UK/C-5/103

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CHALK RIVER PROJECT

RESEARCH AND DEVELOPMENT

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MULTIPLE METAL ROD ASSEMBLIES IN ZEEP

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BY

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(REPORT PREPARED BY E. CRITOPH)

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(Report prepared by E. Critoph)

Atomic Energy of Canada Limited
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Introduction

At present lattice experiments are being done in ZEEP with 19-element, uranium metal rods. The geometrical details of these rods are shown in Fig. 1.

At the time of writing three hexagonal lattices composed of these rods have been assembled in ZEEP. These were lattices with hexagonal spacings of 8.66", 10.00" and 11.50".

Experiments

Part A

The following experiments were performed for each lattice:

I Critical Laplacian

The pile was made critical and radial and vertical distributions were taken from which the extrapolated radius and height were obtained. From this information the critical Laplacian was derived in the normal manner.

II Fine Structure

In each lattice the thermal neutron flux distribution was measured through the central cell. This was done by irradiating 1/4" lengths of Mn wire in the centre of representative elements of the rod, 1/4" lengths of Mn wire in representative positions between elements, and Mn wires which ran radially into the moderator.

III "Mass Epi-Cadmium Absorption"

The cadmium ratio of depleted uranium was measured in the centre of the elements of the central rod for each lattice. The interpretation of these measurements will be discussed in a later talk.

IV Miscellaneous Central Rod Experiments

The following central rod experiments have been performed for each of the lattices:

a) Effect of removal of central rod
b) Effect of replacing the central rod with a 19-element, UO_2 rod of identical design (except fuel diameter = .521")
c) Effect of replacing the central rod by a 19-element, metal rod in which 9 of the elements had the uranium metal replaced with D_2O.
d) Effect of replacing the central rod by a 19-element, metal rod

in which 9 of the elements had the uranium metal replaced with air.

One rod was then revised by the addition of two concentric aluminium tubes. These tubes had the following geometry:

i) Inner tube I.D. = 3.444"
O.D. = 3.526"

ii) Outer tube I.D. = 3.833"
O.D. = 3.9075"

The space within the inner tube not occupied by fuel elements is referred to as coolant space and the space between the two tubes as annulus.

The following experiments were then done in each of the lattices:

e) Critical height with the central rod replaced by the above rod with D_2O in the coolant space and air in the annulus.

f) Critical height with the central rod replaced by the above rod with air in the coolant space and air in the annulus.

g) Critical height with the central rod replaced by the above rod with D_2O in the coolant space and D_2O in the annulus.

The critical heights in e), f) and g) were directly related to the critical height of the uniform pile in the case of the 8.66" and 10" lattices but not in the case of the 11.5" lattice. Therefore for the 8.66" and 10" lattices e), f) and g) can read, "The effect of replacing the central rod by" the rod described.

Part B

In addition the following experiment was done.

V U^{238} : U^{235} Fission Ratio

a) The ratio of U^{238} fissions to U^{235} fissions in a 3 foot length of a normal, 19-element metal rod was measured in the central position of the 10" lattice. In this case the rod was suspended directly in the moderator and hence the spaces between elements were filled with D_2O.

b) The ratio of U^{238} fissions to U^{235} fissions in a 3 foot length of a normal 19-element metal rod was measured in the central position of the 11.5" lattice. In this case the rod was suspended in a 4" aluminium thimble from which D_2O had been excluded and hence the spaces between the elements were filled with air.

I Critical Laplacian

Lattice Pitch	Extrapolated Radius (cm)	δh cm Clamp Correction	Extrapolated Height (cm)	λ_V cm.	λ_R cm.	ν^2 m^{-2}
8.66"	124.1	-15.9	191.1	27.4	38.4	$6.47 \pm .25$
10.00"	128.4	- 1.7	178.9	31.3	29.5	$6.62 \pm .10$
11.50"	125.0	- 5.6	211.0	29.8	31.7	$5.95 \pm .10$

λ_V is the sum of upper and lower extrapolation lengths
λ_R is the radial extrapolation length.
The extrapolated height has been corrected for measuring thimbles as well as clamps.

II Fine Structure

The experimental results for the thermal neutron distribution through a cell for the three lattices are given in Figs. 3, 4, 5, 6, 7 and 8.

III "Mass Epi-Cadmium Absorption"

The measured cadmium ratios of depleted uranium in the three lattices are shown in Figs. 9, 10 and 11.

IV Miscellaneous Central Rod Experiments

The following table shows the measured critical heights for the experiments described.

	Hexagonal Spacing		8.66"	10.00"	11.50"
			Critical Hts. in Cm.		
	Uniform lattice		182.24	149.30	186.78
IV a)	Empty central site		183.58	154.08	203.92
b)	UO_2 Rod in central site		183.31	150.92	191.69
c)	(10 U + 9 D_2O) in central site		181.39	149.94	190.10
d)	(10 U + 9 air) in central site		181.74	150.07	189.84
	Coolant Space	Annulus			
IV e)	D_2O	Air	183.96	150.10	188.33
f)	Air	Air	183.53	149.68	186.90
g)	D_2O	D_2O	183.60	150.05	188.56

N.B. The last 3 values in the 11.5" column cannot be compared with the other values in that column.

