UNCLASSIFIED

ANL-5141

Reactors-Research and Power

LEGAL NOTICE

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

A. Makes any warranty or representation, express or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or

B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission to the extent that such employee or contractor prepares, handles or distributes, or provides access to, any information pursuant to his employment or contract with the Commission.

ARGONNE NATIONAL LABORATORY
P. O. Box 299
Lemont, Illinois

PHYSICS DIVISION

SUPPLEMENT TO QUARTERLY REPORT

JUNE, JULY, AND AUGUST, 1953

Classification change to Unclassified
Authorized by Marshall 276-57
Change by H. H. Turner Date 6-13-12

Louis A. Turner, Division Director

November, 1953

Preceding Quarterly Reports:

ANL-5031 December, 1952, January, February, 1953
ANL-5032 December, 1952, January, February, 1953 (Secret)
ANL-5080 March, April, and May, 1953
ANL-5081 March, April, and May, 1953 (Secret)

Operated by The University of Chicago
under
Contract W-31-109-eng-38

242-001

UNCLASSIFIED

Photostat Price \$ 6.30

Microfilm Price \$ 3.00

Available from the
Office of Technical Services
Department of Commerce
Washington 25, D. C.

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

Titles given in parentheses are those of continuing programs in which no progress has been made, either in work done or in publication during the current quarter.

TABLE OF CONTENTS

	Page
 <u>C-I EXPERIMENTAL NUCLEAR PHYSICS</u>	
3-3 Transmission Measurements with the Fast Neutron Velocity Selector L. Bollinger	6
37-2 Decay Schemes of the Transuranic Elements E. Church	6
97-3 (Pile Oscillator Measurements) D. Rose	12
111-3 Measurement of Neutron Spectra in the EBR V. Krohn	12
113-2 Hydrogen-Filled Cloud Chamber for Neutron Spectrum Studies C. Huddleston	13
 <u>C-II MASS SPECTROSCOPY</u>	
13-3 (Slow Neutron Capture Cross Section of C^{12}) R. Hayden	16
14-3 Fission Yield Determinations	
A. General Considerations R. Hayden	16
B. U^{235} Fission Yield Determination 242-002 R. Hayden	17
C. Spontaneous Fission Yields of U and Th G. Wetherill	17

0000

TABLE OF CONTENTS CONTINUED

		Page
15-3	Nuclear Constants of Fissionable Materials	
	D. Hess	18
30-3	The Heat of Vaporization of Carbon	
	M. Inghram	21
C-III. <u>CRYSTALLOGRAPHY</u>		
3-3	Crystal Structure of KU_2F_9	
	W. Zachariasen	22
4-3	Crystal Structure of Compounds of Elements Ac-Am	
	W. Zachariasen	22
C-IV. <u>EXPERIMENTAL REACTOR PHYSICS</u>		
1-3	Experimental Work with ZPR- <u>1</u> Reactor	
	F. Martens	23
2-3	Thermal Zero Power Reactor Assembly <u>(- II)</u>	
	D. Lennox	28
3-3	Anomalous Activity of the Water in ZPR- <u>11</u>	
	M. Burgy	29
6-2	Report on Exponential Experiments for CP-6	
	B. Spinrad	29
7-2	Feasibility Study for a Fast Exponential Experiment	
	J. Livingood	30
8-2	Safety Report for Fast Exponential Experiment	
	J. Livingood	30
9-2	The Liquid Scintillation Counter as a Spectrum-Measuring Device for the Fast Exponential Experiment	
	B. Spinrad	32

TABLE OF CONTENTS CONTINUED

	Page
C-V. <u>THEORETICAL PHYSICS, GENERAL</u>	
9-1 Calculation of Neutron Cross Sections by the Weisskopf- Porter (Clouded Crystal Ball) Method B. Spinrad	33
50-3 Hartree Functions for Inner Shells of Ions and Atoms R. Meyerott	33
52-3 (Table of Rosseland Mean Opacities for Stellar Mixtures) R. Meyerott	34
53-3 Contributions of Line Absorption to the Rosseland Mean Opacity R. Meyerott	34
C-VI. <u>REACTOR THEORY</u>	
1-3 Lattice Constants for Natural U B. Spinrad	36
2-3 Doppler Effect and Resonance Escape Probability E. Crosbie	36
5-3 Analysis of EBR and Fast Critical Assemblies H. Hummel	37
C-VII. <u>ELECTRONIC DIGITAL COMPUTERS</u>	
9-3 (Monte Carlo Calculation with the AVIDAC) M. Ferentz	39
C-VIII. APPLIED MATHEMATICS AND COMPUTATION, GENERAL	
7-3 Numerical Solutions of Transport Theory Problems W. Feurzeig	40

C-I. EXPERIMENTAL NUCLEAR PHYSICS

3-3 Transmission Measurements with the Fast Neutron Velocity Selector (5211-01, 5261-01)

