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THE AGE OF FISSION NEUTRONS TO INDIUM RESONANCE ENERGY IN GRAPHITE

PART I.

EXPERIMENT

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THE AGE OF FISSION NEUTRONS TO INDIUM RESONANCE ENERGY IN GRAPHITE

PART I.

EXPERIMENT

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CONTENTS

TABLES

FIGURES

ABSTRACT

The age of fission neutrons to indium resonance energy has been measured in AGOT graphite using the point source technique. Corrections to the data arising from the following factors were investigated: (a) source and foil size, (b) finite dimensions of medium, (c) higher and/or lower energy activations, and (d) foils are not scaler flux detectors. The age was determined to be 307.8 $\text{cm}^2 \pm 2.0\ \text{cm}^2$ and the fourth and sixth moments were $6.577 \times 10^6\ \text{cm}^4$ and $3.843 \times 10^{10}\ \text{cm}^6$, respectively. These compare favorably with the values of 307.4 cm^2, $6.590 \times 10^6\ \text{cm}^4$, and $4.006 \times 10^{10}\ \text{cm}^6$ obtained by Monte Carlo calculations.

I. INTRODUCTION

A new measurement of the age of fission neutrons to indium resonance in AGOT graphite has been made using the point source technique. Of the four previous measurements,[1,2,3,4] only the original Fermi measurement used the point source method; however, the source was a 293-gm cube of natural uranium, so that near it, the point source approximation would not be valid. The three other measurements used the plane source technique which requires a calculated finite source size correction[5] which has been open to some criticism.

None of the previous measurements give results which are in agreement with either moments calculations[6] or the Monte Carlo technique[7,8] for the determination of the age. The measurements give a consistently higher value for the age than calculations, and vary from approximately 6 to 30 cm^2 above the theoretical value. The average value of the two most acceptable measurements[2,4] is 7.6 cm^2 high and even this lies outside the limits of errors assigned to both the theory and experiment. In view of these facts, it was felt that an additional measurement would be of considerable value. Since the point source technique gave adequate neutron intensities, it was deemed the more desirable experiment to perform in order to minimize corrections.

II. EXPERIMENTAL PROGRAM

The present measurements were made in two graphite assemblies having average diameters of 5 and 7 ft, each being 8 ft high. The two assembly sizes were studied in order to investigate the effects of epithermal leakage from the finite sized assemblies. The graphite was AGOT grade and cast in the form of 4-ft high hexagonal logs with the distance across the flats being 4 in. The center log was machined to accept a cylindrical graphite foil holder. The stacking of these logs resulted in a 12-sided figure with an irregular boundary that was filled in by the judicious placement of half area logs. The larger assembly was made by adding additional graphite to the existing smaller assembly so that the major inventory of graphite was constant for the two assemblies. The density of the assemblies was determined by weighing all graphite used and by accurately determining the overall dimensions of the as-built assemblies. The resulting density was

$$\rho = 1.697 \pm 0.004 \text{ g/cm}^3 \quad .$$

The assemblies were centered on a 5-ft diameter, cylindrical, graphite thermal column which extended 3-1/2 ft above the core of a 2-kw water-boiler reactor. Figure 1 shows a cutaway view of the reactor, thermal column, and graphite assembly. The thermal flux at the top of the thermal column was $\sim 10^5$ neutrons/cm^2-sec-watt so that maximum fluxes of the order of 2×10^8 neutrons/cm^2-sec were available. For the foils used in these measurements, a cadmium ratio of 375 was measured at the center of the boundary between thermal column and graphite assembly.

The fission sources were 4-mil-thick foils (192.9 mg/cm^2) of uranium enriched to 93.2% U^{235} by weight. The diameters of the two source sizes used were 3-1/2 in. and 1 in. The two sources were used to investigate the effects of finite source size. Each was covered on the top side with 20-mil Cd disk. This served to provide a black sink for thermal neutrons which would otherwise be transmitted through the plate. A varying fraction of these would then be reflected back to the source, depending on how close the nearest cadmium covered foil was placed, thereby changing the production rate of fission neutrons. The sources were located on the axis of each of the graphite assemblies. In

