RESPONSE OF A NEUTRON MONITOR AREA WITH TLDs PAIRS

Guzmán-García, K.A.[a], Gallego, E.[b], Lorente, A.[b],
Borja-Hernández, C.G.[a], Valero-Luna, C.[a],
Hernández-Dávila, V.M.[a] and Vega-Carrillo, H.R.[a],

[a]Unidad Académica de Estudios Nucleares, Universidad Autónoma de Zacatecas
C. Ciprés 10, Fracc. La Peñuela, 98068 Zacatecas, Zac. Mexico
[b]Departamento de Ingeniería Nuclear, Universidad Politécnica de Madrid
C/José Gutiérrez Abascal 2, E-28006 Madrid, Spain

Email: ing_karen_guzman@yahoo.com.mx

Abstract

The response of a passive neutron monitor area has been calculated using the Monte Carlo code MCNP5. The response was the amount of $n(^6Li, T)\alpha$ reactions occurring in a TLD600 located at the center of a cylindrical polyethylene moderator. Fluence, (n, a) and H*(10) responses were calculated for 47 monoenergetic neutron sources. The H*(10) relative response was compared with responses of commercially available neutron monitors being alike. Due to ^6Li cross section (n, α) reactions are mainly produced by thermal neutrons, however TLD600 is sensitive to gamma-rays; to eliminate the signal due to photons monitor area was built to hold 2 pairs of TLD600 and 2 pairs of TLD700, thus from the difference between TLD600 and TLD700 readouts the net signal due to neutrons is obtained. The monitor area was calibrated at the Universidad Politecnica de Madrid using a $^{241}AmBe$ neutron source; net TLD readout was compared with the H*(10) measured with a Berthold LB6411. Performance of the neutron monitor area was determined through two independent experiments, in both cases the H*(10) was statistically equal to H*(10) measured with a Berthold LB6411. Neutron monitor area with TLDs pairs can be used in working areas with intense, mixed and pulsed radiation fields.

1. INTRODUCTION

The neutrons are part of the natural radiation environment in which life developed on Earth; human activity has led to the development of environments where neutrons are produced increasing the neutron dose, (Morales, 2008).

Due to its lack of electric charge the measurement of neutrons is not a trivial task, and the determination of neutron dose has been a problem for many years, (Leake, 1966). One might define in two major groups the devices used to determine the neutron dose, those that use active detectors and those using passive detectors.

The advantages of devices based upon active detectors are that the measurements are obtained in actual time without the need of process the readouts. On the other hand the disadvantage is the need of a voltage source; therefore it cannot be used in locations where neutron intensity is very low or in remote locations where it is needed to do measurements for long time. Another drawback is that cannot being used in pulsed, mixed and intense radiation fields as those presented in linear accelerators or in hot spots inside nuclear facilities (Morales, 2008; Becerra *et al*, 2001).

During its operation passive neutron monitors does not require power supply neither electronics because the incident radiation induces a change in the detector material, the induced change, which depends upon incident radiation features, is measured latter (Morales *et al*, 2008). Pairs of thermoluminiscent dosimeters (Vega, 2002; Tripathy *et al* 2002), activation foils (Begdoni *et al*, 2008), bubble detectors (Zanini et al, 2004), and track detectors (Kralik *et al*, 2008) have been the passive detectors that have been used for long time

The aim of this work was to calculate the response functions of a neutron area monitor with a passive detector consisted in pairs of thermoluminescent dosimeter and to calibrate the neutron monitor area due to the importance of knowing the efficiency.

