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

(CLASSIFICATION)

DOCUMENT NO.

HW-69751

SERIES AND COPY NO.

DATE _____

May 26, 1961

GENERAL ELECTRIC

HANFORD ATOMIC PRODUCTS OPERATION - RICHLAND, WASHINGTON

THIS DOCUMENT CONTAINS INFORMATION AS
DEFINED BY THE SPY ACT OF 1950.
ITS TRANSMISSION OR DISCLOSURE OF ITS
CONTENTS BY ANY MANNER IS UNAUTHORIZED
AND IS PROHIBITED.

TITLE

NPR DELAYED NEUTRON FRACTIONS AND DECAY CONSTANTS

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.

AUTHOR

C. W. ALLEN

ISSUING FILE

TECHNICAL INFORMATION FILE

THIS DOCUMENT IS NOT TO BE LEFT UNATTENDED OR WHERE AN UNAUTHORIZED PERSON MAY HAVE ACCESS TO IT. WHEN IN USE, IT MUST BE KEPT IN AN APPROVED LOCKED REPOSITORY WITH AN APPROVED GUARD AREA. WHILE IT IS IN POSSESSION AND WHEN YOU HAVE OBTAINED A RECEIPT FROM THE FILED FILES, IT IS YOUR RESPONSIBILITY TO KEEP IT AND ITS CONTENTS WITHIN THE LIMITS OF THIS PROJECT AND PREVENT UNAUTHORIZED PEOPLE ITS TRANSMITTAL TO ANY STORAGE AT YOUR PLACE OF RESIDENCE IS PROHIBITED. IT IS NOT TO BE DUPLICATED. IF ADDITIONAL COPIES ARE REQUIRED, OBTAIN THEM FROM THE RELATED ISSUING OFFICE. ALL PERSONS READING THIS DOCUMENT ARE REQUESTED TO SIGN IN THE SPACE PROVIDED BELOW.

[illegible]

54-3000-340 (3-57) AEC-95 RICHLAND, WASH

(CLASSIFICATION)

DECLASSIFIED

HW-69751

This document contains restricted information as defined in the Atomic Energy Act of 1954. The transmittal or disclosure of its contents in any manner to an unauthorized person is prohibited.

This document consists of
7 pages. No. 3 of
13 copies.

DISTRIBUTION:

1. CW Allen
2. JH Brown
3. CE Bowers
4. DL Condotta
5. GC Fullmer
6. R Nilson
7. RE Tiller
8. RE Trumble
9. CD Wilkinson
10. 300 Files
11. Record Center
- 12-13. Extra

This document classified by:

May 26, 1961

Classification Cancelled and Changed To

DECLASSIFIED

By Authority of DS Lewis

CG-PR-2 3-1-94

By D. E. Searly 3-30-94

Verified By K. Hansen 3-30-94

NPR DELAYED NEUTRON FRACTIONS AND DECAY CONSTANTS

C. W. ALLEN

INTRODUCTION

The delayed neutron characteristics of a reactor are a function of the distribution of fissions in the various fissionable isotopes. The delayed neutron characteristics of the NPR, delayed fraction and decay constants, are presented as functions of exposure to 2000 MWD/T for both room temperature and operating temperature.

It is of importance to note that the delayed neutron fraction decreases from 0.693% to 0.539% with increased exposure. Thus 22% less reactivity change represents a prompt critical condition at 2000 MWD/T, compared to the zero exposure condition.

CALCULATION

These calculations were based upon information derived from the following sources:

1. Fast to thermal fission ratio, δ , from a zero exposure IDIOT calculation.

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DECLASSIFIED

2. Isotopic concentrations from a FLEX calculation.
3. Fission cross-sections from a FLEX calculation.
4. Delayed neutron data from "Delayed Neutrons from Fissionable Isotopes of Uranium, Plutonium, and Thorium," by Keepin, Wimett, and Zeigler (J. of Nuclear Energy, 1957, Vol. 6, pgs 1 to 21).

To complete the calculations with available information, the following assumptions were necessary:

1. The fast to thermal fission ratio was assumed constant. Since this value is relatively small, the errors introduced are tolerable for the purpose of this study.
2. The distribution of thermal fissions is assumed to be proportional to the products of concentration and fission cross-section of each isotope.
3. Due to lack of comparable data for the fission of Pu^{241} , all fissions of this isotope were assumed to have the same neutron distribution yield as Pu^{239} .

$$F^{238} = \frac{\delta}{1 + \delta}$$

$$F^j = \frac{1}{(1 + \delta)} \frac{N^j \sigma_f^j}{\sum_n N^n \sigma_f^n} \quad (\text{for thermal fissions})$$

where

F^k = fraction of fissions in fissionable isotope k (k identifies isotopes: U^{235} , thermal fission; Pu^{239} , thermal fission; Pu^{241} , thermal fission; U^{238} , fast fission)

N^k = concentration of isotope k

σ_f^k = thermal fission cross section of isotope k

δ = fast fission to thermal fission ratio

The delay fractions and half-lives were averaged by the following:

