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# PHYSICS DIVISION

## Monthly Report for December 1946

L. W. Nordheim

January 15, 1947

Date Received: 1/15/47

Date Issued: 1/15/47

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The effect of the additions to our staff and the incoming of the trainees during the last year is making itself felt now in an increasing scientific output. This is evidenced by the volume of this report for December, in spite of the holiday season.

Procurement difficulties for the critical experiments have been overcome by vigorous action, and the installation is practically completed. Measurements should start definitely this month.

The new thermal column on the top of the graphite pile has been installed and tested. It is considerably more convenient for operation than the old one, and the flux distribution shows considerably better regularity. The column will be used presently for age measurements in $H_2O$, $H_2O$-Al mixtures, Be and BeO.

With respect to the heterogeneous pile, advances in the development of control instruments should be mentioned especially. A vibrating condenser monitron has been built which will be suitable for the d log n circuit as required for the control of the high flux pile. The improved ionization chamber, mentioned in the previous report, is now undergoing life tests. A promising direct indicator for reactivity changes is being studied. The principle consists in the measuring of the phase angle between a modulation of reactivity and the response of the pile.

In the theoretical work for the new pile, results have been obtained on the reactivity changes due to the Th. blanket and the effectiveness of Th-water control rods. The space distribution of energy loss of fast neutrons has been worked out. It has also been pointed out that thermal neutrons require a finite time to diffuse an appreciable distance, and that this effect will have to be considered in conjunction with the controls of the new pile.

The long range pile group has continued its theoretical studies of various pile types. A systematic program for the study of shielding problems is now under way.

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Experimental results of interest have been obtained in the following investigations:

The apparatus for measurement of total $\gamma$ energy per $\beta$ disintegration by integration of intensity over a large aluminum block is now being used for actual measurements. Runs have been made with $Na^{24}$. It has been confirmed that the two known $\gamma$ rays of 1.38 and 2.76 Mev are emitted in cascade. This result removes a question mark with respect to the disintegration cross section for D and Be for 2.76 Mev gammas, reported previously to be 12.8 and 5.9 x $10^{-28}$ $cm^2$.

The end point of the continuous $\beta$ spectrum of the 4 year "61" has been measured with the 180° spectrometer. The value is .223 Mev.

The apparatus for the investigation of short lived isomers is being refined by installation of a coincidence circuit that will make it possible to extend its range to $10^{-7}$ sec.

Measurements have been made on the rise of thermal flux in a central region of the graphite pile upon removal of metal. The rise in flux is highest if only two adjacent channels are unloaded. No increase in flux results from the presence of 9 or 20 empty channels, as compared to 2, so that any flux increase must be quite sharply localized. It is, however, possible to obtain a region of high cadmium ratio without much sacrifice in flux.

Neutron diffraction measurements have been continued with CaO, CaS and $CaC_2$ powders. From the relative intensities of various peaks relative values of the effective coherent nuclear scattering can be calculated and the ratios of the diffuse scattering cross sections per molecule to the nuclear cross sections can also be obtained. The diffuse scattering observed is rather high, and there seem to be considerable differences between cross section ratios from handbook values and those evaluated from the scattering experiments.

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The temperature dependence of scattering intensities has been studied for CaO and CaS, and it has been found to be small both for the coherent and diffuse scattering.

New observations on BeO, together with older data, show definitely that Ca, O, S, C, Mg and Be all scatter with the same phase. This is in agreement with results reported from the Argonne.

The status of other current investigations can be seen from the detailed reports.

[redacted]

## Physics Section I

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

Total technical personnel (including supervision)..... 14

| Problem Assignment Number | Subject | Status | Man-months of Effort Report Per. | Man-months of Effort Next Per. |
|---|---|---|---|---|
| PX1-7 | $C^{14}$ Production | Active | 1 | 1 |
| PX8-1 | Gamma Ray Spectra | Active | 1 | 1 |
| PX8-2 | Photoneutron Sources | Inactive | 0 | 0 |
| 163-X39P | Service Flux Measurements | Active | $\frac{1}{3}$ | $\frac{1}{3}$ |
| PX8-4 | Gamma Energy per Beta | Active | 1 | 1 |
| PX5-22 | Critical Experiments | Active | 3 | 3 |
| | Neutron Decay | Active | $2\frac{1}{3}$ | $2\frac{1}{3}$ |
| Px10-17 | Fissionability Studies | Active | 1 | 1 |
| PX10-8 | Neutron Diffraction | Active | 2 | 2 |
| PX10-15 | Photoneutrons from Fission Products plus P-9 | Active | 2 | 2 |
| | | Total..... | 14 | 14 |

[redacted]

PX1-7 - Carbon 14 Production - (Norris)

Some details in the half-life determination of $C^{14}$ are being dealt with, looking toward a detailed report on the subject. A short description of the $C^{14}$ factory and its accomplishment has been started through declassification for possible publication in "Science".

PX8-1 - Gamma Ray Spectra - (Haynes)

The earth-compensating coils have been assembled around the spectrometer, and a filter has been installed to reduce the ripple in the lens current. A calibration run with $Cu^{64}$ will be made in the very near future.

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

Two runs have been completed with $Na^{24}$, giving the results respectively of 4.15 and 4.19 Mev of gamma radiation per beta disintegration. This is in good agreement with the sum of the energies of the two gamma rays as measured with spectrometers, viz. 1.38 and 2.76 Mev. Coincidence measurements previously had indicated that the two gammas were in cascade; our new measurement corroborates this by a completely independent method. The suggestion of Sachs in a recent letter to the editor of the "Physical Review" is not supported by this measurement.

PX8-2 - Photoneutron Sources - (Barker, Sternberg, Snell)

Barker's results on the gamma rays of $Na^{24}$, quoted above, allow us to reassert with greater conviction our old measurement (MonP-46) that the photodisintegration cross sections for D and Be for 2.76 Mev gamma rays are respectively 12.8 and $5.9 \times 10^{-28} cm^2$. The figure 12.8 is considerably higher than

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the theoretical value of 10.6 for the deuteron, as derived from the formula of Bethe & Bacher. It also seems high compared with Halban's experimental value of 10 for the gamma ray at 2.62 Mev; however, Halban himself stated that his value is probably low.

Neutron Decay - (Miller, Saxon, Snell)

The electron multiplier tube was found to have lost sensitivity, and its plates have been re-coated with beryllium. It now seems to be more sensitive than ever. The vacuum system has been modified by a change in diffusion pumps, and the inclusion of two right-angle bends between the pump and the main vacuum tank; this should reduce the diffusion of oil into the main tank. A built in "wiggler" has been added, by which the entrance to the multiplier tube can be (1) left open, (2) covered with a 1 mg/cm$^2$ thickness of nylon, or (3) closed, with the presence of a small sample of uranium for standardization purposes, using the alpha-particles. Efforts are now being devoted to improving the counting performance by eliminating some R. F. pickup from the high-voltage supply and one or two other undesirable effects. A thin $B^{10}$ absorber has been made, which will be used to interrupt the beam to give us our desired slow neutron difference.

