North Anna Unit 1 Cycle 8 Core Performance Report

Nuclear Analysis and Fuel
Nuclear Engineering
Services

May, 1991

VIRGINIA POWER

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NORTH ANNA UNIT 1, CYCLE 8

CORE PERFORMANCE REPORT

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

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Section 1

INTRODUCTION AND SUMMARY

On January 12, 1991, North Anna Unit 1 completed Cycle 8. Since the initial criticality of Cycle 8 on July 15, 1989, the reactor core produced approximately 1.1500 x 10^8 MBTU (19,308 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 8. The physics tests that were performed during the startup of this cycle were covered in the North Anna Unit 1, Cycle 8 Startup Physics Test Report[1] and, therefore, will not be included here.

North Anna Unit 1 began operating at a reduced reactor coolant system (RCS) average temperture starting on November 20, 1989 at a burnup of approximately 4897 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. On January 2, 1990 at a burnup of 5946 MWD/MTU Unit 1 increased RCS average temperature from 580.8° F to 583.0° F. This was done because Unit 1 was unable to operate at 100% power with the RCS temperature reduced to 580.8° These changes in RCS average temperature resulted in a net reduction of 3.8° F.

North Anna Unit 1 was in coastdown from September 23, 1990, at which time the burnup was approximately 16,332 MWD/MTU. The coastdown accounted

for an additional core burnup of roughly 2,976 MWD/MTU from the end of full power reactivity.

The Cycle 8 core consisted of 12 sub-batches of fuel: two once-burned batches from Cycle 7 (batches 9A and 9B); four twice burned batches, one from North Anna 2 Cycles 2 and 3 (batch N2/4A), one from North Anna 2 Cycles 3 and 4 (batch N2/5A), one from Cycles 2 and 3 (batch 4A), and one from Cycles 4 and 5 (batch 6A); two thrice burned batches, one from North Anna 2 Cycles 3, 4, and 5 (batch N2/5A), and one from Cycles 5, 6, and 7 (batch 7A); and four fresh batches (batches 10A, 10B, 10C and N2/9B). The North Anna 1, Cycle 8 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 1 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 1, Cycle 8 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 ±0.50% with the burnup accumulation in each batch deviating from design prediction by no more than 2.04%.

2. Reactivity Depletion - The critical boron concentration, used to monitor reactivity depletion, was consistently within ±0.35% 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 1.9%. 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 8 was approximately 0.0088 µCi/gm. This corresponds to less than 1% of the operating limit for the concentration of radioiodine in the primary coolant. Radioiodine analysis indicated there were no fuel rod defects in Cycle 8.

Figure 1.1
NORTH ANNA UNIT 1 - CYCLE 8
CORE LOADING MAP

R	P	N	M	L	K	J	H	G	F	E	D	C	B	A	
						N2/5A SS1	N2/5A S22	N2/5A S28							1
				4A D44	9A J36	N2/9B X44	9A J08	10B K59 SS13	9A J07	4A D35					2
			6A F20	10C K69	10B K57 9P	9A J15	10B K49 12P	9A J06	10B K45 9P	10C K73	6A F08				3
		6A F22	9B J43	10B K58 12P	9B J56	10A K22 12P	9A J31	10A K13 12P	9B J61	10B K55 12P	9B J55	6A F48			4
	N2/4A R51	10C K65	10B K63 12P	9B J58	10A K15 16P	9A J02	9B J51	9A J13	10A K27 16P	9B J50	10B K40 12P	10C K67	N2/4A R49		5
	9A J04	10B K44 9P	9B J40	10A K20 16P	9A J17	10A K32 12P	9B J42	10A K23 12P	9A J29	10A K21 16P	9B J41	10B K39 9P	9A J10		6
N2/5A S08	10B K52 SS14	9A J28	10A K35 12P	9A J23	10A K28 12P	7A G38	10C K70 12P	7A G41	10A K17 12P	9A J16	10A K33 12P	9A J18	10B K64	N2/5A S43	7
N2/5A S13	9A J19	10B K42 12P	9B J60 20DP	9B J45	9B J59	10C K71 12P	9A J09	10C K76 12P	9B J46	9B J47	9B J48 20DP	10B K54 12P	9A J26	6A F45	8
N2/5A S05	10B K58	9A J32	10A K25 12P	9A J03	10A K14 12P	7A G25	10C K66 12P	7A G22	10A K29 12P	9A J11	10A K19 12P	9A J27	10b K47	N2/5A S20	9
	9A J12	10B K48 9P	9B J49	10A K30 16P	9A J05	10A K34 12P	9B J58	10A K18 12P	9A J20	10A K26 16P	9B J53	10B K61 9P	9A J14		10
	N2/4A R31	10C K74	10B K51 12P	9B J59	10A K24 16P	9A J25	9B J52	9A J30	10A K36 16P	9B J57	10B K50 12P	10C K75	N2/4A R04		11
		6A F10	9B J44	10B K62 12P	9B J54	10A K16 12P	9A J21	10A K31 12P	9B J62	10B K43 12P	9B AM1	6A F38			12
			6A F67	10C K72	10B K46 9P	9A J34	10B K37 12P	9A J22	10B K53 9P	10C K68	6A F44				13
				4A D16	9A J35	10B K56 SS15	9A J33	10B K60	9A J01	4A D52					14
						N2/5A SS2	N2/5A S09	N2/5A S27							15

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

A. SS - SECONDARY SOURCE
B. XXP - BURNABLE POISON ASSEMBLY
C. XXDP- DEPLETED BURNABLE POISON ASSEMBLY

FUEL ASSEMBLY DESIGN PARAMETERS

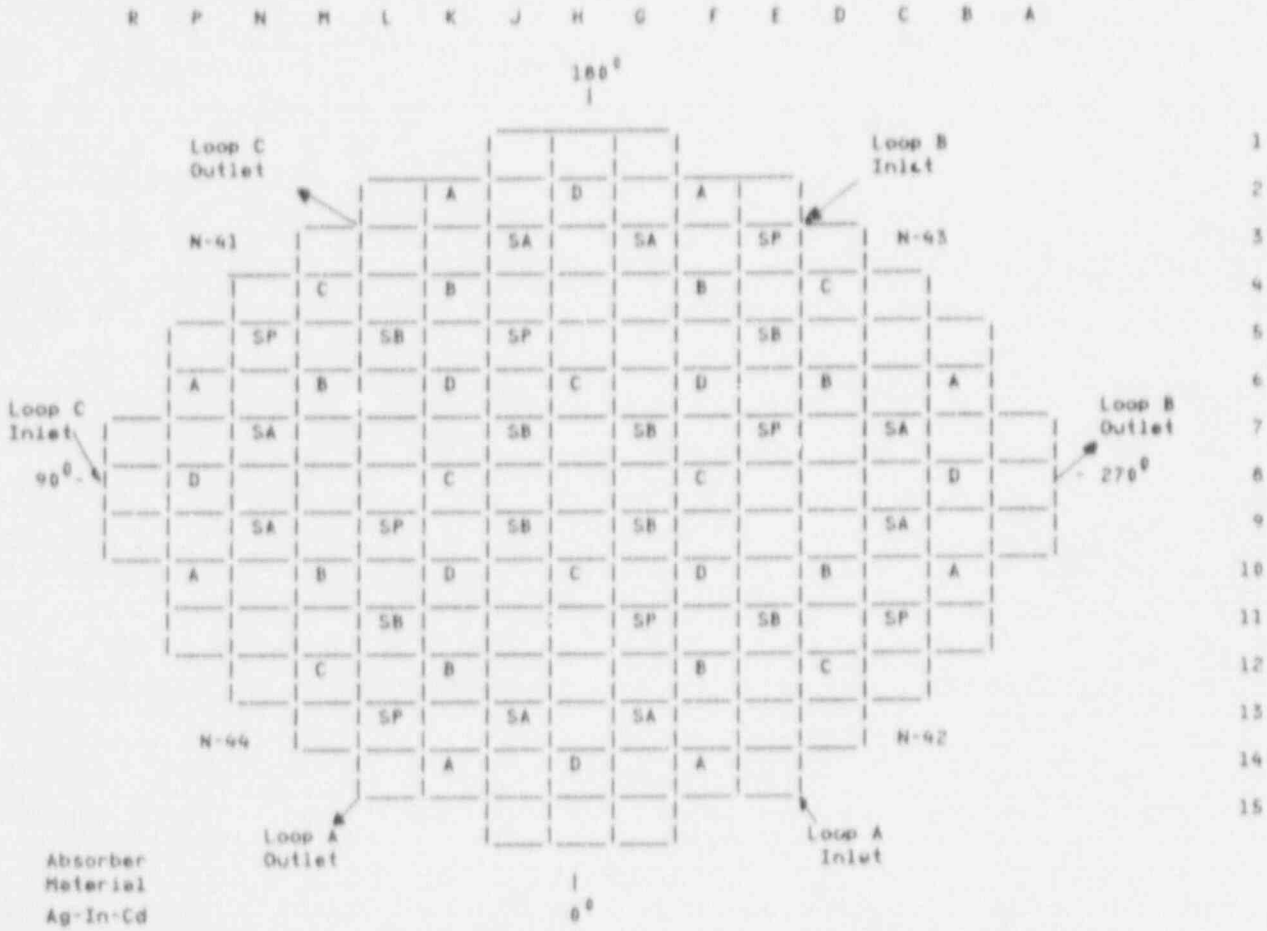
	SUB-BATCH										
	N2/4A	N2/5A	4A	6A	7A	9A	9B	10A	10B	10C	N2/9B
INITIAL ENRICHMENT (W/O U-235)	3.41	3.59	3.21	3.59	3.60	3.79	3.99	3.80	4.00	3.82	4.01
BURNUP AT EOC 8 (MWD/MTU)	31272	35825	28241	39724	49869	40034	41788	25491	22850	22246	19664
ASSEMBLY TYPE	17x17	17x17	17x17	17x17	17x17	17x17	17x17	17x17	17x17	17x17	17X17
NUMBER OF ASSEMBLIES	4	11	4	9	4	35	26	24	27	12	1
FUEL RODS PER ASSEMBLY	264	264	264	264	264	264	264	264	264	264	264

Figure 1.2
NORTH ANNA UNIT 1 - CYCLE 8
MOVABLE DETECTOR AND
THERMOCOUPLE 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 1.3
NORTH ANNA UNIT 1 - CYCLE 8
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 1, Cycle 8 core is graphically depicted in Figure 2.1. The North Anna 1, Cycle 8 core achieved a burnup of 19,308 MWD/MTU. As shown in Figure 2.2, the average load factor for Cycle 8 was 89.0% when referenced to the rated thermal power of 2893 MW(t). Unit 1 performed a power coastdown starting on September 23, 1990 until shutdown for refueling on January 12, 1991.

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 8 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 8 operation is also given. As can be seen from this figure, the accumulated assembly burnups were generally within ±2.92% of the predicted values. In addition, deviation from quadrant symmetry in the core throughout the cycle was no greater than ±0.50%.

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 1, Cycle 8 followed design predictions closely with no batch deviating from prediction by more than 2.04%. Symmetric burnup in conjunction with agreement between actual and predicted assemblywise burnups and batch burnup sharing indicate that the Cycle 8 core did deplete as designed.

