ANL-6218
Physics and Mathematics
(TID-4500, 15th Ed.)
AEC Research and
Development Report

ARGONNE NATIONAL LABORATORY
9700 South Cass Avenue
Argonne, Illinois

CALCULATION OF HETEROGENEITY EFFECTS IN ZPR-III
FAST ASSEMBLIES USING THE DSN PROGRAM

by

D. Meneghetti and M. F. Loomis

Reactor Engineering Division

November 1960

Operated by The University of Chicago
under
Contract W-31-109-eng-38

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ABSTRACT

Reactivity changes, flux variations, and detector-response variations for ZPR-III fast critical assemblies due to variations in heterogeneities caused by various intra-drawer configurations of fuel and diluent plates and deviations of reactivities from ideal homogeneous cores are calculated as reflective boundary slab cells using the DSN⁽²⁾ Code. For these cells the calculated multiplication constants, for a given assembly plate configuration, by $N = 4, 8$, and 16 approximations successively increase such that the eigenvalues obtainable at $N = 16$ are still generally far from the limiting values at large N . This aspect makes for uncertainty especially if differences in k_{eff} values from homogeneous are desired.

I. INTRODUCTION

The mockup of a fast reactor system on the zero-power facility ZPR-III is usually carried out by using finite thicknesses of plates of, for example, enriched uranium, depleted uranium, stainless steel, aluminum, and graphite.⁽¹⁾ The number of such plates corresponding to the composition of interest are placed in some configuration relative to each other within each core drawer (see Fig. 1).

FIG. 1
CUT-AWAY VIEW OF A CORE DRAWER SHOWING
POSITIONING OF PLATES IN DRAWER

The drawers are then inserted into the honeycomb arrays which form the two halves, one of which is movable, of the critical assembly machine. A horizontal cylindrical core thus consists of a repetition of an axially parallel, vertically aligned, configuration of the plates. Vertically, the plate configurations in all higher and lower drawers are in line and, except for the stainless steel honeycomb structure and stainless steel drawer bottoms, the geometry of the composite of plates is essentially a slab. It is of interest to ascertain the reactivity changes of such assemblies with variations in plate configuration as well as the deviations of reactivity from a homogeneous arrangement.

Calculated estimates of heterogeneity effects in various ZPR-III fast assemblies have been reported by previous investigators.^(1,2) The Carlson SNG-Code^(3,4) in S_6 approximation, with both 6 and 10-neutron energy groups, was used to obtain approximate solutions to the one-dimensional neutron transport equation. It has been observed both by these investigators⁽⁵⁾ and by us that the use of the SNG-Code for these slab cell calculations often led to unsymmetrical spatial flux distributions, although the cell configuration and composition distribution are symmetrical. Because of these observations and the need for a more detailed study of the calculation of heterogeneity effects, the present study was undertaken using the more recent Carlson Discrete S_N Code (DSN).⁽⁶⁾

The results to be presented use the DSN-Code solutions to obtain the neutron spatial flux distributions, U^{235} and U^{238} fission detector responses, and multiplication constants for various plate configurations of three ZPR-III fast assemblies and a projected large U^{235} -fueled fast assembly. The calculations were carried out in S_4 , S_8 , and S_{16} approximations using three neutron energy groups having lower energy limits of 1.35 Mev, 9.12 kev, and 1.0 kev. The three ZPR-III assemblies were similar in that they have two 0.32-cm thick plates of 93% enriched U^{235} and 14 diluent plates, 0.32-cm thick, per core drawer. In the assemblies the reflectors were 30-cm thick of high-density depleted uranium.⁽¹⁾ The cores differed in that the diluent was 99.8% depleted U^{238} , 63% density aluminum, and graphite, respectively. [Assembly numbers are 22 (or 11), 23, and 14, respectively, where No. 22 is a reassembly of a previous⁽¹⁾ assembly numbered 11.] Perforations, approximately 0.95 cm in diameter, were used to reduce the aluminum plate density to 63% of its normal value. The experimental critical masses were $244^{7\cdot}$, $260^{7\cdot}$, and $136^{1\cdot}$ kg⁽⁷⁾ for the intradrawer plate configurations in which the two enriched plates per core drawer were symmetrically separated by 8, 8, and 6 diluent plates per drawer in the respective assemblies.

