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**EXPONENTIAL PILE MEASUREMENTS IN
GRAPHITE-URANIUM LATTICES**

**By
E. D. Clayton**

June 1, 1954

**Hanford Atomic Products Operation
Richland, Washington**

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EXPONENTIAL PILE MEASUREMENTS IN GRAPHITE-URANIUM
LATTICES

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ABSTRACT

This paper gives the results from a series of exponential experiments involving thirty graphite-uranium lattices. In these measurements, the diameter of the slug was varied from 0.925" to 1.66", and measurements were also taken with one hollow slug (1.66" O.D., 0.81" I.D.). The lattice spacing was varied from 6-3/16" to 15". Both wet and dry lattice measurements were taken; that is, the lattices were measured with water and without water in the cooling annulus to determine the effect of the cooling water on the buckling or reactivity. The buckling values are given for the following slug sizes and lattice spacings.

<u>Slug Diameter (Inches)</u>		<u>Lattice Spacing (Inches)</u>
0.925	wet and dry	6-3/16, 7-1/2
1.175	wet and dry	6-3/16, 7-1/2
1.36	wet and dry	6-3/16, 7, 7-1/2, 8, 8-3/8
1.66	dry only	6-3/16, 7-1/2, 12-3/8, 15
1.66 O.D., 0.81 I.D.	wet and dry	6-3/16, 7-1/2, 12-3/8, 15

The lattice diffusion lengths, utilization in the moderator, utilization in uranium, and multiplication constant are also listed for those lattices in which these quantities were determined, which includes all of the above with the exception of the hollow slug and the 12-3/8" and 15" lattice spacings with the 1.66" solid slug. Calculated conversion ratios are given for all except the hollow slug size.

EXPONENTIAL PILE MEASUREMENTS IN GRAPHITE-URANIUM LATTICES

INTRODUCTION

Exponential experiments involving subcritical reactors are carried out for the express purpose of determining the various lattice constants, such as the material buckling, multiplication constant, utilization in graphite and process tube assembly, and the lattice diffusion length. The multiplication constant, as herein determined, is based upon a calculated value of the Fermi age, τ , of fast fission neutrons to thermal. The information obtained from these experiments is of considerable interest to those planning new piles as an aid in selection of an "optimum" lattice. These measurements also supplement the existing theory and/or serve as a basis for any improvement from the theoretical standpoint. At present, the theory does not always predict what is experimentally observed to be true; that is, in general the calculated lattice constants agree rather poorly with the experimentally determined values. This, of course, is the principal reason for the exponential experiments.

The question of the "optimum" lattice spacing for a given slug size depends on the objectives set forth. In general, these will be such as to define a lattice which will produce the greatest amount of plutonium, that is, one that will have a high conversion ratio while maintaining a material buckling at a value that will permit the construction of the present-sized piles, since any significant increase in physical dimensions presents engineering difficulties and possibly increased costs. Furthermore reactivity gain with the loss of cooling water should be kept as small as possible, from the safety standpoint.

An exponential pile with the 8-3/8" lattice spacing was measured first to give a reference point for other measurements and to serve as a check on the measurement techniques, since some of the constants of this lattice had been previously measured. In the following

exponential experiments, the lattice spacing has been varied from 6-3/16" to 15", and the slug size from 0.925" to 1.66" in diameter, including measurements with one hollow slug with 1.66" O.D. and 0.81" I.D. The measurements with the 1.36" diameter slug are the most extensive. The results for the other slug sizes are reported here for their somewhat limited but immediate value. Additional experiments are to be carried out with the above slug diameters. This paper describes the experimental procedure and gives the results of the measurements. This paper includes only the results of the lattice measurements taken by the exponential pile group as of October 1953. Various additional experiments relative to the above which were carried out by the exponential pile group simultaneously or along with the experiments listed here will be reported in separate documents to follow, as well as the results from the experiments since the above date.

EXPERIMENTAL PROCEDURES

1. Description of Exponential Piles

Buckling measurements were taken in exponential piles with the following lattice spacings: 6-3/16, 7, 7-1/2, 8, 8-3/8, 12-3/8, and 15 inches, where the 12-3/8 and 15 inch lattices were obtained from the 6-3/16 and 7-1/2 inch exponential piles by removing alternate uranium-filled process tubes and filling these vacant holes with graphite plugs. The physical dimensions of the piles are listed in detail in Appendix I. See Figure 1 for a picture of the 8-3/8" lattice exponential pile which is typical of those referred to in this report. All of the piles consisted of a graphite pedestal which was about 20 inches thick and a lattice region which was approximately an 8-foot cube. A cadmium sheet (~ 22 mil) was placed on the top of the piles and bottom of the graphite pedestals. Cadmium covers were also constructed for the four sides of the piles. Two of these shields are shown in Figure 1. The cadmium covers were used to reduce the effect of the back-scattering of neutrons into the piles from the floor and walls of the building in order to simplify interpretation of the measurements.

As each pile was built, the graphite bars were weighed and from this information the graphite density was calculated. The graphite density values for these different lattices are given in Appendix I.

The density of the uranium of which the slugs were composed was determined from the weights and dimensions of the individual slugs. The results of measurements with five different slug sizes are included in this report. The dimensions of the different slug sizes and other information concerning the various cell components, such as the aluminum process tube thickness, etc., are given in Appendix I.

The 1.36" diameter slug was canned in an aluminum jacket. These canned slugs were then placed into process tubes and inserted into the exponential pile. On account of the aluminum end caps on each canned slug

FIGURE 1
8-3/8 INCH LATTICE EXPONENTIAL PILE

a continuous uranium rod was not, in effect, in the pile. The length of each 1.36" diameter slug was about 4 inches and the end cap thickness about 0.2". The 8" long 0.925" diameter slug was canned in a tube 8 feet in length and 0.4" aluminum spacers were inserted between each slug before canning so as to simulate individually canned slugs with 0.2" thick end caps. The 1.175" diameter slug was canned in a manner similar to that of the 0.925" slug. In the case of the 1.66" diameter slug, no aluminum spacers were placed between the slugs. The 1.66" diameter slug is therefore the only case where the uranium may be considered to consist of a continuous rod in the pile. For the correct comparison of the measured buckling values, variations of this kind must be considered. In calculations with the above described slugs, it is necessary to calculate an equivalent, or effective, uranium density to account for the end caps or aluminum spacers between the slugs. To date there has been no experimental verification of the accuracy of this correction.

The quantity of water in the cooling annulus was determined by measurement for each process tube and slug size.

The inside diameter of the hole in the graphite moderator was 1.744 inches, which was designed to accommodate the Hanford standard size slug (1.36" diameter) and process tube. For those measurements with the smaller slug sizes and correspondingly smaller process tubes, graphite sleeves were inserted in the piles which reduced the process tube hole to the desired size. These sleeves were in 12-inch sections and of two wall thicknesses, ~ 0.11 " and ~ 0.25 ", for the 1.175" and 0.925" diameter slugs, respectively.

2. Methods of Neutron Detection

a) BF₃ Counters

Two sizes of BF₃ counters were used. One was about 4" in length with a 1/2" diameter and the second and smaller counter was 1-3/4" in length with a 5/16" diameter. These counters were mounted in graphite

bars which could be inserted into the measurement holes in the piles. Figure 2 is a picture of the 1/2" diameter BF_3 tube including the mounting in the graphite positioning bar. The 5/16" diameter BF_3 tube is identical to the 1/2" tube except for size. The active or sensitive length of the large counter was about 3-1/4" and that of the small counter about 1". These counters were filled to a pressure of 40 cm Hg with BF_3 enriched in boron 10 (enrichment greater than 97%). The total absorption cross sections of these counters were about 1 cm^2 and 0.1 cm^2 . They possessed good voltage plateaus of 3%/100 volts over a range of about 250 volts. Several different pulse amplifiers were used with these BF_3 counters. The Atomic Instrument 204 C linear amplifier will give satisfactory operation and this was used in a number of the measurements herein reported. For the more recent measurements, the Hanford P-12 D. C. Pulse Amplifier was used. This amplifier was designed and built by the Maintenance Sub-Section. The P-12 amplifier had a good dynamic range for linear operation, and was much simpler in construction than the Atomic Instrument amplifier. The P-12 amplifier proved to be very satisfactory in operation with a minimum of maintenance required. Potter scalers were used throughout for registering the pulses.

b) Foils

Gold foils 2-1/2" x 1" of two different thicknesses were used in several measurements. The thicknesses were 227.5 mg/cm^2 and 297.6 mg/cm^2 . These foils were exposed flat in the pile and then rolled and placed in a foil holder which was then inserted over a thin-walled G-M tube and the activity measured.

Indium foils which were 2-1/2" x 1" and 2.56" x 1" were also used. The thickness of these foils was 110 mg/cm^2 . Some of these foils were exposed flat and then rolled and counted as above. Others, which were mounted permanently in cylindrical graphite holders, were exposed in this geometry in the pile. The foils were then placed on the G-M tubes without removal from the graphite holders, and their activity measured. See Figures 3 and 4 for photographs of these various mountings.

FIGURE 2

1/2 INCH DIAMETER BF₃ TUBE WITH MOUNTING BAR

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FIGURE 3
FLAT FOIL HOLDER FOR EXPOSURE OF FOILS IN FLAT GEOMETRY

FIGURE 4
CYLINDRICALLY MOUNTED IN FOIL HOLDER ARRANGEMENT

c) Fission Chamber

A small fission chamber 1-3/4" x 5/16" in diameter containing 12 mg of uranium (95.7% ^{235}U) and filled with argon was employed for several measurements. The thickness of the ^{235}U on the platinum foil was 2.03 mg/cm². As a consequence of the thick layer of ^{235}U , this counter possessed a rather steep discriminator curve. The counting rate with the amplification and recording system used for this chamber was also only about one-fifth that of the smallest BF_3 counter previously described when placed in the same neutron flux. Because of the high amplification required for the small pulses from the chamber (of the order 500 μV), line noise difficulties were also encountered. Due to the above mentioned problems, the fission chamber was not as reliable or desirable to use as the BF_3 counters.

3. Instrumentation

a) Standardization

The Hanford standard pile⁽¹⁾ was used for standardization of the counters. Counter factors for the BF_3 counters were obtained by positioning the BF_3 tube on the axis of the standard pile. Fifteen one-minute counts were taken and checked for proper distribution by application of the "Chi-squared" test. The average of the counts was used to calculate the counter factor in terms of the neutron flux at that position. A Ra-Be neutron source positioned in the standard pile provided a constant neutron flux at the test hole position where the BF_3 counter was placed.

The standardization of the G-M tubes was accomplished by the exposure of a set of three cylindrically mounted indium foils in the standard pile and then counting their activity. All three foils were counted on each G-M tube and the daily counter factor for each tube was then obtained by the average saturated activity from the three foils. An average counter factor was used in the calculations, which was the average of the five most recent daily counter factors.

(1) Davenport, Lynn, Pound, Hanford Standard Pile, HW-21793.

The counter factors for indium foils did not apply when gold foils were used. This was probably due to different sensitivities of the G-M tubes to the radiation from the gold and indium foils. When gold foils were exposed, data from each counter were considered separately, since gold foil standardization similar to that of indium becomes too lengthy, due to the half life of gold. Uranium glass standards, giving about 5000 c/m, were used for applying the "Chi-squared" tests on the G-M tubes.

b) Neutron Sources

Four 1/2 gram Ra-Be neutron sources were used to drive the piles. Each source was composed of two 1/4 gram Ra-Be cylindrical capsules 16 mm diameter and 9 mm in thickness, which were placed in small aluminum containers designed to facilitate handling by mechanical fingers. The total neutron emission of each source was about 6.6×10^6 neutrons/sec. The relative strength of the neutron sources were: #1 = 1.008, #2 = 1.000, #4 = 1.008, and #5 = 1.000. The sources were paired when placed in the piles, #1 with #4, and #2 with #5, since matched sources were preferred from the standpoint of the data analysis. Source #3 (relative strength) = 1.005 was used to supply a constant neutron flux in the standard pile.

c) Automatic Traverse Mechanism

In an effort to establish the extrapolation length and hence the effective size of a pile, it is necessary to take horizontal traverses of the thermal neutron distribution across the pile. It is those measured points near the surface of the pile which are most effective in this determination. At these points, however, the neutron density falls off and rather long time-consuming counts are required to obtain adequate counting statistics. In order to save time, an automatic traverse mechanism was designed and built which enabled these traverses to be taken during the evening and at other times when normally, other measurements could not be made. This device is briefly described below. (See Figure 5). The

FIGURE 5
AUTOMATIC HORIZONTAL TRAVERSE MECHANISM

essential parts of the traverse gear included a six-decade Potter scaler with provision for pre-set counts, a printing interval timer, and a positioning device with associated control switches. The graphite bar in which the BF_3 tube was mounted was pinned to the end of a positioning bar where the count positions could be pre-set by spacing control pins along the positioning bar, which would close microswitches, which in turn would control the positioning motor. The number of counts at any position was preselected and the counting time required to obtain the preselected number of counts then printed on a tape. The Potter scaler and timer would then reset for the next count. The number of counting intervals at each position could also be varied. The BF_3 counter was normally set to make the traverse into the center of the pile and then reverse and repeat the traverse back to the surface. The counting rate at each position could then be determined from the time record and the preselected count.

THEORY

1. Buckling Determination

The treatment of the exponential pile is similar to that of the sigma or standard pile,⁽²⁾ since the equations for the neutron density are formally identical. For a homogeneous pile with a multiplication constant near unity, the pile equation is

$$\nabla^2 n + Bn = 0$$

$$B \approx \frac{k - 1}{L^2 + k \tau}$$

A schematic diagram is given below showing the source placement in a typical rectangular prism pile as used in the measurements.

(2) Duvall, G. E., Distribution of Thermal Neutrons in Exponential and Sigma Piles, HW-28268.

With four sources placed symmetrically in a diamond array at $(\pm \frac{a}{4}, 0)$ and $(0, \pm \frac{b}{4})$ as indicated in the diagram, the solution for the neutron density may be written^{(2), (3)}

$$(1) n \sim \sum_{l, m \text{ odd}} b_{l, m} \left(\cos \frac{l \pi}{4} + \cos \frac{m \pi}{4} \right) \left(\cos \frac{l \pi x}{a} \cos \frac{m \pi y}{b} \right) \sinh \frac{z'}{b_{l, m}}$$

$$(e^{-z/b_{l, m}}) \left\{ \frac{1 - e^{-2(a_3 - z)/b_{l, m}}}{1 - e^{-2a_3/b_{l, m}}} \right\}$$

z' is the thickness of the graphite pedestal base. In expression (1), the origin is chosen as the lower surface of the graphite pedestal base and, for simplification, the graphite base is considered to have the same relaxation length as the lattice. This expression is valid for values of $z > z'$, and at distances of measurement far enough from the source plane

(2) loc. cit.

(3) Wallace, LeCaine, Elementary Approximations in the Theory of Neutron Diffusion, MT-12.

so that the contribution to nascent thermal neutrons due to slowing down of fast neutrons from the sources is negligible, since, in the derivation, the sources are considered to be point sources of thermal neutrons. The effective widths of the pile are designated by a, and b. Four sources were used primarily for two reasons: to build the flux up to a satisfactory level for measurement and to simplify the calculations, since, with four matched sources placed as indicated, the 1, 3 and 1, 5 coefficients vanish everywhere in a rectangular-based pile.

In the analysis of the data the origin was chosen as the source plane and measurements were expressed in terms of the distance above the source plane. With this consideration, the equation for the neutron density may be written as:

$$(2) n \sim \sum_{l, m \text{ odd}} \frac{A_{l, m} b_{l, m}}{1 + e^{\frac{-2Z}{b_{l, m}}}} \left(\cos \frac{l\pi}{4} + \cos \frac{m\pi}{4} \right) (e^{-z/b_{l, m}}) (1 - e^{\frac{-2(Z-z)}{b_{l, m}}})$$

since measurements were taken at $x = y = 0$.

$$A_{l, m} \sim \frac{1}{1 + \coth \frac{z}{b_{l, m}}}$$

$$\frac{1}{b_{l, m}^2} = \left(\frac{l^2 - 1}{a^2} \right) \pi^2 + \frac{(m^2 - 1)}{b^2} \pi^2 + \frac{1}{b_{ll}^2}$$

By factoring and rewriting, the equation may be put in the form:

$$(3) \quad n \cdot C_e C_h \sim A_{11} b_{11} e^{-z/b_{11}}$$

where $C_e \approx \left\{ 1 - e^{-2\frac{(Z-z)}{b_{11}}} \right\}^{-1}$ is commonly referred to as the end correction. It simply insures that the boundary condition, $n = 0$, at the top of the pile, is satisfied.

$$\text{Further, } C_h \approx \frac{A_{11} b_{11} e^{-z/b_{11}}}{A_{11} b_{11} e^{-z/b_{11}} + A_{17} b_{17} e^{-z/b_{17}} + A_{71} b_{71} e^{-z/b_{71}} + A_{19} b_{19} e^{-z/b_{19}} + A_{91} b_{91} e^{-z/b_{91}} - A_{33} b_{33} e^{-z/b_{33}} - A_{35} b_{35} e^{-z/b_{35}} - A_{53} b_{53} e^{-z/b_{53}} - A_{55} b_{55} e^{-z/b_{55}}}$$

and C_h is called the harmonic correction and gives a measure of the amount by which the neutron density deviates from a pure cosine-cosine distribution across the pile. The buckling is related to b_{11} by the following expression

$$\text{Material Buckling} = \frac{\pi^2}{a^2} + \frac{\pi^2}{b^2} - \frac{1}{b_{11}^2}$$

The quantity b_{11} (relaxation length of the 1,1 harmonics) is determined from measurement. To do this, the usual method is to calculate an approximate value of b_{11} from (3) under the assumption that $C_e C_h = 1$, which will be nearly true if measured values of the relative neutron density are chosen which are far from both the end of the pile and the source plane (values in the center region of the pile). The harmonic and end corrections are then calculated with this value of b_{11} . A least squares analysis is then made to $\ln(nXC_e C_h) = -z/b_{11}$, where n is the measured value of the neutron density at height z . A new value of b_{11} is then obtained. If this value of b_{11} does not agree within a per cent or less of the input b_{11} for the initial

set of harmonic and end corrections, the new b_{11} is used and a new set of corrections calculated with a new least squares analysis. This process is repeated until the input b_{11} is approximately equal to the value found from the least squares analysis. The above method is essentially one of trial and error, the correct value for the relaxation length being obtained when equation (3) is satisfied. Since, however, the harmonic corrections are a slowly varying function of b_{11} it is usually not necessary to repeat the process more than once. The measurement positions are also chosen so that the harmonic and end corrections will not be too large (less than 30%). Because the buckling is the difference of terms of nearly the same size, a small change in the value of either b_{11} or the effective widths significantly affects the value of the buckling. Figure 6 is a plot of the buckling versus b_{11} and Figure 7 is a plot of the buckling versus the width for an 8-foot square pile. From these plots, it is apparent that both b_{11} and $\underline{a}$ must be determined to within small limits of uncertainty. For example, for this 8-foot square pile, a difference of one inch in the effective size of the pile ($\sim 1\%$) could result in a 10% change in the value of the buckling.

2. Effective Pile Size

It is seen from Figure 7 that the buckling depends rather critically upon the effective size of the pile. The flux variation across a pile along the $y = 0$ axis may be written from equation (2) as

$$(4) \quad n \sim A \cos \frac{\pi x}{a} + B \cos \frac{3\pi x}{a} + C \cos \frac{5\pi x}{a} + \dots +$$

Other terms in the series may be neglected. The effective size, $\underline{a}$, of the pile is determined from a horizontal traverse in which a least-squares fit of the data is made to the above equation. The values of A, B, and C are determined for different values of the effective size $\underline{a}$. That value of $\underline{a}$ is chosen as best which produces the smallest sum of the deviations squared from the experimental points.

FIGURE 6

FIGURE 7

From equation (2), it may be shown that for our source distribution the values of A, B, and C are also proportional to the following

$$A \sim A_{1,1} b_{1,1} e^{-z/b_{1,1}} + A_{7,1} b_{7,1} e^{-z/b_{7,1}} + \dots +$$

$$B \sim -A_{3,3} b_{3,3} e^{-z/b_{3,3}} - A_{5,3} b_{5,3} e^{-z/b_{5,3}} + \dots +$$

$$C \sim -A_{3,5} b_{3,5} e^{-z/b_{3,5}} - A_{5,5} b_{5,5} e^{-z/b_{5,5}} + \dots +$$

Now from these relations, the ratios of A/B and A/C may be found and B and C expressed in terms of A. The equation is then written as

$$n = A \cos \frac{\pi x}{a} + \alpha A \cos \frac{3 \pi x}{a} + \beta A \cos \frac{5 \pi x}{a}$$

The α and β are the calculated ratios of B/A and C/A from the theory. From the above formulation a least-squares analysis may be performed in which only one amplitude is determined and the B and C then calculated from this. This method has been called the theoretical ratios method^{(1); (4)} for obtaining the best value of $\underline{a}$. A good fit to the experimental data with the theoretical ratios method tends to serve as a check on the theory involved.

