Calibration of Radiation Monitors at different Source-Detector Distances in Standard $^{90}Sr+^{90}Y$ Beams

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Abstract— **Radiation protection monitors have to be calibrated in standard conditions and in terms of the radioprotection quantities. The Calibration Laboratory (LCI) of the Instituto de Pesquisas Energéticas e Nucleares (IPEN) offers calibration services of these kinds of monitors, in relation to beta radiation, since the 80's; the measurements are taken at the calibration distances given in the source calibration certificate from the German primary dosimetry laboratory: Physikalisch-Technische Bundesanstalt (PTB). However, there are instruments that do not allow their calibration at these reference distances, because absorbed dose rates in these conditions are not adequate. The objective of this work was to establish a procedure to calibrate the monitors with $^{90}Sr+^{90}Y$ sources at other distances. The inverse square law of the response of an ionization chamber was verified. A parallel plate ionization chamber developed at LCI was used in this study. Measurements of the ionization chamber were taken at different distances between source and detector, and the inverse square law was verified, allowing its application in the calibration of radiation monitors.**

Keywords— **Radiation monitors, calibration, beta radiation, $^{90}Sr+^{90}Y$ source, radioprotection.**

I. Introduction

Dose rate monitors are used in radiation protection for area monitoring, with the objective to ensure safety at the workplace. All monitors have to calibrated in relation to quantities used in radiation protection [1].

The calibration of these instruments is necessary mainly to ensure and to certificate the adequate operation of the monitor. This calibration is performed in standard systems, in relation to the radiation beams and the experimental set-up [2].

The Calibration Laboratory (LCI) of the Instituto de Pesquisas Energéticas e Nucleares (IPEN) offers calibration services of monitors using X, gamma and beta radiations; alpha and beta contamination monitors; clinical dosimeters in gamma radiation beams; diagnostic radiology detectors; activimeters used in Nuclear Medicine; and $^{90}Sr+^{90}Y$ clinical applicators.

In relation to beta radiation, the LCI performs detector calibration since the 80's. There are two beta secondary standard systems (BSS1, Buchler GmbH & Co., Germany, and BSS2, Isotrak, Germany), with different beta sources, utilized for the calibration of gamma and beta radiation detectors as standard sources [3]. The beta-gamma monitors are initially calibrated in gamma radiation beams and then in beta radiation beams. In 2010, 866 monitors were calibrated at the LCI; about 5% were calibrated in standard beta radiation beams too.

These instruments are calibrated at the distances provided in the source calibration certificates. However, there are several kinds of monitors that cannot be calibrated at these reference distances, because they are not adequate in relation to the monitor scales.

The objective of this work was to a study the response of a homemade parallel-plate ionization chamber [4] at several distances within the distance interval given in the calibration certificate from the a $^{90}Sr+^{90}Y$ source of the beta secondary standard.

II. Materials and methods

In this work, two $^{90}Sr+^{90}Y$ sources were utilized during the experiments: a) a check source (33 MBq, 1994), PTW, model 8921; b) a $^{90}Sr+^{90}Y$ source of the BSS1 system (1850 MBq, 1981), calibrated at the German Primary Standard Laboratory, Physikalisch-Technische Bundesanstalt (PTB).

Initially, the ionization chamber response was verified in relation to: the leakage current without irradiation and the stability of its response. In this second test, a $^{90}Sr+^{90}Y$ check source was utilized.

A parallel plate ionization chamber utilized in this work was developed at LCI [4], and was made of acrylic material, in cylindrical geometry. This chamber presents an entrance window of aluminized Mylar and collecting electrode of graphite. Its dimensions are presented in Table 1. Figure 1 shows the ionization chamber positioned in the BSS1 system.

Table 1 Characteristics of the parallel plate ionization chamber used in this work

	Materials	Dimensions (mm)
Ionization chamber	PMMA	External diameter = 25.4 Thickness = 17.25
Collecting electrode	Graphited PMMA	Diameter = 6.0
Entrance window	Aluminized Mylar	

For the stability test, a PMMA support was utilized for the reproducible positioning of the source and the parallel plate ionization chamber.

The measurements of ionization currents were taken using a UNIDOS E electrometer from PTW, Freiburg.

