UNCLASSIFIED

APAE-MEMO-13

Dated: March 28, 1956

APPR-1 AXIAL NON-UNIFORM BURN-UP - INITIAL STUDIES

By

F. B. Fairbanks

Photostat Price \$ 4.80

Microfilm Price \$ 2.70

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

CLASSIFICATION CANCELLED

DATE MAR 9 1957

For The Atomic Energy Commission

H. F. Canale
Chief, Declassification Branch

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.

COPY

1
2
3
4
5
6
7
8
9
10-13

UNCLASSIFIED

1 6494

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, 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. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

Schenectady - March 28, 1956

~~CONFIDENTIAL~~

APPR-1 AXIAL NON-UNIFORM BURNUP-INITIAL STUDIES

1. Calculations.

The method used for these calculations is modified 2-group using the adjusted age theory described in AP-Memo 5, page 3. Some calculations have also been done with a straight 2-group theory without fast multiplication or resonance capture. The calculations were performed on the IBM 650 in Dunkirk, using programs 20 and 21 for 10 axial regions. This program will be described in a separate memorandum.

The reactor is assumed to have 20.4 volume % steel. The steel has a density of 7.86 and a composition of 18% chromium, 8% nickel, and 72% iron by weight. The water is assumed to have 79.6 volume % with a density 0.8258 at a temperature of 450°F.

Microscopic cross sections were found by averaging over a Maxwellian at 450°F using data from BNL 325.

The resonance microscopic cross sections were obtained from BNL 325 for 42 lethargy intervals from lethargy 10.8 to 19.2, with uniform lethargy intervals of 0.2.

The self-shielding factor, using the formulation given in AP-Memo 5, page 7, was included by decreasing the concentration of uranium, boron-10, and fission products, and by decreasing half of the concentration of stainless steel components.

Two sets of calculations were done - the first, designated in this report as Loading 1, contained 23.75 kg, U-235 and 25 grams boron-10. This loading did not give adequate operational flexibility at startup. Loading 2 contained 25.75 kg, U-235 and 25 grams boron-10.

~~CONFIDENTIAL~~

486-002

DECLASSIFIED

~~CONFIDENTIAL~~

-2-

The assumed uniform poison to represent the control rods was taken as 0.045 cm^{-1} for the loading 1 calculation. This was evaluated from critical experiment data and is approximately equivalent to 4 rods. For loading 2, a uniform poison of 0.06 was estimated for 5 rods.

2. Results.

Figure 1 shows the control rod position versus reactor lifetime for the two loadings calculated. The rod position number shown on the curve corresponds to an axial distance of 0.997857 cm. Point 22 is at the top of the core and point 78 is at the bottom.

Figures 2 through 5 show the relative concentrations of U-235 and boron-10 averaged over the 7 core regions as a function of average uranium burned.

Figures 2 and 3 are for the 23.75 kg loadings, and Figures 4 and 5, for the 25.75 kg.

Figure 6 compares the results of modified and straight 2 group theory for the initial loading 1. Points on this curve also indicate points calculated by an analytical 2-group calculation, using the same parameters.

Figures 7 and 8 show the modified 2-group fluxes for two cases of the Loading 1 calculation.

Table 1 shows the variation at axial peak to average power over the reactor life.

3. Analysis of Results.

The results indicate that at 15% average burnup the flux shape and reactivity do not vary appreciably from that given by the uniform analysis. This conclusion has also been found by WAPD.

~~CONFIDENTIAL~~

486-003

DECLASSIFIED

~~CONFIDENTIAL~~

-3-

There is a problem in the use of the window shade technique to represent the control rods of the APPR-1. As the window shade technique was originally proposed, it was for a reactor with a large number of fairly uniformly distributed control rods which did not displace uranium from the core as they moved. In the APPR the rods are not too uniformly distributed throughout the core. The rods replace fuel with poison, and fuel is shifted to other regions in the reactor. Also, in the result summarized in this memorandum, no account is taken of radial nonuniformity. There is some evidence that this may be of greater importance than the non-uniform axial burnup.

The table below shows the initial worth of the control rods and the excess multiplication overcome by the rods at their initial position:

	<u>Initial Multiplication with Rods Out</u>	<u>Initial Worth of Rods (Hot)</u>
Loading 1	0 %	14.3%
Loading 2	2.95 %	17.7%

The following table shows the expected lifetime for the two loadings:

	<u>Lifetime to same Control Rod Position Mw-yrs</u>	<u>Lifetime to Same Reactivity Control by Rods Mw-yrs</u>
Loading #1 Uniform	15.4	15.4
Loading #1 Non-uniform	13.4	13.4
Loading #2 Uniform	15.1	-
Loading #2 Non-uniform	12.8	13.9

~~CONFIDENTIAL~~

486 004

DECLASSIFIED

CONFIDENTIAL

-4-

PEAK TO AVERAGE POWER

Loading 2

Average Uranium Burnup
Percent

Axial Peak to Average Power
Uniform Burnup Non-uniform Burnup

0	1.342	1.342
4	-	1.381
8	-	1.395
12	1.412	1.404
16	-	1.403
20	-	1.381
24	-	1.347
28	1.411	1.300
32	1.379	1.257

CONFIDENTIAL

486 005

DECLASSIFIED

~~CONFIDENTIAL~~

4. Calculation Data.

The following table shows the calculations which have been made for this memorandum. These data are available on program output sheets. A memorandum for interpretation of these data is under preparation.

