MASTER

MIT LMFBR BLANKET RESEARCH PROJECT

Quarterly Progress Report

July 1, 1980 - September 30, 1980

Principal Investigator

Michael J. Driscoll

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January 9, 1981

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MGW

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1. General

This quarterly progress report covers work initiated, completed or underway in the period July 1, 1980 through September 30, 1980, since the prior progress report (1).

One of the major subtasks during the past quarter has been completion of MIT's calculations on LCCEWG Benchmark No III.

A copy of our results is appended to this report.

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(1) MIT LMFBF Blanket Research Project, Quarterly Progress Report, April 1, 1980 - June 30, 1980, DOE/ET/37241-43, August 11, 1980.

2. Heterogeneous Assembly Evaluation

Preliminary results have been obtained on the neutronics of a heterogeneously-internally-moderated (HIM) LMFBR assembly.

The base case used as a reference for comparison is an unmoderated driver assembly from LCCEWG Benchmark Problem No. III (1). Twelve zirconium hydride ($\text{ZrH}_{1.6}$) pins were incorporated in the standard 271 pin assembly to form the heterogeneous assembly under study. The general concept is similar to the centrally-moderated version of the FMSR proposed by BNL (2), but instead of BeO , $\text{ZrH}_{1.6}$ is used, following upon the earlier work by Atefi at MIT (3).

We were particularly interested in the sodium void coefficient based on earlier findings at BNL of a beneficial reduction in the positive component of this important safety coefficient. Contradictory results have been obtained to date, as will be explained shortly.

Both the reference and homogeneous assemblies were modelled in two ways, which are designated "smeared" and "discrete". All cases are modelled in 2DB* using the same number of mesh Triangles

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- (1) N.C. Horning, M.B. Parker and R.P. Omberg "Proposed Third Benchmark Problem for the LCCEWG," (Second Revision) HEDL 8051932, May 1980
  - (2) A. Galperin to R.J. Cerbone and G.J. Fisher, "FMSR Log #46" April 17, 1980, and "FMSR Log #47", April 18, 1980.
  - (3) B. Atefi, M.J. Driscoll and D.D. Lanning "An Evaluation of the Breed/Burn Fast Reactor Concept" COO-2250-40, MITNE-229, Dec. 1979.

* In the radial (transverse) direction the assemblies are isolated by a zero-current boundary condition along their entire periphery.

The "smeared" model of Figure 4 is the closest smeared model to the true discrete model of Figure 2.3, but it still represents a significant departure from the lattice heterogeneity. The most completely smeared model of the moderated assembly would smear all number densities over the entire mesh network, a "truly homogeneous" model. This is the conventional way in which assemblies are represented when entire cores are modelled, usually with six mesh triangles per assembly. A comparison was made of the enrichment for the discrete, smeared, and truly homogeneous models to achieve $k = 1.00000$, for the flooded, moderated, $B^2 = 2.8 \times 10^{-4} \text{ cm}^{-2}$ case. Table 2.4 shows that the latter two models differ significantly from the discrete model and insignificantly between themselves.

The following conclusions can be drawn from Tables 2.1-2.4:

1. Discrete and smeared models calculate significantly different enrichments.
2. The smeared model results are insensitive to the degree of smearing.
3. Smeared models as commonly employed in full-core modelling consistently calculate positive sodium void worths.
4. Discrete models calculate negative void worths but these are sensitive to axial buckling.
5. When axial leakage is neglected ($B^2=0.0$), sodium void worth in all models is positive, as expected.
6. When axial leakage is neglected ($B^2=0.0$), the smeared and discrete cases require the same enrichment.
7. Higher enrichment is necessitated whenever moderation is added.
8. When axial leakage is finite ($B^2=2.8 \times 10^{-4} \text{ cm}^{-2}$) mod-

eration reduces sodium void worth (The negative components are enhanced),

9. When axial leakage is neglected ($B^2 \approx 0.0$), moderating effects on void worth are model-dependent (discrete: negative change; smeared: positive change).
10. Searching to enrichment for criticality, then voiding, is a valid method of comparing void worths between the discrete and smeared models (which require different critical enrichments).

