

Characterization of a ^{137}Cs standard source for calibration purposes at CRCN-NE

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Abstract. Radiation protection monitoring instruments should be calibrated by accredited calibration laboratories. To offer calibration services, a laboratory must accomplish all requirements established by the national regulatory agency. The Calibration Service of the Centro Regional de Ciências Nucleares (CRCN-NE), Comissão Nacional de Energia Nuclear, Recife, Brazil, is trying to achieve this accreditation. In the present work, a ^{137}Cs standard source was characterized following the national and international recommendations and the results are presented. This source is a commercially available single source irradiator model 28-8A, manufactured by JLShepherd & Associates, with initial activity of 444 GBq (05/13/03). To provide different air kerma rates, as required for the calibration of portable radiation monitors, this irradiator have a set of four lead attenuators with different thickness, providing attenuation factors equal to 2, 4, 10 and 100 times (nominally). The performed tests included: size and uniformity of the radiation standard field at calibration reference position, variation of the air kerma rate for different lead attenuators, determination of attenuation factors for each lead attenuator configuration, and determination of the radiation scattering at the calibration reference position. The results showed the usefulness of the ^{137}Cs standard source for the calibration of radiation protection monitoring detectors.

KEYWORDS: *radiation protection monitoring instruments, calibration, standard source, gamma radiation.*

1. Introduction

According to national and international regulations, the radiation protection monitoring detectors should be calibrated prior its first utilization and then periodically to guarantee its adequate performance. Following the “Safety Report Series N° 16”, the objectives of calibration are: (1) *to ensure that the instrument is working as properly and hence will be suitable for its intended purpose*; (2) *to determine, under a controlled set of standard conditions, the indication of an instrument as a function of the value of the measurand*; and (3) *to adjust the instrument calibration, if possible, so that the overall measurement accuracy of the instrument is optimized* [1]. This “set of standard conditions” refers to geometrical, environmental and technical conditions which must be accomplished by calibration laboratories worldwide.

In the case of calibration of radiation protection monitoring instruments, Brazilian laboratories must attend the requirements of international standards in addition to those established by the Laboratório Nacional de Metrologia das Radiações Ionizantes (LNMRI), Comissão Nacional de Energia Nuclear. Following the LNMRI recommendations, radiation protection monitoring instruments must be calibrated at radiation fields produced by ^{137}Cs standard sources and the calibration laboratory must know the shield leakage, size and uniformity of the radiation field at calibration reference position, air kerma rates produced at different distances and the room scattered radiation [2]. Besides, the laboratory must established a quality control program based on ABNT NBR ISO/IEC 17025 standard [2,3].

At the Calibration Service of the Centro Regional de Ciências Nucleares do Nordeste (CRCN-NE/CNEN), there are two gamma standard sources (^{137}Cs and ^{60}Co) and two X-ray equipments. Operating since 1998, this laboratory is trying to achieve the LNMRI accreditation to offer calibration services. The aim of this work is to characterize the ^{137}Cs standard source following national and international recommendations in the field of calibration of radiation protection monitoring detectors.

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2. Materials and Methods

2.1 Gamma Irradiator

The single source gamma irradiator model 28-8A, serial number 10354, from JLShepherd & Associates, with initial activity of 444 GBq (05/13/03) was utilized in this work. This irradiator is composed by a lead shield with a cone-shape aperture, and a set of four lead attenuators which provide different air kerma rates at the calibration reference distance. The lead attenuators can reduce (nominally) the air kerma rate by factors of 2, 4, 10 and 100 at the calibration position. Unfortunately, the presence of the lead attenuator cause a little disturbance in the radiation spectrum, reducing the beam mean energy [4] and this change should be taking into account in the overall calibration uncertainty. In order to guarantee the required electronic equilibrium, all measurements are performed at the distance of 100 cm from the external surface of the lead attenuator.

2.2 Ionization Chambers

Three ionization chambers were utilized to perform the measurements: (i) the NE model 2571, serial number 2830 (0.6 cm^3); (ii) the NE model 2530, serial number 672 (35 cm^3); and (iii) the NE model 2575, serial number 518 (600 cm^3).

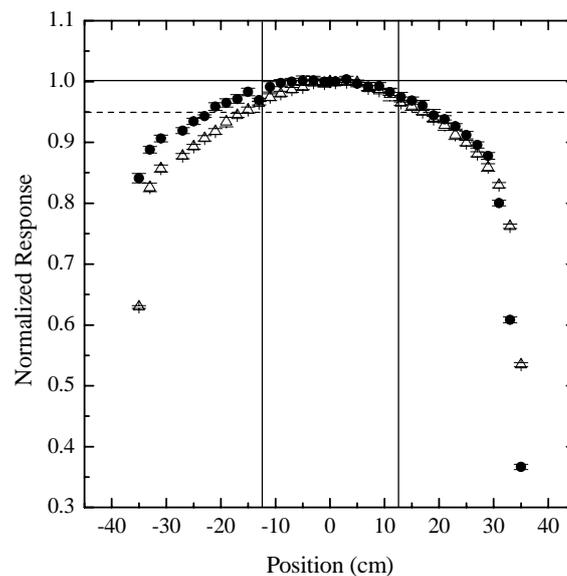
A NE electrometer (Farmer 2670, serial number 148) was utilized and all current measurements were corrected to reference temperature and pressure.