Figure 2.1
NORTH ANNA UNIT 1 - CYCLE 8
CORE BURNUP HISTORY

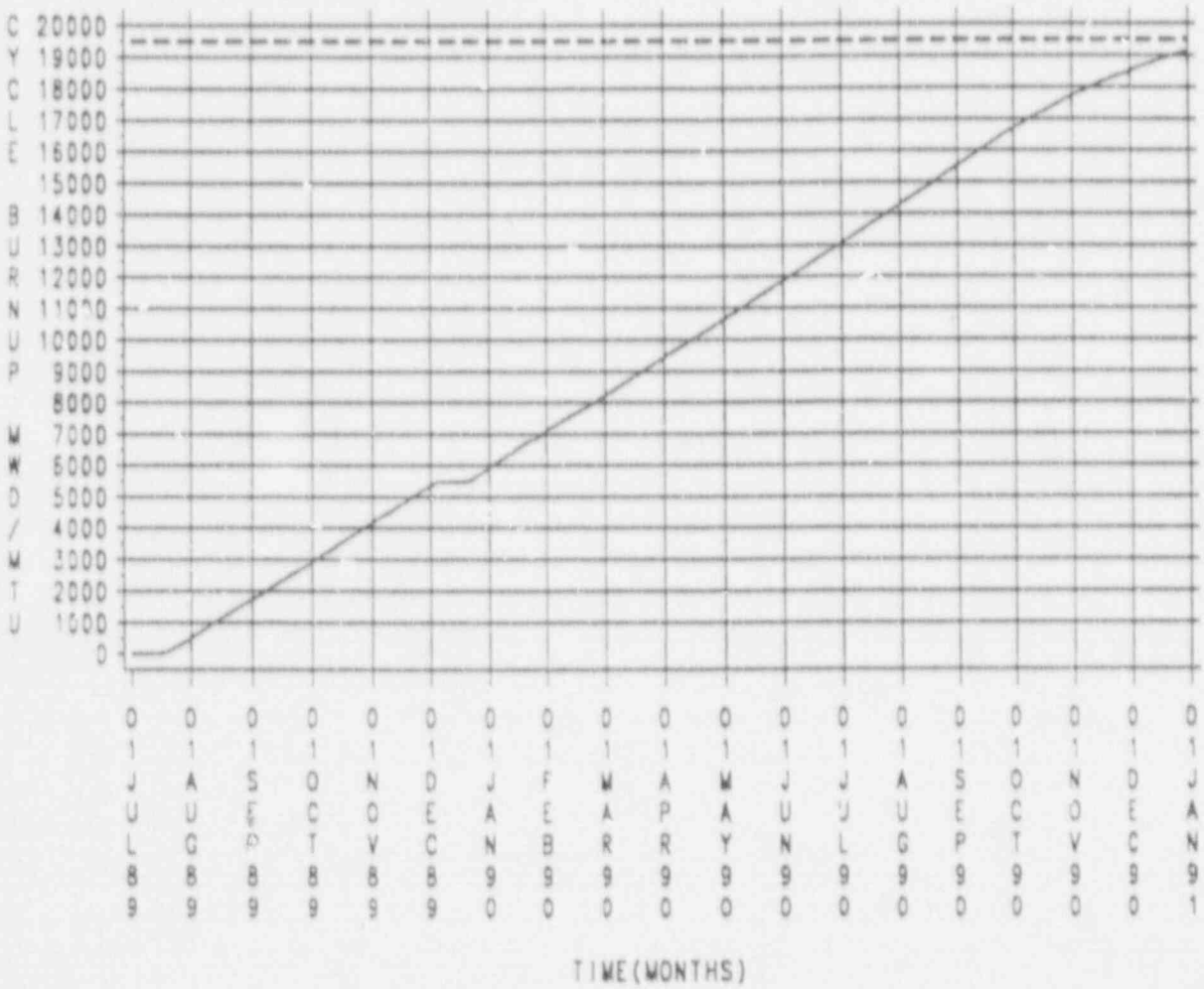


Figure 2.2
NORTH ANNA UNIT 1 - CYCLE 8
MONTHLY AVERAGE LOAD FACTORS

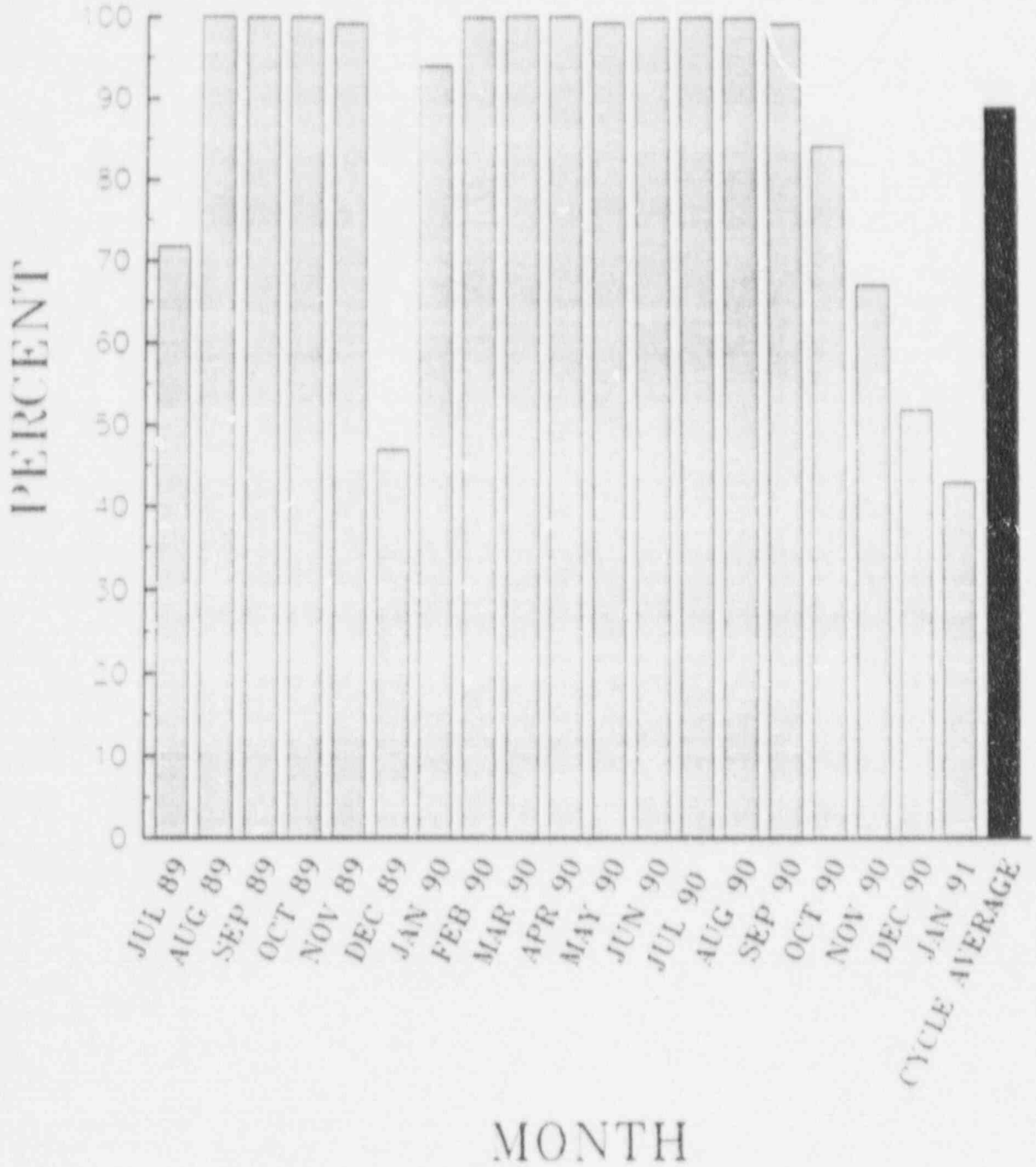


Figure 2.3
NORTH ANNA UNIT 1 - CYCLE 8
EOC ASSEMBLYWISE ACCUMULATED BURNUP
MEASURED AND PREDICTED
(GWD/MTU)

R	P	N	M	L	K	J	H	G	F	E	D	C	B	A	
						35.53	36.49	36.87						MEASURED	1
						35.58	36.26	35.58						PREDICTED	
				28.06	33.80	19.66	37.91	19.87	34.78	28.27					2
				27.90	34.37	19.65	37.94	19.65	34.37	27.90					
			40.26	20.42	22.94	39.23	24.12	39.84	24.15	20.76	40.36				3
			39.79	20.36	23.84	39.72	24.69	39.72	23.84	20.36	39.79				
		39.96	36.89	24.50	43.80	25.40	44.24	25.37	44.57	24.47	37.21	39.97			4
		39.76	37.18	24.53	44.31	25.66	44.13	25.66	44.31	24.53	37.18	39.76			
	31.39	20.14	24.11	43.36	25.57	44.31	40.25	44.16	25.93	43.83	24.47	20.71	31.37		5
	30.95	20.36	24.60	43.84	25.86	44.02	40.18	44.02	25.86	43.84	24.60	20.36	30.95		
	34.24	23.71	44.53	25.53	44.22	26.04	41.55	26.02	44.58	25.62	44.13	23.79	34.76		6
	34.24	23.86	44.30	25.90	44.44	25.80	41.25	25.80	44.44	25.90	44.30	23.86	34.24		
35.96	19.39	38.79	25.28	43.56	25.79	50.72	25.85	49.83	25.94	43.78	24.97	39.37	19.45	35.48	7
35.58	19.67	39.61	25.74	44.11	25.80	49.83	25.53	49.83	25.80	44.11	25.74	39.61	19.67	35.58	
36.14	37.66	24.40	43.15	0.00	41.19	26.14	43.98	25.42	41.58	40.00	42.48	24.58	38.52	36.36	8
36.07	38.87	24.73	43.25	41.25	41.50	25.51	44.51	25.51	41.50	40.25	43.25	24.73	38.07	36.07	
35.16	19.05	38.87	25.34	43.57	25.52	49.56	24.76	49.58	25.42	44.11	25.24	39.75	19.99	35.63	9
35.58	19.67	39.61	25.74	44.11	25.80	49.83	25.53	49.83	25.80	44.11	25.74	39.61	19.67	35.58	
33.74	22.99	43.78	25.83	44.55	25.23	40.61	25.31	43.75	25.58	43.73	23.81	35.14			10
34.24	23.86	44.30	25.90	44.44	25.80	41.25	25.80	44.44	25.90	44.30	23.86	34.24			
30.95	20.52	24.59	43.20	25.58	43.18	39.61	43.33	25.50	43.93	24.81	20.81	31.38			11
30.95	20.36	24.60	43.84	25.86	44.02	40.18	44.02	25.86	43.84	24.60	20.36	30.95			
	40.54	37.68	24.49	44.04	24.95	43.12	25.04	43.73	24.09	37.76	40.15				12
	39.76	37.18	24.53	44.31	25.66	44.13	25.66	44.31	24.53	37.18	39.76				
		40.21	21.53	23.93	39.25	23.85	38.67	23.28	20.08	39.72					13
		39.79	20.36	23.84	39.72	24.69	39.72	23.84	20.36	39.79					
			28.68	35.14	19.11	37.81	19.23	34.23	28.01						14
			27.90	34.37	19.65	37.94	19.65	34.37	27.90						
				35.76	36.58	35.27									15
				35.58	36.26	35.58									

Figure 2.4
NORTH ANNA UNIT 1 - CYCLE 8
EOC 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	
						35.55	36.49	36.07					MEASURED		
						0.61	0.65	1.97					M/P % DIFF		
				28.06	33.80	19.66	37.91	19.87	34.78	28.22					2
				0.57	-1.64	0.05	-0.06	1.08	1.20	1.15					
			40.26	20.42	22.96	39.23	24.12	39.84	24.15	20.76	40.36				3
			1.17	0.30	-3.78	-1.24	-2.29	0.50	1.33	1.97	1.42				
		39.96	36.89	24.50	43.80	25.40	44.24	25.37	44.57	24.47	37.21	39.97			4
		0.52	-0.80	-0.13	-1.17	-1.01	0.25	-1.15	0.57	-0.25	0.06	0.53			
	31.39	20.14	24.11	43.38	25.67	44.31	40.25	44.16	25.93	43.83	24.47	20.71	31.37		5
	1.42	-1.09	-2.00	-1.03	-1.11	0.68	0.19	0.53	0.28	-0.01	-0.55	1.72	1.35		
	34.24	23.71	44.53	25.53	44.22	26.04	41.55	26.02	44.50	26.62	44.13	23.79	34.76		6
	-0.02	-0.60	0.52	-1.42	-0.49	0.93	0.72	0.85	0.15	-1.07	-0.58	-0.25	1.49		
35.96	19.39	38.79	25.28	43.56	25.79	50.72	25.85	49.83	25.94	43.70	24.97	39.37	19.45	35.68	7
1.63	-1.43	-2.06	-1.77	-1.25	-0.07	1.77	1.25	-0.01	0.53	-0.96	-3.00	-0.61	-1.16	0.26	
36.14	37.66	24.40	43.15	40.08	41.19	26.14	44.98	25.42	41.50	40.00	42.48	24.38	38.52	36.36	8
0.28	-1.07	-1.34	-0.24	-0.61	-0.25	2.44	1.06	-0.36	0.49	-0.62	-1.78	-1.40	1.19	0.81	
35.16	19.05	38.87	25.34	43.92	25.52	49.36	24.76	49.58	25.42	44.11	25.24	39.75	19.99	35.63	9
-0.66	-3.19	-1.86	-1.57	-0.43	-1.11	-0.94	-3.00	-0.52	-1.50	0.00	-1.95	0.35	1.58	0.70	
	35.74	22.99	43.78	25.83	44.55	25.23	40.61	25.31	43.75	25.58	43.73	23.81	35.14		10
	-1.47	-3.64	-1.17	-0.25	0.25	-2.20	-1.57	-1.89	-1.55	-1.23	-1.27	-0.18	2.61		
	30.95	20.52	24.59	43.20	25.38	43.18	39.61	43.53	25.50	43.93	24.81	20.81	31.38		11
	-0.11	0.79	-0.04	-1.46	-1.86	-1.91	-1.41	-1.56	-1.38	0.22	0.86	2.19	1.37		
		40.54	37.68	24.49	44.04	24.95	43.12	25.04	43.73	24.09	37.76	40.15			12
		1.96	1.32	-0.17	-0.62	-2.78	-2.28	-2.44	-1.31	-1.80	1.56	0.98			
			40.21	21.33	23.93	39.25	23.85	38.67	23.28	20.08	39.72				13
			1.06	4.77	0.39	-1.20	-3.39	-2.65	-2.32	-1.59	-0.18		ARITHMETIC AVG		
				28.68	35.14	19.11	37.81	19.23	34.23	28.01			PCT DIFF = -0.50		
				2.78	2.24	-2.76	-0.34	-2.14	-0.40	0.38					14
STANDARD DEV = 0.88						35.76	36.58	35.27					AVG ABS PCT DIFF = 1.16		15
						1.08	0.89	-0.50							

CYCLE 8 BATCH SHARING
(MWD/MTU)

BATCH	NO. OF ASSEMBLIES	BOC BATCH BURNUP	EOC BATCH BURNUP	CYCLE BURNUP
N2/4A	4	23,907	31,272	7,365
N2/5A	11	29,535	35,825	6,290
4A	4	20,796	28,241	7,445
6A	9	31,839	39,724	7,885
7A	4	29,751	49,869	20,118
9A	35	20,983	40,034	19,051
9B	26	19,999	41,788	21,789
10A	24	0	25,491	25,491
10B	27	0	22,850	22,850
10C	12	0	22,246	22,246
N2/9B	1	0	19,664	19,664
CYCLE AVERAGE ACCUMULATED BURNUP = 19,308				

