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AEC RESEARCH AND DEVELOPMENT REPORT

A GUIDE WITH ABSTRACTS TO CRITICAL MASS, LAPLACIANS, AND MULTIPLICATION FACTORS

Part 1

A. V. MASKET
H. R. KROEGER

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ORNL-112
Reactors

A GUIDE WITH ABSTRACTS TO CRITICAL MASSES,
LAPLACIANS, AND MULTIPLICATION FACTORS

Part I

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Date Secured: JAN 17 1949

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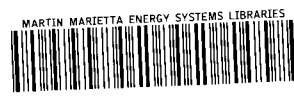


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78. North American Aviation, Inc.
79. Patent Branch, Washington
- 80-84. Technical Information Div., OROO
- 95-97. University of California, Radiation Laboratory



3 4456 0360301 8

[REDACTED]

TABLE OF CONTENTS

	Pages
1. FOREWORD - - - - -	4-5
2. 23 - - - - -	6-8
3. 25 - - - - -	9-23
4. 49 - - - - -	24-31
5. H + 23 - - - - -	32-35
6. H + 25 - - - - -	36-69
7. H + 49 - - - - -	70-74
8. D + 23 - - - - -	75-78
9. D + 25 - - - - -	79-101
10. D + 49 - - - - -	102-104
11. Be + 23 - - - - -	105
12. Be + 25 - - - - -	106-125
13. Be + 49 - - - - -	126-129
14. C + 23 - - - - -	130
15. C + 25 - - - - -	131-144
16. C + 49 - - - - -	145-146
17. BIBLIOGRAPHIES AND SUMMARIES - - - - -	147-148
18. PILE TECHNOLOGY LECTURES - - - - -	149-151
19. NUMERICAL INDEX - - - - -	152-162



FOREWORD

This guide to classified literature is issued with the hope that it will serve as a useful tool to those engaged in or entering into pile development research or engineering. It was felt that a guide would be useful provided something more was said about a report than just giving its title and number. In many cases short tables in toto or slightly abridged are given in the abstract of the report so that the reader will get a rapid survey of the contents of the report. The attempt was made in each case to give quantitative results whenever possible.

It is not to be expected that this guide can be considered complete in view of the very substantial amount of literature published and unpublished. In addition, any such guide is in a sense "dated" by current work (e.g., the results of the G. E. critical pile). Consequently, it is hoped that future additions to the guide will fill in gaps and extend its coverage.

No attempt was made to include the large number of early project exponential experiments as this has been forthcoming in a separate report, nor to include the German work which is being



analyzed by A. M. Weinberg.

It is hoped that much of the unpublished work will become available so that workers in the project may not be forced to duplicate the efforts of others.

A. V. Masket



CF-3199

BREEDER PILE DISCUSSION

SLOW, FAST, AND RESONANCE BREEDERS

E. P. Wigner

June 19-20, 1945

The approximate amounts of fissionable material required for breeders of different types are as follows:

	23 (kg)	49 (kg)	Power (Mw)
Thermal	10	--	100
Resonance	--	80	300
Fast	--	80	← 300

MonP-264

OUTLINE OF A LIQUID METAL PILE

Gale Young

March 6, 1947

An extended discussion (with references) concerning the problems involved in a reactor where the coolant and the liquid active material are separated by a conducting wall. As an example, liquid bismuth

[REDACTED]

serves as a coolant, the active material is a liquid 23-Bi or 23-Pb alloy and the conducting (and moderating) wall is Be. For 3000 Be atoms to 1 23 atom, the radius of a bare cylinder is 74 cm and the length 136 cm. The pile volume is then 2.31 m³, the weight of Be is 2.1 tons, and the weight of 23 is 18 kg. The heat output of such a reactor is estimated at 14,200 kw/kg 23.

MonP-412

INTERIM NOTE ON MIXED PILE STUDIES

J. R. Menke

September 25, 1947

The two-group diffusion theory is used in the computation of some properties of piles containing 49 diluted with Bi in a homogeneous core, surrounded by a shell of 23-Be alloy and a reflector of Be. Results are summarized in a set of curves showing the critical radius as a function of shell and reflector thickness. A summary of the data used is given.

M-3753

PILE TECHNOLOGY

LECTURE 24

FAST AND "MIXED" PILES

J. R. Menke

April 30, 1947

An extended discussion of some properties and problems of fast reactors. Figures 24-5 and 24-6 show the calculated critical mass of ^{23}Pu as a function of dilution and reflector thickness.

	I Fast Pile	II Fertile Diluent	III Composite Pile
Dilution	30/1	15/1	30/1
Materials	23 in Bi	49 in 28	23 in Bi
Crit. Mass	~ 400 kg	~ 400 kg	~ 100 kg
Spec. Power	~ 4000 kw/kg	~ 2000 kw/kg	~ 4000 kw/kg
"g"	~ 1.3	~ 2.1	~ 1.1
Controllability	poor	poor	improved

("g" refers to breeding ratio)

A-4227
(GE-CM-1)

CRITICAL MASS OF Na-K COOLED 25 SPHERE

WITH INFINITE REFLECTOR

Vs.

DILUTION WITH 28

C. Mannal

August 22, 1946

A graph shows the relationships of the critical mass of 25 and the dilution of the active metal with 28 for the following reactor:

Atomic concentration of core

<u>25</u>	<u>28</u>	<u>Na</u>	<u>K</u>	<u>Fe</u>
1	R	0.115	0.0675	0.791

Atomic concentration of an infinite reflector

0	1	0.115	0.0675	0.791
---	---	-------	--------	-------

$$(R = \frac{28 \text{ atoms in the core}}{25 \text{ atoms in the core}})$$

$$\text{For } R = 0 \quad M_c = 38.7 \text{ kg of 25}$$

[REDACTED]

A-4228
(GE-CM-2)

CRITICAL MASS OF Na-K COOLED 25 SPHERE

WITH INFINITE REFLECTOR

Vs.

DILUTION OF CORE WITH 28, Na, K, Fe

C. Mannal

August 22, 1946

A graph shows the relationship of the critical mass of 25 and the dilution of the core for the following reactor:

Atomic concentration of core

<u>25</u>	<u>28</u>	<u>Na</u>	<u>K</u>	<u>Fe</u>
1	R	0.115 (R+1)	0.0675 (R+1)	0.791 (R+1)

Atomic concentration of an infinite reflector

0	1	0.115	0.0675	0.791
---	---	-------	--------	-------

$$(R = \frac{28 \text{ atoms in core}}{25 \text{ atoms in core}})$$

where $R = 0$, $M_c \approx 41 \text{ kg of 25}$.

A-4248
(GE-TMS-6)

A PROPOSED PILE

T. Snyder September 25, 1946

For an unreflected core containing an atomic mixture of 1 (25), 5 (28), 100 (Pb), age theory is employed to determine a critical radius of 100 cm. Absorption in the Pb was neglected. The effect of an infinite 28 reflector is obtained by a 1 velocity diffusion theory which gives 85 cm for the core radius, a critical mass of 328 kg, and a critical volume of $2.56 \times 10^6 \text{ cm}^3$. Report contains considerable detail on the calculations and constants employed, but no engineering.

CF-3

APPROXIMATIONS FOR RADIUS OF SPHERE SUFFICIENT FOR
CHAIN REACTION IN LIGHT ISOTOPE

E. P. Wigner and G. Ereit

January 9, 1942

The Boltzmann Equation for monoenergetic neutrons (fast) without slowing down is solved to give preliminary estimates on critical masses of 25 needed when reflected and unreflected. Values are tabulated for various assumptions about nuclear constants which were

[REDACTED]

known only approximately at the time. Consideration has been given to reflectors of unenriched material, carbon and bismuth.

CF-338

MEMORANDUM ON THE CRITICAL CONDITION FOR A
FAST NEUTRON CHAIN REACTION INSIDE A
SPHERICAL SHELL OF URANIUM METAL

B. T. Feld and L. Szilard

December 26, 1941

"The critical size for the maintenance of a fast neutron chain reaction in a sphere of 25 or other element having high cross section for slow neutron fission is calculated when the material is surrounded by a shell of uranium metal. The first approximation to the appropriate diffusion equation is used, in which we assume that there are two categories of neutrons: "slow", or neutrons below the fission threshold of 28, and "fast" neutrons. We consider the processes of fission, inelastic scattering, and elastic scattering.

It is shown that the addition of the uranium metal shell reduces the mass of reacting material by a factor of about 12. The

[REDACTED]

amount of core material would be 1.5 times greater if there were no fast neutron fission in the 28 shell".

For infinite shells the critical radii given are:

R = 4.80 cm (with creation), R = 5.55 cms (without creation),
R = 5.55 cms (no inelastic scattering).

Creation here refers to fission in the shell. The first radius quoted corresponds to 9.26 kg for the core of 25.

CF-548

CRITICAL AMOUNTS OF URANIUM COMPOUNDS

E. Konopinski, N. Metropolis
E. Teller, and L. Woods

March 19, 1943

Calculations were carried out on the basis of two-group theory applicable to fluorides and oxides for metal reflected spheres and water reflected spheres in isotopic mixtures ranging from 20% to 100% of 25 content.

"The result of the calculation is that approximately rather more than 100 kg of pure 25 isotope must be present..." in a metal reflected sphere for sustained reaction in a container or reflector not more than an inch in thickness. The critical mass is plotted

[REDACTED]

as a function of albedo in the case of a reflector. In the case of UF_6 , the critical radius is 6.75 cm, the critical mass 6.05 kg. The calculations are based on rough constants (see C-334). Metal reflectors considered were Fe, Ni, Cu, Al.

CF-589

STUDIES IN A FIVE TON METAL PILE

A. H. Snell, et al.

April 17, 1943

"A pile of pure metal, 22" high, 22" wide, and 28" long was erected near the Be target of the Chicago cyclotron. Fission/capture measurements were made in it---results lead to the conclusion that a very large body of metal would have to have its 25 concentration increased by a factor of 12 in order to start chain reacting".

The report contains a detailed description of the experiment and data obtained is tabulated. A graph is given showing activity throughout pile.

CF-1627

NEUTRON MULTIPLICATION IN A MASS OF URANIUM METAL

Brolley, Byerley, Feld, Olds,
Scalettar, Slotin, and Stewart

April 1, 1944

Snell's experiment (CF-589) was repeated using 34 tons of



metal (48" x 48" x 48"). Results indicate that for a very large mass of metal the ratio of 28 atoms to 25 atoms must be not more than 12 to 1 for a possible chain reaction.

Ratio 28 atoms/25 atoms	k
139 - - - - -	0.34
14 - - - - -	0.93
13 - - - - -	0.96
12 - - - - -	1.01
11 - - - - -	1.05
10 - - - - -	1.11

CP-2841

PHYSICS DIVISION

MONTHLY REPORT FOR PERIOD ENDING JUNE 30, 1945

OPTIMUM CONCENTRATION OF 25 IN A HOMOGENEOUS REACTOR

A. M. Weinberg

Based on the assumption that maximum slow neutron flux is desirable, the optimum concentration of 25 in a homogeneous reactor is about 1 gram per liter for a critical mass of 2.5 kg and



[REDACTED]

a 15 cm reflector.

CF-3414

DESIGN OF A FAST NEUTRON BREEDER

TEST PILE

W. H. Zinn

January 25, 1946

The active portion of the pile is to consist of a large number of steel encased 25 rods (0.448" diameter) cooled by flowing Na-K. An internal breeding blanket consists of rods of 28 (0.875" diameter) also cooled by the Na-K. An external breeding blanket is to be built of bricks of 28 to a thickness of 5" and is air-cooled. A 60 cm graphite reflector is added and backed up by a small thermal shield of cast iron or lead-cadmium blocks and 5' of concrete.

About 40 kg of 90% enriched uranium or over 100 kg of 35% enriched uranium is required. For conditions outlined, the breeding gain is estimated to be about 15-20%.

CF-3582

DESIGN OF THE FAST NEUTRON BREEDER TEST PILE-PART II

REPORT FOR PERIOD JANUARY-JUNE, 1946

"This report is a statement of the progress in the design of

[REDACTED]

[REDACTED]

the fast neutron breeder test pile. The general design of a test pile operating on fast neutrons and which is to be a converter was sketched out in CF-3414. In this report various details are filled in."

LA-189

MULTIPLICATION OF FISSION NEUTRONS IN A SPHERE OF 25

December 18, 1944

"The multiplication in a sphere of 25 of fission neutrons from a shell source on the surface of the sphere was observed by small 25 and 28 detectors at its center. The values for the multiplication registered by the 25 counter are in agreement with calculations by Rarita for both a $1\frac{1}{2}$ " and 2" diameter sphere...."

The multiplication of the 2" sphere is given as $1.445 \pm .02$ with the 25 detector and one run with the 28 detector gave $1.21 \pm .02$. Results for the $1\frac{1}{2}$ " sphere are also tabulated for both 25 and 28 detectors. The report contains two figures which indicate the experimental geometry and set-up.



LA-191

MULTIPLICATION OF A 2½" 25 SPHERE AS
MEASURED WITH 28 AND 25 FISSION DETECTORS

December 20, 1944

"Data are reported for the multiplication by a 2½" sphere of 71% 25..... Some data for a 2" sphere are also given. For the 2½" sphere the multiplications are found to be:

$$M_{28} = 1.13 \pm .02, M_{25} = 1.37 \pm .02".$$

An 8 curie Po-NaBF₄ mock fission source emitted about 6×10^5 neutrons/second in a central cavity of 0.314" diameter. The mass of material quoted is 1238 gm.

LAMS-227

MULTIPLICATION BY SMALL SPHERES OF ACTIVE MATERIAL

A. O. Hauson, R. Serber, and J. H. Williams April 11, 1945

"Measurements are made of the neutron multiplication which occurs when a mock-fission source is surrounded by a small sphere of 25 or 49. The quantity most directly determined is $\sigma_f (\nu - 1 - \alpha)$, averaged over the fission spectrum....."



[REDACTED]

LAMS-227 - (Continued)

Diameter	Multiplication	
	Calculated	Observed
1½"	1.147	1.152 ± .004
2"	1.233	1.233 ± .010
2¾"	1.343	1.337 ± .006

LA-234

A GRAPHICAL REPRESENTATION OF CRITICAL MASSES
AND MULTIPLICATION RATES

R. Serber

March 6, 1945

"An approximate method of calculating critical masses and multiplication rates is described which gives the results in a very convenient form....

The economy introduced....is so great that all results on the critical radius can be represented by a pair of graphs, which, except for extreme values of the constants, are accurate to 1 percent. A second pair of graphs serves to give multiplication rates".

LA-235

CRITICAL MASSES AND MULTIPLICATION RATES

W. Rarita, R. Serber

March 7, 1945

The table below summarizes critical masses and multiplication rates calculated by a two-group spherical-harmonic method for tamped cores (spherical).

System		M_c	Multiplication Rate in $10^7/\text{sec.}$	
Core	Tamper	Kg	$M/M_c = 3$	$M/M_c = 5$
25	WC	13.3	3.2	4.9
70% 25	WC	25.5	2.3	3.5
25	U	14.5	3.6	5.4

The dividing energy was chosen at 0.4 Mev. The theory is sketched in some detail and all nuclear constants are given in tabular form for the calculations.

LA-402

NEUTRON MULTIPLICATION IN SPHERES OF 25

H. D. Anderson

October 6, 1945

"Experiments on the multiplication in spheres of β^- stage 25

[REDACTED]

embedded in tampers of tuballoy and WC were carried out in order to provide an experimental basis for predicting the critical sizes... For the conventional crit these experiments gave 13.7 kg for WC tamper and 15.0 kg for the tuballoy tamper".

The report gives details of the experiment, method of calculation, photographs of set-up, constants used, and graphs multiplication in core versus position.

LA-609

CRITICAL DIMENSIONS OF WATER-TAMPED SLABS AND
SPHERES OF ACTIVE MATERIAL

E. Greuling

August 6, 1946

"The critical slab thickness is obtained ...by solving an inhomogeneous transport integral equation for the fast neutron current density into the tamper. Extensive use is made of the formulae derived in The Mathematical Development of the End-Point Method, by Frankel and Nelson, LA-258.

....alterations in the theory were made so that one could

[REDACTED]

approximately compute the critical radius of a water-tamped sphere of active material $(\text{UF}_6)^n$.

The report gives the theory in detail and includes several graphs, one of which gives critical dimensions for UF_6 in (a) untamped slab, (b) half water-tamped slab, (c) water-tamped sphere. The dimensions range from 10 cm to 400 cm in the three cases and are plotted as a function of the percentage of 25 .

MS-111

THE CRITICAL SIZE AND TIME CONSTANT OF A SPHEROID

H. Fairbrother

June 16, 1944

This theoretical report gives in detail the mathematical steps leading to the determination of the critical size of an oblate spheroid on the basis of diffusion theory. The problem is solved both for a bare and infinitely reflected spheroid of same mean free path in the reflector as the spheroid. For the latter case the result is graphed, giving the ratio of volume of spheroid to sphere of same time constant vs. the ratio of the axes of the spheroid.

MS-112

CRITICAL RADIUS OF A HEMISPHERE
COMPLETELY SURROUNDED BY A CONTAINER

P. D. Preston, B. Davison

July 5, 1944

This is a theoretical report which derives the result that the radius of a critical hemisphere with infinite reflector on all sides should be slightly less than 1.3 times that of a sphere and reflector of the same material. It is assumed that the mean free path is the same for reflector and hemisphere.

M-3285

INFORMATION MEETING - CLINTON LABORATORIES

OCTOBER 14-16, 1946

RECENT WORK ON THE FAST PILE

W. H. Zinn

The "Zinn" fast pile is to use enriched uranium rods jacketed with stainless steel. The coolant is to be liquid Na-K alloy. No moderator is contemplated.

[REDACTED]

49

CK-2737

PHYSICS DIVISION MONTHLY REPORT FOR MONTH ENDING

FEBRUARY 15, 1945

PART I

Preliminary quotation of a critical mass of 15 kg of ⁴⁹ or ²⁵ to be needed for a fast-breeder pile operating at several hundred kilovolt energy neutron.

