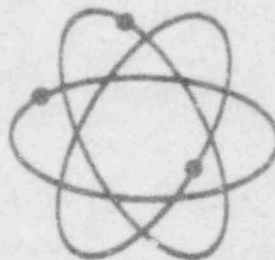


Vepco

NORTH ANNA UNIT 1, CYCLE 3 CORE PERFORMANCE REPORT



**FUEL RESOURCES DEPARTMENT
VIRGINIA ELECTRIC AND POWER COMPANY**

NORTH ANNA UNIT 1, CYCLE 3

COPE PERFORMANCE REPORT

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Section 1

INTRODUCTION AND SUMMARY

On May 17, 1982, North Anna Unit 1 completed Cycle 3. Since the initial criticality of Cycle 3 on April 6, 1981, the reactor core produced approximately 79×10^6 MBTU (13,335 Megawatt days per metric ton of contained uranium) which has resulted in the generation of approximately 7.4×10^9 KWHr gross (7.0×10^9 KWHr net) of electrical energy. The purpose of this report is to present an analysis of the core performance for routine operation during Cycle 3. The physics tests that were performed during the startup of this cycle were covered in the North Anna Unit 1, Cycle 3 Startup Physics Test Report¹ and, therefore, will not be included here.

The third cycle core consisted of four batches of fuel. Two once burned batches and one twice burned batch were brought from Cycles 1 and 2 (Batches 1A3, 3A2, and 4). One fresh batch of fuel was added to the Cycle 3 core. The North Anna 1, Cycle 3 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 identified 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 Specifications² limits thereby ensuring that adequate margins to 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 Specifications², and to assess the integrity of the fuel.

Each of the four performance indicators is discussed in detail for the North Anna 1, Cycle 3 core in the body of this report. The results are summarized below:

1. Burnup Follow - The burnup tilt (deviation from quadrant symmetry) on the core was no greater than $\pm 0.5\%$ with the burnup accumulation in each batch deviating from design prediction by less than 0.9%.

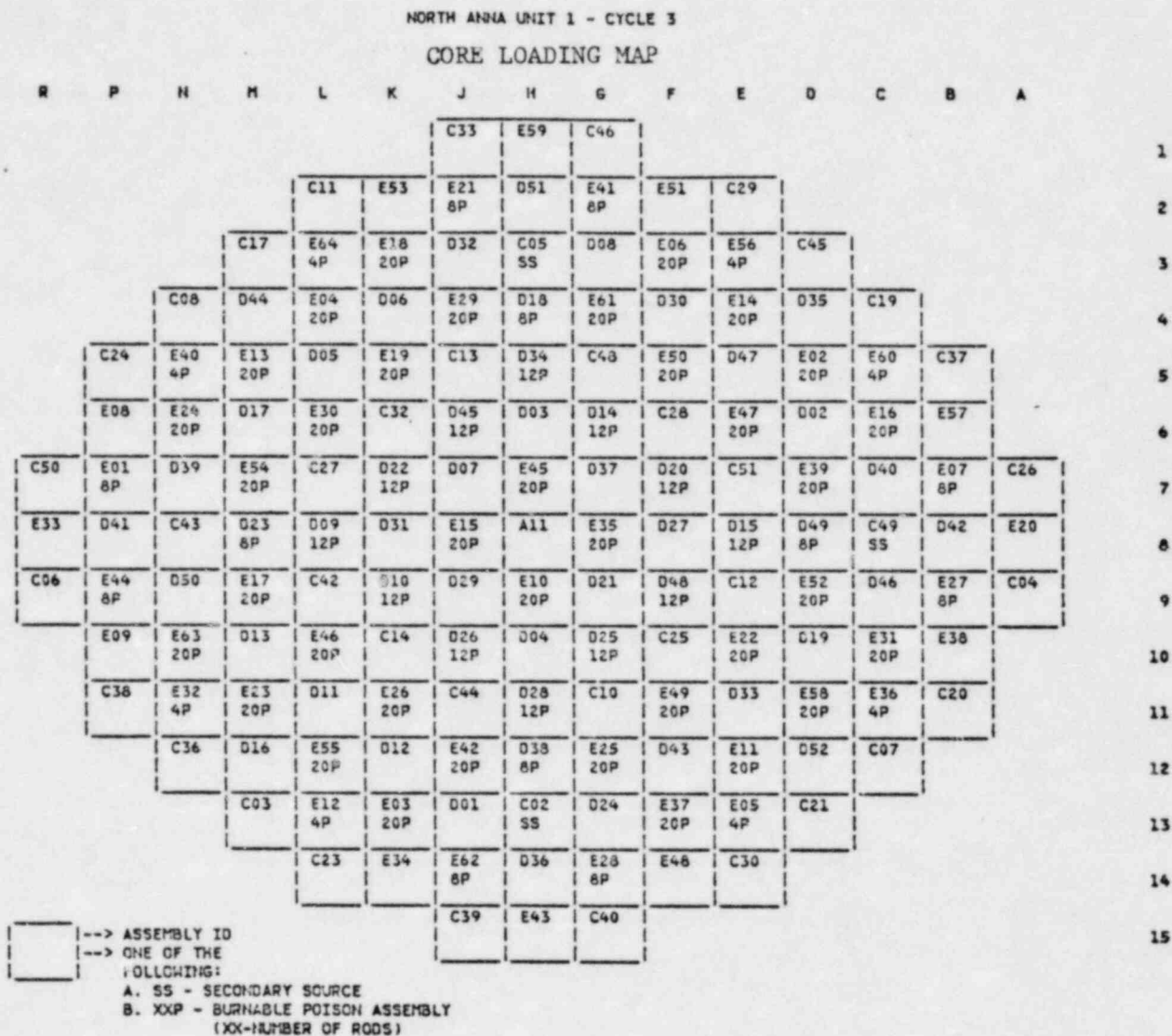
2. Reactivity Depletion Follow - The critical boron concentration, used to monitor reactivity depletion, was consistently within $\pm 0.6\%$ delta K/K of the design prediction which is well within the $\pm 1\%$ delta K/K margin allowed by Section 4.1.1.1.2 of the Technical Specifications.

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

4. Primary Coolant Activity Follow - The average dose equivalent iodine-131 activity level in the primary coolant during Cycle 3 was approximately 8.2×10^{-2} micro-Ci/gm. This corresponds to less than 9% of the operating limit for the concentration of radioiodine in the primary coolant.

In addition, the effects of fuel densification were monitored throughout the cycle. No densification effects were observed.

Figure 1.1



FUEL ASSEMBLY DESIGN PARAMETER

	1A3	3A2	BATCH 4	5
INITIAL ENRICHMENT (W/O U235)	2.11	3.10	3.21	3.41
ASSEMBLY TYPE	17 X 17	17 X 17	17 X 17	17 X 17
NUMBER OF ASSEMBLIES	1	40	52	64
FUEL RODS PER ASSEMBLY	264	264	264	264
ASSEMBLY IDENTIFICATION	A11	C02-C08 C10-C14 C17 C19-C21 C23-C30 C32,C33 C36-C40 C42-C46 C48-C51	D01-D52	E01-E64

Figure 1.2

NORTH ANNA UNIT 1 - CYCLE 3

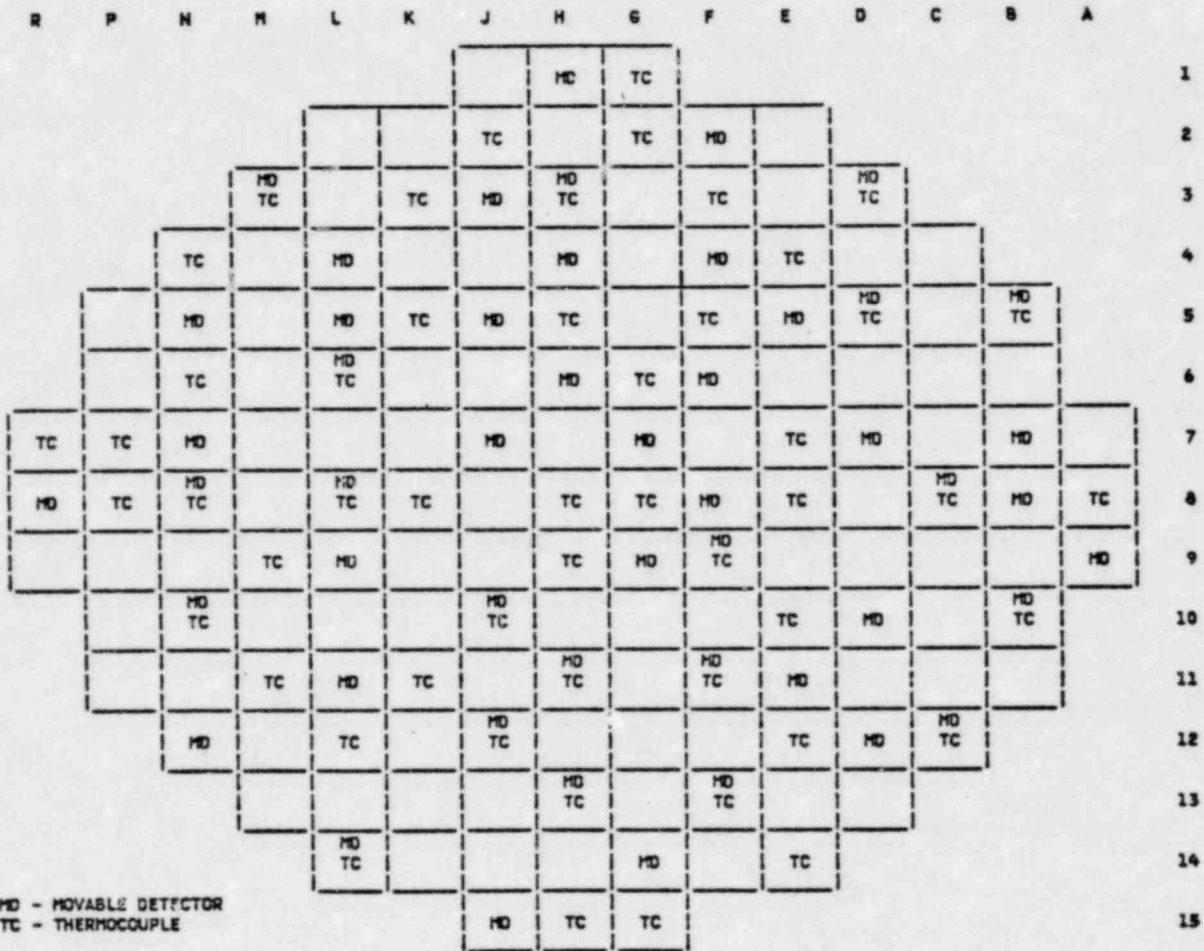
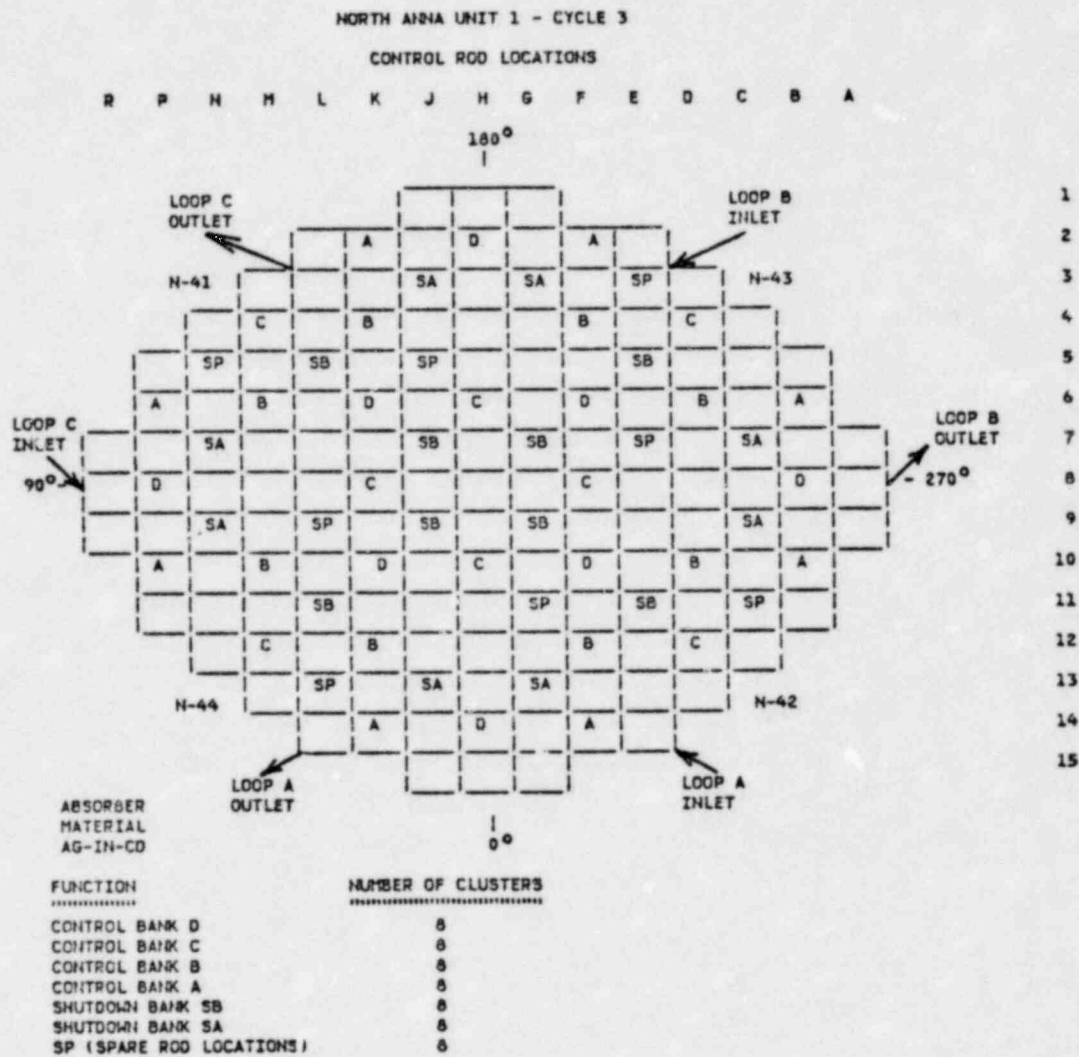
MOVABLE DETECTOR AND
THERMOCOUPLE LOCATIONS

Figure 1.3



Section 2

BURNUP FOLLOW

The burnup history for the North Anna Unit 1, Cycle 3 core is graphically depicted in Figure 2.1. The North Anna 1, Cycle 3 core achieved a burnup of 13,335 MWD/MTU. As shown in Figure 2.2, the average load factor for Cycle 3 was 79.5% when referenced to rated thermal power (2775 MW(t)).

