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ISSUED TO: A. V. Peterson

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PHYSICS DIVISION

MONTHLY REPORT FOR FEBRUARY, 1947

* * * * * * * * *

L. W. Nordheim
Division Director

Date Received: 3/17/47 Date Issued: 3/17/47

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The chief event in the work of the Physics Division was the start up of the critical experiments with enriched U^{235} in light water and aluminum, with a heavy water reflector. These experiments are to study the properties of the high flux pile which is being designed now. The present installation is the result of an arduous task of preparation and procurement. The arrangement as described in more detail in the later parts of this report, had been carefully checked for safety by the most experienced members of the Division and by an independent laboratory committee. It has turned out to be very convenient and manageable. The method of changing the amount of fuel by adding integral tube units containing a fixed amount of reactor material, whose effect is small compared to that of the control rods makes it a much safer instrument than the original water boiler at Los Alamos. The behavior of the unit was beautiful, and it turned out to be very easy to control the neutron level, in spite of the relatively short neutron life time. The experiments have already contributed notably to our knowledge of enriched piles. The theoretical treatment of such piles is difficult, due to the facts that many constants are not too well known, and that the mathematical problem in small piles is a very difficult one. Direct checks by experiment are thus necessary at every step. In the present case satisfactory agreement has now been reached between observed and calculated critical masses. Work is now in progress on the neutron distribution which is of prime importance for the design of the new pile. We have also obtained a sufficient quantity of Be, to use as reflector in the experiments, so that it will be possible to approach more closely the arrangement in the high flux pile.

Very substantial progress has also been made with respect to the control system for the high flux pile. The outline of the integrated system is now

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emerging, and design of the circuit details has already been started. The model servo system has been finished and the incorporation of the Xe effect in the simulator has been accomplished, so that the two systems can now be tied in together. It has been interesting to observe that substantial increase of the Xe effect over the expected value in the new pile would cause a degree of instability which would not be controllable. The design of a modulator type power indicator has progressed so far that it seems quite feasible to obtain an instrument that could measure a range of order 10^{-9} to 10^{-10} to full power.

A report on all the theoretical work on the high flux pile is now being compiled and will be issued in the near future. Active work has continued on control rod effectivity, neutron distribution, heat distribution and other questions. The matrix method for the "Multi-group - Multi-reflector Pile theory" has been brought into a final practical form, and a report has been issued. A study has also been made on the activities to be expected in the pile after prolonged operation, in order to determine how far replacements of pile parts will be possible.

The neutron age program has been continued actively. Calculations have been made on slowing down distances and fast mean free path for various combinations of Be, D_2O, H_2O, Al. The theories for slowing down in H_2O-D_2O mixtures and in heavy elements have been materially advanced. The experiments on age in graphite have been completed, and are being evaluated presently. The tank for age measurements in Al-H_2O mixtures has been installed in the thermal column.

The long range group has continued its studies of various pile types, such as breeders with distributed fertile material, certain modifications of fast and resonance piles, and power piles with fissionable material dissolved in

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liquid metal, and with liquid phosphorous as coolant. Other work of this group refers to collection of nuclear data and shielding problems.

In the nuclear states program, carried out by a number of investigators in different sections, efforts are being made to clarify the disintegration properties of interesting isotopes by different experimental approaches. It has been found that the isomeric state from the decay of the 32 day Yb follows a K capture process, and has thus to be ascribed to Tm, and not to Lu, as previously reported. β spectrographic work has been started on this substance. A β analysis of the 24 hr W has also been made, where the maximum energies of the two components and numerous conversion lines have been measured. The thin lens β spectrometer has been used for the study of Ga after a method of evaporating Ga had been developed, and Ga^{70} has also been studied in the γ integration apparatus.

In the experiment on neutron decay a thorough study has been made of the collection system for the decay protons which has shown the possibility of considerable improvement.

In the neutron diffraction work, comparison of coherent, diffuse and total scattering power have been made on diamond, graphite and charcoal. These observations give a check on the reliability of the use of ratios of coherent to diffuse scattering for other effects. Samples of NaD have been successfully prepared and measurements have been taken. The structure of NaH has been confirmed. It has been found, as expected, that the deuterated compound gives a smaller diffuse background than the hydrogenous one, and also that H and D scatter with opposite phases.

The apparatus for the study of the ranges of delayed neutron emitters has been completed and seems to perform very satisfactorily. Measurements are being started now.

