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Fission cross section

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FISSION CROSS SECTION OF URANIUM 235 FOR 25-KILOVOLT NEUTRONS

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Abstract

The 25 fission cross section is determined for neturons emitted from an Sb-Be photoneutron source. The neutrons from this source are found to be very nearly mono-energetic. The energy of these neutrons has previously been reported to be 25 ± 5 Kev (LA-468). A comparison is made of the counting rate made in a large cylindrical fission chamber by the Sb-Be source and a secondary standard source known as Mock Fission Source #3. The 25 fission cross section for the mock fission neutrons is measured absolutely by use of: 1) a smaller cylindrical fission chamber containing a foil of known weight, and 2) knowledge of the strength of the mock fission #3 source as measured by Walker by comparison with a standard Ra-Be source. Also needed is the ratio of strengths of the MF#3 and the Sb-Be source at several given dates. These comparisons are made in two ways: 1) Mn bath, 2) new "Long Counters" containing B^{10} enriched BF_3. The 25 fission cross section obtained is 2.9 ± 0.1 barns at 25 ± 5 Kev.

Introduction

The fission cross section of 25 was previously measured as a function of neutron energy from 1 Mev to low energies using a certain "long counter" and a 25 fission chamber. Several points were also measured with a double ionization chamber known as the 2 "PG" counter and there was good agreement between the two methods.[1] These gave a value of 3.45 ± 0.1 barns for the 27 Kev point.

Later measurements of the 25 fission cross section did not agree with the above value near 30 Kev. Using Be^7 technique, a value of 2.30 barns was obtained for 29 Kev.[2]

LA-140A indicated the existence of photoneutron source whose neutrons fell in the energy range in which the disputed cross section lay. Further information [3] indicated that it was possible that the neutrons of this source might be mono-energetic.

Experimental Procedure

The first step is to find if the neutrons from the Sb-Be source are mono-energetic or not. The technique used is identical to that used by Hanson and Bailey.[4] A BF_3 chamber is shielded on all sides but the front face with 1" of B^{10} powder. An Sb-Be source is suspended 12 inches in front of the face of the counter and various thickness absorbers of B^{10} (95 percent B^{10} in containers with 15-mil brass faces) are placed over the open face of the counter. If there are only one-energy neutrons

1) J. H. Williams, et al., LA-160
2) R. F. Taschek and C. M. Turner, LA-445
3) S. K. Allison, LAMS-213
4) C. L. Bailey, C. F. Baker, and A. O. Hanson, LAMS-242

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striking the absorber, a simple exponential relation should exist between the thickness of the absorber and the counting rate observed. If neutrons of more than one energy are present either in separated groups or in a continuous spectrum, the above relation should not hold. The experimental setup is shown in Fig. 1a. The data taken are listed in Table 1. The data plotted on semi-log paper appear as the solid heavy line on Fig. 2. The above explanation is admittedly the simplest case and does not consider degradation of neutrons due to non-absorbing collisions. This latter effect must be very small judging from the straightness of the line in Fig. 2. It appears that the neutrons are either mono-energetic or if there is a spread, it is very small. Certainly there is no appreciable group of neutrons of energy much lower than the main group. Such a group would ruin this source for this experiment because a lower-energy group would have a high cross section and thus would make the apparent cross section for the source neutrons too high.

The slope of this line also gives us an estimate of the energy of these neutrons by comparing it with the lines calculated in the same manner using, as the neutron source, relatively mono-energetic neutrons of 10, 30, and 100 Kev obtained from the Li(p,n) reaction at an angle of 120°. The geometry used in this calibration is shown in Fig. 1b. The 10, 30, and 100 Kev work was done by Bailey and Hanson[5] and the original data appear in their paper. The lines resulting from these data appear

5) LAMS-242
6) A. O. Hanson and A. Hemmendinger, LA-468

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on Fig. 2 as dotted lines and their energy is marked thereon. One would estimate from Fig. 2 that the energy of the Sb-Be neutrons is near 30 Kev.

Actual measurement of the energy of the Sb-Be neutrons was done carefully by Hanson and Hemmendinger[6] by observing maximum pulse heights of proton recoils in a hydrogen filled proportional counter. Their value is 25 ± 5 Kev.

The above information indicates this source to be ideal for the problem at hand. A dual approach was decided upon:

1) Place small Sb-Be sources at the center of various diameter spheres of B^{10} for Sb-Be neutrons. From these two pieces of data, simple diffusion theory should give the absorption cross section of B^{10} for this energy neturon. The ratio of $\sigma_{-}(B^{10})/\sigma_f(25)$ has been measured[7] and thus the 25 fission cross section can be evaluated.

2) A certain neutron source called Mock Fission #3 has been calibrated for strength by Walker against a Ra-Be source. The energy spectrum of neutrons from this source is roughly the fission spectrum but, as will be described below, the fission cross section of 25 for the average neutron energy of this source has been measured. The procedure now is to place this MF#3 inside a fission chamber and record the fissions. Then place the Sb-Be source in the same chamber at the same position and record the fissions. If the fission foil in the chamber is 100 percent 25 or 25 oxide, the following equation holds:

$$\sigma_f(25)_{Sb\text{-}Be} = \frac{C_{Sb\text{-}Be}}{C_{MF\#3}} \cdot \frac{S_{MF\#3}}{S_{Sb\text{-}Be}} \; \sigma_f(25)_{MF\#3}$$

where $C_{Sb\text{-}Be}$ is count caused in the fission chamber by the Sb-Be source [redacted]

7) J. H. Williams, et al., LA-150

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$C_{MF\#3}$ is count caused in the fission chamber by the MF#3 source

$S_{MF\#3}$ is the strength of the MF#3 source

S_{Sb-Be} is the strength of the Sb-Be source

and $\sigma_f(25)_{MF\#3}$ is the 25 fission cross section fot the average energy neutron of the MF 3 source.

The remaining step is to evaluate the ratio of the source strengths. This is done most easily by placing the two sources alternately between two "long counters". However, since one of the other measurements of the fission cross secti:n in this region depended upon some long-counter measurements, the ratio of the source strengths is also measured by comparing them in a large manganese bath.

Both methods were used. The B^{10} method however has struck some theoretical difficulties and the data have not yet been analyzed satisfactorily. This paper deals exclusively with the second method.

MF#3 was originally created for multiplication measurements in 49 and 25 spheres and was so used. On March 7, 1945, Walker measured its source strength as 3.64×10^6 neutrons per second.

Two cylindrical fission foils were painted by Zapon technique on the inside of two platinum cylinders. A fission chamber was constructed as shown in Fig. 3. One fission foil was 70.4 percent enriched 25 oxide. The other was 28 oxide. The procedure is to insert the foil, fill the chamber to the proper pressure, place the source somewhere in the room to give a properly weighted background effect (such as would occur because of room-scattered neutrons which will come from the source when it is in the chamber, pass through the foils without fission or absorption, hit

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something in the room and eventually be reflected back into the chamber and cause fission), and count. Then place the source at the geometric center of the foil and count fissions.

