ANL-7416 Supplement 2
Mathematics and Computers
(UC-32)

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ARGONNE CODE CENTER: BENCHMARK PROBLEM BOOK

La Grange Park, Ill.
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Prepared by the
Computational Benchmark Problems Committee of the
MATHEMATICS AND COMPUTATION DIVISION
OF THE AMERICAN NUCLEAR SOCIETY

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ANL-7416 Supplement 2

This publication is the second supplement to, and revision of, ANL-7416, originally published in February 1968, with Supplement 1 issued in December 1972.

Supplemental and replacement pages contained in this publication are as follows:

PAGES TO BE INSERTED	PAGES TO BE REMOVED	COMMENT
Title page	Title page	Revised page
3-6	3-6	Revised pages
9-10	9-10	Revised page
181-618	181	Supplemental pages containing Source Situations 8 through 15 with accompanying Benchmark Problems and Benchmark Problem Solutions

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PREFACE

This book is an outgrowth of activities of the Computational Benchmark Problems Committee of the Mathematics and Computation Division of the American Nuclear Society. This is the second supplement of the original benchmark book which was first published in February, 1968 and contained computational benchmark problems in four different areas. Supplement No. 1, which was published in December, 1972, contained corrections to the original benchmark book plus additional problems in three new areas. The current supplement, Supplement No. 2, contains problems in eight additional new areas.

The objectives of computational benchmark work and the procedures used by the committee in pursuing the objectives are outlined in the original edition of the benchmark book (ANL-7416, February, 1968). The members of the committee who have made contributions to Supplement No. 2 are listed below followed by the contributors to the earlier editions of the benchmark book.

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Constraints

Boundary conditions

Approximations and simplifications

3. Configuration

Description

Reduction from source situation, if applicable

Sketch

4. Data

5. Specific Problems of Interest

Reference problem

Other problems

6. Expected Results

Primary results

Auxiliary results

7. Summary of Available Solutions

Most accurate known solution with the estimated accuracy

Other solutions

8. Documentation of Solutions

References

Sufficient data on techniques to enable duplication of results

Computer characteristics, including essential hardware and software data for the program with which the problem was solved, and significant figures carried in the computation

Solution details

Rigid adherence to any form might hinder rather than aid the specification of benchmark problems. For this reason, format guidelines rather than standard forms have been presented for general use.

IV. BENCHMARK PROBLEMS

Source Situations

1. Small Spherical Critical Experiment
2. A High-temperature Gas-cooled Reactor Configuration
3. An Analytical Two-dimensional Multigroup Diffusion Problem
4. A Simple Highly Nonseparable Reactor
5. Two-dimensional Isolated Source in an Absorbing Medium
6. Infinite Slab Reactor Model
7. Monoenergetic Point Reactor Model
8. Two-dimensional (R-z) Reactor Model
9. Multi-dimensional (Hex-z) HTGR Model
10. PWR Thermal Hydraulics--Flow Between Two Channels With Different Heat Fluxes
11. Multi-dimensional (x-y-z) LWR Model
12. Neutron Transport in a Cylindrical 'Black' Rod
13. Neutron Transport in a BWR Rod Bundle
14. Multi-dimensional (x-y-z) BWR Model
15. Neutronic Depletion Benchmark Problems

BENCHMARK PROBLEM SOLUTION

Identification: 7-A2-2 Benchmark Problem ID.7-A2

Date Submitted: May 1971 By: W. H. Köhler and R. T. Perry (Texas A&M) (Name and Organization)

Date Accepted: January 1973 By: D. A. Meneley (Ontario Hydro) (Name and Organization)

Descriptive Title: AIREK3[1] Finite-difference Solution with Constant Heat Removal

Mathematical Model: See Ref. 1.

Pertinent Features of Solution Methods: See Solution ID.7-A1-3

Computer: IBM 360/65 Date Solved: May 1971

at: Texas A&M

Program: AIREK3

Reference

1. L. R. Blue and M. Hoffman, Generalized Program for the Numerical Solution of Space Independent Reactor Kinetics Equations, Atomics International Document AMTD-131 (1963).

Results

Period of power density oscillation = 0.817 sec

Maximum power density = 6558 w/cm^3

Temperature rise per period = 408.07°C

BENCHMARK SOURCE SITUATION

Identification: 8

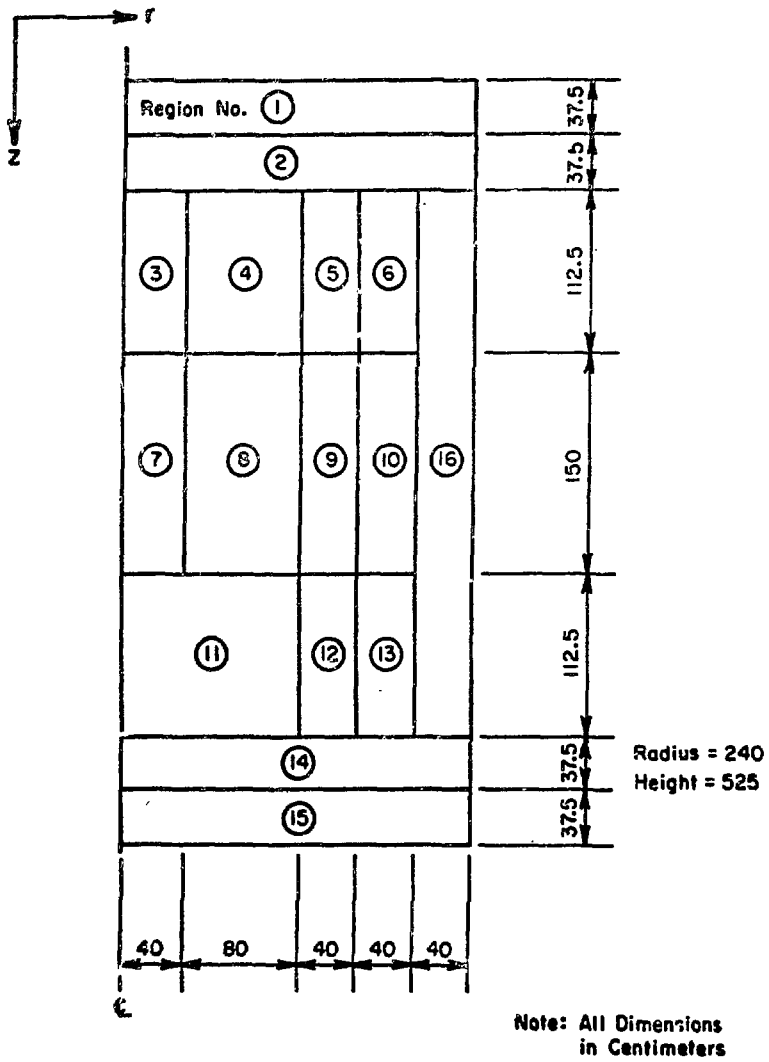
Date Submitted: January 1973 By: H. L. Dodds, Jr. (U. of Tenn.)

Date Adopted: June 1977 By: E. L. Fuller (EPRI)
W. Werner (GRS-Munich)

Descriptive Title: *Two-Dimensional (R-z) Reactor Model*

Suggested Function: Test two-dimensional neutron kinetics solutions

Reactor Configuration:



BENCHMARK PROBLEM

Identification:	8-A1	Source Situation	ID.8
Date Submitted:	January 1973	By:	H. L. Dodds, Jr. (U. of Tenn.)
Date Accepted:	June 1977	By:	E. L. Fuller (EPRI) W. Werner (GRS-Munich)
Descriptive Title:	*Delayed Supercritical Transient; Two-Dimensional, Two-Group Neutron Diffusion Problem in Thermal Reactor*		

Reduction of Source Situation:

1. Two-dimensional (r-z), two-group diffusion theory
2. Six delayed neutron precursor groups

$$\nabla\cdot D_1(\bar{r},t)\nabla\phi_1(\bar{r},t) - \Sigma_1(\bar{r},t)\phi_1(\bar{r},t) + (1-\beta)\left[\nu\Sigma_{f_1}(\bar{r},t)\cdot \phi_1(\bar{r},t) + \nu\Sigma_{f_2}(\bar{r},t)\phi_2(\bar{r},t)\right] + S_1(\bar{r},t) + \sum_{i=1}^{6}\lambda_i C_i(\bar{r},t) = \frac{1}{V_1}\frac{\partial}{\partial t}\phi_1(\bar{r},t)$$

$$\nabla\cdot D_2(\bar{r},t)\nabla\phi_2(\bar{r},t) - \Sigma_2(\bar{r},t)\phi_2(\bar{r},t) + \Sigma_{1\to 2}(\bar{r},t)\phi_1(\bar{r},t) + S_2(\bar{r},t) = \frac{1}{V_2}\frac{\partial}{\partial t}\phi_2(\bar{r},t)$$

$$\beta^i\left[\nu\Sigma_{f_1}(\bar{r},t)\phi_1(\bar{r},t) + \nu\Sigma_{f_2}(\bar{r},t)\phi_2(\bar{r},t)\right] - \lambda_i C_i(\bar{r},t) = \frac{\partial}{\partial t}C_i(\bar{r},t),\ i=1,\ldots,6$$

with zero flux boundary conditions on external surfaces and steady state initial conditions.

Data:

Initial Two-Group Constants

Region	Group i	Di (cm)	Σ_i^* (cm^{-1})	$\nu\Sigma_{f_i}$ (cm^{-1})	$\Sigma_{1\to2}$ (cm^{-1})
1,15	1	1.0684+0	2.8-2	0	2.6-2
	2	0.32051+0	3.3-3	0	-
2,14	1	1.3495+0	1.201-2	0	1.2-2
	2	8.7032-1	1.9-2	0	-
3,4,11	1	1.3052+0	1.0475-2	1.1776-3	8.0351-3
	2	8.8857-1	1.3063-2	1.3268-2	-
5,12	1	1.3052+0	1.0475-2	1.1776-3	8.0351-3
	2	8.8857-1	1.2623-2	1.3268-2	-
6,13	1	1.3052+0	1.0475-2	1.1776-3	8.0351-3
	2	8.8857-1	1.2183-2	1.3268-2	-
7,8	1	1.3052+0	1.0475-2	1.1776-3	8.0351-3
	2	8.8857-1	1.3453-2	1.3268-2	-
9	1	1.3052+0	1.0475-2	1.1776-3	8.0351-3
	2	8.8857-1	1.2973-2	1.3268-2	-
10	1	1.3052+0	1.0475-2	1.1776-3	8.0351-3
	2	8.8857-1	1.2933-2	1.3268-2	-
16	1	1.2997+1	1.0470-2	1.2875-3	7.9061-3
	2	8.7951-1	1.3065-2	1.4246-2	-

Additional parameters for all regions are $V_1 = 10^7$ cm/sec,
$V_2 = 2.2 \times 10^5$ cm/sec,
$S_1 = S_2 = 0.0$

* $\Sigma_1 = \Sigma_{c_1} + \Sigma_{f_1} + \Sigma_{1\to2}$

$\Sigma_2 = \Sigma_{c_2} + \Sigma_{f_2}$

Additional Data:

Delayed Neutron Data

Type	β	λ (sec^{-1})
1	2.47-4	1.27-2
2	1.384-3	3.17-2
3	1.222-3	1.15-1
4	2.645-3	3.11-1
5	8.32-4	1.40+0
6	1.69-4	3.87+0

Initiating Perturbation:

In Regions 3 and 7,

$$\frac{\Sigma_2(t)}{\Sigma_2(0)} = \begin{cases} 1 + 0.03\ t, & t \leqslant 1 \\ 1.03, & t > 1 \end{cases}$$

where t = time (sec).

In Region 11,

$$\frac{\Sigma_2(t)}{\Sigma_2(0)} = \begin{cases} 1 - 0.03\ t, & t \leqslant 1 \\ 0.97, & t > 1 \end{cases}$$

The initial configuration is made critical by dividing the production cross sections by k_{eff}, and the initial precursor concentrations are in equilibrium with the initial critical flux distribution.

Expected Primary Results:

1. Total power versus time
2. Time-dependent group flux distributions

Possible Additional Results:

1. Sensitivity of solution to time-step size

2. Power density averaged over height versus radial position, i.e.,

$$\frac{\frac{1}{N}\sum_{\text{all } j}\int_{V_{ij}}(\Sigma_{f_1}\phi_1 + \Sigma_{f_2}\phi_2)dv}{\sum_{\text{all } j}\int_{V_{ij}} dv} \text{ versus } r_i$$

for i = 1,...,NPX and j = 1,...,NPY

where V_{ij} = mesh volume element ij

NPX = number of radial mesh points

NPY = number of axial mesh points

N = normalization constant (arbitrary)

3. Power density averaged over radius versus axial position, i.e.,

$$\frac{\frac{1}{N}\sum_{\text{all } i}\int_{V_{ij}}(\Sigma_{f_1}\phi_1 + \Sigma_{f_2}\phi_2)dv}{\sum_{\text{all } i}\int_{V_{ij}} dv} \text{ versus } Z_j$$

for i = 1,...,NPX and j = 1,...,NPY

Solutions:

1. Direct finite-difference method: 8-A1-1, 8-A1-3

2. Flux factorization method: 8-A1-2

BENCHMARK PROBLEM SOLUTION

Identification:	8-A1-1	Benchmark Problem ID.8-A1	
Date Submitted:	January 1973	By:	H. L. Dodds, Jr. (U. of Tenn.)
Date Accepted:	June 1977	By:	E. L. Fuller (EPRI) W. Werner (GRS-Munich)
Descriptive Title:	*Direct Finite-Difference Solution with TWØDTA*[1,2]		

Mathematical Model: A 5-point difference approximation with mesh points located at mesh interval boundaries is used for the leakage operator in the neutron diffusion equations[2]. The time dependence is approximated by backward differences.

Computer: IBM-360, Model 195

Code: TWØDTA[1] (single-precision)

Date Solved: January 1973 at Savannah River Laboratory

References:

1. H. L. Dodds, J. W. Stewart, and C. E. Bailey, "Comparison of the Quasistatic and Direct Methods for Two-Dimensional Thermal Reactor Dynamics," *Trans. Am. Nucl. Soc.* *15*(2), 786 (1972).

2. Y. B. Yasinsky, M. Natelson, and L. A. Hageman, *TWIGL -- A Program to Solve the Two-Dimensional, Two-Group, Space-Time Neutron Diffusion Equations with Temperature Feedback*, WAPD-TM-743, Bettis Atomic Power Laboratory (1968).

Results: This solution as well as solutions 8-A1-2 and 8-A1-3 are for a fixed spatial mesh (Δr = 8 cm, 30 intervals and ΔZ = 18.75 cm, 28 intervals). However, different size time steps were used in order to evaluate the temporal discretization error.

Initial k_{eff} = 0.866901.

Although the value of k_{eff} resulting from solution of the eigenvalue problem is 0.867053, the value of k_{eff} actually used in the transient calculation to divide the production cross sections is 0.866901, which is determined by requiring that the unperturbed reactor exhibit a steady state transient behavior.

Exhibit A: Total power (relative to initial value) versus time as a function of Δt.

Exhibit B: Group 1 and Group 2 relative flux distributions at 0.0, 1.0, and 4.0 sec for Δt = 0.001 sec. Zero flux values on the external surfaces are not tabulated.

Exhibit C: Power density averaged over height versus radial position, i.e.,

$$\frac{\frac{1}{N}\sum_{\text{all } j}\int_{V_{ij}}(\Sigma_{f_1}\phi_1 + \Sigma_{f_2}\phi_2)dv}{\sum_{\text{all } j}\int_{V_{ij}} dv} \text{ versus } r_i$$

for i = 1,...,NPX and j = 1,...,NPY

where V_{ij} = mesh volume element ij

NPX = number of radial mesh points

NPY = number of axial mesh points

N = normalization constant (arbitrary)

Exhibit D: Power density averaged over radius versus axial position, i.e.,

$$\frac{\frac{1}{N}\sum_{\text{all } i}\int_{V_{ij}} (\Sigma_{f_1}\phi_1 + \Sigma_{f_2}\phi_2)dv}{\sum_{\text{all } i}\int_{V_{ij}} dv} \text{ versus } Z_j$$

for i = 1,...,NPX and j = 1,...,NPY

Exhibit E: Plot of data presented in Exhibit C.

Exhibit F: Plot of data presented in Exhibit D.

EXHIBIT A

Total Power Versus Time as Function of Time-Step Size

Time (sec)	Δt (sec) 0.001	0.005	0.05	0.2	0.5	1.0
0	1.000	1.000	1.000	1.000	1.000	1.0
0.2	1.039	1.038	1.040	1.043		
0.4	1.108	1.107	1.110	1.113		
0.6	1.209	1.209	1.211	1.217		
0.8	1.360	1.359	1.364	1.373		
1.0	1.596	1.595	1.604	1.623	1.661	1.723
1.2	1.752	1.750	1.749	1.744		
1.4	1.828	1.825	1.828	1.826		
1.6	1.895	1.892	1.895	1.896		
1.8	1.960	1.957	1.960	1.961		
2.0	2.027	2.020	2.023	2.025	2.037	2.078
3.0	2.335	2.329	2.336	2.338	2.351	2.393
4.0	2.659	2.652	2.660	2.663	2.678	2.724
CPU* Time (sec)	3057	727	219	110	85	62

* IBM-360, Model 195

EXHIBIT B

Relative Flux in Group 1 at Time = 0.0 sec

Radial Mesh Point Number

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00										
2	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00										
3	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.01	0.01	0.00										
4	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.19	0.18
	0.18	0.17	0.15	0.14	0.12	0.11	0.09	0.07	0.04	0.02										
5	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.63	0.63	0.61	0.59
	0.57	0.54	0.50	0.45	0.40	0.34	0.28	0.21	0.14	0.07										
6	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.03	1.03	1.03	1.03	1.03	1.02	1.01	0.99	0.96
	0.92	0.87	0.80	0.73	0.64	0.55	0.45	0.34	0.23	0.11										
7	1.35	1.35	1.35	1.35	1.35	1.35	1.35	1.35	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.35	1.33	1.30	1.26
	1.21	1.14	1.06	0.96	0.85	0.73	0.60	0.45	0.30	0.15										
8	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.60	1.58	1.54	1.49
	1.43	1.35	1.25	1.13	1.00	0.86	0.70	0.53	0.36	0.18										
9	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.77	1.76	1.73	1.69	1.64
	1.57	1.48	1.37	1.24	1.09	0.94	0.77	0.58	0.39	0.19										
10	1.86	1.86	1.86	1.86	1.86	1.86	1.86	1.86	1.86	1.86	1.86	1.86	1.86	1.85	1.85	1.85	1.83	1.80	1.75	1.69
	1.61	1.51	1.40	1.26	1.12	0.97	0.80	0.61	0.41	0.20										
11	1.89	1.89	1.89	1.89	1.89	1.89	1.89	1.89	1.89	1.88	1.88	1.88	1.88	1.88	1.87	1.86	1.84	1.81	1.76	1.69
	1.60	1.50	1.38	1.25	1.11	0.96	0.80	0.61	0.41	0.20										
12	1.91	1.91	1.91	1.91	1.91	1.91	1.90	1.90	1.90	1.90	1.90	1.89	1.89	1.89	1.88	1.87	1.85	1.81	1.76	1.69
	1.60	1.50	1.38	1.25	1.11	0.96	0.80	0.61	0.41	0.20										
13	1.92	1.92	1.92	1.92	1.91	1.91	1.91	1.91	1.91	1.91	1.90	1.90	1.90	1.89	1.88	1.87	1.85	1.82	1.76	1.69
	1.60	1.49	1.37	1.24	1.10	0.96	0.79	0.61	0.41	0.20										
14	1.92	1.92	1.92	1.92	1.92	1.92	1.92	1.91	1.91	1.91	1.91	1.90	1.90	1.89	1.89	1.88	1.85	1.82	1.76	1.69
	1.60	1.49	1.37	1.24	1.10	0.96	0.79	0.61	0.41	0.20										
15	1.92	1.92	1.92	1.92	1.91	1.91	1.91	1.91	1.91	1.91	1.90	1.90	1.90	1.89	1.88	1.87	1.85	1.82	1.76	1.69
	1.60	1.49	1.37	1.24	1.10	0.96	0.79	0.61	0.41	0.20										
16	1.91	1.91	1.91	1.91	1.91	1.91	1.90	1.90	1.90	1.90	1.90	1.89	1.89	1.89	1.88	1.87	1.85	1.81	1.76	1.69
	1.60	1.50	1.38	1.25	1.11	0.96	0.80	0.61	0.41	0.20										
17	1.89	1.89	1.89	1.89	1.89	1.89	1.89	1.89	1.89	1.88	1.88	1.88	1.88	1.88	1.87	1.86	1.84	1.81	1.76	1.69
	1.60	1.50	1.38	1.25	1.11	0.96	0.80	0.61	0.41	0.20										
18	1.86	1.86	1.86	1.86	1.86	1.86	1.86	1.86	1.86	1.86	1.86	1.86	1.86	1.85	1.85	1.85	1.83	1.80	1.75	1.69
	1.61	1.51	1.40	1.26	1.12	0.97	0.80	0.61	0.41	0.20										
19	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.77	1.76	1.73	1.69	1.64
	1.57	1.48	1.37	1.24	1.09	0.94	0.77	0.58	0.39	0.19										
20	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.60	1.58	1.54	1.49
	1.43	1.35	1.25	1.13	1.00	0.86	0.70	0.53	0.36	0.18										
21	1.35	1.35	1.35	1.35	1.35	1.35	1.35	1.35	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.35	1.33	1.30	1.26
	1.21	1.14	1.06	0.96	0.85	0.73	0.60	0.45	0.30	0.15										
22	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.03	1.03	1.03	1.03	1.03	1.02	1.01	0.99	0.96
	0.92	0.87	0.80	0.73	0.64	0.55	0.45	0.34	0.23	0.11										
23	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.63	0.63	0.61	0.59
	0.57	0.54	0.50	0.45	0.40	0.34	0.28	0.21	0.14	0.07										
24	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.19	0.18
	0.18	0.17	0.15	0.14	0.12	0.11	0.09	0.07	0.04	0.02										
25	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.01	0.01	0.00										
26	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00										
27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00										

EXHIBIT B (Continued)

Relative Flux in Group 2 at Time = 0.0 sec

Radial Mesh Point Number

Axial Mesh Point Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00										
2	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00										
3	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.03
	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.01	0.01	0.00										
4	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.14	0.14
	0.13	0.13	0.12	0.10	0.09	0.08	0.06	0.05	0.03	0.02										
5	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.40	0.39	0.38	0.37
	0.36	0.34	0.32	0.29	0.25	0.21	0.17	0.13	0.08	0.04										
6	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.63	0.63	0.63	0.63	0.63	0.63	0.62	0.60
	0.58	0.55	0.51	0.46	0.41	0.34	0.27	0.20	0.13	0.07										
7	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.83	0.83	0.83	0.83	0.83	0.83	0.84	0.84	0.83	0.81	0.79
	0.76	0.73	0.67	0.61	0.53	0.45	0.36	0.27	0.18	0.09										
8	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.99	0.99	0.99	0.98	0.96	0.93
	0.90	0.85	0.80	0.72	0.63	0.53	0.42	0.31	0.21	0.10										
9	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.09	1.09	1.09	1.08	1.05	1.02
	0.98	0.93	0.87	0.78	0.69	0.58	0.46	0.34	0.23	0.11										
10	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.13	1.13	1.11	1.08	1.04
	1.00	0.94	0.87	0.79	0.69	0.59	0.47	0.36	0.24	0.12										
11	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.12	1.12	1.12	1.12	1.12	1.13	1.13	1.11	1.08	1.03
	0.98	0.92	0.85	0.77	0.68	0.58	0.47	0.36	0.24	0.12										
12	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.11	1.08	1.03
	0.98	0.92	0.84	0.76	0.67	0.58	0.47	0.36	0.24	0.12										
13	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.13	1.13	1.13	1.13	1.13	1.13	1.11	1.08	1.03
	0.98	0.91	0.84	0.76	0.67	0.58	0.47	0.36	0.24	0.12										
14	1.15	1.15	1.15	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.13	1.13	1.13	1.13	1.13	1.11	1.08	1.03
	0.98	0.91	0.84	0.76	0.67	0.57	0.47	0.36	0.24	0.12										
15	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.13	1.13	1.13	1.13	1.13	1.13	1.11	1.08	1.03
	0.98	0.91	0.84	0.76	0.67	0.58	0.47	0.36	0.24	0.12										
16	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.11	1.08	1.03
	0.98	0.92	0.84	0.76	0.67	0.58	0.47	0.36	0.24	0.12										
17	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.12	1.12	1.12	1.12	1.12	1.13	1.13	1.11	1.08	1.03
	0.98	0.92	0.85	0.77	0.68	0.58	0.47	0.36	0.24	0.12										
18	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.13	1.13	1.11	1.08	1.04
	1.00	0.94	0.87	0.79	0.69	0.59	0.47	0.36	0.24	0.12										
19	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.09	1.09	1.09	1.08	1.05	1.02
	0.98	0.93	0.87	0.78	0.69	0.58	0.46	0.34	0.23	0.11										
20	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.99	0.99	0.99	0.98	0.96	0.93
	0.90	0.86	0.80	0.72	0.63	0.53	0.42	0.31	0.21	0.10										
21	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.83	0.83	0.83	0.83	0.83	0.83	0.84	0.84	0.83	0.81	0.79
	0.76	0.73	0.67	0.61	0.53	0.45	0.36	0.27	0.18	0.09										
22	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.63	0.63	0.63	0.63	0.63	0.63	0.62	0.60
	0.58	0.55	0.51	0.46	0.41	0.34	0.27	0.20	0.13	0.07										
23	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.40	0.39	0.38	0.37
	0.36	0.34	0.32	0.29	0.25	0.21	0.17	0.13	0.08	0.04										
24	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.14	0.14
	0.13	0.13	0.12	0.10	0.09	0.08	0.06	0.05	0.03	0.02										
25	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.03
	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.01	0.01	0.00										
26	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00										
27	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00										

EXHIBIT B (Continued)

Relative Flux in Group 1 at Time = 1.0 sec

Radial Mesh Point Number

Axial Mesh Point Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00										
2	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00										
3	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
	0.05	0.04	0.04	0.04	0.03	0.03	0.02	0.02	0.01	0.01										
4	0.23	0.23	0.23	0.24	0.24	0.24	0.25	0.25	0.25	0.25	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.25	0.24
	0.23	0.22	0.20	0.19	0.16	0.14	0.12	0.09	0.06	0.03										
5	0.73	0.73	0.74	0.74	0.75	0.77	0.78	0.79	0.80	0.81	0.81	0.82	0.83	0.83	0.83	0.84	0.83	0.83	0.81	0.79
	0.75	0.71	0.66	0.60	0.53	0.46	0.37	0.28	0.19	0.09										
6	1.18	1.18	1.19	1.20	1.22	1.24	1.26	1.28	1.29	1.31	1.32	1.33	1.34	1.34	1.35	1.35	1.35	1.34	1.31	1.27
	1.22	1.16	1.07	0.97	0.86	0.74	0.60	0.46	0.31	0.15										
7	1.58	1.58	1.59	1.60	1.63	1.65	1.68	1.70	1.72	1.74	1.75	1.77	1.78	1.79	1.80	1.80	1.79	1.77	1.74	1.69
	1.62	1.53	1.42	1.29	1.14	0.98	0.80	0.61	0.40	0.20										
8	1.89	1.90	1.91	1.93	1.95	1.98	2.02	2.04	2.07	2.09	2.10	2.12	2.13	2.14	2.15	2.15	2.14	2.12	2.07	2.01
	1.93	1.82	1.69	1.53	1.35	1.16	0.95	0.72	0.48	0.24										
9	2.12	2.13	2.14	2.16	2.19	2.22	2.26	2.29	2.31	2.33	2.35	2.37	2.38	2.39	2.40	2.40	2.38	2.35	2.30	2.23
	2.13	2.01	1.86	1.69	1.49	1.28	1.05	0.80	0.53	0.27										
10	2.26	2.26	2.27	2.30	2.33	2.36	2.40	2.43	2.46	2.48	2.49	2.51	2.52	2.53	2.53	2.53	2.51	2.47	2.41	2.33
	2.22	2.09	1.93	1.75	1.55	1.34	1.10	0.84	0.56	0.28										
11	2.35	2.35	2.36	2.39	2.42	2.45	2.49	2.52	2.54	2.57	2.58	2.59	2.60	2.61	2.61	2.60	2.58	2.54	2.47	2.37
	2.25	2.11	1.95	1.76	1.56	1.36	1.12	0.86	0.58	0.29										
12	2.44	2.45	2.46	2.48	2.51	2.55	2.58	2.61	2.64	2.66	2.67	2.68	2.69	2.69	2.69	2.68	2.65	2.60	2.53	2.42
	2.30	2.15	1.98	1.79	1.59	1.38	1.14	0.88	0.59	0.29										
13	2.55	2.56	2.57	2.59	2.62	2.66	2.69	2.72	2.75	2.76	2.77	2.78	2.78	2.78	2.78	2.77	2.74	2.68	2.60	2.49
	2.36	2.20	2.03	1.83	1.63	1.41	1.17	0.90	0.60	0.30										
14	2.68	2.69	2.70	2.72	2.75	2.79	2.83	2.85	2.87	2.89	2.89	2.90	2.90	2.89	2.88	2.87	2.83	2.77	2.68	2.57
	2.43	2.27	2.08	1.88	1.67	1.45	1.20	0.92	0.62	0.31										
15	2.85	2.85	2.87	2.89	2.92	2.95	2.98	3.01	3.02	3.03	3.04	3.04	3.03	3.02	3.00	2.98	2.94	2.87	2.78	2.66
	2.51	2.34	2.15	1.94	1.72	1.49	1.24	0.95	0.64	0.32										
16	3.06	3.06	3.07	3.09	3.12	3.15	3.18	3.20	3.21	3.21	3.21	3.20	3.18	3.17	3.14	3.11	3.06	2.99	2.89	2.76
	2.60	2.43	2.22	2.01	1.78	1.54	1.28	0.98	0.66	0.33										
17	3.33	3.33	3.34	3.35	3.37	3.40	3.42	3.43	3.43	3.43	3.41	3.39	3.37	3.34	3.30	3.26	3.20	3.11	3.00	2.87
	2.70	2.52	2.31	2.09	1.84	1.59	1.32	1.00	0.67	0.34										
18	3.67	3.67	3.67	3.68	3.69	3.70	3.70	3.70	3.69	3.67	3.64	3.61	3.57	3.52	3.47	3.40	3.33	3.23	3.11	2.96
	2.80	2.61	2.40	2.16	1.91	1.64	1.35	1.02	0.68	0.34										
19	3.89	3.89	3.89	3.89	3.89	3.88	3.87	3.85	3.82	3.79	3.75	3.70	3.65	3.59	3.52	3.44	3.34	3.23	3.11	2.96
	2.81	2.62	2.41	2.17	1.91	1.63	1.33	1.01	0.67	0.33										
20	3.78	3.77	3.77	3.76	3.75	3.74	3.72	3.69	3.66	3.62	3.57	3.52	3.46	3.40	3.32	3.23	3.14	3.03	2.91	2.77
	2.62	2.45	2.25	2.03	1.78	1.52	1.24	0.94	0.62	0.31										
21	3.32	3.32	3.32	3.31	3.30	3.28	3.26	3.23	3.20	3.16	3.11	3.06	3.01	2.95	2.88	2.80	2.71	2.61	2.51	2.39
	2.26	2.11	1.94	1.74	1.53	1.31	1.06	0.80	0.53	0.27										
22	2.59	2.59	2.58	2.57	2.56	2.55	2.53	2.51	2.48	2.45	2.41	2.37	2.32	2.27	2.22	2.15	2.09	2.01	1.93	1.84
	1.73	1.62	1.49	1.34	1.17	1.00	0.81	0.61	0.41	0.20										
23	1.63	1.63	1.63	1.62	1.62	1.61	1.59	1.58	1.56	1.54	1.52	1.49	1.46	1.43	1.39	1.35	1.31	1.26	1.21	1.15
	1.08	1.01	0.93	0.83	0.73	0.62	0.51	0.38	0.26	0.13										
24	0.52	0.52	0.51	0.51	0.51	0.51	0.50	0.50	0.49	0.49	0.48	0.47	0.46	0.45	0.44	0.42	0.41	0.40	0.38	0.36
	0.34	0.32	0.29	0.26	0.23	0.19	0.16	0.12	0.08	0.04										
25	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.09	0.09	0.09	0.09	0.08	0.08	0.08	0.08	0.07
	0.07	0.06	0.06	0.05	0.04	0.04	0.03	0.02	0.02	0.01										
26	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00										
27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00										

EXHIBIT B (Continued)

Relative Flux in Group 2 at Time = 1.0 sec

Radial Mesh Point Number

Axial Mesh Point Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00										
2	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00										
3	0.04	0.04	0.04	0.04	0.04	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.04
	0.04	0.04	0.04	0.03	0.03	0.03	0.02	0.02	0.01	0.01										
4	0.17	0.17	0.17	0.17	0.17	0.18	0.18	0.18	0.18	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.18
	0.18	0.17	0.15	0.14	0.12	0.10	0.08	0.06	0.04	0.02										
5	0.44	0.44	0.44	0.45	0.46	0.47	0.48	0.48	0.49	0.49	0.50	0.50	0.51	0.51	0.51	0.52	0.52	0.52	0.51	0.49
	0.48	0.46	0.42	0.38	0.34	0.28	0.22	0.17	0.11	0.06										
6	0.71	0.71	0.71	0.72	0.73	0.75	0.77	0.78	0.79	0.80	0.80	0.81	0.81	0.82	0.83	0.83	0.84	0.83	0.82	0.80
	0.77	0.73	0.68	0.62	0.54	0.45	0.36	0.27	0.18	0.09										
7	0.94	0.94	0.95	0.96	0.97	1.00	1.02	1.04	1.05	1.06	1.07	1.08	1.08	1.09	1.10	1.11	1.11	1.10	1.08	1.05
	1.02	0.97	0.90	0.82	0.72	0.60	0.48	[illegible]	0.24	0.12										
8	1.13	1.13	1.14	1.15	1.17	1.20	1.22	1.24	1.26	1.27	1.28	1.29	1.30	1.31	1.31	1.33	1.33	1.32	1.29	1.26
	1.21	1.16	1.07	0.97	0.85	0.71	0.57	0.43	0.28	0.14										
9	1.26	1.27	1.28	1.29	1.31	1.34	1.37	1.39	1.41	1.42	1.43	1.44	1.45	1.45	1.46	1.48	1.48	1.46	1.43	1.39
	1.34	1.27	1.18	1.07	0.94	0.79	0.63	0.47	0.31	0.16										
10	1.33	1.34	1.34	1.36	1.38	1.41	1.44	1.46	1.48	1.49	1.50	1.51	1.52	1.53	1.53	1.54	1.55	1.53	1.49	1.44
	1.38	1.30	1.20	1.09	0.96	0.81	0.65	0.49	0.33	0.16										
11	1.37	1.38	1.38	1.40	1.42	1.45	1.48	1.50	1.52	1.53	1.54	1.55	1.56	1.56	1.57	1.58	1.58	1.55	1.51	1.4
	1.38	1.30	1.20	1.08	0.95	0.82	0.66	0.51	0.34	0.17										
12	1.43	1.43	1.44	1.45	1.48	1.51	1.54	1.56	1.58	1.59	1.60	1.60	1.61	1.61	1.61	1.62	1.62	1.59	1.55	1.48
	1.41	1.32	1.21	1.10	0.97	0.83	0.68	0.52	0.35	0.17										
13	1.49	1.50	1.50	1.52	1.54	1.57	1.60	1.63	1.64	1.65	1.66	1.66	1.66	1.66	1.67	1.67	1.67	1.64	1.59	1.52
	1.44	1.35	1.24	1.12	0.99	0.85	0.69	0.53	0.35	0.18										
14	1.57	1.57	1.58	1.60	1.62	1.65	1.68	1.70	1.72	1.72	1.73	1.73	1.73	1.73	1.73	1.73	1.73	1.69	1.64	1.57
	1.49	1.39	1.28	1.16	1.02	0.87	0.71	0.54	0.36	0.18										
15	1.67	1.67	1.66	1.69	1.71	1.75	1.78	1.79	1.81	1.81	1.81	1.81	1.81	1.81	1.80	1.80	1.79	1.76	1.70	1.63
	1.54	1.44	1.32	1.19	1.05	0.90	0.73	0.56	0.37	0.19										
16	1.79	1.79	1.80	1.81	1.83	1.86	1.89	1.91	1.92	1.92	1.92	1.91	1.90	1.89	1.88	1.88	1.87	1.83	1.77	1.69
	1.60	1.49	1.37	1.23	1.09	0.93	0.76	0.57	0.39	0.19										
17	1.95	1.96	1.96	1.97	1.99	2.02	2.04	2.05	2.05	2.05	2.04	2.03	2.02	2.00	1.98	1.97	1.95	1.91	1.84	1.76
	1.66	1.55	1.42	1.28	1.13	0.96	0.78	0.59	0.40	0.20										
18	2.21	2.21	2.22	2.22	2.23	2.24	2.25	2.25	2.25	2.24	2.22	2.20	2.17	2.15	2.12	2.09	2.05	1.99	1.92	1.83
	1.74	1.63	1.50	1.35	1.18	1.00	0.80	0.60	0.40	0.20										
19	2.41	2.41	2.41	2.41	2.41	2.40	2.40	2.39	2.37	2.35	2.33	2.30	2.27	2.23	2.18	2.14	2.08	2.01	1.94	1.85
	1.77	1.66	1.53	1.37	1.20	1.00	0.79	0.60	0.40	0.20										
20	2.35	2.35	2.34	2.34	2.33	2.32	2.31	2.29	2.27	2.25	2.22	2.19	2.15	2.11	2.06	2.01	1.95	1.89	1.81	1.73
	1.65	1.56	1.43	1.29	1.12	0.93	0.74	0.55	0.37	0.18										
21	2.07	2.07	2.06	2.06	2.05	2.04	2.02	2.01	1.99	1.96	1.94	1.91	1.87	1.83	1.79	1.74	1.69	1.63	1.56	1.49
	1.42	1.34	1.23	1.11	0.96	0.80	0.63	0.47	0.31	0.16										
22	1.61	1.61	1.61	1.60	1.59	1.58	1.57	1.56	1.54	1.52	1.50	1.47	1.45	1.41	1.38	1.34	1.30	1.25	1.20	1.15
	1.09	1.03	0.95	0.85	0.74	0.61	0.49	0.36	0.24	0.12										
23	1.02	1.02	1.02	1.02	1.01	1.00	1.00	0.99	0.98	0.96	0.95	0.93	0.91	0.89	0.87	0.85	0.82	0.79	0.76	0.72
	0.69	0.65	0.59	0.53	0.46	0.39	0.31	0.23	0.15	0.07										
24	0.38	0.38	0.38	0.38	0.38	0.38	0.37	0.37	0.36	0.36	0.35	0.35	0.34	0.33	0.32	0.32	0.30	0.29	0.28	0.27
	0.25	0.24	0.22	0.19	0.17	0.14	0.11	0.09	0.06	0.03										
25	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.08	0.08	0.08	0.08	0.08	0.07	0.07	0.07
	0.06	0.06	0.05	0.05	0.04	0.03	0.03	0.02	0.01	0.01										
26	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02
	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.00										
27	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00										

EXHIBIT 8 (Continued)

Relative Flux in Group 1 at Time = 4.0 sec

Radial Mesh Point Number

Axial Mesh Point Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00										
2	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00										
3	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
	0.07	0.07	0.07	0.06	0.05	0.04	0.04	0.03	0.02	0.01										
4	0.37	0.38	0.38	0.38	0.39	0.39	0.40	0.40	0.41	0.41	0.41	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.41	0.39
	0.38	0.36	0.33	0.30	0.27	0.23	0.19	0.14	0.09	0.05										
5	1.18	1.18	1.19	1.20	1.22	1.24	1.26	1.27	1.29	1.30	1.31	1.32	1.33	1.34	1.35	1.35	1.35	1.33	1.31	1.27
	1.22	1.15	1.07	0.97	0.86	0.74	0.60	0.46	0.30	0.15										
6	1.91	1.91	1.92	1.94	1.97	2.00	2.03	2.06	2.09	2.11	2.13	2.14	2.16	2.17	2.18	2.19	2.18	2.16	2.12	2.06
	1.97	1.87	1.73	1.57	1.39	1.19	0.98	0.74	0.49	0.24										
7	2.54	2.55	2.56	2.59	2.63	2.67	2.71	2.75	2.78	2.81	2.84	2.86	2.88	2.89	2.91	2.91	2.90	2.87	2.81	2.73
	2.62	2.48	2.30	2.09	1.84	1.58	1.29	0.98	0.65	0.33										
8	3.06	3.07	3.09	3.12	3.16	3.21	3.26	3.31	3.35	3.38	3.41	3.43	3.45	3.47	3.48	3.49	3.48	3.43	3.36	3.26
	3.13	2.96	2.74	2.48	2.19	1.89	1.54	1.17	0.78	0.39										
9	3.44	3.45	3.47	3.50	3.55	3.61	3.66	3.71	3.76	3.79	3.82	3.84	3.86	3.88	3.89	3.89	3.88	3.82	3.74	3.62
	3.46	3.27	3.03	2.74	2.42	2.08	1.71	1.30	0.87	0.43										
10	3.67	3.68	3.70	3.74	3.79	3.85	3.91	3.96	4.00	4.03	4.06	4.09	4.10	4.12	4.12	4.12	4.10	4.03	3.93	3.79
	3.62	3.40	3.14	2.85	2.52	2.18	1.79	1.37	0.92	0.46										
11	3.83	3.84	3.86	3.90	3.95	4.01	4.07	4.12	4.16	4.20	4.22	4.24	4.26	4.27	4.27	4.26	4.23	4.15	4.04	3.88
	3.69	3.45	3.19	2.88	2.56	2.22	1.84	1.40	0.94	0.47										
12	4.01	4.02	4.04	4.08	4.13	4.19	4.25	4.30	4.34	4.37	4.39	4.41	4.42	4.42	4.42	4.40	4.36	4.28	4.15	3.98
	3.78	3.53	3.25	2.94	2.61	2.27	1.88	1.44	0.97	0.48										
13	4.22	4.22	4.25	4.28	4.33	4.39	4.45	4.50	4.54	4.57	4.59	4.60	4.60	4.60	4.59	4.57	4.52	4.43	4.29	4.11
	3.89	3.64	3.35	3.03	2.68	2.33	1.93	1.48	0.99	0.50										
14	4.46	4.47	4.49	4.53	4.58	4.64	4.70	4.74	4.78	4.80	4.81	4.82	4.81	4.81	4.79	4.76	4.70	4.60	4.45	4.26
	4.03	3.76	3.46	3.13	2.77	2.40	1.99	1.53	1.03	0.51										
15	4.76	4.77	4.79	4.83	4.88	4.94	4.99	5.03	5.06	5.07	5.08	5.07	5.06	5.04	5.02	4.98	4.91	4.80	4.64	4.43
	4.19	3.91	3.59	3.24	2.87	2.49	2.06	1.58	1.06	0.53										
16	5.14	5.15	5.17	5.20	5.25	5.30	5.35	5.38	5.39	5.40	5.39	5.37	5.35	5.32	5.28	5.22	5.14	5.01	4.84	4.62
	4.36	4.07	3.73	3.37	2.98	2.58	2.14	1.63	1.10	0.55										
17	5.63	5.63	5.65	5.67	5.71	5.75	5.78	5.80	5.80	5.79	5.76	5.73	5.68	5.63	5.57	5.49	5.39	5.25	5.06	4.82
	4.55	4.24	3.89	3.51	3.10	2.68	2.21	1.69	1.13	0.57										
18	6.24	6.24	6.25	6.26	6.27	6.29	6.29	6.28	6.26	6.23	6.18	6.12	6.05	5.97	5.87	5.76	5.63	5.46	5.25	5.01
	4.73	4.41	4.05	3.65	3.22	2.77	2.27	1.73	1.16	0.57										
19	6.64	6.64	6.64	6.66	6.63	6.61	6.59	6.56	6.51	6.45	6.38	6.30	6.21	6.10	5.98	5.83	5.67	5.48	5.27	5.02
	4.75	4.44	4.08	3.67	3.22	2.76	2.25	1.71	1.14	0.56										
20	6.46	6.46	6.45	6.44	6.42	6.39	6.35	6.30	6.25	6.18	6.10	6.01	5.90	5.78	5.65	5.50	5.34	5.15	4.94	4.71
	4.45	4.16	3.82	3.44	3.02	2.58	2.10	1.59	1.06	0.52										
21	5.70	5.70	5.69	5.67	5.65	5.61	5.58	5.53	5.47	5.40	5.33	5.24	5.14	5.03	4.90	4.77	4.62	4.45	4.27	4.06
	3.84	3.59	3.29	2.96	2.60	2.22	1.80	1.36	0.91	0.45										
22	4.44	4.44	4.43	4.42	4.40	4.37	4.34	4.29	4.25	4.19	4.13	4.05	3.97	3.88	3.79	3.68	3.56	3.43	3.28	3.13
	2.95	2.76	2.53	2.27	1.99	1.70	1.38	1.04	0.70	0.34										
23	2.81	2.80	2.80	2.79	2.77	2.76	2.73	2.71	2.67	2.64	2.60	2.55	2.50	2.44	2.38	2.31	2.23	2.15	2.06	1.96
	1.85	1.72	1.58	1.42	1.24	1.06	0.86	0.65	0.43	0.22										
24	0.89	0.89	0.88	0.88	0.88	0.87	0.86	0.85	0.84	0.83	0.82	0.80	0.79	0.77	0.75	0.73	0.70	0.67	0.65	0.61
	0.58	0.54	0.49	0.44	0.39	0.33	0.27	0.20	0.14	0.07										
25	0.18	0.18	0.18	0.18	0.18	0.17	0.17	0.17	0.17	0.17	0.16	0.16	0.16	0.15	0.15	0.14	0.14	0.13	0.13	0.12
	0.11	0.11	0.10	0.09	0.08	0.06	0.05	0.04	0.03	0.01										
26	0.03	0.03	0.03	0.03	0.03	0.03	0.07	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00										
27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00										

EXHIBIT B (Continued)

Relative Flux in Group 2 at Time = 4.0 sec

Radial Mesh Point Number

Axial Mesh Point Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00										
2	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
	0.03	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.00										
3	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.07	0.07
	0.07	0.06	0.06	0.05	0.05	0.04	0.03	0.02	0.02	0.01										
4	0.27	0.27	0.27	0.28	0.28	0.28	0.29	0.29	0.30	0.30	0.30	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.30	0.29
	0.28	0.27	0.25	0.23	0.20	0.17	0.13	0.10	0.07	0.03										
5	0.71	0.71	0.71	0.72	0.73	0.75	0.77	0.78	0.79	0.80	0.81	0.81	0.82	0.82	0.83	0.84	0.84	0.84	0.82	0.80
	0.77	0.74	0.68	0.62	0.54	0.46	0.36	0.27	0.18	0.09										
6	1.14	1.14	1.15	1.16	1.18	1.21	1.24	1.26	1.27	1.29	1.30	1.31	1.32	1.33	1.34	1.35	1.36	1.35	1.32	1.29
	1.24	1.19	1.10	1.00	0.88	0.73	0.58	0.44	0.29	0.14										
7	1.52	1.52	1.53	1.55	1.57	1.61	1.65	1.67	1.70	1.71	1.73	1.74	1.75	1.76	1.78	1.80	1.80	1.79	1.75	1.71
	1.65	1.57	1.46	1.32	1.16	0.97	0.77	0.58	0.39	0.19										
8	1.83	1.83	1.84	1.86	1.89	1.94	1.98	2.01	2.04	2.06	2.08	2.09	2.10	2.12	2.13	2.15	2.16	2.14	2.10	2.04
	1.97	1.88	1.74	1.58	1.38	1.16	0.92	0.69	0.46	0.23										
9	2.05	2.06	2.07	2.09	2.13	2.18	2.22	2.26	2.28	2.31	2.32	2.34	2.35	2.36	2.38	2.40	2.40	2.38	2.33	2.26
	2.18	2.07	1.92	1.74	1.53	1.28	1.02	0.77	0.51	0.25										
10	2.17	2.18	2.19	2.21	2.25	2.30	2.35	2.38	2.41	2.43	2.45	2.46	2.48	2.49	2.50	2.52	2.52	2.49	2.43	2.35
	2.25	2.12	1.96	1.78	1.56	1.32	1.07	0.81	0.54	0.27										
11	2.25	2.25	2.26	2.29	2.32	2.38	2.43	2.46	2.49	2.51	2.52	2.54	2.55	2.55	2.56	2.58	2.58	2.54	2.47	2.38
	2.26	2.12	1.96	1.77	1.56	1.33	1.09	0.83	0.55	0.28										
12	2.35	2.35	2.37	2.39	2.43	2.48	2.53	2.57	2.59	2.61	2.62	2.63	2.64	2.65	2.65	2.66	2.66	2.62	2.54	2.44
	2.31	2.17	1.99	1.80	1.59	1.36	1.11	0.85	0.57	0.28										
13	2.47	2.47	2.49	2.51	2.55	2.60	2.65	2.69	2.71	2.73	2.74	2.75	2.75	2.75	2.75	2.76	2.76	2.71	2.63	2.52
	2.38	2.23	2.05	1.85	1.64	1.40	1.14	0.87	0.58	0.29										
14	2.61	2.62	2.63	2.65	2.69	2.75	2.80	2.83	2.85	2.87	2.87	2.88	2.88	2.87	2.87	2.88	2.87	2.81	2.72	2.61
	2.47	2.31	2.12	1.91	1.69	1.44	1.18	0.90	0.60	0.30										
15	2.79	2.79	2.81	2.83	2.87	2.92	2.97	3.00	3.02	3.03	3.03	3.03	3.02	3.02	3.01	3.01	2.99	2.93	2.84	2.71
	2.57	2.39	2.20	1.98	1.75	1.50	1.22	0.93	0.62	0.31										
16	3.01	3.02	3.03	3.05	3.08	3.14	3.19	3.21	3.22	3.23	3.22	3.21	3.20	3.18	3.17	3.16	3.14	3.07	2.96	2.83
	2.67	2.49	2.29	2.06	1.82	1.55	1.27	0.96	0.65	0.32										
17	3.31	3.31	3.32	3.34	3.36	3.41	3.45	3.47	3.47	3.46	3.45	3.43	3.40	3.37	3.35	3.33	3.29	3.21	3.10	2.96
	2.79	2.60	2.39	2.15	1.89	1.61	1.31	0.99	0.67	0.33										
18	3.76	3.77	3.77	3.78	3.79	3.81	3.83	3.83	3.82	3.80	3.77	3.73	3.69	3.64	3.59	3.54	3.47	3.37	3.24	3.10
	2.94	2.75	2.53	2.28	1.99	1.68	1.35	1.02	0.68	0.34										
19	4.12	4.12	4.12	4.11	4.11	4.10	4.09	4.07	4.04	4.00	3.96	3.91	3.85	3.79	3.71	3.63	3.53	3.41	3.28	3.14
	2.99	2.81	2.59	2.33	2.03	1.69	1.34	1.01	0.67	0.33										
20	4.02	4.01	4.01	4.00	3.99	3.97	3.95	3.92	3.88	3.84	3.79	3.73	3.67	3.60	3.52	3.43	3.33	3.21	3.08	2.95
	2.81	2.64	2.43	2.18	1.90	1.58	1.25	0.94	0.62	0.31										
21	3.54	3.54	3.54	3.53	3.51	3.49	3.47	3.44	3.40	3.36	3.31	3.26	3.20	3.13	3.05	2.97	2.88	2.77	2.66	2.54
	2.42	2.26	2.09	1.88	1.64	1.36	1.08	0.80	0.53	0.26										
22	2.76	2.76	2.76	2.75	2.73	2.72	2.70	2.67	2.64	2.61	2.57	2.52	2.47	2.42	2.36	2.29	2.22	2.14	2.05	1.96
	1.66	1.75	1.61	1.44	1.26	1.05	0.83	0.62	0.41	0.20										
23	1.76	1.75	1.75	1.74	1.74	1.72	1.71	1.69	1.67	1.65	1.62	1.60	1.56	1.53	1.49	1.45	1.40	1.35	1.29	1.23
	1.17	1.10	1.01	0.91	0.79	0.66	0.52	0.39	0.26	0.13										
24	0.66	0.66	0.66	0.65	0.65	0.65	0.64	0.63	0.63	0.62	0.61	0.60	0.58	0.57	0.55	0.54	0.52	0.50	0.48	0.46
	0.43	0.40	0.37	0.33	0.29	0.24	0.19	0.15	0.10	0.05										
25	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.15	0.15	0.15	0.14	0.14	0.14	0.13	0.13	0.12	0.12	0.11
	0.11	0.10	0.09	0.08	0.07	0.06	0.05	0.04	0.02	0.01										
26	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.05	0.05	0.05	0.05	0.05	0.04	0.04
	0.04	0.04	0.03	0.03	0.03	0.02	0.02	0.01	0.01	0.00										
27	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00										

EXHIBIT C

Relative Power Density Averaged Over Height
Versus Radial Position*

Radius, cm.	t = 0 sec.	t = 1 sec.	t = 4 sec.
0	1.504	2.405	4.028
8	1.504	2.408	4.031
16	1.504	2.414	4.042
24	1.504	2.426	4.062
32	1.503	2.444	4.090
40	1.503	2.470	4.133
48	1.503	2.494	4.172
56	1.502	2.507	4.192
64	1.502	2.512	4.199
72	1.501	2.512	4.197
80	1.500	2.507	4.187
88	1.500	2.497	4.170
96	1.500	2.487	4.147
104	1.499	2.469	4.119
112	1.500	2.452	4.089
120	1.506	2.436	4.061
128	1.503	2.409	4.013
136	1.481	2.355	3.922
144	1.444	2.281	3.798
152	1.393	2.190	3.645
160	1.333	2.086	3.470
168	1.257	1.960	3.261
176	1.162	1.807	3.004
184	1.051	1.630	2.710
192	0.926	1.432	2.381
200	0.815	1.258	2.091
208	0.682	1.052	1.748
216	0.516	0.794	1.320
224	0.345	0.531	0.882
232	0.172	0.264	0.438
240	0.0	0.0	0.0

* $\Delta t = 0.001$ sec.

EXHIBIT D

Power Density Averaged Over Radius Versus Axial Position*

Height,** cm.	t = 0 sec.	t = 1 sec.	t = 4 sec.
0	0.0	0.0	0.0
18.75	0.0	0.0	0.0
37.50	0.0	0.0	0.0
56.25	0.0	0.0	0.0
75.00	0.117	0.153	0.247
93.75	0.645	0.843	1.362
112.50	1.035	1.358	2.195
131.25	1.367	1.802	2.917
150.00	1.619	2.151	3.488
168.75	1.777	2.385	3.877
187.50	1.822	2.412	4.046
206.25	1.815	2.520	4.123
225.00	1.816	2.582	4.244
243.75	1.817	2.659	4.394
262.50	1.817	2.752	4.570
281.25	1.817	2.859	4.774
300.00	1.816	2.984	5.007
318.75	1.815	3.128	5.273
337.50	1.822	3.313	5.605
356.25	1.776	3.390	5.753
375.00	1.619	3.196	5.437
393.75	1.367	2.765	4.713
412.50	1.035	2.130	3.635
431.25	0.645	1.341	2.291
450.00	0.117	2.442	4.171
468.75	0.0	0.0	0.0
487.50	0.0	0.0	0.0
506.25	0.0	0.0	0.0
525.00	0.0	0.0	0.0

* $\Delta t = 0.001$ sec.
** Height is measured from the top of the reactor.

EXHIBIT E

Plot of Data Presented in Exhibit C

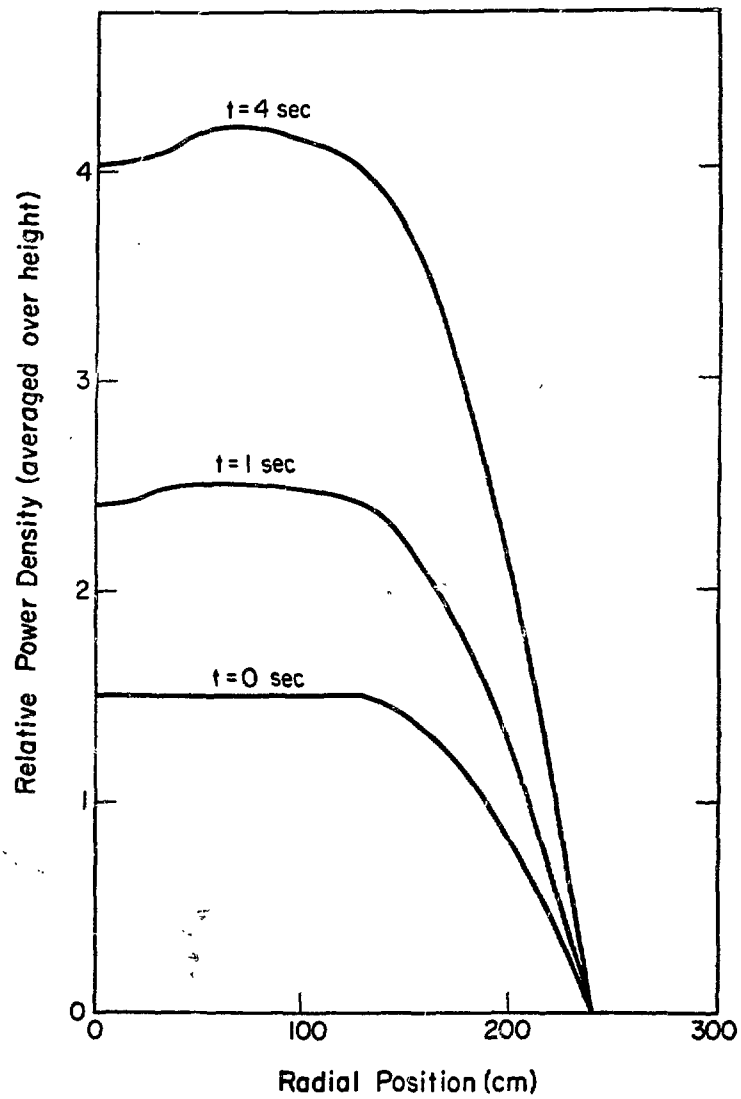
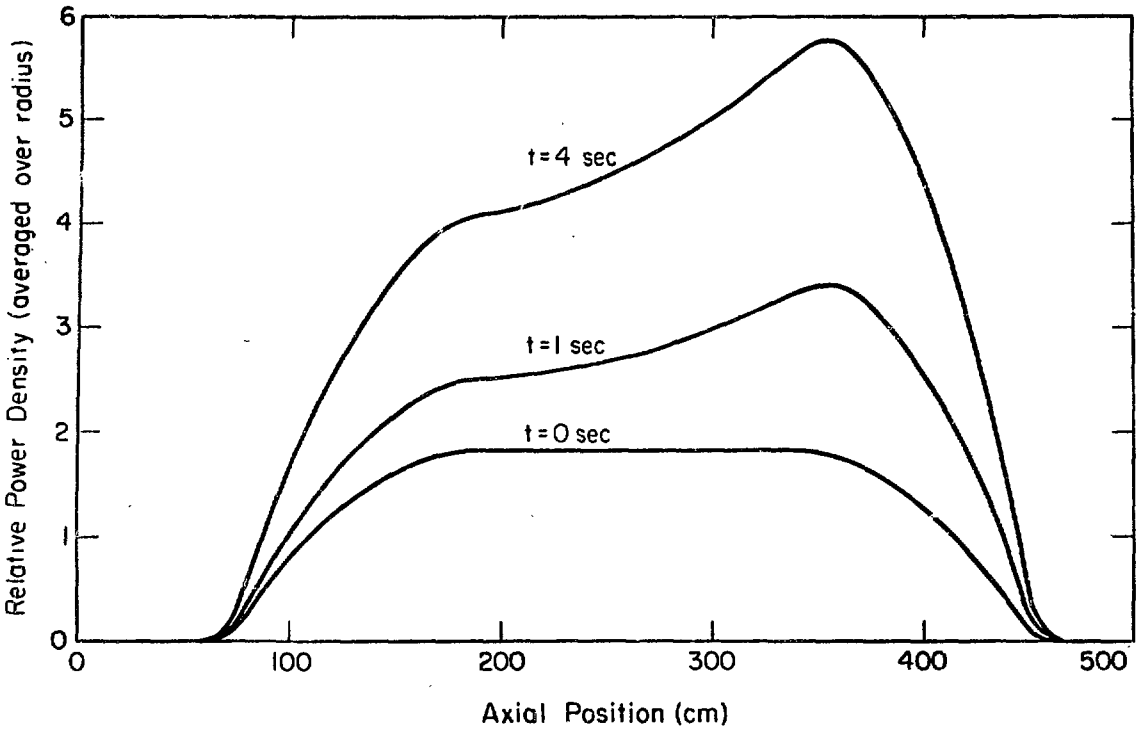


EXHIBIT F

Plot of Data Presented in Exhibit D



BENCHMARK PROBLEM SOLUTION

Identification: 8-A1-2 Benchmark Problem: ID.8-A1

Date Submitted: January 1973 By: H. L. Dodds, Jr. (U. of Tenn.)

Date Accepted: June 1977 By: E. L. Fuller (EPRI)
W. Werner (GRS-Munich)

Descriptive Title: *Flux Factorization Solution with TWØDQD.*[1]

Mathematical Model: A 5-point difference approximation with mesh points located at mesh interval boundaries is used for the leakage operator in the neutron diffusion equations. The improved quasistatic method described in Reference 2 is used to solve the time-dependent problem.

Pertinent Features of the Method: The total flux is factored into the product of a space-energy-time dependent shape function and a purely time-dependent amplitude function. The resulting set of coupled equations are solved iteratively (see Ref. 1 for details).

Computer: IBM-360, Model 195

Code: TWØDQD[1] (single precision)

Date Solved: January 1973 at Savannah River Laboratory

References:

1. H. L. Dodds, "Accuracy of the Quasistatic Method for Two-Dimensional Thermal Reactor Transients with Feedback," *Nucl. Sci. Eng.* *59*, 271 (1976).

2. D. A. Meneley, G. K. Leaf, A. J. Lindeman, T. A. Daly, and W. T. Sha, "A Kinetics Model for Fast Reactor Analysis in Two Dimensions," *Dynamics of Nuclear Systems*, pp 483-500, D. Hetrick, Ed., The University of Arizona Press, Tucson, Arizona (1972).

Results:

Uniform mesh with Δr = 8 cm (30 intervals) and Δt = 18.75 cm (28 intervals).

Initial k_{eff} = 0.866901 (taken from Benchmark Problem Solution 8-A1-1).

Exhibit A: Total power (relative to initial value) versus time as a function of Δt.

Exhibit B: Group 1 and Group 2 relative flux distributions at 0.0, 1.0, and 4.0 sec for Δt = 0.001 sec. Zero flux values on the external surfaces are not tabulated.

Exhibit C: Power density averaged over height versus radial position, i.e.,

$$\frac{\frac{1}{N}\sum_{\text{all } j}\int_{V_{ij}}(\Sigma_{f_1}\phi_1 + \Sigma_{f_2}\phi_2)dv}{\sum_{\text{all } j}\int_{V_{ij}} dv} \text{ versus } r_i$$

for i = 1,...,NPX and j = 1,...,NPY

where V_{ij} = mesh volume element ij

NPX = number of radial mesh points

NPY = number of axial mesh points

N = normalization constant (arbitrary)

Exhibit D: Power density averaged over radius versus axial position, i.e.,

$$\frac{\frac{1}{N}\sum_{\text{all } i}\int_{V_{ij}} (\Sigma_{f_1}\phi_1 + \Sigma_{f_2}\phi_2)dv}{\sum_{\text{all } i}\int_{V_{ij}} dv} \text{ versus } Z_j$$

for i = 1,...,NPX and j = 1,...,NPY

Exhibit E: Plot of data presented in Exhibit C.

Exhibit F: Plot of data presented in Exhibit D.

EXHIBIT A

Total Power Versus Time as a Function of Time-Step Size*

Time (sec)	Δt (sec) 0.001	0.005	0.05	0.2	0.5	1.0
0	1.000	1.000	1.000	1.000	1.000	1.000
0.2	1.039	1.039	1.039	1.040		
0.4	1.109	1.109	1.108	1.109		
0.6	1.210	1.210	1.210	1.210		
0.8	1.361	1.361	1.360	1.360		
1.0	1.598	1.598	1.596	1.596	1.605	1.627
1.2	1.753	1.753	1.757	1.745		
1.4	1.829	1.829	1.830	1.821		
1.6	1.896	1.896	1.895	1.888		
1.8	1.960	1.960	1.961	1.965		
2.0	2.024	2.024	2.025	2.014	2.014	2.019
3.0	2.336	2.336	2.337	2.324	2.322	2.328
4.0	2.661	2.661	2.662	2.646	2.642	2.648
CPU** Time (sec)	2898	607	93	84	70	62

* Δt is defined as the time interval between shape calculations. The time interval between inner product calculations (i.e., calculations of reactivity and generation time) is equal to 0.05 sec for the cases with $\Delta t \geq 0.05$ and is equal to Δt for the cases with $\Delta t < 0.05$. A time-step size of 0.001 sec was used for the solution of the amplitude equations in all of the above cases.

** IBM-360, Model 195.

EXHIBIT B

Relative Flux in Group 1 at Time = 0.0 sec

Radial Mesh Point Number

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00										
2	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00										
3	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.01	0.01	0.00										
4	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.19	0.18
	0.18	0.17	0.15	0.14	0.12	0.11	0.09	0.07	0.04	0.02										
5	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.64	0.64	0.54	0.64	0.64	0.64	0.64	0.63	0.63	0.61	0.59
	0.57	0.54	0.50	0.45	0.40	0.34	0.28	0.21	0.14	0.07										
6	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.03	1.03	1.03	1.03	1.03	1.02	1.01	0.99	0.96
	0.92	0.87	0.80	0.73	0.64	0.55	0.45	0.34	0.23	0.11										
7	1.35	1.35	1.35	1.35	1.35	1.35	1.35	1.35	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.35	1.33	1.30	1.26
	1.21	1.14	1.06	0.96	0.85	0.73	0.60	0.45	0.30	0.15										
8	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.60	1.58	1.54	1.49
	1.43	1.35	1.25	1.13	1.00	0.86	0.70	0.53	0.36	0.18										
9	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.77	1.76	1.73	1.69	1.64
	1.57	1.48	1.37	1.24	1.09	0.94	0.77	0.58	0.39	0.19										
10	1.86	1.86	1.86	1.86	1.86	1.86	1.86	1.86	1.86	1.86	1.86	1.86	1.86	1.85	1.85	1.85	1.83	1.80	1.75	1.69
	1.61	1.51	1.40	1.26	1.12	0.97	0.80	0.61	0.41	0.20										
11	1.89	1.89	1.89	1.89	1.89	1.89	1.89	1.89	1.89	1.88	1.88	1.88	1.88	1.88	1.87	1.86	1.84	1.81	1.76	1.69
	1.60	1.50	1.38	1.25	1.11	0.96	0.80	0.61	0.41	0.20										
12	1.91	1.91	1.91	1.91	1.91	1.91	1.90	1.90	1.90	1.90	1.90	1.89	1.89	1.89	1.88	1.87	1.85	1.81	1.76	1.69
	1.60	1.50	1.38	1.25	1.11	0.96	0.80	0.61	0.41	0.20										
13	1.92	1.92	1.92	1.92	1.91	1.91	1.91	1.91	1.91	1.91	1.90	1.90	1.90	1.89	1.88	1.87	1.85	1.82	1.76	1.69
	1.60	1.49	1.37	1.24	1.10	0.96	0.79	0.61	0.41	0.20										
14	1.92	1.92	1.92	1.92	1.92	1.92	1.92	1.91	1.91	1.91	1.91	1.90	1.90	1.89	1.89	1.88	1.85	1.82	1.76	1.69
	1.60	1.49	1.37	1.24	1.10	0.96	0.79	0.61	0.41	0.20										
15	1.92	1.92	1.92	1.92	1.91	1.91	1.91	1.91	1.91	1.91	1.90	1.90	1.90	1.89	1.88	1.87	1.85	1.82	1.76	1.69
	1.60	1.49	1.37	1.24	1.10	0.96	0.79	0.61	0.41	0.20										
16	1.91	1.91	1.91	1.91	1.91	1.91	1.90	1.90	1.90	1.90	1.90	1.89	1.89	1.89	1.88	1.87	1.85	1.81	1.76	1.69
	1.60	1.50	1.38	1.25	1.11	0.96	0.80	0.61	0.41	0.20										
17	1.89	1.89	1.89	1.89	1.89	1.89	1.89	1.89	1.89	1.88	1.88	1.88	1.88	1.88	1.87	1.86	1.84	1.81	1.76	1.69
	1.60	1.50	1.38	1.25	1.11	0.96	0.80	0.61	0.41	0.20										
18	1.86	1.86	1.86	1.86	1.86	1.86	1.86	1.86	1.86	1.86	1.86	1.86	1.86	1.85	1.85	1.85	1.83	1.80	1.75	1.69
	1.61	1.51	1.40	1.26	1.12	0.97	0.80	0.61	0.41	0.20										
19	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.77	1.76	1.73	1.69	1.64
	1.57	1.48	1.37	1.24	1.09	0.94	0.77	0.58	0.39	0.19										
20	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.60	1.58	1.54	1.49
	1.43	1.35	1.25	1.13	1.00	0.86	0.70	0.53	0.36	0.18										
21	1.35	1.35	1.35	1.35	1.35	1.35	1.35	1.35	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.35	1.33	1.30	1.26
	1.21	1.14	1.06	0.96	0.85	0.73	0.60	0.45	0.30	0.15										
22	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.03	1.03	1.03	1.03	1.03	1.02	1.01	0.99	0.96
	0.92	0.87	0.80	0.73	0.64	0.55	0.45	0.34	0.23	0.11										
23	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.63	0.63	0.61	0.59
	0.57	0.54	0.50	0.45	0.40	0.34	0.28	0.21	0.14	0.07										
24	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.19	0.18
	0.18	0.17	0.15	0.14	0.12	0.11	0.09	0.07	0.04	0.02										
25	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.01	0.01	0.00										
26	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00										
27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00										

EXHIBIT B (Continued)

Relative Flux in Group 2 at Time = 0.0 sec

Radial Mesh Point Number

Axial Mesh Point Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00										
2	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00										
3	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.03
	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.01	0.01	0.00										
4	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.14	0.14
	0.13	0.13	0.12	0.10	0.09	0.08	0.06	0.05	0.03	0.02										
5	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.40	0.39	0.38	0.37
	0.36	0.34	0.32	0.29	0.25	0.21	0.17	0.13	0.08	0.04										
6	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.63	0.63	0.63	0.63	0.63	0.63	0.62	0.60
	0.58	0.55	0.51	0.46	0.41	0.34	0.27	0.20	0.13	0.07										
7	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.83	0.83	0.83	0.83	0.83	0.83	0.84	0.84	0.83	0.81	0.79
	0.76	0.73	0.67	0.61	0.53	0.45	0.36	0.27	0.18	0.09										
8	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.99	0.99	0.99	0.98	0.96	0.93
	0.90	0.86	0.80	0.72	0.63	0.53	0.42	0.31	0.21	0.10										
9	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.09	1.09	1.09	1.08	1.05	1.02
	0.98	0.93	0.87	0.78	0.69	0.58	0.46	0.34	0.23	0.11										
10	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.13	1.13	1.11	1.08	1.04
	1.00	0.94	0.87	0.79	0.69	0.59	0.47	0.36	0.24	0.12										
11	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.12	1.12	1.12	1.12	1.12	1.13	1.13	1.11	1.08	1.03
	0.98	0.92	0.85	0.77	0.68	0.58	0.47	0.36	0.24	0.12										
12	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.11	1.08	1.03
	0.98	0.92	0.84	0.76	0.67	0.58	0.47	0.36	0.24	0.12										
13	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.13	1.13	1.13	1.13	1.13	1.13	1.11	1.08	1.03
	0.98	0.91	0.84	0.76	0.67	0.58	0.47	0.36	0.24	0.12										
14	1.15	1.15	1.15	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.13	1.13	1.13	1.13	1.13	1.11	1.08	1.03
	0.98	0.91	0.84	0.76	0.67	0.57	0.47	0.36	0.24	0.12										
15	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.13	1.13	1.13	1.13	1.13	1.13	1.11	1.08	1.03
	0.98	0.91	0.84	0.76	0.67	0.58	0.47	0.36	0.24	0.12										
16	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.11	1.08	1.03
	0.98	0.92	0.84	0.76	0.67	0.58	0.47	0.36	0.24	0.12										
17	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.12	1.12	1.12	1.12	1.12	1.13	1.13	1.11	1.08	1.03
	0.98	0.92	0.85	0.77	0.68	0.58	0.47	0.36	0.24	0.12										
18	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.13	1.13	1.11	1.08	1.04
	1.00	0.94	0.87	0.79	0.69	0.59	0.47	0.36	0.24	0.12										
19	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.09	1.09	1.09	1.08	1.05	1.02
	0.98	0.93	0.87	0.78	0.69	0.58	0.46	0.34	0.23	0.11										
20	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.99	0.99	0.99	0.98	0.96	0.93
	0.90	0.86	0.80	0.72	0.63	0.53	0.42	0.31	0.21	0.10										
21	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.83	0.83	0.83	0.83	0.83	0.83	0.84	0.84	0.83	0.81	0.79
	0.76	0.73	0.67	0.61	0.53	0.45	0.36	0.27	0.18	0.09										
22	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.63	0.63	0.63	0.63	0.63	0.63	0.62	0.60
	0.58	0.55	0.51	0.46	0.41	0.34	0.27	0.20	0.13	0.07										
23	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.40	0.39	0.38	0.37
	0.36	0.34	0.32	0.29	0.25	0.21	0.17	0.13	0.08	0.04										
24	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.14	0.14
	0.13	0.13	0.12	0.10	0.09	0.08	0.06	0.05	0.03	0.02										
25	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.03
	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.01	0.01	0.00										
26	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00										
27	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00										

EXHIBIT B (Continued)

Relative Flux in Group 1 at Time = 1.0 sec

Radial Mesh Point Number

Axial Mesh Point Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00										
2	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00										
3	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
	0.05	0.04	0.04	0.04	0.03	0.03	0.02	0.02	0.01	0.01										
4	0.23	0.23	0.23	0.24	0.24	0.24	0.25	0.25	0.25	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.25	0.24
	0.23	0.22	0.21	0.19	0.16	0.14	0.12	0.09	0.06	0.03										
5	0.73	0.73	0.74	0.75	0.76	0.77	0.78	0.79	0.80	0.81	0.82	0.82	0.83	0.83	0.84	0.84	0.84	0.83	0.81	0.79
	0.76	0.71	0.66	0.60	0.53	0.46	0.37	0.28	0.19	0.09										
6	1.18	1.19	1.19	1.21	1.22	1.24	1.26	1.28	1.29	1.31	1.32	1.33	1.34	1.35	1.35	1.36	1.35	1.34	1.31	1.27
	1.22	1.16	1.07	0.97	0.86	0.74	0.60	0.46	0.31	0.15										
7	1.58	1.58	1.59	1.61	1.63	1.65	1.68	1.70	1.72	1.74	1.76	1.77	1.78	1.79	1.80	1.80	1.80	1.78	1.74	1.69
	1.62	1.53	1.42	1.29	1.14	0.98	0.80	0.61	0.40	0.20										
8	1.89	1.90	1.91	1.93	1.95	1.99	2.02	2.05	2.07	2.09	2.11	2.12	2.13	2.14	2.15	2.15	2.15	2.12	2.08	2.01
	1.93	1.82	1.69	1.53	1.35	1.16	0.95	0.72	0.48	0.24										
9	2.12	2.13	2.14	2.16	2.19	2.22	2.26	2.29	2.32	2.35	2.35	2.37	2.38	2.39	2.40	2.40	2.39	2.36	2.30	2.23
	2.13	2.01	1.86	1.69	1.49	1.28	1.05	0.80	0.53	0.27										
10	2.26	2.26	2.28	2.30	2.33	2.36	2.40	2.43	2.46	2.48	2.50	2.51	2.52	2.53	2.53	2.53	2.52	2.48	2.41	2.33
	2.22	2.09	1.93	1.75	1.55	1.34	1.10	0.84	0.56	0.28										
11	2.35	2.35	2.37	2.39	2.42	2.46	2.49	2.52	2.55	2.57	2.58	2.60	2.60	2.61	2.61	2.61	2.59	2.54	2.47	2.37
	2.26	2.11	1.95	1.76	1.57	1.36	1.12	0.86	0.58	0.29										
12	2.44	2.45	2.46	2.48	2.51	2.55	2.59	2.62	2.64	2.66	2.67	2.68	2.69	2.69	2.69	2.68	2.66	2.61	2.53	2.43
	2.30	2.15	1.98	1.79	1.59	1.38	1.14	0.88	0.59	0.29										
13	2.55	2.56	2.57	2.59	2.63	2.66	2.70	2.73	2.75	2.77	2.78	2.78	2.79	2.79	2.78	2.77	2.74	2.68	2.60	2.49
	2.36	2.20	2.03	1.83	1.63	1.41	1.17	0.90	0.60	0.30										
14	2.69	2.69	2.71	2.73	2.76	2.79	2.83	2.86	2.88	2.89	2.90	2.90	2.90	2.90	2.89	2.87	2.83	2.77	2.68	2.57
	2.43	2.27	2.09	1.89	1.67	1.45	1.20	0.92	0.62	0.31										
15	2.85	2.86	2.87	2.89	2.92	2.95	2.99	3.01	3.03	3.04	3.04	3.04	3.03	3.02	3.01	2.98	2.94	2.88	2.78	2.66
	2.51	2.34	2.15	1.95	1.72	1.49	1.24	0.95	0.64	0.32										
16	3.06	3.06	3.08	3.09	3.12	3.15	3.18	3.20	3.21	3.21	3.21	3.20	3.19	3.17	3.15	3.12	3.07	2.99	2.89	2.76
	2.61	2.43	2.23	2.01	1.78	1.54	1.28	0.98	0.66	0.33										
17	3.33	3.33	3.34	3.36	3.38	3.40	3.42	3.43	3.44	3.43	3.42	3.40	3.37	3.34	3.30	3.26	3.20	3.12	3.01	2.87
	2.71	2.52	2.32	2.09	1.85	1.60	1.32	1.01	0.68	0.34										
18	3.67	3.67	3.68	3.69	3.69	3.70	3.71	3.70	3.69	3.67	3.65	3.61	3.57	3.53	3.47	3.41	3.33	3.23	3.11	2.97
	2.80	2.62	2.40	2.16	1.91	1.64	1.35	1.02	0.69	0.34										
19	3.90	3.90	3.90	3.89	3.89	3.88	3.87	3.85	3.83	3.79	3.76	3.71	3.65	3.59	3.52	3.44	3.35	3.24	3.11	2.97
	2.81	2.62	2.41	2.17	1.91	1.63	1.33	1.01	0.67	0.33										
20	3.78	3.78	3.77	3.77	3.76	3.74	3.72	3.69	3.66	3.62	3.58	3.53	3.47	3.40	3.32	3.24	3.14	3.03	2.91	2.78
	2.63	2.45	2.25	2.03	1.78	1.52	1.24	0.94	0.62	0.31										
21	3.33	3.33	3.32	3.31	3.30	3.28	3.26	3.23	3.20	3.16	3.12	3.07	3.01	2.95	2.88	2.80	2.71	2.62	2.51	2.39
	2.26	2.11	1.94	1.74	1.53	1.31	1.06	0.80	0.53	0.27										
22	2.59	2.59	2.58	2.58	2.57	2.55	2.53	2.51	2.48	2.45	2.41	2.37	2.33	2.28	2.22	2.16	2.09	2.01	1.93	1.84
	1.74	1.62	1.49	1.34	1.17	1.00	0.82	0.62	0.41	0.20										
23	1.63	1.63	1.63	1.62	1.62	1.61	1.59	1.58	1.56	1.54	1.52	1.49	1.46	1.43	1.39	1.35	1.31	1.26	1.21	1.15
	1.09	1.01	0.93	0.83	0.73	0.62	0.51	0.38	0.26	0.13										
24	0.52	0.52	0.51	0.51	0.51	0.51	0.50	0.50	0.49	0.49	0.48	0.47	0.46	0.45	0.44	0.43	0.41	0.40	0.38	0.36
	0.34	0.32	0.29	0.26	0.23	0.19	0.16	0.12	0.08	0.04										
25	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.09	0.09	0.09	0.09	0.08	0.08	0.08	0.08	0.07
	0.07	0.06	0.06	0.05	0.04	0.04	0.03	0.02	0.02	0.01										
26	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00										
27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00										

EXHIBIT B (Continued)

Relative Flux in Group 2 at Time = 1.0 sec

Radial Mesh Point Number

Axial Mesh Point Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00									
2	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00									
3	0.04	0.04	0.04	0.04	0.04	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
	0.04	0.04	0.04	0.03	0.03	0.03	0.02	0.02	0.01	0.01									
4	0.17	0.17	0.17	0.17	0.17	0.18	0.18	0.18	0.18	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
	0.18	0.17	0.15	0.14	0.12	0.10	0.08	0.06	0.04	0.02									
5	0.44	0.44	0.44	0.45	0.46	0.47	0.48	0.48	0.49	0.50	0.50	0.50	0.51	0.51	0.51	0.52	0.52	0.52	0.51
	0.48	0.46	0.42	0.38	0.34	0.28	0.22	0.17	0.11	0.06									
6	0.71	0.71	0.71	0.72	0.73	0.75	0.77	0.78	0.79	0.80	0.80	0.81	0.82	0.82	0.83	0.84	0.84	0.83	0.82
	0.77	0.73	0.68	0.62	0.54	0.45	0.36	0.27	0.18	0.09									
7	0.94	0.94	0.95	0.96	0.98	1.00	1.02	1.04	1.05	1.06	1.07	1.08	1.08	1.09	1.10	1.11	1.12	1.11	1.08
	1.02	0.97	0.90	0.82	0.72	0.60	0.48	0.36	0.24	0.12									
8	1.13	1.13	1.14	1.15	1.17	1.20	1.23	1.24	1.26	1.27	1.28	1.29	1.30	1.31	1.32	1.33	1.33	1.32	1.29
	1.22	1.16	1.08	0.97	0.85	0.71	0.57	0.43	0.28	0.14									
9	1.27	1.27	1.28	1.29	1.31	1.34	1.37	1.39	1.41	1.42	1.43	1.44	1.45	1.46	1.46	1.48	1.48	1.46	1.43
	1.34	1.28	1.18	1.07	0.94	0.79	0.63	0.47	0.31	0.16									
10	1.33	1.34	1.35	1.36	1.38	1.41	1.44	1.46	1.48	1.49	1.50	1.51	1.52	1.53	1.53	1.54	1.55	1.53	1.49
	1.38	1.30	1.20	1.09	0.96	0.81	0.65	0.49	0.33	0.16									
11	1.38	1.38	1.39	1.40	1.42	1.45	1.48	1.51	1.52	1.53	1.54	1.55	1.56	1.56	1.57	1.58	1.58	1.55	1.51
	1.38	1.30	1.20	1.08	0.96	0.82	0.67	0.51	0.34	0.17									
12	1.43	1.43	1.44	1.46	1.48	1.51	1.54	1.56	1.58	1.59	1.60	1.60	1.61	1.61	1.61	1.62	1.62	1.59	1.55
	1.41	1.32	1.21	1.10	0.97	0.83	0.68	0.52	0.35	0.17									
13	1.49	1.50	1.51	1.52	1.54	1.57	1.61	1.63	1.64	1.65	1.66	1.66	1.67	1.67	1.67	1.67	1.67	1.64	1.59
	1.44	1.35	1.24	1.12	0.99	0.85	0.69	0.53	0.35	0.18									
14	1.57	1.58	1.58	1.60	1.62	1.65	1.68	1.70	1.72	1.73	1.73	1.73	1.73	1.73	1.73	1.73	1.73	1.69	1.64
	1.49	1.39	1.28	1.15	1.02	0.87	0.71	0.54	0.36	0.18									
15	1.67	1.67	1.68	1.69	1.71	1.75	1.78	1.80	1.81	1.81	1.82	1.81	1.81	1.81	1.80	1.80	1.79	1.76	1.70
	1.54	1.44	1.32	1.19	1.05	0.90	0.73	0.56	0.37	0.19									
16	1.79	1.79	1.80	1.81	1.83	1.87	1.90	1.91	1.92	1.92	1.92	1.91	1.90	1.90	1.89	1.88	1.87	1.83	1.77
	1.60	1.49	1.37	1.23	1.09	0.93	0.76	0.58	0.39	0.19									
17	1.96	1.96	1.96	1.97	1.99	2.02	2.04	2.05	2.06	2.05	2.04	2.03	2.02	2.00	1.99	1.98	1.95	1.91	1.84
	1.66	1.55	1.42	1.28	1.13	0.96	0.78	0.59	0.40	0.20									
18	2.22	2.22	2.22	2.23	2.23	2.25	2.26	2.26	2.25	2.24	2.22	2.20	2.18	2.15	2.12	2.09	2.05	1.99	1.92
	1.74	1.63	1.50	1.35	1.18	1.00	0.80	0.60	0.40	0.20									
19	2.42	2.42	2.42	2.41	2.41	2.41	2.40	2.39	2.37	2.35	2.33	2.30	2.27	2.23	2.19	2.14	2.08	2.01	1.94
	1.77	1.66	1.53	1.38	1.20	1.00	0.80	0.60	0.40	0.20									
20	2.35	2.35	2.35	2.34	2.33	2.32	2.31	2.30	2.28	2.25	2.22	2.19	2.15	2.11	2.07	2.01	1.96	1.89	1.82
	1.65	1.56	1.43	1.29	1.12	0.93	0.74	0.55	0.37	0.18									
21	2.07	2.07	2.06	2.06	2.05	2.04	2.03	2.01	1.99	1.97	1.94	1.91	1.87	1.83	1.79	1.74	1.69	1.63	1.57
	1.43	1.34	1.23	1.11	0.97	0.80	0.64	0.47	0.31	0.16									
22	1.61	1.61	1.61	1.60	1.60	1.59	1.57	1.56	1.54	1.52	1.50	1.48	1.45	1.42	1.38	1.34	1.30	1.25	1.20
	1.09	1.03	0.95	0.85	0.74	0.62	0.49	0.36	0.24	0.12									
23	1.02	1.02	1.02	1.02	1.01	1.01	1.00	0.99	0.98	0.96	0.95	0.93	0.91	0.89	0.87	0.85	0.82	0.79	0.76
	0.69	0.65	0.59	0.53	0.46	0.39	0.31	0.23	0.15	0.07									
24	0.38	0.38	0.38	0.38	0.38	0.38	0.37	0.37	0.37	0.36	0.35	0.35	0.34	0.33	0.32	0.32	0.31	0.29	0.28
	0.25	0.24	0.22	0.20	0.17	0.14	0.11	0.09	0.06	0.03									
25	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.08	0.08	0.08	0.08	0.08	0.07	0.07
	0.06	0.06	0.05	0.05	0.04	0.03	0.03	0.02	0.01	0.01									
26	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.00									
27	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00									

EXHIBIT B (Continued)

Relative Flux in Group 1 at Time = 4.0 sec

Radial Mesh Point Number

Axial Mesh Point Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00										
2	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.0
	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00										
3	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.0
	0.07	0.07	0.07	0.06	0.05	0.04	0.04	0.03	0.02	0.01										
4	0.37	0.38	0.38	0.38	0.39	0.39	0.40	0.40	0.41	0.41	0.41	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.41	0.4
	0.38	0.36	0.33	0.30	0.27	0.23	0.19	0.14	0.09	0.05										
5	1.18	1.18	1.19	1.20	1.22	1.24	1.26	1.27	1.29	1.30	1.31	1.33	1.33	1.34	1.35	1.35	1.35	1.33	1.31	1.2
	1.22	1.15	1.07	0.97	0.86	0.74	0.60	0.46	0.30	0.15										
6	1.91	1.91	1.92	1.94	1.97	2.00	2.03	2.06	2.09	2.11	2.13	2.15	2.16	2.17	2.18	2.19	2.18	2.16	2.12	2.0
	1.98	1.87	1.73	1.57	1.39	1.19	0.98	0.74	0.49	0.25										
7	2.54	2.55	2.57	2.59	2.63	2.67	2.71	2.75	2.79	2.81	2.84	2.86	2.88	2.89	2.91	2.91	2.91	2.87	2.82	2.7
	2.62	2.48	2.30	2.09	1.84	1.58	1.30	0.98	0.65	0.33										
8	3.06	3.07	3.09	3.12	3.16	3.21	3.27	3.31	3.35	3.38	3.41	3.44	3.46	3.47	3.49	3.49	3.48	3.44	3.36	3.2
	3.13	2.96	2.74	2.49	2.20	1.89	1.54	1.17	0.78	0.39										
9	3.44	3.45	3.47	3.51	3.55	3.61	3.67	3.72	3.76	3.79	3.82	3.85	3.87	3.88	3.89	3.90	3.88	3.83	3.74	3.6
	3.47	3.27	3.03	2.74	2.43	2.09	1.71	1.30	0.87	0.43										
10	3.68	3.68	3.70	3.74	3.79	3.85	3.91	3.96	4.00	4.04	4.07	4.09	4.11	4.12	4.13	4.13	4.10	4.04	3.93	3.8
	3.62	3.40	3.14	2.85	2.52	2.18	1.79	1.37	0.92	0.46										
11	3.84	3.84	3.87	3.90	3.95	4.01	4.07	4.12	4.17	4.20	4.23	4.25	4.26	4.27	4.27	4.26	4.23	4.15	4.04	3.8
	3.69	3.46	3.19	2.89	2.56	2.22	1.84	1.40	0.94	0.47										
12	4.01	4.02	4.04	4.08	4.13	4.19	4.25	4.30	4.34	4.37	4.40	4.41	4.42	4.43	4.42	4.41	4.36	4.28	4.15	3.9
	3.76	3.53	3.25	2.95	2.61	2.27	1.88	1.44	0.97	0.48										
13	4.22	4.23	4.25	4.29	4.34	4.40	4.46	4.51	4.54	4.57	4.59	4.60	4.60	4.60	4.59	4.57	4.52	4.43	4.29	4.1
	3.87	3.64	3.35	3.03	2.69	2.33	1.93	1.48	1.00	0.50										
14	4.47	4.47	4.50	4.53	4.58	4.64	4.70	4.75	4.78	4.80	4.82	4.82	4.82	4.81	4.79	4.76	4.70	4.60	4.45	4.2
	4.03	3.76	3.46	3.13	2.77	2.40	1.99	1.53	1.03	0.51										
15	4.77	4.78	4.80	4.83	4.88	4.94	4.99	5.03	5.06	5.08	5.08	5.08	5.07	5.05	5.02	4.98	4.91	4.80	4.64	4.4
	4.19	3.91	3.59	3.24	2.87	2.49	2.06	1.58	1.06	0.53										
16	5.15	5.15	5.17	5.21	5.25	5.30	5.35	5.38	5.40	5.40	5.40	5.38	5.35	5.32	5.28	5.23	5.14	5.02	4.84	4.6
	4.37	4.07	3.74	3.37	2.98	2.58	2.14	1.64	1.10	0.55										
17	5.63	5.64	5.65	5.68	5.71	5.75	5.79	5.80	5.81	5.79	5.77	5.73	5.69	5.63	5.57	5.50	5.39	5.25	5.06	4.8
	4.55	4.24	3.89	3.51	3.10	2.68	2.21	1.69	1.13	0.57										
18	6.24	6.25	6.25	6.26	6.28	6.29	6.30	6.29	6.27	6.23	6.18	6.12	6.05	5.97	5.88	5.77	5.63	5.46	5.25	5.0
	4.74	4.42	4.05	3.65	3.22	2.77	2.27	1.73	1.16	0.58										
19	6.65	6.65	6.65	6.64	6.63	6.62	6.59	6.56	6.52	6.46	6.39	6.31	6.21	6.10	5.98	5.84	5.68	5.49	5.27	5.0
	4.76	4.44	4.08	3.67	3.23	2.76	2.25	1.71	1.14	0.57										
20	6.47	6.46	6.46	6.44	6.42	6.39	6.36	6.31	6.25	6.18	6.10	6.01	5.91	5.79	5.66	5.51	5.34	5.15	4.94	4.7
	4.46	4.16	3.82	3.44	3.02	2.58	2.10	1.59	1.06	0.52										
21	5.70	5.70	5.69	5.67	5.65	5.62	5.58	5.53	5.47	5.41	5.33	5.24	5.14	5.03	4.91	4.77	4.62	4.45	4.27	4.0
	3.84	3.59	3.29	2.96	2.60	2.22	1.81	1.36	0.91	0.45										
22	4.45	4.44	4.44	4.42	4.40	4.37	4.34	4.30	4.25	4.19	4.13	4.06	3.98	3.89	3.79	3.68	3.56	3.43	3.28	3.1
	2.96	2.76	2.53	2.27	1.99	1.70	1.39	1.05	0.70	0.35										
23	2.81	2.81	2.80	2.79	2.78	2.76	2.74	2.71	2.68	2.64	2.60	2.55	2.50	2.44	2.38	2.31	2.23	2.15	2.06	1.9
	1.85	1.72	1.58	1.42	1.25	1.06	0.87	0.65	0.43	0.22										
24	0.89	0.89	0.88	0.88	0.88	0.87	0.86	0.85	0.84	0.83	0.82	0.80	0.79	0.77	0.75	0.73	0.70	0.68	0.65	0.61
	0.58	0.54	0.49	0.44	0.39	0.33	0.27	0.20	0.14	0.07										
25	0.18	0.18	0.18	0.18	0.18	0.17	0.17	0.17	0.17	0.17	0.16	0.16	0.16	0.15	0.15	0.14	0.14	0.13	0.13	0.12
	0.11	0.11	0.10	0.09	0.08	0.06	0.05	0.04	0.03	0.01										
26	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00										
27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00										

EXHIBIT B (Continued)

Relative Flux in Group 2 at Time = 4.0 sec

Radial Mesh Point Number

Axial Mesh Point Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00										
2	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
	0.03	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.00										
3	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.07	0.07
	0.07	0.06	0.06	0.05	0.05	0.04	0.03	0.02	0.02	0.01										
4	0.27	0.27	0.27	0.28	0.28	0.28	0.29	0.29	0.30	0.30	0.30	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.30	0.29
	0.28	0.27	0.25	0.23	0.20	0.17	0.13	0.10	0.07	0.03										
5	0.71	0.71	0.71	0.72	0.73	0.75	0.77	0.78	0.79	0.80	0.81	0.81	0.82	0.82	0.83	0.84	0.84	0.84	0.82	0.80
	0.77	0.74	0.68	0.62	0.54	0.46	0.36	0.27	0.18	0.09										
6	1.14	1.14	1.15	1.16	1.18	1.21	1.24	1.26	1.27	1.29	1.30	1.31	1.32	1.33	1.34	1.35	1.36	1.35	1.32	1.29
	1.25	1.19	1.10	1.00	0.88	0.73	0.58	0.44	0.29	0.14										
7	1.52	1.52	1.53	1.55	1.58	1.61	1.65	1.68	1.70	1.71	1.73	1.74	1.75	1.77	1.78	1.80	1.80	1.79	1.76	1.71
	1.65	1.58	1.46	1.33	1.16	0.97	0.77	0.58	0.39	0.19										
8	1.83	1.83	1.85	1.87	1.90	1.94	1.98	2.02	2.04	2.06	2.08	2.09	2.11	2.12	2.13	2.15	2.16	2.14	2.10	2.04
	1.97	1.88	1.74	1.58	1.38	1.16	0.92	0.69	0.46	0.23										
9	2.05	2.06	2.07	2.09	2.13	2.18	2.23	2.26	2.29	2.31	2.33	2.34	2.35	2.37	2.38	2.40	2.41	2.38	2.33	2.26
	2.18	2.07	1.92	1.74	1.53	1.28	1.02	0.77	0.51	0.25										
10	2.17	2.18	2.19	2.21	2.25	2.30	2.35	2.39	2.41	2.44	2.45	2.47	2.48	2.49	2.50	2.52	2.52	2.49	2.43	2.35
	2.25	2.12	1.96	1.78	1.56	1.32	1.07	0.81	0.54	0.27										
11	2.25	2.25	2.27	2.29	2.33	2.38	2.43	2.46	2.49	2.51	2.53	2.54	2.55	2.56	2.56	2.58	2.58	2.54	2.47	2.3[illegible]
	2.26	2.12	1.96	1.77	1.56	1.34	1.09	0.83	0.55	0.28										
12	2.35	2.35	2.37	2.39	2.43	2.48	2.53	2.57	2.59	2.61	2.63	2.64	2.64	2.65	2.65	2.67	2.66	2.62	2.54	2.44
	2.32	2.17	2.00	1.80	1.59	1.36	1.11	0.85	0.57	0.28										
13	2.47	2.47	2.49	2.51	2.55	2.60	2.65	2.69	2.71	2.73	2.74	2.75	2.75	2.75	2.76	2.77	2.76	2.71	2.63	2.52
	2.39	2.23	2.05	1.85	1.64	1.40	1.14	0.87	0.58	0.29										
14	2.61	2.62	2.63	2.66	2.69	2.75	2.80	2.83	2.85	2.87	2.88	2.88	2.88	2.88	2.87	2.88	2.87	2.81	2.73	2.61
	2.47	2.31	2.12	1.92	1.69	1.45	1.18	0.90	0.60	0.30										
15	2.79	2.80	2.81	2.83	2.87	2.92	2.97	3.00	3.02	3.03	3.03	3.03	3.03	3.02	3.01	3.01	3.00	2.93	2.84	2.72
	2.57	2.40	2.20	1.99	1.75	1.50	1.22	0.93	0.62	0.31										
16	3.01	3.02	3.03	3.05	3.09	3.14	3.19	3.21	3.22	3.23	3.22	3.21	3.20	3.18	3.17	3.16	3.14	3.07	2.96	2.83
	2.68	2.49	2.29	2.06	1.82	1.55	1.27	0.96	0.65	0.32										
17	3.31	3.31	3.32	3.34	3.37	3.41	3.46	3.47	3.47	3.47	3.45	3.43	3.41	3.38	3.35	3.33	3.29	3.21	3.10	2.96
	2.79	2.61	2.39	2.15	1.90	1.61	1.31	1.00	0.67	0.33										
18	3.77	3.77	3.77	3.78	3.79	3.82	3.83	3.83	3.82	3.80	3.77	3.73	3.69	3.64	3.59	3.54	3.47	3.37	3.25	3.10
	2.94	2.76	2.53	2.28	2.00	1.68	1.35	1.02	0.68	0.34										
19	4.12	4.12	4.12	4.12	4.11	4.10	4.09	4.07	4.04	4.01	3.96	3.91	3.86	3.79	3.71	3.63	3.53	3.42	3.28	3.14
	2.99	2.82	2.59	2.33	2.03	1.69	1.35	1.01	0.67	0.33										
20	4.02	4.02	4.01	4.00	3.99	3.97	3.95	3.92	3.89	3.84	3.79	3.74	3.67	3.60	3.52	3.43	3.33	3.21	3.08	2.95
	2.81	2.64	2.43	2.18	1.90	1.58	1.25	0.94	0.62	0.31										
21	3.55	3.54	3.54	3.53	3.51	3.49	3.47	3.44	3.40	3.36	3.31	3.26	3.20	3.13	3.05	2.97	2.88	2.78	2.66	2.54
	2.42	2.28	2.10	1.88	1.64	1.36	1.08	0.81	0.53	0.26										
22	2.77	2.76	2.76	2.75	2.74	2.72	2.70	2.67	2.64	2.61	2.57	2.52	2.47	2.42	2.36	2.29	2.22	2.14	2.05	1.96
	1.86	1.75	1.61	1.45	1.26	1.05	0.83	0.62	0.41	0.20										
23	1.76	1.76	1.75	1.75	1.74	1.73	1.71	1.69	1.68	1.65	1.63	1.60	1.56	1.53	1.49	1.45	1.40	1.35	1.29	1.23
	1.17	1.10	1.01	0.91	0.79	0.66	0.52	0.39	0.26	0.13										
24	0.66	0.65	0.66	0.65	0.65	0.65	0.64	0.63	0.63	0.62	0.61	0.60	0.58	0.57	0.56	0.54	0.52	0.50	0.48	0.46
	0.43	0.40	0.37	0.33	0.29	0.24	0.19	0.15	0.10	0.05										
25	0.16	0.15	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.15	0.15	0.15	0.14	0.14	0.14	0.13	0.13	0.12	0.12	0.11
	0.11	0.10	0.09	0.08	0.07	0.06	0.05	0.04	0.02	0.01										
26	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.04
	0.04	0.04	0.03	0.03	0.03	0.02	0.02	0.01	0.01	0.00										
27	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00										

EXHIBIT C

Relative Power Density Averaged Over Height Versus Radial Position*

Radius, cm.	t = 0 sec.	t = 1 sec.	t = 4 sec.
0	1.504	2.408	4.031
8	1.504	2.411	4.035
16	1.504	2.417	4.046
24	1.504	2.429	4.065
32	1.503	2.447	4.093
40	1.503	2.473	4.136
48	1.503	2.497	4.175
56	1.502	2.509	4.195
64	1.502	2.515	4.202
72	1.501	2.514	4.200
80	1.500	2.509	4.190
88	1.500	2.500	4.173
96	1.499	2.487	4.150
104	1.499	2.472	4.122
112	1.500	2.454	4.091
120	1.506	2.439	4.064
128	1.503	2.411	4.016
136	1.481	2.358	3.925
144	1.444	2.284	3.800
152	1.393	2.192	3.647
160	1.333	2.088	3.473
168	1.257	1.962	3.263
176	1.162	1.808	3.006
184	1.051	1.632	2.712
192	0.926	1.434	2.382
200	0.815	1.259	2.093
208	0.682	1.053	1.749
216	0.516	0.795	1.321
224	0.345	0.531	0.882
232	0.172	0.264	0.439
240	0.0	0.0	0.0

* $\Delta t = 0.001$ sec.

EXHIBIT D

Power Density Averaged Over Radius Versus Axial Position*

Height**, cm.	t = 0 sec.	t = 1 sec.	t = 4 sec.
0	0.0	0.0	0.0
18.75	0.0	0.0	0.0
37.50	0.0	0.0	0.0
56.25	0.0	0.0	0.0
75.00	0.117	0.153	0.247
93.75	0.645	0.844	1.363
112.50	1.035	.359	2.196
131.25	1.367	1.804	2.919
150.00	1.619	2.153	3.491
168.75	1.777	2.388	3.879
187.50	1.822	2.484	4.049
206.25	1.815	2.522	4.126
225.00	1.816	2.584	4.247
243.75	1.817	2.662	4.397
262.50	1.817	2.754	4.573
281.25	1.817	2.862	4.777
300.00	1.816	2.987	5.010
318.75	1.815	3.132	5.277
337.50	1.822	3.316	5.609
356.25	1.777	3.393	5.757
375.00	1.619	3.200	5.441
393.75	1.367	2.768	4.716
412.50	1.035	2.133	3.638
431.25	0.645	1.343	2.292
450.00	0.117	0.244	4.174
468.75	0.0	0.0	0.0
487.50	0.0	0.0	0.0
506.25	0.0	0.0	0.0
525.00	0.0	0.0	0.0

* $\Delta t = 0.001$ sec.
** Height is measured from the top of the reactor.