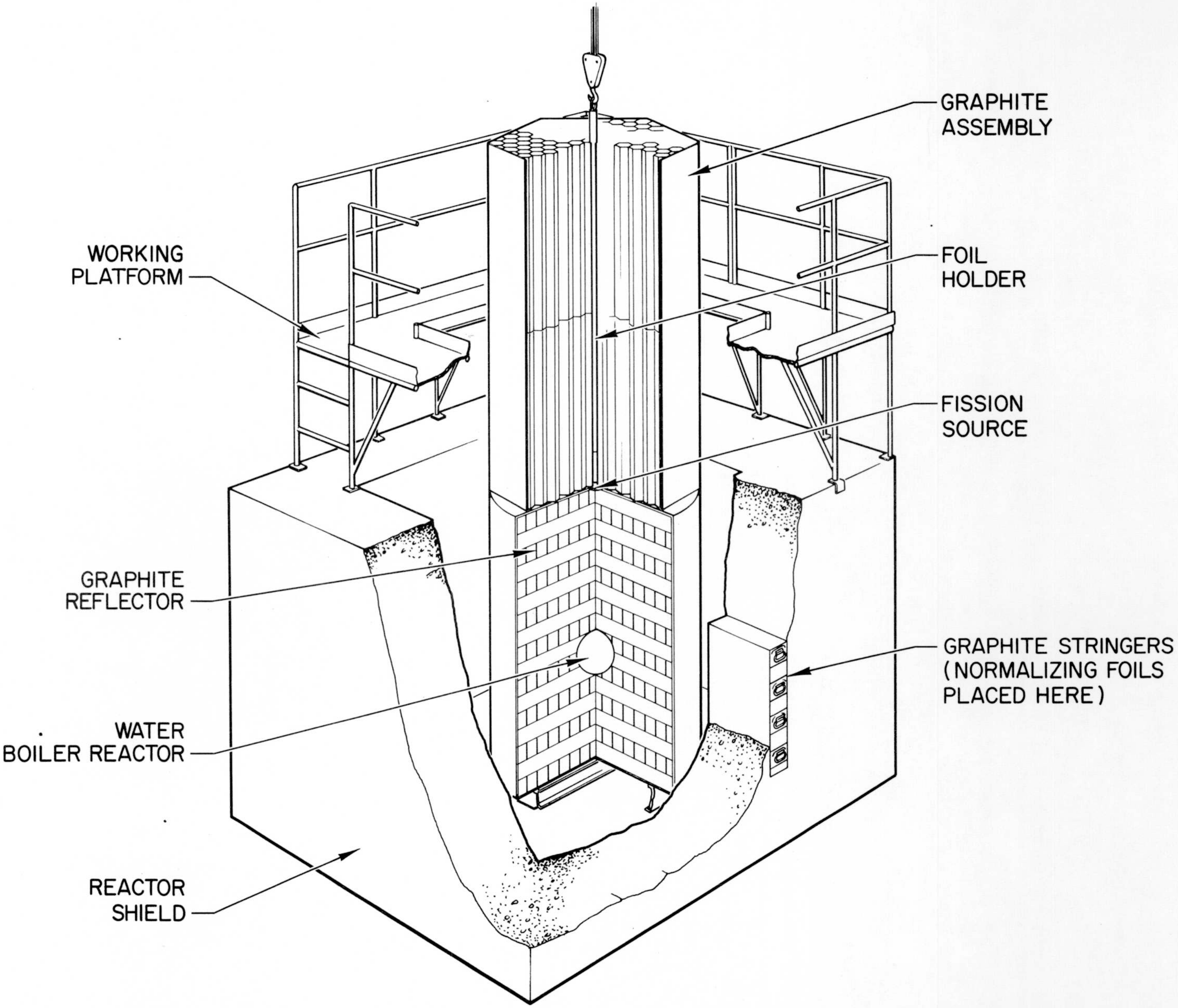

Figure 1. Experimental Arrangement for Age Measurement in Graphite

order to obtain adequate source-to-background ratios, two source locations were used. The large source was located at the bottom face of the graphite assembly. When the small source was used, it was necessary to elevate it 1 ft in the assembly in order to decrease the epithermal background from the reactor. This was possible since the slowing down distribution of epithermals falls off more rapidly than does the diffusion distribution of the thermal neutrons required for fission plate activation. Since the thermal column is also made of graphite, no problems arise due to change of medium in the vicinity of the fission source.

The detector foils were an alloy of 40% indium and 60% tin. The foils were 1 cm square and 5 mil thick. This results in an indium thickness of $\sim 37 \text{ mg/cm}^2$. The foils were contained in cadmium boxes having a thickness of 40 mil. Recent measurements made at this laboratory[9] have determined this thickness adequate to prevent thermal activation of the foils. The foils were placed at least 10 cm apart along the axis of the assembly and no more than 12 foils were exposed at a time. The plane of each foil was placed parallel to the plane of the fission source.

The relative activities of the foils were determined by gross β counting on both front and back faces using the 54-min activity of indium 116. Scintillation counters were used and consisted of 2 mm thick anthracene crystals as detectors mounted on RCA 6655A photomultiplier tubes. Three counting channels were used to obtain adequate counting statistics. Each foil was counted on all three channels to ensure proper channel normalization.

Foils located near the source were also checked for other possible activities. One of these was the 49-day activity from the $\text{In}^{113}(n,\gamma)\text{In}^{114}$ reaction. Since the In^{113} isotope is present to only 4.2%, this activity was obtained only in positions of high thermal neutron flux. The other activity was a 4.5 hr one induced by the reaction $\text{In}^{115}(n,n)\text{In}^{115*}$ which occurred for high energy neutrons close to the fission source. It was found that only foils within 5 cm were affected by these reactions. In addition to correcting the counting rate of the foils for this activity, it was necessary to ensure that these foils were not used in the following runs.

---

*Activated

Normalization between reactor runs was carried out by placing four cadmium-covered indium-tin foils in one of the graphite stringers located in the reactor shielding (see Figure 1). This location was such that the foil activation is not influenced by the presence or absence of the fission source. Exposures of a given type (with or without fission source) were always made with two foils in overlapping positions to serve as a check that the normalizing foils were adequate. Very good agreement was obtained.

III. EXPERIMENTAL RESULTS

The data obtained from the two assemblies, Tables I and II, may be seen in Figures 2 and 3. In each case, two curves are shown. One of these represents the background indium resonance activity obtained with fission source removed; however, the Cd cover plate for the source was not removed. The other curve gives the indium resonance activity both from background and fission source neutrons. The pair of points associated with each curve at a given position are obtained from counting the front and back sides of the foils. The ratio of the front-to-backside counts varies from about 1.02 for foils near the source to ~1.08 for foils far from the source. The activation from the fission plate alone is obtained by the subtraction of the background activity and may be seen in Figures 4 and 5.

Before these data were used for final calculation of the age, the following set of corrections were investigated.

A. SOURCE PERTURBATIONS

The source perturbations arise from several effects. The first of these is the fact that the source is not a true point source but actually a thin disk of finite dimensions. A second effect is a displacement of the graphite medium by the finite-sized fission plate. A third effect is the absorption and scattering of neutrons by the source. The result of these effects due to lateral dimensions of the source was investigated by using a second source of smaller diameter. This smaller source had 0.0816 times the area of the 3-1/2-in diameter plate. This smaller size limited the region of useful data to 76 cm. Over this entire region the ratios of the activations for the large and small fission plates were constant with a random variation of ~3%. The age calculated from the small source yielded an age that differed from the results obtained with large source by only 0.3 cm^2 which is within the uncertainties of the measurements.*

Correction for the finite source size and detector foil size may also be made mathematically, and the derivation of such expressions has been presented for

---

*With the small source an anomalous data point was obtained 0.254 cm from the fission source. The foil activity at this position was considerably higher than the 5.32 cm activity and was found to be more predominant for the higher energy activation as determined by foil covered activities. An age was calculated using this as a legitimate data point and it was found to change the age by only 0.1 cm2.

TABLE I

SATURATED FOIL ACTIVITIES IN THE 5-FT ASSEMBLY WITH 3.5-IN. FISSION PLATE

Distance (cm)	Front Side			Back Side		
	Fission Source Plus Background	Background*	Fission Source Only	Fission Source Plus Background	Background*	Fission Source Only
0.24	2,588,316	674,444	1,913,872	2,560,760	627,945	1,932,815
5.32	2,263,195	420,929	1,842,266	2,214,973	387,200	1,827,773
10.40	1,943,760	258,088	1,685,672	1,892,420	239,300	1,653,120
15.48	1,600,320	158,374	1,441,946	1,545,774	146,977	1,398,797
20.56	1,263,670	98,637	1,165,033	1,214,955	90,968	1,123,987
25.64	944,970	61,759	833,211	905,219	58,181	847,038
30.72	684,978	39,514	645,464	652,543	36,946	615,597
35.80	476,673	25,140	451,533	448,674	23,755	424,919
40.88	318,367	15,505	302,862	299,462	15,002	284,460
45.96	205,972	10,448	195,524	192,723	10,016	182,707
51.04	130,114	6,910	123,204	120,341	6,476	113,865
56.12	80,143	4,745	75,398	74,821	4,460	70,361
61.20	48,178	3,090	45,088	44,854	2,923	41,931
66.28	29,357	2,122	27,235	26,951	1,972	24,979
71.36	17,180	1,400	15,780	15,898	1,380	14,518
76.44	9,977	922	8,985	9,355	963	8,392
81.52	6,253	701	5,552	5,809	672	5,137
86.60	3,571	506	3,065	3,363	485	2,878
91.68	2,129	350	1,779	1,922	345	1,577
96.76	1,315	250	1,065	1,195	250	945
101.84	764	181	583	697	181	516
106.92	465	135	330	425	135	290
112.00	282	99	183	275	99	176
117.08	188	75	113	210	75	135

*Background for the 5- and 7-ft assemblies was identical to within statistics. To obtain the best curve for distances far from the thermal column where neutron intensity was a minimum, data from all runs were averaged to obtain a single background curve.