Then:

$$N_f = \phi\, N_{28}\sigma_f(28)$$

where N_f is the net fission/minute (counts minus background)

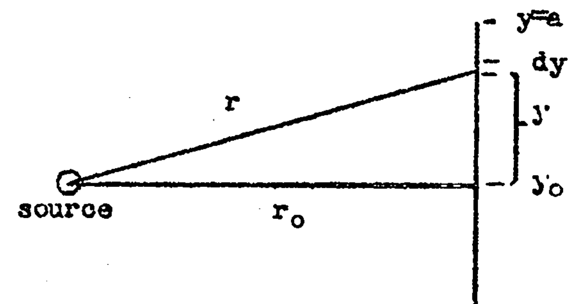
ϕ is the number of neutrons hitting the foil per minute

N_{28} is the number of 28 atoms on the foil

$\sigma_f(28)$ is the cross section per atom

However, the area of the foil is not easily determined accurately and thus ϕ is not known accurately. A way around this difficulty is to calculate the flux through an "average cm^2". For this average area one must calculate an average or effective $1/r^2$.

$$(1/r^2)_{eff} = \frac{\int_0^a \frac{dy}{r_2}}{\int_0^a dy} \qquad \text{for}$$



$$(1/r_2)_{eff} = (1/a)\int_0^a \frac{dy}{r_o^2 + y^2} = (1/a)\left[(1/r_o)\tan^{-1}(y/r_o)\right]_0^a$$

$$= \frac{1}{ar_o}\left[\frac{a}{r_o} - \frac{1}{3}\,\frac{a^3}{r_o^3} = \frac{1}{5}\,\frac{a^5}{r_o^5} - \cdots\cdots\right]$$

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The cylindrical foil used in the case of both 25 and 28 is 1 1/2" diameter and 3/4" wide. Therefore

$$a = (1/2)\,r_o.$$

Therefore

$$\frac{1}{r^2} = \frac{2}{r_o^2}\left[\frac{1}{2} - \frac{1}{24} + \frac{1}{160} - \cdots\right] = \frac{1}{1.078\, r_o^2}$$

Now:

$$N_f = \frac{r}{4\pi r^2}\left[N_a\,\sigma_f\,(28)\,A\right]$$

where all quantities are the same as before except

r is the total number of neutrons emitted per minute by the source, and N_a is the number of 28 atoms per square centimeter of foil and A the area of the foil.

One does not know N_a or A nor does one know if the atoms on the foil are evenly distributed. However, the total weight of the foil is known, and from this the total number of atoms can be calculated. The total number of atoms is simply $N_a \cdot A$. Any uneven distribution of atoms is also integrated out. Therefore:

$$N_f = \frac{r}{4\pi r^2}\left[N_{28}\sigma_f(28)\right]$$

in which all quantities are known except $\sigma_f(28)$, which is thus solved. (See Table II for data, calculations, and results.)

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Exactly the same procedure is followed for the 25 measurement as for 28 except using the 25 foil. The same formula would hold of the 25 cross section if the foil contained no 28. However, it does contain 29.6 percent of the metal as 28, therefore

$$N_f = \frac{r}{4\pi r^2}\left[N_{25}\sigma_f(25) + N_{28}\sigma_f(28)\right]$$

Where N_{25} is the total number of 25 atoms of the foil and N_{28} is the total number of 28 atoms on the foil.

Substituting in the value of $\sigma_f(28)$ just determined, all values are known except $\sigma_f(25)$ and thus it is solved. (See Table II for data, calculations, and results.)

The next step is to place the Sb-Be source and the MF#3 source inside the same cylindrical foil and measure the ratio of counting rates. The Sb-Be sources are of necessity relatively large sources.[8] To approximate the effect of point sources, the cylindrical foil used must be quite large. The foil was painted on a 6" diameter brass cylinder using the Zapon technique. The chamber designed for this foil is shown in Fig. 4. The data taken with this chamber are given in Table III.

The last and most difficult portion of the experiment is the comparison of the strengths of the two sources used. The Sb-Be source has a half-life of 60 days.[9] The ingredients of the MF#3 are $NaBF_4$, BeF_2, and polonium. The half-life would be expected to be that of polonium, 140 days. It very nearly is 140 days, but not quite. It does not even

8) See Appendix of this paper
9) S. K. Allison, LAMS-213

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decay quite exponentially. This is undoubtedly due to the migration of the polonium inside the source. This does not cause particular difficulty for the only place in which the absolute value of the strength of this source enters the calculations is in the evaluation of $\sigma_f(25)_{MF}$ as shown above. No difficulty is encountered here for the strength of the source was measured on March 7, 1945 and the cross section measurement was made on March 9, 1945. The slight difficulty arises in that measurements of the counting ratio in the large fission chamber and measurements of the ratio of the source strengths were never made on the same day. Thus the ratio must be extrapolated back to the day on which the other ratio was taken. Arbitrarily, it is decided to extrapolate source strength ratios back to the dates of counting rate ratios. Enough source strength ratios are taken at various dates so that the effect of the migration factor on the source strength ratios could be estimated in any case with an error less than 1 percent (see Table IV).

Measurements of source-strength ratios are made in two ways. The easiest way experimentally is by comparison with long counters. The counters used are shown in Fig. 5. These counters have been carefully checked for sensitivity for neutrons of several widely different energies, by using several different sources, with and without D_2O degrading sphere. Their sensitivity curve is shown in Fig. 6. The ratio of their sensitivity to MF75 neutrons and Sb-Be neutrons is probably known to within 2 percent. The experimental set-up used is shown in Fig. 7. The data obtained are in Table IV.

The other source strength ratio measurement is made using a

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new $MnSO_4$ bath. The bath is in a lucite container, 30" x 30" x 36", and is filled to a height of 30". The technique is one developed by C. M. Turner.[10] It consists of removing a lucite vessel full of solution, and then putting in one or the other source at the center of the bath. A certain time is allowed for irradiation of the solution by the source, the source is removed, the solution is stirred thoroughly by an electrically driven lucite propeller. A sample of the solution is removed in a lucite vessel and taken to another room where the Geiger counter is set. The counter is of the thin-walled "Chicago" type. A standard lead pig has been set on end, door-side down, and the back plate unscrewed. This plate is carefully lifted straight up and the counter comes with it. The lucite vessel containing irradiated sample just fits into the pig and slides down to a stop mounted in the pig. The level of the solution in the vessel has been so selected that when the counter is carefully lowered into the solution, the back plate will come into position just as the solution covers the active portion of the counter. This gives an easily reproducible geometry. Fig. 8 shows the arrangement.