(See CF-3107, CF-3199).

CF-2796

PHYSICS DIVISION MONTHLY REPORT FOR MONTH ENDING

MARCH 15, 1945

PART I

Some critical masses quoted for the ⁴⁹ fast breeding calculations given in detail in CF-3107.

(See CF-3199).

CF-2926

PHYSICS DIVISION REPORT FOR MONTH ENDING

APRIL 15, 1945

Some preliminary results on fast-breeder calculations by H. Soodak

[REDACTED]

[REDACTED]

are quoted for cylindrical piles whose cores consist of 49 diluted with uranium and cooled by a liquid metal. The reactor consists of 49-U plates 1.5 mm thick, coated on each side with a 1/4 mm jacket. The coolant streams are 1.5 mm thick. A summary table is given in review of CF-3199. A fully detailed report on the 49 fast breeder pile is given in CF-3107.

CF-3107

THE FAST PLUTONIUM BREEDER

H. Soodak

July 4, 1945

This report deals with the size, power, and breeding gain of fast, non-moderated 49 piles and is a rather detailed study. The following is quoted from the abstract:

"The reactor portion of these piles consists of the fission metal which is a mixture of plutonium and a diluting substance (generally uranium). Flowing through spaces in the fission metal is a liquid metal coolant. The fission metal is jacketed in order to protect it from the cooling stream. Surrounding the reactor is a uranium reflector.

It is found that a chain reaction is possible for piles containing anywhere from about 10 kg of 49 on up. It is also found that if



the fissionable material can be fabricated into 2 mm thick plates, then piles containing from 100 to several hundred kg of ^{235}U can be operated at a power of 1000 kw/kg ^{235}U or higher. A breeding gain of 0.5 combined with a specific power of 100 kw/kg gives 6 years as the time necessary to double the ^{235}U by breeding".

The report has a table of contents and gives details of calculations, data used, and tabulates results.

CF-3199

BREEDER PILE DISCUSSION

SLOW, FAST, AND RESONANCE PILES

E. P. Wigner

June 19-20, 1945

(See under 23 for Wigner).

RESONANCE BREEDERS

A. M. Weinberg

Following are estimates of the critical masses of resonance piles consisting of a ^{235}U solution core, a shell of fluorocarbon, and a uranium breeding blanket:

Atomic Ratio	$\text{CF}_{2/49}$	7.5	150	300	450
$\bar{\eta}$		2.87	2.78	2.59	2.43
Critical Mass (kg)		225	126	82	65



[REDACTED]

CF-3199 - (Continued)

FAST PILE DESIGN

H. Soodak

Critical values are tabulated for cylindrical piles where the fissionable material is ^{235}U and the diluent is uranium.

U/49	0	1	4	10	20
Critical Mass (kg)	20	35	90	400	Not
Critical Volume (Liters)	2.2	8	50	460	Chain
Critical Length (cm)	13	20	37	77	Re-
Specific Power (kw/kg)	200	500	1200	1700	actin _g

(See also CF-3107)

CF-3490

QUARTERLY REPORT FOR JANUARY, FEBRUARY, AND

MARCH, 1946

PART I

ARGONNE LABORATORY DIVISION

This report contains a summary of calculations on a Resonance Energy Pile by M. L. Goldberger for bare spherical reactors cooled with Na of volume equal to the Be + ^{235}U in the reactor. Calculations

[REDACTED]

[REDACTED]

were made for the three cases in which (No. atoms Be/No. atoms 49) = 50, 100, 150. The summary is in tabular form and no details of the calculation or structure is given aside from gross data. A portion of the table is as follows:

File Quantity	Be/49 = 50	= 100	= 150
\bar{k}	2.887	2.642	2.521
\bar{c} (cm ²)	55.51	62.56	67.20
R ₀ (cm)	21.9	24.7	26.5
V (liters)	43.8	63.2	78.1
Wt. of 49 (kg)	41.1	30.3	25.4
Kw/kg of 49	3240	5580	7580
Total Output (kw)	4.43 x 10 ⁵	5.63 x 10 ⁵	6.50 x 10 ⁵

LAMS-227

MULTIPLICATION BY SMALL SPHERES OF ACTIVE MATERIAL

A. O. Hanson, R. Serber, and
J. H. Williams

April 11, 1945

A 0.9" sphere of 49 surrounding a mock fission source of strength not stated gave a measured multiplication of $1.197 \pm .004$.

LA-235

CRITICAL MASSES AND MULTIPLICATION RATES

W. Rarita, R. Serber

March 7, 1945

The table gives critical masses and multiplication rates calculated by a two-group spherical-harmonic method for tamped cores of 49 (spherical):

System		M_c	Multiplication Rate in $10^7/\text{sec.}$	
Core	Tamper	Kg	$M/M_c = 3$	$M/M_c = 5$
49	WC	4.72	6.3	10.1
49	U	5.11	6.8	10.5

The dividing energy was chosen at 0.4 Mev. The theory is outlined in some detail and nuclear constants are given in tabular form.

MonP-412

INTERIM NOTE ON MIXED PILE STUDIES

J. R. Menke

September 25, 1947

(See under 23).

MDDC-1080
LADC-406

LOS ALAMOS FAST REACTOR

D. V. Hall, Jane Hall June 27, 1947

A short declassified summary statement of the existence of a 49 reactor at Los Alamos which has been made critical by fast neutron induced fission of 49. No physical data is given other than a mention of a neutron flux of 10^{12} neutrons/cm²/sec. Considerable details may be found in M-3554.

M-3285


INFORMATION MEETING - CLINTON LABORATORIES

OCTOBER 14-16, 1946

THE LOS ALAMOS FAST REACTOR

David Hall

The "Morrison" fast reactor is designed to use plutonium stabilized in its delta phase by gallium. Average neutron energy in the reactor will be about $\frac{1}{2}$ Mev. The coolant will be Hg in a closed system. Active core will be six inches in diameter. Overall dimensions will be about 15 feet.



M-3753

PILE TECHNOLOGY

LECTURE 24

FAST AND MIXED PILES

J. R. Menke

April 30, 1947

(See under 23).

[REDACTED]
H + 23

CRT-293

EXPLORATORY SURVEY OF QUANTITIES OF 23 REQUIRED FOR
SELF-REACTING PILES INCLUDING THE EFFECT OF REFLECTORS
(EXTENSION OF FSD-19)

S. Kushneriuk

October 15, 1946

"The two-group model of neutron multiplication is applied to obtain critical conditions in a system consisting of a spherical core of a homogeneous mixture of pure 23 and a moderator, with and without a reflector. The critical quantity of 23 is plotted as a function of the atomic ratio of moderator to fissile material in the core".

CRT-305

CRITICAL CONDITIONS FOR BARE SPHERICAL CORES CONSISTING
OF HOMOGENEOUS MIXTURES OF PURE FISSILE MATERIAL AND A MODERATOR

S. Kushneriuk and G. M. Volkoff

November, 1946

"By using the migration length as a unit, the two-group model of neutron multiplication yields graphs with which, for any moderator, the critical mass of pure 49 or 23 in a homogeneous mixture with the moderator may be estimated. In order to apply the graphs to a particular moderator it is only necessary to know the diffusion and slowing

[REDACTED]

down lengths, the density and the atomic (or semi-molecular) weight of the moderator and the ratio of capture cross-section of the moderator to the absorption cross-section of the fissile material".

Formulae and constants used in the graphs are presented.

MonP-85

REPORT FOR MONTH ENDING MARCH 31, 1946

THORIUM-23-WATER POWER PILE

F. H. Murray, A. M. Weinberg

"Calculations have been made on a Th plate pile cooled and moderated with H₂O and containing 23 so that as much 23 is produced as is consumed. The pile consists of 1 mm Th-U plates clad with $\frac{1}{2}$ mm Al and separated by 4 mm H₂O layers. Such a pile 35 cm in radius and 80 cm high, which contains 11 kg of 23, can yield 100,000 kw of heat. The pile pressure would be about 1200 p.s.i. and saturated steam at 600 lb. would be generated in a heat exchanger. The overall thermodynamic efficiency of such a system is 22%".

No further details are given.

(See MonP-93).

[REDACTED]

MonP-93

HIGH PRESSURE WATER AS A HEAT TRANSFER MEDIUM
IN NUCLEAR POWER PLANTS

A. M. Weinberg

April 11, 1946

Preliminary calculations of a self-sustaining Th-23 light water power plant are presented. The total pile is cylindrical 35 cm radius x 78 cm high and includes a 5 cm thorium blanket in each dimension. The active pile volume is 0.192 m^3 , of which 0.04 m^3 is Th. The total mass of Th in the machine is 440 kg and the mass of 23 is 11 kg. A reduction in H_2O density at high temperature will increase the critical mass of 23. The pile consists of parallel plates of Th which are 1 mm thick, enriched with 23 and coated with $\frac{1}{8}$ mm of Al. The volume ratio of H_2O to Th is taken as 4. The multiplication is given as

$k = \eta \epsilon pf = 1.59 \times 1.02 \times 0.848 \times 0.94 = 1.29$ and $\tau = 40 \text{ cm}^2$
so that $\Delta \approx \frac{\ln k}{\tau} = 6.35 \times 10^{-3} \text{ cm}^2$. The temperature of the pile is 300°C and under pressure of 1200 p.s.i.

MonP-113

REPORT FOR MONTH ENDING MAY 31, 1946
 H_2O -Th-23 POWER PLANT

S. DeBenedetti

"A plant with H_2O at high pressure as a moderator and a 23-Th

[REDACTED]

[REDACTED]

alloy as fuel might work reproducing the 23 at the same place where it is burned, i.e., without the help of an outside Th blanket. If the fission product losses are assumed to be 8% and the ratio of the total cross section for H₂O and 23 is 0.1, the machine should have a volume ratio H₂O/Th of 1.84. The weight of 23 should be 1.9% of the weight of Th. The machine could be 200 cm long and 100 cm in diameter, making possible the construction of an appropriate pressure vessel; it would contain 3.5 tons of Th and 66 kg of 23".

For details on assumptions and calculations see M-3122.

M-3122

ON THE CONDITIONS FOR REPRODUCING THE FUEL INSIDE

A REACTOR WORKING WITH H₂O-Th-23

S. DeBenedetti

June 12, 1946

This report (memo) fills in some of the assumptions and calculations which were not given in the summary in MonP-113. The k is required to be greater than 1.1. If all the losses do not exceed 18%, and if 10% can be attributed entirely to H₂O in the limiting case, then it is shown that $W_{Th}/W_{H_2O} \cong 6$ gives the relative weights of Th and H₂O. For a machine 200 cm long x 100 cm diameter and with the outside 10 cm for a reflector, the volume of the core is 900 liters. 35% of this volume is to be occupied by Th.



H + 25

A-9

PRELIMINARY ESTIMATES OF AMOUNTS OF 25
NEEDED FOR A SELF-SUSTAINING CHAIN REACTION

G. Breit

July 14, 1941

An approximate form of the Boltzmann Equation assuming Fermi slowing down is used in this early report to get minimum and maximum amounts of 25 for a self-sustaining thermal reaction. The 25 is supposed to be homogeneously distributed through the interior of a slowing down material such as H₂O in a spherical volume with a reflector of H₂O or carbon. The values obtained were approximate because of the uncertainties in constants.

A-4716

CRITICAL MASS STUDIES

Beck, Callihan, and Murray June 10, 1947

A detailed account of 30 assemblies of UF₆ (mock-up) and hydrogenous cubes, 26 of which became critical.

Several graphs show various relations of critical mass. Briefly:

<u>H Cubes:U Cubes</u>	<u>Critical Mass</u> U ²³⁵ (kg)	<u>Critical Mass</u> 95% U ²³⁵ (kg)
0:1	100	105
1:7	60	63
1:4	47.3	49.6

(See next page)



[REDACTED]

A-4716 - (Continued)

<u>H-cubes:U-cubes</u>	<u>Critical Mass</u> U235 (kg)	<u>Critical Mass</u> 95% U235 (kg)
1:2	25.7	27.0
1:1	15.8	16.6
2:1	9.7	10.2
4:1	8.2	8.6
7:1	9.9	10.4

A-7.390.22

CRITICAL CONDITIONS IN CYLINDRICAL VESSELS

Morfitt, Murray, and Schmidt
(Y-12 Special Hazards Group)

January 22, 1947

A rapid method of calculating the critical chemical concentrations and minimum critical masses of aqueous solutions of uranium compounds in cylindrical containers is developed. Results are believed to involve an inherent safety factor and as such are conservative.

Three graphs give the critical dimensions of cylinders for different conditions. Two graphs give the minimum critical masses for cylinders of optimum height.

A-7.390.24

CRITICALITY IN UNTAMPED URANIUM SOLUTIONS

R. L. Murray and G. W. Schmidt

February 6, 1947

A description of a conservative method of determining critical concentrations and masses of pure ^{235}U in water solution. Examples of the calculations are given and the following figures included:

Fig. I. - Critical Mass and Concentration for Untamped Slab

Fig. II. - Critical Mass and Concentration for Untamped Cylinder

Fig. III. - Critical Mass and Concentration for Untamped Sphere

Fig. IV. - Relation of Critical Concentration to k

A-7.390.25

CALCULATIONS OF CRITICAL CONDITIONS

FOR URANYL FLUORIDE SOLUTIONS

R. L. Murray

March 5, 1947

The theoretical determination of the critical concentrations and masses of UO_2F_2 solutions prior to experiments with this material.

Fig. I. - Critical Conditions of a Tamped Sphere

Fig. II. - Critical Conditions of Tamped Cylinder

Fig. III. - Critical Conditions of Untamped Cylinder

CNL-35

QUARTERLY REPORT FOR DECEMBER, 1947.

JANUARY AND FEBRUARY, 1948

A. M. Weinberg

March 26, 1948

Details of 5 critical assemblies of 25 enriched reactors are presented subsequent to those reported in MonP-357. These study effects of geometry, poison content, holes, recesses, control, etc. Data is given for assemblies which are square or rectangular in cross section and each is 66 cm high. The Al/H₂O volume ratio in the core is 0.65. In each case the Be reflector is ~30 cm on each side.

Assembly	Dimensions cm	Crit. Mass kg	Σ Poison cm ²	Σ Pile cm ²	Σ Total cm ²
1.	22x22x66	1.06	36	2611	2647
2.	51x11x66	1.35	0	2950	2950
3.	(a) 71x11x66 (b) 71x11x66 (30 cm of graphite on one side)	1.94 1.94	240 270	4150 4150	4390 4420
4.	71x14x66 (30 cm of graphite on one side)	2.44	572	5200	5772
5.	71x17x66 (30 cm of graphite on one side)	2.94	1028	6290	7318

[REDACTED]

CNL-35 - (Continued)

Neutron distributions are given for thermals and epithermals.

CP-139

ENRICHED URANIUM AND WATER POWER PLANT

R. F. Christy and A. M. Weinberg (no date)

This report summarizes early calculations made to estimate optimal geometry, critical masses, and multiplication constants for a high power metal-water system when the 25 or 49 is enriched in the metal which may be in spheres or rods. The results of some representative estimates for a spherical plant are given in the table below:

R	k	Enrichment	Mass U	Mass (25 or 49)
140 cm	1.03	25%	63 tons	112 kg
86 cm	1.08	40%	14.5 tons	41 kg
42 cm	1.40	180% (?)	1.7 tons	22 kg

The constants used for the calculation are listed and the values of thermal utilization, resonance escape, and η are given in scatter plots of metal size vs. ratio of cell volume to volume of metal for spheres, rods, and plates.

[REDACTED]

CE-140

A PLANT WITH WATER COOLING

Gale Young and E. P. Wigner (no date)

A brief account of a proposed natural uranium reactor of 310,000 kw output, cooled by H₂O and moderated by graphite.

The uranium is in the form of cylinders, canned in aluminum tubes. The center 1/8 of the reactor is to contain metallic uranium; the outer portions a uranium compound, preferably the carbide.

The reactor is to be cylindrical in shape, 8 m in diameter and 5.5 m in height. 440 tons of graphite and 65 tons of uranium will be required.

CP-668

ON THE MULTIPLICATION CONSTANT OF HOMOGENEOUS MIXTURES OF U WITH VARIOUS MODERATORS

E. P. Wigner and J. Stephenson

May 15, 1943

A summary is given in graphical form for

$$k = \eta \epsilon p_1 p_2$$

for such moderators as H, D, C, Be, He, O, U. Formulae are given from which each of the factors were computed and a table of necessary

[REDACTED]

[REDACTED]

constants is included.

CP-834

VALUES OF THE THERMAL UTILIZATION, RESONANCE ABSORPTION
AND MULTIPLICATION CONSTANT IN CYLINDRICAL METAL

H₂O SYSTEMS

R. R. Williamson and A. M. Weinberg

July 31, 1943

"The accompanying figures give, for a metal-H₂O system, curves of p_1 , the fraction of neutrons escaping resonance capture, p_2 , the thermal utilization, $\eta' = \frac{1}{p_1} \times \frac{1}{p_2}$, and $(\eta'/\epsilon)_{\min} = n/k$, where ϵ is the fast multiplication factor and $(\eta'/\epsilon)_{\min}$ is the lowest value of η'/ϵ for a given metal rod size (at the optimum moderator-metal ratio)...The method of calculation is the same as described in CP-372".

For a cell radius to rod radius ratio of 1.8 (rod radius = 1.05 cm) the report gives best $k = 0.93$ and best laplacian = 0.00233 cm^{-2} .

CP-1834

MULTIPLICATION FACTORS AND LAPLACIANS IN MIXED H₂O-P-9 SYSTEMS

A. M. Weinberg and M. Ginsberg

July 3, 1944

This is a summary report in which "accompanying figures give calculated values for the thermal utilization (f), resonance escape probability

[REDACTED]

[REDACTED]

(p), multiplication factor (k), migration area (M^2), and laplacian (Δ) in metal rod ($p = 18.9$) systems moderated with various mixtures of P-9 and H_2O . The curves are plotted for each concentration of P-9 (80%, 90%, 95%, 97.5%, 100%) as functions of r_1/r_0 , the ratio of cell to rod radius. Three sets of curves are given for rod radius $r_0 = 1.0, 1.5, \text{ and } 2.0 \text{ cm}$. The constants used are given and some of the formulae.

