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REPORT NO. MON P-17

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PHYSICS DIVISION

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REPORT FOR MONTH ENDING SEPTEMBER 31, 1945

L. W. Nordheim

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New Unit

Experiments in connection with the new unit play an increasing role in the work of the group. The apparatus for the study of photo-neutrons in P-9 is nearing completion (Bernstein) and so is the apparatus to measure the actual energies of γ rays of short half life from fission (Rose, Burgy). These experiments will give information of the contribution of the photo-neutron effect in P-9 to the delayed neutrons important for the control of the unit.

The problem of turbulent fluctuations in reactivity is investigated both experimentally and theoretically. A small circulating system has been built to study firstly the fluctuations of the flow in a straight pipe. A larger pump for a scale model of the new unit has been ordered (Saxon, Snell). Mr. Murray has developed theoretical formulas that connect temperature and reactivity fluctuations with observed velocity fluctuations.

The thermal utilization for production in the thorium rods has been studied experimentally by Jones and theoretically by G. Nordheim and R. Scalettar.

A very important intermediate step in the development of the new unit will consist in critical experiments on homogeneous solutions of 25 in P-9. Preparations for these experiments, which should give experimental data on critical sizes, temperature and concentration coefficients and effectiveness of control systems, are being made. It is hoped that the experiments can be set up in the next period and that they will lead ultimately to a critical unit that can be used as a precision instrument for danger measurements.

Further theoretical studies have been made on the efficiency of reflectors of various nature and geometry and of their influence on the temperature coefficients.

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General Physics Research

The principal research activities of the Division, apart from work on the new unit, can be summarized as follows:

In Section I, (Snell) the criticality of vessels occupied still a predominant position, and it might be continued under a somewhat different set up. A report on the present phase in is preparation. The availability of a particularly strong gamma ray source gave the opportunity to measure the angular distribution of photo-neutrons from deuterium produced by 2.3 mev γ rays. The measurements indicated a predominantly isotropic distribution with an excess of about 10-15% in the direction perpendicular to the γ rays. This result is in sharp contradiction to early published data by Von Halban but it agrees much better with theoretical expectation. The C^{14} factory has been operated steadily. The present yield is about 65 microcuries per megawatt day. Several details of the process are under investigation in order to improve the yield and in view of the development of future factories.

Section II (Wollan) continued active work on the pile modulator. A new reciprocator giving a swing of about 30 inches has been installed, which increases the sensitivity by at least a factor 2. The linearity of the instrument proved to be satisfactory. A measurement on Pd gave an absorption cross section of about 6 barns in essential agreement with previous data. This result shows, however, that the previously used catalyst must contain absorbing impurities. The investigation of delayed neutron energies has been essentially completed. It has been possible to obtain average energies for the various periods. These energies vary from group to group, however not in a systematic manner. The delayed neutron energies are much smaller than the energies of the prompt neutrons. Further work has been done on the crystal spectrometer and the 180° β ray spectrometer.

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A most interesting result has been obtained by Section IV (Borst) in their fissionability studies. It appears that Pa^{233} is thermo-fissionable with a cross section of order of 50 barns. This result is quite unexpected since Pa^{231} has a threshold for fission of 400 kv, but should be more easily fissionable according to the Bohr-Wheeler theory. Further experiments with new samples will have to be made in order to prove definitely the new effect. The study of the dependence of the fission cross section of 25 with energy by the neutron spectrometer has been started. A new fission chamber has been constructed containing a thin layer of U_3O_8 oriented at a glancing angle to the incident beam. Further work has been done on a process to separate chemically I^{135} which decays into Xe^{135}, in order to obtain samples for the neutron spectrometer, and also on the deuterium γ ray spectrometer.

The final report on the water lattice experiments has been completed by A. M. Weinberg and H. Jones containing a critical evaluation of the extensive series of measurements made during the last year. A uranium water lattice shows a k in slight excess of one at elevated temperatures, and it would appear that a practical pile could be built with very slightly enriched material.

Dr. H. W. Koch from the University of Illinois joined the Physics Division this month, while Drs. H. Jones and L. Pardue will leave the group by October 1.