The intradrawer plate configurations may be varied symmetrically by varying the separation distance between the two fuel plates. The calculated reactivity effects of such changes in configuration were compared with results of analogous experimental configuration changes obtained at the ZPR-III fast facility when all drawers of the fast core were so varied.

In addition, the existence of a limited number of 0.16-cm enriched fuel plates enables sectors of the cylindrical cores in the U^{238} and aluminum diluent assemblies to be further unbunched so as to space the four 0.16-cm thick fuel plates by 1.28 cm of diluent. By extrapolation, the experimental reactivity change was obtained for a corresponding full core change which could be compared with results of calculations.

Analogous calculations are presented for a projected large U^{235} -fueled fast assembly having a spherical critical mass of about 1000 kg, assuming a reflector savings of 20 cm. The average atomic densities of the core are:

$$N^{U^{235}} = 0.0017191$$

$$N^{U^{238}} = 0.0062583$$

$$N^{Fe} = 0.020693$$

$$N^{Al} = 0.020683$$

in units of 10^{24} atoms per cm^3 . In this assembly all core materials other than those materials contained in the enriched fuel plates are homogenized. The cell periodicity for this case is larger than the drawer periodicity, and the homogenized material is considered the diluent. The assumed thickness of diluent between equally spaced 0.32-cm thick fuel plates is 7.067 cm, and half as much between equally spaced 0.16-cm thick fuel plates.

II. PROCEDURE

A schematic drawing of the cross-sectional view of a ZPR-III basic cell is shown in Fig. 2-a. The vertical outer regions, of iron, represent the composite of the stainless steel box sides, the stainless steel sides of the drawers located in the boxes, and the associated void spaces. The top and bottom iron regions represent the top and bottom stainless steel of the box associated with each drawer, the stainless steel bottom of the drawer, and associated void. The central region represents the plate region together with associated void. The following changes were made to enable infinite slab geometry cell calculations with reflective boundary conditions to be applicable:

(1) The presence of stainless steel and void at top and bottom (Fig. 2-a) rather than plate material was accounted for by decreasing the atomic densities of the plates by 0.881 in the idealized cell (see Fig. 2-b). The iron displaced at the top and bottom of the plates was then accounted for by uniformly distributing that quantity of iron throughout the plate regions in the idealized slab geometry.

FIG. 2
CROSS-SECTION VIEWS OF (a) ZPR-III BASIC CELL
AND (b) IDEALIZED SLAB CELL

(2) As an assembly contains a finite repetition of cells in the direction transverse to the plates and also finite dimensions in the directions parallel to the plates, additional, spatially uniform group absorption cross sections were assumed throughout the cell of the idealized slab cell to account for the effect of neutron leakages upon the overall group flux levels relative to each other. This leakage absorption was assumed to be $B^2/3\Sigma_{trj}$, the diffusion theory group leakage term, where B^2 is the calculated material buckling of the homogenized core and Σ_{trj} is the calculated group j macroscopic transport cross section of the homogenized core. The group leakage absorption cross sections were assumed to be identical for a given core composition regardless of the particular configuration of the plates, because overall leakage from configurations of such thin plate regions is more characteristic of average rather than regional compositions.

The three-group fast neutron cross sections used are given in Table I. Group III, though used in this study, is not necessary for the non-carbon-containing assemblies, as very little of the reactivity of these systems is due to neutrons below Group II.

The atomic densities used in the various regions of the idealized slab cell calculations are given in Table II.

The values used for material bucklings in computing the leakage absorption terms in conjunction with homogenized core transport cross sections were 0.005 cm^{-2} , 0.00303 cm^{-2} , and 0.0058 cm^{-2} , respectively, for the U^{238} , aluminum, and graphite diluent assemblies, and 0.0012 cm^{-2} for the large metal system.

