Vepco

NORTH ANNA UNIT 1, CYCLE 4 CORE PERFORMANCE REPORT

NUCLEAR OPERATIONS DEPARTMENT

Virginia Electric and Power Company

VEP-NOS-9

NORTH ANNA UNIT 1, CYCLE 4
CORE PERFORMANCE REPORT

by

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES CONT'D

Section 1

INTRODUCTION AND SUMMARY

On May 12, 1984, North Anna Unit 1 completed Cycle 4. Since the initial criticality of Cycle 4 on November 18, 1982, the reactor core produced approximately 80 x 10^6 MBTU (13,478 Megawatt days per metric ton of contained uranium) which has resulted in the generation of approximately 7.8 x 10^9 KWHr gross (7.4 x 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 4. The physics tests that were performed during the startup of this cycle were covered in the North Anna Unit 1, Cycle 4 Startup Physics Test Report[1] and, therefore, will not be included here.

The second cycle core consisted of three batches of fuel: a twice burned sub-batch from cycles 2 and 3 (4A2), a once-burned batch from cycle 3 (Batch 5A), and one fresh batch (Batch 6A). The North Anna 1, Cycle 4 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 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 4 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 ±0.44% with the burnup accumulation in each batch deviating from design prediction by less than 0.5%.

2. Reactivity Depletion Follow - The critical boron concentration, used to monitor reactivity depletion, was consistently within ±0.40% ΔK/K of the design prediction which is well within the ±1% ΔK/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 2%. 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 4 was approximately 8.1 x 10^{-2} µCi/gm. This corresponds to 8% 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

NORTH ANNA UNIT 1 - CYCLE 4

CORE LOADING MAP

R	P	N	M	L	K	J	H	G	F	E	D	C	B	A	
						E02	F37	E13							1
				D24	F26	F60 12P	E53	F51 12P	F02	D01					2
			D02	F12 12P	F44 20P	E21	E06 SS	E41	F67 20P	F53 12P	D17				3
		D12	E59	F36 20P	E64	F07 20P	E61	F35 20P	E56	F47 20P	E20	D43			4
	D46	F18 12P	F01 20P	E10	F14 20P	D20	E18	D22	F63 20P	E15	F57 20P	F04 12P	D50		5
	F28	F38 20P	E40	F45 20P	E19	F62 20P	E50	F25 20P	E47	F32 20P	E60	F10 20P	F43		6
E55	F50 12P	E01	F56 20P	D26	F15 20P	E39	E51 8P	E25	F24 20P	D25	F46 20P	E07	F17 12P	E11	7
F64	E09	E24	E54	E63	E30	E08 8P	F40 20P	E38 8P	E22	E16	E52	E31 SS	E57	F30	8
E04	F61 12P	E44	F16 20P	D45	F03 20P	E29	E34 8P	E17	F09 20P	D14	F13 20P	E27	F33 12P	E14	9
	F21	F48 20P	E32	F59 20P	E46	F49 20P	E26	F29 20P	E49	F55 20P	E36	F22 20P	F06		10
	D40	F34 12P	F54 20P	E35	F05 20P	D48	E37	D10	F11 20P	E45	F41 20P	F58 12P	D39		11
		D06	E33	F42 20P	E12	F66 20P	E42	F52 20P	E05	F65 20P	E43	D30			12
			D19	F68 12P	F08 20P	E62	E03 SS	E28	F20 20P	F27 12P	D13				13
				D08	F19	F31 12P	E48	F69 12P	F39	D32					14
						E58	F23	E23							15

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

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

FUEL ASSEMBLY DESIGN PARAMETERS

	SUB-BATCH		
	4A2	5A	6A
Initial Enrichment (w/o U-235)	3.21	3.40	3.59
Assembly Type	17X17	17X17	17X17
Number of Assemblies	24	64	69
Fuel Rods per Assembly	264	264	264
Assembly Identification	D01 D02 D06 D08 D10 D12 D13 D14 D17 D19 D20 D22 D24 D25 D26 D30 D32 D39 D40 D43 D45 D46 D48 D50	E01-E64	F01-F69

Figure 1.2

NORTH ANNA UNIT 1 - CYCLE 4

MOVABLE DETECTOR AND THERMOCOUPLE LOCATIONS

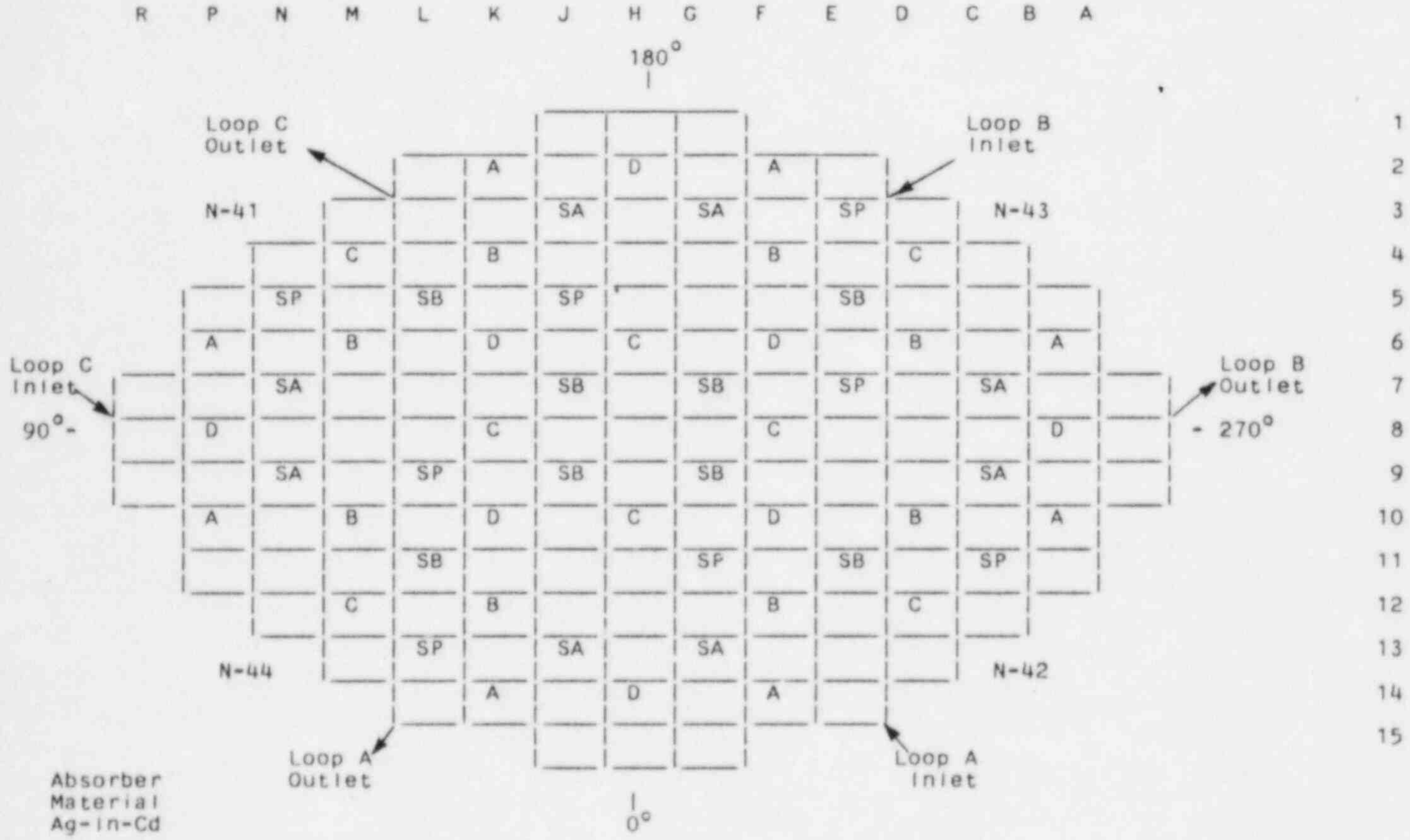
R	P	N	M	L	K	J	H	G	F	E	D	C	B	A	
							MD	TC							1
						TC		TC	MD						2
			MD TC		TC	MD	MD TC		TC		MD TC				3
		TC		MD			MD		MD	TC					4
		MD		MD	TC	MD	TC		TC	MD	MD TC		MD TC		5
		TC		MD TC			MD	TC	MD						6
TC	TC	MD				MD		MD		TC	MD		MD		7
MD	TC	MD TC		MD TC	TC		TC	TC	MD	TC		MD TC	MD	TC	8
			TC	MD			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 4

CONTROL ROD LOCATIONS



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

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 FOLLOW

The burnup history for the North Anna Unit 1, Cycle 4 core is graphically depicted in Figure 2.1. The unit remained shutdown from November 20, 1982, until December 4, 1982, for the replacement of a main station transformer. The unit remained shutdown from December 5, 1982, until March 8, 1983, for the replacement of three main station transformers and the main electrical generator. The North Anna 1, Cycle 4 core achieved a burnup of 13,478 MWD/MTU. As shown in Figure 2.2, the average load factor for Cycle 4 was 65% 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 4 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 4 operation is also given. As can be seen from this figure, the accumulated assembly burnups were generally within ±3% of the predicted values. In addition, deviation from quadrant symmetry in the core, as indicated by the burnup tilt factors, was no greater than ±0.44%.

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 4 followed design predictions closely with each batch deviating less than 0.5% from design. Symmetric burnup in conjunction with agreement between actual and predicted assemblywise burnups and batch burnup sharing indicate that the Cycle 4 core did deplete as designed.

Figure 2.1

NORTH ANNA UNIT 1 - CYCLE 4

CORE BURNUP HISTORY

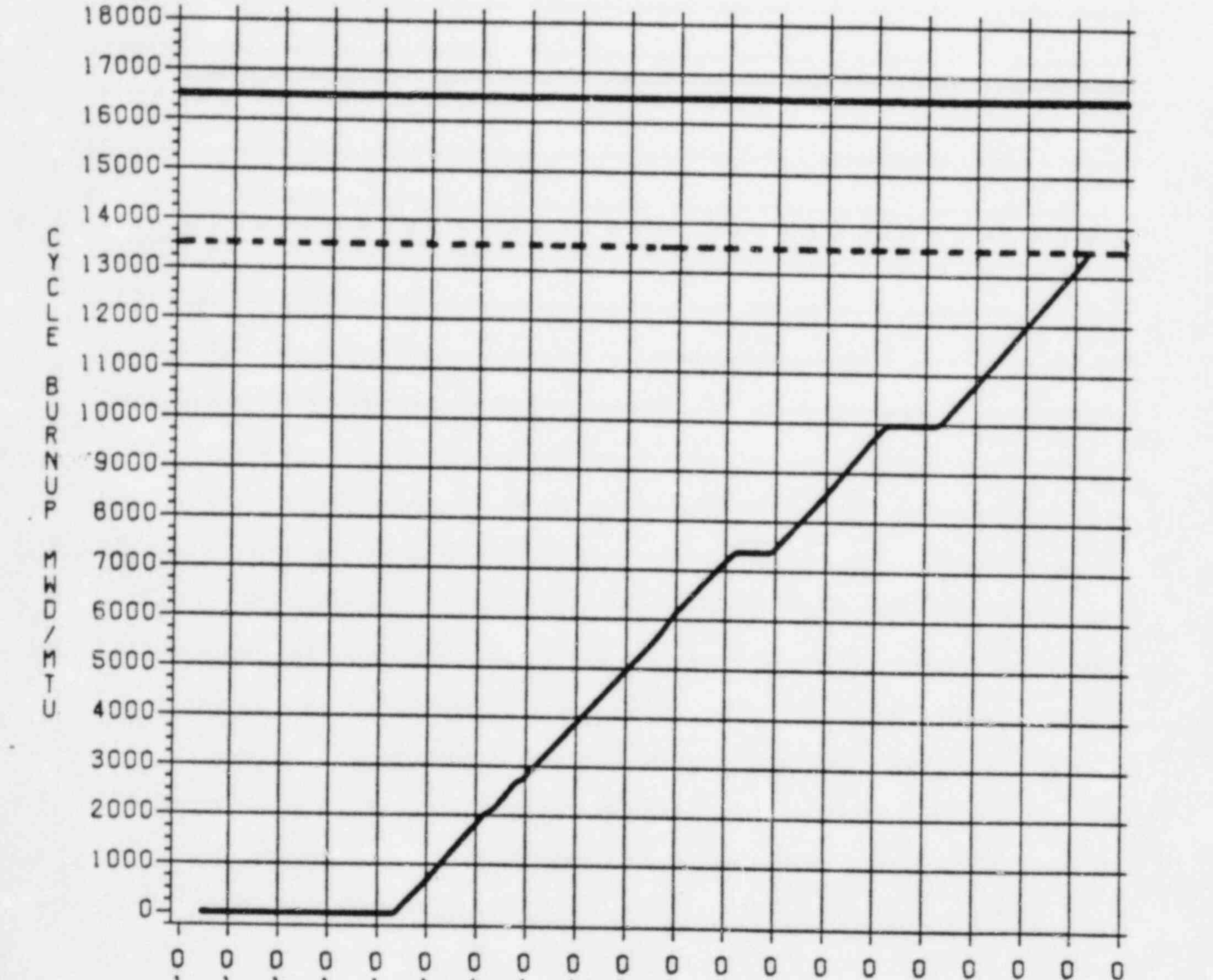
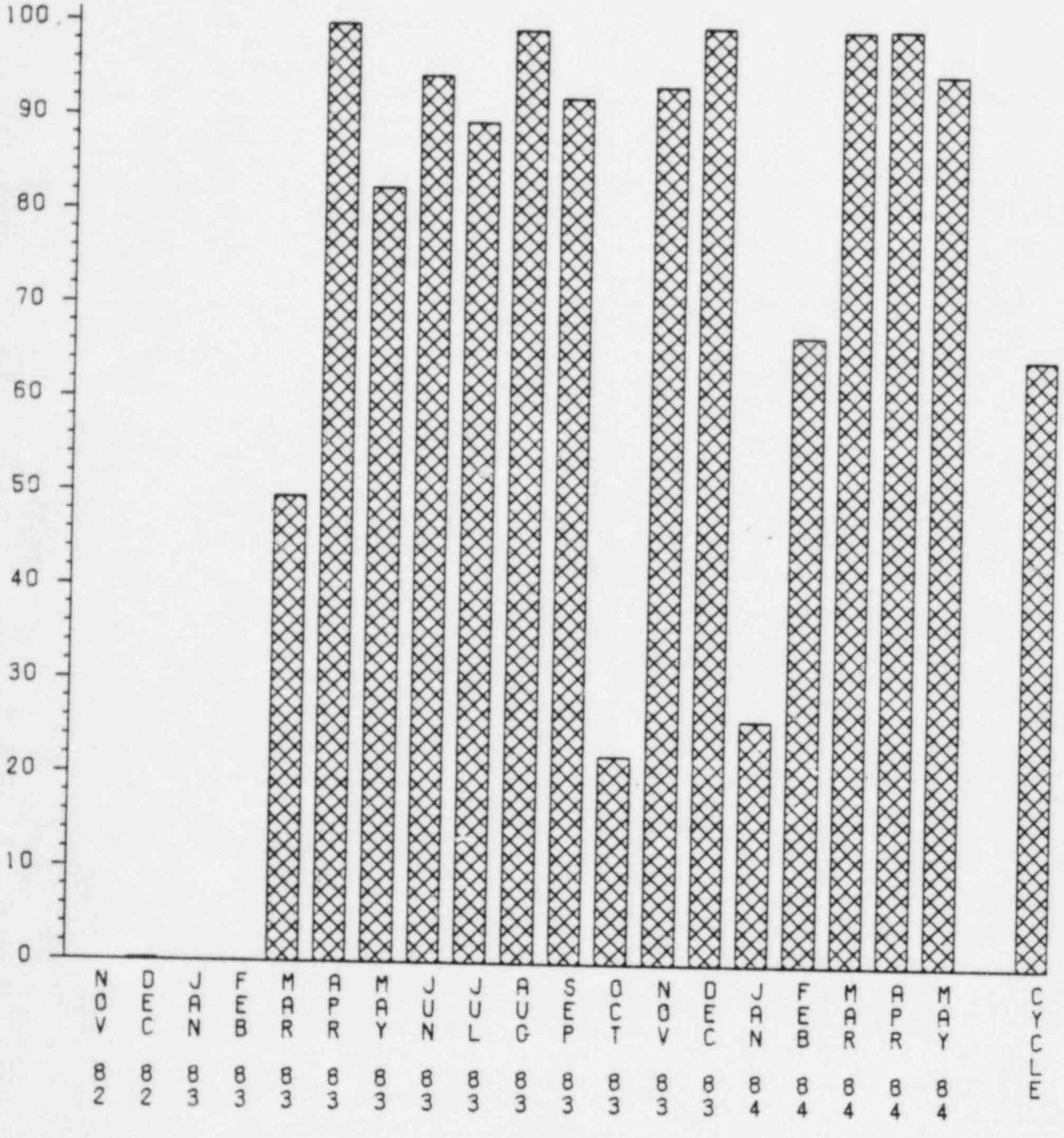


