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LATTICE MEASUREMENTS WITH 19-ELEMENT NATURAL URANIUM METAL ASSEMBLIES

PART I: BUCKLINGS FOR A RANGE OF SPACINGS WITH D_2O AND He COOLANTS

by

K.J. SERDULA and R.E. GREEN

Chalk River, Ontario

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ABSTRACT

Bucklings derived from activation measurements in the ZED-2 reactor are given for 19-element natural uranium metal assemblies. Measurements were made in triangular arrays of 55 assemblies at pitches in the range 20 to 40 cm. "Coolants" used were;

(1) D_2O of moderator purity,

(2) He to simulate a voided condition.

Bucklings obtained with He as coolant are higher than those for D_2O coolant for the pitches investigated.

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1. INTRODUCTION

Experimental values of reactor physics parameters of cluster fuel are required to test the models or recipes used to predict the nuclear properties of lattices with fuel channels having the complex geometry required to provide the necessary heat transfer characteristics. This report describes buckling measurements for 19-element natural uranium metal fuel assemblies moderated with heavy water, which formed one part of a program of lattice parameter measurements for fuel assemblies having large neutron absorption areas. Earlier measurements on heavy-water-moderated, natural-uranium-metal cluster lattices[1] covered a limited range of pitches and the 19 elements of the cluster were arranged in a hexagonal pattern. In present studies the 19-element clusters were arranged in a circular CANDU-type array[2] with the clusters enclosed in a simulated coolant tube which enabled studies to be made both with and without D_2O coolant.

Bucklings derived from Mn activation measurements and cell-boundary In Cd-ratios were measured in a triangular array of 55 assemblies in the ZED-2 reactor. Bucklings are given for both D_2O and He coolant for the following lattice pitches; 20, 22, 24, 26, 28, 32, 36 and 40 cm. The spatial distribution of the In Cd-ratio was measured at pitches of 20, 24 and 28 cm, and the relative In/Cu activation ratio at a pitch of 40 cm.

Radial bucklings were derived from spatial Mn activation distributions using a two-group homogeneous diffusion theory model for a finite cylindrical reactor with a radial reflector. The axial distributions well removed from the core boundaries were fitted to a cosine function. Total bucklings (radial plus axial) are corrected to a moderator condition of 25°C and 99.72 atom % D_2O.

2. ONE-GROUP AND TWO-GROUP DIFFUSION THEORY

The homogeneous two-group diffusion equations for the fundamental radial distributions of the thermal neutron flux ϕ_{th} and fast flux ϕ_f in an infinite cylindrical reactor with a radial reflector can be expressed as[3],

$$\phi_{th}\,(r) = A'J_o(\lambda r) + C'I_o(\beta r) \quad - \; - \; - \; - \quad (1)$$

$$\phi_f\,(r) = SA'J_o(\lambda r) - S'C'I_o(\beta r) \quad - \; - \; - \quad (2)$$

respectively, while for a reactor of finite length with the origin located a distance z_o from the flux maximum, the fundamental solution of the axial distribution f(z), in homogeneous one-group diffusion theory is,

$$f(z) = \phi\,(z_o)\cos\alpha\,(z - z_o) \qquad ------ \quad (3)$$

where

A', C' = amplitude coefficients,

S, S' = fast-thermal coupling coefficients which depend on the core properties,

λ^2 = radial buckling

α^2 = axial buckling = $\frac{\pi^2}{H_{ex}}$

H_{ex} = extrapolated height

$$\beta^2 = \frac{1}{L^2} + \frac{1}{L_s^2} + 2\alpha^2 + \lambda^2 \qquad ------ \quad (4)$$

The total geometrical buckling for a finite cylindrical reactor is

$$B^2 = \alpha^2 + \lambda^2 \qquad ------ \quad (5)$$

For a neutron detector whose activation cross-section can be expressed as,

$$\bar{\Sigma}_{total} = \bar{\Sigma}_{th} + \bar{\Sigma}_f \qquad ------ \quad (6)$$

where

$\bar{\Sigma}_{th}$ and $\bar{\Sigma}_f$ are activation cross-sections averaged over the thermal and fast neutron flux distributions respectively, the total activation Act(r,z), is

$$Act(r,z) = \phi_{th}(r,z)\bar{\Sigma}_{th} + \phi_f(r,z)\bar{\Sigma}_f \qquad --- \quad (7)$$

Substitution of (1) and (2) in (7) and neglecting the axial variation gives the radial variation of the induced activity Act'(r) as

$$Act'(r) = (\bar{\Sigma}_{th} + S\Sigma_f)A'J_o(\lambda r) + (\bar{\Sigma}_{th} - S'\Sigma_f)C'I_o(\beta r) \qquad --- \quad (8)$$

Equation (8) can be expressed in the general form

$$Act'(r) = A\, J_o(\lambda r) + C\, I_o(\beta r) \quad - - - - - - \quad (9)$$

where the magnitude and sign of C will be dependent on the detector parameters and the core properties.

Equations (3) and (9), valid for homogeneous systems, can be applied to a heterogeneous reactor if the neutron flux is measured at identical positions in each cell so that the macroscopic distribution is not distorted by the microscopic distribution. This implies separability of macroscopic and microscopic flux variations.

Total bucklings were determined by measuring neutron flux distributions throughout the reactor core and fitting the measured radial and axial distributions to equations (9) and (3) respectively.

3. EXPERIMENTAL

3.1 Fuel and Lattice Arrangements

Figure 1 shows a cross-sectional view of the 19-element uranium metal fuel assembly.

The natural-uranium fuel is that described in AECL-759[1]. Density of the fuel is 18.93 ±0.05 g/cm^3. Thirteen cylindrical slugs each 15.2 ±0.08 cm long and 1.31 ±0.01 cm in diameter are sheathed in type 1S aluminum tubes of 1.59 cm o.d. and 1.02 mm wall thickness to form a full-length element.

Elements were arranged in a CANDU-type array, i.e. one element at the center, six on a circle of 3.55 cm diameter and twelve on a circle of 6.85 cm diameter. Each cluster of 19 elements was contained in a type 65S aluminum coolant tube with 8.89 cm O.D. and a wall thickness of 1.57 mm to form a fuel assembly. Table 1 gives the cross-sectional areas of the various materials for a cell.

The minimum sheath-to-sheath spacing of 1.8 mm was fixed by a headpiece from which the elements were suspended. Additional constraints were provided by 0.81 mm thick Al plates drilled to fix the elements on a CANDU array. Four plates were used per cluster, at ~ 5 cm, ~ 60 cm, ~ 110 cm and ~ 160 cm from the bottom of the element sheaths. Not all elements were straight so that the sheath-to-sheath spacing varied from its nominal value by ≤ 0.6 mm between positioner plates.

The assemblies were suspended from the rod hangers by a length of stainless steel chain attached to a stainless steel bolt threaded through the headpiece to which the coolant tube flange was bolted. (See Figure 2). This arrangement allowed the bottom of the element sheaths to be suspended ~ 1.7 cm above the bottom of the coolant tube, a feature which allowed free passage of the coolant. Heavy water coolant was expelled through the bottom of the fuel assembly by the introduction of pressurized helium through a Poly-flo coupling located on the top plate of each fuel assembly. (See Figure 3).

Fifty-five fuel assemblies were used for measurements in the triangular arrays with pitches of 22 to 40 cm, inclusive, both with D_2O and He coolants. For the 20 cm lattice a 'driver' region of 36 air-cooled 7-element UO_2 assemblies(4) surrounded the central 55 assemblies to produce criticality with a moderator height less than the fuel height. The 'driver' region was also used in some measurements at 24 cm pitch.

Heavy water purity decreased from 99.74 to 99.70 atom % D_2O throughout the experiments. The purity at any date was obtained from interpolation of the results of analyses of moderator samples taken monthly.

3.2 Determination of the Geometrical Buckling

Total buckling was determined from foil activation measurements made at positions mid-way between fuel assemblies. Figures 4 and 5 show the radial locations of measuring thimbles for two loading patterns. The thimbles contained three foils 10 cm apart at elevations near the vertical flux maximum except for the two central thimbles which contained detectors spaced at 10 cm intervals over the entire moderator height. Detectors fixed to aluminum backing plates were substituted for blank backing plates at the required locations in the suspension system. The backing plates were joined by lengths of 0.076 cm diameter Zircaloy wire. The wire-foil system was supported in an air-filled aluminum thimble of a cruciform cross-section. The main components of the thimble system are illustrated in Figure 6.

Manganese and copper foils were used as neutron detectors. The Mn(11% Ni) circular foils are 1.13 cm diameter, weigh ~ 85 mgm and are fixed to 25 x 20 x 0.5 mm Al backing plates. The foils have been intercalibrated by irradiation to an accuracy of ~ ±0.25%. The Cu foils are of identical area, weigh ~ 115 mgm and are glued to the backing plates. Sensitivities of these latter foils were assumed to be proportional to their weights which are known to a relative accuracy of ~ ±0.2%.

After irradiation the induced 2.58 hr Mn^{56} activity was measured with a TQQB electroscope while the 12.8 hr Cu^{64} γ-activity was counted with a NaI(Tl) scintillation counter. At least two irradiations were performed at each pitch with each coolant.

3.3 Measurement of Spectrum Parameters

Macroscopic neutron-spectrum parameters were measured in D_2O-cooled lattices at pitches of 20, 24, 28 and 40 cm. All measurements were made at moderator positions mid-way between fuel clusters. For the 40 cm lattice the relative In/Cu ratio was derived from the activity induced in Cu foils (as described above) and in similar Pb-In foils, 0.2% In by weight. Cadmium ratios were measured with the Pb-In foils at other listed pitches. For Cd-ratio measurements foils were enclosed in either 0.030" thick Cd or Al boxes cemented to Al backing plates. Detectors were placed every 10 cm along the vertical in thimbles K1W and K1E (Figure 4) and radially throughout the core at either two or three elevations near the flux maximum. Induced γ-activities were counted with a NaI(Tl) scintillation counter.

3.4 Critical Height Measurements

An accurate determination of the critical D_2O level in the ZED-2 calandria was required for a determination of foil loading corrections and derivation of axial extrapolation lengths. Measurements of the moderator height were made with the accurate height indicator described in AECL-1505. Height differences due to 'loading' effects were accurate to ~±0.003 cm. Foil elevations with respect to the moderator level, as required for derivation of axial extrapolation lengths were accurate to ~ ±0.2 cm.

3.5 He-Cooled Lattices

Measurements with He coolant in the 55 assemblies were made by expelling the D_2O coolant into the moderator region through a hole in the bottom of the coolant tube. This was accomplished by varying He pressure in a Poly-flo tube attached to the top of each assembly which altered the level of the D_2O coolant. (Figure 3). The He pressure - D_2O coolant level relationship was determined experimentally by observing the pressure required for the onset of bubbling from the bottom of the assembly for different D_2O levels. During a He-cooled irradiation all but ~ 1 cm of D_2O was excluded from the assemblies.

4. DATA ANALYSIS AND RESULTS

4.1 Neutron Activation Distributions

The counting data from measurements with the Mn-Ni foils were corrected for exponential decay, detector sensitivities, background and electroscope drift. Relative activities were obtained by normalizing to the activity of a foil located near the maximum neutron flux in the core.

γ-counting data from measurements with Cu foils were also corrected for exponential decay, detector sensitivities, dead-time losses and background.

Normalized and corrected activities obtained from each irradiation are given in Tables 1-A to 36-A, Appendix A. The radius, elevation and exact position in the core (refer to Figures 4 and 5) are given for each foil. Foil elevations and the critical moderator height h_c are both measured with respect to the ZED-2 zero plane, i.e. the elevation of the central region of the calandria bottom.

4.2 Derivation of the Geometrical Bucklings

Corrected axial distributions, well-removed from the core boundaries, were fitted by the method of least-squares to the cosine function given by equation (3). Bracketed activities as given in the tables of Appendix A were not included in the fit. The average of the two values of α and z_o obtained from each irradiation is listed in the tables.

Radial distributions were fitted by the method of least-squares to equation (9) but with a fixed value of β calculated from equation (4). Values of L^2 and L_s^2 as calculated by the Chalk River lattice recipe POOOF (5) for a moderator condition of 25°C and 99.75 atom % D_2O were used.

These are listed in Table II. The fitted value of α was used and λ was at first approximated by the value obtained from a $J_0(\lambda r)$ fit to activities obtained in a region of constant Cd-ratio. This fitting procedure was adopted after only limited success was achieved when all four parameters, A, λ, C and β were allowed to vary in the fit. Even in the latter cases when convergence was attained the fit error calculated for λ was ~ 50% and it was concluded that radial bucklings should be obtainable from the measurements to a higher precision. The determination of radial buckling by the above method is described in more detail in (6, 7).

Six values of λ were obtained from each irradiation by combining the west-plus-south (W+S) and east-plus-north (E+N) data for each of the three elevations. $\lambda(n)$, $\lambda(n-1)$ and $\lambda(n-2)$ listed in the tables are the average values of all six results. Here n designates a value derived from a fit to all radial activities, n-1 the results when the outermost point in each set of data is omitted from the fit and n-2 when the two outermost points in each set are omitted. $\lambda^2(n)$ values are used in deriving the geometrical bucklings given in Tables III and IV.

The error quoted for the α, λ and z_0 values is

1) the error obtained from the "goodness-of-fit" of the data to the assumed distribution function, or

2) the standard deviation in the mean of the several values obtained for each parameter, whichever is the larger.

4.3 Corrections to Buckling Values

Corrections for foil and thimble loading effects and small temperature and purity variations during the period of measurements had to be applied to obtain a consistent set of buckling values to compare with lattice calculations.

Corrections for the 'loading effect' were obtained from measurements of the critical height with and without thimbles and foils in the core. It is assumed that the radial buckling is independent of loading and critical height and therefore α_{CORR} is

$$\alpha_{CORR} = \frac{\pi}{\frac{\pi}{\alpha_{FIT}} - \Delta h} \qquad (10)$$

where

α_{FIT} = value derived from the fit.

Δh = difference in critical heights with and without foils and thimbles.

Temperature and purity coefficients of buckling are derived from POOOF calculations[5]. The buckling values listed in Tables III and IV are corrected to a moderator condition of 25°C and 99.72 atom % D_2O.

No corrections have been applied for variation of the radial buckling with loading because it is assumed to be negligible. This assumption was verified both analytically and experimentally. The experiment consisted of loading the central region of one lattice with extra thimbles and foils. The buckling derived from this measurement agreed with the buckling derived from a measurement with a normal thimble and foil loading. A first-order perturbation theory model based on one-group, four-region homogeneous diffusion theory and the measured differences in critical height, also indicated that flux flattening produced by the increased absorption in the central region of the core due to more thimbles and foils per unit volume (see Figure 4), could be ignored.

4.4 Macroscopic Distribution of Cd-Ratio and Relative In/Cu ratio

Results of the macroscopic In Cd-ratio and the In/Cu ratio measurements for D_2O cooled lattices are summarized in Appendix B. Cd-ratio values (Tables 1-B to 3-B) are ratios of Al-covered to Cd-covered activities for foils irradiated at the same elevation at equivalent radial positions (see Figure 4).

Axial variations of the Cd-ratio are shown in Figure 7 and radial variations in Figure 8.

Results of the In/Cu ratios measured in the 40 cm pitch D_2O-cooled lattice are shown in Table 4-B. Axial and radial variations of relative In/Cu ratios are shown in Figures 9 and 10 respectively.

Average values of the In Cd-ratio or relative In/Cu ratios for the region where they are constant within individual experimental errors of ± 3% are listed in Table V. This constant region is defined by the dotted lines in the figures. Errors in averages are the standard deviation, σ, of all the values within the constant region for the axial and radial plots.

Values marked with an asterisk have been omitted from the averages. Many of these omissions are justified because the Cd-covers were found to be loose after irradiation.

4.5 Extrapolation Lengths

Analysis of neutron activation distributions yield values for the extrapolation lengths if the core size and critical height are known. The radial extrapolation length can be defined as

$$\delta R = R_{ex} - R_c = \frac{2.405}{\lambda} - R_c$$

where

R_c = equivalent core radius defined for a triangular array by

$$R_c = 0.525\ d\sqrt{N}$$

where

d = lattice pitch

N = number of rods, 55 in all cases except the driven lattices.

The total axial extrapolation length δZ_t can be defined as

$$\delta Z_t = H_{ex} - (h_c - 15)$$

$$= \frac{\pi}{\alpha} - (h_c - 15) = \delta Z_u + \delta Z_l$$

where

δZ_u, δZ_l = upper and lower extrapolation lengths respectively,

$h_c - 15$ = distance in cm from bottom of fuel to the critical moderator level.

Values of δR, δZ_t, δZ_u and δZ_l obtained from the flux distributions for all lattices are listed in Tables VI and VII. Errors quoted are derived from the errors in α, λ, z_o and h_c.

Figures 12 and 13 show the variation of the radial extrapolation lengths with lattice pitch. Plotted values at each pitch are the average of the measurements listed in Tables VI and VII. Axial extrapolation lengths listed in Tables VI and VII are also plotted as a function of lattice pitch in Figures 13 and 14. Lines in the figures are drawn as guides-to-the-eye only and are not the results of a least-squares fit to the data.

5. DISCUSSION OF RESULTS

5.1 Buckling

Summaries of buckling values for D_2O and He coolants are given in Tables III and IV respectively, and are plotted in Figure 15 as a function of lattice pitch. Figure 15 shows that the maximum buckling is at a pitch of approximately 25 cm for both coolants with the He coolant giving higher values for the range investigated. These results, combined with the critical height measurements (Tables VI and VII), indicate that a positive reactivity effect results from complete loss of D_2O coolant in the cold-clean critical state for the lattices studied.

At a pitch of 24 cm, with both D_2O and He coolants, three buckling values were obtained. The first value is derived from flux distributions measured in the 55-assembly core when surrounded by a driver region of 36 7-element UO_2 assemblies. The other two values are derived from measurements in the 55-assembly core only. Results agree within experimental errors for the D_2O-cooled lattices but for the He-cooled lattices the "driven" result is slightly outside the experimental errors as compared to the "undriven" results. This may be due to the existence of anisotropy in the air-cooled lattices or larger uncertainties in the measured bucklings than those quoted. At this pitch the 55-assembly core result is probably more accurate since the neutron streaming effect, if any, will be less due to the higher critical height.

Apart from systematic effects the quoted buckling errors vary from 0.01 m^{-2} for 40 cm pitch lattices to 0.09 m^{-2} for the 20 cm He-cooled lattice.

5.2 Macroscopic In Cd-Ratios and Relative In/Cu Ratios

The measurements indicate that these ratios are constant within experimental errors at radial positions $\leq 2.6 \times d$ (d = lattice pitch), for all lattices studied. At a pitch of 20 cm the In Cd-ratio at radial positions beyond $2.6 \times d$ does not rise as rapidly due to the presence of the surrounding driver region (see Figure 7.

From the axial plots the region of constant ratio for all lattices studied was found to be:

$40 \text{ cm} \leq Z \leq h_c - 25$, h_c = moderator critical height within experimental errors.

Individual measurements agreed with the average values listed in Table V to better than ± 3%.

5.3 One-Group and Two-Group Models in Analysis

Although analysis of axial distributions was based on homogeneous, one-group diffusion theory, analysis for the radial component of the buckling was based on two-group theory.

Use of the two-group model was considered to be warranted after analysis of activation distributions obtained with the improved measuring techniques discussed indicated a systematic error in the derived radial bucklings. The error increased as the radius of the region analyzed was decreased. A more detailed report of this investigation and adoption of the two-group formulation is given in (7).

Similar trends did not exist as points within the selected region of the axial distributions were omitted in the analysis of the axial distributions.

5.4 Extrapolation Lengths

Radial and axial extrapolation lengths are plotted in Figures 11 to 14 and summarized in Tables VI and VII. Radial extrapolation lengths derived from measurements with D_2O coolant are generally less than He coolant values for all pitches except 20 cm. From Figures 11 and 12 the radial extrapolation length appears to be constant within ± 2 cm for lattice pitches in the range 24 to 32 cm with either coolant.

Total axial extrapolation lengths exhibit the same trend as the radial lengths, i.e. D_2O-cooled values are lower than He-cooled values. Derived upper axial extrapolation lengths are considerably greater than the theoretical values given by 0.71 λ_{tr}. This could be due to neutrons arising from

1) backscattering in the graphite reflector and

2) backscattering and production in the fuel itself,

since both fuel and moderator extend above the critical moderator height.

