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**VERIFICATION, VALIDATION, AND
BENCHMARKING REPORT FOR TRIMHX:
A Three Dimensional Hexagonal
Transient Diffusion Theory Code (U)**

By

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SUMMARY

This report concerns the verification and validation of TRIMHX, a transient two and three dimensional hex-z diffusion theory code. The validation was performed to determine the accuracy of the code, and the verification was performed to determine if the code was correctly using the correct theory and that all the subroutines function as required. For TRIMHX, the validation requirement was satisfied by comparing the results of the code with experiments and benchmarking the code against other standard or validated code results. The verification requirement for TRIMHX was performed indirectly since it is impossible and not necessary to reverify a large code like TRIMHX line by line. The extensive operations history of TRIMHX in conjunction with the comparisons against many numerical experiments (exact solutions) and other diffusion theory codes is sufficient to establish that the code is functioning as intended and therefore it is verified.

This report summaries four sets of experiments performed in 1974, 1977, and 1988, two DIF3D/TRIMHX comparison problems performed in 1991, a DIF3D/FX2-TH/TRIMHX comparison problem produced for this report, and the comparison of TRIMHX/GRIMHX initial static calculations. The results of these experiments show that TRIMHX was correctly implemented and is ready to submit into SCMS production mode.



I INTRODUCTION TO TRIMHX

TRIMHX is a fundamental Reactor Analysis tool in use at the Savannah River Site (SRS) and is an integral part of the Generalized Reactor Analysis Subsystem (GRASS). TRIMHX solves the time dependent multigroup neutron diffusion equation in two and three dimensional hexagonal geometry by standard and coarse mesh finite difference methods. The TRIMHX implementation assumes the solution to this equation can be discretized in space, energy, and time. These are industry accepted approaches which can be found in many nuclear engineering books^{1,2}. TRIMHX was written by M. R. Buckner and J. W. Stewart at Savannah River Laboratory. The calculational flow and the theory implemented in TRIMHX are discussed in References 3 and 4.

II VERIFICATION

As part of the certification process, TRIMHX has to be verified, a process to ensure that the coding correctly implements the intended calculational methods⁵. Since TRIMHX is a large computer code which was developed long before the current verification requirement was in place, the verification performed at that time was not documented sufficiently to meet current requirements today. Reverify TRIMHX line by line would be a monumental task and it has not been deemed necessary. The extensive operations history of TRIMHX in conjunction with the comparisons against many numerical experiments (exact solutions) and other diffusion theory codes is sufficient to establish that the code is functioning as intended and therefore satisfies the verification requirement.

III VALIDATION

Validation refers to the process in which the accuracy of the whole code is determined. This process can be performed by comparing the code results with the experimental data, controlled experiments, operational data, or more accurate calculational methods (benchmarks)⁵. For TRIMHX, the validation was performed by comparing the code results with exact solutions, experimental results, results of other validated codes, and the results from industry standard codes.



Five sets of test problems and experiments produced in the past, a new test problem, and the comparisons of TRIMHX/GRIMHX initial calculations are described in this report. These sets of test problems and experiments are three numerical test problems performed in 1974, a pulsed neutron experiment performed in 1974, five space-time PDP experiments performed in 1974 and 1977, an adiabatic model test problem performed in 1988, and a comparison with a Nodal Diffusion code DIF3D performed in 1991. The new test problem is a two-dimensional problem from the DIF3D paper published in 1991.

Following are short descriptions and the results of these sets of test problems and experiments. For more details, readers are referred to the given references.

IV. Numerical Test Problems

These three test problems were performed by M. R. Buckner and J. W. Stewart in 1974 to demonstrate the accuracy of the TRIMHX method⁶. These test problems have several common characteristics:

1. two energy groups
2. one or six delayed neutron families
3. six-fold sector symmetry in the horizontal plane
4. one mesh point per hex
5. ten axial mesh points for three-dimensional calculations
6. step change in reactivity at time zero.

The results of these test problems are reproduced below. Detailed descriptions and the input data of these test problems can be found in Reference 6.

IV.1 Test Problem I

This is a bare homogeneous reactor problem with a spatially uniform perturbation in the production cross section. Reference solutions are solutions from the few-group point kinetics equation. The results of a 80 cents perturbation case are given in Table 4.1, and the comparisons of the central flux versus time for five reactivity perturbation cases are sketched

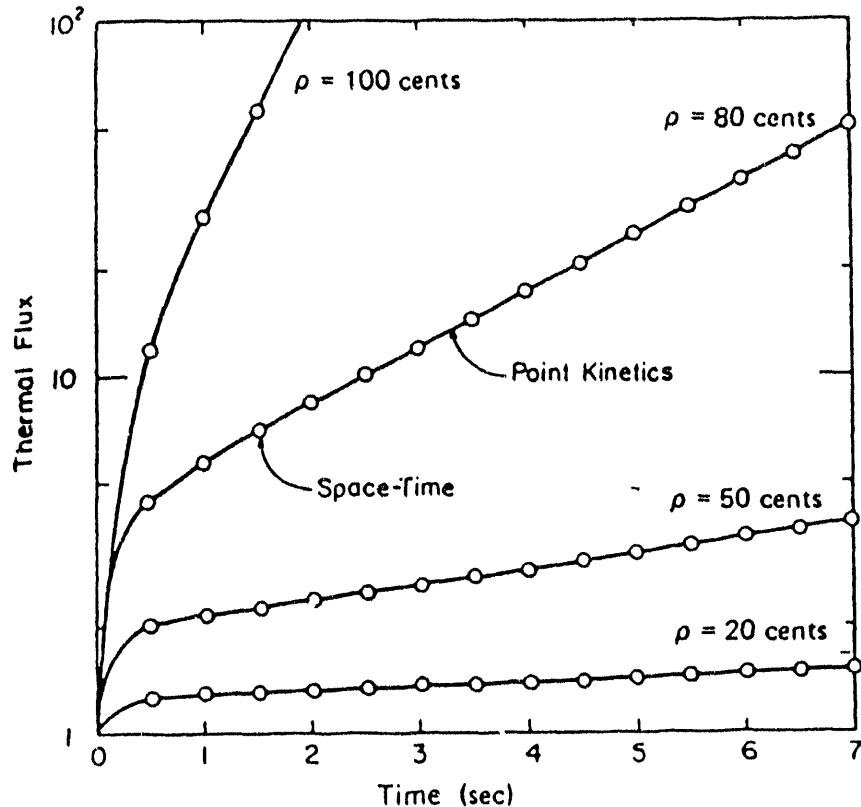


in Figure 4.1.

Table 4.1: Results for 80 cents Perturbation Case

Time (sec)	Point Kinetics			3-D TRIMHX	
	$\Delta t=0.5\text{msec}$	$\Delta t=5\text{msec}$	$\Delta t=50\text{msec}$	Transform	No-Trans.
0	1.000	1.000	1.000	1.000	1.000
1	5.896	5.896	5.896	5.874	5.897
2	8.426	8.430	8.477	8.454	8.488
3	11.975	11.985	12.086	12.054	12.100
4	17.018	17.037	17.230	17.184	17.259
5	24.186	24.220	24.563	24.495	24.610
6	34.373	34.430	34.017	34.918	35.095
7	48.850	48.945	49.920	49.798	50.058

Figure 4.1: Normalized Reactor Midpoint Thermal-neutron Flux versus Time for Four Values of Reactivity





The results show the excellent agreement between the exact solutions and the TRIMHX solutions. The discrepancies between two solutions are less than 0.5% for all cases. It is worthwhile to note that TRIMHX with exponential transformations method gives better results than the standard (without exponential transformation) TRIMHX method.

IV.2 Test Problem II

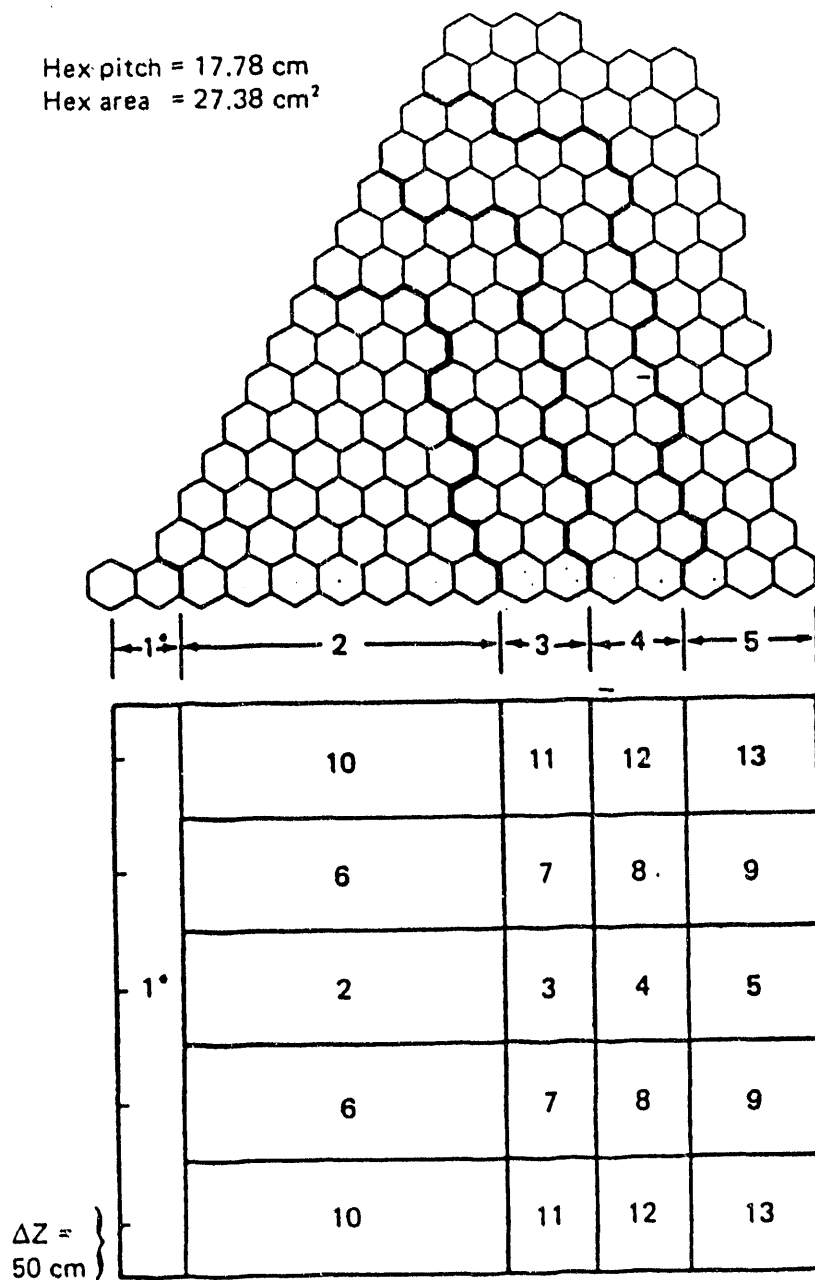
This is a bare heterogeneous reactor problem with a spatially uniform perturbation in the production cross section. The reactor is made up of thirteen difference materials as shown in Figure 4.2. Reference solutions are also solutions from the few-group point kinetics equation. The results of 80 cents perturbation case are given in Table 4.2. The results show the excellent agreement between the exact solutions and the TRIMHX solutions.

Table 4.2: Results for 80 cents Perturbation Case

Time (sec)	Point Kinetics	3-D TRIMHX	
	$\Delta t=50$ msec	Transform	No-Trans.
0	1.000	1.000	1.000
1	5.870	5.896	5.920
2	8.446	8.482	8.512
3	12.039	12.096	12.142
4	17.157	17.249	17.321
5	24.452	24.599	24.708
6	34.848	35.084	35.248



**Figure 4.2: Reactor Geometry for Test Problem II and III
(60-deg sector at midplane and axial cross
section of the reactor).**





IV.3 Test Problem III

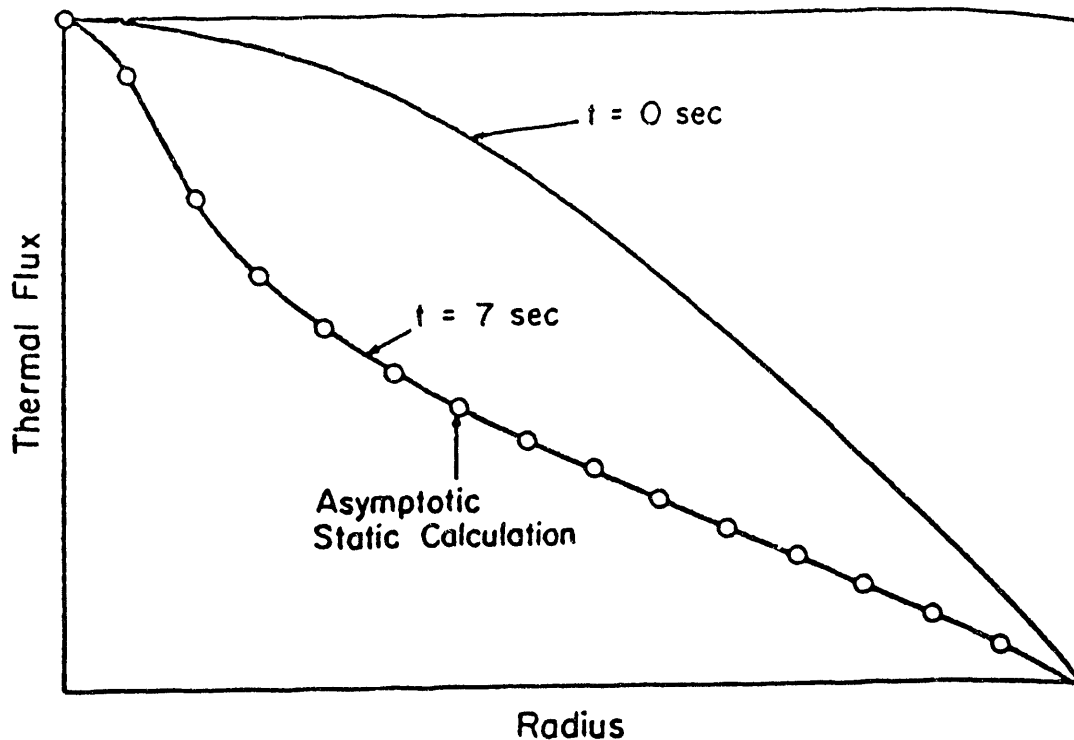
This is a bare heterogeneous reactor problem as Test Problem II with the local perturbation of thermal absorption cross section in the central patch (center hex plus the six surrounding hexes) up to -18%. The perturbation was an axially uniform step change at time zero. Since the point kinetics solution is not valid for this problem, a dynamic reactivity was inferred from the asymptotic period found by using a calculated neutron lifetime. The radial distributions of thermal flux at zero and 7 seconds are shown in Figure 4.3 and the TRIMHX results are shown in Table 4.3. These results are for the case of 15% reduction in thermal absorption cross section. Again, the results show the excellent agreement between the exact solutions and the TRIMHX solutions.

