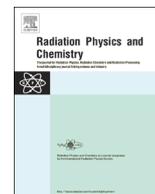




ELSEVIER

Contents lists available at ScienceDirect

Radiation Physics and Chemistry

journal homepage: www.elsevier.com/locate/radphyschem

Characterization tests of a homemade ionization chamber in mammography standard radiation beams



J.O. Silva*, F.B.C. Nonato, L.V.E. Caldas

Instituto de Pesquisas Energéticas e Nucleares, Comissão Nacional de Energia Nuclear—IPEN-CNEN/SP, Avenue Professor Lineu Prestes 2242, São Paulo 05508-000, Brazil

HIGHLIGHTS

- We constructed a mammography homemade ionization chamber. It was submitted to standard mammography X-rays beam qualities.
- The results obtained showed good agreement with international standards.
- This chamber can be used in quality control programs of diagnostic radiology area.

ARTICLE INFO

Article history:

Received 27 September 2012

Accepted 3 March 2013

Available online 15 March 2013

Keywords:

Ionization chamber
Mammography
Instrumentation

ABSTRACT

A mammography homemade ionization chamber was developed to be applied for mammography energy range dosimetry. This chamber has a sensitive volume of 6 cm³ and is made of a Lucite body and graphite coated collecting electrode. Characteristics such as saturation, ion collection efficiency, linearity of chamber response versus air kerma rate and energy dependence were determined. The results obtained with the mammography homemade ionization chamber are within the limits stated in international recommendations. This chamber can be used in quality control programs in the diagnostic radiology area. All measurements were carried out at the Calibration Laboratory of IPEN.

© 2013 Elsevier Ltd. All rights reserved.

1. Introduction

Ionization chambers are the most common type of detector in diagnostic radiology for the routine verification of dosimetric parameters such as air kerma rates in medical X-ray equipment (IAEA, 2007). Therefore, ionization chambers have to follow high quality control standards and be calibrated in well-known radiation fields. Accurate dosimetry is important to guarantee the dose optimization associated with adequate images for correct diagnoses and treatments (ICRP, 2004; Meghizifene et al., 2010). Research centers as IPEN have developed ionization chambers for laboratory and clinical applications (Yoshizumi and Caldas, 2010; Perini et al., 2012; Silva and Caldas, 2012) with low cost materials and high metrological rigor. Among these ionization chambers, mammography chambers were assembled to be utilized in mammography radiation beams and other qualities.

In this work, an ionization chamber is presented for dosimetry in mammography beams. This ionization chamber is made of a plastic material and has a thickness of 2 cm, which is adequate for radiation dosimetry in mammography phantoms with 2 cm in

thickness (IAEA, 2011). Furthermore, this ionization chamber, called mammography homemade ionization chamber, has a sensitive volume of 6.0 cm³. This ionization chamber was characterized with respect to the saturation of ionization current, ion collection efficiency, polarity effect, linearity of response and energy dependence.

2. Materials and methods

The mammography homemade ionization chamber has a sensitive volume of 6.0 cm³ and a distance of 5 mm between the inner electrodes. A picture and a drawing of this ionization chamber are presented in Fig. 1. The chamber body, collecting electrode and guard ring are made of Lucite. The collecting electrode and the guard ring have a graphited coating of around 0.35 μm. To establish the electric field, aluminized polyester with 1.87 mg cm⁻² of superficial density was utilized for the entrance window. A PTW-Freiburg UNIDOS electrometer was utilized to polarize and collect the readings of the mammography homemade ionization chamber. Coaxial cables and connectors were used for the electrical connection between the ionization chamber and the electrometer.

The radiation systems were a PTW 8921 check source of ⁹⁰Sr+⁹⁰Y (33 MBq, 1994) and a Pantak Seifert Isovolt 160HS X-

* Corresponding author. Tel.: +55 11 9 8509 8385.

E-mail addresses: jonas.silva@ipen.br (J.O. Silva), fbnonato@ipen.br (F.B.C. Nonato), lcaldas@ipen.br (L.V.E. Caldas).

