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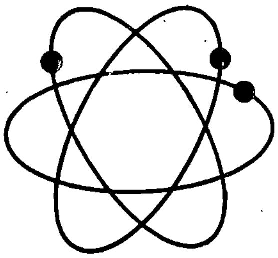
SURRY UNIT 2, CYCLE 5 CORE PERFORMANCE REPORT



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FUEL RESOURCES DEPARTMENT

Virginia Electric and Power Company

VEP-FRD-46

SURRY UNIT 2, CYCLE 5

CORE PERFORMANCE REPORT

BY

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INTRODUCTION AND SUMMARY

On November 7, 1981, after almost fifteen months of operation, Surry Unit 2 completed Cycle 5. Since the initial criticality of Cycle 5 on August 14, 1980, the reactor core produced approximately 82 x 10 ^{6} MBTU (13,971 Megawatt days per metric ton of contained uranium) which has resulted in the generation of approximately 7.8 x 10^9 KWHr gross (7.4 x 10^9 KWHr net) of electrical energy. The purpose of this report is to present an analysis of the core performance for routine operation during Cycle 5. The physics tests that were performed during the startup of this cycle were covered in the Surry 2, Cycle 5 Startup Physics Test Report[1] and, therefore, will not be included here.

The fifth cycle core consisted of six batches of fuel. Two once-burned batches were brought from Cycle 4 (Batches 6A1 and 6B). One twice-burned batch was carried over from Cycles 3 and 4 (Batch 5A). One thrice-burned batch was carried over from Cycles 2,3, and 4 (Batch 4B2). Two fresh batches (Batches 7A and 7B) were added to the Cycle 5 core. The Surry 2, Cycle 5 core loading map specifying the fuel batch identification, fuel assembly locations, burnable poison locations and source assembly locations is shown in Figure 1.1. Movable detector locations and thermocouple locations are identified in Figure 1.2. Control rod locations are shown in Figure 1.3.

Routine core follow involves the analysis of four principal performance indicators. These are burnup distribution, reactivity depletion, power distribution, and primary coolant activity. The core burnup distribution is followed to verify both burnup symmetry and proper batch burnup sharing, thereby, ensuring that the fuel held over for the next cycle will be compatible with the new fuel that is inserted. Reactivity depletion is monitored to detect the existence of any abnormal reactivity behavior, to determine if the core is depleting as designed, and to indicate at what burnup level refueling will be required. Core power distribution follow includes the monitoring of nuclear hot channel factors to verify that they are within the Technical Specifications[2] limits thereby ensuring that adequate margins to linear power density and critical heat flux thermal limits are maintained. Lastly, as part of normal core follow, the primary coolant activity is monitored to verify that the dose equivalent iodine-131 concentration is within the limits specified by the Surry Power Station Technical Specifications, and to assess the integrity of the fuel.

Each of the four performance indicators is discussed in detail for the Surry 2, Cycle 5 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 ±0.14% with the burnup accumulation in each batch deviating from design prediction by less than ±0.6%.

2. Reactivity Depletion Follow - The critical boron concentration, used to monitor reactivity depletion, was consistently within ±0.5% delta K/K of the design prediction which is well within the ±1% delta

K/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 difference of less than 1.4%. All hot channel factors met their respective Technical Specifications limits.

4. Primary Coolant Activity Follow - The dose equivalent iodine-131 activity level in the primary coolant at the end of Cycle 5 was approximately 5.4 x 10^{-3} micro-Ci/gm. The average dose equivalent iodine-131 value during Cycle 5 was 6.2 x 10^{-3} micro-Ci/gm. This corresponds to less than 1% of the operating limit for the concentration of radioiodine in the primary coolant.

