VEP-NOS-1

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SURRY UNIT 1, CYCLE 6 CORE PERFORMANCE REPORT

NUCLEAR OPERATIONS DEPARTMENT

Virginia Electric and Power Company

VEP-NOS-1

SURRY UNIT 1, CYCLE 6

CORE PERFORMANCE REPORT

BY

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Section 1

INTRODUCTION AND SUMMARY

On February 7, 1983, Surry Unit 1 completed Cycle 6. Since the initial criticality of Cycle 6 on July 6, 1981, the reactor core produced approximately 97 x 10^6 MBTU (16,491 Megawatt days per metric ton of contained uranium) which has resulted in the generation of approximately 8.9 x 10^9 KWHr gross (8.4 x 10^9 KWHr net) of electrical energy. Surry 1, Cycle 6 reached the end of full power reactivity at a core burnup of approximately 15,575 MWD/MTU at which point power operation was continued through a combination temperature/power coastdown. The unit was operated in the coastdown mode achieving an additional 916 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 6. The physics tests that were performed during the startup of this cycle were covered in the Surry 1, Cycle 6 Startup Physics Test Report[1] and, therefore, will not be included here.

The sixth cycle core consisted of eight sub-batches of fuel. One thrice-burned sub-batch was brought from Cycle 4 (Batch 4C2). One twice-burned sub-batch (Batch 6C2) and two once-burned sub-batches (Batches 7A and 7B) were carried over from Cycle 5. One once-burned sub-batch was brought from Cycle 2 of Unit 2 (Batch S2/4A4) and one once-burned sub-batch was brought from Cycle 4 of Unit 2 (Batch S2/6B3). Two fresh sub-batches (Batches 8A and 8B) were added to the Cycle 6 core. The Surry 1, Cycle 6 core loading map specifying the fuel sub-batch identifications, 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 sub-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 Surry Unit 1 Technical Specifications[2], and to assess the integrity of the fuel.

Each of the four performance indicators is discussed in detail for the Surry 1, Cycle 6 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 ±0.5% with the burnup accumulation in each sub-batch deviating from design prediction by less than ±1.2%.

2. Reactivity Depletion Follow - The critical boron concentration, used to monitor reactivity depletion, was consistently within ±0.4% ΔK/K of the design prediction which is well within the ±1% ΔK/K margin allowed

by Section 4.10 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 percent 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 6 was approximately 0.18 µ-Ci/gm. This corresponds to 18% of the Technical Specifications[2] operating limit for the concentration of radioiodine in the primary coolant. The relatively high iodine activity indicates that fuel cladding defects were present in the Cycle 6 core.

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

Figure 1.1

SURRY UNIT 1 - CYCLE 6

CORE LOADING MAP

	R	P	N	M	L	K	J	H	G	F	E	D	C	B	A
1							0A3	1C6 SS	0A8						
2					D29	5C4	3C0 12P PS	W14	0C2 12P	3C5	D11				
3				1A6	1C4 8P	4C0 16P	3A9	3A6 SS	5A1	5C5 16P	0C5 8P	1A7			
4			2A0	2A3	4C9 16P	2A6	1B8 16P	4A3	0B8 16P	3A2	1C8 16P	4A8	1A3		
5		D38	0C9 8P	5C6 16P	5A0	0B5 16P	4A6	2C9 20P	4A7	0B2 16P	5A3	4C3 16P	5C0 8P	D20	
6		4C5	0C4 16P	5A9	1B0 16P	2A8	1C7 16P	0A4	4C7 16P	3A8	0B6 16P	5A4	2C3 16P	3C4	
7	1A0	4C2 12P	3A0	1B4 16P	5A8	4C6 16P	J15	0B4 12P	J09	5C2 16P	5A6	1B6 16P	4A9	2C5 12P	0A2
8	1C9	W18	2A7	3A5	1C2 20P	1A4	1B5 12P	S20	0B9 12P	1A1	3C8 20P	5A7	3A4	W31	4C1
9	0A1	0C6 12P	4A5	1B7 16P	5A5	1C1 16P	J42	1B2 12P	J03	0C7 16P	2A9	1B9 16P	6A0	2C1 12P	0A5
10		2C6	3C7 16P	2A1	2B0 16P	4A2	1C5 16P	0A7	3C6 16P	2A5	1B1 16P	4A4	3C1 16P	2C7	
11		D24	4C4 8P	2C0 16P	3A3	0B3 16P	2A4	2C2 20P	6A2	0B1 16P	3A7	5C1 16P	1C3 8P	D37	
12			1A2	6A4	3C3 16P	6A1	1B3 16P	6A3	0B7 16P	2A2	1C0 16P	5A2	0A9		
13				1A5	0C3 8P	5C3 16P	4A1	3A1 SS	4A0	4C8 16P	3C9 8P	0A6			
14					D30	0C1	0C8 12P	W15	3C2 12P PS	2C8	D23				
15							1A9	2C4	1A8						

|--> ASSEMBLY ID
|--> ONE OF THE FOLLOWING:
A. PS - PRIMARY SOURCE
B. SS - SECONDARY SOURCE
C. XXP - BURNABLE POISON ASSEMBLY
(XX-NUMBER OF RODS)

FUEL ASSEMBLY DESIGN PARAMETERS

	SUB-BATCH							
	4C2	6C2	7A	7B	8A	8B	S2/4A4	S2/6B3
INITIAL ENRICHMENT (W/O U235)	3.325	2.902	2.901	3.393	3.217	3.399	2.606	3.203
ASSEMBLY TYPE	15X15	15X15	15X15	15X15	15X15	15X15	15X15	15X15
NUMBER OF ASSEMBLIES	8	4	20	44	20	56	1	4
FUEL RODS PER ASSEMBLY	204	204	204	204	204	204	204	204
ASSEMBLY IDENTIFICATION	D11 D20 D23-D24 D29-D30 D37-D38	J03 J09 J15 J42	0A1-0A9 1A0-1A9 2A0	2A1-2A9 3A0-3A9 4A0-4A9 5A0-5A9 6A0-6A4	0B1-0B9 1B0-1B9 2B0	0C1-0C9 1C1-1C9 2C0-2C9 3C0-3C9 4C0-4C9 5C0-5C6	S20	W14-W15 W18 W31

Figure 1.2

SURRY UNIT 1 - CYCLE 6

MOVABLE DETECTOR AND

THERMOCOUPLE LOCATIONS

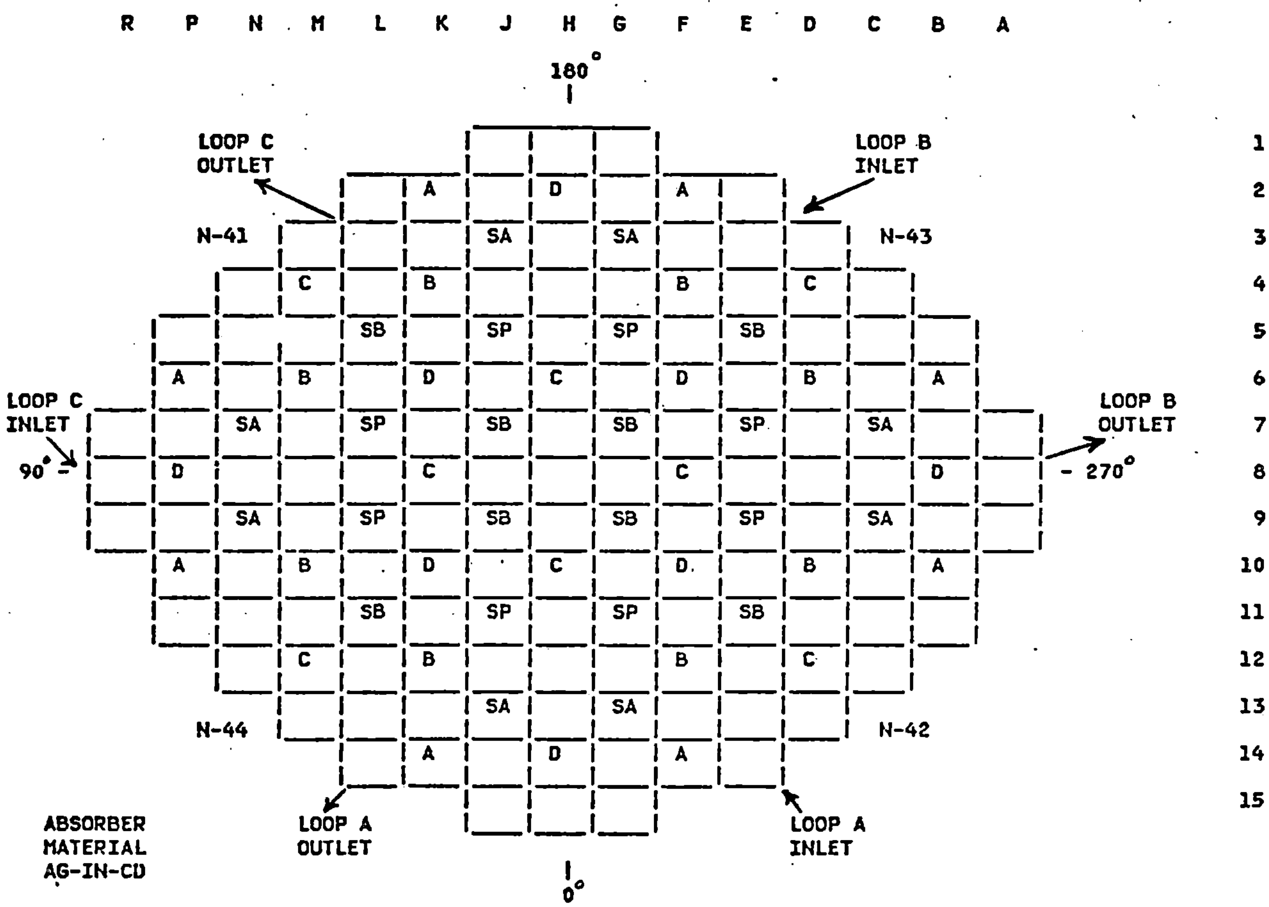
	R	P	N	M	L	K	J	H	G	F	E	D	C	B	A
1								MD	TC						
2							TC		TC	MD					
3				MD TC		TC	MD	MD TC		TC		MD TC			
4			TC		MD			MD		MD	TC				
5			MD		MD	TC	MD	TC		TC	MD	MD TC		MD TC	
6			TC		MD TC			MD	TC	MD					
7	TC	TC	MD				MD		MD		TC	MD		MD	
8	MD	TC	MD TC		MD TC	TC		TC	TC	MD	TC		MD TC	MD	TC
9				TC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

MD - MOVABLE DETECTOR
TC - THERMOCOUPLE

Figure 1.3

SURRY UNIT 1 - CYCLE 6

CONTROL ROD LOCATIONS



ABSORBER
MATERIAL
AG-IN-CD

FUNCTION	NUMBER OF CLUSTERS
CONTROL BANK D	8
CONTROL BANK C	8
CONTROL BANK B	8
CONTROL BANK A	8
SHUTDOWN BANK SB	8
SHUTDOWN BANK SA	8
SP (SPARE ROD LOCATIONS)	8

Section 2

BURNUP FOLLOW

The burnup history for the Surry Unit 1, Cycle 6 core is graphically depicted in Figure 2.1. The Surry 1, Cycle 6 core achieved a burnup of 16,491 MWD/MTU. As shown in Figure 2.2, the average load factor for Cycle 6 was 83% when referenced to rated thermal power (2441 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 6 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 6 operation is given. As can be seen from this figure, the accumulated assembly burnups were generally within ±1.9% of the predicted values. In addition, deviation from quadrant symmetry in the core, as indicated by the burnup tilt factors, was less than ±0.5%.

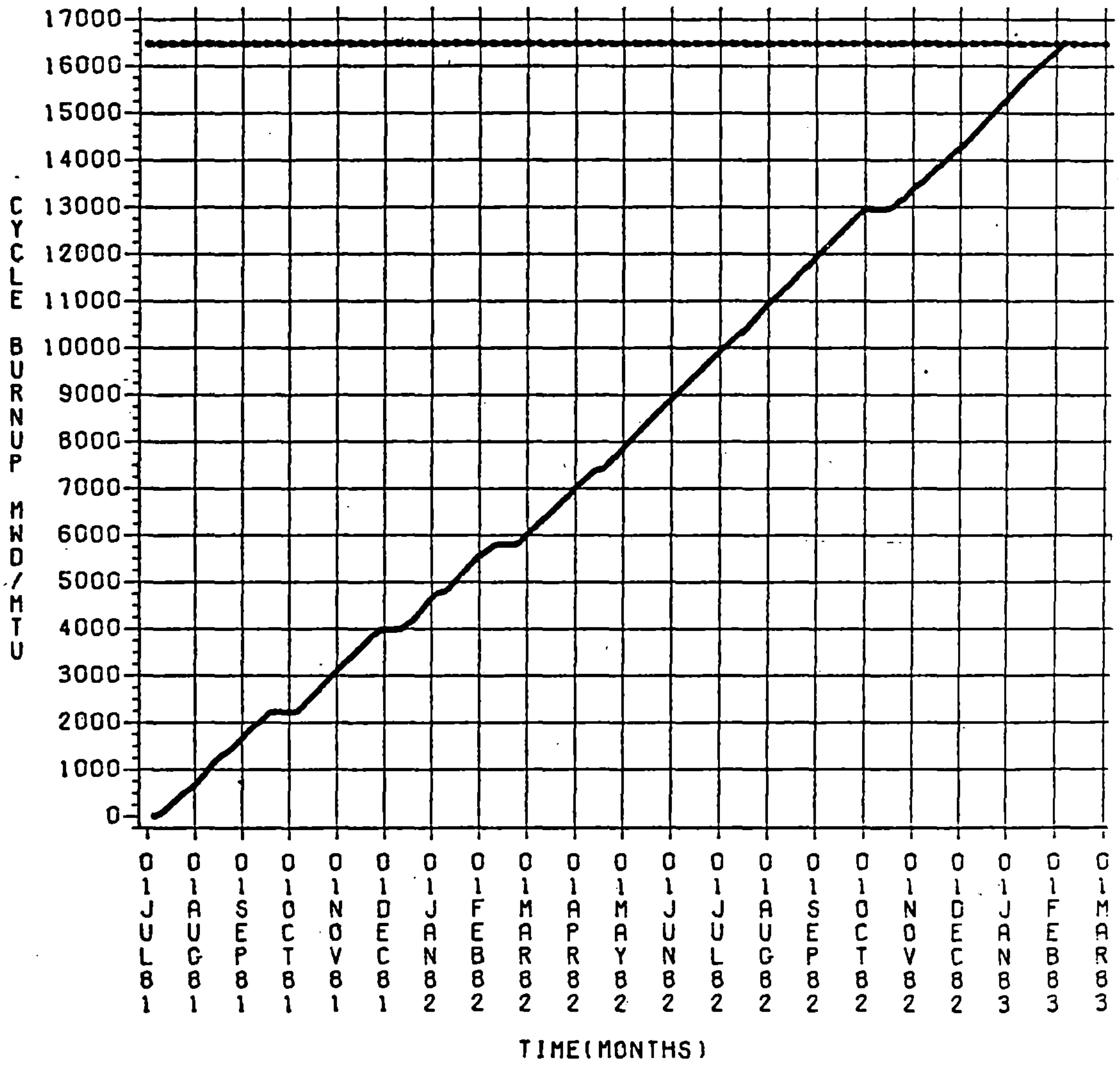
The burnup sharing on a sub-batch basis is monitored to verify that the core is operating as designed and to enable accurate end-of-cycle sub-batch burnup predictions to be made for use in reload fuel design studies. Sub-batch definitions are given in Figure 1.1. As seen in Figure 2.5, the sub-batch burnup sharing for Surry Unit 1, Cycle 6 followed design predictions very closely with each sub-batch deviating less than

1.2% from design; this is considered excellent agreement. Therefore, symmetric burnup in conjunction with good agreement between actual and predicted assemblywise burnups and sub-batch burnup sharing indicate that the Cycle 6 core did deplete as designed.