EXHIBIT E

Plot of Data Presented in Exhibit C

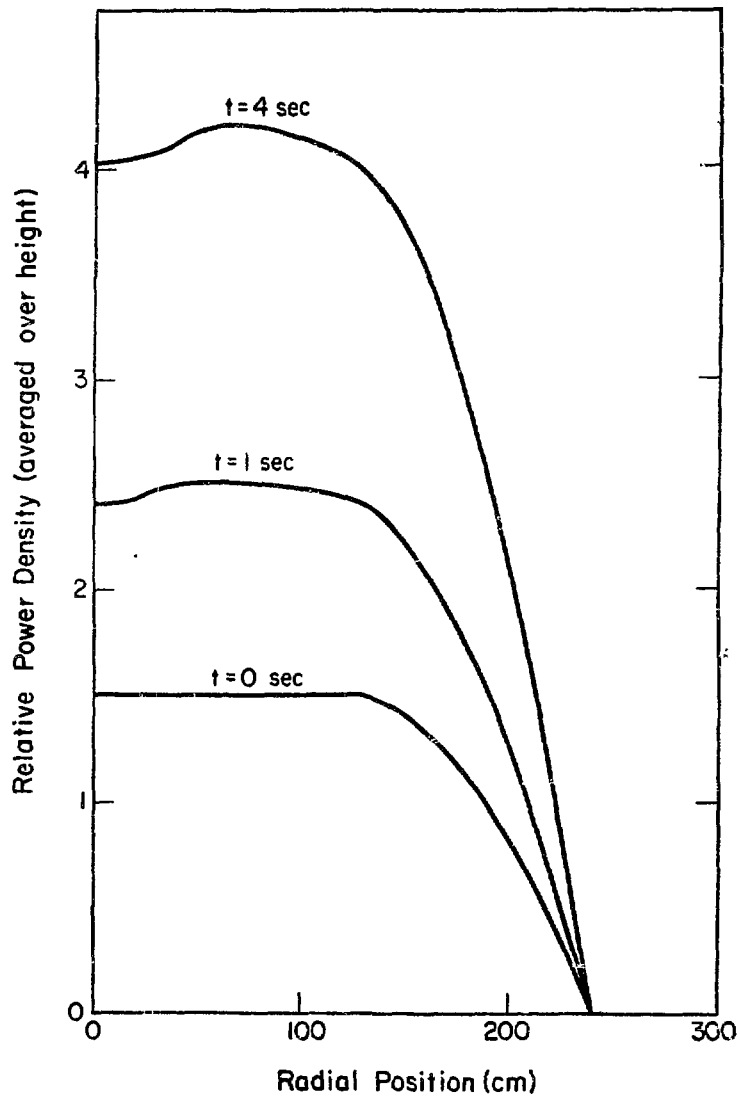
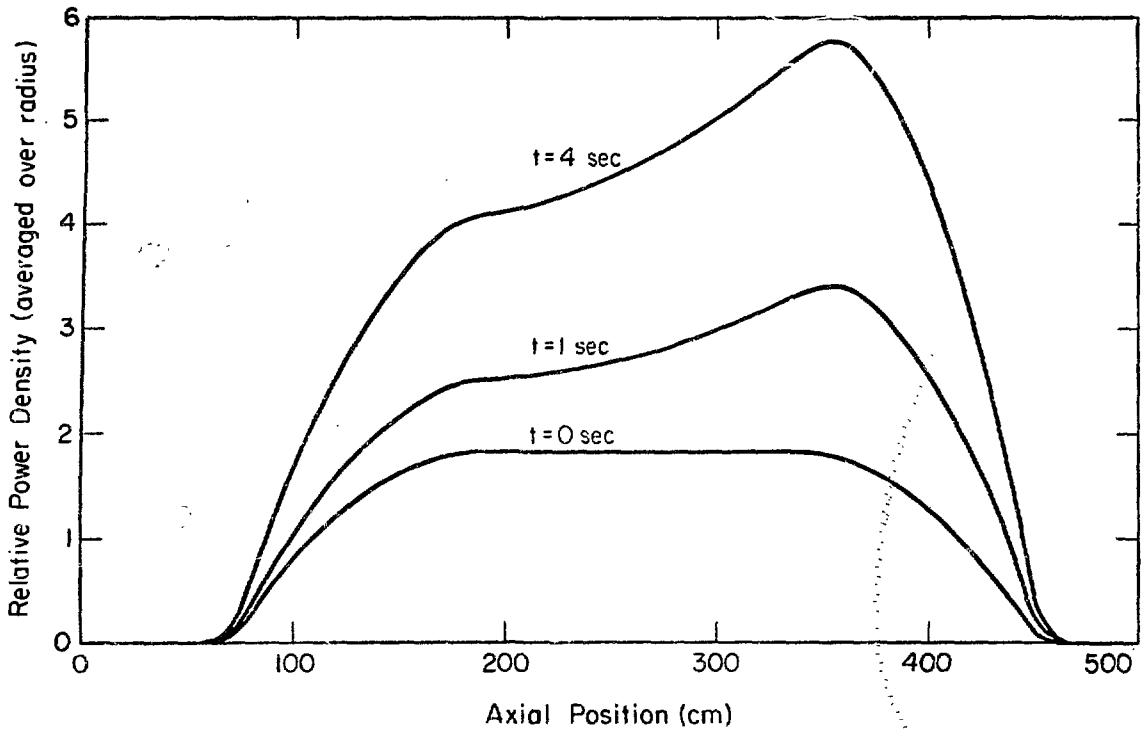


EXHIBIT F

Plot of Data Presented in Exhibit D



BENCHMARK PROBLEM SOLUTION

Identification:	8-A1-3	Benchmark Problem ID.8-A1
Date Submitted:	June 1976	By: F.N. McDonnell (AECL-CRNL)
Date Accepted:	June 1977	By: H.L. Dodds, Jr. (U. of Tenn.) E. L. Fuller (EPRI) W. Werner (GRS-Munich)

Descriptive Title: Direct Finite-Difference Solution with ADEP[1]

Mathematical Model: The alternating-direction explicit method of solution with an exponential transformation is used. Non-derivative terms are approximated by central averaging.

Computer: CDC-6600

Code: ADEP[1]

Date Solved: July 1974 at Chalk River Nuclear Laboratories

Reference: 1. R.G. Denning, "ADEP, One- and Two-Dimensional Few-Group Kinetics Code", BMI-1911(1971).

Results: Uniform Mesh with Δr=8cm (30 intervals) and Δz=18.75 cm (28 intervals) Initial K_{eff} = 0.866861

Exhibit A: Total power (relative to initial value) versus time as a function of Δt.

Exhibit B: Group 1 and Group 2 Relative Flux Distributions at 0.0, 1.0 and 4.0 seconds for Δt=0.0005 seconds.

Exhibit C: Power Density Averaged over Height vs. Radial Position, i.e.

$$\frac{1}{N} \sum_{\text{all } j} \int_{V_{ij}} (\Sigma_{f_1}\phi_1 + \Sigma_{f_2}\phi_2)dv \text{ versus } r_i$$

for i=1,...NPX and j=1,...NPY

where V_{ij} = mesh volume element ij

NPX = number of radial mesh points

NPY = number of axial mesh points

N = normalization constant

Exhibit D:	Power Density Averaged over Radius vs. Axial Position.
Exhibit E:	Plot of data presented in Exhibit C.
Exhibit F:	Plot of data presented in Exhibit D.

Summary of the CP time requirements.

For this problem ADEP takes ∿0.25 ms/mesh point/group/time-step.

For Δt=0.0005 s the total CP time for the transient is ∿3400 s of CDC-6600 time.

EXHIBIT A

TOTAL POWER VERSUS TIME AS FUNCTION OF TIME STEP SIZE

Time (s)	Δt(s)		
	0.0005	0.001	0.005
0.0	1.000	1.000	1.000
0.2	1.041	1.043	1.008
0.4	1.111	1.111	1.061
0.6	1.213	1.212	1.148
0.8	1.365	1.364	1.276
1.0	1.603	1.606	1.466
1.2	1.761	1.767	1.697
1.4	1.838	1.839	1.853
1.6	1.906	1.906	1.963
1.8	1.971	1.971	2.047
2.0	2.035	2.036	2.116
3.0	2.353	2.353	2.405
4.0	2.683	2.683	2.730
CDC-6600 CPU(s)	3400	1700	340

EXHIBIT B

RELATIVE FLUX IN GROUP 1 AT t=0 s

Radial Mesh Point Number

Axial Mesh Point Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00										
2	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01
	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00										
3	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04
	.03	.03	.03	.03	.02	.02	.02	.01	.01	.00										
4	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20	.19	.18
	.18	.17	.15	.14	.12	.11	.09	.07	.04	.02										
5	.63	.63	.63	.63	.63	.63	.63	.63	.63	.63	.64	.64	.64	.64	.64	.64	.63	.62	.61	.59
	.57	.54	.50	.45	.40	.34	.28	.21	.14	.07										
6	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.03	1.03	1.03	1.03	1.02	1.01	.99	.96
	.92	.87	.80	.73	.64	.55	.45	.34	.23	.11										
7	1.35	1.35	1.35	1.35	1.35	1.35	1.35	1.35	1.35	1.35	1.36	1.36	1.36	1.36	1.36	1.36	1.35	1.33	1.30	1.26
	1.21	1.14	1.06	.96	.85	.73	.60	.45	.30	.15										
8	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.60	1.58	1.54	1.49
	1.43	1.35	1.25	1.13	1.00	.86	.70	.53	.36	.18										
9	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.77	1.76	1.73	1.69	1.64
	1.56	1.47	1.36	1.24	1.09	.94	.77	.58	.39	.19										
10	1.86	1.86	1.86	1.86	1.86	1.86	1.86	1.86	1.86	1.86	1.86	1.86	1.86	1.85	1.85	1.84	1.83	1.80	1.75	1.69
	1.61	1.51	1.39	1.26	1.12	.96	.79	.61	.41	.20										
11	1.89	1.89	1.89	1.89	1.89	1.89	1.89	1.89	1.89	1.88	1.88	1.88	1.88	1.87	1.87	1.86	1.84	1.81	1.76	1.69
	1.60	1.50	1.38	1.25	1.11	.96	.80	.61	.41	.20										
12	1.91	1.91	1.91	1.91	1.91	1.90	1.90	1.90	1.90	1.90	1.90	1.89	1.89	1.88	1.88	1.87	1.85	1.81	1.76	1.69
	1.60	1.49	1.38	1.25	1.11	.96	.80	.61	.41	.20										
13	1.92	1.92	1.92	1.92	1.91	1.91	1.91	1.91	1.91	1.91	1.90	1.90	1.90	1.89	1.88	1.87	1.85	1.81	1.76	1.69
	1.60	1.49	1.37	1.24	1.10	.96	.79	.61	.41	.20										
14	1.92	1.92	1.92	1.92	1.92	1.92	1.91	1.91	1.91	1.91	1.91	1.90	1.90	1.89	1.89	1.87	1.85	1.81	1.76	1.68
	1.60	1.49	1.37	1.24	1.10	.96	.79	.61	.41	.20										
15	1.92	1.92	1.92	1.92	1.92	1.91	1.91	1.91	1.91	1.91	1.90	1.90	1.90	1.89	1.88	1.87	1.85	1.81	1.76	1.69
	1.60	1.49	1.37	1.24	1.10	.96	.79	.61	.41	.20										
16	1.91	1.91	1.91	1.91	1.91	1.91	1.90	1.90	1.90	1.90	1.90	1.89	1.89	1.89	1.88	1.87	1.85	1.81	1.76	1.69
	1.60	1.49	1.38	1.25	1.11	.96	.80	.61	.41	.20										
17	1.89	1.89	1.89	1.89	1.89	1.89	1.89	1.89	1.89	1.88	1.88	1.88	1.88	1.88	1.87	1.86	1.84	1.81	1.76	1.69
	1.60	1.50	1.38	1.25	1.11	.96	.80	.61	.41	.20										
18	1.86	1.86	1.86	1.86	1.86	1.86	1.86	1.86	1.86	1.86	1.86	1.86	1.86	1.85	1.85	1.84	1.83	1.80	1.75	1.69
	1.61	1.51	1.40	1.26	1.12	.97	.80	.61	.41	.20										
19	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.77	1.76	1.73	1.69	1.64
	1.56	1.48	1.37	1.24	1.09	.94	.77	.58	.39	.19										
20	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.60	1.58	1.54	1.49
	1.43	1.35	1.25	1.13	1.00	.86	.70	.53	.36	.18										
21	1.35	1.35	1.35	1.35	1.35	1.35	1.35	1.35	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.35	1.33	1.30	1.26
	1.21	1.14	1.06	.96	.85	.73	.60	.45	.30	.15										
22	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.03	1.03	1.03	1.03	1.03	1.02	1.01	.99	.96
	.92	.87	.80	.73	.64	.55	.45	.34	.23	.11										
23	.63	.63	.63	.63	.63	.63	.63	.63	.63	.64	.64	.64	.64	.64	.64	.64	.63	.63	.61	.59
	.57	.54	.50	.45	.40	.34	.28	.21	.14	.07										
24	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20	.19	.18
	.18	.17	.15	.14	.12	.11	.09	.07	.04	.02										
25	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04
	.03	.03	.03	.03	.02	.02	.02	.01	.01	.00										
26	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01
	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00										

EXHIBIT B (Cont'd)

RELATIVE FLUX IN GROUP 2 t=0 s

Radial Mesh Point Number

Axial Mesh Point Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.00	.00	.00	.00
	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00										
2	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01
	.01	.01	.01	.01	.01	.01	.01	.00	.00	.00										
3	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.03	.03
	.03	.03	.03	.03	.02	.02	.02	.01	.01	.00										
4	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.14	.14	.14
	.13	.13	.12	.10	.09	.08	.06	.05	.03	.02										
5	.39	.39	.39	.39	.39	.39	.39	.39	.39	.39	.39	.39	.39	.39	.39	.39	.40	.39	.38	.37
	.36	.34	.32	.29	.25	.21	.17	.13	.08	.04										
6	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62	.63	.63	.63	.63	.63	.61	.60
	.58	.55	.51	.46	.41	.34	.27	.20	.13	.07										
7	.82	.82	.82	.82	.82	.82	.82	.82	.82	.82	.83	.83	.83	.83	.83	.84	.84	.83	.81	.79
	.76	.72	.67	.61	.53	.45	.36	.27	.18	.09										
8	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.99	.99	.99	.98	.96	.93
	.90	.86	.79	.72	.63	.53	.42	.31	.21	.10										
9	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.09	1.09	1.09	1.08	1.05	1.02
	.98	.93	.87	.78	.69	.58	.46	.34	.23	.11										
10	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.11	1.08	1.04
	1.00	.94	.87	.79	.69	.59	.47	.36	.24	.12										
11	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.12	1.12	1.12	1.12	1.12	1.13	1.12	1.11	1.08	1.03
	.98	.92	.85	.77	.68	.58	.47	.36	.24	.12										
12	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.11	1.07	1.03
	.98	.92	.84	.76	.67	.58	.47	.36	.24	.12										
13	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.13	1.13	1.13	1.13	1.13	1.13	1.11	1.07	1.03
	.98	.91	.84	.76	.67	.57	.47	.36	.24	.12										
14	1.15	1.15	1.15	1.15	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.13	1.13	1.13	1.13	1.13	1.13	1.11	1.07	1.03
	.98	.91	.84	.76	.67	.57	.47	.36	.24	.12										
15	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.13	1.13	1.13	1.13	1.13	1.13	1.11	1.08	1.03
	.98	.91	.84	.76	.67	.57	.47	.36	.24	.12										
16	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.11	1.08	1.03
	.98	.92	.84	.76	.67	.58	.47	.36	.24	.12										
17	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.12	1.12	1.12	1.12	1.12	1.13	1.12	1.11	1.08	1.03
	.98	.92	.85	.77	.68	.58	.47	.36	.24	.12										
18	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.13	1.12	1.11	1.08	1.04
	1.00	.94	.87	.79	.69	.59	.47	.36	.24	.12										
19	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.09	1.09	1.09	1.08	1.05	1.02
	.98	.93	.87	.78	.69	.58	.46	.34	.23	.11										
20	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.98	.99	.99	.99	.98	.96	.93
	.90	.86	.80	.72	.63	.53	.42	.31	.21	.10										
21	.82	.82	.82	.82	.82	.82	.82	.82	.82	.83	.83	.83	.83	.83	.83	.84	.84	.83	.81	.79
	.76	.73	.67	.61	.53	.45	.36	.27	.18	.09										
22	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62	.62	.63	.63	.63	.63	.63	.63	.62	.60
	.58	.55	.51	.46	.41	.34	.27	.20	.13	.07										
23	.39	.39	.39	.39	.39	.39	.39	.39	.39	.39	.39	.39	.39	.39	.39	.39	.40	.39	.38	.37
	.36	.34	.32	.29	.25	.21	.17	.13	.08	.04										
24	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.14	.14	.14
	.13	.13	.12	.10	.09	.08	.06	.05	.03	.02										
25	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.03	.03
	.03	.03	.03	.03	.02	.02	.02	.01	.01	.00										
26	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01
	.01	.01	.01	.01	.01	.01	.01	.00	.00	.00										

EXHIBIT B (Cont'd)

RELATIVE FLUX IN GROUP 1 t=1.0 s

Radial Mesh Point Number

Axial Mesh Point Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00										
2	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01
	.01	.01	.01	.01	.00	.00	.00	.00	.00	.00										
3	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05
	.05	.04	.04	.04	.03	.03	.02	.02	.01	.01										
4	.23	.23	.24	.24	.24	.24	.25	.25	.25	.26	.26	.26	.26	.26	.26	.26	.26	.26	.25	.25
	.24	.22	.21	.19	.16	.14	.12	.09	.06	.03										
5	.73	.72	.74	.75	.76	.77	.78	.79	.80	.81	.82	.82	.83	.83	.84	.84	.84	.83	.81	.79
	.76	.72	.66	.60	.53	.46	.37	.28	.19	.09										
6	1.19	1.19	1.20	1.21	1.22	1.24	1.26	1.28	1.30	1.31	1.32	1.33	1.34	1.35	1.36	1.36	1.36	1.34	1.31	1.28
	1.23	1.16	1.08	.98	.86	.74	.61	.46	.31	.15										
7	1.58	1.58	1.59	1.61	1.63	1.66	1.68	1.71	1.73	1.75	1.76	1.77	1.78	1.79	1.80	1.81	1.80	1.78	1.74	1.69
	1.63	1.54	1.43	1.29	1.14	.98	.80	.61	.41	.20										
8	1.90	1.90	1.91	1.93	1.96	1.99	2.02	2.05	2.07	2.09	2.11	2.13	2.14	2.15	2.16	2.16	2.15	2.13	2.08	2.02
	1.94	1.83	1.70	1.54	1.36	1.17	.96	.72	.48	.24										
9	2.13	2.13	2.15	2.17	2.20	2.23	2.26	2.30	2.32	2.34	2.36	2.37	2.39	2.40	2.40	2.41	2.39	2.36	2.31	2.23
	2.14	2.02	1.87	1.69	1.50	1.29	1.06	.80	.54	.27										
10	2.26	2.27	2.28	2.30	2.33	2.37	2.41	2.44	2.46	2.48	2.50	2.52	2.53	2.54	2.54	2.54	2.52	2.48	2.42	2.34
	2.23	2.09	1.94	1.75	1.55	1.34	1.10	.84	.56	.28										
11	2.35	2.36	2.37	2.39	2.42	2.46	2.50	2.53	2.55	2.57	2.59	2.60	2.61	2.62	2.62	2.61	2.59	2.55	2.48	2.38
	2.26	2.12	1.95	1.77	1.57	1.36	1.13	.86	.58	.29										
12	2.45	2.45	2.47	2.49	2.52	2.56	2.59	2.62	2.65	2.67	2.68	2.69	2.70	2.70	2.70	2.69	2.66	2.61	2.54	2.43
	2.31	2.16	1.99	1.80	1.60	1.38	1.15	.88	.59	.30										
13	2.56	2.57	2.58	2.60	2.63	2.67	2.70	2.73	2.76	2.77	2.79	2.79	2.80	2.79	2.79	2.78	2.75	2.69	2.61	2.50
	2.37	2.21	2.03	1.84	1.63	1.42	1.17	.90	.61	.30										
14	2.69	2.70	2.71	2.73	2.77	2.80	2.84	2.86	2.88	2.90	2.91	2.91	2.91	2.90	2.89	2.88	2.84	2.78	2.69	2.58
	2.44	2.28	2.09	1.89	1.68	1.45	1.21	.92	.62	.31										
15	2.86	2.86	2.88	2.90	2.93	2.96	2.99	3.02	3.04	3.05	3.05	3.05	3.04	3.03	3.02	2.99	2.95	2.88	2.79	2.67
	2.52	2.35	2.16	1.95	1.73	1.50	1.24	.95	.64	.32										
16	3.07	3.07	3.08	3.10	3.13	3.16	[illegible]	3.21	3.22	3.22	3.22	3.21	3.20	3.18	3.16	3.12	3.08	3.00	2.90	2.77
	2.61	2.44	2.24	2.02	1.79	1.55	1.28	.98	.66	.33										
17	3.34	3.34	3.35	3.37	3.39	3.41	3.43	3.44	3.45	3.44	3.43	3.41	3.38	3.35	3.31	3.27	3.21	3.13	3.01	2.88
	2.72	2.53	2.32	2.09	1.85	1.60	1.32	1.01	.68	.34										
18	3.68	3.69	3.69	3.70	3.70	3.71	3.72	3.72	3.70	3.68	3.66	3.62	3.58	3.54	3.48	3.42	3.34	3.24	3.12	2.98
	2.81	2.62	2.41	2.17	1.91	1.65	1.35	1.03	.69	.34										
19	3.91	3.91	3.91	3.91	3.90	3.89	3.88	3.86	3.82	3.81	3.77	3.72	3.67	3.60	3.53	3.45	3.36	3.25	3.12	2.98
	2.82	2.63	2.42	2.18	1.91	1.64	1.34	1.01	.68	.34										
20	3.79	3.79	3.79	3.78	3.77	3.75	3.73	3.71	3.67	3.63	3.59	3.54	3.48	3.41	3.33	3.25	3.15	3.04	2.92	2.79
	2.64	2.46	2.26	2.03	1.79	1.53	1.24	.94	.63	.31										
21	3.34	3.34	3.33	3.32	3.31	3.29	3.27	3.24	3.21	3.17	3.13	3.08	3.02	2.96	2.89	2.81	2.72	2.62	2.52	2.40
	2.27	2.12	1.95	1.75	1.54	1.31	1.07	.81	.54	.27										
22	2.60	2.60	2.59	2.58	2.57	2.56	2.54	2.52	2.49	2.46	2.42	2.38	2.33	2.28	2.23	2.16	2.09	2.02	1.93	1.84
	1.74	1.63	1.49	1.34	1.18	1.00	.82	.62	.41	.20										
23	1.64	1.64	1.64	1.63	1.62	1.61	1.60	1.58	1.57	1.55	1.52	1.50	1.47	1.43	1.40	1.36	1.31	1.26	1.21	1.15
	1.09	1.02	.93	.84	.73	.63	.51	.39	.26	.13										
24	.52	.52	.52	.51	.51	.51	.50	.50	.49	.49	.48	.47	.46	.45	.44	.43	.41	.40	.38	.36
	.34	.32	.29	.26	.23	.19	.16	.12	.08	.04										
25	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.09	.09	.09	.09	.09	.08	.08	.08	.07
	.07	.06	.06	.05	.05	.04	.03	.02	.02	.01										
26	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01
	.01	.01	.01	.01	.01	.01	.00	.00	.00	.00										

EXHIBIT B (Cont'd)

RELATIVE FLUX IN GROUP 2 t=1.0 s

Radial Mesh Point Number

Axial Mesh Point Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01
	.01	.01	.01	.00	.00	.00	.00	.00	.00	.00										
2	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02
	.02	.02	.01	.01	.01	.01	.01	.01	.00	.00										
3	.04	.04	.04	.04	.04	.04	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.04
	.04	.04	.04	.03	.03	.03	.02	.02	.01	.01										
4	.17	.17	.17	.17	.17	.18	.18	.18	.19	.19	.19	.19	.19	.19	.19	.19	.19	.19	.19	.18
	.18	.17	.15	.14	.12	.10	.08	.06	.04	.02										
5	.44	.44	.44	.45	.46	.47	.48	.49	.49	.50	.50	.50	.51	.51	.52	.52	52	.52	.51	.50
	.48	.46	.43	.39	.34	.28	.22	.17	.11	.06										
6	.71	.71	.71	.72	.73	.75	.77	.78	.79	.80	.81	.81	.82	.82	.83	.84	.84	.83	.82	.80
	.77	.74	.68	.62	.54	.45	.36	.27	.18	.09										
7	.94	.95	.95	.96	.98	1.00	1.02	1.04	1.05	1.06	1.07	1.08	1.09	1.09	1.10	1.11	1.12	1.11	1.09	1.06
	1.02	.98	.91	.82	.72	.60	.48	.36	.24	.12										
8	1.13	1.14	1.14	1.16	1.17	1.20	1.23	1.25	1.26	1.27	1.29	1.29	1.30	1.31	1.32	1.33	1.34	1.32	1.30	1.26
	1.22	1.16	1.08	.98	.86	.72	.57	.43	.28	.14										
9	1.27	1.27	1.28	1.29	1.31	1.34	1.37	1.39	1.41	1.42	1.44	1.44	1.45	1.46	1.47	1.48	1.48	1.47	1.44	1.39
	1.35	1.28	1.19	1.07	.94	.79	.63	.47	.31	.16										
10	1.34	1.34	1.35	1.36	1.38	1.42	1.45	1.47	1.48	1.50	1.51	1.52	1.52	1.53	1.54	1.55	1.55	1.53	1.49	1.44
	1.38	1.31	1.21	1.09	.96	.81	.66	.50	.33	.16										
11	1.38	1.38	1.39	1.40	1.43	1.46	1.49	1.51	1.53	1.54	1.55	1.56	1.56	1.57	1.57	1.58	1.58	1.56	1.52	1.46
	1.39	1.30	1.20	1.09	.96	.82	.67	.51	.34	.17										
12	1.43	1.44	1.44	1.46	1.48	1.51	1.54	1.57	1.58	1.59	1.60	1.61	1.61	1.61	1.62	1.63	1.62	1.60	1.55	1.49
	1.41	1.32	1.22	1.10	.97	.83	.68	.52	.35	.17										
13	1.50	1.50	1.51	1.52	1.55	1.58	1.61	1.63	1.65	1.66	1.66	1.67	1.67	1.67	1.67	1.68	1.67	1.64	1.59	1.53
	1.45	1.35	1.25	1.13	1.00	.85	.69	.53	.36	.18										
14	1.58	1.58	1.59	1.60	1.62	1.66	1.69	1.71	1.72	1.73	1.74	1.74	1.74	1.74	1.74	1.74	1.73	1.70	1.65	1.58
	1.49	1.39	1.28	1.16	1.02	.87	.71	.54	.36	.18										
15	1.67	1.68	1.68	1.70	1.72	1.75	1.78	1.80	1.81	1.82	1.82	1.82	1.82	1.81	1.81	1.81	1.80	1.76	1.71	1.63
	1.54	1.44	1.32	1.20	1.05	.90	.74	.56	.38	.19										
16	1.80	1.80	1.81	1.82	1.84	1.87	1.90	1.92	1.92	1.93	1.92	1.92	1.91	1.90	1.89	1.89	1.88	1.83	1.77	1.69
	1.60	1.49	1.37	1.24	1.09	.93	.76	.58	.39	.19										
17	1.96	1.96	1.97	1.98	2.00	2.02	2.05	2.06	2.06	2.06	2.05	2.04	2.02	2.01	1.99	1.98	1.96	1.91	1.85	1.76
	1.67	1.55	1.43	1.28	1.13	.96	.78	.59	.40	.20										
18	2.22	2.22	2.23	2.23	2.24	2.25	2.26	2.26	2.26	2.25	2.23	2.21	2.18	2.16	2.13	2.10	2.06	2.00	1.93	1.84
	1.75	1.64	1.50	1.35	1.19	1.00	.80	.61	.40	.20										
19	2.42	2.42	2.42	2.42	2.42	2.41	2.41	2.40	2.38	2.36	2.34	2.31	2.27	2.24	2.19	2.14	2.09	2.02	1.94	1.86
	1.77	1.67	1.54	1.38	1.20	1.00	.80	.60	.40	.20										
20	2.36	2.36	2.35	2.35	2.34	2.33	2.32	2.30	2.28	2.26	2.23	2.20	2.16	2.12	2.07	2.02	1.96	1.90	1.82	1.74
	1.66	1.56	1.44	1.29	1.13	.94	.74	.56	.37	.18										
21	2.07	2.07	2.07	2.07	2.06	2.05	2.03	2.02	2.00	1.97	1.94	1.91	1.88	1.84	1.80	1.75	1.70	1.64	1.57	1.50
	1.43	1.35	1.24	1.11	.97	.81	.64	.48	.32	.16										
22	1.62	1.62	1.61	1.61	1.60	1.59	1.58	1.56	1.55	1.53	1.51	1.48	1.45	1.42	1.38	1.35	1.31	1.26	1.21	1.15
	1.10	1.03	.95	.85	.74	.62	.49	.36	.24	.12										
23	1.03	1.03	1.02	1.02	1.01	1.01	1.00	.99	.98	.97	.95	.94	.92	.90	.87	.85	.82	.79	.76	.73
	.69	.65	.60	.54	.47	.39	.31	.23	.15	.08										
24	.38	.38	.38	.38	.38	.38	.37	.37	.37	.36	.36	.35	.34	.33	.33	.32	.31	.29	.28	.27
	.25	.24	.22	.20	.17	.14	.11	.09	.06	.03										
25	.10	.10	.09	.09	.09	.09	.09	.09	.09	.09	.09	.09	.08	.08	.08	.08	.08	.07	.07	.07
	.06	.06	.05	.05	.04	.04	.03	.02	.01	.01										
26	.04	.04	.04	.04	.04	.04	.04	.04	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03
	.02	.02	.02	.02	.02	.01	.01	.01	.01	.00										
27	.01	.01	.01	.01	.02	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01
	.01	.01	.01	.01	.01	.00	.00	.00	.00	.00										

EXHIBIT B (Cont'd)

RELATIVE FLUX IN GROUP 2 t=4.0 s

Radial Mesh Point Number

Axial Mesh Point Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00										
2	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01
	.01	.01	.01	.01	.01	.01	.01	.00	.00	.00										
3	.08	.08	.08	.08	.08	.08	.08	.08	.08	.08	.08	.08	.08	.09	.09	.09	.08	.08	.08	.08
	.08	.07	.07	.06	.05	.04	.04	[illegible]	.02	.01										
4	.38	.38	.38	.38	.39	.39	.40	.41	.41	.41	.42	.42	.42	.43	.43	.43	.43	.42	.41	.40
	.38	.36	.33	.30	.27	.23	.19	.14	.10	.05										
5	1.19	1.19	1.20	1.21	1.22	1.25	1.27	1.28	1.30	1.31	1.32	1.34	1.34	1.35	1.36	1.36	1.36	1.34	1.32	1.28
	1.23	1.16	1.08	.98	.86	.74	.61	.46	.31	.15										
6	1.92	1.93	1.94	1.96	1.98	2.02	2.05	2.08	2.10	2.13	2.15	2.16	2.18	2.19	2.20	2.21	2.20	2.18	2.13	2.07
	1.99	1.88	1.75	1.59	1.40	1.20	.98	.75	.50	.25										
7	2.56	2.57	2.58	2.61	2.65	2.69	2.73	2.77	2.81	2.84	2.86	2.88	2.90	2.92	2.93	2.94	2.93	2.90	2.84	2.75
	2.64	2.50	2.32	2.10	1.86	1.60	1.31	.99	.66	.33										
8	3.09	3.09	3.11	3.14	3.19	3.2[illegible]	3.29	3.34	3.38	3.41	3.44	3.46	3.48	3.50	3.51	3.52	3.51	3.46	3.39	3.29
	3.15	2.99	2.76	2.51	2.21	1.90	1.56	1.18	.79	.39										
9	3.47	3.48	3.50	3.53	3.58	3.64	3.69	3.74	3.79	3.82	3.85	3.88	3.90	3.91	3.92	3.93	3.91	3.86	3.77	3.65
	3.49	3.30	3.05	2.77	2.45	2.10	1.72	1.31	.87	.43										
10	3.70	3.71	3.73	3.77	3.82	3.88	3.94	3.99	4.03	4.07	4.10	4.12	4.14	4.15	4.16	4.16	4.13	4.07	3.96	3.82
	3.65	3.43	3.17	2.87	2.54	2.20	1.81	1.38	.92	.46										
11	3.87	3.87	3.90	3.93	3.98	4.04	4.10	4.16	4.20	4.23	4.26	4.28	4.29	4.30	4.30	4.30	4.26	4.19	4.07	3.91
	3.72	3.48	3.21	2.91	2.58	2.24	1.85	1.42	.95	.48										
12	4.04	4.05	4.07	4.11	4.16	4.22	4.28	4.33	4.37	4.41	4.43	4.45	4.46	4.46	4.46	4.44	4.40	4.32	4.19	4.02
	3.81	3.56	3.28	2.97	2.63	2.29	1.89	1.45	.98	.49										
13	4.25	4.26	4.28	4.32	4.37	4.43	4.49	4.54	4.58	4.61	4.62	4.64	4.64	4.64	4.63	4.61	4.56	4.46	4.33	4.15
	3.93	3.67	3.37	3.05	2.71	2.35	1.95	1.49	1.00	.50										
14	4.50	4.51	4.53	4.57	4.62	4.68	4.74	4.78	4.82	4.84	4.86	4.86	4.86	4.85	4.83	4.80	4.74	4.64	4.49	4.30
	4.06	3.79	3.49	3.15	2.80	2.42	2.01	1.54	1.04	.52										
15	4.80	4.81	4.83	4.87	4.92	4.98	5.04	5.07	5.10	5.12	5.12	5.12	5.10	5.09	5.06	5.02	4.95	4.86	4.68	4.47
	4.22	3.94	3.62	3.27	2.90	2.51	2.08	1.59	1.07	.53										
16	5.19	5.19	5.21	5.25	5.29	5.34	5.39	5.42	5.44	5.44	5.44	5.42	5.39	5.36	5.32	5.27	5.19	5.06	4.88	4.66
	4.40	4.10	3.77	3.40	3.01	2.60	2.16	1.65	1.11	.55										
17	5.68	5.68	5.70	5.72	5.7[illegible]	5.80	5.83	5.85	5.85	5.84	5.81	5.78	5.73	5.68	5.61	5.54	5.44	5.29	5.10	4.87
	4.59	4.28	3.92	3.54	3.13	2.70	2.23	1.70	1.14	.57										
18	6.29	6.29	6.30	6.31	6.32	6.34	6.35	6.34	6.32	6.28	6.23	6.17	6.10	6.02	5.92	5.81	5.68	5.50	5.29	5.05
	4.77	4.45	4.09	3.68	3.24	2.79	2.29	1.74	1.17	.58										
19	6.70	6.70	6.70	6.69	6.68	6.67	6.65	6.61	6.57	6.51	6.44	6.36	6.26	6.15	6.03	5.88	5.72	5.53	5.31	5.07
	4.79	4.48	4.11	3.75	3.25	2.78	2.27	1.72	1.15	.57										
20	6.52	6.51	6.51	6.49	6.47	6.44	6.40	6.36	6.30	6.23	6.15	6.06	5.95	5.83	5.70	5.55	5.38	5.19	4.98	4.75
	4.49	4.20	3.85	3.47	3.04	2.60	2.12	1.60	1.07	.53										
21	5.75	5.75	5.74	5.72	5.69	5.66	5.62	5.58	5.52	5.45	5.37	5.28	5.18	5.07	4.95	4.81	4.66	4.49	4.30	4.10
	3.88	3.62	3.32	2.99	2.62	2.24	1.82	1.37	.92	.45										
22	4.48	4.48	4.47	4.46	4.43	4.41	4.37	4.33	4.28	4.23	4.16	4.09	4.01	3.92	3.82	3.71	3.59	3.46	3.31	3.15
	2.98	2.78	2.55	2.29	2.01	1.72	1.40	1.05	.70	.35										
23	2.83	2.83	2.82	2.81	2.80	2.78	2.76	2.73	2.70	2.66	2.62	2.57	2.52	2.46	2.40	2.33	2.25	2.17	2.07	1.97
	1.86	1.74	1.59	1.43	1.26	1.07	.87	.66	.44	.22										
24	.89	.89	.89	.89	.88	.88	.87	.86	.85	.84	.83	.81	.79	.78	.75	.73	.71	.68	.65	.62
	.58	.54	.50	.45	.39	.33	.27	.20	.14	.07										
25	.18	.18	.18	.18	.18	.18	.17	.17	.17	.17	.17	.16	.16	.15	.15	.15	.14	.14	.13	.12
	.12	.11	.10	.09	.08	.07	.05	.04	.03	.01										
26	.03	.03	.03	.03	.03	.03	.03	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02
	.02	.02	.01	.01	.01	.01	.01	.01	.00	.00										

EXHIBIT B (Cont'd)

RELATIVE FLUX IN GROUP 2 t=4.0 s

Radial Mesh Point Number

Axial Mesh Point Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01	.01
	.01	.01	.01	.01	.01	.01	.00	.00	.00	.00										
2	.03	.03	.03	.00	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03
	.03	.02	.02	.02	.02	.02	.01	.01	.01	.00										
3	.07	.07	.07	.07	.07	.07	.07	.07	.08	.08	.08	.08	.08	.08	.08	.08	.08	.08	.07	.07
	.07	.07	.06	.05	.05	.04	.03	.03	.02	.01										
4	.27	.27	.27	.28	.28	.29	.29	.30	.30	.30	.31	.31	.31	.31	.31	.31	.31	.31	.31	.30
	.29	.27	.25	.23	.20	.17	.14	.10	.07	.03										
5	.71	.72	.72	.73	.74	.76	.77	.79	.80	.81	.81	.82	.82	.83	.84	.85	.85	.84	.83	.81
	.78	.74	.69	.62	.55	.46	.37	.27	.18	.09										
6	1.15	1.15	1.16	1.17	1.19	1.22	1.25	1.27	1.28	1.30	1.31	1.32	1.33	1.34	1.35	1.36	1.37	1.36	1.33	1.30
	1.25	1.20	1.11	1.01	.88	.74	.59	.44	.29	.15										
7	1.53	1.53	1.54	1.56	1.59	1.62	1.66	1.69	1.71	1.73	1.74	1.76	1.77	1.78	1.79	1.81	1.82	1.80	1.77	1.72
	1.67	1.59	1.48	1.34	1.17	.98	.78	.58	.39	.19										
8	1.84	1.85	1.86	1.88	1.91	1.95	2.01	2.03	2.06	2.08	2.09	2.11	2.12	2.13	2.15	2.17	2.18	2.16	2.11	2.06
	1.99	1.89	1.76	1.59	1.40	1.17	.93	.70	.46	.23										
9	2.07	2.07	2.09	2.11	2.14	2.19	2.24	2.28	2.30	2.33	2.34	2.36	2.37	2.38	2.40	2.42	2.42	2.40	2.35	2.28
	2.20	2.09	1.94	1.75	1.54	1.29	1.03	.77	.51	.26										
10	2.19	2.19	2.21	2.23	2.27	2.32	2.37	2.40	2.43	2.45	2.47	2.49	2.50	2.51	2.52	2.54	2.54	2.51	2.45	2.37
	2.27	2.14	1.98	1.79	1.58	1.33	1.08	.81	.54	.27										
11	2.26	2.27	2.28	2.31	2.34	2.40	2.45	2.48	2.51	2.53	2.55	2.56	2.57	2.58	2.58	2.60	2.60	2.56	2.49	2.40
	2.28	2.14	1.97	1.78	1.58	1.35	1.10	.83	.56	.28										
12	2.37	2.37	2.39	2.41	2.45	2.50	2.55	2.59	2.61	2.63	2.65	2.66	2.66	2.67	2.67	2.69	2.68	2.64	2.56	2.46
	2.33	2.18	2.01	1.82	1.61	1.37	1.12	.85	.57	.29										
13	2.49	2.49	2.51	2.53	2.57	2.62	2.68	2.71	2.73	2.75	2.76	2.77	2.77	2.77	2.78	2.79	2.78	2.73	2.65	2.54
	2.40	2.25	2.07	1.87	1.65	1.41	1.15	.88	.59	.29										
14	2.63	2.64	2.65	2.68	2.71	2.77	2.82	2.85	2.88	2.89	2.90	2.90	2.90	2.90	2.90	2.90	2.89	2.84	2.75	2.63
	2.49	2.33	2.14	1.93	1.70	1.46	1.19	.91	.61	.30										
15	2.81	2.82	2.83	2.85	2.89	2.95	3.00	3.03	3.05	3.06	3.06	3.06	3.05	3.04	3.03	3.04	3.02	2.96	2.86	2.74
	2.59	2.42	2.22	2.00	1.77	1.51	1.23	.94	.63	.31										
16	3.04	3.04	3.05	3.08	3.11	3.16	3.21	3.24	3.25	3.25	3.25	3.24	3.22	3.21	3.19	3.19	3.16	3.09	2.99	2.85
	2.70	2.51	2.31	2.08	1.84	1.57	1.28	.97	.65	.32										
17	3.33	3.34	3.35	3.36	3.39	3.44	3.48	3.50	3.50	3.49	3.48	3.46	3.43	3.40	3.37	3.36	3.32	3.24	3.12	2.98
	2.82	2.63	2.41	2.17	1.91	1.63	1.32	1.00	.67	.33										
18	3.80	3.80	3.80	3.81	3.82	3.85	3.86	3.86	3.85	3.83	3.80	3.76	3.72	3.67	3.62	3.57	3.50	3.40	3.27	3.13
	2.97	2.78	2.55	2.30	2.01	1.70	1.36	1.03	.69	.34										
19	4.16	4.15	4.15	4.15	4.14	4.14	4.12	4.10	4.07	4.02	4.00	3.94	3.89	3.82	3.74	3.66	3.56	3.44	3.31	3.17
	3.02	2.84	2.61	2.35	2.05	1.71	1.36	1.02	.68	.33										
20	4.05	4.05	4.04	4.03	4.02	4.00	3.98	3.95	3.92	3.87	3.82	3.77	3.70	3.63	3.55	3.46	3.35	3.24	3.11	2.97
	2.83	2.66	2.45	2.20	1.92	1.60	1.27	.95	.63	.31										
21	3.57	3.57	3.57	3.56	3.54	3.52	3.50	3.47	3.43	3.39	3.34	3.28	3.22	3.15	3.08	2.99	2.90	2.80	2.69	2.56
	2.44	2.30	2.11	1.90	1.65	1.37	1.09	.81	.54	.27										
22	2.79	2.79	2.78	2.77	2.76	2.74	2.72	2.69	2.66	2.63	2.59	2.54	2.49	2.44	2.38	2.31	2.24	2.16	2.07	1.97
	1.88	1.77	1.62	1.46	1.27	1.05	.83	.62	.41	.20										
23	1.77	1.77	1.77	1.76	1.75	1.74	1.73	1.71	1.69	1.67	1.64	1.61	1.58	1.54	1.50	1.46	1.41	1.36	1.30	1.24
	1.18	1.11	1.02	.92	.80	.66	.52	.39	.26	.13										
24	.66	.66	.66	.66	.66	.65	.65	.64	.63	.62	.61	.60	.59	.57	.56	.54	.53	.51	.48	.46
	.44	.41	.37	.33	.29	.24	.20	.15	.10	.05										
25	.16	.16	.16	.16	.16	.16	.16	.16	.16	.15	.15	.15	.15	.14	.14	.13	.13	.12	.12	.11
	.11	.10	.09	.08	.07	.06	.05	.04	.02	.01										
26	.06	.06	.06	.06	.06	.06	.06	.06	.06	.06	.06	.06	.06	.05	.05	.05	.05	.05	.05	.04
	.04	.04	.03	.03	.03	.02	.02	.01	.01	.00										
27	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02
	.01	.01	.01	.01	.01	.01	.01	.00	.00	.00										

EXHIBIT C

RELATIVE POWER DENSITY (AVERAGED OVER HEIGHT)
VS. RADIAL POSITION*

Radius, cm	t=0 s	t=1 s	t=4 s
0	1.504	2.414	4.062
8	1.504	2.417	4.065
16	1.504	2.424	4.077
24	1.504	2.436	4.096
32	1.503	2.453	4.125
40	1.503	2.480	4.168
48	1.502	2.504	4.208
56	1.502	2.516	4.227
64	1.501	2.522	4.235
72	1.501	2.521	4.231
80	1.500	2.516	4.223
88	1.499	2.507	4.206
96	1.498	2.494	4.183
104	1.498	2.479	4.154
112	1.499	2.461	4.123
120	1.505	2.446	4.096
128	1.502	2.418	4.047
136	1.480	2.365	3.956
144	1.443	2.290	3.830
152	1.392	2.199	3.676
160	1. 32	2.094	3.500
168	1.256	1.968	3.289
176	1.162	1.814	3.030
184	1.051	1.637	2.734
192	0.925	1.438	2.402
200	0.815	1.263	2.110
208	0.682	1.056	1.763
216	0.516	0.798	1.332
224	0.345	0.533	0.889
232	0.172	0.265	0.442
240	0.0	0.0	0.0

* Δt = 0.0005 s

EXHIBIT D

RELATIVE POWER DENSITY (AVERAGED OVER RADIUS) VS. AXIAL POSITION*

Height**	t=0 s	t=1 s	t=4 s
0	0.0	0.0	0.0
18.75	0.0	0.0	0.0
37.50	0.0	0.0	0.0
56.25	0.0	0.0	0.0
75.00	0.118	0.154	0.250
93.75	0.646	0.848	1.375
112.50	1.037	1.365	2.216
131.25	1.369	1.811	2.946
150.00	1.622	2.163	3.524
168.75	1.780	2.398	3.916
187.50	1.826	2.469	4.088
206.25	1.820	2.534	4.167
225.00	1.821	2.597	4.290
243.75	1.822	2.676	4.442
262.50	1.822	2.770	4.621
281.25	1.822	2.879	4.829
300.00	1.821	3.006	5.066
318.75	1.820	3.153	5.338
337.50	1.827	3.341	5.678
356.25	1.781	3.421	5.832
375.00	1.623	3.227	5.514
393.75	1.370	2.792	4.780
412.50	1.038	2.152	3.688
431.25	0.647	1.355	2.324
450.00	0.118	0.247	0.423
468.75	0.0	0.0	0.0
487.50	0.0	0.0	0.0
506.25	0.0	0.0	0.0
525.00	0.0	0.0	0.0

* $\Delta t = 0.0005$ s

** Height is measured from top of the reactor

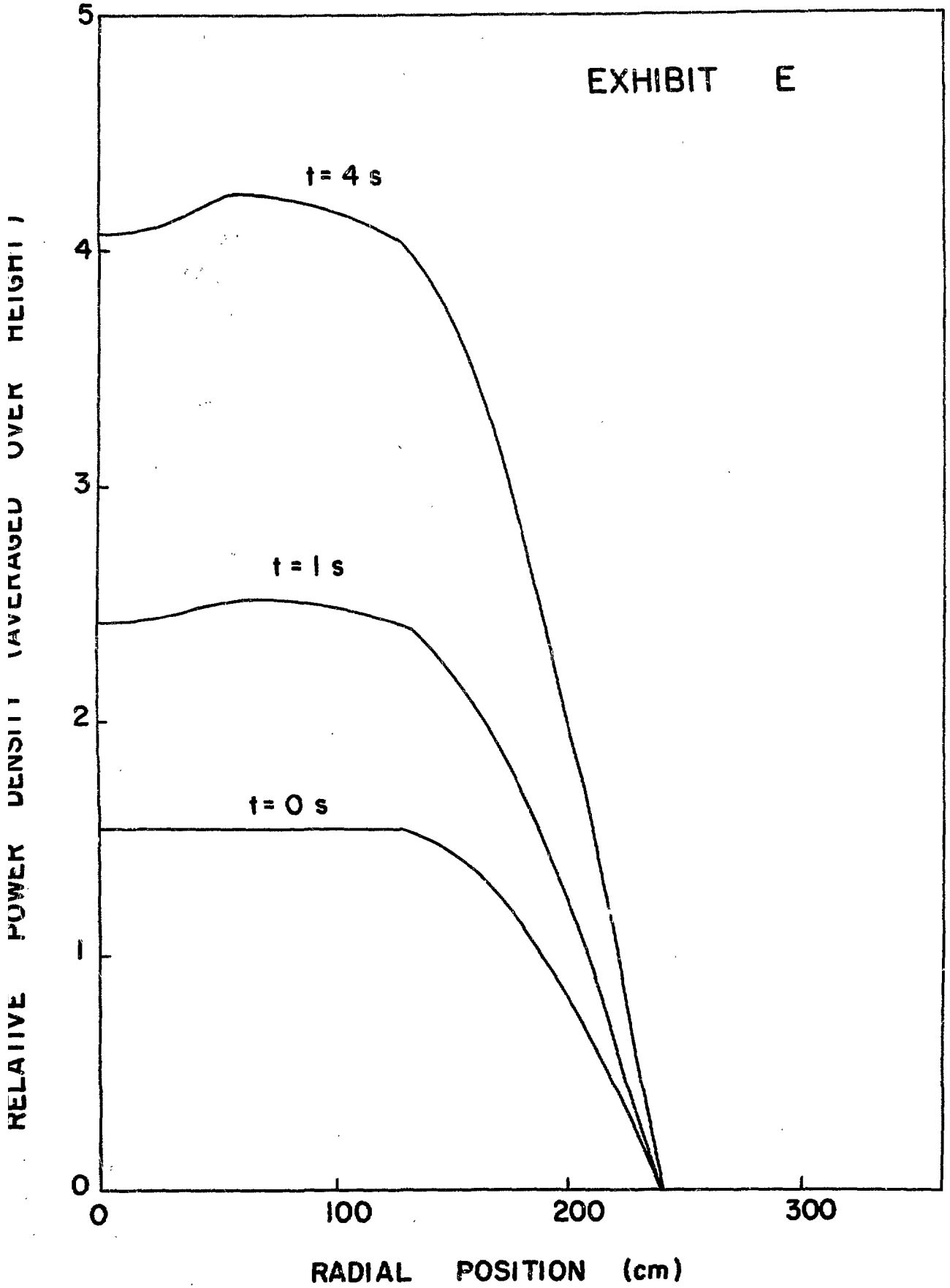


EXHIBIT E
t = 4 s
t = 1 s
t = 0 s
RELATIVE POWER DENSITY (AVERAGED OVER HEIGHT)
RADIAL POSITION (cm)
0
1
2
3
4
5
0
100
200
300

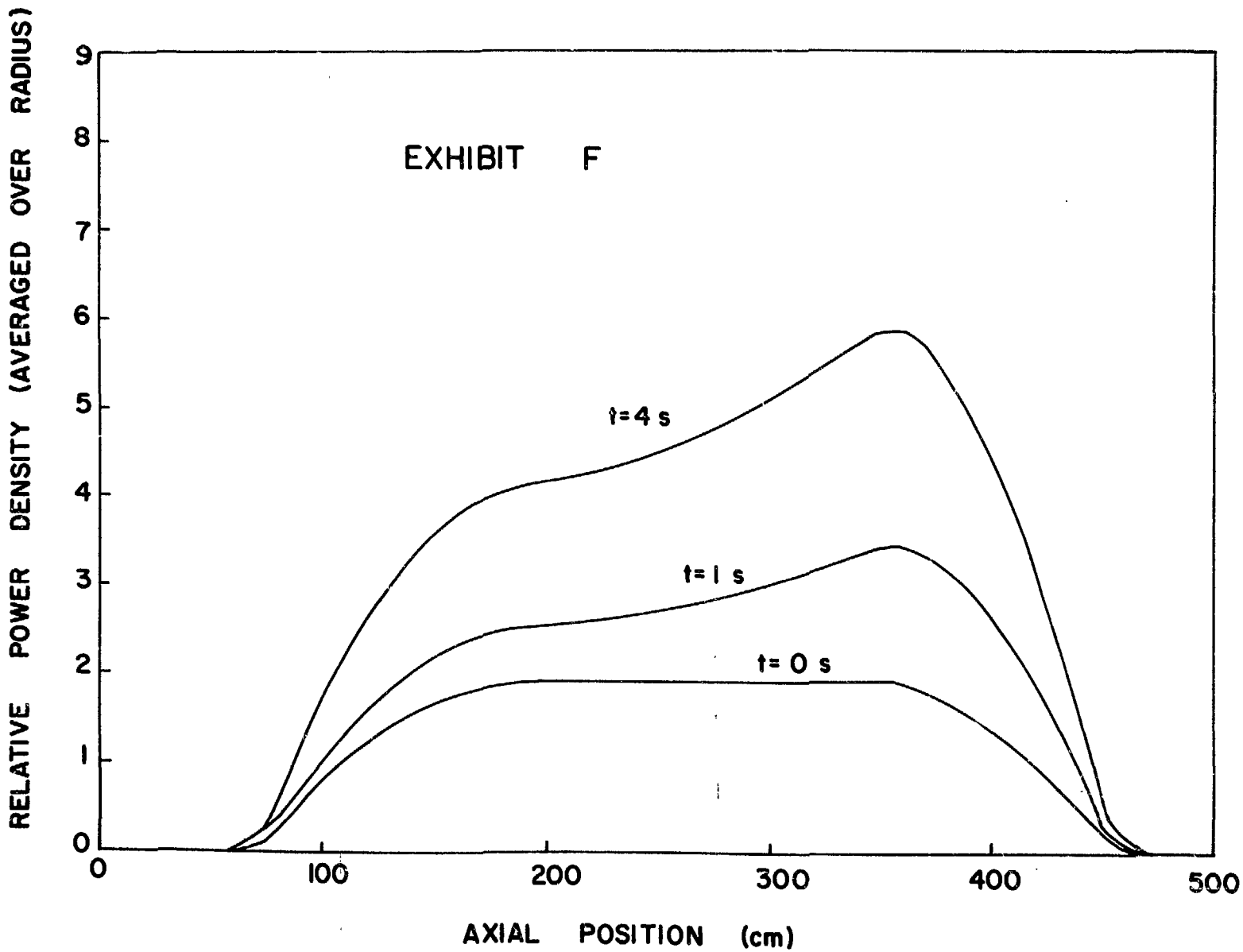


EXHIBIT F
RELATIVE POWER DENSITY (AVERAGED OVER RADIUS)
AXIAL POSITION (cm)
t=4 s
t=1 s
t=0 s
0
1
2
3
4
5
6
7
8
9
0
100
200
300
400
500

BENCHMARK SOURCE SITUATION

Identification: 9

Date Submitted: June 1976 By: R. G. Steinke (LASL)

Date Accepted: June 1977 By: H. L. Dodds, Jr. (U. of Tenn.)
M. R. Wagner (KWU)

Descriptive Title: Multi-dimensional (Hex-z) HTGR Model

Suggested Function: Test multigroup solutions in hexagonal (triangular) geometry

Configuration: Three-dimensional configuration having six-fold rotational symmetry in the x-y plane (three figures)

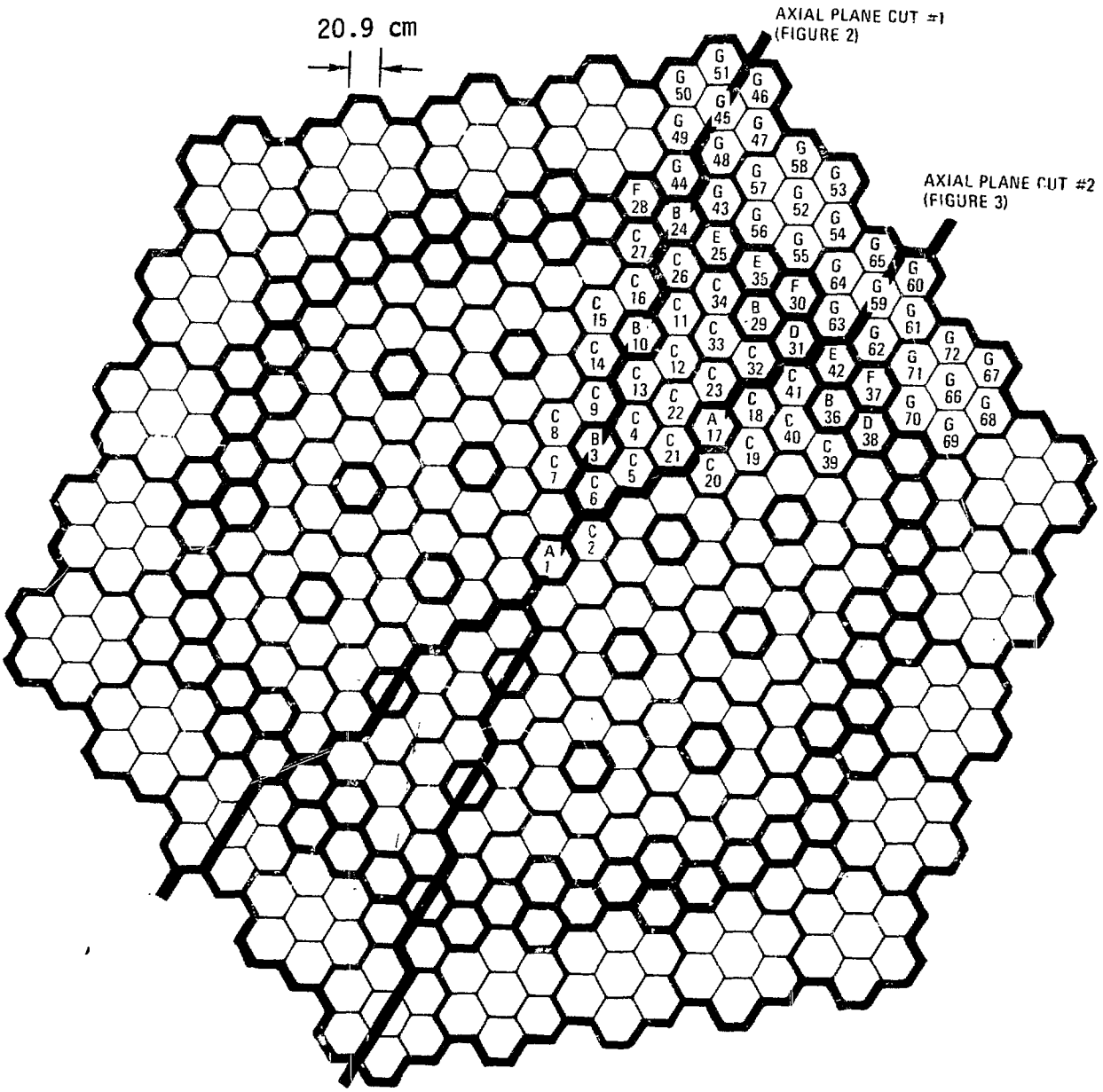


Figure 1. X-Y Plane Diagram of the Top Half of the Reactor. (The composition letter and column number of each hexagon block in the sixty degree rotational symmetry sector are given in their upper and lower halves.)

1																		P	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	G	G	G	G	G
2																		A	C	C	C	B	C	C	C	B	C	C	C	B	G	G	G	G	G
3																		A	C	C	C	B	C	C	C	B	C	C	C	B	G	G	G	G	G
4																		A	C	C	C	B	C	C	C	B	C	C	C	B	G	G	G	G	G
5																		J	K	K	K	J	K	K	K	J	K	K	K	J	G	G	G	G	G
6																		J	K	K	K	J	K	K	K	J	K	K	K	J	G	G	G	G	G
7																		J	K	K	K	J	K	K	K	J	K	K	K	J	G	G	G	G	G
8																		H	H	H	H	H	H	H	H	H	H	H	H	H	G	G	G	G	G
LAYER NUMBER/COLUMN NUMBER																		1	2	2	7	3	9	9	14	10	16	16	27	24	44	44	49	45	51

Figure 2. Axial Plane Cut #1 Diagram (The composition letter of each hexagon block in the sixty degree rotational symmetry sector is shown in the diagram. The composition letters and column numbers are for the counter-clockwise rotated face of the cut.)

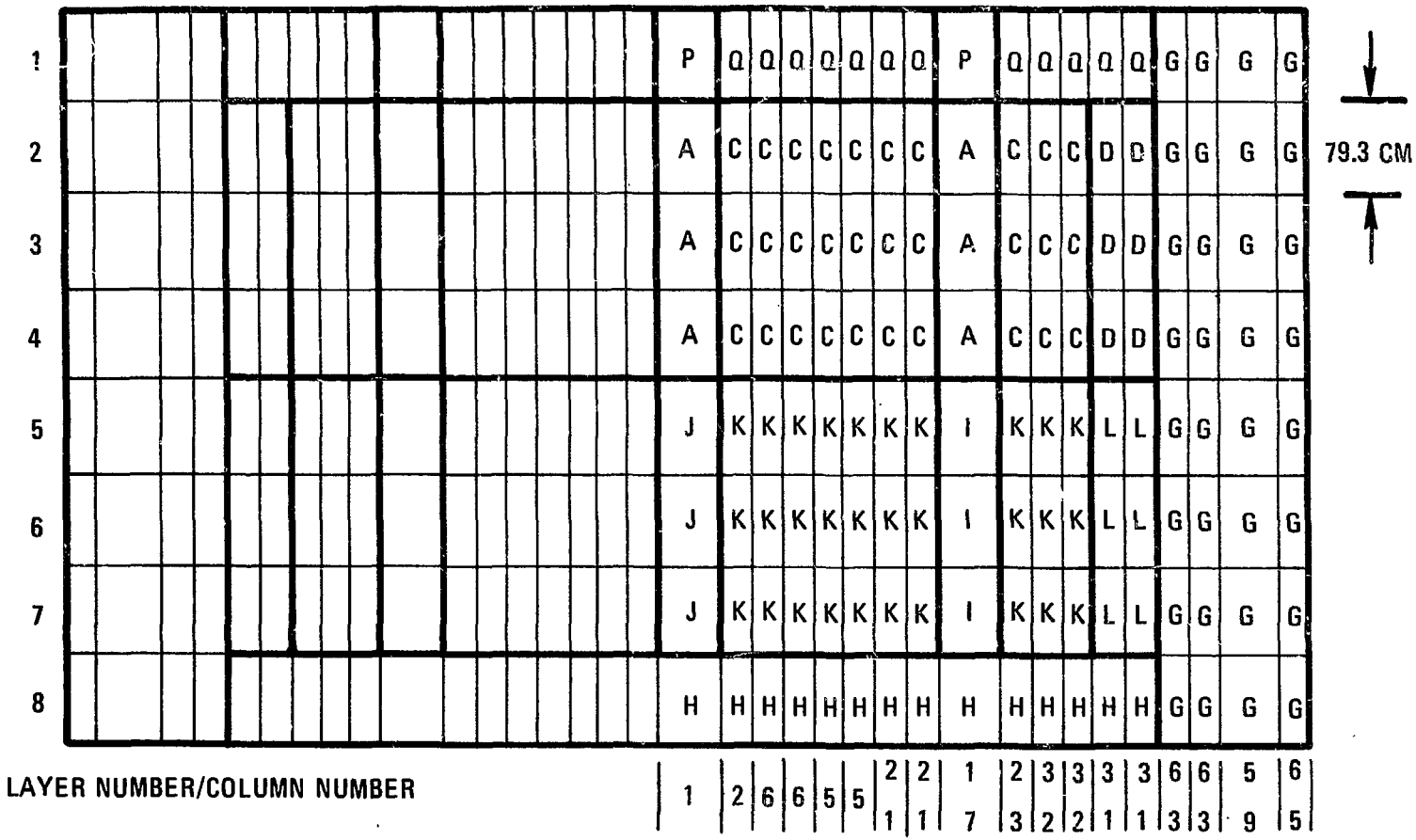


Figure 3. Axial Plant Cut #2 Diagram (The composition letter of each hexagon block in the sixty degree rotational symmetry sector is shown in the diagram. The composition letters and column numbers are for the counter-clockwise rotated face of the cut.)

Boundary Condition: Vacuum boundary condition on outside surface.

Composition: Fuel temperature = 1150°K. Moderator and poison temperature = 1050°K.

Composition Letter		A	B	C	D	E	F	G	H
Composition Description		Controlled Core Top Half	Uncontrolled Core Top Half	Regular Core Top Half	Buffer One Side Top Half	Buffer Two Sides Top Half	Buffer Three Sides Top Half	Radial Reflector	Bottom Reflector
Concentration†	Th-232	1.83-4	1.83-4	3.22-4	3.43-4	3.55-4	3.68-4	0.0	0.0
	U-235	1.21-5	1.21-5	2.13-5	1.92-5	1.79-5	1.66-5	0.0	0.0
	U-238	7.60-7	7.60-7	1.34-6	1.20-6	1.12-6	1.04-6	0.0	0.0
	C	5.49-2	5.49-2	6.15-2	6.15-2	6.15-2	6.15-2	8.93-2	7.26-2
	B(nat)	1.60-3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	B-10	0.0	0.0	4.00-7	4.00-7	4.00-7	4.00-7	0.0	0.0

Composition Letter		I	J	K	L	M	N	P	Q
Composition Description		Controlled Core Bottom Half	Uncontrolled Core Bottom Half	Regular Core Bottom Half	Buffer One Side Bottom Half	Buffer Two Sides Bottom Half	Buffer Three Sides Bottom Half	Controlled Top Reflector	Un-Controlled Top Reflector
Concentration†	Th-232	1.49-4	1.49-4	2.88-4	3.16-4	3.33-4	3.50-4	0.0	0.0
	U-235	8.41-6	8.41-6	1.62-5	1.51-5	1.44-5	1.38-5	0.0	0.0
	U-238	5.27-7	5.27-7	1.02-6	9.48-7	9.05-7	8.62-7	0.0	0.0
	C	5.05-2	5.05-2	6.19-2	6.17-2	6.17-2	6.17-2	6.74-2	6.74-2
	B(nat)	1.60-3	0.0	0.0	0.0	0.0	0.0	1.60-3	0.0
	B-10	0.0	0.0	4.00-7	4.00-7	4.00-7	4.00-7	0.0	0.0

† Units of 10^{24} atoms/cm^3.

BENCHMARK PROBLEM

Identification: 9-A1 Source Situation ID.9

Date Submitted: June 1976 By: R. G. Steinke (LASL)

Date Accepted: June 1977 By: H. L. Dodds, Jr. (U. of Tenn.)
M. R. Wagner (KWU)

Descriptive Title: Few-Group, Two-Dimensional Hexagonal Geometry HTGR Problem

Reduction of Source Situation:

1. Diffusion theory.
2. Four energy groups (G=4) with single group downscatter.
3. Two-dimensional hexagonal (triangular) geometry with zero axial leakage; top half of the core horizontal plane (Figure 1 of Source Situation).
4. Zero flux boundary condition on the outside surface.

The few-group diffusion equations to be solved are

$$-\underline{\nabla} \cdot D^g \underline{\nabla}\phi^g + \Sigma_r^g \phi^g - \Sigma_s^{g-1\to g}\, \phi^{g-1} = (\chi^g/K_{eff}) \sum_{g'=1}^{G} \nu\Sigma_f^{g'}\, \phi^{g'} \quad ; \quad g=1,2,\ldots,G=4$$

where $$\Sigma_r^g = \Sigma_c^g + \Sigma_f^g + \Sigma_s^{g\to g+1} \quad , \quad \Sigma_s^{G\to G+1} = 0$$

and the usual cross section definitions apply.

Additional Data:

Fission Spectrum $\chi^1=0.9675$, $\chi^2=0.0325$, $\chi^3=0.0$, $\chi^4=0.0$

Energy Group Intervals

Energy Group Number	Energy Interval, eV
1	1.83+5 to 1.49+7
2	1.76+1 to 1.83+5
3	2.38 to 1.76+1
4	0.0 to 2.38

Macroscopic Cross Sections

Composition A (Controlled Core)

Group g	D^g	Σ_c^g	Σ_f^g	$\nu\Sigma_f^g$	$\Sigma_s^{g\to g+1}$
1	2.65+0	1.98-4	2.25-5	5.58-5	1.09-2
2	1.37+0	4.55-3	1.49-4	3.61-4	3.28-3
3	1.34+0	9.12-3	4.08-4	9.88-4	2.04-2
4	1.31+0	8.93-3	1.97-3	4.76-3	

Composition B (Uncontrolled Core)

Group g	D^g	Σ_c^g	Σ_f^g	$\nu\Sigma_f^g$	$\Sigma_s^{g\to g+1}$
1	2.65+0	3.61-5	2.25-5	5.58-5	1.09-2
2	1.37+0	7.69-4	1.49-4	3.61-4	3.28-3
3	1.34+0	4.28-4	4.08-4	9.88-4	2.04-2
4	1.31+0	8.70-4	1.97-3	4.76-3	

Composition C (Regular Core)

Group g	D^g	Σ_c^g	Σ_f^g	$\nu\Sigma_f^g$	$\Sigma_s^{g\to g+1}$
1	2.35+0	5.82-5	3.95-5	9.83-5	1.23-2
2	1.21+0	1.36-3	2.62-4	6.36-4	3.67-3
3	1.19+0	8.41-4	7.18-4	1.74-3	2.28-2
4	1.16+0	1.89-3	3.46-3	8.39-3	

Composition D (Buffer Core; One Side On Core-Reflector Interface)

Group g	D^g	Σ_c^g	Σ_f^g	$\nu\Sigma_f^g$	$\Sigma_s^{g\to g+1}$
1	2.35+0	6.08-5	3.76-5	9.31-5	1.23-2
2	1.21+0	1.43-3	2.36-4	5.73-4	3.67-3
3	1.19+0	7.77-4	6.47-4	1.57-3	2.28-2
4	1.16+0	1.87-3	3.12-3	7.56-3	

Composition E (Buffer Core; Two Sides on Core-Reflector Interface)

Group g	D^g	Σ_c^g	Σ_f^g	$\nu\Sigma_f^g$	$\Sigma_s^{g\to g+1}$
1	2.35+0	6.23-5	3.63-5	8.97-5	1.23-2
2	1.21+0	1.46-3	2.20-4	5.34-4	3.67-3
3	1.19+0	7.38-4	6.03-4	1.46-3	2.28-2
4	1.16+0	1.86-3	2.91-3	7.05-3	

Composition F (Buffer Core; Three Sides On Core-Reflector Interface)

Group g	D^g	Σ_c^g	Σ_f^g	$\nu\Sigma_f^g$	$\Sigma_s^{g\to g+1}$
1	2.35+0	6.40-5	3.51-5	8.65-5	1.23-2
2	1.21+0	1.50-3	2.04-4	4.95-4	3.67-3
3	1.19+0	6.99-4	5.59-4	1.36-3	2.28-2
4	1.16+0	1.85-3	2.70-3	6.54-3	

Composition G (Radial Reflector)

Group g	D^g	Σ_c^g	Σ_f^g	$\nu\Sigma_f^g$	$\Sigma_s^{g\to g+1}$
1	1.64+0	1.39-5	0.0	0.0	1.77-2
2	8.50-1	2.18-6	0.0	0.0	5.33-3
3	8.32-1	1.97-5	0.0	0.0	3.31-2
4	8.21-1	1.06-4	0.0	0.0	

Expected Primary Results:

1. Fundamental eigenvalue: K_{eff}.
2. Number of power iterations and computation time for the diffusion calculation versus mesh size.
3. Fundamental eigenvector: Fission rate density and group fluxes
   a. Hexagon averaged values (There are 72 unique hexagon columns)
   b. Radial traverses along axial plane cuts #1 and #2 (See Figure 1 of the Source Situation)

Note: Normalize the core average fission rate density to one fission per cm^3 per second

Possible Additional Results:

1. Neutron balance for each composition type and the core.
2. Change hexagon column 1 from Composition A (Controlled Core) to Composition B (Uncontrolled Core) and report the above.

Best Solution Available:

Solutions Available:

1. Finite difference: 9-A1-1, 9-A1-2, 9-A1-3

BENCHMARK PROBLEM SOLUTION

Identification: 9-A1-1 Benchmark Problem ID.9-A1

Date Submitted: June 1976 By: R. G. Steinke (LASL)

Date Accepted: June 1977 By: H. L. Dodds, Jr. (U. of Tenn.)
M. R. Wagner (KWU)

Descriptive Title: Discrete Few-Group, Two-Dimensional Hexagonal Geometry HTGR Problem

Mathematical Model:

1. Equilateral triangle grid network overlay with mesh lines coinciding with composition interfaces; mesh lines connect mesh points forming a interface centered mesh.
2. Seven-point difference equations with a finite difference first derivative leakage approximation midway between mesh points.

Method of Solution:

1. One line successive over-relaxation with one inner per outer iteration.
2. Coarse mesh rebalance with concentric ring mesh lines becoming coarse mesh points.
3. Periodic asymptotic flux extrapolation.

Program Name: BUG180/HTGR
Type of Program: Two-Dimensional, Triangular Mesh, Multigroup Diffusion-Depletion Program
Program Language: Fortran V with NTRAN
Machine Language Contents: None
Program Ancestors: BUG-2/BUGTRI, GAMTRI, GAMBLE
Computer: UNIVAC 1108
Hardware Used: 64K of central core and 2 drums with 40K of available storage each
Operating System: UNIVAC 1108 EXEC-8 Operating System, Level 31
Significant Figures Carried: Equivalent of eight decimals
Convergence Criteria: Maximum relative flux change less than 10^{-5}
References: W. R. Davison, "BUG180/HTGR, A Two-Dimensional, Triangular Mesh, Multigroup Diffusion-Burnup Code for Use in the Design of 180° Rotationally Symmetric HTGR Cores," General Atomic Report GA-A12674 (April, 1975)

J. P. Dorsey, R. Froehlich and F. Todt, "BUG-2/BUGTRI, Two Dimensional Multigroup Burnup Codes for Rectangular and Hexagonal Geometry," USAEC Report GA-8272, Gulf General Atomic Inc. (August, 1969).

Primary Results:

Mesh Description	Coarse	Fine	Very Fine
Equivalent Number of Mesh Points/Column	3	12	48
Distance Between Mesh Points	20.9 cm	10.45 cm	5.225 cm
Number of Spatial Mesh Points (1/2 core calculation plane)	682	2644	10411
K_{eff} Fundamental Eigenvalue	1.116716	1.117766	1.118149
Number of Power Iterations	55	112	460
Computer Time for Diffusion Calculation (UNIVAC 1108)	1.92 min	13.27 min	160.9

TABLE I

COLUMN AVERAGED FISSION DISTRIBUTION (FISSIONS/CM**3/SEC)
[NORMALIZED TO A CORE AVERAGE VALUE OF ONE]

Column Number	Equivalent No. Points/Column		
	3	12	48
1	0.3798	0.3755	0.3745
2	0.9988	1.0497	1.0655
3	0.7781	0.8207	0.8338
4	1.1891	1.2247	1.2349
5	1.2358	1.2777	1.2902
6	1.2183	1.2662	1.2806
7	1.2450	1.2906	1.3043
8	1.1999	1.2404	1.2522
9	1.2147	1.2470	1.2562
10	0.7442	0.7638	0.7695
11	1.1766	1.1692	1.1665
12	1.1328	1.1431	1.1455
13	1.1938	1.2149	1.2207
14	1.1565	1.1761	1.1812
15	1.1522	1.1551	1.1552
16	1.1802	1.1699	1.1663
17	0.3494	0.3374	0.3339
18	0.8565	0.8673	0.8703
19	0.9093	0.9284	0.9338
20	0.9547	0.9879	0.9977
21	0.9665	1.0048	1.0162
22	0.9419	0.9702	0.9785
23	0.8859	0.9007	0.9048
24	0.7534	0.7280	0.7206
25	1.0347	0.9833	0.9688
26	1.1301	1.1012	1.0928
27	1.1038	1.0702	1.0605
28	0.9614	0.9063	0.8907
29	0.6444	0.6412	0.6404
30	0.9144	0.8673	0.8541
31	0.9867	0.9557	0.9467
32	1.0122	1.0052	1.0028
33	1.0913	1.0852	1.0830
34	1.1010	1.0745	1.0668
35	0.9778	0.9306	0.9174
36	0.6438	0.6409	0.6402
37	0.9128	0.8654	0.8520
38	1.0073	0.9696	0.9587
39	1.1131	1.0972	1.0921
40	1.0477	1.0454	1.0441
41	1.0215	1.0056	1.0008
42	0.9655	0.9256	0.9141

TABLE II

ENERGY GROUP 1 COLUMN AVERAGED FLUX DISTRIBUTION (NEUTRONS/CM**2/SEC)

Column Number	Equivalent No. Points/Column			Column Number	Equivalent No. Points/Column		
	3	12	48		3	12	48
1	127.487	130.467	131.571	37	99.857	102.062	102.886
2	169.477	177.610	180.096	38	139.999	139.480	139.360
3	192.456	195.194	195.811	39	176.456	175.431	175.043
4	190.694	196.893	198.719	40	168.092	168.487	168.502
5	197.946	205.378	207.624	41	158.103	157.898	157.768
6	195.498	203.746	206.268	42	119.647	120.815	121.286
7	199.456	207.498	209.956	43	32.988	27.041	25.275
8	192.469	199.484	201.577	44	29.975	24.738	23.167
9	194.486	200.315	202.026	45	0.091	0.045	0.036
10	184.114	181.724	180.763	46	0.004	0.002	0.001
11	188.270	187.914	187.734	47	0.102	0.050	0.040
12	181.688	183.837	184.395	48	1.888	1.174	1.010
13	191.270	195.396	196.563	49	1.501	0.925	0.796
14	185.564	189.254	190.268	50	0.046	0.023	0.018
15	184.492	185.603	185.840	51	0.003	0.001	0.001
16	188.861	188.077	187.763	52	1.933	1.195	1.027
17	117.302	117.231	117.318	53	0.068	0.036	0.030
18	145.454	146.977	147.331	54	1.406	0.878	0.759
19	154.324	157.142	157.879	55	29.795	24.603	23.027
20	161.897	167.061	168.536	56	33.718	27.583	25.740
21	163.888	169.879	171.627	57	2.052	1.263	1.085
22	159.772	164.108	165.329	58	0.099	0.050	0.040
23	150.443	152.554	153.094	59	2.916	1.818	1.569
24	121.409	120.178	119.863	60	0.098	0.052	0.042
25	128.329	128.996	129.290	61	1.438	0.895	0.772
26	175.705	173.944	173.353	62	30.155	24.877	23.273
27	168.044	166.420	165.866	63	46.225	38.484	36.057
28	105.662	107.535	108.239	64	16.055	12.869	11.964
29	148.656	144.791	143.503	65	0.434	0.262	0.222
30	99.858	102.107	102.960	66	2.510	1.561	1.348
31	137.426	137.510	137.583	67	0.073	0.038	0.031
32	160.448	160.549	160.507	68	0.470	0.279	0.235
33	174.857	174.823	174.745	69	16.760	13.403	12.446
34	169.649	168.309	167.865	70	44.385	37.012	34.691
35	120.082	120.997	121.388	71	15.960	12.800	11.901
36	148.546	144.738	143.446	72	0.423	0.257	0.218

TABLE III

ENERGY GROUP 2 COLUMN AVERAGED FLUX DISTRIBUTION (NEUTRONS/CM**2/SEC)

Column Number	Equivalent No. Points/Column			Column Number	Equivalent No. Points/Column		
	3	12	48		3	12	48
1	300.333	304.512	305.987	37	242.102	236.049	233.903
2	400.118	419.325	425.254	38	328.335	322.002	319.904
3	477.028	493.012	497.895	39	412.029	408.999	407.844
4	450.989	464.459	468.348	40	395.369	395.725	395.537
5	467.542	483.798	488.645	41	367.883	366.146	365.415
6	462.360	480.653	486.177	42	286.128	280.217	278.192
7	471.125	488.822	494.168	43	123.002	112.662	109.970
8	455.166	470.547	475.060	44	111.047	101.982	99.616
9	459.397	471.908	475.505	45	1.936	1.357	1.220
10	456.012	458.782	459.454	46	0.138	0.092	0.082
11	442.440	440.924	440.231	47	2.084	1.483	1.340
12	429.499	433.584	434.539	48	18.657	15.004	14.078
13	451.722	460.248	462.583	49	14.418	11.531	10.809
14	438.792	446.404	448.408	50	0.957	0.690	0.626
15	435.249	436.919	437.129	51	0.113	0.074	0.065
16	443.297	440.890	439.911	52	18.311	14.752	13.846
17	276.273	273.583	272.811	53	1.265	0.963	0.887
18	342.622	346.500	347.458	54	12.916	10.523	9.924
19	364.185	370.932	372.745	55	106.484	97.978	95.785
20	382.115	394.286	397.813	56	121.157	110.948	108.305
21	386.798	400.901	405.067	57	19.707	15.808	14.820
22	377.108	387.353	390.288	58	1.951	1.402	1.271
23	354.832	360.000	361.370	59	25.807	21.038	19.826
24	298.208	291.403	289.166	60	1.752	1.339	1.236
25	303.332	295.934	293.453	61	13.443	10.925	10.293
26	404.874	399.906	398.235	62	109.435	100.609	98.312
27	385.236	380.106	378.379	63	156.395	146.005	143.242
28	253.497	246.472	244.008	64	67.041	59.843	58.020
29	360.212	356.679	355.579	65	5.436	4.306	4.020
30	242.011	236.008	233.907	66	21.944	17.822	16.785
31	323.761	318.614	316.899	67	1.348	1.009	0.926
32	376.045	375.586	375.217	68	6.004	4.659	4.320
33	410.546	409.863	409.450	69	69.155	61.584	59.654
34	392.528	388.299	386.873	70	148.324	138.497	135.861
35	284.604	278.153	275.986	71	66.417	59.328	57.526
36	360.225	356.786	355.662	72	5.225	4.150	3.877

TABLE IV

ENERGY GROUP 3 COLUMN AVERAGED FLUX DISTRIBUTION (NEUTRONS/CM**2/SEC)

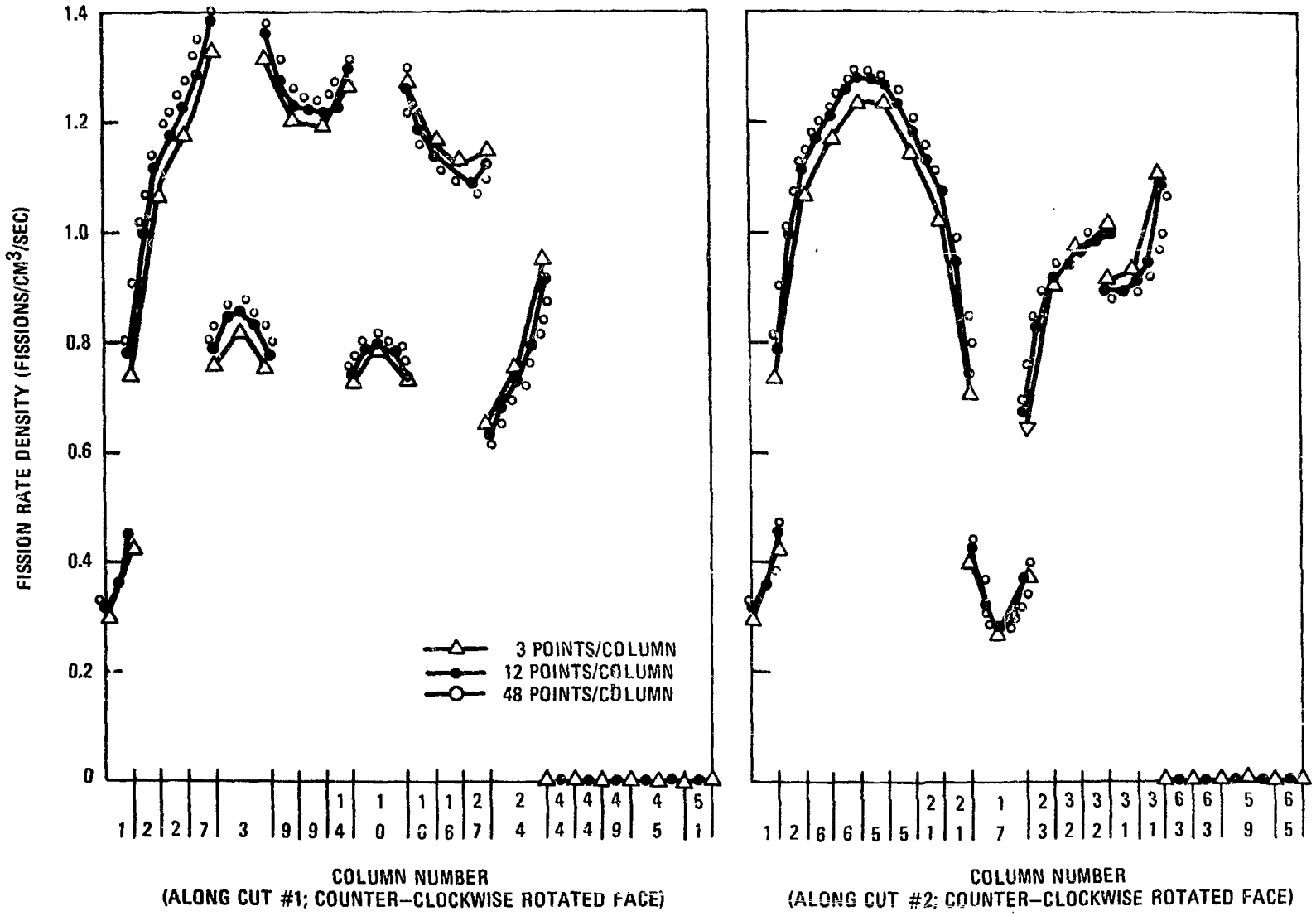
Column Number	Equivalent No. Points/Column			Column Number	Equivalent No. Points/Column		
	3	12	48		3	12	48
1	41.557	41.106	40.938	37	36.986	35.847	35.458
2	59.312	62.355	63.308	38	49.545	48.477	48.129
3	72.274	74.904	75.709	39	61.747	61.266	61.085
4	67.710	69.725	70.306	40	59.282	59.338	59.310
5	70.201	72.617	73.338	41	55.147	54.832	54.706
6	69.416	72.155	72.981	42	43.459	42.393	42.038
7	70.739	73.372	74.167	43	19.982	18.513	18.134
8	68.336	70.638	71.312	44	18.035	16.740	16.406
9	68.979	70.835	71.368	45	0.357	0.253	0.228
10	69.076	69.694	69.856	46	0.026	0.017	0.015
11	66.357	66.117	66.010	47	0.384	0.276	0.250
12	64.474	65.085	65.226	48	3.317	2.708	2.553
13	67.823	69.080	69.424	49	2.560	2.079	1.957
14	65.875	67.012	67.310	50	0.177	0.129	0.117
15	65.330	65.567	65.595	51	0.021	0.014	0.012
16	66.465	66.095	65.945	52	3.247	2.658	2.506
17	38.225	36.929	36.498	53	0.232	0.179	0.165
18	50.732	51.478	51.682	54	2.285	1.893	1.793
19	53.977	55.152	55.484	55	17.235	16.028	15.721
20	56.654	58.642	59.232	56	19.609	18.166	17.797
21	57.352	59.629	60.315	57	3.498	2.850	2.684
22	55.908	57.607	58.108	58	0.359	0.261	0.237
23	52.572	53.511	53.777	59	4.553	3.776	3.576
24	45.304	44.153	43.775	60	0.322	0.249	0.230
25	45.911	44.619	44.197	61	2.382	1.967	1.862
26	60.526	59.732	59.468	62	17.755	16.498	16.174
27	57.583	56.738	56.456	63	25.093	23.705	23.343
28	38.595	37.314	36.880	64	11.079	9.994	9.720
29	54.485	54.033	53.889	65	0.980	0.787	0.738
30	36.969	35.837	35.455	66	3.869	3.196	3.025
31	48.895	48.005	47.714	67	0.248	0.187	0.173
32	56.377	56.297	56.238	68	1.084	0.852	0.793
33	61.556	61.443	61.378	69	11.410	10.269	9.979
34	58.783	58.087	57.855	70	23.763	22.445	22.097
35	43.159	42.003	41.625	71	10.971	9.904	9.633
36	54.497	54.058	53.910	72	0.942	0.758	0.711

TABLE V

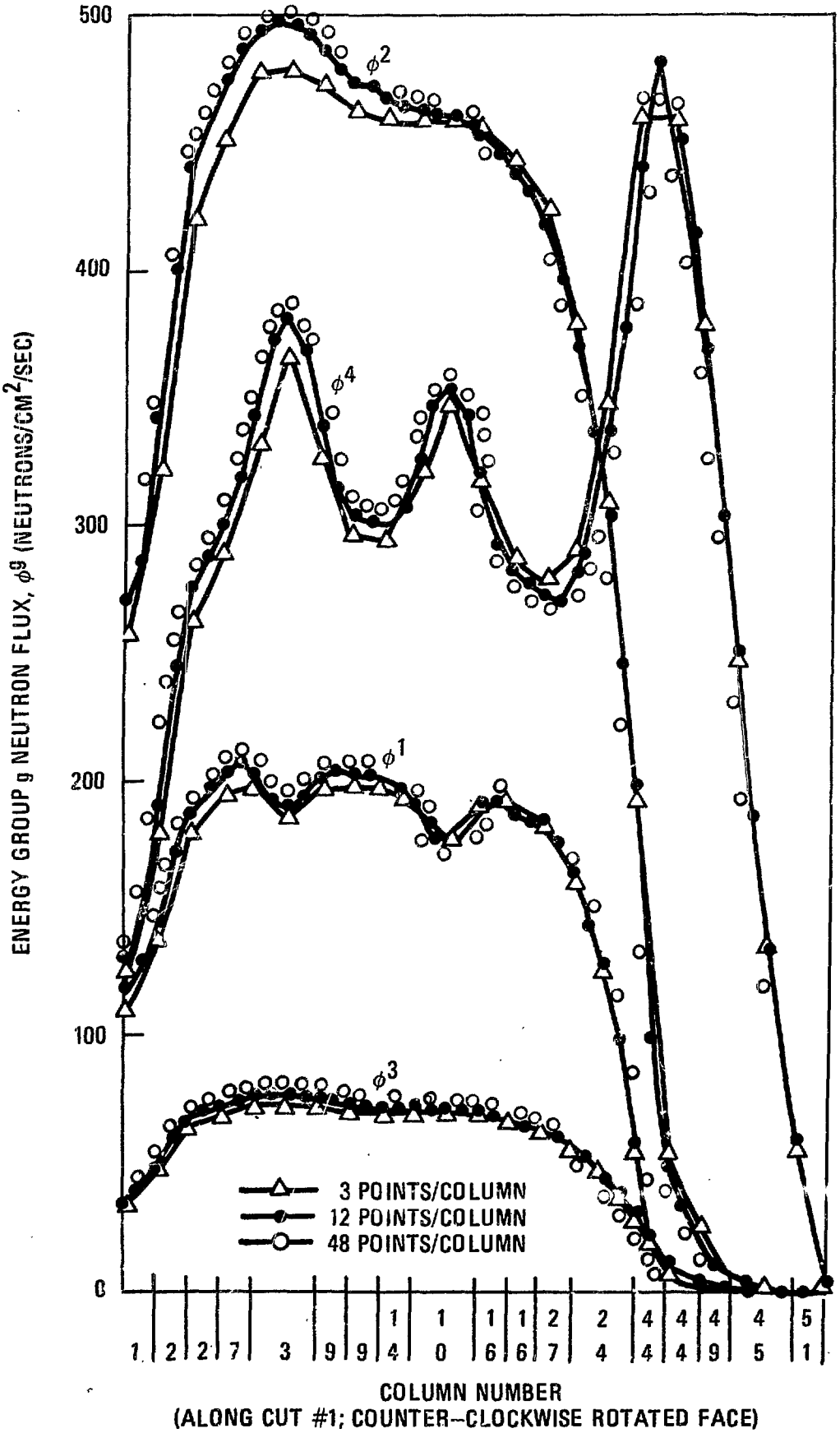
ENERGY GROUP 4 COLUMN AVERAGED FLUX DISTRIBUTION (NEUTRONS/CM**2/SEC)

Column Number	Equivalent No. Points/Column			Column Number	Equivalent No. Points/Column		
	3	12	48		3	12	48
1	160.031	157.568	156.977	37	310.827	293.927	289.190
2	244.130	256.652	260.552	38	286.048	274.672	271.413
3	341.745	361.548	367.650	39	275.689	271.413	270.069
4	293.305	302.064	304.576	40	258.643	257.937	257.567
5	304.946	315.239	318.304	41	254.113	249.740	248.433
6	300.461	312.254	315.792	42	299.644	286.607	282.885
7	307.195	318.393	321.771	43	454.841	454.438	454.208
8	295.961	305.925	308.830	44	430.889	428.974	428.383
9	299.747	307.672	309.949	45	135.792	134.117	133.818
10	326.863	336.509	339.303	46	23.879	25.180	25.717
11	290.630	288.658	287.963	47	119.032	119.114	119.511
12	279.437	281.953	282.522	48	326.682	320.576	318.844
13	294.552	299.720	301.121	49	270.981	266.622	265.438
14	285.239	290.047	291.288	50	64.011	65.081	65.688
15	284.390	285.027	285.048	51	21.220	22.125	22.553
16	291.580	288.868	287.950	52	273.495	271.312	270.817
17	147.231	141.568	139.959	53	49.381	51.802	52.804
18	209.415	212.078	212.801	54	172.251	174.529	175.694
19	222.260	227.001	228.332	55	375.071	376.922	377.647
20	233.378	241.597	244.022	56	423.292	424.833	425.296
21	236.287	245.725	248.554	57	319.434	314.816	313.523
22	230.257	237.251	239.299	58	89.721	90.636	91.319
23	216.547	220.212	221.241	59	295.692	295.769	295.894
24	349.138	336.969	333.499	60	54.350	57.276	58.462
25	321.527	304.684	299.973	61	176.904	179.588	180.874
26	281.396	273.613	271.363	62	382.784	386.177	387.319
27	275.975	266.842	264.241	63	407.756	415.035	417.364
28	327.565	307.905	302.401	64	339.528	341.048	341.597
29	286.889	285.636	285.398	65	106.924	109.309	110.510
30	311.415	294.656	289.991	66	274.640	273.104	272.731
31	279.963	270.602	267.916	67	49.266	51.541	52.500
32	250.525	248.577	247.899	68	146.943	147.262	147.801
33	269.550	267.859	267.275	69	371.097	368.875	368.236
34	274.363	267.172	265.108	70	397.364	401.382	402.772
35	304.073	288.562	284.238	71	334.560	335.637	336.022
36	286.561	285.503	285.273	72	103.093	105.235	106.329

RADIAL TRAVERSES OF THE FISSION RATE DENSITY ALONG CUTS #1 AND #2
IN FIGURE 1 OF THE SOURCE SITUATION



RADIAL TRAVERSE OF THE FOUR GROUP NEUTRON FLUXES
ALONG CUT #1 IN FIGURE 1 OF THE SOURCE SITUATION



RADIAL TRAVERSE OF THE FOUR GROUP NEUTRON FLUXES
ALONG CUT #2 IN FIGURE 1 OF THE SOURCE SITUATION

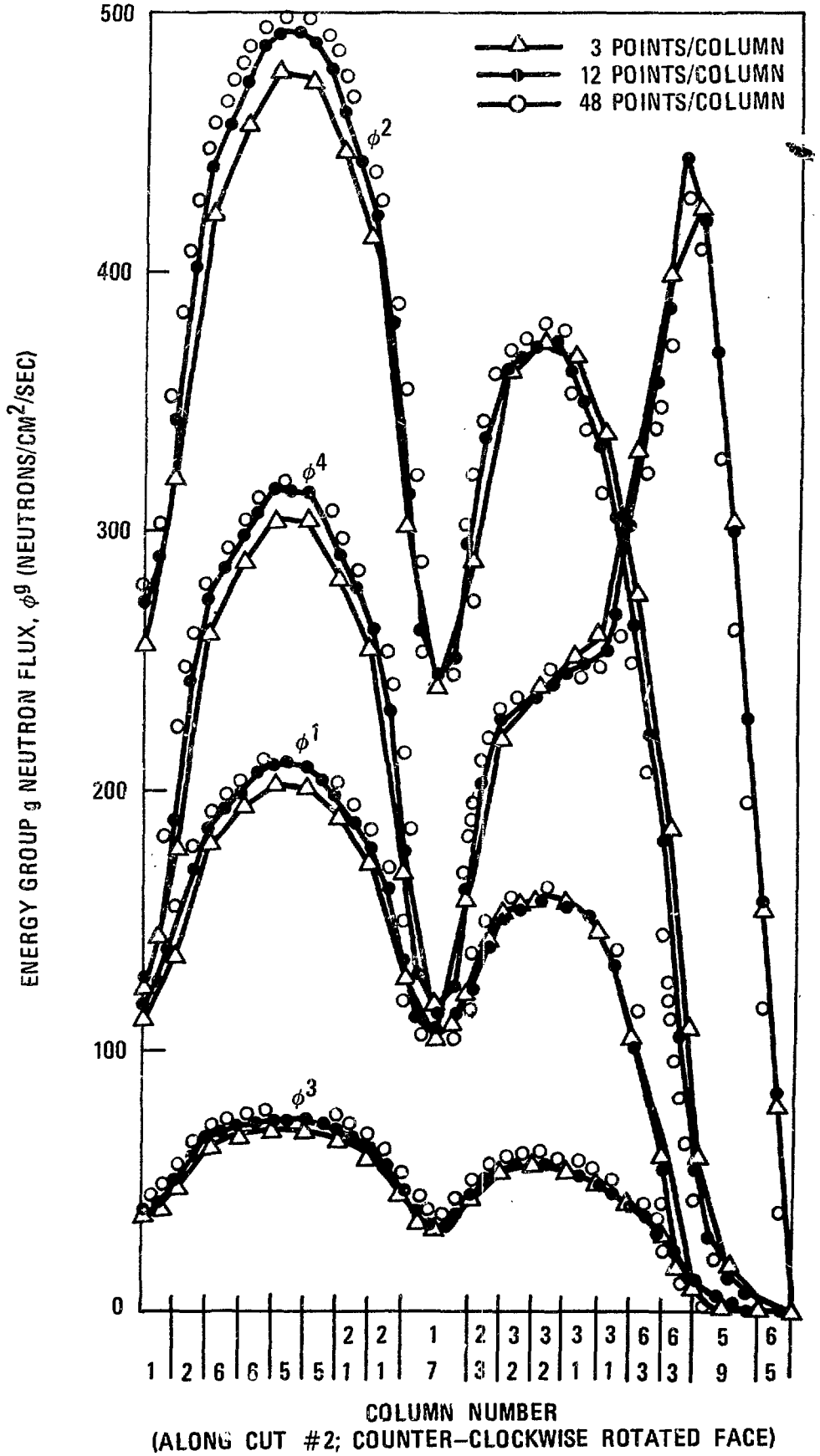


TABLE VI

NEUTRON BALANCE IN EACH COMPOSITION, THE CORE AND THE CORE-REFLECTOR

Comp. Letter	Energy Group	Points/ Column	Average Neutron Flux	Average Group Source	Reaction Rate Type/Source			
					Fission	Capture	Slowing Down	Normal Leakage
A	1	3	118.757	0.7411	0.00361	0.03173	1.74674	-0.78208
		12	119.121	0.7174	0.00374	0.03288	1.80990	-0.84651
		48	119.354	0.7107	0.00378	0.03325	1.83063	-0.86766
	2	3	279.710	1.3193	0.03159	0.96463	0.6958	-0.69160
		12	278.001	1.3225	0.03132	0.95644	0.68947	-0.67723
		48	277.550	1.3248	0.03122	0.95322	0.68715	-0.67159
	3	3	38.701	0.9174	0.01721	0.38471	0.86055	-0.26247
		12	37.526	0.9118	0.01679	0.37532	0.83953	-0.23165
		48	37.132	0.9104	0.01664	0.37199	0.83209	-0.22072
	4	3	149.059	0.7895	0.37194	1.68598	0.0000	-1.05792
		12	143.854	0.7655	0.37019	1.67808	0.0000	-1.04828
		48						
B	1	3	159.036	1.4859	0.00241	0.00386	1.16665	-0.17292
		12	157.325	1.4973	0.00236	0.00379	1.14527	-0.15143
		48	156.677	1.5010	0.00235	0.00377	1.13776	-0.14387
	2	3	390.337	1.7834	0.03261	0.16831	0.71790	0.08118
		12	391.332	1.7651	0.03303	0.17049	0.72718	0.06930
		48	391.551	1.7582	0.03318	0.17126	0.73046	0.06511
	3	3	59.127	1.2803	0.01884	0.01977	0.94212	0.01928
		12	59.368	1.2836	0.01887	0.01980	0.94355	0.01778
		48	59.428	1.2843	0.01888	0.1980	0.94397	0.01735
	4	3	318.239	1.2062	0.51976	0.22954	0.0000	0.25070
		12	321.233	1.2111	0.52252	0.23076	0.0000	0.24673
		48	322.224	1.2123	0.52361	0.23124	0.0000	0.24516

TABLE VI (Continued)

Comp. Letter	Energy Group	Points/ Column	Average Neutron Flux	Average Group Source	Reaction Rate Type/Source			
					Fission	Capture	Slowing Down	Normal Leakage
C	1	3	175.826	2.2904	0.00303	0.00447	0.94421	0.04829
		12	178.688	2.3147	0.00305	0.00449	0.94954	0.04292
		48	179.491	2.3212	0.00305	0.00450	0.95110	0.04134
	2	3	413.328	2.2396	0.04835	0.25099	0.67732	0.02334
		12	419.373	2.2756	0.04828	0.25063	0.67634	0.02474
		48	421.024	2.2857	0.04826	0.25051	0.67600	0.02523
	3	3	61.822	1.5169	0.02926	0.03428	0.92922	0.00724
		12	62.756	1.5391	0.02928	0.03429	0.92965	0.00678
		48	63.014	1.5452	0.02928	0.03430	0.92982	0.00660
	4	3	268.888	1.4096	0.66003	0.36054	0.0000	-0.02057
		12	271.833	1.4308	0.65734	0.35907	0.0000	-0.01641
		48	272.662	1.4367	0.65664	0.35869	0.0000	-0.01533
D	1	3	138.712	2.0936	0.00249	0.00403	0.81493	0.17855
		12	138.495	2.0196	0.00258	0.00417	0.84347	0.14979
		48	138.471	1.9981	0.00261	0.00421	0.85240	0.14078
	2	3	326.048	1.7765	0.04331	0.26215	0.67357	0.02066
		12	320.308	1.7713	0.04268	0.26859	0.66364	0.03510
		48	318.401	1.7703	0.04245	0.25719	0.66007	0.04029
	3	3	49.220	1.1966	0.02661	0.03196	0.93784	0.00358
		12	48.241	1.1755	0.02655	0.03189	0.93566	0.00590
		48	47.921	1.1685	0.02653	0.03186	0.93503	0.00657
	4	3	283.005	1.1222	0.78681	0.47158	0.0000	-0.25840
		12	272.637	1.0999	0.77337	0.46358	0.0000	-0.23690
		48	269.664	1.0926	0.77004	0.46153	0.0000	-0.23157

TABLE VI (Continued)

Comp. Letter	Energy Group	Points/ Column	Average Neutron Flux	Average Group Source	Reaction Rate Type/Source			
					Fission	Capture	Slowing Down	Normal Leakage
E	1	3	122.686	2.0840	0.00214	0.00367	0.72411	0.27009
		12	123.602	1.9853	0.00226	0.00388	0.76580	0.22806
		48	123.988	1.9572	0.00230	0.00395	0.77922	0.21453
	2	3	291.354	1.5790	0.04059	0.26939	0.67716	0.01285
		12	284.768	1.5870	0.03948	0.26198	0.65854	0.04001
		48	282.543	1.5908	0.03907	0.25931	0.65183	0.04978
	3	3	44.177	1.0693	0.02491	0.03049	0.94197	0.00262
		12	43.005	1.0451	0.02481	0.03037	0.93821	0.00661
		48	42.620	1.0369	0.02478	0.03033	0.93712	0.00776
	4	3	308.414	1.0072	0.89105	0.56954	0.0000	-0.46058
		12	293.284	0.9805	0.87041	0.55635	0.0000	-0.42676
		48	289.032	0.9717	0.86555	0.55324	0.0000	-0.41879
F	1	3	101.792	1.9512	0.00183	0.00334	0.64168	0.35315
		12	103.901	1.8448	0.00198	0.00360	0.69276	0.30166
		48	104.695	1.8147	0.00203	0.00369	0.70963	0.28465
	2	3	245.870	1.3176	0.03807	0.27991	0.68485	-0.00282
		12	239.509	1.3400	0.03646	0.26812	0.65599	0.03943
		48	237.272	1.3487	0.03589	0.26389	0.64565	0.05457
	3	3	37.517	0.9023	0.02324	0.02906	0.94795	-0.00026
		12	36.332	0.8790	0.02311	0.02889	0.94241	0.00560
		48	35.931	0.8708	0.02307	0.02884	0.94079	0.00730
	4	3	316.602	0.8554	0.99935	0.68474	0.0000	-0.68410
		12	298.829	0.8284	0.97400	0.66737	0.0000	-0.64137
		48	293.860	0.8192	0.96850	0.66360	0.0000	-0.63210

TABLE VI (Continued)

Comp Letter	Energy Group	Points/ Column	Average Neutron Flux	Average Group Source	Reaction Rate Type/Source			
					Fission	Capture	Slowing Down	Normal Leakage
G	1	3	10.452	0.0000	0.0000	0.0000	0.0000	0.0000
		12	8.474	0.0000	0.0000	0.0000	0.0000	0.0000
		48						
	2	3	41.729	0.1850	0.0000	0.00049	1.20221	-0.20270
		12	37.612	0.1500	0.0000	0.00055	1.33659	-0.33714
		48	36.551	0.1397	0.0000	0.00057	1.39431	-0.39488
	3	3	6.859	0.2224	0.0000	0.00061	1.02080	-0.02140
		12	6.245	0.2005	0.0000	0.00061	1.03112	-0.03173
		48	6.088	0.1948	0.0000	0.00062	1.03430	-0.03492
	4	3	233.029	0.2270	0.0000	0.10880	0.0000	0.89120
		12	233.610	0.2057	0.0000	0.11979	0.0000	0.88021
		48	233.989	0.2015	0.0000	0.12309	0.0000	0.87691
Core	1	3	161.098	2.0995	0.00281	0.00453	0.92868	0.06397
		12	162.988	2.0975	0.00285	0.00459	0.94016	0.05180
		48	163.528	2.0968	0.00286	0.00461	0.94429	0.04824
	2	3	381.416	2.0203	0.04521	0.25825	0.68219	0.01435
		12	384.231	2.0437	0.04507	0.25698	0.67940	0.01854
		48	384.910	2.0504	0.04502	0.25654	0.67839	0.02005
	3	3	57.170	1.3782	0.02721	0.03869	0.93136	0.00274
		12	57.559	1.3885	0.02723	0.03845	0.93084	0.00348
		48	57.652	1.3910	0.02724	0.03837	0.93070	0.00368
	4	3	278.529	1.2836	0.67408	0.40110	0.0000	-0.07518
		12	277.776	1.2925	0.66854	0.39623	0.0000	-0.06477
		48	277.582	1.2946	0.66722	0.39500	0.0000	-0.06222

TABLE VI (Continued)

Comp. Letter	Energy Group	Points/ Column	Average Neutron Flux	Average Group Source	Reaction Rate Type/Source			
					Fission	Capture	Slowing Down	Normal Leakage
Core and Refl.	1	3	97.594	1.2145	0.00281	0.00458	0.99290	-0.00030
		12	97.853	1.2133	0.00285	0.00463	0.99287	-0.00035
		48	97.921	1.2129	0.00286	0.00465	0.99285	-0.00036
	2	3	238.223	1.2466	0.04238	0.24212	0.71472	0.00077
		12	238.115	1.2454	0.04279	0.24396	0.71277	0.00048
		48	238.061	1.2450	0.04289	0.24443	0.71226	0.00042
	3	3	35.962	0.8910	0.02435	0.03468	0.94077	0.00020
		12	35.928	0.8877	0.02464	0.03485	0.94039	0.00013
		48	35.915	0.8868	0.02472	0.03488	0.94030	0.00011
	4	3	259.349	0.8382	0.59711	0.36773	0.0000	0.03516
		12	259.158	0.8348	0.59876	0.36737	0.0000	0.03387
		48	259.205	0.8338	0.59925	0.35730	0.0000	0.03345

BENCHMARK PROBLEM SOLUTION

Identification: 9-A1-2 Benchmark Problem ID.9-A1

Date Submitted: June 1976 By: M. V. Gregory (SRL)

Date Accepted: June 1977 By: H. L. Dodds, Jr. (U. of Tenn.)
M. R. Wagner (KWU)

Descriptive Title: Discrete Four-Group, Two-Dimensional Hexagonal Geometry HTGR Problem

Mathematical Model:

1. Finite difference representation of multigroup neutron diffusion equations.
2. Volume-centered mesh structure. One point per hex - at hexagon center. Three points per hex - at center of each of the three parallelograms making up a hex. Six points per hex - at center of each of the six triangles making up a hex.