Table 4.3: TRIMHX Results

Time (sec)	TRIMHX with Transform			TRIMHX without Transform		
	$\Delta t=5\text{msec}$	$\Delta t=25\text{msec}$	$\Delta t=50\text{msec}$	$\Delta t=5\text{msec}$	$\Delta t=25\text{msec}$	$\Delta t=50\text{msec}$
0.0	1.000	1.000	1.000	1.000	1.000	1.000
0.5	10.647	10.500	10.896	10.874	10.897	10.538
1.0	15.552	15.495	15.477	15.454	15.488	15.581
1.5	20.624	20.623	20.086	20.054	20.100	20.791
2.0	26.988	27.035	27.230	26.184	27.259	27.315
2.5	35.242	35.354	35.563	35.495	35.610	35.793
3.0	46.003	46.210	46.017	45.918	46.095	46.878
3.5	60.044	60.391	61.920	59.798	60.058	61.388
4.0	78.365	78.918	79.860	78.148	79.299	80.384
4.5	102.271	103.121	104.508	101.955	103.646	105.255
5.0	133.458	134.735	136.752	133.003	135.461	137.812



**Figure 4.3: Thermal Neutron Flux at Reactor-Midplane
versus Reactor Radius (linear plot).**





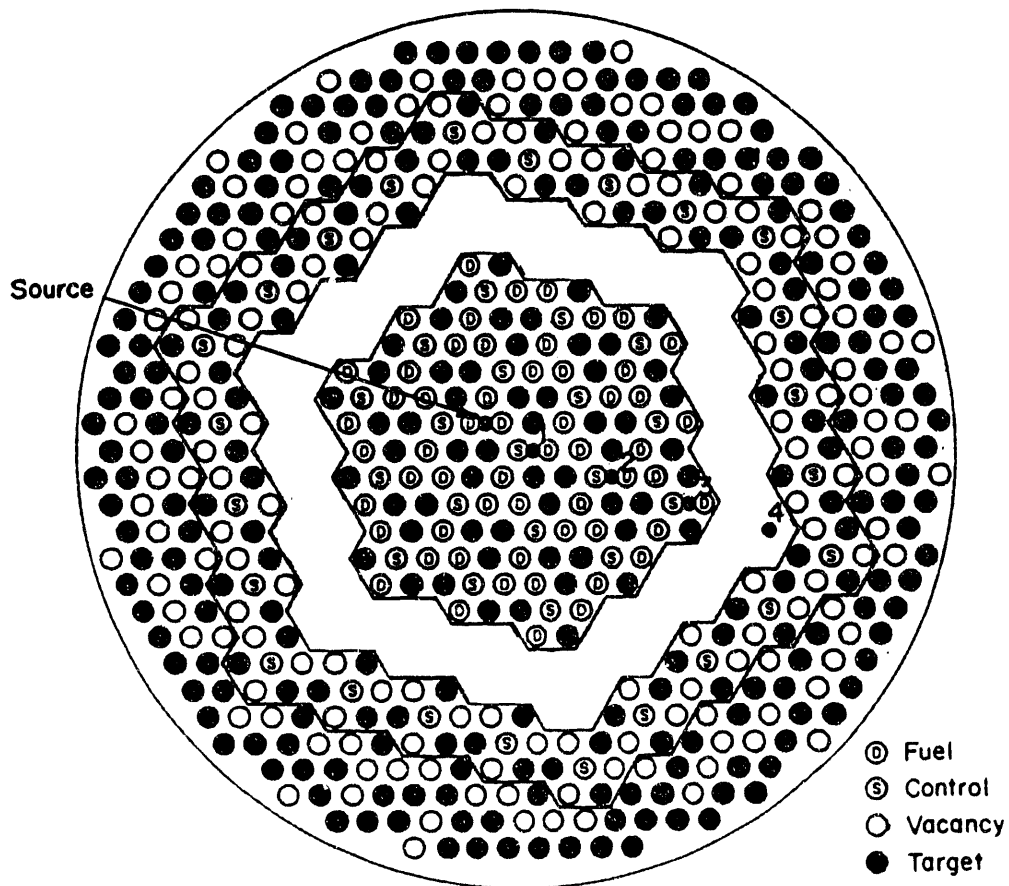
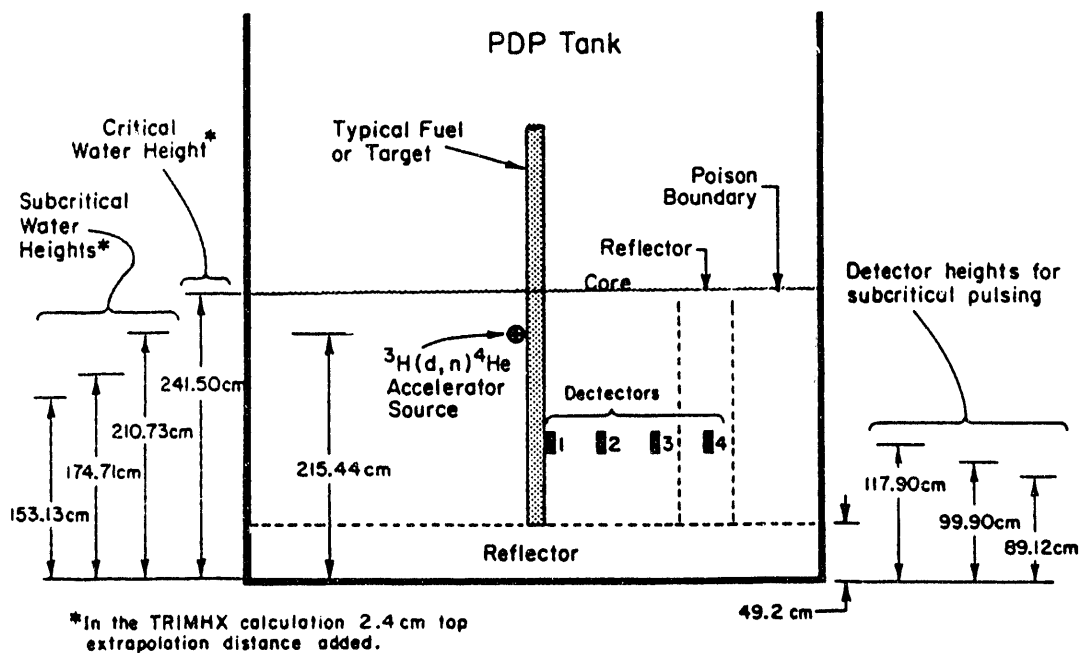
V Pulsed Neutron Experiments

These experiments were carried out by P. B. Parks and J. W. Stewart in 1974⁷. The experiments were performed in the Process Development Pile (PDP) at Savannah River Laboratory (SRL). The tests involved a hexagonal core surrounded by a hexagonal reflector in which control assemblies and fuel assemblies (E-D charge) were representative of typical SRS lattices. The core was then pulsed by a $^3\text{H}(d,n)^4\text{He}$ accelerator source and TRIMHX calculations with 2 energy groups, 60 degree symmetry, 3 points per hex, 20 axial mesh points, and 6 groups of delayed neutron family were performed for comparison.

To eliminate the uncertainties of the input diffusion parameters as well as the errors contributed to the problem from the initial static calculation, two assumptions were incorporated into the TRIMHX analysis. The first of these is the normalization of diffusion parameters by assuming that the discrepancies between calculated and measured values of a case are due to errors in the input diffusion parameters. The diffusion parameters were adjusted so that the measured and calculated prompt neutron response are identical in the static calculation of the reactivity. These diffusion parameters were used for the TRIMHX calculations. The second assumption was the derivation of static subcritical reactivity from the normalized diffusion parameters. This was done by a code of the same neutronic model as TRIMHX code, i.e., the static few-group neutron diffusion theory GRIMHX³ code.

One critical and three subcritical measurements were made on this lattice. The critical measurement established the critical water height at 241.50 cm. The subcritical pulsed experiments were then performed with the water height of 210.73 cm, 174.71 cm, and 153.13 cm. The vertical and radial schematics of the experimental arrangement are shown in Figure 5.1.

Figure 5.1: Vertical and Radial Display of the Experiment





In these reflected lattice experiments, kinetic distortion as well as delayed neutron and prompt harmonics were present. These harmonics problems invalidated the conventional analyses of Gozani's, Sjostrand, and Garelis-Russell⁷. The space-time calculational method, however, is unaffected by these harmonics problems. To the extent the two-group treatment was adequate, the effects of delayed and prompt harmonics and kinetic distortions were directly included in the space-time calculation of the experiments. It is instructive to compare the conventional results with the space-time method results. Table 5.1 below lists the space-time reactivities and the conventional reactivities found using data only after the fundamental mode had been established.

Table 5.1: Measured and Calculated Reactivities for the Reflected Lattice in the PDP

Water Height	Normalized TRIMHX	Detector	Gozani	Garelis-Russell	Sjostrand
241.50	-0.00101				
210.73	-0.01128	1	-0.00918	-0.00855	-0.01038
		2	-0.00952	-0.00939	-0.00995
		3	-0.01043	-0.01049	-0.00939
		4	-0.01157	-0.01068	-0.00914
174.71	-0.03139	1	-0.02278	-0.02269	-0.02805
		2	-0.02430	-0.02344	-0.02669
		3	-0.03122	-0.02967	-0.02971
		4	-0.03818	-0.03515	-0.02972
153.13	-0.05234	1	-0.03737	-0.03937	-0.04857
		2	-0.03854	-0.04193	-0.04553
		3	-0.04673	-0.04675	-0.04412
		4	-0.07129	-0.06628	-0.05427

Comparisons of the calculated to measured data showed that overall prompt neutron response to a pulsed source was well represented. These comparisons were made against experiments at critical conditions and at varying degrees of subcriticality. In all cases there was good agreement between the measured and calculated k_{eff} . Readers are referred to References 7 and 8 for more details about this experiment.



VI. Space-time PDP Experiments

These five experiments were performed by P. B. Parks, N. P. Baumann, C. E. Jewell, W. G. Winn, R. L. Currie in 1974 and 1977 for testing the TRIMHX code⁹⁻¹⁰. The experiments were performed in the D₂O moderated Process Development Pile (PDP) at the Savannah River Laboratory, and the measured data were used to compare against the TRIMHX calculated results. To reduce the uncertainties of the input diffusion parameters as well as the insufficiencies of the static lattice contribution to errors in the initial static calculation, a normalization procedure has been applied to the production cross sections to force the calculated static eigenvalue, static flux distribution, and perturbation worth to agree with the measured values. There were two 2-dimensional experiments and three 3-dimensional experiments performed during this study. The comparison results and short descriptions of each experiment are described below. Detailed descriptions and the input data of these experiments are given in References 9 and 10.

VI.1 TWO-DIMENSIONAL EXPERIMENTS

2-D Experiment #1

In this first two-dimensional experiment, the control assemblies were loaded so that the radial flux shape was peaked at the center. The reactivity transients were initiated by dropping two or more ²³⁵U-bearing rods into the lattice at the desired perturbation sites. To maximize flux tilts, Gang 3 location was chosen as perturbation sites, and the definition of flux tilt is:

$$\text{Tilt} = \frac{[\phi(t) / \phi(0)]_A}{[\phi(t) / \phi(0)]_B}$$

where $\phi(t)$ is time dependent flux,
 $\phi(0)$ is initial flux, and
A, B are positions.

Base lattice flux distribution was measured by gold pin activation method,



and flux tilts were measured by four detectors which are placed in the lattice interstitial positions. Figures 6.1 and 6.2 show the experiment geometry and the TRIMHX calculation geometry. Figure 6.3 shows the measured and calculated flux tilts. Due to computing cost, TRIMHX was used to determine the calculated flux tilt up to 90% of the asymptotic value and GRIMHX was used to determine flux tilt at the asymptotic value.

Figure 6.1: Preparation of perturbation, dummy sites, and location of detectors and gold pins in Exp#1.

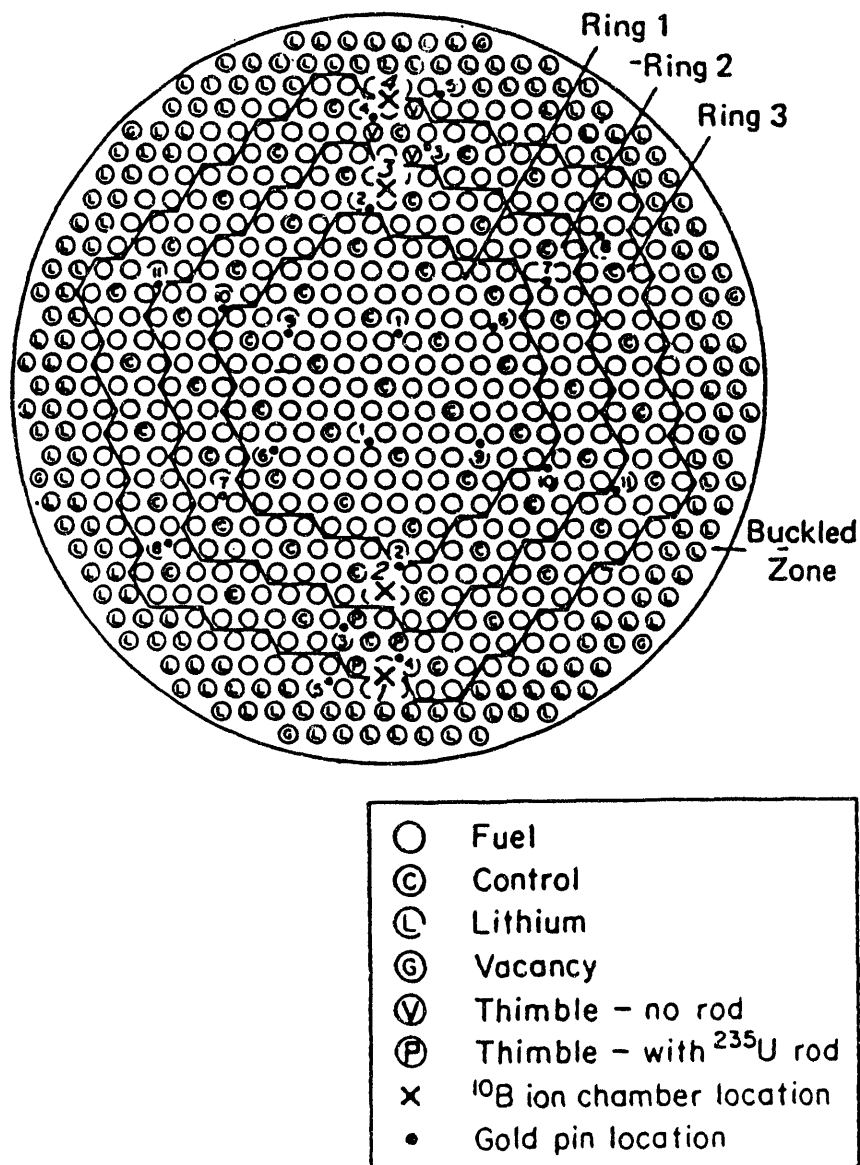
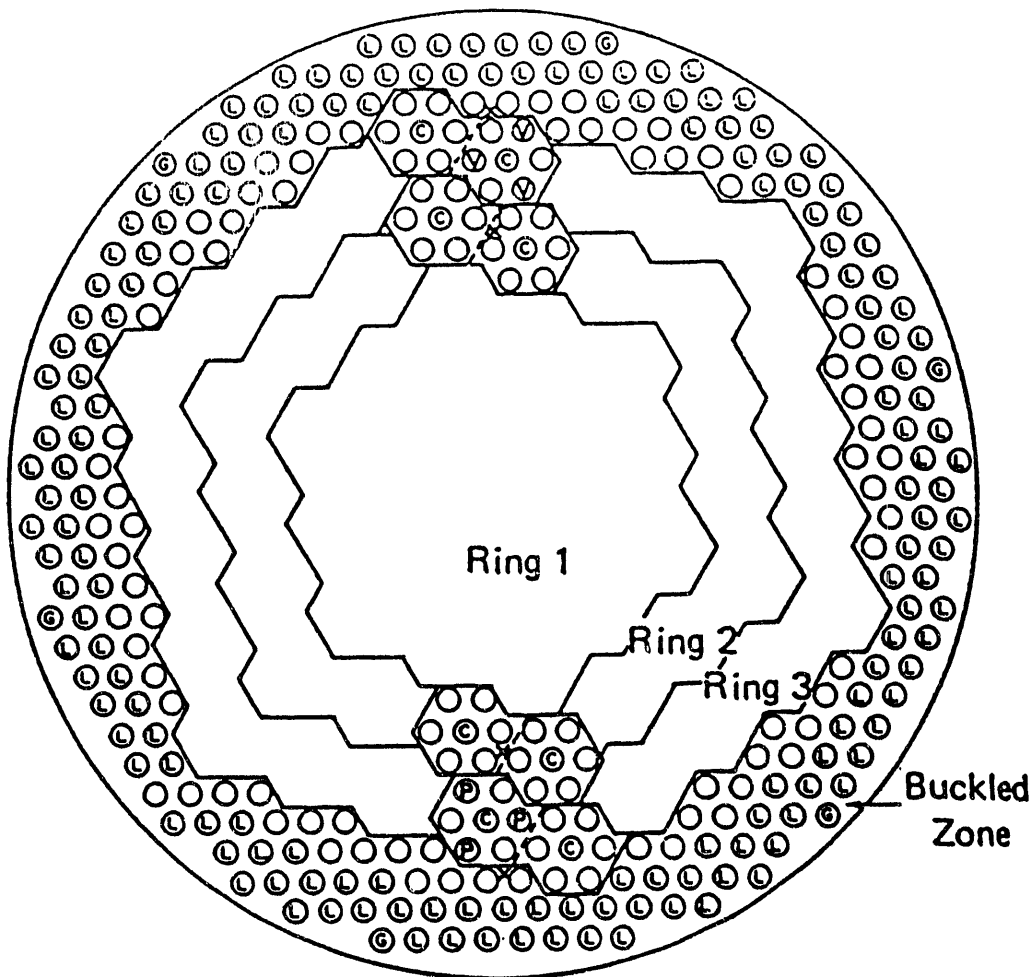