BURNUP TILT

NW = -0.01	NE = 0.49
SW = -0.23	SE = -0.25

Figure 2.5A
NORTH ANNA UNIT 1 - CYCLE 8
SUB-BATCH BURNUP SHARING

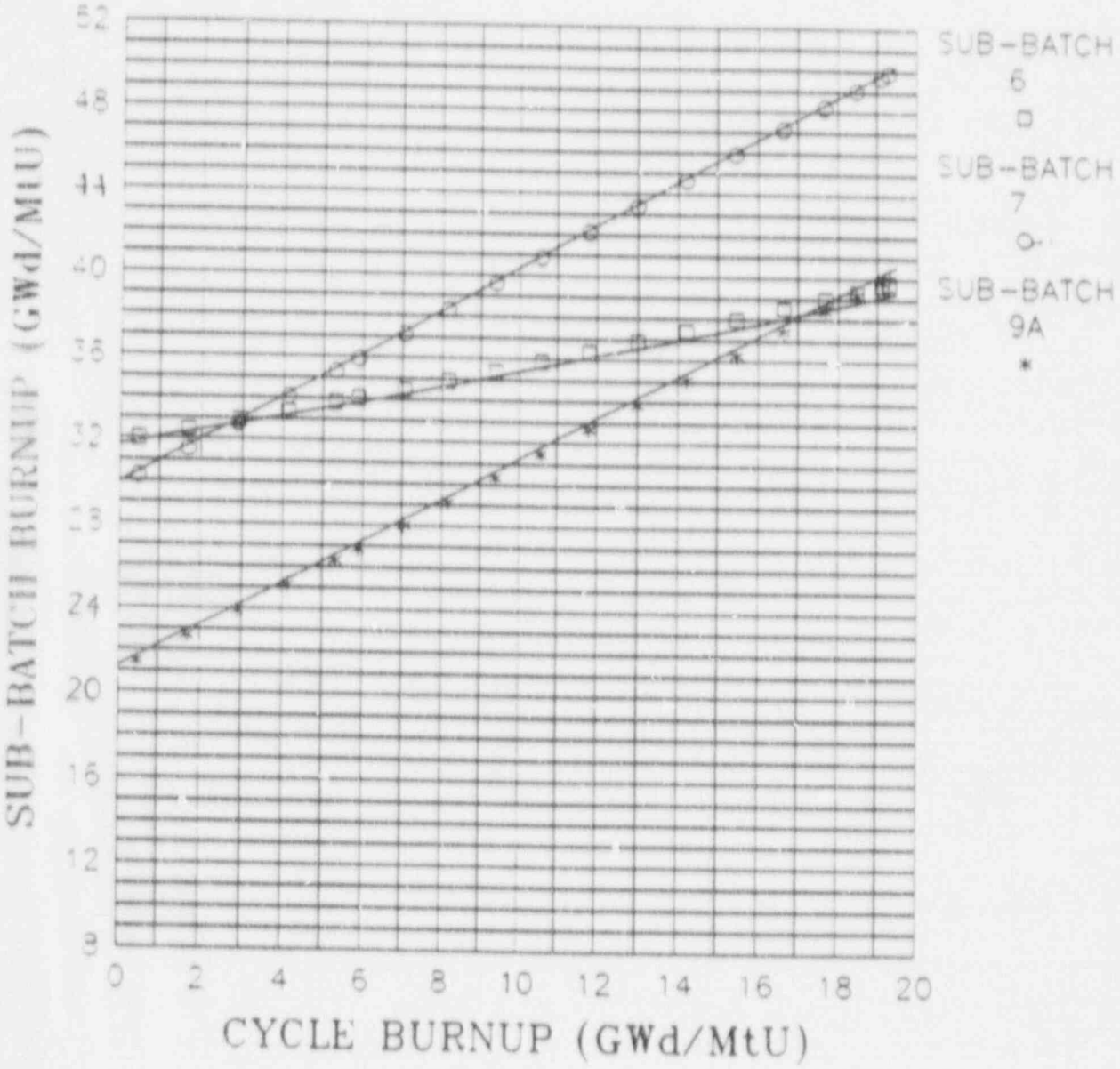


Figure 2.5B
NORTH ANNA UNIT 1 - CYCLE 8
SUB-BATCH BURNUP SHARING

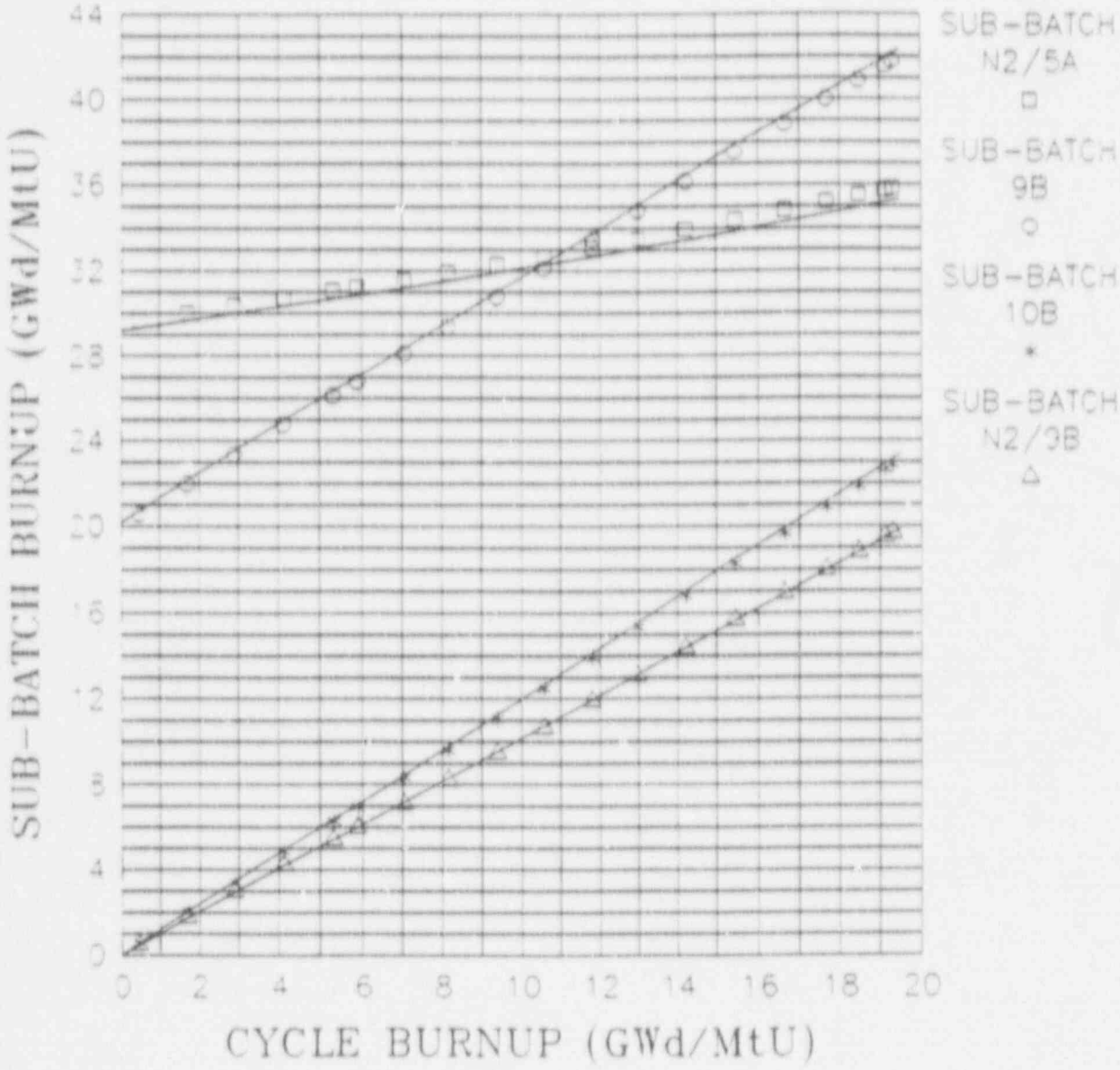
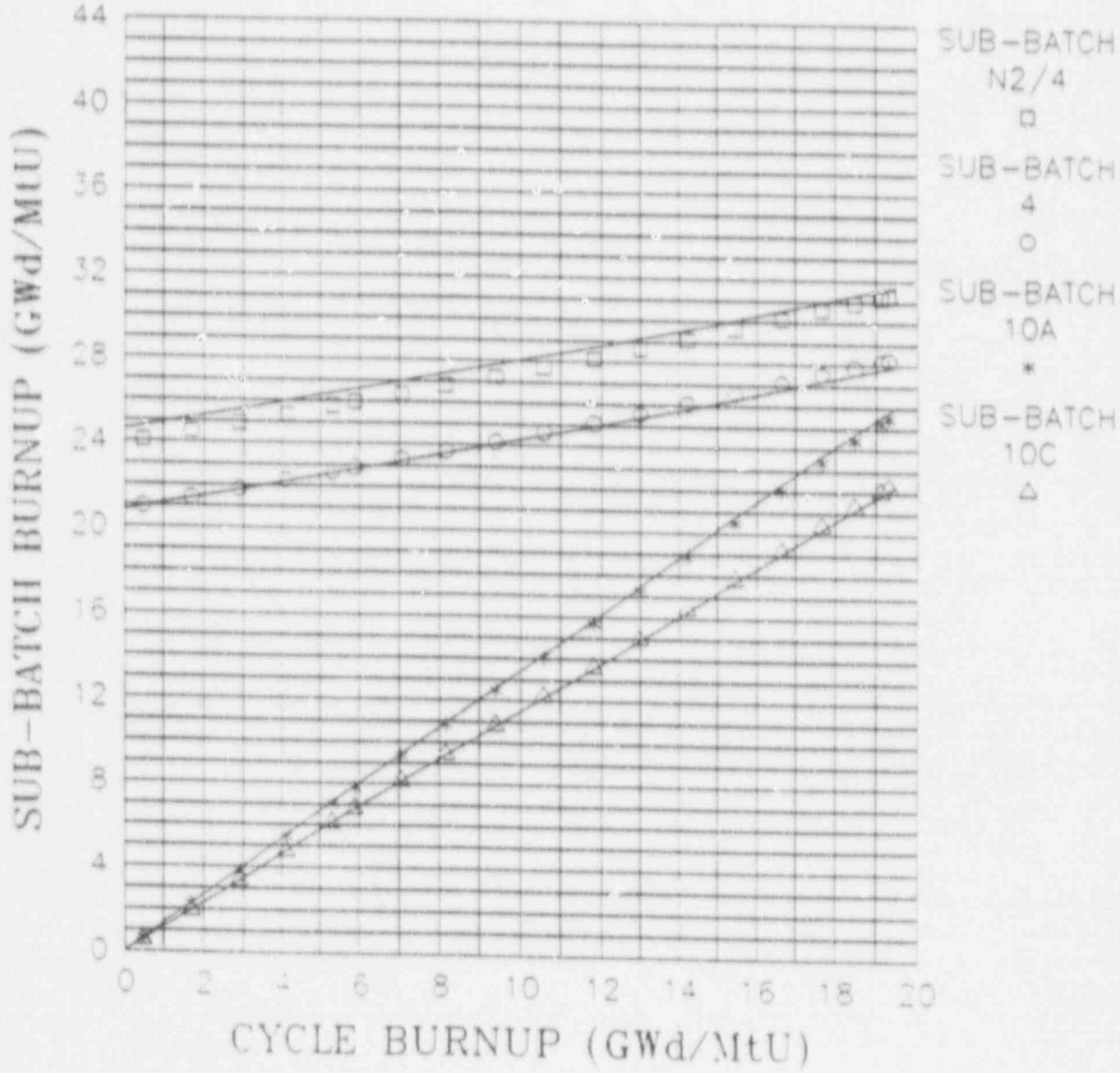


Figure 2.5C
NORTH ANNA UNIT 1 - CYCLE 8
SUB-BATCH BURNUP SHARING

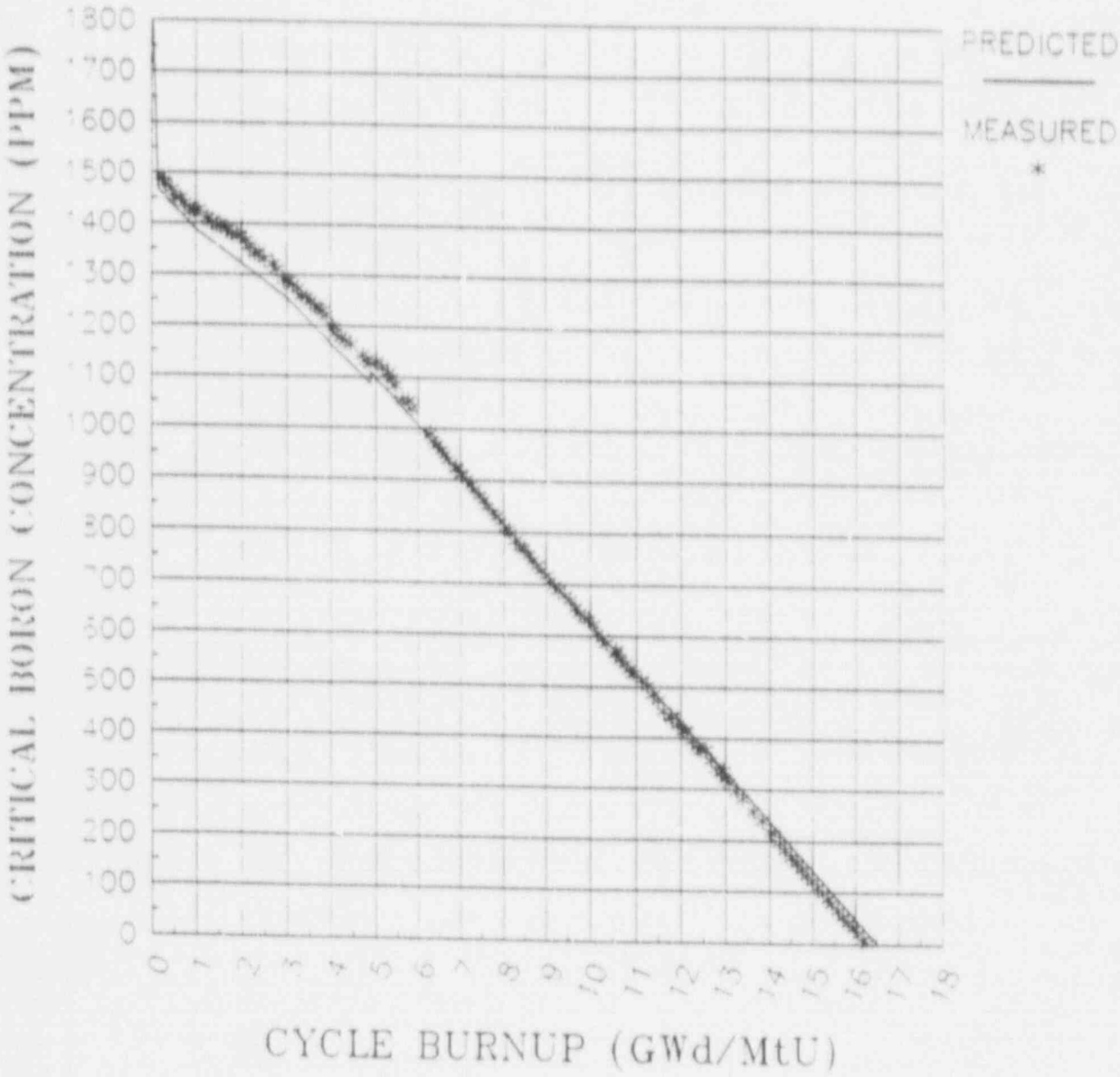


Section 3

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[4] 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 1, Cycle 8 core is shown in Figure 3.1. It can be seen that the measured data typically compared to within 52 ppm of the design prediction. This corresponds to ±0.35% 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 RCS temperature reduction mentioned in the introduction. In conclusion, the trend indicated by the critical boron concentration verifies that the Cycle 8 core depleted as expected without any reactivity anomalies.

