AECA-4217

Photostat Price \$ 1.80

Microfilm Price \$ 1.80

Available from the
Office of Technical Services
Department of Commerce
Washington 25, D. C.

WASH-228-7

This document contains
— pages. This is copy
— Series A.

General Electric Company
KNOLLS ATOMIC POWER LABORATORY
Schenectady, New York

THE EFFECTS OF INTERNAL CONVERSION ON CRITICAL
MASS AND OPERATING LIFE OF A THERMAL REACTOR

T. M. Snyder

July 21, 1952

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.

Operated for the
United States Atomic Energy Commission
by the
General Electric Company
Contract No. W-31-109 Eng-52

SECRET
SECURITY INFORMATION

198-3

Warning Preliminary Report

This report was prepared for preliminary use only in the course of work under W31-109 Eng. 52, and the information contained herein may not be correct or in agreement with more recent experimental and operating data. Any values or opinions expressed in the report may be only those of the author, and the General Electric Company makes no representation or warranty (1) as to the value of this report for any purpose or (2) that any use of the report will not infringe the rights of others.

THE EFFECTS OF INTERNAL CONVERSION ON CRITICAL MASS AND OPERATING LIFE OF A THERMAL REACTOR

The purpose of the following discussion is to make rough predictions of the expected effects of internal conversion on the critical mass and reloading period of thermal reactors. These rough predictions will indicate the desirability of a more careful investigation.

For the analysis, the following approximations are made:

1. The reactor is bare.
2. The spectrum is thermal.
3. The volume of the reactor is occupied primarily by moderator, coolant and structural material. It may therefore be assumed that the atomic densities, other than those of fertile and fissionable material, and the transport cross section, which determines leakage, are independent of the internal conversion ratio.

The criticality relationship at startup is then:

$$(1) \quad \sigma_f^{-1} = \frac{\pi^2/3a^2 \sigma_{tr} + \sigma_a}{\nu - (1 + \alpha)(1 + R)}$$

where σ_f^{-1} , σ_a , and σ_{tr} are the reciprocal mean free paths for fission, absorption by reactor components other than fuel and fertile material and transport, a is the core radius, ν is the number of neutrons per fission, α the capture to fission ratio, and R is the internal conversion ratio. The reciprocal mean free paths are related to atomic cross sections S and atomic densities N by:

$$(2) \quad \sigma = SN$$

The reactivity will change as U-235 is consumed, so that a time when the density of fuel atoms is N_{25} the reactivity is given by:

$$(3) \quad k = \frac{(\nu/S)_{25} N_{25} + (\nu/S)_{49} N_{49}}{[SN(1 + \alpha)]_{25} + \sigma_b + \sigma_a + \pi^2/3 \sigma_{tr} a^2 + [SN(1 + \alpha)]_{49}}$$

where b refers to fertile material. The rate of reactivity change through loss of U-235 and production of new fuel is given initially by:

$$(4) \quad \frac{dk}{dN_{25}} = \frac{S_{25} [\nu - 1 - \alpha]_{25} - S_{49} [\nu - 1 - \alpha]_{49} R}{\nu N_{25}}$$

(since initially $k = 1$). It is assumed that changes in σ_b and σ_{tr} can be neglected.

These relations are in a convenient form to determine the effects of conversion on critical mass and reactivity change with burmp. The re-loading period is roughly proportional to dN_{25}/dk . If $R = 0$,

$$(5) \quad N_{25}(0) = \frac{\pi^2/3a^2 \sigma_{tr} + \sigma_a}{\nu - (1 + \alpha)}$$

hence,

$$(6) \quad \frac{N(R)}{N(0)} = \frac{\nu - (1 + \alpha)}{\nu - (1 + \alpha)(1 + R)}$$

Also, if $R = 0$,

$$(7) \quad \left(\frac{dk}{dN_{25}} \right)_0 = \frac{[\nu - (1 + \alpha)]_{25} S_{25}}{\nu_{25} N_{25}(0)}$$

hence,

$$(8) \quad \frac{(dN_{25}/dk)_R}{(dN_{25}/dk)_0} = \frac{N_{25}(R)}{N_{25}(0)} \left\{ \frac{(\nu - 1 - \alpha)_{25} S_{25}}{[(\nu - 1 - \alpha)S]_{25} - [(\nu - 1 - \alpha)S]_{49} R} \right\}$$

or

$$= \frac{(\nu - 1 - \alpha)_{25}^2 S_{25}}{[\nu_{25} - (1 + \alpha)_{25} (1 + R)] \{ [(\nu - 1 - \alpha)S]_{25} - [(\nu - 1 - \alpha)S]_{49} R \}}$$

This relationship will apply to U-233 conversion if $[(\lambda - 1 - \alpha)S]_{49}$ is replaced by $[(\lambda - 1 - \alpha)S]_{23}$. It is clear that for a given R the longest period is obtained when this quantity is large. The following tabulation of constants shows that for a fixed reactivity change Pu-249 conversion gives much greater burnup than U-233 conversion.

	$\lambda - 1 - \alpha$	S_f (barns)	$(\lambda - 1 - \alpha)S_f$ (barns)
U-233	1.51	518	780
Pu-249	1.5	950	1425
U-235	1.32	568	755

When the constants from this table are applied to the Pu-249 conversion case, relation 8 becomes:

$$(8') \quad \frac{(dN_{25}/dk)_R}{(dN_{25}/dk)_0} = \frac{1}{1 - 2.78 R + 1.68 R^2}$$

This relation is tabulated as follows:

R	$(dN/dk)_R / (dN/dk)_0$
-	-
0	1
.1	1.36
.2	1.93
.3	3.06
.4	5.8

The relation between R and fuel inventory, equation (6), is also tabulated:

R	(N/N_0)
-	-
0	1
.1	1.09
.3	1.36
.5	1.81
.7	2.64

The simultaneous relationship between reactor life and fuel inventory is given in the accompanying graph.

~~SECURITY INFORMATION~~

It is concluded from this graph that with a thermal reactor, a substantial increase in the reloading period can be obtained with only a modest increase of U-235 inventory.

END

~~SECURITY INFORMATION~~

198-7