Present values of extrapolation lengths and previous ones[4] should assist in predicting critical sizes of cores in ZED-2. They should also be of value in assessing the effective worth of reflectors.

6. CONCLUSIONS

Buckling values have been obtained for 19-element natural uranium metal fuel assemblies both with D_2O and He coolants for triangular arrays with pitches from 20 to 40 cm, inclusive. For this range of pitches the He-cooled lattices yielded higher bucklings.

Spatial distributions of the In Cd-ratio with D_2O coolant were measured at pitches of 20, 24 and 28 cm and the distribution of relative In/Cu activation rates was measured at a pitch of 40 cm also with D_2O coolant.

Extrapolation lengths derived from flux plots yield information on reflector effectiveness in ZED-2.

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Table I

Cross-Sectional Areas of Materials Per Cell
for 19-element Natural-uranium Metal Assembly

Triangular Lattice Pitch (cm)	20	22	24	26	28	32	36	40
Cell Area (cm^2)	346.41	419.16	498.83	585.44	678.97	886.82	1122.38	1385.65
Uranium Area (cm^2)	25.69	25.69	25.69	25.69	25.69	25.69	25.69	25.69
Moderator Outside Coolant Tube (cm^2)	284.33	357.09	436.76	523.36	616.90	824.71	1060.30	1323.58
Moderator Inside Coolant Tube (cm^2)	20.13	20.13	20.13	20.13	20.13	20.13	20.13	20.13
Aluminum (cm^2)	13.36	13.36	13.36	13.36	13.36	13.36	13.36	13.36
Air (cm^2)	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90
Moderator / Metal (D_2O Coolant)	11.85	14.68	17.78	21.16	24.80	32.89	42.06	52.30
Moderator / Metal (He Coolant)	11.07	13.90	17.00	20.37	24.01	32.10	41.27	51.52

Table II

Values of L^2 and L_s^2 for

Lattices of 19-element Natural-Uranium Metal Assemblies

as Calculated by POOOF*

Triangular Pitch (cm)	D_2O-Coolant		He-Coolant	
	L^2 (cm^2)	L_s^2 (cm^2)	L^2 (cm^2)	L_s^2 (cm^2)
20	81.08	137.8	83.66	156.7
22	102.5	134.3	105.0	150.2
24	126.6	131.6	127.7	143.4
26	153.0	129.6	153.8	139.3
28	185.0	128.1	184.3	136.3
32	255.8	125.9	253.0	132.0
36	339.4	124.4	334.0	129.1
40	435.8	123.4	427.5	127.1

*For moderator conditions of 25°C, 99.75 atom % D_2O

Table III: Buckling Summary - D_2O Coolant - 19-element Natural-Uranium Metal Fuel Assemblies

Table	Pitch (cm)	α^2 (m^{-2}) †	λ^2 (m^{-2})	$\Delta B^2_\tau (m^{-2})$	$\Delta B^2_\rho (m^{-2})$	$B^2(25^oC)$ (99.72 At %) (m^{-2})	B^2 Average (25^oC, 99.72 % D_2O) (m^{-2})
1-A	20	2.131±.009	2.352±.084	-.007	0.000	4.476±.084	
2-A	20	2.126±.016	2.348±.070	-.007	0.000	4.467±.072	4.473±.064
3-A	20	2.134±.016	2.348±.032	-.007	0.000	4.475±.036	
4-A	22	2.377±.024	3.265±.033	-.007	+.003	5.638±.041	5.658±.060
5-A	22	2.388±.032	3.294±.077	-.005	+.002	5.679±.080	
6-A	24	3.700±.032	2.231±.033	-.008	+.008	5.931±.046 *	
7-A	24	2.974±.018	3.025±.024	-.008	+.006	5.997±.030	6.008±.045
8-A	24	2.968±.038	3.053±.046	-.007	+.004	6.018±.060	
9-A	26	3.266±.026	2.765±.053	-.006	+.003	6.028±.059	6.016±.055
10-A	26	3.228±.040	2.780±.031	-.006	+.002	6.004±.051	
11-A	28	3.246±.021	2.492±.011	-.009	-.006	5.723±.024	5.725±.032
12-A	28	3.249±.035	2.493±.018	-.009	-.006	5.727±.039	
13-A	32	2.905±.032	2.066±.010	-.010	-.011	4.950±.034	4.952±.030
14-A	32	2.912±.025	2.063±.005	-.010	-.011	4.954±.026	
15-A	36	2.388±.019	1.783±.006	-.008	-.016	4.147±.020	4.149±.022
16-A	36	2.381±.023	1.793±.005	-.007	-.016	4.151±.024	
17-A	40	1.843±.008	1.618±.005	-.011	-.025	3.425±.009	3.418±.010
18-A	40	1.836±.009	1.611±.005	-.011	-.025	3.411±.010	

† Loading correction included

* Not included in average - see text, 5.1.

Table IV: Buckling Summary - He Coolant - 19-element Natural-Uranium Metal Fuel Assemblies

Table	Pitch (cm)	α^2 (m^{-2}) †	λ^2 (m^{-2})	ΔB_T^2 (m^{-2})	ΔB^2 (m^{-2})	B^2(25°C) (99.72 At.%) (m^{-2})	B^2 Average (25°C, 99.72 At.% D_2O)(m^{-2})
19-A	20	2.225±.012	2.395±.147	-.006	-.001	4.613±.147	4.587±.087
20-A	20	2.204±.011	2.366±.049	-.006	-.001	4.563±.050	
21-A	20	2.217±.014	2.375±.063	-.007	-.001	4.585±.065	
22-A	22	2.562±.026	3.234±.038	-.006	+.002	5.792±.046	5.817±.052
23-A	22	2.574±.025	3.272±.052	-.006	+.002	5.842±.058	
24-A	24	3.834±.034	2.234±.033	-.008	+.007	6.067±.047*	
25-A	24	3.202±.026	2.954±.023	-.008	+.003	6.151±.035	6.176±.046
26-A	24	3.189±.032	3.018±.047	-.007	+.002	6.202±.057	
27-A	26	3.451±.024	2.741±.029	-.006	+.002	6.188±.038	6.186±.041
28-A	26	3.450±.037	2.740±.024	-.006	+.001	6.185±.044	
29-A	28	3.576±.029	2.491±.010	-.010	-.004	6.053±.031	6.030±.030
30-A	28	3.557±.027	2.464±.012	-.010	-.004	6.007±.030	
31-A	32	3.236±.025	2.054±.007	-.010	-.010	5.270±.026	5.281±.026
32-A	32	3.249±.026	2.064±.007	-.010	-.011	5.292±.027	
33-A	36	2.696±.033	1.771±.004	-.009	-.014	4.444±.033	4.442±.030
34-A	36	2.693±.025	1.769±.005	-.008	-.014	4.440±.026	
35-A	40	2.165±.009	1.603±.004	-.012	-.024	3.732±.010	3.729±.009
36-A	40	2.157±.007	1.605±.004	-.012	-.024	3.726±.008	

† Loading correction included

* Not included in average - see text, 5.1

Table V

Average Values of the Macroscopic In Cd-Ratio or Relative In/Cu Ratio Measured at Cell Boundaries as a Function of Triangular Lattice Pitch

Triangular Lattice Pitch (cm)	In Cd-Ratio	Relative In/Cu Ratio
20	1.982 ±.006	-
24	2.525 ±.006	-
28	3.197 ±.007	-
40	-	59.61 ±.07

Table VI: Summary of Extrapolation Lengths Measured in ZED-2

19-element D_2O-cooled Natural Uranium Assemblies

Table	Pitch (cm)	R_{ex} (cm)	δR (cm)	H_{ex} (cm)	h_c (cm)	z_o (cm)	δZ_t (cm)	δZ_u (cm)	δZ_1 (cm)
1-A	20	156.82±2.79	56.66±2.79	216.41±.45	191.64	89.53±.26	39.77±.49	6.09±.46	33.67±.41
2-A	20	156.95±2.34	56.79±2.34	216.75±.84	191.70	89.54±.17	40.05±.86	6.22±.65	33.84±.62
3-A	20	156.96±1.09	56.80±1.09	216.69±.81	192.09	89.76±.31	39.60±.83	6.01±.68	33.58±.65
4-A	22	133.09±.67	47.44±.67	205.40±1.06	182.75	85.66±.39	37.65±1.08	5.61±.87	32.04±.85
5-A	22	132.52±1.54	46.87±1.54	204.56±1.37	182.33	85.52±.35	37.23±1.39	5.47±1.05	31.76±1.03
6-A	24	161.03±1.20	40.84±1.20	163.33±.71	143.39	66.83±.16	35.44±.74	5.36±.56	30.09±.53
7-A	24	138.28±.55	44.85±.55	183.28±.56	162.64	76.64±.10	35.64±.59	5.64±.45	30.00±.40
8-A	24	137.63±1.05	44.20±1.05	183.10±1.18	162.28	76.14±.52	35.82±1.20	5.41±1.01	30.41±.99
9-A	26	144.64±1.38	43.42±1.38	174.90±.70	156.04	73.85±.27	33.86±.73	5.26±.60	23.60±.57
10-A	26	144.25±.81	43.03±.81	175.56±1.09	155.67	72.97±.50	34.89±1.11	5.08±.94	29.81±.92
11-A	28	152.36±.33	43.36±.33	174.99±.55	155.02	72.81±.13	34.97±.59	5.29±.46	29.69±.41
12-A	28	152.31±.55	43.31±.55	174.90±.93	155.00	73.00±.11	34.90±.96	5.45±.70	29.45±.67
13-A	32	167.30±.42	42.72±.42	184.88±1.03	164.83	77.45±.21	35.05±1.05	5.06±.79	29.99±.76
14-A	32	167.46±.22	42.38±.22	184.63±.78	164.82	77.29±.27	34.81±.81	4.79±.65	30.03±.61
15-A	36	180.12±.30	39.97±.30	204.05±.81	185.05	87.18±.30	34.00±.83	4.15±.68	29.84±.65
16-A	36	179.61±.27	39.46±.27	204.36±1.01	185.06	87.21±.29	34.30±1.03	4.33±.80	29.97±.77
17-A	40	189.10±.25	33.38±.25	232.59±.52	215.66	102.48±.15	31.93±.52	3.12±.44	28.82±.40
18-A	40	189.50±.31	33.78±.31	232.99±.59	215.72	102.49±.25	32.27±.62	3.27±.52	29.01±.48

Table VII: Summary of Extrapolation Lengths Measured in ZED-2

19-element He-cooled Natural Uranium Assemblies

Table	Pitch (cm)	R_{ex} (cm)	δR (cm)	H_{ex} (cm)	h_c (cm)	z_o (cm)	δZ_t (cm)	δT_t (cm)	δZ_1 (cm)
19-A	20	155.40±4.78	55.24±4.78	211.81±.57	184.00	84.65±.10	42.81±.61	6.55±.46	36.25±.42
20-A	20	156.35±1.61	56.19±1.61	213.06±.54	184.25	84.84±.23	43.81±.57	7.12±.49	36.69±.44
21-A	20	156.04±2.07	55.88±2.07	212.07±.67	183.85	84.86±.19	43.22±.70	7.05±.55	36.18±.51
22-A	22	133.73±.78	48.08±.78	197.68±.99	172.20	79.53±.38	40.48±1.01	6.17±.82	34.31±.80
23-A	22	132.95±1.07	47.30±1.07	196.84±.96	171.82	79.47±.37	40.02±.98	6.07±.80	33.95±.78
24-A	24	160.92±1.21	40.73±1.21	160.94±.72	137.07	63.44±.14	38.87±.75	6.84±.56	32.03±.53
25-A	24	139.92±.55	46.49±.55	176.51±.72	154.09	71.79±.16	37.42±.74	5.96±.57	31.47±.53
26-A	24	138.45±1.08	45.02±1.08	176.60±.89	153.83	71.15±.55	37.77±.92	5.62±.86	32.15±.84
27-A	26	145.27±.77	44.05±.77	170.04±.60	147.76	69.22±.20	37.28±.63	6.48±.51	30.80±.47
28-A	26	145.28±.63	44.06±.63	169.76±.92	147.45	68.23±.57	37.31±.94	5.66±.89	31.65±.86
29-A	28	152.38±.32	43.38±.32	166.76±.68	146.50	68.35±.18	35.26±.71	5.23±.55	30.03±.51
30-A	28	153.22±.36	44.22±.36	167.19±.63	146.50	68.29±.17	35.69±.66	5.39±.52	30.30±.48
31-A	32	167.81±.28	43.23±.28	175.16±.68	154.40	71.85±.42	35.76±.70	5.05±.67	30.73±.65
32-A	32	167.40±.27	42.82±.27	174.80±.70	154.40	71.97±.42	35.40±.70	4.97±.68	30.43±.65
33-A	36	180.73±.22	40.58±.22	191.96±1.16	171.23	80.17±.30	35.73±1.18	4.92±.90	30.81±.87
34-A	36	180.80±.24	40.65±.24	192.12±.88	171.27	80.02±.41	35.85±.90	4.81±.77	31.04±.75
35-A	40	189.97±.22	34.25±.22	214.65±.42	196.27	92.90±.26	33.38±.47	3.95±.45	29.42±.39
36-A	40	189.85±.25	34.13±.25	215.03±.35	196.30	92.85±.22	33.73±.41	4.07±.39	29.67±.33

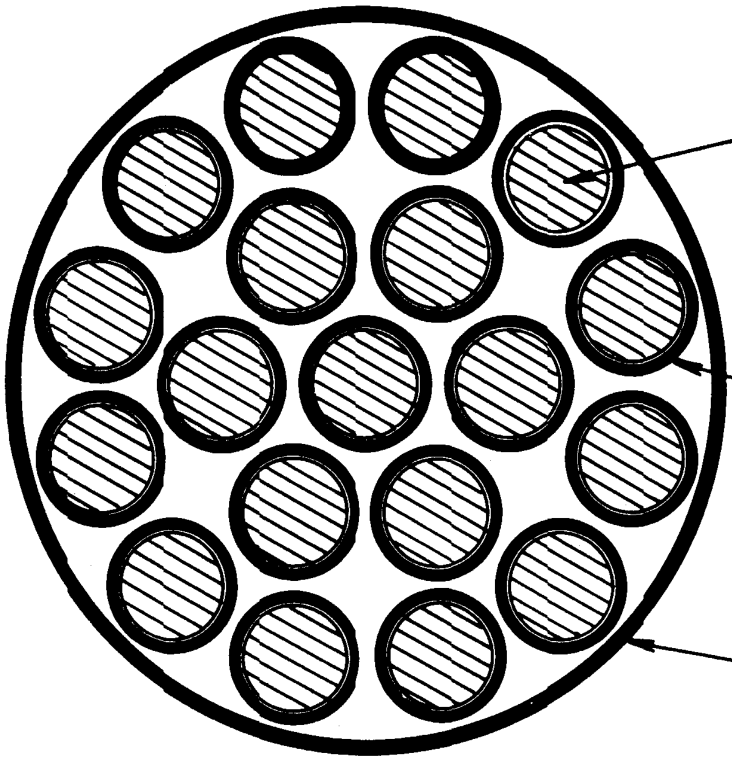


FIGURE 1 - CROSS SECTION OF 19 ELEMENT NATURAL URANIUM METAL ASSEMBLY.