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

Figure 1.1

SURRY UNIT 2 - CYCLE 5

CORE LOADING

R	P	N	M	L	K	J	H	G	F	E	D	C	B	A	
						V19	1N2	V02							1
				T24	5N1	1N3 12P PS	W40	1N9 12P	3N9	T17					2
			W32	4N1 8P	2N3 16P	W45	W34 SS	W19	0N4 16P	1N5 8P	W04				3
		W11	W37	0L2 12P	W46	4N3 16P	V26	2N4 16P	W38	0L4 12P	W25	W41			4
	T18	4N9 8P	0L7 12P	W21	T04	T16	W22 12*	T13	T23	W39	1L1 12P	2N7 8P	T01		5
	2N2	1N7 16P	W28	T22	W35	0N2 16P	V12	1N0 16P	W33	T21	W01	0N1 16P	5N2		6
V07	3N4 12P	W02	4N4 16P	T12	3N1 16P	V22	0L9 12P	V05	4N7 16P	T11	2N1 16P	W10	4N2 12P	V20	7
4N0	W30	W06	V03	W42 12*	V08	0L3 12P	RD2	0L1 12P	V24	W24 12*	V10	W27	W07	2N8	8
V23	0N9 12P	W23	3N6 16P	T09	2N9 16P	V18	0L8 12P	V28	0N5 16P	T07	3N5 16P	W49	1N1 12P	V06	9
	2N5	0N6 16P	W17	T20 SS	W03	3N7 16P	V04	1N4 16P	W51	T02	W44	3N2 16P	1N6		10
	T15	3N8 8P	1L0 12P	W12	T05	T03	W36 12*	T08	T06	W43	0L5 12P	2N6 8P	T14		11
		W48	W09	0L6 12P	W52	0N3 16P	V16	0N7 16P	W08	1L2 12P	W30	W05			12
			W29	2N0 8P	0N8 16P	W47	W13 SS	W16	3N0 16P	4N5 8P	W20				13
				T19	4N6	1N8 12P	W26	3N3 12P PS	4N8	T10					14
						V17	5N0	V21							15

←Assembly Identification
←One or more of the following:
- a. PS - Primary Source
- b. SS - Secondary Source
- c. xxP - Burnable Poison Assembly (xx-number of rods)
- d. xx* - Depleted Burnable Poison Assembly (xx-number of rods)

FUEL ASSEMBLY DESIGN PARAMETERS

	BATCH					
	4B2	5A	6A1	6B	7A	7B
Initial Enrichment (w/o U235)	3.10	3.11	2.91	3.20	3.13	3.41
Assembly Type	17X17	15X15	15X15	15X15	15X15	15X15
Number of Assemblies	1	24	20	48	12	52
Fuel Rods Per Assembly	264	204	204	204	204	204
Assembly Identification	RD2	T01-T24	V02-V08 V10,V12 V16-V24 V26,V28	W01-W13 W16,W17 W19-W30 W32-W52	0L1-0L9 1L0-1L2	0N1-0N9 1N0-1N9 2N0-2N9 3N0-3N9 4N0-4N9 5N0-5N2

