Stability Study of Ionization Chambers in Standard Mammography Radiation Beams

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ABSTRACT

The ionization chambers are widely utilized in diagnostic radiology quality control and dosimetry. They are simple to use, and can be found commercially in various types depending on their applications. They are the recommended devices for the determination of the beam qualities in mammographic range. To assure the reliability of the measurements, the stability of the response of the ionization chamber should be within international limits. In this work, the stability of two ionization chambers of the Calibration Laboratory of IPEN was evaluated. The ionization chambers utilized in this work were a homemade tandem ionization chamber and a reference class ionization chamber. They were irradiated in standard mammography beams at the Calibration Laboratory of IPEN. For the short-term stability, the chambers presented a maximum value for the coefficient of variation of 2.9%, within ± 3% as stated in the IEC 61674 standard. The long-term stability test results for the ionization chambers were within ± 2%, as recommended by the international standard.

Key Words: ionization chambers; stability; dosimetry; mammography

1. Introduction

The ionization chambers are the most common type of radiation detectors for dosimetric purposes in diagnostic radiology [1]. They are easy to use and have a simple principle of charge collection. There are many types of ionization chamber but the plane parallel chamber is the most used one for mammographic quality control and dosimetry [2].

For reliable measurements, the ionization chambers should present stable responses over the time. It is important to reduce the errors in the measuring process and to ensure accurate measurements of the beam qualities. The ionization chamber stability response has to be checked periodically [3]. Some authors have reported that this verification is not important only for mammographic beams, but for monitor ionization chambers [4] and diagnostic radiology beams [5].

In this work, the stability of response of two ionization chambers was analyzed. One of them was designed and constructed at the Calibration Laboratory at Instituto de Pesquisas Energéticas e Nucleares (LCI/IPEN). This chamber is a tandem ionization chamber system that was developed for use in quality control programs in mammographic X-rays [5]. The other one was a Radcal RC6M reference ionization chamber.

2. Materials and Methods

In this work, a Pantak Seifert Isovolt 160HS X-ray equipment with tungsten target was used as the irradiation system. This X-ray generator operates from 5 to 160 kV and the tube electric current from 1 to 45 mA. The mammography qualities [6] utilized in this work were established at the LCI/IPEN, and they are described in Table 1. The effective energies were obtained by calculation based on National Institute of Standards and Technology (NIST) X-ray mass attenuation coefficients [7].

Table 1. PTB mammography radiation qualities implemented at LCI/IPEN. Molybdenum and aluminum additional filtrations

Radiation quality	Tube voltage (kV)	Tube current (mA)	Additional filtration		Half-value layer (mmAl)	Effective energy (keV)	Air-kerma rate (mGy/min)
			mmAl	mmMo			
Direct beams							
WMV 28	28	10	---	0.07	0.37	15.7	11.94
WMV 30	30	10	---	0.07	0.38	15.9	13.48
Attenuated beams							
WMH 28	28	10	2.00	0.07	0.61	18.7	0.66
WMH 30	30	10	2.00	0.07	0.68	19.4	0.83

The ionization chambers utilized in this work were a tandem ionization chamber and the Radcal RC6M reference ionization chamber. The tandem ionization chamber was developed at the LCI, and it consists of two ionization chambers of same geometry, but with collecting electrodes of different materials: aluminum and graphite. They were constructed together in the same acrylic body, as a double ionization chamber, and each ionization chamber has a sensitive volume of 6.0 cm^3.

This kind of tandem ionization chamber has the advantage to allow the determination of the effective energy of unknown X-radiation beams [5]. The Radcal RC6M reference ionization chamber was calibrated at Physikalisch-Technische Bundesanstalt (PTB), and it is the reference system for the LCI/IPEN mammography qualities. In Figure 1 are presented both ionization chambers.

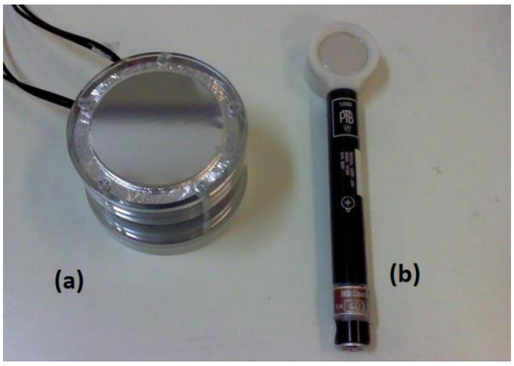

Figure 1. (a) The tandem ionization chamber system and (b) the Radcal RC6M reference ionization chamber

Two electrometers were utilized in this work: a PTW UNIDOS-E and a Keithley 6517A. The first one was utilized for the measurements of the tandem ionization chamber system, which was polarized with +300 V. The Keithley electrometer was utilized with the Radcal RC6M reference ionization chamber, and + 200 V electric potential was applied to the chamber.