Radiation times are 13 hours. Before it is time for the source to be removed, the GM circuit is turned on, allowed to warm up for 15 minutes. It is then checked for plateau drift by placing a given ring of uranium glass around the counter at a definite spot. If the counting rate over a period of 5 minutes is the same as the previous "standardization" it is assumed to be on the plateau. The ring is then removed and

10) R. F. Taschek and C. M. Turner, LA-445

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the vessel of solution taken before the source was introduced into the bath the night before is then placed in the pig and the counter placed in it. The resulting count is a count due to the activity of Mn bath before the source had been introduced (note this activity has decayed the same amount that the original activity of the unradiated bath would decay if the bath had not been radiated). It is used as a "background" count. This background count is timed to end at a few minutes before the source is to be taken from the bath. The source is now removed from the bath and a stop watch is started at the time of its removal. The bath is stirred and the active sample brought to the GM set up. The vessel is put into the pig and the counter is started at some predetermined time, say 10 minutes after the source is removed from the bath. The counter is read at regular intervals "on the run". The counts per interval are then extrapolated back to the time when the source is removed.

A good discussion of the theory of the Mn bath is contained in LA-445. Two points should be discussed here, however. Christy has estimated that a bath a cubic meter in size would lose 1 to 2 percent of the neutrons from a Ra+Be source.[11] In view of this, one would not expect a loss of more than 1 percent of the neutrons of the MF 3 source from this tank and practically no loss of Sb-Be neutrons. Therefore, no correction is made for this effect. The second point is, as discussed in LA-445, that when one source is radiating the bath, the bath itself becomes radioactive with much shorter half-life than the source (2.59 hrs compared to 60 and 140 days). Therefore, a saturation value can be reached. 13 hours gives roughly 96 percent saturation. However, in this experiment where there is simply

11) C. M. Turner, LA Notebook 311

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a comparison of sources, it is simplest to leave the ~~sources in~~ for equal lengths of time and thus the saturation effect cancels out in the ratio. This is done. The ratio of source strengths is considered simply as the ratio of the counting rates, corrected only for the decay of the sources between runs. (See Table IV for data).

As stated before, if the fission foil in the large fission chamber were 100 percent 25 oxide, the equation for the desired cross section would be:

$$\sigma_f(25)_{Sb-Be} = \frac{C_{Sb-Be}}{C_{MF\#3}} \cdot \frac{S_{MF\#3}}{S_{Sb-Be}} \cdot \sigma_f(25)_{MF\#3}$$

However, the foil used was 80 percent 25 and 20 percent 28. The Sb-Be neutrons would cause no fission in the 28 and thus the total counts observed with the Sb-Be source would come solely from 25. The MF#3 source does have some neutrons of high enough energy to cause 28 fission. Thus the counts of the large fission chamber when it contained the MF#3 source are partially due to 28. Thus

$$\frac{C_{Sb-Be}}{C_{MF\#3}} = \frac{S_{Sb-Be}}{S_{MF\#3}} \quad \frac{\sigma_f(25)_{Sb-Be}}{\sigma_f(25)_{MF\#3} + 1/4\sigma_f(28)_{MF\#3}}$$

Using the value .28/1.27 determined with small fission chamber for $\sigma_f(28)_{MF\#3}/\sigma(25)_{MF\#3}$

we have

$$\sigma_f(25)_{Sb-Be} = \frac{C_{Sb-Be}}{C_{MF\#3}} \cdot \frac{S_{MF\#3}}{S_{Sb-Be}} \cdot \sigma_f(25)_{MF\#3} \times 1.05$$

A summary of the results of the measurements of $\frac{C_{Sb-Be}}{C_{MF\#3}} \cdot \frac{S_{MF\#3}}{S_{Sb-Be}}$

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and $\sigma_f(25)_{MP\#3}$ appear in Table V along with the calculations of $\sigma_f(25)_{Sb-Be}$.

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TABLE I

Distance from Sb-Be Source to Open Counter Face 12"

Type of counter: See Fig. 1A.

Circuits: Sands Preamplifier, Sands Amplifier, Higinbotham Scaler, and Battery Pack

ABSORBER	TIME OF RUN	DATA COUNTS per MINUTE	BACKGROUND	100xC/M - BG	TRANSMISSION
1/8" B^{10}	135'	14.2	0.1	14.1	0.876
Dummy	135'	16.6	0.5	16.1	
1" B	63'	5.6	0.1	5.5	0.351
Dummy	60'	16.1	0.5	15.6	
1/2" B^{10}	60'	9.8	0.1	9.7	0.614
Dummy	180'	16.6	0.5	16.1	
2" B^{10}	60'	2.1	0.1	2.0	0.128
Dummy	60'	16.0	0.5	15.5	
1/4" B^{10}	60'	11.5	0.1	11.4	0.745
1" B^{10}	120'	5.1	0.1	5.0	0.327
Dummy	60'	15.7	0.5	15.2	
2" B^{10}	122'	2.4	0.1	2.3	0.150
Dummy	600'	16.0	0.5	15.5	
1/2" B^{10}	60'	10.2	0.1	10.1	0.643
1/4" B^{10}	60'	13.2	0.1	13.1	0.834
Dummy	60'	16.5	0.5	16.0	
1/4" B^{10}	100'	11.1	0.1	11.0	0.700
1/4" B^{10}	825'	11.2	0.1	11.1	0.707
Dummy	131'	15.9	0.5	15.4	
1/4" B^{10}	133'	12.1	0.1	12.0	0.779
Dummy	153'	15.9	0.5	15.4	
1" B^{10}	127'	5.3	0.1	5.2	0.337
Dummy	126'	15.9	0.5	15.4	

Therefore 1/8" B^{10} gives a transmission of 0.88 ± 0.02
1/4" 0.73 ± 0.01
1/2" 0.63 ± 0.02
1" 0.34 ± 0.01
2" 0.14 ± 0.01

TABLE I

Type of counter: See Fig. 3

Circuits: Sands preamplifier, Sands Amplifier, Higinbotham Scaler and battery pack

Diameter of Foils: 1 1/2"
Width of Foils: 3/4"

Weight of 28 foil: 6.7 mg. oxide (contains 5.6 mg 28 or 14.32×10^{18} atoms)
Weight of 25 foil: 5.69 mg. oxide, 70.4%25, 29.6%28
(contains 3.33 mg. 25 or 8.50×10^{18} atoms 25
and 1.40 mg. 28 or 3.53×10^{18} atoms 28)

Strength of MF#3 on March 7, 1945 3.64×10^6 neutrons per second
or 218.4×10^6 neutrons per minute.

