EXPERIMENTAL APPROACH ON THE ELECTRICAL CAPACITY OF A PLAN-PARALEL IONIZATION CHAMBER

[1]Sorin Bercea, [2]Constantin Cenusa, [3]Aurelia Celarel, [4]Elena Iliescu

[1,2,3,4] *"Horia Hulubei" National Institute for Physics and Nuclear Engineering, NIPNE, (IFIN-HH), Bucharest, Romania*
Str. Atomistilor 407, Mãgurele, jud.Ilfov, C.P. MG-6,
cod 077125 tel. (021) 404.23.00, fax (021)457.44.40; bercea@nipne.ro

Abstract - This paper presents an experimental approach on the electrical capacity of an ionization chamber, of a special shape: the electrodes of the chamber are two plan-parallel plates. The distance between the two electrodes can be varied mechanically; in this way, one can obtain also a variation of the sensitive volume of detector.

Such a transducer of a special shape and size is very important in the ionizing radiation metrology, because it allows the use of an absolute method for the measurement of the absorbed dose in beta rays beams or filds.

I. Introduction

They are many cases in the ionizing radiation metrology, when the standards dedicated to the different specific quantities of dosimetry use as sensors/transducers ionization chambers of different shapes and seizes.

An ionization chamber is a detector (sensor) of ionizing radiation, whose operation principle is based on the collection of charged particles generated in the filling gas by the primary ionization processes. The collection of these charged particles is due to an electric field, produced by the polarizing voltage, which is applied between the two electrodes of the detector/sensor.(Figure1)

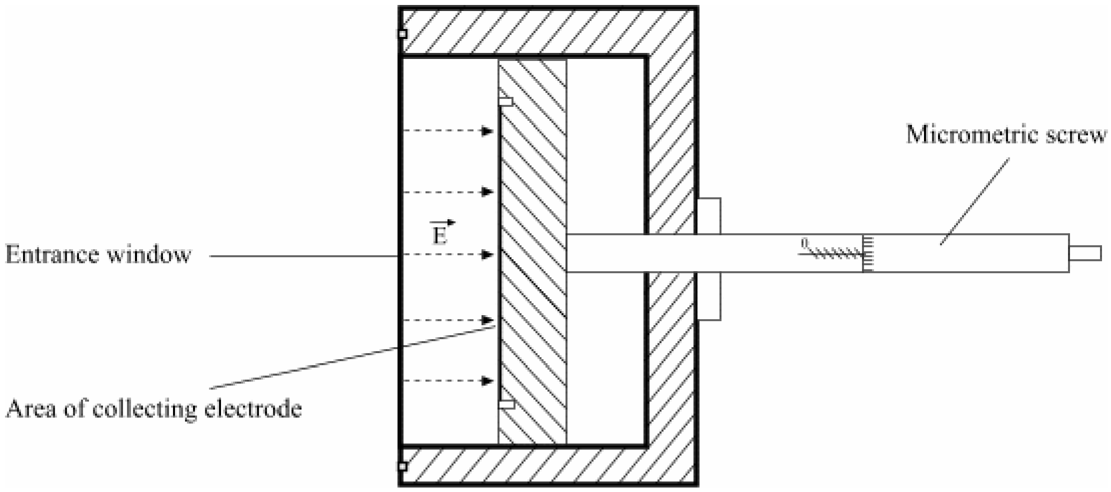

Figure 1. Schematic general view of a plan-parallel ionization chamber

That is, from the electric point of view, such an ionizing radiation sensor (detector) was considered, in certain situations, as a capacitor: its dielectric is the filling gas from the sensitive volume of the detector. But, during the irradiation of the detector, a particularity appears: free charge carriers are produced into the dielectric, as a result of the ionization processes.

So, when it is irradiated, the detector acts no more as a capacitor, but as a direct current source. However, the electrical capacity of the detector may influence its parameters.