Figure 2.2

NORTH ANNA UNIT 1 - CYCLE 4
MONTHLY AVERAGE LOAD FACTOR



$$\text{LOAD FACTOR} = \frac{\text{THERMAL ENERGY GENERATION IN MONTH(MWHT)}}{\text{AUTHORIZED POWER LEVEL (MWT) X HOURS IN MONTH}}$$

(EXCLUDES REFUELING OUTAGES)

Figure 2.3

NORTH ANNA UNIT 1 - CYCLE 4
ASSEMBLYWISE ACCUMULATED BURNUP
MEASURED AND PREDICTED
(1000 MWD/MTU)

| MEASURED |
| PREDICTED |

	R	P	N	M	L	K	J	H	G	F	E	D	C	B	A	
1							22.52 22.42	9.83 9.65	22.24 22.42							1
2					32.59 32.29	11.91 11.97	14.15 14.09	25.23 25.35	14.13 14.09	12.01 11.97	32.59 32.29					2
3				33.44 33.47	13.01 12.72	15.62 15.71	28.81 29.26	30.54 30.98	28.97 29.26	15.75 15.71	12.99 12.72	33.72 33.47				3
4			33.91 33.56	20.76 20.73	15.89 15.73	30.12 30.32	17.02 17.05	31.68 31.82	16.87 17.05	30.16 30.32	15.89 15.73	21.05 20.73	33.85 33.56			4
5		32.34 32.35	12.64 12.72	15.61 15.73	32.23 32.35	17.49 17.47	36.67 36.79	30.77 31.08	36.45 36.79	17.38 17.47	32.25 32.35	15.73 15.73	13.38 12.72	32.87 32.35		5
6		11.79 11.97	15.57 15.71	29.59 30.18	17.32 17.47	32.69 32.98	17.19 17.42	32.54 32.54	17.19 17.42	32.82 32.98	17.21 17.47	30.21 30.18	16.05 15.71	12.62 11.97		6
7	22.26 22.41	13.89 14.09	29.02 29.21	16.77 17.05	36.52 36.82	17.01 17.42	32.11 32.41	27.59 28.12	32.20 32.41	17.18 17.42	36.29 36.82	16.71 17.05	28.74 29.21	13.93 14.09	22.30 22.41	7
8	9.51 9.65	25.14 25.61	30.47 30.76	31.55 31.86	30.94 31.22	32.12 32.36	27.40 27.88	17.11 17.20	28.00 27.88	32.15 32.36	30.91 31.22	31.59 31.86	30.48 30.76	25.72 25.61	9.85 9.65	8
9	22.45 22.41	13.94 14.09	29.01 29.21	16.92 17.05	36.82 36.82	17.25 17.42	32.01 32.41	28.31 28.12	32.16 32.41	17.19 17.42	36.77 36.82	16.78 17.05	29.31 29.21	14.17 14.09	22.77 22.41	9
10		11.90 11.97	15.76 15.71	30.34 30.18	17.66 17.47	32.93 32.98	17.05 17.42	32.08 32.54	17.12 17.42	32.67 32.98	17.26 17.47	30.13 30.18	15.80 15.71	12.23 11.97		10
11		32.62 32.35	13.30 12.72	16.12 15.73	32.41 32.35	17.55 17.47	36.69 36.79	30.83 31.08	36.42 36.79	17.20 17.47	32.12 32.35	15.70 15.73	12.87 12.72	32.28 32.35		11
12			33.61 33.56	21.00 20.73	15.90 15.73	30.73 30.32	16.81 17.05	31.49 31.82	16.76 17.05	29.85 30.32	15.73 15.73	20.99 20.73	33.76 33.56			12
13				33.97 33.47	13.21 12.72	15.94 15.71	29.42 29.26	30.85 30.98	29.03 29.26	15.93 15.71	12.81 12.72	33.57 33.47				13
14					32.60 32.29	12.54 11.97	14.35 14.09	25.52 25.35	14.09 14.09	12.02 11.97	32.12 32.29					14
15							22.97 22.42	10.01 9.65	22.77 22.42							15
	R	P	N	M	L	K	J	H	G	F	E	D	C	B	A	

Figure 2.4

NORTH ANNA UNIT 1 - CYCLE 4

ASSEMBLYWISE ACCUMULATED BURNUP

COMPARISON OF MEASURED AND PREDICTED

(1000 MWD/MTU)

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

                                              ----------------------                           ---------------
 1                                            | 22.52|  9.83| 22.24|                           |  MEASURED   |   1
                                              |  0.47|  1.88| -0.81|                           | M/P % DIFF  |
                                --------------------------------------------------             ---------------
 2                              | 32.59| 11.91| 14.15| 25.23| 14.13| 12.01| 32.59|                               2
                                |  0.94| -0.56|  0.40| -0.49|  0.30|  0.29|  0.93|
                         ----------------------------------------------------------------
 3                       | 33.44| 13.01| 15.62| 28.81| 30.54| 28.97| 15.75| 12.99| 33.72|                        3
                         | -0.08|  2.23| -0.56| -1.56| -1.41| -1.01|  0.25|  2.14|  0.74|
                  ------------------------------------------------------------------------------
 4                | 33.91| 20.76| 15.89| 30.12| 17.02| 31.68| 16.87| 30.16| 15.89| 21.05| 33.85|                 4
                  |  1.03|  0.16|  1.06| -0.64| -0.13| -0.46| -1.01| -0.50|  1.03|  1.52|  0.87|
           --------------------------------------------------------------------------------------------
 5         | 32.34| 12.64| 15.61| 32.23| 17.49| 36.67| 30.77| 36.45| 17.38| 32.25| 15.73| 13.38| 32.87|          5
           | -0.04| -0.61| -0.71| -0.36|  0.10| -0.34| -1.07| -0.94| -0.52| -0.31|  0.04|  5.19|  1.60|
           --------------------------------------------------------------------------------------------
 6         | 11.79| 15.57| 29.59| 17.32| 32.69| 17.19| 32.54| 17.19| 32.82| 17.21| 30.21| 16.05| 12.62|          6
           | -1.55| -0.84| -1.95| -0.89| -0.89| -1.31|  0.01| -1.36| -0.50| -1.52|  0.10|  2.17|  5.41|
    ----------------------------------------------------------------------------------------------------------
 7  | 22.26| 13.89| 29.02| 16.77| 36.52| 17.01| 32.11| 27.59| 32.20| 17.18| 36.29| 16.71| 28.74| 13.93| 22.30|   7
    | -0.67| -1.44| -0.67| -1.61| -0.83| -2.36| -0.92| -1.90|  0.64| -1.38| -1.45| -1.98| -1.60| -1.12| -0.52|
    ----------------------------------------------------------------------------------------------------------
 8  |  9.51| 25.14| 30.47| 31.55| 30.94| 32.12| 27.40| 17.11| 28.00| 32.15| 30.91| 31.59| 30.48| 25.72|  9.85|   8
    | -1.42| -1.82| -0.93| -0.97| -0.90| -0.73| -1.72| -0.55|  0.43| -0.63| -1.01| -0.85| -0.90|  0.45|  2.03|
    ----------------------------------------------------------------------------------------------------------
 9  | 22.45| 13.94| 29.01| 16.92| 36.82| 17.25| 32.01| 28.31| 32.16| 17.19| 36.77| 16.78| 29.31| 14.17| 22.77|   9
    |  0.17| -1.03| -0.71| -0.73| -0.01| -1.00| -1.21|  0.67| -0.77| -1.33| -0.15| -1.53|  0.31|  0.59|  1.59|
    ----------------------------------------------------------------------------------------------------------
10         | 11.90| 15.76| 30.34| 17.66| 32.93| 17.05| 32.08| 17.12| 32.67| 17.26| 30.13| 15.80| 12.23|         10
           | -0.58|  0.31|  0.53|  1.05| -0.16| -2.11| -1.42| -1.72| -0.96| -1.19| -0.18|  0.62|  2.16|
           --------------------------------------------------------------------------------------------
11         | 32.62| 13.30| 16.12| 32.41| 17.55| 36.69| 30.83| 36.42| 17.20| 32.12| 15.70| 12.87| 32.28|         11
           |  0.82|  4.57|  2.53|  0.17|  0.42| -0.28| -0.82| -1.02| -1.58| -0.71| -0.15|  1.16| -0.24|
           --------------------------------------------------------------------------------------------
12                | 33.61| 21.00| 15.90| 30.73| 16.81| 31.49| 16.76| 29.85| 15.73| 20.99| 33.76|                12
                  |  0.15|  1.30|  1.10|  1.37| -1.38| -1.03| -1.66| -1.52|  0.03|  1.26|  0.58|
                  ------------------------------------------------------------------------------
13                       | 33.97| 13.21| 15.94| 29.42| 30.85| 29.03| 15.93| 12.81| 33.57|   ------------------   13
                         |  1.49|  3.81|  1.46|  0.52| -0.41| -0.81|  1.39|  0.72|  0.29|   | ARITHMETIC AVG |
                         ----------------------------------------------------------------   |PCT DIFF = -0.01|
14                              | 32.60| 12.54| 14.35| 25.52| 14.09| 12.02| 32.12|          ------------------   14
                                |  0.97|  4.76|  1.83|  0.67|  0.04|  0.40| -0.53|
    ----------------                                --------------------------------------------------             ---------------
15  | STANDARD DEV |                          | 22.97| 10.01| 22.77|                           | AVG ABS PCT |  15
    |    = 0.92    |                          |  2.46|  3.76|  1.58|                           | DIFF = 1.07 |
    ----------------                          ----------------------                           ---------------

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

BURNUP SHARING
(MWD/MTU)

Batch	Cycle 2	Cycle 3	Cycle 4	Total
4A2	10951	15260	8057	34268
5A	--	14868	13882	28750
6A	--	--	14987	14987
Core Average			13478	

BURNUP TILT

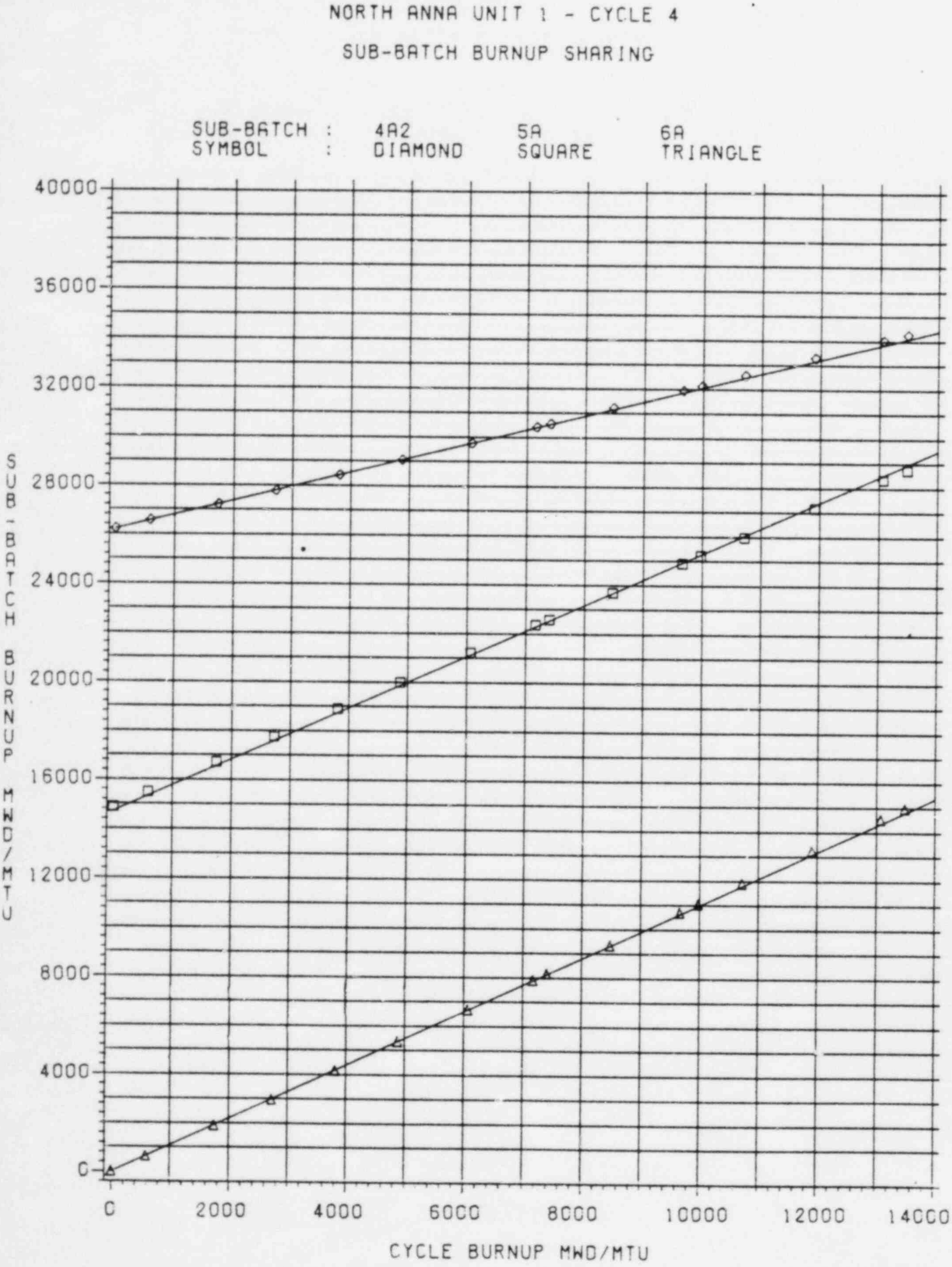
NW = -0.40

NE = +0.03

SW = +0.44

SE = -0.06

Figure 2.5


NORTH ANNA UNIT 1 - CYCLE 4
SUB-BATCH BURNUP SHARING
SUB-BATCH : 4A2 5A 6A
SYMBOL : DIAMOND SQUARE TRIANGLE
SUB-BATCH BURNUP MWD/MTU
40000
36000
32000
28000
24000
20000
16000
12000
8000
4000
0
0
2000
4000
6000
8000
10000
12000
14000
CYCLE BURNUP MWD/MTU

