COMPARISON OF THE ENERGY DEPENDENCE OF TWO HOMEMADE IONIZATION CHAMBERS IN RELATION TO A STANDARD IONIZATION CHAMBER IN LOW-ENERGY KILOVOLTAGE X-RAY BEAMS, THERAPY LEVEL

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Abstract

Two homemade parallel plate ionization chambers and a reference ionization chamber were tested in standard radiation qualities, radiotherapy level (low energies) T-10, T-25, T-30 and T-50 to compare their energy dependence. The result of one homemade ionization chamber with graphite collecting electrode was very good comparing to the result of the standard ionization chamber. The other homemade ionization chamber with aluminum collecting electrode presented a high energy dependence as expected, because both chambers constitute a tandem system.

1. INTRODUCTION

Radiation therapy treatments require high accuracy of the dose delivered to the patient. An excessive dose can cause tissue damage and an insufficient dose does not provide an efficient treatment [1].

The dose delivered needs to vary less than 5% [2]. One very important procedure is the beam calibration to which the patient is submitted. There are many dosimeters used to calibrate gamma and electron radiation beams, as calorimeters, Fricke gel, diodes, thermoluminescent dosimeters and ionization chambers. The ionization chambers are considered practical instruments and they are the most utilized to determine the absorbed doses in radiotherapy, especially to determine absorbed doses in water [3-5].

At the Calibration Laboratory of IPEN, to contribute with the routine of the calibration procedures and to obtain knowledge in the processes of the calibration and instrumentation, several ionization chambers of different types, such as cylindrical and parallel plate ionization chambers, were developed for different applications [6-10].

The objective of this work was to determine the energy dependence of two homemade parallel-plate ionization chambers, in comparison with the energy dependence of a reference ionization chamber utilized to calibrate low-energy kilovoltage X ray beams. This kind of radiation beam is used in skin lesion treatments [11].

2. MATERIALS AND METHODS

Two homemade ionization chambers and one reference ionization chamber PTW 2344-0709 with traceability to the Deutscher Kalibrierdienst (96D033 DKD-K-01501 / 96-11), all parallel-plate type, were tested in standard low-energy kilovoltage X-ray beams. One homemade ionization chamber has a collecting electrode made of aluminum and the other of graphite; both ionization chambers have 0.056 cm^3 of volume and are made of acrylic material (PMMA). The sensitive volume of the standard ionization chamber is 0.2 cm^3. Several characterization tests of the homemade ionization chambers were undertaken, following international recommendations: short-term stability, polarity effects, determination of the ion collection efficiencies, saturation curves and linearity of their response. The results obtained were within the international recommendations [12].

The ionization chambers were polarized to ±300 V and connected to a PTW UNIDOS electrometer. A Pantak Seifert Isovolt 160HS X ray equipment and the standard radiation qualities, radiotherapy level (low energies) T-10, T-25, T-30 and T-50, were utilized. The characteristics of the radiation qualities are presented in Table 1.

TABLE I. CHARACTERISTICS OF THE RADIOTHERAPY LEVEL (LOW ENERGIES) BEAMS, QUALITIES T [13]

Radiation quality	Voltage (kV)	Current (mA)	Half-value layer (mm Al)	Additional filtration (mm Al)	Air kerma rate (mGy/s)
T-10	10	10	0.043	-	3.130 ± 0.013
T-25	25	10	0.279	0.4	2.762 ± 0.011
T-30	30	10	0.185	0.2	9.638 ± 0.042
T-50(a)	50	10	2.411	4.0	0.821 ± 0.004
T-50(b)	50	10	1.079	1.0	4.027 ± 0.016

3. RESULTS

For each ionization chamber, the measurements were obtained taking 10 consecutive readings during 20 seconds, for all qualities. The measurements were collected in electric charge (nC) and then the calibration coefficients were obtained in terms of air kerma. The correction factors were determined in relation to the radiation quality T-30 (reference beams). Correction factors of standard environment conditions (temperature and pressure) were applied. The results are presented in Table 2.

TABLE II. CALIBRATION COEFFICIENTS AND CORRECTION FACTORS OF THE IONIZATION CHAMBERS

Chamber type	Radiation quality	Calibration coefficients (mGy/nC)	Correction factors
Ionization chamber PTW 2344-0709	T-10	100.74 ± 0.83	1.05 ± 0.01
	T-25	92.02 ± 0.75	0.95 ± 0.01
	T-30	96.38 ± 0.81	1.00 ± 0.01
	T50(a)	87.44 ± 0.73	0.91 ± 0.01
	T50(b)	89.88 ± 0.73	0.93 ± 0.01
Homemade chamber (aluminum electrode)	T-10	357.10 ± 2.77	1.38 ± 0.02
	T-25	236.65 ± 1.82	0.92 ± 0.01
	T-30	258.58 ± 2.04	1.00 ± 0.01
	T50(a)	170.35 ± 1.34	0.66 ± 0.007
	T50(b)	177.94 ± 1.31	0.69 ± 0.007
Homemade chamber (Graphite electrode)	T-10	405.83 ± 3.21	1.06 ± 0.01
	T-25	379.21 ± 2.96	0.99 ± 0.01
	T-30	383.43 ± 3.00	1.00 ± 0.01
	T50(a)	351.31 ± 2.79	0.92 ± 0.01
	T50(b)	368.84 ± 2.81	0.96 ± 0.01

