BAW-3867-9, Vol 4
November 1969
TID-4500
UC-34

MASTER

RECEIVED BY DTIC FEB 3 1970

Fast Breeder Reactor
Static Physics Methods
Development and Analysis Project
Volume 4 — Production Tests and Sensitivity
Studies Using the FARED Code

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

Babcock & Wilcox

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

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

LEGAL NOTICE

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

A. Makes any warranty or representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or

B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission, or employee of such contractor, to the extent that such employee or contractor of the Commission, or employee of such contractor prepares, disseminates, or provides access to, any information pursuant to his employment or contract with the Commission, or his employment with such contractor.

LEGAL NOTICE

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

A. Makes any warranty or representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or

B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission, or employee of such contractor, to the extent that such employee or contractor of the Commission, or employee of such contractor, prepares, disseminates, or provides access to, any information pursuant to his employment or contract with the Commission, or his employment with such contractor.

Fast Breeder Reactor
Static Physics Methods
Development and Analysis Project

Volume 4 — Production Tests and Sensitivity
Studies Using the FARED Code

by

R. J. Neuhold

Methods Development Section

Approved by D. H. Roy
Technical Manager

AEC Contract No. AT(30-1)-3867

B&W Contract No. 859-3105

Prepared for
THE UNITED STATES ATOMIC ENERGY COMMISSION
by

BABCOCK & WILCOX
Nuclear Power Generation Department
Power Generation Division
P.O. Box 1260
Lynchburg, Virginia 24505

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

Babcock & Wilcox

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

ABSTRACT

The FARED computer program and associated library have been used to calculate ZPR-3 Assembly 48 and ZPR-3 Assembly 11. The calculated results for k_{eff} , spectral indices, central reactivity worths, Doppler coefficients and fluxes are compared with reported experimental data. Additional calculated data on the two assemblies are provided as B&W's contribution to the CSEWG Phase II, ENDF/B data evaluation.

In addition, sensitivity studies using the B&W-1000 MW(e) Follow-On reference design are presented. These studies include:

- 1) The effect of cross section re-averaging during depletion.
- 2) The effect of homogeneous versus heterogeneous resonance treatment.
- 3) The effect of the number of groups and downscatter groups on criticality and depletion.
- 4) The effect of buckling values in spectrum generation.

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

CONTENTS

	Page
1. INTRODUCTION.	1
2. CROSS SECTIONS.	3
3. GENERAL METHOD OF CALCULATION	4
4. ASSEMBLY 48 AND ASSEMBLY 11	5
4.1. General	5
4.2. Results	10
5. DISCUSSION OF ASSEMBLY 48 AND ASSEMBLY 11 RESULTS	21
6. SENSITIVITY STUDIES FOR 1000-MW(e) REACTOR.	22
6.1. General	22
6.2. Regeneration of Spectrum During Depletion	22
6.3. Effect of Heterogeneous Versus Homogeneous Resonance Treatment	23
6.4. Buckling Values Used in Spectrum Generation	28
6.5. Collapsed Group Structure Used for Criticality Calculations and Depletion.	30
7. DISCUSSION OF 1000-MW(e) SENSITIVITY STUDIES.	33
REFERENCES.	34

List of Tables

Table	
4.1. Fast Reactor Benchmark No. 3 ZPR III Assembly 48	6
4.2. Fast Reactor Benchmark No. 8 ZPR III Assembly 11	7
4.3. Broad Group Structure Used for Assembly 48 and Assembly 11 Calculations	8
4.4. Collapsed Fission Sources Used for Assembly 48 and Assembly 11.	9
4.5. Assembly 48 - Collapsed From 68-Group B1 Spectrum Calculation.	12
4.6. Assembly 11 - Collapsed From 68-Group B1 Spectrum Calculations for the Core Region	13
4.7. Assembly 11 - Collapsed From 68-Group B1 Spectrum Calculation for the Blanket Region	14

Tables (Cont'd)

Table	Page
4.8. Assembly 48 - Eigenvalue, Spectral Indices, and Material Worths.	15
4.9. Assembly 48 - Measured and Diffusion Theory Calculated Flux	16
4.10. Real and Adjoint Central Flux Spectra From Diffusion Calculation (Assemblies 11 and 48)	17
4.11. Measured and Calculated Doppler Effect - Assembly 48 Sample	18
4.12. Assembly 11 - Eigenvalue, Spectral Indices, and Material Worths.	19
6.1. 17 Broad Group Structure	23
6.2. Design Quantities With and Without Spectrum Regeneration	24
6.3. Masses With and Without Spectrum Regeneration.	25
6.4. Group Fluxes Before and After Cross Section Regeneration at 500 Days	26
6.5. Design Quantities With Homogeneous and Heterogeneous Treatment.	27
6.6. Masses With Homogeneous and Heterogeneous Resonance Treatment.	28
6.7. K_{eff} Versus Core Buckling Used in Spectrum Generation.	29
6.8. Design Quantities Versus Degree of Collapse.	30
6.9. Final Core Masses (kg) Versus Degree of Collapse	30
6.10. Final Blanket Masses (kg) Versus Degree of Collapse.	31

1. INTRODUCTION

Two benchmark cases (ZPR-3 Assembly 48 and ZPR-3 Assembly 11) described in CSEWG Newsletter 18¹ have been calculated using the FARED² program. Calculated results for k_{eff} , spectral indices, central reactivity worths, Doppler coefficients and fluxes are compared with reported experimental data and ANL calculations. Some additional data for the two assemblies as requested in the CSEWG newsletter are also presented.

Most of the cross sections used in the evaluation were obtained from the ENDF/B data files. In addition, cross sections obtained from the Oak Ridge GAM library (1965) and ANL MC² calculations were used.

The calculations for Assembly 48 and Assembly 11 used separate collapsed cross section sets (27 groups) for the core and blanket. The cross sections were collapsed from 68 groups internally within the FARED program using calculated 68-group spectra for the core and blanket compositions. The perturbation results presented were also performed internally within the FARED program using first-order perturbation theory.

In general, the calculated results of Assembly 48 and Assembly 11 are in good agreement with experiment. Exceptions are the sodium and oxygen material worths at the core center. Calculated criticality is in better agreement with experiment than data reported by other installations. This is attributed primarily to the ^{238}U cross sections. The calculated n, γ spectral index for ^{238}U , for example, is much lower than that reported by other installations.