Method of Solution:

1. Simultaneous line over-relaxation with two inner iterations per outer iteration.
2. One-group coarse-mesh rebalancing, one coarse-mesh point per collection of seven hexagons.
3. Fission source extrapolation and over-relaxation.
4. Both conventional finite difference and higher order method ("Coarse-Mesh Method," see Ref. 2) solutions presented.

Program Name: GRIMHX

Program Language: FORTRAN-IV

Machine Language Content: None

Program Ancestors: GRIM

Computer: IBM S-360/195

Convergence Criteria: Maximum relative pointwise flux change and pointwise production change both less than 10^{-5}.

References

1. H. C. Honeck and J. W. Stewart, "Simultaneous Line Over-Relaxation (SLOR) in Hexagonal Lattice," *Proceedings National Topical Meeting on New Developments in Reactor Physics and Shielding*, Kiamesha Lake, NY, September 12-15, 1972, U. S. Atomic Energy Commission Report CONF-720901 (1972).

2. H. L. Dodds, Jr., H. C. Honeck, and D. E. Hostetler, "Coarse-Mesh Method for Two-Dimensional Mixed-Lattice Diffusion Theory Calculations," *Trans. Am. Nucl. Soc.*, *21*, 223 (1975).

3. M. V. Gregory and H. C. Honeck, "Control Algorithms in a Coarse-Mesh Rebalance Framework," *Trans. Am. Nucl. Soc.*, *22*, 241 (1975).

PRIMARY RESULTS: FOUR-GROUP, TWO-DIMENSIONAL HEXAGONAL GEOMETRY HTGR PROBLEM WITH SEVEN CONTROL RODS INSERTED (STANDARD DIFFERENCE EQN.)

NUMBER OF MESH POINTS PER COLUMN	1	3	6
DISTANCE BETWEEN MESH POINTS	36.2 CM	18.1 CM	12.067 CM
NUMBER OF SPATIAL MESH POINTS IN THE ONE SIXTH CORE CALCULATION PLANE	72	214	427
NEUTRON MULTIPLICATION CONSTANT KEFF (THE FUNDAMENTAL EIGENVALUE)	1.12725	1.12102	1.12028
NUMBER OF POWER ITERATIONS FOR 1.0-05 POINTWISE FLUX CONVERGENCE	17	18	26
IBM 360/195 COMPUTER TIME FOR THE DIFFUSION CALCULATION	5 SEC	6 SEC	10 SEC
CORE/PERIPHERAL STORAGE (1000 BYTES)	360/80	365/100	375/100

COLUMN AVERAGED FISSION DISTRIBUTION (FISSIONS/CM**3/SEC)
(NORMALIZED TO A CORE AVERAGE VALUE OF ONE)

COLUMN NUMBER	NUMBER OF POINTS/COLUMN 1	3	6	COLUMN NUMBER	NUMBER OF POINTS/COLUMN 1	3	6
1	.3151	.3609	.3611	22	1.0972	1.0794	1.0043
2	1.2811	1.1582	1.1086	23	.9732	.9586	.9209
3	1.0231	.9011	.8723	24	.6316	.6898	.7028
4	1.3553	1.2825	1.2592	25	.7787	.8913	.9265
5	1.4742	1.3354	1.3191	26	.9955	1.0567	1.0718
6	1.4518	1.3399	1.3140	27	.9517	1.0133	1.0367
7	1.4639	1.3439	1.3360	28	.6821	.8018	.8436
8	1.3915	1.2893	1.2801	29	.6481	.6493	.6442
9	1.3628	1.3057	1.2782	30	.6676	.7785	.8177
10	.8578	.8150	.7897	31	.8242	.8958	.9222
11	1.1272	1.1593	1.1591	32	.9768	.9971	.9993
12	1.1719	1.1655	1.1516	33	1.0541	1.0775	1.0782
13	1.2861	1.2545	1.2347	34	.9777	1.0355	1.0476
14	1.2418	1.2242	1.1941	35	.7420	.8482	.8790
15	1.1520	1.1644	1.1558	36	.6481	.6398	.6442
16	1.1161	1.1574	1.1567	37	.6636	.7652	.8112
17	.2591	.3002	.3169	38	.8167	.9013	.9291
18	.9248	.8933	.8638	39	1.0294	1.0646	1.0795
19	1.0172	.9607	.9529	40	1.0302	1.0326	1.0413
20	1.1757	1.0502	1.0272	41	.9467	.9740	.9925
21	1.1733	1.0754	1.0493	42	.7527	.8431	.8803

ENERGY GROUP 1 COLUMN AVERAGED FLUX DISTRIBUTION (NEUTRONS/CM**2/SEC)

COLUMN NUMBER	NUMBER OF POINTS/COLUMN 1	3	6	COLUMN NUMBER	NUMBER OF POINTS/COLUMN 1	3	6
1	121.332	133.395	130.955	37	98.051	103.512	104.837
2	212.785	194.130	186.419	38	128.554	136.493	138.670
3	208.335	196.976	196.541	39	167.233	172.439	173.930
4	220.457	207.751	203.326	40	168.040	167.435	168.839
5	233.386	216.397	213.022	41	152.789	155.853	157.498
6	236.424	216.760	212.388	42	114.927	120.593	122.328
7	238.305	218.344	215.815	43	10.868	17.493	20.489
8	226.431	209.385	206.772	44	9.917	16.026	18.806
9	221.604	210.999	206.277	45	.056	.040	.034
10	174.693	178.089	177.971	46	.004	.002	.001
11	183.237	187.785	187.182	47	.064	.047	.038
12	190.771	188.844	186.033	48	.821	.885	.863
13	209.500	203.463	199.552	49	.601	.645	.674
14	202.287	198.539	193.025	50	.031	.021	.018
15	187.403	188.582	186.597	51	.003	.001	.001
16	181.411	186.846	186.845	52	.806	.882	.865
17	99.786	111.119	114.940	53	.047	.032	.029
18	153.771	149.931	148.842	54	.566	.618	.644
19	169.022	161.796	160.282	55	9.668	15.845	18.586
20	188.477	175.880	172.622	56	10.745	17.607	20.689
21	194.753	180.127	176.297	57	.858	.930	.918
22	182.200	172.520	168.819	58	.061	.046	.038
23	161.755	157.427	155.003	59	1.143	1.244	1.322
24	111.100	117.869	119.030	60	.065	.046	.042
25	119.561	128.533	129.608	61	.584	.647	.657
26	161.048	170.099	171.404	62	9.892	15.939	18.806
27	153.046	162.139	163.956	63	15.143	24.443	29.192
28	101.281	109.172	109.730	64	5.209	8.133	9.609
29	129.077	137.310	139.740	65	.239	.243	.196
30	98.492	105.066	104.976	66	.929	1.188	1.133
31	129.728	136.230	137.531	67	.046	.046	.030
32	158.717	161.069	160.648	68	.245	.253	.205
33	171.904	175.073	174.633	69	5.302	8.416	9.942
34	157.533	165.377	166.392	70	14.321	23.744	28.022
35	113.229	121.309	122.021	71	5.161	8.824	9.557
36	129.068	135.131	139.720	72	.230	.297	.192

ENERGY GROUP 2 COLUMN AVERAGED FLUX DISTRIBUTION (NEUTRONS/CM**2/SEC)

COLUMN NUMBER	NUMBER OF POINTS/COLUMN 1	3	6	COLUMN NUMBER	NUMBER OF POINTS/COLUMN 1	3	6
1	278.663	306.369	302.111	37	215.979	224.871	229.929
2	502.745	458.268	440.346	38	292.722	307.681	314.482
3	548.765	514.049	508.587	39	389.773	400.650	404.710
4	517.950	487.949	478.200	40	393.866	391.631	395.707
5	548.086	507.986	500.406	41	354.416	360.093	364.023
6	555.620	509.086	499.574	42	258.347	267.679	274.052
7	559.713	512.950	507.012	43	65.867	92.629	100.370
8	532.000	492.257	486.292	44	59.561	84.009	90.981
9	520.373	494.860	484.578	45	1.174	1.159	1.124
10	459.927	464.372	460.372	46	.128	.087	.086
11	429.030	439.250	438.256	47	1.296	1.309	1.243
12	448.154	443.518	437.483	48	9.764	11.997	12.453
13	492.045	477.477	468.741	49	7.291	8.915	9.530
14	475.353	466.137	453.994	50	.646	.584	.596
15	439.776	442.116	438.079	51	.097	.069	.067
16	424.469	436.738	437.127	52	9.419	11.720	12.198
17	229.119	255.552	265.138	53	.898	.823	.864
18	362.996	353.696	351.227	54	6.610	8.216	8.819
19	399.298	382.036	378.583	55	56.855	80.837	87.479
20	445.144	415.158	407.592	56	63.937	90.864	98.646
21	459.900	425.227	416.249	57	10.180	12.561	13.065
22	430.370	407.309	398.668	58	1.194	1.246	1.180
23	382.074	371.655	366.073	59	12.981	16.014	17.475
24	268.459	280.239	284.723	60	1.208	1.154	1.199
25	267.909	283.538	287.928	61	6.929	8.785	9.164
26	371.998	390.581	393.459	62	59.014	82.604	89.859
27	351.507	369.687	373.551	63	86.557	119.301	132.015
28	222.521	236.282	239.150	64	34.261	47.135	52.162
29	332.043	348.672	351.880	65	3.189	3.806	3.651
30	216.740	228.342	230.038	66	10.610	15.009	14.735
31	296.099	308.972	312.828	67	.894	1.175	.887
32	370.631	375.428	374.878	68	3.313	3.997	3.051
33	402.565	409.438	408.642	69	34.585	48.305	53.419
34	364.023	380.361	382.922	70	80.837	114.156	124.923
35	253.244	267.517	271.180	71	73.794	51.122	51.695
36	332.181	342.528	352.029	72	3.031	4.533	3.517

ENERGY GROUP 3 COLUMN AVERAGED FLUX DISTRIBUTION (NEUTRONS/CM**2/SEC)

COLUMN NUMBER	NUMBER OF POINTS/COLUMN 1	3	6	COLUMN NUMBER	NUMBER OF POINTS/COLUMN 1	3	6
1	35.641	39.765	39.574	37	32.478	33.794	34.663
2	75.314	68.488	65.743	38	43.931	46.120	47.223
3	84.157	78.556	77.559	39	58.354	59.955	60.596
4	77.685	73.199	71.762	40	59.032	58.687	59.372
5	82.197	76.196	75.079	41	53.016	53.848	54.459
6	83.336	76.373	74.968	42	38.836	40.196	41.262
7	83.943	76.946	76.070	43	11.239	15.574	16.729
8	79.791	73.852	72.974	44	10.155	14.110	15.144
9	78.041	74.223	72.706	45	.217	.216	.210
10	70.525	70.952	70.199	46	.024	.016	.016
11	64.297	65.870	65.698	47	.239	.244	.232
12	67.212	66.530	65.647	48	1.756	2.373	2.262
13	73.791	71.615	70.326	49	1.313	1.616	1.729
14	71.294	69.918	68.126	50	.119	.109	.112
15	65.942	66.296	65.717	51	.018	.013	.013
16	63.602	55.440	65.513	52	1.692	2.120	2.213
17	29.302	33.170	34.730	53	.165	.153	.161
18	54.350	52.635	52.400	54	1.188	1.486	1.598
19	59.811	57.095	56.515	55	9.678	13.541	14.519
20	66.689	62.064	60.860	56	10.894	15.238	16.396
21	68.901	63.572	62.155	57	1.831	2.274	2.372
22	64.472	60.685	59.524	58	.220	.232	.270
23	57.220	55.541	54.636	59	2.328	2.892	3.160
24	40.579	42.270	42.950	60	.222	.214	.223
25	40.221	42.477	43.229	61	1.246	1.591	1.662
26	55.579	58.297	58.735	62	10.060	13.864	14.946
27	52.461	55.114	55.699	63	14.682	19.864	21.781
28	33.420	35.445	35.964	64	5.902	8.019	8.818
29	50.713	53.001	53.442	65	.577	.694	.671
30	32.584	34.371	34.674	66	1.904	2.708	2.664
31	44.464	46.378	47.007	67	.163	.213	.165
32	55.512	56.226	56.164	68	.600	.729	.708
33	60.725	61.349	61.243	69	5.952	8.209	9.019
34	54.409	56.823	57.209	70	13.693	18.971	20.572
35	38.021	40.108	40.754	71	5.819	8.692	8.735
36	50.740	52.097	53.472	72	.548	.826	.646

ENERGY GROUP 4 COLUMN AVERAGED FLUX DISTRIBUTION (NEUTRONS/CM**2/SEC)

COLUMN NUMBER	NUMBER OF POINTS/COLUMN 1	3	6	COLUMN NUMBER	NUMBER OF POINTS/COLUMN 1	3	6
1	130.114	150.244	150.754	37	221.448	259.084	274.526
2	314.131	283.619	271.299	38	228.954	254.412	262.544
3	459.037	400.035	386.040	39	253.969	262.937	266.602
4	333.842	316.156	310.520	40	253.749	254.694	257.037
5	353.287	329.211	325.747	41	234.020	241.276	245.617
6	357.536	330.371	323.960	42	229.642	259.638	271.616
7	360.573	331.107	329.487	43	433.838	462.374	456.183
8	342.734	317.629	315.641	44	405.593	433.227	429.530
9	335.741	322.078	315.294	45	118.249	130.944	134.798
10	384.019	361.879	349.484	46	27.209	25.401	28.790
11	277.865	286.000	286.047	47	109.063	123.750	123.021
12	289.638	287.312	283.967	48	272.699	308.569	313.759
13	316.755	309.235	304.488	49	228.762	256.934	262.593
14	305.817	301.749	294.396	50	62.026	60.224	69.393
15	283.811	287.130	285.106	51	22.577	21.948	24.907
16	275.167	284.577	285.492	52	237.158	268.889	269.992
17	106.989	124.921	132.312	53	53.564	55.711	57.905
18	226.761	218.707	216.261	54	152.076	182.014	181.318
19	249.418	236.201	233.177	55	367.556	388.927	382.901
20	278.416	257.196	251.411	56	411.769	436.405	429.441
21	287.767	263.350	256.829	57	270.707	307.974	309.827
22	269.065	252.081	245.785	58	93.347	101.514	95.291
23	238.608	229.795	225.343	59	263.247	293.456	296.387
24	290.648	318.870	324.970	60	59.556	62.186	64.204
25	237.498	274.448	286.027	61	167.205	186.140	186.835
26	246.168	262.372	265.842	62	379.284	395.172	393.716
27	235.809	253.029	257.918	63	432.471	435.749	428.411
28	227.569	270.352	285.512	64	320.178	347.270	345.136
29	291.887	290.651	287.750	65	103.000	124.235	116.148
30	222.861	262.614	275.439	66	238.544	273.359	272.002
31	230.973	252.475	260.503	67	52.201	66.985	57.296
32	240.930	246.250	246.637	68	132.922	148.781	151.506
33	259.696	265.671	266.010	69	335.072	365.278	367.925
34	241.930	256.803	260.067	70	408.750	414.311	411.346
35	226.559	261.423	271.586	71	313.305	334.699	339.153
36	291.859	286.535	287.691	72	98.712	121.723	111.602

NEUTRON BALANCE IN EACH COMPOSITION, THE CORE AND THE CORE & REFLECTOR

COMP. LETTER	ENERGY GROUP	POINTS/ COLUMN	AVERAGE NEUTRON FLUX	AVERAGE GROUP SOURCE	REACTION RATE TYPE/SOURCE FISSION	CAPTURE	SLOWING DOWN	NORMAL LEAKAGE
		1	102.864	.5543	.00418	.03674	2.02269	-1.06361
	1	3	114.301	.6445	.00399	.03511	1.93302	-.97213
		6	117.227	.6749	.00395	.03439	1.89321	-.93151
		1	236.197	1.1398	.03088	.94285	.67968	-.65341
	2	3	262.811	1.2675	.03089	.94340	.68008	-.65437
		6	270.420	1.3005	.03098	.94614	.68205	-.65918
A								
		1	30.208	.7747	.01591	.35560	.79543	-.16694
	3	3	34.112	.8620	.01615	.36090	.80728	-.18433
		6	35.422	.8870	.01629	.36422	.81469	-.19520
		1	110.293	.6162	.35258	1.59826	.00000	-.95084
	4	3	128.538	.6959	.36388	1.64946	.00000	-1.01334
		6	134.946	.7226	.36769	1.66765	.00000	-1.03554
		1	150.455	1.5738	.00215	.00345	1.04201	-.04762
	1	3	152.075	1.5351	.00224	.00360	1.08690	-.09275
		6	154.600	1.5186	.00229	.00368	1.10968	-.11564
		1	386.275	1.6928	.03418	.17638	.75232	.03712
	2	3	389.972	1.7201	.03378	.17435	.74363	.04824
		6	391.438	1.7362	.03359	.17338	.73952	.05351
B								
		1	59.343	1.2735	.01901	.01994	.95057	.01047
	3	3	59.385	1.2791	.01894	.01987	.94712	.01407
		6	59.524	1.2839	.01892	.01984	.94577	.01547
		1	343.290	1.2106	.55864	.24671	.00000	.19466
	4	3	331.594	1.2115	.53922	.23813	.00000	.22265
		6	327.187	1.2143	.53081	.23442	.00000	.23477
		1	188.307	2.3993	.00310	.00457	.96535	.02698
	1	3	183.518	2.3558	.00306	.00453	.95816	.03423
		6	181.571	2.3376	.00307	.00452	.95539	.03702
		1	441.675	2.3968	.04828	.25059	.67623	.02491
	2	3	429.687	2.3364	.04818	.25012	.67495	.02675
		6	425.417	2.3118	.04821	.25026	.67534	.02619
C								
		1	66.169	1.6208	.02931	.03433	.93064	.00552
	3	3	64.341	1.5770	.02929	.03431	.93026	.00614
		6	63.698	1.5613	.02929	.03431	.93020	.00619
		1	283.786	1.5087	.65064	.35552	.00000	-.00636
	4	3	277.279	1.4670	.65399	.35724	.00000	-.01123
		6	275.029	1.4523	.65523	.35792	.00000	-.01315

NEUTRON BALANCE IN EACH COMPOSITION, THE CORE AND THE CORE & REFLECTOR

COMP. LETTER	ENERGY GROUP	POINTS/ COLUMN	AVERAGE NEUTRON FLUX	AVERAGE GROUP SOURCE	REACTION RATE TYPE/SOURCE FISSION	CAPTURE	SLOWING DOWN	NORMAL LEAKAGE
		1	129.141	1.7068	.00284	.00460	.93065	.06191
	1	3	136.361	1.8797	.00273	.00441	.89228	.10058
		6	138.101	1.9377	.00268	.00433	.87663	.11635
		1	294.410	1.6458	.04222	.25581	.65652	.04545
	2	3	308.327	1.7404	.04181	.25334	.65018	.05468
		6	313.660	1.7637	.04197	.25431	.65267	.05105
D								
		1	44.197	1.0805	.02647	.03178	.93264	.00912
	3	3	46.249	1.1316	.02644	.03176	.93188	.00992
		6	47.115	1.1511	.02648	.03180	.93318	.00853
		1	229.964	1.0077	.71200	.42675	.00000	-.13875
	4	3	253.443	1.0545	.74989	.44945	.00000	-.19934
		6	261.523	1.0742	.75958	.45526	.00000	-.21484
		1	115.906	1.5761	.00267	.00458	.90455	.08820
	1	3	123.478	1.8003	.00249	.00427	.84361	.14963
		6	124.652	1.8733	.00242	.00415	.81646	.17498
		1	259.833	1.4786	.03866	.25657	.64493	.05984
	2	3	272.911	1.5793	.03802	.25230	.63421	.07547
		6	277.720	1.5962	.03828	.25403	.63856	.06913
E								
		1	39.026	.9536	.02468	.03020	.93310	.01202
	3	3	40.927	1.0016	.02464	.03016	.93167	.01354
		6	41.749	1.0192	.02470	.03023	.93391	.01116
		1	231.233	.8898	.75623	.48336	.00000	-.23960
	4	3	265.170	.9331	.82693	.52855	.00000	-.35548
		6	276.410	.9519	.84502	.54012	.00000	-.38514
		1	99.275	1.3956	.00250	.00455	.87495	.11800
	1	3	105.917	1.6349	.00227	.00415	.79683	.19675
		6	106.514	1.7218	.00217	.00396	.76092	.23295
		1	218.413	1.2620	.03514	.25838	.63218	.07430
	2	3	229.832	1.3577	.03453	.25392	.62126	.09028
		6	233.039	1.3630	.03475	.25553	.62520	.08451
F								
		1	32.827	.8016	.02269	.02863	.93373	.01475
	3	3	34.520	.8435	.02208	.02861	.93311	.01541
		6	35.100	.8553	.02294	.02869	.93573	.01264
		1	223.959	.7485	.80791	.55357	.00000	-.36149
	4	3	263.683	.7871	.90456	.61979	.00000	-.52436
		6	276.493	.8003	.93958	.64379	.00000	-.58736

PRIMARY RESULTS: FOUR-GROUP, TWO-DIMENSIONAL HEXAGONAL GEOMETRY HTGR PROBLEM WITH SEVEN CONTROL RODS INSERTED (COARSE MESH EQUATION)

NUMBER OF MESH POINTS PER COLUMN	1	3	6
DISTANCE BETWEEN MESH POINTS	36.2 CM	18.1 CM	12.067 CM
NUMBER OF SPATIAL MESH POINTS IN THE ONE SIXTH CORE CALCULATION PLANE	72	214	427
NEUTRON MULTIPLICATION CONSTANT KEFF (THE FUNDAMENTAL EIGENVALUE)	1.11321	1.11735	1.11863
NUMBER OF POWER ITERATIONS FOR 1.0-05 POINTWISE FLUX CONVERGENCE	26	20	24
IBM 360/195 COMPUTER TIME FOR THE DIFFUSION CALCULATION	8 SEC	7 SEC	10 SEC
CORE/PERIPHERAL STORAGE (1000 BYTES)	360/80	365/100	375/100

COLUMN AVERAGED FISSION DISTRIBUTION (FISSIONS/CM**3/SEC)
(NORMALIZED TO A CORE AVERAGE VALUE OF ONE)

COLUMN NUMBER	NUMBER OF POINTS/COLUMN 1	3	6	COLUMN NUMBER	NUMBER OF POINTS/COLUMN 1	3	6
1	.3828	.3801	.3692	22	1.0539	1.0118	.9953
2	1.1995	1.1266	1.0928	23	.9517	.9287	.9159
3	.9224	.8684	.8563	24	.6664	.7047	.7097
4	1.3044	1.2632	1.2496	25	.8654	.9253	.9431
5	1.3710	1.3118	1.3072	26	1.0192	1.0692	1.0772
6	1.3815	1.3137	1.3007	27	.9809	1.0306	1.0433
7	1.3948	1.3180	1.3230	28	.7867	.8405	.8635
8	1.3331	1.2672	1.2690	29	.6296	.6439	.6417
9	1.3143	1.2876	1.2691	30	.7704	.8160	.8324
10	.7999	.7963	.7807	31	.8825	.9165	.9326
11	1.1706	1.1614	1.1603	32	.9878	1.0008	1.0001
12	1.1579	1.1602	1.1490	33	1.0595	1.0796	1.0795
13	1.2537	1.2422	1.2286	34	1.0013	1.0457	1.0570
14	1.2144	1.2137	1.1889	35	.8263	.8809	.8947
15	1.1458	1.1621	1.1549	36	.6298	.6343	.6416
16	1.1223	1.1566	1.1586	37	.7660	.8025	.8300
17	.3246	.3198	.3261	38	.8769	.9241	.9405
18	.9099	.8656	.8799	39	1.0443	1.0704	1.0829
19	.9888	.9523	.9466	40	1.0347	1.0338	1.0430
20	1.0842	1.0297	1.0166	41	.9654	.9808	.9942
21	1.1143	1.0521	1.0375	42	.8369	.8748	.8954

ENERGY GROUP 1 COLUMN AVERAGED FLUX DISTRIBUTION (NEUTRONS/CM**2/SEC)

COLUMN NUMBER	NUMBER OF POINTS/COLUMN 1	3	6	COLUMN NUMBER	NUMBER OF POINTS/COLUMN 1	3	6
1	141.792	137.737	132.465	37	102.655	103.900	104.693
2	202.736	190.000	184.301	38	134.585	137.872	139.227
3	202.049	195.438	195.922	39	170.564	173.416	174.392
4	212.076	204.344	201.573	40	169.191	167.499	168.852
5	223.208	212.324	210.930	41	156.398	156.748	157.882
6	224.923	212.168	210.038	42	119.672	121.361	122.416
7	227.175	213.939	213.545	43	17.179	20.507	22.176
8	216.870	205.553	204.788	44	15.979	18.849	20.396
9	213.738	207.793	204.638	45	.020	.027	.028
10	175.293	179.176	178.690	46	.001	.001	.001
11	184.237	188.021	187.286	47	.023	.032	.032
12	188.398	187.698	185.423	48	.621	.788	.810
13	204.355	201.240	198.407	49	.455	.574	.638
14	197.792	196.584	192.005	50	.011	.014	.015
15	186.467	188.010	186.294	51	.001	.001	.001
16	182.971	187.291	187.066	52	.628	.796	.820
17	120.258	116.027	116.515	53	.019	.023	.025
18	154.103	149.581	148.645	54	.445	.557	.612
19	167.186	160.675	159.705	55	16.083	18.876	20.261
20	183.175	173.468	171.387	56	17.474	20.891	22.502
21	188.237	177.270	174.847	57	.650	.831	.865
22	178.092	170.572	167.810	58	.023	.031	.031
23	161.009	156.717	154.626	59	.909	1.129	1.260
24	114.553	118.965	119.461	60	.026	.032	.035
25	125.202	129.726	129.840	61	.453	.580	.623
26	166.274	171.811	172.198	62	16.284	18.930	20.478
27	159.014	163.988	164.835	63	25.177	29.214	31.854
28	106.278	109.746	109.663	64	8.171	9.493	10.370
29	135.604	140.153	141.261	65	.167	.210	.178
30	102.997	105.412	104.804	66	.742	1.083	1.084
31	135.057	137.372	137.915	67	.018	.033	.025
32	160.902	161.478	160.807	68	.170	.219	.185
33	173.427	175.364	174.743	69	8.345	9.841	10.740
34	162.317	166.894	167.069	70	24.226	28.445	30.648
35	118.735	122.361	122.226	71	8.121	10.259	10.318
36	136.604	137.924	141.241	72	.163	.256	.174

ENERGY GROUP 2 COLUMN AVERAGED FLUX DISTRIBUTION (NEUTRONS/CM**2/SEC)

COLUMN NUMBER	NUMBER OF POINTS/COLUMN 1	3	6	COLUMN NUMBER	NUMBER OF POINTS/COLUMN 1	3	6
1	327.833	316.465	305.965	37	222.221	226.773	231.358
2	477.128	448.108	435.184	38	302.972	311.225	316.585
3	528.239	506.163	504.412	39	395.916	402.845	405.870
4	497.675	480.172	474.307	40	396.034	391.865	395.912
5	523.080	498.537	495.646	41	360.420	361.988	364.964
6	527.895	498.485	494.273	42	266.028	270.213	275.659
7	532.442	502.777	501.817	43	91.521	102.255	104.824
8	508.893	483.558	481.860	44	83.057	92.818	95.070
9	500.957	487.433	480.879	45	1.125	1.096	1.088
10	458.276	463.650	459.910	46	.080	.074	.078
11	430.672	439.972	438.671	47	1.270	1.246	1.206
12	442.244	441.086	436.286	48	13.101	12.806	12.794
13	478.898	472.359	466.181	49	9.775	9.504	9.815
14	464.152	461.713	451.785	50	.629	.556	.579
15	437.053	440.982	437.549	51	.067	.058	.061
16	427.445	437.972	437.819	52	13.001	12.640	12.593
17	273.803	267.046	270.759	53	.948	.807	.849
18	362.651	352.675	350.668	54	9.203	8.873	9.128
19	393.578	379.125	377.077	55	80.860	89.928	91.628
20	430.898	409.126	404.528	56	90.271	100.896	103.241
21	442.705	418.148	412.633	57	13.738	13.452	13.451
22	419.016	402.386	396.142	58	1.212	1.198	1.150
23	379.058	369.718	365.055	59	18.301	17.359	18.126
24	271.958	282.536	285.868	60	1.299	1.131	1.182
25	275.551	296.505	289.615	61	9.562	9.454	9.470
26	380.313	393.834	395.110	62	83.912	91.777	94.074
27	360.645	373.145	375.344	63	122.360	132.038	138.085
28	228.784	238.815	240.635	64	48.920	52.242	54.657
29	343.240	352.852	353.854	65	4.114	3.989	3.707
30	222.693	230.679	231.418	66	14.990	16.311	15.318
31	304.956	312.236	314.521	67	.936	1.151	.872
32	374.726	376.479	375.414	68	4.219	4.178	3.904
33	405.257	410.199	409.016	69	49.368	53.530	55.989
34	372.023	383.500	384.370	70	115.025	126.246	130.832
35	261.063	270.431	272.094	71	48.383	56.929	54.194
36	343.390	346.446	354.714	72	3.947	4.793	3.577

ENERGY GROUP 3 COLUMN AVERAGED FLUX DISTRIBUTION (NEUTRONS/CM**2/SEC)

COLUMN NUMBER	NUMBER OF POINTS/COLUMN 1	3	6	COLUMN NUMBER	NUMBER OF POINTS/COLUMN 1	3	6
1	43.573	41.980	40.528	37	32.915	33.973	34.871
2	71.243	66.846	64.905	38	45.008	46.560	47.519
3	80.427	77.116	76.803	39	58.998	60.222	60.749
4	74.449	72.001	71.169	40	59.165	58.690	59.342
5	78.229	74.741	74.350	41	53.625	54.074	54.581
6	78.975	74.756	74.164	42	39.535	40.497	41.496
7	79.633	75.380	75.278	43	15.609	17.150	17.438
8	76.127	72.513	72.300	44	14.101	15.533	15.785
9	74.919	73.073	72.137	45	.271	.217	.208
10	69.767	70.625	70.020	46	.023	.015	.015
11	64.307	65.889	65.742	47	.306	.247	.231
12	66.157	66.138	65.461	48	2.710	2.431	2.371
13	71.622	70.809	69.930	49	2.032	1.806	1.816
14	69.437	69.221	67.786	50	.152	.110	.111
15	65.345	66.089	65.626	51	.017	.012	.012
16	63.800	65.573	65.599	52	2.676	2.395	2.370
17	36.955	35.432	35.798	53	.226	.158	.162
18	54.111	52.584	52.260	54	1.893	1.687	1.686
19	58.764	56.559	56.232	55	13.697	14.996	15.164
20	64.339	61.056	60.340	56	15.364	16.862	17.118
21	66.101	62.404	61.552	57	2.842	2.553	2.491
22	62.565	60.042	59.086	58	.291	.237	.220
23	56.585	55.154	54.427	59	3.736	3.282	3.341
24	40.347	42.416	43.116	60	.310	.223	.226
25	40.765	42.788	43.451	61	1.978	1.795	1.751
26	56.404	58.684	58.944	62	14.302	15.357	15.611
27	53.772	55.526	55.928	63	20.542	21.643	22.603
28	33.777	35.717	36.169	64	8.637	8.935	9.254
29	51.810	53.480	53.647	65	.884	.765	.696
30	32.980	34.596	34.874	66	3.063	3.079	2.820
31	45.365	46.795	47.249	67	.224	.227	.167
32	55.905	56.340	56.234	68	.907	.802	.734
33	60.512	61.421	61.264	69	8.686	9.138	9.465
34	55.238	57.216	57.416	70	19.204	20.812	21.449
35	38.626	40.432	40.988	71	8.528	9.725	9.171
36	51.849	52.480	53.679	72	.844	.918	.671

ENERGY GROUP 4 COLUMN AVERAGED FLUX DISTRIBUTION (NEUTRONS/CM**2/SEC)

COLUMN NUMBER	NUMBER OF POINTS/COLUMN 1	3	6	COLUMN NUMBER	NUMBER OF POINTS/COLUMN 1	3	6
1	159.229	158.717	154.355	37	258.768	271.692	281.390
2	293.430	275.630	267.704	38	247.197	261.327	265.961
3	409.289	384.313	378.359	39	257.642	264.379	267.645
4	321.439	311.454	308.159	40	254.843	255.024	257.275
5	337.857	323.455	322.436	41	238.822	243.055	246.576
6	340.356	323.997	320.713	42	257.803	270.286	276.721
7	343.691	324.768	326.313	43	480.421	473.192	460.691
8	328.495	312.236	312.938	44	451.273	443.999	434.002
9	323.927	317.705	313.069	45	154.081	140.726	139.267
10	354.951	352.467	344.988	46	35.561	27.303	29.742
11	278.693	286.516	286.349	47	141.995	133.007	127.095
12	285.288	286.036	283.344	48	345.996	329.872	323.468
13	308.870	306.256	303.020	49	292.162	275.077	270.841
14	299.165	299.204	293.142	50	81.011	64.757	71.710
15	282.371	286.620	284.906	51	29.527	23.592	25.732
16	276.656	285.370	285.948	52	301.921	287.776	278.455
17	135.036	133.476	136.342	53	70.007	59.962	59.862
18	222.532	216.637	215.208	54	206.714	194.896	186.986
19	241.878	232.950	231.538	55	408.238	397.553	386.614
20	265.277	251.972	248.760	56	456.088	445.962	433.331
21	272.666	257.431	253.829	57	343.830	329.793	319.460
22	257.846	247.545	243.490	58	108.708	109.193	98.483
23	232.773	227.179	224.004	59	333.136	313.519	305.444
24	308.055	326.184	328.317	60	77.967	66.993	66.392
25	266.554	285.838	291.569	61	213.631	199.365	192.726
26	252.151	265.056	267.214	62	421.493	404.074	397.499
27	243.293	256.222	259.610	63	453.203	438.263	428.412
28	265.706	284.432	292.721	64	377.911	362.707	351.570
29	281.331	287.474	286.229	65	133.212	133.476	119.982
30	260.344	276.244	282.242	66	303.337	292.360	280.495
31	248.752	258.785	263.667	67	68.425	72.169	59.260
32	243.669	247.211	247.127	68	172.001	159.800	156.519
33	260.999	266.212	266.312	69	395.630	381.572	374.543
34	247.594	259.420	261.403	70	429.750	417.012	411.641
35	254.714	272.348	276.822	71	369.921	348.008	345.519
36	281.449	283.349	286.199	72	127.679	130.604	115.343

NEUTRON BALANCE IN EACH COMPOSITION, THE CORE AND THE CORE & REFLECTOR

COMP. LETTER	ENERGY GROUP	POINTS/ COLUMN	AVERAGE NEUTRON FLUX	AVERAGE GROUP SOURCE	REACTION RATE TYPE/SOURCE FISSION	CAPTURE	SLOWING DOWN	NORMAL LEAKAGE
		1	123.334	.6996	.00397	.03491	1.92169	-.96057
	1	3	119.128	.6875	.00390	.03431	1.88859	-.92680
		6	118.794	.6948	.00385	.03385	1.86369	-.90139
		1	280.807	1.3678	.03059	.93408	.67336	-.63803
	2	3	274.106	1.3216	.03090	.94369	.68029	-.65488
		6	275.360	1.3182	.03112	.95046	.68517	-.66675
A								
		1	37.900	.9210	.01679	.37528	.83944	-.23151
	3	3	36.368	.8991	.01650	.36891	.82519	-.21060
		6	36.474	.9032	.01648	.36830	.82383	-.20960
		1	138.492	.7732	.35287	1.59957	.00000	-.95245
	4	3	137.082	.7419	.36400	1.65001	.00000	-1.01401
		6	138.915	.7441	.36779	1.66721	.00000	-1.03500
		1	152.621	1.5262	.00225	.00361	1.09003	-.09589
	1	3	154.331	1.5202	.00228	.00366	1.10658	-.11253
		6	155.315	1.5111	.00231	.00371	1.12035	-.12638
		1	389.021	1.7148	.03380	.17445	.74409	.04766
	2	3	390.330	1.7333	.03355	.17318	.73865	.05462
		6	391.612	1.7437	.03346	.17271	.73665	.05718
B								
		1	58.640	1.2760	.01881	.01974	.94071	.02074
	3	3	59.223	1.2803	.01867	.01980	.94366	.01767
		6	59.453	1.2845	.01888	.01981	.94422	.01708
		1	327.015	1.2003	.53670	.23702	.00000	.22628
	4	3	326.757	1.2082	.53281	.23530	.00000	.23189
		6	324.618	1.2128	.52760	.23300	.00000	.23946
		1	185.735	2.3827	.00308	.00454	.95878	.03360
	1	3	182.239	2.3456	.00307	.00452	.95562	.03679
		6	180.892	2.3322	.00306	.00451	.95403	.03839
		1	434.140	2.3646	.04810	.24970	.67382	.02038
	2	3	426.600	2.3203	.04817	.25004	.67474	.02705
		6	423.865	2.3033	.04821	.25027	.67537	.02614
C								
		1	64.812	1.5933	.02921	.03421	.92746	.00917
	3	3	63.815	1.5656	.02927	.03428	.92933	.00712
		6	63.438	1.5556	.02928	.03430	.92980	.00662
		1	278.242	1.4777	.65149	.35567	.00000	-.00736
	4	3	275.168	1.4550	.65436	.35744	.00000	-.01180
		6	273.985	1.4464	.65542	.35802	.00000	-.01344

NEUTRON BALANCE IN EACH COMPOSITION, THE CORE AND THE CORE & REFLECTOR

COMP. LETTER	ENERGY GROUP	POINTS/ COLUMN	AVERAGE NEUTRON FLUX	AVERAGE GROUP SOURCE	REACTION RATE TYPE/SOURCE FISSION	CAPTURE	SLOWING DOWN	NORMAL LEAKAGE
		1	134.821	1.8533	.00274	.00442	.89480	.09804
	1	3	137.622	1.9316	.00268	.00433	.87636	.11663
		6	138.571	1.9634	.00265	.00429	.86810	.12496
		1	303.964	1.7206	.04169	.25263	.64837	.05731
	2	3	311.730	1.7576	.04186	.25362	.65090	.05362
		6	315.553	1.7704	.04206	.25488	.65414	.04891
D								
		1	45.196	1.1155	.02621	.03148	.92374	.01856
	3	3	46.678	1.1441	.02640	.03170	.93025	.01166
		6	47.384	1.1581	.02647	.03179	.93288	.00886
		1	247.974	1.0305	.75080	.45000	.00000	-.20079
	4	3	260.056	1.0642	.76239	.45695	.00000	-.21934
		6	264.614	1.0803	.76477	.45837	.00000	-.22315
		1	121.270	1.7751	.00248	.00426	.84030	.15297
	1	3	124.482	1.8751	.00241	.00414	.81656	.17689
		6	124.827	1.9094	.00237	.00407	.80410	.18945
		1	267.547	1.5512	.03794	.25181	.63297	.07727
	2	3	275.716	1.5941	.03805	.25252	.63476	.07467
		6	279.390	1.5995	.03843	.25502	.64104	.06551
E								
		1	39.642	.9819	.02434	.02980	.92050	.02536
	3	3	41.239	1.0119	.02458	.03008	.92921	.01614
		6	41.978	1.0254	.02469	.03021	.93343	.01167
		1	259.690	.9038	.83610	.53441	.00000	-.37051
	4	3	276.157	.9403	.85469	.54629	.00000	-.40098
		6	281.704	.9571	.85650	.54745	.00000	-.40395
		1	103.977	1.6307	.00224	.00408	.76429	.20939
	1	3	106.353	1.7196	.00217	.00396	.76073	.23314
		6	106.387	1.7644	.00212	.00366	.74163	.25239
		1	224.566	1.3337	.03435	.25257	.61795	.09513
	2	3	232.089	1.3659	.03466	.25487	.62359	.08687
		6	234.470	1.3678	.03497	.25713	.62910	.07880
F								
		1	33.224	.8242	.02253	.02818	.91913	.03015
	3	3	34.762	.8518	.02281	.02853	.93050	.01816
		6	35.305	.8605	.02293	.02868	.93544	.01295
		1	261.606	.7575	.93245	.63890	.00000	-.57134
	4	3	277.456	.7926	.94520	.64764	.00000	-.59284
		6	285.437	.8050	.95743	.65601	.00000	-.61744

ADDITIONAL RESULTS: FOUR-GROUP, TWO-DIMENSIONAL HEXAGONAL GEOMETRY HIGR PROBLEM WITH ALL CONTROL RODS INSERTED (STANDARD DIFFERENCE EQN.)

NUMBER OF MESH POINTS PER COLUMN	1	3	6
DISTANCE BETWEEN MESH POINTS	36.2 CM	18.1 CM	12.067 CM
NUMBER OF SPATIAL MESH POINTS IN THE ONE SIXTH CORE CALCULATION PLANE	72	214	427
NEUTRON MULTIPLICATION CONSTANT KEFF (THE FUNDAMENTAL EIGENVALUE)	.98548	.95170	.94064
NUMBER OF POWER ITERATIONS FOR 1.0-05 POINTWISE FLUX CONVERGENCE	21	18	25
IBM 360/195 COMPUTER TIME FOR THE DIFFUSION CALCULATION	6 SEC	7 SEC	10 SEC
CORE/PERIPHERAL STORAGE (1000 BYTES)	360/80	365/100	375/100

ADDITIONAL RESULTS: FOUR-GROUP, TWO-DIMENSIONAL HEXAGONAL GEOMETRY HIGR PROBLEM WITH ALL CONTROL RODS INSERTED (COARSE MESH EQUATION)

NUMBER OF MESH POINTS PER COLUMN	1	3	6
DISTANCE BETWEEN MESH POINTS	36.2 CM	18.1 CM	12.067 CM
NUMBER OF SPATIAL MESH POINTS IN THE ONE SIXTH CORE CALCULATION PLANE	72	214	427
NEUTRON MULTIPLICATION CONSTANT KEFF (THE FUNDAMENTAL EIGENVALUE)	.94102	.93784	.93407
NUMBER OF POWER ITERATIONS FOR 1.0-05 POINTWISE FLUX CONVERGENCE	28	20	24
IBM 360/195 COMPUTER TIME FOR THE DIFFUSION CALCULATION	9 SEC	7 SEC	10 SEC
CORE/PERIPHERAL STORAGE (1000 BYTES)	360/80	365/100	375/100

BENCHMARK PROBLEM SOLUTION

Identification: 9-A1-3 Benchmark Problem: 9-A1

Date Submitted: June 1976 By: D. R. Vondy, G. W. Cunningham, D. B. Selby (ORNL)

Date Accepted: June 1977 By: H. L. Dodds, Jr. (U. of Tenn.) M. R. Wagner (KWU)

Descriptive Title: Two-Dimensional HTGR Problem

Mathematical Model: Diffusion theory, mesh-centered formulation; geometries: hexagonal (6 near neighbors) triangular (3 near neighbors)

Computer: IBM-360/91, 1976, ORNL
IBM-360/195, 1976, UC-CTC

Program: VENTURE, ORNL-5062 Report

Primary Results: Basic results for the problems are shown below. Extrapolation of results is done on the basis of error dependence on the square of the mesh spacing. Convergence level satisfied was a maximum relative flux change on outer iterations $<10^{-5}$, relatively tight. Typically, 4 inner iterations were used, Chebyshev acceleration was done on outer iterations, and the 6 point per hex problems required 21-26 outer iterations.

Note that desired traverses along material interfaces do not pass through mesh-centered points; flux and fission source maps are available.

Results for Two-Dimensional Problems

(1/6 Core Traverse Mocked Up)

Mesh Intervals	Points Per Hex Assembly	Control Rods Inserted	Multiplication Factor	Peak to Average Fission Source*	Computer cp time, Total (min)
29x29 **	1	7	1.127250	1.4232	0.62 (/91)
38x19	6	7	1.120276	1.4016	0.31 (/91)
76x38	24	7	1.118912	1.3976	0.98 (/195)
114x57	54	7	1.118601	1.4092	2.89 (/195)
Extrapolated			1.11835	1.418	
38x19	6	6	1.133425	2.0929	0.38 (/91)
38x19	6	0	1.175391	1.7026	0.34 (/91)
38x19	6	31	0.940643	1.8985	0.33 (/91)

*At a mesh centered meshpoint.

**Whole core treated.

BENCHMARK SOURCE SITUATION

Identification: 10

Date Submitted: June 1976 By: C. D. Morgan (B&W)
V. J. Esposito (W-NES)

Date Accepted: June 1977 By: H. L. Dodds, Jr. (U. of Tenn.)
D. A. Meneley (Ontario Hydro)

Descriptive Title: PWR Thermal Hydraulics--Flow Between Two Channels with Different Heat Fluxes

1. Two adjacent channels are identical in all respects except for heat flux, the first channel receiving a heat flux of 150,000 Btu/hr-ft^2 and the second 200,000 Btu/hr-ft^2.

2. Thermal-hydraulic Information for the two channels is listed in Table 1.

3. Fluid is assumed incompressible, frictionless with negligible cross flow.

4. Turbulent mixing factors 0.0 and 0.02.

TABLE 1

THERMAL-HYDRAULIC INFORMATION

Axial heat flux distribution is uniform.

System Pressure - 1000 psi

Inlet Enthalpy (h_{in}) - 360 Btu/#m

Mass Flux (G) - 0.65 x 10^6 #m/ft^2-hr

Flow Area (A_F) - .0885 in^2

Heated Perimeter (P_h) - .6754 in

Wetted Perimeter (P_w) - 1.243

Heated Length - 6 Ft

Cross Flow Area Between Subchannels (A_{cF}) - .0115 ft^2/ft

BENCHMARK PROBLEM

Identification: 10-A1 Source Situation ID.10

Date Submitted: June 1976 By: C. D. Morgan (B&W)
V. J. Esposito (W-NES)

Date Accepted: June 1977 By: H. L. Dodds, Jr. (U. of Tenn.)
D. A. Meneley (Ontario Hydro)

Descriptive Title: Turbulent Mixing of Flow Between Two Channels with Different Heat Flux

Reduction of Source Situation

Equations to be solved

$$G_1 A_{F1} \frac{dh_1}{dx} = \phi_1 P_{h_1} + \alpha A_{cf} \left(\frac{G_1+G_2}{2}\right) (h_2-h_1)$$

$$G_2 A_{F2} \frac{dh_2}{dx} = \phi_2 P_{h_2} + \alpha A_{cf} \left(\frac{G_1+G_2}{2}\right) (h_1-h_2)$$

where G_i = mass flux in the ith channel, $lbm/ft^2/hr$
A_{fi} = flow area of the ith channel, ft^2
h_i = enthalpy of the ith channel, Btu/lbm
ϕ_i = heat flux to the ith channel, $Btu/hr\ ft^2$
P_{hi} = heated perimeter of the ith channel, ft
α = turbulent mixing coefficient
A_{cf} = cross flow area between subchannels per foot of length, ft^2/ft

Expected Primary Results

1. Axial enthalpy distribution in the two subchannels for each value of mixing factor.

Possible Additional Results

1. Sensitivity to axial increment size.

2. Problem could be expanded to include axial cosine heat flux distribution.

Best Solution Available: analytical solution of the differential equation

Solutions

1. Analytical solution of the governing differential equations: 10-A1-1

2. COBRA IIIC finite-difference solution: 10-A1-2

BENCHMARK PROBLEM SOLUTION

Identification: 10-A1-1 Benchmark Problem ID.10-A1

Date Submitted: June 1976 By: C. D. Morgan (B&W)

Date Accepted: June 1977 By: H. L. Dodds, Jr. (U. of Tenn.)
D. A. Meneley (Ontario Hydro)

Descriptive Title: Analytical Solution of Differential Equations Governing Two Channel Mixing Problem

From the statement of the problem:

$$G_1 = G_2,\ A_{F1} = A_{F2},\ P_{h1} = P_{h2}$$

if we define $q_i = \frac{\phi_i P_h}{A_F G}$ and $B = \frac{\alpha A_{cf}}{A_F}$

then the governing differential equations are

$$\frac{dh_1}{dx} = q_1 + B\ (h_2 - h_1)$$

$$\frac{dh_2}{dx} = q_2 + B\ (h_1 - h_2)$$

The solution, subject to the boundary condition that at $x = 0$, $h_i = h_{in}$ the inlet enthalpy, is

$$h_1 - h_{in} = \left(\frac{q_1 - q_2}{4B}\right)(1 - e^{-2BX}) + \frac{q_1 + q_2}{2}\ x$$

$$h_2 - h_{in} = -\ \frac{q_1 - q_2}{4B}\ \ 1 - e^{-2BX}\ + \frac{q_1 + q_2}{2}\ x$$

for the conditions stated

no mixing $\alpha = 0.0$

$(h_{exit}-h_{in})_1 = 169.07$

$(h_{exit}-h_{in})_2 = 126.80$

$\alpha = .02$

$(h_{exit}-h_{in})_1 = 152.59$

$(h_{exit}-h_{in})_2 = 143.28$

BENCHMARK PROBLEM SOLUTION

Identification: 10-A1-2 Benchmark Problem ID.10-A1

Date Submitted: June 1976 By: C. D. Morgan (B&W)

Date Accepted: June 1977 By: H. L. Dodds, Jr. (U. of Tenn.)
D. A. Meneley (Ontario Hydro)

Descriptive Title: COBRA IIIC Solution for Two-Channel-Mixing Problem

Theory

The finite difference equations solved by COBRA IIIC are

continuity

$$\left\{A_j \frac{\rho_j - \bar{\rho}_j}{\Delta t}\right\} + \left\{\frac{m_j - m_{j-1}}{\Delta x}\right\} = - [s] \{w_j\}$$

energy

$$\left\{\frac{1}{u''_j} \frac{h_j - \bar{h}_j}{\Delta t}\right\} + \left\{\frac{h_j - h_{j-1}}{\Delta x}\right\} = [m_{j-1}]^{-1} \left\{ q_{j-\frac{1}{2}} - [s]^T [\Delta h_{j-1}] w'_{j-1} - [s]^T [t_{j-1}] C_{j-1} + \left[h_{j-1}[s]^T - [s]^T [h_{j-1}]^*\right] w_{j-1}\right\}$$

axial momentum

$$\frac{1}{A_j}\left\{\frac{m_j - \bar{m}_j}{\Delta t}\right\} - \left\{2u_j \frac{\rho_j - \bar{\rho}_j}{\Delta t}\right\} + \left\{\frac{P'_j - P_{j-1}}{\Delta x}\right\} = \left\{a'_j\right\} + [A_j]^{-1} \left[[2u_j] [s]^T - [s]^T [u_j^*]\right] \left\{w_j\right\}$$

transverse momentum

$$\left\{\frac{w_j - \bar{w}_j}{\Delta t}\right\} + \left\{\frac{u_j^* w_j - u_{j-1}^* w_{j-1}}{\Delta x}\right\} + \left(\frac{S}{\ell}\right) \left\{c_j w_j\right\} = \left(\frac{S}{\ell}\right) [s] \left\{P_{j-1}\right\}$$

where the elements of the matrix [s] are defined as: $S_{ki}=0$; except, $S_{ki} = 1$, if $i=i(k)$; and $S_{ki}=-1$, if $i=j(k)$ where k implies the connected subchannel pair i(k), j(k). The problem under consideration is a steady state problem with the geometry and flow conditions chosen such that the pressures in both channels will be equal at equal elevations. Thus the diversion cross flow, w_{j-1} will be zero. The energy transfer between channel due to heat conduction $\left[[s]^T [t_{j-1}] C_{j-1}\right]$ is negligible so that the energy equation becomes

$$\frac{h_j - h_{j-1}}{\Delta x} = [m_{j-1}]^{-1} \left\{ q_{j-\frac{1}{2}} - [s]^T [\Delta h_{j-1}] w'_{j-1} \right\}$$

In the nomenclature of the Benchmark Problem

$$m_{j-1} = G_{j-1} A_{j-1}$$

$$w_{j-1} = \alpha A_{cf} \left(\frac{G_{j-1} + G_j}{2} \right)$$

Computer: CDC 7600 Date Solved: February 1976

at: Babcock & Wilcox

Program: COBRA IIIC

Reference

D. S. Rowe, COBRA IIIC: A Digital Computer Program for Steady State and Transient Thermal-Hydraulic Analysis of Rod Bundle Nuclear Fuel Elements, BNWL-1695 (March 1973).

Results for an axial increment size of 3 inches

No mixing $\alpha=0.0$

$(h_{exit}-h_{in})_1 = 169.07$

$(h_{exit}-h_{in})_2 = 126.82$

$\alpha=0.02$

$(h_{exit}-h_{in})_1 = 152.61$

$(h_{exit}-h_{in})_2 = 143.28$

BENCHMARK SOURCE SITUATION

Identification: 11

Date Submitted: June 1976 By: R. R. Lee (CE)
D. A. Meneley (Ontario Hydro)
B. Micheelsen (Risø-Denmark)
D. R. Vondy (ORNL)
M. R. Wagner (KWU)
W. Werner (GRS-Munich)

Date Accepted: June 1977 By: H. L. Dodds, Jr. (U. of Tenn.)
M. V. Gregory (SRL)

Descriptive Title: Multi-dimensional (x-y-z) LWR Model

Suggested Functions: Designed to provide a severe test for the capabilities of coarse mesh methods and flux synthesis approximations

Configuration: Three-dimensional configuration including space dimensions and region numbers: 2 Figures

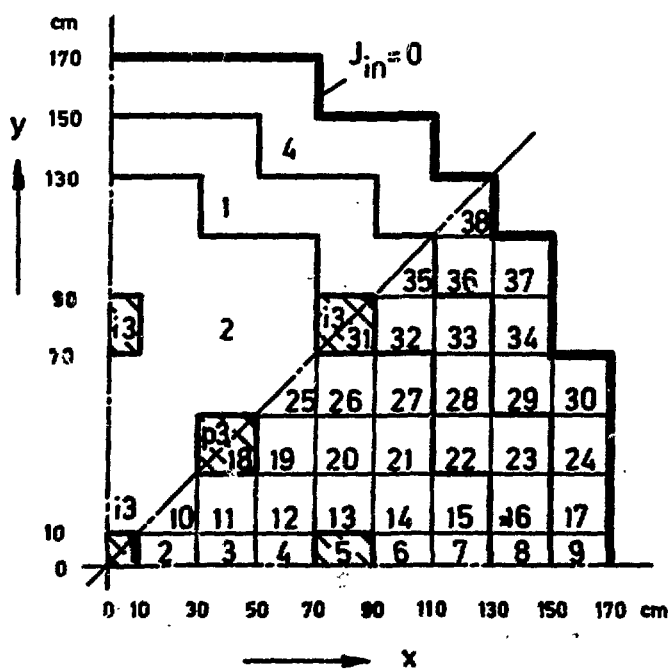


Fig. 1:
Horizontal Cross Section
Upper Octant: Region Assignments
Lower Octant: Fuel Assembly Identification

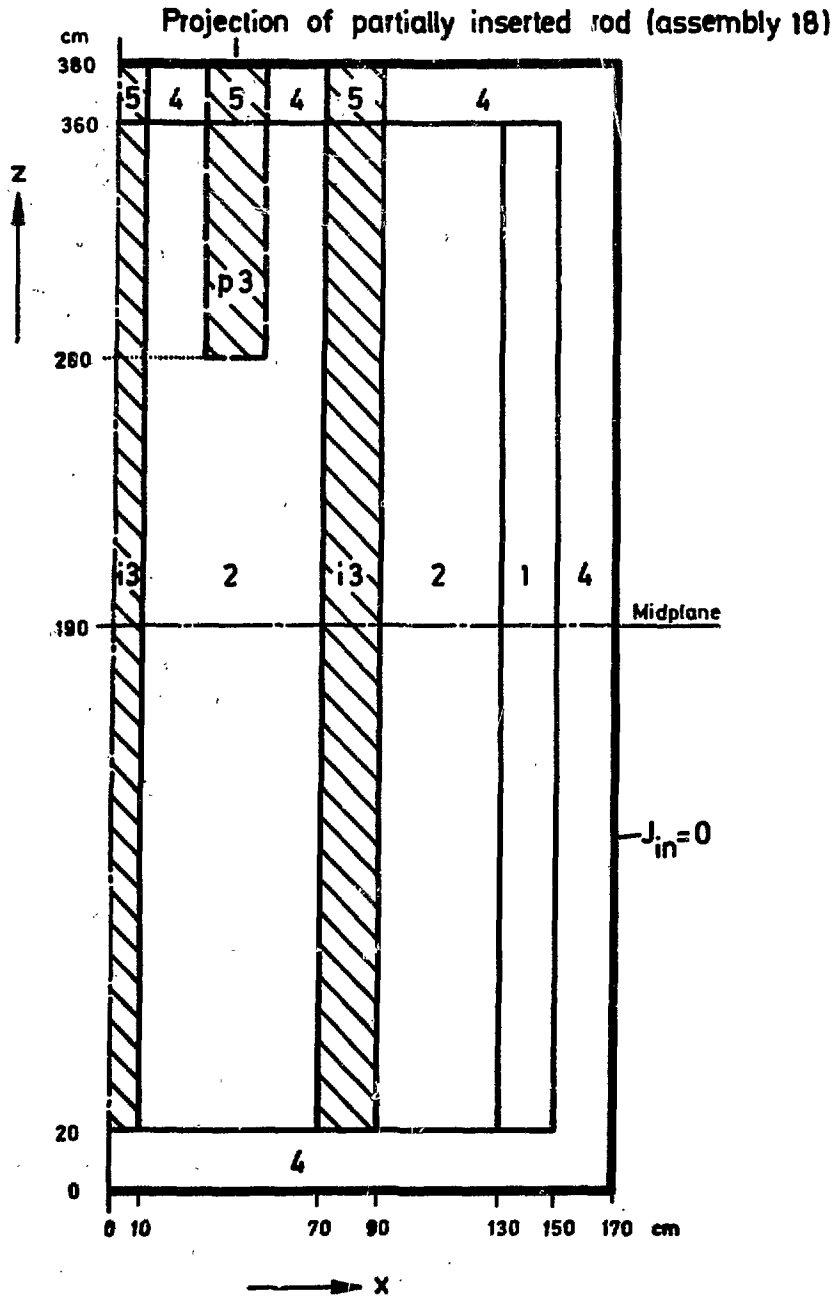


Fig. 2: Vertical Cross Section, y = 0

Boundary Conditions:

External Boundaries: Vacuum, no incoming current
Symmetry Boundaries: Reflection, no net current

BENCHMARK PROBLEM

Identification: 11-A1 Source Situation ID.11

Date Submitted: June 1976 By: R. R. Lee (CE)
D. A. Meneley (Ontario Hydro)
B. Micheelsen (Risø-Denmark)
D. R. Vondy (ORNL)
M. R. Wagner (KWU)
W. Werner (GRS-Munich)

Date Accepted: June 1977 By: H. L. Dodds, Jr. (U. of Tenn.)
M. V. Gregory (SRL)

Descriptive Title: Three-dimensional LWR Problem
(also 3D IAEA Benchmark Problem*)

Reduction of Source Situation:

Two-group diffusion theory

Two-Group Diffusion Equations:

$$-\nabla D_1 \nabla \phi_1 + (\Sigma_{a1} + \Sigma_{1\to 2})\,\phi_1 = \frac{1}{\lambda}\nu\Sigma_{f2}\phi_2$$

$$-\nabla D_2 \nabla \phi_2 + \Sigma_{a2}\phi_2 = \Sigma_{1\to 2}\phi_1$$

*) Benchmark Problem, originally defined by B. Micheelsen (RISØ) by letter of Dec. 14, 1971 to participants of the Panel on Reactor Burn-up Physics which was organized by the IAEA and held in Vienna, 12 - 16 July 1971

Data

Two-group Constants

Region	D_1	D_2	$\Sigma_{1\to2}$	Σ_{a1}	Σ_{a2}	$\nu\Sigma_{f2}$	Material
1	1.5	0.4	0.02	0.01	0.08	0.135	Fuel 1
2	1.5	0.4	0.02	0.01	0.085	0.135	Fuel 2
3	1.5	0.4	0.02	0.01	0.13	0.135	Fuel 2 + Rod
4	2.0	0.3	0.04	0	0.01	0	Reflector
5	2.0	0.3	0.04	0	0.055	0	Refl. + Rod

Boundary Conditions:

$J_g^{in} = 0$ No incoming current at external boundaries.

For finite difference diffusion theory codes the following form is considered equivalent

$$\frac{\partial\phi_g}{\partial n} = -\frac{0.4692}{D_g}\,\phi_g$$

where n the outward directed normal to the surface.
At symmetry boundaries:

$$\frac{\partial\phi_g}{\partial n} = 0$$

Expected Primary Results:

1. Maximum eigenvalue

2. Fundamental flux distributions

2.1 Radial flux traverses in midplane z = 190 cm

ϕ_g (x, o, 190)

ϕ_g (x, x, 190)

2.2 Radial flux traverses in planes z = 275 cm and z = 285 cm

ϕ_g (x, o, 275), ϕ_g (x, o, 285)

ϕ_g (x, x, 275), ϕ_g (x, x, 285)

2.3 Axial flux traverses for partially rodded assembly

ϕ_g (40, 40, z)

Note: The fluxes ϕ_g shall be normalized such that

$$\frac{1}{V_{Core}} \int_{V_{Core}} \sum_g \nu\Sigma_{fg}\phi_g \, dV = 1$$

2.4 Value and location of maximum power density. This corresponds to maximum of ϕ_2 in the core. It is recommended that the maximum values of ϕ_2 both in the inner core and at the core/reflector interface be given.

3. Average subassembly powers P_k

$$P_k = \frac{1}{V_k}\int_{V_k}\sum_g \nu\Sigma_{fg}\Phi_g \, dV \ ,$$

where V_k volume of the k-th subassembly and k designates the fuel subassemblies as shown in lower octant of Fig. 1

4. Number of unknowns in the problem. Number of iterations, total and outer

5. Computing time, iteration time, IO-time, computer used

6. Type and numerical values of convergence criteria

7. Table of average group fluxes for a cubical mesh grid of 20 x 20 x 20 cm

8. Dependence of results on mesh spacing.

Best Solution Available: Extrapolated finite difference solution described in 11-A1-1

Solutions

1. Finite Difference Method: 11-A1-1
2. Finite Element Method: 11-A1-2
3. Nodal Expansion Method: 11-A1-3
4. Finite Difference Method: 11-A1-4

BENCHMARK PROBLEM SOLUTION

Identification: 11-A1-1 Benchmark Problem ID.11-A1

Date Submitted: June 1, 1976 By: D. R. Vondy, T. B. Fowler (ORNL)

Date Accepted: June 1, 1977 By: H. L. Dodds, Jr. (U. of Tenn.)
M. V. Gregory (SRL)

Descriptive Title: Three-Dimensional PWR Problem (IAEA)

Mathematical Model: Diffusion Theory, Various Difference Formulations

Computer: IBM-360/91 1974-76, ORNL
IBM-360/195, 1975-76, UC-CTC

Program: (1) VENTURE, ORNL-5062 Report
(2) VANCER, to be documented (ORNL)

Note: To produce acceptable solutions for benchmarking, a tighter convergence of the iterative process was used than is common practice in application, maximum relative flux change on outer iterations = 10^{-5}.

Primary Results:*

a. Primary results obtained in 1974-75 with the VENTURE code are shown in Table 1. The larger problems were initialized with the results from smaller ones and rather obsolete procedures were in use, so compute times are not representative. A number of reported results for the multiplication factor are shown in Figure 1.

b. Results have also been obtained with the VANCER code as summarized in Table 2.

c. Subassembly power density values, relative to the core average, are shown in Table 3 for the mesh-centered VENTURE cases (see the benchmark source situation for number references).

d. Subassembly power density values are shown in Table 4 for the linear finite-element case with 34x34x38 mesh intervals.

e. Table 5 is the continuing 57 pages of results. These tables of fluxes and power are for the mesh-centered VENTURE calculations, averaged over 20 centimeter cubes, one page to a plane normal to the reactor centerline, normalized to a ratio

* Extrapolation of results is done on the basis of error dependence on the square of the mesh spacing.

of productions to core volume of unity (one neutron generated per cc in the core on the average). Orientation is such that the reactor centerline is at the upper left hand corner so the first group of data is for the cube about the centerline of the core. For Power tables, the thermal flux was multiplied by $\nu\Sigma_f = 0.135$ producing results in the non-fueled zones which should be ignored. The numbers in each group are ordered as follows:

Order	Problem Meshpoints (XYZ)
1	17x17x19
2	34x34x38
3	68x68x76
4	102x102x114
5	Extrapolated for infinite points

Block 1 extends from 0-20 cm, Block 2 from 20-40 cm, etc.

ORNL-DWG 75-6720

Table 1

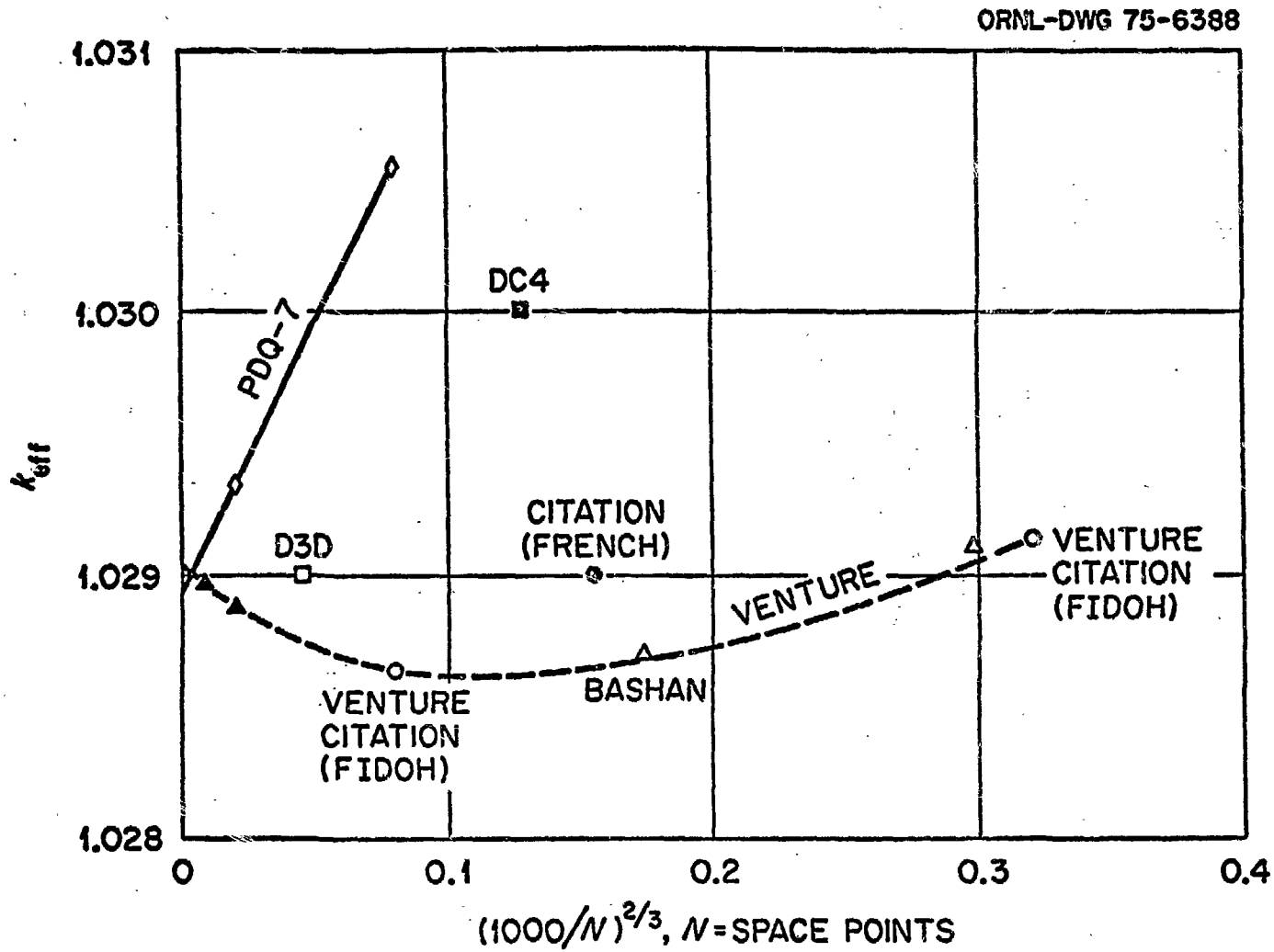
THREE-DIMENSIONAL, TWO-GROUP IAEA BENCHMARK PROBLEM RESULTS

(Non-Return External Boundary Conditions)

Meshpoints (Total Unknowns)	Multiplication Factor	Peak-to-Average Power Density*	IBM-360/91 (or 195) Processor Time (min)
9x9x10(1,620)	1.03176	2.3765	0.3 to 1.
17x17x19(10,982)	1.02913	2.5672	1.6 to 5.
34x34x38(87,856)	1.02864	2.5035	49
68x68x76(702,848)	1.02887	2.4081	192
102x102x114(2,372,112)	1.02896	2.3780	360 (195)
Extrapolated	1.02903	2.354	

*Based on neutrons produced by thermal fission, peak at a point (not interpreted between points); with mesh-center points, values at material interfaces are not estimated.

Figure 1. Three-Dimensional Finite-Difference Results



Three-Dimensional Finite-Difference Results.

Table 2. Results for Mesh-edge Point Location

Formulation (Near Neighbors)	k_{eff}	Peak Power Density	
		Internal	Reflector Edge
VENTURE, Mesh Centered (6)	1.02864	2.50	2.42
VANCER:			
Usual Finite-Difference (6)	1.03064	2.02	2.50
Linear Finite-Element (10)	1.02949	2.21	2.53
Linear Finite-Difference (10)	1.02968	2.18	2.54

Relative computation requirements are estimated at:

Formulation	Memory (Words)	Relative Computation Cost
Mesh Centered (VENTURE)	166,000	1.00
Mesh Edge (VANCER)		
Six Neighbors, Consistent Source	191,000	1.37
Ten Neighbors, Consistent Source	217,000	1.73

Table 3. Subassembly Power Densities (Axial Average)
(Non-Fuel Zone Values Given Also, Mesh Centered, VENTURE Code)

Location/Mesh Intervals	17x17x19	34x34x39	68x68x76	102x102x114	Extrapolated
1	0.7356	0.7500	0.7367	0.7325	0.729
2	1.4485	1.3780	1.3138	1.2957	1.281
3	1.5651	1.5080	1.4508	1.4347	1.422
4	1.3178	1.2657	1.2181	1.2044	1.193
5	0.5802	0.6058	0.6092	0.6098	0.610
6	0.9707	0.9631	0.9569	0.9548	0.953
7	0.9101	0.9317	0.9500	0.9551	0.959
8	0.6574	0.7056	0.7522	0.7659	0.777
(9)	0.9134	1.0125	1.0773	1.0954	1.110
10	1.5604	1.4903	1.4278	1.4109	1.397
11	1.5742	1.5158	1.4595	1.4441	1.432
12	1.4045	1.3557	1.3121	1.3002	1.291
13	1.1406	1.1119	1.0852	1.0779	1.072
14	1.0619	1.0575	1.0555	1.0553	1.055
15	0.9537	0.9438	0.9643	0.9707	0.976
16	0.6366	0.6850	0.7318	0.7460	0.757
(17)	0.8650	0.9595	1.0230	1.0413	1.056
18	1.4797	1.4369	1.3914	1.3786	1.368
19	1.4030	1.3657	1.3292	1.3192	1.311
20	1.2226	1.2067	1.1894	1.1847	1.181
21	1.0755	1.0810	1.0859	1.0877	1.089
22	0.9420	0.9602	0.9855	0.9935	1.000
23	0.5459	0.6138	0.6761	0.6953	0.711
(24)	0.6494	0.7255	0.7825	0.7993	0.813
25	1.2480	1.2180	1.1913	1.1841	1.178
26	1.0083	1.0252	0.9790	0.9753	0.972
27	0.8970	0.9062	0.9168	0.9204	0.923
28	0.7383	0.7898	0.8390	0.8541	0.866
(29)	1.4827	1.6009	1.6807	1.7039	1.722
(30)	0.2759	0.3289	0.3683	0.3802	0.390
31	0.4244	0.4542	0.4685	0.4727	0.476
32	0.6720	0.6783	0.6924	0.6969	0.700
33	0.4725	0.5284	0.5812	0.5976	0.611
(34)	0.6681	0.7462	0.8046	0.8220	0.836
35	0.4717	0.5210	0.5699	0.5852	0.597
(36)	0.9891	1.0610	1.1196	1.1373	1.151
(37)	0.2180	0.2599	0.2917	0.3015	0.309
(38)	0.2560	0.2996	0.3344	0.3451	0.354
18* Rodded Part	0.3042	0.3106	0.3095	0.3094	0.309
18** Unrodded Part	1.8414	1.7834	1.7242	1.7076	1.694

Table 4. Subassembly Power Densities (Axial Average), (Non-Fuel Zone Values Given Also, Linear Finite Element, VANCER Code)

Location/Mesh Intervals	34x34x38
1	0.7220
2	1.2652
3	1.3317
4	1.1351
5	0.6057
6	0.9450
7	0.9700
8	0.8089
(9)	1.1348
10	1.3404
11	1.3732
12	1.2408
13	1.0410
14	1.0500
15	0.9920
16	0.8000
(17)	1.1116
18	1.3174
19	1.2705
20	1.1615
21	1.0931
22	1.0260
23	0.7770
(24)	0.8752
25	1.1495
26	0.9583
27	0.9358
28	0.9203
(29)	1.8108
(30)	0.4325
31	0.4906
32	0.7186
33	0.6717
(34)	0.9038
35	0.6536
(36)	1.2214
(37)	0.3459
(38)	0.3918
18* Rodded Part	0.3162
18** Unrodded Part	1.6254

Start Table 5 (57 pages)

GROUP 1 BLOCK 1 FLUXES

0.491809							
0.581252							
0.649134							
0.680524							
0.705636							
0.583971	0.594469						
0.682275	0.693158						
0.779211	0.794509						
0.825847	0.843363						
0.863155	0.882446						
0.613919	0.568600	0.462309					
0.728490	0.669316	0.555361					
0.844799	0.770182	0.630505					
0.899898	0.818119	0.664297					
0.943976	0.856468	0.691330					
0.555433	0.562112	0.530850	0.517624				
0.660657	0.668454	0.638067	0.626610				
0.766918	0.780260	0.748714	0.743564				
0.816776	0.832811	0.800087	0.797623				
0.856662	0.874851	0.841184	0.840869				
0.446127	0.532850	0.556763	0.477717	0.343918			
0.550602	0.650789	0.689803	0.591222	0.436880			
0.639062	0.773117	0.831680	0.711253	0.521427			
0.677828	0.829231	0.896455	0.765772	0.557738			
0.708841	0.874121	0.948275	0.809386	0.586786			
0.507254	0.540605	0.540891	0.453779	0.327464	0.209493		
0.635891	0.680063	0.686835	0.578032	0.417952	0.273049		
0.771990	0.831707	0.846920	0.715725	0.520178	0.348337		
0.833451	0.900345	0.919081	0.777596	0.565760	0.381501		
0.882636	0.955255	0.976809	0.827093	0.602225	0.408032		
0.486448	0.488443	0.460142	0.344262	0.212694	0.072370	0.015321	
0.630169	0.633037	0.595724	0.451220	0.281629	0.102866	0.021879	
0.788923	0.794060	0.751906	0.575129	0.363149	0.133076	0.027831	
0.859901	0.866034	0.821690	0.629979	0.398960	0.144975	0.030053	
0.916683	0.923612	0.877516	0.673858	0.427608	0.154494	0.031830	
0.320521	0.309686	0.250241	0.109184	0.047193	0.013225	0.0	0.0
0.422504	0.409444	0.334185	0.157344	0.068015	0.019355	0.0	0.0
0.541035	0.525546	0.432559	0.203544	0.087984	0.024846	0.0	0.0
0.593440	0.576833	0.475690	0.221676	0.095711	0.026887	0.0	0.0
0.635363	0.617861	0.510195	0.236181	0.101893	0.028519	0.0	0.0
0.067782	0.064206	0.047990	0.016969	0.0	0.0	0.0	0.0
0.098201	0.093125	0.069499	0.024861	0.0	0.0	0.0	0.0
0.126555	0.120286	0.090293	0.031864	0.0	0.0	0.0	0.0
0.137531	0.130821	0.098363	0.034464	0.0	0.0	0.0	0.0
0.146313	0.139248	0.104819	0.036545	0.0	0.0	0.0	0.0

GROUP 1 BLOCK 2 FLUXES

5.229720							
4.876290							
4.714016							
4.699341							
4.687597							
7.068169	7.264626						
6.314484	6.470860						
6.069390	6.226661						
6.048328	6.207546						
6.031474	6.192250						
7.533952	6.883982	4.914222					
6.829825	6.191372	4.650915					
6.627941	5.992641	4.566707					
6.622412	5.984154	4.573670					
6.617984	5.977359	4.579236					
6.718606	6.859634	6.412583	6.311865				
6.097737	6.219120	5.879041	5.816854				
5.950730	6.088327	5.798501	5.784741				
5.957143	6.101273	5.823526	5.824737				
5.962269	6.111625	5.843542	5.856730				
4.729738	6.431657	6.817832	5.778264	3.669720			
4.585157	5.979685	6.424558	5.438983	3.657712			
4.596798	5.964885	6.467326	5.490326	3.770639			
4.633219	6.011244	6.534152	5.552841	3.832976			
4.662353	6.048327	6.587609	5.602849	3.882842			
6.110683	6.603089	6.648477	5.579135	4.066138	2.629845		
5.819603	6.303431	6.406042	5.397050	3.933128	2.606824		
5.927913	6.439398	6.586513	5.584503	4.109794	2.795335		
6.011868	6.535919	6.697352	5.689708	4.201124	2.878718		
6.079028	6.613131	6.786018	5.773868	4.274185	2.945422		
5.971705	6.018558	5.816412	4.344919	2.679133	0.536357	0.084783	
5.864732	5.913037	5.685014	4.311991	2.695662	0.647983	0.104392	
6.120921	6.182147	5.970173	4.586359	2.910228	0.768197	0.124815	
6.251222	6.317180	6.110500	4.710808	3.001954	0.811967	0.132157	
6.355458	6.425202	6.222757	4.810364	3.075332	0.846982	0.138031	
4.030659	3.898269	3.154867	0.807767	0.324551	0.073240	0.0	0.0
4.017229	3.897941	3.194575	0.988571	0.396238	0.092739	0.0	0.0
4.287787	4.170917	3.456249	1.169500	0.472038	0.111804	0.0	0.0
4.408357	4.291200	3.566901	1.234679	0.499421	0.118576	0.0	0.0
4.504810	4.387424	3.655421	1.286821	0.521327	0.123993	0.0	0.0
0.474359	0.450387	0.335861	0.093673	0.0	0.0	0.0	0.0
0.579692	0.550748	0.409621	0.118323	0.0	0.0	0.0	0.0
0.684175	0.651361	0.488269	0.142332	0.0	0.0	0.0	0.0
0.721501	0.687437	0.516715	0.150861	0.0	0.0	0.0	0.0
0.751362	0.716297	0.539472	0.157683	0.0	0.0	0.0	0.0

GROUP 1 BLOCK 3 FLUXES

10.640157							
10.342917							
9.949892							
9.846301							
9.763422							
14.320156	14.721536						
13.261953	13.583195						
12.631366	12.944482						
12.484147	12.797089						
12.366362	12.679166						
15.231454	13.943526	9.992692					
14.281724	12.992740	9.847260					
13.708546	12.455223	9.611246					
13.577841	12.333158	9.551445					
13.473267	12.235497	9.503597					
13.524257	13.800050	12.890597	12.629105				
12.711818	12.945987	12.230785	12.033804				
12.281475	12.537839	11.934143	11.830535				
12.189589	12.454546	11.879818	11.804875				
12.116072	12.387902	11.836349	11.784338				
9.463999	12.810762	13.559529	11.481140	7.294127			
9.543642	12.317812	13.186732	11.174188	7.564192			
9.501802	12.149380	13.103403	11.151026	7.745007			
9.499599	12.133391	13.113650	11.175657	7.809531			
9.497829	12.120592	13.121839	11.195354	7.861145			
12.048614	13.017533	13.106455	10.994577	8.003810	5.153759		
11.857074	12.822527	13.023960	10.981101	8.014895	5.285331		
11.933986	12.929055	13.211058	11.220655	8.290342	5.615988		
11.990616	12.997600	13.303586	11.324881	8.401200	5.737143		
12.035911	13.052426	13.377598	11.408254	8.489880	5.834062		
11.700757	11.795717	11.400548	8.510855	5.241037	1.043431	0.163607	
11.848229	11.950092	11.494193	8.716574	5.445371	1.306125	0.208420	
12.198562	12.325664	11.914407	9.161203	5.817193	1.537980	0.247738	
12.337196	12.472697	12.078737	9.325022	5.950086	1.613693	0.260601	
12.448095	12.590314	12.210193	9.456071	6.056397	1.674263	0.270891	
[illegible].864830	7.607886	6.153328	1.569190	0.629551	0.141216	0.0	0.0
8.082984	7.845747	6.428634	1.987680	0.795126	0.184904	0.0	0.0
8.519551	8.291454	6.876891	2.332601	0.940221	0.221502	0.0	0.0
8.678107	8.452088	7.035229	2.443312	0.987371	0.233340	0.0	0.0
8.804945	8.580590	7.161894	2.531879	1.025089	0.242810	0.0	0.0
0.918452	0.872165	0.650000	0.180239	0.0	0.0	0.0	0.0
1.160316	1.102655	0.819655	0.235242	0.0	0.0	0.0	0.0
1.357270	1.292635	0.969222	0.281010	0.0	0.0	0.0	0.0
1.419676	1.353194	1.017788	0.295782	0.0	0.0	0.0	0.0
1.469601	1.401639	1.056639	0.307600	0.0	0.0	0.0	0.0

GROUP 1 BLOCK 4 FLUXES

16.793342							
16.559952							
15.897389							
15.694469							
15.532121							
22.632385	23.341119						
21.264527	21.857876						
20.208272	20.784736						
19.924055	20.497747						
19.696667	20.268141						
24.062081	22.143213	15.962351					
22.880912	20.936286	15.949408					
21.903503	20.018613	15.519597					
21.638054	19.770672	15.379701					
21.425679	19.572306	15.267773					
21.177126	21.650793	20.247122	19.658149				
20.166883	20.581989	19.460387	18.960850				
19.416893	19.861238	18.910907	18.555542				
19.216212	19.670914	18.765547	18.454162				
19.055654	19.518641	18.649245	18.373045				
14.552325	19.706391	20.856544	17.600751	11.093175			
14.835445	19.153563	20.498377	17.309573	11.618643			
14.700769	18.798496	20.262738	17.182928	11.833368			
14.648810	18.710327	20.208098	17.160708	11.890151			
14.607232	18.639778	20.164373	17.142919	11.935569			
18.204268	19.692255	19.840064	16.624451	12.062430	7.742822		
18.080384	19.574017	19.893820	16.755385	12.191525	8.013793		
18.095324	19.623567	20.062060	17.022675	12.541560	8.470140		
18.115398	19.655705	20.128432	17.118317	12.664226	8.622908		
18.131443	19.681401	20.181515	17.194819	12.762350	8.745116		
17.533464	17.685352	17.106201	12.775360	7.862754	1.564450	0.245025	
17.907982	18.070867	17.395021	13.197833	8.242122	1.976657	0.315040	
18.328993	18.528667	17.924664	13.790986	8.756419	2.314647	0.372626	
18.468415	18.679989	18.104677	13.986509	8.924806	2.420274	0.390677	
18.579940	18.801034	18.248674	14.142916	9.059509	2.504774	0.405118	
11.736941	11.357537	9.193102	2.347457	0.942527	0.211325	0.0	0.0
12.165875	11.812864	9.686709	2.999027	1.200822	0.279201	0.0	0.0
12.748471	12.411585	10.302988	3.499692	1.412282	0.332762	0.0	0.0
12.937822	12.605501	10.501955	3.652703	1.477948	0.349369	0.0	0.0
13.089293	12.760624	10.661121	3.775110	1.530480	0.362654	0.0	0.0
1.368547	1.299941	0.969360	0.268919	0.0	0.0	0.0	0.0
1.743726	1.657506	1.232782	0.354017	0.0	0.0	0.0	0.0
2.028211	1.932173	1.449699	0.420648	0.0	0.0	0.0	0.0
2.113800	2.015410	1.516945	0.441231	0.0	0.0	0.0	0.0
2.182270	2.081998	1.570741	0.457698	0.0	0.0	0.0	0.0

GROUP 1 BLOCK 5 FLUXES

23.980612							
23.831962							
22.875082							
22.567827							
22.322007							
32.474549	33.856542						
30.774210	32.071622						
29.244054	30.521623						
28.813326	30.084245						
28.468723	29.734320						
34.640052	32.547240	24.524913					
33.221671	31.216968	25.016190					
31.789069	29.895484	24.466059					
31.378221	29.511274	24.250770					
31.049520	29.203885	24.078522					
30.081201	31.055876	29.439842	27.970158				
28.856385	29.823547	28.664522	27.228027				
27.745851	28.757036	27.848418	26.594844				
27.428248	28.450721	27.603724	26.410179				
27.174147	28.205649	27.407949	26.262428				
20.113973	27.307025	28.965182	24.301178	15.112810			
20.598408	26.670481	28.605546	24.006049	15.883591			
20.353801	26.100551	28.188090	23.750882	16.118412			
20.249188	25.935387	28.063291	23.677344	16.164980			
20.165482	25.803238	27.963431	23.618497	16.202223			
24.558953	26.621120	26.857890	22.466665	16.221827	10.370684		
24.471710	26.544781	27.013480	22.711628	16.445412	10.765381		
24.407851	26.518878	27.143729	22.988982	16.855509	11.337119		
24.389603	26.512727	27.181908	23.073693	16.987505	11.519403		
24.374987	26.507787	27.212431	23.141445	17.093090	11.665222		
23.405121	23.626309	22.878780	17.096174	10.514462	2.090781	0.327155	
23.979163	24.213971	23.333003	17.712195	11.054423	2.648437	0.421855	
24.457880	24.740350	23.957383	18.440922	11.701866	3.091063	0.497204	
24.597115	24.894843	24.151484	18.666221	11.903975	3.225937	0.520303	
24.708487	25.018419	24.306748	18.846447	12.065654	3.333834	0.538783	
15.591182	15.094390	12.231341	3.128908	1.257640	0.281917	0.0	0.0
16.211784	15.748059	12.926507	4.008321	1.606683	0.373514	0.0	0.0
16.929990	16.489257	13.700910	4.660677	1.882813	0.443590	0.0	0.0
17.148711	16.714935	13.938793	4.855075	1.966577	0.464845	0.0	0.0
17.323675	16.895466	14.129089	5.010591	2.033588	0.481848	0.0	0.0
1.815252	1.724897	1.287353	0.357485	0.0	0.0	0.0	0.0
2.319786	2.205793	1.641795	0.471863	0.0	0.0	0.0	0.0
2.688999	2.562458	1.923974	0.558706	0.0	0.0	0.0	0.0
2.797128	2.667749	2.009382	0.584927	0.0	0.0	0.0	0.0
2.883630	2.751979	2.077707	0.605904	0.0	0.0	0.0	0.0

GROUP 1 BLOCK 6 FLUXES

31.956508							
31.809071							
30.540113							
30.127386							
29.797182							
43.649274	46.666822						
41.388584	44.195654						
39.334298	42.058047						
38.751045	41.453154						
38.284415	40.969210						
46.980801	47.048406	45.277808					
44.954204	44.809402	43.052014					
42.986849	42.822543	41.169672					
42.419970	42.255025	40.631224					
41.966436	41.800981	40.200436					
40.094836	42.464124	42.380626	38.054806				
38.441225	40.707921	40.865191	36.929094				
36.922945	39.191024	39.532322	35.968168				
36.482689	38.752431	39.143296	35.684379				
36.130458	38.401529	38.832047	35.457322				
35.961447	35.423637	37.795478	31.434641	19.217081			
26.590854	34.577887	37.235683	31.016822	20.193472			
26.223190	33.764399	36.591893	30.604300	20.435583			
26.065277	33.519393	36.391467	30.475999	20.470392			
25.938928	33.323364	36.231101	30.373336	20.498224			
30.870422	33.545223	33.906102	28.305864	20.325337	12.937788		
30.782912	33.460879	34.102046	28.617386	20.616248	13.438641		
30.629352	33.345565	34.176891	28.888606	21.073181	14.114279		
30.572643	33.300552	34.185507	28.960550	21.212374	14.323658		
30.527255	33.264519	34.192376	29.018084	21.323714	14.491150		
29.099955	29.399655	28.504175	21.311336	13.096187	2.602432	0.406837	
29.842338	30.155861	29.089679	22.092552	13.778615	3.298589	0.524943	
30.365697	30.736657	29.792924	22.941524	14.547349	3.839640	0.617080	
30.503615	30.892910	29.999004	23.193936	14.780707	4.002296	0.644968	
30.613927	31.017890	30.163846	23.395849	14.967382	4.132418	0.667277	
19.290241	18.684717	15.157771	3.884538	1.562989	0.350288	0.0	0.0
20.080151	19.514031	16.033553	4.979320	1.997916	0.464386	0.0	0.0
20.920626	20.384075	16.952713	5.774875	2.335162	0.550079	0.0	0.0
21.166425	20.639088	17.226828	6.008543	2.436106	0.575742	0.0	0.0
21.363050	20.843083	17.446109	6.195473	2.516859	0.596271	0.0	0.0
2.242653	2.131832	1.592457	0.442648	0.0	0.0	0.0	0.0
2.868703	2.728608	2.032431	0.584609	0.0	0.0	0.0	0.0
3.317422	3.162248	2.375954	0.690477	0.0	0.0	0.0	0.0
3.446807	3.288343	2.478513	0.722027	0.0	0.0	0.0	0.0
3.550313	3.389216	2.560558	0.747267	0.0	0.0	0.0	0.0

GROUP 1 BLOCK 7 FLUXES

39.412486							
39.416005							
37.883454							
37.378826							
36.975098							
53.989732	58.100077						
51.467362	55.444231						
48.970645	52.867245						
48.255315	52.128118						
47.683016	51.536779						
58.224405	59.031052	58.015407					
56.017341	56.788376	56.062747					
53.621097	54.428184	53.957884					
52.922982	53.739705	53.336542					
52.364451	53.188884	52.839431					
49.287977	52.526915	52.870105	46.847016				
47.468072	50.698902	51.457377	45.746375				
45.610775	48.862440	49.876283	44.572463				
45.065195	48.320681	49.399550	44.214594				
44.628700	47.887240	49.018128	43.928267				
31.354830	42.859093	45.801316	37.938833	22.976331			
32.185693	41.941442	45.238755	37.516215	24.171457			
31.714547	40.921652	44.415174	36.974188	24.422493			
31.510138	40.607314	44.151085	36.798927	24.447249			
31.346589	40.355814	43.939781	36.658691	24.467037			
36.649273	39.885639	40.355603	33.647528	24.073264	15.277292		
36.577292	39.818219	40.620834	34.040862	24.431656	15.874830		
36.341032	39.621264	40.645766	34.305523	24.928575	16.642285		
36.249723	39.541468	40.628144	34.366048	25.073984	16.875823		
36.176650	39.477603	40.614018	34.414443	25.190294	17.062642		
34.273175	34.647106	33.621608	25.148540	15.445897	3.067962	0.479286	
35.167375	35.556317	34.327668	26.080612	16.257316	3.889704	0.618578	
35.727483	36.182672	35.098571	27.035288	17.133576	4.519381	0.725820	
35.863965	36.340253	35.315150	27.311855	17.394864	4.707102	0.758023	
35.973125	36.466292	35.488388	27.533089	17.603881	4.857275	0.783785	
22.633933	21.931813	17.807690	4.570101	1.840396	0.412401	0.0	0.0
23.572824	22.916138	18.844033	5.859352	2.352974	0.546844	0.0	0.0
24.520359	23.899249	19.891173	6.783549	2.745176	0.646581	0.0	0.0
24.790173	24.180310	20.197617	7.052586	2.861601	0.676215	0.0	0.0
25.006007	24.405142	20.442758	7.267810	2.954739	0.699922	0.0	0.0
2.628351	2.499228	1.868205	0.519706	0.0	0.0	0.0	0.0
3.363231	3.199833	2.384883	0.686448	0.0	0.0	0.0	0.0
3.882983	3.702272	2.783296	0.809359	0.0	0.0	0.0	0.0
4.031414	3.847012	2.901243	0.845695	0.0	0.0	0.0	0.0
4.150156	3.962802	2.995595	0.874762	0.0	0.0	0.0	0.0

GROUP 1 BLOCK 8 FLUXES

45.539123							
45.725571							
43.995319							
43.418612							
42.957216							
62.416862	67.247985						
59.747004	64.457107						
56.911855	61.535550						
56.092842	60.690010						
55.437591	60.013535						
67.292767	68.358742	67.301522					
65.004517	66.053091	65.323387					
62.286031	63.380533	62.940878					
61.486262	62.592603	62.229096					
60.846403	61.962214	61.659626					
56.751288	60.533813	60.967625	53.803335				
54.846528	58.645095	59.560293	52.706887				
52.732056	56.557459	57.763598	51.365012				
52.104214	55.933936	57.213558	50.948463				
51.601903	55.435078	56.773484	50.615188				
35.794926	48.945370	52.307181	43.248818	26.076676			
36.820739	48.002001	51.775796	42.848290	27.467157			
36.274160	46.825282	50.819591	42.210679	27.730751			
36.033342	46.456458	50.506326	41.999027	27.748250			
35.840661	46.161366	50.255677	41.829675	27.762229			
41.449276	45.143970	45.694986	38.073119	27.185955	17.223066		
41.406880	45.111027	46.040474	38.551530	27.609343	17.905020		
41.106951	44.852651	46.031281	38.816101	28.141998	18.749835		
40.987970	44.745316	45.993407	38.868256	28.293086	19.003667		
40.892756	44.659416	45.963075	38.909953	28.413936	19.206719		
38.573745	39.008595	37.874289	28.338140	17.400132	3.455272	0.539574	
39.600761	40.052559	38.689088	29.402262	18.322403	4.382244	0.696594	
40.193353	40.718961	39.518593	30.446599	19.288985	5.085892	0.816433	
40.329105	40.878150	39.744423	30.743630	19.573688	5.294523	0.852233	
40.437677	41.005472	39.925059	30.981233	19.801436	5.461424	0.880872	
25.411128	24.629044	20.009480	5.139991	2.071133	0.464078	0.0	0.0
26.475144	25.743765	21.181095	6.591707	2.648659	0.615523	0.0	0.0
27.511940	26.821187	22.335011	7.623103	3.086682	0.726965	0.0	0.0
27.801800	27.123990	22.668422	7.921609	3.216010	0.759909	0.0	0.0
28.033667	27.366213	22.935135	8.160408	3.319471	0.786263	0.0	0.0
2.948550	2.804273	2.097230	0.583731	0.0	0.0	0.0	0.0
3.773795	3.591131	2.677694	0.771098	0.0	0.0	0.0	0.0
4.352499	4.150683	3.121701	0.908174	0.0	0.0	0.0	0.0
4.516741	4.310906	3.252429	0.948487	0.0	0.0	0.0	0.0
4.648131	4.439081	3.357009	0.980737	0.0	0.0	0.0	0.0

GROUP 1 BLOCK 9 FLUXES

49.962814							
50.290832							
48.426326							
47.798620							
47.296420							
68.478260	73.784138						
65.708455	70.891873						
62.638496	67.728934						
61.745718	66.807179						
61.031451	66.069727						
73.784716	74.965601	73.779980					
71.439436	72.600408	71.759841					
68.497395	69.707091	69.178206					
67.625270	68.847453	68.400435					
66.927522	68.159693	67.778168					
62.108843	66.241073	66.685775	58.750369				
60.144445	64.299375	65.263248	57.644133				
57.851758	62.035326	63.312997	56.183928				
57.165443	61.353145	62.709826	55.725169				
56.616350	60.807356	62.227244	55.358122				
39.009572	53.339985	56.989354	47.077696	28.326044			
40.180994	52.380957	56.481111	46.693991	29.860695			
39.585284	51.096987	55.435154	45.992372	30.137103			
39.318922	50.689637	55.087204	45.755171	30.149965			
39.105804	50.363720	54.808805	45.565378	30.160233			
44.950929	48.975507	49.580803	41.295492	29.457089	18.645004		
44.935193	48.973292	49.990336	41.840349	29.930776	19.390311		
44.594315	48.676265	49.962623	42.110050	30.492974	20.293770		
44.456072	48.549889	49.911083	42.157013	30.648820	20.562819		
44.345446	48.448753	49.869815	42.194554	30.773476	20.778044		
41.717214	42.195788	40.981001	30.668399	18.828590	3.738482	0.583671	
42.843970	43.341196	41.878520	31.831650	19.833442	4.742764	0.753712	
43.464441	44.041166	42.755177	32.944895	20.868133	5.501067	0.882851	
43.600361	44.202267	42.988521	33.257487	21.170334	5.725110	0.921301	
43.709067	44.331116	43.175165	33.507536	21.412080	5.904341	0.952060	
27.441268	26.600712	21.619015	5.556610	2.239863	0.501876	0.0	0.0
28.597328	27.811466	22.890382	7.127498	2.865072	0.665800	0.0	0.0
29.701606	28.960058	24.124319	8.238021	3.336922	0.785879	0.0	0.0
30.006495	29.279133	24.477793	8.558233	3.475757	0.821260	0.0	0.0
30.250384	29.534373	24.760554	8.814396	3.586822	0.849564	0.0	0.0
3.182584	3.027240	2.264648	0.630539	0.0	0.0	0.0	0.0
4.073880	3.877162	2.891784	0.833006	0.0	0.0	0.0	0.0
4.695978	4.478760	3.369361	0.980513	0.0	0.0	0.0	0.0
4.871836	4.650360	3.509484	1.023750	0.0	0.0	0.0	0.0
5.012519	4.787636	3.621579	1.058339	0.0	0.0	0.0	0.0

GROUP 1 BLOCK 10 FLUXES

52.513571							
52.925710							
50.995986							
50.341084							
49.817127							
71.966517	77.535535						
69.140968	74.585505						
65.950964	71.299610						
65.018423	70.336874						
64.272343	69.566634						
77.508679	78.741479	77.461837					
75.130755	76.340891	75.415163					
72.075837	73.336220	72.733823					
71.164975	72.438232	71.920912					
70.436234	71.719789	71.270531					
65.177251	69.499916	69.936715	61.562711				
63.177561	67.525357	68.501380	60.446407				
60.794798	65.172693	66.475166	58.928352				
60.077219	64.459254	65.843880	58.447397				
59.503114	63.888456	65.338804	58.062591				
40.848189	55.849928	59.657886	49.258498	29.607474			
42.101704	54.879744	59.159646	48.881319	31.222324			
41.485063	53.543494	58.071784	48.150530	31.510412			
41.205509	53.115890	57.705888	47.900237	31.521547			
40.981836	52.773769	57.413130	47.699968	31.530433			
46.947963	51.160282	51.795190	43.131071	30.750404	19.454427		
46.945023	51.172904	52.238360	43.711157	31.250676	20.234340		
46.587362	50.861044	52.207388	43.989667	31.833634	21.173579		
46.439459	50.725269	52.149552	44.034890	31.993015	21.451810		
46.321103	50.616613	52.103245	44.071036	32.120497	21.674380		
43.504051	44.007739	42.747647	31.993953	19.641286	3.899622	0.608758	
44.684026	45.207355	43.688968	33.211163	20.691588	4.947512	0.786145	
45.325655	45.931815	44.597694	34.367579	21.767451	5.737490	0.920664	
45.462766	46.095124	44.836408	34.689868	22.080135	5.970450	0.960645	
45.572423	46.225738	45.027347	34.947673	22.330267	6.156813	0.992630	
28.592256	27.718840	22.532366	5.793271	2.335796	0.523371	0.0	0.0
29.797583	28.981263	23.858132	7.431200	2.987867	0.694334	0.0	0.0
30.943234	30.173267	25.140035	8.587495	3.479286	0.819400	0.0	0.0
31.257301	30.502221	25.505450	8.920243	3.623612	0.856188	0.0	0.0
31.508532	30.765362	25.797763	9.186435	3.739069	0.885617	0.0	0.0
3.315137	3.153558	2.359554	0.657092	0.0	0.0	0.0	0.0
4.243364	4.038759	3.012821	0.868033	0.0	0.0	0.0	0.0
4.890440	4.664561	3.509721	1.021542	0.0	0.0	0.0	0.0
5.072977	4.842702	3.655243	1.066461	0.0	0.0	0.0	0.0
5.219003	4.985211	3.771659	1.102395	0.0	0.0	0.0	0.0

GROUP 1 BLOCK 11 FLUXES

3.121790							
3.561368							
1.640925							
0.985732							
0.461542							
2.793697	78.420037						
9.963500	75.464653						
6.776418	72.183075						
5.842259	71.219037						
5.094884	70.447756						
8.376922	79.615783	78.297979					
5.998330	77.212984	76.248544					
2.949695	74.214947	73.574749					
2.038069	73.316367	72.761714					
1.308717	72.597452	72.111234					
5.869874	70.228377	70.649687	62.161960				
3.864760	68.248054	69.210799	61.040435				
1.486596	65.901430	67.192580	59.529930				
0.768414	65.187759	66.561693	59.049637				
0.193825	64.616776	66.056935	58.665361				
1.234147	56.374253	60.208986	49.700274	29.856784			
2.502183	55.397726	59.707412	49.318649	31.481986			
1.894611	54.067644	58.628582	48.595526	31.779769			
1.615938	53.640418	58.263826	48.346356	31.792717			
1.392969	53.298599	57.971980	48.146985	31.803052			
7.325188	51.575875	52.216716	43.477097	30.988503	19.600142		
7.316083	51.581999	52.656758	44.055155	31.486715	20.381238		
6.966233	51.279389	52.637309	44.344841	32.079549	21.330396		
6.819576	51.145223	52.581727	44.392482	32.241366	21.611355		
6.702218	51.037853	52.537223	44.430564	32.370797	21.836108		
3.816385	44.326184	43.060691	32.230205	19.785784	3.928199	0.613181	
4.994465	45.524007	43.998947	33.448734	20.838921	4.982505	0.791649	
5.648267	46.261336	44.921530	34.618818	21.925634	5.778844	0.927229	
5.788067	46.427553	45.163620	34.944646	22.241284	6.013660	0.967525	
5.899873	46.560494	45.357260	35.205284	22.493788	6.201508	0.999761	
8.783576	27.905678	22.686881	5.834089	2.352567	0.527130	0.0	0.0
9.988531	29.168429	24.015061	7.481450	3.008492	0.699128	0.0	0.0
1.145923	30.372410	25.308924	8.646719	3.503762	0.825164	0.0	0.0
1.463007	30.704474	25.677576	8.982032	3.649211	0.862236	0.0	0.0
1.716651	30.970102	25.972478	9.250276	3.765567	0.891894	0.0	0.0
3.336777	3.174278	2.375294	0.661549	0.0	0.0	0.0	0.0
4.269681	4.063979	3.031935	0.873634	0.0	0.0	0.0	0.0
4.921385	4.694274	3.532423	1.028258	0.0	0.0	0.0	0.0
5.105222	4.873689	3.678993	1.073504	0.0	0.0	0.0	0.0
5.252288	5.017216	3.796246	1.109700	0.0	0.0	0.0	0.0

