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Study of the Influence of Scattered Radiation at a Gamma Irradiator

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ABSTRACT

The Calibration Laboratory of IPEN offers calibration services for portable radiation monitors using a Buchler gamma irradiator with ^{137}Cs and ^{60}Co radioactive sources. The beam dosimetry measurements are taken periodically between the source-instrument distances of 1m and 4m. The ISO 4037 standard (International Organization for Standardization) states that the air kerma rate due to scattered radiation shall not exceed 5% of that due to direct radiation. To verify if the facility was in accordance to the requirements, the evaluation of the scattered radiation was performed in this work. The air kerma rates were measured on the beam axis at various distances from the source up to 5.5m, and the radiation attenuation curve was obtained. The air kerma rates were proportional within 5% of deviation to the inverse square law from the source centre to the detector centre, as required by the ISO 4037 standard.

1 INTRODUCTION

At the Calibration Laboratory of the Instituto de Pesquisas Energéticas e Nucleares (IPEN), the beam dosimetry measurements are taken annually at the source-instrument distances between 1m and 4m. Calibration against reference photon fields is the main method utilized. The reference beams are produced at the Calibration Laboratory in accordance to the ISO 4037-1 standard [1]. The different air kerma rates are produced by varying the distance and adding filtration.

According to the ISO 4037 standard, the air kerma rate due to scattered radiation shall not exceed 5% of that due to direct radiation. The objective in this work was to verify if the gamma irradiation facility is in accordance to the requirement, performing the evaluation of the scattered radiation up to 5.5m of source-detector distance.

Moreover, in order to complement this study, measurements were taken at distances smaller than 1m. Due to the source decay and instruments with higher dose rate ranges, calibrations at distances smaller than 1m are sometimes necessary [1]. Thus long irradiation time intervals may be avoided.

2 MATERIALS

A secondary standard ionization chamber (Physikalisch-Technische Werkstätten, PTW), model LS01, with one liter of sensitive volume, with traceability to the Brazilian Ionizing Radiation Metrology Laboratory and a PTW cylindrical ionization chamber, model 23361, 30cm^3 of sensitive volume, calibrated against the secondary standard ionization chamber, both coupled to PTW electrometers (model Unidos) were utilized for the air kerma rate measurements. A ^{90}Sr+^{90}Y control source with nominal activity of 33MBq (1988) was utilized for the quality control measurements A gamma irradiator Buchler, model OB85, with a ^{137}Cs radioactive source, with nominal activity of 740GBq (1995) was utilized for the irradiations in this work.

3 RESULTS

3.1 Ionization Chamber Performance

Initially, as recommended by the ISO 4037-2 standard, the behaviour of the ionization chambers was studied in terms of: response repeatability, stability and current leakage tests, using a control source of $^{90}Sr+^{90}Y$ [2].

The response repeatability test consisted of positioning the $^{90}Sr+^{90}Y$ control source on the chamber using a special support (assuring the reproducible geometry). Then, series of ten consecutive integrated charge measurements were taken. This procedure was repeated 10 times, and all series presented uncertainties lower than ±0.5%.

The stability test is the comparison of the repeatability series variation with the time. This variation did not exceed ±0.7%.

The current leakage test consisted of the evaluation of the total detector current flowing at the operating bias in the absence of radiation. The current leakage did not exceed 0.1% of the reference value produced during the time of each measurement.

Since these test results were in agreement with the ISO 4037-2 standard recommendations, the use of both chambers for the radiation measurements was appropriate [2].

3.2 Beam Dosimetry Measurements

The beam dosimetry measurements are usually taken using the laboratory secondary standard system (between 1m and 4m). Nevertheless, this ionization chamber has a relatively large size, which hinders the complete irradiation when positioned closer to the source.

Based on this need, the 30cm^3 cylindrical ionization chamber was chosen for the dosimetry measurements at small distances.

At the irradiator, the air kerma rates measurements were taken on the axis of the beam at distances smaller than 1m for the ^{137}Cs source, using the 30cm^3 cylindrical ionization chamber. The chamber position was changed in steps of 0.1m. At each position between 0.1m and 1m, 6 measurements were taken.

Afterwards, the air kerma rates measurements were taken at distances greater than 2 m, using the one liter ionization chamber. The chamber position was initially changed in steps of 0.5m and, then, 0.25m. At each position between 1m and 5.5m, 6 measurements were taken.

The data obtained from the measurements and the theoretical curve (based on the inverse square law, all data normalized for the response at 1m) are showed in Figures 1 and 2. The results were separated in two images in order to improve the visualization.

