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SURRY POWER STATION UNIT 2
CYCLE 12 CORE PERFORMANCE REPORT

For your information, enclosed are five copies of the Virginia Electric and Power Company Technical Report NE-1011, Revision 0, entitled "Surry Unit 2, Cycle 12 Core Performance Report."

Very truly yours,

ML Bowling

M L. Bowling, Manager
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Surry Unit 2 Cycle 12 Core Performance Report

Nuclear Analysis and Fuel
Nuclear Engineering Services

March 1995

Virginia Power

TECHNICAL REPORT NE-1011 - Rev. 0

SURRY UNIT 2, CYCLE 12

CORE PERFORMANCE REPORT

NUCLEAR ANALYSIS AND FUEL
NUCLEAR ENGINEERING SERVICES
VIRGINIA POWER
MARCH, 1995

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INTRODUCTION AND SUMMARY

On February 3, 1995, Surry Unit 2 completed Cycle 12. Since the initial criticality of Cycle 12 on May 4, 1993, the reactor core produced approximately 1.0994 x 10^8 MBTU (18,551 Megawatt days per metric ton of contained uranium). The purpose of this report is to present an analysis of the core performance for routine operation during Cycle 12. The physics tests that were performed during the startup of this cycle were covered in the Surry Unit 2 Cycle 12 Startup Physics Test Report[1] and, therefore, will not be included here.

Prior to the beginning of Cycle 12, pressurizer safety valve problems forced Unit 2 to operate at a reactor coolant system pressure of 2150 psia instead of the normal 2250 psia. In addition, Unit 2 was unable to maintain 100% power due to material buildup on the steam generator upper tube support plates.

Between May and August of 1993, Unit 2 experienced several short outages due to equipment failure and the associated repairs. There were also three longer outages. First, on August 6, 1993, Unit 2 experienced a 13 day outage due to problems with three pressurizer safety values. It was necessary to send the valves offsite for repairs. The second outage occurred when Unit 2 was shutdown for 15 days, beginning November

15, 1993, for steam generator pressure pulse cleaning. The final outage occurred on June 4, 1994 and lasted for 21 days. During this outage, Unit 2 underwent steam generator chemical cleaning, which allowed Unit 2 to operate at 100% power. Additionally, the pressurizer safety valves were replaced, allowing the reactor coolant system pressure to be returned to 2250 psia.

Surry Unit 2 began a power only coastdown on January 11, 1995, at which time the burnup was approximately 17,845 MWD/MTU. The coastdown accounted for an additional core burnup of 706 MWD/MTU from the end of full power reactivity.

The Cycle 12 core consisted of 8 sub-batches of fuel: two fresh batches (batches 14A and 14B); three once-burned batches, two from Cycle 11 (batches 13A, and 13B) and one from Surry 1 Cycle 6 (batch S1/8B); and three twice-burned batches, all from Cycles 10 and 11 (batches 12A, 12B, and 12C). The Surry 2 Cycle 12 core loading map specifying the fuel batch identification and fuel assembly locations is shown in Figure 1.1. The burnable poison locations and source assembly locations are shown in Figure 1.2. Movable detector locations that were available during Cycle 12 are shown in Figure 1.3. Three movable detector locations (N5, J3, and H13) were out of service throughout Cycle 12. Control rod locations are shown in Figure 1.4.

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 the cycle burnup where coastdown operation will begin. Core power distribution follow includes the monitoring of nuclear hot channel factors to verify that they are within the Technical Specification[2] limits, thereby ensuring that adequate margins for linear power density and critical heat flux thermal limits are maintained. Lastly, as part of normal core follow, the primary coolant activity is monitored to assess the status of the fuel cladding integrity and to compare the concentration of dose equivalent iodine-131 in the reactor coolant with the limits specified by the Surry Technical Specifications[2].

Each of the four performance indicators is discussed in detail for the Surry Unit 2 Cycle 12 core in the body of this report. The results are summarized below:

1. Burnup - The burnup tilt (deviation from quadrant symmetry) on the core was no greater than ±0.30% with the burnup accumulation in each batch deviating from design prediction by no more than ±2.53%.

2. Reactivity Depletion - The critical boron concentration, used to monitor reactivity depletion, was consistently within ±0.26% ΔK/K of the design prediction which is within the ±1% ΔK/K margin allowed by Section 4.10 of the Technical Specifications.

3. Power Distribution - Incore flux maps taken each month indicated that the assemblywise radial power distributions deviated from the design predictions by a maximum average difference of 1.9%. All hot channel factors met their respective Technical Specification limits.

4. Primary Coolant Activity - The average dose equivalent iodine-131 activity level in the primary coolant during Cycle 12 was approximately 0.000763 μCi/gm. This corresponds to less than 1% of the operating limit for the concentration of radioiodine in the primary coolant. Radioiodine analysis indicated that there were no fuel rod defects.

Figure 1.1
SURRY UNIT 2 - CYCLE 12
CORE LOADING MAP

R	P	N	M	L	K	J	H	G	F	E	D	C	B	A	
						12A 1U4	13A 0V3	12A 1U0							1
				12B 3U9	13A 1V3	14A 0W1	13A 2V7	14A 1W9	13A 1V7	12B 5U0					2
			12B 5U1	14A 0W8	14B 5W2	13B 5V2	14B 4W5	13B 4V0	14B 6W5	14A 1W3	12B 3U7				3
		12B 3U0	13B 5V7	14B 3W9	13B 3V3	14B 6W7	13A 1V1	14B 5W7	13B 4V8	14B 4W6	13B 3V4	12B 4U9			4
	12B 4U8	14A 0W6	14B 3W5	13B 5V9	14B 6W3	13B 6V3	14A 0W7	13B 5V4	14B 6W1	13B 4V4	14B 3W3	14A 0W2	12B 3U6		5
	13A 2V4	14B 5W1	13B 6V0	14B 4W7	13A 1V9	14A 1W4	13A 2V1	14A 2W8	13A 2V5	14B 5W6	13B 6V1	14B 6W0	13A 2V3		6
12C 5U3	14A 1W2	13B 5V5	14B 4W9	13B 4V2	14A 2W5	13A 0V4	14A 3W2	13A 0V7	14A 3W0	13B 4V3	14B 4W1	13B 4V5	14A 1W6	12A 0U8	7
13A 2V0	13A 1V5	14B 3W4	13A 0V6	14A 1W7	13A 0V5	14A 2W9	S1/8B 4C1	14A 1W5	13A 0V2	14A 2W4	13A 0V1	14B 4W2	13A 1V0	13A 1V2	8
12A 0U9	14A 2W0	13B 4V9	14B 4W3	13B 3V8	14A 0W4	13A 2V9	14A 2W2	13A 2V2	14A 2W6	13B 5V1	14B 3W6	13B 3V5	14A 2W3	12A 1U8	9
	13A 3V1	14B 6W2	13B 5V0	14B 6W6	13A 3V0	14A 1W8	13A 2V8	14A 3W1	13A 0V9	14B 4W0	13B 4V1	14B 6W8	13A 3V2		10
	12B 4U7	14A 0W5	14B 5W4	13B 3V6	14B 4W8	13B 6V4	14A 0W3	13B 3V7	14B 5W0	13B 5V3	14B 3W8	14A 1W0	12B 4U3		11
		12B 4U5	13B 3V9	14B 4W4	13B 5V6	14B 5W9	13A 1V4	14B 5W5	13B 4V6	14B 5W3	13B 4V7	12B 4U2			12
			12B 2U9	14A 0W9	14B 6W4	13B 6V2	14B 3W7	13B 5V8	14B 5W8	14A 2W1	12B 4U1				13
				12B 3U2	13A 0V8	14A 2W7	13A 2V6	14A 1W1	13A 1V6	12B 4U4					14
						12A 1U1	13A 1V8	12A 1U9							15

|--> BATCH
|--> ASSEMBLY ID

FUEL ASSEMBLY DESIGN PARAMETERS

	SUB-BATCH							
	S1/8B	12A	12B	12C	13A	13B	14A	14B
INITIAL ENRICHMENT (W/O U-235)	3.40	3.79	4.00	3.80	3.81	4.00	3.81	4.00
BURNUP AT BOC 12 (MWD/MTU)	11348	32950	39661	33819	24142	21067	0	0
ASSEMBLY TYPE	15x15	15X15	15X15	15X15	15X15	15X15	15X15	15X15
NUMBER OF ASSEMBLIES	1	7	16	1	32	32	32	36
FUEL RODS PER ASSEMBLY	204	204	204	204	204	204	204	204

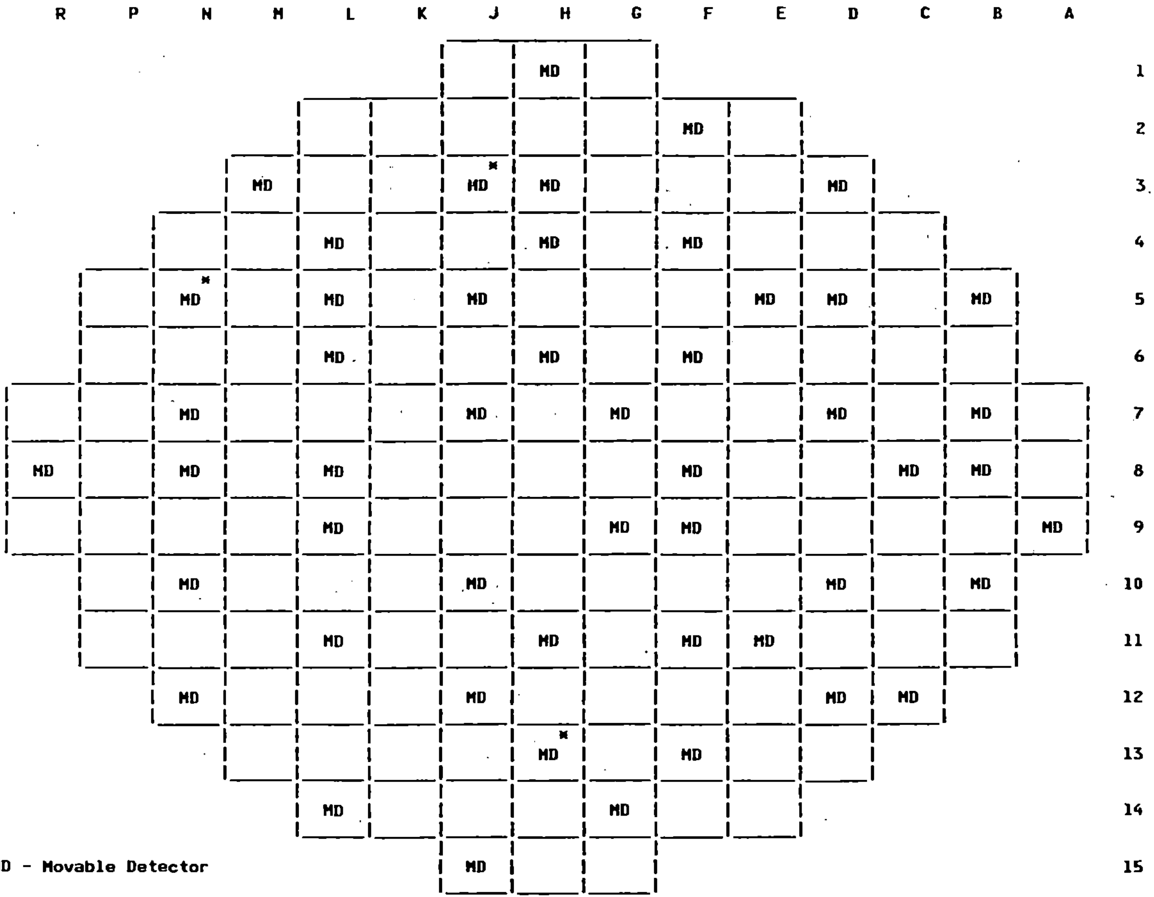
Figure 1.2
SURRY UNIT 2 - CYCLE 12
BURNABLE POISON AND SOURCE ASSEMBLY LOCATIONS

	R	P	N	M	L	K	J	H	G	F	E	D	C	B	A
1															
2															
3					4P BP254	20P BP238		20P BP210		20P BP239	4P BP256				
4					20P BP240		20P BP222		20P BP223		20P BP241				
5		SS4	4P BP255	20P BP242		20P BP230		20P BP206		20P BP231		20P BP243	4P BP257		
6			20P BP244		20P BP232		20P BP214		20P BP215		20P BP233		20P BP245		
7				20P BP224		20P BP216		16P BP202		20P BP217		20P BP225			
8			20P BP211		20P BP207		16P BP203		16P BP204		20P BP208		20P BP212		
9	SS3			20P BP226		20P BP218		16P BP205		20P BP219		20P BP227			SS5
10			20P BP246		20P BP234		20P BP220		20P BP221		20P BP235		20P BP247		
11			4P BP260	20P BP248		20P BP236		20P BP209		20P BP237		20P BP249	4P BP258		
12					20P BP250		20P BP228		20P BP229		20P BP251				
13					4P BP261	20P BP252		20P BP213		20P BP253	4P BP259				
14															
15															

4P - 4 BURNABLE POISON ROD CLUSTER
16P - 16 BURNABLE POISON ROD CLUSTER
20P - 20 BURNABLE POISON ROD CLUSTER
SSx - SECONDARY SOURCE

xxP or SSx	- ± OF BP RODS or SECONDARY SOURCE ID
BP±±±	- BP ASSEMBLY ID

Figure 1.3
SURRY UNIT 2 - CYCLE 12
MOVABLE DETECTOR LOCATIONS

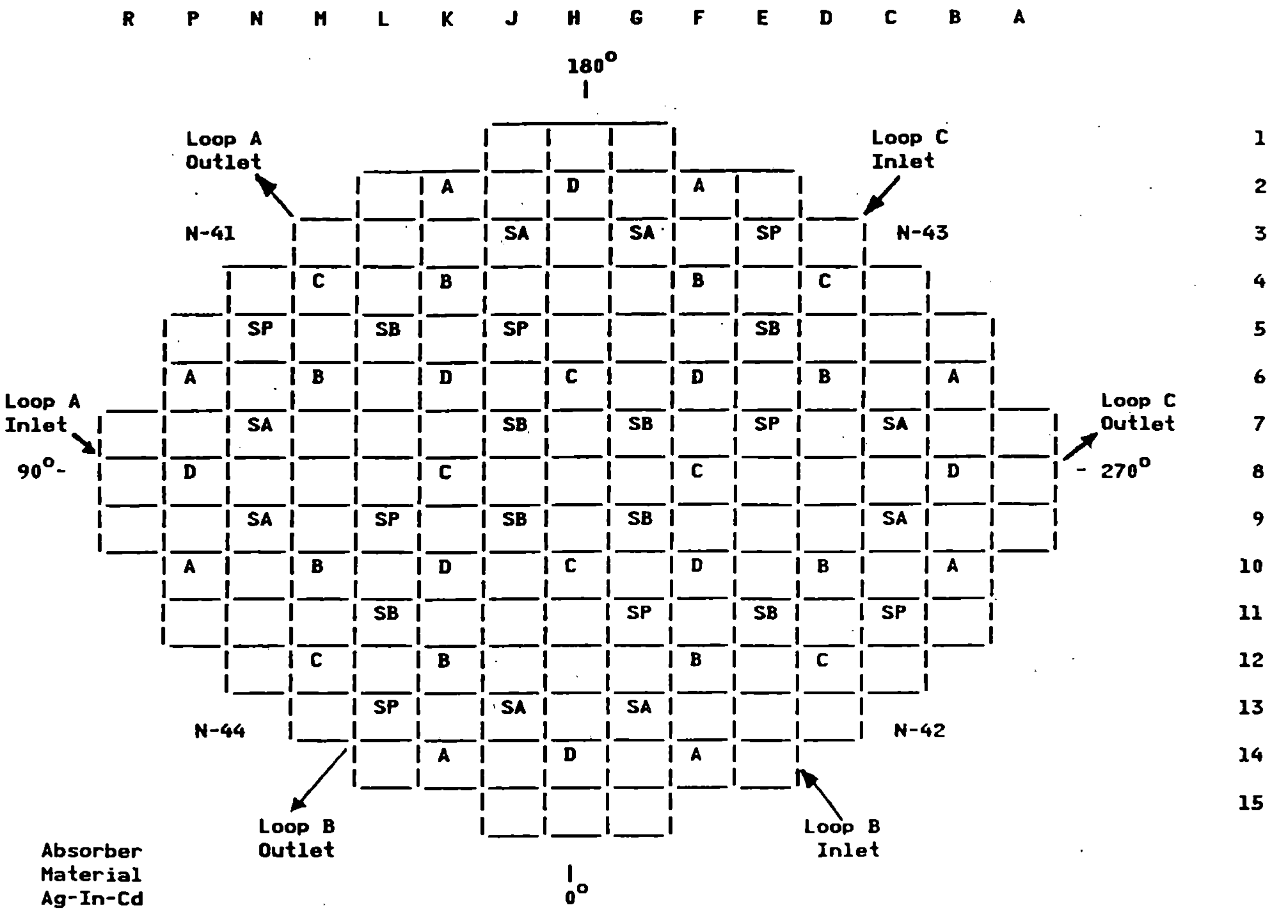


R	P	N	M	L	K	J	H	G	F	E	D	C	B	A	
							MD								1
									MD						2
			MD			MD*	MD				MD				3
				MD			MD		MD						4
		MD*		MD		MD				MD	MD		MD		5
				MD			MD		MD						6
		MD				MD		MD			MD		MD		7
MD		MD		MD					MD			MD	MD		8
				MD				MD	MD					MD	9
		MD				MD					MD		MD		10
				MD			MD		MD	MD				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