In addition, sensitivity studies using the B&W-1000 MW(e) Follow-On reference design³ are reported. These studies were performed to examine effects such as:

- 1) Cross section re-averaging during depletion.
- 2) Homogeneous versus heterogeneous resonance treatment.

- 3) The number of groups and downscatter groups.
- 4) Buckling values for spectrum generation.

2. CROSS SECTIONS

Three sources of cross sections were used in making the basic FARED 68 group library tape.

- 1) ENDF/B tapes 114, 115 and 116.
- 2) Oak Ridge GAM library (1965).
- 3) ANL MC² run.

All of the resonance data was taken from the ENDF/B files, and the following isotopes were treated as resonance absorbers in the Assembly 48 and 11 calculations:

- 1) ²³⁸U
- 2) ²³⁹Pu
- 3) ²⁴⁰Pu
- 4) ²³⁵U
- 5) ²³⁴U

Elastic transfer matrices for all isotopes/elements were obtained from the Oak Ridge GAM library (1965). Smooth data for Al and C were also obtained from the Oak Ridge library. Smooth data for Cr, Mn, Fe and Ni were obtained from an ANL MC² run. Data for the remaining isotopes/elements were obtained from the ENDF/B data files with inelastic and n,2n matrices calculated from the ENDF/B data.

3. GENERAL METHOD OF CALCULATION

All of the calculations were performed with the FARED program using a 68-group library generated with the RETAP² program. The FARED program is a one-dimensional static physics design code with internal spectrum generation, cross section collapse, criticality, depletion, fuel management, perturbation and search routines. Spectra are calculated for various reactor blocks where a block can be a single reactor zone or group of zones. The 68-group cross sections are then collapsed to 30 or less groups with the block spectrum and used for criticality and depletion calculations in those zones making up the block. Different sets of cross sections can thus be used for various sections of the reactor. New sets of cross sections can be generated at various depletion steps by re-calling the spectrum calculation. Criticality calculations can also be re-called during depletion.

The block spectra for flux and current are calculated using the B1 equations with resonance cross sections added to the smooth data on the 68-group FARED tape. The resonance cross sections for the resolved resonance range are obtained using a numerical solution of the integral form of the slowing down equations. The N.R. approximation is used in the unresolved range. Heterogeneous or homogeneous resonance calculations are allowed.

4. ASSEMBLY 48 AND ASSEMBLY 11

4.1. General

The spatial diffusion calculations for Assembly 48 and Assembly 11 were performed in spherical geometry with 27 collapsed broad groups and 15 downscatter groups. Separate collapsed cross sections were generated for the core and blanket. Thirty mesh points were used in the core region and 20 mesh points in the blanket region. An outer boundary condition of zero flux was used.

All resonance calculations were done for homogeneous compositions. A zero buckling was used in the 68-group B1 equations used to collapse the blanket cross section sets. The core composition buckling used for Assembly 48 was $4.543 \times 10^{-3}/\text{cm}^2$. The resulting bare core k_{eff} was 0.9949. Core composition spectra for Assembly 11 were generated for three different bucklings resulting in bare core k_{eff} s of 0.9847, 1.0305 and 1.052. Assembly 11 results are given for only one of the cases, since they were virtually identical. This lack of sensitivity is attributed primarily to the small amount of collapse, i.e., 68 groups to 27 groups.

In general, the calculations made and results presented conform to prescriptions and requests in CSEWG Newsletter 18 (enclosure 2).¹ The spherical dimensions and compositions used were obtained from the CSEWG Newsletter and are given in Tables 4.1 and 4.2.

The 27-broad group structure used in the calculations is given in Table 4.3.

Table 4.4 gives the source distributions by broad group for Assembly 48 and Assembly 11. The 68-group fission energy spectrum for Assembly 48 was calculated from a Maxwellian distribution for a temperature ($\emptyset = 1.41$ MeV) as listed in ENDF/B for ^{239}Pu . The same spectrum was used for the blanket. A ^{235}U fission spectrum was used for Assembly 11 in both the core and blanket.

TABLE 4.1. Fast Reactor Benchmark No. 3
ZPR III Assembly 48

<u>Material</u>	<u>Composition</u>	
	<u>Density, 10^{24} atoms/cc</u>	
	<u>Core</u>	<u>Reflector</u>
^{239}Pu	0.001645	-
^{240}Pu	0.000107	-
^{241}Pu	0.000011	-
^{235}U	0.000016	0.000083
^{238}U	0.007405	0.039976
C	0.020770	-
Na	0.006231	-
Fe	0.010180	0.004925
Cr	0.002531	0.001196
Ni	0.001119	0.000536
Mn	0.000106	0.000051
Al	0.000233	-

Spherical Dimensions

Core Radius	46.46 cm.
Reflector Thickness	30.00 cm.

TABLE 4.2. Fast Reactor Benchmark No. 8
ZPR III Assembly 11

<u>Material</u>	<u>Composition</u>	
	<u>Density, 10^{24} atoms/cc</u>	
	<u>Core</u>	<u>Reflector</u>
^{235}U	0.004567	0.000089
^{238}U	0.034392	0.040025
^{234}U	0.000046	-
Fe	0.005681	0.004925
Cr	0.001486	0.001196
Ni	0.000718	0.000536
Mn	0.000208	0.000111

Spherical Dimensions

Core Radius	31.61 cm.
Reflector Thickness	30.00 cm.

TABLE 4.3. Broad Group Structure Used For
Assembly 48 and Assembly 11 Calculations

<u>Broad Group</u>	<u>Upper Microgroup</u>	<u>Lower Microgroup</u>	<u>Upper Energy Bound (eV)</u>	<u>Lower Energy Bound (eV)</u>
1	1	2	1.00000E+07	6.07000E+06
2	3	4	6.07000E+06	3.68000E+06
3	5	6	3.68000E+06	2.23000E+06
4	7	8	2.23000E+06	1.35000E+06
5	9	10	1.35000E+06	8.21000E+05
6	11	12	8.21000E+05	4.98000E+05
7	13	14	4.98000E+05	3.02000E+05
8	15	16	3.02000E+05	1.83000E+05
9	17	18	1.83000E+05	1.11000E+05
10	19	20	1.11000E+05	6.74000E+04
11	21	22	6.74000E+04	4.09000E+04
12	23	24	4.09000E+04	2.48000E+04
13	25	26	2.48000E+04	1.50000E+04
14	27	28	1.50000E+04	9.12000E+03
15	29	30	9.12000E+03	5.53000E+03
16	31	32	5.53000E+03	3.36000E+03
17	33	34	3.36000E+03	2.04000E+03
18	35	36	2.04000E+03	1.23000E+03
19	37	38	1.23000E+03	7.48000E+02
20	39	40	7.48000E+02	4.54000E+02
21	41	42	4.54000E+02	2.76000E+02
22	43	44	2.75000E+02	1.67000E+02
23	45	46	1.67000E+02	1.01000E+02
24	47	48	1.01000E+02	6.14000E+01
25	49	50	6.14000E+01	3.73000E+01
26	51	52	3.73000E+01	2.26000E+01
27	53	68	2.26000E+01	4.14000E-01