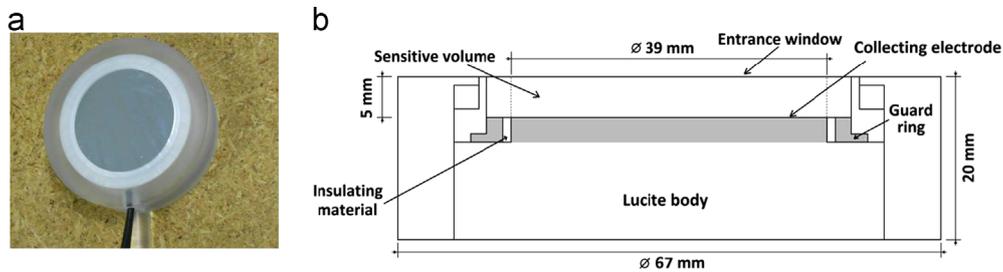


Fig. 1. (a) Photo and (b) scheme of the mammography homemade ionization chamber.

Table 1

PTB mammography radiation qualities established at LCI, with molybdenum and aluminum additional filtrations.

Radiation quality	Tube voltage (kV)	Tube current (mA)	Additional filtration		Half-value layer (mmAl)	Air kerma rate (mGy/min)
			mmAl	mmMo		
<i>Direct beams</i>						
WMV 25	25	10	–	0.07	0.36	9.56
WMV 28	28	10	–	0.07	0.37	11.94
WMV 30	30	10	–	0.07	0.38	13.48
WMV 35	35	10	–	0.07	0.41	17.53
<i>Attenuated beams</i>						
WMH 25	25	10	2.00	0.07	0.56	0.46
WMH 28	28	10	2.00	0.07	0.61	0.66
WMH 30	30	10	2.00	0.07	0.68	0.83
WMH 35	35	10	2.00	0.07	0.93	1.46

ray equipment with tungsten target, which operates from 5 kV to 160 kV (the current can vary from 0.1 mA to 45 mA) with an inherent filtration of 0.8 mm Be. These radiation systems are located at the Calibration Laboratory (LCI) at IPEN. The PTB WMV (direct beams) and WMH (attenuated beams) mammography qualities (PTB, 2009) utilized in this work are established at LCI, and they are described in Table 1. As the mammography homemade ionization chamber is not sealed, it was necessary to make corrections in the readings for the environmental standard conditions of temperature and pressure (20 °C and 101.3 kPa).

3. Results and discussion

The mammography homemade ionization chamber was studied with respect to the saturation curve, ion collection efficiency, polarity effect, linearity of response and energy dependence. The ionization chamber was tested in standard mammography radiation qualities.

4. Saturation curve

The mammography homemade ionization chamber was irradiated sequentially with the WMV 28 radiation quality (Table 1), by using the entrance window for the reference distance of 100 cm. The ionization chamber was polarized with ± 50 V to ± 400 V in steps of ± 50 V. The saturation curve is shown in Fig. 2. The ionization currents were determined as mean values of ten measurements for each voltage value. The uncertainties in the ionization currents were always lower than 0.05% for both polarities. It can be seen that the ionization current is constant starting at ± 50 V, and presents a symmetrical behavior when a change in the polarity signal occurs.

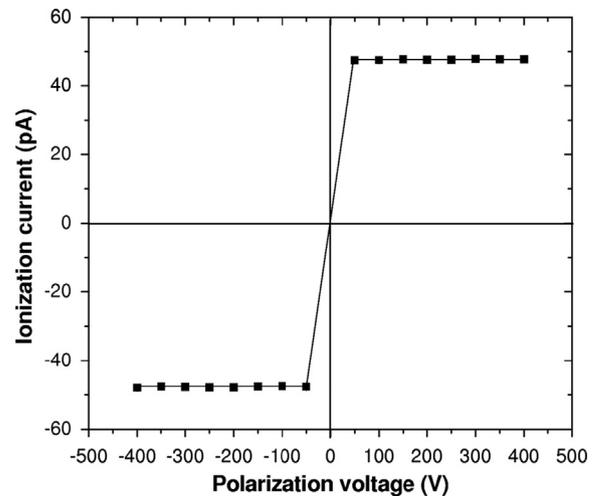


Fig. 2. Saturation curve of the mammography homemade ionization chamber. The uncertainties were lower than 0.05%, not visible in the figure.

