Use of a Standard Ionization Chamber at Different Distances in Diagnostic Radiology Beams

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Abstract— **A secondary standard ionization chamber was calibrated, by a primary standard laboratory, at a determined distance. However, in the routine procedures of a calibration laboratory, sometimes the radiation detector cannot be positioned exactly at the calibration distance, for any reason. In this work, the response of a secondary standard ionization chamber was tested to verify the possibility of its use at different distances than at the calibration distance, using the same calibration factor.**

Keywords— **Ionization chamber, X-radiation, diagnostic radiology beam qualities.**

I. Introduction

All radiation detectors must be calibrated periodically [1]. The calibration frequency depends on the type of radiation detector. The calibration services are offered by calibration laboratories which may be classified as primary, secondary or regional laboratories.

The primary standard laboratories have primary standards, such as radiation sources and ionization chambers that are used to calibrate radiation detectors. For low- and medium-energy X-radiation, the primary standard is usually a free-air ionization chamber [2].

Secondary standard laboratories have equipment and/ or sources calibrated against primary standards. The secondary standards are calibrated under their usage conditions. These laboratories offer calibration service to clinics, hospitals and other medical services that use radiation detectors. In Brazil, the secondary standard laboratory is located in Rio de Janeiro and it is named National Laboratory of Metrology of the Ionizing Radiations (LNMRI).

The Calibration Laboratory of Instituto de Pesquisas Energéticas e Nucleares (IPEN) is a regional laboratory, and it offers calibration services using X, alpha, beta and gamma radiations. Sometimes, in the calibration laboratory routine, a specific radiation detector cannot be calibrated at the recommended distance. This situation may occur when, the radiation field is not large enough to cover the sensitive volume, or when the air kerma rate is too low that a large irradiation time is necessary or even when it is not possible to position the radiation detector because of geometrical problems.

In this work, a secondary standard ionization chamber was tested at different distances than the calibration distance of 100 cm to verify its utilization under several conditions.

II. Materials

For all tests performed in this work an industrial X-ray unit, Pantak/Seifert, model ISOVOLT 160HS was used. This system operates from 5 to 160 kV, 0.5 to 45.0 mA and presents 0.8 mmBe of inherent filtration. Its standardized beam qualities are shown in Table 1.

A secondary standard plane-parallel ionization chamber, *Physikalisch Technische Werksttäten*, PTW, model 77334-2052, traceable to the German primary standard laboratory *Physkalisch Technische Bundesanstalt* (PTB) [3], was used to establish the diagnostic radiology qualities [4] in the X-ray unit and it was used for the tests described in this work.

III. Results

A. Response stability tests

The short- and medium-term stability tests were performed using the quality beam RQR 4 of the X-ray unit, listed in table 1, that corresponds to 60 kV, 10 mA and 2.5 mmAl of total filtration. Over the period of tests, the leakage current of the ionization chamber was always negligible.

For the short-term stability test ten consecutive measurements of the collected charge were taken. The standard deviation of these measurements presented a maximum value of 1.5%. According to international recommendations this value shall not be higher than ±3% [5].

The medium-term stability test verifies the variation of the mean value of the measurements of the short-term stability test along the time. As can be seen in Figure 1, the maximum variation of the values was 1.6%, thus within the international recommendation of ±2% in a period of one year [5].

Table 1 Characteristics of the X-ray beam qualities of the Pantak/ Seifert unit defined at 100 cm.

Beam quality	Voltage (V)	Total filtration (mmAl)	Half-value layer (mmAl)	Energy (keV)	Air kerma rate ($mGy.min^{-1}$)
Direct Beams					
RQR 3	50	2.5	1.79	27.2	22.82
RQR 4	60	2.5	2.09	28.8	33.98
RQR 5	70	2.5	2.35	30.2	45.59
RQR 6	80	2.5	2.65	31.7	58.49
RQR 7	90	2.5	2.95	33.1	72.67
RQR 8	100	2.5	3.24	34.4	87.56
RQR 9	120	2.5	3.84	37.1	119.59
RQR 10	150	2.5	4.73	40.8	172.44
Attenuated Beams					
RQA 3	50	12.5	3.91	37.3	3.46
RQA 4	60	18.5	5.34	43.3	3.11
RQA 5	70	23.5	6.86	49.4	3.45
RQA 6	80	28.5	8.13	54.8	4.04
RQA 7	90	32.5	9.22	59.7	5.00
RQA 8	100	36.5	10.09	64.0	5.94
RQA 9	120	42.5	11.39	71.2	8.06
RQA 10	150	47.5	13.20	82.1	13.48

B. Linearity of response

The linearity of the ionization chamber response was tested using the beam quality RQR 5, with characteristics shown in table 1. In this test the tube current was varied from 0.5 to 40.0 mA, with the ionization chamber positioned at 50, 100 and 250 cm from the X-ray tube. The results are shown in Figure 2. As expected, the ionization chamber response is linear with the tube current variation for all three distances. The maximum uncertainty of the measurements was 3%.

