AIM

Association for Information and Image Management

1100 Wayne Avenue, Suite 1100
Silver Spring, Maryland 20910
301/587-8202

Centimeter

Inches

MANUFACTURED TO AIM STANDARDS
BY APPLIED IMAGE, INC.

1 of 1

**Cover Sheet for a Hanford
Historical Document
Released for Public Availability**

Released 1994

**Prepared for the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830**

**Pacific Northwest Laboratory
Operated for the U.S. Department of Energy
by Battelle Memorial Institute**

DISCLAIMER

This is a **historical document** that is being released for public availability. This was made from the best available copy. Neither the United States Government nor any agency thereof, nor Battelle Memorial Institute, nor any of their employees, makes **any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights.** The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DECLASSIFIED

(CLASSIFICATION)

DOCUMENT NO.

HW-60798

SERIES AND COPY NO.

DATE

June 19, 1959

GENERAL ELECTRIC

HANFORD ATOMIC PRODUCT OPERATION, RICHLAND, WASHINGTON

TITLE

NEUTRON FLUX IN K REACTOR DISCHARGE AREA
DURING OPERATION

AUTHOR

W. L. Bunch

ISSUING FILE

☐ OTHER OFFICIAL CLASSIFIED INFORMATION

THIS MATERIAL CONTAINS INFORMATION AFFECTING
THE NATIONAL DEFENSE OF THE UNITED STATES
WITHIN THE MEANING OF THE ESPIONAGE LAWS,
TITLE 18, U. S. C., SECS. 793 AND 794, THE TRANSMISSION OR REVELATION OF WHICH IN ANY MANNER
TO AN UNAUTHORIZED PERSON IS PROHIBITED BY
LAW.

HANFORD TECHNICAL RECORD

THIS DOCUMENT MUST NOT BE LOANED OUT OR WHERE AN UNAUTHORIZED PERSON MAY HAVE ACCESS
TO IT. WHEN NOT IN USE, IT MUST BE STORED IN AN APPROVED REPOSITORY WITHIN AN APPROVED
GUARDED AREA. WHILE IN YOUR POSSESSION AND YOU HAVE OBTAINED A SIGNED RECEIPT FROM
CLASSIFIED FILE, IT IS YOUR RESPONSIBILITY TO KEEP IT AND ITS CONTENTS WITHIN THE
THIS PROJECT FROM ANY UNAUTHORIZED PERSON, ITS TRANSMITTAL TO, AND SIGNATURE YOUR PLACE
OF REUSE IS PROHIBITED. IT IS TO BE DUPLICATED, IF ADDITIONAL COPIES ARE REQUIRED,
OF THEM FROM THE RELATIVE ISSUING FILE. ALL PERSONS READING THIS DOCUMENT ARE REQUESTED
SIGN IN THE SPACE PROVIDED BELOW.

ROUTE TO:

PAYROLL NO.

LOCATION

FILES ROUTE
DATE

SIGNATURE AND DATE

**RECORD
COPY**

Indefinite Retention

Disposal Date

Authority

DECLASSIFIED

DECLASSIFIED

HW-60798

1. CW Allen
2. WL Bunch
3. WH Clark
4. HS Davis ←
5. RL Dickeman
6. JE Faulkner
7. GC Fullmer-GF Owsley
8. OH Greager-JF Music
9. JE Hanson-AE DeMers
10. PC Jerman-IA Carter
11. CA Mansius
12. JG Myers
13. R Nilson
14. RS Paul
15. EG Peterson
16. WL Smalley
17. JL Weeks
18. 300 Files
19. Record Copy

This document classified by

W.H. Clark

This document consists of
8 pages. No. 4 of
19 copies. Series

Classification Cancelled and Changed To

DECLASSIFIED

By Authority of *CG PR-2*

W.A. Snyder 1-4-94

By Jerry Males 1-10-94 June 19, 1959

Verified By *J.E. Savelly 1-31-91*

THIS DOCUMENT CONTAINS INFORMATION OF A CONFIDENTIAL NATURE
DATE OF DECLASSIFICATION: 1959
EXEMPTED FROM AUTOMATIC DECLASSIFICATION OF THIS
DOCUMENT BY ANNUAL REVIEW AND AUTHORIZED
PERSONNEL IS PROHIBITED.

