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WATER TAMPER MEASUREMENTS

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ABSTRACT

The critical mass of an enriched uranyl sulfate solution in a water tamper was determined to be 1200 ± 50 gm. No direct measurement was possible because of insufficient enriched material for this purpose. The estimate was made by extrapolating counting rate vs. grams of 25 to infinite counting rate. A lattice of tuballoy disks surrounding the sphere was found to be equivalent to about 50 to 100 gm of 25. Distribution measurements were made in the tamper for high and low energy neutrons and it was found that in general the neutron flux decreased exponentially with increasing distance.

WATER TAMPER MEASUREMENTS

CRITICAL MASS

A determination of the critical mass of an enriched uranyl sulfate solution in a water tamper is of interest for several reasons: (1) safety considerations in connection with the processing of enriched materials make the knowledge of the largest amount to be handled safely obviously important; (2) The measurement provides a check on the theoretical methods developed to calculate critical masses; (3) applications to the work of this project may be possible; and (4) a power boiler with a water tamper is an interesting possibility.

The experiments were performed with the sphere and uranyl sulfate solution ("soup") from the low-power water boiler (See LA-134). The BeO tamper was removed and a cylindrical tank 5 feet in diameter and 5 feet high placed around the sphere. This tank was filled with ordinary water and all measurements were taken at room temperature. Because of the limited amount of 25 available for this experiment, it was not possible to reach a critical condition so the critical mass was estimated by measuring the counting rate of various detectors as a function of the mass of 25 in the sphere. Measurements were made at five concentrations: 0, 403, 508, 610 and 717 total grams of 25 in the sphere. The driving source was a 200 m.c. Ra-Be source placed at the center of the sphere in a stainless steel re-entrant tube.

Three detectors were used: a BF_3 chamber placed in the water tamper at 9" and at 18", Mn foils placed in a re-entrant tube at 2-7/8" and at 4-7/8", and a 25 fission chamber placed at 2-7/8", all these measurements being from center of sphere to center of detector. The critical mass was estimated in each case by plotting the reciprocal of the counting rate

against the mass of 25, and extrapolating the curve thus determined to infinite counting rate.

Simple theory gives the relationship

$$1/C = eS/(1 - K),$$

where C is the counting rate and e the efficiency of the detector, S is the source strength and K is the reactivity of the boiler, i.e., $1/(1 - K)$ is the effective multiplication of the source by the boiler. If this equation were true, then the experimental curves mentioned above would be straight lines and the extrapolation to $K = 1$, would be quite straightforward. The original water boiler experiment in approaching the critical mass for BeO tamper (See LA-134) showed that only the detectors which has been (somewhat fortuitously) placed in the proper positions gave straight-line curves. The fact that most detectors do not give linear relations is reasonable when the changes in leakage with changing mass of 25 and the difference between the spectrum of a Ra-Be source and that of a fission source are considered. Non-linearity between $1/C$ and $(1 - K)$ was anticipated in the water tamper experiment and several detectors were used for this reason. One can also obtain a more accurate extrapolation by considering several curves rather than one, since all curves must extrapolate to the same point.

The five curves obtained are shown in Fig. 1 with the dotted portion of each curve representing a reasonable extrapolation made on the basis of the experience with the BeO tamper where criticality was actually reached. The critical mass thus obtained is estimated to be 1200 ± 50 gm. of 25. The 25 fission chamber was placed too close to the source so that the neutrons directly from the source dominated the counting rate until quite a large mass

of 25 had been added. The BF_3 chamber in the 9-inch position, on the other hand, had a large initial increase in counting rate because the leakage of the fission neutrons was greater than that of the source neutrons. The Mn foils were in approximately the correct position and probably give the best extrapolation.

