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TECHNICAL ACTIVITIES REPORT FOR JUNE 1953

PHYSICS UNIT - APPLIED RESEARCH SUB-SECTION

AUTHOR

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D. E. Davenport
G. E. Duvall

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TECHNICAL ACTIVITIES REPORT

for

June 1953

PHYSICS UNIT - APPLIED RESEARCH SUB-SECTION

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EXPERIMENTAL PHYSICS SUB-UNIT - J. E. Faulkner

I. Xe^{135} Cross-Section Measurement

Information has been obtained recently from Oak Ridge National Laboratory on the status of an ORNL program for measuring the total neutron cross section of Xe^{135} (HW-28075). It was found that: a) the ORNL program will produce cross-section information over a wider energy range than the Hanford program, b) the energy resolution of the data from the two sites will be comparable, and c) the data from ORNL will be produced sooner than that from Hanford. After considering these facts and the cost of finishing the experiment, it has been decided to cancel the Hanford program.

A report is being prepared covering the work accomplished to date.

II. C^{12} Cross Section - R. E. Peterson, H. W. Lefevre, E. J. Seppi

An analysis of the $carbon^{12}$ experiment is being made. The object is the determination of the probable error in the final calculated value of the $carbon^{12}$ thermal neutron cross section.

The present course of study can be broken into three major parts: (1) examination of various needed constants to find good values, their reliability and probable error, (2) examination of the solved differential equations to better fit them to experimental conditions and to find their characteristics, and (3) examination of corrections which must be made in the final analysis for cobalt resonances, for total flux variations due to flux variation as a function of position in reactor, and possibly, for variation in MTR neutron spectrum as compared to the Hanford neutron spectrum.

The use of $cobalt^{59}$ as a long term flux monitor in this experiment has been questioned because of neutron capture in 5.2 year Co^{60}. However, a value for this cross section has been reported in Chalk River Progress Report, PR-P-16, as being 3.8 ± 0.9 barns for Chalk River pile neutrons. Assuming that approximately the same neutron temperature exists at the Materials Testing Reactor, this will make a difference of about three per cent in the cobalt activation over the period of a year in the MTR. Two letters have been written to determine if any later work has been done in evaluating this cross section so that the best possible correction can be made.

As described in last month's TAR, ten aliquots of the cobalt sample used as a flux monitor in MTR were prepared by pipetting 0.01% of the cobalt on to microscope slides for coincidence counting. The coincidence counting of these aliquots has been completed. Assuming no systematic errors in the coincidence counting, the activity of the 0.494 milligram cobalt sample activity was $1.922 \pm 0.005 \times 10^9$ dps on June 16. This compares favorably with the activity determined by comparison of gamma counting rates of a Bureau of Standards Co^{60} source and a source prepared from the monitor. The activity determined by this method was 1.89 ± 0.08 x 10^9 dps. As a result of this analysis, one liter of calibrated cobalt solution is available for standard sources.

The cobalt aluminum wire which will be used to determine the integrated flux distribution in MTR for one complete fuel cycle has been mounted for an activity scan. A preliminary activity traverse has been made but, owing to shielding difficulties, it will have to be repeated in an attempt to either reduce or correct for background.

III. Conversion Efficiency for H-10 Load - R. E. Peterson

Three tubes from the H-10 load were selected for which H^3 yield per tube was well known, owing to their not having been mixed with P-10 slugs from other tubes during extraction, (tube Nos. 2476, 1483 and 1478). The conversion efficiency, C, is given by:

$$C = \frac{\text{No. of } H^3 \text{ atoms produced}}{\text{No. of atoms of 25 burned up}}$$

Knowing the number of H^3 atoms produced per tube from Hanford data, it remained to find the amount of U^{235} burned up in the associated J slugs in each tube.

A request was made to the American Cyanamid Company at Arco, Idaho, who is processing the J slugs, to process these three tubes individually. However, due to an oversight at Arco, the requested slugs were mixed in with slugs from other tubes, with the exception of tube No. 1483 which was dissolved with six slugs from tube 1478 in batch No. 1026J. The data, including mass analysis, for this batch as well as those before and after have been received and are being evaluated. The errors in mass analysis and hence burnout of 25 are as yet uncertain. It appears at this time, that one or possibly two values for the conversion efficiency may still be obtained from this information.

