B-46

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PHYSICS DIVISION

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REPORT FOR MONTH ENDING OCTOBER 31, 1946

L. W. Nordheim, Director

Date Received: 11/6/46

Date Issued: 11/7/46

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The progress of work during the current period consisted more in the slow and unspectacular assembly and improvement of apparatus, than in finished results. In contrast to the early days of the project, when new data were coming in fast, and had to be reported even if they were very premature, the average experiments now will stretch over periods of many months. Among the major items, where essential modifications of the set-up are being undertaken, are the critical experiments, the thermal column and the pile oscillator. Active work, which has not yielded reportable results of interest, is being carried out on neutron decay, total gamma intensities per β decay, energy of capture γ rays, the mechanism of emission of prompt fission neutrons, and the pile simulator with control servo mechanism.

In the neutron diffraction work, powder patterns were successfully obtained for NaCl and KCl. These patterns permit a quantitative comparison of diffraction intensities. The present observations lead to a different ratio of the structure factors for Na and K as would be computed from known scattering cross-sections. This may be due to isotope or spin effects, whose investigation constitutes the ultimate purpose of these experiments.

Progress was also made in the study of short lived isomers and in the study of the β spectrum of Au^{198}, which seems to consist of two components.

Theoretical work on the heterogeneous pile is very actively continued. New data have been obtained on the neutron distribution, shielding and control rod effectivity. In general pile theory, an interesting interpretation has been found for the "adjoint" neutron density and the statistical weight formulas containing it. Also, a mathematical method has been found for the direct computation of critical size for a pile with a multiple reflector. The control group has built an experimental ionization chamber for testing of various types of boron coatings and studies on control circuits have been continued. The

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long range pile group has issued a report on the present status of power piles and an extensive summary of new pile studies. It is further continuing its collection of nuclear data, studies of fission product poisoning and on questions of uranium and heavy water production.

During October Dr. L. B. Borst left the laboratory and Drs. A. Householder, M. M. Shapiro and R. P. Metcalf joined the regular staff of the division.

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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.	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

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

In view of the presence of our stockpile of C^{14}, and the imminence of C^{14} production by the calcium nitrate process, it has been decided to cease running the factory on a production basis. This decision is encouraged by increasing signs of corrosion in the piping; the decision also has been conveyed to the Pile Committee. The factory will be run again only for short intervals for the purpose of measurement of gas samples and for obtaining a value of the average neutron flux.

The two mass-spectroscopically analysed samples of C^{14} which were counted in the half-life determination gave somewhat disparate results. An effort to see the reason for this will involve further purification before counting.

Neutron Decay - (Saxon, Miller, Snell)

Efforts are being devoted to finding the origin of counts which are observed when the radiation background is essentially zero (apparatus away from hole, pile off, C^{14} factory off). Several parts of the apparatus have been changed from brass to aluminum, in an effort to reduce electron scattering in the vacuum chamber. The counting rates are being studied as a function of gas pressure and various accelerating voltages. The results have not yet given a clear analysis of the situation.

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PX8-1 - Gamma Ray Spectra - (Haynes)

The thin lens spectrometer is being readied for action again. Computations have been made on the electron orbits, with a view to intelligent placement of baffles.

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

It was found necessary to replace the FP 54 tube during the last month. Intercalibration of the ionization chambers is proceeding.

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

We are now in the process of remodeling cells 6 and 7, increasing safety precautions, etc., in preparation for future experiments.

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Physics Section II

A. M. Weinberg, Section Chief

Total Technical Personnel (including supervision) 10

Composite Reflector Around Slab Pile (Garabedian and Householder)

The calculation of the critical size of a slab pile surrounded by a laminated reflector would, on a 2-group picture, require the solution of a 4n x 4n determinantal equation, where n is the number of reflector regions. Such a computational job is prohibitively complicated. Following a suggestion from C. Mark of Los Alamos, we have found that, in general, this 4n x 4n determinant can be reduced to a single 4 x 4 determinant. The solution of such a determinant is entirely feasible. Attempts are being made to extend the method to cases where the reflector is continuously variable, and to cases where the geometry is spherical or cylindrical.