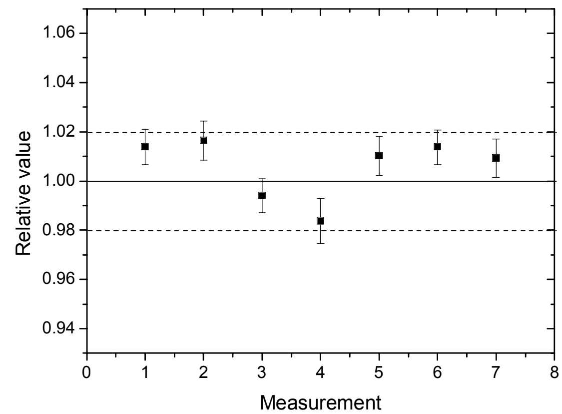

Fig. 1 Response stability of the ionization chamber.

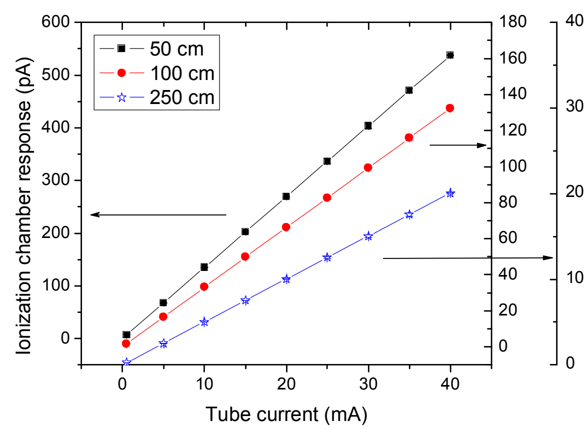

Fig. 2 Response linearity of the ionization chamber at 50, 100 and 250 cm from the X-ray tube.

C. Energy dependence

The energy dependence of the secondary standard ionization chamber was also studied at the distances of 50, 100 and 250 cm.

First of all, the ionization chamber was positioned at the calibration distance of 100 cm. Using the calibration and correction factors given by the primary laboratory [3], the air kerma rates for all X-ray beam quality, diagnostic radiology level, were calculated from the measurements of collected charge. These values of air kerma rate are shown in Table 1.

The same procedure was followed with the ionization chamber positioned at the distances of 50 and 250 cm using the same calibration and correction factors determined for 100 cm. Using the inverse square law, the air kerma rates at these distances were also determined from the values obtained at the distance of 100 cm. The results of measured and calculated values are shown in Figures 3 and 4.

As can be seen in Figures 3 and 4, the measured and calculated values are similar. For direct beam qualities the maximum variations were 5.1% and 3.7% at the distances of 50 and 250 cm, respectively. For attenuated beam qualities the measured and calculated values presented maximum variations of 6.3% and 3.8% at the distances of 50 and 250 cm, respectively. These variations are probably due to the scattered radiation from the beam filtration. The maximum uncertainty of these measurements was only 2%.

In Figure 5 the inverse square law is showed for the radiation quality RQR 5.

IV. CONCLUSIONS

The secondary standard ionization chamber response showed to be stable over the test period.

For the distances of 50, 100 and 250 cm from the X-ray tube focal spot, the ionization chamber response is linear to the tube current range from 0.5 to 40.0 mA.

For the distances of 50 and 250 cm, the measured values of the ionization chamber response in energy were similar to the calculated values, using the inverse square law. The measured values were calculated using the same calibration and correction factors established for the distance of 100 cm by the primary standard laboratory; thus these factors may be used in other distances. The maximum variation was 6% for the attenuated beam quality RQA 10 at the distance of 50 cm.