Overall conclusions must still be very tentative. However it is clear that the purported benefits of heterogeneous assemblies are model-sensitive, and one must, therefore, be very careful when trying to evaluate potential advantages on so subtle an effect as sodium voiding.

TABLE 2.1 RESULTS, $B^2 = 2.8 \times 10^{-4}$

	NO MODERATION	MODERATED
DISCRETE	5. flooded* ϵ 9.33%	1. flooded* ϵ 9.98%
	6. voided k 0.99830	2. voided** k 0.99790
	Δk_{Na} -0.00170	Δk_{Na} -0.00210
SMEARED	7. flooded ϵ 9.07%	3. flooded ϵ 9.46%
	8. voided k 1.00158	4. voided k 1.00129
	Δk_{Na} +0.00158	Δk_{Na} +0.00129

TABLE 2.2 RESULTS, $B^2 \approx 0.0$

	NO MODERATION	MODERATED
DISCRETE	13. flooded ϵ 8.15%	9. flooded ϵ 8.51%
	14. voided k 1.00296	10. voided k 1.00260
	Δk_{Na} +0.00296	Δk_{Na} +0.00260
SMEARED	15. flooded ϵ 8.14%	11. flooded ϵ 8.51%
	16. voided k 1.00200	12. voided k 1.00242
	Δk_{Na} +0.00200	Δk_{Na} +0.00242

Note: ϵ = enrichment, k = eigenvalue

* Na in

** 10% Na voids

TABLE 2.3 RESULTS USING DISCRETE NUMBER DENSITIES IN
SMEARED MODEL

17. Flooded* k	1.01564
18. Voided** k	1.01700
Δk_{Na}	+0.00136

TABLE 2.4 COMPARISON OF ENRICHMENTS FOR VARIOUS MODELS ($k = 1.00000$).

DISCRETE	1.	flooded*	ϵ	9.98%
SMEARED	19.	flooded*	ϵ	9.45%
TRULY HOMOGENEOUS	20.	flooded*	ϵ	9.45%

$$\Delta \epsilon_{1,19} = 0.52\%$$

$$\Delta \epsilon_{1,20} = 0.53\%$$

$$\Delta \epsilon_{19,20} = 0.01\%$$

* Na - in

** 10% Na voids

3. Engineering Compatibility of Heterogeneous Assembly Designs

In parallel with the neutronics effort, which is the main focus of the subject evaluations, work is being done to insure that the configurations examined are practicable from an engineering viewpoint -- particularly with respect to thermal-hydraulic considerations.

A LCCEWG core having 271-pin hexagonal assemblies with wire wrap has been used as a base case for the thermal-hydraulic analysis using COBRA-IV-I. The problem has been modelled using 30° symmetry. COBRA-IV-I has been chosen for the thermal hydraulic analyses because it is much better suited for subsequent modifications: e.g., heterogeneity and use of BeO or ZrHn moderator inserts

A first attempt was made to analyze the 30° geometry, by lumping 28 of the interior subchannels into one large subchannel, so that the total number of subchannels equalled 24, as shown in Fig 3.1. This approach was taken simply to reduce the problem size. Lumping 28 subchannels into one subchannel requires that there should not be more than one rod within that subchannel, and this leads to the omission of certain input details involving the wire wrap (as to which gap or gaps the wire wrap around the rod in the bigger subchannel will be crossing); omission of this detail will affect the mixing in the subchannels and the results may therefore be suspect. Accordingly this approach was not adopted (although the lumping of subchannels and rods works

well in case of LWRs, where grid spacers instead of wire wrap are used).

Figure 3.2 shows the problem being analyzed now, where all the subchannels and rods in the 30° sector are being considered. The model has 30 rods (some partial), 50 subchannels, and 65 gaps. Complete input data have now been prepared for this case.

