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STABILITY RESULTS OF A FREE AIR IONIZATION CHAMBER IN STANDARD MAMMOGRAPHY BEAMS

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ABSTRACT

Free air ionization chambers are absolute dosimeters, because they can measure basic physical quantities directly without the need of their calibration in a standard radiation beam. They are used for measuring exposure and air kerma in X and gamma radiation beams. The Calibration Laboratory (LCI) of IPEN has a free air ionization chamber of the cylindrical type for low energies. The characterization of this ionization chamber was already performed and reported in a previous study. After a modification in the support of the micrometers used for the movement of the internal cylinder devices, the tests were redone. The objective of this work was to present the new alignment protocol of the free air ionization chamber in low energies of X-ray beams of standard mammography qualities, assuring the positioning reproducibility, and new results of stability tests performed with the application of this protocol will be presented.

1. INTRODUCTION

The process that compares the values indicated by a measuring instrument to the values given by a standard (or higher class) equipment is called calibration. The definitions of quantities and measurement units of the International System of Units are on top of that chain of comparisons and immediately after is the Bureau International des Poids et Mesures (BIPM) [1]. Through the calibration, it is possible to obtain an estimated value close to the real value to be measured. It is obtained by a primary standard instrument [2].

The free air ionization chambers receive this name because of the absence of a material in the chamber entry window, causing the primary photons and secondary electrons to interact only with the air sensitive volume [3]. They are absolute dosimeters, for measuring the basic physical quantities and thus the radiological magnitude directly without the need for calibration in a standard radiation beam. It is thus used as a primary standard system for measurement of the exposure and air kerma quantities in beams of X-rays and gamma radiation.

There are different types of free air ionization chambers; the most used is the free air ionization chamber with parallel plates (standard model) and the free air ionization chamber with concentric cylinders (variable volume) [4].

Between these two types of ionization chambers, the conventional model is the most used in calibration laboratories. The main elements of this type of ionization chamber are: entrance opening in the diaphragm and a pair of electrodes separated by a distance d. An electrical potential is applied between the two electrodes, and the guard rings are used to limit the sensitive volume of the ionization chamber [5].

Differently from the conventional model, the cylindrical chamber allows the variation of the sensitive volume lenght. This movement of the cylinders is performed with a high precision equipment which allows a precise determination of the air mass and consequently of the exposure and air kerma values. In this case, the independence of the response to the uniformity of the electric field within the sensitive volume eliminates the need for guard rings. Once the collecting electrode extends throughout the sensitive volume, the collection region is across the internal volume of the cylinder [6].

The ionization chamber with cylinders was proposed by Attix in 1961. For the determination of the air kerma the following equation was used:

$$K_{ar} = \frac{\left(\frac{W_{ar}}{e}\right)(Q_2 - Q_1)}{\rho_{ar}\pi r_{ab}^2 L}\Pi_i k_i \qquad (1)$$

where:

$\frac{W_{ar}}{e}$ is the energy required for the production of a pair of ions in the air;

$(Q_2 - Q_1)$ is the difference between the charge obtained in the second and the first measurements;

ρ_{ar} is the dry air density in the reference environmental conditions;

r_{ab} is the entrance opening radius of the diaphragm;

L is the increase in the sensitive volume length used in the second measurement.

To determine the absolute magnitude of the extension, it is necessary to minimize the uncertainties of the entire system, including the propagation of uncertainties of the X-ray tube, filters and electrometers. In the case of the free air chamber, to define it as a primary standard system, in addition to the concerns about the maintenance of the environmental conditions, it is necessary to minimize the uncertainties related to the correction factors to be applied to the response. One major concern is also related to the alignment of the free air ionization chamber central axis with the X-ray beam. The alignment must be done properly to ensure reproducibility of its positioning.

The objective of this work was to present the new protocol alignment of the free air ionization chamber in X-ray beams of standard mammography qualities, ensuring the reproducibility of positioning and the new results of stability tests performed on the application of this protocol. Furthermore, the performance of the free air ionization chamber was compared with that of the secondary standard ionization chamber used for the calibration of ionization chambers (mammography beams).