Figure 3.1
NORTH ANNA UNIT 1 - CYCLE 8
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 1, Cycle 8 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 8. The measured relative assembly powers were generally within 5.1% and the maximum average percent difference was equal to 1.9%. 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 1 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 4.4 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 8, 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 8 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 15.11%. (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 8. As can be seen from the figure, there was an approximate 16.16% 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 8. A summary of the maximum values for the enthalpy rise hot channel factor measured during Cycle 8 is given in Figure 4.10. As can be seen from this figure, the minimum margin to the limit was approximately 4.4%.

The target delta flux* is the delta flux which would occur at a given power level with 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 -1.3% at the beginning of Cycle 8. Delta flux values decreased steadily to -5.0% near the middle of the cycle, then gradually increased to -3.4% before the

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$$* \text{ Delta Flux} = \frac{Pt - Pb}{2893} \times 100$$

where Pt = power in top of core (MW(t))
Pb = power in bottom of core (MW(t))

coastdown. At the end of Cycle 8, the target delta flux increased to +14% 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 N1-8-06 (Figure 4.12), taken at 1243 MWD/MTU, the axial power distribution had a shape peaked toward the middle of the core with a peaking factor of 1.205. In Map N1-8-13 (Figure 4.13), taken at approximately 9462 MWD/MTU, the axial power distribution peaked slightly toward the bottom of the core with an axial peaking factor of 1.155. Finally, in Map N1-8-21 (Figure 4.14), taken at 16,201 MWD/MTU, the axial peaking factor was 1.151, with the axial power distribution again shifted slightly toward the bottom of the core. The history of F-Z during the cycle can be seen more clearly in a plot of F-Z versus burnup given in Figure 4.15.

In conclusion, the North Anna 1, Cycle 8 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 1 - CYCLE 8
SUMMARY OF FLUX MAPS FOR ROUTINE OPERATION

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 ASSY	PIN	F-DH(N)	CORE F(Z) MAX AXIAL POINT	F(Z)	F(XY) MAX	QPTR[2] MAX	LOC	AXIAL OFF SET (%)	NO. OF THIMBLES
5	07-26-89	257	150	228	C11	DM	29	1.836	L15	MM	1.391	30	1.218	1.392	1.005	MW	-1.546	43
6	08-21-89	1265	169	228	J06	MM	30	1.817	J06	MM	1.390	29	1.205	1.395	1.006	NE	-1.592	43
7	09-22-89	2550	100	225	J06	EM	29	1.801	J06	EM	1.406	37	1.182	1.410	1.007	NE	-2.176	42
8	10-23-89	3786	100	228	J06	EM	30	1.780	J06	EM	1.415	38	1.164	1.425	1.006	NE	-2.956	44
9	11-17-89	4768	100	228	F07	MM	38	1.778	J06	EM	1.421	38	1.151	1.432	1.006	NE	-2.915	44
10	12-27-89	5728	96	228	F05	IM	46	1.759	J06	EM	1.423	46	1.136	1.435	1.007	NE	-2.139	42
11	01-30-90	6970	100	228	J08	HI	47	1.800	J08	HI	1.427	46	1.160	1.436	1.007	NE	-4.600	44
12	02-28-90	8122	100	228	F05	IH	47	1.795	J08	HI	1.424	47	1.157	1.430	1.007	NE	-4.488	44
13	04-02-90	9462	100	228	F05	IH	48	1.789	J08	HI	1.420	47	1.155	1.426	1.008	NE	-4.700	44
14	04-26-90	10387	100	228	J08	HI	48	1.778	J08	HI	1.415	48	1.152	1.420	1.007	NE	-4.734	46
15	05-25-90	11559	100	228	F05	JI	48	1.766	J08	HI	1.408	53	1.153	1.411	1.008	NE	-4.618	45
16	06-20-90	12581	100	228	F05	JI	53	1.779	J08	HI	1.402	53	1.170	1.407	1.009	NE	-4.986	43
19	07-23-90	15898	100	228	F05	JI	53	1.750	J08	HI	1.386	53	1.162	1.395	1.009	NE	-4.598	47
20	08-22-90	15079	100	228	F05	JI	54	1.738	J08	HI	1.376	54	1.166	1.383	1.009	NE	4.648	47
21	09-19-90	16201	100	228	F05	JI	54	1.704	J08	HI	1.369	54	1.151	1.377	1.010	NE	-3.372	47
22	10-17-90	17225	83	228	J08	HI	11	1.757	F05	JI	1.367	11	1.181	1.371	1.007	NE	5.055	44
23	11-15-90	18990	68	228	L10	IH	10	1.862	F05	JI	1.360	11	1.265	1.367	1.005	NE	10.204	44
24	12-17-90	18841	51	228	L10	IH	10	1.959	D11	EM	1.359	10	1.333	1.372	1.005	NW	16.019	44

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 4, 5, 17, AND 18 WERE QUARTER-CORE FLUX MAPS TAKEN FOR INCORE/EXCORE CALIBRATION (I/E CALIBRATION)

Figure 4.1
NORTH ANNA UNIT 1 - CYCLE 8
ASSEMBLYWISE POWER DISTRIBUTION N1-8-06

R	P	N	M	L	K	J	H	G	F	E	D	C	B	A	
	PREDICTED MEASURED PCT DIFFERENCE					0.27 0.29 6.1	0.30 0.31 4.1	0.27 0.28 3.4				PREDICTED MEASURED PCT DIFFERENCE			1
				0.34 0.35 3.5	0.62 0.61 -2.5	1.02 1.03 0.8	0.84 0.84 0.8	1.02 1.04 1.5	0.62 0.64 2.7	0.34 0.35 2.7					2
			0.36 0.36 0.6	1.07 1.07 0.2	1.23 1.20 -3.0	1.15 1.14 -0.9	1.26 1.25 -0.9	1.15 1.15 0.4	1.23 1.26 1.7	1.07 1.09 1.7	0.36 0.36 -1.7				3
		0.36 0.37 1.3	0.82 0.82 0.0	1.25 1.25 0.0	1.23 1.22 -0.4	1.32 1.32 0.0	1.17 1.17 -0.0	1.32 1.32 -0.2	1.23 1.23 0.6	1.25 1.25 -0.1	0.82 0.82 -0.7	0.36 0.37 1.5			4
	0.34 0.34 -0.7	1.07 1.06 -0.7	1.24 1.24 -1.2	1.22 1.20 -1.3	1.30 1.29 -0.6	1.18 1.20 1.1	1.22 1.23 1.0	1.18 1.19 0.7	1.30 1.31 0.6	1.22 1.22 0.0	1.25 1.24 -0.7	1.07 1.08 1.5	0.34 0.35 4.7		5
	0.62 0.62 0.1	1.24 1.24 0.1	1.23 1.23 -0.5	1.30 1.29 -0.7	1.20 1.21 0.8	1.31 1.34 1.8	1.25 1.27 1.9	1.31 1.33 1.2	1.20 1.21 1.1	1.30 1.30 -0.2	1.23 1.22 -0.7	1.24 1.25 0.8	0.62 0.64 2.0		6
0.28 0.28 0.8	1.03 1.02 -0.5	1.15 1.15 -0.4	1.33 1.32 -0.3	1.19 1.19 -0.2	1.32 1.33 0.9	1.03 1.05 2.0	1.28 1.31 2.1	1.03 1.04 1.0	1.32 1.33 0.9	1.19 1.19 0.1	1.33 1.29 -2.6	1.15 1.15 -0.6	1.03 1.02 -0.5	0.28 0.28 0.4	7
0.30 0.30 -1.9	0.84 0.83 -0.6	1.27 1.26 -0.6	1.17 1.17 0.4	1.23 1.24 1.3	1.25 1.28 1.8	1.28 1.32 3.0	1.15 1.19 2.7	1.28 1.28 0.0	1.25 1.25 -0.1	1.23 1.21 -1.3	1.17 1.14 -2.6	1.27 1.26 -0.6	0.84 0.85 1.2	0.30 0.37 2.6	8
0.28 0.27 -2.0	1.03 1.01 -1.9	1.15 1.13 -1.9	1.33 1.32 -0.3	1.19 1.20 1.3	1.32 1.32 0.4	1.03 1.01 -1.5	1.28 1.26 -1.5	1.03 1.02 -1.3	1.32 1.30 -1.4	1.19 1.18 -0.8	1.33 1.31 -1.1	1.15 1.15 -0.2	1.03 1.05 2.0	0.28 0.29 4.4	9
	0.62 0.61 -2.0	1.24 1.21 -2.0	1.23 1.23 -0.2	1.30 1.31 0.7	1.20 1.20 -0.1	1.31 1.30 -0.9	1.25 1.24 -0.8	1.31 1.30 -1.2	1.20 1.18 -1.2	1.30 1.29 -0.8	1.23 1.23 0.4	1.24 1.24 0.3	0.62 0.67 6.7		10
	0.34 0.34 1.3	1.07 1.08 1.3	1.25 1.26 0.9	1.22 1.22 -0.0	1.30 1.29 -1.0	1.18 1.17 -1.1	1.22 1.21 -1.0	1.18 1.18 -0.6	1.30 1.29 -0.7	1.22 1.21 -0.3	1.25 1.26 0.9	1.07 1.08 1.4	0.34 0.35 4.0		11
		0.36 0.38 4.7	0.82 0.84 2.4	1.25 1.25 -0.0	1.23 1.22 -0.8	1.32 1.30 -1.8	1.17 1.15 -1.8	1.32 1.30 -1.8	1.23 1.21 -1.2	1.25 1.24 -0.9	0.82 0.83 1.1	0.36 0.37 2.1			12
			0.36 0.38 4.4	1.07 1.11 4.5	1.23 1.25 1.5	1.15 1.12 -2.7	1.26 1.24 -2.2	1.15 1.12 -2.3	1.23 1.21 -1.7	1.07 1.05 -1.2	0.36 0.37 1.8				13
				0.3 0.35 4.5	0.62 0.65 4.5	1.02 0.99 -3.7	0.84 0.82 -2.4	1.02 1.00 -2.2	0.62 0.61 -1.6	0.34 0.33 -2.2					14
	STANDARD DEVIATION +1.230					0.27 0.29 4.5	0.30 0.30 -1.1	0.27 0.27 -1.1				AVERAGE PCT DIFFERENCE = 1.6			15

SUMMARY

MAP NO: N1-8-06	DATE: 08/21/89	POWER: 100%
CONTROL ROD POSITION:	F-Q(T) = 1.817	QPTR:
D BANK AT 228 STEPS	F-DH(M) = 1.390	NW 1.0014 | NE 1.0044
	F(Z) = 1.205	SW 0.9992 | SE 0.9950
	F(XY) = 1.393	
	BURNUP = 1243 MWD/MTU	A.O.= -1.392%