IV. Lattice Test Experiments - D. J. Donahue, D. D. Lanning

Design has been started this month in cooperation with W. A. Horning for a building and reactor that could be used as a possible prototype of the larger lattice testing facility which has been proposed. An estimate has been made by Project Engineers on the cost of a building with the minimum requirements for such a design study, and an estimate was received from the machine shops on the cost of metal machine work connected with the prototype. A document is now being compiled of these estimates together with some expected results from such an experiment.

V. Critical Mass Problems - D. D. Lanning, R. P. Raftery

A calculation has been made to find the effect of using polyethylene raschig rings in packed solution extraction columns. Figure 1 shows the diameter of

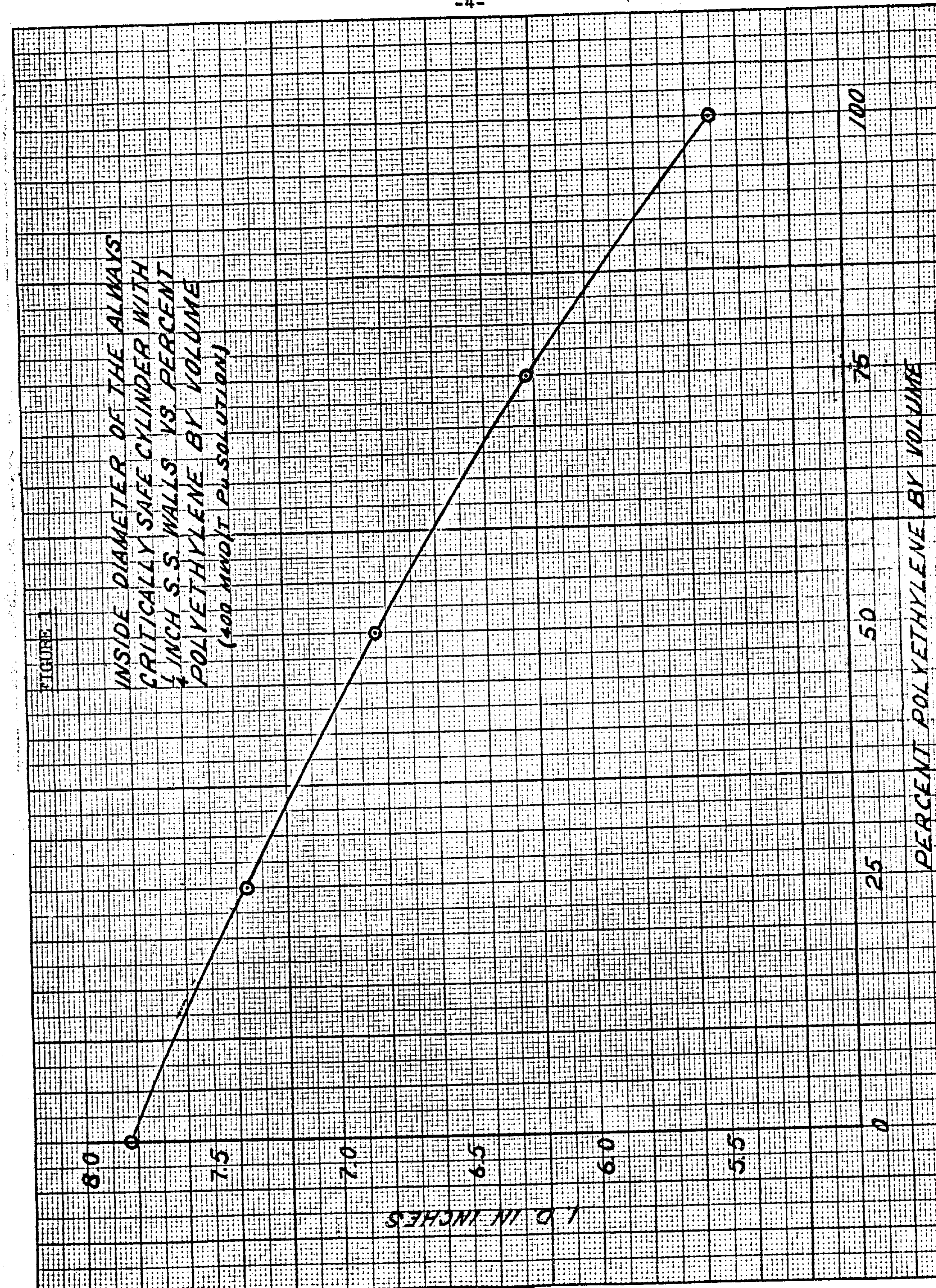


FIGURE 1
INSIDE DIAMETER OF THE ALWAYS
CRITICALLY SAFE CYLINDER WITH
1/4 INCH S.S. WALLS VS PERCENT
POLYETHYLENE BY VOLUME
(400 MHNO/l Pu SOLUTION)
I.D. IN INCHES
8.0
7.5
7.0
6.5
6.0
5.5
0
25
50
75
100
PERCENT POLYETHYLENE BY VOLUME

[redacted]

the critically safe cylinder with 1/4" stainless steel walls for plutonium solutions in water as a function of the per cent of polyethylene by volume which is mixed in the solution. The polyethylene decreases the safe diameter since its hydrogen concentration is greater than that of water, hence making it a better moderating material.

Two documents concerning critical mass problems were written this month. HW-28272 is a summary of three questions asked by E. R. Irish concerning the critical mass of certain vessels in the Redox separation plant. HW-28487 gives an estimate for the critically safe storage of sample cans which are loaded with 400 grams of plutonium each. All calculations indicate that a close-packed array of these cans could be made critical, hence, very conservative limits were given for the storage of these cans with the suggestion that to increase the number of cans which could be stored together, it would be necessary to conduct an experiment involving the measurement of the multiplication of a number of cans to determine the critically safe limit.