DECLASSIFIED

$$\bar{\beta}^j = \frac{\sum_i F_i \nu_i \beta_i^j}{\sum_i F_i \nu_i}$$

$$\bar{\tau}^j = \frac{\sum_i F_i \nu_i \beta_i^j \tau_i^j}{\sum_i F_i \nu_i \beta_i^j} = \frac{\sum_i F_i \gamma_i^j \tau_i^j}{\sum_i F_i \gamma_i^j}$$

$$\bar{\lambda}^j = .69315 / \bar{\tau}^j$$

Where

$\bar{\beta}^j$ = average fraction of neutrons from fission that are in delayed group j (j = 1, 2--6)

$\bar{\tau}^j$ = average half-life of delayed neutrons in delayed group j

$\bar{\lambda}^j$ = average decay constant for neutrons from delayed group j

F_i = fraction of fissions occurring in isotope i

ν_i = average number of neutrons per fission of isotope i

β_i^j = fraction of neutrons from fissions of isotope i that are assigned to delayed group j

τ_i^j = half-life of delayed neutrons in group j from a fission in isotope i

$\gamma_i^j = \nu_i \beta_i^j$ = number of neutrons falling into delay group j from a fission in isotope i

The reactivity required to produce a given stable period can be computed from:

$$\text{Reactivity (in dollars)} = \frac{\tau_p}{\tau_{Tk}} + \sum_{i=1}^6 \frac{\gamma_i}{\gamma} \frac{\beta_i \tau_i}{\beta (T + \tau_i)}$$

DECLASSIFIED

Where

γ_p = prompt neutron lifetime

γ_i = effectiveness of neutrons in group i relative to prompt neutrons

$$\gamma = \sum_{i=1}^6 \gamma_i \beta_i / \sum_{i=1}^6 \beta_i$$

β_i = delayed neutron fraction in group i

$$\beta = \sum_{i=1}^6 \beta_i$$

τ_i = mean neutrons lifetime for group i (= $1/\lambda_i$)

T = stable reactor period

If the assumption is made that $\gamma = \gamma_i = 1$, then the above equation is rearranged and

$$\Delta k = \frac{\frac{\gamma_p}{\gamma} + \sum \frac{\beta_i}{1 + \frac{\beta_i}{\tau_i}}}{1 - \sum \frac{\beta_i}{1 + \frac{\beta_i}{T \lambda_i}}}$$

where $\Delta k = k - 1$

RESULTS

The total fraction of delayed neutrons for both room and operating temperatures are given as a function of exposure in Figure 1.

In Table I the delayed neutron fractions and decay constants for the usual six delay groups are summarized for exposures of zero, 500, 1000, 1500, and 2000 MWD/T exposure. This is a uniform exposure. No weighting or averaging for variations in a reactor loading is considered.

The stable reactor period as a function of Δk was computed for both the zero exposure and 2000 MWD/T, hot, cases. Curves are given in Figure 2 for these functions. All intermediate exposures will fall between these two cases. The significance of the shorter period at higher exposures is not too great, unless periods are being used for rod calibration or such. The difference in the prompt critical reactivity must be accounted for in certain accident investigations.

DELAYED NEUTRON FRACTIONS AS A FUNCTION
OF EXPOSURE

FIGURE 1

DECLASSIFIED

REACTOR PERIOD vs K EXCESS
FIGURE 2

DECLASSIFIED

TABLE I

NPR DELAYED NEUTRON CONSTANTS

Exposure (MWD/T) - Cold

	0	500	1000	1500	2000
1	.0210%	.0196%	.0185%	.0176%	.0169%
2	.1443	.1363	.1302	.1252	.1211
3	.1328	.1243	.1179	.1127	.1083
4	.2729	.2536	.2390	.2272	.2172
5	.0896	.0836	.0790	.0754	.0722
6	.0319	.0294	.0286	.0274	.0265
T	.6926	.6468	.6132	.5856	.5622
1	.0125	.0125	.0125	.0125	.0125
2	.0306	.0306	.0306	.0306	.0306
3	.1138	.1144	.1149	.1153	.1157
4	.3081	.3086	.3096	.3104	.3111
5	1.189	1.191	1.194	1.196	1.198
6	3.180	3.178	3.174	3.171	3.168

Exposure (MWD/T) - Hot

	0	500	1000	1500	2000
1		.0193%	.0180%	.0170%	.0162%
2		.1343	.1272	.1215	.1170
3		.1223	.1147	.1088	.1040
4		.2489	.2317	.2183	.2073
5		.0821	.0768	.0726	.0692
6		.0296	.0279	.0266	.0255
T		.6364	.5962	.5649	.5392
1	Same as zero - exposure, cold	.0125	.0125	.0125	.0125
2		.0306	.0306	.0306	.0306
3		.1146	.1152	.1157	.1162
4		.3090	.3101	.3111	.3120
5		1.192	1.195	1.198	1.200
6		3.177	3.172	3.168	3.165

$$\beta_T = \sum_1 \beta_i$$

C. Wesley Allen

Reactor Physics
Process and Reactor Development

**DATE
FILMED**

9 / 12 / 94

END