NEUTRON FLUX IN K REACTOR DISCHARGE AREA DURING OPERATION

HANFORD ATOMIC PRODUCTS OPERATION
RICHLAND, WASHINGTON

PRELIMINARY REPORT

"This report was prepared only for use within General Electric Company in the course of work under Atomic Energy Commission Contract W-31-109-Eng-52. Any views or opinions expressed in the report are those of the authors only."

LEGAL NOTICE

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

A. Makes any warranty or representation, express or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or

B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission to the extent that such employee or contractor prepares, handles or distributes, or provides access to, any information pursuant to his employment or contract with the Commission.

MASTER

DECLASSIFIED

HW-60798

NEUTRON FLUX IN K REACTOR DISCHARGE AREA DURING OPERATION

Based on the activation of gold foils in an homogeneous medium, the neutron flux incident on the rear wall of the discharge area of the KE reactor is estimated to be 6000 n/cm^2 sec. The effective energy of the neutrons is estimated to be approximately 4 Mev. Neither of these values confirm order-of-magnitude estimates of the neutron flux and neutron energy expected to exist in the discharge area.

DISCUSSION

Neutrons in the discharge area of a K reactor are expected to come from four sources: 1) leakage of fission neutrons through the reactor shield, 2) delayed neutrons from fission products dissolved in the water, 3) decay neutrons from the N^{17} which results from the $O^{17}(n,p)$ reaction in the water, and 4) photoneutrons from the reaction of high energy gamma radiation on the deuterium in the water. The expected intensity and energy distribution of each of these sources is estimated in the appendix to be:

<u>Source</u>	<u>Flux(n/cm^2sec)</u>	<u>Energy (Mev)</u>
1) Pile	200	2
2) Delayed neutrons	Unknown	0.5
3) N^{17} decay	1000	1
4) Photoneutrons	5	4

The present measurement indicated a flux of approximately 6,000 n/cm^2 sec with an effective energy of about 4 Mev. It is not clear why such a large discrepancy should exist between the calculations and the measurement.

The neutron flux and neutron energy were estimated by the use of a "lucite integrator". This device consisted of a stack of lucite plates one inch thick and six inches in diameter interspersed with gold foils. The hydrogen in the lucite slows down the neutrons incident on the surface of the integrator and the activity of the gold foils provides a description of the thermal flux distribution in the integrator. The thermal flux distribution in the integrator is characteristic of the energy of the incident neutrons and the magnitude of the thermal flux is a measure of the intensity of the incident radiation. In the present experiment the lucite integrator was mounted on the end of a wood plug and was positioned at the center of the discharge area wall through an access hole. The assembly was irradiated in this position for 8.1 days (until the gold was 87.5 per cent saturated). The activity of the foils was determined by E. G. Peterson of HLO using an automatic proportional counting system which had been calibrated previously to the neutron flux in the Hanford Standard Pile. The data are shown in Figure 1. No cadmium ratio was obtained, hence it was necessary to estimate the activation due to intermediate energy neutrons. Based on earlier work with lucite integrators, about one-fourth of the activity was attributed to epi-thermal neutrons.

The energy of the incident neutrons can be estimated from the thermal flux distribution in the integrator. If the relaxation length is longer than the diffusion length, then the relaxation length is a measure of the energy. The relaxation length of some mono-energetic neutrons in paraffin has been measured.⁽¹⁾ Because of the high temperature which exist in the discharge area it was necessary to substitute lucite for paraffin. The hydrogen content of lucite is thought to be about 15 per cent less than that of paraffin; hence, relaxation lengths in lucite should be somewhat greater than in paraffin.

