A Method for Measuring Neutron Flux by a Paraffin Oil Bath Technique

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This method is based upon the procedure of slowing down neutrons to thermal energies and then measuring these neutrons with a 'point' neutron scintillation detector.[1,2] (Nuclear-Chicago, Model DS8-10) Though paraffin oil (Esso,Primol D) is unpleasant to handle, nevertheless, it was selected in preference to water in order to avoid any competing reactions from oxygen.[3,4]

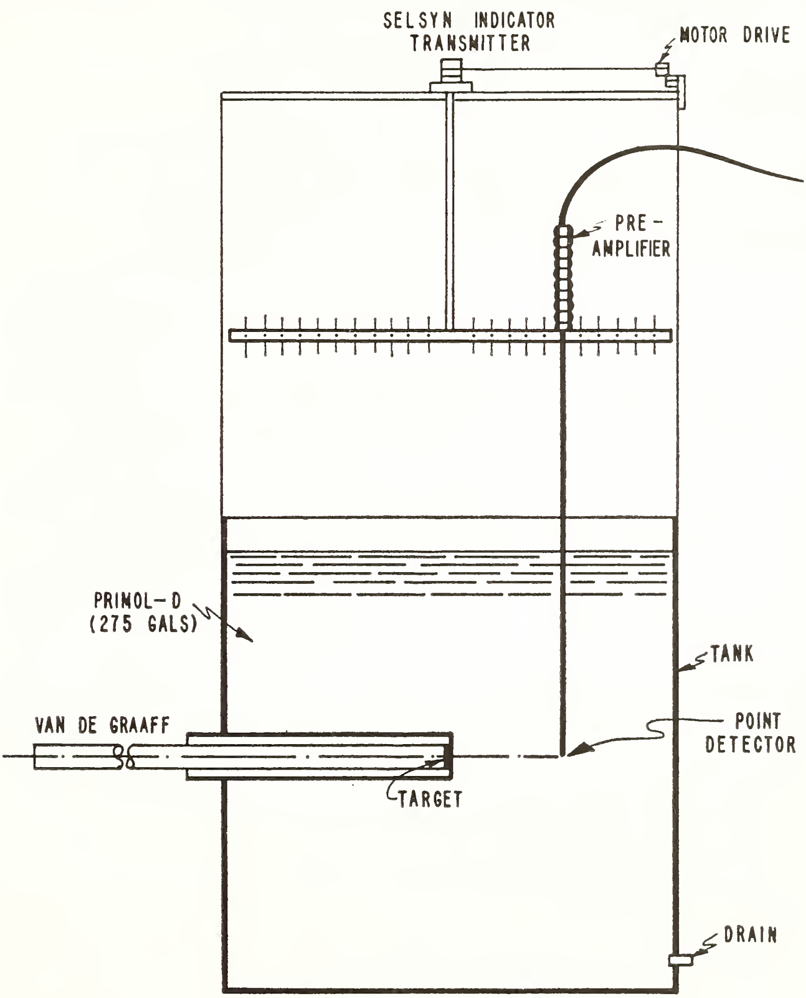


FIGURE 1

An aluminum tank having a radius of 22 inches and a height of 46 inches was constructed. (Figure 1) An opening sufficiently large, so as to accommodate the Van de Graaff target tube, was built into the side of the tank so that the target was essentially at the center of the paraffin oil bath.

In order to facilitate the procedure of taking the experimental data, a rotating motor driven bar with evenly spaced holes was mounted above

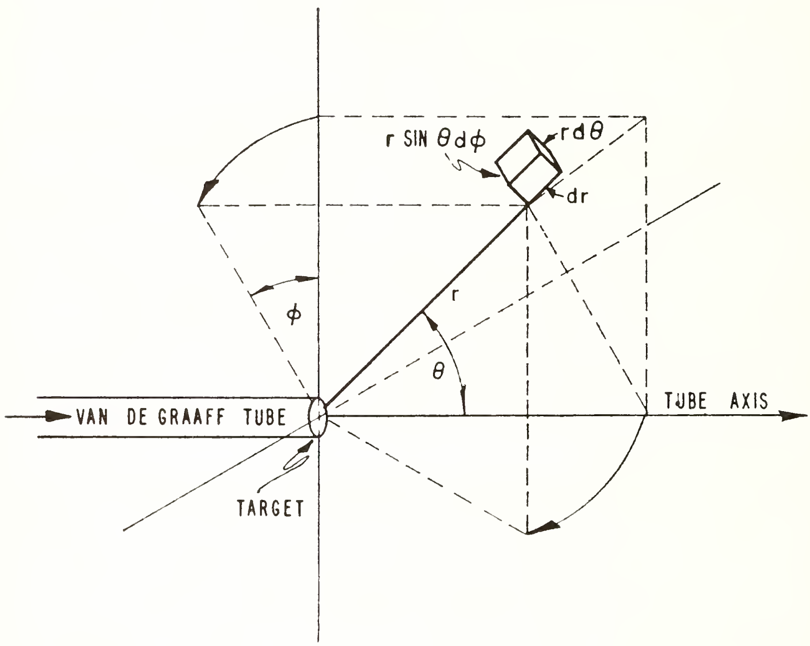


FIGURE 2.

the tank. By inserting the neutron detector through one of the holes in the cross-bar and adjusting the height of the assemblage so that the sensitive tip of the counter was at the center of the target tube, a complete series of measurements could be taken at the same distance from the source target and at the various angles indicated by the selsyn transmitter.