II. Description of the experimental arrangement

a) The extrapolation ionization chamber

The extrapolation ionization chamber is a special ionization chamber, with plan-parallel electrodes and variable volume. A general view of such a chamber is given in Figure1. The fixed electrode is a thin regular foil, whose inner surface is electroconductive due to a very thin layer of aluminum. The other electrode is made of a layer of graphite applied on a circular block of polystyrene. This conductive layer of graphite is insulated from another circular conductive layer witch is the guard ring. This guard ring is electrically connected to the ground, and its function is to define electrically the sensitive volume of the detector/transducer.

The volume of the ionization chamber can be varied by modifying the distance between the two electrodes. This can be made by means of a micrometer screw, in the range 0-16 mm.

A front view of these components of the chamber(the collector and the guard ring), with their dimensions is given in Figure 2.

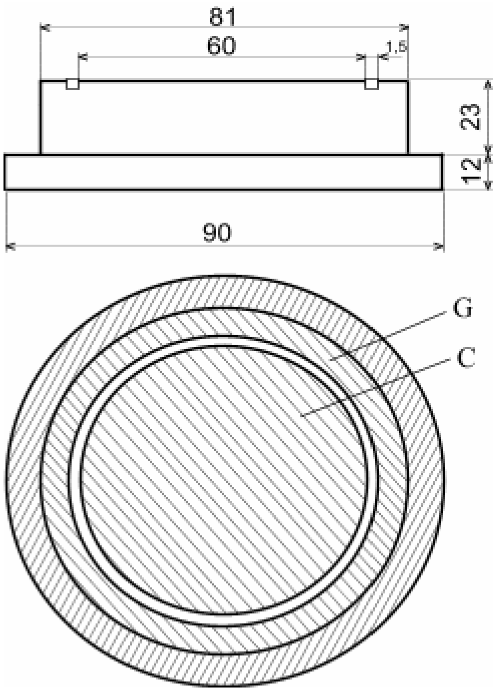

Figure 2. Shape and dimensions of the polystyrene block with the collector (C) and the guard ring (G)

b) Description of the electrical arrangement

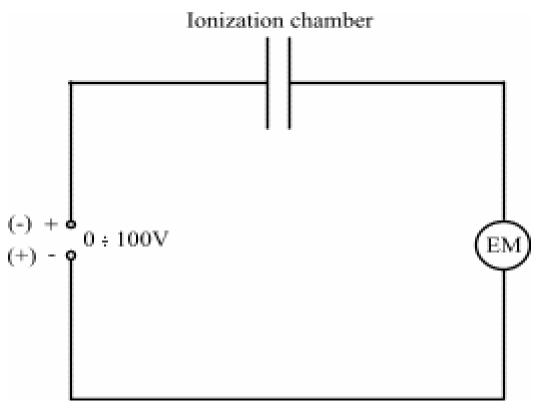

Figure 3. The electrical circuit for the ionization current or charge measurement

The electrical circuit is the same, both for chamber's current and chamber's electrical charge measurement, in view of the electrical capacity calculation.

For charge measurement, the measured quantity is simply changed to electrometer. The polarization voltage was varied in steps from 0V to 100V.

The experimental arrangement for measurements of the electrical capacity of the ionization chamber in Figure 4.

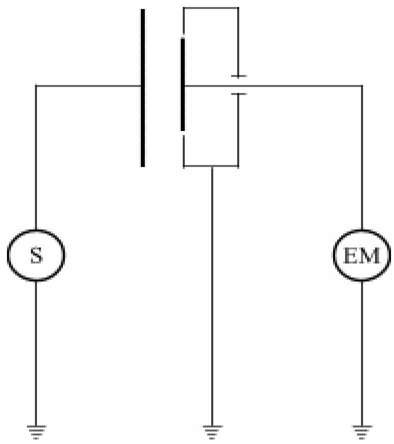

Figure 4. Experimental arrangement for the electrical capacity measurement

For the charge measurement, we used a Keithley 617 type electrometer, witch includes also are internal power supply with the range ±102V, and the maximum current of 2mA. This voltage power supply is galvanically insulated from the electrometer's inputs. The voltage can be varied in all the range, in steps of 0,05V. The polarizing voltage is electronically commanded, just to obtain an step variation.