CP-2048

EXPONENTIAL EXPERIMENTS WITH WATER-METAL ROD LATTICES

October 3, 1944

A detailed description of "measurements on 12 H_2O -metal lattices ranging in water to metal ratio from 3.27 to 0.273 are reported here. The value of k lay between 0.6 and 1.00. With the materials used and no gap a k greater than 1.00 does not seem to be obtainable. By introducing a gap and decreasing the rod size it may be possible to build a lattice having a $k > \text{unity}$ ".

CP-2182

SEMI-MONTHLY REPORT FOR THE PERIOD

ENDING SEPTEMBER 30, 1944

A summary is presented in tabular form for theoretical calculations on critical masses and radii for various concentrations of

[REDACTED]

uranyl sulphate (12½% enriched in 25) in H₂O with an infinite P-9 reflector and for the case of a fixed concentration ξ corresponding to 2.8×10^{-3} atoms of 25 per molecule of H₂O with various reflectors: graphite, P-9, H₂O, BeO, Be, bare. No details of calculations are given but two and three-group methods were employed for spherical geometry.

TABLE I
CRITICAL RADIUS (R) AND AMOUNT (G) OF 25 FOR VARIOUS REFLECTORS WITH $\xi = 2.8 \times 10^{-3}$

Reflector →	Graphite $\rho = 1.6$	D ₂ O	H ₂ O	BeO $\rho = 3$	BeO $\rho = 2$	Be	No Refl.
R (cm)	16.1	16.3	20.7	14.7	16.3	15.5	27.3
G (gm)	600	622	1273	456	622	535	2920

CP-2185

MONTHLY REPORT FOR PERIOD ENDING OCTOBER 31, 1944

The following table extends results on critical mass and size first reported in CP-2182.

R is the critical radius
G is the critical mass
 ξ is the ratio of 25 atoms to H₂O molecules for an infinite P-9 reflector

[REDACTED]

CP-2185 - (Continued)

Z x 10 ³	2	2.4	2.8	3.2	3.6	4.0	5.0	6.0	10
R (cm)	18.3	16.1	14.8	13.8	13.1	12.6	11.6	11.2	9.5
G (gm)	668	544	794	456	438	432	421	453	455

CP-2377

LAPLACIANS OF GRAPHITE FILLED GAP LATTICES

A. M. Weinberg and A. T. Monk

November 16, 1944

"Curves of laplacian, k , M^2 , τ , and L^2 vs. thickness of gap filler are given.....for a sequence of rod lattices in which r_0 , the metal radius, is held at 1.5 cm, and the water to metal volume is always adjusted to the optimum. The highest laplacian in this sequence is $140 \times 10^{-6} \text{ cm}^{-2}$, occurring for a graphite gap thickness of 1 cm and a water to metal volume ratio of 1.65....The multiplication constant in this system is only 1.0107 so that the leeway for k loss from poisoning or temperature is very small".

Details of the calculation are presented, formulae used, and references to sources of constants. Results are in graphical form.

[REDACTED]

CP-2568

MONTHLY REPORT FOR THE PERIOD ENDING JANUARY 31, 1945

A graph is presented summarizing measurements of laplacians in water lattices when the water/metal volume ratio is varied from about 1 to 3; a minimum appears at about 1.44 where $\nabla^2 \times 10^4 \approx 2.0$.

CP-2842

FINAL REPORT - WATER LATTICE EXPERIMENTS

G. Branch, et al

June 30, 1945

"The laplacians and migration areas of water-uranium rod lattices have been studied by the exponential pile technique. The best k obtained at room temperature in a no-gap geometry was 0.993 for a volume ratio of 1.36 and a rod radius of 1.5 cm. An enrichment in 25 to 0.75% would therefore almost certainly make an ordinary water no-gap system potentially chain reacting at room temperature. A one-cm gap around the rods increased the k to 1.003 and shifted the optimum volume ratio to 1.56....The k optimum for 1.4 - 1.5 cm rods is 0.6% higher than for 1.0 cm rods...opposite that predicted by theory".

The report gives a detailed account with diagrams, pictures of the experiments, dimensions of lattices, graphs of activity vs. posi-

[REDACTED]

tion, k vs. volume ratio at different temperatures, a survey of exponential theory, plots of laplacian vs. H_2O to metal volume ratio.

K-126

CRITICAL MASS STUDIES-PART II

Beck, Callihan, and Murray

January 23, 1948

Critical experiments were performed using 30% enriched uranium compounded into cubes having a density of 4.8 with the nuclear properties of UF_6 .

With no intermixed hydrogen but with a paraffin reflector more than 100 kg of 25 could be assembled before criticality was approached. Intermixing hydrogen to ratios of 32 to 1 and 128 to 1 reduced the critical mass to 7.7 kg and 4.0 kg respectively.

Removal of the reflector approximately doubles the critical mass.

At an atomic ratio (H:25) of 16 the critical mass varies as the -1.7 power of the density.

Several tables and curves show trends in the critical mass.

[REDACTED]

LAMS-18

CRITICAL MASS OF 25 IN WATER SOLUTION WITH WATER
REFLECTOR

R. F. Christy

October 4, 1943

A brief summary of several methods (theoretical) used to predict the critical mass of 25 in water reflected water solution. No details of the calculation are given. For a three group calculation, the constants for the ages and diffusion coefficients are stated. It is stated that three methods give $M_c \approx 600$ gm.

LA-105

TAMPER TESTS ON WATER BOILER

R. E. Carter

July 18, 1944

"Tests of various tamper materials have been made by observing their effect either on the criticality of the water boiler or on its multiplication of a natural source, when a rather small part of the normal BeO tamper was replaced by the specimens".

A table is given which gives the effect of each material in change of mass of 25 in gm for thermal neutrons and epithermal neutrons.

[REDACTED]

LA-134

WATER BOILER

C. P. Baker, et al September 4, 1944

"The structural features of the uranyl sulphate water boiler in use at Site Y are given in detail....The structure and function of the control rod, the safety rod, and their related mechanical systems are explained, and an account is given of the temperature controlling system.

The activity of the boiler was measured as the mass of active material approached criticality; the results are discussed in detail. The control rod was calibrated and the effect of temperature change noted."

The core composition was UO_2SO_4 , 14.7% of 25, in 15 liters of water in a stainless steel sphere reflected by BeO one foot thick and contained 565 gm of 25. The report graphs neutron fluxes, counting rate vs. mass, and presents photographs and details of equipment.

LA-234

A GRAPHICAL REPRESENTATION OF CRITICAL
MASSES AND MULTIPLICATION RATES

R. Serber

March 6, 1945

(See under 25).

[REDACTED]

[REDACTED]

LA-241

WATER TAMPER MEASUREMENTS

R. E. Carter, et al March 12, 1945

"The critical mass of an enriched uranyl sulfate solution in a water tamper was determined to be 1200 ± 50 gm...The estimate was made by extrapolating counting rate vs. grams of 25 to infinite counting rate...Distribution measurements were made in the tamper for high and low energy neutrons.....".

The BeO tamper of the H₂O boiler (See LA-134) was removed and a cylindrical tank 5 ft. in diameter and 5 ft. high was placed around the sphere. Neutron distributions in the tamper were determined with BF₃, Mn, 25 and 28.

LA-309

SUMMARY OF KNOWN CRITICAL MASSES OF 25 AND 49

B. T. Feld

June 14, 1945

An enclosed set of tables "summarize our present knowledge (Los Alamos, June, 1945) of the critical masses of active materials in various configurations. The figures quoted have been experimentally determined whenever possible...Unless otherwise stated, the core of active material is spherical in shape...The tables run from the case

[REDACTED]

[REDACTED]

of complete hydration (water boiler) through the hydrides to metal assemblies containing no hydrogen in the core of active material".

LA-394

HIGH POWER WATER BOILER

F. L. Bentzen, et al September 19, 1945

"A detailed description of the design and construction of a 5.5 kw water boiler at Site Y is given. A 14% enriched uranyl nitrate solution in water is used as the reactor and moderator. The 13.5 liters of solution containing 870 gm of ²⁵ are held in a 1 foot diameter stainless steel sphere. The tamper consists of a BeO core surrounded by graphite. A thermal column is connected to one side of the tamper. The operation and performance of the boiler are described".

LA-399

THEORY OF WATER-TAMPED WATER BOILER

E. Greuling

September 27, 1945

"The critical mass of the water-tamped 14% enriched uranyl sulphate water boiler calculated by integral diffusion theory is 1.31 ± 0.10 kg of ²⁵. The calculated thermal neutron distribution

[REDACTED]

in core and tamper of the under-critical boiler containing 717 gm of 25 and a Ra-Be source agrees with the measured distribution (LA-241). Simple formulae and curves appropriate for water-tamped spherical, infinite cylindrical, and plane slab hydride cores are applied to the calculations of the minimum critical mass and the minimum critical dimensions of the above type boilers".

Critical masses and dimensions are plotted for the sphere, cylinder and slab as functions of enrichment and ratio of moderator to 25 concentration.

LA-493

GRAPHICAL METHOD OF OBTAINING CRITICAL MASSES
OF WATER-TAMPED WATER BOILERS

E. Greuling

April 5, 1946

"An approximate method of calculating the critical mass of 25 as a function of spherical core volume of a wide variety of enriched uranium in water solutions surrounded by water is outlined. The results are expressed in such a form that one may read, after selecting a single parameter, the critical mass of 25 and corresponding core volume from the intersection of two superimposed curves...One can rapidly obtain minimum critical masses and optimum water solution concentrations of several uranium compounds having various 25 isotope enrichment percentages. The approximations are in such a direction

[REDACTED]

[REDACTED]

as to yield critical masses that are slightly low".

LA-618

CRITICAL MASSES OF ENRICHED URANIUM HYDRIDES
AND SOME RELATED MEASUREMENTS

C. P. Baker and M. G. Holloway

February 3, 1947

Critical assemblies were built up of $UH_{10}O_4$ ($UH_3 + 4OH_{1.75}$) blocks surrounded by various tampers. The uranium was enriched to approximately 75%.

<u>Tamper</u>	<u>Core Shape</u>	<u>Critical Mass of 25</u>
12" BeO	Cubical	2.80 kg
6" BeO	Cubical	3.52
6½" Tu	Elliptical	6.95
4½" WC	Spherical	7.0
4½" WC	Cubical	7.53
6½" Fe	Elliptical	8.29
6½" Pb	Elliptical	9.2
Untamped	Cubical	18 - 24

MonP-17

PHYSICS DIVISION

REPORT FOR MONTH ENDING SEPTEMBER 31, 1945

L. W. Nordheim

Some summary remarks are given on the effectiveness of an ordinary H_2O -U lattice as a reflector around an enriched homogeneous P-9 machine.



It is stated that a 20 cm thick water lattice with $k = 0.97$ saves about 20 cm in the critical radius of the pile.

MonP-24

REPORT FOR MONTH ENDING OCTOBER 31, 1945

L. W. Nordheim

Enriched Water Lattices.

"....At a volume ratio of $2H_2O:1U$, and with an infinite unenriched lattice as reflector, the critical amounts of enriched material in the seed are as follows:

25 Concentration	Critical Mass	<u>Power in Reflector</u> <u>Power in Seed</u>
0.85%	7.1 tons	2.2
1.0%	1.3 tons	3.7

The 49 to power production ratio is 1.09 higher in the 0.85% seed than in the 1.0% seed".

No further details are given.



MonP-33

PHYSICS DIVISION

REPORT FOR MONTH ENDING NOVEMBER 30, 1945

POWER EXTRACTION FROM THERMAL

BREEDERS (Page 14)

Murray and Weinberg

A brief discussion of a proposal to cool a thorium breeding blanket with steam. Steam at about 200°C and 500 p.s.i. produced by the reactor is passed through tubes in the thorium blanket where the power output is about 15% of pile power. This ratio of super heat to pile heat is within the range of standard practice.

MonP-46

REPORT FOR MONTH ENDING DECEMBER 31, 1945

L. W. Nordheim

A summary table appears, giving the critical mass of metal in core in metric tons for composite spherical piles of enriched U-H₂O lattices surrounded by a finite lattice of ordinary U-H₂O lattice, the whole being encased in an infinite graphite reflector.

CRITICAL AMOUNTS OF ENRICHED METAL

Metal in Core →	0.5	1.0	1.5	2.0	3.6
Enrichment of Core	1.54%	1.14	1.04	0.98	0.90

No further details are given.

[REDACTED]

MonP-47

THE MULTIPLICATION FACTOR FOR PRODUCT DRUMS
CONTAINING URANIUM HEXAFLUORIDE

November 30, 1945

Multiplication in drums containing 300 lbs. of UF_6 was determined in a series of experiments by use of a fission source at the center. The drum was 12" I.D. x 20" long and had convex ends. The walls were 1/4" thick monel. The UF_6 had isotopic concentrations of 25 of 1.1% and 0.53%. The effect of hydrogenous reflectors was studied by immersion in temperature controlled water bath. "An extrapolation of the results indicates that a drum would become critical if it contained hex with about 10% isotopic core of 25, if it were surrounded with H_2O , and had no cadmium cover".

MonP -48

CRITICAL EXPERIMENTS ON FLUORINATED AND HYDROGENATED
MIXTURES CONTAINING ENRICHED URANIUM

A. H. Snell

November 30, 1945

"Experiments are described on the critical sizes of assemblies of fluorinated, hydrogenous mixtures containing 24% enriched uranium. A hydrogenous reflector was used. The critical masses of the uranium as a function of the amount of hydrogen in the mixture under the

[REDACTED]

[REDACTED]

experimental conditions of density and effective molecular weight were as follows:"

H/U	Density of Mixture	Effective Mol. Wt.	Critical Mass of 24% U
30.9	1.67	654	14.9 kg
15.1	1.95	537	25.2 kg
11.0	2.14	506	34.2 kg
30.9 (Cd Covered)	1.67	654	28.7 (Heterogeneous Pile)

The critical assemblies were essentially cubical of the order of 10" x 10" x 10". The experiments are described in detail with diagrams. Some piles were elongated parallelepipeds (rectangular).

MonP-56

REPORT FOR MONTH ENDING JANUARY 31, 1946

L. W. Nordheim

Contains a passing reference to a small pile containing ~600 gm of 25 homogeneously embedded in ~15 liters of a hydrogen containing plastic such as polyethylene. "The total absorption cross section of the pile is ~1000 cm², of which 300 cm² are due to H and 700 cm² to 25. The reactor is surrounded by a graphite reflector..."

No further details are given.

[REDACTED]

MonP-74

REPORT FOR MONTH ENDING FEBRUARY 28, 1948

L. W. Nordheim

The following table compares the laplacians of an enriched pile for pure P-9 and P-9 + 7% moderation with 4 gm of 25/liter P-9 as influenced by various parasitic losses of neutrons (ℓ) over and above a fixed 8.4% loss due to structural Al.

7% H₂O + P-9

100% P-9

ℓ	k	τ	L ²	$-\Delta \times 10^3$	k	τ	L ²	$-\Delta \times 10^3$
-.084	1.72	85 cm ²	72 cm ²	3.66 cm ²	2.09	120 cm ²	122 cm ²	3.33 cm ²
0	1.61	"	67	3.27	1.93	"	112	3.04
0.1	1.49	"	62	2.82	1.76	"	103	2.70
0.2	1.39	"	58	2.38	1.63	"	95	2.38
0.3	1.31	"	55	1.95	1.51	"	88	2.05
0.4	1.23	"	51	1.55	1.41	"	82	1.75

The value $\ell = -.084$ corresponds to the presence of Be instead of Al.

MonP-160

REPORT FOR MONTH ENDING AUGUST 31, 1946

L. W. Nordheim

The results of critical mass calculations by two-group theory are tabulated for cylindrical piles one meter high and no reflector above and below. Core (A) consists of 25 + Al + H₂O, 30.8 gm of 25/liter of core, volume of Al/volume of H₂O = 1.03, $L^2 = 4.69 \text{ cm}^2$, $\tau = 76.7 \text{ cm}^2$, $k = 1.56$ and a finite loaded reflector: 25 + Al + H₂O lattice in P-9, 3.0 gm of 25/liter of reflector, volume of H₂O/volume of D₂O = 0.07, $L^2 = 100 \text{ cm}^2$, $\tau = 85 \text{ cm}^2$, $k = 1.52$. Core (B) same as (A) with infinite reflector of P-9, $L^2 = 10^4 \text{ cm}^2$, $\tau = 120 \text{ cm}^2$. Core (C) same as (A) with finite P-9 reflector, outer radius = 70 cm.

Pile	Core Radius	Mass of 25 kg	Reflector Thickness	$\frac{(nv) \text{ max.}}{(nv)_0}$
A	11.4 cm	1.26 (core) + 1.20 (ref.)	26.1	1.13
B	13.0	1.63	∞	1.76
C	13.3	1.71	56.7	1.67

MonP-178

REPORT FOR MONTH ENDING SEPTEMBER 30, 1946

L. W. Nordheim

Two-group calculations for a cylindrical pile 70 cm high consisting

[REDACTED]

of 25, Al, and H₂O surrounded by a reflector of Be of the same height plus 2% H₂O by volume are tabulated. The critical core radius of such a model is 12.78 cm and contains 35.7 gm of 25/liter with a critical mass of 1.3 kg. The neutron distribution functions are given for the slow and fast flux densities in the core and reflector. Constants used are as follows:

	k	L	τ	λ_{SRS}	$\lambda_{\text{+m}}$
Core	1.606	1.91 cm	64.2 cm ²	0.793	3.73
Reflector		19.9 cm	89 cm ²	1.92	1.80


See MonP-206.

