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NORTH ANNA UNIT 1, CYCLE 1

CORE PERFORMANCE REPORT

BY

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Section 1

INTRODUCTION AND SUMMARY

On September 25, 1979 after more than eighteen months of operation, North Anna Unit 1 completed Cycle 1. Since the initial criticality of Cycle 1 on April 5, 1978, the reactor core produced approximately 94 x 10^6 MBTU (15,892 Megawatt days per metric ton of contained uranium) which has resulted in the generation of approximately 8.7 x 10^9 kwhr gross (8.2 x 10^9 kwhr net) of electrical energy. North Anna 1, Cycle 1 reached the end of full power reactivity at a core burnup of approximately 15,150 MWD/MTU at which point power operation was continued through a power coastdown. The unit was operated in the power coastdown mode and at reduced power levels achieving ar additional 742 MWD/MTU burnup prior to shutting down for refueling. The purpose of this report is to present an analysis of the core performance for routine operation during Cycle 1. The physics tests that were performed during the startup of this cycle were covered in the North Anna 1, Cycle 1 Startup Physics Test Report[1] and, therefore, will not be included here.

The first cycle core consisted of three fresh batches of fuel. The North Anna 1, Cycle 1 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,

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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 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 Specifications, and to assess the integrity of the fuel.

Each of the four performance indicators is discussed in detail for the North Anna 1, Cycle 1 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 ±0.8% with the burnup accumulation in each batch deviating from design prediction by less than 2%.

2. Reactivity Depletion Follow - The critical boron concentration, used to monitor reactivity depletion, was consistently within ±0.6% $\Delta K/K$ of the design prediction which is well within the ±1% $\Delta K/K$ margin allowed by Section 3.1.1.1 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 approximately 1.27%. All hot channel factors met their respective Technical Specifications limits.

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4. <u>Primary Coolant Activity Follow</u> - The dose equivalent iodine-131 activity level in the primary coolant at the end of Cycle 1 was approximately 2.48×10^{-2} μCi/gm. This corresponds to less than 3% 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.

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NORTH ANNA 1 - CYCLE 1 — FIGURE 1.1

CORE LOADING

	R	P	N	M	L	K	J	H	G	F	E	D	C	B	A
1							C32	C22	C05						
2					C13	C36	C40 16P PS	A18	C39 16P	C07	C48				
3				C30	C15 12P	B17 16P	A27	B24 12P SS	A36	B50 16P	C47 12P	C23			
4			C20	A26	B15 16P	A06	B51 16P	A10	B33 16P	A05	B37 16P	A51	C38		
5		C27	C09 12P	B07 16P	A32	B16 16P	A02	B38 20P	A40	B18 16P	A42	B39 16P	C18 12P	C51	
6		C45	B45 16P	A24	B22 16P	A44	B09 16P	A21	B31 16P	A13	B23 16P	A38	B02 16P	C17	
7	C43	C04 16P	A50	B05 16P	A19	B06 16P	A48	B43 20P	A14	B47 16P	A30	B12 16P	A04	C06 16P	C28
8	C52	A43	B27 12P	A25	B41 20P	A08	B35 20P	A01	B14 20P	[illegible]	B03 20P	A49	B08 12P	A34	C41
9	C14	C26 16P	A46	B36 16P	A09	B21 16P	A12	B30 20P	A39	B49 16P	A37	B32 16P	A03	C50 16P	C49
10		C21	B20 16P	A23	B52 16P	A15	B11 16P	A47	B34 16P	A16	B04 16P	A29	B28 16P	C03	
11		C42	C16 12P	B48 16P	A53	B10 16P	A33	B25 20P	A45	B01 16P	A07	B42 16P	C34 12P	C12	
12			C37	A31	B40 16P	A41	B13 16P	A52	B26 16P	A17	B29 16P	A11	C24		
13				C29	C35 12P	B46 16P	A28	B44 12P SS	A22	B19 16P	C01 12P	C11			
14					C44	C08	C46 16P	A35	C33 16P PS	C19	C10				
15							C02	C31	C25						

FUEL ASSEMBLY DESIGN PARAMETERS

	A-Batch 1	B-Batch 2	C-Batch 3
Initial Enrichment (w/o U235)	2.10	2.60	3.10
Assembly Type	17x17	17x17	17x17
No. Of Assemblies	53	52	52
Fuel Rods per Assembly	264	264	264

[box] ← Assembly Identification
← One or more of the following:

a. PS - Primary Source Assembly

b. SS - Secondary Source Assembly

c. xxP - Burnable Poison Assembly (xx - number of rods)

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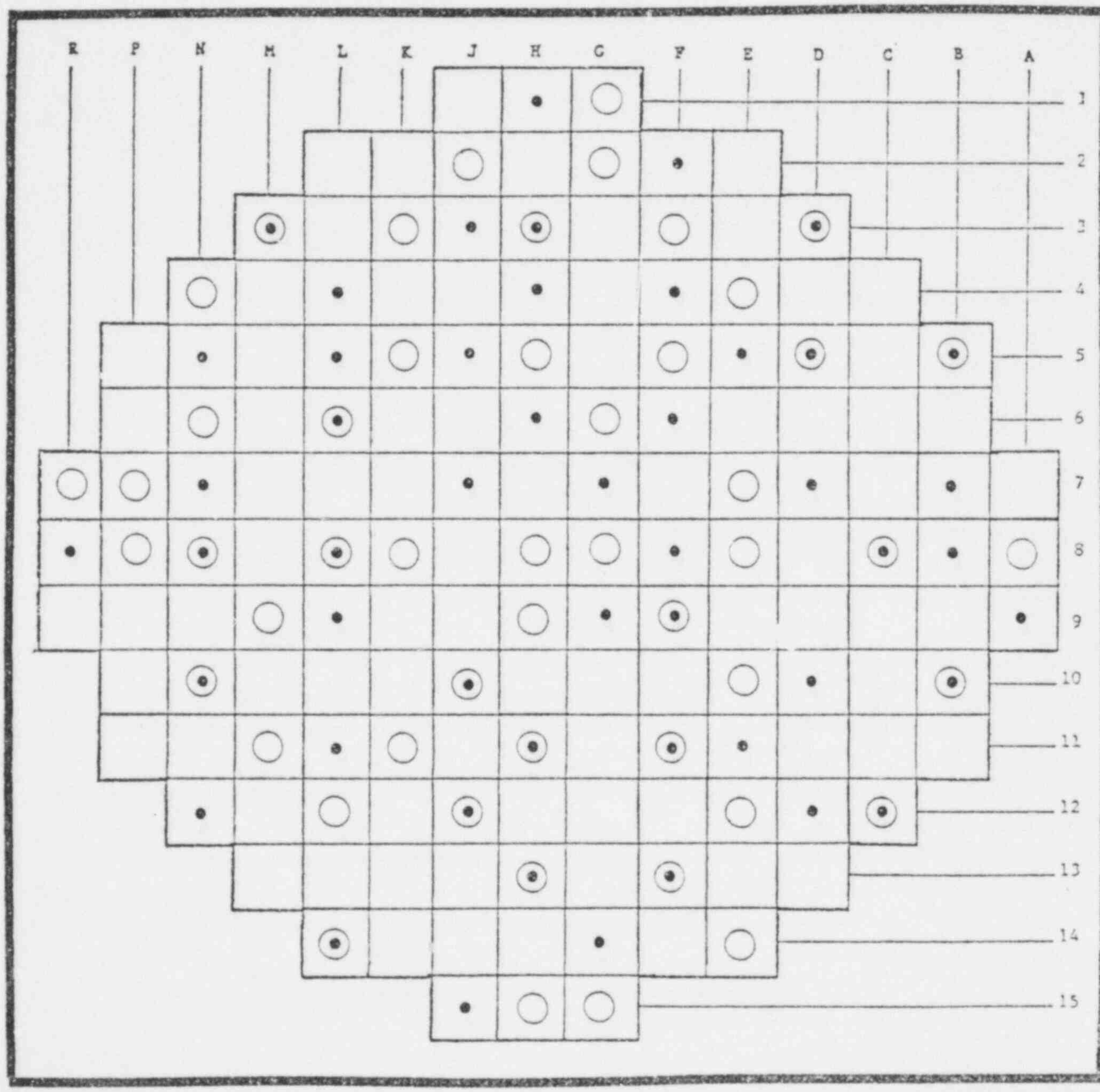
NORTH ANNA UNIT 1-CYCLE 1

MOVABLE DETECTOR AND

THERMOCOUPLE LOCATIONS



• - Movable Detector Location

○ - Thermocouple Location

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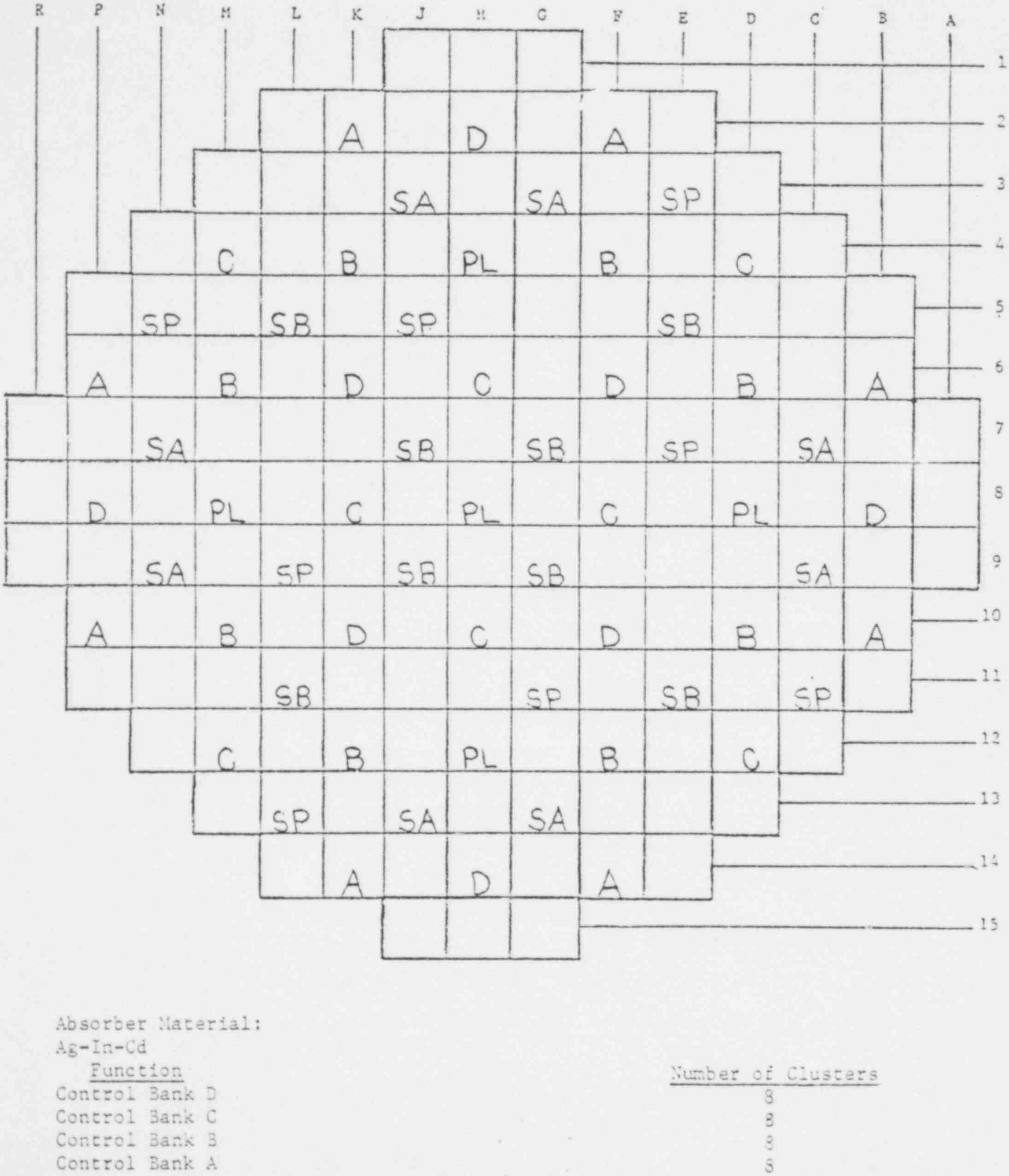
NORTH ANNA 1 - CYCLE 1

CONTROL ROD LOCATIONS

FIGURE 1.3



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 S_B	8
Shutdown Bank S_A	8
Part Length P_L	5
SP (Spare Rod Locations)	8

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BURNUP FOLLOW

The burnup history for the North Anna Unit 1, Cycle 1 core is graphically depicted in Figure 2.1. The North Anna 1, Cycle 1 core achieved a burnup of 15,892 MWD/MTU. As shown in Figure 2.2, the average load factor for Cycle 1 was 76% 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 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 1 operation is given. For comparison purposes, the design values are also given. As can be seen from this figure, the accumulated assembly burnups were generally within ±2.5% of the predicted values. In addition, deviation from quadrant symmetry in the core, as indicated by the burnup tilt factors, was less than ±0.8%. The deviation from quadrant symmetry was slightly higher than expected. It was a direct result of a slight quadrant power tilt that developed approximately two thirds through the cycle. The power tilt will be addressed further in Section 4.

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. As seen in Figure 2.4, the batch burnup sharing for North Anna Unit 1, Cycle 1 followed design predictions very closely with each batch deviating less than 2% from design; this is considered excellent agreement. The good agreement between actual and predicted assemblywise burnups and batch burnup sharing indicate that the Cycle 1 core did deplete essentially as designed.

