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REPORT NO. Bat P-178
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ISSUED TO: G. J. Young

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Contract No. W-35-058, eng. 71

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PHYSICS DIVISION

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REPORT FOR MONTH ENDING SEPTEMBER 30, 1946

L. W. Nordheim, Director

Date Received: 10-8-46
Date Issued: 10-8-46

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The past two months brought considerable changes in the work of the division through the following circumstances: The decision in favor of a modified design for the high flux unit, the influx of a large number of members of the training school program. The process of assimilation of this new group is proceeding rapidly, and it is hoped that the unavoidable confusion of such a transition period will soon be overcome.

A new section, number VI, has been organized under the leadership of G. Young. This group, in conjunction with members of the training program, is engaged in long range pile studies. They will keep up to date records of nuclear data, such as the isotope chart and cross section tables. A systematic study of the economics of power piles is under way. The recently released Baruch report on the cost of power production of Hanford type piles has been prepared essentially by members of this group. Other activities concern the general survey of possibilities for power piles and such detail questions as shielding, neutron utilization in reflector arrangements, and poisoning of fission products.

The decision to build the high flux pile as a light water pile with beryllium reflector has been generally welcomed, and theoretical work on this type is proceeding at a rapid rate. Critical data and neutron distribution fractions have been obtained, and also information of heat production, controls and other data necessary for design. The new type will pose additional problems for the controls, due to a small temperature coefficient and short life time of neutrons in the pile. A summary report on the control problems in small enriched piles will be issued in the near future.

The critical experiments in the P-9 tank have been continued. The layout has proven to be very useful and convenient, and plans are under way for further

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improvements and uses, such as the measurements of danger coefficients.

The thermal column on top of the pile is being rebuilt in order to eliminate streaming of fast neutrons. The column will be used for age measurements in Be and BeO, as soon as the material becomes available.

A new project has been started to study the mechanism of the emission of prompt fission neutrons. The method will consist in the observation of coincidences between measured fission pulses with emitted neutrons. Correlation between pulse size, indicating the masses of the fragments and emission probabilities will be looked for.

The following results from running experiments deserve mention at this time. The life time of C^{14} seems definitely to be shorter than previously assumed (5000 to 6000 years in place of 20,000). This result is being reported in a letter to the Phys. Rev.

The search for short lived isomers has been continued, and the characteristics of the emission of delayed γ-rays from a W^{187} source have been established. A third case (Yb^{175}) is still subject to doubts. The γ-rays from Au^{198} have been investigated with the 180° β-ray spectrometer, and a single γ-ray of .41 Mev energy has been found.

In the fissionability studies with the photographic plate method samples of highly purified U^{234} and of Pa^{234} were investigated. In contrast to observations from Los Alamos for U^{234} ($\sim$ 2 barns) an upper limit of 0.005 barns for thermal fission cross section was obtained and it is made highly probable that the Los Alamos value is due to contamination. No evidence for thermal fission in Pa^{234} was found.

The pile control group completed the development of a fast amplifier for counter circuits and of the pile simulator. Reports on these apparatus are in preparation.

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In the preceding period Dr. Chauncey Starr left the laboratory. The work assigned to him, on radiation effects in solids, has been taken over by Dr. S. Siegel from the training school. Dr. M. Ross and Dr. H. Garabedian joined the regular staff of the Division, strengthening considerably its theoretical group.

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Physics Section I

A. H. Snell, Section Chief

Total technical personnel (including supervision)..... 7

Problem Assignment Number	Subject	Status	Man-months of Effort Report Per.	Man-months of Effort Next Per.
PX1-7	C^{14} Production	Active	1½	1½
PX6-4	Neutron Temperature in Pile	Active	1	0
PX8-1	Gamma Ray Spectra	Inactive	0	1
PX8-2	Photoneutron Sources	Inactive	0	0
163-X39P	Service Flux Measurements	Active	⅓	⅓
PX8-4	Gamma Energy per Beta	Active	1	1
PX5-22	Critical Experiments	Active	2	2⅓
	Neutron Decay	Active	1	2⅓
		Total.....	7	9

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PX5-22 - Critical Experiments - (Snell, Buck, Mann)

The five experimental holes in the P-9 reflector -- cavities intended to accommodate experimental apparatus -- have been removed.