COBRA-IV-I as it existed had dimensions which were too small to handle this problem, and it had to be redimensioned and recompiled. After recompiling the entire input data are being accepted, but the program is not giving the right output so far. There could be either problems with the input data or the program itself. Since all the input data are being accepted, the problem seems to be with the program, although, nothing can be said with certainty at this stage. Debugging is complicated by the fact that no one has used the wrap model in COBRA-IIIC or COBRA-IV-I (at least at M.I.T.) D. Griggs attempted to use the wire wrap model in his Nuclear Engineering thesis for ultra-tight-pitch PWR core analysis, but did not succeed. At this point it is not clear what problems may exist in the program. On the other hand COBRA-IV-I is successfully running at BNL for the FMSR Na-cooled centrally-moderated 61-pin model using wire wrap (on a non IBM computer).

To check the input data, the COBRA-IV-I program at the Yankee Atomic Electric Co., was tried on January 5, 1981, but it was found that their COBRA dimensions were also below the current problem size, and the run could not be completed. Redimensioning

(220.5 with 30° symmetry, or 1/12 of an assembly). The "discrete" model employs number density sets based explicitly on this mesh (see Fig 2.1), while in the "smeared" model zones are homogenized by simple volume-weighting (see Fig 2.2). The 2DB representations of these two approaches are shown in Figs 2.3 and 2.4 respectively. To compute the sodium void coefficient, 10% of the sodium is removed from the assembly. (This avoids the conceptual problem of assigning diffusion coefficient values to all-sodium mesh triangles were 100% voiding employed).

Calculations were done for each combination of the following parameters: moderation / no moderation, sodium-filled ("flooded") / 10% sodium voids, discrete / smeared modelling, and fixed axial buckling / zero axial buckling. Runs are compared through the following convention: A case is selected (sodium-filled), and an enrichment search is carried out to attain criticality, $k = 1.00000$. Using this searched-to number density set, a search for k is then performed with 10% sodium voiding. The Δk between such corresponding pairs of cases is the "void worth". Results for $B^2 = 2.8 \times 10^{-4} \text{ cm}^{-2}$ (representative B^2 for an UNIMOD type FMSR assembly) and $B^2 \approx 0.0$ are summarized in Tables 2.1 and 2.2 respectively. Axial buckling is not changed between sodium-in and sodium-out cases.

An additional check has been made on this type of comparison. The number densities produced by run #1 (see table 2.1) were used in the smeared model (as illustrated in Figures 2.1 and 2.2) and k was calculated. Then k was recalculated for this case with 10% sodium voiding. Table 2.3 shows the resulting Δk_{Na} to be very close to that between runs #3 and #4.

of COBRA at Yankee is not possible, at least, at present.

As the next resort, the COBRA-IV-I program at BNL is being tried. If our input data works there, then the COBRA-IV-I version at BNL may be transferred to M.I.T., or the existing program here will be debugged accordingly.

ROD & SUBCHANNEL LAYOUT

Fig. 3.1

Initial Subchannel Layout for Base Case Analysis

ROD & SUBCHANNEL LAYOUT

Fig. 3.2

Modified Subchannel Layout for Base Case Analysis

4. Administrative Matters

The monthly financial statement for October is attached:
it also includes FY totals to date.

As of September 30, 1980 the project staff was as follows:

Staff

M.J. Driscoll, Principal Investigator

A. Holman, Senior Staff Assistant

Students

D. Lancaster, Research Assistant

S. Ahmad, SM thesis student

M. Plys, Research Assistant, SM thesis student

AS OF OCTOBER 31, 1980

MONTHLY STATEMENT

PAGE 1

SUPERVISOR M J DRISCOLL

EFFECTIVE 10-01-80

ACCOUNT 89957

NW13-200

EXPIRING 11-30-80

DEPARTMENT OF ENERGY

DEPARTMENT 068000

AUTHORIZED TOTAL

3 REFERENCE -PNDGPENDING

FAST REACTOR BLANKET INVESTIGATIONS

RESTRICTIONS	CURRENT MONTH	FISCAL YEAR TO DATE	CUMULATIVE
EXPENDITURES	OCT 1980	AS OF 10/31/80	
SALARIES AND WAGES			
FAC SAL-TEN	766.67	766.67	766.67
SECRETARIAL & CLERICAL-ON	53.22	53.22	53.22
TOTAL SUBJECT TO E. B. .00	819.89	819.89	819.89
RESEARCH ASSISTANT-ON	1,199.00	1,199.00	1,199.00
TOTAL SALARIES AND WAGES .00	2,018.89	2,018.89	2,018.89
EMPLOYEE BENEFITS ON OFF			
BILLING RATES 27.00% 30.60%	221.37	221.37	221.37
OPERATING EXPENSES			
MATERIALS & SERVICES	369.20	369.20	369.20
TEL-BASIC MONTHLY SERVICE	7.43	7.43	7.43
TEL-MESSAGE UNITS	4.12	4.12	4.12
TEL-TOLL CALLS	10.00	10.00	10.00
TOTAL OPERATING EXPENSES .00	390.75	390.75	390.75
COMPUTATION EXPENSES			
E.D.P. EXPENSE	356.70	356.70	356.70
I.P.C. CHARGES	508.85	508.85	508.85
TOTAL COMPUTATION EXPENSES .00	865.55	865.55	865.55
INDIRECT EXPENSES ON OFF			
BILLING RATES 70.50% 13.50%	1,156.74	1,156.74	1,156.74
TOTAL EXPENDITURES	4,653.30	4,653.30	4,653.30
UNEXPENDED BALANCE	4,653.30	4,653.30	4,653.30
PURCHASE ORDER COMMITMENTS			49.41
UNCOMMITTED BALANCE			4,702.71

FAST REACTOR BLANKET INVESTIGATIONS

RESTRICTIONS		CURRENT MONTH	FISCAL YEAR TO DATE	CUMULATIVE
EXPENDITURES		EXPIRED ON	9/30/80	
SALARIES AND WAGES				
FAC SAL-TEN	5,845.00		766.67	6,105.55
RESEARCH STAFF-ON			39.06	616.45
HOURLY PERSONNEL-ON				291.94
SECRETARIAL & CLERICAL-ON	1,744.00	37.25	458.25	1,913.53
EXEMPT-TECH-ON		248.63	306.01	938.62
TECHNICAL OR ADMIN SUPPORT-ON			661.68	
TOTAL SUBJECT TO E. B.	7,589.00	285.88	830.19	9,866.09
GRADUATE STUDENT STAFF-ON				
RESEARCH ASSISTANT-ON	25,296.00		5,395.50	20,668.50
UNDERGRAD SALARIES-UROP			554.65	862.16
TOTAL SALARIES AND WAGES	32,885.00	285.88	6,780.34	31,396.75
EMPLOYEE BENEFITS ON OFF				
BILLING RATES 27.00% 30.60%	1,973.00	77.19	224.16	2,573.50
TOTAL OPERATING EXPENSES	9,880.00	200.00	922.49	7,858.91
COMPUTATION EXPENSES				
E.D.P. EXPENSE			4,647.38	10,076.04
I.P.C. CHARGES	2,000.00		1,495.19	3,814.23
TOTAL COMPUTATION EXPENSES	2,000.00	.00	6,142.57	13,890.27
OTHER CHARGES				
OTHER CHARGES	14,000.00			
TOTAL INDIRECT EXPENSES	15,169.00	247.98	2,562.69	15,554.52
TOTAL EXPENDITURES	75,907.00	811.05	16,632.25	71,273.95
UNEXPENDED BALANCE				4,633.05
BILLINGS				59,907.00
RECORDED COSTS UNBILLED				11,366.95

Attachment No 1

MIT Results for LCCEWG No 3

The material which follows is the MIT transmittal of results for the Third LCCEWG Benchmark Problem.

It is reproduced as submitted. In future reports, as inter-laboratory data is compared, it should be possible to infer a number of interesting conclusions with respect to specific points of comparison.

DEPARTMENT OF NUCLEAR ENGINEERING
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

138 Albany Street

Cambridge, Massachusetts 02139

Room:

November 26, 1980

(617)253-

To: Distribution

Re: Results of the LCCEWG
Third Benchmark Problem

The results requested for the LCCEWG third benchmark problem follow in the tables appended. All cases were run, and some comparisons with preliminary data from GE and AI are tabulated. Results requested but not calculated by 2DB at MIT per se include region radial leakage, individual triangle fission rates, and several neutron balance table items. These were calculated by an utility code written for this purpose which included and modified several 2DB subroutines.