Let Q_s = the total neutron emission from a source or target

$q(r,\varphi,\theta)$ = thermal neutrons/cm^3 – sec. at r, φ, θ

$c(r,\varphi,\theta)$ = the counts which will be registered by the photomultiplier counter at various positions.

$Kc = q$

where K = constant depending upon counter efficiency

then

$$Q_s = K \int_0^{\infty} \int_0^{\pi} \int_0^{2\pi} C(r,\varphi,\theta)\ r^2 \sin\ \theta d\varphi d\theta dr$$

Assuming symmetry around the axis of the Van de Graaff tube (i.r.t. the integration of the angle φ) the volume integral will then become

$Q_s = 2\pi K \int_0^\infty \int_0^\pi C(r,\theta) r^2 \sin\theta \, d\theta dr$, C in this case will be a function of r and θ only

By plotting $C(r,\theta) r^2$ as a function of r for each of the values of θ that could be measured (e.g.) (Figure 3) and integrating under the curve, a series of areas were found.

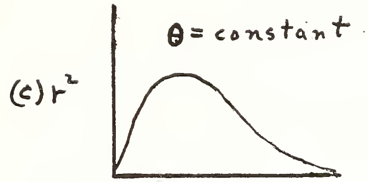


Fig. 3 r →

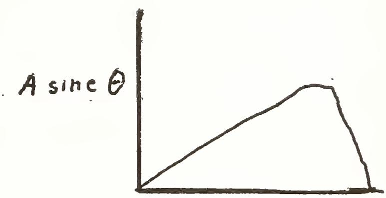


Fig. 4 θ

By plotting each one of these values of $A_o \sin\theta$ as a function θ (e.g. Figure 4)

the volume integral was evaluated.

Experimental Procedures

The apparatus was set up as indicated in Figure 1 with a calibrated source in position where the Van de Graaff target is to be placed. Measurements were taken at angles from 0° to 160° as measured from the forward direction of the tube position. The volume integration was then performed as outlined and a value of K_1 determined equivalent to $2\pi\kappa$ in the above formula.

As a check on the experimental accuracy of this method and the calibration constant, another standard source was measured in a similar manner. Using the obtained constant K_1, a value within 7% of the given value of this source was obtained.

Measurements were made on the neutron output of a deuterium target bombarded with deuterons. A summary of the experimental results is given in Table I below and on the following pages.

Source	Yield (std)	A Final	Measured Yield	% Dev.
200 mg Ra – Be	2.29×10^6 n/sec	23.9		
55 curie Pu-Be	9.16×10^6 ± 10% n/sec	102	9.79×10^6 n/s	7%
H^2 target bombarded with deuterons		209	2×10^7 n/sec. or 4×10^6 n/microcoulomb	

A 200 mg. Ra – Be neutron source having an output of 2.29×10^6 n/sec was used to calibrate the oil bath. Typical graphs for various angular positions are given in Figures 5, 6 and 7. The final value of the volumetric integral is given by the graph as indicated in Figure 8. The value of K_1 was calculated to be 9.6×10^4. (Figure 8)

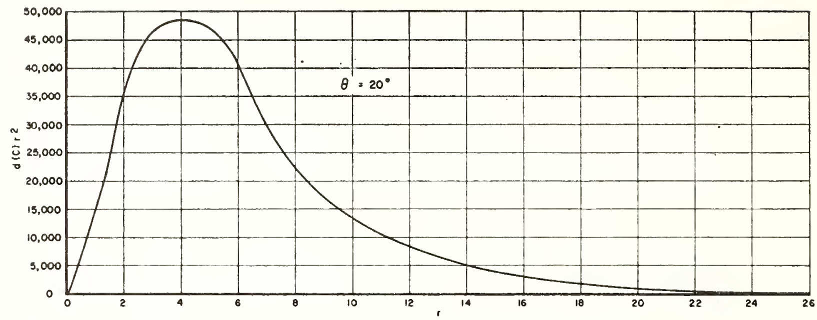


FIGURE 5

The accuracy of the experimental procedure and the value of the constant was checked using a 55 curie Pu – Be source. The value of the source as given by the manufacturer is 9.16 x 10^6 n/s ± 10%. The value as found by this experimental procedure is 9.79 x 10^6 n/sec. The deviations between these two values is less than 7%.