The ionization chambers were positioned at the calibration distance of 100 cm from the X-ray focal spot. The experiment setup is presented in Figure 2.

Figure 2. Experimental setup with the tandem ionization chamber system positioned at the calibration distance

All measurements were corrected for the standard environmental conditions of temperature and pressure. The ambient temperature and pressure in the X-ray laboratory were monitored by a Hart Scientific thermometer, 1529 model, and a GE Druck barometer, DPI 142 model. The relative humidity varied between 50% and 60%, and it was controlled using dehumidifiers and an air-conditioning system.

3. Results

The stability of the chambers was evaluated by the repeatability test (short-term stability test) and reproducibility test (long-term stability test). For the repeatability test, ten consecutive measurements were obtained and the mean values were calculated. The result for this test is presented in terms of coefficient of variation that is the standard deviation of the readings expressed as a percentage of the mean value of these readings [3]. These results are presented in Table 2. The tandem ionization chamber was named in Table 2 depending on its collecting electrode material.

Table 2. Repeatability test of the ionization chambers

Radiation quality	Maximum coefficient of variation (%)		
	Tandem chamber		Reference chamber
	Aluminum collecting electrode	Graphite collecting electrode	Radcal RC6M
WMV 28	0.09	0.26	0.12
WMV 30	0.11	0.18	0.12
WMH 28	1.62	2.87	1.83
WMH 30	0.89	1.98	1.78

As stated in the IEC 61674 standard [3], the coefficient of variation of ionization chambers for mammography energy range should be within ±3%. Table 2 shows results within this limit: all ionization chambers followed the international recommendations.

For the reproducibility test, the readings obtained for the repeatability tests were utilized. The tests were undertaken each month over a period of nine months. The mean values from a series of ten repeatability tests, for the four different radiation qualities were evaluated, and are presented in Figures 3 to 6. The recommended limits of response variation in this kind of test are ±2% [3]; the dotted lines in the figures represent these limits.

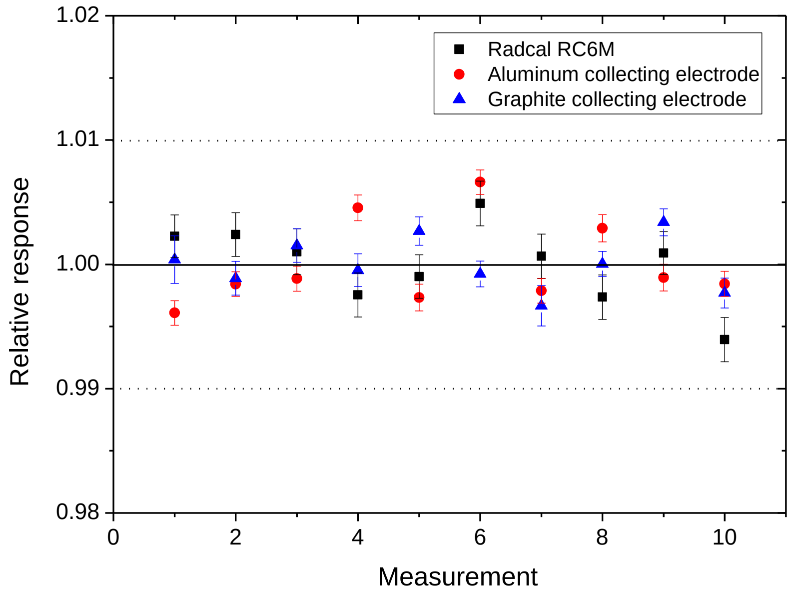

Figure 3. Long-term stability test using the WMV 28 radiation quality of the Radcal RC6M and homemade (with collecting electrodes of aluminum and graphite) ionization chambers. The dotted lines represent the limits of the IEC 61674 standard [3]

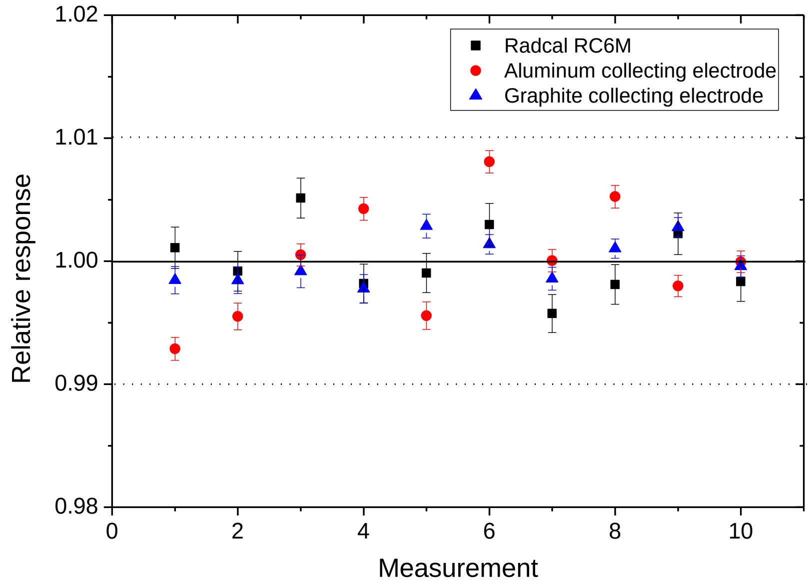

Figure 4. Long-term stability test using the WMV 30 radiation quality of the Radcal RC6M and homemade (with collecting electrodes of aluminum and graphite) ionization chambers. The dotted lines represent the limits of the IEC 61674 standard [3]