TABLE 4.4. Collapsed Fission Sources Used For
Assembly 48 and Assembly 11

Broad Group	Source	
	Assembly 48	Assembly 11
1	3.497580E-02	2.302320E-02
2	1.214779E-01	1.082380E-01
3	2.104389E-01	2.104340E-01
4	2.224280E-01	2.313900E-01
5	1.723701E-01	1.804770E-01
6	1.102027E-01	1.148340E-01
7	6.260210E-02	6.478800E-02
8	3.308310E-02	3.404100E-02
9	1.673012E-02	1.714320E-02
10	8.236770E-03	8.416600E-03
11	3.989720E-03	4.069600E-03
12	1.913511E-03	1.949670E-03
13	9.122410E-04	9.289000E-04
14	4.333170E-04	2.611900E-04
15	2.053769E-04	0.
16	0.	0.
17	0.	0.
18	0.	0.
19	0.	0.
20	0.	0.
21	0.	0.
22	0.	0.
23	0.	0.
24	0.	0.
25	0.	0.
26	0.	0.
27	0.	0.

4.2. Results

The flux and current calculated from the 68-group B1 equations and collapsed to 27 groups are given in Table 4.5 for both the core and blanket compositions of Assembly 48. The flux and current for the Assembly 11 core composition are given in Table 4.6 for two buckling values. Assembly 11 blanket results are given in Table 4.7.

Calculated and measured eigenvalues, spectral indices at the core center and material worths at the core center are given in Table 4.8 for Assembly 48. Two sets of Argonne data calculated with ENDF/B, ETOE, MC², and MACH1 are also given for comparison. The ANL(2)⁴ set represents more recent calculations for the ENDF/B Phase II B data testing. The ANL(1) set material worths at the core center were converted using a quoted 949.7 inhours/% ΔK . A quoted conversion for the ANL(2) set of 1003 inhours/% ΔK was used. The measured data reported in CSEWG Newsletter 18 (Enclosure 2)¹ were used.

Table 4.9 presents the calculated and measured flux for Assembly 48. ANL(1)⁵ results are also given for comparison. The measured data were obtained from an early CSWEG correspondence.⁶

Figure 4.1 presents the calculated distributed sodium worth due to the addition of a small amount of sodium uniformly throughout the spherical core region. The calculation was made with the perturbation routine in FARED.

The 27 broad group real and adjoint flux spectra obtained from the diffusion calculation are given in Table 4.10 for both Assembly 48 and Assembly 11. The real flux is normalized to a total of 100.

Calculated and measured Doppler effects for ²³⁸U and ²³⁹Pu are given in Table 4.11. The measured results for a ²³⁸U sample (274.4 gm UO₂ at core center) and a ²³⁹Pu sample (263.8 gm PuO₂ at core center) are given in reference (6) for temperatures of 300°K to 1100°K. Two methods of calculation were used (Case 1 and Case 2). The calculations were performed as ΔK calculations with the sample temperature at 300°K and with the sample temperature at 1100°K. In both cases (Case 1 and Case 2), the sample occupied the central 2 cm (radius) region in a three-region (sample-core-

blanket) Assembly 48 mockup. This represented sample densities of 8.19 gm/cc and 7.87 gm/cc for the UO_2 and PuO_2 , respectively. In Case 1, homogeneous resonance calculations were made for the sample composition at the two temperatures and ΔK obtained from two separate diffusion calculations. Case 2 was run the same as Case 1 with the following exceptions:

- 1) Non-resonant core materials were added to the sample region.
- 2) The sodium concentration in the sample region was increased so that the sample scattering per absorber atom was equal to that in the surrounding core.

The measured and calculated eigenvalues, spectral indices at the core center and material worths at the core center are given in Table 4.12 for Assembly 11. The sources for the measured and ANL results are the same as that given for Assembly 48. A quoted 483.8 inhours/% ΔK was used to convert the ANL data.

TABLE 4.5. Assembly 48 - Collapsed From 68-Group
B1 Spectrum Calculation

Broad Group	Core Region		Blanket	
	$B^2 = 2.613 \times 10^{-3} \text{ cm}^{-2}$		$B^2 \approx 0.0$	
	Flux	Current	Flux	Current
1	4.378277E-01	8.354200E-02	2.660746E-01	6.358646E-06
2	1.658038E+00	3.012099E-01	8.977061E-01	2.415810E-05
3	3.578458E+00	4.912713E-01	1.620630E+00	2.533985E-05
4	5.326929E+00	6.250027E-01	1.873848E+00	2.183158E-05
5	6.995035E+00	8.160810E-01	4.165882E+00	5.869465E-05
6	9.731338E+00	9.542597E-01	1.071725E+01	1.351342E-04
7	1.102652E+01	9.428526E-01	1.643662E+01	1.882718E-04
8	1.054761E+01	7.779188E-01	1.634684E+01	1.522855E-04
9	9.633822E+00	6.415154E-01	1.428036E+01	1.030616E-04
10	8.104572E+00	4.831775E-01	1.315034E+01	9.125271E-05
11	7.026217E+00	4.132397E-01	1.190917E+01	8.055887E-05
12	5.087666E+00	2.106187E-01	6.495001E+00	3.545202E-05
13	4.966851E+00	2.745867E-01	4.396470E+00	2.599807E-05
14	3.555907E+00	1.674289E-01	1.605174E+00	8.772629E-06
15	2.222526E+00	7.368703E-02	5.230131E-01	2.497271E-06
16	1.347390E+00	4.381502E-02	2.498703E-01	1.221678E-06
17	8.317856E-01	2.025473E-02	8.908127E-02	4.337040E-07
18	1.394806E+00	6.210656E-02	3.576542E-02	1.984165E-07
19	8.819419E-01	3.908896E-02	1.150462E-02	6.626600E-08
20	5.127162E-01	2.227398E-02	4.315296E-03	2.847261E-08
21	2.620358E-01	1.034048E-02	1.670557E-03	1.066818E-08
22	1.235596E-01	4.926450E-03	6.497177E-04	4.177663E-09
23	4.864543E-02	1.847768E-03	1.774710E-04	1.134976E-09
24	1.726196E-02	6.466434E-04	4.019865E-05	2.540568E-10
25	3.832134E-03	1.273271E-04	1.066997E-05	6.997962E-11
26	1.252534E-03	4.823388E-05	1.516179E-07	4.814854E-13
27	2.646073E-04	7.445594E-06	7.115781E-09	3.492475E-14

