VIRGINIA ELECTRIC AND POWER COMPANY

RICHMOND, VIRGINIA 23261

January 28, 19 1

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Gentlemen:

VIRGINIA ELECTRIC AND POWER COMPANY
NORTH ANNA POWER STATION UNIT 2
CYCLE 7 CORE PERFORMANCE REPORT

For your information, enclosed are five copies of the Virginia Electric and Power Company Technical Report NE-799, "North Anna Unit 2, Cycle 7 Core Performance Report."

Very truly yours,

W. L. Stewart
Senior Vice President - Nuclear

Enclosures

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North Anna Power Station

A001
1/1

North Anna Unit 2 Cycle 7 Core Performance Report

Nuclear Analysis and Fuel
Nuclear Engineering Services

January, 1991

VIRGINIA POWER

TECHNICAL REPORT NE-799 - Rev. 0

NORTH ANNA UNIT 2, CYCLE 7

CORE PERFORMANCE REPORT

NUCLEAR ANALYSIS AND FUEL
POWER ENGINEERING SERVICES
VIRGINIA POWER
JANUARY, 1991

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INTRODUCTION AND SUMMARY

On August 21, 1990, North Anna Unit 2 completed Cycle 7. Since the initial criticality of Cycle 7 on May 7, 1989, the reactor core produced approximately 1.0748 x 10^8 MBTU (18,023 Megawatt days per metric ton of contained uranium). The purpose of this report is to present an analysis of the core performance for routine operation during Cycle 7. The physics tests that were performed during the startup of this cycle were covered in the North Anna Unit 2, Cycle 7 Startup Physics Test Report[1] and, therefore, will not be included here.

North Anna Unit 2 began operating at a reduced temperture starting on October 31, 1989 at a burnup of approximately 6867 MWD/MTU. Temperature was reduced from an average of 586.8° F to 580.8° F. This was done to prolong the steam generator life.

North Anna Unit 2 was in coastdown from June 25, 1990, at which time the burnup was approximately 16,234 MWD/MTU. The coastdown accounted for an additional core burnup of roughly 1,789 MWD/MTU from the end of full power reactivity.

The Cycle 7 core consisted of 11 sub-batches of fuel: two once-burned batches from Cycle 6 (batches 8A and 8B); five twice burned batches, two

from Cycles 5 and 6 (batches 7A and 7B), one from North Anna 1 Cycles 4 and 5, one from North Anna 1 Cycle 4 and North Anna 2 Cycle 6 (both batch N1/6A), and one from North Anna 1 Cycles 5 and 6 (batch N1/7A); and four fresh batches (batches 9A, 9B, N1/10A and N1/10B). The North Anna 2, Cycle 7 core loading map specifying the fuel batch identification, fuel assembly locations, burnable poison locations and source assembly locations is shown in Figure 1.1. Movable detector locations and thermocouple locations are shown in Figure 1.2. Control rod locations are shown in Figure 1.3.

Routine core follow involves the analysis of four principal performance indicators. These are burnup distribution, reactivity depletion, power distribution, and primary coolant activity. The core burnup distribution is followed to verify both burnup symmetry and proper batch burnup sharing, thereby ensuring that the fuel held over for the next cycle will be compatible with the new fuel that is inserted. Reactivity depletion is monitored to detect the existence of any abnormal reactivity behavior, to determine if the core is depleting as designed, and to indicate at what burnup level refueling will be required. Core power distribution follow includes the monitoring of nuclear hot channel factors to verify that they are within the Technical Specifications[2] limits, thereby ensuring that adequate margins for linear power density and critical heat flux thermal limits are maintained. Lastly, as part of normal core follow, the primary coolant activity is monitored to verify that the dose equivalent iodine-131 concentration is within the limits specified by the North Anna Unit 2 Technical Specifications[2]. A

radioiodine analysis based on the iodine-131 concentration in the coolant is performed to assess the integrity of the fuel.

Each of the four performance indicators is discussed in detail for the North Anna Unit 2, Cycle 7 core in the body of this report. The results are summarized below:

1. Burnup - The burnup tilt (deviation from quadrant symmetry) on the core was no greater than ±0.45% with the burnup accumulation in each batch deviating from design prediction by no more than 1.78%.

2. Reactivity Depletion - The critical boron concentration, used to monitor reactivity depletion, was consistently within ±0.45% ΔK/K of the design prediction which is within the ±1% ΔK/K margin allowed by Section 4.1.1.1.2 of the Technical Specifications.

3. Power Distribution - Incore flux maps taken each month indicated that the assemblywise radial power distributions deviated from the design predictions by a maximum average difference of 1.6%. All hot channel factors met their respective Technical Specifications limits.

4. Primary Coolant Activity - The average dose equivalent iodine-131 activity level in the primary coolant during Cycle 7 was approximately 0.0109 μCi/gm. This corresponds to less than 2% of the operating limit for the concentration of radioiodine in the primary coolant. Radioiodine analysis indicated several fuel rod defects, which prompted ultrasonic testing (UT) during the Cycle 7 to Cycle 8 refueling outage. During UT testing, it was determined that one fuel rod in one assembly had a defect.

Figure 1.1
NORTH ANNA UNIT 2 - CYCLE 7
CORE LOADING MAP

R	P	N	M	L	K	J	H	G	F	E	D	C	B	A	
						V22	G44	V01							1
				V47	W17	X39 SS11	W50	X24	W13	V53					2
			V55	X37 4DP	X50 12P	W07	X02 12P	W22	X32 12P	X31 4DP	V37				3
		V44	W05	X33 10P	W55	X01 12P	W35	X11 12P	W40	X51 10P	W02	V52			4
	V40	X46 4DP	X40 10P	W46	K06 16P	W58	W34	W53	K01 16P	W54	X35 10P	X52 4DP	V38		5
	W14	X41 12P	W32	K10 16P	W10	X10 16P	W20	X19 16P	W12	K09 16P	W33	X42 12P	W11		6
V26	X48	W26	X18 12P	W48	X07 16P	W51	K11 16P	W60	X06 16P	W61	X08 12P	W01	X47	V35	7
G11	W38	X03 12P	W52	W44	W19	K02 16P	F32	K05 16P	W28	W31	W37 SS16	X15 12P	W64	G35	8
V27	X34	W27	X20 12P	W36	X17 16P	W59	K08 16P	W39	X04 16P	W45	X14 12P	W25	X49	V32	9
	W18	X43 12P	W57	K07 16P	W24	X09 16P	W08	X12 16P	W03	K04 16P	W42	X29 12P	W23		10
	V39	X26 4DP	X22 10P	W47	K03 16P	W41	W62	W30	K12 16P	W49	K41 10P	X23 4DP	V43		11
		V41	W21	X45 10P	W29	X05 12P	W63	X16 12P	W56	X28 10P	W09	V45			12
			V64	X25 4DP	X30 12P	W15	X13 12P	W06	X36 12P	X27 4DP	F41				13
				V51	W16	X38	W43	X21 SS12	W04	V49					14
						V10	G48	V36							15

--> ASSEMBLY ID
--> ONE OF THE FOLLOWING

A. SS - SECONDARY SOURCE
B. XXP - BURNABLE POISON ASSEMBLY
(XX-NUMBER OF RODS)
C.XDP - DEPLETED BURNABLE POISON ASSEMBLY
(X-NUMBER OF RODS)

FUEL ASSEMBLLY DESIGN PARAMETERS

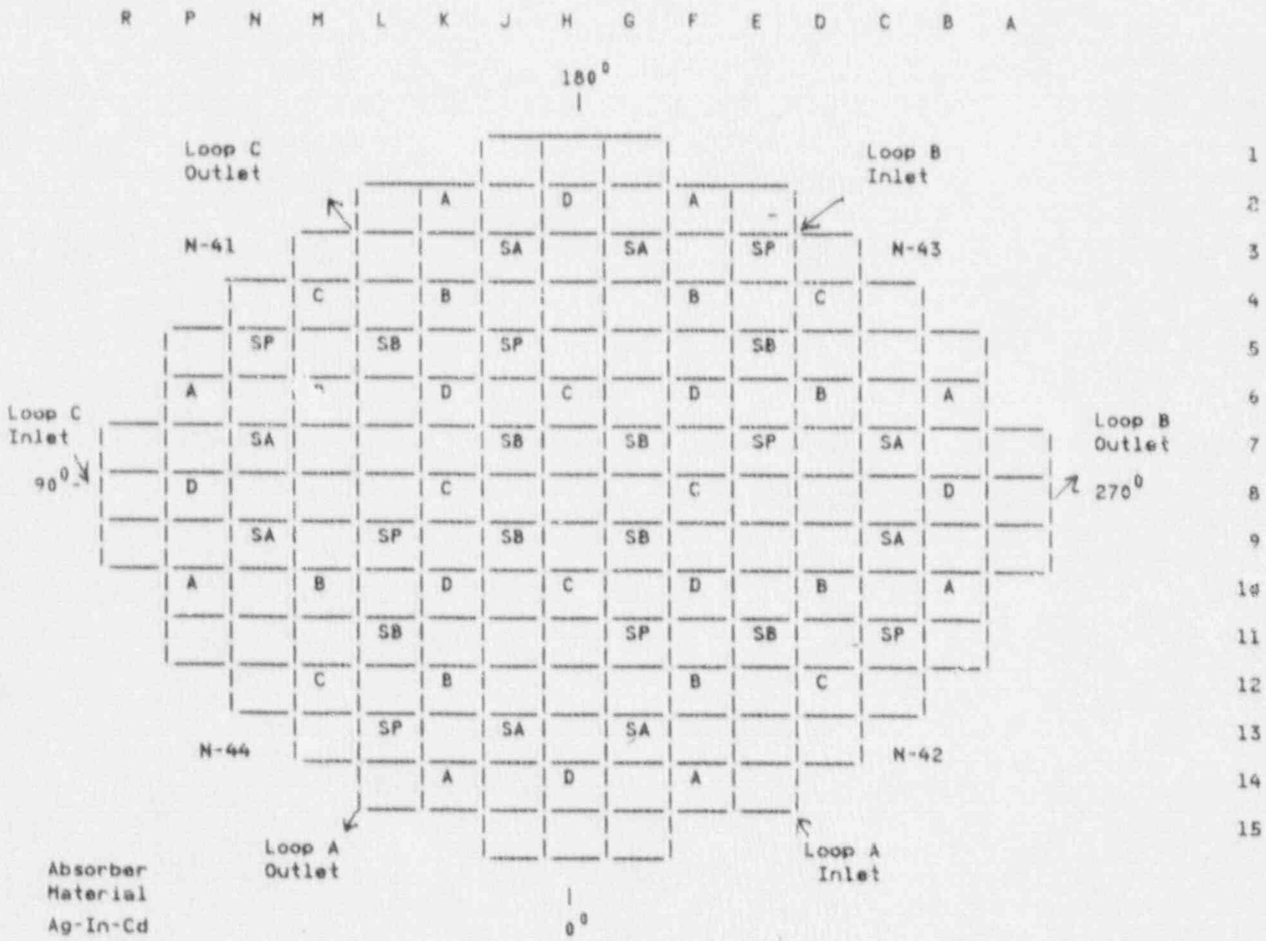
	SUB-BATCH									
	N1/6A	N1/7A	N1/10A	N1/10B	7A	7B	8A	8B	9A	9B
INITIAL ENRICHMENT (W/O U-235)	3.59	3.60	3.80	4.00	3.60	3.79	3.79	4.00	3.80	4.01
ASSEMBLY TYPE	17X17	17X17	17X17	17X17	17X17	17X17	17X17	17X17	17x17	17x17
NUMBER OF ASSEMBLIES	2	4	12	1	8	15	28	36	20	31
FUEL RODS PER ASSEMBLY	264	264	264	264	264	264	264	264	264	264
ASSEMBLY IDENTIFICATION										
	F32	G11	K01	K41	V01	V37	W01 W15	W29 W45 W61	X01 X11	X21 X37
	F41	G35	K02		V10	V38	W02 W16	W30 W46 W62	X02 X12	X22 X38
		G44	K03		V22	V39	W03 W17	W31 W47 W63	X03 X13	X23 X39
		G48	K04		V26	V40	W04 W18	W32 W48 W64	X04 X14	X24 X40
			K05		V27	V41	W05 W19	W33 W49	X05 X15	X25 X41
			K06		V32	V43	W06 W20	W34 W50	X06 X16	X26 X42
			K07		V35	V44	W07 W21	W35 W51	X07 X17	X27 X43
			K08		V36	V45	W08 W22	W36 W52	X08 X18	X28 X45
			K09			V47	W09 W23	W37 W53	X09 X19	X29 X46
			K10			V49	W10 W24	W38 W54	X10 X20	X30 X47
			K11			V51	W11 W25	W39 W55		X31 X48
			K12			V52	W12 W26	W40 W56		X32 X49
						V53	W13 W27	W41 W57		X33 X50
						V55	W14 W28	W42 W58		X34 X51
						V64		W43 W59		X35 X52
								W44 W60		X36

Figure 1.2
NORTH ANNA UNIT 2 - CYCLE 7
MOVABLE DETECTOR AND
THERMOCOUPLE LOCATIONS

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

MD - Movable Detector
TC - Thermocouple

Figure 1.3
NORTH ANNA UNIT 2 - CYCLE 7
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

Section 2

BURNUP

The burnup history for the North Anna Unit 2, Cycle 7 core is graphically depicted in Figure 2.1. The North Anna 2, Cycle 7 core achieved a burnup of 18,023 MWD/MTU. As shown in Figure 2.2, the average load factor for Cycle 7 was 94.3% when referenced to rated thermal power (2893 MW(t)). Unit 2 performed a power coastdown starting on June 25, 1990 until shutdown for refueling on August 21, 1990.

Radial (X-Y) burnup distribution maps show how the core burnup is shared among the various fuel assemblies, and thereby allow a detailed burnup distribution analysis. The NEWTOTE[3] computer code is used to calculate these assemblywise burnups. Figure 2.3 is a radial burnup distribution map in which the assemblywise burnup accumulation of the core at the end of Cycle 7 operation is given. For comparison purposes, the design values are also given. Figure 2.4 is a radial burnup distribution map in which the percentage difference comparison of measured and predicted assemblywise burnup accumulation at the end of Cycle 7 operation is also given. As can be seen from this figure, the accumulated assembly burnups were generally within ±2.59% of the predicted values. In addition, deviation from quadrant symmetry in the core throughout the cycle was no greater than ±0.45%.

The burnup sharing on a batch basis is monitored to verify that the core is operating as designed and to enable accurate end-of-cycle batch

burnup predictions to be made for use in reload fuel design studies. Batch definitions are given in Figure 1.1. As seen in Figures 2.5A, 2.5B and 2.5C the batch burnup sharing for North Anna 2, Cycle 7 followed design predictions closely with no batch deviating from prediction by more than 1.78%. Symmetric burnup in conjunction with agreement between actual and predicted assemblywise burnups and batch burnup sharing indicate that the Cycle 7 core did deplete as designed.