TUBALLOY SLUG EXPERIMENT

Mr. Teller suggested the possibility that tuballoy slugs arranged in a lattice around the sphere would be quite effective in increasing the reactivity, so a frame was constructed to hold 63 tuballoy disks approximately equally spaced on a spherical surface of 20 cm radius. Each disk was either 2.25 or 2.50" in diameter and about 0.7" thick. The total amount of tuballoy was about 50 Kg., making the total 25 content about 350 gm. An attempt to evaluate the effect of the slugs was made by comparing the activities observed with the various detectors with and without the slugs present. This was done for two 25 concentrations in the sphere: 610 and 717 gm. The experiment gave no clear-cut answer since the various detectors showed little agreement with each other. Various explanations of the discrepancies might be proposed but in general it seems apparent that the initial multiplication was too low so that the difference in spectrum between the source neutrons and the boiler neutrons may have confused the picture. Also the neutron distribution was radically changed by the presence of the slugs so that no single position of detector could be depended upon to give the true increase in multiplication. The experimental results are given in Table I, where the reciprocal counts are stated for the several cases. The data have been normalized to unity for zero grams of 25 so may be compared directly with the curves of Fig. 1.

TABLE I.

Reciprocal Counts Relative to Those With No 25

Detector	Position	25 Mass = 610 gm		25 Mass = 717 gm	
		Bare	Slugs	Bare	Slugs
BF_3	9"	.150	.102	.125	.85
	18"	.28	.20	.19	.205
Mn	4-7/8	.40	.326	.335	.273
25	2-7/8"	.74	.49	.67	.445

In view of the ambiguity of the data it is only possible to guess that the effect of the slugs is small, about equivalent to that from adding between 50 and 100 gm. of 25 to the sphere.

NEUTRON DISTRIBUTION MEASUREMENTS

Measurements of the neutron distribution were made with 717 gm. of 25 in the sphere and with 200 mc. Ra-Be source in the center of the sphere. Measurements were taken in the water tamper with a BF_3 chamber, a 25 chamber and a 28 chamber. The results are shown in Figs. 2, 4, and 5. In each case, the curve obtained was a single exponential except in the regions either very close to the sphere or near the edge of the water tamper. The most extensive exploration of neutron distribution was made with Mn foils, the measurements being made both inside and outside the sphere. Those inside the sphere were made in the reentrant tube. According to earlier measurements made with the BeO tamper (see LA-152), the reentrant tube depressed the neutron density by 11 per cent so the interior points shown in Fig. 3 have been raised by this value. A

definite decrease in thermal neutron flux at the boundary between the sphere and tamper may be seen in Fig. 3. This boundary effect is also indicated by the 25 curve of Fig. 4.

WATER ANALYSIS

A sample of the water used in the tamper was analyzed by Mr. Nachtrieb's group. A spectroscopic analysis gave no indication of sufficient impurities to affect the neutron properties of the water.

CHEMICAL ANALYSIS

The manipulations and calculations involved in changing the composition of the soup for these experiments were performed by a section of Group C-5 under the leadership of C. Friedlander. An analysis of the soup was made at the end of the experiment to verify the composition computed from the additions and subtractions. The masses quoted are probably accurate to 0.5 per cent.

