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DETERMINATION OF THE SCATTERED RADIATION AT THE NEUTRON CALIBRATION LABORATORY OF IPEN USING THE SHADOW CONE METHOD

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ABSTRACT

Because of the increase in the demand for the calibration of neutron detectors, there is a need for new calibration services. In this context, the Calibration Laboratory of *Instituto de Pesquisas Energéticas e Nucleares* (IPEN), São Paulo, which already offers calibration services of radiation detectors with standard X, gamma, beta and alpha beams, has recently projected a new test laboratory for neutron detectors. This work evaluated the contribution of dispersed neutron radiation in this laboratory, using the cone shadow method and a Bonner sphere spectrometer to take the measurements at a distance of 100 cm from the neutron source. The dosimetric quantities $\dot{H}^*(10)$ and $\dot{H}p(10)$ were obtained at the laboratory, allowing the calibration of detectors.

1. INTRODUCTION

In recent years, in Brazil there has been a considerable increase in the number of detectors used in the monitoring of workers exposed to neutron fields. This is due to the increased use of techniques in industry, medical area, oil prospecting and in scientific research using neutron-emitting sources. Due to the large neutron energy range, obtaining a reliable measurement is a very difficult task.

Reliable measurements of neutron radiation is a very difficult task because of the large range of neutron energy, its energy-dependent and complex interaction mechanisms with matter, so for instruments to have their measurements reliable, they need to be calibrated periodically.

According to CNEN technical regulation 3.02 [1], it is mandatory to calibrate the measuring instrument by authorized entities that comply with the specific standards, so it is possible to ensure that the instrument is working correctly. This laboratory should be very well characterized, and the calibration conditions controlled. In Brazil, there is only one laboratory for calibration of neutron radiation detectors, located in the National Laboratory of Ionizing

Radiation Metrology (LNMRI / IRD-CNEN, Rio de Janeiro), with a very large demand for services with this type of radiation.
Since there are many neutron radiation detectors at IPEN, used by the workers of two nuclear reactors and two cyclotrons, in addition to many radioactive sources, a second calibration laboratory with neutrons in Brazil was required, at IPEN.
This laboratory intends to meet the internal and external calibration requirements of detectors for neutrons. As part of the characterization process of the IPEN Neutron Calibration Laboratory, the radiation scattered throughout the structural elements of the laboratory contributes significantly to the measurement, influencing the reading of the instrument to be calibrated. The proposed study aims to evaluate the influence of the scattered neutrons by the calibration source of ^{241}AmBe, using the Shade Cone Method suggested by ISO 8529-2 [2].

2. MATERIALS AND METHOD

2.1 Neutron Calibration Laboratory (LCN)

The structural geometry of the neutron calibration laboratory at IPEN is shown in Figure 1. The installation is in the Bunker (semi-buried site), with a room measuring 6.88 m x 5.46 m and concrete walls with a thickness of 15 cm, coated with drywall with 2.5 cm.

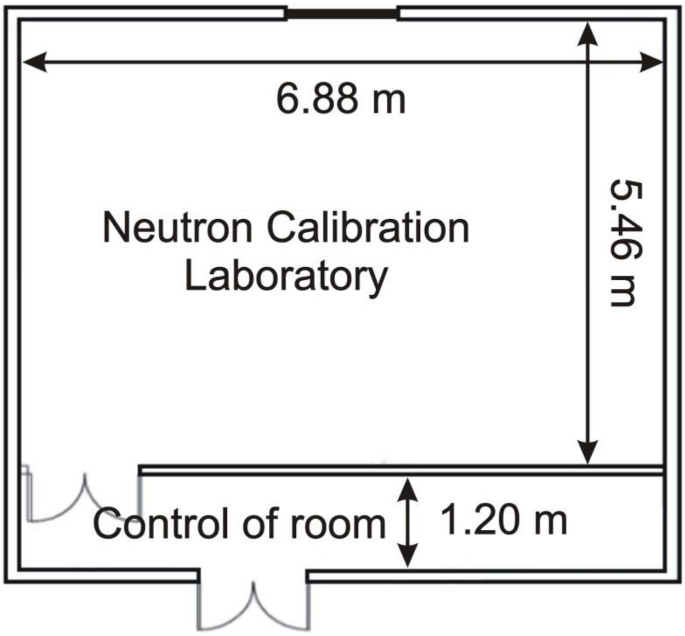

Figure 1: Simplified floor plan of the Neutron Calibration Laboratory.

2.2. Neutron source

The LCN radiation system is composed of a ^{241}Am(Be) AMNK128- model AMN200 source with activity of 3.7×10^{10} Bq (1Ci) and neutron emission rate of 2.46×10^{6} n / s [3]. The source was calibrated at the primary standard system at the LNMRI (IRD/CNEN).

