New thermal neutron calibration channel at LNMRI/IRD

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Abstract: A new standard thermal neutron flux unit was designed in the National Ionizing Radiation Metrology Laboratory (LNMRI) for calibration of neutron detectors. Fluence is achieved by moderation of four ^{241}Am-Be sources with 0.6 TBq each, in a facility built with graphite and paraffin blocks. The study was divided into two stages. First, simulations were performed using MCNPX code in different geometric arrangements, seeking the best performance in terms of fluence and their uncertainties. Last, the system was assembled based on the results obtained on the simulations. The simulation results indicate quasi-homogeneous fluence in the central chamber and H*(10) at 50 cm from the front face with the polyethylene filter.

Keywords: Neutron Metrology; Neutron Fluence; Monte Carlo Simulation; Calibration.

1. Introduction

Due to the growth of soil logging activity in prospecting oil and natural gas, where over 60% of all neutrons sources in the country are concentrated [1], the amount of neutron personal area monitors and survey meters in Brazil have increased significantly. It generates a growing demand for calibration and mechanisms to ensure control of their metrological parameters.

The purpose of this project was to develop an irradiation system with thermal neutrons to calibrate personal dosimeters and survey meters, using radioisotopic neutron sources and moderators materials. It derives from a system previously built with paraffin with graphite blocks (PG) and pure graphite blocks [2]. The results achieved were not satisfactory due to problems in the PG composition, especially regarding the spectra at points of interest.

Although the International Organization for Standardization (ISO) recommends the use of a moderated-reactor or an accelerator-produced neutron to produce thermal neutron fields [3], the use of radioisotopes in a suitable thermal device is desirable, mainly due to its stable fluence and easy operation. In addition, facing technological advances, where new equipment and processes have been producing more accurate measurements, several calibration centres around the world are remaking or rebuilding their thermal fields [4,5].

The current facility remained the external dimensional length of the previous one, built on a cube with the same materials used before, with dimensions of 1.2 x 1.2 x 1.2 m on a steel platform which is about 50 cm above the ground. A central chamber 10 x 10 x 10 cm size in the pile centre, connected to the outside by a central channel (10 x 10 x 55 cm). Four equally spaced ^{241}Am-Be neutrons sources are used in order to obtain a central field, with homogeneous thermal neutron fluence for calibration purposes. The great difference to the previous one is the positioning of moderator material, because while the old were used PG blocks and graphite blocks among the source and the central chamber, the current one uses only graphite in the device core and PG around that graphite core to form the cube, as can be seen in figure 1.

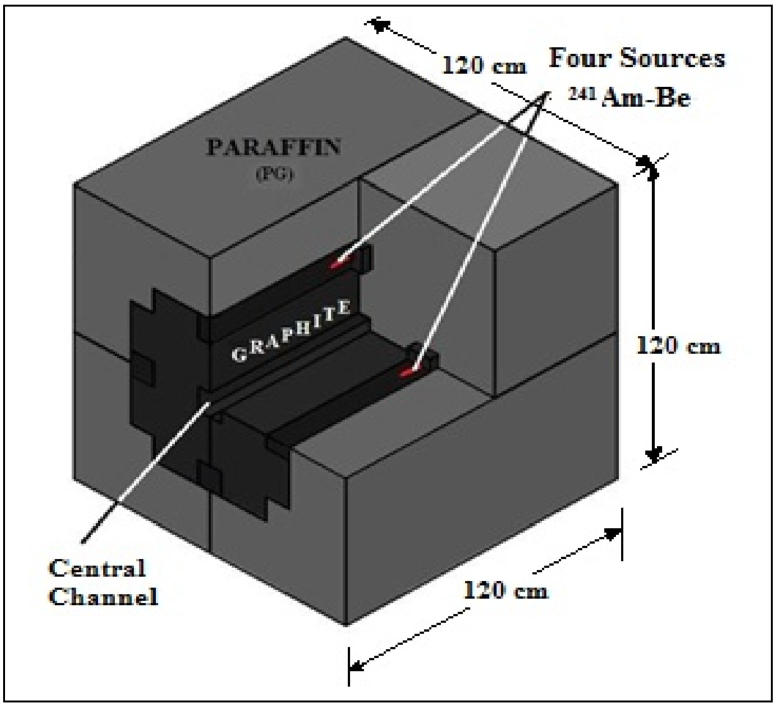

Figure 1 - Schematic 3D view of the new thermal neutron facility.