Figure 2.1

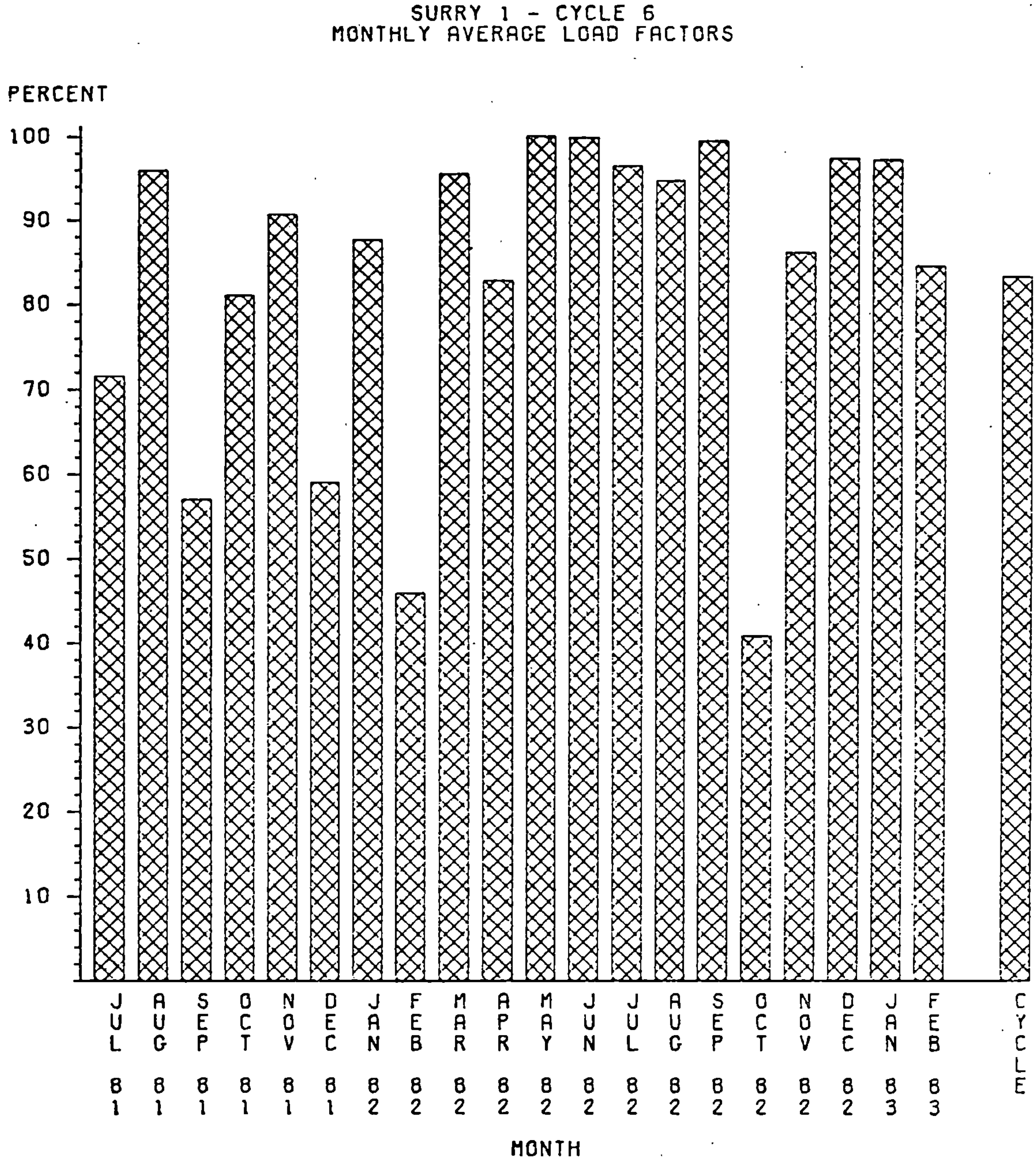
SURRY UNIT 1 - CYCLE 6

CORE BURNUP HISTORY



--- CYCLE 6 MAXIMUM DESIGN BURNUP - 16,500 MWD/MTU

Figure 2.2



LOAD FACTOR = THERMAL ENERGY GENERATION IN MONTH(MWHT) / AUTHORIZED POWER LEVEL (MWT) X HOURS IN MONTH (EXCLUDES REFUELING OUTAGES)

SURRY UNIT 1 - CYCLE 6

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

Row		R	P	N	M	L	K	J	H	G	F	E	D	C	B	A	Row
1	MEASURED							22.73	10.61	23.02							1
	PREDICTED							23.18	11.03	23.18							
2	MEASURED					32.52	13.86	15.70	26.04	15.81	14.05	32.42					2
	PREDICTED					32.21	14.25	16.24	26.79	16.24	14.25	32.21					
3	MEASURED				25.12	16.47	18.81	32.73	30.98	32.79	18.72	16.40	25.10				3
	PREDICTED				24.85	16.16	18.90	33.56	31.90	33.56	18.90	16.16	24.85				
4	MEASURED			25.32	25.60	19.55	34.51	19.91	36.00	19.66	34.99	19.62	25.94	25.13			4
	PREDICTED			24.85	25.76	19.55	34.90	20.39	36.56	20.39	34.90	19.55	25.76	24.85			
5	MEASURED		32.31	16.05	19.45	33.16	20.83	36.80	20.54	36.78	20.81	33.25	19.56	16.59	32.57		5
	PREDICTED		32.21	16.16	19.55	33.70	21.07	37.00	20.46	37.00	21.07	33.70	19.55	16.16	32.21		
6	MEASURED		14.21	18.93	34.72	20.94	36.81	21.02	35.75	20.99	36.62	20.86	34.87	19.20	14.60		6
	PREDICTED		14.25	18.90	34.90	21.07	37.21	20.91	35.47	20.91	37.21	21.07	34.90	18.90	14.25		
7	MEASURED	23.19	16.22	33.40	20.23	36.88	20.75	38.14	20.53	38.30	20.94	36.71	20.17	33.20	16.31	23.33	7
	PREDICTED	23.18	16.24	33.56	20.39	37.00	20.91	38.06	20.33	38.06	20.91	37.00	20.39	33.56	16.24	23.18	
8	MEASURED	11.04	26.50	31.56	36.23	20.30	35.51	19.97	28.96	20.41	35.56	20.47	36.30	31.66	26.75	11.35	8
	PREDICTED	11.03	26.79	31.90	36.56	20.46	35.47	20.33	28.71	20.33	35.47	20.46	36.56	31.90	26.79	11.03	
9	MEASURED	23.40	16.18	33.33	20.24	36.99	20.81	38.26	20.42	38.19	20.84	36.93	20.20	33.56	16.50	23.54	9
	PREDICTED	23.18	16.24	33.56	20.39	37.00	20.91	38.06	20.33	38.06	20.91	37.00	20.39	33.56	16.24	23.18	
10	MEASURED		14.27	19.00	34.80	21.00	37.31	20.72	35.23	20.89	37.19	20.98	34.53	19.02	14.57		10
	PREDICTED		14.25	18.90	34.90	21.07	37.21	20.91	35.47	20.91	37.21	21.07	34.90	18.90	14.25		
11	MEASURED		32.38	16.52	19.76	34.05	20.92	36.62	20.33	36.68	21.02	33.48	19.75	16.48	32.50		11
	PREDICTED		32.21	16.16	19.55	33.70	21.07	37.00	20.46	37.00	21.07	33.70	19.55	16.16	32.21		
12	MEASURED			25.16	25.91	19.55	34.82	20.20	36.05	20.07	34.71	19.64	26.10	25.11			12
	PREDICTED			24.85	25.76	19.55	34.90	20.39	36.56	20.39	34.90	19.55	25.76	24.85			
13	MEASURED				25.01	16.72	19.26	33.49	31.09	32.99	18.99	16.30	25.02				13
	PREDICTED				24.85	16.16	18.90	33.56	31.90	33.56	18.90	16.16	24.85				
14	MEASURED					32.49	14.83	16.56	26.64	16.11	14.21	32.12					14
	PREDICTED					32.21	14.25	16.24	26.79	16.24	14.25	32.21					
15	MEASURED							23.70	11.32	23.30							15
	PREDICTED							23.18	11.03	23.18							
		R	P	N	M	L	K	J	H	G	F	E	D	C	B	A	

Legend: MEASURED / PREDICTED

Figure 2.4

SURRY UNIT 1 - CYCLE 6

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

	R	P	N	M	L	K	J	H	G	F	E	D	C	B	A	
1							22.73	10.61	23.02							1
							-1.93	-3.77	-0.68							
2					32.52	13.86	15.70	26.04	15.81	14.05	32.42					2
					0.96	-2.73	-3.32	-2.79	-2.66	-1.36	0.65					
3				25.12	16.47	18.81	32.73	30.98	32.79	18.72	16.40	25.10				3
				1.10	1.88	-0.47	-2.46	-2.91	-2.27	-0.97	1.44	1.00				
4			25.32	25.60	19.55	34.51	19.91	36.00	19.66	34.99	19.62	25.94	25.13			4
			1.87	-0.59	-0.04	-1.10	-2.34	-1.53	-3.56	0.27	-0.32	0.71	1.12			
5		32.31	16.05	19.45	33.16	20.83	36.80	20.54	36.78	20.81	33.25	19.56	16.59	32.57		5
		0.33	-0.74	-0.54	-1.59	-1.10	-0.55	0.36	-0.59	-1.23	-1.33	0.03	2.65	1.12		
6		14.21	18.93	34.72	20.94	36.81	21.02	35.75	20.99	36.62	20.86	34.87	19.20	14.60		6
		-0.23	0.15	-0.51	-0.61	-1.07	0.52	0.82	0.38	-1.58	-1.00	-0.08	1.55	2.45		
7	23.19	16.22	33.40	20.23	36.88	20.75	38.14	20.53	38.30	20.94	36.71	20.17	33.20	16.31	23.33	7
	0.06	-0.16	-0.46	-0.74	-0.32	-0.78	0.21	0.96	0.62	0.16	-0.79	-1.05	-1.05	0.43	0.64	
8	11.04	26.50	31.56	36.23	20.30	35.51	19.97	28.96	20.41	35.56	20.47	36.30	31.66	26.75	11.35	8
	0.06	-1.09	-1.06	-0.90	-0.81	0.13	-1.79	0.87	0.39	0.27	0.05	-0.72	-0.76	-0.15	2.87	
9	23.40	16.18	33.33	20.24	36.99	20.81	38.26	20.42	38.19	20.84	36.93	20.20	33.56	16.50	23.54	9
	0.95	-0.39	-0.66	-0.72	-0.03	-0.46	0.54	0.44	0.35	-0.36	-0.20	-0.92	0.01	1.60	1.56	
10		14.27	19.00	34.80	21.00	37.31	20.72	35.23	20.89	37.19	20.98	34.53	19.02	14.57		10
		0.14	0.53	-0.28	-0.32	0.28	-0.91	-0.67	-0.11	-0.04	-0.42	-1.04	0.64	2.24		
11		32.38	16.52	19.76	34.05	20.92	36.62	20.33	36.68	21.02	33.48	19.75	16.48	32.50		11
		0.53	2.19	1.07	1.03	-0.67	-1.02	-0.65	-0.86	-0.24	-0.65	0.98	1.94	0.91		
12			25.16	25.91	19.55	34.82	20.20	36.05	20.07	34.71	19.64	26.10	25.11			12
			1.26	0.59	-0.01	-0.23	-0.90	-1.41	-1.53	-0.54	0.42	1.35	1.04			
13				25.01	16.72	19.26	33.49	31.09	32.99	18.99	16.30	25.02				13
				0.62	3.46	1.90	-0.18	-2.55	-1.67	0.44	0.83	0.67				
14					32.49	14.83	16.56	26.64	16.11	14.21	32.12					14
					0.88	4.07	1.95	-0.55	-0.81	-0.26	-0.27					
15							23.70	11.32	23.30							15
							2.24	2.60	0.52							
	R	P	N	M	L	K	J	H	G	F	E	D	C	B	A	

