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Characterization of the collimated output fluence, in a thermal neutron field, in terms of ambient dose equivalent H*(10.0)

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ABSTRACT

The Brazilian Neutron Laboratory at the Institute of Radioprotection and Dosimetry (IRD) developed and built a new standard facility for thermal neutron flux, seeking to provide a new homogeneous fluence to calibrate neutron detectors and personal dosimeters. The purpose of this work is therefore to characterize the collimated output fluence, in a thermal neutron field, in terms of ambient dose equivalent H*(10.0) for calibration and irradiation of personal monitors and neutron survey meters. The neutron fluence in the system irradiation field needs to be well known for personal monitors and neutron survey meters calibrated used in nuclear reactors in addition to studies and development of new materials for neutron dosimetry. The characterization of neutron thermal energy fields at the usual calibration points is one of the recommendations of the International Organization for Standardization ISO 8529, 2001 for international intercomparison of neutron fluence measurements. The determination of the ambient equivalent dose of the new facility was estimated based on a secondary transfer standard internationally known as Long Counter and properly characterized and traced back to the Neutron Laboratory primary standards.

Keywords: **Neutron Detectors, Thermal Fluence, Long Counter.**

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1. INTRODUCTION

Due to the increase in demand for neutron survey meters calibration, it is necessary to standardize new fields to meet the need for these instruments used in industries and hospital services, with the guarantee of their metrological parameters control.

Therefore, the Neutron Metrology Laboratory (LN) designed a facility for thermal neutron flux (FT2) for the relative standardization of neutron monitors and personal dosimeters calibration.

The characterization of neutron thermal energy fields at the usual calibration points is one of the recommendations of the International Organization for Standardization ISO 8529, 2001 [3] for international intercomparison of neutron fluence measurements. The determination of the ambient equivalent dose of the new facility was estimated based on a secondary transfer standard internationally known as Long Counter (LC) and properly characterized and traced back to the LN primary standards.

The new system FT2 generates a neutron thermal field produced by braking and neutron thermalization in moderator material (graphite and paraffin) and is in the energy range below 0.5eV. The study of the emission spectrum and the average energy produced by the FT2 was done by Astuto [1]. And the response of the Long Counter detection system or secondary dose equivalent standard was studied by Fernandes [4].

2. MATERIALS AND METHODS

For recording measurements with LC, the electronics used correspond to the association of a computer with a software for recording counting rates and dead time called Genie2000 (Gamma acquisition), connected to a multichannel analyzer and to a preamplifier connected to the neutron detector.

2.1.Long Counter design and Characteristics

The Long Counter (LC) detector is a secondary reference neutron fluence meter from the Ionizing Radiation Metrology Laboratory (LNMRI) [4]. This device is widely used in international reference laboratories such as the National Physics Laboratory (NPL) and the Institute for Radioprotection and Nuclear Safety (IRSN).

Its internal structures consist of a detector tube filled with BF3 gas with dimensions of 288 mm in length and 38.2 mm in outer diameter, manufactured by Centronic Ltd. The detector tube is covered by a cylinder of high-density polyethylene and, on top of this, a second cylinder of bored paraffin covers the set-in order to minimize the lateral incidence of neutrons scattered in the environment. This set of concentric cylinders is contained in a cylindrical aluminum cover in order to avoid deformations of the boron paraffin and polyethylene. In addition to the borated paraffin, it is also possible to prevent the direct incidence of thermal neutrons, coming from the medium, in the detector tube, by adding a cadmium foil on the front face of the LC [4].

2.2.Standard Thermal Flow System: Design and Features

2.2.1 Standard Thermal Flow

The Thermal Flow installation has the shape of a cube measuring 1.2 x 1.2 x 1.2 m^3 on a steel platform about 50 cm from the floor. A central chamber measuring 10 x 10 x 10 cm^3, located in the center of the pile, is connected to the outside through a channel (10 x 10 x 55 cm^3) [1].

The radionuclide sources used in the arrangement are located inside stacks consisting of paraffin blocks, with the addition of high purity graphite blocks and consist of four sources of 241Am-Be (beryllium americium), each with 596 GBq, to obtain a central field with a homogeneous thermal neutron fluence for calibration purposes.

2.2.2 Flattener

The Flattener is a polyethylene filter made up of 29 discs with diameters ranging from 5 to 34 cm. It is used in order to homogenize the data capture.

2.3.Measurements

A radiation field is characterized by a radiometric magnitude, regardless of the type of radiation emitted [6]. The fluence rate (φ) for measurements of a thermal neutron field is evaluated in this work. It is defined as the ratio between the count rate recorded by the secondary standard metering system and the system response.