FIGURE 1.2

SURRY UNIT 2 - CYCLE 5

MOVEABLE DETECTOR AND THERMOCOUPLE LOCATIONS

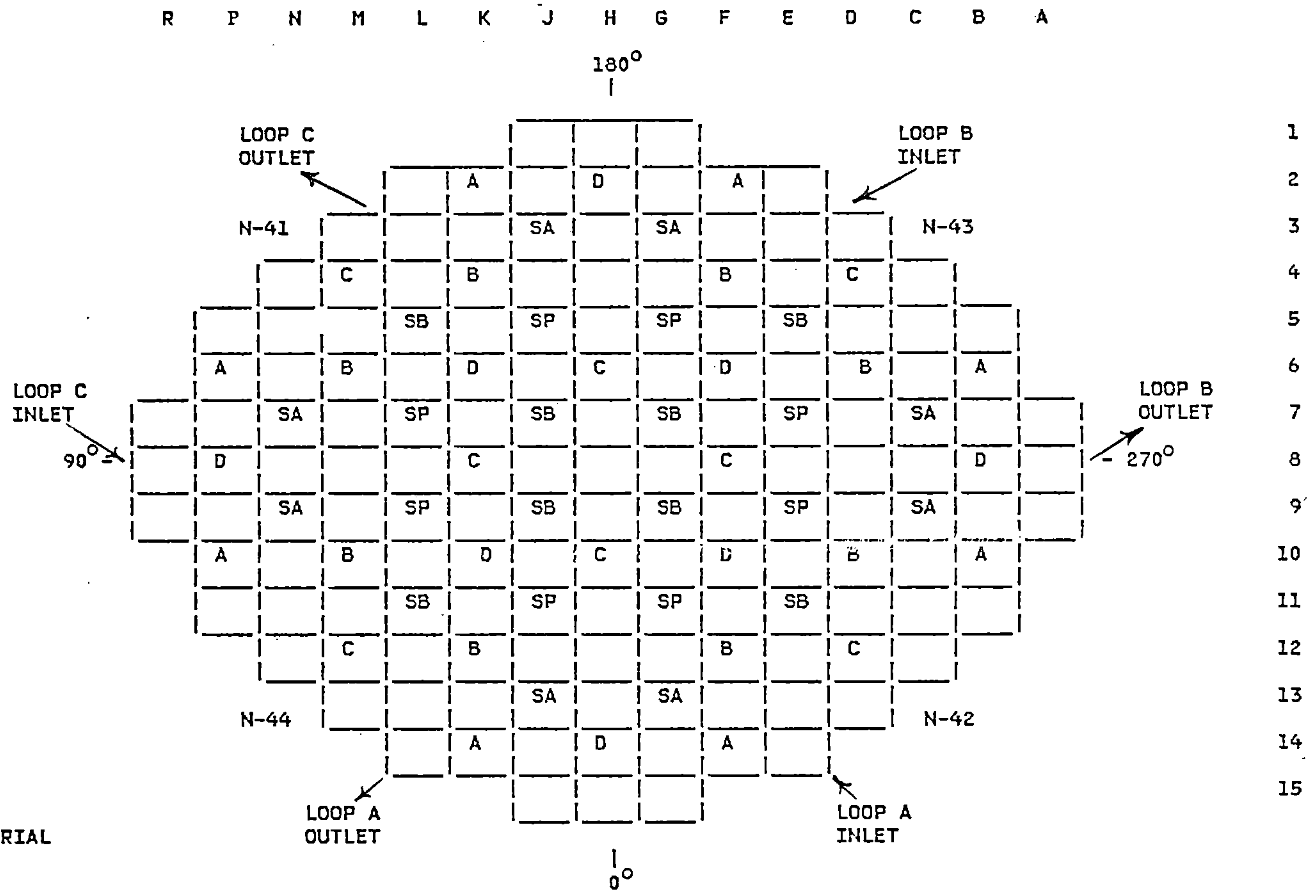
R	P	N	M	L	K	J	H	G	F	E	D	C	B	A	
							MD	TC							1
						TC		TC	MD						2
			MD TC		TC	MD	MD TC		TC		MD TC				3
		TC		MD			MD		MD	TC					4
		MD		MD	TC	MD	TC		TC	MD	MD TC		MD TC		5
		TC		MD TC			MD	TC	MD						6
TC	TC	MD				MD		MD		TC	MD		MD		7
MD	TC	MD TC		MD TC	TC		TC	TC	MD	TC		MD TC	MD	TC	8
			TC	MD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

MD - MOVABLE DETECTOR
TC - THERMOCOUPLE

FIGURE 1.3

SURRY UNIT 2 - CYCLE 5

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 2, Cycle 5 core is graphically depicted in Figure 2.1. The Surry 2, Cycle 5 core achieved a burnup of 13,971 MWD/MTU. As shown in Figure 2.2, the average load factor for Cycle 5 was 90% 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 5 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 5 operation is also given. As can be seen from this figure, the accumulated assembly burnups were generally within ±3.0% of the predicted values. In addition, deviation from quadrant symmetry in the core, as indicated by the burnup tilt factors, was less than ±0.14%.

The burnup sharing on a batch basis is monitored to verify that the core is operating as designed and to enable accurate end-of-cycle batch burnup predictions to be made for use in reload fuel design studies. Batch definitions are given in Figure 1.1. As seen in Figure 2.5, the batch burnup sharing for Surry Unit 2, Cycle 5 followed design predictions very closely with each batch deviating less than ±0.6% from design; this is considered excellent agreement. Therefore, symmetric burnup in conjunction with the good agreement between actual and predicted assemblywise burnups and batch burnup sharing indicate that the Cycle 5 core did deplete as designed.

