ISSN 1512-1461

THERMAL NEUTRON FLUX DISTRIBUTION IN A SMALL VOLUME CYLINDRICAL WATER TANK

Hannan Younis[1], Abdul Waheed, Aziz A. Qureshi and Shahid Manzoor

Radiation Physics Lab, Physics Department, COMSATS Institute of Information Technology
Islamabad Pakistan
[1]Corresponding author: hannan.younis@comsats.edu.pk

Abstract:

The thermal neutron flux distribution of fast neutrons emitted from a small strength of 50 milli-curies Am-Be neutron source placed at the center of a small volume of 50 liters cylindrical water tank has been studied from the instrumental activation analysis point of view.The measurements were made with1" dia $BF_3$and 1/2" dia^{3}He neutron detectors.The experimental results were compared with the Monte Carlo simulation and found to be in agreement. The maximum thermal neutron flux measured is at a distance 1.2 cm away from the neutron source.Total thermal neutron cross-sections of Fe, Cu and Hg have been measured to validate the thermal neutron flux distribution in a small volumetric water tank.

***Keywords**: Am-Be neutron source, BF_3, ^{3}Hedetectors, cylindrical water tank, flux distribution, total cross-sections*

1. Introduction

The neutrons available from Am-Be neutron source are fast and are thermalized by scattering off protons in water. Neutrons are widely used for non-destructive activation analysis (NAA) of materials in papers by Celenk and Ozek(1984), Czanderna et al (1996),Edward et al (1990), Tohamy et al (2010). The various applications in NAA are analysis of bulk minerals, bulk explosives in papers by Bolewski Jr et al (1998), Bolewski Jr et al (2005), Sood et al (2000).The portable radiography for the bulk analysis of materials require significant progress in the area of compact neutron source based on fusion reaction as given in papers Ahmad et al (2006), Rishi et al (2009), Uhm and Lee (1991), Zakaullah et al (2003). The information of thermal neutron flux distribution in a small water cylindrical tank can reveal power level and distribution in a small reactor core and can avoid economic wastage in a very large water tank because of non-uniform thermal neutron flux distribution resulting in a non-uniform burn up of the fuel rods as given in papers by Nwosu (2015). Considering these aspects a small volumetric of 50 liters cylindrical water tank is developed to study the thermal neutron flux distribution across the diameter of the tank similar to a critical thermal reactor core. This arrangement has been studied where the neutron strength is small about 50 millicuries. It has the advantage of obtaining large and stable thermal neutron flux for large thin samples very near the neutron source and prompt gamma neutron activation analysis (PGNAA) can be carried out. The experimental thermal neutron flux distribution in the tank has been compared with the MCNP simulation and agrees very well. The normalized values of MCNP have been taken from reference in Sood et al (2000). To validate the results thermal neutron cross-sections of Fe, Cu, and Hg have also been measured at different distances from the neutron source and are in agreement with the published results as given in reference by Mughabghab (INDC-440 IAEA).

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2. Moderator Water Tank Assembly

The cylindrical water tank and the neutron detector assembly are shown in Figs. 1a and 1b. The tank is of 40 cm in diameter and 40 cm in height. A pipe of s/s having diameter of 47 mm, wall thickness of 1 mm and length of 43 cm is fixed at the base centre of the tank. A wooden stand is inserted in the pipe to place the neutron source at the centre in xyz plane of the tank and also to keep the location of the source at the same center of the tank during measurements. In order to measure the neutron flux distribution in the tank,1 mm wall thickness of 32 mm in diameter, thirteen in number, stainless steel pipes have been welded at distances from 1-13 cm from the centre of the tank. Neutron detectors of 1″diaBF_3 and 1/2″dia ^{3}He have been placed in each pipe in order to measure the thermal neutron flux distribution in the tank. The tank is filled with ordinary tap water. The known flux of the neutron source used is $(1.19 \pm 0.1) \times 10^5$n/s as given in paper by Waheed et al (2015). The leakage of thermal neutrons out of the tank has been measured and is found to be negligible. A replaceable wooden stand has also been used of such a height that the centre of the sensitive area of the neutron detector is always positioned in all the pipes at the same height of the neutron source. The detail is shown in the Fig. 1b. Care was taken that the axis of the neutron detector is always at the axes of the pipes during the measurements. This ensured that distance of the neutron detector is always the same with respect to the neutron source during the repeat of measurements.