Figure 2.1
NORTH ANNA UNIT 2 - CYCLE 7
CORE BURNUP HISTORY

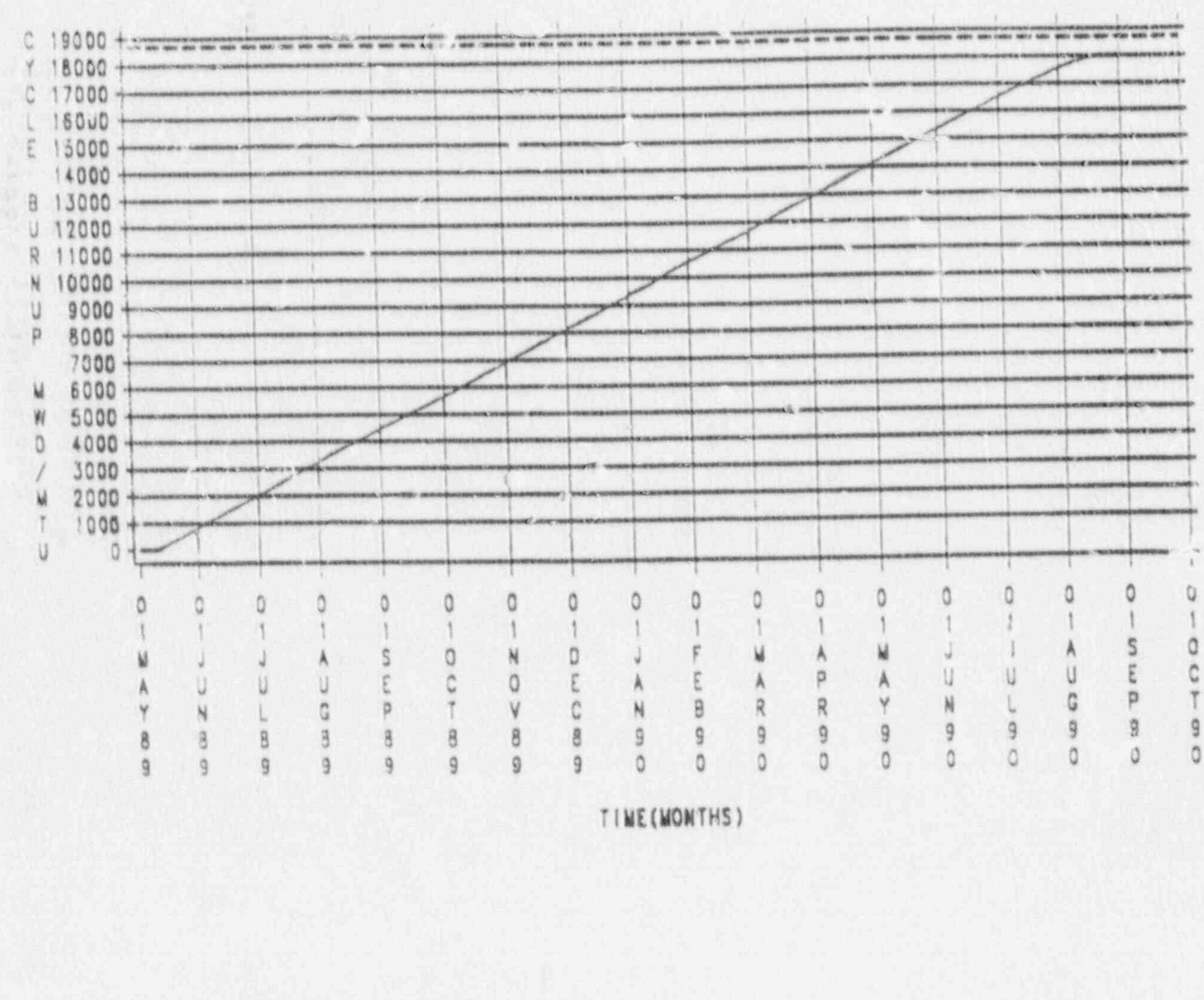


Figure 2.2
NORTH ANNA UNIT 2 - CYCLE 7
MONTHLY AVERAGE LOAD FACTORS

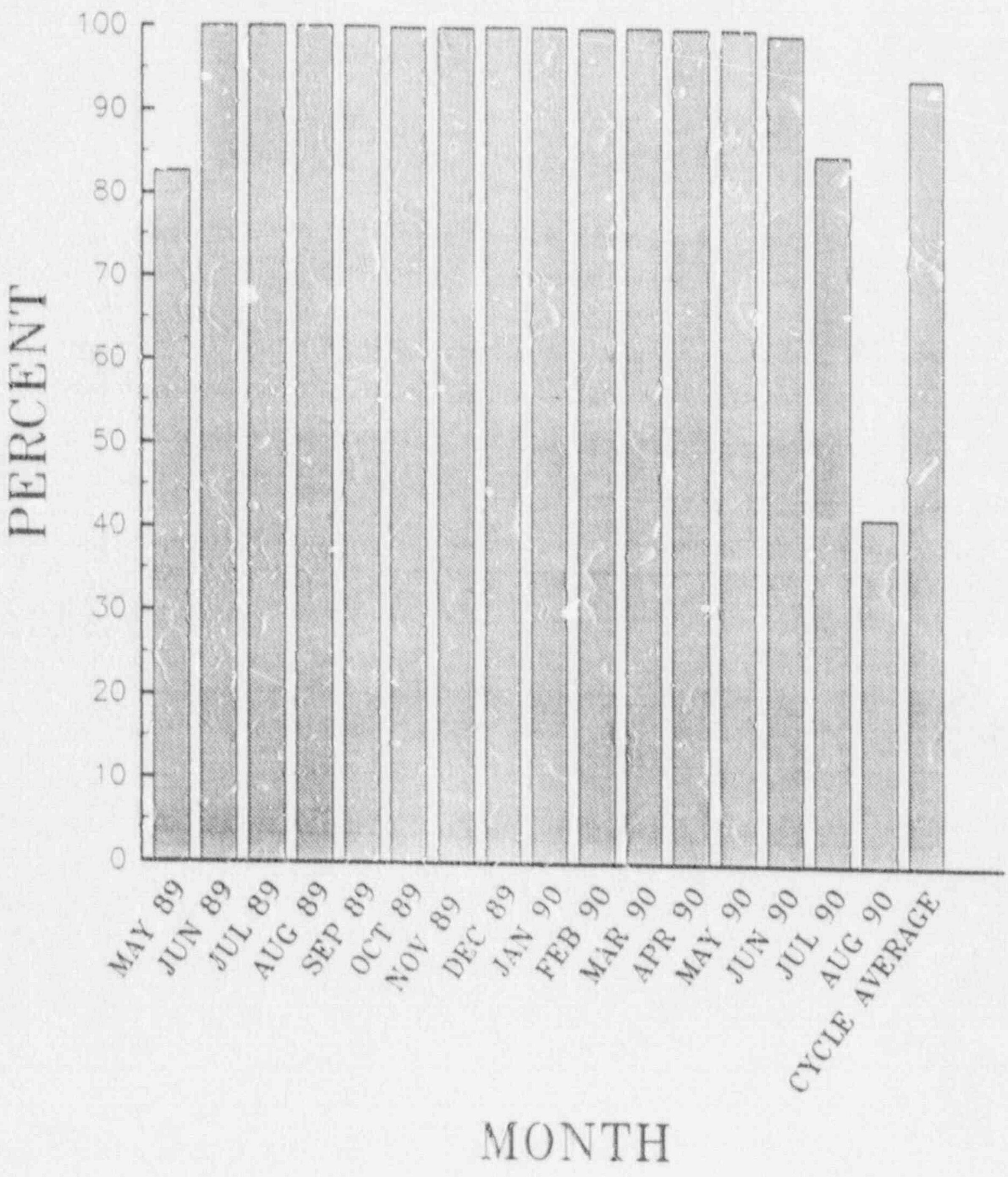


Figure 2.3
NORTH ANNA UNIT 2 - CYCLE 7
ASSEMBLYWISE ACCUMULATED BURNUP
MEASURED AND PREDICTED
(GWD/MTU)

MEASURED
PREDICTED

	R	P	N	M	L	K	J	H	G	F	E	D	C	B	A	
1							38.07 38.09	34.18 33.47	38.74 38.09							1
2					44.30 44.49	34.69 34.85	18.62 18.67	35.28 35.44	18.73 18.67	34.88 34.85	44.64 44.49					2
3				41.33 40.64	19.11 19.12	21.52 21.71	39.21 39.18	22.[illegible]6 [illegible]	38.73 39.18	21.94 21.71	19.43 19.12	41.69 40.64				3
4			43.95 43.41	37.97 37.85	22.90 23.03	42.46 43.20	24.10 24.26	43.14 43.61	23.94 24.26	43.42 43.20	23.10 23.03	38.28 37.83	43.64 43.41			4
5		45.12 44.58	18.86 19.12	22.51 23.03	44.41 44.57	24.08 24.33	44.46 43.98	39.68 39.65	44.06 43.98	24.[illegible]5 24.33	44.59 44.57	22.72 23.03	19.39 19.12	44.81 44.58		5
6		34.73 34.75	21.72 21.71	43.72 43.28	23.91 24.32	44.52 44.60	24.11 24.09	44.36 44.11	23.87 24.09	44.20 44.60	24.03 24.32	42.20 43.28	21.68 21.71	34.94 34.75		6
7	38.33 38.03	18.68 18.68	38.71 39.04	23.96 24.26	43.25 44.02	23.75 24.08	45.03 44.76	23.80 23.83	44.60 44.76	23.91 24.08	43.69 44.02	23.75 24.26	39.19 39.04	18.44 18.68	37.44 38.03	7
8	33.69 33.59	35.60 35.60	22.95 23.24	43.37 43.68	39.47 39.60	43.53 43.86	23.77 23.82	48.31 48.15	23.73 23.82	43.61 43.86	38.99 39.60	43.17 43.68	22.99 23.24	35.59 35.60	34.02 33.59	8
9	38.52 38.03	18.38 18.68	38.16 39.04	23.84 24.26	43.77 44.02	23.80 24.08	43.98 44.76	23.49 23.83	44.45 44.76	23.73 24.08	44.01 44.02	23.95 24.26	38.81 39.04	18.90 18.68	38.60 38.03	9
10		34.95 34.75	21.08 21.71	42.78 43.28	24.20 24.32	44.32 44.60	23.85 24.09	43.52 44.11	23.71 24.09	43.67 44.60	24.[illegible] 24.3[illegible]	43.42 43.28	22.04 21.71	35.06 34.75		10
11		44.75 44.58	19.25 19.12	23.23 23.03	44.27 44.57	24.02 24.33	43.37 43.98	39.26 39.65	43.21 43.98	24.00 24.33	44.37 44.57	23.44 23.03	19.55 19.12	44.63 44.58		11
12			43.94 [illegible]3.41	38.13 37.83	22.94 23.03	43.46 43.20	24.02 24.26	43.47 43.61	23.77 24.26	42.43 43.20	22.82 23.03	37.[illegible] 37.83	43.48 43.41			12
13				41.47 40.64	20.09 19.12	22.08 21.71	38.14 39.18	22.68 23.24	38.96 39.18	21.24 21.71	18.97 19.12	39.39 40.64				13
14					45.29 44.49	35.78 34.85	18.75 18.67	35.38 35.44	18.19 18.67	34.95 34.85	44.72 44.49					14
15							38.82 38.09	33.23 33.67	37.52 38.[illegible]9							15
	R	P	N	M	L	K	J	H	G	F	E	D	C	B	A	

Figure 2.4
NORTH ANNA UNIT 2 - CYCLE 7
ASSEMBLYWISE ACCUMULATED BURNUP
COMPARISON OF MEASURED AND PREDICTED
(GWD/MTU)

	R	P	N	M	L	K	J	H	G	F	E	D	C	B	A
1							38.07	34.18	38.74						
							-0.06	2.12	1.70						
2					44.50	34.69	18.62	35.28	18.73	34.88	44.64				
					-0.45	-0.46	-0.30	-0.43	0.29	0.07	0.33				
3				41.33	19.11	21.52	39.21	22.98	38.73	21.94	19.43	41.69			
				1.69	-0.06	-0.69	0.08	-1.12	-1.15	1.04	1.63	2.58			
4			43.95	37.97	22.90	42.46	24.10	43.14	23.94	43.42	23.10	38.28	43.64		
			1.24	0.36	-0.58	-1.72	-0.66	-1.06	-1.31	0.50	0.31	1.18	0.51		
5		45.12	18.86	22.51	44.41	24.88	44.46	39.68	44.06	24.25	44.59	22.72	19.39	44.81	
		1.20	-1.37	-2.28	-0.35	-1.00	1.[illegible]3	0.09	0.17	-0.30	0.04	-1.37	1.42	0.51	
6		34.73	21.72	43.72	25.91	44.52	24.11	44.36	23.87	44.20	24.03	42.20	21.68	34.96	
		-0.07	0.01	1.02	-1.67	-0.18	0.08	0.57	-0.92	-0.89	-1.19	-2.49	-0.15	0.54	
7	38.33	18.68	[illegible].71	23.96	43.25	23.75	45.0[illegible]	23.80	44.60	23.91	43.69	23.75	39.19	18.44	37.44
	0.77	0.04	[illegible].46	-1.24	-1.75	-1.39	0.62	-0.12	-0.34	-0.71	-0.75	-2.07	0.38	-1.28	-1.57
8	33.69	35.60	22.95	43.37	39.47	43.53	23.77	48.31	23.73	43.61	38.99	43.17	22.99	35.59	34.02
	0.32	0.01	-1.23	-0.72	-0.32	-0.76	-0.20	0.35	-0.38	-0.59	-1.55	-1.17	-1.08	-0.01	1.27
9	38.52	18.38	38.16	23.84	43.77	23.80	43.98	23.49	44.45	23.73	44.01	23.95	38.81	18.90	38.68
	1.27	-[illegible].60	-2.25	-1.76	-0.57	-1.15	-1.73	-1.41	-0.69	-1.44	-0.02	-1.27	-0.60	1.18	1.70
10		[illegible].95	21.08	42.78	24.20	44.32	23.85	43.52	23.71	43.67	24.04	43.42	22.84	35.06	
		[illegible].58	-2.93	-1.14	-0.48	-0.64	-1.01	-1.34	-1.57	-2.08	-1.16	0.32	1.48	0.90	
11		44.75	19.25	23.23	44.27	24.02	43.37	39.26	43.21	24.00	44.37	23.44	19.55	44.63	
		0.38	0.65	0.84	-0.67	-1.24	-1.40	-0.97	-1.75	-1.32	-0.43	1.78	2.24	0.11	
12			[illegible]94	38.13	22.94	43.46	24.02	43.47	23.77	42.43	22.82	37.90	43.48		
			[illegible]2	0.79	-0.39	0.61	-1.00	-0.31	-2.05	-1.79	-0.89	0.19	0.16		
13				41.47	20.09	22.08	38.14	22.68	38.96	21.24	18.97	39.39			
				2.05	5.07	1.70	-2.66	-2.40	-0.56	-2.19	-0.78	-3.07			
14					45.29	35.78	18.75	35.38	18.19	34.95	44.72				
					1.81	2.65	0.42	-0.14	-2.58	0.28	0.51				
15							38.82	35.23	37.52						
							1.91	-0.70	-1.48						

MEASURED
M/P % DIFF

STANDARD DEV = 0.78

ARITHMETIC AVG PCT DIFF = -0.27

AVG ABS PCT DIFF = 1.03

BATCH SHARING
(MWD/MTU)

BATCH	N1C4	N1C5	N1C6	N2C5	N2C6	N2C7	TOTALS
N1/6A (F32)	17208	12203	---	---	---	18906	48315
N1/6A (F41)	15701	---	---	---	16444	7247	39392
N1/7A	---	13282	13587	---	---	6911	33780
7A	---	---	---	20920	11684	5658	38262
7B	---	---	---	19439	17748	6663	43850
8A	---	---	---	---	22259	16811	39070
8B	---	---	---	---	21771	20500	42271
9A	---	---	---	---	---	23683	23683
9B	---	---	---	---	---	20543	20543
N1/10A	---	---	---	---	---	23945	23945
N1/10B	---	---	---	---	---	23443	23443
CYCLE AVERAGE ACCUMULATED BURNUP = 18023							

BURNUP TILT

NW = 0.08	NE = 0.14
SW = 0.10	SE = -0.32

Figure 2.5A
NORTH ANNA UNIT 2 - CYCLE 7
SUB-BATCH BURNUP SHARING

NOTE: Solid lines represent predicted burnup, and symbols represent measured burnup.