2. Methodology

This study was divided into two steps. First one, simulations using the MCNPX code [6] on different geometric arrangements of moderator materials and neutron sources were performed. On second step, the pile system was assembled based on results obtained by the new simulation.

2.1 Simulations

Simulations were made to study how the thermal neutrons fluence could be changed by displacing the source distance to the center of the chamber as well as the cadmium rate (CDR). The CDR is defined as the ratio between total neutron fluence and fluence crossing a cadmium cover. Cadmium acts as a filter by absorbing thermal neutrons (neutrons below 0.5 eV).

To setup the creation of an ambient dose equivalent (H*(10)) low-band variation at a distance of 50 cm from the front face, a polyethylene filter was simulated. When this filter was placed at the outlet of the central channel, an 'homogeneous' H*(10) band over about 35 cm was established, allowing dosimeter calibration that should be carried out on the 30 cm x 30 cm x 15 cm ISO phantom [3]. Various thicknesses were simulated to find one that would provide the desired effect.

3. Experimental Procedure and Measurements

The PG simulations as in the first design were affected by difficulties in obtaining the material density and the correct mass fraction, since the mass of the heavier and lighter blocks varied up to 1 kg. These blocks were radiographed and the images showed the presence of air bubbles and sand impurities inside. The elemental chemical analysis, CNHX, was used to indicate the mass fraction of carbon, hydrogen and nitrogen. This fraction was 89.6% for carbon and 7.4% for hydrogen. The analysis showed the presence of about 3% of impurities in the PG mass fraction, and then 3% of air and sand (SiO_2) were included in the simulated PG composition. The average density of graphite blocks was 1.328(14) g/cm^2.

Six polyethylene spheres with diameters ranging from 5.08 to 30.5 cm of the LNMRI Bonner Multisphere Spectrometer (BMS) were used to get the neutron spectra of the four ^{241}Am-Be sources (S1, S2, S3 and S4) used in the thermal neutron flux facility. The same procedure will be used for the spectra analysis on some points around the pile (figure 2).