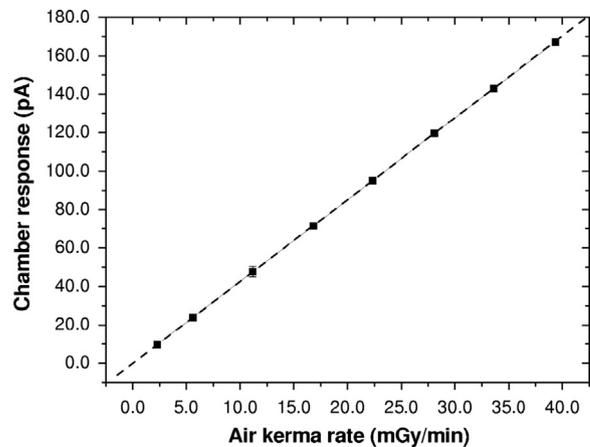


Fig. 3. Linearity of response of the mammography homemade ionization chamber. The maximum uncertainty was 2.7%.

5. Ion collection efficiency and polarity effect

The ion collection efficiency, k_s , was determined by the two-voltage method (IAEA, 2000) using the results obtained for the saturation curve

$$K_s = \frac{(V_1/V_2)^2 - 1}{(V_1/V_2)^2 - (M_1/M_2)} \quad (1)$$

where M_1 and M_2 are the electrometer measurements corrected for the influence of temperature and pressure at voltages V_1 and V_2 and $V_1 = 2V_2$ (IAEA, 2000). The voltage V_1 is the value normally used for this kind of chamber, and in this case it was ± 300 V. For

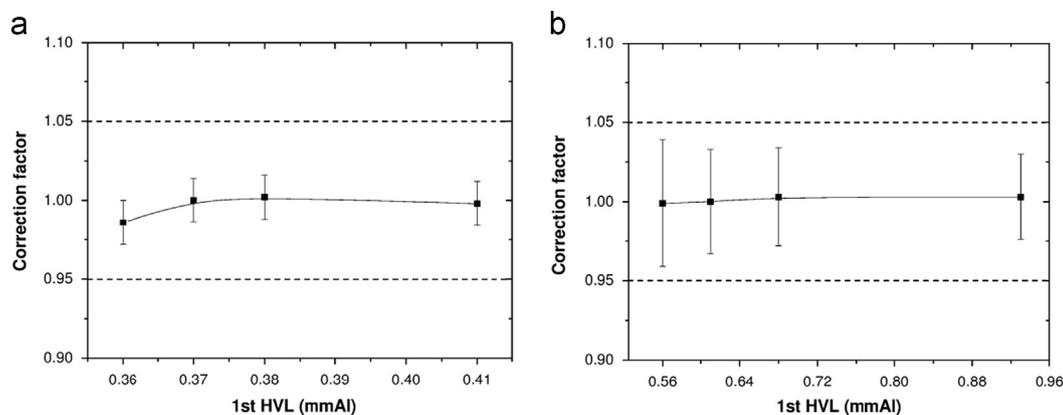


Fig. 4. Energy response of the mammography homemade ionization chamber for (a) WMV radiation qualities (direct beams) and (b) WMH radiation qualities (attenuated beams). The dotted lines represent the IEC limits for this test.

this chamber, the ion collection efficiency is 0.9995 for the positive polarity and 0.9992 for the negative polarity. It can be seen that the mammography homemade ionization chamber presents an ion collection efficiency better than 99.9%, so the recombination losses are lower than 1.0%, as recommended by IEC (1997).

Another important characterization check is the polarity effect that shows how the change in the chamber polarity affects the ionization chamber response (Zhu, 2010), that should be within 1.0%, as stated by IEC (2011). In the saturation region, the effect of the polarity was less than 1.0% for the mammography homemade ionization chamber.