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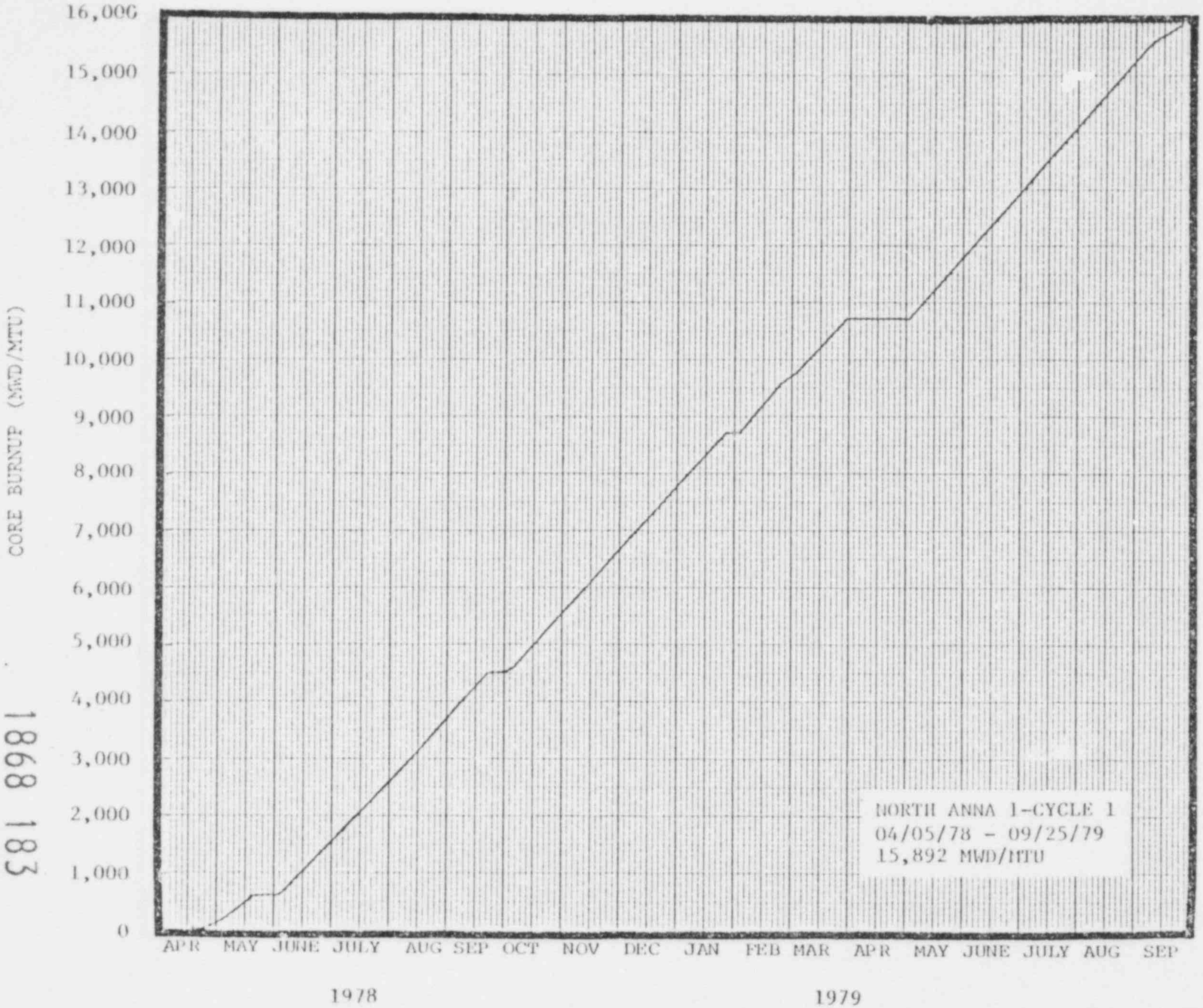
FIGURE 2.1

NORTH ANNA 1 - CYCLE 1

CORE BURNUP HISTORY



POOR ORIGINAL

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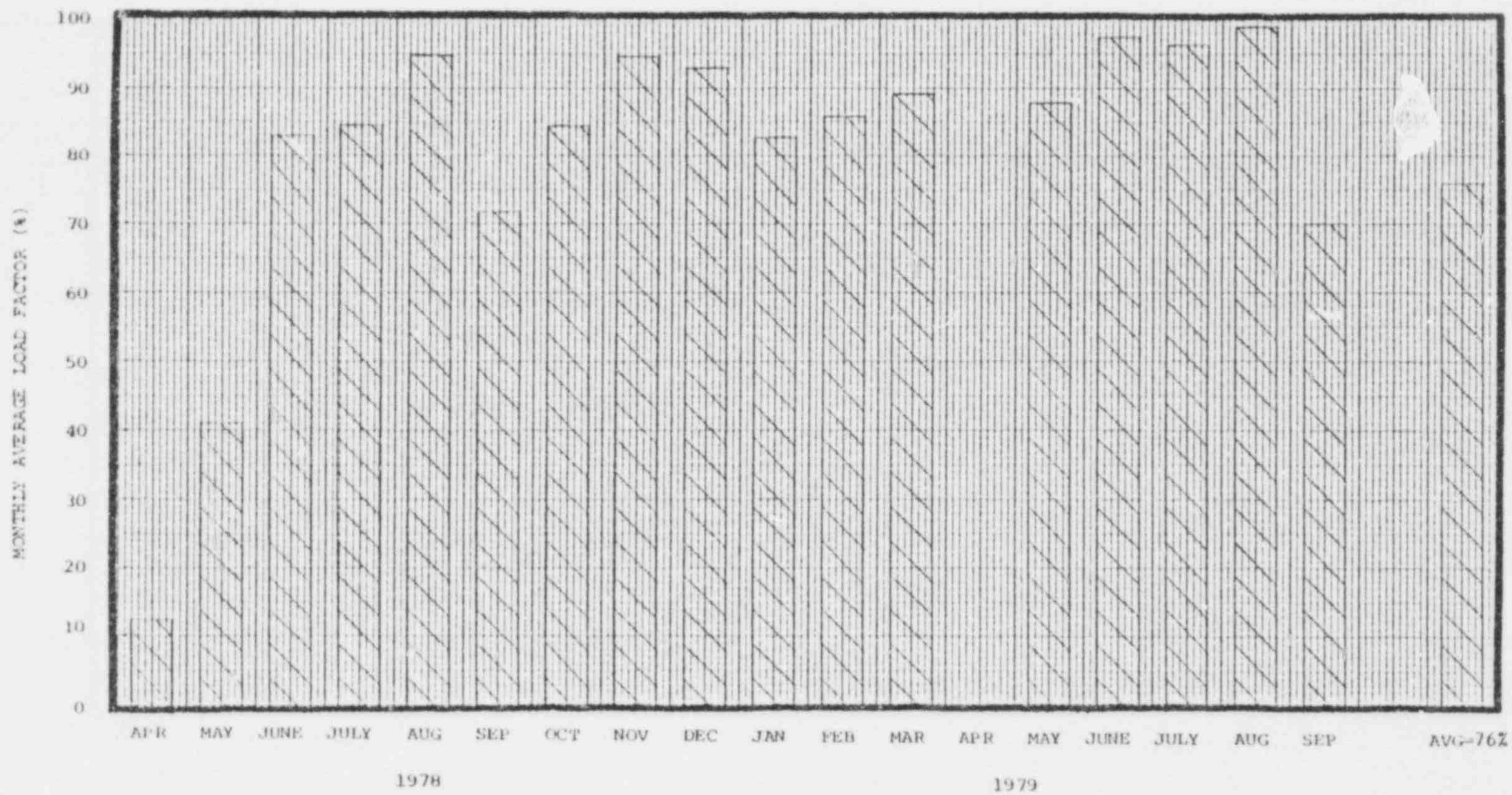
FIGURE 2.2

NORTH ANNA 1 - CYCLE 1

MONTHLY AVERAGE LOAD FACTORS



$$\text{Load Factor} = \frac{\text{Thermal Energy Generation in Reporting Period (MWHt)}}{\text{Authorized Power Level (MWt) x Hours in Reporting Period (excludes refueling outages)}}$$

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NORTH ANNA UNIT 1 - CYCLE 1 FIGURE 2.3

ASSEMBLYWISE ACCUMULATED BURNUP: COMPARISON OF MEASURED WITH PREDICTED

(10^3 MWD/MTU)

	R	P	N	M	L	K	J	H	G	F	E	D	C	B	A
1							9.26 8.90 +4.0	11.68 11.33 +3.1	9.18 8.90 +3.1						
2					9.48 9.26 +2.4	13.67 13.43 +1.8	15.60 15.46 +0.9	15.21 15.17 +0.3	15.57 15.46 +0.7	13.58 13.43 +1.1	9.51 9.26 +2.7				
3				10.31 10.18 +1.3	15.39 15.23 +1.1	16.57 16.39 +1.1	16.99 17.08 -0.5	18.05 18.25 -1.1	17.01 17.08 -0.4	16.72 16.39 +2.0	15.63 15.23 +2.6	10.48 10.18 +2.9			
4			10.21 10.18 +0.3	13.99 13.89 +0.7	16.98 16.77 +1.3	17.72 17.61 +0.6	18.61 18.68 -0.4	18.15 18.28 -0.7	18.56 18.68 -0.6	17.87 17.61 +1.5	17.12 16.77 +2.1	14.17 13.89 +2.0	10.47 10.18 +2.8		
5		9.16 9.26 -1.1	15.04 15.23 -1.2	16.74 16.77 -0.2	17.62 17.68 -0.3	18.84 18.92 -0.4	18.52 18.59 -0.4	18.84 18.84 0.0	18.58 18.59 -0.1	19.13 18.92 +1.1	17.84 17.68 +0.9	16.99 16.77 +1.3	15.64 15.23 +2.7	9.70 9.26 +4.8	
6		13.39 13.43 -0.3	16.44 16.39 +0.3	17.55 17.61 -0.3	18.85 18.92 -0.4	18.59 18.75 -0.9	19.38 19.44 -0.3	18.74 18.78 -0.2	19.41 19.44 -0.2	18.75 18.75 0.0	18.86 18.92 -0.3	17.58 17.61 -0.2	16.55 16.39 +1.0	13.66 13.43 +1.7	
7	9.08 8.90 +2.0	15.46 15.46 0.0	17.02 17.08 -0.4	18.41 18.68 -1.4	18.03 18.59 -3.0	19.06 19.44 -2.0	18.73 18.82 -0.5	19.06 19.03 +0.2	18.77 18.82 -0.3	19.41 19.44 -0.2	18.39 18.59 -1.1	18.35 18.68 -1.8	16.88 17.08 -1.2	15.35 15.46 -0.7	9.03 8.90 +1.5
8	11.13 11.33 -1.8	15.06 15.[illegible]7 -0.[illegible]	18.07 18.25 -1.0	18.03 18.28 -1.4	18.50 18.84 -1.3	18.52 18.78 -1.4	19.07 19.03 +0.2	18.68 18.69 -0.1	18.94 19.03 -0.5	18.60 18.78 -1.0	18.58 18.84 -1.4	17.90 18.28 -2.1	17.97 18.25 -1.5	15.20 15.17 +0.2	11.52 11.33 +1.7
9	8.88 8.[illegible] [illegible].2	[illegible].25 15.46 -1.4	16.76 17.08 -1.9	18.34 18.68 -1.8	18.21 18.59 -2.0	18.92 19.44 -2.7	18.18 18.82 -3.4	18.75 19.03 -1.5	18.57 18.82 -1.3	19.16 19.44 -1.4	18.35 18.59 -1.3	18.47 18.68 -1.1	17.00 17.08 -0.5	15.59 15.46 +0.8	9.10 8.90 +2.2
10		13.26 13.43 -1.3	16.27 16.39 -0.7	17.48 17.61 -0.7	18.80 18.92 -0.6	18.26 18.75 -2.6	18.74 19.44 -3.6	18.30 18.78 -2.6	18.95 19.44 -2.5	18.38 18.75 -2.0	18.70 18.92 -1.2	17.78 17.61 +1.0	16.48 16.39 +0.5	13.61 13.43 +1.3	
11		9.40 9.26 +1.5	15.44 15.23 +1.4	16.99 16.77 +1.3	17.62 17.68 -0.3	18.48 18.92 -2.2	17.98 18.59 -3.3	18.29 18.84 -2.9	18.01 18.59 -3.1	18.73 18.92 -1.0	17.83 17.68 +0.8	17.26 16.77 +2.9	15.62 15.23 +2.6	9.42 9.26 +1.7	
12			10.53 10.18 +3.4	14.30 13.89 +3.0	17.07 16.77 +1.8	17.33 17.61 -1.6	18.08 18.68 -3.2	17.65 18.28 -3.4	18.19 18.68 -2.6	17.50 17.61 -0.6	17.01 16.77 +1.4	14.34 13.89 +3.2	10.36 10.18 +1.7		
13				10.47 10.18 +2.8	15.56 15.23 +2.2	16.26 16.39 -0.8	16.54 17.08 -3.2	17.68 18.25 -3.1	16.70 17.08 -2.2	16.31 16.39 -0.5	15.66 15.23 +2.8	10.57 10.18 +3.8			
14					9.47 9.26 +2.3	13.66 13.43 +1.7	15.37 15.46 -0.6	14.93 15.17 -1.6	15.17 15.46 -1.9	13.29 13.43 -1.0	9.28 9.26 +0.2				
15							9.12 8.90 +2.5	11.32 11.33 -0.1	8.82 8.90 -0.9						

BURNUP SHARING
(10^3 MWD/MTU)

BATCH	BURNUP
1	17.41
2	18.08
3	12.17
CORE AVERAGE 15.89	

Legend (each box, top to bottom): ← MEASURED, ← PREDICTED, ← % DIFFERENCE

BURNUP TILT

NW - 1.0010
NE - 1.0077
SW - 0.9928
SE - 0.9985

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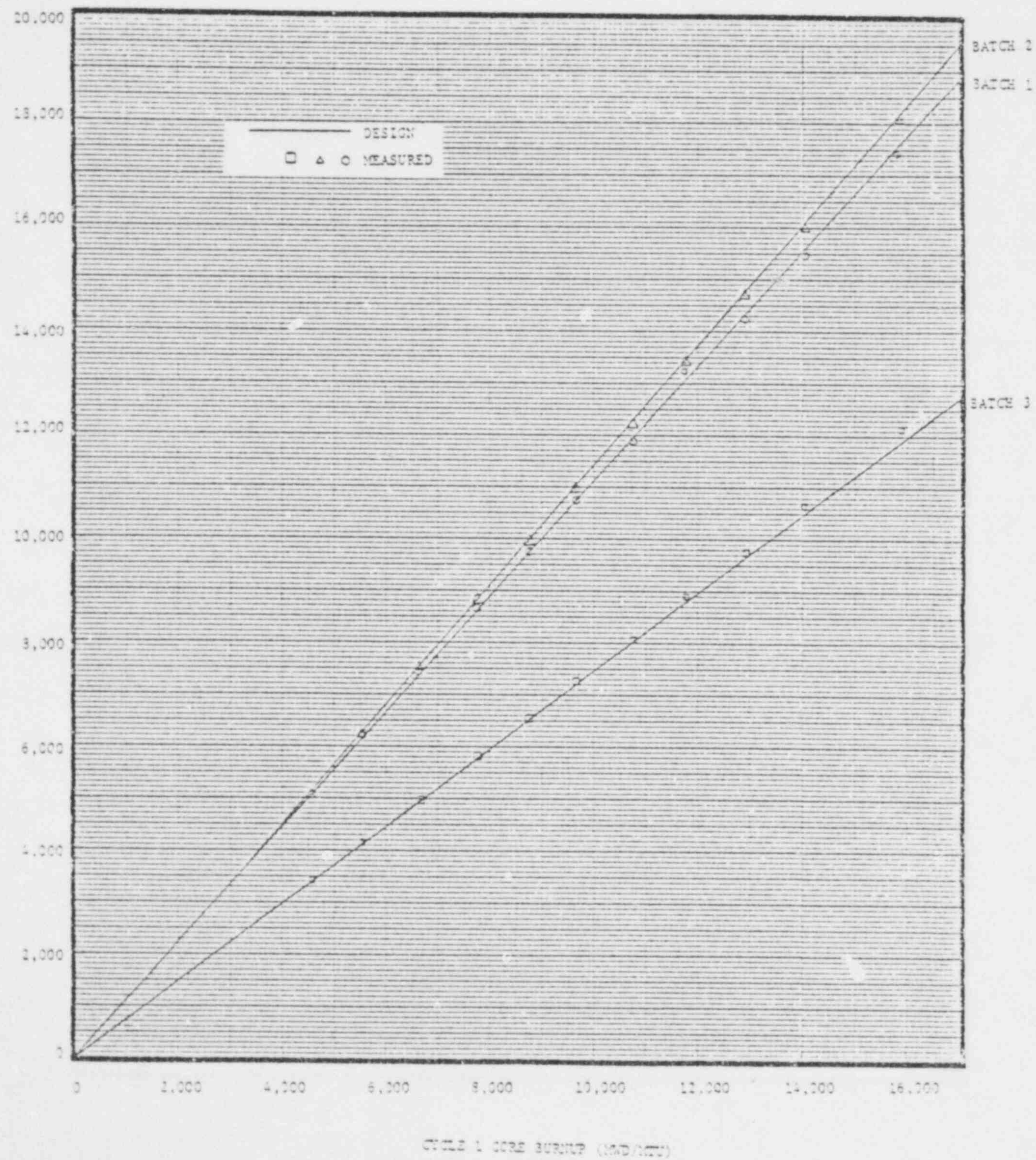
FIGURE 2.4

NORTH ANNA UNIT 1 - CYCLE 1

BATCH BURNUP SHARING



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[4] 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 1 core is shown in Figure 3.1. It can be seen that the measured data compare to within 60 ppm of the design prediction. This corresponds to less than ±0.6% $\Delta K/K$, which is well within the ±1% $\Delta K/K$ criteria for reactivity anomalies set forth in Section 3.1.1.1 of the Technical Specifications. In conclusion, the trend indicated by the critical boron concentration verifies that the Cycle 1 core depleted as expected without any reactivity anomalies.

