Transferring calibration coefficients from secondary standard ionization chambers to transmission chambers

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Abstract

In this work, the response of a double volume transmission ionization chamber, developed at the Instituto de Pesquisas Energéticas e Nucleares, was compared to that of a commercial transmission chamber. Both ionization chambers were tested in different X-ray beam qualities using secondary standard ionization chambers as reference dosimeters. The response of both transmission chambers was compared to that of the secondary standard chambers to obtain coefficients of equivalence. These coefficients allow the transmission chambers to be used as reference equipment.

Keywords: transmission chamber, X radiation, graphite chamber

1. Introduction

Cavity ionization chambers, calibrated against a free-air chamber in a primary standard laboratory, are used by secondary standard laboratories to determine the air kerma rates of an X-ray unit, to establish beam qualities, and to calibrate field detectors.

In the Calibration Laboratory of IPEN there are some secondary standard ionization chambers traceable mostly to the German primary laboratory Physikalisch-Technische Bundesanstalt, PTB. These ionization chambers were calibrated in different radiation energies and distances, covering radioprotection, radiotherapy and diagnostic radiology levels.

The calibration of instruments using secondary standard ionization chambers, in a routine service, is a time-consuming procedure, and it may damage the equipment since it will be put in and out the radiation field many times a day. One solution for this problem is to transfer the calibration coefficients to the monitor transmission chamber [1].

In this work, the calibration coefficients of secondary standard ionization chambers were transferred to two transmission chambers. A commercial transmission chamber, PTW, and a homemade transmission chamber with a double sensitive volume and graphite coated collecting electrodes were used.

The transferred calibration coefficients, called in this work coefficients of equivalence, will allow the transmission chambers to be used as reference systems provided that their responses are stable.

The objective of this work was to verify the response stability of two transmission ionization chambers and to transfer the calibration coefficients from secondary standard chambers to those transmission chambers.

2. Materials and Methods

In this work four different ionization chambers were used to perform two tests: transference of the calibration coefficients and response stability.

2.1. Materials

The homemade transmission chamber, developed at IPEN, was manufactured using two aluminized polyester foils and a graphite coated polyester foil. The chamber body is made of PMMA and the electrodes are connected to co-axial cables. This ioniza-

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tion chamber has two sensitive volumes wtih a total volume of around 64 cm^3 [2].

The commercial transmission chamber utilized in this work is a transmission chamber, Physikalisch-Technische Werskstätten (PTW), Germany, model 34014, with sensitive volume of 86 cm^3.

Two secondary standard chambers were used: an unsealed cylindrical ion chamber, Radcal, model RC6, calibrated in standard diagnostic radiology quality beams and an unsealed parallel plate ion chamber, Radcal, model RC6M, calibrated in standard mammography quality beams.

A $^{90}Sr+^{90}Y$ check source device, PTW, model 8921, with nominal activity of 33 MBq (1994) was utilized in the response stability tests.

An X-ray unit, Pantak/Seifert, model ISOVOLT 160HS, was utilized to perform the tests. In this work, the diagnostic radiology and mammography beam qualities, as shown in Tables 1 and 2, were used.

Table 1: Characteristics of standard diagnostic radiology beam qualities established in the Pantak/Seifert X-ray unit [3].

Radiation Beam Quality	Voltage (kV)	Additional Filtration (mmAl)	Half-value Layer (mmAl)	Air Kerma Rate (mGy/min)
RQR3	50	2.4	1.78	22.4 ± 0.2
RQR5	70	2.8	2.58	38.6 ± 0.3
RQR8	100	3.2	3.97	69.3 ± 0.5
RQR10	150	4.2	6.57	120.0 ± 1.0
RQA3	50	3.8	12.4	3.3 ± 0.1
RQA5	70	6.8	23.8	3.1 ± 0.1
RQA8	100	10.1	37.2	5.1 ± 0.1
RQA10	150	13.3	49.2	11.3 ± 0.1

2.2. *Methods*

To transfer the calibration coefficients from secondary standard ionization chambers to transmission chambers, both chambers were irradiated at the same time, i.e., the transmission chamber, positioned at 30 cm from the X-ray focal spot was simultaneously irradiated with the standard chamber, positioned at 100 cm from the X-ray focal spot. As the transmission chambers were not irradiated at the same position as the reference equipment (substitution method), this procedure was not called calibration. This procedure was adopted, because irradiating the transmission chamber at the calibration distance of 100 cm makes no sense since its recommended usage position is 30 cm. The chamber responses were compared and coefficients of equivalence for the transmission chambers were obtained for each radiation beam quality from the following equation:

Table 2: Characteristics of standard mammography beam qualities established in the Pantak/Seifert X-ray unit [4].