MEASURED
M/P % DIFF

ARITHMETIC AVG PCT DIFF = -0.08

STANDARD DEV = 0.85

AVG ABS PCT DIFF = 1.00

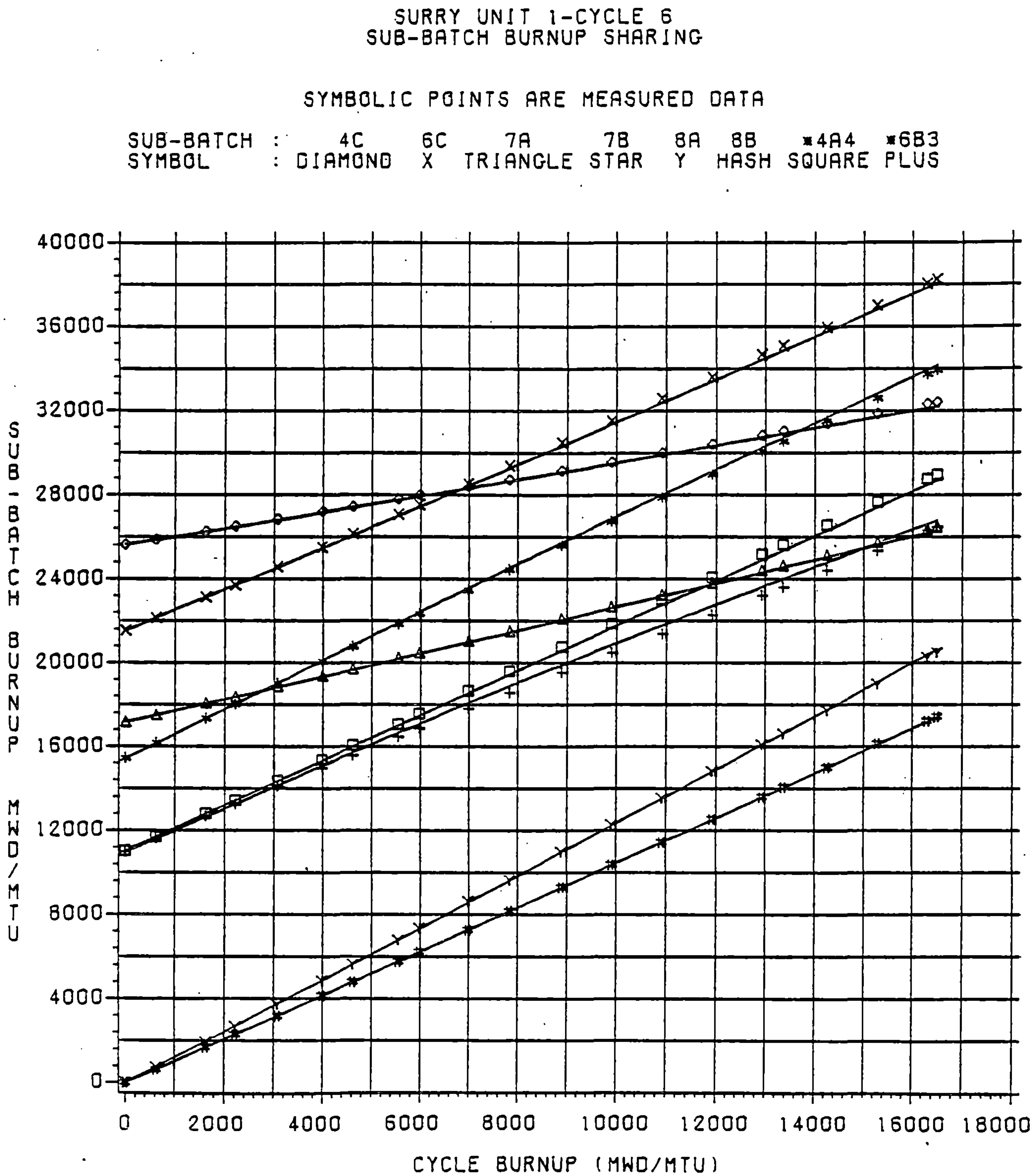
BURNUP SHARING
(1000 MWD/MTU)

BATCH	CYCLE 2	CYCLE 3	CYCLE 4	CYCLE 5	CYCLE 6	TOTAL
4C2	6.07	5.67	13.87	---	6.80	32.41
6C2	---	---	7.85	13.68	16.69	38.22
7A	---	---	---	17.16	9.30	26.46
7B	---	---	---	15.43	18.51	33.94
8A	---	---	---	---	20.47	20.47
8B	---	---	---	---	17.45	17.45
S2/4A4	11.04	---	---	---	17.92	28.96
S2/6B3	---	---	10.95	---	15.53	26.48
CORE AVERAGE					16.49	

BURNUP TILT

NW	-	0.9958
NE	-	0.9990
SW	-	1.0036
SE	-	1.0016

Figure 2.5

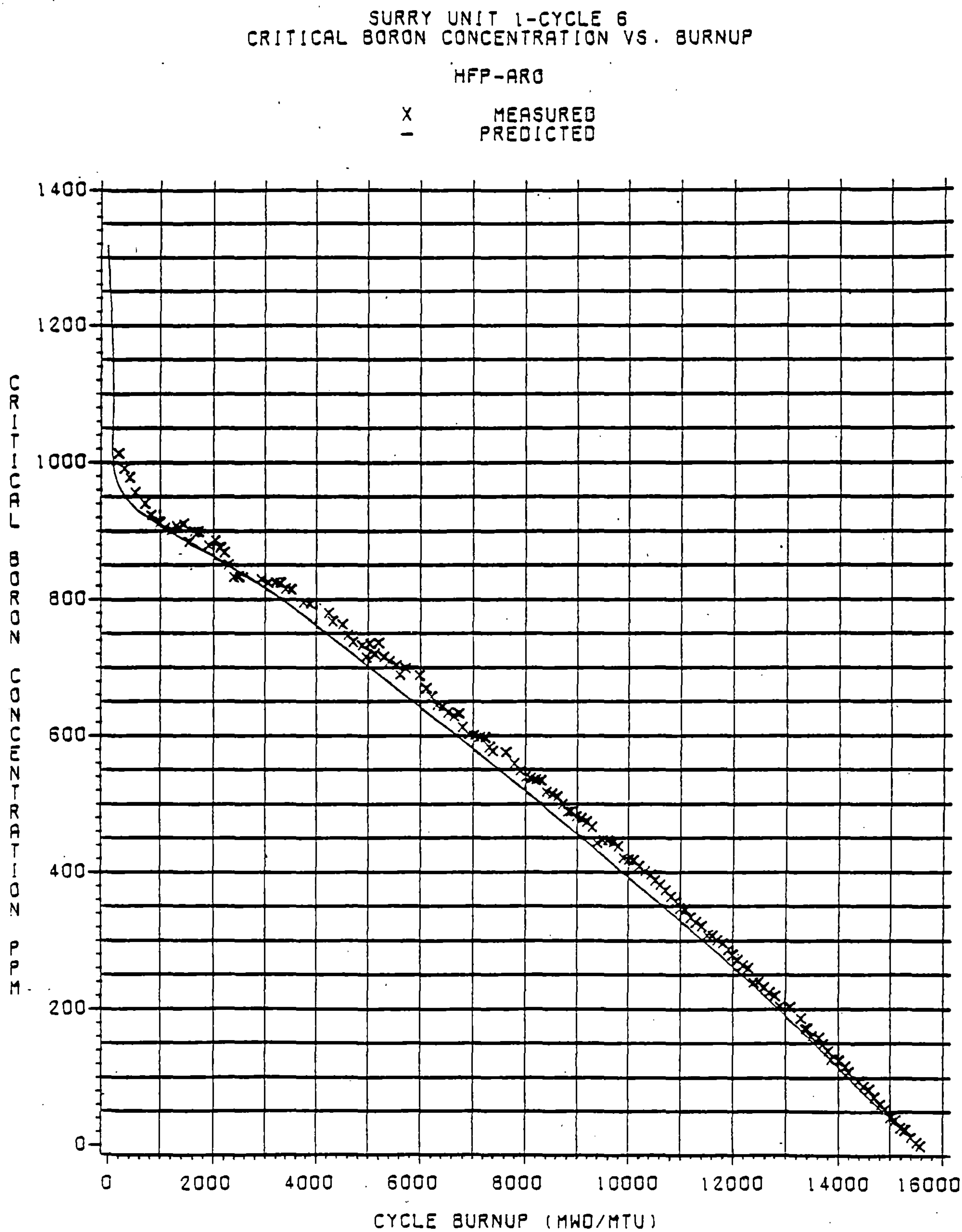

SURRY UNIT 1-CYCLE 6
SUB-BATCH BURNUP SHARING
SYMBOLIC POINTS ARE MEASURED DATA
SUB-BATCH : 4C 6C 7A 7B 8A 8B *4A4 *6B3
SYMBOL : DIAMOND X TRIANGLE STAR Y HASH SQUARE PLUS
SUB-BATCH BURNUP MWD/MTU
40000
36000
32000
28000
24000
20000
16000
12000
8000
4000
0
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
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 Surry 1, Cycle 6 core is shown in Figure 3.1. It can be seen that the measured data compare to within 46 ppm of the design prediction. This corresponds to less than ±0.4% ΔK/K which is well within the ±1% ΔK/K criterion for reactivity anomalies set forth in Section 4.10 of the Technical Specifications[2]. In conclusion, the trend indicated by the critical boron concentration verifies that the Cycle 6 core depleted as expected without any reactivity anomalies.

Figure 3.1



SURRY UNIT 1-CYCLE 6
CRITICAL BORON CONCENTRATION VS. BURNUP
HFP-ARO
X MEASURED
— PREDICTED
CRITICAL BORON CONCENTRATION PPM
1400
1200
1000
800
600
400
200
0
0
2000
4000
6000
8000
10000
12000
14000
16000
CYCLE BURNUP (MWD/MTU)

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-power flux maps taken since the completion of startup physics testing for Surry 1, Cycle 6 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 6 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 3.1% of the predicted values with an average percent difference of less than 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 2.18x 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 2.18 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 6, 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 6 is given in Figure 4.8. Figure 4.9 shows the maximum values for the heat flux hot channel factors measured as a function of burnup during Cycle 6. As can be seen from this figure, there was approximately 17% margin to the limit at the beginning of the cycle, with the margin increasing throughout cycle operation.

The value of the enthalpy rise hot channel factor, F-ΔH, 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-ΔH limit ensures that the value of this parameter used in the LOCA-ECCS analysis is not exceeded during normal operation. The Cycle 6 limit on the enthalpy rise hot channel factor was 1.55 x (1+0.2(1-P)), where P is the fractional power level. The maximum values of F-ΔH versus burnup are shown 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 -2% at the beginning of Cycle 6. By the middle of the cycle, the value of delta flux had shifted to approximately -3%. For the last half of the cycle, delta flux gradually changed to -5.5% before returning to approximately -2.0% by the end of Cycle 6. 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 S1-6-13 (Figure 4.12) taken at approximately 973 MWD/MTU, the axial power distribution had a slightly peaked cosine shape with a peaking factor of 1.22. In Map S1-6-56 (Figure 4.13) taken at approximately 7,518 MWD/MTU, the axial power distribution had flattened somewhat with an axial peaking factor of 1.16. Finally, in Map S1-6-74 (Figure 4.14) taken at approximately 14,752 MWD/MTU, the axial power distribution was slightly concave with an axial peaking factor of 1.16. The history of F-Z during the cycle

*Delta Flux = $\frac{Pt-Pb}{2441} \times 100$ where Pt = power in top of core (MW(t))
Pb = power in bottom of core (MW(t))

can be seen more clearly in a plot of F-Z versus burnup given in Figure 4.15.

In conclusion, the Surry 1, Cycle 6 core performed very satisfactorily with power distribution analyses verifying that design predictions were accurate and that the values of the hot channel factors were within the limits of the Technical Specifications.

TABLE 4.1

SURRY UNIT 1 - CYCLE 6

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] ASSY	PIN	AXIAL POINT	F-Q(T)	F-DH(N) HOT CHNL.FACTOR [2] ASSY	PIN	F-DH(N)	CORE F(Z) MAX AXIAL POINT	F(Z)	F(XY) [3]	QPTR [4] MAX	LOC	AXIAL OFF SET (%)	NO. OF THIMBLES
8	7-21-81	170	100	228	F11	HG	34	1.810	F11	HG	1.413	34	1.223	1.377	1.010	SW	-2.47	42
11 (5)	7-30-81	480	100	213	F11	HG	35	1.826	F11	HG	1.409	34	1.241	1.369	1.010	SW	-5.60	42
13 (6)	8-10-81	973	100	217	F11	HG	33	1.794	F11	HG	1.409	34	1.219	1.368	1.008	SW	-1.85	42
15 (7)	9- 4-81	1750	100	220	K11	HG	34	1.792	L6	GH	1.413	34	1.212	1.365	1.008	SW	-1.48	41
16	9-15-81	2022	100	218	L10	GH	33	1.796	F11	HG	1.424	34	1.215	1.371	1.012	SW	-2.17	40
17	10-12-81	2450	100	223	L06	GH	34	1.787	L06	GH	1.420	34	1.202	1.375	1.010	SW	-1.31	40
21 (8)	11-19-81	3683	100	227	L10	IH	35	1.777	L10	IH	1.426	34	1.183	1.386	1.007	SW	-1.43	40
22	1-11-82	4913	100	228	E10	GH	22	1.757	E10	GH	1.423	34	1.169	1.382	1.005	SE	-1.62	40

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 FIFTEEN 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 1.08.

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

3. F(XY) IS EVALUATED AT THE MIDPLANE.

4. QPTR - QUADRANT POWER TILT RATIO.

5. MAPS 9 AND 10 WERE QUARTER CORE MAPS TAKEN FOR INCORE/EXCORE CALIBRATION.

6. MAP 12 WAS A QUARTER CORE MAP TAKEN FOR INCORE/EXCORE CALIBRATION.

7. MAP 14 WAS A QUARTER-CORE FLUX MAP USED FOR QUADRANT POWER TILT VERIFICATION.

8. MAPS 18,19,AND 20 WERE QUARTER-CORE FLUX MAPS USED FOR INCORE/EXCORE DETECTOR CALIBRATION.

TABLE 4.1 (CONT.)

MAP NO.	DATE	BURN UP MWD/MTU	PWR (%)	BANK D STEPS	F-Q(T) HOT CHANNEL FACTOR: ASSY	PIN	AXIAL POINT	F-Q(T)	F-DH(N) HOT CHNL.FACTOR: ASSY	PIN	F-DH(N)	CORE F(Z) MAX: AXIAL POINT	F(Z)	F(XY) 3	QPTR 4: MAX	LOC	AXIAL OFF SET (%)	NO. OF THIMBLES
25(9)	1-30-82	5511	100	228	L06	IH	44	1.729	L10	IH	1.421	44	1.150	1.381	1.009	SW	-0.94	38
26	2- 8-82	5820	100	228	J06	HI	44	1.767	F11	HI	1.436	44	1.159	1.396	1.002	SE	-1.84	42
27	3- 2-82	6025	100	228	L06	IH	44	1.768	L10	IH	1.424	44	1.179	1.381	1.008	SW	-3.36	40
28	3-15-82	6472	100	228	F11	HI	44	1.749	F11	HI	1.421	44	1.167	1.383	1.005	SW	-3.09	43
56(10)	4-20-82	7518	100	228	F11	HI	44	1.740	F11	HI	1.420	44	1.159	1.381	1.009	SW	-2.53	42
59(11)	5-15-82	8354	100	227	E10	IH	47	1.746	G06	HI	1.419	47	1.159	1.377	1.011	NE	-4.61	41
61(12)	6-17-82	9450	100	222	E10	DG	46	1.732	F09	LG	1.438	46	1.165	1.387	1.009	SE	-5.43	41
62	7-17-82	10420	100	227	J06	GL	44	1.729	F09	LG	1.436	47	1.160	1.386	1.006	SE	-4.90	40
63	8- 3-82	11019	100	224	J06	GL	46	1.707	F09	LG	1.427	46	1.149	1.380	1.005	SE	-3.32	39
66(13)	8-20-82	11577	100	224	J06	GL	46	1.699	J06	GL	1.421	46	1.148	1.379	1.006	SE	-3.70	39
69(14)	9-22-82	12644	100	225	J06	GL	52	1.687	J06	GL	1.414	52	1.139	1.365	1.007	SW	-3.17	39
70	10-28-82	13207	100	222	J06	GL	53	1.679	F09	LG	1.410	53	1.141	1.366	1.006	SW	-3.04	38
73(15)	11-12-82	13684	100	226	J06	GL	53	1.682	J06	GL	1.398	53	1.152	1.341	1.003	SW	-2.97	40
74	12-16-82	14752	100	226	J06	GL	53	1.714	J06	GL	1.422	53	1.155	1.362	1.003	SW	-2.19	40
75	1-18-83	15859	100	228	J06	GL	11	1.676	J06	GL	1.374	11	1.148	1.321	1.007	SW	0.93	40

9. MAPS 23 AND 24 WERE PARTIAL-POWER MAPS TAKEN FOR QUADRANT POWER TILT VERIFICATION.

10. MAP 29 WAS ABORTED DUE TO LOSS OF NIS CHANNEL N-41. MAPS 30 THROUGH 38 WERE QUARTER-CORE FLUX MAPS TAKEN FOR QUADRANT POWER TILT VERIFICATION. MAPS 39 AND 40 WERE QUARTER-CORE FLUX MAPS TAKEN FOR INCORE/EXCORE CALIBRATION. MAPS 41 THROUGH 55 WERE QUARTER-CORE FLUX MAPS TAKEN FOR QUADRANT POWER TILT VERIFICATION.