MonP-196

REPORT FOR MONTH ENDING OCTOBER 31, 1946

L. W. Nordheim

"Two additional pile models having lower k values than the one reported in MonP-178 have been computed." In these piles the ratio of volume of Al/volume of H₂O = 0.75 in the core, and contained 35.7 gm of 25/liter. A partial summary of the table is given:



MonP-196 - (Continued)

Pile	Core Radius	Core Height	Reflector Thickness Be + 2% H ₂ O	k	Crit. Mass of 25
I	17.85 cm	52.6 cm	∞	1.432	1.88 kg
II	21.12	52.2	∞	1.373	2.61 kg

Neutron distribution functions are given. No details of the calculations appear.

See MonP-206.

MonN-201

STATUS OF 1000 PROJECT DESIGN

M. C. Leverett

November 15, 1946

This report surveys the proposed hi-flux, water moderated, Be reflected pile, giving detail as to structure, design, power, flux, heat transfer, engineering, etc.

General Description

"The pile....will consist of 25... ordinary H₂O as moderator and coolant, and Be as reflector. The active portion....will occupy a (cylinder) space 40 cm diameter and about 60 cm high.....The 25

[REDACTED]

will be alloyed with Al...containing 20 to 25% of 25 and thin sheets of this alloy will then be clad on both sides with sheets of ordinary Al.... This will yield plates about 6 cm long, 8 cm wide, and about one mm total thickness. The alloy containing the 25 will occupy the center 1/3 mm of this sheet.... Two mm gaps between plates for the moderating and cooling H₂O streams are contemplated.... Accompanying drawings illustrate a possible arrangement of pile and multiplate assembly".

Range of critical mass considered is from 3 to 4.5 kg of 25.
(See also MonP-206, MonP-272).

MonP-206

PHYSICAL DATA ON NEW HIGH FLUX PILE - I

A. M. Weinberg, et al

November 21, 1946

This report summarizes the physical data of the water-moderated, water-cooled, Be reflected, experimental high flux pile proposed at Oak Ridge, whose engineering features were abstracted in MonN-201. (These are also described in an addendum in this report.) Some of the physical characteristics discussed are poisoning, depletion, temperature, reactivity, neutron distribution, control, local heating, pile period, stability (Xe), bubbles, heat transfer, reflector

heating, shielding, 23 production.

(See also MonP-272, MonN-201).

MonP-228

MONTHLY REPORT FOR DECEMBER, 1946

L. W. Nordheim

January 15, 1947

A tabular summary of critical mass calculations is given. The cores consisted of uniformly heterogeneous mixtures of 30% enriched UF_6C and polyethylene $(H_2C)_n$ cubes surrounded by an infinite reflector of $(H_2C)_n$. The volume of each cube of UF_6C was 1 cu. in. and contained 15.48 gm of ^{235}U . The volume of each polyethylene cube was 1 cu. in. and had a density of 0.90 gm/cm³. It is stated that the integral diffusion method (LA-399) as modified in MonP-48 supplement was employed in the theory for equivalent homogeneous and heterogeneous spherical piles. Some of the critical mass values are given from the appropriate critical experiments:

Homogeneous				Heterogeneous			
$\frac{vol. H_2C}{vol. UF_6C}$	H/25	Res. Escape Prob. P	Crit. Mass 25	Thermal Disadvantage	Res. Escape Prob. P	Crit. Mass 25 Theory	Crit. Mass 25 Exp.
1/2	15.25	0.891	21 kg	-	-	-	17.5 kg
1/1	30.5	0.921	7.9 kg	2.21	0.927	8.6 kg	7.66 kg
2/1	61.0	0.944	3.44 kg	2.68	0.962	4.3 kg	4.58 kg
4/1	122	0.960	1.80 kg	3.29	0.980	3.6 kg	3.97 kg
7/1	213.5	0.970	1.22 kg	3.86	0.987	5.8 kg	6.15 kg

[REDACTED]

MonP-269

REPORT FOR MONTH ENDING FEBRUARY 28, 1947

L. W. Nordheim

March 17, 1947

A brief general description of the initial critical experiment is presented. The work is described in detail in MonP-357 along with succeeding experiments.

MonP-272

PHYSICS OF THE HIGH FLUX PILE-II

E. Greuling, H. Soodak,
A. M. Weinberg

March 27, 1947

This is a continuation of MonP-206 and presents in quantitative form the results of theoretical analysis of the properties of the proposed high flux pile whose structure and engineering features were summarized in MonN-201.

Much of the data is presented in graphical form - neutron fluxes, spatial and energy distributions, reactivity loss, reflector savings, radial weighting factors, heat flux. Calculations were made by the two-group model. The effects of control rods and holes and poisons are also considered. Critical data are presented in a series of tables, some of which were given in MonP-178 and MonP-196.

MonP-314

QUARTERLY REPORT FOR MARCH, APRIL, MAY, 1947

L. W. Nordheim

Full details of the critical experiments reported here to give physical data useful for the design of the experimental high flux pile (MonN-201, MonP-206, MonP-272) will be found in MonP-357.

MonP-357

CRITICAL EXPERIMENTS ON A SMALL REACTOR OF ENRICHED URANIUM WITH Al + H₂O MODERATOR, AND D₂O, Be AND H₂O REFLECTORS

M. M. Mann, et al

August 18, 1947

Details of 5 critical experiments are given in this report, including graphs of neutron distributions for thermal and epithermal neutrons, drawings of experimental facilities, and a photograph of one critical arrangement. Except for the case of the Be reflector, the piles are essentially cylindrical and bare on top and bottom in all cases. Fuel is introduced as UO₂F₂ in H₂O in Al tubes 1"x1"x35" - each fuel tube \cong 20.3 gm of 25 when the solution has a depth of 70 cm. The ratio of Al/H₂O by volume can be varied by introduction of Al spacers. In the P-9 and H₂O reflected experiments a small intermediate region between core and reflector existed, consisting of Al + P-9 or

[REDACTED]

Al + H₂O only to fill in space between core and tank wall when necessary.

CRITICAL MASS TABLE

Reflector	Vol. Ratio Al/H ₂ O	Core Radius	Core & Refl. Height	Observed		Calculated	
				Crit. Mass gross	Crit. Mass Corrected	Two Region	Three Region
D ₂ O (50cm)	0.88	18.3 cm	70 cm	2.48	2.40	2.10	2.64
D ₂ O (50cm)	0.76	18.3 cm	70 cm	2.23	2.15		2.43
Be (25cm)	0.76	12.8x12.8 (square)	70 cm	1.54	1.42	1.54*	
H ₂ O (30cm)	0.76	18.3 cm	70 cm	3.29	3.22		3.34
H ₂ O (30cm)	0.66	18.3 cm	70 cm	2.82	2.72		3.04

*critical k = 0.988 x k of pile, no poison.

MonP-368

QUARTERLY REPORT - JUNE, JULY, AUGUST, 1947

A. M. Weinberg

September 22, 1947

This report contains a summary of the results presented in MonP-357 with additional details on the two-group calculations (theoretical) of the critical masses and flux distributions for the five critical experiments reported in MonP-357.

MonP-402

CRITICAL MASS AND NEUTRON DISTRIBUTION
CALCULATIONS FOR THE H₂O +Al MODERATED
REACTOR WITH D₂O, H₂O, AND Be REFLECTORS

E. Greuling, B. Spinrad,
A. V. Masket

October 29, 1947

"The purpose of this paper is to describe the basis on which theoretical calculations of the critical masses of five experimental piles were made (MonP-357) and attempt to determine to what extent and in which respects the group neutron diffusion theory of small enriched reflected piles may be trusted.

It appears that, with sufficient knowledge of the experimental conditions, two-group theory gives reliable results for the critical masses of enriched water moderated piles.....".

MonP-427

STABILIZATION OF A FLUID PILE AGAINST EXPANSION

G. Young

November 5, 1947

"It is indicated that a tank shape can be chosen so that the reactivity of a fluid pile of fixed mass is not affected by a small uniform density change in the fluid".

[REDACTED]

MonP-437

PHYSICS QUARTERLY REPORT - SEPTEMBER, OCTOBER,
NOVEMBER, 1947

A. M. Weinberg

December 11, 1947

An attempt was made to estimate the critical mass of a bare assembly having a height of 66 cm, Al/H₂O volume ratio of 0.65 as in the critical experiments of MonP-357. Extrapolating from a mass of 5050 gm with a multiplication of 11.6, it is estimated a square assembly would become critical at 5500 gm with 5 holes for control rods and 5300 gm without holes (35.6 gm of 25/liter). The final dimensions achieved were 48 x 43 x 66 cm.

MonP-457

CRITICAL MASS NEEDED TO OVERRIDE Xe

G. Young

January 12, 1947

"Critical mass needs are considered when it is required that the pile be able to override Xe at any time after shutdown. A simplified treatment of the Navy high-pressure water machine is given as an illustration. As total power output increases, the optimum pile size and the amount of fissionable material become larger".

The total amount of fissionable material required is plotted

[REDACTED]

in terms of cross section as a function of the multiplication factor k of the pile with the fission rate (\sim power) as a parameter.

M-4211

HIGH PRESSURE, WATER COOLED PILE

S. Untermeyer

October 8, 1947

A very brief summary of some earlier considerations of a water cooled reactor plus a discussion of some of the engineering problems involved in such a plant. Several possible designs are compared with the Clinton High Flux Pile.

Pile		Spec. Power (kw/kg)	R_c (cm ²)	M_c (kg)
I	Clinton High Flux	10,000	32	5
II	Thick Al Plates	2,000	42	33
III	10 <u>mil.</u> Steel Cans	2,000	42	33
IV	10 <u>mil.</u> Cb Cans	2,000	40	20
V	10 <u>mil.</u> Cb Cans with Al	4,000	32	15

ORNL-51

QUARTERLY REPORT OF THE PHYSICS DIVISION FOR MARCH,

APRIL AND MAY, 1948

The results of seven additional critical experiments are summarized

[REDACTED]

[REDACTED]

in tabular form. These experiments deal with critical masses of 1.21 kg to 3.95 kg in a 25-Al-H₂O reactor. For prior results see MonP-357 and CNL-35.

[REDACTED]


H + 49

CRPP-35

PROGRESS REPORT FOR MAY AND JUNE, 1946

B. W. Sargent

The planning for a small 49 reactor is briefly sketched. It is to contain pure fissile material (mass not stated) in acid solution and to be capable of being pulsed to peak power about equal to that of N. R. X. pile, the pulses to be about 1/50 of a second. The solution to circulate in a tank 13" diameter while under 5 atmospheres pressure to reduce dilution by gas evolution.

CP-139

ENRICHED URANIUM AND WATER POWER PLANT

R. F. Christy, A. M. Weinberg (No date)

(See under H + 25).

CRT-305

CRITICAL CONDITIONS FOR BARE SPHERICAL CORES
CONSISTING OF HOMOGENEOUS MIXTURES OF PURE FISSILE
MATERIAL AND A MODERATOR

S. Kushneriuk and G. M. Volkoff

November, 1946

(See under H + 23).

CP-387

MONTHLY REPORT ENDING DECEMBER 15, 1942

Some brief remarks are given with regard to calculations on homogeneous mixtures of fissionable isotopes and a moderator. For example, in water the minimum mass of 49 is about 1 kg (assuming a neutron absorbing container) and the optimal concentration about 0.024 gm 49/cc of H₂O. The minimum concentration is about 0.008 gm 49/cc H₂O. For graphite the minimum mass of 49 is about 3.8 kg and the optimum concentration about 7.5×10^{-4} gm 49/cc graphite.

CP-400

CHAIN REACTION OF PURE FISSIONABLE MATERIALS IN SOLUTION

R. F. Christy and John A. Wheeler

January 1, 1943

Early calculations based on age theory estimating critical masses, sizes, and densities of 49 in water, P-9, and graphite, the results of which are plotted for spheres, cylinders, and slabs. More accurate measurements of the constants subsequently make the results dated except for orders of magnitude. The problem of stability of a chain reaction in solution and questions of protection are discussed.

CP-2185

MONTHLY REPORT FOR PERIOD ENDING OCTOBER 31, 1944

In the tabular summary for enriched 25 piles in water solution,

[REDACTED]

it is stated that "piles driven with 49 will have practically the same properties as the 25 pile, except that the amount in grams has to be reduced approximately by a factor $\frac{\sigma(25)}{\sigma(49)} \cdot \frac{239}{235} = 0.73$. Small differences will be introduced by use of a different salt, since 49 has chemical properties different from 25". For the tabular values of 25, see CP-2182 (H + 25).

CF-2881

MACROSCOPIC THEORY OF BREEDERS AND CONVERTERS

F. L. Friedman and
A. T. Monk

March 26, 1945

This theoretical report based on Fermi age and multigroup theory tabulates numerical results for a single homogeneous region consisting of thoriated water plus 49. The table gives laplacians, ages, diffusion lengths, multiplication factors, and resonance escape factors.

LA-272

CRITICAL MASS OF A WATER-TAMPED 49 SOLUTION

B. T. Feld and L. Slotin

May 14, 1945

A detailed account is given of the experiment described in the abstract as follows:

"485 grams of 49 as $\text{Pu}(\text{NO}_3)_4$ in 1-molar HNO_3 solution were tested

[REDACTED]

for criticality in an H₂O tamper..... An absolute measurement of the multiplication of 348 gms of 49 as tetravalent nitrate in 10 liters of solution gave $k = 0.87 \pm 5$ per cent.

Starting with 348 gms in 10 liters of solution, 137 gms were added in 35 gm steps until a solution of 485 gms in 11.35 liters was obtained. Criticality was not reached..... Corrections for the nitrogen and other perturbations indicate a mass of 518 ± 50 gms for pure 49 in H₂O solution with infinite H₂O tamper.

The 485 gm solution was made critical by addition of a crudely stacked 2" layer of BeO bricks.....".

LA-309

SUMMARY OF KNOWN CRITICAL MASSES OF 25 and 49

B. T. Feld

June 14, 1945

A tabular summary of Los Alamos critical experiments and calculations according to core composition, tamper, and critical mass includes two references to 49, one of which is detailed in LA-272, and the other mentions the attempt to achieve multiplication with 4 pieces of 49 in H₂O. None found with 1.7 kg for a surface area of 170 cm². No reference given for this latter experiment.

N-1729s

NOTES ON MEETING OF MAY 24, 1944

Fermi described a small (60 cm diameter) reactor to produce about 1000 kw of mechanical power and use about 3 gm of 49 per day. On the basis of such a pile it was estimated that 750 gm per day would be required to operate a fleet of 100 submarines.

Wigner described a "pulsating" pile in which the active material (a solution of a 49 salt) is alternately moved from the reacting chamber through a heat exchanger. Critical mass was estimated at 5 kg of 49 for 10,000 kw.


D + 23

CRT-293

EXPLORATORY SURVEY OF QUANTITIES OF 23
REQUIRED FOR SELF-REACTING PILES INCLUDING
THE EFFECT OF REFLECTORS (Extension of FSD - 19)

S. Kushnerick

October 15, 1946

(See under H + 23).

CRT-305

CRITICAL CONDITIONS FOR BARE SPHERICAL
CORES CONSISTING OF HOMOGENEOUS MIXTURES
OF PURE FISSILE MATERIAL AND A MODERATOR

S. Kushnerick and
G. M. Volkoff

November, 1946

(See under H + 23).

CF-2881

MACROSCOPIC THEORY OF BREEDERS AND CONVERTERS

F. L. Friedman and A. T. Monk

March 26, 1945

(See under H + 49).

[REDACTED]

CF-3199

BREEDER PILE DISCUSSION

THE HOMOGENEOUS PILE PROJECT AT CLINTON

L. W. Nordheim

June 19-20, 1945

A 100 Mw unit might consist of $\frac{1}{2}$ ton P-9 and 12 kg of 23 contained in a Be tank (and surrounded by a slurry of thorium in P-9). Such a pile would "burn" 100 gm of 23 per day and produce, net, 13 gm of new 23.

MonP-226

A PILE WITH SPACE UNIFORM ACTIVITY

G. Goertzel

March 25, 1947

"The system is considered to be divided into two regions: (1) a spherical core containing fissionable material, moderator, and breeding material, and (2) a blanket containing moderator and breeding material. The moderating properties are considered independent of position, both in the spherical core and the blanket. The density of the fissionable material in the core is...constant. In addition, it is required that the thermal neutron flux in the core be constant throughout the core".

Three piles have been considered and their characteristics

[REDACTED]

[REDACTED]

summarized in tabular form.

Pile	$\frac{\Sigma_a (P-9)}{\Sigma_{23}}$	Mass of 23 (kg)	Radius of Core (cm)	Radius of Outside Reflector Surface (cm)
A	0.028	3.7	104	
B	0.02	4.4	99	209
C	0.01	7.2	92	135

The ratio of 23 absorption to breeder absorption vs. cube of radial position is plotted.

N-1569 h
(MUC-EPW-134)

PRELIMINARY CALCULATIONS ON A BREEDER
WITH CIRCULATING URANIUM

E. P. Wigner, A. M. Weinberg,
G. Young

December 23, 1944

This report treats on the possibility of a breeder pile using 23 in P-9 circulating from the pile to the outside for cooling, degassing, and stripping of fission products. The reflector considered is a slurry of ThO₂ in P-9 for breeding. Geometry is spherical and contemplates 3 kg of 23 in 400 liters of core. Reflector

[REDACTED]

thickness is given as 50 cm and contains equal weights of Th and O.
The report gives no details of computations but summary tables,
and rough sketches appear.

[REDACTED]

[REDACTED]
D + 25

A-1203

THEORY AND CALCULATIONS OF HOMOGENEOUS P-9 PILES

Irving Kaplan

September 10, 1943

"This report presents a coherent theoretical treatment of a homogeneous P-9 pile together with calculations of optimum U concentration and minimum masses of U and D₂O based on the most recently measured values of the cross sections of the substances involved".

A graph is presented which plots minimum mass of U and D₂O for a slurry pile as function of absorption coefficient of D₂O in a spherical geometry. Tabular values of k , ϵ_{p_1} , p_2 ($= f$) are given as a function of U concentration per cc of slurry and another table gives the migration area, k^{-1} , critical radius, and mass of D₂O.