3. Thermal Utilization

From the defining equation, the thermal utilization in the metal is given as:

$$f_u = \frac{\phi_u \sigma_u N_u V_u}{\sum_i \phi_i \sigma_i N_i V_i} \quad \text{and in the graphite moderator the expression is}$$

$$f_g = \frac{\phi_g \sigma_g N_g V_g}{\sum_i \phi_i \sigma_i N_i V_i}$$

(1) HW-21793, op. cit.

(4) Clayton, E. D., Exponential Pile Measurements in 7-1/2" Lattice, HW-28674.

The summation extends over the various cell components. ϕ_i corresponds to the average value of the thermal flux in each of these components.

Therefore, if the flux variation in a lattice and the effective cross sections are known, it is possible to obtain values for the utilization.

4. Lattice Diffusion Length

If the utilization in the various cell components can be determined, then the lattice diffusion length may be found from the expression: $L_t^2 = \sum_i L_i^2 f_i^{(5)}$, where L_i is the diffusion length in component i and f_i the corresponding utilization in this component. The above equation is the result of weighting the transport mean free path as to flux and volume and the absorption cross section in the same manner.

5. Multiplication Constant

The multiplication constant is given by the following formula⁽⁶⁾
 $k = (1 + BL^2) e^{B\tau}$, which for k near unity may be written approximately as $k = (L^2 + k\tau) B + 1$. If the buckling (B), the lattice diffusion length (L), and the age (τ) of fast neutrons to thermal are known, then the multiplication constant is determined. In these experiments the buckling was found from a measurement of the relaxation length, and the lattice diffusion length from intracell traverses. In obtaining a value for k , however, it was necessary to calculate the age of fast neutrons to thermal in the lattice. It is therefore somewhat difficult to quote uncertainty in the value of k since the degree to which the theoretical formulas apply is not known accurately.

CALCULATIONS AND MEASUREMENTS

1. Buckling Measurements

In the course of the buckling measurements, several different neutron detectors were used for determining the relaxation length and

(5) Conference on Reactor Calculations, Section A, CRR-546.

(6) Glasstone, S., and M. C. Edland, The Elements of Nuclear Reactor Theory, D. Van Nostrand Co., Inc., 1952.

hence the buckling. Gold foils, indium foils, fission chambers, and BF_3 counters were tried. With sufficient care the buckling could be reproduced with any of the above detectors to within the experimental accuracy of the measurement. The fission chamber was the least reliable on account of the high amplification required for the small pulses (line noise trouble was encountered), and the steep discriminator plateau; the thickness of the U-235 on the platinum foil was 2.03 mg/cm^2 . The BF_3 counter was used for most of the measurements. It proved to be thoroughly reliable and much more convenient in use, and the same statistical accuracy was possible in a shorter measurement time than with the foils.

Both bare and cadmium-covered traverses were taken with sources in the pile, as well as a measurement of the neutron background with the sources removed from the pile. A background measurement was necessary because, although the spontaneous neutron yield contributed only about 0.3% of the neutrons in the lower regions of the piles, this neutron background accounted for about 2% of the total neutrons in the higher regions where the measurements were taken. This was because the neutron density arising from the presence of the sources dropped off exponentially while there was no such variation in the natural neutron background. If the background was neglected in the above circumstance, a large error in the buckling would result (as much as 20 microbucks, depending upon the magnitude of the buckling value).

The thermal neutron density was found by taking the difference between bare and cadmium-covered detector activities and then subtracting the thermal neutron background. For foils the thermal flux activation is given by

Bare $A_s - \alpha \text{Cd } A_s - \frac{(\text{CR} - \alpha)}{\text{CR}} \text{BGA}_s = A_{\text{sth}}$, where α is a factor which accounts for the absorption of resonance neutrons in the cadmium shield. This factor was taken to be 1 for gold foils and 1.08 for the indium foils used. A_{sth} is the saturated activity resulting from the thermal neutrons

with energy below the cadmium cutoff (approx. 0.3 ev for the 22 mil cadmium used). CR is the cadmium ratio, which is here defined as the ratio of the activity of a bare detector to that of a cadmium-covered detector. BG refers to the bare detector measurement of the natural neutron background or saturated activity resulting from spontaneous fission. Bare A_s and Cd A_s are the saturated activities calculated from the exposure with the foil bare and cadmium covered. It is the saturated activity which is proportional to the neutron density. This is the activity which the foil would obtain if exposed for an infinite period of time or a time long compared to its half life. Since it is impractical to expose until saturated activity is obtained, it becomes necessary to calculate the saturated activity from a finite exposure and count time. The formula for this is given as⁽⁷⁾

$$A_s = \frac{\lambda e^{\lambda t_1} (N)}{(1 - e^{-\lambda t_3})(1 - e^{-\lambda t_2})}$$

t_1 = decay time

t_2 = exposure time

t_3 = count time

λ = decay constant

N = net number of counts obtained during t_3 .

For the BF_3 counter and fission chamber the thermal flux is given by the following expression:

$$\text{Bare} - \text{Cd} - \frac{(\text{CR} - 1)}{\text{CR}} \text{BG} = A_{th}$$

The first term designates the counting rate obtained without a cadmium cover and the second term is the counting rate with a cadmium shield over the tube.

(7) Compton, A. H., Preliminary Material for Manual on Graphite Testing, CL-573.

Appendix II is a compilation of the experimental data for the various slug sizes and lattice spacings. The relaxation length and buckling are also listed in this appendix. Table I is a summary of the exponential experiments. The dry and wet listing under buckling designates buckling with water in the cooling annulus and with the cooling annulus dry.

The question of the importance of ribs in the process tubes for centering the uranium was investigated in the 8-3/8" lattice. The uranium slugs were first positioned on the ribs in the process tubes and thus centered in the process tubes. The tubes were then rotated 180° so that the ribs were on top with the slugs positioned on the bottom of the process tubes. For the latter case, the water annulus thickness varied from 0 at the bottom to 0.437 cm at the top. The measured value of the buckling was found to increase by about 10 microbucks when the uranium was not centered in the tubes in the wet lattice. This was considered to be of sufficient importance to require process tubes with ribs for centering the slugs in all the subsequent measurements.

2. Effective Size Determination

The horizontal thermal neutron distribution was measured in several of the exponential piles in an effort to establish the effective pile size of extrapolation length. These measurements could be taken both parallel and perpendicular to the process tubes and at several different heights above the source plane in the piles. The automatic traverse mechanism described in Section III was used for most of these measurements. The small BF₃ counter (5/16" diameter, 1-3/4" length) was normally used for these traverses. The smaller counter enabled one to establish more accurately the position of points near the outer surface of the piles. In those measurements made perpendicular to the process tubes, the "Fine structure" (neutron variation across a cell) was eliminated by multiplying each set of points taken at equivalent positions within the cell by normalizing factors which would bring all points onto a smoothly

decreasing curve. The points were then fitted by least-squares with an equation of the form of Equation (4) as indicated in the section on theory in this report. In general, no trend or variation could be observed in the extrapolation or the effective size of the pile with height above the source plane. The results of the traverses are summarized in Appendix III.

The uncertainty in the extrapolation length is probably no less than $\pm 1/8''$. There is no significant difference between the value of the extrapolation length as found from the theoretical ratios method and that as found from the free-varying coefficients least-squares analysis. The results of the horizontal traverses indicate an extrapolation length ($0.71 \lambda_{tr}$) of slightly larger than $1''$. The traverses served essentially two purposes: to establish approximately the value of the extrapolation length and to indicate any variation which might result from a change in the neutron spectrum due to the lattice spacing. Within the experimental error, there was no variation of the extrapolation length with lattice spacing. The buckling values given in this report are based on a value of $1''$ for the extrapolation length. Since the theoretical extrapolation length for thermal neutrons in a solid graphite stack is about $3/4''$ ($0.71 \lambda_{tr}$), a value of $1''$ does not seem unreasonable for an exponential pile with its faster spectrum. The extrapolation length is not expected to change significantly with lattice spacing. Since the extrapolation length is not known accurately the value of $1''$ is used for each of the lattices in this report. The calculated buckling values in this report will therefore all be high or low and of about the same amount ($\sim 2 \times 10^{-6} \text{ cm}^{-2}$) depending on whether the true extrapolation length is greater or less than $1''$.

3. Cell Traverse, Thermal Utilization

Small indium foils were used for determining the neutron distribution within a lattice cell. These foils were $3/4''$ in diameter, 5 mils thick, and were mounted on thin graphite wafers. (See Figure 8). These foils could be positioned in the center region of the piles by means of removable graphite bars with a hole drilled to accomodate the foils. Graphite shims

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FIGURE 8
INDIUM FOIL MOUNTING ARRANGEMENT FOR INTRA-CELL TRAVERSES

were used to position the foils within the hole and hence in the lattice cell. Foils were exposed directly over the process tube assembly and also on the edge of the cell. (See Figure 9 for a typical foil placement diagram). From 10 to 25 positions were measured in these traverses. Both bare and cadmium-covered foils were exposed so that the thermal neutron distribution could be determined. A single foil was exposed at a time so as to eliminate the possibility of perturbing effects of one foil on another which might have resulted if several foils were exposed at the same time in the lattice cell. The usual exposure time was 20 minutes with a 20-minute count time on each of three G-M tubes. It is to be noted that the traverse was not extended into the slug. On account of the low flux values in the exponential piles it was not practical to perform this part of the cell traverse. For the small foils required in a slug traverse the activity was insufficient to obtain good counting statistics with any reasonable number of exposures. For the 1.36" diameter slug size, the flux curve in the slug was determined from a measurement in the 305 Test Pile. It was then assumed that for the different lattice spacings measured in the exponential experiments this curve would maintain essentially the same shape. In finding the average flux in the various cell components the moderator curve and slug traverse curve were normalized at the process tube surface. For the 0.925" and 1.175" diameter slug sizes the slug surface to center ratio of the thermal flux was measured by means of gold strip foils 2-1/2" long and 1/8" wide. From this measurement, an approximate value for the disadvantage factor could be ascertained assuming an I_0 shape for the curve. Using Simpson's trapezoidal formula for numerical integration, the average thermal flux in the various cell components was calculated. Before this integration was performed, it was necessary to correct the measured activities of the foils for the exponential drop up the pile (reduce the measured values to an equivalent infinite lattice) and correct for the cosine variation in the horizontal direction. There is some question as to the validity of these corrections; for instance,

FIGURE 9
TYPICAL INTRA-CELL FOIL PLACEMENT DIAGRAM

it is questionable whether the exponential drop can be adequately separated from the normal flux variation across the cell. Because of this, the thermal utilizations given in this report should not be taken too seriously in themselves. The relative trend or variations between the different lattices should be quite indicative, however. The thermal utilizations were calculated from the defining equation as mentioned in the section on theory. A summary of these values is given in Table I of this report.

4. Lattice Diffusion Length Determination

If the relative neutron densities can be determined within the lattice components, then it is possible to calculate the thermal utilization from the known cross sections and hence the lattice diffusion length may be calculated from $L_t^2 = \sum L_i^2 f_i$, where i indicates the i^{th} component of the cell unit. Values for the lattice diffusion length as calculated with this formula are listed in Table I. A more complete treatment of the diffusion length in a heterogeneous lattice for those lattices reported here is given in a separate document. (8)

5. Multiplication Constant

The multiplication constant for the infinite pile is given by $k_{\infty} = (1 + BL^2) e^{B\tau}$. For k near unity, this may be written approximately as $k_{\infty} \simeq BM^2 + 1$, where $M^2 = L_t^2 + k\tau$. The buckling was measured directly and a value of L_t^2 obtained from the thermal utilization as mentioned earlier. In the determination of k_{∞} it was necessary to calculate the age (τ) of fission neutrons to thermal. The Standard Project Handbook type formula was used for this purpose. The values of k_{∞} for the various lattices are given in the summary sheet in Table I. k_{∞} is thus seen to be subject to the uncertainty in the calculated (τ), as well as the normal uncertainties in the measurements. Here again the relative values for the different lattices are probably more indicative of the true picture than the absolute values for any individual lattice spacing and slug size.

(8) Thermal Utilization and Lattice Diffusion Length in Graphite-Uranium Lattices from Exponential Pile Measurements, C. R. Richey, E. D. Clayton, D. E. Davenport, HW-31305.

6. Conversion Ratio

The conversion ratio is defined as the number of plutonium atoms produced for each atom of U-235 lost in the reactor. The cold, clean (initial) conversion ratio may be calculated by the following formula:⁽⁹⁾

$$\text{Conversion Ratio} = \frac{\sum_a^{28}}{\sum_a^{25}} \bigg|_{th} + \eta_{25} \epsilon (1 - p)$$

$\sum_a^{28}$ = Macroscopic total absorption cross section of U-238 evaluated at thermal neutron energy.

$\sum_a^{25}$ = Same as above but for U-235.

η = Fission neutrons produced per thermal neutron absorbed in U-235.

ϵ = Fast effect.

p = Resonance escape probability.

The conversion ratios calculated with the above formula are listed in Table I for all but the hollow slugs. The resonance escape probability was determined in the following manner. The value for the effective resonance cross section was adjusted so that the calculated and measured bucklings would be in agreement for the 1.36" slug size, more experimental results being available for this slug size than any other. The volume part of the resonance integral was then determined from the expression:

$$5.6 \bar{\sigma}_r = \int \sigma(E) \frac{dE}{E} = A \left(1 + \frac{2.5}{\frac{M}{S}} \right) + 0.0846$$

M = Mass of slug in grams per cm of length.

S = Surface area of slug in cm^2 per cm of length.

(9) Gast, P. F. and Staff, Evaluation Study of Selected Hanford Type Reactors, HW-28740.

The value for A was found to be 7.87 barns for the particular set of constants used in the calculation. With this value of A the effective resonance cross section was calculated for the other slug sizes from which the resonance escape probability could then be calculated. The calculated bucklings did not agree very well with those measured for the 1.175" slug size and were rather poor for the 1.66" solid slug. The conversion ratios therefore give only a rough qualitative estimate but should provide some indication as to the relative values for the various slug sizes and lattice spacings. Those cases where the value is larger than unity need be cause for no concern since the bucklings for these cases have such values that the reactor could not be self sustaining with natural uranium.

The cold clean initial conversion ratio for the 8-3/8" wet lattice is calculated to be 0.792 with the preceding method.

RESULTS AND DISCUSSION

The results of the experimental determinations are given in Table I. The values for the multiplication constant listed therein should provide the correct relative trend if not the accurate absolute values. The buckling values were calculated from the experimental neutron flux measurements with an extrapolation length ($0.71 \lambda_{tr}$) of 1". The results of the horizontal traverses from which this value was obtained are given in Appendix III. Most of the error in the buckling values is probably due to the uncertainty in the effective size of the pile. The experimental error in these buckling values is probably of the order of $\pm 2 \times 10^{-6} \text{ cm}^{-2}$.

An interesting and informative way in which to compare the relative merits of the various slug sizes and lattice spacings is to plot the buckling versus the ratio of graphite to uranium atoms per unit cell. When this is done a series of curves is obtained, one for each slug size and water annulus. These curves are given in Figures 10, 11, and 12. It is noted that as the lattice spacing is reduced for any particular slug size, that is, with decreasing graphite to uranium ratio, a point is reached where the dry

TABLE I

SUMMARY OF GRAPHITE-URANIUM EXPONENTIAL EXPERIMENTS

Lattice Spacing (inches)	Relaxation Length of 1,1 Harmonic* (cm)		Buckling x 10 ⁶ cm ² *		Average Cadmium Ratio in Moderator from Indium Foil Cell Traverse		Thermal Utilization in the Uranium		Thermal Utilization in Moderator		Lattice Diffusion Length (cm)		Age of Fission Neutrons to Thermal (cm ²) (Calculated)		Multiplication Constant $k = (1+BL^2)e^{B\tau}$		Conversion Ratio (Calculated)	
	dry	wet	dry	wet	dry	wet	dry	wet	dry	wet	dry	wet	dry	wet	dry	wet	dry	wet
(Slug Diameter 0.925 inches)																		
6-3/16	70.56	67.86	114.5	98.2	5.32	5.73	0.905	0.876	0.074	0.087	14.6	15.8	334.8	320.0	1.064	1.057	0.932	0.889
7-1/2	71.96	67.12	95.3	66.4	7.16	7.66	0.868	0.835	0.111	0.129	17.8	19.2	334.2	324.2	1.063	1.047	0.819	0.798
(Slug Diameter 1.17 inches)																		
6-3/16	64.71	65.74	76.6	83.9	3.94	4.47	0.932	0.905	0.050	0.058	12.0	13.0	339.0	313.3	1.038	1.041	0.814	0.795
7-1/2	77.52	72.59	122.0	98.6	5.32	5.99	0.903	0.876	0.079	0.088	15.0	16.0	335.9	318.9	1.070	1.058	0.738	0.729
(Slug Diameter 1.36 inches)																		
6-3/16	56.49	59.25	2.0	30.5	3.45	4.12	0.939	0.911	0.040	0.047	10.9	11.8	344.6	308.9	1.001	1.014	1.013	0.946
7	68.91	68.35	75.0	71.6	4.23	4.88	0.924	0.892	0.056	0.067	12.8	14.0	342.4	315.1	1.039	1.037	0.920	0.877
7-1/2	73.07	70.17	101.1	85.3	4.61	5.34	0.915	0.883	0.065	0.077	13.8	15.0	339.3	315.9	1.055	1.047	0.875	0.842
8	73.59	68.37	112.3	83.0	5.18	5.92	0.905	0.873	0.075	0.087	14.7	15.8	336.3	316.0	1.064	1.048	0.838	0.812
8-3/8	70.65	64.81	118.1	80.5	5.61	6.33	0.901	0.870	0.079	0.091	15.0	16.1	332.1	313.9	1.068	1.047	0.813	0.792
(Slug Diameter 1.66 inches)																		
6-3/16	46.17		-153.7		2.86		0.968		0.029		9.1		351.8		0.935		1.189	
7-1/2	68.02		72.3		3.86		0.950		0.047		11.6		342.5		1.035		0.999	
12-3/8	64.63		76.0		No		No										0.740	
15	58.45		-4.3		traverse		traverse										0.678	
					No		No											
					traverse		traverse											
(Hollow Slug 1.66 inches O.D., 0.81 inches I.D.)																		
6-3/16	51.17	52.11	-66.5	-52.8	3.02	3.21												
7-1/2	72.49	71.48	98.1	92.7	4.02	4.20												
12-3/8	61.51	59.74	51.1	35.2	No	No												
15	56.07	55.08	-29.7	-41.2	traverse	traverse												
					No	No												
					traverse	traverse												

*Average value when several measurements were taken with different detectors.

and wet bucklings have the same value. The graphite to uranium ratio at which this occurs will be referred to as the cross-over point and the buckling as the cross-over buckling. The cross-over point has a particular importance from the standpoint of safety, since there should be no significant change in the reactivity with the loss of cooling water. For the standard slug size (1.36" diameter) the cross-over point occurs at a lattice spacing of about 6.9" ($C/U \approx 59$) and the buckling value is $\approx 68 \times 10^{-6} \text{ cm}^{-2}$. The 1.175" diameter slug has a cross-over point at about 6-1/3" ($C/U \approx 67$) and a buckling value of between $85-90 \times 10^{-6} \text{ cm}^{-2}$. The latter cross-over point is somewhat uncertain due to the limited number of points measured; one on either side of the cross-over point. For the 0.925" diameter slug the cross-over spacing is calculated to be at about 5-1/3" ($C/U \approx 74$) and the buckling at this point is between $76-84 \times 10^{-6} \text{ cm}^{-2}$. Since at this time the measurements had not been extended to include the cross-over point, this value for the 0.925" slug was estimated by empirically fitting the theory to the measured values (adjustment of resonance cross section to insure agreement between calculated and measured values) and then extending the calculations to include the cross-over point. The value for the 0.925" slug is the least certain. However, it must be pointed out that the water to uranium ratio for the above externally cooled slugs is not quite the same for the three different slug sizes. The water to uranium ratio varies from 0.174 to 0.192 in going from the 0.925" slug to the 1.36" slug (see Appendix I). In comparing the cross-over points this fact should be taken into consideration. Figure 13 is a plot of the slug radius (cm) and cross-over buckling versus the graphite to uranium ratio at the cross-over point for a constant H_2O/U ratio (0.192) and Al/U ratio (0.543). In these curves the small water difference has been corrected for, as well as the aluminum difference. Although there are decidedly too few points for any accuracy, the cross-over buckling curve suggests that for a given H_2O/U ratio there is a maximum cross-over buckling which can not be exceeded for any slug size. The value is about $89 \times 10^{-6} \text{ cm}^{-2}$ for the water to uranium ratio of (0.192). What this maximum cross-over

BUCKLING VERSUS GRAPHITE-URANIUM RATIO

Uranium Radius: 1.727 cm.