Table I

THREE-GROUP FAST-NEUTRON CROSS SECTIONS (BARNs)

<u>Group</u>		<u>U²³⁵</u>	<u>U²³⁸</u>	<u>Fe</u>	<u>Al</u>	<u>C</u>
I.	ν_1	2.65	2.8	0	0	0
$\beta^1 = 0.574$	$\nu_1 \sigma_{f1}$	3.445	1.484	0	0	0
1.35 Mev $\rightarrow \infty$	$3\sigma_{tr1}$	14.1	14.1	6.3	5.4	4.8
	σ_{a1}	2.8	2.67	0.7425	0.3803	0.28
	σ_{12}	1.4	2.1	0.74	0.38	0.28
II.	ν_2	2.5	0	0	0	0
$\beta^2 = 0.426$	$\nu_2 \sigma_{f2}$	3.50	0	0	0	0
9.12 kev $\rightarrow$ 1.35 Mev	$3\sigma_{tr2}$	18.0	21.0	8.7	9.0	10.7
	σ_{a2}	1.7	0.18	0.0082	0.0044	0.06
	σ_{23}	0	0	0.0025	0.002	0.06
III.	ν_3	2.50	0	0	0	0
$\beta^3 = 0$	$\nu_3 \sigma_{f3}$	15.0	0	0	0	0
1 kev $\rightarrow$ 9.12 kev	$3\sigma_{tr3}$	57.0	60.0	22.5	4.2	13.0
	σ_{a3}	9.0	0.8	0.015	0.006	0

$$\sigma_{aj} = \sigma_{fj} + \sigma_{cj} + \sigma_{j \rightarrow j+1}$$

Table II

ATOMIC DENSITIES USED IN REGIONS OF THE SLAB CELLS

Cell Region	Atomic Density, * $\text{cm}^{-3} \times 10^{-24}$				
	U ²³⁵	U ²³⁸	Fe	Al	C
Enriched (93%) U ²³⁵ Plates	0.0394	0.00296			
Depleted (99.8%) U ²³⁸ Plates	0.000085	0.0423			
63% density Aluminum Plates				0.0335	
Graphite Plates					0.06634
Sides of Box and Drawer			0.0512		
All Plate Regions**			0.0042		
Homogenized Diluent Regions of the Large Metal System	0.0000128	0.006407	0.02144	0.02162	

*These are reduced densities to account for void, etc., in the slab idealization.

**Accounts for iron at top and bottom of the actual plates due to top and bottom of box and bottom of drawer by a uniform distribution throughout all plate regions.

III. RESULTS AND DISCUSSION

The DSN-Code solutions in slab geometry for various configurations of each assembly were obtained in the S_4 , S_8 , and S_{16} approximations. Mesh point intervals of 0.05 cm were generally employed, although in some cases smaller intervals were necessary in order to insure DSN program convergence of at least $\epsilon = 3 \times 10^{-4}$ as defined in Reference 6. The relative values of the effective multiplication factors are shown in Figs. 3 and 4. The values of k_{eff} for the homogeneous cell calculations are also shown. (These differ slightly from unity because the material bucklings used for the leakage absorptions were not precisely the homogenized cell material bucklings.) For these cells the calculated multiplication constants, for a given assembly cell configuration, by $N = 4, 8$, and 16 approximations successively, increase such that the eigenvalues obtainable at $N = 16$ are still generally far from the limiting values at large N . This especially leads to uncertainty if differences in k_{eff} values from the homogeneous case are desired. For practical comparison of calculated Δk_{eff} values between various plate configurations with corresponding experimental values, this limitation may not be as severe, because the k_{eff} versus N -approximation curves for the heterogeneous configurations generally tend to increase together and, in addition, the accuracy of the experimental Δk_{eff} values is limited by uncertainty introduced in the auxiliary calculations for the conversion of inhours to per cent. Comparison of calculational values with the experimental values of changes in reactivity with changes in heterogeneity are given in Table III. The calculated values listed are obtained from the S_{16} solutions, except when otherwise indicated. In general, the agreement is satisfactory. The case of the two 0.32-cm fuel plates separated by 14 plates of U^{238} is, however, an exception, in that one would by the analyses as presented here expect an increase in reactivity over that for the case of the two fuel plates separated by eight plates of U^{238} . The reason for the discrepancy may be the fact that, whereas as far as internal core regions are concerned, this fully separated configuration tends to bunch fuel plates in adjacent drawers and hence to increase the reactivity; however, in the peripheral core drawers, the outer fuel plates do not have these closely neighboring fuel plates and hence result in an overall reactivity decrease. This latter effect is not accounted for in the analyses.