TABLE 4.6. Assembly 11- Collapsed From 68-Group B1 Spectrum
Calculations For the Core Region

Broad Group	$B^2 = 4.543 \times 10^{-3} \text{ cm}^{-2}$		$B^2 = 6.0 \times 10^{-3} \text{ cm}^{-2}$	
	Flux	Current	Flux	Current
1	1.631605E-01	2.583178E-02	1.594505E-01	2.872858E-02
2	7.444135E-01	1.339408E-01	7.257894E-01	1.486218E-01
3	1.611179E+00	1.734555E-01	1.583319E+00	1.950940E-01
4	1.959895E+00	1.582152E-01	1.929837E+00	1.785994E-01
5	3.683993E+00	3.506708E-01	3.566619E+00	3.877532E-01
6	7.548037E+00	6.471231E-01	7.147358E+00	7.009316E-01
7	9.653953E+00	7.485966E-01	8.974277E+00	7.968943E-01
8	8.433093E+00	5.343026E-01	7.761499E+00	5.635385E-01
9	6.352075E+00	3.134859E-01	5.804081E+00	3.285167E-01
10	4.628203E+00	2.190304E-01	4.178382E+00	2.268966E-01
11	3.080533E+00	1.413461E-01	2.742515E+00	1.443934E-01
12	1.281345E+00	4.674603E-02	1.136300E+00	4.758157E-02
13	6.754389E-01	2.693338E-02	5.957139E-01	2.726303E-02
14	1.924228E-01	7.044399E-03	1.694382E-01	7.121163E-03
15	4.972755E-02	1.534049E-03	4.379929E-02	1.551720E-03
16	1.856791E-02	5.851705E-04	1.635221E-02	5.917715E-04
17	5.162805E-03	1.548126E-04	4.562233E-03	1.571067E-04
18	1.723609E-03	5.845519E-05	1.527303E-03	5.947474E-05
19	4.018809E-04	1.349720E-05	3.578817E-04	1.380262E-05
20	1.104763E-04	4.059717E-06	9.874240E-05	4.165782E-06
21	3.207081E-05	1.079724E-06	2.863095E-05	1.106830E-06
22	9.899595E-06	3.453159E-07	8.792316E-06	3.520818E-07
23	2.751780E-06	9.704076E-08	2.426796E-06	9.825269E-08
24	6.121713E-07	2.103948E-08	5.398027E-07	2.130116E-08
25	7.771570E-09	2.224520E-10	6.814391E-09	2.239431E-10
26	1.001990E-11	3.996946E-14	8.756751E-12	4.001758E-14
27	1.164697E-13	2.992994E-15	1.011637E-13	2.984132E-15

TABLE 4.7. Assembly 11 - Collapsed From 68-Group B1 Spectrum
Calculation For the Blanket Region

Broad Group	$B^2 \approx 0.0$	
	Flux	Current
1	1.742347E-01	4.166962E-06
2	7.967613E-01	2.171703E-05
3	1.607562E+00	2.548304E-05
4	1.910336E+00	2.228403E-05
5	4.214651E+00	5.924848E-05
6	1.077893E+01	1.356766E-04
7	1.648697E+01	1.884985E-04
8	1.637411E+01	1.522603E-04
9	1.428773E+01	1.029243E-04
10	1.314387E+01	9.103319E-05
11	1.189348E+01	8.027430E-05
12	6.488555E+00	3.534033E-05
13	4.387923E+00	2.587540E-05
14	1.600731E+00	8.727953E-06
15	5.151183E-01	2.448546E-06
16	2.471334E-01	1.205282E-06
17	8.628966E-02	4.122654E-07
18	3.734650E-02	2.061079E-07
19	1.189922E-02	6.816892E-08
20	4.433613E-03	2.913340E-08
21	1.610646E-03	9.925208E-09
22	6.886147E-04	4.409788E-09
23	1.859439E-04	1.186171E-09
24	4.134549E-05	2.607120E-10
25	1.079715E-05	7.063158E-11
26	1.518416E-07	4.791094E-13
27	7.049450E-09	3.445107E-14

TABLE 4.8. Assembly 48 - Eigenvalue, Spectral Indices, and Material Worths

	<u>Eigenvalue</u>			<u>Measured</u>
	<u>B&W</u>	<u>Calculated ANL(1)*⁵</u>	<u>ANL(2)⁴</u>	
K_{eff}	0.9949	0.9872	0.9730	1.000

Spectral Indices at Core Center

	<u>B&W</u>	<u>ANL(1)</u>	<u>ANL(2)</u>	<u>Measured</u>
$\sigma_f(U238)/\sigma_f(U235)$	0.0295	0.0303	0.0304	0.0307
$\sigma_f(U233)/\sigma_f(U235)$	1.418	1.422	1.421	1.480
$\sigma_f(Pu239)/\sigma_f(U235)$	0.910	0.928	0.919	0.976
$\sigma_f(Pu240)/\sigma_f(U235)$	0.222	0.225	0.226	0.243
$\sigma_{n,\gamma}(U238)/\sigma_f(U235)$	0.134	0.142	0.142	0.138

Material Worths at Core Center
 $\times 10^5 \Delta k/k$ mole

	<u>B&W</u>	<u>ANL(1)</u>	<u>ANL(2)</u>	<u>Measured</u>
^{239}Pu	128.5	126.6	134.2	106.1
^{240}Pu	17.2	19.0	20.7	19.4
^{235}U	99.1	94.22	101.9	79.3
^{238}U	- 7.6	- 7.8	- 7.9	- 5.9
Fe	- 0.79	- 0.79	- 0.84	- 0.69
Cr	- 0.93	- 1.03	- 1.11	- 0.49
Ni	- 1.35	- 1.01	- 1.10	- 1.07
Mn	- 2.40	- 2.96	- 2.26	- 1.18
Al	- 0.46	- 0.38	- 0.42	- 0.42
Na	- 0.04	- 0.03	- 0.07	- 0.14
C	- 0.06	- 0.07	- 0.02	- 0.05
O	- 0.05	- 0.04	- 0.10	- 0.11

*Based on experimental eigenvalue of 1.013.