The values given in the table above have been corrected for clamps on the central rod. These corrections were in all cases $\leqslant 0.03$ cm in magnitude. Hence the critical heights listed are for central rods without clamps in a lattice of 19-element, metal rods with clamps. The effect of the clamps on the thermal utilization of the lattice can be deduced from the table in section I. (The reason for this treatment is that the clamps on the central rods were different than those on other rods due to the requirement that they had to be removed from the reactor easily)

Part B

V U^{238} : U^{235} Fission Ratio

There are four symmetric positions in the 19-element rod which have been labelled

type A (1 element) - central element
type B (6 elements) - inner ring, radial distance from centre 0.705"
type C (6 elements) - outer ring, " " " " 1.410"
type D (6 elements) - middle ring, " " " " 1.220"

Define:

$$F = \frac{\text{no. of 28 fissions}}{\text{no. of 25 fissions}}$$

The results given below are preliminary.

a) With coolant space filled with D_2O, lattice pitch 10"

$$F_A = 0.106_3$$
$$F_B = 0.091_9$$
$$F_C = 0.060_4$$
$$F_D = (0.070_0)$$

and for the whole rod $F_{AV} = 0.073_5$.

(N.B. The value for F_D was obtained by interpolation since no foils were placed in this position).

The distribution of fissions in the rod is given by the following relative figures:

Type	A	B	C	D
28 fissions	190	187	171	(177)
25 fissions	1789	2031	2825	(2528)

i) To D_2O in coolant space (i.e. in air-filled thimble), lattice pitch 11.5"

$$F_A = 0.10\underline{4}_0$$
$$F_B = 0.09\underline{1}_0$$
$$F_C = 0.05\underline{7}_8$$
$$F_D = 0.06\underline{6}_6$$
$$F_{AV} = 0.07\underline{1}_4$$

The distribution of fissions is given by:

Type	A	B	C	D
28 fissions	65.3	61.6	54.3	56.9
25 fissions	628	677	940	855

The relative values of the F's should be good to about a percent and their absolute values to $\pm$ 3.5 percent.

Sources of Error

Part A

There are several factors which might contribute to errors in this series of experiments.

i) The correction required for clamps was fairly large in the 8.66" lattice. At present, the error associated with the correction in this case is also fairly large due to some uncertainty in positioning of clamps.

ii) The geometry of the rods could also contribute to errors. The positioning of the elements in a rod was checked on some sample rods at a position between the two clamps, and considerable variation in spacing was found, although the outside diameter of the rod was reasonably accurate.

iii) The large error put on the Laplacian of the 8.66" lattice is due largely to an unexplained asymmetry in the radial distributions.