TABLE II

SATURATED FOIL ACTIVITIES IN THE 7-FT ASSEMBLY WITH 3.5-IN. FISSION PLATE

Distance (cm)	Front Side			Back Side		
	Fission Source Plus Background	Background*	Fission Source Only	Fission Source Plus Background	Background*	Fission Source Only
0.24	2,566,399	674,444	1,909,493	2,537,438	627,945	1,891,955
5.32	2,282,846	420,929	1,861,917	2,229,475	387,200	1,842,275
10.40	1,945,681	258,088	1,687,593	1,889,743	239,300	1,650,443
15.48	1,603,095	158,374	1,444,721	1,560,135	146,977	1,413,158
20.56	1,261,668	98,637	1,163,031	1,214,367	90,968	1,123,399
25.64	952,161	61,759	890,402	913,264	58,181	855,083
30.72	690,285	39,514	650,771	652,738	36,946	615,792
35.80	480,722	25,140	455,582	451,833	23,755	428,078
40.88	317,897	15,505	302,392	296,104	15,002	281,102
45.96	206,822	10,448	196,374	192,157	10,016	182,141
51.04	129,972	6,910	123,062	120,990	6,476	114,514
56.12	79,758	4,745	75,013	74,125	4,460	69,665
61.20	48,138	3,090	45,165	44,746	2,923	41,978
66.28	28,967	2,122	27,149	26,636	1,972	24,696
71.36	17,188	1,400	16,004	16,251	1,380	14,844
76.44	10,058	922	9,163	9,324	963	8,334
81.52	6,117	701	5,416	5,417	672	4,745
86.60	3,453	506	2,947	3,203	485	2,718
91.68	2,052	350	1,702	1,896	345	1,551
96.76	1,219	250	969	1,150	250	900
101.84	738	181	557	672	181	491
106.92	450	135	315	432	135	297
112.00	280	99	181	270	99	171
117.08	813	75	108	177	75	102

*Background for the 5- and 7-ft assemblies was identical to within statistics. To obtain the best curve for distances far from the thermal column where neutron intensity was a minimum, data from all runs were averaged to obtain a single background curve.