As explained in the footnotes of the Configuration I results, reaction rates are based upon a 1 cm thick slice at the core midplane with 30° symmetry (1/12 core). The results of Configuration IV are based upon buckling weighted by the search eigenvalue (percent control), not the rods-full-in-buckling; Configuration V uses the rods-full-in buckling set. Since the dummy mesh region between the core edge and the mesh boundary was modelled as identical to the structure region (Region 8), it had an albedo greater than zero, which results in a lower value calculated for radial leakage in the neutron balance tables for all cases compared to that calculated by other LCCEWG participants. This is also reflected in higher absorption by U-28, Cr, Fe, and Ni. Finally, the results do not include separate treatment of n, 2n reactions because there was no time to so modify 2DB. Hence, the balance tables and burnup calculations include whatever errors this omission causes.

All comments on these results are most welcome; my phone number is 617-253-4204.

Sincerely,

A handwritten signature in cursive script, appearing to read "Martin Plys", is written over a horizontal line.

Martin Plys

MP:cr

LCCEWG BENCHMARK 3

GENERAL COMMENTS

A. Codes Used

2DB, modified at MIT for 30⁰ symmetry and group- and zone-dependent buckling, was used for the neutronic calculations. A utility code using 2DB subroutines was written to calculate the results requested by the Benchmark not presently calculated by the MIT version of 2DB.

B. Source of Macroscopic Cross Sections

The ANISN file supplied with XL-589-0037 from GE.

C. Convergence Criteria

Eigenvalue convergence criterion	1.0 - 6
Parameter convergence criterion	1.0 - 5
Flux convergence criterion	5.0 - 3

D. Method of Burnup Calculation

2DB.

LCCEWG BENCHMARK 3
RESULTS FOR CONFIGURATION I

A. General

Keff	1.01313
Reactor	1.642
Reactor	1.107
Computer CPU	603.02 sec ^(a)
Computer I10	154. sec

B. Regional Fission Rates

<u>Region</u>	<u>Fission Source^(b) Rate (n/sec)</u>	<u>Fission Rate^(b) (fission/sec)</u>
1	6.094 + 14	2.274 + 14
2	2.137 + 16	7.379 + 15
3	1.701 + 15	6.309 + 14
4	4.428 + 16	1.529 + 16
5	3.466 + 15	1.292 + 15
6	8.384 + 16	2.893 + 16
7	2.290 + 15	8.558 + 14

(a)

This includes the burnup and keff calculation for configuration VI.

(b)

For 1 cm thick slice, 30° symmetry (1/12 core)

C. Fission Rate Traverse

<u>Triangle Number</u>	<u>Fission Rate (fiss/cm³-sec)</u>
1	1.495 + 11
2	1.829 + 11
3	2.120 + 11
4	3.128 + 11
5	4.361 + 11
6	6.785 + 11
7	1.066 + 12
8	9.006 + 12
9	1.009 + 13
10	1.085 + 13
11	1.112 + 13
12	1.099 + 13
13	1.047 + 13
14	1.348 + 12
15	1.102 + 12
16	1.188 + 12
17-19	0.
20	9.874 + 12
21	9.130 + 12
22	8.275 + 12
23	9.487 + 11
24	6.344 + 11
25	4.872 + 11

C. Fission Rate Traverse (Cont'd)

<u>Tiangle Number</u>	<u>Fission Rate (fiss/cm³-sec)</u>
26	4.740 + 11
27	5.755 + 11
28	8.460 + 11
29-31	0.
32	9.189 + 12
33	9.340 + 12
34	9.220 + 12
35	8.651 + 12
36	7.743 + 12
37	6.559 + 12
38	7.681 + 11
39	4.517 + 11
40	2.689 + 11
41	1.637 + 11
42	1.016 + 11
43	6.624 + 11
44-49	0.

