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Vepco

NORTH ANNA UNIT 2, CYCLE 4 STARTUP PHYSICS TEST REPORT

NUCLEAR OPERATIONS DEPARTMENT

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Virginia Electric and Power Company

VEP-NOS-14

NORTH ANNA UNIT 2, CYCLE 4
STARTUP PHYSICS TEST REPORT

by

B. D. Mann

Reviewed By:

C. A. Ford

C. A. Ford, Senior Engineer
Nuclear Fuel Operation

Approved By:

C. T. Snow

C. T. Snow, Supervisor
Nuclear Fuel Operation

Operations and Maintenance Support Subsection
Nuclear Operations Department
Virginia Electric and Power Company
Richmond, Virginia

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The author would like to acknowledge the cooperation of the North Anna Power Station staff in performing the tests documented in this report.

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PREFACE

The purpose of this report is to present the analysis and evaluation of the physics tests which were performed to verify that the North Anna 2, Cycle 4 core could be operated safely, and to make an initial evaluation of the performance of the core. It is not the intent of this report to discuss the particular methods of testing or to present the detailed data taken. Standard test techniques and methods of data analysis were used. The test data, results, and evaluations, together with the detailed startup procedures, are on file at the North Anna Power Station. Therefore, only a cursory discussion of these items is included in this report. The analyses presented includes a brief summary of each test, a comparison of the test results with design predictions, and an evaluation of the results.

The North Anna 2, Cycle 4 Startup Physics Tests Results and Evaluation Sheets have been included as an appendix to provide additional information on the startup tests results. Each data sheet provides the following information: 1) test identification, 2) test conditions (design), 3) test conditions (actual), 4) test results, 5) acceptance criteria, and 6) comments concerning the test. These sheets provide a compact summary of the startup tests results in a consistent format. The design test conditions and design values of the measured parameters were completed prior to startup physics testing. The entries for the design values were based on the calculations performed by Vepco's Nuclear Engineering Group[1]. During the tests, the data sheets were used as guidelines both to verify that the proper test conditions were met and to facilitate the preliminary comparison between measured and predicted test results, thus enabling a quick identification of possible problems occuring during the tests. The Appendix to this report contains the final completed and approved version of the Startup Physics Tests Results and Evaluation Sheets.

Section 1

INTRODUCTION AND SUMMARY

On August 2, 1984, Unit No. 2 of the North Anna Power Station was shut down for its third refueling. During this shutdown, 64 of the 157 fuel assemblies in the core were replaced with fresh fuel assemblies. The core loading pattern and the design parameters for each batch are shown in Figure 1.1. Fuel assembly burnups are given in Figure 1.2. The incore instrumentation locations are identified in Figure 1.3. Figure 1.4 identifies the location and number of burnable poison rods in the Cycle 4 core. Figure 1.5 identifies the location and number of control rods in the Cycle 4 core.

On November 2, 1984, at 0820, the fourth cycle core achieved initial criticality. Following criticality, startup physics tests were performed as outlined in Table 1.1. A summary of the results of these tests follows:

1. The drop time of each control rod was confirmed to be within the 2.2 second limit of the North Anna Technical Specifications[2].
2. Individual control rod bank worths for all control rod banks were measured using the rod swap technique[3] and were found to be within 6.3% of the design predictions. (The measured worth of 383 pcm for Control Bank A was only 43 pcm, or 11%, different from the predicted worth.) The sum of the individual control rod bank worths was measured to be within 1.6% of the design prediction. These results are within the design tolerance of ±15% for individual bank worths (±10% for the rod swap reference bank worth) and the design tolerance of ±10% for the sum of the individual control rod bank worths.
3. Critical boron concentrations for two control bank configurations were measured to be within 23 ppm of the design

predictions. These results were within the design tolerances and also met the accident analysis acceptance criterion.

4. The boron worth coefficient was measured to be within 2.7% of the design prediction, which is well within the design tolerance of ±10% and meets the accident analysis criterion.
5. The isothermal temperature coefficient was measured to be within 0.60 pcm/°F of design prediction. This result is within the design tolerance of ±3 pcm/°F and also met the accident analysis acceptance criterion.
6. Core power distributions for various HZP and at-power conditions were generally within 8% of the predicted power distributions. For all maps, the hot channel factors were measured to be within the limits of the Technical Specifications. However, at 50% power, there were violations of the Radial Peaking Factor, Fxy(RTP), surveillance limit, and at 4% power, a quadrant power tilt ratio of 3% was measured. Generally, all measured parameters met their respective design tolerances. All measurement parameters met their respective accident analysis acceptance criteria.

In summary, all startup physics tests results were acceptable. Detailed results, together with specific design tolerances and acceptance criteria for each measurement, are presented in the appropriate sections of this report.

Table 1.1

NORTH ANNA 2 - CYCLE 4 STARTUP PHYSICS TESTS

CHRONOLOGY OF TESTS

Test	Date	Time	Power	Reference Procedure
Hot Rod Drop-Hot Full Flow	11/01/84	2103	HSD	2-PT-17.2
Reactivity Computer Checkout	11/02/84	1141	HZP	2-PT-94.2
Boron Endpoint-ARO	11/02/84	1513	HZP	2-PT-94.3
Temperature Coefficient-ARO	11/02/84	1605	HZP	2-PT-94.4
Bank B Worth	11/02/84	1827	HZP	2-PT-94.5
Boron Endpoint-B In	11/02/84	2352	HZP	2-PT-94.3
Bank D Worth - Rod Swap	11/03/84	0028	HZP	2-PT-94.7
Bank C Worth - Rod Swap	11/03/84	0158	HZP	2-PT-94.7
Bank A Worth - Rod Swap	11/03/84	0333	HZP	2-PT-94.7
Bank SB Worth - Rod Swap	11/03/84	0401	HZP	2-PT-94.7
Bank SA Worth - Rod Swap	11/03/84	0429	HZP	2-PT-94.7
Flux Map - ARO, 4% Power	11/03/84	1101	4%	2-PT-21.1
Flux Map - 50% Power	11/10/84	1150	50%	2-PT-22.2
Flux Map - I/E Calibration	11/12/84	0022	70%	2-PT-22.2
Flux Map - I/E Calibration	11/12/84	0612	75%	2-PT-22.2
Flux Map - I/E Calibration	11/12/84	1044	75%	2-PT-22.2
Flux Map - HFP, Eq. Xenon	11/16/84	0928	100%	2-PT-21.1

Figure 1.1

NORTH ANNA UNIT 2 - CYCLE 4

CORE LOADING MAP

	R	P	N	M	L	K	J	H	G	F	E	D	C	B	A
1							4A2 R32	5A S15	4A2 R52						
2					5A S26	5A S27	6A T22	4A2 R09	6A T34	5A S32	5A S18				
3				5A S33	6A T36	6A T59	4A2 R05	6A T61	4A2 R33	6A T07	6A T60	5A S19			
4			5A S12	5A S07	6A T54	5A S54	6A T46	5A S21	6A T51	5A S46	6A T33	5A S48	5A S47		
5		5A S55	6A T19	6A T32	4A2 R37	6A T20	5A S31	5A S53	5A S24	6A T25	4A2 R28	6A T30	6A T05	5A S17	
6		5A S20	6A T44	5A S04	6A T04	4A2 R47	6A T16	4A2 R19	6A T53	4A2 R10	6A T21	5A S10	6A T56	5A S05	
7	4A2 R44	6A T10	4A2 R01	6A T64	5A S56	6A T09	4A2 R12	6A T24	4A2 R43	6A T12	5A S06	6A T45	4A2 R21	6A T11	4A2 R46
8	5A S09	4A2 R14	6A T47	5A S45	5A S03	4A2 R40	6A T31	3A3 P39	6A T41	4A2 R30	5A S11	5A S14	6A T42	4A2 R26	5A S13
9	4A2 R38	6A T03	4A2 R15	6A T14	5A S34	6A T29	4A2 R17	6A T02	4A2 R50	6A T13	5A S36	6A T27	4A2 R24	6A T17	4A2 R11
10		5A S43	6A T58	5A S49	6A T35	4A2 R13	6A T39	4A2 R36	6A T50	4A2 R08	6A T38	5A S52	6A T55	5A S08	
11		5A S23	6A T52	6A T48	4A2 R25	6A T43	5A S02	5A S38	5A S41	6A T63	4A2 R20	6A T26	6A T08	5A S16	
12			5A S42	5A S44	6A T28	5A S37	6A T18	5A S40	6A T40	5A S35	6A T49	5A S01	5A S29		
13				5A S39	6A T37	6A T62	4A2 R29	6A T01	4A2 R16	6A T23	6A T06	5A S50			
14					5A S30	5A S28	6A T57	4A2 R07	6A T15	5A S51	5A S25				
15							4A2 R03	5A S22	4A2 R02						

--> BATCH
--> ASSEMBLY ID

FUEL ASSEMBLY DESIGN PARAMETERS

	SUB-BATCH			
	3A3	4A2	5A	6A
INITIAL ENRICHMENT (W/O U235)	3.10	3.41	3.59	3.60
BURNUP AT BOC 4 (MWD/MTU)	23252	19242	17121	0
ASSEMBLY TYPE	17X17	17X17	17X17	17X17
NUMBER OF ASSEMBLIES	1	36	56	64
FUEL RODS PER ASSEMBLY	264	264	264	264

Figure 1.2

NORTH ANNA UNIT 2 - CYCLE 4

BEGINNING OF CYCLE FUEL ASSEMBLY BURNUPS

	R	P	N	M	L	K	J	H	G	F	E	D	C	B	A
1							R32 17303	S15 13403	R52 18171						
2					S26 18906	S27 18431	T22 0	R09 13808	T34 0	S32 18395	S18 18691				
3				S33 18386	T36 0	T59 0	R05 16049	T61 0	R33 15806	T07 0	T60 0	S19 18282			
4			S12 18437	S07 13596	T54 0	S54 17382	T46 0	S21 18576	T51 0	S46 17397	T33 0	S48 13917	S47 17980		
5		S55 18686	T19 0	T32 0	R37 21892	T20 0	S31 14811	S53 18178	S24 14972	T25 0	R28 21973	T30 0	T05 0	S17 19164	
6		S20 18119	T44 0	S04 17675	T04 0	R47 23240	T16 0	R19 23565	T53 0	R10 23479	T21 0	S10 17466	T56 0	S05 18222	
7	R44 17474	T10 0	R01 16352	T64 0	S56 15321	T09 0	R12 23458	T24 0	R43 24627	T12 0	S06 14689	T45 0	R21 15964	T11 0	R46 17449
8	S09 13743	R14 13723	T47 0	S45 18026	S03 18219	R40 23275	T31 0	P39 23252	T41 0	R30 23234	S11 18694	S14 18191	T42 0	R26 13713	S13 13452
9	R38 17640	T03 0	R15 15747	T14 0	S34 14744	T29 0	R17 23280	T02 0	R50 23288	T13 0	S36 14746	T27 0	R24 16235	T17 0	R11 17087
10		S43 18618	T58 0	S49 17277	T35 0	R13 23656	T39 0	R36 23065	T50 0	R08 23565	T38 0	S52 17409	T55 0	S08 18490	
11		S23 18914	T52 0	T48 0	R25 22081	T43 0	S02 15100	S38 17997	S41 14899	T63 0	R20 21994	T26 0	T08 0	S16 18896	
12			S42 18412	S44 13648	T28 0	S37 17625	T18 0	S40 17943	T40 0	S35 17367	T49 0	S01 14351	S29 18262		
13				S39 18138	T37 0	T62 0	R29 16051	T01 0	R16 16240	T23 0	T06 0	S50 18230			
14					S30 19177	S28 18547	T57 0	R07 13559	T15 0	S51 18315	S25 18825				
15							R03 17371	S22 13445	R02 17399						

--> ASSEMBLY ID
--> ASSEMBLY BURNUP

Figure 1.3

NORTH ANNA UNIT 2 - CYCLE 4

INCORE INSTRUMENTATION LOCATIONS

R	P	N	M	L	K	J	H	G	F	E	D	C	B	A	
							MD	TC							1
						TC		TC	MD						2
			MD TC		TC	MD	MD TC		TC		MD TC				3
		TC		MD			MD		MD	TC					4
		MD		MD	TC	MD	TC		TC	MD	MD TC		MD TC		5
		TC		MD TC			MD	TC	MD						6
TC	TC	MD				MD		MD		TC	MD		MD		7
MD	TC	MD TC		MD TC	TC		TC	TC	MD	TC		MD TC	MD	TC	8
			TC	MD			TC	MD	MD TC					MD	9
		MD TC				MD TC				TC	MD		MD TC		10
			TC	MD	TC		MD TC		MD TC	MD					11
		MD		TC		MD TC				TC	MD	MD TC			12
							MD TC		MD TC						13
				MD TC				MD		TC					14
						MD	TC	TC							15

MD - Movable Detector
TC - Thermocouple

Figure 1.4

NORTH ANNA UNIT 2 - CYCLE 4

BURNABLE POISON AND SOURCE ASSEMBLY LOCATIONS

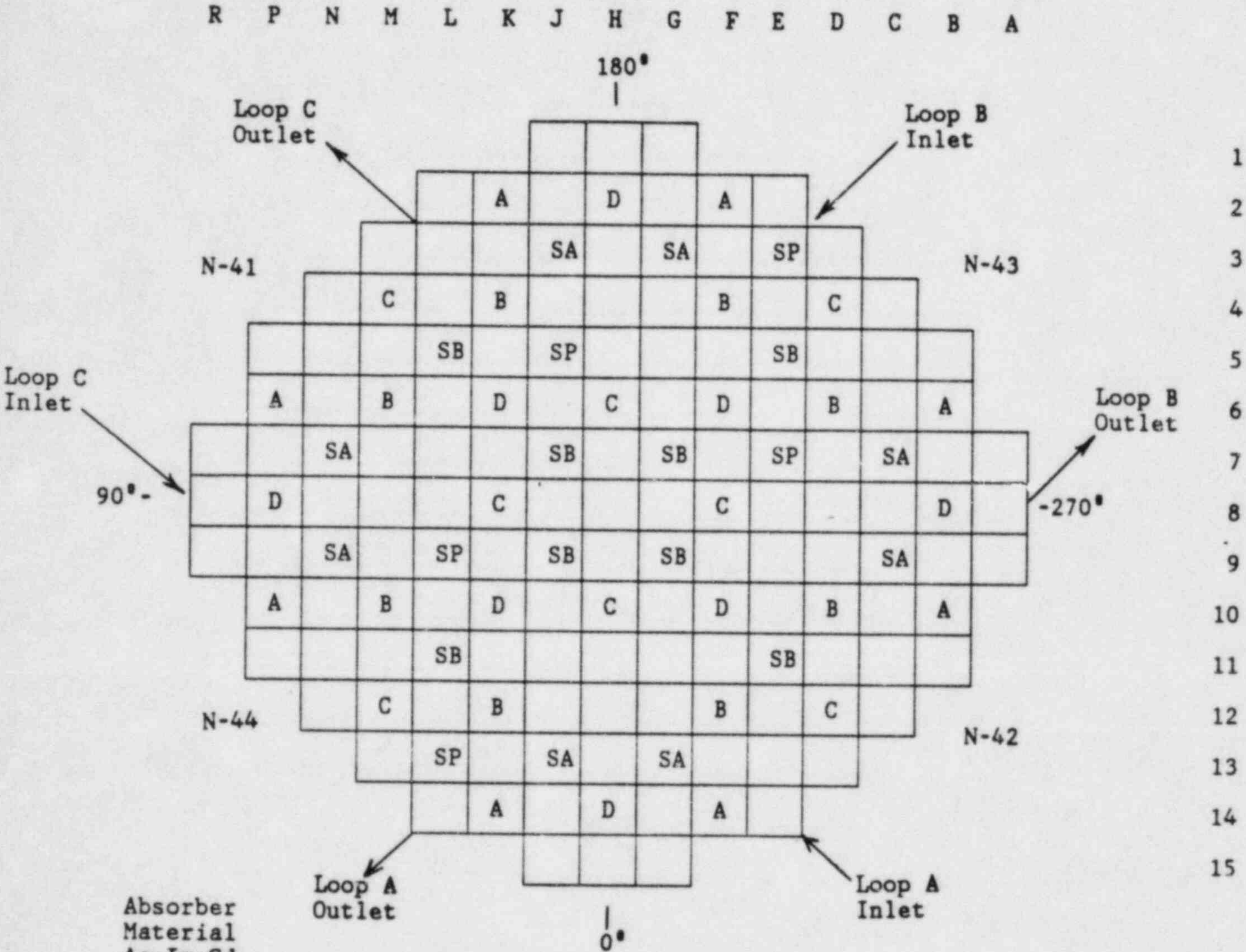
R	P	N	M	L	K	J	H	G	F	E	D	C	B	A	
															1
						4P		4P							2
				4P	16P		20P		16P	4P					3
				16P		20P	SS	20P		16P					4
		4P	16P		20P	4P		4P	20P		16P	4P			5
		16P		20P		16P		16P		20P		16P			6
	4P		20P	4P	16P		16P		16P	4P	20P		4P		7
		20P				16P		16P			SS	20P			8
	4P		20P	4P	16P		16P		16P	4P	20P		4P		9
		16P		20P		16P		16P		20P		16P			10
		4P	16P		20P	4P		4P	20P		16P	4P			11
				16P		20P	SS	20P		16P					12
				4P	16P		20P		16P	4P					13
						4P		4P							14
															15