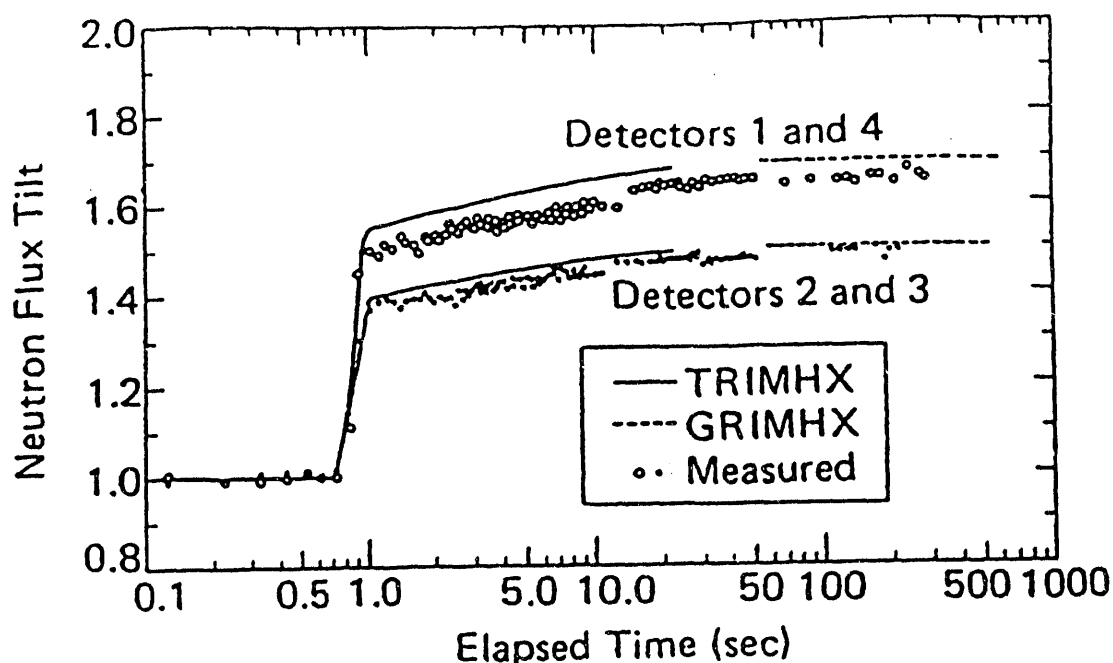


Figure 6.2: Geometry of TRIMHX calculations of Exp#1.



- Fuel
- Ⓒ Control
- Ⓕ Lithium
- Ⓖ Vacancy
- Ⓥ Thimble - no rod
- Ⓟ Thimble - with ^{235}U rod
- x ^{10}B ion chamber location

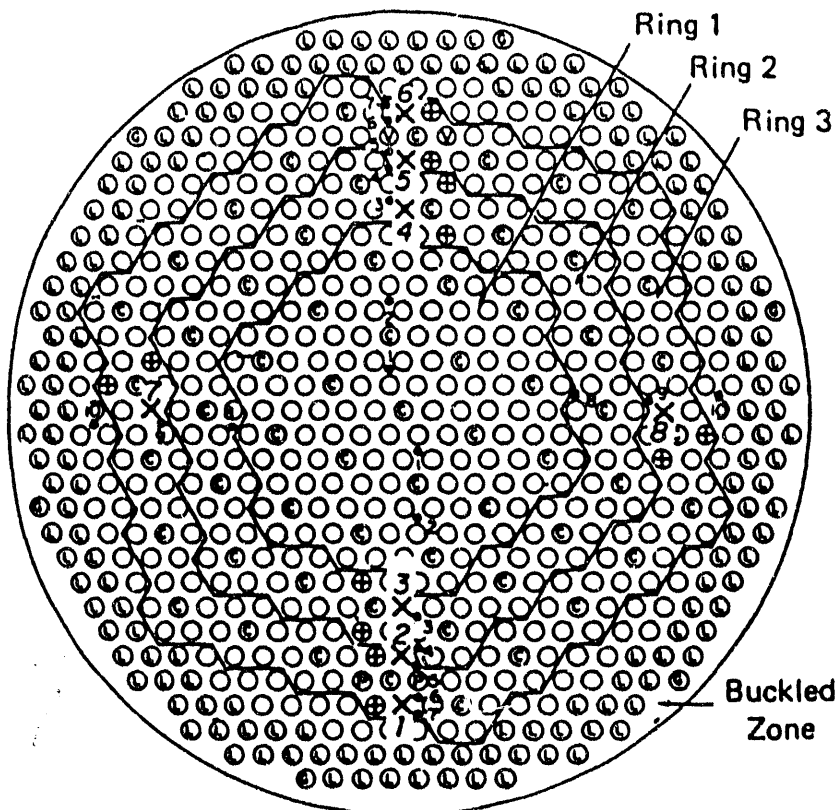
Figure 6.3: Measured and calculated flux tilts from Exp#1.



2-D Experiment #2

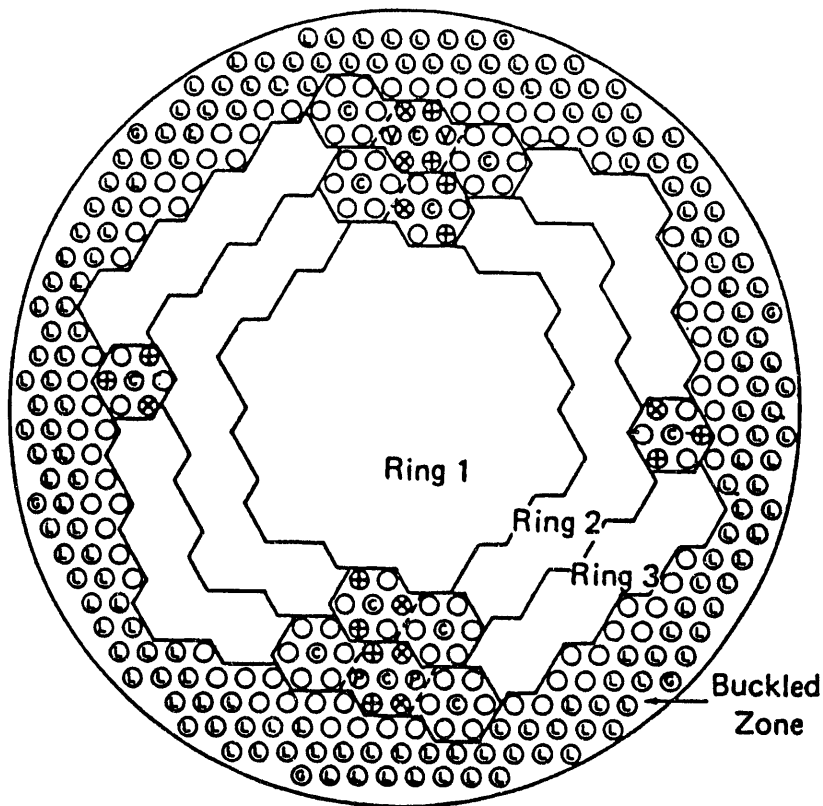
In this second two-dimensional experiment, the control assemblies were loaded so that the radial flux shape was depressed at the center. The reactivity transients were initiated by dropping two perturbation rods into the desired fuel sites. Base flux distribution was also measured by gold pin activation method but the flux tilts were measured by eight detectors placed in the actual fuel sites. Figures 6.4 and 6.5 show the experiment geometry and the TRIMHX calculation geometry. Figure 6.6 shows the measured and calculated flux tilts. Again, due to computing cost, TRIMHX was used to determine the calculated flux tilt up to 90% of the asymptotic value and GRIMHX was used to determine flux tilt at the asymptotic value.

Figure 6.4: Preparation of perturbation, dummy sites, and location of detectors and gold pins in Exp#2.



- Fuel
- ⊙ Control
- ⊕ Lithium
- ⊖ Vacancy
- ⊙ Thimble - no rod
- ⊙ Thimble - with ^{235}U rod
- ⊗ ^{10}B ion chamber inside dry well in fuel element
- ⊕ Fuel element with dry well but no detector
- Gold pin location

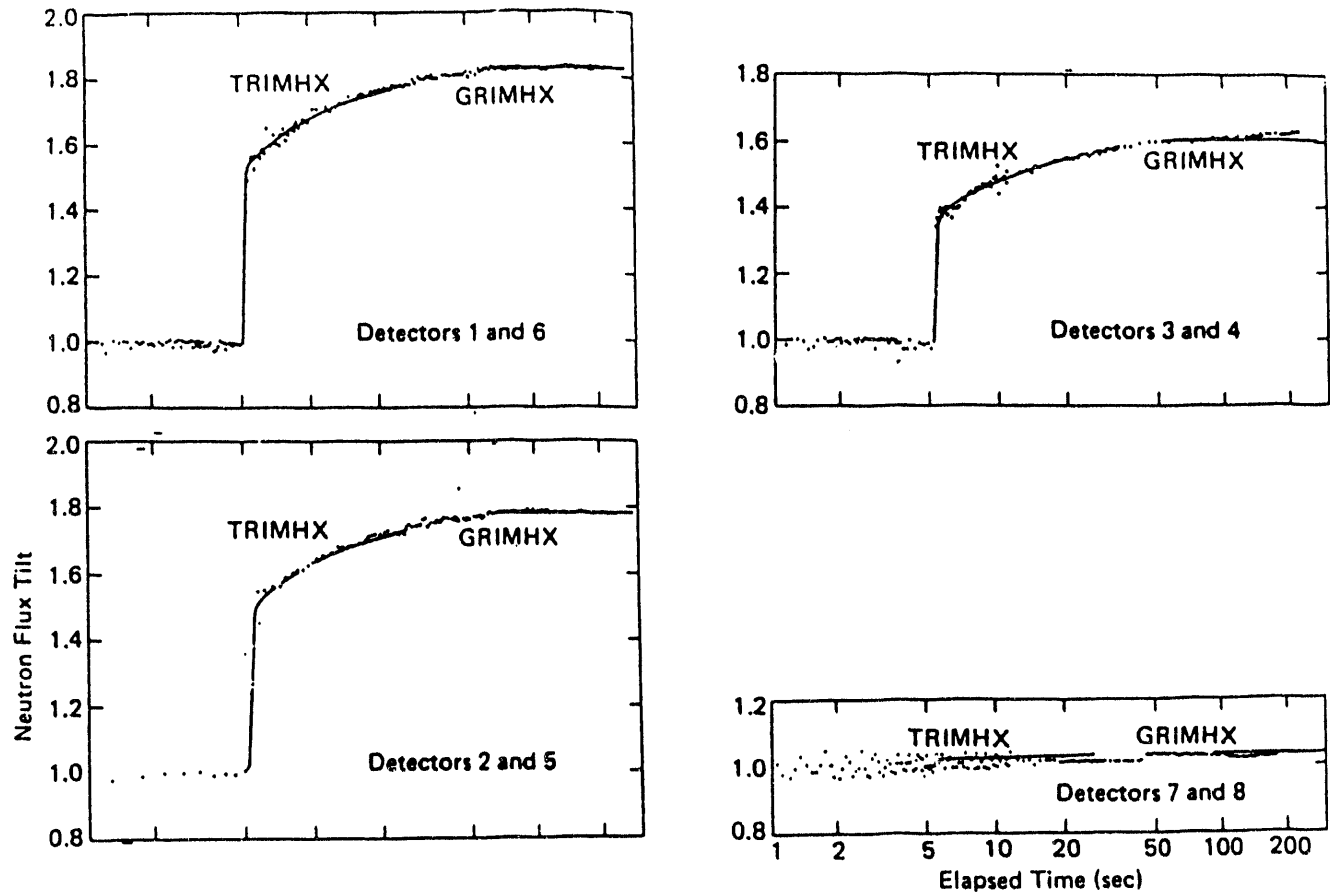
Figure 6.5: Geometry of TRIMHX calculations of Exp#2.



- Fuel
- ⊙ Control
- ⊙ Lithium
- ⊙ Vacancy
- ⊙ Thimble - no rod
- ⊙ Thimble - with ^{235}U rod
- ⊗ ^{10}B ion chamber inside dry well in fuel element
- ⊕ Fuel element with dry well but no detector



Figure 6.6: Measured and calculated flux tilts from Exp#2.



Overall, the tilt between the detector pairs resulting from the reactivity insertion has been well represented by TRIMHX/GRIMHX calculations. For Experiment #1, the largest discrepancy (~ 4%) of the outer detector pair (1 and 4) flux tilt is due to the interstitial locations of the detectors. Since there is a strong variation of flux across the dummy sites and TRIMHX edits the product of cell flux and volume instead of the local value of the interstitial space, large discrepancy at this location is expected. For Experiment #2, since there is no interstitial position of the detectors but all detectors were placed in the selected fuel cells, the agreement of the measured and calculated values are excellent.