11. MAPS 57 AND 58 WERE QUARTER-CORE MAPS TAKEN FOR INCORE/EXCORE CALIBRATION.

12. MAP 60 WAS ABORTED DUE TO AN INSUFFICIENT NUMBER OF THIMBLES.

13. MAPS 64 AND 65 WERE QUARTER-CORE MAPS TAKEN FOR INCORE/EXCORE CALIBRATION.

14. MAP 67 WAS A QUARTER-CORE FLUX MAP USED FOR QUADRANT POWER TILT VERIFICATION. MAP 68 WAS ABORTED DUE TO AN INSUFFICIENT NUMBER OF THIMBLES.

15. MAPS 71 AND 72 WERE QUARTER-CORE MAPS TAKEN FOR INCORE/EXCORE CALIBRATION.

Figure 4.1

SURRY UNIT 1 - CYCLE 6

ASSEMBLYWISE POWER DISTRIBUTION

S1-6-13

Row		R	P	N	M	L	K	J	H	G	F	E	D	C	B	A
1	MEASURED							0.39	0.68	0.40						
1	PCT DIFFERENCE							-5.2	-5.3	-3.8						
2	MEASURED					0.39	0.86	0.97	1.01	0.99	0.88	0.38				
2	PCT DIFFERENCE					1.7	-4.1	-4.7	-4.8	-3.3	-1.6	-0.8				
3	MEASURED				0.43	0.95	1.11	1.14	1.17	1.15	1.10	0.94	0.43			
3	PCT DIFFERENCE				1.5	0.7	-0.2	-4.1	-4.2	-3.1	-1.6	-0.3	0.5			
4	MEASURED			0.44	0.90	1.12	1.20	1.18	1.17	1.16	1.20	1.13	0.90	0.44		
4	PCT DIFFERENCE			1.7	0.1	-0.3	-0.9	-2.3	-2.9	-4.1	-0.7	0.1	0.3	1.9		
5	MEASURED		0.39	0.92	1.12	1.22	1.21	1.19	1.15	1.19	1.20	1.23	1.13	0.97	0.40	
5	PCT DIFFERENCE		-0.2	-1.9	-0.5	-1.3	-0.7	-1.0	-0.6	-0.9	-1.3	-0.6	0.6	2.6	4.4	
6	MEASURED		0.90	1.11	1.21	1.23	1.19	1.18	1.05	1.18	1.18	1.21	1.22	1.14	0.92	
6	PCT DIFFERENCE		-0.2	-0.2	0.0	0.9	-0.2	-0.6	-0.1	-0.4	-1.6	-0.3	0.8	2.0	2.7	
7	MEASURED	0.41	1.01	1.18	1.21	1.22	1.20	0.97	1.18	0.98	1.18	1.21	1.22	1.18	1.03	0.41
7	PCT DIFFERENCE	-0.7	-0.7	-0.4	0.1	1.2	1.2	-0.0	0.3	0.3	-0.5	0.2	1.4	-0.0	0.4	0.0
8	MEASURED	0.71	1.05	1.21	1.20	1.17	1.06	1.19	1.07	1.18	1.05	1.16	1.20	1.21	1.05	0.73
8	PCT DIFFERENCE	-0.7	-0.9	-1.4	-0.1	0.9	0.7	1.0	0.7	0.1	-0.2	0.3	-0.1	-1.3	-0.8	1.4
9	MEASURED	0.41	1.02	1.18	1.21	1.21	1.20	0.98	1.19	0.97	1.19	1.20	1.20	1.17	1.03	0.43
9	PCT DIFFERENCE	-0.7	-0.3	-0.1	0.3	0.4	0.6	0.3	1.4	-0.2	-0.1	-0.1	-0.8	-1.0	0.5	3.6
10	MEASURED		0.91	1.13	1.22	1.22	1.19	1.21	1.07	1.20	1.20	1.22	1.21	1.11	0.90	
10	PCT DIFFERENCE		1.3	1.3	0.5	-0.2	-0.2	1.4	1.4	0.8	0.4	0.1	-0.1	-0.1	0.4	
11	MEASURED		0.40	0.96	1.14	1.23	1.22	1.22	1.17	1.22	1.23	1.23	1.13	0.95	0.39	
11	PCT DIFFERENCE		2.3	2.3	1.0	-0.6	0.3	1.6	1.4	1.3	1.0	-0.1	0.3	0.9	1.2	
12	MEASURED			0.44	0.92	1.12	1.22	1.22	1.20	1.21	1.22	1.13	0.90	0.44		
12	PCT DIFFERENCE			3.4	1.8	-0.6	0.9	1.3	-0.3	0.1	1.1	0.4	0.0	2.6		
13	MEASURED				0.44	0.94	1.14	1.17	1.18	1.17	1.13	0.95	0.43			
13	PCT DIFFERENCE				3.4	-0.6	1.9	-1.1	-3.3	-1.1	1.6	1.0	1.0			
14	MEASURED					0.40	0.93	1.03	1.05	1.01	0.90	0.39				
14	PCT DIFFERENCE					3.5	3.5	0.5	-1.2	-1.1	0.4	1.9				
15	MEASURED							0.43	0.73	0.41						
15	PCT DIFFERENCE							3.4	1.6	-1.1						

STANDARD DEVIATION = 1.215

AVERAGE PCT. DIFFERENCE = 1.2

SUMMARY

MAP NO: S1-6-13 | DATE: 8/10/81 | POWER: 100%

CONTROL ROD POSITIONS: | F-Q(T) = 1.794 | QPTR:

D BANK AT 217 STEPS | F-DH(N) = 1.409 | NW 0.9903 | NE 0.9990

F(Z) = 1.219 | SW 1.0078 | SE 1.0029

F(XY) = 1.368

BURNUP = 973 MWD/MTU | A.O = -1.85(%)

Figure 4.2

SURRY UNIT 1 - CYCLE 6

ASSEMBLYWISE POWER DISTRIBUTION

S1-6-56

Key: MEASURED / PCT DIFFERENCE

Row		R	P	N	M	L	K	J	H	G	F	E	D	C	B	A
1	MEASURED							0.37	0.61	0.37						
	PCT DIFFERENCE							-5.5	-5.5	-4.4						
2	MEASURED					0.41	0.82	0.92	0.88	0.93	0.83	0.39				
	PCT DIFFERENCE					2.5	-3.6	-4.6	-4.6	-3.7	-2.5	-0.6				
3	MEASURED				0.46	0.99	1.13	1.04	1.04	1.05	1.11	0.98	0.46			
	PCT DIFFERENCE				2.1	0.7	-1.0	-3.6	-3.6	-3.2	-2.5	0.5	2.4			
4	MEASURED			0.45	0.91	1.18	1.17	1.22	1.11	1.20	1.18	1.20	0.92	0.46		
	PCT DIFFERENCE			0.4	0.1	-0.7	-0.7	-1.5	-2.2	-3.6	0.1	0.8	1.1	2.1		
5	MEASURED		0.39	0.97	1.18	1.20	1.29	1.19	1.26	1.20	1.29	1.21	1.20	1.00	0.41	
	PCT DIFFERENCE		-1.0	-1.0	-0.7	-0.7	-0.4	0.0	0.3	0.3	-0.0	0.1	0.3	2.0	3.7	
6	MEASURED		0.84	1.13	1.17	1.30	1.20	1.29	1.09	1.30	1.20	1.29	1.18	1.15	0.87	
	PCT DIFFERENCE		-0.6	-0.6	-0.3	0.4	-0.0	0.3	0.8	0.8	0.0	-0.0	-0.0	1.0	2.2	
7	MEASURED	0.39	0.96	1.07	1.24	1.19	1.29	1.02	1.27	1.03	1.30	1.19	1.23	1.08	0.97	0.39
	PCT DIFFERENCE	-0.1	-0.5	-0.4	-0.4	-0.0	-0.0	0.7	1.2	1.4	0.8	-0.1	-0.6	-0.3	0.5	0.7
8	MEASURED	0.65	0.92	1.07	1.13	1.25	1.08	1.25	1.10	1.26	1.09	1.25	1.12	1.07	0.94	0.67
	PCT DIFFERENCE	-0.1	-0.6	-1.2	-0.5	-0.5	-0.1	-0.7	1.6	0.8	0.6	-0.4	-0.8	-0.8	1.2	3.4
9	MEASURED	0.39	0.96	1.07	1.24	1.20	1.29	1.03	1.27	1.02	1.28	1.19	1.24	1.08	0.98	0.41
	PCT DIFFERENCE	-0.1	-0.3	-0.4	-0.1	0.6	0.2	1.5	1.5	1.0	-1.1	-0.5	-0.1	-0.3	1.7	4.7
10	MEASURED		0.85	1.15	1.18	1.30	1.21	1.28	1.09	1.29	1.20	1.29	1.18	1.15	0.85	
	PCT DIFFERENCE		0.4	0.4	0.5	0.6	0.6	-0.6	0.3	-0.0	-0.2	-0.0	0.5	0.3	0.6	
11	MEASURED		0.40	0.99	1.20	1.22	1.30	1.19	1.25	1.19	1.30	1.22	1.20	0.99	0.40	
	PCT DIFFERENCE		1.1	1.1	0.8	0.5	0.5	-0.6	-0.6	-0.6	0.7	0.6	1.0	1.3	1.4	
12	MEASURED			0.46	0.92	1.20	1.18	1.22	1.11	1.22	1.17	1.19	0.92	0.46		
	PCT DIFFERENCE			1.8	1.3	0.5	0.5	-1.9	-1.9	-1.9	-0.9	-0.1	0.8	2.9		
13	MEASURED				0.46	1.01	1.18	1.05	1.05	1.06	1.12	0.97	0.46			
	PCT DIFFERENCE				2.6	3.5	3.5	-3.2	-2.9	-1.9	-1.8	-1.0	1.5			
14	MEASURED					0.41	0.88	0.98	0.92	0.95	0.84	0.39				
	PCT DIFFERENCE					3.5	4.2	1.9	-0.2	-1.0	-1.3	-1.9				
15	MEASURED							0.41	0.67	0.39						
	PCT DIFFERENCE							5.3	2.9	-0.7						

STANDARD DEVIATION = 1.283

AVERAGE PCT. DIFFERENCE = 1.3

SUMMARY

MAP NO: S1-6-56

DATE: 4/20/82

POWER: 100%

CONTROL ROD POSITIONS:

D BANK AT 228 STEPS

F-Q(T) = 1.740

F-DH(N) = 1.420

F(Z) = 1.159

F(XY) = 1.381

BURNUP = 7518 MWD/MTU

A.O = -2.53(%)

QPTR:

NW 0.9921	NE 1.0020
SW 1.0087	SE 0.9972

Figure 4.3

SURRY UNIT 1 - CYCLE 6

ASSEMBLYWISE POWER DISTRIBUTION

S1-6-74

Row		R	P	N	M	L	K	J	H	G	F	E	D	C	B	A
1	MEASURED							0.41	0.66	0.42						
	PCT DIFFERENCE							-1.8	-1.8	-0.9						
2	MEASURED					0.45	0.86	0.98	0.91	0.98	0.86	0.43				
	PCT DIFFERENCE					4.0	0.6	-1.0	-1.5	-1.0	0.5	0.5				
3	MEASURED				0.51	1.06	1.19	1.05	1.02	1.04	1.18	1.03	0.48			
	PCT DIFFERENCE				4.0	4.0	0.6	-0.1	-2.2	-1.7	0.5	0.5	-1.1			
4	MEASURED			0.49	0.94	1.24	1.15	1.22	1.07	1.21	1.13	1.21	0.92	0.50		
	PCT DIFFERENCE			0.8	1.4	1.6	0.3	-1.3	-2.2	-2.5	-0.8	-0.9	-1.0	2.4		
5	MEASURED		0.42	1.01	1.21	1.16	1.27	1.15	1.28	1.14	1.25	1.15	1.21	1.05	0.45	
	PCT DIFFERENCE		-1.3	-1.3	-0.8	-0.2	-0.5	0.3	0.3	-0.7	-1.7	-1.0	-1.1	2.4	5.9	
6	MEASURED		0.86	1.18	1.14	1.26	1.13	1.32	1.09	1.29	1.12	1.26	1.13	1.20	0.89	
	PCT DIFFERENCE		0.6	0.6	-0.2	-1.1	-0.8	3.0	2.9	0.8	-2.0	-1.6	-1.0	2.0	3.5	
7	MEASURED	0.43	1.00	1.07	1.23	1.12	1.25	1.03	1.26	1.01	1.28	1.13	1.21	1.05	1.00	0.42
	PCT DIFFERENCE	2.4	1.3	2.0	-0.3	-2.3	-2.3	3.0	2.5	1.7	0.1	-1.0	-2.2	-0.1	0.9	1.1
8	MEASURED	0.67	0.93	1.04	1.09	1.25	1.04	1.19	1.07	1.24	1.06	1.26	1.07	1.02	0.93	0.70
	PCT DIFFERENCE	-0.4	0.7	0.0	-0.3	-2.5	-1.3	-3.3	2.7	1.1	0.5	-1.0	-2.2	-1.4	1.3	3.7
9	MEASURED	0.42	0.99	1.05	1.23	1.16	1.27	0.97	1.24	1.02	1.25	1.13	1.23	1.05	1.02	0.45
	PCT DIFFERENCE	-0.4	-0.4	-0.4	-0.3	1.0	-0.8	-2.5	1.1	2.2	-2.1	-1.2	-0.6	-0.5	2.9	7.4
10	MEASURED		0.85	1.17	1.15	1.29	1.14	1.25	1.05	1.27	1.14	1.27	1.15	1.18	0.93	
	PCT DIFFERENCE		-0.4	-0.4	0.4	1.0	-0.5	-2.5	-1.2	-0.4	-0.6	-0.8	0.3	0.3	8.1	
11	MEASURED		0.44	1.05	1.24	1.17	1.27	1.12	1.24	1.11	1.27	1.17	1.23	1.04	0.44	
	PCT DIFFERENCE		2.4	2.4	1.4	0.2	-0.7	-1.9	-2.6	-2.9	-0.2	-0.0	1.0	1.9	3.4	
12	MEASURED			0.51	0.96	1.22	1.14	1.23	1.07	1.21	1.14	1.23	0.94	0.50		
	PCT DIFFERENCE			5.2	3.2	0.2	-0.1	-0.7	-2.1	-1.9	0.1	0.4	1.3	3.1		
13	MEASURED				0.51	1.07	1.21	1.04	1.01	1.04	1.18	1.03	0.50			
	PCT DIFFERENCE				5.1	5.0	2.4	-1.6	-2.5	-1.0	0.2	0.6	2.0			
14	MEASURED					0.45	0.90	0.96	0.91	0.99	0.86	0.43				
	PCT DIFFERENCE					5.0	5.0	-3.0	-1.5	-0.3	0.1	0.2				
15	MEASURED							0.44	0.67	0.42						
	PCT DIFFERENCE							5.0	-0.1	-0.1						

