Evaluation of ionization chambers in X-rays beams used for instruments calibration

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Abstract. The periodically evaluation of ionization chambers and quality control of standard X-ray beams used for purpose to calibration is important to guarantee the calibration procedures of dosimeters and instruments used in radiation protection, diagnostic radiology and radiotherapy routines to ensure that procedures are following the national and international recommendations. Based on that, a quality control routine must be made periodically, to guarantee the good working of these reference ionization chambers and X-ray beams. In this work was compared the performance of different kind of ionization chambers in X-ray beams, level mammography. It has been used as reference a 6 cm³ ionization chamber, from Radcal™, with Mylar™ window, specific for use in mammography beams. The performance of that ionization chamber was compared with other two 180 cm³ (parallel plate chambers) and two 6 cm³ (cylindrical type). The ionization chambers' stability has been made using a $^{90}Sr+^{90}Y$ radioactive source (20 MBq, 2007). After the stability control, the ionization chambers were placed on X-ray beams, mammography level (25, 27.5 and 35 kV, and current of 30 mA), tungsten target with additional filtration of 0.06 mm of molybdenum for direct beams, and plus 2 mm of aluminum for attenuated beams. The results show that the 6 cm³ cylindrical ionization chambers have a maximum variation of 5.08% in the energies range studied, the results show that they could be used as working standard in the calibration laboratory. The 180 cm³ ionization chambers have an average variation of about 20% to direct beams, and about 7,8% to attenuated beams. It is possible conclude, that the 180 cm³ ionization chambers are not very efficient to low energies measurements, although they also can be used in diagnostic radiology X-ray qualities, but to higher energies, and can also be used in radiation protection X-ray qualities.

KEYWORDS: mammography, X-ray beams, quality control, calibration.

1. Introduction

The mammography exam is an important way to diagnosis breast cancer at its beginning. But, in order to be confident in the diagnostic, the mammography equipment must be well calibrated periodically and a carefully quality control program must be established to minimize the dose application to patient[1]. The IAEA published, in 2007, a code of practice to support calibration laboratories and clinics to improve methods in diagnostic radiology[2]. For this, medical diagnostic radiology clinics must use a specific kind of ionization chamber (a 6 cm³ chamber, with Mylar™ window). Although, in some development countries, like Brazil, sometimes is difficult to obtain the right kind of ionization chamber, considering that a medical clinic must also have other ionization chambers (CT chamber, radiation protection chamber, and others). The need of a specific kind of ionization chamber for mammography equipment calibration comes from the fact that the energies used in this diagnostic are relatively low (energy range of 14.8, 15.1 and 16.2 keV), and for this is necessary that the window of the ionization chamber be made of an appropriate material, so the X-rays can pass through it with as less interactions as possible[3]. In some cases, the only kind of ionization chamber that some medical clinics have is the 180 cm² chamber or the 6 cm³ chamber, both used commonly in conventional diagnostic radiology and radiation protection. These ionization chambers have a thicker window than the ionization chamber with a Mylar™ window, what can difficult the measurements of low energy photons. The objective of this work is to analyze the behavior of different kinds of ionization chambers in X-ray beams, mammography level, and show how trustworthy they are when they are used to calibrate or verify the constancy of mammography equipments.

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2. Materials and Methods

For this work, the selected ionization chambers have been studied and compared, based on each ionization chambers volume, type and usefulness. The table 1 shows the comparison between the ionization chambers, and the Fig. 1 shows the ionization chambers.

Table 1: Main characteristics of the ionization chambers used in this comparison

Code [(a)]	Ionization Chamber Model [(b)]	Type [(c)]	Application [(d)]
C1	180cm³	Parallel Plate	Diagnostic Radiology and Radiation Protection
C2	180cm³	Parallel Plate	Diagnostic Radiology and Radiation Protection
C3	6cm³	Cylindrical Type	Conventional Diagnostic Radiology
C4	6cm³	Cylindrical Type	Conventional Diagnostic Radiology
C5	6cm³-mammo	Parallel Plate Mylar™ window	Standard X-rays beams mammography level

[(a)] Identification of each ionization chamber
[(b)] Volume of each ionization chamber
[(c)] Ionization chamber type
[(d)] Most common use for each ionization chamber.