CONCLUSION

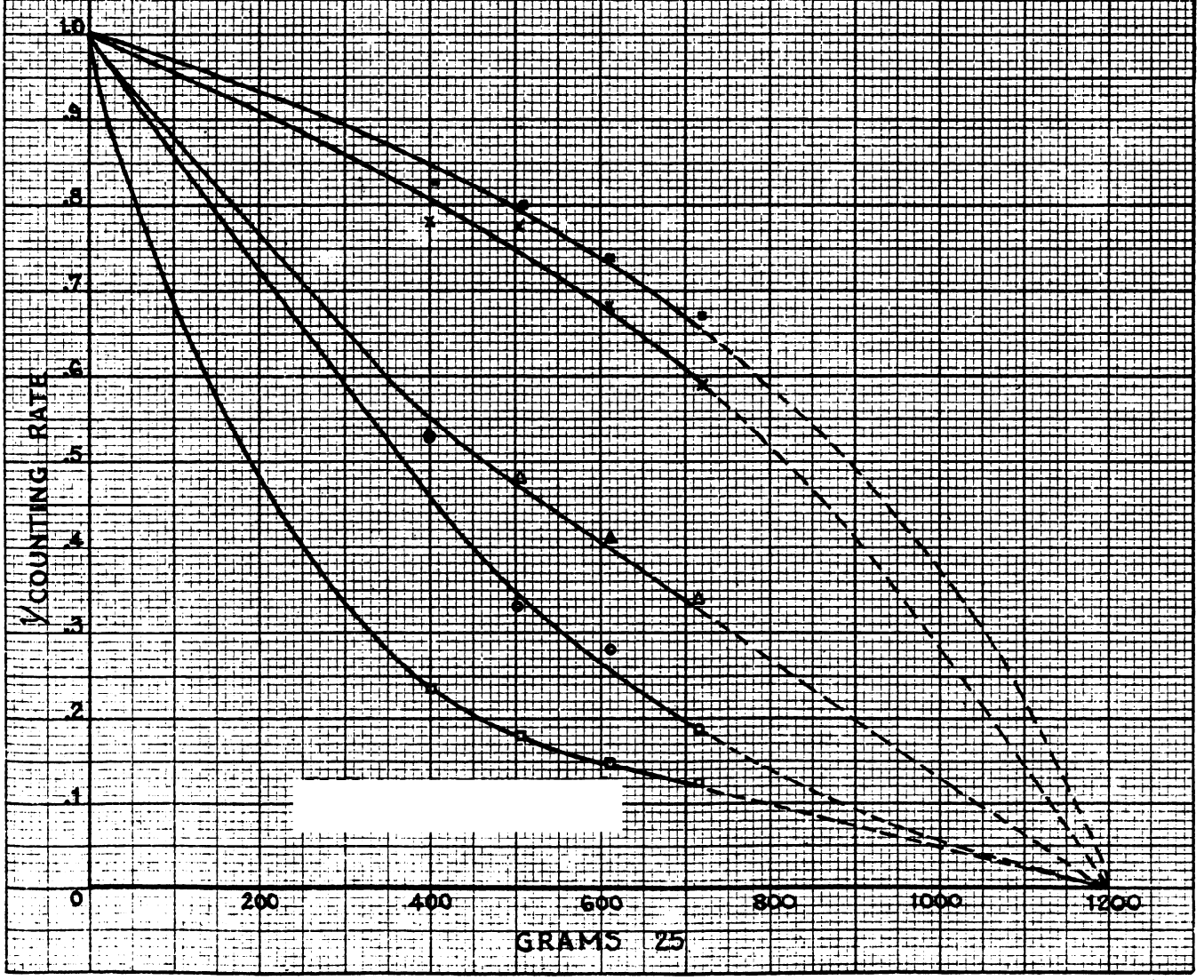
No discussion of the results of the above experiments will be given in this report since they are being treated in a report to be published by Group F-1 under E. Teller. We wish to thank Teller for his advice and helpful suggestions regarding this work.

FIG. 1

WATER TAMPER

- ● 25 CHAMBER — $2\frac{7}{8}$"
- × Mn FOIL — $2\frac{7}{8}$"
- △ Mn FOIL — $4\frac{7}{8}$"
- ○ BF_3 CHAMBER - 18"
- □ BF_3 CHAMBER - 9"

NOTE: DISTANCES ARE FROM SPHERE CENTER TO DETECTOR CENTER IN EACH CASE.