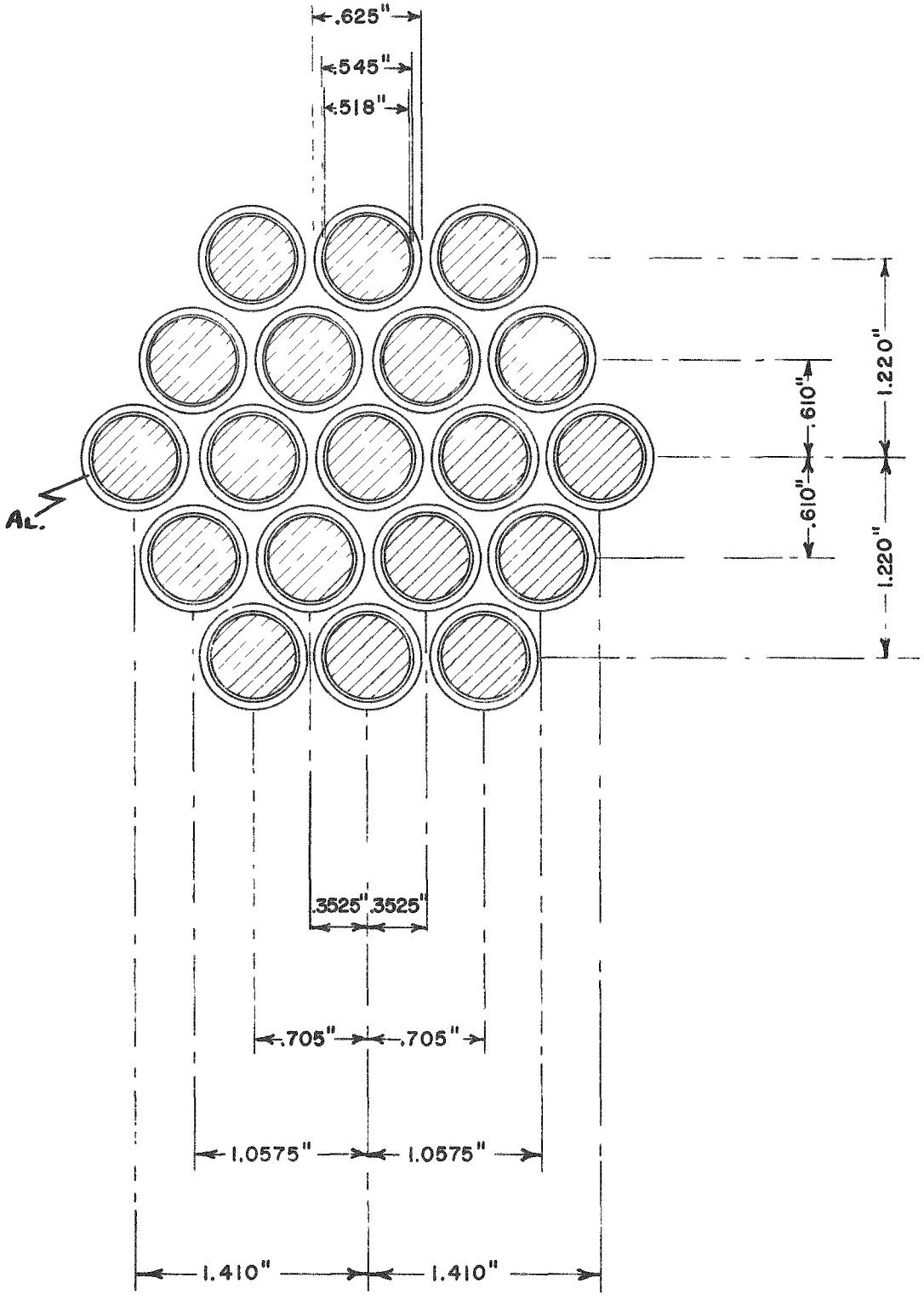
Predictions and Interpretation

Before the experiments were done, the Laplacians were predicted by the methods labelled "conventional" in CRRP-655. These predictions and the experimental results are given in Fig. 2.

The interpretation of these experiments will be discussed fully at a later date.