MD - Movable Detector

* - Unavailable Location

Figure 1.4
SURRY UNIT 2 - CYCLE 12
CONTROL ROD LOCATIONS



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

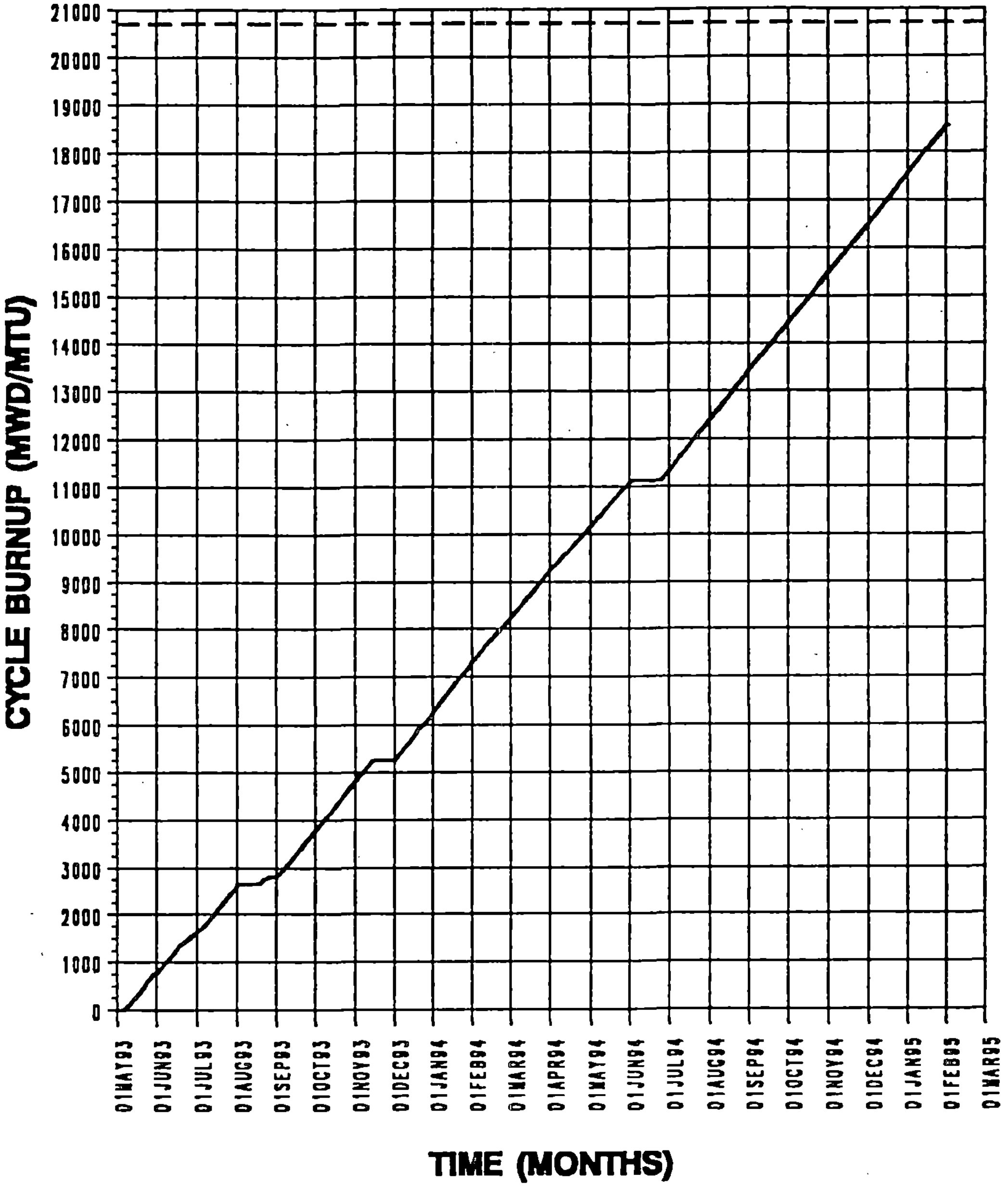
BURNUP

The Surry Unit 2 Cycle 12 burnup history is graphically depicted in Figure 2.1. Surry 2 Cycle 12 achieved a cycle burnup of 18,551 MWD/MTU. As shown in Figure 2.2, the average load factor for Cycle 12 was 86.0% when referenced to rated thermal power (2441 MW(t)). Unit 2 performed a power coastdown starting on January 11, 1995 until shutdown for refueling on February 3, 1995.

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 TOTE[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 12 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 12 operation is given. As can be seen from this figure, the accumulated assembly burnups were generally within ±4.24% of the predicted values. In addition, deviation from quadrant symmetry in the core throughout the cycle was no greater than ±0.30%.

The burnup sharing on a batch basis is monitored to verify that the core is operating as designed and to enable accurate end-of-cycle batch burnup predictions to be made for use in reload fuel design studies. Batch definitions are given in Figure 1.1. As seen in Figures 2.5A, 2.5B, and 2.5C, the batch burnup sharing for Surry 2 Cycle 12 followed design predictions closely. Batch S1/8B had a batch burnup that deviated from predicted by as much as ±2.53%. S1/8B is a single assembly batch located in the center of the core. The batch burnup sharing deviations in conjunction with reasonable agreement between actual and predicted assemblywise burnups, and symmetric core burnups indicate that the Cycle 12 core did deplete as designed.

Figure 2.1
SURRY UNIT 2 - CYCLE 12
CYCLE BURNUP HISTORY



----- MAXIMUM DESIGN BURNUP - 20700 MWD/MTU

Figure 2.2
SURRY UNIT 2 - CYCLE 12
MONTHLY AVERAGE LOAD FACTORS

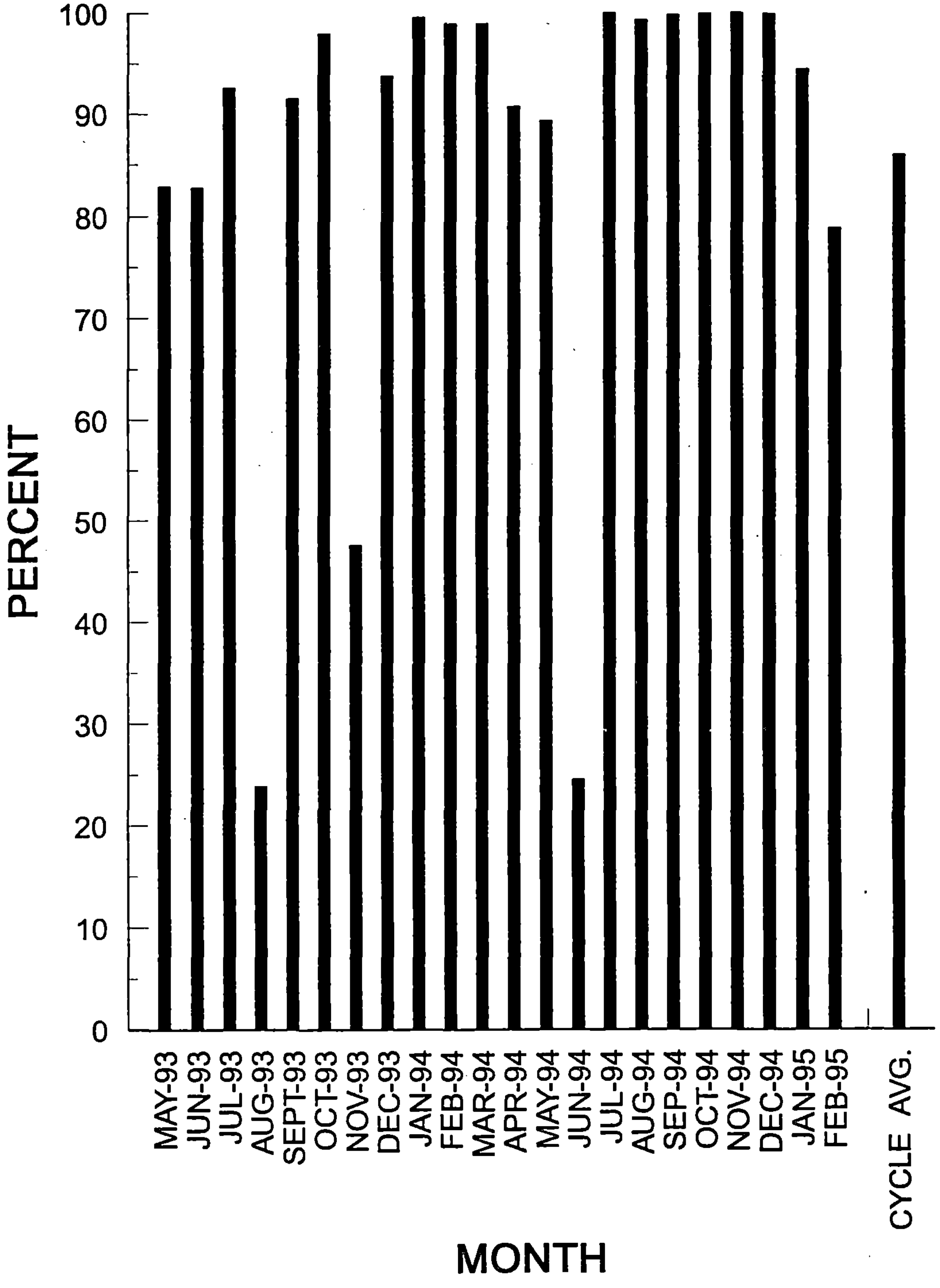


Figure 2.3
SURRY UNIT 2 - CYCLE 12
ASSEMBLYWISE ACCUMULATED BURNUP
MEASURED AND PREDICTED
(GWD/MTU)

MEASURED
PREDICTED

	R	P	N	M	L	K	J	H	G	F	E	D	C	B	A	
1							38.45 38.30	31.70 32.09	38.46 38.30							1
2					47.75 48.09	35.61 36.02	18.04 18.44	39.64 39.80	18.18 18.44	36.36 36.02	47.61 48.09					2
3				45.85 45.56	19.14 19.20	21.75 22.45	40.24 40.23	22.82 23.50	39.68 40.23	22.48 22.45	19.88 19.20	45.33 45.56				3
4			45.35 45.57	37.54 38.17	22.76 23.61	41.54 42.46	24.77 24.96	44.43 45.14	24.89 24.96	42.53 42.46	23.74 23.61	38.23 38.17	44.57 45.57			4
5		48.00 48.10	19.14 19.22	23.18 23.62	44.77 44.85	24.70 24.96	45.46 46.10	24.53 24.36	45.92 46.10	25.12 24.96	43.96 44.85	22.98 23.62	19.08 19.22	47.41 48.10		5
6		35.67 36.02	22.37 22.45	41.92 42.39	24.45 24.93	45.31 45.88	24.56 23.99	45.52 45.80	24.43 23.99	45.70 45.88	24.87 24.93	41.56 42.39	22.08 22.45	35.86 36.02		6
7	39.46 38.89	18.31 18.38	39.68 40.21	24.72 24.96	45.26 46.07	24.15 23.99	46.04 45.69	25.00 24.47	46.16 45.69	24.48 23.99	45.16 46.07	24.29 24.96	39.80 40.21	17.97 18.38	38.54 38.89	7
8	31.98 31.98	39.69 39.74	23.29 23.47	44.26 45.13	23.70 24.36	45.20 45.81	24.95 24.47	34.95 34.30	24.90 24.47	46.15 45.81	24.40 24.36	43.74 45.13	23.03 23.47	40.08 39.74	31.41 31.98	8
9	38.64 38.89	17.97 18.38	39.30 40.21	24.58 24.96	45.57 46.07	23.85 23.99	45.03 45.69	24.57 24.47	45.65 45.69	23.72 23.99	45.94 46.07	24.40 24.96	39.69 40.21	18.53 18.38	39.02 38.89	9
10		35.80 36.02	21.49 22.45	41.84 42.39	24.84 24.93	45.14 45.88	23.61 23.99	45.99 45.80	23.87 23.99	45.09 45.88	24.80 24.93	42.60 42.39	22.55 22.45	36.10 36.02		10
11		47.51 48.10	18.83 19.22	23.34 23.62	44.22 44.85	24.68 24.96	45.29 46.10	24.08 24.36	45.30 46.10	24.32 24.96	44.96 44.85	23.88 23.62	19.61 19.22	47.48 48.10		11
12			45.35 45.57	38.00 38.17	23.47 23.61	42.56 42.46	24.33 24.96	44.09 45.14	24.41 24.96	41.75 42.46	23.42 23.61	37.95 38.17	45.56 45.57			12
13				44.81 45.56	19.64 19.20	22.43 22.45	39.47 40.23	22.91 23.50	39.19 40.23	21.67 22.45	18.88 19.20	45.06 45.56				13
14					48.10 48.09	35.96 36.02	18.59 18.44	39.36 39.80	17.92 18.44	35.15 36.02	47.13 48.09					14
15							38.99 38.30	32.14 32.09	38.16 38.30							15
	R	P	N	M	L	K	J	H	G	F	E	D	C	B	A	

Figure 2.4
SURRY UNIT 2 - CYCLE 12
ASSEMBLYWISE ACCUMULATED BURNUP
COMPARISON OF MEASURED AND PREDICTED
(GWD/MTU)

