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DETERMINATION OF THE EFFECTIVE VOLUME OF AN EXTRAPOLATION CHAMBER FOR X-RAY DOSIMETRY

M.T.T. Figueiredo[1]; T.A. da Silva[1,2]

[1] Post graduation Course on Science and Technology of Radiation, Minerals and Materials, CDTN/CNEN, Belo Horizonte, Brazil
[2]Development Center of Nuclear Technology, CDTN/CNEN, Belo Horizonte, Brazil

ABSTRACT

The measurement of air kerma in low energy x-rays is performed at primary calibration laboratories with free-in-air ionization chamber. Although an extrapolation chamber is designed to be used for beta radiation dosimetry it may also be feasible for low energy x-ray since its small changeable volume makes possible to comply the Bragg-Gray cavity principle. An inherent capacitance is associated with any parallel-plate ionization chamber; therefore, there should be a well-defined relationship among the capacitance, the effective colleting area and the electrode spacing of an extrapolation chamber.

In this work, a critical analysis of the methodology for determining the air sensitive volume of an extrapolation chamber through its capacitance in standardized condition was done. Low energy filtered x-rays were used with different tube currents and potentials; the relationship between the capacitance and the effective volume of a 23392 Böhm model PTW ionization chamber was analyzed within 0.4 to 5.0 mm electrode distances.

author e-mail mttf@cdtn.br

1. INTRODUCTION

Defined as intersection region between both, radiation and electric fields, the knowledge of the sensitive volume of the ionization chamber is an essential part of the primary dosimetric procedure. In most practical cases, when the chamber is uniformly irradiated, its sensitive volume is almost equal to its inner geometric volume, but it depends on the extent of the electrical field perturbation that occurs on the separating groove between the measuring electrode and the guard ring. Besides, there are cases where the incident radiation field and the window size of the extrapolation chamber do not allow a homogeneous field inside the chamber. These are the reasons that many authors have recommended the use of indirect methods for determining the effective area of the measuring electrode for primary measurements.

An inherent capacitance is associated with any parallel-plate ionization chamber; therefore, there should be a well-defined relationship among the capacitance, the effective colleting area and the electrode spacing of an extrapolation chamber. The knowledge of the capacitance allows the effective area of the measuring electrode of the extrapolation chamber to be calculated within reasonable uncertainties. The aim of this paper is to discuss the measurement of the electrode effective area and, consequently, the sensitive volume of a 23392 Böhm Type PTW extrapolation chamber by using an indirect determination method.

2. MATERIALS AND METHODOLOGY

Capacitance is the ability of a body to store electrical charge. The parallel-plate capacitor is the most common device of energy storage. The capacitance of a parallel plate capacitor, which is defined as the ratio of the charge stored and the voltage applied to the plates, is directly proportional to the area of the conductive plates and inversely to the distance between them, as given by Equation 1.

$$C = \varepsilon_0 \varepsilon_r \frac{A}{d} \tag{1}$$

where:

C is the capacitance, in Farads;

A is the area of overlap of the two plates, in square meters;

ε_r is the relative static permittivity or dielectric constant of the material between the plates (it depends on the dielectric material and it varies within wide limits)

ε_0 is the vacuum permittivity ($\varepsilon_0 \approx 8.854 \times 10^{-12}$ F m^{-1});

d is the separation between the plates, in meters;

One can analyze an extrapolation chamber as a parallel plate capacitor that the distance between the plates can vary continuously and accurately.

By the capacitance definition given in Equation 2.

$$C = \frac{\Delta Q}{\Delta V} \tag{2}$$

With proper facilities it is possible to produce variations of the voltage applied between the extrapolation chamber electrodes in order to observe the resulting changes in the collected charge for a given time interval. The function, which associates the distance between electrodes and the inverse of the capacitance, can be drawn; it results in a line whose slope gives the value of the area of the electrode. Figure 1 shows the result graph obtained by ZANKOWISKI [1].