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As a sideline, it may be mentioned that a personnel monitoring meter has been constructed that is easily carried and that integrates the total irradiation. It then gives an audible signal when a preset total irradiation is reached, and permits thus to carry out work in danger areas with the assurance of indication when tolerance exposure has been reached.

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Physics Section I

A. H. Snell, Section Chief
S. Bernstein, Associate Section Chief

Total technical personnel (including supervision)..... 17

PX1-7 - Carbon 14 Production - (Norris)

A number of samples of the mass-spectrographically analyzed C^{14} have been recrystallized and recounted for absolute specific activity. These samples had been suspected of containing impurities which would have affected the half-life determination.

Neutron Decay - (Saxon, Miller, Snell)

A rubber-model investigation is being made of the efficiency with which the protons were focused for counting. In the arrangement used thus far, the efficiency was found to be low -- perhaps 10 percent. It has been found that if the entrance slit to the multiplier can be widened from about 1/2" to 1-1/2", collecting efficiencies up to about 90% can be realized, even without grid-wires. The possibility of eliminating grid-wires is very attractive, for they furnish the remaining surfaces of high curvature which promote field emission and cause the troublesome counts which appear when the collecting voltage is turned on. A wide slit can be used if the first plate of the multiplier can be considerably enlarged. The problem thus becomes one of focusing the electrons from the large first plate onto a considerably smaller second plate, without losing them through the wide slit to the positive electrodes outside. Rubber model studies are now in progress in relation to this problem.

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PX8-1 - Gamma Ray Spectra - (Haynes)

The thin lens beta-ray spectrometer has been used during February for the study of the beta-spectra of $_{31}Ga^{72}$ and $_{31}Ga^{70}$. Careful calibration runs were made with the annihilation radiation of $_{29}Cu^{64}$ using Au and U radiators.

Gallium has been successfully evaporated in vacuum. A report on this is being given at the meeting of the S. E. Section of the American Physical Society, in April.

The spectrum of $_{31}Ga^{72}$ has been investigated out to 2.1 Mev. The existence of two beta-ray components found by Siegel and Glendenin[1] by absorption has been verified. The exact end-point of the high-energy component cannot yet be assigned because its end-point is of the order of 3 Mev. The Kurie plot of the high energy spectrum deviates markedly from a straight line around 1 Mev where the end-point of the low energy spectrum occurs thus making the exact determination of this end-point very difficult.

A rough spectrum of $_{31}Ga^{70}$ (half-life $\sim$ 20 min) was obtained by subtracting the $_{31}Ga^{72}$ (14.1 hr) counts from the early readings of the run. The Kurie plot is straight indicating a single beta-ray component with an end-point between 1.6 and 1.7 Mev.

A thin window counter for the measurement of 30 kev conversion electrons of $_{46}Pd^{103}$ is being made with the assistance of Mr. R. L. Butenoff of the Chemistry Division.

The program for the future is as follows:

1. Take measures both to know and to reduce external background, γ-ray background and scattering background.
2. Provide a standard source for counter calibration.
3. Make several short irradiations to obtain a better spectrum of $_{31}Ga^{70}$.

(1) Siegel and Glendenin, CC-2835, June 1945.

[redacted]

4. Lengthen the spectrometer to get the high energy end of the spectrum $_{31}Ga^{72}$.

5. Measure 30 kev conversion line of $_{46}Pd^{103}$ in conjunction with Brosi, Borkowski, and Butenhoff of the Chemistry Division.

6. Construct coincidence circuits for the separation of the two spectra of $_{31}Ga^{72}$.

PX8-4 - Gamma Energy per Beta - (Barker)

Studies were made of the 20 minute Ga^{70} activity. A value 20.3 minutes was found for the half-life, and absorption measurements gave 1.62 Mev for the maximum beta energy. The work is being coordinated with that of Haynes, using the magnetic lens.

PX10-15 - Photoneutrons from Fission Products Program - (Blizard, Levy, McKinney, Bernstein)

We are now taking measurements for the system 49 + D_2O.

PX10-8 - Capture Cross-section of Xe with the Crystal Spectrometer - (Shapiro, Dial, Stanford, Bernstein)

We are continuing with our work of improving the crystal spectrometer. We have had several conferences with the chemists, Freed, Parker, Brosi, and their associates for the purpose of discussing problems in the preparation of the sample, analysis of the sample for amount of Xe it contains, procedure to be used in taking the spectrometer measurements, etc. We plan to continue these seminar meetings once every two weeks as long as it seems profitable to do so.

