[redacted]

ORNL 939, Series A
PROGRESS REPORT 8a

AEC RESEARCH AND DEVELOPMENT REPORT

MARTIN MARIETTA ENERGY SYSTEMS LIBRARIES
3 4456 0050903 7

PHYSICS DIVISION

QUARTERLY PROGRESS REPORT FOR PERIOD ENDING DECEMBER 20, 1950

LABORATORY RECORDS

OAK RIDGE NATIONAL LABORATORY
CENTRAL RESEARCH LIBRARY
CIRCULATION SECTION
4500N ROOM 175
LIBRARY LOAN COPY
DO NOT TRANSFER TO ANOTHER PERSON
If you wish someone else to see this report, send in name with report and the library will arrange a loan.
UCN-7969 (3 9-77)

DECLASSIFIED
CLASSIFICATION CHANGED TO:
BY AUTHORITY OF: E. J. Murphy 8-4-61
BY: S. Beidel 6-13-62

OAK RIDGE NATIONAL LABORATORY
OPERATED BY
CARBIDE AND CARBON CHEMICALS DIVISION
UNION CARBIDE AND CARBON CORPORATION
UCC
POST OFFICE BOX P
OAK RIDGE, TENNESSEE

[redacted]

[redacted]

ORNL-939

This document consists of 13 pages.
Copy 8 of 107. Series A

Contract No. W-7504, eng 26

PHYSICS DIVISION

A. H. Snell, Director
E. O. Wollan, Associate Director

QUARTERLY PROGRESS REPORT

for Period Ending December 20, 1950

M. E. Rose, Editor

DATE ISSUED FEB 19 1951

OAK RIDGE NATIONAL LABORATORY
operated by
CARBIDE AND CARBON CHEMICALS DIVISION
Union Carbide and Carbon Corporation
Post Office Box P
Oak Ridge, Tennessee

MARTIN MARIETTA ENERGY SYSTEMS LIBRARIES

3 4456 0050903 7

[redacted]

[redacted]

INTERNAL DISTRIBUTION

1. G. T. Felbeck (C&CCD)
2-3. Chemistry Library
4. Physics Library
5. Biology Library
6. Health Physics Library
7. Metallurgy Library
8-9. Training School Library
10-13. Central Files
14. C. E. Center
15. C. E. Larson
16. W. B. Humes (K-25)
17. W. D. Lavers (Y-12)
18. A. M. Weinberg
19. J. A. Swartout
20. E. D. Shipley
21. E. J. Murphy
22. E. C. VonderLage
23. A. H. Snell
24. E. H. Taylor
25. A. Hollaender
26. K. Z. Morgan
27. F. L. Steahly
28. M. T. Kelley
29. W. H. Pennington
30. E. O. Wollan
31. M. E. Rose
32. D. W. Cardwell
33. A. S. Householder
34. L. D. Roberts
35. J. A. Lane
36. M. M. Mann
37. R. N. Lyon
38. W. C. Koehler
39. W. K. Ergen
40. E. P. Blizard
41. G. E. Boyd
42. Lewis Nelson
43. R. W. Stoughton
44. C. E. Winters
45. W. H. Jordan
46. E. C. Campbell
47. D. S. Billington
48. M. A. Bredig
49. R. S. Livingston
50. C. P. Keim
51. G. H. Clewett
52. C. D. Susano
53-58. Central Files (O.P.)