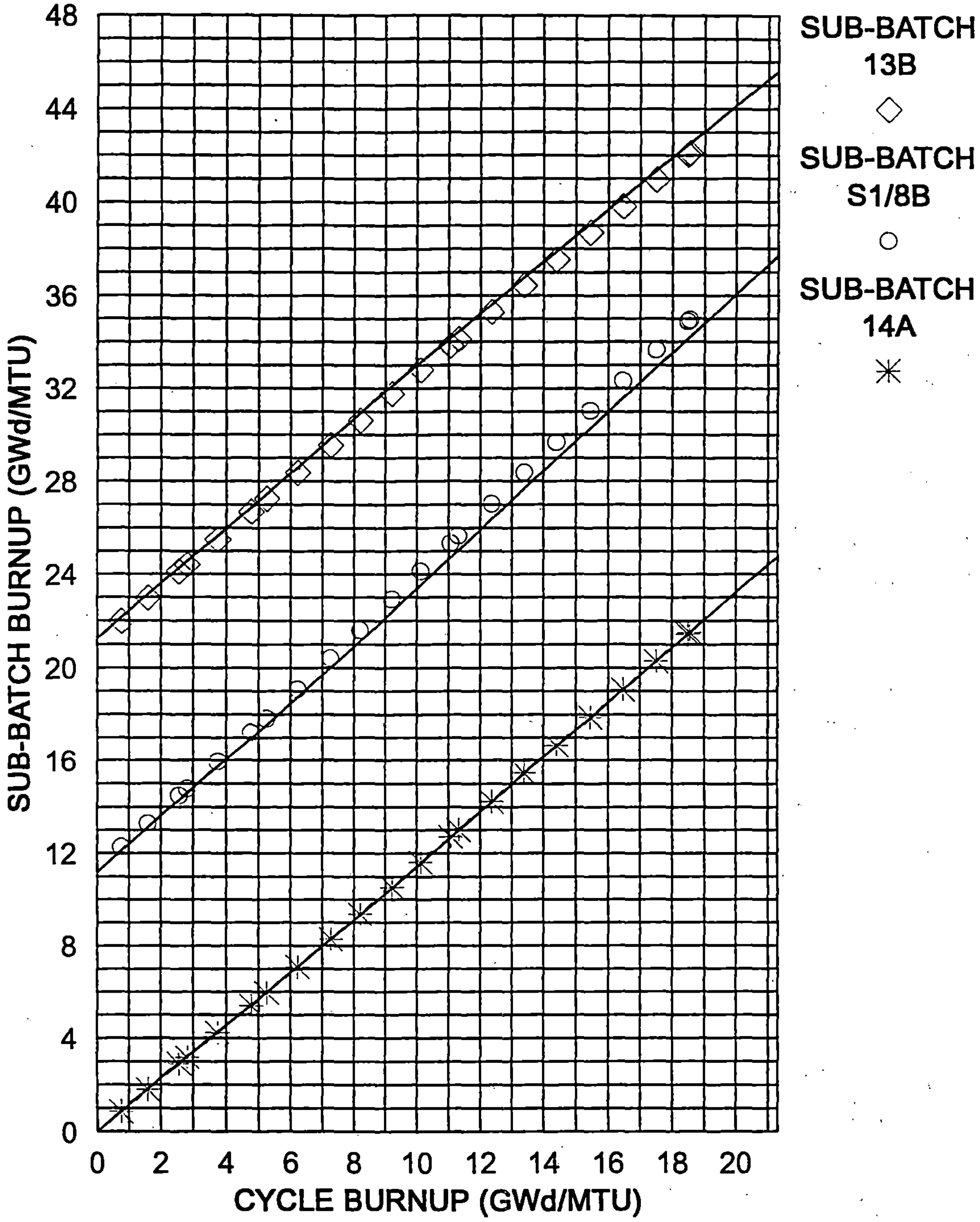
```
         R      P      N      M      L      K      J      H      G      F      E      D      C      B      A

                                                ----------------------                           --------------
  1                                             | 38.45| 31.70| 38.46|                           | MEASURED   |        1
                                                |  0.40| -1.20|  0.43|                           | M/P % DIFF |
                                  --------------------------------------------------             --------------
  2                               | 47.75| 35.61| 18.04| 39.64| 18.18| 36.36| 47.61|                                  2
                                  | -0.70| -1.15| -2.18| -0.41| -1.39|  0.93| -0.99|
                           ----------------------------------------------------------------
  3                        | 45.85| 19.14| 21.75| 40.24| 22.82| 39.68| 22.48| 19.88| 45.33|                           3
                           |  0.64| -0.32| -3.09|  0.02| -2.89| -1.38|  0.16|  3.52| -0.50|
                    ------------------------------------------------------------------------------
  4                 | 45.35| 37.54| 22.76| 41.54| 24.77| 44.43| 24.89| 42.53| 23.74| 38.23| 44.57|                    4
                    | -0.49| -1.65| -3.61| -2.17| -0.79| -1.55| -0.30|  0.16|  0.54|  0.17| -2.21|
             --------------------------------------------------------------------------------------------
  5          | 48.00| 19.14| 23.18| 44.77| 24.70| 45.46| 24.53| 45.92| 25.12| 43.96| 22.98| 19.08| 47.41|             5
             | -0.21| -0.42| -1.84| -0.20| -1.05| -1.40|  0.72| -0.39|  0.62| -2.00| -2.69| -0.73| -1.43|
             --------------------------------------------------------------------------------------------
  6          | 35.67| 22.37| 41.92| 24.45| 45.31| 24.56| 45.52| 24.43| 45.70| 24.87| 41.56| 22.08| 35.86|             6
             | -0.97| -0.35| -1.11| -1.93| -1.23|  2.35| -0.60|  1.81| -0.37| -0.21| -1.94| -1.65| -0.46|
      ----------------------------------------------------------------------------------------------------------
  7   | 39.46| 18.31| 39.68| 24.72| 45.26| 24.15| 46.04| 25.00| 46.16| 24.48| 45.16| 24.29| 39.80| 17.97| 38.54|      7
      |  1.48| -0.37| -1.31| -0.95| -1.76|  0.65|  0.77|  2.19|  1.02|  2.01| -1.97| -2.70| -1.02| -2.23| -0.89|
      ----------------------------------------------------------------------------------------------------------
  8   | 31.98| 39.69| 23.29| 44.26| 23.70| 45.20| 24.95| 34.95| 24.90| 46.15| 24.40| 43.74| 23.03| 40.08| 31.41|      8
      |  0.02| -0.12| -0.77| -1.92| -2.68| -1.34|  1.97|  1.90|  1.74|  0.72|  0.20| -3.07| -1.87|  0.86| -1.78|
      ----------------------------------------------------------------------------------------------------------
  9   | 38.64| 17.97| 39.30| 24.58| 45.57| 23.85| 45.03| 24.57| 45.65| 23.72| 45.94| 24.40| 39.69| 18.53| 39.02|      9
      | -0.64| -2.24| -2.26| -1.53| -1.09| -0.59| -1.44|  0.43| -0.09| -1.16| -0.29| -2.24| -1.29|  0.84|  0.35|
      ----------------------------------------------------------------------------------------------------------
 10          | 35.80| 21.49| 41.84| 24.84| 45.14| 23.61| 45.99| 23.87| 45.09| 24.80| 42.60| 22.55| 36.10|            10
             | -0.62| -4.24| -1.29| -0.36| -1.61| -1.61|  0.44| -0.50| -1.71| -0.53|  0.50|  0.47|  0.21|
             --------------------------------------------------------------------------------------------
 11          | 47.51| 18.83| 23.34| 44.22| 24.68| 45.29| 24.08| 45.30| 24.32| 44.96| 23.88| 19.61| 47.48|            11
             | -1.24| -2.00| -1.17| -1.40| -1.10| -1.76| -1.14| -1.74| -2.56|  0.24|  1.14|  2.03| -1.28|
             --------------------------------------------------------------------------------------------
 12                 | 45.35| 38.00| 23.47| 42.56| 24.33| 44.09| 24.41| 41.75| 23.42| 37.95| 45.56|                   12
                    | -0.48| -0.45| -0.58|  0.23| -2.54| -2.33| -2.23| -1.67| -0.78| -0.57| -0.04|
                    ------------------------------------------------------------------------------
 13                        | 44.81| 19.64| 22.43| 39.47| 22.91| 39.19| 21.67| 18.88| 45.06|      ------------------   13
                           | -1.65|  2.26| -0.09| -1.90| -2.52| -2.58| -3.47| -1.69| -1.11|      | ARITHMETIC AVG |
                           ----------------------------------------------------------------      |PCT DIFF = -0.75|
 14                               | 48.10| 35.96| 18.59| 39.36| 17.92| 35.15| 47.13|             ------------------   14
                                  |  0.02| -0.17|  0.82| -1.11| -2.82| -2.41| -1.99|
      ----------------                --------------------------------------------------             ---------------
 15   | STANDARD DEV |                          | 38.99| 32.14| 38.16|                           | AVG ABS PCT |      15
      |    = 0.88    |                          |  1.82|  0.17| -0.35|                           | DIFF = 1.26 |
      ----------------                          ----------------------                           ---------------

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

SUB-BATCH SHARING
(MWD/MTU)

SUB BATCH	NO. OF ASSEMBLIES	BOC BATCH BURNUP	EOC BATCH BURNUP	CYCLE BURNUP
S1/8B	1	11,348	34,955	23,607
12A	7	32,950	38,609	5,659
12B	16	39,661	46,429	6,768
12C	1	33,819	39,463	5,644
13A	32	24,142	40,501	16,359
13B	32	21,067	42,090	21,023
14A	32	0	21,515	21,515
14B	36	0	23,606	23,606
CYCLE AVERAGE ACCUMULATED BURNUP = 33,562				

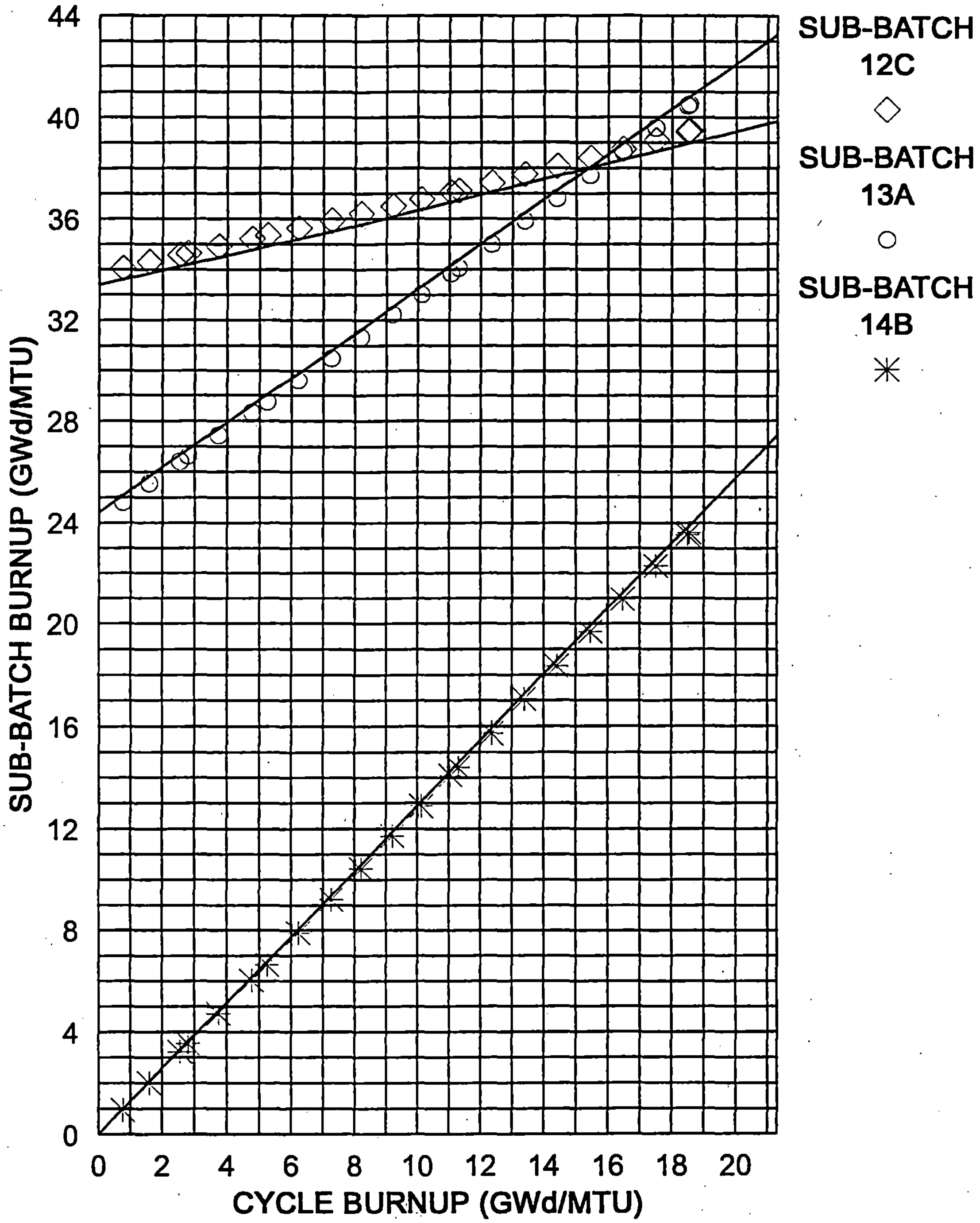
```
      BURNUP TILT

