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Quality Control of a Pencil Ionization Chamber

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Abstract. This work presents a set of quality control tests that were applied to a Victoreen pencil ionization chamber. An acrylic support was developed for the repeatability and reproducibility tests since no supports are commercially available. The highest coefficients of variation obtained for the repeatability and reproducibility tests were 0.32% and 2.74% respectively, both within the limits of 1% and 3% of international recommendations. The maximum variation obtained for the calibration coefficients was 1.3% in the energy dependence test (32 – 46 keV). In the case of the linearity test, measurements were taken at several air kerma rates, and a linear fit was obtained. The uncertainty obtained in the angular coefficient was ±0.07 %. For the angular dependence test, the pencil ionization chamber was rotated around its central axis. The maximum variation obtained was 0.65%, far below the limit of 3% of international recommendations.

INTRODUCTION

Pencil ionization chambers have a special design, presenting some particular properties, because they were developed for computed tomography (CT) dosimetric purposes [1,2]. A typical characteristic of those chambers is their partial volume response, i.e., the chamber reading is proportional to the irradiated length. Moreover, these chambers present uniform response around their central axis, which is very important since X-ray tubes rotate around the patients during CT medical procedures [3,4].

The external aspect of those chambers is very similar to a thimble chamber; they are just longer and thinner. The sensitive length of a typical pencil ionization chamber is about 10–15cm, its external diameter is about 9 mm, and its sensitive volume is about 3 cm^3 [5].

As all instruments used for dosimetric purposes, pencil ionization chambers have to be submitted to a quality control program to assure their good performance. This work presents a set of quality control tests that were applied to a pencil ionization chamber.

MATERIALS AND METHODS

A Victoreen pencil ionization chamber, model 660-6, was coupled to a Victoreen electrometer, model 660. The sensitive volume of this chamber is 3.2 cm^3, the sensitive length is 10 cm, and it is filled with atmospheric air. The physical quantity measured by this chamber is the exposure in air length product, and the electrometer readout is in the old units

R.cm or R.cm/min, with a range from 0.01 R.cm/min (0.001 R.cm) to 999 R.cm/min (99.9 R.cm).

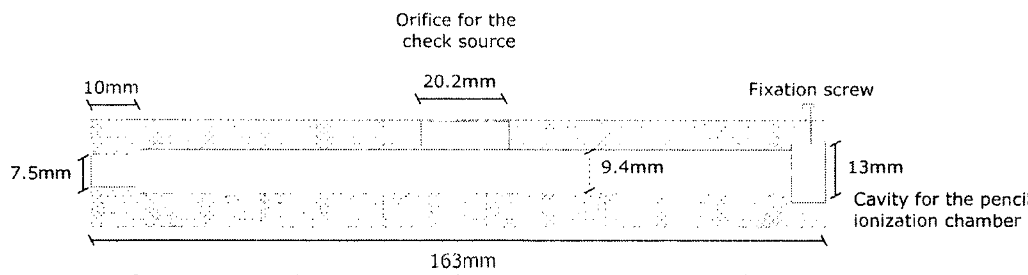
A $^{90}Sr + ^{90}Y$ check source, Physikalisch-Technische Werkstätten (PTW; 5.77 MBq, 2003), was used to perform the repeatability and reproducibility tests. An X-ray system, diagnostic radiology level, Medicor Mövek Röntgengyara, model Neo-Diagnomax, that operates from 40 to 125 kV at the radiographic mode and from 45 to 100 kV at the fluoroscopic mode, was used for the energy dependence test. Diagnostic qualities defined by the International Electrotechnical Commission, IEC 61267 [6], were used in this system, and their parameters are listed in Table 1. The reference system for these qualities was a parallel plate ionization chamber with 1 cm^3 of sensitive volume, PTW, model 77334, with a PTW electrometer, model UNIDOS 10001. This chamber was calibrated by PTW, with traceability to Physikalisch-Technische Bundesanstalt (PTB), Germany. Another X-ray system, therapy level, Pantak, model HF320, which operates up to 320 kV, was used for the linearity and angular dependence tests. For the linearity test, the air kerma rates were determined using a reference ionization chamber. This reference system was a cylindrical ionization chamber NE, model 2505/3 (0.6 cm^3 sensitive volume) with a PTW electrometer, model UNIDOS 10001. This chamber was calibrated in air kerma by the Brazilian Laboratory for Ionizing Radiation Metrology, Rio de Janeiro, Brazil; the calibration is traceable to the Bureau International des Poids et Mesures (BIPM).

TABLE 1. IEC diagnostic radiology qualities in the *Medicor Mövek Röntgengyara* X-ray equipment.

Radiation Quality	Tube Voltage (kV)	Total Filtration (mmAl)	Half-Value Layer (mmAl)	Effective Energy (keV)
RQR3	52	2.5	1.82	32.0
RQR5	70	2.5	2.45	39.2
RQR7	90	2.5	3.10	46.0

RESULTS AND DISCUSSION

For most types of ionization chambers, supports for repeatability and reproducibility tests are commercially available. However, this is not the case of supports for pencil ionization



chambers. Therefore, an acrylic support (Figure 1) was developed for those two tests.

FIGURE 1. Acrylic support for repeatability and reproducibility tests of the Victoreen pencil ionization chamber.

The repeatability test was performed by taking several measurements with the chamber exposed to a check source under reproducible conditions. By IEC 61674 [7], the maximum acceptable coefficient of variation is 1% for CT specific chambers. The highest coefficient of variation obtained was 0.32%, far below the recommended limit.