GROUP 1 BLOCK 12 FLUXES

51.787866							
52.202704							
50.367939							
49.741797							
49.240848							
70.961705	76.442018						
68.183794	73.539788						
65.124902	70.392155						
64.230369	69.469796						
63.514697	68.731859						
76.390857	77.593161	76.294288					
74.049523	75.226970	74.270495					
71.128644	72.355689	71.713196					
70.257506	71.497533	70.938113					
69.560546	70.810958	70.317997					
64.179743	68.420186	68.818584	60.535188				
62.203305	66.465415	67.388921	59.415873				
59.926048	64.221025	65.463843	57.979055				
59.240505	63.540834	64.864451	57.524406				
58.692027	62.996636	64.384890	57.160645				
0.149966	54.889787	58.618059	48.379628	29.054775			
41.365104	53.913057	58.100825	47.983054	30.618874			
40.796835	52.648059	57.082170	47.304332	30.923513			
40.534552	52.243702	56.739545	47.071956	30.942526			
40.324697	51.920179	56.465404	46.886022	30.957714			
46.044867	50.182867	50.806562	42.300160	30.145030	19.064029		
46.009128	50.159571	51.204843	42.836978	30.610742	19.811050		
45.690981	49.889461	51.210562	43.138845	31.201056	20.742608		
45.557678	49.769201	51.167018	43.193959	31.364662	21.019925		
45.451002	49.672958	51.132147	43.238018	31.495525	21.241765		
42.610584	43.107680	41.878947	31.346748	19.243170	3.820413	0.596336	
43.728124	44.244136	42.764062	32.511003	20.254356	4.842616	0.769393	
44.383228	44.980702	43.680070	33.663005	21.319775	5.618980	0.901541	
44.527967	45.151263	43.924155	33.986517	21.630928	5.848440	0.940904	
44.643727	45.287680	44.119392	34.245303	21.879834	6.032004	0.972395	
27.983721	27.130967	22.058507	5.673100	2.287824	0.512624	0.0	0.0
29.135570	28.339596	23.334242	7.270116	2.923747	0.679436	0.0	0.0
30.272893	29.521899	24.601867	8.406020	3.406501	0.802259	0.0	0.0
30.587039	29.850477	24.965085	8.733704	3.548605	0.838467	0.0	0.0
30.838334	30.113317	25.255642	8.995844	3.662286	0.867432	0.0	0.0
3.243748	3.085855	2.309259	0.643198	0.0	0.0	0.0	0.0
4.147747	3.948017	2.945589	0.848807	0.0	0.0	0.0	0.0
4.782819	4.562215	3.433245	0.999450	0.0	0.0	0.0	0.0
4.962443	4.737502	3.576396	1.043633	0.0	0.0	0.0	0.0
5.106138	4.877729	3.690914	1.078979	0.0	0.0	0.0	0.0

GROUP 1 BLOCK 13 FLUXES

48.575577							
48.919352							
47.244825							
46.678079							
46.224648							
66.557704	71.695284						
63.892390	68.908231						
61.083578	66.020627						
60.271060	65.184173						
59.621002	64.514963						
71.642203	72.766721	71.540347					
69.380078	70.479743	69.574047					
66.705083	67.851932	67.238904					
65.916962	67.076487	66.541063					
65.286417	66.456083	65.982743					
60.178627	64.151146	64.517839	56.743570				
58.267716	62.256080	63.113111	55.636187				
56.184828	60.207167	61.363478	54.336747				
55.566138	59.595209	60.827724	53.933596				
55.071148	59.105600	60.399077	53.611037				
37.632830	51.447264	54.938565	45.338765	27.223977			
38.730909	50.478262	54.395545	44.918306	28.657547			
38.230864	49.334999	53.485971	44.318862	28.965388			
38.001138	48.976761	53.187315	44.119615	28.995180			
37.817330	48.690136	52.948352	43.960185	29.018993			
43.138888	47.016917	47.601261	39.629983	28.239708	17.857709		
43.056986	46.942336	47.920542	40.087498	28.643147	18.535950		
42.792690	46.726123	47.963330	40.401166	29.217648	19.422037		
42.685446	46.632741	47.942327	40.469409	29.382842	19.689693		
42.599619	46.558002	47.925491	40.523974	29.514977	19.903803		
39.910389	40.376683	39.226831	29.362184	18.024753	3.578488	0.558563	
40.909592	41.393069	40.009480	30.417415	18.949874	4.530665	0.719815	
41.553783	42.113909	40.897269	31.518858	19.961548	5.260914	0.844070	
41.706314	42.290863	41.142589	31.834728	20.261110	5.477976	0.881283	
41.828309	42.432397	41.338816	32.087402	20.500745	5.651622	0.911053	
26.206236	25.408050	20.658494	5.313362	2.142846	0.480141	0.0	0.0
27.252731	26.508627	21.827516	6.801089	2.735254	0.635635	0.0	0.0
28.337493	27.634966	23.030313	7.869527	3.189241	0.751093	0.0	0.0
28.643191	27.953903	23.379833	8.179623	3.323633	0.785311	0.0	0.0
28.887729	28.209032	23.659433	8.427694	3.431144	0.812685	0.0	0.0
3.037544	2.889729	2.162562	0.602361	0.0	0.0	0.0	0.0
3.879437	3.692680	2.755175	0.793967	0.0	0.0	0.0	0.0
4.476703	4.270279	3.213660	0.935562	0.0	0.0	0.0	0.0
4.646717	4.436152	3.349017	0.977318	0.0	0.0	0.0	0.0
4.782724	4.568847	3.457300	1.010723	0.0	0.0	0.0	0.0

GROUP 1 BLOCK 14 FLUXES

43.610201							
43.843701							
42.398750							
41.920714							
41.538255							
59.752880	64.363745						
57.261583	61.755169						
54.816193	59.244780						
54.126502	58.536832						
53.574710	57.970433						
64.313347	65.321144	54.215748					
62.174876	63.158366	62.341479					
59.655478	60.882352	60.326368					
59.191366	60.230372	59.743631					
58.660035	59.708745	59.277398					
54.016324	57.580119	57.905547	50.923541				
52.209425	55.780851	56.544349	49.840348				
50.407530	54.013721	55.046103	48.736786				
49.888624	53.503456	54.604948	48.410018				
49.473463	53.095206	54.251985	48.148568				
33.771827	46.168231	49.299588	40.683012	24.426063			
34.694800	45.217112	48.724073	40.232427	25.665006			
34.289242	44.247549	47.968112	39.743761	25.971663			
34.107679	43.957786	47.734459	39.593355	26.016828			
33.962404	43.725945	47.547502	39.473002	26.052941			
36.702946	42.182808	42.707064	35.554603	25.334461	16.019872		
36.558194	42.038211	42.914179	35.898464	25.648537	16.597166		
38.367218	41.894530	43.003657	36.222158	26.193588	17.410731		
38.298251	41.840515	43.015346	36.309030	26.360243	17.663059		
38.243050	41.797273	43.024667	36.378501	26.493549	17.864908		
35.800757	36.219404	35.188505	26.339737	16.169316	3.210115	0.501059	
36.628349	37.061608	35.823386	27.235232	16.967326	4.056638	0.644496	
37.248588	37.751062	36.661011	28.254278	17.893862	4.715920	0.756620	
37.411723	37.936459	36.906945	28.557531	18.175155	4.913940	0.790531	
37.542204	38.084749	37.103666	28.800113	18.400176	5.072353	0.817660	
23.505592	22.789879	18.530162	4.766127	1.922204	0.430703	0.0	0.0
24.398082	23.732151	19.541791	6.089122	2.448990	0.569112	0.0	0.0
25.398500	24.769070	20.642424	7.053841	2.858755	0.673262	0.0	0.0
25.690567	25.072570	20.970450	7.336950	2.981313	0.704428	0.0	0.0
25.924203	25.315352	21.232856	7.563433	3.079357	0.729360	0.0	0.0
2.724429	2.591874	1.939697	0.540296	0.0	0.0	0.0	0.0
3.472934	3.305774	2.466546	0.710808	0.0	0.0	0.0	0.0
4.012215	3.827241	2.880302	0.838533	0.0	0.0	0.0	0.0
4.167517	3.978700	3.003728	0.876575	0.0	0.0	0.0	0.0
4.291756	4.099865	3.102467	0.907008	0.0	0.0	0.0	0.0

GROUP 1 BLOCK 15 FLUXES

37.075704							
37.168147							
36.013788							
35.650542							
35.359919							
50.798890	54.718047						
48.542142	52.350516						
46.560198	50.320682						
46.029636	49.779118						
45.605154	49.345831						
54.673793	55.529646	54.587618					
52.704621	53.537208	52.841891					
50.837442	51.708317	51.232734					
50.333756	51.215985	50.798656					
49.930771	50.822082	50.451357					
45.917026	48.945457	49.220191	43.283212				
44.253316	47.279254	47.923990	42.239254				
42.808540	45.869613	46.743452	41.382367				
42.418604	45.490663	46.424233	41.153860				
42.106625	45.187471	46.168825	40.971025				
28.704355	39.240310	41.900938	34.576524	20.758714			
29.402919	38.319799	41.290680	34.093210	21.747189			
29.114232	37.568991	40.726541	33.742041	22.047574			
28.994515	37.367337	40.576268	33.654116	22.111854			
28.898720	37.205986	40.456021	33.583752	22.163261			
32.890661	35.848234	36.293819	30.215205	21.529491	13.613662		
32.670741	35.619692	36.361862	30.416872	21.731432	14.062030		
32.568975	35.563524	36.504811	30.747317	22.233426	14.777778		
32.548753	35.559537	36.557703	30.857185	22.400940	15.009307		
32.532553	35.556321	36.599991	30.945057	22.534935	15.194519		
30.421641	30.777596	29.901957	22.382886	13.740421	2.727919	0.425794	
31.031907	31.399151	30.350424	23.074578	14.375335	3.436938	0.546039	
31.614705	32.041319	31.116318	23.981114	15.187507	4.002635	0.642175	
31.790349	32.236358	31.361645	24.266725	15.444137	4.175522	0.671730	
31.930841	32.392366	31.557885	24.495196	15.649430	4.313829	0.695374	
19.972925	19.364908	15.745626	4.050017	1.633434	0.366003	0.0	0.0
20.668922	20.104894	16.555247	5.158662	2.074821	0.482164	0.0	0.0
21.555056	21.020965	17.518980	5.986654	2.426299	0.571416	0.0	0.0
21.828328	21.303313	17.618059	6.234157	2.533243	0.598557	0.0	0.0
22.046930	21.529175	18.057309	6.432154	2.618797	0.620269	0.0	0.0
2.314942	2.202324	1.648193	0.459106	0.0	0.0	0.0	0.0
2.942036	2.800444	2.089531	0.602169	0.0	0.0	0.0	0.0
3.404945	3.247980	2.444386	0.711636	0.0	0.0	0.0	0.0
3.540850	3.380435	2.552087	0.744782	0.0	0.0	0.0	0.0
3.649572	3.486397	2.638246	0.771298	0.0	0.0	0.0	0.0

GROUP 1 BLOCK 16 FLUXES

29.209624							
29.139970							
28.326066							
28.098573							
27.916559							
40.020937	43.108125						
38.056581	41.041615						
36.620417	39.577284						
36.278291	39.232633						
36.004564	38.956884						
43.072572	43.746315	43.002997					
41.318308	41.970249	41.423426					
39.982600	40.666575	40.290351					
39.668620	40.362947	40.031774					
39.417408	40.120016	39.824883					
36.172506	38.557716	38.773187	34.095431				
34.690985	37.062236	37.566134	33.108628				
33.665625	36.071855	36.757049	32.539239				
33.428047	35.847882	36.581457	32.426198				
33.237962	35.668678	36.440957	32.335742				
32.611087	30.910351	33.005780	27.236019	16.351572			
23.047059	30.035999	32.363792	26.721752	17.044520			
22.892669	29.540116	32.021606	26.528748	17.332816			
22.845432	29.441974	31.968935	26.513684	17.418496			
22.807626	29.363438	31.926774	26.501614	17.487028			
25.906721	28.236412	28.587526	23.799902	16.958807	10.723906		
25.604939	27.916102	28.497536	23.838276	17.031415	11.020820		
25.603928	27.957995	28.697338	24.170478	17.476930	11.615803		
25.640155	28.011783	28.797269	24.305772	17.643717	11.821048		
25.669118	28.054794	28.877193	24.413990	17.777133	11.985236		
23.961076	24.241589	23.552370	17.630556	10.823565	2.148913	0.335434	
24.318261	24.606052	23.784358	18.082978	11.265980	2.693614	0.427953	
24.849930	25.185080	24.457686	18.849266	11.937430	3.146080	0.504745	
25.038399	25.389424	24.699955	19.111759	12.163106	3.288398	0.529002	
25.189156	25.552880	24.893752	19.321739	12.343638	3.402249	0.548407	
15.731450	15.252684	12.402321	3.190168	1.286714	0.288328	0.0	0.0
16.196598	15.754657	12.973249	4.042612	1.626024	0.377882	0.0	0.0
16.941137	16.521276	13.768826	4.705198	1.906990	0.449116	0.0	0.0
17.190167	16.776549	14.031659	4.909401	1.994949	0.471364	0.0	0.0
17.389378	16.980756	14.241914	5.072760	2.065314	0.489162	0.0	0.0
1.823383	1.734694	1.298263	0.361648	0.0	0.0	0.0	0.0
2.305429	2.194484	1.637422	0.471888	0.0	0.0	0.0	0.0
2.675998	2.552624	1.921057	0.559278	0.0	0.0	0.0	0.0
2.788325	2.661978	2.009647	0.586475	0.0	0.0	0.0	0.0
2.878185	2.749459	2.080519	0.608232	0.0	0.0	0.0	0.0

GROUP 1 BLOCK 17 FLUXES

20.295270							
20.053891							
19.616741							
19.539402							
19.477517							
27.807620	29.952089						
26.189503	28.242337						
25.360099	27.406229						
25.226942	27.279858						
25.120399	27.178741						
29.926909	30.394464	29.877159					
28.431845	28.879232	28.501195					
27.685869	28.157961	27.895134					
27.582009	28.063230	27.830545					
27.498901	27.987425	27.778853					
25.132500	26.789190	26.938061	23.688082				
23.871414	25.501792	25.846545	22.779307				
23.311206	24.975769	25.447609	22.526544				
23.242147	24.923054	25.430383	22.540467				
23.186883	24.880865	25.416583	22.551590				
15.709194	21.475583	22.930848	18.922630	11.360855			
15.858059	20.666315	22.266042	18.384348	11.726367			
15.849689	20.451234	22.166661	18.363370	11.996197			
15.881723	20.466838	22.220816	18.427635	12.103770			
15.907338	20.479306	22.264124	18.479033	12.189820			
17.998767	19.617103	19.861005	16.535959	11.784856	7.454301		
17.615537	19.204561	19.603120	16.398579	11.717543	7.583522		
17.722269	19.350381	19.859553	16.725881	12.093463	8.037076		
17.819388	19.466297	20.009244	16.886764	12.256667	8.210200		
17.897071	19.559017	20.128983	17.015459	12.387221	8.348693		
16.646928	16.841894	16.364186	12.251707	7.523281	1.494125	0.233337	
16.727110	16.924498	16.359248	12.439053	7.751327	1.853593	0.294559	
17.194273	17.424998	16.920005	13.039681	8.258494	2.176402	0.349143	
17.394097	17.636559	17.155189	13.272730	8.446674	2.283300	0.367235	
17.553944	17.805795	17.343325	13.450160	8.597212	2.368818	0.381709	
10.931497	10.599039	8.619552	2.217586	0.894674	0.200567	0.0	0.0
11.140928	10.836827	8.924112	2.781032	1.118851	0.260082	0.0	0.0
11.719477	11.428454	9.523659	3.254225	1.319026	0.310646	0.0	0.0
11.938276	11.650251	9.742693	3.408267	1.384968	0.327206	0.0	0.0
12.113307	11.827679	9.917914	3.531498	1.437720	0.340455	0.0	0.0
1.267454	1.205838	0.902604	0.251527	0.0	0.0	0.0	0.0
1.585991	1.509671	1.126539	0.324706	0.0	0.0	0.0	0.0
1.850930	1.765526	1.328620	0.386766	0.0	0.0	0.0	0.0
1.935966	1.848137	1.395068	0.407045	0.0	0.0	0.0	0.0
2.003994	1.914225	1.448226	0.423269	0.0	0.0	0.0	0.0

GROUP 1 BLOCK 18 FLUXES

10.639729							
10.211849							
10.147739							
10.215478							
10.269662							
14.584353	15.705715						
13.336321	14.372508						
13.115340	14.162073						
13.184710	14.246072						
13.240196	14.313262						
15.690918	15.934602	15.662036					
14.464173	14.688619	14.493321					
14.300500	14.540531	14.401036					
14.397704	14.644953	14.519599					
14.475457	14.728481	14.614440					
13.180178	14.046326	14.121871	12.419408				
12.153329	12.975927	13.144572	11.588117				
12.052575	12.903639	13.138684	11.634674				
12.144139	13.012669	13.268523	11.764770				
12.217381	13.099883	13.372385	11.868839				
8.234985	11.262620	12.021896	9.922623	5.955418			
8.073864	10.521729	11.324383	9.355596	5.965583			
8.196764	10.573303	11.444697	9.487546	6.195106			
8.300595	10.693051	11.593475	9.620671	6.315673			
8.383653	10.788841	11.712490	9.727164	6.412121			
9.439586	10.285547	10.411057	8.670343	6.184858	3.920502		
8.968007	9.768652	9.962660	8.335809	5.962113	3.864096		
9.160464	9.991075	10.241481	8.625363	6.238602	4.143529		
9.307223	10.156116	10.425947	8.797834	6.385558	4.271084		
9.424623	10.288142	10.573512	8.935804	6.503119	4.373125		
8.727225	8.828638	8.580864	6.431795	3.955753	0.790045	0.124323	
8.500401	8.597271	8.308408	6.323281	3.946516	0.946100	0.151684	
8.864377	8.978032	8.710368	6.712644	4.253622	1.119715	0.181033	
9.059834	9.180256	8.919849	6.898007	4.389953	1.184108	0.191772	
9.216194	9.342028	9.087427	7.046292	4.499016	1.235622	0.200362	
5.738583	5.564221	4.530313	1.171391	0.473736	0.106861	0.0	0.0
5.665181	5.509506	4.540314	1.417510	0.572115	0.133905	0.0	0.0
6.036745	5.884734	4.901775	1.672545	0.679803	0.161047	0.0	0.0
6.208984	6.056682	5.060229	1.766146	0.719422	0.170852	0.0	0.0
6.346769	6.194236	5.186989	1.841026	0.751116	0.178696	0.0	0.0
0.669969	0.637423	0.477635	0.133955	0.0	0.0	0.0	0.0
0.809814	0.770773	0.575713	0.167110	0.0	0.0	0.0	0.0
0.953723	0.909521	0.684530	0.200457	0.0	0.0	0.0	0.0
1.006007	0.960113	0.724543	0.212498	0.0	0.0	0.0	0.0
1.047833	1.000586	0.756552	0.222130	0.0	0.0	0.0	0.0

GROUP 1 BLOCK 19 FLUXES

1.009072							
1.255014							
1.479058							
1.563564							
1.667168							
1.216794	1.294537						
1.480917	1.575436						
1.752656	1.868810						
1.881975	2.008421						
1.985429	2.120108						
1.290484	1.309604	1.286779					
1.580335	1.603843	1.581828					
1.880543	1.910802	1.891479					
2.022698	2.056046	2.037356					
2.136422	2.172241	2.154057					
1.097710	1.157336	1.160541	1.022779				
1.347284	1.421705	1.435070	1.268835				
1.608169	1.701940	1.726277	1.533464				
1.730889	1.833679	1.862468	1.656616				
1.829064	1.939068	1.971420	1.755137				
0.780977	0.939620	0.988510	0.825394	0.560764			
0.992144	1.168216	1.236862	1.035571	0.727616			
1.194446	1.412596	1.504232	1.263656	0.895721			
1.286432	1.525922	1.627872	1.368678	0.971008			
1.360019	1.616582	1.726782	1.452695	1.031236			
0.789170	0.847377	0.852285	0.709606	0.501288	0.314103		
0.997454	1.069879	1.082811	0.906141	0.644920	0.411200		
1.225411	1.316727	1.338929	1.127699	0.812269	0.528500		
1.329638	1.429803	1.455949	1.228513	0.887877	0.580706		
1.413019	1.520262	1.549564	1.309163	0.948362	0.622472		
0.714550	0.720146	0.682350	0.512322	0.315702	0.107143	0.022600	
0.923588	0.930465	0.880098	0.669278	0.417381	0.152056	0.032193	
1.158140	1.168309	1.111142	0.853437	0.539014	0.197069	0.040995	
1.264171	1.275857	1.215613	0.935918	0.593018	0.215018	0.044325	
1.348994	1.361895	1.299190	1.001903	0.636220	0.229377	0.046988	
0.458385	0.444022	0.360967	0.159082	0.069209	0.019411	0.0	0.
0.601374	0.584121	0.479441	0.227838	0.099223	0.028273	0.0	0.
0.770034	0.749579	0.620219	0.294470	0.128287	0.036281	0.0	0.
0.845356	0.823415	0.682581	0.320937	0.139675	0.039296	0.0	0.
0.905613	0.882483	0.732470	0.342111	0.148786	0.041709	0.0	0.
0.096149	0.091263	0.068543	0.024405	0.0	0.0	0.0	0.
0.138382	0.131468	0.098543	0.035466	0.0	0.0	0.0	0.
0.178200	0.169664	0.127883	0.045384	0.0	0.0	0.0	0.
0.193785	0.184641	0.139395	0.049113	0.0	0.0	0.0	0.
0.206252	0.196623	0.148605	0.052095	0.0	0.0	0.0	0.

GROUP 2 BLOCK 1 FLUXES

0.489074							
0.598900							
0.650410							
0.665694							
0.677921							
1.899366	2.001086						
1.953516	2.069368						
1.929215	2.055268						
1.927212	2.056881						
1.925609	2.058171						
2.086484	1.851758	0.459863					
2.214946	1.918753	0.572516					
2.230968	1.908616	0.632135					
2.241266	1.910755	0.650258					
2.249503	1.912464	0.664755					
1.810772	1.893578	1.726303	1.744965				
1.894888	1.997131	1.827634	1.873741				
1.900585	2.020005	1.855436	1.926791				
1.907444	2.032826	1.869203	1.948796				
1.912930	2.043081	1.880215	1.966399				
0.444362	1.736642	1.896037	1.563634	0.341218			
0.568363	1.867571	2.101378	1.704125	0.449357			
0.641590	1.918749	2.200670	1.772060	0.521814			
0.664428	1.939951	2.237249	1.798077	0.545024			
0.682698	1.956911	2.266511	1.818889	0.563591			
1.651644	1.833651	1.841376	1.534003	1.046338	0.720626		
1.824393	2.054758	2.091061	1.741215	1.178839	0.845058		
1.917051	2.180774	2.239898	1.871419	1.272099	0.942834		
1.951481	2.226453	2.292717	1.917564	1.305288	0.976458		
1.979024	2.262995	2.334971	1.954478	1.331838	1.003356		
1.656331	1.660752	1.554313	1.179079	0.738602	0.346653	0.086849	
1.918960	1.925007	1.805690	1.392240	0.885891	0.440264	0.113646	
2.086959	2.097965	1.983126	1.548503	0.999746	0.519539	0.136657	
2.145543	2.158280	2.045233	1.602298	1.038438	0.549282	0.145255	
2.192410	2.206530	2.094917	1.645333	1.069392	0.573076	0.152132	
1.098742	1.060686	0.870573	0.522691	0.233587	0.074478	0.0	0.0
1.305848	1.263991	1.052614	0.670813	0.303734	0.099410	0.0	0.0
1.459176	1.415635	1.192411	0.790957	0.362221	0.120464	0.0	0.0
1.511881	1.467687	1.239885	0.835956	0.384025	0.128290	0.0	0.0
1.554043	1.509328	1.277863	0.871955	0.401468	0.134551	0.0	0.0
0.326456	0.308663	0.232882	0.095693	0.0	0.0	0.0	0.0
0.424665	0.401973	0.304610	0.128054	0.0	0.0	0.0	0.0
0.503388	0.477485	0.364522	0.155002	0.0	0.0	0.0	0.0
0.532874	0.505789	0.386858	0.165002	0.0	0.0	0.0	0.0
0.556462	0.528431	0.404726	0.173002	0.0	0.0	0.0	0.0

GROUP 2 BLOCK 2 FLUXES

0.853762							
0.819833							
0.820458							
0.830348							
0.838259							
1.671712	1.725899						
1.521356	1.571812						
1.499969	1.556677						
1.512243	1.571925						
1.522061	1.584123						
1.790595	1.628354	0.802261					
1.661583	1.491975	0.781985					
1.661825	1.481335	0.794525					
1.682620	1.496583	0.808276					
1.699255	1.508781	0.818957					
1.589359	1.629719	1.516513	1.499612				
1.469578	1.510867	1.416520	1.413310				
1.471151	1.522539	1.433474	1.446985				
1.489984	1.545582	1.456706	1.475991				
1.505050	1.564015	1.475290	1.499194				
0.772234	1.521292	1.620482	1.367421	0.600585			
0.771107	1.441222	1.563454	1.311908	0.617283			
0.800486	1.475257	1.622610	1.359199	0.659524			
0.819208	1.504400	1.661584	1.391102	0.680936			
0.834185	1.527714	1.692761	1.416624	0.698065			
1.445127	1.569223	1.581790	1.328183	1.014119	0.726963		
1.402591	1.533165	1.561503	1.316222	0.999500	0.784135		
1.466449	1.614082	1.656271	1.404631	1.071279	0.896452		
1.505050	1.660259	1.707344	1.450649	1.107668	0.943229		
1.535930	1.697200	1.748202	1.487463	1.136779	0.980650		
1.420692	1.433209	1.458777	1.142421	0.734029	1.544161	0.403304	
1.429550	1.443411	1.460571	1.198866	0.803506	1.597060	0.454675	
1.539316	1.557597	1.581352	1.338718	0.925534	1.728198	0.517964	
1.593754	1.613813	1.640049	1.399674	0.975633	1.782324	0.541629	
1.637302	1.658784	1.687005	1.448439	1.015712	1.825624	0.560560	
1.051000	1.015702	0.867460	2.341896	1.052805	0.344856	0.0	0.0
1.107189	1.072636	0.955696	2.441916	1.135242	0.396407	0.0	0.0
1.241034	1.204863	1.102926	2.632244	1.254689	0.454525	0.0	0.0
1.298808	1.261772	1.163124	2.710859	1.300982	0.476003	0.0	0.0
1.345027	1.307299	1.211283	2.773749	1.338015	0.493185	0.0	0.0
1.475666	1.395194	1.044677	0.443416	0.0	0.0	0.0	0.0
1.579768	1.494761	1.127648	0.510321	0.0	0.0	0.0	0.0
1.724981	1.635491	1.247263	0.584128	0.0	0.0	0.0	0.0
1.782339	1.691002	1.293560	0.611331	0.0	0.0	0.0	0.0
1.828223	1.735410	1.330597	0.633094	0.0	0.0	0.0	0.0

GROUP 2 BLOCK 3 FLUXES

1.726815							
1.708811							
1.671354							
1.663657							
1.657499							
3.346049	3.454374						
3.087574	3.184965						
2.931379	3.033112						
2.893929	2.997887						
2.863967	2.969706						
3.575168	3.258404	1.621637					
3.352032	3.025277	1.626843					
3.217520	2.890824	1.614398					
3.186858	2.859220	1.613754					
3.162326	2.833935	1.613238					
3.160722	3.238148	3.011584	2.963405				
2.960114	3.035549	2.847067	2.821697				
2.850617	2.937820	2.769218	2.772141				
2.826015	2.917636	2.753516	2.765504				
2.806331	2.901486	2.740953	2.760193				
1.536087	2.993455	3.182757	2.684055	1.186722			
1.576957	2.867921	3.095038	2.603392	1.254342			
1.596327	2.819743	3.075492	2.590070	1.307154			
1.605340	2.812860	3.077915	2.592959	1.326259			
1.612548	2.807351	3.079852	2.595268	1.341543			
2.814771	3.055184	3.079554	2.585134	1.972850	1.407116		
2.760075	3.008428	3.061991	2.584166	1.970434	1.539503		
2.769342	3.032627	3.107790	2.642556	2.033338	1.702947		
2.779431	3.048449	3.130177	2.667787	2.058435	1.759106		
2.787501	3.061104	3.148085	2.687971	2.078510	1.804031		
2.749072	2.774181	2.824760	2.210340	1.418204	2.980495	0.773785	
2.785339	2.813830	2.851498	2.343127	1.570961	3.167836	0.897126	
2.869391	2.905450	2.958462	2.517396	1.747448	3.381455	1.012432	
2.902579	2.941193	2.999700	2.578045	1.807296	3.455592	1.051193	
2.929128	2.969784	3.032689	2.626562	1.855173	3.514899	1.082200	
2.025558	1.957917	1.671157	4.514534	2.026464	0.661110	0.0	0.0
2.153034	2.086633	1.861678	4.833469	2.243855	0.781081	0.0	0.0
2.319469	2.252994	2.073078	5.133616	2.447588	0.886707	0.0	0.0
2.376715	2.310143	2.144287	5.236332	2.515709	0.921843	0.0	0.0
2.422511	2.355860	2.201253	5.318500	2.570204	0.949952	0.0	0.0
2.835750	2.681467	2.006445	0.848428	0.0	0.0	0.0	0.0
3.115153	2.948135	2.222491	1.002954	0.0	0.0	0.0	0.0
3.351439	3.178499	2.424093	1.135997	0.0	0.0	0.0	0.0
3.429988	3.255278	2.491185	1.179990	0.0	0.0	0.0	0.0
3.492825	3.316698	2.544856	1.215184	0.0	0.0	0.0	0.0

GROUP 2 BLOCK 4 FLUXES

2.725430							
2.736019							
2.670475							
2.651860							
2.636965							
5.287992	5.476582						
4.950623	5.125051						
4.689792	4.870154						
4.618505	4.801817						
4.561652	4.747144						
5.647551	5.174050	2.589888					
5.370183	4.874468	2.634319					
5.140904	4.645857	2.606096					
5.078640	4.583052	2.597702					
5.028825	4.532805	2.590985					
4.949224	5.079973	4.729597	4.612453				
4.696447	4.825885	4.529250	4.445816				
4.507342	4.653753	4.387279	4.347879				
4.455663	4.608115	4.348600	4.323157				
4.414317	4.571601	4.317654	4.303377				
2.361940	4.604454	4.895222	4.114524	1.804752			
2.451364	4.459367	4.811009	4.032864	1.926623			
2.469786	4.362902	4.755809	3.991251	1.997099			
2.475525	4.337556	4.743029	3.981766	2.019185			
2.480114	4.317276	4.732801	3.974175	2.036853			
4.252324	4.621407	4.661368	3.908577	2.972907	2.113400		
4.208248	4.592313	4.676936	3.942845	2.996900	2.333384		
4.198590	4.602800	4.719308	4.008853	3.075640	2.567405		
4.198608	4.609961	4.735871	4.032419	3.102554	2.642887		
4.198619	4.615687	4.749117	4.051269	3.124083	2.703271		
4.119164	4.159047	4.238133	3.317092	2.127164	4.465670	1.158186	
4.209752	4.254916	4.315159	3.546702	2.377170	4.789794	1.355357	
4.311339	4.367572	4.450691	3.788418	2.629675	5.086522	1.522149	
4.345012	4.404878	4.496050	3.865560	2.710149	5.180453	1.575257	
4.371948	4.434719	4.532334	3.927270	2.774527	5.255595	1.617742	
3.022360	2.922467	2.496406	6.749430	3.031606	0.988798	0.0	0.0
3.240053	3.141196	2.804841	7.289183	3.386594	1.178895	0.0	0.0
3.470259	3.371995	3.105598	7.699317	3.674549	1.331644	0.0	0.0
3.542805	3.444824	3.200665	7.825679	3.763841	1.379819	0.0	0.0
3.600840	3.503086	3.276716	7.926763	3.835272	1.418358	0.0	0.0
4.223038	3.994324	2.990391	1.265328	0.0	0.0	0.0	0.0
4.679451	4.429657	3.341100	1.508874	0.0	0.0	0.0	0.0
5.006598	4.749521	3.624530	1.700128	0.0	0.0	0.0	0.0
5.105629	4.846935	3.711806	1.759936	0.0	0.0	0.0	0.0
5.184851	4.924863	3.781623	1.807780	0.0	0.0	0.0	0.0

GROUP 2 BLOCK 5 FLUXES

3.892212							
3.937934							
3.843098							
3.813751							
3.790270							
7.587765	7.943831						
7.164920	7.519954						
6.787184	7.151887						
6.679687	7.047882						
6.593685	6.964672						
8.130277	7.604370	3.997069					
7.797175	7.267641	4.161209					
7.461118	6.938852	4.153797					
7.364739	6.842602	4.151691					
7.287631	6.765597	4.150003					
7.030763	7.286702	6.875951	6.562710				
6.721023	6.992834	6.670502	6.384296				
6.442060	6.738395	6.460780	6.231821				
6.361166	6.665193	6.397391	6.187242				
6.296447	6.606627	6.346676	6.151575				
3.264816	6.380444	6.798390	5.681102	2.458750			
3.403849	6.209621	6.713778	5.593399	2.633877			
3.419774	6.057814	6.615947	5.517325	2.720299			
3.422207	6.012722	6.586713	5.494315	2.745153			
3.424151	5.976644	6.563320	5.475902	2.765033			
5.736260	6.247463	6.310116	5.282065	3.997748	2.830038		
5.695204	6.227700	6.350628	5.344340	4.042139	3.133459		
5.662458	6.220062	6.385033	5.413766	4.132995	3.434999		
5.651913	6.218101	6.395284	5.435105	4.161071	3.529135		
5.643473	6.216528	6.403479	5.452172	4.183529	3.604441		
5.498574	5.556153	5.668227	4.438152	2.844125	5.964903	1.545841	
5.636909	5.701320	5.788027	4.758413	3.187463	6.416283	1.814327	
5.752923	5.831743	5.948396	5.063906	3.513144	6.789335	2.030451	
5.786840	5.870335	5.997457	5.156942	3.613651	6.901493	2.097327	
5.813969	5.901205	6.036702	5.231368	3.694054	6.991215	2.150827	
4.014565	3.883720	3.321358	8.992239	4.042810	1.318689	0.0	0.0
4.316991	4.187034	3.742643	9.738290	4.528863	1.576728	0.0	0.0
4.607736	4.479045	4.129382	10.249391	4.896371	1.774761	0.0	0.0
4.695058	4.567015	4.247625	10.397548	5.005750	1.835486	0.0	0.0
4.764912	4.637389	4.342216	10.516066	5.093249	1.884065	0.0	0.0
5.599502	5.298093	3.969720	1.681745	0.0	0.0	0.0	0.0
6.223464	5.893033	4.448080	2.010947	0.0	0.0	0.0	0.0
6.635804	6.296894	4.808755	2.257932	0.0	0.0	0.0	0.0
6.754169	6.413799	4.915172	2.332913	0.0	0.0	0.0	0.0
6.848855	6.507318	5.000301	2.392897	0.0	0.0	0.0	0.0

GROUP 2 BLOCK 6 FLUXES

5.187528							
5.256816							
5.131679							
5.092102							
5.060437							
10.199213	10.951459						
9.636794	10.367773						
9.129760	9.863006						
8.984311	9.719996						
8.867946	9.605582						
11.026878	11.042186	10.610146					
10.550854	10.514643	10.069660					
10.089332	10.046019	9.603498					
9.956339	9.911549	9.462125					
9.849938	9.803966	9.349020					
9.372180	9.965320	9.946616	8.930713				
8.954622	9.549827	9.588996	8.663660				
8.574559	9.190950	9.273915	8.435578				
8.462961	9.087041	9.181383	8.368093				
8.373678	9.003906	9.107350	8.314099				
4.214361	8.277150	8.871003	7.349141	3.126616			
4.394492	8.050975	8.739305	7.227446	3.348650			
4.406364	7.836917	8.588386	7.110061	3.448982			
4.405604	7.771337	8.541414	7.072680	3.476374			
4.404993	7.718868	8.503830	7.042771	3.498285			
7.209822	7.872392	7.965964	6.654799	5.008638	3.529762		
7.163168	7.850241	8.016953	6.733890	5.066722	3.910194		
7.104787	7.821193	8.039274	6.802890	5.166432	4.274683		
7.083642	7.809973	8.042883	6.821558	5.195149	4.386380		
7.066721	7.800991	8.045764	6.836488	5.218119	4.475734		
6.836434	6.913834	7.061811	5.531354	3.541938	7.420699	1.921675	
7.015151	7.100333	7.215840	5.933417	3.971947	7.987387	2.257007	
7.142485	7.245123	7.397035	6.297487	4.366060	8.429346	2.519279	
7.176366	7.284649	7.449259	6.405376	4.485471	8.558141	2.599116	
7.203465	7.316264	7.491032	6.491682	4.580997	8.661171	2.662983	
4.966683	4.807138	4.115916	11.158905	5.021533	1.638012	0.0	0.0
5.346392	5.187613	4.641873	12.092477	5.628834	1.959862	0.0	0.0
5.692909	5.536068	5.108909	12.694579	6.069804	2.200319	0.0	0.0
5.794041	5.638196	5.248997	12.862636	6.197908	2.272871	0.0	0.0
5.874942	5.719894	5.361064	12.997073	6.300388	2.330911	0.0	0.0
6.915599	6.545669	4.908591	2.082040	0.0	0.0	0.0	0.0
7.693822	7.287514	5.504589	2.491202	0.0	0.0	0.0	0.0
8.184255	7.768437	5.936541	2.790237	0.0	0.0	0.0	0.0
8.320549	7.903429	6.060793	2.879487	0.0	0.0	0.0	0.0
8.429577	8.011416	6.160191	2.950886	0.0	0.0	0.0	0.0

GROUP 2 BLOCK 7 FLUXES

6.398207							
6.514411							
6.366114							
6.318285							
6.280017							
12.615576	13.634611						
11.983855	13.006883						
11.366879	12.398588						
11.188335	12.223975						
11.045491	12.084276						
13.665875	13.855335	13.616804					
13.147402	13.328398	13.158057					
12.585273	12.774716	12.664323					
12.421485	12.613194	12.518570					
12.290447	12.483967	12.401959					
11.521690	12.326902	12.409283	10.994153				
11.058623	11.894003	12.077197	10.732561				
10.593457	11.459821	11.706345	10.454279				
10.455311	11.331634	11.594531	10.369372				
10.344787	11.229076	11.505073	10.301439				
5.090078	10.014622	10.750062	8.870004	3.738298			
5.319377	9.765650	10.617647	8.742316	4.008359			
5.329393	9.498384	10.424569	8.590460	4.121902			
5.326218	9.414884	10.362665	8.540642	4.151774			
5.323674	9.348078	10.313134	8.500783	4.175668			
8.558984	9.360341	9.481149	7.910561	5.931904	4.167346		
8.510794	9.341687	9.549320	8.009944	6.003906	4.617798		
8.428752	9.293081	9.560764	8.078324	6.110978	5.038692		
8.398024	9.273567	9.558485	8.094608	6.140180	5.166191		
8.373436	9.257949	9.556654	8.107629	6.163537	5.268187		
8.051748	8.147840	8.329543	6.526386	4.176969	8.744734	2.263302	
8.266886	8.371857	8.514968	7.002844	4.685543	9.415055	2.658964	
8.403603	8.528782	8.714075	7.419090	5.140987	9.917675	2.962545	
8.437393	8.569090	8.769072	7.540313	5.277413	10.061204	3.054020	
8.464419	8.601330	8.813062	7.637286	5.386549	10.176020	3.127198	
5.827262	5.642211	4.835385	13.123931	5.910236	1.928036	0.0	0.0
6.275654	6.091355	5.455194	14.225113	6.626510	2.307423	0.0	0.0
6.671557	6.489834	5.993921	14.907076	7.132778	2.585861	0.0	0.0
6.785016	6.604605	6.153608	15.092727	7.277614	2.669035	0.0	0.0
6.875779	6.696417	6.281354	15.241238	7.393479	2.735573	0.0	0.0
8.102814	7.671561	5.756752	2.444187	0.0	0.0	0.0	0.0
9.017951	8.543851	6.457404	2.924948	0.0	0.0	0.0	0.0
9.577232	9.092766	6.952487	3.270420	0.0	0.0	0.0	0.0
9.729442	9.243824	7.092631	3.372452	0.0	0.0	0.0	0.0
9.851203	9.364663	7.204741	3.454075	0.0	0.0	0.0	0.0

GROUP 2 BLOCK 8 FLUXES

7.392887							
7.557334							
7.393321							
7.339359							
7.296185							
14.584752	15.781399						
13.911798	15.121267						
13.210265	14.431531						
13.005627	14.231752						
12.841908	14.071919						
15.794316	16.044674	15.796543					
15.256715	15.502861	15.331605					
14.618997	14.875904	14.772715					
14.431358	14.691046	14.605738					
14.281237	14.543150	14.472147					
13.266660	14.205960	14.309885	12.626693				
12.778125	13.758230	13.978983	12.365614				
12.248160	13.264622	13.557559	12.047519				
12.089187	13.117087	13.428549	11.948709				
11.962000	12.999050	13.325331	11.869654				
5.810943	11.436788	12.277060	10.111590	4.242741			
6.085510	11.176834	12.151908	9.985046	4.554884			
6.095708	10.868739	11.927732	9.807370	4.680240			
6.090893	10.771076	11.854295	9.747838	4.712352			
6.087038	10.692939	11.795536	9.700206	4.738038			
9.679648	10.594352	10.735538	8.950971	6.698711	4.697648		
9.634052	10.583392	10.823315	9.071236	6.784466	5.207470		
9.533499	10.520038	10.827449	9.140362	6.898261	5.675601		
9.495051	10.493952	10.820642	9.154928	6.927987	5.816314		
9.464286	10.473075	10.815188	9.166575	6.951764	5.928881		
9.062054	9.173500	9.383055	7.353494	4.705130	9.846380	2.547584	
9.309021	9.430484	9.596686	7.893525	5.280047	10.604571	2.993851	
9.453992	9.598010	9.811265	8.353635	5.786785	11.157948	3.331885	
9.487816	9.639087	9.868695	8.486052	5.937426	11.313783	3.433062	
9.514869	9.671943	9.914632	8.591979	6.057934	11.438443	3.514000	
6.542023	6.335857	5.433185	14.757429	6.649407	2.169330	0.0	0.0
7.047790	6.842438	6.131496	15.999698	7.457230	2.596891	0.0	0.0
7.484783	7.282556	6.729923	16.748355	8.017977	2.906988	0.0	0.0
7.608503	7.407853	6.905931	16.948697	8.176764	2.999012	0.0	0.0
7.707473	7.508085	7.046732	17.108959	8.303788	3.072629	0.0	0.0
9.088287	8.606261	6.461119	2.745076	0.0	0.0	0.0	0.0
10.117053	9.586893	7.248835	3.285468	0.0	0.0	0.0	0.0
10.733408	10.192194	7.796323	3.669532	0.0	0.0	0.0	0.0
10.898823	10.356582	7.949663	3.782187	0.0	0.0	0.0	0.0
11.031147	10.488085	8.072328	3.872309	0.0	0.0	0.0	0.0

GROUP 2 BLOCK 9 FLUXES

8.111038							
8.311864							
8.137942							
8.079742							
8.033177							
16.001099	17.315269						
15.299887	16.630827						
14.539506	15.884022						
14.316280	15.666220						
14.137689	15.491967						
17.318045	17.595390	17.317123					
16.767007	17.039538	16.842263					
16.076849	16.360795	16.236663					
15.872235	16.159114	16.054206					
15.708533	15.997759	15.908230					
14.519259	15.545335	15.652009	13.787682				
14.012716	15.084752	15.317485	13.523967				
13.437702	14.549393	14.860045	13.177815				
13.263906	14.387979	14.718572	13.069006				
13.124859	14.258837	14.605384	12.981950				
6.332829	12.463652	13.376017	11.006845	4.608719			
6.640897	12.196434	13.256258	10.881325	4.951796			
6.652153	11.860251	13.011037	10.686163	5.086351			
6.646298	11.752546	12.929467	10.619782	5.120202			
6.641610	11.666374	12.864202	10.566670	5.147279			
10.497205	11.493526	11.648442	9.708521	7.258218	5.085209		
10.454687	11.489490	11.751814	9.845051	7.354721	5.638911		
10.341904	11.416821	11.752114	9.915946	7.474274	6.142221		
10.298037	11.386187	11.742266	9.929476	7.504534	6.292723		
10.262937	11.361672	11.734380	9.940294	7.528737	6.413120		
9.800531	9.923010	10.152680	7.957784	5.091207	10.652049	2.755540	
10.071388	10.204784	10.387732	8.544974	5.715071	11.475338	3.239043	
10.223363	10.381070	10.614691	9.038072	6.259944	12.066957	3.602612	
10.257379	10.422886	10.674087	9.178844	6.421104	12.231999	3.710954	
10.284583	10.456330	10.721597	9.291455	6.550027	12.364024	3.797625	
7.064512	6.842908	5.870187	15.951699	7.189978	2.345835	0.0	0.0
7.612361	7.391652	6.626129	17.298019	8.065244	2.808807	0.0	0.0
8.079986	7.862803	7.268796	18.096969	8.666599	3.142342	0.0	0.0
8.211311	7.995900	7.456848	18.308328	8.835735	3.240899	0.0	0.0
8.316364	8.102372	7.607285	18.477402	8.971038	3.319743	0.0	0.0
9.808539	9.289435	6.976005	2.965056	0.0	0.0	0.0	0.0
10.920320	10.349269	7.827451	3.549133	0.0	0.0	0.0	0.0
11.579119	10.996491	8.413819	3.961703	0.0	0.0	0.0	0.0
11.754312	11.170749	8.576909	4.082186	0.0	0.0	0.0	0.0
11.894459	11.310147	8.707375	4.178569	0.0	0.0	0.0	0.0

GROUP 2 BLOCK 10 FLUXES

8.525119							
8.747328							
8.569744							
8.509489							
8.461279							
16.816180	18.195626						
16.099112	17.497331						
15.308358	16.721424						
15.075055	16.493928						
14.888402	16.311920						
18.192098	18.481637	18.181303					
17.633370	17.917442	17.700180					
16.916734	17.212578	17.071192					
16.703037	17.001905	16.880497					
16.532067	16.833354	16.727928					
15.236656	16.310118	16.415046	14.447692				
14.719537	15.841583	16.077486	14.181424				
14.121510	15.285225	15.602229	13.821529				
13.939741	15.116412	15.454165	13.707460				
13.794316	14.981351	15.335703	13.616195				
6.631317	13.050133	14.002350	11.516753	4.817209			
6.958348	12.778247	13.884918	11.391103	5.177587			
6.971409	12.428102	13.629872	11.187676	5.318117			
6.965205	12.315067	13.544097	11.117735	5.353116			
6.960237	12.224630	13.475468	11.061773	5.381112			
10.963461	12.006243	12.168672	10.140048	7.576832	5.305814		
10.922134	12.005525	12.280259	10.285226	7.678949	5.884062		
10.803896	11.929233	12.280088	10.358513	7.802742	6.408093		
10.757245	11.896350	12.268860	10.371742	7.833509	6.564328		
10.719916	11.870034	12.259869	10.382317	7.858116	6.689312		
10.220301	10.349112	10.590328	8.301511	5.310852	11.110409	2.873837	
10.503920	10.644165	10.836757	8.914853	5.962110	11.969798	3.378254	
10.661125	10.826704	11.072056	9.427770	6.529376	12.584507	3.756724	
10.695507	10.869204	11.132844	9.573528	6.696682	12.755090	3.869237	
10.723006	10.903196	11.181467	9.690126	6.830522	12.891548	3.959245	
7.360723	7.130443	6.118167	16.630009	7.497261	2.446198	0.0	0.0
7.931632	7.702334	6.906165	18.033813	8.410152	2.929062	0.0	0.0
8.417438	8.191881	7.574668	18.863255	9.035505	3.276245	0.0	0.0
8.553251	8.329576	7.769725	19.081305	9.210740	3.378599	0.0	0.0
8.661896	8.439727	7.925765	19.255731	9.350922	3.460479	0.0	0.0
10.216374	9.676376	7.267808	3.089835	0.0	0.0	0.0	0.0
11.373866	10.779856	8.154484	3.698304	0.0	0.0	0.0	0.0
12.057774	11.451847	8.763674	4.127409	0.0	0.0	0.0	0.0
12.238751	11.631931	8.932477	4.252424	0.0	0.0	0.0	0.0
12.383523	11.775989	9.067513	4.352433	0.0	0.0	0.0	0.0

GROUP 2 BLOCK 11 FLUXES

8.623846							
8.852372							
8.678104							
8.618440							
8.570702							
17.009457	18.403195						
16.290621	17.703574						
15.499937	16.928612						
15.266049	16.700797						
15.078928	16.518533						
18.395884	18.686647	18.377556					
17.836993	18.122127	17.895778					
17.121834	17.418820	17.268563					
16.907966	17.208017	17.077846					
16.736859	17.039362	16.925260					
15.398622	16.481074	16.582390	14.588327				
14.879729	16.011134	16.243990	14.320796				
14.282314	15.456145	15.770610	13.962637				
14.100247	15.287267	15.622647	13.848716				
13.954583	15.152154	15.504265	13.757569				
6.693975	13.172645	14.131699	11.620058	4.857771			
7.024539	12.898848	14.013481	11.493046	5.220643			
7.040233	12.549753	13.760556	11.291109	5.363570			
7.034584	12.436672	13.675054	11.221326	5.399160			
7.030060	12.346199	13.606642	11.165491	5.427629			
11.051496	12.103771	12.267696	10.221390	7.635468	5.345471		
11.008375	12.101497	12.378603	10.366155	7.736893	5.926616		
10.891637	12.027343	12.381194	10.442127	7.862939	6.455325		
10.845167	11.994831	12.370518	10.455947	7.894233	6.612906		
10.807983	11.968812	12.361968	10.466995	7.919262	6.738966		
10.293672	10.423996	10.667870	8.362686	5.349865	11.191407	2.894641	
10.576888	10.718715	10.913619	8.978378	6.004433	12.053949	3.401814	
10.736996	10.904366	11.152413	9.496353	6.576636	12.674627	3.783407	
10.772028	10.947583	11.214051	9.643480	6.745354	12.846810	3.896839	
10.800047	10.982148	11.263353	9.761175	6.880324	12.984547	3.987582	
7.409917	7.178447	6.160110	16.746573	7.550719	2.463710	0.0	0.0
7.982327	7.751948	6.951533	18.155047	8.467782	2.949223	0.0	0.0
8.472386	8.245762	7.625456	18.992543	9.098591	3.299216	0.0	0.0
8.609340	8.384610	7.822055	19.212666	9.275329	3.402391	0.0	0.0
8.718896	8.495683	7.979329	19.388750	9.416712	3.484929	0.0	0.0
10.282660	9.739557	7.315974	3.110747	0.0	0.0	0.0	0.0
11.443954	10.846728	8.205874	3.722132	0.0	0.0	0.0	0.0
12.133573	11.524304	8.819983	4.154506	0.0	0.0	0.0	0.0
12.316041	11.705864	8.990133	4.280471	0.0	0.0	0.0	0.0
12.462007	11.851104	9.126247	4.381241	0.0	0.0	0.0	0.0

GROUP 2 BLOCK 12 FLUXES

8.407288							
8.627808							
8.464170							
8.408159							
8.363344							
16.581376	17.939003						
15.876217	17.252011						
15.116578	16.508597						
14.892311	16.290606						
14.712887	16.116202						
17.929733	18.212111	17.907263					
17.379605	17.656005	17.431525					
16.694420	16.982438	16.831642					
16.490059	16.781127	16.649837					
16.326559	16.620066	16.504381					
15.003541	16.056731	16.152606	14.206553				
14.492676	15.592927	15.816391	13.939658				
13.919887	15.062036	15.364863	13.598887				
13.745796	14.901055	15.224294	13.491019				
13.606513	14.772260	15.111829	13.404715				
6.517969	12.825776	13.758291	11.311296	4.727282			
6.836609	12.553153	13.636412	11.181820	5.077512			
6.855756	12.220244	13.397602	10.991124	5.219054			
6.851793	12.112837	13.317296	10.925562	5.254775			
6.848618	12.026903	13.253041	10.873104	5.283348			
10.752481	11.776860	11.936393	9.944689	7.427622	5.199213		
10.704256	11.767783	12.037279	10.079512	7.521620	5.760724		
10.595836	11.701337	12.045588	10.158134	7.647571	6.277316		
10.552796	11.672117	12.037682	10.173645	7.679529	6.431803		
10.518356	11.648733	12.031349	10.186046	7.705091	6.555388		
10.010393	10.137443	10.375097	8.133389	5.203116	10.884099	2.815078	
10.279205	10.417364	10.607301	8.726537	5.835929	11.715251	3.306127	
10.439439	10.602500	10.844182	9.233977	6.394805	12.323686	3.678534	
10.475577	10.646632	10.906274	9.378875	6.560136	12.493543	3.789566	
10.504479	10.681930	10.955940	9.494787	6.692397	12.629419	3.878390	
7.203973	6.979129	5.989483	16.284128	7.342720	2.395883	0.0	0.0
7.755213	7.531601	6.754428	17.641821	8.229023	2.866119	0.0	0.0
8.234797	8.014754	7.412370	18.463405	8.845762	3.207596	0.0	0.0
8.369534	8.151296	7.604956	18.681050	9.019355	3.308557	0.0	0.0
8.477318	8.260524	7.759020	18.855153	9.158223	3.389324	0.0	0.0
9.995754	9.468027	7.112407	3.024433	0.0	0.0	0.0	0.0
11.116884	10.536976	7.971989	3.616336	0.0	0.0	0.0	0.0
11.791660	11.199825	8.572137	4.038091	0.0	0.0	0.0	0.0
11.971317	11.378491	8.739213	4.161344	0.0	0.0	0.0	0.0
12.115034	11.521415	8.872867	4.259944	0.0	0.0	0.0	0.0

GROUP 2 BLOCK 13 FLUXES

7.885798							
8.085146							
7.939334							
7.890275							
7.851022							
15.552305	16.825064						
14.876983	16.165475						
14.178511	15.483372						
13.974312	15.285636						
13.810942	15.127437						
16.815173	17.079282	16.791451					
16.283676	16.541817	16.329255					
15.656178	15.925372	15.781492					
15.471302	15.743473	15.617814					
15.323390	15.597943	15.486861					
14.068199	15.054880	15.143165	13.316726				
13.575754	14.605410	14.812845	13.052902				
13.050895	14.120651	14.402477	12.744593				
12.893261	13.975768	14.276842	12.648885				
12.767146	13.859852	14.176324	12.572309				
6.109336	12.021380	12.894673	10.600338	4.429406			
6.401244	11.753391	12.766775	10.467630	4.752265			
6.424555	11.451240	12.553549	10.297465	4.888574			
6.423557	11.355388	12.483559	10.2 0330	4.924068			
6.422754	11.278699	12.427558	10.194614	4.952460			
10.073854	11.033877	11.183343	9.316932	6.958149	4.870197		
10.017399	11.012996	11.265200	9.432557	7.038131	5.389900		
9.923681	10.959389	11.281780	9.513472	7.161403	5.877607		
9.887447	10.936539	11.279031	9.531917	7.194265	6.024702		
9.858453	10.918252	11.276824	9.546666	7.220549	6.142373		
9.376042	9.495205	9.718057	7.618427	4.873655	10.194751	2.636743	
9.616649	9.746074	9.924041	8.164508	5.460029	10.960437	3.093061	
9.773919	9.926760	10.153302	8.645724	5.987353	11.538199	3.444009	
9.811759	9.972152	10.215608	8.784965	6.144646	11.701986	3.549409	
9.842024	10.008459	10.265445	8.896352	6.270476	11.833007	3.633726	
6.746369	6.535910	5.609337	15.251354	6.877308	2.244045	0.0	0.0
7.254005	7.044959	6.318268	16.503464	7.698377	2.681330	0.0	0.0
7.708273	7.502423	6.938843	17.284785	8.281455	3.003004	0.0	0.0
7.837578	7.633338	7.122022	17.495659	8.447413	3.098789	0.0	0.0
7.941016	7.738064	7.268560	17.664347	8.580174	3.175414	0.0	0.0
9.360204	8.866152	6.660492	2.832394	0.0	0.0	0.0	0.0
10.397615	9.855364	7.456547	3.382676	0.0	0.0	0.0	0.0
11.036800	10.482997	8.023759	3.779949	0.0	0.0	0.0	0.0
11.209513	10.654562	8.183479	3.896913	0.0	0.0	0.0	0.0
11.347676	10.791806	8.311249	3.990481	0.0	0.0	0.0	0.0

GROUP 2 BLOCK 14 FLUXES

7.079712							
7.246265							
7.124963							
7.086106							
7.055016							
13.962243	15.104537						
13.333035	14.487408						
12.723744	13.894279						
12.549648	13.726844						
12.410361	13.592887						
15.095013	15.331709	15.072271					
14.592598	14.823467	14.631749					
14.048526	14.289560	14.159068					
13.892749	14.136631	14.022397					
13.768117	14.014278	13.913050					
12.627620	13.512802	13.591175	11.950866				
12.164251	13.086309	13.271137	11.693132				
11.708935	12.668078	12.919742	11.431135				
11.575906	12.547187	12.816302	11.353462				
11.459475	12.450465	12.733540	11.291315				
5.482539	10.787858	11.571144	9.511811	3.974179			
5.734177	10.528381	11.435666	9.375651	4.256013			
5.762180	10.270381	11.258469	9.234451	4.383313			
5.765424	10.191726	11.203726	9.189778	4.418273			
5.768014	10.128795	11.159924	9.154033	4.446237			
9.037958	9.899413	10.033508	8.358817	6.242303	4.368966		
8.970722	9.862454	10.088298	8.446879	6.302294	4.826115		
8.897389	9.826161	10.115180	8.529417	6.420178	5.268898		
8.871199	9.812643	10.119897	8.552005	6.454181	5.404549		
8.850241	9.801822	10.123663	8.570069	6.481380	5.513065		
8.410576	8.517555	8.717600	6.834192	4.371961	9.145236	2.365281	
8.610253	8.726223	8.885709	7.310323	4.888778	9.813612	2.769400	
8.761288	8.898384	9.101589	7.750184	5.367133	10.342831	3.087174	
8.801421	8.945388	9.163902	7.880546	5.512000	10.497006	3.183884	
8.833521	8.982984	9.213747	7.984830	5.627890	10.620338	3.261250	
6.051123	5.862409	5.031436	13.680495	6.169118	2.012981	0.0	0.
6.494147	6.307060	5.656625	14.775702	6.892620	2.400707	0.0	0.
6.908786	6.724350	6.219376	15.493064	7.423211	2.691809	0.0	0.
7.029623	6.846502	6.388053	15.693107	7.577288	2.779617	0.0	0.
7.126288	6.944219	6.522990	15.853130	7.700544	2.849861	0.0	0.
8.395278	7.952222	5.974040	2.540548	0.0	0.0	0.0	0.
9.308037	8.822681	6.675354	3.028374	0.0	0.0	0.0	0.
9.891573	9.395311	7.191380	3.387920	0.0	0.0	0.0	0.
10.053431	9.555790	7.339687	3.495209	0.0	0.0	0.0	0.
10.182910	9.684167	7.458328	3.581038	0.0	0.0	0.0	0.

GROUP 2 BLOCK 15 FLUXES

6.018895							
6.142962							
6.051990							
6.026220							
6.005600							
11.869995	12.840936						
11.302761	12.281131						
10.807389	11.801371						
10.672326	11.673168						
10.564268	11.570598						
12.832509	13.033518	12.812423					
12.369906	12.565352	12.402165					
11.931927	12.136344	12.024723					
11.813790	12.020872	11.922929					
11.719271	11.928487	11.841485					
10.734216	11.486434	11.552609	10.157814				
10.310568	11.091817	11.247912	9.909827				
9.943812	10.758006	10.971048	9.706170				
9.842614	10.668096	10.896212	9.651698				
9.761648	10.596160	10.836335	9.608115				
4.659882	9.169051	9.834601	8.084096	3.377492			
4.859562	8.922406	9.691030	7.944988	3.606324			
4.892539	8.720208	9.558820	7.839957	3.721033			
4.901115	8.663713	9.523633	7.811262	3.755115			
4.907973	8.618511	9.495477	7.788300	3.782379			
7.680662	8.412822	8.526793	7.103534	5.304773	3.712736		
7.600975	8.356625	8.547974	7.157064	5.339789	4.088939		
7.552761	8.341254	8.586542	7.240227	5.449515	4.472083		
7.539405	8.339597	8.600655	7.267910	5.484756	4.592526		
7.528715	8.338266	8.611939	7.290051	5.512945	4.688878		
7.146874	7.237829	7.407909	5.807527	3.715219	7.771507	2.009990	
7.294693	7.392987	7.528182	6.193525	4.141943	8.314438	2.346328	
7.436135	7.552528	7.725041	6.578016	4.555363	8.778419	2.620203	
7.478945	7.601308	7.787014	6.696444	4.683739	8.919556	2.705397	
7.513188	7.640327	7.836588	6.791183	4.786436	9.032458	2.773550	
5.141693	4.981375	4.275360	11.624982	5.242322	1.710590	0.0	0.0
5.501529	5.343069	4.792128	12.517825	5.839498	2.033928	0.0	0.0
5.863290	5.706789	5.278299	13.149009	6.300222	2.284604	0.0	0.0
5.972789	5.817218	5.427751	13.334226	6.438424	2.361848	0.0	0.0
6.060384	5.905558	5.547309	13.482391	6.548981	2.423642	0.0	0.0
7.133432	6.757012	5.076227	2.158783	0.0	0.0	0.0	0.0
7.885108	7.473988	5.654991	2.565521	0.0	0.0	0.0	0.0
8.394379	7.973259	6.102969	2.875213	0.0	0.0	0.0	0.0
8.541644	8.118857	6.236046	2.969698	0.0	0.0	0.0	0.0
8.659449	8.235330	6.342503	3.045283	0.0	0.0	0.0	0.0

GROUP 2 BLOCK 16 FLUXES

4.741911							
4.816104							
4.760094							
4.749665							
4.741319							
9.351553	10.116386						
8.861257	9.628128						
8.500201	9.281795						
8.411400	9.200026						
8.340354	9.134604						
10.109586	10.267824	10.093366					
9.697511	9.850551	9.722215					
9.384215	9.544762	9.456460					
9.310586	9.473564	9.395840					
9.251677	9.416598	9.347336					
8.456205	9.048661	9.100568	8.001606				
8.082647	8.694883	8.816891	7.767675				
7.820050	8.460095	8.627163	7.632029				
7.756495	8.406751	8.586019	7.604826				
7.705645	8.364070	8.553097	7.583058				
3.670699	7.222642	7.746815	6.367867	2.660441			
3.809098	6.993600	7.595867	6.227165	2.826483			
3.847028	6.856610	7.515708	6.163953	2.925309			
3.861698	6.826196	7.503411	6.153941	2.956071			
3.873432	6.801860	7.493568	6.145928	2.984279			
6.049766	6.626491	6.716296	5.595312	4.178579	2.924650		
5.957084	6.549310	6.699222	5.609126	4.184913	3.204621		
5.937555	6.557413	6.750093	5.691544	4.283670	3.515178		
5.939127	6.569461	6.774914	5.724829	4.319965	3.616954		
5.940381	6.579094	6.794767	5.751452	4.348999	3.698373		
5.629113	5.700788	5.834866	4.574482	2.926554	6.122118	1.583474	
5.716512	5.793540	5.899522	4.853706	3.246054	6.516269	1.838924	
5.844983	5.936428	6.071943	5.170318	3.580513	6.899800	2.059451	
5.890492	5.986805	6.132928	5.273878	3.688672	7.024424	2.130540	
5.926894	6.027102	6.181712	5.356722	3.775197	7.124118	2.187410	
4.049804	3.923565	3.367577	9.157077	4.129634	1.347593	0.0	0.0
4.311112	4.186951	3.755279	9.809688	4.576381	1.594043	0.0	0.0
4.608218	4.485192	4.148399	10.334337	4.951711	1.795626	0.0	0.0
4.703642	4.581086	4.274308	10.500553	5.070234	1.859944	0.0	0.0
4.779978	4.657798	4.375033	10.633518	5.165049	1.911397	0.0	0.0
5.618799	5.322355	3.998563	1.700556	0.0	0.0	0.0	0.0
6.178918	5.856781	4.431445	2.010477	0.0	0.0	0.0	0.0
6.597220	6.266226	4.796321	2.259639	0.0	0.0	0.0	0.0
6.726240	6.393251	4.910533	2.338460	0.0	0.0	0.0	0.0
6.829451	6.494866	5.001899	2.401515	0.0	0.0	0.0	0.0

GROUP 2 BLOCK 17 FLUXES

3.294952							
3.314477							
3.296544							
3.302872							
3.307932							
6.498171	7.029491						
6.098258	6.625690						
5.886554	6.427465						
5.849095	6.397149						
5.819125	6.372892						
7.024652	7.134471	7.013050					
6.673226	6.778250	6.689524					
6.498148	6.608961	6.547274					
6.473791	6.586747	6.532137					
6.454301	6.568971	6.520023					
5.875751	6.287284	6.323153	5.559572				
5.561965	5.982957	6.066448	5.344455				
5.414922	5.857740	5.972812	5.283621				
5.393042	5.844788	5.968793	5.286388				
5.375534	5.834422	5.965574	5.288597				
2.550398	5.018431	5.382495	4.424483	1.848554			
2.620995	4.812101	5.226055	4.284368	1.944621			
2.663498	4.747019	5.202733	4.266774	2.024646			
2.684592	4.745316	5.215469	4.277166	2.055513			
2.701465	4.743950	5.225655	4.285476	2.080206			
4.203390	4.604044	4.666429	3.887844	2.903954	2.033185		
4.098440	4.505657	4.608453	3.858687	2.879297	2.205252		
4.109830	4.538585	4.671344	3.938566	2.964183	2.432160		
4.127588	4.565359	4.707450	3.977425	3.000981	2.512034		
4.141792	4.586776	4.736332	4.008509	3.030417	2.575931		
3.911092	3.960910	4.054355	3.179163	2.034430	4.257956	1.101855	
3.932171	3.985022	4.057910	3.338946	2.233522	4.484905	1.266039	
4.044327	4.107324	4.200653	3.576738	2.477054	4.773300	1.424770	
4.092130	4.158710	4.259600	3.662513	2.561535	4.877282	1.479179	
4.130370	4.199816	4.306755	3.731131	2.629117	4.960464	1.522705	
2.814392	2.726721	2.340709	6.367245	2.872305	0.937709	0.0	0.0
2.965566	2.880130	2.583362	6.749479	3.149536	1.097394	0.0	0.0
3.187872	3.102613	2.869384	7.147654	3.425167	1.242188	0.0	0.0
3.266563	3.181243	2.967745	7.289623	3.519945	1.291253	0.0	0.0
3.329514	3.244145	3.046432	7.403193	3.595765	1.330504	0.0	0.0
3.906357	3.700834	2.780816	1.183110	0.0	0.0	0.0	0.0
4.251440	4.029808	3.049393	1.383750	0.0	0.0	0.0	0.0
4.563378	4.334269	3.317397	1.562875	0.0	0.0	0.0	0.0
4.670118	4.438680	3.408881	1.623196	0.0	0.0	0.0	0.0
4.755507	4.522206	3.482066	1.671452	0.0	0.0	0.0	0.0

GROUP 2 BLOCK 18 FLUXES

1.753069							
1.762882							
1.846284							
1.899188							
1.941509							
3.452451	3.733197						
3.225063	3.499512						
3.263979	3.557355						
3.323613	3.627983						
3.371317	3.684482						
3.730089	3.787999	3.723178					
3.522848	3.577397	3.529750					
3.593961	3.654092	3.618886					
3.668681	3.731545	3.699408					
3.728454	3.793505	3.763822					
3.121393	3.338792	3.357068	2.952098				
2.940569	3.159494	3.201326	2.821596				
3.001316	3.241285	3.301756	2.922542				
3.063252	3.313922	3.380782	2.996131				
3.112800	3.372030	3.444001	3.054999				
1.356846	2.666090	2.857868	2.350154	0.983291			
1.393789	2.544355	2.758083	2.263924	1.032817			
1.491292	2.631245	2.876135	2.362902	1.131120			
1.543157	2.695453	2.954071	2.427121	1.178596			
1.584649	2.746819	3.016418	2.478494	1.216576			
2.233253	2.444860	2.477131	2.064377	1.543280	1.082732		
2.167094	2.378557	2.429712	2.034879	1.519405	1.161206		
2.277798	2.509626	2.578203	2.173732	1.635103	1.328120		
2.344074	2.586370	2.661474	2.248390	1.694414	1.399056		
2.397093	2.647762	2.728089	2.308114	1.741862	1.455804		
2.076410	2.102530	2.152132	1.689670	1.083113	2.268605	0.590364	
2.072982	2.099578	2.135212	1.756027	1.175328	2.325578	0.659597	
2.231383	2.264050	2.308752	1.957218	1.351751	2.512143	0.750095	
2.312506	2.347793	2.396144	2.047476	1.425816	2.592064	0.784729	
2.377402	2.414786	2.466056	2.119680	1.485067	2.655999	0.812435	
1.495869	1.449289	1.245594	3.388788	1.532265	0.502440	0.0	0.0
1.560780	1.515493	1.358190	3.494489	1.634744	0.571726	0.0	0.0
1.746797	1.699469	1.564296	3.757165	1.802225	0.654057	0.0	0.0
1.829017	1.780562	1.650319	3.870223	1.869195	0.685178	0.0	0.0
1.894791	1.845434	1.719136	3.960666	1.922770	0.710075	0.0	0.0
2.080448	1.970823	1.482549	0.633603	0.0	0.0	0.0	0.0
2.203465	2.088481	1.582153	0.720483	0.0	0.0	0.0	0.0
2.401030	2.280134	1.745789	0.822474	0.0	0.0	0.0	0.0
2.481501	2.358079	1.810942	0.860905	0.0	0.0	0.0	0.0
2.545877	2.420433	1.863063	0.891649	0.0	0.0	0.0	0.0

GROUP 2 BLOCK 19 FLUXES

3.621994							
3.977359							
4.041360							
4.067709							
4.088784							
4.210581	4.448545						
4.575986	4.838931						
4.697730	4.983622						
4.756288	5.051651						
4.803132	5.106071						
4.426973	4.489504	4.409653					
4.844286	4.914110	4.845202					
5.005800	5.084412	5.031638					
5.078614	5.160401	5.112116					
5.136862	5.221188	5.176495					
3.794157	3.975772	3.978182	3.511908				
4.159347	4.365503	4.396701	3.894506				
4.307427	4.537542	4.593103	4.086901				
4.371609	4.611101	4.674244	4.164396				
4.422951	4.669944	4.739152	4.226389				
2.803161	3.251260	3.390260	2.849988	2.004195			
3.144140	3.609522	3.790672	3.194114	2.297378			
3.263493	3.785939	4.003273	3.381786	2.439185			
3.304265	3.856102	4.086401	3.453850	2.485879			
3.336879	3.912229	4.152900	3.511500	2.523234			
2.734099	2.910647	2.914022	2.427630	1.719770	1.100976		
3.084716	3.284568	3.309741	2.771531	1.981289	1.303061		
3.286314	3.509496	3.554855	2.995543	2.167299	1.464449		
3.361933	3.594301	3.646279	3.078074	2.234602	1.521361		
3.422427	3.662142	3.719416	3.144097	2.288443	1.566890		
2.443768	2.456901	2.311972	1.760193	1.101726	0.514145	0.128161	
2.822860	2.838158	2.674956	2.070547	1.317822	0.651562	0.167229	
3.074233	3.095852	2.938253	2.303464	1.488862	0.769865	0.201248	
3.165219	3.189121	3.033758	2.386322	1.548724	0.815073	0.214171	
3.238006	3.263734	3.110160	2.452606	1.596613	0.851239	0.224509	
1.575232	1.524510	1.258852	0.761922	0.342616	0.109344	0.0	0.0
1.862487	1.806882	1.513185	0.971634	0.443067	0.145233	0.0	0.0
2.080661	2.022818	1.712866	1.144387	0.527981	0.175907	0.0	0.0
2.157725	2.098975	1.782446	1.210321	0.560211	0.187497	0.0	0.0
2.219374	2.159900	1.838109	1.263067	0.585994	0.196769	0.0	0.0
0.463285	0.438905	0.332752	0.137672	0.0	0.0	0.0	0.0
0.598613	0.567640	0.432050	0.182745	0.0	0.0	0.0	0.0
0.708914	0.673566	0.516357	0.220832	0.0	0.0	0.0	0.0
0.750904	0.713920	0.548296	0.235190	0.0	0.0	0.0	0.0
0.784495	0.746203	0.573847	0.246677	0.0	0.0	0.0	0.0

BLOCK 1 POWER

0.066025							
0.080852							
0.087805							
0.089869							
0.091519							
0.256414	0.270147						
0.263725	0.279365						
0.260444	0.277461						
0.260174	0.277679						
0.259957	0.277853						
0.281675	0.249987	0.062082					
0.299018	0.259032	0.077290					
0.301181	0.257663	0.085338					
0.302571	0.257952	0.087785					
0.303683	0.258183	0.089742					
0.244454	0.255633	0.233051	0.235570				
0.255810	0.269613	0.246731	0.252955				
0.256579	0.272701	0.250484	0.260117				
0.257505	0.274431	0.252342	0.263087				
0.258245	0.275816	0.253829	0.265464				
0.059989	0.234447	0.255965	0.211091	0.046064			
0.076729	0.252122	0.283686	0.230057	0.060663			
0.086615	0.259031	0.297090	0.239228	0.070445			
0.089698	0.261893	0.302029	0.242740	0.073578			
0.092164	0.264183	0.305979	0.245550	0.076085			
0.222972	0.247543	0.248586	0.207090	0.141256	0.097284		
0.246293	0.277392	0.282293	0.235064	0.159143	0.114083		
0.258802	0.294405	0.302386	0.252642	0.171733	0.127283		
0.263450	0.300571	0.309517	0.258871	0.176214	0.131822		
0.267168	0.305504	0.315221	0.263855	0.179798	0.135453		
0.223605	0.224202	0.209832	0.159176	0.099711	0.046798	0.011725	
0.259060	0.259876	0.243768	0.187952	0.119595	0.059436	0.015342	
0.281739	0.283225	0.267722	0.209048	0.134966	0.070138	0.018449	
0.289648	0.291368	0.276106	0.216310	0.140189	0.074153	0.019609	
0.295975	0.297882	0.282814	0.222120	0.144368	0.077365	0.020538	
0.148330	0.143193	0.117527	0.070563	0.031534	0.010055	0.0	0.0
0.176289	0.170639	0.142103	0.090560	0.041004	0.013420	0.0	0.0
0.196989	0.191111	0.160975	0.106779	0.048900	0.016263	0.0	0.0
0.204104	0.198138	0.167384	0.112854	0.051843	0.017319	0.0	0.0
0.209796	0.203759	0.172512	0.117714	0.054198	0.018164	0.0	0.0
0.044072	0.041670	0.031439	0.012919	0.0	0.0	0.0	0.0
0.057330	0.054266	0.041122	0.017287	0.0	0.0	0.0	0.0
0.067957	0.064460	0.049210	0.020925	0.0	0.0	0.0	0.0
0.071938	0.068281	0.052226	0.022275	0.0	0.0	0.0	0.0
0.075122	0.071338	0.054638	0.023355	0.0	0.0	0.0	0.0

BLOCK 2 POWER

0.115258							
0.110677							
0.110762							
0.112097							
0.113165							
0.225681	0.232996						
0.205383	0.212195						
0.202496	0.210151						
0.204153	0.212210						
0.205478	0.213857						
0.241730	0.219828	0.108305					
0.224314	0.201417	0.105568					
0.224346	0.199980	0.107315					
0.227154	0.202039	0.109117					
0.229399	0.203685	0.110559					
0.214563	0.220012	0.204729	0.202448				
0.198393	0.203967	0.191230	0.190797				
0.198605	0.205543	0.193519	0.195343				
0.201148	0.208654	0.196655	0.199259				
0.203182	0.211142	0.199164	0.202391				
0.104252	0.205374	0.218765	0.184602	0.081079			
0.104099	0.194565	0.211066	0.177108	0.083333			
0.108066	0.199160	0.219052	0.183492	0.089036			
0.110593	0.203094	0.224314	0.187799	0.091926			
0.112615	0.206241	0.228523	0.191244	0.094239			
0.195092	0.211845	0.213542	0.179305	0.136906	0.098140		
0.189350	0.206977	0.210803	0.177690	0.134932	0.105858		
0.197971	0.217901	0.223597	0.189625	0.144623	0.121021		
0.203182	0.224135	0.230491	0.195838	0.149535	0.127336		
0.207351	0.229122	0.236007	0.200808	0.153465	0.132388		
0.191793	0.193483	0.196935	0.154227	0.099094	0.208462	0.054446	
0.192989	0.194860	0.197177	0.161847	0.108473	0.215603	0.061381	
0.207808	0.210276	0.213483	0.180727	0.124947	0.233307	0.069925	
0.215157	0.217865	0.221407	0.188956	0.131710	0.240614	0.073120	
0.221036	0.223936	0.227746	0.195539	0.137121	0.246459	0.075676	
0.141885	0.137120	0.117107	0.316156	0.142129	0.046556	0.0	0.0
0.149471	0.144806	0.129019	0.329659	0.153258	0.053515	0.0	0.0
0.167540	0.162656	0.148895	0.355353	0.169383	0.061361	0.0	0.0
0.175339	0.170339	0.157022	0.365966	0.175633	0.064260	0.0	0.0
0.181579	0.176485	0.163523	0.374456	0.180632	0.066580	0.0	0.0
0.199215	0.188351	0.141031	0.059861	0.0	0.0	0.0	0.0
0.213269	0.201793	0.152232	0.068893	0.0	0.0	0.0	0.0
0.232872	0.220791	0.168360	0.078857	0.0	0.0	0.0	0.0
0.240616	0.228285	0.174631	0.082530	0.0	0.0	0.0	0.0
0.246810	0.234280	0.179631	0.085468	0.0	0.0	0.0	0.0

BLOCK 3 POWER

0.233120							
0.230690							
0.225633							
0.224594							
0.223762							
0.451717	0.466340						
0.416822	0.429970						
0.395736	0.409470						
0.390680	0.404715						
0.386636	0.400910						
0.482648	0.439884	0.218921					
0.452524	0.408412	0.219624					
0.434365	0.390261	0.217944					
0.430226	0.385995	0.217857					
0.426914	0.382581	0.217787					
0.426697	0.437150	0.406564	0.400060				
0.399615	0.409799	0.384354	0.380929				
0.384833	0.396606	0.373844	0.374239				
0.381512	0.393881	0.371725	0.373343				
0.378855	0.391701	0.370029	0.372626				
0.207372	0.404116	0.429672	0.362347	0.160207			
0.212889	0.387169	0.417830	0.351458	0.169336			
0.215504	0.380665	0.415191	0.349659	0.176466			
0.216721	0.379736	0.415519	0.350049	0.179045			
0.217694	0.378992	0.415780	0.350361	0.181108			
0.379994	0.412450	0.415740	0.348993	0.266335	0.189961		
0.372610	0.406138	0.413369	0.348862	0.266009	0.207833		
0.373861	0.409405	0.419552	0.356745	0.274501	0.229898		
0.375223	0.411541	0.422574	0.360151	0.277889	0.237479		
0.376313	0.413249	0.424991	0.362876	0.280599	0.243544		
0.371125	0.374514	0.381343	0.298396	0.191458	0.402367	0.104461	
0.375021	0.379867	0.384952	0.316322	0.212080	0.427658	0.121112	
0.387368	0.392236	0.399392	0.339848	0.235905	0.456496	0.136678	
0.391848	0.397061	0.404960	0.348036	0.243985	0.466505	0.141911	
0.395432	0.400921	0.409413	0.354586	0.250448	0.474511	0.146097	
0.273450	0.264319	0.225606	0.609462	0.273573	0.089250	0.0	0.0
0.290660	0.281695	0.251326	0.652518	0.302920	0.105446	0.0	0.0
0.313128	0.304154	0.279866	0.693038	0.330424	0.119705	0.0	0.0
0.320857	0.311869	0.289479	0.706905	0.339621	0.124449	0.0	0.0
0.327039	0.318041	0.297169	0.717998	0.346978	0.128243	0.0	0.0
0.382826	0.361998	0.270870	0.114538	0.0	0.0	0.0	0.0
0.420546	0.397998	0.300036	0.135399	0.0	0.0	0.0	0.0
0.452444	0.429097	0.327253	0.153360	0.0	0.0	0.0	0.0
0.463048	0.439462	0.336310	0.159299	0.0	0.0	0.0	0.0
0.471531	0.447754	0.343556	0.164050	0.0	0.0	0.0	0.0

BLOCK 4 POWER

0.367933							
0.369362							
0.360514							
0.358001							
0.355990							
0.713879	0.739338						
0.668334	0.691882						
0.633122	0.657471						
0.623512	0.648245						
0.615823	0.640864						
0.762419	0.698497	0.349635					
0.724975	0.658053	0.355633					
0.694022	0.627191	0.351823					
0.685616	0.618712	0.350690					
0.678891	0.611929	0.349783					
0.668145	0.685796	0.638496	0.622681				
0.634020	0.651494	0.611449	0.600185				
0.608491	0.628257	0.592283	0.586964				
0.601514	0.622096	0.587061	0.583626				
0.595933	0.617166	0.582883	0.580956				
0.318862	0.621601	0.660855	0.555461	0.243642			
0.330934	0.602015	0.649486	0.544437	0.260094			
0.333421	0.588992	0.642034	0.538819	0.269608			
0.334196	0.585570	0.640309	0.537538	0.272590			
0.334815	0.582832	0.638928	0.536514	0.274975			
0.574064	0.623890	0.629285	0.527658	0.401342	0.285309		
0.568113	0.619962	0.631386	0.532284	0.404582	0.315007		
0.566810	0.621378	0.637107	0.541195	0.415211	0.346600		
0.566812	0.622345	0.639342	0.544376	0.418845	0.356790		
0.566813	0.623118	0.641131	0.546921	0.421751	0.364942		
0.556087	0.561471	0.572148	0.447807	0.287167	0.602865	0.156355	
0.568316	0.574414	0.582546	0.478805	0.320918	0.646622	0.182973	
0.582031	0.589622	0.600843	0.511436	0.355006	0.686680	0.205490	
0.586577	0.594658	0.606967	0.521851	0.365870	0.699361	0.212660	
0.590213	0.598687	0.611865	0.530181	0.374561	0.709505	0.218395	
0.408019	0.394533	0.337015	0.911173	0.409267	0.133488	0.0	0.0
0.437407	0.424061	0.378653	0.984040	0.457190	0.159151	0.0	0.0
0.468485	0.455219	0.419256	1.039408	0.496064	0.179772	0.0	0.0
0.478279	0.465051	0.432090	1.056467	0.508119	0.186276	0.0	0.0
0.486113	0.472917	0.442357	1.070113	0.517762	0.191478	0.0	0.0
0.570110	0.539234	0.403703	0.170819	0.0	0.0	0.0	0.0
0.631726	0.598004	0.451049	0.203698	0.0	0.0	0.0	0.0
0.675891	0.641185	0.489312	0.229517	0.0	0.0	0.0	0.0
0.689260	0.654336	0.501094	0.237591	0.0	0.0	0.0	0.0
0.699955	0.664856	0.510519	0.244050	0.0	0.0	0.0	0.0

BLOCK 5 POWER

0.525449							
0.531621							
0.518818							
0.514856							
0.511686							
1.024348	1.072417						
0.967264	1.015194						
0.916270	0.965505						
0.901758	0.951464						
0.890147	0.940231						
1.097587	1.026590	0.539604					
1.052619	0.981132	0.561763					
1.007251	0.936745	0.560763					
0.994240	0.923751	0.560478					
0.983830	0.913356	0.560250					
0.949153	0.983705	0.928253	0.885966				
0.907338	0.944032	0.900518	0.861830				
0.869678	0.909683	0.872205	0.841296				
0.858757	0.899801	0.863648	0.835278				
0.850020	0.891895	0.856801	0.830463				
0.440750	0.861360	0.917783	0.766949	0.331931			
0.459520	0.838299	0.906360	0.755109	0.355573			
0.461669	0.817805	0.893153	0.744839	0.367240			
0.461998	0.811717	0.889206	0.741732	0.370596			
0.462260	0.806847	0.886048	0.739247	0.373279			
0.774395	0.843407	0.851866	0.713079	0.539696	0.382055		
0.768852	0.840740	0.857335	0.721486	0.545689	0.423017		
0.764432	0.839708	0.861979	0.730858	0.557954	0.463725		
0.763008	0.839444	0.863363	0.733739	0.561745	0.476433		
0.761869	0.839231	0.864470	0.736043	0.564776	0.486600		
0.742307	0.750081	0.765211	0.599151	0.383957	0.805262	0.208689	
0.760983	0.769678	0.781384	0.642386	0.430307	0.866198	0.244934	
0.776645	0.787285	0.803033	0.683627	0.474274	0.916560	0.274111	
0.781223	0.792495	0.809657	0.696187	0.487843	0.931702	0.283139	
0.784886	0.796663	0.814955	0.706235	0.498697	0.943814	0.290362	
0.541966	0.524302	0.448383	1.213952	0.545779	0.178023	0.0	0.0
0.582794	0.565249	0.505257	1.314669	0.611397	0.212858	0.0	0.0
0.622044	0.604671	0.557467	1.383668	0.661010	0.239593	0.0	0.0
0.633833	0.616547	0.573429	1.403669	0.675776	0.247791	0.0	0.0
0.643263	0.626047	0.586199	1.419669	0.687589	0.254349	0.0	0.0
0.755933	0.715243	0.535912	0.227036	0.0	0.0	0.0	0.0
0.840168	0.795559	0.600491	0.271478	0.0	0.0	0.0	0.0
0.895834	0.850081	0.649182	0.304821	0.0	0.0	0.0	0.0
0.911813	0.865863	0.663548	0.314943	0.0	0.0	0.0	0.0
0.924595	0.878488	0.675041	0.323041	0.0	0.0	0.0	0.0

BLOCK 6 POWER

0.700316							
0.709670							
0.692777							
0.687434							
0.683159							
1.376894	1.478447						
1.300967	1.399549						
1.232518	1.331506						
1.212882	1.312199						
1.197173	1.296753						
1.488628	1.490695	1.432370					
1.424365	1.419477	1.359404					
1.362060	1.356212	1.296472					
1.344106	1.338059	1.277387					
1.329742	1.323535	1.262118					
1.265244	1.345318	1.342793	1.205646				
1.208901	1.289226	1.294514	1.169594				
1.157565	1.240778	1.251978	1.138803				
1.142500	1.226750	1.239487	1.129693				
1.130446	1.215527	1.229492	1.122403				
0.566939	1.117415	1.197585	0.992134	0.422093			
0.593256	1.086882	1.179806	0.975705	0.452068			
0.594859	1.057984	1.159432	0.959858	0.465613			
0.594757	1.049130	1.153091	0.954812	0.469310			
0.594674	1.042047	1.148017	0.950774	0.472268			
0.973326	1.062773	1.075405	0.898398	0.676166	0.476518		
0.967028	1.059782	1.082289	0.909075	0.684007	0.527876		
0.959146	1.055861	1.085302	0.918390	0.697468	0.577082		
0.956292	1.054346	1.085789	0.920910	0.701345	0.592161		
0.954007	1.053134	1.086178	0.922926	0.704446	0.604224		
0.922918	0.933368	0.953344	0.746733	0.478162	1.001794	0.259426	
0.947045	0.958545	0.974138	0.801011	0.536213	1.076297	0.304696	
0.964235	0.978092	0.998600	0.850161	0.589418	1.127962	0.340103	
0.968809	0.983427	1.005650	0.864726	0.605539	1.155349	0.350881	
0.972468	0.987696	1.011289	0.876377	0.618435	1.169258	0.359503	
0.670502	0.648964	0.555649	1.506452	0.677907	0.221132	0.0	0.0
0.721763	0.700328	0.626653	1.632484	0.759893	0.264581	0.0	0.0
0.768543	0.747369	0.689703	1.713768	0.819423	0.297043	0.0	0.0
0.782195	0.761156	0.708615	1.736456	0.836718	0.306838	0.0	0.0
0.793117	0.772186	0.723744	1.754605	0.850552	0.314673	0.0	0.0
0.933606	0.883665	0.662660	0.231075	0.0	0.0	0.0	0.0
1.038666	0.983814	0.743119	0.336312	0.0	0.0	0.0	0.0
1.104874	1.048739	0.801433	0.376682	0.0	0.0	0.0	0.0
1.123274	1.066963	0.818207	0.388731	0.0	0.0	0.0	0.0
1.137993	1.081541	0.831626	0.398370	0.0	0.0	0.0	0.0

BLOCK 7 POWER

0.863758							
0.879445							
0.859425							
0.852968							
0.847802							
1.703103	1.840672						
1.617820	1.755929						
1.534529	1.673809						
1.510425	1.650237						
1.491141	1.631377						
1.844893	1.870470	1.838268					
1.774899	1.799334	1.776338					
1.699012	1.724587	1.709684					
1.676900	1.702781	1.690007					
1.659210	1.685335	1.674264					
1.555428	1.664132	1.675253	1.484211				
1.492914	1.605690	1.630422	1.448896				
1.430117	1.547076	1.580356	1.411328				
1.411467	1.529770	1.565262	1.399865				
1.396546	1.515925	1.553185	1.390694				
0.687161	1.351974	1.451258	1.197451	0.504670			
0.718116	1.318363	1.433382	1.180213	0.541128			
0.719468	1.282282	1.407317	1.159712	0.556457			
0.719039	1.271009	1.398960	1.152987	0.560489			
0.718696	1.261990	1.392273	1.147606	0.563715			
1.155463	1.263646	1.279955	1.067926	0.800807	0.562592		
1.148957	1.261128	1.289158	1.081342	0.810527	0.623403		
1.137881	1.254566	1.290703	1.090574	0.824982	0.680223		
1.133733	1.251931	1.290395	1.092772	0.828924	0.697436		
1.130414	1.249823	1.290148	1.094530	0.832077	0.711205		
1.086986	1.099958	1.124488	0.881062	0.563891	1.180539	0.305546	
1.116029	1.130201	1.149521	0.945384	0.632548	1.271032	0.358960	
1.134486	1.151386	1.176400	1.001577	0.694033	1.338886	0.399944	
1.139048	1.156827	1.183825	1.017942	0.712451	1.358262	0.412293	
1.142697	1.161180	1.189763	1.031034	0.727184	1.373763	0.422172	
0.786680	0.761698	0.652777	1.771730	0.797882	0.260285	0.0	0.0
0.847213	0.822333	0.736451	1.920390	0.894579	0.311502	0.0	0.0
0.900660	0.876128	0.809179	2.012455	0.962925	0.349091	0.0	0.0
0.915977	0.891622	0.830737	2.037518	0.982478	0.360320	0.0	0.0
0.928230	0.904016	0.847983	2.057567	0.998120	0.369302	0.0	0.0
1.093880	1.035661	0.777161	0.329965	0.0	0.0	0.0	0.0
1.217423	1.153420	0.871749	0.394868	0.0	0.0	0.0	0.0
1.292926	1.227523	0.938586	0.441507	0.0	0.0	0.0	0.0
1.313475	1.247916	0.957505	0.455281	0.0	0.0	0.0	0.0
1.329912	1.264229	0.972640	0.466300	0.0	0.0	0.0	0.0

BLOCK 8 POWER

0.998040							
1.020240							
0.998098							
0.990813							
0.984985							
1.968941	2.130489						
1.878093	2.041371						
1.783386	1.948256						
1.755760	1.921286						
1.733657	1.899709						
2.132232	2.166031	2.132533					
2.059656	2.092886	2.069767					
1.973564	2.008247	1.994316					
1.948233	1.983291	1.971775					
1.927967	1.963325	1.953740					
1.790999	1.917804	1.931834	1.704603				
1.725047	1.857361	1.887163	1.669358				
1.653502	1.790724	1.830270	1.626415				
1.632040	1.770807	1.812854	1.613076				
1.614870	1.754872	1.798920	1.602403				
0.784477	1.543966	1.657403	1.365064	0.572770			
0.821544	1.508872	1.640507	1.347981	0.614909			
0.822920	1.467280	1.610244	1.323995	0.631832			
0.822271	1.454095	1.600330	1.315958	0.636167			
0.821750	1.443547	1.592397	1.309528	0.639635			
1.306752	1.430237	1.449298	1.208381	0.904326	0.634182		
1.300597	1.428758	1.461147	1.224617	0.915903	0.703008		
1.287022	1.420205	1.461705	1.233949	0.931265	0.766206		
1.281832	1.416683	1.460787	1.235915	0.935278	0.785202		
1.277679	1.413865	1.460050	1.237488	0.938488	0.800399		
1.223377	1.238422	1.266712	0.992722	0.635192	1.329261	0.343924	
1.256718	1.273115	1.295553	1.065626	0.712806	1.431617	0.404170	
1.276289	1.295731	1.324521	1.127741	0.781216	1.506323	0.449805	
1.280855	1.301277	1.332274	1.145617	0.801552	1.527361	0.463463	
1.284507	1.305712	1.338475	1.159917	0.817821	1.544190	0.474390	
0.883173	0.855341	0.733480	1.992253	0.897670	0.292859	0.0	0.0
0.951452	0.923729	0.827752	2.159959	1.006726	0.350580	0.0	0.0
1.010446	0.983145	0.908540	2.261028	1.082427	0.392443	0.0	0.0
1.027148	1.000060	0.932301	2.288074	1.103863	0.404867	0.0	0.0
1.040509	1.013591	0.951309	2.309709	1.121011	0.414805	0.0	0.0
1.226919	1.161845	0.872251	0.370585	0.0	0.0	0.0	0.0
1.365802	1.294230	0.978593	0.443538	0.0	0.0	0.0	0.0
1.449010	1.375946	1.052504	0.495387	0.0	0.0	0.0	0.0
1.471341	1.398138	1.073204	0.510595	0.0	0.0	0.0	0.0
1.489205	1.415891	1.089764	0.522762	0.0	0.0	0.0	0.0

BLOCK 9 POWER

1.094990							
1.122102							
1.098622							
1.090765							
1.084479							
2.160148	2.337561						
2.065485	2.245161						
1.962833	2.144343						
1.932698	2.114940						
1.908588	2.091415						
2.337936	2.375377	2.337811					
2.263546	2.300337	2.273705					
2.170374	2.208707	2.191949					
2.142752	2.181480	2.167318					
2.120652	2.159697	2.147611					
1.960100	2.098620	2.113021	1.861337				
1.891717	2.036441	2.067860	1.825735				
1.814090	1.964168	2.006106	1.779005				
1.790627	1.942377	1.987007	1.764316				
1.771856	1.924943	1.971727	1.752563				
0.854932	1.682593	1.805762	1.485924	0.622177			
0.896521	1.646518	1.789595	1.468979	0.668492			
0.898041	1.601134	1.756490	1.442632	0.686657			
0.897250	1.586594	1.745478	1.433671	0.691227			
0.896617	1.574960	1.736667	1.426500	0.694883			
1.417123	1.551626	1.572540	1.310650	0.979859	0.686503		
1.411383	1.551081	1.586495	1.329082	0.992887	0.761253		
1.396157	1.541271	1.586535	1.338653	1.009027	0.829200		
1.390235	1.537135	1.585206	1.340479	1.013112	0.849518		
1.385496	1.533826	1.584141	1.341940	1.016379	0.865771		
1.323072	1.339606	1.370612	1.074301	0.687313	1.438026	0.371998	
1.359637	1.377646	1.402344	1.153571	0.771534	1.549171	0.437271	
1.380154	1.401444	1.432983	1.220140	0.845092	1.629039	0.486353	
1.384746	1.407089	1.441002	1.239144	0.866849	1.651320	0.500979	
1.388419	1.411604	1.447415	1.254346	0.884254	1.669143	0.512679	
0.953709	0.923793	0.792475	2.153479	0.970647	0.316688	0.0	0.0
1.027669	0.997873	0.894527	2.335232	1.088808	0.379189	0.0	0.0
1.090798	1.061478	0.981287	2.443091	1.169991	0.424216	0.0	0.0
1.108527	1.079446	1.006674	2.471624	1.192824	0.437521	0.0	0.0
1.122709	1.093820	1.026983	2.494449	1.211090	0.448165	0.0	0.0
1.324153	1.254074	0.941761	0.400283	0.0	0.0	0.0	0.0
1.474243	1.397151	1.056706	0.479133	0.0	0.0	0.0	0.0
1.563181	1.484526	1.135865	0.534830	0.0	0.0	0.0	0.0
1.586832	1.508051	1.157883	0.551095	0.0	0.0	0.0	0.0
1.605752	1.526870	1.175496	0.564107	0.0	0.0	0.0	0.0

BLOCK 10 POWER

1.150891							
1.180889							
1.156915							
1.148781							
1.142273							
2.270184	2.456409						
2.173380	2.362140						
2.066628	2.257392						
2.035132	2.226680						
2.009934	2.202109						
2.455933	2.495021	2.454476					
2.380505	2.418855	2.389524					
2.283759	2.323698	2.304611					
2.254910	2.295257	2.278867					
2.231829	2.272503	2.258270					
2.056948	2.201866	2.216031	1.950438				
1.987137	2.138614	2.170460	1.914492				
1.906404	2.063505	2.106301	1.865906				
1.881865	2.040715	2.086312	1.850507				
1.862233	2.022482	2.070320	1.838186				
0.895228	1.761768	1.890317	1.554762	0.650323			
0.939377	1.725063	1.874464	1.537799	0.698974			
0.941140	1.677794	1.840033	1.510336	0.717946			
0.940303	1.662534	1.828453	1.500894	0.722671			
0.939632	1.650325	1.819188	1.493339	0.726450			
1.480067	1.620843	1.642771	1.368906	1.022872	0.716285		
1.474488	1.620746	1.657835	1.388505	1.036658	0.794348		
1.458526	1.610446	1.657812	1.398399	1.053370	0.865092		
1.452228	1.606007	1.656296	1.400185	1.057524	0.886184		
1.447189	1.602455	1.655082	1.401613	1.060846	0.903057		
1.379740	1.397130	1.429694	1.120704	0.716965	1.499905	0.387968	
1.418029	1.436962	1.462962	1.203505	0.804885	1.615923	0.456064	
1.439252	1.461605	1.494727	1.272749	0.881466	1.698908	0.507158	
1.443893	1.467342	1.502934	1.292426	0.904052	1.721937	0.522347	
1.447606	1.471931	1.509498	1.308167	0.922120	1.740359	0.534498	
0.993698	0.962610	0.825953	2.245051	1.012130	0.330237	0.0	0.0
1.070770	1.039815	0.932332	2.434565	1.135370	0.395423	0.0	0.0
1.136354	1.105904	1.022580	2.546539	1.219793	0.442293	0.0	0.0
1.154689	1.124493	1.048913	2.575976	1.243450	0.456111	0.0	0.0
1.169356	1.139363	1.069978	2.599524	1.262374	0.467165	0.0	0.0
1.379210	1.306311	0.981154	0.417128	0.0	0.0	0.0	0.0
1.535472	1.455280	1.100855	0.499271	0.0	0.0	0.0	0.0
1.627799	1.545999	1.183096	0.557200	0.0	0.0	0.0	0.0
1.652231	1.570311	1.205884	0.574077	0.0	0.0	0.0	0.0
1.671776	1.589758	1.224114	0.587578	0.0	0.0	0.0	0.0

BLOCK 11 POWER

1.164219							
1.195070							
1.171544							
1.163489							
1.157045							
2.296277	2.484431						
2.199234	2.389982						
2.092491	2.285362						
2.060916	2.254607						
2.035655	2.230002						
2.483444	2.522724	2.480970					
2.407994	2.446487	2.415930					
2.311447	2.351541	2.331256					
2.282575	2.323082	2.305509					
2.259476	2.300314	2.284910					
2.078814	2.224945	2.238622	1.969424				
2.008763	2.161503	2.192938	1.933307				
1.928112	2.086579	2.129032	1.884956				
1.903533	2.063781	2.109057	1.869576				
1.883869	2.045541	2.093076	1.857272				
0.903687	1.778307	1.907779	1.568708	0.655799			
0.948313	1.741344	1.891820	1.551561	0.704787			
0.950431	1.694217	1.857675	1.524300	0.724082			
0.949669	1.678951	1.846132	1.514879	0.728887			
0.949058	1.666737	1.836897	1.507341	0.732730			
1.491952	1.634009	1.656139	1.379888	1.030788	0.721639		
1.486131	1.633702	1.671111	1.399431	1.044480	0.800093		
1.470371	1.623691	1.671461	1.409687	1.061497	0.871469		
1.464097	1.619302	1.670020	1.411553	1.065721	0.892742		
1.459078	1.615789	1.668866	1.413044	1.069100	0.909760		
1.389646	1.407239	1.440162	1.128963	0.722232	1.510840	0.390777	
1.427880	1.447026	1.473339	1.212081	0.810598	1.627283	0.459245	
1.449494	1.472089	1.505576	1.282008	0.887846	1.711075	0.510760	
1.454224	1.477924	1.513897	1.301870	0.910623	1.734319	0.526073	
1.458006	1.482590	1.520553	1.317759	0.928844	1.752914	0.538323	
1.000339	0.969090	0.831615	2.260787	1.019347	0.332601	0.0	0.0
1.077614	1.046513	0.938457	2.450931	1.143151	0.398145	0.0	0.0
1.143772	1.113178	1.029437	2.563993	1.228310	0.445394	0.0	0.0
1.162261	1.131922	1.055977	2.593710	1.252169	0.459323	0.0	0.0
1.177051	1.146917	1.077209	2.617481	1.271256	0.470465	0.0	0.0
1.388159	1.314840	0.987656	0.419951	0.0	0.0	0.0	0.0
1.544934	1.464308	1.107793	0.502488	0.0	0.0	0.0	0.0
1.638032	1.555781	1.190698	0.560858	0.0	0.0	0.0	0.0
1.662665	1.580292	1.213668	0.577864	0.0	0.0	0.0	0.0
1.682371	1.599899	1.232043	0.591467	0.0	0.0	0.0	0.0

BLOCK 12 POWER

1.134984							
1.164754							
1.142663							
1.135101							
1.129051							
2.238486	2.421765						
2.143289	2.329021						
2.040738	2.228660						
2.010462	2.199232						
1.986240	2.175687						
2.420514	2.458635	2.417480					
2.346246	2.383560	2.353256					
2.253746	2.292629	2.272271					
2.226158	2.265452	2.247728					
2.204085	2.243709	2.228091					
2.025478	2.167659	2.180602	1.917884				
1.956511	2.105045	2.135213	1.881854				
1.879185	2.033375	2.074256	1.835850				
1.855682	2.011642	2.055280	1.821287				
1.836879	1.994255	2.040097	1.809636				
0.879926	1.731480	1.857369	1.527025	0.638183			
0.922942	1.694676	1.840916	1.509546	0.685464			
0.925527	1.649733	1.808676	1.483802	0.704572			
0.924992	1.635233	1.797835	1.474951	0.709395			
0.924563	1.623632	1.789160	1.467869	0.713252			
1.451585	1.589876	1.611413	1.342533	1.002729	0.701894		
1.445074	1.588651	1.625033	1.360734	1.015419	0.777698		
1.430438	1.579680	1.626154	1.371348	1.032422	0.847438		
1.424627	1.575736	1.625087	1.373442	1.036736	0.868293		
1.419978	1.572579	1.624232	1.375116	1.040187	0.884977		
1.351403	1.368555	1.400638	1.098007	0.702421	1.469353	0.380036	
1.387693	1.406344	1.431986	1.178082	0.787850	1.581559	0.446327	
1.409324	1.431337	1.463964	1.246587	0.863299	1.663698	0.496602	
1.414203	1.437295	1.472347	1.266148	0.885618	1.686628	0.511591	
1.418105	1.442060	1.479052	1.281796	0.903473	1.704971	0.523583	
0.972536	0.942182	0.808580	2.198357	0.991267	0.323444	0.0	0.0
1.046954	1.016766	0.911848	2.381646	1.110918	0.386926	0.0	0.0
1.111697	1.081992	1.000670	2.492559	1.194178	0.433025	0.0	0.0
1.129887	1.100425	1.026669	2.521942	1.217613	0.446655	0.0	0.0
1.144438	1.115171	1.047468	2.545445	1.236360	0.457559	0.0	0.0
1.349427	1.278184	0.960175	0.408298	0.0	0.0	0.0	0.0
1.500779	1.422492	1.076218	0.488205	0.0	0.0	0.0	0.0
1.591874	1.511976	1.157238	0.545142	0.0	0.0	0.0	0.0
1.616128	1.536096	1.179794	0.561781	0.0	0.0	0.0	0.0
1.635529	1.555391	1.197837	0.575092	0.0	0.0	0.0	0.0