Radiation Beam Quality	Voltage (kV)	Additional Filtration (mmMo)	Half-value Layer (mmAl)	Air Kerma Rate (mGy/min)
WMV 25	25	0.07	0.36	9.8 ± 0.1
WMV 28	28	0.07	0.37	12.2 ± 0.1
WMV 30	30	0.07	0.38	13.8 ± 0.1
WMV 35	35	0.07	0.41	17.9 ± 0.1

$$N = \frac{M^* \cdot k_T^* \cdot k_p^* \cdot k_c^*}{M \cdot k_T \cdot k_p},$$

where M is the mean value measured with the transmission chamber, k_T and k_p are the correction factors for temperature and pressure, respectively, and k_c is the calibration coefficient of the standard chamber. The symbol ($*$) refers to the secondary standard chamber terms.

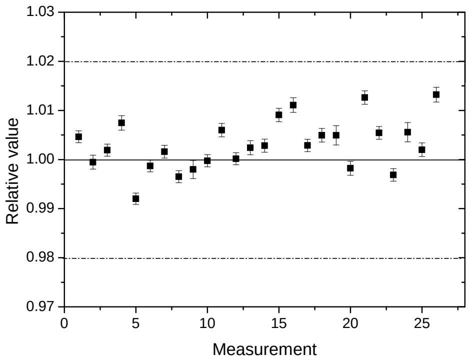
The response stability test of the transmission chambers was performed using both a beta check source device and an X-ray equipment. In this test, the leakage current was evaluated during 20 minutes before and after irradiation. In the repeatability test, 10 measurements were taken consecutively; the standard deviation shall be less than 3% [5]. And, at last, the medium-term stability test was performed evaluating the chamber response during a time interval. According to the IEC publication [5], the response variation shall not exceed ±2%.

3. Results

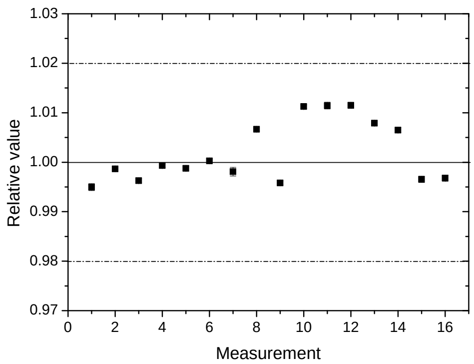
The transmission chambers were first tested using the check source device to verify their response stability. Then, they were tested in X-radiation fields and their coefficients of equivalence and response stabilities were obtained.

3.1. Response stability: Check source device

The leakage current of both transmission chambers was negligible. The repeatability test was performed several times and the maximum variation obatined was 0.3% and 0.8% for the commercial and homemade transmission chambers, respectively. For the medium-term stability test, the maximum variation obtained was 1.3% and 1.1% for the commercial and homemade chambers, respectively. This result can be seen in Figure 1.



(a)



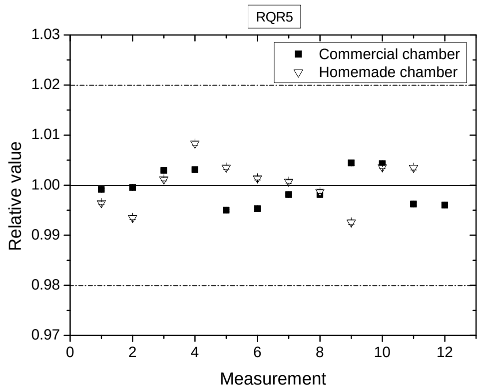
(b)

Figure 1: Medium-term stability test of (a) commercial and (b) homemade transmission chambers using a check source device. The uncertainties in the homemade chamber measurements are lower than 0.1%, and they are not visible in the figure.