VI.2 THREE-DIMENSIONAL EXPERIMENTS

3-D Experiment #1

This is a center perturbation problem in which the transient was initiated by the insertion of three perturbation rods simultaneously into the three dry lithium-aluminum thimbles at the radial center of the reactor core. Each perturbation rod contained a column of ^{235}U slugs in the bottom and a column of lithium slugs in the top. The induced transient flux shapes were distorted axially and radially but retained azimuthal symmetry. In this experiment, the space-time effects of the delayed neutron holdback was relatively small as shown by the small difference between tilts at the end of rod insertion (~5.1 seconds) and the asymptotic tilts.

Figures 6.7 show the experiment geometry. Figures 6.8, 6.9, and 6.10 show the measured and calculated values of axial, radial, and diagonal flux tilts.

Figure 6.7a: Face map of reactor core.

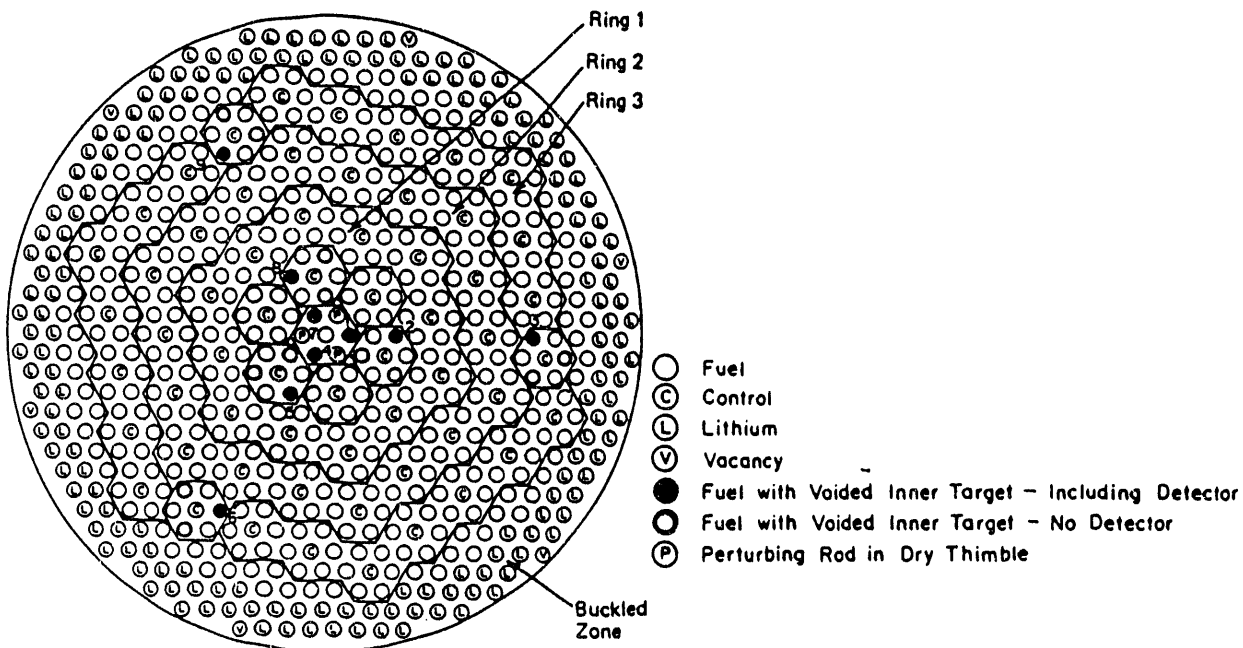




Figure 6.7b: Axial construction and layout of reactor core.

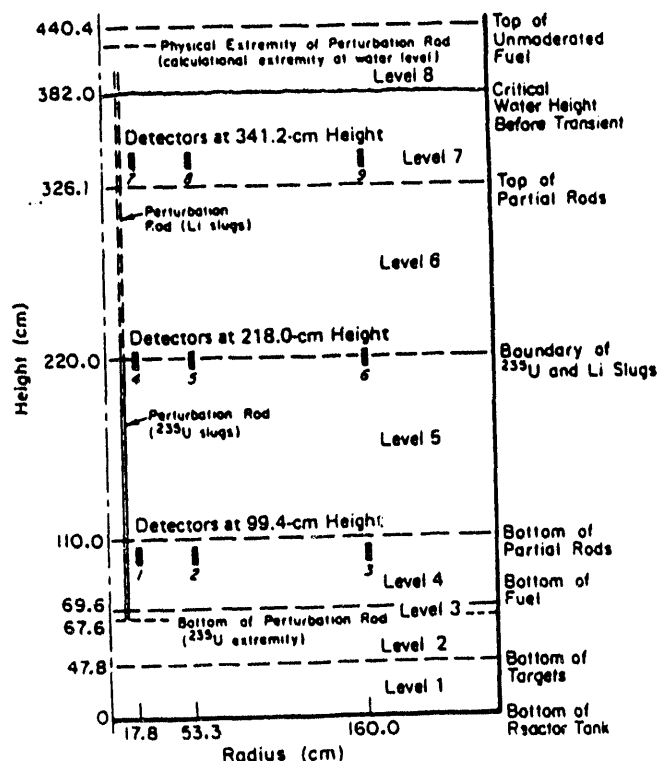
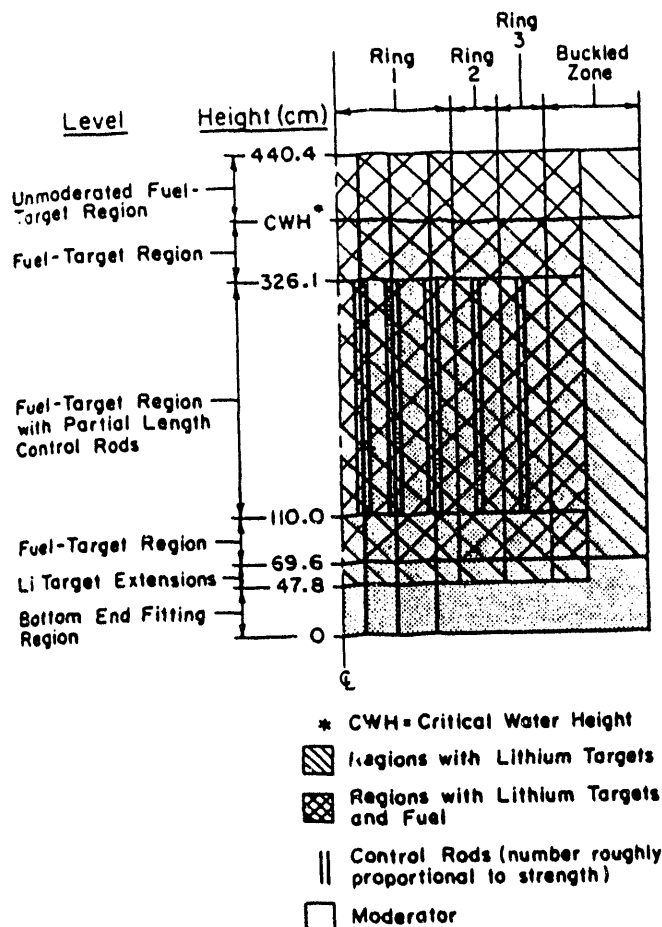




Figure 6.8: Measured and calculated axial flux tilts from Exp#1.

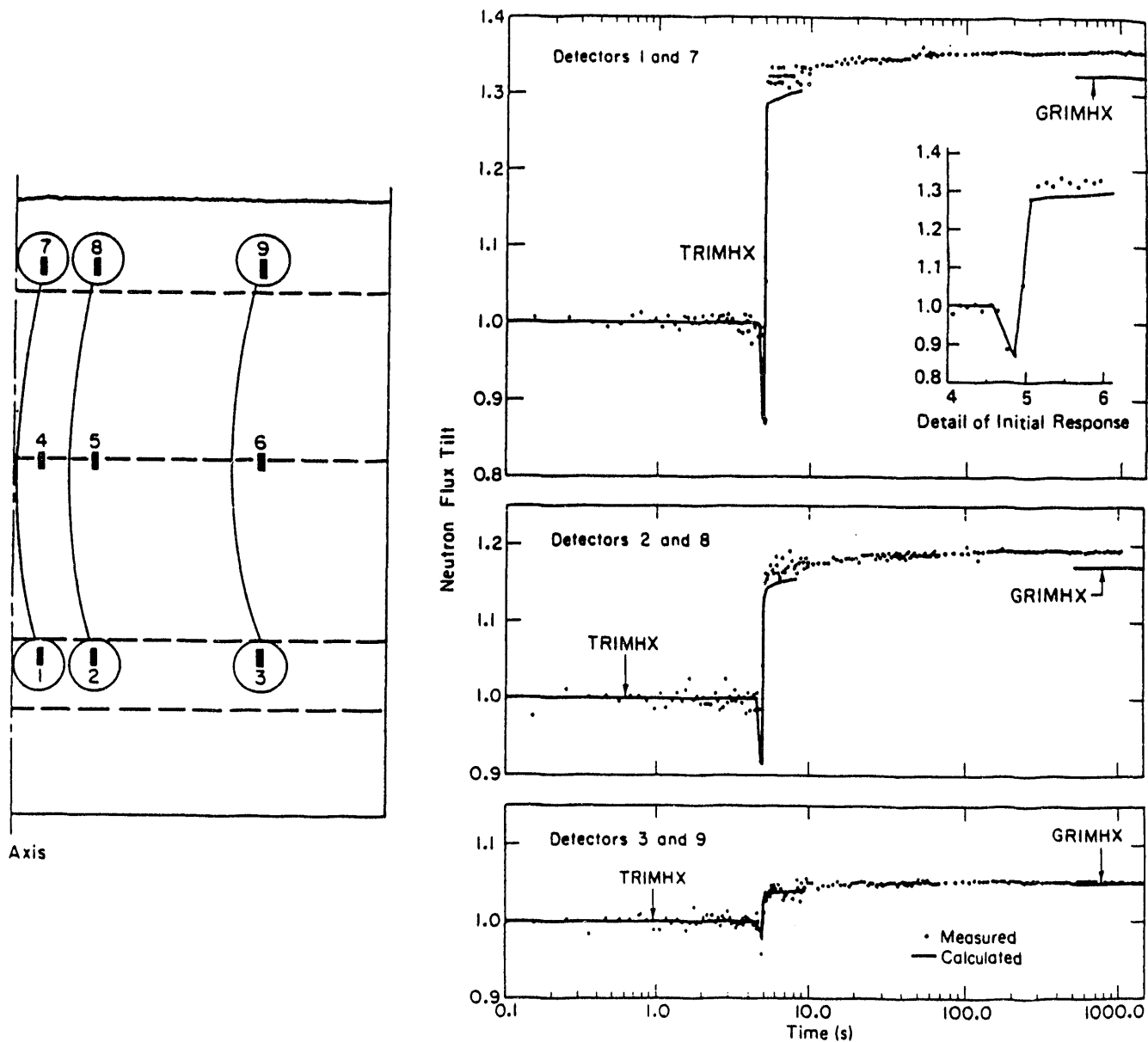




Figure 6.9: Measured and calculated radial flux tilts from Exp#1.

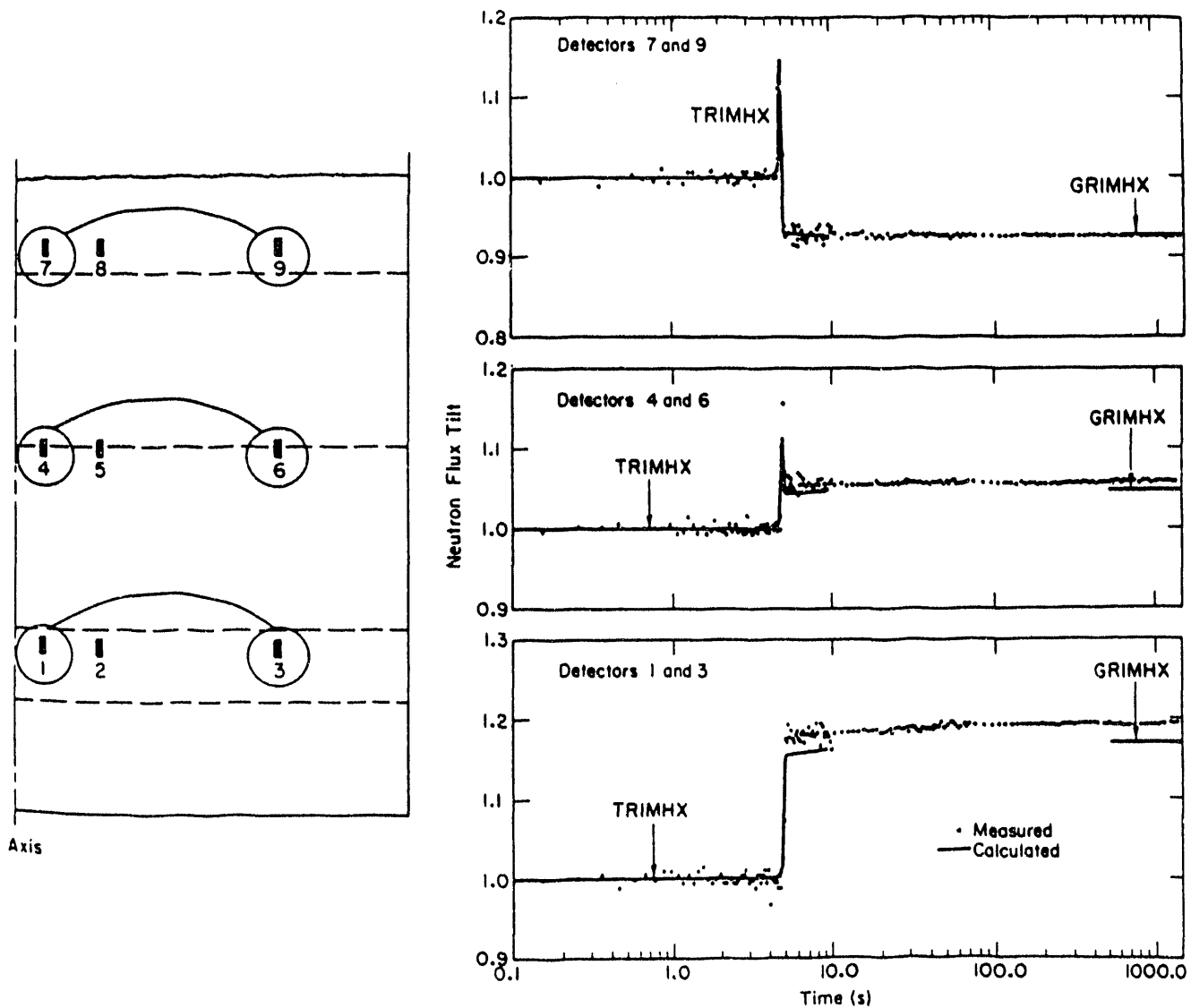
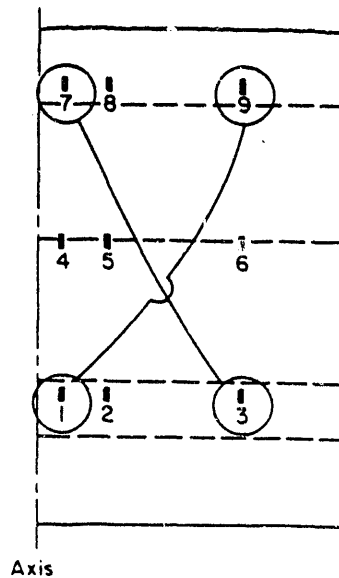
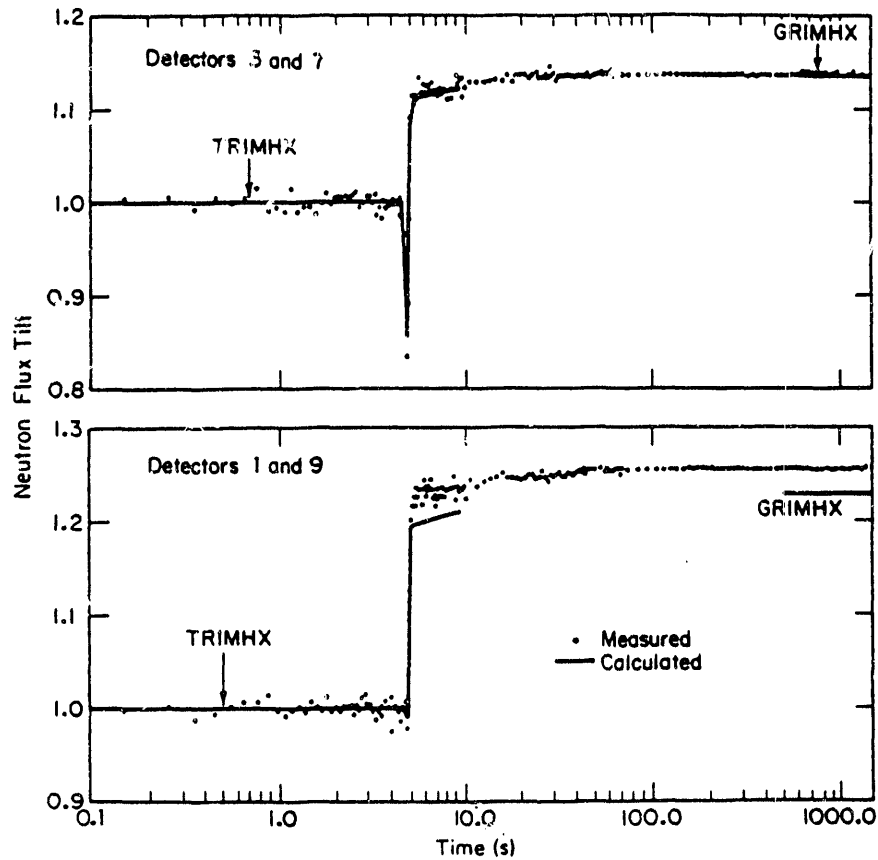