FIGURE 10

BUCKLING VERSUS GRAPHITE-URANIUM RATIO

Uranium Radius: 1.175 cm.
1.492 cm.

FIGURE 11

BUCKLING VERSUS GRAPHITE-URANIUM RATIO

FIGURE 12

buckling will be for a different H_2O/U ratio can not be inferred as yet, since the effect of adding water and displacing graphite for any single slug size has not been fully determined.

The cross-over point for the hollow slug (1.66" O. D. , 0.81" I. D.) is quite uncertain because of the nature of the curves in this region. The uncertainty in a number obtained from the buckling curves for this slug would render the value of little use. The important fact is that throughout the graphite to uranium range of about 38 to 57 the wet and dry buckling difference is small as can be seen from Figure 12.

The wet buckling will have a higher value than the dry only when the dry lattice is considerably undermoderated. When this occurs the increased absorption in the water (over that in graphite) plays a smaller role in determining the relaxation length than the increased moderation provided by the water, which increases the resonance escape and decreases the age of fast neutrons to thermal. With a hollow internally cooled slug, the wet and dry buckling values are generally closer together. The water in this case does not shield the uranium from the thermal neutrons produced in the graphite, nor is the water as large an effective neutron absorber, since it is placed in the lowest thermal flux in the interior of the slug. Measurements will also be taken with a 1.66" O. D. , 1.10" I. D. slug. The effect on the buckling as the water annulus is increased for a fixed slug size and lattice spacing is also to be investigated in the near future. The theoretical analysis, or comparison of the measured values with the theory, will be reported in detail in a separate report to follow.

SUMMARY AND CONCLUSIONS

From the results and discussion treated in Section VI, it is apparent that some of the more important objectives as set forth in the introduction can be met if the slug size and lattice spacing are properly chosen. For example, if a slug diameter of 1.175" were used with a H_2O/U ratio of 0.19 and the lattice spacing of about 6-1/3" then the safety requirement would

FIGURE 13
CROSSOVER POINT BUCKLING AND SLUG RADIUS VERSUS
GRAPHITE-URANIUM RATIO AT THE CROSSOVER POINT

be met. This reactor would also have enough reactivity ($85-90 \times 10^{-6} \text{ cm}^{-2}$) to operate with natural uranium. Small lattice spacings such as a 6-1/3" lattice present engineering difficulties, however. The important thing is that it does appear possible to construct a graphite-moderated, externally water-cooled reactor that will be a good producer of plutonium and also be ideal from the safety standpoint, that is, small change in reactivity will result from the loss of water from the cooling annulus. Furthermore, there is no reason not to believe that with a different $\text{H}_2\text{O}/\text{U}$ ratio, some other slug size and lattice spacing might appear even more attractive, although the $\text{H}_2\text{O}/\text{U}$ ratio is fixed by the power level at which any reactor is designed to operate.

The hollow slug looks attractive from the standpoint of safety since, in general, the water has a smaller effect on the reactivity when placed in the internal cooling annulus. There appear to be some engineering difficulties with regards to the canning of this type slug, however.

There appeared to be no significant variation in the extrapolation length ($0.71 \lambda_{\text{tr}}$) of the exponential piles as the lattice spacing and slug size was varied. Any differences which did exist were within the experimental accuracy of the measurements.

APPENDIX I

DESCRIPTION OF MATERIAL IN GRAPHITE-URANIUM EXPONENTIAL EXPERIMENTS

For Slug Diameter (in inches)	0.925	1.175	1.36	1.66	1.66 O. D., 0.81 I. D.
<u>URANIUM:</u>					
Volume of U/cm of length (cc/cm)	4.38	7.00	9.37	13.96	10.62
Slug length (cm)	19.43	19.43	10.27	10.16	10.16
Slug radius (cm)	1.17	1.49	1.73	2.11	2.11
Slug density (solid in g/cc)	18.91	18.90	18.75	18.75	18.75
Slug density (equivalent in g/cc)	18.04	18.09	17.11	18.75	
Nuclei density (equivalent in atoms/cc)	0.0455×10^{24}	0.0457×10^{24}	0.0432×10^{24}	0.0474×10^{24}	
<u>ALUMINUM:</u>					
Volume of process tube/cm of length (cc/cm)	1.36	1.75	2.31	0.97	0.97
Outside radius of Al process tube (cm)	1.55	1.91	2.20	2.20	2.20
Effective inside radius of Al process tube with the Al ribs taken into consideration (cm)	1.40	1.75	2.02	2.13	2.13
Volume of can/cm of length (cc/cm)	0.68	0.87	1.00	no can	no can
Outside radius of Al can (cm)	1.27	1.59	1.83	no can	no can
Inside radius of Al can (cm)	1.18	1.50	1.74	no can	no can
Outside radius of Al tube in hollow slug for cooling channel (cm)	-----No Internal Cooling-----				1.02
Inside radius of Al tube in hollow slug for cooling channel (cm)	-----No Internal Cooling-----				0.87
Double end cap, or Al spacer thickness between slugs (cm)	1.02	1.02	0.94	no end cap	no end cap
Total volume of Al/cm of length (cc/cm)	2.25	2.93	4.10	0.97	1.86
<u>WATER:</u>					
Volume of water/cm of length (cc/cm)	1.03	1.73	2.33	no water	2.38
Water annulus thickness (cm)	0.13	0.16	0.19	no water	no annulus
Radius of internal cooling channel for hollow slug (cm)	-----No Internal Cooling-----				0.87

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APPENDIX I (contd.)

DESCRIPTION OF MATERIAL IN GRAPHITE-URANIUM EXPONENTIAL EXPERIMENTS (contd.)

<u>For Lattice Spacing</u> <u>(in inches)</u>	<u>6-3/16</u>	<u>7</u>	<u>7-1/2</u>	<u>8</u>	<u>8-3/8</u>	<u>12-3/8</u>	<u>15</u>
<u>GRAPHITE:</u>							
Density (g/cc)	1. 656	1. 647	1. 648	1. 650	1. 657	1. 656	1. 648
Nuclei density (atoms/cc)	0.0829×10^{24}	0.0825×10^{24}	0.0825×10^{24}	0.0826×10^{24}	0.0830×10^{24}	0.0829×10^{24}	0.0825×10^{24}
Reciprocal diffusion length (cm ⁻¹)	0. 0190	0. 0189	0. 0189	0. 0189	0. 0190	0. 0190	0. 0189
Equivalent outside radius of cell (cm)	8. 87	10. 03	10. 75	11. 46	12. 00	17. 73	21. 49

APPENDIX I (contd.)

DESCRIPTION OF MATERIAL IN GRAPHITE URANIUM
EXPONENTIAL EXPERIMENTS

Graphite: Radii of holes for accommodation of process tubes are: 1.567, 1.922, 2.215, 2.215 cm for the 0.925, 1.17, 1.36, and 1.66 inch diameter slug sizes respectively.

Microscopic cross section at 0.025 ev is: 4.40 millibarns.

Reciprocal of diffusion length at density 1.6 g/cm³ is: 0.0184 cm⁻¹.

Ratios of Al, H₂O, and C Atoms to U Atoms Per Cell

<u>Slug Diameter</u> <u>(inches)</u>	<u>Lattice Spacing</u> <u>(inches)</u>	<u>Al/U</u>	<u>H₂O/U</u>	<u>C/U</u>
0.925	6-3/16	0.612	0.174	100.5
	7-1/2			148.5
1.17	6-3/16	0.492	0.186	61.2
	7-1/2			90.9
1.36	6-3/16	0.543	0.192	47.4
	7			61.3
	7-1/2			70.8
	8			81.8
	8-3/8			89.6
1.66	6-3/16	0.078	no water	29.1
	7-1/2			43.4
	12-3/8			122.1
	15			179.4
1.66 O.D., 0.81 I.D.	6-3/16	0.103	0.158	38.21
	7-1/2			57.06
	12-3/8			160.48
	15			235.83

APPENDIX I (contd.)

PHYSICAL DIMENSIONS OF EXPONENTIAL PILES

<u>Lattice Spacing</u> <u>(inches)</u>	<u>Cross-Sectional</u> <u>Dimensions</u> <u>(inches)</u>	<u>Height</u> <u>Measured from</u> <u>Source Plane</u> <u>(inches)</u>	<u>Graphite Base</u> <u>Reflector</u> <u>Thickness</u> <u>(inches)</u>
6-3/16	96 x 97	98	20
7	101-1/2 x 101-1/2	102.5	20
7-1/2	101 x 101	102	20
8	99-1/2 x 99-1/2	100.5	20
8-3/8	96 x 96	97.3	20
12-3/8	96 x 97	100	20
15	101 x 101	102	20

APPENDIX II

EXPERIMENTAL DATA, BUCKLING VALUES, HARMONIC CORRECTIONS

- . The following items are tabulated in this appendix:
 1. Relative thermal neutron density or saturated activity.
 2. Distance from source plane at measurement positions.
 3. Pile neutron back-ground values, or the contribution to the total neutron density resulting from spontaneous fission.
 4. Cadmium ratio.
 5. Harmonic corrections.
 6. Relaxation length of 1, 1 harmonic.
 7. Buckling values.
 8. Method of neutron detection.
 9. Lattice spacing, slug size, wet or dry lattice.

Experiment I-22(I)

8-3/8" Lattice
1.36" Slugs

Wet Uranium
Cylindrical Indium Foils

$a = 98''$
Sources displaced $\pm 24''$

Slot	Cm above $\bar{L}$ of Source Plane	Pile Neutron BG	$A_{th}(1)$	Cadmium Ratio	$C_e C_h$
8	82.31	82	21,392	7.91	1.0030
12	124.85	81	11,180	7.95	1.0044
14	146.12	81	7,812	7.89	1.0234
16	167.40	77	5,414	7.92	1.0644
18	188.67	65	3,614	7.85	1.1544
20	209.94	51	2,158	7.87	1.3792

Corrections calculated with B_{11} of 65.00 cm.
Relaxation length (B_{11}) of 1,1 harmonic from least-squares analysis:
64.62 cm.
Buckling: $79.1 \times 10^{-6} \text{ cm}^{-2}$.

Experiment I-22(II)

8-3/8" Lattice
1.36" Slugs

Wet Uranium
Cylindrical Indium Foils

$a = 98''$
Sources displaced $\pm 24''$

Slot	Cm above $\bar{L}$ of Source Plane	Pile Neutron BG	A_{th}	Cadmium Ratio	$C_e C_h$
8	82.31	82	21,630	7.90	1.0030
12	124.85	81	11,239	7.88	1.0044
14	146.12	81	7,929	7.89	1.0234
16	167.40	77	5,463	7.80	1.0644
18	188.67	65	3,628	7.79	1.1544
20	209.94	51	2,163	7.74	1.3792

Corrections calculated with B_{11} of 65.00 cm.
Relaxation length (B_{11}) of 1,1 harmonic from least-squares analysis:
64.38 cm.
Buckling: $77.3 \times 10^{-6} \text{ cm}^{-2}$.

(1) $A_{th} = A_{bare} - 1.08 A_{cad} - \left(\frac{\overline{CR} - 1.00}{\overline{CR}} \right) A_{BG}$, where $\overline{CR} = 7.85$

Experiment I-33

8-3/8" Lattice
1.36" Slugs

Wet Uranium
BF₃ #11

a = 98"
Sources displaced ± 24.6"

Slot	Cm above E of Source Plane	Pile Neutron BG(2)	A _{th} (1)	Cadmium Ratio	C _e C _h
8	82.3	207	56,415	38.0	1.0283
12	124.9	208	29,432	38.0	1.0257
14	146.1	207	20,977	38.6	1.0441
16	167.4	184	14,517	39.8	1.0854
18	188.7	165	9,614	36.8	1.1767
20	209.9	120	5,875	38.7	1.4055

Corrections calculated with B₁₁ of 65.00 cm.

Relaxation length (B₁₁) of 1,1 harmonic from least squares analysis:

65.34 cm.

Buckling: $84.3 \times 10^{-6} \text{ cm}^{-2}$.

(1) $A_{th} = A_{bare} - A_{cad} - A_{BG}$.

(2) A_{BG} measured in Experiment I-31.

Experiment I-54

8-3/8" Lattice
1.36" Slugs

Wet Uranium
Cylindrical Indium Foils

a = 98"
Sources displaced ± 24.6"

Slot	Cm above E of Source Plane	Pile Neutron BG(2)	A _{th} (1)	Cadmium Ratio	C _e C _h
8	82.3	71	20,899	7.73	1.0283
10	103.6	71	15,248	7.86	1.0206
12	124.9	71	10,910	7.72	1.0257
14	146.1	71	7,693	7.77	1.0441
16	167.4	68	5,288	7.54	1.0854

Corrections calculated with B₁₁ of 65.00 cm.

Relaxation length (B₁₁) of 1,1 harmonic from least squares analysis:

64.42 cm.

Buckling: $77.6 \times 10^{-6} \text{ cm}^{-2}$.

(1) $A_{th} = A_{bare} - 1.08 A_{cad} - \left(\frac{CR-1.00}{CR} \right) A_{BG}$.

(2) A_{BG} values per slots 8, 12, and 16 are taken from Experiment 23;
values in slots 10 and 14 are approximated.

Experiment I-55

8-3/8" Lattice
1. 36" Slugs

Wet Uranium
BF₃ #19

a = 98"
Sources displaced ± 24. 6"

Slot	Cm above L of Source Plane	Pile Neutron BG	A _{th} (1)	Cadmium Ratio	C _e C _h
8	82. 3	192	55, 086	38. 44	1. 0283
10	103. 6	191	40, 123	38. 05	1. 0206
12	124. 9	195	28, 825	38. 38	1. 0257
14	146. 1	172	20, 496	38. 13	1. 0441
16	167. 4	171	14, 163	37. 88	1. 0854

Corrections calculated with B₁₁ of 65. 00 cm.
Relaxation length (B₁₁) of 1, 1 harmonic from least squares analysis:
65. 30 cm.
Buckling: 84. 0 x 10⁻⁶ cm⁻².

$$(1) A_{th} = A_{bare} - A_{cad} - A_{BG}$$

Experiment I-25

8-3/8" Lattice
1. 36" Slugs

Wet Uranium
Cylindrical Indium Foils
- Process Tubes Inverted

a = 98"
Sources displaced ± 24"

Slot	Cm above L of Source Plane	Pile Neutron BG	A _{th} (1)	Cadmium Ratio	C _e C _h
8	82. 3	80	21, 857	7. 84	1. 0030
12	124. 9	80	11, 567	7. 91	1. 0044
14	146. 1	80	8, 120	7. 72	1. 0234
16	167. 4	80	5, 746	7. 91	1. 0644
18	188. 7	65	3, 815	7. 89	1. 1544

Corrections calculated with B₁₁ of 65. 00 cm.
Relaxation length (B₁₁) of 1, 1 harmonic from least squares analysis:
66. 30 cm.
Buckling: 91. 1 x 10⁻⁶ cm⁻².

$$(1) A_{th} = A_{bare} - 1. 08 A_{cad} - A_{BG}$$

Experiment I-42

8-3/8" Lattice
1.36" Slugs

Dry Uranium
BF₃ #11

a = 98"
Sources displaced ± 24.6"

Slot	Cm above L of Source Plane	Pile Neutron BG	A _{th} (1)	Cadmium Ratio	C _e C _h
8	82.3	196	57,280	30.48	1.0287
10	103.6	193	42,711	33.05	1.0234
12	124.9	198	31,442	32.20	1.0322
14	146.1	186	22,742	33.53	1.0552
16	167.4	167	16,037	32.88	1.1039
18	188.7	148	10,823	31.78	1.2076

Corrections calculated with B₁₁ of 70.00 cm.

Relaxation length (B₁₁) of 1,1 harmonic from least squares analysis:
70.61 cm.

Buckling: $117.0 \times 10^{-6} \text{ cm}^{-2}$.

$$(1) A_{th} = A_{bare} - A_{cad} - A_{BG}$$

Experiment I-47

8-3/8" Lattice
1.36" Slugs

Dry Uranium
BF₃

a = 98"
Sources displaced ± 24.6"

Slot	Cm above L of Source Plane	Pile Neutron BG(2)	A _{th} (1)	Cadmium Ratio	C _e C _h
8	82.3	196	56,647	33.02	1.0287
10	103.6	193	41,998	32.60	1.0239
12	124.9	198	30,955	32.99	1.0322
14	146.1	186	22,455	33.39	1.0552
16	167.4	167	15,786	33.15	1.1039

Corrections calculated with B₁₁ of 70.00 cm.

Relaxation length (B₁₁) of 1,1 harmonic from least squares analysis:
70.69 cm.

Buckling: $118.3 \times 10^{-6} \text{ cm}^{-2}$.

$$(1) A_{th} = A_{bare} - A_{cad} - A_{BG}$$

(2) A_{BG} taken directly from Experiment I-42.

Experiment II-13

8" Lattice
1. 36" Slugs

Dry Uranium
Large BF_3

$a = 101.5''$
Sources displaced $\pm 25.46''$

Slot	Cm above L of Source Plane	Pile Neutron BG	$A_{th}(1)$	Cadmium Ratio	C_e	C_h
11	76.84	228	55,911	29.42	1.0071	1.0280
14	97.16	237	42,856	30.40	1.0124	1.0122
17	117.48	224	32,510	29.96	1.0219	1.0055
20	137.80	230	24,399	30.17	1.0388	1.0025
23	158.12	226	17,901	29.40	1.0697	1.0011
26	178.44	189	13,015	31.28	1.1282	1.0005
29	198.76	169	8,867	29.11	1.2474	1.0002
32	219.08	120	5,501	29.40	1.5292	1.0001
35	239.40	69	2,512	28.84	2.5035	1.0000

Corrections calculated with B_{11} of 73.00 cm.
Relaxation length (B_{11}) of 1.1 harmonic from least squares analysis: 73.59
Buckling: $112.32 \times 10^{-6} \text{ cm}^{-2}$.

$$(1) A_{th} = A_{bare} - A_{cad} - A_{BG}$$

Experiment II-15

8" Lattice
1. 36" Slugs

Dry Uranium
Cylindrical Indium Foils

$a = 101.5''$
Sources displaced $\pm 25.46''$

Slot	Cm above L of Source Plane	Pile Neutron BG ⁽²⁾	$A_{th}(1)$	Cadmium Ratio	C_e	C_h
11	76.84	100	21,179	6.27	1.0071	1.0280
14	97.16	104	16,290	6.22	1.0124	1.0122
17	117.48	98	12,379	6.20	1.0219	1.0055
20	137.80	105	9,267	6.31	1.0388	1.0025
23	158.12	99	6,732	6.13	1.0697	1.0011
26	178.44	83	4,848	6.17	1.1282	1.0005
29	198.76	74	3,330	6.16	1.2474	1.0002

Corrections calculated with B_{11} of 73.00 cm.
Relaxation length (B_{11}) of 1.1 harmonic from least squares analysis: 73.29 cm.
Buckling: $110.81 \times 10^{-6} \text{ cm}^{-2}$.

$$(1) A_{th} = A_{bare} - 1.08 A_{cad} - \left(\frac{CR-1.00}{CR} \right) BG.$$

$$(2) A_{BG} \text{ interpolated from Experiment II-13.}$$

Experiment II-16

8" Lattice
1.36" Slugs

Dry Uranium
Large BF_3

$a = 101.5''$
Sources displaced $\pm 25.46''$

Slot	Cm above $\bar{L}$ of Source Plane	Pile Neutron BG (2)	$A_{th}(1)$	Cadmium Ratio	C_e	C_h
14	97.16	242	42,788	29.74	1.0124	1.0122
17	117.48	230	32,409	29.04	1.0219	1.0055
20	137.80	236	24,295	29.46	1.0388	1.0025
23	158.12	232	17,928	29.27	1.0697	1.0011
26	178.44	193	12,907	29.86	1.1282	1.0005
29	198.76	173	8,895	30.10	1.2474	1.0002

Corrections calculated with B_{11} of 73.00 cm.

Relaxation length (B_{11}) of 1.1 harmonic from least squares analysis: 73.89 cm.

Buckling: $113.81 \times 10^{-6} \text{ cm}^{-2}$.

$$(1) A_{th} = A_{bare} - A_{cad} - \frac{CR-1.00}{CR} A_{BG}$$

(2) BG interpolated from Experiment II-13.

Experiment II-22A

8" Lattice
1.36" Slugs

Wet Uranium
 BF_3 #11

$a = 101.5''$
Sources displaced $\pm 25.46''$

Slot	Cm above $\bar{L}$ of Source Plane	Pile Neutron BG	$A_{th}(1)$	Cadmium Ratio	C_e	C_h
11	76.84	216	56,099	34.18	1.0049	1.0307
14	97.16	223	42,356	34.57	1.0089	1.0136
17	117.48	220	31,484	34.03	1.0164	1.0061
20	137.80	217	23,147	34.42	1.0302	1.0028
23	158.12	209	16,732	31.59	1.0563	1.0013
26	178.44	193	11,870	30.00	1.1073	1.0006
29	198.76	167	8,056	33.24	1.2137	1.0003

Corrections calculated with B_{11} of 68.00 cm.