Shielding of New Pile - (Weinberg)

We have made some estimates of the neutron and γ-ray fluxes incident on the graphite reflector of the new pile as compared to the fluxes incident on the reflectors at Hanford and at Clinton. The results follow:

	Hanford	Clinton
Ratio of γ-fluxes in new pile to	8.2	151
Ratio of neutron fluxes in new pile to	2.85	34

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In these estimates we assume Hanford at 2.5×10^5 kw, Clinton at 4×10^3 kw, and the new pile at 30×10^5 kw.

From these figures we estimate that one extra Fe-masonite sandwich added to a standard Hanford shield, or 70 cm of concrete added to the Clinton shield should be sufficient.

Adjoint Neutron Density - (H. Soodak)

Before the report CP-3048 was issued, perturbation and statistical weight calculations were made solely on the basis of a one-group approximation. In the above report, E. P. Wigner showed that perturbation calculations could be made in real piles with neutrons of all energies present if the "adjoint neutron density, n^*, was introduced. During the past month, it was found that n^* has the following simple physical meaning:

A neutron of energy E placed at a position x in a just critical pile will in effect, be spread out by the pile into the equilibrium neutron distribution (in both energy and space). The total number of neutrons in this equilibrium distribution is $n^*(E,x)$. Thus $n^*_{th}(x)$, the thermal adjoint density, equals the number of neutrons (of all generations) resulting from one thermal neutron placed at position x.

Knowing this, the s tatistical weight formulas which involve such products as $n(x)n^*(x)$ are easy to understand. The factor n comes from the fact that an absorber placed at x absorbs a number of neutrons proportional to n and the factor $n^*(x)$ represents the importance of one neutron absorbed at x.

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In the one group theory, $n^*(x)$ is proportional to $n(x)$.

Further Heterogeneous Pile Calculations - (E. Greuling and R. Arnette)

Two additional pile models having lower k values than the one reported last month (Mon P-) have been computed. The following table is a summary of results obtained to date on:

A) Critical Dimensions and Reflector savings

a = cylindrical core radius

δa = Be metal plus 2% water reflector savings

h = cylindrical core height

δh = water plus Al reflector savings $V_{Al}/V_{H_2O} = 3/4$

B) Radial flux distributions and their adjoint functions

Core: $r \leq a$ ∞ Reflector, $r \geq a$

Slow Flux = $J_o(\mu_o r) + BI_o(\nu_o r)$, $RK_o(\mu_1 r) - \delta K_o(\nu_1 r)$

Fast Flux = $A_f J_o(\mu_o r) - B_f I_o(\nu_o r)$, $RK_o(\mu_1 r) + \delta_f K_o(\nu_1 r)$

Slow Adjoint = $A^* J_o(\mu_o r) - B^* I_o(\nu_o r)$, $R^* K_o(\mu_1 r)$

Fast Adjoint = $J_o(\mu_o r) + B_f^* I_o(\nu_o r)$, $R_f^*(\mu_1 r) - \delta_f^* K_o(\nu_1 r)$

	k = 1.606	k = 1.432	k = 1.373
a	12.78cm	17.85cm	21.12cm
δa	16.69 "	19.17"	20.17 "
h	53.4	52.6	52.2
δh	16.6	17.4	17.8
B	$(2.005)10^{-3}$	$(1.502)10^{-4}$	$(2.632)10^{-5}$
A_f	3.867	3.834	3.823
B_f	$(6.632)10^{-4}$	$(4.469)10^{-5}$	$(7.532)10^{-6}$

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R	8.632	12.98	16.54
S	15.12	29.00	43.30
S_f	12.49	23.95	35.75
A*	1.557	1.400	1.347
B*	$(1.756)10^{-3}$	$(1.029)10^{-4}$	$(1.592)10^{-5}$
B_f^*	$(9.654)10^{-5}$	$(5.707)10^{-6}$	$(9.408)10^{-7}$
R^*	1.673	2.328	2.884
R_f^*	2.160	3.007	3.725
S_f^*	1.577	2.339	3.122
μ_o	.08161	.06497	.05824
ν_o	.5487	.5465	.5457