The tandem factors were obtained by the ratio of the response of the homemade parallel-plate ionization chambers and are presented in Table 3. The tandem curve was obtained by the tandem factors in function of the half-value layer. The correction factors in function of the half-value layers and a tandem curve are presented in Figure 1 for a better visualization of their behaviors.

TABLE 3. TANDEM FACTORS OF THE HOMEMADE IONIZATION CHAMBERS

Radiation quality	Half-value layer (mm Al)	Tandem factors
T-10	0.043	1.136 ± 0.013
T-25	0.279	1.160 ± 0.017
T-30	0.185	1.482 ± 0.016
T50(a)	2.411	2.062 ± 0.023
T50(b)	1.079	2.073 ± 0.022

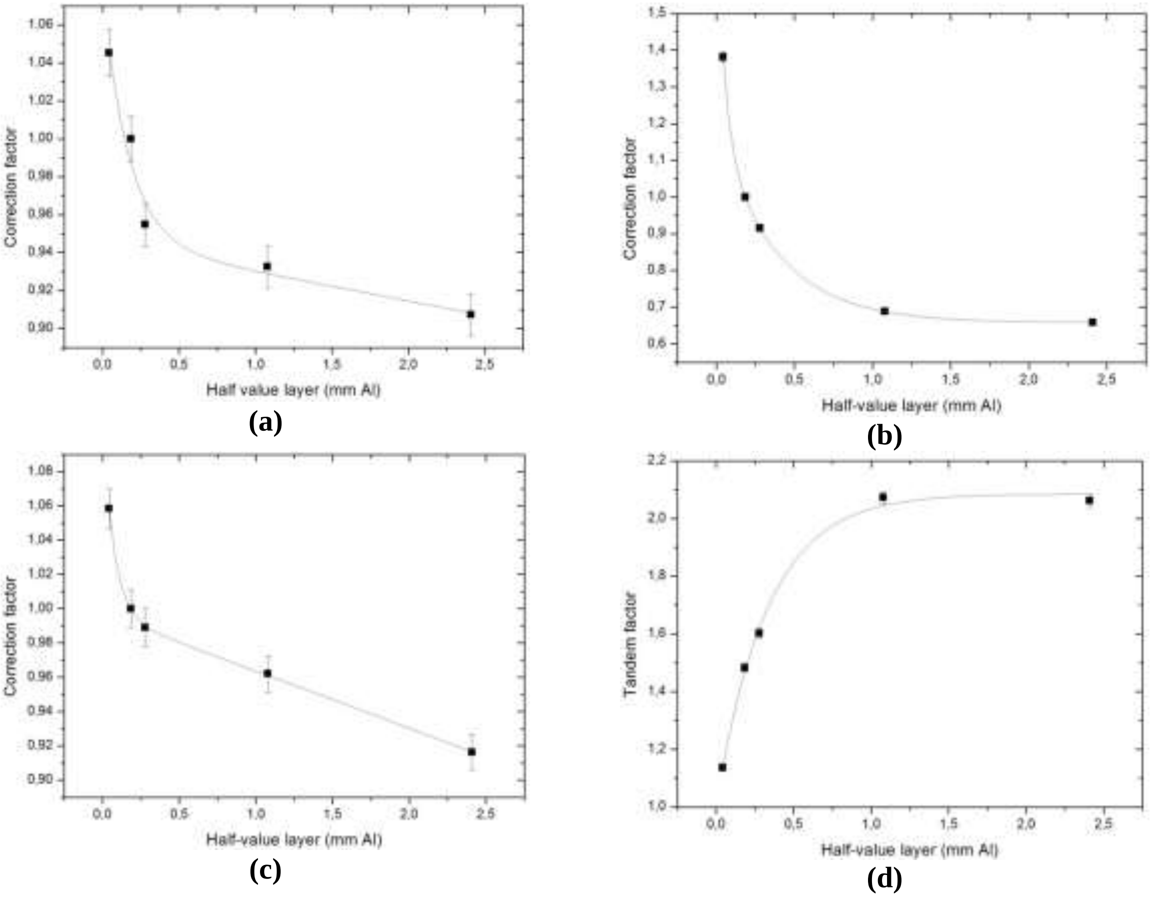

FIG. 1. Correction factors in relation to the half-value layers of: (a) the ionization chamber PTW 2344-070, (b) homemade ionization chamber with aluminum collecting electrode, (c) homemade ionization chamber with graphite collecting electrode and (d) a tandem curve.