VII. <u>Neutron Beam Catcher Design</u> - W. P. Stinson, S. M. Hauser

Neutron and gamma flux measurements have been taken in a cubical water tank 3 feet on a side. Measurements were made with no boron and with hydrogen to boron ratios (H/B) 456 and 142.

Additional measurements will be made in a paraffin and boric acid mixture and paraffin and borax mixture with a H/B of 14 and 10.

VII. <u>Ratio of Pu^{239} Fission Cross Section to U^{235} Fission Cross Section</u> - B. R. Leonard, Jr., S. M. Hauser

The standard foils for the measurement of σ_f49/σ_f25 have been received from KAPL. These foils are uranium foil #229 (approximately 1.9 mg U^{235} with a surface uniformity of ± 1.5%) and plutonium foil #318 (approximately 1.4 mg Pu^{239} with a surface uniformity of ± 1.7%). The fissile material of these foils was sputtered on to an 11.4 cm^2 area as compared to 15.5 cm^2 for previous foils. The surface of foil #318 has undergone considerable coloration since its arrival, and tests are underway at KAPL to assure the continued reliability of the surface uniformity of this foil. The new foil set has been mounted in the fission chamber and data have been taken at 0.15 ev with 0.25% statistical accuracy. The recent remounting of the crystal spectrometer which, as discussed in the May TAR, allows a determination of most instrumental errors, has determined the source of an important discrepancy previously observed. The data obtained for neutrons incident on one face of the Be crystal, designated as #1 in Table 1, are seen to be inconsistent for the symmetric crystal planes $10\bar{1}1$, $10\bar{1}\bar{1}$. The source of this disagreement is probably due to crystal imperfection on this face. This discrepancy was eliminated when the opposite crystal face (#2) was used.

The data of Table 1 also shows an attempt to deduce the correct angle between the $10\bar{1}1$ and $10\bar{1}\bar{1}$ planes. Seemingly better agreement is found with an angle of