Effect of Removing Central Uranium upon the Central Thermal Flux in the Clinton Pile - (Snell, Arnette)

These measurements were undertaken following a suggestion made by A. M. Weinberg to the effect that a local increase in thermal flux might be obtained over that prevailing in the smooth distribution of a fully loaded pile, if some of the uranium near the center were removed so as to leave a region

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of pure graphite. As it turned out, one channel (No. 1868) of the Clinton pile is normally uncharged, and a neighboring one (1867) is mostly uncharged (it contains only two "doughnuts") so that the looked-for effect had already been achieved. However, it may be worth while to put on record the measured effect of unloading a larger region.

Fig. 1 is a sketch of the central region of the loading face of the Clinton pile; it shows the locations of various holes and slots which concern us here. Channel 1870 is loaded with molybdenum. The position of foil slot 62, which was used in the measurements, is indicated.

Measurements were made with 6.5 x 4 cm indium foils using the spontaneous and delayed neutrons present in the pile when it is shut down, and all of its control rods in. After a wait subsequent to shutdown, four foils were simultaneously inserted at positions respectively designated as A', B', C' and D'. A' and B' were designed to be monitoring positions; they were in slot 61, respectively 17½ and 14 feet in from the outside of the pile shield. C' and D' were in slot 62, respectively 22 and 19 feet in from the outside of the charging face. The effect under study, therefore, was a change in neutron flux at C' and D' relative to A' and B' as the loading was changed. Fig. 2 gives the positions A', B', C' and D' in a horizontal section of the pile. The four positions were coplanar vertically.

It was found necessary to seal the foils in aluminum boxes, using scotch tape; otherwise they picked up large contamination activities. No measurements were taken with cadmium-covered foils.

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The saturation activities $A_s$ of the indium foils are given in counts per minute in the following table. The loading conditions are there described with reference to the channels marked X, Y and Z in Fig. 1.

The figures show that the central flux ($C^0$ and $D^0$) is relatively highest when only the two channels X are empty; further unloading merely flattens the flux distribution. H. W. Newson informs us that a flux increase of the type sought had been observed in one channel when a neighboring channel had been emptied, and that one might, for example, examine the flux in hole A (Fig. 1) before and after discharging channels 1967 and 1968. Further, we find that observation of the peaking effect is already on record in CP-2602 (H. Jones and others).

The net results of the present measurements are (1) no increase in central flux results from the presence of 9 or 20 empty channels as against the two already empty, and that therefore (2) any flux increase must be quite sharply localized. On the other hand, a region of high cadmium ratio is apparently obtainable without great sacrifice of flux. It seems that the method might be useful around holes from which thermal beams are to be drawn; unloading the uranium for a few inches around the hole will increase the thermal flux and the cadmium ratio.

We are indebted to E. C. Barker for counting some of the foils.

[redacted]

| Loading Conditions | $A_s$: Counts per Minute | | | | Relative Activities | | | | Relative Activities | | Waiting Time after Shutdown |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | A' | B' | C' | D' | C'/A' | D'/B' | D'/A' | C'/B' | A'/B' | C'/D' | |
| Channels X empty | 836 | 780 | 2897 | 1558 | 3.46 | 2.00 | 1.86 | 3.71 | 1.07 | 1.86 | 29 min. |
| Channels X and Y empty | 683 | 661 | 1459* | 996 | 2.14* | 1.51 | 1.46 | 2.21* | 1.03 | 1.46* | 52 min. |
| Channels X, Y and Z empty | 390 | 400 | 680 | 550 | 1.74 | 1.37 | 1.41 | 1.70 | 0.98 | 1.24 | 580 min. |

* This foil showed evidence of contamination; these figures are therefore high.

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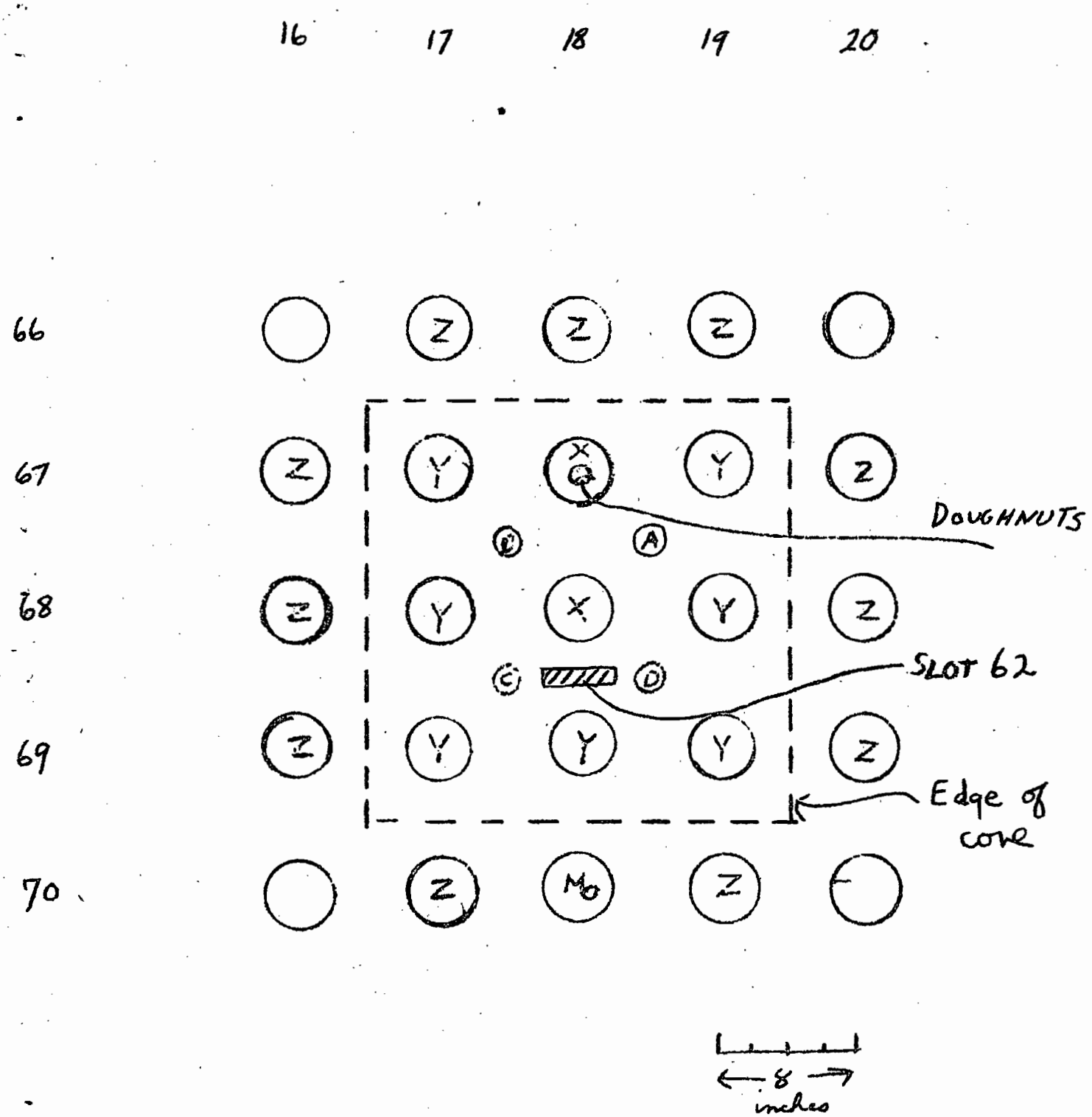
16
17
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Y
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A
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Mo
DOUGHNUTS
SLOT 62
Edge of core
8
inches