Figure 4.2
NORTH ANNA UNIT 1 - CYCLE 8
ASSEMBLYWISE POWER DISTRIBUTION N1-8-13

R	P	N	M	L	K	J	H	G	F	E	D	C	B	A	
	PREDICTED MEASURED PCT DIFFERENCE					0.30 0.31 4.6	0.34 0.35 4.6	0.30 0.31 4.1				PREDICTED MEASURED PCT DIFFERENCE			1
				0.37 0.38 4.9	0.63 0.61 -3.2	1.00 1.01 0.7	0.83 0.84 0.7	1.00 1.02 1.7	0.63 0.65 3.6	0.37 0.38 3.6					2
			0.39 0.40 1.4	1.04 1.05 0.9	1.22 1.19 -3.0	1.10 1.08 -1.6	1.27 1.25 -1.7	1.10 1.11 0.4	1.22 1.25 2.4	1.04 1.07 2.4	0.39 0.39 -1.5				3
		0.39 0.40 2.2	0.84 0.85 0.5	1.27 1.28 0.5	1.18 1.18 -0.5	1.33 1.32 -0.5	1.12 1.12 -0.5	1.33 1.32 -0.6	1.18 1.20 1.2	1.27 1.28 0.3	0.84 0.84 -0.2	0.39 0.40 2.7			4
	0.36 0.36 -0.4	1.04 1.04 -0.4	1.27 1.26 -1.3	1.19 1.18 -1.5	1.35 1.34 -0.8	1.15 1.16 0.8	1.17 1.18 0.7	1.15 1.16 0.7	1.35 1.37 1.0	1.19 1.20 0.4	1.27 1.27 -0.3	1.04 1.07 2.7	0.36 0.39 6.8		5
	0.63 0.63 0.2	1.23 1.23 0.2	1.19 1.18 -0.4	1.36 1.34 -0.9	1.18 1.19 0.7	1.35 1.37 1.7	1.21 1.23 1.9	1.35 1.37 1.3	1.18 1.20 1.5	1.36 1.35 -0.3	1.19 1.18 -0.8	1.23 1.24 0.8	0.63 0.65 3.3		6
0.30 0.30 0.8	1.00 0.99 -1.0	1.10 1.09 -0.9	1.34 1.32 -1.1	1.15 1.14 -1.1	1.35 1.35 0.4	1.05 1.07 2.1	1.34 1.37 2.2	1.05 1.06 1.3	1.35 1.37 1.4	1.15 1.15 -0.2	.34 0 .4	1.10 1.10 -0.7	1.00 1.00 -0.2	0.30 0.30 1.2	7
0.34 0.33 -2.9	0.83 0.82 -1.1	1.28 1.26 -1.2	1.15 1.12 -0.6	1.17 1.17 -0.0	1.21 1.23 1.1	1.34 1.38 3.3	1.16 1.19 3.0	1.34 1.37 0.4	1.21 1.22 0.4	1.17 1.16 -1.1	1.15 1.10 -2.5	1.28 1.27 -0.7	0.83 0.85 1.6	0.34 0.35 3.3	8
0.30 0.29 -2.0	1.00 0.98 -2.5	1.10 1.08 -2.5	1.34 1.32 -1.2	1.15 1.15 0.0	1.35 1.34 -0.8	1.05 1.02 -2.6	1.34 1.31 -2.6	1.05 1.04 -0.8	1.35 1.34 -0.9	1.15 1.15 -0.3	1.34 1.32 -1.1	1.10 1.10 0.0	1.00 1.02 2.4	0.30 0.32 5.3	9
	0.63 0.62 -2.0	1.23 1.20 -2.0	1.19 1.18 -0.7	1.36 1.36 0.0	1.18 1.17 -0.9	1.35 1.33 -1.6	1.21 1.19 -1.5	1.35 1.33 -1.5	1.18 1.17 -1.4	1.36 1.35 -0.8	1.19 1.19 0.4	1.23 1.23 0.8	0.63 0.68 7.4		10
	0.36 0.37 1.7	1.04 1.06 1.7	1.27 1.29 1.1	1.19 1.19 -0.2	1.35 1.33 -1.7	1.15 1.13 -1.8	1.17 1.15 -1.7	1.15 1.14 -1.0	1.35 1.34 -0.9	1.19 1.19 -0.1	1.27 1.30 1.7	1.04 1.07 2.4	0.36 0.36 5.9		11
		0.39 0.42 5.4	0.84 0.86 2.7	1.27 1.27 -0.2	1.18 1.17 -1.3	1.33 1.30 -2.3	1.12 1.10 -2.3	1.33 1.30 -2.3	1.18 1.17 -1.6	1.27 1.26 -1.0	0.84 0.86 2.1	0.39 0.41 3.4			12
			0.39 0.42 5.6	1.04 1.10 5.7	1.22 1.24 1.7	1.10 1.07 -3.2	1.27 1.24 -2.5	1.10 1.07 -2.6	1.22 1.20 -2.0	1.04 1.07 -1.3	0.39 0.41 3.1				13
				0.37 0.39 5.7	0.63 0.67 5.7	1.00 0.96 -4.1	0.83 0.81 -2.5	1.00 0.98 -2.5	0.63 0.62 -1.9	0.37 0.35 -2.9					14
	STANDARD DEVIATION =1.508					0.30 0.32 5.7	0.34 0.33 -0.8	0.30 0.30 -0.8				AVERAGE PCT DIFFERENCE = 1.8			15

SUMMARY

MAP NO: N1-8-13	DATE: 04/02/90	POWER: 100%
CONTROL ROD POSITION:	F-Q(T) = 1.789	QPTR:
D BANK AT 228 STEPS	F-DH(M) = 1.420	NW 0.9999 | NE 1.0075
	F(Z) = 1.155	SW 0.9961 | SE 0.9964
	F(XY) = 1.426	
	BURNUP = 9462 MWD/MTU	A.O. = -4.700%

Figure 4.3
NORTH ANNA UNIT 1 - CYCLE 8
ASSEMBLYWISE POWER DISTRIBUTION N1-8-21

PREDICTED MEASURED PCT DIFFERENCE					0.35 0.37 4.6	0.40 0.42 4.6	0.35 0.37 4.1							PREDICTED MEASURED PCT DIFFERENCE	1
			0.41 0.43 5.5	0.68 0.65 5.6	1.04 1.05 0.5	0.88 0.89 0.5	1.04 1.06 1.6	0.68 0.70 3.7	0.41 0.43 4.9						2
		0.44 0.44 1.8	1.05 1.07 1.3	1.23 1.19 -2.9	1.10 1.08 -1.9	1.28 1.25 -2.0	1.10 1.10 0.1	1.23 1.25 2.3	1.05 1.09 3.6	0.44 0.46 6.2					3
	0.44 0.45 2.5	0.87 0.88 0.7	1.26 1.27 0.8	1.16 1.15 -0.4	1.30 1.29 -0.8	1.10 1.09 -0.9	1.30 1.29 -0.9	1.16 1.17 1.1	1.26 1.29 1.9	0.87 0.89 2.2	0.44 0.45 4.1				4
0.41 0.40 -0.5	1.05 1.04 -0.5	1.26 1.25 -1.1	1.16 1.15 -1.2	1.32 1.31 -0.7	1.12 1.12 0.4	1.14 1.14 0.4	1.12 1.12 0.5	1.32 1.33 1.1	1.16 1.17 0.6	1.26 1.27 0.1	1.05 1.08 3.0	0.41 0.43 7.0			5
0.67 0.67 -0.0	1.22 1.22 -0.0	1.16 1.15 -0.3	1.32 1.31 -0.6	1.14 1.15 0.8	1.30 1.32 1.6	1.17 1.19 1.9	1.30 1.32 1.4	1.14 1.16 1.7	1.32 1.32 -0.1	1.16 1.15 -0.5	1.22 1.23 0.8	0.67 0.69 3.0			6
0.35 0.35 0.4	1.04 1.03 -1.2	1.10 1.09 -1.2	1.30 1.29 -1.1	1.12 1.11 -1.0	1.30 1.31 0.5	1.03 1.05 2.1	1.30 1.33 2.2	1.03 1.04 1.4	1.30 1.32 1.7	1.12 1.12 0.1	1.30 1.27 -2.4	1.10 1.09 -1.2	1.04 1.03 -0.9	0.35 0.35 0.1	7
0.40 0.39 -3.0	0.88 0.87 -1.3	1.28 1.26 -1.4	1.10 1.09 -0.7	1.14 1.14 -0.1	1.17 1.18 1.1	1.30 1.34 3.5	1.12 1.15 3.2	1.30 1.31 0.8	1.17 1.17 0.7	1.14 1.13 -0.8	1.10 1.07 -2.5	1.28 1.26 -1.3	0.88 0.89 0.8	0.40 0.41 2.3	8
0.35 0.34 -2.8	1.04 1.01 -2.9	1.10 1.07 -2.9	1.30 1.28 -1.4	1.12 1.12 -0.1	1.30 1.29 -0.9	1.03 1.00 -2.7	1.30 1.26 -2.7	1.03 1.02 -0.5	1.30 1.30 -0.5	1.12 1.11 -0.2	1.30 1.28 -1.4	1.10 1.11 0.4	1.04 1.06 2.1	0.35 0.37 4.0	9
0.67 0.66 -2.8	1.22 1.19 -2.8	1.14 1.14 -1.0	1.32 1.32 -0.0	1.14 1.13 -0.9	1.30 1.28 -1.9	1.17 1.15 -1.8	1.30 1.28 -1.6	1.14 1.12 -1.4	1.32 1.31 -0.9	1.16 1.16 0.1	1.22 1.25 1.9	0.67 0.71 4.8			10
0.41 0.41 1.5	1.05 1.06 1.5	1.26 1.28 0.9	1.16 1.16 -0.2	1.32 1.30 -1.8	1.12 1.09 -2.1	1.14 1.11 -2.0	1.12 1.10 -1.3	1.32 1.31 -1.1	1.16 1.16 -0.4	1.26 1.28 1.5	1.05 1.08 2.5	0.41 0.42 4.6			11
	0.44 0.46 5.7	0.87 0.90 2.8	1.26 1.26 -0.2	1.16 1.14 -1.5	1.30 1.27 -2.6	1.10 1.08 -2.6	1.30 1.27 -2.5	1.16 1.14 -1.[illegible]	1.26 1.25 -1.1	0.87 0.89 2.0	0.44 0.45 3.3				12
		0.44 0.46 5.8	1.05 1.11 5.8	1.23 1.25 1.6	1.10 1.06 -3.5	1.28 1.24 -3.0	1.10 1.07 -3.0	1.23 1.20 -2.3	1.05 1.04 -1.3	0.44 0.45 3.0					13
			0.41 0.43 5.8	0.68 0.71 4.7	1.04 1.04 -0.3	0.88 0.88 -0.9	1.04 1.01 -2.9	0.68 0.66 -2.3	0.41 0.40 -2.8						14
STANDARD DEVIATION =1.477					0.35 0.37 5.6	0.40 0.41 1.0	0.35 0.35 -1.7							AVERAGE PCT DIFFERENCE = 1.9	15

SUMMARY

MAP NO: N1-8-21	DATE: 09/19/90	POWER: 100%
CONTROL ROD POSITION:	F-Q(T) = 1.704	QPTR:
D BANK AT 228 STEPS	F-DH(M) = 1.369	NW 0.9996 | NE 1.0098
	F(Z) = 1.151	SW 0.9954 | SE 0.9952
	F(XY) = 1.377	
	BURNUP = 16201 MWD/MTU	A.O.=-3.372%