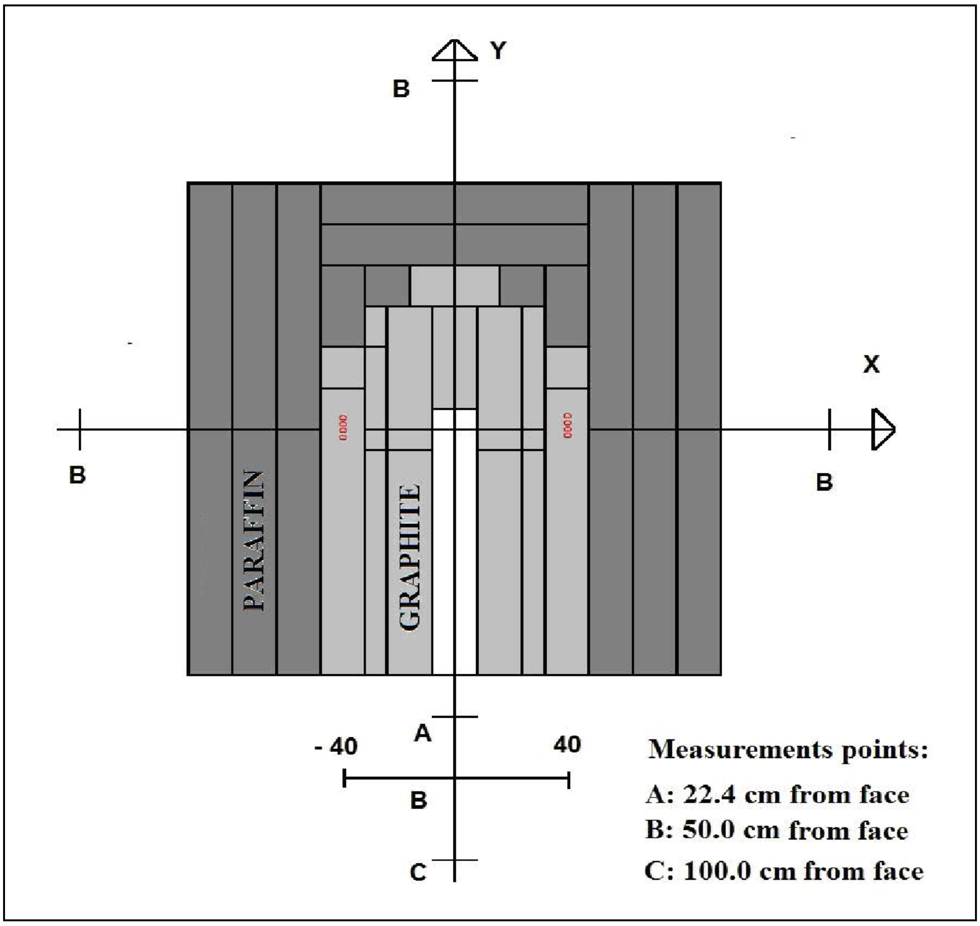

Figure 2 - Measurement points scheme in the facility room, at Z = 0 slice.

To test the thermal neutrons beam homogeneity, the fluence was simulated at 19 points within the central chamber and points around the installation (preferably at a distance of 50 cm from the faces) to determine the net fluence for calibration. In the front face, fluence variation over a distance of 50 cm was investigated. The determination of the ambient dose equivalent rate, H*(10), on points of interest, was performed through the definition of point detectors F5 (F5 tally) for neutrons, available on MCNPX program. The results were modified with the use of ED/DF dose function cards, with the introduction of conversion coefficients for ambient dose equivalent H*(10)/Φ, in pSv.cm^2, given by ICRP 74 [7].

One of the four sources used (S1) was calibrated on a Primary and Absolute Neutron Standardization System traceable to BIPM by CCRI-III K9 international key comparison relative to ^{241}Am-Be emission rates [8]. The other three sources (S2, S3 and S4) emission rates were intercompared with the source S1 using the BSS at a distance of 1 m and then normalized.

The polyethylene filter was simulated, designed and built with 29 discs with diameters ranging from 5 to 34 cm and a thickness of 4 mm each. A commercial monitor WENDI, FHT 762 model, manufactured by ThermoElectron, was used to perform measurements of H*(10).

4. Results

Table 1 shows the emission rate of the four sources used in the pile, measured with BSS and the contribution of them to total fluence. It can be seen that the major difference between the sources emission is about 10%, a fact that was weighted during the positioning and the system simulations.

Table 1 - Source emission and weight

LN code	Source	Emission (n/s)	Weight	Weight (n)
A-639	S1 (*)	3.952(59)E+07	1.00	0.254
A-441	S2	3.868(58)E+07	0.9788	0.249
A-397	S3	3.627(54)E+07	0.9177	0.233
A-597	S4	4.097(62)E+07	1.037	0.264
	Total	1.554(23)E+08	3.933	1.00

The results obtained for fluence simulation in the central chamber, showed less than 2% variation over CDR calculations among the 19 points, indicating a probable homogeneous fluence inside the central chamber. The average fluence rate calculated in the chamber center was 1.934(23)x10^{5}n/cm^2.s. The external points values are listed in table 2.