2. MATERIALS AND METHODS

The passive neutron monitor area has of two parts, the moderator and the neutron detector. Moderator is 20.5 Ø X 20.5 cm2 polyethylene cylinder with a density of 0.94 g/cm3. It has two sections, as shown in figure 1.
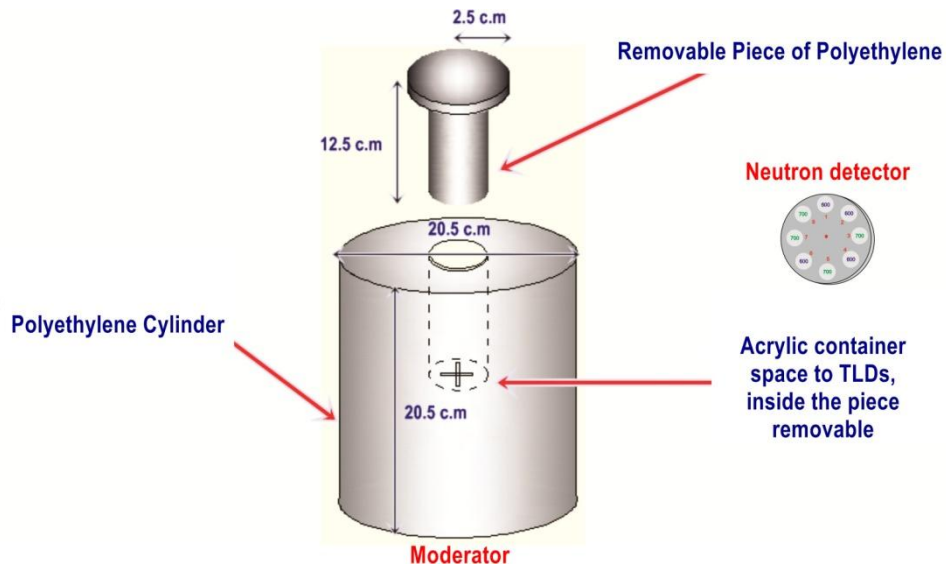
Figure 1. Passive neutron area monitor

Section 1 is a plug, when is fully inserted in the section 2 leaves the thermal neutron detector at the centre. The thermal neutron detector is 4 pairs of thermoluminiscent dosimeters of TLD600 and TLD700, each TLD is located in a fixed position inside an acrylic box as it is shown in figure 2.
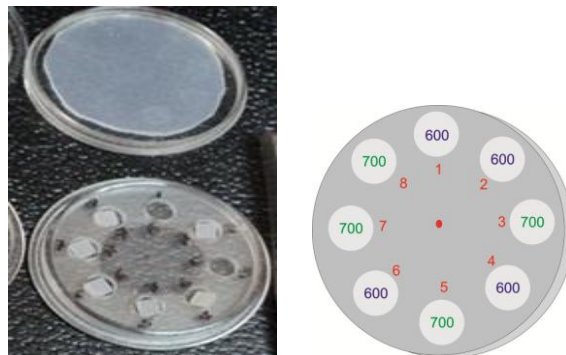

Figure 2. TLDs' holder

TLDs are ribbon type 0.3175 x 0.3175 x 0.0889 cm3. TLD600 contains 95.6% of ^{6}Li, meanwhile TLD700 IS 99.9% of ^{7}Li. Both lithium isotopes have different cross section to neutrons, as is shown in figure 3 (NNDC, 2010).
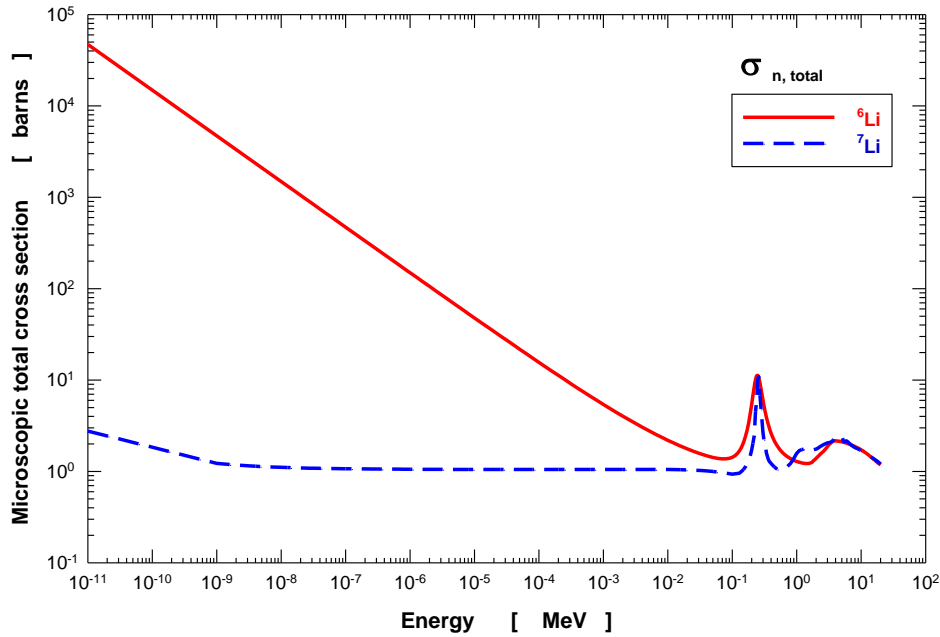
Figure 3. Total cross sections of lithium isotopes