TABLE 1

VALUES OF I^{49}/I^{25} FOR DIFFERENT ANGLES BETWEEN THE $10\bar{1}1$ and $10\bar{1}\bar{1}$ CRYSTAL PLANES

$\theta_B = 12.32°$ E = 0.15 ev

Crystal Surface Facing Incident Neutron Beam	Plane	I^{49}/I^{25} + Side	I^{49}/I^{25} - Side	I^{49}/I^{25} Average	Agreement of $10\bar{1}\bar{1}$ with $10\bar{1}1$	Angular Displacement of $10\bar{1}\bar{1}$ from $10\bar{1}1$
#1	$10\bar{1}1$	2.075 ± 0.005	2.066 ± 0.005	2.0705 ± 0.0035		
	$10\bar{1}\bar{1}$	2.098 ± 0.005	2.102 ± 0.005	2.100 ± 0.0035	0.0295 (1.4%)	57.81°(2)
#2	$10\bar{1}1$	2.099 ± 0.005	2.098 ± 0.005	2.0985 ± 0.0035		
	$10\bar{1}\bar{1}$	2.117 ± 0.005	2.081 ± 0.005	2.099 ± 0.0035	0.0005 (0.025%)	57.88°(1)
		2.095 ± 0.005	2.108 ± 0.005	2.101 ± 0.0035	0.0030 (0.15%)	57.81°(2)

(1) Calculated angular spacing

(2) Experimental angular spacing based on rocking curve data

57.81° rather than the value of 57.88° deduced from the published lattice constants of beryllium. This disagreement, though small, deserves a further investigation to determine the correct lattice constants.

VIII. Study of Neutron Flux Measurement Techniques - R. E. Heineman

It would appear that the most feasible way of measuring neutron flux as a function of energy and position in a lattice cell would entail the activation of foils, whose physical size can be smaller than the distances over which the flux would be expected to vary appreciably and whose presence would perturb the flux only negligibly.

A scheme for measuring the absolute epi-Cd flux as a function of energy using foil activation techniques has been reported in the literature recently. The method is claimed by the author to be accurate to ± 15%. A critical analysis of his calibration data and assumptions leads to the preliminary conclusion that the degree of certainty claimed for the results is overly optimistic. A search of the literature reveals no better calibration data than those the author used. However, since the general method appears promising, more work has been and will be done to try to improve the assumptions, especially in the "threshold detector" region of the spectrum (0.5 to 10 Mev).

In the "resonance region" (1 to 10^4 ev) another recently reported foil technique shows more promise. The calibration is perhaps more tedious, but can be done in Hanford piles without additional facilities other than the special foils.

In connection with the above work, average thermal and resonance flux spectra for a Hanford-type reactor as a function of power level and flattening have been calculated by making simple approximations and have been issued as Document HW-28303. These spectra are intended to be useful only for purposes which are equally approximate.

John E. Faulkner

APPLIED RESEARCH SUB-SECTION

JE Faulkner:as

EXPONENTIAL PHYSICS SUB-UNIT - D. E. Davenport

Hollow Slug Program - W. B. Farrand

Preparation for drilling of solid slugs for the 0.810" central water tube has been carried out with Fuel Technology Sub-Section. Fuel Technology Sub-Section is acting as liaison agent with Manufacturing who will do the actual drilling of the slugs. The thin wall of the outside can (0.028") and the great weight of the loaded can (160#) have made safe handling of loaded tubes somewhat difficult. For these reasons, many of initially fabricated cans have been broken or kinked and are no longer useful. Only a very few extra cans were received in the initial shipment and efforts to complete the shipment by July 15 have been initiated.

Irradiated Slug-Wafer Traverse - W. B. Farrand

The Radiometallurgy Sub-Unit has cut two wafers from one of the Bluenose slugs. Using a 6-inch lead collimator and Al filters with an anthracene crystal and photomultiplier as the detector, several traverses were made across the two wafers. In attempting to detect beta particles in such an intense gamma field, some difficulty was encountered with photo electrons and gamma activation of the crystal. At the present, no interpretable curves have been found from the traverses. Refinement of measuring techniques and counting equipment is under way, and it is hoped that reasonable data will soon be forthcoming.

Exponential Pile Enrichment

Document HW-27899, "Increased Flux Level by Exponential Pile Enrichment", was issued during the month.

Exponential Pile Measurements with 1.66 Inch Diameter Slugs - E. D. Clayton, R. C. Lloyd

The buckling value for the large slug size in the 6-3/16" lattice, utilizing a BF_3 counter, is $-152.7 \pm 2 \times 10^{-6}$ cm^{-2}. This value was checked by taking a partial vertical traverse with In foils and calculating the appropriate background for these foils. A value of $-158.7 \pm 3 \times 10^{-6}$ cm^{-2} was obtained with the In foils.