Section 3

REACTIVITY DEPLETION FOLLOW

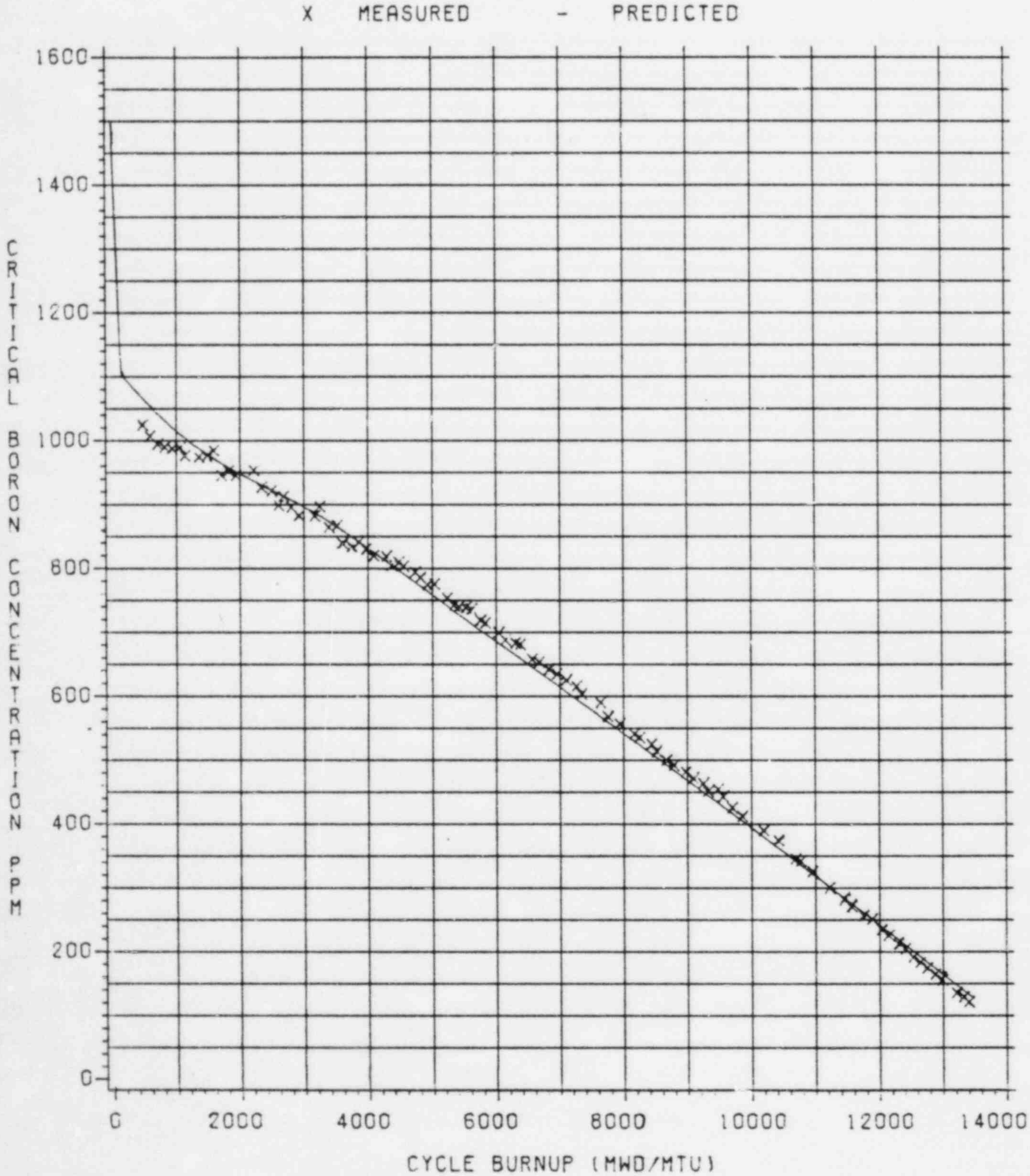
The primary coolant critical boron concentration is monitored for the purposes of following core reactivity and to identify any anomalous reactivity behavior. The FOLLOW[4] computer code was used to normalize "actual" critical boron concentration measurements to design conditions taking into consideration 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 4 core is shown in Figure 3.1. It can be seen that the measured data typically compare to within 51 ppm of the design prediction. This corresponds to less than ±0.40% ΔK/K which is well within the ±1% ΔK/K criterion 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 4 core depleted as expected without any reactivity anomalies.

Figure 3.1

NORTH ANNA UNIT 1 - CYCLE 4

CRITICAL BORON CONCENTRATION VS. BURNUP

HFP-ARO



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 full core flux maps taken since the completion of startup physics testing for North Anna 1, Cycle 4 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 at the end of Cycle 4 life. 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 5.1% of the predicted values with an average percent difference of approximately 1.7% which is considered good agreement. In addition, as indicated by the INCORE tilt factors, the power distributions were essentially symmetric for all cases.

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 Technical Specifications limit on the axially dependent heat flux hot channel factor $F_Q(Z)$ was 2.20 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 2.20 $F_Q(Z)$ 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 through 4.7. Throughout Cycle 4, 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 4 is given in Figure 4.8. Figure 4.9 shows the maximum values for the Heat Flux Hot Channel Factor measured during Cycle 4. As can be seen from the figure, there was a 19% margin to the limit at the beginning of the cycle, with the margin remaining relatively constant 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 4 limit on the enthalpy rise hot channel factor was set at 1.55 x (1+0.3(1-P)) x (1-RBP(BU)), where P is the fractional power level, and RBP(BU) is the rod bow penalty. A summary of the maximum values for the Enthalpy Rise Hot Channel Factor measured during Cycle 4 is given in Figure 4.10.

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 the target delta flux versus burnup, given in Figure 4.11, shows the value of this parameter to have been approximately -1% at the beginning of Cycle 4. After approximately one-half of the cycle, delta flux values had shifted to -6.5% and then moved to -5% by the end of Cycle 4.

The power shift indicated by the delta flux values 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 N1-4-07 (Figure 4.12), taken at approximately 300 MWD/MTU, the axial power distribution had a slightly flattened cosine shape with a peaking factor of 1.18. In Map N1-4-18 (Figure 4.13), taken at approximately 7,000 MWD/MTU, the axial power distribution had shifted toward the bottom of the core with an axial peaking factor of 1.17. Finally, in Map N1-4-30 (Figure 4.14), taken at approximately 12,500 MWD/MTU, the axial peaking factor was 1.18. 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.

---

*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))

In conclusion, the North Anna 1, Cycle 4 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 4

SUMMARY OF INCORE FLUX MAPS FOR ROUTINE OPERATION

MAP NO.	DATE	BURN UP MWD/ MTU *	PWR (%)	BANK D STEPS	F-Q (T) HOT CHANNEL FACTOR 1				F-DH(N) HOT CHNL.FACTOR 2			CORE F(Z) MAX		F(XY) MAX 3	QPTR 4		AXIAL OFF SET (%)	NO. OF THIMBLES
					ASSY	PIN	AXIAL POINT	F-Q(T)	ASSY	PIN	F-DH(N)	AXIAL POINT	F(Z)		MAX	LOC		
7	3-24-83	305	100	221	B06	DE	29	1.765	K09	JI	1.393	29	1.176	1.513	1.009	NE	-1.16	45
10(5)	4-14-83	1112	100	222	K09	JI	30	1.700	K09	JI	1.398	29	1.177	1.502	1.007	SW	-0.89	47
11	5-16-83	2232	100	227	B06	DE	29	1.722	J06	IH	1.404	29	1.170	1.472	1.007	SW	-0.64	39
12	5-20-83	2382	100	228	L10	IH	39	1.710	J06	IH	1.401	38	1.175	1.465	1.006	SW	-3.01	40
13	6-20-83	3394	100	224	L10	IH	38	1.714	L10	IH	1.414	38	1.159	1.483	1.007	SW	-2.70	40
16(6)	7-20-83	4480	100	228	L10	IH	39	1.719	L10	IH	1.421	39	1.153	1.495	1.007	NE	-2.62	42
17	8-17-83	5520	100	216	L06	IJ	46	1.740	L10	IH	1.436	38	1.154	1.516	1.008	SW	-3.11	42

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

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

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

(3). F(XY) INCLUDES A TOTAL UNCERTAINTY OF 1.05 X 1.03.

(4). QPTR - QUADRANT POWER TILT RATIO.

(5). MAPS 8 AND 9 WERE TAKEN FOR INCORE/EXCORE CALIBRATION.

(6). MAPS 14 AND 15 WERE TAKEN FOR INCORE/EXCORE CALIBRATION.

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 THIMBLES
					ASSY	PIN	AXIAL POINT	F-Q(T)	ASSY	PIN	F-DH(N)	AXIAL POINT	F(Z)		MAX	LOC		
18	9-20-83	6834	100	214	K05	HI	48	1.757	L10	IH	1.435	47	1.169	1.510	1.008	SW	-6.29	48
23(7)	11-16-83	7963	100	216	L10	IH	47	1.778	L10	IH	1.443	47	1.171	1.518	1.011	SW	-5.54	39
24	12-15-84	9023	100	218	L10	IH	47	1.767	L10	IH	1.442	47	1.165	1.517	1.007	SW	-5.26	40
25	2-15-84	10170	100	226	L10	IH	48	1.750	L10	IH	1.450	47	1.147	1.522	1.007	SW	-3.96	39
28(8)	3- 7-84	10965	100	225	L10	IH	47	1.763	L10	IH	1.444	48	1.163	1.513	1.008	SW	-5.28	40
29	4- 9-84	12241	100	222	L10	IH	48	1.739	L10	IH	1.435	53	1.162	1.506	1.005	SW	-4.84	40
30	4-16-84	12511	100	228	L10	IH	48	1.768	L10	IH	1.437	53	1.180	1.509	1.006	SW	-5.62	40

(7). MAPS 19, 20, 21, AND 22 WERE TAKEN FOR INCORE/EXCORE CALIBRATION.

(8). MAPS 26 AND 27 WERE TAKEN FOR INCORE/EXCORE CALIBRATION.