Fig. 1

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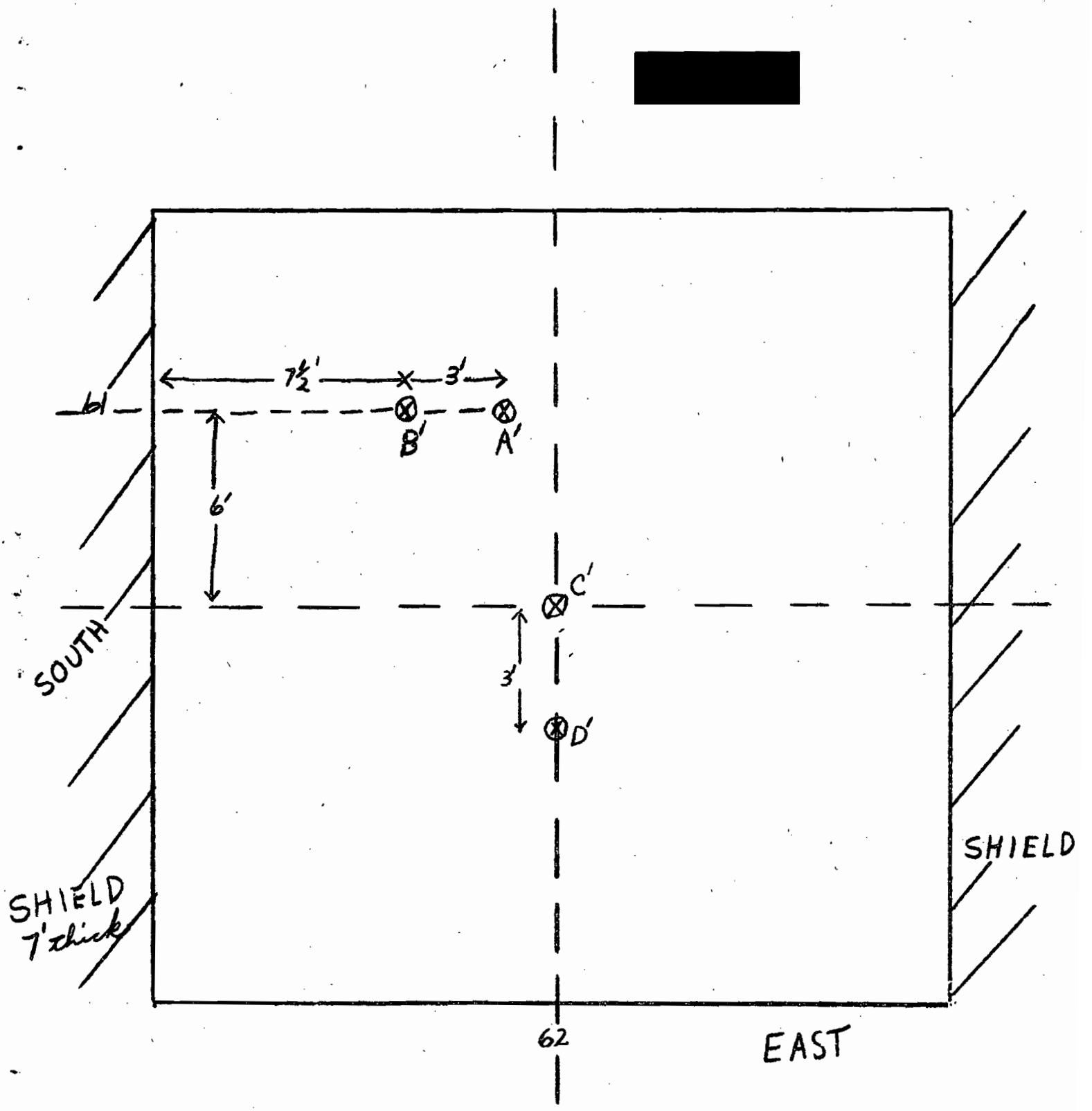


Fig. 2. Horizontal Mid-Section of Pile, showing relative positions of points A', B', C' and D'.

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

During the month the major portion of the design and drawing for the next experiment was completed. Shop work is now in progress. Work on change in concentration of fuel solutions will start in a few days. Assembly of the equipment will begin shortly.

PX10-15 - Photoneutron Measurements - (Bernstein, Levy, Arnette, Jackson)

During the past month we have accumulated a set of data on the photoneutrons from 25 + P-9. This data is now being worked up. Final results should be achieved during this month.

We have received some samples of 49 ordered sometime ago, which we hope to use for further photoneutron measurements.

PX10-8 - Crystal Spectrometer - (Bernstein, Shapiro, Dial, Floyd, Stanford)

We have been working to improve the crystal spectrometer so that we can proceed with measurements on the capture cross-section Xenon. Our main problems are to improve the detecting apparatus and sample handling apparatus so that acceptable reproducibility of the data will be obtained in the time which shall be available, and to reduce the background count of our instrument. This problem which was initiated by L. B. Borst, is now being pursued with the cooperation of Mr. Fried, Mr. Parker and their colleagues of the Chemistry Department. They are making plans for preparing the Xenon sample.

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Identification of Hard Gamma Emitters

We have been cooperating with Messrs. Feldman and Levy of the Chemistry Division in their efforts to identify the fission products which emit the hard gamma rays. Mr. Feldman separated the halogen fission products. The sample was then placed at the center of our P-9 sphere. No photoneutrons were detected. Mr. Feldman is now making plans to separate the rare earth fission products in order to make the same test for them. The interest of the chemists in this problem has grown to the extent that they are making plans for constructing their own photoneutron detecting apparatus and remote control apparatus for short-lived fission product separation on a larger scale.

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## SOLID-STATES RESEARCH

S. Siegel, Acting Chief

1. Irradiation of Low Temperatures - (Metcalf)

A design for a cryostat has been completed. Details of construction and shielding are now being planned.

