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NUCLEAR PHYSICS RESEARCH OPERATION

MONTHLY REPORT

JUL 10 1956

J. E. Faulkner

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NUCLEAR PHYSICS RESEARCH OPERATION:

MONTHLY REPORT,

JULY 1958

Compiled by Members of
 Nuclear Physics Research
 Physics and Instrument Research and Development
 HANFORD LABORATOIRES OPERATION

Submitted by: John E. Faulkner

August 11, 1958

HANFORD ATOMIC PRODUCTS OPERATION
 RICHLAND, WASHINGTON

Operated for the Atomic Energy Commission by the
 General Electric Company under Contract No. W-31-105-Eng-52

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FISSIONABLE MATERIALS - 2000 PROGRAM

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METALLURGY

Nuclear Safety Considerations - N. Ketzlach

A meeting was held with members of the Fuel Fabrication Development Operation, H.L.O., to discuss the nuclear safety in the storage and handling of fuels of all enrichments. Criteria were given to the group for the design of safe storage racks for these fuels.

An inquiry was received from the Radiometallurgy Laboratory Operation, H.L.O., regarding the shipment of 64 pounds of 1.75 percent U-235 enriched fuel; this quantity of uranium constitutes less than the minimum critical mass for water reflection and, therefore, in itself presents no criticality hazard.

At the request of the A.E.C. - H.O.O., an appraisal was made of the nuclear safety of shipping uranium-233 metal together with plutonium metal. The results of this appraisal are given in HW-56889, "Nuclear Safety in Uranium-233 Metal Shipments".

REACTOR

STUDIES RELATED TO PRESENT PRODUCTION REACTORS

Exposure and Temperature Coefficient with Synthetic Slugs - R. I. Smith

The normalization of the U-235 - Al and Pu-239 - Al alloy pins in a very thermal flux in the P.C.T.R. core has been completed. This normalization allows the determination of the ratio of the pile fission cross sections of Pu-239 to U-235 as a function of position in the fuel rod:

$$\frac{\hat{\sigma}_f^{49}(r)}{\hat{\sigma}_f^{25}(r)} = \frac{\int \sigma_f^{49}(E) \phi(E, r) dE}{\int \sigma_f^{25}(E) \phi(E, r) dE}$$

The pin traverse data was obtained as a function of radial position in the rod, the temperature of the fuel and moderator, and the simulated exposure of the fuel element. The simulated slugs used were the 1000 and 2000 MWD/T fuel in a 7 1/2-inch graphite lattice. Further analysis of the data and comparison with theory is under way.

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Lattice Neutron Temperature Study - W. P. Stinson

The data for calibration of the fission detector foils are being analyzed.

Thermal Neutron Flux in a Medium with a Temperature Discontinuity - D. A. Kottwitz and R. A. Bennett

Work continued on the precise evaluation of the universal constants which arise in the analytical solution.

The iteration scheme for the numerical solution of the partial differential equation was tested further. In particular, the effects of shifting the boundaries and changing the mesh size were studied.

A measurement of the distance that a neutron diffuses while slowing down from a high temperature thermal distribution to a room temperature distribution is now in progress. A plane slab of graphite has been positioned in the core of the P.C.T.R. The slab may be heated with rod type heaters or cooled with liquid nitrogen. The energy distribution of the flux near the interface is monitored by foil activities. The results of these preliminary measurements will be compared with the predictions of the Selengut-Kottwitz two-group theory. If the simplifications made in formulating this diffusion model do not seriously affect the validity of calculations using the model, this theory will enable lattice calculations or reactor calculations to be made where the moderator temperature varies from point to point.

Machine Computational Programs - D. D. Matsumoto

A 702 program has been written to use double-precision arithmetic in calculating the numerical coefficients in the analytical solution of the temperature discontinuity problem. Assembly and debugging are incomplete. The OMNICODE program for the numerical solution of this problem was tested under several different conditions. As an outgrowth of these tests, a few desirable changes have been made in the program.

At the request of R. A. Bennett, a program which calculates reactor reactivities from flux multiplication data has been written in OMNICODE. Assembly has not been made because of unavailability of 702 machine time.