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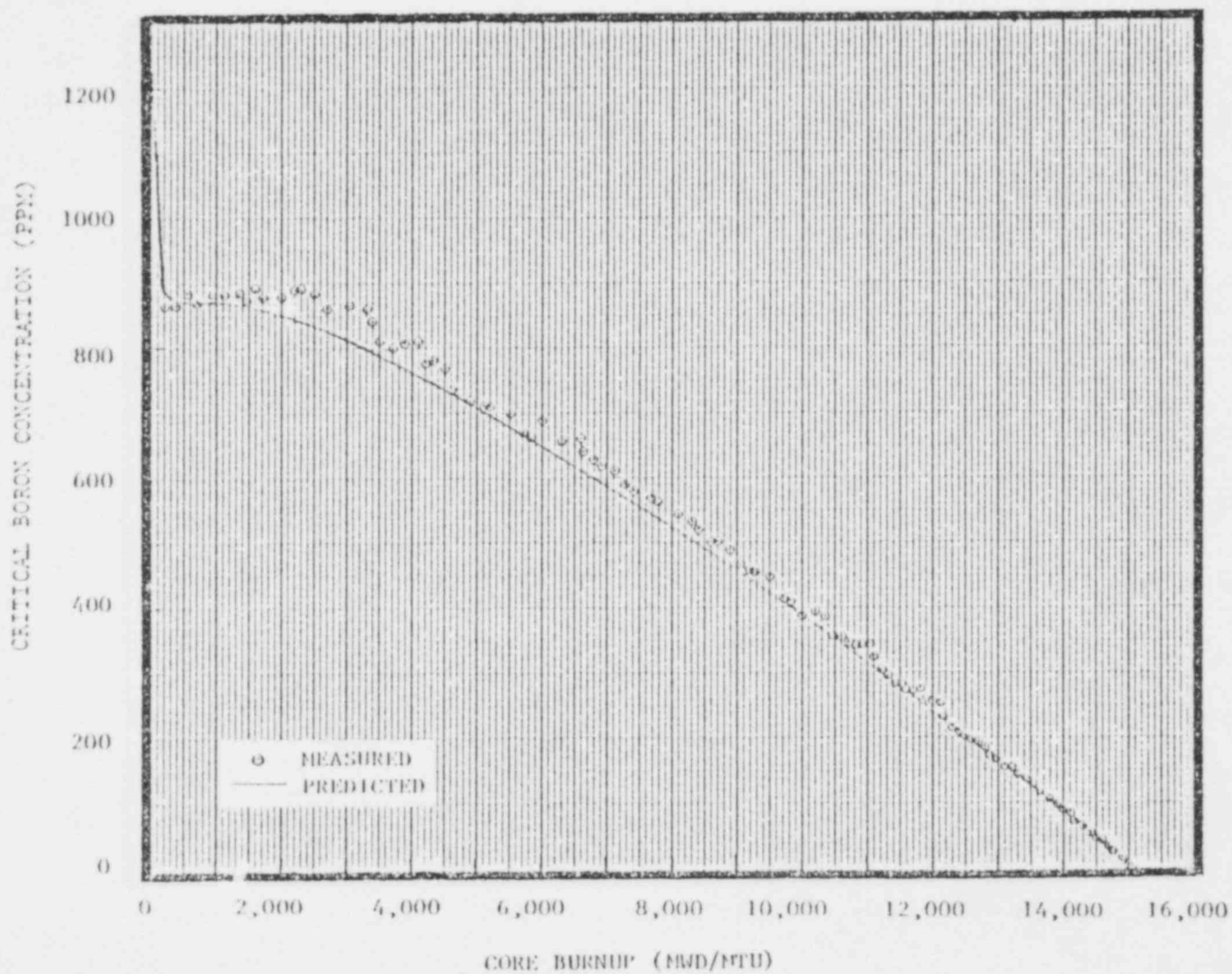
FIGURE 3.1

NORTH ANNA UNIT 1 - CYCLE 1

CRITICAL BORON CONCENTRATION vs. BURNUP

HFP-ARO



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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 INCORE[5] computer program. A summary of all monthly flux maps taken since the completion of startup physics testing for North Anna 1, Cycle 1 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 1 life. Most of the radial power distributions were taken under equilibrium operating conditions with the unit operating at approximately full power. In each case, the measured relative assembly powers were generally within 2.2% of the predicted values with an average percent difference of less than 1.3% which is considered good agreement.

With the core burnup at approximately 10,800 MWD/MTU, the quadrant power tilt ratio was determined to be 1.3% at full power. This represented a significant increase with respect to earlier values. The Technical Specifications limit for the quadrant power tilt ratio is 2%. Potential mechanisms

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for causing the tilt indication including measurement inadequacies, fuel variation, system perturbations, and reactivity control component anomalies were reviewed. The results of this review suggested that several rod cluster control assembly (RCCA) rodlets may have dropped into the core. However, based on an inspection that was performed during the refueling shutdown it was determined that the RCCA rodlets were intact. At this time, the mechanism causing the tilt indication has not been identified.

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. The initial Cycle 1 Technical Specifications limit on the axially dependent heat flux hot channel factor, $F^T_Q(Z)$, was 2.05 x K(Z), where K(Z) is the hot channel factor normalized operating envelope. On May 19, 1978 with the core at a burnup of approximately 601 MWD/MTU, the Technical Specifications limit for $F^T_Q(Z)$ was changed to 2.21 x K(Z) by taking advantage of available margin to the 2200 ^oF LOCA limit on peak clad temperature.[6] Figure 4.4 is a plot of the K(Z) curve associated with the 2.21 $F_Q(Z)$ limit. This curve is representative of the K(Z) curves used throughout Cycle 1 since K(Z) changes only slightly with changes in the $F_Q(Z)$ limit. The axially dependent heat flux hot channel factors, $F^T_Q(Z)$, for a representative set of flux maps are given in Figures 4.5 through 4.7. Throughout Cycle 1, the measured values of $F^T_Q(Z)$ were within the Technical Specifications limit. A summary of the maximum values of all heat flux hot channel factors measured during Cycle 1 is given in Figure 4.8. As can be seen from this figure, there was approximately 3% margin to the limit at the beginning of the cycle, with the margin increasing substantially throughout cycle operation.

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The value of the enthalpy rise hot channel factor, $F^N_{\Delta H}$, 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 also 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 $F^N_{\Delta H}$ limit ensures that the value of this parameter used in the LOCA-ECCS analysis is not exceeded during normal operation. The Cycle 1 Technical Specifications limit on the enthalpy rise hot channel factor was set at 1.55 x (1+0.2(1-P)) x (1-RBP(BU)) where RBP(BU) is the thimble cell rod bow penalty and P is percent thermal power. The RBP(BU) values specified in the Technical Specifications are given in Figure 4.9. Figure 4.10 shows that all measured values for $F^N_{\Delta H}$, were within the Technical Specifications limits during Cycle 1.

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 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 delta flux versus burnup, given in Figure 4.11, shows the value of this parameter

*Delta Flux = $\frac{Pt-Pb}{2775}$ x 100 where Pt = power in top of core (Mw(t))
Pb = power in bottom of core (Mw(t))

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to have been approximately -8% at the beginning of Cycle 1. By the middle of the cycle, the value of delta flux had shifted to approximately -3%, and then shifted to approximately -1.5% by the end of Cycle 1. This power shift can also be observed in the corresponding core average axial power distribution for a representative series of maps given in Figures 4.12 through 4.14. In Map N1-1-25 (Figure 4.12) taken at approximately 300 MWD/MTU, the axial power distribution had a cosine shape with a peak toward the bottom of the core and a peaking factor of 1.39. In Map N1-1-49 (Figure 4.13) taken at approximately 7,260 MWD/MTU, the axial power distribution had flattened considerably and was peaked slightly toward the bottom of the core with an axial peaking factor of 1.17. Finally, in Map N1-1-73 (Figure 4.14) taken at approximately 14,577 MWD/MTU, the axial power distribution was peaked very slightly toward the bottom of the core with a peaking factor of 1.16. The history of $\overline{F}_z$ during the cycle can be seen more clearly in the plot of $\overline{F}_z$ versus burnup given in Figure 4.15.

In conclusion, the North Anna 1, Cycle 1 core performed 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.

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SUMMARY OF INCORE FLUX MAPS FOR ROUTINE OPERATION

MAP NO.	DATE	% PWR	BANK D (STEPS)	CORE $\bar{F}_z$	F_Q^T HOT CHANNEL FACTOR				$F_{\Delta H}^N$ HOT CHANNEL FACTOR			TILT		DELTA FLUX (%)	BURNUP (MWD/MTU)	NO. OF MONITORED THIMBLES
					ASSY.	PIN	AXIAL POINT	$F_Q^{T(1)}$	ASSY.	PIN	$F_{\Delta H}^{N(2)}$	MAX.	QUAD LOC.			
NI-1-25	05/14/78	96.0	216	1.385	J6	AA	37	1.986	J6	AA	1.367	1.0042	NW	-8.5	~300	48
NI-1-26	06/02/78	61.0	191	1.430	P9	QQ	36	2.063	P9	QQ	1.365	1.0055	NE	N/A	~615	47
NI-1-27	06/13/78	90.0	209	1.381	K7	QQ	37	1.973	J6	IA	1.371	1.0057	NE	-8.0	~900	48
NI-1-28(3)	06/13/78	91.0	201	1.416	K7	QQ	37	2.022	J6	IA	1.367	1.0053	NE	N/A	~900	48
NI-1-30	07/03/78	91.0	220	1.353	F7	AI	37	1.939	G6	IA	1.379	1.0060	NE	N/A	~1650	45
NI-1-31	07/11/78	92.9	217	1.331	F7	AI	37	1.913	F7	AI	1.381	1.0079	NE	-5.5	~1970	39
NI-1-32	07/25/78	95.0	224	1.331	F7	AI	37	1.911	G6	IA	1.385	1.0043	NE	-7.5	~2324	48
NI-1-33	08/01/78	98.0	237	1.311	F7	AI	37	1.880	F7	AI	1.380	1.0045	NE	N/A	~2600	48
NI-1-34	08/10/78	87.0	194	1.340	K7	AI	38	1.894	K7	QI	1.360	1.0034	NE	N/A	~2900	48
NI-1-35(4)	08/10/78	86.6	185	1.390	K7	AI	38	1.971	G6	IA	1.366	1.0048	NE	N/A	~2906	39
NI-1-37(5)	08/14/78	96.0	213	1.295	F7	AI	37	1.830	K7	QI	1.369	1.0063	NE	-5.5	~3047	39
NI-1-39	09/11/78	99.0	213	1.259	K9	IQ	37	1.771	K7	QI	1.362	1.0072	NE	N/A	~4095	38
NI-1-40	10/03/78	48.0	178	1.342	G6	IA	29	1.898	G6	AI	1.364	1.0069	NE	N/A	~4545	47
NI-1-41	10/03/78	96.5	202	1.233	K9	IQ	38	1.731	G6	IA	1.351	1.0017	NE	N/A	~4545	45
NI-1-42	10/05/78	73.4	184	1.331	G10	IQ	29	1.879	K7	QI	1.355	1.0051	NE	N/A	~4570	47
NI-1-43	10/06/78	74.7	186	1.282	K9	IQ	37	1.802	K7	QI	1.349	1.0066	NE	N/A	~4595	46
NI-1-44(6)	10/06/78	74.7	179	1.327	K9	IQ	38	1.883	K9	IQ	1.356	1.0063	NE	N/A	~4595	44
NI-1-46	10/06/78	99.5	206	1.233	J6	IA	29	1.754	J6	IA	1.378	1.0036	NW	N/A	~4595	42
NI-1-47	10/17/78	99.8	216	1.223	F7	AI	38	1.707	G6	AI	1.356	1.0055	NE	-5.0	~5011	45
NI-1-48	11/16/78	96.0	220	1.183	G6	IA	21	1.644	K7	QI	1.347	1.0047	NE	N/A	~6060	38
NI-1-49	12/18/78	96.9	224	1.168	G6	IB	20	1.602	G6	IB	1.337	1.0082	NE	-2.5	~7260	39
NI-1-50(7)	12/20/78	96.0	205	1.231	K7	QI	46	1.689	J6	IB	1.333	1.0068	NW	N/A	~7340	38
NI-1-52	01/18/79	96.4	218	1.167	K7	QI	46	1.591	F7	BI	1.317	1.0067	NE	-3.0	~8405	38
NI-1-53	02/14/79	96.7	220	1.158	F5	IB	47	1.562	G6	IB	1.309	1.0082	NE	-2.5	~9135	39
NI-1-54	03/19/79	97.4	228	1.135	F5	IB	47	1.532	F5	IB	1.302	1.0073	NE	-1.5	~10346	39
NI-1-55	05/03/79	99.4	228	1.155	E6	AI	48	1.558	F5	IB	1.295	1.0110	NE	N/A	~10766	45

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 Q, 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 measurement uncertainty of 1.05 and an engineering uncertainty of 1.03.

(2) $F_{\Delta H}^N$ includes a measurement uncertainty of 1.04.

(3) NI-1-29 was a partial map taken for I/E calibration.

(4) NI-1-36 was a partial map taken for I/E calibration.

(5) NI-1-38 was not analyzed; map data was taken during a power distribution transient.

(6) NI-1-45 was a partial map taken for I/E calibration.

(7) NI-1-51 was a partial map taken for I/E calibration.

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TABLE 4.1 (contd.)

NORTH ANNA 1 CYCLE 1

SUMMARY OF INCORE FLUX MAPS FOR ROUTINE OPERATION

MAP NO.	DATE	% PWR	BANK D (STEPS)	CORE $\overline{F}_z$	F_Q^T HOT CHANNEL FACTOR				$F_{\Delta H}^N$ HOT CHANNEL FACTOR			TILT		DELTA FLUX (%)	BURNUP (MWD/MTU)	NO. OF MONITORED THIMBLES
					ASSY.	PIN	AXIAL POINT	$F_Q^{T(1)}$	ASSY.	PIN	$F_{\Delta H}^{N(2)}$	MAX.	QUAD LOC.			
NI-1-56(8)	05/07/79	98.0	216	1.184	E6	A1	48	1.594	F5	FE	1.294	1.0092	NE	N/A	~10890	42
NI-1-58	05/10/79	99.5	228	1.146	F7	EF	12	1.574	F7	EF	1.284	1.0142	NE	N/A	~11003	38
NI-1-59	05/21/79	100.2	228	1.156	K5	LE	52	1.536	F5	FE	1.289	1.0106	NE	N/A	~11390	44
NI-1-60	05/29/79	99.9	218	1.183	F5	FE	53	1.571	F5	FE	1.286	1.0115	NE	-4.0	~11694	47
NI-1-61	05/31/79	65.5	182	1.206	F5	FE	28	1.621	F5	EL	1.296	1.0239	NE	N/A	~11750	47
NI-1-62	06/07/79	99.2	228	1.169	F7	EF	53	1.547	F5	FE	1.277	1.0135	NE	N/A	~12001	49
NI-1-63	06/18/79	99.0	228	1.201	F7	EF	53	1.582	F5	FE	1.278	1.0134	NE	N/A	~12425	49
NI-1-64	07/02/79	100.2	227	1.170	K5	LE	53	1.546	F5	FE	1.262	1.0119	NE	-2.5	~12960	46
NI-1-65(9)	07/17/79	99.3	219	1.168	F5	EL	53	1.529	F5	EL	1.270	1.0153	NE	-2.0	~13525	48
NI-1-67	07/28/79	47.8	165	1.287	L10	FM	53	1.666	E3	ED	1.295	1.0156	NE	N/A	~13961	48
NI-1-68	08/01/79	100.0	220	1.166	F5	EL	53	1.532	F5	EL	1.266	1.0147	NE	N/A	~14070	49
NI-1-69(10)	08/02/79	100.0	213	1.238	F5	EL	53	1.624	F5	EL	1.272	1.0177	NE	N/A	~14110	48
NI-1-72	08/09/79	100.0	220	1.169	F5	EL	53	1.525	F5	EL	1.266	1.0155	NE	N/A	~14382	48
NI-1-73	08/14/79	100.0	220	1.163	F5	EL	53	1.520	F5	EL	1.265	1.0141	NE	-1.5	~14577	48
NI-1-74	08/23/79	100.0	222	1.144	G6	GN	12	1.511	F5	EL	1.264	1.0152	NE	N/A	~14918	48
NI-1-75	08/29/79	97.3	224	1.152	G6	HM	11	1.530	F5	EL	1.258	1.0146	NE	+0.5	~15142	49
NI-1-76	09/07/79	89.3	225	1.180	G6	MN	11	1.563	G5	DE	1.256	1.0140	NE	N/A	~15469	48
NI-1-77	09/14/79	34.0	98-106	1.581	E11	FN	10	2.492	E3	ED	1.437	1.0172	NE	N/A	~15668	49

(8) NI-1-57 was a partial map taken for I/E calibration.