STANDARD DEVIATION = 1.446

AVERAGE PCT. DIFFERENCE = 1.6

SUMMARY

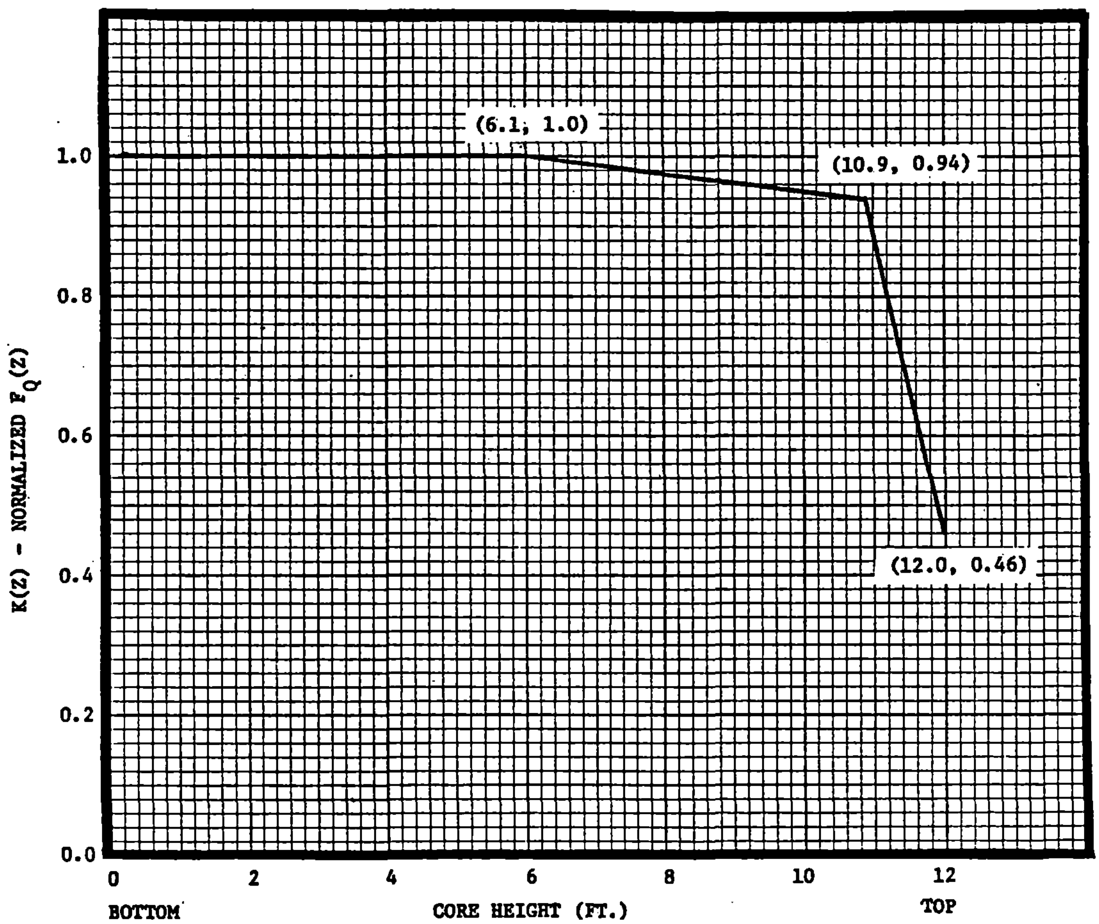
MAP NO: S1-6-74	DATE: 12/16/82	POWER: 100%
CONTROL ROD POSITIONS:	F-Q(T) = 1.714	QPTR:
D BANK AT 226 STEPS	F-DH(N) = 1.422	NW 1.0010 | NE 0.9950
	F(Z) = 1.155	SW 1.0034 | SE 1.0006
	F(XY) = 1.362	
	BURNUP = 14752 MWD/MTU	A.O = -2.19(%)