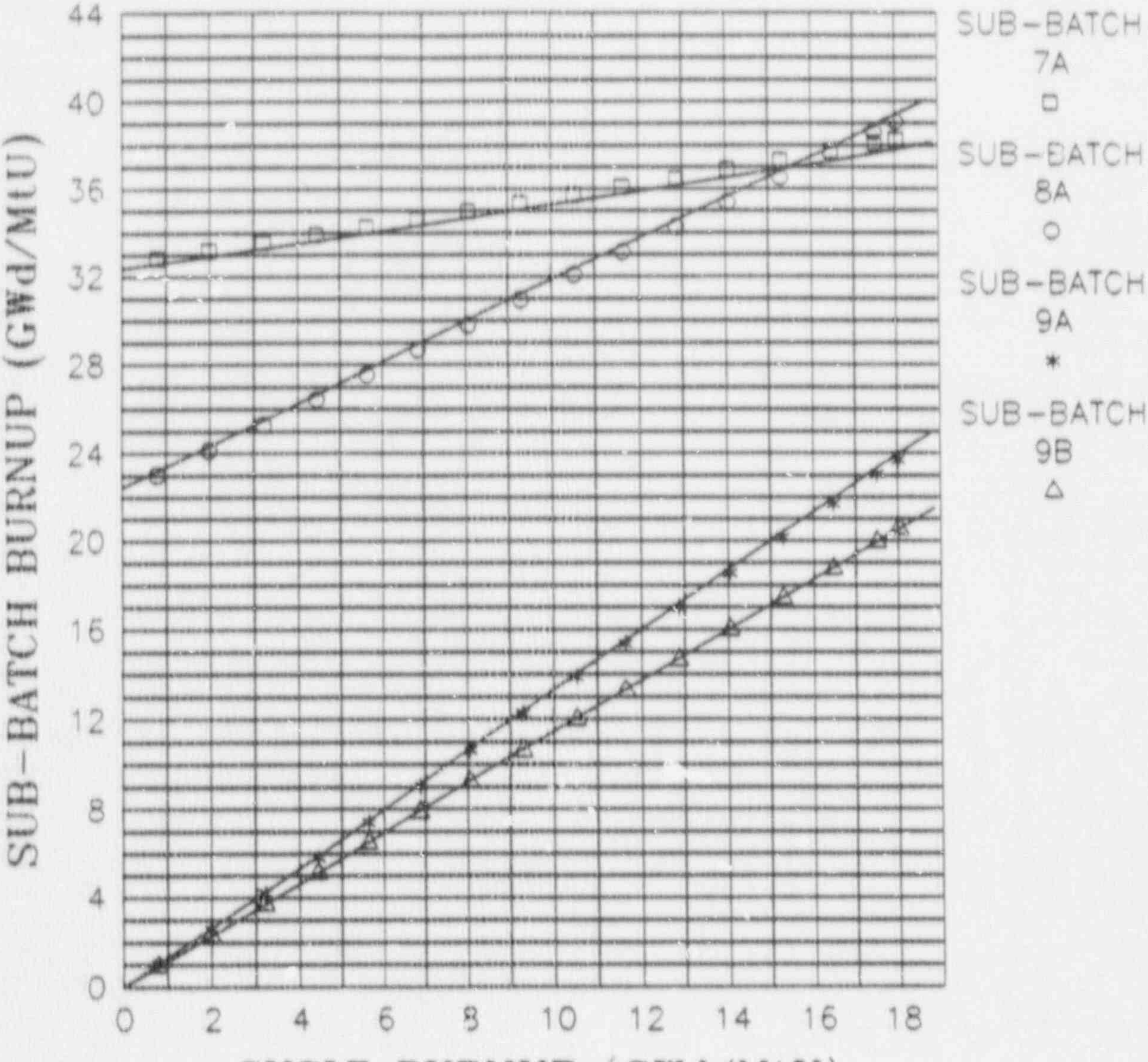


Figure 2.5B
NORTH ANNA UNIT 2 - CYCLE 7
SUB-BATCH BURNUP SHARING

NOTE: Solid lines represent predicted burnup, and symbols represent measured burnup.

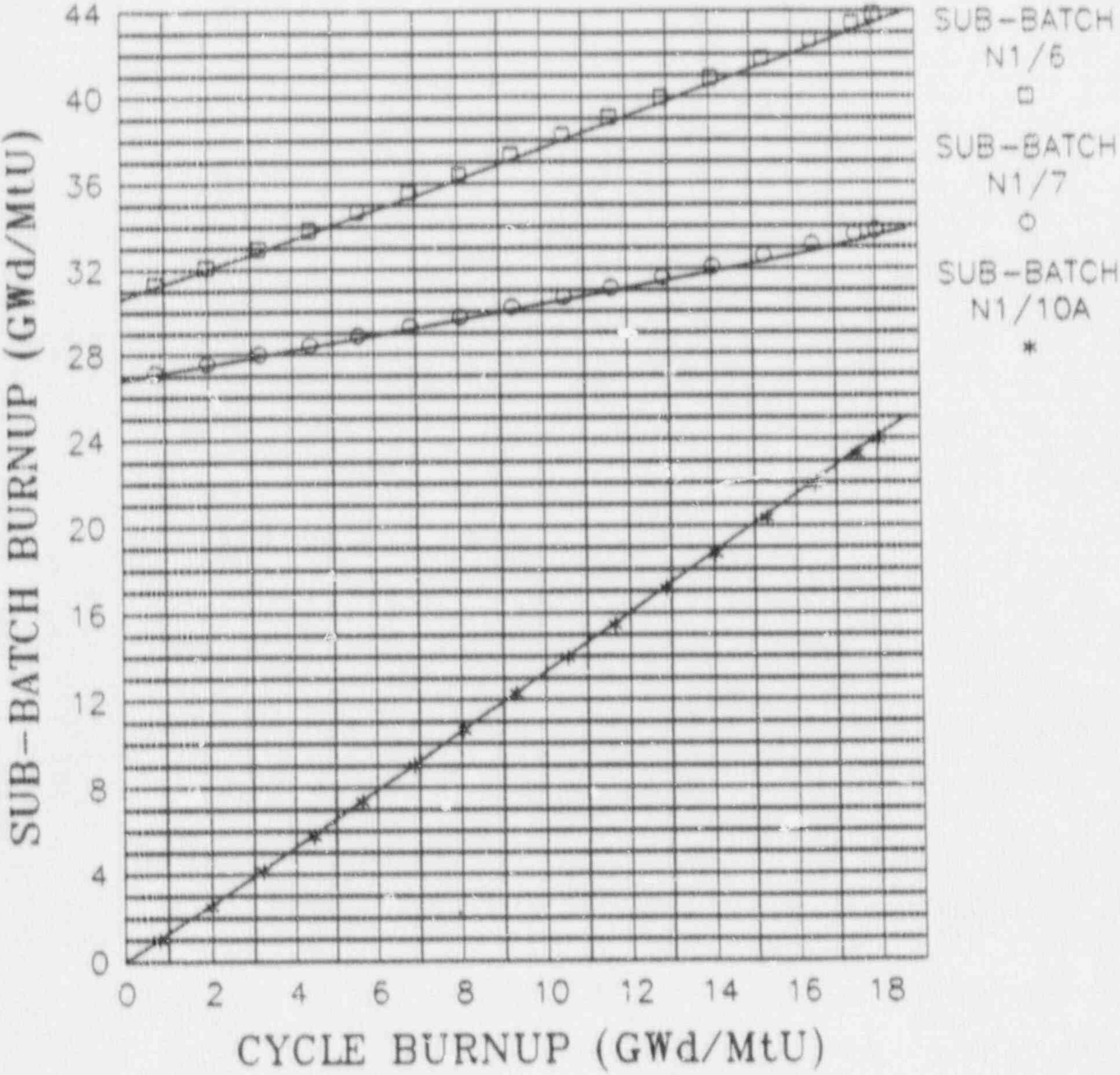
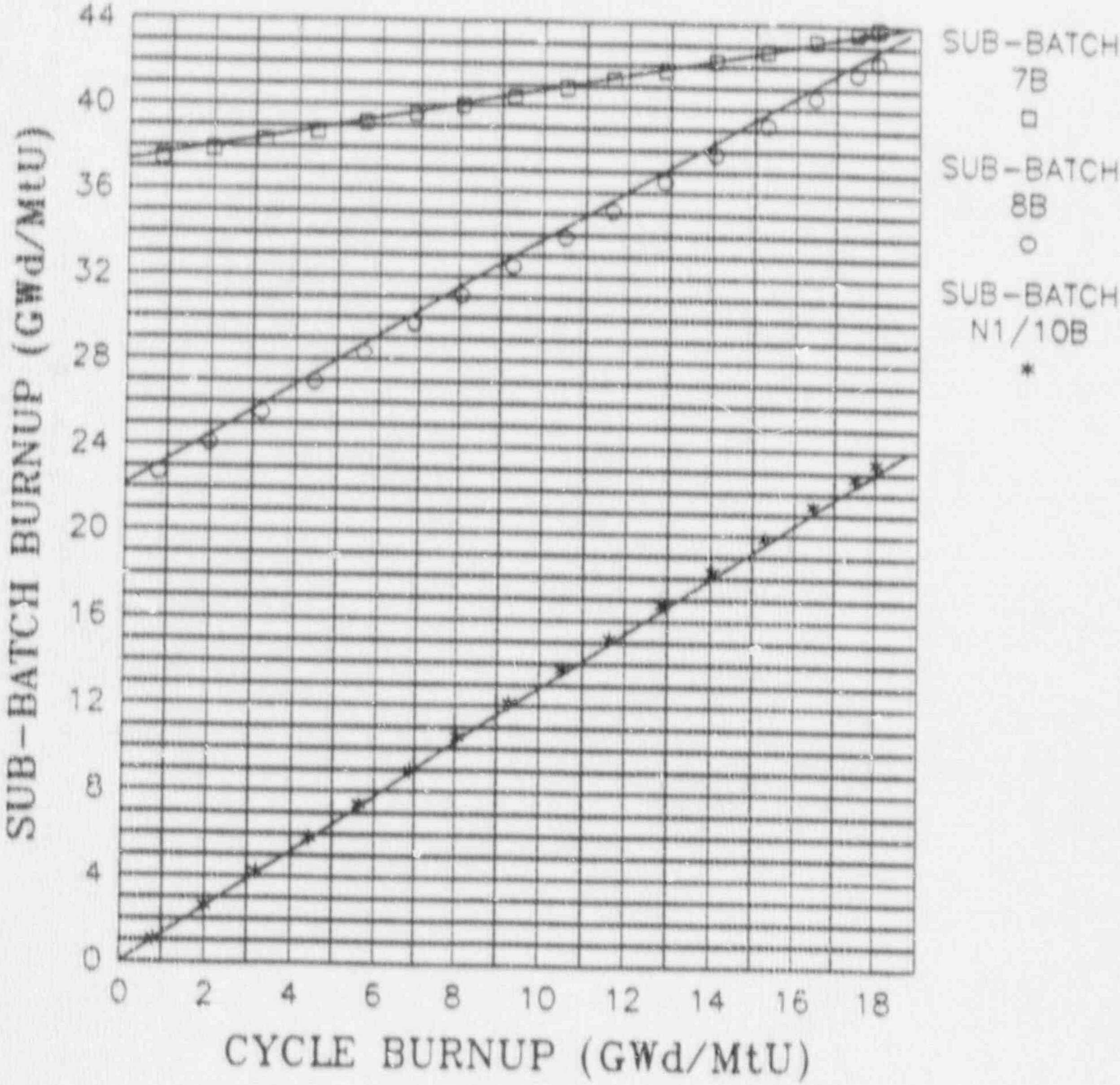


Figure 2.5C
NORTH ANNA UNIT 2 - CYCLE 7
SUB-BATCH BURNUP SHARING

NOTE: Solid lines represent predicted burnup, and symbols represent measured burnup.

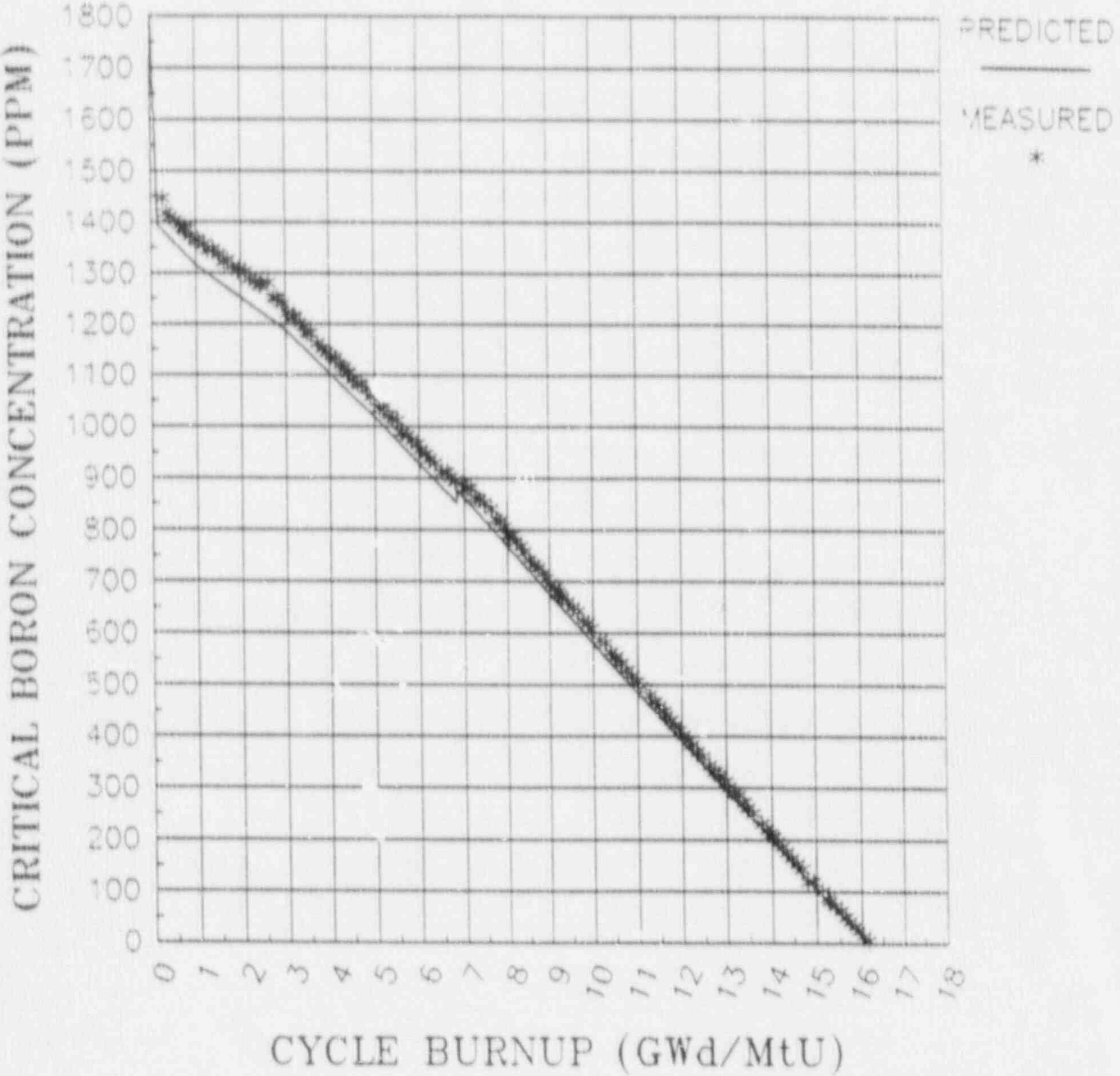


Section 3

REACTIVITY DEPLETION

The primary coolant critical boron concentration is monitored for the purposes of following core reactivity and to identify any anomalous reactivity behavior. The FOLLOW* computer code was used to normalize "actual" critical boron concentration measurements to design conditions taking into consideration control rod position, xenon concentration, moderator temperature, and power level. The normalized critical boron concentration versus burnup curve for the North Anna 2, Cycle 7 core is shown in Figure 3.1. It can be seen that the measured data typically compared to within 67 ppm of the design prediction. This corresponds to ±0.45% ΔK/K which is within the ±1% ΔK/K criterion for reactivity anomalies set forth in Section 4.1.1.1.2 of the Technical Specifications. The discontinuity in Figure 3.1 is due to the reduced temperature operation mentioned in the introduction. In conclusion, the trend indicated by the critical boron concentration verifies that the Cycle 7 core depleted as expected without any reactivity anomalies.

Figure 3.1
NORTH ANNA UNIT 2 - CYCLE 7
CRITICAL BORON CONCENTRATION vs. BURNUP
(HFP,ARO)



Section 4

POWER DISTRIBUTION

Analysis of core power distribution data on a routine basis is necessary to verify that the hot channel factors are within the Technical Specifications limits and to ensure that the reactor is operating without any abnormal conditions which could cause an "uneven" burnup distribution. Three-dimensional core power distributions are determined from movable detector flux map measurements using the INCORE[5] computer program. A summary of all full core flux maps taken since the completion of startup physics testing for North Anna 2, Cycle 7 is given in Table 4.1. Power distribution maps were generally taken at monthly intervals with additional maps taken as needed.

Radial (X-Y) core power distribution for a representative series of incore flux maps are given in Figures 4.1, 4.2, and 4.3. Figure 4.1 shows a power distribution map that was taken early in cycle life. Figure 4.2 shows a power distribution map that was taken near mid-cycle burnup. Figure 4.3 shows a map that was taken near the end of Cycle 7. The measured relative assembly powers were generally within 4.6% and the maximum average percent difference was equal to 1.6%. In addition, as indicated by the INCORE tilt factors, the power distributions were essentially symmetric for each case.

An important aspect of core power distribution follow is the monitoring of nuclear hot channel factors. Verification that these factors are

within Technical Specifications limits ensures that linear power density and critical heat flux limits will not be violated, thereby providing adequate thermal margin and maintaining fuel cladding integrity. North Anna Unit 2 Technical Specification 3.2.2 limited the axially dependent heat flux hot channel factor, $F_Q(Z)$, to 2.19 x K(Z), where K(Z) is the hot channel factor normalized operating envelope. Figure ..4 is a plot of the K(Z) curve associated with the 2.19 $F_Q(Z)$ limit.