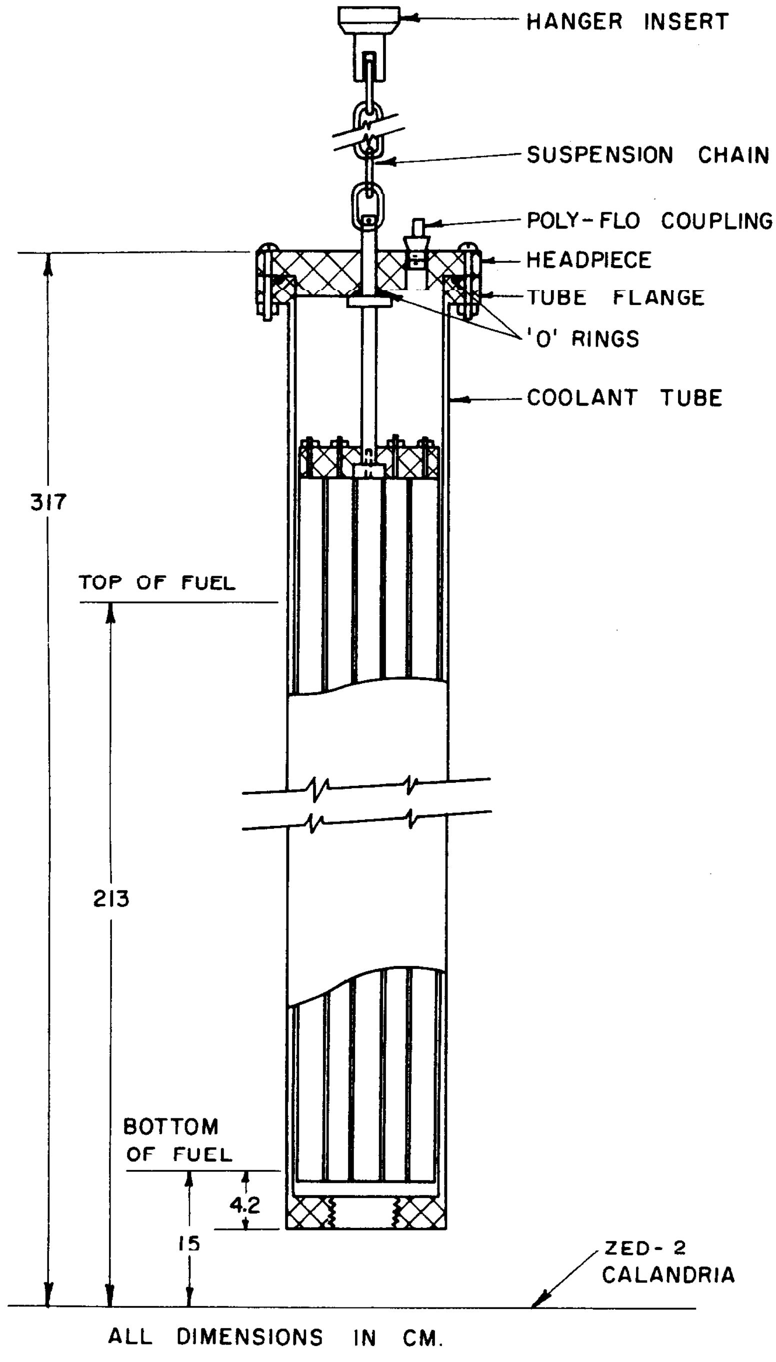


FIGURE 2 PARTIAL CUT-AWAY OF 19-ELEMENT NATURAL URANIUM FUEL ASSEMBLY

EAST- WEST SECTION

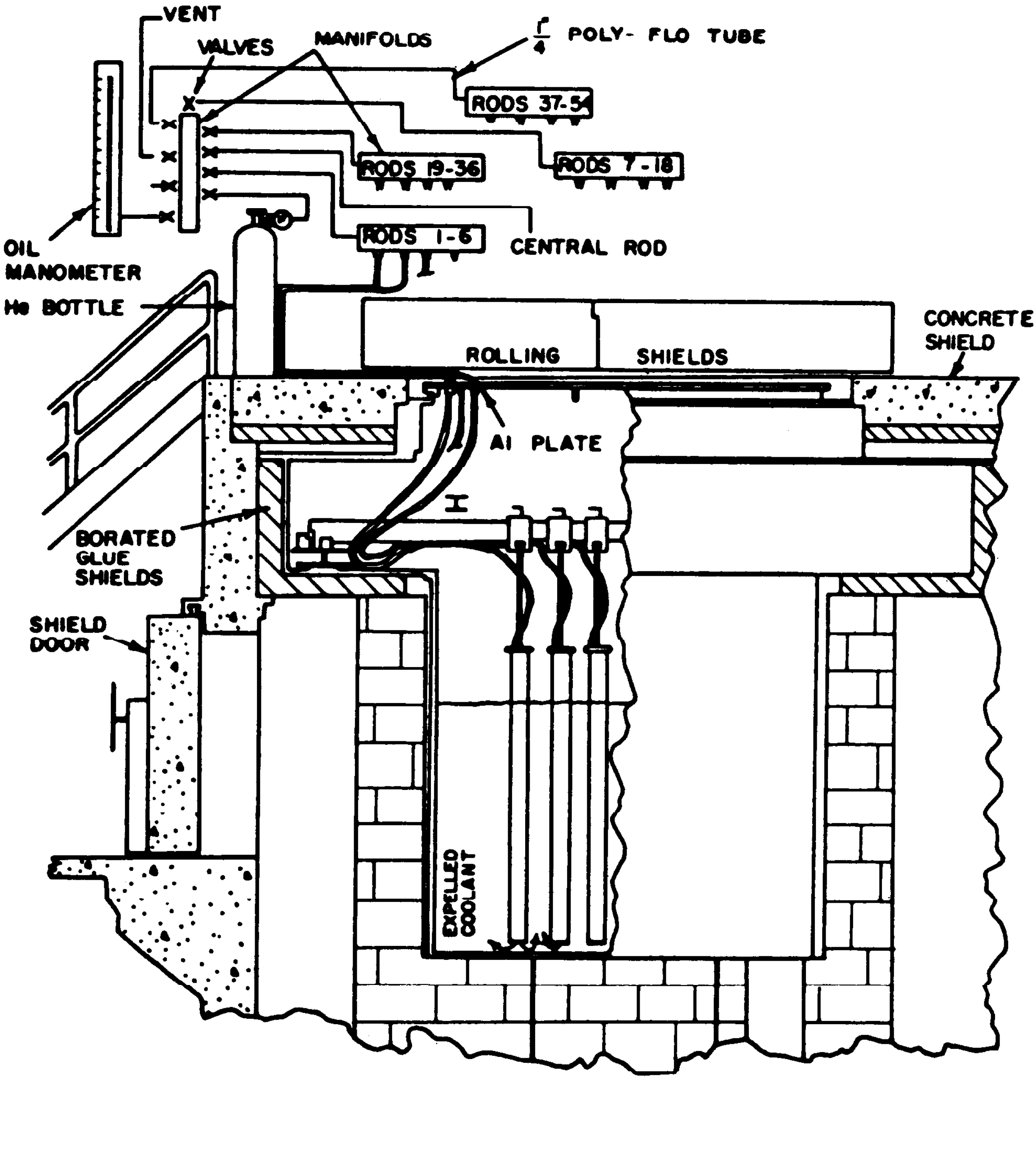
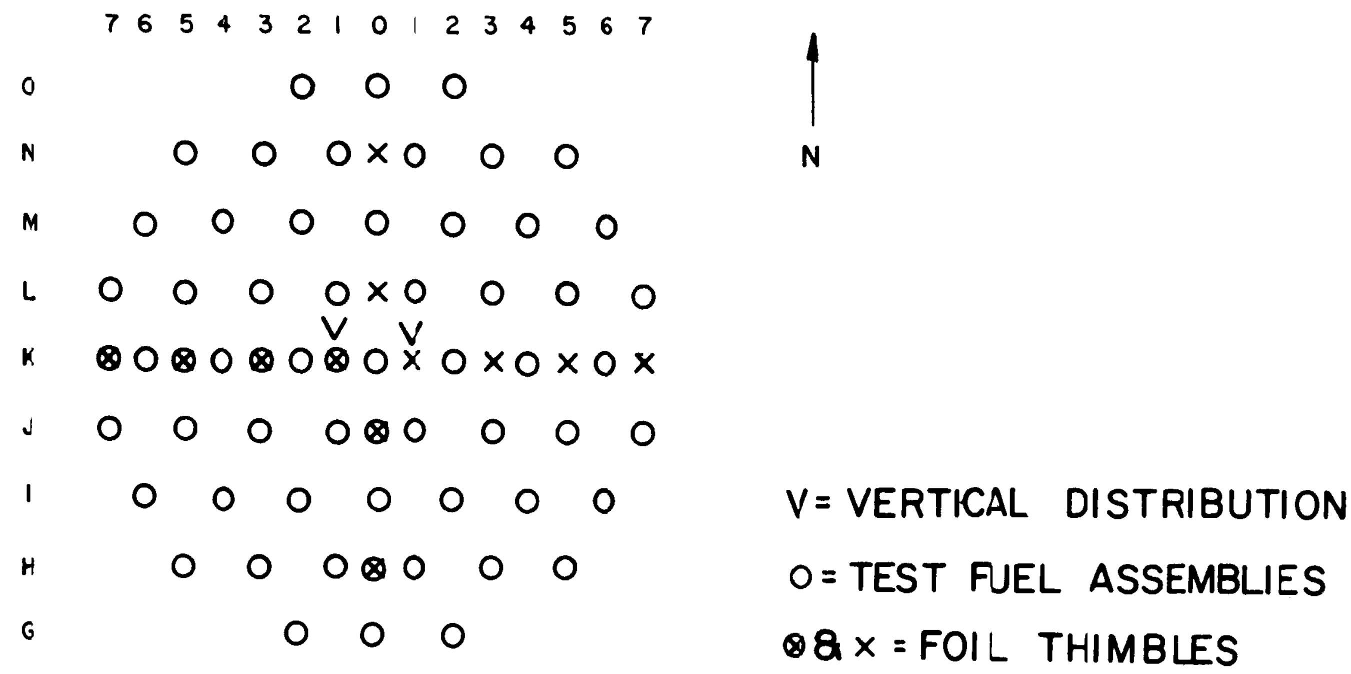
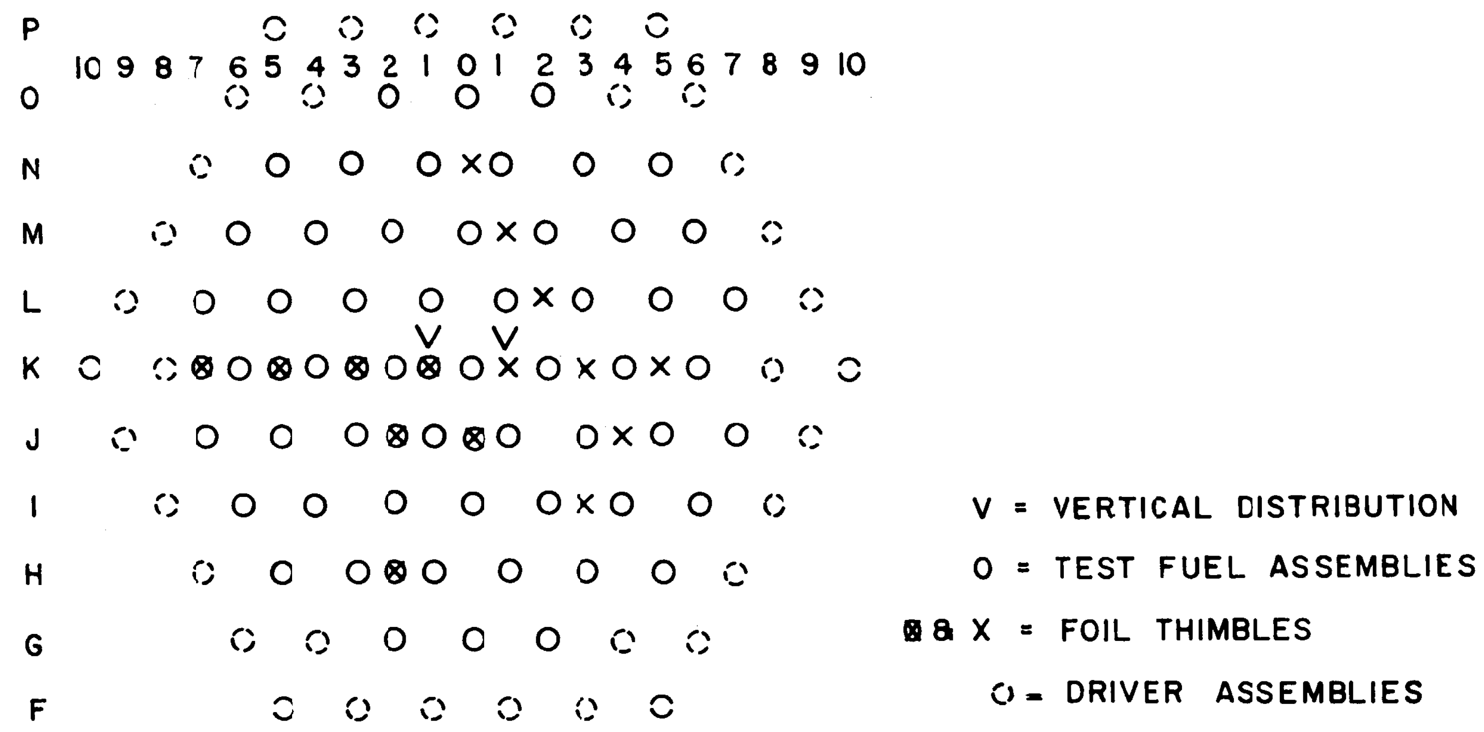


FIGURE 3 COOLANT EXCLUSION CIRCUIT IN ZED-2



FOIL LOADING PATTERN A (6 DIFFERENT RADII)

FIGURE 4



FOIL LOADING PATTERN B (12 DIFFERENT RADII)

FIGURE 5

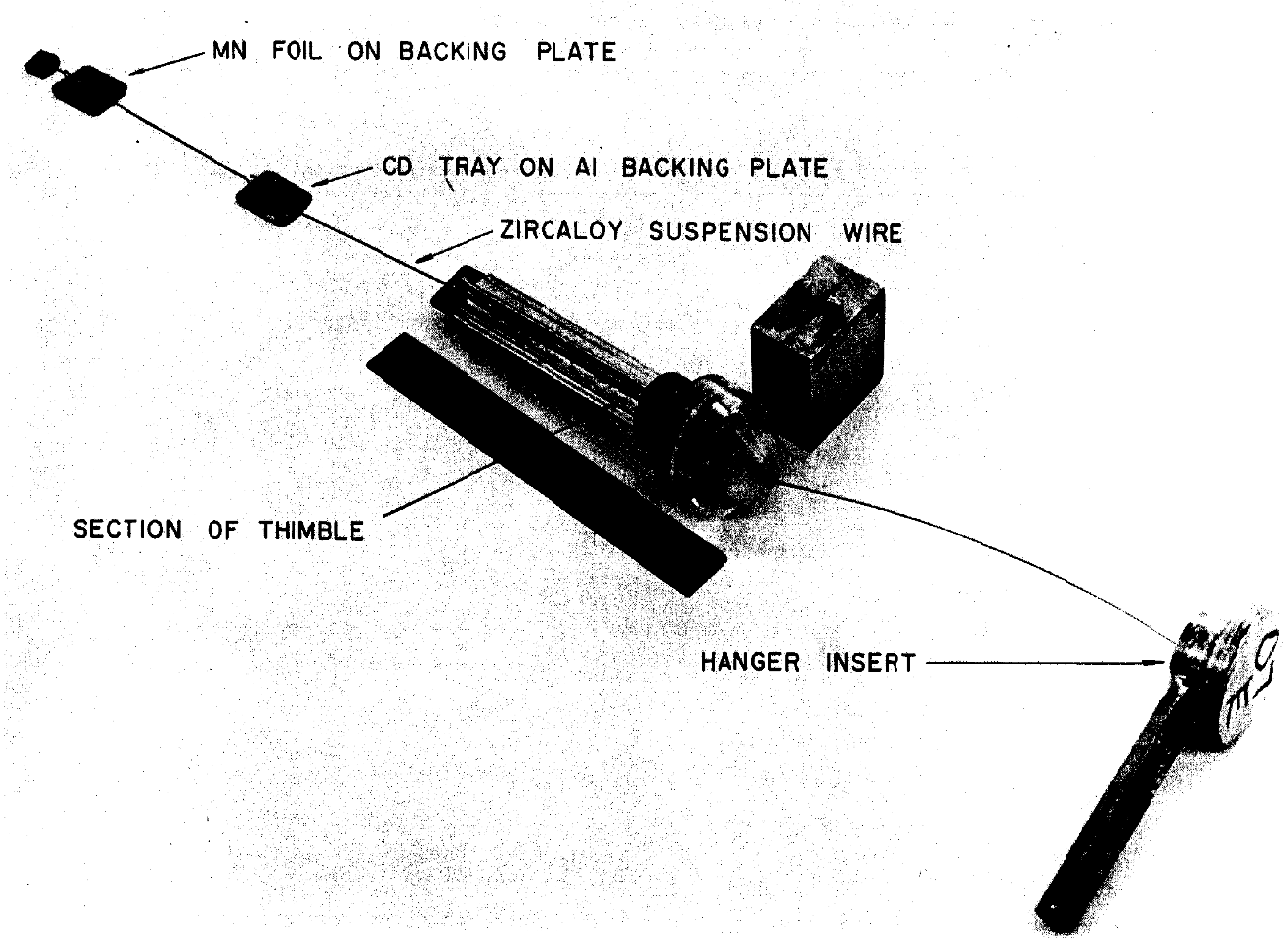


FIGURE 6 - COMPONENTS OF THE DETECTOR SUSPENSION SYSTEM.

FIGURE 7. AXIAL VARIATION OF ln CD-RATIO (D_2O-COOLANT)

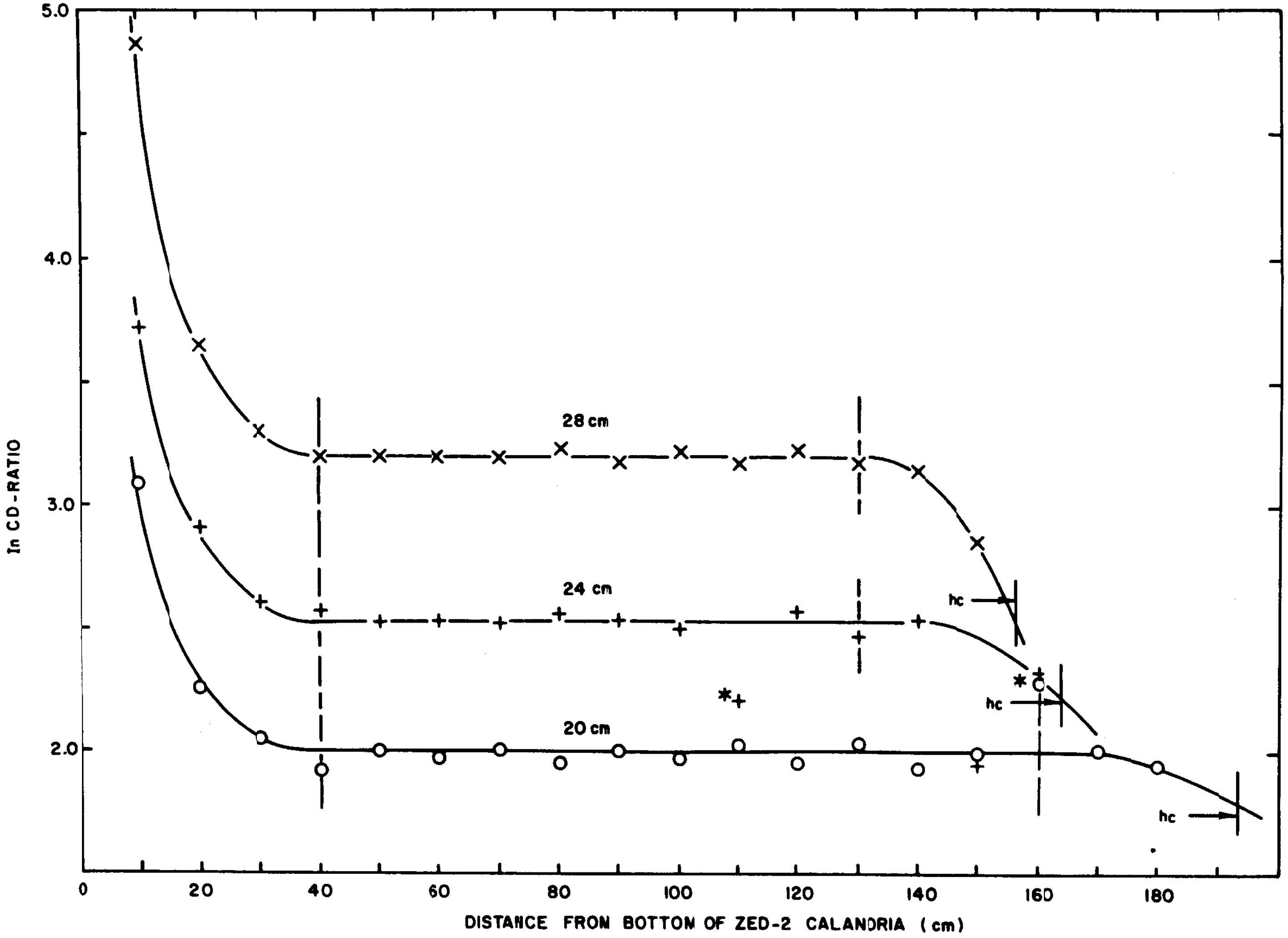


FIGURE 8. RADIAL VARIATION OF IN CD-RATIO (D_2O-COOLANT)