Figure 4.4

SURRY UNIT 1 CYCLE 6

HOT CHANNEL FACTOR NORMALIZED

OPERATING ENVELOPE



SURRY UNIT 1 - CYCLE 6

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

S1-6-13

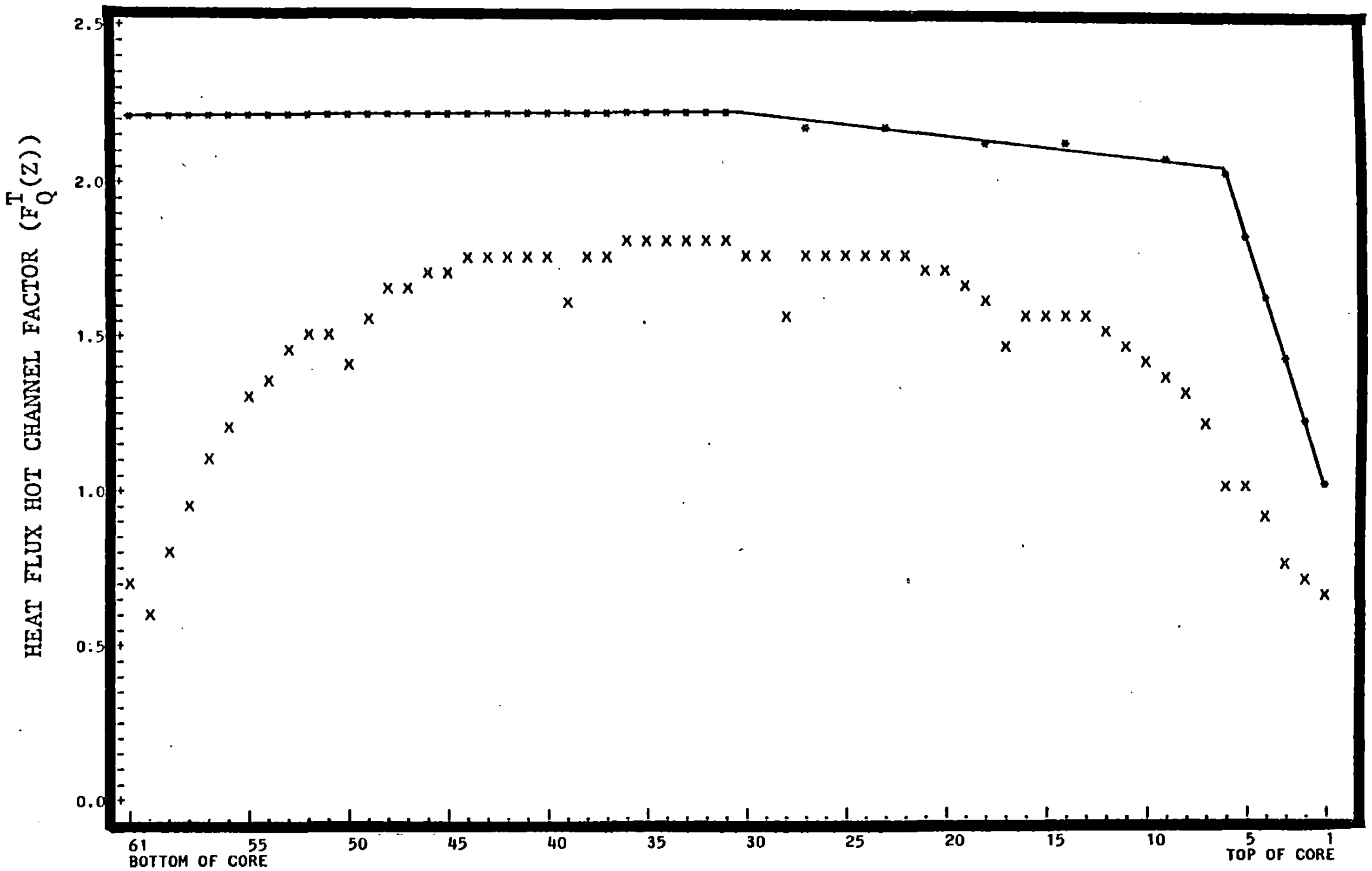


Figure 4.5

SURRY UNIT 1 - CYCLE 6

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

S1-6-56

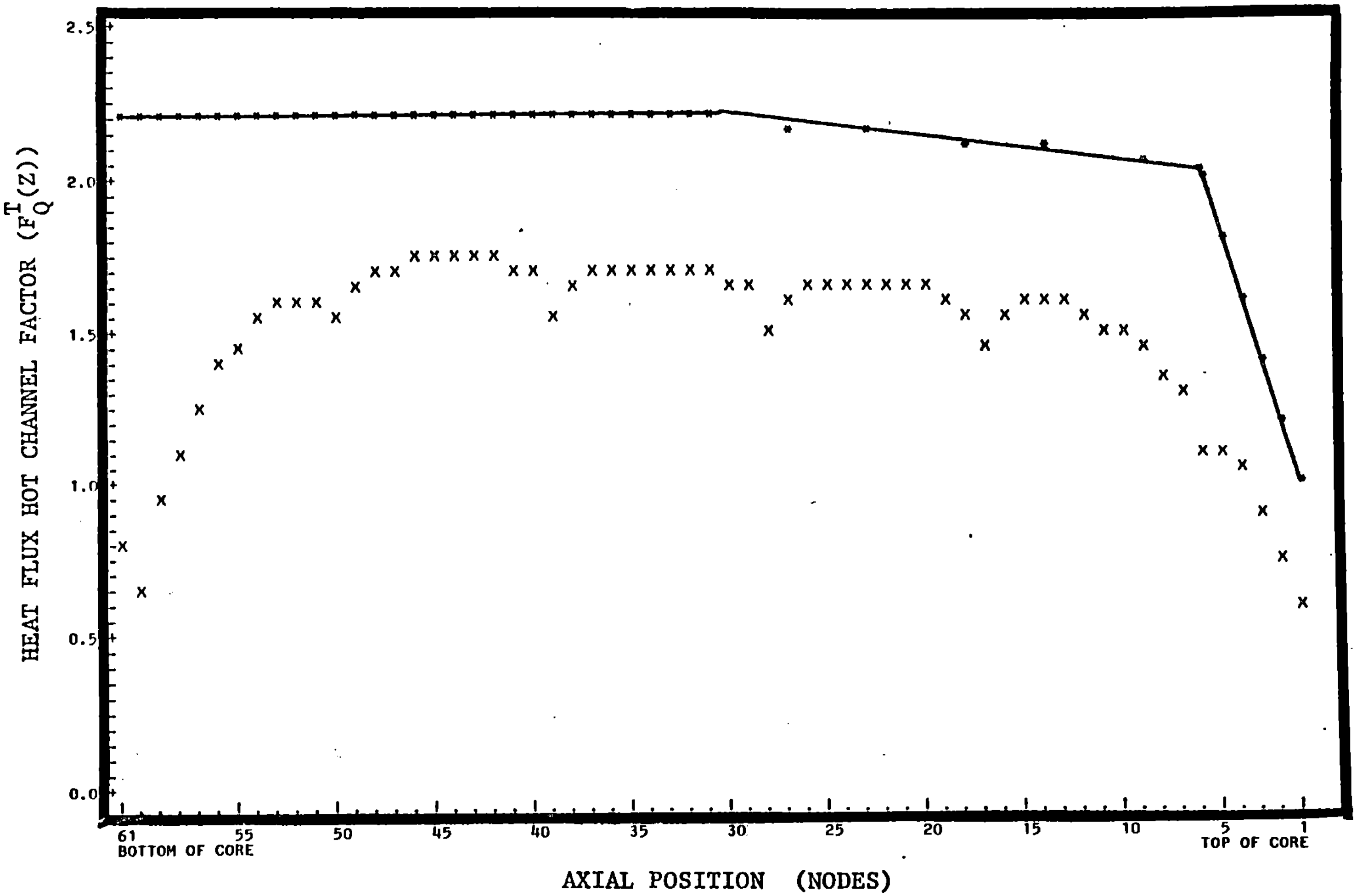


Figure 4.6

SURRY UNIT 1 - CYCLE 6

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

S1-6-74

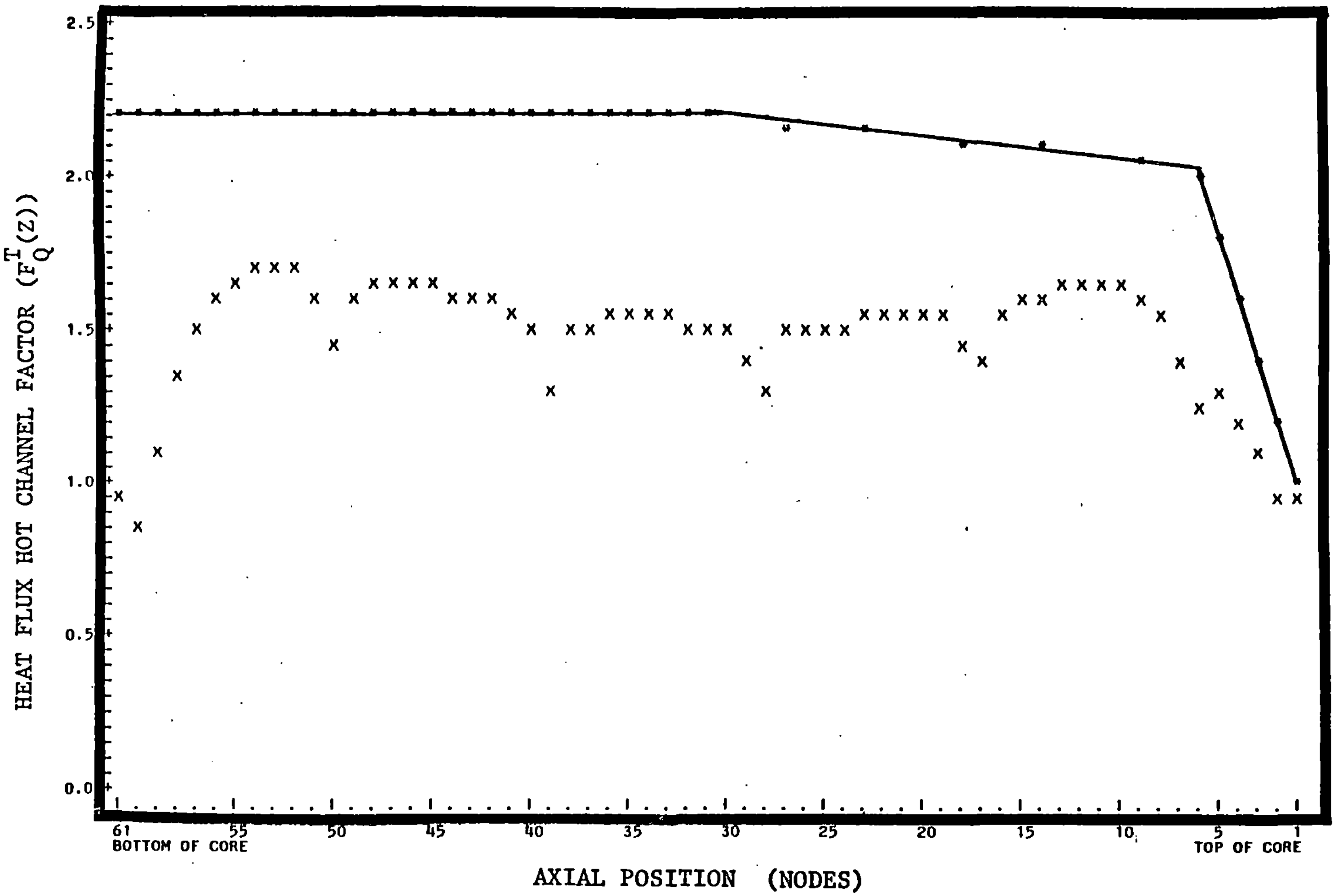
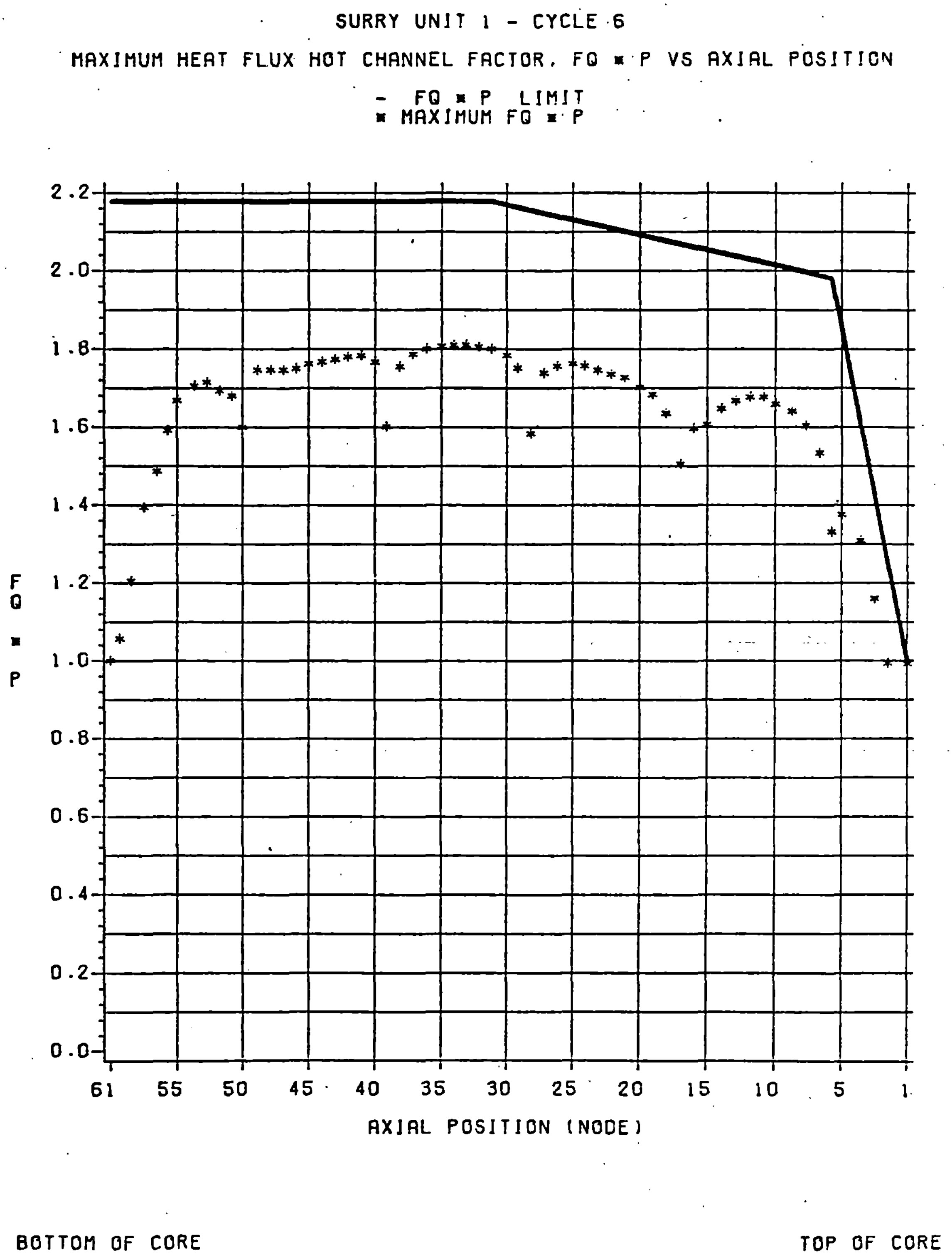


Figure 4.7

Figure 4.8



SURRY UNIT 1 - CYCLE 6
MAXIMUM HEAT FLUX HOT CHANNEL FACTOR, FQ * P VS AXIAL POSITION