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

Readers of these monthly reports may have noted that the critical experiments group did not submit a report on January activities. That month saw a good amount of strenuous activity in final preparation for the critical experiments on which we are able to report now. For example, a description of the experiment for review by the Commission was submitted to Dr. Murphy on Jan. 6; the major portion of construction work was completed in the shop by January 20; preparation of fuel tubes (glyptal coating on inside) was pushed vigorously so that the Chemistry group was able to deliver a considerable quantity of fuel ready for use by the first of February.

By February 1, installation and checking of equipment was completed. Therefore, on February 3, at our request, the laboratory Safety Committee - Coe, Leverett, Morgan - inspected and approved the arrangement.

Experiments are now in progress on pile arrangements similar to the proposed high flux experimental pile. We are using a small aluminum tank which holds the reactor proper and this tank is surrounded with P-9 acting as reflector. There are no top and bottom reflectors. The reactor assembly consists of 1" x 1" square aluminum tubes, containing UO_2F_2 dissolved in H_2O, packed closely together.

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The present reactor shape is cylindrical. To insure that no air gaps exist between reactor and reflector, we therefore insert into unused tube spaces tubes containing P-9. Furthermore, the reactor tank is filled with P-9 to the height of the active fuel so that no air gaps exist due to the jagged periphery of a square tube assembly in a round tank.

One of the items of major interest in these experiments is the volume ratio of aluminum to water. The apparatus is therefore arranged so that we may vary this ratio from 0.303 to approximately 0.88. We are now using Al/H_2O (volume) of 0.88 and find a critical mass of 2488 grams. The last two digits of this figure are in question until quantitative analyses of uranium content of our fuel tubes are completed. This work is in progress.

The critical mass quoted is obtained with five holes in the reactor, each hole being 1" x 1" in cross section and extending over the full height of the reactor. These holes are control rod ports, one being in the center and four on the periphery, placed symmetrically.

Neutron distributions are being obtained and we expect to report on this subject, both theory and experiment, next month.

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SOLID-STATES RESEARCH

S. Siegel, Acting Chief

Little to report in the way of results. Design, building, and testing of apparatus continued. Work on the construction of the hot laboratory was begun. Some samples were prepared and measured previous to insertion in the pile.

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Physics Section II

A. M. Weinberg, Section Chief

Part of the section (Spinrad, Soodak and Weinberg) has moved to 735-B to devote more time to problems connected with design of the experimental pile. Mr. V. Haskett of the training school has joined the group.

Experimental Pile (Spinrad, Soodak, Greuling, Weinberg)

A report is being prepared which will contain all relevant calculated data on the experimental pile. This report will bring Mon P-206 (Physics of the High-Flux Pile) up to date. It is hoped that the major part of the theoretical work on the pile will be complted with the appearance of the report.

Several jobs directly connected with the pile have received our attention. Among them are

1) Completion of calculations of control rod effectiveness (Spinrad). According to our calculations 6 Th rods and 7 Cd rods give a control of about 11% and 29% respectively in a pile in which all removable Be is replaced by active assemblies.

2) Design of a hydraulic shock absorber for safety rods (Soodak).

3) Calculation of neutron distribution outside of pile to show effect of a Th blanket at various distances from pile interface (Spinrad).

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4) Calculation of heat dissipation in concrete shield (Coveyou, Weinberg). We now believe that the thermal shield should be 6 inches thick.

Constants Calculations (V. Maskett, P. O. Levy, M. E. Rose)

Slowing down distances and fast mean free paths in several more systems have been calculated this month. The results follow:

Material	τ (to .03 ev)	λ_f
Be + 2% H_2O	87 cm^2	1.93 cm
D_2O (isotropic scattering)	149.6	3.38
D_2O (anisotropic scattering)	147.5	3.41
D_2O + 35% Al	279.8	4.78

The average age of fission neutrons in D_2O has been calculated by age theory assuming isotropic scattering in the c. of g. system, and assuming a non-isotropic scattering law suggested by Buckingham and Massey's calculated phase shifts for the doublet and quartet p waves. The procedure used was described in January monthly report. The results are very nearly the same-149.6, and 147.5 cm^2 respectively. These values are considerably higher than the observed 125 cm^2 and higher than Plass' reported calculation of 125 cm^2. The discrepancy between our value and Plass' arises from the fact that Plass used a set of ages computed by Fermi in which the first and last collision corrections were not applied.