CNL-36

THEORETICAL CALCULATIONS OF CRITICAL

MASSES FOR CERTAIN P-9 PILES

H. L. Garabedian

March 3, 1948

Calculations were made for three different pile arrangements (Case I, II, and III) as treated experimentally by A. H. Snell. The two-group model and the Gaussian-Yukawa model were used for both the homogeneous and inhomogeneous cases.

[REDACTED]

CNL-36 - (Continued)

	R_c Two-Group cm	R_c G-Y cm	R_c Exp. cm	M_c Two-Group gm	M_c G-Y gm	M_c Exp. gm
Case I (hom)	16.3	18.7	20.8	534	703	869
Case II (hom)	22.5	24.7	30.4	508	612	930
Case I (inhom)	17.1	20.1	20.8	588	812	869
Case II (inhom)	25.0	27.1	30.4	627	737	930
Case III (inhom)	34.0	36.3	40.4	937	1068	1323

CRP-306

EXPONENTIAL EXPERIMENTS ON A LATTICE OF X-METAL
RODS IN POLYMER

Booker, Cavanagh, Hereward,
Niemi, and Sargent

November 15, 1946

Results are given for two exponential experiments on the
following lattice:

[REDACTED]

CRP-306 - (Continued)

X-metal rods	3.264 cm diameter
Thickness of inner Al jackets	1.48 mm
Thickness of outer Al jackets	1.94 mm
Width of annular water gaps	3.01 mm
Mean pitch of hex lattice	13.33 cm
Number of rods	120
Polymer available	7600 lb.

Laplacians for this lattice:

(a) empty jackets	$-(650 \pm 15) \times 10^{-6} \text{ cm}^{-2}$
(b) water filled jackets	$-(605 \pm 15) \times 10^{-6} \text{ cm}^{-2}$

CRP-314

MEASUREMENT OF THE LAPLACIAN IN ZEEP

F. W. Fenning

January 25, 1947

ZEEP (Zero power experimental pile) consists of metal rods inserted into P-9 in an aluminum tank.

The density distribution of thermal neutrons in ZEEP was explored with small manganese detectors. From an analysis of these measurements the laplacian of the lattice is -7.71 metre^{-2} ($-771 \times 10^{-6} \text{ cm}^{-2}$) with a probable error of about one percent.

CS-347

REPORT FOR MONTH ENDING NOVEMBER 15, 1942

This early report gives the results of some initial calculations by E. P. Wigner and A. M. Weinberg on the possibility of a P-9 or

[REDACTED]

[REDACTED]

CD₂ + U₃O₈ lattice pile. The calculations were made based on the theory given in CP-1. Later reports are based on better information of cross sections and constants.

CRP-355

DISTRIBUTION OF NEUTRON DENSITY AND THE
DERIVED LAPLACIAN IN ZEEP

M. W. Johns and B. W. Sargent

September 24, 1948

ZEEP (Zero power experimental pile) consists of metal rods inserted in P-9 in an aluminum tank.

A determination of laplacian was made by measuring the distribution of neutron density with small manganese and indium detectors.

Laplacian	7.94 ± 0.06 m ⁻² (=794 x 10 ⁻⁶ cm ⁻²)
Effective radius (cyl)	132.1 ± 0.5 cm
Effective height (cyl)	146.0 ± 0.5 cm
Actual reacting volume	3.75 m ³
Bare reacting volume	6.61 m ³

CRP-356

AN EXPONENTIAL EXPERIMENT ON A LATTICE OF STAINLESS
STEEL JACKETED RODS OF X-METAL IN POLYMER

Bayly, Bocker, Burrow, Cavanagh,
Hereward, Niemi, Nirenberg and Sargent

October 8, 1947

Results are given for an exponential experiment on the following

[REDACTED]

[REDACTED]

lattice:

X-metal rods	1.285" diameter
S.S. inner jacket (.018" wall)	1.298" I.D.
S.S. outer jacket (.017" wall)	1.544" I.D.
Annular gap	0.105"
Mean pitch of hex array	7.44"
Number of rods	63
Polymer available (99.74% pure)	7600 lb.
Laplacian	$(397 \pm 10) 10^{-6} \text{ cm}^{-2}$
V_c (critical volume)	$18.7 \pm 0.7 \text{ m}^3$
Relaxation length	$47.83 \pm 0.18 \text{ cm.}$

CE-805

GENERAL ENGINEERING DESIGN FEATURES OF THE PILE FOR
A LIGHT-WATER COOLED P-9 POWER PLANT

L. A. Ohlinger

July 16, 1943

This report outlines the engineering possibilities and design of a P-9 production plant. "...The uranium in the pile would be in the form of rods 2 cm in diameter with an Al sheath contained within and flowing through a ribbed Al tube not over 3 mm in thickness.... About 6 tons of these rods would be required in the form of 460 individual rods, each about 7 ft. long arranged in a square geometry at about 4" centers both ways. About 10 tons of the P-9 moderator would be required and would be contained within an Al tank about 8' in diameter by about 9' long.... Immediately surrounding

[REDACTED]

the moderator tank on all sides, but not the ends, would be a dry reflector made of graphite....about 18" thick and extending the full height of the moderator tank".

Structural details and accessory works are described and depicted in drawings.

CS-853 (Revised)

MEMORANDUM FROM P-9 COMMITTEE

(Revised November 3, 1943)

H. D. Smyth, E. P. Wigner, August 10, 1943
and H. C. Vernon

This report reviews the study of eight P-9 moderated piles:

(1) light H₂O cooling, (2) heavy water-cooling, (3) He cooling, (4) homogeneous pile, (5) heterogeneous slurry, (6) circulated hex, (7) bismuth cooling, and (8) deuterocarbon pile and concludes that on the basis of speed of construction, reliability as a prototype production unit, and usefulness as a research tool, that only three of the eight (1, 2, and 4) justify serious consideration. The critical data, structure, properties, etc., of all eight are concisely summarized in an Appendix which is in addition to the extended reviews in the main body of the report.

[REDACTED]

CP-923

VALUES OF THERMAL UTILIZATION, RESONANCE ABSORPTION,
AND CRITICAL SIZES IN METAL P-9 SYSTEMS

H. Castle, et al

August 23, 1943

In this report, "accompanying figures give, for various P-9 and metal lattices, the values of p_2 , the thermal utilization; p_1 , the fraction of neutrons escaping capture; $\eta' = \frac{1}{p_1} \times \frac{1}{p_2}$; $\eta'/\epsilon (= \eta/k)$ where ϵ is the fast multiplication factor; and the amount of P-9 required to reach the critical condition. The following lattice geometries were considered: solid rods of density 4.9, and 18.9.... being contained in cylindrical cells, and density 18.9 plates of half-thickness r_0 in cells of half thickness r_1 .

The methods of calculation are the same as described by Plass and Wigner in CP-372".

CP-964

REPORT FOR MONTH ENDING SEPTEMBER 25, 1943

Critical Sizes of P-9 Piles (Homogeneous).

The following table appears for P-9 slurry piles summarizing some calculations (details not given):

[REDACTED]

CP-964 - (Continued)

σ_a (P-9)	Optimum Concentration gm of U/cc	k	$-\Delta \times 10^6$	Metric Tons of P-9 (spherical pile)
0	0.184	1.140	402	17
0.003×10^{-24}	0.21	1.095	294	28
0.004×10^{-24}	0.21	1.084	261	34

These data refer to ordinary temperatures.

Hex P-9 Pile.

Some quantitative results are discussed which explore the possibility of a lattice pile containing cylinders of hex in P-9. Cylinder radii considered are 3, 4, 5 and 6 cm (for hex density of 3.67) and lattice radii to cylinder radii from 2.9 to 2.6, respectively. About nine tons of hex is estimated in a cylindrical pile of 20 m^3 , with a laplacian of $378 \times 10^{-6} \text{ cm}^{-2}$.

CE-1034

SEMI-WORKS P-9 PLANT WITH WATER COOLING

A. M. Weinberg and G. Young

May 19, 1943

A preliminary description of a proposed P-9 plant capable of pro-

[REDACTED]



ducing sufficient power to answer the many questions concerning erosion, graphite changes, etc., which will be encountered in production plants. The pile will consist of vertical metal (U) rods moderated by P-9 and cooled by H₂O. The reflector is graphite.

Power	. . . . .	50000 kw
D ₂ O	. . . . .	10 tons
C	. . . . .	80 tons
H ₂ O	. . . . .	0.8 tons/sec.
U	. . . . .	6 tons
Al	. . . . .	0.54 tons

(Above figures are approximate)

CE-1132
(A-1620)

TERMINAL REPORT ON DESIGN OF SEMI-WORKS,
LIGHT WATER-COOLED HETEROGENEOUS P-9 PILE

J. T. Weills, J. R. Huffman,
and H. C. Vernon

December 14, 1943

This report summarizes the structure, content, and engineering features of a high-power (~ 50,000 kw) P-9 moderated, cylindrical lattice pile which was proposed in CE-1034. An abridgment of the tabulated data is as follows:



[REDACTED]

CE-1132 - (Continued)
(A-1620)

Height of pile proper = 2.17 m, radius = 1.18 m
Volume of pile proper = 9.4 m³
Average thickness of reflector = 50 cm
Quantity of reflector = 82 tons (C)
Spacing of rods (square lattice) = 9.7 cm, number of rods = 456
Rod dimensions: length = 217 cm, radius = 1 cm
Quantity of metal = 5.9 tons

CP-1361

RECALCULATION OF THE CRITICAL SIZE AND MULTIPLICATION

CONSTANT OF A HOMOGENEOUS UO₂-D₂O MIXTURE

E. P. Wigner, A. M. Weinberg,
and J. Stephenson

February 11, 1944

Details of the calculations are not given here but are identical to those in CP-668. "The following table (abridged) gives.... Δ , and volume of critical sphere as function of the number N of D₂O molecules per U molecule and weight of U in gm/cm³.

W(gm/cm ³)	N	k	$-\Delta \times 10^6$ (cm ⁻²)	V(m ³)
0.22	60	1.0467	164	62
0.165	80	1.0662	196	47.5
0.132	100	1.0759	194	48.2
0.110	120	1.0795	181	53.3
0.095	140	1.0815	167	60.3
0.082	160	1.0794	148	72.2
0.073	180	1.0777	133	84.6
0.066	200	1.0739	117	102

[REDACTED]

A plot of critical size and k appears as a function of W in addition to the above table.

CC-1383

THE HEAVY-WATER HOMOGENEOUS PILE:

A REVIEW OF CHEMICAL RESEARCHES AND PROBLEMS

C. F. Hiskey and M. L. Eidenoff

February 28, 1944

This survey of the chemical problems associated with a P-9 homogeneous pile contains a graph of critical mass of metal and P-9 as a function of D_2O cross section for absorption based on data taken from A-1203.

CP-1531

NUCLEAR PHYSICS RESEARCH

REPORT FOR MONTH ENDING MARCH 25, 1944

W. H. Zinn

First experiments with a considerable (about one ton) quantity of P-9 gave the following results:

Laplacian for a lattice of 1.395 cm radius rods on a 13.65 cm square was $880 \times 10^{-6} \text{ cm}^{-2}$.

The "age" to indium resonance was 96.0 cm^2 .

CP-1834

MULTIPLICATION FACTOR AND LAPLACIANS IN MIXED

H₂O - P-9 SYSTEMS

A. M. Weinberg and M. Ginsburg

July 3, 1944

(See under H + 25).

CP-2185

MONTHLY REPORT FOR THE

PERIOD ENDING OCTOBER 31, 1944

Forman, Nordheim

Theory of Enriched Piles.

"Calculations have...been made for heavy water as moderator and reflector. The results are summarized....":

CRITICAL RADII (R), VOLUMINA (V), AND AMOUNTS OF ²⁵ REQUIRED AS A FUNCTION OF RATIO Z OF ²⁵ ATOMS TO D₂O MOLECULES FOR AN INFINITE D₂O REFLECTOR. (a) FOR PURE ²⁵ and (b) FOR A MIXTURE CONTAINING 12.5% ²⁵

Z	R (cm)		V (liters)		M ₂₅ (gm)	
	(a)	(b)	(a)	(b)	(a)	(b)
0.1 x 10 ⁻³	40.4	42.2	277	315	362	411
0.1 x 10 ⁻³	29.9	31.5	112	131	292	342
0.25 x 10 ⁻³	27.5	28.9	87	101	284	329
0.3 x 10 ⁻³	25.5	27.2	70	84	273	330
0.5 x 10 ⁻³	20.7	23.4	37	54	242	350
1.0 x 10 ⁻³	17.4	19.3	22	30	288	393
2.0 x 10 ⁻³	14.6	16.9	13	20	340	527

[REDACTED]

CP-2185 - (Continued)

To compare these with H₂O moderated piles, see this same report under H + 25.

CP-2222

MONTHLY REPORT FOR THE PERIOD ENDING DECEMBER 31 1944

Enriched Piles.

The following table gives the critical radii without reflectors for various concentrations Z in P-9 and for various ratios d of (28 atoms)/(25 atoms), ($d = 0$, pure 25; $d = 7$, 25 in 12.5% concentration; $d = 14$, 25 in 6.7% concentration).

$Z \backslash d$	0	7	14
0.15		65	
0.20	56.7	59.7	62.6
0.23	54.4	57.8	60.5
0.25	53.1	56.2	59.3
0.27	51.8	55.3	58.3
0.30	50.3	54.0	57.1

CP-2813 X

MONTHLY REPORT FOR PERIOD ENDING APRIL 30, 1945

On the basis of two-group theory the following table, (a revision

[REDACTED]

[REDACTED]

of one appearing in CP-2589X) summarizes the calculation of laplacians ($-\Delta$), resonance absorption (R), reciprocal age (K_f^2), thermal diffusion length (K_t^2), as a function of concentration of 25 in D_2O , (z), multiplication k.

z	K_t^2 (cm ⁻²)	K_f^2 (cm ⁻²)	R	k	$-\Delta = \mu_1^2$	μ_2^2
0.08×10^{-3}	2.437×10^{-3}	0.793×10^{-2}	0.0157	1.873	1.43×10^{-3}	1.18×10^{-2}
0.09	2.704	0.7871	0.0175	1.903	1.58	1.216
0.10	2.973	0.7786	0.0195	1.928	1.72	1.248
0.125	3.642	0.7569	0.0243	1.977	2.03	1.324
0.150	4.312	0.7406	0.0291	2.016	2.31	1.403
0.175	4.983	0.7442	0.0339	2.046	2.55	1.478
0.20	5.653	0.7088	0.0386	2.073	2.77	1.551
0.23	6.457	0.6927	0.0443	2.103	3.01	1.639
0.25	6.992	0.6822	0.0480	2.120	3.15	1.696

CRITICAL DATA OF SOLUTIONS OF 25 IN P-9 FOR VARIOUS
GRAPHITE REFLECTORS OF THICKNESS t FOR TWC CONCENTRATIONS

t (cm)	Radius (core)		Volume		Mass of 25	
	$z=0.15 \times 10^{-3}$	$z=0.25 \times 10^{-3}$	$z=0.15 \times 10^{-3}$	$z=0.25 \times 10^{-3}$	$z=0.15 \times 10^{-3}$	$z=0.25 \times 10^{-3}$
∞	40.4 cm	32.8 cm	276 liters	147 liters	540 gm	479 gm
50	42.9	34.8	331	176	647	574
30	46.7	37.9	426	228	833	743
20	50.4	41.2	536	294	1048	958
0	65.3	56.0	1167	736	2283	2398

CP-3199

BREEDER PILE DISCUSSION

THE HOMOGENEOUS PILE PROJECT AT CLINTON

L. W. Nordheim

June 19-20, 1945

A "pilot" breeder pile is proposed for Clinton. A tank of 12-15,000 liter capacity will be used containing D₂O and about 1.5 kg of ²⁵. Neutron flux will be about 10¹⁴ at a power of 10⁴ kw. 13 gm ²⁵ will be used and 5-6 gm ²³ produced per day.

CP-3364

EXPONENTIAL EXPERIMENTS WITH D₂O AND SOLUTIONS

OF UO₂F₂

A. Wattenberg

November 1, 1945

A series of seven homogeneous exponential piles were constructed. Uranium concentration varied from 0.015 to 0.27 gm/cm³ of D₂O originally 99.84% pure.

TABLE 7

Concentration Gm UO ₂ F ₂ /cm ³	R _e cm	D ₂ O Liters	Uranium kg.
0.0238	452	358,000	6,602
0.7034	247	62,700	3,583
0.1484	208	37,300	4,348
0.2004	205	35,400	5,598
0.2493	209	37,100	7,343
0.2986	223	47,900	11,438
0.3476	244	52,200	14,586

[REDACTED]

CP-3364 - (Continued)

Figure 5 shows the variation of laplacian with concentration of UO_2F_2 .

CP-3406

EXPONENTIAL LATTICE EXPERIMENT IN D_2O

G. Plass and A. Wattenberg

January 18, 1946

In two exponential experiments using the Argonne CP-3 lattice in D_2O the laplacian was found to be -922×10^{-6} and $-924 \times 10^{-6} \text{ cm}^{-2}$, the relaxation length in D_2O alone was 24.05 and 23.6 cm. The age of fission neutrons to indium resonance in D_2O was found to be 104 cm^2 .

MonP-17

REPORT FOR MONTH ENDING SEPTEMBER 31, 1945

L. W. Nordheim

Spherical Pile with Cylindrical Reflector.

By first order, one-group, perturbation theory, the critical size of a spherical enriched P-9 pile in a cylindrical P-9 reflector has been calculated. A 65 cm radius sphere is critical if surrounded by a cylinder with 85 cm radius and 170 cm height. This corresponds to a uniform reflector saving of 19.4 cm all around the sphere.

MonP-33

REPORT FOR MONTH ENDING NOVEMBER 30, 1945

L. W. Nordheim

Truncated Cone Reservoir Tank.