944 --- FRESH BURNABLE POISON RODS
SS --- SECONDARY SOURCE

Figure 1.5

NORTH ANNA UNIT 2 - CYCLE 4

CONTROL ROD LOCATIONS



Absorber
Material
Ag-In-Cd

Function	Number of Clusters
Control Bank D	8
Control Bank C	8
Control Bank B	8
Control Bank A	8
Shutdown Bank SB	8
Shutdown Bank SA	8
SP (Spare Rod Locations)	8

CONTROL ROD DROP TIME MEASUREMENTS

The drop time of each control rod was measured at hot RCS conditions in order to confirm satisfactory operation and to verify that the rod drop times were less than the maximum allowed by the Technical Specifications. The control rod drop time measurements were run with the RCS at hot, full flow conditions (547 °F, 2235 psig) and are described below.

The rod drop time measurements were performed by first withdrawing a rod bank to its fully withdrawn position, and then removing the movable gripper coil fuse and stationary gripper coil fuse for the test rod. This allows the rod to drop into the core as it would in a normal plant trip. The data recorded during this test are the stationary gripper coil voltage, the LVDT (Linear Variable Differential Transformer) primary coil voltage and a 60Hz timing trace which are recorded via a visicorder. The rod drop time to the dashpot entry and to the bottom of the dashpot are determined from this data. Figure 2.1 provides an example of the data that is recorded during a rod drop time measurement.

As shown in Figure 2.1, the initiation of the rod drop is indicated by the decay of the stationary gripper coil voltage when the stationary coil fuse is removed. A voltage is then induced in the LVDT primary coil as the rod drops. The magnitude of this voltage is a function of the rod velocity. When the rod enters the dashpot section of its guide tube, the velocity slows causing a voltage decrease in the LVDT coil. The LVDT voltage then reaches a minimum as the rod reaches the bottom of the dashpot. Subsequent variations in the trace are caused by the rod bouncing. This procedure was repeated for each control rod.

The measured drop times for each control rod are recorded on Figure 2.2. The slowest, fastest, and average drop times are summarized in Table 2.1. Technical Specification 3.1.3.4 specifies a maximum rod drop time from loss of stationary gripper coil voltage to dashpot entry of 2.2 seconds with the RCS at hot, full flow conditions. All test results met this limit.

Table 2.1

NORTH ANNA UNIT 2 - CYCLE 4 STARTUP PHYSICS TESTS
HOT ROD DROP TIME SUMMARY

ROD DROP TIME TO DASHPOT ENTRY

SLOWEST ROD	FASTEST ROD	AVERAGE TIME
B-6, 1.77 Sec.	M-4, 1.38 Sec.	1.60 Sec.

ROD DROP TIME TO BOTTOM OF DASHPOT

SLOWEST ROD	FASTEST ROD	AVERAGE TIME
B-6, 2.43 Sec.	M-4, 1.98 Sec.	2.23 Sec.

Figure 2.1

TYPICAL ROD DROP TRACE

NORTH ANNA 2, CYCLE 4 BOL PHYSICS TEST

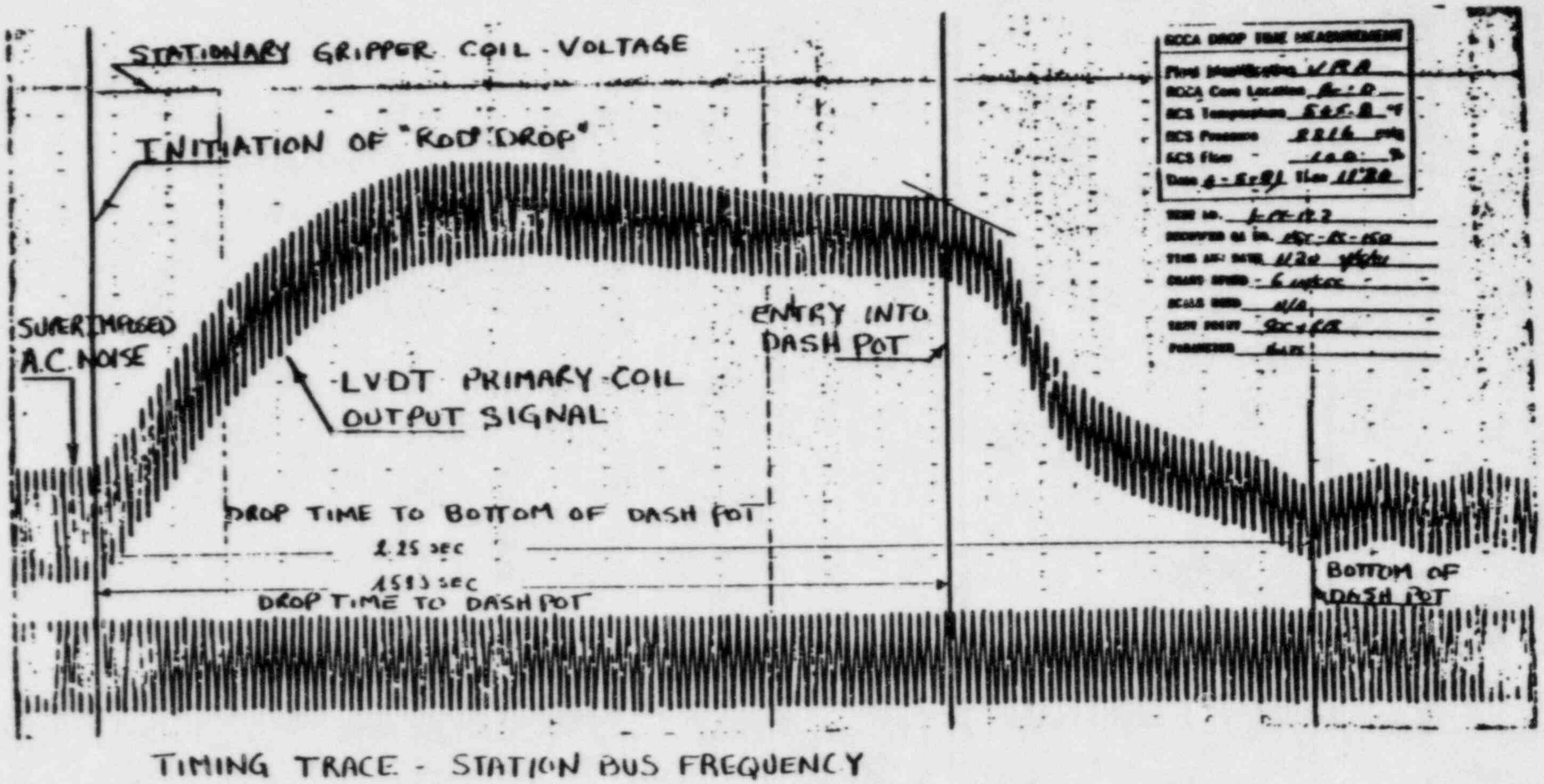


Figure 2.2

NORTH ANNA UNIT 2 - CYCLE 4 STARTUP PHYSICS TESTS

ROD DROP TIMES - HOT FULL FLOW CONDITIONS

	R	P	N	M	L	K	J	H	G	F	E	D	C	B	A
1															
2						1.63 2.30		1.60 2.23		1.60 2.27					
3							1.57 2.23		1.60 2.15						
4				1.38 1.98		1.70 2.28				1.58 2.15		1.66 2.23			
5					1.58 2.20						1.63 2.22				
6		1.56 2.21		1.67 2.27		1.63 2.23		1.60 2.21		1.58 2.23		1.57 2.15		1.77 2.43	
7			1.54 2.25				1.51 2.17		1.53 2.17				1.58 2.37		
8		1.62 2.25				1.58 2.08				1.51 2.17				1.71 2.32	
9			1.61 2.27				1.52 2.10		1.56 2.21				1.47 2.08		
10		1.63 2.31		1.58 2.17		1.60 2.21		1.54 2.21		1.58 2.18		1.62 2.17		1.61 2.30	
11					1.65 2.30						1.55 2.17				
12				1.58 2.25		1.57 2.15				1.54 2.13		1.65 2.27			
13							1.60 2.22		1.61 2.32						
14						1.72 2.38		1.68 2.33		1.68 2.32					
15															

|--Rod Drop Time to Dashpot Entry(sec.)
|--Rod Drop Time to Bottom of Dashpot(sec.)

Section 3

CONTROL ROD BANK WORTH MEASUREMENTS

Control rod bank worth measurements were obtained for all control and shutdown banks using the rod swap technique[3]. The first step in the rod swap procedure was to dilute the most reactive control rod bank (hereafter referred to as the reference bank) into the core and measure its reactivity worth using conventional test techniques. The reactivity changes resulting from the reference bank movements were recorded continuously by the reactivity computer[4] and were used to determine the differential and integral worth of the reference bank (Control Bank B). At the completion of the reference bank reactivity worth measurement, the reactor coolant system temperature and boron concentration were stabilized such that the reactor was critical with the reference bank near full insertion. Initial statepoint data for the rod swap maneuver were obtained by moving the reference bank to its fully inserted position and recording the core reactivity and moderator temperature. At this point, a rod swap maneuver was performed by withdrawing the reference bank while one of the other control rod banks (i.e., a test bank) was inserted. The core was kept nominally critical throughout this rod swap and the maneuver was continued until the test bank was fully inserted and the reference bank was at the position at which the core was just critical. This measured critical position (MCP) of the reference bank with the test bank fully inserted is the major parameter of interest and was used to determine the integral reactivity worth of the test bank. Statepoint data (core reactivity, moderator temperature, and the differential worth of the reference bank) were recorded with the reference bank at the MCP. The rod swap maneuver was then performed in reverse order such that the reference bank once again was near full insertion and the test bank was once again fully withdrawn from the core. The rod swap process was then repeated for all of the other control rod banks (control and shutdown).

A summary of the results for these tests is given in Table 3.1. As shown by this table and the Startup Physics Tests Results and Evaluation Sheets given in the Appendix, the individual measured bank worths for all of the control and shutdown banks were within the design tolerance (±10% for the reference bank and ±15% for the test banks). The sum of the individual rod bank worths was measured to be within 1.6% of the design prediction. This is well within the design tolerance of ±10% for the sum of the individual control rod bank worths.

The integral and differential reactivity worths of the reference bank (Control Bank B) are shown in Figures 3.1 and 3.2, respectively. The design predictions and the measured data are plotted together in order to illustrate their agreement. In summary, all measured rod worth values were satisfactory.

Table 3.1

NORTH ANNA UNIT 2 - CYCLE 4 STARTUP PHYSICS TESTS
CONTROL ROD BANK WORTH SUMMARY

BANK	MEASURED WORTH (PCM)	PREDICTED WORTH (PCM)	PERCENT DIFFERENCE (M-P)/P X 100
B-Reference Bank	1372	1399	-1.9
D	1036	1070	-3.2
C	801	851	-5.9
A	426	383	11.2 (43 pcm)
SB	853	910	-6.3
SA	1103	1068	3.3
Total Worth	5591	5681	-1.6