The loaded process tubes were then removed and inserted in the 7-1/2" lattice. At present, these two lattices, 6-3/16" and 7-1/2", are available for measurements, having already been built and adaptable to various slug sizes by means of graphite sleeves in the process tube holes. The buckling obtained in the 7-1/2" lattice with the BF_3 counter was $73.1 \pm 1 \times 10^{-6}$ cm^{-2}. A rough check on this value was obtained with In foils which gave a value of $71.5 \pm 1 \times 10^{-6}$ cm^{-2} for the buckling.

It is to be noted that in the above measurements there were no spacers between the slugs in the process tubes to simulate end caps on canned slugs. To investigate the effect of end caps on the buckling, a single layer of process tubes with 0.4" thick aluminum spacers between each slug has been loaded in the 7-1/2" lattice pile. If a difference in the observed flux variation above the layer can be observed between a layer with the aluminum spacers between the slugs and one without, an effort will be made to correlate this to a buckling change due to the presence of the aluminum spacers. This measurement is presently being completed and is similar to the measurements taken by R. K. Cole for blackness determinations.

The drilling operation, whereby the large solid slugs will become hollow, has commenced. This is being done in the 300 Area. The first hole size will have a diameter of 0.810 inch.

Exponential Pile Measurements with 1.176 Inch Diameter Slugs

The 6-3/16" lattice has been resleeved to accomodate the 1.176" diameter slug. This pile is being loaded and measurements are about to begin. The buckling will be measured both wet and dry and the metal then placed in the 7-1/2" lattice and the wet and dry buckling in this lattice obtained. Cell traverses utilizing small In foils will also be taken in both lattices. The 1.176" diameter slug will be the fourth slug size measured.

Correlation of Lattice Measurements with Theory - E. D. Clayton, C. R. Richey

The calculations mentioned in the May TAR have not been completed, but the preliminary calculations look encouraging; that is, the calculated values fit the measured values of the buckling better than was anticipated. An adjustment was required for the volume part of the resonance integral which is about 7.7 barns in contrast to the previous value of 9.25 barns. This lower value is in the direction of agreement with other recent interpretation of exponential experiments by P. Mummery of Harwell, who reported 7.3 barns and H. H. Clayton of Chalk River, who found a value of 6.45 barns. Also, A. T. Biehl of North American Aviation reported that the value of 7.8 barns more closely agreed with his experimental data. A value of $\eta\epsilon$ = 1.339 appears to fit fairly well to the wet and dry lattice measurements with the standard slug size. An $\eta\epsilon$ = 1.328 approximately fits the small slug size. The calculations are now being refined and extended to the 1.66" slug size. The final analysis will be reported on at a later date.

A trip was taken during the latter part of June for the purpose of discussing lattice calculations. Various people with whom discussions on this subject took place were Dr. B. I. Spinrad of Argonne National Laboratory, Dr. J. Chernick and Dr. H. Kouts of Brookhaven National Laboratory, Dr. M. Kells of the New York AEC Office and Dr. H. Soodack and others of NDA.

The several points mentioned by Dr. Spinrad are listed below.

1) Slug Traverse: Recent experimental evidence had indicated that the curve of thermal flux across the slug was much steeper near the edge than was previously thought to be. For their slug size ($\sim$ 1") the experiment resulted in an edge to average value of 1.19 while the calculated value was 1.10 using the formula:

$$\frac{\varkappa^2 r^2}{8} = \frac{\text{edge}}{\text{average}} - 1 \text{ with } \varkappa = 0.70$$

2) <u>τ Age</u>: In calculating the age (τ), the resonance escape probability should be taken into consideration; that is, an effective age should be used which is defined by

$$\tau_{eff} = \tau - \tau_{res}(1-P)$$

τ_{res} is the age from resonance to thermal which is about 86 cm^2 for graphite.

P is the resonance escape probability. From the above considerations, the age will be lowered by about 10 cm in graphite lattices.

3) <u>Temperature Considerations</u>: The question of the temperature of the neutrons in a lattice cell has still not been resolved; that is, there is experimental evidence to indicate that the neutrons are in thermal equilibrium at the temperature of the graphite and also information to the contrary which indicates the neutrons to have an average velocity which would correspond to a temperature of about 50-100° above the graphite temperature.