(9) NI-1-66 data analysis was not reliable; map data was taken during a power distribution transient.

(10) NI-1-70 and NI-1-71 data analyses were not reliable; map data was taken during a power distribution transient.

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NORTH ANNA UNIT 1-CYCLE 1

ASSEMBLYWISE POWER DISTRIBUTION N1-1-25

PREDICTED / MEASURED / PCT DIFFERENCE

Row		R	P	N	M	L	K	J	H	G	F	E	D	C	B	A
1	Predicted							0.60	0.79	0.60						
	Measured							0.60	0.79	0.59						
	Pct Difference							1.0	0.9	-0.2						
2	Predicted					0.59	0.88	0.99	1.01	0.99	0.88	0.59				
	Measured					0.59	0.89	0.99	1.01	0.99	0.87	0.58				
	Pct Difference					0.3	0.7	0.0	-0.1	-0.7	-1.3	-1.1				
3	Predicted				0.64	0.92	0.99	1.12	1.18	1.12	0.99	0.92	0.64			
	Measured				0.63	0.91	0.98	1.11	1.17	1.11	0.99	0.91	0.63			
	Pct Difference				-0.7	-0.9	-0.6	-0.4	-0.5	-0.6	-0.0	-0.3	-0.3			
4	Predicted			0.64	0.85	0.99	1.12	1.15	1.19	1.15	1.12	0.99	0.85	0.64		
	Measured			0.63	0.85	0.99	1.12	1.16	1.19	1.15	1.13	0.99	0.85	0.64		
	Pct Difference			-0.4	-0.6	-0.5	0.3	0.2	0.1	-0.3	0.9	0.2	-0.2	0.1		
5	Predicted		0.59	0.92	0.99	1.11	1.15	1.19	1.13	1.19	1.15	1.11	0.99	0.92	0.59	
	Measured		0.58	0.91	0.99	1.11	1.16	1.20	1.14	1.20	1.16	1.12	0.99	0.92	0.59	
	Pct Difference		-1.0	-1.0	-0.6	-0.4	0.3	1.1	1.0	0.7	0.9	0.5	0.1	0.5	1.2	
6	Predicted		0.88	0.99	1.12	1.15	1.20	1.19	1.19	1.19	1.20	1.15	1.12	0.99	0.88	
	Measured		0.88	0.99	1.12	1.16	1.21	1.21	1.21	1.21	1.22	1.15	1.11	0.98	0.88	
	Pct Difference		0.1	0.1	0.2	0.3	1.1	1.7	1.8	1.7	1.3	-0.4	-0.4	-0.4	0.1	
7	Predicted	0.60	0.99	1.12	1.15	1.19	1.19	1.19	1.12	1.19	1.19	1.19	1.15	1.12	0.99	0.60
	Measured	0.60	1.00	1.12	1.15	1.18	1.19	1.20	1.14	1.20	1.20	1.18	1.13	1.11	1.00	0.60
	Pct Difference	1.3	0.1	0.2	-0.2	-0.6	0.2	1.5	1.7	1.4	1.3	-0.5	-1.8	-0.2	0.2	1.3
8	Predicted	0.79	1.01	1.18	1.19	1.13	1.19	1.12	1.15	1.12	1.19	1.13	1.19	1.18	1.01	0.79
	Measured	0.78	1.02	1.18	1.19	1.13	1.20	1.13	1.17	1.12	1.19	1.12	1.17	1.17	1.02	0.80
	Pct Difference	-1.1	0.1	0.0	0.3	0.4	0.9	1.7	1.4	0.4	0.3	-0.8	-1.8	-0.2	0.5	1.4
9	Predicted	0.60	0.99	1.12	1.15	1.19	1.19	1.19	1.12	1.19	1.19	1.19	1.15	1.12	0.99	0.60
	Measured	0.59	0.99	1.11	1.15	1.20	1.19	1.18	1.12	1.18	1.18	1.19	1.15	1.12	1.00	0.60
	Pct Difference	-0.3	-0.7	-0.7	0.0	0.7	0.3	-0.3	0.0	-0.2	-0.3	0.1	-0.3	0.3	0.3	1.1
10	Predicted		0.88	0.99	1.12	1.15	1.20	1.19	1.19	1.19	1.20	1.15	1.12	0.99	0.88	
	Measured		0.88	0.99	1.13	1.18	1.22	1.18	1.18	1.17	1.20	1.16	1.13	0.99	0.88	
	Pct Difference		-0.3	-0.3	1.4	2.2	1.3	-0.9	-0.5	-1.0	-0.2	0.2	1.7	-0.3	-0.5	
11	Predicted		0.59	0.92	0.99	1.11	1.15	1.19	1.13	1.19	1.15	1.11	0.99	0.92	0.59	
	Measured		0.59	0.92	1.00	1.13	1.16	1.18	1.11	1.17	1.16	1.13	1.01	0.92	0.58	
	Pct Difference		0.0	0.0	0.7	1.8	0.1	-1.1	-1.2	-1.5	0.2	1.1	1.8	0.3	-0.3	
12	Predicted			0.64	0.85	0.99	1.12	1.15	1.19	1.15	1.12	0.99	0.85	0.64		
	Measured			0.64	0.86	1.01	1.12	1.13	1.16	1.13	1.11	0.99	0.87	0.65		
	Pct Difference			0.3	1.1	1.8	0.1	-2.4	-2.4	-2.4	-0.6	0.2	1.9	1.8		
13	Predicted				0.64	0.92	0.99	1.12	1.18	1.12	0.99	0.92	0.64			
	Measured				0.64	0.91	0.98	1.08	1.15	1.09	0.97	0.92	0.65			
	Pct Difference				0.0	-0.3	-0.9	-2.9	-2.5	-2.6	-1.9	-0.1	1.8			
14	Predicted					0.59	0.88	0.99	1.01	0.99	0.88	0.59				
	Measured					0.58	0.88	0.97	0.99	0.97	0.87	0.57				
	Pct Difference					-0.3	-0.1	-2.1	-2.0	-2.6	-1.8	-2.3				
15	Predicted							0.60	0.79	0.60						
	Measured							0.60	0.73	0.59						
	Pct Difference							-0.0	-0.7	-1.4						

STANDARD DEVIATION =0.011

AVERAGE PCT DIFFERENCE = 0.0

MAP NO. N1-1-25

CONTROL ROD POSITIONS

BANK C AT 228 STEPS

BANK D AT 216 STEPS

BANK P/L AT 228 STEPS

DATE 5/14/78

$F^{N}_{\Delta H}$ =1.367* AT J6-AA

F^{T}_{Q} =1.986* AT J6-AA

$\overline{F}_{Z}$ =1.385

A.O.=-8.823

BURNUP= ~300 MWD/MTU

POWER ~2664 MWT

INCORE TILT

NW - 1.002

NE - 1.002

SW - 0.999

SE - 0.997

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*Includes uncertainties

NORTH ANNA UNIT 1-CYCLE 1

ASSEMBLYWISE POWER DISTRIBUTION N1-1-49

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

Row	Value	R	P	N	M	L	K	J	H	G	F	E	D	C	B	A
1	Predicted							0.55	0.69	0.55						
1	Measured							0.57	0.72	0.56						
1	Pct Diff.							3.9	3.9	2.1						
2	Predicted					0.58	0.83	0.96	0.93	0.96	0.83	0.58				
2	Measured					0.59	0.85	0.97	0.94	0.96	0.84	0.58				
2	Pct Diff.					0.7	1.7	1.0	0.9	0.4	0.2	0.2				
3	Predicted				0.64	0.96	1.04	1.06	1.14	1.06	1.04	0.96	0.64			
3	Measured				0.64	0.96	1.04	1.06	1.13	1.06	1.05	0.97	0.64			
3	Pct Diff.				-0.1	-0.2	0.3	-0.1	-0.3	-0.1	1.0	1.0	-0.3			
4	Predicted			0.64	0.87	1.07	1.10	1.18	1.14	1.18	1.10	1.07	0.87	0.64		
4	Measured			0.63	0.87	1.07	1.11	1.18	1.14	1.18	1.12	1.08	0.88	0.64		
4	Pct Diff.			-1.3	-0.4	0.4	1.1	0.4	0.3	-0.1	1.9	1.2	0.8	-0.3		
5	Predicted		0.58	0.96	1.07	1.11	1.20	1.16	1.20	1.16	1.20	1.11	1.07	0.96	0.58	
5	Measured		0.56	0.93	1.06	1.11	1.21	1.18	1.22	1.18	1.22	1.12	1.07	0.96	0.58	
5	Pct Diff.		-3.1	-3.1	-0.8	0.5	1.0	1.5	1.5	1.4	1.9	1.2	0.7	-0.3	-0.3	
6	Predicted		0.83	1.04	1.10	1.20	1.17	1.23	1.18	1.23	1.17	1.20	1.10	1.04	0.83	
6	Measured		0.83	1.03	1.11	1.22	1.19	1.26	1.20	1.26	1.20	1.20	1.10	1.03	0.83	
6	Pct Diff.		-0.5	-0.5	0.4	2.0	2.0	2.0	2.0	2.0	2.1	0.2	0.1	-0.8	-0.3	
7	Predicted	0.55	0.96	1.06	1.18	1.16	1.23	1.16	1.22	1.18	1.23	1.16	1.18	1.06	0.96	0.55
7	Measured	0.56	0.96	1.06	1.17	1.15	1.24	1.21	1.24	1.21	1.26	1.16	1.16	1.04	0.94	0.56
7	Pct Diff.	2.2	0.2	0.3	-0.3	-1.4	0.4	1.9	2.0	1.9	[illegible]	0.1	-1.4	-1.4	-1.6	2.5
8	Predicted	0.69	0.93	1.14	1.14	1.20	1.18	1.22	1.18	1.22	1.18	1.20	1.14	1.14	0.93	0.69
8	Measured	0.68	0.93	1.14	1.13	1.18	1.18	1.24	1.21	1.23	1.19	1.20	1.12	1.12	0.94	0.71
8	Pct Diff.	-1.9	0.1	0.0	-0.4	-1.4	0.3	2.0	2.1	1.1	1.1	-0.3	-1.4	-1.4	0.4	2.5
9	Predicted	0.55	0.96	1.06	1.18	1.16	1.23	1.18	1.22	1.18	1.23	1.16	1.18	1.06	0.96	0.55
9	Measured	0.54	0.94	1.04	[illegible]	1.15	1.21	1.16	1.22	1.19	1.24	1.16	1.16	1.04	0.96	0.55
9	Pct Diff.	-1.7	-1.8	-1.3	-1.5	-1.4	-1.6	-1.9	0.1	0.8	0.6	0.1	-1.5	-1.4	[illegible]	-0.9
10	Predicted		0.83	1.04	1.10	1.20	1.17	1.23	1.18	1.23	[illegible]	1.20	1.10	1.04	0.83	
10	Measured		0.82	1.02	1.08	1.18	1.15	1.21	1.17	1.22	[illegible]	1.19	1.12	1.02	0.84	
10	Pct Diff.		-1.7	-1.7	-1.7	-1.7	-1.9	-2.2	-0.9	-0.8	[illegible]	-0.3	1.6	-1.1	0.5	
11	Predicted		0.58	0.96	1.07	1.11	1.20	1.16	1.20	1.16	1.20	1.11	1.07	0.96	0.58	
11	Measured		0.59	0.97	1.07	1.09	1.18	1.14	1.18	1.14	1.20	1.13	1.09	0.98	0.58	
11	Pct Diff.		0.7	0.7	0.7	-1.7	-1.4	-1.8	-1.9	-1.9	0.1	1.6	2.4	1.5	-0.0	
12	Predicted			0.64	0.87	1.07	1.10	1.18	1.14	1.18	1.10	1.07	0.87	0.64		
12	Measured			0.66	0.90	1.10	1.09	1.15	1.11	1.15	1.10	1.08	0.90	0.66		
12	Pct Diff.			3.1	3.1	3.1	-1.0	-2.2	-2.3	-2.0	-0.2	1.0	2.5	2.7		
13	Predicted				0.64	0.96	1.04	1.06	1.14	1.06	1.04	0.96	0.64			
13	Measured				0.66	0.99	1.03	1.04	1.11	1.04	1.02	0.98	0.66			
13	Pct Diff.				3.1	3.1	-1.0	-2.1	-2.3	-2.2	-1.6	1.7	2.9			
14	Predicted					0.58	0.83	0.96	0.93	0.96	0.83	0.58				
14	Measured					0.59	0.84	0.95	0.92	0.94	0.82	0.58				
14	Pct Diff.					1.3	1.3	-0.9	-1.5	-2.2	-1.6	-0.9				
15	Predicted							0.55	0.69	0.55						
15	Measured							0.56	0.69	0.54						
15	Pct Diff.							1.3	-0.5	-2.4						