".....a variational calculation was carried out to find its critical laplacian for 2000 gm of 25 present in various volumes of P-9 in the tank. The laplacian is given by

$$\mu^2 = \frac{\int |\nabla \varphi|^2 d\tau}{\int \varphi^2 d\tau}, \quad (\varphi = \text{flux})$$

where φ was selected so as to vanish on the boundary of the tank:

$$\varphi = J_0 \left(\frac{2.4048 r}{r_1 + z \tan \alpha} \right) \sin \frac{\pi z}{h},$$

where z is measured from the tank base, h is the height of the tank, r the radial distance from the central axis, r_1 the radius of the tank base, and α the half-angle of the vertex of the cone....". With 2000 gm the following results were obtained:

h (ft.)	V (liters)	Cone gm/liter	Laplacian at this cone	Laplacian required for criticality
1	108	18.5	$< 62 \times 10^{-4}$	162×10^{-4}
3	597	3.35	$\sim 35 \times 10^{-4}$	43×10^{-4}
5	1610	1.25	$\sim 18 \times 10^{-4}$	25×10^{-4}
6	2370	0.845	$\sim 12 \times 10^{-4}$	19×10^{-4}

[REDACTED]

MonP-74

REPORT FOR MONTH ENDING FEBRUARY 28, 1946

L. W. Nordheim

February, 1948

(See under H + 25).

MonP-104

REPORT FOR MONTH ENDING APRIL 30, 1946

L. W. Nordheim

A critical mass of 869 gm of 25 is reported for a reactor consisting of tubes of 25 in P-9 lowered into a tank of P-9, giving an effective concentration of 10 gm/liter in the core. For complete experimental details, see Progress Report of May 24, 1946, Goodman and Slawson.

MonP-130

PHYSICS DIVISION

REPORT FOR MONTH ENDING JUNE 30, 1946

A brief description is given of critical experiments on heterogeneous 25-D₂O systems. A comparison is made of experimental and theoretical results.

[REDACTED]

[REDACTED]

MonP-130 - (Continued)

Concentration Gm/Liter	M_c (Exp.) gm	M_c (Theor.) gm
2.6	1320	1140
5.2	930	850
10.4	869	830

MP-246

THE MEASUREMENT OF THE LAPLACIAN IN A LATTICE
OF AIR-COOLED X-METAL RODS AND POLYMER

Booker, Cavanagh, Fenning,
Hereward, Niemi, and Sargent

April 3, 1946

A detailed report of an exponential experiment on the following lattice:

X-metal rods 3.264 cm diameter
Inner Al jackets 1.99 mm thick
Outer Al jackets 3.20 mm thick
Annular gaps 2.54 mm
Mean hexagonal pitch 17.08 cm
Number of rods in tank 69

For this lattice:

Relaxation length 73.0 ± 0.5 cm
Laplacian $(-640 \pm 15) \times 10^{-6}$ cm⁻²



MonP-314

QUARTERLY REPORT, MARCH-MAY, 1947

L. W. Nordheim

Calculations were carried out to determine critical masses by an exact two-group method for comparison with some of the experimental results reported in MonP-454.

Concentration of 25 in gm/liter	Height cm	Reflector Thickness		Crit. Mass of 25 in gm	
		Top and Bottom	-Lateral	Exp.	Theory
10.35	61.8	82 cm	50.2 cm	869	734
5.17	61.8	82	40.6	930	758
2.58	100	44	30.6	1323	958

MonC-374

THE HOMOGENEOUS NATURAL URANIUM-D₂O PILE

AS A SOURCE OF POWER

H. C. Ott

January 14, 1948

".....calculations were made for a circulating homogeneous pile with a slurry of UO₂ in D₂O and a study made of the effect of heavy isotope production during operation on the reactivity and breeding



[REDACTED]

possibilities.

The volume of the critical sphere with various ratios of moderator to uranium were recalculated, using the most recent values of the constants involved. This showed a minimum volume of 19 m³ reactor volume for a ratio of ~80 mols D₂O per atom of 28 (in natural U). This would require ~21 tons of D₂O and 3.12 metric tons of uranium at a concentration of 0.164 gm/cm³ (0.186 gm/cm³ of UO₂)".

The report gives in some detail the derivation of important formulae, graph of critical volume vs. diffusion area (L²) for various multiplication constants (k), discusses effect of heavy isotope build-up, and considers critical mass and size reduction by initial presence of 49.

MonP-454

CRITICALITY STUDIES ON ENRICHED

URANIUM-HEAVY WATER SYSTEMS

A. H. Snell

December 15, 1947

"The critical mass for systems (lattices, cylindrical) consisting of 25 dissolved in D₂O have been studied for mean concentrations of 2.58, 5.17, and 10.35 gm of 25/liter. The values obtained were

[REDACTED]

respectively 1323, 930, and 869 of 25 in roughly cylindrical geometry surrounded with D₂O reflector on all sides".

The report details the experimental arrangements, effect of holes, control rods, temperature, poison, utilization of neutron leakage for breeding, and neutron distributions.

M-3952

THE CANADIAN PILE

J. R. Haffman

This report (two lectures given during the Pile Technology Lecture Series, Clinton Labs., 1946-47) gives a complete description of the Canadian heavy water lattice pile.

N-1569 b

AN ENRICHED PILE AS A RESEARCH INSTRUMENT

L. Nordheim and H. Soodak

August 28, 1944

This a letter memo discussing the need for a high flux enriched reactor for experimental work in pile physics and technology. Fluxes to be achieved and critical mass requirements are tabulated as a function of 25 concentrations.

N-2232
(MUC-WHZ-337)

THE ARGONNE HEAVY WATER PILE

November 20, 1945

"The 27 figures in this book are the figures which will accompany the description of the heavy water moderated chain reacting pile at Argonne (CP-3). Practically all of the information essential to the construction of the pile is given in the figures...".


D + 49

CRT-305

CRITICAL CONDITIONS FOR BARE SPHERICAL CORES CONSISTING
OF HOMOGENEOUS MIXTURES OF PURE FISSILE
MATERIAL AND A MODERATOR

S. Kushneriuk and G. M. Volkoff November, 1946

(See under H + 23).

CP-400

CHAIN REACTION OF PURE FISSIONABLE MATERIALS IN SOLUTION

R. F. Christy and John A. Wheeler January 1, 1943

(See under H + 49).

CP-2203X

MONTHLY REPORT FOR THE PERIOD ENDING NOVEMBER 30, 1944

Forman, Nordheim, Soodak

Theory of Enriched Piles.

"In continuation of the systematic studies on homogeneous solution type piles with enriched 25 or 49 with light or heavy water as moderator, the following new results have been obtained:

[REDACTED]

CP-2203X - (Continued)

TABLE I
CRITICAL VOLUMES V_c ; AMOUNT OF REACTOR G AS FUNCTION OF
RATIO Z OF 49 ATOMS TO D_2O MOLECULES WITH PURE 49 AS
REACTOR: D_2O MODERATOR AND INFINITE REFLECTOR

$Z (10^{-3})$	0.1	0.2	0.25	0.3	0.5	1.0	2.0
V (Liters)	180	80	62	51	32	18	11
G (gm)	290	210	205	205	210	240	290

It is seen that the minimum amount is slightly over 200 gm of 49 in 50-60 liters of P-9. The amount of 49 required is less than 2/3 of the amount of 25 in a 12.5% concentration".

CP-2589X

MONTHLY REPORT FOR THE PERIOD ENDING FEBRUARY 28, 1945

A recalculation by two-group theory of the laplacian ($-\Delta$), and multiplication (k), is summarized in tabular form for homogeneous type piles with pure 25 or 49 as reactor and P-9 as solvent. The formulae employed were those given in CP-2568, Section II, Part I,

[REDACTED]

██████████

and the variable is $Z = (\text{atoms } 49)/(\text{molecule P-9})$.

TABLE III

(Abridged)

Z	$K_f^2 (\text{cm}^{-2})$	$K_s^2 (\text{cm}^{-2})$	k	$-\Delta$
0.08×10^{-3}	0.7435×10^{-2}	3.831×10^{-3}	1.882	1.91×10^{-3}
0.09	0.7281	4.271	1.910	2.07
0.10	0.7120	4.715	1.936	2.23
0.125	0.6751	5.820	1.992	2.57
0.150	0.6534	6.926	2.042	2.86
0.175	0.6130	8.031	2.088	3.095
0.20	0.5838	9.137	2.133	3.32
0.23	0.5530	10.46	2.191	3.53
0.25	0.5337	11.35	2.226	3.65

CF-2881

MACROSCOPIC THEORY OF BREEDERS AND CONVERTERS

F. L. Friedman and A. T. Monk

March 26, 1945

(See H + 49).

[REDACTED]
Be + 23

CRT-305

CRITICAL CONDITIONS FOR BARE SPHERICAL CORES CONSISTING OF
HOMOGENEOUS MIXTURES OF PURE FISSILE MATERIAL AND A MODERATOR

S. Kushneriuk and G. M. Volkoff

November, 1946

(See under H + 23).

MonP-264

OUTLINE OF A LIQUID METAL PILE

Gale Young

March 6, 1947

(See under 23).

MonP-389

THERMAL GAS-COOLED PILES

H. E. Stevens, Jr. September 25, 1947

Methods and graphs are given for quickly estimating the critical size and mass of cylindrical piles having various fuels and moderators and operating at different average pile temperatures. Some 40 graphs are shown.

MonP-412

INTERIM NOTE ON MIXED PILE STUDIES

J. R. Menke

September 25, 1947

(See under 23).
[REDACTED]


Be +25

A-4206

KNOLLS ATOMIC POWER LABORATORY

PROGRESS REPORT NO. 8

May 21, 1947

Multigroup calculations for a 25 cm radius core of 25% Na by volume with 50 Be and 5 Fe atoms per 25 atoms, were made to determine the ν necessary for criticality.

5 group ... $\nu = 2.25$

4 group ... $\nu = 2.33$

3 group ... $\nu = 2.83$

A-4207

FEASIBILITY REPORT FOR THE ZERO POWER PILE AT THE

SACANDAGA LABORATORY

May 16, 1947

A description of methods, equipment, and procedures to be used in a zero power pile. Subjects considered are (1) Controls, (2) Instrumentation, (3) Handling of Active Material, (4) Radiation Protection, (5) Security, (6) Materials Required from A.E.C. The pile considered is in the form of a horizontal hexagon split vertically--

[REDACTED]

one half is movable. The pile is Na cooled with a Be moderator and reflector. The structural material is steel. The fissionable material is 90% enriched uranium. A blanket of 28 is to be provided to take advantage of the breeding characteristics since the pile will operate at intermediate neutron energies (10-10,000 ev). 25 required will be 50-70 kg.

A-4208

SURVEY OF ATOMIC POWER PLANTS FOR NAVAL SHIP PROPULSION

June 16, 1947

A detailed investigation of the present feasibility of applying thermal, intermediate, or fast reactors to a small naval vessel (D.E.).
Briefly:

I. Thermal

- (a) Fuel will consist of plates of Be-25 alloy of atomic ratio greater than 600
- (b) Moderator is Be blocks
- (c) Coolant is liquid Na - 8 tons
- (d) Estimated total critical mass is 15 kg of 25
- (e) Weight (including heat exchangers) estimated at 500 tons
- (f) Conversion ratio is about 0.4 to 0.6.



II. Intermediate

- (a) Fuel will consist of rods of Be-25 alloy of atomic ratio of about 150
- (b) Moderator consists of Be in the structure
- (c) Coolant is liquid Na
- (d) Estimated total critical mass is 30 kg of 25
- (e) Weight same as in I.
- (f) Conversion ratio is about 0.8 to 1.0.

III. Fast

- (a) Estimated total critical mass is about 200 kg of 25
- (b) Conversion ratio is about 1.2.

Several curves are shown which give the critical mass and size and the atomic ratio for the different reactors.

A-4294

G. E. NUCLEONICS PROJECT

KNOLLS ATOMIC POWER LABORATORY

PROGRESS REPORT NO. 6

January 1-31, 1947

Criticality of Be-25 mixtures were calculated assuming a fission





spectrum source.

<u>Atoms Be/Atoms 25</u>	<u>τ</u>	<u>V_c (Liters)</u>	<u>M_c (kg)</u>
19.3	39.2	21.1	46.0
28.9	41.4	24.3	36.9
48.3	47.4	77.7	26.1
89.5	54.1	33.3	17.3
151.0	58.2	39.0	12.1

Calculations indicate that for effective control of piles in the intermediate range both fissionable material and moderator must be removed.

Following are the general specifications of the proposed Schenectady pile as presented to A.E.C. on January 16, 1947:

1. 10,000 kw heat output.
2. Neutrons of high intermediate energy (1/2 fissions produced by neutrons above 10,000 ev.).
3. Na coolant - exit temperature 450°C.
4. Be moderator and reflector.
5. Active material - 90% enriched uranium in Fe can. About 40 kg required.
6. Natural uranium blanket with layers of Be in Fe.

CP-1016

NUCLEAR PHYSICS RESEARCH

MONTH ENDING OCTOBER 23, 1943

Williamson

October 23, 1943

A cubic lattice with 3.5 radius U spheres and a Be-U ratio of



[REDACTED]

17 will have a k of 1.086 and a laplacian of $- 267 \times 10^{-6} \text{ cm}^{-2}$ and will required 56 metric tons of Be to react.

For BeO of density 2 the maximum laplacian is $- 100 \times 10^{-6} \text{ cm}^{-2}$, $k = 1.066$ for spheres of radius 3 (volume ratio 33), and would require 260 metric tons of BeO (93 tons Be).

CP-1231

VALUES OF THE THERMAL UTILIZATION, RESONANCE ABSORPTION
AND CRITICAL QUANTITIES IN METAL-Be, BeO SYSTEMS

R. R. Williamson
A. M. Weinberg

December 27, 1943

The use of Be and BeO (of densities 2 and 3) as moderators for a natural uranium pile is investigated. Various results are tabulated for different geometries. Briefly:

<u>Geometry</u>	<u>Sphere</u>	<u>Cyl.</u>	<u>Slab</u>	<u>Sphere</u>	<u>Sphere</u>	<u>Cyl.</u>
Moderator	Be	Be	Be	BeO (P=2)	BeO (P=3)	BeO
Vol. -(m ³)	27.4	26.3	34.6	120	42.5	46
Mod. Wt. (tons)	52	49	64	237	134	146
U Wt. (tons)	44	47	69	71	40	36

[REDACTED]

CF-3070

PHYSICS DIVISION

REPORT FOR MONTH OF JUNE, 1945

Class

June, 1945

Some calculated results are given for a high temperature (1500°C) BeO moderated pile burning ^{235}U (density of BeO is 3).

UO ₂ -% By Wt.	Neutron Loss to BeO	k	Δ	R _c	Wt. of UO ₂	Wt. of UO ₂ with 30% voids
2	1.6%	2.09	3×10^{-3}	57.5 cm	36 kg	72 kg
1	3.2%	2.03	2.6×10^{-3}	61.2	22	44
0.5	6.2%	1.97	2.2×10^{-3}	67.3	14.5	29
0.25	11.7%	1.86	1.6×10^{-3}	77.8	11	22

NOTE: τ used in these calculations is obsolete. (See CF-3403).

CF-3290

SKETCH OF A GAS TURBINE POWER PLANT

Gale Young

August 10, 1945

Some calculations are made for a Be metal pile cooled by helium operating in a gas turbine cycle to give mechanical power output.

[REDACTED]



An efficiency of about 20% is indicated.

File calculations were based on a bare Be-25 alloy in the shape of an optimum circular cylinder. Certain values were based on Goldberger's work in MUC-WC-MLG-7.

Mean pile temperature - 627°C
 Wt. 25/Wt. Be - - - - - 0.3%
 Wt. 25 - - - - - 17.3 kg
 Wt. Be - - - - - 5.8 tons
 Pile Radius - - - - - 103 cm
 Pile Height - - - - - 190 cm

CF-3403

ARGONNE REPORT FOR SEPTEMBER, OCTOBER,
NOVEMBER, AND DECEMBER, 1945

January 12, 1946

Gale Young presents a summary, with references for a group of pile studies concerning piles which can provide useful power.

M. L. Goldberger has re-examined the values for the Fermi age for Be and BeO. The use of the new values (98 cm² for Be and 110 cm² for BeO) results in laplacians more nearly in line with experimental results.



CP-3407

THE LAPLACIAN FOR A BERYLLIUM METAL LATTICE
OF VOLUME RATIO 17.2

Goldberger, Wattenberg,
and Zinn

January 16, 1946

A portion of the Argonne CP-2 pile was replaced by a Be metal lattice containing 3.3 kg of uranium.

The laplacian from the experimental results was calculated to be $-407 \times 10^{-6} \text{ cm}^{-2}$. The value is experimentally rather uncertain.

For comparison, a theoretical value was calculated to be $-420 \times 10^{-6} \text{ cm}^{-2}$.

CF-3749

DESIGN OF A PILE FOR THE GENERATION OF POWER

W. H. Zinn and H. V. Lichtenberger

January 13, 1947

A table of pile constants is given for two proposed Be moderated, Na-K cooled power piles. Briefly:

Spacing	8"	6"
Reflector (Be) Thickness	6"	6"
Total Diameter	60"	48"
Total U (25 and 28)	330 kg	330 kg
Atomic Ratio - Be/25	4100	2200

[REDACTED]

MUC-JEW-33

SUMMARY OF WORK ON A BeO MODERATED, STEAM
COOLED PILE DESIGNED TO OPERATE AT HIGH
TEMPERATURES FOR USE IN THE PRODUCTION OF
ELECTRICAL ENERGY FROM ATOMIC POWER

John E. Willard

September 14, 1945

A preliminary discussion of the above subject which attempts to establish the extent of the necessary work.

The following critical values were assumed.

1. 45 kg of 25 as 20% enriched U.
2. 15 tons of BeO.
3. 4 tons of ThO₂.

MUC-GY-39

THERMAL PILES FOR POWER

Gale Young

November 9, 1945

A pile consisting of close packed Be rods cooled by liquid Na is considered.