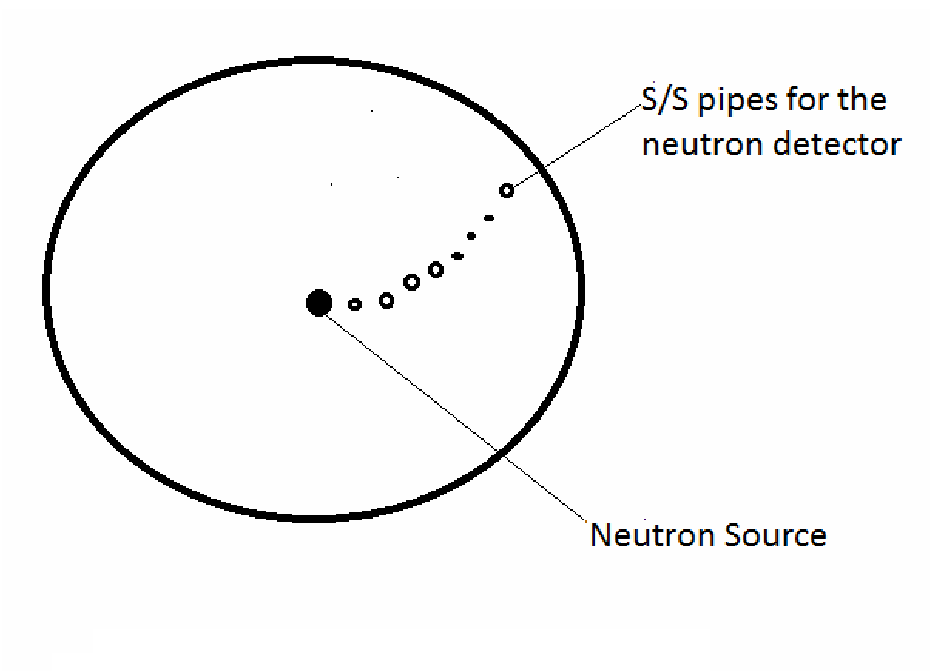

Fig. 1a. Top view of the water tank with pipe housings fixed at the bottom.

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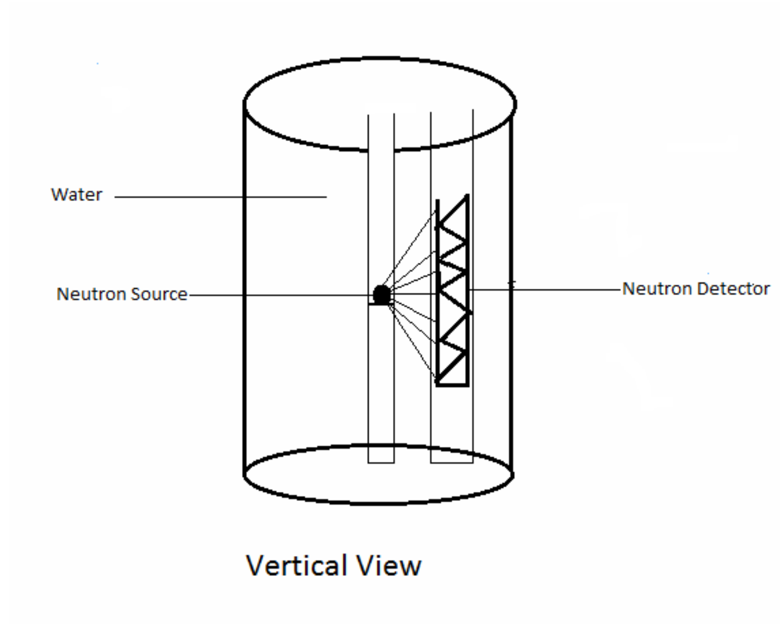

Fig. 1b. Vertical view of the water tank assembly.

3. Thermal Neutron Flux Measurement

The efficiency of the 1″ diameter BF_3 neutron detector has been measured with the known neutron flux of Am-Be source, using a wax moderator rectangular assembly box of 15 cm by 15 cm and height of 20 cm with a central axis hole of about 1″ in diameter for placing the neutron detector. The efficiency of the 1″ dia BF_3 neutron detector was measured to be 4.16 % with in less than 1% statistical error. Similarly the efficiency of ^3He neutron detector was measured to be 6% with in less than 1% statistical error. The thermal neutron flux has been measured in each pipe of the tank being water as the moderator. Set of ten measurements in each pipe for 100 seconds each has been carried out. The back ground of the detector has also been measured of by removing the neutron source from the assembly. A graph of thermal neutron flux measured by the $BF_3$and ^3He detectors at different distances from the neutron source is shown in Fig.2 and represents the thermal neutron flux distribution across the diameter of the water tank per unit area falling on the $BF_3$and ^3He detectors of 12 cm and 8.4 cm as active length respectively and shows a very close agreement. The thermal neutron flux distribution in a small volume water tank across the diameter is a straight line and is inversely proportional to the distance of the source in this case. The neutrons thermalized in water are of both thermal and epithermal in energy. The ratio of flux of epithermal neutrons to the total thermal and epithermal neutrons is in the ratio of 5.56 % and is neglected in the present case, as in the paper by Waheed et al (2015). The experimental results are compared with the MCNP simulation results from reference, Sood et al (2000) and are shown in Fig. 3. The experimental results of both the neutron detectors are in agreement with the simulated values.