- FQ * P LIMIT
* MAXIMUM FQ * P
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
FQ * P
61
55
50
45
40
35
30
25
20
15
10
5
1
AXIAL POSITION (NODE)
BOTTOM OF CORE
TOP OF CORE

Figure 4.9

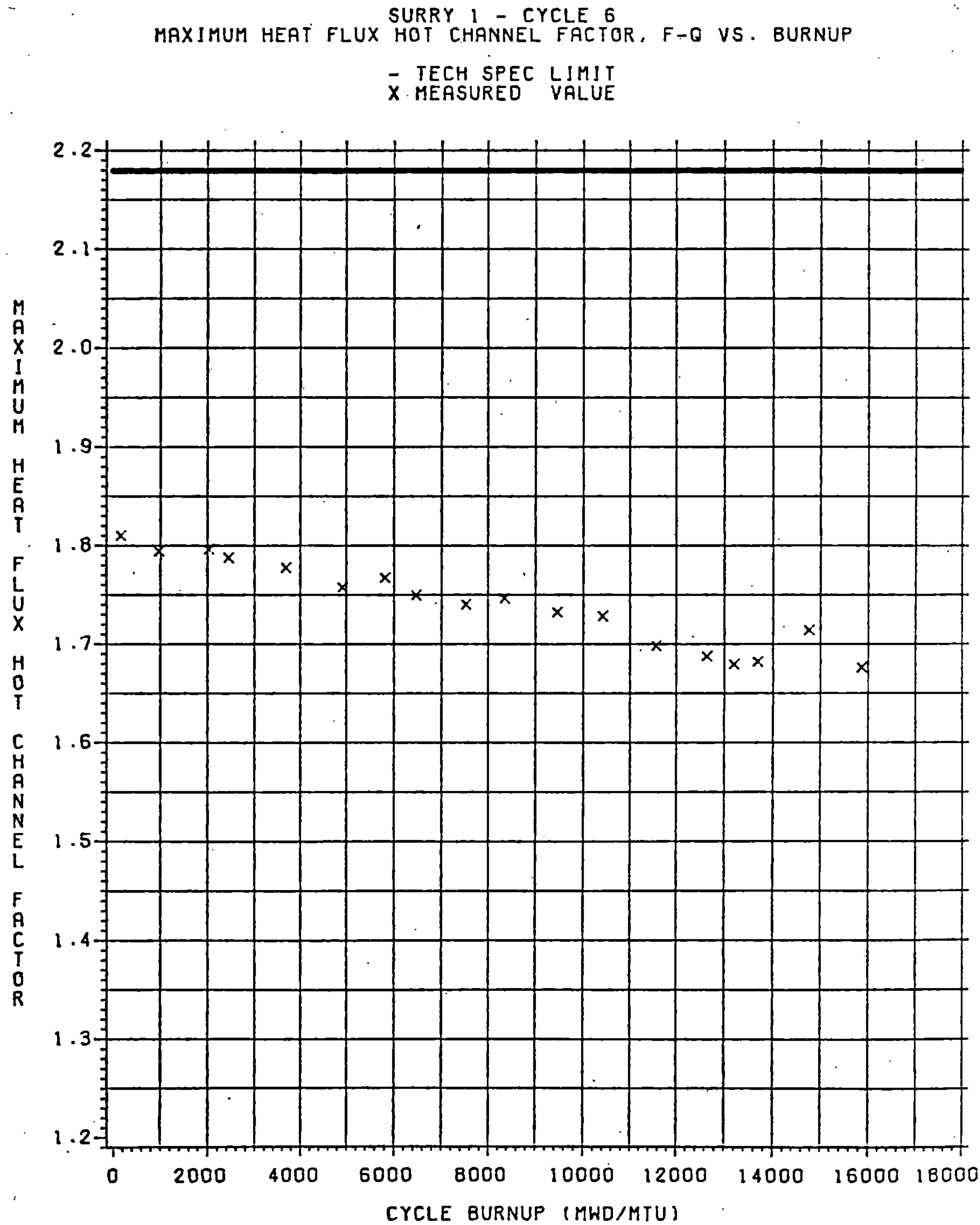

SURRY 1 - CYCLE 6
MAXIMUM HEAT FLUX HOT CHANNEL FACTOR, F-Q VS. BURNUP
- TECH SPEC LIMIT
X MEASURED VALUE
MAXIMUM HEAT FLUX HOT CHANNEL FACTOR
2.2
2.1
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
CYCLE BURNUP (MWD/MTU)

Figure 4.10

SURRY UNIT 1 - CYCLE 6
ENTHALPY RISE HOT CHANNEL FACTOR, F-DH(N) VS. BURNUP

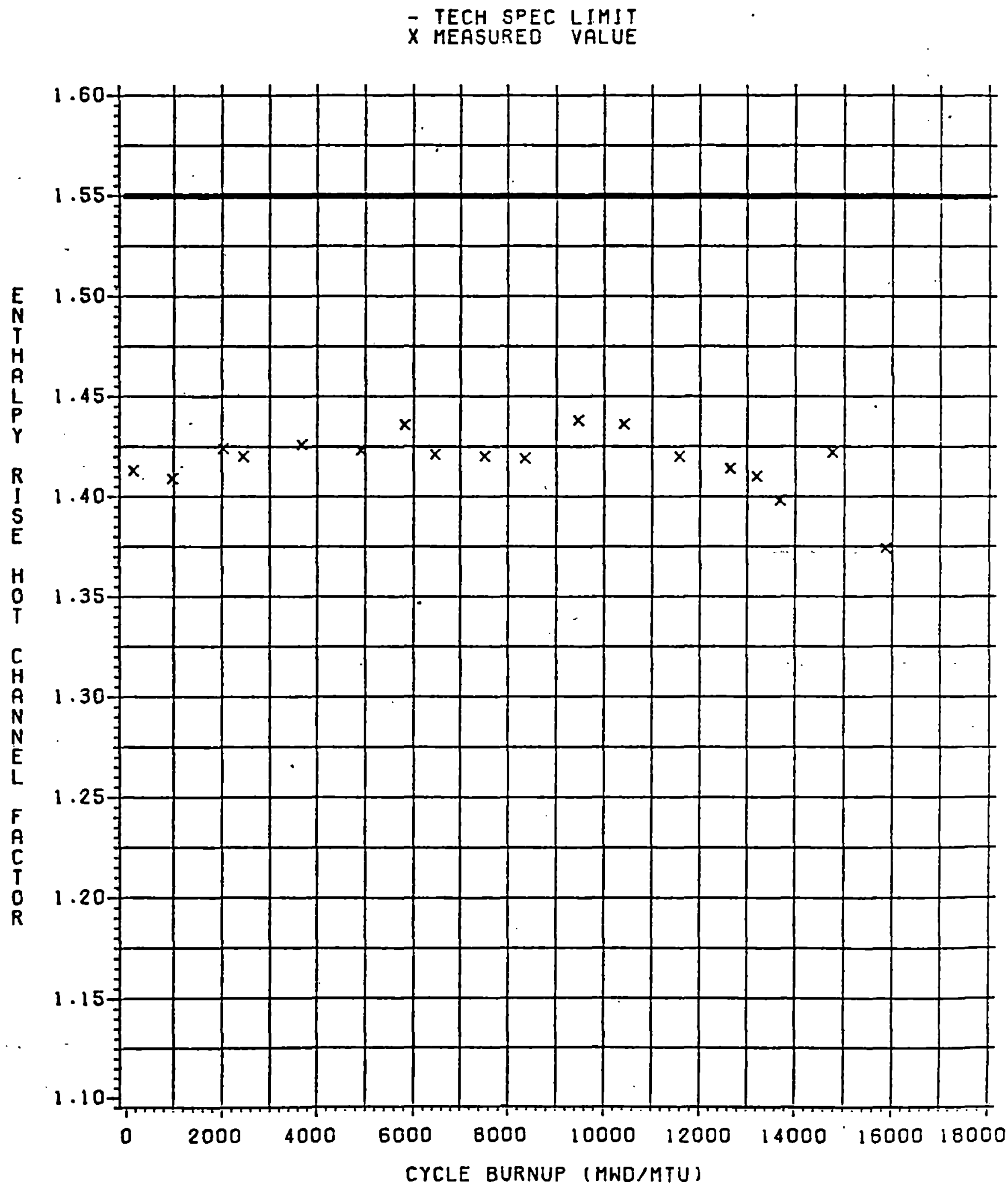
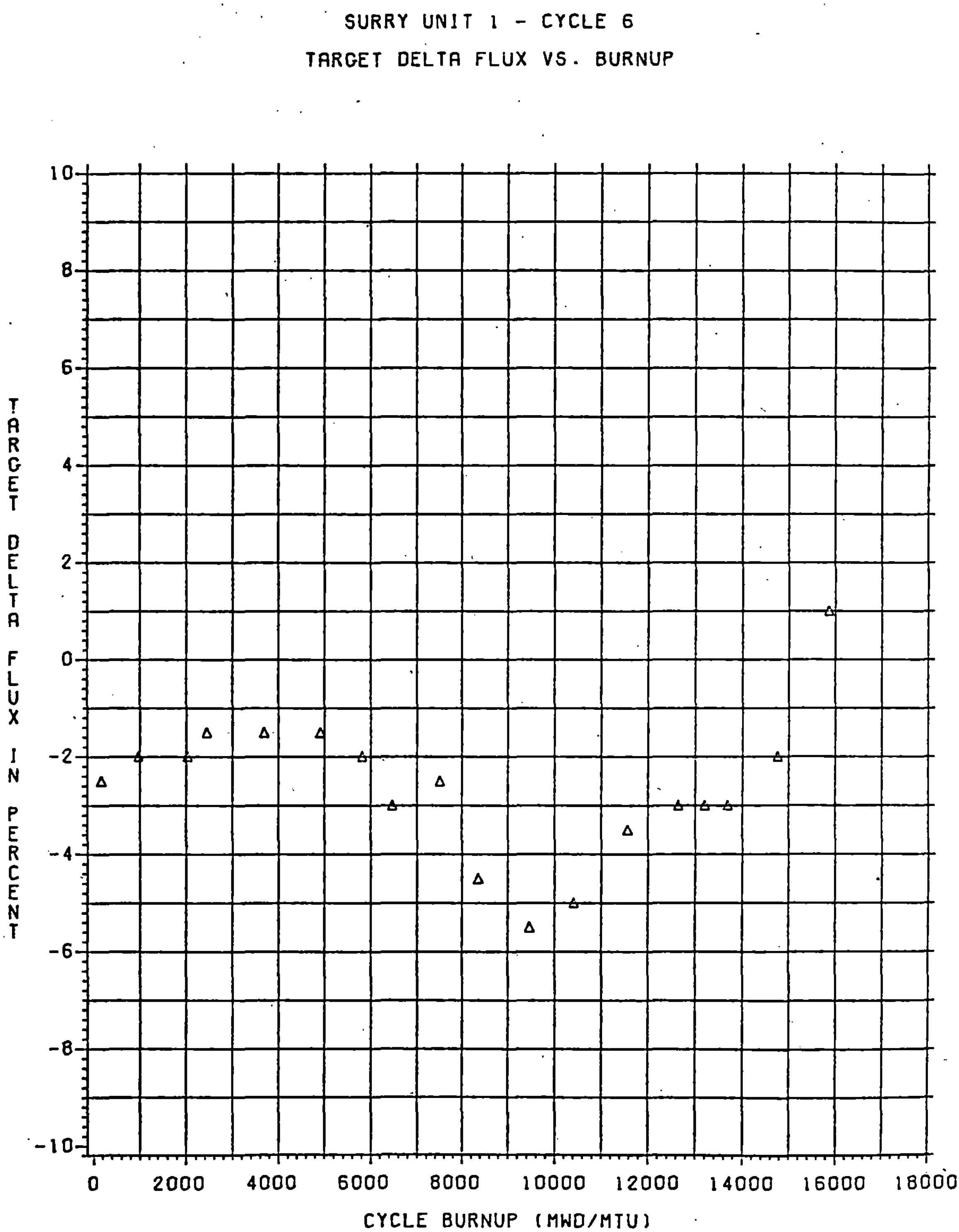


