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PHYSICS DIVISION

REPORT FOR MONTH ENDING JULY 31, 1946

L. W. Nordheim, Director

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Physics Section I

A. H. Snell, Section Chief

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

Problem Assignment Number	Subject	Status	Man-months of Effort Report Per.	Next Per.
PX1-7	C^{14} Production	Active	2	2
PX8-4	Neutron Temperature in Pile	Inactive	0	0
PX8-1	Gamma Ray Spectra	Inactive	0	0
PX8-2	Photoneutron Sources	Inactive	0	0
163-X39P	Service Flux Measurements	Active	1/2	1/2
PX8-4	Gamma Energy per Beta	Active	1	1
PX5-22	Critical Experiments	Active	$3\frac{1}{2}$	$3\frac{1}{2}$
	Neutron Decay	Active	2	2
		Total.....	9	9

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Neutron Half-Life - (Shrader, Saxon)

The collimator for producing the neutron beam was completed and installed in the north end of hole 17 during the past month. Flux determinations are now being made. A second multiplier has been made and tested after the first one became photosensitive and lost in overall multiplication. Comparison has been made between pulses produced by 4500 volt protons and by gamma rays from a radium source. The average proton pulse is roughly five times as large as a gamma ray pulse. Considerable time during the past month has been spent in the trouble shooting of vacuum systems and electronic equipment. Complete assembly of all equipment is expected within the next week.

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

The factory has been down some two weeks this month for repairs and alterations. Work on the half-life is also progressing, and a final report should be ready, perhaps by September.

PX5-22 - Critical Experiments - (Branch, Goodman, Scalettar, Slawson, Snell)

Subsequent to the experimental determination of the disadvantage factor reported last month, Scalettar made a theoretical calculation which indicated a value of 67%. Repeat measurements established that the gold foil, which was contained in a lucite holder that dipped into the uranyl fluoride solution, had become contaminated with short-lived fission products. Upon delaying the counting of these foils until the pure 2.6 day gold half-life was present, a

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disadvantage factor of 45% was obtained. The outer foil was cut into several annular strips in order to determine the radial distribution within the 1 cm annulus. A special fuel tube containing 94 gms of U^{235} dissolved in light water was tested in place of one of the regular tubes in which the U^{235} was dissolved in heavy water. No detectable difference between these two assemblies was observed with the pilito at critical. Accordingly, arrangements were made with the Chemistry Division to remove the D_2O by distillation from all fuel tubes and re-dissolve the uranyl fluoride in H_2O. After some minor difficulties with decomposition of the uranyl fluoride, this exchange has been completed. The light-water solutions are contained in glyptal-coated aluminum tubes 2" o.d. x 1-7/8" i.d. The height of the solution is 100 cm. These aluminum tubes form the central section of fuel tube assemblies in which the outer tube is 3" o.d. x 2-7/8" i.d. In the experiments now in progress, the 1 cm annulus between these tubes will be filled successively with air, aluminum strips and D_2O. Preliminary results indicate a critical mass of about 3100 gms when the annuli contain air, with the reactor covered by a thin coat of thermal insulation as arranged in the previous experiments. In order to more closely simulate the proposed heterogeneous pile, Weinberg suggested that the thermal insulation be removed from the reactor and a graphite reflector mounted around the periphery. The installation of this reflector reduced the critical mass by approximately 200 gms, i.e. to about 2900 gms.

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Physics Section II

A. M. Weinberg, Section Chief

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

Age of Fission Neutrons in H_2O - Al Mixtures -(N. Dismuke, R. Arnette, P. Levy and H. Soodak)

The thermal age of fission neutrons ($\bar{\tau}$) in various H_2O - Al mixtures has been calculated. The age for each energy was obtained from the formula given in CP-1251 for the second moment of the slowing down range on the assumption that Al has infinite atomic weight. The ages are therefore somewhat too large since the Al actually has some moderating power.

Cross sections used were taken from the curves of H. H. Goldsmith and H. W. Ibser, MUC-HHG-7. In calculating $\bar{\tau}$ the thermal fission spectrum from LA-84 was used.