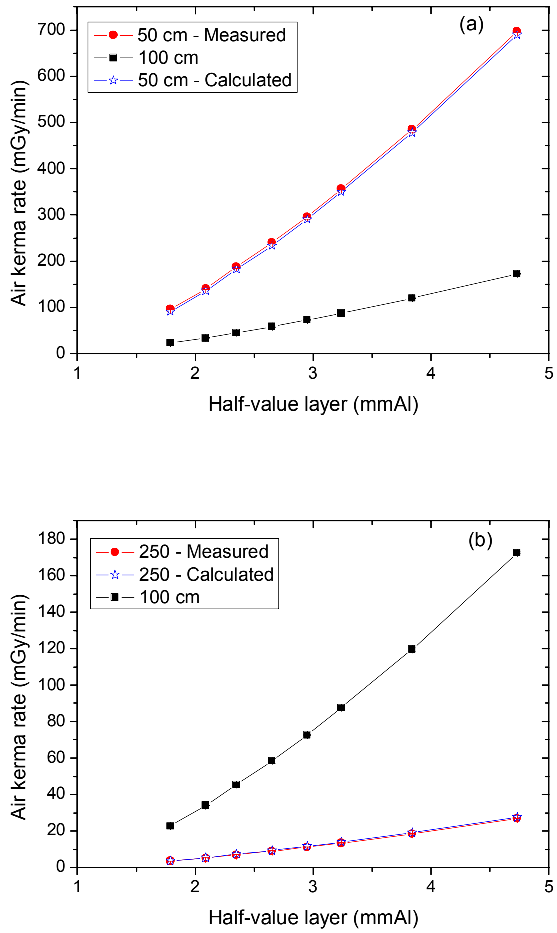

Fig. 3 Energy dependence of the ionization chamber at (a) 50 cm and (b) 250 cm from the X-ray tube for direct beam qualities RQR 3 to RQR 10.

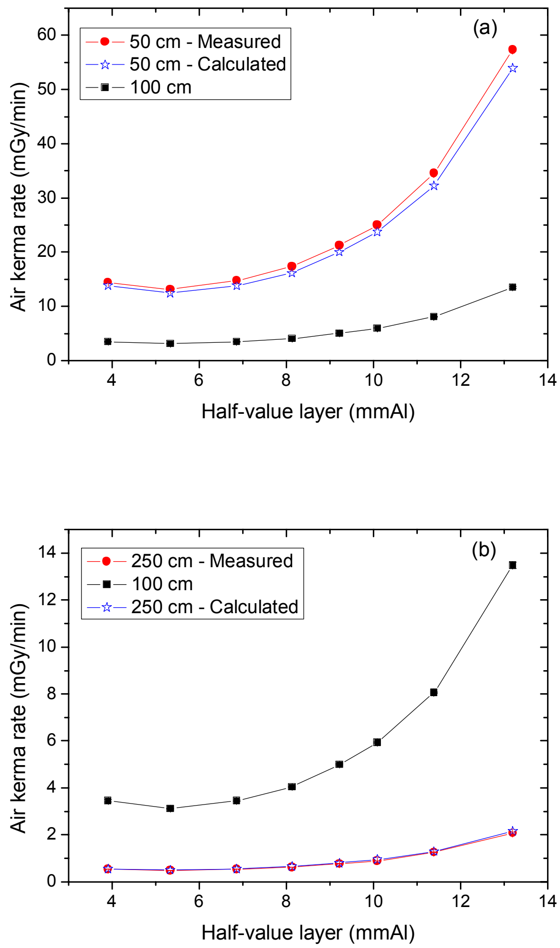

Fig. 4 Energy dependence of the ionization chamber at (a) 50 cm and (b) 250 cm from the X-ray tube for attenuated beam qualities RQA 3 to RQA 10.

In both cases, direct and attenuated beams, the measured values were higher than the calculated values at 50 cm of distance and the contrary occurred at 250 cm of distance. These facts are probably due to the increase in the ionization chamber response with the scattered radiation produced by the beam filtration at 50 cm, and the decrease in the ionization chamber response due to the air attenuation of the X-ray beam at the distance of 250 cm.

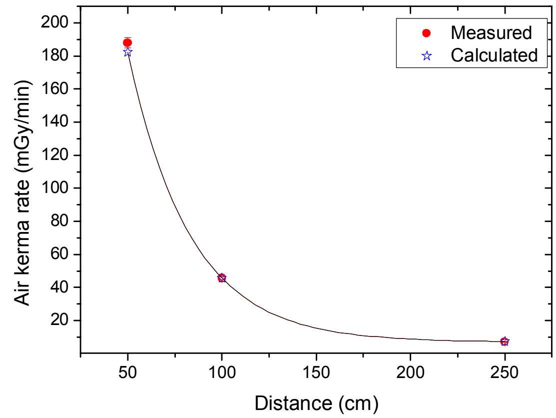

Fig. 5 Inverse square law for the diagnostic radiology beam quality RQR 5.

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