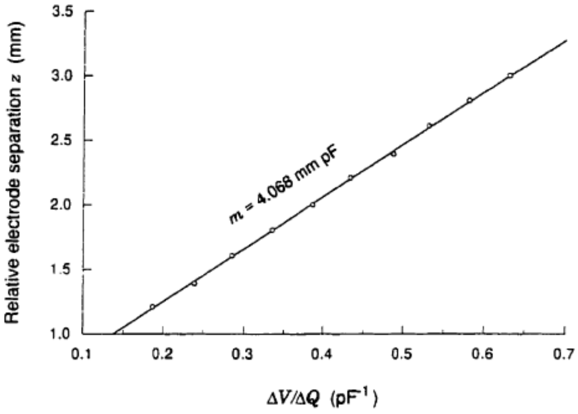


Figure 1 - Plot of a relative electrode separation z as a function of the inverse capacitance. Source (ZANKOWISKI [1],)

The operation of the ionization chamber in the saturation region establishes there is no dependence between the collected charge and the applied voltage due the action of the radiation field. On the other hand, any potential difference between the voltage source and the capacitor plates results in transitory current that may be loading or unloading, depending on the signal. This transitory current may change the observed charge, for a given time interval. In this case, the variation detected in load due to changed voltage is exclusively related to the electric field, and thus, Equation 1 can be applied to determine the effective area.

By using this procedure, ZANKOWISKI[1] got the value of 4.597 cm^2 for the effective area of an extrapolation chamber with 2.5 cm diameter circular groove. CALDAS [2] got the effective area of 7.035 cm^2 of a nominal value of 7.065 cm^2 of another extrapolation chamber.

The procedures reported by ZANKOWISKI [1] and CALDAS [2] were done by means of beta and gamma radiation sources; in fact, accurate capacitance measurements requires that the radiation field stability must be absolute, which is impossible for X-ray equipment.

In this work, capacitance measurements of a 23392 PTW extrapolation chamber was done in absence of the radiation field; Inc L-C meter with resolution down to 0.25 pF. The L-C meter operates by measuring the change in frequency when an unknown capacitance is added to an oscillator tank circuit.

3. RESULTS AND DISCUSSIONS

Figure 2 shows a graph of capacitance as a function for the relative distance between the plates. The result of capacitance measurements exhibit in the Figure 2, clearly indicate the existence of a approximate 9 pF parallel capacitance, independent of the distance between the plates.

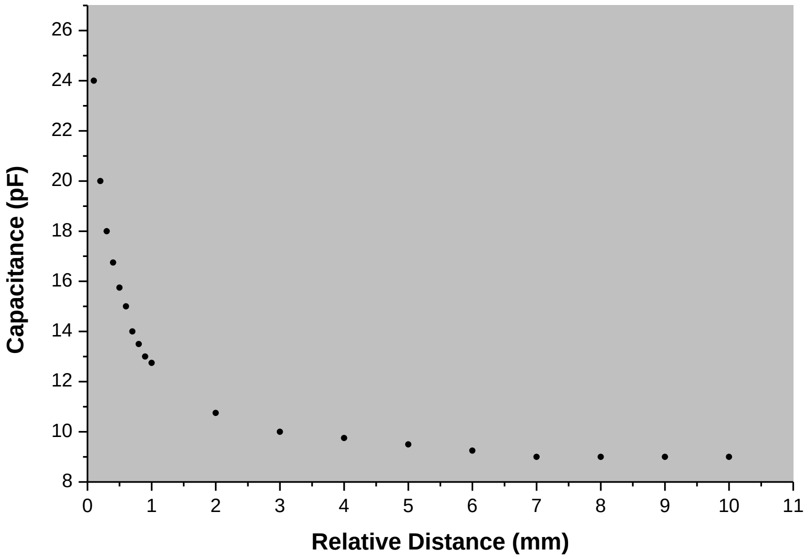


Figure 2 - Capacitance variation as a function of the relative distance between the electrode plates of the 23392 PTW extrapolation chamber.