Relaxation length (B_{11}) of 1.1 harmonic from least squares analysis: 68.32 cm.

Buckling: $82.72 \times 10^{-6} \text{ cm}^{-2}$.

$$(1) A_{th} = A_{bare} - A_{cad} - A_{BG}$$

Experiment II-22B

8" Lattice
1. 36" Slugs

Wet Uranium
BF₃ #11

a = 101.5"
Sources displaced $\pm 25.46''$

Slot	Cm above $\bar{L}$ of Source Plane	Pile Neutron BG(2)	A _{th} (1)	Cadmium Ratio(2)	C _e	C _h
11	76.84	216	56,307	34.31	1.0049	1.0307
14	97.16	223	42,416	34.61	1.0089	1.0136
17	117.48	220	31,340	33.87	1.0164	1.0061
20	137.80	217	23,324	34.65	1.0302	1.0028
23	158.12	209	16,805	31.71	1.0563	1.0013
26	178.44	193	11,982	30.27	1.1073	1.0006
29	198.76	167	8,046	33.21	1.2137	1.0003

Corrections calculated with B₁₁ of 68.00 cm.

Relaxation length (B₁₁) of 1,1 harmonic from least squares analysis: 68.40 cm.

Buckling: $83.25 \times 10^{-6} \text{ cm}^{-2}$.

(1) $A_{th} = A_{bare} - A_{cad} - A_{BG}$

(2) A_{BG} and A_{cad} taken from Experiment II-22A.

Experiment II-22C

8" Lattice
1. 36" Slugs

Wet Uranium
BF₃ #11

a = 101.5"
Sources displaced $\pm 25.46''$

Slot	Cm above $\bar{L}$ of Source Plane	Pile Neutron BG(2)	A _{th} (1)	Cadmium Ratio	C _e	C _h
11	76.84	216	55,798	35.03	1.0049	1.0307
14	97.16	223	42,259	34.92	1.0089	1.0136
17	117.48	220	31,450	35.62	1.0164	1.0061
20	137.80	217	23,193	34.61	1.0302	1.0028
23	158.12	209	16,718	35.48	1.0563	1.0013
26	178.44	193	11,876	34.41	1.1073	1.0006
29	198.76	167	8,068	33.56	1.2137	1.0003

Corrections calculated with B₁₁ of 68.00 cm.

Relaxation length (B₁₁) of 1,1 harmonic from least squares analysis: 68.53 cm.

Buckling: $84.08 \times 10^{-6} \text{ cm}^{-2}$.

(1) $A_{th} = A_{bare} - A_{cad} - A_{BG}$

(2) A_{BG} from Experiment II-22A.

Experiment II-22D

8" Lattice
1. 36" Slugs

Wet Uranium
BF₃ #11

a = 101.5"
Sources displaced ± 25.46"

Slot	Cm above L of Source Plane	Pile Neutron BG(2)	A _{th} (1)	Cadmium Ratio(3)	C _e	C _h
11	76.84	215	55,981	35.14	1.0049	1.0307
14	97.16	223	42,070	34.76	1.0089	1.0136
17	117.48	220	31,395	35.56	1.0164	1.0061
20	137.80	217	23,248	34.69	1.0302	1.0028
23	158.12	209	16,752	35.55	1.0563	1.0013
26	178.44	193	11,778	34.14	1.1073	1.0006
29	198.76	167	8,001	33.30	1.2137	1.0003

Corrections calculated with B₁₁ of 68.00 cm.

Relaxation length (B₁₁) of 1,1 harmonic from least squares analysis: 68.22 cm.

Buckling: 82.11 x 10⁻⁶ cm⁻².

(1) A_{th} = A_{bare} - A_{cad} - A_{BG}.

(2) A_{BG} from Experiment II-22A.

(3) A_{cad} from Experiment II-22C.

Experiment II-23

8" Lattice
1. 36" Slugs

Wet Uranium
Cylindrical Indium Foils

a = 101.5"
Sources displaced ± 25.46"

Slot	Cm above L of Source Plane	Pile Neutron BG	A _{th} (1)	Cadmium Ratio	C _e	C _h
11	76.84	103	21,034	7.10	1.0049	1.0307
14	97.16	87	15,856	7.15	1.0089	1.0136
17	117.48	96	11,828	7.16	1.0164	1.0061
20	137.80	94	8,660	7.10	1.0302	1.0028
23	158.12	88	6,372	7.21	1.0563	1.0013
26	178.44	86	4,445	7.05	1.1073	1.0006
29	198.76	91	2,999	6.95	1.2137	1.0003

Corrections calculated with B₁₁ of 68.00 cm.

Relaxation length (B₁₁) of 1,1 harmonic from least squares analysis: 68.26 cm.

Buckling: 82.37 x 10⁻⁶ cm⁻².

(1) A_{th} = A_{bare} - 1.08 A_{cad} - $\left(\frac{CR-1.08}{CR}\right) A_{BG}$.

Experiment II-27

8" Lattice
1. 36" Slugs

Wet Uranium
Cylindrical Indium Foils

a = 101. 5"
Sources displaced $\pm 25. 46''$

Slot	Cm above L of Source Plane	Pile Neutron BG(2)	A _{th} (1)	Cadmium Ratio	C _e	C _h
11	76. 84	103	21, 162	7. 16	1. 0049	1. 0307
14	97. 16	87	16, 039	7. 16	1. 0089	1. 0136
17	117. 48	96	11, 829	7. 05	1. 0164	1. 0061
20	137. 80	94	8, 839	7. 31	1. 0302	1. 0028
23	158. 12	88	6, 322	7. 10	1. 0563	1. 0013
26	178. 44	86	4, 516	7. 16	1. 1073	1. 0006
29	198. 76	91	3, 043	7. 13	1. 2137	1. 0003

Corrections calculated with B₁₁ of 68. 00 cm.

Relaxation length (B₁₁) of 1, 1 harmonic from least squares analysis: 68. 47 cm.

Buckling: $83. 71 \times 10^{-6} \text{ cm}^{-2}$.

$$(1) A_{th} = A_{bare} - 1. 08 A_{cad} - \left(\frac{CR-1. 08}{CR} \right) A_{BG}$$

(2) A_{BG} from Experiment II-23.

Experiment III-4

7" Lattice
1. 36" Slugs

Wet Uranium
BF₃ #19

a = 103. 5"
Sources displaced $\pm 25. 96''$

Slot	Cm above L of Source Plane	Pile Neutron BG	A _{th} (1)	Cadmium Ratio	C _e	C _h
10	87. 00	225	39, 953	26. 94	1. 0057	1. 0226
12	104. 78	231	31, 153	26. 86	1. 0096	1. 0114
14	122. 56	233	23, 858	26. 76	1. 0164	1. 0058
16	140. 34	224	18, 358	26. 79	1. 0280	1. 0030
18	158. 12	215	13, 882	26. 09	1. 0481	1. 0016
20	175. 90	194	10, 246	27. 01	1. 0839	1. 0008
22	193. 68	179	7, 606	27. 94	1. 1502	1. 0004
24	211. 46	148	5, 214	26. 08	1. 2826	1. 0002

Corrections calculated with B₁₁ of 68. 00 cm.

Relaxation length (B₁₁) of 1, 1 harmonic from least squares analysis: 68. 58 cm.

Buckling: $72. 98 \times 10^{-6} \text{ cm}^{-2}$.

$$(1) A_{th} = A_{bare} - A_{cad} - A_{BG}$$

Experiment III-8

7" Lattice
1.36" Slugs

Wet Uranium
Cylindrical Indium Foils

a = 103.5"
Sources displaced $\pm 25.96''$

Slot	Cm above $\bar{L}$ of Source Plane	Pile Neutron BG ⁽²⁾	A _{th} ⁽¹⁾	Cadmium Ratio	C _e	C _h
10	87.00	84	15,277	5.80	1.0057	1.0226
12	104.78	86	11,974	5.83	1.0096	1.0114
14	122.56	87	9,242	5.87	1.0164	1.0058
16	140.34	84	7,028	5.77	1.0280	1.0030
18	158.12	80	5,254	5.65	1.0481	1.0016
20	175.90	72	3,886	5.64	1.0839	1.0008
22	193.68	67	2,872	5.65	1.1502	1.0004
24	211.46	55	2,004	5.62	1.2826	1.0002

Corrections calculated with B₁₁ of 68.00 cm.

Relaxation length (B₁₁) of 1,1 harmonic from least squares analysis: 68.18 cm.

Buckling = $70.47 \times 10^{-6} \text{ cm}^{-2}$.

$$(1) A_{th} = A_{bare} - 1.08 A_{cad} - \left(\frac{CR-1.00}{CR} \right) A_{BG}$$

(2) A_{BG} as listed above is interpolated from Experiment III-4, and has been multiplied by the $\left(\frac{CR-1.00}{CR} \right)$ factor.

Experiment III-9

7" Lattice
1.36" Slugs

Wet Uranium
BF₃ #13

a = 103.5"
Sources displaced $\pm 25.96''$

Slot	Cm above $\bar{L}$ of Source Plane	Pile Neutron BG ⁽²⁾	A _{th} ⁽¹⁾	Cadmium Ratio	C _e	C _h
10	87.00	225	39,831	26.75	1.0057	1.0226
12	104.78	230	31,084	27.07	1.0096	1.0114
14	122.56	233	23,870	26.34	1.0164	1.0058
16	140.34	224	18,287	26.56	1.0280	1.0030
18	158.12	215	13,841	25.15	1.0481	1.0016
20	175.90	193	10,159	25.20	1.0839	1.0008
22	193.68	178	7,557	25.14	1.1502	1.0004
24	211.46	148	5,197	23.44	1.2826	1.0002

Corrections calculated with B₁₁ of 68.00 cm.

Relaxation length (B₁₁) of 1,1 harmonic from least squares analysis: 68.42 cm.

Buckling: $72.02 \times 10^{-6} \text{ cm}^{-2}$.

$$(1) A_{th} = A_{bare} - A_{cad} - A_{BG}$$

(2) A_{BG} interpolated from Experiment III-4.

Experiment III-12

7" Lattice
1. 36" Slugs

Wet Uranium
BF₃ #13

a = 103.5"
Sources displaced ± 25.96"

Slot	Cm above L of Source Plane	Pile Neutron BG(2)	A _{th} (1)	Cadmium Ratio	C _e	C _h
10	87.00	225	40,004	26.32	1.0057	1.0226
12	104.78	230	31,070	26.51	1.0096	1.0114
14	122.56	233	23,812	26.04	1.0164	1.0058
16	140.34	224	18,317	26.04	1.0280	1.0030
18	158.12	215	13,860	25.99	1.0481	1.0016
20	175.90	193	10,244	25.84	1.0839	1.0008
22	193.68	178	7,605	23.91	1.1502	1.0004
24	211.46	148	5,189	22.03	1.2826	1.0002

Corrections calculated with B₁₁ of 68.00 cm.
Relaxation length (B₁₁) of 1,1 harmonic from least squares analysis: 68.50 cm.
Buckling: 72.50 x 10⁻⁶ cm⁻².

(1) $A_{th} = A_{bare} - A_{cad} - A_{BG}$

(2) A_{BG} taken directly from Experiment III-9; see footnote (2) for Exp. III-9.

Experiment III-13

7" Lattice
1. 36" Slugs

Wet Uranium
Cylindrical Indium Foils

a = 103.5"
Sources displaced ± 25.96"

Slot	Cm above L of Source Plane	Pile Neutron BG(2)	A _{th} (1)	Cadmium Ratio	C _e	C _h
10	87.00	84	15,285	5.79	1.0057	1.0226
12	104.78	86	11,900	5.79	1.0096	1.0114
14	122.56	87	9,087	5.77	1.0164	1.0058
16	140.34	84	7,016	5.73	1.0280	1.0030
18	158.12	80	5,255	5.66	1.0481	1.0016

Corrections calculated with B₁₁ of 68.00 cm.
Relaxation length (B₁₁) of 1,1 harmonic from least squares analysis: 68.05 cm.
Buckling: 69.69 x 10⁻⁶ cm⁻²

(1) $A_{th} = A_{bare} - 1.08 A_{cad} - \left(\frac{CR-1.00}{CR} \right) A_{BG}$

(2) A_{BG} taken directly from Experiment III-8; see footnote (2) from Exp. III-8.

Experiment III-15

7" Lattice
1. 36" Slugs

Wet Uranium
BF₃ #13

a = 103.5"
Sources displaced $\pm 25.96''$

Slot	Cm above $\bar{L}$ of Source Plane	Pile Neutron BG(2)	A _{th} (1)	Cadmium Ratio	C _e	C _h
10	87.00	225	40,281	26.69	1.0057	1.0226
12	104.78	230	31,205	26.88	1.0096	1.0114
14	122.56	233	23,994	26.78	1.0164	1.0058
16	140.34	224	18,392	26.00	1.0280	1.0030
18	158.12	215	13,906	25.37	1.0481	1.0016
20	175.90	193	10,377	24.34	1.0839	1.0008
22	193.68	178	7,481	24.45	1.1502	1.0004
24	211.46	148	5,216	22.98	1.2826	1.0002

Corrections calculated with B₁₁ of 68.00 cm.

Relaxation length (B₁₁) of 1,1 harmonic from least squares analysis: 68.18 cm.

Buckling: $70.55 \times 10^{-6} \text{ cm}^{-2}$.

(1) $A_{th} = A_{bare} - A_{cad} - A_{BG}$

(2) A_{BG} taken directly from Experiment III-9; see footnote (2) for Exp. III-9.

Experiment III-16

7" Lattice
1. 36" Slugs

Wet Uranium
BF₃ #104

a = 103.5"
Sources displaced $\pm 25.96''$

Slot	Cm above $\bar{L}$ of Source Plane	Pile Neutron BG(2)	A _{th} (1)	Cadmium Ratio	C _e	C _h
10	87.00	24.6	4,332	23.69	1.0057	1.0226
12	104.78	25.2	3,384	23.78	1.0096	1.0114
14	122.56	25.4	2,586	22.78	1.0164	1.0058
16	140.34	24.5	1,991	22.62	1.0280	1.0030
18	158.12	24.3	1,521	22.22	1.0481	1.0016
20	175.90	21.7	1,127	21.63	1.0839	1.0008
22	193.68	20.4	811	19.23	1.1502	1.0004
24	211.46	16.7	567	16.86	1.2826	1.0002

Corrections calculated with B₁₁ of 68.00 cm.

Relaxation length (B₁₁) of 1,1 harmonic from least squares analysis: 68.52 cm.

Buckling: $72.62 \times 10^{-6} \text{ cm}^{-2}$.

(1) $A_{th} = A_{bare} - A_{cad} - A_{BG}$

(2) A_{BG} interpolated from Experiment III-4.

Experiment III-18

7" Lattice
1.36" Slugs

Wet Uranium
Flat Indium Foils (3/4" diam)

$a = 103.5''$
Sources displaced $\pm 25.96''$

Slot	Cm above E of Source Plane	Pile Neutron BG(2)	$A_{th}(1)$	Cadmium Ratio	C_e	C_h
10	87.00	12.6	2,209	5.12	1.0057	1.0226
12	104.78	13.0	1,725	5.01	1.0096	1.0114
14	122.56	13.1	1,352	5.14	1.0164	1.0058
16	140.34	12.6	1,020	5.03	1.0280	1.0030
18	158.12	12.1	763	4.74	1.0481	1.0016

Corrections calculated with B_{11} of 68.00 cm.
Relaxation length (B_{11}) of 1,1 harmonic from least squares analysis: 68.37 cm.
Buckling: $71.71 \times 10^{-6} \text{ cm}^{-2}$.

$$(1) A_{th} = A_{bare} - 1.08 A_{cad} - \left(\frac{CR-1.00}{CR} \right) A_{BG}$$

(2) A_{BG} interpolated from Experiment III-8; see footnote (2) for Exp. III-8.

Experiment III-23 (I)

7" Lattice
1.36" Slugs

Dry Uranium
 BF_3 #19

$a = 103.5''$
Sources displaced $\pm 25.96''$

Slot	Cm above E of Source Plane	Pile Neutron BG(2)	$A_{th}(1)$	Cadmium Ratio	C_e	C_h
10	87.00	217	35,765	22.31	1.0061	1.0221
12	104.78	213	27,962	22.22	1.0103	1.0111
14	122.56	195	21,648	21.82	1.0174	1.0056
16	140.34	195	16,557	22.44	1.0295	1.0029
18	158.12	195	12,501	22.01	1.0504	1.0015
20	175.90	80	9,275	21.98	1.0874	1.0008
22	193.68	159	6,775	21.73	1.1554	1.0004
24	211.46	128	6,751	22.52	1.2906	1.0002

Corrections calculated from B_{11} of 69.00 cm.
Relaxation length (B_{11}) of 1,1 harmonic from least squares analysis: 69.06 cm.
Buckling = $75.93 \times 10^{-6} \text{ cm}^{-2}$.

$$(1) A_{th} = A_{bare} - A_{cad} - A_{BG}$$

Experiment III-23 (II)

7" Lattice
1.36" Slugs

Dry Uranium
BF₃ #19

$a = 103.5''$
Sources displaced $\pm 25.96''$

Slot	Cm above L of Source Plane	Pile Neutron BG(2)	$A_{th}(1)$	Cadmium Ratio(3)	C_e	C_h
10	87.00	217	35,662	22.25	1.0061	1.0221
12	104.78	213	27,950	22.21	1.0103	1.0111
14	122.56	195	21,508	21.68	1.0174	1.0056
16	140.34	195	16,400	22.24	1.0295	1.0029
18	158.12	195	12,531	22.06	1.0504	1.0015
20	175.90	180	9,280	21.99	1.0874	1.0008
22	193.68	159	6,822	21.87	1.1554	1.0004
24	211.46	128	4,740	22.48	1.2906	1.0002

Corrections calculated with B_{11} of 69.00 cm.
Relaxation length (B_{11}) of 1,1 harmonic from least squares analysis: 69.29 cm.
Buckling: $77.36 \times 10^{-6} \text{ cm}^{-2}$.

(1) $A_{th} = A_{bare} - A_{cad} - A_{BG}$

(2) A_{BG} taken from Experiment III-23 (I).

(3) A_{cad} taken from Experiment III-23 (I).

Experiment III-25

7" Lattice
1.36" Slugs

Dry Uranium
Cylindrical Indium Foils

$a = 103.5''$
Sources displaced $\pm 25.96''$

Slot	Cm above L of Source Plane	Pile Neutron BG(2)	$A_{th}(1)$	Cadmium Ratio	C_e	C_h
10	87.00	80	13,805	5.02	1.0061	1.0221
12	104.78	79	10,894	5.06	1.0103	1.0111
14	122.56	72	8,385	5.01	1.0174	1.0056
16	140.34	72	6,372	4.96	1.0295	1.0029
18	158.12	72	4,763	4.83	1.0504	1.0015
20	175.90	67	3,561	4.88	1.0874	1.0008
22	193.68	59	2,572	4.77	1.1554	1.0004
24	211.46	48	1,782	4.65	1.2906	1.0002

Corrections calculated from B_{11} of 69.00 cm.
Relaxation length (B_{11}) of 1,1 harmonic from least squares analysis: 67.91 cm.
Buckling: $68.75 \times 10^{-6} \text{ cm}^{-2}$.

(1) $A_{th} = A_{bare} - 1.08 A_{cad} - A_{BG}$

(2) A_{BG} calculated from BF₃ ratios; Experiment III-26.

Experiment III-26

7" Lattice
1. 36" Slugs

Dry Uranium
BF₃ #10

a = 103.5"
Sources displaced $\pm 25.96''$

Slot	Cm above L of Source Plane	Pile Neutron BG	A _{th} (1)	Cadmium Ratio	C _e	C _h
10	87.00	217	35,963	22.29	1.0061	1.0221
12	104.78	213	27,941	22.54	1.0103	1.0111
14	122.56	195	21,585	22.26	1.0174	1.0056
16	140.34	195	16,480	21.66	1.0295	1.0029
18	158.12	195	12,512	21.97	1.0504	1.0015
20	175.90	180	9,370	22.09	1.0874	1.0008
22	193.68	159	6,757	21.88	1.1554	1.0004
24	211.46	128	4,765	22.31	1.2906	1.0002

Corrections calculated with B₁₁ of 69.00 cm.

Relaxation length (B₁₁) of 1,1 harmonic from least squares analysis: 69.11 cm.

Buckling: $76.24 \times 10^{-6} \text{ cm}^{-2}$.

$$(1) A_{th} = A_{bare} - A_{cad} - A_{BG}$$

Experiment III-31

7" Lattice
1. 36" Slugs

Dry Uranium
BF₃ #104

a = 103.5"
Sources displaced $\pm 25.96''$

Slot	Cm above L of Source Plane	Pile Neutron BG(2)	A _{th} (1)	Cadmium Ratio(3)	C _e	C _h
10	87.00	23.8	3,876		1.0061	1.0221
12	104.78	23.4	3,011		1.0103	1.0111
14	122.56	21.4	2,349		1.0174	1.0056
16	140.34	21.4	1,813		1.0295	1.0029
18	158.12	21.5	1,368		1.0504	1.0015
20	175.90	19.8	1,006		1.0874	1.0008
22	193.68	17.5	732		1.1554	1.0004
24	211.46	14.1	519		1.2906	1.0002

Corrections calculated with B₁₁ of 69.00 cm.