Figure 1: From left to right, C1, C2, C3, C4 and C5 ionization chambers

The ionization chambers' stability control has been made using a $^{90}Sr+^{90}Y$ radioactive source (20 MBq, 2007). After the control, all the ionization chambers have been placed on X-ray beams, mammography level (25, 27.5 and 35 kV,current of 30 mA, focal spot distance of 1 m), X-ray tube with tungsten target with additional filtration of 0.06 mm of molybdenum (purity of 99.99%) for direct beams, and plus 2 mm of aluminum for attenuated beams[3]. The X-ray equipment used in this work was a *Rigaku Denki Co. Ltda* generator, Japan, *Geigerflex* type (constant potential).

The calibration method used in this work was the substitution method[4]. The C5 ionization chamber has been placed on X-ray beam, mammography level. Ten successive measurements have been taken (kerma rate in air, in mGy/min). The values of temperature and atmospheric pressure have also been noted, and with these values, the correction factor for temperature and pressure could be calculated, using the following equation:

$$f_c = \left(\frac{101.325}{p} \, x \, \frac{273.15 + T}{273.15 + T_c} \right) \quad (1)$$

p = measured pressure (kPa)
T = measured temperature (ºC)
T_c = reference temperature (20 ºC)

This correction factor must be multiplied by the measurement, obtaining the corrected measurement. After that, the measurements were multiplied by the calibration coefficients supplied by the Food and Drug Administration, traceable to NIST and the air kerma rates were obtained. After this, the other ionization chambers have been placed on the same X-ray beam quality, in the same conditions and the procedure has been followed.

The average value (corrected measurement) of each ionization chamber has been compared with the average kerma rate in air obtained with the reference ionization chamber, for each quality. A calibration coefficient has been determined. With this result is possible to compare the behavior of each ionization chamber in relation with the reference ionization chamber obtained measurements.

3. Results

The results obtained are shown in table 2. The values in the columns *Calibration Coefficient* have been calculated dividing each value of *air Kerma rate* (value obtained with the standard ionization chamber), for each quality, by the respective Corrected measurement (value obtained with the tested ionization chamber). In each table, the first three values are for direct beams, and the last three, with an *x* index, are for attenuated beams. For the uncertain have been used the expanded uncertainty of ± 3% using a coverage factor of 2, which corresponds approximately to a 95% confidence level. This uncertainty has been provided by ***U.S. Food and Drug Administration (FDA)*** in the calibration report of the standard ionization chamber, which has made the calibration of these kind ionization chambers. This is the biggest uncertainty that we have in this arrangement, if comparing with other uncertainties, like electrometer measurements uncertainties and the uncertainties in the correction factor for temperature and pressure. Because of that is reasonable assure that the main uncertainties in the measurements is closer that in calibration report of the standard ionization chamber used in this work.

Table 2: The compared results obtained for all the ionization chambers.

Beam quality	**Air Kerma rate (mGy/min)**	**Calibration Coefficient**			
		C1	**C2**	**C3**	**C4**
M25	31,143	1,2051	1,2197	1,0073	1,0351
M28	37,694	1,1988	1,2126	1,003	1,0324
M35	57,548	1,184	1,1967	0,9998	1,0246
M25x	1,433	1,0938	1,102	0,9567	0,9723
M28x	1,96	1,0687	1,0889	0,9565	0,9695
M35x	4,523	1,0575	1,0557	0,9492	0,9581

The uncertainty is of ± 3% for all the values

4. Conclusion

The results show that C1 and C2 ionization chambers are not good to be used as reference ionization chambers in non-attenuated X-ray beams, mammography level. The calibration factors were from 18.4% to 21.97% to those radiation qualities. This happened because these ionization chambers have a different volume and geometry comparing with C5 standard ionization chamber, causing a difference between the responses of those ionization chambers. Beyond this, these ionization chambers have a very thick wall, which can attenuate the incident photon with low energy. Although, for attenuated beams, the calibration factor were from 5.57% to 10.20%. This happens because, in this situation, the aluminum filter (2 mm) cut low energies, making the beam most hard. In this case, in a graphic *counts* x *energy*, the peak for high energies increase, and the photons have less difficult to get through the ionization chamber wall and get the sensible volume of it. In this case these ionization chambers can be used as reference.

About the C3 and C4 ionization chambers, the results show that both can be used as reference, in any quality, for attenuated and non-attenuated beams. This happens because these ionization chambers have the same volume of air that the reference ionization chamber (C5 ionization chamber, specific for use in mammography qualities) has. Beyond this, the window of these ionization chambers is very thin, so it can be used in X-ray beams with low energy photon.

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