AIP Journal of Applied Physics

The Attenuation of Neutrons of Various Energies in Water

C. E. Falk and E. Creutz

Citation: Journal of Applied Physics **20**, 1183 (1949); doi: 10.1063/1.1698304
View online: http://dx.doi.org/10.1063/1.1698304
View Table of Contents: http://scitation.aip.org/content/aip/journal/jap/20/12?ver=pdfcov
Published by the AIP Publishing

The Attenuation of Neutrons of Various Energies in Water

C. E. Falk and E. Creutz
Department of Physics, Carnegie Institute of Technology, Pittsburgh, Pennsylvania
(Received May 17, 1949)

Threshold detectors (In^{115}, Ag^{107}, and C^{12}) were used to determine the relative intensities of neutrons at various distances inside a large water tank. Neutrons with energies up to 30 Mev were produced by (d, n) reactions. At distances in the water >20 cm the "half-thickness" of water was found to be almost independent of neutron energy (about 8 cm).

A KNOWLEDGE of the attenuation of neutrons by passage through matter is useful for the designing of shields for nuclear particle accelerators. For these experiments neutrons ranging from 1.4 ev to greater than 21 Mev were studied with the University of Pittsburgh cyclotron, by bombarding various targets with deuterons of approximately 16 Mev energy. Threshold detectors were used to measure the density of various energy groups throughout a water tank, as indicated in Table I.

One difficulty in medium scale attenuation experiments is brought about by the desirability of establishing conditions which approach those of an attenuation medium of infinite extent. The water in these experiments was in a $2' \times 2' \times 4'$ brass tank, the square front of which was 60 cm from the neutron source (see Fig. 1). The attenuation was measured along the central axis. Due to the great number of room-scattered neutrons, it was important to shield the sides of the tank. This was accomplished by surrounding the tank by a 2-in. thick mixture of paraffin and B_2O_3. Next to this were placed water cans filled with $Na_2B_4O_7 \cdot 10H_2O$ solution, and in addition to this cement blocks which had been soaked in paraffin. The tank was placed lengthwise along the forward direction of the neutron beam (see Fig. 1). The indium detectors were foils 1 cm $\times$1 cm $\times$0.005 inches thick. These were wedged between cadmium plates and into slits in a hollow aluminum tube (1 cm diameter) which was held in position along the central line of the parallelopiped of water by means of a light aluminum framework.

The silver and carbon detectors were made in the form of hollow cylinders. Such detectors could be slipped over the Geiger-Mueller tubes used in detecting the various activities. This helped considerably in obtaining fairly high counting rates. The cylinders were 1 inch in outside diameter and 2 inches in length. During bombardment they were surrounded by cadmium cylinders in order to cut down the intensity of reactions induced by thermal neutrons. The cylinders were suspended by thin wires from a thin brass bar placed over the top of the tank.

A thick Be target was used for all experiments, except those involving neutrons of 21 Mev and above. In the latter case $LiBO_2$ was fused onto a copper cup which was then used as a rotating target. Due to the tendency of lithium-containing targets to sputter, it was not

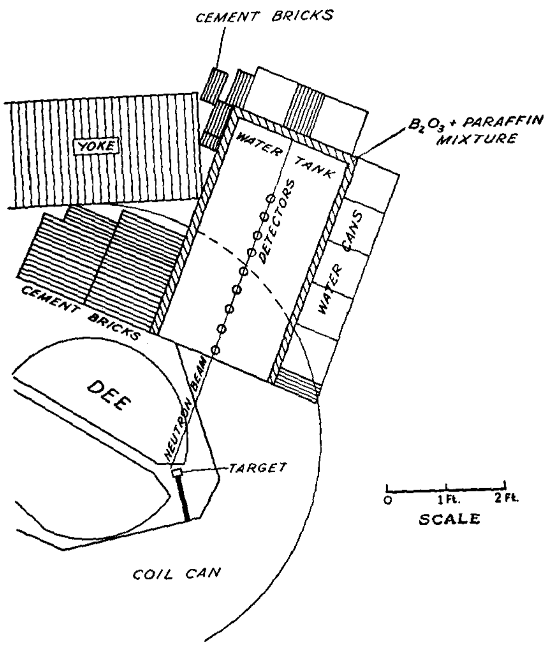

Fig. 1. Plan view of experimental arrangement.