EXTERNAL DISTRIBUTION

59-66. Argonne National Laboratory
67-69. Atomic Energy Commission, Washington
70-73. Brookhaven National Laboratory
74-75. Knolls Atomic Power Laboratory
76-77. General Electric Company, Richland
78-81. Los Alamos
82-83. New York Operations Office
84. Patent Branch, Washington
85-87. NEPA Project
88-102. Technical Information Branch, ORE
103-106. University of California Radiation Laboratory
107. U. S. Atomic Energy Commission, Wilmington

[redacted]

[redacted]

TABLE OF CONTENTS

	Page No.
INTRODUCTION AND SUMMARY	4
SHIELDING PROGRAM	5
Shielding for ANP	5
New Bulk Shielding Facility	5
Approximate Method for Calculating Shield Transmissions	6
Fission-fragment Decay Gammas	9
ANP PHYSICS GROUP	11
Outstanding Results	12
U^{238} EFFECTIVE RESONANCE INTEGRALS	13

[redacted]

[redacted]

INTRODUCTION AND SUMMARY

This report covers classified work in the Physics Division for the period September 20 to December 20, 1950. The material under items 1 and 5 below is presented in greater detail in the ANP Quarterly Report. The unclassified section of the Physics Division Quarterly Report appears separately (ORNL-940).

1. A number of configurations, including iron and water shields, were investigated in the lid tank. B_4C is currently under investigation.

2. The reactor in the new bulk shielding facility has been made critical, and its construction is described. The problem of possible degradation of the neutron-fission spectrum when neutrons are collimated under water is being studied.

3. A method for calculating shield transmissions which would apply to computation of neutron and γ-ray dosages in the lid tank has been developed. No numerical computations have been made as yet.

4. Evidence based on the number of photoneutrons per fission is presented to show that La^{140} accounts for almost all the long-lived fission-fragment decay gammas of U^{235} which are energetic enough to liberate photoneutrons. Data of interest in connection with activity of the reactor after shutdown are presented.

5. Attempts to improve reactivity calculations and calculations of kinetic characteristics of variations in reactor design are described. Specific results obtained by this ANP group are given on p. 12.

6. Methods of calibrating the foils used in the cylinder experiments, wherein the effective resonance integral is measured, are described. Tentative values have been obtained.

[redacted]

SHIELDING PROGRAM

SHIELDING FOR ANP

E. P. Blizard

Shielding research is regularly reported in the ANP Quarterly Report, the period covering September, October, and November appearing in ORNL-919. The introduction to the section on Shielding, Section 5, is here quoted:

"During the past quarter the shielding groups at ORNL and NEPA collaborated in an effort to apply the available information to the actual design of several realistic aircraft shields (ANP-53). There resulted a number of configurations which were light enough to be highly interesting and sufficiently well founded in experiment to lend considerable confidence as to their adequacy. Iron and water shields were investigated in the lid tank, but to a limited extent only, since the shield weights appear to be excessive for these materials. The shielding properties of B_4C are currently being measured and several interesting effects have been discovered with this material. Measurements using the liquid-metal duct are being made, but as yet no conclusions can be reached regarding its effectiveness in the shield. Completion of the New Bulk Shielding Facility has been delayed by the building contractor. The first test, probably of an ideal unit shield, will commence sometime in March. Some previous lid tank experiments on lead, iron, and water have now been analyzed according to simple theory. A more general approach to shield optimizing is being explored, with the hope of carrying out this procedure theoretically as well as experimentally."

NEW BULK SHIELDING FACILITY

W. M. Breazeale and J. L. Meem

The reactor in this facility was loaded, and the critical condition was reached on December 17. Fuel required was 2420 g of U^{235}. The active lattice consists of MTR fuel elements which contain approximately 140 g of U^{235} per element. The ratios of aluminum to fuel to water are about the same as those used in the early critical experiments for the MTR described in ORNL-79 and 167, and this experiment may be of interest in this connection. Under critical

conditions the active lattice consisted of sixteen full fuel elements and three half-elements in the center, the latter containing the control and safety rods. These were stacked in a rectangle 4 units by 5 units (12 by 15 in.) with one corner missing. The lattice was surrounded on three sides by 2¾ in. of BeO (density 2.3) and on the fourth side by 3¾ in. of BeO. There was no BeO on top or bottom. The entire assembly was submerged under 16 ft of water.