Figure 4.1

NORTH ANNA UNIT 1 - CYCLE 4

ASSEMBLYWISE POWER DISTRIBUTION N1-4-07

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

        .................                       .........................               .................
        .   MEASURED    .                       . 0.50 . 0.82 . 0.49 .                  .   MEASURED    .                     1
        .PCT DIFFERENCE.                        .  5.8 .  5.8 .  3.6 .                  .PCT DIFFERENCE.
        .................       .........................................................  .................
                                . 0.34 . 0.92 . 1.12 . 1.12 . 1.12 . 0.93 . 0.34 .                                     2
                                .  1.4 .  1.0 .  2.4 .  2.5 .  2.5 .  1.1 .  1.3 .
                        .........................................................................
                        . 0.33 . 0.87 . 1.12 . 1.20 . 1.20 . 1.19 . 1.12 . 0.88 . 0.34 .                             3
                        . -0.2 . -0.4 . -0.5 .  0.2 .  0.2 . -0.4 . -0.7 .  0.1 .  1.6 .
                .........................................................................................
                . 0.33 . 0.80 . 1.07 . 1.17 . 1.25 . 1.21 . 1.23 . 1.16 . 1.07 . 0.82 . 0.34 .                     4
                . -1.4 . -1.5 . -0.8 . -0.3 .  0.5 .  0.4 . -1.0 . -1.5 . -0.5 .  0.6 .  3.8 .
        .........................................................................................................
        . 0.32 . 0.84 . 1.05 . 1.10 . 1.21 . 1.06 . 1.19 . 1.04 . 1.21 . 1.11 . 1.07 . 0.93 . 0.36 .             5
        . -4.0 . -4.0 . -2.6 . -2.0 . -1.2 .  0.0 . -0.1 . -1.4 . -1.5 . -1.4 . -0.5 .  6.0 .  6.0 .
        .........................................................................................................
        . 0.89 . 1.10 . 1.15 . 1.20 . 1.19 . 1.26 . 1.21 . 1.25 . 1.19 . 1.22 . 1.17 . 1.16 . 0.97 .             6
        . -2.4 . -2.4 . -2.2 . -2.1 . -0.7 .  0.3 .  0.6 . -0.2 . -0.3 . -0.8 . -0.4 .  2.8 .  6.0 .
.........................................................................................................................
. 0.47 . 1.09 . 1.19 . 1.23 . 1.04 . 1.24 . 1.21 . 1.18 . 1.21 . 1.25 . 1.05 . 1.25 . 1.20 . 1.10 . 0.48 .     7
. -0.7 . -0.1 . -0.1 . -0.9 . -1.7 . -1.0 . -0.1 .  0.4 . -0.0 . -0.0 . -0.7 . -0.0 .  0.5 .  0.9 .  1.3 .
.........................................................................................................................
. 0.78 . 1.10 . 1.20 . 1.21 . 1.20 . 1.21 . 1.17 . 1.24 . 1.18 . 1.21 . 1.19 . 1.21 . 1.21 . 1.10 . 0.78 .     8
.  0.6 . -0.0 .  0.0 .  0.4 .  0.7 .  0.6 .  0.2 .  0.9 .  0.5 .  0.5 . -0.3 .  0.0 .  0.5 .  0.8 .  1.3 .
.........................................................................................................................
. 0.47 . 1.09 . 1.20 . 1.25 . 1.07 . 1.26 . 1.21 . 1.18 . 1.21 . 1.26 . 1.05   1.23 . 1.20 . 1.10 . 0.48 .     9
. -0.5 .  0.1 .  0.1 .  0.5 .  0.9 .  0.6 .  0.0 .  0.5 .  0.2 .  0.1 . -1.1 . -1.3 . -0.0 .  0.9 .  1.2 .
.........................................................................................................................
        . 0.91 . 1.12 . 1.18 . 1.23 . 1.20 . 1.26 . 1.21 . 1.25 . 1.19 . 1.20 . 1.15 . 1.11 . 0.92 .             10
        . -0.5 . -0.5 .  0.2 .  0.6 .  0.4 .  0.0 .  0.5 . -0.4 . -0.9 . -1.9 . -2.6 . -1.0 .  0.9 .
        .........................................................................................................
        . 0.34 . 0.88 . 1.07 . 1.12 . 1.22 . 1.05 . 1.19 . 1.04 . 1.20 . 1.10 . 1.05 . 0.86 . 0.34 .             11
        .  0.6 .  0.5 . -0.0 . -1.1 . -0.7 . -0.4 . -0.4 . -1.9 . -2.0 . -2.4 . -2.1 . -1.4 .  0.2 .
        .........................................................................................................
                . 0.34 . 0.81 . 1.06 . 1.16 . 1.24 . 1.20 . 1.24 . 1.16 . 1.06 . 0.80 . 0.33 .                     12
                .  1.6 .  0.3 . -1.1 . -1.0 . -0.4 . -0.4 . -0.6 . -1.3 . -1.8 . -1.9 . -1.6 .
                .........................................................................................
                        . 0.34 . 0.89 . 1.13 . 1.19 . 1.21 . 1.21 . 1.14 . 0.86 . 0.33 .                             13
                        .  1.8 .  1.9 .  0.5 . -0.4 .  0.5 .  0.8 .  1.0 . -1.4 . -1.8 .
                        .........................................................................
                                . 0.34 . 0.95 . 1.13 . 1.13 . 1.10 . 0.93 . 0.34 .                                     14
                                .  1.9 .  4.1 .  3.3 .  2.9 .  0.9 .  1.2 . -0.1 .
                                .........................................................
                                                . 0.50 . 0.81 . 0.48 .                                                 15
                                                .  6.3 .  4.5 .  2.5 .
                                                .........................

STANDARD DEVIATION = 1.341                                                          AVERAGE PCT. DIFFERENCE =   1.2
```

SUMMARY

```
MAP NO: N1-4- 7             DATE:  3/24/83            POWER:  100%

CONTROL ROD POSITIONS:      F-Q(T)  = 1.765           QPTR:

D BANK AT 221 STEPS         F-DH(N) = 1.393           NW  0.995   | NE  1.009
                                                      ------------|----------
                            F(Z)    = 1.176           SW  1.004   | SE  0.992

                            F(XY)   = 1.513

                            BURNUP  =    305 MWD/MTU    A.O =  -1.16(%)
```

Figure 4.2

NORTH ANNA UNIT 1 - CYCLE 4

ASSEMBLYWISE POWER DISTRIBUTION N1-4-18

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

       ................                   ......................             ................
       .   MEASURED   .                   . 0.45 . 0.70 . 0.44 .             .   MEASURED   .                   1
       .PCT DIFFERENCE.                   .  0.8 .  0.7 . -0.1 .             .PCT DIFFERENCE.
       ................     ..................................................  ................
                            . 0.37 . 0.89 . 1.04 . 0.97 . 1.03 . 0.87 . 0.37 .                                  2
                            .  1.1 .  1.3 .  1.4 .  1.2 .  0.5 . -1.2 .  0.9 .
                     ................................................................
                     . 0.39 . 0.97 . 1.18 . 1.11 . 1.08 . 1.10 . 1.16 . 0.97 . 0.40 .                           3
                     .  0.8 .  0.8 .  0.9 .  0.3 .  0.2 . -0.6 . -1.0 .  0.5 .  3.3 .
              ..............................................................................
              . 0.38 . 0.89 . 1.20 . 1.19 . 1.27 . 1.12 . 1.26 . 1.17 . 1.20 . 0.90 . 0.39 .                    4
              . -1.0 . -0.2 .  0.6 .  0.8 .  0.4 .  0.2 . -0.6 . -0.3 .  0.9 .  1.5 .  2.9 .
       ............................................................................................
       . 0.36 . 0.93 . 1.18 . 1.16 . 1.31 . 1.03 . 1.11 . 1.03 . 1.30 . 1.16 . 1.20 . 0.99 . 0.38 .             5
       . -2.9 . -2.9 . -0.9 . -0.1 .  0.2 . -0.8 . -1.0 . -1.6 . -0.7 . -0.2 .  0.6 .  2.8 .  4.4 .
       ............................................................................................
       . 0.87 . 1.16 . 1.17 . 1.30 . 1.18 . 1.29 . 1.14 . 1.28 . 1.17 . 1.31 . 1.18 . 1.20 . 0.92 .             6
       . -1.3 . -1.3 . -1.0 . -0.6 . -0.1 . -0.2 . -0.2 . -0.9 . -0.6 . -0.1 .  0.4 .  1.8 .  4.5 .
..........................................................................................................
. 0.45 . 1.02 . 1.10 . 1.25 . 1.02 . 1.28 . 1.16 . 1.16 . 1.16 . 1.29 . 1.03 . 1.25 . 1.10 . 1.02 . 0.45 .      7
.  0.1 . -0.4 . -0.3 . -1.1 . -1.9 . -1.5 . -0.8 . -0.5 . -0.8 . -0.8 . -0.8 . -1.2 . -0.7 . -0.9 .  0.6 .
..........................................................................................................
. 0.69 . 0.96 . 1.07 . 1.11 . 1.11 . 1.14 . 1.16 . 1.29 . 1.16 . 1.14 . 1.11 . 1.10 . 1.07 . 0.98 . 0.72 .      8
. -1.0 . -0.5 . -0.4 . -0.4 . -0.5 . -0.5 . -0.6 .  0.1 . -0.2 . -0.3 . -0.6 . -1.3 . -0.8 .  1.3 .  3.6 .
..........................................................................................................
. 0.45 . 1.02 . 1.10 . 1.26 . 1.04 . 1.29 . 1.16 . 1.16 . 1.17 . 1.29 . 1.03 . 1.25 . 1.10 . 1.04 . 0.46 .      9
.  0.0 . -0.5 . -0.5 . -0.4 . -0.2 . -0.4 . -0.6 .  0.1 . -0.3 . -0.4 . -0.8 . -1.6 . -0.6 .  1.3 .  2.8 .
..........................................................................................................
       . 0.88 . 1.17 . 1.19 . 1.32 . 1.18   1.28 . 1.14 . 1.28 . 1.17 . 1.30 . 1.17 . 1.17 . 0.91 .             10
       . -0.1 . -0.1 .  0.6 .  1.0 .  0.4 . -1.1 . -0.5 . -0.8 . -0.7 . -1.0 . -0.7 . -0.2 .  3.1 .
       ............................................................................................
       . 0.38 . 0.99 . 1.21 . 1.16 . 1.30 . 1.03 . 1.11 . 1.03 . 1.30 . 1.15 . 1.19 . 0.96 . 0.37 .             11
       .  2.5 .  2.5 .  1.8 .  0.4 . -0.4 . -1.1 . -1.1 . -1.5 . -1.1 . -1.1 . -0.4 . -0.1 .  0.9 .
       ............................................................................................
              . 0.40 . 0.91 . 1.19 . 1.17 . 1.25 . 1.11 . 1.25 . 1.17 . 1.18 . 0.88 . 0.38 .                    12
              .  5.2 .  2.8 .  0.3 . -0.3 . -0.9 . -0.9 . -1.0 . -0.9 . -1.1 . -0.3 .  0.2 .
              ..............................................................................
                     . 0.40 . 1.00 . 1.19 . 1.10 . 1.08 . 1.11 . 1.18 . 0.95 . 0.38 .                           13
                     .  4.6 .  4.0 .  1.5 . -0.6 . -0.0 .  0.1 .  0.2 . -1.1 .  0.0 .
                     ................................................................
                            . 0.38 . 0.92 . 1.05 . 0.98 . 1.03 . 0.88 . 0.37 .                                  14
                            .  4.0 .  4.4 .  2.3 .  1.7 .  0.2 .  0.3 . -0.6 .
                            ..................................................
                                          . 0.47 . 0.71 . 0.45 .                                                15
                                          .  4.7 .  2.9 .  1.1 .
                                          ......................

STANDARD DEVIATION = 1.084                                                     AVERAGE PCT. DIFFERENCE =   1.1
```

```
                                    SUMMARY
                                    -------

MAP NO: N1-4-18                  DATE:  9/20/83              POWER:  100%

CONTROL ROD POSITIONS:           F-Q(T)   = 1.757            QPTR:

D BANK AT 214 STEPS              F-DH(N)  = 1.435            NW  0.997 | NE  1.001
                                                             ----------|----------
                                 F(Z)     = 1.169            SW  1.008 | SE  0.994

                                 F(XY)    = 1.510

                                 BURNUP  =  6834 MWD/MTU     A.O =  -6.29(%)
```

Figure 4.3

NORTH ANNA UNIT 1 - CYCLE 4

ASSEMBLYWISE POWER DISTRIBUTION N1-4-30

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

       ................                   ......................                ................
       .   MEASURED   .                   . 0.47 . 0.71 . 0.47 .                .   MEASURED   .              1
       .PCT DIFFERENCE.                   .  2.6 .  2.6 .  1.9 .                .PCT DIFFERENCE.
       ................     ..................................................  ................
                            . 0.41 . 0.87 . 1.03 . 0.96 . 1.03 . 0.88 . 0.41 .                                2
                            .  5.1 . -0.7 .  1.0 .  1.0 .  1.0 .  1.1 .  3.5 .
                     ................................................................
                     . 0.42 . 1.02 . 1.17 . 1.07 . 1.03 . 1.08 . 1.20 . 1.03 . 0.44 .                         3
                     .  1.9 .  1.5 . -2.2 . -0.7 . -0.7 .  0.1 .  0.5 .  2.4 .  6.0 .
              ..............................................................................
              . 0.44 . 0.93 . 1.24 . 1.16 . 1.27 . 1.08 . 1.26 . 1.16 . 1.25 . 0.94 . 0.43 .                  4
              .  5.1 .  0.8 .  0.6 . -0.2 .  0.8 .  0.7 . -0.4 . -0.1 .  1.1 .  1.8 .  3.6 .
       ............................................................................................
       . 0.39 . 1.00 . 1.21 . 1.13 . 1.31 . 1.03 . 1.08 . 1.02 . 1.31 . 1.14 . 1.20 . 1.03 . 0.42 .           5
       .  0.2 . -0.5 . -2.0 . -1.9 . -0.9 .  0.5 .  0.3 . -0.9 . -0.6 . -1.2 . -2.4 .  2.5 .  7.3 .
       ............................................................................................
       . 0.88 . 1.20 . 1.15 . 1.29 . 1.16 . 1.29 . 1.10 . 1.28 . 1.16 . 1.29 . 1.13 . 1.20 . 0.91 .           6
       .  0.2 .  0.2 . -1.2 . -2.0 . -0.7 . -0.1 . -0.1 . -0.8 . -0.5 . -2.2 . -2.7 .  0.4 .  3.6 .
..........................................................................................................
. 0.46 . 1.02 . 1.08 . 1.24 . 1.00 . 1.26 . 1.12 . 1.13 . 1.12 . 1.28 . 1.01 . 1.23 . 1.06 . 1.01 . 0.46 .    7
.  0.2 .  0.2 .  0.2 . -1.8 . -2.8 . -2.1 . -1.2 . -0.7 . -0.8 . -0.5 . -2.1 . -2.3 . -1.5 . -0.7 . -0.1 .
..........................................................................................................
. 0.69 . 0.95 . 1.04 . 1.08 . 1.07 . 1.10 . 1.13 . 1.28 . 1.13 . 1.09 . 1.05 . 1.05 . 1.02 . 0.97 . 0.72 .    8
.  0.2 .  0.2 .  0.2 . -0.2 . -0.5 . -0.6 . -0.8 . -0.3 . -0.9 . -1.0 . -2.9 . -2.2 . -1.5 .  2.0 .  4.1 .
..........................................................................................................
. 0.45 . 1.02 . 1.07 . 1.26 . 1.03 . 1.27 . 1.10 . 1.12 . 1.11 . 1.27 . 1.02 . 1.26 . 1.08 . 1.05 . 0.48 .    9
. -0.4 . -0.4 . -0.4 . -0.4 . -0.2 . -1.2 . -3.1 . -1.6 . -1.4 . -1.6 . -1.1 . -0.4 .  0.1 .  2.7 .  5.0 .
..........................................................................................................
       . 0.87 . 1.19 . 1.17 . 1.34 . 1.16 . 1.25 . 1.08 . 1.26 . 1.15 . 1.31 . 1.17 . 1.21 . 0.91 .           10
       . -0.4 . -0.4 .  0.6 .  1.2 . -0.3 . -2.9 . -2.0 . -2.2 . -1.4 . -1.1 .  0.7 .  0.9 .  4.3 .
       ............................................................................................
       . 0.40 . 1.04 . 1.26 . 1.16 . 1.30 . 1.00 . 1.05 . 1.00 . 1.30 . 1.15 . 1.24 . 1.02 . 0.40 .           11
       .  2.9 .  2.9 .  2.2 .  0.9 . -1.4 . -2.6 . -2.6 . -3.0 . -1.4 . -0.4 .  0.6 .  0.7 .  1.3 .
       ............................................................................................
              . 0.44 . 0.95 . 1.25 . 1.16 . 1.24 . 1.06 . 1.24 . 1.15 . 1.23 . 0.92 . 0.42 .                  12
              .  6.2 .  3.6 .  0.9 . -0.7 . -1.8 . -1.7 . -1.6 . -0.8 . -0.5 .  0.6 .  0.2 .
              ..............................................................................
                     . 0.44 . 1.07 . 1.22 . 1.06 . 1.02 . 1.07 . 1.20 . 1.01 . 0.42 .                         13
                     .  6.2 .  6.2 .  2.0 . -1.3 . -1.2 . -0.2 .  0.1 .  0.1 .  0.2 .
                     ................................................................
                            . 0.42 . 0.93 . 1.05 . 0.97 . 1.02 . 0.88 . 0.39 .                                14
                            .  6.2 .  6.4 .  3.2 .  3.0 . -0.2 .  0.1 .  0.1 .
                            ..................................................
                                          . 0.49 . 0.74 . 0.49 .                                              15
                                          .  6.6 .  6.6 .  6.6 .
                                          ......................