Relaxation length (B₁₁) of 1,1 harmonic from least squares analysis: 69.28 cm.

Buckling: $77.29 \times 10^{-6} \text{ cm}^{-2}$.

$$(1) A_{th} = A_{bare} - A_{cad} - A_{BG}$$

(2) A_{BG} interpolated from Experiment III-26.

(3) A_{cad} calculated from Experiment III-23 (I) and Experiment III-26.

Experiment III-32

7" Lattice
1.36" Slugs

Dry Uranium
Cylindrical Indium Foils

$a = 103.5''$
Sources displaced $\pm 25.96''$

Slot	Cm above Σ of Source Plane	Pile Neutron BG(2)	$A_{th}(1)$	Cadmium Ratio	C_e	C_h
10	87.00	80	13,805	5.07	1.0061	1.0221
12	104.78	79	10,812	4.96	1.0103	1.0111
14	122.56	72	8,304	4.96	1.0174	1.0056
16	140.34	72	6,140	4.86	1.0295	1.0029
18	158.12	72	4,798	4.83	1.0504	1.0015
20	175.90	67	3,471	4.07	1.0874	1.0008
22	193.68	59	2,564	4.63	1.1554	1.0004
24	211.46	48	1,770	4.67	1.2906	1.0002

Corrections calculated from B_{11} of 69.00 cm.
Relaxation length of 1,1 harmonic from least squares analysis: 67.82 cm.
Buckling: $68.20 \times 10^{-6} \text{ cm}^{-2}$

(1) $A_{th} = A_{bare} - 1.08 A_{cad} - A_{BG}$

(2) A_{BG} interpolated from Experiment III-26.

Experiment III-34

7" Lattice
1.36" Slugs

Dry Uranium
 BF_3 #104

$a = 103.5''$
Sources displaced $\pm 25.96''$

Slot	Cm above Σ of Source Plane	Pile Neutron BG(2)	$A_{th}(1)$	Cadmium Ratio	C_e	C_h
10	87.00	23.8	3,881	20.20	1.0061	1.0221
13	104.78	23.4	2,998	20.06	1.0103	1.0111
14	122.56	21.4	2,362	19.52	1.0174	1.0056
16	140.34	21.4	1,792	18.94	1.0295	1.0029
18	158.12	21.5	1,365	18.35	1.0504	1.0015
20	175.90	19.8	1,012	18.55	1.0874	1.0008
22	193.68	17.5	741	17.17	1.1554	1.0004
24	211.46	14.1	531	15.75	1.2906	1.0002

Corrections calculated with B_{11} of 69.00 cm.
Relaxation length (B_{11}) of 1,1 harmonic from least squares analysis: 69.27 cm.
Buckling: $77.21 \times 10^{-6} \text{ cm}^{-2}$.

(1) $A_{th} = A_{bare} - A_{cad} - A_{BG}$

(2) A_{BG} interpolated from Experiment III-26.

Experiment III-35

7" Lattice
1.36" Slugs

Dry Uranium
BF₃ #21

a = 103.5"
Sources displaced ± 25.96"

Slot	Cm above $\bar{L}$ of Source Plane	Pile Neutron BG(2)	A _{th} (1)	Cadmium Ratio	C _e	C _h
10	87.00	217	35,823	22.28	1.0061	1.0221
12	104.78	213	27,890	22.17	1.0103	1.0111
14	122.56	195	21,667	22.71	1.0174	1.0056
16	140.34	195	16,453	21.77	1.0295	1.0029
18	158.12	195	12,433	21.12	1.0504	1.0015
20	175.90	180	9,384	21.99	1.0874	1.0008
22	193.68	159	6,764	21.57	1.1554	1.0004
24	211.46	128	4,704	20.73	1.2906	1.0002

Corrections calculated with B₁₁ of 69.00 cm.

Relaxation length (B₁₁) of 1,1 harmonic from least squares analysis:

68.93 cm. (68.70 cm for slots 10-18).

Buckling: 75.16 x 10⁻⁶ cm⁻² (73.77 cm for slots 10-18).

(1) $A_{th} = A_{bare} - A_{cad} - A_{BG}$

(2) A_{BG} taken from Experiment III-26.

Experiment III-36

7" Lattice
1.36" Slugs

Dry Uranium
BF₃ #10

a = 103.5"
Sources displaced ± 25.96"

Slot	Cm above $\bar{L}$ of Source Plane	Pile Neutron BG(2)	A _{th} (1)	Cadmium Ratio	C _e	C _h
10	87.00	217	36,022	22.61	1.0061	1.0221
12	104.78	213	28,158	22.89	1.0103	1.0111
14	122.56	195	21,607	22.98	1.0174	1.0056
16	140.34	195	16,425	22.60	1.0295	1.0029
18	158.12	195	12,530	22.30	1.0504	1.0015
20	175.90	180	9,431	22.99	1.0874	1.0008
22	193.68	159	6,806	22.09	1.1554	1.0004
24	211.46	128	4,723	22.54	1.2906	1.0002

Corrections calculated with B₁₁ of 69.00 cm.

Relaxation length (B₁₁) of 1,1 harmonic from least squares analysis: 68.94 cm.

Buckling: 75.19 x 10⁻⁶ cm⁻².

(1) $A_{th} = A_{bare} - A_{cad} - A_{BG}$

(2) A_{BG} taken from Experiment III-26.

Experiment III-37

7" Lattice
1.36" Slugs

Dry Uranium
BF₃ #10

a = 103.5"
Sources displaced ± 25.96"

Slot	Cm above L of Source Plane	Pile Neutron BG(2)	A _{th} (1)	Cadmium Ratio	C _e	C _h
10	87.00	227	37,534	21.96	1.0061	1.0221
12	104.78	223	29,209	22.47	1.0103	1.0111
14	122.56	204	22,621	22.17	1.0174	1.0056
16	140.34	204	17,232	21.53	1.0295	1.0029
18	158.12	204	13,211	21.72	1.0504	1.0015

Corrections calculated with B₁₁ of 69.00 cm.

Relaxation length (B₁₁) of 1,1 harmonic from least squares analysis: 69.46 cm.

Buckling: 78.34 x 10⁻⁶ cm⁻².

(1) A_{th} = A_{bare} - A_{cad} - A_{BG}.

(2) A_{BG} interpolated from Experiment III-26.

Experiment IV-5

7-1/2" Lattice
1.36" Slugs

Dry Uranium
BF₃ #103

Four neutron sources located at x = 0, ± $\frac{a}{4}$; y = 0, ± $\frac{b}{4}$ with a total neutron emission of about 2.6 x 10⁷ neutrons/second, where a and b are the effective widths of the pile.

Slot	Cm above L of Source Plane	Pile Neutron BG	A _{th} (1)	Cadmium Ratio	C _e	C _h
11	73.02	20	5,119	24.68	1.0057	1.0352
14	92.08	21	4,013	25.01	1.0096	1.0164
17	111.12	21	3,119	24.43	1.0164	1.0077
20	130.18	21	2,351	24.25	1.0279	1.0037
23	149.22	20	1,781	24.39	1.0480	1.0018
26	168.28	19	1,329	25.07	1.0837	1.0009
29	187.32	18	962	25.48	1.1497	1.0004
32	206.38	17	667	24.52	1.2816	1.0002

Corrections calculated with B₁₁ of 72.90 cm.

Relaxation length (B₁₁) of 1,1 harmonic from least squares analysis: 72.59 cm.

Buckling = 98.63 x 10⁻⁶ cm⁻².

(1) A_{th} = A_{bare} - A_{cad} - $\left(\frac{CR-1.00}{CR}\right) A_{BG}$.

Experiment IV-6

7-1/2" Lattice
1.36" Slugs

Dry Uranium
BF₃ #15

Four neutron sources located at $x = 0, \pm \frac{a}{4}$; $y = 0, \pm \frac{b}{4}$ with a total neutron emission of about 2.6×10^7 neutrons/second, where a and b are the effective widths of the pile.

Slot	Cm above E. of Source Plane	Pile Neutron BG	A _{th} (1)	Cadmium Ratio	C _e	C _h
11	73.02	242	61,925	25.92	1.0057	1.0352
14	92.08	249	48,659	26.11	1.0096	1.0164
17	111.12	255	37,692	26.42	1.0164	1.0077
20	130.18	250	28,804	26.55	1.0279	1.0037
23	149.22	245	21,793	26.33	1.0480	1.0018
26	168.28	227	16,273	26.82	1.0837	1.0009
29	187.32	208	11,813	26.52	1.1497	1.0004
32	206.38	169	8,149	26.21	1.2816	1.0002

Corrections calculated with B₁₁ of 72.90 cm.

Relaxation length (B₁₁ of 1,1 harmonic from least squares fit: 73.24 cm.

Buckling: $101.97 \times 10^{-6} \text{ cm}^{-2}$.

$$(1) A_{th} = A_{bare} - A_{cad} - \left(\frac{CR-1.00}{CR} \right) A_{BG}.$$

Experiment IV-12

7-1/2" Lattice
1.36" Slugs

Dry Uranium
Fission Chamber

Four neutron sources located at $x = 0, \pm \frac{a}{4}, y = 0, \pm \frac{b}{4}$ with a total neutron emission of about 2.6×10^7 neutrons/second, where a and b are the effective widths of the pile.

Slot	Cm above L of Source Plane	Pile Neutron BG ⁽²⁾	A _{th} ⁽¹⁾	Cadmium Ratio	C _e	C _h
11	73.02	5.4	1,095	19.88	1.0057	1.0352
14	92.08	5.4	858	21.01	1.0096	1.0164
17	111.12	5.4	658	20.32	1.0164	1.0077
20	130.18	5.3	505	20.70	1.0279	1.0037
23	149.22	5.3	385	20.00	1.0480	1.0018
26	168.28	5.2	287	18.91	1.0837	1.0009
29	187.32	5.1	209	19.93	1.1497	1.0004
32	206.38	4.5	145	20.44	1.2816	1.0002

Corrections calculated with B₁₁ of 72.90 cm.

Relaxation length (B₁₁) of 1,1 harmonic from least squares fit: 73.59 cm.

Buckling = $103.73 \times 10^{-6} \text{ cm}^{-2}$.

$$(1) A_{th} = A_{bare} - A_{cad} - \left(\frac{CR-1.00}{CR} \right) A_{BG}$$

(2) Calculated from BF₃ ratios.

Experiment IV-13

7-1/2" Lattice
1.36" Slugs

Dry Uranium
Flat Indium Foils

Four neutron sources located at $x = 0, \pm \frac{a}{4}$, $y = 0, \pm \frac{b}{4}$ with a total neutron emission of about 2.6×10^7 neutrons/second, where a and b are the effective widths of the pile.

Slot	Cm above E of Source Plane	Pile Neutron BG	$A_{th}(1)$	Cadmium Ratio	C_e	C_h
11	73.02	110	24,293	4.83	1.0057	1.0352
14	92.08	115	19,143	4.83	1.0096	1.0164
17	111.12	121	14,891	4.90	1.0164	1.0077
20	130.18	118	11,285	4.85	1.0279	1.0037
23	149.22	114	8,547	4.83	1.0480	1.0018
26	168.28	105	6,391	4.79	1.0837	1.0009
29	187.32	94	4,630	4.81	1.1497	1.0004
32	206.38	80	3,195	4.79	1.2816	1.0002

Corrections calculated with B_{11} of 72.90 cm.

Relaxation length (B_{11}) of 1,1 harmonic from least squares fit: 73.10 cm.

Buckling = $101.23 \times 10^{-6} \text{ cm}^{-2}$.

$$(1) A_{th} = A_{bare} - 1.08 A_{cad} - \left(\frac{CR - 1.08}{CR} \right) A_{BG}$$

Experiment IV-14

7-1/2" Lattice
1.36" Slugs

Dry Uranium
Cylindrical Indium Foils

Four neutron sources located at $x = 0, \pm \frac{a}{4}, y = 0, \pm \frac{b}{4}$ with a total neutron emission of about 2.6×10^7 neutrons/second, where a and b are the effective widths of the pile.

Slot	Cm above L of Source Plane	Pile Neutron BG(2)	$A_{th}(1)$	Cadmium Ratio	C_e	C_h
11	73.02	99	22,528	5.64	1.0057	1.0352
14	92.08	103	18,044	5.74	1.0096	1.0164
17	111.12	108	13,806	5.65	1.0164	1.0077
20	130.18	106	10,614	5.66	1.0279	1.0037
23	149.22	102	7,991	5.67	1.0480	1.0018
26	168.28	94	5,906	5.68	1.0837	1.0009
29	187.32	84	4,327	5.67	1.1497	1.0004
32	206.31	71	2,990	5.70	1.2816	1.0002

Corrections calculated with B_{11} of 72.90 cm.

Relaxation length (B_{11}) of 1,1 harmonic from least squares fit: 73.11 cm.

Buckling = $101.32 \times 10^{-6} \text{ cm}^{-2}$.

$$(1) A_{th} = A_{bare} - 1.08 A_{cad} - \left(\frac{CR - 1.08}{CR} \right) A_{BG}$$

(2) A_{BG} interpolated from flat indium foils.

Experiment IV-15

7-1/2" Lattice
1.36" Slugs

Dry Uranium
Flat Gold Foils
(wt: 4.8 gms ~6 mil)

Four neutron sources located at $x = 0, \pm \frac{a}{4}$, $y = 0, \pm \frac{b}{4}$ with a total neutron emission of about 2.6×10^7 neutrons/second, where a and b are the effective widths of the pile.

Slot	Cm above L of Source Plane	Pile Neutron BG(2)	$A_{th}(1)$	Cadmium Ratio	C_e	C_h
11	73.02	46	9,498	4.03	1.0057	1.0352
14	92.08	52	7,333	3.99	1.0096	1.0164
17	111.12	49	5,739	4.07	1.0164	1.0077
23	149.22	46	3,287	4.06	1.0480	1.0018
26	168.28	43	2,479	4.12	1.0837	1.0009
29	187.32	39	1,784	4.05	1.1497	1.0004

Corrections calculated with B_{11} of 72.90 cm.

Relaxation length (B_{11}) of 1,1 harmonic from least squares analysis: 72.99 cm.

Buckling = $100.69 \times 10^{-6} \text{ cm}^{-2}$.

(1) $A_{th} = A_{bare} - A_{cad} - \left(\frac{CR-1.00}{CR} \right) A_{BG}$

(2) A_{BG} interpolated from thin gold foils (Experiment IV-16).

Experiment IV-16

7-1/2" Lattice
1.36" Slugs

Dry Uranium
Flat Gold Foils
(wt: 3.67 gms ~ 4.7 mil)

Four neutron sources located at $x = 0, \pm \frac{a}{4}$, $y = 0, \pm \frac{b}{4}$ with a total neutron emission of about 2.6×10^7 neutrons/second, where a and b are the effective widths of the pile.

Slot	Cm above L of Source Plane	Pile Neutron BG	$A_{th}(1)$	Cadmium Ratio	C_e	C_h
11	73.02	50	9,778	4.02	1.0057	1.0352
14	92.08	55	7,675	4.10	1.0096	1.0164
17	111.12	50	5,972	4.15	1.0164	1.0077
20	130.18	49	4,568	4.17	1.0279	1.0037
23	149.22	47	3,442	4.25	1.0480	1.0018
26	168.28	47	2,539	4.18	1.0837	1.0009
29	187.32	42	1,841	4.12	1.1497	1.0004
32	206.38	34	1,293	4.22	1.2816	1.0002

Corrections calculated with B_{11} of 72.90 cm.

Relaxation length (B_{11}) of 1,1 harmonic from least squares analysis: 72.96 cm.

Buckling = $100.52 \times 10^{-6} \text{ cm}^{-2}$.

$$(1) A_{th} = A_{bare} - A_{cad} - \left(\frac{CR-1.00}{CR} \right) A_{BG}$$

Experiment IV-21

7-1/2" Lattice
1. 36" Slugs

Wet Uranium
Flat Gold Foils

Four neutron sources located at $x = 0, \pm \frac{a}{4}$, $y = 0, \pm \frac{b}{4}$ with a total neutron emission of about 2.6×10^7 neutrons/second, where a and b are the effective widths of the pile.

Slot	Cm above E of Source Plane	Pile Neutron BG(2)	$A_{th}(1)$	Cadmium Ratio	C_e	C_h
11	73.02	47	10,169	4.55	1.0048	1.0367
14	92.08	50	7,843	4.52	1.0082	1.0171
17	111.12	50	5,976	(3)	1.0142	1.0081
20	130.18	50	4,520	4.52	1.0246	1.0039
23	149.22	48	3,434	4.53	1.0430	1.0019
26	168.28	45	2,518	(3)	1.0762	1.0009
29	187.32	40	1,802	4.44	1.1383	1.0005
32	206.38	33	1,254	4.50	1.2637	1.0002

Corrections calculated with B_{11} of 70.50 cm.

Relaxation length (B_{11}) of 1,1 harmonic from least squares analysis: 70.11 cm.

Buckling: $84.98 \times 10^{-6} \text{ cm}^{-2}$.

$$(1) A_{th} = A_{bare} - A_{cad} - \frac{CR-1.00}{CR} A_{BG}$$

(2) A_{BG} interpolated from BF_3 .

(3) A_{cad} calculated from avg CR at these points.

Experiment IV-22

7-1/2" Lattice
• 1.36" Slugs

Wet Uranium
Cylindrical Indium Foils

Four neutron sources located at $x = 0, \pm \frac{a}{4}$, $y = 0, \pm \frac{b}{4}$ with a total neutron emission of about 2.6×10^7 neutrons/second, where a and b are the effective widths of the pile.

Slot	Cm above L of Source Plane	Pile Neutron BG	$A_{th}(1)$	Cadmium Ratio	C_e	C_h
11	73.02	98	23,469	6.56	1.0048	1.0367
14	92.08	111	18,339	6.59	1.0082	1.0171
17	111.12	110	14,163	6.62	1.0142	1.0081
20	130.18	109	10,555	6.56	1.0246	1.0039
23	149.22	106	7,994	6.60	1.0430	1.0019
26	168.28	102	5,873	6.53	1.0762	1.0009
29	187.32	87	4,248	6.53	1.1383	1.0005
32	206.38	73	2,900	6.59	1.2637	1.0002

Corrections calculated with B_{11} of 70.50 cm.

Relaxation length (B_{11}) of 1,1 harmonic from least squares analysis: 70.17 cm.

Buckling: $85.28 \times 10^{-6} \text{ cm}^{-2}$.

$$(1) A_{th} = A_{bare} - 1.08 A_{cad} - \frac{CR-1.08}{CR} A_{BG}$$

Experiment IV-23

7-1/2" Lattice
1.36" Slugs

Wet Uranium
BF₃ #22

Four neutron sources located at $x = 0, \pm \frac{a}{4}$; $y = 0, \pm \frac{b}{4}$ with a total neutron emission of about 2.6×10^7 neutrons/second, where a and b are the effective widths of the pile.

Slot	Cm above L of Source Plane	Pile Neutron BG	A _{th} (1)	Cadmium Ratio	C _e	C _h
11	73.02	243	65,266	31.47	1.0048	1.0367
14	92.08	258	50,624	31.53	1.0082	1.0171
17	111.12	263	38,893	31.19	1.0142	1.0081
20	130.18	262	29,448	31.36	1.0246	1.0039
23	149.22	249	21,975	31.31	1.0430	1.0019
26	168.28	236	16,288	31.16	1.0762	1.0009
29	187.32	207	11,739	31.28	1.1383	1.0005
32	206.38	173	8,074	31.59	1.2637	1.0002

Corrections calculated with B₁₁ of 70.50 cm.

Relaxation length (B₁₁) of 1,1 harmonic from least squares analysis: 70.22 cm.

Buckling: $85.56 \times 10^{-6} \text{ cm}^{-2}$.

$$(1) A_{th} = A_{bare} - A_{cad} - \left(\frac{CR - 1.00}{CR} \right) A_{BG}$$

Experiment V-1

6-3/16" Lattice
1.36" Slugs

Dry Uranium
BF₃ #31

a = 98" b = 99"
Sources displaced ± 24.5", ± 24.75"

Slot	Cm above L of Source Plane	Pile Neutron BG	A _{th} (l)	Cadmium Ratio	C _e	C _h
7	55.01	143	41,848	17.03	1.0009	1.0840
9	70.72	151	32,945	17.17	1.0016	1.0441
11	86.44	159	25,256	17.15	1.0029	1.0235
13	102.16	162	19,418	17.28	1.0050	1.0127
15	117.87	160	14,683	17.12	1.0088	1.0070
17	133.59	156	11,089	17.27	1.0155	1.0039
19	149.30	154	8,311	17.34	1.0274	1.0021
21	165.02	146	6,181	17.47	1.0489	1.0012
23	180.74	130	4,489	17.22	1.0887	1.0007

Corrections calculated with B₁₁ of 56.40 cm.