If the flux in the $\frac{1}{E}$ part of the spectrum is considered, the average energy for absorption may be written as

$$\bar{E}\text{ (absorption)} = \frac{\int E_{th}\,\sigma_{th}\,\varphi_{th} + \int E_f\,\varphi_f\,\sigma_f}{\int \sigma_{th}\,\varphi_{th} + \int \sigma_f\,\varphi_f}$$

$$\varphi_f = \frac{q}{\xi\sigma_s}\frac{dE}{E}, \quad \varphi_{th} = vM(v)dv$$

It is thus evident that, with the consideration of the $\frac{1}{E}$ tail, the average velocity is increased. Approximately 10% of the neutrons absorbed are above thermal. This will lead to a higher temperature based on a Maxwellian distribution. It, therefore, appears to be a matter of interpretation as to what the actual temperature of the neutrons is.

4) <u>Resonance Escape</u>: Recent analysis of some of our data results in a value of about 7.7 barns for the volume of the resonance integral. This value is obtained when $\eta\epsilon$ is so chosen as to best fit the measured values of bucklings. Dr. Spinrad was of the opinion that the value (9.25) for the volume part of the resonance integral should be lowered to 7 or 8. He pointed out, however, that the coefficient of the surface to mass term should probably remain

unchanged, that is, the effective absorption cross section should be written as

$$\sigma_{eff} = \text{volume part of resonance integral} + (9.25)\ (2.67)\ S/M$$

A lower value for the volume part of the resonance integral has also been reported by P. Mummery of Harwell, who gave a value of 7.3 barns and H. H. Clayton of Chalk River, who used a value of 6.45 barns.

5) Asymmetry: In the case of heavy water, a definite asymmetry was believed to exist due to streaming between the rods, although Dr. Mummery had measured the buckling in several ways in a graphite moderated lattice and reported no such effect for his lattice. If there is asymmetry, then the buckling would have a slightly different value depending upon the source placement and direction in which the traverse was taken.

6) Diffusion Length: The expression $L_t^2 = \sum L_i^2 f_i$ is considered to be fairly good. In obtaining the above expression, λ is averaged according to the variation of flux in the lattice cell. instead of averaging σ_{tr} weighted by the flux.
order of 1% from the approximation

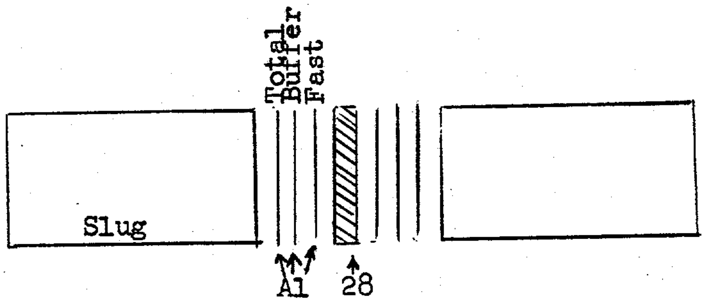
Discussion with Dr. J. Chernik and Dr. H. Kouts of Brookhaven:

1) Exponential Experiments: A series of exponential experiments are being conducted in which three rod sizes and three enrichments for each rod size will be used. Light water is being used for the moderator. With their very small lattice spacings, they must consider the interaction effect between adjacent rods on ϵ and ρ, etc. Dr. Chernick was of the opinion that the diffusion type of expressions for utilization, etc., would give very poor results when applied to their water-moderated lattice.

2) Cell Traverse: Cell traverses are being taken with very small dysprosium oxide foils, about 10 mils thick and 1/16 inch in diameter. The diameter of the uranium rods used varies from 1" down to 0.6", which necessitates the use of these small foils. Dysprosium is considered to be a $\frac{1}{v}$ adsorber. The cross section for thermal neutrons is about 1100 barns. Dysprosium is available only in the oxide form and, when used for foils, must be mixed with a suitable plastic. Dysprosium is also very rare and hard to obtain. It may be possible for us to obtain some dysprosium foils from Brookhaven. We have considered the use of this kind of foil for slug traverses and slug blackness measurements. The higher cross section might make it possible to perform these experiments in the exponential pile.