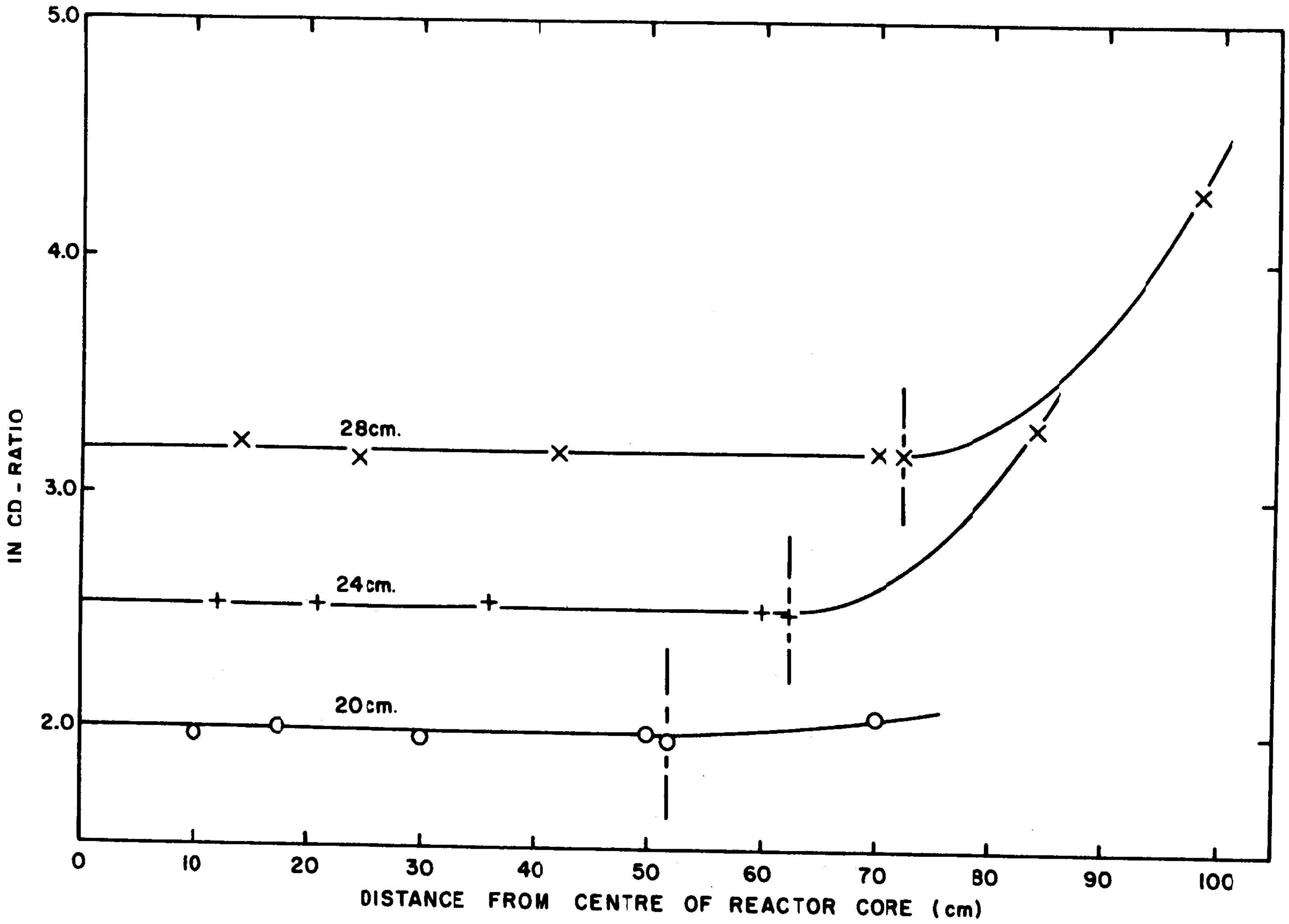


FIGURE 9 AXIAL VARIATION OF RELATIVE In/Cu RATIO FOR 40 cm D_2O - COOLED LATTICE

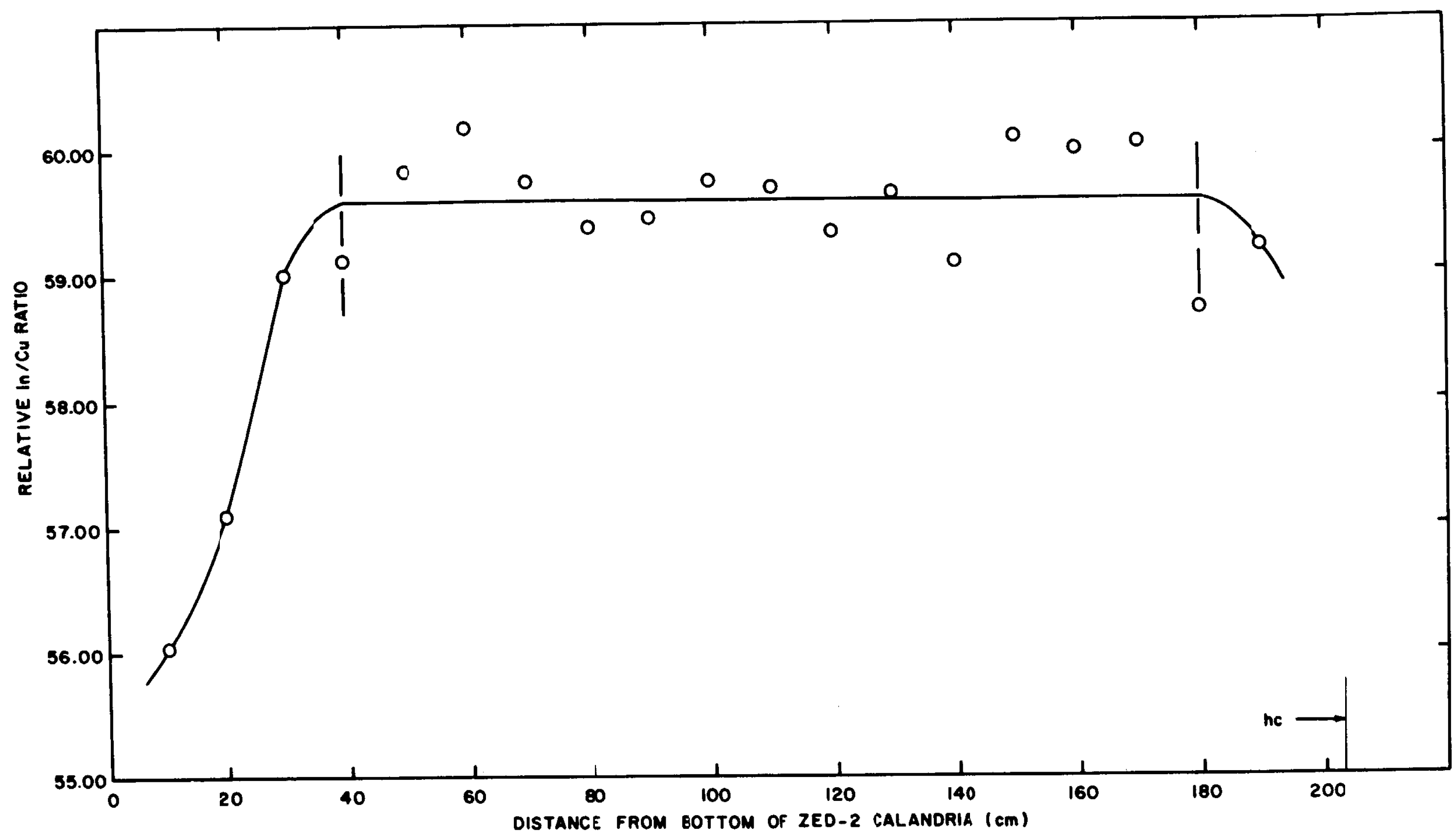


FIGURE 10. RADIAL VARIATION OF RELATIVE In/Cu RATIO FOR 40 cm. D_2O COOLED LATTICE

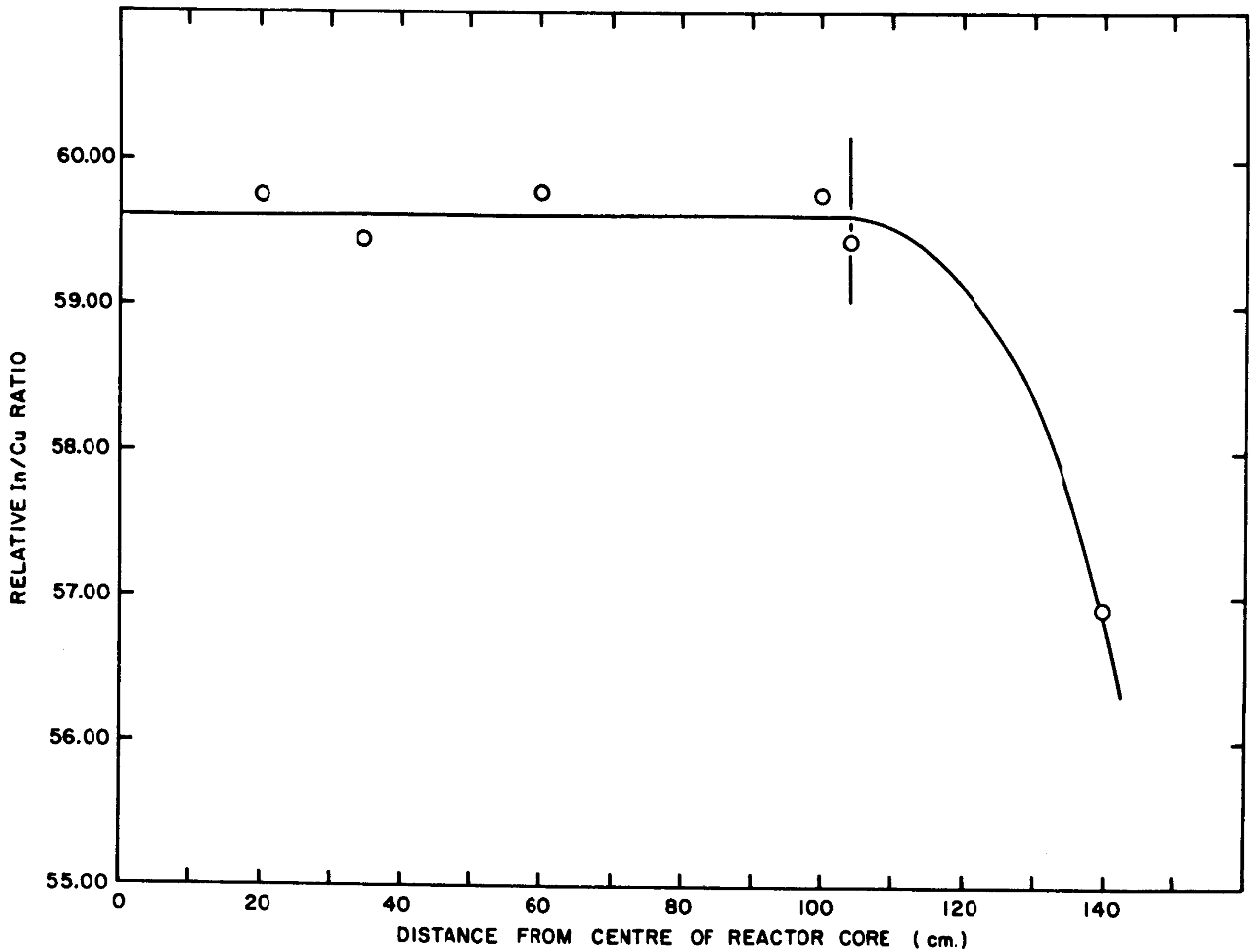


FIGURE 11. RADIAL EXTRAPOLATION LENGTHS δR, MEASURED IN ZED-2 (D_2O COOLANT)

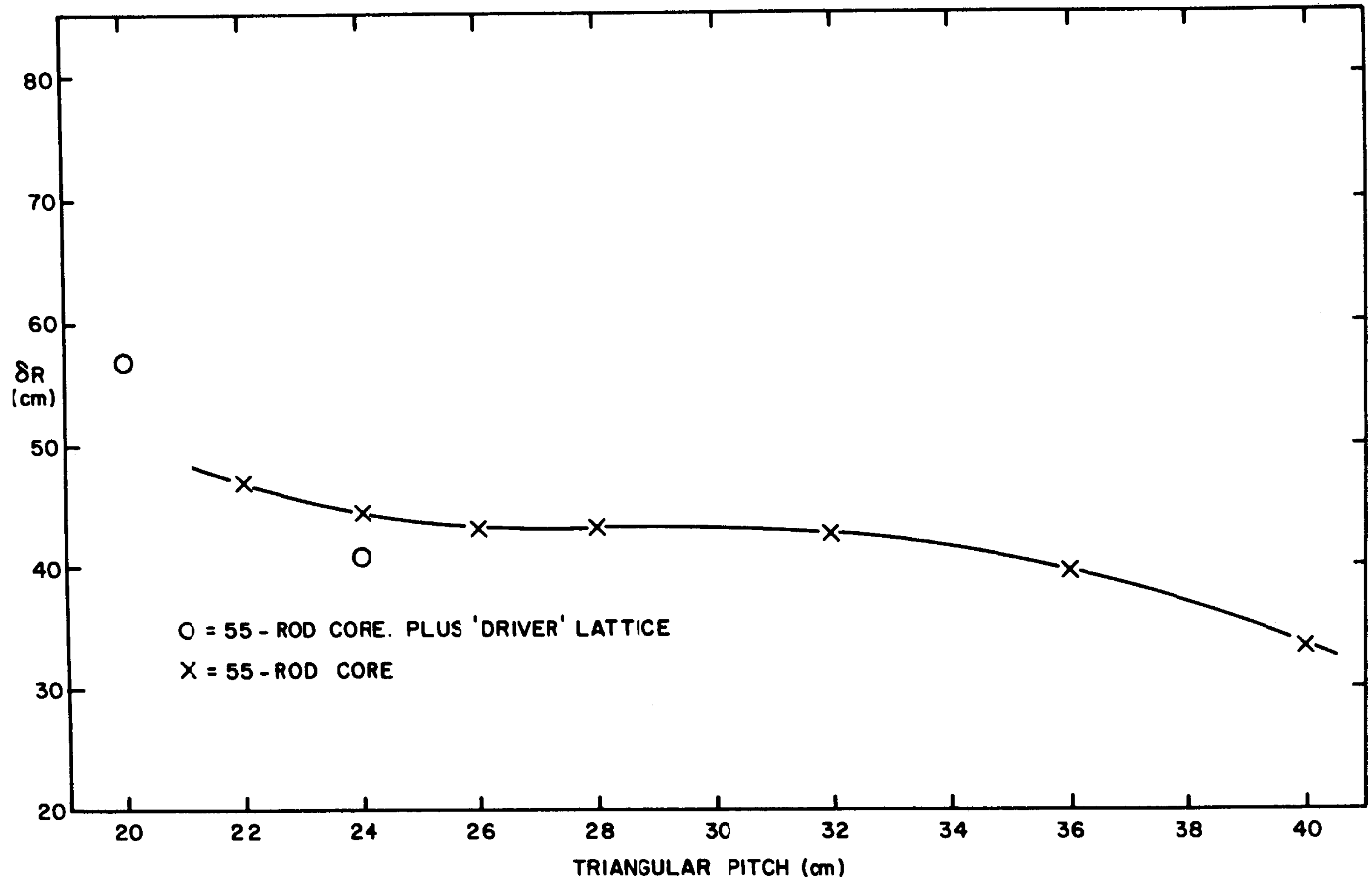


FIGURE 12: RADIAL EXTRAPOLATION LENGTHS δR, MEASURED IN ZED-2 (He-COOLANT)

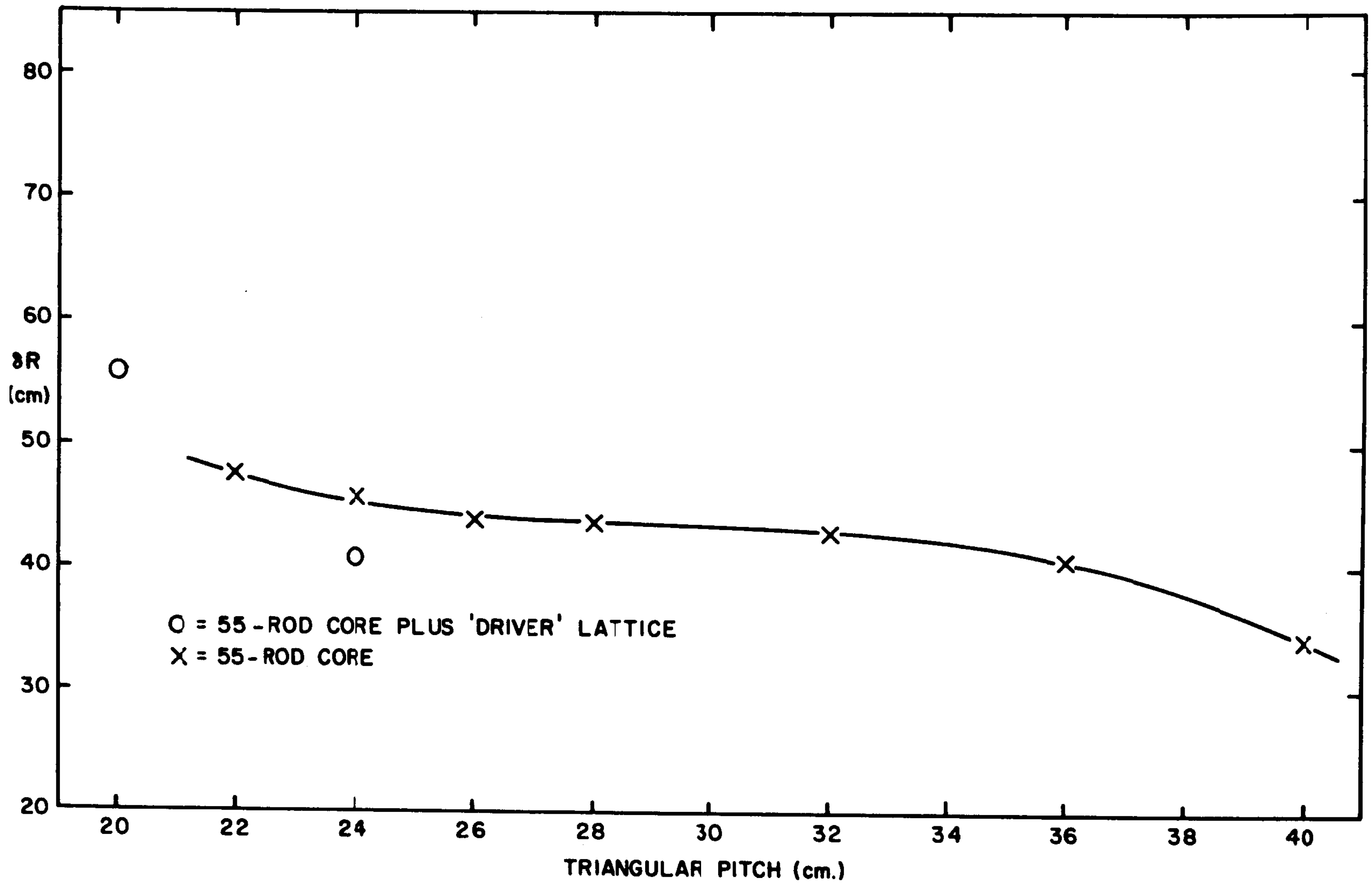


FIGURE 13. AXIAL EXTRAPOLATION LENGTHS, $\delta Z_{T(TOTAL)}$, $\delta Z_{L(LOWER)}$ AND $\delta Z_{U(UPPER)}$ MEASURED IN ZED-2 (D_2O-COOLANT)

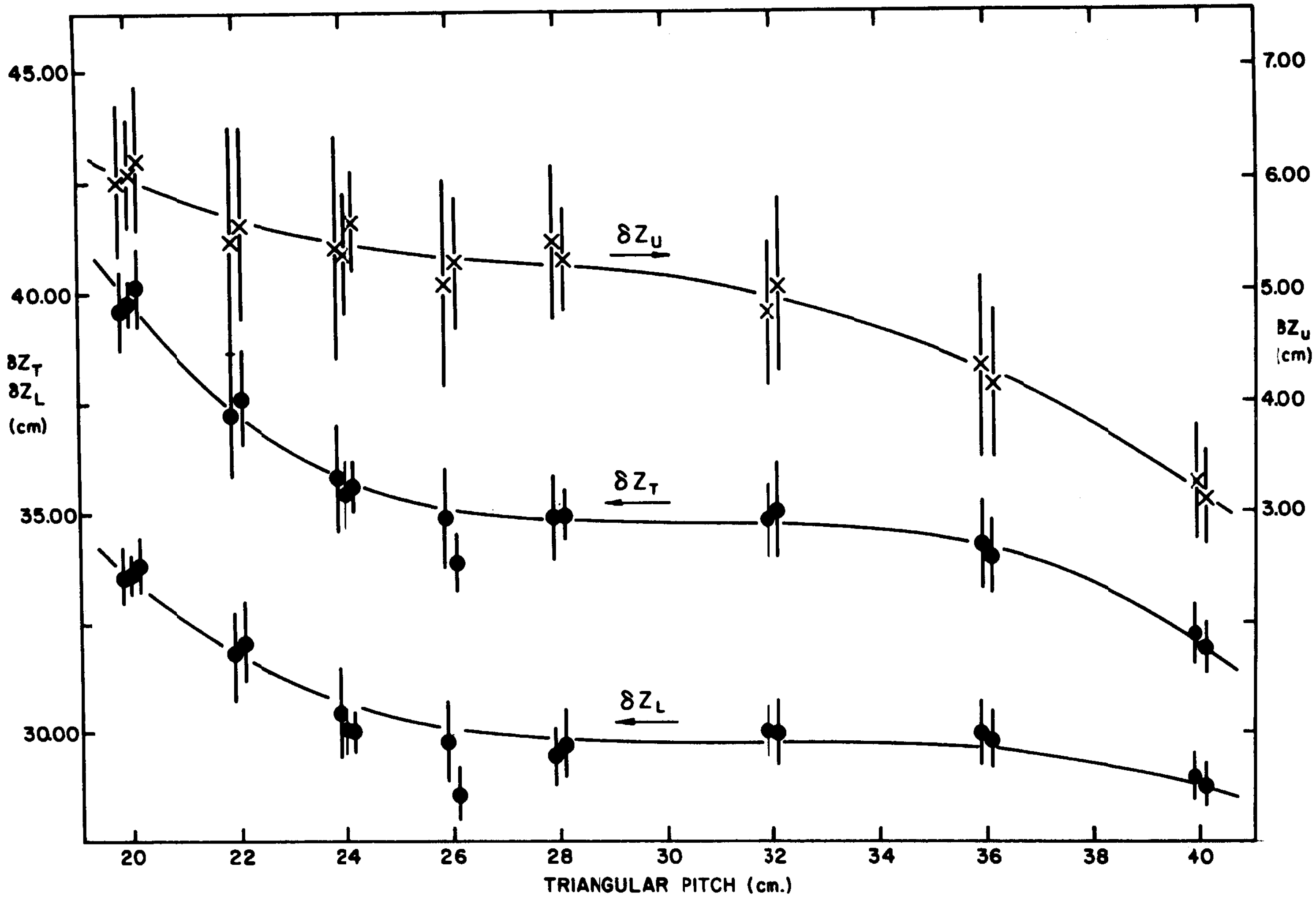
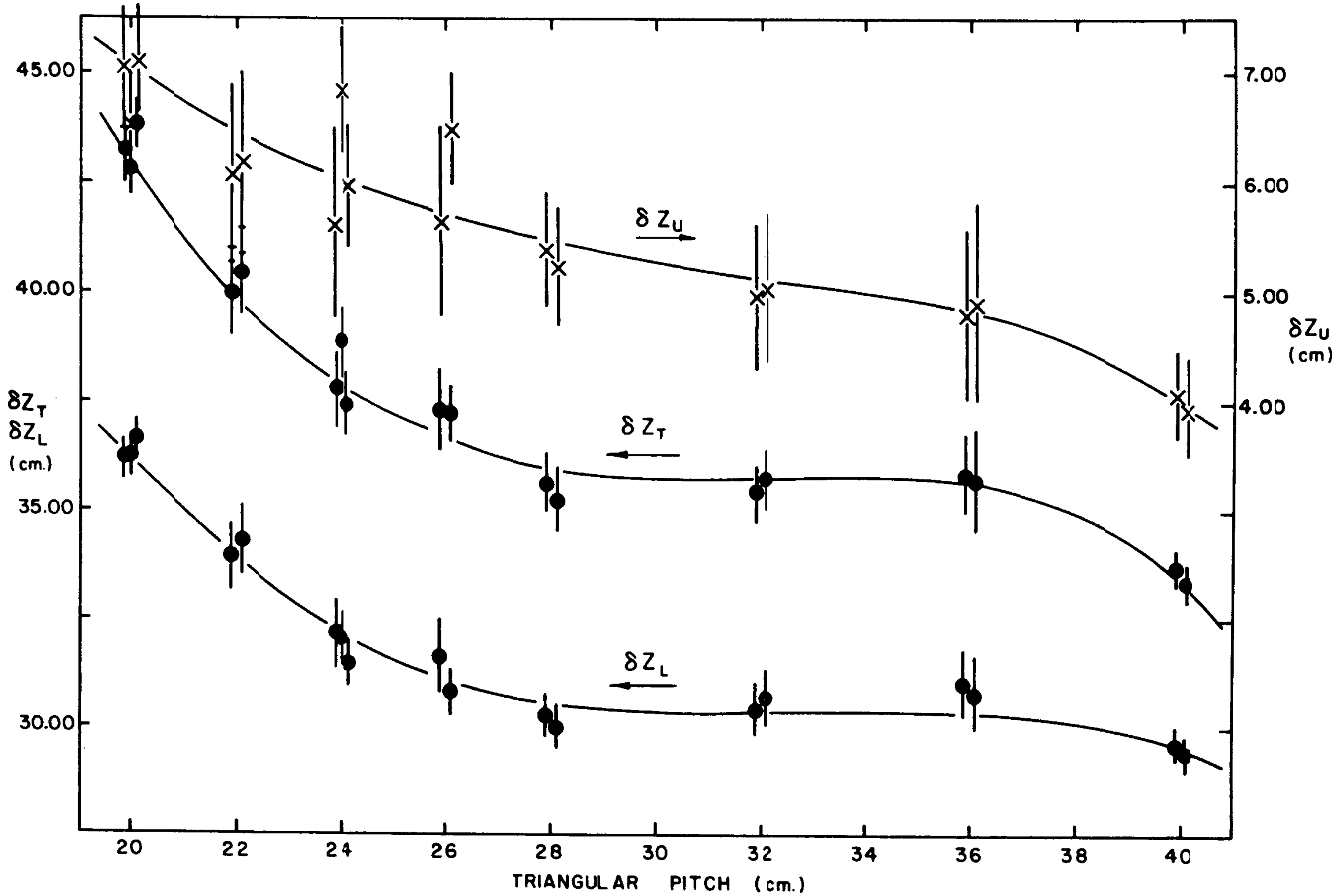