FIG. 1 UK/C/5/103

SCALE: FULL SIZE



19-ELEMENT, U-METAL ROD FOR ZEEP

FIG. 2. UK/C/5/103

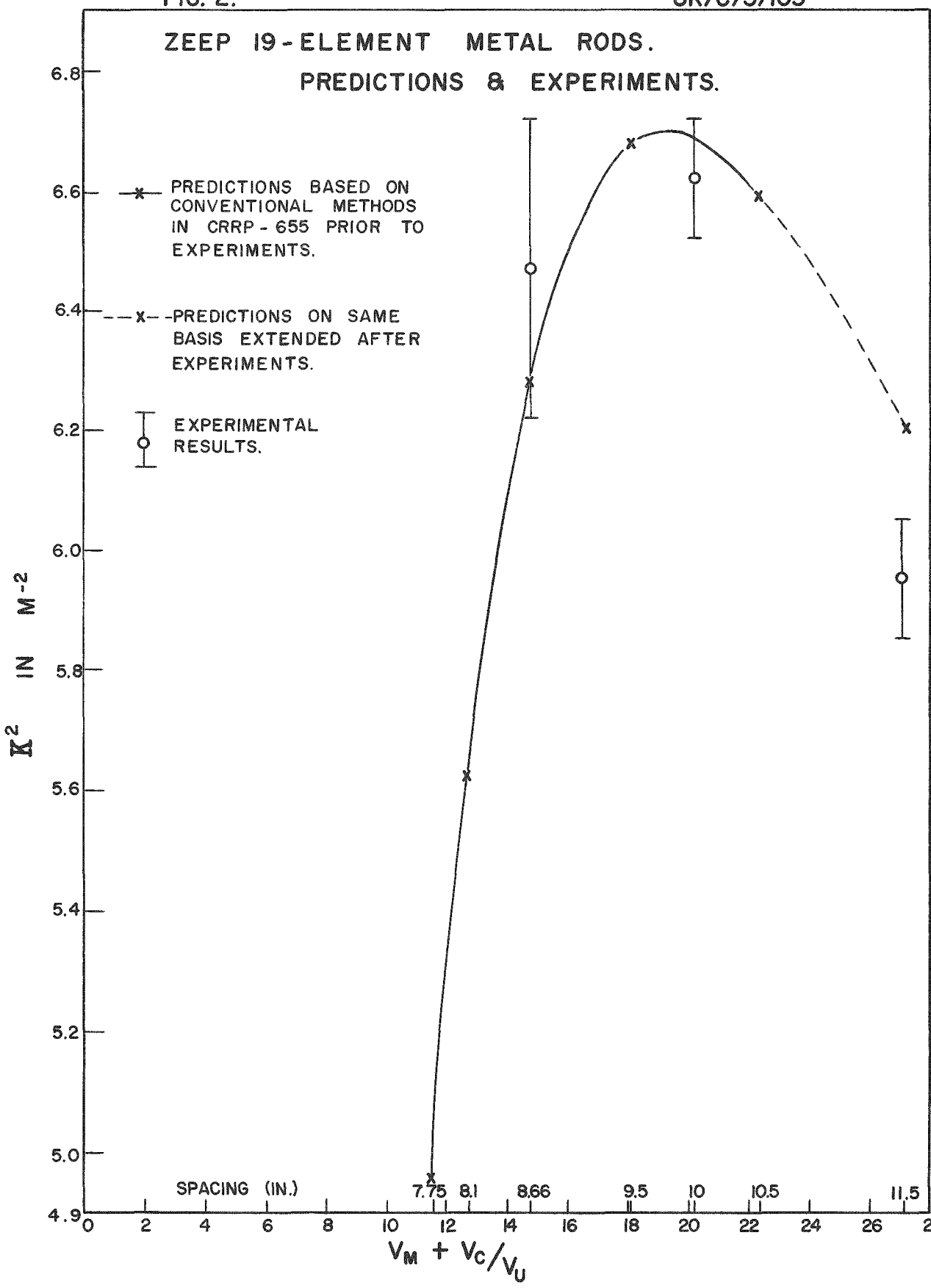


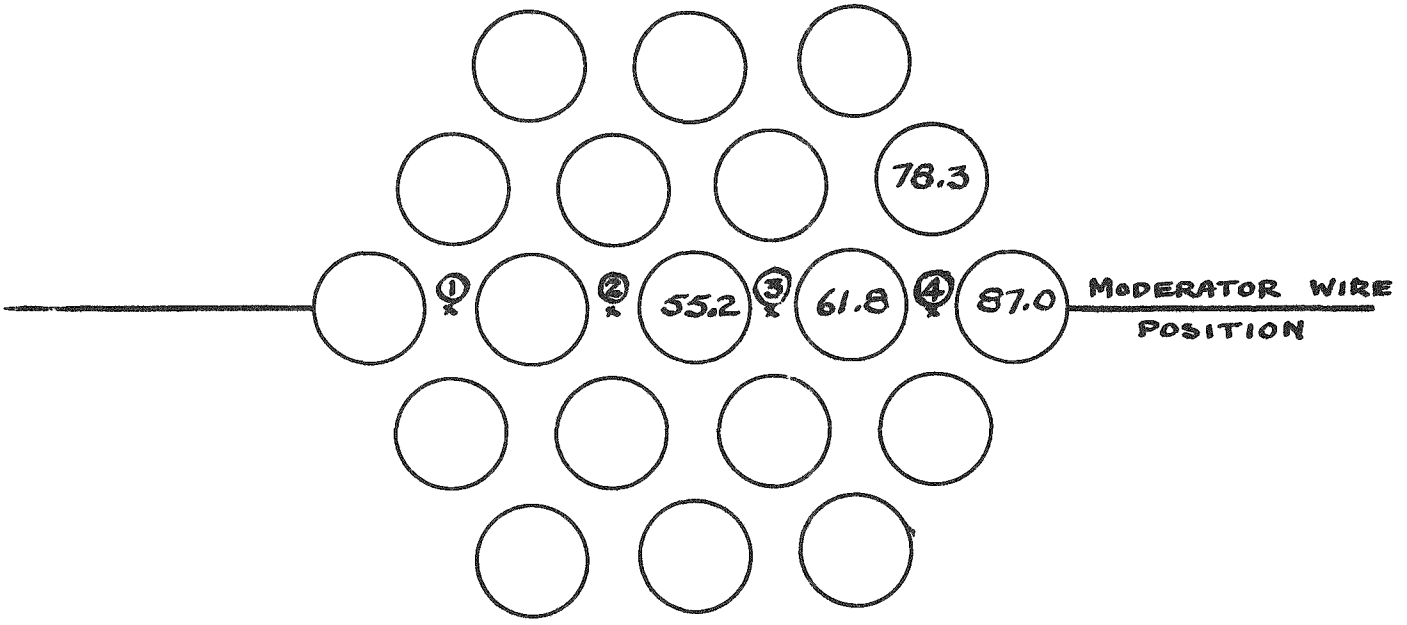
FIG. 3 UK/C/5/103

PRELIMINARY RESULTS

NOTE:

POINTS SHOWN IN THE ELEMENTS ARE FOR THE CENTRE OF THE ELEMENT.

INTERMEDIATE POINTS ARE NUMBERED ON THE DIAGRAM AND LISTED BELOW.



(1)	80.6	(3)	63.2
(2)	62.5	(4)	74.8

ESTIMATED PROBABLE ERRORS ±2%

THERMAL NEUTRON FLUX DISTRIBUTION IN THE CENTRAL ROD OF THE 8.66" LATTICE OF 19-ELEMENT, METAL RODS.

FIG. 4.

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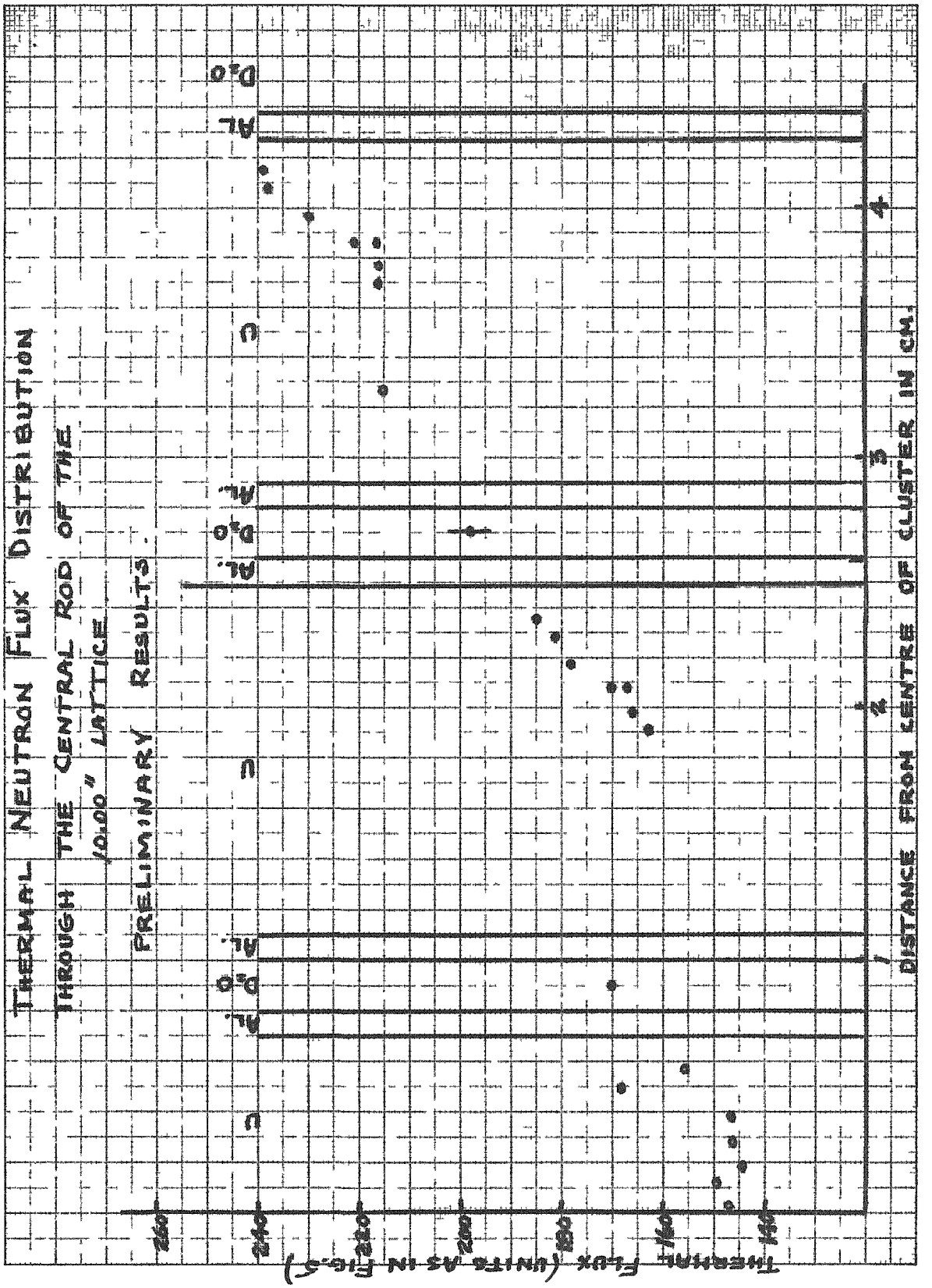


