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TITLE

EFFECTIVE DELAYED NEUTRON FRACTIONS AND
DECAY CONSTANTS IN THE HANFORD PRODUCTION
REACTORS

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EFFECTIVE DELAYED NEUTRON FRACTIONS AND DECAY CONSTANTS
IN THE HANFORD PRODUCTION REACTORS

INTRODUCTION

The effective delayed neutron characteristics of a reactor are dependent on the relative fission rates in the various fissionable isotopes present. The delayed neutron characteristics of the production reactors are presented as a function of exposure.

SUMMARY

The effective delayed neutron fractions and decay constants as a function of exposure are presented in Tables 1 through 4. In all cases, hot, operating conditions were assumed.

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TABLE 1

EFFECTIVE DELAYED NEUTRON FRACTIONS - KIVN LATTICE

	<u>Exposure (MWD/Ton)</u>					
	<u>0</u>	<u>200</u>	<u>400</u>	<u>600</u>	<u>800</u>	<u>1000</u>
β_1	.0002107	.0002004	.0001920	.0001850	.0001791	.0001738
β_2	.001442	.001384	.001336	.001284	.001251	.001222
β_3	.001326	.001265	.001215	.001173	.001138	.001107
β_4	.002723	.002584	.002471	.002377	.002297	.002227
β_5	.0008910	.0008478	.0008125	.0007554	.0007591	.0007372
β_6	.0003172	.0003037	.0002926	.0002834	.0002756	.0002687
β_{Tot}	.006910	.006585	.006319	.006058	.005900	.005736

TABLE 2

EFFECTIVE DISINTEGRATION CONSTANTS^a OF DELAYED
NEUTRON EMITTERS - KIVN LATTICE

	<u>Exposure (MWD/Ton)</u>					
	<u>0</u>	<u>200</u>	<u>400</u>	<u>600</u>	<u>800</u>	<u>1000</u>
λ_1 (sec ⁻¹)	0.01248	0.01248	0.01249	0.01250	0.01251	0.01252
λ_2	0.03063	0.03063	0.03062	0.03062	0.03061	0.03060
λ_3	0.1138	0.1141	0.1144	0.1147	0.1150	0.1153
λ_4	0.3081	0.3087	0.3092	0.3098	0.3103	0.3108
λ_5	1.187	1.188	1.190	1.191	1.1930	1.195
λ_6	3.180	3.177	3.174	3.171	3.1680	3.165

^a $\lambda = 0.693$ divided by the half life.

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TABLE 3

EFFECTIVE DELAYED NEUTRON FRACTIONS - OIIN LATTICE

	Exposure (MWD/Ton)					
	0	200	400	600	800	1000
β_1	.0002107	.0002014	.0001937	.0001871	.0001815	.0001763
β_2	.001446	.001393	.001350	.001313	.001280	.001252
β_3	.001332	.001277	.001232	.001192	.001159	.001129
β_4	.002741	.002615	.002511	.002424	.002347	.002280
β_5	.0009054	.0008662	.0008341	.0008067	.0007827	.0007617
β_6	.0003218	.0003097	.0002994	.0002908	.0002833	.0002767
β_{Tot}	.006952	.006662	.006420	.006214	.006034	.005876

TABLE 4

EFFECTIVE DISINTEGRATION CONSTANTS OF DELAYED
NEUTRON EMITTERS - OIIN LATTICE

	Exposure (MWD/Ton)					
	0	200	400	600	800	1000
λ_1 (sec ⁻¹)	0.01248	0.01249	0.01250	0.01250	0.01251	0.01252
λ_2	0.03064	0.03064	0.03063	0.03063	0.03062	0.03060
λ_3	0.1140	0.1144	0.1146	0.1148	0.1151	0.1155
λ_4	0.3081	0.3088	0.3093	0.3099	0.3104	0.3110
λ_5	1.189	1.190	1.192	1.193	1.195	1.197
λ_6	3.194	3.191	3.188	3.184	3.182	3.180

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DISCUSSION

The results presented are based on information obtained from the following sources:

1. Fast to thermal fission ration, δ , from IDIOT⁽¹⁾ calculations.
2. Plutonium and uranium isotopic concentrations, and fission cross sections from MOFDA⁽²⁾ calculations.
3. Delayed neutron data for the isotopes from Reference (3).

The values shown in Tables 1 through 4 were then determined as follows,

$$\bar{\beta}_1 = \frac{\sum_j f_j \nu_j \beta_{j1}}{\sum_j f_j \nu_j}, \text{ and} \quad (1)$$

$$\bar{T}_1 = \frac{\sum_j f_j \nu_j \beta_{j1} T_{j1}}{\sum_j f_j \nu_j \beta_{j1}}, \text{ where} \quad (2)$$

- f_j = fraction of fissions which occur in isotope j ,
 ν_j = number of neutrons emitted per fission of isotope j ,
 β_{j1} = delayed neutron fraction in group 1 from fissions in isotope j ,
 T_{j1} = half life of group 1 neutron precursors which are created from fission of isotope j .

To determine the appropriate values for f_j , the equations

$$f_{28} = \frac{\delta}{\delta + 1}, \quad (3)$$

(1) Richey, C. R. IDIOT - A Lattice Parameter Code for the IBM 7090, HW-66215. June, 1960.

(2) MOFDA is an extensive engineering and physics code devised by R. O. Gumprecht for the IBM 7090.

(3) Keepin, G. R., et al. "Delayed Neutrons from Fissionable Isotopes of Uranium, Plutonium, and Thorium," Journal of Nuclear Energy, VOL6. 1-21. 1957.

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$$f_{49} = \frac{1}{(1 + \delta) \left[1 + \frac{\rho_{25} \sigma_{25} A_{49}}{A_{25} \rho_{49} \sigma_{49}} \right]}, \text{ and} \quad (4)$$

$$f_{25} = 1 - f_{28} - f_{49}, \quad (5)$$

were used, where

- δ - fast to thermal fission ratio,
- σ - microscopic fission cross section,
- ρ - density,
- A - atomic mass.

The subscripts 28, 49, and 25 represent U-238, Pu-239, and U-235, respectively.

Since there are no delayed neutron data available for Pu-241, its concentration was simply added to the Pu-239 concentration. This may not be correct; however, it is a very small factor and will effect the results very little.

The effective delayed fractions were determined only for the OIIN and KIVN lattices. The values shown can, however, be used for the enriched columns at zero exposure. Even at higher enriched column exposures, these results can be used conservatively, since the enriched fuel has a lower conversion ratio than the natural fuel. This, of course, results in the E-metal having larger delayed neutron fractions than natural metal at the same exposure.

The results for the KIVN lattice may also be used, with a very slight conservatism, for the KVN lattice. This arises because the KV lattice has a slightly larger fast to thermal fission ratio, while the conversion ratios of the two lattices are nearly identical.

It should also be pointed out that the isotopic concentrations and corresponding exposures used were on a "column" basis. Thus, the exposures listed will correspond to the reactor exposure only if the reactor is on a "block-discharge" scheme. In most cases the error introduced by this will be negligible, however, and can be ignored.

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