FIGURE 14. AXIAL EXTRAPOLATION LENGTHS, $\delta Z_{T(TOTAL)}$, $\delta Z_{L(LOWER)}$ AND $\delta Z_{U(UPPER)}$ MEASURED IN ZED-2 (He-COOLANT)



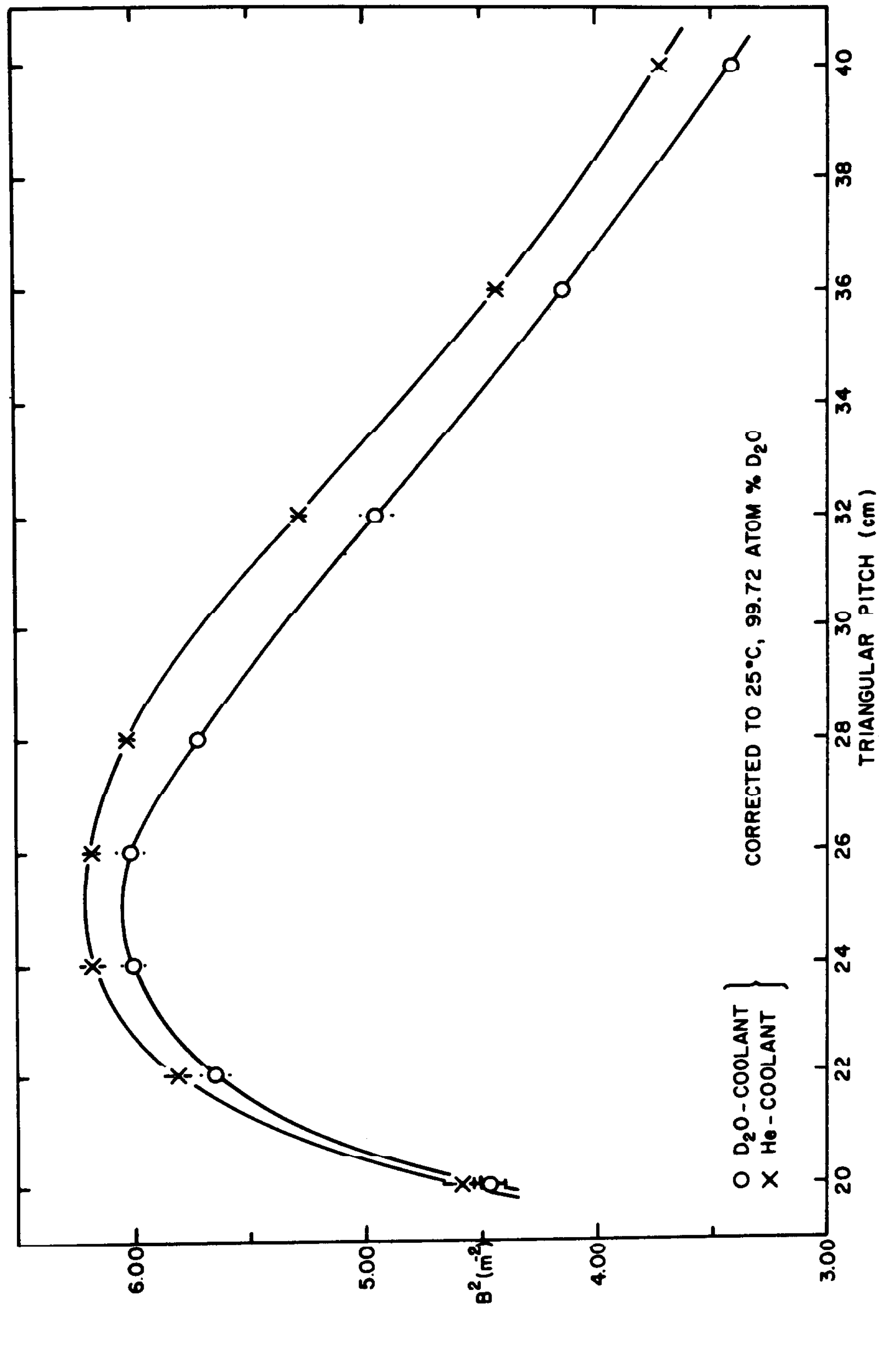


FIGURE 15. BUCKLINGS FOR 19-ELEMENT NATURAL URANIUM METAL FUEL ASSEMBLIES

APPENDIX A

Summary of Relative Activation Distributions Measured in Cores of 19-element Natural-Uranium Metal Assemblies

Table 1-A : Buckling Data - 20 cm Hex Lattice (D_2O Coolant)

55 19-element U-metal Clusters plus
a 'Driver Region' of 36 7-element UO_2 (air-cooled) Clusters

Mar. 12 (pm)/1964 Manganese Foils h_c = 191.642 cm Temp : 24.1°C Moderator Purity : 99.708 at % D_2O

Direction	W	S	W	W	S	W	E	N	E	E	N	E
Thimble	K7	H	K5	K3	J	K1*	K1	L	K3	K5	N	K7
Radius cm	70.00	51.96	50.00	30.00	17.32		10.00	17.32	30.00	50.00	51.96	70.00
Elevation cm												
180						(.2478)	(.2484)					
170						(.3910)	(.3941)					
160						.5221	.5288					
150						.6419	.6506					
140						.7474	.7570					
130						.8358	.8486					
120						.9060	.9230					
110						.9609	.9763					
100	.7953	.8712	.8775	.9554	.9901	.9904	1.0130	1.0015	.9608	.8709	.8551	.8004
90	.8022	.8775	.8857	.9674	1.0030	1.0000	1.0203	1.0099	.9681	.8799	.8671	.8070
80	.7936	.8709	.8755	.9581	.9954	.9906	1.0107	1.0040	.9611	.8694	.8563	.7980
70						.9594	.9807					
60						.9083	.9299					
50						.8389	.8609					
40						.7517	.7737					
30						(.6615)	(.6806)					
20						(.6066)	(.6171)					
10						(.6255)	(.6302)					

	$\lambda(m^{-1})$
$\lambda(n)$	1.5336 ±.0273
$\lambda(n-1)$	1.5828 ±.0169

	Thimble K1W	Thimble K1E	Average
z_o(cm)	89.79	89.27	89.53 ±0.26
$\alpha(m^{-1})$	1.4533	1.4501	1.4517 ±0.0030
$\alpha_{corr}(m^{-1})$			1.4599 ±0.0030

*K1W omitted radial fit.

Table 2-A : Buckling Data - 20 cm Hex Lattice (D_2O Coolant)

55 19-element U-metal Clusters plus
a 'Driver Region' of 36 7-element UO_2 (air-cooled) Clusters

Mar. 13 (pm)/1964 Manganese Foils h_c = 191.701 cm Temp : 24.2°C Moderator Purity : 99.708 at % D_2O

Direction	W	S	W	W	S	W	E	N	E	E	N	E
Thimble	K7	H	K5	K3	J	K1	K1	L	K3	K5	N	K7
Radius cm	70.00	51.96	50.00	30.00	17.32	10.00	10.00	17.32	30.00	50.00	51.96	70.00
Elevation cm												
170						(.3850)	(.3888)					
160						(.5165)	(.5203)					
150						.6335	.6387					
140						.7366	.7415					
130						.8260	.8313					
120						.8965	.9045					
110						.9454	.9551					
100	.7819	.8501	.8542	.9353	.9706	.9788	.9873	.9723	.9361	.8514	.8374	.7846
90	.7847	.8589	.8664	.9457	.9802	.9883	1.0000	.9878	.9457	.8612	.8457	.7890
80	.7785	.8484	.8567	.9345	.9709	.9807	.9873	.9771	.9386	.8501	.8379	.7819
70						.9487	.9576					
60						.9010	.9053					
50						.8331	.8354					
40						.7510	.7507					
30						(.6590)	(.6617)					
20						(.6009)	(.6038)					
10						(.6136)	(.6132)					

	$\lambda(m^{-1})$
$\lambda(n)$	1.5323 ±.0228
$\lambda(n-1)$	1.5649 ±.0210
$\lambda(n-2)$	1.5810 ±.0298

	Thimble K1W	Thimble K1E	
z_o(cm)	89.38	89.71	89.54 ±0.17
$\alpha(m^{-1})$	1.4439	1.4550	1.4494 ±0.0056

$\alpha_{corr}(m^{-1})$ 1.4580 ±0.0056

Table 3-A : Buckling Data - 20 cm Hex Lattice (D_2O Coolant)

55 19-element U-metal Clusters plus
a 'Driver Region' of 36 7-element UO_2 (air-cooled) Clusters

Mar. 13 (am)/1964 — Manganese Foils — h_c = 192.061 cm — Moderator: Temp : 24.2°C Purity : 99.708 at % D_2O

Direction	W	E	S	S	E	W	E	N	E	E	W	E	N	S	E	W
Thimble	K1W	K1E	JO	J2W	L2E	K3W	K3E	M1E	J4E	I3E	K5W	K5E	NO	H2W	L6E	K7W
Radius cm	10.00	10.00	17.32	26.46	26.46	30.00	30.00	36.06	43.58	45.82	50.00	50.00	51.96	55.68	62.44	70.00
Elevation cm																
180	(.2489)	(.2456)														
170	(.3886)	(.3868)														
160	.5164	.5150														
150	.6326	.6323														
140	.7340	.7305														
130	.8200	.8231														
120	.8897	.8933														
110	.9391	.9463														
100	.9667	.9745	.9597	.9382	.9324	.9237	.9239	.9126	.8717	.8603	.8480	.8401	.8296	.8152	.7805	.7706
90	1.0000	.9826	.9707	.9480	.9438	.9344	.9372	.9187	.8304	.8715	.8564	.8474	.8394	.8236	.7869	.7754
80	.9645	.9734	.9579	.9387	.9340	.9268	.9254	.9110	.8708	.8616	.8467	.8392	.8302	.8154	.7783	.7692
70	.9364	.9457														
60	.8893	.8954														
50	.8204	.8298														
40	.7344	.7472														
30	(.6478)	(.6586)														
20	(.5916)	(.5978)														
10	(.6059)	(.6066)														

	$\lambda(m^{-1})$
$\lambda(n)$	1.5322 ±.0106
$\lambda(n-1)$	1.5089 ±.0279
$\lambda(n-2)$	1.5071 ±.0386

	Thimble K1W	Thimble K1E	Average
z_o(cm)	90.07	89.45	89.76 ±0.31
$\alpha(m^{-1})$	1.4551	1.4444	1.4498 ±0.0054
$\alpha_{corr}(m^{-1})$	1.4608 ±0.0054		

Table 4-A : Buckling Data - 22 cm Hex Lattice (D_2O Coolant)

55 19-element U-metal Clusters plus
a 'Driver Region' of 36 7-element UO_2 (air-cooled) Clusters

Mar. 10 (am)/1964 Manganese Foils h_c = 182.746 cm Moderator Temp : 24.1°C Purity : 99.709 at % D_2O

Direction	W	E	S	S	E	W	E	N	E	E	W	E	N	S	E	W
Thimble	K1W	K1E	JO	J2W	L2E	K3W	K3E	M1E	J4E	I3E	K5W	K5E	NO	H2W	L6E	K7W
Radius cm	11.00	11.00	19.05	29.11	29.11	33.00	33.00	39.67	47.94	50.40	55.00	55.00	57.16	61.25	68.68	77.00
Elevation cm																
170	(.2685)	(.2679)														
160	(.4182)	(.4202)														
150	(.5570)	(.5589)														
140	.6789	.6827														
130	.7873	.7922														
120	.8757	.8778														
110	.9419	.9450														
100	.9856	.9898														
90	1.0050	1.0125	.9757	.9533	.9512	.9331	.9285	.8982	.8380	.8248	.7980	.7957	.7686	.7464	.5913	.7694
80	1.0000	1.0113	.9832	.9516	.9461	.9252	.9299	.8988	.8357	.8194	.7960	.7923	.7673	.7469	.5907	.7644
70	.9762	.9859	.9512	.9254	.9206	.8994	.9060	.8713	.8108	.7976	.7720	.7721	.7462	.7272	.5706	.7476
60	.9259	.9415														
50	.8535	.8728														
40	.7653	.7850														
30	(.6703)	(.6847)														
20	(.5941)	(.6023)														
10	(.5576)	(.5632)														

	$\lambda(m^{-1})$
$\lambda(n)$	1.8070 ±.0091
$\lambda(n-1)$	1.7657 ±.0231
$\lambda(n-2)$	1.7859 ±.0325

	Thimble K1W	Thimble K1E	Average
z_c(cm)	86.05	85.27	85.66 ±0.39
$\alpha(m^{-1})$	1.5374	1.5216	1.5295 ±0.0079
$\alpha_{corr}(m^{-1})$			1.5419 ±0.0079

Table 5-A : Buckling Data - 22 cm Hex Lattice (D_2O Coolant)

55 19-element U-metal Clusters plus
a 'Driver Region' of 36 7-element UO_2 (air-cooled) Clusters

Mar. 6 (pm)/1964 Manganese Foils h_c = 182.334 cm Temp : 24.4°C Moderator Purity : 99.711 at % D_2O

Direction	W	S	W	W	S	W	E	N	E	E	N	E
Thimble	K7	H	K5	K3	J	K1	K1	L	K3	K5	N	K7
Radius cm	77.00	57.16	55.00	33.00	19.05	11.00	11.00	19.05	33.00	55.00	57.16	77.00
Elevation cm												
170						(.2615)	(.2628)					
160						(.4130)	(.4145)					
150						(.5504)	(.5550)					
140						.6746	.6799					
130						.7815	.7898					
120						.8697	.8753					
110						.9390	.9432					
100						.9855	.9889					
90	.7672	.7864	.7973	.9316	.9835	1.0094	1.0118	.9983	.9310	.7959	.7661	.7671
80	.7655	.7835	.7949	.9267	.9808	1.0000	1.0110	.9943	.9293	.7941	.7621	.7646
70	.7449	.7642	.7736	.9015	.9556	.9752	.9867	.9709	.9045	.7725	.7428	.7450
60						.9250	.9399					
50						.8576	.8715					
40						.7668	.7859					
30						(.6699)	(.6857)					
20						(.5934)	(.6025)					
10						(.5578)	(.5636)					

	$\lambda(m^{-1})$
$\lambda(n)$	1.8148 ±.0211
$\lambda(n-1)$	1.7901 ±.0322
$\lambda(n-2)$	1.8292 ±.0239

	Thimble K1W	Thimble K1E	Average
z_o(cm)	85.86	85.17	85.52 ±0.35
$\alpha(m^{-1})$	1.5460	1.5255	1.5358 ±0.0103
$\alpha_{corr}(m^{-1})$	1.5453 ±0.0103		

Table 6-A : Buckling Data - 24 cm Hex Lattice (D_2O Coolant)

55 19-element U-metal Clusters plus
a 'Driver Region' of 36 7-element UO_2 (air-cooled) Clusters

Mar. 23 (am)/1964 Manganese Foils h_c = 143.393 cm Temp : 24.0°C Moderator Purity : 99.705 at % D_2O

Direction	W	S	W	W	S	W	E	N	E	E	N	E
Thimble	K7	H	K5	K3	J	K1	K1	L	K3	K5	N	K7
Radius cm	34.00	62.35	60.00	36.00	20.79	12.00	12.00	20.79	36.00	60.00	62.35	84.00
Elevation cm												
140						(.1264)	(.1234)					
130						(.3410)	(.3402)					
120						(.5260)	(.5271)					
110						.6849	.6891					
100						.8150	.8190					
90						.9135	.9213					
80						.9819	.9881					
70	.6813	.8197	.8295	.9496	.9897	1.0112	1.0185	.9986	.9482	.8287	.8090	.5739
60	.6802	.8064	.8223	.9414	.9835	1.0000	1.0114	.9964	.9429	.8235	.8028	.5792
50	.6529	.7760	.7865	.8988	.9448	.9592	.9669	.9568	.9032	.7915	.7686	.5488
40						.8829	.8885					
30						(.7825)	(.7929)					
20						(.6942)	(.6995)					
10						(.6244)	(.6279)					

	$\lambda(m^{-1})$
$\lambda(n)$	1.4935 ±.0111
$\lambda(n-1)$	1.4874 ±.0200
$\lambda(n-2)$	1.5045 ±.0253

	Thimble K1W	Thimble K1E	Average
z_c(cm)	66.84	66.82	66.83 ±0.16
$\alpha(m^{-1})$	1.9140	1.9212	1.9176 ±0.0083
$\alpha_{corr}(m^{-1})$	1.9236 ±0.0083		

Table 7-A : Buckling Data - 24 cm Hex Lattice (D_2O Coolant)

Moderator

Feb. 28 (am)/1964 Manganese Foils Temp : 24.0°C Purity : 99.714 at % D_2O h_c = 162.640 cm