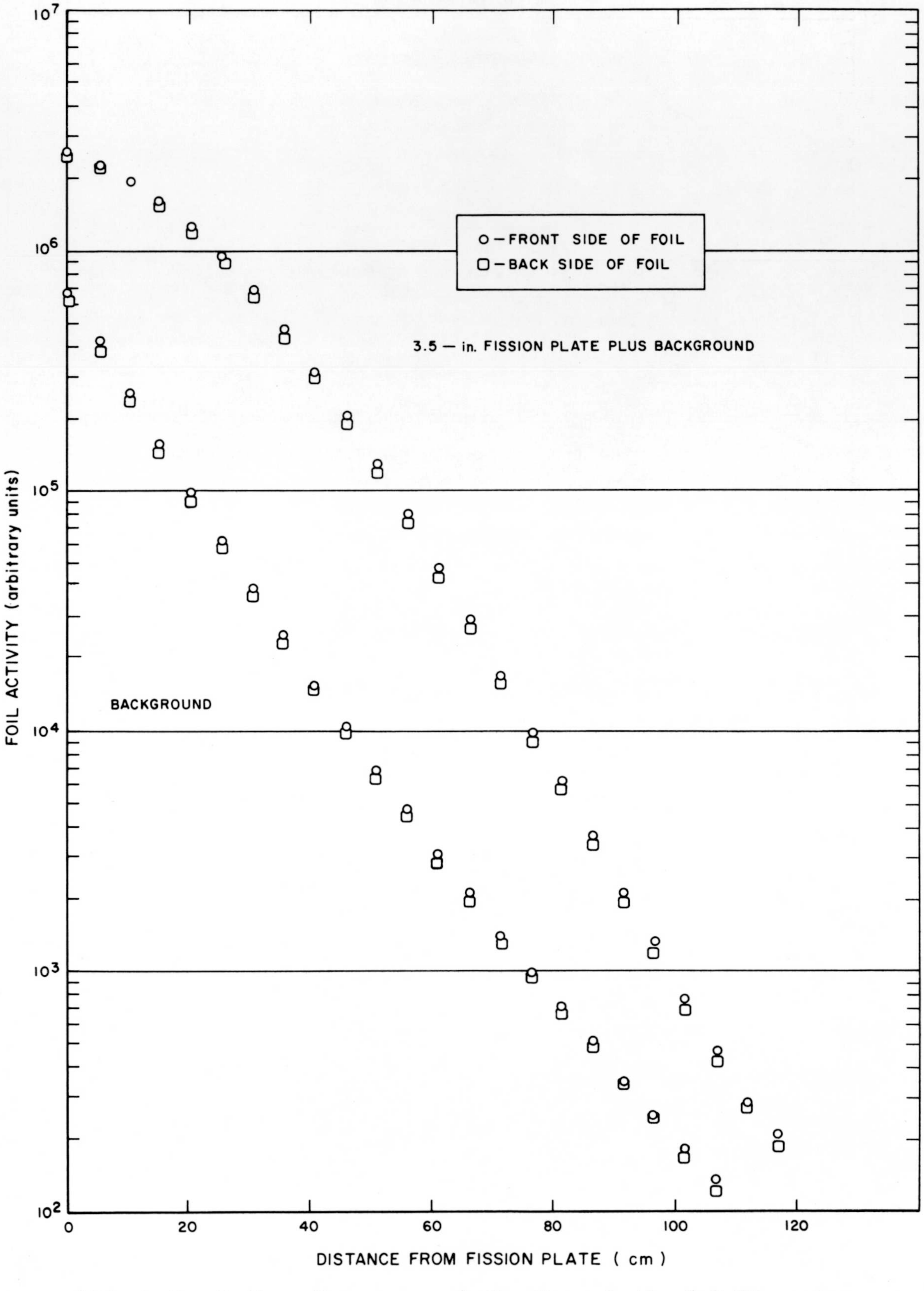

Figure 2. Indium Resonance Activations in the 5-ft Diameter Graphite Assembly

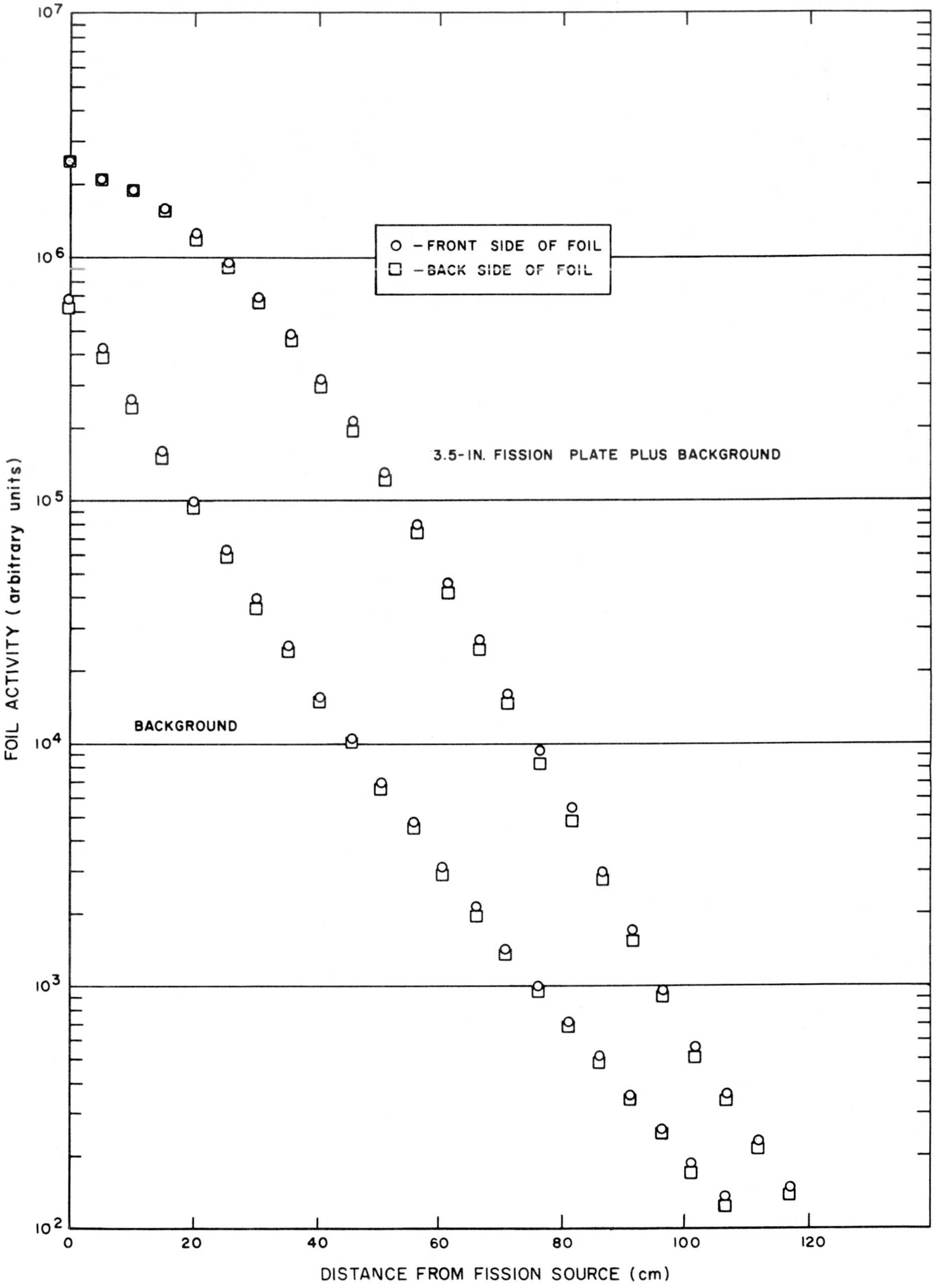

Figure 3. Indium Resonance Activations in the 7-ft Diameter Graphite Assembly

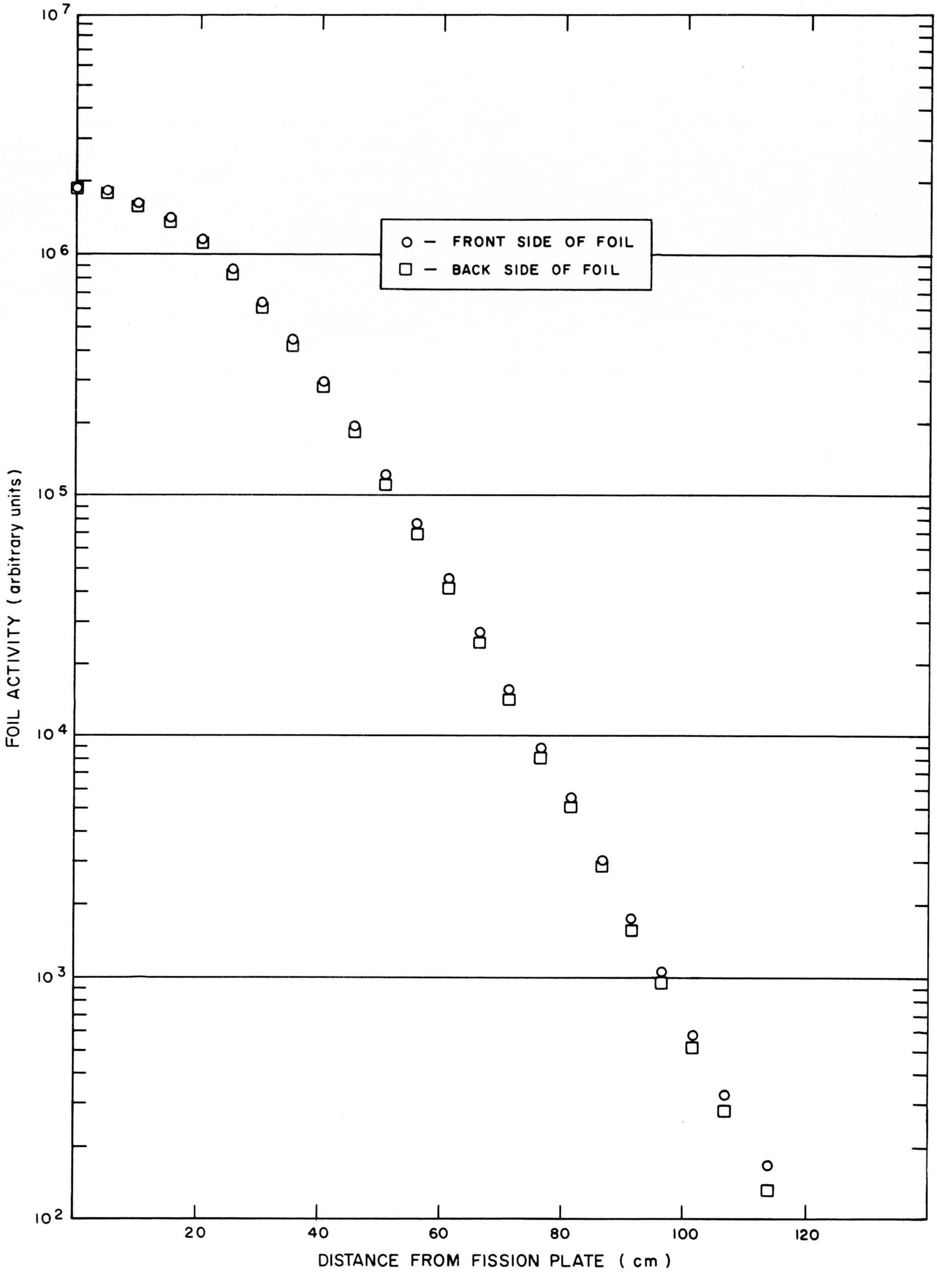

Figure 4. Indium Resonance Activation From 3.5-in. Fission Plate (5-ft Assembly)