L. Bollinger and R. Palmer
Reported by L. Bollinger

Uranium

Data that have been obtained during the past year on the transmission of four thin samples of normal uranium have been re-examined. Using the results of the Columbia calculation on the influence of Doppler effect on the area above a transmission dip, an area analysis of the uranium data gives the following parameters for the 6.6-ev resonance in U^{238} :

$$\sigma_0 \Gamma^2 = (11.6 \pm 1.2) \text{ b (ev)}^2$$

$$\sigma_0 = (32,000 \pm 10,000) \text{ b}$$

$$\Gamma = (0.019 \pm 0.003) \text{ ev}$$

$$E_0 = (6.62 \pm 0.05) \text{ ev}$$

37-2 Decay Schemes of the Transuranic Elements (5211-01)

E. Church

The non-relativistic calculations of the L-shell conversion coefficients of Hebb and Nelson¹ have been separated to show explicitly the relative contributions of the P and S subshells. * In the limit

* As pointed out by M. Hamermesh.

1 M. H. Hebb and E. Nelson, Phys. Rev. 58, 486 (1940).

SECRET

considered, the conversion coefficients are strict functions of the parameter $Z^2/\hbar\omega$, and aside from the usual statistical weighing factors, no distinction is made between the $P_{1/2}$ and $P_{3/2}$ electronic states. The results for the first four electric multipoles are shown in Figure 1, where $(P/S)_L = (L_{II} + L_{III})/L_I$, and $\hbar\omega$ is the transition energy in kev.

Figure 1

Due to the vanishing of the L_I conversion coefficient, the above ratio becomes infinite at $Z^2/\hbar\omega \sim 202, 100, \text{ and } 65$, for E2, E3, and E4 transitions, respectively.

Also plotted in Figure 1 are the results of the relativistic calculations of Gellman et al.² for E1 and E2 transitions for three particular values of Z. The latter have received some experimental verification.^{3,4} As expected, the conversion ratio is no longer a strict function of $Z^2/\hbar\omega$, and the infinite $(P/S)_L$ ratio obtained in the non-relativistic calculations takes a finite value dependent on Z. The possible effects of screening have been neglected in all cases.

On the basis of the comparison in Figure 1, it may be concluded that for low energy transitions in heavy elements, electric transitions other than dipole convert almost entirely in the L_{II} and L_{III}

2 H. Gellman, et al., Phys. Rev. 85, 944 (1952).

3 J. B. Swan and R. D. Hill, Phys. Rev. 91, 424 (1953).

4 J. W. Mihelich, Phys. Rev. 87, 646 (1952).

SECRET

DECLASSIFIED

FIGURE 1

PHC-507
P.6-5.5
B.G.

2002 08

0000000000

SECRET

subshells. For E2 and E3 transitions this has already been noted in the rare-earth region.⁴

It is hoped that the above observation, in conjunction with experimental L subshell conversion data and lifetime measurements, may prove useful in identifying the character of transitions in the transuranic region which are below the threshold for K conversion.

The energies of the electric quadrupole transitions observed thus far, which may be interpreted as the ground-state transitions in even-even nuclei, are summarized in Table I.

Table I

Energies of first excited states in kev

$\begin{array}{c} Z \\ \backslash \\ N \end{array}$	92	94	96
142	43.6		
144		44.1	
146			42.2
148		44.6	

Table I

The uncertainty to be associated with each of the above values is ± 0.3 kev. The levels in ${}_{92}\text{U}^{234}$ and ${}_{94}\text{Pu}^{238}$ were excited by alpha decay, while those of ${}_{94}\text{Pu}^{242}$ and ${}_{96}\text{Cm}^{242}$ were observed following beta decay from ${}_{95}\text{Am}^{242\text{m}}$. The consistencies of the above

SECRET

DECLASSIFIED

SECRET

energies offer no evidence for the closing of a neutron subshell at $N = 148$.

Two further electric quadrupole transitions have been observed, one of 100.0 ± 0.4 kev in ${}_{92}\text{U}^{234}$ following alpha decay from ${}_{94}\text{Pu}^{238}$, and the second of 98.9 ± 0.4 kev converting in ${}_{93}\text{Np}$, present in a source of americium believed to be purely ${}_{95}\text{Am}^{241}$. The first of these transitions may be interpreted as originating from the second excited state of ${}_{92}\text{U}^{234}$. The assignment and significance of the 98.9-kev transition have not yet been decided.

According to Bohr and Mottelson,⁵ the lowest excitation states of even-even nuclei far from closed shells are principally those of rotation. The energies of excitation should then be proportional to $I(I+1)$, where $I = 0+, 2+, 4+ \dots$ are the spins and parities of the ground, first excited, second excited, etc., states. Transitions to the ground state should then consist of a cascade of electric quadrupole transitions, with energies in the ratio $1:7/3:11/3 \dots$. In the case of ${}_{92}\text{U}^{234}$ discussed above, $43.6:100.0 = 1:2.29$, in good agreement with this prediction.