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 NEWTOTE³ 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 3 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 3 operation is also given. As can be seen from this figure, the accumulated assembly burnups were generally within $\pm 3\%$ of the predicted values. In addition, deviation from quadrant symmetry in the core, as indicated by the burnup tilt factors, was less than $\pm 0.5\%$.

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 Figure 2.5, the

batch burnup sharing for North Anna Unit 1, Cycle 3 followed design predictions very closely with each batch deviating less than 0.9% from design; this is considered excellent agreement. Therefore, symmetric burnup in conjunction with good agreement between actual and predicted assemblywise burnups and batch burnup sharing indicate that the Cycle 3 core did deplete as designed.

FIGURE 2.1

NORTH ANNA UNIT 1 - CYCLE 3

CORE BURNUP HISTORY

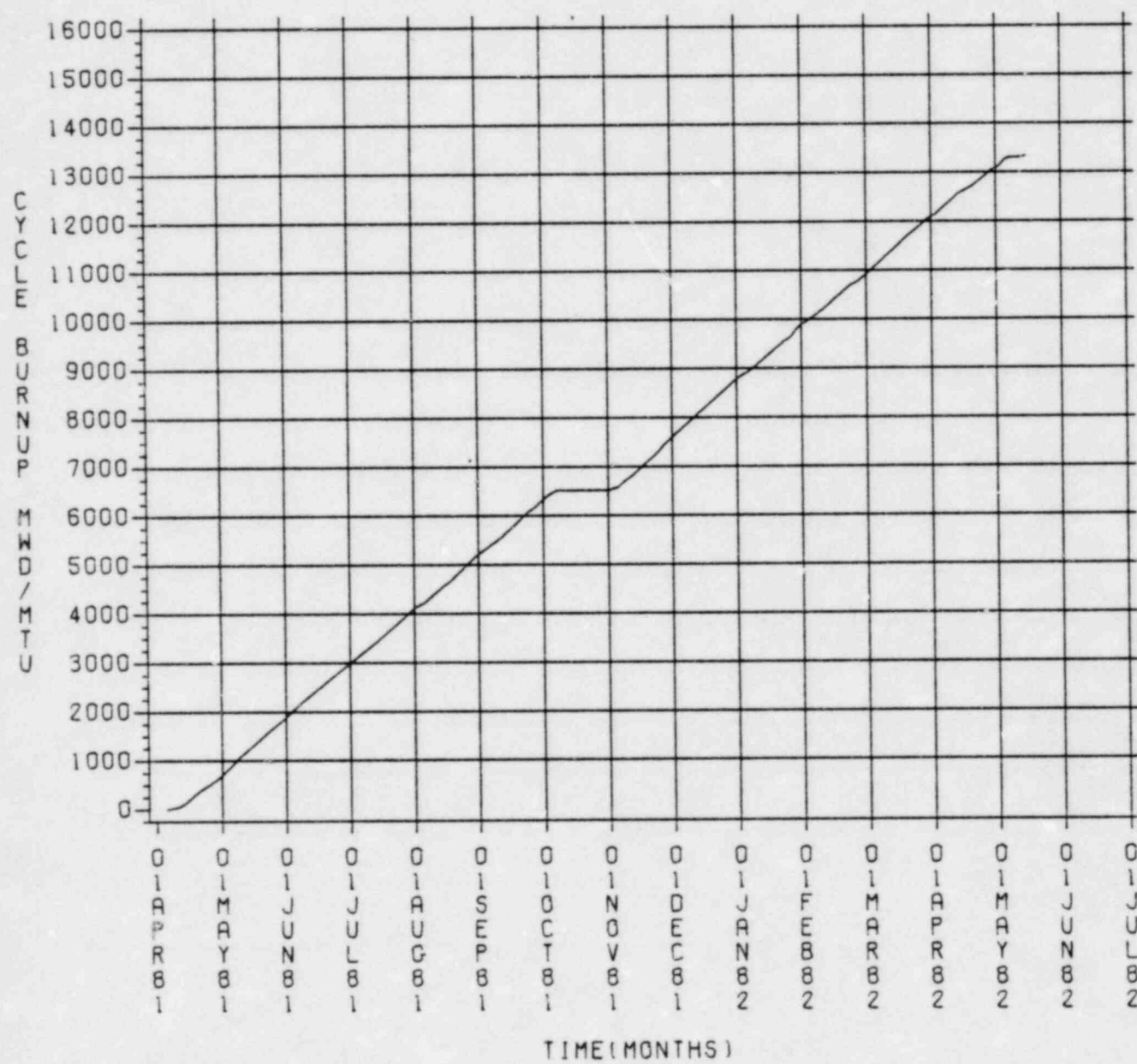
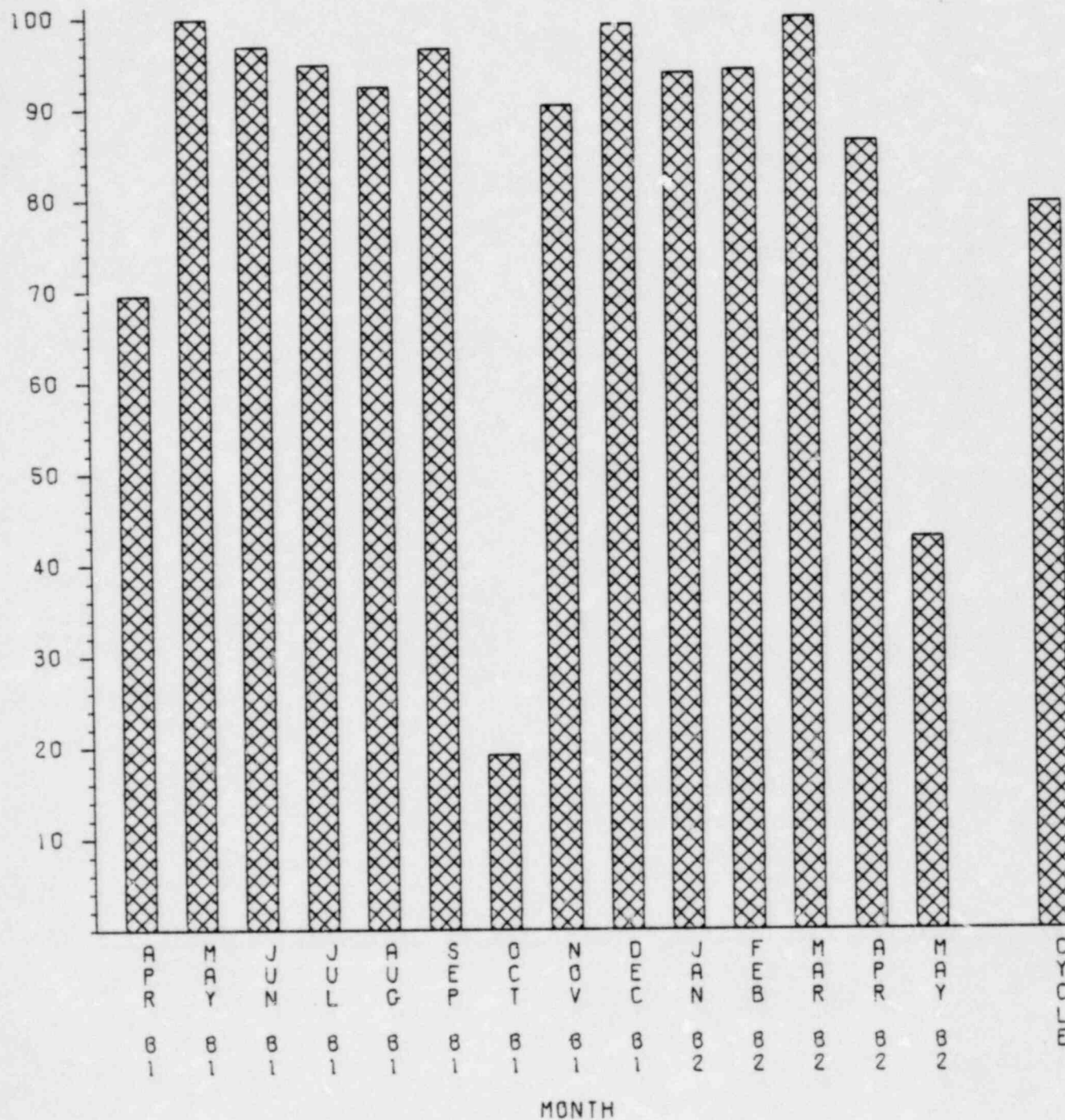


FIGURE 2.2

NORTH ANNA 1 - CYCLE 3
MONTHLY AVERAGE LOAD FACTORS

PERCENT



$$\text{LOAD FACTOR} = \frac{\text{THERMAL ENERGY GENERATION IN MONTH (MWH)}}{\text{AUTHORIZED POWER LEVEL (MW) X HOURS IN MONTH (EXCLUDES REFUELING OUTAGES)}}$$

Figure 2.3

NORTH ANNA UNIT 1 - CYCLE 3

ASSEMBLYWISE ACCUMULATED BURNUP
MEASURED AND PREDICTED
(1000 MWD/MTU)

[illegible]

Figure 2.4

NORTH ANNA UNIT 1 - CYCLE 3

ASSEMBLYWISE ACCUMULATED BURNUP
COMPARISON OF MEASURED WITH PREDICTED
(1000 MWD/MTU)

[illegible]

R P N M L K J H G F E D C B A

Burnup Sharing
(10³ MWD/MTU)

Batch	Cycle			Total
	1	2	3	
1A3	14.05	-	13.14	27.19
3A2	11.57	11.70	8.66	31.93
4	-	9.94	15.06	25.00
5	-	-	14.87	14.87
Core Average			13.34	

Burnup Tilt

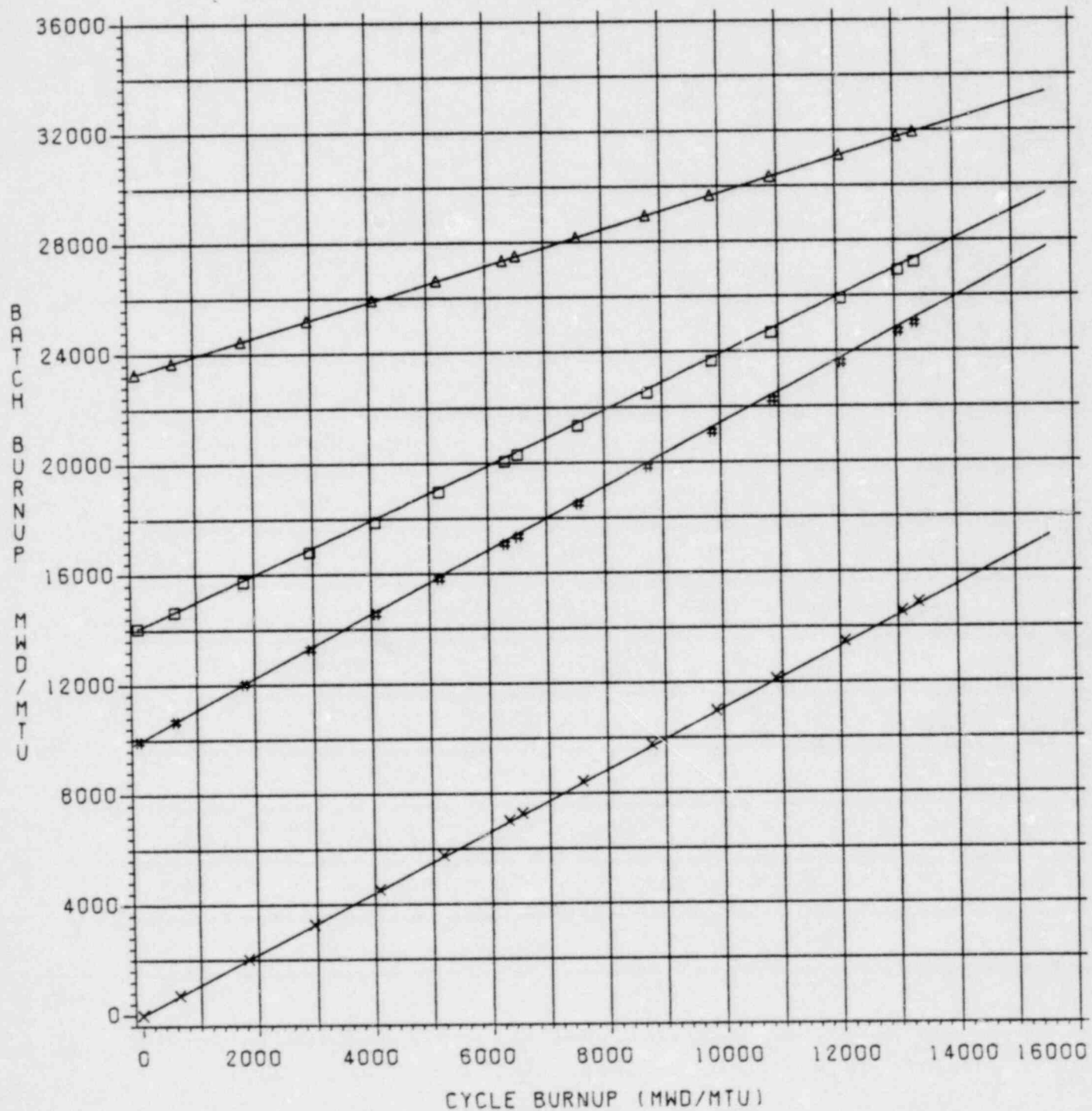
NW	-	0.9951
NE	-	1.0019
SW	-	1.0037
SE	-	0.9993