BLOCK 13 POWER

1.064583							
1.091495							
1.071810							
1.065187							
1.059868							
2.099561	2.271383						
2.008393	2.182339						
1.914099	2.090255						
1.886532	2.063561						
1.864477	2.042204						
2.270048	2.305703	2.266846					
2.198296	2.233145	2.204449					
2.113584	2.149925	2.130501					
2.088626	2.125369	2.108405					
2.068657	2.105722	2.090726					
1.899207	2.032409	2.044327	1.797758				
1.832727	1.971730	1.999734	1.762142				
1.761871	1.906288	1.944334	1.720520				
1.740590	1.886729	1.927374	1.707599				
1.723565	1.871080	1.913804	1.697262				
0.824760	1.622886	1.740781	1.431045	0.597970			
0.864168	1.586708	1.723514	1.413130	0.641556			
0.867315	1.545917	1.694729	1.390158	0.659957			
0.867180	1.532977	1.685280	1.382444	0.664749			
0.867072	1.522624	1.677720	1.376273	0.668582			
1.359970	1.489573	1.509751	1.257786	0.939350	0.657477		
1.352349	1.486754	1.520802	1.273395	0.950148	0.727636		
1.339697	1.479517	1.523040	1.284319	0.966789	0.793477		
1.334805	1.476433	1.522669	1.286809	0.971226	0.813335		
1.330891	1.473964	1.522371	1.288800	0.974774	0.829220		
1.265766	1.281853	1.311938	1.028488	0.657943	1.376291	0.355960	
1.298248	1.315720	1.339745	1.102209	0.737104	1.479659	0.417563	
1.319479	1.340113	1.370696	1.167173	0.808293	1.557657	0.464941	
1.324587	1.346240	1.379107	1.185970	0.829527	1.579768	0.479170	
1.328673	1.351142	1.385835	1.201007	0.846514	1.597456	0.490553	
0.910760	0.882348	0.757260	2.058933	0.928437	0.302946	0.0	0.0
0.979291	0.951069	0.852966	2.227968	1.039281	0.361979	0.0	0.0
1.040617	1.012827	0.936744	2.333446	1.117996	0.405406	0.0	0.0
1.058073	1.030500	0.961473	2.361914	1.140401	0.418336	0.0	0.0
1.072037	1.044639	0.981256	2.384687	1.158323	0.428681	0.0	0.0
1.263628	1.196930	0.899166	0.382373	0.0	0.0	0.0	0.0
1.403678	1.330474	1.006634	0.456661	0.0	0.0	0.0	0.0
1.489968	1.415204	1.083207	0.510293	0.0	0.0	0.0	0.0
1.513284	1.438366	1.104770	0.526083	0.0	0.0	0.0	0.0
1.531936	1.456894	1.122019	0.538715	0.0	0.0	0.0	0.0

BLOCK 14 POWER

0.955761							
0.978246							
0.961870							
0.956624							
0.952427							
1.884903	2.039112						
1.799960	1.955800						
1.717705	1.875728						
1.694202	1.853124						
1.675399	1.835040						
2.037827	2.069781	2.034756					
1.970001	2.001168	1.975286					
1.896651	1.929090	1.911474					
1.875521	1.908445	1.893023					
1.858696	1.891927	1.878262					
1.704729	1.824228	1.834808	1.613367				
1.642174	1.766652	1.791603	1.578573				
1.580706	1.710190	1.744165	1.543203				
1.562747	1.693870	1.730201	1.532717				
1.548379	1.680813	1.719028	1.524327				
0.740143	1.456361	1.562104	1.284094	0.536514			
0.774114	1.421331	1.543815	1.265713	0.574562			
0.777894	1.386501	1.519893	1.246651	0.591747			
0.778332	1.375883	1.512503	1.240620	0.596467			
0.778682	1.367387	1.506590	1.235794	0.600242			
1.220124	1.336421	1.354524	1.128440	0.842711	0.589810		
1.211047	1.331431	1.361920	1.140329	0.850810	0.651525		
1.201147	1.326532	1.365549	1.151471	0.866724	0.711301		
1.197612	1.324707	1.366186	1.154521	0.871314	0.729614		
1.194782	1.323246	1.366694	1.156959	0.874986	0.744264		
1.135428	1.149870	1.176876	0.922616	0.590215	1.234607	0.319313	
1.162384	1.178040	1.199571	0.986694	0.659985	1.324838	0.373869	
1.182774	1.201282	1.228714	1.046275	0.724563	1.396282	0.416768	
1.188192	1.207627	1.237127	1.063874	0.744120	1.417096	0.429824	
1.192525	1.212703	1.243856	1.077952	0.759765	1.433746	0.440269	
0.816902	0.791425	0.679244	1.846867	0.832831	0.271752	0.0	0.0
0.876710	0.851453	0.763644	1.994720	0.930504	0.324095	0.0	0.0
0.932686	0.907787	0.839616	2.091564	1.002133	0.363394	0.0	0.0
0.948999	0.924278	0.862387	2.118569	1.022934	0.375248	0.0	0.0
0.962049	0.937470	0.880604	2.140172	1.039573	0.384731	0.0	0.0
1.133362	1.073550	0.806495	0.342974	0.0	0.0	0.0	0.0
1.256585	1.191062	0.901173	0.408830	0.0	0.0	0.0	0.0
1.335362	1.268367	0.970836	0.457369	0.0	0.0	0.0	0.0
1.357213	1.290032	0.990858	0.471853	0.0	0.0	0.0	0.0
1.374693	1.307362	1.006874	0.483440	0.0	0.0	0.0	0.0

BLOCK 15 POWER

0.812551							
0.829300							
0.817019							
0.813540							
0.810756							
1.602449	1.733526						
1.525873	1.657953						
1.458997	1.593185						
1.440764	1.575878						
1.426176	1.562031						
1.732389	1.759525	1.729677					
1.669937	1.696322	1.674292					
1.610810	1.638406	1.623337					
1.594862	1.622818	1.609595					
1.582102	1.610346	1.598600					
1.449119	1.550668	1.559602	1.371305				
1.391927	1.497395	1.518468	1.337827				
1.342415	1.452331	1.481091	1.310333				
1.328753	1.440193	1.470988	1.302979				
1.317822	1.430481	1.462905	1.297095				
0.629084	1.237822	1.327671	1.091353	0.455961			
0.656041	1.204525	1.308289	1.072573	0.486854			
0.660493	1.177228	1.290441	1.058394	0.502339			
0.661651	1.169601	1.285690	1.054520	0.506941			
0.662576	1.163499	1.281889	1.051420	0.510621			
1.036889	1.135731	1.151117	0.958977	0.716144	0.501219		
1.026131	1.128144	1.153976	0.966204	0.720871	0.552007		
1.019623	1.126069	1.159183	0.977431	0.735685	0.603731		
1.017820	1.125846	1.161088	0.981168	0.740442	0.619991		
1.016376	1.125666	1.162612	0.984157	0.744248	0.632998		
0.964828	0.977107	1.000068	0.784016	0.501555	1.049153	0.271349	
0.984784	0.998053	1.016305	0.836126	0.559162	1.122449	0.316754	
1.003878	1.019591	1.042880	0.888032	0.614974	1.185087	0.353727	
1.009658	1.026177	1.051247	0.904020	0.632305	1.204140	0.365229	
1.014280	1.031444	1.057939	0.916810	0.646169	1.219382	0.374429	
0.694128	0.672486	0.577174	1.569372	0.707713	0.230930	0.0	0.0
0.742706	0.721314	0.646937	1.689906	0.788332	0.274580	0.0	0.0
0.791544	0.770416	0.712570	1.775116	0.850530	0.308422	0.0	0.0
0.806326	0.785324	0.732746	1.800120	0.869187	0.318850	0.0	0.0
0.818152	0.797250	0.748887	1.820123	0.884112	0.327192	0.0	0.0
0.963013	0.912197	0.685291	0.291436	0.0	0.0	0.0	0.0
1.064490	1.008988	0.763424	0.346345	0.0	0.0	0.0	0.0
1.133241	1.076390	0.823901	0.388154	0.0	0.0	0.0	0.0
1.153122	1.096046	0.841866	0.400909	0.0	0.0	0.0	0.0
1.169026	1.111769	0.856238	0.411113	0.0	0.0	0.0	0.0

BLOCK 16 POWER

0.640158							
0.650174							
0.642613							
0.641205							
0.640078							
1.262460	1.365712						
1.196270	1.299797						
1.147527	1.253042						
1.135539	1.242003						
1.125948	1.233171						
1.364794	1.386156	1.362604					
1.309164	1.329824	1.312499					
1.266869	1.288543	1.276622					
1.256929	1.278931	1.268438					
1.248976	1.271241	1.261890					
1.141588	1.221569	1.228577	1.080217				
1.091157	1.173809	1.190280	1.048636				
1.055707	1.142113	1.164667	1.030324				
1.047127	1.134911	1.159112	1.026651				
1.040262	1.129149	1.154668	1.023713				
0.495544	0.975057	1.045820	0.859662	0.359159			
0.514228	0.944136	1.025442	0.840667	0.381575			
0.519349	0.925642	1.014620	0.832134	0.394917			
0.521329	0.921536	1.012960	0.830782	0.399340			
0.522913	0.918251	1.011632	0.829700	0.402878			
0.816718	0.894576	0.906700	0.755367	0.564108	0.394828		
0.804206	0.884157	0.904395	0.757232	0.564963	0.432624		
0.801570	0.885251	0.911262	0.768358	0.578295	0.474549		
0.801782	0.886877	0.914613	0.772852	0.583195	0.488289		
0.801951	0.888178	0.917293	0.776446	0.587115	0.499280		
0.759930	0.769606	0.787707	0.617555	0.395085	0.826486	0.213769	
0.771729	0.782128	0.796435	0.655250	0.438217	0.879696	0.248255	
0.789073	0.801418	0.819712	0.697993	0.483369	0.931473	0.278026	
0.795216	0.808219	0.827945	0.711973	0.497971	0.948297	0.287623	
0.800131	0.813659	0.834531	0.723157	0.309652	0.961756	0.295300	
0.546724	0.529681	0.454623	1.236205	0.557501	0.181925	0.0	0.0
0.582000	0.565238	0.506963	1.324308	0.617811	0.215196	0.0	0.0
0.622109	0.605501	0.560034	1.395135	0.668481	0.242409	0.0	0.0
0.634992	0.618447	0.577032	1.417575	0.684482	0.251092	0.0	0.0
0.645297	0.628803	0.590629	1.435525	0.697282	0.258039	0.0	0.0
0.758538	0.718518	0.539806	0.229575	0.0	0.0	0.0	0.0
0.834154	0.790665	0.598245	0.271414	0.0	0.0	0.0	0.0
0.890625	0.845940	0.647503	0.305051	0.0	0.0	0.0	0.0
0.908042	0.863089	0.662922	0.315692	0.0	0.0	0.0	0.0
0.921976	0.876807	0.675256	0.324204	0.0	0.0	0.0	0.0

BLOCK 17 POWER

0.444818							
0.447454							
0.445033							
0.445888							
0.446571							
0.877253	0.948981						
0.823265	0.894468						
0.794685	0.867708						
0.789628	0.863615						
0.785582	0.860340						
0.948328	0.963154	0.946762					
0.900885	0.915064	0.903086					
0.877250	0.892210	0.883882					
0.873962	0.889211	0.881838					
0.871331	0.886811	0.880203					
0.793226	0.848783	0.853626	0.750542				
0.750865	0.807699	0.818970	0.721501				
0.731014	0.790795	0.806330	0.713289				
0.728061	0.789046	0.805787	0.713662				
0.725697	0.787647	0.805352	0.713961				
0.344304	0.677488	0.726637	0.597305	0.249555			
0.353834	0.649634	0.705517	0.578390	0.262524			
0.359572	0.640848	0.702369	0.576014	0.273327			
0.362420	0.640618	0.704088	0.577417	0.277494			
0.364698	0.640433	0.705463	0.578539	0.280828			
0.567458	0.621546	0.629968	0.524859	0.392034	0.274480		
0.553289	0.608264	0.622141	0.520923	0.388705	0.297709		
0.554827	0.612709	0.630631	0.531706	0.400165	0.328342		
0.557224	0.616323	0.635506	0.536952	0.405132	0.339125		
0.559142	0.619215	0.639405	0.541149	0.409106	0.347751		
0.527997	0.534723	0.547338	0.429187	0.274648	0.574824	0.148750	
0.530843	0.537978	0.547818	0.450758	0.301526	0.605462	0.170915	
0.545984	0.554489	0.567088	0.482860	0.334402	0.644395	0.192344	
0.552438	0.561426	0.575046	0.494439	0.345807	0.658433	0.199689	
0.557600	0.566975	0.581412	0.503703	0.354931	0.669663	0.205565	
0.379943	0.368107	0.315996	0.859578	0.387761	0.126591	0.0	0.0
0.400351	0.388818	0.348754	0.911180	0.425187	0.148148	0.0	0.0
0.430363	0.418853	0.387367	0.964933	0.462398	0.167695	0.0	0.0
0.440986	0.429468	0.400646	0.984099	0.475193	0.174319	0.0	0.0
0.449484	0.437960	0.411268	0.999431	0.485428	0.179618	0.0	0.0
0.527426	0.499613	0.375410	0.159720	0.0	0.0	0.0	0.0
0.573944	0.544024	0.411668	0.186806	0.0	0.0	0.0	0.0
0.616056	0.585126	0.447849	0.210988	0.0	0.0	0.0	0.0
0.630466	0.599222	0.460199	0.219131	0.0	0.0	0.0	0.0
0.641993	0.610498	0.470079	0.225646	0.0	0.0	0.0	0.0

BLOCK 18 POWER

0.236664							
0.237989							
0.249248							
0.256390							
0.262104							
0.466081	0.503982						
0.435384	0.472434						
0.440637	0.480243						
0.448688	0.489778						
0.455128	0.497405						
0.503562	0.511380	0.502629					
0.475584	0.482949	0.476516					
0.485185	0.493302	0.488550					
0.495272	0.503759	0.499420					
0.503341	0.512123	0.508116					
0.421388	0.450737	0.453204	0.398533				
0.396977	0.426532	0.432179	0.380915				
0.405178	0.437573	0.445737	0.394543				
0.413539	0.447379	0.456406	0.404478				
0.420228	0.455224	0.464940	0.412425				
0.183174	0.359922	0.385812	0.317271	0.132744			
0.188161	0.343489	0.372341	0.305630	0.139430			
0.201324	0.355218	0.388278	0.318992	0.152701			
0.208326	0.363886	0.398800	0.327661	0.159110			
0.213928	0.370820	0.407216	0.334597	0.164238			
0.301489	0.330056	0.334413	0.278691	0.208343	0.146169		
0.292558	0.321105	0.328011	0.274709	0.205120	0.156763		
0.307503	0.338800	0.348057	0.293454	0.220739	0.179296		
0.316450	0.349160	0.359299	0.303533	0.228746	0.188873		
0.323608	0.357448	0.368292	0.311595	0.235151	0.196533		
0.280315	0.283842	0.290538	0.228105	0.146220	0.306262	0.079699	
0.279853	0.283443	0.288254	0.237064	0.158669	0.313953	0.089046	
0.301237	0.305647	0.311681	0.264224	0.182486	0.339139	0.101263	
0.312188	0.316952	0.323479	0.276409	0.192485	0.349929	0.105938	
0.320949	0.325996	0.332918	0.286157	0.200484	0.358560	0.109679	
0.201942	0.195654	0.168155	0.457486	0.206856	0.067829	0.0	0.0
0.210705	0.204592	0.183356	0.471756	0.220690	0.077183	0.0	0.0
0.235818	0.229428	0.211180	0.507217	0.243300	0.088298	0.0	0.0
0.246917	0.240376	0.222793	0.522480	0.252341	0.092499	0.0	0.0
0.255797	0.249134	0.232083	0.534690	0.259574	0.095860	0.0	0.0
0.280860	0.266061	0.200144	0.085536	0.0	0.0	0.0	0.0
0.297458	0.281945	0.213591	0.097265	0.0	0.0	0.0	0.0
0.324139	0.307818	0.235682	0.111034	0.0	0.0	0.0	0.0
0.335003	0.318341	0.244477	0.116222	0.0	0.0	0.0	0.0
0.343693	0.326758	0.251514	0.120373	0.0	0.0	0.0	0.0

BLOCK 19 POWER

0.488969							
0.536943							
0.545584							
0.549141							
0.551986							
0.568428	0.600554						
0.617758	0.653256						
0.634193	0.672789						
0.642099	0.681973						
0.648423	0.689319						
0.597641	0.606083	0.595303					
0.653979	0.663405	0.654102					
0.675783	0.686396	0.679271					
0.685613	0.696654	0.690136					
0.693476	0.704860	0.698827					
0.512211	0.536729	0.537054	0.474108				
0.561512	0.589343	0.593555	0.525758				
0.581503	0.612568	0.620069	0.551732				
0.590167	0.622499	0.631023	0.562193				
0.597098	0.630442	0.639786	0.570562				
0.378427	0.438920	0.457685	0.384748	0.270566			
0.424459	0.487285	0.511741	0.431205	0.310146			
0.440572	0.511102	0.540442	0.456541	0.329290			
0.446076	0.520574	0.551664	0.466270	0.335594			
0.450479	0.528151	0.560642	0.474052	0.340637			
0.369103	0.392937	0.393393	0.327730	0.232169	0.148632		
0.416437	0.443417	0.446815	0.374157	0.267474	0.175913		
0.443652	0.473782	0.479905	0.404398	0.292585	0.197701		
0.453861	0.485231	0.492248	0.415540	0.301671	0.205384		
0.462028	0.494389	0.502121	0.424453	0.308940	0.211530		
0.329909	0.331682	0.312116	0.237626	0.148733	0.069410	0.017302	
0.381086	0.383151	0.361119	0.279524	0.177906	0.087961	0.022576	
0.415021	0.417940	0.396664	0.310968	0.200996	0.103932	0.027168	
0.427305	0.430531	0.409557	0.322153	0.209078	0.110035	0.028913	
0.437131	0.440604	0.419872	0.331102	0.215543	0.114917	0.030309	
0.212656	0.205809	0.169945	0.102859	0.046253	0.014761	0.0	0.0
0.251436	0.243929	0.204280	0.131171	0.059814	0.019606	0.0	0.0
0.280889	0.273080	0.231237	0.154492	0.071277	0.023747	0.0	0.0
0.291293	0.283362	0.240630	0.163393	0.075628	0.025312	0.0	0.0
0.299616	0.291587	0.248145	0.170514	0.079109	0.026564	0.0	0.0
0.062543	0.059252	0.044921	0.018586	0.0	0.0	0.0	0.0
0.080813	0.076631	0.058327	0.024671	0.0	0.0	0.0	0.0
0.095703	0.090931	0.069708	0.029812	0.0	0.0	0.0	0.0
0.101372	0.096379	0.074020	0.031751	0.0	0.0	0.0	0.0
0.105907	0.100737	0.077469	0.033301	0.0	0.0	0.0	0.0

BENCHMARK PROBLEM SOLUTION

Identification: 11-A1-2 Benchmark Problem ID.11-A1

Date Submitted: June 1976 By: Ib Misfeldt (Risø-Denmark)

Date Accepted: June 1977 By: H. L. Dodds, Jr. (U. of Tenn.)
M. V. Gregory (SRL)

Descriptive Title: Three-dimensional PWR Problem

Mathematical Model: FEM (2nd order Lagrange interpolation, box-shaped elements)

Pertinent features of solution method

The calculations were performed with a rather coarse grid (16 x 16 x 13 meshes; 33 x 33 x 27 flux-points). To obtain the required additional results interpolation was used.

Computer: B 6700 Date solved: Spring 1975
at: Risø, Denmark

Program: FEM3D

Reference: Ib Misfeldt, "Solution of the multigroup neutron diffusion equations by the finite element method," Risø-M-1809 (1975).

Results

1. Maximum eigenvalue $k_{eff} = 1.0292$

2. Fundamental flux distributions

   2.1, 2.2, 2.3 See Tables 3A-G of flux traverses

   2.4 Maximum power density
   Uninterpolated values are given

   $(\phi_2)_{max,1} = 17.60$ at $(x,y,z) = (130,55,190)$

   $(\phi_2)_{max,2} = 16.80$ at $(x,y,z) = (30,35,190)$

3. Average subassembly powers

   See Table 3H

4. Number of unknowns and iteration-number

   33 x 33 x 27 x 2 unknowns; 71 iterations

5. Computing times

   23 hours cp-time, io-time 6 hours, on B 6700

6. Convergence criteria

   Maximal flux-error-estimate less than 0.1% of $\emptyset_{max}$ in each group

7. Average group fluxes for 20 x 20 x 20 cm grid

   See Table 3J

8. Dependence of results on mesh spacing

   No data available

Table 3A
z = 190 cm
FLUX ALONG X-AXIS

X	PHI1	PHI2
0.000	43.616	7.293
5.000	45.454	7.443
10.000	50.801	10.175
20.000	62.837	14.868
30.000	68.498	15.878
35.000	69.391	16.270
40.000	69.316	16.261
45.000	68.233	16.014
50.000	66.143	15.522
55.000	62.978	14.775
60.000	58.612	13.683
65.000	52.690	12.233
70.000	45.393	8.903
75.000	39.323	6.431
80.000	36.430	6.073
85.000	36.604	5.985
90.000	39.638	7.748
95.000	43.655	10.127
100.000	46.378	10.820
105.000	47.713	11.193
110.000	48.029	11.273
115.000	47.493	11.151
120.000	46.228	10.867
125.000	44.342	10.429
130.000	41.822	10.100
135.000	38.279	9.498
140.000	33.227	8.613
145.000	26.979	7.287
150.000	16.812	12.443
155.000	8.252	20.102
160.000	4.090	14.566
165.000	2.041	7.785
170.000	1.082	0.324

Table 3B
z = 190 cm
FLUX ALONG THE DIAGONAL X=Y

X	Y	PHI1	PHI2
0.000	0.000	43.616	7.293
5.000	5.000	47.151	7.463
10.000	10.000	55.944	12.195
20.000	20.000	68.322	16.028
30.000	30.000	71.653	16.800
35.000	35.000	71.455	16.759
40.000	40.000	70.383	16.510
45.000	45.000	68.542	16.076
50.000	50.000	65.926	15.470
55.000	55.000	62.409	14.648
60.000	60.000	57.761	13.552
65.000	65.000	51.559	12.079
70.000	70.000	43.017	9.168
75.000	75.000	33.780	5.344
80.000	80.000	28.426	4.741
85.000	85.000	27.423	4.341
90.000	90.000	28.739	6.350
95.000	95.000	27.729	6.896
100.000	100.000	23.086	6.346
105.000	105.000	16.539	4.911
110.000	110.000	6.969	9.840
115.000	115.000	2.264	8.707
120.000	120.000	0.788	3.862
125.000	125.000	0.275	1.069
130.000	130.000	0.091	0.012
135.000	135.000	0.000	0.000
140.000	140.000	0.000	0.000
145.000	145.000	0.000	0.000
150.000	150.000	0.000	0.000
155.000	155.000	0.000	0.000
160.000	160.000	0.000	0.000
165.000	165.000	0.000	0.000
170.000	170.000	0.000	0.000

Table 3C
z = 275 cm
FLUX ALONG X-AXIS

X	PHI1	PHI2
0.000	24.388	4.077
5.000	25.402	4.159
10.000	28.350	5.677
20.000	34.940	8.268
30.000	37.995	8.806
35.000	38.499	9.025
40.000	38.526	9.037
45.000	38.057	8.930
50.000	37.086	8.702
55.000	35.553	8.341
60.000	33.361	7.787
65.000	30.277	7.028
70.000	26.382	5.170
75.000	23.178	3.790
80.000	21.816	3.636
85.000	22.268	3.641
90.000	24.443	4.781
95.000	27.203	6.312
100.000	29.141	6.799
105.000	30.188	7.082
110.000	30.567	7.175
115.000	30.377	7.133
120.000	29.693	6.980
125.000	28.582	6.723
130.000	27.036	6.530
135.000	24.803	6.154
140.000	21.568	5.592
145.000	17.537	4.738
150.000	10.940	8.101
155.000	5.373	13.096
160.000	2.665	9.495
165.000	1.331	5.076
170.000	0.705	0.211

Table 3D
z = 275 cm
FLUX ALONG THE DIAGONAL X=Y

X	Y	PHI1	PHI2
0.000	0.000	24.388	4.077
5.000	5.000	26.335	4.168
10.000	10.000	31.140	6.786
20.000	20.000	37.364	8.765
30.000	30.000	37.260	8.641
35.000	35.000	35.874	8.018
40.000	40.000	34.891	7.824
45.000	45.000	34.736	7.762
50.000	50.000	34.993	8.096
55.000	55.000	34.584	8.114
60.000	60.000	33.036	7.750
65.000	65.000	30.203	7.075
70.000	70.000	25.692	5.473
75.000	75.000	20.540	3.249
80.000	80.000	17.586	2.933
85.000	85.000	17.210	2.724
90.000	90.000	18.207	4.024
95.000	95.000	17.666	4.394
100.000	100.000	14.763	4.060
105.000	105.000	10.604	3.150
110.000	110.000	4.475	6.322
115.000	115.000	1.455	5.600
120.000	120.000	0.507	2.486
125.000	125.000	0.177	0.689
130.000	130.000	0.059	0.008
135.000	135.000	0.000	0.000
140.000	140.000	0.000	0.000
145.000	145.000	0.000	0.000
150.000	150.000	0.000	0.000
155.000	155.000	0.000	0.000
160.000	160.000	0.000	0.000
165.000	165.000	0.000	0.000
170.000	170.000	0.000	0.000

Table 3E
z = 285 cm
FLUX ALONG X-AXIS

X	PHI1	PHI2
0.000	21.093	3.525
5.000	21.962	3.595
10.000	24.488	4.902
20.000	30.098	7.122
30.000	32.643	7.560
35.000	33.055	7.738
40.000	33.084	7.752
45.000	32.719	7.667
50.000	31.950	7.491
55.000	30.715	7.205
60.000	28.915	6.747
65.000	26.337	6.112
70.000	23.042	4.514
75.000	20.341	3.326
80.000	19.244	3.207
85.000	19.736	3.227
90.000	21.750	4.254
95.000	24.277	5.632
100.000	26.064	6.081
105.000	27.049	6.344
110.000	27.429	6.437
115.000	27.291	6.407
120.000	26.703	6.276
125.000	25.725	6.049
130.000	24.349	5.880
135.000	22.350	5.544
140.000	19.443	5.040
145.000	15.814	4.271
150.000	9.867	7.307
155.000	4.847	11.814
160.000	2.404	8.566
165.000	1.200	4.580
170.000	0.636	0.191

Table 3F
z = 285 cm
FLUX ALONG THE DIAGONAL X=Y

X	Y	PHI1	PHI2
0.000	0.000	21.093	3.525
5.000	5.000	22.759	3.602
10.000	10.000	26.848	5.843
20.000	20.000	31.748	7.443
30.000	30.000	29.525	6.504
35.000	35.000	26.448	4.497
40.000	40.000	24.924	4.410
45.000	45.000	25.628	4.355
50.000	50.000	27.851	6.010
55.000	55.000	29.012	6.796
60.000	60.000	28.397	6.658
65.000	65.000	26.314	6.163
70.000	70.000	22.579	4.808
75.000	75.000	18.173	2.875
80.000	80.000	15.649	2.609
85.000	85.000	15.381	2.434
90.000	90.000	16.314	3.606
95.000	95.000	15.854	3.942
100.000	100.000	13.262	3.646
105.000	105.000	9.531	2.831
110.000	110.000	4.024	5.685
115.000	115.000	1.309	5.037
120.000	120.000	0.456	2.236
125.000	125.000	0.159	0.620
130.000	130.000	0.053	0.007
135.000	135.000	0.000	0.000
140.000	140.000	0.000	0.000
145.000	145.000	0.000	0.000
150.000	150.000	0.000	0.000
155.000	155.000	0.000	0.000
160.000	160.000	0.000	0.000
165.000	165.000	0.000	0.000
170.000	170.000	0.000	0.000

Table 3G

AXIAL FLUX-DISTRIBUTION FOR (X.Y) = (40.000 40.000)

Z	PHI1	PHI2
380.000	0.151	0.014
375.000	0.279	0.263
370.000	0.530	0.481
365.000	0.995	0.845
360.000	1.833	0.673
355.000	3.067	0.522
350.000	4.169	0.722
325.000	9.577	1.584
300.000	16.735	2.857
290.000	21.264	3.460
280.000	29.515	5.793
270.000	39.539	9.351
260.000	46.650	10.888
225.000	62.711	14.727
190.000	70.383	16.510
155.000	70.217	16.482
120.000	62.311	14.625
85.000	47.642	11.181
50.000	27.822	6.537
40.000	21.502	5.037
30.000	14.924	3.641
25.000	11.577	2.936
20.000	7.053	5.023
15.000	3.451	8.316
10.000	1.706	6.035
5.000	0.849	3.227
0.000	0.450	0.134

Table 3H

Average subassembly powers

170.00									
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
150.00									
	0.8009	0.7809	0.7406	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
130.00									
	0.9703	0.9868	1.0131	0.8893	0.6350	0.0000	0.0000	0.0000	0.0000
110.00									
	0.9501	1.0543	1.0916	0.9288	0.7073	0.6204	0.0000	0.0000	0.0000
90.00									
	0.6119	1.0568	1.1701	0.9650	0.4812	0.7073	0.6350	0.0000	0.0000
70.00									
	1.1687	1.2682	1.2923	1.1652	0.9649	0.9286	0.8892	0.0000	0.0000
50.00									
	1.3891	1.4016	1.3448	1.2922	1.1699	1.0913	1.0127	0.7402	0.0000
30.00									
	1.2450	1.3636	1.4016	1.2681	1.0565	1.0538	0.9862	0.7802	0.0000
10.00									
	0.7236	1.2450	1.3890	1.1686	0.6118	0.9496	0.9695	0.8001	0.0000
0.00	10.00	30.00	50.00	70.00	90.00	110.00	130.00	150.00	170.00

Table 3J
Flux averages

GROUP 1
340.00<Z< 360.00

170.00									
	0.8293	0.7907	0.5981	0.1812	0.0140	0.0029	0.0001	0.0000	0.0000
150.00									
	4.7282	4.6081	3.8544	1.3932	0.5746	0.1416	0.0065	0.0001	0.0000
130.00									
	6.5806	6.6569	6.4660	5.0205	3.2295	0.9174	0.1567	0.0065	0.0001
110.00									
	6.2107	6.7652	6.9601	5.9401	4.4247	3.0833	0.9166	0.1414	0.0029
90.00									
	4.6794	6.0951	6.6669	5.6863	3.9627	4.4197	3.2235	0.5732	0.0139
70.00									
	5.9155	6.0807	5.8430	5.8898	5.6801	5.9277	5.0062	1.3881	0.1804
50.00									
	6.5214	5.8895	4.5251	5.8385	6.6554	6.9408	6.4419	3.8367	0.5949
30.00									
	5.9089	6.0754	5.8874	6.0748	6.0830	6.7434	6.6283	4.5841	0.7860
10.00									
	4.5685	5.9083	6.5188	5.9098	4.6695	6.1887	6.5501	4.7017	0.8239
0.00	10.00	30.00	50.00	70.00	90.00	110.00	130.00	150.00	170.00

Table 3J, group 1 (cont'd)

320.00<Z< 340.00

170.00									
1.6005	1.5269	1.1565	0.3491	0.0268	0.0055	0.0002	0.0000	0.0000	
150.00									
9.1254	8.8995	7.4613	2.7073	1.1161	0.2740	0.0125	0.0002	0.0000	
130.00									
12.7242	12.8781	12.5296	9.7515	6.2877	1.7924	0.3041	0.0125	0.0002	
110.00									
12.1443	13.1881	13.5525	11.5946	8.6846	6.0399	1.7911	0.2737	0.0055	
90.00									
9.4201	12.0735	13.1226	11.2287	7.9239	8.6769	6.2785	1.1141	0.0267	
70.00									
11.8987	12.1875	11.6860	11.7086	11.2191	11.5755	9.7293	2.6994	0.3478	
50.00									
13.1482	11.9219	9.2528	11.6789	13.1047	13.5223	12.4916	7.4331	1.1514	
30.00									
12.0072	12.3195	11.9187	12.1781	12.0542	13.1535	12.8327	8.8609	1.5192	
10.00									
9.4312	12.0063	13.1441	11.8896	9.4039	12.1091	12.6751	9.0823	1.5918	
0.00	10.00	30.00	50.00	70.00	90.00	110.00	130.00	150.00	170.00

Table 3J, group 1 (cont'd)

300.00<Z< 320.00

170.00	2.3610	2.2532	1.7080	0.5162	0.0397	0.0081	0.0002	0.0000	0.0000
150.00	13.4772	13.1492	11.0355	4.0115	1.6562	0.4068	0.0186	0.0003	0.0000
130.00	18.8722	19.1105	18.6097	14.4957	9.3492	2.6661	0.4522	0.0186	0.0002
110.00	18.1938	19.7766	20.3334	17.3804	12.9844	9.0041	2.6650	0.4065	0.0081
90.00	14.4449	18.5091	20.1025	17.1350	11.9829	12.9770	9.3408	1.6544	0.0397
70.00	18.7114	19.2237	18.4579	18.2553	17.1249	17.3607	14.4731	4.0033	0.5148
50.00	20.9408	19.1558	15.0116	18.4501	20.0828	20.3002	18.5679	11.0042	1.7023
30.00	19.1535	19.7530	19.1524	19.2132	18.4872	19.7369	19.0577	13.1039	2.2442
10.00	15.0237	19.1526	20.9365	18.7013	14.4264	18.1527	18.8142	13.4258	2.3506
	0.00	10.00	30.00	50.00	70.00	90.00	110.00	130.00	150.00	170.00

280.00<Z< 300.00

170.00	3.1082	2.9673	2.2510	0.6809	0.0525	0.0108	0.0003	0.0000	0.0000
150.00	17.7762	17.3510	14.5753	5.3055	2.1932	0.5388	0.0246	0.0003	0.0000
130.00	25.0137	25.3459	24.7049	19.2531	12.4125	3.5375	0.5997	0.0246	0.0003
110.00	24.3726	26.5438	27.3221	23.3113	17.3333	11.9752	3.5370	0.5387	0.0108
90.00	19.8591	25.5188	27.7593	23.5100	16.2033	17.3285	12.4075	2.1922	0.0525
70.00	26.5757	27.6400	26.9427	25.9487	23.5019	23.2961	19.2362	5.2992	0.6797
50.00	30.2291	28.4241	23.4369	26.9360	27.7422	27.2936	24.6690	14.5479	2.2459
30.00	27.5939	28.8630	28.4213	27.6307	25.4990	26.5075	25.2969	17.3083	2.9588
10.00	21.5251	27.5932	30.2254	26.5666	19.8421	24.3343	24.9584	17.7266	3.0981
	0.00	10.00	30.00	50.00	70.00	90.00	110.00	130.00	150.00	170.00

Table 3J, group 1 (cont'd)

260.00<Z< 280.00

170.00									
3.8154	3.6440	2.7665	0.8375	0.0647	0.0133	0.0004	0.0000	0.0000	
150.00									
21.8603	21.3471	17.9502	6.5438	2.7080	0.6652	0.0304	0.0004	0.0000	
130.00									
30.9100	31.3424	30.5806	23.8428	15.3622	4.3750	0.7410	0.0304	0.0004	
110.00									
30.4490	33.2290	34.2481	29.1623	21.5744	14.8439	4.3750	0.6652	0.0133	
90.00									
25.4995	32.8969	35.9005	30.1737	20.4571	21.5721	15.3601	2.7077	0.0647	
70.00									
35.3115	37.6279	38.1858	35.0010	30.1684	29.1528	23.8326	6.5398	0.8368	
50.00									
40.8837	40.7689	39.2855	38.1808	35.8883	34.2277	30.5549	17.9299	2.7627	
30.00									
37.1180	39.8158	40.7668	37.6210	32.8819	33.2014	31.3044	21.3132	3.6372	
10.00									
28.7379	37.1175	40.8811	35.3046	25.4863	30.4194	30.8661	21.8200	3.8074	
0.00	10.00	30.00	50.00	70.00	90.00	110.00	130.00	150.00	170.00

240.00<Z< 260.00

170.00									
4.4587	4.2595	3.2359	0.9803	0.0759	0.0156	0.0004	0.0000	0.0000	
150.00									
25.5826	24.9913	21.0319	7.6766	3.1795	0.7809	0.0357	0.0005	0.0000	
130.00									
36.3205	36.8488	35.9817	28.0630	18.0715	5.1435	0.8706	0.0357	0.0004	
110.00									
36.0936	39.4466	40.6912	34.5947	25.4932	17.4831	5.1440	0.7811	0.0156	
90.00									
30.8402	39.8645	43.5556	36.4306	24.4274	25.4937	18.0727	3.1799	0.0759	
70.00									
43.6762	46.9634	48.2105	43.3687	36.4284	34.5913	28.0595	7.6747	0.9799	
50.00									
51.1028	51.9433	51.6857	48.2077	43.5488	40.6707	35.9662	21.0188	3.2332	
30.00									
46.3326	50.1808	51.9424	46.9594	39.8552	39.4284	36.8222	24.9667	4.2543	
10.00									
35.7497	46.3323	51.1016	43.6722	30.8316	36.0729	36.2885	25.5523	4.4523	
0.00	10.00	30.00	50.00	70.00	90.00	110.00	130.00	150.00	170.00

Table 3J, group 1 (cont'd)

220.00<Z< 240.00

170.00									
4.9816	4.7594	3.6172	1.0964	0.0850	0.0175	0.0005	0.0000	0.0000	
150.00									
28.6083	27.9542	23.5383	8.5985	3.5633	0.8751	0.0400	0.0006	0.0000	
130.00									
40.7292	41.3358	40.3834	31.5023	20.2789	5.7696	0.9762	0.0400	0.0005	
110.00									
40.7056	44.5239	45.9474	39.0254	28.6894	19.6348	5.7706	0.8755	0.0175	
90.00									
35.1987	45.5225	49.7359	41.4964	27.6604	28.6922	20.2840	3.5645	0.0850	
70.00									
50.4507	54.3338	55.8300	49.9311	41.4973	39.0285	31.5057	8.5988	1.0963	
50.00									
59.3457	60.5222	60.3913	55.8296	49.7346	45.9449	40.3777	23.5321	3.6157	
30.00									
53.8322	58.4216	60.5225	54.3331	45.5191	44.5147	41.3200	27.9382	4.7558	
10.00									
41.4999	53.8324	59.3462	50.4499	35.1951	40.6932	40.7080	28.5873	4.9762	
0.00	10.00	30.00	50.00	70.00	90.00	110.00	130.00	150.00	170.00

200.00<Z< 220.00

170.00									
5.3559	5.1180	3.8908	1.1797	0.0915	0.0188	0.0005	0.0000	0.0000	
150.00									
30.7805	30.0810	25.3382	9.2608	3.8393	0.9429	0.0431	0.0006	0.0000	
130.00									
43.8981	44.5614	43.5478	33.9759	21.8671	6.2199	1.0521	0.0431	0.0005	
110.00									
44.0252	48.1765	49.7259	42.2102	30.9883	21.1830	6.2215	0.9434	0.0188	
90.00									
38.3279	49.5722	54.1441	45.1140	29.9796	30.9943	21.8752	3.8412	0.0915	
70.00									
55.2861	59.5494	61.1664	54.5573	45.1178	42.2191	33.9858	9.2634	1.1799	
50.00									
65.2207	66.5603	66.4184	61.1684	54.1482	49.7316	43.5525	25.3391	3.8905	
30.00									
59.2056	64.2788	66.5620	59.5521	49.5745	48.1764	44.5573	30.0741	5.1160	
10.00									
45.6383	59.2063	65.2231	55.2888	38.3288	44.0219	43.8892	30.7687	5.3525	
0.00	10.00	30.00	50.00	70.00	90.00	110.00	130.00	150.00	170.00

Table 3J, group I (cont'd)

180.00<Z< 200.00

170.00									
5.5777	5.3311	4.0536	1.2293	0.0954	0.0196	0.0006	0.0000	0.0000	
150.00									
32.0747	31.3483	26.4115	9.6561	4.0046	0.9835	0.0449	0.0006	0.0000	
130.00									
45.7928	46.4904	45.4404	35.4564	22.8185	6.4897	1.0976	0.0449	0.0006	
110.00									
46.0172	50.3664	51.9876	44.1164	32.3657	22.1112	6.4918	0.9840	0.0197	
90.00									
40.1994	51.9802	56.7471	47.2545	31.3631	32.3742	22.8294	4.0070	0.0954	
70.00									
58.1499	62.5873	64.2110	57.2291	47.2612	44.1306	35.4731	9.6614	1.2299	
50.00									
68.6936	70.0439	69.7809	64.2155	56.7569	52.0015	45.4565	26.4203	4.0547	
30.00									
62.4153	67.7244	70.0470	62.5937	51.9883	50.3758	46.4990	31.3513	5.3310	
10.00									
48.1317	62.4168	68.6981	58.1565	40.2050	46.0239	45.7974	32.0728	5.5771	
0.00	10.00	30.00	50.00	70.00	90.00	110.00	130.00	150.00	170.00

160.00<Z< 180.00

170.00									
5.6131	5.3647	4.0795	1.2373	0.0960	0.0198	0.0006	0.0000	0.0000	
150.00									
32.2856	31.5568	26.5892	9.7230	4.0326	0.9905	0.0452	0.0006	0.0000	
130.00									
46.1257	46.8302	45.7747	35.7182	22.9869	6.5377	1.1056	0.0453	0.0006	
110.00									
46.4001	50.7896	52.4233	44.4797	32.6219	22.2798	6.5402	0.9912	0.0198	
90.00									
40.6069	52.5022	57.3038	47.7013	31.6384	32.6326	23.0015	4.0363	0.0961	
70.00									
58.8332	63.3080	64.9215	57.8272	47.7104	44.4996	35.7428	9.7310	1.2384	
50.00									
69.5572	70.9125	70.6140	64.9282	57.3181	52.4463	45.8014	26.6064	4.0823	
30.00									
63.2297	68.5975	70.9168	63.3173	52.5155	50.8079	46.8489	31.5692	5.3668	
10.00									
48.7684	63.2317	69.5634	58.8430	40.6174	46.4151	46.1399	32.2943	5.6144	
0.00	10.00	30.00	50.00	70.00	90.00	110.00	130.00	150.00	170.00

Table 3J, group 1 (cont'd)

140.00<Z< 160.00

170.00									
	5.4593	5.2176	3.9678	1.2035	0.0934	0.0192	0.0005	0.0000	0.0000
150.00									
	31.4050	30.6972	25.8660	9.4595	3.9235	0.9636	0.0440	0.0006	0.0000
130.00									
	44.8870	45.5736	44.5471	34.7601	22.3693	6.3619	1.0759	0.0440	0.0005
110.00									
	45.1851	49.4619	51.0514	43.3101	31.7565	21.6842	6.3645	0.9645	0.0193
90.00									
	39.5904	51.1854	55.8586	46.4862	30.8170	31.7675	22.3851	3.9276	0.0935
70.00									
	57.4231	61.7853	63.3462	56.3969	46.4953	43.3311	34.7867	9.4681	1.2047
50.00									
	67.9275	69.2509	68.9480	63.3530	55.8734	51.0760	44.5760	25.8855	3.9710
30.00									
	61.7648	67.0057	69.2551	61.7946	51.1993	49.4812	45.5940	30.7121	5.2203
10.00									
	47.6423	61.7668	67.9336	57.4329	39.6015	45.2008	44.9027	31.4168	5.4610
	0.00	10.00	30.00	50.00	70.00	90.00	110.00	130.00	150.00	170.00

120.00<Z< 140.00

170.00									
	5.1186	4.8922	3.7203	1.1284	0.0876	0.0180	0.0005	0.0000	0.0000
150.00									
	29.4480	28.7839	24.2543	8.8701	3.6791	0.9035	0.0413	0.0006	0.0000
130.00									
	42.0981	42.7426	41.7796	32.5995	20.9767	5.9654	1.0088	0.0413	0.0005
110.00									
	42.3955	46.4090	47.8982	40.6296	29.7850	20.3347	5.9679	0.9043	0.0181
90.00									
	37.1712	48.0549	52.4357	43.6298	28.9138	29.7946	20.9908	3.6826	0.0877
70.00									
	53.9463	58.0392	59.4943	52.9529	43.6368	40.6466	32.6213	8.8774	1.1294
50.00									
	63.8348	65.0739	64.7760	59.4990	52.4467	47.9161	41.8016	24.2692	3.7227
30.00									
	58.0529	62.9750	65.0766	58.0455	48.0639	46.4207	42.7558	28.7938	4.8938
10.00									
	44.7814	58.0543	63.8388	53.9531	37.1779	42.4038	42.1070	29.4542	5.1195
	0.00	10.00	30.00	50.00	70.00	90.00	110.00	130.00	150.00	170.00

Table 3J, group 1 (cont'd)

100.00<Z< 120.00

170.00	4.5919	4.3888	3.3374	1.0122	0.0786	0.0162	0.0005	0.0000	0.0000
150.00	26.4181	25.8215	21.7576	7.9566	3.3000	0.8104	0.0370	0.0005	0.0000
130.00	37.7676	38.3455	37.4805	29.2431	18.8147	5.3498	0.9046	0.0370	0.0005
110.00	38.0405	41.6416	42.9759	36.4497	26.7156	18.2358	5.3514	0.8109	0.0162
90.00	33.3631	43.1295	47.0567	39.1482	25.9372	26.7202	18.8226	3.3021	0.0786
70.00	48.4318	52.1020	53.4001	47.5204	39.1493	36.4554	29.2526	7.9600	1.0126
50.00	57.3164	58.4243	58.1463	53.3997	47.0569	42.9779	37.4854	21.7611	3.3379
30.00	52.1286	56.5449	58.4237	52.1009	43.1271	41.6372	38.3411	25.8179	4.3879
10.00	40.2126	52.1286	57.3159	48.4308	33.3601	38.0336	37.7592	26.4099	4.5902
	0.00	10.00	30.00	50.00	70.00	90.00	110.00	130.00	150.00	170.00

80.00<Z< 100.00

170.00	3.9166	3.7430	2.8462	0.8632	0.0670	0.0138	0.0004	0.0000	0.0000
150.00	22.5318	22.0224	18.5552	6.7853	2.8137	0.6909	0.0316	0.0004	0.0000
130.00	32.2128	32.7044	31.9652	24.9376	16.0427	4.5610	0.7711	0.0316	0.0004
110.00	32.4483	35.5196	36.6561	31.0861	22.7795	15.5453	4.5612	0.6911	0.0138
90.00	28.4655	36.7968	40.1440	33.3919	22.1172	22.7777	16.0429	2.8143	0.0670
70.00	41.3303	44.4596	45.5619	40.5372	33.3861	31.0785	24.9330	6.7840	0.8630
50.00	48.9155	49.8589	49.6166	45.5560	40.1320	36.6409	31.9507	18.5458	2.8446
30.00	44.4896	48.2569	49.8550	44.4503	36.7820	35.4985	32.6804	22.0033	3.7394
10.00	34.3202	44.4882	48.9102	41.3206	28.4526	32.4258	32.1844	22.5079	3.9118
	0.00	10.00	30.00	50.00	70.00	90.00	110.00	130.00	150.00	170.00

Table 3J, group 1 (cont'd)

60.00<Z< 80.00

170.00									
	3.1105	2.9724	2.2600	0.6853	0.0532	0.0109	0.0003	0.0000	0.0000
150.00									
	17.8939	17.4882	14.7334	5.3871	2.2336	0.5484	0.0250	0.0004	0.0000
130.00									
	25.5838	25.9726	25.3833	19.7998	12.7352	3.6200	0.6119	0.0250	0.0003
110.00									
	25.7737	28.2120	29.1125	24.6850	18.0842	12.3374	3.6191	0.5482	0.0109
90.00									
	22.6139	29.2314	31.8879	26.5202	17.5601	18.0774	12.7289	2.2326	0.0531
70.00									
	32.8383	35.3227	36.1948	32.1973	26.5093	24.6670	19.7828	5.3816	0.6845
50.00									
	38.8660	39.6138	39.4173	36.1845	31.8667	29.0833	25.3519	14.7122	2.2563
30.00									
	35.3501	38.3417	39.6076	35.3077	29.2077	28.1775	25.9321	17.4559	2.9663
10.00									
	27.2698	35.3476	38.8575	32.8228	22.5939	25.7385	25.5390	17.8566	3.1031
0.00	10.00	30.00	50.00	70.00	90.00	110.00	130.00	150.00	170.00

40.00<Z< 60.00

170.00									
	2.1779	2.0809	1.5818	0.4795	0.0372	0.0077	0.0002	0.0000	0.0000
150.00									
	12.5311	12.2451	10.3140	3.7696	1.5626	0.3835	0.0175	0.0002	0.0000
130.00									
	17.9201	18.1899	17.7734	13.8599	8.9117	2.5320	0.4277	0.0175	0.0002
110.00									
	18.0575	19.7637	20.3909	17.2854	12.6584	8.6312	2.5304	0.3831	0.0076
90.00									
	15.8450	20.4810	22.3399	18.5760	12.2942	12.6485	8.9008	1.5602	0.0371
70.00									
	23.0100	24.7493	25.3577	22.5534	18.5622	17.2611	13.8339	3.7610	0.4781
50.00									
	27.2325	27.7543	27.6134	25.3450	22.3138	20.3530	17.7302	10.2837	1.5765
30.00									
	24.7689	26.8633	27.7471	24.7317	20.4529	19.7213	18.1390	12.2040	2.0729
10.00									
	19.1067	24.7659	27.2225	22.9919	15.8215	18.0149	17.8655	12.4852	2.1687
0.00	10.00	30.00	50.00	70.00	90.00	110.00	130.00	150.00	170.00

Table 3J, group 1 (cont'd)

20.00<Z< 40.00

170.00									
	1.1532	1.1014	0.8365	0.2546	0.0199	0.0041	0.0001	0.0000	0.0000
150.00									
	6.6443	6.4895	5.4563	1.9888	0.8260	0.2036	0.0094	0.0001	0.0000
130.00									
	9.5245	9.6609	9.4257	7.3408	4.7157	1.3358	0.2270	0.0094	0.0001
110.00									
	9.6255	10.5230	10.8420	9.1873	6.7231	4.5699	1.3346	0.2033	0.0041
90.00									
	8.4531	10.9200	11.8945	9.8957	6.5443	6.7160	4.7073	0.8242	0.0198
70.00									
	12.2690	13.1865	13.5010	12.0114	9.8863	9.1700	7.3218	1.9824	0.2536
50.00									
	14.5051	14.7789	14.6996	13.4924	11.8765	10.8154	9.3949	5.4346	0.8327
30.00									
	13.2090	14.3141	14.7742	13.1746	10.9009	10.4940	9.6258	6.4610	1.0959
10.00									
	10.1951	13.2070	14.4986	12.2569	8.4372	9.5965	9.4874	6.6132	1.1470
0.00	10.00	30.00	50.00	70.00	90.00	110.00	130.00	150.00	170.00

Group 2

Table 3J, group 2

340.00<Z< 360.00

170.00									
	1.9372	1.8395	1.4151	0.6774	0.0045	0.0009	0.0000	0.0000	0.0000
150.00									
	1.4382	1.3988	1.3077	2.9051	1.4098	0.5270	0.0022	0.0000	0.0000
130.00									
	1.7195	1.7428	1.7741	1.5404	1.0921	1.9119	0.5932	0.0022	0.0000
110.00									
	1.5868	1.7587	1.8170	1.5514	1.1889	1.0514	1.9102	0.5262	0.0009
90.00									
	0.8632	1.5547	1.7329	1.4534	0.7304	1.1876	1.0901	1.4064	0.0045
70.00									
	1.5091	1.5758	1.4917	1.5270	1.4518	1.5482	1.5360	2.8949	0.6744
50.00									
	1.6886	1.5015	0.8379	1.4905	1.7300	1.8121	1.7676	1.3018	1.4077
30.00									
	1.5057	1.5736	1.5010	1.5743	1.5516	1.7531	1.7354	1.3916	1.8288
10.00									
	0.8472	1.5055	1.6879	1.5077	0.8614	1.5813	1.7117	1.4302	1.9249
0.00	10.00	30.00	50.00	70.00	90.00	110.00	130.00	150.00	170.00

320.00<Z< 340.00

170.00									
	3.6559	3.4735	2.6748	1.2862	0.0086	0.0017	0.0000	0.0000	0.0000
150.00									
	2.5286	2.4610	2.3239	5.5056	2.6782	1.0046	0.0041	0.0000	0.0000
130.00									
	2.9973	3.0405	3.1102	2.7293	1.9519	3.6405	1.1340	0.0041	0.0000
110.00									
	2.8078	3.0926	3.1902	2.7341	2.1219	1.8937	3.6380	1.0034	0.0017
90.00									
	1.6272	2.7882	3.0756	2.5978	1.3684	2.1200	1.9491	2.6731	0.0086
70.00									
	2.7502	2.8536	2.7003	2.7418	2.5956	2.7297	2.7231	5.4900	1.2816
50.00									
	3.0727	2.7526	1.5878	2.6987	3.0715	3.1833	3.1011	2.3155	2.6631
30.00									
	2.7728	2.8843	2.7519	2.8514	2.7839	3.0847	3.0302	2.4506	3.4563
10.00									
	1.6385	2.7726	3.0717	2.7481	1.6245	2.7999	2.9862	2.5170	3.6364
0.00	10.00	30.00	50.00	70.00	90.00	110.00	130.00	150.00	170.00

Table 3J, group 2 (cont'd)

300.00<Z< 320.00

170.00	5.3909	5.1236	3.9484	1.9009	0.0127	0.0026	0.0000	0.0000	0.0000
150.00	3.7317	3.6334	3.4351	8.1539	3.9715	1.4908	0.0061	0.0000	0.0000
130.00	4.4424	4.5089	4.6163	4.0533	2.8999	5.4116	1.6854	0.0061	0.0000
110.00	4.2030	4.6343	4.7830	4.0955	3.1700	2.8202	5.4095	1.4898	0.0025
90.00	2.4941	4.2717	4.7082	3.9619	2.0684	3.1682	2.8973	3.9669	0.0127
70.00	4.3229	4.4983	4.2638	4.2721	3.9596	4.0909	4.0469	8.1378	1.8959
50.00	4.8910	4.4224	2.6178	4.2620	4.7037	4.7753	4.6062	3.4257	3.9352
30.00	4.4205	4.6219	4.4216	4.4959	4.2667	4.6253	4.4968	3.6212	5.1033
10.00	2.6091	4.4203	4.8900	4.3206	2.4910	4.1937	4.4292	3.7177	5.3675
	0.00	10.00	30.00	50.00	70.00	90.00	110.00	130.00	150.00	170.00

280.00<Z< 300.00

170.00	7.0967	6.7469	5.2032	2.5078	0.0168	0.0034	0.0000	0.0000	0.0000
150.00	4.9246	4.7970	4.5394	10.7825	5.2580	1.9746	0.0081	0.0000	0.0000
130.00	5.8928	5.9848	6.1327	5.3850	3.8512	7.1786	2.2349	0.0081	0.0000
110.00	5.6336	6.2249	6.4317	5.4970	4.2340	3.7515	7.1776	1.9742	0.0034
90.00	3.4311	5.8939	6.5064	5.4404	2.7984	4.2327	3.8497	5.2553	0.0168
70.00	6.1455	6.4724	6.2284	6.0770	5.4385	5.4934	5.3801	10.7701	2.5038
50.00	7.0647	6.5676	4.1420	6.2268	6.5025	6.4251	6.1239	4.5311	5.1915
30.00	6.3731	6.7583	6.5670	6.4703	5.8894	6.2165	5.9735	4.7853	6.7277
10.00	3.7404	6.3729	7.0639	6.1435	3.4282	5.6250	5.8802	4.9111	7.0740
	0.00	10.00	30.00	50.00	70.00	90.00	110.00	130.00	150.00	170.00

Table 3J, group 2 (cont'd)

260.00<Z< 280.00

170.00									
8.7084	8.2828	6.3927	3.0844	0.0207	0.0042	0.0000	0.0000	0.0000	
150.00									
6.0540	5.8998	5.5891	13.2932	6.4889	2.4374	0.0100	0.0001	0.0000	
130.00									
7.2807	7.3995	7.5898	6.6650	4.7642	8.8734	2.7610	0.0100	0.0000	
110.00									
7.0359	7.7913	8.0607	6.8754	5.2682	4.6474	8.8734	2.4373	0.0042	
90.00									
4.4056	7.5974	8.4137	6.9823	3.5327	5.2676	4.7634	6.4878	0.0207	
70.00									
8.1685	8.8206	8.9519	8.2057	6.9811	6.8731	6.6620	13.2854	3.0816	
50.00									
9.5800	9.5574	9.0866	8.9507	8.4109	8.0559	7.5835	5.5830	6.3837	
30.00									
8.5745	9.3328	9.5569	8.8190	7.5940	7.7850	7.3907	5.8906	8.2674	
10.00									
4.9946	8.5743	9.5794	8.1669	4.4034	7.0292	7.2707	6.0431	8.6906	
0.00	10.00	30.00	50.00	70.00	90.00	110.00	130.00	150.00	170.00

240.00<Z< 260.00

170.00									
10.1743	9.6793	7.4754	3.6101	0.0243	0.0049	0.0000	0.0000	0.0000	
150.00									
7.0837	6.9058	6.5480	15.5892	7.6156	2.8609	0.0118	0.0001	0.0000	
130.00									
8.5550	8.6993	8.9299	7.8420	5.6027	10.4277	3.2432	0.0118	0.0000	
110.00									
8.3389	9.2490	9.5768	8.1558	6.2242	5.4716	10.4286	2.8614	0.0049	
90.00									
5.3287	9.2067	10.2078	8.4308	4.2183	6.2242	5.6030	7.6163	0.0243	
70.00									
10.1053	11.0102	11.3126	10.1685	8.4303	8.1549	7.8408	15.5857	3.6085	
50.00									
11.9766	12.1883	12.0981	11.3119	10.2062	9.5741	8.9261	6.5440	7.4691	
30.00									
10.7037	11.7635	12.1881	11.0093	9.2046	9.2449	8.6932	6.8991	9.6678	
10.00									
6.2139	10.7036	11.9763	10.1043	5.3272	8.3343	8.5477	7.0755	10.1603	
0.00	10.00	30.00	50.00	70.00	90.00	110.00	130.00	150.00	170.00

Table 3J, group 2 (cont'd)

220.00<Z< 240.00

170.00									
	11.3664	10.8134	8.3546	4.0372	0.0272	0.0055	0.0000	0.0000	0.0000
150.00									
	7.9207	7.7236	7.3277	17.4577	8.5326	3.2056	0.0132	0.0001	0.0000
130.00									
	9.5935	9.7586	10.0221	8.8011	6.2859	11.6939	3.6359	0.0132	0.0000
110.00									
	9.4037	10.4394	10.8138	9.2001	7.0040	6.1436	11.6958	3.2068	0.0055
90.00									
	6.0819	10.5135	11.6562	9.6036	4.7766	7.0047	6.2874	8.5353	0.0272
70.00									
	11.6737	12.7384	13.1028	11.7075	9.6037	9.2008	8.8019	17.4584	4.0369
50.00									
	13.9090	14.2040	14.1772	13.1027	11.6559	10.8131	10.0207	7.3260	8.3512
30.00									
	12.4364	13.6955	14.2040	12.7382	10.5127	10.4374	9.7550	7.7193	10.8053
10.00									
	7.2135	12.4364	13.9090	11.6735	6.0813	9.4010	9.5887	7.9150	11.3540
	0.00	10.00	30.00	50.00	70.00	90.00	110.00	130.00	150.00	170.00

200.00<Z< 220.00

170.00									
	12.2190	11.6268	8.9855	4.3439	0.0292	0.0059	0.0000	0.0000	0.0000
150.00									
	8.5216	8.3107	7.8878	18.7997	9.1923	3.4536	0.0142	0.0001	0.0000
130.00									
	10.3400	10.5202	10.8074	9.4909	6.7775	12.6047	3.9184	0.0142	0.0000
110.00									
	10.1702	11.2960	11.7030	9.9509	7.5649	6.6271	12.6077	3.4552	0.0059
90.00									
	6.6227	11.4489	12.6894	10.4411	5.1771	7.5663	6.7799	9.1965	0.0292
70.00									
	12.7932	13.9614	14.3558	12.7924	10.4419	9.9529	9.4935	18.8052	4.3448
50.00									
	15.2861	15.6216	15.5992	14.3562	12.6904	11.7043	10.8085	7.8882	8.9849
30.00									
	13.6779	15.0687	15.6220	13.9620	11.4494	11.2959	10.5193	8.3089	11.6223
10.00									
	7.9330	13.6780	15.2866	12.7938	6.6229	10.1695	10.3380	8.5184	12.2112
	0.00	10.00	30.00	50.00	70.00	90.00	110.00	130.00	150.00	170.00

Table 3J, group 2 (cont'd)

180.00<Z< 200.00

170.00									
	12.7236	12.1103	9.3610	4.5266	0.0305	0.0061	0.0001	0.0000	0.0000
150.00									
	8.8796	8.6606	8.2218	19.6005	9.5871	3.6023	0.0148	0.0001	0.0000
130.00									
	10.7863	10.9757	11.2771	9.9038	7.0720	13.1502	4.0877	0.0148	0.0001
110.00									
	10.6302	11.8095	12.2354	10.4003	7.9010	6.9170	13.1543	3.6042	0.0062
90.00									
	6.9462	12.0051	13.2996	10.9366	5.4161	7.9030	7.0752	9.5927	0.0305
70.00									
	13.4562	14.6737	15.0696	13.4189	10.9382	10.4036	9.9083	19.6116	4.5288
50.00									
	16.0999	16.4383	16.3736	15.0706	13.3018	12.2386	11.2810	8.2246	9.3633
30.00									
	14.4194	15.8765	16.4390	14.6751	12.0070	11.8117	10.9779	8.6614	12.1100
10.00									
	8.3664	14.4197	16.1009	13.4577	6.9471	10.6318	10.7875	8.8791	12.7228
	0.00	10.00	30.00	50.00	70.00	90.00	110.00	130.00	150.00	170.00

160.00<Z< 180.00

170.00									
	12.8040	12.1860	9.4204	4.5560	0.0307	0.0062	0.0001	0.0000	0.0000
150.00									
	8.9376	8.7179	8.2769	19.7358	9.6538	3.6277	0.0149	0.0001	0.0000
130.00									
	10.8646	11.0558	11.3600	9.9765	7.1239	13.2469	4.1176	0.0149	0.0001
110.00									
	10.7184	11.9086	12.3378	10.4859	7.9634	6.9694	13.2517	3.6303	0.0062
90.00									
	7.0164	12.1255	13.4299	11.0400	5.4635	7.9659	7.1282	9.6623	0.0307
70.00									
	13.6143	14.8425	15.2363	13.5590	11.0420	10.4904	9.9831	19.7519	4.5599
50.00									
	16.3021	16.6421	16.5718	15.2378	13.4331	12.3431	11.3664	8.2823	9.4266
30.00									
	14.6073	16.0809	16.6431	14.8446	12.1285	11.9128	11.0602	8.7213	12.1908
10.00									
	8.4768	14.6077	16.3035	13.6165	7.0182	10.7219	10.8680	8.9401	12.8073
	0.00	10.00	30.00	50.00	70.00	90.00	110.00	130.00	150.00	170.00

170.00									
12.4531	11.8515	9.1621	4.4314	0.0299	0.0060	0.0001	0.0000	0.0000	
150.00									
8.6938	8.4804	8.0518	19.2005	9.3922	3.5295	0.0145	0.0001	0.0000	
130.00									
10.5730	10.7593	11.0554	9.7087	6.9325	12.8905	4.0067	0.0145	0.0001	
110.00									
10.4377	11.5974	12.0151	10.2103	7.7522	6.7830	12.8955	3.5324	0.0060	
90.00									
6.8409	11.8216	13.0914	10.7589	5.3217	7.7548	6.9372	9.4017	0.0299	
70.00									
13.2882	14.4857	14.8669	13.2238	10.7610	10.2150	9.7160	19.2180	4.4358	
50.00									
15.9203	16.2525	16.1845	14.8685	13.0947	12.0207	11.0624	8.0579	9.1695	
30.00									
14.2690	15.7079	16.2535	14.4878	11.8247	11.6019	10.7641	8.4845	11.8578	
10.00									
8.2812	14.2694	15.9217	13.2904	6.8428	10.4414	10.5768	8.6972	12.4572	
0.00	10.00	30.00	50.00	70.00	90.00	110.00	130.00	150.00	170.00

120.00<Z< 140.00

170.00									
11.6759	11.1124	8.5906	4.1551	0.0280	0.0056	0.0000	0.0000	0.0000	
150.00									
8.1523	7.9521	7.5503	18.0039	8.8073	3.3094	0.0136	0.0001	0.0000	
130.00									
9.9166	10.0915	10.3691	9.1056	6.5011	12.0869	3.7569	0.0136	0.0000	
110.00									
9.7938	10.8822	11.2735	9.5789	7.2713	6.3611	12.0918	3.3121	0.0057	
90.00									
6.4234	11.0991	12.2898	10.0984	4.9935	7.2735	6.5053	8.8153	0.0280	
70.00									
12.4844	13.6081	13.9636	12.4169	10.0999	9.5827	9.1114	18.0187	4.1586	
50.00									
14.9618	15.2729	15.2049	13.9646	12.2923	11.2776	10.3744	7.5550	8.5961	
30.00									
13.4121	14.7637	15.2735	13.6095	11.1011	10.8849	10.0946	7.9548	11.1162	
10.00									
7.7845	13.4124	14.9627	12.4859	6.4245	9.7957	9.9188	8.1541	11.6780	
0.00	10.00	30.00	50.00	70.00	90.00	110.00	130.00	150.00	170.00

Table 3J, group 2 (cont'd)

100.00<Z< 120.00

170.00									
10.4741	9.9688	7.7063	3.7273	0.0251	0.0051	0.0000	0.0000	0.0000	
150.00									
7.3130	7.1331	6.7726	16.1494	7.8997	2.9681	0.0122	0.0001	0.0000	
130.00									
8.8958	9.0526	9.3014	8.1675	5.8306	10.8395	3.3689	0.0122	0.0000	
110.00									
8.7870	9.7635	10.1142	8.5928	6.5215	5.7042	10.8427	2.9698	0.0051	
90.00									
5.7646	9.9607	11.0282	9.0604	4.4789	6.5225	5.8330	7.9044	0.0251	
70.00									
11.2073	12.2150	12.5322	11.1422	9.0606	8.5940	8.1700	16.1566	3.7287	
50.00									
13.4330	13.7111	13.6464	12.5321	11.0282	10.1147	9.3026	6.7739	7.7074	
30.00									
12.0425	13.2552	13.7110	12.2148	9.9601	9.7626	9.0517	7.1322	9.9669	
10.00									
6.9894	12.0424	13.4328	11.2071	5.7641	8.7855	8.8940	7.3109	10.4706	
0.00	10.00	30.00	50.00	70.00	90.00	110.00	130.00	150.00	170.00

80.00<Z< 100.00

170.00									
8.9333	8.5016	6.5718	3.1784	0.0214	0.0043	0.0000	0.0000	0.0000	
150.00									
6.2366	6.0830	5.7753	13.7715	6.7354	2.5306	0.0104	0.0001	0.0000	
130.00									
7.5866	7.7201	7.9320	6.9643	4.9712	9.2409	2.8716	0.0104	0.0000	
110.00									
7.4945	8.3273	8.6260	7.3276	5.5601	4.8622	9.2415	2.5311	0.0043	
90.00									
4.9177	8.4973	9.4072	7.7275	3.8187	5.5597	4.9713	6.7365	0.0214	
70.00									
9.5631	10.4223	10.6918	9.5040	7.7262	7.3259	6.9631	13.7693	3.1776	
50.00									
11.4630	11.7000	11.6444	10.6904	9.4046	8.6226	7.9286	5.7727	6.5682	
30.00									
10.2768	11.3114	11.6991	10.4203	8.4941	8.3226	7.7147	6.0730	8.4938	
10.00									
5.9644	10.2765	11.4619	9.5609	4.9156	7.4896	7.5803	6.2303	8.9231	
0.00	10.00	30.00	50.00	70.00	90.00	110.00	130.00	150.00	170.00

Table 3J, group 2 (cont'd)

60.00<Z< 80.00

170.00									
	7.0946	6.7511	5.2182	2.5234	0.0170	0.0034	0.0000	0.0000	0.0000
150.00									
	4.9538	4.8315	4.5865	10.9335	5.3466	2.0085	0.0083	0.0000	0.0000
130.00									
	6.0268	6.1324	6.3001	5.5305	3.9469	7.3342	2.2786	0.0083	0.0000
110.00									
	5.9544	6.6157	6.8525	5.8202	4.4151	3.8595	7.3326	2.0079	0.0034
90.00									
	3.9083	6.7520	7.4744	6.1388	3.0331	4.4135	3.9451	5.3441	0.0170
70.00									
	7.6002	8.2826	8.4958	7.5506	6.1364	5.8161	5.5259	10.9230	2.5204
50.00									
	9.1104	9.2982	9.2533	8.4935	7.4696	6.8459	6.2926	4.5803	5.2099
30.00									
	8.1678	8.9896	9.2968	8.2792	6.7468	6.6079	6.1233	4.8229	6.7377
10.00									
	4.7411	8.1673	9.1084	7.5967	3.9050	5.9466	6.0167	4.9439	7.0784
0.00	10.00	30.00	50.00	70.00	90.00	110.00	130.00	150.00	170.00

40.00<Z< 60.00

170.00									
	4.9665	4.7253	3.6515	1.7652	0.0119	0.0024	0.0000	0.0000	0.0000
150.00									
	3.4665	3.3804	3.2083	7.6486	3.7396	1.4043	0.0058	0.0000	0.0000
130.00									
	4.2178	4.2912	4.4078	3.8684	2.7599	5.1284	1.5927	0.0058	0.0000
110.00									
	4.1680	4.6306	4.7955	4.0720	3.0879	2.6981	5.1254	1.4030	0.0024
90.00									
	2.7348	4.7266	5.2319	4.2962	2.1208	3.0855	2.7566	3.7340	0.0119
70.00									
	5.3209	5.7984	5.9470	5.2845	4.2931	4.0665	3.8613	7.6318	1.7603
50.00									
	6.3780	6.5091	6.4765	5.9441	5.2260	4.7869	4.3974	3.1993	3.6395
30.00									
	5.7180	6.2931	6.5074	5.7944	4.7204	4.6210	4.2796	3.3694	4.7077
10.00									
	3.3175	5.7173	6.3757	5.3168	2.7309	4.1585	4.2054	3.4542	4.9462
0.00	10.00	30.00	50.00	70.00	90.00	110.00	130.00	150.00	170.00

Table 3J, group 2 (cont'd)

20.00<z< 40.00

170.00									
	2.6899	2.5587	1.9762	0.9517	0.0064	0.0013	0.0000	0.0000	0.0000
150.00									
	2.0216	1.9705	1.8523	4.1390	2.0217	0.7571	0.0031	0.0000	0.0000
130.00									
	2.4934	2.5338	2.5900	2.2510	1.5944	2.7761	0.8581	0.0031	0.0000
110.00									
	2.4777	2.7451	2.8364	2.4074	1.8207	1.5588	2.7737	0.7560	0.0013
90.00									
	1.6534	2.8104	3.1010	2.5513	1.2781	1.8188	1.5916	2.0172	0.0064
70.00									
	3.1634	3.4402	3.5245	3.1338	2.5489	2.4029	2.2452	4.1261	0.9480
50.00									
	3.7820	3.8582	3.8376	3.5223	3.0964	2.8297	2.5818	1.8452	1.9674
30.00									
	3.4007	3.7343	3.8570	3.4372	2.8056	2.7378	2.5249	1.9621	2.5463
10.00									
	2.0057	3.4002	3.7804	3.1604	1.6504	2.4705	2.4840	2.0124	2.6759
0.00	10.00	30.00	50.00	70.00	90.00	110.00	130.00	150.00	170.00

BENCHMARK PROBLEM SOLUTION

Identification: 11-A1-3 Benchmark Problem ID.11-A1

Date Submitted: June 1976 By: H. Finnemann (KWU)

Date Accepted: June 1977 By: H. L. Dodds, Jr. (U. of Tenn.)
M. V. Gregory (SRL)

Descriptive Title: Fifth Order Nodal Solution with IQSBOX

Mathematical Model

The IQSBOX program solves the time-dependent two-group neutron diffusion equation in one, two or three dimensions by the nodal expansion method (NEM).

NEM is a consistent nodal technique that converges towards the exact solution of the diffusion equation for small mesh sizes. Subsidiary 1-D diffusion equations are solved in each box by polynomial expansion to obtain spatial coupling coefficients. Polynomials up to fifth order can be used.

Computer: CDC 6600

References

H. Finnemann
A Consistent Nodal Method for the Analysis of Space-Time Effects in Large LWR's.
Proc. of the Joint NEACRP/CSNI Specialists' Meeting on New Developments in Three-Dimensional Neutron Kinetics and Review of Kinetics Benchmark Calculations
Munich, January 22-24 (1975), MRR 145

F. Bennewitz, H. Finnemann, H. Moldaschl
Solution of the Multidimensional Neutron Diffusion Equation by Nodal Expansion
CONF-750413, Proc. Conf. on Comput. Methods in Nucl. Eng., April 15 - 17, 1975
Charleston, South Carolina

F. Bennewitz, H. Finnemann, M. R. Wagner
Higher Order Corrections in Nodal Reactor Calculations.
Trans. Am. Nucl. Soc. 22, 250 (1975).

Results

1 Maximum Eigenvalue

1.1	Solution 1	$k_{eff} = 1.02911$
	Mesh size	20 cm
	Number of Unknowns	5054 per group
	44 iterations were required for a pointwise flux convergence of	$\varepsilon < 10^{-5}$
	Computing time	50 s
1.2	Solution 2	$k_{eff} = 1.02904$
	Mesh size in the x-y plane and in the axial reflector	10 cm
	Axial mesh size in the core	20 cm
	Number of Unknowns	18669 per group
	74 iterations were required for a pointwise flux convergence of	$\varepsilon < 10^{-5}$
	Computing time	4.6 min

2 Power and Flux Distributions

2.1 Average Subassembly Powers

Table I : Axial Average

Table II: Average Subassembly Powers for layers 2 to 18 where 2 is lowest and 18 the highest layer in the core consisting of cubical boxes with a sidelength of 20 cm.

2.2 Average Subassembly Thermal Core Fluxes

Table III: Axial Average

Table IV : Thermal Core Fluxes
for layers 2 to 18 defined above.

2.3 Average Subassembly Fast Core Fluxes

Table V : Axial Average

Table VI: Fast Core Fluxes
for layers 2 to 18 defined above.

Table I

Average Subassembly Powers
Axial average

					.598	20 x 20 x 20		mesh
					.597	10 x 10 x 20 (10)		mesh
				.474	.703	.611		
				.475	.699	.608		
			1.179	.972	.926	.866		
			1.179	.972	.923	.864		
		1.366	1.311	1.181	1.087	.995	.707	
		1.369	1.311	1.181	1.088	.997	.707	
	1.398	1.431	1.291	1.072	1.054	.974	.752	
	1.398	1.432	1.291	1.072	1.055	.974	.753	
.726	1.282	1.423	1.194	.608	.953	.958	.770	
.729	1.283	1.423	1.195	.610	.953	.958	.773	

Table II

Average Subassembly Powers
Layer 2

					.199	20 x 20 x 20		mesh
					.197	10 x 10 x 20 (10)		mesh
				.166	.237	.202		
				.165	.253	.201		
			.416	.337	.315	.288		
			.413	.335	.312	.287		
		.511	.468	.410	.370	.334	.233	
		.509	.466	.408	.369	.333	.232	
	.501	.515	.459	.373	.360	.328	.250	
	.499	.513	.456	.372	.358	.326	.249	
.264	.458	.506	.423	.216	.326	.323	.256	
.263	.456	.504	.421	.215	.324	.321	.255	

Table II cont.

Average Subassembly Powers
Layer 3

					.349	20 x 20 x 20		mesh
					.347	10 x 10 x 20 (10)		mesh
				.281	.412	.356		
				.279	.408	.353		
			.717	.580	.545	.505		
			.713	.577	.540	.502		
		.882	.808	.708	.641	.581	.411	
		.878	.804	.704	.638	.579	.409	
	.864	.890	.791	.643	.621	.568	.437	
	.859	.885	.786	.639	.618	.565	.435	
.446	.788	.874	.728	.364	.561	.559	.447	
.445	.784	.870	.724	.363	.558	.555	.446	

Table II cont.

Average Subassembly Powers
Layer 4

					.501	20 x 20 x 20		mesh
					.499	10 x 10 x 20 (10)		mesh
				.402	.590	.511		
				.402	.587	.508		
			1.026	.831	.780	.724		
			1.025	.830	.777	.722		
		1.262	1.157	1.013	.917	.832	.589	
		1.263	1.156	1.012	.918	.833	.589	
	1.236	1.273	1.132	.920	.889	.814	.626	
	1.235	1.273	1.131	.919	.889	.813	.626	
.638	1.128	1.251	1.042	.521	.803	.800	.640	
.640	1.127	1.250	1.042	.523	.802	.799	.642	

Table II cont.

Average Subassembly Powers
Layer 5

					.634	20 x 20 x 20		mesh
					.632	10 x 10 x 20 (10)		mesh
				.509	.747	.647		
				.510	.744	.64[illegible]		
			1.299	1.052	.988	.917		
			1.299	1.052	.984	.915		
		1.598	1.464	1.283	1.162	1.054	.746	
		1.600	1.464	1.283	1.163	1.056	.746	
	1.564	1.611	1.433	1.164	1.125	1.031	.793	
	1.564	1.612	1.432	1.165	1.126	1.031	.794	
.808	1.428	1.584	1.319	.660	1.017	1.014	.811	
.810	1.428	1.584	1.319	.662	1.017	1.013	.814	

Table II cont.

Average Subassembly Powers

Layer 6

					.745	20 x 20 x 20		mesh
					.743	10 x 10 x 20 (10)		mesh
				.598	.878	.761		
				.599	.874	.757		
			1.526	1.236	1.160	1.078		
			1.526	1.237	1.157	1.076		
		1.876	1.720	1.507	1.365	1.239	.877	
		1.880	1.721	1.508	1.367	1.242	.877	
	1.837	1.892	1.682	1.368	1.322	1.211	.932	
	1.837	1.894	1.683	1.369	1.324	1.211	.933	
.948	1.676	1.859	1.549	.775	1.195	1.191	.953	
.952	1.677	1.860	1.550	.778	1.195	1.191	.957	

Table II cont.

Average Subassembly Powers
Layer 7

					.830	20 x 20 x 20		mesh
					.828	10 x 10 x 20 (10)		mesh
				.666	.978	.847		
				.667	.974	.844		
			1.698	1.376	1.292	1.200		
			1.699	1.377	1.289	1.198		
		2.088	1.914	1.677	1.520	1.380	.977	
		2.092	1.915	1.678	1.522	1.383	.977	
	2.043	2.105	1.872	1.522	1.472	1.349	1.038	
	2.044	2.107	1.873	1.524	1.474	1.350	1.039	
1.055	1.865	2.069	1.723	.862	1.330	1.326	1.061	
1.059	1.866	2.070	1.725	.866	1.331	1.327	1.066	

Table II cont.

Average Subassembly Powers
Layer 8

					.885	20 x 20 x 20		mesh
					.884	10 x 10 x 20 (10)		mesh
				.710	1.043	.904		
				.712	1.039	.900		
			1.810	1.467	1.378	1.281		
			1.811	1.468	1.375	1.278		
		2.224	2.039	1.788	1.621	1.472	1.042	
		2.229	2.041	1.790	1.624	1.476	1.043	
	2.175	2.242	1.994	1.623	1.570	1.439	1.108	
	2.178	2.245	1.996	1.624	1.573	1.440	1.109	
1.123	1.985	2.203	1.835	.919	1.418	1.415	1.133	
1.128	1.988	2.205	1.838	.923	1.420	1.416	1.138	

Table II cont.

Average Subassembly Powers
Layer 9

					.910	20 x 20 x 20		mesh
					.908	10 x 10 x 20 (10,		mesh
				.729	1.072	.929		
				.731	1.067	.925		
			1.857	1.506	1.415	1.316		
			1.858	1.507	1.412	1.314		
		2.280	2.091	1.835	1.665	1.513	1.071	
		2.285	2.094	1.837	1.668	1.517	1.072	
	2.229	2.298	2.045	1.665	1.612	1.479	1.139	
	2.231	2.301	2.047	1.667	1.615	1.480	1.141	
1.150	2.034	2.257	1.882	.943	1.457	1.454	1.164	
1.155	2.037	2.260	1.885	.947	.1458	1.455	1.170	

Table II cont.

Average Subassembly Powers
Layer 10

					.903	20 x 20 x 20		mesh
					.901	10 x 10 x 20 (10)		mesh
				.722	1.063	.922		
				.725	1.059	.918		
			1.837	1.491	1.404	1.306		
			1.839	1.493	1.401	1.304		
		2.252	2.068	1.817	1.651	1.501	1.064	
		2.258	2.070	1.819	1.654	1.505	1.065	
	2.200	2.269	2.021	1.648	1.599	1.468	1.131	
	2.203	2.273	2.023	1.650	1.602	1.469	1.133	
1.153	2.008	2.229	1.859	.934	1.445	1.443	1.157	
1.140	2.010	2.232	1.863	.938	1.446	1.445	1.162	

Table II cont.

Average Subassembly Powers
Layer 11

					.865	20 x 20 x 20		mesh
					.864	10 x 10 x 20 (10)		mesh
				.691	1.018	.884		
				.693	1.014	.881		
			1.752	1.424	1.344	1.252		
			1.753	1.426	1.341	1.250		
		2.142	1.969	1.734	1.580	1.439	1.021	
		2.147	1.972	1.736	1.583	1.443	1.022	
	2.089	2.156	1.923	1.573	1.530	1.407	1.085	
	2.092	2.160	1.925	1.575	1.533	1.409	1.087	
1.078	1.906	2.118	1.769	.891	1.383	1.384	1.110	
1.082	1.909	2.120	1.772	.895	1.384	1.385	1.116	

Table II cont.

Average Subassembly Powers
Layer 12

					.800	20 x 20 x 20		mesh
					.799	10 x 10 x 20 (10)		mesh
				.636	.940	.817		
				.638	.936	.814		
			1.602	1.307	1.239	1.158		
			1.603	1.309	1.236	1.156		
		1.948	1.796	1.590	1.456	1.331	.946	
		1.953	1.799	1.592	1.459	1.335	.947	
	1.898	1.960	1.753	1.441	1.410	1.302	1.006	
	1.900	1.963	1.755	1.443	1.413	1.303	1.008	
.979	1.732	1.926	1.612	.816	1.275	1.281	1.029	
.983	1.734	1.928	1.615	.820	1.277	1.282	1.034	

Table II cont.

Average Subassembly Powers
Layer 13

					.711	20 x 20 x 20		mesh
					.710	10 x 10 x 20 (10)		mesh
				.560	.834	.727		
				.562	.830	.724		
			1.390	1.146	1.096	1.029		
			1.391	1.147	1.094	1.028		
		1.669	1.551	1.391	1.287	1.183	.843	
		1.675	1.553	1.392	1.289	1.186	.844	
	1.630	1.683	1.515	1.260	1.247	1.158	.897	
	1.632	1.686	1.517	1.262	1.249	1.159	.899	
.842	1.490	1.658	1.395	.714	1.128	1.139	.918	
.846	1.491	1.659	1.397	.717	1.129	1.140	.922	

Table II cont.

Average Subassembly Powers

Layer 12

					.800	20 x 20 x 20		mesh
					.799	10 x 10 x 20 (10)		mesh
				.636	.940	.817		
				.638	.936	.814		
			1.602	1.307	1.239	1.158		
			1.603	1.309	1.236	1.156		
		1.948	1.796	1.590	1.456	1.331	.946	
		1.953	1.799	1.592	1.459	1.335	.947	
	1.898	1.960	1.753	1.441	1.410	1.302	1.006	
	1.900	1.963	1.755	1.443	1.413	1.303	1.008	
.979	1.732	1.926	1.612	.816	1.275	1.281	1.029	
.983	1.734	1.928	1.615	.820	1.277	1.282	1.034	

Table II cont.

Average Subassembly Powers
Layer 13

					.711	20 x 20 x 20		mesh
					.710	10 x 10 x 20 (10)		mesh
				.560	.834	.727		
				.562	.830	.724		
			1.390	1.146	1.096	1.029		
			1.391	1.147	1.094	1.028		
		1.669	1.551	1.391	1.287	1.183	.843	
		1.675	1.553	1.392	1.289	1.186	.844	
	1.630	1.683	1.515	1.260	1.247	1.158	.897	
	1.632	1.686	1.517	1.262	1.249	1.159	.899	
.842	1.490	1.658	1.395	.714	1.128	1.139	.918	
.846	1.491	1.659	1.397	.717	1.129	1.140	.922	

Table. II cont.

Average Subassembly Powers

Layer 14

					.604	20 x 20 x 20		mesh
					.603	10 x 10 x 20 (10)		mesh
				.470	.706	.618		
				.471	.703	.616		
			1.122	.950	.925	.875		
			1.123	.951	.922	.873		
		1.254	1.229	1.148	1.084	1.006	.720	
		1.261	1.231	1.148	1.085	1.008	.720	
	1.297	1.323	1.215	1.041	1.051	.985	.766	
	1.298	1.325	1.216	1.042	1.052	.986	.768	
.679	1.197	1.330	1.130	.591	.952	.970	.784	
.682	1.198	1.330	1.131	.594	.953	.970	.788	

Table II cont.

Average Subassembly Powers

Layer 15

					.487	20 x 20 x 20		mesh
					.486	10 x 10 x 20 (10)		mesh
				.371	.566	.499		
				.372	.564	.497		
			.831	.739	.738	.705		
			.831	.739	.735	.704		
		.558	.856	.885	.863	.811	.583	
		.560	.856	.886	.864	.813	.583	
	.941	.912	.893	.807	.838	.795	.622	
	.941	.913	.893	.807	.839	.795	.622	
.509	.891	.983	.850	.460	.761	.783	.636	
.511	.891	.984	.850	.461	.761	.783	.639	

<u>Table II</u> cont.
Average Subassembly Powers
Layer 16

					.365	20 x 20 x 20		mesh
					.364	10 x 10 x 20 (10)		mesh
				.274	.423	.375		
				.274	.421	.373		
			.582	.537	.549	.530		
			.581	.536	.546	.528		
		.349	.583	.639	.640	.609	.440	
		.349	.583	.639	.640	.610	.440	
	.642	.612	.618	.583	.623	.598	.470	
	.641	.612	.617	.583	.623	.597	.470	
.355	.617	.679	.597	.333	.566	.589	.481	
.356	.616	.679	.596	.334	.566	.589	.483	

<u>Table II</u> cont.

Average Subassembly Powers

Layer 17

					.244	20 x 20 x 20		mesh
					.243	10 x 10 x 20 (10)		mesh
				.181	.282	.251		
				.180	.279	.249		
			.374	.351	.365	.355		
			.372	.349	.362	.353		
		.217	.372	.417	.425	.408	.296	
		.217	.369	.414	.423	.407	.295	
	.403	.384	.393	.380	.414	.401	.317	
	.400	.382	.391	.378	.412	.399	.315	
.223	.388	.429	.380	.217	.377	.396	.324	
.223	.386	.426	.378	.217	.375	.393	.324	

Table II cont.
Average Subassembly Powers
Layer 18

					.134	20 x 20 x 20		mesh
					.133	10 x 10 x 20 (10)		mesh
				.094	.155	.138		
				.094	.153	.137		
			.204	.193	.203	.197		
			.203	.191	.201	.195		
		.110	.201	.230	.237	.228	.164	
		.111	.199	.229	.236	.227	.164	
	.216	.205	.213	.208	.230	.225	.177	
	.214	.204	.212	.206	.229	.224	.176	
.113	.207	.231	.205	.112	.209	.222	.181	
.113	.206	.230	.203	.113	.207	.221	.181	

Table III

Average Subassembly Thermal Fluxes

Axial Average

					4.430	20 x 20 x 20		mesh
					4.419	10 x 10 x 20 (10)		mesh
				3.511	5.205	4.526		
				3.519	5.179	4.507		
			8.734	7.199	6.856	6.413		
			8.732	7.201	6.834	6.398		
		10.12	9.711	8.747	8.054	7.372	5.239	
		10.14	9.714	8.747	8.061	7.387	5.240	
	10.36	10.60	9.566	7.939	7.805	7.215	5.573	
	10.36	10.61	9.566	7.941	7.812	7.214	5.579	
5.379	9.498	10.54	8.844	4.501	7.060	7.098	5.702	
5.398	9.500	10.54	8.849	4.517	7.060	7.097	5.726	

Table IV

Average Subassembly Thermal Fluxes

Layer 2

					1.471	20 x 20 x 20		mesh
					1.462	10 x 10 x 20 (10)		mesh
				1.227	1.758	1.500		
				1.222	1.742	1.489		
			3.079	2.495	2.331	2.136		
			3.062	2.483	2.313	2.123		
		3.784	3.467	3.036	2.744	2.471	1.729	
		3.771	3.451	3.022	2.732	2.465	1.722	
	3.711	3.817	3.397	2.765	2.664	2.429	1.849	
	3.693	3.801	3.380	2.752	2.653	2.417	1.843	
1.956	3.393	3.751	3.132	1.597	2.413	2.391	1.893	
1.951	3.378	3.736	3.119	1.593	2.401	2.379	1.892	

Table IV cont.

Average Subassembly Therm. Fluxes

Layer 3

					2.588	20 x 20 x 20		mesh
					2.570	10 x 10 x 20 (10)		mesh
				2.080	3.051	2.640		
				2.070	3.019	2.617		
			5.312	4.299	4.034	3.744		
			5.279	4.275	3.998	3.716		
		6.536	5.988	5.244	4.747	4.304	3.045	
		6.506	5.953	5.214	4.723	4.288	3.030	
	6.399	6.592	5.859	4.760	4.599	4.210	3.236	
	6.362	6.556	5.824	4.733	4.575	4.184	3.222	
3.306	5.840	6.477	5.393	2.700	4.155	4.139	3.310	
3.293	5.807	6.441	5.365	2.689	4.130	4.114	3.306	

Table IV cont.

Average Subassembly Therm. Fluxes

Layer 4

					3.708	20 x 20 x 20		mesh
					3.696	10 x 10 x 20 (10)		mesh
				2.976	4.371	3.784		
				2.981	4.346	3.765		
			7.602	6.154	5.776	5.364		
			7.593	6.151	5.754	5.347		
		9.351	8.568	7.506	6.796	6.165	4.363	
		9.357	8.562	7.500	6.797	6.172	4.360	
	9.154	9.430	8.383	6.812	6.583	6.028	4.637	
	9.148	9.427	8.376	6.809	6.583	6.023	4.637	
4.726	8.356	9.267	7.716	3.860	5.947	5.927	4.742	
4.739	8.351	9.262	7.715	3.871	5.943	5.922	4.757	

Table IV cont.

Average Subassembly Therm. Fluxes

Layer 5

					4.698	20 x 20 x 20		mesh
					4.685	10 x 10 x 20 (10)		mesh
				3.769	5.537	4.794		
				3.777	5.508	4.772		
			9.625	7.793	7.316	6.795		
			9.620	7.794	7.293	6.778		
		11.84	10.85	9.504	8.607	7.810	5.528	
		11.85	10.85	9.502	8.613	7.823	5.527	
	11.59	11.94	10.61	8.626	8.337	7.636	5.874	
	11.59	11.94	10.61	8.627	8.342	7.634	5.878	
5.982	10.58	11.73	9.768	4.887	7.532	7.508	6.007	
6.001	10.58	11.73	9.773	4.903	7.531	7.506	6.031	

Table IV cont.

Average Subassembly Therm. Fluxes
Layer 6

					5.521	20 x 20 x 20		mesh
					5.507	10 x 10 x 20 (10)		mesh
				4.428	6.506	5.634		
				4.439	6.474	5.610		
			11.30	9.155	8.596	7.985		
			11.30	9.160	8.572	7.968		
		13.90	12.74	11.16	10.11	9.177	6.496	
		13.93	12.74	11.17	10.12	9.197	6.498	
	13.60	14.02	12.46	10.13	9.794	8.973	6.903	
	13.61	14.03	12.47	10.14	9.806	8.974	6.911	
7.023	12.42	13.77	11.47	5.740	8.849	8.822	7.059	
7.049	12.42	13.78	11.48	5.762	8.852	8.823	7.090	

Table IV cont.

Average Subassembly Therm. Fluxes
Layer 7

					6.148	20 x 20 x 20		mesh
					6.135	10 x 10 x 20 (10)		mesh
				4.930	7.244	6.274		
				4.943	7.211	6.249		
			12.58	10.19	9.571	8.892		
			12.58	10.20	9.547	8.875		
		15.46	14.18	12.43	11.26	10.22	7.235	
		15.50	14.19	12.43	11.28	10.24	7.239	
	15.13	15.59	13.87	11.28	10.90	9.992	7.688	
	15.14	15.61	13.87	11.29	10.92	9.997	7.700	
7.811	13.81	15.32	12.76	6.389	9.852	9.825	7.863	
7.843	13.82	15.33	12.78	6.415	9.858	9.829	7.899	

Table IV cont.

Average Subassembly Therm. Fluxes
Layer 8

					6.558	20 x 20 x 20	mesh
					6.546	10 x 10 x 20 (10)	mesh
				5.257	7.727	6.693		
				5.273	7.693	6.668		
			13.41	10.86	10.21	9.486		
			13.41	10.88	10.18	9.470		
		16.47	15.10	13.25	12.01	10.90	7.720	
		16.51	15.12	13.26	12.03	10.93	7.726	
	16.11	16.61	14.77	12.02	11.63	10.66	8.204	
	16.13	16.63	14.78	12.03	11.65	10.67	8.217	
8.317	14.71	16.32	13.60	6.809	10.51	10.48	8.390	
8.353	14.72	16.33	13.61	6.838	10.52	10.49	8.431	

Table IV cont.

Average Subassembly Therm. Fluxes
Layer 9

					6.739	20 x 20 x 20		mesh
					6.727	10 x 10 x 20 (10)		mesh
				5.398	7.939	6.878		
				5.415	7.905	6.854		
			13.76	11.15	10.49	9.748		
			13.76	11.17	10.46	9.734		
		16.89	15.49	13.59	12.33	11.20	7.936	
		16.93	15.51	13.61	12.35	11.24	7.943	
	16.51	17.02	15.15	12.33	11.94	10.96	8.434	
	16.53	17.04	15.16	12.35	11.97	10.96	8.449	
8.520	15.07	16.72	13.94	6.987	10.79	10.77	8.626	
8.558	15.09	16.74	13.96	7.018	10.80	10.78	8.669	

Table IV cont.

Average Subassembly Therm. Fluxes
Layer 10

					6.688	20 x 20 x 20		mesh
					6.676	10 x 10 x 20 (10)		mesh
				5.351	7.875	6.827		
				5.368	7.843	6.803		
			13.61	11.05	10.40	9.675		
			13.62	11.06	10.38	9.661		
		16.68	15.32	13.46	12.23	11.12	7.880	
		16.73	15.34	13.47	12.25	11.15	7.888	
	16.30	16.81	14.97	12.21	11.84	10.87	8.376	
	16.32	16.83	14.99	12.22	11.86	10.88	8.392	
8.409	14.87	16.51	13.77	6.916	10.70	10.69	8.567	
8.447	14.89	16.53	13.80	6.947	10.71	10.70	8.610	

Table IV cont.

Average Subassembly Therm. Fluxes
Layer 11

					6.411	20 x 20 x 20		mesh
					6.400	10 x 10 x 20 (10)		mesh
				5.117	7.544	6.545		
				5.134	7.513	6.523		
			12.97	10.55	9.953	9.275		
			12.98	10.56	9.933	9.262		
		15.86	14.59	12.85	11.70	10.66	7.562	
		15.91	14.60	12.86	11.72	10.69	7.570	
	15.48	15.97	14.25	11.65	11.33	10.43	8.040	
	15.50	16.00	14.26	11.66	11.35	10.44	8.055	
7.982	14.12	15.69	13.10	6.598	10.24	10.25	8.223	
8.018	14.14	15.71	13.13	6.628	10.25	10.26	8.266	

Table IV cont.

Average Subassembly Therm. Fluxes
Layer 12

					5.926	20 x 20 x 20		mesh
					5.916	10 x 10 x 20 (10)		mesh
				4.710	6.965	6.053		
				4.725	6.936	6.032		
			11.86	9.684	9.178	8.576		
			11.87	9.697	9.159	8.564		
		14.43	13.31	11.78	10.78	9.857	7.005	
		14.47	13.32	11.79	10.80	9.885	7.011	
	14.06	14.52	12.99	10.68	10.45	9.643	7.449	
	14.08	14.54	13.00	10.69	10.47	9.652	7.464	
7.250	12.83	14.26	11.94	6.047	9.445	9.485	7.621	
7.283	12.84	14.28	11.96	6.074	9.456	9.493	7.660	

Table IV cont.

Average Subassembly Therm. Fluxes
Layer 13

					5.267	20 x 20 x 20		mesh
					5.257	10 x 10 x 20 (10)		mesh
				4.151	6.176	5.383		
				4.164	6.150	5.363		
			10.30	8.488	8.119	7.624		
			10.30	8.497	8.100	7.612		
		12.37	11.49	10.30	9.531	8.763	6.244	
		12.41	11.51	10.31	9.547	8.787	6.250	
	12.08	12.47	11.22	9.335	9.236	8.576	6.644	
	12.09	12.49	11.23	9.347	9.251	8.583	6.656	
6.240	11.03	12.28	10.33	5.289	8.357	8.439	6.799	
6.269	11.05	12.29	10.35	5.312	8.365	8.445	6.833	

Table IV cont.

Average Subassembly Therm. Fluxes
Layer 14

					4.476	20 x 20 x 20		mesh
					4.466	10 x 10 x 20 (10)		mesh
				3.479	5.230	4.579		
				3.489	5.207	4.561		
			8.314	7.035	6.849	6.482		
			8.319	7.014	6.831	6.470		
		9.289	9.105	8.500	8.026	7.450	5.330	
		9.344	9.116	8.502	8.038	7.469	5.334	
	9.606	9.801	9.004	7.712	7.785	7.296	5.677	
	9.614	9.814	9.011	7.719	7.796	7.301	5.686	
5.030	8.865	9.852	8.367	4.378	7.054	7.183	5.810	
5.052	8.872	9.853	8.377	4.396	7.060	7.187	5.838	

Table IV cont.

Average Subassembly Therm. Fluxes
Layer 15

					3.607	20 x 20 x 20		mesh
					3.597	10 x 10 x 20 (10)		mesh
				2.752	4.195	3.695		
				2.758	4.174	3.679		
			6.158	5.475	5.465	5.225		
			6.155	5.475	5.448	5.214		
		4.135	6.342	6.559	6.389	6.005	4.319	
		4.146	6.343	6.562	6.397	6.019	4.320	
	6.973	6.757	6.613	5.977	6.207	5.887	4.604	
	6.972	6.763	6.612	5.977	6.213	5.888	4.610	
3.773	6.600	7.285	6.299	3.406	5.636	5.800	4.714	
3.786	6.598	7.290	6.300	3.418	5.638	5.801	4.735	

Table IV cont.

Average Subassembly Therm. Fluxes
Layer 16

					2.707	20 x 20 x 20		mesh
					2.698	10 x 10 x 20 (10)		mesh
				2.028	3.135	2.777		
				2.032	3.118	2.763		
			4.310	3.976	4.064	3.925		
			4.304	3.973	4.048	3.915		
		2.585	4.320	4.734	4.742	4.512	3.261	
		2.585	4.315	4.731	4.744	4.519	3.261	
	4.757	4.534	4.579	4.320	4.612	4.427	3.480	
	4.750	4.531	4.574	4.317	4.613	4.425	3.482	
2.626	4.570	5.032	4.420	2.468	4.196	4.365	3.565	
2.634	4.564	5.029	4.416	2.476	4.195	4.362	3.578	

Table IV cont.

Average Subassembly Therm. Fluxes

Layer 17

					1.810	20 x 20 x 20		mesh
					1.798	10 x 10 x 20 (10)		mesh
				1.338	2.090	1.861		
				1.336	2.069	1.844		
			2.772	2.602	2.703	2.631		
			2.754	2.587	2.678	2.612		
		1.609	2.752	3.089	3.151	3.025	2.195	
		1.610	2.735	3.069	3.135	3.015	2.186	
	2.984	2.845	2.914	2.815	3.066	2.971	2.345	
	2.964	2.828	2.895	2.799	3.050	2.955	2.336	
1.653	2.875	3.174	2.816	1.607	2.791	2.931	2.403	
1.653	2.857	3.153	2.799	1.607	2.777	2.914	2.402	

Table IV cont.
Average Subassembly Therm. Fluxes
Layer 18

					.990	20 x 20 x 20		mesh
					.984	10 x 10 x 20 (10)		mesh
				.697	1.148	1.026		
				.699	1.136	1.017		
			1.513	1.428	1.502	1.457		
			1.502	1.418	1.488	1.448		
		.818	1.489	1.705	1.757	1.688	1.216	
		.821	1.478	1.694	1.748	1.684	1.211	
	1.600	1.522	1.579	1.540	1.707	1.666	1.308	
	1.587	1.511	1.567	1.529	1.698	1.658	1.304	
.837	1.536	1.713	1.518	.832	1.546	1.645	1.341	
.840	1.524	1.701	1.507	.836	1.536	1.636	1.341	

Table V

Average Subassembly Fast Fluxes

Axial Average

					14.27	20 x 20 x 20		mesh
					14.27	10 x 10 x 20 (10)		mesh
				20.65	21.18	14.76		
				20.61	21.14	14.71		
			37.13	30.93	28.96	23.04		
			37.13	30.97	28.92	23.03		
		43.90	41.31	37.18	34.13	29.65	17.01	
		43.99	41.33	37.17	34.16	29.70	17.03	
	44.03	45.10	40.67	34.14	33.17	30.47	20.29	
	44.05	45 14	40.68	34.18	33.21	30.50	20.32	
31.77	40.85	44.80	38.01	26.58	30.38	30.05	20.76	
31.77	40.90	44.80	38.07	26.58	30.42	30.08	20.81	

Table VI

Average Subassembly Fast Fluxes

Layer 2

					4.375	20 x 20 x 20		mesh
					4.366	10 x 10 x 20 (10)		mesh
				6.485	6.543	4.515		
				6.429	6.498	4.490		
			11.94	9.769	8.993	7.066		
			11.87	9.724	8.930	7.032		
		14.68	13.45	11.78	10.62	9.109	5.182	
		14.61	13.37	11.71	10.57	9.073	5.172	
	14.39	14.80	13.17	10.84	10.33	9.376	6.192	
	14.31	14.73	13.10	10.79	10.28	9.328	6.174	
10.37	13.30	14.56	12.27	8.467	9.464	9.246	6.339	
10.30	13.24	14.47	12.22	8.408	9.418	9.201	6.323	

Table VI cont.

Average Subassembly Fast Fluxes

Layer 3

					8.351	20 x 20 x 20		mesh
					8.342	10 x 10 x 20 (10)		mesh
				12.25	12.44	8.630		
				12.20	12.39	8.586		
			22.62	18.51	17.08	13.48		
			22.57	18.49	17.02	13.45		
		27.82	25.49	22.33	20.16	17.35	9.903	
		27.81	25.44	22.28	20.13	17.34	9.897	
	27.25	28.06	24.95	20.51	19.59	17.82	11.81	
	27.21	28.02	24.91	20.50	19.56	17.79	11.80	
19.55	25.16	27.59	23.22	15.96	17.92	17.56	12.08	
19.51	25.15	27.53	23.21	15.93	17.90	17.54	12.08	

Table VI cont.

Average Subassembly Fast Fluxes

Layer 4

					11.98	20 x 20 x 20		mesh
					11.97	10 x 10 x 20 (10)		mesh
				17.55	17.84	12.38		
				17.50	17.78	12.32		
			32.40	26.51	24.47	19.33		
			32.37	26.52	24.42	19.30		
		39.84	36.50	31.99	28.89	24.87	14.20	
		39.86	36.48	31.95	28.88	24.88	14.20	
	39.02	40.17	35.73	29.38	28.06	25.54	16.93	
	39.00	40.16	35.71	29.39	28.06	25.53	16.94	
27.99	36.03	39.50	33.25	22.86	25.67	25.17	17.32	
27.95	36.04	39.46	33.27	22.83	25.67	25.17	17.34	

Table VI cont.