FIGURE 3.1

NORTH ANNA UNIT 2 - CYCLE 4 BOL PHYSICS TEST

BANK B INTEGRAL ROD WORTH - HZP

BANK B WITH ALL OTHER RODS OUT

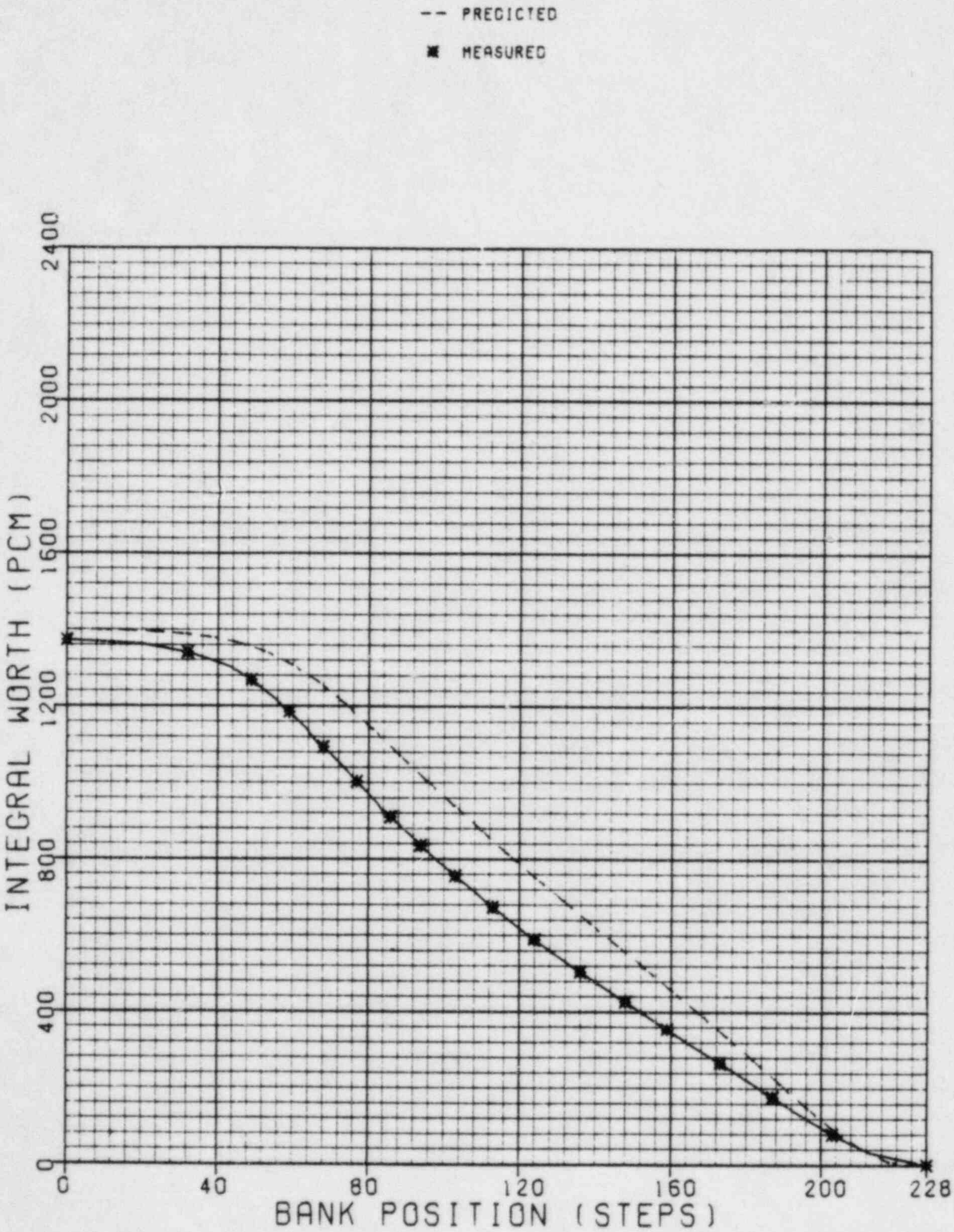
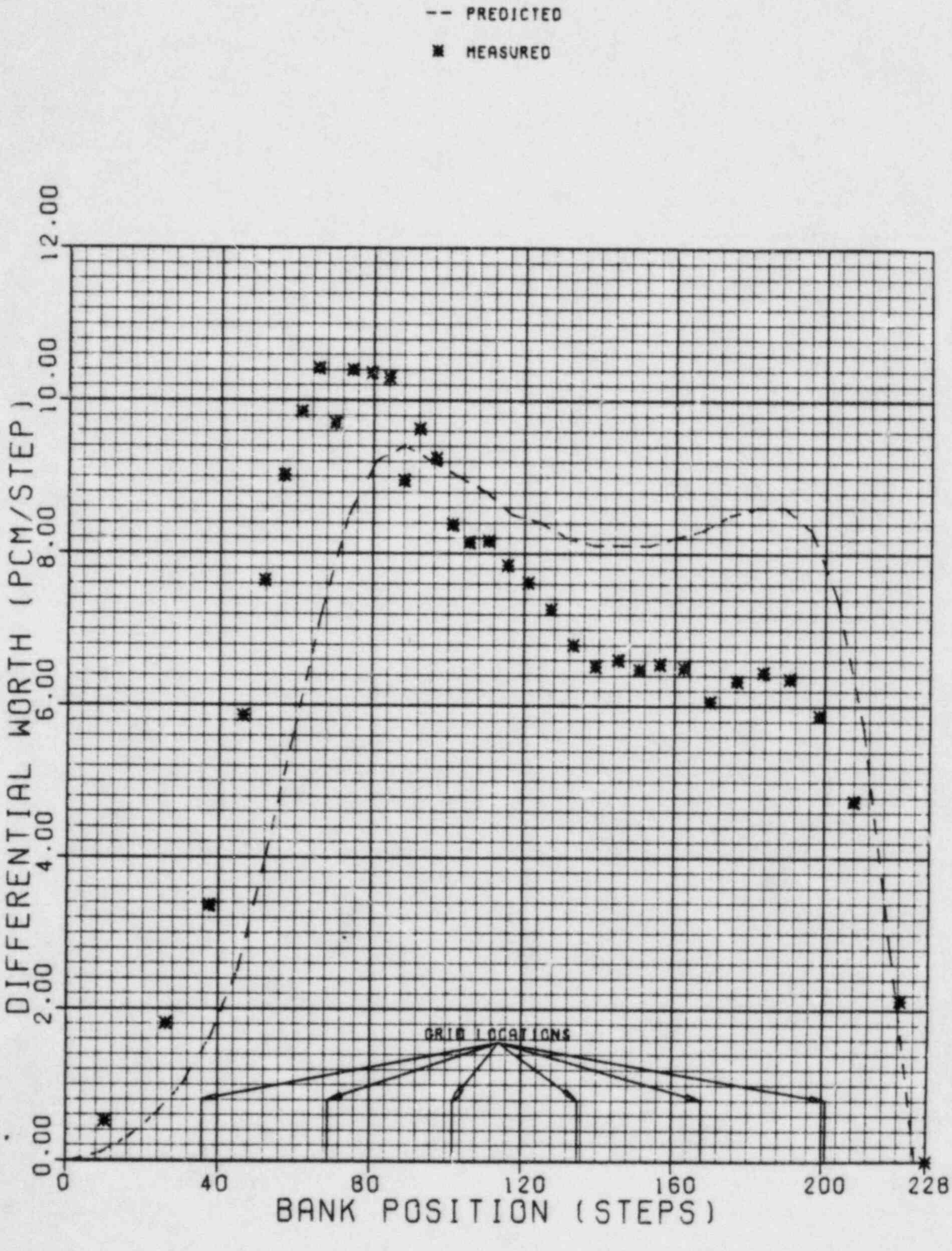


FIGURE 3.2

NORTH ANNA UNIT 2 - CYCLE 4 BOL PHYSICS TEST
BANK B DIFFERENTIAL ROD WORTH - HZP
BANK B WITH ALL OTHER RODS OUT



Section 4

BORON ENDPOINT AND WORTH MEASUREMENTS

Boron Endpoint

With the reactor critical at hot zero power, reactor coolant system boron concentrations were measured at selected rod bank configurations to enable a direct comparison of measured boron endpoints with design predictions. For each measurement, the RCS conditions were stabilized with the control banks at or very near a selected endpoint position. The critical boron concentration was then measured. If necessary, an adjustment to the measured critical boron concentration was made to account for off-nominal core conditions, such as rod position and moderator temperature.

The results of these measurements are given in Table 4.1. As shown in this table and in the Startup Physics Tests Results and Evaluation Sheets given in the Appendix, all measured critical boron endpoint values were within their respective design tolerances. All measured values met the accident analysis acceptance criterion. In summary, all results were satisfactory.

Boron Worth Coefficient

The measured boron endpoint values provide stable statepoint data from which the boron worth coefficient was determined. A plot of the boron concentration as a function of integrated reactivity can be constructed by relating each endpoint concentration to the integrated rod worth present in the core at the time of the endpoint measurement. The value of the boron coefficient, over the range of boron endpoint concentrations, is obtained directly from this plot.

The boron worth plot is shown in Figure 4.1. As indicated in this figure and in the Appendix, the boron worth coefficient of reactivity was measured to be -7.80 pcm/ppm. The measured boron worth coefficient is within 2.7% of the predicted value of -7.60 pcm/ppm and is well within the design tolerance of ±10%. The measurement result also met the accident analysis acceptance criterion. In summary, this result was satisfactory.

Table 4.1

NORTH ANNA UNIT 2 - CYCLE 4 STARTUP PHYSICS TESTS

BORON ENDPOINTS SUMMARY

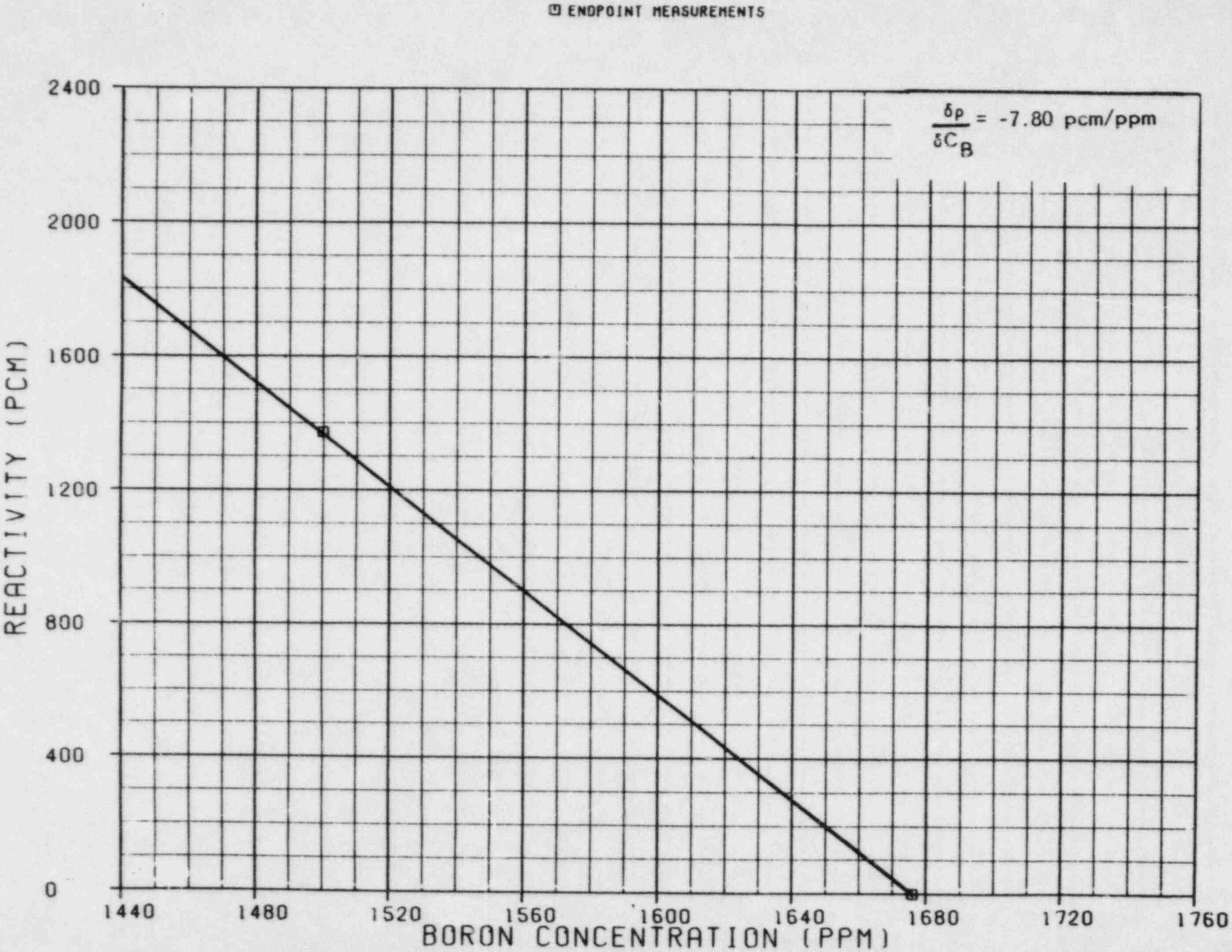
Control Rod Configuration	Measured Endpoint (ppm)	Predicted Endpoint (ppm)	Difference M-P (ppm)
ARO	1676	1699	-23
B Bank In	1500	1494*	6

*The predicted endpoint for the B Bank in configuration has been adjusted for the difference between the measured and predicted values of the endpoint taken at the ARO configuration as shown in the boron endpoint Startup Physics Test Results and Evaluation Sheets in the Appendix.

FIGURE 4.1

NORTH ANNA 2 - CYCLE 4 BOL PHYSICS TEST

BORON WORTH COEFFICIENT



Section 5

TEMPERATURE COEFFICIENT MEASUREMENTS

The isothermal temperature coefficient measurements were accomplished by controlling the RCS heat gains/losses with the steam dump valves to the condenser, establishing a constant and uniform heatup/cooldown rate, and then monitoring the resulting reactivity changes on the reactivity computer. These measurements were performed at very low power levels in order to minimize the effects of non-uniform nuclear heating, thus, the moderator and fuel were approximately at the same temperature (between 542 and 546 °F) during these measurements. To eliminate the boron reactivity effect of outflow from the pressurizer, the pressurizer level was maintained constant or slightly increasing during these measurements.

Reactivity measurements were taken during both RCS heatup and cooldown ramps during which the RCS temperature varied approximately 3°F. Reactivity was determined using the reactivity computer and was plotted against the RCS temperature on an x-y recorder. The temperature coefficient was then determined from the slope of the plotted lines. The X-Y recorder plot of reactivity change versus RCS temperature for the all-rods-out configuration is shown in Figure 5.1.

The predicted and measured isothermal temperature coefficient values are compared in Table 5.1. As can be seen from this summary and from the Startup Physics Test Results and Evaluation Sheet given in the Appendix, the measured isothermal temperature coefficient value was within the design tolerance of ±3 pcm/°F and met the accident analysis acceptance criterion. In summary, the measured result was satisfactory.

Table 5.1

NORTH ANNA UNIT 2 - CYCLE 4 STARTUP PHYSICS TESTS

ISOTHERMAL TEMPERATURE COEFFICIENT SUMMARY

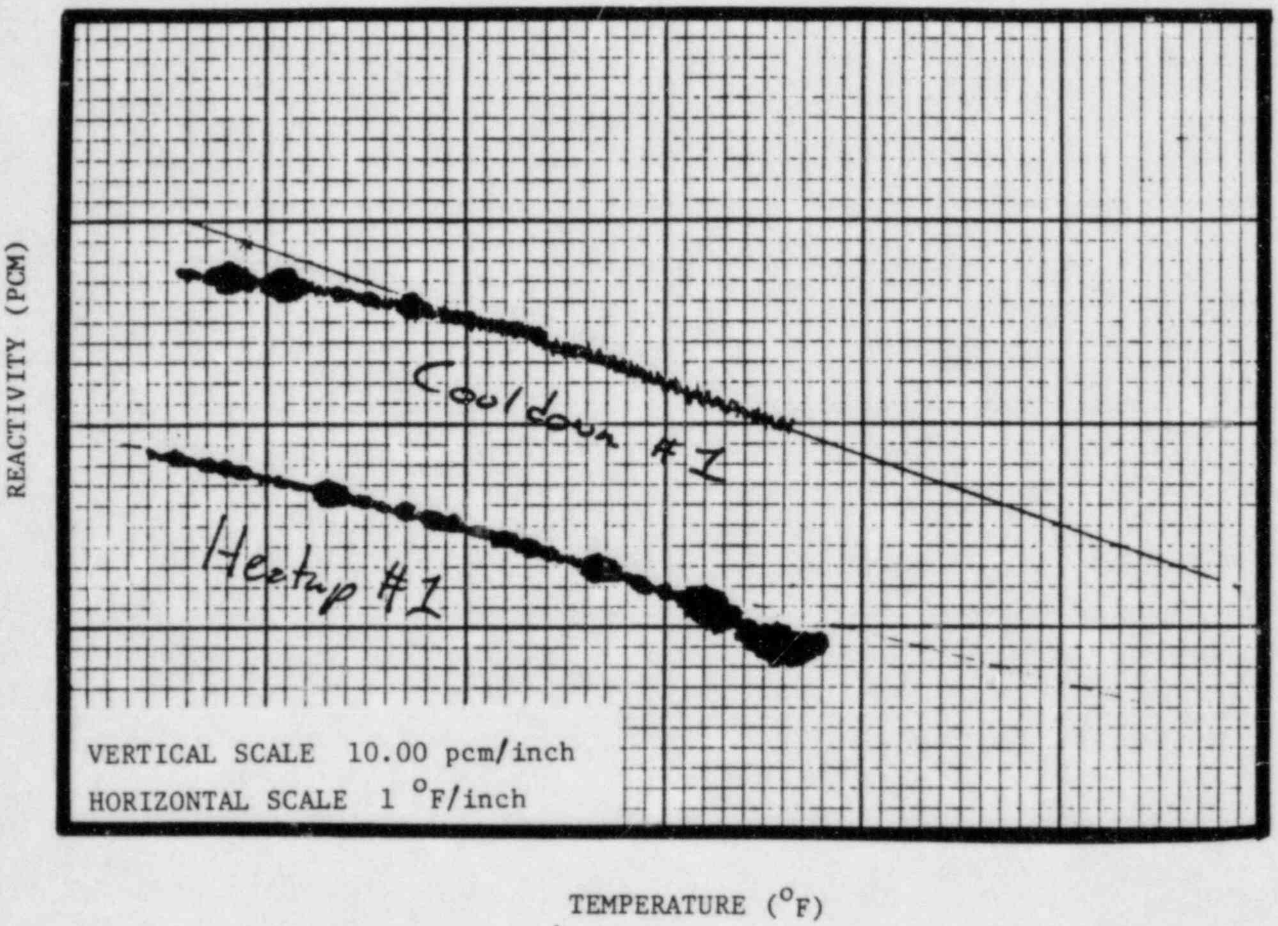
BANK POSITION	TEMPERATURE RANGE (°F)	BORON CONCENTRATION (PPM)	ISOTHERMAL TEMPERATURE COEFFICIENT (PCM/°F)				
			HEATUP	COOL DOWN	AVER.	PRED.	DIFFER (M-P)
All Rods Out	542.4 to 545.6	1669	-2.5	-3.4	-2.95	-3.55	0.60