Figure 4.11


SURRY UNIT 1 - CYCLE 6
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
16000
18000
CYCLE BURNUP (MWD/MTU)

SURRY UNIT 1 - CYCLE 6

CORE AVERAGE AXIAL POWER DISTRIBUTION

S1-6-13

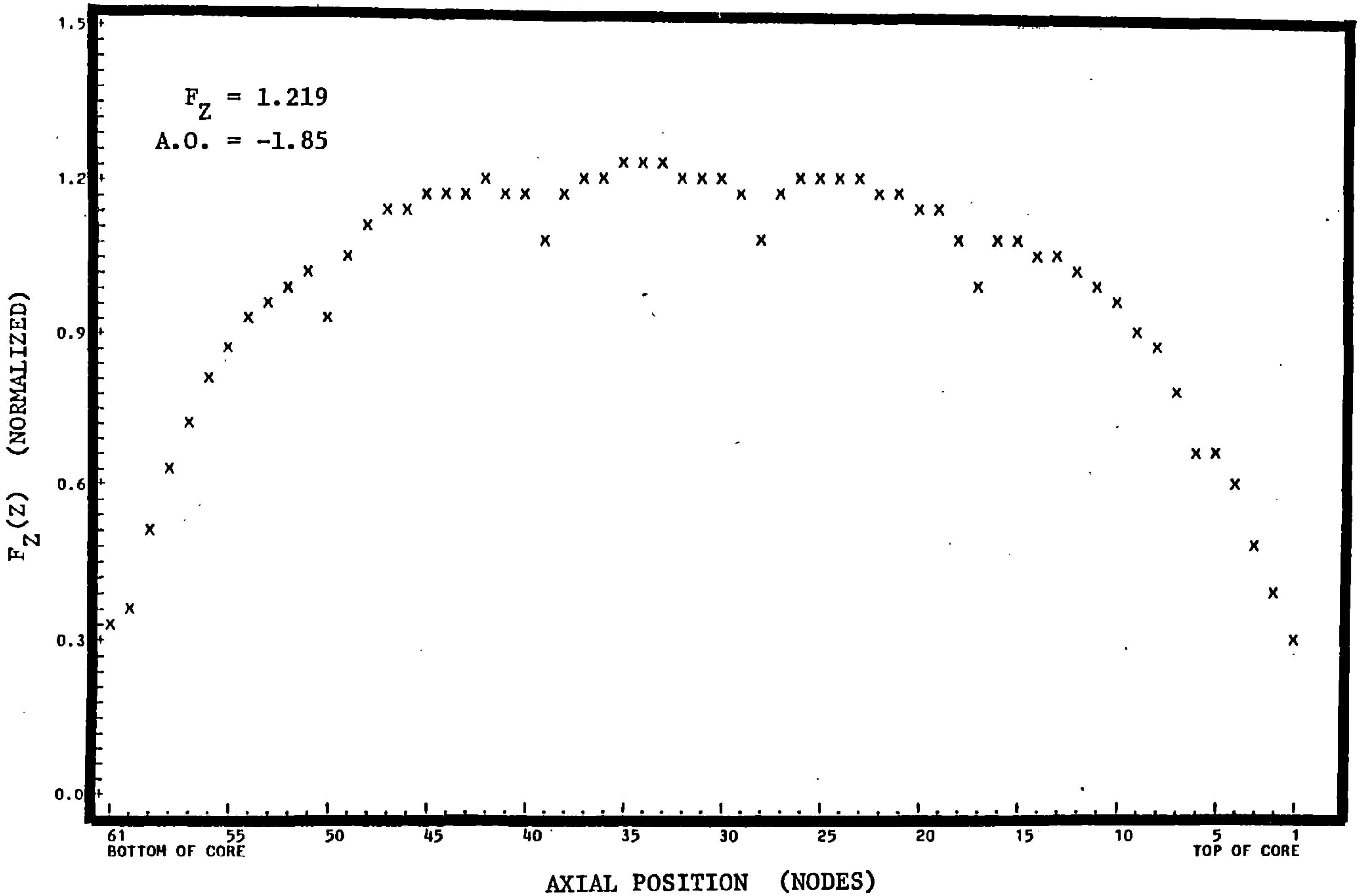


Figure 4.12

SURRY UNIT 1 - CYCLE 6

CORE AVERAGE AXIAL POWER DISTRIBUTION

S1-6-56

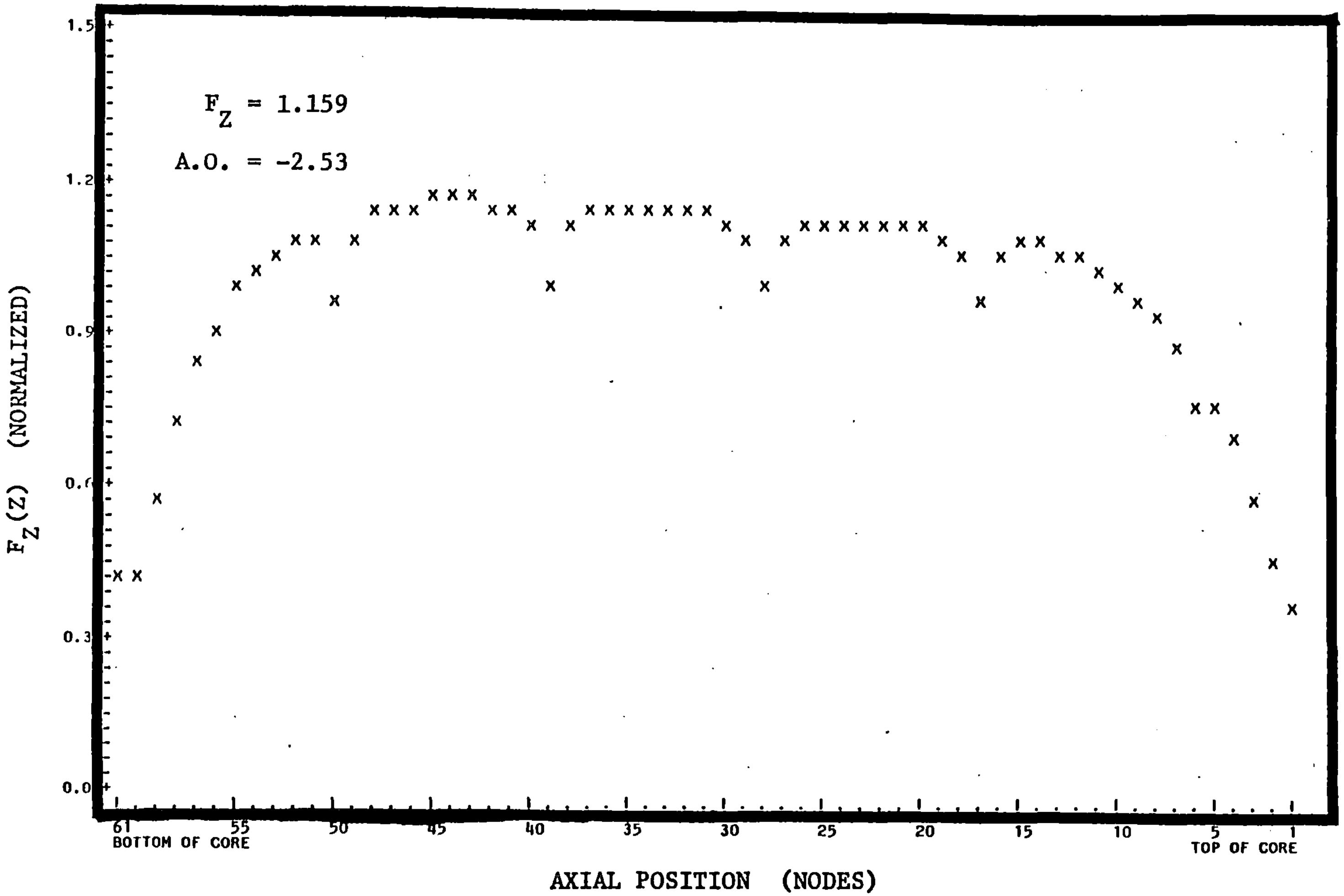


Figure 4.13

SURRY UNIT 1 - CYCLE 6

CORE AVERAGE AXIAL POWER DISTRIBUTION

S1-6-74

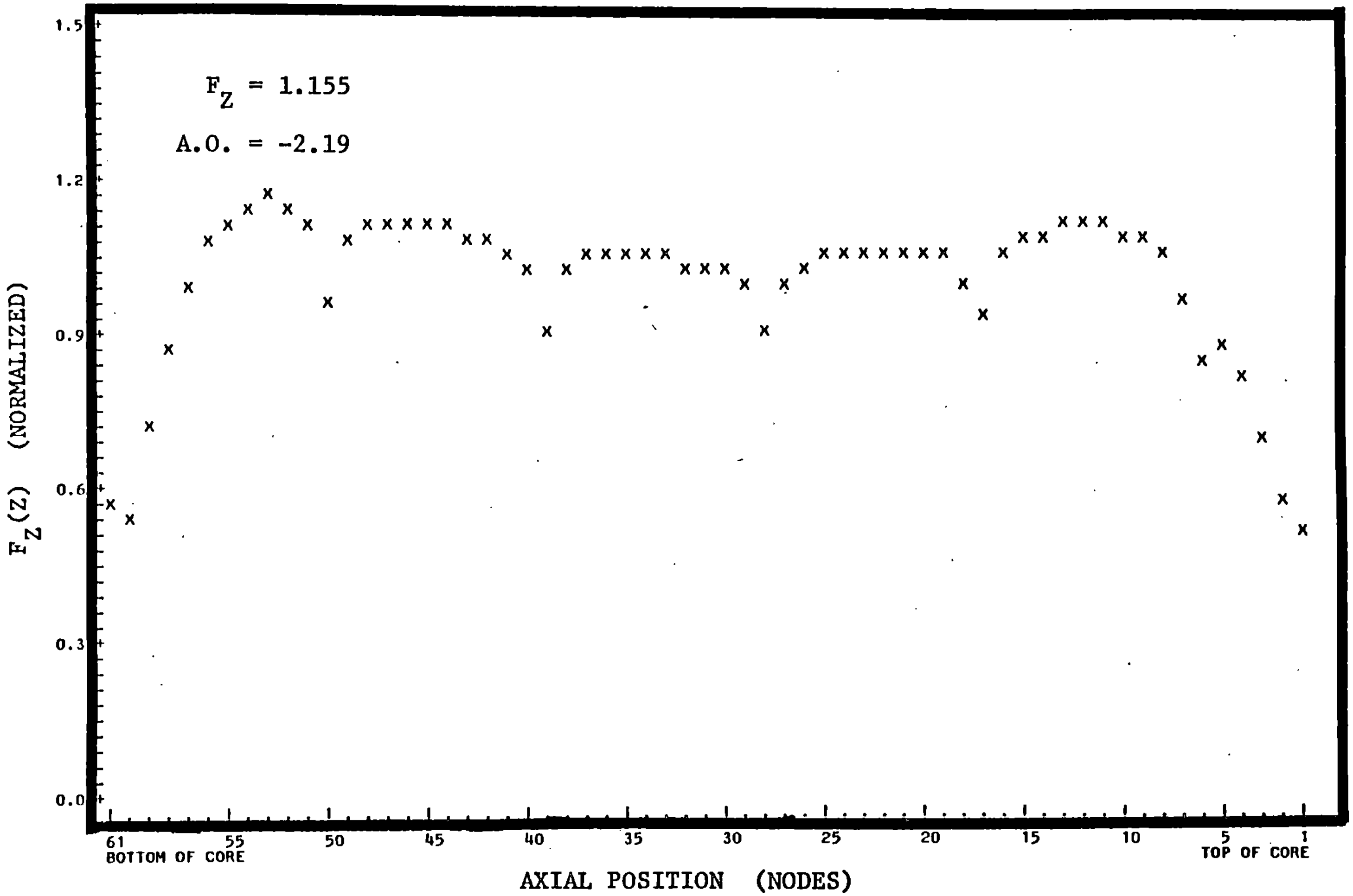
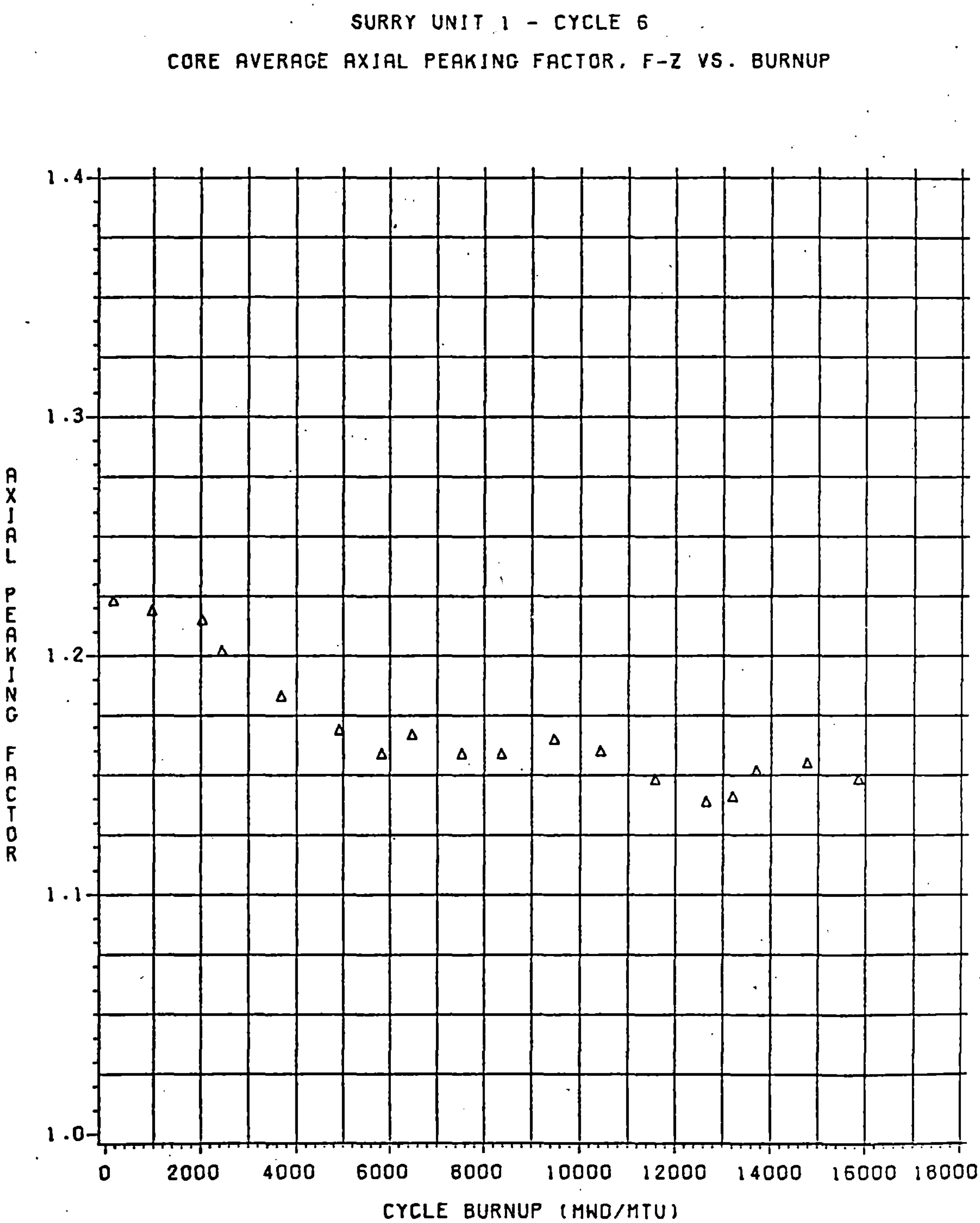


Figure 4.14

Figure 4.15



SURRY UNIT 1 - CYCLE 6
CORE AVERAGE AXIAL PEAKING FACTOR, F-Z VS. BURNUP
AXIAL PEAKING FACTOR
1.4
1.3
1.2
1.1
1.0
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
CYCLE BURNUP (MWD/MTU)

Section 5

PRIMARY COOLANT ACTIVITY FOLLOW

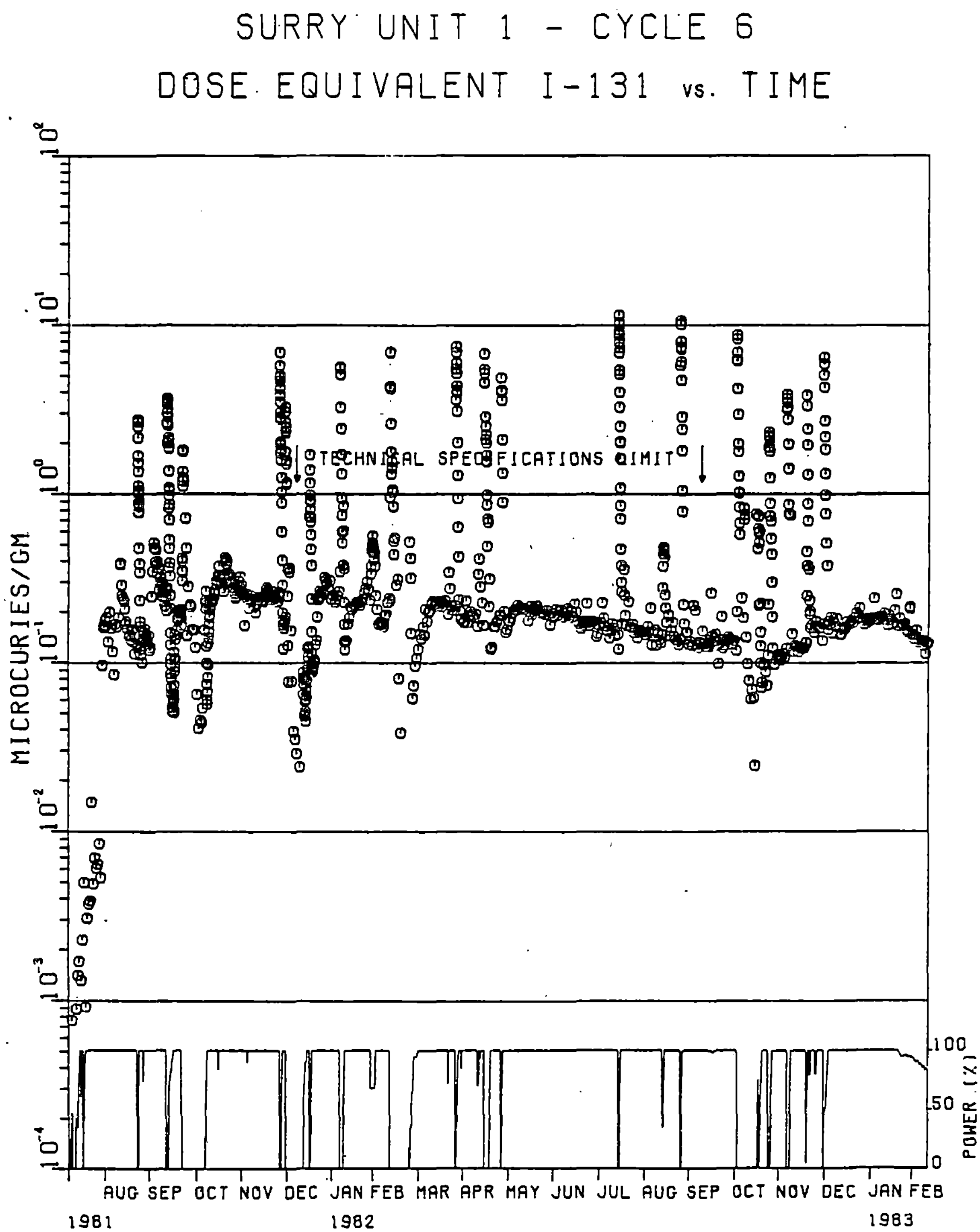
Activity levels of iodine-131 and 133 in the primary coolant are important in core performance follow analysis because they are used as indicators of defective fuel. Additionally, they are also important with respect to the offsite dose calculation values associated with accident analyses. Both I-131 and I-133 can leak into the primary coolant system through a breach in the cladding. As indicated in the Surry Power Station Technical Specifications, the dose equivalent I-131 concentration in the primary coolant is limited to 1.0 μ-Ci/gm for normal steady state operation. Figure 5.1 shows the dose equivalent I-131 activity level history for the Surry 1, Cycle 6 core (the letdown flow rate averaged 108 gpm during power operation). Reactor coolant system activity data indicate that probably two discrete fuel defect events occurred during July and August, 1981 at a core burñup of less than 2,000 MWD/MTU. The failure mechanism is unknown at this time.

The data on Figure 5.1 shows that during Cycle 6 the core operated below the 1.0 μ-Ci/gm limit during steady state operation (the spike data is associated with power transients and unit shutdown) and that the equilibrium activity levels tended to decrease following the initial defect events. Specifically, the value of dose equivalent I-131 reached approximately 0.31 μ-Ci/gm early in Cycle 6, but decreased during the cycle such that the average dose equilavent I-131 concentration was 0.18 μ-Ci/gm, which is 18% 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 0.5 or more. In the case of large leaks, uranium particles in the coolant, and/or "tramp" uranium*, where the diffusion mechanism is negligible, the I-131/I-133 ratio will generally be less than 0.1. Figure 5.2 shows the I-131/I-133 ratio data for the Surry 1, Cycle 6 core. The I-131/I-133 ratio generally remained above 0.5, which indicates possible pinhole defects in the fuel cladding.

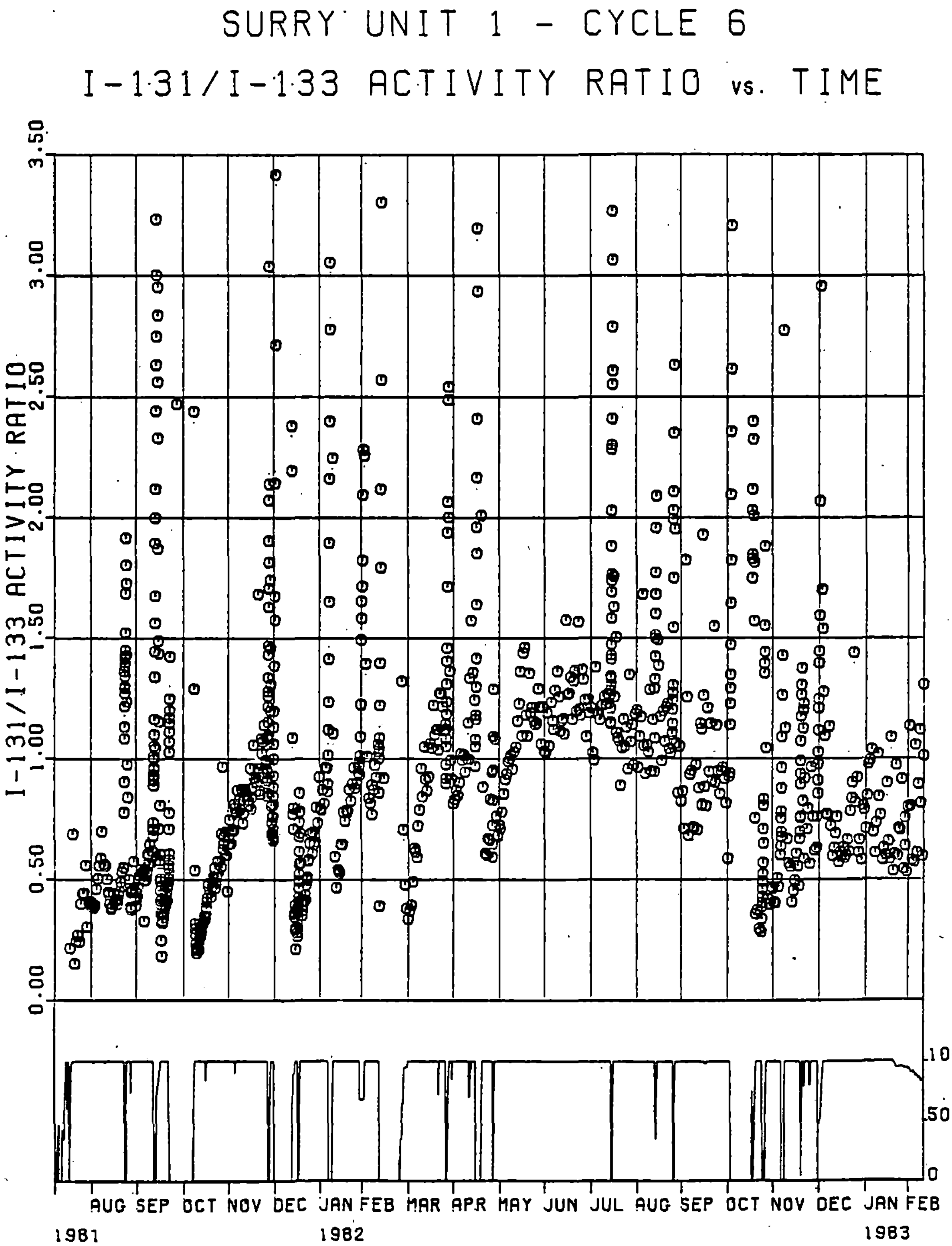
*"Tramp" uranium consists of small particles of uranium which adhere to the outside of the fuel during the manufacturing process.

Figure 5.1



SURRY UNIT 1 - CYCLE 6
DOSE EQUIVALENT I-131 vs. TIME
TECHNICAL SPECIFICATIONS LIMIT
MICROCURIES/GM
10^2
10^1
10^0
10^-1
10^-2
10^-3
10^-4
100
50
0
POWER (%)
AUG SEP OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB
1981
1982
1983

Figure 5.2


SURRY UNIT 1 - CYCLE 6
I-131/I-133 ACTIVITY RATIO vs. TIME
I-131/I-133 ACTIVITY RATIO
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
100
50
0
POWER (%)
AUG SEP OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB
1981
1982
1983

Section 6

CONCLUSIONS

The Surry 1 Cycle 6 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. The analysis of radioiodine data for Cycle 6 indicates that there are pinhole leaks in the fuel cladding.

Section 7

REFERENCES

1) Mr. J. H. Leberstien, "Surry Unit 1, Cycle 6 Startup Physics Test Report," VEP-FRD-44, September, 1981.

2) Surry Power Station Unit 1 and 2 Technical Specifications, Sections 3.1.D, 3.12.B, and 4.10 .

3) Mrs. S. F. Cornwell, "NEWTOTE Code", VEPCO NFO-CCR-6, November, 1982.

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

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

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