2. Thermal Conductivity of Fuel Rods - (Hunter)

A satisfactory method of impregnating graphite with uranium oxide has been developed, using a vacuum impregnation technique.

3. Hot Laboratory - (Siegel, Hunter, MacPherson)

The designs for the laboratory, and for some of the experimental apparatus, are pregressing satisfactorily.

4. Irradiation at Clinton Pile - (Siegel, Wagner)

Single crystal samples of well annealed pure Al, and of $Cu_3Au$ in ordered and disordered states have been prepared. The elastic moduli, density, and electrical resistivity of these samples will be measured, and then the samples irradiated in the pile.

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PHYSICS SECTION II

A. M. Weinberg, Section Chief

Total Technical Personnel . . . . . 10

Reactivity Change Caused by Th Blanket in High Flux Pile (Spinrad and Crook)

Calculations have been made on the effective change in multiplication constants of a 3 Kg cubical, reflected pile when it is surrounded by a Th sheet placed 20 cm from the edge of the active reactor. We find that a 1.26 cm thick Th sheet takes up 0.42% in $\delta k_{eff}/k$, while an infinitely thick one takes up 0.57%. The 1.26 cm blanket contains the same amount of Th as will be in the rods surrounding the high flux pile, assuming all rods are in place.

Control Rods in High Flux Pile (Spinrad)

Further computations of the effectiveness of an array of Th-water control rods in the high flux pile have been made. The method consists in calculating the critical k of a circular pile region which contains a centrally located rod, and across whose boundary there is no net neutron flow. The problem would therefore correspond accurately to an array of rods in an infinite slab pile. The error involved in assuming no net flow across the boundary is now being estimated.

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The results of this calculation are that the effective change in reactivity, $\frac{\delta k_{eff}}{k}$, produced by a 3.9 cm radius control rod whose composition by volume is 1 Th - 1 Al - 4 $H_2O$, is

$$\frac{\delta k_{eff}}{k} = 0.72\ R$$

where R is the ratio of volume of control elements to volume of active pile material.

Other Work on High Flux Pile (G. P. Nordheim, Soodak, Weinberg)

Various other problems connected with the design of the high flux pile have been considered during this month. Among these are

1) Average Energy of Neutrons Emitted from Reactor

We now believe the average neutron energy incident on the Be reflector is around 1 MeV rather than 100 KeV as was previously supposed.

2) Space Distribution of Energy Loss of Neutrons

We have derived a formula for the spatial distribution of the energy loss of fast neutrons, assuming the mean free path is constant. We find that the energy loss is distributed exponentially (not Gaussian) with a relaxation length $\sqrt{\tau/u}$, where $\tau$ is the age and u is the log of the initial to final energy ratio.

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3) Time Lag of Thermal Neutron Signal

Since a sudden burst of thermal neutrons diffuses as $\frac{e^{-\frac{x^2}{4Dt}}}{(4\pi Dt)^{\frac{3}{2}}}$, the time required for a signal to reach a maximum at a distance x from the source of the burst is of the order $x^2/2D$. Thus to "travel" 20 cm in graphite requires about a millisecond; this time is uncomfortably long for some of the control circuits in the high flux pile.

The existence of time lags of such an order suggests the possibility that the diffusion coefficient for thermals could be measured directly by observing the rise of thermal neutron intensity following a sudden burst of thermal neutrons some distance away.

Critical Mass Calculations (E. Greuling, R. Crook)

In connection with the critical mass measurements recently completed at K-25 under the direction of C. K. Beck, the following critical assemblies were computed.

The core which consisted of a uniformly heterogeneous mixture of 30% enriched $UF_6C$ cubes and polyethylene ($H_2C$) cubes was surrounded by an infinite reflector of $H_2C$. The volume of each cube of $UF_6C$ was one cubic inch and contained 15.48 gm of $U^{235}$. The volume of each polyethylene cube was one cubic inch and had a density of 0.90 gm/cm$^3$.

The integral diffusion method, as reported in LA-399, and as modified for heterogeneous piles (Cf. Mon P-48 supple-

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ment), was used. The thermal disadvantage factors, $\bar{n}_1/\bar{n}_o$, were calculated for equivalent spherical cells. The $U^{238}$ resonance escape probability, P, was obtained from the curves in Chap. IV of the project handbook. A correction on P, due to slowing down of neutrons in the reflector, was made according to the method explained in LA-399.

The theoretical results tabulated below are for equivalent homogeneous and heterogeneous spherical piles. The first column ($v_1/v_o$), is the $H_2C$ to $UF_6C$ volume ratio. The volume of the cell in cubic inches is $v_1 + v_o$. The second column (H/25) is the ratio, atoms of hydrogen to atoms of $U^{235}$ in the core. The fourth and seventh columns are respectively the theoretical critical masses of $U^{235}$ for the homogeneous and heterogeneous piles. The last column lists the experimental critical masses of the roughly cubical heterogeneous piles surrounded by essentially infinite polyethylene reflectors.

| Homogeneous | | | | Heterogeneous | | | |
|---|---|---|---|---|---|---|---|
| $v_1/v_o$ | H/(25) | P | $M_{25}$ | $\bar{n}_1/\bar{n}_o$ | P | $M_{25}$ | $M_{exp.}$ |
| 1/2 | 15.25 | .891 | 21 Kg | - | - | - | 17.5 Kg |
| 1/1 | 30.5 | .921 | 7.9 " | 2.21 | .927 | 8.6Kg | 7.66 |
| 2/1 | 61.0 | .944 | 3.44" | 2.68 | .962 | 4.3" | 4.58 |
| 4/1 | 122 | .960 | 1.80" | 3.29 | .980 | 3.6" | 3.97 |
| 7/1 | 213.5 | .970 | 1.22" | 3.86 | .987 | 5.8" | 6.15 |

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For atomic ratios, $H/(25) < 30$ or $H/U < 9$, the theory breaks down because one can no longer neglect fissions produced by resonance energy neutrons. Also in this region the core and reflector differ so much in their slowing down power that the integral method is no longer applicable.

High Energy Photo-Disintegration of the Deuteron (Goertzel, Rose)

During the month of December practically the entire time was devoted to the problem of the high energy photo-disintegration of the deuteron. Here the phenomenological tensor force model, introduced by Schwinger, is being used.

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Physics Section III.

E. C. Wollan, Section Chief

Total Technical Personnel (including supervision).....11.

PX10-8 Neutron Diffraction (Shull, Wollan, Marney)

A series of three compounds, CaO, CaS, and $CaC_2$ whose nuclei were of the zero-spin and monoisotopic* variety were examined in the powdered crystal spectrometer. Diffraction patterns for a neutron wave-length of 1.05 angstroms were obtained over selected diffraction peaks and neighboring background. Typical diffraction peaks for these compounds are given in Figure 1. The three patterns were obtained under similar geometrical conditions with a constant primary beam intensity.