Average Subassembly Fast Fluxes

Layer 5

					15.17	20 x 20 x 20		mesh
					15.17	10 x 10 x 20 (10)		mesh
				22.22	22.59	15.68		
				22.18	22.54	15.62		
			41.03	33.57	31.00	24.49		
			41.01	33.60	30.95	24.46		
		50.43	46.21	40.51	36.59	31.50	17.99	
		50.50	46.21	40.49	36.61	31.54	18.01	
	49.39	50.85	45.24	37.20	35.54	32.35	21.45	
	49.40	50.87	45.24	37.24	35.57	32.37	21.47	
35.42	45.61	50.01	42.10	28.94	32.51	31.88	21.94	
35.41	45.65	49.98	42.15	28.93	32.54	31.90	21.98	

Table VI cont.

Average Subassembly Fast Fluxes

Layer 6

					17.83	20 x 20 x 20		mesh
					17.84	10 x 10 x 20 (10)		mesh
				26.11	26.55	18.43		
				26.07	26.49	18.36		
			48.19	39.44	36.42	28.77		
			48.19	39.49	36.38	28.76		
		59.22	54.27	47.59	42.99	37.01	21.15	
		59.33	54.30	47.58	43.03	37.08	21.17	
	57.99	59.71	53.12	43.69	41.75	38.01	25.21	
	58.03	59.76	53.15	43.76	41.80	38.05	25.24	
41.59	53.55	58.71	49.43	33.99	38.19	37.46	25.78	
41.59	53.63	58.71	49.52	34.00	38.24	37.50	25.84	

Table VI cont.

Average Subassembly Fast Fluxes

Layer 7

					19.85	20 x 20 x 20		mesh
					19.87	10 x 10 x 20 (10)		mesh
				29.07	29.56	20.52		
				29.03	29.51	20.45		
			53.63	43.90	40.55	32.04		
			53.65	43.97	40.52	32.03		
		65.89	60.39	52.97	47.86	41.22	23.55	
		66.03	60.44	52.97	47.92	41.30	23.59	
	64.51	66.43	59.11	48.63	46.48	42.33	28.08	
	64.57	66.51	59.15	48.72	46.56	42.39	28.12	
46.26	59.56	65.31	55.00	37.83	42.52	41.72	28.72	
46.27	49.67	65.33	55.11	37.85	42.59	41.78	28.79	

Table VI cont.

Average Subassembly Fast Fluxes

Layer 8

					21.18	20 x 20 x 20		mesh
					21.20	10 x 10 x 20 (10)		mesh
				31.00	31.53	21.89		
				30.96	31.48	21.82		
			57.15	46.80	43.24	34.18		
			57.19	46.89	43.22	34.18		
		70.18	64.34	56.46	51.04	43.97	25.13	
		70.35	64.42	56.48	51.12	44.07	25.17	
	68.69	70.75	62.97	51.83	49.57	45.16	29.96	
	68.77	70.85	63.03	51.93	49.66	45.23	30.01	
49.25	63.43	69.56	58.59	40.33	45.35	44.51	30.64	
49.28	63.55	69.59	58.72	40.35	45.43	44.58	30.73	

Table VI cont.

Average Subassembly Fast Fluxes
Layer 9

						21.77	20 x 20 x 20		mesh
						21.79	10 x 10 x 20 (10)		mesh
					31.83	32.39	22.50		
					31.80	32.35	22.43		
				58.64	48.04	44.42	35.13		
				58.68	48.14	44.40	35.13		
			71.95	65.99	57.94	52.42	45.19	25.83	
			72.13	66.07	57.97	52.51	45.30	25.88	
		70.38	72.51	64.57	53.19	50.91	46.41	30.80	
		70.47	72.62	64.64	53.30	51.01	46.49	30.86	
	50.46	64.98	71.28	60.07	41.38	46.58	45.74	31.50	
	50.49	65.11	71.32	60.21	41.41	46.67	45.82	31.59	

Table VI cont.

Average Subassembly Fast Fluxes
Layer 10

					21.60	20 x 20 x 20		mesh
					21.62	10 x 10 x 20 (10)		mesh
				31.55	32.13	22.33		
				31.52	32.09	22.26		
			58.02	47.58	44.05	34.86		
			58.06	47.68	44.04	34.86		
		71.09	65.26	57.37	51.97	44.85	25.65	
		71.27	65.34	57.40	52.06	44.96	25.70	
	69.48	71.61	63.82	52.65	50.48	46.06	30.59	
	69.58	71.72	63.90	52.77	50.58	46.15	30.65	
49.80	64.14	70.39	59.36	40.95	46.19	45.40	31.29	
49.84	64.28	70.44	59.51	40.99	46.28	45.49	31.38	

Table VI cont.

Average Subassembly Fast Fluxes
Layer 11

					20.70	20 x 20 x 20		mesh
					20.72	10 x 10 x 20 (10)		mesh
				30.17	30.78	21.41		
				30.15	30.74	21.34		
			55.31	45.45	42.17	33.42		
			55.35	45.54	42.15	33.42		
		67.59	62.14	54.76	49.74	42.99	24.61	
		67.77	62.22	54.79	49.83	43.10	24.66	
	65.98	68.04	60.73	50.24	48.31	44.17	29.36	
	66.07	68.16	60.81	50.35	48.41	44.25	29.42	
47.27	60.90	66.87	56.47	39.07	44.21	43.54	30.03	
47.31	61.03	66.92	56.61	39.11	44.30	43.62	30.12	

Table VI cont.

Average Subassembly Fast Fluxes
Layer 12

					19.14	20 x 20 x 20		mesh
					19.16	10 x 10 x 20 (10)		mesh
				27.77	28.42	19.79		
				27.75	28.38	19.74		
			50.57	41.72	38.88	30.90		
			50.61	41.81	38.87	30.90		
		61.48	56.69	50.21	45.84	39.75	22.80	
		61.64	56.77	50.24	45.92	39.86	22.84	
	59.93	61.86	55.37	46.05	44.53	40.85	27.20	
	60.02	61.96	55.44	46.15	44.62	40.92	27.26	
42.93	55.32	60.80	51.47	35.81	40.76	40.28	27.83	
42.97	55.44	60.84	51.60	35.84	40.85	40.35	27.91	

Table VI cont.

Average Subassembly Fast Fluxes
Layer 13

					17.00	20 x 20 x 20		mesh
					17.02	10 x 10 x 20 (10)		mesh
				24.48	25.20	17.60		
				24.45	25.16	17.55		
			43.89	36.57	34.39	27.46		
			43.93	36.64	34.38	27.46		
		52.70	48.96	43.91	40.51	35.34	20.32	
		52.85	49.03	43.92	40.57	35.43	20.36	
	51.48	53.12	47.84	40.26	39.37	36.33	24.26	
	51.55	53.20	47.89	40.34	39.44	39.39	24.31	
36.95	47.59	52.34	44.52	31.32	36.06	35.83	24.83	
36.99	47.68	52.37	44.63	31.35	36.14	35.89	24.90	

Table VI cont.

Average Subassembly Fast Fluxes
Layer 14

					14.44	20 x 20 x 20		mesh
					14.45	10 x 10 x 20 (10)		mesh
				20.51	21.34	14.97		
				20.49	21.30	14.92		
			35.44	30.31	29.01	23.34		
			35.47	30.36	28.99	23.33		
		40.00	38.81	36.23	34.12	30.04	17.35	
		40.18	38.86	36.22	34.16	30.11	17.38	
	40.95	41.77	38.38	33.26	33.18	30.91	20.72	
	40.99	41.83	38.42	33.32	33.23	30.95	20.76	
29.79	38.23	42.00	36.07	25.93	30.44	30.50	21.21	
29.81	38.30	41.98	36.14	25.94	30.50	30.55	21.27	

Table VI cont.

Average Subassembly Fast Fluxes
Layer 15

					11.63	20 x 20 x 20		mesh
					11.63	10 x 10 x 20 (10)		mesh
				16.23	17.11	12.07		
				16.20	17.08	12.03		
			26.27	23.59	23.15	18.81		
			26.27	23.61	23.12	18.80		
		24.08	27.37	27.97	27.16	24.22	14.05	
		24.09	27.40	27.96	27.19	24.26	14.07	
	29.75	29.15	28.21	25.78	26.46	24.94	16.80	
	29.75	29.20	28.21	25.80	26.48	24.97	16.83	
22.35	28.47	31.08	27.16	20.17	24.32	24.63	17.21	
22.34	28.48	31.06	27.18	20.17	24.35	24.65	17.25	

Table VI cont.

Average Subassembly Fast Fluxes
Layer 16

					8.728	20 x 20 x 20		mesh
					8.723	10 x 10 x 20 (10)		mesh
				11.96	12.78	9.072		
				11.93	12.75	9.031		
			18.39	17.13	17.21	14.12		
			18.37	17.13	17.18	14.10		
		15.30	18.64	20.18	20.16	18.19	10.61	
		15.29	18.64	20.15	20.16	18.21	10.62	
	20.29	19.56	19.54	18.63	19.66	18.75	12.70	
	20.27	19.56	19.52	18.63	19.66	18.76	12.71	
15.56	19.71	21.46	19.06	14.62	18.10	18.53	13.01	
15.54	19.70	21.42	19.06	14.61	18.11	18.54	13.03	

Table VI cont.

Average Subassembly Fast Fluxes
Layer 17

					5.830	20 x 20 x 20		mesh
					5.822	10 x 10 x 20 (10)		mesh
				7.887	8.515	6.073		
				7.862	8.482	6.040		
			11.81	11.20	11.44	9.455		
			11.78	11.19	11.40	9.432		
		9.530	11.86	13.16	13.38	12.19	7.137	
		9.522	11.84	13.11	13.36	12.19	7.135	
	12.72	12.26	12.42	12.13	13.06	12.58	8.550	
	12.68	12.24	12.39	12.12	13.04	12.56	8.547	
9.788	12.39	13.53	12.13	9.517	12.03	12.43	8.764	
9.773	12.37	13.47	12.12	9.503	12.02	12.42	8.767	

Table VI cont.

Average Subassembly Fast Fluxes
Layer 18

					2.946	20 x 20 x 20		mesh
					2.937	10 x 10 x 20 (10)		mesh
				3.906	4.297	3.087		
				3.888	4.267	3.065		
			5.896	5.630	5.808	4.817		
			5.853	5.596	5.763	4.793		
		4.604	5.879	6.634	6.811	6.227	3.645	
		4.591	5.841	6.579	6.772	6.203	3.639	
	6.238	6.013	6.153	6.077	6.639	6.438	4.378	
	6.190	5.976	6.109	6.042	6.600	6.406	4.366	
4.712	6.068	6.675	5.996	4.684	6.098	6.370	4.491	
4.697	6.028	6.613	5.959	4.670	6.068	6.336	4.481	

BENCHMARK PROBLEM SOLUTION

Identification: 11-A1-4 Benchmark Problem ID.11-A1

Date Submitted: June 1976 By: D. A. Meneley (Ontario Hydro)

Date Accepted: June 1977 By: H. L. Dodds, Jr. (U. of Tenn.)
M. V. Gregory (SRL)

Descriptive Title: Three-dimensional PWR Problem

Mathematical Model: Seven-point central-difference formula with fluxes calculated at the center of the mesh cell. Two term Taylor series expansion to cell boundary in each direction to satisfy flux and current continuity at cell boundaries.

Special Acceleration Techniques: The code is based on I/O transfer of all data for one mesh plane in a single group. Line inversion with successive overrelaxation is used in each plane, with optimum overrelaxation factor calculated from data for all planes and groups. Inner iteration is continued for all points in a plane until the error norm is 10 percent of that found in the first iteration (arbitrary choice). The planar fluxes are overrelaxed using a second optimum overrelaxation factor calculated from the rate of relaxation of plane fluxes. A one-dimensional rebalance calculation is carried out in the direction perpendicular to the mesh planes. Asymptotic acceleration of all fluxes is carried out periodically when the convergence rate becomes asymptotic.

Initialization: Group one fluxes set to 1.0 and group two fluxes set to 0.25. Eigenvalue set to 1.0. Over relaxation factor for iterations in plane set to 1.2 and factor for overrelaxation of plane fluxes set to 1.4.

Convergence: Maximum value of flux change over two iterations relative to root mean square flux in the reactor less than 5×10^{-5}.

Primary Results:

1. Maximum Eigenvalue

Uniform Mesh	Eigenvalue
17 x 17 x 19	1.02913
34 x 34 x 38	1.02864

2. Fundamental flux distributions (Values for 34 x 34 x 38 mesh).

2.1 Radial Flux Traverses in Midplane

x(cm)	$\phi_1(x,2.5,185)$	$\phi_2(x,2.5,185)$	$\phi_1(x,x,195)$	$\phi_2(x,x,85)$
2.5	49.61	7.872	49.61	7.872
7.5	53.46	8.40	56.77	9.707
12.5	61.56	13.97	67.70	15.80
17.5	67.76	15.85	73.78	17.31
22.5	72.10	16.92	77.09	18.09
27.5	74.86	17.56	78.48	18.42
32.5	76.25	17.90	78.48	18.42
37.5	76.49	17.96	77.39	18.16
42.5	75.71	17.77	75.41	17.70
47.5	73.78	17.32	72.58	17.04
52.5	70.83	16.62	68.85	16.16
57.5	66.68	15.64	64.15	15.06
62.5	61.14	14.30	58.12	13.64
67.5	53.98	12.27	50.24	11.73
72.5	45.27	7.510	39.24	6.728
77.5	40.34	6.403	31.08	4.935
82.5	38.54	6.108	27.38	4.345
87.5	39.70	6.554	27.20	4.682
92.5	43.92	9.954	27.67	6.812
97.5	46.74	10.92	24.01	6.011
102.5	48.12	11.29	17.86	4.831
107.5	48.36	11.35	10.30	4.825
112.5	47.69	11.19	2.911	9.539
117.5	46.25	10.86	0.9978	4.870
122.5	44.17	10.38	0.3278	1.757
127.5	41.52	9.803	0.08347	0.2827
132.5	38.29	9.430		
137.5	33.71	8.383		
142.5	27.79	7.155		
147.5	20.27	6.993		
152.5	9.298	18.09		
157.5	4.598	14.99		
162.5	2.229	9.171		
167.5	.9918	3.633		

2.2 Radial Flux Traverses at z = 275

x(cm)	$\phi_1(x,2.5,275)$	$\phi_2(x,2.5,275)$	$\phi_1(x,x,275)$	$\phi_2(x,x,275)$
2.5	27.74	4.466	27.74	4.400
7.5	29.87	4.938	38.68	5.414
12.5	34.32	7.787	37.61	8.774
17.5	37.73	8.822	40.67	9.545
22.5	40.06	9.394	41.93	9.839
27.5	41.51	9.743	41.81	9.809
32.5	42.26	9.918	40.62	9.472
37.5	42.43	9.960	39.26	9.135
42.5	42.06	9.870	38.37	8.931
47.5	41.16	9.659	37.94	8.846
52.5	39.71	9.322	37.39	8.774
57.5	37.63	8.828	35.93	8.431
62.5	34.78	8.136	33.36	7.829
67.5	30.99	7.041	29.40	6.860
72.5	26.32	4.356	23.34	4.001
77.5	23.74	3.766	18.79	2.983
82.5	23.00	3.648	16.80	2.667
87.5	24.02	3.966	16.87	2.907
92.5	26.86	6.090	17.29	4.256
97.5	28.84	6.740	15.07	3.773
102.5	29.91	7.026	11.24	3.042
107.5	30.24	7.095	6.499	3.045
112.5	29.98	7.035	1.838	6.024
117.5	29.20	6.855	.6307	3.080
122.5	27.99	6.572	.2074	1.112
127.5	26.40	6.235	.05286	0.1790
132.5	24.40	6.011		
137.5	21.53	5.353		
142.5	17.78	4.576		
147.5	12.99	4.481		
152.5	5.966	11.60		
157.5	2.955	9.617		
162.5	1.430	5.886		
167.5	0.6367	2.333		

2.3 Radial Flux Traverses at z = 285

x(cm)	$\phi_1(x,2.5,285)$	$\phi_2(x,2.5,285)$	$\phi_1(x,x,285)$	$\phi_2(x,x,285)$
2.5	24.01	3.808	24.01	3.808
7.5	25.83	4.270	27.38	4.678
12.5	29.65	6.728	32.39	7.559
17.5	32.55	7.613	34.80	8.166
22.5	34.50	8.094	35.38	8.305
27.5	35.71	8.377	34.15	7.968
32.5	36.31	8.521	30.16	5.205
37.5	36.44	8.552	27.20	4.390
42.5	36.14	8.475	26.54	4.283
47.5	35.42	8.311	28.11	4.844
52.5	34.25	8.040	30.58	7.137
57.5	32.55	7.637	30.50	7.155
62.5	30.18	7.059	28.83	6.764
67.5	26.99	6.126	25.67	5.993
72.5	23.01	3.808	20.53	3.518
77.5	20.85	3.307	16.62	2.639
82.5	20.29	3.218	14.94	2.371
87.5	21.28	3.514	15.06	2.593
92.5	23.88	5.414	15.45	3.805
97.5	25.70	6.007	13.49	3.338
102.5	26.70	6.265	10.07	2.724
107.5	27.04	6.343	5.822	2.729
112.5	26.83	6.301	1.647	5.402
117.5	26.17	6.144	0.5655	2.762
122.5	25.11	5.898	0.1860	0.9978
127.5	23.70	5.595	0.04741	0.1606
132.5	21.92	5.399		
137.5	19.34	4.811		
142.5	15.98	4.114		
147.5	11.68	4.030		
152.5	5.358	10.44		
157.5	2.652	8.654		
162.5	1.287	5.295		
167.5	0.5727	2.098		

2.4 Axial Flux Traverses for Partially Rodded Assembly

z(cm)	$\phi_1(37.5,37.5,z)$	$\phi_2(37.5,37.5,z)$
5	0.6295	2.556
15	2.596	7.324
25	11.08	2.852
35	18.48	4.346
45	25.61	6.011
55	32.50	7.631
65	39.10	9.177
75	45.35	10.65
85	51.18	12.01
95	56.55	13.27
105	61.38	14.41
115	65.72	15.42
125	69.39	16.28
135	72.46	17.00
145	74.80	17.56
155	76.55	17.96
165	77.51	18.20
175	77.81	18.26
185	77.39	18.16
195	76.25	17.89
205	74.38	17.45
215	71.79	16.84
225	68.48	16.07
235	64.45	15.13
245	59.74	14.02
255	54.21	12.72
265	47.63	11.18
275	39.26	9.135
285	27.20	4.390
295	20.93	3.321
305	16.75	2.656
315	13.44	2.132
325	10.57	1.678
335	7.986	1.267
345	5.554	0.8816
355	3.172	0.5210
365	0.8491	0.6746
375	0.2221	0.2007

2.5 Value and Location of Maximum Power Density (Values for 34 x 34 x 38 mesh)

Max/Avg in Core	Location
2.503	27.5,32.5,165
2.243*	57.5,130,165

* Interpolated between adjacent points using finite-difference equation.

4. Convergence Data (34 x 34 x 38 mesh)

Number of unknowns in problem	:	73,264
Number of outer iterations	:	73
Average number of iterations on each plane per outer iteration	:	3

5. Computer Data (34 x 34 x 38 mesh)

Machine	:	CDC6600
Field Length	:	34,368 words
Iteration Time	:	1037 CP seconds
Total Time	:	1200 CP seconds
		4470 PP seconds

BENCHMARK PROBLEM

Identification: 11-A2 Source Situation ID.11

Date Submitted: June 1976 By: R. R. Lee (CE)
D. A. Meneley (Ontario Hydro)
B. Micheelsen (Risø-Denmark)
D. R. Vondy (ORNL)
M. R. Wagner (KWU)
W. Werner (GRS-Munich)

Date Accepted: June 1977 By: H. L. Dodds, Jr. (U. of Tenn.)
M. V. Gregory (SRL)

Descriptive Title: Two-dimensional LWR Problem, also 2D IAEA Benchmark Problem

Reduction of Source Situation

1. Two-group diffusion theory
2. Two-dimensional (x,y)-geometry

Two-Group Diffusion Equations:

$$-\nabla D_1 \nabla \Phi_1 + (\Sigma_{a1} + \Sigma_{1\to 2} + D_1 B_{z1}^2)\Phi_1 = \frac{1}{\lambda} \nu\Sigma_{f2}\Phi_2$$

$$-\nabla D_2 \nabla \Phi_2 + (\Sigma_{a2} + D_2 B_{z2}^2)\Phi_2 = \Sigma_{1\to 2}\Phi_1$$

Data

Two-group Constants

Region	D_1	D_2	$\Sigma_{1\to 2}$	Σ_{a1}	Σ_{a2}	$\nu\Sigma_{f2}$	Material
1	1.5	0.4	0.02	0.01	0.08	0.135	Fuel 1
2	1.5	0.4	0.02	0.01	0.085	0.135	Fuel 2
3	1.5	0.4	0.02	0.01	0.13	0.135	Fuel 2 + Rod
4	2.0	0.3	0.04	0	0.01	0	Reflector

Axial buckling $B^2_{z,g} = 0.8 \cdot 10^{-4}$ for all regions and energy groups.

Note: This 2D IAEA Benchmark Problem represents the midplane z = 190 cm of the 3D IAEA Benchmark Problem

Boundary Conditions:

$J_g^{in} = 0$ No incoming current at external boundaries.

For finite difference diffusion theory codes the following form is considered equivalent

$$\frac{\partial \phi_g}{\partial n} = -\frac{0.4692}{D_g} \phi_g ,$$

where n the outward directed normal to the surface.
At symmetry boundaries:

$$\frac{\partial \phi_g}{\partial n} = 0$$

Expected Primary Results:

1. Maximum eigenvalue

2. Fundamental flux distributions

   2.1 Radial flux traverses $\phi_g(x,o)$ and $\phi_g(x,x)$

Note: The fluxes shall be normalized such that

$$\frac{1}{V_{Core}} \int_{V_{Core}} \sum_g \nu\Sigma_{fg} \phi_g \, dV = 1$$

   2.2 Value and location of maximum power density. This corresponds to maximum of ϕ_2 in the core. It is recommended that the maximum values of ϕ_2 both in the inner core and at the core/reflector interface be given.

3. Average subassembly powers P_k

$$P_k = \frac{1}{V_k} \int_{V_k} \sum_g \nu\Sigma_{fg}\Phi_g \, dV$$

where V_k volume of the k-th subassembly and k designates the fuel subassemblies as shown in lower octant of Fig. 1

4. Number of unknowns in the problem, number of iterations, total and outer

5. Total computing time, iteration time, IO-time, computer used

6. Type and numerical values of convergence criteria

7. Table of average group fluxes for a square mesh grid of 20 x 20 cm

8. Dependence of results on mesh spacing

Best Solution Available: Extrapolated finite difference solution described in 11-A2-1

Solutions

1. Finite Difference Method: 11-A2-1
2. Finite Element Method: 11-A2-2
3. Nodal Expansion Method: 11-A2-3
4. Finite Difference Method: 11-A2-4

BENCHMARK PROBLEM SOLUTION

Identification: 11-A2-1 Benchmark Problem 11.A2

Date Submitted: June 1, 1976 By: D. R. Vondy, T. B. Fowler (ORNL)

Date Accepted: June 1, 1977 By: H. L. Dodds, Jr. (U. of Tenn.)
M. V. Gregory (SRL)

Descriptive Title: Two-dimensional PWR Problem (IAEA)

Mathematical Model: Diffusion theory, various difference formulations

Computer: IBM-369/91, 1973-76, ORNL
IBM-360/195, 1976 UC-CTC

Program: (1) VENTURE, ORNL-5062 Report
(2) EXTERMINATOR-2, ORNL-4078
(3) VANCER, to be documented (ORNL)

Note: To produce acceptable solutions for benchmarking, tighter convergence of the iterative process was required than is common practice in application, maximum relative flux change on outer iterations = 10^{-5}.

Primary Results:*

a. Primary results obtained in 1973-74 are shown in Table 1. The larger problems were initialized with the flux solution from the smaller problems, and an early version of the VENTURE code used obsolete procedures, so compute times are not representative. Apparent finite-difference error in the multiplication factor is displayed in Fig. 1. Tables 2 and 3 present zone average flux values. Normalization is to one neutron produced for the problem.+

b. Recent results with the VANCER code using the mesh-edge formulation parameterized to admit different approximations are shown in Table 4 from calculations on the IBM-360/91 done in 1976. These calculations were done with rather obsolete procedures oriented to use of an extended, slow memory, so representative computation times are not available.

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* Extrapolation of results is done on the basis of error dependence on the square of the mesh spacing.

+ To obtain the proper normalization, results in Tables 2 and 3 should be multiplied by 1.78.

ORNL-DWG 74-10811

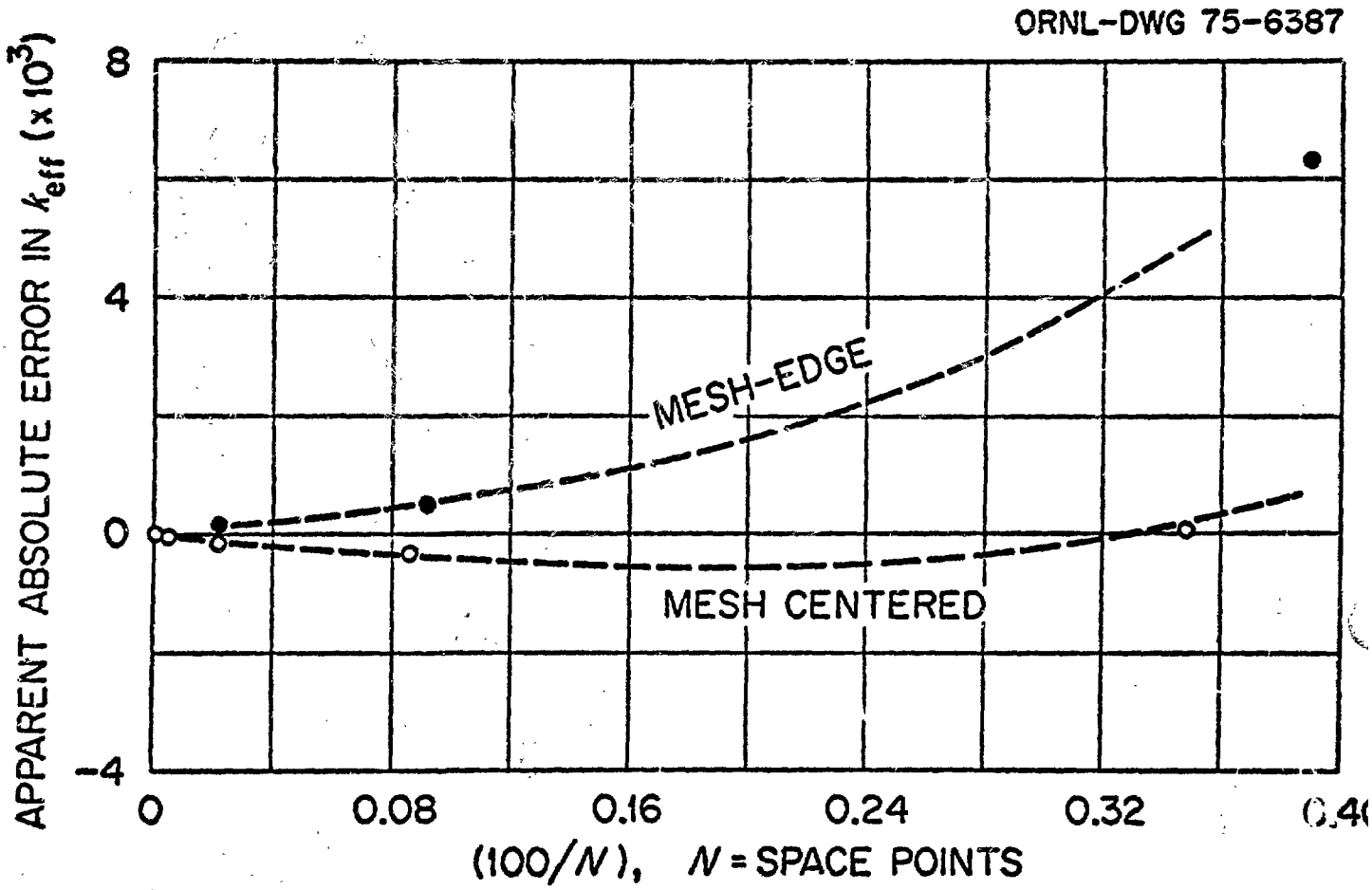
Table 1

IAEA BENCHMARK PROBLEM

(Two-Group, Two-Dimensional, $B_1^2=8\times10^{-5}$)

Meshpoints (Total Unknowns)	k_{eff}	Peak-to-Average Power Density	IBM-360/91 Processor Time (min)
Old Code Extern. ator-2 (mesh-edge points, zero flux external boundary)			
16x16(512)	1.03651	2.2404	0.20
33x33(2,178)	1.03065	1.6538	1.0
67x67(8,978)	1.03033	1.5314	(10.)
Extrapolated	1.03022	1.491	
VENTURE (mesh-centered points, non-return external boundary)			
9x9(162)	1.03208	1.5493	0.05
17x17(578)	1.02965	1.6486	0.06
34x34(2,312)	1.02924	1.5985	0.32
68x68(9,248)	1.02944	1.5442	3.4
136x136(36,992)	1.02954	1.5217	13.5
272x272(147,968)	1.02958	1.5149	80
Extrapolated	1.02959	1.5126	

Figure 1. Two-Dimensional Finite-Difference Results



Two-Dimensional Finite-Difference Results.

Table 2. Zone Average Fast Group Flux - Mesh Centered VENTURE

(Results below should be multiplied by 1.78 for proper normalization)

Location/ Intervals	9x9	17x17	34x34	68x68	272x272	Extrapolated
1	17.35	19.28	19.37	18.77	18.37	18.34
2	25.20	26.42	25.30	24.27	23.71	23.67
3	27.12	28.43	27.46	26.49	25.96	25.92
4	23.48	23.87	23.06	22.30	21.89	21.86
5	13.14	14.92	15.32	15.16	15.02	15.01
6	17.53	17.09	17.01	16.95	16.92	16.92
7	16.19	15.80	16.15	16.45	16.61	16.62
8	11.55	10.37	10.76	11.21	11.47	11.49
9	0.954	1.202	1.531	1.772	1.898	1.906
10	27.14	28.46	27.28	26.23	25.65	25.61
11	27.61	28.87	27.90	26.94	26.42	26.39
12	24.73	25.45	24.63	23.90	23.49	23.46
13	19.56	20.39	19.96	19.56	19.35	19.34
14	18.77	18.62	18.54	18.51	18.49	18.49
15	16.45	15.98	16.34	16.67	16.85	16.86
16	11.23	10.06	10.46	10.93	11.20	11.22
17	0.921	1.144	1.458	1.690	1.813	1.821
18	27.28	28.38	27.53	26.99	26.23	26.18
19	24.82	25.59	24.96	24.35	24.01	23.99
20	21.14	21.77	21.50	21.20	21.04	21.03
21	19.02	18.85	18.93	19.00	19.03	19.03
22	16.96	15.53	15.80	16.19	16.42	16.43
23	9.222	8.176	8.616	9.114	9.394	9.413
24	0.733	0.856	1.088	1.272	1.373	1.380
25	22.21	22.50	22.00	21.55	21.30	21.28
26	17.86	17.97	17.75	17.57	17.46	17.45
27	16.14	15.70	15.83	16.00	16.09	16.10
28	12.77	11.62	12.01	12.48	12.74	12.76
29	1.682	2.104	2.686	3.115	3.346	3.361
30	0.188	0.239	0.3136	0.3704	0.4012	0.4033
31	9.374	10.79	11.32	11.48	11.52	11.52
32	12.26	11.18	11.31	11.57	11.72	11.73
33	8.075	7.136	7.482	7.903	8.141	8.157
34	0.712	0.849	1.080	1.263	1.362	1.369
35	8.206	7.071	7.320	7.690	7.904	7.918
36	1.217	1.417	1.789	2.083	2.244	2.255
37	0.150	0.190	0.2511	0.2975	0.3226	0.3243
38	0.190	0.221	0.2844	0.3343	0.3616	0.3634

Table 3. Zone Average Thermal Group Flux - Mesh Centered VENTURE

(Results below should be multiplied by 1.78 for proper normalization)

Location/ Intervals	9x9	17x17	34x34	68x68	272x272	Extrapolated
1	2.796	3.131	3.202	3.155	3.122	3.120
2	5.898	6.173	5.891	5.633	5.491	5.482
3	6.367	6.673	6.446	6.218	6.093	6.085
4	5.501	5.581	5.372	5.181	5.075	5.068
5	2.113	2.422	2.531	2.548	2.552	2.552
6	4.105	3.990	3.957	3.921	3.915	3.914
7	3.803	3.712	3.797	3.869	3.908	3.911
8	2.900	2.670	2.863	3.050	3.153	3.160
9	3.286	3.706	4.105	4.368	4.505	4.514
10	6.372	6.678	6.401	6.151	6.015	6.006
11	6.483	6.777	6.548	6.342	6.202	6.193
12	5 806	5.972	5.779	5.604	5.510	5.503
13	4.580	4.766	4.647	4.541	4.481	4.477
14	4.407	4.371	4.351	4.342	4.336	4.336
15	3.865	3.759	3.848	3.930	3.974	3.977
16	2.818	2.587	2.781	2.969	3.072	3.079
17	3.163	3.510	3.891	4.149	4.284	4.293
18	6.406	6.662	6.462	6.265	6.157	6.149
19	5.826	6.005	5.860	5.714	5.635	5.630
20	4.964	5.111	5.047	4.977	4.938	4.935
21	4.468	4.430	4.450	4.469	4.479	4.480
22	4.201	3.847	3.918	4.019	4.076	4.080
23	2.369	2.220	2.494	2.746	2.887	2.896
24	2.498	2.637	2.944	3.176	3.299	3.307
25	5.214	5.280	5.162	5.055	4.996	4.992
26	4.185	4.201	4.138	4.082	4.049	4.047
27	3.794	3.690	3.726	3.768	3.792	3.794
28	3.223	3.016	3.224	3.423	3.533	3.540
29	5.641	6.040	6.518	6.844	7.013	7.024
30	0.9503	1.122	1.336	1.497	1.584	1.590
31	1.506	1.755	1.878	1.937	1.967	1.969
32	3.031	2.756	2.780	2.836	2.867	2.869
33	2.071	1.930	2.156	2.371	2.490	2.498
34	2.543	2.724	3.041	3.280	3.406	3.414
35	2.115	1.929	2.129	2.327	2.440	2.448
36	4.045	4.038	4.330	4.570	4.698	4.707
37	0.7636	0.889	1.059	1.190	1.261	1.266
38	0.9518	1.045	1.222	1.364	1.443	1.448

Table 4. TWO-DIMENSIONAL, TWO-GROUP IAEA BENCHMARK PROBLEM RESULTS

Formulation (Near Neighbors)	Mesh Intervals	k_{eff}	Peak Relative Power Density Internal	Peak Relative Power Density Near Reflector
Meshpoint Centered, VENTURE (4)	9^2	1.03208	1.549	
	17^2	1.02965	1.649	
	34^2	1.02924	1.599	
	68^2	1.02944	1.544	
	136^2	1.02954	1.522	
	272^2	1.02958	1.515	
Extrapolated	(∞)	1.02959	1.513	
Mesh Edge, VANCER				
Usual Finite-Difference (4)	9^2	1.07647	none	4.28
	17^2	1.03733	0.962	2.231
	34^2	1.03077	1.364	1.660
	68^2	1.02983	1.475	1.546
	(∞)	1.02952	1.512	1.508
Taylor Series (8)	34^2	1.03080	1.364	1.652
Higher Order Taylor Series (8)	17^2	1.03442	1.095	2.043
	34^2	1.03036	1.405	1.629
	68^2	1.02975	1.485	1.544
	(∞)	1.02955	1.512	1.516
Linear Finite-Element (8)*	17^2	1.03109	1.309	1.779
	34^2	1.02985	1.462	1.605
	68^2	1.02965	1.499	1.545
	(∞)	1.02958	1.511	1.525
Linear Finite-Difference (8)*	17^2	1.03236	1.214	1.887
	34^2	1.03006	1.437	1.614
	68^2	1.02969	1.493	1.544
	(∞)	1.02957	1.512	1.521
Compromise (8)	17^2	1.03390	1.123	2.009
	34^2	1.03028	1.412	1.625
	68^2	1.02973	1.487	1.544
	(∞)	1.02955	1.512	1.517
Simple Compromise (4)	34^2	1.03051	1.389	1.645
	68^2	1.02978	1.481	1.544
	(∞)	1.02954	1.512	1.510
Compensated Difference (4)*	17^2	1.03206	1.228	1.900
	34^2	1.03002	1.438	1.628
	68^2	1.02968	1.493	1.547
	(∞)	1.02957	1.511	1.520
Local Source				
H-O Taylor Series (8)	34^2	1.03162	1.393	1.724
Linear Finite-Element (8)	34^2	1.03229	1.402	1.792
Linear Finite-Difference (8)	34^2	1.03280	1.422	1.860
Compromise (8)	34^2	1.03178	1.387	1.737
Simple Compromise (4)	34^2	1.03126	1.375	1.700
Compensated Difference (4)	34^2	1.03224	1.403	1.799
Apparent Solution		1.02958	1.51	1.52

BENCHMARK PROBLEM SOLUTION

Identification: 11-A2-2 Benchmark Problem ID.11-A2

Date Submitted: June 1976 By: Ib Misfeldt (Risø-Denmark)

Date Accepted: June 1977 By: H. L. Dodds, Jr. (U. of Tenn.)
M. V. Gregory (SRL)

Descriptive Title: Two-dimensional PWR Problem

Mathematical Model: FEM (2nd order Lagrange interpolation, rectangular elements)

Pertinent Features of Solution Method: The grid had 36 x 36 meshes and 73 x 73 flux points.

Computer: B 6700 Date Solved: August 25, 1975
at: Risø, Denmark

Program: FEMB

References

1. Ib Misfeldt, "Solution of the multigroup neutron diffusion equations by the finite element method," Risø-M-1809 (1975).

2. G. K. Kristiansen, "Investigation of the accuracy of centerpoint-, cornerpoint-, and finite-element-methods for solution of the neutron diffusion equation," NEACRP-L-149 (1976).

Results

1. Maximum eigenvalue: $k_{eff} = 1.0296$

2. Fundamental flux distributions

   2.1. See Tables 2A and 2B of flux traverses.

   2.2. Maximum power density

   Uninterpolated values are given

   $(\phi_2)_{max,1} = 11.31$ at $(x,y) = (130,55)$

   $(\phi_2)_{max,2} = 11.18$ at $(x,y) = (30,30)$

3. Average subassembly powers

   See Table 2C.

4. Number of unknowns and iteration number

   73 x 73 x 2 unknowns; 120 iterations.

5. Computing times

   2½ hours cp=time; ½ hour io-time, on B 6700.

6. Convergence criteria

   Maximal flux-error-estimate less than 0.01% of $\emptyset_{max}$ in each group.

7. Average group-fluxes for 20 x 20 cm grid

   See Table 2D.

8. Dependence of results on mesh spacing

   See Refs. 1 and 2.

Table 2A

Flux along x-axis

X	PHI1	PHI2
0.000	29.350	4.620
1.250	29.422	4.633
2.500	29.641	4.675
3.750	30.009	4.750
5.000	30.531	4.868
6.250	31.211	5.049
7.500	32.052	5.336
8.750	33.046	5.809
10.000	34.166	6.646
12.500	36.512	8.164
15.000	38.666	8.945
17.500	40.501	9.468
20.000	42.030	9.853
22.500	43.280	10.155
25.000	44.282	10.393
27.500	45.061	10.577
30.000	45.635	10.712
32.500	46.019	10.802
35.000	46.223	10.850
37.500	46.255	10.857
40.000	46.120	10.826
42.500	45.819	10.755
45.000	45.355	10.646
47.500	44.725	10.498
50.000	43.926	10.310
52.500	42.950	10.081
55.000	41.788	9.808
57.500	40.426	9.486
60.000	38.845	9.107
62.500	37.021	8.656
65.000	34.934	8.085
67.500	32.576	7.289
70.000	30.063	5.846
72.500	27.763	4.618
75.000	25.984	4.157
77.500	24.760	3.909
80.000	24.042	3.787
82.500	23.801	3.756
85.000	24.035	3.840
87.500	24.765	4.107
90.000	25.939	5.020
92.500	27.277	6.087
95.000	28.463	6.579
97.500	29.398	6.871
100.000	30.097	7.055
102.500	30.582	7.176
105.000	30.879	7.247
107.500	31.010	7.279
110.000	30.991	7.274
112.500	30.836	7.238
115.000	30.557	7.173

Table 2A (cont'd)

117.500	30.164	7.081
120.000	29.664	6.964
122.500	29.064	6.827
125.000	28.371	6.676
127.500	27.585	6.525
130.000	26.689	6.434
132.500	25.629	6.300
135.000	24.355	6.025
137.500	22.854	5.677
140.000	21.128	5.292
142.500	19.178	4.920
145.000	16.945	4.746
147.500	14.273	5.182
150.000	10.430	7.976
152.500	7.301	12.063
155.000	5.107	12.443
157.500	3.565	11.132
160.000	2.480	9.136
162.500	1.711	6.976
165.000	1.162	4.838
167.500	0.762	2.743
170.000	0.459	0.580

Table 2B

Flux along the diagonal x = y

x	y	PHI1	PHI2
0.000	0.000	29.350	4.620
1.250	1.250	29.494	4.647
2.500	2.500	29.927	4.730
3.750	3.750	30.642	4.876
5.000	5.000	31.628	5.101
6.250	6.250	32.865	5.440
7.500	7.500	34.317	5.961
8.750	8.750	35.921	6.778
10.000	10.000	37.562	8.030
12.500	12.500	40.453	9.391
15.000	15.000	42.671	10.000
17.500	17.500	44.343	10.406
20.000	20.000	45.590	10.701
22.500	22.500	46.493	10.913
25.000	25.000	47.108	11.058
27.500	27.500	47.480	11.145
30.000	30.000	47.642	11.183
32.500	32.500	47.621	11.178
35.000	35.000	47.436	11.135
37.500	37.500	47.106	11.057
40.000	40.000	46.640	10.948
42.500	42.500	46.046	10.808
45.000	45.000	45.325	10.639
47.500	47.500	44.476	10.440
50.000	50.000	43.493	10.209
52.500	52.500	42.363	9.944
55.000	55.000	41.073	9.641
57.500	57.500	39.601	9.295
60.000	60.000	37.922	8.901
62.500	62.500	35.998	8.448
65.000	65.000	33.776	7.916
67.500	67.500	31.177	7.241
70.000	70.000	28.120	6.013
72.500	72.500	24.843	4.306
75.000	75.000	21.997	3.572
77.500	77.500	19.869	3.146
80.000	80.000	18.479	2.914
82.500	82.500	17.783	2.815
85.000	85.000	17.681	2.873
87.500	87.500	18.019	3.145
90.000	90.000	18.447	4.081
92.500	92.500	18.398	4.495
95.000	95.000	17.696	4.385
97.500	97.500	16.444	4.103
100.000	100.000	14.747	3.746
102.500	102.500	12.688	3.400
105.000	105.000	10.293	3.301
107.500	107.500	7.555	3.832
110.000	110.000	4.283	6.272
112.500	112.500	2.399	6.920

Table 2B (cont'd)

115.000	115.000	1.382	5.429
117.500	117.500	0.803	3.767
120.000	120.000	0.463	2.387
122.500	122.500	0.260	1.360
125.000	125.000	0.138	0.652
127.500	127.500	0.066	0.211
130.000	130.000	0.025	0.010
132.500	132.500	0.000	0.000

Table 2C

Average subassembly powers

170.00									
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
150.00									
	0.7571	0.7379	0.6952	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
130.00									
	0.9350	0.9512	0.9761	0.8485	0.5997	0.0000	0.0000	0.0000	0.0000
110.00									
	0.9345	1.0359	1.0706	0.9068	0.6859	0.5874	0.0000	0.0000	0.0000
90.00									
	0.6099	1.0684	1.1783	0.9661	0.4712	0.6860	0.5998	0.0000	0.0000
70.00									
	1.2083	1.3128	1.3433	1.1916	0.9662	0.9070	0.8487	0.0000	0.0000
50.00									
	1.4509	1.4772	1.4671	1.3434	1.1785	1.0708	0.9764	0.6954	0.0000
30.00									
	1.3068	1.4323	1.4773	1.3130	1.0686	1.0362	0.9516	0.7382	0.0000
10.00									
	0.7443	1.3068	1.4510	1.2084	0.6100	0.9348	0.9354	0.7574	0.0000
0.00	10.00	30.00	50.00	70.00	90.00	110.00	130.00	150.00	170.00

Table 2D, group 1

Flux averages

Group 1

170.00									
	3.3944	3.2431	2.4578	0.7188	0.0215	0.0040	0.0000	0.0000	0.0000
150.00									
	20.3675	19.8959	16.7075	5.9875	2.4387	0.5778	0.0100	0.0000	0.0000
130.00									
	29.4320	29.8661	29.1220	22.6278	14.4753	4.0186	0.6479	0.0100	0.0000
110.00									
	29.9296	32.7203	33.6976	28.5075	20.7859	14.0517	4.0194	0.5781	0.0040
90.00									
	20.5281	34.1781	37.1833	30.8752	20.3850	20.7890	14.4796	2.4397	0.0215
70.00									
	38.6266	41.4685	42.3909	37.6359	30.8782	28.5131	22.6343	5.9895	0.7190
50.00									
	45.7876	46.6162	46.2972	42.3941	37.1893	33.7055	29.1304	16.7128	2.4586
30.00									
	41.8016	45.2435	46.6185	41.4731	34.1849	32.7299	29.8766	19.9035	3.2444
10.00									
	32.3916	41.8032	45.7911	38.6309	26.5336	29.9397	29.4437	20.3760	3.3959
0.00	10.00	30.00	50.00	70.00	90.00	110.00	130.00	150.00	170.00

Table 2D, group 2

Group 2

170.00									
	8.0138	7.6236	5.8770	2.8301	0.0293	0.0053	0.0000	0.0000	0.0000
150.00									
	5.6078	5.4661	5.1497	12.4623	6.0648	2.2525	0.0143	0.0000	0.0000
130.00									
	6.9263	7.0461	7.2307	6.2849	4.4419	8.3528	2.5767	0.0143	0.0000
110.00									
	6.9224	7.6736	7.9302	6.7171	5.0810	4.3515	8.3545	2.2534	0.0054
90.00									
	4.5176	7.9143	8.7280	7.1565	3.4904	5.0817	4.4432	6.0674	0.0293
70.00									
	8.9502	9.7246	9.9503	8.8264	7.1572	6.7184	6.2867	12.4665	2.8309
50.00									
	10.7476	10.9421	10.8673	9.9511	8.7293	7.9321	7.2328	5.1513	5.8789
30.00									
	9.6798	10.6093	10.9427	9.7256	7.9158	7.6758	7.0485	5.4682	7.6265
10.00									
	5.5137	9.6801	10.7484	8.9512	4.5185	6.9247	6.9290	5.6102	8.0174
0.00	10.00	30.00	50.00	70.00	90.00	110.00	130.00	150.00	170.00

BENCHMARK PROBLEM SOLUTION

Identification: 11-A2-3 Benchmark Problem ID.11-A2

Date Submitted: June 1976 By: K. Koebke (KWU)
M. R. Wagner (KWU)

Date Accepted: June 1977 By: H. L. Dodds, Jr. (U. of Tenn.)
M. V. Gregory (SRL)

Descriptive Title: Nodal Solutions for Two-dimensional LWR Problem (2D IAEA Benchmark Problem)

Mathematical Model

The nodal expansion method, a higher order nodal method as described in References 1 to 4, is used. Nodal balance equations are obtained by integrating the P1-form of the group diffusion equations over parallelepipeds (nodes). The spatial coupling between nodes is expressed in terms of interface current relations.

Pertinent Features of Solution Methods

A consistent scheme is used for the iterative self-generation of spatial coupling coefficients as an integral part of the overall calculational procedure. The nodal coefficients are computed from auxiliary one-dimensional diffusion equations for the transverse average of the group fluxes, for each space direction of every node.

The channel fluxes are represented by high order polynomial expansion and a Galerkin scheme is used to determine the free expansion coefficients. The spatial distribution of the transverse leakage is approximated by a second order polynomial based on information from adjacent nodes, see Refs. 3 and 4 for details.

After convergence local flux and power distributions may be computed a posteriori by a high order local interpolation method, Ref. 5. The point fluxes in Exhibits A1 and A2 and in Tables 1 and 2, as well as the maximum local power densities per assembly, shown in Table 3, were obtained in that way.

Solution Technique

A conventional outer fission source iteration is used with one inner per outer iteration. For convergence acceleration a combination of coarse mesh rebalancing and asymptotic source extrapolation is applied.

Program Name: MEDIUM-2 (KWU)

Type of Program: Multidimensional LWR depletion code

Results of two solutions for an octant with a square mesh of h = 3 $^1/3$ and h = 10 cm are given below. The order of approximation is G_3B^2 (5th-order polynomial expansion for the channel fluxes and second order approximation for the transverse neutron leakage).

1. k-effective: 1.029585 h = 3 $^1/3$ cm
   1.029611 h = 10 cm

2. Fundamental Flux Distributions

   2.1 Radial flux traverses, see Exhibits A1 and A2. The pointwise flux values are given in Tables 1 and 2.

   2.2 Value and Location of Maximum Thermal Flux ϕ_2

h (cm)	Inner Core Value	Inner Core Location	at Core Boundary Value	at Core Boundary Location
3 $^1/3$	11.206	(31, 31)	11.317	(130, 55.35)
10	11.195	(30, 30)	11.335	(130, 56)

3. Average Subassembly Powers P_k, see Table 3

	h = 3 1/3 cm	10 cm
4. Number of Unknowns/Group	5481	609
Number of Iterations	42	26

Note: Number of unknowns per node and energy group: average node flux plus 4 partial out-currents

	h = 3 1/3 cm	10 cm
5. Iteration Time (CP)	15.12 sec	1.34 sec
Computer Used	CYBER 175	

6. Pointwise Convergence Criterium:

$$\max_m \left| \frac{Q_{fm}^n - Q_{fm}^{n-1}}{Q_{fm}^{n-1}} \right| < \varepsilon_{point}$$

where

$$Q_{fm}^n = \sum_g \nu\Sigma_{fg}{}^m \, \phi_g^{m,n}$$

$\phi_g^{m,n}$ average group flux for node m, outer iteration n.

Numerical value of $\varepsilon_{point} = 1.10^{-6}$ for h = 3 1/3 cm
$= 7.10^{-6}$ h = 10 cm

7. Table of average group fluxes, see Tables 4 and 5.

References

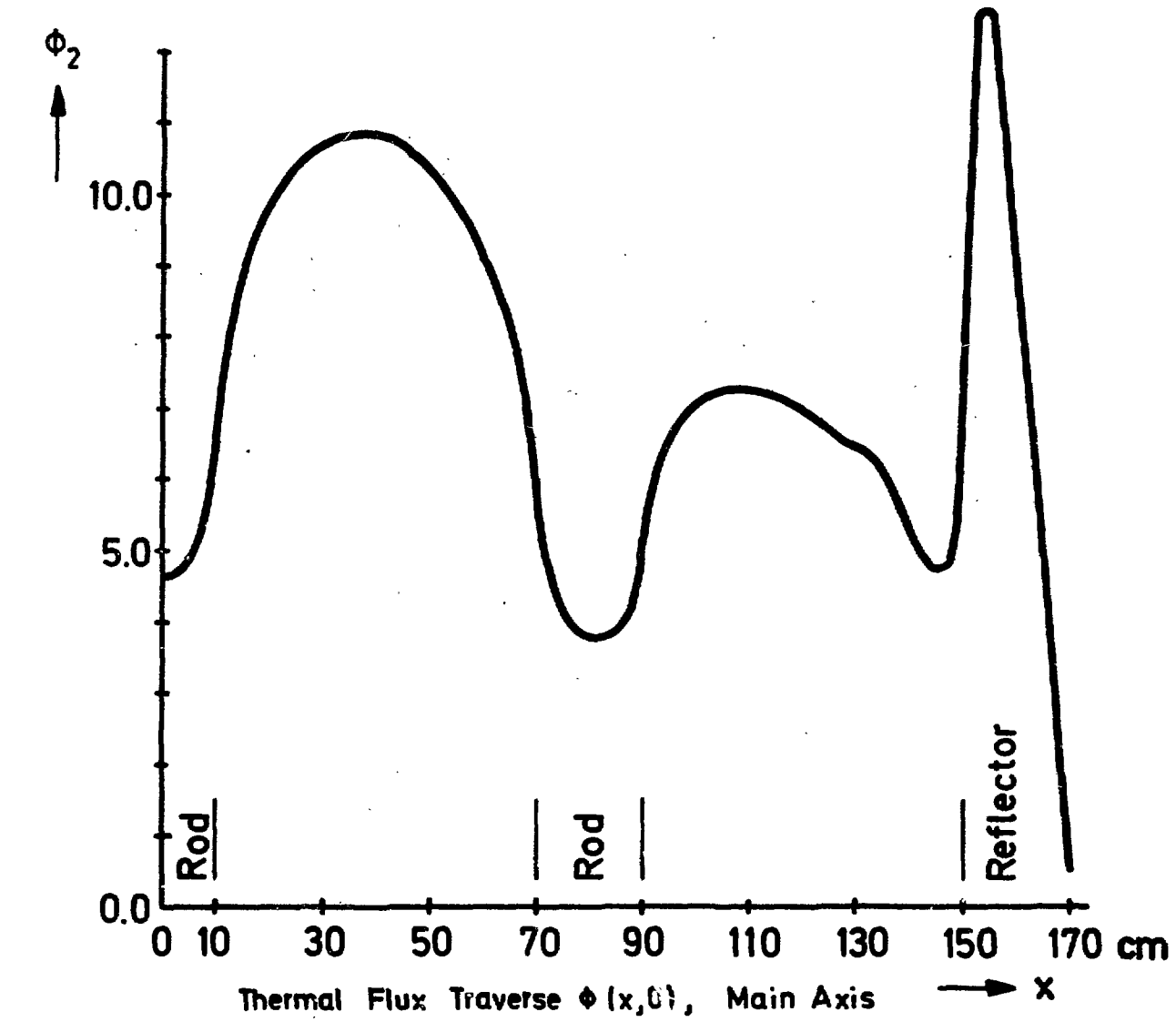
1. H. Finnemann, A Consistent Nodal Method for the Analysis of Space-Time Effects in Large LWR's Proc. of the Joint NEACRP/CSNI Specialists' Meeting on New Developments in Three-Dimensional Neutron Kinetics and Review of Kinetics Benchmark Calculations MRR 145. p. 131 (1975)

2. F. Bennewitz, H. Finnemann, H. Moldaschl, CONF-750413, Proc. Conf. on Comput. Methods in Nucl. Eng., April 15 - 17, 1975 Charleston, South Carolina

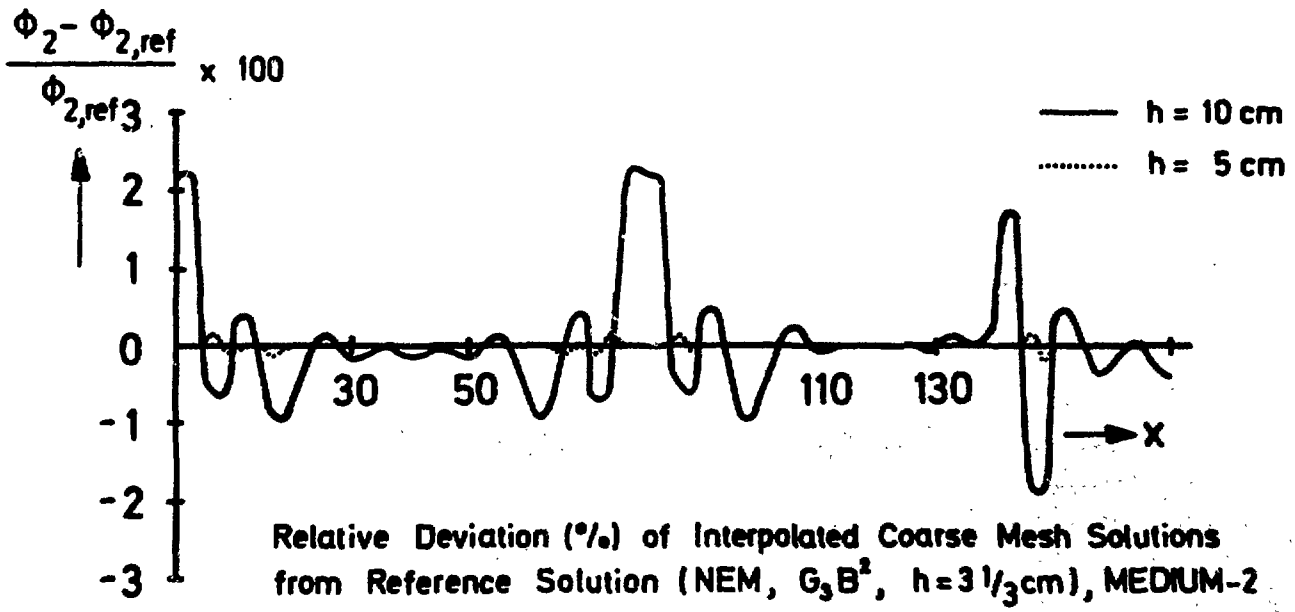
3. H. Finnemann, M.R. Wagner, The Nodal Expansion Method: A New Computational Technique for the Solution of Multidimensional Neutron Diffusion Problems, IAEA Specialists' Meeting on Methods of Neutron Transport Theory in Reactor Calculations, Bologna, Italy 3 - 5 Nov. 1975.

4. F. Bennewitz, H. Finnemann, M.R. Wagner, Higher Order Corrections in Nodal Reactor Calculations, Trans. Am. Nucl. Soc. 22, 250 (1975).

5. K. Koebke, Berechnung lokaler Fluß- und Leistungsverteilungen durch nachträgliche Interpolation nodaler Grobmaschenverfahren, Reactor-Congress Düsseldorf 1976, Paper No. 120, Proceedings p. 79 - 82.



Thermal Flux Traverse $\Phi(x,0)$, Main Axis



Relative Deviation (%) of Interpolated Coarse Mesh Solutions from Reference Solution (NEM, G_3B^2, $h = 3\,1/3$ cm), MEDIUM-2

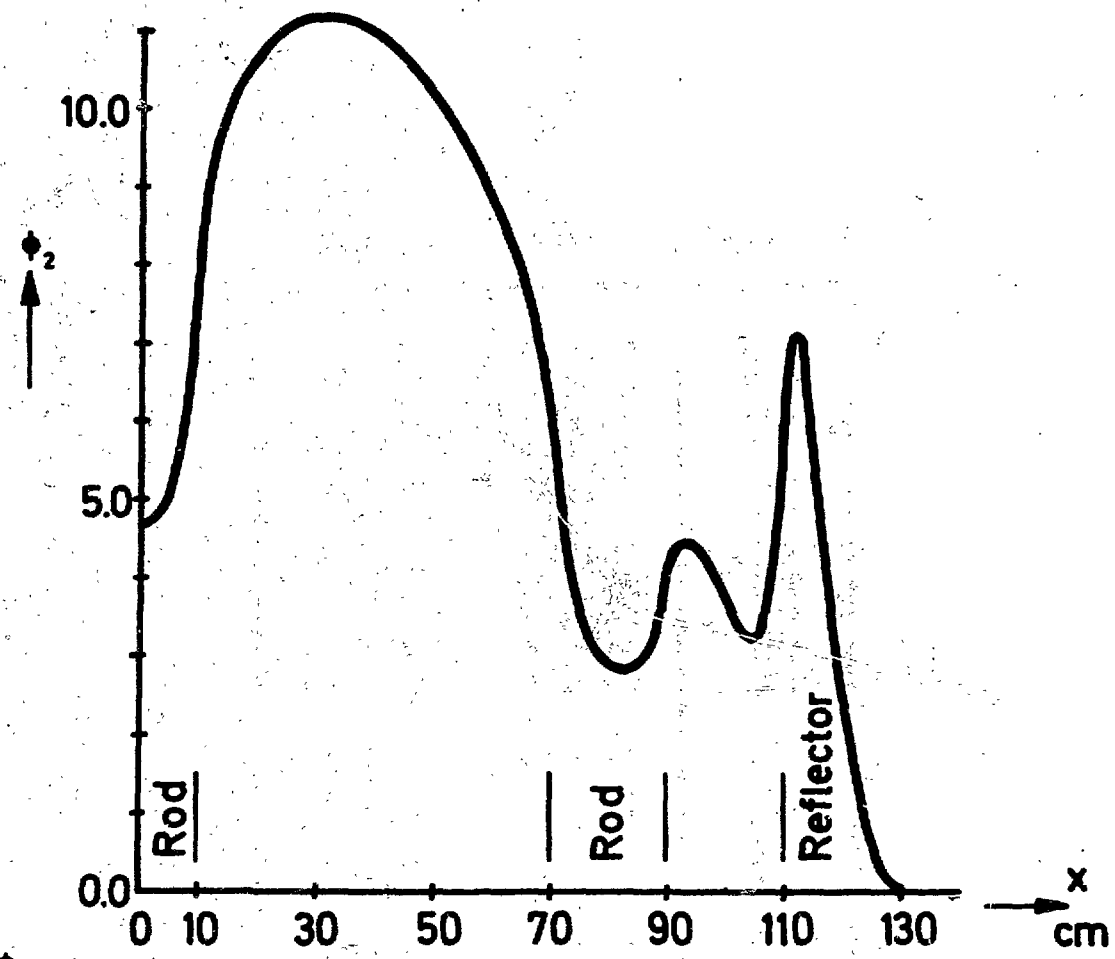
Exhibit A1

x(cm)	$\phi_1(x,0)$	$\phi_2(x,0)$	x(cm)	$\phi_1(x,0)$	$\phi_2(x,0)$
0	29.419	4.631	60	38.909	9.123
2	29.603	4.665	62	37.469	8.770
4	30.171	4.780	64	35.859	8.351
6	31.135	5.017	66	34.075	7.824
8	32.506	5.506	68	32.132	7.083
10	34.246	6.654	70	30.111	5.863
12	36.133	7.953	72	28.225	4.789
14	37.921	8.701	74	26.668	4.301
16	39.521	9.200	76	25.468	4.037
18	40.917	9.576	78	24.607	3.878
20	42.116	9.875	80	24.071	3.789
22	43.140	10.122	82	23.835	3.756
24	43.999	10.326	84	23.908	3.786
26	44.709	10.494	86	24.289	3.910
28	45.282	10.628	88	24.983	4.224
30	45.725	10.733	90	25.954	5.030
32	46.047	10.808	92	27.030	5.940
34	46.252	10.856	94	28.025	6.425
36	46.345	10.878	96	28.871	6.718
38	46.329	10.874	98	29.559	6.916
40	46.206	10.846	100	30.095	7.056
42	45.978	10.792	102	30.497	7.155
44	45.644	10.714	104	30.774	7.222
46	45.205	10.611	106	30.939	7.262
48	44.659	10.482	108	31.003	7.277
50	44.003	10.328	110	30.973	7.270
52	43.236	10.148	112	30.857	7.243
54	42.349	9.940	114	30.659	7.196
56	41.339	9.702	116	30.386	7.133
58	40.197	9.432	118	30.042	7.052

Table 1: Radial Flux Traverse $\phi_g(x,0)$ Along Main Axis

x(cm)	$\phi_1(x,0)$	$\phi_2(x,0)$
120	29.631	6.956
122	29.156	6.847
124	28.621	6.727
126	28.027	6.603
128	27.372	6.489
130	26.643	6.423
132	25.810	6.329
134	24.843	6.134
136	23.731	5.880
138	22.475	5.587
140	21.078	5.273
142	19.537	4.968
144	17.833	4.742
146	15.904	4.764
148	13.573	5.473
150	10.371	7.978
152	7.797	11.582
154	5.858	12.527
156	4.397	11.993
158	3.294	10.702
160	2.461	9.077
162	1.828	7.350
164	1.344	5.630
166	.971	3.946
168	.676	2.271
170	.437	.538

Table 1: (continued)



Thermal Flux Traverse Φ_2 (x,x), Diagonal

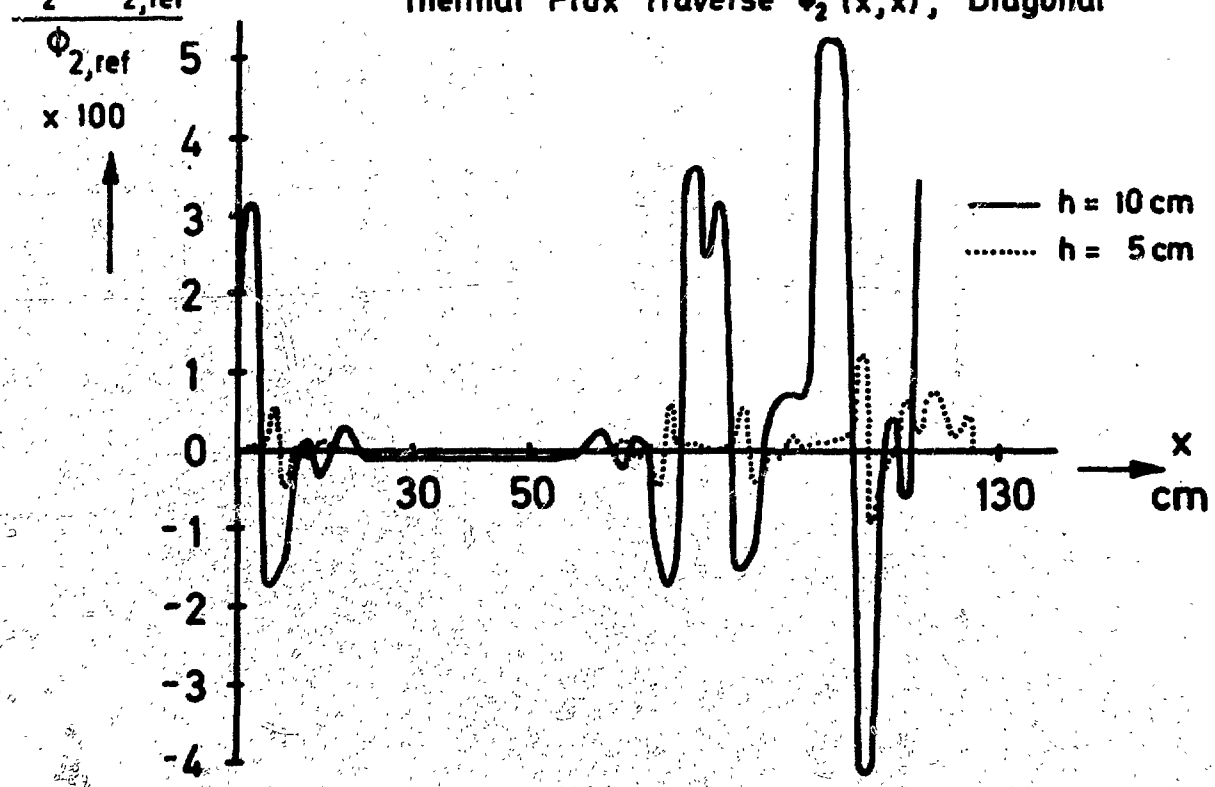


Exhibit A2 Relative Deviation (%) of Interpolated Coarse Mesh Solutions from Reference Solution

x(cm)	$\phi_1(x,x)$	$\phi_2(x,x)$	x(cm)	$\phi_1(x,x)$	$\phi_2(x,x)$
0	29.419	4.631	70	28.145	6.024
2	29.789	4.700	72	25.498	4.568
4	30.889	4.925	74	23.077	3.801
6	32.673	5.372	76	21.073	3.363
8	35.025	6.257	78	19.543	3.085
10	37.649	8.040	80	18.486	2.910
12	40.019	9.242	82	17.874	2.821
14	41.945	9.814	84	17.659	2.818
16	43.487	10.201	86	17.772	2.933
18	44.715	10.494	88	18.100	3.276
20	45.682	10.722	90	18.430	4.081
22	46.428	10.898	92	18.440	4.476
24	46.984	11.028	94	18.021	4.451
26	47.374	11.120	96	17.222	4.276
28	47.617	11.177	98	16.101	4.022
30	47.729	11.203	100	14.709	3.726
32	47.724	11.202	102	13.087	3.439
34	47.612	11.175	104	11.258	3.255
36	47.402	11.126	106	9.216	3.363
38	47.102	11.056	108	6.889	4.150
40	46.716	10.965	110	4.254	6.257
42	46.247	10.855	112	2.669	7.066
44	45.698	10.726	114	1.711	6.074
46	45.068	10.578	116	1.106	4.723
48	44.354	10.411	118	.715	3.444
50	43.552	10.223	120	.459	2.372
52	42.657	10.013	122	.289	1.525
54	41.662	9.779	124	.176	.889
56	40.556	9.519	126	.102	.437
58	39.328	9.231	128	.055	.149
60	37.964	8.911	130	.033	.030
62	36.443	8.553			
64	34.740	8.149			
66	32.818	7.680			
68	30.632	7.080			

Table 2: Radial Flux Traverse $\phi_g(x,x)$ Along Diagonal

J/I	1	2	3	4	5	6	7	8
	.746	1.310	1.454	1.211	.610	.935	.934	.755
1	1.085	1.464	1.479	1.407	.951	.998	.993	1.077
	11 11	11 11	4 11	1 11	1 11	9 11	1 11	11 6
		1.435	1.480	1.315	1.070	1.036	.950	.736
2		1.513	1.513	1.446	1.265	1.123	1.059	1.068
		11 11	1 11	1 11	1 11	1 11	1 11	11 1
			1.469	1.345	1.179	1.070	.975	.692
3			1.513	1.446	1.275	1.132	1.130	1.446
			1 1	1 1	1 4	1 4	11 11	3 11
				1.193	.967	.906	.846	
4				1.380	1.207	1.062	1.525	
				1 1	1 1	1 1	11 4	
					.471	.686	.597	
5					.813	.811	1.077	
					1 1	6 1	11 1	

h = 3 1/3 cm

6 Average Subassembly Power — .585
Maximum Power ——— 1.044
Location of Maximum ——— 11 3
(2 cm Grid)

J/I	1	2	3	4	5	6	7	8
	.744	1.308	1.452	1.210	.609	.935	.934	.755
1	1.085	1.462	1.478	1.406	.951	.998	.993	1.079
	11 11	11 11	4 11	1 11	1 11	9 11	1 11	11 6
		1.434	1.479	1.314	1.069	1.036	.951	.736
2		1.511	1.511	1.446	1.265	1.122	1.059	1.070
		11 11	1 11	1 11	1 11	1 11	1 11	11 1
			1.468	1.344	1.179	1.071	.976	.693
3			1.511	1.446	1.274	1.132	1.125	1.439
			1 1	1 1	1 4	1 4	11 11	3 11
				1.192	.967	.907	.847	
4				1.379	1.206	1.062	1.530	
				1 1	1 1	1 1	11 4	
					.471	.686	.599	
5					.814	.810	1.079	
					1 1	6 1	11 1	
						.587		
6						1.043		
						11 3		

h = 10 cm

Table 3 Average and Maximum Power Density per Subassembly

Table 4 2D IAEA Benchmark Problem

Table of average fast group fluxes ϕ_1
for a square mesh grid of 20 x 20 cm

						.642 .652		
					14.015 14.040	3.993 4.001	.573 .579	
				20.391 20.392	20.766 20.801	14.439 14.464	2.421 2.431	
			37.677 37.661	30.896 30.898	28.498 28.511	22.587 22.612	5.952 5.959	.712 .718
h = 3 1/3 cm		46.372	42.448	37.215	33.697	29.089	16.662	2.438
h = 10 cm		46.332	42.423	37.204	33.700	29.111	16.683	2.439
	45.334	46.702	41.535	34.215	32.726	29.842	19.854	3.220
	45.288	46.660	41.503	34.205	32.723	29.849	19.867	3.218
32.467	41.890	45.877	38.695	26.564	29.938	29.411	20.327	3.370
32.422	41.855	45.835	38.669	26.542	29.941	29.416	20.334	3.369

Table 5 2D IAEA Benchmark Problem

Table of average thermal group fluxes ϕ_2

for a square mesh grid of 20 x 20 cm

						2.564 2.608		
					4.332 4.345	8.334 8.355	2.238 2.270	
				3.486 3.486	5.078 5.084	4.424 4.435	6.078 6.061	
			8.836 8.833	7.163 7.163	6.714 6.718	6.268 6.276	12.441 12.483	2.812 2.853
h = 3 1/3 cm		10.885	9.964	8.735	7.929	7.223	5.127	5.839
h = 10 cm		10.875	9.958	8.732	7.930	7.226	5.137	5.833
	10.630 10.621	10.962 10.952	9.740 9.734	7.924 7.920	7.675 7.675	7.040 7.041	5.450 5.453	7.579 7.580
5.523 5.514	9.701 9.692	10.768 10.758	8.968 8.961	4.519 4.514	6.926 6.926	6.921 6.922	5.592 5.593	7.968 7.969

BENCHMARK PROBLEM SOLUTION

Identification: 11-A2-4 Benchmark Problem ID.11-A2

Date Submitted: June 1976 By: D. A. Meneley (Ontario Hydro)

Date Accepted: June 1977 By: H. L. Dodds, Jr. (U. of Tenn.)
M. V. Gregory (SRL)

Descriptive Title: Two-dimensional PWR Problem

Mathematical Model: Five-point central difference formula with fluxes calculated at the center of the mesh cell. Two-term Taylor series expansion to cell boundary in each direction to satisfy flux and current continuity at cell boundaries.

Special Acceleration Techniques: Line inversion with successive overrelaxation, with optimum overrelaxation factor calculated from dominance ratio estimates. Inner iteration on all points in one group is continued until the error norm is 10 percent of that found on the first iteration (arbitrary choice). Outer iterations are accelerated using a second optimum overrelaxation factor.

Initialization: Group one fluxes set to 1.0 and group two fluxes set to 0.25. Eigenvalue set to 1.0. Overrelaxation factor for plane fluxes set to 1.2 and outer iteration factor set to 1.4.

Convergence: Maximum value of flux change over two iterations relative to root mean square flux in the reactor less than 5×10^{-5}.

Primary Results:

1. Maximum eigenvalue

Uniform Mesh	Eigenvalue
34 x 34	1.02924
68 x 68	1.02942
Non-Uniform Mesh	
88 x 88	1.02968

Mesh description-non-uniform mesh problem.

No. of Intervals In Each Direction	Mesh Spacing
16	2.5
4	2.0
4	1.0
4	2.0
8	2.5
4	2.0
4	1.0
8	2.0
4	1.0
8	2.0
4	1.0
8	2.0
4	1.0
4	2.0
4	2.5

Note: This mesh places two intervals of 1.0 cm width on each side of core-reflector boundary.

2. Fundamental flux distributions- values for 88 x 88 mesh

2.1 Radial Flux Traverses $\phi_g(x,o)$ and $\phi_g(x,x)$

x(cm)	$\phi_1(x,1.25)$	$\phi_2(x,1.25)$	$\phi_1(x,x)$	$\phi_2(x,x)$
1.25	29.83	4.704	29.83	4.704
3.75	30.42	4.822	30.99	4.936
6.25	31.62	5.116	33.22	5.493
8.75	33.48	5.817	36.32	6.726
11.25	35.89	7.776	39.62	9.085
13.75	38.18	8.756	42.16	9.862
16.25	40.16	9.362	44.07	10.34
18.75	41.82	9.797	45.50	10.68
21.25	43.19	10.13	46.55	10.93
23.75	44.30	10.40	47.29	11.10
26.25	45.18	10.60	47.76	11.21
28.75	45.84	10.76	48.01	11.27
31.25	46.31	10.87	48.06	11.28
33.75	46.59	10.94	47.93	11.25
36.25	46.70	10.96	47.66	11.19
38.75	46.64	10.95	47.24	11.09
41.00	46.43	10.90	46.74	10.97
43.00	46.15	10.83	46.22	10.85
45.00	45.76	10.74	45.62	10.71

2.1 Radial Flux Traverses $\phi g(x,o)$ and $\phi g(x,x)$ (Continued)

x(cm)	$\phi_1(x,1.25)$	$\phi_2(x,1.25)$	$\phi_1(x,x)$	$\phi_2(x,x)$
47.00	45.26	10.62	44.93	10.55
48.50	44.80	10.52	44.36	10.41
49.50	44.47	10.44	43.95	10.32
50.50	44.12	10.36	43.52	10.22
51.50	43.73	10.26	43.06	10.11
53.00	43.11	10.12	42.35	9.939
55.00	42.16	9.894	41.29	9.691
57.00	41.08	9.640	40.11	9.415
59.00	39.87	9.351	38.81	9.109
61.25	38.34	8.981	37.17	8.725
63.75	36.38	8.484	35.10	8.235
66.25	34.16	7.840	32.70	7.650
68.75	31.68	6.875	29.87	6.855
71.25	29.10	5.066	26.52	4.926
73.75	27.02	4.376	23.37	3.872
76.25	25.50	4.044	20.85	3.324
78.75	24.52	3.866	19.06	3.007
81.00	24.07	3.794	18.11	2.855
83.00	23.97	3.788	17.68	2.803
85.00	24.17	3.855	17.62	2.847
87.00	24.69	4.042	17.84	3.037
88.50	25.32	4.381	18.13	3.410
89.50	25.80	4.753	18.29	3.790
90.50	26.33	5.368	18.40	4.259
91.50	26.86	5.795	18.39	4.422
93.00	27.64	6.252	18.19	4.471
95.00	28.54	6.608	17.56	4.351
97.00	29.29	6.838	16.57	4.128
99.00	29.88	6.998	15.30	3.846
101.00	30.32	7.112	13.78	3.547
103.00	30.64	7.190	12.05	3.292
105.00	30.84	7.239	10.13	3.202
107.00	30.94	7.262	7.995	3.517
108.50	30.94	7.262	6.139	4.446
109.50	30.92	7.257	4.836	5.414
110.50	30.87	7.247	3.695	6.774
111.50	30.81	7.231	2.927	7.032
113.00	30.68	7.201	2.072	6.570
115.00	30.43	7.143	1.337	5.303
117.00	30.11	7.067	0.8669	3.977
119.00	29.72	6.976	0.5602	2.818
121.00	29.26	6.871	0.3578	1.882
123.00	28.75	6.754	0.2232	1.163
125.00	28.17	6.628	0.1339	0.6348
127.00	27.54	6.502	0.07498	0.2724
128.50	27.02	6.423	0.04537	0.09840
129.50	26.65	6.385	0.03048	0.02939

2.1 Radial Flux Traverses $\phi_g(x,o)$ and $\phi_g(x,x)$ (Continued)

x(cm)	$\phi_1(x,1.25)$	$\phi_2(x,1.25)$	$\phi_1(x,x)$	$\phi_2(x,x)$
130.50	26.26	6.371		
131.50	25.85	6.319		
133.00	25.17	6.200		
135.00	24.13	5.970		
137.00	22.94	5.693		
139.00	21.61	5.387		
141.00	20.14	5.073		
143.00	18.52	4.794		
145.00	16.72	4.649		
147.00	14.65	4.883		
148.50	12.71	5.794		
149.50	11.16	6.926		
150.50	9.479	6.214		
151.50	8.227	10.87		
153.00	6.599	12.27		
155.00	4.963	12.25		
157.00	3.728	11.23		
159.00	2.796	9.740		
161.25	2.002	7.854		
163.75	1.374	5.741		
166.25	0.9195	3.690		
168.75	0.5818	1.648		

2.2 Value and Location of Maximum Power Density

Mesh	Max/Avg Power Density in Core	Location	Refl. Boundary Location*	
34 x 34	1.598	27.5,32.5	1.435	130,52.5
68 x 68	1.545	31.25,31.25	1.508	130,56.25
88 x 88	1.523	31.25,31.25	1.521	130,55

* Interpolated between adjacent points.

3. Average subassembly powers (88 x 88 mesh)

Subassembly Number	Average Power
1	0.7421
2	1.325
3	1.464
4	1.222
5	0.6054
6	0.9357
7	0.9303
8	0.7464
10	1.448
11	1.4905
12	1.323
13	1.077

3. Average subassembly powers (88 x 88 mesh) (Continued)

Subassembly Number	Average Power
14	1.036
15	0.9457
16	0.7272
18	1.478
19	1.351
20	1.182
21	1.069
22	0.9702
23	0.6810
25	1.198
26	0.9714
27	0.9041
28	0.8370
31	0.4656
32	0.6831
33	0.5876
35	0.5762

4. Convergence data

	34x34	68x68	88x88
Number of unknowns	1,928	7,712	11,328
Outer iterations	42	57	73
Avg. No. of inner iteration per outer iteration	5	4	5

5. Computer data (CDC6600 machine)

	34x34	68x68	88x88
Field length (words)	33,664	68,544	100,352
Iteration time (CP)	19	160	340
Total time (CP)	26	182	378
(PP)	70	309	606

6. Type and numerical values of convergence criteria.

Type and value noted above.

7. Average group fluxes on subassembly mesh grid (20x20 cm, 88 x 88 mesh)

Subassembly Number	$\bar{\phi}_1$	$\bar{\phi}_2$
1	32.71	5.497
2	42.29	9.817
3	46.21	10.85
4	38.98	9.054
5	26.63	4.484
6	29.94	6.931
7	29.29	6.891
8	20.17	5.529
9	3.295	7.898
10	45.72	10.72
11	47.02	11.04
12	41.79	9.802
13	34.37	7.979
14	32.73	7.677
15	29.71	7.005
16	19.69	5.387
17	3.147	7.510
18	46.63	10.95
19	42.64	10.01
20	37.30	8.756
21	33.66	7.919
22	28.94	7.187
23	16.49	5.044
24	2.381	5.777
25	37.82	8.871
26	30.97	7.196
27	28.43	6.697
28	22.42	6.200
29	5.812	12.32
30	0.6944	2.768
31	20.79	3.449
32	20.67	5.060
33	14.30	4.353
34	2.364	5.964
35	13.90	4.293
36	3.899	8.251
37	0.5584	2.197
38	0.6269	2.517

BENCHMARK SOURCE SITUATION

Identification: 12

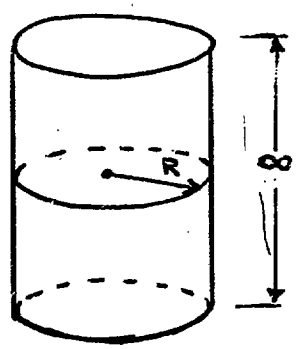
Date Submitted: June 1976 By: C. T. McDaniel (GE-San Jose)

Date Accepted: June 1977 By: H. L. Dodds, Jr. (U. of Tenn.)
D. R. Vondy (ORNL)

Descriptive Title: Neutron Transport in a Cylindrical 'Black' Rod

Suggested Function: Provide severe test of transport programs and approximations

Configuration



Details

Infinite cylinder of radius R

Known angular input current, I

Specified Total Cross Section, Σ_T

Variable ratio, C ($C = \Sigma_S/\Sigma_T$)

Vacuum Boundary

Isotropic scattering

BENCHMARK PROBLEM

Identification: 12-A1 Source Situation ID.12

Date Submitted: June 1976 By: C. T. McDaniel (GE-San Jose)

Date Accepted: June 1977 By: H. L. Dodds, Jr. (U. of Tenn.)
D. R. Vondy (ORNL)

Descriptive Title: Cylindrical 'Black' Rod with Known Input Current

Reduction of Source Problem

1. One Group Problem
2. Isotropic Scattering Assumed
3. Input Current: 1 neutron per sec per unit length
4. Input Current Angular Distribution:

Cos θ to surface normal

Data:

Rod Radius R(cm)	0.5
Total Cross Section, Σ_T (cm^{-1})	1.0; 2.0; 10.0, 100.0
Ratio C, ($C = \Sigma_S/\Sigma_T$)	0(.2)1.0

The equation to be solved is:

$$\bar{\Omega}\cdot\nabla\psi + \Sigma_T\psi = \int\Sigma_S\psi(\bar{r},\bar{\Omega}')d\Omega'$$

Expected Primary Results

Indicated Solution Method

Rod Multiple Scattering Albedo

Rod Absorption Rate

Interior spatial flux distribution, $\phi(r)$

Rod Average Flux, $\bar{\phi}$

Rod Surface Flux, $\phi(R)$

The Ratio of Rod Surface Flux to Rod Average Flux, $G(R) \equiv \phi(R)/\bar{\phi}$

Best Solution Available

Monte Carlo

Analytic Solution Available for $\Sigma_{S/\Sigma_T} = 0$

References

1. Case, K. M., F. deHoffman and G. Placzek, "Introduction to the Theory of Neutron Diffusion," Vol. 1, U. S. Government Printing Office (1953).

2. Kushneriuk, S. A., "The One Velocity Neutron Flux Distribution in a Cylindrical Cell," AECL-2709 (May 1967).

3. McDaniel, C. T., et al., "Benchmark Calculations for a Cylindrical 'Black' Rod," TANSAO 23, 212, Toronto, Canada (June 1976).

Solutions

1. Semi-Analytic Transport Theory 12-A1-1

2. Modified Collision Probability Method 12-A1-2

3. Collision Probability Using Ray Tracing 12-A1-3

4. Weakly Singular Integral Transport 12-A1-4

5. Monte Carlo Solution 12-A1-5

BENCHMARK PROBLEM SOLUTIONS

Identification: 12-A1-1 Benchmark Problem ID.12-A1
12-A1-2
12-A1-3
12-A1-4
12-A1-5

Date Submitted: June 1976 By: 12-A1-1 S. A. Kushneriuk (AECL-CNRL)
12-A1-2 A. Leonard (NASA-Ames)
C. T. McDaniel (GE-San Jose)
12-A1-3 P. T. Choong (GE-San Jose)
12-A1-4 S. K. Loyalka (U. of Mo.)
12-A1-5 D. F. Biron (GAAA-France)
C. T. McDaniel (GE-San Jose)

Date Accepted: June 1977 By: H. L. Dodds, Jr. (U. of Tenn.)
D. R. Vondy (ORNL)

Descriptive Title: Cylindrical 'Black' Rod with Known Input Current

Mathematical Models and Solution Methods:

12-A1.1 A Semi-Analytic Transport Solution[1]

The asymptotic solution to the transport equation is found and the extrapolation distance, λ, for the asymptotic distribution is obtained explicitly. In the transient region near the rod surface, another quantity, termed $\gamma(r)$, which is the functional behavior of the transient flux, is also obtained. These two quantities, along with diffusion theory, enable one to describe the neutron flux distribution with the cell.

12-A1-2 A Modified Collision Probability Method[2]

The current-coupling collision probability method is used to solve the integral transport equation. First flight neturons are treated explicitly on flights to interior radial rings, whereas a cosine current coupling for multiply scattered neutrons is assumed.

12-A1-3 Collision Probability Solutions Using Ray Tracing[3]

The integral transport equation is solved by means of the slicing technique, in which the rod is subdivided into radial rings and ring-to-ring collision probabilities developed using Bickley function kernels and a variable number of slices normal to the rod diameter.

12-A1-4 The Weakly Singular Integral Transport Method[4]

The weakly singular integral transport equation is solved by means of a method based on removal of the singularity. Bickley function kernels are used with a Gaussian integration procedure for the radial variation of flux.

12-A1-5 The Monte Carlo Method[5]

Here, the three dimensional rod geometry and scattering mechanics are modeled explicitly. The angular distribution of incident neutrons is treated exactly and neutrons are followed until they escape or are absorbed.

Primary Results

The results for each of these five methods are given in Tables I. For Methods 2 and 3, the calculations have been performed for (a) equal radial increment rings, (b) equal volume rings, and (c) the "onion skin" technique[2] where rings are clustered near the outer surface of the rod. Where possible, the "exact" results of Case, deHoffman and Placzek[6] are also quoted. Table II contains a comparison of computing time for the various methods. The computed radial flux distributions are given in Table III.

References

1. Kusneriuk, S. A., "The One Velocity Neutron Flux Distribution in a Cylindrical Cell", AECL-2709, May 1967. Results quoted by personal communication.

2. Leonard, A., McDaniel, C. T., and Petrick, W. P., "Integral Transport Calculation of Spatial Gadolinium Depletion", Transactions of the American Nuclear Society 19, p. 406 (1974).

3. Choong, P. T., "Implementation of the Slicing Technique for GE BWR Calculations", Transactions of the American Nuclear Society 20, p. 221 (1975).

4. Loyalka, S. K. and Tsai, R. W., "Integral Transport for 2-D Benchmark Shielding Problems", Transactions of the American Nuclear Socity 20, p. 230 (1975).

5. Biron, D. F., "A One-Rod Cell Monte Carlo Program", personal communication.

6. Case, K. M., deHoffman, F. and Placzek, G., "Introduction to the Theory of Neutron Diffusion", Volume 1, U. S. Government Printing Office (1953).

Table I
Benchmark Black Rod Problem
(R = 0.5 cm)

Σ_T	Quantity	Method	Σ_S/Σ_T 0	.2	.4	.6	.8	1.0
1.0 cm^{-1}	Absorption Rate	1	.5964	.5186	.4264	.3144	.1760	0.0
		2 (a)	.59595	.51801	.42558	.31391	.17582	0.0
		(b)	.59595	.51832	.42618	.31468	.17650	0.0
		(c)	.59595	.51793	.42542	.31368	.17560	0.0
		3 (a)	.59632	.51833	.42579	.31397	.17575	0.0
		(b)	.59619	.51821	.42569	.31389	.17570	0.0
		(c)	.59634	.51833	.42576	.31391	.17569	0.0
		4	.59595	.51814	.42568	.31396	.17581	0.0
		5 (b)	.5964	.51721	.4257	.3127	.17621	0.0
			±.0006	±.0004	±.0004	±.0003	±.0002	
		Exact	.59595	----	----	----	----	0.0
	Scattering Albedo	1	0.0	.07775	.1700	.2819	.4203	.5964
		2 (a)	0.0	.07794	.17037	.28204	.42013	.59595
		(b)	0.0	.07763	.16977	.28127	.41945	.59595
		(c)	0.0	.07802	.17053	.28227	.42035	.59595
		3 (a)	0.0	.07799	.17053	.28235	.42057	.59634
		(b)	0.0	.07798	.17050	.28230	.42049	.59619
		(c)	0.0	.07801	.17053	.28243	.42065	.59634
		4	0.0	.07781	.17027	.28099	.42014	.59595
		5 (b)	0.0	.07883	.1726	.2801	.4205	.5950
				±.001	±.002	±.004	±.006	±.008
		Exact	0.0	----	----	----	----	.59595
	Rod Average Flux	1	.7593	.8254	.9049	1.009	1.1207	1.2732
		2 (a)	.75879	.82443	.90312	.99921	1.1193	1.2738
		(b)	.75879	.82494	.90439	1.0017	1.1236	1.2812
		(c)	.75879	.82431	.90277	.99848	1.1179	1.2713
		3 (a)	.75926	.82494	.90356	.99939	1.1189	1.2720
		(b)	.75909	.82476	.90335	.99914	1.1186	1.2717
		(c)	.75928	.82494	.90350	.99922	1.1185	1.2713
		4	.75879	.82465	.90331	.99938	1.1192	1.2732
		5 (b)	.75939	.8232	.9033	.9955	1.1214	1.259
			±.0007	±.0007	±.0008	±.0008	±.001	±.012
		Exact	.75879	----	----	----	----	1.2732
	Ratio, Surface to Average Flux	1	1.2295	1.1852	1.1393	1.0939	1.0472	1.0
		2 (a)	1.2306	1.1875	1.1429	1.0968	1.0489	1.0004
		(b)	1.2306	1.1869	1.1415	1.0945	1.0456	.9946
		(c)	1.2306	1.1876	1.1433	1.0974	1.0500	1.0007
		3 (a)	1.2298	1.1868	1.1425	1.0968	1.0496	1.0007
		(b)	1.2301	1.1871	1.1429	1.0972	1.0499	1.0009
		(c)	1.2298	1.1868	1.1425	1.0969	1.0498	1.0011
		4*	1.2124	1.1475	1.1316	1.0890	1.0447	1.0
		5 (b)	1.2251	1.2031	1.1517	1.1005	1.0428	.9876
			±.030	±.025	±.016	±.016	±.013	±.009
		Exact	1.2306	----	----	----	----	1.0

*Calculated at relative radius of .99204.

Table I (cont)

Benchmark Black Rod Problem
(R = 0.5 cm)

Σ_T	Quantity	Method	Σ_S/Σ_T 0	.2	.4	.6	.8	1.0
2.0 cm^{-1}	Absorption Rate	1	.8137	.7367	.6370	.5022	.3079	0.0
		2 (a)	.81429	.73630	.63645	.50234	.30933	0.0
		(b)	.81429	.73659	.63717	.50357	.31081	0.0
		(c)	.81429	.73648	.63688	.50303	.31010	0.0
		3 (a)	.81505	.73648	.63575	.50055	.30683	0.0
		(b)	.81475	.73616	.63544	.50029	.30667	0.0
		(c)	.81487	.73625	.63548	.50027	.30659	0.0
		4	.8143	.7359	.6354	.5005	.3070	0.0
		5 (b)	.8142 ±.0009	.7386 ±.0010	.6369 ±.0008	.4991 ±.00005	.3076 ±.0003	0.0
		Exact	.81430					0.0
	Scattering Albedo	1	0.0	.07697	.1766	.3115	.5058	.8137
		2 (a)	0.0	.07799	.17784	.31195	.50496	.81429
		(b)	0.0	.07770	.17712	.31072	.50348	.81429
		(c)	0.0	.07781	.17741	.31108	.50419	.81429
		3 (a)	0.0	.07857	.17930	.31450	.50822	.81505
		(b)	0.0	.07859	.17931	.31446	.50808	.81475
		(c)	0.0	.07862	.17939	.31460	.50828	.81487
		4	0.0	.07842	.1789	.3138	.5073	.8143
		5 (b)	0.0	.07846 ±.002	.1799 ±.004	.3125 ±.008	.5081 ±.013	.8135 ±.010
		Exact	0.0					.81430
	Rod Average	1	.5180	.5862	.6759	.7992	.9800	1.2732
		2 (a)	.51839	.58593	.67529	.79950	.98462	1.2917
		(b)	.51839	.58616	.67606	.80145	.98933	1.3036
		(c)	.51839	.58607	.67575	.80060	.98708	1.2974
		3 (a)	.51888	.58607	.67455	.79665	.97668	1.2701
		(b)	.51869	.58582	.67422	.79624	.97617	1.2695
		(c)	.51876	.58589	.67427	.79620	.97591	1.2686
		4	.5184	.5856	.6741	.7965	.9773	1.2729
		5 (b)	.5184 ±.0005	.5878 ±.0008	.6758 ±.0008	.7944 ±.0007	.9790 ±.0009	1.274 ±.0009
		Exact	.51840					1.2732
	Ratio, Surface to Average Flux	1	1.5632	1.4576	1.3501	1.2391	1.1232	1.0
		2 (a)	1.5603	1.4605	1.3547	1.2418	1.1203	.9882
		(b)	1.5603	1.4604	1.3538	1.2395	1.1161	.9814
		(c)	1.5603	1.4605	1.3543	1.2407	1.1182	.9851
		3 (a)	1.5589	1.4603	1.3565	1.2464	1.1287	1.0015
		(b)	1.5594	1.4613	1.3576	1.2475	1.1295	1.0018
		(c)	1.5592	1.4610	1.3574	1.2473	1.1296	1.0023
		4*	1.5108	1.4225	1.3282	1.2270	1.1173	.9973
		5 (b)	1.5623 ±.022	1.4419 ±.020	1.3470 ±.029	1.2520 ±.024	1.127 ±.013	.9980 ±.017
		Exact	1.5603					1.0

*Calculated at relative radius of .99204.

Table I (cont)

Benchmark Black Rod Problem
(R = 0.5 cm)

Σ_T	Quantity	Method	Σ_S/Σ_T 0	.2	.4	.6	.8	1.0
10.0 cm^{-1}	Absorption Rate	1	.9923	---	.8702	.77185	.6032	0.0
		2 (a)	.99226	.94269	.87592	.77828	.60917	0.0
		(b)	.99227	.93996	.87069	.77131	.60287	0.0
		(c)	.99228	.93909	.87039	.77477	.61459	0.0
		3 (a)	.99568	.94639	.87986	.78219	.61181	0.0
		(b)	.99496	.94365	.87527	.77623	.60602	0.0
		(c)	1.0	.94806	.87964	.78192	.61536	0.0
		4	.99203	.93969	.87038	.77068	.60071	0.0
		5	.9924 ±.001	.9367 ±.0011	.8686 ±.001	.7712 ±.001	.6003 ±.001	0.0
		Exact	.99227	---	---	---	---	0.0
	Scattering Albedo	1	0.0	---	.1221	.2205	.3891	.9923
		2 (a)	0.0	.04958	.11634	.21398	.38309	.99226
		(b)	0.0	.05232	.12158	.22096	.38940	.99227
		(c)	0.0	.05318	.12188	.21781	.37769	.99228
		3 (a)	0.0	.04930	.11532	.21349	.38387	.99568
		(b)	0.0	.05132	.11969	.21873	.38894	.99496
		(c)	0.0	.05194	.12036	.21808	.38464	1.0
		4	0.0	.05201	.12132	.22102	.39099	.99170
		5 (b)	0.0	.05232 ±.008	.1229 ±.011	.2212 ±.023	.3939 ±.04	.9925 ±.09
		Exact	0.0	---	---	---	---	.99227
	Rod Average Flux	1	.12634	---	.1847	.2457	.3840	1.2732
		2 (a)	.12634	.15003	.18588	.24773	.38781	1.3026
		(b)	.12634	.14960	.18477	.24551	.38380	1.3259
		(c)	.12634	.14946	.18470	.24652	.39126	1.3417
		3 (a)	.12677	.15062	.18671	.24898	.38949	1.2639
		(b)	.12668	.15019	.18574	.24708	.38580	1.2624
		(c)	.12732	.15089	.18667	.24889	.39175	1.2497
		4	.12631	.14956	.18470	.24532	.38242	1.27327
		5 (b)	.12636 ±.0002	.1491 ±.0002	.1843 ±.0002	.2455 ±.0003	.3821 ±.0006	1.2676 ±.001
		Exact	.12634	---	---	---	---	1.2732
	Ratio, Surface to Average Flux	1	5.2931	---	4.0825	3.3347	2.4117	1.0
		2 (a)	5.2923	4.6774	4.0119	3.2642	2.3579	.9783
		(b)	5.2927	4.7085	4.0626	3.3203	2.3988	.9620
		(c)	5.2929	4.7207	4.0712	3.3053	2.3398	.9523
		3 (a)	5.2741	4.6590	3.9941	3.2489	2.3500	1.0039
		(b)	5.2784	4.6898	4.0420	3.3021	2.3919	1.0045
		(c)	5.2520	4.6753	4.0306	3.2817	2.3493	1.0099
		4*	4.5592	4.1441	3.6603	3.0720	2.2966	.9982
		5 (b)	5.2719 ±.11	4.6725 ±.078	4.0685 ±.076	3.3327 ±.031	2.4153 ±.048	1.0143 ±.033
		Exact	5.2929	---	---	---	---	1.0

*Calculated at relative radius of .99204.

Table I (cont)

Benchmark Black Rod Problem
(R = 0.5 cm)

Σ_T	Quantity	Method	Σ_S/Σ_T 0	.2	.4	.6	.8	1.0
100 cm^{-1}	Absorption Rate	1	---	---	---	---	---	---
		2 (a)	.99993	.98713	.96711	.93119	.84674	0.0
		(b)	.99991	.97736	.94374	.88775	.77207	0.0
		(c)	.99992	.95267	.89309	.81425	.70091	0.0
		3 (a)	1.0000	.98718	.96712	.93115	.84658	0.0
		(b)	1.0000	.97740	.93472	.88764	.77184	0.0
		(c)	1.0000	.95139	.88907	.80519	.68257	0.0
		4						
		5 (b)	.99991	.95456 ± 0008	.89135 ±.0008	.79807 ±.0006	.65430 ±.0008	0.0
		Exact	.99997					0.0
	Scattering Albedo	1	---	---	---	---	---	---
		2 (a)	0.0	.01280	.03282	.06874	.15319	.99993
		(b)	0.0	.02255	.05617	.11216	.22784	.99991
		(c)	0.0	.04725	.10683	.18567	.29901	.99992
		3 (a)	0.0	.01282	.03288	.06885	.15342	1.0000
		(b)	0.0	.02260	.05628	.11236	.22816	1.0000
		(c)	0.0	.04861	.11093	.19481	.30743	1.0000
		4						
		5 (b)	0.0	.04725 ±.019	.10937 ±.035	.19953 ±.075	.34663 ±.09	.99991
		Exact	0.0					.99997
	Rod Average Flux	1	---	---	---	---	---	---
		2 (a)	.012732	.015711	.020523	.029641	.053905	1.2733
		(b)	.012731	.015555	.020027	.208258	.049152	1.2738
		(c)	.012731	.015162	.018952	.025919	.044621	1.3466
		3 (a)	.012732	.015711	.020523	.029639	.053895	1.2508
		(b)	.012732	.015556	.020026	.028254	.049137	1.2396
		(c)	.012732	.015142	.018867	.02563	.043454	1.1162
		4						
		5(b)	.012752 ±.000007	.015192 ±.00001	.018915 ±.00002	.025403 ±.00002	.041654 ±.00005	---
		Exact	.012732					1.2732
	Ratio, Surface to Average Flux	1	---	---	---	---	---	---
		2 (a)	50.064	41.088	32.075	22.979	13.633	1.0
		(b)	50.122	41.954	33.663	25.129	15.953	.99956
		(c)	50.253	44.458	37.800	29.748	18.991	.94482
		3 (a)	50.060	41.087	32.075	22.980	13.634	1.0102
		(b)	50.117	41.952	33.665	25.132	15.957	1.0245
		(c)	50.249	44.411	37.808	29.916	19.384	1.0707
		4						
		5 (b)	50.205 ±1.01	44.018 ±.37	38.035 ±.52	31.239 ±1.04	21.518 ±1.07	---
		Exact	50.172					1.0

*Calculated at relative radius of .99204.

Table II

Comparison of Computing Time and Cost

Method	Machine	Processor Time† 24 Cases	Processor Time† per Case	Computing Cost $ (all cases)
1	----	-----	-----	-----
2 (a)	H-6000	.240	∿.010	$ 1.71
(b)	H-6000	.246	∿.010	$ 1.76
(c)	H-6000	.186	∿.008	$ 1.48
3 (a)	H-6000	.618	∿.026	$ 3.21
(b)	H-6000	.708	∿.030	$ 3.62
(c)	H-6000	.348	∿.015	$ 2.09
4	IBM 370/168	∿.960	.04	$ 30.24
5	H-6000	4.6 (hrs.)	11.5 (min.)	$700.0

†Time in minutes unless noted otherwise.

Table III

Benchmark Black Rod Problem

Computed Radial Flux Distribution

Method 1

(The Radial Flux results from Method 1 are not available.)