2.3. Shadow Cone Method

The Shadow Cone Method is one of the methods recommended by the norm of ISO 8529-2 part 2 [2]; its objective is to evaluate experimentally the contribution of neutron scattered. For the application of this method, ISO 8529-2 [2] recommends the use of a cone made of two types of materials, the front part is composed of 20 cm of iron and the back part has 30 cm of polyethylene. In Figure 2 the scheme of the shadow cone may be seen.

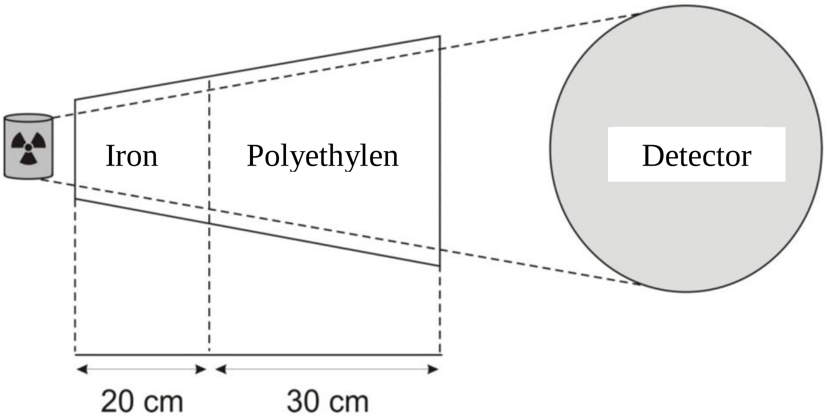

Figure 2: Shadow cone scheme [4].

The cone must be positioned between the neutron source and the detector, in order to avoid the passage of the primary neutron source beam. Thus, the response is obtained by the difference of the measurements without the shadow cone (M_T (l)), and with the shadow cone (M_S (l)) at a given distance (d), which is multiplied by the air attenuation correction factor (F_A (d)) which can be calculated as described in Annex C of ISO 8529-2 [2].

$$M_D(l) = [M_T(l) - M_S(l)]\, F_A(d) \qquad (1)$$

For ^{241}AmBe neutron source, F_A(l) distance of 1 m from the source.

2.4. Bonner Sphere Spectrometer

This method of detection was first described by Bramblett et al [5]; is composed of a thermal neutron detector located in the center of the moderating spheres made of polyethylene. The diameters of the spheres can vary from 2 to 12 inches, thus enabling the measurement of neutrons in a wide range of energy. One of the most used detectors with the Bonner spheres is the ^{6}Li(Eu) enriched lithium-6 iodide scintillator detector, which has a shock section for thermal neutrons of 940 barns and is detected by means of the reaction ^{6}Li(n,α). This detector was used in conjunction with Genie 2000 software, which is a responsible acquisition system for counting.

2.5. Software NeuraLN

This software was developed and validated by Lemos [6], is based on an artificial intelligence technique by the use of neural networks to perform the spectrum splitting, where it has a multilayer architecture, based on a network configuration fully interconnected with supervised learning, in an error back-propagation algorithm with cross-correlation stopping criterion.

The results obtained by the Software consist of the neutron fluence of rate values in 84 energy intervals, where it is possible to determine the spectra from the set of 7 input vectors representing the seven normalized one-unit counting rates and performed with the spheres of different diameters of the spectrometer [6].

3. RESULTS AND DISCUSSION

The measurement occurred at a distance of one meter from the source, where the detector was positioned at the same height of the cone and the radiation source. The irradiation process took place in two stages: at the first, there was a measurement with the cone interposed between the detector and the source, and the measurement was performed without the cone. The counting rates were obtained using the naked detector (without the sphere of moderation). The counting rates were obtained using the detector without moderation (without the sphere of moderation) and using the 2” (5,08 cm) , 3”(7,62 cm), 5”(12,70 cm), 8”(20,32 cm), 10” (25,40 cm) and 12”(30,48 cm) spheres.
Each sphere was exposed separately for one hour, thus allowing an uncertainty of less than 2%. In order to calculate the net count rate, the background measurement was performed for a time interval of one hour. In order to perform the spectrum splitting, the net counting rates were entered into the Neura LN Software, which provided the values of spectral fluence, values of fluence-average Energy (E_{Φ}), $\dot{H}_P(10)$ and $\dot{H}^*(10)$ for the beam without and with the cone. Table 1 shows the results obtained by the LN neural network program for the spectrum with and without the cone

Table 1: Values obtained by beam deconvolution with and without cone.