STANDARD DEVIATION =0.015

AVERAGE PCT DIFFERENCE = 1.3

MAP NO. N1-1-49

DATE 12/18/78

POWER ~2689

CONTROL ROD POSITIONS

BANK C AT 228 STEPS

BANK D AT 224 STEPS

BANK P/L AT 228 STEPS

$F^N_{\Delta H}$ =1.337* AT G6-IB

F^T_Q =1.602* AT G6-IB

$\overline{F}_Z$ =1.168

A.O.=-2.377

BURNUP= ~7260MWD/MTU

INCORE TILT

NW - 1.004

NE - 1.005

SW - 0.993

SE - 0.998

*Includes uncertainties

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FIGURE 4.3

NORTH ANNA UNIT 1-CYCLE 1

ASSEMBLYWISE POWER DISTRIBUTION N1-1-73

	R	P	N	M	L	K	J	H	G	F	E	D	C	B	A
1							0.59 0.61 4.2	0.72 0.75 4.2	0.59 0.61 3.6						
2					0.62 0.64 2.7	0.86 0.88 2.1	1.01 1.02 1.1	0.95 0.96 1.1	1.01 1.02 1.4	0.86 0.89 3.0	0.62 0.64 3.2				
3				0.68 0.69 0.8	1.03 1.03 0.6	1.09 1.09 0.3	1.06 1.06 -0.1	1.13 1.13 -0.4	1.06 1.07 0.7	1.09 1.12 2.9	1.03 1.06 3.1	0.68 0.70 3.4			
4			0.68 0.68 [illegible]	0.91 0.91 0.0	1.11 1.12 0.6	1.09 1.10 0.9	1.16 1.17 0.3	1.10 1.10 0.2	1.16 1.16 0.0	1.09 1.12 2.5	1.11 1.14 2.3	0.91 0.93 2.2	0.68 0.70 3.5		
5		0.62 0.61 -2.4	1.03 1.00 -2.4	1.11 1.10 -1.5	1.09 1.08 -1.0	1.17 1.16 -0.4	1.10 1.11 0.7	1.16 1.17 0.7	1.10 1.12 1.5	1.17 1.20 2.5	1.09 1.12 2.2	1.11 1.13 1.5	1.03 1.06 3.6	0.62 0.66 6.2	
6		0.86 0.86 -0.5	1.09 1.08 -0.5	1.09 1.08 -0.7	1.17 1.15 -1.1	1.10 1.10 0.2	1.16 1.17 0.9	1.10 1.11 0.9	1.16 1.18 1.3	1.10 1.12 2.0	1.17 1.18 1.2	1.09 1.10 0.5	1.09 1.10 1.3	0.86 0.89 2.8	
7	0.59 0.60 1.5	1.01 1.00 -0.5	1.06 1.05 -0.4	1.16 1.14 -2.2	1.10 1.06 -3.9	1.16 1.14 -2.3	1.10 1.10 0.5	1.16 1.17 0.7	1.10 1.11 1.1	1.16 1.18 1.5	1.10 1.11 0.6	1.16 1.14 -1.5	1.06 1.05 -1.2	1.01 1.00 -1.1	0.59 0.58 -0.7
8	0.72 0.70 -2.7	0.95 0.95 -0.7	1.13 1.12 -0.8	1.10 1.08 -1.5	1.16 1.14 -2.4	1.10 1.09 -1.2	1.16 1.17 0.9	1.10 1.11 0.9	1.16 1.16 0.0	1.10 1.10 -0.0	1.16 1.15 -1.1	1.10 1.08 -1.5	1.13 1.12 -1.3	0.95 0.96 0.5	0.72 0.73 1.7
9	0.59 0.57 -2.0	1.01 0.99 -2.3	1.06 1.03 -2.3	1.16 1.14 -2.2	1.10 1.08 -2.0	1.16 1.13 -2.6	1.10 1.06 -3.7	1.16 1.14 -1.4	1.10 1.09 -0.4	1.16 1.16 -0.5	1.10 1.10 0.1	1.16 1.17 0.3	1.06 1.06 -0.0	1.01 1.02 0.7	0.59 0.60 2.0
10		0.86 0.85 -2.0	1.09 1.06 -2.0	1.09 1.09 -0.4	1.17 1.17 0.5	1.10 1.09 -1.0	1.16 1.12 -3.6	1.10 1.07 -2.2	1.16 1.14 -1.7	1.10 1.09 -0.5	1.17 1.17 0.0	1.09 1.11 2.0	1.09 1.09 0.8	0.86 0.88 1.4	
11		0.62 0.62 0.1	1.03 1.03 0.1	1.11 1.11 0.3	1.09 1.10 0.6	1.17 1.14 -2.1	1.10 1.06 [illegible]	1.16 1.12 -3.5	1.10 1.07 -2.7	1.17 1.16 -0.1	1.09 1.11 1.5	1.11 1.14 2.7	1.03 1.05 2.0	0.62 0.63 1.1	
12			0.68 0.69 2.1	0.91 0.93 1.4	1.11 1.12 0.6	1.09 1.08 -1.4	1.16 1.12 -3.4	1.10 1.06 -3.4	1.16 1.14 -2.3	1.09 1.09 -0.1	1.11 1.12 1.0	0.91 0.94 2.9	0.68 0.70 3.3		
13				0.68 0.69 1.6	1.03 1.04 1.1	1.09 1.07 -1.0	1.06 1.02 -3.4	1.13 1.10 -2.7	1.06 1.04 -1.6	1.09 1.08 -0.6	1.03 1.04 1.7	0.68 0.70 3.3			
14					0.62 0.63 1.1	0.86 0.88 1.5	1.01 1.00 -0.8	0.95 0.94 -1.0	1.01 0.99 -1.6	0.86 0.86 -0.6	0.62 0.62 -0.1				
15							0.59 0.60 1.9	0.72 0.72 0.4	0.59 0.58 -1.2						

PREDICTED
MEASURED
PCT DIFFERENCE

STANDARD DEVIATION =0.018

AVERAGE PCT DIFFERENCE = 1.5

MAP NO. N1-1-73

DATE 08/14/79

POWER ~100%

CONTROL ROD POSITIONS

BANK C AT 228 STEPS

BANK D AT 220 STEPS

BANK P/L AT 228 STEPS

$F^N_{\Delta H}$ =1.265* AT F5-EL

F^T_Q =1.520* AT F5-EL

$\overline{F}_Z$ =1.163

A.O.=-1.481

BURNUP= ~14577

INCORE TILT

NW - 0.9981

NE - 1.0137

SW - 0.9882

SE - 1.0000

*Includes uncertainties

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HOT CHANNEL FACTOR NORMALIZED

OPERATING ENVELOPE

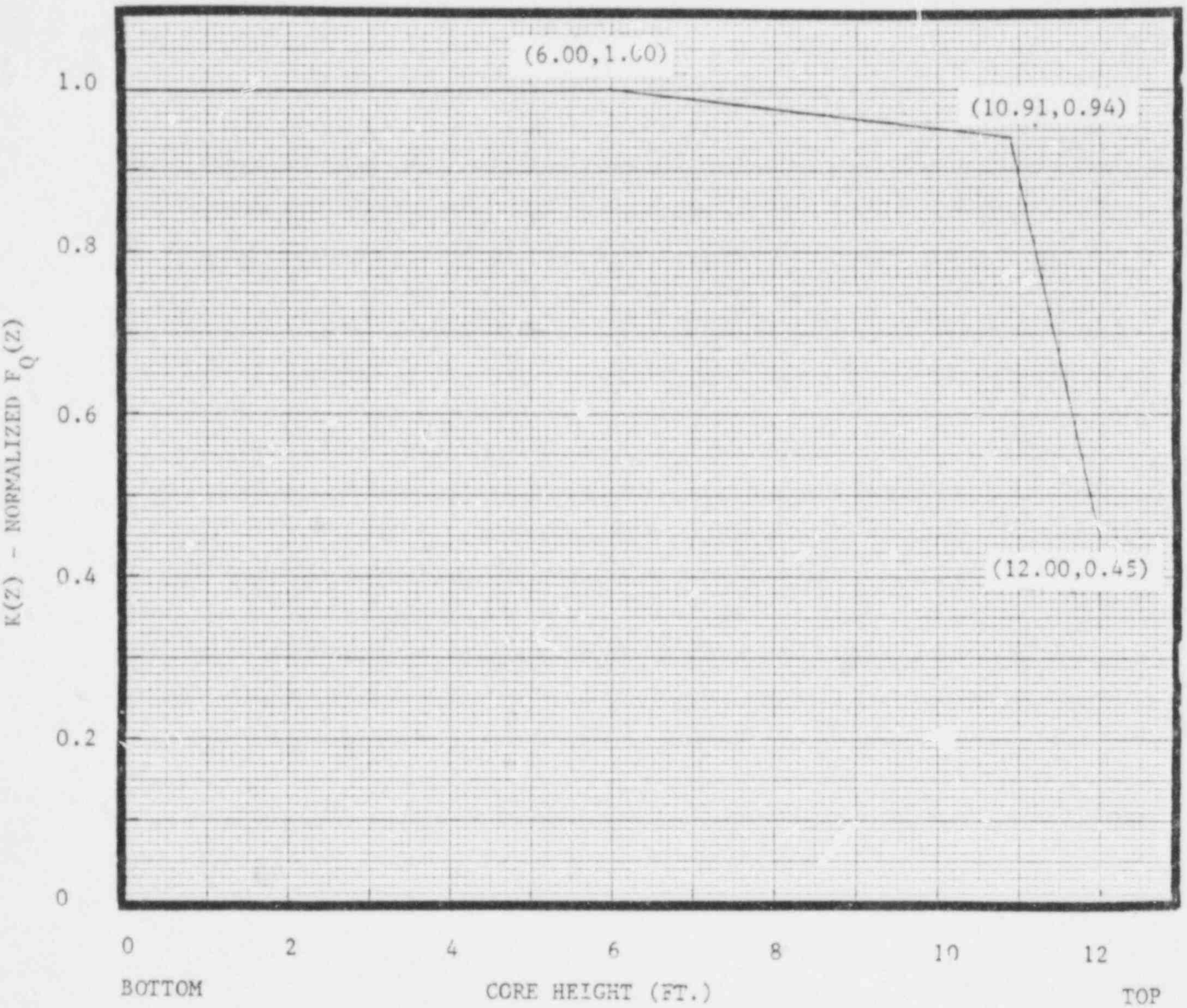

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FIGURE 4.5

NORTH ANNA UNIT 1-CYCLE 1

HEAT FLUX HOT CHANNEL FACTOR, $F_Q^T(Z)$

N1-1-25

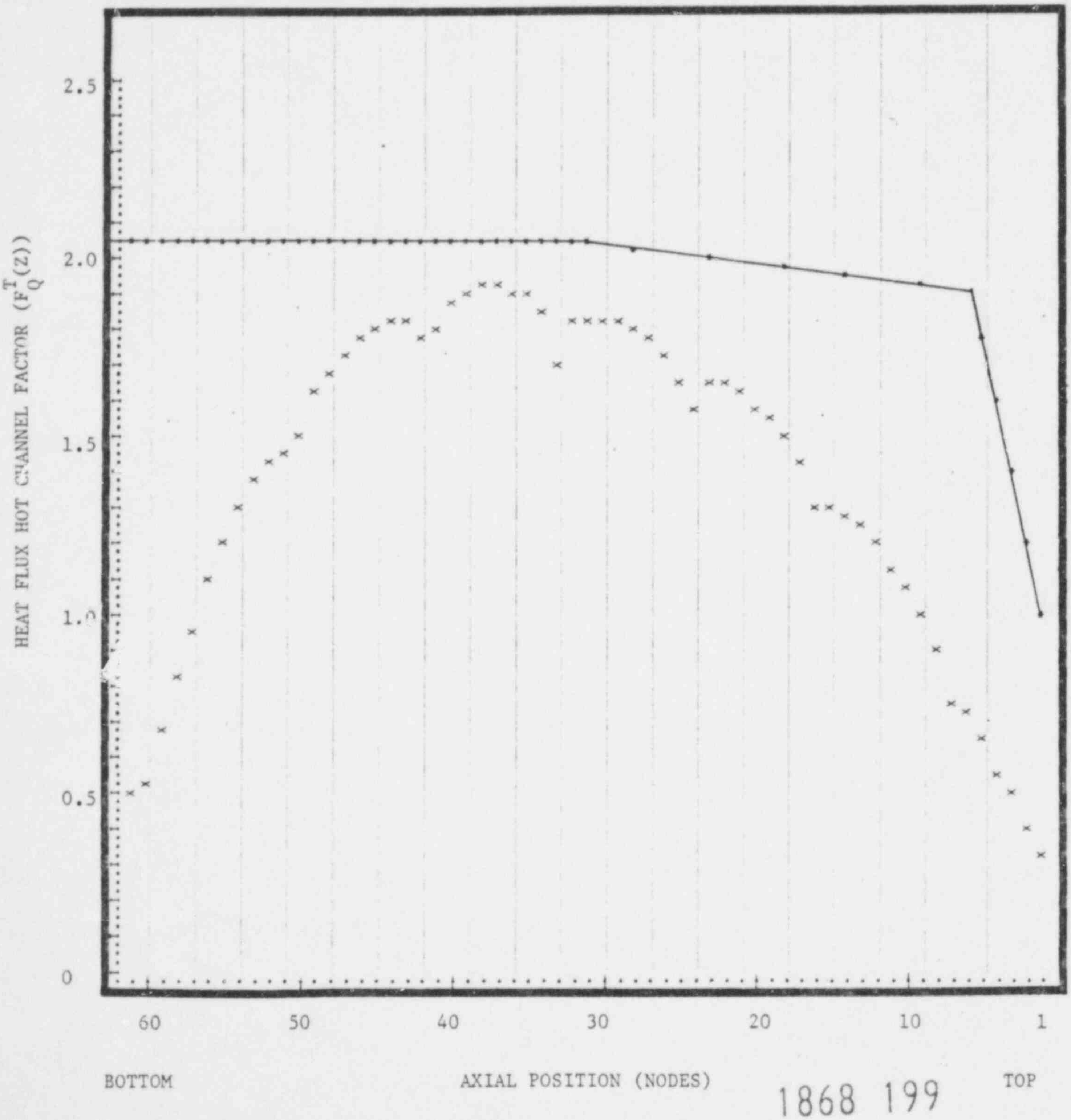

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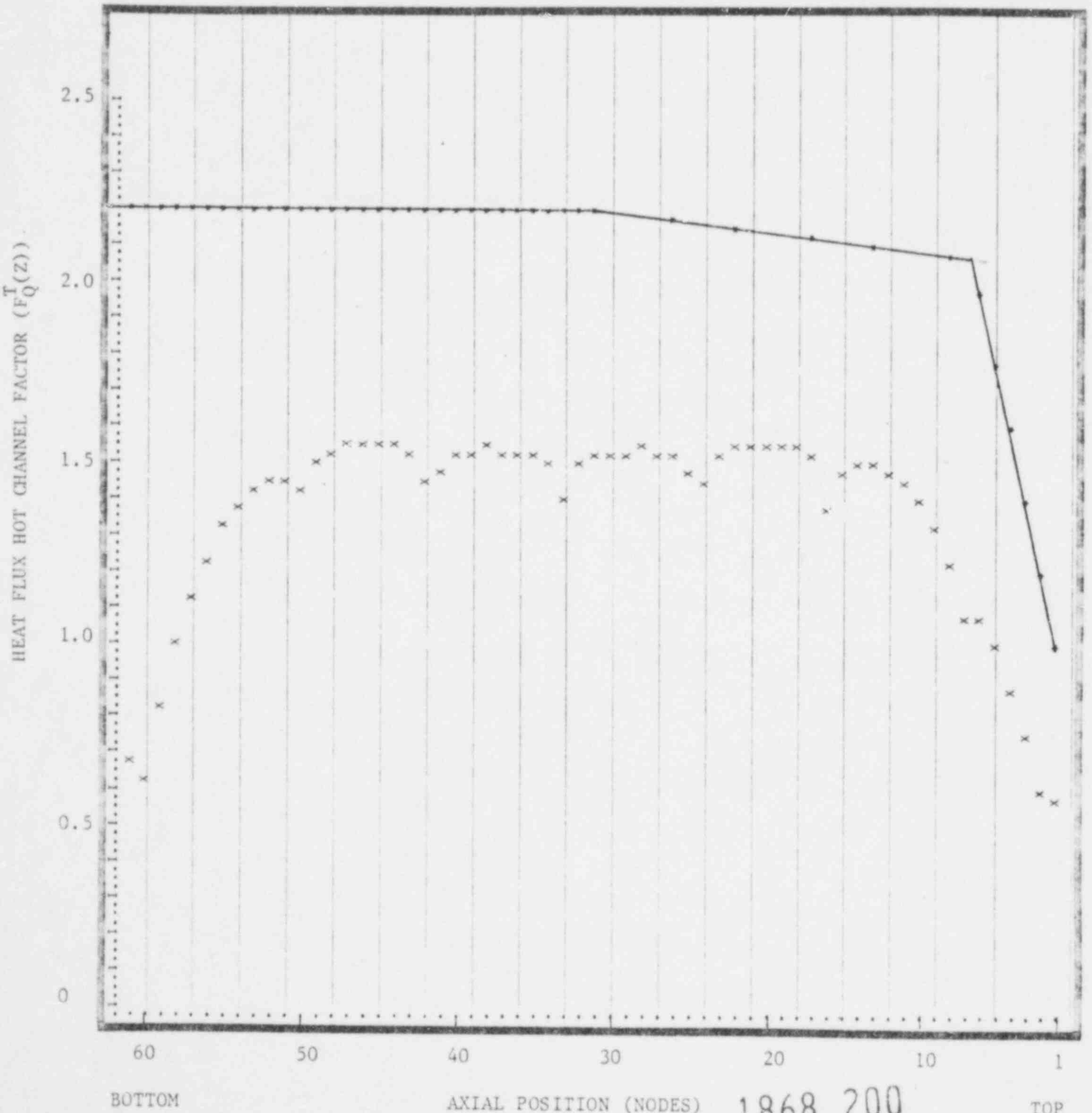
FIGURE 4.6