Figure 6.10: Measured and calculated diagonal flux tilts
from Exp#1.





3-D Experiment #2

This is an off-center perturbation problem in which the transient was initiated by the drop of six perturbation rods simultaneously into the six dry lithium-aluminum thimbles. Each perturbation rod contained a column of ^{235}U -bearing slugs in the bottom half of the rod. The induced transient flux shapes were distorted axially, radially, and azimuthally. In this experiment, the space-time effects of the delayed neutron holdback was most pronounced in the radial and azimuthal directions, but again relatively small in the axial tilts.

Figures 6.11 show the experiment geometry. Figures 6.12, 6.13, and 6.14 show the measured and calculated values of axial, radial, and diagonal flux tilts.

Figure 6.11a: Axial layout.

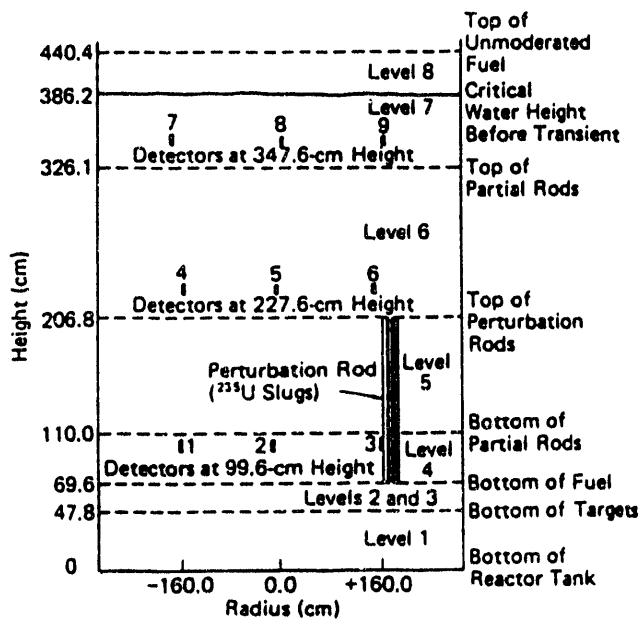


Figure 6.11b: Face map of reactor core.

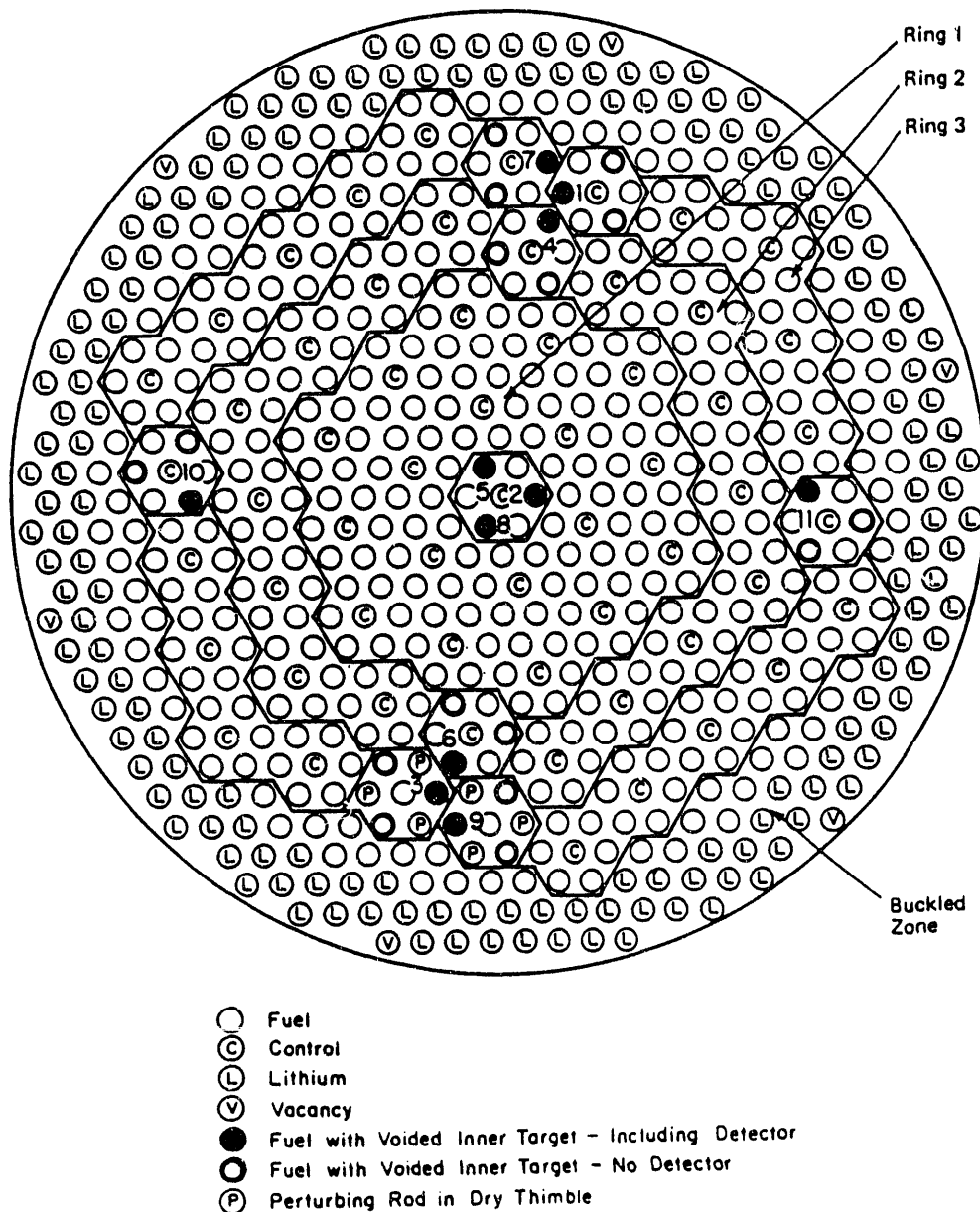


Figure 6.12: Measured and calculated axial flux tilts from Exp#2.

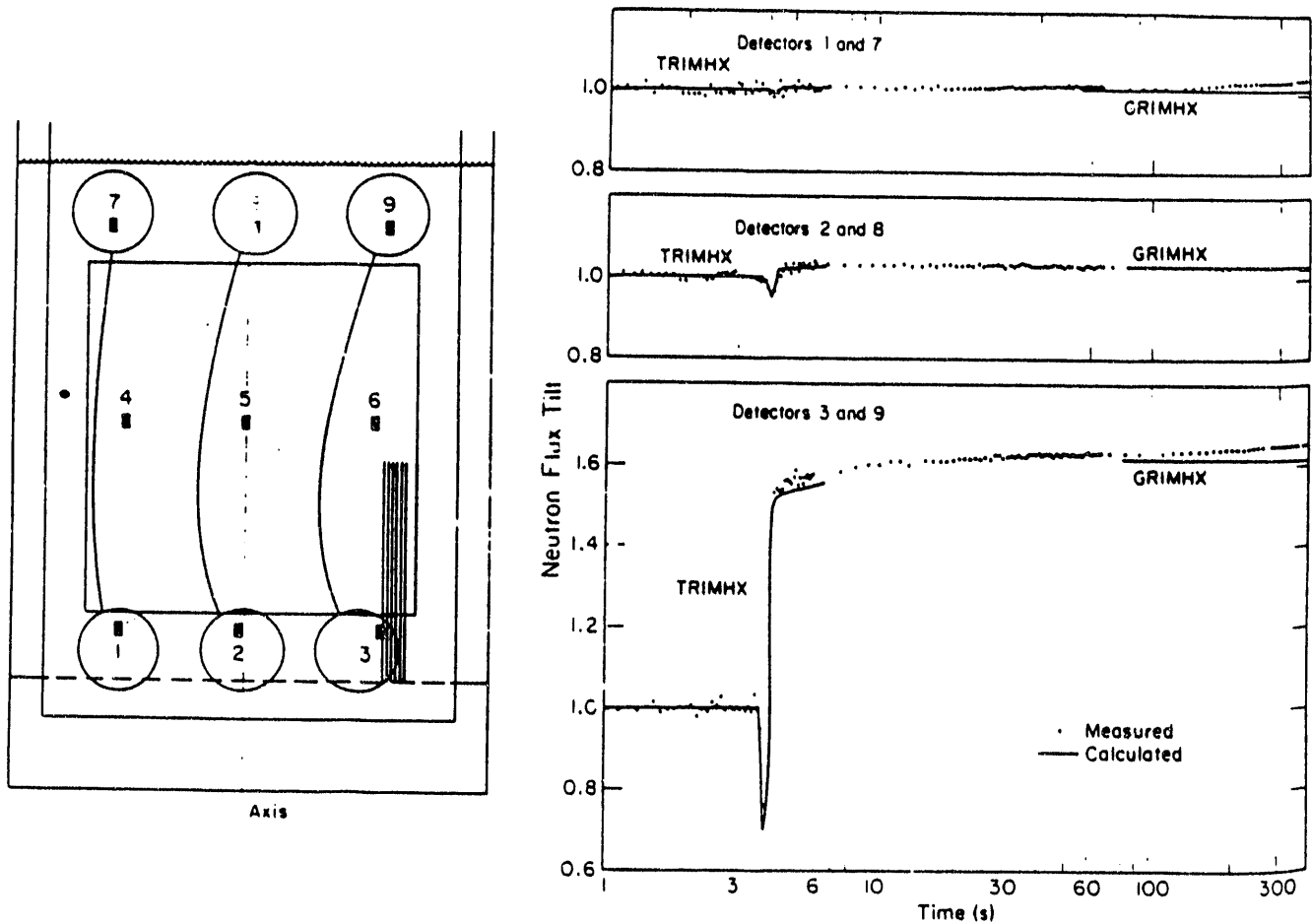




Figure 6.13: Measured and calculated radial flux tilts from
Exp#2.

