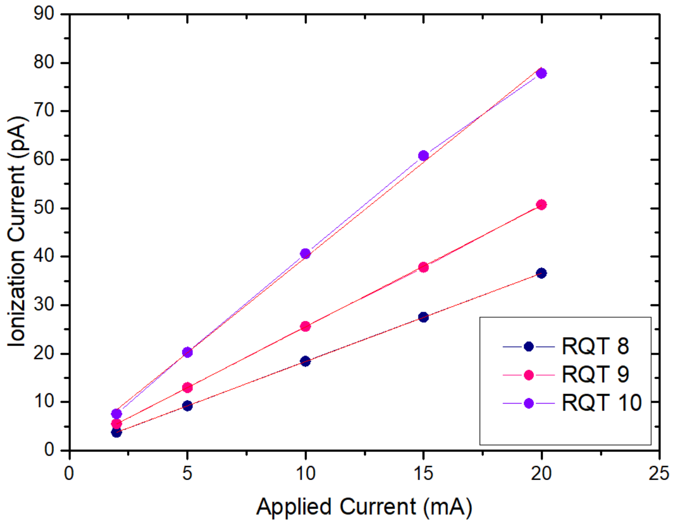

Table 4: Correlation factor for the linearity of response curve of the extrapolation chamber.

Radiation Quality	R^2
RQT 8	0.999
RQT 9	0.999
RQT 10	0.998

As can be observed in Figure 2 and Table 4, the lowest correlation factor for the linearity of response curve was 0.998, for the RQT 10 radiation quality.

4. CONCLUSION

The results obtained for the characterization tests of the homemade extrapolation chamber in standard computed tomography beams were in agreement with the international recommendations in all three radiation quality.

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