STUDIES RELATED TO FUTURE PRODUCTION REACTORS

Exponential Pile Measurements - G. W. R. Endres, E. Z. Block

Additional measurements have been completed in the small exponential piles using the seven-rod clusters of 0.5-inch natural uranium rods. The results are:

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L.S. Inches	Bucklings (10^{-6} cm^{-2})			Volume Ratios		
	Dry	Wet	MIPB	$\frac{G}{U}$	$\frac{Al}{U}$	$\frac{Coolant}{U}$
8 3/8	65	-14	4	48.42	0.711	0.864
10 3/8	54*					

Measurement of the bucklings of the 3 3/16-inch lattice with MIPB coolant was completed, but the results have not been received from Data Processing. This series of exponential measurements with 1/2-inch O.D. fuel elements is thus complete.

A method has been developed for separating fuel elements of different enrichments using a gamma ray spectrometer. The method is acceptable for rapid sorting purposes but does not give the absolute magnitude of the enrichment. The differences in enrichment should be of the order of 10 to 15 percent for the results to be reliable when one-minute counts are taken on each fuel element. The method is being used to separate fuel elements which had become mixed inadvertently.

Resonance Escape Theory - R. H. Meichle

A report summarizing the work on an analytical method for the determination of the resonance escape probability in heterogeneous lattices of natural uranium is being prepared for publication as HW-56848.

This report will complete the work which was begun by H. Neumann prior to his termination last year.

Computer Codes - R. I. Smith

An IBM-650 program has been written in cooperation with D. D. Matsumoto and R. A. Bennett for the calculation of pile reactivity directly from the observed time during which the pile flux is multiplied by a factor of two or from observed rod positions. The reactivity is calculated in cents. This program will be most useful in reducing data taken during measurements of the temperature coefficients of fuel or moderator. An unclassified description of the program will be distributed in the near future.

STUDIES RELATED TO SEPARATIONS PLANTS

Criticality Studies in Support of Processing Power Reactor Fuels

Experiments with Heterogeneous Systems - H. E. Handler, R. C. Lloyd

Experimental work proceeded on the determination of criticality parameters for reprocessing of power reactor fuels. Critical approach measurements were made

* Reported incorrectly last month.

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in the T.T.R. room of the 305-B Building with 1.6 percent and three percent enriched uranium in water moderated lattices.

The 1.6 percent enriched fuel elements were 1.394 inches in O.D., with an I.D. of 0.464 inch. The I and E fuel elements were positioned in Type 3-S aluminum tubes which were 1.50 inches in O.D., with a 49-mil wall thickness. A critical approach was made in a 2.2-inch lattice with the fuel element cores water filled. The assembly was water reflected on the sides and bottom but unreflected on top. The results are given below:

Number of Rods for Criticality

(40 inches in length)

<u>Lattice Spacing</u>	<u>H₂O/U (by Volume)</u>	<u>Buckling</u>	<u>Critical Number of Rods Calculated from Buckling</u>	<u>Critical Number of Rods from Multiplication Measurement</u>
2.2 inches	1.91	$7000 \times 10^{-6} \text{ cm.}^{-2}$	63.0	60.5

The material buckling was known from previous exponential experiments; with the above buckling value, the critical number of rods is overestimated by about four percent. The observed difference between the number of rods for criticality as calculated from the exponential experiment and measured in the critical approach is consistent with the differences observed in the previous measurements with a 2.2-inch lattice (dry fuel core), and a 2.4-inch lattice (dry and wet fuel cores). Agreement can be obtained between the exponential and critical approach experiments through adjustment of the reflector savings for water by about one cm., i.e., by changing the value which had been assumed from the Brookhaven data. (The Brookhaven experiments were conducted with smaller rod diameters and enrichments than used in these experiments).¹

The first measurements with the three percent enriched uranium were taken with 0.925-inch-diameter fuel elements positioned in Lucite tubes forming uranium rods 24 inches in length. A hexagonal pattern was used for the lattices, which were totally reflected. Three different rod separations were used. The sub-critical reactors contained about 96 percent of the critical mass for the cylindrical geometry at the final loading. Preliminary results are given below:

1. Kouts, H., et al, Exponential Experiments with Slightly Enriched Uranium Rods in Ordinary Water - Proceedings of the International Conference on the Peaceful Uses of Atomic Energy; Volume 5, Physics of Reactor Design, 8 August, 20 August 1955, Geneva

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Results of Multiplication Measurements
With Three Percent Enriched Uranium

<u>Lattice Spacing</u>	<u>H₂O/U (by Volume)</u>	<u>Number of 24-Inch Rods For Criticality</u>	<u>Quantity of Uranium</u>	<u>Calculated* Buckling</u>
1.5 inches	1.89	61	671 lbs.	$12,900 \times 10^{-6} \text{cm.}^{-2}$
1.6 inches	2.29	58	573 lbs.	$13,300 \times 10^{-6} \text{cm.}^{-2}$
1.7 inches	2.72	49	540 lbs.	$13,000 \times 10^{-6} \text{cm.}^{-2}$

*Brookhaven data were used for estimating the reflector savings for the buckling calculations.