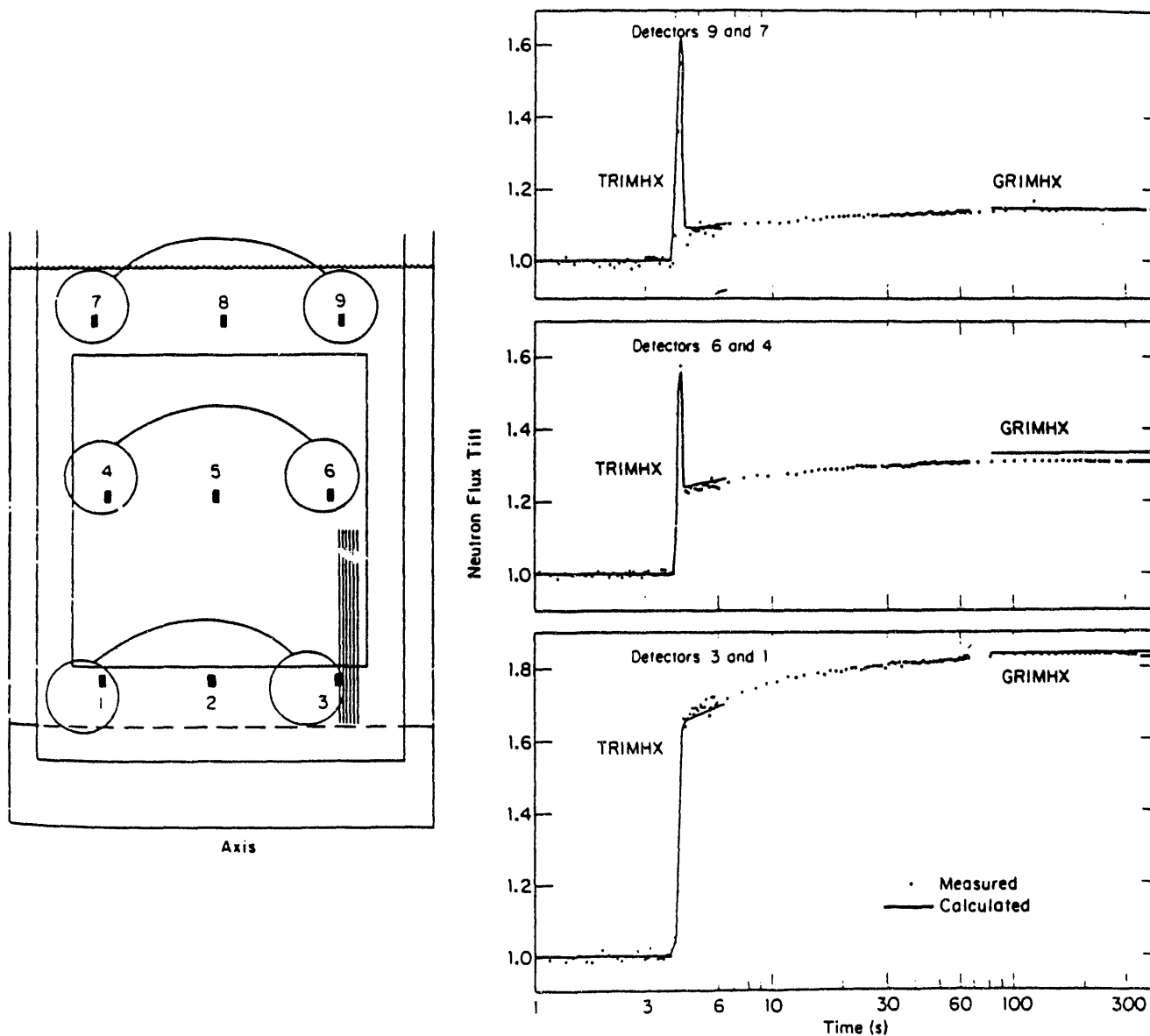
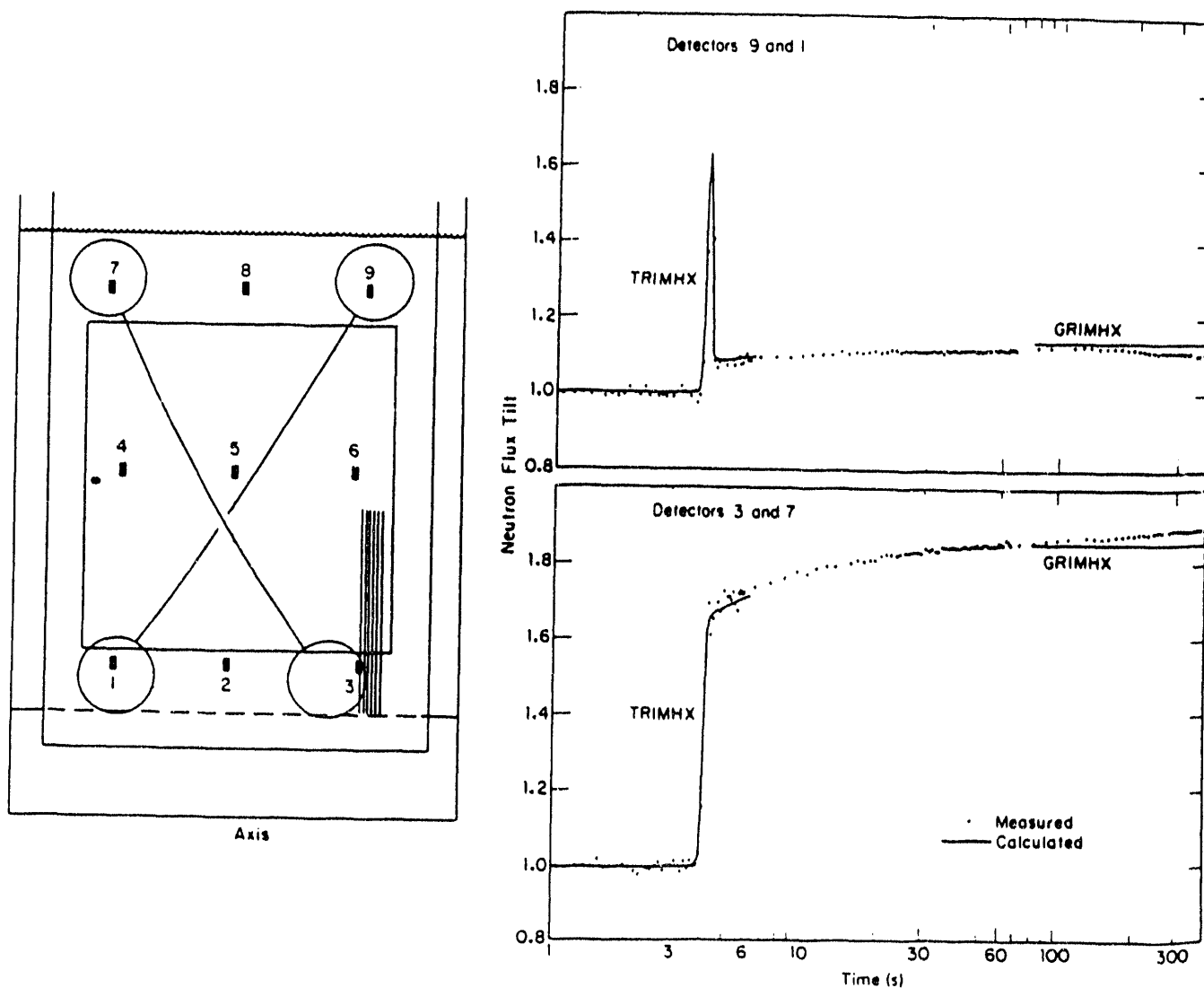




Figure 6.14: Measured and calculated diagonal flux tilts
from Exp#2.





3-D Experiment #3

This is a control rod withdrawal problem in which the experiment geometry is same as for Experiment #1. The transient was initiated by the simultaneous withdrawal of one full length cadmium rod from each control rod assembly in the central region at a rate of 3.05 cm/s. The induced transient flux shapes were distorted axially and radially but retained azimuthal symmetry. In this experiment, the space-time effects of the delayed neutron holdback was relatively small due to the slow rate of withdrawal.

Figure 6.15 shows the experiment geometry. Figures 6.16, 6.17, and 6.18 show the measured and calculated values of axial, radial, and diagonal flux tilts.

Figure 6.15: Geometry of Experiment#3.

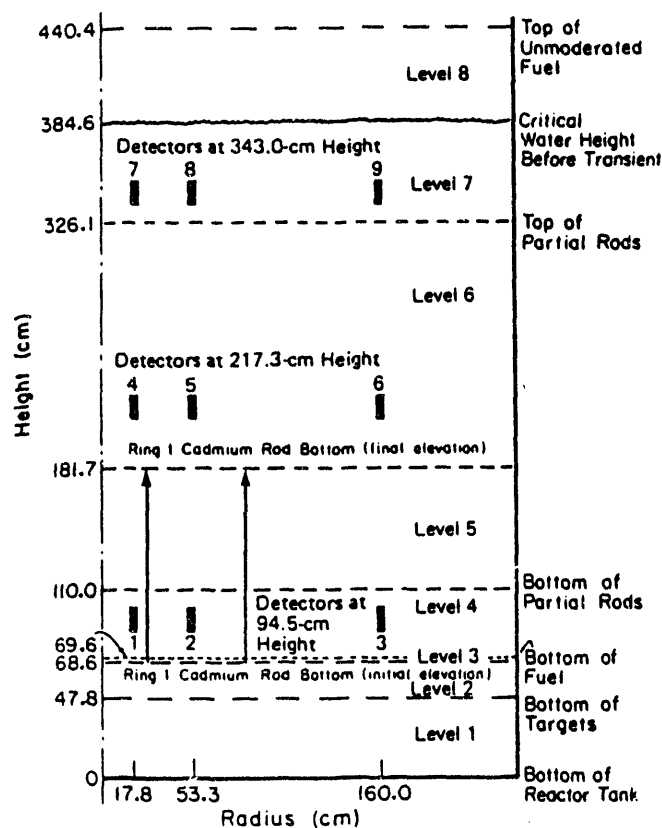




Figure 6.16: Measured and calculated axial flux tilts from Exp#3.

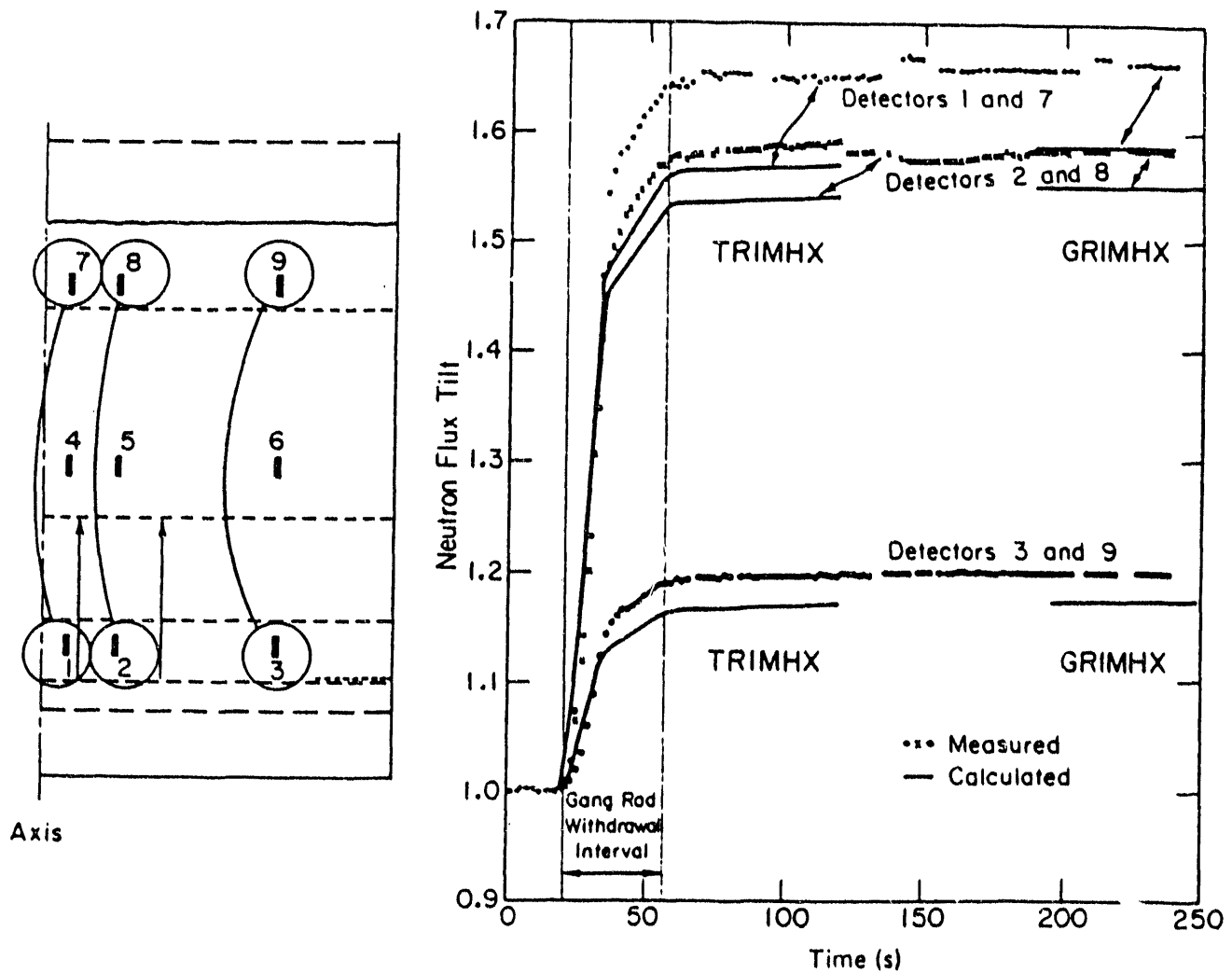




Figure 6.17: Measured and calculated radial flux tilts from Exp#3.

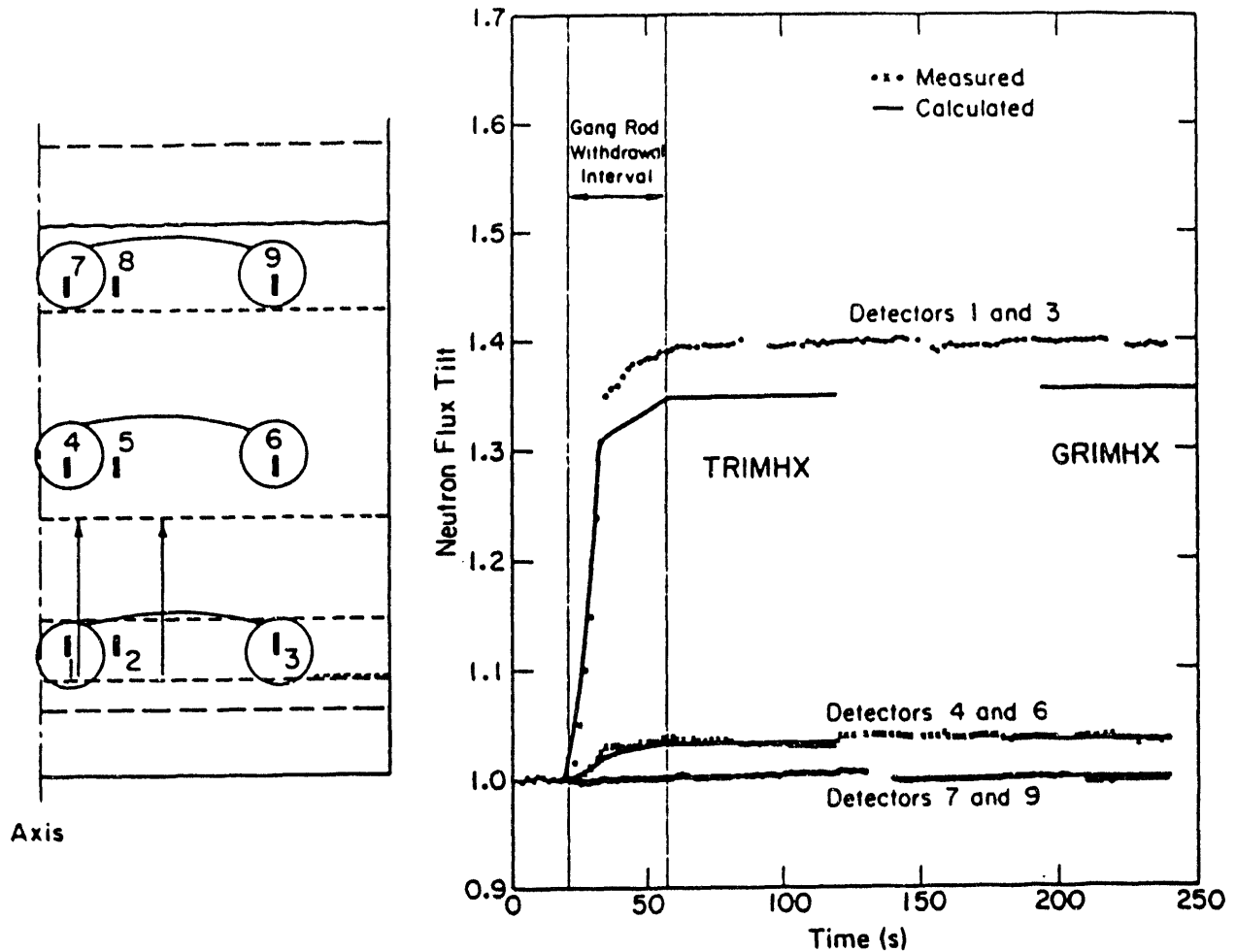
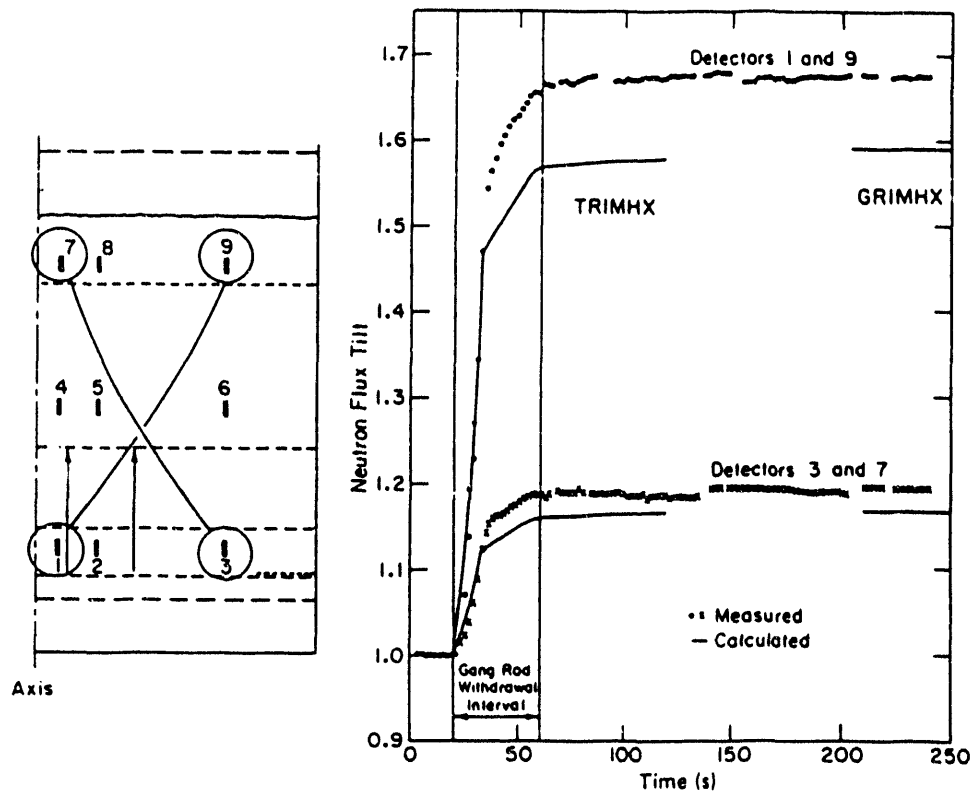


Figure 6.18: Measured and calculated diagonal flux tilts from Exp#3.