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Critical Experiments

a) Light Water-Al Systems: P-9 Reflector (Greuling, Spinrad and Haskett)

Agreement between two group calculated critical mass and the observations is excellent at an Al-H_2O volume ratio of 0.88. The calculated critical mass is 2.5 kg, the observed is about 2.4 kg. The observed neutron distribution has not yet been compared with the calculated.

b) P-9 System: P-9 Reflector-(Garabedian, G.Nordheim,Soodak)

The two group calculations do not agree very well with the critical masses observed last year by Snell and his associates. The discrepancies are of the order of 15% to 25%, the calculated values being low.

A variation treatment of the problem in which the P-9 slowing down kernel is represented by three groups is being undertaken. Presumably very accurate results should be obtained this way.

Slowing Down in Heavy-Light Water Mixtures-(M. E. Rose)

The problem of the second moment in heavy-light water mixtures appears to be solved. From a certain general set of equations (to be discussed in a forthcoming report) it is possible to obtain approximate formulas applicable in two limiting cases: (1) small amount of light water, (2) small amount of heavy water.

Slowing Down in Heavy Elements-(M. E. Rose)

Starting from the integral equations for the moments an improvement on the Fermi age has been obtained for a slowing

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down mixture which does not contain hydrogen or deuterium but is otherwise arbitrary.

Photo-Disintegration of the Deuteron - (M. E. Rose, G. Goertzel)

This work is now completed and is to be presented at the May 1-3 meeting of the American Physical Society.

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Physics Section III

E. O. Wollan, Section Chief

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

Neutron Diffraction -- (Shull, Wollan, Marney)

Diffraction patterns have been obtained for powder samples of diamond, graphite and charcoal. From measurements of the diffraction peaks and the diffuse background, the ratios of the coherent, diffuse and total scattering cross sections could be evaluated. Relative values for these cross sections are given in the following table.

	Relative Cross Sections (no units)		
	Coherent (Bragg)	Diffuse	Total
Diamond	15.3	8.8	24
Graphite	16.2	13.4	30
Charcoal	small	$\sim$ 35	$\sim$ 35

The somewhat lower value of the total cross section for diamond may have been caused by extinction effects. The diamond data above were taken with an 800 mesh powder and this may not have given a particle size small enough to eliminate primary extinction. Comparative tests on 300 and 800 mesh powder showed a 15-20 percent difference between these sizes. It is to be noted that even with diamond an appreciable amount of diffuse scattering (some 30 percent of total) is present. Attempts are being made to compare this with that predicted by the Weinstock theory.

Diffraction of Neutrons by Hydrogen and Deuterium Containing Crystals
(Morton, Davidson, Shull, Wollan, Marney)

In order to confirm the diffraction results reported last month for a sample of commercially obtained NaH, suitable equipment for manufacturing this compound was set up and a batch of NaH was prepared and examined.

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The diffraction pattern obtained for the Clinton Laboratory preparation checked excellently with that for the earlier sample.

The chemical manufacturing equipment was then used to prepare a sample of NaD and a preliminary examination of this material has been obtained. In contrast to NaH (which shows a (111) peak and a little or no (200) peak), the (200) peak for NaD is two or three times stronger than the (111) peak. This indicates that deuterium and sodium scatter with the same phase, whereas hydrogen scatters with opposite phase. The diffraction pattern for NaD and an estimate of the coherent scattering cross section for deuterium will be given in the next schedule.

Delayed Neutron Problem --(Good, Wollan)

The apparatus for the delayed neutron problem has been essentially completed. The performance has been found to be most satisfactory. In particular, (a) it has been observed that the remote control works well and it will be possible to work indefinitely without danger of over-exposure; (b) counting can be started within three to four seconds after the rabbit starts to leave the pile so that the 4.5 second activity should be easily accessible to study; (c) on an overnight test, the rabbit was shown to have no significant leakage. Significant means that the chamber did not leak in excess of the 0.1 mm, which is the present limit of pressure measurement of the gas in the rabbit. It is expected that measurements can be started at once.

PX10-23 - Neutron Age Measurements (Hill, Roberts)

Twelve experiments were made with the source in the position three feet above the top of the thermal column as described in the monthly report for January.