Estimated deviations of heterogeneity from homogeneity by extrapolation of the k_{eff} versus DSN approximation are given in Table IV for plate configurations studied which most closely approximate equally spaced fuel plates of 0.64-cm, 0.32-cm, and 0.16-cm thicknesses.

Comparison of S_4 , S_8 , and S_{16} spatial distributions of the group fluxes are shown in Figs. 5, 6, and 7 for the U^{238} and aluminum diluent cells having the two 0.32-cm thick fuel plates per cell separated by 2.56 cm of diluent, and for the graphite diluent cell having fuel plates separated by 1.92 cm of diluent, respectively.

CORE DRAWER COMPOSITIONS: TWO ENRICHED URANIUM PLATES 0.32 cm THICK & FOURTEEN DILUENT PLATES 0.32 cm THICK.

○ TWO ENRICHED PLATES ADJACENT AT DRAWER CENTER.

◇ 0.64 cm SEPARATION BETWEEN THE TWO ENRICHED PLATES.

□ 2.56 cm SEPARATION BETWEEN THE TWO ENRICHED PLATES.

▽ TWO ENRICHED PLATES FULLY SEPARATED WITHIN DRAWER.

△ FOUR 0.16 cm ENRICHED PLATES SEPARATED BY 1.28 cm OF DILUENT.

FIG. 3

RELATIVE k_{eff} VALUES FOR VARIOUS FUEL PLATE SEPARATIONS WITHIN CORE DRAWER CELLS OF ZPR-III ASSEMBLIES #22 (OR 11), 23, AND 14 AS CALCULATED BY DSN CODE.

AVERAGE COMPOSITION
(FUEL & DILUENT HOMOGENIZED)

$$V_f U-235 = .0355$$

$$V_f U-238 = .2055$$

$$V_f Fe = .244$$

$$V_f Al = .302$$

FIG. 4

RELATIVE k_{eff} FOR TWO FUEL
PLATE THICKNESSES FOR A LARGE
(1,000 kg CRITICAL MASS)
SYSTEM AS CALCULATED BY THE
DSN CODE

Table III

COMPARISON OF CALCULATED AND EXPERIMENTAL CHANGES
IN k_{eff} WITH CHANGES IN FUEL-PLATE CONFIGURATION

Assembly (Primary Diluent)	Plate Configuration D = 0.32-cm diluent plate F = 0.32-cm fuel plate (F) = 0.16-cm fuel plate	Change in % k_{eff} Relative to Standard* Configuration	
		Calculated, S_{16}	Experimental, (in hours)**
22 (U^{238})	DDDDDDFFDDDDDDDD	0.4% k	0.4% k, (190.6 ih)
	DDDDDDFFDDDDDDDD	0.9	0.9 (415.3)
	D(F)DDDD(F)DDDD(F)DDDD(F)D	-0.4	-0.4 (-182.)
	FDDDDDDDDDDDDDDDD	0.3***	-0.2 (-95.8)
23 (Al)	DDDDDDFFDDDDDDDD	1.2	1.1 (468.6)
	D(F)DDDD(F)DDDD(F)DDDD(F)D	-0.5	-0.4 (-160.)
14 (Graphite)	DDDDDDFFDDDDDDDD	1.4	1.3(5) (424.)

*DDDFDDDDDDDDFFDDDD for Assemblies 22 and 23.

DDDFDDDDDDDDFFDDDD for Assembly 14.

**Experimental inhour change obtained by ZPR-III Experimental Group.⁽⁷⁾

Significant figures in % k_{eff} based on the possible estimated uncertainty range in calculated values of inhours per per cent.

***Estimate of value at S_{16} by extrapolation from calculated S_4 and S_8 values. See text for possible explanation of discrepancy between experiment and calculation for this configuration.