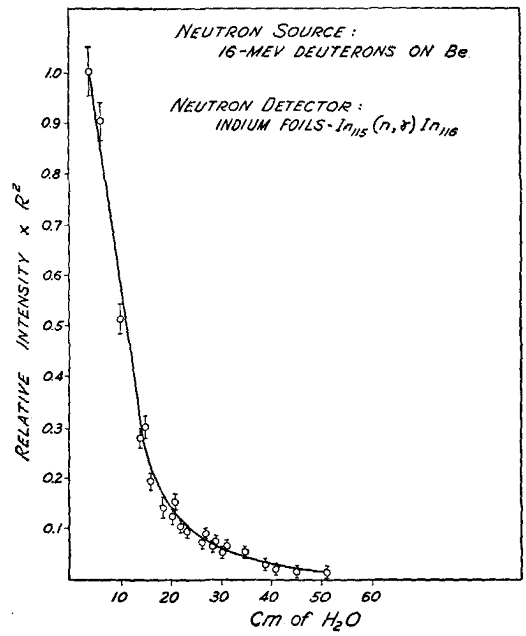

Fig. 2. Spatial distribution of indium resonance (1.4 volt) neutrons in water.

Table I.

Detector	Energy	Reaction	Half-life
In	1.4 ev (resonance)	$In^{115}(n, \gamma)In^{116}$	54 min.
Ag	6 Mev (threshold)	$Ag^{107}(n, 2n)Ag^{106}$	24.5 min.
C	20.5 Mev (threshold)	$C^{12}(n, 2n)C^{11}$	20.5 min.

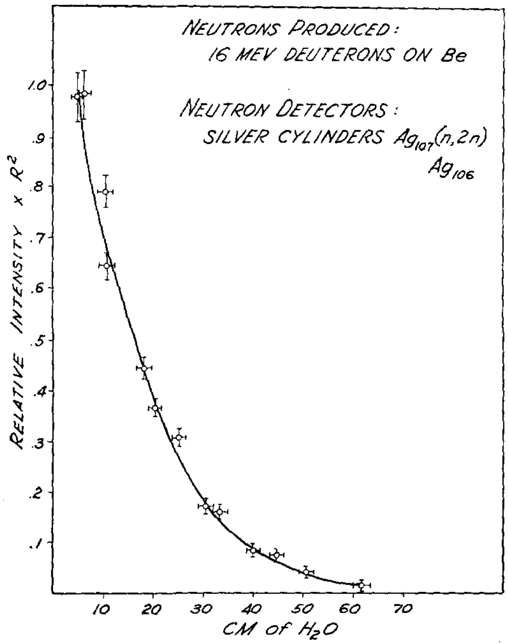

Fig. 3. Spatial distribution of neutrons of energies greater than 6 Mev in water. Spatial experimental uncertainties are due to cylindrical shape of detectors.