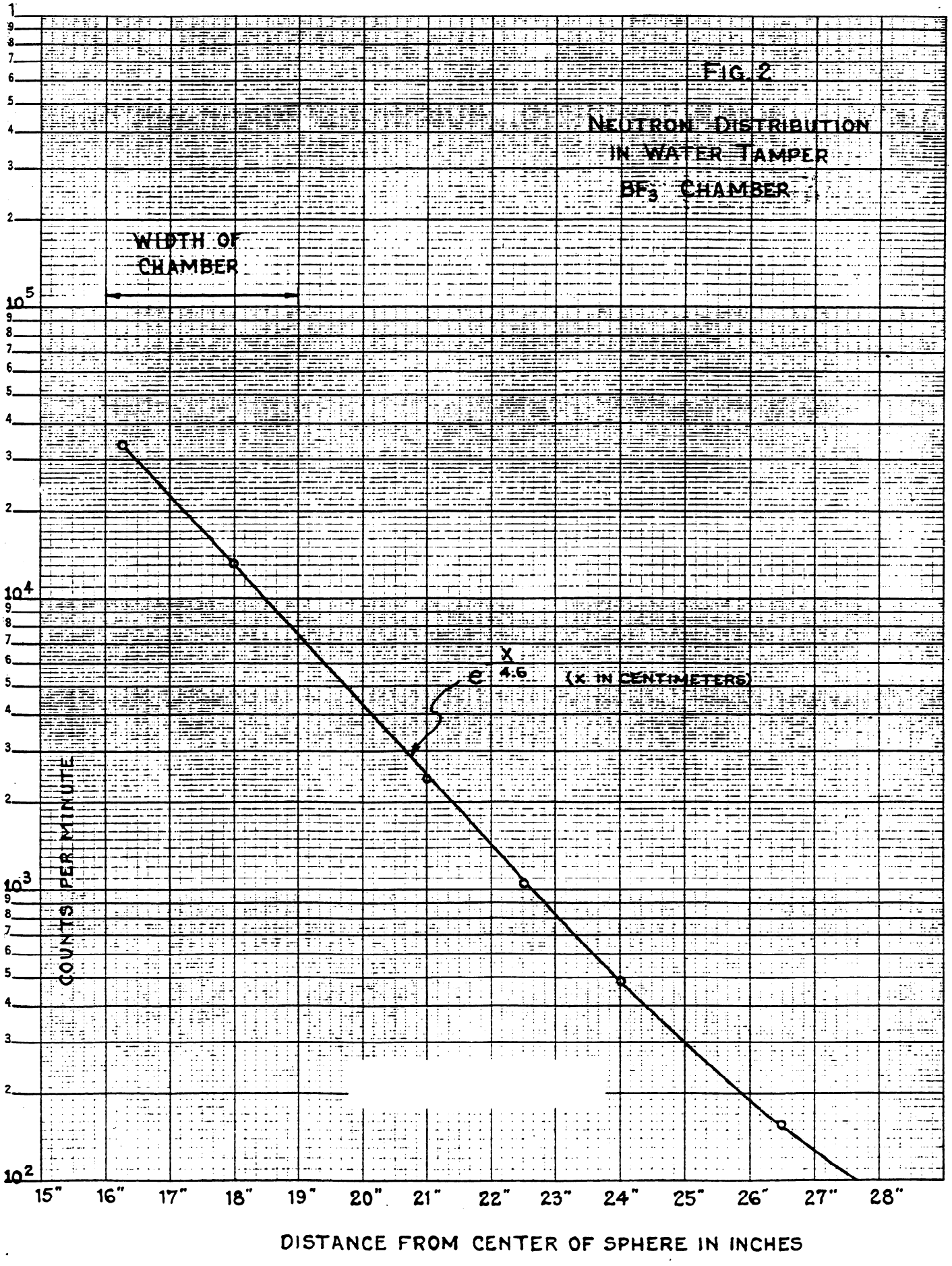


FIG. 2
NEUTRON DISTRIBUTION IN WATER TAMPER
BF_3 CHAMBER
WIDTH OF CHAMBER
$e^{\frac{x}{4.6}}$
(x IN CENTIMETERS)
COUNTS PER MINUTE
10^5
10^4
10^3
10^2
15" 16" 17" 18" 19" 20" 21" 22" 23" 24" 25" 26" 27" 28"
DISTANCE FROM CENTER OF SPHERE IN INCHES