Direction	W	E	S	S	E	W	E	N	E	E	W	E	N	S	E	W
Thimble	K1W	K1E	JO	J2W	L2E	K3W	K3E	M1E	J4E	I3E	K5W	K5E	NO	H2W	L6E	K7W
Radius cm	12.00	12.00	20.78	31.75	31.75	36.00	36.00	43.27	52.30	54.98	60.00	60.00	62.35	66.82	74.93	84.00
Elevation cm																
150	(.2963)	(.3001)														
140	(.4626)	(.4687)														
130	.6128	.6200														
120	.7423	.7492														
110	.8472	.8562														
100	.9279	.9375														
90	.9831	.9922														
80	1.0065	1.0170	.9875	.9471	.9484	.9249	.9255	.8928	.8239	.8058	.7722	.7655	.7460	.7134	.6424	.6824
70	1.0000	1.0085	.9805	.9431	.9453	.9210	.9198	.8901	.8195	.8003	.7690	.7623	.7448	.7111	.6371	.6760
60	.9632	.9765	.9438	.9165	.9140	.8884	.8882	.8578	.7939	.7748	.7433	.7357	.7204	.6852	.6163	.6535
50	.9034	.9152														
40	.8153	.8258														
30	(.7130)	(.7217)														
20	(.6238)	(.6300)														
10	(.5575)	(.5623)														

	$\lambda(m^{-1})$
$\lambda(n)$	1.7392 ±.0069
$\lambda(n-1)$	1.6933 ±.0169
$\lambda(n-2)$	1.6823 ±.0210

	Thimble K1W	Thimble K1E	Average
z_o(cm)	76.72	76.55	76.64 ±0.10
$\alpha(m^{-1})$	1.7175	1.7107	1.7141 ±0.0052
$\alpha_{corr}(m^{-1})$	1.7244 ±0.0052		

Table 8-A : Buckling Data - 24 cm Hex Lattice (D_2O Coolant)

Feb. 24 (pm)/1964 Manganese Foils Temp : 24.1°C Moderator Purity : 99.716 at % D_2O h_c = 162.277 cm

Direction	W	S	W	W	S	W	E	N	E	E	N	E
Thimble	K7	H	K5	K3	J	K1	K1	L	K3	K5	N	K7
Radius cm	84.00	62.35	60.00	36.00	20.79	12.00	12.00	20.79	36.00	60.00	62.35	84.00
Elevation cm												
150						(.2916)	(.2902)					
140						(.4585)	(.4605)					
130						.6088	.6134					
120						.7390	.7403					
110						.8465	.8465					
100						.9281	.9330					
90						.9822	.9892					
80	.6794	.7562	.7710	.9258	.9894	1.0076	1.0160	.9955	.9285	.7701	.7470	.6781
70	.6753	.7520	.7690	.9235	.9838	1.0000	1.0151	.9933	.9225	.7631	.7456	.6767
60	.6529	.7265	.7443	.8911	.9525	.9553	.9860	.9607	.8925	.7392	.7205	.6556
50						.9032	.9171					
40						.8142	.8398					
30						(.7139)	(.7362)					
20						(.6245)	(.6415)					
10						(.5579)	(.5728)					

	$\lambda(m^{-1})$
$\lambda(n)$	1.7474 ±.0133
$\lambda(n-1)$	1.7304 ±.0274
$\lambda(n-2)$	1.7331 ±.0329

	Thimble K1W	Thimble K1E	Average
z_o(cm)	76.66	75.62	76.14 ±0.52
$\alpha(m^{-1})$	1.7268	1.7047	1.7158 ±0.0111
$\alpha_{corr}(m^{-1})$	1.7227 ±0.0111		

Table 9-A : Buckling Data - 26 cm Hex Lattice (D_2O Coolant)

Moderator

Feb. 20 (pm)/1964 Manganese Foils Temp : 24.2°C Purity : 99.717 at % D_2O h_c = 156.041 cm

Direction	W	N	E	S	W	N	E	E	N	S	W	S	W	N	E	N	W	E
Thimble	K1W	K .5E	J 1.5E	JO	K 2.5W	L .5W	K3E	J 3.5E	M1E	H .5W	K 4.5W	H 1.5E	K5W	NO	J 5.5E	N .5W	K 6.5W	K7E
Radius cm	13.00	13.00	22.52	22.52	34.40	34.40	39.00	46.88	46.88	56.65	59.57	59.57	65.00	57.55	72.38	79.07	85.25	91.00
Elevation cm																		
150	(.1807)			(.1823)														
140	(.3654)			(.3626)														
130	.5301			.5233														
120	.6746			.6634														
110	.7972			.7824														
100	.8919			.8753														
90	.9603			.9385														
80	.9952	1.0023	.9768	.9752	.9306	.9311	.9065	.8617	.8626	.8062	.7817	.7879	.7429	.7152	.5789	.6308	.5920	.6067
70	1.0000	1.0088	.9818	.9763	.9349	.9373	.9136	.8660	.8697	.8101	.7846	.7933	.7453	.7192	.6829	.6361	.5940	.6081
60	.9720	.9795	.9530	.9485	.9112	.9142	.8917	.8469	.8467	.7909	.7653	.7713	.7242	.7011	.6643	.6183	.5779	.5912
50	.9144			.8784														
40	.8263			.8073														
30	(.7237)			(.7036)														
20	(.6248)			(.6081)														
10	(.5342)			(.5199)														

	$\lambda(m^{-1})$
$\lambda(n)$	1.6627 ±.0159
$\lambda(n-1)$	1.6366 ±.0221
$\lambda(n-2)$	1.6311 ±.0216

	Thimble K1W	Thimble Jo	Average
z_o (cm)	73.58	74.12	73.85 ±0.27
$\alpha(m^{-1})$	1.7945	1.7980	1.7962 ±0.0072
$\alpha_{corr}(m^{-1})$		1.8073 ±0.0072	

Table 10-A : Buckling Data - 26 cm Hex Lattice (D_2O Coolant)

Feb. 19 (am)/1964 Manganese Foils Temp : 24.2°C Moderator Purity : 99.718 at % D_2O h_c = 155.667 cm

Direction	W	S	W	W	S	W	E	N	E	E	N	E
Thimble	K7	H	K5	K3	J	K1	K1	L	K3	K5	N	K7
Radius cm	91.00	67.55	65.00	39.00	22.52	13.00	13.00	22.52	39.00	65.00	67.55	91.00
Elevation cm												
150						(.1728)	(.1708)					
140						(.3585)	(.3583)					
130						.5265	.5262					
120						.6720	.6683					
110						.7941	.7933					
100						.8921	.8896					
90						.9630	.9596					
80	.6014	.7252	.7408	.9085	.9731	.9969	1.0003	.9760	.9068	.7366	.7201	.6052
70	.6051	.7292	.7437	.9104	.9752	1.0000	1.0090	.9842	.9147	.7396	.7240	.6064
60	.5895	.7104	.7242	.8863	.9520	.9753	.9834	.9582	.8935	.7202	.7033	.5893
50						.9146	.9285					
40						.8292	.8455					
30						(.7257)	(.7444)					
20						(.6256)	(.6407)					
10						(.5379)	(.5533)					

	$\lambda(m^{-1})$
$\lambda(n)$	1.6672 ±.0094
$\lambda(n-1)$	1.6719 ±.0088
$\lambda(n-2)$	1.6550 ±.0082

	Thimble K1W	Thimble K1E	Average
z_o(cm)	73.47	72.47	72.97 ±0.50
$\alpha(m^{-1})$	1.8006	1.7784	1.7895 ±0.0111
$\alpha_{corr}(m^{-1})$		1.7967 ±0.0111	

Table 11-A : Buckling Data - 28 cm Hex Lattice (D_2O Coolant)

Jan. 29(pm)/1964 Manganese Foils Temp : 23.6°C Moderator Purity : 99.726 at % D_2O h_c = 155.015 cm

Direction	W	S	W	W	S	W	E	N	E	E	N	E
Thimble	K7	H	K5	K3	J	K1	K1	L	K3	K5	N	K7
Radius cm	98.00	72.75	70.00	42.00	24.25	14.00	14.00	24.25	42.00	70.00	72.75	98.00
Elevation cm												
150						(.1593)	(.1580)					
140						(.3484)	(.3484)					
130						.5184	.5173					
120						.6660	.6661					
110						.7950	.7937					
100						.8936	.8935					
90						.9617	.9571					
80	.5574	.7106	.7277	.9054	.9710	.9994	.9978	.9795	.9035	.7303	.7058	.5560
70	.5625	.7150	.7325	.9080	.9793	1.0000	1.0042	.9831	.9114	.7336	.7096	.5619
60	.5507	.6986	.7132	.8838	.9536	.9830	.9797	.9598	.8860	.7126	.6922	.5480
50						.9233	.9251					
40						.8369	.8413					
30						(.7304)	(.7351)					
20						(.6222)	(.6280)					
10						(.5179)	(.5258)					

	$\lambda(m^{-1})$
$\lambda(n)$	1.5785 ±.0034
$\lambda(n-1)$	1.5751 ±.0109
$\lambda(n-2)$	1.5726 ±.0156

	Thimble K1W	Thimble K1E	Average
z_o(cm)	72.94	72.68	72.81 ±0.13
$\alpha(m^{-1})$	1.7993	1.7912	1.7953 ±0.0057
$\alpha_{corr}(m^{-1})$		1.8018 ±0.0057	

Table 12-A : Buckling Data - 28 cm Hex Lattice (D_2O Coolant)

Jan. 29 (am)/1964 Manganese Foils Temp : 23.6°C Moderator Purity : 99.726 at % D_2O h_c = 154.997 cm

Direction	W	S	W	W	S	W	E	N	E	E	N	E
Thimble	K7	H	K5	K3	J	K1	K1	L	K3	K5	N	K7
Radius cm	98.00	72.75	70.00	42.00	24.25	14.00	14.00	24.25	42.00	70.00	72.75	98.00
Elevation cm												
150						(.1578)	(.1595)					
140						(.3459)	(.3486)					
130						(.5146)	(.5163)					
120						.6637	.6642					
110						.7882	.7395					
100						.8884	.8391					
90						.9552	.9545					
80	.5538	.7072	.7239	.8958	.9620	.9937	.9934	.9685	.8958	.7218	.6992	.5546
70	.5585	.7126	.7282	.9029	.9668	1.0000	1.0008	.9754	.9025	.7251	.7048	.5563
60	.5462	.6934	.7086	.8782	.9423	.9742	.9744	.9499	.8784	.7055	.6870	.5423
50						.9158	.9168					
40						.8309	.8354					
30						(.7248)	(.7281)					
20						(.6190)	(.6216)					
10						(.5145)	(.5208)					

	$\lambda(m^{-1})$
$\lambda(n)$	1.5790 ±.0057
$\lambda(n-1)$	1.5944 ±.0107
$\lambda(n-2)$	1.5919 ±.0154

	Thimble K1W	Thimble K1E	Average
z_o(cm)	73.05	72.95	73.00 ±0.11
$\alpha(m^{-1})$	1.7998	1.7926	1.7962 ±0.0096
α_{corr}	1.8026 ±0.0096		

Table 13-A : Buckling Data - 32 cm Hex Lattice (D_2O Coolant)

Jan. 20 (pm)/ 1964 — Manganese Foils — Moderator Temp : 23.1°C Purity : 99.729 at % D_2O — h_c = 164.831 cm

Direction	W	S	W	W	S	W	E	N	E	E	N	E
Thimble	K7	H	K5	K3	J	K1	K1	L	K3	K5	N	K7
Radius cm	112.00	83.14	80.00	48.00	27.71	16.00	16.00	27.71	48.00	80.00	83.14	112.00
Elevation cm												
160						(.1409)	(.1410)					
150						(.3190)	(.3197)					
140						.4820	.4816					
130						.5299	.6215					
120						.7506	.7688					
110						.8539	.8460					
100	.4583	.6366	.6559	.8354	.9026	.9350	.9233	.9046	.8281	.6526	.6348	.4558
90	.4815	.6673	.6886	.8801	.9425	.9670	.9835	.9531	.8711	.6876	.6704	.4790
80	.4910	.6819	.7045	.8971	.9680	1.0000	.9969	.9688	.8942	.7057	.6825	.4878
70						.9897	.9932					
60						.9570	.9569					
50						.8912	.8952					
40						.8032	.8086					
30						(.6979)	(.7066)					
20						(.5835)	(.5934)					
10						(.4652)	(.4781)					

	$\lambda(m^{-1})$
$\lambda(n)$	1.4375 ±.0036
$\lambda(n-1)$	1.4338 ±.0193
$\lambda(n-2)$	1.4293 ±.0252

	Thimble K1W	Thimble K1E	Average
z_o(cm)	77.56	77.34	77.45 ±0.21
$\alpha(m^{-1})$	1.7008	1.6978	1.6993 ±0.0095

$\alpha_{corr}(m^{-1})$ 1.7044 ±0.0095

Table 14-A : Buckling Data - 32 cm Hex Lattice (D_2O Coolant)

Jan. 20 (am)/1964 Manganese Foils Temp : 23.1°C Moderator Purity : 99.729 at % D_2O h_c = 164.821 cm

Direction	W	S	W	W	S	W	E	N	E	E	N	E
Thimble	K7	H	K5	K3	J	K1	K1	L	K3	K5	N	K7
Radius cm	112.00	83.14	80.00	48.00	27.71	16.00	16.00	27.71	48.00	80.00	83.14	112.00
Elevation cm												
160						(.1452)	(.1443)					
150						(.3272)	(.3267)					
140						.4935	.4931					
130						.6412	.6393					
120						.7695	.7657					
110						.8760	.8719					
100	.4697	.6541	.6726	.8578	.9254	.9552	.9513	.9283	.8522	.6700	.6510	.4670
90	.4942	.6862	.7082	.9013	.9759	1.0032	1.0000	.9781	.8960	.7064	.6884	.4904
80	.5043	.7035	.7260	.9182	.9942	1.0253	1.0229	.9978	.9163	.7213	.7009	.5030
70						1.0173	1.0160					
60						.9807	.9841					
50						.9159	.9204					
40						.8248	.8312					
30						(.7148)	(.7222)					
20						(.5970)	(.6067)					
10						(.4779)	(.4907)					

	$\lambda(m^{-1})$
$\lambda(n)$	1.4362 ±.0019
$\lambda(n-1)$	1.4409 ±.0070

	Thimble K1W	Thimble K1E	Average
z_o(cm)	77.55	77.02	77.29 ±0.27
$\alpha(m^{-1})$	1.7088	1.6944	1.7016 ±0.0072
$\alpha_{corr}(m^{-1})$	1.7066 ±0.0072		

Table 15-A : Buckling Data - 36 cm Hex Lattice (D_2O Coolant)

Jan. 16 (am)/1964 Manganese Foils

Moderator: Temp : 23.1°C Purity : 99.731 at % D_2O h_c = 185.050 cm

Direction	W	S	W	W	S	W	E	N	E	E	N	E
Thimble	K7	H	K5	K3	J	K1	K1	L	K3	K5	N	K7
Radius cm	126.00	93.53	90.00	54.00	31.18	18.00	18.00	31.18	54.00	90.00	93.53	126.00
Elevation cm												
180						(.1282)	(.1269)					
170						(.2875)	(.2866)					
160						.4342	.4331					
150						.5694	.5688					
140						.6910	.6900					
130						.7955	.7931					
120						.8783	.8708					
110						.9445	.9423					
100	.4261	.6488	.6692	.8740	.9567	.9848	.9821	.9549	.8721	.6665	.6437	.4222
90	.4331	.6606	.6827	.8889	.9699	1.0000	1.0009	.9699	.8865	.6773	.6577	.4298
80	.4305	.6562	.6771	.8840	.9671	.9946	.9989	.9643	.8815	.6747	.6519	.4279
70						.9659	.9655					
60						.9128	.9177					
50						.8409	.8470					
40						.7449	.7553					
30						(.6411)	(.6515)					
20						(.5278)	(.5392)					
10						(.4102)	(.4232)					

	$\lambda(m^{-1})$
$\lambda(n)$	1.3352 ±.0022
$\lambda(n-1)$	1.3408 ±.0046
$\lambda(n-2)$	1.3339 ±.0053

	Thimble K1W	Thimble K1E	Average
z_o(cm)	87.48	86.88	87.18 ±0.30
$\alpha(m^{-1})$	1.5456	1.5335	1.5396 ±0.0061
$\alpha_{corr}(m^{-1})$	1.5452 ±0.0061		

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Table 16-A : Buckling Data - 36 cm Hex Lattice (D_2O Coolant)

Jan. 15 (pm)/1964 Manganese Foils Temp : 23.4°C Moderator Purity : 99.731 at % D_2O h_c = 185.063 cm

Direction	W	S	W	W	S	W	E	N	E	E	N	E
Thimble	K7	H	K5	K3	J	K1	K1	L	K3	K5	N	K7
Radius cm	126.00	93.53	90.00	54.00	31.18	18.00	18.00	31.18	54.00	90.00	93.53	126.00
Elevation cm												
180						(.1277)	(.1272)					
170						(.2866)	(.2857)					
160						.4341	.4327					
150						.5699	.5685					
140						.6910	.6897					
130						.7928	.7931					
120						.8766	.8730					
110						.9441	.9330					
100	.4308	.6456	.6660	.8733	.9585	.9811	.9801	.9581	.8720	.6655	.6452	.4222
90	.4321	.6565	.6774	.8876	.9725	1.0000	.9949	.9711	.8842	.6771	.6553	.4294
80	.4249	.6516	.6745	.8830	.9632	.9946	.9936	.9692	.8799	.6741	.6521	.4276
70						.9632	.9642					
60						.9120	.9163					
50						.8368	.8455					
40						.7452	.7546					
30						(.6407)	(.6507)					
20						(.5276)	(.5373)					
10						(.4095)	(.4226)					

	$\lambda(m^{-1})$
$\lambda(n)$	1.3390 ±.0020
$\lambda(n-1)$	1.3407 ±.0080
$\lambda(n-2)$	1.3313 ±.0114

	Thimble K1W	Thimble K1E	Average
z_o(cm)	87.50	86.92	87.21 ±0.29
$\alpha(m^{-1})$	1.5449	1.5297	1.5373 ±0.0076
$\alpha_{corr}(m^{-1})$			1.5430 ±0.0076

Table 17-A : Buckling Data - 40 cm Hex Lattice (D_2O Coolant)

Dec. 18 (pm)/1963   Copper Foils   Moderator: Temp : 21.4°C Purity : 99.735 at % D_2O h_c = 215.660 cm

Direction	W	S	W	W	S	W	E	N	E	E	N	E
Thimble	K7	H	K5	K3	J	K1	K1	L	K3	K5	N	K7
Radius cm	140.00	103.92	100.00	60.00	34.64	20.00	20.00	34.64	60.00	100.00	103.92	140.00
Elevation cm												
210						(.3556)	(.3431)					
200						(.7591)	(.7503)					
190						1.1508	1.1404					
180						1.5232	1.5094					
170						1.8662	1.8512					
160						2.1611	2.1592					
150						2.4296	2.4223					
140						2.6560	2.6496					
130						2.8288	2.8300					
120	1.0855	1.8252	1.9122	2.5686	2.8672	2.9486	2.9388	2.8569	2.5758	1.8975	1.8231	1.0689
110	1.1083	1.8717	1.9476	2.6297	2.9251	3.0170	3.0066	2.9193	2.6362	1.9479	1.8645	1.0966
100	1.1112	1.8798	1.9578	2.6468	2.9169	3.0309	3.0419	2.9402	2.6514	1.9468	1.8725	1.1011
90						2.9833	2.9830					
80						2.8944	2.8955					
70						2.7530	2.7386					
60						2.5350	2.5505					
50						2.2994	2.3079					
40						2.0100	2.0287					
30						(1.7041)	(1.7221)					
20						(1.3832)	(1.4033)					
10						(1.0492)	(1.0697)					

	$\lambda(m^{-1})$
$\lambda(n)$	1.2718 ±.0017
$\lambda(n-1)$	1.2736 ±.0050
$\lambda(n-2)$	1.2744 ±.0074

	Thimble K1W	Thimble K1E	Average
z_o(cm)	102.62	102.34	102.48 ±0.15
$\alpha(m^{-1})$	1.3510	1.3504	1.3507 ±0.0030
$\alpha_{corr}(m^{-1})$	1.3574 ±0.0030		