The axially dependent heat flux hot channel factors, $F_Q(Z)$, for a representative set of flux maps are given in Figures 4.5, 4.6, and 4.7. Throughout Cycle 7, the measured values of $F_Q(Z)$ were within the Technical Specifications limit. A summary of the maximum values of axially-dependent heat flux hot channel factors measured during Cycle 7 is given in Figure 4.8. This figure indicates that the minimum margin to the F_Q limit in the axial region covered by the Technical Specification 4.2.2.2 is 9.6%. (Technical Specification 4.2.2.2.g states that F_Q surveillence is not applicable in the lower core region from 0% to 15% inclusive, and the upper core region from 85% to 100% inclusive.)

Figure 4.9 shows the maximum values for the heat flux hot channel factor measured during Cycle 7. As can be seen from the figure, there was an approximate 13.88% margin from the maximum $F_Q(Z)$ to the 2.19 limit at the beginning of the cycle, with the margin generally increasing throughout cycle operation. The $F_Q(Z)$ increases seen at EOC in Figure 4.9 are a result of the coastdown.

The value of the enthalpy rise hot channel factor, F-delta-H, which is the ratio of the integral of the power along the rod with the highest integrated power to that of the average rod, is routinely followed. The Technical Specifications limit for this parameter is set such that the departure from nucleate boiling ratio (DNBR) limit will not be violated. Additionally, the F-delta-H limit ensures that the value of this parameter used in the LOCA-ECCS analysis is not exceeded during normal operation. North Anna Technical Specification 3.2.3 limited the enthalpy rise hot channel factor to 1.49(1+0.3(1-P)) for Cycle 7. A summary of the maximum values for the enthalpy rise hot channel factor measured during Cycle 7 is given in Figure 4.10. As can be seen from this figure, the minimum margin to the limit was approximately 5.2%.

The target delta flux* is the delta flux which would occur at conditions of full power, all rods out, and equilibrium xenon. The delta flux is measured with the core at or near these conditions and the target delta flux is established at this measured point. Since the target delta flux varies as a function of burnup, the target value is updated monthly. By maintaining the value of delta flux relatively constant, adverse axial power shapes due to xenon redistribution are avoided.

The plot of the target delta flux versus burnup, given in Figure 4.11, shows the value of this parameter to have been approximately -1.7% at the beginning of Cycle 7. Delta flux values decreased steadily to -4.6% near the middle of the cycle, then gradually increased to -3.9% before the

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* Delta Flux = $\frac{Pt-Pb}{2893} \times 100$ where Pt = power in top of core (MW(t))
Pb = power in bottom of core (MW(t))

coastdown. At the end of Cycle 7, the target delta flux increased to -3.5% due to the coastdown. This axial power shift can also be observed in the corresponding core average axial power distribution for a representative series of maps given in Figures 4.12 through 4.14. In Map N2-7-08 (Figure 4.12), taken at 800 MWD/MTU, the axial power distribution had a shape peaked toward the middle of the core with a peaking factor of 1.215. In Map N2-7-15 (Figure 4.13), taken at approximately 8339 MWD/MTU, the axial power distribution peaked slightly toward the bottom of the core with an axial peaking factor of 1.148. Finally, in Map N2-7-24 (Figure 4.14), taken at 15,823 MWD/MTU, the axial peaking factor was 1.150, with the axial power distribution shifted slight[illegible] [illegible]ard the top. The history of F-Z during the cycle can be se[illegible] more clearly in a plot of F-Z versus burnup given in Figure 4.15.

In conclusion, the North Anna 2, Cycle 7 core performed satisfactorily with power distribution analyses verifying that design predictions were accurate and that the values of the $F_Q(Z)$ and F-delta-H hot channel factors were within the limits of the Technical Specifications.

Table 4.1
NORTH ANNA UNIT 2 - CYCLE 7
SUMMARY OF FLUX MAPS FOR ROUTINE OPERATION

MAP NO.[3]	DATE	BURN UP MWD/MTU	PWR (%)	BANK D STEPS	F-Q(T) HOT CHANNEL FACTOR				F-DH(N) HOT CHNL. FACTOR			CORE F(Z) MAX		F(XY) MAX	QPTR[2]		AXIAL OFF SET (%)	NO. OF THIMBLES
					ASSY	PIN	AXIAL POINT	F-Q(T)	ASSY	PIN	F-DH(N)	AXIAL POINT	F(Z)		MAX	LOC		
8	06-01-89	800	100	228	L13	MO	37	1.886	L13	MO	1.411	37	1.215	1.417	1.007	SW	-1.701	46
9	06-13-89	1700	100	228	L13	MO	37	1.845	J12	EM	1.403	37	1.200	1.406	1.006	SW	-1.838	44
10	07-24-89	2914	100	228	J04	EE	38	1.818	J04	EE	1.409	38	1.185	1.411	1.004	SW	-2.492	46
11	08-22-89	4066	100	228	J04	EE	38	1.789	J04	EE	1.406	38	1.169	1.409	1.003	SW	-2.800	45
12	09-21-89	5257	100	228	L10	IJ	45	1.782	J10	HI	1.413	46	1.158	1.420	1.003	SW	-3.597	45
13	10-20-89	6409	100	228	L10	JI	46	1.784	L10	IJ	1.414	46	1.156	1.424	1.001	SW	-3.918	45
14	11-06-89	7095	100	228	F05	IH	46	1.765	L10	JI	1.417	46	1.140	1.429	1.002	NE	-2.710	46
15	12-08-89	8339	100	228	F05	IH	47	1.776	F05	IH	1.417	47	1.148	1.430	1.003	NE	-3.613	47
16	01-08-90	9572	100	228	F05	IH	48	1.774	H07	IJ	1.416	47	1.149	1.428	1.004	NE	-4.036	47
17	02-05-90	10686	100	228	F05	IH	48	1.774	H07	IJ	1.412	48	1.153	1.431	1.004	NE	-4.597	47
18	03-07-90	11892	140	228	F05	IH	48	1.760	H07	IJ	1.408	48	1.151	1.418	1.004	NE	-4.608	47
19	03-27-90	12691	100	228	H07	IJ	52	1.762	H07	IJ	1.398	52	1.156	1.415	1.005	NE	-4.467	46
22	04-25-90	13841	100	228	F05	IH	53	1.744	F05	IH	1.386	53	1.154	1.404	1.005	NE	-4.478	46
23	05-18-90	14731	100	228	H07	IJ	53	1.740	H07	IJ	1.379	53	1.158	1.398	1.005	NE	-4.487	47
24	06-14-90	15823	100	228	D09	EE	54	1.712	F05	IH	1.366	53	1.150	1.396	1.005	NE	-3.879	47
25	07-16-90	17014	85	228	D11	EM	12	1.716	F05	IH	1.362	11	1.160	1.385	1.005	NE	3.741	47
26	08-16-90	17932	50	112	E04	DM	11	1.844	E04	DM	1.423	47	1.135	1.424	1.002	SW	-3.501	47

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. QPTR - QUADRANT POWER TILT RATIO.

3. MAPS 20 and 21 WERE QUARTER-CORE FLUX MAPS TAKEN FOR INCORE/EXCORE CALIBRATION.(I/E CALIBRATION)

Figure 4.1
NORTH ANNA UNIT 2 - CYCLE 7
ASSEMBLYWISE POWER DISTRIBUTION N2-7-08

Row		R	P	N	M	L	K	J	H	G	F	E	D	C	B	A
1	PREDICTED							0.29	0.34	0.29						
	MEASURED							0.30	0.36	0.29						
	PCT DIFFERENCE							3.7	3.7	2.7						
2	PREDICTED					0.31	0.60	1.08	0.95	1.08	0.60	0.31				
	MEASURED					0.32	0.61	1.09	0.96	1.09	0.61	0.31				
	PCT DIFFERENCE					3.0	0.8	1.0	1.0	1.3	1.8	2.0				
3	PREDICTED				0.36	1.09	1.20	1.17	1.30	1.17	1.20	1.09	0.36			
	MEASURED				0.37	1.09	1.18	1.17	1.30	1.17	1.21	1.11	0.37			
	PCT DIFFERENCE				0.2	-0.1	-1.1	-0.2	-0.4	-0.0	0.7	1.3	2.3			
4	PREDICTED			0.37	0.79	1.28	1.22	1.34	1.23	1.34	1.22	1.28	0.79	0.37		
	MEASURED			0.37	0.78	1.27	1.22	1.34	1.23	1.33	1.22	1.27	0.78	0.37		
	PCT DIFFERENCE			0.4	-0.7	-0.5	-0.6	0.0	-0.1	-0.9	-0.4	-0.5	-0.6	0.8		
5	PREDICTED		0.31	1.09	1.28	1.18	1.30	1.21	1.19	1.21	1.30	1.18	1.28	1.09	0.31	
	MEASURED		0.30	1.07	1.25	1.16	1.28	1.21	1.20	1.20	1.29	1.17	1.25	1.09	0.32	
	PCT DIFFERENCE		-2.1	-2.1	-2.0	-2.0	-1.4	0.1	0.1	-0.8	-0.8	-1.5	-2.2	0.1	4.0	
6	PREDICTED		0.60	1.20	1.22	1.30	1.18	1.25	1.11	1.25	1.18	1.30	1.22	1.20	0.60	
	MEASURED		0.60	1.19	1.21	1.28	1.17	1.25	1.11	1.24	1.16	1.27	1.20	1.19	0.61	
	PCT DIFFERENCE		-0.5	-0.5	-1.0	-1.6	-0.8	0.1	0.0	-1.0	-1.1	-1.9	-2.0	-0.7	1.3	
7	PREDICTED	0.29	1.08	1.17	1.34	1.21	1.25	1.14	1.19	1.14	1.25	1.21	1.34	1.17	1.08	0.29
	MEASURED	0.30	1.09	1.17	1.34	1.19	1.24	1.13	1.19	1.13	1.24	1.19	1.32	1.16	1.07	0.29
	PCT DIFFERENCE	3.5	1.1	-0.0	-0.5	-1.0	-1.0	-0.4	-0.4	-0.7	-0.8	-1.1	-1.6	-0.8	-0.5	-0.0
8	PREDICTED	0.35	0.95	1.30	1.23	1.19	1.11	1.19	0.95	1.19	1.11	1.19	1.23	1.30	0.95	0.35
	MEASURED	0.36	0.96	1.30	1.23	1.20	1.12	1.20	0.95	1.19	1.11	1.18	1.21	1.29	0.96	0.35
	PCT DIFFERENCE	3.5	1.1	-0.2	0.3	0.7	0.7	0.6	0.1	-0.4	-0.4	-0.9	-1.6	-0.8	1.0	2.0
9	PREDICTED	0.29	1.08	1.17	1.34	1.21	1.25	1.14	1.19	1.14	1.25	1.21	1.34	1.17	1.08	0.29
	MEASURED	0.30	1.08	1.15	1.34	1.21	1.25	1.13	1.18	1.13	1.25	1.20	1.34	1.18	1.10	0.30
	PCT DIFFERENCE	3.5	0.1	-1.7	-0.5	0.7	0.2	-0.9	-0.9	-0.5	-0.5	-0.1	-0.4	0.7	2.1	3.4
10	PREDICTED		0.60	1.20	1.22	1.30	1.18	1.25	1.11	1.25	1.18	1.30	1.22	1.20	0.60	
	MEASURED		0.59	1.17	1.22	1.31	1.18	1.26	1.12	1.26	1.17	1.30	1.23	1.22	0.63	
	PCT DIFFERENCE		-2.0	-2.0	-0.2	0.7	0.2	0.6	0.8	0.3	-0.3	-0.1	0.7	1.5	3.9	
11	PREDICTED		0.31	1.09	1.28	1.18	1.30	1.21	1.19	1.21	1.30	1.18	1.28	1.09	0.31	
	MEASURED		0.31	1.11	1.30	1.19	1.30	1.21	1.20	1.22	1.30	1.19	1.30	1.11	0.32	
	PCT DIFFERENCE		1.6	1.6	1.3	0.7	-0.0	0.6	0.7	0.9	0.0	0.4	1.5	2.0	3.1	
12	PREDICTED			0.37	0.79	1.28	1.22	1.34	1.23	1.34	1.22	1.28	0.79	0.37		
	MEASURED			0.39	0.81	1.29	1.23	1.35	1.24	1.34	1.22	1.28	0.80	0.38		
	PCT DIFFERENCE			5.1	3.0	0.7	0.4	0.6	0.6	-0.2	-0.6	-0.1	1.8	2.5		
13	PREDICTED				0.36	1.09	1.20	1.17	1.30	1.17	1.20	1.09	0.36			
	MEASURED				0.38	1.15	1.23	1.17	1.30	1.16	1.18	1.09	0.37			
	PCT DIFFERENCE				5.1	5.0	2.6	-0.3	-0.4	-1.0	-1.3	-0.5	2.3			
14	PREDICTED					0.31	0.60	1.08	0.95	1.08	0.60	0.31				
	MEASURED					0.32	0.63	1.11	0.96	1.06	0.59	0.30				
	PCT DIFFERENCE					5.0	5.5	2.8	1.5	-1.0	-1.2	-1.8				
15	PREDICTED							0.29	0.34	0.29						
	MEASURED							0.30	0.35	0.28						
	PCT DIFFERENCE							6.1	2.8	-0.6						

STANDARD DEVIATION =1.233

AVERAGE PCT DIFFERENCE = 1.3

SUMMARY

MAP NO: N2-7-08 DATE: 06/01/89 POWER: 100%

CONTROL ROD POSITION: F-Q(T) = 1.886 QPTR:

D BANK AT 228 STEPS F-DH(N) = 1.411

NW 0.9960	NE 0.9950
SW 1.0073	SE 1.0017

F(Z) = 1.215

F(XY) = 1.417

BURNUP = 800 MWD/MTU A.O. = -1.701%

Figure 4.2
NORTH ANNA UNIT 2 - CYCLE 7
ASSEMBLYWISE POWER DISTRIBUTION N2-7-15

Legend (each cell): PREDICTED / MEASURED / PCT DIFFERENCE

	R	P	N	M	L	K	J	H	G	F	E	D	C	B	A
1							0.29 0.30 3.9	0.36 0.37 3.9	0.29 0.30 3.4						
2					0.32 0.34 5.0	0.60 0.61 1.9	1.01 1.02 1.2	0.89 0.90 1.2	1.01 1.02 1.6	0.60 0.62 2.8	0.32 0.33 3.8				
3				0.38 0.38 1.4	1.04 1.05 1.0	1.19 1.19 -0.5	1.10 1.10 -0.0	1.28 1.27 -0.2	1.10 1.10 0.2	1.19 1.21 1.7	1.04 1.07 2.8	0.38 0.40 4.9			
4			0.38 0.39 1.9	0.78 0.78 0.3	1.27 1.28 0.5	1.18 1.18 -0.1	1.34 1.35 0.1	1.16 1.16 0.0	1.34 1.34 -0.6	1.18 1.18 0.6	1.27 1.28 1.0	0.78 0.79 1.2	0.38 0.39 3.1		
5		0.32 0.32 -1.0	1.04 1.03 -1.0	1.27 1.25 -1.5	1.16 1.14 -1.6	1.37 1.35 -1.1	1.19 1.19 0.1	1.17 1.17 0.1	1.19 1.19 -0.1	1.37 1.37 0.3	1.16 1.16 -0.3	1.27 1.26 -0.8	1.04 1.06 2.1	0.32 0.34 6.4	
6		0.60 0.60 0.1	1.19 1.20 0.1	1.18 1.17 -0.5	1.36 1.35 -1.1	1.19 1.19 -0.5	1.36 1.37 0.2	1.15 1.15 0.1	1.36 1.36 -0.3	1.19 1.20 0.2	1.36 1.35 -0.9	1.18 1.16 -1.2	1.19 1.20 0.6	0.60 0.62 3.2	
7	0.29 0.31 4.2	1.01 1.02 1.1	1.10 1.10 -0.4	1.34 1.33 -0.9	1.19 1.17 -1.3	1.36 1.35 -1.3	1.21 1.20 -0.2	1.36 1.36 -0.2	1.21 1.20 -0.2	1.36 1.36 -0.2	1.19 1.18 -0.9	1.34 1.32 -2.0	1.10 1.09 -0.5	1.01 1.01 0.1	0.29 0.30 1.0
8	0.36 0.37 4.2	0.89 0.90 1.1	1.28 1.27 -0.6	1.16 1.16 -0.5	1.17 1.16 -0.5	1.15 1.14 -0.5	1.36 1.36 -0.3	1.07 1.07 -0.1	1.36 1.35 -1.2	1.15 1.14 -1.1	1.17 1.15 -1.5	1.16 1.14 -1.9	1.28 1.27 -0.5	0.89 0.91 1.7	0.36 0.37 3.0
9	0.29 0.31 4.3	1.01 1.01 -0.2	1.10 1.07 -2.4	1.34 1.32 -1.4	1.19 1.18 -0.5	1.36 1.35 -1.1	1.21 1.18 -2.3	1.36 1.33 -2.3	1.21 1.19 -1.5	1.36 1.35 -1.3	1.19 1.18 -0.7	1.34 1.34 -0.6	1.10 1.11 1.1	1.01 1.04 2.[illegible]	0.29 0.31 4.3
10		0.60 0.58 -2.6	1.19 1.16 -2.6	1.18 1.16 -1.0	1.36 1.36 -0.1	1.19 1.18 -0.9	1.36 1.35 -1.0	1.15 1.14 -0.8	1.36 1.35 -1.3	1.19 1.18 -1.3	1.36 1.35 -0.7	1.18 1.18 0.7	1.19 1.22 2.1	0.60 0.63 5.1	
11		0.32 0.32 1.5	1.04 1.06 1.5	1.27 1.28 1.1	1.16 1.17 0.5	1.37 1.35 -1.1	1.19 1.17 -1.1	1.17 1.16 -0.9	1.19 1.18 -0.8	1.37 1.35 -0.8	1.16 1.16 0.2	1.27 1.29 1.9	1.04 1.07 2.7	0.32 0.33 4.2	
12			0.38 0.40 5.5	0.78 0.80 3.1	1.27 1.28 0.5	1.18 1.17 -0.6	1.34 1.33 -1.2	1.16 1.15 -1.2	1.34 1.32 -1.6	1.18 1.16 -1.2	1.27 1.26 -0.5	0.78 0.80 2.4	0.38 0.39 3.2		
13				0.38 0.40 5.7	1.04 1.10 5.9	1.19 1.22 2.2	1.10 1.08 -2.1	1.28 1.25 -2.0	1.10 1.08 -2.2	1.19 1.17 -2.0	1.04 1.04 -0.4	9.38 0.39 3.1			
14					0.32 0.34 5.9	0.60 0.63 5.7	1.01 1.02 1.6	0.89 0.90 0.3	1.01 0.99 -2.1	0.60 0.59 -2.0	0.32 0.31 -2.2				
15							0.29 0.31 5.5	0.36 0.37 2.0	0.29 0.29 -1.7						