NW =  0.06 | NE =  0.19
 ----------|------------
SW = -0.16 | SE = -0.10
```

Figure 2.5A
SURRY UNIT 2 - CYCLE 12
SUB-BATCH BURNUP SHARING



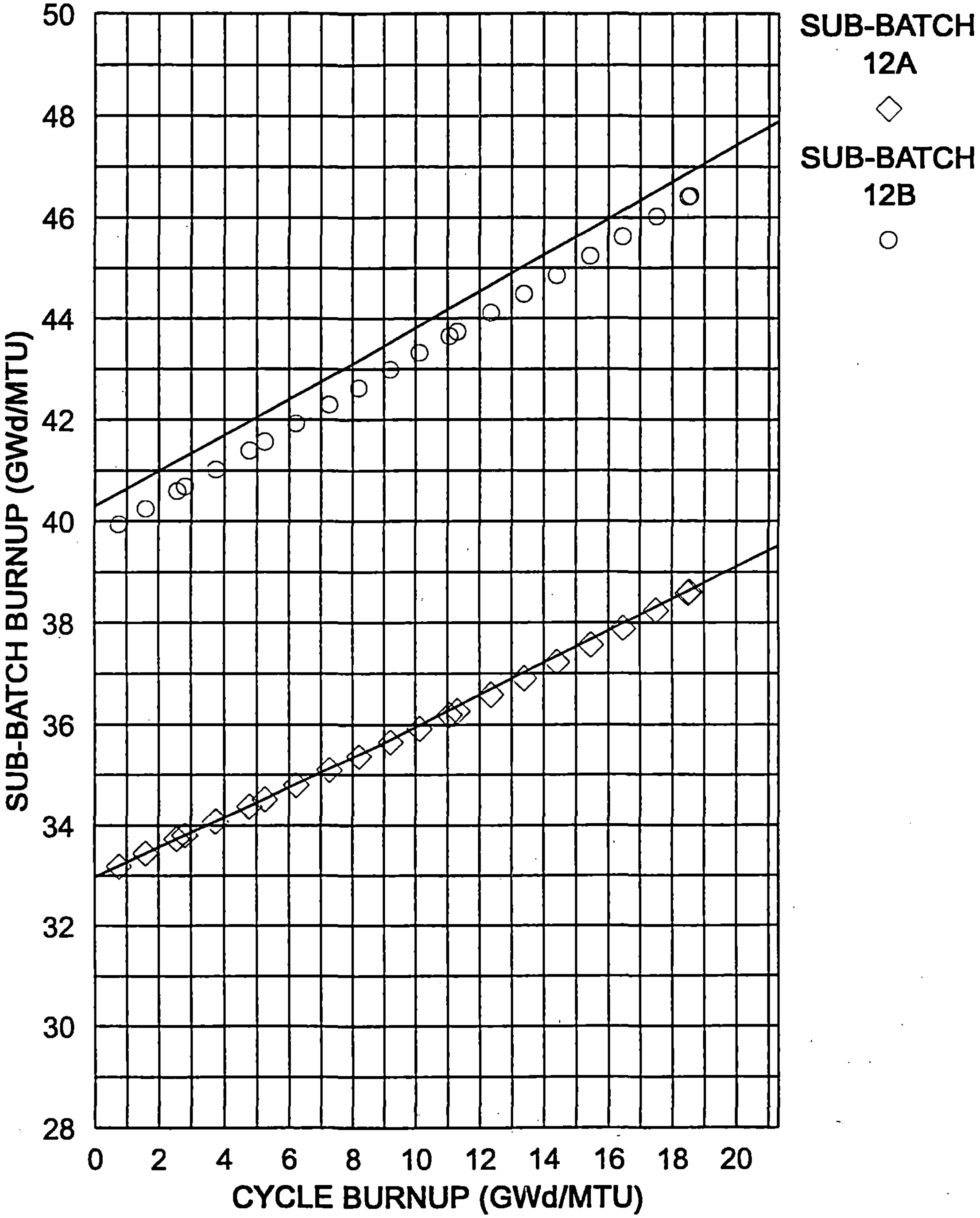
LINES ARE PREDICTED VALUES, SYMBOLS ARE MEASURED VALUES.

Figure 2.5B
SURRY UNIT 2 - CYCLE 12
SUB-BATCH BURNUP SHARING



LINES ARE PREDICTED VALUES, SYMBOLS ARE MEASURED VALUES.

Figure 2.5C
SURRY UNIT 2 - CYCLE 12
SUB-BATCH BURNUP SHARING



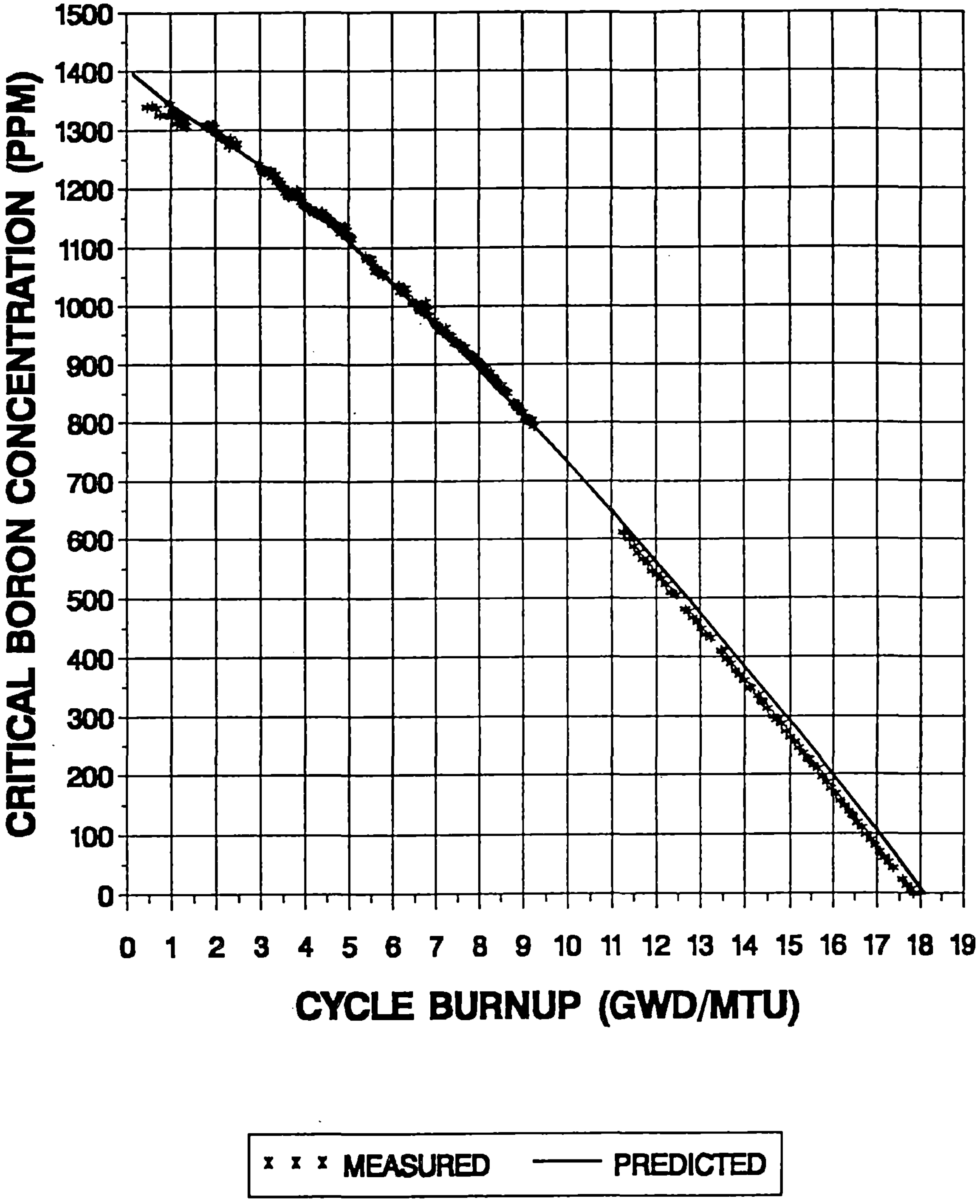
LINES ARE PREDICTED VALUES, SYMBOLS ARE MEASURED VALUES.

Section 3

REACTIVITY DEPLETION

The primary coolant critical boron concentration is monitored for the purposes of following core reactivity and to identify any anomalous reactivity behavior. The FOLLOW[4] computer code was used to normalize "actual" critical boron concentration measurements to design conditions taking into consideration control rod position, xenon concentration, moderator temperature, and power level. The normalized critical boron concentration versus burnup curve for the Surry 2 Cycle 12 core is shown in Figure 3.1. It can be seen that the measured data typically compared to within 36 ppm of the design prediction. The largest reactivity anomaly was ±0.26% ΔK/K which is within the ±1% ΔK/K criterion for reactivity anomalies set forth in Section 4.10 of the Technical Specifications. In conclusion, the trend indicated by the critical boron concentration verifies that the Cycle 12 core depleted as expected without any reactivity abnormalities.

Figure 3.1
SURRY UNIT 2 - CYCLE 12
CRITICAL BORON CONCENTRATION vs. BURNUP
(HFP,ARO)



Section 4

POWER DISTRIBUTION

Analysis of core power distribution data on a routine basis is necessary to verify that the hot channel factors are within the Technical Specification 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 both the INCORE[5] and CECOR[6] computer programs. The INCORE program was used from the beginning of the cycle through flux map 18. The CECOR program was used from flux map 19 to the end of the cycle. A summary of all full core flux maps taken for Surry 2 Cycle 12 is provided in Table 4.1, excluding the initial power ascension flux maps which were included in the S2C13 Startup Physics Tests Report. 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, 4.2, and 4.3. Figure 4.1 shows a power distribution map that was taken early in cycle life. Figure 4.2 shows a power distribution map that was taken near the mid-cycle burnup. Figure 4.3 shows a map that was taken near the end of Cycle 12. The maximum relative assembly power difference between measured and predicted was 10.6% and the maximum average percent difference was equal to 1.9%. In addition, as indicated by the INCORE tilt factors, the power distributions were essentially symmetric for each case.

An important aspect of core power distribution follow is the monitoring of nuclear hot channel factors. Verification that these factors are within Technical Specification limits ensures that linear power density and critical heat flux limits will not be violated, thereby providing adequate thermal margin and maintaining fuel cladding integrity. Surry Technical Specification 3.12 limited the axially dependent heat flux hot channel factor, $F_Q(Z)$, to 2.32 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 2.32 $F_Q(Z)$ limit.

The axially dependent heat flux hot channel factors, $F_Q(Z)$, for a representative set of flux maps are given in Figures 4.5, 4.6, and 4.7. Throughout Cycle 12, the measured values of $F_Q(Z)$ were within the Technical Specification limit. A summary of the maximum values of axially-dependent heat flux hot channel factors measured during Cycle 12 is given in Figure 4.8. The minimum margin to the $F_Q(Z)$ limit was 17.89%. Figure 4.9 shows the maximum values for the heat flux hot channel factor measured during Cycle 12.

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 Specification limit for this parameter is set such that the departure from nucleate boiling ratio (DNBR) limit will not be violated. Additionally, the F-delta-H limit ensures that the value of this parameter used in the LOCA-ECCS analysis is not exceeded during normal operation. Surry Technical Specification 3.12 limited the enthalpy rise hot channel factor to 1.56(1+0.3(1-P)) for Cycle 12, where 1.56 is the F-delta-H at rated thermal power and 0.3 is the power factor multiplier, both as specified in the COLR. A summary of the maximum values for the enthalpy rise hot channel factor measured during Cycle 12 is given in Figure 4.10. As can be seen from this figure, the minimum margin to the limit was 5.77% for Cycle 12.

The target delta flux* is the delta flux which would occur at conditions of full power, all rods out, and equilibrium xenon. The delta flux is measured with the core at or near these conditions and the target delta flux is established at this measured point. Since the target delta flux varies as a function of burnup, the target value is updated monthly. By maintaining the value of delta flux relatively constant, adverse axial power shapes due to xenon redistribution are avoided. This target delta-flux was also used to establish the operational axial flux difference bands while under CAOC.

The plot of the target delta flux versus burnup, given in Figure 4.11, shows the value of this parameter to have been approximately 2.5% at the beginning of Cycle 12 and decreasing to -1.5% where it leveled off until the middle of the cycle. After an outage near the middle of Cycle 12, the delta flux was approximately -4.5 where it increased until the end of the cycle. This axial power shift can also be observed in the corresponding core average axial power distribution for a representative series of maps given in Figures 4.12 through 4.14. In Map S2-12-04

---

* 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))

(Figure 4.12), taken at 646 MWD/MTU, the axial power distribution had a shape peaked towards core midplane with an axial peaking factor (F-Z) of 1.228. In Map S2-12-16 (Figure 4.13), taken at approximately 9,368 MWD/MTU, the axial power distribution peaked toward the bottom of the core with an axial peaking factor of 1.143. Finally, in Map S2-12-28 (Figure 4.14), taken at 17,575 MWD/MTU, the axial peaking factor was 1.144, with an axial power distribution similar to Map S2-12-16. The history of F-Z during the cycle can be seen more clearly in a plot of F-Z versus burnup given in Figure 4.15.

In conclusion, the Surry 2 Cycle 12 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
SURRY UNIT 2 - CYCLE 12
SUMMARY OF FLUX MAPS FOR ROUTINE OPERATION

MAP NO.	DATE	BURN UP MWD/ MTU	PWR (%)	BANK D STEPS	1 F-Q(Z) HOT CHANNEL FACTOR				2 F-DH(N) HOT CHNL. FACTOR			CORE F(Z) MAX		3 CORE TILT		AXIAL OFF SET (%)	NO. OF THIMBLES
					ASSY	PIN	AXIAL POINT	F-Q(Z)	ASSY	PIN	F-DH(N)	AXIAL POINT	F(Z)	MAX	LOC		
4	5-29-93	646	99.9	224	D11	HI	32	1.890	F04	OO	1.424	31	1.228	1.007	NE	0.271	46
5	6-25-93	1464	66.2	186	D11	HI	30	2.005	E04	GH	1.457	30	1.285	1.009	NE	-0.057	43
6	7-26-93	2368	98.2	223	D11	HI	30	1.901	D11	HI	1.443	30	1.209	1.012	NE	0.335	43
7	9-14-93	3169	99.8	224	D11	HI	31	1.879	D11	HI	1.445	35	1.196	1.012	NE	-1.236	43
8	10-15-93	4238	98.0	224	D11	HI	32	1.834	D11	HI	1.436	36	1.178	1.011	NE	-1.329	43
9	11-15-93	5221	95.1	217	D11	GL	31	1.800	D11	GL	1.430	36	1.164	1.010	NE	-1.454	42
10	12-16-93	5727	100.1	219	F05	HI	41	1.797	D11	GL	1.428	41	1.166	1.009	NE	-2.609	43
11	12-22-93	5895	60.7	178	L10	GH	32	1.914	D11	FL	1.438	31	1.240	1.008	NW	-4.503	41
12	1-20-94	6863	100.0	223	F05	HI	43	1.784	F05	HI	1.425	44	1.156	1.007	NE	-2.568	43
13	2-17-94	7805	98.0	222	J08	NM	42	1.791	J08	NM	1.432	45	1.148	1.005	NE	-2.317	43
14	3-14-94	8629	96.7	222	J08	NM	42	1.792	J08	NM	1.445	47	1.139	1.004	NE	-1.956	43
15	4-03-94	9276	65.8	187	J08	NM	30	1.861	J08	NM	1.454	30	1.175	1.007	SW	-2.818	43
16	4-06-94	9368	94.0	217	H07	MB	46	1.806	J08	NM	1.454	47	1.143	1.002	NE/SW	-2.232	42
17	4-12-94	9548	60.6	181	J08	NM	42	1.878	J08	NM	1.461	42	1.170	1.007	SW	-5.315	43
18	4-18-94	9722	94.0	218	H07	MB	46	1.808	J08	NM	1.460	47	1.138	1.002	NE	-2.002	41
19	5-09-94	10375	90.0	222	H07	--	47	1.791	J08	--	1.460	48	1.129	1.003	NW	-1.944	43
20	6-26-94	11164	67.8	184	H07	--	20	1.781	H07	--	1.461	20	1.125	1.006	SW	-2.376	46
21	6-30-94	11291	100.1	223	G08	--	48	1.856	G08	--	1.466	48	1.161	1.003	NE	-4.555	46
22	7-26-94	12134	100.0	223	G08	--	48	1.841	H07	--	1.465	52	1.152	1.002	NE	-3.788	46
23	8-15-94	12828	99.9	222	G08	--	48	1.841	H07	--	1.465	52	1.153	1.002	NW	-3.560	43
24	9-13-94	13800	99.9	224	G08	--	52	1.844	H07	--	1.469	52	1.153	1.004	NE	-3.618	44
25	10-13-94	14809	100.0	223	G08	--	53	1.850	H07	--	1.470	52	1.153	1.004	NE	-3.593	44
26	10-31-94	15416	100.0	223	G08	--	52	1.841	G08	--	1.464	52	1.149	1.007	NE	-3.075	41
27	11-28-94	16362	100.0	224	G08	--	52	1.827	H07	--	1.455	52	1.151	1.008	NE	-2.886	43
28	1-03-95	17575	100.0	224	G08	--	52	1.805	G08	--	1.443	52	1.144	1.003	NE	-2.509	43
29	1-24-95	18259	89.3	216	H07	--	11	1.759	H07	--	1.452	11	1.114	1.004	SW	0.150	44

NOTES: HOT SPOT LOCATIONS ARE SPECIFIED BY GIVING ASSEMBLY LOCATIONS (E.G. H08 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). AFTER IMPLEMENTATION OF THE CECOR CODE, PIN LOCATIONS WERE NO LONGER AVAILABLE AND ARE NOT INDICATED.
IN THE "Z" DIRECTION THE CORE IS DIVIDED INTO 61 AXIAL POINTS STARTING FROM THE TOP OF THE CORE.

1. F-Q(Z) INCLUDES A TOTAL UNCERTAINTY OF 1.08.

2. F-DH(N) INCLUDES NO UNCERTAINTY.

3. CORE TILT - QUADRANT POWER TILT AS DEFINED BY THE INCORE/CECOR CODE.

4. FLUX MAPS 4 THROUGH 18 WERE ANALYZED USING THE INCORE CODE, WHILE FLUX MAPS 19 THROUGH 29 WERE ANALYZED USING THE CECOR CODE.

Figure 4.1
SURRY UNIT 2 - CYCLE 12
ASSEMBLYWISE POWER DISTRIBUTION S2-12-04

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

       ................                   ......................                ................
       .  PREDICTED   .                   . 0.32 . 0.40 . 0.32 .                .  PREDICTED   .
       .  MEASURED    .                   . 0.31 . 0.40 . 0.32 .                .  MEASURED    .                  1
       .PCT DIFFERENCE.                   . -1.2 . -1.2 .  0.4 .                .PCT DIFFERENCE.
       ................     ..................................................  ................
                            . 0.32 . 0.65 . 1.11 . 0.92 . 1.11 . 0.65 . 0.32 .
                            . 0.34 . 0.64 . 1.09 . 0.90 . 1.11 . 0.67 . 0.34 .                                    2
                            .  6.6 . -1.5 . -1.4 . -1.4 .  0.4 .  2.7 .  5.5 .
                     ................................................................
                     . 0.38 . 1.09 . 1.24 . 1.25 . 1.28 . 1.25 . 1.23 . 1.09 . 0.38 .
                     . 0.40 . 1.12 . 1.21 . 1.25 . 1.26 . 1.26 . 1.26 . 1.15 . 0.42 .                             3
                     .  5.7 .  2.2 . -2.1 . -0.4 . -1.1 .  0.6 .  1.9 .  5.4 .  9.9 .
              ..............................................................................
              . 0.38 . 0.86 . 1.28 . 1.31 . 1.28 . 1.20 . 1.28 . 1.31 . 1.28 . 0.86 . 0.38 .
              . 0.41 . 0.87 . 1.26 . 1.30 . 1.29 . 1.21 . 1.28 . 1.32 . 1.31 . 0.89 . 0.40 .                      4
              .  6.6 .  1.7 . -1.1 . -0.5 .  0.8 .  1.0 .  0.5 .  1.0 .  2.4 .  3.7 .  4.0 .
       ............................................................................................
       . 0.32 . 1.09 . 1.28 . 1.23 . 1.24 . 1.18 . 1.17 . 1.18 . 1.24 . 1.23 . 1.28 . 1.09 . 0.32 .
       . 0.32 . 1.09 . 1.26 . 1.23 . 1.23 . 1.20 . 1.18 . 1.20 . 1.25 . 1.25 . 1.27 . 1.10 . 0.33 .               5
       . -2.2 . -0.1 . -1.0 . -0.5 . -0.2 .  1.6 .  1.4 .  1.4 .  1.4 .  1.0 . -0.6 .  1.0 .  2.9 .
       ............................................................................................
       . 0.65 . 1.24 . 1.31 . 1.23 . 1.11 . 1.11 . 1.09 . 1.11 . 1.11 . 1.23 . 1.31 . 1.23 . 0.65 .
       . 0.63 . 1.21 . 1.29 . 1.22 . 1.12 . 1.14 . 1.11 . 1.13 . 1.13 . 1.24 . 1.30 . 1.22 . 0.64 .               6
       . -2.2 . -2.2 . -1.3 . -1.3 .  0.7 .  2.2 .  1.3 .  1.5 .  1.9 .  0.4 . -0.9 . -1.1 . -0.6 .
..........................................................................................................
. 0.31 . 1.10 . 1.25 . 1.28 . 1.18 . 1.11 . 1.07 . 1.15 . 1.08 . 1.12 . 1.18 . 1.28 . 1.25 . 1.10 . 0.31 .
. 0.30 . 1.08 . 1.23 . 1.25 . 1.16 . 1.12 . 1.11 . 1.18 . 1.09 . 1.13 . 1.18 . 1.24 . 1.21 . 1.06 . 0.30 .        7
. -2.5 . -2.3 . -2.2 . -1.8 . -1.5 .  0.8 .  3.5 .  2.1 .  1.4 .  1.3 . -0.3 . -2.5 . -3.0 . -3.7 . -2.8 .
..........................................................................................................
. 0.40 . 0.91 . 1.27 . 1.20 . 1.16 . 1.09 . 1.14 . 1.19 . 1.17 . 1.09 . 1.17 . 1.20 . 1.27 . 0.91 . 0.40 .
. 0.39 . 0.89 . 1.24 . 1.18 . 1.15 . 1.09 . 1.19 . 1.21 . 1.17 . 1.10 . 1.16 . 1.16 . 1.23 . 0.90 . 0.39 .        8
. -2.5 . -2.4 . -2.2 . -1.2 . -1.3 .  0.4 .  3.7 .  2.1 .  0.6 .  0.3 . -0.9 . -3.2 . -3.4 . -1.6 . -1.6 .
..........................................................................................................
. 0.30 . 1.10 . 1.25 . 1.27 . 1.18 . 1.11 . 1.07 . 1.15 . 1.08 . 1.12 . 1.18 . 1.28 . 1.26 . 1.10 . 0.31 .
. 0.30 . 1.06 . 1.19 . 1.25 . 1.18 . 1.10 . 1.07 . 1.16 . 1.09 . 1.11 . 1.18 . 1.26 . 1.24 . 1.09 . 0.31 .        9
. -2.5 . -3.5 . -4.5 . -1.6 . -0.1 . -0.3 .  0.1 .  0.7 .  0.7 . -0.8 . -0.4 . -1.3 . -1.4 . -1.2 . -0.8 .
..........................................................................................................
       . 0.64 . 1.23 . 1.30 . 1.23 . 1.11 . 1.11 . 1.09 . 1.11 . 1.11 . 1.23 . 1.31 . 1.24 . 0.65 .
       . 0.61 . 1.18 . 1.28 . 1.23 . 1.11 . 1.11 . 1.10 . 1.12 . 1.11 . 1.24 . 1.32 . 1.24 . 0.65 .               10
       . -4.5 . -4.5 . -1.8 .  0.2 .  0.1 .  0.2 .  0.8 .  0.1 . -0.3 .  0.1 .  0.5 .  0.1 . -0.1 .
       ............................................................................................
       . 0.32 . 1.09 . 1.27 . 1.23 . 1.23 . 1.18 . 1.17 . 1.18 . 1.24 . 1.23 . 1.28 . 1.09 . 0.32 .
       . 0.32 . 1.07 . 1.26 . 1.23 . 1.23 . 1.18 . 1.18 . 1.18 . 1.23 . 1.25 . 1.31 . 1.12 . 0.33 .               11
       . -1.7 . -1.7 . -0.9 .  0.2 . -0.2 .  0.1 .  1.0 .  0.0 . -0.8 .  1.2 .  2.2 .  2.5 .  2.2 .
       ............................................................................................
              . 0.38 . 0.86 . 1.28 . 1.31 . 1.28 . 1.20 . 1.28 . 1.31 . 1.28 . 0.86 . 0.38 .
              . 0.39 . 0.86 . 1.28 . 1.30 . 1.27 . 1.20 . 1.27 . 1.30 . 1.29 . 0.89 . 0.40 .                      12
              .  1.0 .  0.7 .  0.2 . -0.6 . -0.8 .  0.1 . -0.7 . -0.9 .  0.6 .  3.0 .  5.1 .
              ..............................................................................
                     . 0.38 . 1.09 . 1.23 . 1.26 . 1.28 . 1.25 . 1.23 . 1.09 . 0.38 .
                     . 0.39 . 1.14 . 1.26 . 1.24 . 1.25 . 1.22 . 1.21 . 1.09 . 0.40 .                             13
                     .  2.9 .  4.7 .  1.8 . -1.1 . -1.8 . -2.3 . -2.2 . -0.3 .  3.8 .
                     ................................................................
                            . 0.32 . 0.65 . 1.11 . 0.92 . 1.11 . 0.65 . 0.32 .
                            . 0.34 . 0.67 . 1.12 . 0.91 . 1.08 . 0.63 . 0.32 .                                    14
                            .  4.7 .  3.5 .  1.6 . -0.9 . -2.5 . -2.3 . -2.1 .
       ................     ..................................................  ................
       .   STANDARD   .                   . 0.32 . 0.40 . 0.32 .                .    AVERAGE   .
       .  DEVIATION   .                   . 0.32 . 0.40 . 0.31 .                .PCT DIFFERENCE.                  15
       .   =1.529     .                   .  1.6 . -0.0 . -2.5 .                .    =  1.7    .
       ................                   ......................                ................
```

```
                                   SUMMARY

MAP NO: S2-12-04            DATE:  5/29/93          POWER:  99.9%

CONTROL ROD POSITION:       F-Q(Z)  = 1.890         QPTR:

D BANK AT 224 STEPS         F-DH(N) = 1.424         NW 0.9989  |NE 1.0069
                                                    ___________|__________
                            F(Z)    = 1.228         SW 0.9947  |SE 0.9994

                            BURNUP  = 646 MWD/MTU   A.O.  =   0.271%
```

