BNL - 2754

[redacted]

BNL LOG No. C-9435

This document consists of 18 pages
No. of 42 copies, Series A

BROOKHAVEN NATIONAL LABORATORY

M E M O R A N D U M

Date: April 3, 1956

TO: Irving Kaplan

FROM: H. Kouts, G. Price, V. Walsh

SUBJECT: Thermal Utilization, 0.387" Diameter 1.15% Enriched Uranium Rods in Light Water

Distribution:

1A - I. Kaplan, BNL
2A - H. J. C. Kouts, BNL
3A - G. A. Price, BNL
4A - K. W. Downes, BNL
5A - J. Hendrie, BNL
6A - R. Sher, BNL
7A - J. Chernick, BNL
8A - C. Williams, BNL
9A - N. Corngold, BNL
10A - T. Auerbach, BNL
11A - J. Fleck, BNL
12A - S. Oleksa, BNL
13A - Y. Shimamoto, BNL
14A - S. Krasik, WAPD
15A - A. F. Henry, WAPD
16A - R. Hellens, WAPD
17A - J. Feldmeier, WAPD
18A - A. Z. Kranz, WAPD
19A - J. R. Brown, WAPD
20A - D. Okrent, ANL
21A - J. W. Weil, GE, Schenectady
22A - R. W. Deutsch, KAPL
23A - A. Radkowsky, USAEC, Washington
24A - I. F. Zartman, USAEC, Wash.
25A - J. R. Triplett, Hanford
26A - G. M. Muller, Hanford
27A - H. Neumann, Hanford
28A - G. W. Stuart, Hanford
29A - Hanford Files
30A - A. B. Martin, NAA
31A - L. D. P. King, Los Alamos
32A - G. Dessauer, Dupont, Savannah River
33A - A. D. Callihan, ORNL
34A - R. Charpie, ORNL
35A - H. F. Henry, K-25 (Oak Ridge)
36A - 39A - TIS, [illegible]
40A - 42A - CDS, BNL

BROOKHAVEN NATIONAL LABORATORY
M E M O R A N D U M

Date: April 3, 1956

TO: Irving Kaplan

FROM: H. Kouts, G. Price, V. Walsh

SUBJECT: Thermal Utilization, 0.387" Diameter 1.15% Fnriched Uranium Rods in Light Water

The measurements reported in this memorandum refer to 1.143% enriched uranium rods, 0.387" in diameter, formed into lattices with uniform spacing and hexagonal geometry, and moderated by light water. The quantity measured is f, and the method is the same as that reported in our previous memoranda on this subject, namely: the determination of the intracell distribution of thermal neutrons, by activation of very small foils of dysprosium oxide.

We have reported earlier the discovery that this measurement is fairly sensitive to the choice of material which is used to hold the detector foils in place in the water. By means of a study of how the experimental results depend on the thickness of aluminum or lucite used for this purpose, we have found that any feasible thickness of aluminum disturbs the measured flux distribution more than we care to allow, whereas the effect of lucite is relatively small. In particular, we have determined a thickness of 0.015" of lucite depresses the thermal neutron flux in water by less than 1%. The foil holders are therefore now made of this thickness of this material.

Experimental Methods: The dysprosium oxide foils are 1/16" in diameter, and are 0.010" thick. They are made of a mixture of dysprosium oxide and polyethelene powder, hot-pressed into a sheet; from this the foils are punched. All foils used have now been intercalibrated a great many times, so that their intercalibration factors are (with a few exceptions) known to about 1% accuracy or better.

In each measurement, nine foils were placed in milled depressions in a cross-section cut of a fuel rod. This rod section was then placed in a fuel rod tube along with other fuel rod pieces, so that the physical appearance was that of a complete rod with the detector foils imbedded within it. This rod was then placed in the lattice in a fuel position.

The foils in the water were located in a 0.015" thick lucite plate (as mentioned earlier). The latter was held fixed just by the pressure of the three neighboring fuel rods which it is placed between. Figure 1 shows a typical arrangement of foils in the uranium and in the foil holder in the water. As is apparent in the figure, the measurement of flux in the water took place along two radii, one of which was along the line to a nearest neighboring rod, and the other of which was along a line to a next nearest neighbor.

All foils were counted to 1% statistical accuracy or better in end-window β-counters. In accordance with our usual counting practice, six counters were used, and every foil was counted in every counter. Thus the need for counter intercalibrations was avoided.

All of the measurements except that with the 3:1 volume ratio were done with full-sized exponential experiments. The 3:1 volume ratio result was obtained with a small assembly ($\sim$ 1 feet diameter, 18" high) of rods exposed in the animal tunnel. This we call a miniature assembly, to distinguish it from the standard-sized ones.