STANDARD DEVIATION = 1.471

AVERAGE PCT DIFFERENCE = 1.6

SUMMARY

MAP NO: N2-7-15 | DATE: 12/08/89 | POWER: 100%

CONTROL ROD POSITION: | F-Q(T) = 1.776 | QPTR:

D BANK AT 228 STEPS | F-DH(N) = 1.417 |

NW 0.9991	NE 1.0033
SW 1.0000	SE 0.9976

F(Z) = 1.148

F(XY) = 1.430

BURNUP = 8339 MWD/MTU | A.O. = -3.613%

Figure 4.3
NORTH ANNA UNIT 2 - CYCLE 7
ASSEMBLYWISE POWER DISTRIBUTION N2-7-24

PREDICTED
MEASURED
PCT DIFFERENCE

R	P	N	M	L	K	J	H	G	F	E	D	C	B	A	
						0.35 0.36 3.1	0.43 0.44 3.1	0.35 0.35 2.4							1
				0.36 0.38 5.1	0.65 0.66 1.1	1.04 1.05 0.6	0.93 0.94 0.5	1.04 1.05 0.8	0.65 0.66 1.7	0.36 0.38 3.7					2
			0.42 0.43 1.7	1.05 1.06 1.3	1.21 1.20 -0.6	1.09 1.09 -0.7	1.27 1.26 -0.9	1.09 1.09 -0.4	1.21 1.22 1.0	1.05 1.08 2.7	0.42 0.45 5.7				3
		0.42 0.43 2.4	0.81 0.82 0.8	1.26 1.27 0.7	1.15 1.14 -0.3	1.31 1.30 -0.6	1.13 1.12 -0.7	1.31 1.30 -1.0	1.15 1.15 0.8	1.26 1.28 1.5	0.81 0.83 1.9	0.42 0.44 4.0			4
	0.36 0.36 -0.1	1.05 1.05 -0.1	1.26 1.24 -1.0	1.13 1.12 -1.3	1.33 1.32 -1.0	1.15 1.14 -0.4	1.13 1.13 -0.4	1.15 1.14 -0.2	1.33 1.34 0.5	1.13 1.13 0.1	1.26 1.25 -0.2	1.05 1.08 3.2	0.36 0.39 7.7		5
	0.65 0.65 0.6	1.21 1.21 0.6	1.15 1.14 -0.1	1.33 1.32 -0.9	1.15 1.14 -0.6	1.33 1.33 -0.2	1.12 1.11 -0.2	1.33 1.33 -0.2	1.15 1.16 0.5	1.33 1.33 -0.3	1.15 1.14 -0.4	1.21 1.22 1.3	0.65 0.67 3.8		6
0.35 0.36 3.1	1.04 1.05 0.7	1.09 1.09 -0.4	1.31 1.30 -1.0	1.15 1.13 -1.5	1.33 1.31 -1.5	1.16 1.16 -0.2	1.33 1.33 -0.2	1.16 1.16 -0.1	1.33 1.33 0.0	1.15 1.14 -0.3	1.31 1.29 -1.3	1.09 1.09 -0.3	1.04 1.04 -0.0	0.35 0.35 0.8	7
0.43 0.44 3.1	0.94 0.94 0.7	1.27 1.26 -0.7	1.13 1.12 -0.8	1.13 1.12 -1.0	1.12 1.11 -1.0	1.33 1.32 -1.0	1.06 1.06 0.2	1.33 1.32 -0.8	1.12 1.11 -0.7	1.13 1.12 -0.9	1.13 1.11 -1.4	1.27 1.27 -0.3	0.94 0.95 1.5	0.43 0.44 2.7	8
0.35 0.36 3.1	1.04 1.04 -0.4	1.09 1.07 -2.2	1.31 1.29 -1.6	1.15 1.13 -1.0	1.33 1.31 -1.3	1.16 1.14 -2.1	1.33 1.31 -2.1	1.16 1.15 -0.8	1.33 1.32 -0.9	1.15 1.14 -0.4	1.31 1.30 -0.6	1.09 1.10 0.8	1.04 1.07 2.5	0.35 0.36 4.0	9
	0.65 0.63 -2.2	1.21 1.18 -2.2	1.15 1.13 -1.0	1.33 1.32 -0.4	1.15 1.14 -1.0	1.33 1.31 -1.3	1.12 1.10 -1.2	1.33 1.31 -1.4	1.15 1.14 -1.1	1.33 1.32 -0.6	1.15 1.15 0.5	1.21 1.23 1.8	0.65 0.68 4.7		10
	0.36 0.37 1.9	1.05 1.07 1.9	1.26 1.27 1.3	1.13 1.13 0.2	1.33 1.31 -1.3	1.15 1.13 -1.5	1.13 1.12 -1.4	1.15 1.13 -1.2	1.33 1.32 -0.8	1.13 1.13 0.1	1.26 1.28 2.0	1.05 1.08 2.7	0.36 0.38 4.4		11
		0.42 0.45 6.0	0.81 0.84 3.2	1.26 1.26 0.2	1.15 1.14 -0.9	1.31 1.29 -1.7	1.13 1.11 -1.7	1.31 1.29 -1.8	1.15 1.13 -1.1	1.26 1.25 -0.4	0.81 0.84 2.5	0.42 0.44 3.6			12
			0.42 0.45 5.9	1.05 1.11 5.7	1.21 1.23 1.9	1.09 1.07 -2.4	1.27 1.24 -2.2	1.09 1.07 -2.1	1.21 1.19 -1.7	1.05 1.05 -0.3	0.42 0.44 3.4				13
				0.36 0.38 5.7	0.65 0.68 5.3	1.04 1.05 1.1	[illegible]	1.04 1.02 -2.1	0.65 0.64 -1.7	0.36 0.36 -1.8					14
						0.35 0.36 4.9	[illegible] 0.43 1.7	0.35 0.34 -1.6							15

STANDARD DEVIATION =1.458

AVERAGE PCT DIFFERENCE = 1.6

SUMMARY

MAP NO: N2-7-24	DATE: 06/14/90	POWER: 100%
CONTROL ROD POSITION:	F-Q(T) = 1.712	QPTR:
D BANK AT 228 STEPS	F-DH(N) = 1.366	NW 0.9983 | NE 1.0050
	F(Z) = 1.150	SW 0.9985 | SE 0.9981
	F(XY) = 1.396	
	BURNUP = 15823 MWD/MTU	A.O.=-3.879