For all three piles the reflector was the same and $\nu_1 = .1151$, $\mu_1 = .06744$. Each core contains 35.7 gms of 25 per liter. The three critical masses obtained were:

$k = 1.606$ $\quad$ $M = 0.98$ Kg

$k = 1.432$ $\quad$ $M = 1.88$ Kg

$k = 1.373$ $\quad$ $M = 2.61$ Kg

The mass reported last month for the $k = 1.606$ case (namely 1.28 Kg) is reduced by taking into account the end reflector savings, namely $M = \frac{h}{h + \delta h}(1.280) = .98$ Kg.

Fast Mean Free Path in Two-Group Theory - (P. O. Levy and H. C. Schweinler)

The proper boundary condition in the two-group method is continuity of flux and density of neutrons. In order to ensure that these conditions are fulfilled, it is necessary to choose for the mean free paths a particular sort of average. To obtain this average we note that, for neutrons of energies between E and E + dE we then have;

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$(nv)_0\ dE = (nv)_1\ dE$ and $\lambda_0 (nv)_0'\ dE = \lambda_1 (nv)_1'\ dE$, where primes represent differentration with respect to the normal to the intervase. The "proper" mean free path for the fast group, that is, the fast mean free path which will assure continuity of flow of the total of epithermal neutrons, is therefore

$$\int \lambda nv(E)\ dE / \int nv(E)\ dE.$$

At the center of the pile the nv is approximately

$$\frac{\int_E^\infty F(E')\ dE'}{N \sigma_s \xi E}$$

where $F(E')\ dE'$ is the fraction of primary fission neutrons with energies between E' and E' + dE'. The formula which is now being used for the fast mean free path λ_f is therefore

$$\lambda_f = \frac{\int_{.03\,ev}^{\infty} \frac{\int_E^\infty F(E')\ dE'}{\left[\sum N_i \sigma_{s_i} (1-\bar{\mu}_i)\right]\left[\sum N_i \sigma_{s_i} \xi_i\right]} \frac{dE}{E}}{\int_{.03ev}^{\infty} \frac{\int_E^\infty F(E')\ dE'}{\left[\sum N_i \sigma_{s_i} \xi_i\right]}}$$

Calculations are being carried out, for several aluminum-to-water volume ratios, to determine the values of λ_f. These will be of great value in future applications of two-group theory.

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Control of New Pile (Spinrad)

Using the two group method, calculations have been made of the size of thorium absorber necessary to control supercritical piles of varying multiplication constant and shape. For these calculations, an infinite Beryllium-Water reflector was assumed for two dimensions, and an infinite water reflector for the third dimension. All computations are for a pile with a Uranium concentration of 65.7 g/liter.

The results follow:

Shape of Pile	k	Thickness of Thorium Absorber	Critical k
1) Rectangular parellelopiped, 40x40x60 cm	1.606	1.86 cm	1.36
2) Rectangular parallelopiped, 40x40x60 cm	1.55	1.46 cm	1.36
3) " "	1.50	.50 cm	1.36
4) Right Circular Cylinder, 22.6x60 cm	1.606	5.85 cm radius	1.32
5) " "	1.606	4.81 cm radius	1.41

Calculations having also been begun on the rate of U^{233} production in the thorium control rods per atom of U^{235} destroyed in the pile. The percentage 23 production/25 destroyed for the first three cases are, respectively, 8.57, 8.11, and 5.76.

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Physics Section III

E. O. Wollan, Section Chief

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

PX10-8 Neutron Diffraction (Shull, Wollan)

Powder diffraction patterns were obtained for NaCl and KCl under controlled conditions which permit a quantitative comparison of their diffraction intensities. From these data the ratio of the structure factors for Na and K is calculated as

$$\frac{F_{Na}}{F_K} = 1.14.$$

Using the Handbook values for the scattering cross-sections for these nuclei and the present diffraction theory for the relationship between the structure factor and the scattering cross-section, the above ratio becomes 1.53. It is not known at present whether this discrepancy may be accounted for by the nuclear spin present in these nuclei. Experiments toward this end are in progress.