Table 18-A : Buckling Data - 40 cm Hex Lattice (D_2O Coolant)

Dec. 18 (am)/1963 Manganese Foils Temp : 21.4°C Moderator Purity : 99.735 at % D_2O h_c = 215.722 cm

Direction	W	S	W	W	S	W	E	N	E	E	N	E
Thimble	K7	H	K5	K3	J	K1	K1	L	K3	K5	N	K7
Radius cm	140.00	103.92	100.00	60.00	34.64	20.00	20.00	34.64	60.00	100.00	103.92	140.00
Elevation cm												
210						(.1200)	(.1157)					
200						(.2546)	(.2506)					
190						(.3836)	(.3815)					
180						.5048	.5018					
170						.6186	.6159					
160						.7197	.7176					
150						.8095	.8056					
140						.8827	.8800					
130						.9414	.9368					
120	.3608	.6101	.6356	.8552	.9488	.9813	.9788	.9490	.8572	.6315	.6041	.3584
110	.3694	.6231	.6520	.8784	.9707	1.0000	.9990	.9699	.8785	.6465	.6176	.3664
100	.3703	.6259	.6531	.8839	.9740	1.0069	1.0053	.9738	.8797	.6478	.6229	.3682
90						.9946	.9916					
80						.9597	.9594					
70						.9082	.9096					
60						.8416	.8470					
50						.7631	.7681					
40						.6700	.6751					
30						(.5678)	(.5720)					
20						(.4629)	(.4677)					
10						(.3499)	(.3590)					

	$\lambda(m^{-1})$
$\lambda(r)$	1.2691 ±.0021
$\lambda(r-1)$	1.2602 ±.0052
$\lambda(r-2)$	1.2585 ±.0062

	Thimble K1W	Thimble K1E	Average
z_o(cm)	102.73	102.25	102.49 ±0.25
$\alpha(m^{-1})$	1.3518	1.3450	1.3484 ±0.0034
$\alpha_{corr}(m^{-1})$	1.3550 ±0.0034		

Table 19-A : Buckling Data - 20 cm Hex Lattice (He Coolant)

55 19-element U-metal Clusters plus
a 'Driver Region' of 36 7-element UO_2 (air-cooled) Clusters

Mar. 16(pm)/1964 Manganese Foils h_c = 184.004 cm Temp : 24.2°C Moderator Purity : 99.707 at % D_2O

Direction	W	S	W	W	S	W	E	N	E	E	N	E
Thimble	K7	H	K5	K3	J	K1	K1	L	K3	K5	N	K7
Radius cm	70.00	51.96	50.00	30.00	17.32	10.00	10.00	17.32	30.00	50.00	51.96	70.00
Elevation cm												
180						(.1331)	(.1355)					
170						(.2942)	(.3065)					
160						(.4385)	(.4556)					
150						.5668	.5910					
140						.6844	.7137					
130						.7855	.8184					
120						.8689	.9075					
110						.9378	.9739					
100	.8153	.8674	.8737	.9556	.9839	.9799	1.0196	.9947	.9565	.8689	.8522	.8242
90	.8294	.8853	.8923	.9753	1.0085	1.0000	1.0423	1.0175	.9772	.8837	.8649	.8353
80	.8291	.8737	.8909	.9741	1.0099	1.0019	1.0412	1.0188	.9750	.8833	.8703	.8348
70						.9805	1.0208					
60						.9355	.9764					
50						.8734	.9133					
40						.7911	.8279					
30						(.7092)	(.7387)					
20						(.6670)	(.6888)					
10						(.7103)	(.7188)					

	$\lambda(m^{-1})$
$\lambda(n)$	1.5476 ±.0476
$\lambda(n-1)$	1.4684 ±.1134
$\lambda(n-2)$	1.4739 ±.1445

	Thimble K1W	Thimble K1E	Average
z_o(cm)	84.75	84.56	84.65 ±0.10
$\alpha(m^{-1})$	1.4870	1.4793	1.4832 ±0.0040
$\alpha_{corr}(m^{-1})$	1.4918 ±0.0040		

Table 20-A : Buckling Data - 20 cm Hex Lattice (He Coolant)

55 19-element U-metal Clusters plus
a 'Driver Region' of 36 7-element UO_2 (air-cooled) Clusters

Mar. 13 (pm)/1964 Manganese Foils h_c = 184.250 cm

Moderator
Temp : 24.2°C Purity : 99.708 at % D_2O

Direction	W	E	S	S	E	W	E	N	E	E	W	E	N	S	E	W
Thimble	K1W	K1E	JO	J2W	L2E	K3W	K3E	M1E	J4E	I3E	K5W	K5E	NO	H2W	L6E	K7W
Radius cm	10.00	10.00	17.32	26.46	26.46	30.00	30.00	36.06	43.58	45.82	50.00	50.00	51.96	55.68	62.44	70.00
Elevation cm																
170	(.3012)	(.2976)														
160	(.4425)	(.4418)														
150	.5728	.5738														
140	.6879	.6897														
130	.7883	.7935														
120	.8728	.8751														
110	.9357	.9377														
100	.9782	.9804	.9616	.9456	.9400	.9365	.9334	.9233	.8793	.8685	.8564	.8492	.8360	.8278	.7937	.8068
90	1.0000	1.0043	.9860	.9589	.9630	.9586	.9550	.9400	.8985	.8880	.8749	.8557	.8517	.8439	.8108	.8180
80	.9955	1.0042	.9864	.9710	.9621	.9560	.9519	.9404	.8952	.8889	.8748	.8660	.8516	.8445	.8073	.8183
70	.9747	.9820														
60	.9318	.9417														
50	.8701	.8797														
40	.7903	.7986														
30	(.7036)	(.7144)														
20	(.6615)	(.6646)														
10	(.5977)	(.6984)														

	$\lambda (m^{-1})$
$\lambda(n)$	1.5382 ±.0159
$\lambda(n-1)$	1.4643 ±.0230
$\lambda(n-2)$	1.4427 ±.0341

	Thimble K1W	Thimble K1E	Average
z_o(cm)	85.06	84.61	84.84 ±0.23
$\alpha(m^{-1})$	1.4775	1.4715	1.4745 ±0.0037
$\alpha_{corr}(m^{-1})$		1.4847 ±0.0037	

Table 21-A : Buckling Data - 20 cm Hex Lattice (He Coolant)

55 19-element U-metal Clusters plus
a 'Driver Region' of 36 7-element UO_2 (air-cooled) Clusters

Mar. 12 (am)/1964 Manganese Foils h_c = 183.850 cm Temp : 24.1°C Moderator Purity : 99.709 at % D_2O

Direction	W	S	W	W	S	W*	E	N	E	E	N	E
Thible	K7	H	K5	K3	J	K1	K1	L	K3	K5	N	K7
Radius cm	70.00	51.96	50.00	30.00	17.32	10.00	10.00	17.32	30.00	50.00	51.96	70.00
Elevation cm												
170						(.2975)	(.2983)					
160						(.4404)	(.4442)					
150						.5703	.5785					
140						.6878	.6991					
130						.7897	.8021					
120						.8725	.8880					
110						.9350	.9555					
100	.8128	.8614	.8668	.9505	.9810	.9778	.9987	.9880	.9476	.8622	.8505	.8095
90	.8261	.8797	.8878	.9709	1.0035	1.0000	1.0207	1.0121	.9707	.8805	.8683	.8243
80	.8253	.8782	.8860	.9688	1.0031	.9983	1.0223	1.0144	.9702	.8813	.8703	.8226
70						.9787	.9996					
60						.9322	.9449					
50						.8691	.8934					
40						.7894	.8136					
30						(.7045)	(.7229)					
20						(.6639)	(.6776)					
10						(.7112)	(.7119)					

	$\lambda(m^{-1})$
$\lambda(n)$	1.5413 ±.0204
$\lambda(n-1)$	1.5559 ±.0229

	Thimble K1W	Thimble K1E	Average
z_o(cm)	85.05	84.68	84.86 ±0.19
$\alpha(m^{-1})$	1.4827	1.4800	1.4814 ±0.0047
$\alpha_{corr}(m^{-1})$		1.4888 ±0.0047	

* K1W omitted from radial fits.

Table 22-A : Buckling Data - 22 cm Hex Lattice (He Coolant)

55 19-element U-metal Clusters plus
a 'Driver Region' of 36 7-element UO_2 (air-cooled) Clusters

Mar. 9 (pm)/1964 Manganese Foils h_c : 172.202 cm **Moderator** Temp : 24.2°C Purity : 99.710 at % D_2O

Direction	W	E	N	S	W	E	N	E	E	W	E	N	S	E	W
Thimble	K1W	K1E	LO	J2W	K3W	K3E	M1E	J4E	I3E	K5W	K5E	NO	H2W	L6E	K7W
Radius cm	11.00	11.00	19.05	29.11	33.00	33.00	39.67	47.94	50.40	55.00	55.00	57.16	61.25	68.68	77.00
Elevation cm															
160	(.2756)	(.2745)													
150	(.4322)	(.4339)													
140	.5730	.5740													
130	.6975	.7002													
120	.8037	.8061													
110	.8890	.8920													
100	.9517	.9562													
90	.9886	.9937	.9795	.9429	.9183	.9161	.8900	.8307	.8148	.7887	.7923	.7610	.7438	.6887	.7921
80	1.0000	1.0072	.9903	.9525	.9303	.9289	.8976	.8396	.8242	.7991	.7998	.7701	.7516	.6981	.8004
70	.9884	.9964	.9791	.9416	.9175	.9181	.8863	.8291	.8142	.7912	.7881	.7594	.7436	.6884	.7915
60	.9502	.9603													
50	.8898	.9043													
40	.8060	.8231													
30	(.7137)	(.7266)													
20	(.6469)	(.6546)													
10	(.6237)	(.6277)													

	$\lambda(m^{-1})$
$\lambda(n)$	1.7984 ±.0105
$\lambda(n-1)$	1.7379 ±.0177
$\lambda(n-2)$	1.7562 ±.0291

	Thimble K1W	Thimble K1E	Average
z_o(cm)	79.90	79.15	79.53 ±0.38
$\alpha(m^{-1})$	1.5971	1.5812	1.5892 ±0.0080
$\alpha_{corr}(m^{-1})$		1.6006 ±0.0080	

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Table 23-A : Buckling Data - 22 cm Hex Lattice (He Coolant)

55 19-element U-metal Clusters plus
a 'Driver Region' of 36 7-element UO_2 (air cooled) Clusters

Mar. 9 (am)/1964 Manganese Foils h_c = 171.824 cm Temp : 24.2°C Moderator Purity : 99.710 at % D_2O

Direction	W	S	W	W	S	W	E	N	E	E	N	E
Thimble	K7	H	K5	K3	J	K1	K1	L	K3	K5	N	K7
Radius cm	77.00	57.16	55.00	33.00	19.05	11.00	11.00	19.05	33.00	55.00	57.16	77.00
Elevation cm												
160						(.2709)	(.2702)					
150						(.4272)	(.4289)					
140						.5709	.5709					
130						.6940	.6977					
120						.8021	.8036					
110						.8888	.8901					
100						.9543	.9536					
90	.7893	.7725	.7902	.9180	.9706	.9898	.9938	.9758	.9165	.7910	.7607	.7894
80	.8009	.7827	.8016	.9292	.9840	1.0000	1.0063	.9891	.9298	.8009	.7711	.7986
70	.7908	.7721	.7904	.9163	.9691	.9923	.9976	.9796	.9179	.7917	.7495	.7901
60						.9511	.9632					
50						.8895	.9033					
40						.8071	.8197					
30						(.7149)	(.7288)					
20						(.6471)	(.6546)					
10						(.6233)	(.6291)					

	$\lambda (m^{-1})$
$\lambda(n)$	1.8090 ±.0145
$\lambda(n-1)$	1.7233 ±.0398
$\lambda(n-2)$	1.7969 ±.0195

	Thimble K1W	Thimble K1E	Average
z_o(cm)	79.84	79.10	79.47 ±0.37
$\alpha(m^{-1})$	1.6038	1.5882	1.5960 ±0.0078
$\alpha_{corr}(m^{-1})$			1.6044 ±0.0078

Table 24-A : Buckling Data - 24 cm Hex Lattice (He Coolant)

55 19-element U-metal Clusters plus
a 'Driver Region' of 36 7-element UO_2 (air-cooled) Clusters

Mar. 23 (pm)/1964 Manganese Foils h_c = 137.066 cm Temp : 24.0°C Moderator Purity : 99.705 at % D_2O

Direction	W	S	W	W	S	W	E	N	E	E	N	E
Thimble	K7	H	K5	K3	J	K1	K1	L	K3	K5	N	K7
Radius cm	84.00	62.35	60.00	36.00	20.79	12.00	12.00	20.79	36.00	60.00	62.35	84.00
Elevation cm												
130						(.2389)	(.2364)					
120						(.4409)	(.4421)					
110						.6158	.6167					
100						.7595	.7626					
90						.8750	.8760					
80						.9514	.9599					
70	.6836	.8043	.8180	.9357	.9754	.9963	.9977	.9820	.9336	.8142	.7952	.6875
60	.6905	.8098	.8213	.9399	.9823	1.0000	1.0034	.9928	.9393	.8200	.8013	.6897
50	.6686	.7854	.7960	.9075	.9538	.9682	.9748	.9626	.9088	.7955	.7748	.6682
40						.9001	.9079					
30						(.8097)	(.8187)					
20						(.7312)	(.7373)					
10						(.6743)	(.6783)					

	$\lambda(m^{-1})$
$\lambda(n)$	1.4945 ±.0112
$\lambda(n-1)$	1.4831 ±.0180
$\lambda(n-2)$	1.4945 ±.0200

	Thimble K1W	Thimble K1E	Average
z_o(cm)	63.58	63.30	63.44 ±0.14
$\alpha(m^{-1})$	1.9569	1.9471	1.9520 ±0.0087
$\alpha_{corr}(m^{-1})$	1.9580 ±0.0087		

Table 25-A : Buckling Data - 24 cm Hex Lattice (He Coolant)

Feb. 28 (pm)/1964 — Manganese Foils — Moderator: Temp : 24.0°C Purity : 99.714 at % D_2O — h_c = 154.090 cm

Direction	W	E	S	S	E	W	E	N	E	E	W	E	N	S	E	W
Thimble	K1W	K1E	JO	J2W	L2E	K3W	K3E	M1E	J4E	I3E	K5W	K5E	NO	H2W	L6E	K7W
Radius cm	12.00	12.00	20.78	31.75	31.75	36.00	36.00	43.27	52.30	54.98	60.00	60.00	62.35	66.32	74.93	84.00
Elevation cm																
150	(.1449)	(.1477)														
140	(.3352)	(.3396)														
130	(.5038)	(.5028)														
120	.6502	.6584														
110	.7760	.7823														
100	.8761	.8822														
90	.9484	.9557														
80	.9888	.9986	.9714	.9297	.9326	.9114	.9100	.8774	.8127	.7966	.7640	.7589	.7383	.7071	.6347	.6870
70	1.0000	.9993	.9789	.9393	.9417	.9188	.9176	.8882	.8221	.8031	.7698	.7654	.7480	.7151	.6402	.6940
60	.9761	.9833	.9563	.9221	.9223	.8999	.8995	.8688	.8040	.7882	.7545	.7483	.7304	.6997	.6273	.6786
50	.9223	.9302														
40	.8454	.8522														
30	(.7483)	(.7557)														
20	(.6683)	(.6712)														
10	(.6100)	(.6130)														

	$\lambda(m^{-1})$
$\lambda(n)$	1.7188 ±.0068
$\lambda(n-1)$	1.6764 ±.0099
$\lambda(n-2)$	1.6772 ±.0125

	Thimble K1W	Thimble K1E	Average
z_o(cm)	71.80	71.78	71.79 ±0.16
$\alpha(m^{-1})$	1.7863	1.17732	1.7798 ±0.0072
$\alpha_{corr}(m^{-1})$	1.7893 ±0.0072		

Table 26-A : Buckling Data - 24 cm Hex Lattice (He Coolant)

Feb. 24 (pm)/1964 Manganese Foils Temp : 24.1°C Moderator Purity : 99.716 at % D_2O h_c = 153.826 cm

Direction	W	S	W	W	S	W	E	N	E	E	N	E
Thimble	K7	H	K5	K3	J	K1	K1	L	K3	K5	N	K7
Radius cm	84.00	62.35	60.00	36.00	20.79	12.00	12.00	20.79	36.00	60.00	62.35	84.00
Elevation cm												
150						(.1419)	(.1395)					
140						(.3341)	(.3355)					
130						(.5036)	(.5050)					
120						.6520	.6518					
110						.7766	.7785					
100						.8796	.8812					
90						.9530	.9559					
80	.6906	.7487	.7653	.9122	.9754	.9945	1.0025	.9804	.9153	.7642	.7405	.6852
70	.6981	.7581	.7743	.9212	.9853	1.0000	1.0153	.9933	.9260	.7693	.7500	.6959
60	.6833	.7443	.7557	.9018	.9643	.9818	.9992	.9759	.9037	.7538	.7328	.6809
50						.9300	.9495					
40						.8483	.8699					
30						(.7545)	(.7746)					
20						(.6715)	(.6879)					
10						(.6128)	(.6298)					

	$\lambda(m^{-1})$
$\lambda(n)$	1.7371 ±.0136
$\lambda(n-1)$	1.7386 ±.0191
$\lambda(n-2)$	1.7502 ±.0261

	Thimble K1W	Thimble K1E	Average
z_o(cm)	71.70	70.60	71.15 ±0.55
$\alpha(m^{-1})$	1.7868	1.7710	1.7789 ±0.0090
$\alpha_{corr}(m^{-1})$	1.7858 ±0.0090		

Table 27-A : Buckling Data - 25 cm Hex Lattice (He Coolant)

Feb. 21(am)/1964 — Manganese Foils — Moderator: Temp : 24.2°C Purity : 99.717 at % D_2O — h_c = 147.762 cm

Direction	W	N	E	S	W	N	E	E	N	S	W	S	W	N	E	N	W	E
Thimble	K1W	K.5E	J.5E	JO	K2.5W	L.5W	K3E	J3.5E	M1E	H.5W	K4.5W	H1.5E	K5W	NO	J5.5E	N.5W	K6.5W	K7E
Radius cm	13.00	13.00	22.52	22.52	34.40	34.40	39.00	46.88	46.88	56.65	59.57	59.57	65.00	67.55	72.38	79.07	85.25	91.00
Elevation cm																		
140	(.2346)			(.2364)														
130	(.4224)			(.4189)														
120	.5867			.5803														
110	.7284			.7158														
100	.8447			.8291														
90	.9282			.9115														
80	.9790	.9902	.9624	.9594	.9208	.9167	.8944	.8549	.8571	.7986	.7911	.7793	.7357	.7080	.6779	.6259	.5887	.6109
70	1.0000	1.0084	.9820	.9787	.9386	.9364	.9146	.8735	.8728	.8150	.7876	.7930	.7481	.7234	.6902	.6378	.5986	.6241
60	.9869	.9978	.9682	.9639	.9235	.9260	.9028	.8644	.8623	.8040	.7782	.7838	.7386	.7134	.6826	.6304	.5932	.6144
50	.9403			.9178														
40	.8614			.8389														
30	(.7632)			(.7438)														
20	(.6684)			(.6496)														
10	(.5833)			(.5676)														

	$\lambda(m^{-1})$
$\lambda(n)$	1.6555 ±.0088
$\lambda(n-1)$	1.6182 ±.0094
$\lambda(n-2)$	1.6388 ±.0116
$\lambda(n-3)$	1.6408 ±.0158

	Thimble K1W	Thimble Jo	Average
z_o(cm)	69.02	69.41	69.22 ±0.20
$\alpha(m^{-1})$	1.8468	1.8482	1.8475 ±0.0065
$\alpha_{corr}(m^{-1})$		1.8577 ±0.0065	

Table 28-A : Buckling Data - 26 cm Hex Lattice (He Coolant)

Feb. 19 (pm)/1964 Manganese Foils Moderator Temp : 24.2°C Purity : 99.717 at % D_2O h_c = 147.448 cm