FIGURE 2.5

NORTH ANNA 1 - CYCLE 3
BATCH BURNUP SHARING

SYMBOLIC POINTS ARE MEASURED DATA

BATCH : 1A3 3A2 4 5
SYMBOL : SQUARE TRIANGLE HASH X



Section 3

REACTIVITY DEPLETION FOLLOW

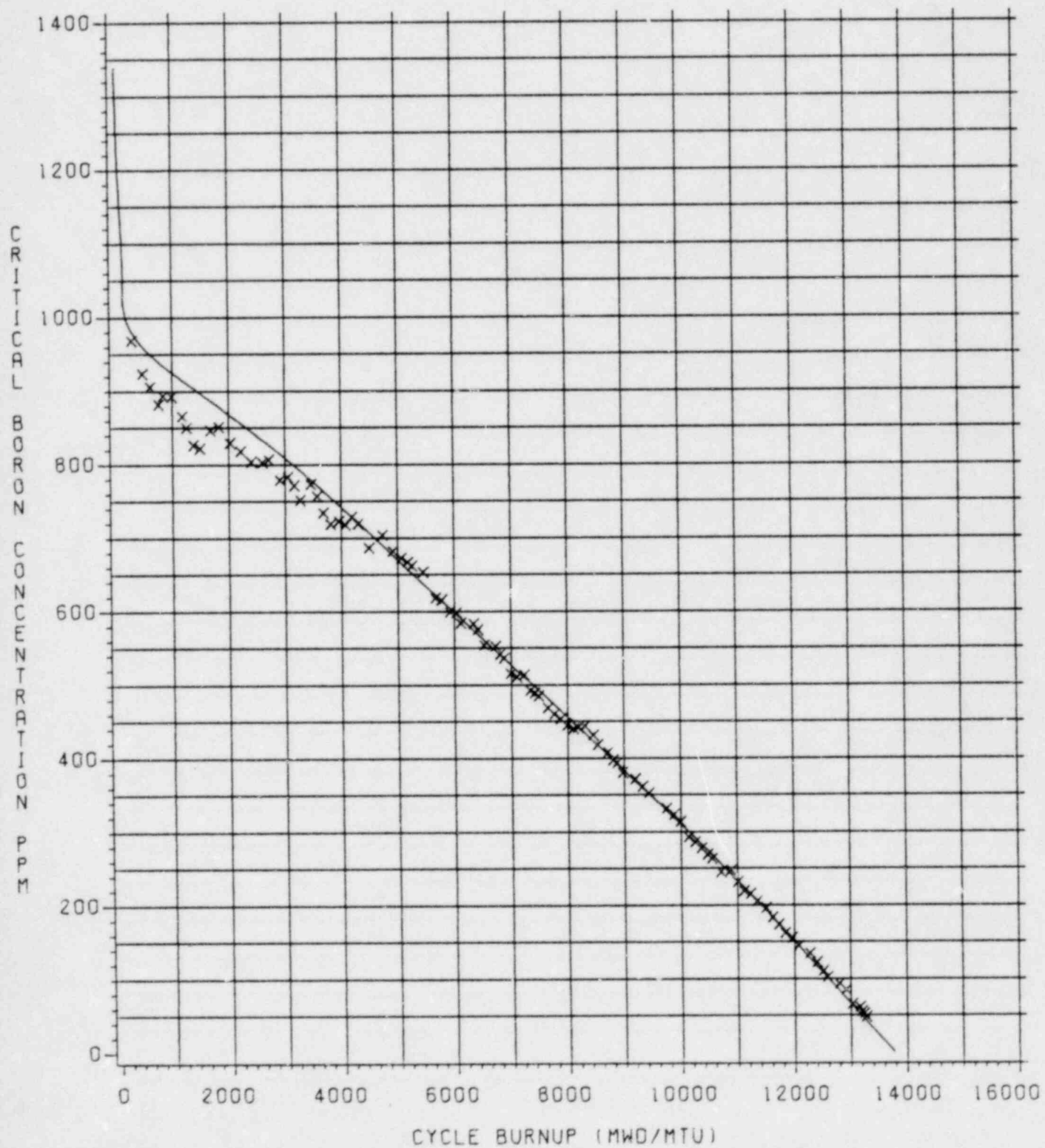
The primary coolant critical boron concentration is monitored for the purposes of following core reactivity and to identify any anomalous reactivity behavior. The FOLLOW[®] computer code was used to normalize "actual" critical boron concentration measurements to design conditions taking into consideration control rod position, xenon and samarium concentrations, moderator temperature, and power level. The normalized critical boron concentration versus burnup curve for the North Anna 1, Cycle 3 core is shown in Figure 3.1. It can be seen that the measured data typically compare to within 75 ppm of the design prediction. This corresponds to less than $\pm 0.6\%$ delta K/K which is well within the $\pm 1\%$ delta K/K criteria for reactivity anomalies set forth in Section 4.1.1.1.2 of the Technical Specifications. In conclusion, the trend indicated by the critical boron concentration verifies that the Cycle 3 core depleted as expected without any reactivity anomalies.

FIGURE 3.1

NORTH ANNA UNIT 1-CYCLE 3
CRITICAL BORON CONCENTRATION VS. BURNUP

HFP-ARO

X MEASURED
- PREDICTED



Section 4

POWER DISTRIBUTION FOLLOW

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 INCORE⁵ computer program. A summary of all full core flux maps taken since the completion of startup physics testing for North Anna 1, Cycle 3 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 distributions for a representative series of incore flux maps, are given in Figures 4.1 through 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 late in Cycle 3 life. Most of the radial power distributions were taken under equilibrium operating conditions with the unit at approximately full power. In each case, the measured relative assembly powers were generally within 5% of the predicted values with an average percent difference of approximately 2.2%.

The North Anna Unit 1 quadrant power tilt anomaly was described in the Cycle 2 Core Performance Report⁶ and in the Cycle 3 Startup Physics

Test Report¹. Further evaluations of the power tilt behavior during Cycle 3 indicated that the measured quadrant tilt did not exceed 1.2% at beginning-of-life, full-power, equilibrium conditions, and had decreased to less than 0.5% by the end of cycle operation.

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 margins and maintaining fuel cladding integrity. During most of Cycle 3 the Technical Specifications limit on the axially dependent heat flux hot channel factor, $F-Q(Z)$, was $2.10 \times K(Z)$, 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 $2.10 F-Q(Z)$ limit. On April 13, 1982, the Nuclear Regulatory Commission issued Amendment No. 39 to the Operating License for North Anna Power Station⁷, which revised the Technical Specifications limit on $F-Q(Z)$ to be $2.14 \times K(Z)$. All of the full core flux maps were performed prior to this license amendment. Therefore the results of those maps were compared to the original limit value. The axially dependent heat flux hot channel factors, $F-Q(Z)$, for a representative set of flux maps are given in Figures 4.5 through 4.7. Throughout Cycle 1, the measured values of $F-Q(Z)$ were within the Technical Specifications limit. The maximum values for the Heat Flux Hot Channel Factor measured during Cycle 3 are given in Figure 4.8. As can be seen from the figure, there was a 7% margin to the limit at the beginning of the cycle, with the margin generally increasing throughout cycle operation.

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 critical heat flux (DNB) 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. The Cycle 3 limit on the enthalpy rise hot channel factor was set at $1.55 \times (1+0.2(1-P)) \times (1-RBP(BU))$, where P is the fractional power level, and RBP(BU) is the rod bow penalty. At end-of-life, the rod bow penalty reduced the F-delta H limit by approximately 1%. A summary of the maximum values for the Enthalpy Rise Hot Channel Factor measured during Cycle 3 is given in Figure 4.9. As can be seen from this figure, there was a 4% margin to the limit at the beginning of the cycle, with the margin generally increasing throughout cycle operation.

The Technical Specifications require that target delta flux* values be determined periodically. The target delta flux is the delta flux which would occur at conditions of full power, all rods out, and equilibrium xenon. Therefore, 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

$$*\text{Delta Flux} = \frac{P_t - P_b}{2775} \times 100 \quad \text{where } P_t = \text{power in top of core (MW(t))}$$

$$P_b = \text{power in bottom of core (MW(t))}$$

burnup, the target value is updated monthly. Operational delta flux limits are then established about this target value. 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 4.10, shows the value of this parameter to have been approximately -8% at the beginning of Cycle 3. By the middle of the cycle, the value of delta flux had shifted to -5% and then moved to -4% by the end of Cycle 3. This power shift can also be observed in the corresponding core average axial power distribution for a representative series of maps given in Figures 4.11 through 4.13. In Map N1-3-14 (Figure 4.11), taken at approximately 500 MWD/MTU, the axial power distribution had a cosine shape with a peaking factor of 1.26. In Map N1-3-33 (Figure 4.12), taken at approximately 6,900 MWD/MTU, the axial power distribution had flattened somewhat with an axial peaking factor of 1.18. Finally, in Map N1-3-87 (Figure 4.13), taken at approximately 12,400 MWD/MTU, the axial power distribution was slightly concave with an axial peaking factor of 1.16. The history of F-Z during the cycle can be seen more clearly in a plot of F-Z versus burnup given in Figure 4.14.

In conclusion, the North Anna 1, Cycle 3 core performed very satisfactorily with power distribution analyses verifying that design predictions were accurate and that the values of the hot channel factors were within the limits of the Technical Specifications.

TABLE 4.1
NORTH ANNA UNIT 1 - CYCLE 3

SUMMARY OF INCORE FLUX MAPS FOR ROUTINE OPERATION

MAP NO.	DATE	BURN UP MWD/ MTU	PWR (%)	BANK D STEPS	1				2			CORE F(Z)		3	4		AXIAL OFF SET (%)	NO. OF THIM BLES	
					F-Q(T) HOT CHANNEL FACTOR				F-DH(N) HOT CHNL.FACTOR			MAX			F(XY) MAX	QPTR			
					ASSY	PIN	POINT	F-Q(T)	ASSY	PIN	F-DH(N)	POINT	F(Z)			MAX			LOC
14	4-27-81	486	100	224	K14	MN	37	1.953	K14	MN	1.474	38	1.264	1.553	1.013	SW	-7.88	42	
15	5-13-81	1120	100	218	K14	MN	37	1.912	K14	MN	1.452	38	1.261	1.523	1.009	SW	-6.88	46	
16	5-18-81	1332	100	218	L13	OK	37	1.910	K14	MN	1.447	38	1.256	1.524	1.009	SW	-6.59	46	
17	5-18-81	1333	98	207	L13	OK	37	1.953	K14	MN	1.451	38	1.289	1.522	1.011	SW	-10.33	45	
20(5)	5-19-81	1351	100	218	L13	OK	35	1.887	K14	MN	1.450	37	1.239	1.534	1.012	SW	-3.66	46	
21	5-20-81	1389	100	221	L13	OK	36	1.890	K14	MN	1.447	37	1.249	1.522	1.011	SW	-5.22	46	
23(6)	6-11-81	2232	100	221	L13	OK	36	1.864	L13	OK	1.438	38	1.237	1.517	1.011	SW	-5.42	46	
24	7-15-81	3440	100	216	L13	OK	46	1.824	L13	OK	1.414	38	1.231	1.487	1.009	SW	-7.39	46	
25	8-10-81	4415	100	211	F05	QQ	39	1.781	L13	OK	1.403	38	1.214	1.469	1.006	SW	-6.39	46	
27(7)	8-12-81	4475	100	205	L13	OK	46	1.849	L13	OK	1.412	45	1.243	1.479	1.007	SW	-9.80	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 1.05×1.03 .
2. F-DH(N) INCLUDES A MEASUREMENT UNCERTAINTY OF 1.04.
3. F(XY) INCLUDES A TOTAL UNCERTAINTY OF 1.05×1.03 .
4. QPTR - QUADRANT POWER TILT RATIO.
5. MAPS 18 AND 19 WERE QUARTER CORE MAPS TAKEN FOR INCORE/EXCORE CALIBRATION.
6. MAP 22 WAS ABORTED DUE TO AN INSUFFICIENT NUMBER OF THIMBLES.
7. MAP 26 WAS NOT USABLE FOR INCORE/EXCORE CALIBRATION DUE TO ITS AXIAL FLUX DIFFERENCE SIMILARITY TO MAP 25. THEREFORE, MAP 26 WAS NOT ANALYZED.

TABLE 4.1 (CONT.)