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

The cloud chamber has been overhauled and is now in operation. The field stabalizer is satisfactory. A new light source is being tried out.

PX6-1 Pile Oscillator (Pomerance)

Reconstruction of the circuits and repair of the oscillator mechanism are continuing.

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

The graphite for the thermal column has been cut and the column should be installed this month. The 25 for the source has not yet been received.

PX10-24 Range of Fission Fragments (Good, Wollan)

Several tests of the old equipment have been made and on the basis of these a new setup has now been designed and turned over to the shop.

Physics Section IV

S. De Benedetti, Section Chief

Total Technical Personnel (including supervision) 7

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

Work with W^{187} sources has been continued. The number of delayed coincidences recorded has been further increased by using a very thin source. The times of delay have been measured again using pulses from a Geiger counter (instead of pulses from a pulse generator) to trigger the delay circuit. We unexpectedly found that the delay times measured in this way were shorter than those previously obtained. The reason for the discrepancy is not yet understood, but we feel that the last calibration is more reliable because it was made under conditions similar to those of the experiment. Assuming the last values, the decay curve of Re^{187*} is a good exponential corresponding to a half life of 0.65 μsec.

We found in a report by Curtiss and Miller that the γ rays of 130 KV of W^{187} are strongly internally converted. This is consistent with our assignment of the energy of the metastable state. From our measurement the number of delayed conversion electrons per disintegration is of the order of 0.1, which corresponds to a higher (0.3?) coefficient of internal conversion for the γ rays, since these are not emitted once per disintegration.

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

In the determination of the shape of the beta spectrum of 2.7 day Au^{198} which we discussed several months ago we mentioned that at low energies the intensity was greater than predicted by Fermi's theory. To rule out the possibility that this was due to an impurity we studied the decay with a slightly thicker and stronger source. Three runs were made and it appears that all parts of the spectrum decay with the same half-life. The deviation from the theory occurs at approximately the same energy with both sources, but the thicker source gives rise to a greater deviation. In addition, with the stronger source, there is an indication of weak conversion lines at $H\rho \approx 1043$ and $H\rho \approx 1348$. We are attempting to ascertain if this deviation is instrumental, arising primarily from back scattering, or is due to the beta spectrum having two components. The latter hypothesis is supported by the appearance of the weak conversion lines.

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

Some work has been done to prepare the equipment required. From tests on the fast neutron counter it seems possible to obtain efficiencies of the order of 1%, without too great a sensitivity to γ rays. However, the counter is not yet sufficiently stable.

Physics Section V
Henry W. Newson, Section Chief

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

Ionization Chamber (Armistead, Mead)

An experimental ionization chamber has been built for testing various types of boron coatings. In order to be useful as a guide in the construction of the chamber for the high flux pile both the materials and the methods of fabrication were carefully selected to give a minimum beta-gamma activity. The chamber is presently being tested with boron trifluoride, which has been used extensively as a primary standard in experiments involving boron coatings. A report has been completed which discusses in detail the desired properties of the final chamber.

Other Instrument Developments for the High Flux Pile

The model servo system is still in the shop. There seems to be a good chance that it will be ready for trial about December 1st. Meanwhile, the simulator is being calibrated in preparation for this experiment. Work continues on the $\frac{d \ln n}{dt}$ circuit, mostly in the direction of increasing its range.

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Physics Section VI

G. Young, Section Chief

Total Technical Personnel (including supervision) . . . . 9 and 5 Trainees

Nuclear Data - (Dismuke and Way)

Work is under way to bring all the data on cross-sections up to date. The information collected thus far is available in room 201 or 203 of the Training School Building; in particular, data sheets supplementing MUC-HHG-7 have been recently put together for Al, Na, Mg, Mn, Au, and Rh. References to cross-section measurements in periodicals that might be missed will be very much appreciated.