STANDARD DEVIATION = 1.672                                               AVERAGE PCT. DIFFERENCE =   1.7
```

SUMMARY

```
MAP NO: N1-4-30              DATE:  4/16/84               POWER:  100%

CONTROL ROD POSITIONS:       F-Q(T)   = 1.768             QPTR:

D BANK AT 228 STEPS          F-DH(N)  = 1.437             NW  0.997 | NE  1.002
                                                          ----------|----------
                             F(Z)     = 1.180             SW  1.006 | SE  0.995

                             F(XY)    = 1.509

                             BURNUP   = 12511 MWD/MTU   A.0 =  -5.62(%)
```

Figure 4.4

HOT CHANNEL FACTOR NORMALIZED OPERATING ENVELOPE

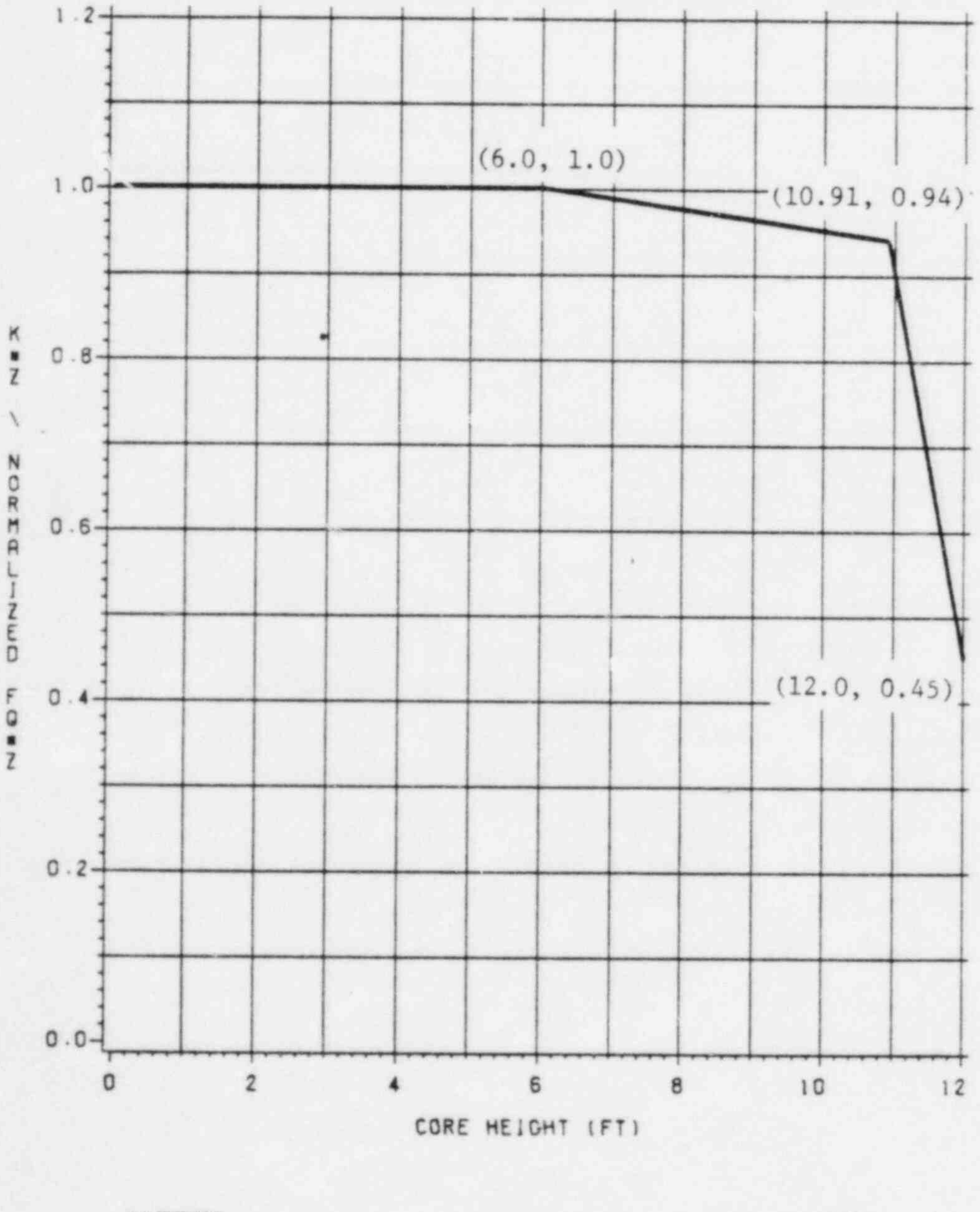


Figure 4.5

NORTH ANNA UNIT 1 - CYCLE 4
HEAT FLUX HOT CHANNEL FACTOR, $F_Q^T(Z)$
N1-4-07

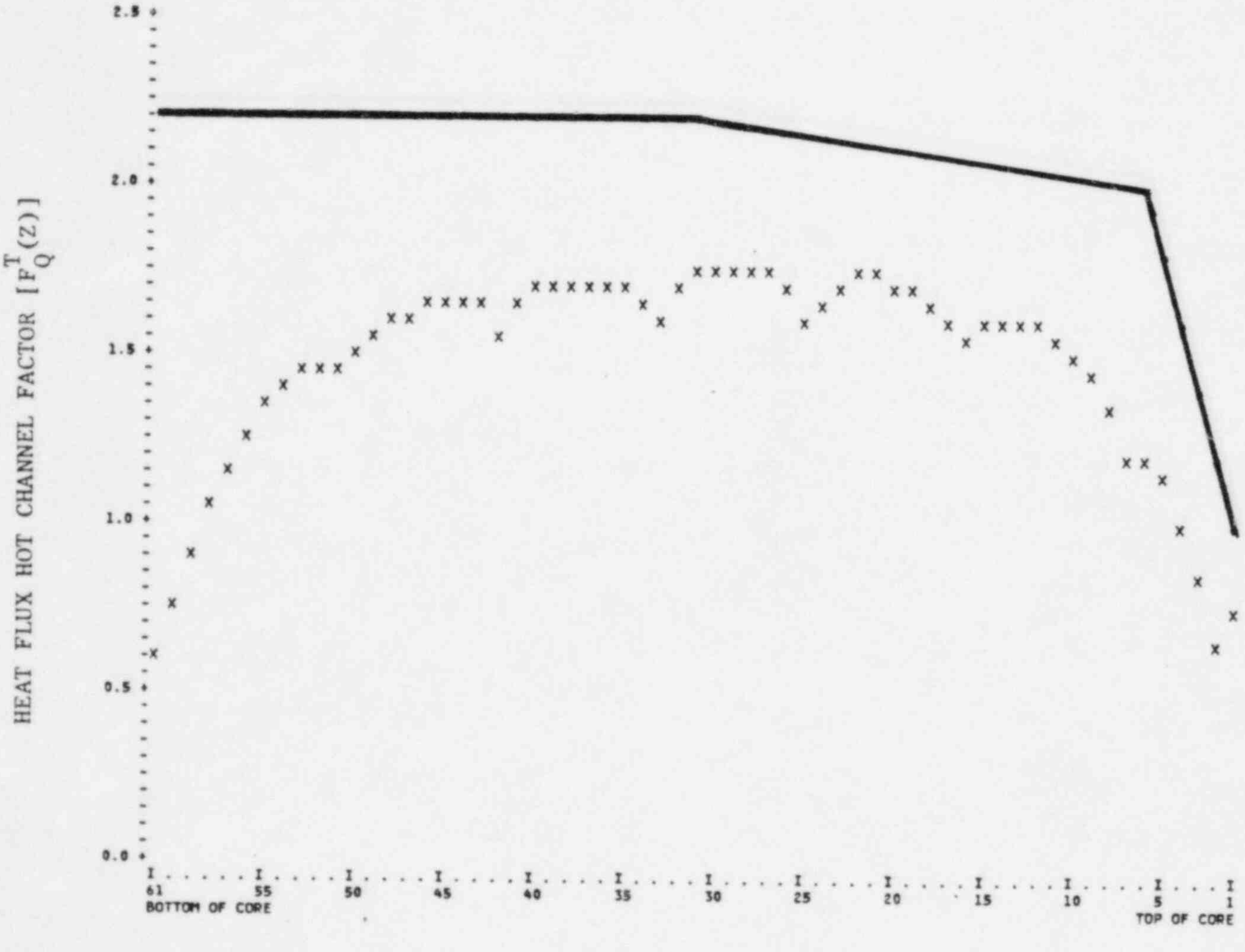


Figure 4.6

NORTH ANNA UNIT 1 - CYCLE 4

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

N1-4-18

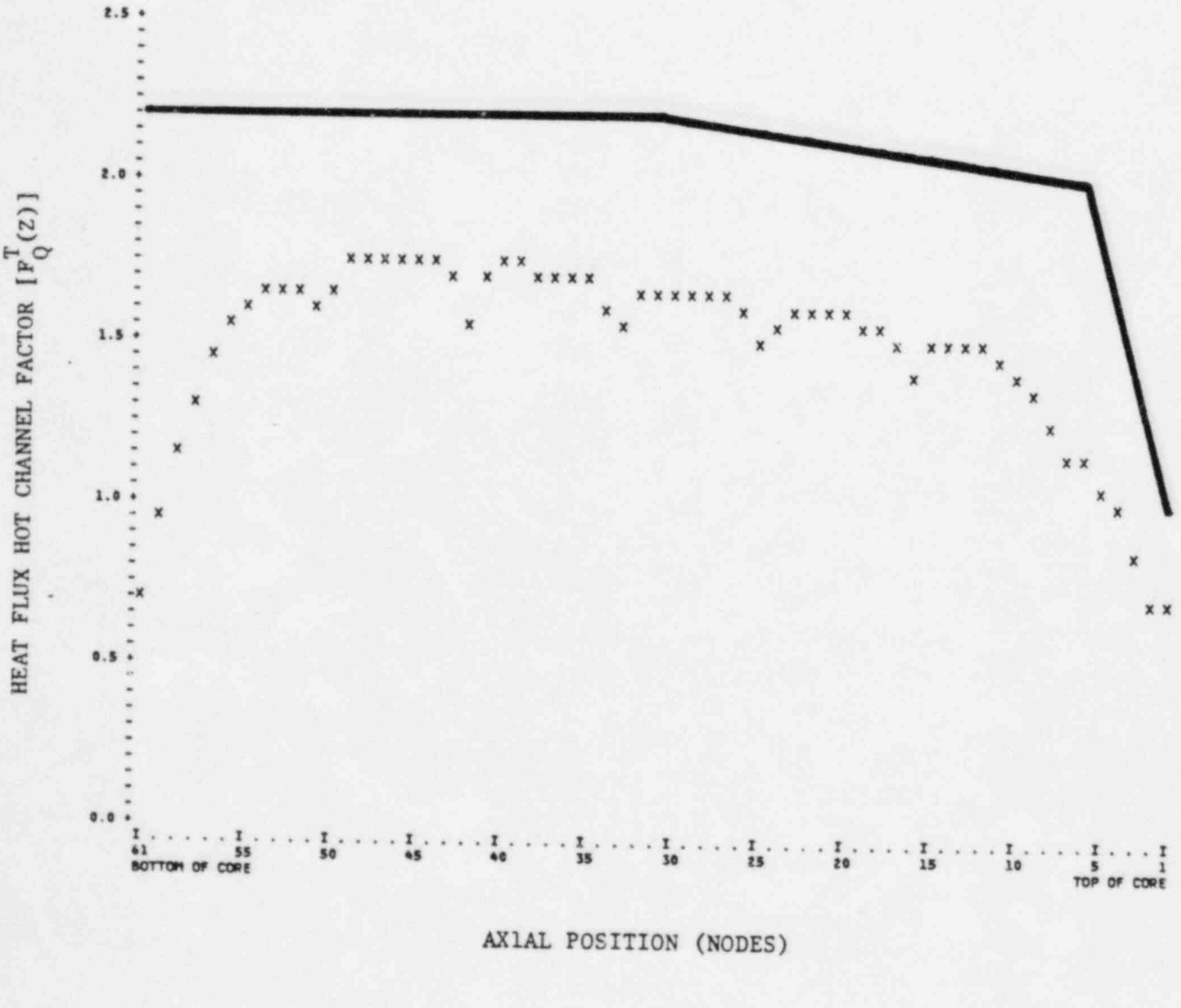


Figure 4.7

NORTH ANNA UNIT 1 - CYCLE 4

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

N1-4-30

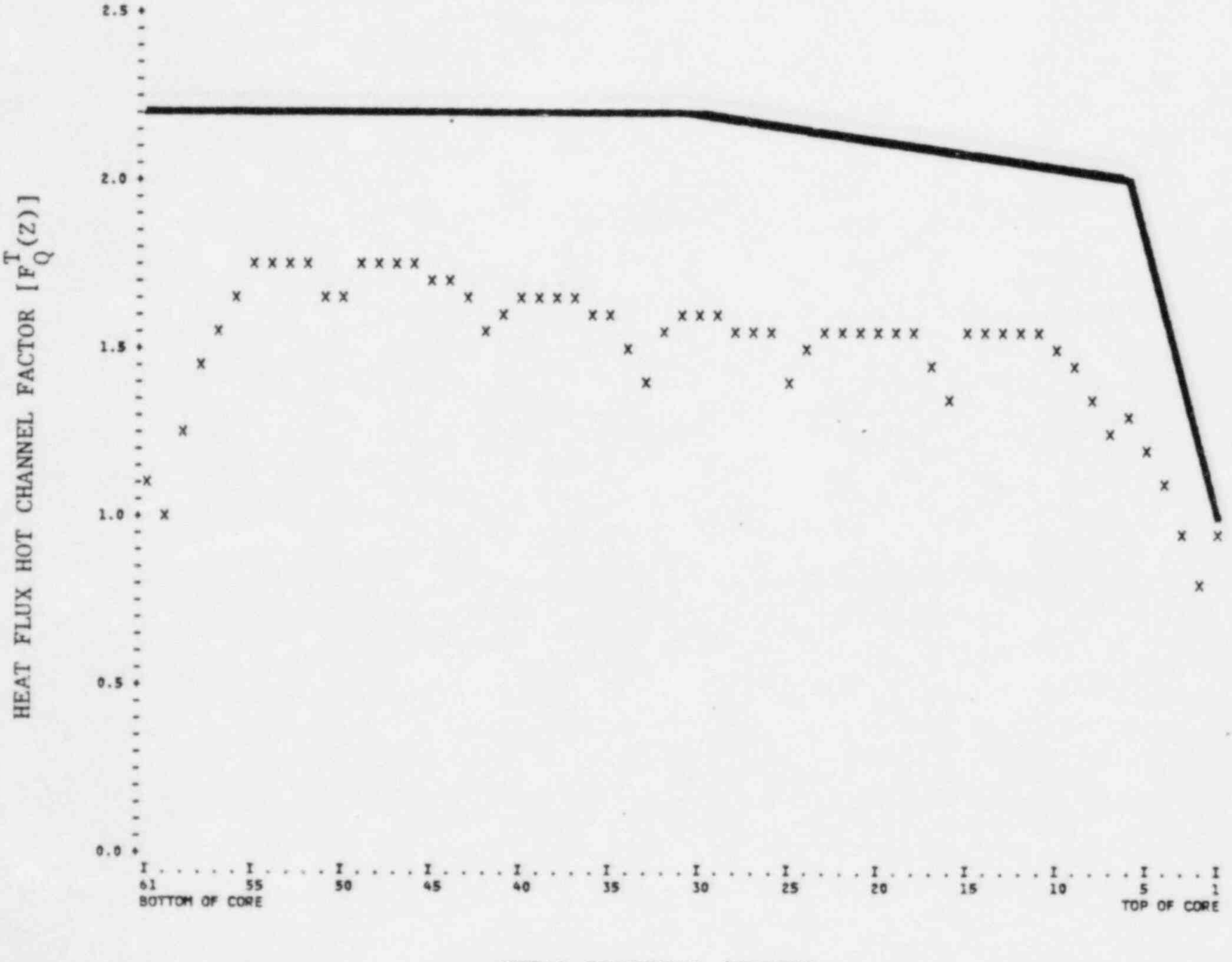


Figure 4.8

NORTH ANNA UNIT 1 - CYCLE 4