Data were obtained on the control rod lengths from multiplication curves with the control rods in the full-in, and then the full-out positions and the difference in the extrapolated number of uranium rods for criticality under these two conditions.

Experiments with Homogeneous Systems - J. A. Berberet, V. I. Neeley

Experiments were begun in the P.C.T.R. to determine the maximum k_{∞} of hydrogen moderated three percent enriched uranium oxide, as well as the H/U ratio (dilution) for which $k_{\infty} \leq$ unity. An H/U atom ratio of four was used and a preliminary value for $k_{\infty} = 1.32$ was obtained, which compares favorably with a calculated value of 1.36.

Pertinent to these studies was a measurement of the boron cross section in the P.C.T.R. A value of 770 barns was obtained for natural boron (B^{10} isotopic content measured to be 18.93 percent). The uncertainty in the above cross section is of the order of two or three percent.

Plutonium Critical Mass Laboratory - J. A. Berberet, E. D. Clayton

In reference to the Plutonium Critical Mass Laboratory, comparative cost estimates were obtained for two different types of facilities: (1) a reactor station consisting of a hemispherical steel shell-type structure located remotely from the control center, and (2) a reactor station consisting of a thick walled concrete structure adjacent to the control center. There is little difference between the costs of the two types of facilities unless later expansion to two reactor stations is considered, in which case the concrete structure would be significantly more economical to build. On the basis of the cost estimates and the greater operational convenience in having the reactor station located adjacent to the control center, it is now recommended that the conventional concrete type structure be built.

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Preliminary Project Proposal Revision No. 2 (Project CG-731, Rev. 2), HW-56698, was prepared by members of Laboratory Auxiliaries for the Critical Mass Laboratory. Revision No. 2 requests that the General Electric Company be authorized to revise the scope of the project to one employing conventional construction.

Design of the facility has been initiated and is in the advanced scoping stage.

Critical Mass Experiment for E-Metal Dissolver - E. D. Clayton

About 12 tons of 0.95 percent enriched I and E type fuel elements were shipped to the Oak Ridge Critical Mass Laboratory for criticality studies. The critical mass will be measured for the 0.95 percent enriched uranium in a uniform array and also in a random distribution in a mock-up of a Hanford-type dissolver. This work is an extension of the Hanford exponential experiments which were conducted with randomly distributed fuel elements in connection with the processing of slightly enriched uranium in existing dissolvers.

Neutron Age Measurements - D. G. Foster, Jr., R. A. Laing

Two age measurements in water have been completed, one with each size of source. The first run with the small source suffered from two difficulties: the source did not settle to the bottom of the support basket so that it was misplaced by a measurable amount from the foil center line, and an erratic background was encountered in the foil counting. The source misplacement can be corrected for; the erratic background will worsen the precision of the measurement, but the run has not been evaluated as yet. The second run with the large source was more successful although the observed dispersions were about twice the statistical deviations. A program of data reduction is being written for the IBM-650.

Mass Spectrometer for Plutonium Analyses - C. R. Lagergren, W. J. Friesen

The electrical power distribution system is about 75 percent complete. When this job is complete the component testing of the spectrometer will be started.

Nuclear Safety, Critical Mass Consultations - N. Ketzlach

1. Nuclear Safety in 234-5 Building Processing

A review was made of the preliminary drawings on the vacuum cleaning system for Hood 9A. The recommended changes in these drawings were made to insure nuclear safety and were approved by Research and Engineering of C.P.D.

The rough draft of HW-56573, "Revised Nuclear Safety Specifications RMA Fabrication Line," by R. E. Smith was reviewed and recommended changes transmitted to Finished Product Technology Operation of C.P.D.

A study was made of the effect on the nuclear safety of lowering the Hydrogen Peroxide Head Tank in Hood 7 to the same level as the T.H.T. (transfer head tank) and three feet away from it; the T.H.T. remains safe under the 500 grams per liter restriction.

Criteria for the installation of a neutron monitor vessel to the solvent extraction hood was presented to the Finished Products Operation. This monitor is for estimating the plutonium concentration in the C.C.W. stream leaving the bottom of the H-3 column.

Vessels G-63 and G-64, Condensate Receivers for the Continuous Concentrator being installed in the Reception and Blending Hood, were reviewed for nuclear safety. This review was necessary since the original criteria for the installation of these vessels was not exactly followed. The vessels were still judged safe under the original limits which were set.