FIGURE 2.1

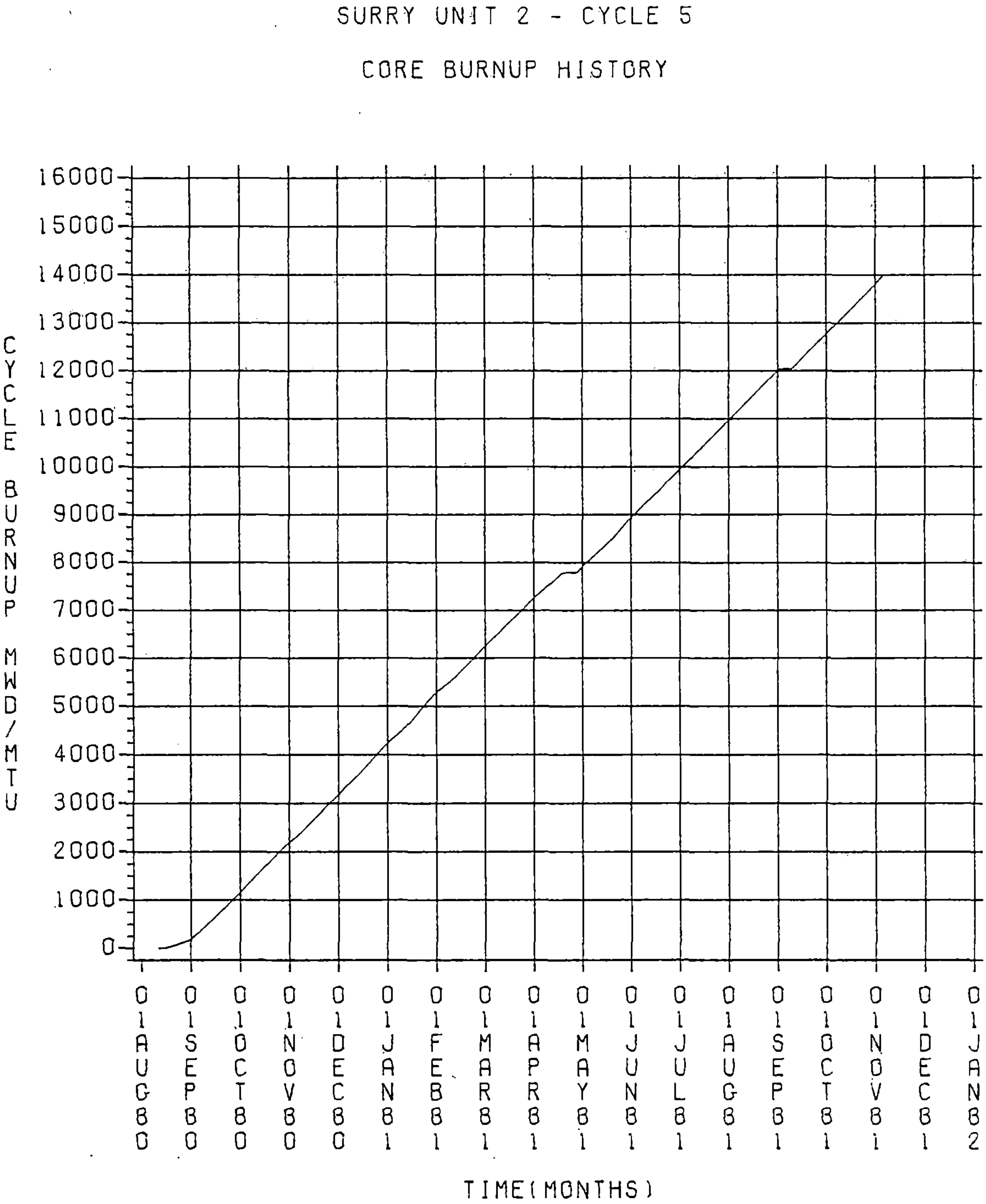
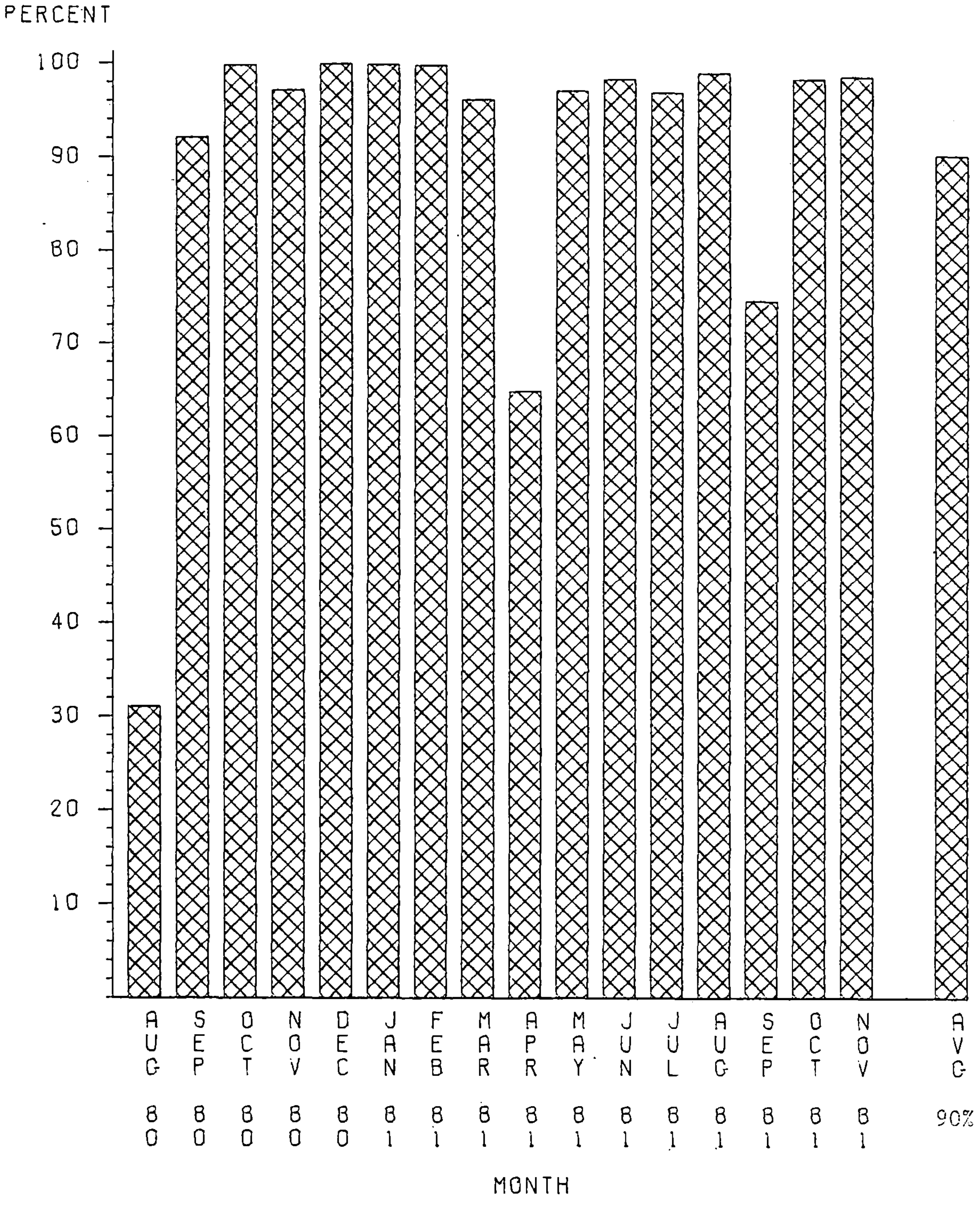