The following table shows the thermal ages obtained for three volume ratios of Al to H_2O:

(see following page)

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Energy (mev) E	τ(E, .025 ev) in cm^2 $\frac{V_{Al}}{V_{H_2O}} = 0$	$\frac{V_{Al}}{V_{H_2O}} = 0$	$\frac{V_{Al}}{V_{H_2O}} = 1$
1×10^{-7}	.24	.52	.89
1×10^{-6}	.99	2.03	3.44
1×10^{-5}	1.90	3.95	6.40
1×10^{-4}	2.59	5.91	9.63
1×10^{-3}	3.53	7.88	12.92
1×10^{-2}	4.61	10.01	16.43
1×10^{-1}	6.54	13.41	21.78
1	14.42	26.47	40.03
6	91.46	128.96	170.13
$\bar{\tau}$	30.00	47.53	67.57

The observed age in pure H_2O is about 33 cm^2.

Temperature Coefficient of Plutonium Piles - (E. Greuling)

A thermal neutron pile made of a mixture of Plutonium and moderator having a 1/v absorption cross section, under certain conditions, has a positive temperature coefficient. The plutonium resonance at 0.3 ev is sufficiently broad to cause the fission rate and the 49 absorption rate of neutrons in an approximately Maxwellian distribution to increase with the temperature of the neutrons.

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The essential condition for a possibly dangerous temperature coefficient is that the thermal utilization be small.

The following temperature coefficients were calculated for a spherical homogeneous 49 graphite pile of radius R in meters.

k	f	R	$(\frac{\Delta k_{eff}}{k})$ per $10^{\circ}C$ temperature increase
1.00	.505	∞	+ .48%
1.03	.535	5	+ .40%
1.43	.722	1-2/3	+ .05%
1.77	.835	1	- .15%

Combined with the fact that a $\Delta k_{eff}/k$ of only 0.32% is required to over run the delayed neutrons from plutonium fission, it is clear that a 49-graphite pile with a thermal utilization less than ~~.5~~ 0.57 will be on the prompt neutron chain after a temperature increase of less than $10^{\circ}C$.

The Blocking Effect (R. Scalettar)

In the first critical experiments designed to determine the required 25 mass of the Huffman lattice, the light water cooling was simulated by paraffin cylinders surrounding the 25-D_2O fuel tubes. It was found that the pile did not go critical even with well over 3300 gms. of 25, much more than the expected value. The primary reason for this has now been traced down to the so-called

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blocking effect of the paraffin i.e. the paraffin shell is several thermal scattering mean free paths thick (due to the high hydrogen thermal scattering cross-section) and thermal neutrons entering the paraffin from the rest of the lattice diffuse out more slowly (small diffusion constant) raising the neutron density over that which would prevail in a homogeneous mixture. The resulting increased absorption in the paraffin decreases the effective multiplication constant of the pile and increases the critical mass.

A theoretical estimate of this effect has been made and it has been found that the average neutron density in the paraffin is 67% higher than in the fuel tube. Since the ratio of the absorption cross sections of paraffin and fuel is 28%, the blocking effect increases the ratio effectively to 47%. The resultant reduction in k_∞ has been estimated to be sufficient to account for the high observed critical mass. An experimental determination of the relative neutron densities in paraffin and fuel was made (G. M. Branch) by foil measurements and the value obtained for the ratio was $\sim$1.45. Considering both the experimental and the theoretical difficulties in the way of an accurate determination we believe the agreement to be reasonably good.

Measurements have now been begun in which the 25 compound is actually dissolved in light water to simulate the cooling, and the first results indicate critical masses only slightly higher than theoretically expected.

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Carbon 14 Production - (R. Scalettar)

An estimate of the expected yield of Carbon 14 from the 6500 cans(730 kg) of $Ca(NO_3)_2$ situated on the radial periphery of the active lattice of the Xe-graphite pile has been made. The average neutron flux at the carbon 14 position has been calculated to be

$$\overline{nv} = 4.7 \times 10^7 \ P$$

where P is the power in kilowatts. Using an absorption cross section of 1.7 barns for the $N^{14}(n\ p)\ C^{14}$ reaction we find 0.92 mg. of C^{14} produced per megawatt day. Adopting the Norris value for the half life of C^{14} (6100 yrs.) we have then 3.84 millicuries per megawatt day. Considering the average power at which the pile operates we get for the annual production of C^{14} 4.4 curies. This is in good agreement with an extraction already made by Tompkins and Anthony. (See memo Cohn to Koenig), and thus constitutes an independent approximate check of the Norris half-life. The above estimate is to be used as the basis for the price determination of C^{14}.