MAP NO.	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		AXIAL OFF SET (%)	NO. OF THIM- BLES
					ASSY	PIN	POINT	F-Q(T)	ASSY	PIN	F-DH(N)	AXIAL POINT	F(Z)		MAX	LOC		
28	8-13-81	4512	100	217	L13	OK	29	1.729	L13	OK	1.406	29	1.179	1.476	1.006	SW	-1.61	46
29	8-24-81	4938	100	219	F11	QA	37	1.726	L13	OK	1.401	29	1.174	1.472	1.007	SW	-1.50	44
30	9- 9-81	5497	75	143	F05	LK	29	1.804	F05	QQ	1.411	29	1.227	1.482	1.007	SE	-4.21	47
31	9-15-81	5720	100	215	F05	LK	38	1.751	F05	LK	1.405	38	1.186	1.484	1.005	SW	-5.23	44
32	9-17-81	5794	100	195	F05	LK	38	1.817	F05	LK	1.407	38	1.226	1.485	1.005	SW	-8.67	46
33	11-13-81	6883	100	213	F11	LG	47	1.743	F05	LK	1.417	46	1.176	1.494	1.006	SW	-5.10	48
36(8)	12-10-81	7926	99	217	F05	LK	46	1.717	F05	LK	1.546	46	1.156	1.504	1.005	SW	-3.62	48
39(9)	1- 4-82	8899	98	219	L10	GF	47	1.733	F05	LK	1.433	47	1.150	1.512	1.007	NE	-3.23	46
79(10)	1-18-82	9413	99	219	F05	LK	47	1.709	F05	LK	1.437	47	1.142	1.510	1.009	NE	-3.19	47
83(11)	2-10-82	10218	100	218	F05	LK	48	1.736	F05	LK	1.435	47	1.161	1.509	1.007	NE	-5.04	47
84	3-15-82	11434	100	216	F05	ML	53	1.717	F05	ML	1.427	53	1.146	1.503	1.006	NE	-3.92	48
87(12)	4-12-82	12433	99	214	F05	ML	53	1.738	F05	ML	1.427	53	1.155	1.503	1.005	NE	-3.90	48

8. MAPS 34 AND 35 WERE QUARTER CORE MAPS TAKEN FOR INCORE/EXCORE CALIBRATION.

9. MAPS 37 AND 38 WERE 8 SYMMETRIC THIMBLE MAPS TAKEN FOR QUADRANT POWER TILT RATIO VERIFICATION.

10. MAPS 40 AND 42 WERE QUARTER CORE MAPS TAKEN FOR INCORE/EXCORE CALIBRATION. MAPS 41, 43, 44, AND 46 THROUGH 78 WERE SYMMETRIC THIMBLE MAPS TAKEN FOR QUADRANT POWER TILT RATIO VERIFICATION. MAP 45 WAS NOT ANALYZED DUE TO EXCESSIVE POWER CHANGES DURING THE MAPPING.

11. MAPS 80, 81, AND 82 WERE 8 SYMMETRIC THIMBLE MAPS TAKEN FOR QUADRANT POWER RATIO VERIFICATION.

12. MAPS 85 AND 86 WERE QUARTER CORE MAPS TAKEN FOR INCORE/EXCORE CALIBRATION.

Figure 4.1

NORTH ANNA UNIT 1-CYCLE 2

ASSEMBLYWISE POWER DISTRIBUTION

N1-3-14

R	P	N	M	L	K	J	H	G	F	E	D	C	B	A	
MEASURED PCT DIFFERENCE															1
0.40 0.75 0.39 3.5 3.5 7.9															
0.41 0.93 1.13 1.14 1.14 0.96 0.43 -1.0 -0.5 0.7 0.7 1.6 2.2 4.3															2
0.40 1.04 1.15 1.17 1.02 1.18 1.16 1.08 0.43 -1.0 -1.0 -0.8 -1.9 -2.0 -1.1 0.5 2.6 6.6															3
0.41 0.93 1.14 1.19 1.17 1.11 1.17 1.20 1.17 0.95 0.42 1.5 -0.6 -1.6 -1.8 -2.4 -2.5 -2.3 -1.1 1.1 2.1 3.6															4
0.42 1.07 1.14 1.22 1.17 0.95 1.03 0.97 1.18 1.23 1.15 1.06 0.41 1.5 1.5 -1.1 -2.0 -2.3 -4.9 -5.0 -3.7 -1.4 -0.9 -0.2 0.6 1.2															5
0.96 1.18 1.21 1.17 0.98 1.05 1.17 1.05 0.99 1.18 1.20 1.16 0.95 2.0 2.0 -0.2 -2.4 -3.1 -4.8 -5.0 -4.5 -1.6 -1.1 -0.8 -0.0 1.2															6
0.39 1.15 1.22 1.17 0.96 1.06 1.15 1.15 1.16 1.06 0.97 1.18 1.19 1.13 0.39 2.6 2.6 2.6 -1.8 -4.2 -4.1 -5.3 -5.5 -4.7 -3.5 -3.0 -1.3 -0.4 0.5 1.2															7
0.74 1.16 1.07 1.13 1.04 1.19 1.17 0.92 1.17 1.18 1.04 1.13 1.04 1.18 0.77 2.6 2.6 2.6 -1.4 -3.5 -3.6 -4.0 -3.1 -4.2 -4.3 -4.1 -1.2 -0.4 3.9 6.4															8
0.39 1.14 1.21 1.17 0.97 1.07 1.17 1.18 1.17 1.06 0.96 1.18 1.18 1.19 0.43 1.3 1.3 1.3 -1.8 -3.1 -3.5 -3.9 -3.0 -4.1 -4.3 -4.2 -1.3 -1.3 5.6 11.3															9
0.95 1.17 1.20 1.18 0.98 1.06 1.19 1.07 0.98 1.17 1.19 1.13 1.04 1.3 1.3 -0.5 -1.4 -2.3 -3.8 -3.3 -3.1 -2.3 -2.2 -1.4 -2.1 11.3															10
0.43 1.09 1.18 1.22 1.18 0.98 1.06 0.98 1.19 1.23 1.17 1.08 0.44 3.9 3.9 1.9 -1.9 -1.7 -2.3 -2.4 -2.4 -0.8 -1.2 1.2 2.3 6.5															11
0.43 0.95 1.13 1.20 1.20 1.14 1.20 1.21 1.16 0.96 0.43 6.5 2.4 -1.9 -0.5 0.2 0.1 0.3 0.4 0.4 3.1 6.5															12
0.44 1.16 1.22 1.22 1.07 1.23 1.20 1.08 0.43 8.1 9.8 5.3 2.0 3.0 3.6 3.6 2.7 6.5															13
0.45 1.04 1.21 1.21 1.16 0.97 0.42 9.8 10.8 7.7 6.5 3.7 3.7 2.7															14
0.43 0.78 0.40 11.9 8.5 4.8															15
STANDARD DEVIATION = 2.363															
AVERAGE PCT. DIFFERENCE = 2.9															

SUMMARY

MAP NO: N1-3-14	DATE: 4/27/81	POWER: 100%
CONTROL ROD POSITIONS:	F-Q(T) = 1.953	QPTR:
D BANK AT 224 STEPS	F-DH(N) = 1.474	NW 0.987 NE 0.993
	F(Z) = 1.264	SW 1.013 SE 1.007
	F(XY) = 1.553	
BURNUP = 486 MWD/MTU	A.O = -7.88(%)	

Figure 4.2

NORTH ANNA UNIT 1-CYCLE 3
ASSEMBLYWISE POWER DISTRIBUTION

N1-3-33

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

STANDARD DEVIATION = 1.574

AVERAGE PCT. DIFFERENCE = 1.8

SUMMARY

MAP NO: N1-3-33

DATE: 11/13/81

POWER: 100%

CONTROL ROD POSITIONS:

F-Q(T) = 1.743

QPTR:

D BANK AT 213 STEPS

F-DH(N) = 1.417

NW 0.992 | NE 1.006

F(Z) = 1.176

SW 1.006 | SE 0.996

F(XY) = 1.494

BUPNUP = 6883 MWD/MTU A.O = -5.10(%)

Figure 4.3

NORTH ANNA UNIT 1-CYCLE 3

ASSEMBLYWISE POWER DISTRIBUTION

N1-3-87

R	P	N	M	L	K	J	H	G	F	E	D	C	B	A	
..... MEASURED PCT DIFFERENCE															1
						0.37	0.65	0.37							
						2.0	1.9	2.0							
..... MEASURED PCT DIFFERENCE															2
						0.45	0.86	1.00	0.95	1.00	0.87	0.44			
						6.4	0.7	0.7	0.6	1.2	1.9	4.0			
..... MEASURED PCT DIFFERENCE															3
						0.45	1.06	1.19	1.08	0.95	1.08	1.21	1.07	0.47	
						2.8	2.4	-0.5	-0.6	-0.7	0.1	1.5	3.2	6.2	
..... MEASURED PCT DIFFERENCE															4
						0.45	0.95	1.26	1.18	1.28	1.16	1.28	1.19	1.26	0.96
						2.5	0.9	1.3	-0.3	-0.5	-0.6	-0.5	0.9	1.6	1.8
..... MEASURED PCT DIFFERENCE															5
						0.42	1.03	1.22	1.19	1.29	1.03	1.14	1.04	1.32	1.22
						-1.1	-1.1	-1.6	-1.7	-1.3	-1.5	-1.6	-0.7	0.9	0.3
..... MEASURED PCT DIFFERENCE															6
						0.65	1.19	1.17	1.28	1.02	1.15	1.18	1.16	1.04	1.30
						-0.1	-0.1	-1.0	-2.0	-1.2	-1.3	-1.1	-0.7	0.5	-0.7
..... MEASURED PCT DIFFERENCE															7
						0.37	1.00	1.09	1.27	1.01	1.14	1.17	1.31	1.18	1.16
						0.9	1.0	1.0	-1.2	-3.6	-2.7	-1.8	-1.3	-1.0	-0.5
..... MEASURED PCT DIFFERENCE															8
						0.64	0.95	0.97	1.17	1.14	1.17	1.31	1.02	1.31	1.18
						1.0	0.9	1.0	-0.3	-1.8	-1.5	-1.0	-0.5	-1.3	-1.4
..... MEASURED PCT DIFFERENCE															9
						0.36	0.99	1.08	1.27	1.03	1.14	1.16	1.30	1.17	1.15
						-0.7	0.2	0.2	-0.7	-1.6	-2.0	-2.9	-1.6	-1.7	-1.8
..... MEASURED PCT DIFFERENCE															10
						0.85	1.18	1.17	1.31	1.03	1.13	1.16	1.14	1.02	1.29
						-0.8	-0.8	-0.4	-0.1	-1.0	-3.2	-2.3	-2.4	-1.5	-1.2
..... MEASURED PCT DIFFERENCE															11
						0.43	1.06	1.25	1.21	1.28	1.01	1.13	1.01	1.29	1.20
						1.9	1.9	1.1	-0.5	-1.9	-3.0	-3.1	-3.3	-1.6	-0.8
..... MEASURED PCT DIFFERENCE															12
						0.46	0.96	1.24	1.15	1.25	1.14	1.26	1.16	1.23	0.97
						4.7	2.2	-0.5	-1.6	-2.2	-2.2	-1.9	-1.2	-1.2	3.0
..... MEASURED PCT DIFFERENCE															13
						0.47	1.11	1.22	1.07	0.95	1.08	1.18	1.03	0.47	
						5.9	7.1	2.3	-1.5	-1.2	-0.5	-0.6	-0.6	5.8	
..... MEASURED PCT DIFFERENCE															14
						0.45	0.92	1.03	0.96	0.99	0.85	0.42			
						7.1	7.3	3.6	1.7	-0.6	-0.6	-0.6			
..... MEASURED PCT DIFFERENCE															15
						0.39	0.66	0.36							
						7.3	3.3	-0.7							
..... MEASURED PCT DIFFERENCE															

STANDARD DEVIATION = 1.633

AVERAGE PCT. DIFFERENCE = 1.8

SUMMARY

MAP NO: N1-3-87

DATE: 4/12/82

POWER: 99%

CONTROL ROD POSITIONS: F-Q(T) = 1.738

QPTR:

D BANK AT 214 STEPS

F-DH(N) = 1.427

NW 0.996 | NE 1.005

F(Z) = 1.155

SW 1.001 | SE 0.998

F(XY) = 1.503

BURNUP = 12433 MWD/MTU A.O = -3.90(%)