Once the measurement has been carried out, the count rate (C) is calculated, which is given by:

$$\frac{Mt(ctg)}{t(s)} \tag{1}$$

Then, the neutron fluence rate (φ) is calculated:

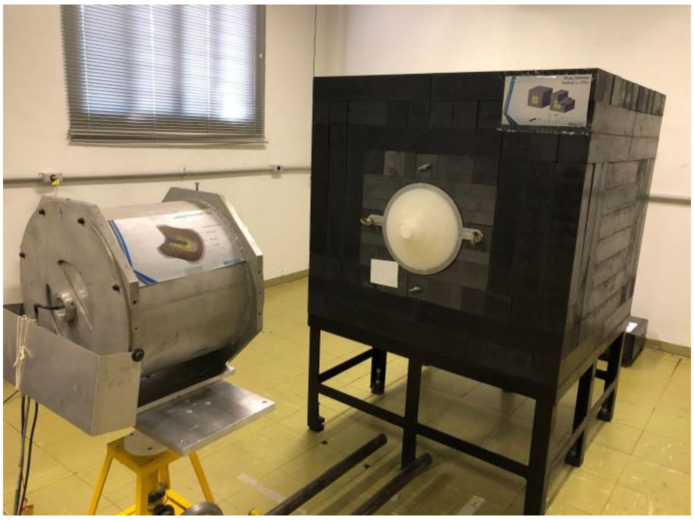
$$\frac{C}{R_{\emptyset}} \tag{2}$$

Where R_{Φ} is the response of the measurement system, which generally varies with the energy and directional distribution of the incident neutrons [4].

The first measurement step was performed with the Long Counter (LC), positioned in front of the system, with the center of its front face aligned with the axis of the central channel as seen in Figure 1. This experimental arrangement obeys the following combinations:

- Measurements with a flattener, where the device is positioned in front of the thermal field, in order to evaluate, by distance association, a set of measurements with and without cadmium foil, for each distance, 20 and 240 cm. Five readings were performed for each position.
- Measurements without a flattener, where the device is positioned in the thermal field in order to evaluate the reading as a function of distance, collecting a set of measurements with and without cadmium (Cd) foil, evaluating the same conditions of the arrangement with a flattener.

Figure 1: *Measurement with LC at the Standard Thermal Neutron Flow Unit installations, LT2, at LNMRI/IRD.*



3. RESULTS AND DISCUSSION

The value of R_Φ (cm^2) of the LC response for the average energy of the thermal system obtained by Monte Carlo simulation with the MCNPx code were 3.72 with Cd foil and 3.74 without the Cd foil. The measurements were performed with the LC, and they achieved results in agreement with the ambient dose equivalent values [4] by the Bonner multisphere system which can be found in Figures 2, 3 and 4.

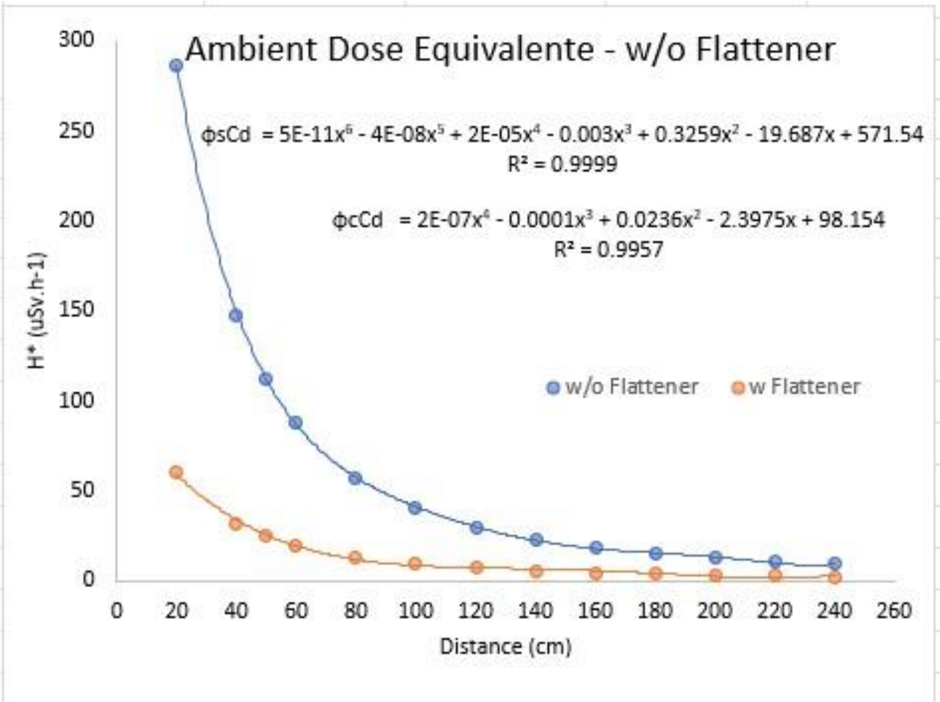


Figure 2: *Ambient dose equivalent H*(10.0) for measurements without a flattener.*