The first report of the Clinton isotope committee on new information on half lives, decay energies, abundances, etc. to be found in reports and periodicals which became available during September and October 1946 is being issued as a memorandum, CLM-KW-1

Fission and Fission Products - (Way and Nodorer)

A summary of the way the fission of U^{235} and Pu^{239} takes place on the average, energy release in different forms, number of neutrons emitted, etc. is being issued as Mon P-192 with the title "The Average Fission in U^{235} and Pu^{239}."

As part of a program of investigation of fission product poisoning, the statistics of MUC-KW-41 on thermal cross-sections have been brought up to date as indicated in the graph below. The average values of the Sm cross-section over Maxwell distributions at several temperatures have also been calculated.

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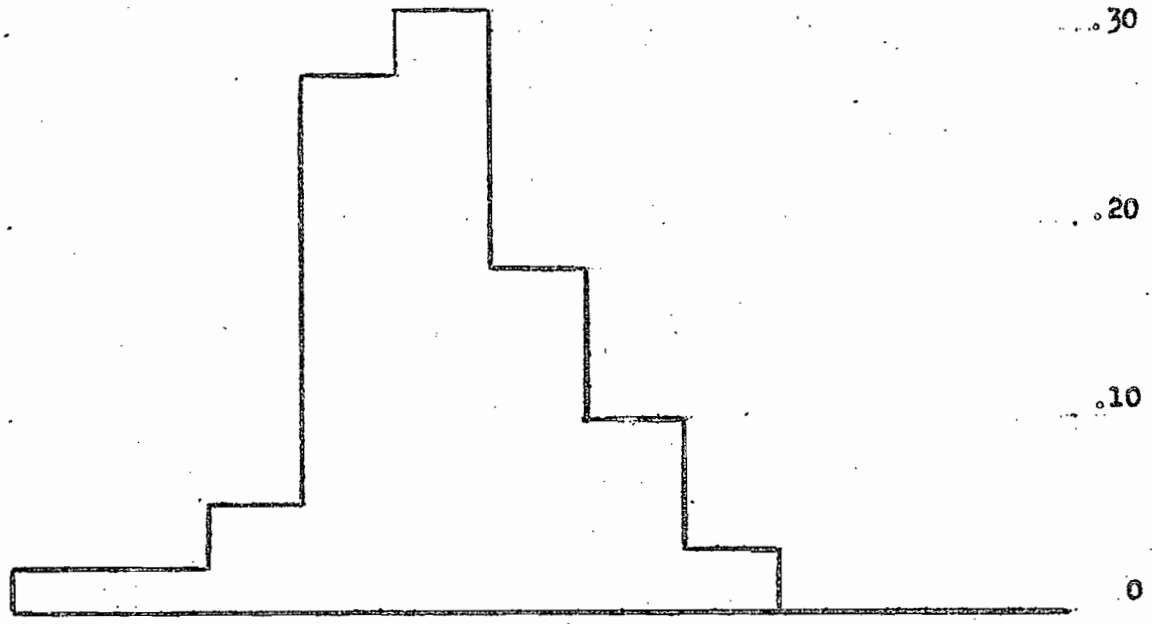
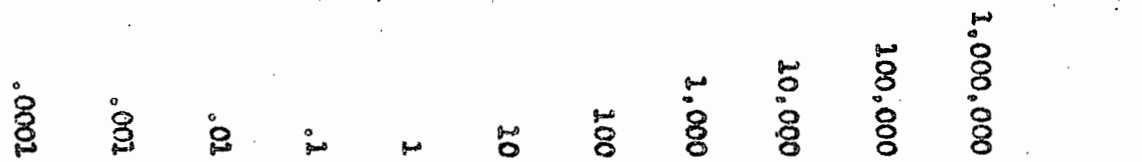
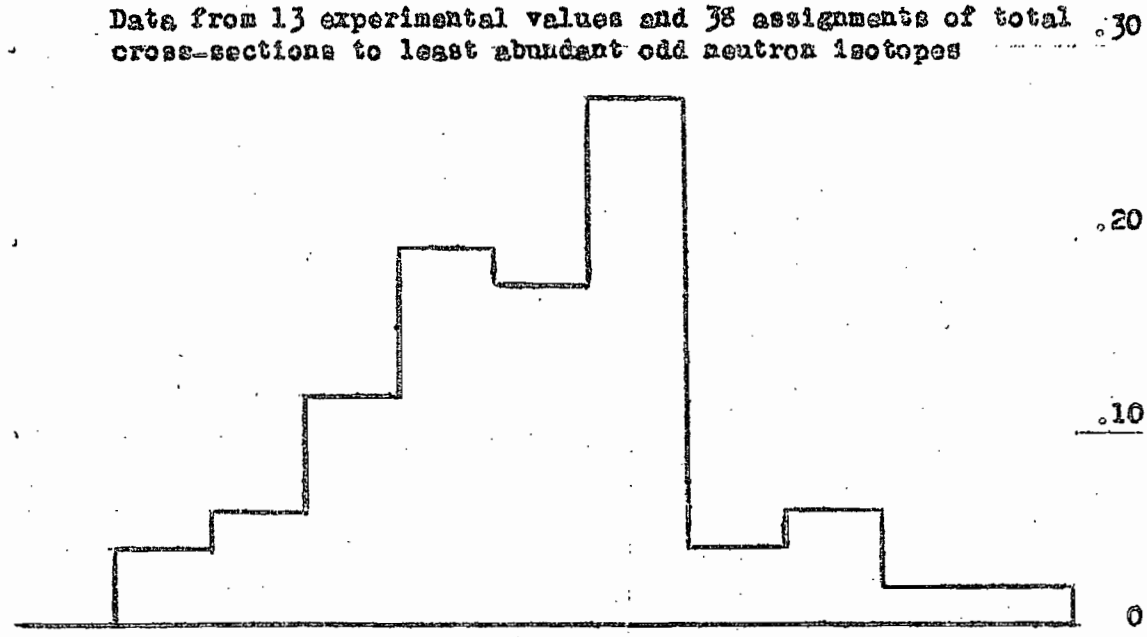
Data from 90 experimental values