2. MATERIALS AND METHODS

The X-ray equipment, Pantak/Seifert, model ISO - VOLT 160 HS, operating between 5 kV and 160 kV, was utilized in this work. Table 1 shows the standard mammography qualities established at the LCI.

Table 1- Standard mammography qualities established at the Calibration Laboratory at IPEN [8].

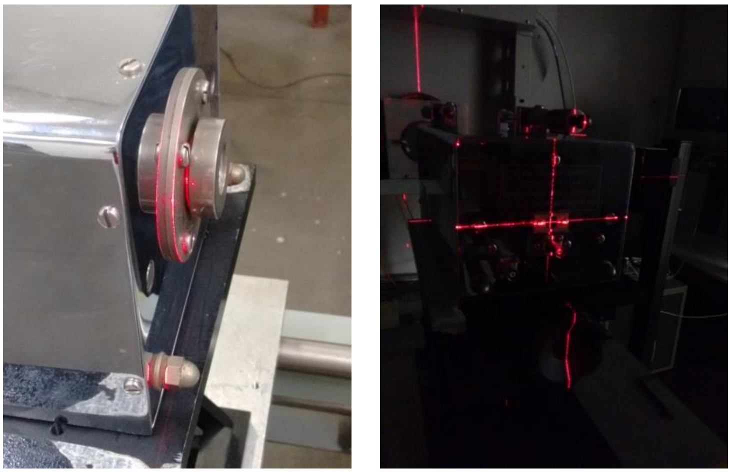
Radiation Quality	Tube Voltage (kV)	Tube Current (mA)	Additional Filtration (mm)	HVL (mmAl)	Air Kerma Rate (mGy/min)
RQR-2M	28	10	0.07 Mo	0.37	13.0
RQR-4M	35	10	0.07 Mo	0.41	19.2
RQA-2M	28	10	0.07Mo+2.0Al	0.61	0.68
RQA-4M	35	10	0.07Mo+2.0Al	0.93	1.48

The free air ionization chamber used was of the cylindrical type, Victoreen, model 481. The secondary standard system, a parallel plate ionization chamber, Radcal, model RC6M, calibrated at the Physikalisch-Technische Bundesanstalt (PTB), was also utilized for comparison purposes in this work.

3. RESULTS AND DISCUSSION

3.1. The new alignment protocol

Initially, the ionization chamber was aligned at 1.0 m distance from the focal point of the X-ray system in the beam, as shown in Figure 1 (a). The central axis of the ionization chamber was then aligned using a laser positioning system, as shown in Figure 1 (b).



(a) (b)

Figure 1 – Alignment of the free air ionization chamber using the positioning lasers. (a) Alignment at the entrance window with the laser positioning at 1.0 m from the focal point; (b) Alignment of the central axis of the ionization chamber

The characterization of this ionization chamber with this alignment procedure was already performed and reported in a previous study, in which the stability tests showed values within those recommended by the IEC 61674 standard (diagnostic radiology beams) [10], but about

13% above the limit recommended by the IEC 60731 (radiotherapy beams) [11]. The characterization tests showed good results for the chamber, except in the volumetric response linearity test [9].

To evaluate the correct positioning of the ionization chamber, a fluorescent screen, composed of a material that scintillates in the X-ray beam, with a video camera, was positioned at the end of the free air ionization chamber with the objective of observing the formed pattern. The system may be seen in Figure 2.