Since ordinary filtered water will probably be used in the pool, at least at first, the fuel elements have been allodized, i.e., treated with a solution of dichromate salts, to inhibit corrosion of the aluminum. This work was under the supervision of J. L. English and A. R. Olsen.

Design work at NEPA for a mock-up of the reactor part of a divided shield has been completed and procurement of the material has started. This mock-up conforms closely to the divided shield described in the Shielding Board Report, ANP-53.

A polonium-beryllium source and nuclear plates are being used to investigate the degradation of the neutron-fission spectrum when neutrons are collimated under water. If, as seems probable from work elsewhere, the change in the spectrum is small, then the problem of providing a collimated beam of neutrons under water for the proton recoil counter is solved.

A steel water tank 6 ft in diameter and 8 ft high has been installed in one corner of the pool room and will be equipped with a known source and used for standardizing chambers and counters.

APPROXIMATE METHOD FOR CALCULATING SHIELD TRANSMISSIONS

A. Simon

The attenuation of primary neutrons and γ rays in a spherical shield surrounding a spherical reactor is computed on the assumption that:

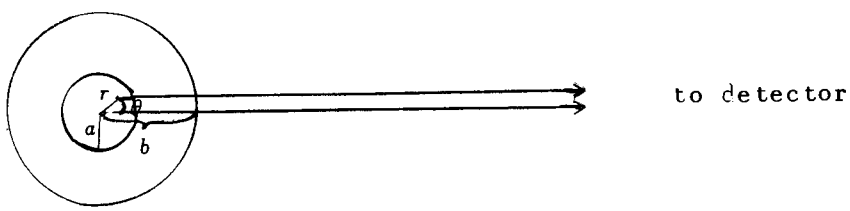
1. Neutrons and γ rays are attenuated in the shield material with a cross section which depends only on the radial distance. A collision results in the complete removal of the neutron.
2. Neutrons and γ rays are produced isotropically and uniformly in the reactor core and are absorbed with constant cross sections in the core.
3. An essential part of the caluclation is the assumption that all relaxation lengths, for both neutrons and γ rays, are short compared to the dimensions of the shield and reactor core. This assumption corresponds to the conditions expected in most shields.

These assumptions are identical to those made previously by Ascoli.[1] The details available on this calculation, however, are incomplete. In view of this it was decided to rederive the results for the case of the spherical reactor in an independent way and thus obtain a complete check on the results. Furthermore, these methods can then be applied to cases involving a different geometry, in particular, that of the lid tank. The immediate objective of this analysis will be an attempt to compute the neutron and γ-ray dosages in the lid tank to see if the actual measurements can be understood on the basis of the simple assumptions made above.

The secondary γ-ray dose is also computed making equally simple assumptions:

4. A one-collision-and-out picture is used. Thus a high-energy neutron (over 2 Mev) produces a γ ray by an inelastic scattering only, which scattering completely removes the neutron.
5. The absorption coefficients for the secondary photons are taken to be the same as for the primary photons, and the photons are assumed to be produced isotropically.

Full account is taken of the geometry as sketched below:



The radius of the reactor is taken as a, and that of the shield is b. If the detector is assumed to be far away, the dose of primary neutrons at the detector can be written as

$$N \approx 2\pi \int_0^a r^2\, dr \int_{-1}^{+1} d(\cos\theta) \exp\left[-\sigma_0 \left(\sqrt{a^2 - r^2 \sin^2\theta} - r\cos\theta\right) - \int_a^b \frac{\sigma(r')r'\, dr'}{\sqrt{r'^2 - r^2 \sin^2\theta}}\right]$$

If assumption 3 is now introduced, the quantities in the exponents can be expanded in a Taylor series in $\sin^2 \theta$ and solved approximately to obtain the total primary neutron dose as

$$N = N_0 \frac{3}{4a\sigma_0} \frac{\exp\left[-\int_a^b \sigma(r')\, dr'\right]}{\frac{1}{2}\int_a^b \sigma(r') \frac{a^2}{r'^2}\, dr'} \tag{1}$$

where

σ_0 = absorption coefficient of reactor for neutrons

$\sigma(r,E)$ = absorption coefficient of shield for neutrons

$N_0 \equiv$ dose that would be observed at detector without self-shielding and shield