Figure 5.1

NORTH ANNA UNIT 2 - CYCLE 4 BOL PHYSICS TESTS

ISOTHERMAL TEMPERATURE COEFFICIENT

HZP, ARO



Section 6

POWER DISTRIBUTION MEASUREMENTS

The core power distributions were measured using the incore movable detector flux mapping system. This system consists of five fission detectors which traverse fuel assembly instrumentation thimbles in 50 core locations (see Figure 1.3). For each traverse, the detector output is continuously monitored on a strip chart recorder. The output is also scanned for 61 discrete axial points by the PRODAC P-250 process computer. Full core, three-dimensional power distributions are then determined by analyzing this data using the Westinghouse computer program, INCORE[5]. INCORE couples the measured flux map data with predetermined analytic power-to-flux ratios in order to determine the power distribution for the whole core.

A list of all the full-core flux maps taken during the test program together with a list of the measured values of the important power distribution parameters is given in Table 6.1. The measured power distribution parameter values are compared with their Technical Specifications limits in Table 6.2. Flux map 1 was taken at 3% power. This flux map served as the base case design check. Figure 6.1 shows the resulting radial power distribution associated with the flux map. Map 1 indicated a quadrant power tilt value that was slightly above the established design tolerance for HZP flux maps (the measured power tilt was 1.030 compared to the 1.020 design tolerance). However, there is no Technical Specification limit for power tilt below 50% power. All subsequent measurements of power tilt above 5% power were within the full-power limits.

Flux maps 2 through 7 were taken over a wide range of power levels and control rod configurations. These flux maps were taken to check the at-power design predictions and hot channel factors, to establish a target delta flux for operation, and to measure core power distributions at various operating conditions. These maps also provide incore/excore detector calibration data for the nuclear instrumentation system. The radial power distributions for the full-core maps taken during the escalation to 100% power are given in Figures 6.2 through 6.5. These figures show that the measured relative assembly power values are generally within 6% of the predicted values. At 50% power, a violation of the Radial Peaking Factor, Fxy(RTP), surveillance limit was measured. However, at higher power levels, the values of Fxy were within the limit.

In conclusion, all power distribution measurement results were considered to be acceptable with respect to the design tolerances and the Technical Specification limits. It is therefore anticipated that the core will continue to operate safely throughout Cycle 4.

TABLE 6.1

NORTH ANNA 2 - CYCLE 4 STARTUP PHYSICS TESTS

INCORE FLUX MAP SUMMARY

MAP DESCRIPTION	MAP NO.	DATE	BURN UP MWD/MTU	PWR (%)	BANK D STEPS	F-Q(T) HOT CHANNEL FACTOR [1] ASSY	PIN	AXIAL POINT	F-Q(T)	F-DH(N) HOT CHNL. FACTOR [2] ASSY	PIN	F-DH(N)	CORE F(Z) MAX AXIAL POINT	F(Z)	F(XY) MAX [3]	QPTR [4] MAX	LOC	AXIAL OFF SET (%)	NO. OF THIMBLES
ARO	1	11- 3-84	0	3	211	N05	OG	18	2.499	N11	QQ	1.508	18	1.575	1.596	1.030	NW	31.60	46
DELTA I TARGET	2	11-10-84	65	50	162	L13	KO	29	2.001	L13	KO	1.487	30	1.315	1.548	1.011	NW	-4.50	47
QPTR VERIFICATION	3	11-11-84	77	50	155	N05	OG	31	2.027	N05	OG	1.487	36	1.334	1.556	1.019	NW	-7.91	47
I/E CAL.	4	11-12-84	82	70	171	N05	OG	30	1.931	N05	OG	1.448	30	1.298	1.517	1.015	NW	-4.61	47
HFP, EQ. XENON (5)	7	11-16-84	230	100	216	P07	OG	37	1.789	P07	OG	1.420	37	1.203	1.493	1.015	NW	-2.47	46

NOTES: HOT SPOT LOCATIONS ARE SPECIFIED BY GIVING ASSEMBLY LOCATIONS (E.G. H-8 IS THE CENTER-OF-CORE ASSEMBLY), FOLLOWED BY THE PIN LOCATION (DENOTED BY THE "Y" COORDINATE WITH THE SEVENTEEN ROWS OF FUEL RODS LETTERED A THROUGH R AND THE "X" COORDINATE DESIGNATED IN A SIMILAR MANNER). IN THE "Z" DIRECTION THE CORE IS DIVIDED INTO 61 AXIAL POINTS STARTING FROM THE TOP OF THE CORE.

1. F-Q(T) INCLUDES A TOTAL UNCERTAINTY OF 1.05 X 1.03.

2. F-DH(N) INCLUDES A MEASUREMENT UNCERTAINTY OF 1.04.

3. F(XY) IS THE MAXIMUM UNRODDED F(XY) AND INCLUDES A TOTAL UNCERTAINTY OF 1.05 X 1.03.

4. QPTR - QUADRANT POWER TILT RATIO.

5. FLUX MAPS 5 AND 6 WERE QUARTER-CORE MAPS TAKEN FOR EXCORE DETECTOR CALIBRATION.

Table 6.2

NORTH ANNA UNIT 2 - CYCLE 4 STARTUP PHYSICS TESTS

COMPARISION OF MEASURED POWER DISTRIBUTION PARAMETERS

WITH THEIR TECHNICAL SPECIFICATION LIMITS

MAP NO.	F-Q(T) HOT CHANNEL FACTOR[1]			F-DH(N) HOT CHANNEL FACTOR[2]			F(XY) MAX[3]			
	MEAS	LIMIT	MARGIN (%)	MEAS	LIMIT	MARGIN (%)	MEAS	AXIAL POINT	LIMIT	MARGIN (%)
2	2.00	4.37	54.2	1.49	1.78	16.6	1.73	11	1.71	-1.2
3	2.03	4.40	53.7	1.49	1.78	16.5	1.75	11	1.71	-2.1
4	1.93	3.16	38.8	1.45	1.69	14.4	1.66	10	1.71	3.1
7	1.79	2.20	18.7	1.42	1.55	8.4	1.49	52	1.61	7.3

1 The Technical Specification's limit for the heat flux hot channel factor, F-Q(T) is a function of core height. The value for F-Q(T) listed above is the maximum of F-Q(T) in the core. The Technical Specification's limit listed above is evaluated at the plane of maximum F-Q(T). The minimum margin values listed above are the minimum percent difference between the measured values of F-Q(T) and the Technical Specification's limit for each map. All measured F-Q(T) hot channel factors include 5% measurement uncertainty and 3% engineering uncertainty.

2 The measured values for the enthalpy rise hot channel factor, F-ΔH(N) includes 4% measurement uncertainty.

3 All measured F(XY) MAX values include 5% measurement uncertainty and 3% engineering uncertainty. For maps 2, 3, and 4, the rodded F(XY) values and limits are shown. There were no rodded F(XY) values for map 7, therefore, the unrodded value and limit are shown.

FIGURE 6.1
NORTH ANNA UNIT 2, CYCLE 4
ASSEMBLYWISE POWER DISTRIBUTION
ARO, 4% POWER

PREDICTED
MEASURED
PCT DIFFERENCE

	R	P	N	M	L	K	J	H	G	F	E	D	C	B	A
1							0.38 0.41 10.1	0.49 0.53 9.9	0.38 0.40 7.3						
2					0.43 0.46 8.4	0.68 0.64 -5.0	1.08 1.11 2.6	0.99 1.01 2.4	1.08 1.12 3.2	0.68 0.71 4.4	0.43 0.43 0.7				
3				0.51 0.53 4.8	1.12 1.17 4.4	1.18 1.19 0.5	1.16 1.13 -2.7	1.24 1.21 -2.8	1.16 1.15 -1.4	1.18 1.18 0.0	1.12 1.11 -1.1	0.51 0.49 -3.3			
4			0.50 0.53 7.2	0.91 0.96 4.9	1.23 1.28 4.0	1.26 1.28 1.8	1.26 1.25 -0.6	1.26 1.25 -0.8	1.26 1.22 -3.2	1.26 1.19 -5.6	1.23 1.18 -4.2	0.91 0.88 -4.0	0.50 0.49 -1.4		
5		0.42 0.45 6.0	1.11 1.17 6.0	1.22 1.26 3.3	1.06 1.08 1.9	1.19 1.22 2.4	1:20 1.21 0.9	1.20 1.21 0.7	1.20 1.18 -1.8	1.19 1.14 -4.4	1.06 1.02 -3.9	1.22 1.16 -4.3	1.11 1.10 -0.4	0.42 0.43 1.0	
6		0.67 0.71 6.1	1.18 1.25 6.1	1.26 1.32 4.7	1.19 1.23 3.4	1.01 1.03 2.3	1.20 1.21 1.0	1.03 1.02 -0.2	1.20 1.17 -2.1	1.01 0.97 -4.1	1.19 1.15 -3.6	1.26 1.20 -4.2	1.18 1.17 -0.3	0.67 0.69 2.2	
7	0.38 0.39 3.1	1.08 1.11 3.1	1.16 1.20 3.0	1.26 1.31 4.4	1.20 1.26 5.0	1.20 1.24 3.5	0.99 0.99 0.0	1.15 1.13 -1.3	0.99 0.95 -3.1	1.20 1.15 -3.9	1.20 1.16 -3.9	1.26 1.20 -4.4	1.16 1.15 -1.2	1.08 1.08 -0.1	0.38 0.38 1.9
8	0.48 0.50 3.2	0.99 1.02 3.2	1.24 1.28 3.0	1.26 1.33 5.3	1.20 1.28 6.6	1.03 1.08 4.6	1.16 1.16 0.6	0.92 0.89 -2.8	1.16 1.09 -5.4	1.03 0.98 -5.5	1.20 1.14 -5.5	1.26 1.21 -4.5	1.24 1.22 -1.4	0.99 1.00 1.1	0.48 0.50 3.3
9	0.38 0.39 4.7	1.08 1.12 3.8	1.16 1.21 3.8	1.26 1.32 5.2	1.20 1.28 6.5	1.20 1.23 2.1	0.99 0.92 -6.8	1.15 1.08 -6.0	0.99 0.93 -5.9	1.20 1.13 -6.0	1.20 1.15 -4.8	1.26 1.21 -3.4	1.16 1.15 -1.4	1.08 1.09 0.8	0.38 0.39 2.9
10		0.67 0.70 4.5	1.18 1.23 4.5	1.26 1.32 5.0	1.19 1.26 5.2	1.01 1.02 1.0	1.20 1.14 -4.5	1.03 0.98 -4.5	1.20 1.13 -5.1	1.01 0.95 -5.5	1.19 1.14 -4.4	1.26 1.23 -2.2	1.18 1.17 -0.5	0.67 0.70 3.5	
11		0.42 0.46 7.7	1.11 1.19 7.7	1.22 1.30 6.5	1.06 1.11 4.2	1.19 1.17 -1.4	1.20 1.16 -3.5	1.20 1.16 -3.3	1.20 1.15 -4.2	1.19 1.13 -5.0	1.06 1.03 -3.3	1.22 1.19 -2.0	1.11 1.09 -1.1	0.42 0.42 -0.3	
12			0.50 0.55 11.0	0.91 0.98 7.7	1.23 1.28 4.2	1.26 1.27 0.9	1.26 1.21 -3.7	1.26 1.22 -3.8	1.26 1.19 -5.3	1.26 1.20 -4.9	1.23 1.18 -4.0	0.91 0.90 -2.0	0.50 0.49 -1.7		
13				0.51 0.54 6.0	1.12 1.13 1.1	1.18 1.18 -0.5	1.16 1.11 -5.0	1.24 1.19 -3.7	1.16 1.11 -4.3	1.18 1.15 -2.8	1.12 1.08 -3.4	0.51 0.50 -1.7			
14					0.43 0.43 1.1	0.68 0.69 2.8	1.08 1.07 -1.6	0.99 0.97 -1.5	1.08 1.04 -4.0	0.68 0.66 -2.6	0.43 0.40 -5.1				
15							0.38 0.39 4.2	0.49 0.50 2.0	0.38 0.38 -0.1						

STANDARD DEVIATION =2.139

AVERAGE PCT DIFFERENCE = 3.5

SUMMARY

MAP NO: N2-4- 1

DATE: 11/ 3/84

POWER: 3%

CONTROL ROD POSITIONS:

D BANK AT 211 STEPS

F-Q(T) = 2.499

F-DH(N) = 1.508

F(Z) = 1.575

F(XY) = 1.596

BURNUP = 0 MWD/MTU A.O = 31.60(%)

QPTR:

NW 1.030	NE 0.981
SW 1.020	SE 0.969

FIGURE 6.2
NORTH ANNA UNIT 2, CYCLE 4
ASSEMBLYWISE POWER DISTRIBUTION
50% POWER

PREDICTED
MEASURED
PCT DIFFERENCE

R	P	N	M	L	K	J	H	G	F	E	D	C	B	A	
						0.38 0.37 -2.9	0.47 0.46 -2.8	0.38 0.39 3.8							1
				0.45 0.47 4.6	0.69 0.67 -3.0	1.06 1.03 -2.9	0.92 0.89 -2.7	1.06 1.07 0.5	0.69 0.72 3.8	0.45 0.46 1.5					2
			0.54 0.55 1.4	1.15 1.16 1.0	1.19 1.16 -2.4	1.15 1.13 -1.7	1.21 1.19 -1.7	1.15 1.15 -0.2	1.19 1.21 1.3	1.15 1.15 0.5	0.54 0.54 -1.0				3
		0.53 0.55 3.1	0.95 0.97 1.7	1.24 1.26 1.5	1.26 1.27 0.5	1.25 1.24 -0.8	1.26 1.25 -0.8	1.25 1.23 -1.5	1.26 1.25 -1.1	1.24 1.22 -1.8	0.95 0.93 -2.2	0.53 0.53 -0.7			4
	0.45 0.46 1.9	1.13 1.15 1.9	1.23 1.23 -0.1	1.07 1.06 -0.6	1.17 1.17 -0.3	1.19 1.20 0.3	1.20 1.21 0.3	1.19 1.19 -0.4	1.17 1.16 -0.8	1.07 1.05 -1.6	1.23 1.19 -3.4	1.13 1.13 -0.5	0.45 0.46 2.5		5
	0.69 0.72 4.0	1.18 1.23 4.0	1.26 1.28 1.9	1.17 1.17 -0.3	0.95 0.95 0.3	1.18 1.19 0.8	1.04 1.04 0.7	1.18 1.18 -0.0	0.95 0.95 -0.4	1.17 1.14 -2.9	1.26 1.20 -4.4	1.18 1.17 -1.1	0.69 0.71 2.[illegible]		6
0.38 0.41 10.1	1.06 1.12 5.4	1.15 1.19 3.1	1.25 1.26 1.0	1.20 1.18 -1.0	1.18 1.18 -0.2	1.00 1.00 0.9	1.16 1.17 0.7	1.00 0.99 -0.2	1.18 1.18 -0.5	1.20 1.17 -2.4	1.25 1.19 -4.5	1.15 1.14 -0.8	1.06 1.07 0.9	0.38 0.39 2.8	7
0.47 0.52 9.7	0.92 0.97 5.2	1.20 1.24 2.6	1.26 1.28 2.1	1.21 1.23 1.6	1.04 1.06 1.5	1.17 1.19 1.5	0.94 0.95 0.6	1.17 1.15 -1.6	1.04 1.02 -1.7	1.21 1.16 -3.9	1.26 1.20 -4.4	1.20 1.19 -0.8	0.92 0.94 2.6	0.47 0.50 4.9	8
0.38 0.41 10.1	1.06 1.09 3.1	1.15 1.14 -0.7	1.25 1.25 0.4	1.20 1.22 1.6	1.18 1.18 -0.5	1.00 0.95 -4.6	1.16 1.14 -2.4	1.00 0.97 -2.2	1.18 1.15 -2.6	1.20 1.17 -2.4	1.25 1.23 -1.8	1.15 1.16 0.6	1.06 1.09 3.2	0.38 0.40 5.6	9
	0.69 0.68 -1.1	1.18 1.17 -1.2	1.26 1.27 1.0	1.17 1.20 2.1	0.95 0.95 -0.5	1.18 1.14 -3.2	1.04 1.01 -2.0	1.18 1.14 -3.0	0.95 0.93 -2.6	1.17 1.15 -2.2	1.26 1.27 0.5	1.18 1.20 1.0	0.69 0.73 5.7		10
	0.45 0.46 2.4	1.13 1.16 2.4	1.23 1.26 2.4	1.07 1.09 2.3	1.17 1.15 -2.0	1.19 1.15 -3.3	1.20 1.17 -3.1	1.19 1.16 -2.9	1.17 1.15 -1.8	1.07 1.06 -0.8	1.23 1.24 0.9	1.13 1.15 1.1	0.45 0.46 2.5		11
		0.53 0.56 6.0	0.95 0.99 4.2	1.24 1.27 2.3	1.26 1.25 -1.0	1.25 1.21 -3.3	1.26 1.22 -3.2	1.25 1.21 -3.5	1.26 1.23 -2.4	1.24 1.22 -1.8	0.95 0.96 1.2	0.53 0.54 1.3			12
			0.54 0.57 4.5	1.15 1.18 3.0	1.19 1.18 -0.5	1.15 1.10 -4.3	1.21 1.18 -2.3	1.15 1.13 -2.1	1.19 1.17 -1.3	1.15 1.12 -2.3	0.54 0.55 1.1				13
				0.45 0.47 3.0	0.69 0.74 6.3	1.06 1.09 2.6	0.92 0.94 2.0	1.06 1.04 -1.8	0.69 0.69 -1.0	0.45 0.43 -4.1					14
						0.38 0.41 9.1	0.47 0.50 5.6	0.38 0.38 2.1							15

STANDARD DEVIATION =1.851

AVERAGE PCT DIFFERENCE = 2.3

SUMMARY

MAP NO: N2-4- 2

DATE: 11/10/84

POWER: 50%

CONTROL ROD POSITIONS:

D BANK AT 162 STEPS

F-Q(T) = 2.001

F-DH(N) = 1.487

F(Z) = 1.315

F(XY) = 1.548

BURNUP = 65 MWD/MTU

A.O = -4.50(%)

QPTR:

NW 1.011	NE 0.995
SW 1.005	SE 0.989

FIGURE 6.3
NORTH ANNA UNIT 2, CYCLE 4
ASSEMBLYWISE POWER DISTRIBUTION
50% POWER

PREDICTED
MEASURED
PCT DIFFERENCE

	R	P	N	M	L	K	J	H	G	F	E	D	C	B	A
1							0.37 0.39 4.5	0.47 0.46 -2.4	0.37 0.39 3.3						
2					0.45 0.47 4.0	0.70 0.72 4.3	1.06 1.07 1.1	0.91 0.92 1.0	1.06 1.06 0.5	0.70 0.72 3.2	0.45 0.46 1.3				
3				0.54 0.55 1.2	1.15 1.16 0.9	1.19 1.21 1.1	1.15 1.16 0.8	1.20 1.21 0.4	1.15 1.15 0.0	1.19 1.21 1.5	1.15 1.16 0.7	0.54 0.54 -0.9			
4			0.53 0.55 3.0	0.95 0.97 2.1	1.25 1.27 1.9	1.26 1.29 1.9	1.25 1.26 0.7	1.26 1.27 0.6	1.25 1.24 -1.0	1.26 1.26 -0.3	1.25 1.22 -1.8	0.95 0.93 -2.6	0.53 0.53 -1.2		
5		0.45 0.46 2.3	1.14 1.16 2.3	1.24 1.24 0.5	1.07 1.07 0.1	1.17 1.17 0.2	1.19 1.20 0.5	1.20 1.21 0.5	1.19 1.19 -0.1	1.17 1.16 -0.5	1.07 1.05 -1.8	1.24 1.18 -4.3	1.14 1.12 -1.3	0.45 0.46 1.7	
6		0.69 0.72 4.5	1.19 1.24 4.4	1.26 1.29 2.5	1.17 1.18 0.5	0.94 0.95 0.7	1.18 1.19 0.9	1.04 1.04 0.8	1.18 1.17 -0.1	0.94 0.93 -0.7	1.17 1.13 -3.4	1.26 1.20 -5.0	1.19 1.17 -1.7	0.69 0.70 1.6	
7	0.37 0.40 6.6	1.05 1.09 3.7	1.15 1.19 3.8	1.25 1.27 1.4	1.20 1.19 -0.9	1.18 1.18 -0.1	0.99 1.01 1.1	1.16 1.17 0.8	0.99 0.99 -0.3	1.18 1.17 -0.7	1.20 1.17 -2.6	1.25 1.19 -4.5	1.15 1.14 -0.9	1.05 1.06 0.8	0.37 0.38 2.6
8	0.47 0.47 0.9	0.91 0.94 3.8	1.20 1.24 3.4	1.26 1.29 2.5	1.21 1.23 1.5	1.04 1.06 1.5	1.17 1.19 1.6	0.94 0.95 0.7	1.17 1.15 -1.9	1.04 1.02 -2.0	1.21 1.15 -4.5	1.26 1.20 -4.4	1.20 1.19 -0.9	0.91 0.93 2.5	0.47 0.49 4.6
9	0.37 0.37 -0.8	1.05 1.05 -0.1	1.15 1.15 -0.2	1.25 1.26 0.6	1.20 1.22 1.6	1.18 1.18 -0.4	0.99 0.95 -4.4	1.16 1.14 -2.0	0.99 0.97 -2.6	1.18 1.15 -3.0	1.20 1.16 -3.1	1.25 1.23 -2.0	1.15 1.16 0.5	1.05 1.09 3.2	0.37 0.39 5.3
10		0.69 0.68 -1.1	1.19 1.17 -1.2	1.26 1.27 0.9	1.17 1.20 2.0	0.94 0.94 -0.4	1.18 1.14 -3.1	1.04 1.02 -1.9	1.18 1.14 -3.3	0.94 0.91 -3.0	1.17 1.14 -2.7	1.26 1.26 0.1	1.19 1.19 0.6	0.69 0.73 5.4	
11		0.45 0.46 2.6	1.14 1.17 2.6	1.24 1.27 2.5	1.07 1.10 2.2	1.17 1.15 -2.0	1.19 1.15 -3.3	1.20 1.17 -3.1	1.19 1.15 -3.2	1.17 1.15 -2.0	1.07 1.06 -1.1	1.24 1.24 0.3	1.14 1.14 0.5	0.45 0.46 1.7	
12			0.53 0.57 6.4	0.95 1.00 4.4	1.25 1.27 2.2	1.26 1.25 -1.0	1.25 1.21 -3.2	1.26 1.22 -3.1	1.25 1.20 -3.7	1.26 1.23 -2.8	1.25 1.22 -2.0	0.95 0.96 0.7	0.53 0.54 0.3		
13				0.54 0.57 4.2	1.15 1.17 2.1	1.19 1.18 -1.0	1.15 1.11 -4.0	1.20 1.18 -2.0	1.15 1.13 -2.0	1.19 1.17 -1.5	1.15 1.12 -2.6	0.54 0.55 0.3			
14					0.45 0.46 2.1	0.70 0.73 5.5	1.06 1.08 2.6	0.91 0.93 2.0	1.06 1.04 -1.7	0.70 0.69 -1.1	0.45 0.43 -4.7				
15							0.37 0.41 8.5	0.47 0.49 5.4	0.37 0.38 2.3						

STANDARD DEVIATION =1.566

AVERAGE PCT DIFFERENCE = 2.1

SUMMARY

MAP NO: N2-4- 3 DATE: 11/11/84 POWER: 50%

CONTROL ROD POSITIONS: F-Q(T) = 2.027 QPTR:

D BANK AT 155 STEPS F-DH(N) = 1.487

NW 1.019	NE 0.990
SW 1.003	SE 0.988

F(Z) = 1.334

F(XY) = 1.556

BURNUP = 77 MWD/MTU A.O = -7.91(%)

FIGURE 6.4
NORTH ANNA UNIT 2, CYCLE 4
ASSEMBLYWISE POWER DISTRIBUTION
70% POWER

PREDICTED
MEASURED
PCT DIFFERENCE

Row	R	P	N	M	L	K	J	H	G	F	E	D	C	B	A
1							0.40	0.51	0.40						
							0.42	0.53	0.42						
							5.0	4.8	3.5						
2					0.47	0.71	1.07	0.94	1.07	0.71	0.47				
					0.48	0.70	1.09	0.96	1.09	0.72	0.46				
					1.5	-1.8	1.7	1.5	1.8	1.7	-0.9				
3				0.56	1.13	1.17	1.15	1.20	1.15	1.17	1.13	0.56			
				0.56	1.14	1.17	1.14	1.19	1.15	1.18	1.13	0.54			
				0.6	0.5	-0.4	-0.7	-0.8	-0.0	0.7	-0.8	-3.6			
4			0.55	0.95	1.22	1.24	1.23	1.24	1.23	1.24	1.22	0.95	0.55		
			0.56	0.97	1.24	1.26	1.23	1.24	1.22	1.25	1.21	0.94	0.53		
			2.1	1.7	1.3	1.3	-0.1	-0.1	-0.5	0.5	-1.1	-1.5	-2.1		
5		0.47	1.12	1.21	1.06	1.16	1.18	1.20	1.18	1.16	1.06	1.21	1.12	0.47	
		0.48	1.16	1.23	1.07	1.17	1.19	1.20	1.19	1.17	1.06	1.21	1.11	0.46	
		2.8	2.8	1.1	0.6	0.7	0.8	0.8	0.3	0.5	-0.2	-0.5	-1.4	-0.5	
6		0.71	1.17	1.24	1.16	0.97	1.18	1.04	1.18	0.97	1.16	1.24	1.17	0.71	
		0.74	1.22	1.27	1.17	0.97	1.19	1.05	1.18	0.96	1.15	1.22	1.16	0.71	
		4.4	4.4	2.6	0.8	0.6	0.7	0.4	-0.1	-0.2	-1.5	-1.6	-1.2	0.7	
7	0.40	1.07	1.15	1.23	1.19	1.18	1.01	1.17	1.01	1.18	1.19	1.23	1.15	1.07	0.40
	0.43	1.11	1.18	1.25	1.19	1.19	1.01	1.17	1.00	1.17	1.15	1.19	1.14	1.08	0.41
	6.1	3.2	3.2	1.7	0.3	0.3	0.6	0.1	-0.6	-1.3	-2.7	-3.2	-0.4	1.0	2.4
8	0.51	0.94	1.20	1.24	1.20	1.05	1.18	0.96	1.18	1.05	1.20	1.24	1.20	0.94	0.51
	0.51	0.97	1.23	1.27	1.23	1.07	1.18	0.96	1.15	1.03	1.16	1.20	1.19	0.96	0.52
	0.3	3.2	2.8	2.8	2.8	2.0	0.4	-0.4	-2.0	-2.0	-3.4	-3.1	-0.4	1.3	2.5
9	0.40	1.07	1.15	1.23	1.19	1.18	1.01	1.17	1.01	1.18	1.19	1.23	1.15	1.07	0.40
	0.40	1.07	1.15	1.24	1.22	1.19	0.97	1.15	0.98	1.15	1.16	1.22	1.15	1.08	0.41
	-0.1	-0.0	-0.2	1.3	2.8	0.7	-3.5	-2.0	-2.3	-2.6	-2.1	-0.9	0.3	1.1	2.2
10		0.71	1.17	1.24	1.16	0.97	1.18	1.04	1.18	0.97	1.16	1.24	1.17	0.71	
		0.71	1.17	1.26	1.19	0.97	1.15	1.02	1.15	0.95	1.15	1.25	1.17	0.72	
		-0.4	-0.5	1.6	2.7	0.4	-2.3	-1.7	-2.5	-2.1	-1.4	1.0	0.2	1.6	
11		0.47	1.12	1.21	1.06	1.16	1.18	1.20	1.18	1.16	1.06	1.21	1.12	0.47	
		0.47	1.14	1.23	1.09	1.15	1.16	1.17	1.16	1.15	1.06	1.22	1.12	0.47	
		1.5	1.5	1.7	2.0	-1.0	-2.0	-1.9	-1.9	-0.9	-0.1	0.5	0.0	-0.2	
12			0.55	0.95	1.22	1.24	1.23	1.24	1.23	1.24	1.22	0.95	0.55		
			0.57	0.98	1.25	1.24	1.20	1.22	1.20	1.22	1.21	0.96	0.55		
			3.6	2.8	2.0	0.0	-1.9	-1.9	-2.4	-1.5	-0.9	0.4	-0.2		
13				0.56	1.13	1.17	1.15	1.20	1.15	1.17	1.13	0.56			
				0.56	1.12	1.16	1.12	1.18	1.13	1.17	1.12	0.55			
				1.1	-1.4	-1.6	-2.4	-1.1	-1.3	-0.7	-1.4	-0.1			
14					0.47	0.71	1.07	0.94	1.07	0.71	0.47				
					0.46	0.72	1.08	0.95	1.06	0.71	0.46				
					-1.4	1.4	0.6	0.8	-1.0	-0.4	-2.9				
15							0.40	0.51	0.40						
							0.42	0.52	0.41						
							4.0	2.9	1.9						