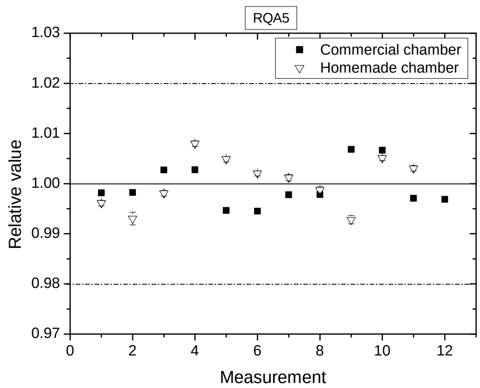
The results obtained in the medium-term stability test were within the recommended value of ±2% [5].

3.2. Response stability: X-rays

The response stability tests were also performed using the X-ray unit. The leakage current of the transmission chambers was negligible. The repeatability and medium-term stability tests were performed using the radiation qualities RQR5 and RQA5, presented in Table 1. The maximum variation obtained for the repeatability test was 0.1% and 0.5% for the commercial and homemade transmission chambers, respectively. For the medium-term stability test, the maximum variation obtained was 0.7% and 0.8% for the commercial and homemade chambers, respectively. Figure 2 shows the results obtained for the medium-term stability test.



(a)



(b)

Figure 2: Medium-term stability test of the transmission chambers using beam qualities (a) RQR5 and (b) RQA5. The uncertainties in the commercial chamber measurements are lower than 0.2%, and they are not visible in the figure.

The results obtained in the medium-term stability test were within the recommended value of ±2% [5].

3.3. *Coefficients of equivalence*

Using the radiation beam qualities listed in Tables 1 and 2, the coefficients of equivalence for both transmission chambers were obtained. Table 3 shows the results for the diagnostic radiology beam qualities and Table 4 shows them for the mammography qualities.

Table 3: Coefficients of equivalence of the transmission chambers using diagnostic radiology beam qualities [3].

	Commercial Chamber	Homemade Chamber
Radiation Beam Quality	Coefficient of Equivalence ($x10^4$ Gy.C^{-1})	Coefficient of Equivalence ($x10^3$ Gy.C^{-1})
RQR3	11.552 ± 0.095	76.237 ± 0.599
RQR5	11.092 ± 0.091	71.272 ± 0.596
RQR8	11.203 ± 0.088	66.497 ± 0.517
RQR10	11.358 ± 0.096	57.520 ± 0.443
RQA3	0.839 ± 0.007	5.492 ± 0.051
RQA5	0.443 ± 0.004	2.847 ± 0.023
RQA8	0.406 ± 0.003	2.416 ± 0.019
RQA10	0.523 ± 0.004	2.692 ± 0.021

Table 4: Coefficients of equivalence of the transmission chambers using mammography beam qualities [4].

	Commercial Chamber	Homemade Chamber
Radiation Beam Quality	Coefficient of Equivalence ($x10^5$ Gy.C^{-1})	Coefficient of Equivalence ($x10^4$ Gy.C^{-1})
WMV25	1.581 ± 0.002	8.274 ± 0.083
WMV28	1.558 ± 0.002	8.196 ± 0.078
WMV30	1.543 ± 0.002	8.151 ± 0.079
WMV35	1.496 ± 0.001	8.029 ± 0.077

The coefficients of equivalence can be used to calibrate other radiation detectors since they are directly related to the calibration coefficients of the standard ionization chambers. This procedure may be utilized since these coefficients of equivalence present good stability. As shown in this work, the transmission chambers of the Calibration Laboratory of IPEN present maximum variations on the response stability of 0.7% and 0.8%. So, in this case, this variation may be considered in the final results and the transmission chamber response stability shall be frequently checked.

4. Conclusions

In this work the calibration coefficients of secondary standard ionization chambers were transferred to two transmission chambers, and coefficients of equivalence were obtained. This transference was adopted to allow the transmission chambers to be used as reference equipment during calibration procedures. The commercial and homemade transmission chambers showed stable responses (0.7% and 0.8%, respectively), within the limits recommended by IEC 61674 [5]. The final result of calibration procedures must consider this response variation, and the response of the transmission chamber shall be frequently checked to confirm its stability.

Acknowledgements

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