Critical masses have been observed as follows:

		Critical Mass (grams) Gross	Corrected
I	Lattice 2c containing 4" central thimble	2256	2095
II	Lattice 3c containing fuel at center	1880	1855

Corrections noted above allow for the effect of thimble, control rod part, position of control rod, etc.

An attempt was made to evaluate the effect of control rod as a function of rod size, but all our rods are of such large size that this preliminary trial yielded no accurate comparison of rods.

It has been suggested by Weinberg that the pilito might be useful for the measurement of absorption cross-sections, at least on a semi-quantitative basis. With this in mind, a piece of gold foil, total weight 3.66 grams, was inserted in the center of the lattice and compared to one of our stainless steel rods in poisoning effect.

Using the stainless steel as standard (perhaps a dubious procedure) and assuming the control rod to be linear in effect -- this is so for displacements of a few inches -- a value of 98 barns is obtained for gold.

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It is possible that the use of a smaller control rod to get more displacement will enable us to obtain better data.

Considerable thinking and talking is going on about the improvement of instruments and facilities in general if the critical experiments are to continue for some time.

PX1-7 - C^{14} Production - (Norris)

The factory has operated approximately 21 days this past month. It has been shut down twice, once to facilitate other research, once for inspection and repair of the pump. Attempts to get material of higher specific activity have not been completed as yet.

A preliminary value for the half-life (5000-6000 yrs.) has been reported in a letter to the Physical Review. This work should be completed in the near future.

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Physics Section II

A. M. Weinberg, Section Chief

Total Technical Personnel (including supervision).....

Heating of Reflector in Heterogeneous Pile - (A. M. Weinberg)

Computations of the heat load in the reflector of the latest version of the heterogeneous pile have been carried out. About 900 KW of heat will be dissipated in the Be reflector and about 80 KW will be dissipated in the graphite (which backs up the Be) when the pile runs at 30,000 KW. The maximum heat production rate in the Be is about 2.3 cal. per c.c. per sec. at points in the medial plane adjacent to the pile surface. The maximum heat production in the graphite, about 0.22 cal. per cc. per sec. occurs at points backing up experimental holes of size 10 cm. x 10 cm. This heat load is about the same as the maximum heat load at Hanford. However, since this graphite is exposed to a much heavier fast neutron bombardment than the Hanford graphite -- with the result that the thermal conductivity will fall very much more drastically -- it may be advisable to reduce the heat load by facing the graphite exposed to a hole with a few inches of Pb or Bi.

Disposition of Control Sheets in Heterogeneous Pile -- (M. R. Spiegel and A. M. Weinberg)

Calculations are being made on the disposition of Th or Cd control sheets necessary to hold a 3.5 Kg heterogeneous pile. A Cd sheet that cuts the pile and reflector in two equal halves is very nearly sufficient to hold a 3.5 Kg pile. The overall control margin in this case is about 10% in $\frac{\delta k_{eff}}{k}$. Calculations on how large and how many Th sheets are needed to accomplish the same purpose are still in progress.

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Adjoint Functions for the Heterogeneous Pile -- (Greuling and Arnette)

Two group calculations of the slow and fast neutron fluxes (ϕ_s and ϕ_f) and their adjoint functions (ϕ_s^+ and ϕ_f^+) for the following pile model were completed.

A cylindrical core 70 cm. high consisting of a mixture of 25, aluminum and H_2O is surrounded by a reflector of the same height consisting of beryllium metal plus 2% water by volume. The pertinent constants used were:

$k = 1.606$

In Core: Thermal diffusion length = 1.91 cm.

Age = 64.2 cm^2

Thermal transport m.f.p. = .793 cm.

Fast " " = 3.73 cm.

In Reflector: Thermal diffusion length = 19.9 cm.

Age = 89 cm^2

Thermal transport m.f.p. = 1.92 cm.

Fast " " = 1.80 cm.

The critical core radius of such a model is 12.78 cm. The core containing 35.7 gms. of 25 per liter has a critical mass of 1.3 Kg.