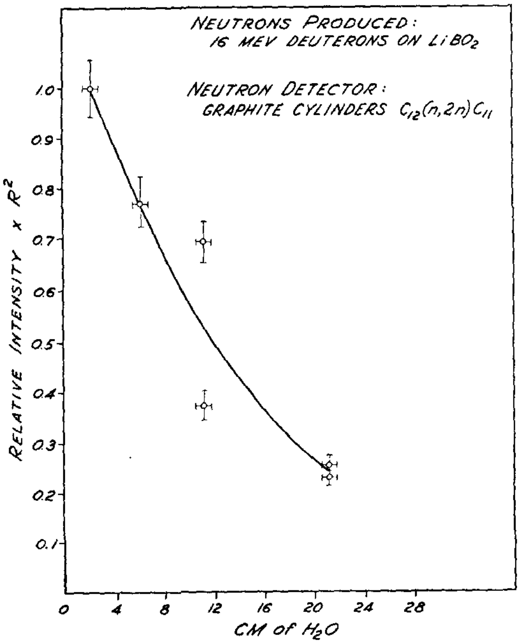

Fig. 4. Spatial distribution of neutrons of energies greater than 20.5 Mev. Spatial experimental uncertainties are due to cylindrical shape of detectors.

possible to use the full strength of the deuteron beam (about 200 microamperes). As a result the high energy neutron flux was comparatively weak, and the attenuation could be measured only over a short distance and with low accuracy.

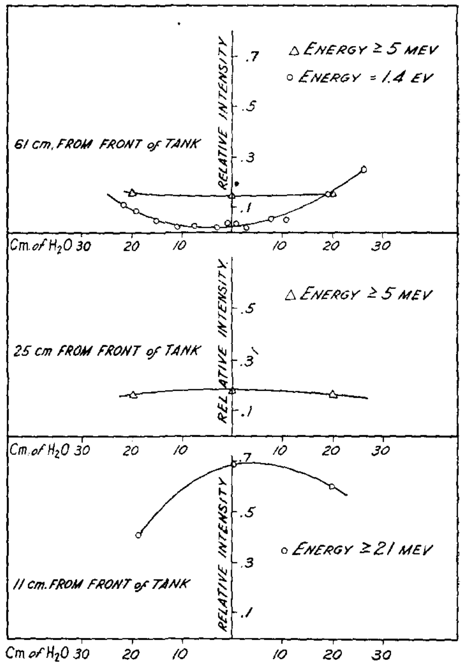

Fig. 5. Transverse spatial distributions of various energy neutrons at several distances from the front of the tank.

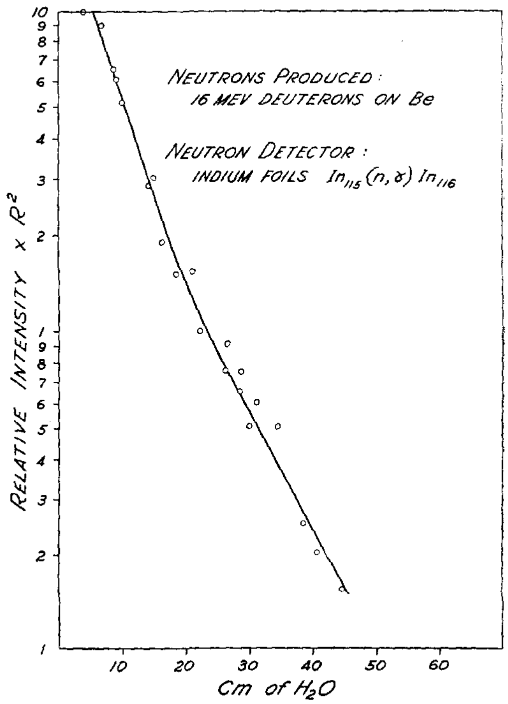

Fig. 6. Semilogarithmic plot of spatial distribution of indium resonance neutrons in water. Change of slope shows that characteristic length λ_0 increases with distance.

