A SUPERFICIAL IONIZATION CHAMBER IN STANDARD BETA RADIATION BEAMS

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Abstract: A commercial parallel plate ionization chamber was studied in relation to the possibility of its application in beta radiation beams. The chamber was characterized to verify its response to beta radiation through different tests as leakage current, short- and medium-term stability and saturation curve. The tests showed results within the limits of international recommendations.

Keywords: ionization chamber, beta radiation, beta dosimetry.

1. INTRODUCTION

For the precise determination of the absorbed dose in a medium exposed to beta radiation, it is necessary to perform dosimetric procedures, with application in several areas. One of the areas in which dosimetry has great importance is Medicine [1].

The calibration of a metrological instrument with beta radiation is a complex procedure, because this radiation has low penetrating power and high dose gradient. Publications of the International Atomic Energy Agency (IAEA) present recommendations about the calibration of radiation beams, as used in brachytherapy and radiotherapy [2-5]. Ionization chambers are the instruments most often used in beta radiation dosimetry and in the calibration of beta sources, specially the extrapolation chambers [6-8].

The Calibration Laboratory (LCI) of Instituto de Pesquisas Energéticas e Nucleares (IPEN) has a parallel plate ionization chamber, Nuclear Enterprises (NE), secondary standard system for low energy X-rays, radiotherapy level; it was already tested in X radiation beams at different conditions [8,9].

The objective of this work was to verify the performance of this superficial ionization chamber in standard beta radiation beams.

2. MATERIALS AND METHODS

A superficial ionization chamber (Figure 1a) from Nuclear Enterprises (NE), model 2536/3, with an active volume of 0.3 cm^3, was studied in this work.

For the stability test, a $^{90}Sr+^{90}Y$ check source (33 MBq, 1988), PTW, model 8921, was utilized. This source was positioned on a PMMA holder as can be seen in Figure 1b.

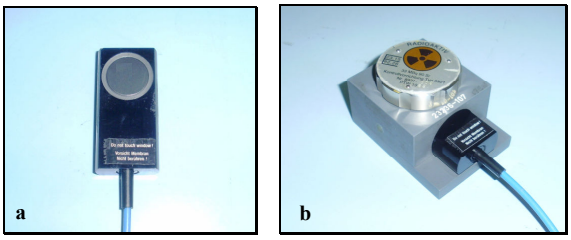

Fig. 1. a) Superficial ionization chamber and b) chamber during the stability test, with the $^{90}Sr+^{90}Y$ check source.

For the saturation, ion collection efficiency and ion recombination, linearity of response tests, and determination of the calibration coefficients of the ionization chamber, four different beta radiation sources were utilized. These sources (Table 1) compose the two beta secondary standard systems of the LCI: BSS1 system, Buchler GmbH & Co., Germany, and BSS2, Isotrak, Germany. The source of $^{90}Sr+^{90}Y$ of the BSS1 system was used without its field flattening filter, and the sources from BSS2 system were used with their field flattening filters, according to the calibration certificate of each source.

Table 1. Characteristics of the beta radiation sources from BSS1 and BSS2 systems, used in this work with or without field flattening filters.

Standard System	Source	Nominal Activity (MBq)	Absorbed Dose Rate in Air µGy/s)	Calibration Date
BSS1	$^{90}Sr+^{90}Y$	1850	70.60 ± 0.71	04.02.1981
BSS2	$^{90}Sr+^{90}Y$	460	10.56 ± 0.14	08.12.2004
	^{85}Kr	3700	39.70 ± 0.50	30.11.2004
	^{147}Pm	3700	2.35 ± 0.05	19.11.2004

The measurements obtained in this work were taken in terms of electric charge, using an electrometer UNIDOS E, from Physikalish-Technische Werkstätten (PTW), Freiburg. The polarity voltage applied to the chamber during the experiments was ± 300 V. All measurements were corrected for the reference environmental conditions of temperature and pressure.

3. RESULTS

The response of the ionization chamber in beta radiation beams was verified through the tests of leakage current without irradiation, short- and medium-term stability and saturation curve.

3.1. Leakage current

The leakage current of the superficial ionization chamber was measured with the presence of the radiation source. This test was performed during a time interval of 20 min of charge collection, and the polarity voltage used in this test was + 300 V. The result obtained in these measurements was 0.04% of the maximum value of the readings, which is within the recommended limit of 60731 [10]. According to this international recommendation, the value of leakage current should not exceed to 0.5%.

3.2. Short- and medium-term stability tests

The ionization chamber response was studied exposing it to the $^{90}Sr+^{90}Y$ check source. The short-term stability test, or repetitivity test, was performed taking ten charge readings in the polarity voltage of ± 300 V. These measurements were taken during a time interval of 60 s. The maximum variation coefficient obtained was 0.2%, and the recommended limit by the IEC 60731 is 0.3% [10].

The medium-term stability test, or reproducibility test, was obtained performing successive repetitivity tests. The maximum variation coefficient obtained in this work was 0.26%, and the recommended maximum value by IEC 60731 is 0.5% [10]. The results of the stability tests can be observed in Figure 2.