On the basis of considerable experimental and theoretical evidence, the ground-state transitions in even-even nuclei are electric quadrupole. A recent survey of all the known spins and parities of the second excited states of such nuclei indicate that they are always $\leq 4+$, with $2+$ and $4+$ being preferred.⁶

5 A. Bohr and B. Mottelson, Phys. Rev. 89, 316 (1953).

6 G. Scharff-Goldhaber, Phys. Rev. 90, 587 (1953).

SECRET

It is of interest to determine whether or not the spins of the excited states of even-even nuclei following alpha decay can be distinguished on the basis of the experimental alpha branching ratios to the levels in question. In the transuranic region the branching is observed to be $\sim 75:25: \angle 1$ to the ground, first excited and second excited states, respectively.⁷

The present status of the theory of alpha decay does not appear to be sufficiently well defined to allow unambiguous spin assignments to be made on the basis of empirical branching ratios. Using the formulas of Blatt and Weisskopf,⁸ and assuming a parent level density independent of the orbital angular momentum of the ejected alpha particle, the branching ratios shown in Table II were obtained for the particular case of ${}_{92}\text{U}^{234}$.

Table II

Theoretical alpha branching in percent

<u>Spins</u>	<u>Ground</u>	<u>1st Excited</u>	<u>2nd Excited</u>
000	59	33	8
020	68	23	9
024	73	25	2
004	63	35	2

⁷ F. Asaro and I. Perlman, Phys. Rev. 91, 763 (1953). These authors have apparently normalized their data relative to the equivalent 0-0 transitions(c.f. UCRL-2180).

⁸ J. M. Blatt and V. F. Weisskopf, Theoretical Nuclear Physics, (New York; John Wiley and Sons, (1952)), p. 573.

SECRET

DECLASSIFIED

2002 10

SECRETTable II

Although the 024 order of levels of Bohr and Mottelson is favored by the above results, the quantitative agreement for the population of the second excited state is poor. Similar disagreements are found with more refined treatments.⁹

97-3 (Pile Oscillator Measurements) (5261-01)

D. Rose

No work has been done with the pile oscillator during this quarter.

111-3 Measurement of Neutron Spectra in the EBR (4110-22)

C. Curtis (Reactor Engineering), V. Krohn, R. Ringo
Reported by V. Krohn

Glass loaded with Li^6 has been received from Corning Glass Works, ground into specks about three microns in diameter, tested for the stability of the bond between the lithium and the glass, and forwarded to Ilford, Ltd., where the specks will be loaded into 100-micron nuclear emulsions (type E-1). These plates should be ready for irradiation in the Experimental Breeder Reactor immediately after the scheduled reloading of the reactor core.

An attempt has been made to extract a neutron beam with a representative spectrum from the core of the EBR. U^{235} and U^{238} fission counters and the activity produced by the reactions $\text{Au}^{197}(\text{n}, \gamma)$,

⁹ G. H. Winslow, private communication (1953).

SECRET

SECRET

Au¹⁹⁸, and P³¹ (n,p) Si³¹ were used to study the spectrum in the core and in the beam. The measurements indicate that the spectrum in the beam was degraded in energy relative to the spectrum at the center of the core. The ratio of U²³⁵ to U²³⁸ fissions and the ratio of gold to phosphorous activity in the beam were the same as the ratios which are found about 10 cm from the center of the core.

As the beam obtained is not satisfactory for the required spectrum measurements, further attempts will be made to extract a suitable beam. Additional collimators and methods for checking alignment are being developed. Also, the iron slugs which were placed in an experimental thimble to serve as a beam source will be replaced by an assembly of U²³⁵ and NaK.

113-2 Hydrogen-Filled Cloud Chamber for Neutron Spectrum Studies
(4110-22)

C. Egger and C. Huddleston
Reported by C. Huddleston

The fission spectrum of U²³⁵ has been investigated by observing recoil protons stereoscopically in a hydrogen-filled cloud chamber.

The source of fission neutrons was a uranium converter placed over the thermal column on top of CP-2. The cloud chamber sat about five feet above the converter.

SECRET

DECLASSIFIED

SECRET

Only those tracks originating within a certain volume inside the chamber were considered, in order to equalize the probability of seeing the full lengths of long and of short tracks. The stereo-camera arrangement was used to select only those tracks which dipped less than 5° from the plane of the cloud chamber. Energy corrections were kept small by using only those protons which recoiled at angles less than 30° from the direction of the incident neutron.

About 1000 feet of film were exposed, and approximately 1500 usable stereo-pairs were obtained. Measurements were made at three pressures between 10 cm Hg and 1 atmosphere. A histogram plot of all data obtained showed satisfactory agreement with Watt's empirical curve¹ from 1200 kev down to 300 kev. Below 300 kev the number of neutrons per energy interval remained almost constant instead of falling off rapidly with decreasing energy as the Watt curve predicts.

A shadow cone experiment, in which the direct path from converter plate to cloud chamber was blocked by three feet of paraffin, indicated that many of the low energy neutrons can be ascribed to scattered and degraded fission neutrons which reach the cloud chamber by indirect routes. When this "background" is properly normalized for pile power and subtracted from the original data, good agreement with the Watt curve is found over the entire energy range from 50 to 1200 kev.