COUNTING RATES

TIME OF RUN	COUNTS	COUNTS/MINUTE	BACKGROUND	FOIL
213'	3774	17.7	negligible	28
137'	2432	17.8	negligible	28
152'	2685	17.7	negligible	28
40'	2128	53.2	0.13	25
47'	2380	50.6	0.13	25
120'	6364	53.0	0.13	25
90'	4720	52.5	0.13	25
105'	5434	51.7	0.13	25

$N_f(28)$/minute 17.7

$N_f(25)$/minute 52.1

for the 28 foil* $\sigma_f(28)_{MF\#3} = \dfrac{4\pi \times 1.01 \times 1.07 \times (1.90)^2 \times 17.7}{218.4 \times 10^6 \times 14.32 \times 10^{18}} = 0.28b \pm 6$

for the 25 foil* $\sigma_f(25)_{MF\#3} = \dfrac{1}{N_{25}} \left(\dfrac{N_f \times 4\pi r^2}{S} - N_{28} \sigma_f(28)_{MF\#3} \right)$

$$= \frac{1}{8.50 \times 10^{18}} \left(\frac{52.1 \times 4\pi \times 1.01 \times 1.078 \times (1.90)^2}{218.4 \times 10^6} - 3.53 \times 10^{18} \times 0.28 \times 10^{-24} \right)$$

$= 1.27b \pm 6\%$

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* factor of 1.01 due to finite source size.

TABLE III

Type of counter: See Fig. 4

Circuits: Sands preamplifier, Sands Amplifier, Higinbotham Scaler, and battery pack

Weight of foil: Unimportant in calculations approximately 142 mg. UF_4. Metal is 80% 25, 20% 28.

Diameter of foil: Unimportant in calculations; approximately 6".

DATE	NET COUNTS DUE TO Sb-Be / NET COUNTS DUE TO MF#5	RELATIVE PROBABLE ERROR
8/10/45	1.12	1.2 %
8/12/45	1.18	3 %
8/25/45	1.16	1.5%
12/6/45	1.58 *	2.5 %
12/11/45	1.52 *	2 %

* These values are for a new Sb-Be source of greater strength.

TABLE IV

Type of counters: Long counters; see Fig. 5
GM counter thinwalled aluminum "Chicago" type.

Circuits: Sands preamplifier, Sands Amplifier, Higinbotham Scaler, and battery pack.

DATE	Model METHOD	GM circuit STRENGTH OF MF#3 / STRENGTH OF Sb-Be	RELATIVE PROBABLE SOURCE ERROR
8/2/45	LC	[illegible].16	3 %
8/15/45	LC	1.79	3 %
8/25/45	Mn Bath	1.92	3 %
12/14/45	LC	1.42 *	3 %
12/20/45 to 1/25/46 extrapolated back to 12/6/45	Mn Bath	1.36 *	4 %

* These values for new Sb-Be source of greater strength.

[redacted]

TABLE V

DATA	DATE TAKEN	DATE TO WHICH EXTRAPOLATED AND AVERAGED	EXTRAPOLATED AND AVERAGED VALUE	ITEM #	COUNTER
From Table III	8/10/45	8/11/45			LC
	8/12/45	8/11/45	1.14 ± 4%	1	FISSION
	8/25/45	8/25/45	1.16 ± 1.5%	2	FISSION
	12/6/45	12/6/45	1.58 ± 2.5%	3	FISSION
	12/11/45	12/11/45	1.52 ± 2%	4	FISSION
From Table IV	8/2/45	8/11/45			LC
	8/15/45	8/11/45	1.69 ± 3%	5	
	8/25/45	8/25/45	1.92 ± 3%	6	MN BATH
	12/14/45	12/6/45	1.45 ± 3%	7	LC
	12/14/45	12/11/45	1.49 ± 3%	8	
	12/20/45 TO 1/25/46	12/6/45	1.36 ± 4%	9	MN BATH
		12/11/45	1.40 ± 4%	10	

Using formula derived on page 11:

$$\sigma_f(28) = \frac{C_{Sb-Be}}{C_{MF\#3}} \cdot \frac{S_{MF\#3}}{S_{Sb-Be}} \times 1.05 \times \sigma_f(25)_{MF\#3}$$

And using items 1 and 5, $\sigma_f(25)_{Sb-Be} = 2.6 \pm 0.2$ b

Using items 2 and 6, $\sigma_f(25)_{Sb-Be} = 3.0 \pm 0.2$ b

Using items 3 and 7, $\sigma_f(25)_{Sb-Be} = 3.1 \pm 0.2$ b

Using items 4 and 8, $\sigma_f(25)_{Sb-Be} = 3.0 \pm 0.2$ b

Using items 3 and 9, $\sigma_f(25)_{Sb-Be} = 2.9 \pm 0.2$ b

Using items 4 and 10, $\sigma_f(25)_{Sb-Be} = 2.9 \pm 0.2$ b

Final conclusion: $\sigma_f(25)_{Sb-Be} = 2.9 \pm 0.1$ b

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Appendix CONSTRUCTION OF SB-BE SOURCES

Two Sb-Be sources were used in this experiment, and two others were used in the B^{10} absorption cross section work. The first source used was messy, dangerous to construct, and inefficient. A slug of hot Sb was sent from the Argonne pile in a special aluminum container which is very securely fastened to the Sb. Removal was done by Lindsay Helmholtz by brute force; a piece 3/4" long was cut off with a hack saw in a hood. All possible precautions were taken but the job was nasty. This slug was placed in divided sphere of Be which had a cylindrical hole machined in the center. The two hemispheres were held together by brass screws.

The second source was made here out of cold Sb and Be, <u>then</u> sent to the Argonne pile and heated. Two hemispherical shells were machined to 1" I D and 1.25" O D. Each shell was then used as a crucible to melt Sb in it -- enough to fill the shell and leave a good sized meniscus over the top. As the Sb solidifies, it expands and can be removed from the Be only by remelting. Next the Sb meniscus was filed off so that two solid hemispheres resulted. The two hemispheres were then clamped solidly together with a "C" clamp and a heavy spring to take up expansion. The resulting sphere was than heated to a dull red insuring complete metling of the Sb inside and then allowed to cool. The two Be hemispherical caps were found to be so tightly locked together that they could not be removed except by breaking of the sphere or remelting.