Figure 4.2
SURRY UNIT 2 - CYCLE 12
ASSEMBLYWISE POWER DISTRIBUTION S2-12-16

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

        ................                  ......................                  ................
        .   PREDICTED  .                  . 0.29 . 0.37 . 0.29 .                  .   PREDICTED  .
        .   MEASURED   .                  . 0.29 . 0.37 . 0.29 .                  .   MEASURED   .            1
        .PCT DIFFERENCE.                  . -0.3 . -0.3 . -0.3 .                  .PCT DIFFERENCE.
        ................    ..................................................    ................
                            . 0.31 . 0.59 . 0.94 . 0.79 . 0.94 . 0.59 . 0.31 .
                            . 0.33 . 0.57 . 0.93 . 0.77 . 0.93 . 0.59 . 0.34 .                                2
                            .  5.4 . -3.0 . -1.6 . -1.7 . -1.6 .  0.1 .  7.0 .
                     ................................................................
                     . 0.38 . 1.01 . 1.19 . 1.11 . 1.25 . 1.11 . 1.19 . 1.01 . 0.38 .
                     . 0.39 . 1.02 . 1.15 . 1.09 . 1.22 . 1.10 . 1.19 . 1.05 . 0.40 .                         3
                     .  4.4 .  0.7 . -4.0 . -1.5 . -2.5 . -1.1 .  0.1 .  4.3 .  7.0 .
              ..............................................................................
              . 0.38 . 0.81 . 1.27 . 1.22 . 1.36 . 1.16 . 1.36 . 1.21 . 1.27 . 0.81 . 0.38 .
              . 0.40 . 0.82 . 1.23 . 1.19 . 1.35 . 1.16 . 1.36 . 1.21 . 1.28 . 0.82 . 0.38 .                  4
              .  5.4 .  0.7 . -2.6 . -2.2 . -0.7 .  0.2 . -0.4 .  0.1 .  0.9 .  1.4 .  1.9 .
       ............................................................................................
       . 0.31 . 1.01 . 1.27 . 1.18 . 1.37 . 1.21 . 1.36 . 1.21 . 1.37 . 1.18 . 1.27 . 1.01 . 0.31 .
       . 0.32 . 1.02 . 1.25 . 1.17 . 1.35 . 1.22 . 1.37 . 1.22 . 1.39 . 1.18 . 1.23 . 1.00 . 0.32 .           5
       .  1.8 .  0.7 . -1.4 . -0.2 . -1.3 .  1.0 .  1.0 .  1.2 .  1.1 .  0.3 . -3.1 . -0.6 .  2.6 .
       ............................................................................................
       . 0.59 . 1.20 . 1.22 . 1.37 . 1.16 . 1.34 . 1.18 . 1.34 . 1.16 . 1.37 . 1.21 . 1.19 . 0.59 .
       . 0.60 . 1.22 . 1.21 . 1.35 . 1.17 . 1.37 . 1.20 . 1.37 . 1.19 . 1.36 . 1.18 . 1.17 . 0.59 .           6
       .  1.8 .  1.8 . -0.1 . -1.5 .  0.5 .  2.6 .  1.6 .  2.0 .  2.1 . -0.4 . -2.5 . -1.7 .  0.2 .
..........................................................................................................
. 0.28 . 0.94 . 1.11 . 1.36 . 1.21 . 1.34 . 1.16 . 1.36 . 1.17 . 1.34 . 1.21 . 1.36 . 1.11 . 0.94 . 0.28 .
. 0.29 . 0.96 . 1.13 . 1.36 . 1.18 . 1.34 . 1.21 . 1.39 . 1.20 . 1.37 . 1.21 . 1.32 . 1.09 . 0.92 . 0.28 .    7
.  2.2 .  2.0 .  1.7 . -0.5 . -2.2 .  0.5 .  3.7 .  2.5 .  2.2 .  2.1 . -0.2 . -3.2 . -2.0 . -1.7 . -0.4 .
..........................................................................................................
. 0.37 . 0.78 . 1.25 . 1.16 . 1.36 . 1.17 . 1.35 . 1.26 . 1.36 . 1.18 . 1.36 . 1.16 . 1.25 . 0.78 . 0.37 .
. 0.37 . 0.80 . 1.27 . 1.16 . 1.33 . 1.18 . 1.40 . 1.30 . 1.38 . 1.19 . 1.35 . 1.12 . 1.22 . 0.79 . 0.37 .    8
.  2.2 .  1.9 .  1.7 . -0.2 . -1.9 .  0.4 .  3.9 .  2.7 .  1.3 .  1.3 . -0.7 . -3.4 . -2.6 .  1.0 .  0.9 .
..........................................................................................................
. 0.28 . 0.94 . 1.11 . 1.36 . 1.21 . 1.34 . 1.16 . 1.35 . 1.17 . 1.34 . 1.21 . 1.36 . 1.11 . 0.94 . 0.28 .
. 0.29 . 0.93 . 1.07 . 1.35 . 1.22 . 1.33 . 1.21 . 1.38 . 1.19 . 1.33 . 1.20 . 1.31 . 1.11 . 0.95 . 0.29 .    9
.  2.2 . -0.6 . -3.5 . -1.2 .  0.6 . -0.3 .  3.9 .  1.9 .  1.4 . -0.9 . -0.4 . -3.5 . -0.4 .  0.9 .  1.6 .
..........................................................................................................
       . 0.59 . 1.19 . 1.21 . 1.37 . 1.16 . 1.34 . 1.18 . 1.34 . 1.16 . 1.37 . 1.21 . 1.20 . 0.59 .
       . 0.57 . 1.15 . 1.20 . 1.38 . 1.18 . 1.32 . 1.17 . 1.33 . 1.15 . 1.36 . 1.23 . 1.21 . 0.60 .           10
       . -3.5 . -3.5 . -0.9 .  1.1 .  1.1 . -1.3 . -0.1 . -0.6 . -0.7 . -0.8 .  1.0 .  1.3 .  1.4 .
       ............................................................................................
       . 0.31 . 1.01 . 1.27 . 1.18 . 1.37 . 1.21 . 1.36 . 1.21 . 1.37 . 1.18 . 1.27 . 1.01 . 0.31 .
       . 0.31 . 1.00 . 1.27 . 1.19 . 1.36 . 1.18 . 1.34 . 1.19 . 1.34 . 1.18 . 1.29 . 1.04 . 0.32 .           11
       . -0.5 . -0.5 .  0.1 .  1.0 . -0.4 . -1.9 . -1.4 . -1.9 . -2.0 .  0.5 .  2.0 .  2.8 .  2.7 .
       ............................................................................................
              . 0.38 . 0.81 . 1.27 . 1.21 . 1.36 . 1.16 . 1.36 . 1.21 . 1.27 . 0.81 . 0.38 .
              . 0.39 . 0.83 . 1.28 . 1.20 . 1.33 . 1.14 . 1.33 . 1.19 . 1.26 . 0.83 . 0.39 .                  12
              .  2.4 .  1.8 .  1.0 . -1.1 . -2.3 . -1.9 . -2.5 . -2.0 . -0.5 .  1.7 .  4.3 .
              ..............................................................................
                     . 0.37 . 1.01 . 1.20 . 1.11 . 1.25 . 1.11 . 1.19 . 1.01 . 0.38 .
                     . 0.39 . 1.06 . 1.21 . 1.09 . 1.22 . 1.08 . 1.15 . 0.99 . 0.39 .                         13
                     .  3.8 .  5.3 .  1.4 . -2.5 . -2.3 . -2.8 . -3.4 . -1.7 .  2.7 .
                     ................................................................
                            . 0.31 . 0.59 . 0.94 . 0.79 . 0.94 . 0.59 . 0.31 .
                            . 0.33 . 0.62 . 0.98 . 0.79 . 0.92 . 0.57 . 0.30 .                                14
                            .  5.3 .  4.7 .  3.7 .  0.0 . -2.2 . -2.8 . -3.6 .
        ................    ..................................................    ................
        .   STANDARD   .                  . 0.29 . 0.37 . 0.29 .                  .    AVERAGE   .
        .   DEVIATION  .                  . 0.30 . 0.37 . 0.28 .                  .PCT DIFFERENCE.            15
        .    =1.381    .                  .  3.6 .  1.3 . -2.1 .                  .     = 1.8    .
        ................                  ......................                  ................
```

SUMMARY

MAP NO: S2-12-16   DATE: 4/06/94   POWER: 94.0%

CONTROL ROD POSITION: F-Q(Z) = 1.806   QPTR:

D BANK AT 217 STEPS   F-DH(N) = 1.454   NW 1.0015 | NE 1.0017

F(Z) = 1.143   SW 1.0017 | SE 0.9951

BURNUP = 9368 MWD/MTU   A.O. = -2.232%

Figure 4.3
SURRY UNIT 2 - CYCLE 12
ASSEMBLYWISE POWER DISTRIBUTION S2-12-28

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

        ................                        .........................                 ................
        .  PREDICTED   .                        . 0.341 . 0.440 . 0.343 .                 .  PREDICTED   .
        .   MEASURED   .                        . 0.344 . 0.458 . 0.350 .                 .   MEASURED   .                  1
        .PCT DIFFERENCE.                        .   0.9 .   4.1 .   2.0 .                 .PCT DIFFERENCE.
        ................        .........................................................  ................
                                . 0.346 . 0.624 . 0.975 . 0.836 . 0.975 . 0.624 . 0.347 .
                                . 0.345 . 0.620 . 0.968 . 0.833 . 0.985 . 0.653 . 0.359 .                                   2
                                .  -0.4 .  -0.7 .  -0.6 .  -0.4 .   1.0 .   4.6 .   3.3 .
                        .........................................................................
                        . 0.407 . 0.992 . 1.168 . 1.087 . 1.250 . 1.088 . 1.168 . 0.992 . 0.406 .
                        . 0.442 . 0.990 . 1.159 . 1.074 . 1.214 . 1.086 . 1.184 . 1.017 . 0.447 .                           3
                        .   8.7 .  -0.2 .  -0.8 .  -1.2 .  -2.9 .  -0.2 .   1.3 .   2.5 .  10.1 .
                .........................................................................................
                . 0.407 . 0.815 . 1.214 . 1.156 . 1.344 . 1.127 . 1.344 . 1.155 . 1.214 . 0.815 . 0.407 .
                . 0.409 . 0.817 . 1.183 . 1.144 . 1.337 . 1.128 . 1.343 . 1.155 . 1.224 . 0.830 . 0.412 .                   4
                .   0.4 .   0.3 .  -2.5 .  -1.0 .  -0.5 .   0.1 .  -0.1 .   0.0 .   0.8 .   1.8 .   1.3 .
        .........................................................................................................
        . 0.346 . 0.993 . 1.214 . 1.127 . 1.364 . 1.176 . 1.350 . 1.175 . 1.364 . 1.126 . 1.214 . 0.993 . 0.347 .
        . 0.349 . 0.999 . 1.216 . 1.125 . 1.359 . 1.176 . 1.346 . 1.174 . 1.365 . 1.121 . 1.216 . 1.001 . 0.369 .           5
        .   0.9 .   0.6 .   0.2 .  -0.2 .  -0.4 .   0.0 .  -0.3 .  -0.1 .   0.1 .  -0.5 .   0.1 .   0.8 .   6.2 .
        .........................................................................................................
        . 0.624 . 1.169 . 1.156 . 1.364 . 1.153 . 1.365 . 1.165 . 1.364 . 1.153 . 1.363 . 1.156 . 1.168 . 0.623 .
        . 0.633 . 1.180 . 1.158 . 1.358 . 1.150 . 1.366 . 1.150 . 1.362 . 1.163 . 1.356 . 1.144 . 1.166 . 0.629 .           6
        .   1.3 .   1.0 .   0.1 .  -0.4 .  -0.3 .   0.0 .  -1.2 .  -0.1 .   0.9 .  -0.5 .  -1.1 .  -0.2 .   0.9 .
.........................................................................................................................
. 0.335 . 0.973 . 1.089 . 1.345 . 1.177 . 1.365 . 1.167 . 1.397 . 1.169 . 1.364 . 1.175 . 1.344 . 1.087 . 0.972 . 0.335 .
. 0.347 . 0.992 . 1.111 . 1.344 . 1.162 . 1.360 . 1.186 . 1.396 . 1.168 . 1.363 . 1.160 . 1.295 . 1.079 . 0.975 . 0.340 .   7
.   3.5 .   1.9 .   2.0 .  -0.1 .  -1.3 .  -0.4 .   1.6 .   0.0 .  -0.1 .  -0.1 .  -1.2 .  -3.7 .  -0.7 .   0.4 .   1.5 .
.........................................................................................................................
. 0.436 . 0.834 . 1.250 . 1.128 . 1.351 . 1.165 . 1.394 . 1.249 . 1.399 . 1.165 . 1.350 . 1.127 . 1.249 . 0.833 . 0.436 .
. 0.466 . 0.847 . 1.256 . 1.115 . 1.294 . 1.147 . 1.387 . 1.243 . 1.396 . 1.165 . 1.340 . 1.118 . 1.262 . 0.873 . 0.454 .   8
.   7.0 .   1.6 .   0.4 .  -1.2 .  -4.2 .  -1.6 .  -0.5 .  -0.4 .  -0.2 .   0.1 .  -0.8 .  -0.8 .   1.0 .   4.8 .   4.1 .
.........................................................................................................................
. 0.333 . 0.972 . 1.087 . 1.345 . 1.176 . 1.365 . 1.167 . 1.397 . 1.168 . 1.364 . 1.175 . 1.344 . 1.089 . 0.973 . 0.335 .
. 0.341 . 0.976 . 1.083 . 1.336 . 1.169 . 1.347 . 1.148 . 1.382 . 1.166 . 1.314 . 1.162 . 1.348 . 1.108 . 1.009 . 0.352 .   9
.   2.5 .   0.5 .  -0.4 .  -0.7 .  -0.6 .  -1.3 .  -1.6 .  -1.1 .  -0.2 .  -3.7 .  -1.1 .   0.3 .   1.8 .   3.7 .   5.1 .
.........................................................................................................................
        . 0.623 . 1.169 . 1.157 . 1.364 . 1.153 . 1.365 . 1.165 . 1.364 . 1.152 . 1.363 . 1.156 . 1.168 . 0.624 .
        . 0.619 . 1.149 . 1.151 . 1.360 . 1.136 . 1.317 . 1.140 . 1.340 . 1.124 . 1.359 . 1.173 . 1.199 . 0.655 .           10
        .  -0.6 .  -1.7 .  -0.5 .  -0.3 .  -1.5 .  -3.6 .  -2.1 .  -1.8 .  -2.4 .  -0.3 .   1.5 .   2.6 .   5.0 .
        .........................................................................................................
        . 0.346 . 0.993 . 1.215 . 1.127 . 1.365 . 1.175 . 1.350 . 1.175 . 1.364 . 1.126 . 1.214 . 0.993 . 0.346 .
        . 0.346 . 0.996 . 1.222 . 1.142 . 1.354 . 1.147 . 1.321 . 1.147 . 1.313 . 1.134 . 1.239 . 1.025 . 0.360 .           11
        .  -0.1 .   0.3 .   0.6 .   1.3 .  -0.8 .  -2.4 .  -2.2 .  -2.4 .  -3.8 .   0.7 .   2.1 .   3.2 .   3.9 .
        .........................................................................................................
                . 0.407 . 0.816 . 1.214 . 1.155 . 1.344 . 1.127 . 1.344 . 1.155 . 1.214 . 0.816 . 0.407 .
                . 0.429 . 0.827 . 1.225 . 1.147 . 1.304 . 1.105 . 1.320 . 1.136 . 1.218 . 0.843 . 0.440 .                   12
                .   5.4 .   1.4 .   0.9 .  -0.7 .  -3.0 .  -1.9 .  -1.8 .  -1.7 .   0.3 .   3.3 .   8.0 .
                .........................................................................................
                        . 0.406 . 0.992 . 1.169 . 1.089 . 1.250 . 1.087 . 1.168 . 0.992 . 0.406 .
                        . 0.413 . 1.010 . 1.173 . 1.082 . 1.240 . 1.077 . 1.152 . 0.990 . 0.412 .                           13
                        .   1.6 .   1.8 .   0.4 .  -0.7 .  -0.8 .  -0.9 .  -1.4 .  -0.2 .   1.4 .
                        .........................................................................
                                . 0.346 . 0.624 . 0.975 . 0.836 . 0.974 . 0.624 . 0.346 .
                                . 0.379 . 0.637 . 0.989 . 0.841 . 0.979 . 0.621 . 0.345 .                                   14
                                .   9.6 .   2.1 .   1.4 .   0.6 .   0.5 .  -0.5 .  -0.3 .
        ................        .........................................................  ................
        .   STANDARD   .                        . 0.341 . 0.440 . 0.341 .                 .   AVERAGE    .
        .  DEVIATION   .                        . 0.372 . 0.451 . 0.345 .                 .PCT DIFFERENCE.                  15
        .   =1.927     .                        .   9.1 .   2.6 .   1.2 .                 .    = 1.6     .
        ................                        .........................                 ................
```

SUMMARY

```
MAP NO:  S2-12-28          DATE: 01/03/95             POWER: 100.0%

CONTROL ROD POSITION:      F-Q(Z)  = 1.805            QPTR:

D BANK AT 224 STEPS        F-DH(N) = 1.443            NW 0.9996 | NE 1.0031
                                                      __________|__________
                           F(Z)    = 1.144            SW 0.9971 | SE 1.0003

                           BURNUP  = 17575 MWD/MTU    A.O.= -2.509%
```