Shielding Studies (F. H. Murray)

The neutron energy as a function of penetration distance has been calculated for a beam of neutrons impinging on a semi-infinite slab. The formulae used were derived by an analysis of successive collisions. The results will be of some use in connection with shielding against fast neutrons.

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Studies are also in progress for the purpose of estimating the inelastic scattering by nuclei for which experimental data is not available.

Calculation of $\delta k_{eff}/k$ for a Pile with Non-Uniform Depletion - (H. C. Schweinler)

In the high neutron fluxes contemplated for the new pile, the depletion of 25 produces relatively large changes in reactivity after several days of operation. Since the greatest change occurs in the region of largest statistical weight, first-order perturbation calculations are not valid. Therefore a variational method has been used, the pile equation $\nabla^2 \varphi + B\varphi = 0$ being written in the form $\delta \int \left[(\nabla\varphi)^2 - B\varphi^2 \right] d\tau = 0$, with $\varphi = \left(\frac{1}{L^2_f} + \frac{1}{L^2_s} - \Delta_1\right) n_s$ and $B = (k + \delta k_{eff} - 1) \Big/ (L^2_f + L^2_s - L^2_f \; L^2_s \; \Delta_1)$. (Here L^2_f, L_s, Δ_1, n_s, k and δk_{eff} are respectively the age, thermal diffusion length (space-variable), laplacian of the neutron density at time t = 0, thermal neutron density, local multiplication constant, and uniform change in k needed to keep the pile critical).

Calculations have been made for a spherical pile of k = 1.4 and 1.6 originally, on the assumption that the numerical density of 25 at any point r is $N^{25} = No^{25} \exp - .022\, T \dfrac{\sin \frac{\pi r}{r}}{\frac{\pi r}{R}}$ with T the time in days and R the radius of the pile. (This corresponds to a central flux of 4×10^{14} cm^{-2} sec^{-1}.) The results are given in the accompanying table.

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T (days)	1	10	20	
$\delta k_{eff}/k$ for $k_o = 1.4$	.86	9.0	19.2	%
$\delta k_{eff}/k$ for $k_o = 1.6$	.80	8.4	17.8	%

A report giving the details of this calculation is being prepared.

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Physics Section III

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

Total technical personnel (including supervision).....$8\frac{1}{2}$

Problem Assignment Number	Subject	Status	Man-Months of Effort Report Per.	Man-Months of Effort Next Per.
PX6-1	Pile Oscillator	Active	1	$\frac{1}{2}$
PX10-8	Neutron Diffraction	Active	$\frac{1}{2}$	1
PX10-16	Characteristics of Fission Products and Neutron Induced Activities	Active	1	1
PX10-19	Capture Gamma Energies	Active	$1\frac{1}{2}$	$1\frac{1}{2}$
PX10-22	Short Lived Isomers	Active	$1\frac{1}{2}$	1
	Ranges of Delayed Neutron Emitters	Active	1	$1\frac{1}{2}$
	Studies of Prompt Fission Neutron Emission	Active	1	$1\frac{1}{2}$
	Supervision and Report Writing	Active	1	1
		Total.....	$8\frac{1}{2}$	9

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PX10-22 Search for Short Isomeric Lives (De Benedetti, McGowan)

A special cell was built to investigate the existence of a short isomeric state in Cs^{133} (spin 7/2) using a source of Xe^{133}: negative result.

Also negative results were obtained with sources of supposedly Sn^{123} (assignment uncertain, class D) which should decay to Sb^{123} (spin 7/2) and sources of Dy^{165} decaying with Ho^{165} (reported in some papers as having spin 7/2). Sources of Cr^{35} similarly showed no effect.

The following sources of odd-odd isotopes were used to investigate whether short lived isomers could be observed in their even-even daughters: Mg^{56}, Co^{60}, Cu^{64}, Ga^{72}, As^{76}, Br^{82}, Rb^{86}, Y^{90}, Sb^{122}, Sb^{124}, Cs^{134}, La^{140}, Pr^{142}, To^{182}, Au^{198}, Bi^{210}. No delayed coincidences were observed.