Figure 4.4
NORTH ANNA Unit 1 - CYCLE 8
HOT CHANNEL FACTOR NORMALIZED
OPERATING ENVELOPE

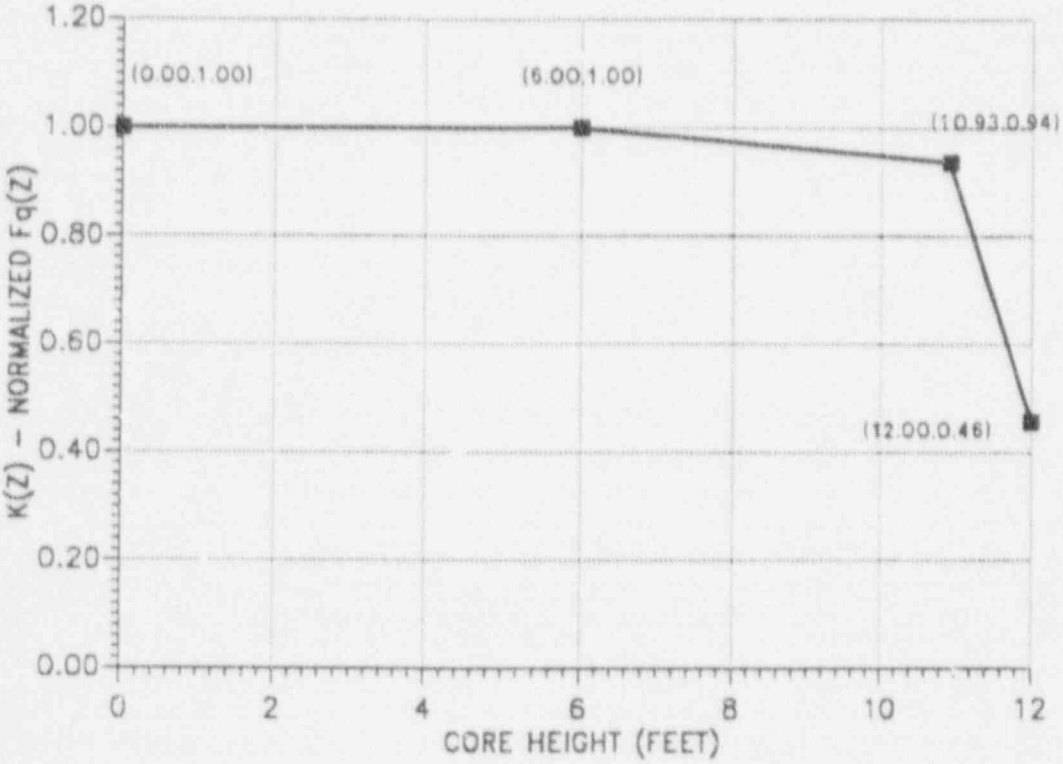


Figure 4.5
NORTH ANNA Unit 1 - CYCLE 8
HEAT FLUX HOT CHANNEL FACTOR, $F_Q(Z)$
N1-8-06

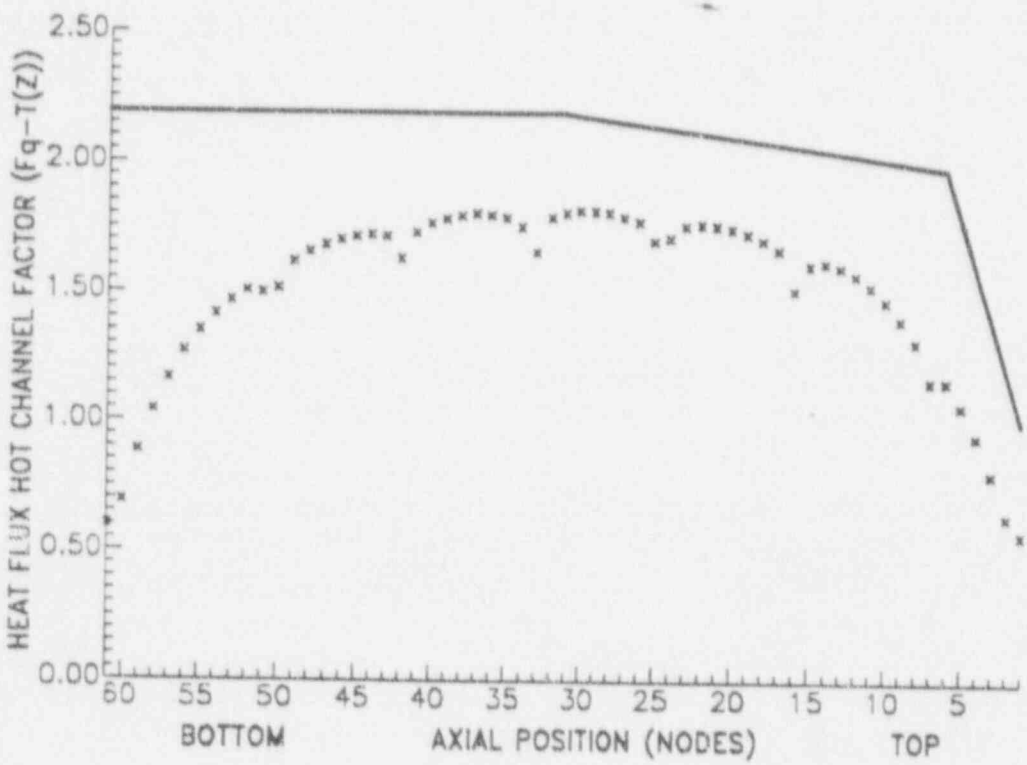


Figure 4.6
NORTH ANNA Unit 1 - CYCLE 8
HEAT FLUX HOT CHANNEL FACTOR, $F_Q(Z)$
N1-8-13

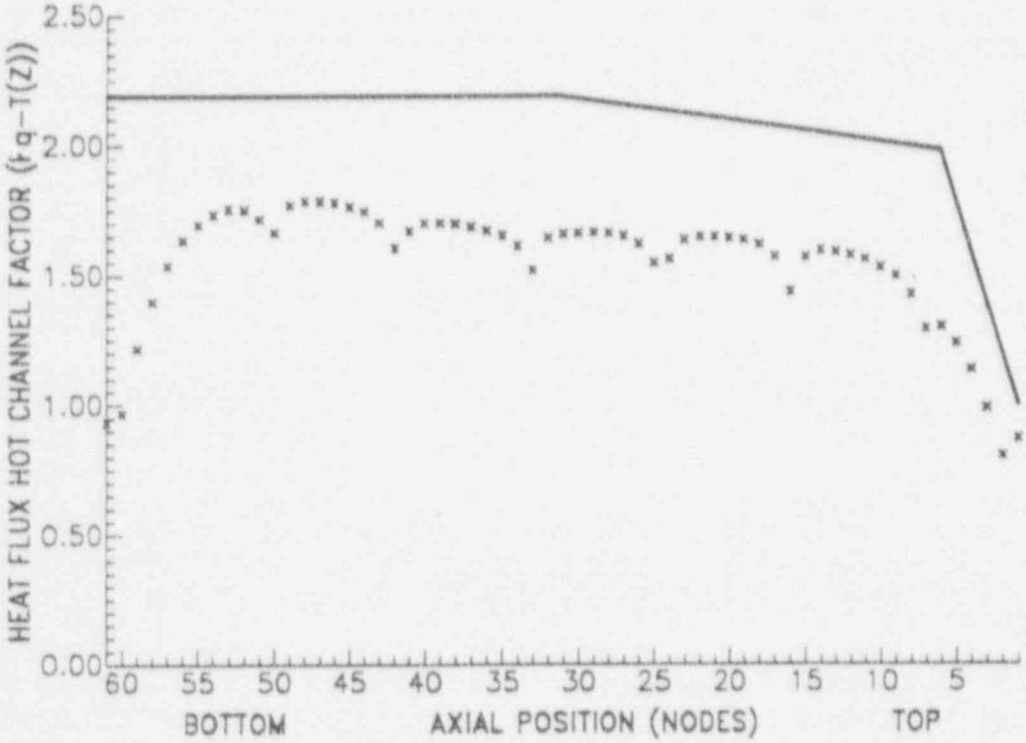


Figure 4.7
NORTH ANNA Unit 1 - CYCLE 8
HEAT FLUX HOT CHANNEL FACTOR, $F_Q(Z)$
N1-8-21

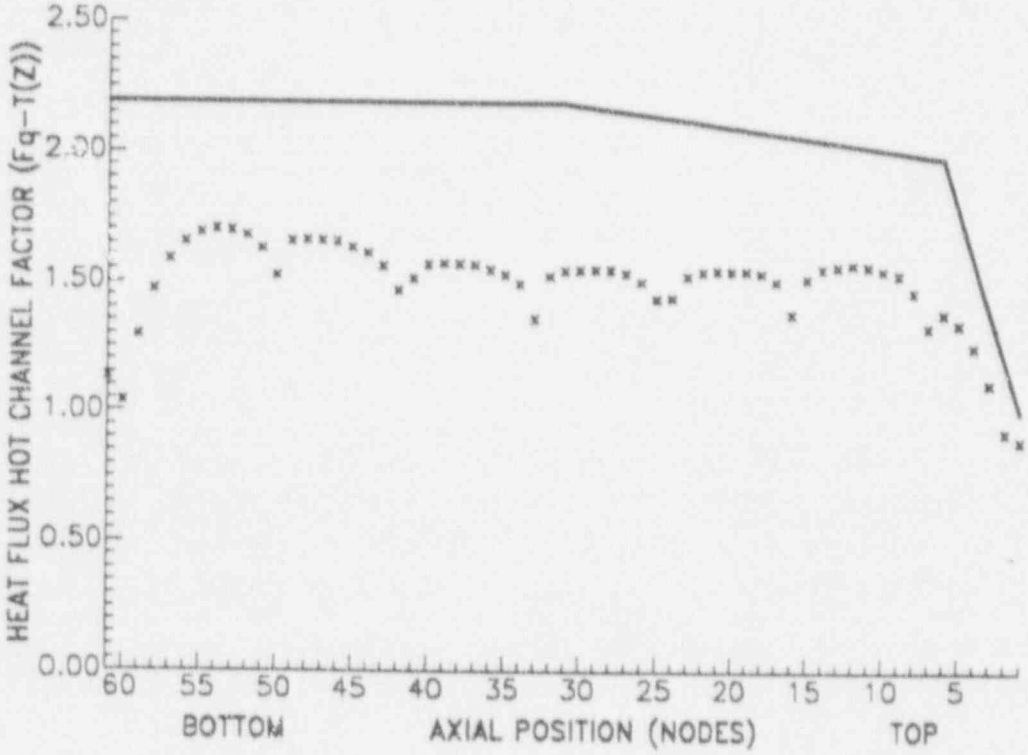
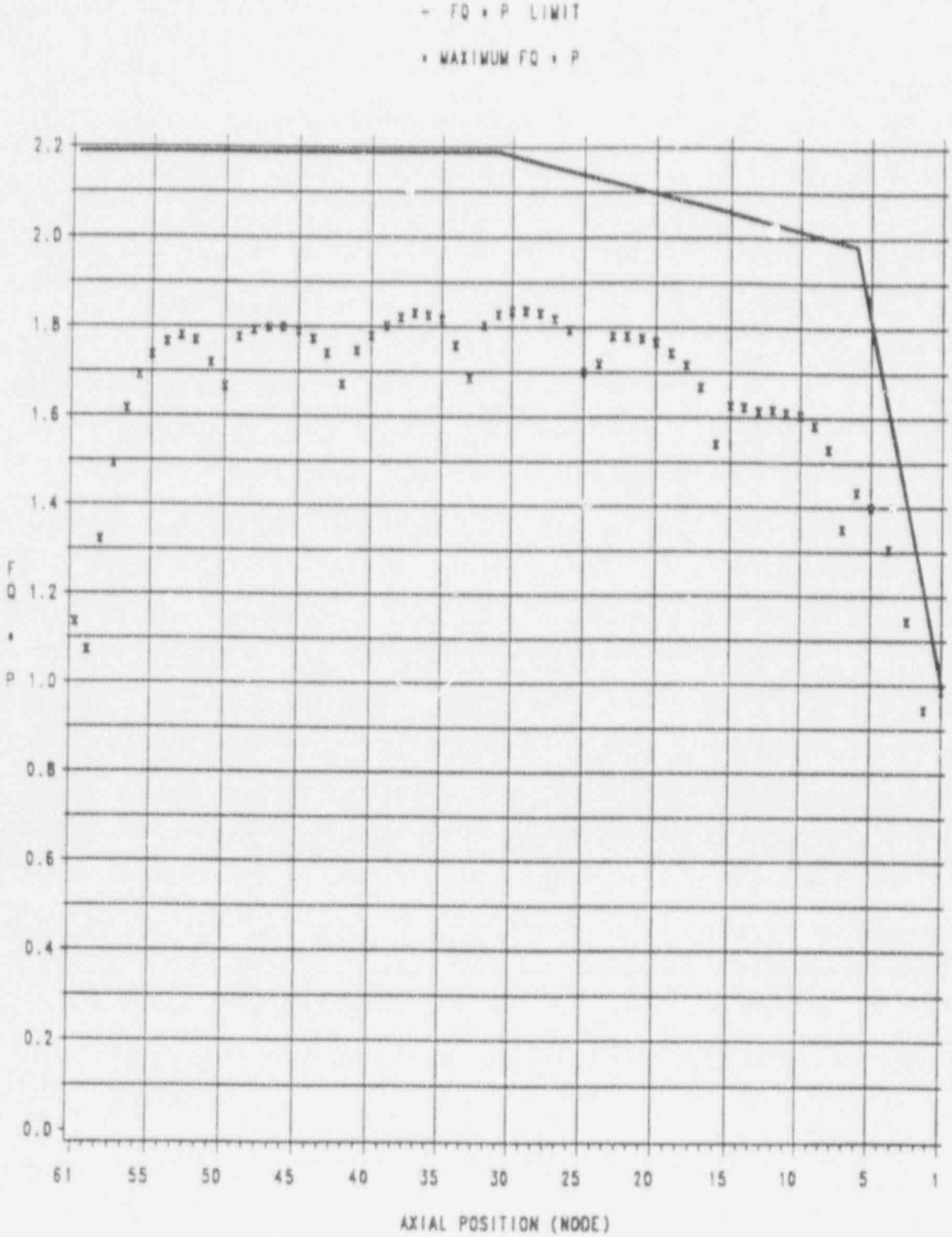


Figure 4.8
NORTH ANNA Unit 1 - CYCLE 8
MAXIMUM HEAT FLUX HOT CHANNEL FACTOR, $F_Q(Z)*P$, vs. AXIAL POSITION



BOTTOM OF CORE

TOP OF CORE

Figure 4.9
NORTH ANNA Unit 1 - CYCLE 8
MAXIMUM HEAT FLUX HOT CHANNEL FACTOR, $F_Q(Z)$, vs. BURNUP

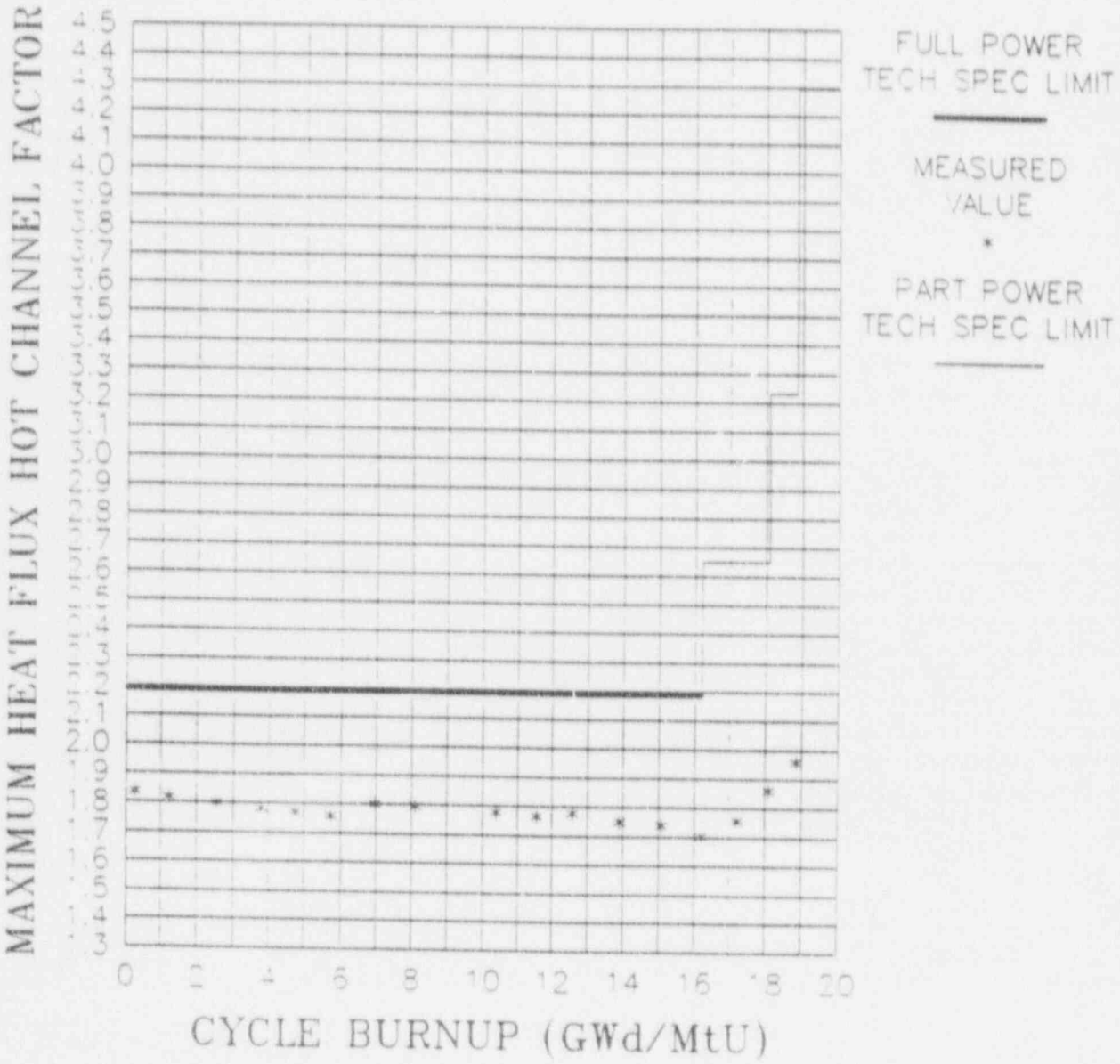


Figure 4.10
NORTH ANNA Unit 1 - CYCLE 8
MAXIMUM ENTHALPY RISE HOT CHANNEL FACTOR, F-delta-H, vs. BURNUP