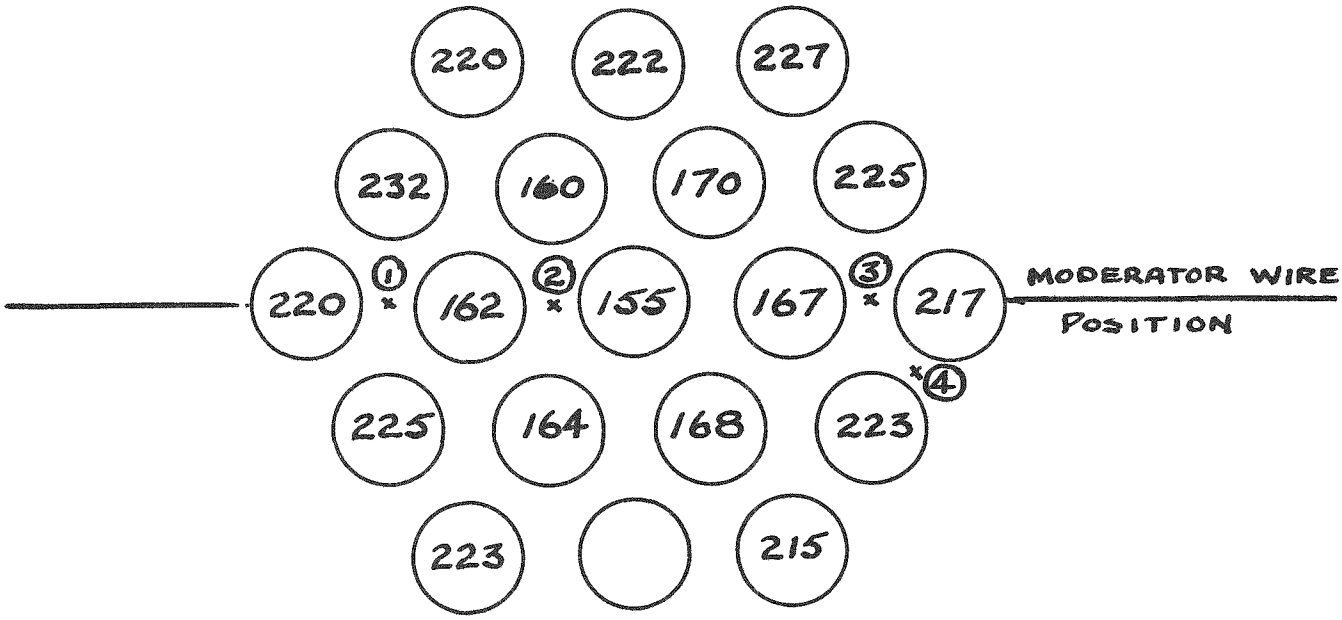
FIG. 5. UK/C/5/103

PRELIMINARY RESULTS

NOTE :

POINTS SHOWN IN THE ELEMENTS ARE FOR THE CENTRE OF THE ELEMENT.

INTERMEDIATE POINTS ARE NUMBERED ON THE DIAGRAM AND LISTED BELOW.