¹ B. E. Watt, Phys. Rev. 87, 1037 (1952).

SECRET

DECLASSIFIED

20 23

SECRET

Plans for the near future include a possible repetition of the fission spectrum work with a geometry which should greatly reduce the background of degraded neutrons * and the construction of a refrigerated housing to allow the cloud chamber to operate at lower pressure. It is hoped that the lower limit of observable neutron energy may be reduced from 50 to 25 kev.

* Note added 9/24/53. Such experiments have been done and, contrary to expectations, show no appreciable reduction of the relative number of low energy neutrons.

SECRET

DECLASSIFIED

SECRETC-II. MASS SPECTROSCOPY13-3 (Slow Neutron Capture Cross Section of C¹²) (5261-01)

R. Hayden, D. Hess, M. Inghram, H. Stanton
Reported by R. Hayden

No progress was made on this problem this quarter.

14-3 Fission Yield Determinations (5261-01)A. General Considerations - Reported by R. Hayden

This problem has been taken almost as far as it can be until samples in which the number of fissions can be measured by mass spectrometric means are obtained. More work remains to be done in cleaning up and measuring the neodymium sample, but the major need now is to recompute carefully all the data. Glendenin and Steinberg, who have been correlating the data, have at different times made several different assumptions as to number of fissions, errors in isotopic mixing, etc., designed to make the partial curves of the different elements fit together better and to make the absolute curve integrate to 200%. These calculations have indicated where errors may have occurred, but to my knowledge no complete consistent calculation of the results has been made. Inghram and I intend to get together with Glendenin and Steinberg to do this in the fall. After this the work will be published, although it is not definite in nature. Certainly the relative yields of a given element

SECRET

DECLASSIFIED

SECRET

are correct. The fitting of the elemental yield curves by means of isotope dilution now leads to fairly reliable results. The number of fissions is not known to better than $\pm 10\%$, so that absolute yields can be determined only by adjusting yields to integrate to 200%.

B. U^{235} Fission Yield Determination

L. Glendenin and E. Steinberg (Chemistry Division),
R. Hayden, M. Inghram
Reported by R. Hayden

Analyses of fission cerium with and without isotopic tracers have been made. From these data the absolute fission yields of Ce^{140} , Ce^{142} , and Ce^{144} from slow neutron irradiation of U^{235} will be obtained.

Attempts to calibrate the molybdenum tracer by means of isotopic dilution were inconclusive. This is probably because we have never been able to eliminate completely the molybdenum background coming from tungsten or tantalum filaments.

C. Spontaneous Fission Yields of U and Th - G. Wetherill (University of Chicago)

Work on extracting Xe and Kr from geologically old uranium and thorium minerals in order to determine their fission yields has been completed, and a paper has been submitted for publication in The Physical Review.

SECRET

DECLASSIFIED

SECRET15-3 Nuclear Constants of Fissionable Materials (5261-01)

D. Hess, M. Inghram, and members of the Chemical
Engineering Division
Reported by D. Hess

In order to study the variation of the capture and fission cross sections of Plutonium-239 at various energies as produced in the EBR, we have determined the isotopic composition of plutonium recovered from the inner and outer blankets.

The results, together with the amount of Plutonium-239 destroyed by fission, calculated by S. Untermeyer, are shown in the tables.

Table V is for material having about 4.3 times the irradiation of the material used for Tables III and IV. This brick was located on the medium plane of the reactor and could see only graphite on its outer boundary.

It is to be noted that the value of alpha, the ratio of capture to fission cross sections, appears to increase with an increase in distance from the center corresponding to a decrease in energy. This is in agreement with values reported in KAPL-583 showing a downward trend in alpha for energies above 100 electron volts.

The rather high value of 0.94 in the outer 1/5 of the blanket may be due to an error in the number used for burn-up. This is calculated from the U^{235} burn-up, and the ratio may vary. Plutonium fission measurements are being made by the Reactor Engineering Division and will give more correct values.

SECRET

DECLASSIFIED

Table III - Inner blanket

Hole number	235	308	343
Rod number	37-75	---	124-4-113-1-90
Distance from center	11.07 cm	15.45 cm	17.6 cm
240/239 ratio	0.000011 $\pm$ 0.000002	0.0000100 $\pm$ 0.0000008	0.000009 $\pm$ 0.000002
Fission burn-up	0.000194	0.000128	0.000104
Alpha	0.057	0.075	0.087

Table IV - Outer blanket

Sample from	<u>Brick No. 5</u>	Center 1/3	Outer 1/3	<u>Top 6 bricks</u>
	Inner 1/3			Average
Sample number	16279	16285	16280	16340
Approx. distance from center	25 cm	31 cm	36.5 cm	
240/239 ratio	0.000004 $\pm$ 0.000001	0.000008 $\pm$ 0.000001	0.000021 $\pm$ 0.000006	0.000011 $\pm$ 0.000002
Fission burn-up	0.000042	0.000033	0.000042	0.000037
Alpha	0.1	0.24	0.50	0.28