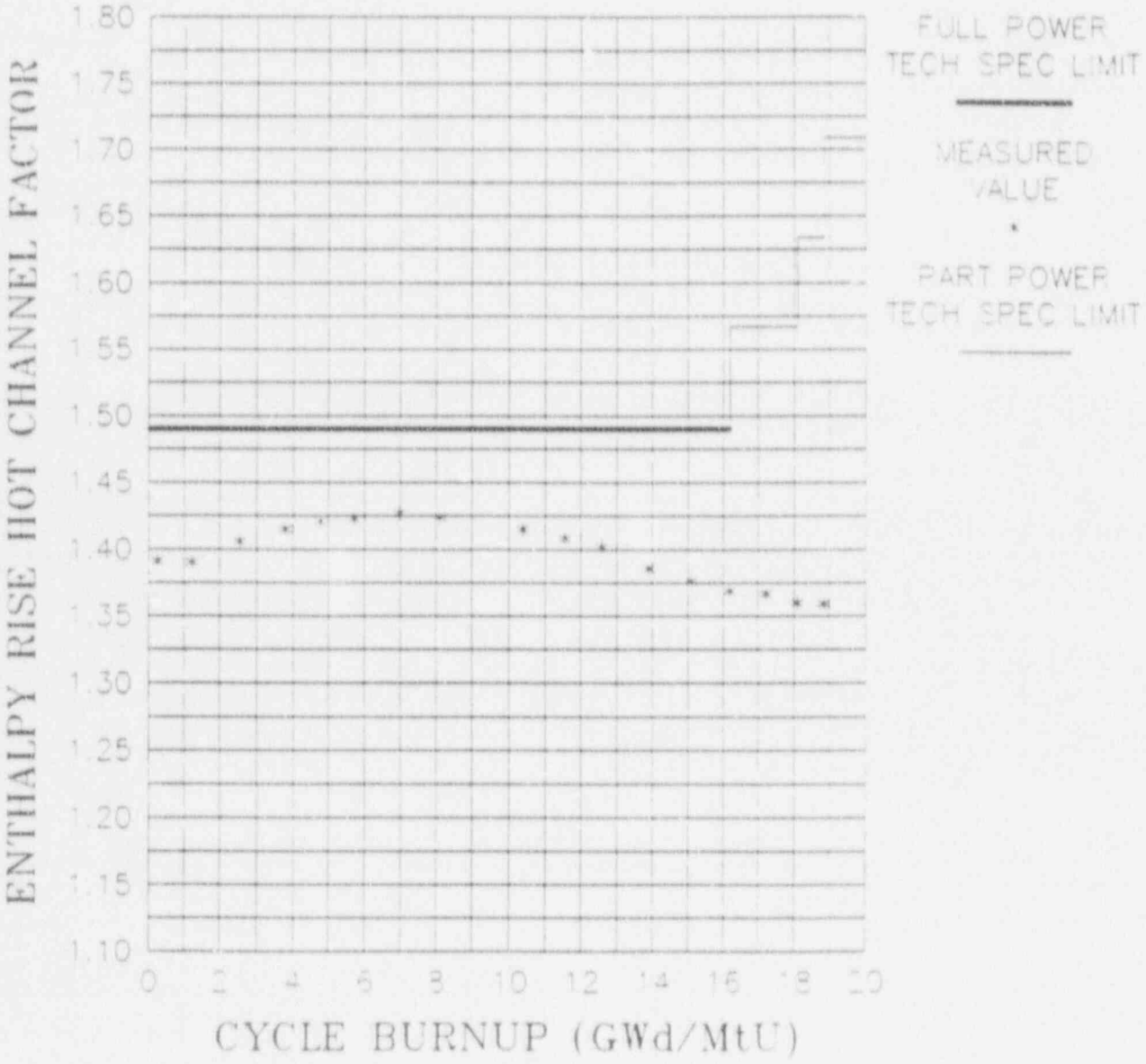


Figure 4.11
NORTH ANNA Unit 1 - CYCLE 8
TARGET DELTA FLUX vs. BURNUP

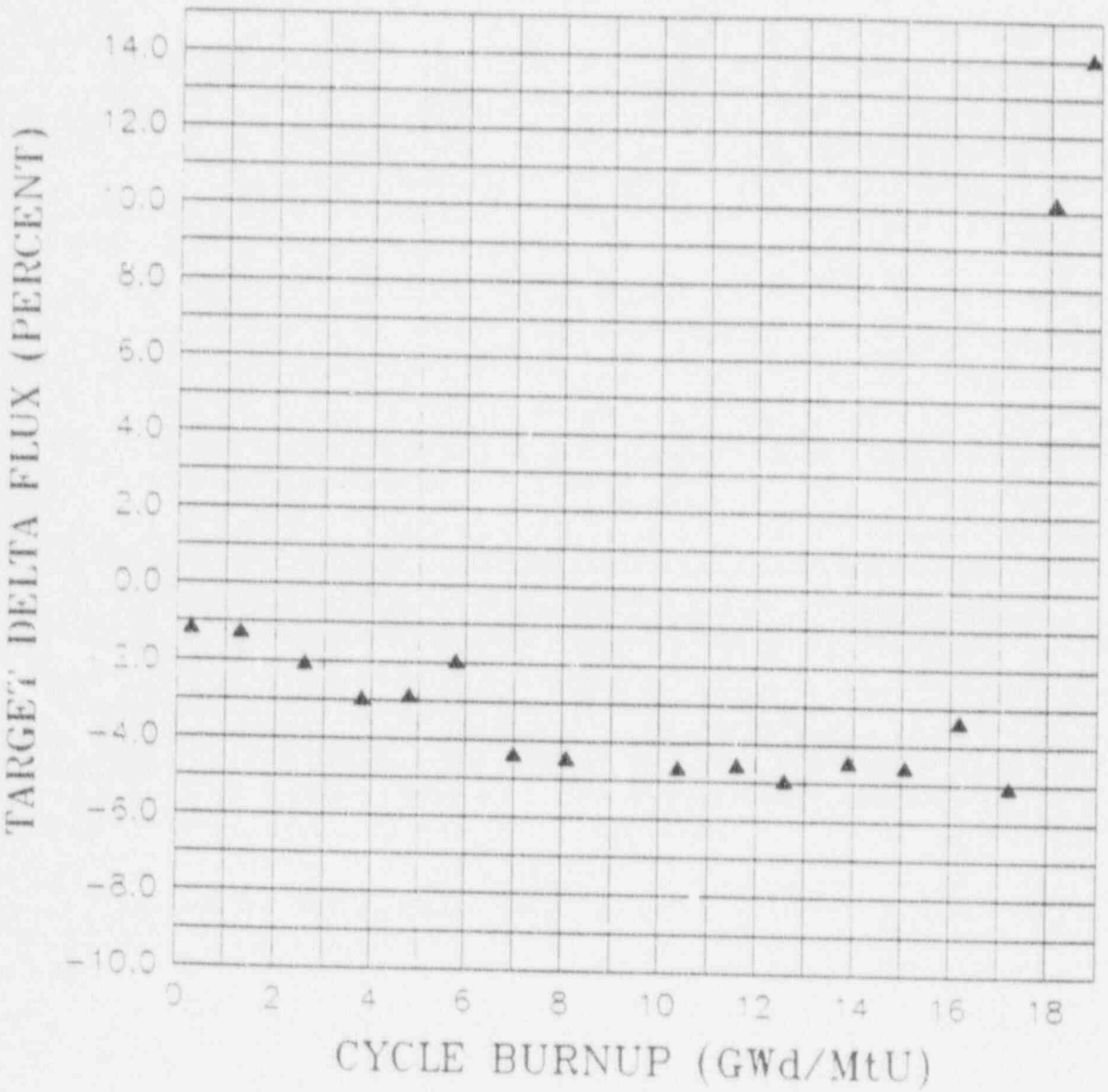


Figure 4.12
NORTH ANNA Unit 1 - CYCLE 8
CORE AVERAGE AXIAL POWER DISTRIBUTION
N1-8-06

Fz = 1.205
AXIAL OFFSET = -1.392

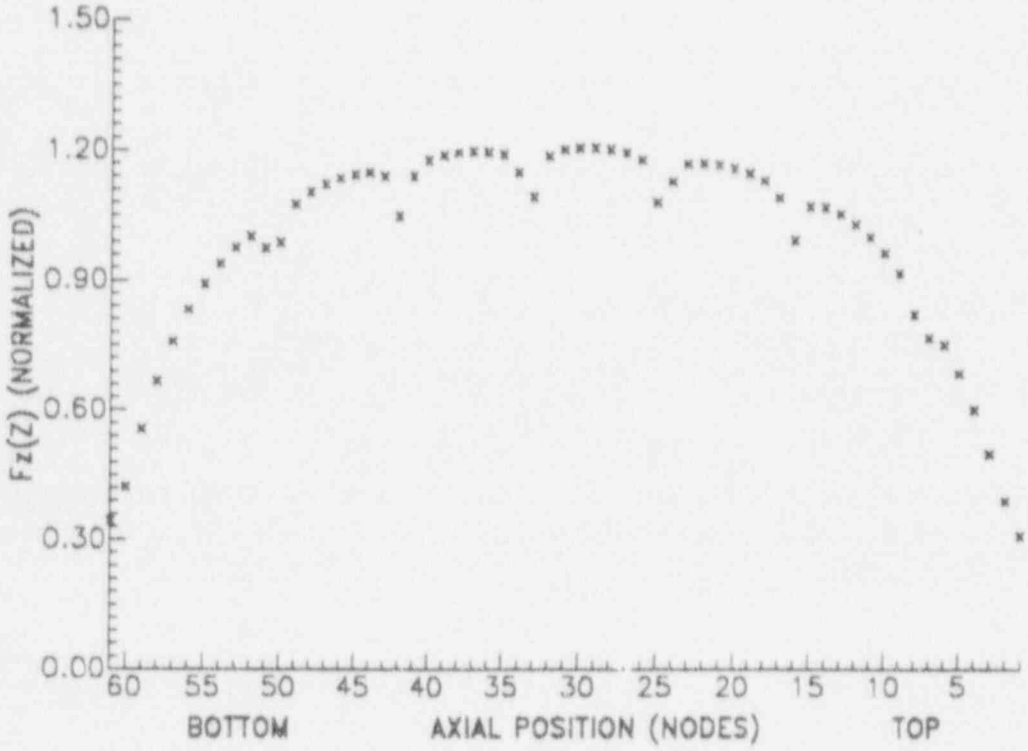


Figure 4.13
NORTH ANNA Unit 1 - CYCLE 8
CORE AVERAGE AXIAL POWER DISTRIBUTION
N1-8-13

Fz = 1.155
AXIAL OFFSET = -4.700

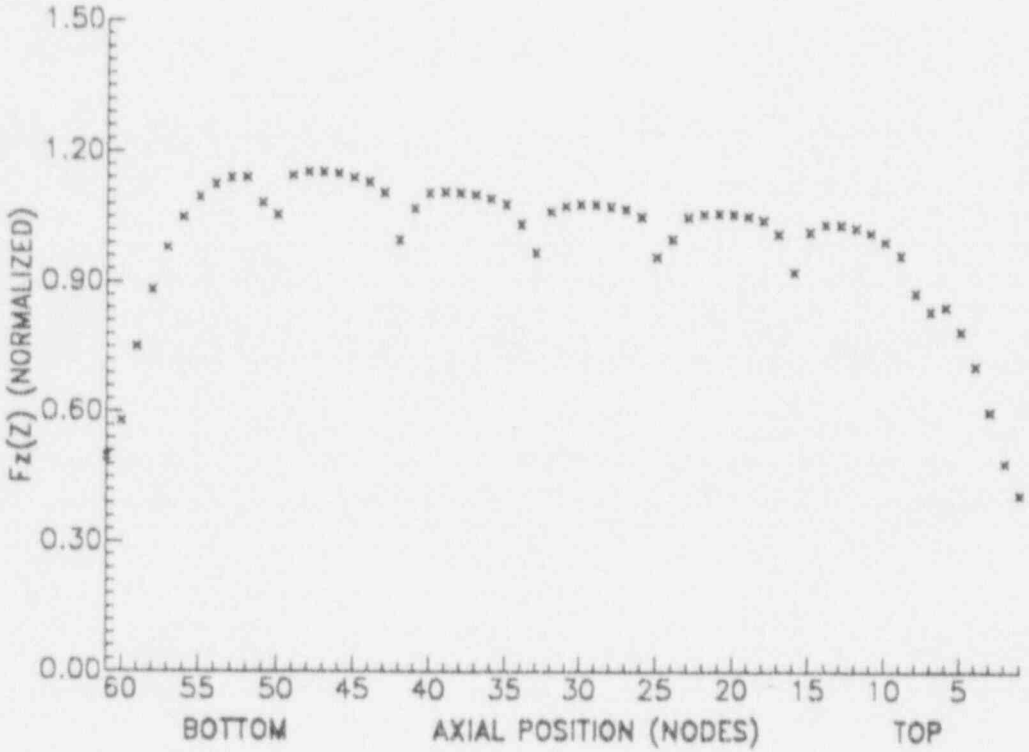


Figure 4.14
NORTH ANNA Unit 1 - CYCLE 8
CORE AVERAGE AXIAL POWER DISTRIBUTION
N1-8-21

Fz = 1.151
AXIAL OFFSET = -3.372

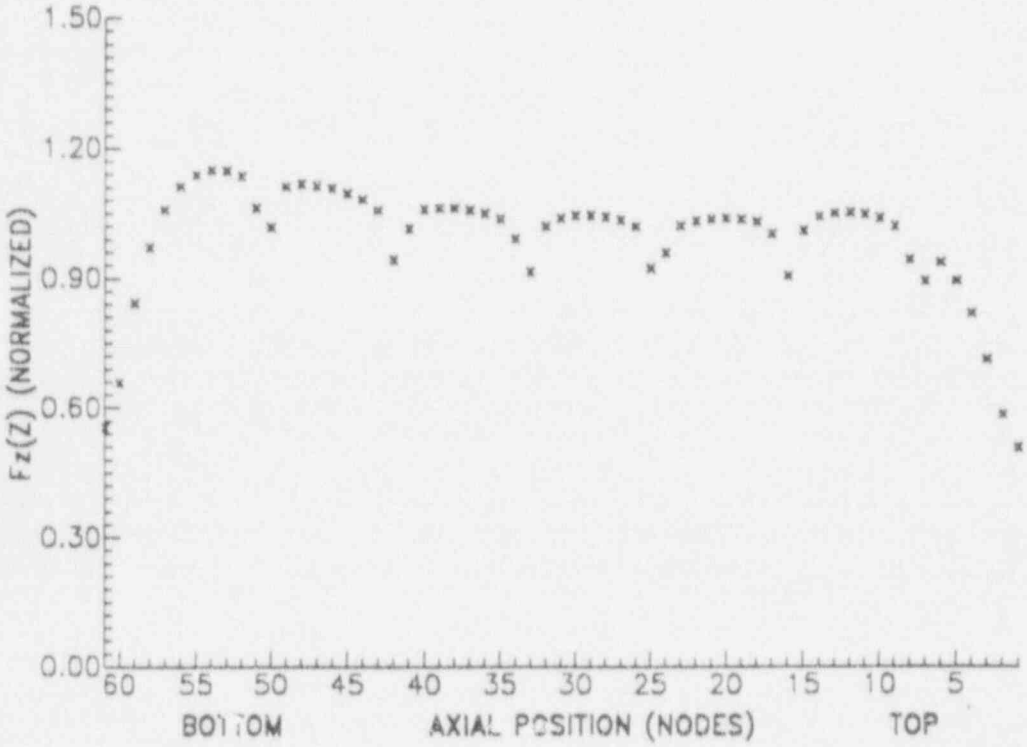
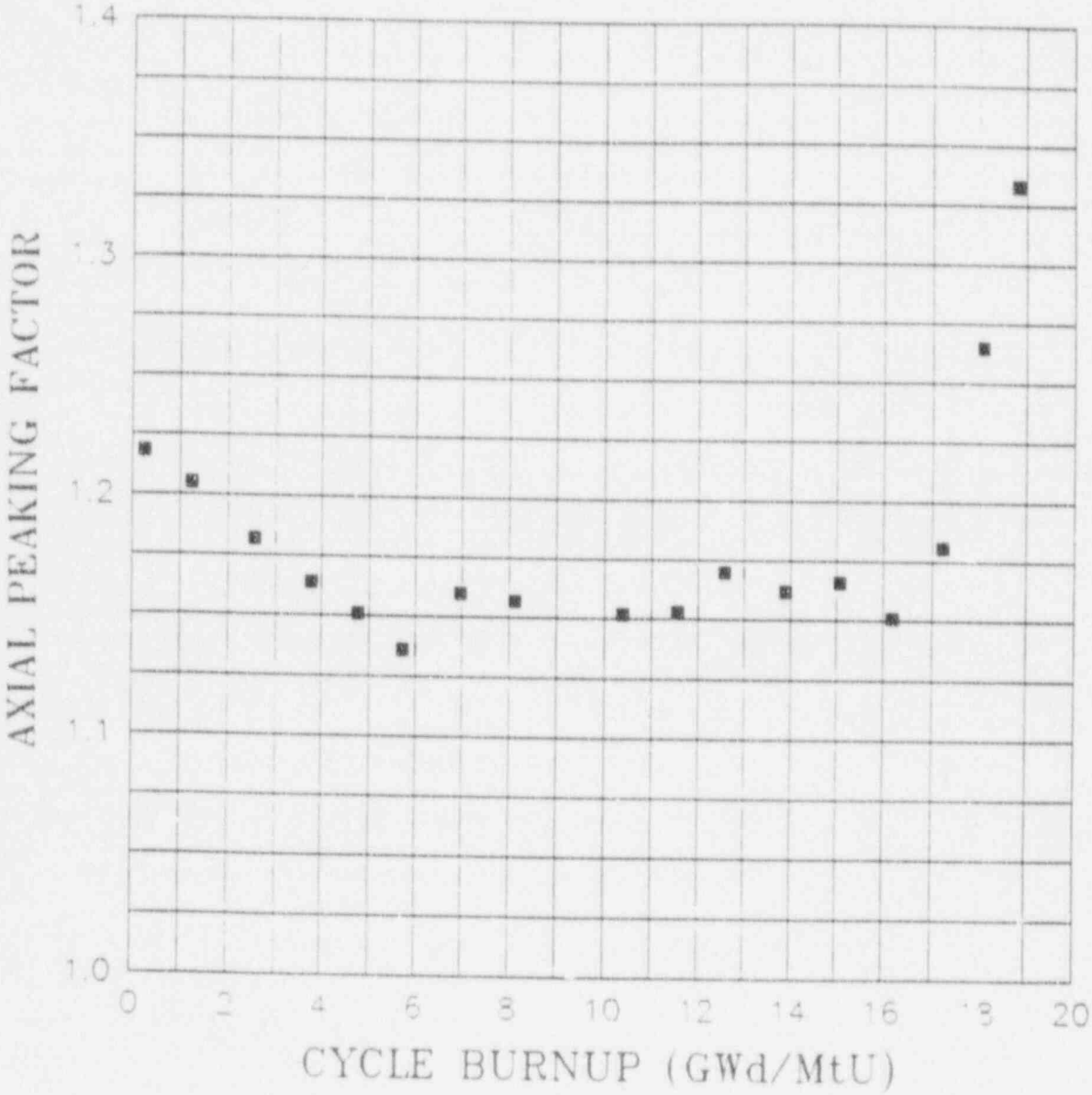


Figure 4.15
NORTH ANNA Unit 1 - CYCLE 8
CORE AVERAGE AXIAL PEAKING FACTOR vs. BURNUP



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 1 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 8. 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 operation of Cycle 8. The average full

power equilibrium dose equivalent I-131 concentration was 8.8 X 10^{-3} µCi/gm which corresponds to less than 1% of the Technical Specification limit.