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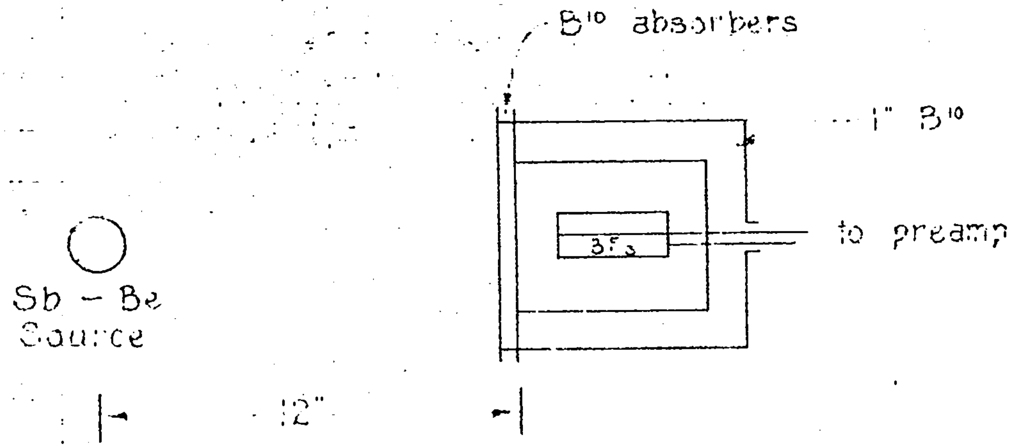
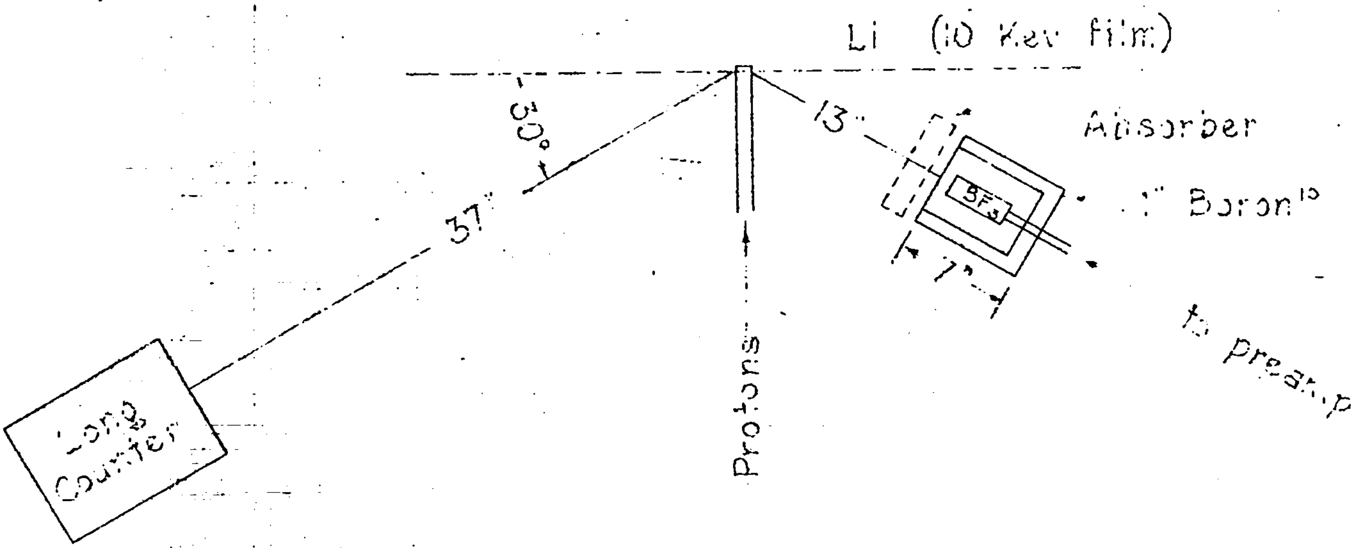


Set up for determination of energy distribution of Sb – Be neutrons.

FIGURE 1a.