Distance (cm)	**Fluence rate n/cm^2.s**	**$\dot{H}^*(10)$ pSv/s**	**$\dot{H}_p(10)$ μSv/h**	E_{Φ} **MeV**
Spectrum without cone				
100	46.6	318.4	64.9	3.9
Spectrum with cone				
100	29.4	297.4	36.7	3.6

To obtain the direct beam, the formula described in the shadow cone method was applied, where it was possible to obtain the value for the direct beam. The scattering fraction was obtained by dividing the direct beam by the value of the scattered beam (with cone). Table 2 presents the values obtained by the LN neural network program for the direct spectrum.

Table 2: Direct beam values

Distance (cm)	**Fluence rate n/cm^2.s**	**$\dot{H}^*(10)$ pSv/s**	**$\dot{H}_p(10)$ μSv/h**
100	17.2	342.7	25.0
Spreading fraction (%)			
100	36.8	107.6	38.4

In order to validate the deconvolution, the experimentally obtained values of the direct beam with the values quoted in the ISO 8529-2 [2]. Table 3 presents the comparison between the values of the direct beam and from the standard ISO 8529-2 [2].

Table 3: Comparison between reference and experimental values

	ISO 8529-1	Experimental	Difference %
$\dot{H}_p(10)$ pSv/s	391	343	12.4
Energy MeV	4.19	4.25	1.4

The experimental values obtained for mean energy and Ḣp have a percentage difference of less than 20% when compared to the reference values. Figure 3 shows the reference spectra, total beam (scattered and direct) to the distance of 100 cm from the source.

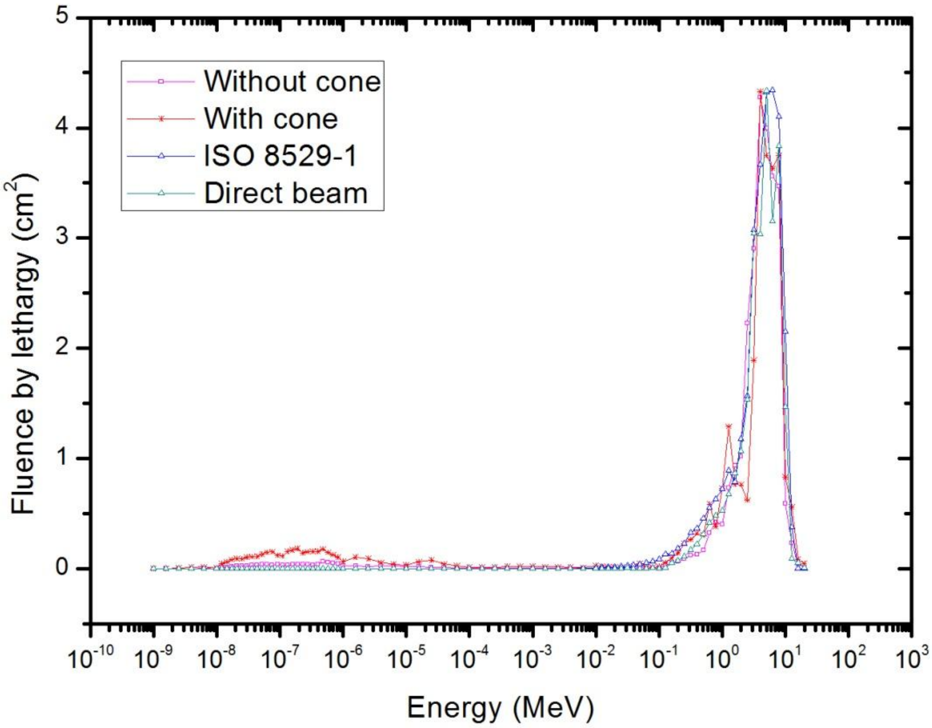

Figure 3: Spectra of reference, total, scattered and direct beans of a ^{241}AmBe source at the source-detector distance of 100 cm.

The scattering correction factors for fluency rate, Ḣ* (10) and Ḣp (10) were calculated by the ratio between the experimental values measured from the full beam (with scattering) and direct beam values (without scattering). Table 4 presents the correction factors for fluence rate, Ḣ * (10) and Ḣp (10).

Table 4: Correction factors for the radiation scattering

Distance (cm)	Fluence rate n/cm^2-s	$\dot{H}^*(10)$ pSv/s	$\dot{H}_p(10)$ µSv/h
100	0.4	1.1	0.4

4. CONCLUSIONS

The contribution of scattered neutron radiation at the Neutron Calibration Laboratory (LCN) was evaluated in this work. A Shadow Cone method and a Bonner Sphere Spectrometer were used to perform the measurements at a distance of 100 cm from the source. Using this method, it was possible to estimate the scattering contribution to $\dot{H}p$ (10), obtaining a result lower than 40%, thus obeying the maximum scattering allowed in o reading. The calibration factors for the fluence rate, $\dot{H}$ *(10) and $\dot{H}p$ (10) were obtained.

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