STANDARD DEVIATION =1.158

AVERAGE PCT DIFFERENCE = 1.5

SUMMARY

MAP NO: N2-4- 4   DATE: 11/12/84   POWER: 70%

CONTROL ROD POSITIONS: F-Q(T) = 1.931   QPTR:

D BANK AT 171 STEPS   F-DH(N) = 1.448

F(Z) = 1.298

F(XY) = 1.517

BURNUP = 82 MWD/MTU   A.O = -4.61(%)

QPTR	
NW 1.015	NE 0.993
SW 1.001	SE 0.991

FIGURE 6.5
NORTH ANNA UNIT 2, CYCLE 4
ASSEMBLYWISE POWER DISTRIBUTION
HFP, EQUILIBRIUM XENON

PREDICTED
MEASURED
PCT DIFFERENCE

R	P	N	M	L	K	J	H	G	F	E	D	C	B	A	
						0.42 0.45 5.4	0.54 0.57 5.3	0.42 0.44 3.9							1
				0.47 0.48 2.1	0.71 0.74 3.4	1.09 1.12 2.0	1.01 1.03 1.9	1.09 1.11 1.6	0.71 0.73 2.2	0.47 0.47 0.2					2
			0.55 0.55 0.1	1.10 1.10 -0.1	1.15 1.16 0.6	1.14 1.15 0.4	1.20 1.20 -0.0	1.14 1.14 -0.5	1.15 1.16 0.9	1.10 1.10 -0.1	0.55 0.54 -1.9				3
		0.54 0.55 1.6	0.93 0.94 0.9	1.19 1.19 0.7	1.21 1.23 1.1	1.21 1.21 0.4	1.22 1.23 0.3	1.21 1.19 -1.7	1.21 1.22 0.5	1.19 1.18 -0.9	0.93 0.92 -1.2	0.54 0.53 -1.6			4
	0.47 0.47 1.1	1.09 1.11 1.1	1.18 1.18 -0.3	1.06 1.05 -0.7	1.16 1.16 -0.4	1.18 1.19 0.7	1.19 1.20 0.8	1.18 1.19 0.5	1.16 1.17 0.8	1.06 1.05 -0.2	1.18 1.17 -0.9	1.09 1.08 -1.4	0.47 0.47 0.4		5
	0.71 0.73 2.8	1.15 1.18 2.7	1.21 1.23 1.2	1.17 1.16 -0.4	1.03 1.03 0.3	1.20 1.21 0.9	1.05 1.06 0.9	1.20 1.21 0.9	1.03 1.04 1.1	1.17 1.16 -0.9	1.21 1.19 -1.8	1.15 1.13 -1.5	0.71 0.71 0.4		6
0.42 0.44 4.6	1.09 1.14 4.5	1.14 1.19 4.4	1.21 1.22 0.8	1.18 1.17 -1.1	1.20 1.20 -0.3	1.02 1.04 1.1	1.18 1.19 1.0	1.02 1.03 0.7	1.20 1.21 0.6	1.18 1.17 -0.9	1.21 1.17 -3.6	1.14 1.12 -2.3	1.09 1.08 -1.4	0.42 0.42 0.4	7
0.54 0.56 4.5	1.01 1.06 4.4	1.20 1.25 4.4	1.22 1.25 2.5	1.19 1.21 1.5	1.06 1.07 1.4	1.18 1.20 1.2	0.97 0.98 0.7	1.18 1.17 -0.9	1.06 1.05 -1.0	1.19 1.16 -2.8	1.22 1.18 -3.6	1.20 1.17 -2.4	1.01 1.02 0.7	0.54 0.56 3.0	8
0.42 0.44 4.6	1.09 1.11 1.4	1.14 1.12 -1.8	1.21 1.22 0.5	1.18 1.20 1.6	1.20 1.20 -0.1	1.02 0.99 -3.5	1.18 1.16 -1.6	1.02 1.01 -1.5	1.20 1.18 -1.7	1.18 1.16 -1.7	1.21 1.19 -1.8	1.14 1.13 -0.9	1.09 1.11 1.2	0.42 0.44 3.6	9
	0.71 0.70 -1.8	1.15 1.13 -1.8	1.21 1.22 0.7	1.17 1.19 2.1	1.03 1.03 0.1	1.20 1.17 -2.2	1.05 1.04 -1.3	1.20 1.17 -2.2	1.03 1.01 -1.7	1.17 1.15 -1.6	1.21 1.22 0.9	1.15 1.15 0.5	0.71 0.73 3.2		10
	0.47 0.47 0.9	1.09 1.10 0.9	1.18 1.20 1.3	1.06 1.08 2.1	1.16 1.15 -1.5	1.18 1.15 -2.5	1.19 1.16 -2.3	1.18 1.15 -2.2	1.16 1.15 -1.0	1.06 1.05 -0.3	1.18 1.19 0.6	1.09 1.10 0.3	0.47 0.47 0.7		11
		0.54 0.56 3.6	0.93 0.96 2.9	1.19 1.21 2.1	1.21 1.20 -0.8	1.21 1.18 -2.7	1.22 1.19 -2.6	1.21 1.17 -2.8	1.21 1.19 -1.6	1.19 1.17 -1.1	0.93 0.94 0.7	0.54 0.54 0.1			12
			0.55 0.56 2.0	1.10 1.11 0.3	1.15 1.13 -1.6	1.14 1.10 -3.7	1.20 1.16 -3.7	1.14 1.10 -3.5	1.15 1.12 -3.1	1.10 1.08 -1.6	0.55 0.55 0.1				13
				0.47 0.47 0.3	0.71 0.73 3.0	1.09 1.11 1.1	1.01 1.02 0.7	1.09 1.06 -3.5	0.71 0.69 -3.0	0.47 0.45 -3.1					14
						0.42 0.45 5.7	0.54 0.57 5.6	0.42 0.45 5.7							15

PREDICTED
MEASURED
PCT DIFFERENCE

STANDARD DEVIATION =1.351

AVERAGE PCT DIFFERENCE = 1.7

SUMMARY

MAP NO: N2-4- 7   DATE: 11/16/84   POWER: 100%

CONTROL ROD POSITIONS: F-Q(T) = 1.789   QPTR:

D BANK AT 216 STEPS   F-DH(N) = 1.420

NW 1.015	NE 0.996
SW 1.001	SE 0.988

F(Z) = 1.203

F(XY) = 1.493

BURNUP = 230 MWD/MTU   A.O = -2.47(%)

Section 7

REFERENCES

1. C. B. Laroe, M. E. Paul, "North Anna Unit 2, Cycle 4, Design Report," NE Technical Report No. 385, Vepco, September, 1984.

2. North Anna Unit 2 Technical Specifications, Sections 3.1.3.4, 3/4.2.

3. T. K. Ross, W. C. Beck, "Control Rod Reactivity Worth Determination By The Rod Swap Technique," VEP-FRD-36A, December 1980.

4. "Technical Manual for Westinghouse Solid State Reactivity Computer," Westinghouse Electric Corporation.

5. W. Leggett and L. Eisenhart, "The INCORE Code," WCAP-7149, December, 1967.

APPENDIX

STARTUP PHYSICS TESTS RESULTS AND EVALUATION SHEETS

2-PT-94.2
[illegible]
[illegible]

NORTH ANNA POWER STATION UNIT 2 CYCLE 4
STARTUP PHYSICS TEST RESULTS AND EVALUATION SHEET

I Reference	Test Description: Reactivity Computer Checkout Proc No /Section: 2-PT-94.2 Sequence Step No: 3	
II Test Conditions (Design)	Bank Positions (Steps) SDA: 228 SDB: 228 CA: 228 CB: 228 CC: 228 CD: *	RCS Temperature (°F): 547 Power Level (% F.P.): 0 Other (specify): Below Nuclear Heating
III Test Conditions (Actual)	Bank Positions (Steps) SDA: 228 SDB: 228 CA: 228 CB: 228 CC: 228 CD: 180	RCS Temperature (°F): 543.5°F Power Level (% F.P.): 0 Other (Specify): Below Nuclear Heating
	Date/Time Test Performed: 11/2/84 1141	
IV Test Results	Measured Parameter (Description)	ρ_c = Meas. Reactivty using ρ-computer ρ_t = Inferred React from react period
	Measured Value	ρ_c = 63.5 pcm -50 pcm ρ_t = 64.4 pcm -52 pcm %D = -1.4% -3.8%
	Design Value (Actual Conditions)	$\%D = [(\rho_c - \rho_t)/\rho_t] \times 100\% \leq 4.0\%$
	Design Value (Design Conditions)	$\%D = [(\rho_c - \rho_t)/\rho_t] \times 100\% \leq 4.0\%$
	Reference	WCAP 7905, Rev. 1, Table 3.6
V Acceptance Criteria	FSAR/Tech Spec	Not Applicable
	Reference	Not Applicable
VI Comments	Design Tolerance is met : ✓ YES ___ NO Acceptance Criteria is met : ✓ YES ___ NO	
	* At the just critical position Allowable Range = ± 50 pcm	

Completed By: [signature]
Test Engineer

Evaluated By: B D Mann

Recommended for Approval By : C J Snow
NFO Engineer

NORTH ANNA POWER STATION UNIT 2 CYCLE 4
STARTUP PHYSICS TEST RESULTS AND EVALUATION SHEET

I Reference	Test Description: Critical Boron Concentration ARO Proc No /Section: 2-PT-94.3 Sequence Step No: 4	
II Test Conditions (Design)	Bank Positions (Steps) SDA: 228 SDB: 228 CA: 228 CB: 228 CC: 228 CD: 228	RCS Temperature (°F): 547 Power Level (% F.P.): 0 Other (specify): Below Nuclear Heating
III Test Conditions (Actual)	Bank Positions (Steps) SDA: 228 SDB: 228 CA: 228 CB: 228 CC: 228 CD: 228	RCS Temperature (°F): 545°F Power Level (% F.P.): 0 Other (Specify): Below Nuclear Heating
	Date/Time Test Performed: 11/2/84 1513	
IV	Meas Parameter (Description)	$(C_B)^M_{ARO}$; Critical Boron Concentration - ARO
Test Results	Measured Value	$(C_B)^M_{ARO}$ = 1676 ppm
	Design Value (Actual Cond)	C_B =1699 ± 50 ppm
	Design Value (Design Cond)	C_B =1699 ± 50 ppm
	Reference	NE REPORT NO. 385
V Acceptance Criteria	FSAR/Tech Spec	$\alpha_{C_B} \times C_B \leq 24{,}000$ pcm
	Reference	UFSAR Section 15.2.4
	Design Tolerance is met : ✓ YES __ NO Acceptance Criteria is met : ✓ YES __ NO	
VI Comments	α_{C_B} = -7.60 pcm/ppm for preliminary analysis α_{C_B} = -7.80 pcm/ppm for final analysis.	

Completed By: [illegible]
Test Engineer

Evaluated By: [illegible]

Recommended for Approval By: C. T. Snow
NFO Engineer

NORTH ANNA POWER STATION UNIT 2 CYCLE 4
STARTUP PHYSICS TEST RESULTS AND EVALUATION SHEET

I Reference	Test Description: Isothermal Temperature Coefficient - ARO Proc No /Section: 2-PT-94.4 Sequence Step No: 5	
II Test Conditions (Design)	Bank Positions (Steps) SDA: 228 SDB: 228 CA: 228 CB: 228 CC: 228 CD: 228	RCS Temperature (°F): 547 Power Level (% F.P.): 0 Other (specify): Below Nuclear Heating
III Test Conditions (Actual)	Bank Positions (Steps) SDA: 228 SDB: 228 CA: 228 CB: 228 CC: 228 CD: 222	RCS Temperature (°F): 545.0°F Power Level (% F.P.): 0 Other (Specify): Below Nuclear Heating
	Date/Time Test Performed: 11/2/84 1605	
IV Test Results	Meas Parameter (Description)	$(\alpha_T^{ISO})_{ARO}$ Isothermal Temp Coeff - ARO
	Measured Value	$(\alpha_T^{ISO})_{ARO}$ = -2.95 pcm/°F (C_B = 1669 ppm)
	Design Value (Actual Cond)	$(\alpha_T^{ISO})_{ARO}$ = -3.55±3.0 pcm/°F (C_B = 1669 ppm)
	Design Value (Design Cond)	$(\alpha_T^{ISO})_{ARO}$ = -3.25 ± 3.0 pcm/°F (C_B = 1699 ppm)
	Reference	NE REPORT NO. 385
V Acceptance Criteria	FSAR/Tech Spec	$\alpha_T^{ISO} \leq -2.12$ * pcm/°F α_T^{Dop} = -2.12 pcm/°F
	Reference	TS 3.1.1.4, NE REPORT NO. 385
VI	Design Tolerance is met : ✓ YES __ NO Acceptance Criteria is met : ✓ YES __ NO	
Comments	* A measured value more positive than -2.12 pcm/°F requires implementation of control rod withdrawal limits.	