Table 2 - Fluence in external points around the pile

Reference position	**Fluence rate (n.cm^2.s^{-1})**	**Percentage of total fluence (%)**		
		< 0.5eV	**0.5eV-100keV**	**>100keV**
(0,0,0)	**1.934(23)x10^5**	**7.3**	**6.9**	**85.8**
A(-y)^1	**1948.8(6)**	**67.0**	**22.7**	**10.2**
B(-y)^1	**715.4(4)**	**67.3**	**21.7**	**11.0**
C(-y)^1	**242.5(6)**	**65.7**	**22.3**	**12.0**
B(y)^2	**24.26(2)**	**44.6**	**16.4**	**39.0**
B(-x)^2	**57.13(4)**	**42.6**	**14.2**	**43.2**
B(x)^2	**55.85(5)**	**42.5**	**14.6**	**42.9**

^{1}(-y) = frontal face values at points A, B and C;
^{2}(y), (-x), (x) = back and lateral face values at point B.

The graph of figure 3 shows the results of H*(10) variations over a range of 36 cm at a distance of 50 cm from the front face (point B) with MCNPX simulations and WENDI measurements.

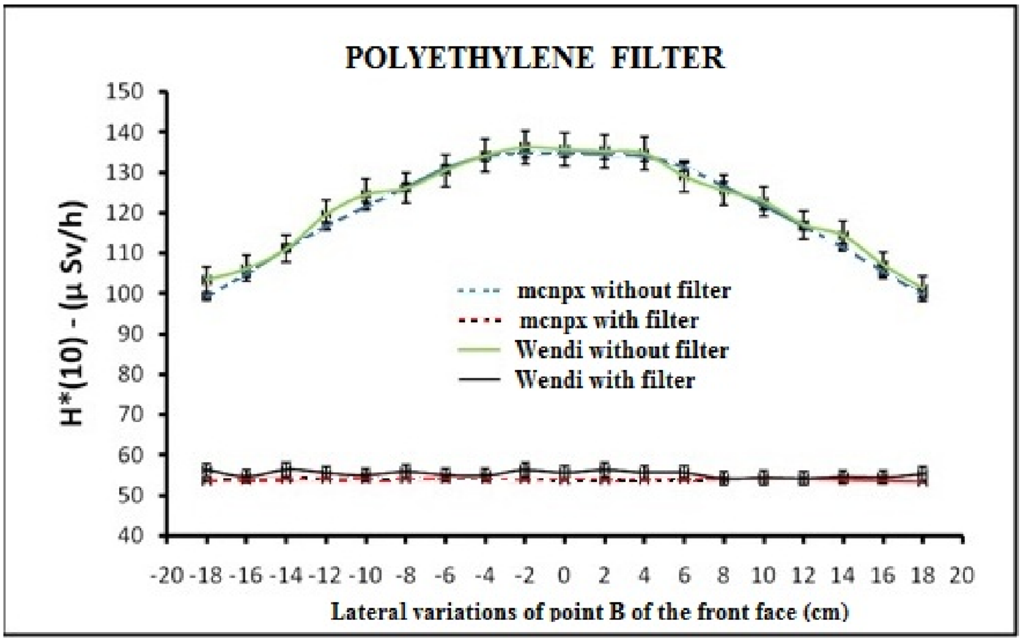

Figure 3 - Measurements along the dimension -50 cm (B), on the front face of the installation.

5. Conclusions

In order to confirm the thermal neutron field, fluence rate and H*(10) at points around the pile and in the central chamber (inside the channel), measurements will be performed using the BMS at first, and then survey meters and their respective response functions. In the central chamber it will be necessary to use another measuring method, such as the gold foils activation with measurement traceability. These steps will be performed in a future stage.

The CDR in the new arrangement is lower than the previous arrangement, however, due to sources proximity, greater fluence is achieved.

The Figure 3 indicates that results obtained with polyethylene filter reached the proposed objectives.

6. References

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