TABLE 4.9. Assembly 48 - Measured and Diffusion
Theory Calculated Flux

<u>Energy Interval (keV)</u>	<u>B&W</u>	<u>ANL(1)*</u>	<u>Measured</u>
500 - 825	9.99	9.56	10.32
300 - 500	11.32	11.18	11.05
180 - 300	10.83	10.85	10.52
110 - 180	9.87	9.67	9.63
67 - 110	8.31	8.50	8.46
41 - 67	7.22	7.17	6.66
25 - 41	5.23	5.81	5.48
15 - 25	5.12	4.83	4.63
9.1- 15	3.68	3.72	3.69
5.5- 9.1	2.30	2.47	2.69
2.0- 5.5	2.26	2.33	2.97

*ANL data renormalized to measured total.

TABLE 4.10. Real and Adjoint Central Flux Spectra From
Diffusion Calculation (Assemblies 11 and 48)

Broad Group	Real Flux		Adjoint Flux	
	Assembly 48	Assembly 11	Assembly 48	Assembly 11
	Normalized to Sum of 100		Unnormalized	
1	0.4356	0.3001	2.3844	3.158
2	1.7628	1.6069	2.1755	2.600
3	3.7860	3.4127	2.1553	2.506
4	5.5816	4.1278	1.9931	2.231
5	7.3407	7.6816	1.7994	1.788
6	10.1871	15.2611	1.7895	1.741
7	11.5448	19.3198	1.7897	1.828
8	11.0459	16.7402	1.7905	1.881
9	10.0737	12.4330	1.7796	1.882
10	8.4776	8.9851	1.7639	1.840
11	7.3653	5.9302	1.7284	1.801
12	5.3338	2.4592	1.7491	1.781
13	5.2259	1.2914	1.7674	1.751
14	3.7503	0.3680	1.8352	1.804
15	2.3472	0.9525(-1)	1.9195	1.902
16	1.4246	0.3559(-1)	2.0036	2.028
17	0.8802	0.9907(-2)	2.0695	2.177
18	1.4811	0.3298(-2)	2.1203	2.444
19	0.9383	0.7568(-3)	2.2339	2.438
20	0.5464	0.2062(-3)	2.4331	2.998
21	0.2796	0.757(-4)	2.5723	3.083
22	0.1319	0.177(-4)	2.7639	4.064
23	0.5192(-1)	0.52(-5)	2.6930	3.871
24	0.1842(-1)	0.12(-5)	3.1258	3.798
25	0.4088(-2)	0.15(-7)	2.9184	3.852
26	0.1335(-2)	0.19(-10)	1.4420	0.510
27	0.2817(-3)	0.22(-12)	2.2014	0.487
SUM	100	100		

TABLE 4.11. Measured and Calculated Doppler Effect -
Assembly 48 Sample

(300°K → 1100°K)

	Case 1	Case 2	Measured
²³⁸ U Sample (274.4 gm UO ₂)	$-3.1 \times 10^{-6} \Delta K$	$-3.3 \times 10^{-6} \Delta K$	$-4.9 \times 10^{-6} \Delta K$
²³⁹ Pu Sample (263.8 gm PuO ₂)		$-2.8 \times 10^{-6} \Delta K$	$-1.16 \times 10^{-6} \Delta K$

TABLE 4.12. Assembly 11 - Eigenvalue, Spectral Indices, and Material Worths

	<u>Eigenvalue</u>		
	<u>Calculated</u>		<u>Measured</u>
	<u>B&W</u>	<u>ANL</u> ⁴	
Eigenvalue	0.9845	0.9572	1.000

Spectral Indices at Core Center

	<u>B&W</u>	<u>ANL</u>	<u>Measured</u>
$\sigma_f(\text{U238})/\sigma_f(\text{U235})$	0.0344	0.0331	0.038
$\sigma_f(\text{U234})/\sigma_f(\text{U235})$	0.2950	0.289	0.310
$\sigma_f(\text{U233})/\sigma_f(\text{U235})$	1.503	1.502	1.520
$\sigma_f(\text{Pu239})/\sigma_f(\text{U235})$	1.114	1.102	1.19
$\sigma_f(\text{Pu240})/\sigma_f(\text{U235})$	0.323	0.3164	0.34
$\sigma_f(\text{Np237})/\sigma_f(\text{U235})$	0.305	0.2975	0.33
$\sigma_{n,\gamma}(\text{U238})/\sigma_f(\text{U235})$	0.115	0.1280	0.112

Material Worths at Core Center
x 10⁵ $\Delta k/k$ mole

	<u>B&W</u>	<u>ANL</u>	<u>Measured</u>
²³⁵ U	139	145	123
²³⁸ U	-7.5	-8.1	-6.6
²³³ U	234	245	221
²³⁹ Pu	211	219	209
Mn	-2.4	-2.0	-1.8
Fe	-1.7	-1.5	-1.7
Cr	-1.7	-1.8	-1.7
Ni	-3.1	-2.7	-2.4
Na	-0.4	-0.6	-0.7
Al	-0.8	-0.8	-1.0
O	-0.21	-0.4	-0.87
C	-0.27	-0.3	-0.85

Figure 4.1. Assembly 48 - Distributed Sodium Worth

5. DISCUSSION OF ASSEMBLY 48 AND ASSEMBLY 11 RESULTS

Buckling iteration to a $k = 1.0 \pm 10^{-4}$ for core spectrum calculations was not made as requested in CSEWG Newsletter 18. Instead, several bucklings were used, resulting in bare core k_{eff} s ranging from 0.98 to 1.05. The results were totally insensitive to the buckling. This is attributed primarily to the small amount of group collapse used in these calculations.

The B&W-calculated eigenvalues are closer to the measured data than are those calculated by other installations. It appears that the primary source of this difference is the lower ^{238}U (n, γ) ratio calculated by B&W.

In both Assembly 48 and Assembly 11, the fission ratio for ^{239}Pu is considerably lower than experimental values.

The calculated Doppler effects for the ^{238}U and ^{239}Pu samples vary sufficiently from experimental values to warrant further investigation.