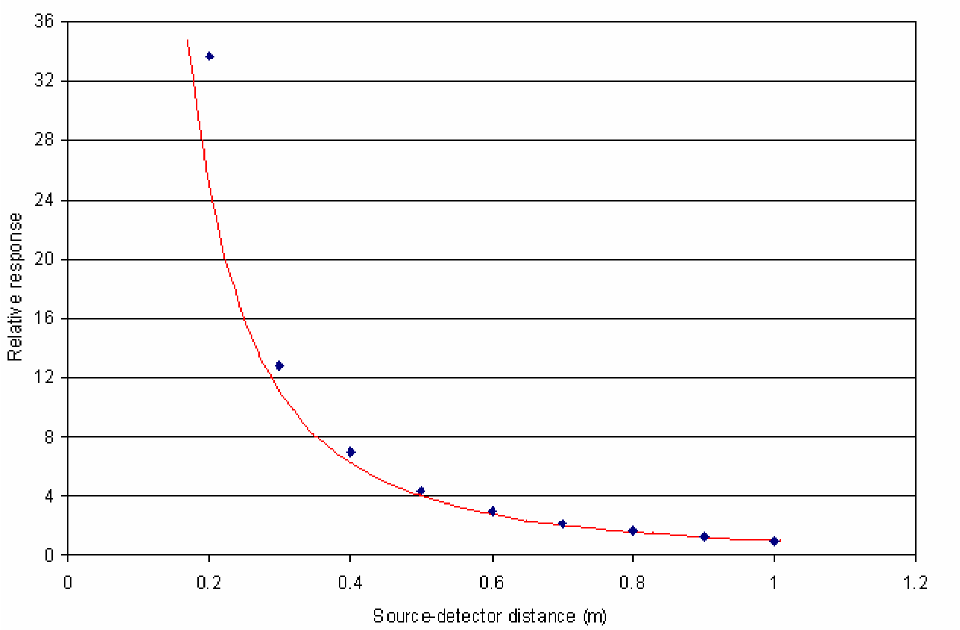

Figure 1: Attenuation curve (between 0.2m and 1m) of the gamma radiation (^{137}Cs) beam intensity in relation to the source-detector distance, using the cylindrical ionization chamber (dots); and the theoretical curve, based on the inverse square law (line)

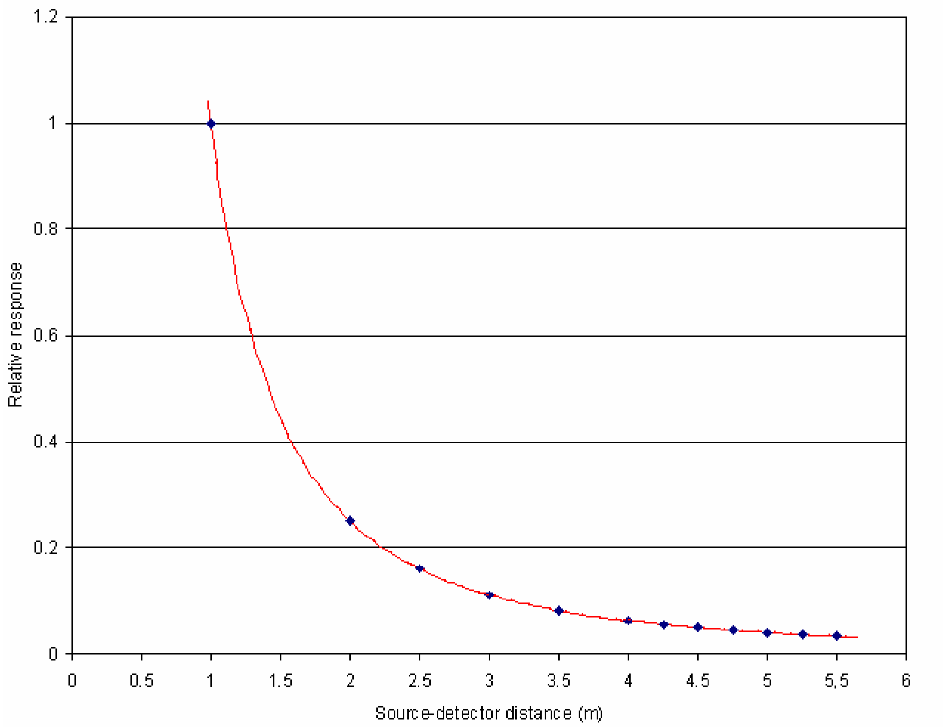

Figure 2: Attenuation curve (between 1m and 5.5m) of the gamma radiation (^{137}Cs) beam intensity in relation to the source-detector distance, using the cylindrical ionization chamber (dots); and the theoretical curve, based on the inverse square law (line)

The theoretical and the experimental curves for larger distances diverged of a maximum of 1%. This result fulfills the ISO 4037-1 requirement of a maximum scatter of 5% [1]. For source-detector distances smaller than 1m, the results diverged of more than 5% at distances smaller than 0.5m.

4 CONCLUSIONS

The performance tests led with both ionization chambers showed results within the international recommendations. Therefore, the use of both ionization chambers for the dosimetry measurements was appropriate. In this work the inverse square law was verified at larger source-detector distances. The theoretical and the experimental curves diverged from 1% at this region. This result fulfills the ISO 4037-1 requirement of a maximum scatter of 5%. The inverse square law was also verified at source-detector distances smaller than 1m but larger than 0.5m. Therefore, source-detector distances smaller than 1m (but larger than 0.5m) and larger than 4m can be used to achieve even wider air kerma rates range for calibrating radiation monitoring instruments, using the ^{137}Cs.

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