Table IV

DEVIATIONS IN PER CENT k_{eff} FROM HOMOGENEOUS BY
EXTRAPOLATION OF RELATIVE k_{eff}
VERSUS DSN APPROXIMATION

Assembly (Primary Diluent)	Fuel Plate Thickness		
	0.64 cm	0.32 cm	0.16 cm
22 (U^{238})	a. $1.6 \pm 0.1^*$	b. 0.8 ± 0.2	c. 0.3 ± 0.1
23 (Al)	a. 2.3 ± 0.3	b. 1.1 ± 0.3	c. 0.3 ± 0.1
14 (Graphite)	a. 2.5 ± 0.1	d. 1.2 ± 0.2	
Large Metal (Al+ Fe+ U^{238})		e. 1.3 ± 0.2	f. 0.5 ± 0.1

*Errors in all cases represent only the estimated
reliance of extrapolation to asymptotic.

aDDDDDDDDFFDDDDDDDD

bDDDFDDDDDDDDDFDDDD

cD(F)DDDD(F)DDDD(F)DDDD(F)D

dDDDDFDDDDDDDFDDDD

e7.067 cm of homogenized diluent between equally
spaced 0.32-cm enriched fuel plates.

f3.5335 cm of homogenized diluent between equally
spaced 0.16-cm enriched fuel plates.

The necessity for many angular intervals (i.e., high N) in order to insure that eigenvalue and flux shape of such thin region slab cells be sufficiently converged to the value and shape at $N \rightarrow \infty$ indicates that the neutrons traveling at very small oblique angles to the slab planes are very important in determining the flux shape. Thus, a high-order approximation is required to characterize adequately the small tangential directions. This suggests that an integral transport approach, in which the angle dependence is integrated out early in the method of solution, may be more amenable for such problems. Possibly also a tangentially more favorable division of μ -space in the DSN method may be helpful.

FIG. 7

CALCULATED GROUP FLUXES FOR ASSEMBLY 14 CELL CONFIGURATION HAVING TWO 0.32 cm FUEL PLATES SEPARATED BY 1.92 cm OF GRAPHITE DILUENT BY DSN APPROXIMATIONS: $N = 4, 8, \& 16$

The spatial distribution of the group fluxes across the various configurations of the cells as obtained by the S_{16} solutions and the corresponding calculated responses of U^{238} and U^{235} fission detectors across the cells are shown in Figs. 8 to 18. It is observed in some cases that the group fluxes do not approach the cell boundary with zero slope, as should be required by a reflective boundary condition. The reason is not readily apparent.

FIG. 8

CALCULATED DSN ($N = 16$) GROUP FLUXES & FISSION
DETECTOR RESPONSES FOR ASSEMBLY 22 CELL CONFIGURATION
HAVING TWO 0.32 cm FUEL PLATES ADJACENT

FIG. 9

CALCULATED DSN ($N = 16$) GROUP FLUXES & FISSION DETECTOR RESPONSES FOR ASSEMBLY 22 CELL CONFIGURATION HAVING TWO 0.32 cm FUEL PLATES SEPARATED BY 0.64 cm

FIG. 10

CALCULATED DSN ($N = 16$) GROUP FLUXES & FISSION DETECTOR RESPONSES FOR ASSEMBLY 22 CELL CONFIGURATION HAVING TWO 0.32 cm FUEL PLATES SEPARATED BY 2.56 cm

FIG. 11

CALCULATED DSN ($N = 16$) GROUP FLUXES & FISSION DETECTOR RESPONSES FOR ASSEMBLY 22 CELL CONFIGURATION HAVING FOUR 0.16 cm FUEL PLATES SEPARATED BY 1.28 cm

FIG. 12

CALCULATED DSN (N = 16) GROUP FLUXES & FISSION
DETECTOR RESPONSES FOR ASSEMBLY 23 CELL CONFIGURATION
HAVING TWO 0.32 cm FUEL PLATES ADJACENT

FIG. 13

CALCULATED DSN (N = 16) GROUP FLUXES & FISSION DETECTOR
RESPONSES FOR ASSEMBLY 23 CELL CONFIGURATION HAVING
TWO 0.32 cm FUEL PLATES SEPARATED BY 2.56 cm

FIG. 14

CALCULATED DSN (N = 16) GROUP FLUXES & FISSION
 DETECTOR RESPONSES FOR ASSEMBLY 23 CELL
 CONFIGURATION HAVING FOUR 0.16 cm FUEL PLATES
 SEPARATED BY 1.28 cm