Both TLDs have approximately the same density and effective atomic number, having roughly the same response to gamma-rays. The response to thermal neutrons of TLD600 is larger than TLD700 response. When both are exposed in a neutron and gamma-ray radiation field the response to neutrons is obtained by equation (1).

$$R_{600}^{n} = R_{600}^{n+\gamma} - k\, R_{700}^{n+\gamma} \tag{1}$$

Here, k is an empirical correction factor accounting the difference in the response to gamma-rays between TLD600 and TLD700 (Vega, 2002).

Passive neutron monitor area with TLDs, NM/TLDs, response was calculated with Monte Carlo method using the MCNP5 code (MCNP, 2003). The response was calculated using two irradiation geometries, one with a disk source on the top of the NM/TLDs and another with a lateral square source, both geometries are shown in figure 4.

For each irradiation condition the response was calculated with the thermal neutron detector in two different positions, one parallel to the source and another perpendicular to the source. In the calculations 47 monoenergetic neutron sources, ranging from 1E(-9) to 20 MeV were used.

The response functions were calculated in terms of the ambient dose equivalent, H*(10), using the ICRP74 conversion coefficients, h*(10), (ICRP, 1996) as is shown in equation (2).

$$R_{H*(10)}(E) = \int_{\forall E} \Phi_E(E)\, h*(10)(E)\; dE \tag{2}$$

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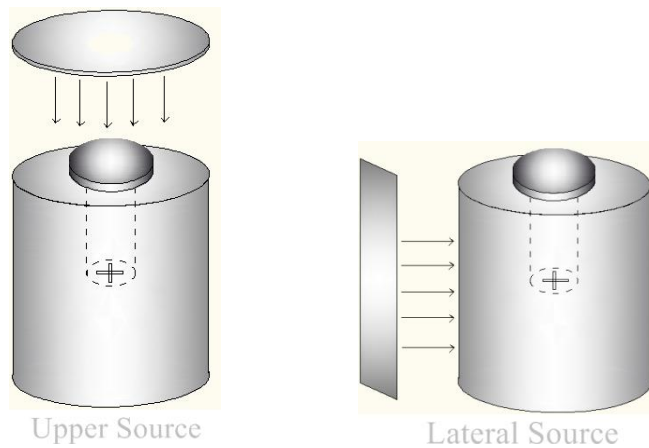**Figure 4. Irradiation conditions**

The monitor area was calibrated at the Universidad Politecnica de Madrid using a [241]AmBe neutron source. First we measurement the H*(10) to 100 com from the source whit the Berthold LB6411, with 58 readings were made to verify the average value is 79.5µSv/h, the value was 80.457µSv/h applying the calibration factor 0.992 ± 0.085gives a value more approximately to 79.5µSv/h it was 79.813µSv/h, figure 5.
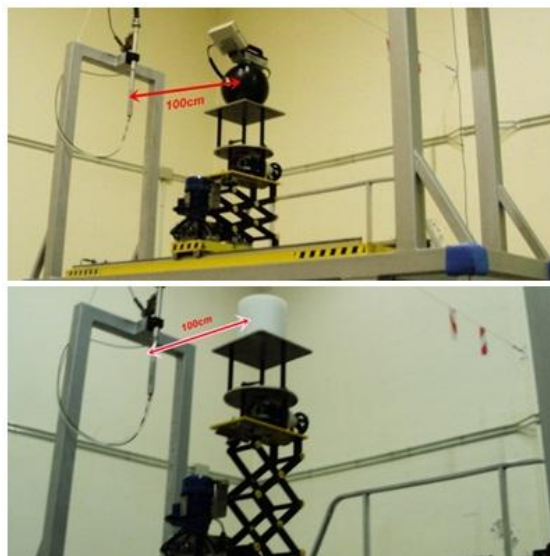

Figure 5. Berthold and neutron area monitor at 100 cm from [241]AmBe

The container with the pairs of TLDs was inserted in the Removable piece of polyethylene and placed pieces of black polyethylene moderator to avoid leaving empty spaces, it was collocated in front the AmBe source as shown in Figure 6. The neutron monitor area was collocated in the same position as the Berthold irradiated for 15h.