For the 23392 PTW extrapolation chamber, the capacitance between the electrodes can be defined by Equation 3. Numerical values are shown in Table 1.

$$C_{(d)} = C_{total} - C_0 \tag{3}$$

where:

$C_{(d)}$; Capacitance of the electrodes that depends on the distance between them;

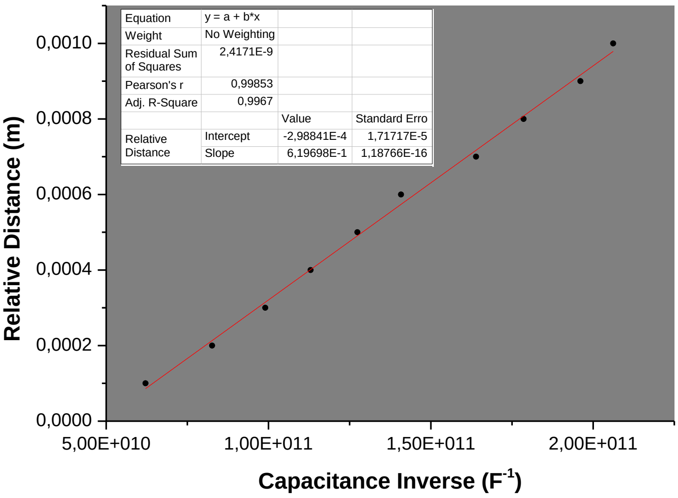
C_0 ; Added or inherent parallel capacitance that is independent of the distance between the electrodes;

C_{total}; Capacitance measured by the L- C meter

Table 1 – Capacitance inverse of the 23392 PTW extrapolation chamber

Relative Distance (mm)	C_{total} (pF)	C_0 (pF)	$C_{(d)}$ (pF)	Capacitance Inverse (pF^{-1})
0.0	28	9	16	0.0625
0.1	24	9	15	0.0667
0.2	20	9	11	0.0909
0.3	18	9	9	0.1111
0.4	16.75	9	7.75	0.1290
0.5	15.75	9	6.75	0.1481
0.6	15	9	6	0.1667
0.7	14	9	5	0.2000
0.8	13.5	9	4.5	0.2222
0.9	13	9	4	0.2500
1.0	12.75	9	3.75	0.2667
2.0	10.75	9	1.75	0.5714
3.0	10	9	1	1.000
4.0	9.75	9	0.75	1.3333
5.0	9.5	9	0.5	2.000
6.0	9.25	9	0.25	4.000
7.0	9.0	9	0	-
8.0	9.0	9	0	-
9.0	9.0	9	0	-
10.0	9.0	9	0	-

Figure 3 shows the linear fitting of the results of the relative distance between the electrodes of the 23392 PTW extrapolation chamber as a function of the inverse of the capacitance.



Equation	y = a + b*x		
Weight	No Weighting		
Residual Sum of Squares	2,4171E-9		
Pearson's r	0,99853		
Adj. R-Square	0,9967		
		Value	Standard Erro
Relative Distance	Intercept	-2,98841E-4	1,71717E-5
	Slope	6,19698E-1	1,18766E-16

Figure 3 – Variation of the capacitance inverse in function of the relative distance between electrodes of the 23392 PTW extrapolation chamber.

Since the relative distance can be defined by the Equation 4, the slope b obtained by linear fit (Equation 5) allowed calculating the effective area (Equation 6), resulting in 7.00 cm^2.

$$d_{(r)} = \varepsilon_r \varepsilon_0 A_{effective} \frac{1}{C} \tag{4}$$

$$b = \varepsilon_r \varepsilon_0 A_{effective} \tag{5}$$

$$A_{effective} = \frac{b}{\varepsilon_r \varepsilon_0} \tag{6}$$

The value of the total capacitance for zero distance and the effective area calculated by the experimental procedure allow the determination of the true-null electrode distance of 0.38 mm, by the Equation 7.

$$d_0 = \frac{\varepsilon_r \varepsilon_0 A_{efetiva}}{C(0)} \tag{7}$$

The sensitive volume of the 23392 PTW extrapolation chamber can also be calculated by Equation 8.

$$V_{sensitive} = (d_r + 0{,}038) \times 7.00\, cm^3 \tag{8}$$

4. **CONCLUSIONS**

The methodology used in this study for both the effective area and the true-null electrode distance showed consistency to results found by studies with other methodologies to the 23392 PTW extrapolation chamber. However, uncertainties of the results need to be assessed, because the method would be justified only if the uncertainties are lower than those provided by manufacturers of the extrapolation chamber.

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