Table III (cont)

BENCHMARK BLACK ROD PROBLEM

COMPUTED RADIAL FLUX DISTRIBUTION

METHOD: 2
EQUAL ΔR

Total Cross Section, Σ_T = 1.0; Rod Radius = 0.5

Normalized Radius (r/R)	Σ_S/Σ_T 0.0	.2	.4	.6	.8	1.0
0.0						
.1	.6470	.7314	.8348	.9640	1.1291	1.3458
.2	.6494	.7323	.8337	.9602	1.1214	1.3327
.3	.6565	.7373	.8359	.9584	1.1141	1.3176
.4	.6676	.7458	.8409	.9587	1.1078	1.3020
.5	.6830	.7583	.8494	.9616	1.1032	1.2869
.6	.7035	.7753	.8618	.9679	1.1010	1.2731
.7	.7301	.7979	.8792	.9784	1.1023	1.2617
.8	.7646	.8278	.9033	.9949	1.1088	1.2544
.9	.8106	.8687	.9376	1.0209	1.1238	1.2547
1.0	.8791	.9314	.9[illegible]31	1.0672	1.1583	1.2736
Surface Flux	.9338	.9790	1.0322	1.0959	1.1740	1.2727
Average Flux	.7588	.8244	.9031	.9992	1.1193	1.2738

Table III (cont)

BENCHMARK BLACK ROD PROBLEM

COMPLETED RADIAL FLUX DISTRIBUTION

METHOD: 2

EQUAL ΔR

Total Cross Section, Σ_T = 2.0; Rod Radius = 0.5

Normalized Radius (r/R)	Σ_S/Σ_T 0.0	.2	.4	.6	.8	1.0
0.0						
.1	.3503	.4281	.5372	.6981	.9522	1.3978
.2	.3545	.4319	.5399	.6985	.9478	1.3830
.3	.3644	.4411	.5475	.7026	.9447	1.3643
.4	.3798	.4556	.5599	.7105	.9434	1.3436
.5	.4015	.4762	.5777	.7227	.9446	1.3219
.6	.4309	.5039	.6018	.7401	.9490	1.3000
.7	.4701	.5406	.6341	.7641	.9580	1.2792
.8	.5226	.5897	.6774	.7976	.9741	1.2623
.9	.5957	.6581	.7385	.8469	1.0034	1.2552
1.0	.7114	.7676	.8388	.9331	1.0671	1.2790
Surface Flux	.8089	.8558	.9148	.9928	1.1030	1.2765
Average Flux	.5184	.5859	.6753	.7995	.9846	1.2917

Table III (cont)

BENCHMARK BLACK ROD PROBLEM

COMPUTED RADIAL FLUX DISTRIBUTION

METHOD: 2
EQUAL ΔR

Total Cross Section, Σ_T = 10.0; Rod Radius = 0.5

Normalized Radius (r/R)	Σ_S/Σ_T 0.0	.2	.4	.6	.8	1.0
0.0						
.1	.00423	.00638	.01142	.02672	.09915	1.3516
.2	.00498	.00756	.01343	.03059	.1075	1.3503
.3	.00671	.01016	.01770	.03840	.1233	1.3479
.4	.00996	.01492	.02521	.05142	.1480	1.3441
.5	.01582	.02324	.03779	.07188	.1834	1.3380
.6	.02644	.03776	.05858	.1033	.2325	1.3283
.7	.04620	.06349	.09313	.1513	.2992	1.3131
.8	.08480	.1107	.1518	.2251	.3891	1.2902
.9	.1669	.2036	.2574	.3442	.5144	1.2607
1.0	.3879	.4341	.4960	.5855	.7384	1.2738
Surface Flux	.6686	.7018	.7457	.8086	.9144	1.2743
Average Flux	.12634	.1500	.1859	.2477	.3878	1.3026

Table III (cont)

BENCHMARK BLACK ROD PROBLEM

COMPUTED RADIAL FLUX DISTRIBUTION

METHOD: 2
EQUAL ΔR

Total Cross Section, Σ_T = 100; Rod Radius = 0.5

Normalized Radius (r/R)	Σ_S/Σ_T 0.0	.2	.4	.6	.8	1.0
0.0						
.1	---	---	---	---		1.2733
.2	---	---	---	---		1.2733
.3	---	---	---	---		1.2733
.4	---	---	---	---		1.2733
.5	---	---	---	---	.00003	1.2733
.6	---		.0000002	.000004	.00015	1.2733
.7		.0000003	.0000046	.000054	.00095	1.2733
.8	.0000005	.0000182	.000129	.000742	.00598	1.2733
.9	.000124	.001202	.003648	.01037	.03807	1.2732
1.0	.06689	.08160	.1047	.1461	.2442	1.2732
Surface Flux	.63739	.64553	.65827	.6811	.7349	1.2732
Average Flux	.01273	.01571	.02052	.02964	.05391	1.2733

Table III (cont)

BENCHMARK BLACK ROD PROBLEM

COMPUTED RADIAL FLUX DISTRIBUTION

METHOD: 2
EQUAL VOLUME

Total Cross Section, Σ_T = 1.0; Rod Radius = 0.5

Normalized Radius (r/R)	Σ_S/Σ_T 0.0	.2	.4	.6	.8	1.0
0.0						
.3162	.6550	.7381	.8399	.9668	1.1288	1.3417
.4472	.6714	.7498	.8453	.9635	1.1134	1.3091
.5477	.6919	.7667	.8572	.9686	1.1093	1.2921
.6325	.7131	.7843	.8701	.9754	1.1076	1.2788
.7071	.7358	.8036	.8849	.9842	1.1085	1.2687
.7746	.7605	.8248	.9016	.9952	1.1118	1.2617
.8367	.7877	.8485	.9209	1.0089	1.1180	1.2579
.8944	.8182	.8755	.9435	1.0258	1.1278	1.2580
.9487	.8540	.9076	.9712	1.0480	1.1428	1.2636
1.0	.9002	.9503	1.0094	1.0805	1.1683	1.2800
Surface Flux	.9338	.9791	1.0324	1.0963	1.1748	1.2742
Average Flux	.7588	.8249	.9044	1.0017	1.1236	1.2812

Table III (cont)

BENCHMARK BLACK ROD PROBLEM

COMPUTED RADIAL FLUX DISTRIBUTION

METHOD: 2
EQUAL VOLUME

Total Cross Section, Σ_T = 2.0; Rod Radius = 0.5

Normalized Radius (r/R)	Σ_S/Σ_T 0.0	.2	.4	.6	.8	1.0
0.0						
.3162	.3614	.4392	.5478	.7069	.9570	1.3951
.4472	.3859	.4623	.5673	.7187	.9532	1.3576
.5477	.4143	.4892	.5907	.7352	.9560	1.3321
.6325	.4450	.5180	.6157	.7532	.9608	1.3103
.7071	.4789	.5494	.6431	.7734	.9678	1.2916
.7746	.5163	.5843	.6735	.7962	.9775	1.2763
.8367	.5588	.6237	.7081	.8229	.9909	1.2651
.8944	.6080	.6695	.7485	.8551	1.0095	1.2595
.9487	.6676	.7250	.7982	.8961	1.0369	1.2629
1.0	.7481	.8001	.8679	.9569	1.0837	1.2860
Surface Flux	.8089	.8560	.9153	.9934	1.1041	1.2794
Average Flux	.5184	.5862	.6761	.8015	.9893	1.3036

Table III (cont)

BENCHMARK BLACK ROD PROBLEM

COMPUTED RADIAL FLUX DISTRIBUTION

METHOD: 2
EQUAL VOLUME

Total Cross Section, Σ_T = 10.0; Rod Radius = 0.5

Normalized Radius (r/R)	Σ_S/Σ_T 0.0	.2	.4	.6	.8	1.0
0.0						
.3162	.00610	.00926	.01626	.03584	.1184	1.3852
.4472	.01163	.01715	.02838	.05622	.1558	1.3798
.5477	.02008	.02886	.04557	.08326	.2008	1.3716
.6325	.03269	.04572	.06907	.1177	.2524	1.3600
.7071	.05134	.06964	.1007	.1606	.3107	1.3443
.7746	.07890	.1034	.1428	.2139	.3760	1.3239
.8367	.1200	.1514	.1992	.2801	.4492	1.2990
.8944	.1828	.2209	.2762	.3641	.5331	1.2713
.9487	.2838	.3275	.3876	.4774	.6371	1.2491
1.0	.4761	.5221	.5819	.6660	.8045	1.2948
Surface Flux	.6687	.7044	.7506	.8152	.9207	1.2755
Average Flux	.1263	.1496	.1848	.2455	.3838	1.3259

Table III (cont)

BENCHMARK BLACK ROD PROBLEM

COMPUTED RADIAL FLUX DISTRIBUTION

METHOD: 2
Equal Volume

Total Cross Section, Σ_T = 100; Rod Radius = 0.5

Normalized Radius (r/R)	Σ_S/Σ_T 0.0	.2	.4	.6	.8	1.0
0.0						
.3162	---	---	---	---	---	1.2739
.4472	---	---	---	---	---	1.2739
.5477	---	---	---	---	.000006	1.2739
.6325	---	---	---	---	.000038	1.2739
.7071	---	---	---	.000006	.000211	1.2739
.7746	---	---	.000006	.000058	.001064	1.2739
.8367	.000006	.000020	.000090	.000528	.005004	1.2739
.8944	.000148	.000408	.001246	.004397	.02213	1.2939
.9487	.003575	.007454	.01519	.03337	.09223	1.2732
1.0	.1236	.1477	.1837	.2442	.3708	1.2732
Surface Flux	.6381	.6526	.6742	.7101	.7841	1.2732
Average Flux	.01273	.01556	.020027	.02826	.04915	1.2738

Table III (cont)

BENCHMARK BLACK ROD PROBLEM

COMPUTED RADIAL FLUX DISTRIBUTION*

METHOD: 2
ONION SKIN

Total Cross Section, Σ_T = 1.0; Rod Radius = 0.5

Normalized Radius (r/R)	Σ_S/Σ_T 0.0	.2	.4	.6	.8	1.0
0.0						
.3998	.6605	.7401	.8370	.9571	1.1095	1.3081
.5932	.6928	.7658	.8539	.9621	1.1098	1.2737
.7536	.7384	.8051	.8848	.9819	1.1029	1.2551
.8880	.7965	.8563	.9273	1.0131	1.1192	1.2543
1.0	.8745	.9274	.9897	1.0644	1.1563	1.2726
Surface Flux	.9338	.9790	1.0321	1.0958	1.1738	1.2722
Average Flux	.7588	.8243	.9028	.9985	1.1179	1.2713

* Numbers tabulated represent $\int_{r_1}^{r_2} \phi(r)\, r dr$

Table III (cont)

BENCHMARK BLACK ROD PROBLEM

COMPUTED RADIAL FLUX DISTRIBUTION*

METHOD: 2

Onion Skin

Total Cross Section, Σ_T = 2.0; Rod Radius = 0.5

Normalized Radius (r/R)	Σ_S/Σ_T 0.0	.2	.4	.6	.8	1.0
0.0	---	---	---	---	---	---
.4298	.3722	.4490	.5552	.7093	.9489	1.3633
.5810	.4172	.4914	.5917	.7342	.9509	1.3177
.6999	.4662	.5376	.6324	.7647	.9624	1.2914
.7966	.5214	.5891	.6777	.7993	.9783	1.2716
.8768	.5835	.6469	.7287	.8395	1.0004	1.2606
.9440	.6548	.7134	.7880	.8881	1.0318	1.2618
1.0	.7441	.7974	.8649	.9545	1.0821	1.2850
Surface Flux	.8089	.8560	.9152	.9933	1.1038	1.2781
Average Flux	.5184	.5861	.6758	.8006	.9871	1.2974

* Numbers tabulated represent $\int_{r_1}^{r_2} \phi(r)\, r dr$

Table III (cont)

BENCHMARK BLACK ROD PROBLEM

COMPUTED RADIAL FLUX DISTRIBUTION

METHOD: 2
ONION SKIN

Total Cross Section, Σ_T = 10.0; Rod Radius = 0.5

Normalized Radius (r/R)	Σ_S/Σ_T 0.0	.2	.4	.6	.8	1.0
0.0						
.7862	.0355	.0492	.0737	.1244	.2666	1.3755
.8455	.1283	.1589	.2043	.2799	.4399	1.3326
.8859	.1819	.2189	.2717	.3545	.5155	1.3037
.9162	.2377	.2787	.3353	.4206	.5775	1.2789
.9400	.2966	.3397	.3977	.4827	.6326	1.2595
.9593	.3596	.4034	.4611	.5436	.6848	1.2469
.9754	.4283	.4715	.5276	.6063	.7378	1.2426
.9888	.5056	.5474	.6008	.6748	.7962	1.2502
1.0	.6007	.6402	.6904	.7590	.8703	1.2797
Surface Flux	.6687	.7056	.7520	.8148	.9155	1.2777
Average Flux	.1263	.1495	.1847	.2465	.3913	1.3417

Table III (cont)

BENCHMARK BLACK ROD PROBLEM

COMPUTED RADIAL FLUX DISTRIBUTION

METHOD: 2
ONION SKIN

Total Cross Section, Σ_T = 100; Rod Radius = 0.5

Normalized Radius (r/R)	Σ_S/Σ_T 0.0	.2	.4	.6	.8	1.0
0.0						
.9786	.00263	.00374	.00581	.01045	.02592	1.3499
.9846	.1092	.1326	.1653	.2134	.2929	1.3115
.9886	.1596	.1901	.2318	.2916	.3864	1.2854
.9916	.2131	.2482	.2951	.3608	.4617	1.2632
.9940	.2703	.3082	.3577	.4257	.5276	1.2461
.9959	.3321	.3713	.4216	.4894	.5890	1.2354
.9975	.4000	.4392	.4889	.5549	.6501	1.2330
.9989	.4768	.5151	.5631	.6260	.7156	1.2423
1.0	.5717	.6084	.6538	.7129	.7962	1.2734
Surface Flux	.6398	.6741	.7164	.7710	.8474	1.2723
Average Flux	.01273	.01516	.01895	.02592	.04462	1.3466

Table III (cont)

BENCHMARK BLACK ROD PROBLEM

COMPUTED RADIAL FLUX DISTRIBUTION

METHOD: 3
EQUAL ΔR

Total Cross Section, Σ_T *= 1.0; Rod Radius = 0.5*

Normalized Radius (r/R)	Σ_S/Σ_T 0.0	.2	.4	.6	.8	1.0
0.0						
.1	.6450	.7214	.8147	.9308	1.0786	1.2720
.2	.6492	.7253	.8181	.9335	1.0802	1.2720
.3	.6564	.7319	.8239	.9381	1.0830	1.2720
.4	.6675	.7422	.8329	.9451	1.0872	1.2720
.5	.6830	.7564	.8453	.9548	1.0930	1.2720
.6	.7035	.7751	.8615	.9675	1.1004	1.2720
.7	.7307	.7999	.8828	.9839	1.1101	1.2720
.8	.7652	.8310	.9093	1.0042	1.1220	1.2720
.9	.8113	.8721	.9440	1.0305	1.1371	1.2720
1.0	.8802	.9326	.9942	1.0680	1.1583	1.2720
Surface Flux	.9338	.9791.	1.0323	1.0962	1.1744	1.2729
Average Flux	.7593	.8249	.9036	.9994	1.1189	1.2720

Table III (cont)

BENCHMARK BLACK ROD PROBLEM

COMPUTED RADIAL FLUX DISTRIBUTION

METHOD: 3
EQUAL ΔR

Total Cross Section, Σ_T = 2.0; Rod Radius = 0.5

Normalized Radius (r/R)	Σ_S/Σ_T 0.0	.2	.4	.6	.8	1.0
0.0						
.1	.3487	.4196	.5181	.6616	.8832	1.2701
.2	.3547	.4256	.5239	.6668	.8888	1.2701
.3	.3644	.4356	.5337	.6756	.8951	1.2701
.4	.3798	.4511	.5488	.6892	.9047	1.2701
.5	.4015	.4730	.5699	.7080	.9179	1.2701
.6	.4308	.5022	.5980	.7327	.9350	1.2701
.7	.4709	.5417	.6354	.7651	.9570	1.2701
.8	.5233	.5925	.6826	.8054	.9839	1.2701
.9	.5963	.6619	.7459	.8582	1.0182	1.2701
1.0	.7123	.7690	.8404	.9343	1.0660	1.2701
Surface Flux	.8089	.8558	.9150	.9929	1.1023	1.2721
Average Flux	.5189	.5861	.6746	.7967	.9767	1.2701

Table III (cont)

BENCHMARK BLACK ROD PROBLEM

COMPUTED RADIAL FLUX DISTRIBUTION

METHOD: 3
EQUAL ΔR

Total Cross Section, Σ_T = 10.0; Rod Radius = 0.5

Normalized Radius (r/R)	Σ_S/Σ_T 0.0	.2	.4	.6	.8	1.0
0.0						
.1	.00419	.00702	.01328	[illegible]	.1073	1.2639
.2	.00748	.01079	.01784	.03704	.1167	1.2639
.3	.00822	.01224	.02067	.04274	.1289	1.2639
.4	.01101	.01633	.02712	.05390	.1500	1.2639
.5	.01656	.02409	.03867	.07246	.1820	1.2639
.6	.02694	.03805	.05841	.1021	.2285	1.2639
.7	.04740	.06422	.09310	.1499	.2955	1.2639
.8	.08535	.1108	.1516	.2246	.3888	1.2639
.9	.1668	.2047	.2602	.3498	.5248	1.2639
1.0	.3871	.4334	.4955	.5855	.7395	1.2639
Surface Flux	.6686	.7018	.7457	.8089	.9153	1.2688
Average Flux	.1268	.1506	.1867	.2490	.3895	1.2639

Table III (cont)

BENCHMARK BLACK ROD PROBLEM

COMPUTED RADIAL FLUX DISTRIBUTION

METHOD: 3
EQUAL ΔR

Total Cross Section, Σ_T = 100; Rod Radius = 0.5

Normalized Radius (r/R)	Σ_S/Σ_T 0.	.2	.4	.6	.8	1.0
0.0						
.1	---	---	---		---	1.2314
.2	---	---	---		---	1.2314
.3	---	---	---		---	1.2398
.4	---	---	---		.000004	1.2460
.5	---	---	---		.000025	1.2508
.6	---	---	.0000002	.000004	.000153	1.2547
.7	---	---	.0000046	.000054	.000952	1.2529
.8	---	.000018	.000128	.000743	.005991	1.2619
.9	.000119	.001198	.003647	.01038	.03809	1.2653
1.0	.06691	.08161	.1047	.1461	.2441	1.2684
Surface Flux	.6374	.6455	.6583	.6811	.7348	1.2708
Average Flux	.01273	.01571	.02052	.02964	.05390	1.2580

Table III (cont)

BENCHMARK BLACK ROD PROBLEM

COMPUTED RADIAL FLUX DISTRIBUTION

METHOD: 3
EQUAL VOLUME

Total Cross Section, Σ_T = 1.0; Rod Radius = 0.5

Normalized Radius (r/R)	Σ_S/Σ_T 0.0	.2	.4	.6	.8	1.0
0.0						
.3162	.6531	.7288	.8212	.9359	1.0816	1.2717
.4472	.6749	.7488	.8385	.9494	1.0896	1.2717
.5477	.6926	.7651	.8528	.9606	1.0962	1.2717
.6325	.7133	.7840	.8691	.9733	1.1037	1.2717
.7071	.7358	.8044	.8866	.9868	1.1116	1.2717
.7746	.7603	.8265	.9055	1.0012	1.1201	1.2717
.8367	.7880	.8513	.9265	1.0172	1.1293	1.2717
.8944	.8185	.8784	.9492	1.0344	1.1392	1.2717
.9487	.8541	.9099	.9754	1.0540	1.1503	1.2717
1.0	.9005	.9503	1.0087	1.0786	1.1641	1.2717
Surface Flux	.9338	.9791	1.0324	1.0962	1.1744	1.2728
Average Flux	.7591	.8248	.9034	.9991	1.1186	1.2717

Table III (cont)

BENCHMARK BLACK ROD PROBLEM

COMPUTED RADIAL FLUX DISTRIBUTION

METHOD: 3
EQUAL VOLUME

Total Cross Section, Σ_T = 2.0; Rod Radius = 0.5

Normalized Radius (r/R)	Σ_S/Σ_T 0.0	.2	.4	.6	.8	1.0
0.0						
.3162	.3597	.4309	.5291	.6716	.8921	1.2695
.4472	.3906	.4617	.5288	.6977	.9103	1.2695
.5477	.4152	.4866	.5829	.7193	.9254	1.2695
.6325	.4451	.5163	.6112	.7441	.9424	1.2695
.7071	.4785	.5490	.6421	.7707	.9605	1.2695
.7746	.5158	.5852	.6758	.7994	.9797	1.2695
.8367	.5590	.6266	.7137	.8314	1.0006	1.2695
.8944	.6080	.6729	.7556	.8660	1.0230	1.2695
.9487	.6673	.7280	.8047	.9059	1.0483	1.2695
1.0	.7478	.8013	.8684	.9564	1.0794	1.2695
Surface Flux	.8089	.8560	.9153	.9933	1.1026	1.2719
Average Flux	.5187	.5858	.6742	.7962	.9762	1.2695

Table III (cont)

BENCHMARK BLACK ROD PROBLEM

COMPUTED RADIAL FLUX DISTRIBUTION

METHOD: 3
EQUAL VOLUME

Total Cross Section, Σ_T = 10.0; Rod Radius = 0.5

Normalized Radius (r/R)	Σ_S/Σ_T 0.0	.2	.4	.6	.8	1.0
0.0						
.3162	.00603	.00973	.01765	.03878	.1228	1.2624
.4472	.01781	.02417	.03645	.06542	.1643	1.2624
.5477	.02060	.02957	.04636	.08372	.1986	1.2624
.6325	.03284	.04553	.06819	.1153	.2461	1.2624
.7071	.05128	.06885	.09868	.1567	.3028	1.2624
.7746	.07862	.1022	.1404	.2099	.3695	1.2624
.8367	.1204	.1512	.1985	.2792	.4489	1.2624
.8944	.1825	.2212	.2777	.3679	.5420	1.2624
.9487	.2828	.3289	.3924	.4874	.6557	1.2624
1.0	.4740	.5205	.5811	.6666	.8074	1.2624
Surface Flux	.6687	.7043	.7508	.8159	.9228	1.2681
Average Flux	.1267	.1502	.1857	.2471	.3858	1.2624

Table III (cont)

BENCHMARK BLACK ROD PROBLEM

COMPUTED RADIAL FLUX DISTRIBUTION

METHOD: 3
EQUAL VOLUME

Total Cross Section, Σ_T = 100; Rod Radius = 0.5

Normalized Radius (r/R)	Σ_S/Σ_T 0.0	.2	.4	.6	.8	1.0
0.0						
.3162	---	---	---	---	---	1.2047
.4472	---	---	---	---	---	1.2047
.5477	---	---	---	---	.000006	1.2253
.6325	---	---	---	---	.000039	1.2349
.7071	---	---	---	.000006	.000212	1.2417
.7746	---	---	.000006	.000058	.001068	1.2471
.8367	.000004	.000017	.000875	.000525	.00500	1.2515
.8944	.000120	.000373	.001198	.004330	.022022	1.2570
.9487	.003558	.007441	.01519	.03338	.09227	1.2621
1.0	.1236	.1477	.1838	.2442	.3708	1.2669
Surface Flux	.6381	.6526	.6742	.7101	.7841	1.2700
Average Flux	.01273	.01556	.02003	.02825	.04914	1.2396

Table III (cont)

BENCHMARK BLACK ROD PROBLEM

COMPUTED RADIAL FLUX DISTRIBUTION

METHOD: 3
ONION SKIN

Total Cross Section, Σ_T = 1.0, Rod Radius = 0.5

Normalized Radius (r/R)	Σ_S/Σ_T 0.0	.2	.4	.6	.8	1.0
0.0						
.3998	.6584	.7339	.8257	.9395	1.0836	1.2713
.5932	.6959	.7681	.8554	.9626	1.0973	1.2713
.7536	.7389	.8073	.8890	.9886	1.1126	1.2713
.8880	.7966	.8590	.9329	1.0220	1.1319	1.2713
1.0	.8748	.9278	.9902	1.0648	1.1562	1.2713
Surface Flux	.9338	.9790	1.0323	1.0960	1.1742	1.2727
Average Flux	.7593	.8249	.9035	.9992	1.1185	1.2713

Table III (cont)

BENCHMARK BLACK ROD PROBLEM

COMPUTED RADIAL FLUX DISTRIBUTION

METHOD: 3
ONION SKIN

Total Cross Section, Σ_T = 2.0; Rod Radius = 0.5

Normalized Radius (r/R)	Σ_S/Σ_T 0.0	.2	.4	.6	.8	1.0
0.0						
.4298	.3704	.4418	.5400	.6814	.8989	1.2686
.5810	.4234	.4944	.5901	.7253	.9292	1.2686
.6999	.4668	.5375	.6313	.7613	.9539	1.2686
.7966	.5211	.5092	.6804	.8032	.9819	1.2686
.8768	.5827	.6490	.7340	.8481	1.0112	1.2686
.9440	.6536	.7153	.7933	.8965	1.0421	1.2686
1.0	.7436	.7974	.8649	.9534	1.0772	1.2686
Surface Flux	.8089	.8560	.9152	.9931	1.1023	1.2715
Average Flux	.5188	.5859	.6743	.7962	.9759	1.2686

Table III (cont)

BENCHMARK BLACK ROD PROBLEM

COMPUTED RADIAL FLUX DISTRIBUTION

METHOD: 3
ONION SKIN

Total Cross Section, Σ_T = 10.0; Rod Radius = 0.5

Normalized Radius (r/R)	Σ_S/Σ_T 0.0	.2	.4	.6	.8	1.0
0.0						
.7862	.03476	.04812	.07178	.1207	.2568	1.2497
.8454	.1541	.1847	.2299	.3046	.4599	1.2497
.8860	.1844	.2221	.2762	.3614	.5255	1.2497
.9162	.2356	.2781	.3373	.4274	.5918	1.2497
.9400	.2920	.3377	.4000	.4918	.6524	1.2497
.9593	.3531	.4007	.4640	.5550	.7088	1.2497
.9754	.4214	.4692	.5316	.6192	.7634	1.2497
.9888	.4968	.5430	.6023	.6842	.8163	1.2497
1.0	.5998	.6313	.6843	.7567	.8724	1.2497
Surface Flux	.6687	.7055	.7524	.8168	.9204	1.2621
Average Flux	.12732	.1509	.1867	.2489	.3918	1.2497

Table III (cont)

BENCHMARK BLACK ROD PROBLEM

COMPUTED RADIAL FLUX DISTRIBUTION

METHOD: 3
ONION SKIN

Total Cross Section, Σ_T = 100; Rod Radius = 0.5

Normalized Radius (r/R)	Σ_S/Σ_T 0.0	.2	.4	.6	.8	1.0
0.0						
.9786	.00230	.00334	.00528	.00964	.02413	1.1162
.9846	.1578	.1829	.2170	.2659	.3438	1.1162
.9986	.1787	.2108	.2540	.3156	.4115	1.1162
.9916	.2183	.2543	.3025	.3702	.4736	1.1162
.9940	.2640	.3027	.3537	.4241	.5295	1.1162
.9959	.3139	.3541	.4062	.4770	.5811	1.1162
.9975	.3741	.4141	.4653	.5338	.6329	1.1162
.9989	.4354	.4743	.5234	.5882	.6806	1.1162
1.0	.5105	.5460	.5903	.6484	.7306	1.1162
Surface Flux	.6398	.6725	.7133	.7667	.8423	1.1951
Average Flux	.01273	.01514	.01887	.02563	.04345	1.1162

Table III (cont)

BENCHMARK BLACK ROD PROBLEM

COMPUTED RADIAL FLUX DISTRIBUTION

METHOD: 4

Total Cross Section, Σ_T = 1.0; Rod Radius = 0.5

Normalized Radius (r/R)	Σ_S/Σ_T 0.0	.2	.4	.6	.8	1.0
0.0						
.00796	.6447	.7215	.8145	.9308	1.0790	1.2732
.0469	.6451	.7223	.8148	.9311	1.0792	1.2732
.1229	.6474	.7256	.8167	.9325	1.0800	1.2732
.2308	.6542	.7335	.8222	.9369	1.0827	1.2732
.3602	.6684	.7483	.8336	.9459	1.0880	1.2932
.5000	.6920	.77-8	8525	.9606	1.0968	1.2732
.6398	.7263	.8014	.8795	.9816	1.1092	1.2732
.7692	.7714	.8387	.9142	1.0082	1.1247	1.2732
.8771	.8244	.8798	.9540	1.0383	1.1420	1.2732
.9531	.8783	.9187	.9933	1.0675	1.1585	1.2730
.9920	.9199	.9463	1.0222	1.0883	1.1692	1.2720
1.0	---	---	---	---	---	---
*Surface Flux	.9199	.9463	1.0222	1.0883	1.1692	1.2720
Average Flux	.7588	.8247	.0933	.9994	1.1192	1.2732

*"Surface" Flux at r/R = .9920

Table III (cont)

BENCHMARK BLACK ROD PROBLEM

COMPUTED RADIAL FLUX DISTRIBUTION

METHOD: 4

Total Cross Section, Σ_T = 2.0; Rod Radius = 0.5

Normalized Radius (r/R)	Σ_S/Σ_T 0.0	.2	.4	.6	.8	1.0
0.0						
.00796	.3484	.4191	.5174	.6610	.8853	1.2731
.0469	.3489	.4196	.5179	.6615	.8856	1.2731
.1229	.3520	.4228	.5211	.6643	.8876	1.2731
.2308	.3613	.4323	.5304	.6727	.8937	1.2731
.3602	.3809	.4522	.5498	.6901	.9060	1.2731
.5000	.4143	.4557	.5822	.7189	.9261	1.2731
.6398	.4644	.5353	.6294	.7602	.9544	1.2731
.7692	.5331	.6019	.6914	.8132	.9898	1.2731
.8771	.6181	.6825	.7646	.8740	1.0293	1.2730
.9531	.7091	.7666	.8389	.9338	1.0668	1.2727
.9920	.7832	.8330	.8954	.9774	1.0920	1.2695
1.0	---	---				
*Surface Flux	.7832	.8330	.8954	.9774	1.0920	1.2695
Average Flux	.5184	.5856	.6741	.7965	.9773	1.2729

*"Surface" Flux at r/R = .9920

Table III (cont)

BENCHMARK BLACK ROD PROBLEM

COMPUTED RADIAL FLUX DISTRIBUTION

METHOD: 4

Total Cross Section, Σ_T = 10. Rod Radius = 0.5

Normalized Radius (r/R)	Σ_S/Σ_T 0.0	.2	.4	.6	.8	1.0
0.0						
.00796	.00405	.00642	.01177	.02720	.09630	1.27328
.0469	.00412	.00653	.01195	.02751	.09694	1.27328
.1229	.00459	.00721	.01303	.02944	.10090	1.27328
.2308	.00616	.00948	.01660	.03571	.11341	1.27328
.3602	.01020	.01522	.02535	.05042	.14106	1.27329
.5000	.01991	.02841	.04439	.08018	.19153	1.27330
.6398	.04256	.05769	.08389	.13635	.27459	1.27330
.7692	.09338	.11950	.16090	.23458	.39669	1.27330
.8771	.19678	.23679	.29473	.38671	.56201	1.27337
.9531	.37062	.41977	.48540	.58003	.73970	1.27388
.9920	.57587	.61980	.67606	.75362	.87827	1.27096
1.0						
*Surface Flux	.57587	.61980	.67606	.75362	.87827	1.27096
Average Flux	.12631	.14956	.18470	.24532	.38242	1.27327

*"Surface" Flux at r/R = .9920

Table III (cont)

BENCHMARK BLACK ROD PROBLEM

COMPUTED RADIAL FLUX DISTRIBUTION

METHOD: 5

Total Cross Section, Σ_T = 1.0; Rod Radius = 0.5

Normalized Radius (r/R)	Σ_S/Σ_T 0.0	.2	.4	.6	.8	1.0
0.0						
.3162	.6515±.0014	.7204±.0009	.8282±.0010	.9298±.0011	1.0955±.0014	1.2838±.0015
.4472	.6715±.0007	.7411±.0010	.8341±.0007	.9380±.0008	1.1011±.0009	1.2804±.0017
.5477	.6910±.0008	.7644±.0008	.8498±.0008	.9498±.0007	1.0947±.0009	1.2740±.0012
.6325	.7099±.0009	.7844±.0007	.8629±.0010	.9648±.0009	1.1039±.0014	1.2802±.0013
.7071	.7369±.0005	.7994±.0006	.8841±.0010	.9785±.0010	1.1152±.0014	1.2739±.0009
.7746	.7629±.0007	.8219±.0007	.9052±.0009	1.0063±.0006	1.1177±.0013	1.2710±.0007
.8367	.7912±.0007	.8512±.0005	.9280±.0008	1.0208±.0008	1.1289±.0009	1.2743±.0008
.8944	.8198±.0005	.8787±.0007	.9522±.0006	1.0319±.0009	1.1393±.0008	1.2692±.0010
.9487	.8572±.0004	.9147±.0005	.9796±.0005	1.0546±.0007	1.1514±.0004	1.2695±.0006
1.0	.9021±.0005	.9555±.0003	1.0085±.0005	1.0802±.0005	1.1662±.0004	1.2719±.0007
Surface Flux	.9304±.0220	.9903±.0202	1.0403±.0142	1.0955±.0162	1.1693±.0146	1.2683±.0089
Average Flux	.7594±.0007	.8232±.0007	.9033±.0008	.9954±.0008	1.1214±.0010	1.2748±.0010

Table III (cont)

BENCHMARK BLACK ROD PROBLEM

COMPUTED RADIAL FLUX DISTRIBUTION

METHOD: 5

Total Cross Section, Σ_T = 2.0; Rod Radius = 0.5

Normalized Radius (r/R)	Σ_S/Σ_T 0.0	.2	.4	.6	.8	1.0
0.0						
.3162	.3622±.0009	.4347±.0012	.5281±.0018	.6694±.0008	.8858±.0017	1.2744±.0018
.4472	.3848±.0006	.4545±.0012	.5556±.0013	.6911±.0011	.9104±.0012	1.2783±.0009
.5477	.4181±.0003	.4854±.0009	.5840±.0009	.7166±.0006	.9276±.0006	1.2718±.0006
.6325	.4468±.0006	.5230±.0008	.6133±.0006	.7388±.0007	.9498±.0007	1.2764±.0006
.7071	.4779±.0004	.5555±.0007	.6453±.0007	.7694±.0008	.9674±.0011	1.2752±.0008
.7746	.5142±.0005	.5976±.0007	.6768±.0012	.7952±.0006	.9886±.0008	1.2747±.0010
.8367	.5587±.0004	.6338±.0007	.7161±.0008	.8306±.0006	1.0023±.0006	1.2757±.0008
.8944	.6065±.0005	.6712±.0008	.7589±.0004	.8673±.0007	1.0247±.0009	1.2780±.0010
.9487	.6657±.0006	.7234±.0004	.8074±.0004	.9090±.0009	1.0484±.0008	1.2693±.0010
1.0	.7486±.0007	.7987±.0007	.8721±.0007	.9562±.0006	1.0851±.0005	1.2723±.0006
Surface Flux	.8098±.0115	.8476±.0120	.9102±.0199	.9969±.0193	1.1036±.0131	1.2721±.0217
Average Flux	.5184±.0005	.5878±.0008	.6758±.0009	.7944±.0008	.9790±.0009	1.2746±.0009

Table III (cont)

BENCHMARK BLACK ROD PROBLEM

COMPUTED RADIAL FLUX DISTRIBUTION

METHOD: 5

Total Cross Section, Σ_T = 10.0; Rod Radius = 0.5

Normalized Radius (r/R)	Σ_S/Σ_T 0.0	.2	.4	.6	.8	1.0
0.0						
.3162	.00635±.00008	.00907±.0001	.01569±.0001	.03730±.0003	.1143±.0006	1.2667±.002
.4472	.01185±.00007	.01669±.0002	.02770±.0001	.05605±.0003	.1477±.0006	1.2668±.002
.5477	.02035±.0001	.02765±.0002	.04396±.0001	.08137±.0002	.1904±.0007	1.2606±.002
.6325	.03267±.0001	.04482±.0001	.06579±.0002	.1125 ±.0002	.2432±.0007	1.2641±.002
.7071	.05212±.0001	.06858±.0001	.09786±.0002	.1552 ±.0002	.3037±.0008	1.2619±.0009
.7746	.07930±.0002	.1021 ±.0002	.1396 ±.0003	.2091 ±.0003	.3682±.0008	1.2693±.0008
.8367	.1201 ±.0003	.1515 ±.0002	.1972 ±.0004	.2766 ±.0005	.4470±.0006	1.2734±.001
.8944	.1825 ±.0002	.2206 ±.0003	.2773 ±.0002	.3669 ±.0004	.5398±.0007	1.2722±.001
.9487	.2842 ±.0002	.3283 ±.0003	.3933 ±.0002	.4898 ±.0004	.6547±.0005	1.2717±.001
1.0	.4742 ±.0003	.5215 ±.0002	.5949 ±.0003	.6699 ±.0003	.8124±.0004	1.2696±.0008
Surface Flux	.6662 ±.0141	.6966 ±.0117	.7499 ±.0139	.8181 ±.008	.9230±.0181	1.2858±.0422
Average Flux	.1264 ±.0002	.1490 ±.0002	.1843 ±.0002	.2455 ±.0003	.3821±.0006	1.2676±.001

Table III (cont)

BENCHMARK BLACK ROD PROBLEM

COMPUTED RADIAL FLUX DISTRIBUTION

METHOD: 5

Total Cross Section, Σ_T = 100; Rod Radius = 0.5

Normalized Radius (r/R)	Σ_S/Σ_T 0.0	.2	.4	.6	.8	1.0
0.0						
.3162	---	---	---	---	---	---
.4472	---	---	---	---	---	---
.5477	---	---	---	---	---	---
.6325	---	---	---	---	---	---
.7071	---	---	---	.0000017 ±.0000005	.00000011 ±.00000002	---
.7746	---	.00000257 ±.0000006	.0000014 ±.0000002	.0000206 ±.000002	.000076 ±.000005	---
.8367	.00001034 ±.0000008	.0000184 ±.000001	.0000196 ±.000001	.0000917 ±.000003	.000917 ±.00003	---
.8944	.0001722 ±.000004	.000299 ±.000009	.000484 ±.000009	.001417 ±.00002	.007437 ±.00004	---
.9487	.003689 ±.00001	.005618 ±.00004	.008976 ±.00003	.01792 ±.00005	.05293 ±.0001	---
1.0	.12365 ±.00005	.1460 ±.00009	.1797 ±.0001	.2346 ±.0001	.3552 ±.0003	---
Surface Flux	.6402 ±.0130	.6687 ±.0056	.7194 ±.0098	.7936 ±.0264	.8963 ±.0447	---
Average Flux	.012752 ±.0000007	.01519 ±.00001	.01892 ±.00002	.02540 ±.00002	.04165 ±.00005	---

BENCHMARK SOURCE SITUATION

Identification: 13

Date Submitted: November 1975 By: B. A. Zolotar (EPRI)

Date Accepted: June 1977 By: H. L. Dodds, Jr. (U. of Tenn.)
W. A. Wittkopf (B&W)

Descriptive Title: Neutron Transport in a BWR Rod Bundle
7 x 7 BWR Fuel Assembly as Shown in Figure 1

Suggested Functions: Test Methods for Few-group, Two-dimensional Assembly Analysis

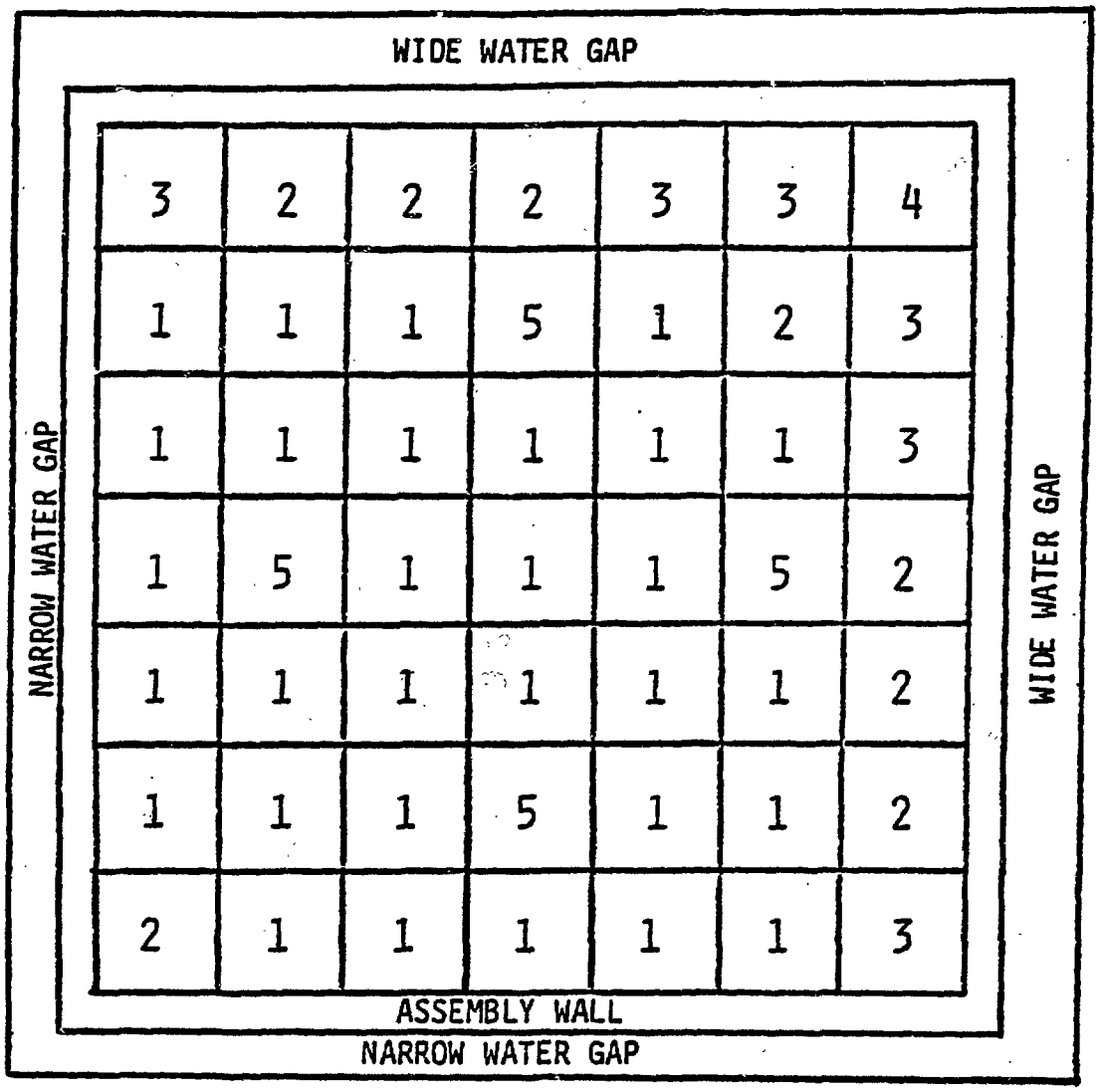


Figure 1. Bundle Diagram - Materials 1-4 represent fuel, material 5 contains fuel with poison, and the assembly wall is stainless steel.

BENCHMARK PROBLEM

Identification: 13-A1 Source Situation ID.13

Date Submitted: November 1975 By: B. A. Zolotar (EPRI)

Date Accepted: June 1977 By: H. L. Dodds, Jr. (U. of Tenn.)
W. A. Wittkopf (B&W)

Descriptive Title: Two-group, Two-dimensional (X-Y) Discrete Ordinates Model of a BWR Fuel Bundle as Shown in Figure 2

Reflective boundary conditions on external surfaces.

Two-Group Constants

Composition	Group i	$\Sigma_f(cm^{-1})$	$\Sigma_a(cm^{-1})$	$\nu\Sigma_f(cm^{-1})$	$\Sigma_T(cm^{-1})$	$\Sigma_{1\to2}(cm^{-1})$
1	1	2.281-3	8.983-3	5.925-3	2.531-1	1.069-2
	2	4.038-2	5.892-2	9.817-2	5.732-1	--
2	1	2.003-3	8.726-3	5.242-3	2.536-1	1.095-2
	2	3.385-2	5.174-2	8.228-2	5.767-1	--
3	1	1.830-3	8.587-3	4.820-3	2.535-1	1.112-2
	2	2.962-2	4.717-2	7.200-2	5.797-1	--
4	1	1.632-3	8.480-3	4.337-3	2.533-1	1.113-2
	2	2.428-2	4.140-2	5.900-2	5.837-1	--
5	1	2.155-3	9.593-3	5.605-3	2.506-1	1.016-2
	2	9.968-3	1.626-1	2.424-2	5.853-1	--
19	1	--	1.043-3	--	2.172-1	9.095-3
	2	--	4.394-3	--	4.748-1	--
20	1	--	1.983-4	--	2.476-1	3.682-2
	2	--	7.796-3	--	1.123+0	--

NOTE: Material 19 represents stainless steel; Material 20 represents water; Material 5 represents poison pins.

Expected Primary Results: 1. Group flux distribution
2. K_{eff}

Solutions: Solutions by DOT-III (13-A1-1) and TWØTRAN-II (13-A1-2)

20	20	20	20	20	20	20	20	20	20	20	20	0.47625
20	20	20	20	20	20	20	20	20	20	20	20	0.47625
20	19	19	19	19	19	19	19	19	19	20	20	0.34544
20	19	3	2	2	2	3	3	4	19	20	20	1.87452
20	19	1	1	1	5	1	2	3	19	20	20	1.87452
20	19	1	1	1	1	1	1	3	19	20	20	1.87452
20	19	1	5	1	1	1	5	2	19	20	20	1.87452
20	19	1	1	1	1	1	1	2	19	20	20	1.87452
20	19	1	1	1	5	1	1	2	19	20	20	1.87452
20	19	2	1	1	1	1	1	3	19	20	20	1.87452
20	19	19	19	19	19	19	19	19	19	20	20	0.34544
20	20	20	20	20	20	20	20	20	20	20	20	0.47498
0.47498	0.34544	1.87452	1.87452	1.87452	1.87452	1.87452	1.87452	1.87452	0.34544	0.47625	0.47625	

NOTE: All dimensions in centimeters.

Figure 2. Bundle Configuration and Material Assignments

BENCHMARK PROBLEM SOLUTION

Identification: 13-A1-1 Benchmark Problem ID.13-A1

Date Submitted: June 1976 By: B. A. Zolotar (EPRI)
F. J. Rahn (EPRI)

Date Accepted: June 1977 By: H. L. Dodds, Jr. (U. of Tenn.)
W. A. Wittkopf (B&W)

Descriptive Title: Discrete Ordinate Solution

Computer: IBM-360, Model 195

Code: DOT III[1]

Date Solved: May 1976 at EPRI

References

1. W. A. Rhoades and F. R. Mynatt, The DOT III Two-Dimensional Discrete Ordinates Transport Code," ORNL-TM-4280, Oak Ridge National Lab. (1973).

Results

Discrete Ordinate Representation: S_8

Mesh Spacing: 4x4 = 16 meshes per region in configuration map

K_{eff} = 1.08714 Convergence criteria = 2×10^{-5}

Exhibit A: Benchmark Solution

Exhibit B: S_8 Angular Quadrature

Exhibit C: Mesh and Angular Quadrature Convergence of K_{eff}

Exhibit D: Mesh Convergence - Group 1 Fluxes

Exhibit E: Mesh Convergence - Group 2 Fluxes

Exhibit F: Angular Quadrature Convergence - Group 1 Fluxes

Exhibit G: Angular Quadrature Convergence - Group 2 Fluxes

.1767 .1115	.1757 .1108	.1764 .1065	.1793 .0998	.1792 .0957	.1781 .0953	.1755 .0991	.1721 .1069	.1660 .1183	.1629 .1260	.1629 .1283	.1625 .1303
.1779 .1081	.1774 .1066	.1788 .1015	.1819 .0944	.1820 .0903	.1808 .0900	.1783 .0939	.1747 .1018	.1680 .1137	.1642 .1222	.1638 .1256	
.1788 .1066	.1797 .1011	.1827 .0950	.1863 .0876	.1862 .0834	.1851 .0831	.1824 .0871	.1788 .0952	.1716 .1076	.1663 .1171		
.1840 .0945	.1864 .0902	.1924 .0827	.1970 .0748	.1964 .0703	.1944 .0690	.1922 .0741	.1891 .0828	.1805 .0960			
.1920 .0813	.1949 .0773	.2023 .0687	.2064 .0607	.2048 .0554	.1999 .0497	.2015 .0587	.1984 .0687				
.1954 .0733	.1980 .0693	.2048 .0606	.2080 .0520	.2082 .0490	.2071 .0483	.2055 .0518					
.1972 .0699	.1995 .0659	.2054 .0565	.2060 .0441	.2096 .0459	.2098 .0471						
.1976 .0706	.2000 .0667	.2066 .0580	.2100 .0495	.2103 .0466		Group 1 Flux Group 2 Flux					
.1969 .0750	.1997 .0710	.2067 .0626	.2111 .0546								
.1928 .0834	.1951 .0790	.2014 .0708									
.1906 .0884	.1916 .0853										
.1910 .0903											

$K_{eff} = 1.08714$

BENCHMARK SOLUTION

S_8 - 4x4 Mesh Intervals

EXHIBIT A

ANGL	WEIGHT	ETA	MU
1	0.0	-0.2182178E+00	-0.9758998E+00
2	0.2665018E-01	-0.2182178E+00	-0.9511893E+00
3	0.2529317E-01	-0.2182178E+00	-0.7867955E+00
4	0.2529317E-01	-0.2182178E+00	-0.5773501E+00
5	0.2665018E-01	-0.2182178E+00	-0.2182178E+00
6	0.2665018E-01	-0.2182178E+00	0.2182178E+00
7	0.2529317E-01	-0.2182178E+00	0.5773501E+00
8	0.2529317E-01	-0.2182178E+00	0.7867955E+00
9	0.2665018E-01	-0.2182178E+00	0.9511893E+00
10	0.0	-0.5773501E+00	-0.8164963E+00
11	0.2529317E-01	-0.5773501E+00	-0.7867955E+00
12	0.1829034E-01	-0.5773501E+00	-0.5773501E+00
13	0.2529317E-01	-0.5773501E+00	-0.2182178E+00
14	0.2529317E-01	-0.5773501E+00	0.2182178E+00
15	0.1829034E-01	-0.5773501E+00	0.5773501E+00
16	0.2529317E-01	-0.5773501E+00	0.7867955E+00
17	0.0	-0.7867955E+00	-0.6172131E+00
18	0.2529317E-01	-0.7867955E+00	-0.5773501E+00
19	0.2529317E-01	-0.7867955E+00	-0.2182178E+00
20	0.2529317E-01	-0.7867955E+00	0.2182178E+00
21	0.2529317E-01	-0.7867955E+00	0.5773501E+00
22	0.0	-0.9511893E+00	-0.3086066E+00
23	0.2665018E-01	-0.9511893E+00	-0.2182178E+00
24	0.2665018E-01	-0.9511893E+00	0.2182178E+00
25	0.0	0.2182178E+00	-0.9758998E+00
26	0.2665018E-01	0.2182178E+00	-0.9511893E+00
27	0.2529317E-01	0.2182178E+00	-0.7867955E+00
28	0.2529317E-01	0.2182178E+00	-0.5773501E+00
29	0.2665018E-01	0.2182178E+00	-0.2182178E+00
30	0.2665018E-01	0.2182178E+00	0.2182178E+00
31	0.2529317E-01	0.2182178E+00	0.5773501E+00
32	0.2529317E-01	0.2182178E+00	0.7867955E+00
33	0.2665018E-01	0.2182178E+00	0.9511893E+00
34	0.0	0.5773501E+00	-0.8164963E+00
35	0.2529317E-01	0.5773501E+00	-0.7867955E+00
36	0.1829034E-01	0.5773501E+00	-0.5773501E+00
37	0.2529317E-01	0.5773501E+00	-0.2182178E+00
38	0.2529317E-01	0.5773501E+00	0.2182178E+00
39	0.1829034E-01	0.5773501E+00	0.5773501E+00
40	0.2529317E-01	0.5773501E+00	0.7867955E+00
41	0.0	0.7867955E+00	-0.6172131E+00
42	0.2529317E-01	0.7867955E+00	-0.5773501E+00
43	0.2529317E-01	0.7867955E+00	-0.2182178E+00
44	0.2529317E-01	0.7867955E+00	0.2182178E+00
45	0.2529317E-01	0.7867955E+00	0.5773501E+00
46	0.0	0.9511893E+00	-0.3086066E+00
47	0.2665018E-01	0.9511893E+00	-0.2182178E+00
48	0.2665018E-01	0.9511893E+00	0.2182178E+00

S_8 ANGULAR QUADRATURE

Mesh convergence with S_8

1x1 K_{eff}=1.08441
2x2 K_{eff}=1.08709
4x4 K_{eff}=1.08714 (Benchmark Solution)

Angular Quadrature Convergence with 2x2 Mesh Interval

S_2 K_{eff}=1.09195
S_4 K_{eff}=1.08724
S_8 K_{eff}=1.08709

MESH AND ANGULAR QUADRATURE CONVERGENCE OF K_{eff}

EXHIBIT C

.1771	.1757	.1764	.1788	.1796	.1782	.1760	.1718	.1658	.1631	.1632	.1630
.1768	.1758	.1764	.1793	.1793	.1781	.1756	.1721	.1659	.1629	.1629	.1627
.1767	.1757	.1764	.1793	.1792	.1781	.1755	.1721	.1660	.1629	.1629	.1625
.1777	.1774	.1787	.1818	.1826	.1809	.1788	.1746	.1680	.1642	.1634	
.1779	.1772	.1788	.1820	.1821	.1809	.1784	.1748	.1680	.1641	.1637	
.1779	.1774	.1788	.1819	.1820	.1808	.1783	.1747	.1680	.1642	.1638	
.1785	.1792	.1824	.1858	.1867	.1852	.1827	.1785	.1716	.1649		
.1785	.1796	.1835	.1863	.1863	.1850	.1825	.1789	.1715	.1664		
.1788	.1797	.1827	.1863	.1862	.1851	.1824	.1788	.1716	.1663		
.1838	.1860	.1916	.1964	.1957	.1937	.1917	.1886	.1796			
.1840	.1863	.1923	.1969	.1962	.1944	.1921	.1890	.1803			
.1840	.1864	.1924	.1970	.1964	.1944	.1922	.1891	.1805			
.1919	.1946	.2018	.2075	.2052	.2014	.2018	.1996				
.1921	.1950	.2023	.2065	.2050	.2001	.2016	.1984				
.1920	.1949	.2023	.2064	.2048	.1999	.2015	.1984				
.1963	.1984	.2042	.2086	.2080	.2073	.2053					
.1965	.1981	.2047	.2082	.2082	.2072	.2055					
.1954	.1980	.2048	.2080	.2082	.2071	.2055					
.1975	.1999	.2046	.2074	.2095	.2114						
.1973	.1996	.2054	.2062	.2096	.2100						
.1972	.1995	.2054	.2060	.2096	.2098						
.1984	.2005	.2060	.2104	.2101							
.1977	.2001	.2065	.2101	.2103							
.1976	.2000	.2066	.2100	.2103							
.1967	.1992	.2061	.2120								
.1970	.1997	.2066	.2112								
.1969	.1997	.2067	.2111								
.1926	.1947	.2006									
.1928	.1950	.2013									
.1928	.1951	.2014									
.1907	.1907										
.1904	.1916										
.1906	.1916										
.1911											
.1911											
.1910											

1x1, 2x2, 4x4 } meshes per interval

MESH CONVERGENCE WITH S_8

GROUP 1 FLUXES

EXHIBIT D

1.1085	1.1040	1.0629	.9944	.9546	.9544	.9901	1.0686	1.1853	1.2602	1.2825	1.3006
1.1136	1.1067	1.0651	.9971	.9563	.9533	.9902	1.0684	1.1836	1.2599	1.2828	1.3022
1.1145	1.1075	1.0651	.9976	.9570	.9532	.9906	1.0685	1.1831	1.2602	1.2833	1.3027
1.0751	1.0618	1.0120	.9393	.9000	.9008	.9370	1.0161	1.1380	1.2212	1.2530	
1.0802	1.0654	1.0153	.9437	.9023	.8996	.9376	1.0176	1.1374	1.2215	1.2548	
1.0814	1.0661	1.0151	.9444	.9034	.8996	.9385	1.0179	1.1368	1.2221	1.2556	
1.0374	1.0078	.9531	.8741	.8358	.8418	.8750	.9532	1.0828	1.1678		
1.0416	1.0112	.9507	.8760	.8345	.8305	.8710	.9528	1.0770	1.1710		
1.0659	1.0113	.9503	.8757	.8343	.8306	.8713	.9522	1.0761	1.1708		
.9435	.9109	.8350	.7502	.7034	.6907	.7426	.8325	.9705			
.9450	.9086	.8285	.7485	.7029	.6910	.7413	.8284	.9610			
.9447	.9016	.8274	.7479	.7030	.6898	.7413	.8275	.9595			
.8072	.7717	.6893	.6080	.5480	.5068	.5822	.6898				
.8119	.7734	.6877	.6076	.5543	.4973	.5871	.6874				
.8128	.7731	.6871	.6073	.5544	.4965	.5871	.6867				
.7278	.6921	.6048	.5123	.4778	.4740	.5050					
.7314	.6928	.6054	.5193	.4878	.4820	.5154					
.7328	.6930	.6057	.5197	.4898	.4827	.5175					
.6975	.6663	.5632	.4479	.4503	.4802						
.6986	.6587	.5657	.4413	.4578	.4704						
.6991	.6592	.5649	.4409	.4587	.4705						
.7003	.6648	.5786	.4870	.4539							
.7048	.6662	.5797	.4944	.4635							
.7064	.6665	.5802	.4947	.4655							
.7424	.7068	.6260	.5448								
.7489	.7102	.6260	.5462								
.7501	.7102	.6258	.5463								
.8240	.7905	.7135									
.8276	.7900	.7089									
.8341	.7897	.7082									
.8793	.8484										
.8832	.8521										
.8844	.8529										
.8918											
.8989											
.9031											

1x1, 2x2, 4x4 } meshes per interval

MESH CONVERGENCE WITH S_8

GROUP 2 FLUXES x 10

EXHIBIT E

.1904	.1901	.1840	.1817	.1871	.1861	.1830	.1735	.1718	.1771	.1772	.1797
.1788	.1778	.1774	.1801	.1827	.1797	.1770	.1726	.1664	.1647	.1648	.1648
.1768	.1758	.1764	.1793	.1793	.1781	.1756	.1721	.1659	.1629	.1629	.1627
.1903	.1879	.1857	.1837	.1879	.1875	.1838	.1754	.1733	.1755	.1794	
.1797	.1787	.1793	.1826	.1831	.1818	.1793	.1751	.1680	.1652	.1656	
.1779	.1772	.1788	.1820	.1821	.1809	.1784	.1748	.1680	.1641	.1637	
.1884	.1897	.1876	.1867	.1889	.1897	.1846	.1786	.1757	.1771		
.1797	.1808	.1825	.1861	.1867	.1852	.1827	.1785	.1710	.1670		
.1785	.1796	.1835	.1863	.1863	.1850	.1825	.1789	.1715	.1664		
.1870	.1882	.1933	.1963	.1933	.1932	.1888	.1880	.1829			
.1840	.1860	.1914	.1959	.1955	.1938	.1913	.1878	.1793			
.1840	.1863	.1923	.1969	.1962	.1944	.1921	.1890	.1803			
.1908	.1925	.1990	.2052	.2023	.1937	.1986	.1979				
.1926	.1949	.2015	.2055	.2047	.1987	.2013	.1973				
.1921	.1950	.2023	.2065	.2050	.2001	.2016	.1984				
.1995	.1998	.2013	.2047	.2044	.2051	.2019					
.1973	.1990	.2042	.2081	.2079	.2072	.2050					
.1965	.1981	.2047	.2082	.2082	.2072	.2055					
.2022	.2033	.2042	.2003	.2069	.2103						
.1990	.2006	.2051	.2064	.2097	.2110						
.1973	.1996	.2054	.2062	.2096	.2100						
.2019	.2020	.2031	.2072	.2070		S_2					
.1993	.2011	.2061	.2100	.2102		S_4					
.1977	.2001	.2065	.2101	.2103		S_8					
.1949	.1972	.2042	.2098								
.1978	.1999	.2061	.2103								
.1970	.1997	.2066	.2112								
.1971	.1973	.2008									
.1936	.1952	.2008									
.1928	.1950	.2013									
.1980	.2025										
.1919	.1934										
.1904	.1916										
.2008											
.1929											
.1911											

ANGULAR QUADRATURE CONVERGENCE WITH 2x2 MESH INTERVAL

GROUP 1 FLUXES

EXHIBIT F

1.0650	1.0722	1.0488	.9679	.9365	.9404	.9758	1.0501	1.1835	1.2547	1.2616	1.2615
1.1185	1.1161	1.0734	1.0042	.9619	.9595	.9957	1.0755	1.1923	1.2705	1.2937	1.3129
1.1136	1.1067	1.0651	.9971	.9563	.9533	.9902	1.0684	1.1836	1.2599	1.2828	1.3022
1.0437	1.0397	1.0031	.9170	.8851	.8903	.926[illegible]	1.0007	1.1402	1.2162	1.2389	
1.0825	1.0716	1.0213	.9478	.9056	.9027	.9407	1.0220	1.1437	1.2302	1.2628	
1.0802	1.0654	1.0153	.9437	.9023	.8996	.9376	1.0176	1.1374	1.2215	1.2548	
1.0201	1.0004	.9472	.8626	.8247	.8327	.8673	.9477	1.0872	1.1726		
1.0458	1.0175	.9557	.8789	.8378	.8337	.8748	.9560	1.0825	1.1793		
1.0416	1.0112	.9507	.8760	.8345	.8305	.8710	.9528	1.0770	1.1710		
.9351	.9061	.8363	.7587	.7030	.7026	.7455	.8462	.9803			
.9483	.9119	.8326	.7503	.7040	.6930	.7425	.8303	.9668			
.9450	.9086	.8285	.7485	.7029	.6910	.7413	.8284	.9610			
.7793	.7551	.6463	.6199	.5652	.5001	.6003	.6927				
.8145	.7754	.6890	.6065	.5531	.4987	.5859	.6866				
.8119	.7734	.6877	.6076	.5543	.4973	.5871	.6874				
.7066	.6764	.6011	.5268	.4783	.4901	.5075					
.7323	.6948	.6063	.5179	.4852	.4817	.5129					
.7314	.6928	.6054	.5193	.4878	.4820	.5154					
.6751	.6481	.5690	.4382	.4632	.4803						
.6996	.6609	.5676	.4418	.4577	.4716						
.6986	.6587	.5657	.4413	.4578	.4704						
.6760	.6461	.5716	.4997	.4525		S_2					
.7059	.6686	.5808	.4931	.4612		S_4					
.7048	.6662	.5797	.4944	.4635		S_8					
.7194	.6833	.6278	.5519								
.7516	.7127	.6277	.5451								
.7489	.7102	.6260	.5462								
.8069	.7755	.7047									
.8311	.7938	.7133									
.8276	.7900	.7089									
.8407	.8246										
.8860	.8587										
.8832	.8521										
.8355											
.8973											
.8989											

ANGULAR QUADRATURE CONVERGENCE WITH 2x2 MESH INTERVAL

GROUP 2 FLUXES x 10

EXHIBIT G

BENCHMARK PROBLEM SOLUTION

Identification: 13-A1-2

Benchmark Problem ID.13-A1

Date Submitted: July 1976

By: A. N. Mallen (SRL)

Date Accepted: June 1977

By: H. L. Dodds, Jr. (U. of Tenn.
W. A. Wittkopf (B&W)

Descriptive Title: Discrete Ordinate Solution

Computer: IBM-360, Model 195

Code: TWOTRAN-II[1]

Date Solved: June, 1976 at SRL

References

1. K. D. Lathrop, F. W. Brinkley, "TWOTRAN-II, An Interfaced, Exportable Version of the TWOTRAN Code for Two Dimensional Transport," LA-4848-MS, Los Alamos Scientific Laboratory (1973)

2. B. A. Zolotar, F. J. Rahn, A. Nero, "BWR Rod Bundle Benchmark Problem," Trans. of Am. Nucl. Soc. 23, 214 (1976)

Results:

Discrete Ordinate Representation: S_8

Mesh Spacing: 4x4 = 16 meshes per region in configuration map

Normalization = 1 source neutron; K_{eff} convergence criteria = 2×10^{-5}

K_{eff} = 1.08727

Exhibit A-1: Benchmark Solution

Exhibit A-2: Comparison with DOT-III Benchmark Solution

Exhibit B: S_8 Angular Quadrature

Exhibit C-1: Mesh and Angular Quadrature Convergence of K_{eff}

Exhibit C-2: Difference in Benchmark Solutions of K_{eff} {(DOT-III)-(TWOTRAN2)}

Exhibit D: Mesh Convergence - Group 1 Fluxes

Exhibit E: Mesh Convergence - Group 2 Fluxes

Exhibit F: Angular Quadrature Convergence - Group 1 Fluxes

Exhibit G: Angular Quadrature Convergence - Group 2 Fluxes

Exhibit H: TWOTRAN2 Execution Parameters

.1745	.1738	.1752	.1783	.1781	.1769	.1747	.1715	.1652	.1614	.1611	.1603
.1119	.1110	.1066	.0999	.0960	.0956	.0995	.1073	.1188	.1267	.1292	.1312
.1761	.1758	.1779	.1811	.1812	.1801	.1777	.1742	.1675	.1631	.1623	
.1086	.1068	.1016	.0946	.0907	.0903	.0943	.1023	.1142	.1229	.1264	
.1775	.1787	.1822	.1860	.1860	.1848	.1823	.1789	.1715	.1655		
.1045	.1012	.0950	.0876	.0836	.0832	.0875	.0955	.1079	.1175		
.1834	.1860	.1928	.1976	.1969	.1950	.1929	.1899	.1811			
.0946	.0908	.0825	.0747	.0703	.0690	.0742	.0828	.0961			
.1914	.1948	.2029	.2071	.2055	.2004	.2023	.1994				
.0815	.0774	.0686	.0606	.0554	.0496	.0588	.0687				
.1946	.1976	.2052	.2085	.2088	.2076	.2062					
.0736	.0695	.0605	.0520	.0491	.0483	.0519					
.1961	.1989	.2058	.2062	.2099	.2099						
.0701	.0660	.0564	.0440	.0459	.0469						
.1966	.1996	.2069	.2103	.2107							
.0710	.0668	.0580	.0494	.0466							
.1961	.1992	.2070	.2115								
.0752	.0711	.0624	.0545								
.1919	.1945	.2016									
.0829	.0789	.0706									
.1890	.1904										
.0887	.0854										
.1891											
.0906											

S-8 (4X4) MESH GROUP 1
S-8 (4X4) MESH GROUP 2

BENCHMARK SOLUTION

S_8 - 4x4 Mesh Intervals

EXHIBIT A-1

.988	.989	.993	.994	.994	.993	.995	.997	.995	.991	.989	.986
1.004	1.002	1.001	1.001	1.003	1.003	1.004	1.004	1.004	1.006	1.007	1.007
.990	.991	.995	.996	.996	.996	.997	.997	.997	.993	.991	
1.005	1.002	1.001	1.003	1.004	1.003	1.004	1.005	1.004	1.006	1.006	
.993	.994	.998	.998	.999	.998	.999	1.001	.999	.995		
.980	1.001	1.000	1.000	1.002	1.001	1.005	1.004	1.004	1.003		
.997	.998	1.002	1.003	1.003	1.003	1.004	1.004	1.003			
1.001	1.007	.998	.999	1.000	1.000	1.001	1.000	1.001			
.997	.999	1.003	1.003	1.003	1.003	1.004	1.005				
1.002	1.001	.999	.998	1.000	.998	1.002	1.000				
.996	.998	1.002	1.002	1.003	1.002	1.003					
1.004	1.003	.998	1.000	1.002	1.000	1.002					
.994	.990	1.002	1.001	1.001	1.000						
1.003	1.002	.998	.998	1.000	.996						
.995	.998	1.001	1.001	1.002							
1.006	1.001	1.000	.998	1.000							
.996	.997	1.001	1.002								
1.003	1.001	.997	.998								
.995	.997	1.001									
.994	.999	.997									
.992	.994										
1.003	1.001										
.990											
1.003											

Group 1 Flux
Group 2 Flux

TWOTRAN2 K_{eff} = 1.08727
DOT-III K_{eff} = 1.08714

BENCHMARK FLUX RATIO
(TWOTRAN2/DOT-III)
S_8 - 4x4 Mesh Intervals
EXHIBIT A-2

ANGLE	MU	ETA	WEIGHT
1	0.192327	0.962299	0.291971
2	0.577350	0.793521	0.233138
3	0.192327	0.793521	0.233138
4	0.793521	0.577350	0.233138
5	0.577350	0.577350	0.225257
6	0.192327	0.577350	0.233138
7	0.962299	0.192327	0.291971
8	0.793521	0.192327	0.233138
9	0.577350	0.192327	0.233138
10	0.192327	0.192327	0.291971

S_8 ANGULAR QUADRATURE

EXHIBIT B

MESH CONVERGENCE WITH S_8

(1x1) K_{eff} = 1.08427

(2x2) K_{eff} = 1.08712

(4x4) K_{eff} = 1.08727

ANGULAR QUADRATURE CONVERGENCE WITH 2x2 MESH INTERVAL

S_2 K_{eff} = 1.09214

S_4 K_{eff} = 1.08708

S_8 K_{eff} = 1.08712

MESH AND ANGULAR QUADRATURE
CONVERGENCE OF K_{eff}

EXHIBIT C-1

MESH CONVERGENCE WITH S_8

(1x1) $\Delta K_{eff} = +0.00014$

(2x2) $\Delta K_{eff} = -0.00003$

(4x4) $\Delta K_{eff} = -0.00013$

ANGULAR QUADRATURE CONVERGENCE WITH 2x2 MESH INTERVAL

S_2 $\Delta K_{eff} = -0.00019$

S_4 $\Delta K_{eff} = +0.00016$

S_8 $\Delta K_{eff} = -0.00003$

$\Delta K_{eff} = K_{eff}$ (DOT-III) - K_{eff} (TWOTRAN2)

DIFFERENCE IN K_{eff} SOLUTIONS
OF BENCHMARK PROBLEM

EXHIBIT C-2

.1751	.1736	.1751	.1778	.1785	.1768	.1750	.1711	.1648	.1613	.1617	.1607
.1747	.1738	.1751	.1783	.1781	.1770	.1746	.1715	.1651	.1613	.1610	.1605
.1745	.1738	.1752	.1783	.1781	.1769	.1747	.1715	.1652	.1614	.1611	.1603
.1762	.1760	.1775	.1811	.1816	.1801	.1781	.1742	.1672	.1630	.1616	
.1762	.1757	.1779	.1811	.1812	.1801	.1777	.1743	.1674	.1629	.1623	
.1761	.1758	.1779	.1811	.1812	.1801	.1777	.1742	.1675	.1631	.1623	
.1770	.1782	.1818	.1855	.1863	.1849	.1824	.1786	.1711	.1645		
.1773	.1785	.1821	.1860	.1860	.1847	.1823	.1789	.1714	.1655		
.1775	.1787	.1822	.1860	.1860	.1848	.1823	.1789	.1715	.1655		
.1831	.1855	.1918	.1971	.1962	.1940	.1922	.1893	.1801			
.1834	.1859	.1926	.1975	.1968	.1950	.1928	.1899	.1809			
.1834	.1860	.1928	.1976	.1969	.1950	.1929	.1899	.1811			
.1915	.1947	.2024	.2085	.2059	.2021	.2026	.2008				
.1915	.1949	.2028	.2072	.2056	.2005	.2024	.1994				
.1914	.1948	.2029	.2071	.2055	.2004	.2023	.1994				
.1955	.1980	.2045	.2092	.2084	.2077	.2058					
.1946	.1976	.2051	.2086	.2088	.2076	.2062					
.1946	.1976	.2052	.2085	.2088	.2076	.2062					
.1964	.1993	.2048	.2078	.2098	.2118						
.1962	.1989	.2058	.2063	.2099	.2101						
.1961	.1989	.2058	.2062	.2099	.2099						
.1974	.2001	.2062	.2109	.2103							
.1966	.1996	.2068	.2104	.2107							
.1966	.1996	.2069	.2103	.2107							
.1961	.1990	.2066	.2128								
.1962	.1993	.2070	.2117								
.1961	.1992	.2070	.2115								
.1916	.1941	.2006									
.1919	.1944	.2014									
.1919	.1945	.2016									
.1892	.1894										
.1888	.1903										
.1890	.1904										
.1895											
.1893											
.1891											

S-8 (1X1) MESH
S-8 (2X2) MESH
S-8 (4X4) MESH

MESH CONVERGENCE WITH S_8

GROUP 1 FLUXES

EXHIBIT D

.1113	.1106	.1064	.0996	.0957	.0956	.0993	.1072	.1188	.1264	.1289	.1308
.1118	.1108	.1066	.0999	.0959	.0956	.0994	.1073	.1188	.1266	.1291	.1312
.1119	.1110	.1066	.0999	.0960	.0956	.0995	.1073	.1188	.1267	.1292	.1312
.1079	.1064	.1013	.0941	.0903	.0903	.0940	.1019	.1140	.1226	.1258	
.1084	.1067	.1016	.0945	.0905	.0902	.0942	.1022	.1142	.1228	.1263	
.1086	.1068	.1016	.0946	.0907	.0903	.0943	.1023	.1142	.1229	.1264	
.1040	.1009	.0953	.0875	.0838	.0844	.0878	.0956	.1084	.1171		
.1044	.1012	.0950	.0877	.0836	.0832	.0874	.0956	.1080	.1176		
.1045	.1012	.0950	.0876	.0836	.0832	.0875	.0955	.1079	.1175		
.0945	.0910	.0833	.0749	.0703	.0690	.0743	.0832	.0970			
.0946	.0908	.0826	.0747	.0703	.0691	.0742	.0829	.0962			
.0946	.0908	.0825	.0747	.0703	.0690	.0742	.0828	.0961			
.0810	.0773	.0688	.0607	.0548	.0506	.0582	.0689				
.0814	.0774	.0686	.0606	.0554	.0496	.0588	.0688				
.0815	.0774	.0686	.0606	.0554	.0496	.0588	.0687				
.0731	.0695	.0605	.0512	.0479	.0474	.0506					
.0735	.0694	.0605	.0519	.0489	.0482	.0517					
.0736	.0695	.0605	.0520	.0491	.0483	.0519					
.0701	.0668	.0562	.0447	.0451	.0479						
.0701	.0660	.0565	.0440	.0458	.0469						
.0701	.0660	.0564	.0440	.0459	.0469						
.0704	.0667	.0578	.0487	.0455							
.0708	.0668	.0579	.0494	.0465							
.0710	.0668	.0580	.0494	.0466							
.0745	.0708	.0625	.0544								
.0751	.0711	.0625	.0545								
.0752	.0711	.0624	.0545								
.0826	.0791	.0712									
.0829	.0790	.0707									
.0829	.0789	.0706									
.0884	.0850										
.0886	.0853										
.0887	.0854										
.0899											
.0905											
.0906											

S-8 (1X1) MESH
S-8 (2X2) MESH
S-8 (4X4) MESH

MESH CONVERGENCE WITH S_8

GROUP 2 FLUXES

EXHIBIT E

.1904	.1901	.1840	.1817	.1872	.1862	.1831	.1737	.1719	.1773	.1774	.1798
.1764	.1756	.1756	.1788	.1792	.1780	.1757	.1717	.1649	.1624	.1623	.1621
.1747	.1738	.1751	.1783	.1781	.1770	.1746	.1715	.1651	.1613	.1610	.1605
.1903	.1879	.1857	.1837	.1879	.1876	.1839	.1755	.1735	.1756	.1796	
.1774	.1765	.1778	.1815	.1820	.1806	.1785	.1744	.1667	.1631	.1633	
.1762	.1757	.1779	.1811	.1812	.1801	.1777	.1743	.1674	.1629	.1623	
.1884	.1897	.1876	.1867	.1890	.1898	.1847	.1787	.1758	.1772		
.1778	.1790	.1813	.1855	.1860	.1846	.1824	.1782	.1700	.1652		
.1773	.1785	.1821	.1860	.1860	.1847	.1823	.1789	.1714	.1655		
.1869	.1882	.1933	.1963	.1934	.1933	.1889	.1881	.1831			
.1832	.1852	.1912	.1962	.1960	.1944	.1919	.1884	.1790			
.1834	.1859	.1926	.1975	.1968	.1950	.1928	.1899	.1809			
.1908	.1925	.1990	.2052	.2024	.1938	.1987	.1981				
.1923	.1949	.2021	.2065	.2056	.2008	.2022	.1983				
.1915	.1949	.2028	.2072	.2056	.2005	.2024	.1994				
.1995	.1998	.2012	.2047	.2044	.2052	.2020					
.1966	.1987	.2049	.2089	.2089	.2081	.2061					
.1946	.1976	.2051	.2086	.2088	.2076	.2062					
.2022	.2032	.2041	.2002	.2068	.2111						
.1980	.2000	.2055	.2070	.2105	.2115						
.1962	.1989	.2058	.2063	.2099	.2101						
.2018	.2019	.2030	.2071	.2070							
.1985	.2007	.2065	.2107	.2109							
.1966	.1996	.2068	.2104	.2107							
.1948	.1971	.2041	.2097								
.1973	.1997	.2065	.2112								
.1962	.1993	.2070	.2117								
.1970	.1972	.2007									
.1926	.1945	.2007									
.1919	.194[illegible]	.2014									
.1981	.2024										
.1904	.1921										
.1888	.1903										
.2007											
.1911											
.1893											

S-2 (2X2) MESH
S-4 (2X2) MESH
S-8 (2X2) MESH

ANGULAR QUADRATURE CONVERGENCE WITH 2x2 MESH INTERVAL

GROUP 1 FLUXES

EXHIBIT F

.1065	.1072	.1048	.0968	.0937	.0941	.0977	.1052	.1187	.1258	.1266	.1265
.1130	.1125	.1078	.1010	.0968	.0965	.1002	.1081	.1197	.1278	.1303	.1328
.1118	.1108	.1066	.0999	.0959	.0956	.0994	.1073	.1188	.1266	.1291	.1312
.1043	.1039	.1003	.0917	.0885	.0891	.0928	.1003	.1143	.1220	.1243	
.1092	.1078	.1025	.0953	.0911	.0907	.0946	.1027	.1148	.1236	.1272	
.1084	.1067	.1016	.0945	.0905	.0902	.0942	.1022	.1142	.1228	.1263	
.1020	.1000	.0947	.0863	.0825	.0833	.0869	.0950	.1090	.1176		
.1052	.1021	.0957	.0881	.0841	.0835	.0878	.0959	.1084	.1183		
.1044	.1012	.0950	.0877	.0836	.0832	.0874	.0956	.1080	.1176		
.0935	.0906	.0836	.0759	.0703	.0703	.0747	.0848	.0983			
.0952	.0913	.0830	.0748	.0704	.0692	.0742	.0829	.0964			
.0946	.0908	.0826	.0747	.0703	.0691	.0742	.0829	.0962			
.0779	.0755	.0696	.0620	.0565	.0500	.0601	.0707				
.0820	.0779	.0687	.0604	.0552	.0496	.0585	.0684				
.0814	.0774	.0686	.0606	.0554	.0496	.0588	.0688				
.0706	.0676	.0601	.0527	.0478	.0490	.0508					
.0739	.0699	.0607	.0517	.0487	.0482	.0515					
.0735	.0694	.0605	.0519	.0489	.0482	.0517					
.0675	.0648	.0569	.0438	.0463	.0480						
.0706	.0664	.0568	.0441	.0458	.0471						
.0701	.0660	.0565	.0440	.0458	.0469						
.0676	.0646	.0571	.0499	.0452							
.0713	.0673	.0581	.0493	.0463							
.0708	.0668	.0579	.0494	.0465							
.0705	.0683	.0627	.0551								
.0759	.0717	.0627	.0544								
.0751	.0711	.0625	.0545								
.0806	.0775	.0704									
.0837	.0797	.0712									
.0829	.0790	.0707									
.0840	.0824										
.0896	.0865										
.0886	.0853										
.0835											
.0911											
.0905											

S-2 (2X2) MESH
S-4 (2X2) MESH
S-8 (2X2) MESH

ANGULAR QUADRATURE CONVERGENCE WITH 2x2 MESH INTERVAL

GROUP 2 FLUXES

EXHIBIT G

S_n	Mesh	K_{eff} Convergence	CPU Time Min:Sec	Core Size Bytes
2	1x1	$2x10^{-5}$	:11	310K
4	1x1	$2x10^{-5}$	:13	310K
8	1x1	$2x10^{-5}$	:21	312K
2	2x2	$2x10^{-5}$	:21	319K
4	2x2	$2x10^{-5}$	:40	320K
8	2x2	$2x10^{-5}$	1:17	323K
2	4x4	$2x10^{-5}$	1:07	355K
4	4x4	$2x10^{-5}$	2:16	357K
8	4x4	$2x10^{-5}$	4:35	363K

TWOTRAN2 EXECUTION PARAMETERS

EXHIBIT H

BENCHMARK PROBLEM

Identification: 13-A2 Source Situation ID.13

Date Submitted: January 1977 By: B. A. Zolotar (EPRI)

Date Accepted: June 1977 By: H. L. Dodds, Jr.(U. of Tenn.)
W. A. Wittkopf (B&W)

Descriptive Title: Diffusion Theory Problem for the LWR Bundle

This problem is defined precisely the same as Problem 13-A1 but with $D = \frac{1}{3\Sigma_T}$ (for each group) resulting in a two-group, two-dimensional diffusion theory problem.

Solutions:

1. Finite difference and linear finite-element: 13-A2-1
2. Finite difference: 13-A2-2

BENCHMARK PROBLEM SOLUTION

Identification: 13-A2-1 Benchmark Problem ID.13-A2

Date Submitted: January 1977

By: T. B. Fowler and D. R. Vondy (ORNL)

By: H. L. Dodds, Jr. (U. of Tenn.)
W. A. Wittkopf (B&W)

Date Accepted: June 1977

Descriptive Title: Diffusion Theory Solution of LWR Bundle Problem

Computer: IBM-360/95

Code: VENTURE (Report ORNL-5062), mesh-centered finite difference

VANCER (Report to be published), mesh-edge finite difference

Results: The problem was solved with several uniform meshpoint arrangements assuming $D = \frac{1}{3\Sigma_T}$, and results normalized to one neutron source for the problem are displayed in Table 1. The VANCER code is not yet structured to solve small problems the most efficiently. For short execution times, the processor use time allocation is often more than reasonable under the multi-tasking system executing several jobs simultaneously. Fission source values by fueled assembly are shown in Table 2 for the mesh-centered formulation and in Table 3 for the mesh edge formulations; data is for horizontal rows of assemblies to the diagonal from the top down, normalized to one neutron source per unit volume in the fueled zone (unit average fission source). It should be noted that if the error from the difference formulation is assumed to be proportional to the square of the mesh spacing, there is little difference between these formulations for this problem (13^2 is somewhat $> 12^2$). The convergence level satisfied for these problems was 5×10^{-5} maximum relative flux change on outer iteration. Flux values for the 48 x 48 VENTURE mesh centered case are shown in Table 4 normalized to one source neutron (times 100).

Table 1. LWR Bundle Problem
Diffusion Theory Solutions

Meshpoints	Points Per Assembly	k_{eff}	Peak to Average Point Source	Peak Point Fast Flux	Processor Time* (min)
Mesh-centered finite-difference (VENTURE)					
12 x 12	1	1.09238	1.2543	0.1900	0.074
24 x 24	4	1.08759	1.3379	0.1907	0.102
48 x 48	16	1.08606	1.3851	0.1909	0.229
96 x 96	64	1.08565	1.4100	0.1910	0.921
Extrapolated	(∞)	1.0855	1.418	0.1910	
Mesh-edge finite-difference (VANCER) usual finite-difference (4 neighbors)					
13 x 13	(1)	1.08061	1.2607	0.1917	0.224
25 x 25	(4)	1.08389	1.3411	0.1912	0.477
49 x 49	(16)	1.08506	1.3861	0.1911	1.198
Linear finite-element (8 neighbors) (VANCER)					
13 x 13	(1)	1.08185	1.2659	0.1919	0.238
25 x 25	(4)	1.08454	1.3429	0.1913	0.500
49 x 49	(16)	1.08525	1.3869	0.1911	1.465

*Eigenvalue problem set up and solution; for the VENTURE solutions, the flux solution from the next smaller problem was used as a starting guess.

Table 2. LWR Bundle Problem Assembly Fission Source
(Mesh-centered VENTURE code results)

Assembly (Horizontal row to diagonal, starts at top)	Mesh Points 12X12	24X24	48X48	96X96	Extrapolated
1	1.09074	1.09238	1.09363	1.09388	1.09396
2	1.14093	1.14285	1.14351	1.14372	1.14379
3	1.08737	1.08492	1.08435	1.08426	1.08423
4	1.06877	1.06881	1.06852	1.06841	1.06837
5	1.00338	1.00068	0.99999	0.99983	0.99978
6	1.09826	1.10063	1.10136	1.10157	1.10164
7	1.03213	1.03492	1.03581	1.03608	1.03617
8	1.25429	1.25888	1.26031	1.26072	1.26086
9	1.13426	1.13782	1.13862	1.13882	1.13889
10	1.05726	1.05700	1.05669	1.05655	1.05650
11	0.36380	0.37364	0.37668	0.37750	0.37777
12	1.10952	1.11015	1.11011	1.11004	1.11002
13	1.06466	1.06756	1.06812	1.06826	1.06830
14	1.13258	1.13063	1.13026	1.13022	1.13021
15	1.00320	1.00120	1.00048	1.00025	1.00017
16	0.96005	0.95104	0.94875	0.94820	0.94802
17	0.94115	0.93831	0.93728	0.93695	0.93684
18	1.00445	0.99613	0.99400	0.99350	0.99333
19	1.06608	1.06594	1.06565	1.06554	1.06550
20	0.34673	0.35498	0.35756	0.35825	0.35848
21	0.90326	0.89939	0.89814	0.89776	0.89763
22	0.91053	0.91070	0.91023	0.91006	0.91000
23	1.09183	1.08898	1.08838	1.08828	1.08825
24	0.96327	0.96071	0.95985	0.95958	0.95949
25	0.92118	0.91180	0.90943	0.90885	0.90866
26	1.15758	1.15953	1.16027	1.16051	1.16059
27	1.03817	1.03928	1.03946	1.03950	1.03951
28	1.08032	1.08162	1.08220	1.08241	1.08248

Table 3. LWR Bundle Problem Assembly Fission Source
(Mesh-edge VANCER code results,
49X49 meshpoints)

Assembly	Usual Finite-Difference	Linear Finite-Element
1	1.09375	1.09424
2	1.14367	1.14399
3	1.08403	1.08412
4	1.06794	1.06824
5	0.99960	0.99954
6	1.10163	1.10157
7	1.03615	1.03609
8	1.26091	1.26123
9	1.13887	1.13908
10	1.05647	1.05633
11	0.37864	0.37822
12	1.11008	1.10975
13	1.06824	1.06821
14	1.13013	1.13024
15	1.00001	1.00001
16	0.94817	0.94750
17	0.93688	0.93650
18	0.99358	0.99272
19	1.06515	1.06558
20	0.35922	0.35893
21	0.89758	0.89734
22	0.90980	0.90992
23	1.08814	1.08834
24	0.95938	0.95939
25	0.90875	0.90824
26	1.16055	1.16100
27	1.03941	1.03975
28	1.08225	1.08291

Table 4. Average Flux Values x 100 for the 48 x 48 Mesh-Centered VENTURE Case by Zone (Fast and Thermal Values for the Map)

16.82	16.84	16.96	17.11	17.12	17.01	16.80	16.47	16.01	15.74	15.66	15.62
10.01	9.916	9.527	8.921	8.561	8.534	8.915	9.669	10.77	11.52	11.77	11.95
16.90	16.93	17.06	17.23	17.24	17.12	16.91	16.58	16.11	15.81	15.72	
9.718	9.553	9.105	8.476	8.108	8.078	8.972	9.240	10.37	11.17	11.52	
17.01	17.06	17.22	17.41	17.41	17.29	17.08	16.75	16.25	15.92		
9.335	9.090	8.612	7.956	7.580	7.546	7.955	8.739	9.901	10.72		
		→ Fuel ↓									
17.38	17.46	17.71	17.74	17.93	17.78	17.58	17.26	16.70			
8.435	8.202	7.636	6.929	6.512	6.410	6.889	7.729	8.969			
17.94	18.03	18.33	18.56	18.52	18.30	18.21	17.89				
7.216	6.966	6.350	5.616	5.134	4.793	5.469	6.400				
18.25	18.34	18.61	18.82	18.85	18.74	18.57					
6.456	6.203	5.563	4.783	4.476	4.414	4.760					
18.40	18.48	18.72	18.86	18.99	18.95						
6.119	5.862	5.175	4.205	4.167	4.241						
18.46	18.54	18.81	19.02	19.07							
6.190	5.936	5.304	4.531	4.230							
18.39	18.48	18.78	19.03								
6.589	6.338	5.731	5.001								
18.16	18.24	18.51									
7.274	7.034	6.460									
17.98	18.04										
7.765	7.534										
17.94											
7.929											

BENCHMARK PROBLEM SOLUTION

Identification: 13-A2-2

Benchmark Problem ID.13-A2

Date Submitted: January 1977

By: B. A. Zolotar (EPRI)
F. J. Rahn (EPRI)

Date Accepted: June 1977

By: H. L. Dodds, Jr. (U. of Tenn.)
W. A. Wittkopf (B&W)

Descriptive Title: Diffusion Theory Solution with CITATION

Computer: IBM-360, Model 195

Code: CITATION

Date Solved: November 1975 at EPRI

Results:

K_{eff} = 1.087575

Mesh Spacing: 4 meshes per region in configuration map

Convergence criteria: eigenvalue 0.0001
flux 0.00004

Exhibit A: Group 1 Fluxes

Exhibit B: Group 2 Fluxes

.1679	.1681	.1692	.1707	.1709	.1697	.1676	.1642	.1597	.1571	.1563	.1558
.1687	.1689	.1703	.1719	.1720	.1708	.1687	.1654	.1607	.1579	.1569	
.1698	.1703	.1719	.1737	.1738	.1726	.1705	.1672	.1622	.1589		
.1735	.1743	.1769	.1793	.1792	.1777	.1757	.1725	.1668			
.1791	.1800	.1832	.1855	.1850	.1827	.1820	.1787				
.1822	.1831	.1861	.1880	.1883	.1872	.1856					
.1836	.1845	.1871	.1883	.1898	.1893						
.1843	.1851	.1880	.1901	.1906							
.1836	.1843	.1877	.1901								
.1813	.1820	.1850									
.1795	.1801										
.1791											

Exhibit A: Group 1 Fluxes

.1003	.0994	.0955	.0894	.0858	.0855	.0894	.0969	.1079	.1154	.1179	.1197
.0975	.0958	.0913	.0850	.0813	.0809	.0850	.0926	.1039	.1120	.1155	
.0936	.0909	.0863	.0796	.0759	.0755	.0797	.0892	.0992	.1072		
.0846	.0821	.0763	.0693	.0651	.0641	.0690	.0772	.0896			
.0724	.0698	.0635	.0562	.0514	.0474	.0548	.0639				
.0648	.0622	.0557	.0479	.0449	.0443	.0478					
.0615	.0588	.0518	.0415	.0418	.0425						
.0620	.0595	.0530	.0454	.0424							
.0661	.0636	.0573	.0500								
.0730	.0705	.0646									
.0778	.0754										
.0795											

Exhibit B: Group 2 Fluxes

BENCHMARK SOURCE SITUATION

Identification: 14

Date Submitted: June 1976 By: S. Langenbuch (GRS-Munich)
W. Werner (GRS-Munich)

Date Accepted: June 1977 By: H. L. Dodds, Jr. (U. of Tenn.)
F. N. McDonnell (AECL-CRNL)

Descriptive Title: Multi-dimensional (x-y-z) BWR Model

Suggested Function: Test 2d, 3d Neutron Kinetics Solution, Especially for Coarse Mesh Methods

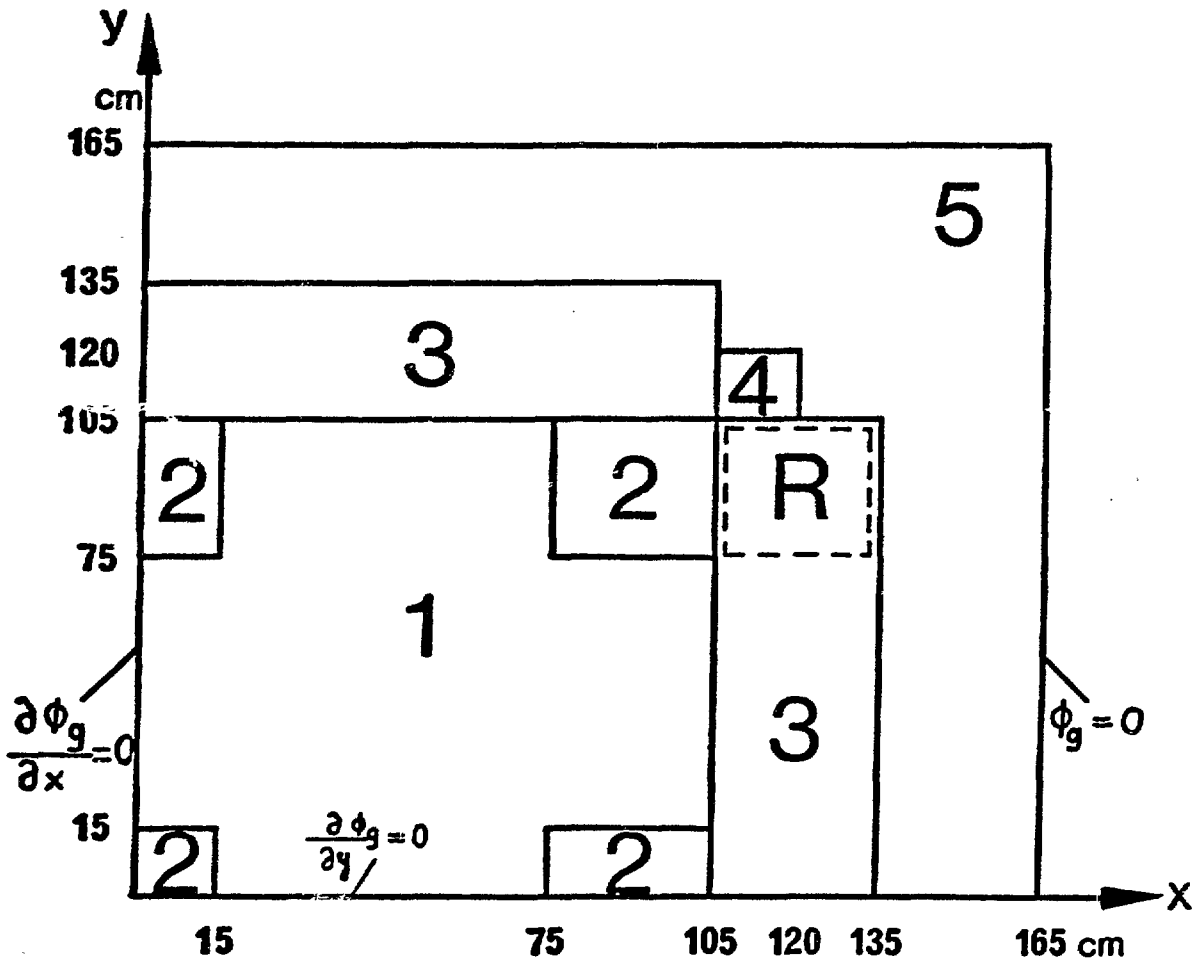


Fig. 1: Quadrant of Reactor Horizontal Cross Section, Region Assignment

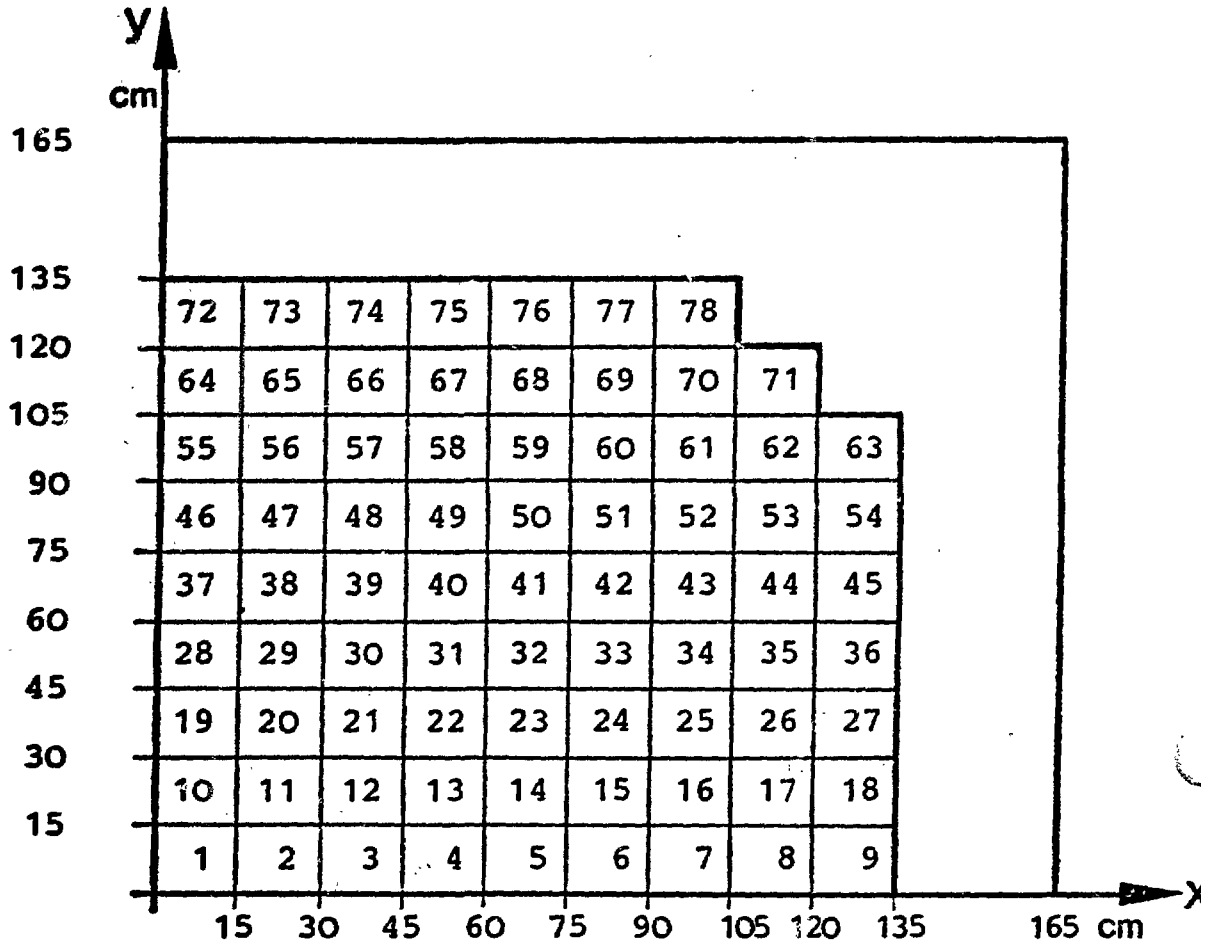


Fig. 2: Quadrant of Reactor Horizontal Cross Section, Fuel Assembly Identification

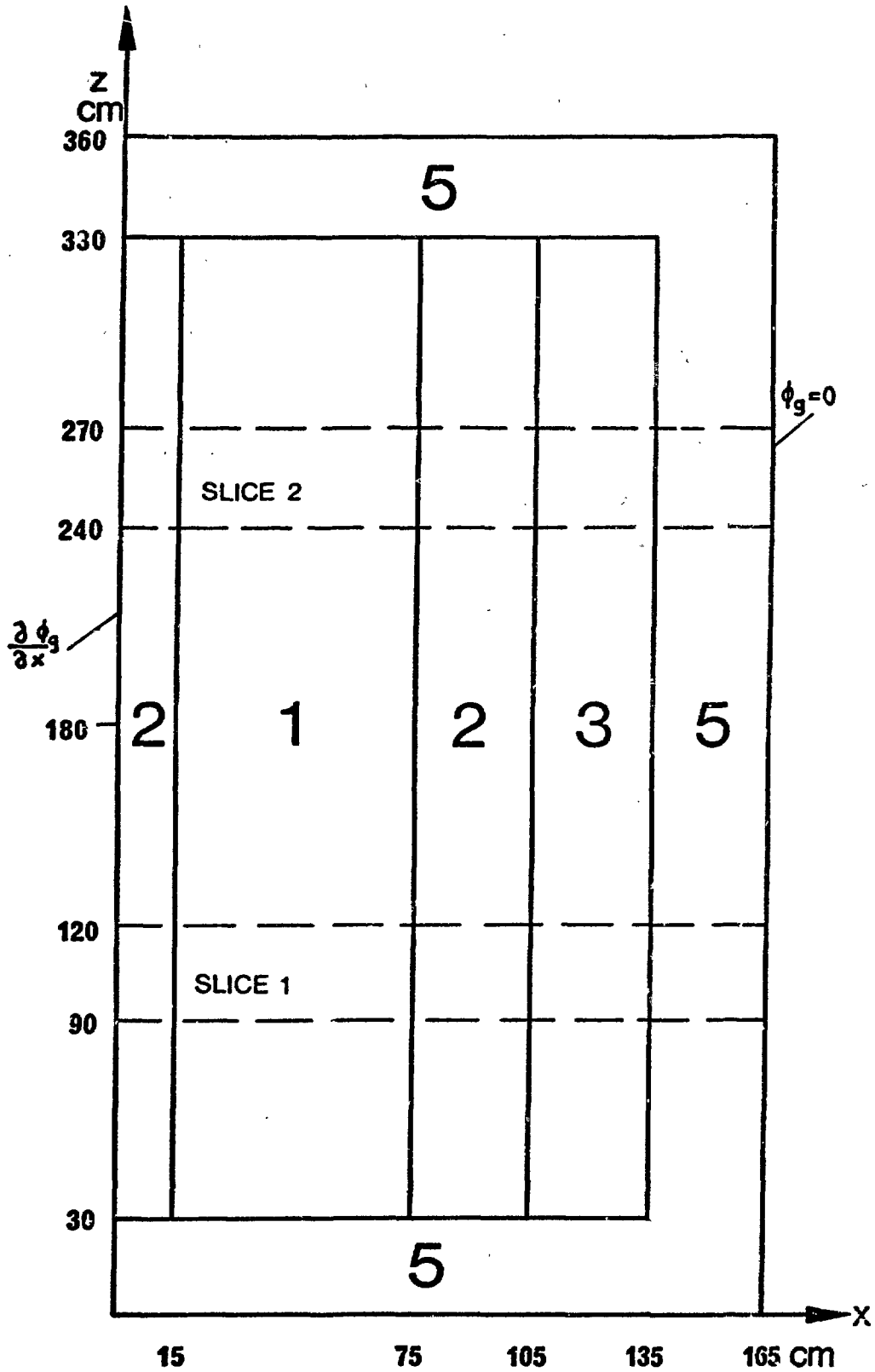


Fig. 3: Vertical Cross Section, y=0, Region Assignment, Vertical Slice Identification

BOUNDARY CONDITIONS:

External Boundaries: zero flux

Symmetry Boundaries: Reflection, $\frac{\partial \phi_g}{\partial n} = 0$

BENCHMARK PROBLEM

Identification: 14-A1 Source Situation ID.14

Date Submitted: June 1976 By: S. Langenbuch and W. Werner (GRS-Munich)

Date Accepted: June 1977 By: H. L. Dodds, Jr. (U. of Tenn.) F. N. McDonnell (AECL-CRNL)

Descriptive Title: Super Prompt-critical Transient; Two-dimensional, Two-group Neutron Diffusion Problem, with Adiabatic Heatup and Doppler Feedback in Thermal Reactor

Reduction of Source Situation:

1. Two-dimensional (xy), two-group diffusion theory
2. Two delayed neutron precursor groups.

$$\nabla D_1(\vec{x},t)\nabla\phi_1(\vec{x},t)-(\Sigma a_1(\vec{x},t)+\Sigma_{1\to2}(\vec{x},t))\phi_1(\vec{x},t)+\nu(1-\beta)\Big[\Sigma f_1(\vec{x},t)\phi_1(\vec{x},t)$$

$$+\Sigma f_2(\vec{x},t)\phi_2(\vec{x},t)\Big]+\sum_{i=1}^{2}\lambda_i C_i(\vec{x},t) = \frac{1}{v_1}\frac{\partial}{\partial t}\phi_1(\vec{x},t)$$

$$\nabla D_2(\vec{x},t)\nabla\phi_2(\vec{x},t)-\Sigma a_2(\vec{x},t)\phi_2(\vec{x},t)+\Sigma_{1\to2}(\vec{x},t)\phi_1(\vec{x},t) = \frac{1}{v_2}\frac{\partial}{\partial t}\phi_2(\vec{x},t)$$

$$\nu\beta_i(\Sigma f_1(\vec{x},t)\phi_1(\vec{x},t)+\Sigma f_2(\vec{x},t)\phi_2(\vec{x},t))-\lambda_i C_i(\vec{x},t) = \frac{\partial}{\partial t}C_i(\vec{x},t),\ i=1,2.$$

with zero flux boundary conditions on external surfaces, reflection conditions at symmetry boundaries, and steady state initial conditions.

3. Adiabatic Heatup

$$\alpha\Big[\Sigma f_1(\vec{x},t)\phi_1(\vec{x},t)+\Sigma f_2(\vec{x},t)\phi_2(\vec{x},t)\Big] = \frac{\partial}{\partial t}T(\vec{x},t)$$

4. Doppler Feedback

$$\Sigma a_1(\vec{x},t) = \Sigma a_1(\vec{x},t=0)\left[1+\gamma(\sqrt{T(x,t)}-\sqrt{T_o})\right]$$

5. Power

$$P(\vec{x},t) = \varepsilon\left[\Sigma f_1(\vec{x},t)\phi_1(\vec{x},t)+\Sigma f_2(\vec{x},t)\phi_2(\vec{x},t)\right]$$

Data:

Initial Two-Group Constants

Region	Material	Group i	D_i(cm)	Σa_i(cm^{-1})	$\nu\Sigma f_i$(cm^{-1})	$\Sigma_{1\to2}$(cm^{-1})
1	Fuel 1 with rod	1 2	1.255 0.211	0.008252 0.1003	0.004602 0.1091	 0.02533
2	Fuel 1 without rod	1 2	1.268 0.1902	0.007181 0.07047	0.004609 0.08675	 0.02767
3	Fuel 2 with rod	1 2	1.259 0.2091	0.008002 0.08344	0.004663 0.1021	 0.02617
4	Fuel 2 without rod	1 2	1.259 0.2091	0.008002 0.073324	0.004663 0.1021	 0.02617
5	Reflector	1 2	1.257 0.1592	0.0006034 0.01911	0 0	 0.04754

Additional Parameters for all Regions:

$B^2 = 1.0 \cdot 10^{-4}$ axial buckling for both energy groups

$\nu = 2.43$ mean number of neutrons per fission

$v_1 = 3.0 \cdot 10^7$ cm·sec^{-1}

$v_2 = 3.0 \cdot 10^5$ cm·sec^{-1}

Delayed Neutron Data:

Group	β_i	λ_i(sec^{-1})
1	0.0054	0.00654
2	0.001087	1.35

Data for Feedback Model

$\alpha = 3.83 \quad 10^{-11}\ {}^{o}K\ cm^{3}$ conversion factor

$\gamma = 2.034 \quad 10^{-3}\ {}^{o}K^{1/2}$ feedback constant

$\varepsilon = 3.204 \quad 10^{-11}$ Wsec/p.fission energy conversion factor

The initial configuration is made critical by dividing the production cross sections by k_{eff}. The initial flux distribution shall be normalized such that the average power density

$$\overline{P} = \frac{\varepsilon}{V_{core}} \int_{V_{core}} (\Sigma f_1 \phi_1 + \Sigma f_2 \phi_2) dV = 1.0 \cdot 10^{-6}\ W\ cm^{-3}$$

The initial precursor concentrations are in equilibrium with the initial critical flux distribution.