The primary γ-ray dose is

$$\Gamma = \Gamma_0 \frac{3}{4a\eta_0} \frac{\exp\left[-\int_a^b \eta(r')\, dr'\right]}{\frac{1}{2}\int_a^b \eta(r') \frac{a^2}{r'^2}\, dr'} \tag{2}$$

where

$\eta(r)$ = absorption coefficient of shield for neutrons and η_0 refers to the reactor

These results differ from those of Ascoli by a relatively unimportant additive quantity, equal to unity, in the denominator.

The expression for the secondary γ dose is also obtained by the same techniques. However, care must be taken in making several of the approximations.

The result here is

$$\Gamma_s = N_0 \frac{3}{4a\sigma_0} E \int_a^b \frac{\sigma_i(r)dr \exp\left[-\int_a^r \sigma\, dr - \int_r^b \eta\, dr\right]}{\left\{1 + \int_a^r \sigma \frac{a^2}{r'^2} dr'\right\}\left\{1 + \int_r^b \frac{\eta r^2}{r'^2} dr'\right\}} \tag{3}$$

Here σ_i is the cross section for inelastic collision of a neutron in the shield material. These expressions have been checked by obtaining the exact solution for the case of σ and η independent of r.

Preliminary expressions have been obtained for the lid tank geometry. These give the secondary and primary doses to be expected on the center line of the lid tank.

FISSION-FRAGMENT DECAY GAMMAS

W. K. Ergen (NEPA)

Some of the long-lived decay gammas of U^{235} fission fragments are energetic enough to liberate photoneutrons from Be.[1] As will be shown below, La^{140} accounts for almost all these long-lived energetic gammas.

In the original publication the number of photoneutrons was given in terms of the saturated activity (measured immediately after the end of the irradiation) of the delayed neutrons with the 22-sec period. Since this activity accounts for 0.17%[2] of the fission neutrons and since there are 2.5 neutrons per fission, it is possible to determine the number of photoneutrons per fission.

(1) Bernstein, S., Talbott, F. L., Leslie, J. K., and Stanford, C. E, *Yield of Photoneutrons from U^{235} Fission Products in Be*, AECD-1833 (Feb. 20, 1948).

(2) See, for example, Glasstone, S., *Sourcebook on Atomic Energy*, p. 357, Van Nostrand, New York, 1950.

From the known yield of La^{140} [3] (6.1%) and the known half-lives of La^{140} and its long-lived parent Ba^{140} (40 hr[4] and 12.8 days,[5] respectively), the number of La^{140} disintegrations occurring at any given waiting time after any given irradiation time can be computed. One gram of Be at a distance of 1 cm from a 1-curie La^{140} source yields 0.23×10^4 photoneutrons/sec.[6] From this and from the known Compton scattering (photoeffect and pair production are negligible in Be for 2.5-Mev gammas) cross section per electron (1.27×10^{-25} cm^2) at the energy of the hard La^{140} gamma (2.5 Mev[7]), the number of photoneutrons liberated in an infinite Be sphere by one La^{140} disintegration is obtained.

When these results are combined, it is found that the La^{140} fission fragments should liberate 4.91×10^{-8} photoneutrons/fission in an infinite Be sphere 715.2 hr after a 74-hr irradiation of U^{235}. The experimental value, converted as indicated above to photoneutrons per fission, is 4.87×10^{-8}.

This excellent agreement is probably somewhat fortuitous, because a few corrections should be applied to the experimental result. Furthermore, 15.4-day Eu^{156}, formed with a low fission yield of 0.013%,[8] gives, in 60% of its disintegrations, a 2-Mev gamma.[9] This fragment should add about 4% to the La^{140} photoneutrons. Also short-lived hard-gamma emitters should make a minor contribution to the photoneutron yield even at long waiting times.