3) Fast Effect: At Brookhaven, the fast effect (ϵ) was being measured by the

use of a 5-10 mil 28 foil, which was sandwiched between 1/2 mil aluminum foils as indicated in the sketch.



The activity of the fission fragments collected on the aluminum foils was measured and from this the fast effect obtained.

4) Effect of Water Annulus on ϵ: There was some discussion as to the effect of scattering from O_2 on ϵ in the wet lattice. Subsequent calculations indicate this to be of negligible importance.

The visit to NDA did not add additional information of any consequence to the above and will therefore not be reported.

D E Davenport
PHYSICS UNIT
APPLIED RESEARCH SUB-SECTION

DE Davenport:as

THEORETICAL PHYSICS SUB-UNIT - G. E. Duvall

W. A. Horning has attended a meeting of the American Mathematical Society in Missoula, Montana, this month. C. D. Thimsen has taken a week of vacation. J. O. Erkman has formally transferred from the Experimental Physics group to this group.

A procedure for improving communications between the Pile Physics group and this group has been established. Two members of this group are charged with spending Monday afternoon in 1703-D Building, discussing problems of mutual interest with members of Pile Physics. The first few visits have been profitable and it appears feasible to continue the scheme. The current visiting members are G. E. Duvall and G. M. Muller. It is planned to rotate the responsibility among the members of the Theoretical Group.

I. Critical Lattice Experiments - R. K. Cole

The experiments in the exponential pile designed to test the "strong transient" scheme for interpreting lattice experiments have been completed. The interpretation of the data is in progress, the only results obtained at this time are for the blackness of process tubes loaded with P-10 (dry).

The experiments are as follows: The flux is measured on the axis of the empty exponential pile with 6-3/16" lattice at a point several diffusion lengths above the plane in which the sources are located. The reading obtained is R_1. One tube-bearing layer of the pile is next loaded with process tubes containing P-10 material and the flux at the same point is again measured. The reading obtained is R_2. Then from the small source theory, the blackness of the process tube is given by the expression

$$\beta = \frac{4\varkappa D b\,(1-R)}{\pi a - b\varkappa a\,(1-R)\left[\sum_{i \neq j} K_0\left\{\varkappa\left|\vec{\rho}_i - \vec{\rho}_j\right|\right\} - 2\varkappa D\,K_1(\varkappa a)\right]}$$

where
$R = R_2/R_1$
$\vec{\rho}_k$ = position of k^{th} tube
$\varkappa^{-1}$ = diffusion length in graphite
a = radius of process tube
b = lattice spacing

Two experiments were performed; in the first, every lattice site in the layer contained a P-10 tube. The blackness obtained from this experiment is $\beta = 0.50$. In the second experiment, only every other lattice site was filled and the blackness obtained was 0.47. These values are to be corrected for transverse leakage from the pile, and it is hoped that such correction will reduce the difference between the two blacknesses to within the experimental error.

[redacted]

II. Lattice Theory

A. Neutron Currents at the Surface of a Slab Absorber - R. W. Woodruff

An infinite slab of absorber of thickness, a, is located at $0 < z < a$ in a flux of thermal neutrons which is dependent only on z, the coordinate perpendicular to the slab. Assuming isotropic scattering, the inward thermal neutron current is calculated from the number of scattering collisions per unit volume per unit time, the probability that the neutrons after scattering will travel in the proper direction to pass thru a given increment of area on the surface of the slab, and the probability that they will reach the surface without deviation from their path. The result obtained for the inward current is

$$J_{in} = \frac{\Sigma_{SM}}{2} \int_{z=0}^{-\infty} \phi(z) \left[-e^{\Sigma_M z} + \Sigma_M z \, Ei(\Sigma_M z) \right] dz$$

where Σ_{SM} and Σ_M are the scattering and total macroscopic cross sections of the material on either side of the slab and ϕ is the flux. The outward current is

$$J_{out} = \frac{\Sigma_{SA}}{2} \int_{z=0}^{a} \phi(z) \left[e^{-\Sigma_A z} + \Sigma_A z \, Ei(-\Sigma_A z) \right] dz$$

$$+ \frac{\Sigma_{SM}}{2} \int_{z=0}^{\infty} \phi(z) \left[e^{-x} + x \, Ei(-x) \right] dz$$

where

$$x = a(\Sigma_A - \Sigma_M) + \Sigma_M z$$

and Σ_{SA} and Σ_A are the scattering and total macroscopic cross sections of the absorber.