Figure 4.4
SURRY UNIT 2 - CYCLE 12
HOT CHANNEL FACTOR NORMALIZED OPERATING ENVELOPE

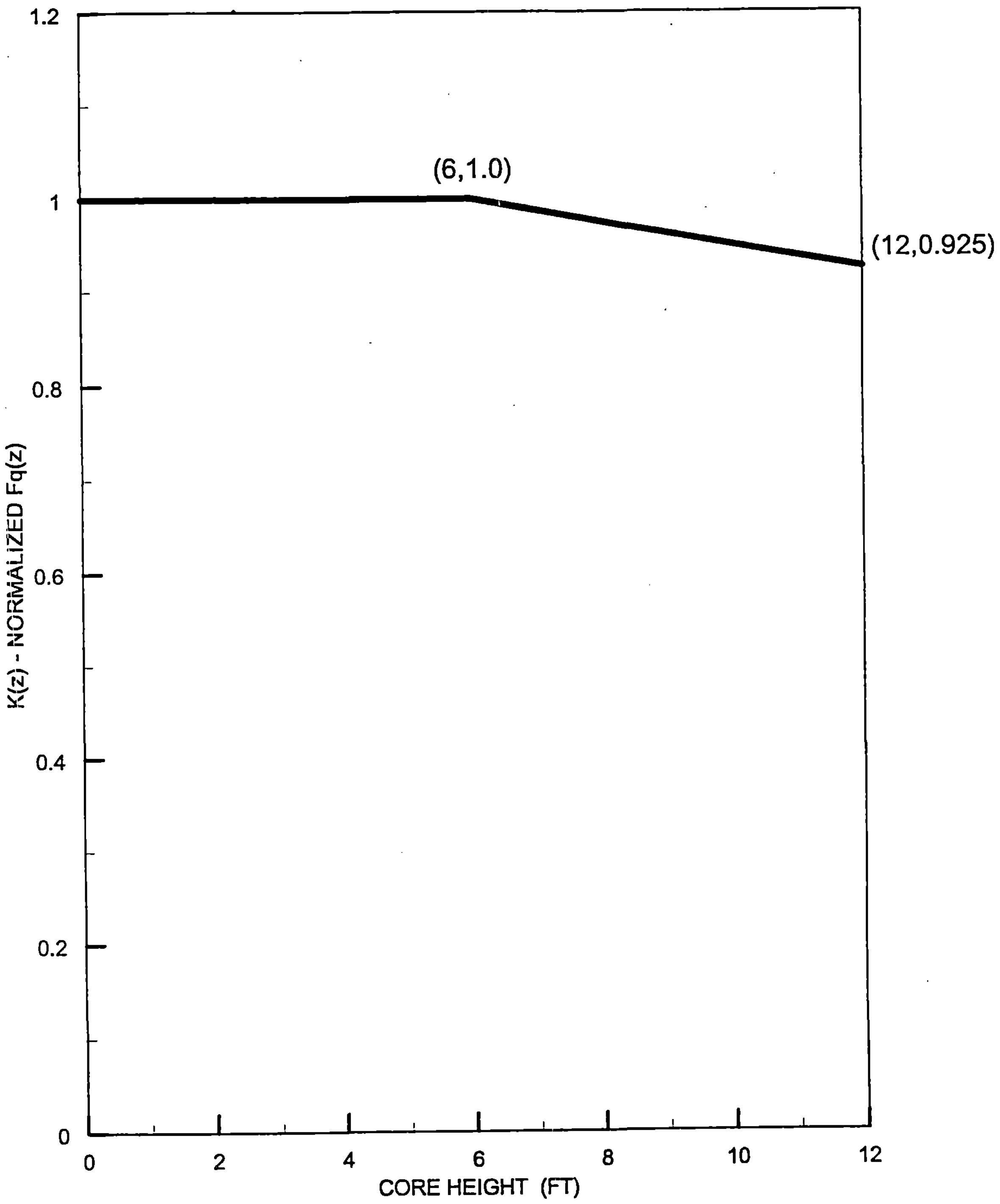


Figure 4.5
SURRY UNIT 2 - CYCLE 12
HEAT FLUX HOT CHANNEL FACTOR, $F_Q(Z)$
S2-12-04

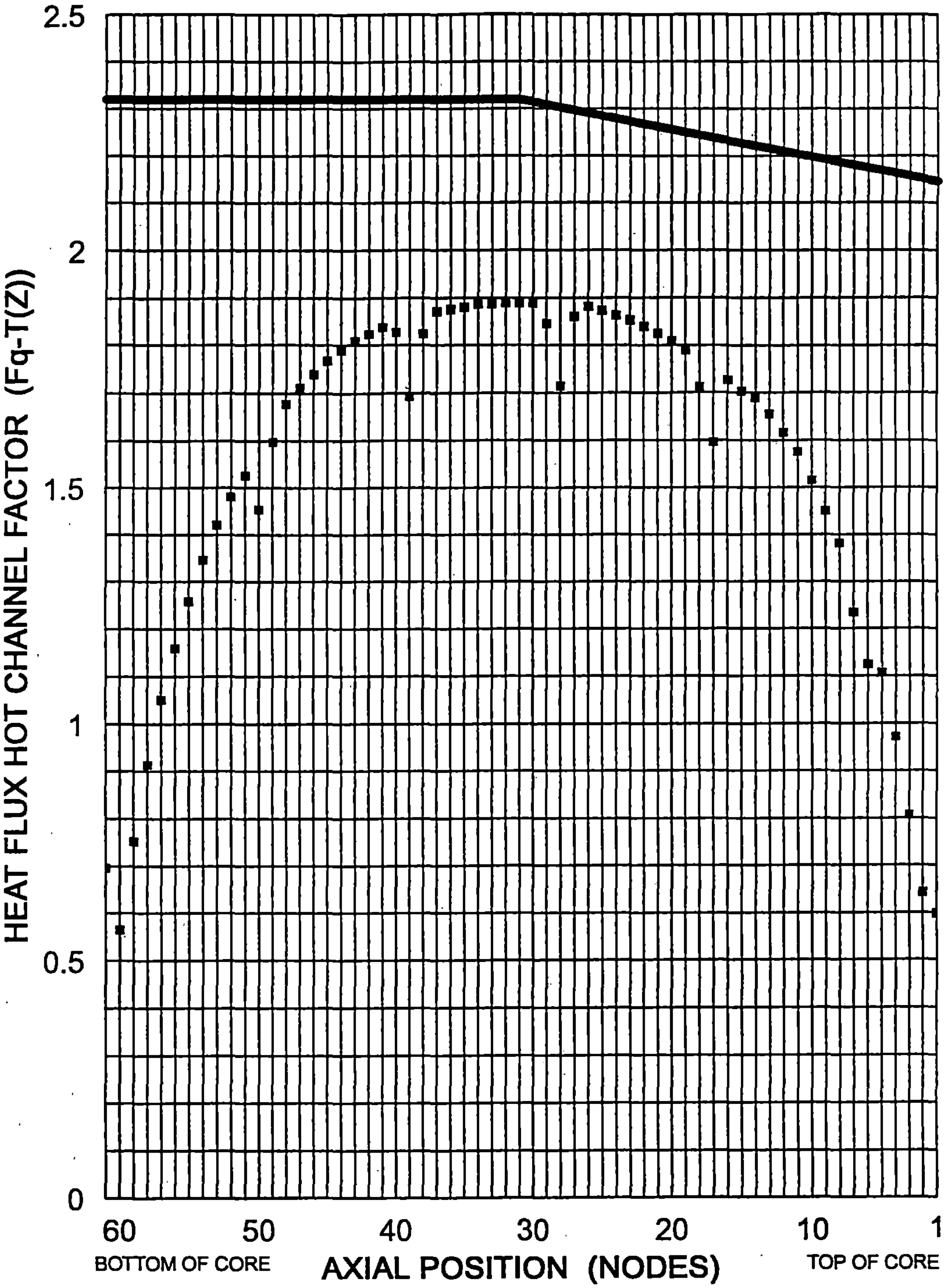


Figure 4.6
SURRY UNIT 2 - CYCLE 12
HEAT FLUX HOT CHANNEL FACTOR, $F_Q(Z)$
S2-12-16

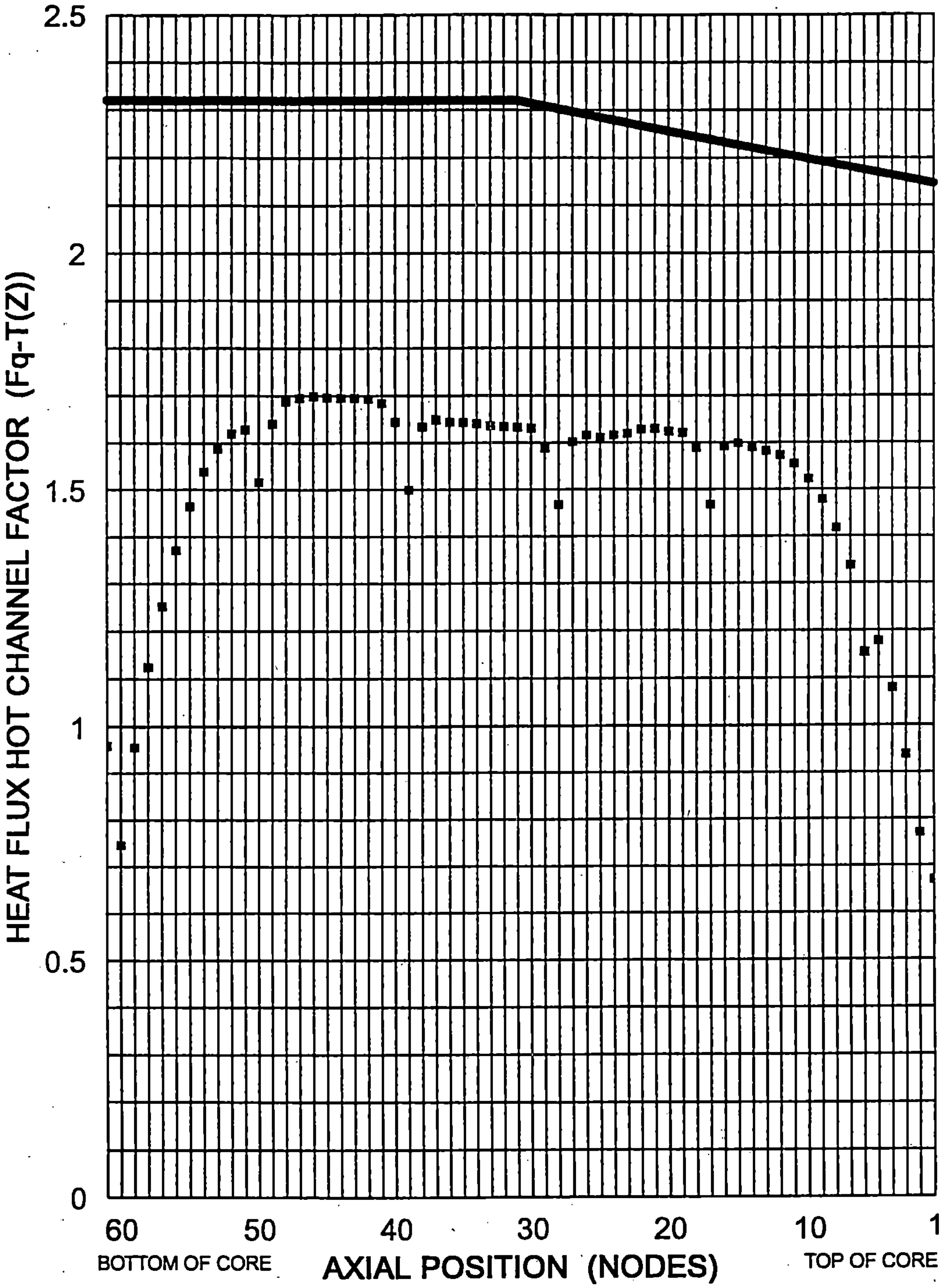


Figure 4.7
SURRY UNIT 2 CYCLE 12
HEAT FLUX HOT CHANNEL FACTOR, $F_Q(Z)$
S2-12-28

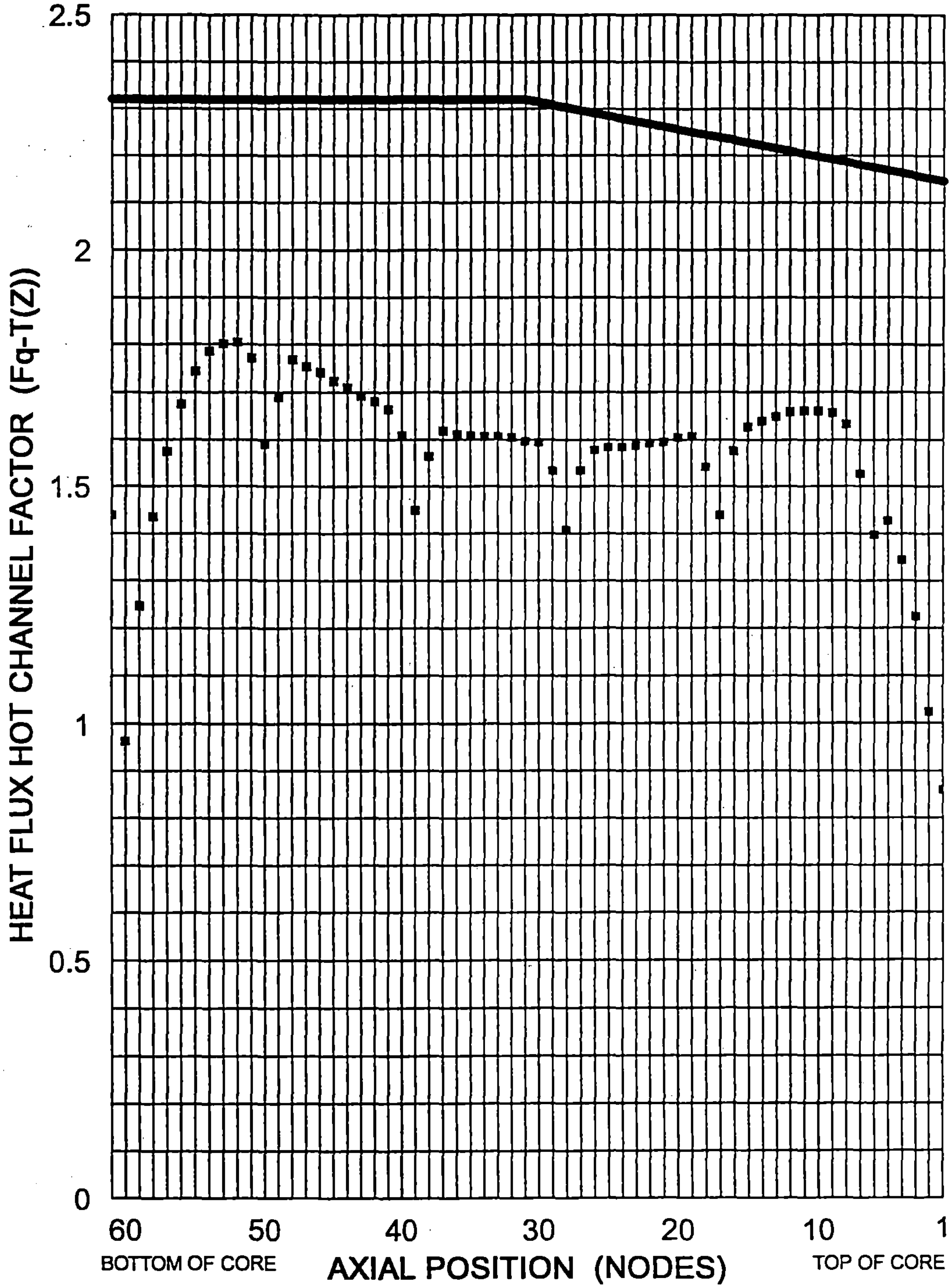
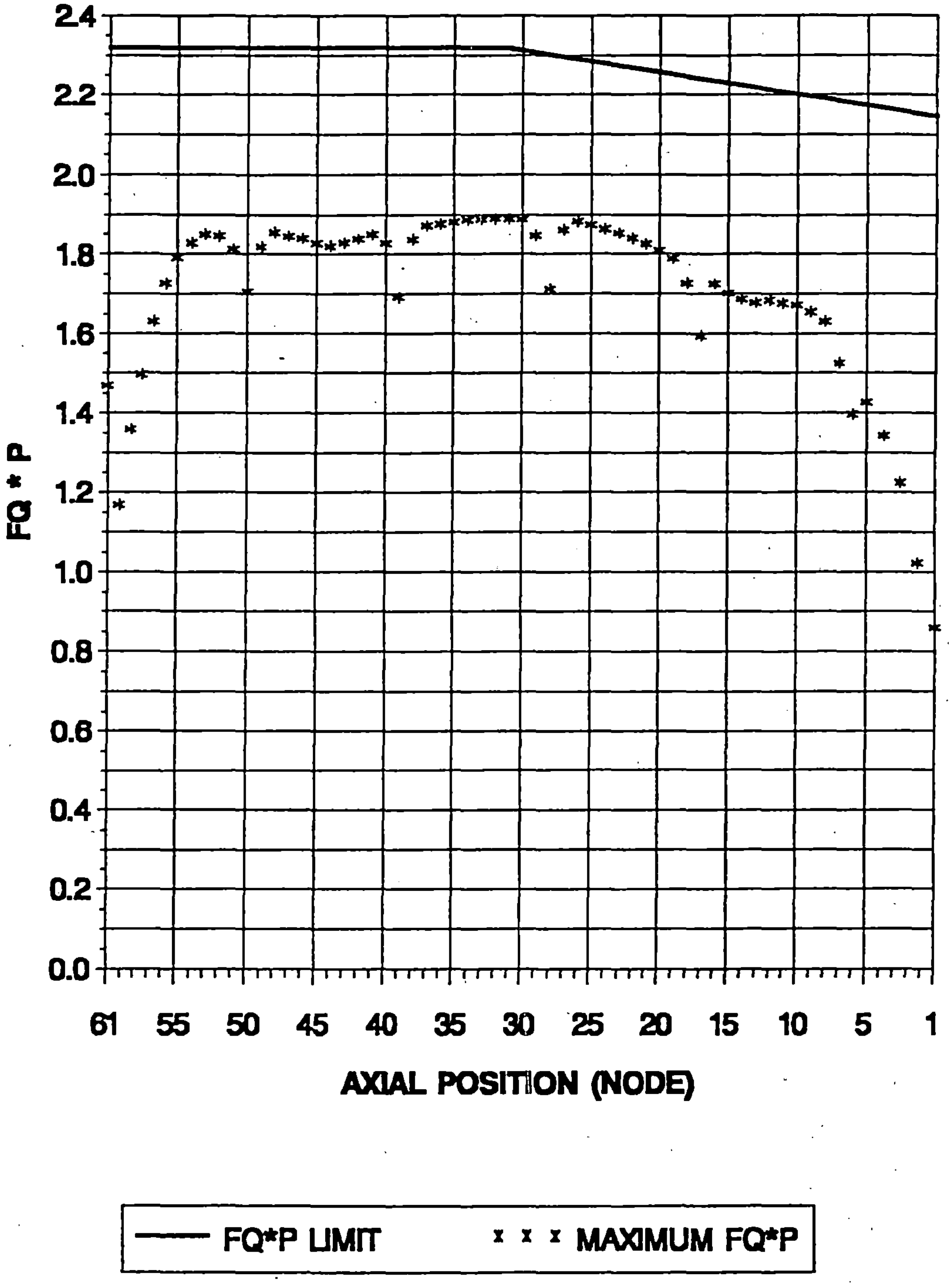