[redacted]

Physics Section I

A. H. Snell, Section Chief
H. Jones, Associate Section Chief

Total technical personnel (including supervision)..... 10 (this period)

Problem Assignment Number	Subject	Status	Percentage of Section Manpower Report Per.	Next Per.
PX1-7	C^{14} Production	Active	15	20
PX6-4	Neutron Temperature in Pile	Inactive	0	5
PX8-1	Gamma Ray Spectra	Inactive	0	0
PX8-2	Photo-Neutron Sources	Active	15	15
PX10-2	Water Lattices	Active	15	0
PX10-4	Be^{10}	Inactive	0	0
PX10-6	Fast Neutron Yields	Inactive	0	0
PX14-1	Criticality of Vessels	Active	25	20
163-X39P	Service Flux Measurements	Active	5	10
PX5-14	Lattice Layer	Active	10	10
PX8-4	Mean Gamma Energy per Beta	Active	5	5
PX5-15	Controls	Active	10	15
		Total	100	100

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

The factory ran steadily during the past month. A repetition of the yield determination was carried out, in which the microbalance was used for weighing the small samples for beta-counting instead of the analytical balance used previously. The resulting yield figure is 65 microcuries per megawatt day, replacing the old figure of 100. This yield is lower than is to be expected from the flux and cross-section data, and emphasizes the importance of looking for C^{14} in the solution. Radiation harder than the C^{14} betas is emitted by our samples, and work is under way to see whether this is due to impurities or whether there are low energy gammas associated with the C^{14} decay. One of the quartz tubes containing solid calcium nitrate, which was irradiated some months ago, was opened in a system connected to a manometer to see if the calcium nitrate had decomposed under radiation to yield gaseous products. The gas evolution was too small to be observed in the apparatus used. This observation is of interest in consideration of manufacture of C^{14} in canned slugs. We have 18.4 millicuries of C^{14} on hand, plus 12 unassayed samples, containing an estimated 5 millicuries. 1.8 millicuries were shipped to Chicago during the last month.

PX14-1 - Criticality of Vessels - (Meiners, Rush, Snell)

A Beach-Russ pump has been put in operation for evacuating the hex sampling system. The writing of a report on this work is well advanced, including the preparation of figures. Corrections have been determined for

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the absorption of neutrons in the walls of the pipes in which the readings were taken. When a couple of samples are successfully withdrawn from the vessel, this phase of this problem will be considered finished.

PX8-2 - Photo-Neutron Sources - (Barker, Sternberg, Snell, et al)

The availability of a 1000-curie lanthanum source, kindly placed at our disposal by the Health-Physics Section, gave us an opportunity to measure the angular distribution of photo-neutrons emitted from deuterium by the 2.3 mev gamma ray. The low intensity of this gamma makes a powerful lanthanum source necessary. The measurements were not very accurate, but they indicated a predominantly isotropic distribution, with an excess of only 10-15% at an angle of 90° to the direction of the gamma rays. Like our results with Na and Ga, this is in sharp contradiction to early results of V. Halban.

PX8-4 - Mean Gamma Energy per Beta

Apparatus is nearly complete, but measurements may have to be deferred because of lack of manpower.

PX5-15 - Turbulence Studies-(Saxon)

A small circulating system has been built, and photographing will start soon on flow in a straight pipe at moderate Reynolds numbers. This will serve to check theory, and will give experience in the techniques involved. A larger pump has been ordered to drive a model of the homogeneous reactor.

[redacted]

163-X39P - Service Flux Measurements - (Arnette)

Recently two checks have been obtained for the nv value at the center of the pneumatic tube of the pile while operating at 4000 KW. A value of 5.60×10^{11} n cm^{-2} sec^{-1} was obtained with Cu wires placed in the pneumatic tube. A value of 5.45×10^{11} n cm^{-2} sec^{-1} was found with Ag wire. These two values check the value of 5.55×10^{11} n cm^{-2} sec^{-1} found with manganese in connection with problem assignment TX6-12.

PX5-14 - Neutron Transmission through a Lattice Layer - (Jones, Arnette)

All measurements have been completed and calculations are being made by R. Scalettar (see this problem assignment under Section II).

PX6-4 - Neutron Temperature in Pile

No work has been done on this problem during this period.

PX10-2 - Water Lattices - (Jones, Branch)

Final report will be issued within a week (CP-2842).