The initial temperature $T_o = 300\ {}^{o}K$.

<u>Initiating Perturbation:</u>

$$\frac{\Sigma a_2(t)}{\Sigma a_2(0)} = \begin{cases} 1 - 0.0606184 \cdot t & t \leq 2 \\ 0.8787631 & t > 2 \end{cases}$$

where t = time (sec).

Expected Primary Results:

1. Maximum eigenvalue for initial flux distribution

2. Normalized Power Densities P_k for initial flux distribution:

$$P_k = \frac{\varepsilon}{V_k \overline{P}} \int_{V_k} (\Sigma f_1 \phi_1 + \Sigma f_2 \phi_2) dV, \quad V_k = \text{Volume of Fuel Assembly } k$$

$$k = 1, \ldots, 78$$

3. Maximum eigenvalue for configuration of withdrawn rod for cold reactor (feedback effects neglected)

4. Average Power density $\overline{P}$ versus time

5. Normalized Power Densities P_k at t=0,4 sec, 0,8 sec, 1,2 sec, 1,4 sec, 2,0 sec, 3,0 sec.

6. Maximum of $\overline{P}$, time of occurence

7. Average temperature $\overline{T} = \frac{1}{V_{core}} \int_{V_{core}} T(\vec{x},t) dV$ versus time

8. Number of unknowns in the problem, number of time-steps, computing time, and computer used.

Possible additional results:

9. Table of temperatures in volumes V_k, k=1,...,78.

10. Dependence of results on spatial and temporal discretization.

Solutions:

Coarse-mesh finite-difference methods

1. Flux expansion: 14-A1-1

2. Nodal expansion: 14-A1-2

BENCHMARK PROBLEM SOLUTION

Identification: 14-A1-1 Benchmark Problem ID.14-A1

Date Submitted: February 1977 By: S. Langenbuch (GRS-Munich)
W. Werner (GRS-Munich)

Date Accepted: June 1977 By: H. L. Dodds, Jr. (U. of Tenn.)
F. N. McDonnell (AECL-CRNL)

Descriptive Title: Direct 2d-Coarse Mesh Solution with CUBBOX.[1,2,3]

Mathematical Model: A 5-point difference operator with coupling coefficients derived from expansion of neutron flux into local polynomials is used for the approximation of the spatial differential operator,[1,2,3]. Time integration is performed by a combined ADE-ADI technique[4] with spectral matching[5], and frequency prediction from space-averaged kinetic equations[6].

Computer: IBM-360, Model 91

Code: CUBBOX[7] with 6-order nonseparated polynomials

Date Solved: February 1977 at Laboratorium für Reaktorregelung und Anlagensicherung (LRA)

References:

1 A. Birkhofer and W. Werner, Efficiency of Various Methods for the Analysis of Space-Time Kinetics, Proc. Conf. Mathematical Models and Computational Techniques for Analysis of Nuclear Systems, CONF-730414, Vol. 2, p. IX-31-41 (1973)

2 A. Birkhofer, S. Langenbuch and W. Werner, Coarse-Mesh Method for Space-Time Kinetics, Trans. Am. Nuc. Soc., 18, 153 (1974)

3 S. Langenbuch, W. Maurer and W. Werner, High Order Schemes for Neutron Kinetics Calculations, Based on Local Polynomial Approximation, to be publ. Nucl. Sci. Eng. Oct. 1977

4 S. Langenbuch and W. Werner, Implicit Matrix Decomposition Scheme for Coarse-Mesh Methods, Trans. Am. Nuc. Soc. 21, 224 (1974)

5 J. Devought and E. Mund, A - Stable Algorithms for Neutron Kinetics, MRR 145, Proc. of the Joint NEACRP/CSNI Specialists' Meeting on New Developments in Three-Dimensional Neutron Kinetics, 21-71 (1975)

6 S. Langenbuch and W. Werner, Eine Methode zur Verbesserung der Zeitintegration in 3d Neutronenkinetik-Rechnungen durch eine Form der Periodenfaktorisierung, Proc. Reaktortangung (1976)

7 Program Description of the QUABOX/CUBBOX Code, Internal Report, LRA, D-8046 Garching

Results:

Uniform mesh width $\Delta x = \Delta y$ = 15 cm (11 x 11 intervals)

1. Maximum eigenvalue for initial flux distribution:
   $k_{eff} = 0.99633$
2. Exhibit A:
   Normalized Power Densities P_{ki} for initial flux distribution:

   $$P_{ki} = \frac{\varepsilon}{\bar{P}V_{ki}} \int_{V_{ki}} (\Sigma f_1 \phi_1 + \Sigma f_2 \phi_2) dV, \quad V_k = \text{Volume of Fuel}$$

   Assembly k

   $k = 1, \ldots, 78$

3. Maximum eigenvalue for configuration of withdrawn rod for cold reactor (feedback effects neglected):
   $k_{eff} = 1.01546$
4. Exhibit B:
   Average Power density $\bar{P}$ versus time
5. Exhibit C:
   Normalized Power Densities P_k at t = 0.4 sec, 0.8 sec, 1.2 sec, 1.4 sec, 2.0 sec, 3.0 sec.
6. Maximum of $\bar{P} = 5.734 \cdot 10^3$; time of occurrence = 1.421 sec.
7. Exhibit D:
   Average temperature $\bar{T} = \frac{1}{V_{core}} \int_{V_{core}} T(\vec{x},t) dV$ versus time
8. Number of unknowns in the problem 121 x (2 prompt neutron groups + 2 delayed precursor groups + temperature) = 605
   Number of time-steps: 1200
   Computing time: 180 sec on IBM-360/91
9. Exhibit E:
   Average temperatures in volumes V_k, k = 1,...,78, at t = 0.4 sec, 0.8 sec, 1.2 sec, 1.4 sec, 2.0 sec, 3.0 sec.

EXHIBIT A

NORMALIZED POWER DENSITY INITIAL STATE

Y/X	1	2	3	4	5	6	7	8	9
1	0.6214	0.4438	0.4134	0.5107	0.7939	1.3984	1.6725	1.4769	0.9059
2	0.4438	0.4010	0.4092	0.4931	0.6708	0.9416	1.1512	1.2703	0.6538
3	0.4134	0.4092	0.4275	0.4958	0.6209	0.7794	0.9608	1.1655	0.8145
4	0.5107	0.4931	0.4958	0.5565	0.6816	0.8400	1.0173	1.2168	0.8427
5	0.7939	0.6708	0.6209	0.6816	0.8655	1.1570	1.3450	1.4185	0.9260
6	1.3984	0.9416	0.7794	0.8400	1.1570	1.8739	2.0743	1.6882	0.9580
7	1.6725	1.1512	0.9608	1.0173	1.3450	2.0743	2.1888	1.6176	0.8403
8	1.4769	1.2703	1.1655	1.2168	1.4185	1.6882	1.6176	1.3323	0.0
9	0.9059	0.6538	0.8145	0.8427	0.9260	0.9580	0.8403	0.0	0.0

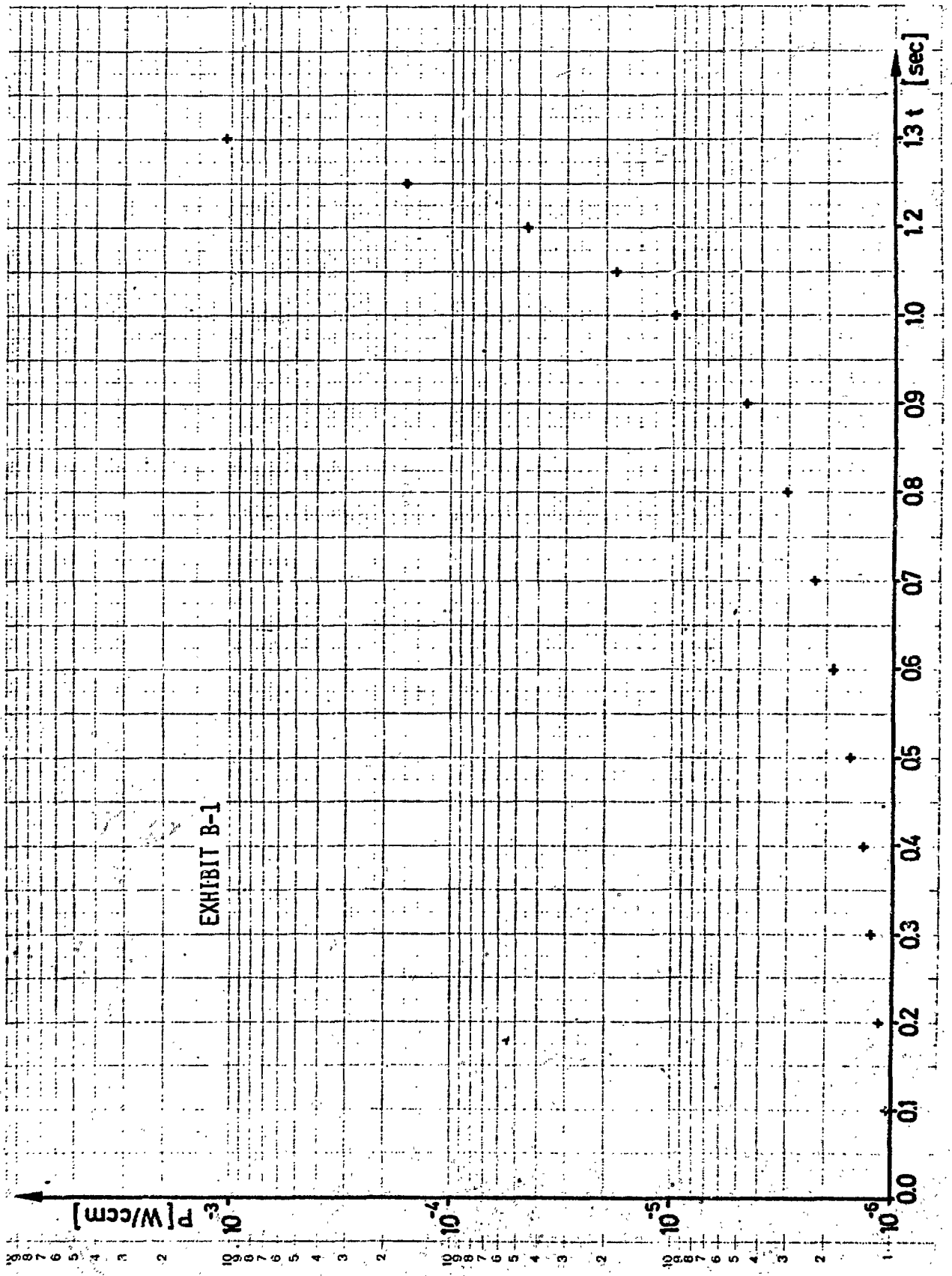


EXHIBIT B-1
P[W/ccm]
10^{-3}
10^{-4}
10^{-5}
10^{-6}
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.2
1.3 t [sec]

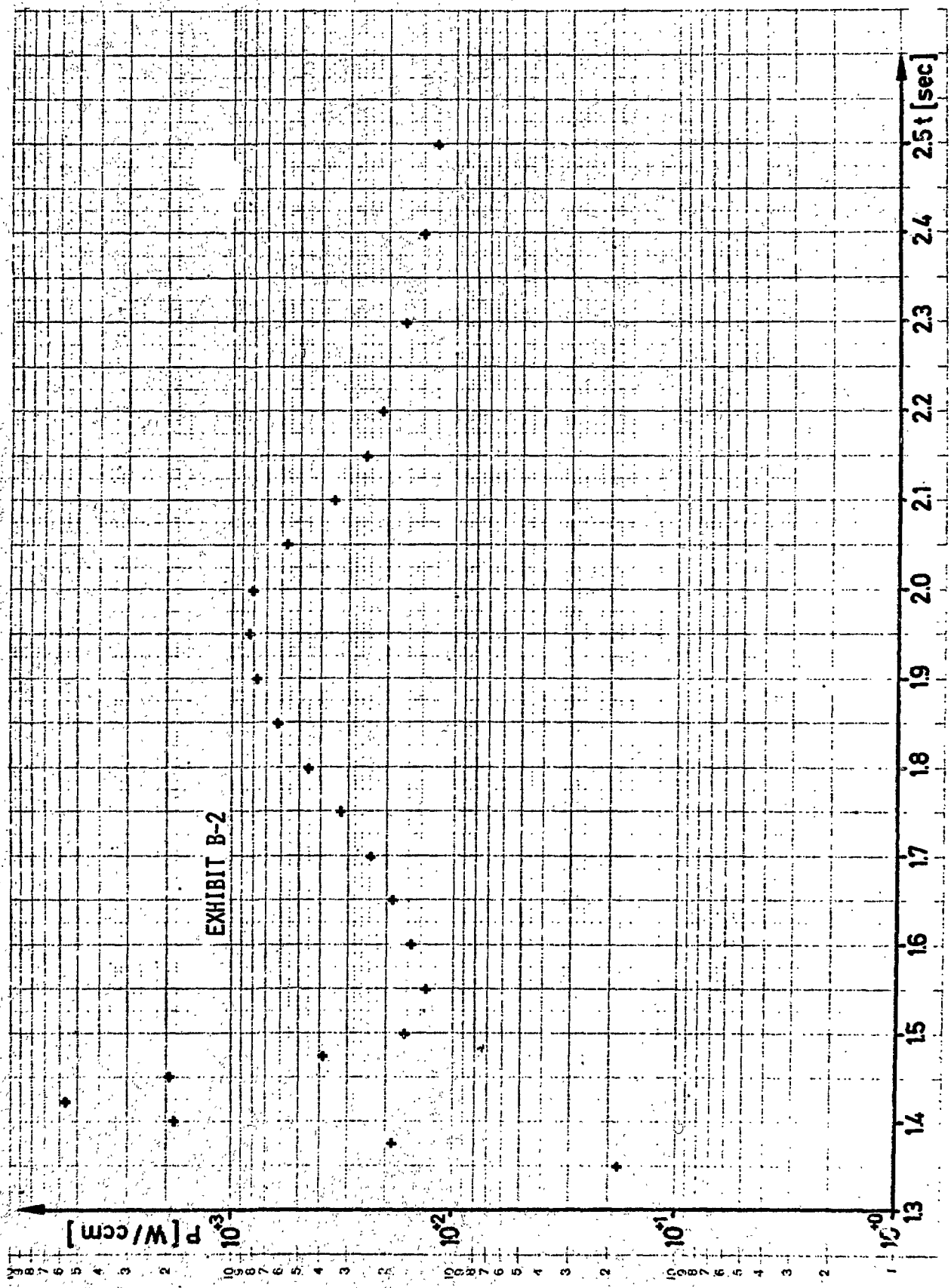


EXHIBIT B-2
P [W/ccm]
10^{+3}
10^{+2}
10^{+1}
10^{+0}
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2.0
2.1
2.2
2.3
2.4
2.5 t [sec]

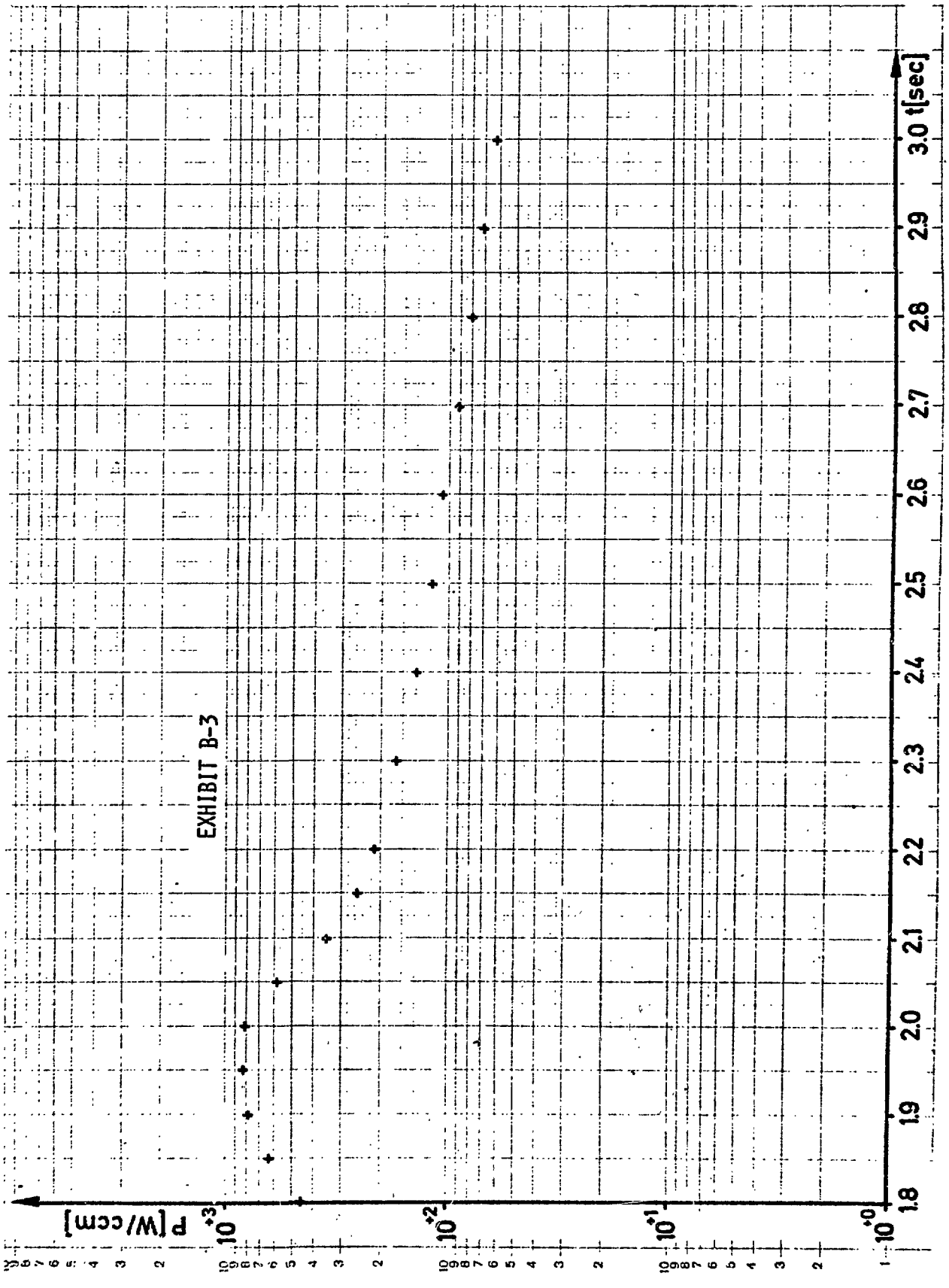


EXHIBIT B-3
P [W/ccm]
10^{+3}
10^{+2}
10^{+1}
10^{+0}
1.8
1.9
2.0
2.1
2.2
2.3
2.4
2.5
2.6
2.7
2.8
2.9
3.0 t[sec]

EXHIBIT C-1

NORMALIZED POWER DENSITY T = 0.4 SEC

Y/X	1	2	3	4	5	6	7	8	9
1	0.5647	0.4056	0.3820	0.4770	0.7466	1.3193	1.5820	1.4007	0.8607
2	0.4046	0.3679	0.3799	0.4635	0.6358	0.8967	1.1012	1.2202	0.8221
3	0.3789	0.3778	0.4002	0.4718	0.5992	0.7603	0.9452	1.1526	0.8079
4	0.4697	0.4574	0.4679	0.5375	0.6733	0.8456	1.0398	1.2563	0.8747
5	0.7308	0.6230	0.5889	0.6659	0.8712	1.1956	1.4265	1.5428	1.0200
6	1.2869	0.8742	0.7405	0.8248	1.1757	1.9589	2.2457	1.9520	1.1405
7	1.5396	1.0692	0.9131	0.9985	1.3663	2.1688	2.3712	1.8785	1.0139
8	1.3604	1.1812	1.1071	1.1914	1.4330	1.7540	1.7310	1.4795	0.0
9	0.8349	0.7943	0.7734	0.8233	0.9313	0.9880	0.8876	0.0	0.0

EXHIBIT C-2

NORMALIZED POWER DENSITY T = 0.8 SEC

Y/X	1	2	3	4	5	6	7	8	9
1	0.4776	0.3469	0.3342	0.4264	0.6764	1.2029	1.4492	1.2889	0.7945
2	0.3443	0.3172	0.3354	0.4190	0.5840	0.8309	1.0281	1.1474	0.7761
3	0.3255	0.3295	0.3587	0.4360	0.5676	0.7332	0.9238	1.1360	0.7999
4	0.4063	0.4023	0.4256	0.5094	0.6622	0.8559	1.0760	1.3182	0.9244
5	0.6331	0.5493	0.5401	0.6429	0.8815	1.2559	1.5507	1.7298	1.1617
6	1.1145	0.7702	0.6812	0.8026	1.2059	2.0899	2.5030	2.3413	1.4134
7	1.3344	0.9429	0.8402	0.9709	1.4004	2.3137	2.6446	2.2635	1.2739
8	1.1812	1.0443	1.0181	1.1538	1.4568	1.8550	1.9018	1.6987	0.0
9	0.7259	0.7033	0.7110	0.7945	0.9404	1.0345	0.9593	0.0	0.0

EXHIBIT C-3

NORMALIZED POWER DENSITY T = 1.2 SEC

Y/X	1	2	3	4	5	6	7	8	9
1	0.3671	0.2724	0.2731	0.3610	0.5846	1.0491	1.2731	1.1409	0.7064
2	0.2677	0.2527	0.2783	0.3615	0.5162	0.7442	0.9315	1.0505	0.7144
3	0.2576	0.2677	0.3052	0.3893	0.5258	0.6970	0.8948	1.1127	0.7878
4	0.3248	0.3313	0.3705	0.4720	0.6462	0.8679	1.1225	1.3991	0.9891
5	0.5067	0.4537	0.4759	0.6110	0.8917	1.3312	1.7130	1.9807	1.3535
6	0.8903	0.6346	0.6025	0.7703	1.2395	2.2524	2.8393	2.8764	1.7966
7	1.0668	0.7777	0.7429	0.9302	1.4370	2.4917	2.9998	2.7914	1.6400
8	0.9472	0.8645	0.8985	1.0983	1.4784	1.9767	2.1196	1.9877	0.0
9	0.5832	0.5833	0.6266	0.7518	0.9456	1.0882	1.0475	0.0	0.0

EXHIBIT C-4

NORMALIZED POWER DENSITY T = 1.4 SEC

Y/X	1	2	3	4	5	6	7	8	9
1	0.3266	0.2449	0.2499	0.3348	0.5458	0.9816	1.1944	1.0743	0.6669
2	0.2395	0.2287	0.2565	0.3384	0.4876	0.7061	0.8879	1.0060	0.6861
3	0.2321	0.2443	0.2845	0.3703	0.5076	0.6801	0.8801	1.0996	0.7807
4	0.2935	0.3037	0.3484	0.4558	0.6374	0.8699	1.1396	1.4318	1.0167
5	0.4569	0.4157	0.4493	0.5956	0.8912	1.3562	1.7790	2.0942	1.4444
6	0.8004	0.5799	0.5690	0.7527	1.2442	2.3051	2.9778	3.1392	1.9948
7	0.9589	0.7103	0.7005	0.9070	1.4394	2.5457	3.1418	3.0478	1.8288
8	0.8527	0.7905	0.8458	1.0669	1.4731	2.0095	2.2000	2.1123	0.0
9	0.5256	0.5337	0.5892	0.7281	0.9383	1.1000	1.0766	0.0	0.0

EXHIBIT C-5

NORMALIZED POWER DENSITY

T = 2.0 SEC

Y/X	1	2	3	4	5	6	7	8	9
1	0.3031	0.2261	0.2287	0.3031	0.4893	0.8760	1.0653	0.9619	0.6025
2	0.2206	0.2101	0.2349	0.3086	0.4427	0.6399	0.8078	0.9237	0.6370
3	0.2105	0.2224	0.2604	0.3412	0.4710	0.6374	0.8363	1.0599	0.7632
4	0.2611	0.2726	0.3175	0.4226	0.6023	0.8412	1.1341	1.4628	1.0617
5	0.3991	0.3675	0.4059	0.5518	0.8483	1.3362	1.8421	2.2956	1.6435
6	0.6919	0.5064	0.5093	0.6933	1.1844	2.2846	3.1584	3.7559	2.5321
7	0.8242	0.6164	0.6226	0.8293	1.3607	2.5086	3.3176	3.6522	2.3560
8	0.7319	0.6862	0.7506	0.9721	1.3823	1.9583	2.2663	2.3526	0.0
9	0.4532	0.4655	0.5248	0.6649	0.8806	1.0662	1.0910	0.0	0.0

EXHIBIT C-6

NORMALIZED POWER DENSITY T = 3.0 SEC

Y/X	1	2	3	4	5	6	7	8	9
1	0.3333	0.2466	0.2454	0.3203	0.5115	0.9105	1.1035	0.9943	0.6228
2	0.2412	0.2277	0.2506	0.3241	0.4599	0.6604	0.8298	0.9461	0.6523
3	0.2279	0.2385	0.2749	0.3542	0.4827	0.6473	0.8443	1.0673	0.7685
4	0.2800	0.2896	0.3315	0.4330	0.6076	0.8399	1.1251	1.4476	1.0510
5	0.4254	0.3881	0.4206	0.5595	0.8459	1.3179	1.8054	2.2439	1.6073
6	0.7357	0.5335	0.5255	0.6992	1.1735	2.2410	3.0795	3.6504	2.4622
7	0.8748	0.6481	0.6413	0.8352	1.3466	2.4579	3.2311	3.5456	2.2883
8	0.7761	0.7206	0.7732	0.9805	1.3713	1.9225	2.2113	2.2894	0.0
9	0.4809	0.4890	0.5413	0.6723	0.8766	1.0508	1.0694	0.0	0.0

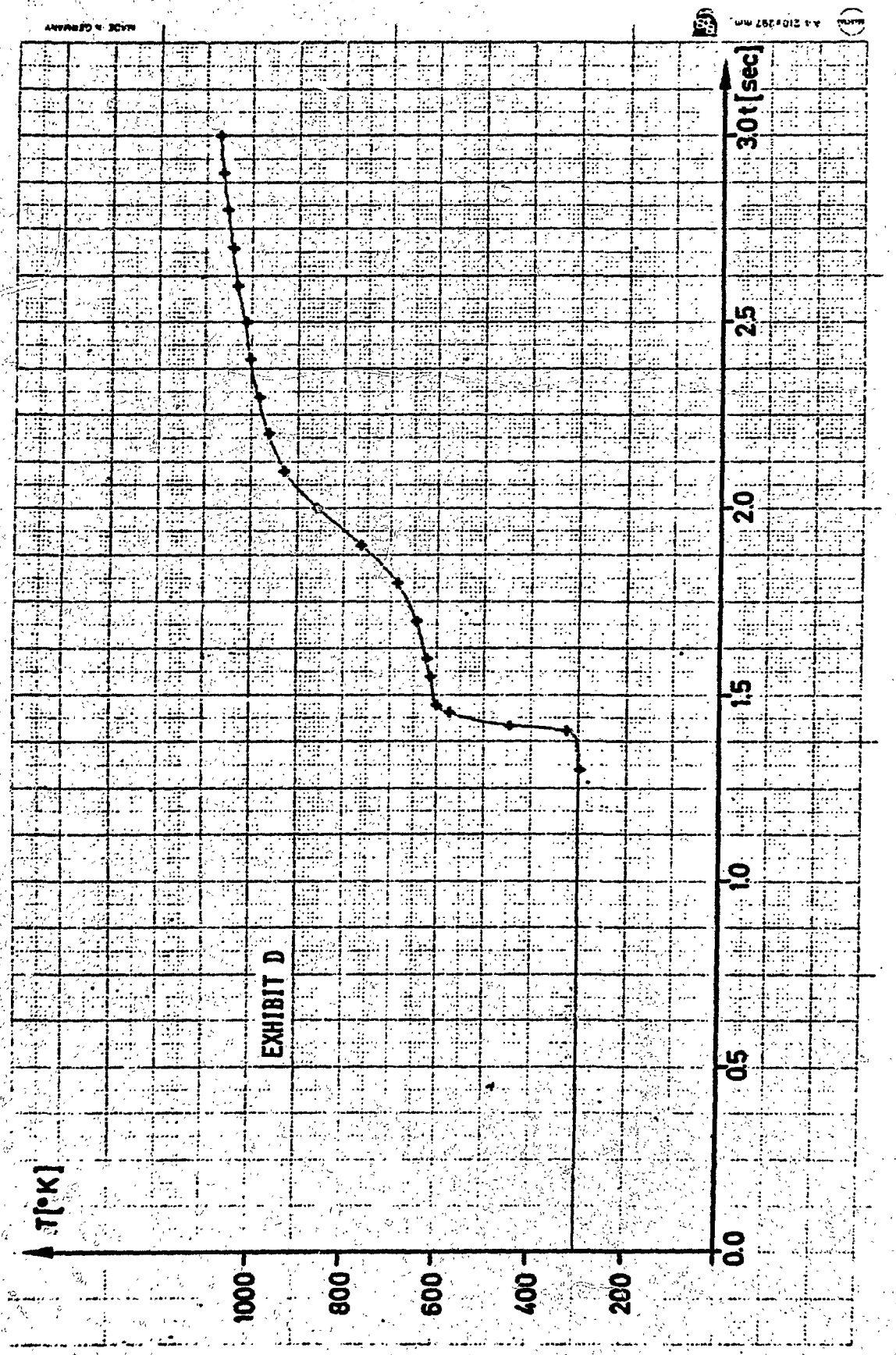

T[°K]
1000
800
600
400
200
0.0
0.5
1.0
1.5
2.0
2.5
3.0 t [sec]
EXHIBIT D

EXHIBIT E-1
AVERAGE FUEL TEMPERATURE

T = 0.4 SEC

VALUES ARE IDENTICAL TO 300.0

EXHIBIT E-2
AVERAGE FUEL TEMPERATURE T = 0.8 SEC

VALUES ARE IDENTICAL TO 300.0

EXHIBIT E-3

AVERAGE FUEL TEMPERATURE T = 1.2 SEC

VALUES ARE IDENTICAL TO 300.0

EXHIBIT E-4

AVERAGE FUEL TEMPERATURE T = 1.4 SEC

Y/X	1	2	3	4	5	6	7	8	9
1	3.0838D+02	3.0630D+02	3.0642D+02	3.0861D+02	3.1406D+02	3.2524D+02	3.3071D+02	3.2766D+02	3.1716D+02
2	3.0616D+02	3.0587D+02	3.0659D+02	3.0870D+02	3.1252D+02	3.1818D+02	3.2287D+02	3.2585D+02	3.1764D+02
3	3.0596D+02	3.0628D+02	3.0731D+02	3.0951D+02	3.1305D+02	3.1749D+02	3.2263D+02	3.2627D+02	3.2006D+02
4	3.0754D+02	3.0781D+02	3.0895D+02	3.1171D+02	3.1639D+02	3.2236D+02	3.2929D+02	3.3680D+02	3.2611D+02
5	3.1176D+02	3.1067D+02	3.1155D+02	3.1531D+02	3.2287D+02	3.3491D+02	3.4579D+02	3.5374D+02	3.3707D+02
6	3.2057D+02	3.1493D+02	3.1463D+02	3.1936D+02	3.3205D+02	3.5926D+02	3.7649D+02	3.8057D+02	3.5112D+02
7	3.2465D+02	3.1829D+02	3.1801D+02	3.2333D+02	3.3710D+02	3.6545D+02	3.8075D+02	3.7809D+02	3.4708D+02
8	3.2195D+02	3.2031D+02	3.2175D+02	3.2745D+02	3.3786D+02	3.5176D+02	3.5651D+02	3.5457D+02	3.0000D+02
9	3.1352D+02	3.1372D+02	3.1515D+02	3.1872D+02	3.2414D+02	3.2830D+02	3.2785D+02	3.0000D+02	3.0000D+02

EXHIBIT E-5

AVERAGE FUEL TEMPERATURE T = 2.0 SEC

Y/X	1	2	3	4	5	6	7	8	9
1	4.9314D+02	4.4354D+02	4.4380D+02	4.8959D+02	6.0611D+02	8.4705D+02	9.6380D+02	8.9754D+02	6.7194D+02
2	4.4053D+02	4.3273D+02	4.4688D+02	4.9107D+02	5.7227D+02	6.9334D+02	7.9391D+02	8.5924D+02	6.8340D+02
3	4.3424D+02	4.4032D+02	4.6145D+02	5.0778D+02	5.8273D+02	6.7765D+02	7.8927D+02	9.1404D+02	7.3841D+02
4	4.6749D+02	4.7242D+02	4.9581D+02	5.5367D+02	6.5289D+02	7.8182D+02	9.3511D+02	1.1054D+03	8.7701D+02
5	5.5873D+02	5.3360D+02	5.5047D+02	6.2892D+02	7.8936D+02	1.0503D+03	1.2981D+03	1.4967D+03	1.1390D+03
6	7.5075D+02	6.2506D+02	6.1536D+02	7.1328D+02	9.8273D+02	1.5724D+03	1.9777D+03	2.1493D+03	1.5039D+03
7	8.3830D+02	6.9702D+02	6.8702D+02	7.9650D+02	1.0877D+03	1.7014D+03	2.0672D+03	2.0924D+03	1.4154D+03
8	7.7857D+02	7.4[illegible]63D+02	7.6761D+02	8.8469D+02	1.1037D+03	1.4052D+03	1.5267D+03	1.5210D+03	3.0000D+02
9	5.9538D+02	5.9846D+02	6.2661D+02	7.0032D+02	8.1445D+02	9.0524D+02	9.0380D+02	3.0000D+02	3.0000D+02

EXHIBIT E-6

AVERAGE FUEL TEMPERATURE T = 3.0 SEC

Y/X	1	2	3	4	5	6	7	8	9
1	5.5905D+02	4.9259D+02	4.9303D+02	5.5440D+02	7.1037D+02	1.0329D+03	1.1895D+03	1.1015D+03	7.9962D+02
2	4.8854D+02	4.7810D+02	4.9733D+02	5.5690D+02	6.6612D+02	8.2894D+02	9.6480D+02	1.0541D+03	8.1786D+02
3	4.7972D+02	4.8817D+02	5.1713D+02	5.8022D+02	6.8219D+02	8.1172D+02	9.6471D+02	1.1363D+03	8.9835D+02
4	5.2364D+02	5.3084D+02	5.6336D+02	6.4288D+02	7.7925D+02	9.5751D+02	1.1713D+03	1.4098D+03	1.0979D+03
5	6.4443D+02	6.1200D+02	6.3656D+02	7.4491D+02	9.6607D+02	1.3282D+03	1.6802D+03	1.9715D+03	1.4793D+03
6	8.9890D+02	7.3325D+02	7.2316D+02	8.5863D+02	1.2295D+03	2.0456D+03	2.6302D+03	2.9248D+03	2.0267D+03
7	1.0146D+03	8.2862D+02	8.1866D+02	9.7020D+02	1.3711D+03	2.2205D+03	2.7524D+03	2.8445D+03	1.9635D+03
8	9.3532D+02	8.8677D+02	9.2637D+02	1.0885D+03	1.3910D+03	1.8114D+03	1.9944D+03	2.0099D+03	3.0000D+02
9	6.9241D+02	6.9772D+02	7.3765D+02	8.3984D+02	9.9806D+02	1.1265D+03	1.1312D+03	3.0000D+02	3.0000D+02

BENCHMARK PROBLEM SOLUTION

Identification: 14-A1-2 Benchmark Problem ID.14-A1

Date Submitted: June 1976 By: H. Finnemann (KWU)

Date Accepted: June 1977 By: H.L. Dodds, Jr.(U. of Tenn.)
F.N. McDonnell (AECL-CRNL)

Descriptive Title: BWR Kinetics Benchmark Problem: 2-D Nodal Solution: Fifth Order Polynomial Expansion

Mathematical Model

The IQSBOX program solves the time-dependent two-group neutron diffusion equation in one, two or three dimensions by the nodal expansion method (NEM).

NEM is a consistent nodal technique that converges towards the exact solution of the diffusion equation for small mesh sizes. Subsidiary 1-D diffusion equations are solved in each box by polynomial expansion to obtain spatial coupling coefficients. Polynomials up to fifth order can be used. Time integration is performed by the backwards-difference algorithm combined with an exponential transformation technique.

Computer: CDC CYBER 175
Code: IQSBOX
Date Solved: January 1976 at Kraftwerk Union Erlangen

References

H. Finnemann
A Consistent Nodal Method for the Analysis of Space-Time Effects in Large LWR's.
Proc. of the Joint NEACRP/CSNI Specialists' Meeting on New Developments in Three-Dimensional Neutron Kinetics and Review of Kinetics Benchmark Calculations
Munich, January 22-24 (1975), MRR 145

F. Bennewitz, H. Finnemann, H. Moldaschl
Solution of the Multidimensional Neutron Diffusion Equation by Nodal Expansion
CONF-750413, Proc. Conf. on Comput. Methods in Nucl. Eng., April 15 - 17, 1975
Charleston, South Carolina

F. Bennewitz, H. Finnemann, M.R. Wagner
Higher Order Corrections in Nodal Reactor Calculations.
Trans. Am. Nucl. Soc. 22, 250 (1975).

Results:

Uniform mesh with $\Delta x = \Delta y = 15$ cm (11 x 11 intervals)

1. Maximum eigenvalue for initial flux distribution: $k_{eff} = .99631$

2. Exhibit A:
   Normalized local power densities P_{ki} for initial flux distribution:
   $$P_{ki} = \frac{\varepsilon}{V_k} \int_{V_k} (\Sigma f_1 \Phi_1 + \Sigma f_2 \Phi_2)\, dV / \bar{P}$$
   Assembly k, V_k = Volume of Fuel
   $k = 1,\ldots,78$

3. Maximum eigenvalue for configuration of withdrawn rod for cold reactor (feedback effects neglected): $k_{eff} = 1.01531$

4. Exhibit B:
   Average Power densitiy $\bar{P}$ versus time

5. Exhibit C:
   Normalized Local Power Densities P_k and Average temperatures in volumes V_k, $k = 1,\ldots,78$, at $t = 0.4$ sec, 0.8 sec, 1.2 sec, 1.4 sec, 2.0 sec, 3.0 sec.

6. Maximum of $\bar{P} = 5.451 \cdot 10^3$; time of occurrence $= 1.445$ sec.

7. Exhibit D:
   Average temperature $\bar{T} = \frac{1}{V_{core}} \int_{V_{core}} T(\vec{x},t)dV$ versus time

8. Number of unknowns in the problem: The unknowns are average node fluxes, average partial currents on the six surfaces of the node and average delayed precursor concentrations. The number of unknowns per mesh is given by $(2N+1) \cdot G + I$, where G is the number of energy groups, N the spatial deminsion, and I the number of delayed precursor groups. The number of unknowns is independent on the degree of the approximating polynomial.
   The total number of unknowns for this problem is thus given by $(5 \cdot 2 + 2) * 121 = 1452$
   Number of time steps: 522 (automatic time-step selection such that local power change less than 12 % between time steps).

   Computing time: 255 sec

EXHIBIT A

AVERAGE SUBASSEMBLY POWER (ABOVE) AND AVERAGE FUEL TEMPERATURE (BELOW)

9	.919 300.	.862 300.	.821 300.	.846 300.	.924 300.	.965 300.	.834 300.		
8	1.484 300.	1.285 300.	1.173 300.	1.221 300.	1.422 300.	1.675 300.	1.614 300.	1.311 300.	
7	1.672 300.	1.150 300.	.967 300.	1.022 300.	1.334 300.	2.054 300.	2.161 300.	1.614 300.	.834 300.
6	1.396 300.	.942 300.	.785 300.	.845 300.	1.150 300.	1.857 300.	2.054 300.	1.675 300.	.965 300.
5	.792 300.	.674 300.	.620 300.	.680 300.	.866 300.	1.150 300.	1.334 300.	1.422 300.	.924 300.
4	.515 300.	.493 300.	.495 300.	.555 300.	.680 300.	.845 300.	1.022 300.	1.221 300.	.846 300.
3	.416 300.	.409 300.	.427 300.	.495 300.	.620 300.	.785 300.	.967 300.	1.173 300.	.821 300.
2	.443 300.	.403 300.	.409 300.	.493 300.	.674 300.	.941 300.	1.150 300.	1.285 300.	.862 300.
1	.621 300.	.443 300.	.416 300.	.515 300.	.792 300.	1.396 300.	1.672 300.	1.484 300.	.919 300.
	1	2	3	4	5	6	7	8	9

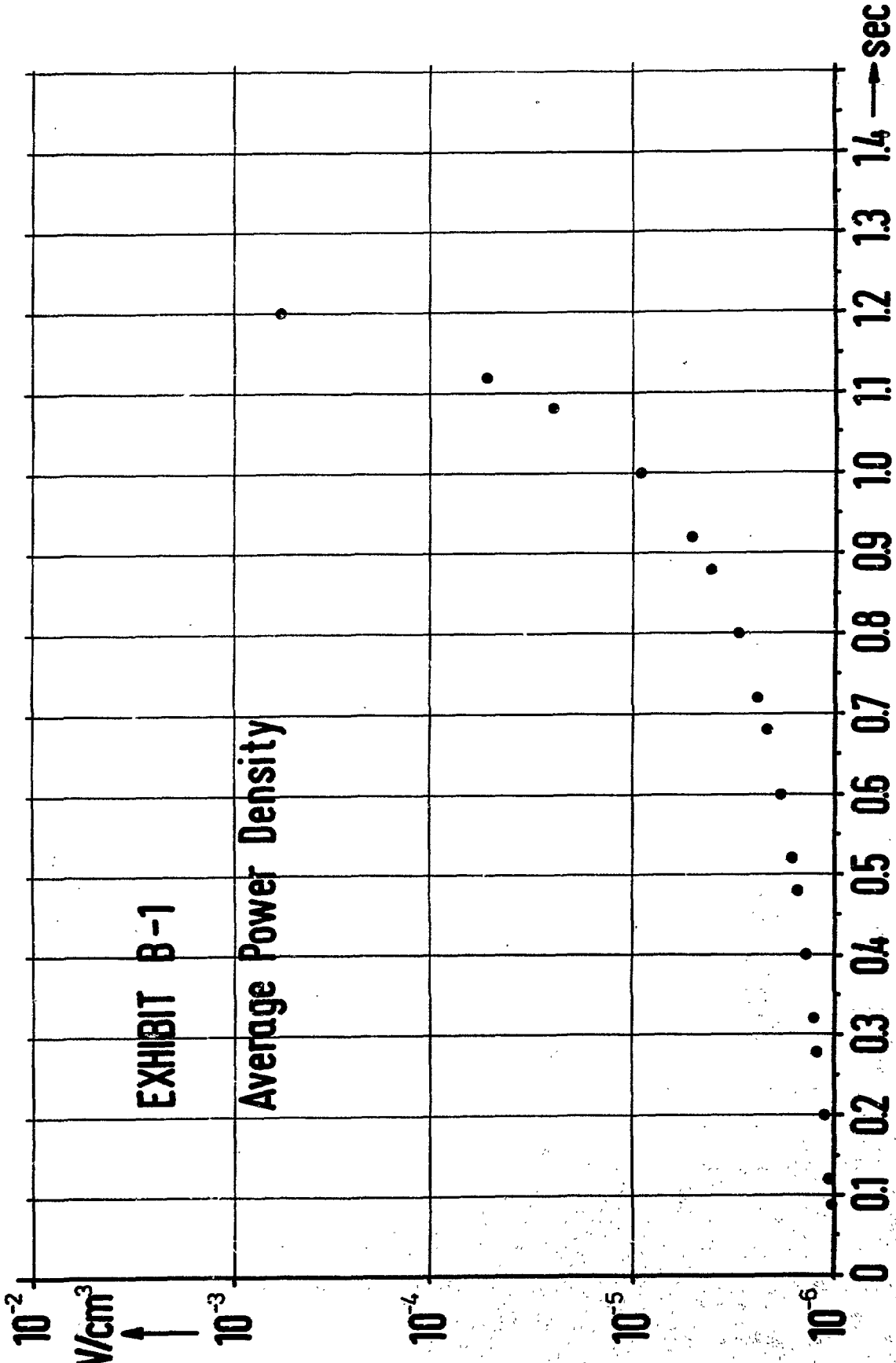


EXHIBIT B-1
Average Power Density
W/cm³
10⁻²
10⁻³
10⁻⁴
10⁻⁵
10⁻⁶
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
1.3
1.4
sec

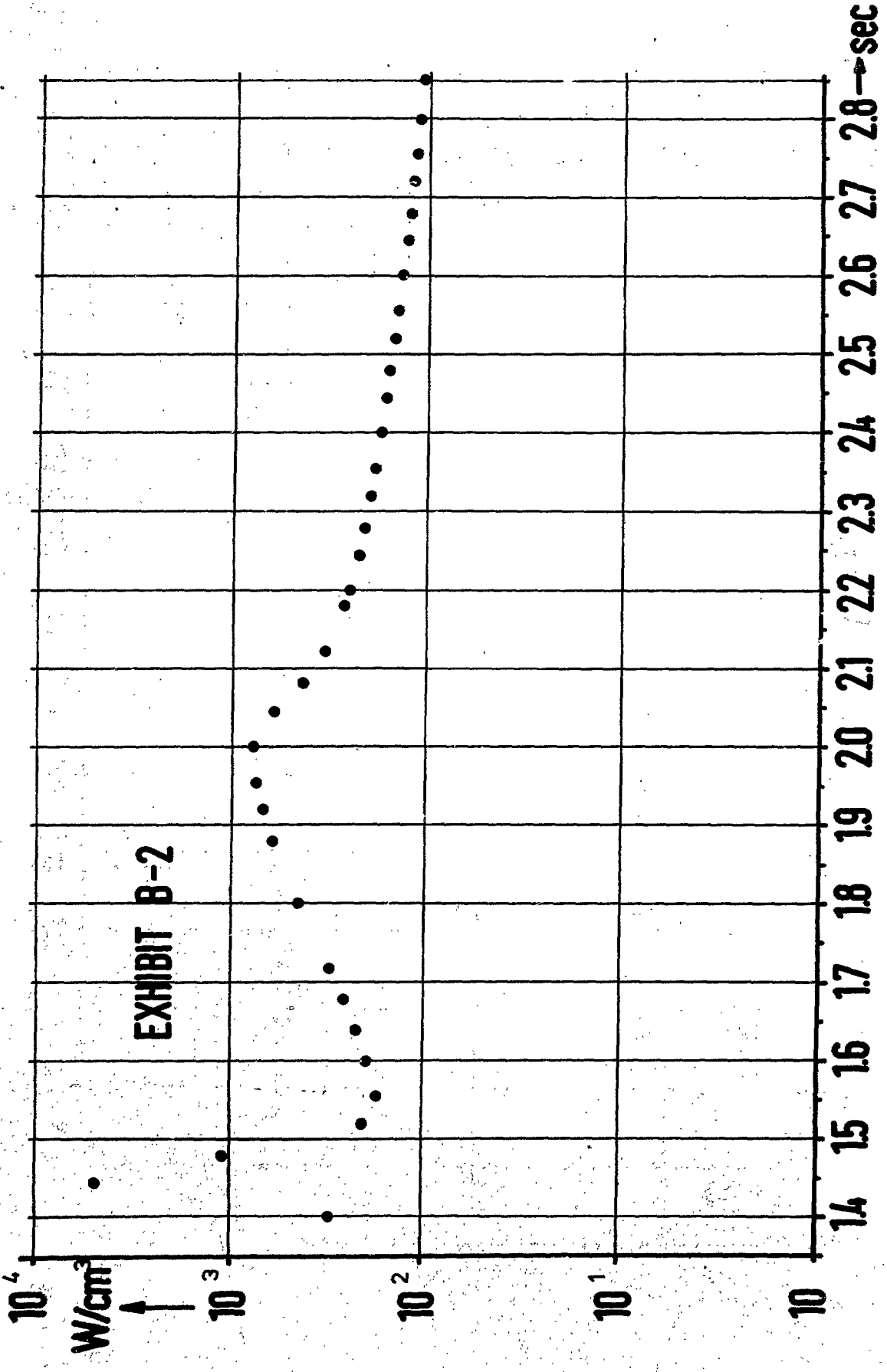


EXHIBIT B-2
W/cm³
10⁴
10³
10²
10¹
10
1.4
1.5
1.6
1.7
1.8
1.9
2.0
2.1
2.2
2.3
2.4
2.5
2.6
2.7
2.8 → sec

EXHIBIT C-1 t = 0.4 sec

AVERAGE SUBASSEMBLY POWER (ABOVE) AND AVERAGE FUEL TEMPERATURE (BELOW)

9	.842	.798	.777	.826	.930	.998	.883		
	300.	300.	300.	300.	300.	300.	300.		
8	1.358	1.188	1.111	1.194	1.439	1.744	1.733	1.461	
	300.	300.	300.	300.	300.	300.	300.	300.	
7	1.529	1.062	.916	1.003	1.357	2.154	2.349	1.881	1.010
	300.	300.	300.	300.	300.	300.	300.	300.	300.
6	1.276	.869	.744	.830	1.171	1.948	2.232	1.945	1.153
	300.	300.	300.	300.	300.	300.	300.	300.	300.
5	.724	.623	.587	.664	.874	1.192	1.420	1.558	1.023
	300.	300.	300.	300.	300.	300.	300.	300.	300.
4	.471	.455	.465	.535	.673	.853	1.048	1.265	.882
	300.	300.	300.	300.	300.	300.	300.	300.	300.
3	.379	.376	.398	.470	.599	.767	.953	1.163	.816
	300.	300.	300.	300.	300.	300.	300.	300.	300.
2	.401	.368	.378	.462	.638	.896	1.100	1.235	.831
	300.	300.	300.	300.	300.	300.	300.	300.	300.
1	.560	.402	.382	.480	.743	1.316	1.581	1.407	.874
	300.	300.	300.	300.	300.	300.	300.	300.	300.
	1	2	3	4	5	6	7	8	9

EXHIBIT C-2 t = 0.8 sec

AVERAGE SUBASSEMBLY POWER (ABOVE) AND AVERAGE FUEL TEMPERATURE (BELOW)

9	.734 300.	.708 300.	.715 300.	.796 300.	.938 300.	1.043 300.	.952 300.		
8	1.182 300.	1.053 300.	1.023 300.	1.157 300.	1.461 300.	1.841 300.	1.900 300.	1.673 300.	
7	1.328 300.	.939 300.	.844 300.	.976 300.	1.390 300.	2.294 300.	2.613 300.	2.260 300.	1.264 300.
6	1.107 300.	.768 300.	.686 300.	.809 300.	1.201 300.	2.075 300.	2.482 300.	2.326 300.	1.424 300.
5	.629 300.	.551 300.	.539 300.	.642 300.	.885 300.	1.251 300.	1.541 300.	1.736 300.	1.163 300.
4	.408 300.	.401 300.	.424 300.	.508 300.	.662 300.	.864 300.	1.084 300.	1.327 300.	.932 300.
3	.326 300.	.329 300.	.358 300.	.435 300.	.588 300.	.741 300.	.933 300.	1.148 300.	.810 300.
2	.342 300.	.318 300.	.335 300.	.419 300.	.588 300.	.888 300.	1.030 300.	1.164 300.	.787 300.
1	.475 300.	.345 300.	.386 300.	.430 300.	.675 300.	1.203 300.	1.452 300.	1.299 300.	.809 300.
	1	2	3	4	5	6	7	8	9

EXHIBIT C-3 t = 1.2 sec

AVERAGE SUBASSEMBLY POWER (ABOVE) AND AVERAGE FUEL TEMPERATURE (BELOW)

9	.596 300.	.593 300.	.634 300.	.755 300.	.941 300.	1.094 300.	1.035 300.		
8	.958 300.	.880 300.	.908 300.	1.102 300.	1.480 300.	1.954 300.	2.109 300.	1.946 300.	
7	1.073 300.	.782 300.	.751 300.	.938 300.	1.424 300.	2.461 300.	2.948 300.	2.771 300.	1.617 300.
6	.894 300.	.639 300.	.611 300.	.779 300.	1.233 300.	2.229 300.	2.801 300.	2.841 300.	1.798 300.
5	.509 300.	.459 300.	.479 300.	.612 300.	.895 300.	1.323 300.	1.696 300.	1.978 300.	1.348 300.
4	.330 300.	.334 300.	.372 300.	.473 300.	.647 300.	.875 300.	1.130 300.	1.406 300.	.996 300.
3	.261 300.	.270 300.	.307 300.	.391 300.	.523 300.	.705 300.	.904 300.	1.126 300.	.798 300.
2	.270 300.	.256 300.	.281 300.	.364 300.	.523 300.	.749 300.	.937 300.	1.070 300.	.727 300.
1	.370 300.	.275 300.	.277 300.	.367 300.	.587 300.	1.054 300.	1.281 300.	1.155 300.	.723 300.
	1	2	3	4	5	6	7	8	9

EXHIBIT C-4 t = 1.4 sec

AVERAGE SUBASSEMBLY POWER (ABOVE) AND AVERAGE FUEL TEMPERATURE (BELOW)

9	.539 302.	.543 302.	.596 302.	.731 303.	.934 304.	1.106 305.	1.064 304.		
8	.865 304.	.806 303.	.856 304.	1.071 305.	1.475 306.	1.988 308.	2.191 309.	2.069 309.	
7	.968 304.	.716 303.	.709 303.	.915 304.	1.428 306.	2.517 311.	3.091 313.	3.029 313.	1.803 308.
6	.807 303.	.586 302.	.578 302.	.762 303.	1.238 305.	2.283 310.	2.940 312.	3.103 313.	1.996 308.
5	.461 302.	.422 302.	.453 302.	.597 302.	.895 304.	1.349 306.	1.763 307.	2.091 309.	1.438 306.
4	.299 301.	.307 301.	.350 301.	.457 302.	.638 303.	.877 304.	1.147 305.	1.438 306.	1.023 304.
3	.236 301.	.247 301.	.286 301.	.371 302.	.509 302.	.687 303.	.889 304.	1.111 305.	[illegible]0 [illegible]8.
2	.242 301.	.232 301.	.259 301.	.341 301.	.493 302.	.710 303.	.893 303.	1.023 304.	.697 303.
1	.329 301.	.247 301.	.254 301.	.341 301.	.548 302.	.985 304.	1.201 305.	1.086 305.	.682 303.
	1	2	3	4	5	6	7	8	9

EXHIBIT C-5 t = 2.0 sec

AVERAGE SUBASSEMBLY POWER (ABOVE) AND AVERAGE FUEL TEMPERATURE (BELOW)

9	.461	.471	.529	.667	.877	1.074	1.080		
	595.	596.	622.	692.	800.	895.	880.		
8	.737	.696	.757	.975	1.386	1.942	2.266	2.309	
	772.	738.	761.	.872	1087.	1368.	1497.	1464.	
7	.825	.618	.628	.836	1.352	2.487	3.272	3.640	2.328
	829.	689.	682.	788.	1062.	1655.	2001.	2048.	1373.
6	.692	.508	.514	.701	1.180	2.269	3.125	3.722	2.537
	742.	619.	611.	708.	962.	1532.	1921.	2089.	1480.
5	.399	.370	.407	.552	.852	1.331	1.830	2.296	1.641
	553.	531.	546.	621.	780.	1028.	1266.	1470.	1118
4	.264	.273	.318	.422	.602	.849	1.143	1.475	1.073
	466.	469.	492.	548.	645.	775.	925.	1092.	869.
3	.212	.223	.261	.341	.472	.645	.846	1.076	.776
	433.	438.	458.	503.	577.	673.	783.	908.	735.
2	.220	.211	.236	.310	.447	.645	.814	.943	.651
	438.	431.	444.	488.	569.	687.	785.	858.	682.
1	.303	.226	.231	.307	.491	.881	1.074	.977	.619
	490.	441.	442.	488.	600.	836.	954.	892.	673.
	1	2	3	4	5	6	7	8	9

EXHIBIT C-6 t = 3.0 sec

AVERAGE SUBASSEMBLY POWER (ABOVE) AND AVERAGE FUEL TEMPERATURE (BELOW)

9	.502	.503	.553	.677	.871	1.053	1.050		
	714.	717.	756.	858.	1016.	1157.	1142.		
8	.802	.746	.789	.987	1.371	1.894	2.192	2.225	
	963.	916.	952.	1115.	1427.	1841.	2046.	2022.	
7	.900	.664	.654	.844	1.332	2.419	3.157	3.497	2.236
	1043.	848.	840.	996.	1393.	2260.	2794.	2927.	1935.
6	.756	.547	.537	.708	1.163	2.208	3.018	3.579	2.439
	922.	750.	741.	881.	1251.	2084.	2678.	2989.	2093.
5	.437	.400	.427	.561	.848	1.303	1.776	2.222	1.589
	657.	626.	649.	758.	990.	1353.	1710.	2027.	1516.
4	.291	.297	.337	.435	.607	.844	1.127	1.450	1.055
	535.	540.	573.	654.	794.	983.	1205.	1452.	1131.
3	.237	.245	.280	.358	.487	.656	.855	1.083	.781
	486.	496.	525.	590.	696.	8 4.	993.	1174.	927.
2	.250	.236	.257	.331	.471	.672	.843	.973	.670
	496.	487.	505.	567.	683.	849.	990.	1095.	845.
1	.346	.255	.254	.331	.521	.929	1.128	1.021	.646
	570.	501.	502.	567.	725.	1062.	1227.	1139.	829.
	1	2	3	4	5	6	7	8	9

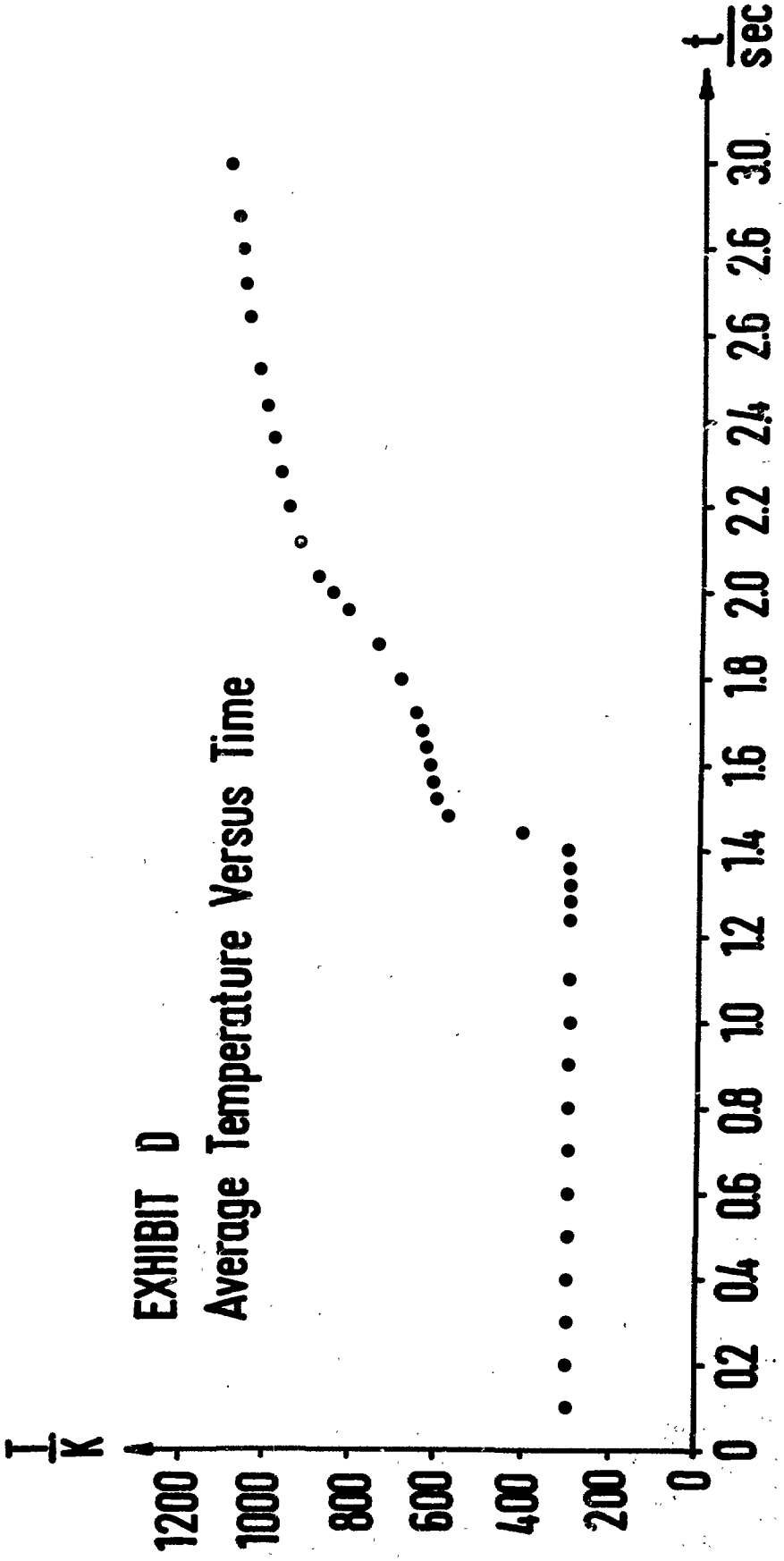


EXHIBIT D
Average Temperature Versus Time
T/K
1200
1000
800
600
400
200
0
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.6
2.6
3.0
t/sec

BENCHMARK SOURCE SITUATION

Identification: 15

Date Submitted: July 1976 By: M. V. Gregory (SRL)

Date Adopted: June 1977 By: H. L. Dodds, Jr. (U. of Tenn.)
R. R. Lee (CE)

Descriptive Title

Neutronic Depletion Benchmark Problems

Suggested Function

Test solutions of the neutronic depletion equations.

Configuration

An infinite homogeneous medium with the isotopic concentrations given below. At time zero, the neutron flux becomes nonzero.

Details

Isotope	Concentration, atom/(barn-cm)
^{235}U	0.74003E-4*
^{238}U	0.69360E-2
All others	0

* E-X = 10^{-X}

BENCHMARK PROBLEM

Identification: 15-A1 Source Situation ID.15

Date Submitted: July 1976 By: M. V. Gregory (SRL)

Date Accepted: June 1977 By: H. L. Dodds, Jr. (U. of Tenn.)
R. R. Lee (CE)

Descriptive Title

Two-Group Constant Parameter Point Depletion Problem

Reduction from Source Situation

1. Solution of isotopic depletion equations at a point with constant flux and cross sections.

$$\frac{d}{dt}\underline{N}(t) = \underline{\underline{A}}\,\underline{N}(t)$$

where

$\underline{N}$ = vector of isotopic concentrations

$\underline{\underline{A}}$ = net production matrix coupling the isotopes

The general ij^{th} entry in $\underline{\underline{A}}$ (i.e., the production rate of isotope i from isotope j) is

$$A_{ij} = Y_{ij}\sum_g \sigma^g_{fj}\phi^g + \lambda_{ij} + \sum_g \sigma^g_{c_{ij}}\phi^g$$

where

g = energy group index

Y_{ij} = fission yield of isotope i from the fissioning of isotope j (Y_{ii} is defined as -1.0)

σ^g_{fj} = microscopic fission cross section of isotope j in group g

ϕ^g = flux in group g

λ_{ij} = decay constant for production of isotope i from the decay of isotope j (λ_{ii} is the negative of the decay constant)

$\sigma^g_{c_{ij}}$ = microscopic capture cross section in group g for isotope j that produces i ($\sigma^g_{c_{ii}}$ is the negative of the capture cross section)

2. Constant two-group flux:

   Group 1 = 6.1374E+14 n/(cm^2-sec)

   Group 2 = 2.5078E+14 n/(cm^2-sec)

3. Fission product yields are defined in Table B.1.

4. Decay constants are defined in Table B.2.

5. Microscopic cross sections are defined in Table B.3.

6. Depletion chains are defined in Figure B.1 where the dashed line processes (α-, β^+-decay) are excluded, resulting in a triangular matrix for $\underline{\underline{A}}$.

Expected Primary Results

1. Variation of isotopic concentrations with time; 50-day concentrations.

2. Calculational statistics.

Solutions Available

1. Fourth-order Runge-Kutta integration of depletion equations, various time-step sizes: 15-A1-1

2. Analytical and finite-difference solutions for various time-step sizes: 15-A1-2, 15-A1-3

TABLE B.1. Fission Product Yield, %

Fission Product	Fissioning Isotope			
	^{235}U	^{238}U	^{239}Pu	^{241}Pu
^{135}I	6.17	5.78	6.93	6.26
^{135}Xe	0.24	0.22	0.27	0.24
^{149}Pm	1.13	2.10	1.30	1.20
^{147}Nd	2.36	2.80	2.05	2.20
Long-Lived Fission Products	90.10	89.10	89.45	90.10

TABLE B.2. Decay Constants

Isotope	Emitted Particle	Decay Constant, sec^{-1}
^{135}I	β^-	2.874E-5*
^{135}Xe	β^-	2.093E-5
^{147}Nd	β^-	7.228E-7
^{147}Pm	β^-	8.289E-9
^{148}Pm	β^-	1.488E-6
^{148m}Pm	β^-	1.976E-7
^{149}Pm	β^-	3.626E-6
^{237}U	β^-	1.190E-6
^{239}U	β^-	4.915E-4
^{238}Np	β^-	3.820E-6
^{239}Np	β^-	3.410E-6
^{240}Np	β^-	1.583E-3
^{241}Pu	β^-	1.680E-9
^{243}Pu	β^-	3.886E-5
^{242}Am	β^-	9.930E-6
^{244}Am	β^-	4.440E-4

* $E\text{-}X = 10^{-X}$

TABLE B.3. Microscopic Cross Sections, barns*

Isotope	σ_{c_1}	σ_{c_2}	σ_{f1}	σ_{f2}	$\sigma^m_{(n,\gamma)_1}$	$\sigma^m_{(n,\gamma)_2}$
^{234}U	33.575	26.368	0.42744	0	0	0
^{235}U	5.9872	26.420	12.370	148.18	0	0
^{236}U	16.859	1.4399	0.16664	0	0	0
^{237}U	16.991	132.12	0.17139	0.55512	0	0
^{238}U	0.53258	0.73141	0.081338	0	0	0
^{239}U	0.40015	6.1613	0.27283	4.2009	0	0
^{237}Np	24.072	71.864	0.41867	0.0094250	0	0
^{238}Np	5.2648	55.512	47.412	555.12	0	0
^{239}Np	26.341	16.654	0	0	0	0
^{240}Np	0	0	0	0	0	0
^{238}Pu	7.3125	119.91	1.587	3.5496	0	0
^{239}Pu	9.8658	196.77	14.40	348.89	0	0
^{240}Pu	366.09	96.479	0.54033	0.016744	0	0
^{241}Pu	8.0305	152.24	29.986	352.73	0	0
^{242}Pu	51.820	5.1903	0.43460	0	0	0
^{243}Pu	11.030	21.649	28.382	49.960	0	0
^{241}Am	50.633	392.68	1.1130	2.3817	6.7486	39.543
^{242}Am	2.3381	0	31.137	693.90	0	0
^{242m}Am	20.016	444.09	108.79	1776.4	0	0
^{243}Am	91.056	24.080	0.30784	0	0	0
^{244}Am	0	0	26.192	403.29	0	0
^{242}Cm	3.1202	1.7185	0	0.83267	0	0
^{243}Cm	9.9059	69.389	92.299	194.29	0	0
^{244}Cm	32.129	3.6915	1.5663	0.33307	0	0
^{245}Cm	4.8993	82.972	37.165	537.15	0	0
^{135}I	0	0	0	0	0	0
^{135}Xe	243.47	1064780.0	0	0	0	0
^{147}Nd	0	0	0	0	0	0
^{147}Pm	248.78	65.814	0	0	117.44	31.087
^{148}Pm	3368.4	420.09	0	0	0	0
^{148m}Pm	2921.0	7561.6	0	0	0	0
^{149}Pm	0	0	0	0	0	0
^{149}Sm	105.85	23387.4	0	0	0	0
Fission Products	10.376	19.429	0	0	0	0

*

σ_{c_1} = capture in Group 1 [all captures except fission and (n,2n); includes (n,γ) to excited state, if any].

σ_{c_2} = capture in Group 2.

σ_{f_1} = fission in Group 1.

σ_{f_2} = fission in Group 2.

$\sigma^m_{(n,\gamma)_1}$ = (n,γ) to first excited state, Group 1.

$\sigma^m_{(n,\gamma)_2}$ = (n,γ) to first excited state, Group 2.

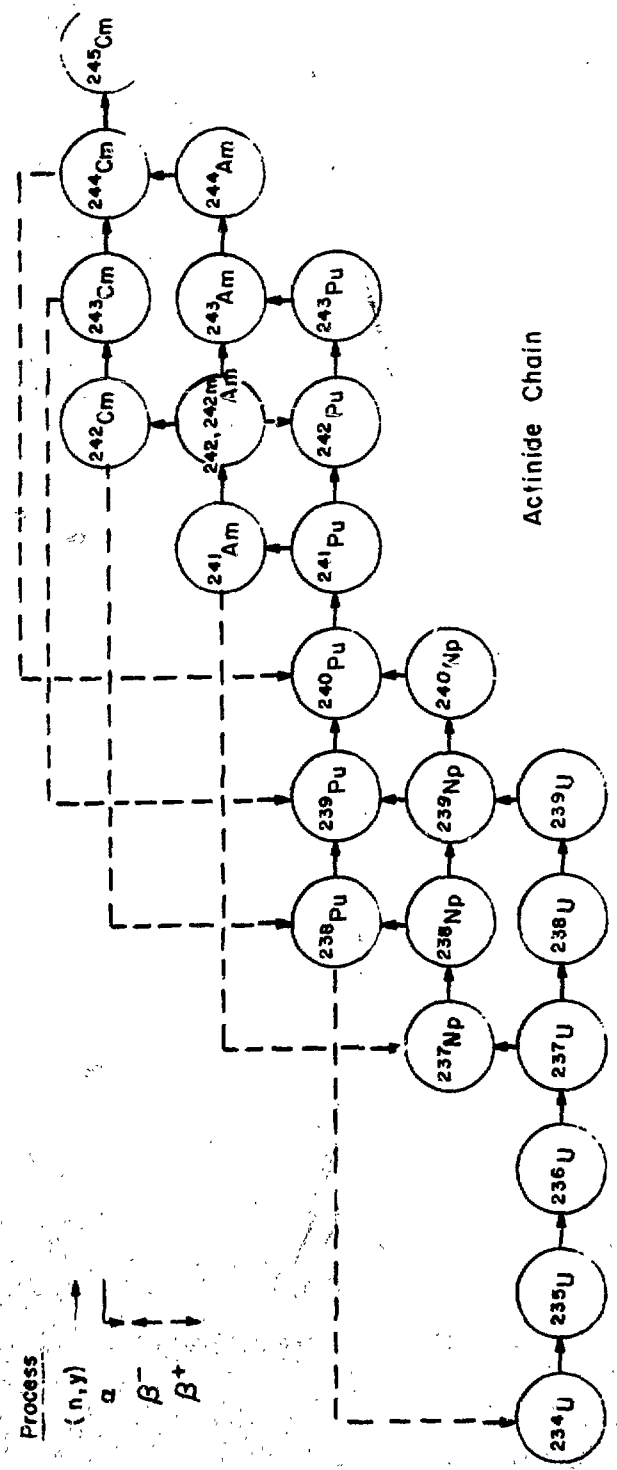


FIGURE B.1 Depletion Chains

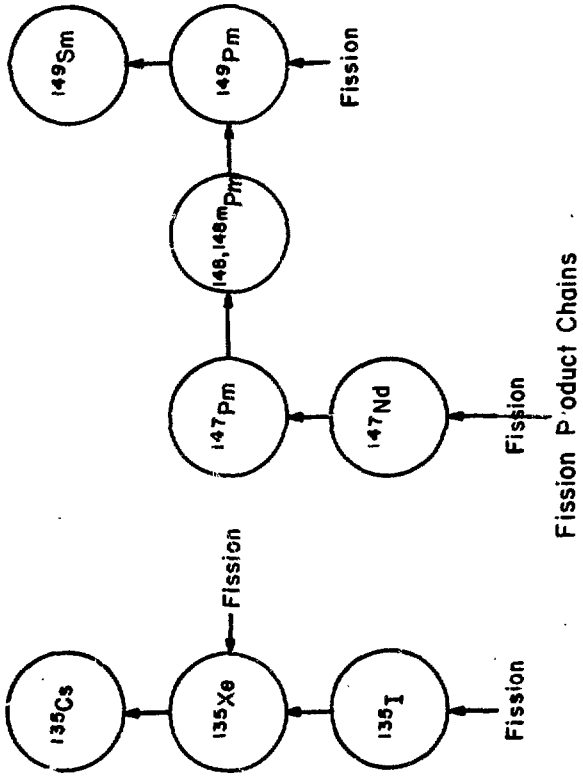


FIGURE B.1 Depletion Chains (Continued)

BENCHMARK PROBLEM SOLUTION

Identification: 15-A1-1 Benchmark Problem ID.15-A1
Date Submitted: July 1976 By: M. V. Gregory (SRL)
Date Accepted: June 1977 By: H. L. Dodds, Jr. (U. of Tenn.)
R. R. Lee (CE)

Descriptive Title

Two-Group Constant Parameter Point Depletion Problem

Technique Used

1. Fourth-order Runge-Kutta-Gill numerical integration technique (Reference 1).

2. Time-step selection may be automatic or user defined. Automatic time-step selection is defined by

$$\Delta t = 0.13/\left|\left(\sum_i A_{ij}\right)_{max}\right|$$

where the denominator is the maximum absolute columnar sum in the $\underline{A}$ matrix. Some isotopes have very large time constants (e.g., decay very rapidly) and are excluded from the time-step determination and defined in equilibrium:

$$N_i(t + \Delta t) = \left(\sum_{j \neq i} A_{ij}N_j/A_{ii}N_i\right)_t \cdot N_i(t)$$

The criterion is that for $\left|\left(\sum_i A_{ij}\right)_{max}\right| > 1.0E\text{-}5$, the isotope j is defined to be in equilibrium. Solutions will be presented both with and without the use of defined equilibrium.

Computer

IBM 360/195

Program

BURGR

References

1. *The JOSHUA System, Volume 10.1 Generalized Reactor Analysis Subsystem: Physics.* (draft) DPSTM-500 (1975).

2. M. M. Anderson et al., "Three-Dimensional Coupled Neutronics and Engineering Calculation of Savannah River Reactors," CONF-750413, Vol. II., p. VI-123.

Primary Results

Isotopic concentrations at 50 days are summarized in Table C.1 for a range of time-step sizes. The "Δt = 1 min" and "Δt = 10 min" results make no assumptions about equilibrium. The "Δt = 1 hr" solution uses the standard equilibrium condition. The "$\Delta t \sim 6.09$ hr" solution uses automatic time-step selection and the standard equilibrium condition to set Δt to 21923 seconds.

Computational statistics are summarized at the end of the table.

TABLE C.1. SRL Solutions to Constant-Parameter Problem, atoms/(barn-cm) at 50 days

Isotope	Δt Integration Time Step		
	1 min, 10 min[a]	1 hour[b]	~6.09 hours[c]
^{235}U	0.583393E-4	0.583393E-4	0.583391E-4
^{236}U	0.286054E-5	0.286054E-5	0.286059E-5
^{237}U	0.206091E-7	0.206091E-7	0.206095E-7
^{238}U	0.691915E-2	0.691915E-2	0.691915E-2
^{239}U	0.718357E-8	0.718356E-8	0.718356E-8
^{237}Np	0.450818E-7	0.450818E-7	0.450837E-7
^{238}Np	0.324870E-9	0.324870E-9	0.324885E-9
^{239}Np	0.102943E-5	0.102943E-5	0.102943E-5
^{240}Np	0.132291E-10	0.132291E-10	0.132291E-10
^{238}Pu	0.147272E-8	0.147272E-8	0.147282E-8
^{239}Pu	0.105746E-4	0.105774E-4	0.105717E-4
^{240}Pu	0.995886E-6	0.996402E-6	0.995317E-6
^{241}Pu	0.334194E-6	0.334479E-6	0.333869E-6
^{242}Pu	0.163642E-7	0.163842E-7	0.163404E-7
^{243}Pu	0.136270E-10	0.139428E-10	0.139055E-10
^{241}Am	0.586414E-9	0.587114E-9	0.585583E-9
^{242}Am	0.617228E-11	0.669732E-11	0.667986E-11
^{242m}Am	0.504837E-11	0.505566E-11	0.503955E-11
^{243}Am	0.456826E-9	0.470206E-9	0.467301E-9
^{244}Am	0.637702E-13	0.658008E-13	0.653939E-13
^{242}Cm	0.549962E-10	0.610962E-10	0.607208E-10
^{243}Cm	0.115382E-12	0.130911E-12	0.129927E-12
^{244}Cm	0.206820E-10	0.214767E-10	0.212434E-10
^{245}Cm	0.243404E-12	0.254329E-12	0.251092E-12
^{135}I	0.882735E-8	0.883435E-8	0.883286E-8
^{135}Xe	0.914750E-9	0.915483E-9	0.915350E-9
^{147}Nd	0.121154E-6	0.121163E-6	0.121144E-6
^{147}Pm	0.201810E-6	0.201826E-6	0.201795E-6
^{148}Pm	0.457029E-8	0.457067E-8	0.456997E-8
^{148m}Pm	0.386726E-8	0.386758E-8	0.386699E-8
^{149}Pm	0.199678E-7	0.199694E-7	0.199662E-7
^{149}Sm	0.119776E-7	0.119786E-7	0.119766E-7
Fission Products	0.145224E-4	0.145238E-4	0.145212E-4
CPU time, sec IBM 360/195	429.8 (Δt = 1 min) 43.2 (Δt = 10 min)	7.0	1.2

a. No equilibrium assumption.

b. Equilibrium assumed.

c. Equilibrium assumed and time step automatically selected.

BENCHMARK PROBLEM SOLUTION

Identification: 15-A1-2 Benchmark Problem ID.15-A1

Date Submitted: July 1976 By: B. A. Weate (GA)

Date Accepted: June 1977 By: H. L. Dodds, Jr. (U. of Tenn.)
R. R. Lee (CE)

Descriptive Title

Two-Group Constant Parameter Point Depletion Problem

Technique Used

1. In solving the nuclide depletion equation over a time-step, the flux and reaction rate cross sections are assumed constant.

2. Both analytic and difference solutions are defined. The difference solution is used when the nuclide and all chain nuclides above or below it have a removal rate $[(\lambda + \sigma\phi)\Delta t]$ less than a (where $e^{-a} - \frac{2-a}{2+a} = \varepsilon$ {error criterion}). Otherwise, the analytic solution is used. For the present solution, $a = 0.05$ and $\varepsilon = 10^{-5}$.

Computer

Univac 1110

Program

BURNUP

Reference

1. M. R. Wagner, *GAUGE, A Two-Dimensional Few Group Neutron Diffusion-Depletion Program for a Uniform Triangular Mesh.* GA-8307, "Chapter 4 - Nuclear Depletion Calculation" (1968).

Primary Results

Fifty-day isotopic concentrations are described in Table C.5 for time-step sizes ranging from 2 days to 10 minutes.

Computational statistics are defined in the table by SUP time, which is a combination of CPU time and I/Ø time.

TABLE C.5. GA Solutions to Constant Parameter Problem. atoms/(barn-cm) at 50 days

Isotope	GA Small Time Step 10 min	1 hr	2 days
^{235}U	5.83386-5	5.83387-5	5.83393-5
^{236}U	2.86058-6	2.86058-6	2.86060-6
^{237}U	2.06103-8	2.06103-8	2.05937-8
^{238}U	6.91924-3	6.91938-3	6.91923-3
^{239}U	7.18270-9	7.18385-9	7.18404-9
^{237}Np	4.50845-8	4.50846-8	4.50933-8
^{238}Np	3.24895-10	3.24895-10	3.25098-10
^{239}Np	1.02945-6	1.02947-6	1.02946-6
^{240}Np	1.32294-11	1.32297-11	1.32295-11
^{238}Pu	1.47281-9	1.47284-9	1.47573-9
^{239}Pu	1.05749-5	1.05747-5	1.05744-5
^{240}Pu	9.95921-7	9.95925-7	9.95900-7
^{241}Pu	3.34194-7	3.34204-7	3.34495-7
^{242}Pu	1.63649-8	1.63651-8	1.64266-8
^{243}Pu	1.36278-11	1.36274-11	1.30074-11
^{241}Am	5.86427-10	5.86434-10	5.88396-10
^{242}Am	6.17245-12	6.17252-12	6.07897-12
^{242m}Am	5.04845-12	5.04856-12	5.07729-12
^{243}Am	4.56845-10	4.56857-10	4.61643-10
^{244}Am	6.37716-14	6.37420-14	5.89385-14
^{242}Cm	5.49980-11	5.49992-11	5.56397-11
^{243}Cm	1.15385-13	1.15390-13	1.17834-13
^{244}Cm	2.06829-11	2.06835-11	2.11112-11
^{245}Cm	2.43419-13	2.43427-13	2.51613-13
^{135}I	8.82753-9	8.82752-9	8.81797-9
^{135}Xe	9.14759-10	9.14758-10	9.13807-10
^{147}Nd	1.21159-7	1.21157-7	1.21155-7
^{147}Pm	2.01810-7	2.01815-7	2.01813-7
^{148}Pm	4.57034-9	4.57045-9	4.55895-9
^{148m}Pm	3.86715-9	3.86724-9	3.85696-9
^{149}Pm	1.99681-8	1.99682-8	1.99655-8
^{149}Sm	1.19776-8	1.19777-8	1.19778-8
Fission Products	1.45224-5	1.45228-5	1.45235-5
SUP	45.16	9.41	2.14 (seconds)

BENCHMARK PROBLEM SOLUTION

Identification:	15-A1-3	Benchmark Problem ID.15-A1	
Date Submitted:	June 1976	By:	M. R. Wagner (KWU)
Date Accepted:	June 1977	By:	H. L. Dodds, Jr. (U. of Tenn.) R. R. Lee (CE)

Descriptive Title: Two-group Constant Parameter Point Depletion Problem

Mathematical Model

For each time-step the reaction rates, which are the entries of the nuclide depletion matrix $\underline{\underline{A}}$ are assumed constant. Furthermore, the matrix $\underline{\underline{A}}$ is assumed to be a lower triangular matrix which can be decomposed into

1. a number of lower triangular submatrices corresponding to independent heavy nuclide and fission product chains,

2. a rectangular matrix which provides the coupling of the fission product chains to the heavy nuclide chains.

Both analytic and third-order difference solutions are defined.

Pertinent Features of Solution Method

The code automatically investigates the structure of the depletion matrix and separates the independent fuel and fission product chains. The depletion equations for the fuel chains are solved first. A constant fission product source vector $\underline{S}$ is then computed

$$S_i = \sum_{j=1}^{N_{fuel}} Y_{ij} \; \bar{N}_j^{\Delta t} \sum_g \sigma_{fj}^g \; \phi^g$$

where S_i is the component for fission product i, to replace the actual time-dependent rates $S_i(t)$ of fission product formation. Finally the decoupled fission product depletion chains are solved for that source.

In solving the depletion chains the code decides internally for every time-step and each nuclide whether the analytic solution or difference approximation will be applied. An input error criterion ε is used and by solving the equation

$$e^{-\alpha} - \frac{2 - \alpha}{2 + \alpha} = \varepsilon$$

a critical value α for the magnitude of the removal term $|A_{ii}| \; \Delta t$ is determined. If

$$|A_{ii}| \; \Delta t > \varepsilon$$

an analytic solution is requested for nuclide i.

Table 1 shows that the analytic solution ($\varepsilon \rightarrow 0$) deteriorates with reduced time-step lengths due to buildup of round-off errors for very long depletion chains.

Table 2 illustrates that the error buildup is reduced when using a combination of analytic and difference solutions.

Table 3 shows the dependence of the solution on the parameter ε for a time step length of $\Delta t = 2$ days

Column 1 of Table 2 is considered the best solution of this series.

Computer: CYBER 175 Date Solved: May 1976

at: KWU

Program: MEDIUM-2

Type of Program: Multidimensional LWR depletion code

References

1. M.R. Wagner, GAUGE, A Two-Dimensional Few-Group Neutron Diffusion-Depletion Program for a Uniform Triangular Mesh, GA 8307, Gulf General Atomic (1968)

2. M.R. Wagner, MEDIUM, ein mehrdimensionales Abbrandprogramm für Druckwasserreaktoren, Reaktortagung 1972 des Deutschen Atomforums/KTG, Hamburg, April 1972, Proceedings p. 161

Table 1. MEDIUM-2 Solutions to Constant-Parameter Problem
atoms/ (barn-cm) at 50 days
Analytic Solutions, $\varepsilon = 10^{-20}$

	Time Steps		
	10 min.	1 hour	2 days
U 235	.583394E-04	.583394E-04	.583394E-04
U 236	.286058E-05	.286058E-05	.286058E-05
U 237	.206103E-07	.206103E-07	.206103E-07
U 238	.691924E-02	.691924E-02	.691924E-02
U 239	.718370E-08	.718370E-08	.718370E-08
Np 237	.450845E-07	.450845E-07	.450845E-07
Np 238	.324894E-09	.324894E-09	.324894E-09
Np 239	.102945E-05	.102945E-05	.102945E-05
Np 240	.132294E-10	.132294E-10	.132294E-10
Pu 238	.147282E-08	.147283E-08	.147283E-08
Pu 239	.105747E-04	.105747E-04	.105747E-04
Pu 240	.995928E-06	.995928E-06	.995928E-06
Pu 241	.334210E-06	.334206E-06	.334205E-06
Pu 242	.163653E-07	.163651E-07	.163651E-07
Pu 243	.136281E-10	.136280E-10	.136280E-10
Am 241	.586454E-09	.586437E-09	.586433E-09
Am 242	.617274E-11	.617255E-11	.617251E-11
Am 242m	.504883E-11	.504860E-11	.504854E-11
Am 243	.456904E-09	.456855E-09	.456858E-09
Am 244	.637807E-13	.637740E-13	.637743E-13
Cm 242	.550017E-10	.549986E-10	.549984E-10
Cm 243	.113558E-12	.115114E-12	.115372E-12
Cm 244	.203962E-10	.206754E-10	.206821E-10
Cm 245	.199554E-12	.241771E-12	.243340E-12
I 135	.882757E-08	.882757E-08	.881793E-08
Xe 135	.914763E-09	.914763E-09	.913803E-09
Nd 147	.121157E-06	.121157E-06	.121154E-06
Pm 147	.201815E-06	.201815E-06	.201816E-06
Pm 148	.457044E-08	.457044E-08	.457048E-08
Pm 148m	.386724E-08	.386724E-08	.386727E-08
Pm 149	.199683E-07	.199683E-07	.199657E-07
Sm 149	.119777E-07	.119777E-07	.119776E-07
Fission Products	.145228E-04	.145228E-04	.145228E-04
CPU time, sec	88.94	15.74	0.39

CYBER 175

Table 2. MEDIUM-2 Solutions to Constant Parameter Problem
atoms/ (barn-cm) at 50 days
Combination of Analytic and Difference Solutions $\varepsilon=10^{-5}$

	Time Steps		
	10 min.	1 hour	2 days
U 235	.583394E-04	.583394E-04	.583393E-04
U 236	.286058E-05	.286058E-05	.286059E-05
U 237	.206103E-07	.206103E-07	.205936E-07
U 238	.691924E-02	.691924E-02	.691924E-02
U 239	.718370E-08	.718371E-08	.718404E-08
Np 237	.450845E-07	.450845E-07	.450929E-07
Np 238	.324894E-09	.324894E-09	.325096E-09
Np 239	.102945E-05	.102945E-05	.102946E-05
Np 240	.132294E-10	.132294E-10	.132295E-10
Pu 238	.147283E-08	.147284E-08	.147572E-08
Pu 239	.105747E-04	.105747E-04	.105744E-04
Pu 240	.995928E-06	.995929E-06	.995900E-06
Pu 241	.334205E-06	.334206E-06	.334496E-06
Pu 242	.163651E-07	.163652E-07	.164267E-07
Pu 243	.136280E-10	.136275E-10	.130075E-10
Am 241	.586433E-09	.586435E-09	.588397E-09
Am 242	.617251E-11	.617253E-11	.607898E-11
Am 242m	.504854E-11	.504857E-11	.507732E-11
Am 243	.456858E-09	.456861E-09	.461644E-09
Am 244	.637734E-13	.637426E-13	.589387E-13
Cm 242	.549983E-10	.549993E-10	.556398E-10
Cm 243	.115387E-12	.115390E-12	.117634E-12
Cm 244	.206834E-10	.206836E-10	.211114E-10
Cm 245	.243424E-12	.243428E-12	.251615E-12
I 135	.882757E-08	.882757E-08	.881797E-08
Xe 135	.914763E-09	.914763E-09	.913807E-09
Nd 147	.121157E-06	.121157E-06	.121155E-06
Pm 147	.201815E-06	.201815E-06	.201813E-06
Pm 148	.457044E-08	.457044E-08	.455895E-08
Pm 148m	.386724E-08	.386724E-08	.385697E-08
Pm 149	.199683E-07	.199683E-07	.199655E-07
Sm 149	.119777E-07	.119777E-07	.119778E-07
Fission Products	.145228E-04	.145228E-04	.145234E-04
CPU time, sec	36.40	7.26	0.23

CYBER 175

Table 3. MEDIUM-2 Solutions to Constant Parameter Problem
atoms/ (barn-cm) at 50 days
Combination of Analytic and Difference Solutions, ΔT=2 days

	$\varepsilon = 10^{-5}$ $\alpha = 0.050$	$\varepsilon = 10^{-6}$ $\alpha = 0.023$	$\varepsilon = 10^{-7}$ $\alpha = 0.0106$
U 235	.583393E-04	.583393E-04	.583393E-04
U 236	.286059E-05	.286059E-05	.286059E-05
U 237	.205936E-07	.205936E-07	.205936E-07
U 238	.691924E-02	.691924E-02	.691924E-02
U 239	.718404E-08	.718404E-08	.718404E-08
Np 237	.450929E-07	.450929E-07	.450929E-07
Np 238	.325096E-09	.325096E-09	.325096E-09
Np 239	.102946E-05	.102946E-05	.102946E-05
Np 240	.132295E-10	.132295E-10	.132295E-10
Pu 238	.147572E-08	.147582E-08	.147582E-08
Pu 239	.105744E-04	.105747E-04	.105747E-04
Pu 240	.995900E-06	.995927E-06	.995927E-06
Pu 241	.334496E-06	.334205E-06	.334205E-06
Pu 242	.164267E-07	.163640E-07	.163651E-07
Pu 243	.130075E-10	.129556E-10	.136280E-10
Am 241	.588397E-09	.586297E-09	.586432E-09
Am 242	.607898E-11	.605585E-11	.617250E-11
Am 242m	.507732E-11	.504976E-11	.504853E-11
Am 243	.461644E-09	.458475E-09	.456857E-09
Am 244	.589387E-13	.585170E-13	.637742E-13
Cm 242	.556398E-10	.552501E-10	.549979E-10
Cm 243	.117834E-12	.116581E-12	.115757E-12
Cm 244	.211114E-10	.208856E-10	.206816E-10
Cm 245	.251615E-12	.247885E-12	.244501E-12
I 135	.881797E-08	.881792E-08	.881792E-08
Xe 135	.913807E-09	.913802E-09	.913802E-09
Nd 147	.121155E-06	.121154E-06	.121154E-06
Pm 147	.201813E-06	.201816E-06	.201816E-06
Pm 148	.455895E-08	.457048E-08	.457048E-08
Pm 148m	.385697E-08	.386727E-08	.386727E-08
Pm 149	.199655E-07	.199657E-07	.199657E-07
Sm 149	.119778E-07	.119776E-07	.119776E-07
Fission Products	.145234E-04	.145228E-04	.145228E-04
CPU time, sec	0.23	0.237	0.279

CYBER 175

BENCHMARK PROBLEM SOLUTION

Identification: 15-A1-4

Benchmark Problem ID.15-A1

Date Submitted: January 1977

By: G. W. Cunningham and D. R. Vondy (ORNL)

Date Accepted: June 1977

By: H. L. Dodds, Jr. (U. of Tenn.)
R. R. Lee (CE)

Descriptive Title: Two-Group Constant Parameter Point Depletion Problem

Computer: IBM-360/91

Code: BURNER module of the system containing the VENTURE neutronics code (Report ORNL-5180)

Date Solved: Dec. 1976 at ORNL

Results: Primary results are shown in Table 1 for benchmark quality calculations applying the matrix exponential method and the difference solution using average generation rates, to the linear chain equations. Other results have been obtained, as to test the explicit chain solution and criteria on series termination and dependence of the results on steps taken, which could be made available. These calculations were done with minimum computer memory use; only the direct coupling terms were stored, not the matrices, a procedure of calculation which is not directed toward minimizing processor time. No assumptions about equilibrium were used in obtaining the results. Calculations were done in double-precision (IBM long word).

TABLE 1. ORNL SOLUTIONS TO CONSTANT-PARAMETER PROBLEM, ATOMS/(BARN-CM) AT 50 DAYS

NUCLIDE	MATRIX EXPONENTIAL	AVERAGE GENERATION RATE		
	(570 STEPS)	(24 STEPS)	(768 STEPS)	(1536 STEPS)
U 235	5.83394-05	5.83394-05	5.83394-05	5.83394-05
U 236	2.86058-06	2.86061-06	2.86058-06	2.86058-06
U 237	2.06102-08	2.05921-08	2.06102-08	2.06102-08
U 238	6.91923-03	6.91923-03	6.91923-03	6.91923-03
U 239	7.18369-09	7.18404-09	7.18369-09	7.18369-09
NP237	4.50843-08	4.50166-08	4.50842-08	4.50843-08
NP238	3.24893-10	3.22611-10	3.24891-10	3.24892-10
NP239	1.02945-06	1.02951-06	1.02945-06	1.02945-06
NP240	1.32294-11	1.32307-11	1.32294-11	1.32294-11
PU238	1.47282-09	1.46092-09	1.47281-09	1.47282-09
PU239	1.05747-05	1.03861-05	1.05725-05	1.05741-05
PU240	9.95924-07	9.60185-07	9.95490-07	9.95805-07
PU241	3.34204-07	3.14777-07	3.33954-07	3.34134-07
PU242	1.63650-08	1.50433-08	1.63467-08	1.63599-08
PU243	1.36279-11	1.18517-11	1.36113-11	1.36232-11
AM241	5.86430-10	5.39966-10	5.85792-10	5.86249-10
AM242	6.17244-12	5.55259-12	6.16540-12	6.17045-12
AM242M	5.04867-12	4.57492-12	5.04189-12	5.04674-12
AM243	4.56854-10	3.83676-10	4.56117-10	4.56645-10
AM244	6.37737-14	4.85960-14	6.35965-14	6.37245-14
CM242	5.49975-11	4.81328-11	5.49124-11	5.49732-11
CM243	1.15385-13	9.88914-14	1.15162-13	1.15321-13
CM244	2.06831-11	1.49807-11	2.06116-11	2.06631-11
CM245	2.43421-13	1.69228-13	2.42425-13	2.43141-13
I 135	8.82755-09	8.76837-09	8.82697-09	8.82740-09
XE135	9.14763-10	9.06947-10	9.14688-10	9.14743-10
CS135	7.71695-08	7.39781-08	7.71478-08	7.71639-08
ND147	1.21157-07	1.20533-07	1.21150-07	1.21155-07
PM147	2.01814-07	2.00596-07	2.01801-07	2.01811-07
PM148	4.57044-09	4.52948-09	4.57012-09	4.57035-09
PM148M	3.86722-09	3.83199-09	3.86695-09	3.86715-09
PM149	1.99682-08	1.98139-08	1.99669-08	1.99679-08
SM149	1.19777-08	1.18613-08	1.19769-08	1.19775-08
FPLL	1.45228-05	1.44349-05	1.45217-05	1.45225-05
IBM 360/91 CPU TIME (SEC)	14.19	4.79	9.87	14.04

BENCHMARK PROBLEM

Identification:	15-A2	Source Situation ID.15	
Date Submitted:	July 1976	By:	M. V. Gregory (SRL)
Date Accepted:	June 1977	By:	H. L. Dodds, Jr. (U. of Tenn.)
			R. R. Lee (CE)

Descriptive Title

Two-Group Constant Parameter Point Depletion Problem with Feedback

Reduction from Source Situation

1. Identical to Problem 15-A1 with the exception that α-decay and β^+-decay are NOT excluded, thus matrix $\underline{\underline{A}}$ is not simply triangular.

2. The additional data required for the problem with feedback are given in Table C.2a. Remaining data same as in Problem 15-A1.

Expected Primary Results

1. 50-day concentrations
2. Calculational statistics

Solutions Available

1. Fourth-order Runge-Kutta integration of depletion equations: 15-A2-1
2. Matrix exponential method and finite difference solution: 15-A2-2

The above two solutions are identical to four significant places with the smallest time-step.

BENCHMARK PROBLEM SOLUTION

Identification:	15-A2-1	Benchmark Problem ID 15-A2	
Date Submitted:	July 1976	By:	M. V. Gregory (SRL)
Date Accepted:	June 1977	By:	H. L. Dodds, Jr. (U. of Tenn.)
			R. R. Lee (CE)

Descriptive Title

Two-Group Constant Parameter Point Depletion Problem with Feedback

Technique Used

Identical to solution of Problem ID 15-A1 without feedback, using atypically small integration time-step of 1 minute.

Computer

IBM-360/195

Program

BURGR

References

1. *The JOSHUA System, Volume 10.1 Generalized Reactor Analysis Subsystem: Physics.* (Draft) DPSTM-500 (1975)

2. M. M. Anderson et al., "Three-Dimensional Coupled Neutronics and Engineering Calculation of Savannah River Reactors," CONF-750413, Vol. II., p. VI-123.

Primary Results

The isotopic inventory at 50 days is given in Table C.2b. A fixed time-step of 1 minute was used for the Runge-Kutta integration. The CPU time required was 430 seconds. BURGR was constrained to such a small time-step size for the specific purpose of obtaining a benchmark-quality solution, thus the long running time should not be considered typical of production runs.

TABLE C.2a. Extra Data Required for Full-Chain Problem

Decay Constants

Isotope	Emitted Particle	Constant, sec^{-1}
^{238}Pu	α	2.550E-10
^{241}Am	α	5.090E-11
^{242}Am	β^+	2.030E-6
^{242}Cm	α	4.910E-8
^{243}Cm	α	6.860E-10
^{244}Cm	α	1.250E-9

(n,2n) Microscopic Cross Sections

(Group 1 only)

Isotope	σ, barns
^{235}U	0.002603
^{238}U	0.0043972
^{237}Np	0.00020144

TABLE C.2b. SRL Solution to Full-Chain Constant Parameter Point Depletion Problem, atoms/barn-cm at 50 days, Integration Time-Step of 1 minute

Isotope	Concentration	Isotope	Concentration
^{234}U	0.428817E-9	^{241}Am	0.586390E-9
^{235}U	0.583395E-4	^{242}Am	0.520984E-11
^{236}U	0.286054E-5	^{242m}Am	0.504819E-11
^{237}U	0.356768E-7	^{243}Am	0.457037E-9
^{238}U	0.691916E-2	^{244}Am	0.637996E-13
^{239}U	0.718357E-8	^{242}Cm	0.449667E-10
^{237}Np	0.104736E-6	^{243}Cm	0.950949E-13
^{238}Np	0.780485E-9	^{244}Cm	0.206737E-10
^{239}Np	0.102944E-5	^{245}Cm	0.243318E-12
^{240}Np	0.132292E-10	^{135}I	0.882738E-8
^{238}Pu	0.441854E-8	^{135}Xe	0.914753E-9
^{239}Pu	0.105748E-4	^{147}Nd	0.121154E-6
^{240}Pu	0.995892E-6	^{147}Pm	0.201810E-6
^{241}Pu	0.334195E-6	^{148}Pm	0.457029E-8
^{242}Pu	0.163736E-7	^{148m}Pm	0.386727E-8
^{243}Pu	0.136348E-10	^{149}Pm	0.199679E-7
		^{149}Sm	0.119776E-7
		Fission Products	0.145225E-4

BENCHMARK PROBLEM SOLUTION

Identification: 15-A2-2

Benchmark Problem ID.15-A2

Date Submitted: January 1977

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Date Accepted: June 1977

By: H. L. Dodds, Jr. (U. of Tenn.)
R. R. Lee (CE)

Descriptive Title: Solutions for the Constant Parameter Depletion Problem with Feedback

Computer: IBM-360/91

Code: BURNER module of the system containing the VENTURE neutronics code (Report ORNL-5180)

Date Solved: December 1976 at ORNL

Results: Primary results are shown in Table 1 for benchmark quality calculations applying the matrix exponential method and the difference solution using average generation rates, to the linear chain equations with feedback. Other results have been obtained, as to test the explicit chain solution and criteria on series termination and dependence of the results on steps taken, which could be made available. These calculations were done with minimum computer memory use; only the direct coupling terms were stored, not the matrices, a procedure of calculation which is not directed toward minimizing processor time. Calculations were done in double-precision (IBM long word).

Table 1. Nuclide Concentrations for the Constant Parameter Point Depletion Problem with Feedback

Nuclide	Matrix Exponential (570 steps)	Average Generation Rate (24 steps)	(768 steps)	(1536 steps)
^{234}U	.428821-9	.43280-9	.42895-9	.42888-9
^{235}U	.583390-4	.58339-4	.58339-4	.58339-4
^{236}U	.286057-5	.28606-5	.28606-5	.28606-5
^{237}U	.356780-7	.35661-7	.35678-7	.35678-7
^{238}U	.691915-2	.69191-2	.69191-2	.69191-2
^{239}U	.718360-8	.71840-8	.71836-8	.71836-8
^{237}Np	.104739-6	.10462-6	.10474-6	.10474-6
^{238}Np	.780515-9	.77641-9	.78051-9	.78052-9
^{239}Np	.102944-5	.10295-5	.10294-5	.10294-5
^{240}Np	.132292-10	.13231-10	.13229-10	.13229-10
^{238}Pu	.441870-8	.43857-8	.44187-8	.44187-8
^{239}Pu	.105747-4	.10386-4	.10573-4	.10574-4
^{240}Pu	.995926-6	.96019-6	.99549-6	.99580-6
^{241}Pu	.334204-6	.31478-6	.33395-6	.33413-6
^{242}Pu	.163743-7	.15050-7	.16356-7	.16369-7
^{243}Pu	.136356-10	.11857-10	.13619-10	.13631-10
^{241}Am	.586404-9	.53994-9	.58577-9	.58622-9
^{242}Am	.520999-11	.46704-11	.52040-11	.52083-11
^{242m}Am	.504831-11	.45746-11	.50415-11	.50464-11
^{243}Am	.457064-9	.38380-9	.45632-9	.45685-9
^{244}Am	.638030-13	.48611-13	.63625-13	.63754-13
^{242}Cm	.449681-10	.39205-10	.44899-10	.44948-10
^{243}Cm	.950979-13	.81087-13	.94915-13	.95045-13
^{244}Cm	.206748-10	.14973-10	.20603-10	.20655-10
^{245}Cm	.243334-12	.16915-12	.24234-12	.24305-12
^{135}I	.882752-8	.87683-8	.88269-8	.88274-8
^{135}Xe	.914759-9	.90694-9	.91468-9	.91474-9
^{135}Cs	.771693-7	.73978-7	.77148-7	.77164-7
^{147}Nd	.121156-6	.12053-6	.12115-6	.12115-6
^{147}Pm	.201814-6	.20060-6	.20180-6	.20181-6

Table 1 (continued)

Nuclide	Matrix Exponential (570 steps)	Average Generation Rate (24 steps)	(768 steps)	(1536 steps)
^{148}Pm	.457042-8	.45295-8	.45701-8	.45703-8
^{148m}Pm	.386722-8	.38320-8	.38669-8	.38671-8
^{149}Pm	.199682-7	.19814-8	.19967-7	.19968-7
^{149}Sm	.119776-7	.11861-7	.11977-7	.11977-7
F.P.	.145227-4	.14435-4	.14522-4	.14522-4
Processor Time (min)	0.18	0.02	0.11	0.19