NORTH ANNA UNIT 1-CYCLE 1

HEAT FLUX HOT CHANNEL FACTOR, $F_Q^T(Z)$

N1-1-49



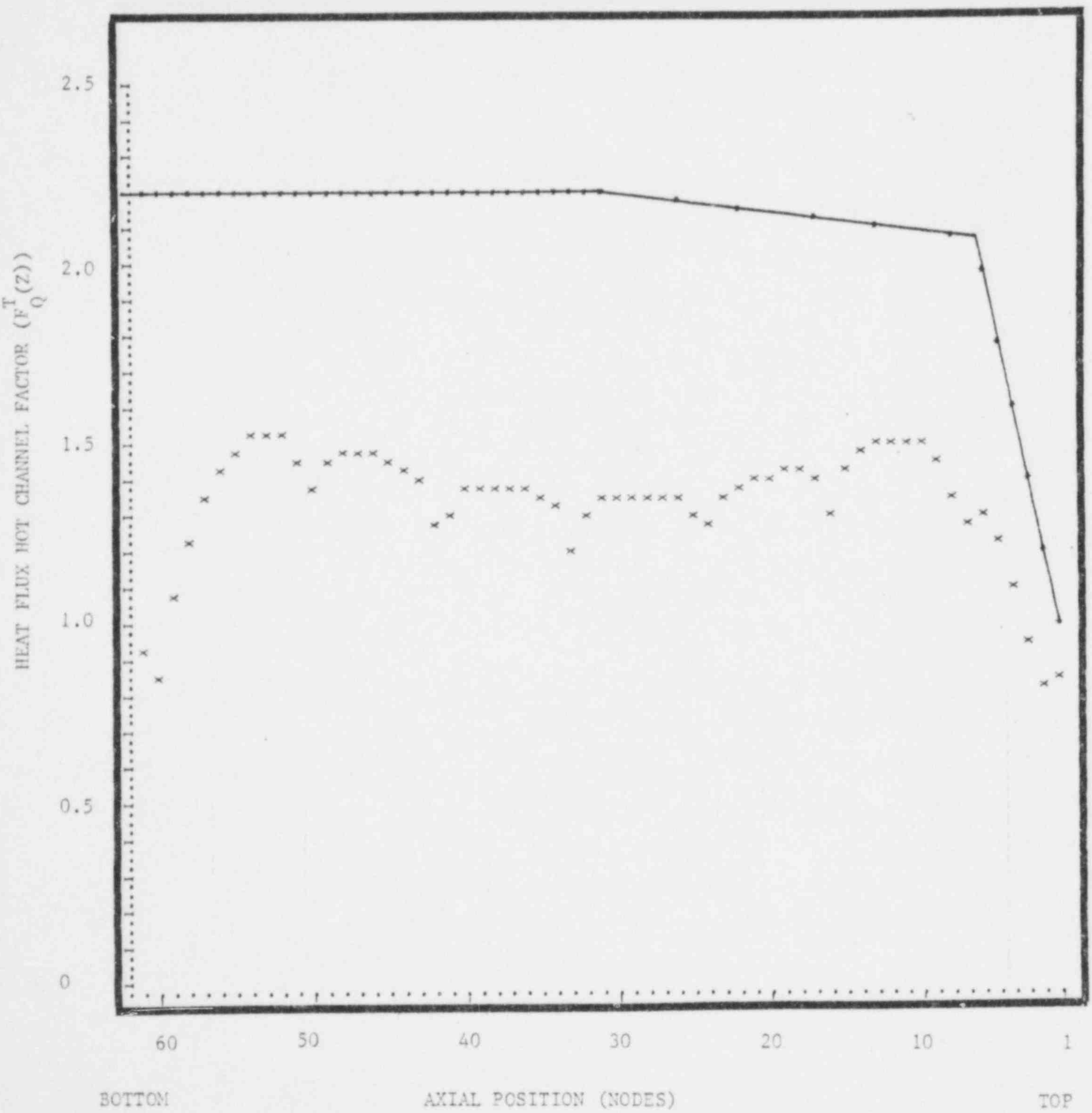
1868 200

FIGURE 4.7

NORTH ANNA UNIT 1-CYCLE 1

HEAT FLUX HOT CHANNEL FACTOR, $F_Q^T(Z)$

N1-1-73



1868 201

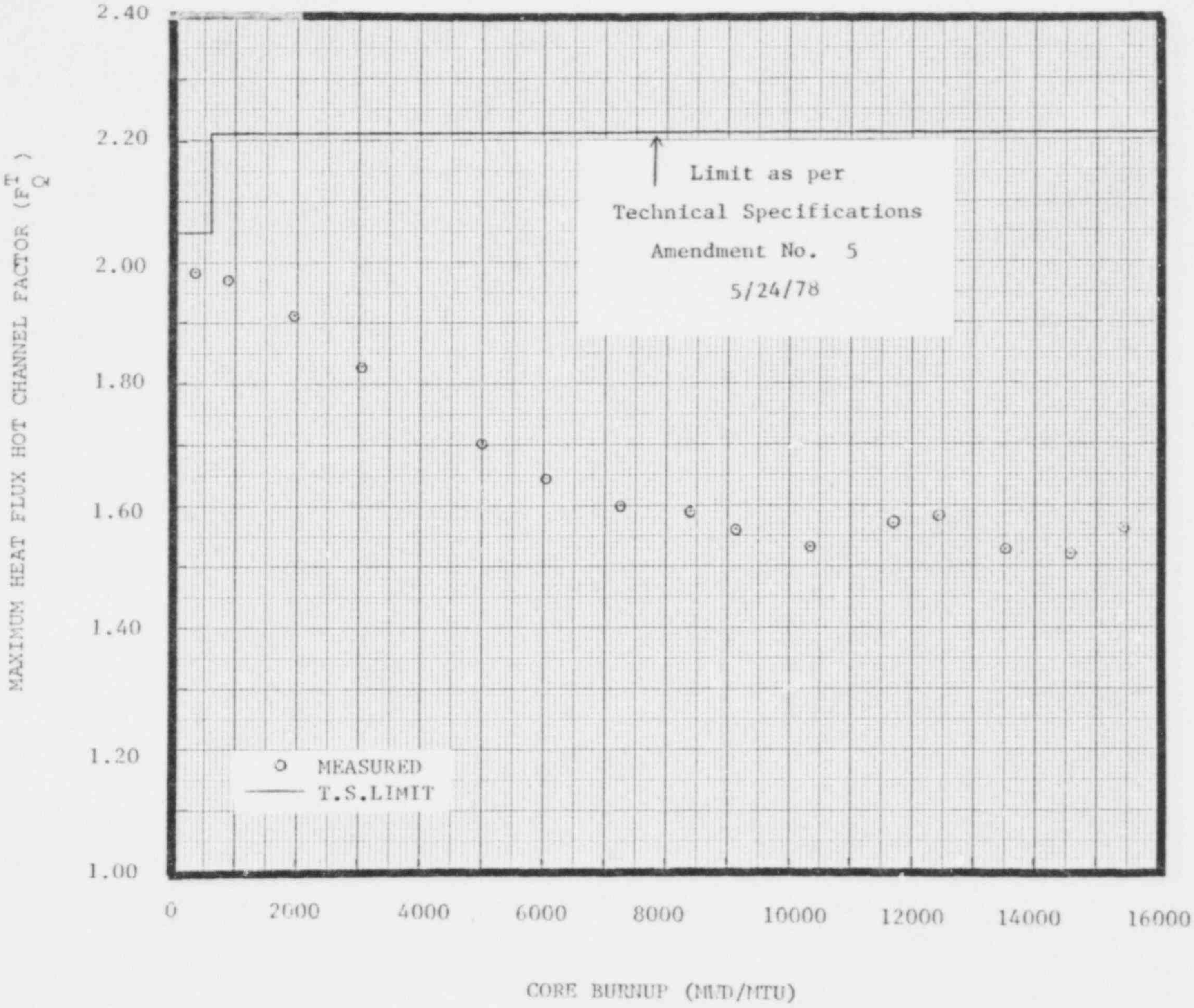
FIGURE 4.8

NORTH ANNA UNIT 1-CYCLE 1

MAXIMUM HEAT FLUX HOT CHANNEL FACTOR

VS.

BURNUP



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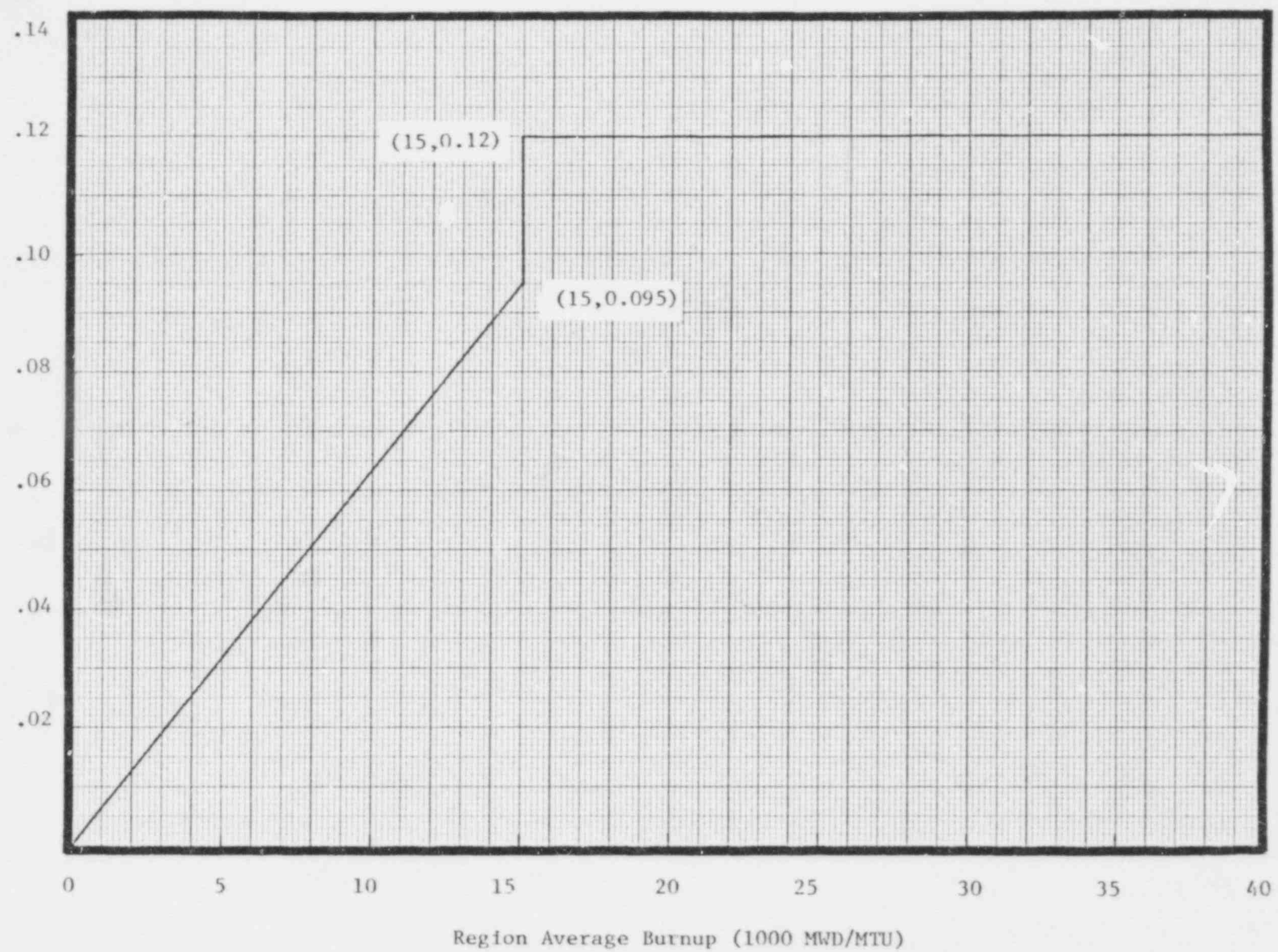
NORTH ANNA UNIT 1-CYCLE 1

FIGURE 4.9

ROD BOW PENALTY ON $F^N_{\Delta H}$



1868 203

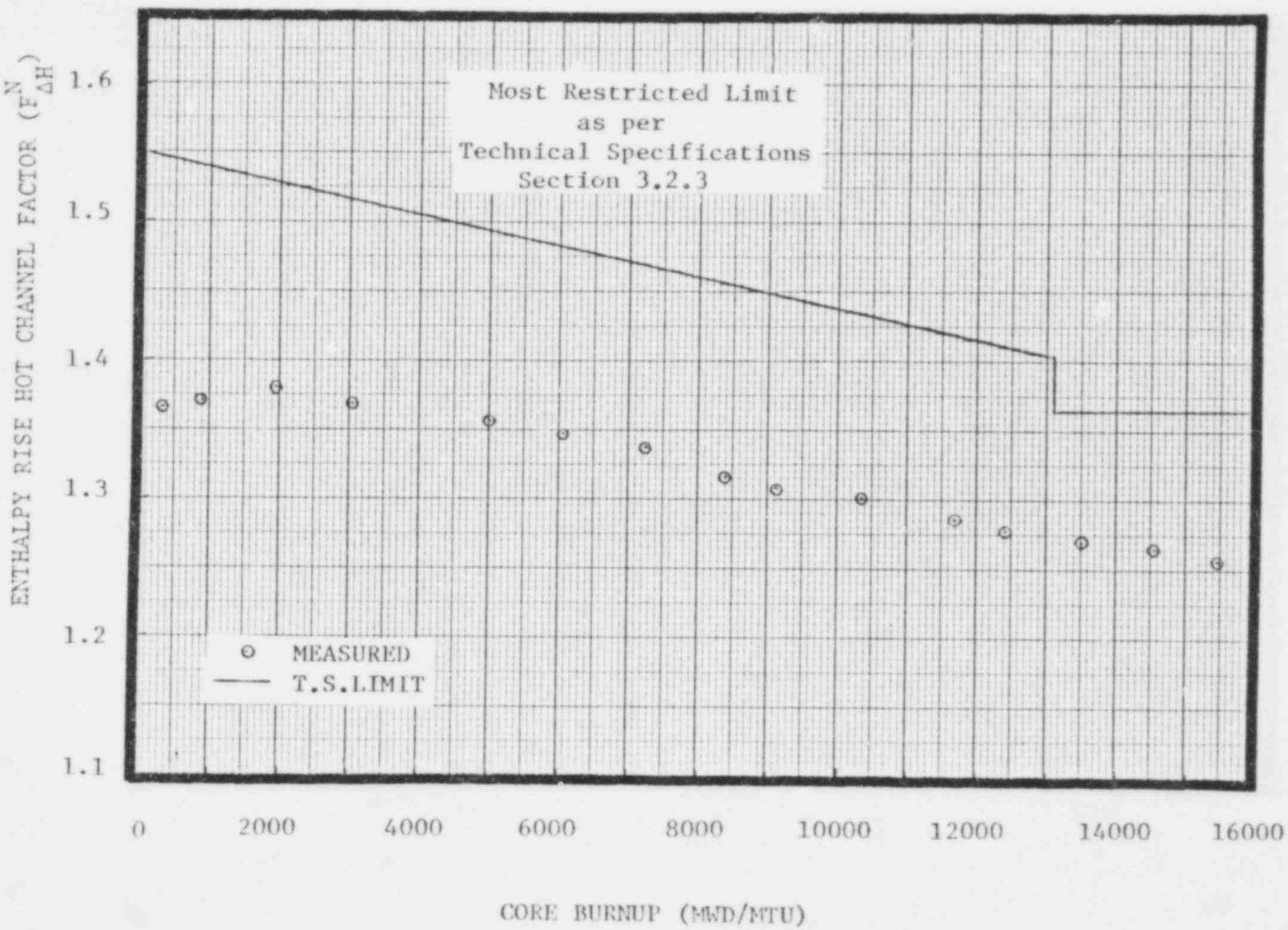
FIGURE 4.10

NORTH ANNA UNIT 1-CYCLE 1

ENTHALPY RISE HOT CHANNEL FACTOR

VS.