Relaxation length (B₁₁) of 1,1 harmonic from least squares analysis: 56.48 cm.
Buckling: 1.86 x 10⁻⁶ cm⁻².

$$(1) A_{th} = A_{bare} - A_{cad} - \left(\frac{CR-1.00}{CR} \right) A_{BG}$$

Experiment V-2

6-3/16" Lattice
1.36" Slugs

Dry Uranium
Cylindrical Indium Foils

a = 98" b = 99"
Sources displaced ± 24.5", ± 24.75"

Slot	Cm above L of Source Plane	Pile Neutron BG	A _{th} (l)	Cadmium Ratio	C _e	C _h
7	55.00	69	15,703	4.11	1.0009	1.0840
9	70.72	72	12,233	4.10	1.0016	1.0441
11	86.44	77	9,555	4.15	1.0029	1.0235
13	102.16	77	7,238	4.13	1.0050	1.0127
15	117.87	76	5,460	4.12	1.0088	1.0070
17	133.59	74	4,114	4.11	1.0155	1.0039
19	149.30	73	3,091	4.14	1.0274	1.0021
21	165.02	69	2,322	4.18	1.0489	1.0012
23	180.78	62	1,689	4.18	1.0887	1.0007

Corrections calculated with B₁₁ of 56.40 cm.

Relaxation length (B₁₁) of 1,1 harmonic from least squares analysis: 56.501 cm.
Buckling: 2.12 x 10⁻⁶ cm⁻².

$$(1) A_{th} = A_{bare} - 1.08 A_{cad} - \left(\frac{CR-1.08}{CR} \right) A_{BG}$$

Experiment V-8

6-3/16" Lattice
1.36" Slugs

Wet Uranium
BF₃ #10

a = 98" b = 99"
Sources displaced ± 24.5", ± 24.75"

Slot	Cm above $\bar{L}$ of Source Plane	Pile Neutron BG	A _{th} (1)	Cadmium Ratio	C _e	C _h
7	55.01	187	52,392	21.54	1.0013	1.0788
9	70.72	199	41,734	21.42	1.0023	1.0410
11	86.44	209	32,577	21.62	1.0038	1.0217
13	102.16	213	25,213	21.50	1.0065	1.0116
15	117.87	211	19,343	21.68	1.0112	1.0063
17	133.59	210	14,751	22.02	1.0191	1.0035
19	149.30	202	11,121	21.41	1.0329	1.0019
21	165.02	188	8,292	20.91	1.0573	1.0010
23	180.78	172	6,201	21.14	1.1014	1.0006

Corrections calculated with B₁₁ of 59.30 cm.

Relaxation length (B₁₁) of 1,1 harmonic from least squares analysis: 59.22 cm.
Buckling = 30.19 x 10⁻⁶ cm⁻².

$$(1) A_{th} = A_{bare} - A_{cad} - \frac{CR-1.00}{CR} A_{BG}$$

Experiment V-12

6-3/16" Lattice
1.36" Slugs

Wet Uranium
Cylindrical Indium Foils

a = 98" b = 99"
Sources displaced ± 24.5", ± 24.75"

Slot	Cm above $\bar{L}$ of Source Plane	Pile Neutron BG	A _{th} (1)	Cadmium Ratio	C _e	C _h
7	55.01	85	19,605	4.83	1.0013	1.0787
9	70.72	90	15,402	4.86	1.0023	1.0410
11	86.44	94	12,033	4.76	1.0038	1.0217
13	102.16	97	9,397	4.87	1.0065	1.0116
15	117.87	96	7,189	4.93	1.0112	1.0063
17	133.59	95	5,459	4.95	1.0191	1.0035
19	149.30	92	4,147	4.90	1.0329	1.0019
21	165.02	86	3,100	4.90	1.0573	1.0011
23	180.74	78	2,303	4.95	1.1014	1.0006

Corrections calculated with B₁₁ of 59.30 cm.

Relaxation length (B₁₁) of 1,1 harmonic from least squares analysis: 59.29 cm.
Buckling = 30.91 x 10⁻⁶ cm⁻².

$$(1) A_{th} = A_{bare} - 1.08 A_{cad} - \frac{CR-1.08}{CR} A_{BG}$$

Experiment VI-1

7-1/2" Lattice
0.926" Slugs

Dry Uranium
BF₃ #3

Four neutron sources located at $x = 0, \pm \frac{a}{4}$; $y = 0, \pm \frac{b}{4}$, with a total neutron emission of about 2.6×10^7 neutrons/second, where a and b are the effective widths of the pile.

Slot	Cm above L of Source Plane	Pile Neutron BG	$A_{th}^{(1)}$	Cadmium Ratio	C_e	C_h
11	73.02	158	82,474	43.37	1.0053	1.0357
14	92.08	167	64,309	43.28	1.0091	1.0166
17	111.12	167	49,507	43.32	1.0155	1.0079
20	130.18	167	37,796	43.48	1.0266	1.0038
23	149.22	159	28,545	43.53	1.0461	1.0019
26	168.28	152	21,178	43.45	1.0809	1.0009
29	187.32	135	15,307	43.51	1.1454	1.0004
32	206.38	119	10,533	42.91	1.2748	1.0002

Corrections calculated with B_{11} of 72.00 cm.

Relaxation length (B_{11}) of 1,1 harmonic from least squares analysis: 71.90 cm.

Buckling: $94.97 \times 10^{-6} \text{ cm}^{-2}$.

$$(1) A_{th} = A_{bare} - A_{cad} - \left(\frac{CR-1}{CR} \right) A_{BG}$$

Experiment VI-5

7-1/2" Lattice
0.926" Slugs

Dry Uranium
Fission Chamber

Four neutron sources located at $x = 0, \pm \frac{a}{4}$; $y = 0, \pm \frac{b}{4}$ with a total neutron emission of about 2.6×10^7 neutrons/second, where a and b are the effective widths of the pile.

Slot	Cm above E of Source Plane	Pile Neutron BG(2)	$A_{th}(1)$	Cadmium Ratio	C_e	C_h
11	73.02	4.1	2,127	36.57	1.0053	1.0357
14	92.08	4.3	1,664		1.0091	1.0166
17	111.12	4.3	1,280	36.26	1.0155	1.0079
20	130.18	4.3	970		1.0266	1.0038
23	149.22	Not Measured			1.0461	1.0019
26	168.28	3.9	546		1.0809	1.0009
29	187.32	3.5	395		1.1454	1.0004
32	206.38	3.1	274		1.2748	1.0002

Corrections calculated with B_{11} of 72.00 cm.

Relaxation length (B_{11}) of 1,1 harmonic from least squares analysis: 72.02 cm.

Buckling: $95.59 \times 10^{-6} \text{ cm}^{-2}$.

$$(1) A_{th} = A_{bare} - A_{cad} - \left(\frac{\overline{CR} - 1.00}{\overline{CR}} \right) A_{BG}, \text{ where } A_{cad} = \frac{A_{bare}}{\overline{CR}}; \text{ where } \overline{CR} = 36.72 \text{ (weighted)}$$

(2) A_{BG} interpolated from Experiment VI-1.

Experiment VI-6

7-1/2" Lattice
0.926" Slugs

Wet Uranium
BF₃ #3

Four neutron sources located at $x = 0, \pm \frac{a}{4}$; $y = 0, \pm \frac{b}{4}$ with a total neutron emission of about 2.6×10^7 neutrons/second, where a and b are the effective widths of the pile.

Slot	Cm above E of Source Plane	Pile Neutron BG	$A_{th}(1)$	Cadmium Ratio	C_e	C_h
11	73.02	151	78,969	47.03	1.0037	1.0390
14	92.08	160	60,592	47.69	1.0065	1.0183
17	111.12	162	45,610	47.47	1.0115	1.0088
20	130.18	162	34,315	47.35	1.0204	1.0043
23	149.22	156	25,538	47.78	1.0365	1.0021
26	168.28	148	18,655	47.19	1.0663	1.0010
29	187.32	133	13,351	47.56	1.1230	1.0005
32	206.38	111	9,107	46.03	1.2395	1.0003

Corrections calculated with B_{11} of 67.20 cm.

Relaxation length (B_{11}) of 1,1 harmonic from least squares analysis: 67.12 cm.

Buckling: $66.43 \times 10^{-6} \text{ cm}^{-2}$.

$$(1) A_{th} = A_{bare} - A_{cad} - \left(\frac{CR-1.00}{CR} \right) A_{BG}$$

Experiment VII-1

6-3/16" Lattice
0.926" Slugs

Dry Uranium
BF₃ #1

a = 98" b = 99"
Sources displaced ± 24.5", ± 24.75"

Slot	Cm above L of Source Plane	Pile Neutron BG	A _{th} (1)	Cadmium Ratio	C _e	C _h
7	55.01	151	82,371	29.18	1.0038	1.0642
9	70.72	161	67,936	29.59	1.0060	1.0326
11	86.44	169	55,092	29.45	1.0094	1.0168
13	102.16	169	44,309	29.74	1.0147	1.0088
15	117.87	168	35,291	29.76	1.0231	1.0046
17	133.59	169	27,915	29.78	1.0366	1.0025
19	149.30	166	21,948	29.82	1.0583	1.0013
21	165.02	150	16,967	29.85	1.0942	1.0007
23	180.74	138	12,833	29.56	1.1554	1.0004

Corrections calculated from B₁₁ of 70.50 cm.

Relaxation length (B₁₁) of 1,1 harmonic from least squares analysis: 70.64 cm.

Buckling: 114.98 x 10⁻⁶ cm⁻².

$$(1) A_{th} = A_{bare} - A_{cad} - \left(\frac{\overline{CR} - 1.00}{\overline{CR}} \right) A_{BG}, \text{ where } A_{cad} = \frac{A_{bare}}{\overline{CR}}, \text{ where } \overline{CR} = 29.64.$$

Experiment VII-5

6-3/16" Lattice
0.926" Slugs

Dry Uranium
Fission Chamber

a = 98" b = 99"
Sources displaced ± 24.5", ± 24.75"

Slot	Cm above L of Source Plane	Pile Neutron BG(2)	A _{th} (1)	Cadmium Ratio	C _e	C _h
7	55.00	3.8	2,034	20.66	1.0038	1.0642
9	70.72	4.0	1,671		1.0060	1.0326
11	86.44	4.2	1,353		1.0094	1.0168
13	102.16	4.3	1,100		1.0147	1.0088
15	117.87	4.2	861	20.81	1.0231	1.0046
17	133.59	4.2	684		1.0366	1.0025
19	149.30	4.1	537		1.0583	1.0013
21	165.02	3.7	412		1.0942	1.0007
23	180.74	3.5	318		1.1554	1.0004

Corrections calculated with B₁₁ of 70.50 cm.

Relaxation length (B₁₁) of 1,1 harmonic from least squares analysis: 70.48 cm.

(omitting Slot 13)

Buckling: 114.06 x 10⁻⁶ cm⁻² (omitting Slot 13).

$$(1) A_{th} = A_{bare} - A_{cad} - \left(\frac{\overline{CR} - 1.00}{\overline{CR}} \right) A_{BF}, \text{ where } A_{cad} = \frac{A_{bare}}{\overline{CR}}, \text{ and } \overline{CR} = 20.73.$$

(2) A_{BG} interpolated from Experiment VII-1.

Experiment VII-6

6-3/16" Lattice
0.926" Slugs

Wet Uranium
BF₃ #3

a = 98" b = 99"
Sources displaced ± 24.5", ± 24.75"

Slot	Cm above L of Source Plane	Pile Neutron BG	A _{th} (1)	Cadmium Ratio	C _e	C _h
7	55.01	159	83,432	32.95	1.0030	1.0671
9	70.72	164	68,356	32.94	1.0049	1.0343
11	86.44	172	55,276	33.03	1.0077	1.0177
13	102.16	175	43,931	32.75	1.0124	1.0093
15	117.87	172	34,852	33.46	1.0198	1.0049
17	133.59	172	27,272	33.81	1.0319	1.0027
19	149.30	169	21,241	33.27	1.0517	1.0014
21	165.02	153	16,364	33.34	1.0847	1.0008
23	180.74	141	12,249	32.73	1.1418	1.0004

Corrections calculated with B₁₁ of 67.80 cm.

Relaxation length (B₁₁) of 1,1 harmonic from least squares analysis: 67.86 cm.

Buckling: 98.19 x 10⁻⁶ cm⁻².

$$(1) A_{th} = A_{bare} - A_{cad} - \left(\frac{CR-1.00}{CR} \right) A_{BG}, \text{ where } A_{cad} = \frac{A_{bare}}{CR}, \text{ and } CR = 33.10$$

Experiment VIII-1

6-3/16" Lattice
1.66" Solid Slugs

Dry Uranium
BF₃ #3

a = 98" b = 99"
Sources displaced ± 24.5", ± 24.75"

Slot	Cm above L of Source Plane	Pile Neutron BG	A _{th} (1)	Cadmium Ratio	C _e	C _h
7	55.01	147	24,617	12.78	1.0002	1.1105
9	70.72	148	18,142	12.92	1.0004	1.0598
11	86.44	149	13,296	12.62	1.0008	1.0330
13	102.16	153	9,598	12.49	1.0016	1.0185
15	117.87	151	6,868	12.65	1.0031	1.0105
17	133.59	155	4,905	12.70	1.0061	1.0060
19	149.30	148	3,508	12.81	1.0121	1.0035
21	165.02	140	2,443	12.40	1.0243	1.0020
23	180.74	127	1,702	12.31	1.0491	1.0012

Corrections calculated with B₁₁ of 46.20 cm.

Relaxation length (B₁₁) of 1,1 harmonic from least squares analysis: 46.26 cm.

(omitting Slots 7 and 19)

Buckling: -151.93 x 10⁻⁶ cm⁻² (omitting Slots 7 and 19).

$$(1) A_{th} = A_{bare} - A_{cad} - \left(\frac{CR-1.00}{CR} \right) A_{BG}, \text{ where } A_{cad} = \frac{A_{bare}}{CR}, \text{ and } CR = 12.63.$$

Experiment VIII-4

6-3/16" Lattice
1.66" Solid Slugs

Dry Uranium
Cylindrical Indium Foils

a = 98" b = 99"
Sources displaced $\pm 24.5"$, $\pm 24.75"$

Slot	Cm above E of Source Plane	Pile Neutron BG(Z)	A _{th} (1)	Cadmium Ratio	C _e	C
7	55.01	76	9,377	3.32	1.0002	1.1105
9	70.72	76	6,888		1.0004	1.0598
11	86.44	77	5,038		1.0008	1.0330
13	102.16	79	3,645		1.0016	1.0185
15	117.87	78	2,598	3.39	1.0031	1.0105
17	133.59	79	1,850		1.0061	1.0060
19	149.30	75	1,308		1.0121	1.0035
21	165.02	71	909		1.0243	1.0020

Corrections calculated with B₁₁ of 46.20 cm.

Relaxation length (B₁₁) of 1,1 harmonic from least squares analysis: 46.09 cm.
(omitting Slots 7 and 21)

Buckling: $-155.42 \times 10^{-6} \text{ cm}^{-2}$ (omitting Slots 7 and 21)

$$(1) A_{th} = A_{bare} - 1.08 A_{cad} - \left(\frac{\overline{CR} - 1.08}{\overline{CR}} \right) A_{BG}, \text{ where } A_{cad} = \frac{A_{bare}}{\overline{CR}}, \text{ and } \overline{CR} = 3.35.$$

(2) A_{BG} interpolated from Experiment VIII-1.

Experiment VIII-5

6-3/16" Lattice - 12-3/8" Loading
1.66" Solid Slugs

Dry Uranium
BF₃ #3

a = 98" b = 99"
Sources displaced ± 24.5", ± 24.75"

Slot	Cm above L of Source Plane	Pile Neutron BG	A _{th} (1)	Cadmium Ratio	C _e	C _h
7	55.01	183	115,717	52.87	1.0023	1.0707
9	70.72	171	82,997	51.70	1.0038	1.0364
11	86.44	204	75,656	55.28	1.0062	1.0190
13	102.16	176	52,765	51.69	1.0101	1.0100
15	117.87	198	46,800	54.98	1.0165	1.0054
17	133.59	172	32,254	52.27	1.0270	1.0029
19	149.30	194	27,973	55.26	1.0446	1.0016
21	165.02	159	18,942	51.91	1.0746	1.0009
23	180.74	158	15,988	55.60	1.1270	1.0005

Slots 7, 11, 15, 19, and 23:

Corrections calculated with B₁₁ of 64.80 cm.

Relaxation length (B₁₁) of 1,1 harmonic from least squares analysis:

64.56 cm. (omitting Slot 7)

Buckling: 75.45 x 10⁻⁶ cm⁻² (omitting Slot 7)

Slots 9, 13, 17, and 21:

Corrections calculated with B₁₁ of 64.80 cm.

Relaxation length (B₁₁) of 1,1 harmonic from least squares analysis:

64.70 cm. (omitting Slot 9)

Buckling: 76.47 x 10⁻⁶ cm⁻² (omitting Slot 9)

Average:

Corrections calculated with B₁₁ of 64.80 cm.

Relaxation length (B₁₁) of 1,1 harmonic from least squares analysis:

64.63 cm. (omitting Slots 7 and 9).

Buckling: 75.96 x 10⁻⁶ cm⁻² (omitting Slots 7 and 9)

(1) $A_{th} = A_{bare} - A_{cad} - \left(\frac{\overline{CR} - 1.00}{\overline{CR}} \right) A_{BG}$, where $A_{cad} = \frac{A_{bare}}{\overline{CR}}$ and:

$\overline{CR}$ (Slots 11, 15, 19, and 23) = 55.28 and

$\overline{CR}$ (Slots 9, 13, 17, and 21) = 51.89.

Experiment VIII-6

6-3/16" Lattice
1.66" Hollow Slugs - 0.81" Hole

Dry Uranium
BF₃ #3

a = 98" b = 99"
Sources displaced ± 24.5", ± 24.75"

Slot	Cm above E of Source Plane	Pile Neutron BG	A _{th} (1)	Cadmium Ratio	C _e	C _h
7	55.01	123	31,299	14.07	1.0005	1.0957
9	70.72	131	23,882	14.54	1.0008	1.0510
11	86.44	135	17,904	14.10	1.0016	1.0276
13	102.16	144	13,401	14.23	1.0029	1.0152
15	117.87	142	9,840	14.18	1.0054	1.0085
17	133.59	138	7,247	14.49	1.0101	1.0048
19	149.30	138	5,308	14.37	1.0188	1.0027
21	165.02	126	3,849	14.35	1.0352	1.0015
23	180.74	118	2,741	14.22	1.0672	1.0009

Corrections calculated with B₁₁ of 51.15 cm.

Relaxation length (B₁₁) of 1,1 harmonic from least squares analysis: 51.17 cm.

Buckling: -66.51 x 10⁻⁶ cm⁻².

(1) $A_{th} = A_{bare} - A_{cad} - \frac{(CR-1.00)}{\overline{CR}} A_{BG}$, where $A_{cad} = \frac{A_{bare}}{CR}$, and $\overline{CR} = 14.28$.

Experiment VIII-8

6-3/16" Lattice 12-3/8" Spacing
1.66" Hollow Slugs 0.81" Hole

Dry Uranium
BF₃ #3

a = 98" b = 99"
Sources displaced ± 24.5", ± 24.75"

Slot	Cm above L of Source Plane	Pile Neutron BG	A _{th} (1)	Cadmium Ratio	C _e	C _h
7	55.01	137	111,901	58.66	1.0018	1.0748
9	70.72	126	79,760	54.33	1.0027	1.0388
11	86.44	148	71,293	58.95	1.0047	1.0204
13	102.16	135	49,571	55.86	1.0080	1.0109
15	117.87	146	43,163	59.35	1.0133	1.0058
17	133.59	131	29,617	54.46	1.0225	1.0032
19	149.30	139	25,383	59.63	1.0382	1.0018
21	165.02	120	17,106	56.44	1.0647	1.0010
23	180.74	119	14,105	58.18	1.1127	1.0005

Slots 7, 11, 15, 19, and 23:

Corrections calculated with B₁₁ of 61.80 cm.

Relaxation length (B₁₁) of 1,1 harmonic from least squares analysis:

61.34 cm. (omitting Slot 7)

Buckling: 49.62 x 10⁻⁶ cm⁻² (omitting Slot 7).

Slots 9, 13, 17, and 21:

Corrections calculated with B₁₁ of 61.80 cm.

Relaxation length (B₁₁) of 1,1 harmonic from least squares analysis:

61.68 cm. (omitting Slot 9).

Buckling: 52.53 x 10⁻⁶ cm⁻² (omitting Slot 9).

Average:

Corrections calculated with B₁₁ of 61.80 cm.