D. Region Reaction Rates

<u>Region</u>	^{239}Pu (b) <u>Fission Rate</u> <u>(fiss/sec)</u>	^{238}U (b) <u>Capture Rate</u> <u>(n/sec)</u>
1	0.	2.728 + 15
2	4.988 + 15	4.947 + 15
3	0.	5.683 + 15
4	1.032 + 16	1.020 + 16
5	0.	1.459 + 16
6	1.943 + 16	1.857 + 16
7	0.	1.054 + 16

E. Region Radial Leakage

<u>Region</u>	<u>Radial Leakage (n/sec)</u>
1	-2.752 + 15
2	+5.286 + 15
3	-5.518 + 15
4	+1.091 + 16
5	-1.461 + 16
6	+2.162 + 16
7	-1.067 + 16
8(c)	-1.391 + 15
9	-1.490 + 15
10	-8.342 + 14

(c) Defined as $-\text{TC}_8 - \text{DB}_8^2 + \text{TC}_{11} + \text{DB}_{11}^2$ where TC_i = total region i captures, DB_i^2 = region i axial leakage, and region 11 is the dummy region.

F. Neutron Balance for ReactorSource

Fission 1.00000

Total Source 1.00000

Losses ^{239}Pu Fission 0.22053 ^{238}U Fission 0.05785

Other Fission 0.06818

Total Fission 0.34656

 ^{238}U Capture 0.42635

CR,FE,NI Capture 0.03583

NA Capture 0.00236

 ^{239}Pu Capture 0.05838

Other Capture 0.04617

Total Capture 0.56909

DB² Losses 0.08170

Total 0.99735

Radial Leakage 0.00265

Total Losses 1.00000

LCCEWG BENCHMARK 3
RESULTS FOR CONFIGURATION 1

A. General

K_{eff} 1.02134

F. Neutron Balance for Reactor

Source

Fission 1.00000

Total Source 1.00000

Losses

^{239}Pu fission 0.21956

^{238}U fission 0.06144

Other fission 0.06803

Total fission 0.34903

^{238}U capture 0.42558

Cr, Fe, Ni capture 0.03570

Na capture 0.00107

^{239}Pu capture 0.05242

Other capture 0.04347

Total capture 0.55824

DB^2 losses 0.09075

Total 0.99751

Radial leakage 0.00249

Total losses 1.00000

LCCEWG BENCHMARK 3
RESULTS FOR CONFIGURATION III

A. General

k_{eff} 1.02707

F. Neutron Balance for Reactor

Source

Fission 1.00000

Total source 1.00000

Losses

^{239}Pu fission 0.22065

^{238}U fission 0.06220

Other fission 0.06815

Total fission 0.35100

^{238}U capture 0.42306

Cr, Fe, Ni capture 0.03537

Na capture 0.00060

^{239}Pu capture 0.05210

Other capture 0.04293

Total capture 0.55406

DB^2 losses 0.09239

Total 0.99745

Radial leakage 0.00255

Total losses 1.00000

LCCEWG BENCHMARK 3
RESULTS FOR CONFIGURATION IV

(d)
A. General

k_{eff} 1.00000

C. Fission Rate Traverse

<u>Triangle Number</u>	<u>Fission Rate (fiss/cm³-sec)</u>
1	2.117 + 11
2	2.590 + 11
3	3.128 + 11
4	4.423 + 11
5	6.165 + 11
6	9.587 + 11
7	1.506 + 12
8	1.263 + 13
9	1.413 + 13
10	1.514 + 13
11	1.545 + 13
12	1.516 + 13
13	1.434 + 13
14	1.846 + 12
15	1.480 + 12
16	1.560 + 12
17-19	0.0
20	1.248 + 13

(d) Buckling value weighted between rods-full-out and rods-full-in value by the search eigenvalue (control fraction).

C. Fission Rate Traverse (contd.)

<u>Triangle Number</u>	<u>Fission Rate (fiss/cm³-sec)</u>
21	1.135 + 13
22	1.003 + 13
23	1.153 + 12
24	7.334 + 11
25	5.084 + 11
26	4.245 + 11
27	4.361 + 11
28	5.709 + 11
29-31	0.0
32	5.685 + 12
33	6.254 + 12
34	6.511 + 12
35	6.237 + 12
36	5.683 + 12
37	4.848 + 12
38	5.740 + 11
39	3.383 + 11
40	2.023 + 11
41	1.234 + 11
42	7.681 + 10
43	5.014 + 10
44-49	0.0