Direction	W	S	W	W	S	W	E	N	E	E	N	E
Thimble	K7	H	K5	K3	J	K1	K1	L	K3	K5	N	K7
Radius cm	91.00	67.55	65.00	39.00	22.52	13.00	13.00	22.52	39.00	65.00	67.55	91.00
Elevation cm												
140						(.2229)	(.2187)					
130						(.4129)	(.4095)					
120						.5809	.5737					
110						.7222	.7178					
100						.8388	.8354					
90						.9271	.9223					
80	.6107	.7209	.7336	.8961	.9593	.9854	.9812	.9622	.8956	.7291	.7091	.6068
70	.6250	.7353	.7469	.9151	.9812	1.0000	1.0074	.9847	.9157	.7475	.7255	.6234
60	.6153	.7265	.7378	.9027	.9686	.9883	.9969	.9734	.9057	.7366	.7202	.6159
50						.9428	.9546					
40						.8639	.8800					
30						(.7659)	(.7837)					
20						(.6737)	(.6854)					
10						(.5897)	(.6026)					

	$\lambda(m^{-1})$
$\lambda(n)$	1.6554 ±.0072
$\lambda(n-1)$	1.6513 ±.0114
$\lambda(n-2)$	1.6337 ±.0089

	Thimble K1W	Thimble K1E	Average
z_o(cm)	68.80	67.66	68.23 ±0.57
$\alpha(m^{-1})$	1.8605	1.8406	1.8506 ±0.0100
$\alpha_{corr}(m^{-1})$	1.8573 ±0.0100		

Table 29-A : Buckling Data - 28 cm Hex Lattice (He Coolant)

Jan. 30 (pm)/1964 Manganese Foils Temp : 23.6°C Moderator Purity : 99.725 at % D_2O h_c = 146.504 cm

Direction	W	S	W	W	S	W	E	N	E	E	N	E
Thimble	K7	H	K5	K3	J	K1	K1	L	K3	K5	N	K7
Radius cm	98.00	72.75	70.00	42.00	24.25	14.00	14.00	24.25	42.00	70.00	72.75	98.00
Elevation cm												
140						(.1981)	(.1979)					
130						(.3925)	(.3917)					
120						.5623	.5628					
110						.7097	.7091					
100						.8292	.8294					
90						.9210	.9193					
80	.5560	.6930	.7127	.8822	.9468	.9737	.9770	.9564	.8806	.7144	.6931	.5564
70	.5703	.7109	.7292	.9035	.9676	1.0000	1.0008	.9763	.9014	.7298	.7081	.5698
60	.5669	.7031	.7199	.8899	.9587	.9901	.9902	.9646	.8907	.7185	.6996	.5631
50						.9396	.9413					
40						.8604	.8671					
30						(.7613)	(.7691)					
20						(.6609)	(.6672)					
10						(.5598)	(.5677)					

	$\lambda(m^{-1})$
$\lambda(n)$	1.5783 ±.0033
$\lambda(n-1)$	1.5973 ±.0124
$\lambda(n-2)$	1.6045 ±.0174

	Thimble K1W	Thimble K1E	Average
z_o(cm)	68.52	68.17	68.35 ±0.18
$\alpha(m^{-1})$	1.8916	1.8762	1.8839 ±0.0077
$\alpha_{corr}(m^{-1})$		1.8910 ±0.0077	

Table 30-A : Buckling Data - 28 cm Hex Lattice (He Coolant)

Jan. 30(am)/1964 Manganese Foils Temp : 23.6°C Moderator Purity : 99.725 at % D_2O h_c = 146.496 cm

Direction	W	S	W	W	S	W	E	N	E	E	N	E
Thimble	K7	H	K5	K3	J	K1	K1	L	K3	K5	N	K7
Radius cm	93.00	72.75	70.00	42.00	24.25	14.00	14.00	24.25	42.00	70.00	72.75	98.00
Elevation cm												
140						(.1984)	(.1972)					
130						(.3921)	(.3920)					
120						.5635	.5607					
110						.7082	.7075					
100						.8308	.8285					
90						.9229	.9183					
80	.5566	.6957	.7152	.8855	.9430	.9764	.9768	.9538	.8823	.7162	.6918	.5571
70	.5715	.7136	.7294	.9036	.9666	1.0000	.9973	.9735	.9025	.7313	.7086	.5690
60	.5663	.7044	.7214	.8932	.9559	.9857	.9865	.9661	.8930	.7220	.6972	.5633
50						.9409	.9437					
40						.8639	.8654					
30						(.7637)	(.7705)					
20						(.6619)	(.6671)					
10						(.5598)	(.5673)					

	$\lambda(m^{-1})$
$\lambda(n)$	1.5696±.0037
$\lambda(n-1)$	1.5608±.0159
$\lambda(n-2)$	1.5650±.0209

	Thimble K1W	Thimble K1E	Average
z_o(cm)	68.45	68.12	68.29±0.17
$\alpha(m^{-1})$	1.8837	1.8745	1.8791±0.0071
$\alpha_{corr}(m^{-1})$			1.8861±0.0071

Table 31-A : Buckling Data - 32 cm Hex Lattice (He Coolant)

Jan.22 (am)/1964 Manganese Foils Temp : 23.2°C Moderator Purity : 99.729 at % D_2O h_c = 154.399 cm

Direction	W	S	W	W	S	W	E	N	E	E	N	E
Thimble	K7	H	K5	K3	J	K1	K1	L	K3	K5	N	K7
Radius cm	112.00	83.14	80.00	48.00	27.71	16.00	16.00	27.71	48.00	80.00	83.14	112.00
Elevation cm												
150						(.1446)	(.1448)					
140						(.3362)	(.3361)					
130						(.5032)	(.5054)					
120						.6579	.6534					
110						.7871	.7806					
100						.8903	.8805					
90	.4797	.6588	.6791	.8625	.9288	.9591	.9565	.9329	.8528	.6753	.6581	.4774
80	.4980	.6862	.7074	.8968	.9696	1.0000	.9990	.9731	.8933	.7061	.6850	.4974
70	.5029	.6916	.7120	.9054	.9774	1.0105	1.0104	.9804	.9050	.7124	.6385	.4998
60						.9867	.9892					
50						.9281	.9368					
40						.8477	.8559					
30						(.7414)	(.7516)					
20						(.6301)	(.6406)					
10						(.5114)	(.5221)					

	$\lambda(m^{-1})$
$\lambda(n)$	1.4332 ±.0024
$\lambda(n-1)$	1.4416 ±.0090
$\lambda(n-2)$	1.4387 ±.0129

	Thimble K1W	Thimble K1E	Average
z_o(cm)	72.27	71.44	71.85 ±0.0042
$\alpha(m^{-1})$	1.8004	1.7866	1.7935 ±0.0069
$\alpha_{corr}(m^{-1})$	1.7989 ±0.0069		

Table 32-A: Buckling Data - 32 cm Hex Lattice (He Coolant)

Jan. 21 (pm)/1964 Manganese Foils Temp: = 23.2°C Moderator Purity : 99.729 at % D_2O h_c = 154.405 cm

Direction	W	S	W	W	S	W	E	N	E	E	N	E
Thimble	K7	H	K5	K3	J	K1	K1	L	K3	K5	N	K7
Radius cm	112.00	83.14	80.00	48.00	27.71	16.00	16.00	27.71	48.00	80.00	83.14	112.00
Elevation cm												
150						(.1464)	(.1433)					
140						(.3387)	(.3355)					
130						(.5099)	(.5048)					
120						.6591	.6533					
110						.7863	.7787					
100						.8883	.8813					
90	.4786	.6573	.6768	.8630	.9268	.9596	.9546	.9305	.8532	.6741	.6541	.4761
80	.4986	.6837	.7052	.8975	.9668	1.0000	.9961	.9718	.8921	.7047	.6817	.4947
70	.5017	.6905	.7135	.9052	.9780	1.0105	1.0093	.9807	.9023	.7104	.6892	.4997
60						.9840	.9878					
50						.9254	.9349					
40						.8444	.8522					
30						(.7405)	(.7516)					
20						(.6266)	(.6402)					
10						(.5089)	(.5209)					

	$\lambda(m^{-1})$
$\lambda(n)$	1.4367 ±.0023
$\lambda(n-1)$	1.4357 ±.0092
$\lambda(n-2)$	1.4344 ±.0147

	Thimble K1W	Thimble K1E	Average
z_o(cm)	72.40	71.55	71.97 ±0.43
$\alpha(m^{-1})$	1.8044	1.7901	1.7972 ±0.0072

$\alpha_{corr}(m^{-1})$ 1.8026 ±0.0072

— 70 —

Table 33-A: Buckling Data - 36 cm Hex Lattice (He Coolant)

Jan.17 (am)/1964 Manganese Foils Temp: = 23.1°C Moderator Purity: 99.730 at % D_2O h_c = 171.233 cm

Direction	W	S	W	W	S	W	E	N	E	E	N	E
Thimble	K7	H	K5	K3	J	K1	K1	L	K3	K5	N	K7
Radius cm	126.00	93.53	90.00	54.00	31.18	18.00	18.00	31.18	54.00	90.00	93.53	126.00
Elevation cm												
170						(.0727)	(.0713)					
160						(.2514)	(.2512)					
150						(.4157)	(.4153)					
140						.5646	.5649					
130						.6954	.6958					
120						.8092	.8071					
110						.8993	.8965					
100	.4241	.6362	.6582	.8591	.9347	.9652	.9616	.9356	.8529	.6538	.6347	.4197
90	.4394	.6615	.6840	.8922	.9713	1.0018	1.0000	.9757	.8891	.6832	.6588	.4360
80	.4449	.6698	.6931	.9002	.9842	1.0165	1.0124	.9857	.8952	.6907	.6670	.4413
70						.9997	1.0015					
60						.9569	.9626					
50						.8904	.8972					
40						.8000	.8084					
30						(.6910)	(.7063)					
20						(.5783)	(.5888)					
10						(.4539)	(.4669)					

	$\lambda(m^{-1})$
$\lambda(n)$	1.3307 ±.0016
$\lambda(n-1)$	1.3336 ±.0057
$\lambda(n-2)$	1.3303 ±.0080

	Thimble K1W	Thimble K1E	Average
z_o(cm)	80.47	79.87	80.17 ±0.30
$\alpha(m^{-1})$	1.6464	1.6267	1.6366 ±0.0099
$\alpha_{corr}(m^{-1})$	1.6420 ±0.0099		

Table 34-A: Buckling Data - 36 cm Hex Lattice (He Coolant)

Jan. 16 (pm) 1964 — Manganese Foils — Moderator Temp: = 23.1°C Purity: 99.730 at % D_2O h_c = 171.256 cm

Direction	W	S	W	W	S	W	E	N	E	E	N	E
Thimble	K7	H	K5	K3	J	K1	K1	L	K3	K5	N	K7
Radius cm	126.00	93.53	90.00	54.00	31.18	18.00	18.00	31.18	54.00	90.00	93.53	126.00
Elevation cm												
170						(.0727)	(.0712)					
160						(.2515)	(.2502)					
150						(.4158)	(.4145)					
140						.5646	.5623					
130						.6928	.6901					
120						.8074	.8016					
110						.8951	.8908					
100	.4214	.5344	.6560	.8551	.9299	.9599	.9569	.9309	.8539	.6516	.6331	.4182
90	.4380	.5611	.6805	.8864	.9706	1.0000	.9952	.9707	.8891	.6788	.6600	.4345
80	.4429	.5669	.6888	.8991	.9802	1.0121	1.0097	.9817	.8967	.6864	.6643	.4392
70						.9970	.9980					
60						.9538	.9596					
50						.8870	.8936					
40						.7987	.8105					
30						(.6918)	(.7039)					
20						(.5758)	(.5886)					
10						(.4537)	(.4676)					

	$\lambda(m^{-1})$
$\lambda(n)$	1.3302 ±.0018
$\lambda(n-1)$	1.3291 ±.0068
$\lambda(n-2)$	1.3153 ±.0062

	Thimble K1W	Thimble K1E	Average
z_o(cm)	80.42	79.61	80.02 ±0.41
$\alpha(m^{-1})$	1.6427	1.6277	1.6352 ±0.0075
$\alpha_{corr}(m^{-1})$			1.6409 ±0.0075

Table 35-A : Buckling Data - 40 cm Hex Lattice (He Coolant)

Dec. 19 (pm)/1963 Manganese Foils Temp : 21.5°C Moderator Purity : 99.735 at % D_2O h_c = 196.269 cm

Direction	W	S	W	W	S	W	E	N	E	E	N	E
Thimble	K7	H	K5	K3	J	K1	K1	L	K3	K5	N	K7
Radius cm	140.00	103.92	100.00	60.00	34.64	20.00	20.00	34.64	60.00	100.00	103.92	140.00
Elevation cm												
190						(.1433)	(.1391)					
180						(.2908)	(.2876)					
170						.4313	.4280					
160						.5616	.5576					
150						.6786	.6768					
140						.7802	.7772					
130						.8662	.8622					
120						.9306	.9297					
110	.3630	.6097	.6329	.8518	.9449	.9764	.9779	.9429	.8510	.6306	.6060	.3601
100	.3722	.6264	.6509	.8783	.9703	1.0000	1.0035	.9713	.8790	.6469	.6238	.3690
90	.3742	.6283	.6522	.8841	.9758	1.0077	1.0054	.9733	.8789	.6494	.6263	.3706
80						.9881	.9868					
70						.9487	.9518					
60						.8906	.8917					
50						.8150	.8226					
40						.7199	.7269					
30						(.6147)	(.6225)					
20						(.5028)	(.5108)					
10						(.3851)	(.3937)					

	$\lambda(m^{-1})$
$\lambda(n)$	1.2660 ±.0015
$\lambda(n-1)$	1.2715 ±.0042
$\lambda(n-2)$	1.2662 ±.0058

	Thimble K1W	Thimble K1E	Average
z_o(cm)	93.15	92.64	92.90 ±0.26
$\alpha(m^{-1})$	1.4664	1.4607	1.4636 ±0.0029
$\alpha_{corr}(m^{-1})$		1.4715 ±0.0029	

Table 36-A: Buckling Data - 40 cm Hex Lattice (He Coolant)

Dec. 19 (am)/1963 Manganese Foils Temp: = 21.5°C Moderator Purity: 99.735 at % D_2O h_c = 196.303 cm

Direction	W	S	W	W	S	W	E	N	E	E	N	E
Thimble	K7	H	K5	K3	J	K1	K1	L	K3	K5	N	K7
Radius cm	140.00	103.92	100.00	60.00	34.64	20.00	20.00	34.64	60.00	100.00	103.92	140.00
Elevation cm												
190						(.1473)	(.1428)					
180						(.2994)	(.2953)					
170						.4423	.4383					
160						.5749	.5715					
150						.6943	.6898					
140						.7974	.7929					
130						.8849	.8834					
120	.3556	.5925	.6213	.8307	.9248	.9513	.9516	.9219	.8339	.6171	.5883	.3524
110	.3728	.6217	.6514	.8738	.9645	1.0000	.9988	.9662	.8750	.6482	.6197	.3698
100	.3832	.6379	.6677	.8982	.9940	1.0295	1.0292	.9915	.9009	.6653	.6338	.3788
90						1.0313	1.0306					
80						1.0114	1.0090					
70						.9712	.9727					
60						.9114	.9162					
50						.8314	.8379					
40						.7361	.7436					
30						(.6308)	(.6371)					
20						(.5156)	(.5231)					
10						(.3942)	(.4030)					

	$\lambda(m^{-1})$
$\lambda(n)$	1.2668 ±.0017
$\lambda(n-1)$	1.2586 ±.0050
$\lambda(n-2)$	1.2671 ±.0058

	Thimble K1W	Thimble K1E	Average
z_o(cm)	93.07	92.63	92.85 ±0.22
$\alpha(m^{-1})$	1.4629	1.4590	1.4510 ±0.0024
$\alpha_{corr}(m^{-1})$			1.4688 ±0.0024

APPENDIX B

Spatial Distributions of In Cd-ratios and Relative In/Cu Ratios

Table 1-B: In Cadmium Ratio - 20 Cm Lattice with D_2O Coolant

March 18, 1964 — Critical Height : 193.6 Cm — Moderator Temperature : 24.2°C

Thimble	K7W	H_o	K5W	K3W	J_o	K1W	K1E	L_o	K3E	K5E	N_o	K7E
Radius (Cm)	70.00	51.96	50.00	30.00	17.32	10.00	10.00	17.32	30.00	50.00	51.96	70.00
Elevation (cm)												
180						(1.936)						
170							(2.007)					
160						*2.281						
150							1.995					
140						1.931						
130							2.029					
120						1.952						
110							2.027					
100			1.995		1.984	1.973			1.963		1.967	(2.078)
90	(2.058)	2.000		1.967			2.003	1.978		1.993		
80			2.000		2.020	1.946			1.985		1.956	(2.077)
70							2.006					
60						1.968						
50							2.000					
40						1.922						
30							(2.058)					
20						(2.257)						
10							(3.092)					

Radial Average = 1.982±.005 Axial Average = 1.979±.010

Average = 1.981 ±.006

*Omitted from average

Table 2-B: In Cadmium Ratio - 24 cm Lattice with D_2O Coolant

March 2, 1964 | Critical Height : 164.3 cm | Moderator Temperature : 24.1°C

Thimble	K7W	Ho	K5W	K3W	Jo	K1W	K1E	Lo	K3E	K5E	No	K7E
Radius (cm)	84.00	62.35	60.00	36.00	20.78	12.00	12.00	20.78	36.00	60.00	62.35	84.00
Elevation (cm)												
160						(2.332)						
150							(1.942)					
140						(2.531)						
130							2.474					
120						2.571						
110							*2.195					
100						2.492						
90							2.531					
80		2.510	2.518			2.548		2.539	2.545			(3.275)
70	(3.252)			2.531	2.522		2.521			2.557	2.503	
60		2.487	2.483			2.533		2.525	2.555			(3.421)
50							2.520					
40						2.568						
30							(2.600)					
20						(2.912)						
10							(3.718)					

Radial average = 2.525±.006   Axial Average = 2.529±.011

Average = 2.526±.006

*Omitted from average

Table 3-B: In Cadmium Ratio - 28 cm Lattice with D_2O Coolant

January 31, 1964 Critical Height : 156.4 cm Moderator Temperature : 23.6°C

Thimble	K7W	Ho	K5W	K3W	Jo	K1W	K1E	Lo	K3E	K5E	No	K7E
Radius (cm)	98.00	72.75	70.00	42.00	24.25	14.00	14.00	24.25	42.00	70.00	72.75	98.00
Elevation (cm)												
150							(2.862)					
140						(3.142)						
130							3.182					
120						3.230						
110							3.170					
100						3.217						
90							3.175					
80			3.218		3.121	3.245			3.165		3.182	(4.351)
70	(4.268)	3.221		3.229			3.188	3.204		3.198		
60						3.206						
50							3.202					
40						3.201						
30							(3.308)					
20						(3.647)						
10							(4.873)					

Radial Average = 3.197±.011 Axial Average = 3.202±.008

Average = 3.197±.007

Table 4-B: Relative In/Cu Ratio - 40 cm Lattice with D_2O Coolant

December 20, 1963 Critical Height : 215.8 cm Moderator Temperature : 22.0°C

Thimble	K7W	H_o	K5W	K3W	J_o	K1W	K1E	L_o	K3E	K5E	N_o	K7E
Radius (cm)	140.00	103.92	100.00	60.00	34.64	20.00	20.00	34.64	60.00	100.00	103.92	140.00
Elevation (cm)												
190						(59.48)	(59.07)					
180						59.31	58.12					
170						59.88	60.19					
160						59.94	60.04					
150						60.42	59.78					
140						59.28	58.93					
130						59.71	59.62					
120						59.63	59.07					
110	(56.89)	59.47	59.48	60.12	58.71	59.82	59.60	59.12	59.96	59.45	58.46	(56.44)
100	(56.83)	59.62	60.73	60.23	60.28	59.85	59.68	60.07	59.78	59.82	60.07	(57.12)
90		59.27	60.09	59.14	58.74	59.08	59.83	59.77	59.42	59.14	59.77	(57.35)
80						59.16	59.51					
70						59.01	60.51					
60						59.97	60.41					
50						60.08	59.59					
40						59.44	58.82					
30						(59.42)	(58.60)					
20						(57.32)	(56.89)					
10						(56.02)	(56.06)					

Radial average = 59.62 Axial Average = 59.61

Average = 59.61 ±.07