Figure 4.4

HOT CHANNEL FACTOR NORMALIZED

OPERATING ENVELOPE

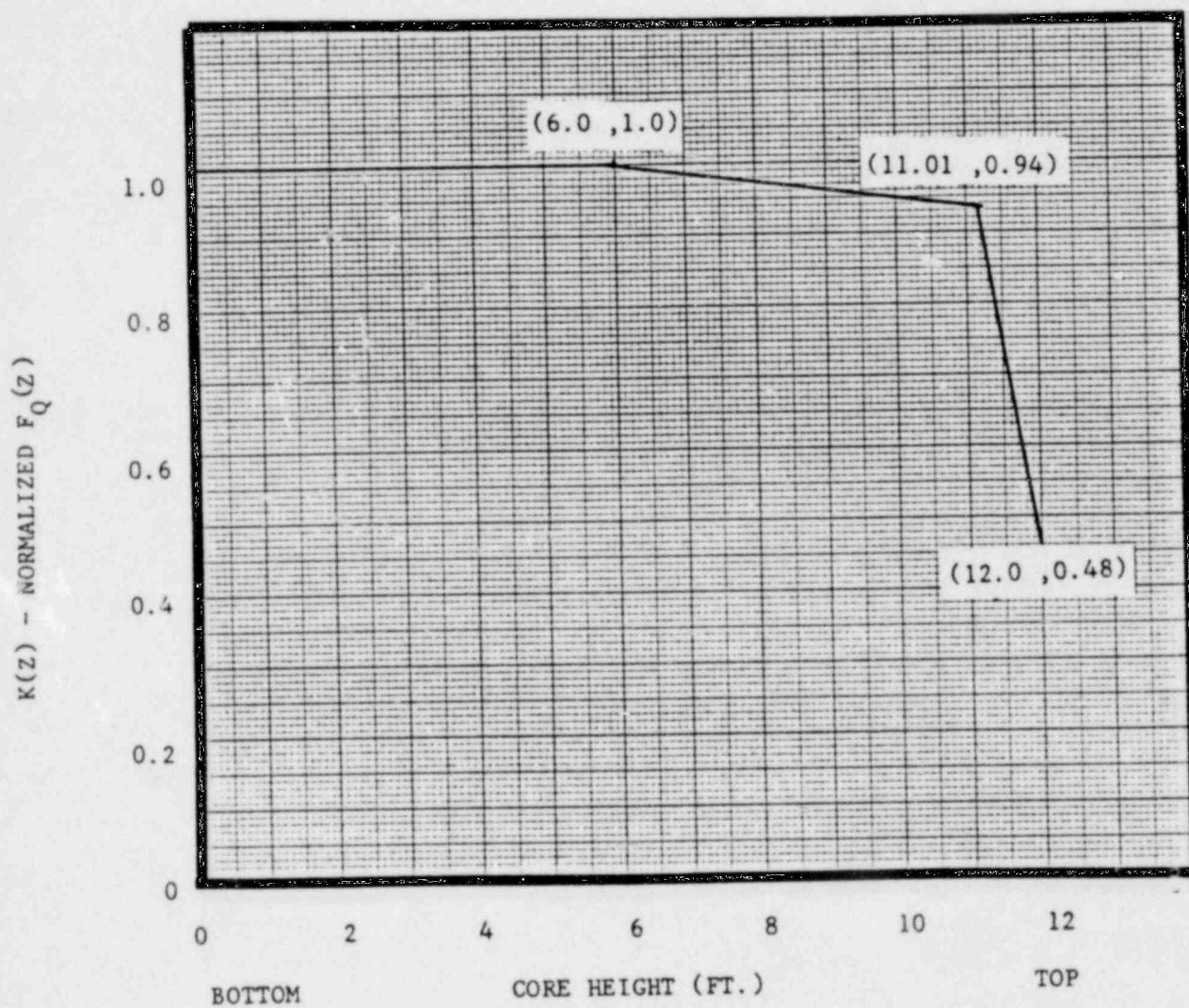


Figure 4.5

NORTH ANNA UNIT 1-CYCLE 3
HEAT FLUX HOT CHANNEL FACTOR, $F_Q^T(z)$
N1-3-14

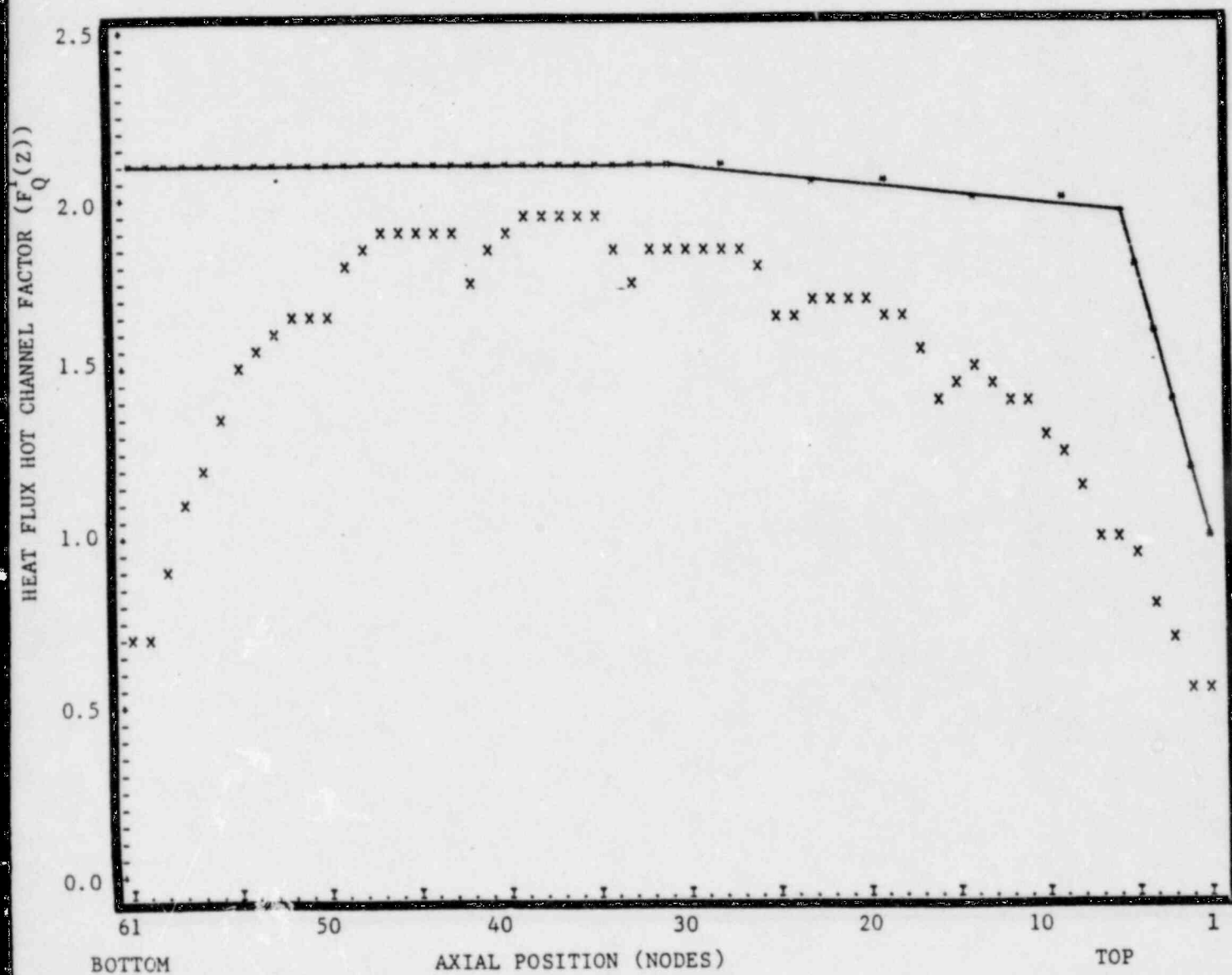


Figure 4.6

NORTH ANNA UNIT 1-CYCLE 3
HEAT FLUX HOT CHANNEL FACTOR, $F_Q^T(Z)$
N1-3-33

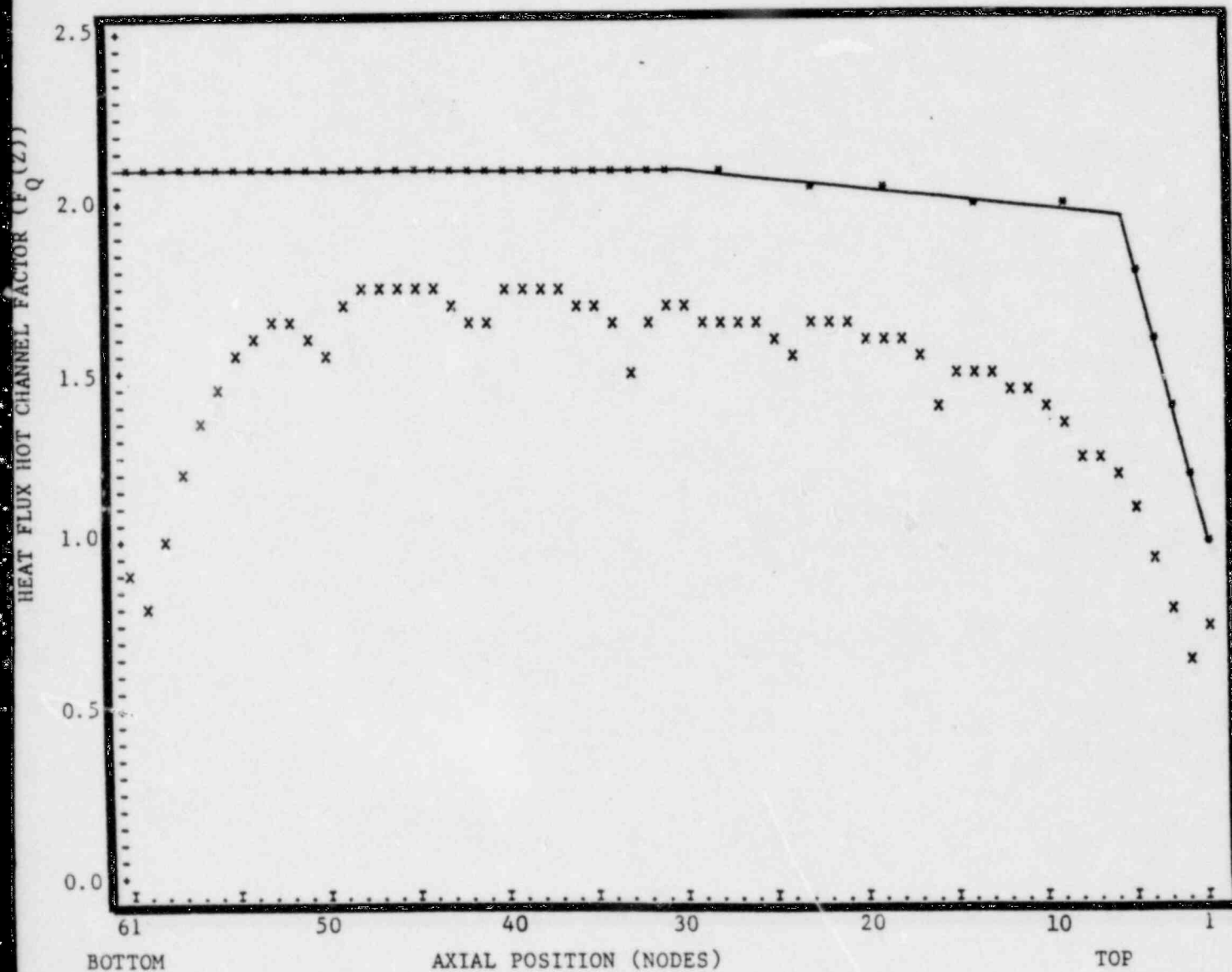


Figure 4.7

NORTH ANNA UNIT 1-CYCLE 3
 HEAT FLUX HOT CHANNEL FACTOR, $F_Q^T(Z)$