FIG. 15
CALCULATED DSN (N=16) GROUP FLUXES & FISSION
DETECTOR RESPONSES FOR ASSEMBLY 14 CELL
CONFIGURATION HAVING TWO 0.32 cm FUEL
PLATES ADJACENT

FIG. 16

CALCULATED DSN ($N = 16$) GROUP FLUXES & FISSION DETECTOR RESPONSES FOR ASSEMBLY 14 CELL CONFIGURATION HAVING TWO 0.32 cm FUEL PLATES SEPARATED BY 1.92 cm

ATOMIC DENSITY (10^{24})		
U ²³⁵	U ²³⁸	Fe
.0394	.00297	.0042
.0000128	.00641	.0214

FIG. 17

CALCULATED DSN ($N = 16$) GROUP FLUXES & FISSION
DETECTOR RESPONSES FOR A LARGE U-235 - U-238
SYSTEM HAVING EQUALLY SPACED 0.32 cm FUEL
PLATES SEPARATED BY 7.04 cm OF DILUENT

FIG. 18

CALCULATED DSN ($N = 16$) GROUP FLUXES & FISSION DETECTOR RESPONSES FOR A LARGE U-235 - U-238 SYSTEM HAVING EQUALLY SPACED 0.16 cm FUEL PLATES SEPARATED BY 3.52 cm OF DILUENT

It is of interest to estimate to what extent a measurement of fission detector ratio at a given position in a cell differs from that for the corresponding homogeneous cell, and to what extent the detector ratio of the average U^{238} response divided by the average U^{235} response across a heterogeneous cell differs from that for the corresponding homogeneous cell. The calculated maximum and minimum range of values for U^{238} to U^{235} fission detector ratios deviate from the calculated homogeneous ratios by the ranges shown in Fig. 19, depending upon the location of the detectors within the cell, i.e., whether at the peak, trough, or intermediate positions. The calculated deviations of the mean U^{238} detector response divided by the mean U^{235} detector response across the various cells relative to the corresponding homogeneous ratios are shown in Fig. 20. It should be noted that the latter deviations for the case of the assemblies having U^{238} diluent are negligible, and the apparent deviations are greater than unity for the case of 0.16-cm thick fuel plates, due to limits of accuracy in the calculations.

FIG. 19

CALCULATED INTRA-DRAWER RANGE OF DEVIATION OF U-238 TO U-235 FISSION DETECTOR RATIOS FROM HOMOGENEOUS RATIO FOR THE ZPR-III ASSEMBLIES 22, 23, & 14 AND FOR A LARGE METAL SYSTEM

FIG. 20

CALCULATED DEVIATIONS FROM HOMOGENEOUS OF SPATIAL
AVERAGE U-238 FISSION DETECTOR RESPONSE TO SPATIAL
AVERAGE U-235 FISSION DETECTOR RESPONSE FOR ZPR-III
ASSEMBLIES 22, 23, & 14 AND FOR A LARGE METAL SYSTEM

ACKNOWLEDGMENT

The authors wish to thank Dr. J. K. Long for communicating experimental results prior to publication. The authors are also indebted to Mrs. Sarah M. Cavanaugh for machine computation of the DSN problems, and to Dr. R. Avery for helpful discussions.

REFERENCES

1. J. K. Long et al., Fast Neutron Power Reactor Studies with ZPR-III, Proc. of the Second United Nations Intern. Conf. on the Peaceful Uses Atomic Energy, Geneva (1958) Vol. 12, p. 119.
2. W. B. Loewenstein and D. Okrent, Fast Reactor Cell Calculations, American Nuclear Society Meeting, Paper XIII-4, Washington, D. C. (1956).
3. B. Carlson et al., Solution of the Transport Equation by the S_N Method, Proc. of the Second United Nations Intern. Conf. on the Peaceful Uses Atomic Energy, Geneva (1958) Vol. 16, p. 535
4. B. G. Carlson, Solutions of the Transport Equation by S_N Approximations, LA-1891 (1955).
5. W. B. Loewenstein, personal communication.
6. B. Carlson et al., The DSN and TDC Neutron Transport Codes, LAMS-2346 (1960).
7. J. K. Long, personal communication.