Due to the cost of computing time, TRIMHX was used to determine the calculated flux tilt up to 90% of the asymptotic value and GRIMHX was used to determine flux tilt at the asymptotic value. The results from these experiments show that measured tilts are well represented by the TRIMHX calculations. The influence of delayed neutron holdback in the tilts was calculated accurately. The maximum discrepancy between calculated and measured tilts was 2.3% in Experiment #1, 2.4% in Experiment #2, and 4.8% in Experiment #3. In all comparisons, the tilt discrepancy was largest when a detector close to a region of positive reactivity insertion was involved.



VII Adiabatic Model Test Problem

This test problem was performed by W. E. Graves in 1988 to test the adiabatic approximation in case of fast scram against the TRIMHX results¹¹. During the perturbation, diffusion parameters at desired time values were calculated, and an adiabatic approximation model used the static reactor code GRIMHX to calculate the values of k_{eff} and used the point kinetic code AA3¹² to calculate the equivalent reactor powers at these times. Since this adiabatic model assumes the equilibrium of delayed neutron precursors at all times, the computed flux shape changes are expected to be a little larger than would be computed by a space-time code TRIMHX in which the delayed neutron holdback is computed.

The test problem was a two dimensional problem in which the thermal absorption cross sections in three perturbed regions were linearly increased in 50 msec. The calculations were performed for each 5 msec step. Both the GRIMHX and TRIMHX used one point per hex and coarse mesh finite difference option.

The results of TRIMHX and adiabatic approximation are given in Tables 7.1-7.5. The maximum discrepancies between the two methods happened at the end of the perturbation and less than 1%. Detail of the calculations and the input data are given in Reference 11.

Table 7.1: Relative Total Reactor Power

Time (sec)	TRIMHX	Adia. Appro.	Time	TRIMHX	Adia. Appro.
0.05	1.0000	1.0000	0.06	0.9856	0.9899
0.07	0.9596	0.9658	0.08	0.9281	0.9352
0.09	0.8952	0.9026	0.10	0.8630	0.8704
0.20	0.8096	0.8094	0.30	0.8006	0.8035
0.40	0.7953	0.7982	0.50	0.7905	0.7934
1.00	0.7704	0.7732	2.00	0.7407	0.7424
3.00	0.7161	0.7175	4.00	0.6945	0.6958
5.00	0.6753	0.6764			



Table 7.2: Relative Position 1 (central hex) Power

Time (sec)	TRIMHX	Adia. Appro.	Time	TRIMHX	Adia. Appro.
0.05	1.0000	1.0000	0.06	0.9909	0.9979
0.07	0.9707	0.9808	0.08	0.9445	0.9564
0.09	0.9163	0.9292	0.10	0.8883	0.9013
0.20	0.8350	0.8381	0.30	0.8260	0.8320
0.40	0.8206	0.8265	0.50	0.8157	0.8216
1.00	0.7952	0.8007	2.00	0.7649	0.7688
3.00	0.7396	0.7430	4.00	0.7176	0.7205
5.00	0.6978	0.7004			

**Table 7.3: Relative Position 2 (far from perturbation)
Power**

Time (sec)	TRIMHX	Adia. Appro.	Time	TRIMHX	Adia. Appro.
0.05	1.0000	1.0000	0.06	0.9916	0.9981
0.07	0.9721	0.9811	0.08	0.9464	0.9566
0.09	0.9184	0.9297	0.10	0.8905	0.9019
0.20	0.8361	0.8387	0.30	0.8269	0.8326
0.40	0.8214	0.8271	0.50	0.8165	0.8221
1.00	0.7960	0.8012	2.00	0.7656	0.7693
3.00	0.7404	0.7435	4.00	0.7183	0.7210
5.00	0.6985	0.7009			



**Table 7.4: Relative Position 3 (few lattice pitches from
perturbation) Power**

Time (sec)	TRIMHX	Adia. Appro.	Time	TRIMHX	Adia. Appro.
0.05	1.0000	1.0000	0.06	0.9808	0.9827
0.07	0.9490	0.9518	0.08	0.9124	0.9153
0.09	0.8750	0.8777	0.10	0.8390	0.8413
0.20	0.7859	0.7823	0.30	0.7770	0.7766
0.40	0.7718	0.7715	0.50	0.7670	0.7668
1.00	0.7472	0.7473	2.00	0.7181	0.7175
3.00	0.6940	0.6935	4.00	0.6730	0.6725
5.00	0.6541	0.6538			

Table 7.5: Relative Position 4 (next to perturbation) Power

Time (sec)	TRIMHX	Adia. Appro.	Time	TRIMHX	Adia. Appro.
0.05	1.0000	1.0000	0.06	0.9673	0.9672
0.07	0.9224	0.9232	0.08	0.8744	0.8749
0.09	0.8273	0.8271	0.10	0.7831	0.7820
0.20	0.7328	0.7272	0.30	0.7246	0.7219
0.40	0.7196	0.7171	0.50	0.7151	0.7128
1.00	0.6965	0.6947	2.00	0.6691	0.6670
3.00	0.6464	0.6446	4.00	0.6267	0.6251
5.00	0.6091	0.6077			



VIII. Comparisons with Other Codes

VIII.1 COMPARISON WITH DIF3D

In 1991, T. A. Taiwo and H. S. Khalil at Reactor Analysis Division of Argonne National Laboratory tested the performance of the Hex-Z geometry option of the Nodal kinetics DIF3D code by comparing the DIF3D results with the TRIMHX results¹³. Test problem 3 in section IV.3 and test problem 2 in section VI.1 were used for this testing and the results show a very good agreement between the two codes. Figure 8.1 shows the results of test problem 3 in Section IV.3 for case of 87 cents reactivity insertion and Figure 8.2 shows the flux tilts of test problem 2 in Section VI.1. Details of the comparison can be found in Reference 13.

Figure 8.1: Relative Thermal Flux at Central Assembly Midplane vs. Time of TRIMHX and DIF3D

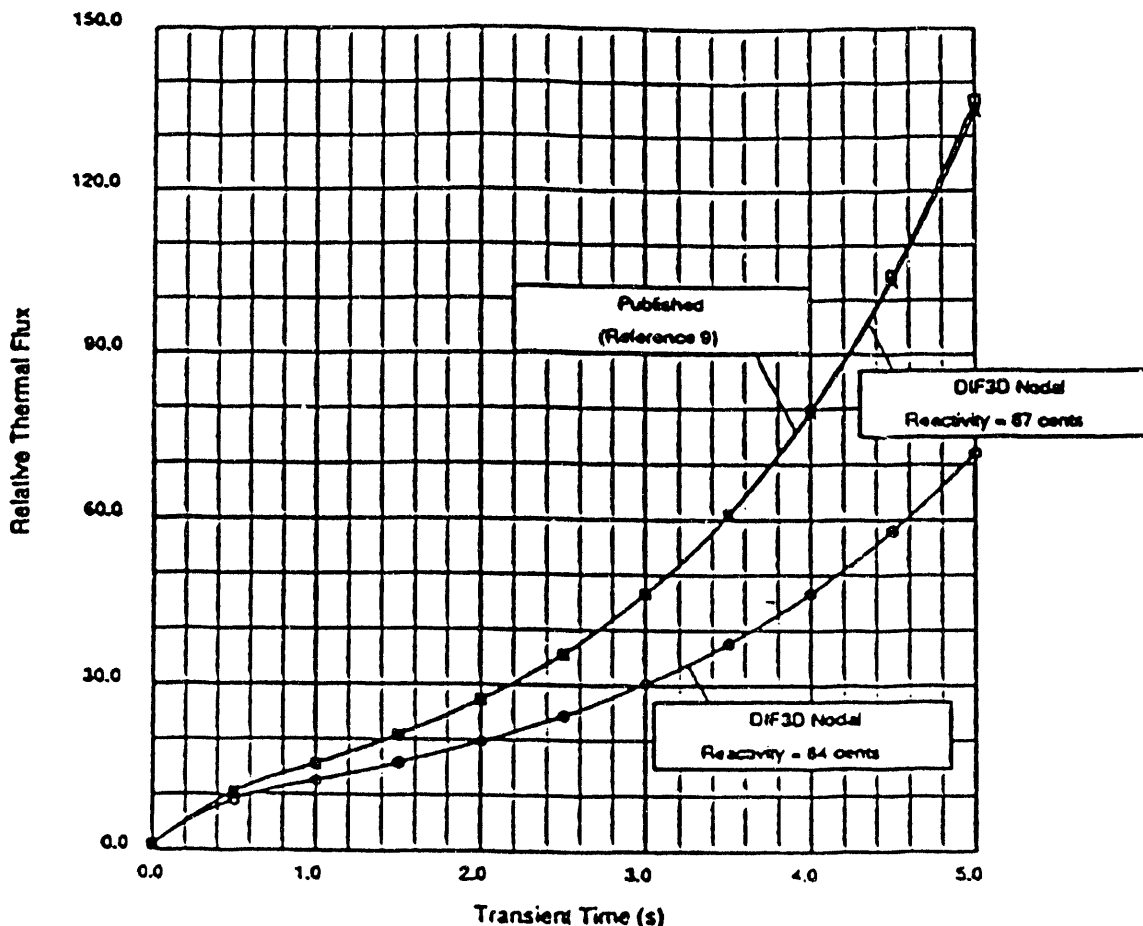
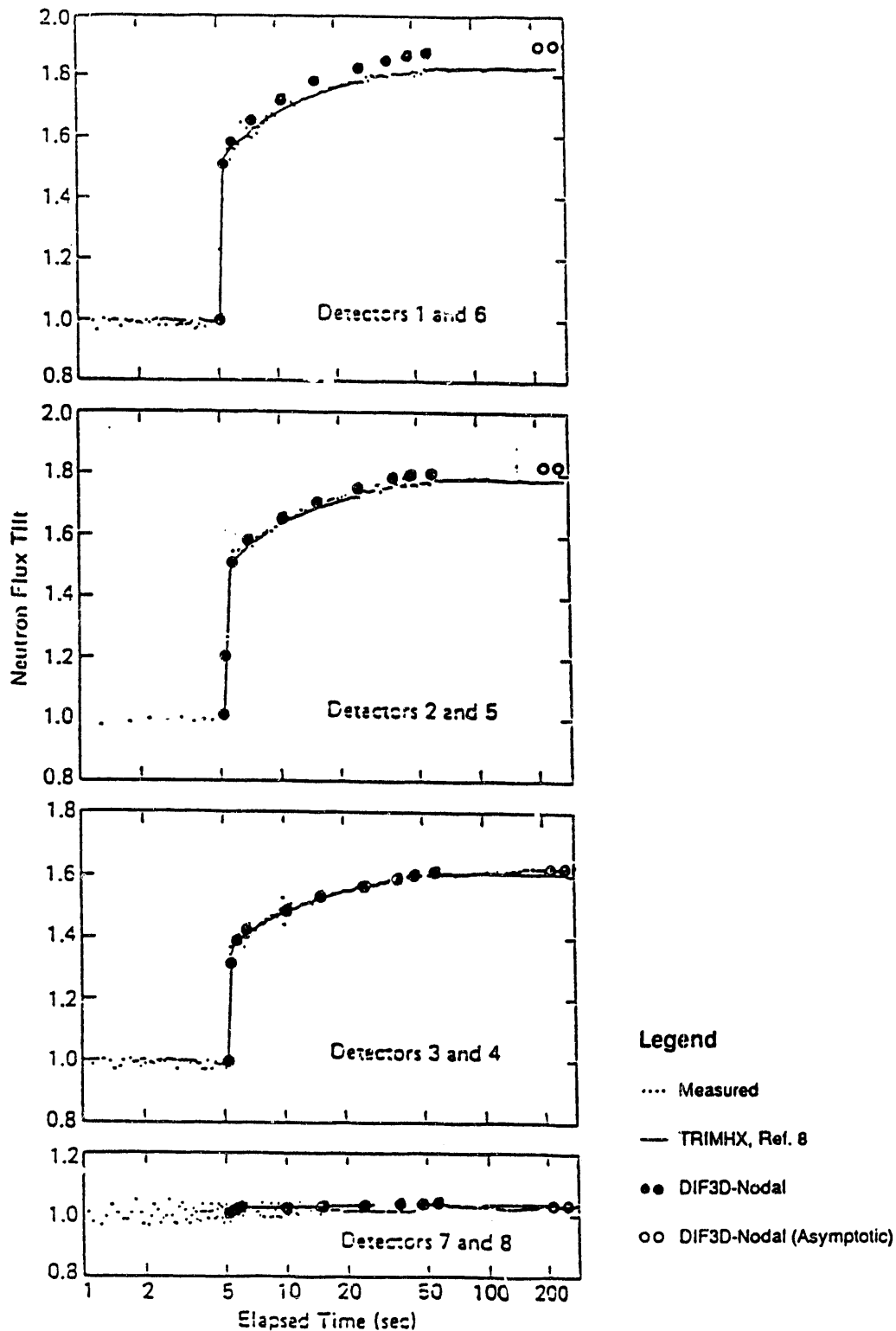




Figure 8.2: Measured and Calculate Flux Tilts





VIII.2 COMPARISON WITH DIF3D AND FX2-TH

A two-dimensional problem in the T. A. Taiwo report¹³ was used to compare the TRIMHX results to the nodal DIF3D and the finite-difference quasi-static FX2-TH¹⁴ results. The original problem configuration is shown in Figure 8.3 and the problem data are listed in Tables 8.1 to 8.3. Since TRIMHX requires closed patch geometry, the problem configuration in TRIMHX run is not exactly identical to the problem configuration in DIF3D and FX2-TH runs; they are different at the reactor core boundary. Figure 8.4 shows the TRIMHX problem configuration and Figure 8.5 shows relative core power versus time from the TRIMHX, DIF3D, and FX2-TH solutions.