For 1% by weight of fissionable material, the pile would be a cube 0.8 m on a side. Weight of fissionable material about 8 kg. Weight of Be about 0.8 ton (based on temperature rise of Na of 300°)

[REDACTED]

and power of 13,000 kw/kg).

MUC-LAO-41

NOTE ON MEETING OF WEDNESDAY, JULY 26, 1944

HIGH FLUX RADIATION SOURCE

Morrison

July 26, 1944

A brief description and discussion of a high flux reactor for use as a radiation source. Reactivity is maintained by adding pellets of moderator and ^{235}U (in the desired ratio) to a central Be chamber. A Bi-Pb reflector containing thorium is separated from the core by 5 cm of graphite. The reactor features a thermal column and control by a variable water layer between the pile and an absorber.

MonN-188


PRELIMINARY DESIGN PROPOSAL

DANIELS EXPERIMENTAL POWER PILE

C. R. McCullough

November 1, 1946

A complete and comprehensive (145 pages and 45 figures) consideration of the many facets of power pile design. Briefly, the reactor considered consists of 6' diameter x 5.5' high core of



50% enriched UO_2 moderated by BeO and cooled by helium. The reflector is 6" of BeO and 12" of graphite. The operating temperature is $650^{\circ}C$. The 25 required for operation is about 15 kg, of which 6.5 kg is reserved for possible design changes.

MonP-190

SOME NOTES ON POWER PILES

Gale Young

October 30, 1946

This report reviews, summarizes, and tabulates a variety of information from other sources. Power piles are discussed from several viewpoints such as coolants, heat transfer, breeding, moderators, and economics.

Table IV compares some physical properties of Be , BeO , graphite, uranium, concrete. Table V compares some physical and nuclear properties of Be , BeO , and graphite. Table VI compares Be and graphite (on basis of $Be = 1$ for all properties).

MonN-336

POSSIBLE APPLICATIONS OF UF_6 IN PILES

D. E. Hull

July 1, 1947

Various means of using UF_6 as a fuel are considered in detail.

[REDACTED]

A pile containing UF_6 under 10 atmospheres pressure and $800^{\circ}C$ in a porous Be moderator requires 16 kg of ^{235}U and 1100 kg of Be. Temperature of He cooling gas at the outlet would be $1250^{\circ}F$ at a rating of 96,000 kw (heat). Breeding ratio for ^{235}U is 0.99. If ^{239}Pu is used, the breeding ratio will be about 1.18.

MonN-383

SUMMARY REPORT ON DESIGN AND DEVELOPMENT
OF HIGH TEMPERATURE GAS-COOLED POWER PILE

C. R. McCullough

September 15, 1947

A very complete and comprehensive account of the work done and the results obtained by the Power Pile Division to September 15, 1947. The introduction serves as a brief history of the Division. Report consists of 313 pages and 108 illustrations.

Figures 1, 4, 5, 8, 9, 10, 11, and 12 show relationships of critical sizes and masses for different conditions.

MonN-389

THERMAL GAS COOLED PILES

H. E. Stevens, Jr. September 25, 1947

(See under Be † 23).

M-3416

A STUDY OF THE WEIGHT AND SPACE REQUIREMENTS
OF GAS-COOLED THERMAL PILES

H. G. Rickover

January 15, 1947

A rather detailed analysis of the size and weight of nuclear power plants for naval vessels that require 15,000 to 212,000 SHP. The analysis is based on the Daniels pile as a prototype. The weight required for large vessels approximates the weight of present machinery plus fuel.

Pile	Daniels	CVB	CV	DD	SS
Power (kw)	40,000	198,000	140,000	112,000	56,000
Core Dia. (ft)	6	6.85	5.7	5.15	4.15
Weight 25 (kg)	15	33	21.1	19.2	15.5
Weight BeO (tons)	9.6	13	7.5	5.4	2.8
Weight Re-flector (tons)	17.7	25.5	17.1	10.6	5.5



M-3556

THE RESONANCE PILE

H. G. Rickover May 6, 1947

A brief discussion and comparison of fast, resonance, and thermal reactors from several different viewpoints.

A table in the appendix gives a brief tabulated comparison of the three types of reactors. The initial mass of ^{25}Pu required is:

Thermal	3 - 15 kg
Resonance	40 - 100 kg
Fast	40 - 60 kg

M-3975

PILE TECHNOLOGY LECTURES #37 AND #38

C. R. McCullough No date

A rather detailed description of the proposed "Daniels" pile. The permanent structure of the reactor consists of 8272 hollow hexagonal BeO bricks. Core portion of pile will be filled with fuel elements, reflector portion with BeO slugs, and conversion portion with thorium slugs. For a 61 cm radius reactor with a 30 cm



[REDACTED]

reflector and no thorium, the 25 required will be 3.64 kg plus 360 gm for moderator impurities, plus 150 gm for fission product poisons, plus 450 gm for depletion = 4.6 kg. Curves and drawings aid the description.

M-4157

DESIGN STUDY FOR A BERYLLIUM METAL

POWER PILE

February 1, 1947

A detailed consideration of the problems involved in the design and construction of a pile using metallic Be as a moderator. The reactor considered consists of a 4.6' diameter x 4.25' high core built up of a Be-25 alloy. The 25 required for operation is about 17.5 kg, of which 6.5 kg is reserved for possible design changes.

M-4167

GAS-COOLED POWER PILE FOR NAVAL APPLICATION

W. T. Moore

October 23, 1947

Preliminary design estimates are made for a naval power reactor to produce 15,000 shaft hp. and fit in a 15' 10" diameter space.

[REDACTED]

[REDACTED]

Pile is Be moderated and reflected and cooled by He under 60 atmospheres pressure. Core is 3'3" diameter x 3' long. 3.5 kg of 30% enriched 25 is required. This figure based on 20% voids for cooling and overall reflector dimension 1.5 times the core dimensions. Several drawings aid the description.

N-1190

LETTER TO WARREN NYER FROM A. WATTENBERG

June 2, 1944

A laplacian of $450 \times 10^{-6} \text{ cm}^{-2}$ is estimated for a lattice of 36 cells made up of 1" x 2" x 3" and 1" x 3" x 3" Be plates. The volume of Be per cell was 3126 cm^3 and the volume of heavy metal per cell was 182 cm^3 .

N-2059

Be AND BeO PILES

M. L. Goldberger July 21, 1945

Results of calculations on Be and BeO moderated piles are shown in graphical and tabular form. Briefly:

N-2059 - (Continued)

$$T = 900^{\circ}\text{K}$$

$$\tau = 100 \text{ cm}^2$$

Percent by Wt.				
Be	U	R_c (cm)	M_c (kg)	M_c (kg) (30% voids)
98%	2%	40.4	10.2	20.4
99	1	43.3	6.3	12.6
99.5	0.5	48.6	4.4	8.9
99.75	0.25	58.7	3.9	7.9
99.9	0.1	90.2	5.7	10.4 (11.4?)

$$T = 1800^{\circ}\text{K}$$

$$\tau = 222 \text{ cm}^2$$

Percent by Wt.				
BeO	UO ₂	R_c (cm)	M_c (kg)	M_c (kg) (30% voids)
98%	2%	56.2	44.6	89.2
99	1	59.2	26.1	52.2
99.5	0.5	63.0	15.2	30.4
99.75	0.25	70.3	10.9	21.8
99.9	0.1	91.0	9.5	18.9

NOTE: Above values of τ are considered obsolete. (See CF-3403).

N-2100

Be AND BeO PILES USING ENRICHED URANIUM

M. L. Goldberger

September 4, 1945

Results of a preliminary investigation of critical size and mass of the Daniels type reactor are given. Four tables and two graphs are shown. L^2 , k , $\bar{\kappa}^2$, R_c , V_c , Wt. U, and total weight are given for different percentages of 10% and 20% enriched U and UO_2 . (Moderator is Be and BeO).

Typical: For 2% of pile of 10% U^{25} , $L^2 = 136$, $k = 1.49$,
 $\bar{\kappa}^2 = -.0018$, $R_c = 74$ cm, $V_c = 1.7$ m³, and U = 63 kg.

For 0.5% of pile of 20% $U^{25}O_2$, $L^2 = 288$, $k = 1.64$,
 $\bar{\kappa}^2 = 0.00104$, $R_c = 97$, $V_c = 3.9$, $UO_2 = 58.1$

N-2212

SLOW CHANGES IN THE LAPLACIAN OF A THERMAL PILE

K. Way

December 28, 1945

For a pile in which originally $B = 1.49 \times 10^{-3}$, $L^2 = 288$, and $\tau = 103$, the percent change in B is given by

$$\frac{dB}{B} = 2.2 \frac{dK}{K} - 0.57 \frac{dL^2}{L^2}$$

This applies particularly to a homogeneous BeO- UO_2 pile where UO_2 is 0.5% of the weight of BeO and the U is 20% enriched.

N-2251

CHANGE IN LAPLACIAN WITH CHANGE IN TEMPERATURE IN

A BeO PILE

K. Way

April 12, 1946

The laplacian of several homogeneous BeO- U_3O_8 piles was calculated



at 290°K and 1040°K.

$\frac{\text{Wt. U}_3\text{O}_8}{\text{Wt. BeO}}$	B (209°K) x 10 ³	B (1040°K) x 10 ³	B Cold/B Hot
0.001	1.98	1.25	1.58
0.002	2.70	1.96	1.30
0.003	2.98	2.30	1.30
0.004	3.10	2.47	1.26
0.005	3.16	2.56	1.23
0.006	3.18	2.62	1.21

N-2281

THE CONTROL PROBLEM AND THE CRITICAL
SIZE OF AN ENRICHED BeO MODERATED PILE

A. V. Martin

May 15, 1946

Three graphs and three tables give the results of calculations concerning the control problem and critical size of BeO piles.

Briefly:

(See following page)



[REDACTED]

N-2281 - (Continued)

CYLINDER PILE

Wt. UO ₂ /Wt. BeO	Radius	Height	M _c (kg)
.004	87.9	162	9.7
.008	72.3	134	10.8
.0275	63.3	117	24.9

ORNL-26

THE POOR MAN'S PILE - FIRST APPROXIMATION

M. C. Leverett

April 1, 1948

A description of certain modifications in the high flux pile design which would result in a research pile at a cost within the means of at least some universities.

Physics Specifications:

Power	3000 kw
Fast Flux	$\sim 10^{13}$ n/cm ² /sec.
Thermal Flux	$\sim 2 \times 10^{13}$
U ²³⁵	~ 3 kg
U ²³⁵ Replacement	1/2 - 2 years.

[REDACTED]
Be + 49

CRT-305

CRITICAL CONDITIONS FOR BARE SPHERICAL CORES
CONSISTING OF HOMOGENEOUS MIXTURES OF PURE
FISSILE MATERIAL AND A MODERATOR

S. Kushneriuk and
G. M. Volkoff

November, 1946

(See under H + 23).

CF-3352

NEW PILES MEETING

October 16-17, 1945

13. Sodium as a Coolant. - S. Dancoff

Sodium as a coolant is considered in terms of a particular fast pile. The pile consists of a set of 2 mm plates of 49-Be alloy separated by 3 mm for the circulation of Na. The ratio uranium (?): plutonium is 10:1. The volume is 1.06 m³ of which 3/5 is liquid sodium. The critical mass is 670 kg and the flux is 10¹⁶ neutrons per cm² per second.

15. Calculations of Resonance Piles. - M. L. Goldberger

A bare spherical pile is assumed with a Be to 49 ratio of 100 to 1. The average age is about 68 cm², the critical radius

[REDACTED]

about 27 cm, the critical volume about 82 liters, and the critical mass about 24 kg of 49. Reflectors should reduce the radius by 3-4 cm.

If 50% of the material is Na (for cooling) the volume goes to 540 liters and the critical mass to 133 kg of 49.

CF-3490

QUARTERLY REPORT FOR JANUARY, FEBRUARY, AND

MARCH, 1946

PART I

ARGONNE LABORATORY DIVISION

(See under 49).

MonS-124

PROJECT COUNCIL - INFORMATION MEETING

RESONANCE ENERGY PILES

M. L. Goldberger

June 7, 1946

Critical sizes were computed for bare spherical Na cooled, Be moderated reactors. Various results were tabulated for Be to 49 ratios of 50, 100, and 150.

[REDACTED]

MonS-124 - (Continued)

Ratio	50	100	150
C (cm ²)	55.5	62.6	67.2
Radius (cm)	21.9	24.7	26.5
Volume (liters)	43.8	63.2	78.1
W (kg)	41.1	30.3	25.4

MonP-198

CRITICAL SIZE AND BREEDING GAIN OF RESONANCE

FILES

F. L. Friedman and
M. L. Goldberger

November 1, 1946

A presentation of the details of the calculation methods used in computing the critical constants mainly of beryllium systems.

Tabulated results may be found in (1) MonS-124, pages 42-43, (2) CF-3490, Part I, pages 30-32, and (3) CF-3352.

MonP-349

APPROXIMATE EVALUATION OF A FERMI PILE THEORY INTEGRAL

P. J. Bendt

August 1, 1947

Some estimates are made for the critical mass for bare piles operating in the high-intermediate energy region, using an empirical approximation to the Fermi pile theory integral.

For 50 atoms of Be to 1 atom of 49, the radius of a spherical pile is 31.1 cm; volume = 0.126 m³; weight of Be, 232 kg, and weight of 49, 123 kg. A slowing down correction reduces the 123 kg to 47 kg, which compares with 41 kg given by Goldberger (MonS-124). Fission energy (E_0) assumed to be 2.5 Mev.

A table (II) gives the weight of 49 calculated for different dilutions of Li⁷, Be, Na, Mg, Al, and Al-Mg. For this table, $E_0 = 2.1$ Mev.

Throughout the report \sum_{tr} is assumed equal to \sum_s .

MonN-389

THERMAL GAS-COOLED PILES

H. E. Stevens, Jr.

September 25, 1947

(See under Be + 25).


C + 23

CRT-293

EXPLORATORY SURVEY OF QUANTITIES OF 23
REQUIRED FOR SELF-REACTING PILES, IN-
CLUDING THE EFFECT OF REFLECTORS

S. Kushneriuk

October 15, 1946

(See under H + 23).

CRT-305

CRITICAL CONDITIONS FOR BARE SPHERICAL CORES
CONSISTING OF HOMOGENEOUS MIXTURES OF PURE
FISSILE MATERIAL AND A MODERATOR

S. Kushneriuk and
G. M. Volkoff

November, 1946

(See under H + 23).

C + 25

A-9

PRELIMINARY ESTIMATE OF THE AMOUNTS OF 25
NEEDED FOR A SELF-SUSTAINING CHAIN REACTION

G. Breit

July 14, 1941

(See under H + 25).

A-38

SIZE OF LATTICE FOR ENRICHED URANIUM OXIDE

John A. Wheeler

No Date

A method is presented for estimating the effect of enrichment on the uranium required for a chain reactor.

<u>Original k</u>	<u>Enrichment</u>	<u>Tons U</u>
1.05	1/139	110
1.05	5/139	1
0.94	5/139	1.4

A-3939

HANFORD ENGINEER WORKS TECHNICAL MANUAL

May 1, 1944

A comprehensive (about 1200 pages) description of the construction

[REDACTED]

and operation of the Hanford Engineer Works.

Part II concerns the producing unit - the pile.

A-7,390,21

CRITICALITY IN GRAPHITE SYSTEMS

Raymond Murray and
George Schmidt

January 13, 1947

A method is developed for determining the critical dimensions of stored quantities of graphite which are contaminated with 25.

For a contamination equal to 0.12% by weight of 25,

R_c (sphere) = 38.3 in.

Side of Cube = 66.3 in.

BNL-14

BROOKHAVEN NUCLEAR REACTOR PROJECT

PROGRESS REPORT

January 1, 1948

A complete report on the various aspects of designing and constructing BNR No. 1.

The theoretical group presents a method of determining the effect of a transverse gap in the pile. A table shows their results in the form of relative critical lengths for gaps to 12 cm.

[REDACTED]

[REDACTED]

Another table shows the values of excess k required for various gap widths and linear dimensions.

Estimates of excess k for (1) Xenon = 0.008, (2) temperature effect = 0.0075, (3) experiments = 0.0075---Total = 0.023.

C-11

THE USE OF REFLECTORS AND SEEDS IN A

POWER PLANT

G. Breit and E. Fermi

March 9, 1942

This early report concerns the use of reflectors and seeds in a natural uranium-graphite pile.

Tables 2 and 4 show the required amounts of oxide (uranium oxide) in the seed and in the screen for different pile arrangements.

C-118

VALUES OF η' FOR OXIDE SPHERES OF DENSITY 6

G. N. Plass and
E. P. Wigner

No date

A table and a contour graph show η' as a function of the radius of the uranium sphere and the cube root of the ratio $\frac{\text{total volume}}{\text{uranium volume}}$.

CE-140

A PLANT WITH WATER COOLING

Gale Young and
E. P. Wigner

No Date

(See under H + 25).

C-171

π' AND RESONANCE ABSORPTION FOR OXIDE RODS

OF DENSITY 6

R. F. Christy and
A. T. Monk

No Date

This report presents a table and a contour graph for π' and a table for the "Resonance Absorption Factor".

C-197

ON A PLANT WITH WATER COOLING

Weinberg, Young, Christy,
Plass, Wigner, and Williamson

September 2, 1942

An investigation of the feasibility of a 100,000 kw plant with water cooling.

Water as a cooling agent cannot be ruled out on the basis of its adverse effect on k. The estimated metal (U) required is 9

[REDACTED]

tons and the carbide (UC₂) is 63 tons.

CP-341

METALLURGICAL PROJECT

REPORT FOR MONTH ENDING NOVEMBER 15, 1942

A brief description is given of a water cooled pile design consisting of rods or tubes of U (about 200 tons) distributed in graphite.

CP-360

SHORT MEMO ON BISMUTH COOLED POWER UNIT

L. Szilard

November 23, 1942

A short discussion of a U-C reactor cooled by liquid bismuth.

