

Proposed Algorithm to Angular Radiation Incidence Correction of Fast Neutron Track Dosimeter

Eduardo de Brito Souto^{a,b*}, Letícia Lucente Campos^a

^aInstituto de Pesquisas Energéticas e Nucleares – IPEN/CNEN-SP, Av. Lineu Prestes 2242, 05.508-000, São Paulo, Brazil.

^bPRO-RAD Consultores em Radioproteção Ltda. S/S, Av. Alberto Bins 658 / 302, 90.030-140, Porto Alegre, Brazil.

Abstract. Aiming to improve the dosimetry of workers potentially exposed to neutron radiation in Brazil, the Instituto de Pesquisas Energéticas e Nucleares – IPEN, a governmental Research Center, in association with PRO-RAD, a private Monitoring Service, designed and developed an individual dosimeter for gamma-neutron mixed field monitoring using the techniques of Thermoluminescent Albedo Dosimetry (TLAD) and Solid State Nuclear Track Dosimetry (SSNTD). Neutron doses are preferably estimated according to albedo neutrons dosimeter response. Track detectors are used just to high fast neutron doses confirmation. Thermoluminescent detectors Harshaw TLD-600 and TLD-700 were used to evaluate gamma and intermediate (albedo) neutrons doses. A commercial polycarbonate produced in Brazil, named SS-1, was used as track detector to measure fast neutrons doses. Previous study shown that SS-1 directional (angular) response presents a cosine behavior. Knowing the incidence angle, a correction factor, equal to the inverse of this angle's cosine, must be applied in the dose calculation algorithm. The ratio of fast and albedo neutrons responses could be considered constant as a function of dose, but decreases proportionally with increasing radiation incidence angle. This variation allows estimating the incidence angle and, then, correcting the fast neutrons dose response. An algorithm to directional incidence correction applied to Americium-Beryllium neutron sources and dose range of radiation protection interest (up to 20 mSv) was proposed based on these premises and considering that correction factor will be applied only if the ratio of fast and albedo neutron responses is below its average to normal incidence less 30% (~ 200 tracks/cm².nC).

KEYWORDS: *neutron dosimetry, SSNTD, TLAD.*

1. Introduction

Neutron dose measurement is a difficult matter; different neutron detection techniques has been employed. Dosimetry of reflected neutrons from the human body can be made by means of albedo dosimetry techniques, developed by different authors [1-3]. The main advantages are the high (n - γ) discrimination capability and the very small dimension. The use of polymeric detectors, especially polycarbonates and CR-39, has been studied to be applied as etched-track detectors in fast neutron dosimetry [4-7] with the advantage of including permanent registration [8,9]. In both methods, to determine the neutron dose the neutron spectrum must be known and the calibration method is defined for a specific type, energy and angular distribution of radiation. For personal dosimeters, basic physical requirements like the correct dependence of the response of the dosimeter on energy and angle of the incident neutrons are required.

Neutron personal monitoring in Brazil is growing up due to the increasing use of neutron sources in industrial and medical applications. Aiming to improve the dosimetry of workers potentially exposed to neutron radiation, the Instituto de Pesquisas Energéticas e Nucleares – IPEN/CNEN-SP, a governmental Research Center, in association with PRO-RAD, a private Monitoring Service, designed and developed a passive individual gamma-neutron mixed field dosimeter calibrated to be used to ²⁴¹AmBe sources [10]. The dosimeter uses the techniques of Albedo Thermoluminescence Dosimetry (TLAD) and Solid State Nuclear Track Dosimetry (SSNTD). A previous study shown that SS-1 fast neutron track detector response is highly angular dependent and presents cosine behaviour [11].

*ebsouto@prorad.com.br

An algorithm to directional incidence correction applied to $^{241}\text{AmBe}$ neutron sources and dose range of radiation protection interest (up to 20 mSv) was proposed.

2. Dosimeter Description

The developed dosimeter consists of a SS-1 track detector and two TLD-700/TLD-600 thermoluminescent detectors pairs between a cadmium filter in a polyethylene holder [10]. Incident fast neutrons are detected by the SS-1 detector. Albedo neutrons are detected by the TLD-600 rear cadmium filter. Incident thermal neutrons and gamma radiation are detected by the TL detectors pair on the front of cadmium filter.