A deuterium target of 446 micrograms per sq. cm. was measured for neutron output when bombarded with deuterons at 1 mev. The target output was measured to be 2 x 10^7 n/sec. or 4 x 10^6 n/microcoulomb.

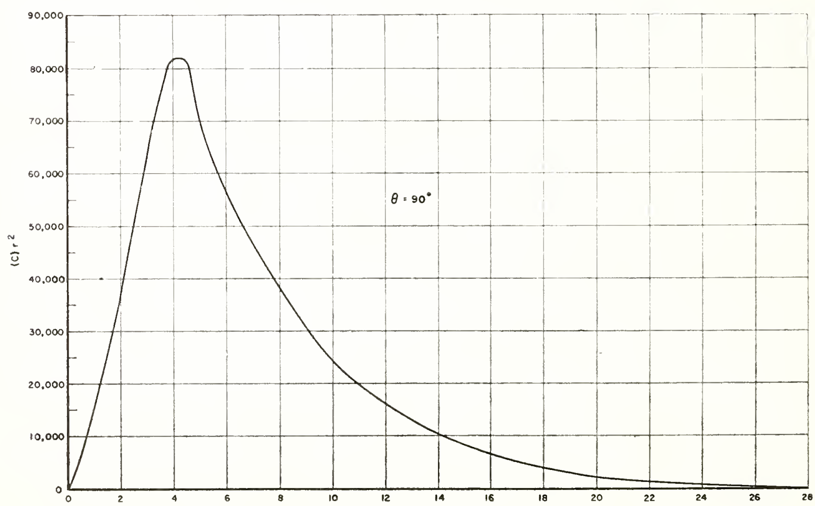
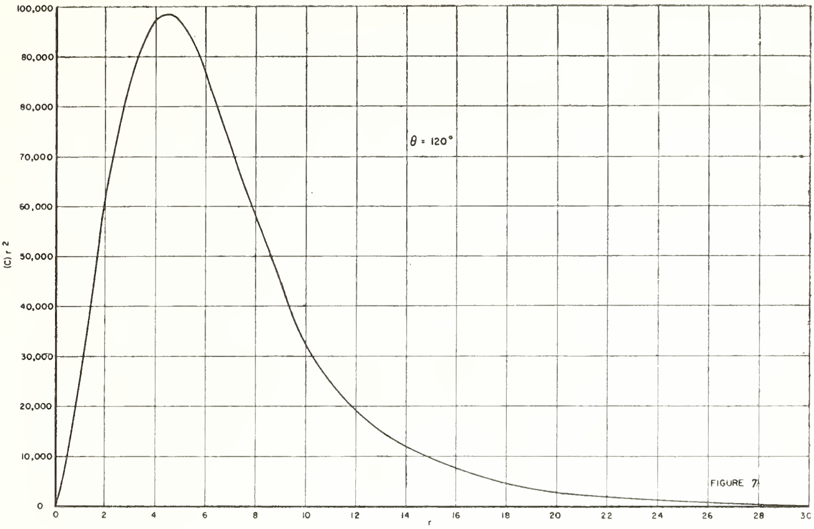


FIGURE 6

The following errors might be considered: errors in extrapolation, determination of areas under the experimental curves, flux depressions by the [5] introduction of the neutron counter, loss from the sides of the [6,7] vessel due to neutron escape, fast neutron absorption and neutron [8] energy variations. Since, however, the value of the constant K_1 was determined and used under identical conditions, these errors should be minimized. It would be well to make a systematic study of the above in order to increase the accuracy of this experimental procedure.



$$Q_S = 2\pi K \int_0^{\infty}\int_0^{\pi} C(r_1\theta)\, r^2 \sin\theta \, d\theta \, dr$$

$$(2.29)(10)^6 = K_1(23.90)$$

$$K_1 = (9.6)(10)^4$$

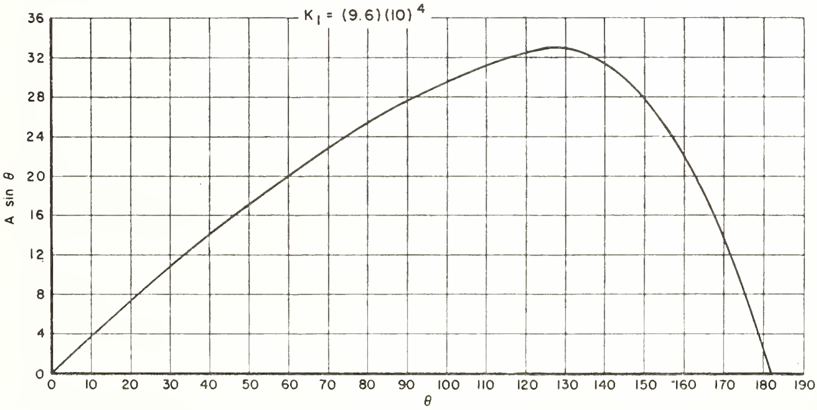


FIGURE 8

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