As proposed, the reactor would be a cylinder 8 m high and 9.5 m in diameter, weighing about 1000 tons and containing 150 tons of (natural uranium in the form of uranium carbide. Power production would be 1.3×10^6 kw and the initial production of ⁹⁴ would be 1.3 kg.

CP-372

VALUES OF THERMAL UTILIZATION, RESONANCE ABSORPTION

AND FAST EFFECT FOR OXIDE AND METAL SPHERES AND CYLINDERS

G. N. Plass and E. P. Wigner

December 14, 1942

Six tables and 7 graphs present values of $\frac{1}{P_1}$, $\frac{1}{P_2}$, η' ,

[REDACTED]

$\tilde{\epsilon}$, and $\frac{\eta'(\text{min})}{\tilde{\epsilon}}$ for different parameters for oxide and metal spheres and cylinders in a graphite moderator.

CE-407

PRELIMINARY PROCESS DESIGN OF A LIQUID COOLED

POWER PLANT PRODUCING 5×10^5 KW

Boissevain, Leverett, Ohlinger,
Weinberg, Wigner, and Young

January 9, 1943

A detailed discussion of the problems involved in the design and operation of a 500,000 kw water cooled pile for the production of 500 gm of ^{235}U /day. 200 tons of U in the form of Al coated rods (1695) are dispensed in Al lined holes in 1200 tons of graphite. (Cylindrical shape - 4.9 m radius x 7 m long) $M^2 = 640 \text{ cm}^2$, k (with reflector) = 1.024 required; k actual 1.0334.

CP-413

EXPERIMENTAL PRODUCTION OF A DIVERGENT CHAIN REACTION

E. Fermi

December 2, 1942

A detailed account of the construction and preliminary operation of the first pile or chain reactor.

Pile was egg-shaped - built of layers - using about 6 tons of U in the form of metal and oxide dispersed in a graphite lattice.

CN-442

π' . THERMAL UTILIZATION, AND RESONANCE

ABSORPTION IN HEX

Sacher, Weinberg, and Wigner

January 29, 1943

Two graphs show π' and the reciprocals of thermal utilization and resonance escape probability for a Hex*-graphite reactor.

CP-445

LOW DENSITY UO₂ PILE

H. W. Ibsen

February 24, 1943

A determination of size and k for a pile cooled by the flow of UO₂ suspended as a dust in He. Neutrons being "swept" from the pile would reduce k by less than 0.002.

For ρ (UO₂ + He) = 1; k = 1.0177

For a square cylinder $R_c = 18.3'$; $L = 36.6'$

Would require 276 tons UO₂ and 1490 tons of graphite.

Isopleths of k and $\frac{k-1}{M^2}$ are shown as functions of lattice spacing and C to UO₂ mass ratio.

*Hex is UF₆

CS-495

LABORATORY COUNCIL - INFORMATION MEETING

SITE X TECHNOLOGY

March 1, 1943

A brief discussion of the details of a proposed pile at Site X. Pile is to be a 24' cube of graphite with 1225 holes provided.

CP-510

PHYSICS RESEARCH

REPORT FOR MONTH ENDING MARCH 6, 1943

Dr. Froman's group measured the laplacians for metal in graphite (AGOT).

For 2665 gm cylinder in an 8" cubic lattice, $\nabla^2 = -105 \times 10^{-6} \text{ cm}^{-2}$.

For 5.53 cm diameter rods in a 12" square lattice,

$$\nabla^2 = -96 \times 10^{-6} \text{ cm}^{-2}.$$

CP-1136

LOADING FOR HANFORD 305 PILE

H. L. Anderson

December 11, 1943

Assuming the Hanford 305 pile will be an 18' cube, graphite

[REDACTED]

$\rho = 1.6$, diffusion length 50.7 cm, and loaded with uranium slugs 1.44" diameter x $8\frac{1}{4}$ " long, 20 to a channel, the weight of uranium for criticality is 32 ± 3 short tons. For a 10 second period, 34 ± 3 tons are needed. To completely load the pile, 53 tons are needed and will give an excess k of about 1%.

A table compares the pile properties of West Stands (CP 781), Clinton, Hanford 305 (Rods) and Hanford 305 (Spaced Slugs).

CP-2012X

NEW PILE STUDIES

A CYLINDRICAL URANIUM-CARBIDE AND GRAPHITE

SYSTEM

J. A. Lane

August 18, 1944

An approximate method of calculating optimum cell dimensions of a lattice pile is given.

For a pile consisting of UC_2 cylinders in a graphite moderator:

Maximum $k = 1.055$ occurs at a cylinder radius of 1.5 cm.


Minimum weight of UC_2 (73.8 tons) occurs at a cylinder radius of 2.0 cm.

Minimum pile size ($1.92 \times 10^8 \text{ cm}^3$) occurs at a cylinder radius of 2.0 cm.

Minimum η' occurs at a cylinder radius of 1.25 cm.

(Assumption: coolant and structure absorption is compensated for by enrichment).

[REDACTED]


CP-2012X - (Continued)

Curves are shown for:

φ vs. $\frac{V_1}{V_0}$ and vs. r_s/r_0

P vs. η'

ϵ vs. $N \sigma R$

CP-2377

LAPLACIANS OF GRAPHITE FILLED GAP LATTICES

A. M. Weinberg and
A. T. Monk

November 16, 1944

(See under H + 25).

CP-2459

A BRIEF GENERAL DESCRIPTION OF THE

ARGONNE URANIUM-GRAPHITE PILE (CP-2)

H. E. Metcalf

December 20, 1944

A description (6 sketches) of the main features of the Argonne
U-C pile (CP-2).

[REDACTED]

MonP-190

SOME NOTES ON POWER PILES

Gale Young

October 30, 1946

Table IX, page 17, compares the moderators, D₂O, H₂O, and graphite for different pile properties for an assumed pile radius (spherical) of 60 cm, and an assumed power of 100,000 kw.

MonN-389

THERMAL GAS-COOLED PILES

H. E. Stevens, Jr.

September 25, 1947

(See under Be + 25).

M-3445

EXISTING PILES

PILE TECHNOLOGY LECTURES #14 AND #15

Gale Young

No Date

A brief review of existing piles and some mention of proposed piles.

(See table on following page).

[REDACTED]

M-3445 - (Continued)

File	Power	Moderator	Wt. U.	Wt. Mod.	Cooling
U. of C. (1st)	Low	Graphite	40 tons	200 tons	Uncooled
Clinton	3,000 kw	Graphite	50 tons		Air Cooled
Hanford Test	Low	Graphite			Uncooled
Hanford Prod.	300,000 kw	Graphite	200 tons	1000 tons	Water Cooled
Argonne	300 kw	D ₂ O	3 tons	5 tons	D ₂ O Cooled
Zeep	Zero	D ₂ O			D ₂ O
Chalk River	30,000 kw	D ₂ O			H ₂ O
L.A. Water Boiler	1-5 kw	H ₂ O	1 kg 25		H ₂ O
L. A. Dragon					
L. A. Fast	Low		49		Hg

Proposed piles involve such coolants as liquid metals (Na, Bi,....), high pressure gas, and high pressure water. Some compounds such as diphenyl flouorocarbons, HF, and DF have also been proposed.

M-3891

NUCLEAR POWERED ROCKETS

PILE TECHNOLOGY LECTURES #31 AND #32

Nicholas M. Smith, Jr.

No Date

A method is presented for computing and optimizing a 25-C reactor

[REDACTED]

[REDACTED]

for powering a rocket.

Several tables and curves are shown, including curves of critical weight and size for two assumed temperatures (300°K and 1700°K).

N-253

SUMMARY OF k of W PILE

A. M. Weinberg November 16, 1943

A discussion of changes in k due to small changes in the W lattice and changes in the quality of the graphite used.

To be just critical at start-up, 690 tubes of the W pile must be filled with 83 metric tons of metal, - at 250 Mw, 730 tubes filled with 88 metric tons of metal are needed.


C + 49

CRT-305

CRITICAL CONDITIONS FOR BARE SPHERICAL CORES
CONSISTING OF HOMOGENEOUS MIXTURES OF PURE
FISSILE MATERIAL AND A MODERATOR

S. Kushneriuk and G. M. Volkoff November, 1946

(See under H + 23)

CP-387

MONTHLY REPORT ENDING DECEMBER 15, 1942

(See under H + 49)

CP-400

CHAIN REACTION OF PURE
FISSIONABLE MATERIALS IN SOLUTION

R. F. Christy and John A. Wheeler January 1, 1943

(See under H + 49)

CF-2848

PRELIMINARY REPORT ON RESONANCE BREEDERS

A. M. Weinberg May 12, 1945

This report deals with the assumptions and calculations for a

[REDACTED]

breeder pile. The pile is composed of ^{239}Pu dissolved in aluminum plates and both cooled and moderated by the fluorocarbon CF_2 . The pile is classified as a "resonance" pile. Briefly: $R_c = 0.9$ m, $L_c = 1.67$ m, $^{239}\text{Pu} = 85$ kg, power output = 1.6×10^6 kw, excess fertility = 0.15, ^{239}Pu production = 280 gm/day.

MonP-424

PLUTONIUM THERMAL PILES

R. C. Mason

January 2, 1948

"Through the fission of Pu^{241} , the higher isotopes of Pu increase the breeding ratio in a pile which uses ^{239}Pu as the major fuel..... Probable values of the breeding ratio in a graphite moderated pile of the Hanford type are worked out and factors affecting them are discussed."

[REDACTED]

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(Continued)

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[REDACTED]

PILE TECHNOLOGY LECTURES

<u>Lecture Number</u>	<u>Title</u>	<u>Author</u>	<u>Report Number</u>
1-2	Multiplication and Conversion	Gale Young	M-3309
3-4	File Types	Gale Young	M-3309
5-6	File Types	Gale Young	M-3338
7-9	Metallurgy of U, Th, and Be	F. Foote	M-3992
10-11	Metallurgy of Be	Gale Young	M-3444
12-13	Shielding	F. L. Friedman	M-3998
14-15	Existing Piles	Gale Young	M-3445
16	Fission Product Poisoning	K. Way	M-3690
17	Effects of Heavy Isotopes on Pile Operation	R. W. Stoughton	M-3578
18	The Investigation of Heat Transfer by Liquid Metals at the Argonne National Laboratory	Meyer Novick	M-3446
19	Beryllium Oxide	C. R. McCullough	M-3752
20	Breeder Blanket Problems	R. W. Stoughton	M-3754
21-22	Production and Properties of Graphite	H. G. MacPherson	M-3448
23	Breeding Losses	Gale Young	M-3481
24	Fast and "Mixed" Piles	J. R. Menke	M-3753

[REDACTED]

PILE TECHNOLOGY LECTURES

(Continued)

<u>Lecture Number</u>	<u>Title</u>	<u>Author</u>	<u>Report Number</u>
25a	UF ₆ and Other Fluorine Compounds	F. T. Miles	M-3795
25b	Chemical Properties of UF ₆ and Related Compounds	R. W. Wiswall	M-3795
26	Distribution of U, Th, and Be Ores and Estimated Cost	Clark Goodman	M-3791
27	Corrosion	R. B. Briggs	M-3893
28a	Application of Automatic Control Principles	J. J. Grebe	M-3906
28b	Automatic Control Principles as Applied to Piles	J. J. Grebe	M-3963
29	Naval Design	H. G. Rickover	M-3828
30	Film Formation and Heat Transfer	R. B. Briggs	M-3878
31-32	Nuclear Powered Rockets	N. M. Smith	M-3891
33	Effects of Radiation on Materials - Solids	S. Siegel	M-3855
34	Effects of Radiation on Materials - Chemical Compounds	A. O. Allen	M-3796
35-36	The Clinton High Flux Pile	M. C. Leverett	M-3856
37-38	High Temperature Power Pile	C. R. McCullough	M-3975
39	Possible Applications of UF ₆ in Piles	D. E. Hull	MonN-336

[REDACTED]

PILE TECHNOLOGY LECTURES

(Continued)

<u>Lecture Number</u>	<u>Title</u>	<u>Author</u>	<u>Report Number</u>
40-41	Pile Control	H. Soodak	M-3966
42-43	Pile Control	H. W. Newson	M-3892
44-45	Canadian Pile	J. R. Huffman	M-3952
46	Heat Transfer Mechanisms for Energy Removal from Piles	R. M. Boarts	M-4128
47	Heat Transfer Experience on the Project	R. N. Lyon	M-3974
48	Analogy between Fluid Fric- tion and Heat Transfer as Applied to Liquid Metals	R. N. Lyon	(M-4083 M-3997)
49	Economic Aspects of Atomic Energy	S. H. Schurr	M-3905
50	Homogeneous Piles	E. Shapiro	M-3969
51a	Homogeneous Piles	R. W. Stoughton	M-3967
51b	Homogeneous Piles	L. W. Nordheim	M-3967
52-53	Chemical Reprocessing Costs	A. P. Weber	M-3993

[REDACTED]

NUMERICAL INDEX

	Pages
A-9	36, 131
A-38	131
A-1203	79
A-1620	87-88
A-3939	131-132
A-4206	106
A-4207	106-107
A-4208	107-108, 147
A-4227	9
A-4228	10
A-4248	11
A-4261	147
A-4294	108-109
A-4716	36-37
A-7.390.21	132
A-7.390.22	37
A-7.390.24	38
A-7.390.25	38
BNL-14	132-133

[REDACTED]

NUMERICAL INDEX

	Pages
CF-3	11-12
C-11	133
CRPP-35	70
CNL-35	39-40
CNL-36	79-80
CNL-40	147
C-118	133
CP-139	40, 70
CP-140	41, 134
C-171	134
C-197	134-135
GRT-293	32, 75, 130
GRT-305	32-33, 70, 75, 102, 105, 126, 130, 145
GRP-306	80-81
GRP-314	81
C-338	12-13
C-341	135
C-347	81-82


NUMERICAL INDEX

	Pages
CRP-355	82
CRP-356	82-83
C-360	135
C-372	135-136
C-387	71, 145
CP-400	71, 102, 145
C-407	136
C-413	136
C-442	137
C-445	137
C-495	138
C-510	138
CF-548	13-14
C-589	14
CP-668	41-42a
CP-805	83-84
CP-834	42a
CP-853 (Rev.)	84
CP-923	85



NUMERICAL INDEX

	Pages
CP-964	85-86
C-1016	109-110
CP-1034	86-87
CE-1132	87-88
CP-1136	138-139
C-1151	147
C-1231	110
C-1361	88-89
CP-1383	89
CP-1531	89
CF-1627	14-15
CP-1834	42a-42b, 90
C-2012X	139-140
CP-2048	42b
CP-2182	42b, 43
CP-2185	43-44, 71-72, 90-91
CP-2203X	102, 103
CP-2222	91



[REDACTED]

NUMERICAL INDEX

	Pages
C-2377	44, 140
C-2459	140-141
CP-2568	45
CP-2589X	103-104
CK-2737	24
C-2796	24
CP-2813X	91-92
CP-2841	15-16
CP-2842	45-46
C-2848	145-146
CF-2881	72, 75, 104
C-2926	24-25
C-3070	111
CA-3087	147
C-3107	25-26
C-3199	6, 26-27, 76, 93
C-3290	111-112
C-3352	126-127
CP-3364	93-94

[REDACTED]

NUMERICAL INDEX

	Pages
C-3403	112
CP-3406	94
C-3407	113
C-3414	16
CF-3490	27-28, 127
C-3582	16-17
C-3633	147
C-3749	113
GE-CM-1	9
GE-CM-2	10
GE-TMS-6	11
K-126	46
LAMS-18	47
LA-105	47
LA-134	48
LA-189	17
LA-191	18

[REDACTED]

NUMERICAL INDEX

	Pages
LAMS-227	18-19, 28
LA-234	19, 48
LA-235	20, 29
LA-241	49
LA-272	72-73
LA-309	49-50, 73, 147
LA-394	50
LA-399	50-51
LA-402	20-21
LADC-406	30
LA-493	51-52
LA-609	21-22
LA-618	52
MonP-17	52-53, 94
MonP-24	53
MonS-29	141
MonP-33	54, 95
MUG-JEW-33	114
MUG-GY-39	114-115

[REDACTED]

NUMERICAL INDEX

	Pages
MUC-LAO-41	115
MonP-46	54
MonP-47	55
MonP-48	55-56, 141
MonP-56	56
MonP-74	57, 96
MonP-85	33
MonP-93	34
MonP-104	96
MS-111	22
MS-112	23
MonP-113	34-35
MonS-124	127-128
MonP-130	96-97
MUC-EPW-134	77-78
MonP-160	58
MonP-178	58-59
MonN-188	115-116
MonP-190	116, 142
MonP-196	59-60

[REDACTED]

NUMERICAL INDEX

	Pages
MonP-198	128
MonN-201	60-61
MonP-206	61-62
MonP-226	76-77
MonP-228	62
MP-246	97
MonP-264	6-7, 105
MonP-269	63
MonP-272	63
MonP-314	64, 98
MonP-336	116-117
MUG-WHZ-337	101
MonP-349	129
MonP-357	64-65
MonP-368	65
MonP-374	98-99
MonP-383	117
MonN-389	105, 117, 129, 142
MonP-402	66

[REDACTED]

NUMERICAL INDEX

	Pages
MonP-412	7, 29, 105
MonP-424	146
MonP-427	66
MonP-437	67
MonP-454	99-100
MonP-457	67-68
LDDC-1080	30
M-3122	35
M-3194	147
M-3285	23, 30, 147
M-3391	147
M-3416	118
M-3445	142-143
M-3554	147
M-3556	119, 147
M-3753	8, 31
M-3891	143-144
M-3952	100
M-3975	119-120

[REDACTED]

NUMERICAL INDEX

	Pages
M-4157	120
M-4163	148
M-4167	120-121
M-4211	68
N-253	144
N-1190	121
N-1569b	100
N-1569h	77-78
N-1729s	74
N-2000	148
N-2059	121-122
N-2100	123
N-2212	123
N-2232	101
N-2251	123-124
N-2281	124-125
ORNL-26	125
ORNL-51	68-69