MAXIMUM HEAT FLUX HOT CHANNEL FACTOR, FQ * P VS AXIAL POSITION

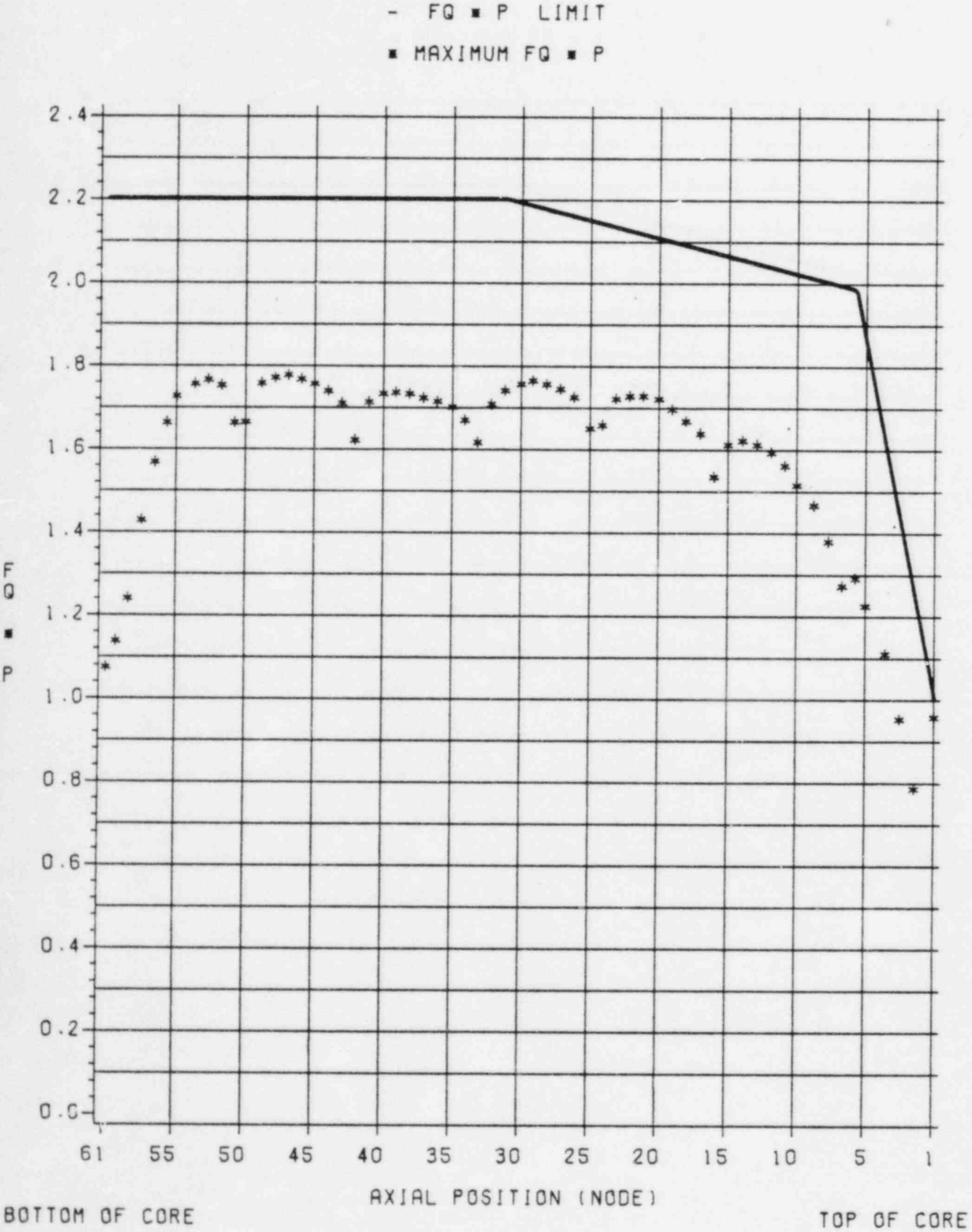


Figure 4.9

NORTH ANNA UNIT 1 - CYCLE 4

MAXIMUM HEAT FLUX HOT CHANNEL FACTOR, F-Q VS. BURNUP

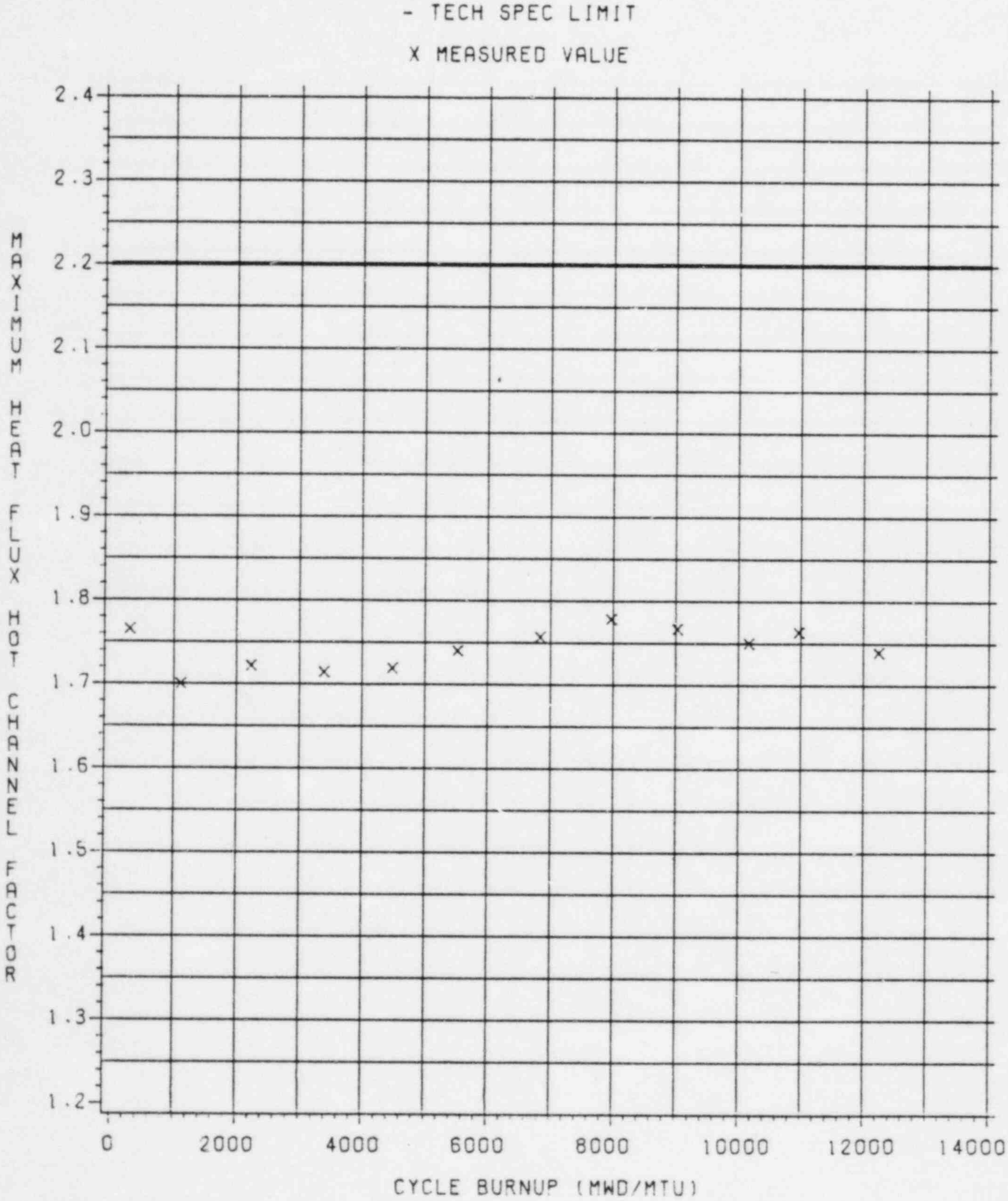


Figure 4.10

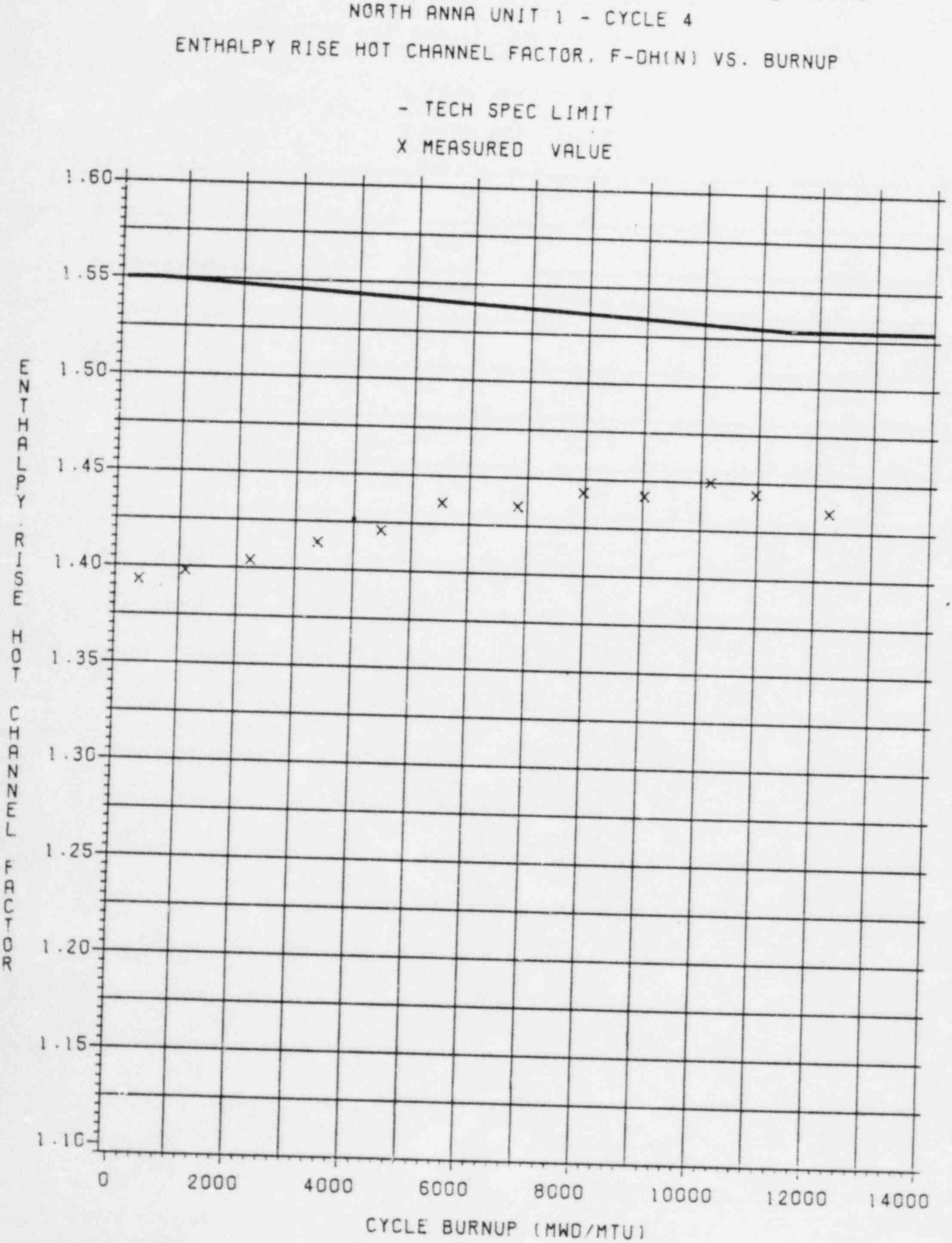

NORTH ANNA UNIT 1 - CYCLE 4
ENTHALPY RISE HOT CHANNEL FACTOR, F-DH(N) VS. BURNUP
- TECH SPEC LIMIT
X MEASURED VALUE
ENTHALPY RISE HOT CHANNEL FACTOR
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1.25
1.20
1.15
1.10
0
2000
4000
6000
8000
10000
12000
14000
CYCLE BURNUP (MWD/MTU)

Figure 4.11

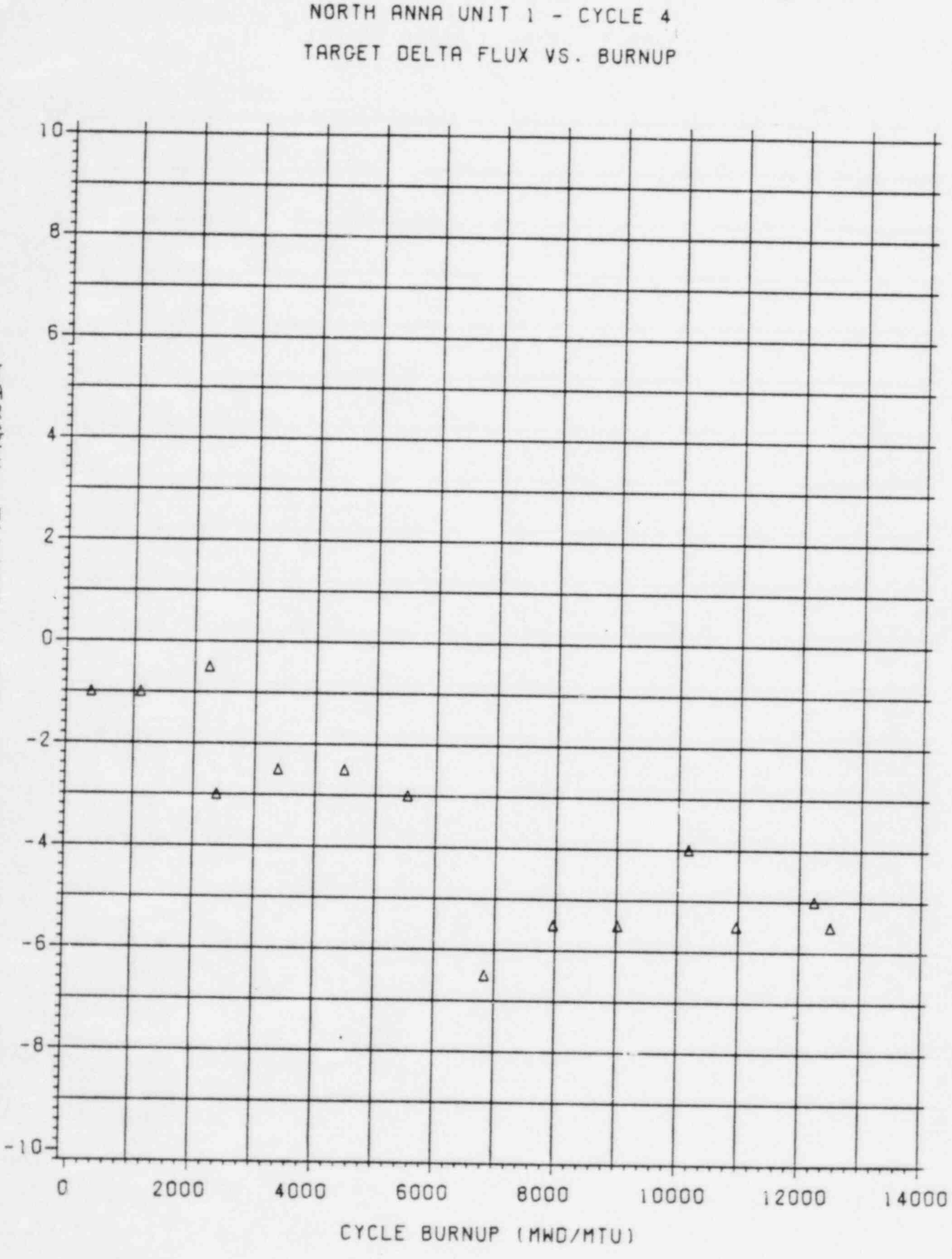

NORTH ANNA UNIT 1 - CYCLE 4
TARGET DELTA FLUX VS. BURNUP
TARGET DELTA FLUX IN PERCENT
10
8
6
4
2
0
-2
-4
-6
-8
-10
0
2000
4000
6000
8000
10000
12000
14000
CYCLE BURNUP (MWD/MTU)

Figure 4.12

NORTH ANNA UNIT 1 - CYCLE 4

CORE AVERAGE AXIAL POWER DISTRIBUTION

N1-4-07

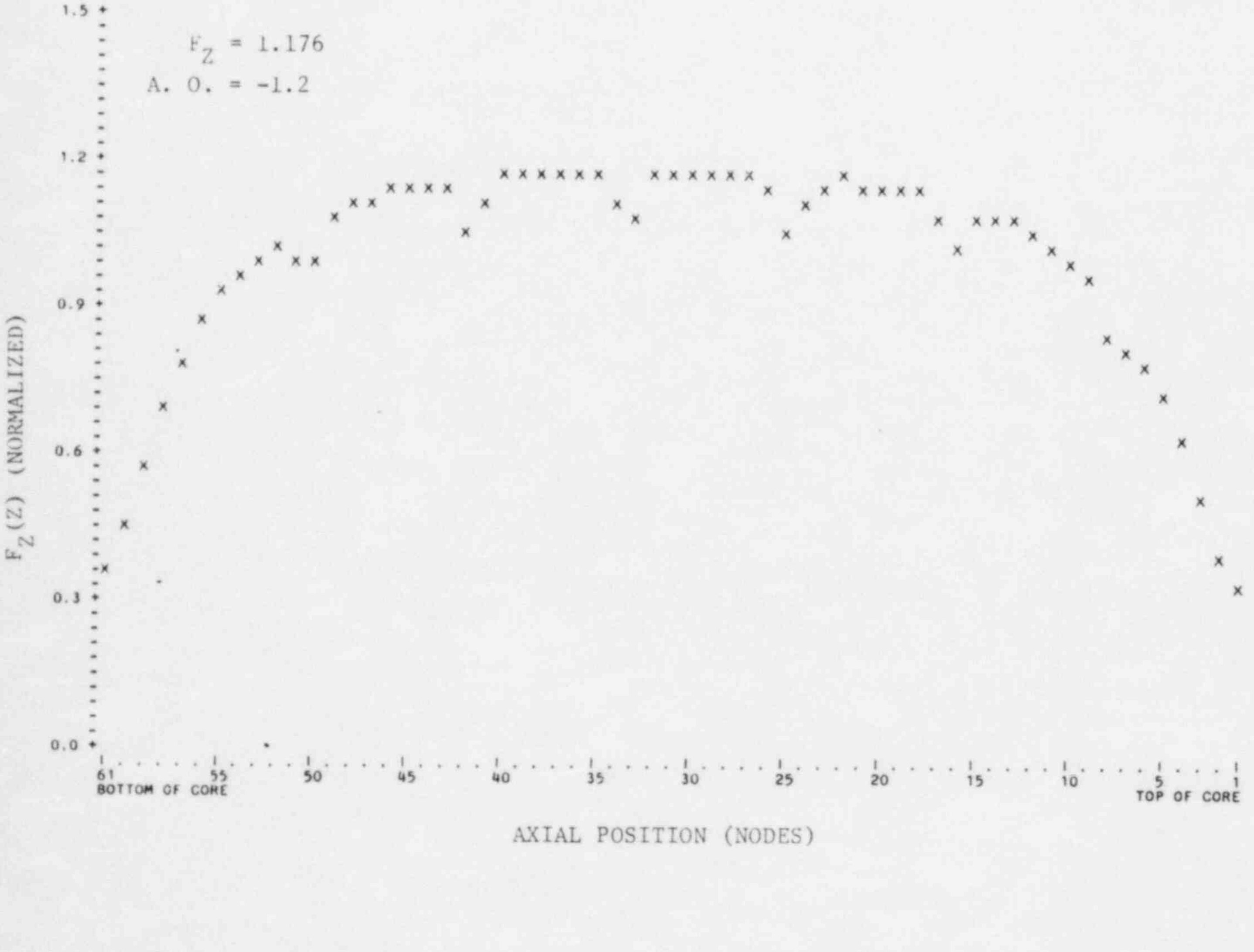


Figure 4.13

NORTH ANNA UNIT 1 - CYCLE 4

CORE AVERAGE AXIAL POWER DISTRIBUTION

N1-4-18

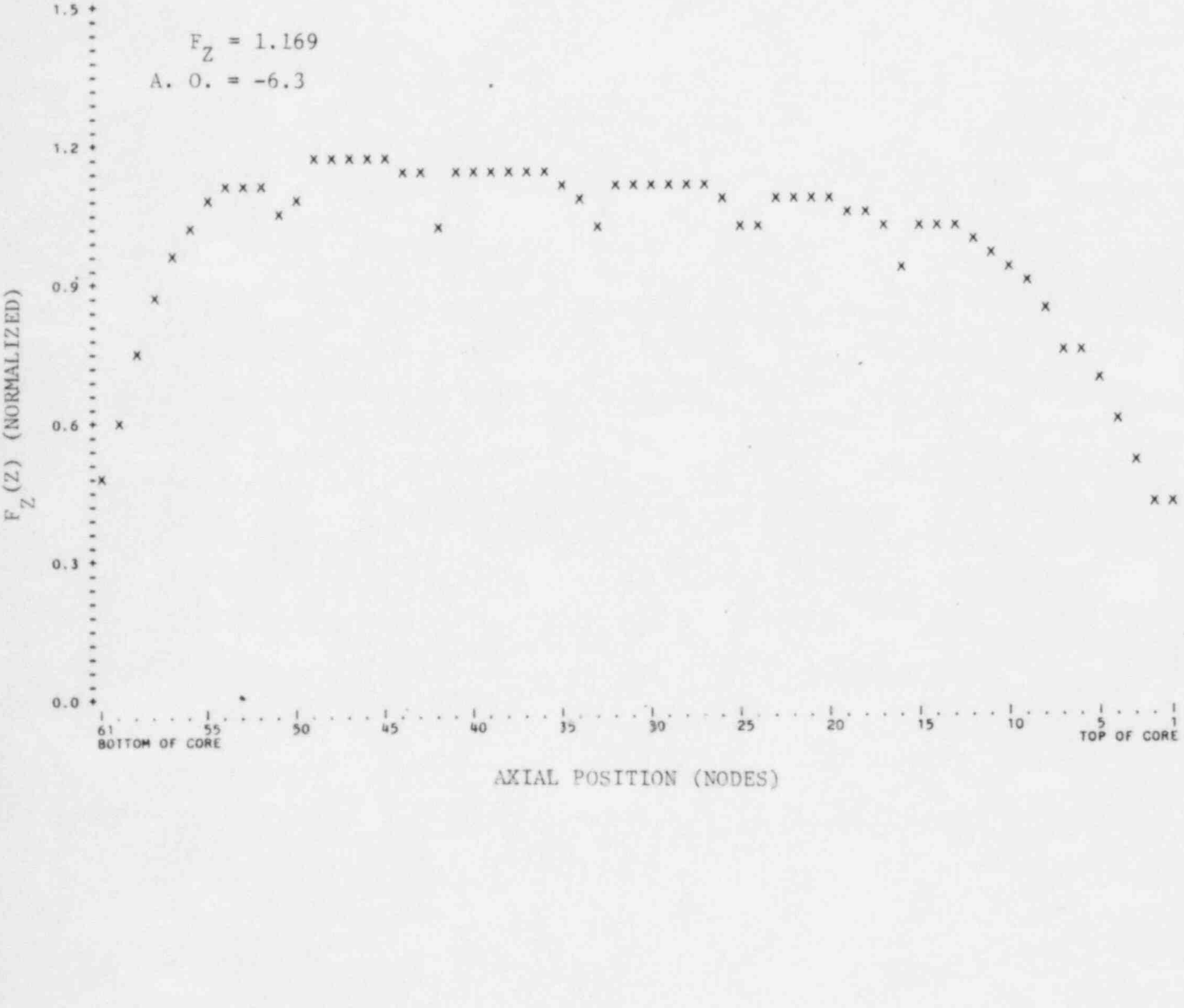


Figure 4.14

NORTH ANNA UNIT 1 - CYCLE 4
CORE AVERAGE AXIAL POWER DISTRIBUTION
N1-4-30

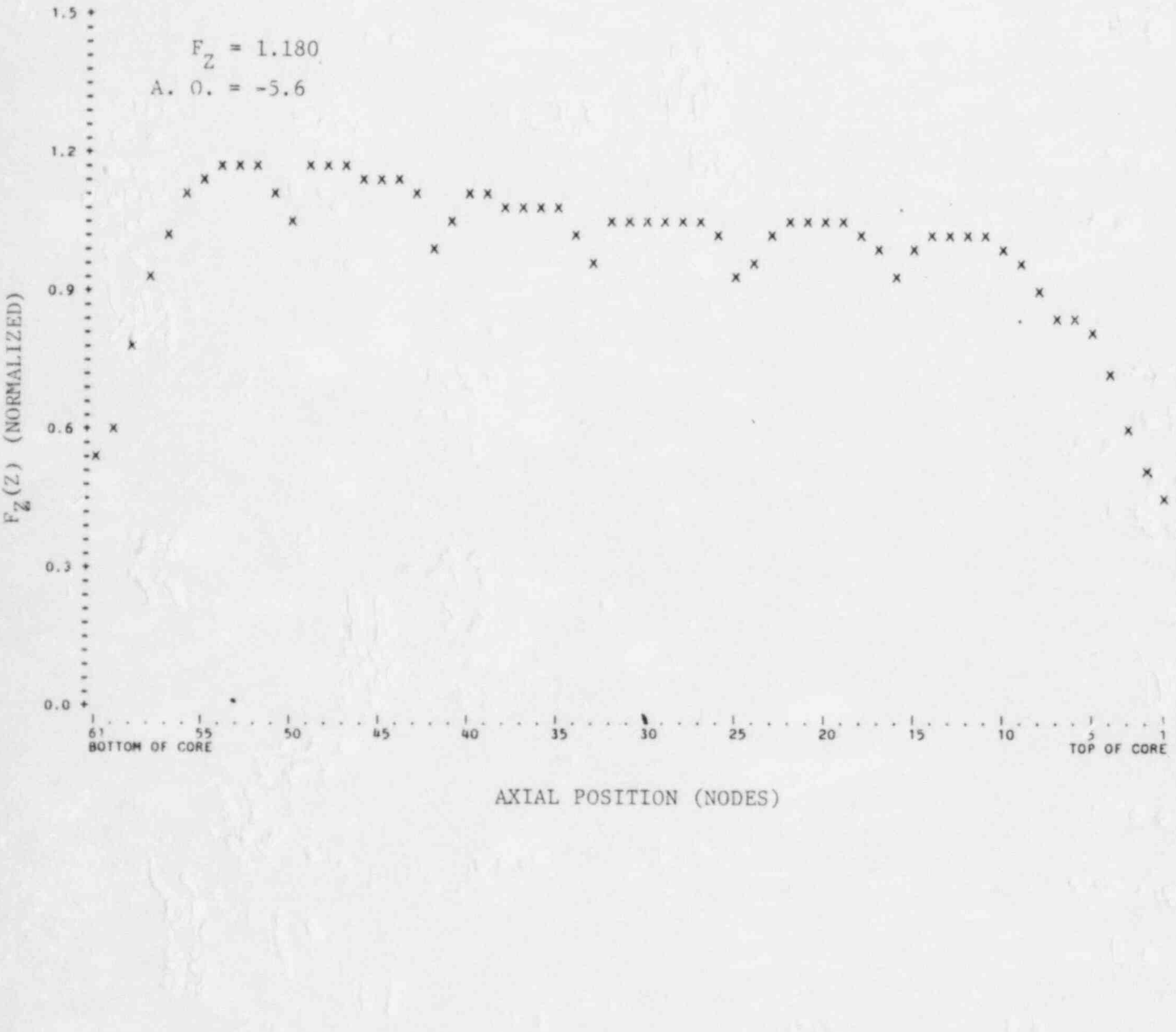