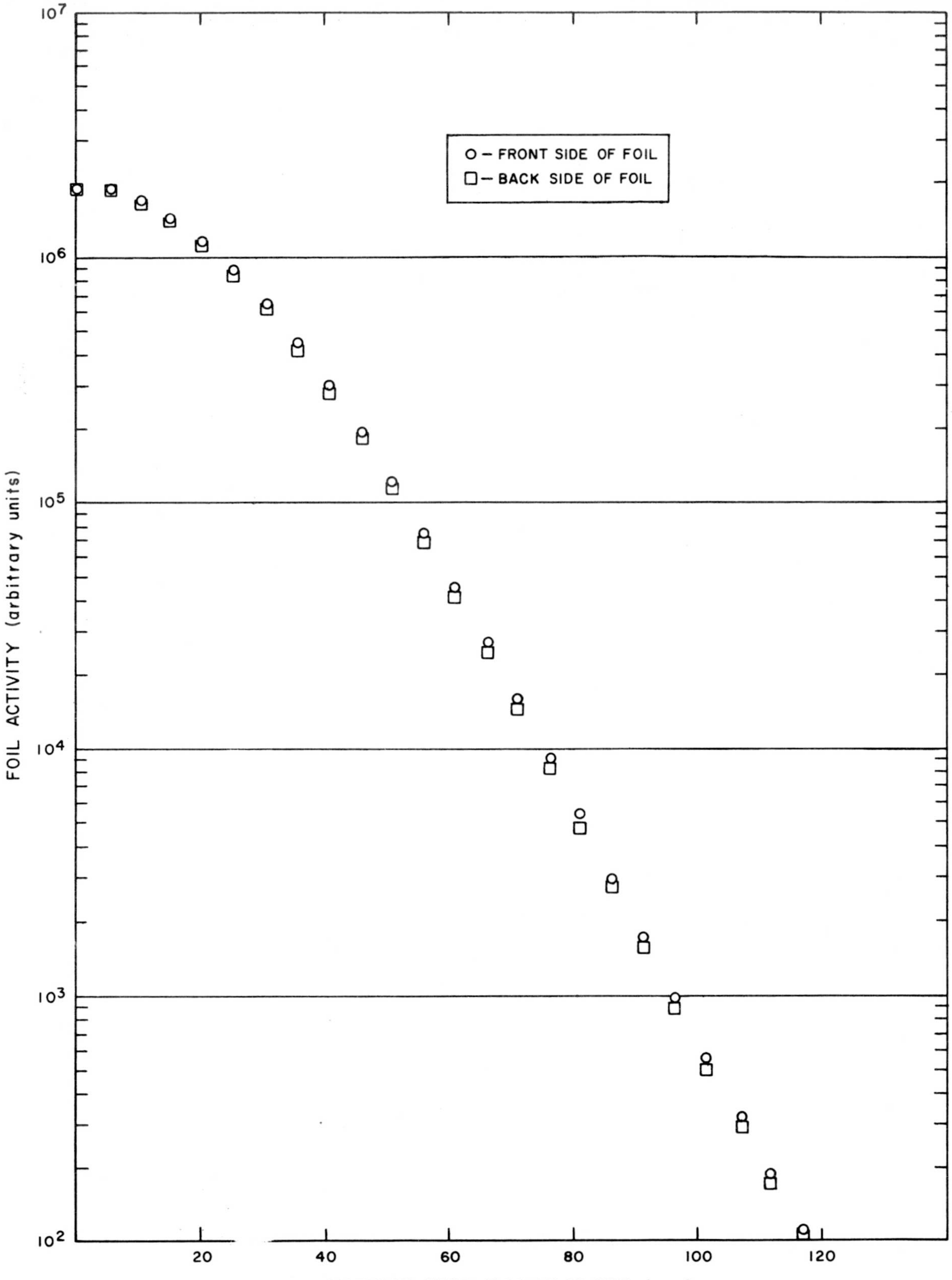

Figure 5. Indium Resonance Activation From 3.5-in. Fission Plate (7-ft Assembly)

general reference by Hill, Roberts, and Fitch.[10] It will suffice here to quote their results for a circular source of radius a' and rectangular detector of dimensions a and b as

$$A(r)_{\text{true}} = A(r)_{\text{measured}} - \frac{(a^2 + b^2) + 6a'^2}{24r_o} \frac{dA(r)}{dr} .$$

True activities were calculated using this expression where the derivative of the A(r) was approximated by

$$\frac{dA(r)}{dr} = - \frac{2r}{4\tau(E)} A(r)$$

and $\tau(E)$ was obtained from the slope of the experimental curve of foil activation vs r^2 at any point. The age as determined from these corrected activities increased by only 0.05 cm^2.

B. DETECTOR FOIL PERTURBATIONS

As in the case of the source, the foils and their cadmium boxes displace a certain amount of moderator. In addition, the possibility of shadowing exists. It was shown experimentally that with foils placed a minimum distance of 10 cm apart and a maximum of 12 foils/run, these effects become of negligible importance in graphite.

A problem does arise from the fact that it is not possible to uniquely determine the neutron energy at which foil activation occurs. Two competing effects existin addition to the 1.46 ev activation. One of these is the activation of the higher energy resonances, although the two large resonances immediately above the 1.46 at 3.8 ev and 8.6 ev do not lead to the 54-min activity.[11] The other is activation by neutrons between the cadmium cutoff and the 1.46 ev resonance. In order to investigate this problem, a series of measurements was made in which the detector foils were covered with indium as well as being placed in cadmium boxes. The indium covers were 5-mil thick foils of pure indium. The activities of the detector foils may be seen in Figure 6. These data were then used to determine an age for the foil-covered foils and was found to agree with