BURNUP



POOR ORIGINAL

1868 204

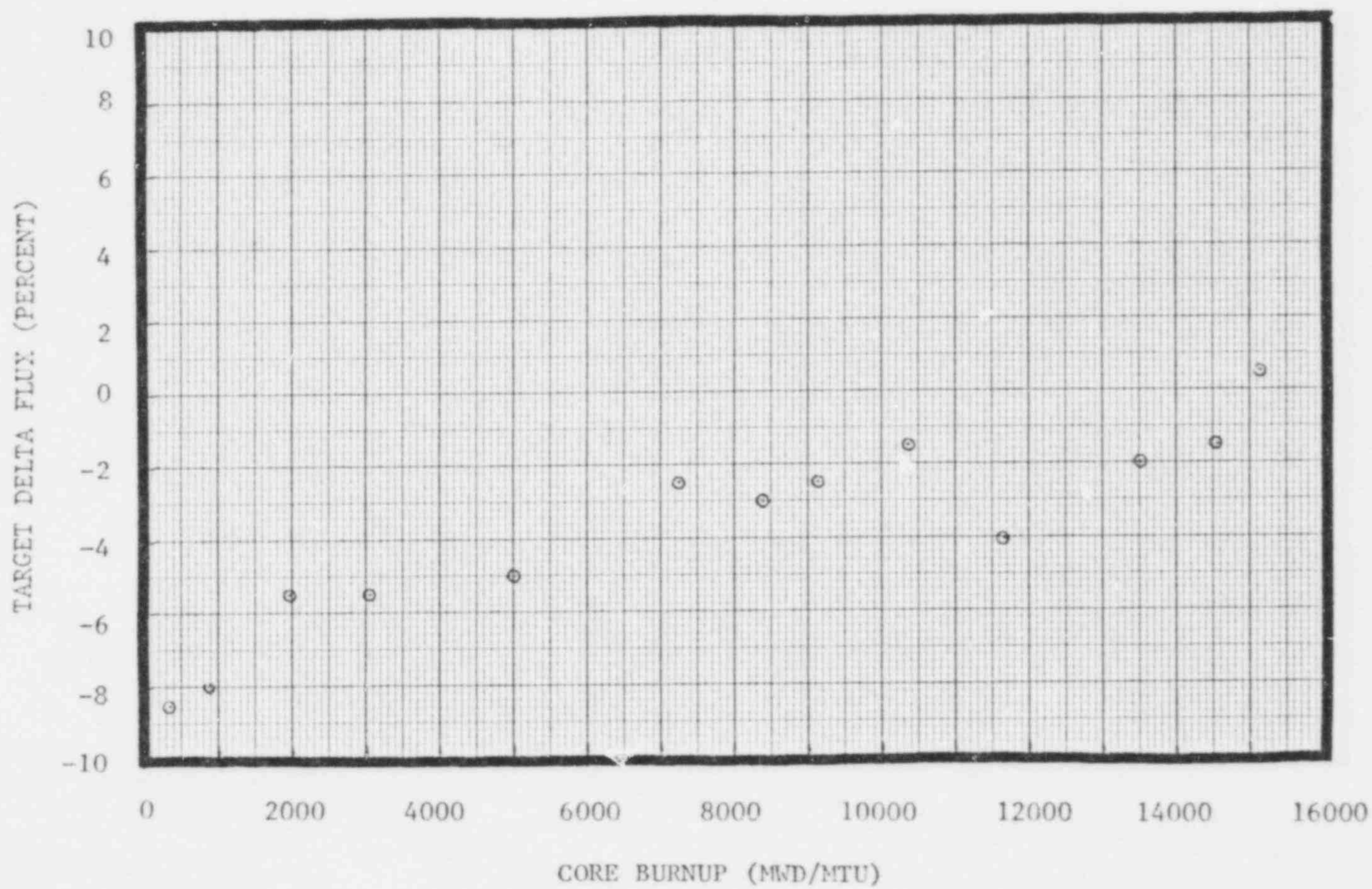
FIGURE 4.11

NORTH ANNA UNIT 1 - CYCLE 1

TARGET DELTA FLUX

VS.

BURNUP



1868 205

FIGURE 4.12

NORTH ANNA UNIT 1-CYCLE 1

CORE AVERAGE AXIAL POWER DISTRIBUTION

N1-1-25

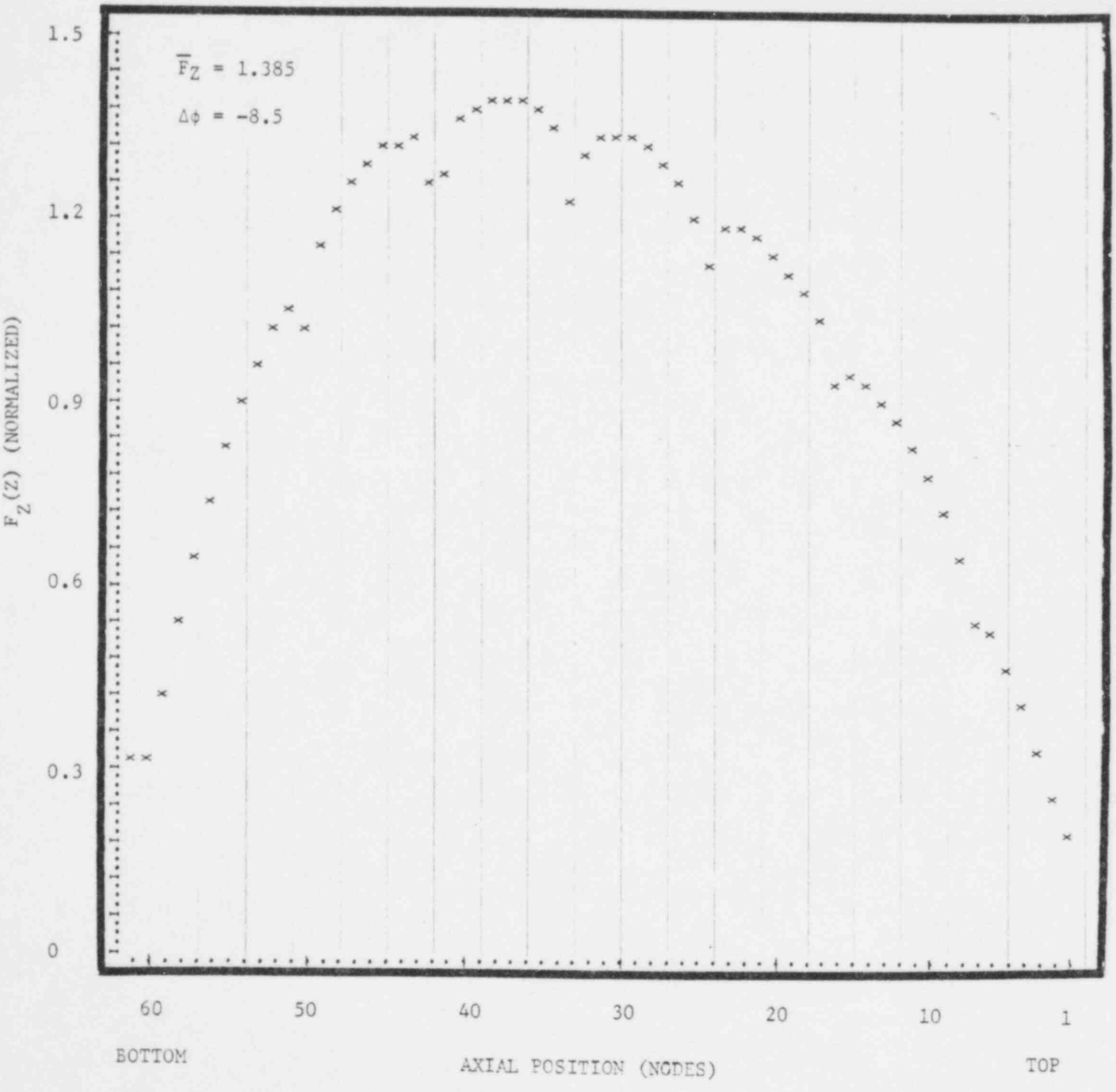


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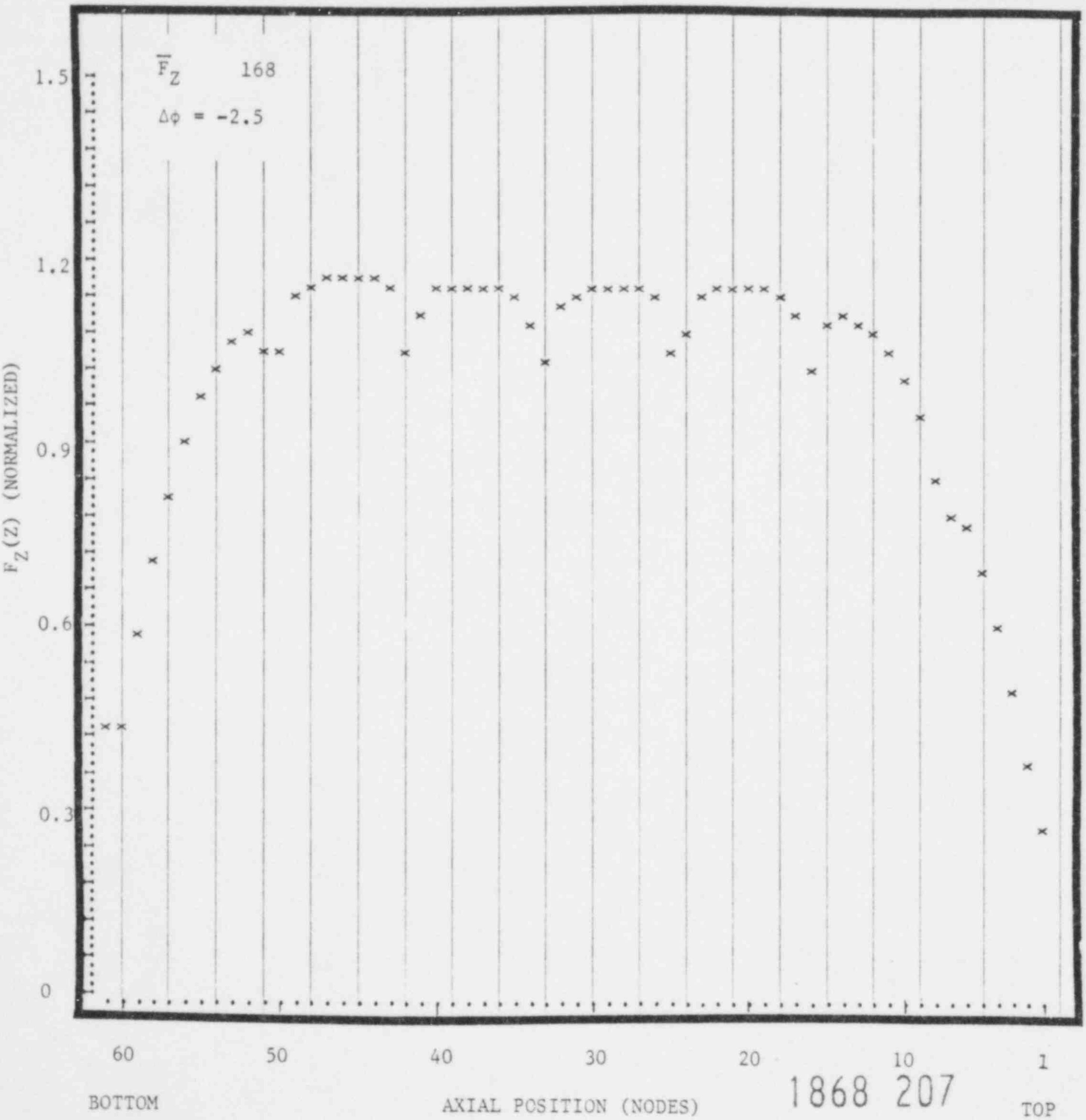
FIGURE 4.13