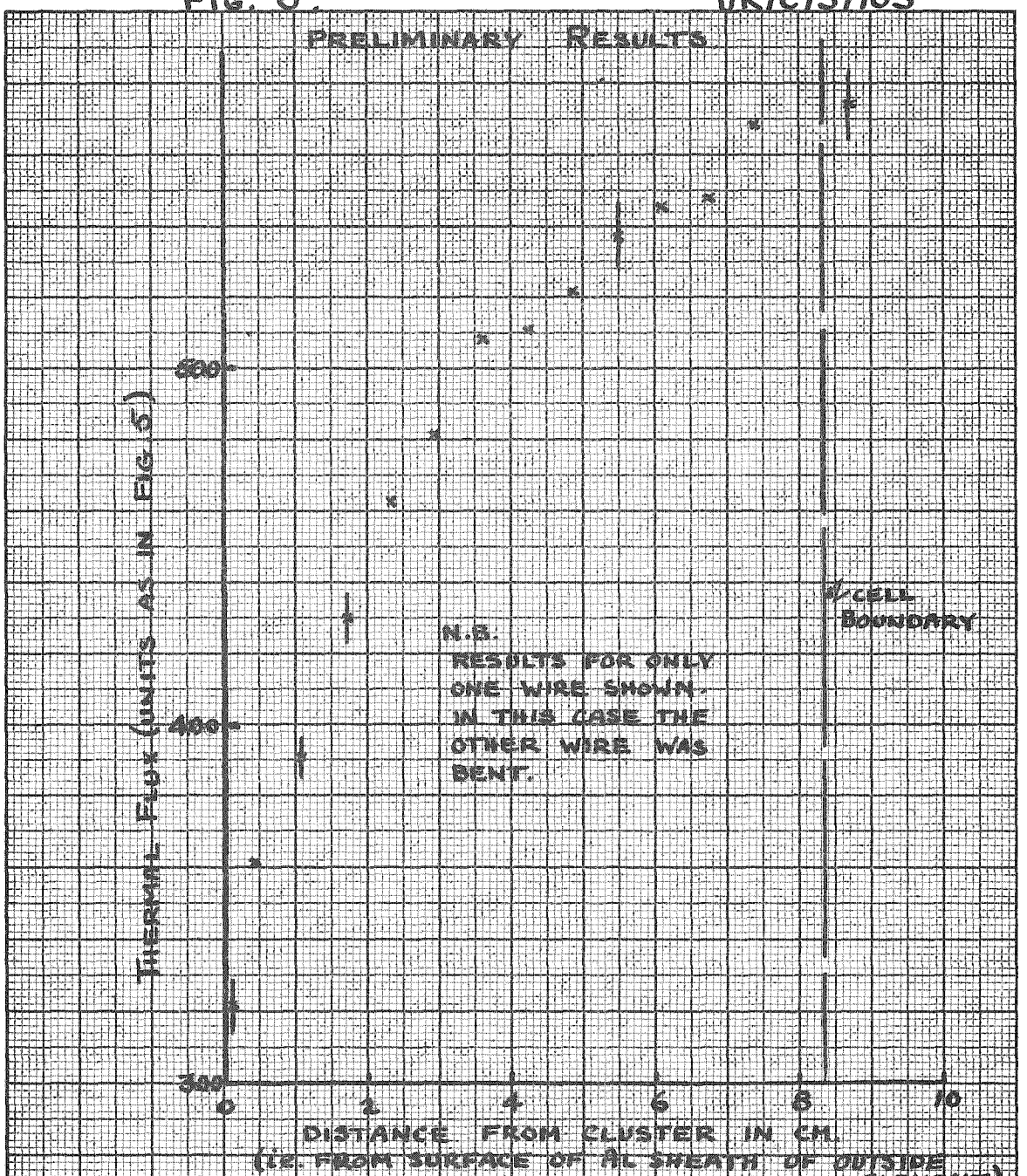
① 198
② 170
③ 222
④ 199
} POSSIBLE INTERCHANGE OF POINTS

ESTIMATED PROBABLE ERRORS ±2%

THERMAL NEUTRON FLUX DISTRIBUTION IN THE CENTRAL ROD OF THE 10.00" LATTICE OF 19-ELEMENT, METAL RODS.

FIG. 6.

UK/C/5/103

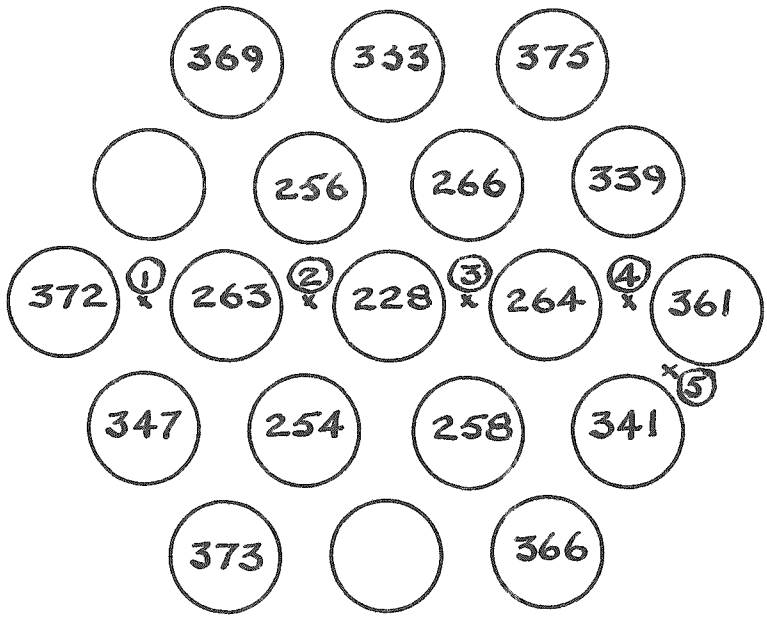


THERMAL NEUTRON FLUX DISTRIBUTION IN THE MODERATOR OF THE CENTRAL CELL OF THE 10.00" LATTICE OF 19-ELEMENT, METAL RODS.