 N1-3-87

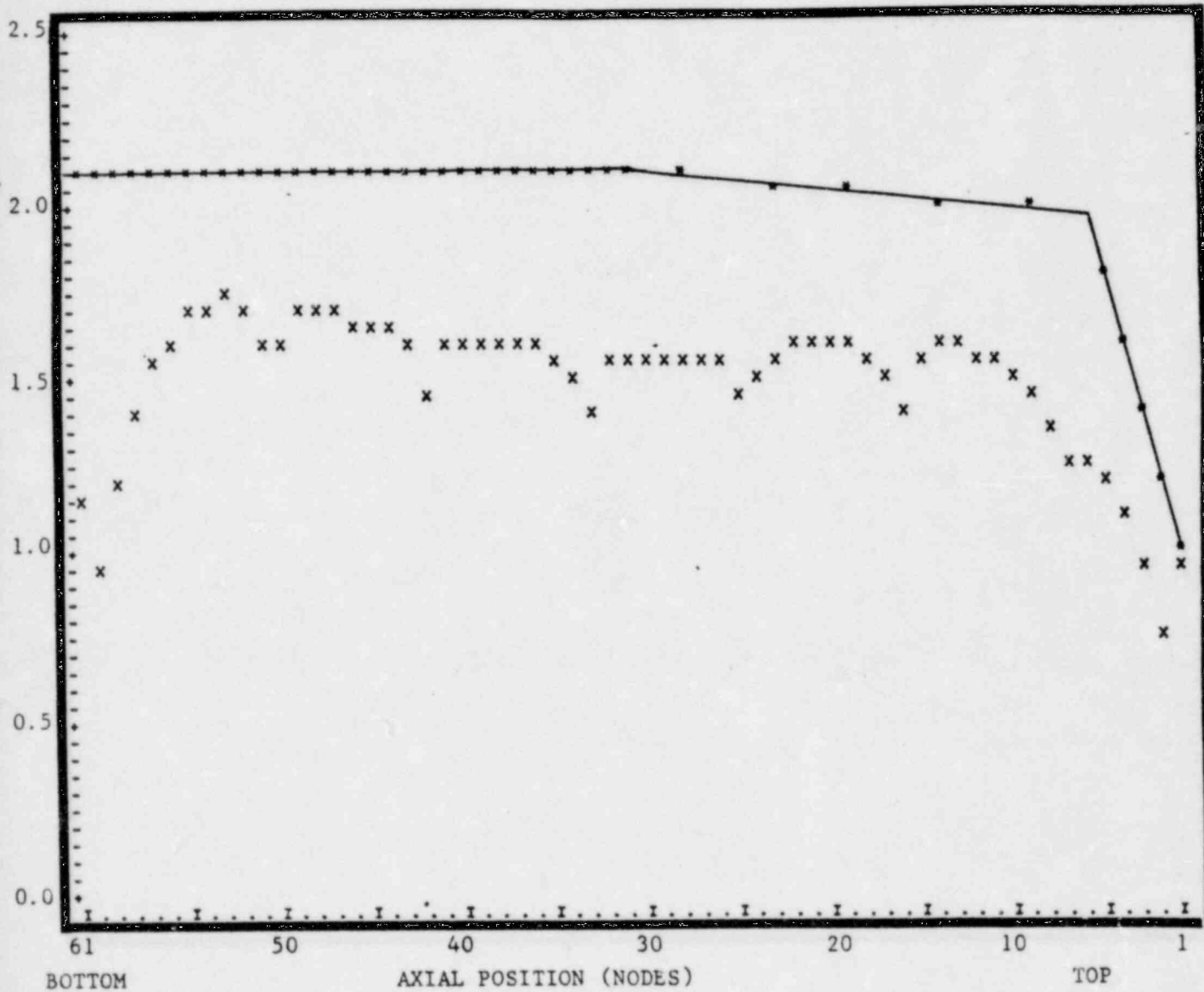


FIGURE 4.8

NORTH ANNA UNIT 1 - CYCLE 3
 MAXIMUM HEAT FLUX HOT CHANNEL FACTOR, F-Q VS. BURNUP

- TECH SPEC LIMIT
 X MEASURED VALUE

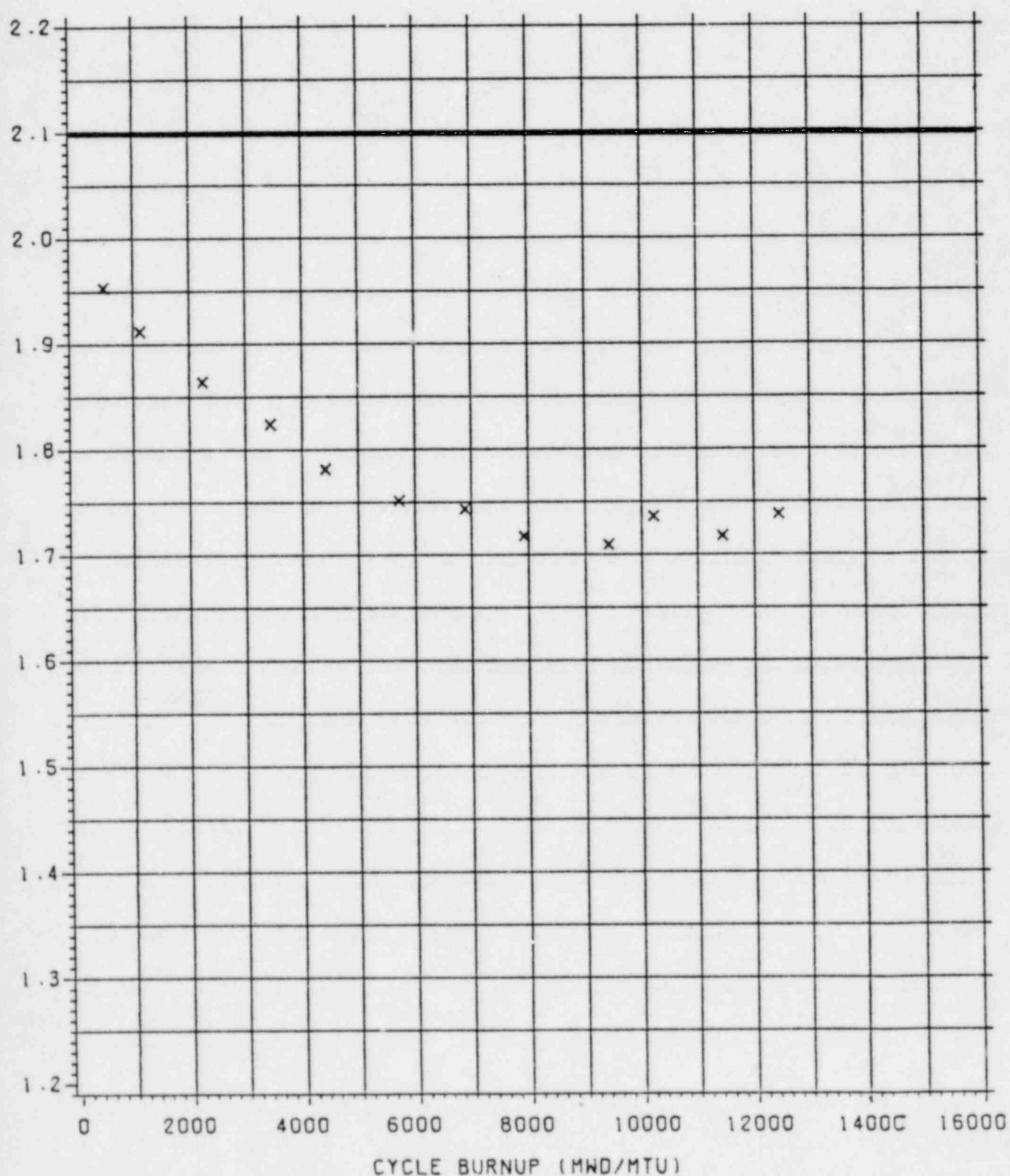


FIGURE 4.9

NORTH ANNA UNIT 1 - CYCLE 3
 ENTHALPY RISE HOT CHANNEL FACTOR, F-DH(N) VS. BURNUP

- TECH SPEC LIMIT
 X MEASURED VALUE

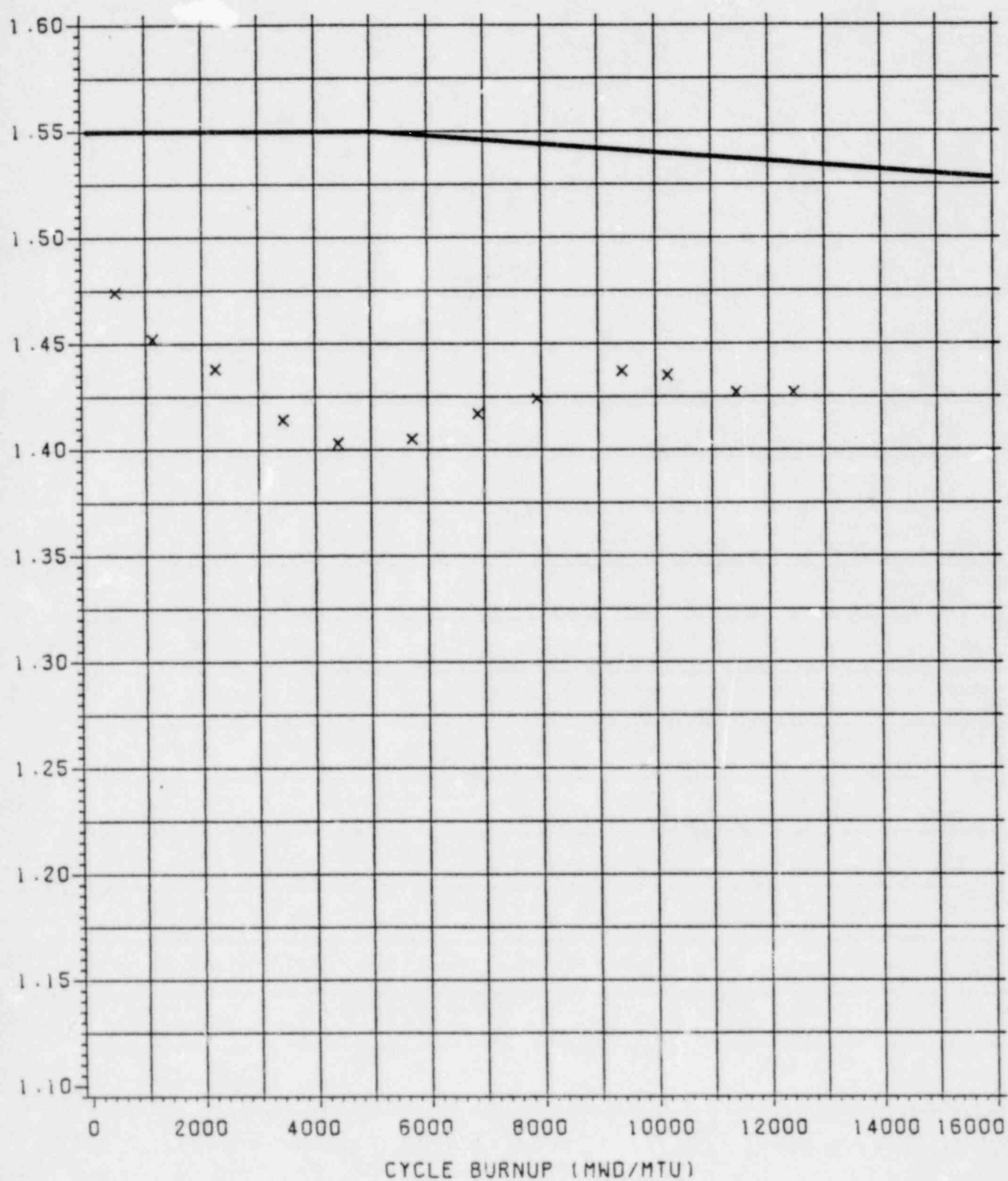


FIGURE 4.10.