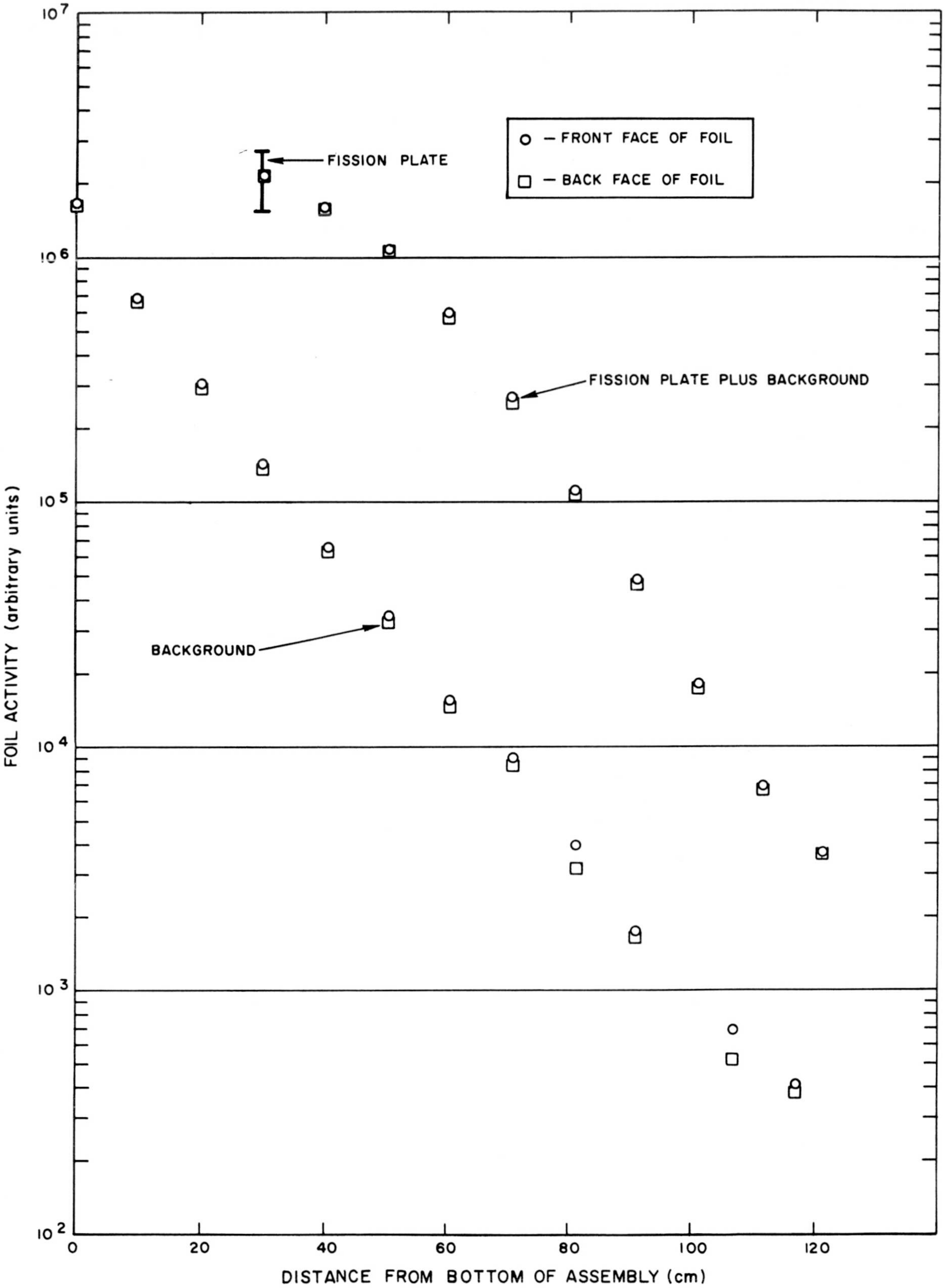

Figure 6. Indium Resonance Activation for Foil-Covered Foils

the standard values to within 0.2%. This is a strong indication that results are affected little by either the high energy activations or activation in the region from Cd cutoff to the 1.46 ev resonance.

C. FOILS ARE NOT FLUX DETECTORS

The ideal measurement would be one that measured the scaler flux at a given position. Foils measuring this flux would then have the same "front" and "back" age. The experimentally observed activations, however, are always affected by the angular distribution of the neutrons. This is true even for foils sufficiently thin to be transparent at the resonance energy since the neutrons must still travel varying path lengths through the cadmium covers. Since the foils were β counted, further effects occur due to their attenuation in the foil before reaching the detector. Amster and Gast[12] have investigated this angular sensitivity theoretically and have compared their results with measurements. They were unsuccessful in finding a reasonably thick tin-indium alloy adjusted so that the foil activation and β attenuation would compensate to give a resulting count rate proportional to the scaler flux. Doerner et al.,[13] have reported ratios of the second moments obtained in water from the front-side and back-side activities of indium foils for various thicknesses, and below 40 mg/cm^2 this ratio was less than 1.02. Foils of this thickness should serve as reasonably good flux detectors but are extremely difficult to handle experimentally.

The present measurement used foils which were not transparent to neutrons at the indium resonance energy. Since the flux becomes more nonisotropic at large distances from the source, this resulted in a front-to-backside foil activity ratio that varied from 1.02 to 1.08 for foils located near and far from the source, respectively. The ages determined from the separate front and backside activities varied by 4.0 cm^2. An appropriate age can be obtained, however, by averaging the front and back activities and then determining the age. This method eliminates the P_1 component of the Legendre expansion of the epicadmium flux. Measurements made with the foil planes, both parallel and perpendicular to the vertical axis of the assembly, showed that the epicadmium attenuation did not change as a function of their orientation.[9] This absence of change indicates a negligible effect from the Legendre components higher than P_1.

D. EPITHERMAL LEAKAGE FROM THE FINITE MEDIUM

The epithermal leakage from the finite sized assembly was investigated by the use of two assembly sizes. No effects of this leakage were observed, however, when data from the two assemblies were compared. The slight difference in ages obtained is in the opposite direction to be accounted for by this leakage, and is within the limits set by the experimental uncertainties of the two measurements. In view of this, the two measurements may be considered as independent determinations of the resonance energy flux distribution.

IV. CALCULATION OF THE AGE

Using the experimentally determined foil activations, the moments were calculated as follows:

$$M_n = \frac{\int_o^\infty r^n(r^2\varphi)dr}{\int_o^\infty (r^2\varphi)dr}$$

where the age = $1/6\ M_2$.

M_4 and M_6 were also calculated to allow a more sensitive comparison with theoretical calculations.

The integrals over the experimental points were obtained by two methods. The first of these fitted the $\ln(r^n\varphi)$ vs r curve to a 6th degree polynomial by means of least squares, and the integration then performed by Simpson's rule. The second method was to fit three data points at a time to a parabola, find the area under this curve, then move on, one point at a time, repeating this process over the whole curve. One must, of course, take into account all of the areas that are calculated twice. The results of the two methods are shown in Tables III and IV, where it can be seen that the ages agree to within 0.6 cm^2 and differences in the higher moments are of the order of 3 cm^2. Comparisons with data points indicate that the method of parabolas gives a somewhat better fit and has been accepted here as the preferred method.

Since the integrals extend to infinity, it was necessary to extrapolate the experimental curves. It is desirable to obtain some function of the foil activation such that its extrapolation is linear. This allows a more accurate determination over this region. Two possibilities were available. The first of these was the curve of the log of the foil activation as a function of distance from the fission source. Here the data were linear over the last seven or eight foil positions (see Figures 3 and 4). The other curve was that of the log of the product of foil activity multiplied by the square of the distance from the source plotted as a function of that distance. Again, the curve appeared linear over the same region (see Figures 7 and 8). Both curves were used, each with the linear region being machine fitted to a straight line by the method of least squares.