6. SENSITIVITY STUDIES FOR 1000-MW(e) REACTOR

6.1. General

In order to provide some guidelines on the use of FARED and similar programs, sensitivity studies using the B&W 1000-MW(e) Follow-On Reference Design were performed. The reactor was calculated using 3 blocks (core, blanket, and reflector) and 5 zones. The first block contained the first three zones with averaged concentrations. Spectra were calculated for each of the blocks using the 68-group FARED library tape. Calculated resonance cross sections were added to the smooth cross sections prior to spectrum generation. The cross sections were collapsed to 30 or less groups for the spatial diffusion calculation and depletion. The studies included:

- 1) The effect of cross section re-averaging during depletion.
- 2) The effect of homogeneous versus heterogeneous resonance treatment.
- 3) The effect of buckling values used in spectrum generation.
- 4) The effect of the number of collapsed groups on criticality and depletion.

6.2. Regeneration of Spectrum During Depletion

In order to examine the effect of cross section re-averaging during depletion, two FARED runs were made on the B&W 1000-MW(e) LMFBR Follow-On Study Reference Design using the 68-group FARED library tape. Both cases were depleted to 1000 days in 100-day steps using a reactor power of 2342.2 MW(t) ($\approx 100,000$ MW/tonne). After each 100-day step, the spatial diffusion calculation was repeated by calling the RAIM routine. The initial cross section sets (17 groups, 5 downscatter groups) for the two cases were identical. They were obtained separately for the core, blanket, and reflector by collapsing the 68-group data with REGA routine calculated 68-group composition dependent spectra (B1 equations). For one of the two cases, the REGA routine was recalled at 500 days and 1000 days in order to

generate new sets of 17 group cross sections consistent with the depleted compositions. The 17-group structure used for these calculations is shown in Table 6.1.

Table 6.2 summarizes some of the design quantities as a function of burnup. Case 1 uses the beginning-of-life microscopic cross sections throughout the 1000 days of depletion. For Case 2, microscopic cross sections are regenerated at 500 days and 1000 days.

Table 6.3 presents the masses of the important isotopes in the core and blanket at the beginning-of-life and after 1000 days. One set of data represents the case of no spectrum regeneration, and the other set represents data with spectrum regeneration at 500 days.

Table 6.4 presents the central zone core flux and the blanket flux before and after cross section regeneration at 500 days. Median fission energies and median absorption energies are also presented. The data in Table 6.4 do show substantial flux differences at lower energies. This is not inconsistent with the integral data in Tables 6.2 and 6.3, since the lower energy bound for group 7 is already 748 eV. The flux deviations in the middle groups may, however, be significant with respect to Doppler calculations.

6.3. Effect of Heterogeneous Versus Homogeneous Resonance Treatment

Heterogeneous versus homogeneous resonance treatment was examined by running two cases through the same depletion sequence and group structure outlined in Section 6.2. In one case resonance cross sections were obtained for a heterogeneous representation of core and blanket fuel pins. In the other case, resonance cross sections were obtained for the homogeneous compositions. The pin dimensions, etc., are summarized below.

	<u>Core (cm)</u>	<u>Blanket (cm)</u>
Pin O.D.	0.7112	1.5494
Fuel O.D.	0.6604	1.4580
Pitch (Triangular)	0.85598	1.6205

TABLE 6.1. 17 Broad Group Structure

<u>Broad Group</u>	<u>Upper Microgroup</u>	<u>Lower Microgroup</u>	<u>Upper Energy Bound (eV)</u>	<u>Lower Energy Bound (eV)</u>
1	1	5	1.00000E+07	2.87000E+06
2	6	9	2.87000E+06	1.05000E+06
3	10	13	1.05000E+06	3.88000E+05
4	14	17	3.88000E+05	1.43000E+05
5	18	23	1.43000E+05	3.18000E+04
6	24	31	3.18000E+04	4.31000E+03
7	32	38	4.31000E+03	7.48000E+02
8	39	41	7.48000E+02	3.54000E+02
9	42	44	3.54000E+02	1.67000E+02
10	45	47	1.67000E+02	7.89000E+01
11	48	50	7.89000E+01	3.73000E+01
12	51	53	3.73000E+01	1.76000E+01
13	54	56	1.76000E+01	8.32000E+00
14	57	59	8.32000E+00	3.93000E+00
15	60	62	3.93000E+00	1.86000E+00
16	63	65	1.86000E+00	8.76000E-01
17	66	68	8.76000E-01	4.14000E-01

TABLE 6.2. Design Quantities With and Without
Spectrum Regeneration

Time, Days	K_{eff}		Core Breeding Ratio		Blanket Breeding Ratio	
	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2
0	1.01358	1.01358	1.0232	1.0232	0.1592	0.1592
100	1.01263	1.01263				
200	1.01179	1.01179				
300	1.01011	1.01011				
400	1.00789	1.00789				
500	1.00502	1.00502	0.9550	0.9550	0.1530	0.1530
500		1.00453		0.9590		0.1529
600	1.00173	1.00143				
700	0.99804	0.99790				
800	0.99394	0.99396				
900	0.98946	0.98962				
1000	0.98460	0.98489	0.9049	0.9081	0.1616	0.1616
1000		0.98459		0.9110		0.1619

TABLE 6.3. Masses With and Without
Spectrum Regeneration

Mass (kg)				
<u>No Recalculation of Spectrum</u>				
	Core		Blanket	
	BOL	EOL	BOL	EOL
	<u>0 Days</u>	<u>1000 Days</u>	<u>0 Days</u>	<u>1000 Days</u>
²³⁸ U	19928	17533	16048	15662
²³⁹ Pu	2574	2522	0	233.8
²⁴⁰ Pu	1003	1100	0	9.01
²⁴¹ Pu	193.7	156.1	0	0.227
²⁴² Pu	0	24.69	0	0.0030
F.P.	0	2195	0	41.6

Mass (kg)				
<u>Spectrum Recalculation at 500 Days</u>				
	Core		Blanket	
	BOL	EOL	BOL	EOL
	<u>0 Days</u>	<u>1000 Days</u>	<u>0 Days</u>	<u>1000 Days</u>
²³⁸ U	19928	17530	16048	15663
²³⁹ Pu	2574	2525	0	334.0
²⁴⁰ Pu	1003	1100	0	8.76
²⁴¹ Pu	193.7	155.7	0	0.211
²⁴² Pu	0	24.62	0	0.0028
F.P.	0	2196	0	41.2