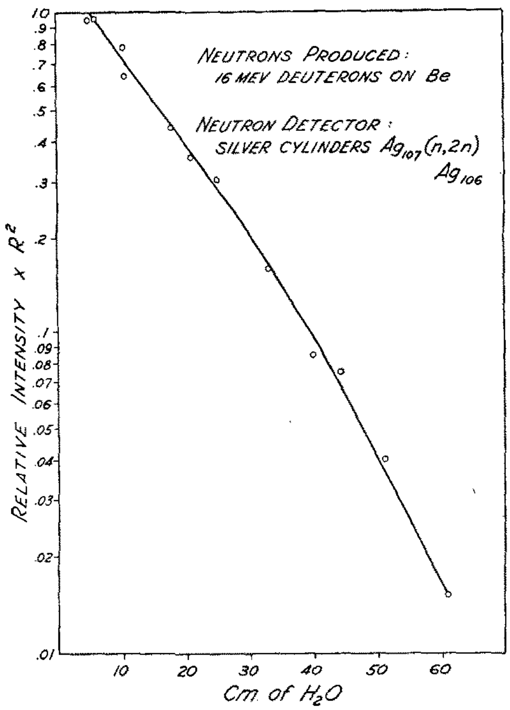

FIG. 7. Semilogarithmic plot of spatial distribution of neutrons of energies greater than 6 Mev. Change of slope shows decrease of characteristic length λ_0 with distance.

Figures 2–4 show the experimental curves obtained. Transverse distribution measurements were also made for each target (Fig. 5). As can be seen, there is no neutron influx from the sides of the tank for energies of 5 Mev or greater. However, the side shielding is much less satisfactory for the very large slow neutron room background, as seen from Fig. 5.

The above data is replotted on a semi-logarithmic scale in Figs. 6, 7, and 8. If the points followed a straight line, the expression $IR^2 = C\exp[-x/\lambda_0]$ would be correct and would indicate a characteristic length λ_0. Here I is the intensity, R the distance from the target, and x the distance in water. ($R = x + 60$ cm.) It is seen that for neutrons of 5–30 Mev and 21–30 Mev λ_0 becomes slightly smaller with increasing distance in the water, while for 1.4-ev neutrons it increases with distance.

Since the tank is far from the source, there is an essentially plane neutron wave with a continuous energy spectrum incident upon the water, and neutrons are continually being slowed down. Upon their first collision in the tank the fast neutrons lose a considerable part of their energy. Slow neutrons then diffuse out from the region of this collision. The slow neutron density should therefore follow about the same spatial pattern as that of the fast. This can be observed in Figs. 6 and 7 beyond 20 cm of H_2O. However, at values of x less than about 20 cm the principle source of low energy neutrons is directly from the target. The half-thickness of water at small distances then is smaller, corresponding to the larger scattering cross section for these lower energy neutrons.

The decrease of penetrating power for the fast neutrons at large distances in the water (Fig. 7) is probably due to the "softening" of the spectrum after most of the neutrons have made several small angle collisions with hydrogen.

The measured "half-thickness" of water for each energy group is shown in Table II.

TABLE II.

Neutron energy group	Thickness of water to reduce neutron intensity to one-half	
	$x<20$ cm	$x>20$ cm
Indium resonance (1.4 ev)	4.5±0.5 cm	8.0±0.5 cm
6 Mev to 30 Mev	10.5±0.5 cm	8.0±1 cm
20.5 Mev to 30 Mev	10 ±1 cm	

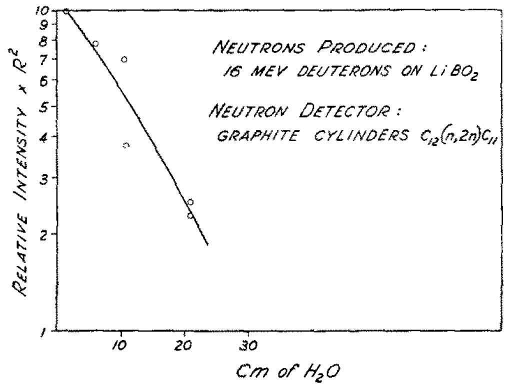

FIG. 8. Semilogarithmic plot of spatial distribution of neutrons of energies greater than 20.5 Mev. Change of slope suggests decrease of characteristic length λ_0 with distance.

We wish to thank Professor A. J. Allen of the University of Pittsburgh for his helpful cooperation and for the use of the cyclotron.