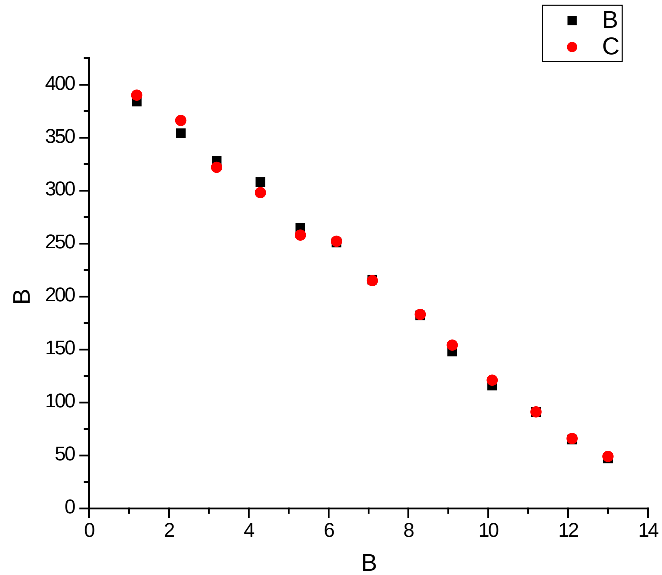

Fig2. Flux distribution measured by BF_3 and ^3He detectors.

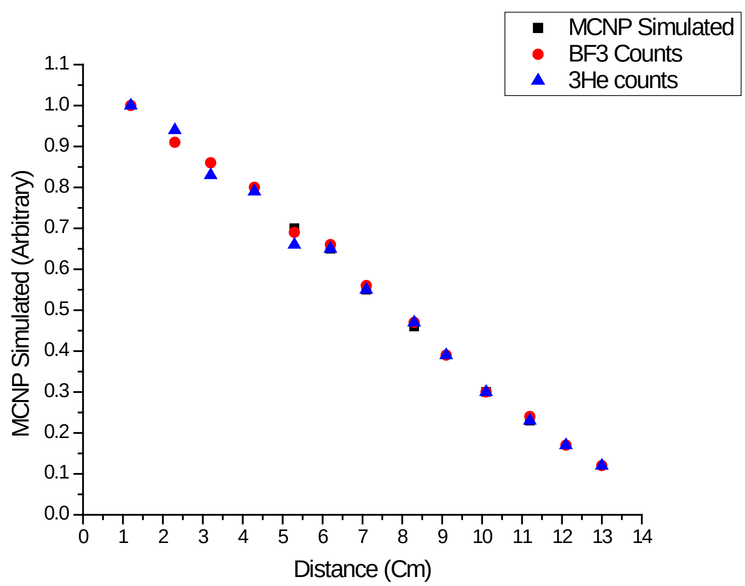

Fig.3 Flux distribution measured with neutron detectors and MCNP simulations.

4. Thermal Neutron Cross-Section Measurement

Total cross-sections of Fe, Cu and Hg have also been measured for thermal neutrons to validate the thermal neutron flux measurement. The samples of Fe, and Cu and Hg were made of dimensions given in Table 1. For the measurement of total cross-section of Hg a cylindrical container of very thin walled mild steel of internal diameter 14mm and outer diameter of 21 mm was filled with Hg in this way the

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thickness of Hg in the container was 1.5 mm. The length of the container was again 120 mm. Total cross-section is given by the well known relation:

$$ø = ø_0 \exp\{-\sigma_T \times t \times n\} \qquad 1$$

Where, $ø_o$ is the incident thermal neutron flux without the scatterer and ø is the transmitted, through the scatterer, neutron flux measured by the neutron detector, σ_T is the total scattering cross-section, t is the thickness in cm and n is the number of nuclei per cc of the target material.

Neutron detector of ½″ diameter ^{3}He is used for the measurement of thermal neutron cross-sections. The neutron source is placed at the central position of the water tank in xyz plane. The ^{3}He neutron detector is inserted axially into the annular sample and both as one unit is inserted into the small s/s pipe of the water tank so that the center of the sensitive area of the neutron detector is at the same height as that of the neutron source, and is shown in the Fig. 4. For this purpose wooden stands are again used to fix the heights of both the detector and the neutron source. This arrangement ensured repeatability of the central position of the neutron source as well as the centers of the sample and sensitive area of the ^{3}He detector. The total cross-sections are measured at distances of 1.2 cm to 7.1 cm from the neutron source. The cross-sections of Fe, Cu, and Hg at various distances from the neutron source are given in Table 1. From the table it is evident that the neutrons are thermalized at a distance of 1.2 cm from the neutron source and thermal neutron flux available at such a distance is384 ± 0.6n/cm^{2}secin a small cylindrical water tank and can be utilized for the instrumental activation analysis of bulk materials.