Figure 6. Plug, and plug being inserted on moderator

At the end readings were taken both TLDs irradiated and the TLDs background, to resting the avarages the readings of TLD600 irradiated to the TLD600 background we obtain the Net of TLD600 and the same for the Net of TLD700, the difference of the rest is related with the H*(10) of the Berthold and obtained the average of the calibration. This proceeding was done in triplicate.

After for verify the quality of calibration factor, we done two measurement experiments. And both was compared with the measurement to H*(10) with the LB6411. Figure 8.

Figure 7. Two experiments

3. RESULTS

In figure 8 is shown the NM/TLD's ambient dose equivalent response, $R_{H*(10)}$, when it is irradiated with an upper source with the TLD perpendicular and parallel to the source. It can be noticed that below 0.3 MeV both responses are the same. Above 0.3 MeV there are small differences in the responses probable due to the amount of polyethylene between the source and the TLD, which increase the neutron moderation.

In figure 9 is shown the $R_{H*(10)}$ of the neutron area monitor when it is irradiated with a side source for both TLD positions, perpendicular and parallel to the source. It can be noticed that in this case both responses are alike.

Of this process was obtained following calibration factor.

$$K = 1.57 \pm 0.041\,\mu Sv - h^{-1} - cpm^{-1}$$

The first experiment was obtained

$$H*(10)_{mp} = n1*K = (3,95\,cmp)(1.57\,\mu Sv - cpm^{-1}) = 6.20\,\mu Sv$$

In the same place we measurement the H*(10) with the Berthold LB6411

$$H*(10)_{LB6411} = 6.33\,\mu Sv$$

Comparing both measurements the Berthold LB6411 give a dose 2.09% more than the Passive Neutron Monitor.

The second experiment was obtained.

$$H*(10)_{mp} = n2*K = (0.14\,cmp)(1.57\,\mu Sv - cpm^{-1}) = 0.22\,\mu Sv$$

In the same place we measurement the H*(10) with the Berthold LB6411

$$H*(10)_{LB6411} = 0.27\,\mu Sv$$

Comparing both measurements the Berthold LB6411 give a dose 22.72% more than the passive Neutron Monitor. The probable cause is due to the low total dose.

4. CONCLUSIONS

For the lateral irradiation of the monitor area it produces a response to the fluence for the lateral source for both positions to the TLD, more uniform for higher energy neutrons at 2 Mev that when irradiated since the top.

In the comparison, calculated response is alike to response of commercial available neutron monitors as the Berthold LB6411, Berthold LB6411-b and the Leake (ICRP, 2007; ICRP 1996) with the advantage that our monitor can be used also in high and pulsed mixed radiation fields like those founded in radiotherapy vault rooms with linear accelerators (Leake et al, 2010).