The maximum energy dependence of the reference ionization chamber PTW 2344-0709 was 9.3%. The homemade ionization chamber (graphite collecting electrode) presented a good result of 8.4%, comparing with the standard ionization chamber. The homemade ionization chamber (aluminum electrode) presented 38% of energy dependence which is an expected result due to the aluminum collecting electrode. The two homemade ionization chambers were designed to compose a tandem ionization chamber, with the characteristics of very different energy dependences. The tandem curve**,** according to Figure 1, enables a routine check of the beam effective energy in radiotherapy T qualities, without the need for additional absorbers.

4. CONCLUSION

Two homemade parallel-plate ionization chambers and a reference parallel-plate ionization chamber were tested in standard radiation qualities, radiotherapy level (low energies) with the objective of comparing their energy dependence. The homemade ionization chamber with graphite collecting electrode presented good result with a maximum energy dependence of 8.4%, when compared with the reference ionization chamber (9.3%). The homemade ionization chamber with alumium collecting electrode presented 38% of energy dependence as expected because the pair of ionization chambers compose a tandem system, which allows their use in quality control programs for the routine verification of their radiation qualities.The results are satisfactory, and the two homemade ionization chambers can be used to calibrate the radiation beams of equipment of ortovoltage utilized to treat patients with skin lesions.

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REFERENCES

[1] INTERNATIONAL ELECTROTECHNICAL COMMISSION, Medical Electrical Equipment-Dosimeters with Ionization Chambers as Used in Radiotherapy, IEC 60731, IEC, Genève (1997).

[2] INTERNATIONAL COMMISSION ON RADIATION UNITS AND MEASUREMENTS, Determination of Absorbed Dose in a Patient Irradiated by Beams of X or Gamma Rays in Radiotherapy Procedures, ICRU-24, ICRU, Maryland (1976).

[3] INTERNATIONAL ATOMIC ENERGY AGENCY; Radiation Oncology Physics: A handbook for Teachers and Students, E.B. Podgorsak (Ed.), STI/PUB/1196, IAEA, Vienna (2005).

[4] INTERNATIONAL ATOMIC ENERGY AGENCY, Absorbed Dose Determination in External Beam Radiotherapy: An International Code of Practice for Dosimetry Based on Standards of Absorbed Dose to Water, Technical Reports Series 398, STI/DOC/010/398, IAEA, Vienna (2006).

[5] INTERNATIONAL ATOMIC ENERGY AGENCY. Calibration of Reference Dosimeters for External Beam Radiotherapy, Technical Reports Series 469, STI/DOC/010/469, IAEA,Vienna (2009).

[6] ALBUQUERQUE, M.P.P., CALDAS, L.V.E., New ionization chambers for beta and X-radiation, Nucl. Instr. Meth. Phys. Res., **A280** (1989) 310-313.

[7] SOUZA, C.N., CALDAS, L.V.E., SIBATA, C.H., et al., Two new parallel-plate ionization chambers for electron beam dosimetry, Radiat. Meas., **26** 1 (1996) 65-74.

[8] MAIA, A.F. , CALDAS, L.V.E. , A new extended-length parallel-plate ionization chamber, Phys. Med. Biol. **50** (2005) 3837-3847.

[9] YOSHIZUMI, M.T., VIVOLO, V., CALDAS, L.V.E., Preliminary studies of a new monitor ionization chamber, Appl. Radiat. Isot. **68** (2010) 620-622.

[10] SILVA, J.O., CALDAS, L.V.E., establishment of a tandem ionization chamber system in standard mammography beams, International Joint Conference - II Congresso de Proteção Contra Radiações da Comunidade dos Países de Língua Portuguesa, II Congresso Brasileiro de Proteção Radiológica e V Congresso Internacional de Radioproteção Industrial, Recife (2011).

[11] NEVILLE, J. A., WELCH, E., LEFFELL, D.J., Management of nonmelanoma skin cancer in 2007, Nat. Clin. Pract. Oncol., v. 4, n.8, pp.462-469 (2007).

[12] NONATO, F.B.C., SILVA, J.O., VIVOLO, V., CALDAS, L.V.E., Comparison of four parallel-plate ionization chambers in standard X-ray beams, therapy level, Symposium on Radiation Measurements and Applications, SORMA WEST (2012).

[13] BUREAU INTERNATIONAL DES POIDS ET MESURES, measuring conditions used for the calibration of ionization chambers at the BIPM, Rapport BIPM-04/17, BIPM, Sèvres (2004).