Figure 4.4
NORTH ANNA Unit 2 - CYCLE 7
HOT CHANNEL FACTOR NORMALIZED
OPERATING ENVELOPE

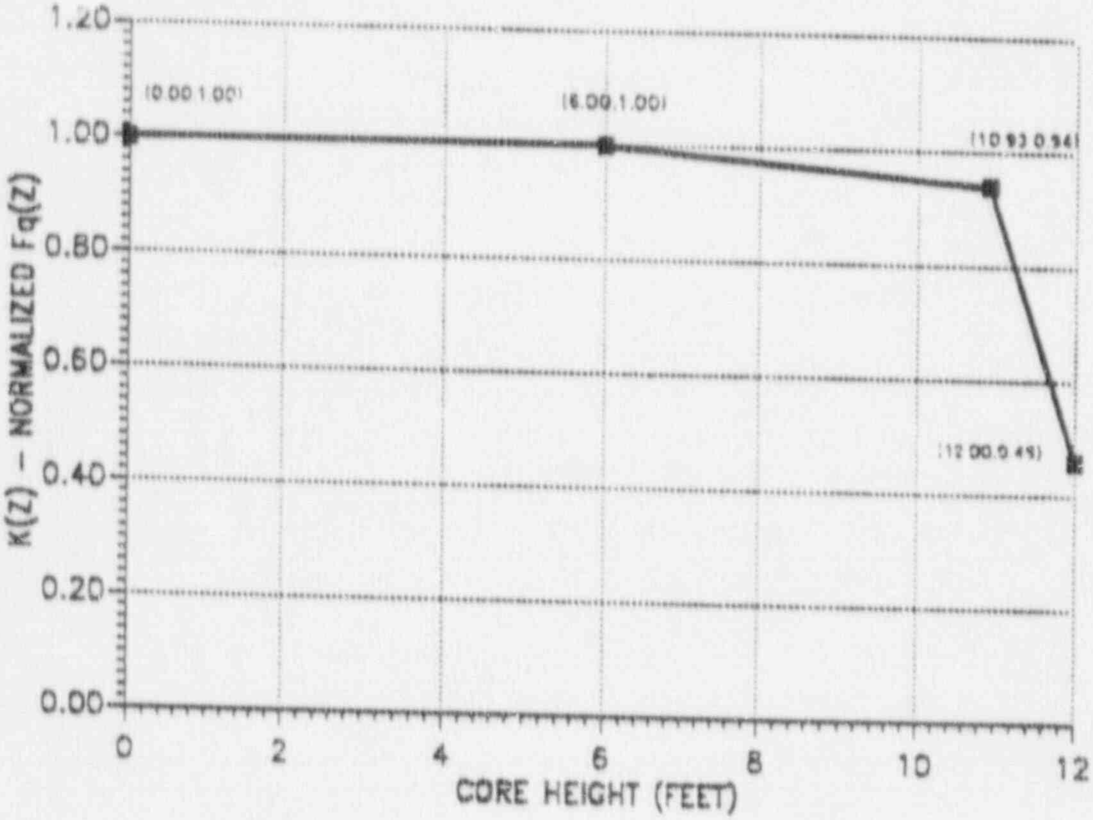


Figure 4.5
NORTH ANNA Unit 2 - CYCLE 7
HEAT FLUX HOT CHANNEL FACTOR, $F_Q(Z)$
N2-7-08

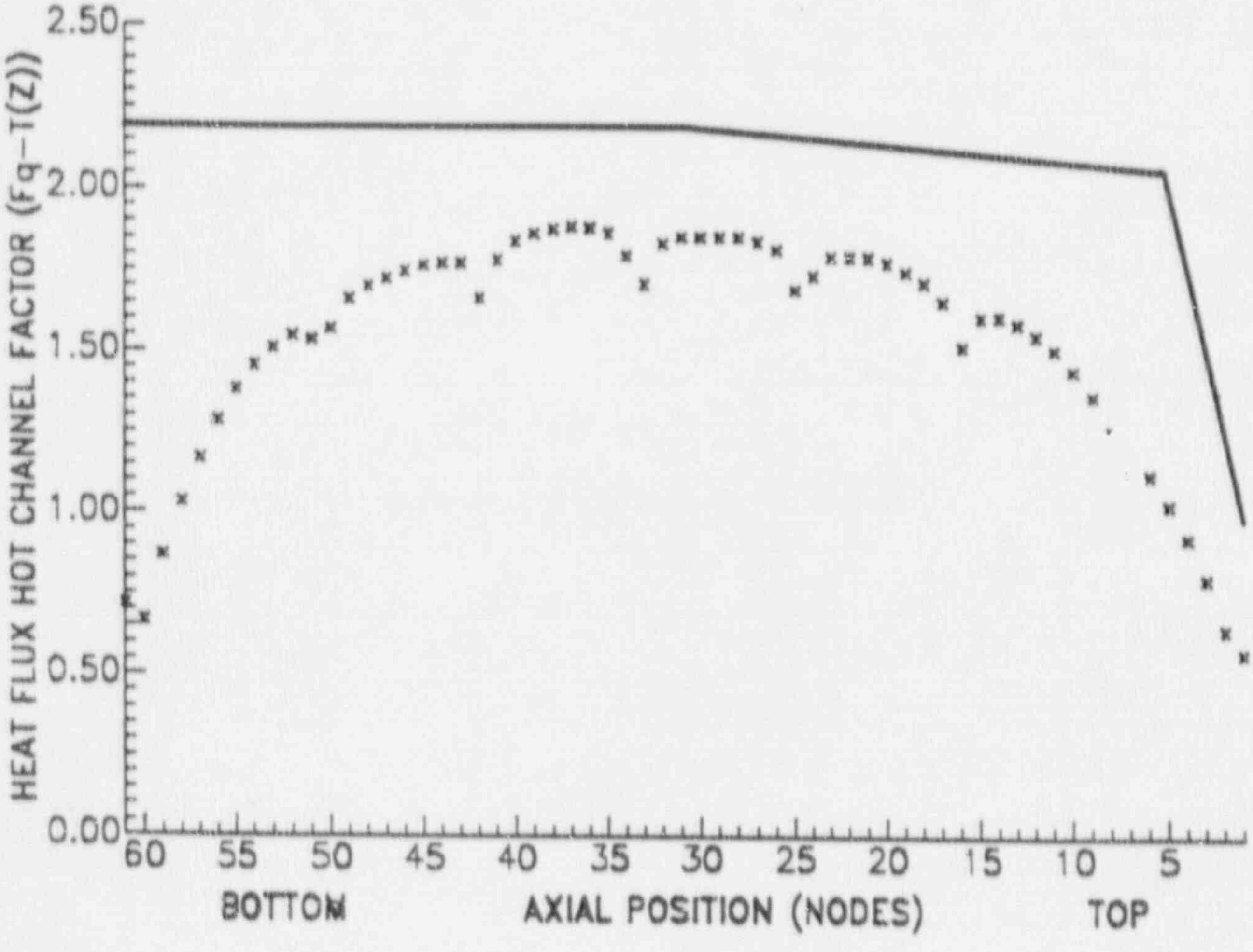


Figure 4.6
NORTH ANNA Unit 2 - CYCLE 7
HEAT FLUX HOT CHANNEL FACTOR, $F_Q(Z)$
N2-7-15

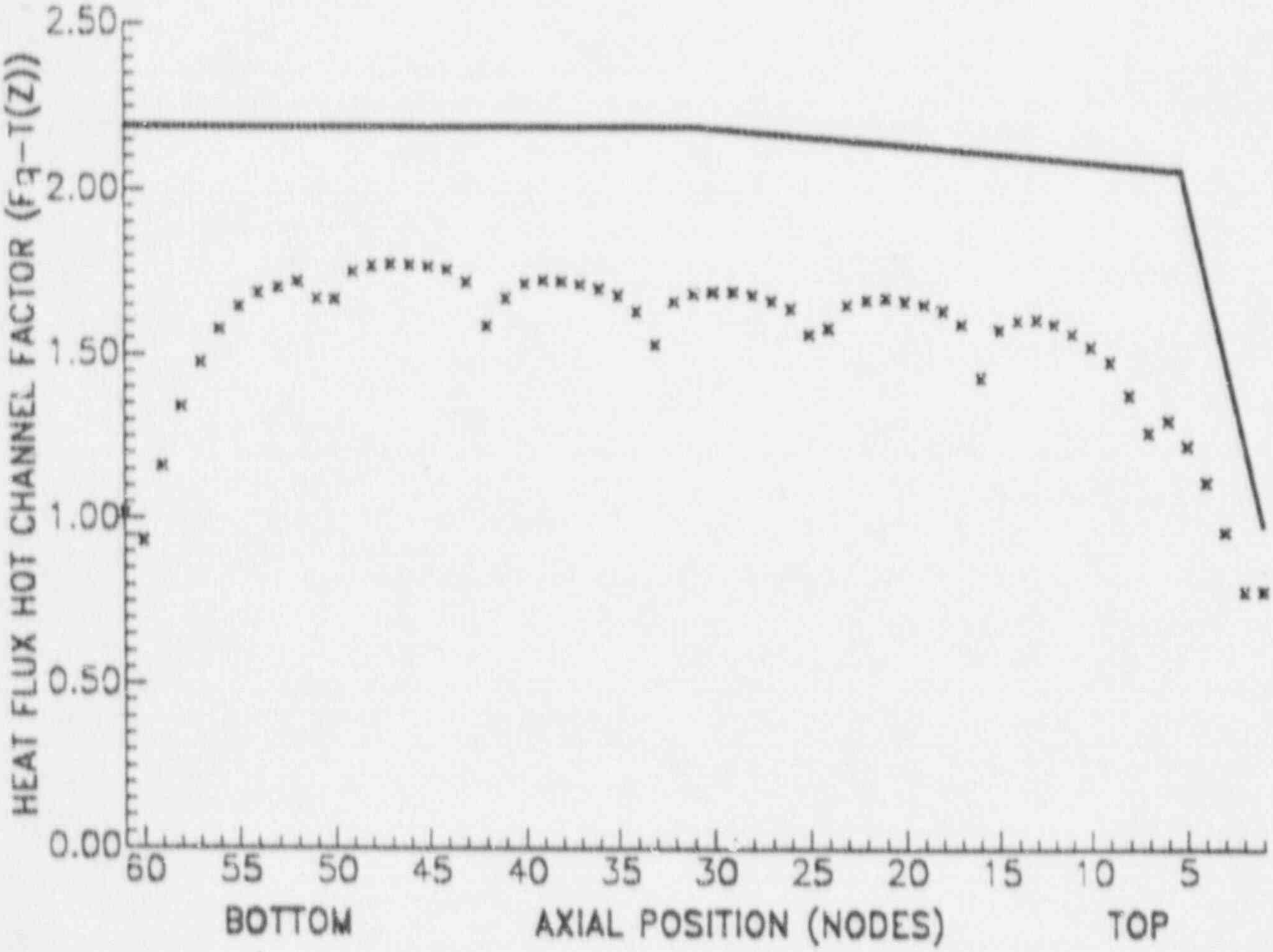


Figure 4.7
NORTH ANNA Unit 2 - CYCLE 7
HEAT FLUX HOT CHANNEL FACTOR, $F_Q(Z)$
N2-7-24

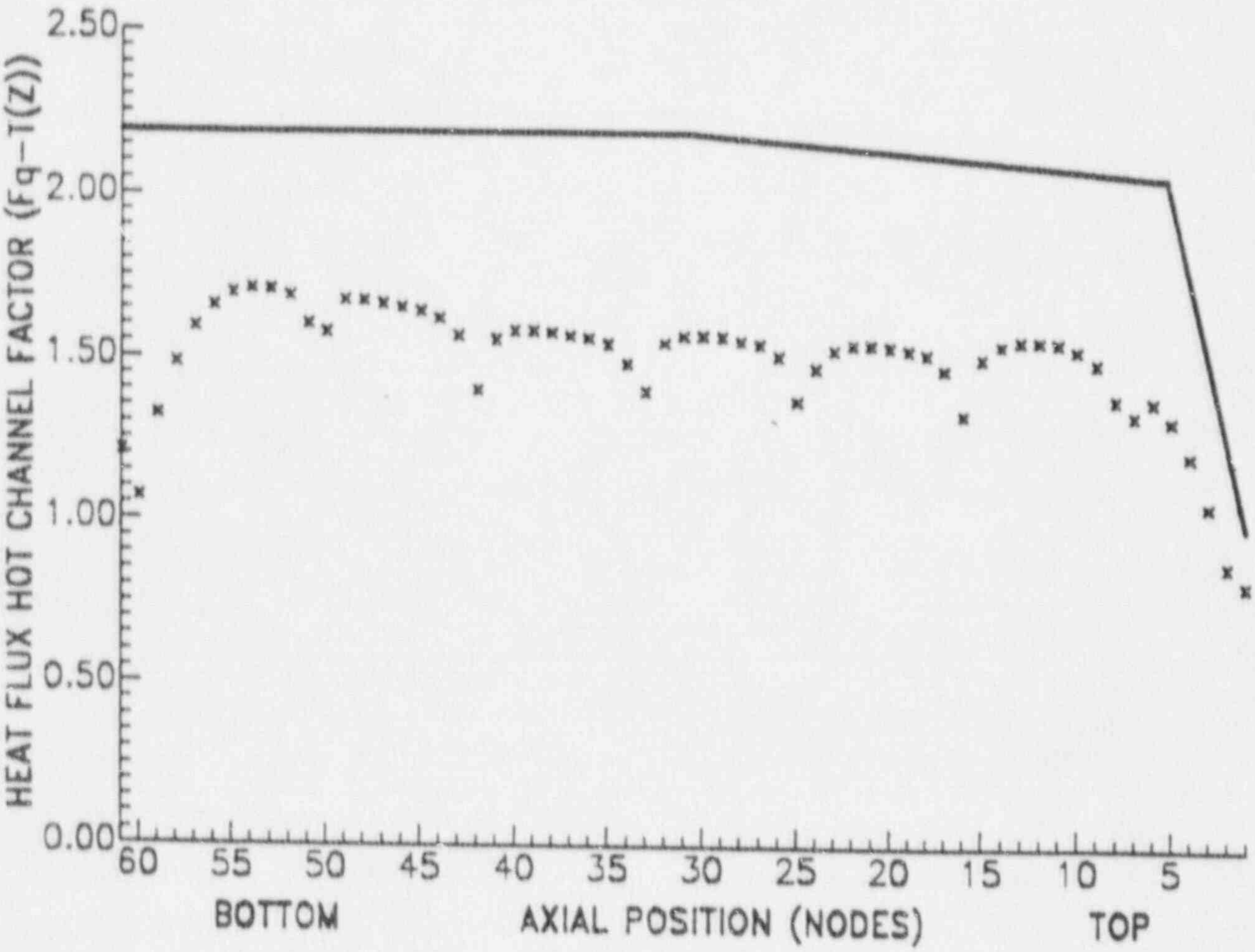


Figure 4.8
NORTH ANNA Unit 2 - CYCLE 7
MAXIMUM HEAT FLUX HOT CHANNEL FACTOR, $F_Q(z)*P$, vs. AXIAL POSITION

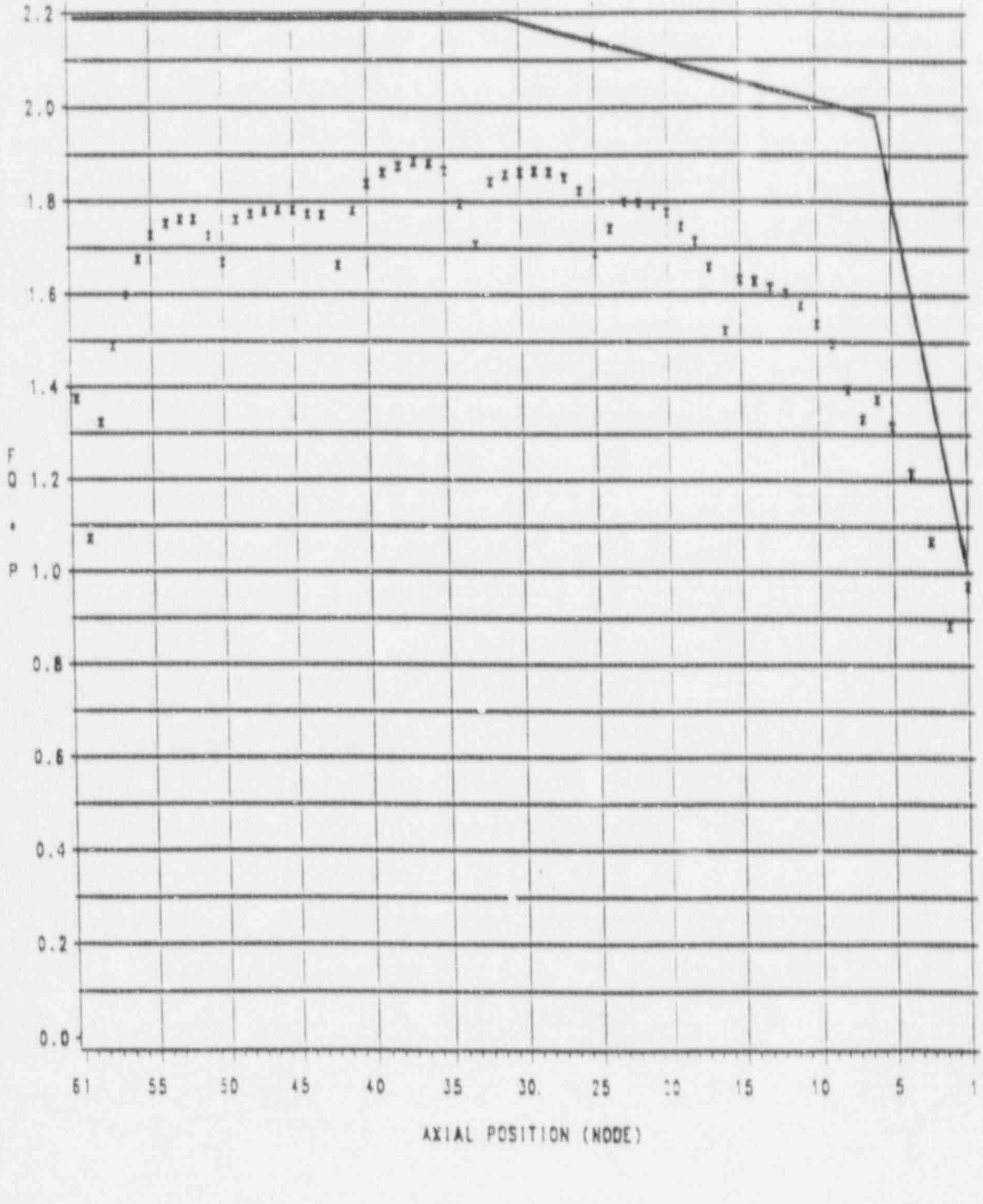


Figure 4.9
NORTH ANNA Unit 2 - CYCLE 7
MAXIMUM HEAT FLUX HOT CHANNEL FACTOR, $F_Q(Z)$, vs. BURNUP

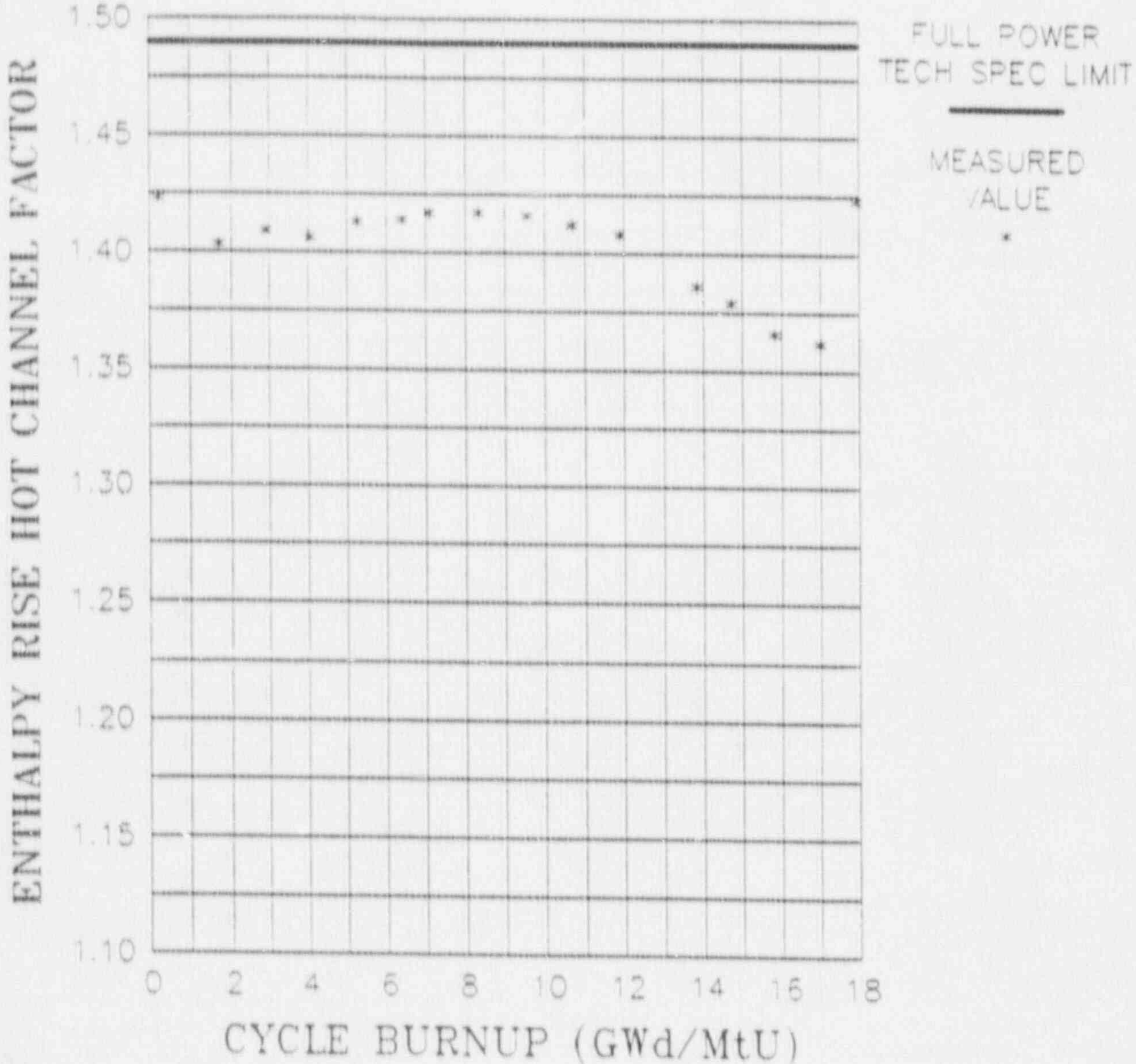


Figure 4.10
NORTH ANNA Unit 2 - CYCLE 7
MAXIMUM ENTHALPY RISE HOT CHANNEL FACTOR, F-delta-H, vs. BURNUP