Below are the computed neutron fluxes and their adjoints.

$$\phi_s = \begin{cases} J_0(.08161r) + 2.005 \times 10^{-3} \times I_0(.5487r) & , r \leq 12.78 \text{ cm.} \\ 8.632\, K_0(.06744r) - 15.12\, K_0(.1151r) & , r \geq 12.78 \end{cases}$$

$$\phi_f = \begin{cases} 3.867\, J_0(.08161r) - 6.633 \times 10^{-4} \times I_0(.5487r) & , r \leq 12.78 \\ 12.49\, K_0(.1151r) & , r \geq 12.78 \end{cases}$$

$$\phi_s^+ = \begin{cases} 1.5565\, J_0(.08161r) - 1.756 \times 10^{-3} \times I_0(.5487r) & , r \leq 12.78 \\ 1.6725\, K_0(.06744r) & , r \geq 12.78 \end{cases}$$

$$\phi_f^+ = \begin{cases} J_0(.08161r) + 9.654 \times 10^{-5} \times I_0(.5487r) & \\ 2.160\, K_0(.06744r) - 1.577\, K_0(.1151r) & , r \geq 12.78 \end{cases}$$

The Bessel functions, J_0, I_0, and K_0, are defined in the notation of "Watson" - Bessel Functions.

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Slowing Down of Neutrons in H-D Mixtures -- (M. E. Rose)

As described in the last Monthly Report a fairly rigorous formula for slowing down length of neutrons - hydrogenous mixtures was developed. Unfortunately the calculations required in order to obtain specific numerical values represents a long-time undertaking. Therefore the problem was re-examined and two methods were followed. The first was an attempt to extend the so-called "age-theory" to a higher approximation; the second method, considerably more ambitious, was an attempt at an exact solution for the spatial, angular and energy distribution. It is felt that even though an exact solution may not be feasible the problem will be better understood by virtue of this attempt and that other methods of approximation may thereby be developed.

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Physics Section III

E. O. Wollan, Section Chief
S. De Benedetti, Associate Section Chief

Total technical personnel (including supervision).....11

Problem Assignment Number	Subject	Status	Man-Months of Effort Report Per.	Next Per.
PX6-1	Pile Oscillator	Active	1	2
PX10-8	Neutron Diffraction	Active	1	2
PX10-16	Characteristics of Fission Products and Neutron Induced Activities	Active	1	1
PX10-19	Capture Gamma Energies	Active	1	1
PX10-22	Short Lived Isomers	Active	1	1
	Ranges of Delayed Neutron Emitters	Active	1	1
	Studies of Prompt Fission Neutron Emission	Active	1	2
	Supevision and Report Writing	Active	1	1
		Total.....	8	11

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Neutron "Age" Measurements - Hill, Roberts, Wollan

The old thermal column has been removed and a new one is now being built. The reason for this is that the work of Hayden Jones et al on water lattices had shown a streaming of fast neutrons along the central plug.

PX10-19 Energy of Capture Gamma Rays - Moak, Wollan

The magnetic field current stabilizing equipment is still in the process of construction and other construction jobs will require at least another month.

PX10-8 Neutron Diffraction - Shull, Wollan

Work on the determination of the absolute integrated intensities from powdered crystals was continued. Difficulties with a fluctuating counter background and a non-uniform efficiency for oof-axis radiation were encountered and are being studied. A new shield block with a larger slit opening was placed in the pile hole and the monochromator and the spectrometer were realigned in an attempt to increase the low counting rates which have to be measured.

PX6-1 Pile Oscillator - Pomerance

The circuits are being rebuilt by Dr. Jordan. It is hoped that an improvement in sensitivity can be achieved.

Correlation of Delayed Neutron Emitters from U^{235} with Fission Fragment Range - Wollan

It is now planned to redesign some of the equipment for this experiment. The hazards associated with this work have been too great with the present arrangement.

Mechanism of Emission of Prompt Fission Neutrons - De Benedetti, Francis, Preston

The work of preparing the experimental equipment is continuing. This month most of the attention has been given to the fast neutron counter. We

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are attempting to build a highly efficient counter, according to a design developed at Los Alamos. The counter has been assembled but not yet tested.