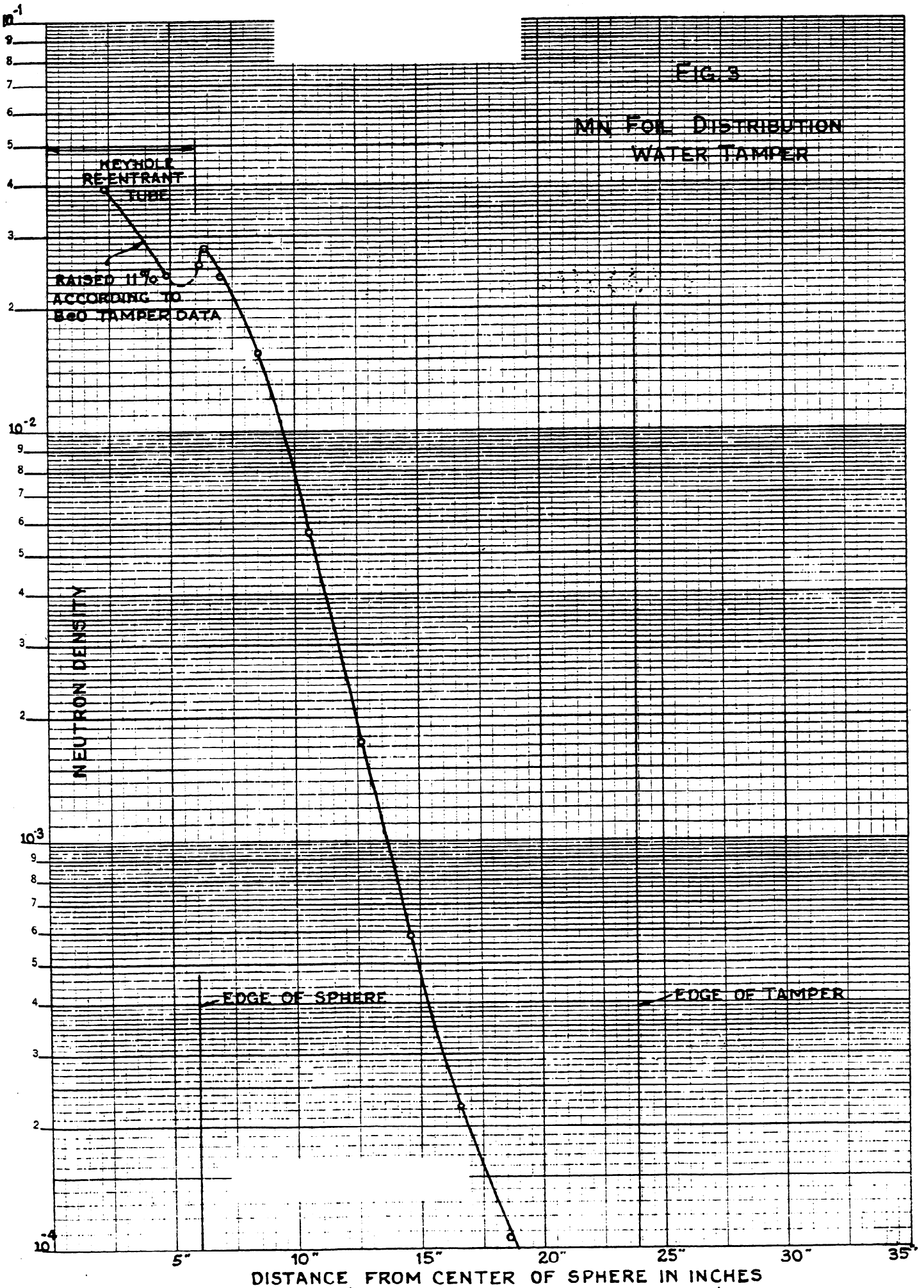


FIG. 3
MN FOIL DISTRIBUTION
WATER TAMPER
KEYHOLE
RE-ENTRANT
TUBE
RAISED 11%
ACCORDING TO
BeO TAMPER DATA
NEUTRON DENSITY
EDGE OF SPHERE
EDGE OF TAMPER
5"
10"
15"
20"
25"
30"
35"
DISTANCE FROM CENTER OF SPHERE IN INCHES