CCEWG BENCHMARK III
RESULTS FOR CONFIGURATION IV

F. Neutron Balance for Reactor

Source

Fission	1.00000	
Total Source		1.00000

Losses

^{239}Pu fission	0.21703	
^{238}U fission	0.05787	
Other fission	0.06715	
Total fission		0.34205
^{238}U capture	0.41769	
Cr, Fe, Ni capture	0.03395	
Na capture	0.00228	
^{239}Pu capture	0.05720	
Other capture	0.06519	
Total capture		0.57631
DB ² Losses		0.07974
Total		0.99810
Radial Leakage		0.00191
Total Losses		1.00001

G. Control Inventory^(a)

^{10}B inventory (kg)	2.246E-2

LCCEWG BENCHMARK 3
RESULTS FOR CONFIGURATION V

A. General

k_{eff}	1.00674
Δk_{Na}	0.00674

F. Neutron Balance for Reactor

Source

Fission	1.00000	
Total source		1.00000

Losses

^{239}Pu fission	0.21580	
^{238}U fission	0.06138	
Other fission	0.06686	
Total fission		0.34404
^{238}U capture	0.41522	
Cr, Fe, Ni capture	0.03375	
Na capture	0.00101	
^{239}Pu capture	0.05122	
Other capture	0.06421	
Total capture		0.56541
DB^2 losses		0.08858
Total		0.99803
Radial leakage		0.00197
Total losses		1.00000

LCCEWG BENCHMARK 3

RESULTS FOR CONFIGURATION VI

A. General

Keff	1,00308
Reactor 2	1,6699
Reactor n	1,0940
ΔK cycle	0.01005

B. Regional Fission Rates

<u>Region</u>	<u>Fission Source Rate (n/sec)</u>	<u>Fission Rate (fiss/sec)</u>
1	2.218 + 15	7.826 + 14
2	2.338 + 16	7.994 + 15
3	6.163 + 15	2.160 + 15
4	4.510 + 16	1.542 + 16
5	1.145 + 16	4.024 + 15
6	6.664 + 16	2.278 + 16
7	4.033 + 15	1.439 + 15

C. Fission Rate Traverse

<u>Triangle Number</u>	<u>Fission Rate (fiss/cc/sec)</u>
1	1.156 + 12
2	1.263 + 12
3	1.375 + 12
4	1.612 + 12
5	1.879 + 12
6	2.137 + 12
7	2.870 + 12
8	9.944 + 12
9	1.097 + 13
10	1.170 + 13
11	1.201 + 13
12	1.195 + 13
13	1.155 + 13
14	3.621 + 11
15	4.352 + 12
16	4.410 + 12
17-19	0.0
20	1.044 + 13
21	9.692 + 12
22	8.847 + 12
23	2.926 + 12
24	2.476 + 12
25	2.197 + 12
26	2.094 + 12

Triangle NumberFission Rate (fiss/cc/sec)

27	2.137 + 12
28	2.369 + 12
29-31	0.0
32	7.374 + 12
33	7.285 + 12
34	7.042 + 12
35	6.532 + 12
36	5.815 + 12
37	4.933 + 12
38	1.019 + 12
39	7.149 + 12
40	5.004 + 11
41	3.554 + 11
42	2.552 + 11
43	1.915 + 11
44-49	0.0

D. Region Reaction Rates

<u>Region</u>	<u>^{239}Pu Fission Rate (fiss/sec)</u>	<u>^{238}U Capture Rate (capt/sec)</u>
1	4.502 + 14	3.368 + 15
2	5.544 + 15	5.645 + 15
3	1.351 + 15	6.246 + 15
4	1.069 + 16	1.087 + 16
5	2.465 + 15	1.446 + 16
6	1.570 + 16	1.557 + 16
7	6.683 + 14	8.715 + 15

F. Neutron Balance for ReactorSource (n/sec)

Total source	1.00000

Losses (n/sec)