Figure 4.8
SURRY UNIT 2 - CYCLE 12
MAXIMUM HEAT FLUX HOT CHANNEL FACTOR, $F_Q(Z)*P$, vs. AXIAL POSITION



BOTTOM OF CORE

TOP OF CORE

Figure 4.9
SURRY UNIT 2 - CYCLE 12
MAXIMUM HEAT FLUX HOT CHANNEL FACTOR, $F_Q(Z)$, vs. BURNUP

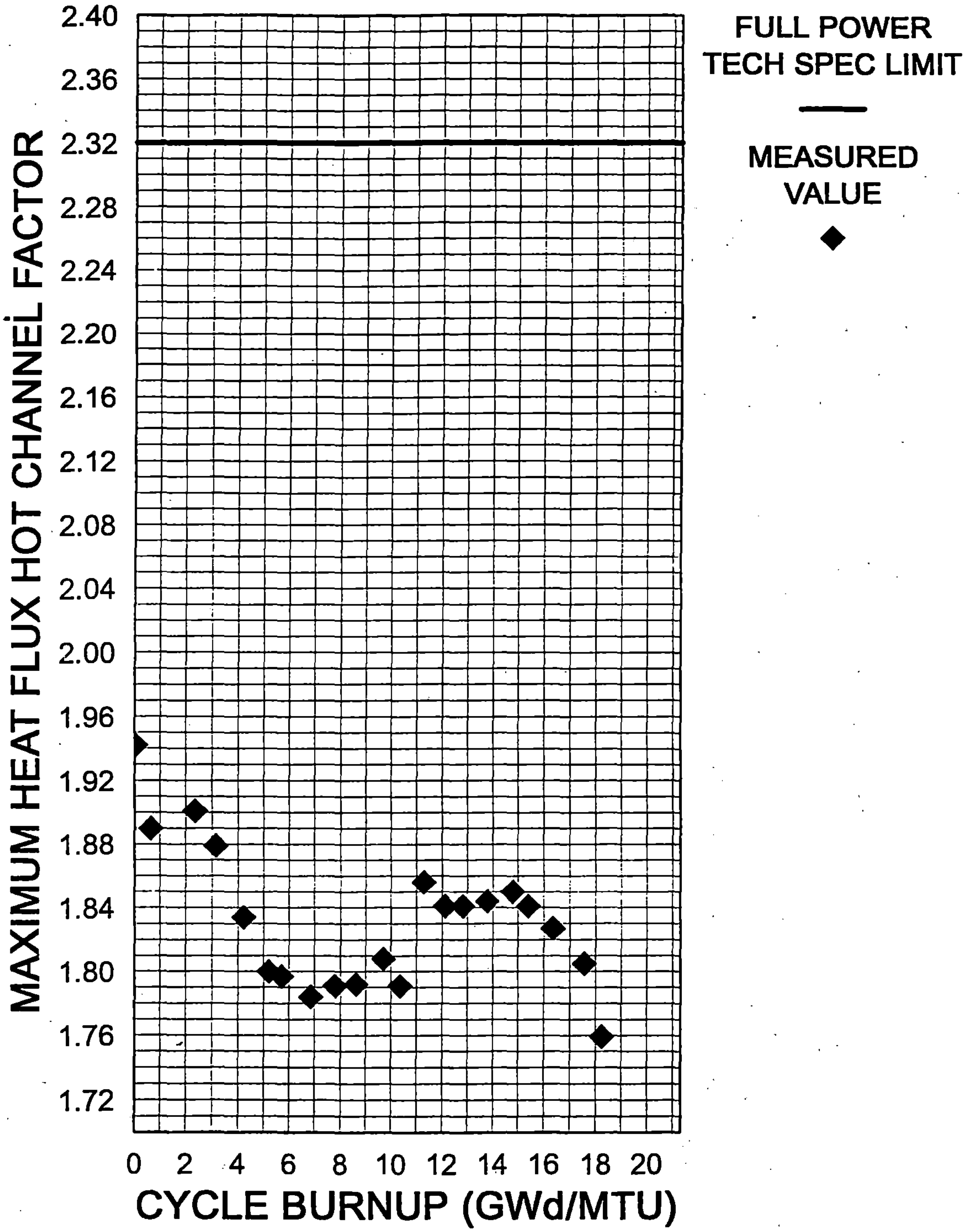


Figure 4.10
SURRY UNIT 2 - CYCLE 12
MAXIMUM ENTHALPY RISE HOT CHANNEL FACTOR, F-delta-H, vs. BURNUP

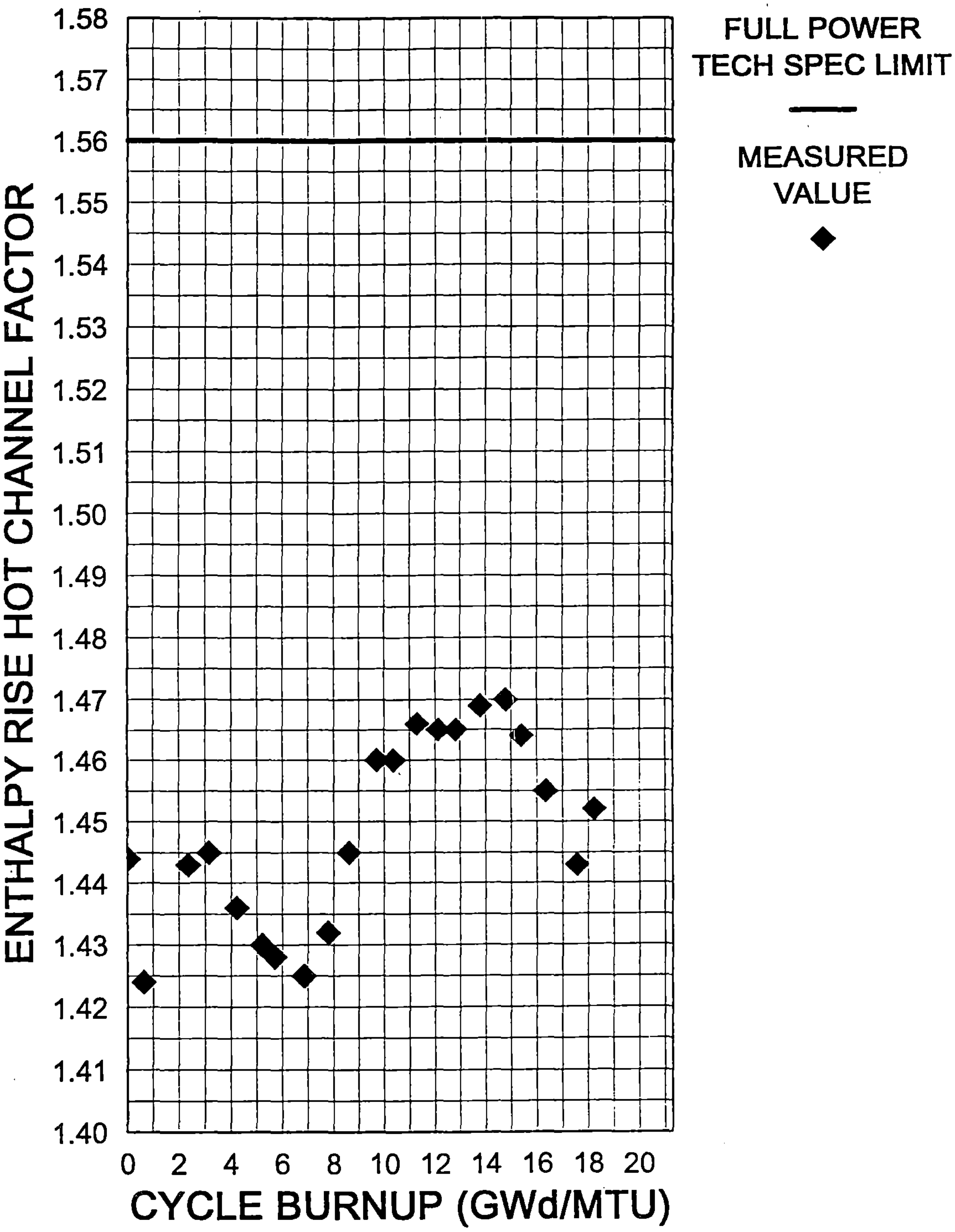


Figure 4.11
SURRY UNIT 2 - CYCLE 12
TARGET DELTA FLUX vs. BURNUP

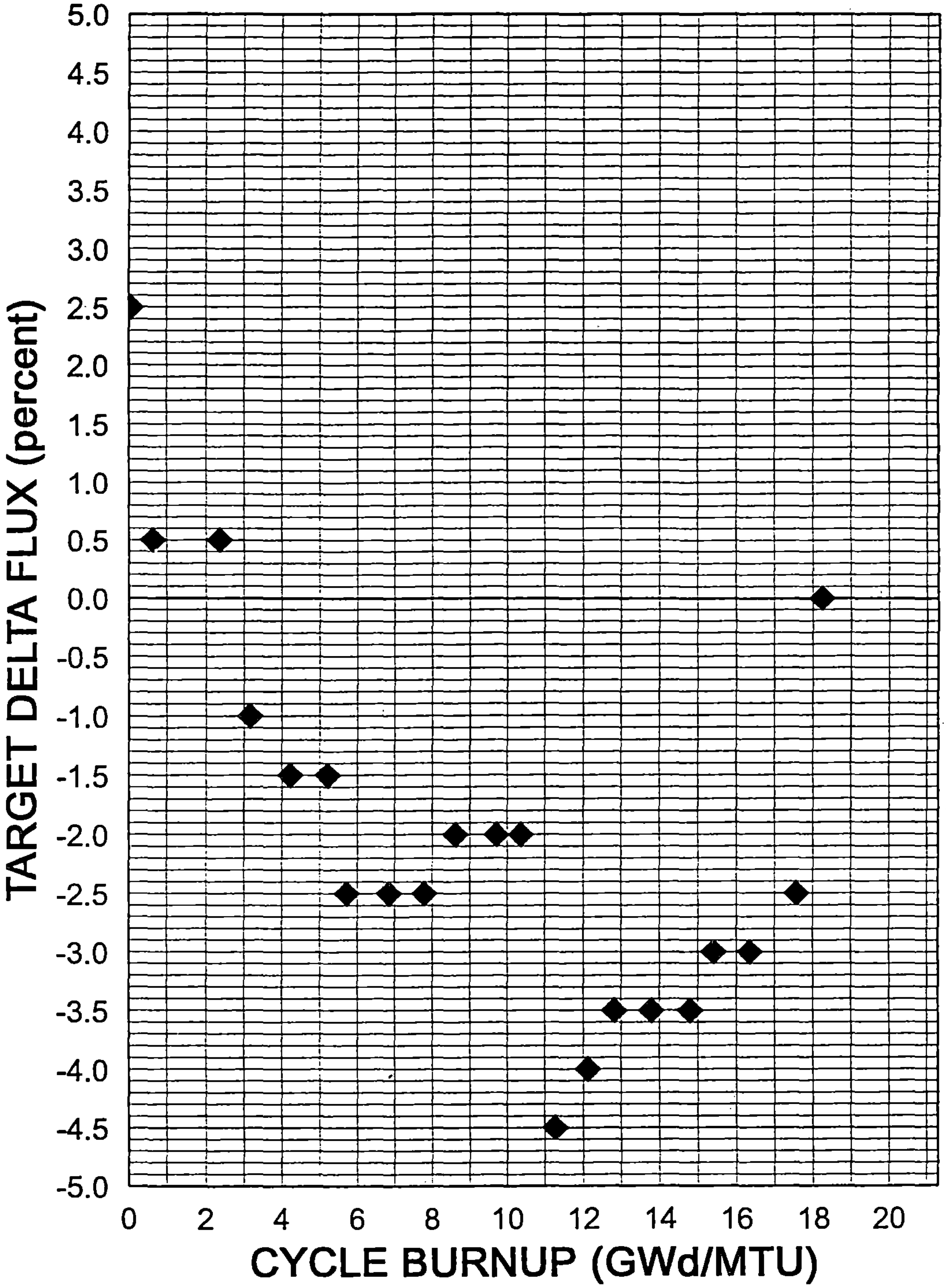


Figure 4.12
SURRY UNIT 2 - CYCLE 12
CORE AVERAGE AXIAL POWER DISTRIBUTION
S2-12-04

Fz = 1.228
AXIAL OFFSET = 0.271

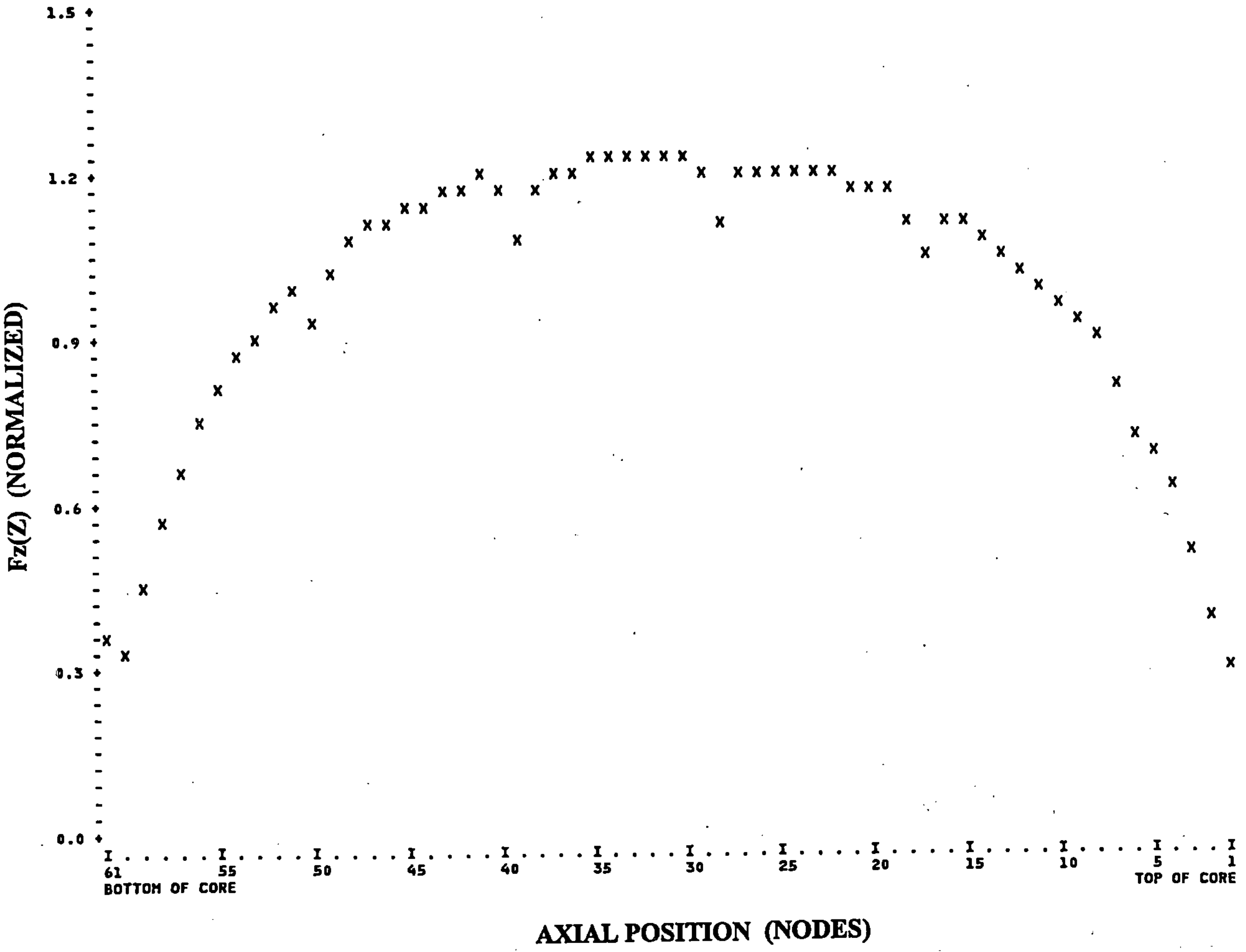


Figure 4.13
SURRY UNIT 2 - CYCLE 12
CORE AVERAGE AXIAL POWER DISTRIBUTION
S2-12-16

Fz = 1.143
AXIAL OFFSET = -2.232

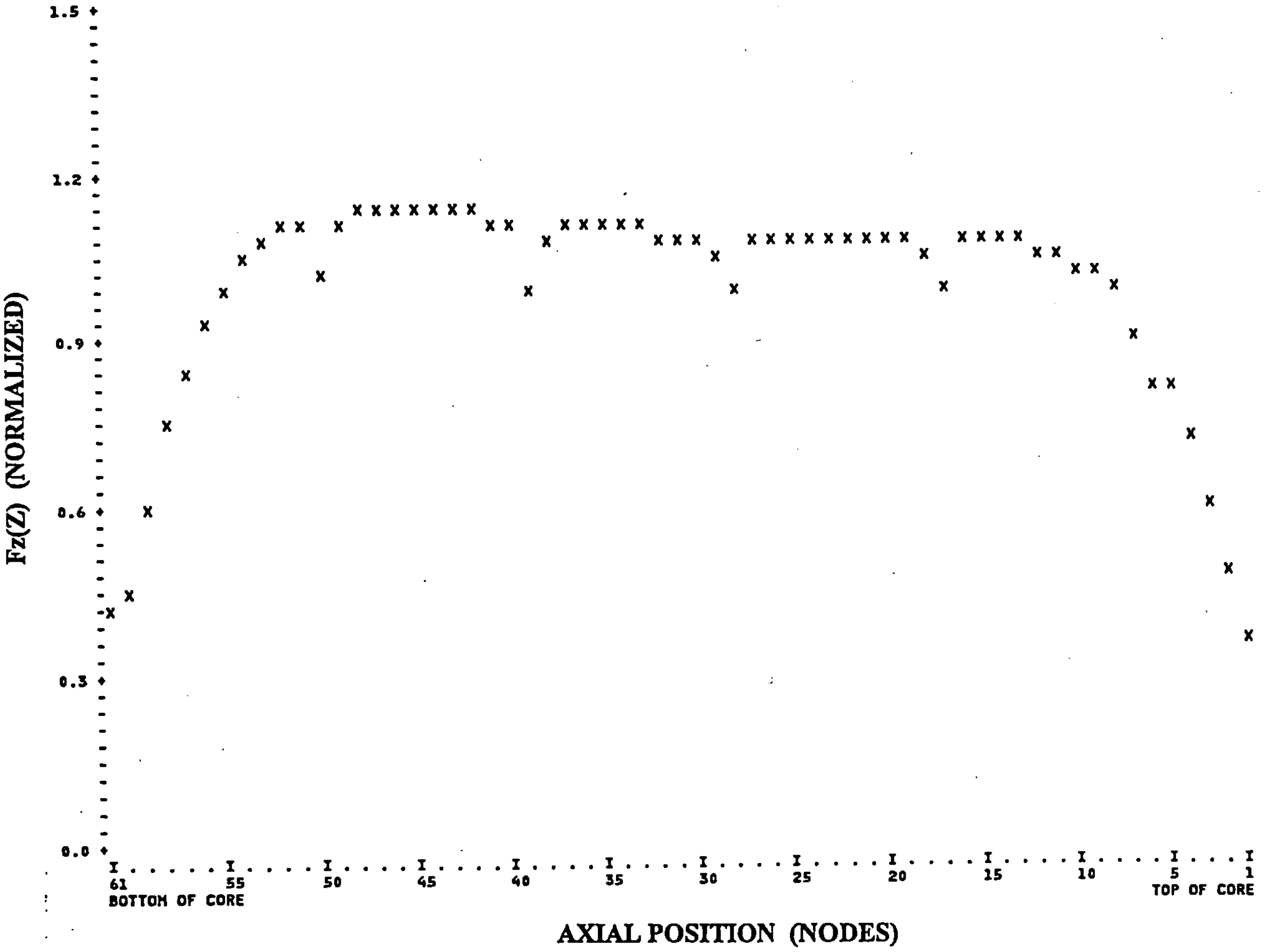


Figure 4.14
SURRY UNIT 2 - CYCLE 12
CORE AVERAGE AXIAL POWER DISTRIBUTION
S2-12-28

Fz = 1.144
AXIAL OFFSET = -2.509

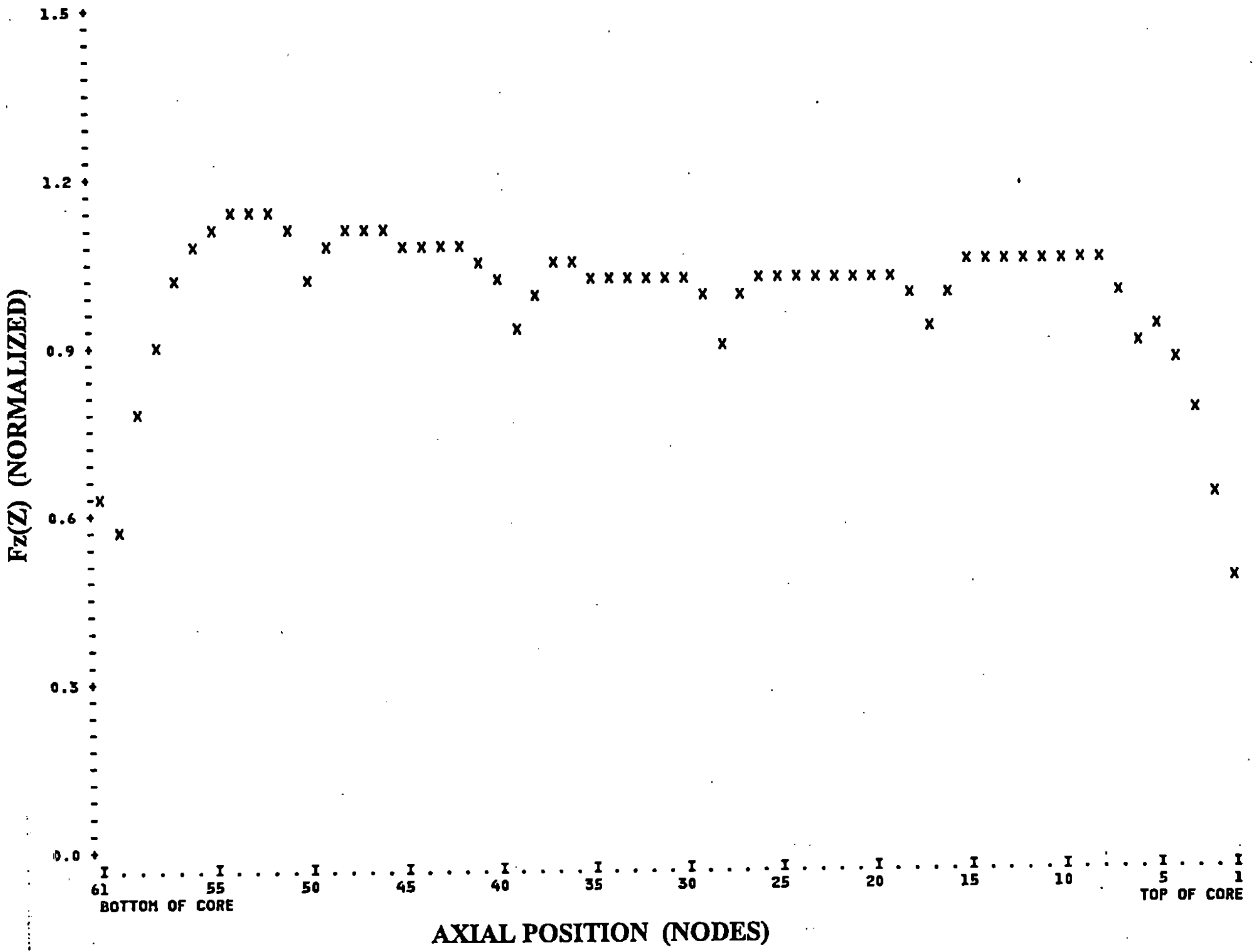
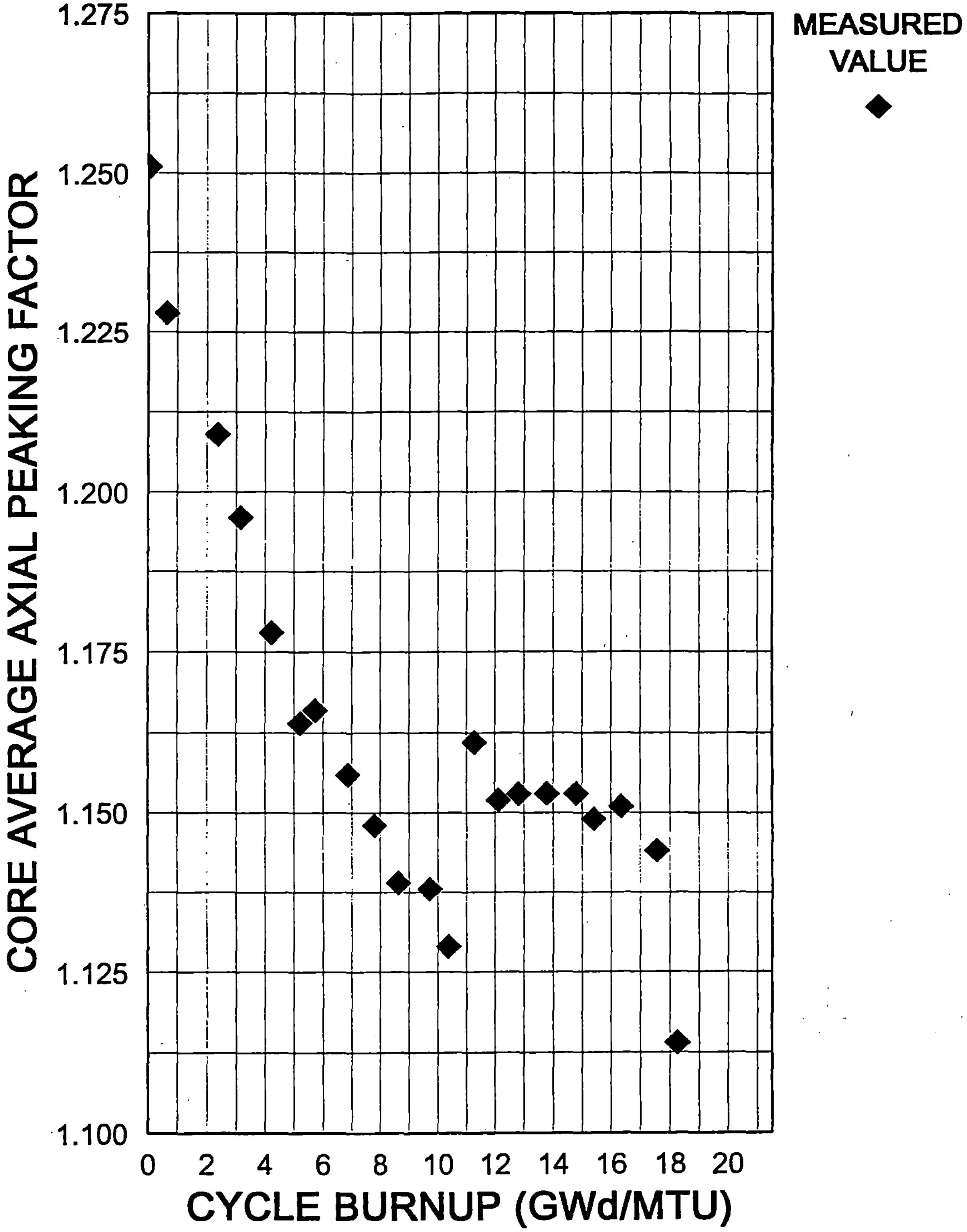


Figure 4.15
SURRY UNIT 2 - CYCLE 12
CORE AVERAGE AXIAL PEAKING FACTOR vs. BURNUP



Section 5

PRIMARY COOLANT ACTIVITY

The specific activity levels of radioiodines in the primary coolant are important to core and fuel performance as indicators of failed fuel and are important with respect to offsite dose calculations associated with accident analyses. Two mechanisms are primarily responsible for the presence of radioiodines in the primary coolant. Radioiodines are always present due to direct fission product recoil from trace fissile materials plated onto core components and fuel structured surfaces or trace fissile materials existing as impurities in core structural materials. This fissile material is generally referred to as "tramp" material, and the resulting iodines are referred to as tramp iodine. Fission products will also diffuse into the primary coolant if a breach in the cladding (fuel defects) exists. Fuel defects, when they exist, are generally the predominant source of radioiodines in the primary coolant.

Surry Technical Specification 3.1.D conditionally limits the primary coolant radioiodine dose equivalent I-131 to a value of 1.0 µCi/gram with provisions that ultimately limit the dose equivalent I-131 activity to a maximum of 10.0 µCi/gm[2]. Figure 5.1 shows the dose-equivalent I-131 activity history for Cycle 12. These data show that the dose equivalent I-131 activity remained substantially below 1.0 µCi/gm throughout Cycle 12 operation. The cycle average steady state power dose equivalent I-131 concentration was 7.63 X 10^{-4} µCi/gm which is less than .1% of the Technical Specification limit.

Correcting the I-131 concentration for tramp iodine involves calculating the I-131 activity from tramp fissile sources and subtracting this value from the measured I-131. The resultant tramp-corrected I-131 activity is theoretically the I-131 activity from defective fuel. The magnitude of the tramp-corrected I-131 can then be used as an indication of the number of defective fuel rods. The cycle average tramp corrected iodine-131 concentration was 2.90 X 10^{-5} µCi/gm. A tramp-corrected I-131 activity of this low magnitude is a good indication of a defect free core. The fact that there were no spikes in the iodine data during rapid power transients substantiates the conclusion that the Cycle 12 core contained no defective fuel rods and the reactor coolant system radioiodines resulted from tramp fissile sources. The demineralizer flow rate averaged approximately 100 gpm during power operation.