From the intensities of the diffraction peaks and the diffuse background values, both the effective coherent and diffuse scattering cross sections may be evaluated using formulae analagous to those for the scattering of x-rays by powdered crystals. The intensity of diffraction in an (h k $\ell$) peak is given by

$$\frac{P_{hk\ell}}{P_o} = \frac{\lambda^3 \ell}{4\pi r} \frac{h\rho^0}{\rho} \frac{e^{-\mu h \sec \theta}}{\sin^2 2\theta} j \cdot M^2 \cdot F^2_{hk\ell}$$

where $P_{hk\ell}$ is the power in the diffracted beam, M is the number of molecules per cc of crystal and $F^2_{hk\ell}$ is the effective coherent scattering cross section per molecule per unit solid angle. Other terms are defined as in Compton and Allison. In the x-ray case, $F^2_{hk\ell}$ is defined as the ratio of the crystal scattering to the Thomson scattering per electron, whereas in the neutron case this quantity has the dimensions of a cross section. A corresponding expression for the intensity of diffuse scattering is

* This is obviously only approximately true especially for Ca and S.

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given by

$$\frac{P_d}{P_o} = M\left(e^{-\mu h \sec\theta} \; \frac{h\rho'}{\rho} \sec\theta\right) \cdot \frac{\ell \Delta\theta}{r} \cdot S^2$$

where $P_d$ is the power in the diffusely scattered beam as measured through a defining slit of angular aperature $\Delta\theta$ and $S^2$ is the effective diffuse scattering per molecule per unit solid angle.

Since the intensity of the primary beam $P_o$ is not known as yet to any accuracy, it is necessary to intercompare the diffraction peak and diffuse background intensities. From the relative intensities of the diffraction peaks (for example the (200) and (111)) relative values of the effective coherent nuclear scattering cross section can be calculated.* Likewise, through use of the ratio of the above two equations

$$\frac{P_{hk\ell}}{P_d} = \frac{\lambda^3}{4\pi\Delta\theta} \; \frac{j\,M}{\sin^2 2\theta \sec\theta} \; \frac{F^2_{hk}}{S^2}$$

the value of the diffuse scattering cross section per molecule of crystal can be obtained relative to the nuclear cross sections. Table I summarizes the data calculated in this fashion. Also included in this table are data calculated from previously obtained measurements on NaCl and KCl.

It is to be noted in the first two columns of this table that the ratios of coherent to diffuse scattering cross sections vary over wide limits. The data in the third column indicate that the coherent scattering cross section for calcium varies by more than a factor of two from one compound to another. The last column in the table contains the ratios of handbook cross sections for the atoms in the compound and in certain cases, these are seen to differ considerably from the ratios of coherent scattering cross sections.

* These quantities will be designated by $f^2_{Ca}$, $f^2_{O}$, etc.

[redacted]

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TABLE I.

Relative Coherent and Diffuse Scattering Cross Sections from Powdered Crystal Measurements

| Crystal | $\frac{f_R^2}{S^2}$ | $\frac{f_X^2}{S^2}$ | $k^2 f_R^2$ | $k^2 f_X^2$ | $\frac{f_R^2}{f_X^2}$ | $\frac{\sigma_R}{\sigma_S}$ |
|---|---|---|---|---|---|---|
| CaO | 0.52 | 0.17 | 7.1 | 2.4 | 3.0 | 2.3 |
| CaS | 0.10 | 0.021 | 3.3 | 0.69 | 4.8 | 8.5 |
| $CaC_2$ | 0.11 | 0.10 | 4.9 | 4.2 | 1.1 | 2.0 |
| | | | * | * | | |
| KCl | 0.11 | 0.82 | 1.9 | 13.8 | 0.135 | 0.11 |
| NaCl | 0.08 | 0.55 | 1.9 | 12.6 | 0.145 | 0.25 |

* Note $k^2$ is different for NaCl and KCl than it is for the calcium compounds since modifications were made in the apparatus between the times these measurements were made.

The subscripts R and X refer to the first and second elements in the compounds respectively.

The large amount of diffuse scattering observed for these crystals is not easily accounted for. The rather high characteristic temperatures to these substances makes the diffuse scattering due to the Debye-Waller temperature effect small (see also later section). The theory of the diffuse scattering as worked out by Weinstock (Phys. Rev. 65, 1, 1944) and the extension of this theory by Seitz and Goldberger (CP-2489) seem also to predict less diffuse scattering than we observe. This point is being more thoroughly investigated. The effect of the small percent of the less abundant isotopes in calcium and sulphur must also be considered as a possible source of diffuse scattering.

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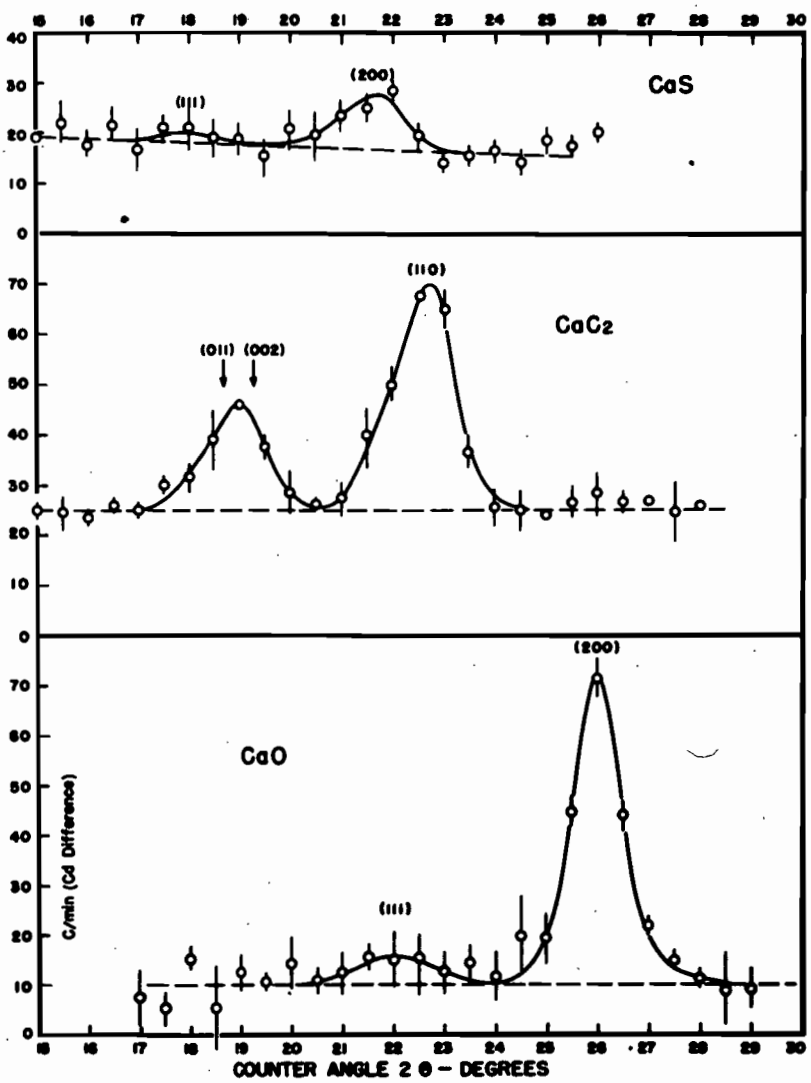