The delayed coincidences previously reported for very short delays with sources of W^{187} were confirmed. Their origin is still dubious.

It was decided to study whether a tube working on the principle of the electron multiplier could be used for the investigation of lives shorter than 10^{-6} sec.

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

As an extension of R. R. Wilson's work on the directional properties of fission neutrons (LA-588) we are planning an experiment to study the mechanism of emission of prompt fission neutrons by means of coincidences between the fission fragments going in a certain direction and the neutrons emitted in the same direction. The size of the fission pulses connected with a prompt neutron will either be recorded photographically or will be studied by counting coincidences with different settings of pulse height selectors in the amplifier of the fission chamber. As a result of this experiment we should be able to decide which fission fragments (if any) are preferentially responsible for the emission of fission neutrons.

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For the moment we have done no more than considering what is needed to carry on this experiment. Some work has been done to try to develop an efficient counter for fast neutrons and to study the neutron flux available in the top thermal column of the X pile.

A proportional counter with the inside wall coated with hydrogenous material has been prepared. Within certain limits of voltage this counter appears to be sensitive only to fast neutrons. Its efficiency is, however, very low. In order to increase the efficiency we have attempted (following an idea of Dr. W. Wilson) to build a proportional counter with a large number of hydrogenous films perpendicular to the wire. We have not yet been successful in this work, probably because we did not use the right materials.

The flux of slow neutrons has been measured in several positions in the thermal column. We are now going to measure the background of the fast neutron counter in the slow neutrons flux. In some very rough preliminary experiments this background seemed to be prohibitively high.

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

We have completed the improvements on the spectrometer and power supply mentioned in the previous monthly report. As a result the total absorption of the counter window has been reduced from 5.2 mg/cm^2 to 1.2 mg/cm^2.

At present we are attempting to make a careful determination of the shape of the beta spectrum of 2.7 day Au^{198}. To this end a method of making sources approximately .2 mg/cm^2 thick mounted on zapon $\ll$ .1 mg/cm^2 has been developed.

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PX6-1 Pile Oscillator (C. D. Moak)

This apparatus is in a shape for routine cross section measurements. Some measurements of this type have been made during the month.

PX10-19 Energies of Capture Gamma Rays (Moak, Burgy)

There has been some delay in the progress of this work due to failure of the current regulator for the Helmholz coils. More work will also be required on the magnetic field measuring equipment. We hope, however, to begin making measurements this month.

Correlation of Delayed Neutron Emitters from U^{235} with Fission Fragment Range. (Rose, Burgy, Wollan)

Some changes have been made in our rabbit to improve its operation. Another rabbit is being built with further changes in design, in order to get more reliable behavior. The preamplifier and amplifier in our counting system have been changed to eliminate counts due to piling up of γ-ray counts. We find that we are getting a considerable number of spurious counts and we have been occupied recently with eliminating them.

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Physics Section IV

L. B. Borst, Section Chief

S. Bernstein, Associate Section

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

Problem Assignment Number	Subject	Status	Man-Months of Effort Report Per.	Man-Months of Effort Next Per.
PX4-5	Heat Evolution from Pa^{233}	Inactive	0	0
PX10-15	Photoneutrons from Fission Products Plus P-9	Active	3	3
PX10-10	Deuterium Gamma Ray Spectrometer	Inactive	0	0
PX10-14	Poisoning Coefficients	Inactive	0	0
PX10-7	Fissionability of 40-10	Active	1	1
	Plutonium Project Record	Active	0	1
PX10-8	Neutron Diffraction	Active	2	1
PX10-17	Fissionability Studies	Active	1	1
		Total	7	7

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

The past month has been spent in (1) checking the accuracy of our photoneutron measurements by measuring the strengths of an Sb - γ - Be and a Po - α - Be source in our apparatus in each case with and without D_2O in the 10" radius sphere. (2) Compiling and analyzing all of the measurements made thus far in preparation for a final report on 25. (3) Procuring and preparing a sample of 150 mg of 23 for photoneutron yield measurements.

A complete discussion of items (1) and (2) shall appear in our final report on 25.