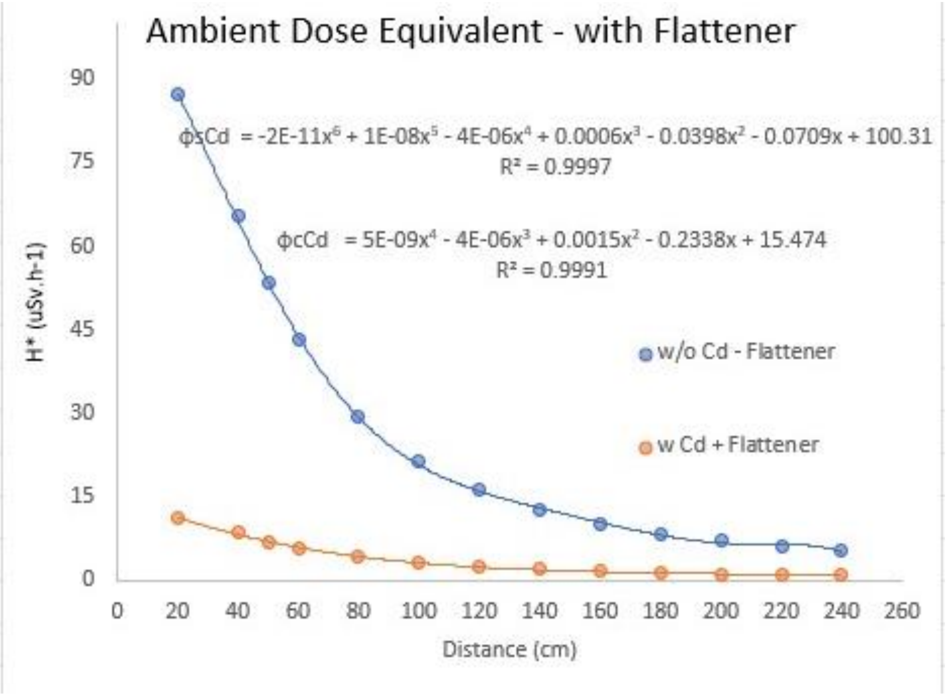


Figure 3: *Ambient dose equivalent H*(10.0) for measurements with a flattener.*

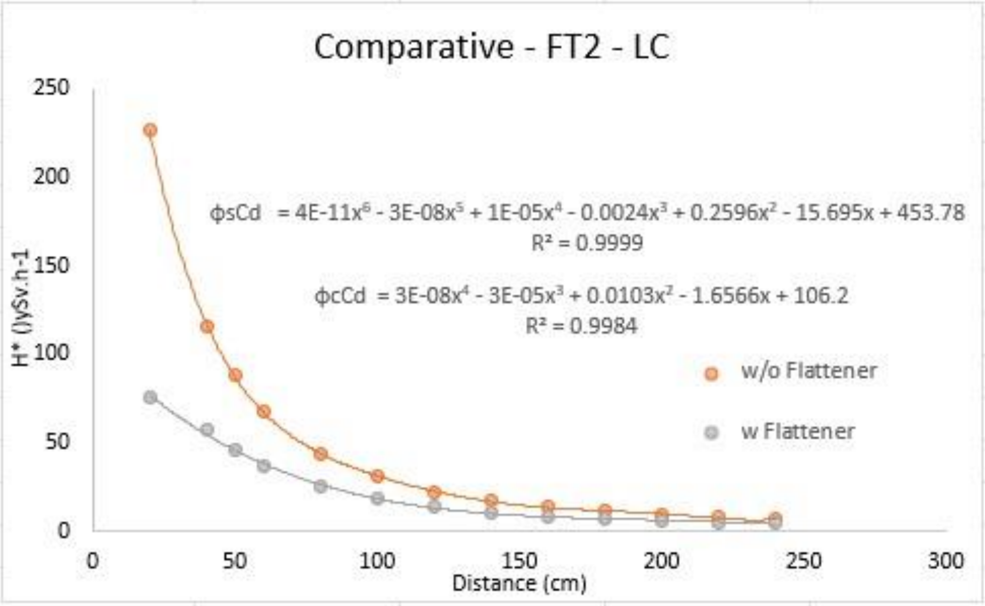


Figure 4: *Ambient dose equivalent H*(10.0) for measurements with and without a flattener.*

The curves underwent a polynomial fit of order 6. There is a discrepancy in the results from both Figures 2 and 3 due to the fact that the Cadmium shield minimizes direct detection of incident thermal neutrons. Also, as it can be seen in Figure 4, the further away we move from the FT2, the closer the values of ambient dose equivalent become from each other, since the flattener does not interfere as much on the homogeneity of the rays.

4. CONCLUSION

The curves obtained can be used to characterize the fluence and dose equivalent fields as a function of the distance from the thermal face to the measurement point. Some improvements have however to be made. It is expected in future works, to assess the reproducibility by evaluating several sets of measurements.

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