FIG. I

DIFFRACTION OF MONOENERGETIC NEUTRONS
(E = 0.074 ev, λ = 1.05 Å) BY POWDERED CRYSTALS

[redacted]

Effect of Temperature on Intensity of Coherent and Diffuse Scattering (Shull, Wollan, Marney)

Samples of CaO and CaS were examined in the neutron diffraction spectrometer at both room temperature (26° C) and at liquid nitrogen temperature (-197° C) to determine the effect of temperature on the intensity of both coherent and diffuse scattering. The same specimen and the same specimen holder were used for the measurements at the two temperatures. Neutron counting rates were determined at the center of the (200) peak and at the diffuse background on either side of this peak. Table II summarizes these measurements.

TABLE II.

Effect of Temperature on the Intensity of Neutron Diffraction

| | | Counting Rate at 299° K | 77°K |
|---|---|---|---|
| | diffuse background | 13 | 13 |
| CaO | (200) peak | 69 | 68 |
| | diffuse background | 14 | 11 |
| | diffuse background | 16 | 20 |
| CaS | (200) peak | 24 | 27 |
| | diffuse background | 22 | 22 |

It is concluded that the temperature dependence of the intensity of coherent scattering and of the diffuse background is small.

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Relative Phase of Neutron Scattering for Various Nuclei (Wollan, Shull, Marney)

The examination of the diffraction pattern for BeO appeared to be of interest in connection with results of total reflection of Be and the energy spectrum of neutrons transmitted by BeO as reported from Argonne in CF-3574 and CP-3647. Accordingly the diffraction pattern over the (100), (002) and (101) peaks for powdered BeO was determined as shown in Figure 2. A simple calculation of the expected powder diffraction intensities based on the same and opposite phases for Be and O shows definitely that the two nuclei scatter with the same phase. The calculated intensities for the two cases are shown on the top of Figure 2.

Previously reported data from similar powder diffraction measurements together with the results of the first section of this report and some unreported measurements on MgO show that Ca, O, S, C, Mg, and Be all scatter with the same phase. This is in accord with results obtained at the Argonne.

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

The new thermal column, now in operation, differs from the old one in the following details.

(1) The graphite completely fills the hole in the concrete. There was a 2-3 inch gap around the edges of the old one.

(2) The neutron shutter of boron carbide plastic in an aluminum frame is at floor level. It should be permanent while the canvas of the old shutter had rotted and the shutter was completely inoperable when the old column was removed.

(3) There is a two foot high pedestal of graphite surrounded by cadmium and lead above the shutter to give additional $\gamma$-ray protection at a small cost in neutron flux. This two feet of graphite increases the time limit at the column from 15 minutes to 1 hour, shutters closed.

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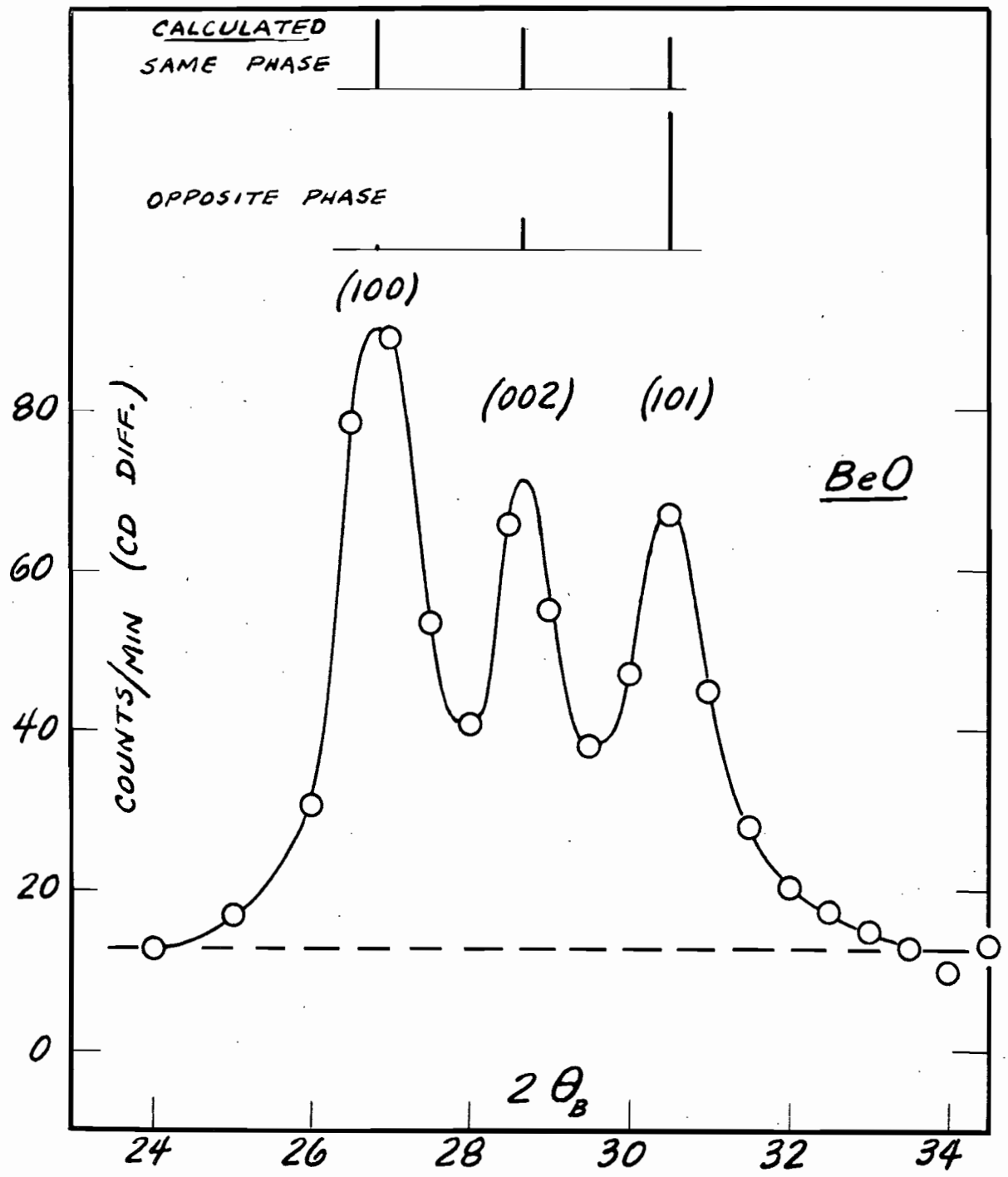


FIGURE 2

NEUTRON DIFFRACTION BY BeO

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(4) There are a set of four stepped plugs which may be withdrawn from the center of the thermal column and which extend down 5 feet below floor level. The smallest cross section dimension is 8" x 8".