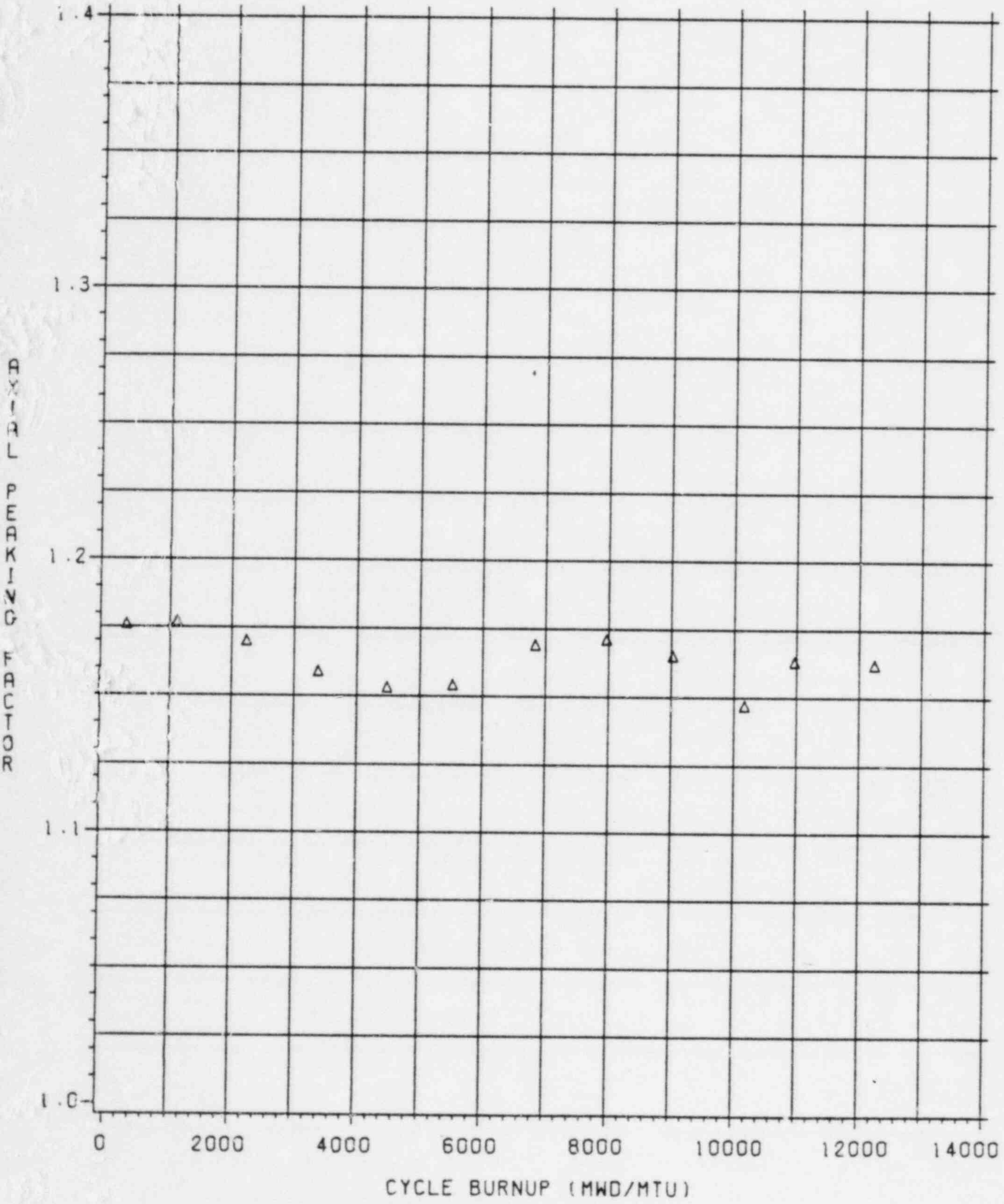


Figure 4.15

NORTH ANNA UNIT 1 - CYCLE 4

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 throught 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 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 4 core. The demineralizer flow rate averaged 120 gpm during power operation. The data shows that during Cycle 4, the core operated substantially below the 1.0 µCi/gm limit during steady state operation (the spike data is associated with power transients and unit shutdown). Specifically, the average dose equivalent I-131 concentration of 0.081 µCi/gm is equal to 8% of the Technical Specifications 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 0.4 or more for a demineralizer flow rate of 120 gpm. In the case of large leaks, uranium particles in the coolant, and "tramp" uranium*, where the diffusion mechanism is negligible, the I-131/I-133 ratio will generally be less than 0.08 for a demineralizer flow rate of 120 gpm. Figure 5.2 shows the I-131/I-133 ratio data for the North Anna 1, Cycle 4 core. These data generally indicate there were probably pinhole defects in the fuel used during Cycle 4.

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