NORTH ANNA UNIT 1-CYCLE 1

CORE AVERAGE AXIAL POWER DISTRIBUTION

N1-1-49



1868 207

FIGURE 4.14

NORTH ANNA UNIT 1-CYCLE 1

CORE AVERAGE AXIAL POWER DISTRIBUTION

N1-1-73

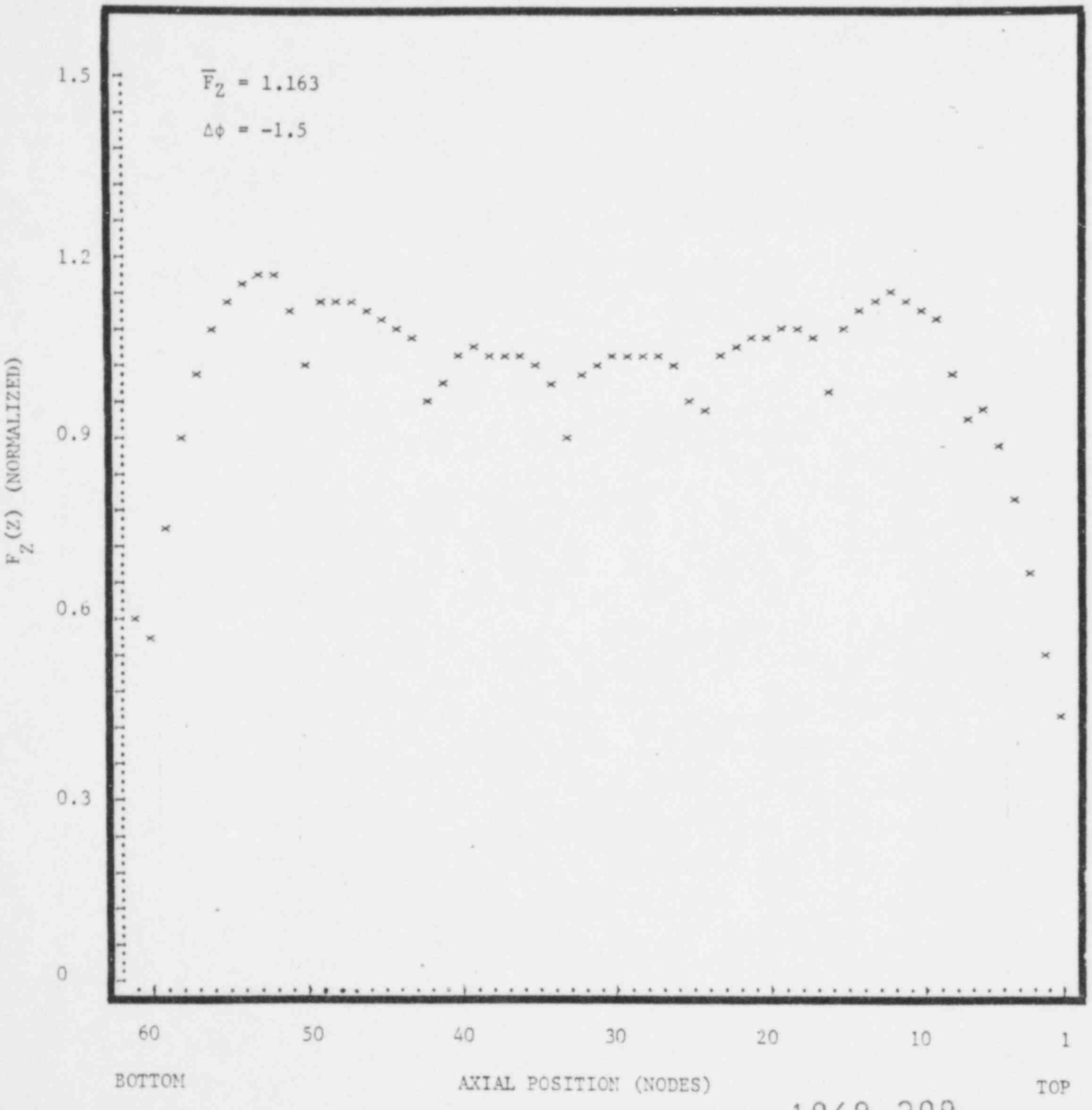


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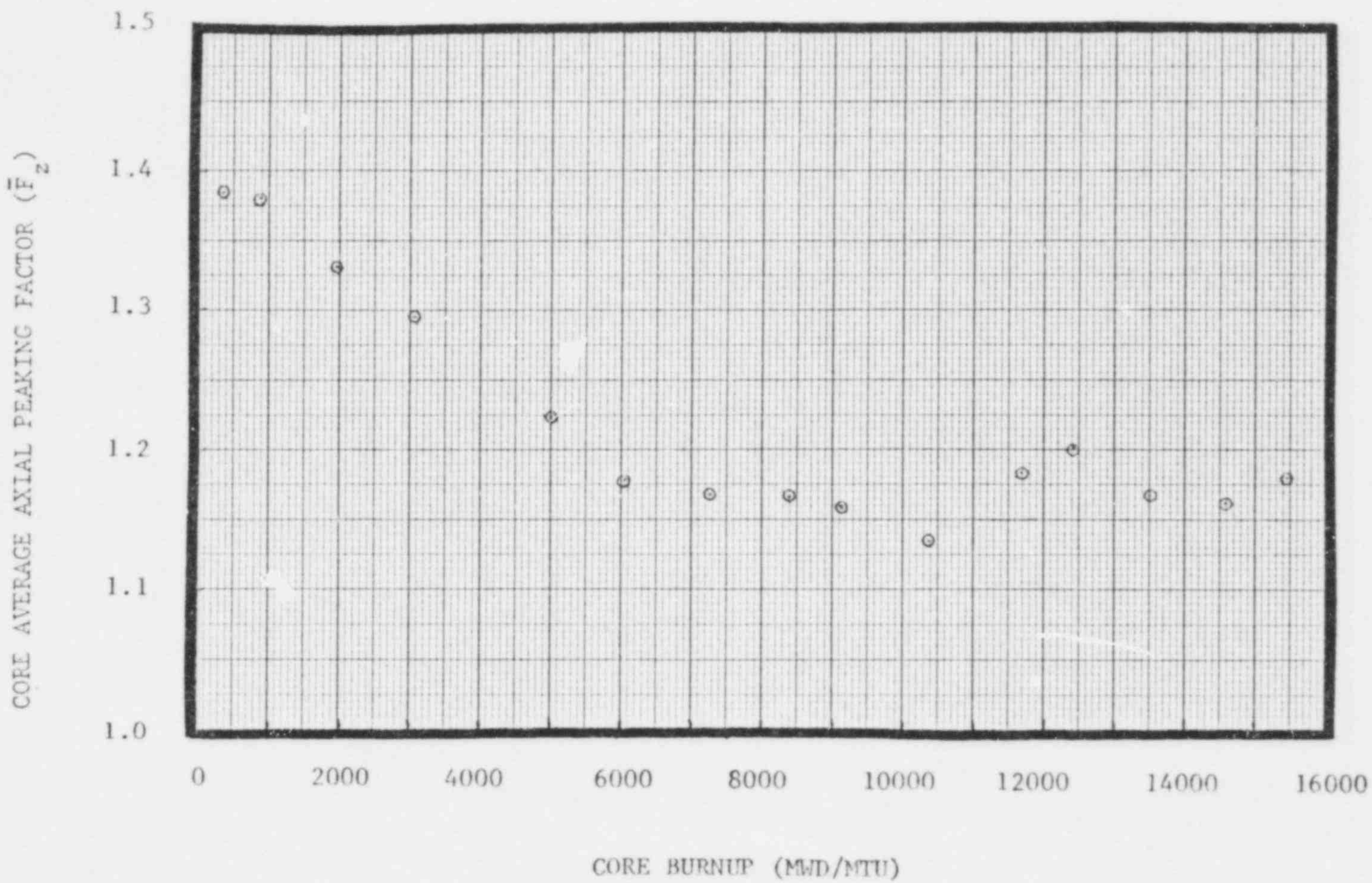
FIGURE 4.15

NORTH ANNA UNIT 1-CYCLE 1

CORE AVERAGE AXIAL PEAKING FACTOR

VS.

BURNUP



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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 Section 3.4.8 of the North Anna Technical Specifications, the dose equivalent I-131 concentration in the primary coolant was limited to 1.0 μCi/gm for normal steady state operation. Figure 5.1 shows the dose equivalent I-131 activity level history for the North Anna 1, Cycle 1 core. Reactor coolant system activity data indicated that two discrete fuel defect events occurred within one week at approximately 2500 MWD/MTU burnup (end of July, 1978). The failure mechanism is unknown at this time; however, it is believed that the defects were not a result of a design deficiency or core operation tactics. A visual (binocular) inspection of the fuel, which was performed during the refueling shutdown, did not reveal the identity of the defected fuel.

The data on Figure 5.1 shows that the core operated substantially below the 1.0 μCi/gm limit during steady state operation (the spike data is associated with power transients and/or shutdowns), and that the equilibrium activity levels tended to decrease following the initial defect events. The average equilibrium dose equivalent I-131 concentration during Cycle 1 was 3.9×10^{-2} μCi/gm which is less than 4% of the Technical Specifications limit.

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The ratio 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 24 hours) compared to that of I-131 (approximately eight days) so that for pinhole defects where the diffusion time through the defect is on the order of days, the I-133 decays out leaving 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. As shown in Figure 5.3, the I-131/I-133 ratio data points associated with equilibrium operation following the defect events are greater than 0.5 indicating pinhole defects.

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

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POOR ORIGINAL

FIGURE 5.1

NORTH ANNA UNIT 1 - CYCLE 1

DOSE EQUIVALENT I-131 CONCENTRATION vs. TIME

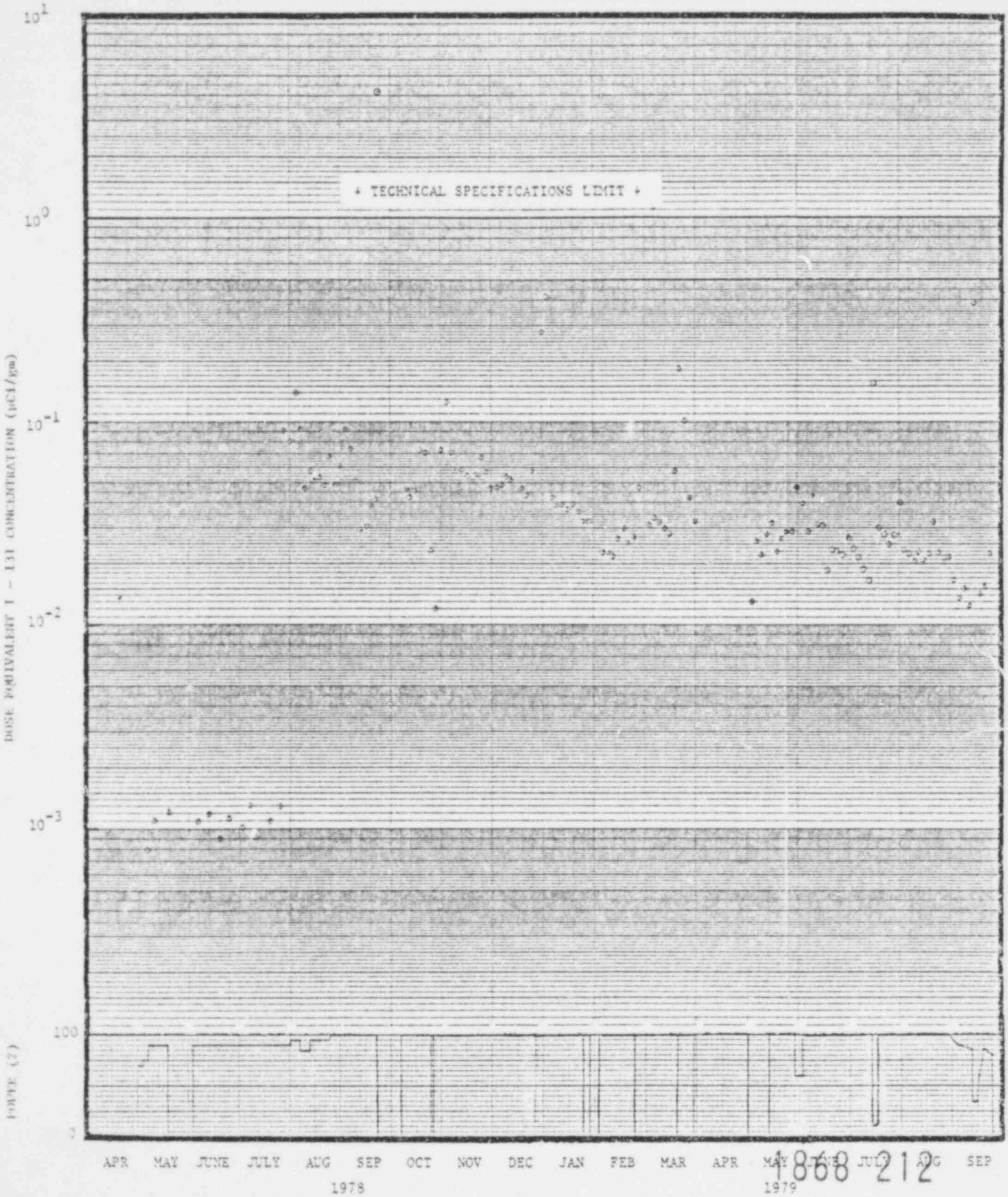

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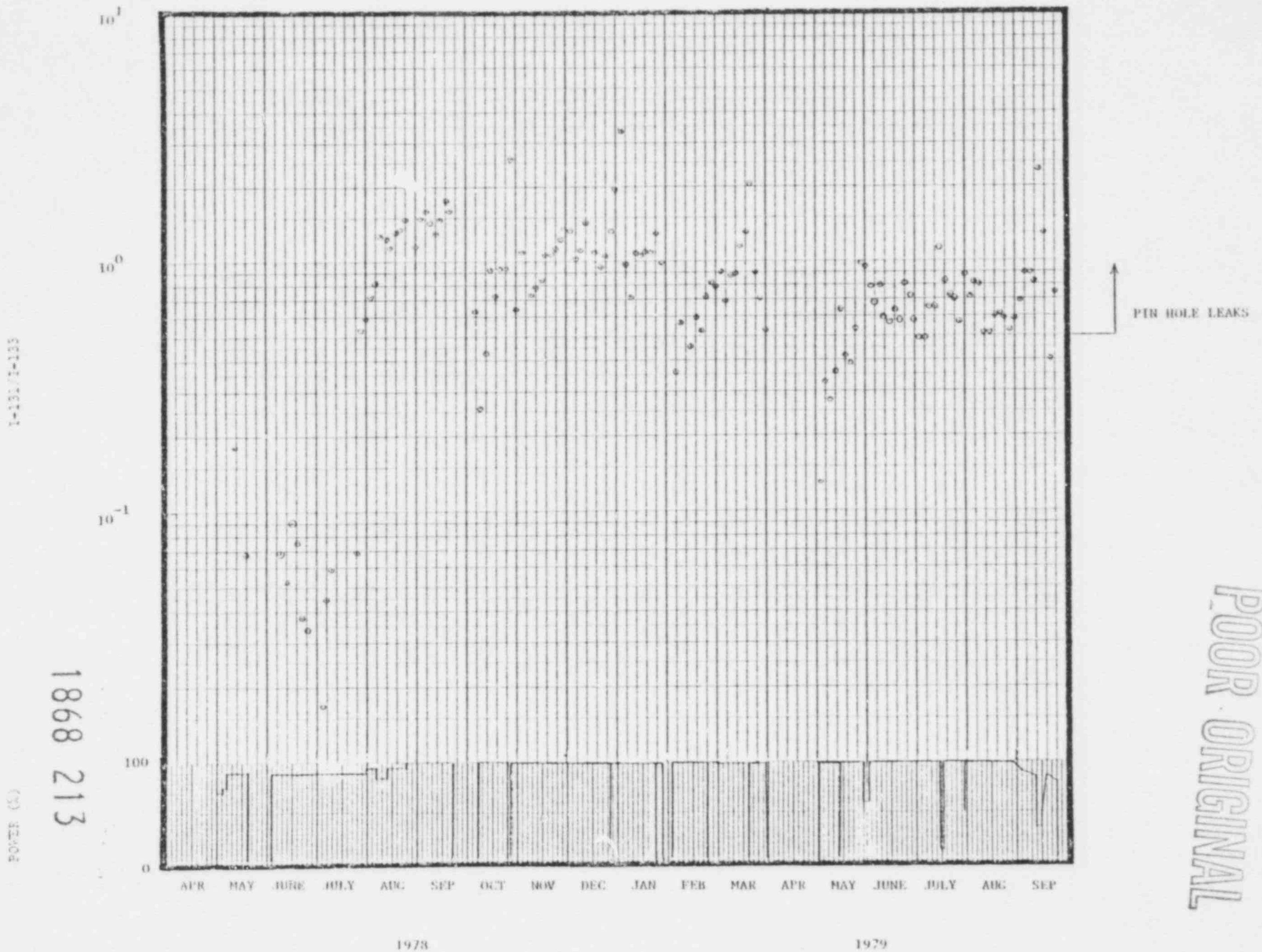
FIGURE 5.2

NORTH ANNA UNIT 1 - CYCLE 1

I-131/I-133 RATIO vs. TIME



Section 6

CONCLUSIONS

The North Anna 1 core has completed Cycle 1 operation. Throughout the cycle, all core performance indicators compared favorably with the design predictions and all core related Technical Specifications limits were met with significant margin during full power operation. No abnormalities in reactivity or batch burnup accumulation were detected. However, the indicated increase in quadrant power tilt is somewhat anomalous. The analysis of radioiodine data for Cycle 1 indicates that there are pinhole leaks in the fuel cladding. However, based on the coolant activity level and the inability to observe any fuel defects during the refueling shuffle, it is concluded that the fuel defect level was low.

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REFERENCES

1) T. K. Ross and J. H. Leberstien, "North Anna Unit 1, Cycle 1 Startup Physics Test Report," VEP-FRD-31, September, 1978.

2) North Anna Power Station Unit 1 Technical Specifications.

3) T. K. Ross, "NEWTOTE Code," NFO-CCR-6, August, 1978.

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.

6) Letter from O. D. Parr (NRC) to W. L. Proffitt (Vepco), dated May 19, 1978 (Docket No. 50-338).

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