FIG. 7. UK/C/5/103

PRELIMINARY RESULTS

NOTE:
POINTS SHOWN IN THE ELEMENTS ARE FOR THE CENTRE OF THE ELEMENT.
INTERMEDIATE POINTS ARE NUMBERED ON THE DIAGRAM AND LISTED BELOW.



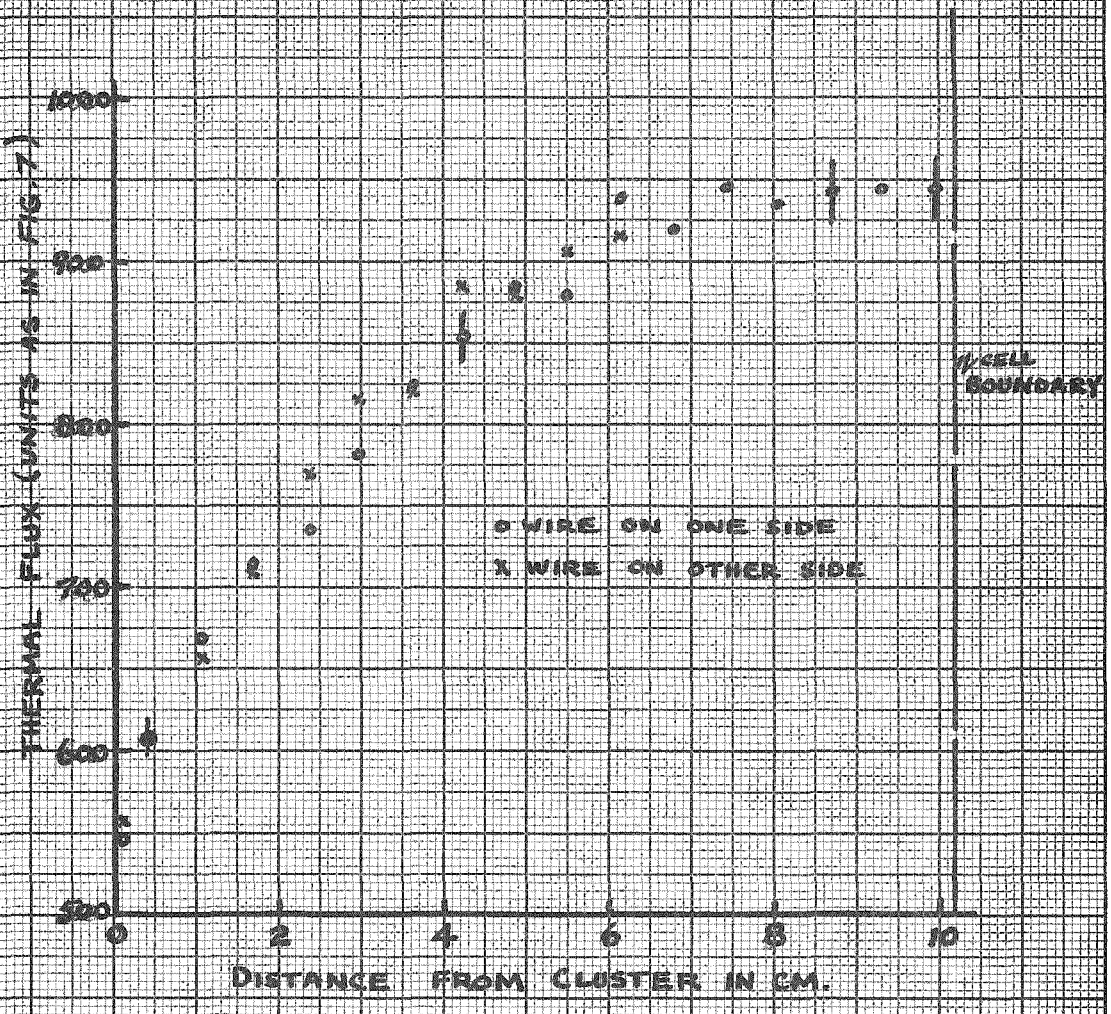
① 338
② 277
③ 268
④ 334
⑤ 375

ESTIMATED PROBABLE ERRORS ±2%

THERMAL NEUTRON FLUX DISTRIBUTION IN THE CENTRAL ROD OF THE 11.50" LATTICE OF 19-ELEMENT, METAL RODS.

FIG. 8. UK/C/S/103

PRELIMINARY RESULTS

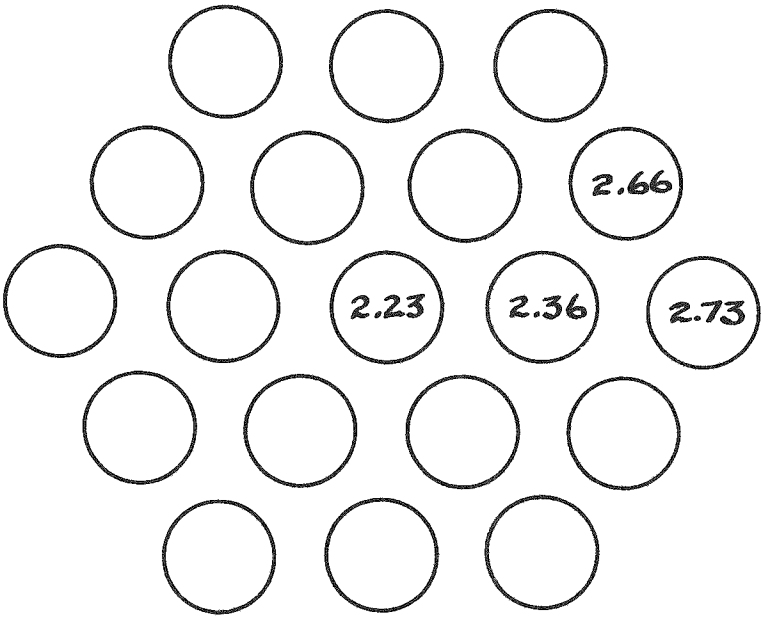


THERMAL NEUTRON FLUX DISTRIBUTION IN THE MODERATOR OF THE CENTRAL CELL OF THE 11.50" LATTICE OF 19-ELEMENT, METAL RODS.