Calibration run

FIGURE 1b

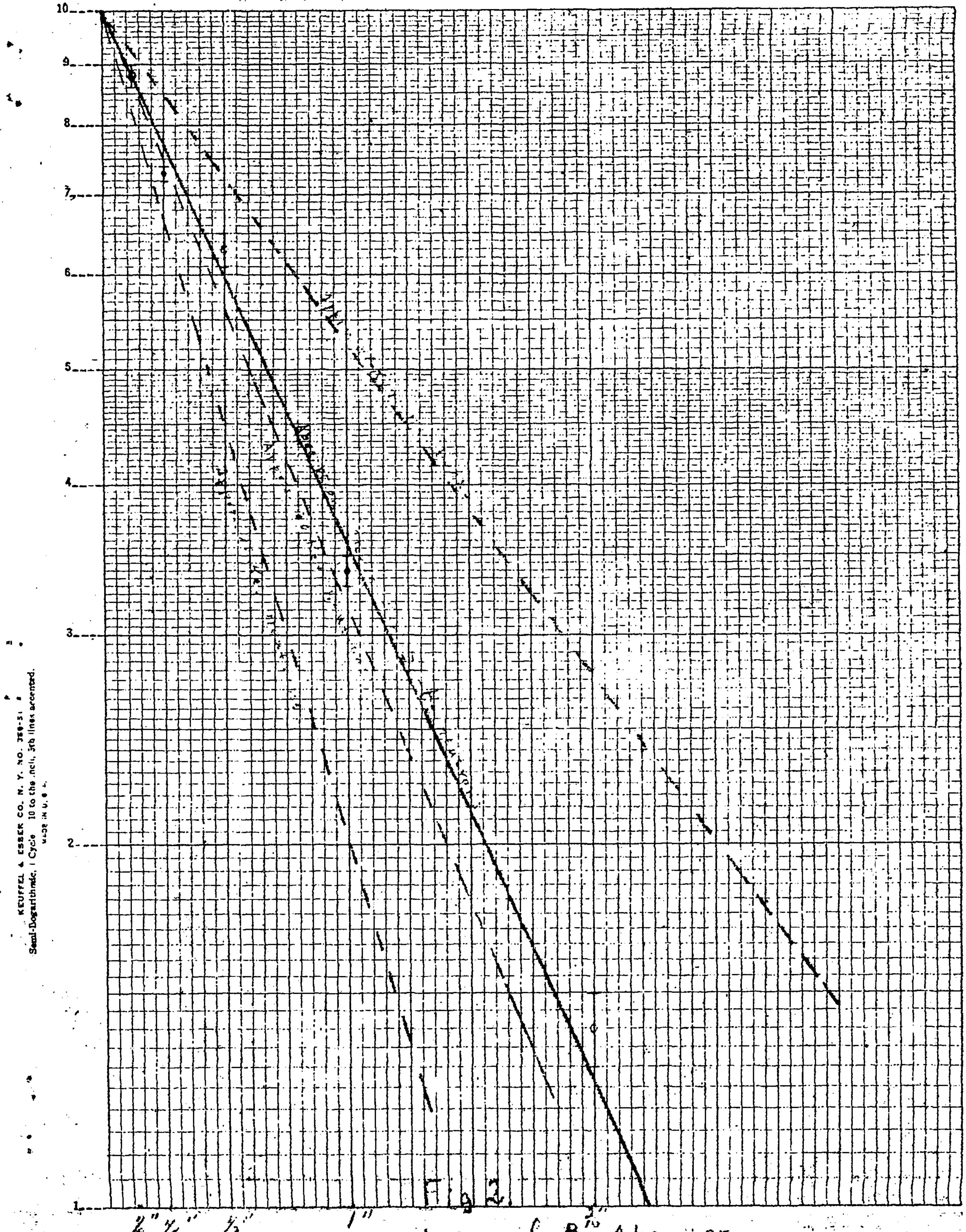


Fig 2

Thickness of B Absorber

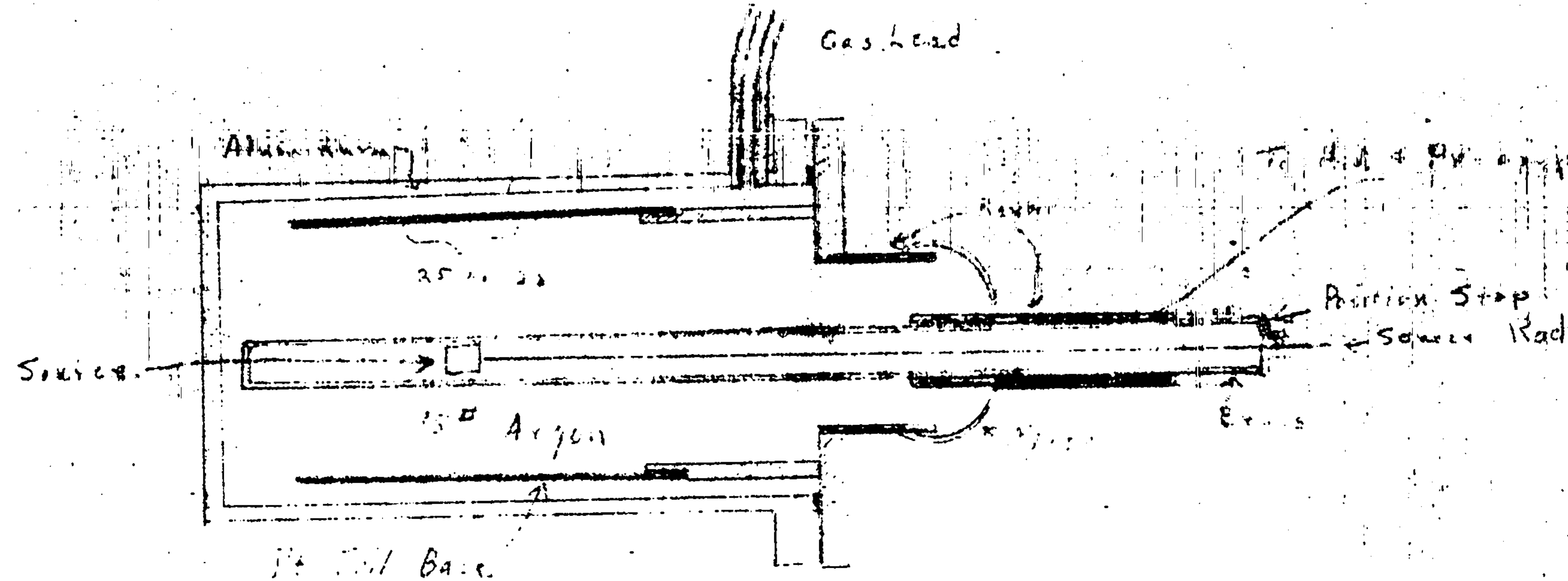


Fig. 3. Small Cylindrical Fission Chamber

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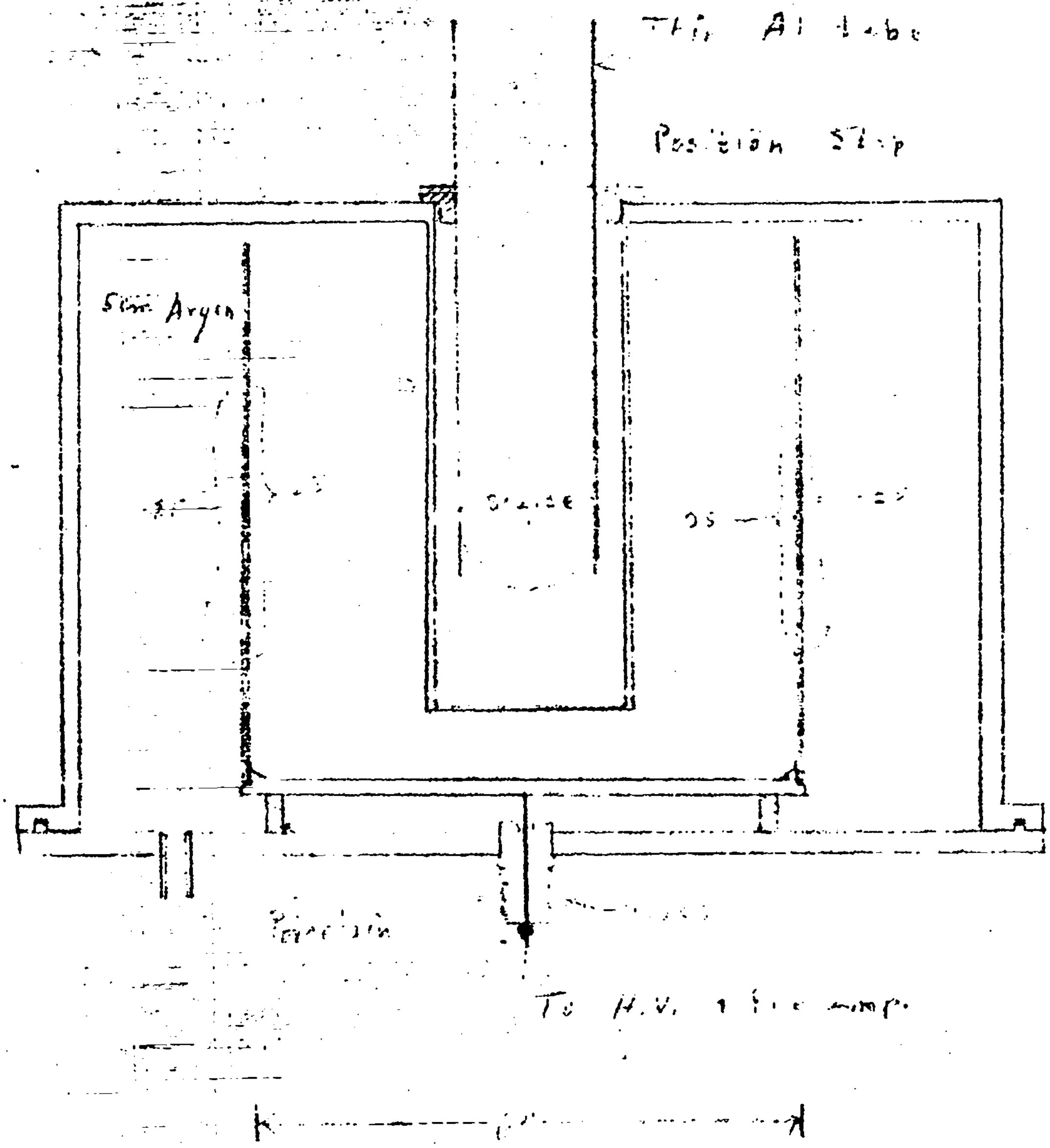