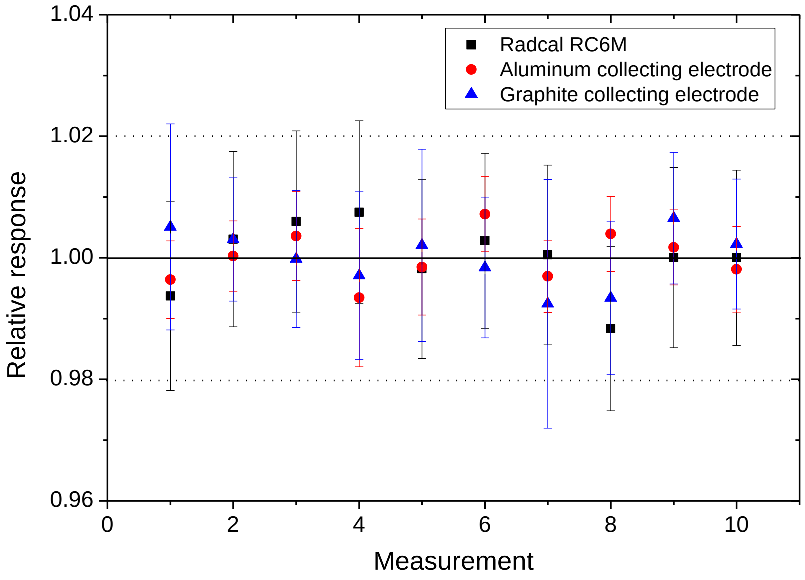

Figure 5. Long-term stability test using the WMH 28 radiation quality of the Radcal RC6M and homemade (with collecting electrodes of aluminum and graphite) ionization chambers. The dotted lines represent the limits of the IEC 61674 standard [3]

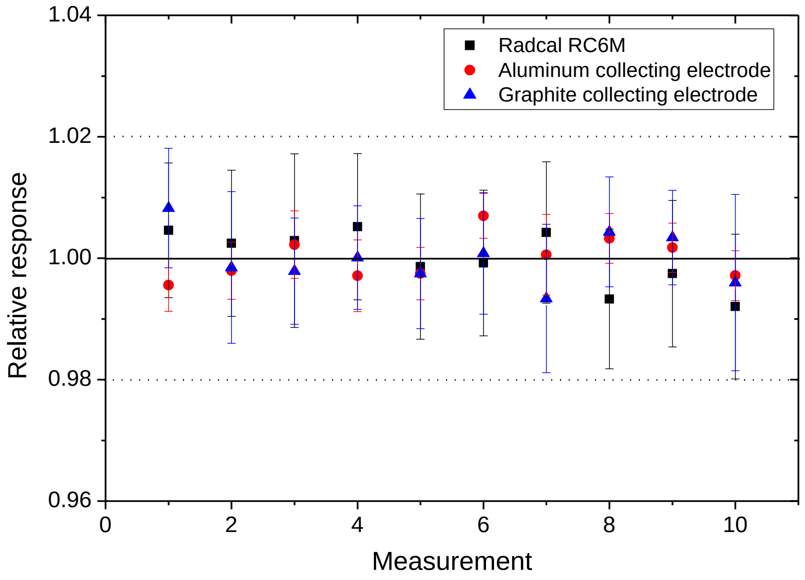

Figure 6. Long-term stability test using the WMH 30 radiation quality of the Radcal RC6M and homemade (with collecting electrodes of aluminum and graphite) ionization chambers. The dotted lines represent the limits of the IEC 61674 standard [3]

As seen in Figures 3 to 6, the ionization chambers utilized in this work presented a long-term stability within the limits stated in the international standard. The maximum variations were presented by the attenuated beams, as shown by the error bars of Figures 5 and 6. This fact is due to the lower air kerma rates in the attenuated beams in relation to those in the direct beams.

4. Conclusions

In this work, the stability of two ionization chambers in standard mammography beams was evaluated. The maximum variation for the repeatability test (short-term stability) was 2.9% for the homemade ionization chamber with the graphite collecting electrode in the standard WMH 28 beam. All ionization chambers presented long-term stability test results within the limits stated in the IEC 61674 standard [3].

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