Relaxation length (B₁₁) of 1,1 harmonic from least squares analysis:

61.51 cm. (omitting Slots 7 and 9)

Buckling: 51.07 x 10⁻⁶ cm⁻² (omitting Slots 7 and 9).

$$(1) A_{th} = A_{bare} - A_{cad} - \left(\frac{CR-1.00}{\overline{CR}} \right) A_{BG}, \text{ where } A_{cad} = \frac{A_{bare}}{\overline{CR}}, \text{ and:}$$

$$\overline{CR} (\text{Slots 7, 11, 15, 19, and 23}) = 58.95$$

$$\text{and } \overline{CR} (\text{Slots 9, 13, 17, and 21}) = 55.27$$

Experiment VIII-9

6-3/16" Lattice
1.66" Hollow Slugs - 0.81" Hole

Wet Uranium
BF₃ #3

a = 98" b = 99"
Sources displaced ± 24.5", ± 24.75"

Slot	Cm above L of Source Plane	Pile Neutron BG	A _{th} (1)	Cadmium Ratio	C _e	C _h
7	55.01	138	33,764	15.51	1.0005	1.0929
9	70.72	146	25,794	15.41	1.0010	1.0495
11	86.44	155	19,565	15.27	1.0018	1.0264
13	102.16	165	14,712	15.39	1.0033	1.0145
15	117.87	157	10,888	15.88	1.0061	1.0081
17	133.59	152	8,030	15.57	1.0111	1.0045
19	149.16	148	5,900	15.45	1.0205	1.0026
21	165.02	136	4,293	15.62	1.0381	1.0015
23	180.74	130	3,082	15.74	1.0715	1.0008

Corrections calculated with B₁₁ of 52.30 cm.

Relaxation length (B₁₁) of 1,1 harmonic from least squares analysis: 52.11 cm.
(omitting Slots 9 and 13)

Buckling: -52.83 x 10⁻⁶ cm⁻² (omitting Slots 9 and 13)

$$(1) A_{th} = A_{bare} - A_{cad} - \left(\frac{\overline{CR} - 1.00}{\overline{CR}} \right) A_{BG}, \text{ where } A_{cad} = \frac{A_{bare}}{\overline{CR}} \text{ and } \overline{CR} = 15.54.$$

Experiment VIII-11

6-3/16" Lattice (12-3/8" Spacing
1.66" Hollow Slugs 0.81" Hole

Wet Uranium
BF₃ #3

a = 98" b = 99"
Sources displaced ± 24.5", ± 24.75"

Slot	Cm above L of Source Plane	Pile Neutron BG	A _{th} (1)	Cadmium Ratio	C _e	C _h
7	55.01	124	108,770	60.05	1.0013	1.0788
9	70.72	120	77,739	56.50	1.0023	1.0410
11	86.44	141	68,208	61.05	1.0038	1.0217
13	102.16	127	47,441	56.80	1.0065	1.0116
15	117.87	142	40,662	59.39	1.0112	1.0063
17	133.59	117	27,848	56.33	1.0191	1.0035
19	149.16	125	23,631	61.50	1.0329	1.0019
21	165.02	116	15,832	57.40	1.0573	1.0010
23	180.74	113	12,979	60.30	1.1014	1.0006

Slots 7, 11, 15, 19, and 23:

Corrections calculated with B₁₁ of 59.30 cm.

Relaxation length (B₁₁) of 1,1 harmonic from least squares analysis:
59.73 cm.

Buckling: 35.04 x 10⁻⁶ cm⁻².

Slots 9, 13, 17, and 21:

Corrections calculated with B₁₁ of 59.30 cm.

Relaxation length (B₁₁) of 1,1 harmonic from least squares analysis:
59.76 cm.

Buckling: 35.39 x 10⁻⁶ cm⁻².

Average:

Corrections calculated with B₁₁ of 59.30 cm.

Relaxation length (B₁₁) of 1,1 harmonic from least squares analysis:
59.74 cm.

Buckling: 35.21 x 10⁻⁶ cm⁻².

$$(1) A_{th} = A_{bare} - A_{cad} - \left(\frac{\overline{CR} - 1.00}{\overline{CR}} \right) A_{BG}, \text{ where } A_{cad} = \frac{A_{bare}}{\overline{CR}},$$

and $\overline{CR}$ (Slots 7, 11, 15, 19, and 23) = 60.46

and $\overline{CR}$ (Slots 9, 13, 17, and 21) = 56.76

Experiment IX-1

7-1/2" Lattice
1.66" Solid Slugs

Dry Uranium
BF₃ #3

Four neutron sources located at $x = 0, \pm \frac{a}{4}, y = 0, \pm \frac{b}{4}$ with a total neutron emission of about 2.6×10^7 neutrons/second, where a and b are the effective widths of the pile.

Slot	Cm above L of Source Plane	Pile Neutron BG	A _{th} (1)	Cadmium Ratio	C _e	C _h
11	73.02	316	48,272	19.25	1.0040	1.0388
14	92.08	324	36,877	19.26	1.0070	1.0180
17	111.12	326	28,366	19.55	1.0123	1.0086
20	130.18	333	21,394	19.35	1.0216	1.0042
23	149.22	312	15,991	19.64	1.0384	1.0021
26	168.28	301	11,669	19.20	1.0692	1.0010
29	187.32	274	8,372	18.93	1.1276	1.0005
32	206.38	242	5,713	18.21	1.2468	1.0003

Corrections calculated with B₁₁ of 68.20 cm.

Relaxation length (B₁₁) of 1,1 harmonic from least squares analysis:

68.15 cm. (omitting Slots 14 and 23)

Buckling: $73.11 \times 10^{-6} \text{ cm}^{-2}$ (omitting Slots 14 and 23)

(1) $A_{th} = A_{bare} - A_{cad} - \left(\frac{\overline{CR} - 1.00}{\overline{CR}} \right) A_{BG}$, where $A_{cad} = \frac{A_{bare}}{\overline{CR}}$, and $\overline{CR} = 19.35$ (weighted)

Experiment IX-3

7-1/2" Lattice
1.66" Solid Slugs

Dry Uranium
Cylindrical Indium Foils

Four neutron sources located at $x = 0, \pm \frac{a}{4}, y = 0, \pm \frac{b}{4}$ with a total neutron emission of about 2.6×10^7 neutrons/second, where a and b are the effective widths of the pile.

Slot	Cm above L of Source Plane	Pile Neutron BG(2)	$A_{th}(1)$	Cadmium Ratio	C_e	C_h
11	73.02	146	18,077	4.64	1.0040	1.0383
14	92.08	151	13,910		1.0070	1.0180
17	111.12	150	10,571		1.0123	1.0086
20	130.18	153	7,949		1.0216	1.0042
23	149.22	142	5,898	4.64	1.0384	1.0021
26	168.28	139	4,350		1.0692	1.0010
29	187.32	126	3,102		1.1276	1.0005
32	206.38	111	3,123		1.2468	1.0003

Corrections calculated with B_{11} of 68.20 cm.

Relaxation length (B_{11}) of 1,1 harmonic from least squares analysis: 67.89 cm.

Buckling: $71.46 \times 10^{-6} \text{ cm}^{-2}$.

(1) $A_{th} = A_{bare} - 1.08 A_{cad} - \left(\frac{CR-1.08}{\overline{CR}} \right) A_{BG}$, where $A_{cad} = \frac{A_{bare}}{\overline{CR}}$, and $\overline{CR} = 4.64$

(2) A_{BG} interpolated from Experiment IX-1.

Experiment IX-4

7-1/2" Lattice (15" Spacing)
1.66" Solid Slugs

Dry Uranium
BF₃ #3

Four neutron sources located at $x = 0, \pm \frac{a}{4}$, $y = 0, \pm \frac{b}{4}$ with a total neutron emission of about 2.6×10^7 neutrons/second, where a and b are the effective widths of the pile.

Slot	Cm above $\bar{L}$ of Source Plane	Pile Neutron BG	$A_{th}(1)$	Cadmium Ratio	C_e	C_h
11	73.02	129	85,012	75.86	1.0016	1.0472
14	92.08	142	60,383	74.30	1.0030	1.0228
17	111.12	136	46,101	79.15	1.0058	1.0112
20	130.18	136	31,675	74.44	1.0112	1.0056
23	149.22	136	23,837	77.08	1.0218	1.0029
26	168.28	125	16,081	74.30	1.0426	1.0015
29	187.32	118	11,656	78.03	1.0852	1.0008
32	206.38	94	7,255	72.90	1.1776	1.0004

Slots 11, 17, 23, and 29:

Corrections calculated with B_{11} of 58.40 cm.

Relaxation length (B_{11}) of 1,1 harmonic from least squares analysis:
58.54 cm.

Buckling: $-3.44 \times 10^{-6} \text{ cm}^{-2}$.

Slots 14, 20, 26 and 32:

Corrections calculated with B_{11} of 58.40 cm.

Relaxation length (B_{11}) of 1,1 harmonic from least squares analysis:
58.37 cm (omitting Slot 23).

Buckling: $-5.10 \times 10^{-6} \text{ cm}^{-2}$ (omitting Slot 23)

Average:

Corrections calculated with B_{11} of 58.40 cm.

Relaxation length (B_{11}) of 1,1 harmonic from least squares analysis:
58.45 cm. (omitting Slot 23)

Buckling: $-4.27 \times 10^{-6} \text{ cm}^{-2}$ (omitting Slot 23).

$$(1) A_{th} = A_{bare} - A_{cad} - \left(\frac{CR-1.00}{CR} \right) A_{BG}$$

Experiment IX-5

7-1/2" Lattice

Dry Uranium

1.66" Hollow Slugs 0.81" Hole

BF₃ #3

Four neutron sources located at $x = 0, \pm \frac{a}{4}$, $y = 0, \pm \frac{b}{4}$ with a total neutron emission of about 2.6×10^7 neutrons/second, where a and b are the effective widths of the pile.

Slot	Cm above L of Source Plane	Pile Neutron BG	A _{th} (1)	Cadmium Ratio	C _e	C _h
11	73.02	259	55,389	22.10	1.0057	1.0352
14	92.08	266	43,212	22.15	1.0096	1.0164
17	111.12	267	33,347	21.98	1.0164	1.0077
20	130.18	267	25,488	21.69	1.0279	1.0037
23	149.22	250	19,182	21.96	1.0480	1.0018
26	168.28	233	14,310	21.94	1.0837	1.0009
29	187.32	213	10,341	21.75	1.1497	1.0004
32	206.38	171	7,150	21.85	1.2816	1.0002

Corrections calculated with B₁₁ of 72.90 cm.

Relaxation length (B₁₁) of 1,1 harmonic from least squares analysis:
72.45 cm.

Buckling: $97.89 \times 10^{-6} \text{ cm}^{-2}$.

(1) $A_{th} = A_{bare} - A_{cad} - \left(\frac{\overline{CR} - 1.00}{\overline{CR}} \right) A_{BG}$, where $A_{cad} = \frac{A_{bare}}{\overline{CR}}$, and $\overline{CR} = 21.93$.

Experiment IX-7

7-1/2" Lattice
1.66" Hollow Slugs 0.81" Hole

Dry Uranium
Cylindrical Indium Foils

Four neutron sources located at $x = 0, \pm \frac{a}{4}, y = 0, \pm \frac{b}{4}$ with a total neutron emission of about 2.6×10^7 neutrons/second, where a and b are the effective widths of the pile.

Slot	Cm above L of Source Plane	Pile Neutron BG ⁽²⁾	A _{th} (1)	Cadmium Ratio	C _e	C _h
11	73.02	115	20,224	4.94	1.0057	1.0352
17	111.12	119	12,197		1.0164	1.0077
23	149.22	112	7,046	4.93	1.0480	1.0018
29	187.32	95	3,785		1.1497	1.0004

Corrections calculated with B₁₁ of 72.90 cm.

Relaxation length (B₁₁) of 1,1 harmonic from least squares analysis: 72.54 cm.

Buckling: $98.36 \times 10^{-6} \text{ cm}^{-2}$.

$$(1) A_{th} = A_{bare} - 1.08 A_{cad} - \left(\frac{\overline{CR} - 1.08}{\overline{CR}} \right) A_{BG}, \text{ where } A_{cad} = \frac{A_{bare}}{\overline{CR}} \text{ and } \overline{CR} = 4.94.$$

(2) A_{BG} interpolated from Experiment IX-5.

Experiment IX-8

7-1/2" Lattice (15" Spacing)
1.66" Hollow Slugs 0.81" Hole

Dry Uranium
BF₃ # L-2

Four neutron sources located at $x = 0, \pm \frac{a}{4}$, $y = 0, \pm \frac{b}{4}$ with a total neutron emission of about 2.6×10^7 neutrons/second, where a and b are the effective widths of the pile.

Slot	Cm above L of Source Plane	Pile Neutron BG	$A_{th}(l)$	Cadmium Ratio	C_e	C_h
11	73.02	92	83,114	82.46	1.0021	1.0502
14	92.08	94	58,887	78.95	1.0023	1.0244
17	111.12	101	43,988	83.13	1.0046	1.0121
20	130.18	98	30,143	79.47	1.0092	1.0061
23	149.22	94	22,211	81.67	1.0184	1.0031
26	168.28	89	14,914	78.25	1.0370	1.0016
29	187.32	82	10,618	82.99	1.0757	1.0008
32	206.38	68	6,620	76.68	1.1615	1.0004

Slots 11, 17, 23, and 29:

Corrections calculated with B_{11} of 56.00 cm.

Relaxation length (B_{11}) of 1,1 harmonic from least squares analysis:
56.19 cm.

Buckling: $-28.34 \times 10^{-6} \text{ cm}^{-2}$.

Slots 14, 20, 26, and 32:

Corrections calculated with B_{11} of 56.00 cm.

Relaxation length (B_{11}) of 1,1 harmonic from least squares analysis:
55.95 cm (omitting Slot 32)

Buckling: $-31.02 \times 10^{-6} \text{ cm}^{-2}$ (omitting Slot 32).

Average:

Corrections calculated with B_{11} of 56.00 cm.

Relaxation length (B_{11}) of 1,1 harmonic from least squares analysis:
56.07 cm (omitting Slot 32)

Buckling: $-29.68 \times 10^{-6} \text{ cm}^{-2}$ (omitting Slot 32).

$$(1) A_{th} = A_{bare} - A_{cad} \left(\frac{\overline{CR} - 1.00}{\overline{CR}} \right) A_{BG}, \text{ where } A_{cad} = \frac{A_{bare}}{\overline{CR}}, \text{ and}$$

$\overline{CR}$ (Slots 11, 17, 23, and 29) = 82.56
and $\overline{CR}$ (Slots 14, 20, 26, and 32) = 78.89 (omitting Slot 32)

Experiment IX-9

7-1/2" Lattice

Wet Uranium

1.66" Hollow Slugs 0.81" Hole

BF₃ #3

Four neutron sources located at $x = 0, \pm \frac{a}{4}$, $y = 0, \pm \frac{b}{4}$ with a total neutron emission of about 2.6×10^7 neutrons/second, where a and b are the effective widths of the pile.

Slot	Cm above L of Source Plane	Pile Neutron BG	$A_{th}(1)$	Cadmium Ratio	C_e	C_h
11	73.02	248	55,642	23.38	1.0053	1.0357
14	92.08	265	43,180	23.12	1.0091	1.0166
17	111.12	269	33,265	23.14	1.0155	1.0079
20	130.18	268	25,264	22.89	1.0266	1.0038
23	149.22	255	18,996	23.33	1.0461	1.0019
26	168.28	235	14,118	22.97	1.0809	1.0009
29	187.32	219	10,202	23.18	1.1454	1.0004
32	206.38	173	7,038	23.22	1.2748	1.0002

Corrections calculated with B_{11} of 72.00 cm.

Relaxation length (B_{11}) of 1,1 harmonic from least squares analysis:

71.48 cm.

Buckling: $92.66 \times 10^{-6} \text{ cm}^{-2}$

$$(1) A_{th} = A_{bare} - A_{cad} - \left(\frac{CR-1.00}{CR} \right) A_{BG}, \text{ where } A_{cad} = \frac{A_{bare}}{CR}, \text{ and } CR = 23.15$$

Experiment IX-11

7-1/2" Lattice (15" Spacing)
1. 66" Hollow Slugs 0.81" Hole

Wet Uranium
BF₃ #3

Four neutron sources located at $x = 0, \pm \frac{a}{4}$, $y = 0, \pm \frac{b}{4}$ with a total neutron emission of about 2.6×10^7 neutrons/second, where a and b are the effective widths of the pile.

Slot	Cm above L of Source Plane	Pile Neutron BG	$A_{th}(1)$	Cadmium Ratio	C_e	C_h
11	73.02	93	79,574	84.47	1.0010	1.0515
14	92.08	99	56,003	82.60	1.0021	1.0252
17	111.12	102	41,519	83.98	1.0042	1.0126
20	130.18	100	38,298	80.40	1.0085	1.0064
23	149.22	103	20,786	86.15	1.0171	1.0033
26	168.28	91	13,842	76.96	1.0347	1.0017
29	187.32	85	9,882	81.27	1.0719	1.0009
32	206.38	69	6,054	78.41	1.1550	1.0005

Slots 11, 17, 23, and 29:

Corrections calculated with B_{11} of 55.00 cm.

Relaxation length (B_{11}) of 1,1 harmonic from least squares analysis:
55.30 cm.

Buckling: $-38.57 \times 10^{-6} \text{ cm}^{-2}$.

Slots 14, 20, 26, and 32

Corrections calculated with B_{11} of 55.00 cm.

Relaxation length (B_{11}) of 1,1 harmonic from least squares analysis:
54.87 cm. (omitting Slot 32).

Buckling: $-43.81 \times 10^{-6} \text{ cm}^{-2}$ (omitting Slot 32).

Average:

Corrections calculated with B_{11} of 55.00 cm.

Relaxation length (B_{11}) of 1,1 harmonic from least squares analysis:
55.08 cm. (omitting Slot 32).

Buckling: $-41.18 \times 10^{-6} \text{ cm}^{-2}$ (omitting Slot 32).

$$(1) A_{th} = A_{bare} - A_{cad} - \left(\frac{\overline{CR} - 1.00}{\overline{CR}} \right) A_{BG}, \text{ where } A_{cad} = \frac{A_{bare}}{\overline{CR}}$$

and $\overline{CR}$ (Slots 11, 17, 23, and 29) = 83.97.

and $\overline{CR}$ (Slots 14, 20, 26, and 32) = 79.57

Experiment X-1

6-3/16" Lattice
1.17" Slugs

Dry Uranium
BF₃ #3

a = 98" b = 99"
Sources displaced ± 24.5", ± 24.75"

Slot	Cm above L of Source Plane	Pile Neutron BG	A _{th} (1)	Cadmium Ratio	C _e	C _h
7	55.01	188	58,593	20.71	1.0023	1.0707
9	70.72	201	47,098	20.54	1.0038	1.0364
11	86.44	195	37,749	20.32	1.0062	1.0190
13	102.16	201	29,862	20.49	1.0101	1.0100
15	117.87	211	23,387	20.30	1.0165	1.0054
17	133.59	207	18,198	20.30	1.0270	1.0029
19	149.30	206	14,064	20.00	1.0446	1.0016
21	165.02	188	10,684	20.37	1.074	1.0009
23	180.74	169	8.017	19.87	1.1270	1.0005

Corrections calculated with B₁₁ of 64.80 cm.

Relaxation length (B₁₁) of 1,1 harmonic from least squares analysis: 64.79 cm. (omitting Slot 9)

Buckling: 77.17 x 10⁻⁶ cm⁻² (omitting Slot 9)

(1) $A_{th} = A_{bare} - A_{cad} \left(\frac{\overline{CR} - 1.00}{\overline{CR}} \right) A_{BG}$, where $A_{cad} = \frac{A_{bare}}{\overline{CR}}$, and $\overline{CR} = 20.32$.

Experiment X-3

6-3/16" Lattice
1.17" Slugs

Dry Uranium
Cylindrical Indium Foils

a = 98" b = 99"
Sources displaced $\pm 24.5"$, $\pm 24.75"$

Slot	Cm above L of Source Plane	Pile Neutron BG(2)	A _{th} (1)	Cadmium Ratio	C _e	C _h
7	55.01	85	21,546	4.74	1.0023	1.0707
9	70.72	91	17,262		1.0038	1.0364
11	86.44	89	13,941		1.0062	1.0190
13	102.16	91	11,020		1.0101	1.0100
15	117.87	96	8,590	4.69	1.0165	1.0054
17	133.59	94	6,697		1.0270	1.0029
19	149.30	93	5,132		1.0446	1.0016
21	165.02	84	3,878		1.0746	1.0009

Corrections calculated with B₁₁ of 64.80 cm.

Relaxation length (B₁₁) of 1.1 harmonic from least squares analysis:

64.64 cm. (omitting Slots 9 and 21).

Buckling: $76.01 \times 10^{-6} \text{ cm}^{-2}$ (omitting Slots 9 and 21).

(1) $A_{th} = A_{bare} - 1.08 A_{cad} - \left(\frac{CR-1.08}{CR} \right) A_{BG}$, where $A_{cad} = \frac{A_{bare}}{CR}$ and $CR = 4.71$

(2) A_{BG} interpolated from Experiment X-1.