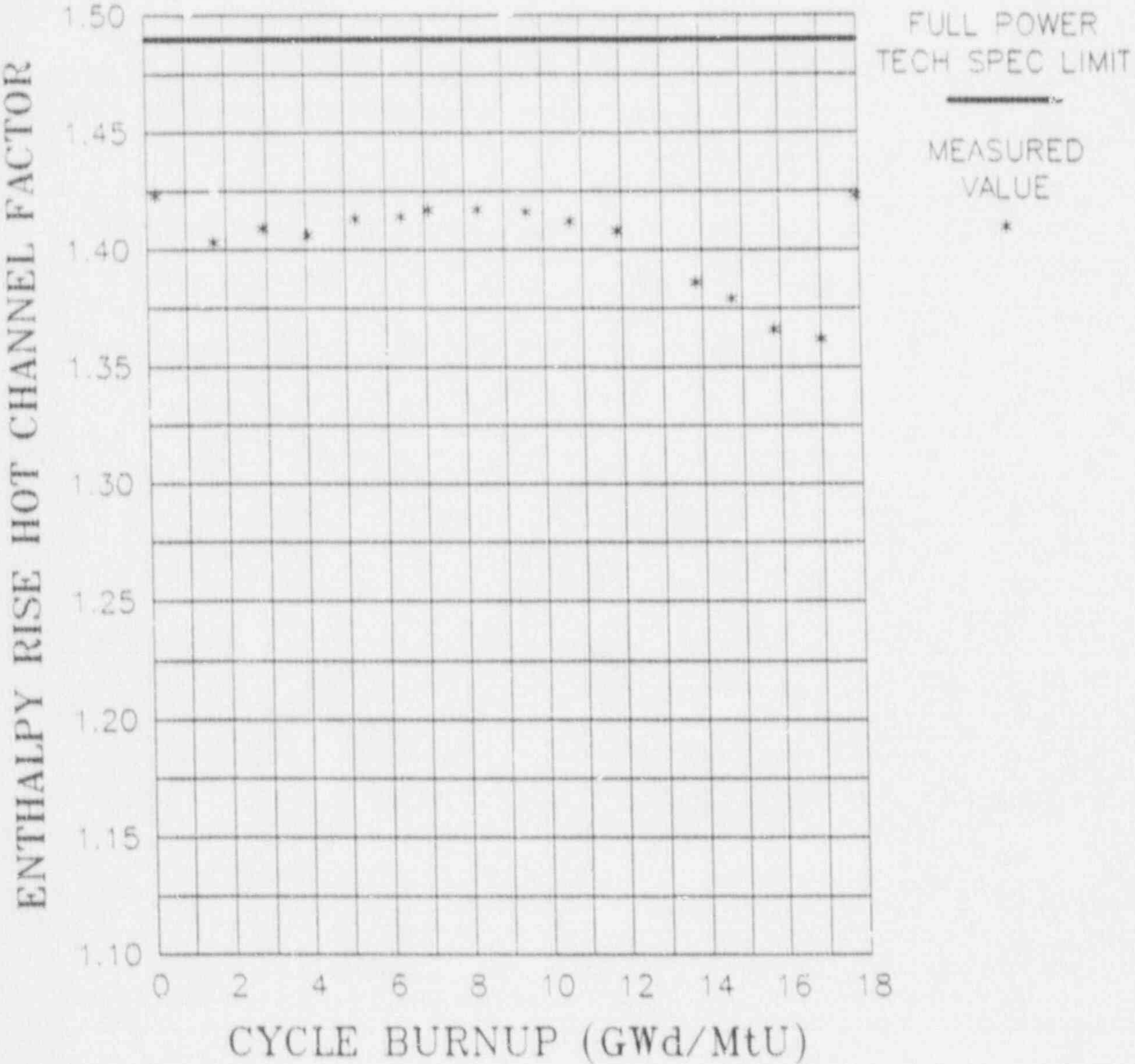


Figure 4.11
NORTH ANNA Unit 2 - CYCLE 7
TARGET DELTA FLUX vs. BURNUP

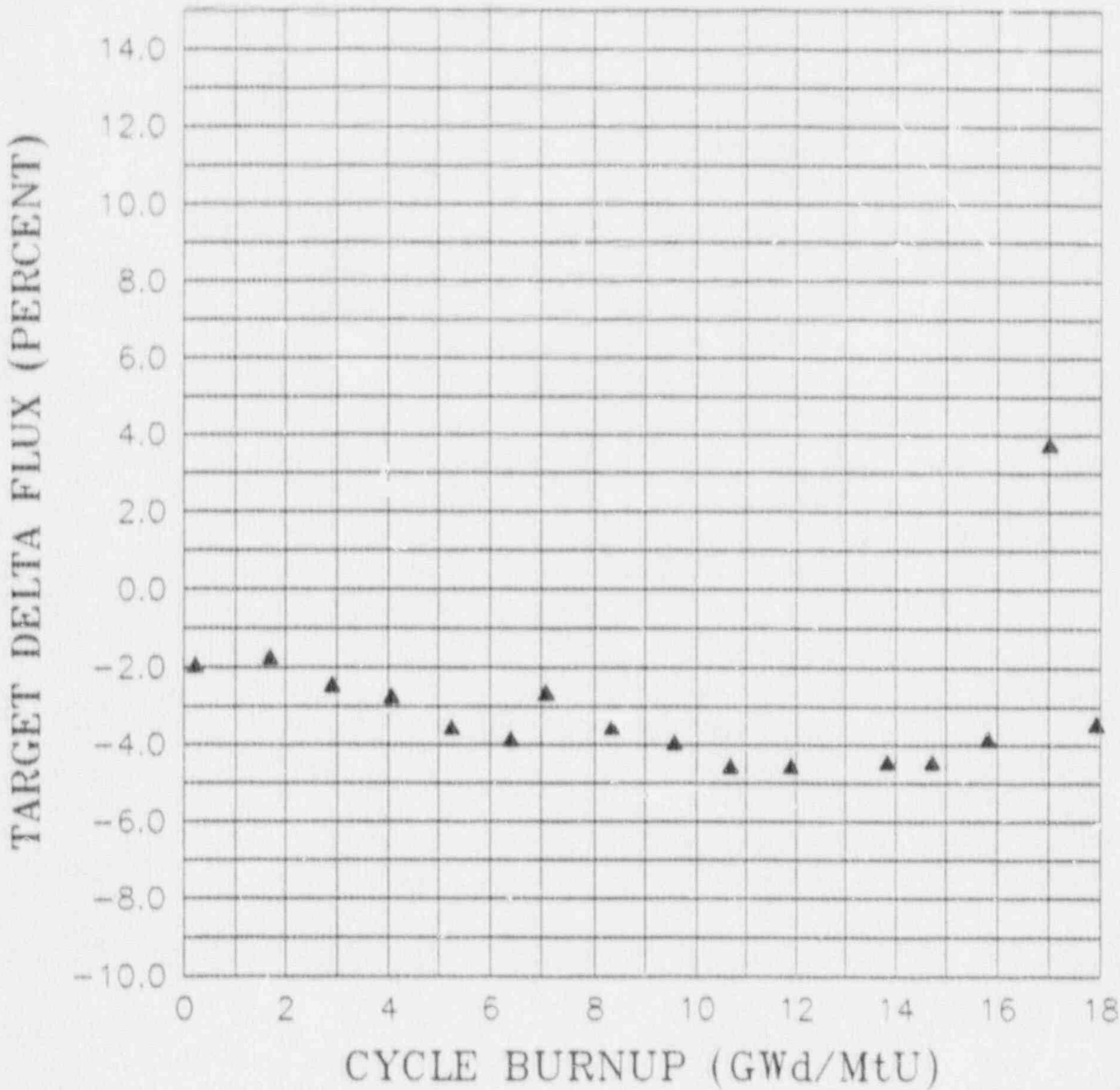


Figure 4.12
NORTH ANNA Unit 2 - CYCLE 7
CORE AVERAGE AXIAL POWER DISTRIBUTION
N2-7-08

Fz = 1.215
AXIAL OFFSET = -1.701

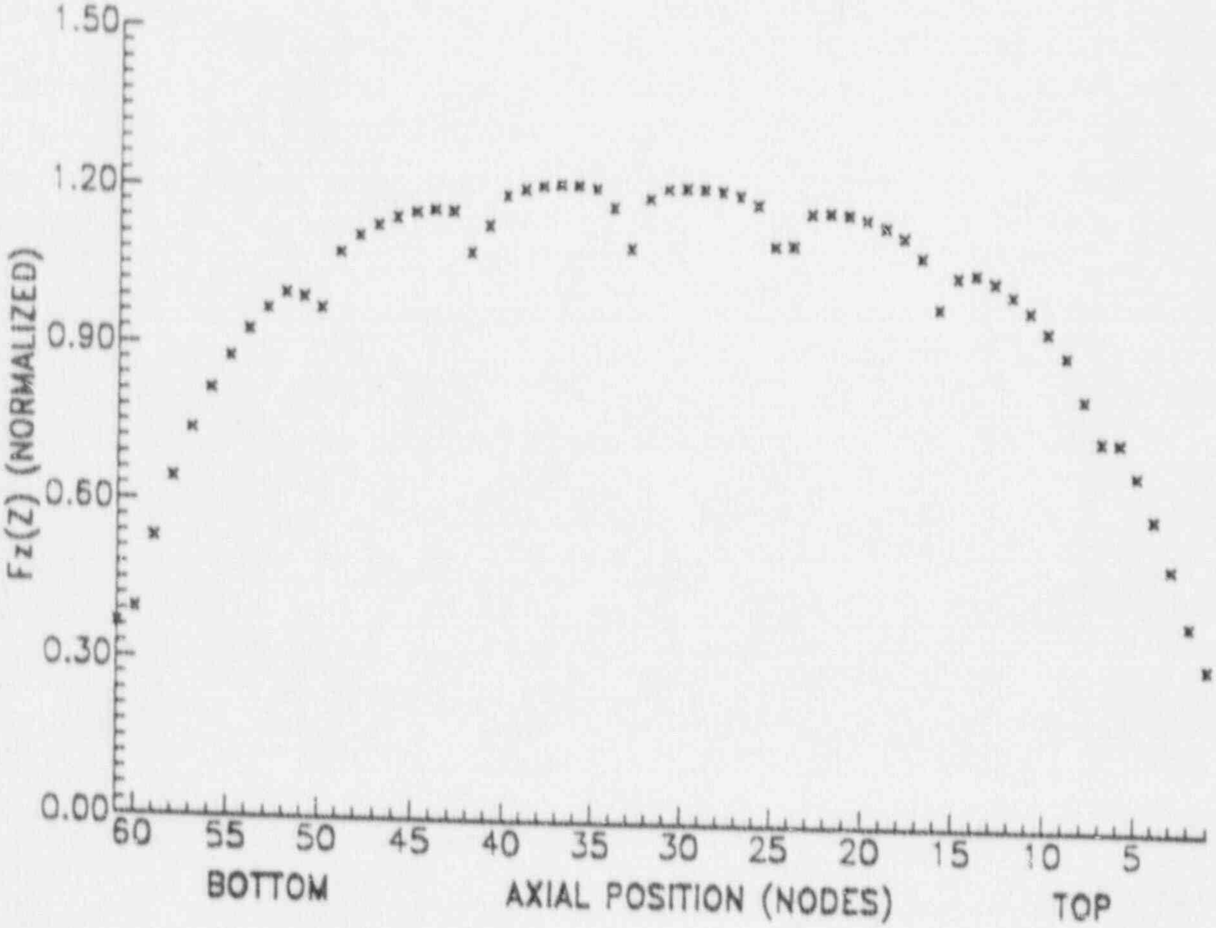
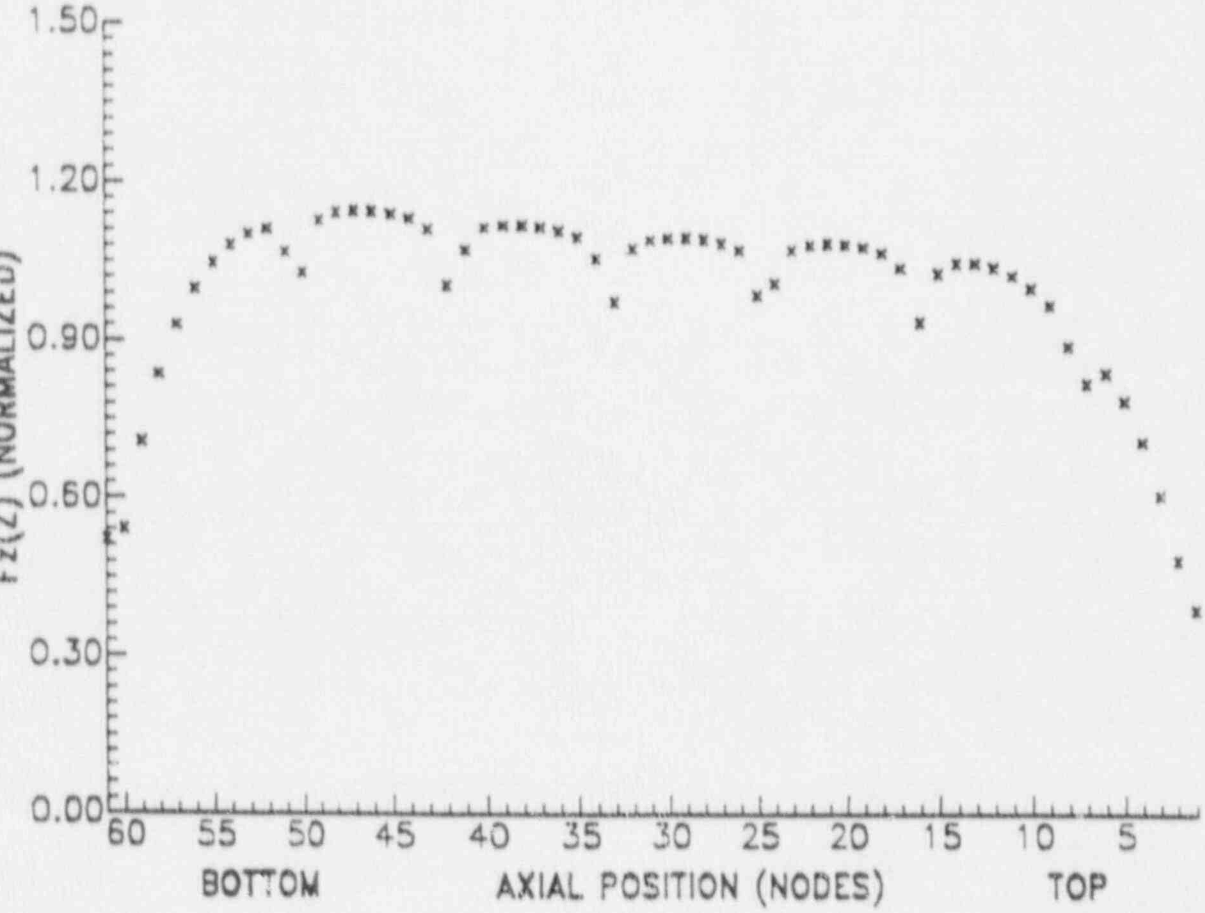