FIG. 9.

UK/C/5/103

$$\text{CADMIUM RATIO} \equiv \frac{\text{BARE ACTIVATION } (U^{238})}{\text{COVERED ACTIVATION } (U^{238})}$$

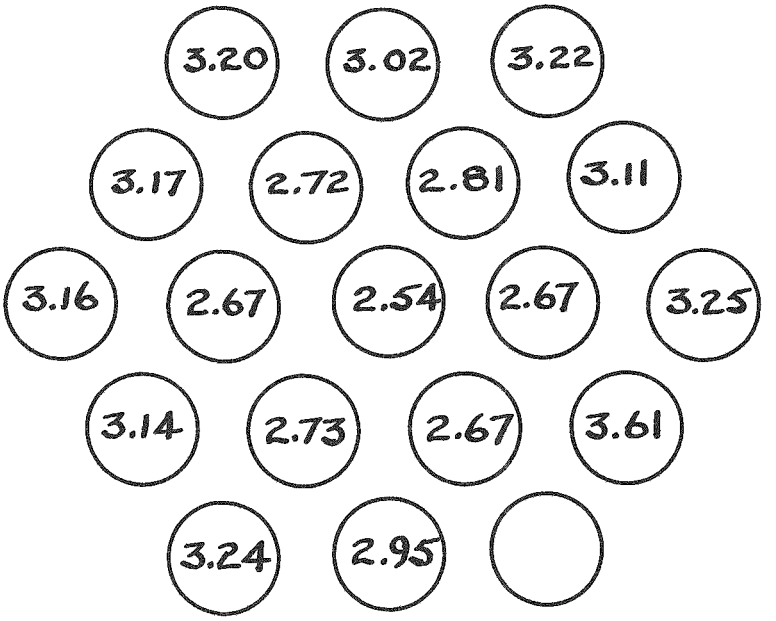


ESTIMATED PROBABLE ERRORS ±2%

CADMIUM RATIOS OF DEPLETED URANIUM WIRES AT THE CENTRE OF THE ELEMENTS OF THE CENTRAL ROD OF THE 8.66" LATTICE.

FIG. 10. UK/C/5/103

$$\text{CADMIUM RATIO} \equiv \frac{\text{BARE ACTIVATION } (U^{238})}{\text{COVERED ACTIVATION } (U^{238})}$$

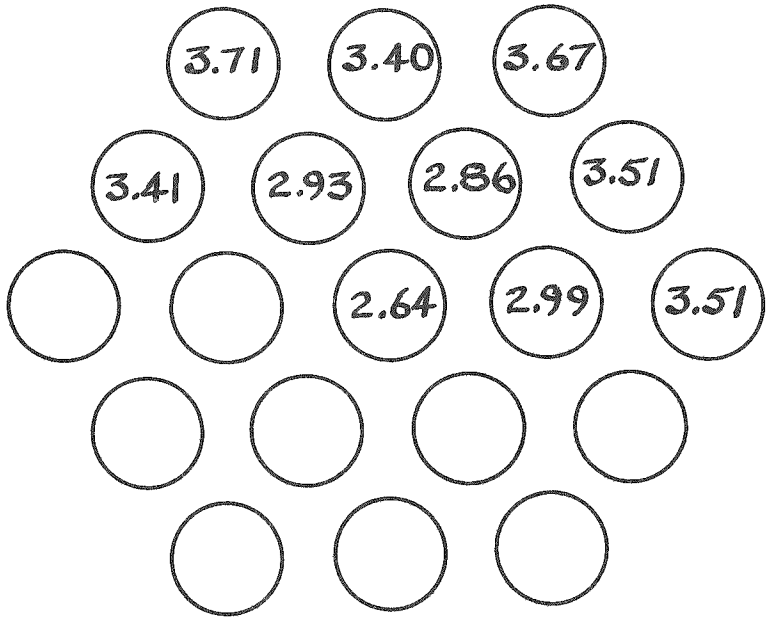


ESTIMATED PROBABLE ERRORS ±2%

CADMIUM RATIOS OF DEPLETED URANIUM WIRES AT THE CENTRE OF THE ELEMENTS OF THE CENTRAL ROD OF THE 10.00" LATTICE.

FIG. 11. UK/C/5/103

$$\text{CADMIUM RATIO} \equiv \frac{\text{BARE ACTIVATION } (U^{238})}{\text{COVERED ACTIVATION } (U^{238})}$$



ESTIMATED PROBABLE ERRORS ±2%

CADMIUM RATIOS OF DEPLETED URANIUM WIRES AT THE CENTRE OF THE ELEMENTS OF THE CENTRAL ROD OF THE 11.50" LATTICE.