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Also, seven experiments were carried out with the source in the position at the top of the thermal column to get information for points far from the source. Data were taken out to 140 cm in this position.

The results of these two sets of experiments are being analyzed.

The graphite sample used in the above experiments has been moved to the edge of the pile for use with an Sb-Be neutron source and the water tank described in the January report installed on the thermal column, after removing two feet of graphite to increase the neutron intensity for the water experiments. A sample and source holder for these experiments has been constructed and everything is in readiness for the water measurements.

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Physics Section IV

S. DeBenedetti, Section Chief

PX10-22 -- Search for Short Lived Isomers (DeBenedetti, McGowan, Schweinler)

Work with sources of 32 days Yb was continued. In order to explain the origin of the abundant soft electromagnetic radiation preceding the short lived isomer it was suggested by Dr. Good that the 32 days Yb decays by K capture. It was then rather gratifying to learn that this isotope had already been studied by Bothe (Zeit.f.Naturf. 1, 173, 1946) and it had been found to decay by K capture. If this is the case the delayed coincidences observed are due to an isomeric state of Tm, and not of Lu as reported in the last monthly report.

Mr. P. W. Levy (see under PX10-16) has started some β-spectrographic work for the determination of the energy of the short lived isomers of Re and Tm. It is honed that this work might contribute to the clarification of the disintegration schemes, and also to the knowledge of the polarity of these forbidden transitions, through a study of internal conversion coefficients. The 22 μsec La could not be studied in this respect because we were unable to prepare good Hf sources for the spectrograph.

Assembly work for the completion of the circuit to explore the range of 10^{-7} sec. is under way.

Mechanism of emission of Prompt Fission Neutrons -- (DeBenedetti, Preston, Francis)

Hole #57 of the pile has been opened to let out the neutron beam with which we hope to perform the experiment on the coincidences between fission neutrons. An appropriate catcher and shutter for the beam have been installed. The intensity of slow neutrons seems to be more than sufficient; it is feared, however, that the fast neutron background might be too high in the present conditions of the hole.

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The work on instrumentation has been summarily described in two abstracts which have been submitted for declassification, for presentation at the next Washington meeting of the American Physical Society.

PX10-16 -- 24.1 Hour Tungsten -- (P. W. Levy)

Preliminary values for the maximum energies of the two components of the β-ray spectrum of the 24.1 hour tungsten activity have been determined with the 180° spectrometer as .562 and 1.35 Mev. Numerous conversion electrons are observed. Additional work on the γ-rays is under way.

An attempt to observe the β-ray and conversion electron spectra of Yt was inconclusive as the source used was much too weak.

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Physics Section V

Henry W. Newson, Section Chief

Total Technical Personnel.....10

A large part of the time of senior members of the group has been taken up with discussions of the integrated control system. We now feel that we have solved the problems of the conflicting demands of various parts of the system. Mr. Trimmer and Mr. Epler, an electrical engineer who will join the group March 24, will prepare the circuit diagrams.

A brief summary of the control scheme is given in MonP-272. A discussion of some of the principles of the control of this pile will appear in MonP-271.

Mr. Jordan has been considering the usefulness of a modulated ion chamber similar to that used in the pile oscillator. He estimates that with such a device we may obtain continuous indication of the neutron intensity in the high flux pile when it has been reduced in power by a factor of 10^9 to 10^{10}. This is a considerable improvement over our previous plans which allowed continuous measurement over a factor of only 10^6 to 10^7. It is hoped to modulate the neutron intensity by 25 to 75%.

The simulator including the effect of Xenon and Iodine has been completed for some time. There is provision for

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reducing the Xenon and Iodine periods by a factor of 100. Under this condition the instability is beautifully demonstrated. When the simulator is set to the actual periods of Xenon and Iodine the instability is much less marked and it is not difficult to maintain the pile at a constant level by manual manipulation of the simulated control rod.

Development is still proceeding on the circuit for measuring $\frac{d \ln n}{dt}$. The logarithm of the intensity can now be measured sufficiently accurately over a factor of 10^5 in intensity. However, the part of the circuit which takes the time derivative needs further development.

An instrument called a "pocket-screamer" has been invented by Bell. This is a pocket ionization chamber together with suitable circuits which will warn an an experimenter that he has been exposed to 0.1 R or any other arbitrary value. We feel that this will be a great convenience in experimental work where strong radioactive sources are involved.