Figure 5.1

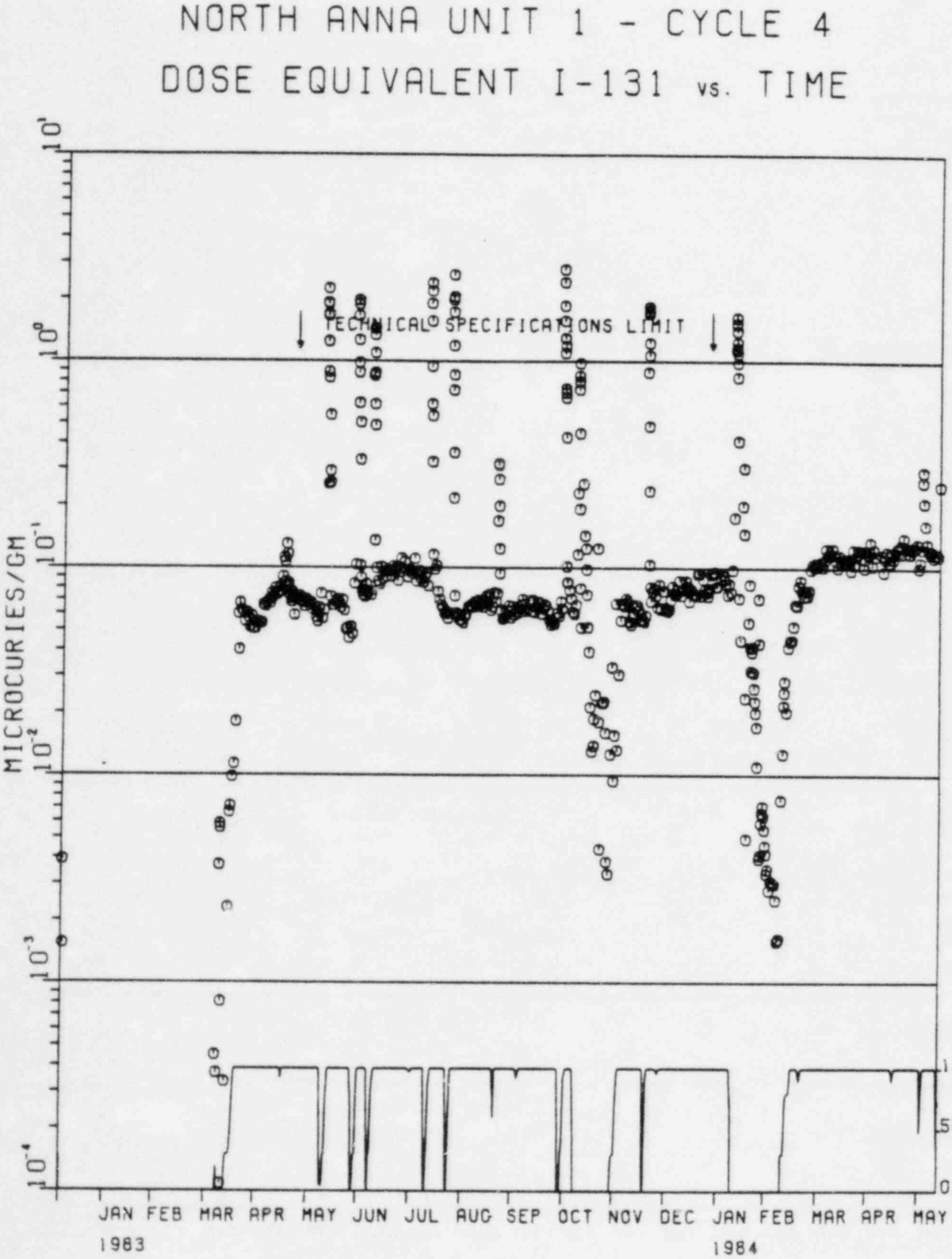
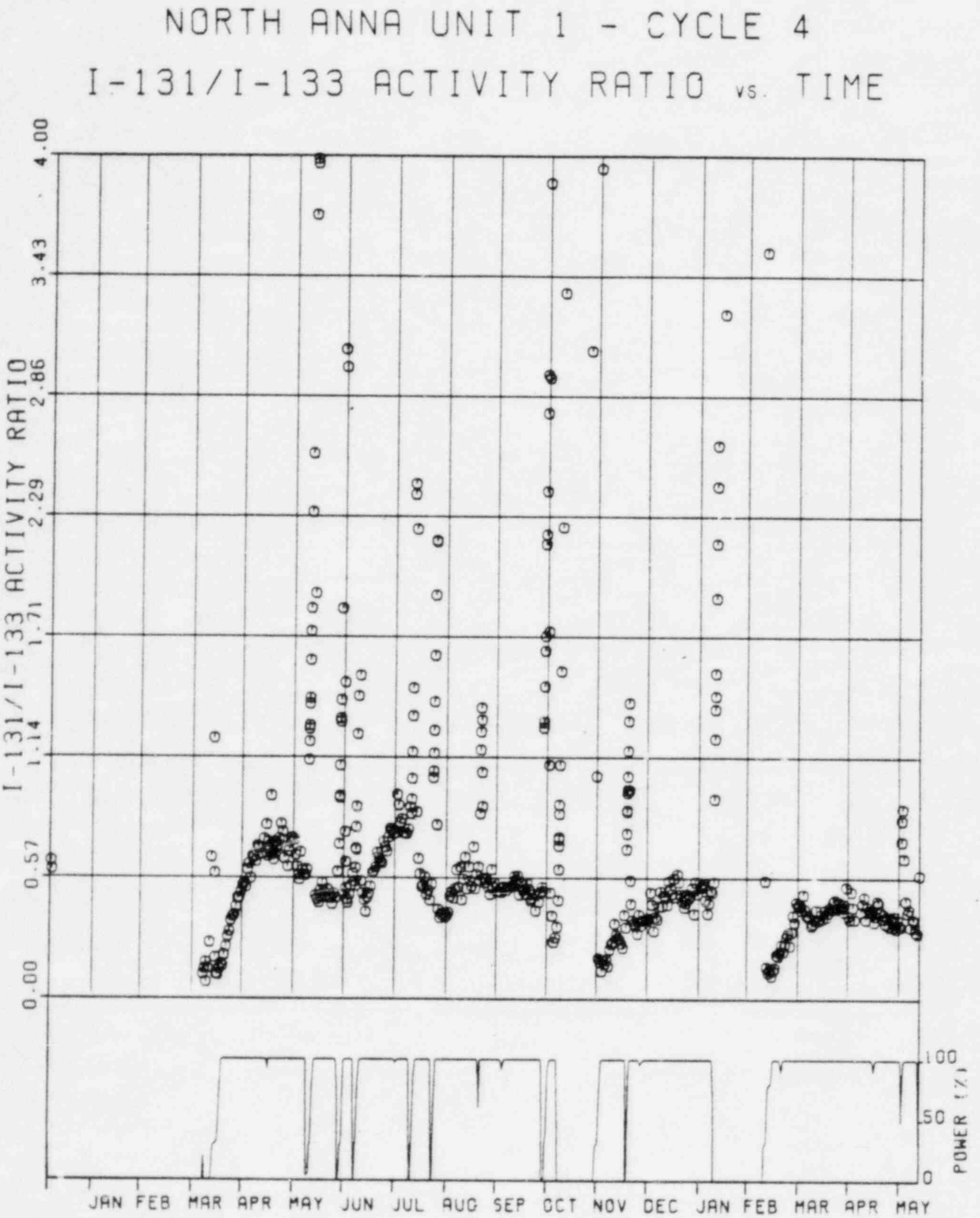

NORTH ANNA UNIT 1 - CYCLE 4
DOSE EQUIVALENT I-131 vs. TIME
MICROCURIES/GM
10^1
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
TECHNICAL SPECIFICATIONS LIMIT
POWER (%)
100
50
0
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
1983
1984

Figure 5.2



NORTH ANNA UNIT 1 - CYCLE 4
I-131/I-133 ACTIVITY RATIO vs. TIME
I-131/I-133 ACTIVITY RATIO
4.00
3.43
2.86
2.29
1.71
1.14
0.57
0.00
100
50
0
POWER (%)
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR APR MAY
1983
1984

Section 6

CONCLUSIONS

The North Anna 1, Cycle 4 core has completed 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 power distribution, or burnup accumulation were detected. In addition, the mechanical integrity of the fuel has not changed significantly throughout Cycle 4 as indicated by the radioiodine analysis.

Section 7

REFERENCES

1) C. A. Ford, "North Anna Unit 1, Cycle 4 Startup Physics Test Report," VEP-NOS-2, March, 1983.

2) North Anna Power Station Unit 1 Technical Specifications, Sections 3/4.1 and 3/4.2.

3) T. K. Ross, "NEWTOTE Code", VEPCO NFO-CCR-6 Rev-8, 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.