TABLE 6.4. Group Fluxes Before and After Cross Section
Regeneration at 500 Days

Group	Central Core Zone		Blanket	
	Before Re-Avg	After Re-Avg	Before Re-Avg	After Re-Avg
1	1.512+14	1.520+14	8.052+12	7.986+12
2	4.324+14	4.351+14	2.725+13	2.706+13
3	8.596+14	8.684+14	7.494+13	7.474+13
4	1.232+15	1.238+15	1.344+14	1.339+14
5	1.620+15	1.633+15	2.267+14	2.266+14
6	9.213+14	9.261+14	1.621+14	1.620+14
7	2.224+14	2.231+14	4.690+13	4.672+13
8	3.764+13	3.710+13	1.175+13	1.151+13
9	9.864+12	9.366+12	5.869+12	5.698+12
10	2.416+12	2.214+12	3.086+12	2.983+12
11	3.405+11	2.955+11	1.226+12	1.248+12
12	4.966+10	3.610+10	5.133+11	4.906+11
13	3.155+9	2.196+9	1.908+11	2.080+11
14	1.458+8	9.911+7	6.022+10	6.194+10
15	2.349+7	1.042+7	5.530+10	5.649+10
16	2.279+6	9.227+5	2.916+10	3.813+10
17	4.373+4	1.362+4	1.854+10	2.058+10
Median Fiss. Energy	169.3 keV	170.7 keV	507.1 keV	556.1 keV
Median Abs. Energy	46.9 keV	47.3 keV	17.1 keV	17.2 keV

Table 6.5 shows some of the design quantities as a function of burnup. A homogeneous resonance treatment was used for Case 1, and a heterogeneous resonance treatment was used for Case 2.

Table 6.6 summarizes beginning- and end-of-life core and blanket masses versus resonance treatment.

TABLE 6.5. Design Quantities With Homogeneous and Heterogeneous Treatment

Time, Days	K_{eff}		Core Breeding Ratio		Blanket Breeding Ratio	
	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2
0	1.0054	1.0136	1.0497	1.0232	.1635	.1592
500	1.0040	1.0050	.9697	.9550	.1523	.1530
1000	.9872	.9846	.9140	.9059	.1600	.1617

6.4. Buckling Values Used In Spectrum Generation

The reference core and group structure described in the last two sections were used to examine the effect of buckling values used in spectrum generation. For each case examined, the same depletion sequence previously outlined was used. In order to examine the effect of core buckling, three cases were run using an infinite medium spectrum for the blanket. The core bucklings used in the three cases were:

- Case 1) Bare core geometric buckling.
- Case 2) Twice the bare core geometric buckling.
- Case 3) Zero buckling (infinite medium spectrum).

The effect of these bucklings on k_{eff} , collapsed cross sections and final masses (1000 days) was negligible. Consequently, any reasonable approximation to the bare core geometric buckling is satisfactory for core spectrum generation in a large fast reactor. Table 6.7 summarizes beginning- and end-of-life k_{eff} s for the three cases described.

TABLE 6.6. Masses With Homogeneous and Heterogeneous Resonance Treatment

	Mass (kg)			
	<u>Homogeneous Resonance Treatment</u>			
	Core		Blanket	
	<u>BOL</u> <u>0 Days</u>	<u>EOL</u> <u>1000 Days</u>	<u>BOL</u> <u>0 Days</u>	<u>EOL</u> <u>1000 Days</u>
^{238}U	19928	17497	16048	15662
^{239}Pu	2574	2557	0	336.6
^{240}Pu	1003	1100	0	8.21
^{241}Pu	193.7	156.0	0	0.177
^{242}Pu	0	24.1	0	0.0021
F.P.	0	2198	0	40.1

	Mass (kg)			
	<u>Heterogeneous Resonance Treatment</u>			
	Core		Blanket	
	<u>BOL</u> <u>0 Days</u>	<u>EOL</u> <u>1000 Days</u>	<u>BOL</u> <u>0 Days</u>	<u>EOL</u> <u>1000 Days</u>
^{238}U	19928	17533	16048	15662
^{239}Pu	2574	2522	0	333.8
^{240}Pu	1003	1100	0	9.01
^{241}Pu	193.7	156.1	0	0.227
^{242}Pu	0	24.7	0	0.0030
F. P.	0	2195	0	41.6

Two additional cases were run to determine the effect of blanket buckling on blanket spectrum calculations. In one case an infinite medium spectrum was used for the blanket and in the other case the bare core geometric buckling was used for blanket spectrum calculation. The results for the two cases were identical. However, although blanket spectra are frequently calculated with zero buckling, neither one of the two cases described necessarily provides an adequate blanket spectrum.

TABLE 6.7. K_{eff} Versus Core Buckling Used in
Spectrum Generation

	K_{eff} <u>0 Days</u>	K_{eff} <u>1000 Days</u>
Case 1	1.0136	0.9846
Case 2	1.0146	0.9854
Case 3	1.0124	0.9837

6.5. Collapsed Group Structure Used for Criticality Calculations and Depletion

The effect of the number of collapsed groups used for spatial diffusion theory calculations and depletion was examined for large fast reactors using the 1000-MW(e) reference core. In all cases, spectra were generated in 68 groups for the core, blanket, and reflector. The 68-group structure covered the energy range of 10 MeV to 0.414 eV in 0.25 lethargy widths. The 68-group spectra and 68-group cross sections were used to obtain separate collapsed cross section sets for the core, blanket, and reflector. The collapsed cross section sets were used in diffusion theory calculations and depletion. Three cases were examined:

- Case 1) Cross sections collapsed to 30 groups and 15 downscatter groups.
- Case 2) Cross sections collapsed to 10 groups and 9 downscatter groups.
- Case 3) Cross sections collapsed to 5 groups and 4 downscatter groups.

The 30-group structure consisted of 0.5 lethargy widths from 10 MeV to 3.05 eV. Each group of the 10-group structure contained 3 groups of the 30-group structure. Each group of the 5-group structure contained 6 groups of the 30-group structure.

The data presented in Tables 6.8, 6.9, and 6.10 show that the effect of the degree of collapse on criticality and depletion is not very important. The major differences, although very small, occur in the blanket. This implies that an infinite medium spectrum to describe the blanket is a reasonable choice for the degree of collapse used in this study.