TABLE III

TABLE OF INTEGRALS USING PARABOLIC FIT
(arbitrary units)

n	$\int_0^{r_o} r^n(r^2\varphi)dr$	$\int_{r_o}^{\infty} r^n(r^2\varphi)dr$	$\int_0^{\infty} r^n(r^2\varphi)dr$
		5-ft Assembly	
0	4.786×10^{10} cm^2	0.003×10^{10} cm^2	4.789×10^{10} cm^2
2	7.829×10^{13} cm^4	0.053×10^{13} cm^4	7.882×10^{13} cm^4
4	2.416×10^{17} cm^6	0.091×10^{17} cm^6	2.507×10^{17} cm^6
6	1.149×10^{21} cm^8	0.163×10^{21} cm^8	1.312×10^{21} cm^8
		7-ft Assembly	
0	4.793×10^{10} cm^2	0.003×10^{10} cm^2	4.796×10^{10} cm^2
2	7.805×10^{13} cm^4	0.053×10^{13} cm^4	7.858×10^{13} cm^4
4	2.392×10^{17} cm^6	0.091×10^{17} cm^6	2.483×10^{17} cm^6
6	1.128×10^{21} cm^8	0.165×10^{21} cm^8	1.293×10^{21} cm^8

TABLE IV

MEASURED AGE AND HIGHER MOMENTS*

	Age and Higher Moments	Data Fitted by 6-Degree Polynomial 1	Data Fitted 3 Points at a Time by Parabola		Percent Determined by Extrapolation
			1	2	
5-ft Assembly	$\tau = M_2/6$ (cm^2)	308.0	308.6	308.3	0.605
	M_4(10^6 cm^4)	6.591	6.624	6.602	3.56
	M_6(10^{10} cm^6)	3.860	3.901	3.849	12.4
7-ft Assembly	$\tau = M_2/6$ (cm^2)	307.0	307.2	307.0	0.608
	M_4(10^6 cm^4)	6.533	6.552	6.530	3.62
	M_6(10^{10} cm^6)	3.806	3.837	3.787	12.7

*Corrected to a standard density of 1.60 gm/cm^3

1. Linear extrapolation of $r^2 \varphi$ vs r. 2. Linear extrapolation of φ vs r.

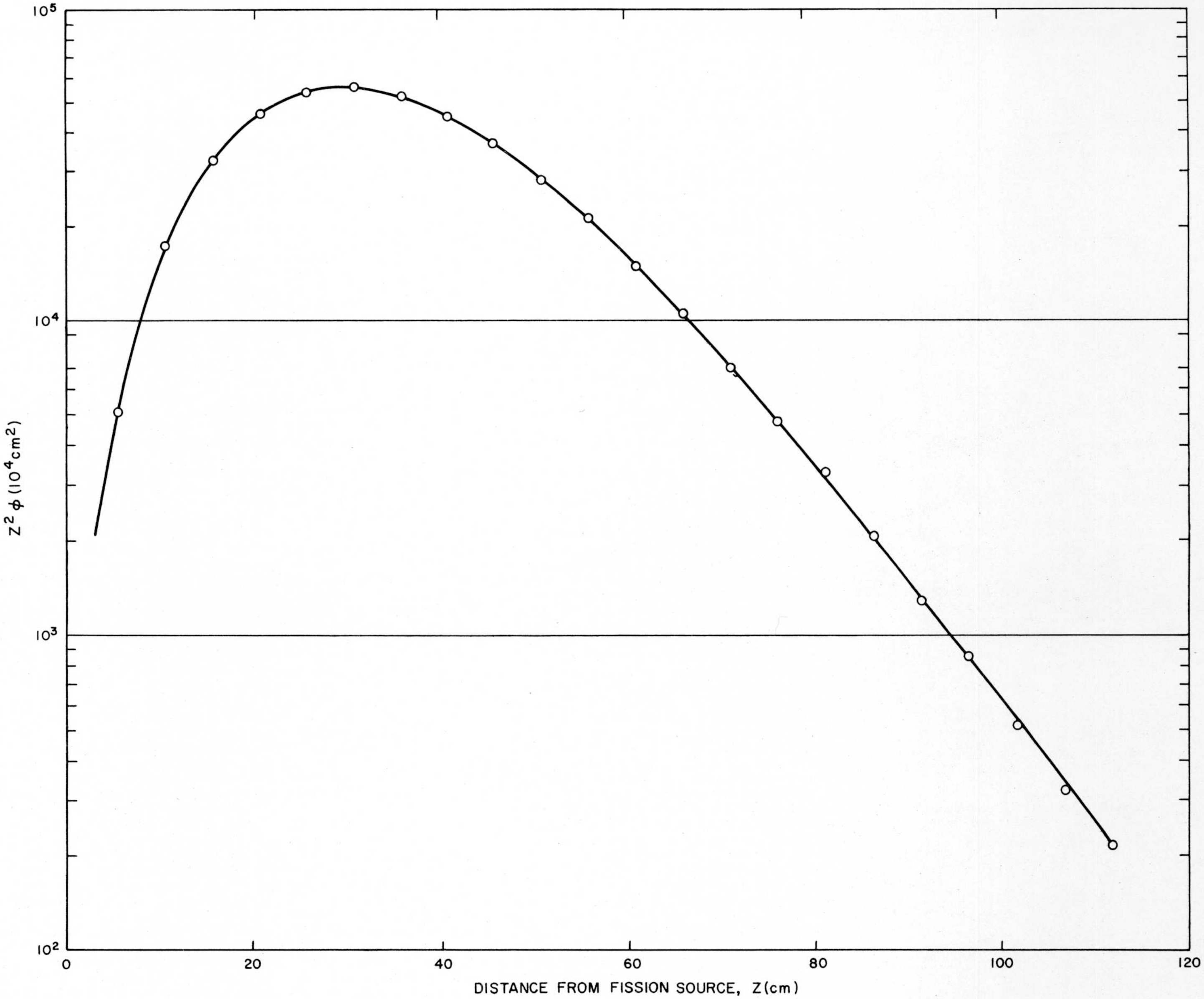

Figure 7. Distance Squared (Z^2) Times Indium Resonance Activation (5-ft Assembly)