If the La^{140} activity is "peeled off" the Be photoneutron measurements, the data at waiting times above 100 hr seem to be due to a so-far undiscovered gamma of I^{132}, the decay of which is controlled by 77.7-hr Te^{132}. The evidence is the half-life, approximately known from the photoneutron data, and the fact that no other fission fragment with approximately the right half-life seems to have sufficient total decay energy. At waiting times below 100 hr, other short-lived hard-gamma emitters become evident.

(3) See, for example, Way, K., and Dismuke, N., *Fission Product Yields*, ORNL-280 (May 18, 1950).

(4) Ballou, N. E., Rubinson, W., and Glendenin, L. E., "Characteristics of 40h La^{140}," Paper 165 in *Radiochemical Studies: The Fission Products*, Ed. C. D. Coryell and N. Sugarman, McGraw-Hill, New York, in press; Weimer, K. E., Pool, M. L., and Kurbatov, J. D., "Radioactive Isotopes of La," *Phys. Rev.* 63, 67 (1943).

(5) Engelkemeir, D. W., Freedman, M. S., Glendenin, L. E., and Metcalf, R. P., "Characteristics of 12.8d Ba^{140}," Paper 163 in *Radiochemical Studies: The Fission Products*, Ed. C. D. Coryell and N. Sugarman, McGraw-Hill, New York, in press; Seiler, J. A., "Half Life Studies," *Summary Report for July, August, and September, 1946, Chemistry Division, Section C-II*, ANL-4000, p. 119 (Aug. 22, 1947).

(6) Russell, B., Sachs, D., Wattenberg, A., and Fields, R., "Yields of Neutrons from Photoneutron Sources," *Phys. Rev.* 73, 545 (1948).

(7) Wattenberg, A., "Photoneutron Sources and the Energy of the Photoneutrons," *Phys. Rev.* 71, 497 (1947).

(8) Way and Dismuke, *op. cit.*

(9) Winsberg, L., "Study of the Fission Chain ~10h $Sm^{(156)}$ → 15.4d $Eu^{(156)}$," Paper 198 in *Radiochemical Studies: The Fission Products*, Ed. C. D. Coryell and N. Sugarman, McGraw-Hill, New York, in press.

ANP PHYSICS GROUP

Nicholas M. Smith, Jr.

The ANP Physics Group is comprised of personnel* detached from the Physics Division, the Mathematics Panel, and the Reactor Training School of ORNL, from the NEPA Division of Fairchild, and from the USAF who have been attached as a group to the ANP Division for theoretical physics calculations pertaining to the program of the ANP.

The activities and results of the group for the past quarter are described in great detail in the ANP Quarterly Report now in preparation.[1] The reader is referred to this report for results, mathematical development, illustrations, references, and acknowledgments. The content is described below.

The effort of the ANP Physics Group in the last quarter has been twofold. A large proportion of the work has been directed toward getting together all the essential elements of an accurate calculation of reactivity. The achievement along this line thus far permits the calculation of multiregion—but otherwise homogeneous—reactors. The principal effect not yet handled is that brought about by the heterogeneous character of the core, i.e., self-shielding caused by lumping. Thus the present values for critical masses of uranium may be in error from 50 to 100%. The effects of perturbations are obtained more accurately, however. Addition of methods of calculating "effective homogeneous" cross sections to replace the atomic cross sections now used, and which correct for the lumping effects, should reduce the pre-experimental errors of critical mass to around 30%. Experience with calculating results of critical assemblies should ultimately allow us to make calculations on a new reactor within 10 to 15%. In spite of these large errors the present refinement of the calculation is valuable in guiding design in a semiquantitative sense and for gaining an understanding of the overall field of intermediate reactors through exploratory calculations. As more accurate results are obtained and the estimated critical mass is corrected, it will be necessary to adjust slightly the median energy of fission in order to obtain desired characteristics. Otherwise the