PX10-7 - Fissionability of 40-10-(Schofield)

A sample of PuI_3 is being prepared in readiness for a 240 collection problem. A new design for the main tube top has been discussed so that the furnace-type ion source may be installed. Vacuum troubles have hindered operation but the program progresses slowly.

PX10- 8 - Neutron Diffraction - (Dial)

Transmission measurements are in progress with the dysprosium and yttrium samples. Measurements taken so far indicate that resonances in the region between 0.1 and 0.25 ev are unlikely. There is only fair comparison between the measurements of this series and earlier work by Borst and Ulrich on dysprosium in this region.

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PX10-17 - Fissionability Studies - (Osborne)

Observation of the photographic films exposed with UX_1 in the pile are proceeding, but no definite results can be given yet.

Additional exposures have been made for Dr. McRae of K-25 in connection with his attempt to use thermal fission as a method of routine isotopic analysis. These exposures were made in the thermal column, since hole 59, where previous exposures had been made, was found to have too high a fast neutron flux.

An apparatus has been constructed for determining the fission cross section at fission energies. It consists of uranium metal slabs appropriately spaced to permit the insertion of the test sample. A preliminary test with thorium indicates a flux of greater than 10^{10} neutrons/cm^2.

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Physics Section V

H. Newson, Section Chief

Total Technical Personnel (including supervision).....6

Ionization Chamber Development -(F. C. Armistead)

Efforts have been directed chiefly toward reducing the activity that can be induced in the G.E. differential ion chamber. This reduction in chamber activity is important since it permits wider range of pile power which can be followed by one instrument. The ion chamber in hole 34 was removed from the shielding, and readings were taken of the ion current due to the chamber's own activity over a period of 7 hours. The activity observed can be fairly well represented by the sum of three decay curves with initial partial intensities as shown:

10 parts	1.8 hr activity from A gas in chamber
5 parts	2.6 hr activity from Mn in steel
1 part	Long lives suspected to be mostly 5. yr Co in Kovar alloy.

These intensities are those expected from the quantities of respective materials involved.

We have had consultation with Drs. H. Pearlman of Y-12 and C. Starr on possible substitutes for the fragile and highly active Kovar-glass insulators used in the G.E. ion chamber. Several suggestions look promising, and the simplest one is under test now, viz. standard automobile spark plugs. Two "Champion J-9" plugs, with the brass fittings removed, show a neutron-induced activity which decayed as the activity of steel, and all activity seemed to be at the steel ends rather than the porcelain ends of the plugs. It is thought therefore that no source of strong activity will be introduced by the use of spark plugs in the ion chamber.

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To test the behavior of the plugs under fast neutron bombardment, they are scheduled for a week in the "doughnut" tube of the X-pile. Two plugs have been tested, prior to this irradiation, for electrical insulation and for leak tightness quantitatively, both before and after machining and soft soldering the metal parts of the plugs. Similar tests will be made subsequent to irradiation of the plugs in the pile, to check deterioration due to the "Wigner effect" in them.

Collaborating with the instrument department, we have repaired a discarded G. E. differential ion chamber and are using it for test purposes. It is found that when filled with N_2 the chamber has at least the sensitivity (ion current per thermal neutron flux unit) that it has when filled with A. After long irradiations in the standard location for an ionization chamber in the X-pile, the nitrogen filled chamber showed about half the background (when removed from the pile) as did the same chamber when filled with Argon. This seems reasonably good verification of the estimated fraction of the Argon activity in the background. A further large decrease in background should be obtainable by building the chamber of low manganese steel.

Pile Control -(Henry Straus)

The simulator has been in operation and behaved qualitatively as expected. In order to facilitate study of transient phenomena at low levels when starting from a shut-off condition, the integrator amplifier has been modified by addition of an internal feed back net. The cathode resistor of the delayed neutron cathode followers are to be modified to make the source setting less critical.

A gear train has been designed and at present under construction. This unit will be used in a model of the control system in studies on the response of the simulator to the control system. The d.c. amplifier design

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for the model system is completed.

A 6 channel amplifier is under construction for use with the recorder to make possible legible records of simulator performance under a wide range of intensity.

Electronic Development -(P. R. Bell, W. H. Jordan)

See last report.

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