(5) Studies of the neutron flux distribution across the column show that the flux is symmetrical within 2%. The thermal flux for the new column is about the same as for the old column, about $10^7$ at floor level.

A 4' x 4' x 6' high column of graphite has been piled on the pedastal to study age in graphite using a 2' x 2' square plane source of aluminum $U^{235}$ alloy. Preliminary measurements have been made on the age of fission neutrons in graphite.

This is introductory to the determination of age in $H_2O$, $H_2O$ mixtures, Be and BeC.

PX10-19 Energy of Capture Gamma Rays (Moak, Dabbs)

Since the last report several changes have been made in the experimental set-up of the cloud chamber. Chief among these was the change from an Al Compton recoil radiator to a Pb pair radiator. It was felt that a larger background could be tolerated by using pairs, since the origin of any pair can be determined; also the errors in geometry would not be as great because total pair energy is not dependent on the direction of the $\gamma$ ray. The pairs will also be more easily identified since the cloud chamber walls will not contribute an appreciable pair background. Data from pair measurements for Cd capture $\gamma$'s are now being obtained.

PX10-24 Identification of Fission Fragments Giving Rise to Delayed Neutrons (Good)

This problem, which was begun sometime ago, has been delayed due to the construction in the shop of new equipment for handling the special "rabbit" used in this work. This equipment has been completely redesigned to make the work safer from a radiation hazards point of view. The equipment is practically complete and it is hoped that work on this problem can be resumed in the near future.

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Physics Section IV.

S. De Benedetti, Section Chief

Total Technical Personnel (including supervision).....7.

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

Further experiments with Yb sources to investigate the possibility of a short lived isomer in $Lu^{175}$ failed to give conclusive results, though some delayed coincidence could be counted.

In order to make easier the work for delays around one microsecond or smaller, we started the construction of a new coincidence circuit to explore the range of $10^{-7}$ sec. With this circuit we also plan to study the time lag of our Geiger counters, hoping that it will be possible to reduce them. Harold Schweinler, who has recently joined our group, is interested and active in this field.

In the meantime the negative results obtained with the old circuit will be reexamined.

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

The end point of the continuous beta-ray spectrum of the 4 year "61" activity has been determined with the 180° counter spectrometer as .223 Mev. This is a preliminary value as more detailed study of this spectrum will be made as soon as a thinner source is available. The source used in the preliminary study was prepared by G. Parker's group of the Chemistry Division.

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Mechanism of Emission of Prompt Fission Neutrons (De Benedetti, Francis, Preston)

The work on instrumentation is continuing. The fast neutron counters at pressure higher than atmospheric were prepared, assembled, and tested. Their performance shows some improvement in respect to the counters previously used. The coincidence circuit with the differential pulse height selector has been built. From the tests made to date it was found to behave satisfactorily, despite some adjustments still needed.

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Physics Section V

Henry W. Newson, Section Chief

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

Model Servo System (H. A. Straus)

The gear train of the model servo system has been received. The system has been assembled and run under power. After running in for a few hours the gear train is in excellent condition. Essentially all test equipment of which need is seen is now on hand, including a modification of the mechanical modulator to produce sine waves at 0.1 cps. A db-log frequency study of the loop transfer characteristic of the basic servo loop is now in progress as a preliminary to design modification of the system.

Monitron (P. R. Bell)

A vibrating condenser monitron has been built which shows considerable improvement over the present monitrons. That this is true is not surprising, for the advantages of using a varying capacity for converting from direct voltages to easily amplified alternating voltages has been demonstrated many times. The chief difficulty has been in procuring a vibrating reed or condenser in any quantity that is satisfactory for the purpose. The availability of vibrating condensers from the AN/APN-1 FM altimeter has led us to investigate their suitability for this job. Consequently, one of their condensers built into a feedback amplifier circuit and attached to an ionization chamber. A balanced demodulator was used so that the output voltage was a linear function of the input voltage. (The monitron circuit in common use is not only non-linear but is double valued.) The gain is independent of line voltage fluctuation and tube constants. Adjustments such as gain,

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zero setting, and relay triggering level are easily made and independent of each other.

The completed circuit gives a full scale meter reading (50 volts) with a 0.6 volt input. It operates very well with an input resistance of $10^{12}$ ohms. The input zero drift is about 2 millivolts. The zero of the instrument is independent of the value of the input resistance. When a portion of the output signal is connected to a Brown recorder, individual alpha particles give sizeable deflections. The instrument has been running continuously for the past two months without failure. Life tests are being continued and drawings are being modified in preparation for making a number of these instruments.

This investigation was undertaken with the idea of developing a suitable instrument for control of the high flux pile. In particular, the d log n circuit requires such a device.

Indicator for $\delta k_{eff}$ (S. MacNeille)

If the neutron density of a pile is made to oscillate about an average value by modulation either of the reactivity or of an artificial source, the phase lag between driving and resultant oscillations depends only on the frequency and the average reactivity of the pile. Thus the measure of this phase angle provides a rather direct measure of $\delta k_{eff}$ - one which is independent of pile level, oscillator amplitude, or background current in the ion chamber. The relation is:

$$\tan \phi = \frac{2\pi f\, l}{\delta k_{eff} - \beta} ,$$

where $\phi$ = phase angle, f = driving frequency, l = mean life of a neutron in the pile, $\beta$ = fraction of delayed neutrons, and it holds as long as the amplitude of oscillation of $\delta k_{eff}$ is small compared with $\left| \delta k_{eff} - \beta \right|$.

(If f is not much larger than $\lambda$, the decay constant for delayed neutrons, then constant terms must be added to both numberator and denominator in the above expression).

For maximum sensitivity near critical ($\delta k_{eff} = 0$), one should set

$$f = \frac{\beta}{2\pi l}$$

($\cong$ 5 cycles for high flux pile). Under these conditions the minimum detectable increment in $\delta k_{eff}$ is

$$\Delta(\delta k_{eff}) = 2\beta\Delta\phi$$

where $\Delta\phi$ is the minimum detectable increment in phase angle. For $\Delta\phi = 1^{\circ}$,

$$(\delta k_{eff}) = 2.7 \times 10^{-4}.$$

Thus the method appears feasible for continuous visual indication of $\delta k_{eff}$ during start-up of the high flux pile, though it is probably too slow for use with automatic control.