Some preliminary calculations have been made on the possibility of a major change in the high flux pile after it has been operated for a year or more. Data in CP-1861 seem to indicate that rather large quantities of graphite and and aluminum, and smaller quantities of iron and chromium may be removed from the shielding. However, stainless steel can probably not be handled without a very heavy coffin. Mr. Overman of the chemistry division has agreed to make measure-

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ments which will increase our knowledge on these points.

Preliminary experiments are now underway to lead up to the neutron age measurements in Building 105E. A γ-n source containing only 1 curie of anamony is being used. A far stronger source must be used in the actual measurements.

A second life-test of various types of boron coatings confirmed the selection of B_{10} suspended in aquadag. Although this coating apparently loses most of its original resistance to abrasion, its sensitivity decreases only 15% after irradiation for 3.4×10^{13} nv-days.

A series of rough qualitative tests on various materials of construction indicated chemical lead as a possible material for an ionization chamber. Such a chamber was built consisting entirely of chemical lead with quartz insulators. In a flux of 2×10^{9} nv/cm^2/sec, the chamber shows 85% saturation at 500 volts. Mr. Mead will test its useful range shortly.

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Physics Section VI

G. Young, Section Chief

Total Technical Personnel (including supervision). . . 9 and 6 Trainees

Nuclear Data - An up-to-date list of thermal neutron absorption cross-sections is being compiled (Diamuke, Noderer, Way). A list of neutron resonances with widths where known is also in preparation (Haines, Way). A study is being made of the energy distribution of neutron sources (Diamuke).

Fission Product Poisoning - (Noderer, Householder).

A summary of known thermal cross-sections, with certain simple statistical data on these, is being prepared.

A memo (CL-LCN-1, Feb. 17, 1947) has been issued.

Multiple Group Theory - (Garabedian, Householder).

A report entitled "Multi-group, Multi-reflector Pile Theory" has been issued as MonP-246; this considerably extends the discussion given earlier in MonP-202. The matrix methods here developed are being employed by Spinrad in calculations on the hi-flux pile.

Flat Piles - (Goertzel).

Calculations are being made on piles in which the breeding absorber is distributed in such a way as to keep the thermal neutron flux uniform throughout the pile proper; thus, only fast neutrons flow to the reflector.

Resonance Piles - (Bendt).

Some calculations for piles operating at high resonance energies (Above 50 ev) have been made using analytic approximations for the fission cross-section dependence on energy.

Fast Piles - (Menke).

Some one-group calculations have been made to see how the thickness of a Bi reflector affects

(1) the saving in pile size.

(2) the fraction of the leakage neutrons which survive passage through the reflector to an exterior absorber, i.e. the "breeding efficiency" of the reflector. This is a particularly simple example of the types of breeding blanket problems being studied by Goertzel and Householder.

Calculations on mixed fast and slow piles (MonP-250, p. 32-34) are in abeyance until a computer can be obtained.

Pile Blankets - (Householder, Goertzel).

Work continues on putting together the results obtained so far, with attempts to obtain improved mathematical analyses.

Shielding - (Murray, Libbey).

A first draft of a paper giving further theoretical calculations on neutron penetration has been written, and data from pile shielding experiments is being compiled.

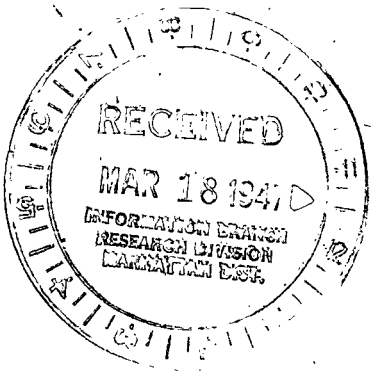
Power Plants - (Grebe).

A report is being written on the use of phosphorus instead of

mercury in the high temperature end of binary power plants. As a fluid element with a not unduly large capture cross-section (about 0.2 to 0.3 barns) for thermal neutrons, phosphorus may possibly be of some interest for pile use. Information from TVA on corrosion by phosphorus is not discouraging.

Power Pile - (Young)

A report entitled "Outline of a Liquid Metal Pile" is being typed. The unit considered is a thermal pile with Bi coolant and Be metal moderator, and with the fissionable material (23) dissolved in liquid metal.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