III. Methodology

Theoretical calculation of the electrical capacity of the ionization chamber.
The geometrical dimensions of this ionization chamber are:

$r = 60$ mm

and so the electrical capacity is

$$C = \varepsilon_0 \, \varepsilon_{aer} \, (S/d)$$

where: $\varepsilon_0 = 8{,}854 \cdot 10^{-12}$ F/m
$\varepsilon_{aer} = 1.00059$
$S = \pi r^2 = 28{,}2743$ cm^2
$d = 0{,}5;\ 5;\ 10;\ 15$ mm.

The corresponding values of the capacity, for different values at d are (Table I):

d (mm)	C(pF)
0,5	50,098
5	5,0098
10	2,5049
15	1,6699

Table I. Experimental measurement of the electrical capacity of the ionization chamber.

The experimental arrangement for the measurement of the electrical capacity of the ionization chamber is shown in Figure 3. The collected charge was measured by a Keithley 617 electrometer.

Because of the low value of the charges to be measured, the electrometer was put into operation with minimum 24h before the measurement started, in order to achieve a good stability of the indication. After 24h, we checked the "zero" of the instrument, using the "ZERO CHECK" taste of the instrument. The measurements ware done in "AUTO RANGE".

The charge values recording was started, and after 5 seconds, the polarizing voltage is applied an the chamber (A sudden variation of the voltage, from 0V to 100V is applied, in 5 seconds). In the first 5 seconds of the measurement, the charge on the chamber's electrodes was Q_1. After 5 seconds, by charge collection in the inner electric field of the chamber, by applying the polarizing voltage of 100V, the charge on the chamber is Q_2.

$$Q = Q_2 - Q_1$$

$$V = 100V$$

and so, the chamber's capacity is : $C = Q/V = (Q_2-Q_1)/V$

Experimental results

D(mm)	V(V)	$Q_1(10^{-10}C)$	$Q_2(10^{-10}C)$	$C(10^{-12} F)$
0.5	100	0.0006	0.5039	50.33
0.5	100	0.0008	0.5052	50.44
5	100	-0.00041	0.04730	4.771
5	100	-0.0013	0.04702	4.832
10	100	-0.00012	0.02073	2.085
10	100	-0.00013	0.0206	2.073
15	100	-0.000103	0.012555	1.2658
15	100	0.000102	0.012285	1.2183

Table II. The results of the measurements

IV. Conclusions

The experimental results obtained during the present work lead to the following conclusions:
- for small values of d (the distance between the electrodes), electrical capacity of the ionization chamber C, is high, and for the high values of d, the electrical capacity of the ionization chamber is small; this fact affects the variation rate of the ionization current produced by the chamber, witch depends on the time constant RC;
- for a dosimetric measuring system witch uses, as a detector, such a chamber and integrates the ionization current (for absorbed dose measurement, for instance), limitation are imposed on the possibility of discerning the fast variation of the dose rate in a fast variable radiation field.
- high values of the electrical capacity, C, mean a low sensibility and a low rate of variation of the ionization current, as well as low values of the capacity mean a high sensibility and high rate of variation of the ionization current.

These conclusions are very important when someone has to design an experiment involving dose or dose rate measurements in variable radiation fields (as in an medical betatron, for instance).

References

[1] S. Bercea, "Masurarea debitului dozei absolute pentru radiatii beta prin metoda camerei de ionizare de extrapolare", *Metodologia Aplicata*, vol. XXXIV, nr.2, pp 78-83/ 1987
[2] J. Jabtonska, M. Kuchta, *"An extrapolation chamber for measurement of β-ray sources"* , Warscawa 1972;
[3] R. Loevinger, N. G. Trott, "Desing and operation of an extrapolation chamber with removable electrodes." *Int. J. Appl. Rad. Isotops*, vol I, pp.103-111, 1996.
[4] Jürgen Böhm, "*Standardisation and calibration in beta dosimetry*", Physikalish – Technishe Buudesanstalt, D-3300 Braunshweig, Germany,
[5] H. J. Gale, L. H. J. Peaple, "*The measurement of beta dose and the calibration of some beta-gamma survey instruments*", Helth Physics and Medical Division Atomic Energy Research Establishment, Harwell, Berkshire, 1963.