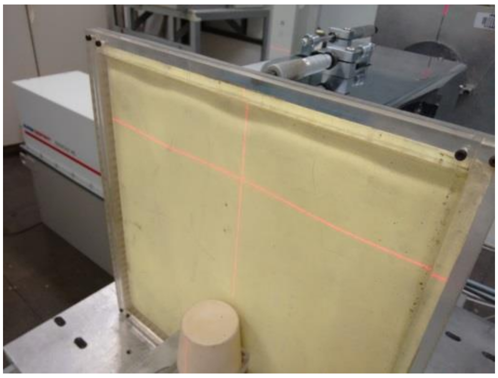
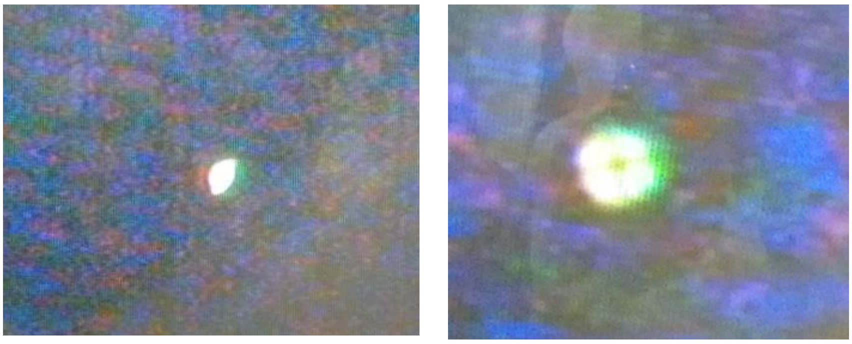


Figure 2 – Positioning of the screen in the X-ray beam.

Using the image formed as a guide, it was possible to make the necessary adjustments for the correct positioning of the ionization chamber. In Figure 3 it is possible to compare the image formed before and after the adjustment.



(a) (b)

Figure 3 – a) Image formed by the X-ray beam before adjustments; b) Image formed by the X-ray beam after adjustments

3.2. Stability Tests

For the stability test, the standard radiation quality of the mammography beam (RQR-2M) was utilized. The ionization chamber was positioned using the new alignment protocol at 1.0 m from the focal point. Ten consecutive measurements were performed after 15 min irradiation, during 3 months, in order to observe the degree of agreement between the measurements. As this test has a continuous feature, it is still in progress.

The results on the repeatability tests were within the limit recommended by the standard IEC 61674 [10], which is 1.0%. Long-term stability was observed with the results obtained in the repeatability tests over a period of three months. According to the IEC 61674 [10], the maximum variation on the measurements results should be 2.0% [10]. As shown in Figure 4, the results obtained are consistent with those recommended.

The standard IEC 60731 [11] recommends a 0.5% limit, and it was used for comparison, because of its most restrictive limit.

The secondary standard ionization chamber used for the calibration of radiation detectors in mammography beams was studied by Corrêa, in relation to its long-term stability, and showed results within 2.0% [8].

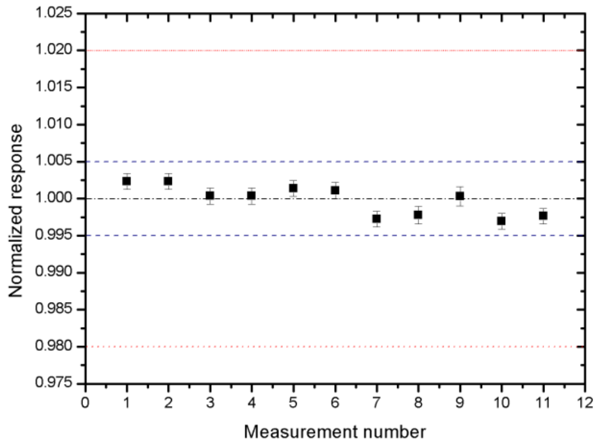


Figure 4 – Long term stability test for the free air ionization chamber. The dotted lines show the limits set by IEC 61674 [10]. The dashed lines show the limits recommended by IEC 60731 [11].

4. CONCLUSIONS

The new alignment protocol was proved effective, and the results obtained from the stability tests show a good operation of the free air ionization chamber, with results within the limits recommended by IEC 61674 [10] and consistent results compared to those of the secondary standard ionization chamber.

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