Figure 4.13
NORTH ANNA Unit 2 - CYCLE 7
CORE AVERAGE AXIAL POWER DISTRIBUTION
N2-7-15

Fz = 1.148
AXIAL OFFSET = -3.613



✓

Figure 4.14
NORTH ANNA Unit 2 - CYCLE 7
CORE AVERAGE AXIAL POWER DISTRIBUTION
N2-7-24

Fz = 1.150
AXIAL OFFSET = -3.879

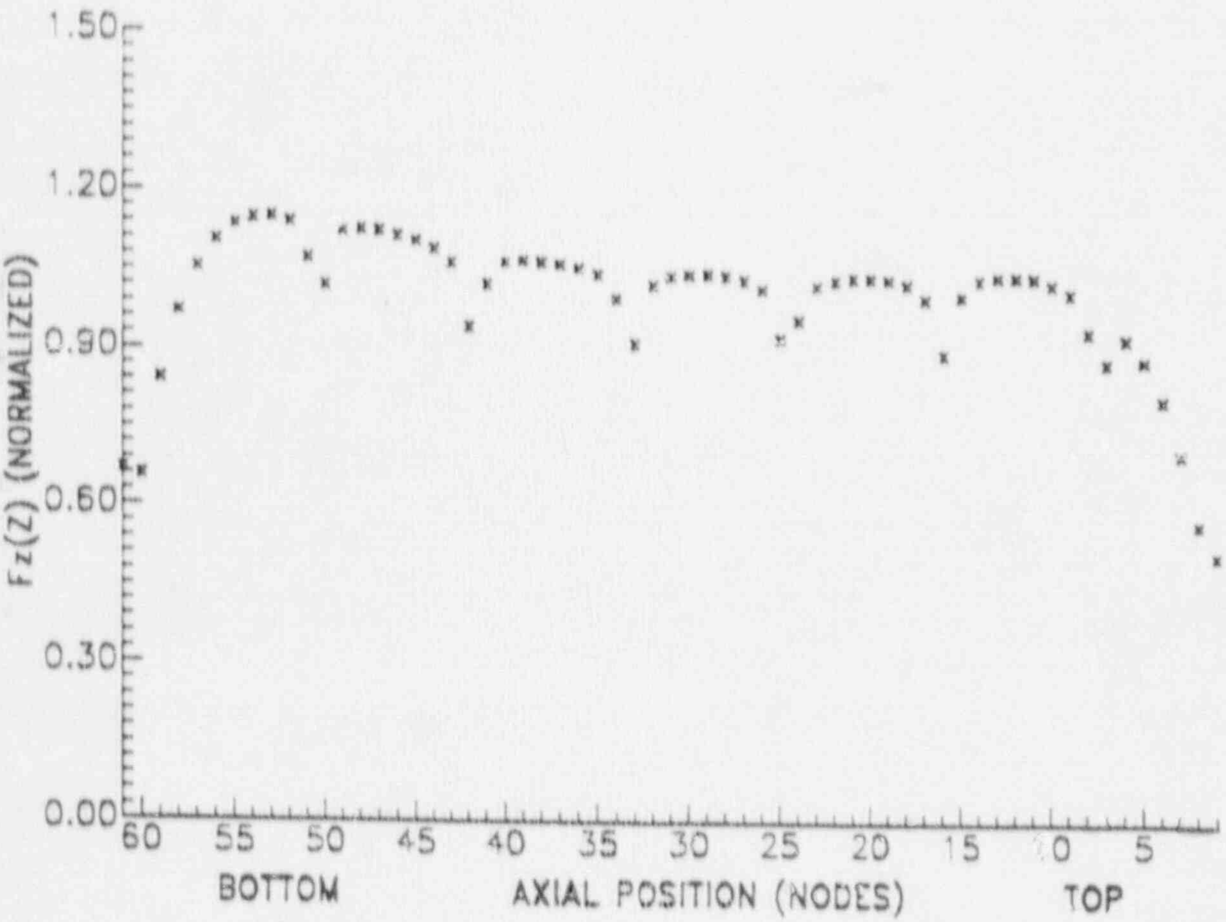
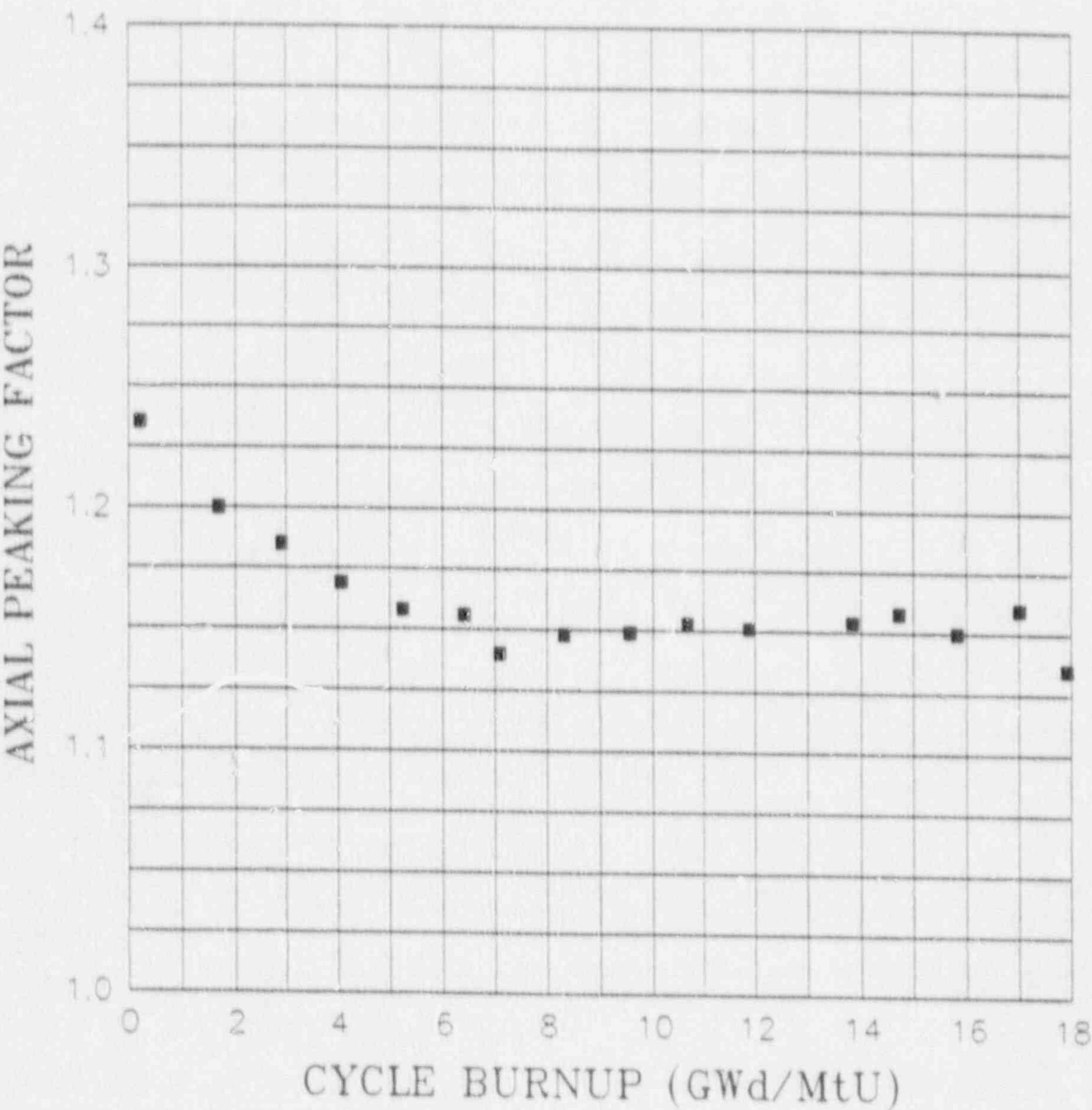


Figure 4.15
NORTH ANNA Unit 2 - CYCLE 7
CORE AVERAGE AXIAL PEAKING FACTOR vs. BURNUP



Section 5

PRIMARY COOLANT ACTIVITY

The specific activity levels of radioiodines in the primary coolant are important to core and fuel performance as indicators of failed fuel and are important with respect to offsite dose calculations associated with accident analyses.

Two mechanisms are responsible for the presence of radioiodines in the primary coolant. Radioiodines are always present due to direct fission product recoil from trace fissile materials plated onto core components and fuel structured surfaces or trace fissile materials existing as impurities in core structural materials. This fissile material is generally referred to as "tramp" material, and the resulting iodines are referred to as tramp iodine. Fission products will also diffuse into the primary coolant if a breach in the cladding (fuel defects) exists. Fuel defects are generally the predominant source of radioiodines in the primary coolant.

North Anna 2 Technical Specification 3.4.8 limits the radioiodines in the primary coolant to a dose equivalent I-131 value of 1.0 μCi/gm for modes one through five, inclusive. Figure 5.1 shows the dose-equivalent I-131 activity history for Cycle 7. These data show that the dose equivalent I-131 activity was substantially below the 1.0 μCi/gm limit for steady state power operation. There are no indications that the 1.0 μCi/gm limit was exceeded during any of the iodine spike events.

The average full power equilibrium dose equivalent I-131 concentration was 1.1×10^{-2} μCi/gm which corresponds to less than 2% of the Technical Specification limit. Correcting the I-131 concentration for tramp iodine involves calculating the I-131 activity from tramp fissile sources and subtracting this value from the measured I-131. The resultant is the I-131 activity from defective fuel. The magnitude of the tramp-corrected I-131 can be used as an indication of the number of defective fuel rods. The cycle average tramp corrected iodine-131 concentration was 7.16×10^{-3} μCi/gm. The demineralizer flow rate averaged approximately 90 gpm during power operation.

The ratio of the specific activities of I-131 to I-133 is used to characterize the type of fuel failure which may have occurred in the reactor core. Use of the ratio for this determination is feasible because I-133 has a short half-life (approximately 21 hours) compared to that of I-131 (approximately eight days). For pinhole defects, where the diffusion time through the defect is on the order of days, the I-133 decays leaving the I-131 dominant in activity, thereby causing the ratio to be roughly 0.5 or more. In the case of large leaks and tramp material, where the diffusion mechanism is negligible, the I-131/I-133 ratio will generally be less than 0.1. The use of these ratios with regard to defect size is empirically determined and generally used throughout the commercial nuclear power industry. Figure 5.2 shows the I-131/I-133 ratio data for the North Anna 2, Cycle 7 core at a general average value of 0.09 through August, 1989. After August, 1989, the I-131/I-133 ratio gradually increased, eventually reaching an average value of 0.50. It is not believed that fuel defects existed in the Cycle 7 core until August, 1989.

The radioiodine data prior to this time is strictly due to tramp material in the core.

During ultrasonic testing following Cycle 7, fuel assembly X10 was identified as having one failed fuel rod. This was the first cycle of operation for this fuel assembly.

Figure 5.1
NORTH ANNA UNIT 2 - CYCLE 7
DOSE EQUIVALENT I-131 vs. TIME

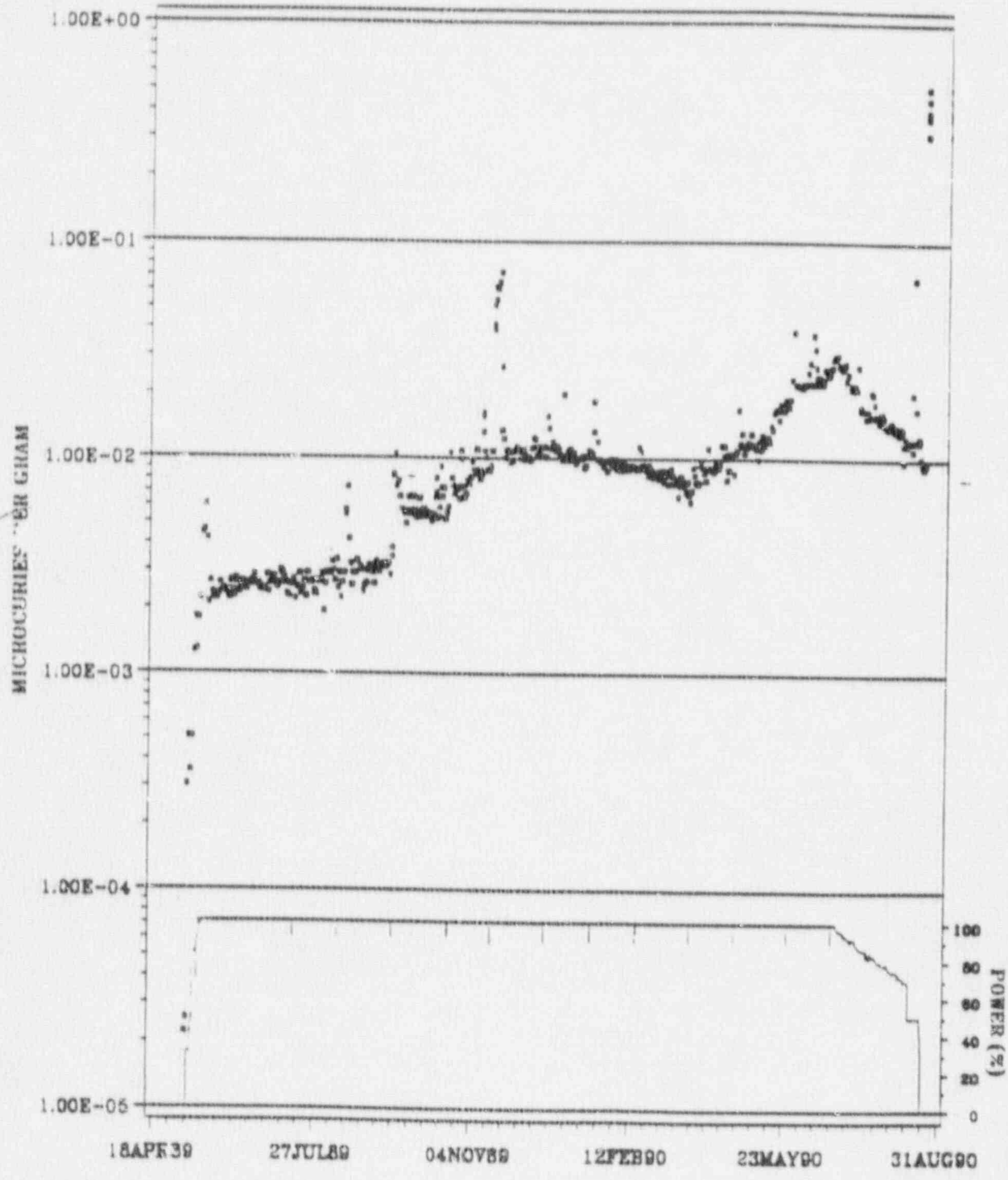
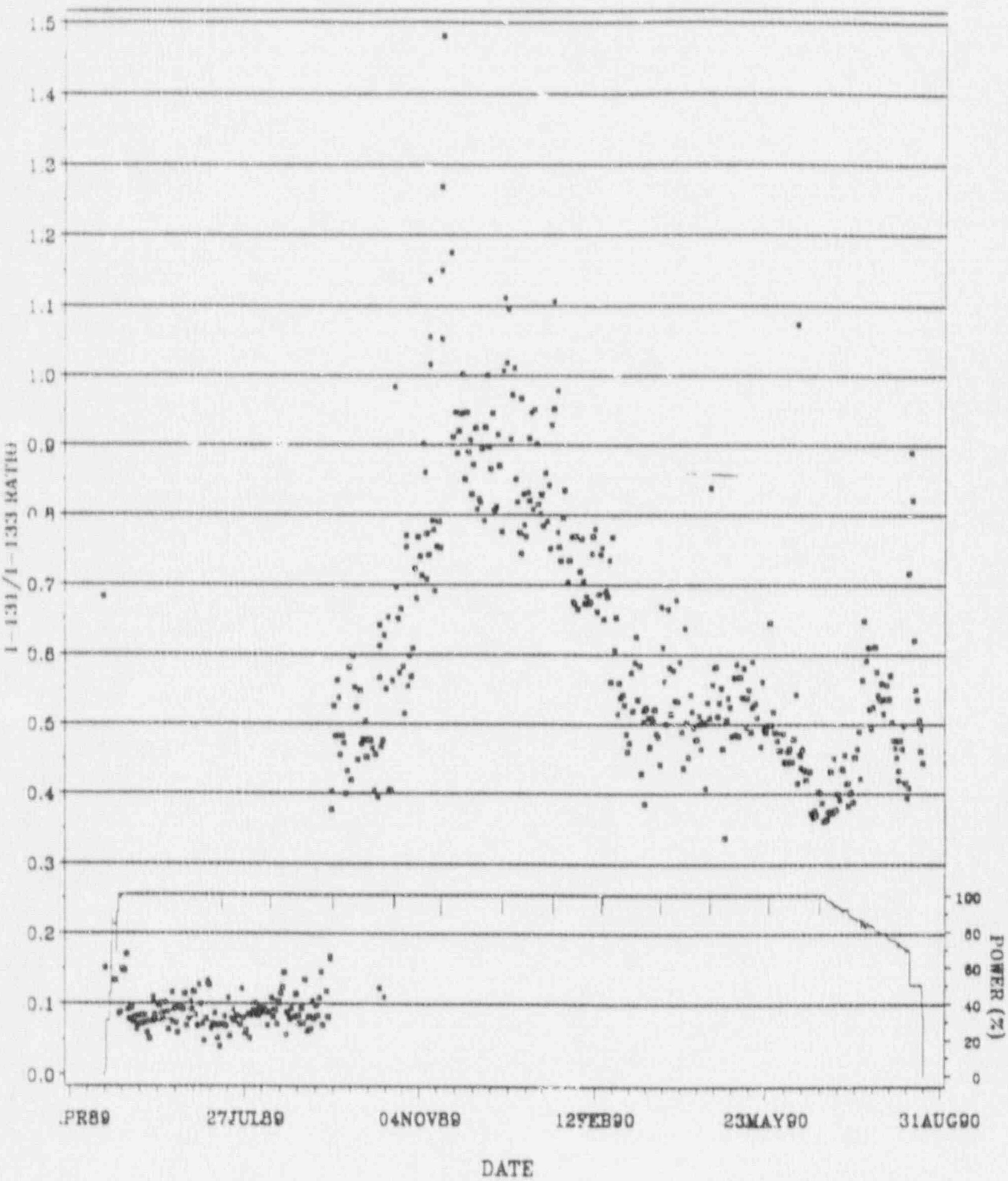


Figure 5.2
NORTH ANNA UNIT 2 - CYCLE 7
I-131 / I-133 ACTIVITY RATIO vs. TIME



Section 6

CONCLUSIONS

The North Anna 2, Cycle 7 core has completed operation. Throughout this cycle, all core performance indicators compared favorably with the design predictions and the core related Technical Specifications limits were met with significant margin. No significant abnormalities in reactivity or burnup accumulation were detected. Radioiodine analysis indicated that there were apparent fuel rod defects during Cycle 7. During ultrasonic testing of the fuel, it was discovered that a single fuel rod in one assembly had a cladding defect and was subsequently restricted from future use.

Section 7

REFERENCES

1) D. A. Trace, "North Anna Unit 2, Cycle 7 Startup Physics Test Report," VEP-NOS-34, July, 1989.

2) North Anna Power Station Unit 2 Technical Specifications, Sections 3/4.1, 3/4.2 and 3/4.4.8.

3) T. K. Ross, "NEWTOTE Code", VEPCO NFO-CCR-6 , Rev. 9, April, 1984.

4) R. D. Klatt, W. D. Leggett, III, and L. D. Eisenhart, "FOLLOW Code," WCAP-7482, February, 1970.

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