^{239}Pu fission	0.23116

^{238}U fission	0.05654

Other fission	0.05573

Total fission	0.34343

^{238}U capture	0.40683

Cr, Fe, Ni capture	0.03488

Na capture	0.00232

^{239}Pu capture	0.06567

Other capture	0.06378

Total capture	0.57348

DB^2 Losses	0.0851

Total	0.99742

Radial Leakage	0.00258

Total Losses	1.00000

FINAL ATOM DENSITIES (atoms/barn-cm)

	1	2	3	4	5	6	7
U-235	2.393-5	1.398-5	2.086-5	1.383-5	2.247-5	1.470-5	2.642-5
U-238	1.321-2	8.326-3	1.298-2	8.315-3	1.311-2	8.382-3	1.337-2
PU-239	2.925-4	1.275-3	4.497-4	1.271-3	3.687-4	1.282-3	1.634-4
PU-240	9.378-6	4.406-4	2.079-5	4.415-4	1.456-5	4.318-4	3.097-6
PU-241	1.900-7	1.507-4	5.996-1	1.498-4	3.603-7	1.544-4	3.781-8
PU-242	2.307-9	5.387-5	1.144-8	5.400-5	5.587-9	5.288-5	2.515-10
F.P.	4.860-5	4.486-4	1.163-4	4.638-4	7.289-5	3.920-4	2.068-5

H. Inventories

LCCEWG BENCHMARK 3
RESULTS FOR CONFIGURATION VII

A. General

K_{eff}	1.01429
Δk_{Na}	0.01121

F. Neutron Balance for Reactor

Source

Fission	1.00000	
Total source		1.00000

Losses

^{239}Pu fission	0.23199	
^{238}U fission	0.05994	
Other fission	0.05504	
Total fission		0.34697
^{238}U capture	0.40670	
Cr, Fe, Ni capture	0.03485	
Na capture	0.00107	
^{239}Pu capture	0.06038	
Other capture	0.05866	
Total capture		0.56166
DB^2 losses		0.08871
Total		0.99734
Radial leakage		0.00267
Total		1.0001

COMPARISON OF LCCEWG NEUTRON BALANCE

		(Rate)/(Source/keff)		
<u>Case Interaction</u>		<u>MIT</u>	<u>Rockwell</u>	<u>GE</u>
1	U23	0.42635	0.42670	0.42958
	CrFeNi	0.03583	0.03532	0.03535
	Total	0.56909	0.56788	0.57095
	R.L.	0.00265	0.00394	0.00383
2	U28	0.42558	0.42536	0.42835
	CrFeN:	0.03570	0.03516	0.03518
	Total	0.55824	0.55689	0.56002
	R.L.	0.00264	0.00410	0.00429
3	U28	0.42306	0.42288	0.42582
	CrFeNi	0.03537	0.03336	0.03481
	Total	0.55406	0.55268	0.55578
	RL	0.00255	0.00394	0.00422
4	U28	0.41769		0.42039
	CrFeNi	0.03395		0.03360
	Total	0.57631		0.57824
	RL	0.00191		0.00281
5	U28	0.41522		0.41797
	CrFeNi	0.03375		0.03336
	Total	0.56541		0.56748
	RL	0.00197		0.00324
6	U28	0.40683	0.40740	0.41016
	CrFeN:	0.03488	0.03445	0.03448
	Total	0.57348	0.57169	0.57471
	RL	0.00258	0.00388	0.00380
7	U28	0.40670		0.40890
	CrFeN:	0.03485		0.03431
	Total	0.56166		0.56286
	R.L.	0.00267		0.00428

COMPARISON OF LCCEWG K_{eff}

-keff-

<u>Case</u>	<u>MIT</u>	<u>Rockwell</u>	<u>GE</u>
1	1.01313	1.01316	1.01322
2	1.02134	1.02134	1.02117
3	1.02707	1.02714	1.02692
4	1.00000	_____	1.00000
5	1.00674	_____	1.00643
6	1.00308	1.00494	1.00498
7	1.01429	_____	1.01591
	(2DB,	(2DB,AI)	(SN2D)

Notes on problem 6: the keff discrepancy is difficult to explain because

- 1) the initial keff (case 1) agrees
- 2) the interaction rates for the regions agree in case 1
- 3) the final atom densities for U28, P49 agree very well