[redacted]

B. Thermal Utilization - G. W. Stuart

A Serber-Wilson calculation has been performed for the 7-1/2" dry lattice. The thermal utilization is reduced 0.041 or 4.24% under the result yielded by diffusion theory. A large discontinuity in flux is found at the slug-graphite interface, however, which suggests the inapplicability of the Serber-Wilson theory to this situation. An extension of Serber-Wilson theory is accordingly devised which consists in expanding the flux distribution in a lattice cell in Taylor series about the origin, the various derivatives satisfying the exact integral equation. Relations determining these derivatives out to the fourth order have been worked out. Numerical calculations await completion of the tables of integrals being compiled by G. M. Muller. A report will be issued at that time.

C. Thermal Utilization - H. Neumann

Uranium and moderator utilization expressions have been derived for the following cases: solid or hollow slugs, dry; solid or hollow slugs, cooled externally; hollow slugs cooled internally; hollow slugs cooled internally and externally, the coolants not necessarily being identical. These expressions account for end caps, inner and outer cans and process tubes. Experimental disadvantage factors may be inserted, if desired. These formulae will be given in a forthcoming report.

D. Diffusion Length in P-10 Lattices - H. Neumann

Calculations using small-source analysis to relate lattice diffusion length and the blacknesses of wet and dry process tube assemblies have been extended to include three more measured diffusion lengths. The diffusion lengths measured are used to determine the process tube blacknesses.

Lattice	$1/\kappa$ wet	β wet	$1/\kappa$ dry	β dry
8-3/8"	16.11 cm	0.454	15.26 cm	0.518
8"	15.10 cm	0.474	14.56 cm	0.517
7-1/2"	14.30 cm	0.459	13.54 cm	0.522
7"	13.27 cm	0.463	12.51 cm	0.529
6-3/16"	11.59 cm	0.471	11.34 cm	0.505
Average		0.464		0.518
Standard Deviation		0.015		0.016

An uncertainty of ± 0.1 cm in the measured diffusion length would lead to an uncertainty in the blackness of about ± 0.007. It appears from the experimental data that uncertainties of perhaps a few tenths of a centimeter do exist in the measured diffusion lengths, the situation being worse for the smaller lattices, both wet and dry.

III. Radiation Damage

A. Thermal Conductivity of Graphite - G. W. Stuart

Although the thermal conductivity of graphite has been reported as predominantly electronic in origin[1], it seems more likely at this time that both electronic and lattice contributions are appreciable.

The modern theory of lattice thermal conductivity has been developed by Debye[2], Peierls[3], and others. Due to the intractable form of the matrix elements involved for any real lattice geometry, the theory has been transformed to a semiempirical formulation in which the temperature and wave number dependence of the various contributions are multiplied by constants determined from the structure of the individual lattices[4]. In practice, these constants are evaluated by matching the experimental curve in various regions where one or another effect will predominate[5].

It seems likely that if the electronic contribution to the thermal conductivity of graphite could be rather accurately stated along with the effect of radiation damage on its magnitude, then the effect of radiation damage on the lattice thermal conductivity could also be stated as a function of lattice dislocations. The machinery to substantiate this remark seems to have been accumulated by Klemens[5]. A restriction to temperatures in the liquid helium-liquid hydrogen range would simplify the problem by making possible omission of longitudinal phonons from consideration in unirradiated graphite. In the case of extremely damaged graphite, the opposite situation would be achieved in which the major contribution comes from longitudinal phonons. In addition, restriction to low temperatures would obviate consideration of multiphonon processes[4] and processes conserving momentum.

It should be reiterated that the first step in such a program as stated above must be an attack on the electronic phase of the problem.

IV. Plant Assistance

A. Technique of Two-Group Computations - G. M. Muller

A series of four two-hour lectures on the above topic has been prepared, to be given on June 30th, July 2nd, 7th and 9th. The purpose of these lectures is to explain and illustrate certain time-saving computational techniques developed by the author during the last few years. An invitation to attend these lectures has been extended to interested physicists

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5. Klemens, P., 1951, Proc. Roy. Soc. A, 208, 108