Neutron doses are preferably estimated according to albedo neutrons dosimeter response. Track detectors are used just to high fast neutron doses confirmation.

3. Fast Neutron Dose Algorithm

Considering only normal angle incidence the track dosimeter shows a linear dose response in the dose range between 0.5 and 20 mSv. The dose calculation algorithm is a linear equation of this:

$$Dose = a \cdot TD + b \quad (1)$$

Where TD is the SS-1 track density (tracks/cm²) and a and b are, respectively, the angular and the linear coefficients.

4. Dosimeter Angular Dependence Response

The ratio of fast and albedo neutron responses could be considered constant as a function of dose [10] between 17 % fluctuation (Table 1), but decreases as a cosine function with increasing radiation incidence angle (Figure 1).

Table 1: Dosimeter response as a function of neutron dose.

Dose (mSv)	Ratio response (normal incidence)	
	Na / Nth	Nf / Na
2.0	4.5 ± 0.7	310 ± 80
5.0	4.6 ± 0.4	250 ± 50
10	4.0 ± 0.3	230 ± 40
12	4.1 ± 0.5	290 ± 50
15	4.0 ± 0.3	240 ± 40
17	4.2 ± 0.5	370 ± 50
20	4.1 ± 0.3	330 ± 50
average	4.2 ± 0.5	290 ± 50

Na albedo neutrons response
 Nth thermal neutrons response
 Nf fast neutrons response

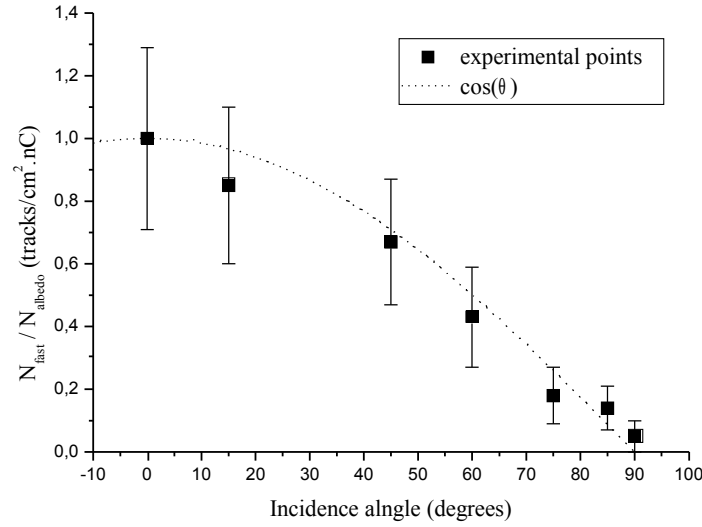


Figure 1: Fast and albedo neutron ratio responses as a function of neutron incidence angle

Knowing the incidence angle, a correction factor, equal to the inverse of this angle's cosine, must be applied in the dose calculation algorithm. Since the fast neutron dosimeter response depends on SS-1 angular response, this correction factor should be applied on SS-1 track density, maintaining the original dose algorithm:

$$Dose = a.TD.cos^{-1}(\theta) + b \quad (2)$$

5. Angular Correction Factor

The incidence angle is estimated by the variation of the ratio responses of fast and albedo neutrons. Using the average of the ratio responses, 290 tracks/cm².nC,

$$\theta = \arccos\left(\frac{Nf}{290 Na}\right) \quad (3)$$

then

$$\cos^{-1}(\theta) = \cos\left(\arccos\left(\frac{Nf}{290 Na}\right)\right) = \frac{Nf}{290 Na} \quad (4)$$

6. Algorithm to Angular Dependence Correction

$$Dose = a.TD.\frac{Nf}{290 Na} + b \quad (5)$$

According to ISO/DIS21909 [12], the response of a solid state nuclear track dosimeter at angles until 60° from normal shall not differ by more than 40% from the corresponding response at normal incidence. To ensure this condition, the correction factor will be applied only if the ratio of fast and albedo neutron responses is below 200 tracks/cm².nC (its average to normal incidence less 30%).

7. Conclusion

Results of field tests performed using the developed neutron dosimeter and the dose calculation and angular dependence response correction algorithms permit to state that this system can be applied to monitoring workers potentially exposed to neutron radiation according to ISO/DIS21909 requirements.

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