NORTH ANNA UNIT 1 - CYCLE 3

TARGET DELTA FLUX VS. BURNUP

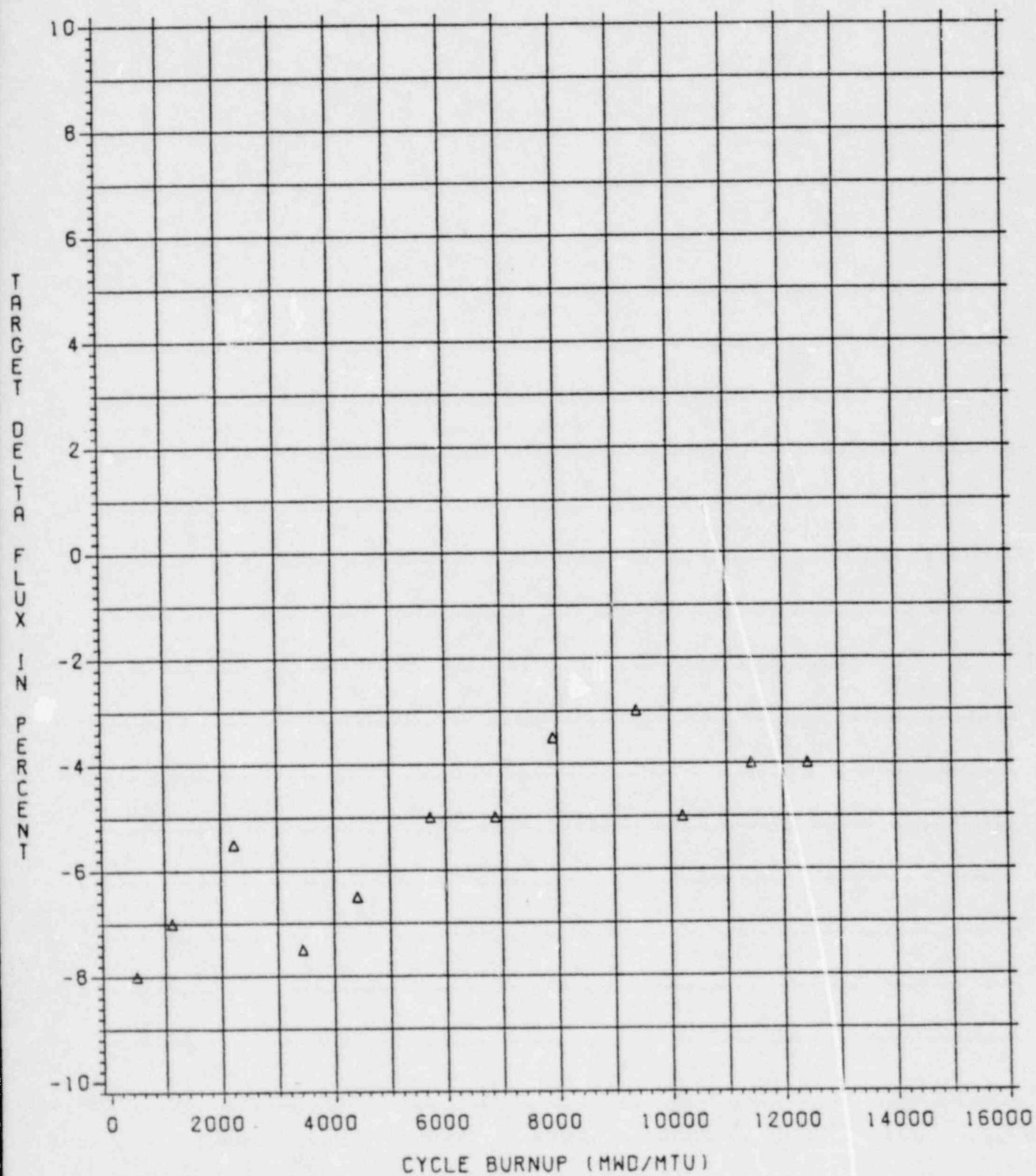


Figure 4.11

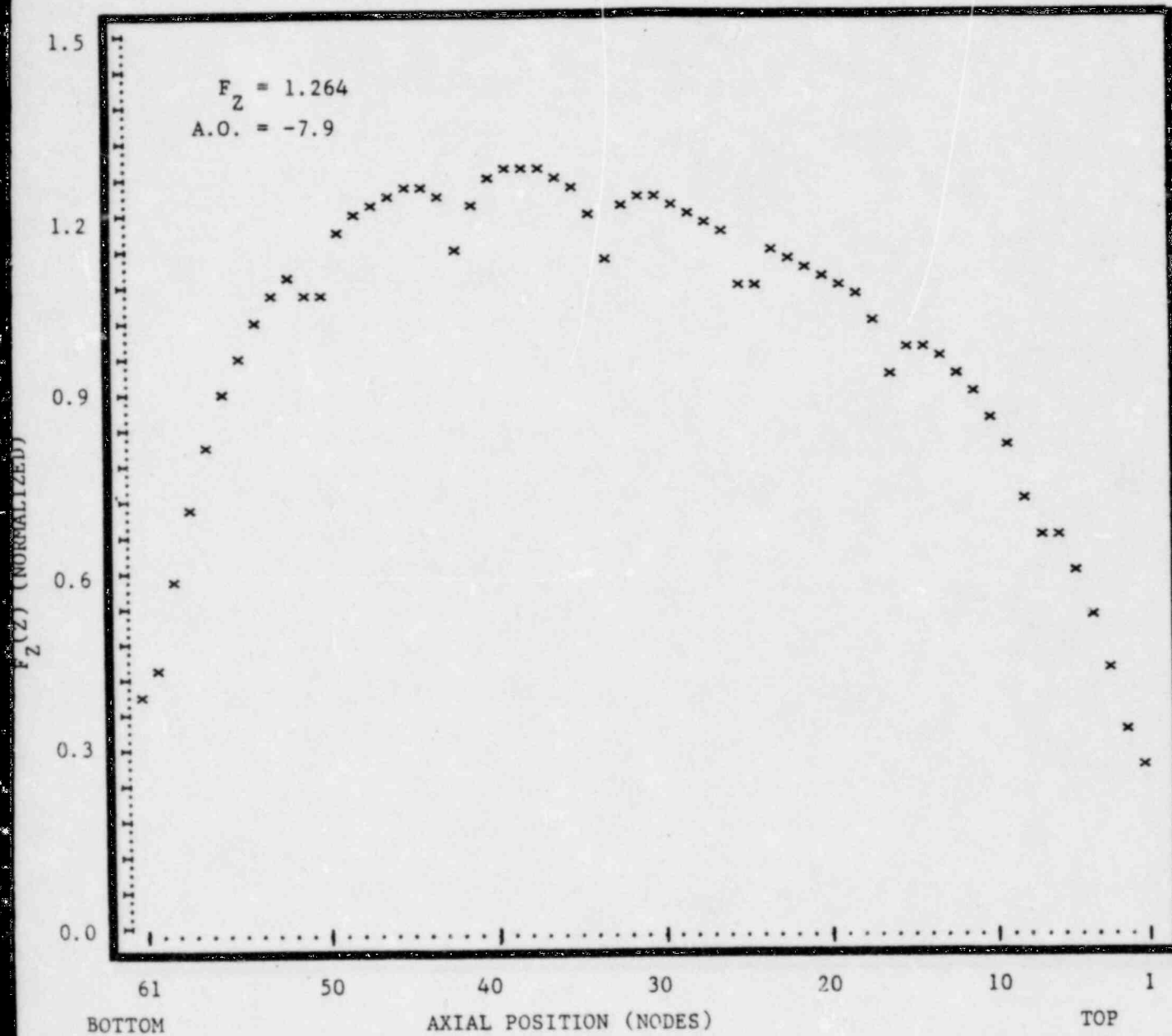
NORTH ANNA UNIT 1-CYCLE 3CORE AVERAGE AXIAL POWER DISTRIBUTIONN1-3-14

Figure 4.12

NORTH ANNA UNIT 1-CYCLE 3
CORE AVERAGE AXIAL POWER DISTRIBUTION
N1-3-33

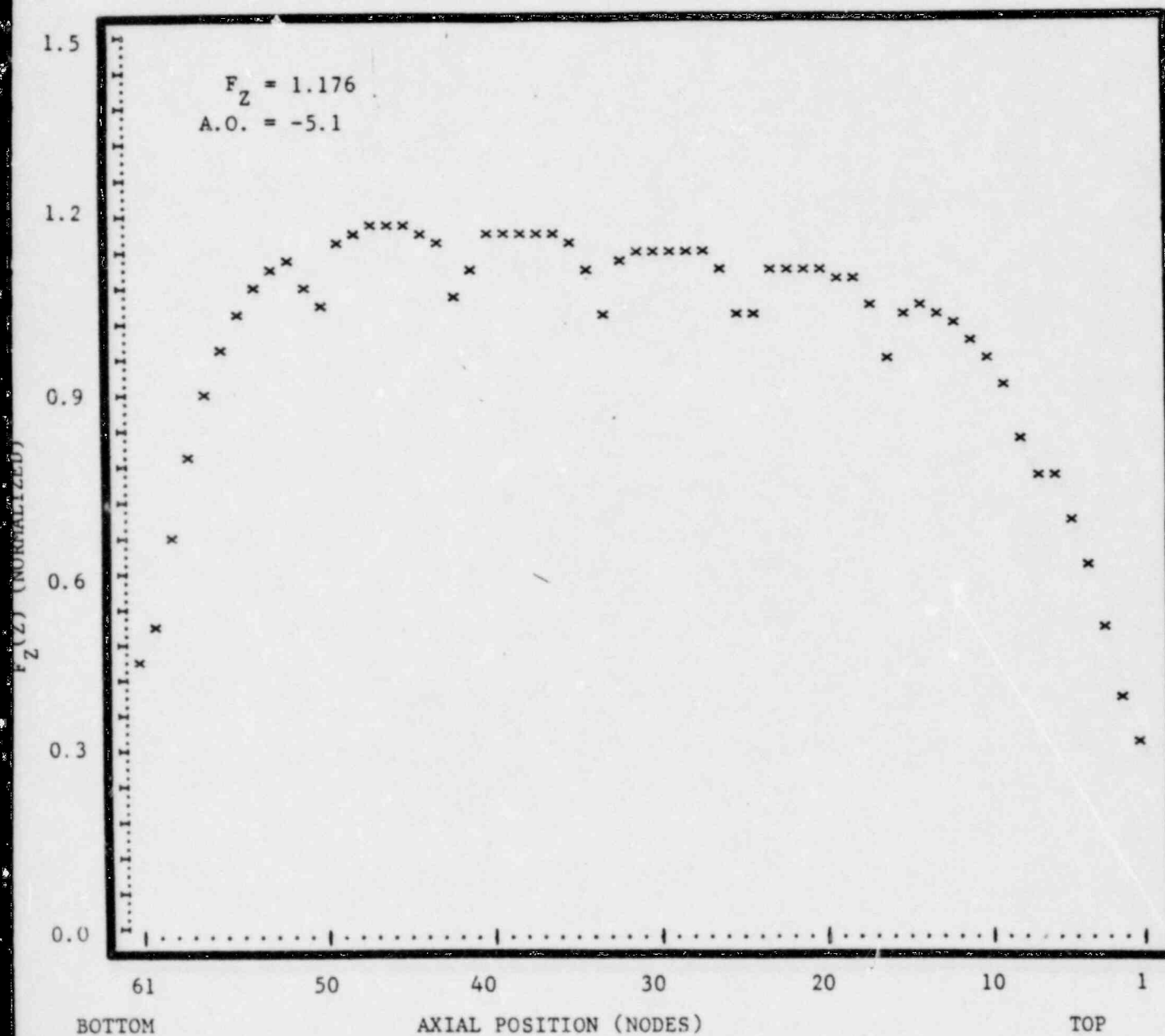


Figure 4.13

NORTH ANNA UNIT 1-CYCLE 3
CORE AVERAGE AXIAL POWER DISTRIBUTION

N1-3-87

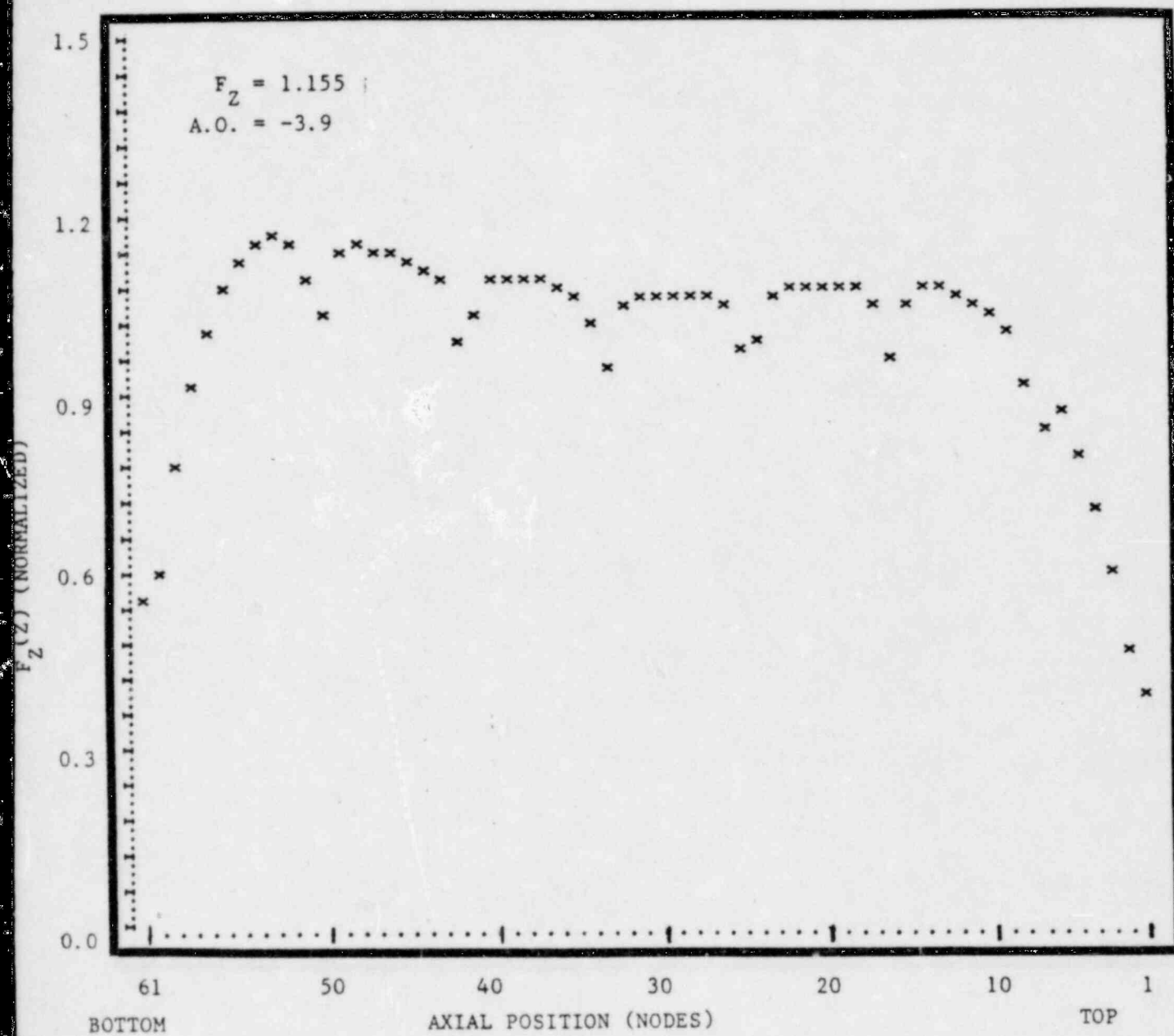
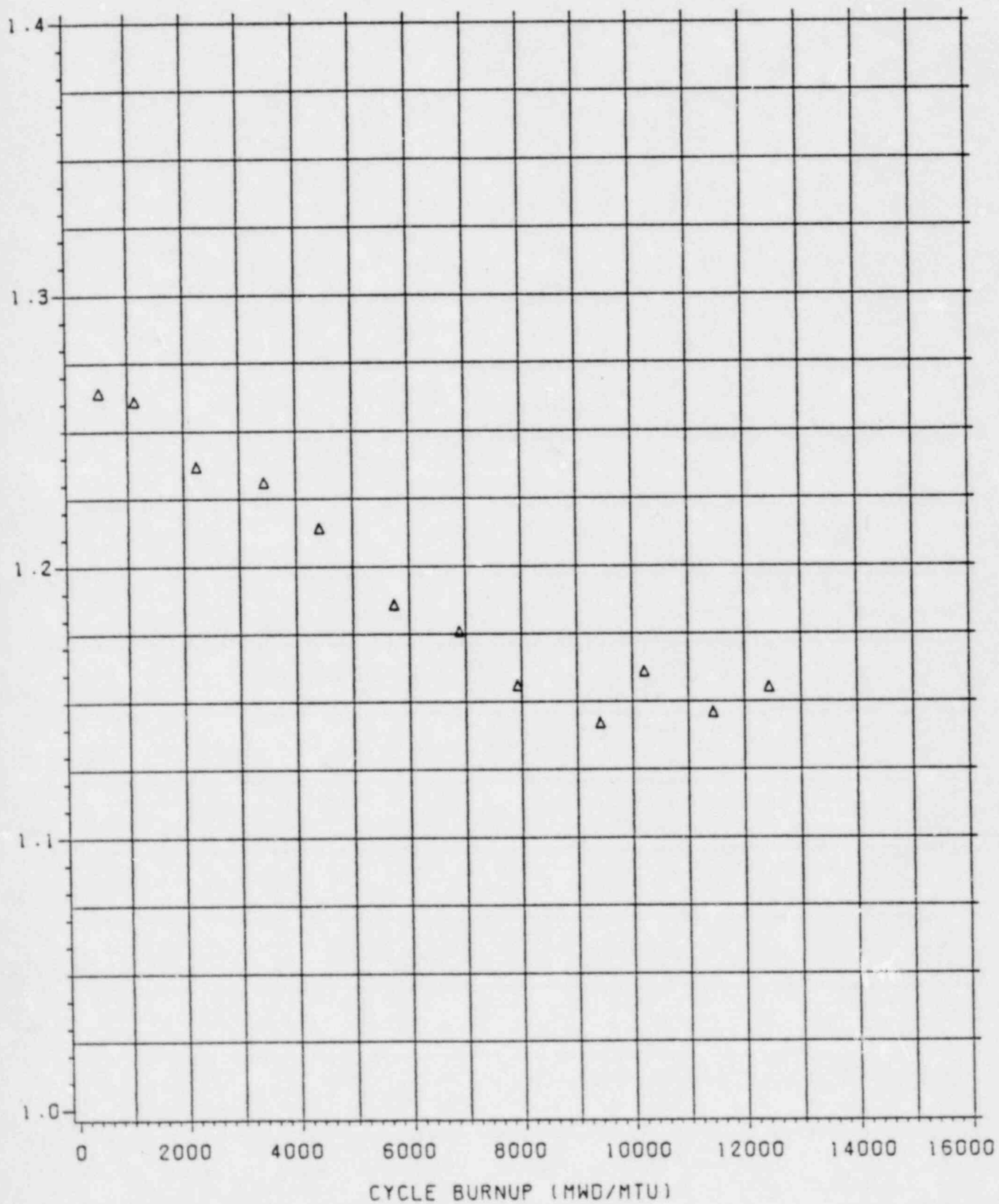