Correcting the measured RCS 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 3.74 X 10^{-4} µCi/gm. A tramp-corrected I-131 concentration of this small magnitude is a clear indication of core operating with no fuel defects. The absence of fuel defects is also substantiated by the fact that there was no spike in the measured I-131 when the Unit was shut down. The demineralizer flow rate averaged approximately 91 gpm during power operation.

The ratio of the specific activities of I-131 to I-133 is generally used to characterize the size of fuel defects. 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 1, Cycle 8 core at a general average value of 0.09 through January, 1991. Since no fuel defects existed in the Cycle 8 core, the radioiodine data is strictly due to tramp fissile material.

Figure 5.1
NORTH ANNA UNIT 1 - CYCLE 8
DOSE EQUIVALENT I-131 vs. TIME

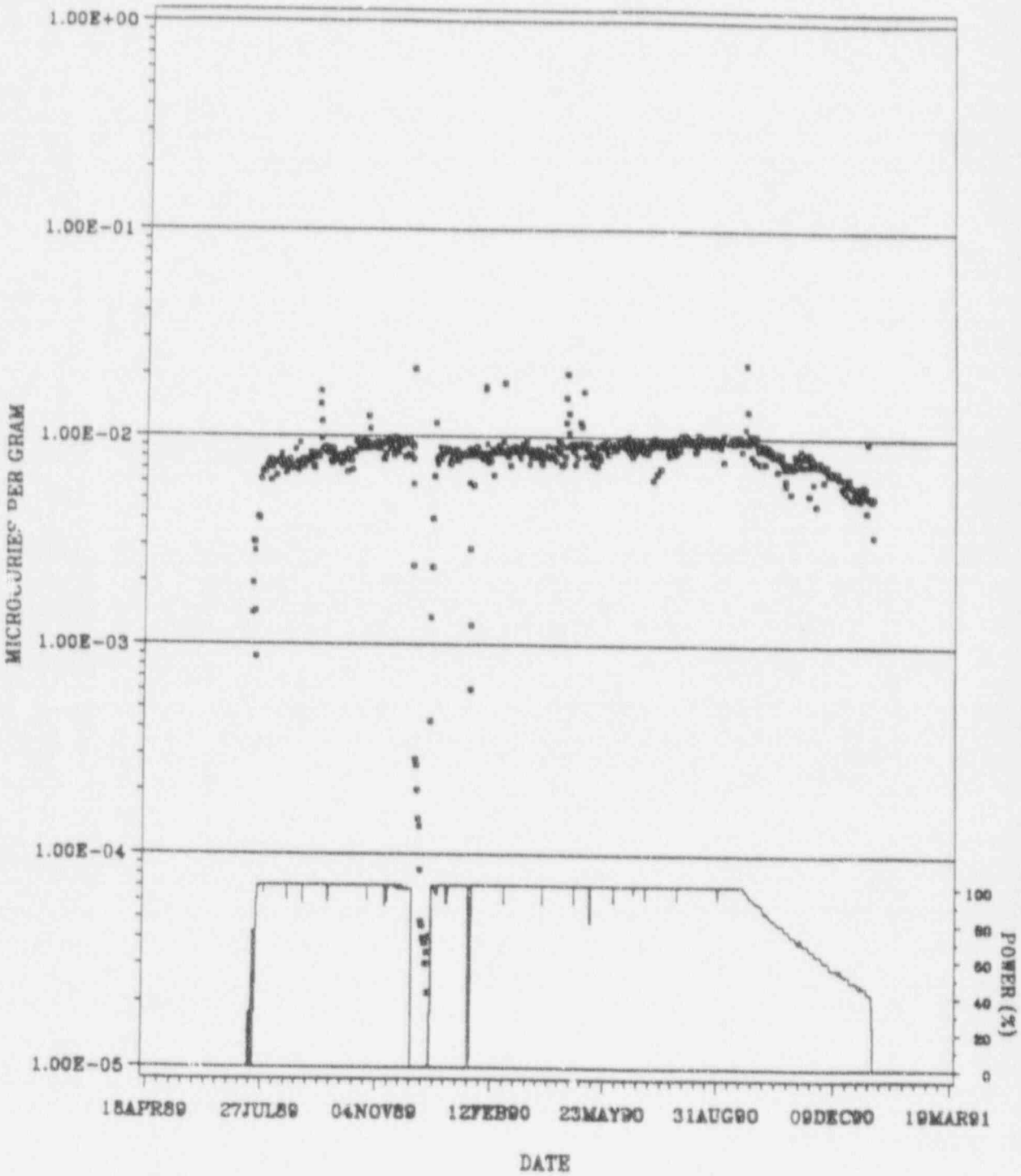
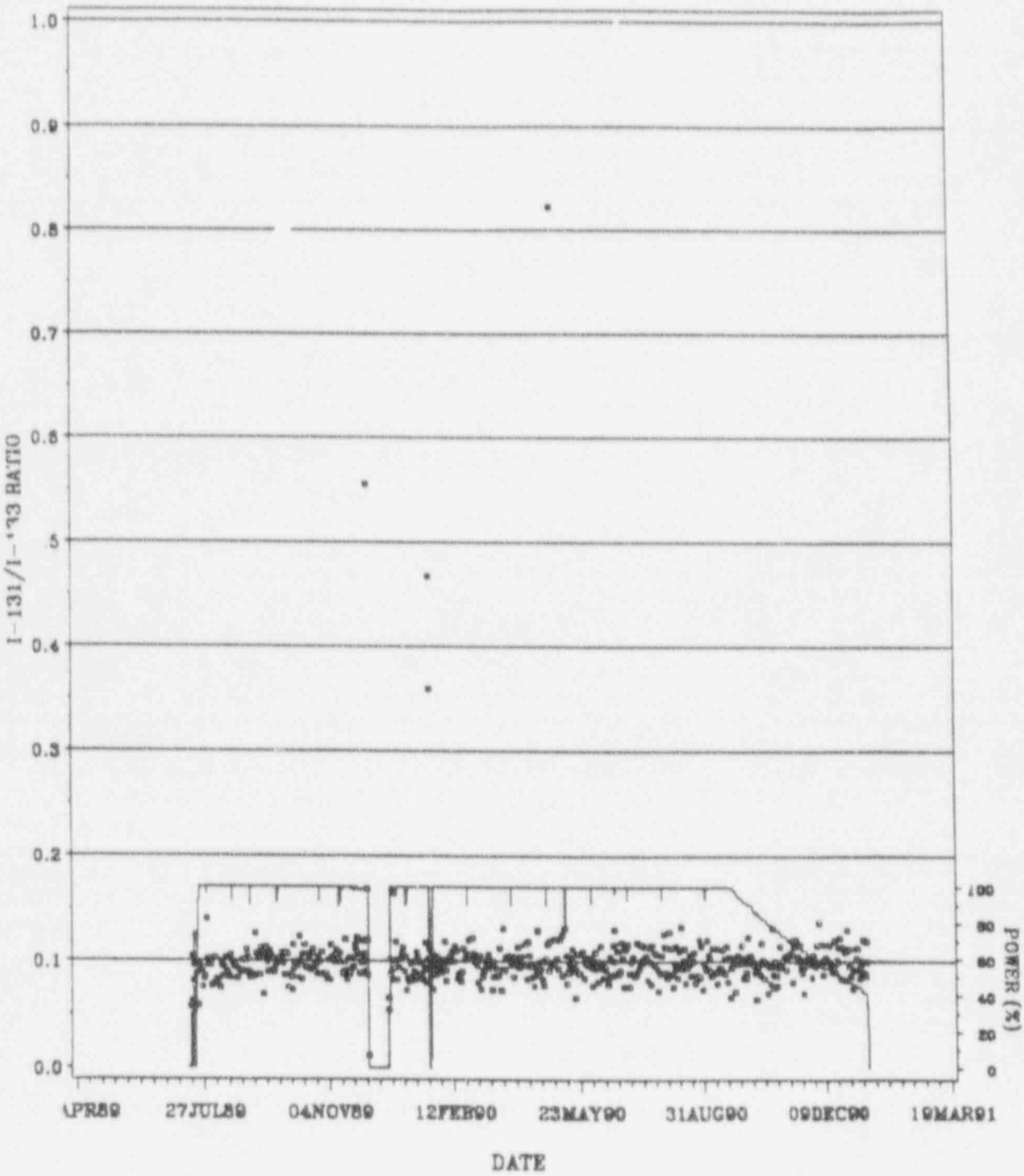


Figure 5.2
NORTH ANNA UNIT 1 - CYCLE 8
I-131 / I-133 ACTIVITY RATIO vs. TIME



Section 6

CONCLUSIONS

The North Anna 1, Cycle 8 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 no apparent fuel rod defects during Cycle 8.

Section 7

REFERENCES

1) A. P. Main, "North Anna Unit 1, Cycle 8 Startup Physics Test Report," Technical Report NE-734, Rev. 0, October, 1989.

2) North Anna Power Station Unit 1 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.