Vessel J-4 in the load-out station hood of Recuplex no longer meets capacity requirements; in order to increase capacity, criteria were submitted for the installation of a six-inch-diameter by 36-inch-tall glass vessel. Under the proposed conditions this vessel would be safe for all plutonium solution concentrations up to 500 grams per liter. The safety of this vessel is very sensitive to the size and quantity of neutron reflectors in the vicinity of the vessel. The presence of more neutron reflecting materials than that stipulated can reduce the minimum critical mass of this vessel to 1800 grams plutonium.

Criteria for the design of a safe array for plutonium metal pieces were presented to Facilities Engineering, C.P.D.. The array consists of two vertical and parallel arrays separated by three feet in a vault. The vault is located in Room 192 of the Radiography Room of final inspection.

2. Purex Technology Operation

Nuclear safety of a ten-foot-diameter organic recycle tank has been investigated. The hydrogen density in the organic solvent is equivalent to 67 percent that of water. Under these conditions the maximum safe mass for this vessel is 10 kg of plutonium, and the maximum safe concentration is 2.5 grams per liter plutonium.

3. Power Fuels

Several meetings were held with members of the Chemical Processing Department to discuss designs for a fuel element cask to handle all power fuels to be processed at H.A.P.O. One suggested method for a safe cask is based on having two parallel safe slabs separated by at least one foot. There should be a sheet of cadmium against each of the inside slab faces. These slabs should be so designed as to insure the presence of water between the slabs when it is present inside the slabs. One question which may require a few experiments before an answer can be obtained is whether or not the interacting slabs are still safe when the water level is only part way up the sides of the slab.

4. Miscellaneous Studies

From the results of a study made on the nuclear safety of plutonium in an organic solvent, it became apparent that some uncertainty exists in the

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interpretation and use of the critically safe concentrations which are given for full water density, i.e., eight grams plutonium per liter, and 11.6 grams of uranium-235 per liter. Therefore, a study was made to show the effect of the moderator density on the critical parameters. Similar studies have been made at K.A.P.L.^(1,2) The results of the present study will be reported in HW-56938, "Criticality of Highly Enriched U-235 Fuels."

REACTOR DEVELOPMENT - 4000 PROGRAM

STUDIES RELATED TO THE PLUTONIUM RECYCLE PROGRAM

Fuel Isotopic Concentrations - J. R. Worden

The set of linear differential equations for calculating isotope concentrations as a function of local exposure has been turned over to J. G. Bradley for programming on the Lytton DDA. As the computer is still not generally available for individual use, the equations will not only serve as a source of numerical results but will also be utilized in demonstrating the use of the computer to the classes to be held in the near future.

A variational principle suitable for finding the spatial isotope distribution is still being sought. Methods employed to date have resulted in expressions much too cumbersome to handle. Recent work done by K.A.P.L. physicists using the variational principle is being studied with hopes of applying the results to the present problem.

Fuel Temperature Coefficient for UO_2 - F. C. Engesser

As previously reported⁽³⁾ the change in the effective resonance integral of uranium oxide with temperature may be inferred from the metal temperature coefficient of k_{∞} measured for the 19-rod clusters of uranium oxide with air coolant and the k_{∞} and f measurements for the seven-inch and eight-inch uranium oxide lattices. The value reported was $(2.0 \pm 0.2) \times 10^{-4}/^{\circ}C$.

It is of some interest to observe, however, that the above value for the temperature coefficient of the resonance integral includes a small effect due to the thermal expansion of the aluminum spiders holding the cluster of rods. The expansion of the aluminum expands the cluster and increases the effective surface-to-mass ratio of the fuel. This effect has been calculated to reduce the above value by five percent, so that the true doppler coefficient is $\frac{1}{\Sigma_0} \frac{\Delta \Sigma}{\Delta T} \approx (1.9 \pm 0.2) \times 10^{-4}/^{\circ}C$ for a cluster having a fixed separation. Σ_0 is the value of the effective resonance integral at $20^{\circ}C$.

Critoph's⁽⁴⁾ conventional method of calculating the resonance escape probability, P , for multiple rods yields a value of 0.892 for an air-cooled, 19-rod cluster

- (1) C. V. Larrick, "Some Criteria for Safe Storage of U-235 Fuel," KAPL-M-CVL-4 Del, January 19, 1956.
- (2) "Criticality Manual for the Knolls Atomic Power Laboratory," KAPL-A-CM-1, April 23, 1958.
- (3) Monthly Report for October 1957.
- (4) Critoph, E., CRRP-655 (1956).