3. Results

3.1 Radiation Field Uniformity

Uniformity measurements in a plane perpendicular to the source axis were carried out. The chamber position was varied by steps of 2 cm in y- and z-directions, in this plane, while the distance between the source and the chamber (x-direction) remained constant (100 cm). These results are shown in Figure 1. In this figure, the term “Normalized Response” means a mean value of current measured in each position divided by the mean value of current obtained at the source central position ($x=100 \text{ cm}$, $y=0 \text{ cm}$ and $z=0 \text{ cm}$).

Figure 1: Radiation field uniformity in y-direction (●) and in z-direction (△).



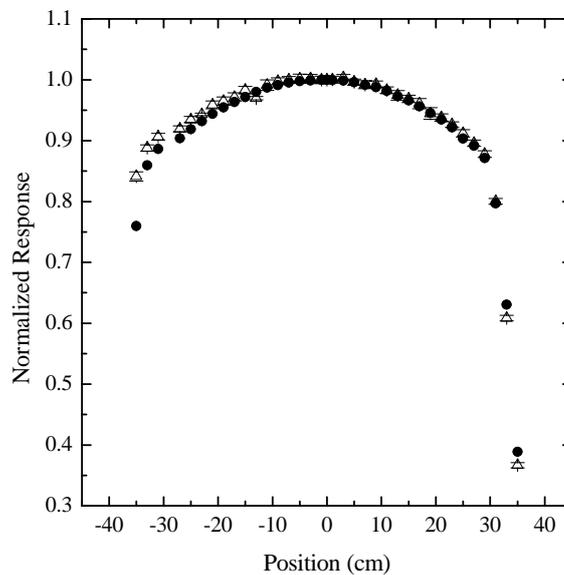
The required field uniformity for calibration and irradiation purposes is 95% according to ISO 4037 [5]. Therefore, the diameter of the useful radiation beam is 25 cm at 1 m.

3.2 Intercomparison between NE 2571 and NE 2530 Ionization Chambers

Because of its small sensitive volume, the NE 2571 ionization chamber is very useful to perform beam uniformity measurements. However, for very low air kerma rates, it is impossible to perform measurements in the electrometer “current” mode and the measurement becomes time consuming.

While the magnitude of the measured signal depends on the ionization chamber sensitive volume, a 35 cm³ chamber (NE 2530) was tested to verify the feasibility of its utilization to perform beam uniformity measurements. The measurement was repeated in the y-direction and in Figure 2 the results are compared, showing a very good agreement.

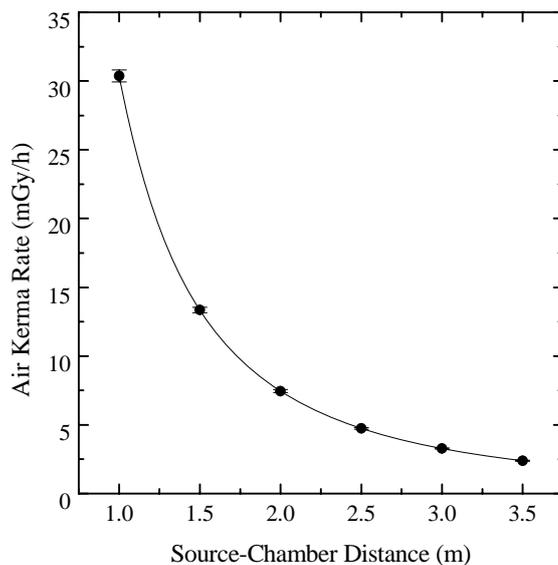
Figure 2: Comparison between the NE 2530 (●) and the NE 2571 (△) ionization chambers.



3.3 Chamber Response as a Function of the Distance to the Source

The variation on chamber response with the distance between the source and the chamber was obtained by varying the distance between the chamber and the source surface from 100 cm up to 350 cm. The result is shown in Figure 3. The measurements relative combined uncertainty [6] was better than 3.5% for a coverage factor k of 2. The major component of this estimated uncertainty was relative to the positioning, which results from the combined uncertainties from the positioning of the chamber in x-, y- and z-directions.

Figure 3: Air kerma rate as a function of source-chamber distance. The full line represents the theoretical result.



3.3 Effect of the Presence of the Lead Attenuators in the Air Kerma Rate

Air kerma rates were measured to each lead attenuator configuration (X0, X2, X4, X10 and X100). The attenuation factor is defined by the ratio between the air kerma rate obtained with the lead attenuator and the air kerma rate obtained without the lead attenuator. These factors were compared with the nominal value provided by the manufacturer. The results are presented in Table 1.

Table 1: Attenuation Factors for Each Lead Attenuator Configuration.

Lead Attenuator	Attenuation Factor		Difference (%)
	Nominal	Experimental	
X2	0.5	0.4813	-3.7
X4	0.25	0.2318	-7.3
X10	0.1	0.09425	-5.7
X100	0.01	0.01087	+8.7

4. Conclusions

The results obtained showed the feasibility of the utilization of the single source irradiator for the calibration of radiation protection monitoring detectors.

To achieve lower air kerma rates, an additional lead attenuator must be confectioned with a nominal attenuation factor equal to 1000. These lower air kermas rates are desirable for the calibrations of sensitive detectors.

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