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SIXTH UK/CANADA TECHNICAL CONFERENCE

CHALK RIVER, ONTARIO, OCTOBER 21-22, 1957

LATTICE EXPERIMENTS WITH 19-ELEMENT UO_2 RODS IN ZEEP.
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BY

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CHALK RIVER, ONTARIO

SEPTEMBER 16, 1957

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INTRODUCTION

At present, ZEEP is being used to study the lattice properties of 19 element UO_2 rods. At the time of writing, two lattices of UO_2 rods have been assembled in Zeep. They are:

- (a) a 24.13 cm. hexagonal lattice of 55 UO_2 rods, and
- (b) a 21.59 cm. hexagonal lattice of 55 UO_2 rods with 30 ZEEP rods placed around the UO_2 core with the same spacing as the core.

In the first experiment, the pile did not go critical and no flux distributions were obtained. However, an estimate of the Laplacian for this lattice was made using the results of the approach-to-critical experiment. In (b) full scale flux distributions, central rod experiments and fine structure measurements have been made and practically all the results quoted below will be those obtained with this 21.59 cm. lattice.

Details of UO₂ Rods

The UO₂ used in these experiments was in the form of cylindrical pellets with an average length of 1.90 cm., an average diameter of 1.32 cm. and an average density of 9.53 gm/cc. These pellets were sheathed in aluminum tubes with an outside diameter of 1.588 cm. and a wall thickness of 0.102 cm. 19 sheaths containing the UO₂ were then assembled in a hexagonal array with a distance between sheaths of 0.203 cm. (i.e. the distance between centres of neighbouring oxide elements in a cluster is 1.791 cm.). The pellets filled the sheaths to a height of 217 cm. Fig. 1 is a cross-sectional sketch of a typical rod. The four symmetric elements in the cluster are lettered A, B, C and D, and reference will be made to these later.

The 24.13 cm. Lattice Experiment:

This assembly would not go critical with the 55 UO₂ rods at this spacing. In the approach-to-critical experiment, the counting rate in a BF₃ chamber located in the graphite reflector was recorded as a function of moderator height and from these data, a plot of the reciprocal of the counting rate (1/A) vs. the reciprocal of the square of the extrapolated height (1/h²) of the pile was made. From the extrapolation of the resulting straight line to 1/A = 0, a value for h_c, the extrapolated height of the critical pile, was determined. The result was h_c = (309 ± 15) cm. Using an empirical relation between radial extrapolation length and core radius, (obtained from previous Zeep measurements), the extrapolated radius was calculated as 125 ± 6 cm; combining these values the uncorrected Laplacian becomes:

$$\lambda_0^2 = \left(\frac{\pi}{3.09}\right)^2 + \left(\frac{2.405}{1.25}\right)^2 = 4.73 \pm 0.15 \text{ m}^{-2}$$

Fairly large Al clamps with stainless steel screws were used on these rods and a correction must be made for these. A calculation of this effect gave a change in λ^2 of (0.22 ± 0.05) m⁻². Thus the corrected Laplacian is:

$$\lambda^2 = 4.95 \pm 0.20 \text{ m}^{-2}$$

at 25°C.

4. / 2

The 21.59 cm. Lattice(a) Measurement of Laplacian

The experiment with the 24.13 cm. lattice had pointed up the necessity of having additional reactivity in order to obtain critical assemblies with the UO_2 rods. Thus it was decided to try a smaller spacing and also to add Zeep rods in the remaining space outside, to drive the UO_2 core. The second lattice consisted of 55 19-element UO_2 rods plus 30 Zeep rods assembled at a spacing of 21.59 cm., with the Zeep rods occupying the outer positions of the lattice. This assembly did go critical and full scale flux measurements were made. The Cd ratio was found to be constant out to a radius of ~ 60 cm. and the radial Laplacian was determined by fitting values of neutron density at 9.20 cm. and 52.38 cm. to a $Jo(\lambda r)$ distribution. From this the radial Laplacian λ^2 was determined as:

$$\lambda^2 = (3.12 \pm 0.06) \text{ m}^{-2}$$

The vertical distribution was fitted to a cosine function and the resulting axial buckling was $\alpha^2 = (1.89 \pm 0.04) \text{ m}^{-2}$. These two results give a value for the uncorrected Laplacian of

$$\lambda_o^2 = (5.01 \pm .07) \text{ m}^{-2} .$$

Correcting for the loading due to experimental thimbles and foils and clamps (which were much smaller in this pile) we get

$$\lambda^2 = 5.05 \pm .08 \text{ m}^{-2}$$

at 25.6°C. The Laplacian measurements for these two lattices are summarized in Table I.

