The silver counter neutron detector revisited

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Abstract. The silver counter neutron detector is revisited. The detector characterization methodology based on the use of an isotopic source is revised. The effect of the moderator geometry on the counting efficiency of the detector is experimentally studied. Preliminary results are presented.

1. Introduction

The so-called 'silver activation counter' is one of the most common detection system used for measurement of the neutron strength in pulsed fast neutron sources. In this detector, the energy of fast neutrons is decreased to epithermal and thermal energies by a moderator. The moderated neutrons activate a silver foil and the subsequent beta decay is monitored by a Geiger Müller counter tube (GM). This system was first proposed by Lanter and Bannerman in the late sixties [1]. In plasma focus research, these systems have been used since forty years. The state of the art calibration technique is usually referred to the methodologies reported by Gentilini et al [2]. By using these methods, the calibration constant is usually obtained with experimental errors of the order of 20 – 30%. For small laboratories, the most suitable methodologies reported in the work by Gentilini presents several systematic errors, which are related mostly with gamma counting. In a recent work by Moreno et al [3], a new calibration method is outlined. The methodology aims to deal with systematic errors and is based only on the use of a continuous neutron source as reference. In this case, the experimental error in the calibration constant was reduced to less than 10%.

In this work, the characterization of the detector is revised and the response of the detector is studied as a function of the moderator geometry. Preliminary results of this study are presented.

2. Counting model an efficiency

The accumulated counts as a function of time when irradiating the detector by a pulsed source are given by

\[ G(T) = Z_c Y \left[ a_1 \left( 1 - e^{-\lambda_1 t} \right) + \left( 1 - a_1 \right) \left( 1 - e^{-\lambda_2 t} \right) \right] \]  

(1)

where \( Y \) is the number of neutrons impinging on the detector, \( \lambda_1 \) and \( \lambda_2 \) are the decay constant of both stable isotopes present in pure silver \(^{108}\text{Ag} \) and \(^{110}\text{Ag} \). Constants \( a_1 \) and \( Z_c \) are obtained by...
characterization of the detector using a continuous source [3]. \( Z_c \) is the counting efficiency of the detector

\[
Z_c = \frac{4\pi R_{\text{sat}}}{I_0 \Omega F(\alpha)}
\]

(2)

where \( I_0 \) is the intensity of the reference continuous source and \( F(\alpha) \) is the source anisotropy correction [4], \( \Omega \) is the solid angle subtended by the detector and \( R_{\text{sat}} \) is the measured neutron counting rate at saturation. The counting efficiency is dependent on the efficiency for moderating neutron energy from fast to epithermal and thermal, the geometry of the silver foil and the beta counting efficiency of the Geiger tube. Therefore, while keeping the same silver foil geometry and the Geiger tube, the detector counting efficiency will depend ultimately on the moderator material and its geometry.

Analogously to equation (1), when irradiating the detector until saturation, the accumulated counts after removal of the source are by

\[
G(t) = M\left[A_1\left(1 - e^{-\lambda_1 t}\right) + \left(1 - A_1\right)\left(1 - e^{-\lambda_2 t}\right)\right]
\]

(3)

By using non-linear least squares, the constants \( M \) and \( A_1 \) are obtained from the experimental decays. Thus,

\[
a_1 = \frac{A_1 \lambda_1}{\left(A_1 \lambda_1 + \left(1 - A_1\right) \lambda_2\right)}
\]

(4)

and

\[
R_{\text{sat}} = M\left(A_1 \lambda_1 + \left(1 - A_1\right) \lambda_2\right)
\]

(5)

The term \( 4\pi/I_0 F(\alpha) \) in equation (2) can be considered a constant while keeping the same relative angle between source and detector. Thus, in order to seek improvements for the counting efficiency, the quotient \( R_{\text{sat}}/\Omega \) should be studied as a function of the moderator geometry for a given moderator material.

3. Experimental setup and results

We build a polyethylene moderator with variable geometry as shown in figure 1. The main piece is a \( 4 \times 4 \times 13 \text{ cm}^3 \) parallelepiped which contains the silver foil and the Geiger tube inside. The axis of the Geiger tube is along the parallelepiped axis. The moderator geometry is modified by adding pieces at the outer surface. Two configurations of the detector were studied (C1, C2). They are shown in figures 2 and 3. In C1, the counter axis intersects the source, while in C2 the counter axis is perpendicular to the line which intersects the source. A \( ^{252}\text{Cf} \) neutron source was used for the study. The source is placed in a holder at \( D = 20 \text{ cm} \) from the counter face and aligned with its center as shown in figure 2 and 3. The GM is fed by a 900 V voltage source. The acquisition system consists in a Canberra 2015A amplifier, connected to a Canberra multiport II MP2-1E in multi scalerimeter mode. The irradiation time was set to 800 s, while the data acquisition during decay, after removing the source, was set to 1000 s. This period was found be enough to allow obtaining the background counting rate after acquisition of decays. The analysis of data was done using the non-linear least squares routine provided by GNUPLOT [5]. From the present data, constant \( a_1 \) was found to have a mean value of 0.86±0.009, which is consistent with previous studies [3]. In figures 4 and 5 the experimental results from configurations C1 and C2, respectively, are shown. Configuration C1 shows a narrow optimum around
a side length of 12 cm. In the case of configuration C2, it shows a flat optimum from 8-12 cm. Configuration C1 presents a slightly higher counting efficiency than C2 (12 cm side length). However, high counting efficiencies can be achieved with less than a half of the moderator material in configuration C2 (8 cm side height).

Figure 1. Moderator with variable geometry.  
Figure 2. C1: Axis of the GM counter intersects the source.  
Figure 3. C2: Axis of the GM counter is perpendicular to the line which intersects the source.

Figure 4. Experimental results for configuration C1 (see figure 2), $R_{\text{sat}}/\Omega$ as function of side length.  
Figure 5. Experimental results for configuration C2 (see figure 3), $R_{\text{sat}}/\Omega$ as function of side height.

4. Remarks and future work
This work is a part of a systematic effort to improve the calibration methodologies and efficiency of this kind of detection system. Future work is related with the validation of the found optimum geometries for experiments when irradiation is done at larger distances ($D > 1 m$). The effect on the counting efficiency by adding a frontal moderator in configuration C1 and the linearity of the counting efficiency when adding more than one counter at different positions inside the moderator will be also studied.

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