Table 8.1: Cross Section Data

Comp	Group	Diffusion	Capure	Fission	Nu*Fission	Scattering
1	1	1.38250	1.63052E-3	9.30113E-4	2.26216E-3	8.16457E-3
	2	0.89752	1.25423E-2	9.51810E-3	2.30623E-2	
2	1	1.38255	1.65429E-3	9.15899E-4	2.22750E-3	8.22378E-3
	2	0.89749	1.27782E-2	9.36233E-3	2.26849E-2	
3	1	1.37442	1.27299E-3	8.80841E-4	2.14281E-3	8.08816E-3
	2	0.88837	8.24602E-3	8.45594E-3	2.04887E-2	
4	1	1.38139	1.43233E-3	9.84814E-4	2.39469E-3	7.76568E-3
	2	0.90367	1.06673E-2	1.09869E-2	2.66211E-2	
5	1	1.30599	2.74282E-4			1.10975E-2
	2	0.85662	4.10254E-5			
6	1	1.29193	1.44797E-6			1.15582E-2
	2	0.81934	7.50003E-5			
7	1	1.06510	1.85500E-3			2.61980E-2
	2	0.32283	3.32600E-2			



Table 8.2: Delayed Neutron Data

Family Number	Delayed Neutron Fraction	Decay Constant (1/sec)
1	1.68000E-04	3.87100E-00
2	8.25700E-04	1.40000E-00
3	3.09920E-03	3.05800E-01
4	1.21090E-03	1.15000E-01
5	1.76570E-03	2.78100E-02
6	1.10900E-04	2.59800E-03

Table 8.3: Additional Data

Lattice Pitch = 17.18 cm (7.0 inches)
Buckling = 2.753E-04 1/cm²

	<u>Group 1</u>	<u>Group 2</u>
Fission Spectrum:	1.0000E-00	0.0000E-00
Neutron Velocity:	1.1286E+07	3.0806E+05

Transient: Thermal absorption cross section of composition 1
reduces 4.5% in 0.2 second.



Figure 8.3: FX2-TH and DIF3D Problem Configuration

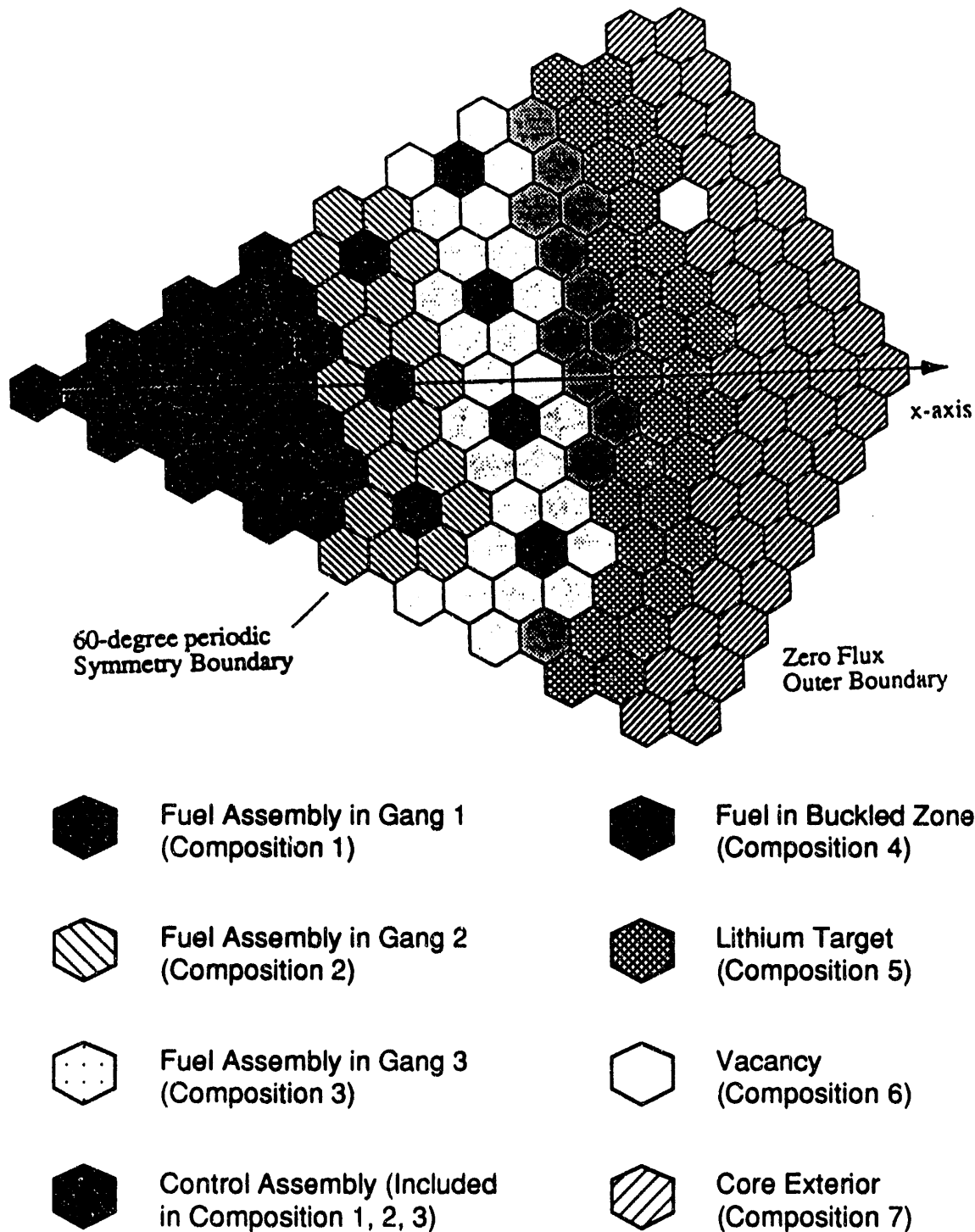
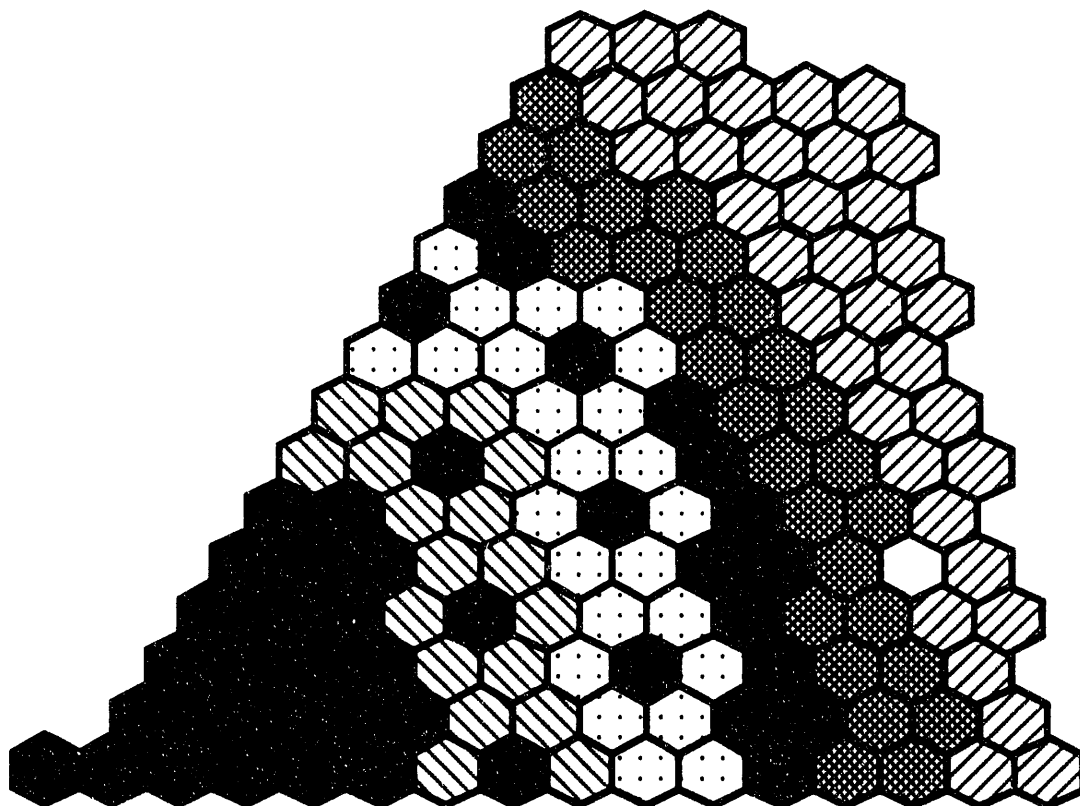




Figure 8.4: TRIMHX Problem Configuration



Fuel Assembly in Gang 1
(Composition 1)



Fuel in Buckled Zone
(Composition 4)



Fuel Assembly in Gang 2
(Composition 2)



Lithium Target
(Composition 5)



Fuel Assembly in Gang 3
(Composition 3)



Vacancy
(Composition 6)



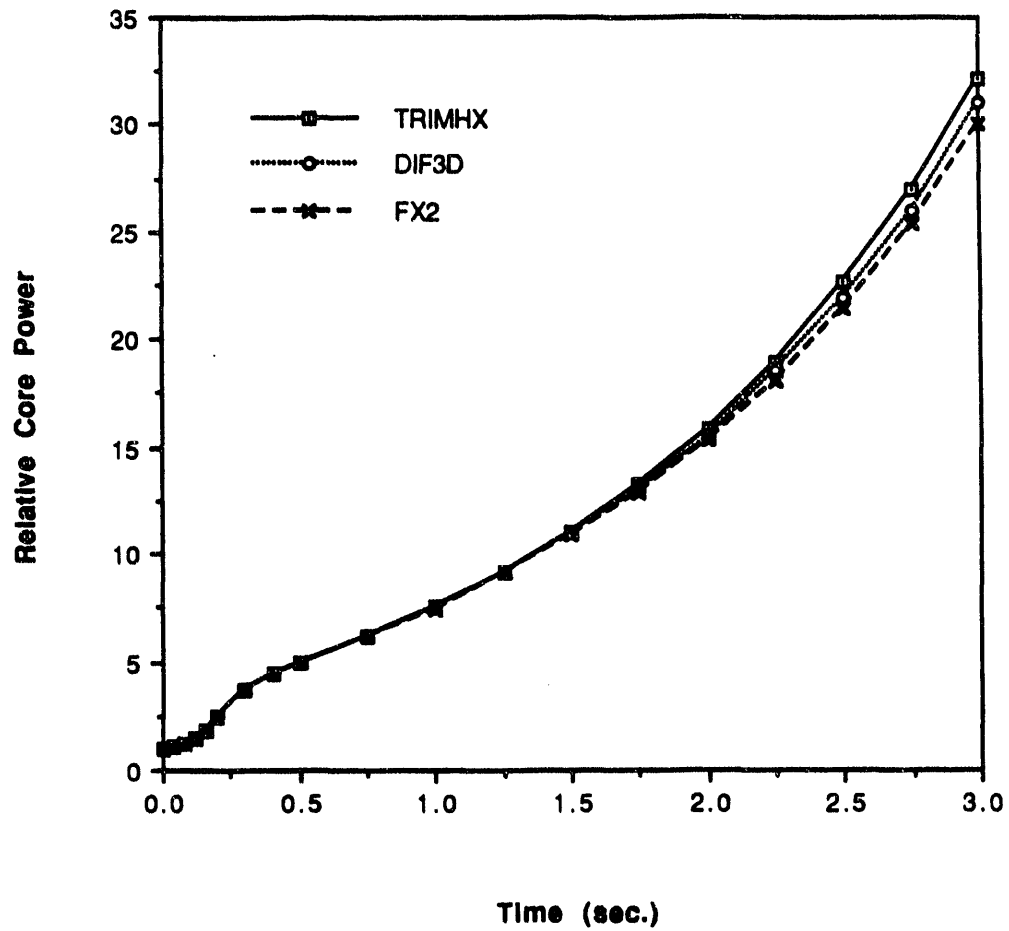
Control Assembly (Included
in Composition 1, 2, 3)



Core Exterior
(Composition 7)



Figure 8.5: Core Power vs. Time





IX Comparisons of Initial TRIMHX to GRIMHX Results

In 1989, the two-dimensional HTGR benchmark problem of GRIMHX was run by both GRIMHX and TRIMHX codes on the IBM by E. F. Trumble to test the static calculations of TRIMHX^{8,15}. The comparison results in Tables 9.1 and 9.2 show the excellent agreements in static calculations of the GRIMHX and TRIMHX codes. Details of the comparison can be found in Reference 15.

Table 9.1: k_{eff} of Static TRIMHX & GRIMHX Calculations

Code	Normalization	k_{eff}
GRIMHX	Power	1.11320
TRIMHX	Power	1.11320
GRIMHX	Production	1.11320
TRIMHX	Production	1.11320

Table 9.2: Fluxes in Center Hex of Static TRIMHX & GRIMHX Calculations

Group	Power Normalization		Production Normalization	
	GRIMHX	TRIMHX	GRIMHX	TRIMHX
1	1.788E19	1.787E19	1.418E2	1.417E2
2	4.071E19	4.062E19	3.228E2	3.223E2
3	5.495E18	5.487E18	4.357E1	4.351E1
4	2.008E19	2.006E19	1.592E2	1.590E2

The same HTGR problem was run for this report by T. T. Le for both J80 (new JOSHUA system¹⁶) versions of GRIMHX and TRIMHX on the VAX to test the initial calculations of the TRIMHX code and to verify the conversion of J70 (old JOSHUA system) TRIMHX to J80 TRIMHX. The comparison results in Tables 9.3 and 9.4 show the excellent agreements in static calculations of the J70 and J80 GRIMHX and TRIMHX codes.



Table 9.3: k_{eff} of Static TRIMHX & GRIMHX Calculations

Code	Normalization	k_{eff}
GRIMHX	Power	1.11320
TRIMHX	Power	1.11320
GRIMHX	Production	1.11320
TRIMHX	Production	1.11320

Table 9.4: Fluxes in Center Hex of Static TRIMHX & GRIMHX Calculations

Group	Power Normalization	Production Normalization		
	GRIMHX	TRIMHX	GRIMHX	TRIMHX
1	1.788E19	1.789E19	2.368E2	2.369E2
2	4.072E19	4.072E19	5.392E2	5.392E2
3	5.496E18	5.496E18	7.277E1	7.277E1
4	2.008E19	2.008E19	2.659E2	2.659E2

Another three-dimensional GRIMHX test problem was run for this report by T. T. Le. Again, the comparison results in Tables 9.5 and 9.6 show the excellent agreements in static calculations of the GRIMHX and TRIMHX codes.

Table 9.5: k_{eff} of Static TRIMHX & GRIMHX Calculations

Code	Normalization	k_{eff}
GRIMHX	Power	0.98759
TRIMHX	Power	0.98758
GRIMHX	Production	0.98759
TRIMHX	Production	0.98758



Table 9.6: Fluxes in Center Hex of Static TRIMHX & GRIMHX Calculations

Group	Power Normalization		Production Normalization	
	GRIMHX	TRIMHX	GRIMHX	TRIMHX
1	1.189E18	1.189E18	1.567E01	1.567E01
2	9.666E17	9.669E17	1.274E01	1.274E01

X CONCLUSIONS

TRIMHX has been verified and validated by comparing the results of test problems to the exact solutions, measured data, and other codes' calculated results. For the initial k_{eff} , initial flux distributions, and transient flux distributions, TRIMHX solutions show very good agreements with other results. It is the conclusion of this study that TRIMHX correctly implemented the theory and that TRIMHX is certified for use in production calculations.

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