	<u>Input Data Listing</u>	<u>Line No.</u>	<u>K</u>	<u>Final Control Rod Position</u>
Loading #1	0 % uniform	* 1	.99961	22
	0 % uniform (Control rod at 76)	* 2	.857	76
	0 %	* 3	.99932	22
	4 %	* 4	.99854	37
	8 %	* 5	1.00226	40
	12 %	* 6	1.00373	41
	12 % uniform	08	1.00170	42
	16 %	* 7	.99847	42
	20 %	* 8	1.00298	38
	24 %	01	.99788	35
	28 %	02	1.00006	22
	28 % uniform	06	.99945	35
Loading #2	0 % uniform	10	.99749	40
	0 % uniform (Control rod at 22)	14	1.02953	22
	0 % uniform (Control rod at 76)	21	.85218	76
	4 %	11	.99746	45
	8 %	12	1.00333	46
	12 %	13	1.00099	47
	12 % (Control rod at 22)	35	1.06571	22
	12 % uniform	23	1.00073	47
	16 %	15	.99613	47
	20 %	16	.99592	45
	24 %	17	.99835	41
	24 % (Control rod at 22)	34	1.04194	22
	28 %	18	.99763	36
	28 % (Control rod at 22)	33	1.02429	22
	28 % uniform	20	.99649	42
	32 %	36	.99990	26
	32 % uniform	37	.99670	38

A slight error has been found in the calculation of the resonance escape probability. This comparison is indicated in Lines 101 and 105 with the proper calculation in Line 105. The error in the resonance escape probability is less than 0.20 %, and this error should have a very small effect on the validity of these calculations.

It has been found that the Xenon concentration in all of the above calculations is too small as the source term is based on only that part of the power resulting from thermal fission. On the average, it may be expected that the xenon poisoning is about 75% of the proper figure.

486 - 006

~~CONFIDENTIAL~~

CONFIDENTIAL

6

FIG 1

EE 1-20-55
 486 - 007

CONFIDENTIAL

NO. 340. M. DIETZEN (GRAPH P)
 MILLIMETER
 EUGENE DIETZEN CO.
 PRINTED IN U. S. A.

CONFIDENTIAL

RELATIVE U235 CONCENTRATION
AS A FUNCTION OF REGION FOR
DIFFERENT PERCENTAGE BURNUP

IBM 450 CALCULATION
LOADING 23.75 KG U

EUGENE DIETZGEN CO.
PRINTED IN U.S.A.

NO. 340 M DIETZGEN GRAPH PA
MILLIMETER

RELATIVE CONCENTRATION

AVG 0

4

8

12

16

20

24

28

% BURNUP

FIG 2

REGION

CONFIDENTIAL

486

008

RELATIVE U235 CONCENTRATION
AS A FUNCTION OF REGION FOR
DIFFERENT PERCENTAGE BURNUP

IBM 450 CALCULATION
LOADING 25.75 KG U

EUGENE DIETZGEN CO.
PRINTED IN U. S. A.
NO. 340. M DIETZGEN GRAPH P.
MILLIMETER

RELATIVE CONCENTRATION

% BURNUP

FIG 4

RELATIVE BORON CONCENTRATION
AS A FUNCTION OF REGION FOR
DIFFERENT PERCENTAGE U BURNUP

IBM 650 CALCULATION
LOADING 25.75 KG U

EUGENE DIETZGEN CO.
PRINTED IN U. S. A.
NO. 340- M DIETZGEN GRAPH P.
MILLIMETER

RELATIVE CONCENTRATION

FIG. 5

% URANIUM BURNUP

11
CONFIDENTIAL

TWO GROUP FLUX CALCULATIONS

STRAIGHT TWO GROUP (IBM 650)
MODIFIED TWO GROUP (IBM 650)
WITH RESONANCE
ABSORPTION AND
FISSION

STRAIGHT TWO GROUP (ANALYTICAL)
○ SLOW FLUX
△ FAST FLUX

U LOADING = 23.75 KG
TEMPERATURE = 450°F

12

13

486-012

14
CONFIDENTIAL

15. INTERVAL NUMBER

CORE REFLECTOR

FIG 6

UNCLASSIFIED

IBM 650 PROBLEM 20 1-14-56
0% NON-UNIFORM BURNUP
(RODS @ INTERFACE)

FIG. 7

UNCLASSIFIED

REFLECTOR INTERVAL NUMBER

CHARLES BRUNING COMPANY
CROSS SECTION 10 X 10 REFLECTOR

PRINTED IN U.S.A.

486-013

IBM 650, PROBLEM 20 1-15-56

12% NON-UNIFORM BURNUP

(RODS @ INTERVAL NO. 41)

RELATIVE FLUX (AXIAL)

FAST

THERMAL

FIG. 8

INTERVAL NUMBER

UNCLASSIFIED

REFLECTOR

486-14

24