* From Physics Division:	N. M. Smith, Jr., D. K. Holmes, M. C. Edlund, and K. M. Martin
Mathematics Panel:	R. R. Coveyou, Ann Forbes, Rooney Currey, and Vivian Gordon
Reactor Training School:	O. A. Schulze and B. M. Macauley
NEPA Division:	J. W. Webster, T. Rubin, Phyllis Brown, and Marina Tsagaris
USAF:	Lt. Col. M. J. Nielsen
ANP Division:	Marie Pickard

(1) *Aircraft Nuclear Propulsion Project Quarterly Progress Report for Period Ending December 10, 1950,* ORNL-919, in preparation.

conclusions made now are valid. Inclusion of lumping effects in the IBM calculations must wait for a shakedown period for the present IBM homogeneous calculations. These latter have only recently been made possible with completion of the necessary programing boards. Thus far, results of two calculations are available, one of which is described in detail.

Almost all the remaining effort has been expended in obtaining the kinetic characteristics of variations on the present designs, which involves computation of neutron lifetimes, coefficients of reactivity, power coefficients of reactivity, buckling and expansion coefficients of reactivity, etc. In addition, an investigation into the kinetic response of the heterogeneous reactor has been initiated. The first part of the perturbation theory survey is described. Some effort has been used in the calculation of thermal relaxation times required for the kinetic considerations. Longer range work, such as development of adequate difference equations in cylindrical geometry, has continued. Work along these lines, together with frequent consultation sessions with the remainder of the ANP staff, has comprised our activities for the past quarter.

OUTSTANDING RESULTS

The outstanding results from the work done this quarter, listed below, are given in Section 2 of the ANP Quarterly Report ORNL-919:

1. Evaluation of positive xenon temperature coefficient of reactivity which is coupled to the moderator temperature, Part B.
2. Investigation into characteristics of reactors with higher energy fissioning spectra in regard to eliminating xenon effects, Parts B and E.
3. First successful IBM calculations of reflected reactors, Part C.
4. Initiation of investigation into the characteristics of liquid-fueled reactors Part D.

[redacted]

U^{238} EFFECTIVE RESONANCE INTEGRALS

G. B. Arfken, Jr. T. R. Cuykendall
R. J. Stephenson

The determination of the effective resonance integral for U^{238} cylinders was described briefly by Risser and Arfken in the last Quarterly Progress Report (ORNL-864, p. 17). To calibrate these results the foils used in the cylinder experiments have been shielded with slabs of uranium, and the resonance integral has been determined as a function of shielding thickness. This permits three possible independent calibrations:

First, as the shielding thickness is increased, the foil activity relative to an inside indium monitor approaches a constant value equal to the mass term in the usual expression for the effective resonance integral. This value has been determined by Creutz, Mitchell, Hughes, and coworkers to within 10%. Second, this shielded-foil curve may be calibrated by measuring the activation of a thin U^{238} foil exposed to a $1/E$ flux and then measuring its activation when shielded. This true resonance integral is also known to only 10%. The third method is similar to the second but makes use of the known thermal cross section of U^{238}. To carry out this calibration the effective resonance integral of the indium monitors must be measured in terms of very thin gold foils.

All three of the above methods are being attempted. In addition to calbration of the cylinder experiments, it is hoped that consistency checks on the published values of the above cross sections will be obtained.

A tentative calibration of the Risser data by the first method using the value of Goldstein and Hughes (CP-3580), 9.0 barns, for the mass term lead to

$$\left[\int \sigma \frac{dE}{E}\right]_{eff} = 9.0 \left[1 + 2.69 \frac{S}{M} \frac{\text{cm}^2}{\text{g}}\right] \quad \text{barns}$$

for the uranium cylinders. This indicates that a value of $\kappa \approx 0.42$ should be used in the disadvantage factor corrections. It should be emphasized that this calibration is not yet complete. A final value will be published at a later date.

[redacted]