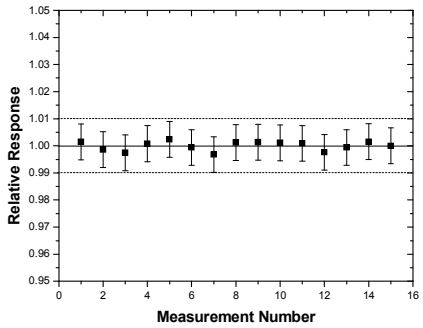

Fig. 2. Medium-term stability test of the parallel plate ionization chamber, using the $^{90}Sr+^{90}Y$ check source.

3.3. Saturation, ion collection efficiency and ion recombination

A saturation curve was obtained for the ionization chamber response, for the determination of the best voltage to be applied to the chamber.

In this test, the distance between the BSS1 $^{90}Sr+^{90}Y$ source and the ionization chamber was 30 cm. The positioning of the chamber can be observed in Figure 3. The polarity voltage used in this test was varied from – 300 V to + 300 V, in steps of 50 V. The charge collection time during the measurements was 60 s. The saturation curve can be observed in Figure 4.

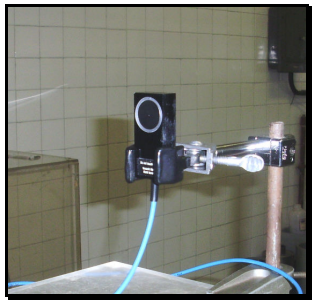

Fig. 3. Superficial ionization chamber positioned at the BSS1 system.

The mean values of the ionization currents obtained in all measurements was 0.89 pA for the positive polarity, and 1.02 pA for the negative polarity. The mean value obtained between both polarities was 0.95 pA, and the maximum variation coefficient was 3.6%.

The results of this test demonstrate that the superficial ionization chamber achieved saturation in the whole polarity voltage interval.

The ion collection efficiency can be obtained through the saturation curve of the chamber response. This study is performed taking into consideration the collected charges for both polarity voltages and the minimum and maximum values of voltage.

The result obtained in this work was better than 99.44%, and it is within the recommended limit of the IEC 60731 [10], which is 99.0%. This result represents that the losses by ion recombination were less than 0.54%.

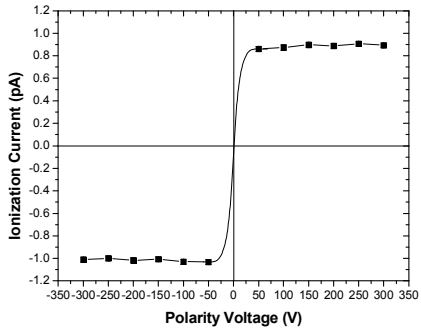

Fig. 4. Saturation curve of the ionization chamber.

3.4. Linearity of response

The linearity of the response of the parallel plate ionization chamber was studied. For this study, the charge collecting time varied from 30 s to 240 s during the measurements, and the voltage used was 300 V, in both polarities. This test was performed using the $^{90}Sr+^{90}Y$ check source.

For this test, a linear behavior was observed (Figure 5), with a correlation factor, R^2, of 1.000. The maximum variation coefficient of all measurements was 0.07%, not visible in the figure.

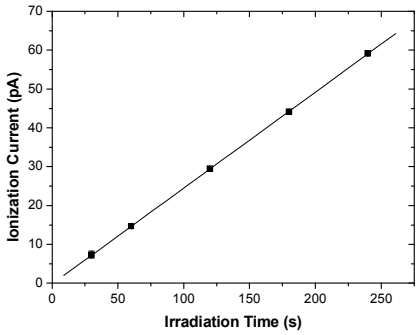

Fig. 5. Linearity test of the parallel plate ionization chamber response, using the $^{90}Sr+^{90}Y$ check source.

3.5. Calibration coefficients

During this work, the ionization chamber was calibrated using the three sources of the BSS2 system: $^{90}Sr+^{90}Y$, ^{85}Kr and ^{147}Pm, at the calibration distances of 30 cm, 30 cm and 20 cm, respectively

The charge collection time in the measurements varied for each source: 120 s, 60 s, and 900 s, for the $^{90}Sr+^{90}Y$, ^{85}Kr and ^{147}Pm sources, respectively.

In the case of the ^{147}Pm source, a correction factor for air density was also considered, for the determination of the calibration coefficient, following the recommendation in the calibration certificate. The calibration coefficients obtained can be observed in Table 2.

Table 2. Calibration coefficients of the ionization chamber obtained in this work for the sources of BSS2 system.

Source	Beta Mean Energy (MeV)	Absorbed Dose Rate (μGy/s)	Calibration Coefficient ($\mu Gy.s^{-1}/pA$)
$^{90}Sr+^{90}Y$	0.800	9.027 ± 0.140	77.984 ± 0.377
^{85}Kr	0.150	26.062 ± 0.500	89.349 ± 0.539
^{147}Pm	0.060	0.629 ± 0.050	37.865 ± 1.141

The maximum variation coefficient of the measurements was 2.9%. The results show that the studied ionization chamber presents high energy dependence.

4. CONCLUSIONS

The superficial ionization chamber studied in this work was designed to be a secondary standard, radiotherapy level. However, the leakage current without irradiation, short- and medium-term stability, saturation curve and linearity tests demonstrated that this chamber may be useful in beta radiation beams too, because the results obtained were within the limits recommended by international recommendations.

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