Experiment X-6

6-3/16" Lattice
1.17" Slugs

Wet Uranium
BF₃ #L-2

a = 98" b = 99"
Sources displaced ± 24.5", ± 24.75"

Slot	Cm above Σ of Source Plane	Pile Neutron BG	A _{th} (1)	Cadmium Ratio	C _e	C _h
7	55.01	195	66,294	24.12	1.0025	1.0698
9	70.72	212	54,327	24.58	1.0039	1.0358
11	86.44	220	43,437	24.34	1.0065	1.0187
13	102.16	226	34,570	24.93	1.0106	1.0099
15	117.87	216	27,062	24.82	1.0173	1.0053
17	133.59	224	21,107	24.71	1.0283	1.0028
19	149.30	209	16,304	24.35	1.046	1.0015
21	165.02	197	12,472	24.62	1.0768	1.0008
23	180.74	181	9,393	1.1307	1.1307	1.0005

Corrections calculated with B₁₁ of 65.50 cm.

Relaxation length (B₁₁) of 1,1 harmonic from least squares analysis: 65.74 cm. (omitting Slots 7 and 13).

Buckling: $83.95 \times 10^{-6} \text{ cm}^{-2}$ (omitting Slots 7 and 13).

$$(1) A_{th} = A_{bare} A_{cad} - \left(\frac{\overline{CR} - 1.00}{\overline{CR}} \right) A_{BG}, \text{ where } A_{cad} = \frac{A_{bare}}{\overline{CR}}, \text{ and } \overline{CR} = 24.52.$$

Experiment XI-1

7-1/2" Lattice
1.17" Slugs

Dry Uranium
BF₃ #3

Four neutron sources located at $x = 0, \pm \frac{a}{4}$, $y = 0, \pm \frac{b}{4}$ with a total neutron emission of about 2.6×10^7 neutrons/second, where a and b are the effective widths of the pile.

Slot	Cm above L of Source Plane	Pile Neutron BG	$A_{th}(1)$	Cadmium Ratio	C_e	C_h
11	73.02	232	75,763	29.01	1.0077	1.0328
14	92.08	235	59,681	28.55	1.0126	1.0150
17	111.12	249	46,943	28.38	1.0208	1.0070
20	130.18	237	36,381	28.86	1.0345	1.0033
23	149.22	238	27,823	28.19	1.0577	1.0016
26	168.28	217	20,919	28.14	1.0981	1.0008
29	187.32	197	15,346	27.00	1.1713	1.0004
32	206.38	154	10,724	26.55	1.3149	1.0002

Corrections calculated with B_{11} of 77.30 cm.

Relaxation length (B_{11}) of 1,1 harmonic from least squares analysis: 77.47 cm.

Buckling: $121.78 \times 10^{-6} \text{ cm}^{-2}$.

$$(1) A_{th} = A_{bare} - A_{cad} - \left(\frac{\overline{CR} - 1.00}{\overline{CR}} \right) A_{BG}, \text{ where } A_{cad} = \frac{A_{bare}}{\overline{CR}}, \text{ and } \overline{CR} =$$

28.52 (omitting Slots 21 and 23).

Experiment XI-3

7-1/2" Lattice
1.17" Slugs

Dry Uranium
Cylindrical Indium Foils

Four neutron sources located at $x = 0, \pm \frac{a}{4}$, $y = 0, \pm \frac{b}{4}$ with a total neutron emission of about 2.6×10^7 neutrons/second, where a and b are the effective widths of the pile.

Slot	Cm above E of Source Plane	Pile Neutron BG(2)	$A_{th}(1)$	Cadmium Ratio	C_e	C_h
11	73.02	96	27,170	6.61	1.0077	1.0328
14	92.08	99	21,766		1.0126	1.0150
17	111.12	104	16,951		1.0208	1.0070
20	130.18	99	13,189		1.0345	1.0033
23	149.22	100	10,068		1.0577	1.0016
26	168.28	92	7,641	6.56	1.0981	1.0008
29	187.32	82	5,554		1.1713	1.0004
32	206.38	65	3,902		1.3149	1.0002

Corrections calculated with B_{11} of 77.30 cm.

Relaxation length (B_{11}) of 1,1 harmonic from least squares analysis: 77.58 cm. (omitting Slot 11)

Buckling: $122.25 \times 10^{-6} \text{ cm}^{-2}$ (omitting Slot 11).

$$(1) A_{th} = A_{bare} - 1.08 A_{cad} \left(\frac{\overline{CR} - 1.08}{\overline{CR}} \right) A_{BG}, \text{ where } A_{cad} = \frac{A_{bare}}{\overline{CR}}, \text{ and}$$

$$\overline{CR} = 6.58.$$

(2) A_{BG} interpolated from Experiment XI-1.

Experiment XI-4

7-1/2" Lattice
1.17" Slugs

Wet Uranium
BF₃ #L-2

Four neutron sources located at $x = 0, \pm \frac{a}{4}$, $y = 0, \pm \frac{b}{4}$ with a total neutron emission of about 2.6×10^7 neutrons/second, where a and b are the effective widths of the pile.

Slot	Cm above L of Source Plane	Pile Neutron BG	$A_{th}(1)$	Cadmium Ratio	C_e	C_h
11	73.02	227	74,921	34.66	1.0057	1.0352
14	92.08	239	58,450	34.48	1.0096	1.0164
17	111.12	245	45,385	35.19	1.0164	1.0077
20	130.18	241	34,470	35.72	1.0297	1.0037
23	149.22	222	26,084	34.69	1.0480	1.0018
26	168.28	221	19,412	35.00	1.0837	1.0009
29	187.32	194	14,034	34.66	1.1497	1.0004
32	206.38	169	9,688	34.28	1.2816	1.0002

Corrections calculated with B_{11} of 72.90 cm.

Relaxation length (B_{11}) of 1,1 harmonic from least squares analysis:

72.59 cm. (omitting Slot 17)

Buckling: $98.64 \times 10^{-6} \text{ cm}^{-2}$ (omitting Slot 17)

(1) $A_{th} = A_{bare} - A_{cad} - \frac{\overline{CR} - 1.00}{\overline{CR}} A_{BG}$, where $A_{cad} = \frac{A_{bare}}{\overline{CR}}$, and $\overline{CR} = 34.84$.

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APPENDIX III

RECORD OF HORIZONTAL TRAVERSES - DRY

Lattice	Slug Size	Exp. No.	Layer	Cm Above Source Plane	Detector	Physical Size (in cm)	A (in cm)	Extrapolation Each Side (in cm)	A ₁	A ₃	A ₅	A ₇	A ₃ /A ₁ (%)	A ₅ /A ₁ (%)	A ₇ /A ₁ (%)	Method	Remarks
8-3/8"	1.36"	I-40	8	82.31	BF ₃ #13	243.84	250.19	3.17	57,032.76	-997.33	-336.12		-1.75	-0.59		Free-varying coefficients	Composite of no metal and 1.03 metal
"	"	I-48	8	82.31	BF ₃ #13	243.84	248.92	2.54	57,823.48	-1101.76	-188.07		-1.90	-0.34		Free-varying coefficients	Composite of no metal and 1.03 metal
"	"	I-49	14	146.13	BF ₃ #13	243.84	250.19	3.17	22,211.77	133.06	-281.11		+0.60	-1.27		Free-varying coefficients	Composite of no metal and 1.03 metal
8"	1.36"	II-14	II	76.84	BF ₃ #13	252.73	257.81	2.54	59,481.50	-1459.49	-252.59		-2.45	-0.42		Theoretical ratios	Composite of no metal and 1.03 metal
"	"	II-18A	II	76.84	BF ₃ #13	252.73	259.08	3.17	22,862.03	2246.87	262.91		+9.83	+1.15		Free-varying coefficients	Composite of no metal and 1.03 metal - one source
7"	1.36"	III-19	10R	87.00	BF ₃ #13	257.81	264.67	3.43	42,185.02	-887.40	-132.93		-2.10	-0.31		Theoretical ratios	Composite of no metal and 1.03 metal
"	"	III-24	10L	87.00	BF ₃ #104	257.81	262.89	2.54	4,124.25	-79.93	-3.11		-1.94	-0.07		Free-varying coefficients	Composite of no metal, 1.03 metal, and 1.011 between
"	"	III-28	18R	158.12	BF ₃ #10	257.81	263.65	2.92	12,848.38	-19.79	-0.74		-0.15	-0.00		Theoretical ratios	Composite of no metal and 1.03 metal
"	"	III-29	14R	122.56	BF ₃ #19	257.81	263.65	2.92	22,359.31	-124.26	-9.21		-0.56	-0.04		Theoretical ratios	Composite of no metal and 1.03 metal
"	"	III-30	8B	69.22	BF ₃ #104	257.81	261.62	1.90	5,156.41	-228.47	-17.26		-4.43	-0.33		Free-varying coefficients	Traverse taken parallel to the tubes
7-1/2"	1.36"	IV-7	20R	130.18	BF ₃ #15	256.54	261.62	2.54	28,866.94	-101.63	-8.27		-0.35	-0.02		Theoretical ratios	Composite of no metal and 1.03 metal
"	"	IV-8	13B	83.18	BF ₃ #15	256.54	261.62	2.54	54,216.7	-1022.7	-332.3		-1.89	-0.61		Free-varying coefficients	Traverse taken parallel to the tubes
"	"	IV-9	26	168.28	BF ₃ #101	256.54	261.62	2.54	1,332.1	-1.3	-0.05		-0.10	-0.00		Theoretical ratios	Composite of no metal, 1.03 metal, and 1.011 between
"	"	IV-10	14L	92.08	BF ₃ #101	256.54	262.89	3.17	4,079.5	-61.5	-8.2		-1.51	-0.20		Theoretical ratios	Composite of no metal, 1.03 metal, and 1.011 between
"	"	IV-10	14L	92.08	BF ₃ #101	256.54	261.62	2.54	4,088.4	-80.3	+5.8		-1.96	+0.14		Free-varying coefficients	Composite of no metal, 1.03 metal, and 1.011 between
"	"	IV-10	20L	130.18	BF ₃ #101	256.54	261.62	2.54	2,371.2	-8.4	-0.5		-0.35	-0.02		Theoretical ratios	Composite of no metal and 1.03 metal
6-3/16"	1.36"	V-3	19F	149.30	BF ₃ #315	243.84	250.19	3.17	685.19	-4.55	+3.84		-0.66	+0.56		Free-varying coefficients	Traverse taken parallel to the tubes
"	"	V-3	19F	149.30	BF ₃ #315	243.84	249.55	2.85	687.26	-9.43	-0.95	-0.003	-1.37	-0.14	0.00	Theoretical ratios	Traverse taken parallel to the tubes
"	"	V-4	13F	102.16	BF ₃ #315	243.84	250.19	3.17	1,618.41	-23.73	-0.45		-1.47	-0.03		Free-varying coefficients	Traverse taken parallel to the tubes
"	"	V-4	13F	102.16	BF ₃ #315	243.84	250.19	3.17	1,618.91	-22.57	-2.22	-0.007	-1.38	-0.14	0.00	Theoretical ratios	Traverse taken parallel to the tubes
7-1/2"	0.925"	VI-2	13F	83.18	BF ₃ #1	256.54	260.98	2.22	5,992.27	-165.01	-6.21	-22.44	-2.75	-0.10	-0.37	Free-varying coefficients	Traverse taken parallel to the tubes
"	"	VI-2	13F	83.18	BF ₃ #1	256.54	262.25	2.85	5,973.22	-147.48	23.24	+0.22	-2.47	-0.39	+0.00	Theoretical ratios	Traverse taken parallel to the tubes
"	"	VI-4	14L	92.08	BF ₃ #1	256.54	261.62	2.54	5,399.01	-97.27	-10.71	-46.25	-1.80	-0.20	-0.86	Free-varying coefficients	Composite of no metal, 1.03 metal, and 1.011 between
"	"	VI-4	14L	92.08	BF ₃ #1	256.54	262.89	3.17	5,363.57	-95.46	-12.68	0.08	-1.78	-0.24	+0.00	Theoretical ratios	Composite of no metal, 1.03 metal, and 1.011 between
6-3/16"	0.925"	VII-2	19F	149.30	BF ₃ #1	243.84	249.55	2.86	1,777.04	-8.39	-1.14	-1.39	-0.47	-0.06	-0.08	Free-varying coefficients	Traverse taken parallel to the tubes
"	"	VII-2	19F	149.30	BF ₃ #1	243.84	250.19	3.17	1,768.78	-2.73	-0.10	0.00	-0.15	-0.01	+0.00	Theoretical ratios	Traverse taken parallel to the tubes
"	"	VII-4	13F	102.16	BF ₃ #1	243.84	250.19	3.17	3,643.20	-27.23	7.89	17.53	-0.75	+0.22	+0.48	Free-varying coefficients	Traverse taken parallel to the tubes
"	"	VII-4	13F	102.16	BF ₃ #1	243.84	249.55	2.86	3,664.84	-34.88	-3.27	0.01	-0.95	-0.09	0.00	Theoretical ratios	Traverse taken parallel to the tubes
6-3/16"	1.66" solid	VIII-2	13F	102.16	BF ₃ #1	243.84	247.01	1.59	796.54	-9.24	0.46	-0.47	-1.16	-0.06	+0.06	Free-varying coefficients	Traverse taken parallel to the tubes

APPENDIX III
RECORD OF HORIZONTAL TRAVERSES WET

Lattice	Slug Size	Exp. No.	Layer	Cm Above Source Plane	Detector	Physical Size		Extrapolation Each Side					A ₃ /A ₁	A ₅ /A ₁	A ₇ /A ₁	Method	Remarks	
						(in cm)	(in cm)		A ₁	A ₃	A ₅	A ₇	(%)	(%)	(%)			
8 3/8	1 36"	I 23	8	82 31	Cyl Ind	243 84	249 71	2 93	25 182 28	318 71	129 55		1 27	0 51		Free varying coefficients		
		I 23	9	92 95	Cyl Ind	243 84	251 46	3 81	21 024 1	88 3	75 7		0 42	0 36		Free varying coefficients		
		I 33	8	82 31	BF ₃ #11	243 84	249 71	2 93	57 964 84	1498 13	102 52		2 58	0 18		Free varying coefficients	Composite of no metal and 1 03 metal	
	I 33	16	187 40	BF ₃ #11	243 84	251 46	3 81	14 588 72	29 31	26 93		0 20	+0 18		Free varying coefficients	Composite of no metal and 1 03 metal		
	I 27	8	82 31	BF ₃ #11	243 84	250 19	3 17	27 674 92	1539 76	123 72		5 56	0 45		Free varying coefficients	Composite of no metal and 1 03 metal		
	I 27	9	92 95	BF ₃ #11	243 84	249 71	2 93	26 549 52	1845 69	107 79		6 95	0 41		Free varying coefficients	Composite of no metal and 1 03 metal		
	I 30	8	82 31	BF ₃ #11	243 84	252 73	4 44	61 469 61	799 65	321 56		1 30	0 52		Free varying coefficients	Composite of no metal and 1 03 metal		
	I 30	8L	82 31	BF ₃ #11	243 84	250 19	3 17	60 918 25	1182 06	173 59		1 94	+0 28		Free varying coefficients	Composite of no metal and 1 03 metal		
	I 30	8R	82 31	BF ₃ #11	243 84	250 19	3 1	61 070 03	1217 09	79 80		1 99	+0 13		Free varying coefficients	Composite of no metal and 1 03 metal		
	I 30	9	92 95	BF ₃ #11	243 84	250 19	3 17	51 038 80	742 84	235 02		1 45	0 46		Free varying coefficients	Composite of no metal and 1 03 metal		
	I 56	8R	82 31	BF ₃ #104	243 84	249 71	2 93	6 219 94	141 54	19 05		2 28	+0 31		Free varying coefficients	Composite of no metal 1 03 metal and 1 011 between		
	I 57	12R	124 86	BF ₃ #104	243 84	249 71	2 93	3 164 22	12 32	9 48		0 39	0 30		Free varying coefficients	Composite of no metal 1 03 metal and 1 011 between		
	8"	1 36	II 25	11B	76 84	BF ₃ #16	252 73	256 62	1 94	57 586 82	1524 79	264 15		2 65	0 46		Theoretical Ratios	Traverse taken parallel to the tubes
			II 26	11R	76 84	BF ₃ #16	252 73	257 81	2 54	58 732 71	1589 48	277 52		2 71	0 47		Theoretical Ratios	Traverse taken parallel to the tubes
II 28			20R	137 80	BF ₃ #17	252 73	259 08	3 17	23 826 45	66 28	3 44		0 28	0 01		Theoretical Ratios	Traverse taken parallel to the tubes	
II 29A			11	76 84	BF ₃ #104	252 73	257 81	2 54	6 544 4	177 1	30 92		2 71	0 47		Theoretical Ratios	Traverse taken parallel to the tubes	
II 29B			11	6 84	BF ₃ #104	252 73	259 08	3 17	6 321 79	129 72	60 78		2 05	0 96		Theoretical Ratios	Traverse taken parallel to the tubes	
7"	1 36	III 7	8B	69 22	BF ₃ #104	257 81	261 62	1 90	5 889 84	259 58	28 93		4 41	0 49		Free varying coefficients	Traverse taken parallel to the tubes	
		III 10	10L	87 00	Cyl Ind	257 81	261 62	1 90	16 051 95	324 68	60 18		2 02	+0 37		Free varying coefficients	Composite of no metal and 1 03 metal	
		III 11	10L	87 00	BF ₃ #104	257 81	262 64	2 41	4 561 13	105 63	0 47		2 32	0 01		Free varying coefficients	Composite of no metal 1 03 metal and 1 011 between	
		III 14	14L	122 56	BF ₃ #104	257 81	261 62	1 90	2 596 98	33 17	15 87		1 28	+0 61		Free varying coefficients	Composite of no metal 1 03 metal and 1 011 between	
		III 17	18L	158 12	BF ₃ #104	257 81	262 89	2 54	1 555 58	4 20	0 23		0 27	0 0		Free varying coefficients	Composite of no metal 1 03 metal and 1 011 between	
7 1/2	1 36	IV 24	20	130 18	BF ₃ #315	256 54	262 89	3 17	2 415 32	6 70	1 01		0 28	0 04		Free varying coefficients	Composite of no metal 1 03 metal and 1 011 between	
		IV 24	20	130 18	BF ₃ #315	256 54	262 89	3 17	2 412 5	9 4	0 6		0 39	0 02		Theoretical Ratios	Composite of no metal 1 03 metal and 1 011 between	
		IV 25	13F	83 18	BF ₃ #315	256 54	262 89	3 17	4 629 3	104 1	16 5		2 25	0 36		Theoretical Ratios	Traverse taken parallel to the tubes	
		IV 25	13F	83 18	BF ₃ #315	256 54	260 35	1 90	4 683 2	144 0	9 2		3 09	0 20		Free varying coefficients	Traverse taken parallel to the tubes	
		IV 26	14L	92 08	BF ₃ #315	256 54	262 89	3 17	4 226 3	67 8	9 0		1 60	0 21		Theoretical Ratios	Composite of no metal 1 03 metal and 1 011 between	
		IV 26	14L	92 08	BF ₃ #315	256 54	261 62	2 54	4 233 0	92 6	0 06		2 19	0 00		Free varying coefficients	Composite of no metal 1 03 metal and 1 011 between	
6 3/16	1 36	V 9	19	149 30	BF ₃ #71	243 84	251 46	3 81	909 13	3 62	1 28	0 30	0 40	+0 14	+0 03	Free varying coefficients	Traverse taken parallel to the tubes	
		V 11	13	102 16	BF ₃ #71	243 84	250 19	3 17	2 101 92	42 58	3 57	5 89	2 03	0 17	0 28		Free varying coefficients	Traverse taken parallel to the tubes
7 1/2	0 925	VI 7	14L	92 08	BF ₃ #1	256 54	262 25	2 86	5 038 53	97 83	8 39	4 66	1 94	0 17	+0 09		Free varying coefficients	Composite of no metal 1 03 metal and 1 011 between
6 3/16	0 925	VII 7	19F	149 30	BF ₃ #1	243 84	250 19	3 17	1 760 88	0 89	0 81	5 89	0 05	0 06	+0 33		Free varying coefficients	Traverse taken parallel to the tubes
		VII 7	19F	149 30	BF ₃ #1	243 84	249 55	2 86	1 764 84	2 89	0 10	0 00	0 16	0 01	0 00		Theoretical Ratios	Traverse taken parallel to the tubes
		VII 9	13F	102 16	BF ₃ #1	243 84	250 19	3 17	3 645 37	41 74	5 72	5 38	1 58	0 16	+0 15		Free varying coefficients	Traverse taken parallel to the tubes
		VII 9	13F	102 16	BF ₃ #1	243 84	250 19	3 17	3 642 50	57 42	3 85	0 01	1 03	0 10	0 00		Theoretical Ratios	Traverse taken parallel to the tubes

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