A first experimental model of the fission chamber has been designed.

PX10-22 Search for Short Lived Isomers - De Benedetti, Mc Gowan

Absorption curves of the delayed γ rays and conversion electrons emitted by W^{187} sources were obtained. From these it appears that the energy of the conversion electrons is about .09 Mev, and that of the γ rays about .13 Mev. If one adds to .09 Mev the binding energy of electrons in the k shell, one obtains .16 Mev. The disagreement between this value and that obtained from the γ rays is probably due to the inaccuracy of the experiments. γ rays of .086, .101, .136, .94 Mev have been reported for W^{187} sources and it is probable, though not certain, that the metastable level has to be attributed to the .135 Mev line.

The double Geiger counter for measurement of coincidences without window absorption was made to work. With it, the number of delayed coincidences per β ray for W^{187} sources has been found to be about 6 times higher than with the mica-window counters. A more accurate determination of the half-life of the metastable level was therefore possible. This gave a result of 1 μsec.

We had the opportunity of borrowing a sample of Yb from Dr. Ketelle. By activation in the pile this element should give Yb^{175} which in turn decays into Lu^{175}, of reported spin 7/2. Only one measurement could be done with this source. The result seems to indicate the existence of source delays (half-life between 1 and 2 μ sec), but not all of the points obtained lie on an exponential curve. The existence of a metastable state in Lu^{175} cannot be considered as proved.

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PX10-16 Characteristics of Fission Product and Neutron Induced Activities - Levy

Gamma Rays from 2.7 Day Au^{198}

The 180° Beta-ray Spectrometer has been used to determine the Photo-electron and Compton Recoil Distribution from 2.7 day A^{198}. From this data (see Figure) we conclude that only one gamma ray (namely one of .41 Mev) is present to any great extent. If a gamma ray of .28 Mev is present, as is reported in Seaborg's table, its intensity cannot be greater than 3% of the intensity of the .41 Mev gamma ray.

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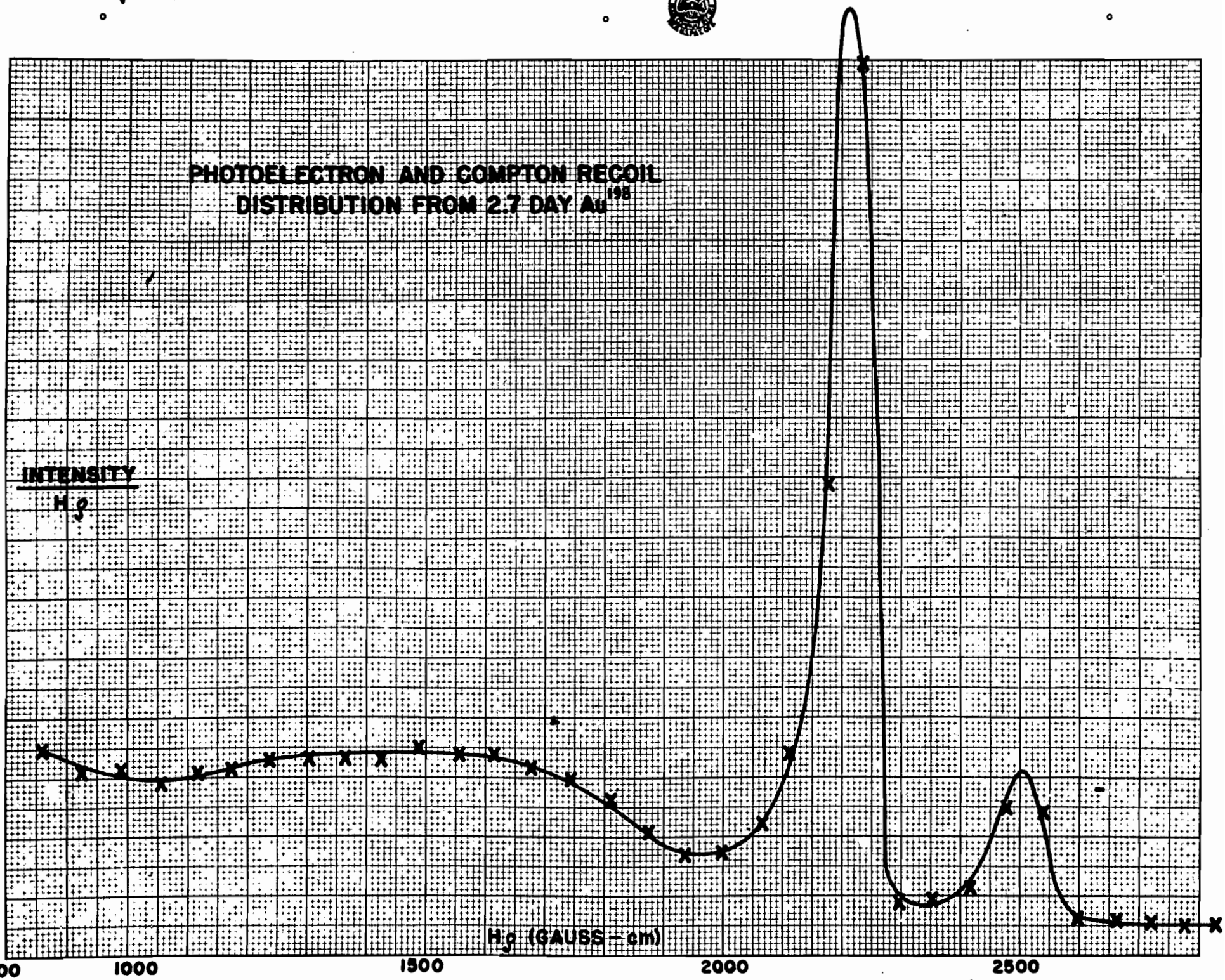