TABLE I

<u>LATTICE SPACING (cm.)</u>	<u>TEMP. °C</u>	<u>EXTRAPOLATED RADIUS (cm.)</u>	<u>CLAMP CORRECTION (cm.)</u>	<u>LOADING CORRECTION (cm.)</u>	<u>EXTRAPOLATED HT. (cm.)</u>	<u>λ^2 (m⁻²)</u>
24.13	25	125 ± 6	- 29	-	280	4.95 ± .20
21.59	25.6	136.2	- 1.6	- 1.1	226.0	5.05 ± .08

(b) Central Rod Experiments:

A series of central rod experiments were also carried out in this pile and these can be divided into two groups - (i) rod replacement experiments and (ii) coolant tube experiments. The results of the rod replacement experiments are given in Table II below. The critical heights for the various assemblies and the changes in critical height, Δh , produced by replacing the UO_2 rod by the various assemblies, are given; a positive Δh signifying a negative change in reactivity. (Asymmetrical loading of the rods in cases (h), (i) and (j) causes small variations in rod position because the rod suspension is a gimbal. This produces changes in Δh of the same order as the quoted errors and no corrections have been applied.)

TABLE II

	<u>Central Assembly</u>	<u>h_c (cm.)</u>	<u>Δh (cm.)</u>
(a)	19-element UO_2 Rod	196.56	-
(b)	Empty central position	199.55	+2.99 \pm 0.01
(c)	19-element U-metal Rod (.203 cm. sheath spacing)	194.50	-2.06 "
(d)	19-element U-metal Rod (.406 cm. sheath spacing)	194.95	-1.61 "
(e)	10 U-metal elements + 9 D_2O elements (.203 cm. sheath spacing)	194.79	-1.77 "
(f)	10 U-metal elements + 9 Air elements (.203 cm. sheath spacing)	194.96	-1.60 "
(g)	18-element UO_2 rod element "A" missing	196.56	<0.01 "
(h)	18-element UO_2 rod element "B" missing	196.55	-0.01 "
(i)	18-element UO_2 rod element "C" missing	196.50	-0.06 "
(j)	18-element UO_2 rod element "D" missing	196.51	-0.05 "
(k)	7-element UO_2 rod (outer 12 elements removed)	196.82	+0.26 "
(l)	12-element UO_2 rod (inner 7 elements removed)	196.34	-0.22 "

For the coolant tube experiments the UO_2 rod was enclosed in a double walled aluminum tube whose dimensions were:

Inner Tube	I.D. = 8.75 cm. O.D. = 8.96 cm.
Outer Tube	I.D. = 9.73 cm. O.D. = 9.92 cm.

The space within the inner tube is called the coolant space and that between the walls is the annulus. Critical heights were measured with air and D_2O in these spaces separately and together and the results of these measurements are given in Table III. The changes in critical height are computed from the case where there is D_2O in the coolant space and air in the annulus.

TABLE III

<u>Central Assembly</u>		<u>Critical Ht.</u> <u>h_c (cm.)</u>	<u>Δh (cm.)</u>
<u>Coolant Space</u>	<u>Annulus</u>		
(a) D_2O	Air	199.51	-
(b) Air	Air	199.54	+0.03 \pm 0.01
(c) Air	D_2O	198.25	-1.26 \pm 0.01
(d) D_2O	D_2O	198.25	-1.26 \pm 0.01

(c) Fine Structure Measurements:

The fine structure measurements have been made using a 90 cm. section of a 19-element rod which is placed in the central position in the pile. The following types of measurement have been made.

- (1) Average neutron density distribution throughout this central rod using Cu foils of 1.31 cm. diameter placed between the UO_2 pellets. The results of two such experiments are given in Figs. 2 & 3 for sheath spacings on the short section of 0.203 cm. and 0.406 cm. respectively.

