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BROOKHAVEN NATIONAL LABORATORY

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MEMORANDUM

CLASSIFICATION CANCELLED
DATE 12-13-55
For The Atomic Energy Commission
H. F. Carroll
Chief, Declassification Branch

Date: April 28, 1953

TO: I. Kaplan

FROM: H. Kouts

SUBJECT: Accuracy of Relaxation Length Measurements

We consider here the accuracy of relaxation lengths measured during the water-uranium lattice experiments. Since such an analysis for all measurements would take a great deal of time, we have applied it to just one lattice. This one (2:1 water-to-metal ratio) was chosen completely at random.

We define three separate measures of the error in an individual relaxation length. These are:

(1) The probable error associated with the least squares fit of an exponential to the measured fluxes. We call this δL.

(2) The probable error as derived from statistical considerations of the accuracy to which foils were counted. This we call ΔL.

(3) The standard deviations of the measured relaxation lengths from the values predicted by least-squares fits to B^2 and λ. These we term dL.

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If the major contribution to the size of δL comes from the statistics of flux measurements, we should expect that δL and ΔL will be comparable. In other words, the quantity

$$\delta L - \Delta L \qquad (1)$$

should be negative about as often as it is positive. An example of a cause which would upset this balance is changing counter sensitivities during foil counting. Another cause might be improper taking into account of end corrections during calculation of L from the flux levels.

dL is a measure of another kind of error. For instance, in our analysis leading to values of B^2 and λ, we assume that we can replace any geometrical loading shape used by an "equivalent cylinder" having the same total area. If this assumption is poor, we may expect that the quantity

$$\delta L - |dL| \qquad (2)$$

is more often negative than positive. Another cause of such deviation of the sign of (2) from randomness might be a changing reflector savings with loading. Other causes could be varying enrichments or sizes of fuel rods, contamination of the water by neutron absorbers, plating out of cadmium on rods, etc.

In Table I we give the values of δL, ΔL, and dL for the relaxation lengths measured with the 2:1 lattice. Inspection shows that quantity (1) is positive in eleven cases, and is negative in thirteen cases. I think it can be concluded from this good agreement that our values of L are as good as we have been trying to make them.

On the other hand, the quantity (2) is negative in fifteen instances, and positive in just seven. One would hope for a more equitable distribution.

We have evidence that some at least of this effect derives from our assumption that any loading can be replaced by its equivalent cylinder. The first

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such evidence appeared strongly during the relaxation length measurements on the 2:1 lattice. Least squares fits of the L's to B^2 and λ were consistently poor, the trouble being clearly associated with the relaxation lengths measured at loadings of 271, 277, and 283 rods. Rerunning these measurements confirmed their L's, which still deviated from the expected values by about two centimeters. We then decided to find out if the difficulty was related to the hexagonal 271 rod loading. The relaxation length of the latter was remeasured, with the uranium having a more cylindrical loading. The results were:

Geometry	L
Hexagon	42.998 cm
Better cylinder	43.496 cm

Remeasurement of the relaxation length of the 283 rod loading in a better cylindrical geometry gave the even more striking results:

Geometry	L
Hexagon + 2 on each side	61.589 cm
Better cylinder	62.605 cm

These changes were so great that we decided not to use the three loadings involved in the B^2 determinations.

Inspection of other relaxation length measurements* for all lattices shows consistently large values of $|dL|$ for measurements made with hexagonal loadings. As a result, we are not longer using hexagonal shapes, and are in-

*See for instance the memorandum from Chernick to Kaplan, "Analysis of the Clean Bucklings of 1.3 per cent Enriched Uranium-Water Lattices", BNL Log No. C-7027, April 6, 1953.

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stead rounding out all loadings as much as geometry permits.

These geometrical effects are of course understandable. The six corner rods in a hexagonal or nearly hexagonal loading are farther from the center of the loading than are other perimeter rods. Too, they have less uranium near them than do other rods. Thus they contribute less to the reactivity.

It does not follow that the equivalent cylinder assumption necessarily causes all the excessive negative values of (2). We find occasionally (by remeasurement of suspicious values of L) cases in which apparently too many or too few fuel rods were loaded during a given run, and this must be added as a partial cause. It is known that fuel rod diameters do not vary appreciably, and analysis makes variation of the enrichment factor unlikely. We have looked for plating out of cadmium in the past but have not seen any. Evidence indicates that the water does not become noticeably poisoned with use.

In an attempt to discover how much of the departure from randomness is due to geometrical effects, we have redone the B^2, λ calculation, leaving out the rod loadings at hexagons and within six rods of hexagons. The improvement in accuracy of the least squares fits were marked, the new values being

$$B^2 = 61.58 \pm .37 \times 10^{-4}\ \text{cm}^{-2}$$

$$\lambda = 6.97 \pm .07\ \text{cm}$$

The residuals from this least squares fit are shown in Table II. These values lead to four cases with (2) negative, seven with (2) positive, and three cases in which ΔL and $|dL|$ are equal within the accuracy of the analysis. Such a distribution is not too unlikely; in fact, it has a P of .27.

Use of the ΔL in Table II leads to expected accuracies in B^2 and λ of $\pm .30 \times 10^{-4}\ \text{cm}^{-2}$ and .06 cm, respectively. Thus the accuracy of the buckling

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fits is quite closely what is expected, when allowance is made for geometrical effects.

The analysis does not seem to lead to discovery of any factors other than geometrical ones causing departures from randomness in the least squares fits.

Table I

No. of Rods	L	δL	ΔL	δL
283	62.595	.175	.544	
277	50.860	.152	.391	
271	42.998	.409	.272	
265	40.291	.284	.238	-.208
259	37.475	.321	.218	+.437
253	34.586	.171	.171	-.260
247	32.466	.327	.162	-.447
241	30.071	.055	.127	+.016
235	28.340	.105	.125	-.010
229	26.944	.128	.107	+.094
223	25.657	.095	.091	+.144
217	23.924	.053	.096	-.387
211	23.177	.096	.089	-.042
205	22.044	.064	.088	-.176
199	21.415	.063	.059	+.186
193	20.224	.076	.060	-.165
187	19.685	.046	.066	-.081
181	18.869	.053	.059	-.002
175	18.301	.035	.055	+.126
169	17.208	.037	.065	-.316
163	16.844	.040	.088	-.062
157	16.218	.007	.060	-.098
145	15.301	.107	.075	+.089
139	14.885	.074	.069	+.191
133	14.308	.044	.059	+.113

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Table II

No. of Rods	ΔL	δL
259	.218	−.043
253	.171	−.049
247	.162	+.221
241	.127	−.149
235	.125	−.128
229	.107	+.012
205	.088	−.178
199	.059	+.126
193	.060	−.207
187	.066	+.056
181	.059	−.011
157	.060	−.069
145	.075	+.129
139	.069	+.236

END

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