SECRET

Table V

Centrally located brick from outer blanket, divided into five sections

Sample number	25	26	27	28	29
Distance from center	37.6 cm	34.1 cm	29.8 cm	26.5 cm	23.9 cm
240/239 ratio	0.00023 ± 0.00002	0.000068 ± 0.000007	0.000035 ± 0.000004	0.000028 ± 0.000003	0.00003 ± 0.000003
Fission burn-up	0.00024	0.00015	0.00015	0.00018	0.00022
Alpha	0.94	0.44	0.24	0.16	0.14

SECRET

SECRET30-3 The Heat of Vaporization of Carbon (5211-08)

W. Chupka and M. Inghram
Reported by M. Inghram

The entire quarter was devoted to designing and machining the special electronic and mass spectrometric equipment necessary to do a Knudsen cell experiment in the mass spectrometer. Machining is still underway, and a first run with the new equipment should be made about November 15.

SECRET

DECLASSIFIED

SECRETC-III. CRYSTALLOGRAPHY3-3 Crystal Structure of KU_2F_9 (5211-11)

W. Zachariasen

Further intensity measurements have been carried out, and the experimental part of the work has been completed.

Intensity calculations are in progress.

4-3 Crystal Structure of Compounds of Elements Ac-Am (5211-11)

A. Plettinger and W. Zachariasen
Reported by W. Zachariasen

 $K_3UO_2F_5$

The unit cell dimensions and the uranium positions of $K_3UO_2F_5$ were reported some years ago.¹ A complete structure determination is being undertaken, and suitable single crystals have been prepared for the purpose.

In other uranyl compounds, uranium has been found to form either six (UO_2F_2 , $CaUO_2O_2$) or four ($MgUO_2O_2$, $BaUO_2O_2$) secondary bonds. The formation of five secondary bonds as suggested by the formula $K_3UO_2F_5$ seems improbable. It is hoped that the complete structure determination will provide a definitive answer as to the number of secondary bonds.

¹ W. H. Zachariasen, Report CK-2737, p. 12 (March, 1945).

SECRET

DECLASSIFIED

200 21

SECRETC-IV. EXPERIMENTAL REACTOR PHYSICS1-3 Experimental Work with ZPR-9 Reactor (4302-22)

Performed by: F. Beyer, M. Burgy, G. Helfrich,
F. Martens, R. Nobles, P. Roggenkamp, D. Satkus,
E. Sowa (Reactor Engineering), K. Weberg
Reported by F. Martens

Boron-Poisoning Experiments in ZPR-9

A poisoning experiment was performed on the ZPR-9 reactor (moderated with H_2O). The reactor was loaded to full size, with nineteen control rods set in the following configuration: at the center was the No. 1 or central control rod; around this were six rods which are referred to as xenon rods; surrounding this, another ring of twelve rods, referred to as the shim rods. The core contained 21.059 kg of U^{235} . Boron in the form of H_3BO_3 was dissolved in the moderator water to poison the reactor. This poison was added in small increments as the experiment was carried on. After each of these increments, critical positions with the rods were found. Since there was uncertainty about the exact volume of water in the reactor tank, the concentration of this H_3BO_3 was determined both by chemical analysis and by the material balance. Prior to the addition of poison, the reactor went critical with the No. 1 rod at 53.4 cm, the xenon rods all the way down, and the shim rods at 50.4 cm. Poison was then added in small increments until the reactor went critical with the No. 1 rod still at 53.4 cm, the xenon rods down, and the shim rods withdrawn as far as possible. After this the shim rods had to be raised in all of the following

SECRET

RECORDED

SECRET

runs. More poison was added to the reactor, which now became critical only when the xenon rods were raised. After each addition of poison the critical position and the worth of the ganged xenon rods were determined. When sufficient poison had been added to the reactor, it was possible to go critical only by pulling the xenon rods all the way out. After this, criticality could be reached by raising the No. 1 rod above the 53.4 cm position. When the reactor went critical with the No. 1 rod out as far as possible, still more poison was added, the decrease in reactivity being then offset by replacing the control rod channels with fuel elements. The final configuration was a clean cylindrical core containing only one channel for the centrally located No. 1 rod. A condensation of these data is given in Table VI which shows the position of the various rods against the poison concentration given in grams boron/liter. By positive period measurements, the worth of the rods at every critical position was determined and, from this, the worth of the poison was also determined. This worth was approximately 0.7 ih/gm or 1.72×10^4 ih/gm/liter in the initial stages of the experiment, and this decreased to approximately 0.6 ih/gm (1.48×10^4 ih/gm/liter). A good average value for the worth of the poison is 0.65 ih/gm or 1.6×10^4 ih/gm/liter. Using this value, the total deviation in inhours and percent ΔK is shown for each of the poison concentrations in the table.