(1) BNL-351, "Neutron Monitoring With Indium Foils", F.B. Oleson, July, 1955

DECLASSIFIED

HW-60798

Measured relaxation lengths for three monoergic neutron sources in paraffin are shown in Figure 2 with the relaxation length found in the lucite integrator in the present irradiation. On the basis of this it is concluded that the neutron flux incident on the rear wall is about 4 Mev. It is also apparent from the initial distribution (see Figure 1) that lower energy neutrons (down to thermal) are also present.

W. L. Bunch

W. L. Bunch
Irradiation Testing Sub-Section
Research & Engineering Section
IRRADIATION PROCESSING DEPARTMENT

Figure 1
Thermal Neutron Flux in Lucite Integrator

DECLASSIFIED

Figure 2

Asymptotic Relaxation length of Neutrons
in Hydrogenous Moderator. Monoergic
Sources in Paraffin from Reference 1.

DECLASSIFIED

HW-60798

APPENDIX

An estimate of the neutron flux in the discharge area can be made by considering each of the four known sources. In most cases data for the calculations are meager; hence, only rough order-of-magnitude estimates have been made.

(1) Leakage from the pile

It is estimated that fast flux incident on the rear biological shield is about 2×10^8 n/cm²sec. The temperature of the shield is about 100C, hence the attenuation coefficient should be ~ 0.12 cm⁻¹. The shield is 45 inches thick (114 cm). The radiation leakage should be:

$$I = I_0 \exp(-ux) = 2 \times 10^8 \exp(-0.12 \times 114)$$

$$I = 200 \text{ n/cm}^2 \text{ sec.}$$

The energy of these neutrons would be greater than 1 Mev and would probably average about 2 Mev based on a slightly modified fission spectrum.

(2) Delayed Neutrons

It is impossible to estimate delayed neutrons in the effluent. If the reactor had never experienced a rupture there should be no delayed neutrons in the water. Since ruptures have occurred the potential for delayed neutrons does exist. The energy of these neutrons is relatively low, i.e., ~ 0.5 Mev.

(3) N¹⁷ decay

Nitrogen 17 should exist in the effluent water because of the threshold reaction N¹⁷; (n, p) N¹⁷. The threshold energy for this reaction is ~ 7.9 Mev; the cross section for 12 Mev neutrons is approximately 0.01 barns; the half-life is 4.14 second and the decay includes a 1 Mev neutron. When the cross section is averaged over the entire fission spectrum the effective value becomes 7 microbarns. The abundance of O¹⁷ in oxygen is 0.037 per cent. For a time in the pile of one second and a decay time of one-half second the activity per unit volume becomes:

$$\begin{aligned} A_v &= \phi N \sigma e^{-bt_0} (1 - e^{-bt_1}) \\ &= (3 \times 10^{13})(3.3 \times 10^{22} \times 0.00037)(7 \times 10^{-30})(e^{-0.167 \times 0.5})(1 - e^{-0.167}) \\ &\approx 400 \text{ neutrons/cm}^3 \text{ sec} \end{aligned}$$

For an order-of-magnitude estimate of the flux incident on the rear wall consider half the neutrons from the water in the headers to contribute (little contribution would be expected from risers because of self absorption and decay).

Total header volume is:

$$\begin{aligned} V &= \pi R^2 L N \\ &= \pi 26 \times 1500 \times 60 \\ &\approx 10^7 \text{ cm}^3 \end{aligned}$$

DECLASSIFIED

HW-60798

Surface area of the source and wall is:

$$A = 1500^2 \approx 2 \times 10^6$$

The 1 Mev neutron flux becomes:

$$(1/2) \frac{400 \times 10^7}{2 \times 10^6} \approx 10^3 \text{ neutrons/cm}^2 \text{ sec.}$$