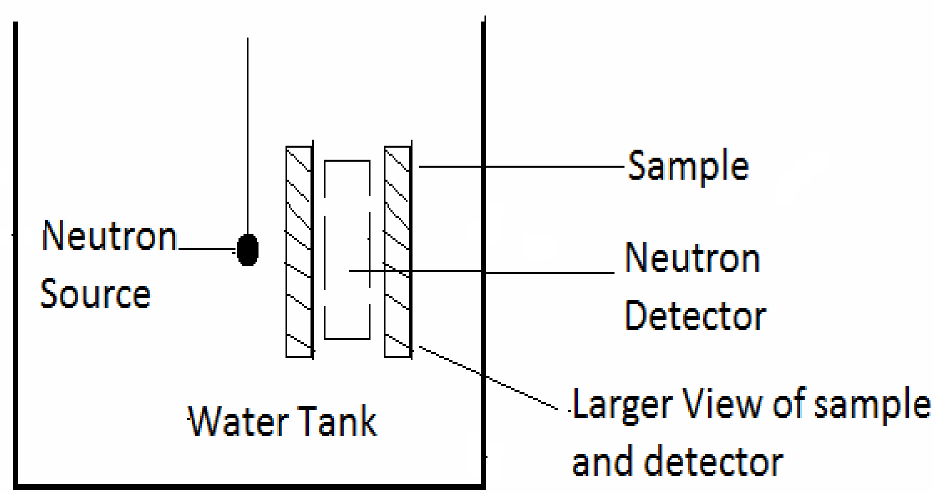

Fig.4 Neutron Source, neutron detector and the annular sample arrangement in the water tank for the measurement of cross-section

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Sr. No.	Distance from Neutron Source (Cm)	Cross-section Barns (Fe) i.d. =16mm o.d. = 27mm Length = 12.0 cm	Cross-section (Barns) (Cu) i.d. = 16 mm o.d. = 27 mm Length = 12.0 cm	Cross-section (Barns) (Hg) i.d , o.d as in the text Length = 12.0 cm
1.	1.2	13.8 ± 0.01	11.8 ± 0.01	399.5 ± 0.09
2.	2.3	12.6 ± 0.01	11.0 ± 0.01	398.7 ± 0.09
3.	3.2	13.3 ± 0.01	11.5 ± 0.01	402.8 ± 0.09
4.	4.3	12.2 ± 0.01	11.0 ± 0.01	404.5± 0.09
5.	5.3	13.2 ± 0.01	10.7 ± 0.01	401.1 ± 0.09
6.	6.2	13.4 ± 0.01	10.8 ± 0.01	400.1 ± 0.09
7.	7.1	14.4 ± 0.01	11.4 ± 0.01	398.4 ± 0.09
Average		13.3 ± 0.7	11.2 ± 0.4	400.7 ± 2.2

Table 1 Cross-sections of Fe, Cu and Hg measured by ½ " dia^{3}He detector at different distances from the neutron source.

5. Conclusion

A small volumetric water tank has been utilized to obtain the thermal neutron flux at a small distance from the 50 milli-curie Am-Be neutron source. The neutron flux distribution of thermal neutrons has been measured by 1″ dia BF_3 and1/2″ dia^{3}He neutron detectors and is in agreement with the MCNP simulations. The maximum thermal neutron flux of 384 ± 0.6 n/cm^{2}secis available at the neutron detector, 1.2 cm away from the neutron source and can be utilized for the activation analysis of bulk material, where neutron source available is of small in strength. It is also observed that the thermal neutron flux distribution across the diameter of a small volumetric water tank is a straight line and is inversely proportional to the distance of the source. Also the thermal neutron cross-sections of Fe, Cu and Hg were measured at different distances up to 7.1 cm from the neutron source and average values are 13.3 ± 0.7 (barns), 11.2 ± 0.4 (barns) and 400.7± 2.2 (barns) respectively. These are in agreement with the published values with in their standard deviations. The thermal neutrons in a small volumetric water tank can be generated at a distance of 1.2 cm away from the Am-Be neutron source in this case.

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Acknowledgements:

The financial support given by Higher Education Commission in this project is acknowledged by HannanYounis under HEC project No. 21-129 SRGP/R&D/HEC/2014.

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Article received on: 2016-05-30