SECRET

23

DECLASSIFIED

SECRET

Counting rates were also taken on the reactor as poisoning progressed. With two counters mounted a short distance outside the reactor tank, the initial counting rate was taken with the source up, the water up, and all of the rods down with the exception of the No. 1 rod, which was at 43.4 cm. As the poisoning progressed, a counting rate was taken with each poisoning addition. When the counting rate with rods withdrawn to the unpoisoned critical position was down to the same rate as initially with the rods in the shutdown position, the poison concentration would give us an indication of the shutdown ΔK for the reactor. Two figures for this were obtained, one $\sim 12\%$ and the other $\sim 15\%$ for each of the different counters. This is somewhat in agreement with the conclusion presented in the last report, where the shutdown was quoted as greater than 8 and less than 14%. A complete account of the poisoning experiment is found in ANL-FHM-45.

A flux distribution was made in the poisoned ZPR-~~I~~^{II} core containing only the 3" cross control rod. The area of this core was 691 sq in, containing 15.425 kg of U^{235} , and the concentration of boric acid was 6.14 grams boron/liter. Both axial and radial plots were made in this, using the manganese wire technique as usual. The indium activating flux cadmium ratio were found in order to obtain experimental data from which the Fermi age in the reflector with the high poison concentration could be determined. The cadmium ratio inside of the core for

SECRET

DECLASSIFIED

SECRET

these runs was determined to be 7.5. The complete diagrams and data for this experiment is found in memo report ANL-FHM-47.

Table VI

Poison Concentration (gm/l)	Rod Positions (cm)			Reactivity		
	No. 1	Xenon	Shims	lh	%	K/K
0.000	53.4	0.0	50.4			
0.498	53.4	0.0	64.3			
1.086	53.4	0.0	106.2	1,780	4.52	
1.120	53.4	10.0	106.2			
2.068	53.4	23.5	106.2			
2.620	53.4	30.2	106.2			
3.370	53.4	41.5	106.2			
4.084	53.4	50.5	106.2			
4.480	53.4	60.1	106.2			
4.890	53.4	74.9	106.2			
4.93	53.4	93.9	106.2			
5.01	53.8	115.0	106.2	8,405	21.2	
5.04	57.2	115.0	106.2			
5.08	61.12	115.0	106.2			
5.16	70.48	115.0	106.2			
5.23	83.28	115.0	106.2			
5.26	91.20	115.0	106.2	8,870	22.4	

Critical Experiments with Stainless Steel Supported Fuel

A completely new type of fuel assembly composed of 93% enriched uranium metal foil, 0.003" thick, 20" long, and 0.7" wide, was used in ZPR-~~4~~ 1. The fuel was suspended in elements containing three strips of stainless steel, each of these being 0.110" thick, 0.910" wide, and extending the full 43" height of the reactor. The average weight of fuel in these assemblies was 53.4 gm, and the metal to water ratio was 1:2.33. A configuration approximating a cylinder was built up in

SECRET

DECLASSIFIED

SECRET

steps until the reactor became clean critical, at a mass of 8.152 kg of U^{235} in a circle of equal area radius of 6.99". A flux plot was made on this core using iron-manganese wires and thermal neutron detectors. The cadmium ratio inside the reactor was found to be 4.5. Axial flux plots at several different positions in the reactor also were made. Control rods were studied by rod-drop experiments and by measurements of positive periods. Four elements from the center of the core were removed to give a 2" square hole, into which were placed the various control rods: a stainless steel rod of 1-1/2" diameter, two stainless steel tubes of different diameters filled with boron carbide powder, and a pure aluminum rod of 1-1/2" diameter. The aluminum rod gave positive reactivity of 30 ih when dropped into the reactor.

A rectangular pile of 10" x 19" cross section was built up to show the effect of various thicknesses of an iron reflector on the long side; the results are given in the table.

Table VII

Thickness of Iron Reflector (in)	Change of Reactivity from Water Reflector	
	Ih	% $\Delta K/K$
0	0	0
1	-137	-.347
2	-6	-.015
3	+111	+.281
4	+214	+.537
6	+321	+.814

SECRET

DECLASSIFIED

SECRET

Finally, the pile was made symmetrical about the center line with a 4" iron reflector on both of the long faces. A flux plot through both core and reflector, complete with cadmium ratio, was made for this assembly. These results are presented in detail in ANL-5108.

2-3 Thermal Zero Power Reactor Assembly II (2812-05)

J. Armstrong, F. Beyer, D. Lennox, W. Olliff,
R. Vollmer
Reported by D. Lennox

Conversion Ratio

The experiment to measure in ZPR-II the plutonium atoms produced per U^{235} atom destroyed has been repeated in cooperation with the Reactor Engineering Division. The counting techniques employed were basically the same as described in the previous quarterly report. Improved methods for foil alignment were used to reduce the error introduced by edge effect corrections for the surface activity of the natural uranium foils. In addition, a series of measurements were made with a heavily loaded lattice to determine the resultant increase in conversion ratio. The standard one-inch natural uranium fuel elements were symmetrically replaced by 1.3-inch elements until only a small amount of excess reactivity was available. When the analysis of the data is completed, it will appear in a Reactor Engineering Division report.