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Physics Section IV

L. B. Borst, Section Chief

S. Bernstein, Associate Section Chief

Total technical personnel (including supervision)..... 7

Problem Assignment Number	Subject	Status	Man-months of effort Report Per.	Next Per.
PX10-17	Fissionability Studies	Active	1	
PX10-8	Neutron Diffraction	Active	3	
PX10-15	Photoneutrons from Fission Products plus P-9	Active	2	
	Plutonium Project Record	Active	1	
		Total....	7	

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PX10-17 - Fissionability Studies

Fissionability of UX_1 and U^{234} - (Osborne, Coveyou)

Three new samples have been prepared by the Chemistry Division, comprising 0.2 micrograms of highly purified UX_1 (U^{234}), 0.2 micrograms of U^{234} and the UZ (Pa^{234}) in equilibrium with the UX fraction. These samples were studied for fissionability as a function of time, and aliquots were taken for beta ray study. In contrast to the previous samples which showed growth before a decay of the beta count, the present samples showed only simple decay. Several exposures have been examined to detect the presence of fission tracks for each of the samples. In no case was more than one track observed. Converting these isolated events to an estimated cross-section gives a value for UX of .02 barns, for U^{234} of .005 barns.

This last value is in direct contrast to the value reported from Los Alamos of approximately 2 barns. In these studies the presence of contamination is always a difficult factor to reckon with. The observed tracks might well be due to fission of uranium present in the emulsion or to ordinary uranium included with the sample. The cross-section cannot, therefore, be easily assigned to the isotope specified. It must be considered as an upper limit exclusively. Its use as a valid upper limit, however, is well justified. It is the author's opinion that the value observed at Los Alamos was due to a small amount of contamination present in the original sample. The absence of fissionable contaminants in the

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present sample permits the assignment of this relatively low cross-section to U^{234}.

The examination of the UZ sample shows no definitive evidence of thermal fission in UZ.

PX10-8 - Neutron Diffraction

Xe^{135} - (Dial, Floyd, Osborne, Borst)

The chemical process previously developed by Hasbrouck, has been in satisfactory operation during the past month. Preparations have been continuing for the high activity run required to prepare a satisfactory amount of Xe. Chemical recoveries of 60% or 70% have been achieved with the equipment and process previously used. A semi-hot run has been successfully carried to completion, the radiation level in this case was approximately 1% of that to be expected in the final run. A second comparable run will be made before the final separation is carried out. The spectrometer is now ready for use in this experiment.