Fig. 4. Large Cylindrical Fission Chamber

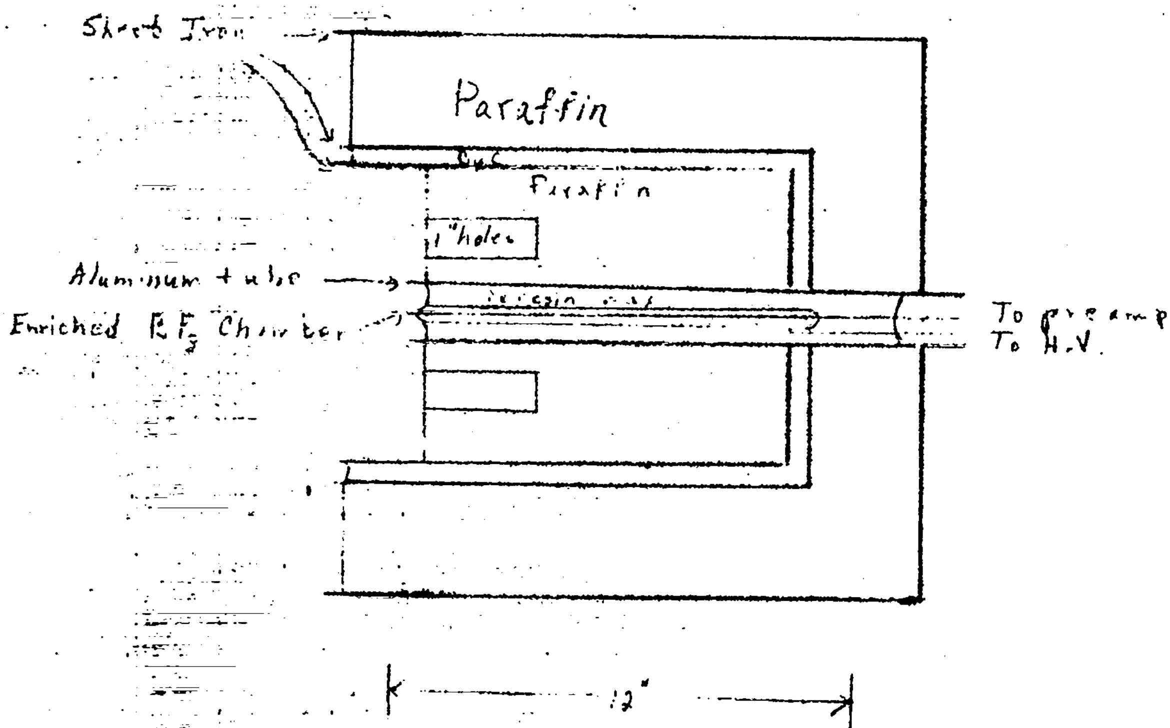

Fig. 5. Long Counter (Fat Man #1+2)