Fig. 1 Experimental set-up used in the measurements with the parallel plate ionization chamber and the $^{90}Sr+^{90}Y$ source (1850 MBq, 1981)

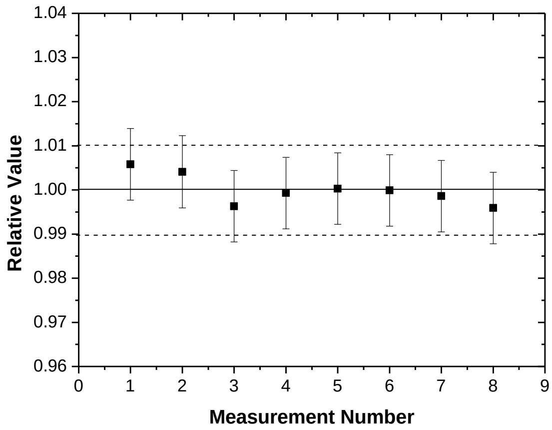

Fig. 2 Stability test of the parallel plate ionization chamber response using the $^{90}Sr+^{90}Y$ check source

III. Results

A. Leakage current without irradiation

Before and after each irradiation, the leakage current was verified without the presence of $^{90}Sr+^{90}Y$ source. This ionization current was always measured during a time interval of 20 min.

According to the IEC standard [5], the recommended limit for the leakage current is 0.5%. In this work, the maximum leakage value obtained was 0.03% that is within the recommended limit and is comparable to the results presented in a previous work [6].

B. Stability tests

The stability of the ionization chamber response was analyzed in relation to the repeatability and reproducibility tests, and using a $^{90}Sr+^{90}Y$ check source.

The repeatability test was obtained after ten readings of charge in both polarities, during a time interval of 60s and voltage of ± 300 V.

The IEC standard [5] recommends that the maximum variation coefficient for this test should be 0.3%, and in this work the value obtained was 0.17%.

The reproducibility test consisted of successive repeatability tests. The maximum variation coefficient obtained in these measurements was 0.5%, and it is within the value specified in IEC standard [5], that recommends the same value. These results are also within the coefficients obtained by Antonio and Caldas in a previous work [6]. In Fig. 2 the results obtained for the stability test may be observed.

C. Variation of the ionization chamber response in relation to distance

The ionization chamber response was verified in relation to the variation between the $^{90}Sr+^{90}Y$ source (BSS1) and the detector.

This test was performed positioning the chamber at close distances at the calibration distances of the certificate of the beta source. The voltage used was + 300 V. Table 2 shows the relation of the distances used and the respective time intervals for the collecting charge.

In Fig. 3 are the results obtained in this study, and the behavior of the ionization chamber response can be observed when the distance between the $^{90}Sr+^{90}Y$ source and the chamber was varied. The maximum standard deviation of the experimental data was 0.6%.

Table 2 Distances and charge collecting time intervals for the study of variation of the chamber response

Distance (cm)	Charge Collecting Time (s)	Distance (cm)	Charge Collecting Time (s)
10	60	32	90
11	60	35	120
12	60	40	120
15	60	45	150
20	60	48	150
25	60	50	180
28	90	52	180
30	90	55	180

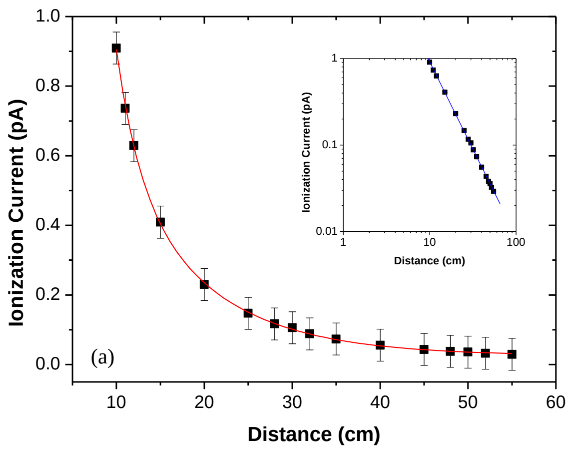

Fig. 3 Variation of the ionization chamber response in function of the distance between chamber and $^{90}Sr+^{90}Y$ source

The results were analyzed and they show that the chamber response follows the inverse square law in relation to the source-chamber distance.

IV. CONCLUSIONS

The results of the leakage current test without irradiation and of the stability tests showed that the system (ionization chamber, electrometer and cables) presents good performance, within the international recommendations.

The study of the ionization chamber response in relation to the variation of the distance between the $^{90}Sr+^{90}Y$ source (1850 MBq, 1981) and the ionization chamber demonstrated that the results obtained follow the inverse square law. This fact is important, because now it is possible to calibrate the radiation protection monitors at different distances than those of the calibration certificate of the $^{90}Sr+^{90}Y$ source.

For the Calibration Laboratory, this result is significant, because it allows the calibration of all models and kinds of monitors by the determination of the absorbed dose rates at any distance between 10 and 55 cm.

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