SECRET

DECLASSIFIED

SECRETKinetics

The influence of delayed photoneutrons on positive periods is being investigated in a flattened lattice loaded with one-inch fuel elements. Periods are measured after operation times ranging from 5 to 360 minutes for different amounts of reactivity that have been added by water level control. From the curves obtained, an attempt will be made to correct the normal delayed neutron equation for the photoneutron contribution. This experiment will complete the program for ZPR-II

3-3 Anomalous Activity of the Water in ZPR-I (4302-22)

M. Burgy

The decay of the two active specimens prepared from the ZPR-I water has been followed further during the past quarter. Towards the end of the quarter, some erratic results were obtained, and the cause of the trouble has not been found. Recently a new counter has been obtained at a different location where much longer counts can be made without interference and the background is much lower. This change should improve considerably the data taken with the smaller of the two samples.

6-2 Report on Exponential Experiments for CP-6 (2812-05)

B. Spinrad

This report was not worked on in the last quarter, during the author's leave of absence. It will be resumed during the next quarter.

SECRET

DECLASSIFIED

SECRET

- 7-2 Feasibility Study for a Fast Exponential Experiment (4110-21)
R. Brittan, H. Hummel, J. Livingood, F. Martens,
B. Spinrad
Reported by J. Livingood

This proposal, ANL-5061, was completed on June 10, 1953, and was summarized in the Supplement to the Quarterly Report for March, April, and May, 1953. No further reports on the feasibility study will be made.

- 8-2 Safety Report for Fast Exponential Experiment (4110-21)
R. Brittan, H. Hummel, J. Livingood, F. Martens,
B. Spinrad
Reported by J. Livingood

This report (ANL-5071) was completed on July 17 and submitted to the Safeguards Committee of the AEC. A summary of important information is as follows.

The core, composed of BORAX type enriched plates, will contain between 2.6 and 3.5 kilograms of U^{235} , moderated with H_2O . Control will be by means of one control rod and two safety rods; rate of withdrawal will be limited so that the rate of reactivity increase will not exceed 0.05% δk per second.

The pedestal of natural U will be of such thickness that the exponential assembly will not increase the available excess reactivity to more than 0.5%. The worth of the rods will be 1.5% δk .

SECRET

DECLASSIFIED

SECRET

The loading of the assembly will be carried out in steps, each partial load being advanced by remote control into contact with the pedestal-reactor complex for a multiplication measurement and then withdrawn for further addition of material.

The reactor will be self-quenching on a slow runaway, due to reduction of moderator density by heating; the maximum energy production estimate is 4.8×10^8 joules, corresponding to 1.5×10^{19} fissions.

On a fast runaway, the reaction will cease with the vaporization of the Al in the fuel plates, after the release of about the same quantity of energy as above. The sudden rise in air pressure would destroy the building.

No reasonable scheme for making the exponential assembly super critical by itself can be postulated. Assuming, however, that such a situation could be brought about and that a fast runaway occurs, it is expected that shutdown would occur at least by the time all the sodium vaporizes. For such an assumption, the nuclear energy release would be 1.8×10^9 joules, accompanied by 5.8×10^{19} fissions. The chemical energy released by the reaction of Na and water (if in some undetermined manner water could reach the Na) would yield 1.9×10^9 joules. A very severe fire would be expected.

The exclusion radius, involved with the largest number of fissions in the above postulated disasters, would be about 2000 feet.

SECRET

SECRET

Inasmuch as the Safeguards Committee has approved this experiment, there will be no further Safety Report.

9-2 The Liquid Scintillation Counter as a Spectrum-Measuring
Device for the Fast Exponential Experiment (4110-21)

B. Spinrad

This program is being dropped, except for some Monte Carlo calculations on the AVIDAC. These are of a preliminary nature. If the machine proves able to solve such problems rapidly, a broader computation might be justified, provided that there is reason for so doing.

Although early IBM calculations were encouraging in that there seemed to be some spectrum-sensitivity on the response of counters of different thickness, nobody seems interested enough in getting experimental data, which seems somewhat easier to obtain than Monte Carlo computations.

SECRET

DECLASSIFIED

SECRETC-V. THEORETICAL PHYSICS, GENERAL9-1 Calculation of Neutron Cross Sections by the Weisskopf-Porter (Clouded Crystal Ball) Method (5211-07)

B. Spinrad

It is hoped that a successful correlation between data now existing for various elements of particular interest for fast reactors and the "Clouded Crystal Ball" theory can be made to yield useful data on inelastic cross sections and angular distribution of elastic scattering. Methods of attack, including the possibility of using the ILIAC (University of Illinois computer) are being looked at. (The ILIAC has been coded to solve for nuclear cross sections on this theory.)

As a by-product of this study, it is also hoped that expected forward scattering of oxygen at high energies may be correlated with the discrepancy between measured and computed fission neutron ages in water.

50-3 Hartree Functions for Inner Shells of Ions and Atoms (5211-14)

R. Meyerott and L. Renick
Reported by R. Meyerott

The evaluation of $\Delta I_{2p}^{nd} [\Delta_{2p} [\Delta_{1s} (1s^0)]]$ mentioned in CV-50-2 has been completed. The new values will be incorporated into a final report during the following quarter.