<u>Analysis and Results</u>: The values of relative flux were determined by applying the proper intercalibration factors to the measured foil activities (after the latter were corrected for decay, dead time, and counter background). All flux curves were then normalized to the value unity at the center. This normalization was based on a least squares fitting of the measured flux values in the rod to the parabolic form

$$\phi = A \left(1 + a r^2 \right)$$

The results of the measurements for the five volume ratios studied are listed in tables I-V and are shown in figures 2-6.

Flux averages in the water were obtained by numerical integration of the curves. Flux averages in the uranium were found from analytical integration of the least squares curves. Flux averages in the aluminum were found by inspection of the curves. These flux averages were then inserted in the expression

$$f = \frac{\Sigma_a^u \bar{\phi}_u}{\Sigma_a^u \bar{\phi}_u + \Sigma_a^{al} \bar{\phi}_{al} + \Sigma_a^w \bar{\phi}_w}$$

for evaluation of the thermal utilization.

The cross-sections used were those listed in BNL-325, averaged over a Maxwell distribution. The atom density of the uranium was found from measurements of the specific gravity (18.91 ± 0.02). The constants used were

	atom density (cm^{-3})	σ_a (cm^2)	Σ_a (cm^{-1})
hydrogen	6.69×10^{22}	0.293×10^{-24}	1.957×10^{-2}
aluminum	6.03×10^{22}	0.204×10^{-24}	1.230×10^{-2}
U^{235}	5.537×10^{20}	5.975×10^{-22}	3.308×10^{-1}
U^{238}	4.729×10^{22}	2.438×10^{-24}	1.153×10^{-1}
Total Uranium	-	-	4.461×10^{-1}

The values of f are shown in table VII and figure 7.

An interesting result of this set of measurements is the behavior of the flux dips observed in the rods. As the water-to-uranium volume ratio is decreased from 4:1, the observed flux dip (represented by the quantity a in the least-squares fit) remains apparently constant, except for the 1:1 volume ratio lattice. This seems to imply that the neutron temperature is nearly the same for all the wider-spaced lattices. It is unlikely that the neutron temperature could remain constant over such a large range of water to uranium ratios unless it is actually very near that of the moderator.

We do not have any reliable measurements of neutron temperature yet for these assemblies, but we should have some soon, after we begin critical experiments with them.

Table I

Relative Fluxes, 1:1 Lattice

Inches from Rod Center	ϕ
0.000	0.975
0.075	1.029
0.151	1.082
0.262	1.267
0.329	1.277
0.396	1.232
0.463	1.223
0.247	1.247

Table II

Relative Fluxes, 1.5:1 Lattice

Inches from Rod Center	ϕ
0.000	1.010
0.075	1.024
0.151	1.110
0.263	1.263
0.330	1.349
0.397	1.328
0.464	1.304
0.531	1.287
0.263	1.292
0.330	1.286

Table III

Relative Fluxes, 2:1 Lattice

Inches from Rod Center	ϕ
0.000	1.040
0.075	0.014
0.151	1.112
0.261	1.283
0.328	1.345
0.396	1.334
0.462	1.351
0.529	1.310
0.261	1.240
0.328	1.312
0.395	1.252

Table IV

Relative Fluxes, 3:1 Lattice

Inches from Rod Center	ϕ
0.000	1.007
0.075	1.023
0.151	1.105
0.262	1.319
0.328	1.401
0.395	1.405
0.462	1.419
0.529	1.387
0.596	1.400
0.663	1.453
0.261	1.298
0.328	1.359
0.394	1.369
0.462	1.412

Table V

Relative Fluxes, 4:1 Lattice

Inches from Rod Center	∅
0.000	0.999
0.075	1.028
0.151	1.109
0.262	1.355
0.329	1.413
0.395	1.447
0.462	1.465
0.530	1.438
0.597	1.503
0.664	1.451
0.731	1.460
0.260	1.328
0.327	1.439
0.395	1.470
0.462	1.434
0.529	1.359
0.597	1.293

Table VI

Average Fluxes in Fuel, Aluminum, and Water

Volume Water / Volume Uranium	$\bar{\phi}_u$	$\bar{\phi}_{al}$	$\bar{\phi}_w$
1	1.069	1.145	1.221
1.5	1.090	1.185	1.288
2	1.090	1.190	1.300
3	1.086	1.179	1.353
4	1.089	1.181	1.418

Table VII

Thermal Utilizations

Volume Water / Volume Uranium	f
1	0.944
1.5	0.920
2	0.898
3	0.852
4	0.808