Nuclei with even numbers of neutrons



Data from 13 experimental values and 38 assignments of total cross-sections to least abundant odd neutron isotopes



Nuclei with odd numbers of neutrons

Fraction of nuclei with cross-sections in given cross-section interval expressed in barns

Multiple Reflectors - (Garabedian and Householder)

A forthcoming report "The Two Group Theory of Piles with Multiple Reflectors" shows how the two-group calculation of the critical size of a slab pile with any number of reflectors can be reduced to a 4 x 4 fundamental determinant. The corresponding problem in a spherical system is being considered. This study was suggested by Mr. Weinberg.

Slowing Down - (Murray)

Some formulations and partial results on this problem will be indicated in a memo "Scattering and Energy Reduction of Neutrons from a Plane Source in an Infinite Medium." This material has some relation to current work by Mr. Rose (Mon P-178, p. 10) and by Mr. Coveyou.

Ore - (Menke)

A study of marginal ore concentrations and production costs for a number of metals indicates that materials can be concentrated from underground deposits for about ten dollars per ton of rock processed. Details are being reported in a memo entitled "Some Estimates on the Availability of U and Th and their Cost in the United States."

Heavy Water - (Grebe)

A proposed modification in the cells for large scale industrial salt electrolysis might possibly contribute to deuterium production; this question is being discussed with Mr. Karl Cohen.

The possibility that recently developed resins may permit effective use of ion-exchange columns to concentrate deuterium is being looked into with Mr. Boyd of the Chemistry Division and with the cooperation of Dow Chemical Company.

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Power Piles - (Young)

Mon P-190 gives some comparison of different moderators and coolants for high temperature power piles, and makes an attempt to estimate certain of the cost items involved.

School - (Young)

A memo "Summary of New Pile Studies" is being issued as an outline and reading guide to members of the Pile Technology class, and to a number of other people at Clinton Laboratory and at cooperating laboratories.

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