6. Linearity of response

The linear relationship between the ionization current and the air kerma rate was determined by exposing the chamber to the WMV 28 radiation quality. The ionization chamber was positioned at the calibration distance, and it was polarized with +300 V. The tube current varied from 2.0 mA to 35.0 mA to obtain different values of air kerma rates. For each point, ten measurements were taken, and the average values are presented in Fig. 3 with their respective uncertainties. The mammography homemade ionization chamber exhibited a linear response in the studied range of air kerma rate, and the correlation coefficient was greater than 0.9999.

7. Energy dependence

The response variation of the mammography homemade ionization chamber with the beam quality was studied using the radiation qualities listed in Table 1. In Fig. 4 are presented the response of the ionization chamber in terms of correction factors, normalized to the qualities WMV 28 and WMH 28.

It can be seen that the mammography homemade ionization chamber has a flat response with a variation within $\pm 5.0\%$, as recommended by IEC for this kind of detector (IEC, 1997).

8. Conclusions

The mammography homemade ionization chamber was tested in standard mammography radiation fields established at LCI. This ionization chamber showed an adequate response in all characterization tests using the reference mammography WMV 28 quality

and the $^{90}\text{Sr} + ^{90}\text{Y}$ control source. Using the saturation curve data, it was possible to verify the polarity effect, that was negligible for this ionization chamber in the polarization voltages utilized in this work. The recombination losses were within international recommendations too.

The ionization chamber presented a flat energy response over the studied range of direct and attenuated mammography beams. Therefore, it can be concluded that the mammography homemade ionization chamber can be used in the mammography radiation qualities established at LCI, in quality control programs.

Acknowledgments

The authors are thankful to the Brazilian agencies CNPq, CAPES, FAPESP and MCT (INCT for Radiation Metrology in Medicine), for partial financial support.

References

- IAEA (International Atomic Energy Agency), 2000. Absorbed dose determination in external beam radiotherapy: an international code of practice for dosimetry based on standards of absorbed dose to water. Technical Report Series no. 398. IAEA, Vienna.
- IAEA (International Atomic Energy Agency), 2007. Dosimetry in diagnostic radiology: an international code of practice. Technical Report Series no. 457. IAEA, Vienna.
- IAEA (International Atomic Energy Agency), 2011. Quality assurance programme for digital mammography. Human Health Series no. 17. IAEA, Vienna.
- ICRP (International Commission on Radiological Protection), 2004. Managing patient dose in digital radiology. ICRP Publication 93, ICRP, Ottawa.
- IEC (International Electrotechnical Commission), 1997. Medical electrical equipment: dosimeters with ionization chambers and/or semi-conductor detectors as used in X-ray diagnostic imaging. Standard IEC 61674. IEC, Geneva.
- IEC (International Electrotechnical Commission), 2011. Medical electrical equipment: dosimeters with ionization chambers as used in radiotherapy. Standard IEC 60731. IEC, Geneva.
- Meghizifene, A., Dance, D.R., McLean, D., Kramer, H.-M., 2010. Dosimetry in diagnostic radiology. *Eur. J. Radiol.* 76 (1), 11–14.
- Perini, A.P., Neves, L.P., Vivolo, V., Xavier, M., Khoury, H.J., Caldas, L.V., 2012. Characterization of a CT ionization chamber for radiation field mapping. *Appl. Radiat. Isot.* 70 (7), 1300–1303.
- PTB (Physikalisch-Technische Bundesanstalt), 2009. Radiation qualities used for studies in radiation protection ISO-PTB. Available from: (www.ptb.de/en/org/6/62/625/pdf/strhlq.pdf) (accessed 21.09.12).
- Silva, J.O., Caldas, L.V.E., 2012. Characterization of a new ionization chamber in radiotherapy beams: angular dependence and variation of response with distance. *Appl. Radiat. Isot.* 70, 2534–2538.
- Yoshizumi, M.T., Caldas, L.V.E., 2010. A new ring-shaped graphite monitor ionization chamber. *Nucl. Instrum. Methods Phys. Res. A* 619, 207–210.
- Zhu, T.C., 2010. Small field: dosimetry in electron disequilibrium region. *J. Phys. Conf. Ser.* 250, 1–10.