- (ii) Neutron density distributions, using 0.635 cm. long, .051 cm. diameter Mn-Ni wire, throughout the rod and into the moderator past the cell boundary. Figs. 4 & 5 show the results of these measurements for the two sheath spacings used. For the 0.203 cm. spacing, 72 wires were used to map the flux between elements, and for the 0.406 cm. spacing, 24 wires. Figs. 4 & 5 have also the Cu foil data of Figs. 2 & 3 plotted. All the data on Figs. 4 & 5 are normalized to Cu foil activity equal to 1.00 in element A.
- (iii) Bare and Cd covered Mn-Ni wire flux measurements across the individual elements of the cluster. These results are given in Figs. 6, 7 for the two sheath spacings used.

Conclusions

The results presented above are only preliminary and no interpretation will be attempted at this time. Other experiments with larger and smaller lattice spacings are planned and the results of the present measurements will be presented in more detail in a full report on oxide lattices.

SCALE: FULL SIZE
DIMENSIONS IN CM.

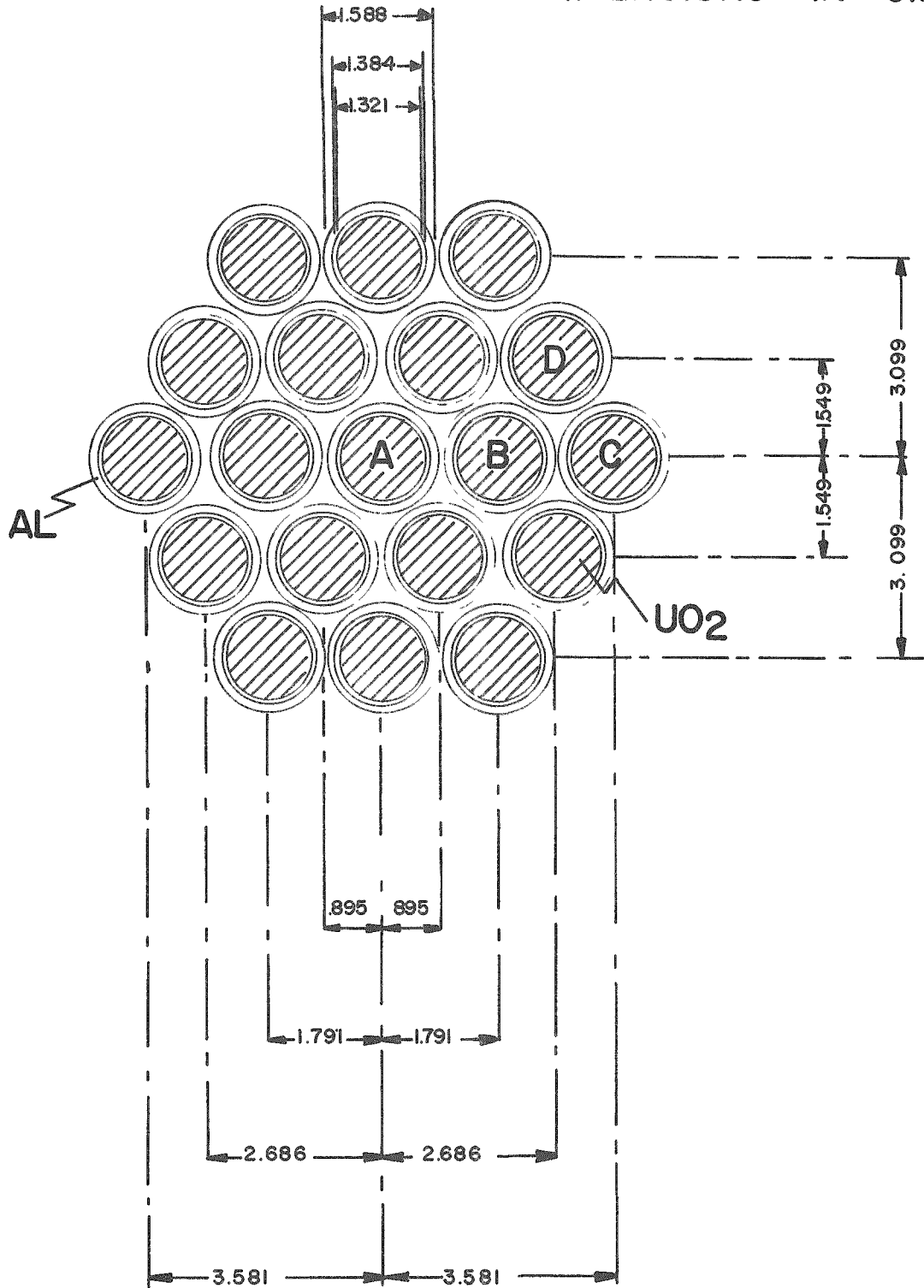


FIGURE 1: 19-ELEMENT, UO₂ ROD FOR ZEEP

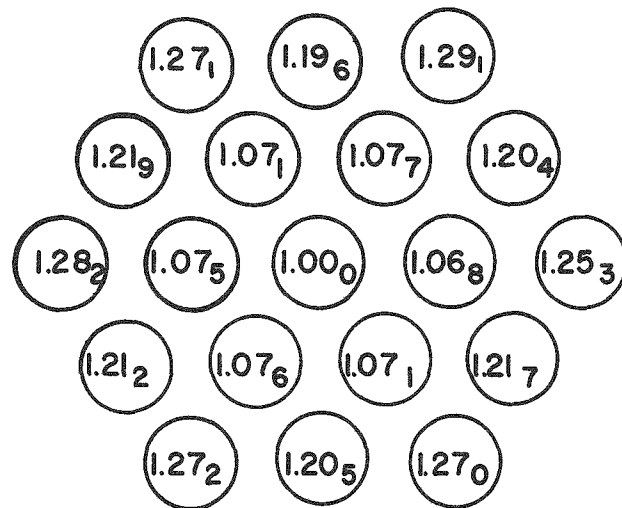


FIGURE 2

AVERAGE NEUTRON DENSITY IN UO₂ ELEMENTS OF CENTRAL ROD
 IN 21.59 CM. UO₂ LATTICE USING Cu. FOILS OF 1.31 CM. DIAMETER
 (CENTRAL ROD SHEATH SPACING = 0.203 CM.)
 (THESE RESULTS ARE PLOTTED ON THE Mn-Ni FINE STRUCTURE
 GRAPH OF FIGURE 4)

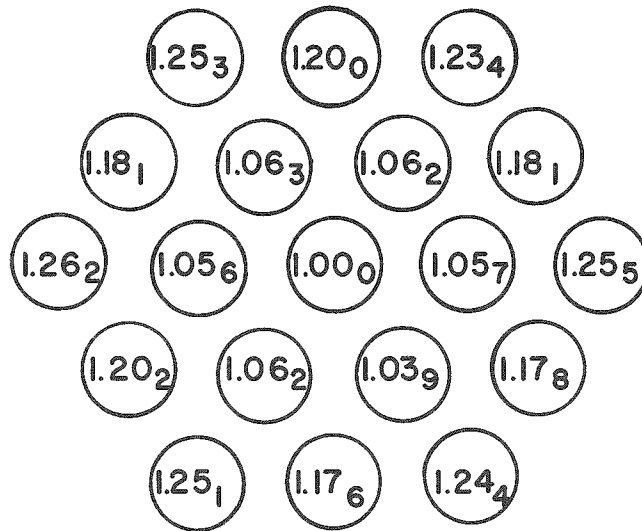


FIGURE 3

AVERAGE NEUTRON DENSITY IN UO₂ ELEMENTS OF CENTRAL
 ROD IN 21.59 CM. UO₂ LATTICE USING Cu. FOILS OF 1.31 CM. DIAMETER
 (CENTRAL ROD. SHEATH SPACING=0.406 CM.)
 (THESE RESULTS ARE PLOTTED ON THE Mn-Ni FINE STRUCTURE
 GRAPH OF FIGURE 5.)