FIGURE 4.14

NORTH ANNA UNIT 1 - CYCLE 3
CORE AVERAGE AXIAL PEAKING FACTOR, F-Z VS. BURNUP



Section 5

PRIMARY COOLANT ACTIVITY FOLLOW

Activity levels of iodine-131 and 133 in the primary coolant are important in core performance follow analysis because they are used as indicators of defective fuel. Additionally, they are also important with respect to the offsite dose calculation values associated with accident analyses. Both I-131 and I-133 can leak into the primary coolant system through a breach in the cladding. As indicated in the North Anna 1 Technical Specifications, the dose equivalent I-131 concentration in the primary coolant was limited to 1.0 micro-Ci/gm for normal steady state operation. Figure 5.1 shows the dose equivalent I-131 activity level history for the North Anna 1, Cycle 3 core (the demineralizer flow rate averaged 87 gpm during power operation). The data demonstrate considerable scatter due to the erratic power history but the trend shows a decreasing equilibrium coolant activity level during Cycle 3. The large increase in the coolant activity level that occurred early in Cycle 3 indicates a possible defect formation event during the first weeks of Cycle 3 operation. After that time, the equilibrium coolant activity level shows that no further cladding degradation occurred during the remainder of the cycle.

Despite the increased coolant activity level, Figure 5.1 shows that the core operated substantially below the 1.0 micro-Ci/gm limit during steady-state operation (the spike data are associated with power transients and unit shutdown). Specifically, the average dose

equivalent I-131 concentration of 8.2×10^{-2} micro-Ci/gm is less than 9% of the Technical Specification limit.

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 out leaving the I-131 dominant in activity, thereby causing the ratio to be 0.5 or more. In the case of large leaks, uranium particles in the coolant, and/or "tramp" uranium*, where the diffusion mechanism is negligible, the I-131/I-133 ratio will generally be less than 0.1. Figure 5.2 shows the I-131/I-133 ratio data for the North Anna 1, Cycle 3 core. These data generally indicate there were probably pinhole defects in the fuel used during Cycle 3.

The core off-load fuel inspection following Cycle 3 operation revealed no fuel assembly damage which would adversely affect the performance of the fuel to be used in subsequent cycles. The absence of any significant fuel integrity anomalies during the core off-load indicates that satisfactory fuel operability can be expected during Cycle 4.

*"Tramp" uranium consists of small particles of uranium which adhere to the outside of the fuel during the manufacturing process.

FIGURE 5.1

NORTH ANNA UNIT 1 - CYCLE 3 DOSE EQUIVALENT I-131 vs. TIME

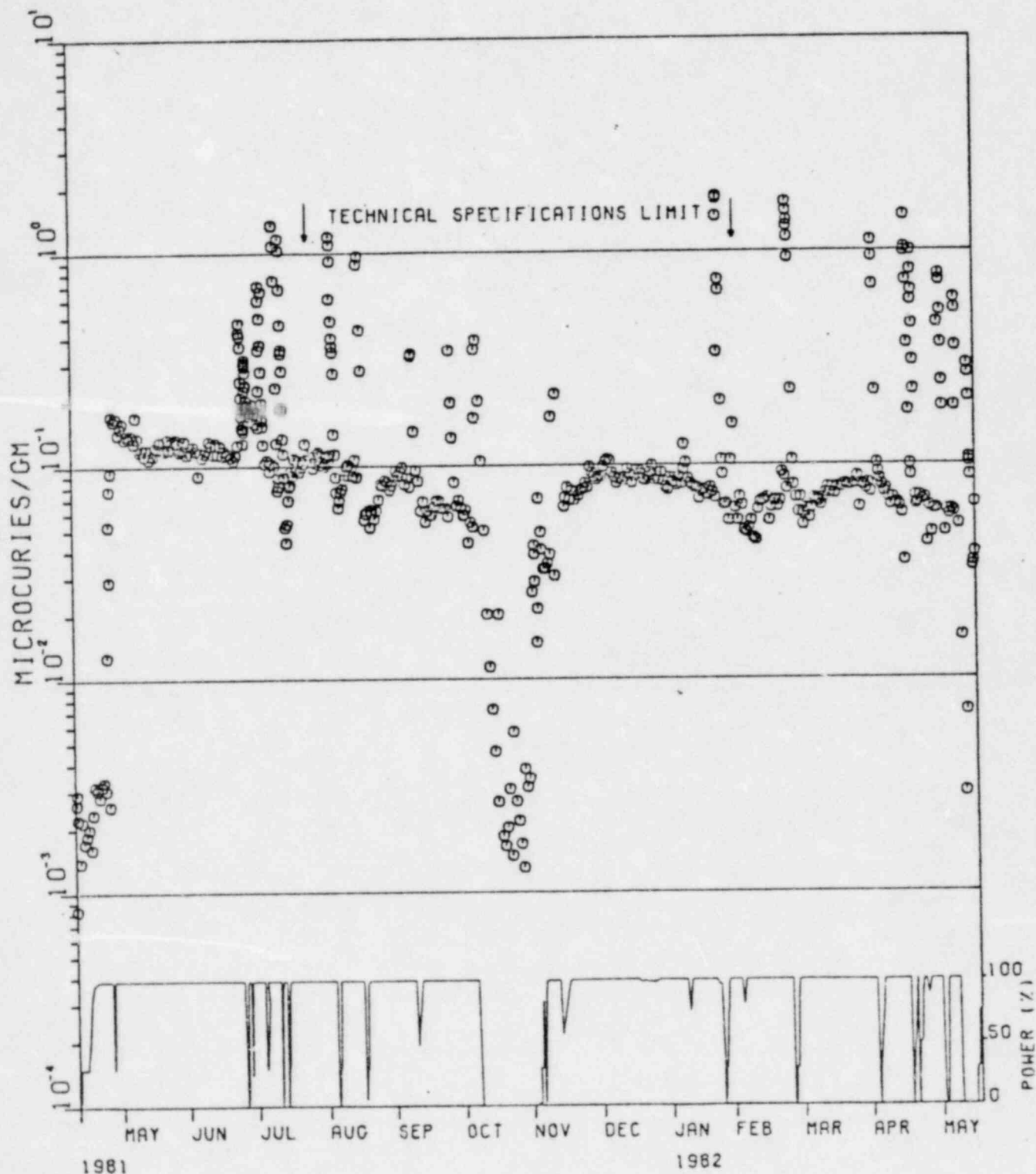
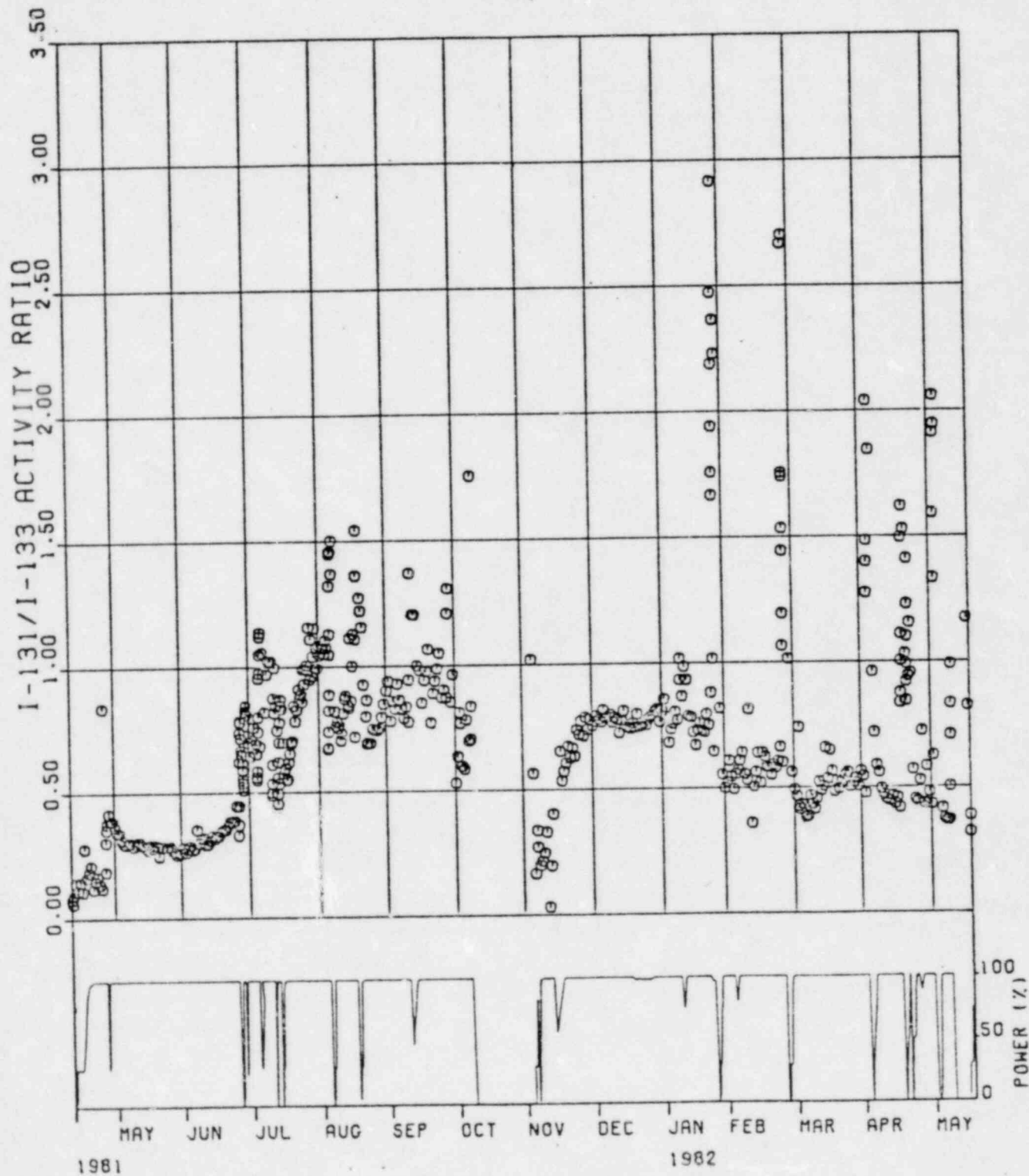


FIGURE 5.2

NORTH ANNA UNIT 1 - CYCLE 3 I-131/I-133 ACTIVITY RATIO. vs. TIME



Section 6

CONCLUSIONS

The North Anna 1 core has completed Cycle 3 operation. Throughout this cycle, all core performance indicators compared favorably with the design predictions and all core related Technical Specifications limits were met with significant margin. No abnormalities in reactivity or burnup accumulation were detected. In addition, the mechanical integrity of the fuel has not changed significantly throughout Cycle 3 as indicated by the radioiodine analysis.

Section 7

REFERENCES

- 1) T. S. Rotella and D. M. Kapuschinsky, "North Anna Unit 1, Cycle 3 Startup Physics Test Report," VEP-FRD-43, May, 1981.
- 2) North Anna Power Station Unit 1 Technical Specifications, Sections 3/4.1, 3/4.2, and 3/4.4.
- 3) T. K. Ross, "NEWTOTE Code", Vepco NFO-CCR-6, Revision 3, February, 1982.
- 4) R. D. Klatt, W. D. Leggett, III, and L. D. Eisenhart, "FOLLOW Code," WCAP-7182, February, 1970.
- 5) W. D. Leggett, III and L. D. Eisenhart, "INCORE Code," WCAP-7149, December, 1967.
- 6) J. R. Ju and T. S. Rotella, "North Anna Unit 1, Cycle 2 Core Performance Report," VEP-FRD-40, March, 1981.
- 7) Letter from L. B. Engle (NRC) to R. H. Leasburg (Vepco), dated April 13, 1982 (Docket Nos. 50-338 and 50-339).