SECRET

DECLASSIFIED

SECRET52-3 (Table of Rosseland Mean Opacities for Stellar Mixtures)
(5211-14)

G. Keller and R. Meyerott
Reported by R. Meyerott

No further results were obtained this quarter.

53-3 Contributions of Line Absorption to the Rosseland Mean Opacity
(5211-14)

H. Margenau (Yale University) and R. Meyerott
Reported by R. Meyerott

The most complete data on the widths of spectral lines of one-electron systems in gaseous discharges at high ion density has been published by H. N. Olsen and W. S. Huxford.¹ They attribute the line broadening in the Balmer spectrum of hydrogen to the inter-atomic Stark effect.² The observed shapes of H_{α} and H_{β} can be made to fit the Holtzmark distribution in the wings of the line but not in the center of the line. In the case of H_{α} , there is one component of the line which is not affected by the electric field and hence should show no broadening due to the inter-atomic Stark effect. If there is any electron broadening, it might be observed by a closer analysis of the line center.

Since the field independent component of the H_{α} line was not included in the theoretical profiles by Olsen and Huxford, the difference between the observed profile and the theoretical profile in Figure 12a of their paper should be the profile of the field-independent component. Theoretically, the field independent component should represent 45%

1 H. N. Olsen and W. S. Huxford, Phys. Rev. 87, 922 (1952).

2 See first report, CV-53-1.

SECRET

of the intensity of the line, while the above difference amounts to only 28% of the intensity.

A possible explanation of this discrepancy is that the central component was reduced in comparison with the wings by absorption. Since this can be determined experimentally, it seems advisable to withhold further theoretical analysis of these line widths until further data are available.

SECRET

DECLASSIFIED

202 34

SECRETC-VI. REACTOR THEORY1-3 Lattice Constants for Natural U (4520-01)

B. Spinrad

A paper analyzing discrepancies between results of various methods of measurement of lattice constants is contemplated for submission to Reactor Science and Technology. The tentative thesis of this paper is that microscopic measurements of E, the fast fission effect, require appreciable correction, because of fast neutron absorption, before they can be used properly in the four-factor formula. Some calculation is required to prove this thesis.

2-3 Doppler Effect and Resonance Escape Probability (4105-21)

E. Crosbie

The study of absorption of neutrons in uranium lumps of specified temperatures is being continued. The calculation of the averages mentioned in the previous quarterly report has been switched from the IBM calculator to the ORACLE. Because of the limited time available for the use of this machine, only about half of the required calculations have been performed. The remaining calculations should be completed in the near future, after which the sought-for resonance escape probabilities can be calculated.

SECRET

REF ID: A57177

SECRET5-3 Analysis of EBR and Fast Critical Assemblies (4110-21)

E. Dershem, H. Hummel, N. Rosenzweig
Reported by H. Hummel

(Previously reported under VI-4, Theory of Fast Reactors, and VI-5, Analysis of the Energy Spectra of EBR and Fast Critical Assemblies.)

The multigroup Serber-Wilson calculation has been checked for two groups against a numerical integration of the Boltzmann equation for Topsy, performed by the IBM group at Los Alamos. The Serber calculation gave a critical radius 2.8% too low, which is reasonable since about the same error is found for one-group calculations. The energy spectrum at the center of the reactor was given accurately by the Serber calculation, while the group fluxes in the tamper were accurate to within 10% at locations more than 4 cm away from the core-tamper interface.

A similar check was made with two groups for Godiva. The energy spectrum was given with good accuracy up to 1 or 2 cm from the boundary, although there was an error in the buckling of about 2%. The critical radius in this case was about 5% low, as compared to 4% for the one-group calculation.

The following table gives critical masses for Topsy, EBR, and the Slotin Experiment No. 17, using four-group Serber-Wilson calculations with the same set of cross-sections for all three assemblies:

SECRET

DECLASSIFIED

SECRET

Table VIII		
Critical Mass (kg U ²³⁵)		
	<u>Calculated</u>	<u>Experimental</u>
Topsy	16.8	16.3
Slotin No. 17	40.7	33.2
EBR	46.0	51.7

All the calculated results are probably about 8% too low for the cross-sections used because of inaccuracy of the Serber method. Also, the result for the EBR should be too low because geometrical peculiarities have not been taken into account.

SECRET

DECLASSIFIED

C-VII. ELECTRONIC DIGITAL COMPUTERS

9-3 (Monte Carlo Calculation with the AVIDAC) (4520-02)

M. Ferentz

This project has been inactive in the last quarter while awaiting availability of the AVIDAC.

DECLASSIFIED

C-VIII. APPLIED MATHEMATICS AND COMPUTATION, GENERAL

7-3 Numerical Solutions of Transport Theory Problems
(4520-02)

W. Feurzeig

The problem corresponding to the lattice $N = 28$ has been started and is within 2% of convergence at present. This author's contribution to ANL report 5049 has been completed as a first draft.

DECLASSIFIED

242-039