To compare the value of H*(10) obtained with the Passive Monitor Whit TLDs with measured with the Berthold LB6411 was found that the values are statistically similar. With the experimental results was valid the monitor design that can be used in working areas with intense, mixed and pulsed radiation fields or in low neutron fields, has due to cosmic rays.
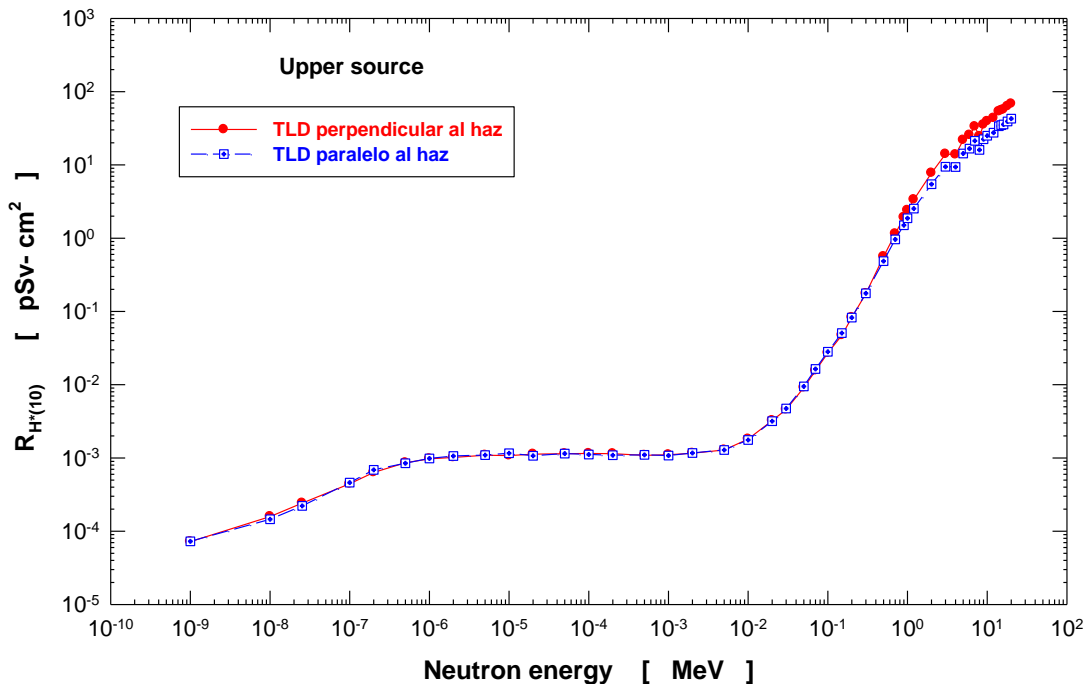

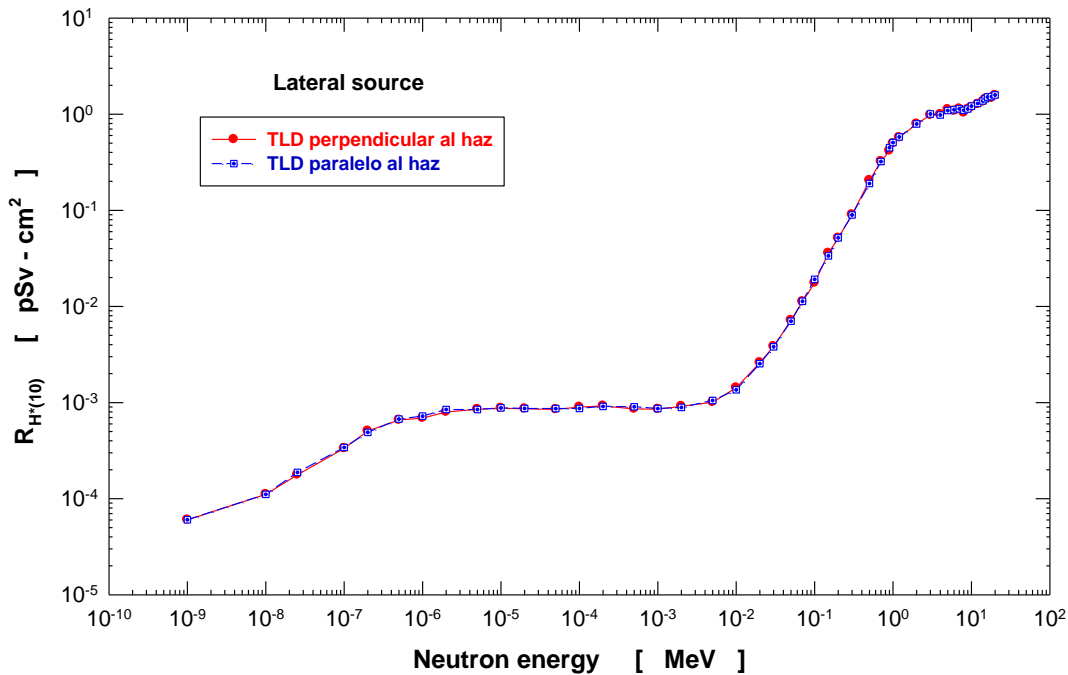Figure 8. $R_{H*(10)}$ for the two positions of the TLD using an upper source

Figure 9. $R_{H*(10)}$ for the two positions of the TLD using a lateral source

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