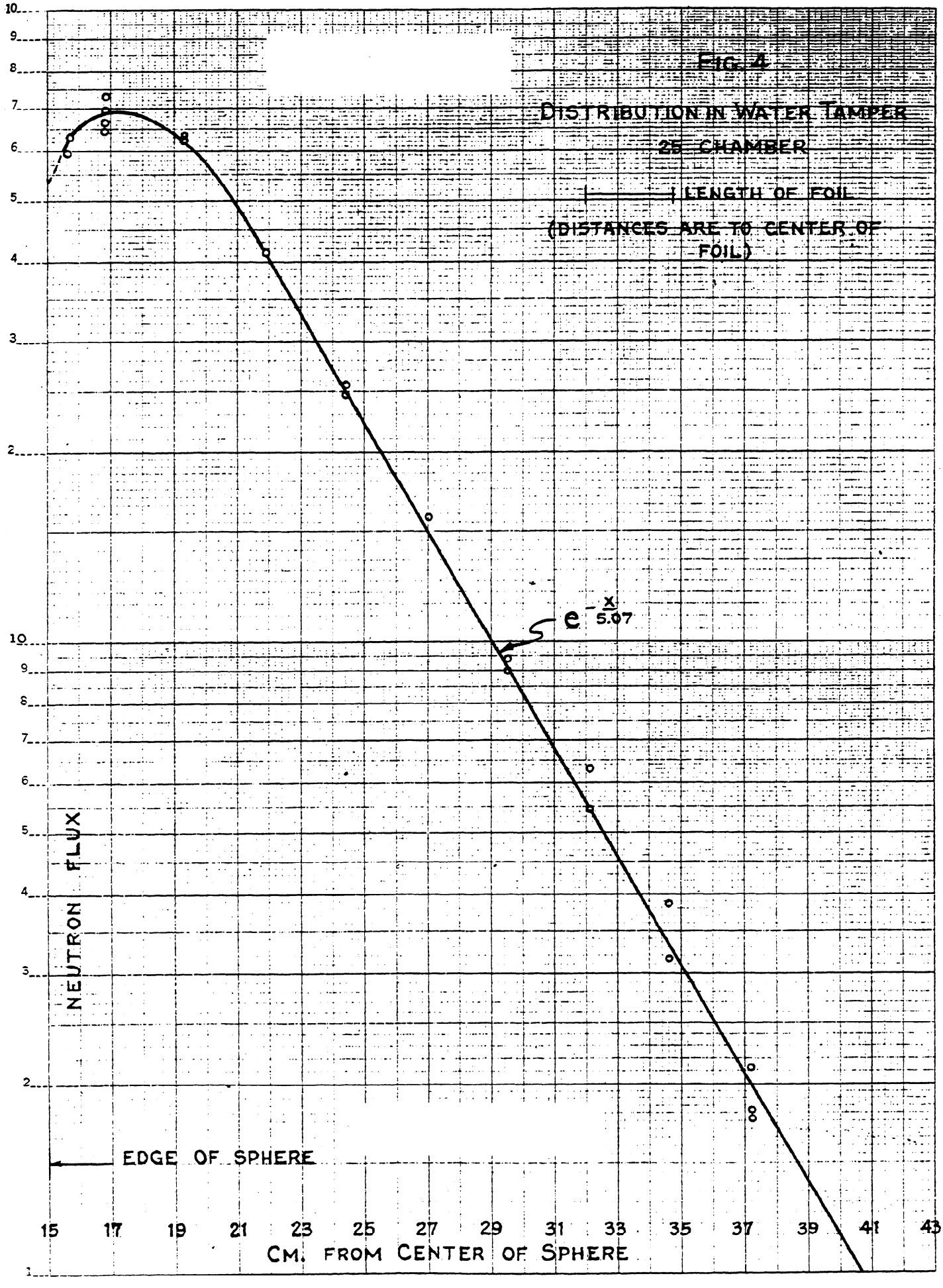


FIG. 4
DISTRIBUTION IN WATER TAMPER
25 CHAMBER
LENGTH OF FOIL
(DISTANCES ARE TO CENTER OF FOIL)
$e^{-\frac{x}{5.07}}$
NEUTRON FLUX
EDGE OF SPHERE
CM. FROM CENTER OF SPHERE
10
9
8
7
6
5
4
3
2
1
15
17
19
21
23
25
27
29
31
33
35
37
39
41
43

FIG. 5

DISTRIBUTION IN WATER TAMPER

28 CHAMBER

.46 GM. OF OXIDE ON 330 CM^2

R = 1000

| LENGTH OF FOIL

(AXIS OF CYLINDRICAL FOIL ALONG RADIUS OF SPHERE)