PX10-15 - Photoneutrons from Fission Products Plus P-9 - (Bernstein)

This work has been stalemated this past month because of the complete lack of laboratory-assistant-type help to take and work up the data.

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Physics Section V
Henry W. Newson, Section Chief

Total Technical Personnel (including supervision).....10

A-1 Amplifier (W. H. Jordan)

Two units have been built by the electronic shop. After correcting a few minor errors in design and construction, they both performed quite well. In the wide band position, the pulse rise time was about 0.2 microseconds. When switched to medium band width, the rise time was 0.8 microseconds; narrow band width gave a rise time of 4 microseconds. The signal to noise ratio for alpha particles improves greatly as the band width is narrowed. Amplifiers of this type should now be available for general use in the laboratory. A report on this development will be issued shortly.

Pile Simulator (W. H. Jordan and P. R. Bell)

The effect of the growth and decay of Xe has been successfully incorporated into the pile simulator. A report on this development is to be issued soon.

Pile Power Control (H. A. Straus)

The model servo system and the necessary electronic apparatus is still under construction. It will be some time before this equipment is ready to try on the pile simulator.

Ionization Chamber (F. C. Armistead)

Low background ionization chambers, for measuring pile intensity over as great a range as possible, are being designed. A test chamber for

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trying different Boron coating methods is being built. It is hoped that a useful range of a factor of 10^6 is feasible.

Period Control Circuit (F. C. Armistead and P. R. Bell)

The circuit for measuring $\frac{d \ln n}{dt}$ is still under test. It is now able to give a constant output for 6 periods of an exponentially changing signal from a discharging RC circuit. It is now being tested in conjunction with the pile simulator.

A report is now in preparation which discusses the general philosophy of control of piles capable of very short periods. These ideas are particularly applicable to heterogeneous piles of the type under design here, but they have some application to other piles.

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Physics Section VI

G. Young, Section Chief

Total technical personnel (including supervision)..... 5

Recent activities associated with the section may be loosely classed under the following headings:

Nuclear Data

Miss Way and Mrs. Dismuke are revising and bringing up to date the compilations of cross section data and references which had been made earlier by Castle, Dismuke, and others.

A laboratory group of chemists and physicists consisting of Mr. Boyd, Mr. Stoughton, Mr. Sullivan, Mr. Levy, Mr. Schweinler, and Miss Way has assumed the responsibility of keeping the Seaborg table of isotope information up to date from information in current reports and journals and will issue a monthly report beginning November 1st. Similar work in both the cross section and isotope fields is of course being done at other sites. It is hoped that an over-all integration can be achieved.

Power

Studies by Mr. Thompson extending over the past few months, with the assistance of a number of people at the Standard Oil Development Laboratory and of a number at Clinton Laboratories, have culminated in the recently released Baruch report on the cost of obtaining useful power from high temperature Hanford type piles. This work is being continued and extended to other types of piles, and a report entitled "Some Notes on Power Piles" is being prepared.

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Some estimates by Goodman on United States deposits of U and Th ores were reported in "Recent Meetings of New Pile Group", Young 9-6-46; and a brief account of the Hanford power pile estimates were given in a memo of the same name dated 7-29-46. Mr. Monke, who had made some similar estimates in connection with the economic studies of Prof. Marshak at the University of Chicago, is continuing his work here.

Fission Products

Miss Way and Mr. Noderer are revising and extending MUC-KW-41.

Shielding

There has been some correspondence with Jette at Los Alamos on the subject of getting thinner shields by the use of heavy metal and hydrogen compounds, and Mr. Murray is making calculations in this connection. This is similar to the work by Mr. Borst on the development of shielding concrete containing iron-hydrogen compounds.

Pile Blankets

Mr. Goertzel is beginning a study of the problems involved in capturing a high percentage of the leakage neutrons in thorium or 28 outside a pile.

General

An annotated bibliography entitled "Summary of New Pile Studies" is being prepared.

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