Completed By: [signature] Test Engineer

Evaluated By: B O Mann

Recommended for Approval By: C. J. Snow NFO Engineer

NORTH ANNA POWER STATION UNIT 2 CYCLE 4
STARTUP PHYSICS TEST RESULTS AND EVALUATION SHEET

<table>
<tr><td>I
Reference</td><td colspan="2">Test Description: Cntl Bank B Worth Meas., Rod Swap Ref. Bank
Proc No /Section: 2-PT-94.5 Sequence Step No: 7</td></tr>
<tr><td rowspan="2">II
Test
Conditions
(Design)</td><td>Bank Positions (Steps)</td><td rowspan="2">RCS Temperature (°F): 547
Power Level (% F.P.): 0
Other (specify):
Below Nuclear Heating</td></tr>
<tr><td>SDA: 228 SDB: 228 CA: 228
CB: Moving CC: 228 CD: 228</td></tr>
<tr><td rowspan="2">III
Test
Conditions
(Actual)</td><td>Bank Positions (Steps)</td><td rowspan="3">RCS Temperature (°F): 545 °F
Power Level (% F.P.): 0
Other (Specify):
Below Nuclear Heating</td></tr>
<tr><td>SDA: 228 SDB: 228 CA: 228
CB: Moving CC: 228 CD: 228</td></tr>
<tr><td rowspan="6">IV

Test
Results</td><td>Date/Time Test Performed:
11/2/84 1827</td></tr>
<tr><td>Measured Parameter
(Description)</td><td>I_B^{REF}; Integral Worth of Cntl Bank B, All Other Rods Out</td></tr>
<tr><td>Measured Value</td><td>I_B^{REF} = 1372 pcm</td></tr>
<tr><td>Design Value
(Actual Conditions)</td><td>I_B^{REF} = 1399 ± 140 pcm</td></tr>
<tr><td>Design Value
(Design Conditions)</td><td>I_B^{REF} = 1399 ± 140 pcm</td></tr>
<tr><td>Reference</td><td>NE REPORT NO. 585</td></tr>
<tr><td rowspan="2">V
Acceptance
Criteria</td><td>FSAR/Tech Spec</td><td>If Design Tolerance is exceeded, SNSOC shall evaluate impact of test result on safety analysis. SNSOC may specify that additional testing be performed.</td></tr>
<tr><td>Reference</td><td>VEP-FRD-36A</td></tr>
<tr><td>VI
Comments</td><td colspan="2">Design Tolerance is met : ✓ YES ___ NO
Acceptance Criteria is met : ✓ YES ___ NO</td></tr>
</table>

Completed By: [signature]
Test Engineer

Evaluated By: E. I. Hal

Recommended for Approval By: C. T. Snow
NFO Engineer

NORTH ANNA POWER STATION UNIT 2 CYCLE 4
STARTUP PHYSICS TEST RESULTS AND EVALUATION SHEET

I Reference	Test Description: Critical Boron Concentration - B Bank In Proc No /Section: 2-PT-94.3 Sequence Step No: 8	
II Test Conditions (Design)	Bank Positions (Steps) SDA: 228 SDB: 228 CA: 228 CB: 0 CC: 228 CD: 228	RCS Temperature (°F): 547 Power Level (% F.P.): 0 Other (specify): Below Nuclear Heating
III Test Conditions (Actual)	Bank Positions (Steps) SDA: 228 SDB: 228 CA: 228 CB: 0 CC: 228 CD: 228	RCS Temperature (°F): 544 °F Power Level (% F.P.): 0 Other (Specify): Below Nuclear Heating
	Date/Time Test Performed: 11/2/84 2352	
IV Test Results	Meas Parameter (Description)	$(C_B)_B^M$; Critical Boron Concentration - B Bank In
	Measured Value	$(C_B)_B^M$ = 1500 ppm
	Design Value (Actual Cond)	C_B = 1494 ± 28ppm
	Design Value (Design Cond)	$C_B = 1517 + \Delta C_B^{Prev} \pm (10 + 139.5/\lvert\alpha_{C_B}\rvert)$ppm
	Reference	NE REPORT NO. 385
V Acceptance Criteria	FSAR/Tech Spec	$\alpha_{C_B} \times C_B \leq 24{,}000$ pcm
	Reference	UFSAR Section 15.2.4
VI Comments	Design Tolerance is met : ✓ YES __NO Acceptance Criteria is met : ✓ YES __NO	
	α_{C_B} = -7.60 pcm/ppm for preliminary analysis $\Delta C_B^{Prev} = (C_B)_{ARO}^M - 1699$ α_{C_B} = -7.80 pcm/ppm for final analysis.	

Completed By: [signature] Test Engineer

Evaluated By: E. D. [signature]

Recommended for Approval By: C. T. Snow NFO Engineer

NORTH ANNA POWER STATION UNIT 2 CYCLE 4
STARTUP PHYSICS TEST RESULTS AND EVALUATION SHEET

I Reference	Test Description: HZP Boron Worth Coefficent Measurement Proc No /Section: 2-PT-94.5 Sequence Step No: 8	
II Test Conditions (Design)	Bank Positions (Steps) SDA: 228 SDB: 228 CA: 228 CB:Moving CC: 228 CD: 228	RCS Temperature (°F): 547 Power Level (% F.P.): 0 Other (specify): Below Nuclear Heating
III Test Conditions (Actual)	Bank Positions (Steps) SDA: 228 SDB: 228 CA: 228 CB:Moving CC: 228 CD: 228	RCS Temperature (°F): 545.0°F Power Level (% F.P.): 0 Other (Specify): Below Nuclear Heating
IV Test Results	Date/Time Test Performed: 11-2-84 1513	
	Measured Parameter (Description)	α_{C_B}, Boron Worth Coefficient
	Measured Value	α_{C_B} = -7.80 pcm/ppm
	Design Value (Actual Conditions)	α_{C_B} = -7.60 ± 0.76 pcm/ppm
	Design Value (Design Conditions)	α_{C_B} = -7.60 ± 0.76 pcm/ppm
	Reference	NE REPORT NO. 385
V Acceptance Criteria	FSAR/Tech Spec	$\alpha_{C_B} \times C_B \leq 24{,}000$ pcm
	Reference	UFSAR Section 13.2.4
VI Comments	Design Tolerance is met : ✓ YES __ NO Acceptance Criteria is met : ✓ YES __ NO	

Completed By: [signature]
Test Engineer

Evaluated By: E. J. [signature]

Recommended for Approval By: C. T. Snow
NFO Engineer

NORTH ANNA POWER STATION UNIT 2 CYCLE 4
STARTUP PHYSICS TEST RESULTS AND EVALUATION SHEET

I Reference	Test Description: Cntl Bank D Worth Measurement-Rod Swap Proc No /Section: 2-PT-94.7 Sequence Step No: 10	
II Test Conditions (Design)	Bank Positions (Steps) SDA: 228 SDB: 228 CA: 228 CB:Moving CC: 228 CD:Moving	RCS Temperature (°F): 547 Power Level (% F.P.): 0 Other (specify): Below Nuclear Heating
III Test Conditions (Actual)	Bank Positions (Steps) SDA: 228 SDB: 228 CA: 228 CB:Moving CC: 228 CD:Moving	RCS Temperature (°F): 544.5°F Power Level (% F.P.): 0 Other (Specify): Below Nuclear Heating
IV Test Results	Date/Time Test Performed: 11/3/84 0028	
	Meas Parameter (Description)	I_D^{RS}; Int Worth of Cntl Bank D-Rod Swap
	Measured Value	I_D^{RS}= 1036 pcm (Adj. Meas. Crit. Ref Bank Position = 162 steps)
	Design Value (Actual Cond)	I_D^{RS}= 1070±161 pcm (Adj. Meas. Crit. Ref Bank Position = 162 steps)
	Design Value (Design Cond)	I_D^{RS}= 1067 ± 160 pcm (Critical Ref Bank Position = 175 steps)
	Reference	NE REPORT NO. 385, VEP-FRD-36A, NFO-TI-2.2A
V Acceptance Criteria	FSAR/Tech Spec	If Design Tolerance is exceeded, SNSOC shall evaluate impact of test result on safety analysis. SNSOC may specify that additional testing be performed.
	Reference	VEP-FRD-36A
VI Comments	Design Tolerance is met : ✓ YES __NO Acceptance Criteria is met : ✓ YES __NO	

Completed By: [signature]
Test Engineer

Evaluated By: E. S. Hall

Recommended for Approval By: C. T. Snow
NFO Engineer

NORTH ANNA POWER STATION UNIT 2 CYCLE 4
STARTUP PHYSICS TEST RESULTS AND EVALUATION SHEET

<table>
<tr><td>I
Reference</td><td colspan="2">Test Description: Cntl Bank C Worth Measurement-Rod Swap
Proc No /Section: 2-PT-94.7 Sequence Step No: 11</td></tr>
<tr><td rowspan="2">II
Test
Conditions
(Design)</td><td>Bank Positions (Steps)</td><td rowspan="2">RCS Temperature (°F): 547
Power Level (% F.P.): 0
Other (specify):
Below Nuclear Heating</td></tr>
<tr><td>SDA: 228 SDB: 228 CA: 228
CB:Moving CC:Moving CD: 228</td></tr>
<tr><td rowspan="2">III
Test
Conditions
(Actual)</td><td>Bank Positions (Steps)</td><td rowspan="2">RCS Temperature (°F): 544.7°F
Power Level (% F.P.): 0
Other (Specify):
Below Nuclear Heating</td></tr>
<tr><td>SDA: 228 SDB: 228 CA: 228
CB:Moving CC:Moving CD: 228</td></tr>
<tr><td rowspan="6">IV
Test
Results</td><td colspan="2">Date/Time Test Performed:
11-3-84 0158</td></tr>
<tr><td>Meas Parameter
(Description)</td><td>I_C^{RS}; Int Worth of Cntl Bank C-Rod Swap</td></tr>
<tr><td>Measured Value</td><td>I_C^{RS} = 801 pcm (Adj. Meas. Crit. Ref Bank Position = 127 steps)</td></tr>
<tr><td>Design Value
(Actual Cond)</td><td>I_C^{RS} = 851 ± 128 pcm (Adj. Meas. Crit. Ref Bank Position = 127 steps)</td></tr>
<tr><td>Design Value
(Design Cond)</td><td>I_C^{RS} = 852 ± 128 pcm (Critical Ref Bank Position = 149 steps)</td></tr>
<tr><td>Reference</td><td>NE REPORT NO. 385, VEP-FRD-36A, NFO-TI-2.2A</td></tr>
<tr><td rowspan="2">V
Acceptance
Criteria</td><td>FSAR/Tech Spec</td><td>If Design Tolerance is exceeded, SNSOC shall evaluate impact of test result on safety analysis. SNSOC may specify that additional testing be performed.</td></tr>
<tr><td>Reference</td><td>VEP-FRD-36A</td></tr>
<tr><td rowspan="2">VI
Comments</td><td colspan="2">Design Tolerance is met : ✓ YES __NO
Acceptance Criteria is met : ✓ YES __NO</td></tr>
<tr><td colspan="2"></td></tr>
</table>

Completed By: [signature]
Test Engineer

Evaluated By: C. A. Ford

Recommended for Approval By : C. J. Snow
NFO Engineer

NORTH ANNA POWER STATION UNIT 2 CYCLE 4
STARTUP PHYSICS TEST RESULTS AND EVALUATION SHEET

I Reference	Test Description: Cntl Bank A Worth Measurement-Rod Swap Proc No /Section: 2-PT-94.7 Sequence Step No: 12	
II Test Conditions (Design)	Bank Positions (Steps) SDA: 228 SDB: 228 CA:Moving CB:Moving CC: 228 CD: 228	RCS Temperature (°F): 547 Power Level (% F.P.): 0 Other (specify): Below Nuclear Heating
III Test Conditions (Actual)	Bank Positions (Steps) SDA: 228 SDB: 228 CA:Moving CB:Moving CC: 228 CD: 228	RCS Temperature (°F): 544.2 °F Power Level (% F.P.): 0 Other (Specify): Below Nuclear Heating
	Date/Time Test Performed: 11-3-84 0333	
IV Test Results	Meas Parameter (Description)	I_A^{RS}; Int Worth of Cntl Bank A - Rod Swap
	Measured Value	I_A^{RS} = 426 pcm (Adj. Meas. Crit. Ref Bank Position = 82 steps)
	Design Value (Actual Cond)	I_A^{RS} = 383 ± 100 pcm (Adj. Meas. Crit. Ref Bank Position = 82 steps)
	Design Value (Design Cond)	I_A^{RS} = 391 ± 100 pcm (Critical Ref Bank Position = 95 steps)
	Reference	NE REPORT NO. 385, VEP-FRD-36A, NFO-TI-2.2A
V Acceptance Criteria	FSAR/Tech Spec	If Design Tolerance is exceeded, SNSOC shall evaluate impact of test result on safety analysis. SNSOC may specify that additional testing be performed.
	Reference	VEP-FRD-36A
VI Comments	Design Tolerance is met : ✓ YES __ NO Acceptance Criteria is met : ✓ YES __ NO	

Completed By: [signature]
Test Engineer

Evaluated By: C. A. Ford

Recommended for Approval By : C. T. Snow
NFO Engineer

NORTH ANNA POWER STATION UNIT 2 CYCLE 4
STARTUP PHYSICS TEST RESULTS AND EVALUATION SHEET

I Reference	Test Description: Shutdown Bank B Worth Meas. - Rod Swap Proc No /Section: 2-PT-94.7 Sequence Step No: 13	
II Test Conditions (Design)	Bank Positions (Steps) SDA: 228 SDB:Moving CA: 228 CB:Moving CC: 228 CD: 228	RCS Temperature (°F): 547 Power Level (% F.P.): 0 Other (specify): Below Nuclear Heating
III Test Conditions (Actual)	Bank Positions (Steps) SDA: 228 SDB:Moving CA: 228 CB:Moving CC: 228 CD: 228	RCS Temperature (°F): 544.2 °F Power Level (% F.P.): 0 Other (Specify): Below Nuclear Heating
IV Test Results	Date/Time Test Performed: 11-3-84 0401	
	Meas Parameter (Description)	I_{SB}^{RS}; Int Worth of Shutdown Bank B-Rod Swap
	Measured Value	I_{SB}^{RS} = 853 pcm (Adj. Meas. Crit. Ref Bank Position = 134 steps)
	Design Value (Actual Cond)	I_{SB}^{RS} = 910 ± 137 pcm (Adj. Meas. Crit. Ref Bank Position = 134 steps)
	Design Value (Design Cond)	I_{SB}^{RS} = 917 ± 138 pcm (Critical Ref Bank Position = 157 steps)
	Reference	NE REPORT NO. 385, VEP-FRD-36A, NFO-TI-2.2A
V Acceptance Criteria	FSAR/Tech Spec	If Design Tolerance is exceeded, SNSOC shall evaluate impact of test result on safety analysis. SNSOC may specify that additional testing be performed.
	Reference	VEP-FRD-36A
VI Comments	Design Tolerance is met : ✓YES __NO Acceptance Criteria is met : ✓YES __NO	

Completed By: [signature]
Test Engineer

Evaluated By: C. A. Ford

Recommended for Approval By: C. T. Snow
NFO Engineer

NORTH ANNA POWER STATION UNIT 2 CYCLE 4
STARTUP PHYSICS TEST RESULTS AND EVALUATION SHEET

I Reference	Test Description: Shutdown Bank A Worth Meas. - Rod Swap Proc No /Section: 2-PT-94.7 Sequence Step No: 14	
II Test Conditions (Design)	Bank Positions (Steps) SDA:Moving SDB: 228 CA: 228 CB:Moving CC: 228 CD: 228	RCS Temperature (°F): 547 Power Level (% F.P.): 0 Other (specify): Below Nuclear Heating
III Test Conditions (Actual)	Bank Positions (Steps) SDA:Moving SDB: 228 CA: 228 CB:Moving CC: 228 CD: 228	RCS Temperature (°F): 544.2 °F Power Level (% F.P.): 0 Other (Specify): Below Nuclear Heating
IV Test Results	Date/Time Test Performed: 11-3-84 0429	
	Meas Parameter (Description)	I_{SA}^{RS}; Int Worth of Shutdown Bank A-Rod Swap
	Measured Value	I_{SA}^{RS}= 1103 pcm (Adj. Meas. Crit. Ref Bank Position = 173 steps)
	Design Value (Actual Cond)	I_{SA}^{RS}= 1068 ± 160 pcm (Adj. Meas. Crit. Ref Bank Position = 173 steps)
	Design Value (Design Cond)	I_{SA}^{RS}=1067 ± 160 pcm (Critical Ref Bank Position = 175 steps)
	Reference	NE REPORT NO. 385, VEP-FRD-36A, NFO-TI-2.2A
V Acceptance Criteria	FSAR/Tech Spec	If Design Tolerance is exceeded, SNSOC shall evaluate impact of test result on safety analysis. SNSOC may specify that additional testing be performed.
	Reference	VEP-FRD-36A
VI Comments	Design Tolerance is met : ✓YES __NO Acceptance Criteria is met : ✓YES __NO	

Completed By: [signature]
Test Engineer

Evaluated By: C. A. Ford

Recommended for Approval By : C. T. Snow
NFO Engineer

PG.1
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NORTH ANNA POWER STATION UNIT 2 CYCLE 4
STARTUP PHYSICS TEST RESULTS AND EVALUATION SHEET