Physics Section II

A. M. Weinberg, Section Chief

Total Technical Personnel (including supervision).....8(this period)

Turbulent fluctuations in homogeneous pile

Mr. Murray has continued his calculations on the effect of turbulence on pile activity. The temperature fluctuations caused by turbulence in the enriched pile cause fluctuations in reactivity, and consequently, in power. If the reactivity fluctuations $\left(\frac{\Delta k}{k}\right)_{eff}$ are small, the power fluctuations will be

$$\sqrt{\left(\frac{\Delta P}{P}\right)^2} = \frac{1}{\beta} \sqrt{\left(\frac{\Delta k}{k}\right)^2}_{eff}$$

where β is the effective fraction of fission neutrons which are delayed. At an output of 10 KW/li, and a temperature coefficient of 1×10^{-3} / °C, the root mean square reactivity change due to turbulence is estimated to be about .001. This is based on a mixing length equal to 1/5 of the pile radius, and an average turbulent velocity equal to the mean flow velocity. Since the delayed neutrons contribute about $\frac{1}{2}$% to the reactivity the power fluctuations from this cause will be of the order of 20%.

Experiments to measure the mixing length and the turbulent velocity, quantities which are very difficult to estimate accurately, are being planned by Mr. Snell and Mr. Saxon.

Water lattice as a reflector

Mr. Cashwell has made calculations on the effectiveness of an ordinary water-uranium lattice as a reflector around an enriched homogeneous P-9 machine. He finds that a 20 cm thick water lattice in which $k = 0.97$ saves about 20 cm in the

critical radius of the pile. The effectiveness of the water lattice reflector is largely due to the small diffusion coefficient in the water compared to that in the pile proper.

Reflector temperature coefficients

The reflector temperature coefficient of the enriched pile has been calculated by Mr. Cashwell. He finds that a given increase in the temperature of the P-9 reflector has only about 1/10 as much effect on reactivity as the same temperature rise of the pile fluid would have. His results are summarized in the following:

Reflector temperature rise(°C)	20°-30°	20°-40°	20°-50°	20°-60°	20°-70°	20°-80°-20°-90°
$(\Delta k/k)_{eff}$	-.0004	-.0010	-.0018	-.0027	-.0038	-.0050 -.0064

Spherical pile with cylindrical reflector

Mr. Schweinler has calculated, by first order, one group, perturbation theory, the critical size of a spherical enriched P-9 pile in a cylindrical P-9 reflector. He finds that a 65 cm radius sphere is critical if surrounded by a cylinder with 85 cm radius and 170 cm height. This corresponds to a uniform reflector saving of 19.4 cm all around the sphere.

These calculations were started several months ago when it was believed that the reactor tank would be spherical instead of cylindrical.

Myrnaloy utilization

Mrs. Nordheim is continuing her calculations on the utilization of thermal neutrons in various myrnaloy rod arrays. A single row of 2 cm radius myrnaloy rods spaced 10 cm apart and placed in the P-9 reflector 20 cm from the pile tank wall

will absorb 94% of the thermal neutrons leaving the pile. If the rods are 1 cm in radius the utilization will be 84%. At present the 2 cm rods on a 10 cm pitch are favored for the new unit.

Analysis of experiments on utilization in rod arrays.

Mr. Scalettar has analyzed experimental data obtained by Mr. Jones's group on the utilization of thermal neutrons in a double row of iron rods imbedded in a graphite block. These experiments were undertaken to check the calculational methods used for the myrnaloy utilization problem. The comparison between theory and experiment follows:

distance from source to Fe	absorbed in iron / total neutron flux		Expt./Theory	absorbed in 2nd row / absorbed in 1st row	
	Theory	Expt.		Theory	Expt.
45.7 cm	.207	.143	0.69	.204	.293
40 cm	.259	.180	0.70	.204	.293
30 cm	.378	.269	0.71	.204	.293
20 cm	.533	.395	0.74	.204	.293

The theoretical iron utilizations were calculated on the assumption that the rods are smeared into a continuous sheet. This overestimates the iron utilization and accounts for the fact that the theoretical iron utilizations are consistently larger than the experimental. However, the dependence of observed utilization on distance from the neutron source is very well predicted by the simple theory; this is evidenced by the near constancy of the ratio experimental utilization/theoretical utilization.

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Physics Section III

E. O. Wollan, Section Chief
L. A. Pardue, Associate Section Chief

Total technical personnel (including supervision)..... 9 (this period)

Problem Assignment Number	Subject	Status	Percentage of Section Manpower Report Per.	Next Per.
PX6-1	Pile Modulation	Active	30	30
PX10-5	Energies of Delayed Neutrons	Active	15	15
313-X41P	Beta Ray Spectrometer	Active	10	10
PX10-8	Crystal Spectrometer	Active	15	15
	New Pile	Active	10	10
PX10-18	Energy of Gamma Rays from Short Life F.P's	Active	10	10
	Unassigned	Active	10	10
		Total.....	100	100

[redacted]

[redacted]

Dr. L. A. Pardue, who has been with the Project at Chicago and at Clinton Laboratories for the past two years, is returning to his permanent position as Professor of Physics at the University of Kentucky, on October 1. We are sorry that he finds it necessary to leave at this time, but we wish him well in his postwar activities.