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of uranium oxide in an eight-inch, D_2O -moderated lattice. The effective surface used in the formula for the effective resonance integral was that generated by a rubber band stretched around the fuel in the cluster, as proposed by Cohen.⁽¹⁾ This calculated value of 0.892 is to be compared to a value of 0.895 inferred from k_{∞} and f measurements on the seven-inch and eight-inch uranium oxide lattices. The agreement is satisfying. A value of $\xi\sigma_s$ per D_2O molecule of $5.38 \times 10^{-24} \text{cm}^2$ was used instead of Critoph's value of $2.66 \times 10^{-24} \text{cm}^2$. It is not clear what the latter value actually represents.

Cross Section Program

Subthreshold Fission - Np-237 and Am-241 - E. J. Seppi, B. R. Leonard, Jr., S. J. Friesenhahn

High resolution data have been taken on these fission cross sections in the region of 1 ev. to 1.5 ev. The resolution used was 0.5 $\mu\text{sec}/\text{m}$ with what should be a well defined resolution function. In addition, a new sample of Am-241 was used which is known to be free of plutonium contaminants. The fission counting rates obtainable are quite low and the data are not complete. However, the 1.25 ev. resonance in Am-241 has been observed with about five times the peak cross section observed in the low resolution run. This indicates a much worse resolution function for the low resolution technique than would be calculated. The increased peak height is not significant in the theoretical description of this resonance phenomenon. Further data are being taken to attempt to ascertain if the resonance is a doublet. The fission counting rates in the Np-237 are too close to background to obtain much information. It does appear, however, that the peak cross section of the 1.35 ev. resonance in Np-237 has increased by a similar factor over the low resolution data.

Three Crystal Spectrometer - E. J. Seppi, J. H. McCrary, S. J. Friesenhahn

The defective beam shutter mechanism furnished on the Project CG-672 has been repaired and now operates satisfactorily. Most of the instrumentation for the spectrometer operation programming controls and data recording system are complete and partly installed. The third axis drive system has been installed. Two counting systems have been installed: a parallel plate boron chamber for use as a monoenergetic neutron beam monitor, and a low background, high efficiency BF_3 counter assembly for the detection of scattered neutrons.

Time-of-Flight - H. W. Lefevre, J. T. Russell

The Van de Graaff accelerator has not been available because of the installation of the minus 25-degree beam port. Design work has been started on a motor-driven mounting platform for aligning the Van de Graaff and on a new constant current belt charge system.

Offsite Program - C. R. Lagergren, W. J. Friesen

The component testing of the mass spectrometer for this program will begin when the electrical distribution work is finished.

(1) Fillmore, F. L., North American Aviation, NAA-SR-1535 (1956)

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Experimental Reactor OperationsP.C.T.R. - H. A. Fowler, H. L. Henry

Operation of the P.C.T.R. continued routinely during the month on a one- and two-shift basis. There were no unscheduled shutdowns.

The first set of experiments was completed investigating k_{∞} of the three percent enriched $\text{UO}_2\text{-H}_2\text{O}$ system. Neutron thermalization experiments were being done at month end. A new core heating system was devised for this work. It is now possible to remove the resistance elements before making the irradiation.

Construction of the addition to the 305-B Building, CA-778, was started during the month. Footings and foundations have been completed.

T.T.R. - W. P. Stinson, H. L. Henry

Critical mass experiments were conducted in the reactor room for three weeks. The reactor was out of operation the remainder of the month due to construction work on the addition to the 305-B Building.

A breadboard has been completed by U. R. Call to determine the characteristics of the beam switching tubes and to work out the circuit component values for application in the scanner-converter unit for the automatic counter system.

REPORTS PUBLISHED

HW-56760 "Nuclear Physics Research Operation - Monthly Report - June, 1958,"
J. E. Faulkner, et al, July 14, 1958 (Secret - Informal)

PAPERS ACCEPTED

D. G. Foster, Jr., et al	"The Slowing Down of Neutrons in Hydrogenous Media - Status of Theory and Experiment" - Accepted for publication in the proceedings of the Geneva Conference.
R. E. Heineman, et al	"Determination of k_{∞} from Critical Experiments in the P.C.T.R." - Accepted for publication in Nuclear Science and Engineering.
R. E. Heineman	"Experience in the Use of the Physical Constants Testing Reactor - A Prototype Lattice Testing Reactor" - Accepted for publication in the proceedings of the Geneva Conference.

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