(4) Photoneutrons

The primary source of photoneutrons in the water is expected to come from the action of high energy gammas on the deuterium in the water. The $D(\gamma, n)H$ reaction requires photons with energy greater than 2.2 Mev. In the absence of fission products the only significant source of high energy gamma in the water should be from 7.35 second N^{16} atoms which result from the $O^{16}(n, p)N^{16}$ reaction. This is also a threshold reaction requiring the neutron energy to be greater than 9.4 Mev. Although the cross section is nearly 0.1 barn for 13.5 Mev neutrons, the effective cross-section averaged over the fission spectrum is only 20 microbarns. A high energy gamma (6-7 Mev) is emitted 82 per cent of the time. The gamma activity due to the $O^{16}(n, p)N^{16}$ reaction assuming the same flux, buildup and decay times as above becomes:

$$\begin{aligned} S_v &= \phi N \sigma e^{-bt_0} (1 - e^{-bt_1})(0.82) \\ &= (3 \times 10^{13})(3.3 \times 10^{22})(20 \times 10^{-30}) e^{-0.094 \times 0.5} (1 - e^{-0.094})(0.82) \\ &\approx 2 \times 10^6 \text{ photons/cm}^3 \text{ sec} \end{aligned}$$

The gamma flux on the rear wall from this source would be

$$(1/2) \left(2 \times 10^6 \right) \frac{10^7}{2 \times 10^6} = 5 \times 10^6 \text{ photons/cm}^2 \text{ sec}$$

and the intensity would be approximately 50 R/hr. This is of the same order-of-magnitude as the measured value so it seems to be realistic. To obtain the neutron flux resulting from these gamma requires a consideration of the pipe geometry. The gamma flux in the water in one header is approximately:

$$g = \frac{B S_v}{\mu} G(\mu l, \mu R)$$

where B = buildup factor

μ = water absorption coefficient for 6-7 Mev photons = 0.026 cm^{-1}

l, R = pipe length and radius, 1500 cm and 5 cm respectively

$G(\mu l, \mu R)$ is graphed in TID-7004

$$g \approx \frac{B 2 \times 10^6}{0.026} G(\geq 5, 0.13) \approx \frac{B 2 \times 10^6}{0.026} 0.35$$

$$\approx 2.7 \times 10^7 B \text{ photons/cm}^2 \text{ sec.}$$

B is difficult to estimate in this case: The nearby sources which predominate have little buildup but the far away sources which contribute little have a large buildup. As an order-of-magnitude estimate a total value (including buildup) of 1×10^8 photons/cm² sec is used.

DECLASSIFIED

HW-60798

The gamma flux from the two adjacent headers is given by the relation:

$$g \approx \frac{B S_v R_0^2}{(a + z)} F \left(\frac{a}{2}, \frac{1}{2} z + \frac{1}{2} R \right)$$

where

$a = 14$ cm, distance from edge of one header to center of next,

$z = \approx 1/2 R_0 = 2.5$ cm

$\frac{1}{2} z + \frac{1}{2} R = 0.07 + 0.13 = 0.2$

F is also tabulated in TID-7004

$$g \approx \frac{B \cdot 2 \times 10^6}{16.5} \cdot 25 \cdot 1.0 = 3.0 \times 10^6 \text{ B photons/cm}^2 \text{ sec}$$

It is concluded that the adjacent headers do not contribute materially to the gamma flux. The total value is approximately 1×10^8 photons/cm² sec.

The neutron source due to these gammas is the product

$$n_v = g N \sigma$$
$$= (1 \times 10^8)(6.7 \times 10^{22} \times 0.015\%)(22 \times 10^{-28})$$

$$n_v = 2.2 \text{ neutrons/cm}^3 \text{ sec}$$

The neutron flux on the rear wall from this source should be approximately

$$\frac{1}{2} \frac{2.2 \times 10^7}{2 \times 10^6} \approx 5 \text{ n/cm}^2 \text{ sec.}$$

The energy of this flux would be the difference between the photon energy and the threshold energy; i.e., 6 or 7 minus 2.2 or about 4 Mev.

DATE

FILMED

9 / 27 / 94

END