Dr. H. W. Koch joined this section during the month. He is on leave from the University of Illinois.

PX10-5 - Energies of Delayed Neutrons - (Burgy, Willard)

The investigation of delayed neutron energies, using a hydrogen-filled cloud chamber and a pneumatic tube, has been completed. Preliminary analysis of our data yields energy spectra for the several periods with the following most probable and average energies:

$\tau_{1/2}$ (sec)	Most Probable Energy (Mv)	Average Energy (Mv)
0.43	0.35	0.38
1.52	0.72	0.72
4.51	0.35	0.40
22.0	0.52	0.58

The average energies are in reasonable agreement with those reported by Hughes, Dabbs and Cohn, CP-3094. This analysis did not provide us with information on the energies of neutrons associated with the 55.6 sec half life. However, a more thorough analysis will be carried through, and may enable us to report on the 55.6 sec half life neutrons. This will be given in the final report on this problem which is now being prepared.

[redacted]

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PX10-18 - Short Half Life Gamma Energies - (Rose, Burgy)

Most of the apparatus needed for this experiment has been obtained or constructed and absorption measurements are being made.

PX10-8 - Crystal Spectrometer - (Peterson, Sawyer)

Work on the total cross-section of iridium is nearing completion. A second sample of $IrCl_4$ solution, more concentrated than the first, has been used to investigate the regions of low absorption. This sample, like the first, has been quantitatively analyzed by Mr. Hume's section of the Chemistry Division. A third sample, having a concentration comparable to that of the first, has also been prepared and is being used to check the peak values again. A final report on this problem will soon be issued.

PX6-1 - Pile Modulation - (Pardue, Moak, Strong, Wollan)

The linearity and sensitivity of the instrument have been established. As shown in Fig. 1, adding absorbers up to 0.06 cm^2 to the sample container gives good linear performance. The sensitivity of the instrument is such that 0.005 cm^2 can be measured with about 30% accuracy relative to the standard. The accuracy becomes proportionately better for larger absorbers. Pieces of Cd, thick enough to be black, are at present being used as standards (Fig. 1). A preliminary value of 6 barns has been obtained for Pd. Considerable time has been consumed in recent days in installing the new reciprocator which gives a larger amplitude of oscillation -- about 30 inches. Already it appears that the sensitivity has been increased by a factor of at least 2.

[redacted]

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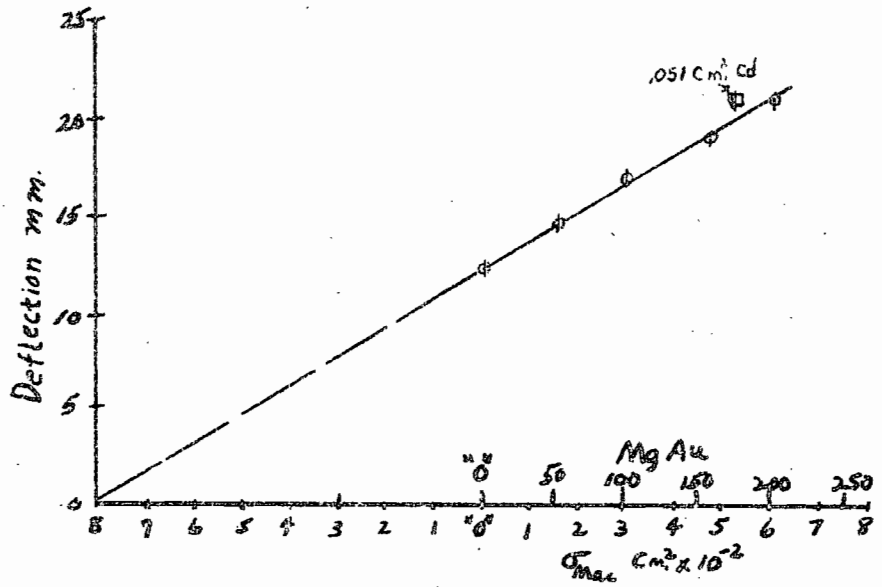
FIG. 1.