FIGURE 4:- (a) Mn-Ni WIRE NEUTRON DENSITY DISTRIBUTION IN CENTRAL UO₂ ROD OF 21.59 CM. LATTICE (SHORT SECTION SHEATH SPACING = 0.203 CM.) (b) AVERAGE Cu. FOIL ACTIVATION IN ELEMENTS - (ALL DATA NORMALIZED TO Cu = 1.00 IN ELEMENT A)

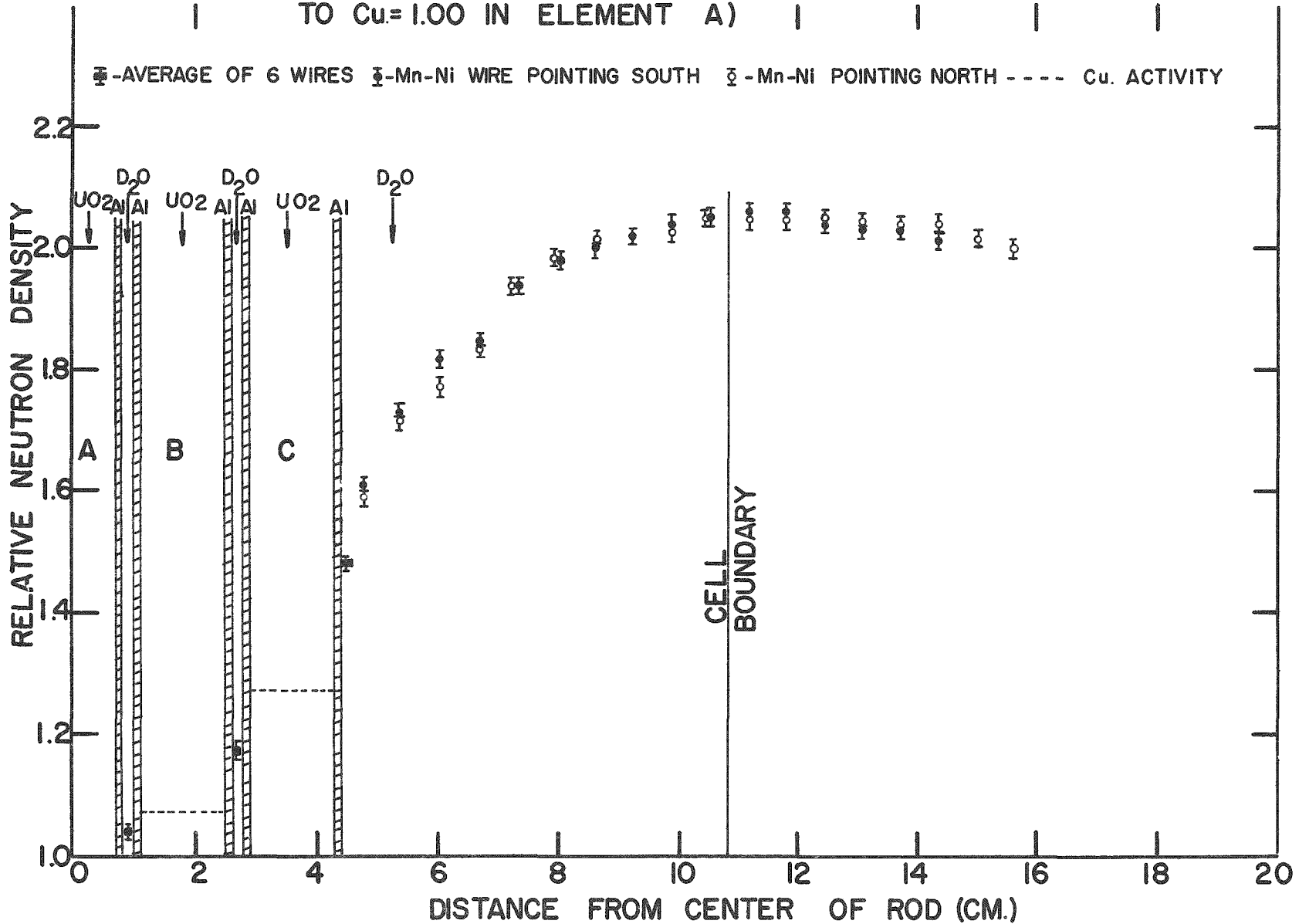
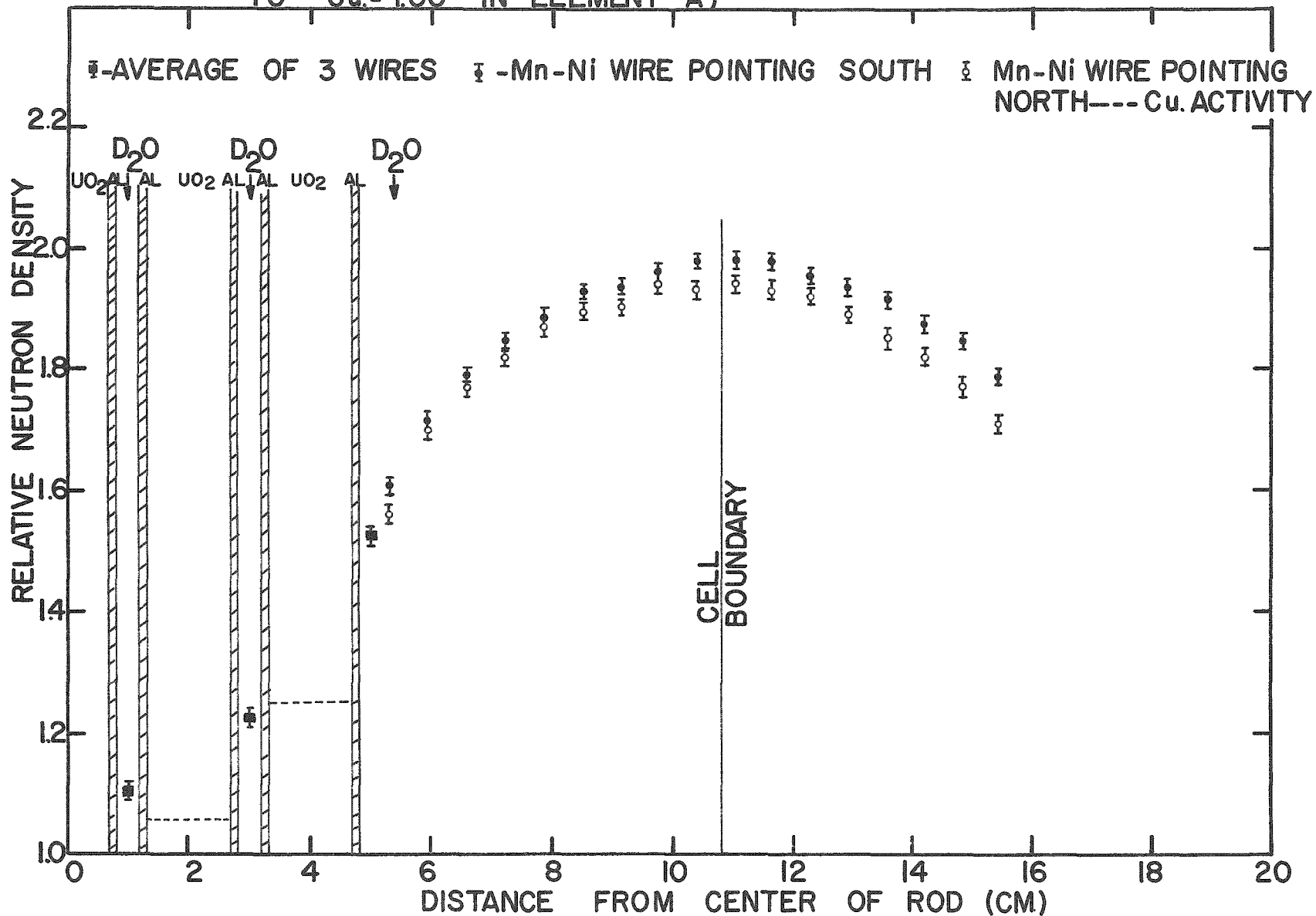