TABLE 6.8. Design Quantities Versus Degree of Collapse

Time, Days	K_{eff}			Core Breeding Ratio			Blanket Breeding Ratio		
	Case 1	Case 2	Case 3	Case 1	Case 2	Case 3	Case 1	Case 2	Case 3
0	1.0136	1.0132	1.0122	1.02251	1.02376	1.0255	0.16106	0.15946	0.15841
500	1.0052	1.0045	1.0032	0.95446	0.95479	0.95574	0.15479	0.15340	0.15295
1000	0.9853	0.9838	0.9822	0.90522	0.90524	0.90563	0.16328	0.16214	0.16226

TABLE 6.9. Final Core Masses (kg) Versus Degree of Collapse

	Case 1		Case 2	Case 3
	BOL 0 Days	EOL 1000 Days	EOL	EOL
^{238}U	19928	17536	17535	17534
^{239}Pu	2574	2522	2522	2524
^{240}Pu	1003	1099	1101	1102
^{241}Pu	193.7	155.8	156.2	156.7
^{242}Pu	0.0	24.59	24.72	24.80

Table 6.10. Final Blanket Masses (kg) Versus
Degree of Collapse

	Case 1		Case 2	Case 3
	BOL 0 Days	EOL 1000 Days	EOL	EOL
^{238}U	16048	15658	15660	15657
^{239}Pu	--	337.1	334.2	332.6
^{240}Pu	--	9.22	9.24	9.40
^{241}Pu	--	0.182	0.185	0.197
^{242}Pu	--	0.00236	0.00235	0.00253

7. DISCUSSION OF 1000-MW(e) SENSITIVITY STUDIES

The sensitivity studies made using the B&W-1000 MW(e) Follow-On Reference Design led to the following conclusions:

- 1) The effect of cross section re-averaging (68 groups to 17 groups) during depletion on criticality, breeding ratio, external breeding ratio, and end-of-life masses was found to be unimportant in this study. The effect of cross section re-averaging on the Doppler coefficient and void coefficient was not examined.
- 2) The effect of a homogeneous versus heterogeneous resonance treatment led to a k_{eff} difference of 0.8% ΔK . The effect on final masses was particularly pronounced in the blanket region and suggests a heterogeneous treatment for blanket materials.
- 3) An estimated bare core geometric buckling should be satisfactory for spectrum generation in the core region for the large core examined. Substantial deviations from the bare core buckling led to negligible effects on collapsed cross section sets, criticality, and final core masses. Small variations around zero buckling for the blanket spectrum calculation had little effect. A completely adequate description of the blanket spectrum for comparison was not attempted.
- 4) Sixty-eight group cross sections were collapsed to 30, 10, and 5 groups for criticality and depletion calculations. The effects on k_{eff} , breeding ratio, external breeding ratio, and final masses were very small. The 68-group spectrum generated for the blanket and used to collapse blanket cross sections was an infinite medium spectrum. This implies that collapsed cross sections based on an infinite medium blanket spectrum are satisfactory for a collapse of at least as few as 5 groups in typical fast reactor blankets.

REFERENCES

1. Pearlstein, S., CSEWG Newsletter 18, March 20, 1969.
Davey, W.G. and Hess, A. L., Enclosure 2, "Additional Fast Reactor Benchmarks for Phase II Data Testing of ENDF/B," February 21, 1969
2. Roy, D. H., et al., FARED - A One-Dimensional Fast Reactor Physics Design and Analysis Code, BAW-3867-9, Vol 1 (1969).
3. 1000-MWe LMFBR Follow-On Study, Vol 2, BAW-1328 (1969).
4. Davey, W. G. and Hess, A. L., CSEWG Correspondence, "Status Report on Phase II B Data Testing for Fast Reactor as of September, 1968,"
Revised Category 1 Data Used (ENDF/B-ETOE-MC²-MACH1), September 13, 1968.
5. Meneley, D. A., CSEWG Correspondence, Category 1 Data Used (ENDF/B-ETOE-MC²-MACH1), January 12, 1968.
6. Greebler, P., CSEWG Correspondence, Testing of ENDF/B Cross Section Data - Information on Simplified Model of ZPR-III Critical Assembly No. 48, January 16, 1967.

DISTRIBUTION

1. U.S. Atomic Energy Commission (3)
Division of Reactor Development and Technology
Washington, D.C. 20545
Attn: J. W. Lewellen
2. U.S. Atomic Energy Commission
Division of Technical Information Extension
Post Office Box 62
Oak Ridge, Tennessee 37830
3. U.S. Atomic Energy Commission (2)
New York Operations Office
376 Hudson Street
New York, New York 10014
Attn: L. S. Hartman
Reports Library
4. Argonne National Laboratory (11)
9700 South Cass Avenue
Argonne, Illinois 60439
Attn: Dr. Robert Avery (5)
Fred Thalgott (3)
A. Amorosi, LMFBR Program Office (3)
5. Atomic Power Development Association, Inc.
1911 First Street
Detroit, Michigan 48226
Attn: John Nims
6. Atomics International
Post Office Box 309
Canoga Park, California 91304
Attn: Harry Morewitz
7. Brookhaven National Laboratory (2)
Upton, Long Island, N. Y. 11973
Attn: Jack Chernick
Herbert Kouts

8. Combustion Engineering, Inc.
Windsor, Connecticut 06095
Attn: Sidney Visner
9. General Electric Company
Atomic Power Division
175 Curtner Avenue
San Jose, California 95125
Attn: Dr. Paul Greebler
10. Los Alamos Scientific Laboratory
Post Office Box 1663
Los Alamos, New Mexico 87544
Attn: David Hall
11. Oak Ridge National Laboratory
Post Office Box X
Oak Ridge, Tennessee 37830
Attn: Fred Maienschein
12. Pacific Northwest Laboratory
Post Office Box 999
Richland, Washington 99352
Attn: Peter Hofmann
13. Rensselaer Polytechnic Institute
Troy, New York 12181
Attn: Erwin Gaertner
14. Westinghouse Electric Corporation
Post Office Box 355
Pittsburgh, Pennsylvania 15230
Attn: Lee Strawbridge
15. Babcock & Wilcox (36)

Barringer, HS	Livolsi, AZ
Bhatnagar, SK	Neuhold, RJ
Carmichael, CD	Poor, HH/Alliance
Central Files (6)	Probert, PB/Barberton
Colpo, PN	Rowand, WH
Engelder, TC	Roy, DH (2)
Green, ID	Stewart, JE (5)
Holt, CD	Tilford, JM
Hostetler, DR	Travis, CC/TRG
Jacobsen, JA	Webb, RA
Library (2)	Whitaker, BW
Littrell, LW (2)	Wolfe, GE