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PX10-16 - Characteristics of Fission Product and Neutron Induced Activities - (P. W. Levy)

Considerable effort has been expended to improve the stability of the G. M. counters in the 180° spectrometer. As a check on a new coincidence circuit, preliminary to investigating the gamma spectrum of Pa^{233}, the gamma spectrum of 57 day iridium is being investigated by the method of photoelectric emission from a radiator. The coincidence circuit has proved troublesome and still requires improvement.

PX1-11 - Search for Soft Gamma Emitter - (P. W. Levy)

We have received another request for a one curie source of gammas whose energy is in the 100 to 200 kev region. From a survey of the literature it appears that 48 day In^{114}, which emits a gamma of 190 kev, may prove satisfactory.

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Physics Section IV

L. B. Borst, Section Chief
S. Bernstein, Associate Section Chief

Total technical personnel (including supervision)..... 8 (this period)

Problem Assignment Number	Subject	Status	Percentage of Section Manpower Report Per.	Next Per.
PX10-7	Fissionability of 40-10	Inactive	0	0
PX10-8	Neutron Diffraction	Active	35	25
PX10-10	Deuterium Gamma Ray Spectrometer	Active	15	15
PX10-14	Poisoning Coefficients	Inactive	0	0
PX10-15	Photoneutrons from Fission	Active	25	35
PX10-17	Fissionability Studies	Active	25	25
		Total.....	100	100

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PX10-7 - Fissionability of 40-10

Inactive.

PX10-8 - Neutron Diffraction - (Osborne, Hasbrouck, Ulrich)

A study of the fission cross-section of U^{235} as a function of energy, has been started. For the purpose of measurement, a special fission chamber has been constructed by Mr. Borkowski's group. The active surface is 1" x 14" and is oriented at a glancing angle with the beam. The enriched layer consists of 40 mg of U_3O_8 deposited electrolytically upon a platinum strip. This chamber shows adequate sensitivity in the thermal region to permit a study of the first and perhaps the second resonance in U^{235}. No data are yet available on this spectrum.

A chemical process has been developed for the separation of a few curies of I^{135}. This amount after decay to Xe^{135}, should be adequate for spectrometer measurements of the thermal resonance. After preliminary runs have been made with the shielded apparatus, an attempt will be made to prepare such a sample.

PX10-10 - Deuterium Gamma Ray Spectrometer - (Bernstein, Wolfe)

The thermal column on top of the pile is now free. It is being adapted for use with the deuterium ion chamber. Hole No. 52 has been abandoned because tests showed the presence of fast neutrons in the beam. Changes in the ion chamber are being made which we hope will reduce considerably the microphonic disturbances.

PX10-14 - Poison Coefficients

Inactive.

PX10-15 - Photoneutrons from Fission - (Bernstein, Wolfe)

The apparatus for this experiment is nearing completion in the shops. Measurements will be started within the next month.

PX10-17 - Fissionability Studies - (Floyd, Dial)

The thermal fission cross-section of Bi^{209} has been limited to $\sigma < 10^{-30}$ cm^2. This value was obtained using the photographic track technique. A specimen of metallic bismuth was placed in contact with the fission sensitive plate and exposed to a thermal flux of 2×10^{11} $n/cm^2/sec$ for ten seconds ($nvt = 2 \times 10^{12}$). An area of 0.077 cm^2 was examined without observing a single fission track. Additional surveys in other parts of the plate likewise showed no fission tracks. Assuming all fissions occurring within 1 mg/cm^2 of the surface of the bismuth to record as a recognizable track, the cross-section for thermal fission amounts to less than 10^{-30} cm^2.

A deposit of Pa^{233} was prepared by Mr. Bohlman's group with the assistance of Mr. Rose of Section P-III. The deposit had the following estimated analysis:

Pa^{233}	0.2 μg
U^{233}	$< 10^{-4}$ μg
Th^{232}	.01 - .1 μg

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The growth of U^{233} has been followed by standard exposure and counting. The data (preliminary in character) indicate a thermal fission cross-section at zero time of about 10% that of U^{233} or $\sim$ 50 barns. In the light of the above analysis this cross-section cannot be attributed to contamination by U^{233} nor to normal uranium. It is, therefore, presumed that Pa^{233} must be thermally fissionable with a cross-section of 50 $\pm$ 30 barns.

The thermal fission of Pa^{233} is unexpected and cannot be predicted from the Bohr-Wheeler theory of fission. Pa^{231} has a fission threshold of 400 KV and Pa^{233} should be fissionable only at higher energies. Under the conditions of the experiment the observed cross-section cannot be accounted for by fast fission.

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