The ratio of the specific activities of I-131 to I-133 is used to characterize the type (size) 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 leaving the I-131 dominant in activity, thereby causing the ratio to be roughly 0.5 or more. In the case of large leaks and tramp material, where the diffusion mechanism is negligible, the I-131/I-133 ratio will generally be less than 0.1. The use of these ratios with regard to defect size is empirically determined and generally used throughout the commercial nuclear power industry. Figure 5.2 shows the I-131/I-133 ratio data for the Surry 2 Cycle 12. The "spikes" in the ratio data shown on

Figure 5.2 primarily occurred when the unit was down and is the result of I-133 decay thus increasing the ratio substantially. While the unit was in full power operation, the I-131/I-133 ratio remained consistantly under .1, which is typical for a core with zero defective fuel rods.

Figure 5.1
SURRY UNIT 2 - CYCLE 12
DOSE EQUIVALENT I-131 vs. TIME

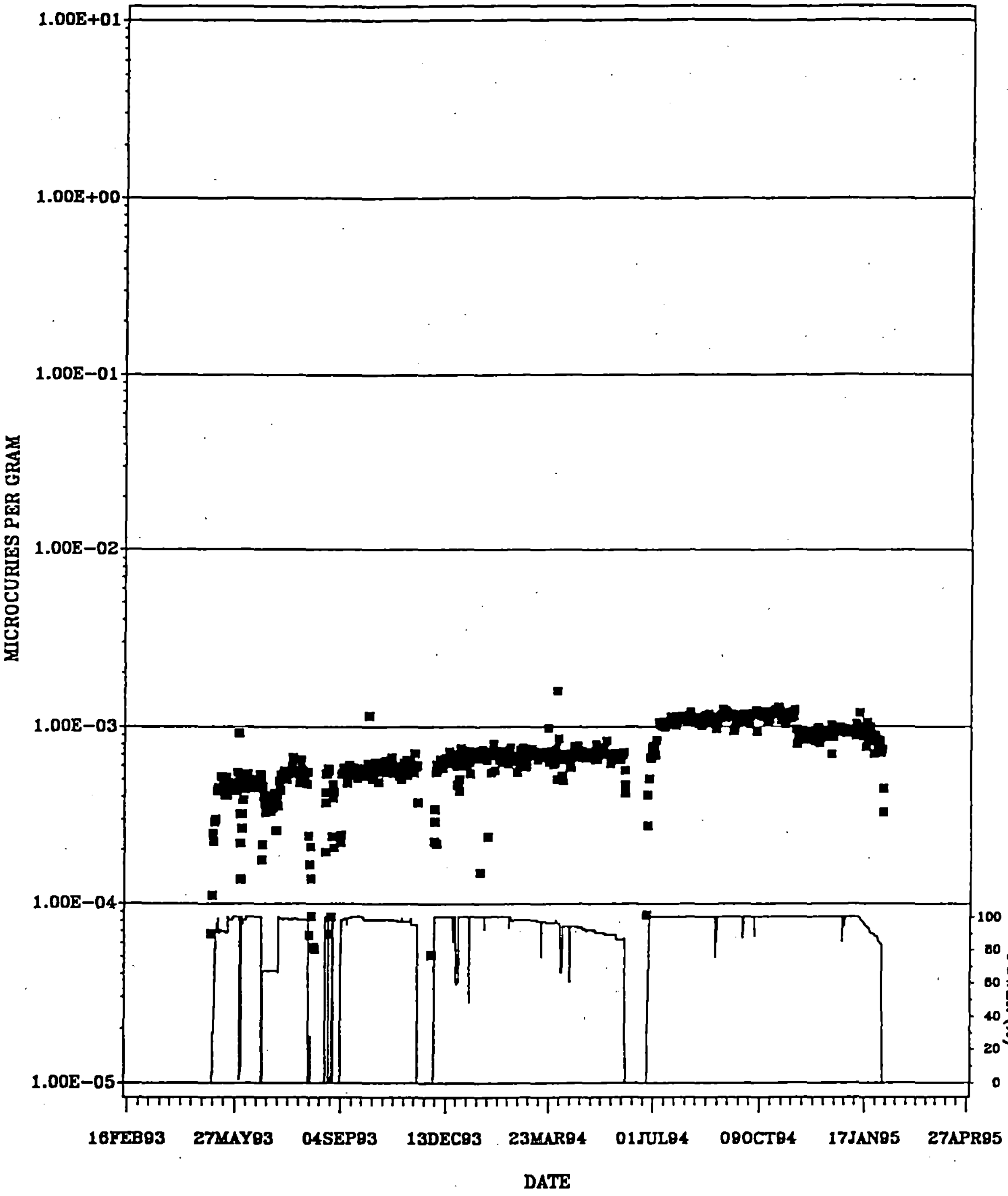
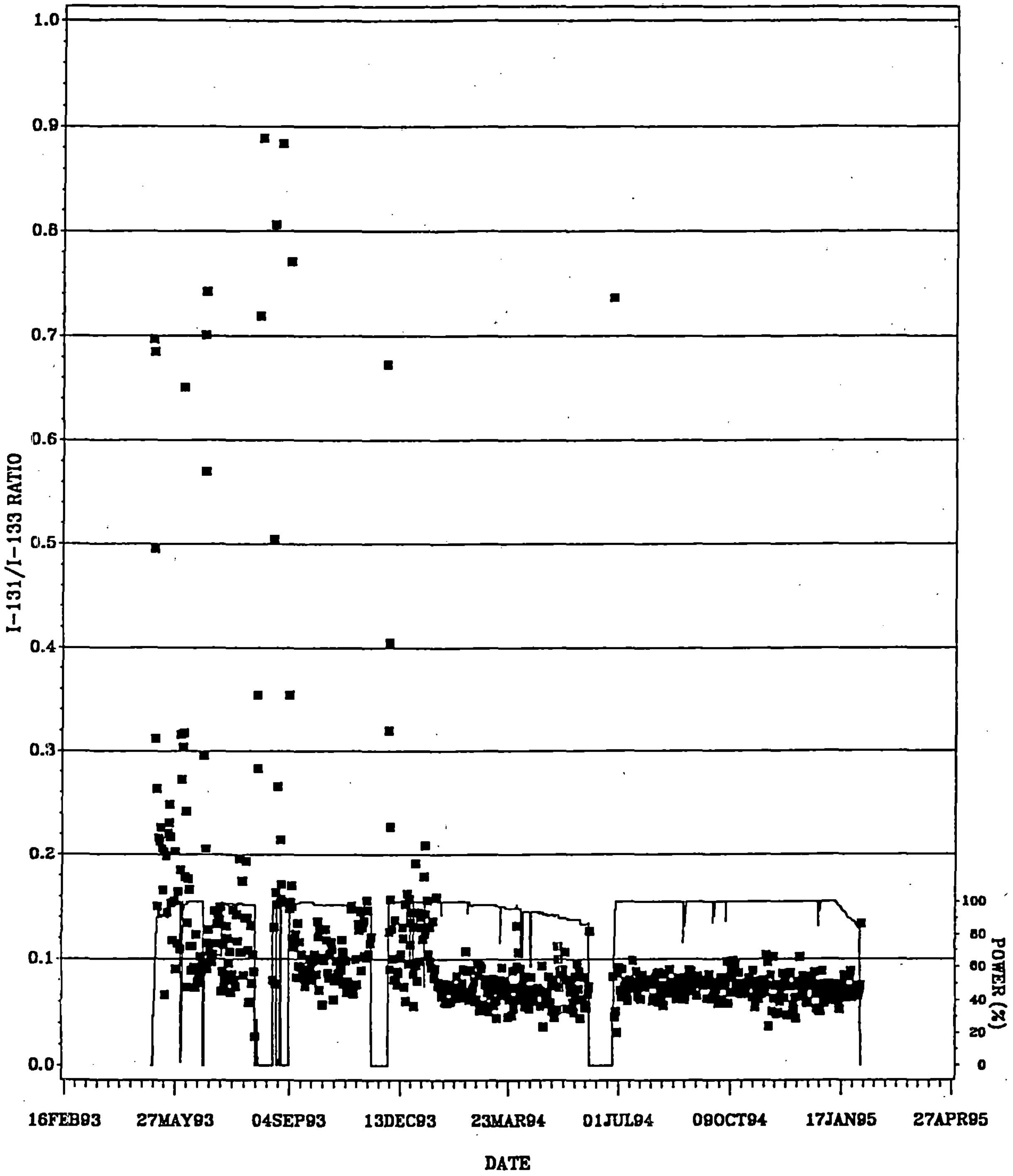


Figure 5.2
SURRY UNIT 2 - CYCLE 12
I-131 / I-133 ACTIVITY RATIO vs. TIME



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Section 6

CONCLUSIONS

The Surry 2, Cycle 12 core has completed operation. Throughout this cycle, all core performance indicators compared favorably with the design predictions and the core related Technical Specification limits were met with significant margin. No significant abnormalities in reactivity or burnup accumulation were detected. Radioiodine analysis indicated that there were no fuel rod defects.

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Section 7

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4) D. L. Gilliatt, "The Virginia Power FOLLOW Code Manual," Technical Report NE-679, Rev. 1, Virginia Power, April, 1991.

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

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8) Letter from B. C. Buckley (NRC) to W.L. Stewart, "Surry Units 1 and 2 - Issuance of Amendments Re: F-Delta-H Limit and Statistical DNBR Methodology (TAC Nos. M81271 and M82168)", Serial No. 92-405, dated June 1, 1992.

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10) "Surry Unit 2 Cycle 12 TOTE Calculations", Calculational Note PM-489, Rev. 0 and associated addenda, Virginia Power.

11) R. A. Hall, et al, "Surry Unit 2 Cycle 12 Flux Map Analysis", PM-491, Rev. 0, and Addenda, May 1993 - January 1995.

12) W. S. Miller, "Surry Unit 2, Cycle 12 FOLOW Calculations", Calculational Note PM-495, Rev. 0, Addendum B, Virginia Power, February, 1995.

13) Nuclear Standard, "Fuel Integrity Monitoring", ENNS-2904, Rev. 0, May 26, 1992.