I Reference	Test Description: Total Rod Worth - Rod Swap Proc No /Section: 2-PT-94.7 Sequence Step No: 14		
II Test Conditions (Design)	Bank Positions (Steps) SDA:Moving SDB:Moving CA:Moving CB:Moving CC:Moving CD:Moving		RCS Temperature (°F): 547 Power Level (% F.P.): 0 Other (specify): Below Nuclear Heating
III Test Conditions (Actual)	Bank Positions (Steps) SDA:Moving SDB:Moving CA:Moving CB:Moving CC:Moving CD:Moving		RCS Temperature (°F): 545.0 °F Power Level (% F.P.): 0 Other (Specify): Below Nuclear Heating
IV Test Results	Date/Time Test Performed: 11-2-84 1827		
	Meas Parameter (Description)	I_{Total}: Int Worth of All Banks - Rod Swap	
	Measured Value	I_{Total} = 5591 pcm	
	Design Value (Actual Cond)	I_{Total} = 5681 ± 568 pcm	
	Design Value (Design Cond)	I_{Total} = 5693 ± 569 pcm	
	Reference	NE REPORT NO. 385, VEP-FRD-36A, NFO-TI-2.2A	
V Acceptance Criteria	FSAR/Tech Spec	If Design Tolerance is exceeded, SNSOC shall evaluate impact of test result on safety analysis. SNSOC may specify that additional testing be performed.	
	Reference	VEP-FRD-36A	
VI Comments	Design Tolerance is met : ✓ YES ___ NO Acceptance Criteria is met : ✓ YES ___ NO		

Completed By: [signature] Test Engineer

Evaluated By: C. A. Ford

Recommended for Approval By: C. T. Snow NFO Engineer

NORTH ANNA POWER STATION UNIT 2 CYCLE 4
STARTUP PHYSICS TEST RESULTS AND EVALUATION SHEET

I Reference	Test Description : M/D Flux Map - HZP, ARO Proc No / Section: 2-PT-21.1 Sequence Step No: 42A
II Test Conditions (Design)	Bank Positions (Steps) SDA: 228 SDB: 228 CA: 228 CB : 228 CC : 228 CD: 228
	RCS Temperature (°F): T_{REF} ±1 Power Level (% F.P.): ~ 3 Other (specify) Must have ≥ 38 thimbles
III Test Conditions (Actual)	Bank Positions (Steps) SDA: 228 SDB: 228 CA: 228 CB : 228 CC : 228 CD: 211
	RCS Temperature(°F): 547°F Power Level (% F.P.): 3% Other (Specify): 46 thimbles
	Date/Time Test Performed: 11/3/84 1101

		MAX. REL ASSY PWR % DIFF (M-P)/P	NUC ENTHAL RISE HOT CHAN FACT F-dH(N)	TOTAL HEAT FLUX HOT CHAN FACT F-Q(T)	QUADRANT POWER TILT RATIO QPTR	RADIAL PEAKING FACTOR F-XY
IV Test Results	Meas Parameter (Description)					
	Measured Value	7.7% for $N11 = 1.19$ 11% for $N12 = 0.55$	1.508	2.499	1.03	1.596
	Design Value (Design Conds)	[illegible]	[illegible]	[illegible]	≤ 1.02	[illegible]
	Reference	WCAP-7905 REV. 1	NONE	NONE	WCAP-7905 REV. 1	NONE
V Acceptance Criteria	FSAR/Tech Spec	NONE	NA	NA	NA	NA
	Reference	NONE	TS 3.2.3	TS 3.2.2	TS 3.2.4	TS 4.2.2

VI Comments

Design Tolerance is met : __YES ✓NO #
Acceptance Criteria is met : ✓YES __NO

The test results are acceptable as indicated by North Anna Power Station Deviation Report No. 84-1605.

Completed By: [signature] Test Engineer

Evaluated By: B O Mann

Recommended for Approval By: C. T. Snow NFO Engineer

* The final limit for unrodded Fxy was 1.61.

NORTH ANNA POWER STATION UNIT 2 CYCLE 4
STARTUP PHYSICS TEST RESULTS AND EVALUATION SHEET

I Reference	Test Description : M/D Flux Map-At Power, NI Calibration Proc No / Section: 2-PT-22.2 Sequence Step No: 43
II Test Conditions (Design)	Bank Positions (Steps) SDA: 228 SDB: 228 CA: 228 CB : 228 CC : 228 CD: *
	RCS Temperature (°F): T_{REF} ±1 Power Level (% F.P.): ~ 50 Other (specify)
III Test Conditions (Actual)	Bank Positions (Steps) SDA: 228 SDB: 228 CA: 228 CB : 228 CC : 228 CD: 162
	RCS Temperature(°F): TREF Power Level (% F.P.): 50.1% Other (Specify): 47 thimbles
	Date/Time Test Performed: 11/10/84 1150

		MAX. REL ASSY PWR % DIFF (M-P)/P	NUC ENTHAL RISE HOT CHAN FACT F-dH(N)	TOTAL HEAT FLUX HOT CHAN FACT F-Q(T)	QUADRANT POWER TILT RATIO QPTR	RADIAL PEAKING FACTOR F-XY
IV	Meas Parameter (Description)					
Test Results	Measured Value	5.4% for P_{R7} = 1.12 10.1% for P_{R9} = 0.41	1.487	2.001	1.0107	1.730#
	Design Value (Design Conds)	± 10% for P_i ≥ 0.9 ± 15% for P_i < 0.9 (P_i = Assy Pwr)	NA	NA	≤ 1.02	NA
	Reference	WCAP-7905 REV.1	NONE	NONE	WCAP-7905 REV.1	NONE
V Acceptance Criteria	FSAR/Tech Spec	NONE	$F^N_{\Delta H}$ ≤ 1.55[1+.3(1-P)] [1-RBP(BU)]	[illegible]	NA	[illegible]
	Reference	NONE	TS 3.2.3	TS 3.2.2	TS 3.2.4	TS 4.2.2

VI Comments

Design Tolerance is met : ✓ YES ___ NO
Acceptance Criteria is met : ___ YES ✓ NO

*As Required
Must have at least 38 thimbles for a full-core flux map, or at least 16 thimbles for a quarter-core flux map.

Completed By: [signature] Test Engineer

Evaluated By: C. A. Ford

Recommended for Approval By: C. T. Snow NFO Engineer

\# A violation of the F_{xy}^{RTP} Technical Specifications limit occured, but was deemed acceptable as per North Anna Power Station Deviation Report 84-1663.

NORTH ANNA POWER STATION UNIT 2 CYCLE 4
STARTUP PHYSICS TEST RESULTS AND EVALUATION SHEET

I Reference	Test Description : M/D Flux Map-At Power, NI Calibration Proc No / Section: 2-PT-22.2 Sequence Step No: 44	
II Test Conditions (Design)	Bank Positions (Steps) SDA: 228 SDB: 228 CA: 228 CB : 228 CC : 228 CD: *	RCS Temperature (°F): T_{REF} ±1 Power Level (% F.P.): ~ 70 Other (specify)
III Test Conditions (Actual)	Bank Positions (Steps) SDA: 228 SDB: 228 CA: 228 CB : 228 CC : 228 CD: 171	RCS Temperature(°F): T_{REF} Power Level (% F.P.): 69.5% Other (Specify): 47 thimbles
	Date/Time Test Performed: 11/12/84 0022	

IV	Meas Parameter (Description)	MAX. REL ASSY PWR % DIFF (M-P)/P	NUC ENTHAL RISE HOT CHAN FACT F-dH(N)	TOTAL HEAT FLUX HOT CHAN FACT F-Q(T)	QUADRANT POWER TILT RATIO QPTR	RADIAL PEAKING FACTOR F-XY
Test Results	Measured Value	4.4% for P_{N-L} = 1.22 6.1% for P_{RT} = 0.43	1.448	1.931	1.0150	1.517
	Design Value (Design Conds)	[illegible]	NA	NA	≤ 1.02	NA
	Reference	WCAP-7905 REV.1	NONE	NONE	WCAP-7905 REV.1	NONE
V Acceptance Criteria	FSAR/Tech Spec	NONE	[illegible]	[illegible]	NA	[illegible]
	Reference	NONE	TS 3.2.3	TS 3.2.2	TS 3.2.4	TS 4.2.2

VI Comments	Design Tolerance is met : ✓ YES __ NO Acceptance Criteria is met : ✓ YES __ NO
	Must have at least 38 thimbles for a full-core flux map or, at least 16 thimbles for a quarter-core flux map. *As Required

Completed By: [signature]
Test Engineer

Evaluated By: B O Mann

Recommended for Approval By: C. T. Snow
NFO Engineer

NORTH ANNA POWER STATION UNIT 2 CYCLE 4
STARTUP PHYSICS TEST RESULTS AND EVALUATION SHEET

I Reference	Test Description : M/D Flux Map-At Power, NI Calibration Proc No / Section: 2-PT-22.2 Sequence Step No: 45	
II Test Conditions (Design)	Bank Positions (Steps) SDA: 228 SDB: 228 CA: 228 CB : 228 CC : 228 CD: *	RCS Temperature (°F): T_{REF} ±1 Power Level (% F.P.): ~ 70 Other (specify)
III Test Conditions (Actual)	Bank Positions (Steps) SDA: 228 SDB: 228 CA: 228 CB : 228 CC : 228 CD: 184	RCS Temperature(°F): TREF Power Level (% F.P.): 74.8% Other (Specify): 25 thimbles
	Date/Time Test Performed: 11/12/84 0612	Quarter-core Flux Map

		MAX. REL ASSY PWR % DIFF (M-P)/P	NUC ENTHAL RISE HOT CHAN FACT F-dH(N)	TOTAL HEAT FLUX HOT CHAN FACT F-Q(T)	QUADRANT POWER TILT RATIO QPTR	RADIAL PEAKING FACTOR F-XY
IV	Meas Parameter (Description)					
Test Results	Measured Value	3.1% for P_{H3} = 1.16 3.7% for P_{B11} = 0.40	NA[1]	NA[1]	NA[1]	NA[1]
	Design Value (Design Conds)	[illegible]	NA	NA	≤ 1.02	NA
	Reference	WCAP-7905 REV.1	NONE	NONE	WCAP-7905 REV.1	NONE
V Acceptance Criteria	FSAR/Tech Spec	NONE	[illegible]	[illegible]	NA	[illegible]
	Reference	NONE	TS 3.2.3	TS 3.2.2	TS 3.2.4	TS 4.2.2

VI Comments	Design Tolerance is met : ✓ YES ___ NO Acceptance Criteria is met : ✓ YES ___ NO
	Must have at least 38 thimbles for a full-core flux map or, at least 16 thimbles for a quarter-core flux map. *As Required

Completed By: [signature] Test Engineer

Evaluated By: B O Mann

Recommended for Approval By: C. J. Snow NFO Engineer

1 These parameters are not verified using a partial-core map obtained for NI calibration.

NORTH ANNA POWER STATION UNIT 2 CYCLE 4
STARTUP PHYSICS TEST RESULTS AND EVALUATION SHEET

I Reference	Test Description : M/D Flux Map-At Power, NI Calibration Proc No / Section: 2-PT-22.2 Sequence Step No: 46					
II Test Conditions (Design)	Bank Positions (Steps) SDA: 228 SDB: 228 CA: 228 CB : 228 CC : 228 CD: *			RCS Temperature (°F): T_{REF} ±1 Power Level (% F.P.): ~ 70 Other (specify)		
III Test Conditions (Actual)	Bank Positions (Steps) SDA: 228 SDB: 228 CA: 228 CB : 228 CC : 228 CD: 172			RCS Temperature (°F): T_{REF} Power Level (% F.P.): 74.5% Other (Specify): 19 thimbles		
	Date/Time Test Performed: 11/12/84 1044			Quarter-core Flux Map		
IV	Meas Parameter (Description)	MAX. REL ASSY PWR % DIFF (M-P)/P	NUC ENTHAL RISE HOT CHAN FACT F-dH(N)	TOTAL HEAT FLUX HOT CHAN FACT F-Q(T)	QUADRANT POWER TILT RATIO QPTR	RADIAL PEAKING FACTOR F-XY
Test Results	Measured Value	4.5% for $P_{H-2} = 0.99$ 4.8% for $P_{H-15} = 0.53$	NA [1]	NA [1]	NA [1]	NA [1]
	Design Value (Design Conds)	[illegible]	NA	NA	≤ 1.02	NA
	Reference	WCAP-7905 REV.1	NONE	NONE	WCAP-7905 REV.1	NONE
V Acceptance Criteria	FSAR/Tech Spec	NONE	[illegible]	[illegible]	NA	[illegible]
	Reference	NONE	TS 3.2.3	TS 3.2.2	TS 3.2.4	TS 4.2.2
VI Comments	Design Tolerance is met : ✓ YES __ NO Acceptance Criteria is met : ✓ YES __ NO					
	Must have at least 38 thimbles for a full-core flux map or, at least 16 thimbles for a quarter-core flux map. *As Required					

Completed By: [signature]
Test Engineer

Evaluated By: B O Mann

Recommended for Approval By: C. J. Snow
NFO Engineer

1 These parameters are not verified using a partial-core map obtained for NI calibration.

NORTH ANNA POWER STATION UNIT 2 CYCLE 4
STARTUP PHYSICS TEST RESULTS AND EVALUATION SHEET

I Reference	Test Description : M/D Flux Map - HFP, ARO, Eq. Xe Proc No / Section: 2-PT-21.1 Sequence Step No: 47	
II Test Conditions (Design)	Bank Positions (Steps) SDA: 228 SDB: 228 CA: 228 CB : 228 CC : 228 CD: *	RCS Temperature (°F): T_{REF} ±1 Power Level (% F.P.): 95 ± 5 Other (specify) Must have ≥ 38 thimbles
III Test Conditions (Actual)	Bank Positions (Steps) SDA: 228 SDB: 228 CA: 228 CB : 228 CC : 228 CD: 216	RCS Temperature(°F): T_{REF} Power Level (% F.P.): 100% Other (Specify): 46 thimbles
	Date/Time Test Performed: 11/16/84 0928	

	Meas Parameter (Description)	MAX. REL ASSY PWR % DIFF (M-P)/P	NUC ENTHAL RISE HOT CHAN FACT F-dH(N)	TOTAL HEAT FLUX HOT CHAN FACT F-Q(T)	QUADRANT POWER TILT RATIO QPTR	RADIAL PEAKING FACTOR F-XY
IV Test Results	Measured Value	4.5% for P_{PT} = 1.14 5.7% for P_{a15} = 0.45	1.420	1.789	1.015	1.493
	Design Value (Design Conds)	[illegible]	NA	NA	≤ 1.02	NA
	Reference	WCAP-7905 REV.1	NONE	NONE	WCAP-7905 REV.1	NONE
V Acceptance Criteria	FSAR/Tech Spec	NONE	[illegible]	[illegible]	NA	[illegible]
	Reference	NONE	TS 3.2.3	TS 3.2.2	TS 3.2.4	TS 4.2.2

VI Comments	Design Tolerance is met : ✓ YES __ NO Acceptance Criteria is met : ✓ YES __ NO
	*As Required

Completed By: [signature]
Test Engineer

Evaluated By: [signature]

Recommended for Approval By: [signature] for C.T. Snow
NFO Engineer