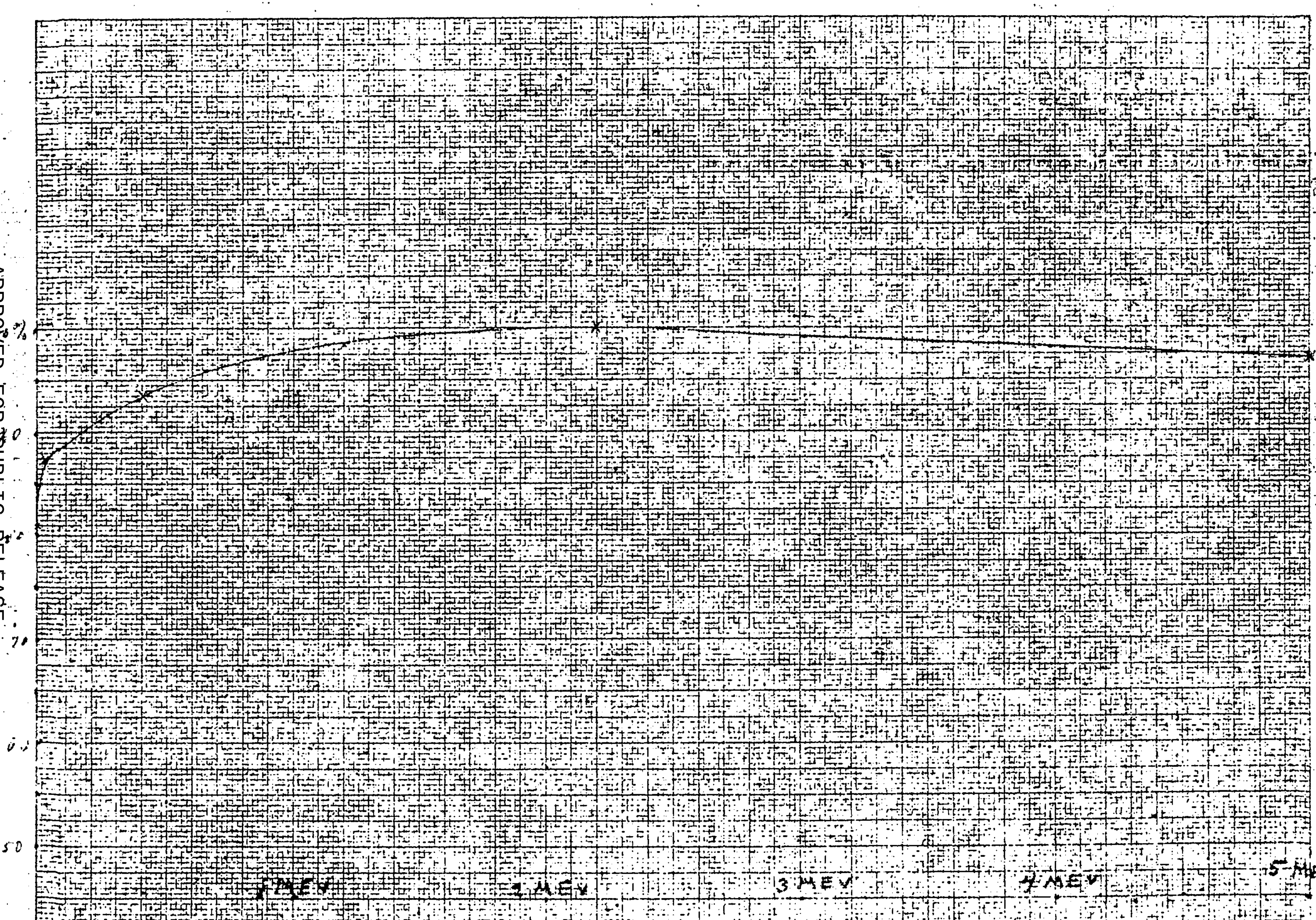

Fig. 6 Long Counter Sensitivity Curve

Neutron Energy in Mev

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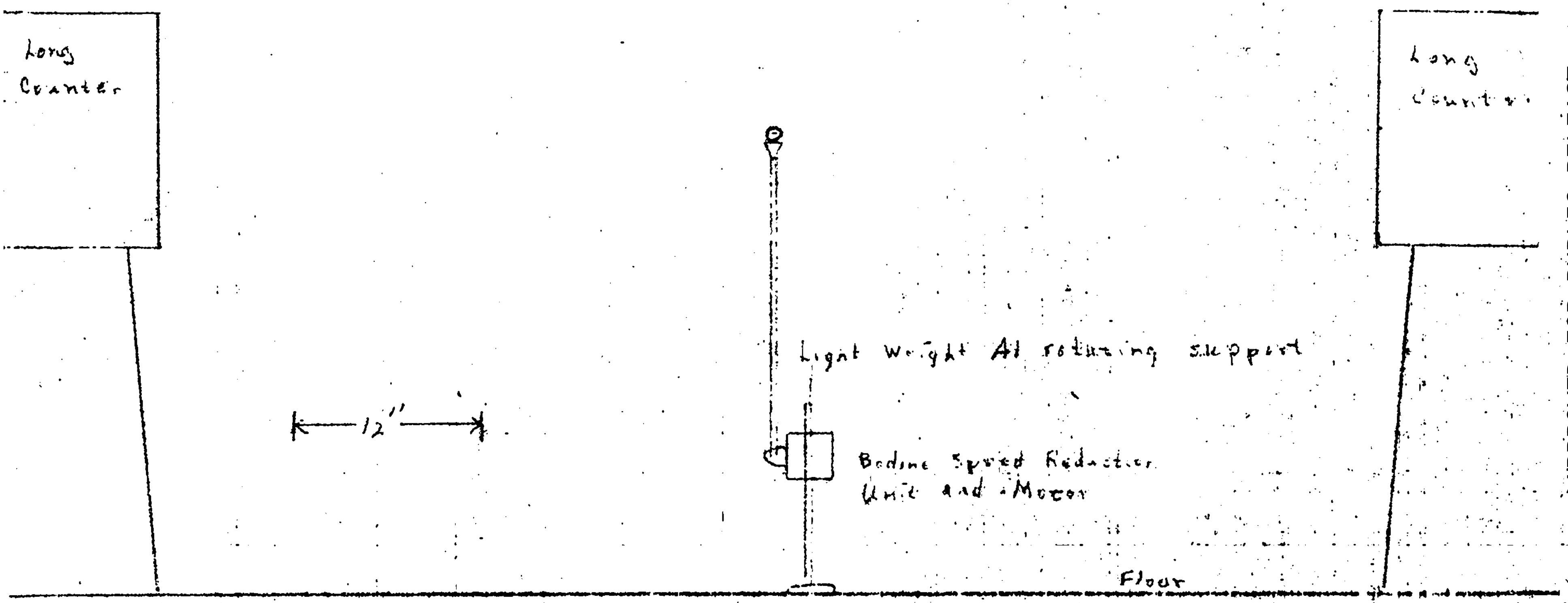

Fig. 7 [illegible] Counting Set up

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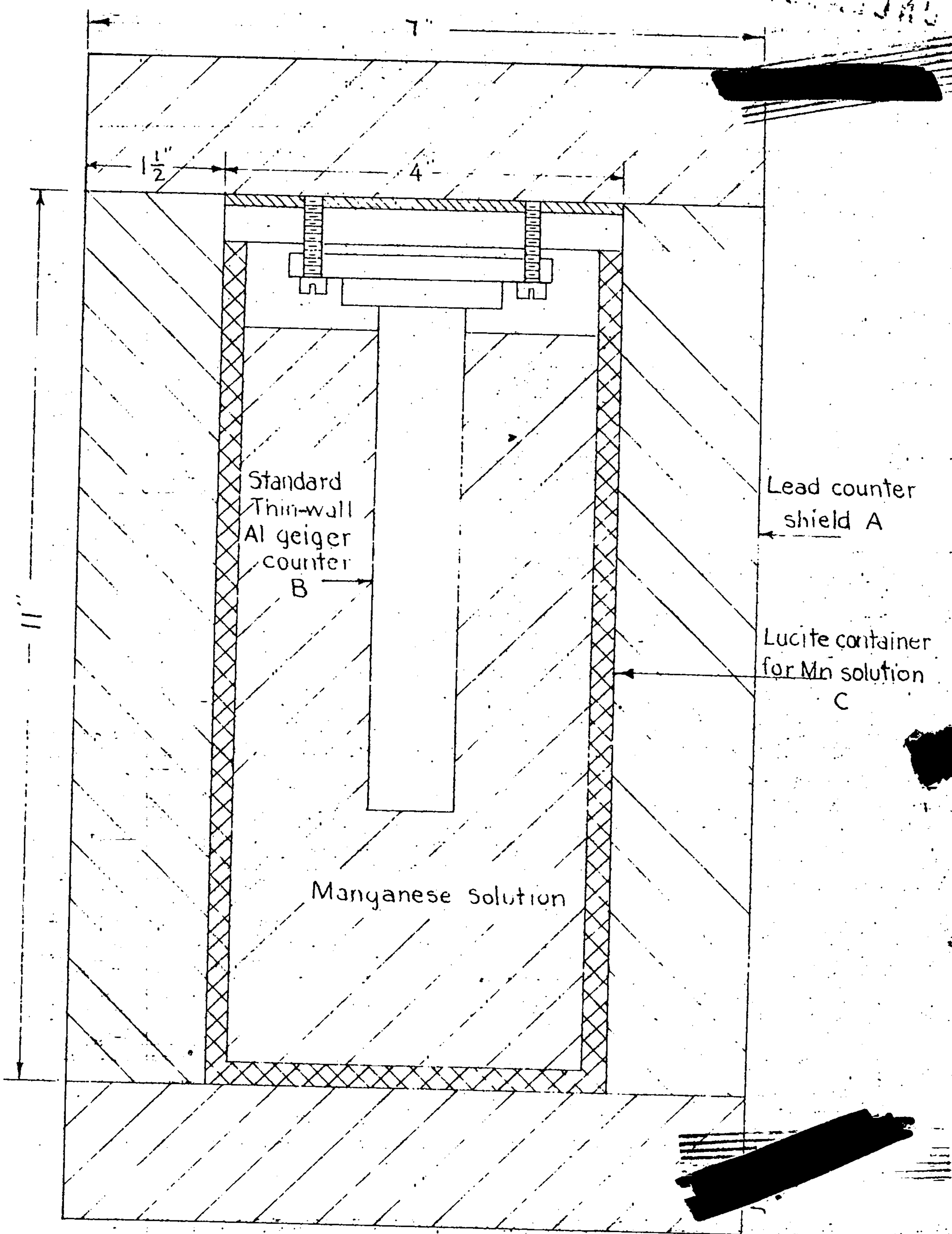

Fig. 8

GEIGER COUNTER ARRANGEMENT

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DOCUMENT ROOM

REC. FROM Jc

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