FIGURE 5: (a) Mn-Ni WIRE NEUTRON DENSITY DISTRIBUTION IN CENTRAL UO₂ ROD OF 21.59 CM. LATTICE. (SHORT SECTION SHEATH SPACING = 0.406 CM.)
 (b) AVERAGE Cu. FOIL ACTIVATION IN ELEMENTS - (ALL DATA NORMALIZED TO Cu = 1.00 IN ELEMENT A)



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FIGURE 6: - BARE AND Cd COVERED Mn-Ni WIRE FLUX DISTRIBUTIONS IN CENTRAL UO₂ ROD OF 21.59CM. LATTICE (SHEATH SPACING IN CENTRAL ROD = 0.203 CM.)

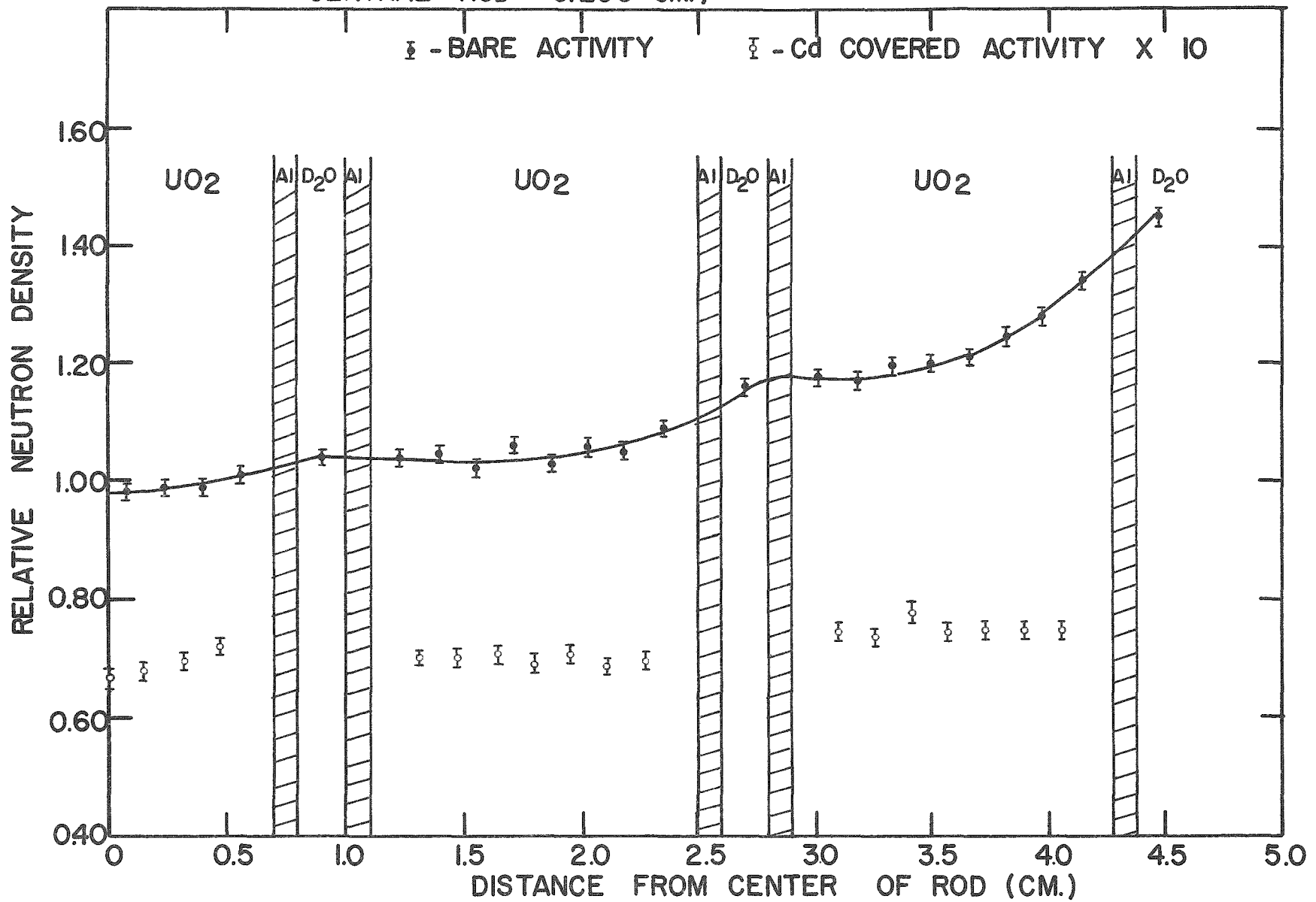


FIGURE 7 :- BARE AND Cd COVERED Mn-Ni WIRE FLUX DISTRIBUTIONS IN CENTRAL UO₂ ROD OF 21.59 CM. LATTICE (SHEATH SPACING IN CENTRAL ROD=0.406CM.)