The reproducibility test was obtained by plotting the results of the repeatability test in function of time, so the long-term stability of the ionization chamber could be observed. By IEC 61674 [7], the medium value obtained in each repeatability test must not differ from the reference value more than 3%. Figure 2 shows the results obtained for the pencil ionization chamber. All values obtained in this work were within the recommended limit.

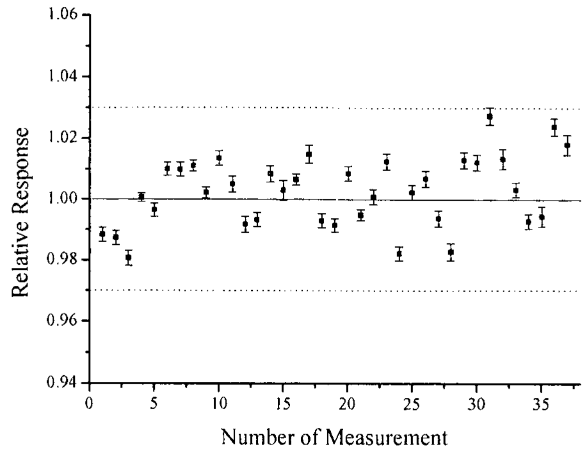


FIGURE 2. Reproducibility test of the Victoreen pencil ionization chamber, using a ^{90}Sr + ^{90}Y check source.

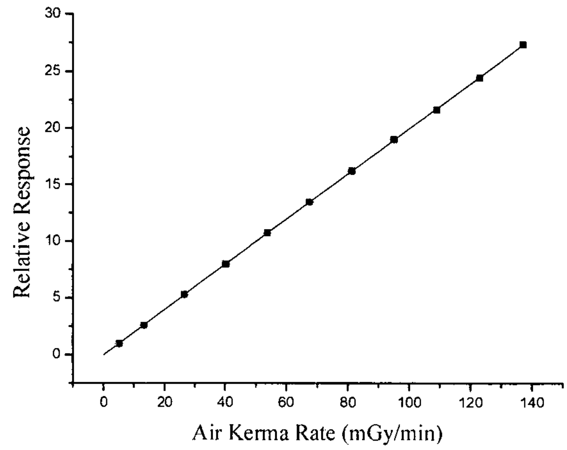
For the energy dependence test, the chamber was calibrated in the beam qualities described in Table 1. For those qualities, the maximum variation obtained for the calibration coefficients was 1.3%, as shown from data in Table 2.

TABLE 2. IEC Calibration coefficients for the Victoreen pencil ionization chamber in diagnostic radiology standard beams.

Radiation Quality	Calibration Coefficient (dimensionless)
RQR3	1.044 ± 0.026
RQR5	1.058 ± 0.026
RQR7	1.052 ± 0.024

In the case of the linearity test, the pencil ionization chamber was exposed to several air kerma rates. In order to provide the air kerma rate variation, the nominal current was varied between 1 and 25 mA at the fixed potencial of 100 kV, half-value layer (HVL) of 4.027 mmAl of the Pantak X-ray system. The air kerma rates were determined using the reference system calibrated for this quality beam. Figure 3 shows the chamber response variation, normalized for the reading using a current of 1 mA, in function of the air kerma rate. A linear fit was provided, and the uncertainty obtained in the angular coefficient was ±0.07 %.

For the angular dependence test, the pencil ionization chamber was exposed to the same standard beam of the Pantak X-ray system. The chamber was rotated around its central axis



from –180° to +180°, in steps of 30°. By IEC 61674 (7), the value obtained in each angle must not differ from 0° more than 3%. The maximum variation obtained was only 0.65%, as shown in Figure 4.

FIGURE 3. Linearity test of the Victoreen pencil ionization chamber, in standard X-ray beams (100 kV, HVL of 4.027 mmAl). Normalization of the chamber response was performed in relation to 1mA current.

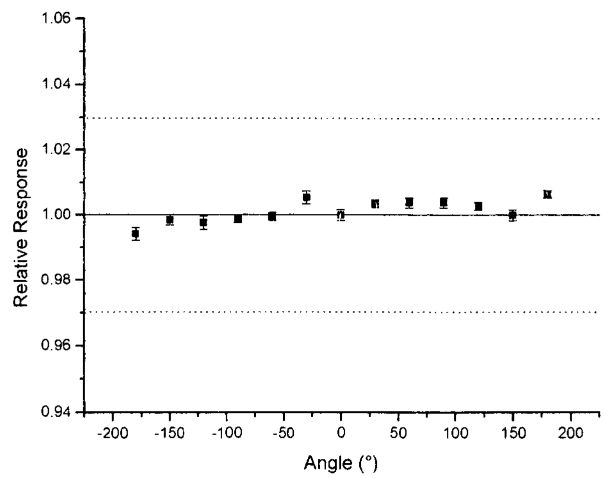


FIGURE 4. Angular dependence test results of the Victoreen pencil ionization chamber, in standard X-ray beams (100 kV, 5 mA, HVL of 4.027 mmAl). Normalization of the chamber response was performed in relation to 0°.

It was not possible to measure the leakage current in the chamber response because of its manual zero adjustment.

CONCLUSIONS

It is very important to keep pencil ionization chambers in a quality control program to assure their proper performance and the high reliance of the measurements. All quality control tests realized in this work showed results within the acceptable limits.

Most of the users of pencil ionization chambers do not perform repeatability and reproducibility tests because of the lack of commercial supports. This work shows that this deficiency can easily be fulfilled, since the developed acrylic support is very simple, presents low cost, and is adequate to perform this kind of tests.

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