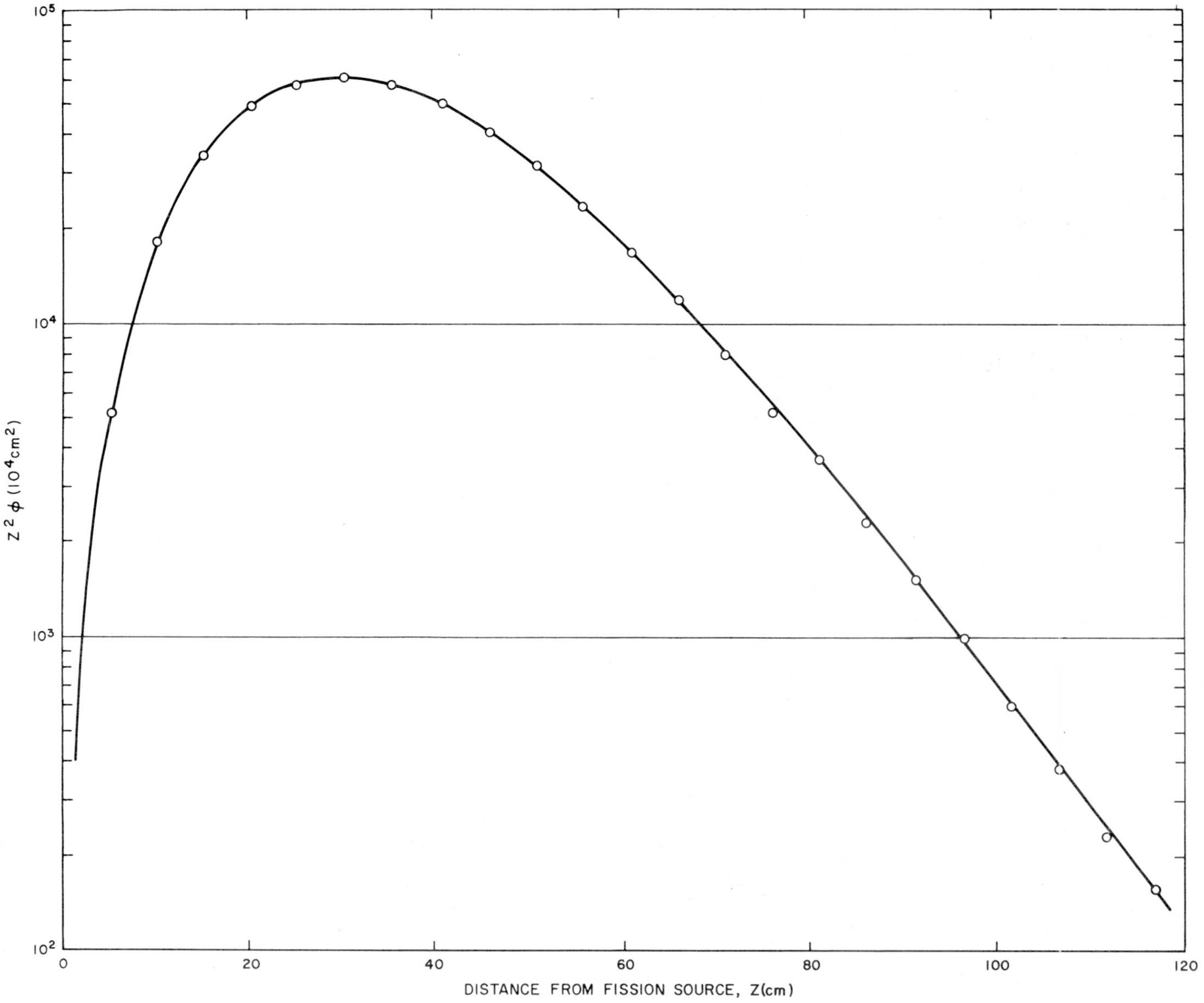

Figure 8. Distance Squared (Z^2) Times Indium Resonance Activation (7-ft Assembly)

The differences between the various moments were quite small, as may be seen by comparison of the figures in Table IV. The absolute accuracy of the extrapolated area is difficult to estimate but the good agreement between the two methods gives one reasonable confidence in the results.

In addition to the factors discussed under the set of corrections in Section III, there are other contributions to the uncertainty in the final value of the age. These may be summarized as follows:

a) The 0.24% uncertainty in the graphite density gives a variation of $\sim 1.5 \text{ cm}^2$ in the age. Variation in density between the 5- and 7-ft assembly within the 0.24% limit may, in part, account for the 1.4 cm^2 difference in age, measured in these assemblies.

b) Uncertainties due to counting statistics and foil positioning in both foil holder and counters give a maximum variation of $\pm 1.0 \text{ cm}^2$.

c) Uncertainties in the extrapolated portion of the flux distribution will give variations of the order of $\pm 0.4 \text{ cm}^2$ in the age.

The resulting uncertainty in the age is $\pm 2.0 \text{ cm}^2$.

V. COMPARISON WITH OTHER EXPERIMENTS AND THEORY

The final results of this measurement are listed in Table V along with other available experimental and theoretical values.

TABLE V

AGE IN GRAPHITE (density = 1.60 gm/cm^3)

Reference	1/6 M_2 (age) (cm^2)	M_4 (10^6 cm^4)	M_6 (10^{10} cm^6)
A. Present Work			
Experiment	307.8 ± 2.0	6.577	3.843
Theory[8]	307.4 ± 1.0	6.590 ± 0.06	4.01 ± 0.09
B. Experiment Reference			
1 (Fermi)	317.0		
2 (Hill)	310.6 ± 3.0	6.89	4.4
3 (Davey)	337.9		
4 (Hendrie)	312.6 ± 0.5	6.87	4.3
C. Theory Reference			
6 (Joanou)	305.0		
7 (Goldstein)	304.0 ± 3.0		

It can be seen that the present value disagrees with the only other point source measurement by Fermi et al., although no estimates of the error were given for this measurement. There were two apparent sources of error in this early measurement. One of these was the large (293 gm) "point" source and the other is the excessively thick (0.102 in.) cadmium boxes used. No other information is available as to detector size, assembly size, exact treatment of the data, and observed higher moments. It is, therefore, not possible to estimate the errors.

The present measurement agrees within the limits of error to the value obtained by Hill et al. Their measurements did, however, use large foil sizes (4 cm x 6.35 cm) and thick (0.135 in.) cadmium boxes. Detector interactions and/or perturbations near the source cannot be ruled out. Davey et al.,[3] also believe that an error was introduced in the Hill measurement by the use of smoothed curves in the integrations. These data were reanalyzed by Davey using the actual experimental points. This increased Hill's age by 4.6 cm^2 which would bring his value nearer that of Fermi.

The value of 312.6 cm^2 reported by Hendrie et al.,[4] is assigned an error of ±0.5 cm^2 due to counting statistics only. No estimate is made of the other uncertainties and data such as the graphite density uncertainty are not presented to enable this to be done. For this situation it is not possible to make a firm statement as to agreement or disagreement with the present measurement.

The value obtained by Davey[3] of 337.9 cm^2 at a density of 1.60 g/cm^3 disagrees strongly with all other measured values. Considerable effort was spent by them in attempting to resolve this discrepancy. The most obvious source of disagreement is the use of a planar distribution of natural uranium rods 0.9 in. in diameter. Davey points out that this measurement may be a preferred age for reactor calculations using such rods.

Three theoretical values are also listed, including the value to be presented in part II of this present work. These three theoretical values are in good agreement with one another and yield a weighted average of 306.1 cm^2. Although error limits are not given for Reference 6, a value of ±2 cm^2 is considered a reasonable limit for the calculational techniques. The average theoretical value differs from the present measurement by only 1.7 cm^2 and the difference is within the error limits assigned.

A more realistic measure of the agreement of theory and experiment lies in a comparison of the higher moments. It is this region that offers a more sensitive test of the problem. The results of Hill and Hendrie agree extremely well with each other in the fourth and sixth moments but differ considerably from the theoretical values. This close agreement between the two experiments may be an indication of the similarity between the two experimental methods and treatment of their data rather than a confirmation of the experimental results. The present measurement matches theory considerably better than the previous measurements, and yields differences of 0.2% for the fourth moment and ~4.0% for the sixth moment.

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