Ionization Chamber (Armistead, Mead)

The experimental ion chamber has been exposed for 10 days in hole 57 at the middle of the pile for the purpose of testing the effects of intense pile radiation upon the boron coatings. Five test plates were included in the chamber, with binders respectively of Amphenol 912, rubber cement, Duco cement, aquadag, and collodion. Boron 10 was the neutron-sensitive material. Visual inspection of the plates after removal reveals a slight deterioration of the organic binders as evidenced by loose boron dust. Incomplete tests of the comparative sensitivity (ratio of ion current to neutron flux) before and after the exposure in the pile indicate no appreciable loss in sensitivity has resulted. More data is forthcoming on this. How this life test compares with conditions to be met by the ion chambers in the high flux pile is difficult to say until the final decisions

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about chamber positioning in the new pile have been made. However, it is safe to say that the X-pile test exposure was equally as severe, as to temperature and flux, as the actual conditions of use will be; and perhaps the actual conditions will have slightly lower temperature and 10 to 100 times less flux.

A test is now being made ready for a second exposure in the X-pile with the difference that ion current will be continually drawn from the chamber during the test.

A sample of boron coating deposited by the diborane method has been received from G. E., and is undergoing tests. The sensitivity is being compared with that of our own powder coats. A life test will be given this coat also.

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Physics Section V1

G. Young, Section Chief

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

Nuclear Data - (Way, Dismuke, Thompson, and Bendt)

A memorandum is being prepared (Thompson) on methods of measurement of $\int \sigma \, dE/E$ and on values for this quantity which are known. A critical study is being made (Bendt) of the existing data on Pb and Bi neutron cross-sections. A memorandum, CLM-KW-1, is being issued (Dismuke and Way) giving a summary of data on slow neutron constants of $U^{233}$, $U^{235}$, and $Pu^{239}$; this contains measured values and notes on the methods of measurement of the absorption and fission cross-sections $\sigma$, $\nu$, and $\eta$ for these nuclei. The Isotope Information Committee has issued, under the number CLM-IIC-2, its second monthly summary of new nuclear data in project and non-project literature.

Mrs. Dismuke has begun a few months leave of absence (mother and son are doing nicely), and Mrs. Haynes is joining the section to assist in the data work.

Slow 49 Piles - (Mason)

A study is being undertaken of thermal piles operating wholly or in part on 49. This includes power piles which begin operation on natural U and retain the resulting 49 for their own use, as considered by Thompson in his work which led to volume IV of Baruch's information transmitted to the United Nations. It has been suggested (see e.g., "On International Hazards of Power Piles," Young, 11/14/46) that the strong self-denaturing action of such piles might be advantageous from the standpoint of international inspection and control, and it seems desirable to look into these matters

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more closely. The pile effects of the Pu isotopes formed by neutron capture are being discussed with Stoughton and Ott, and the effect of temperature on reactivity is being considered with Greuling (lecture No. 7 in "Meetings of New Pile Group," Young, 7/29/46; p. 58 in "Summary of New Pile Studies," Young, 10/22/46).

Shielding - (Murray and Libbey)

A mathematical memorandum, CL-FHM-1, on neutron shielding has been issued under the title, "The Energy Loss of Particles Traversing a Slab of Finite Thickness" (instead of a title previously announced in Mon P-196, p.20). One of the results obtained by path length considerations in this memorandum (top of p.19) is being developed further.

Through the courtesy of F. L. Friedman of M.I.T., the O.S.R.D. report underlying an abstract on "Scattering and Absorption of High Voltage X Rays in Steel" (Feshbach and Hornbeck, Physical Review 69, p.691) has been made available at Clinton. The methods of analysis used in this report and those used in LA-564 by Hirshfelder, Hull, and Magee are being studied.

The Navy has expressed interest in initiating a shielding program, and some preliminary suggestions have been obtained in discussions with Morgan, Wollan, Fairchild, and others.

The situation with regard to the production of $\gamma$ rays from neutron capture in boron, the $B(n,\alpha)Li^7$ reaction, has been somewhat clarified in discussions between Way and Snell. From the fact that Bøggild (Kgl. Danske Videnskab. Selskab, Mat. and fys. Medd. 23, No. 4, 1945) observes $\alpha$ particles of two ranges in the reaction, the shorter range occurring in 93% of the cases, it seems probable that in 90% of the B disintegrations $Li^7$ is left in a state .42 Mev. above ground and so presumably emits

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$\gamma$ rays of this energy.

Fission Product Poisoning - (Noderer, Householder, and Way)

Published memoranda on this subject include MUC-KW-41 and the recently issued CL-GY-1; a memorandum giving some additional formulae is being prepared.

An approach to a study of the distribution of thermal absorption cross-sections is being attempted by the methods of statistical sampling theory.

Pile Blankets - (Goertzel and Householder)

Progress has been made toward determining, in terms of Euler equations and certain discontinuities, optimum distributions of an absorber (e.g., thorium) in a medium with given thermal neutron properties and located in a given slowing down field.

Fast Piles - (Menke)

Calculations are continuing on fast piles strongly diluted with weak absorbers such as Bi, and surrounded by various kinds of reflectors such as thick Bi layers or slow pile layers.

Computing Machines - (Householder and Garabedian)

A visit has been made to discuss, in a preliminary way, the use of the ENIAC machine on Clinton problems. It is planned to attend a conference on computing devices at Harvard in January.

Miscellaneous

An attempt is being made (e.g., CL-GY-3) to gain a better understanding of the Po health hazard attending the use of Bi as a pile coolant; some information has been obtained from Lum (12/16/46), Morgan (12/18/46), and de Benedetti.

Grebe, (1/3/47) gives an account of a visit with Boarts and Matheson to discuss with TVA personnel the possibility of using phosphorus as the

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working substance in heat engine cycles and as a pile coolant.

Some remarks on pile unloading are made in CL-GY-2 entitled "Notes on Unloading Entire Pile."

Grebe and Boyd are continuing their inquiry into the possibility of producing heavy water at appreciably lower cost by ion exchange columns; the significance which a successful effort in this direction would have has been lately argued (Weinberg and Young, 12/12/46). Minett has discussed some isotope separation possibilities with K-25 and with Schweinler; we understand that a trial run for concentrating $N^{15}$ is being made at K-25, and that a report on this and other light isotope separations will be available.

Doan of Phillips Petroleum Company is sending us some samples of the most radioactive oil shales, and possible interest in the U or Th content of such materials is being discussed with Goodman of M.I.T. Menke has been looking a little into the Be ore situation; a recent Madison Square Area report (M-3166) gives some useful information on Be deposits.

A little time has been spent (Weinberg, Wigner and Young) in putting together some suggestions as to contents for a handbook of formulae and tables being considered by Arnold Lowan, head of the Mathematical Tables Project, Bureau of Standards.

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