SURRY UNIT 2 - CYCLE 5
CORE BURNUP HISTORY
CYCLE BURNUP MWD/MTU
16000
15000
14000
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
01AUG80
01SEP80
01OCT80
01NOV80
01DEC80
01JAN81
01FEB81
01MAR81
01APR81
01MAY81
01JUN81
01JUL81
01AUG81
01SEP81
01OCT81
01NOV81
01DEC81
01JAN82
TIME(MONTHS)

FIGURE 2.2

SURRY 2 - CYCLE 5
MONTHLY AVERAGE LOAD FACTORS



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

(EXCLUDES REFUELING OUTAGES)

FIGURE 2.3

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

MEASURED
PREDICTED

	R	P	N	M	L	K	J	H	G	F	E	D	C	B	A	
1							22.51 22.36	10.09 10.20	22.21 22.36							1
2					28.36 28.23	12.96 12.92	14.51 14.65	23.23 23.58	14.48 14.65	12.92 12.92	28.27 28.23					2
3				17.48 17.46	14.82 14.70	16.73 16.65	29.77 29.96	30.35 30.89	29.71 29.96	16.68 16.65	14.83 14.70	17.70 17.46				3
4			17.59 17.46	28.11 28.17	16.38 16.49	29.85 30.11	16.99 17.09	30.59 30.78	16.92 17.09	29.92 30.11	16.48 16.49	28.23 28.17	17.71 17.46			4
5		28.48 28.23	14.75 14.70	16.36 16.49	25.98 26.33	36.88 36.95	35.90 35.88	24.99 25.11	35.69 35.88	36.62 36.95	26.20 26.33	16.50 16.49	15.19 14.70	28.60 28.23		5
6		12.91 12.92	16.69 16.65	29.87 30.11	36.85 36.95	26.26 26.60	17.69 17.66	31.17 31.24	17.61 17.66	26.15 26.60	36.71 36.95	30.12 30.11	16.97 16.65	13.35 12.92		6
7	22.43 22.36	14.58 14.65	29.71 29.96	16.97 17.09	35.80 35.88	17.59 17.66	31.56 31.45	17.65 17.56	31.59 31.45	17.62 17.66	35.38 35.88	17.00 17.09	29.96 29.96	14.75 14.65	22.45 22.36	7
8	10.12 10.20	23.30 23.58	30.72 30.89	30.64 30.78	24.71 25.11	31.16 31.24	17.75 17.56	42.51 42.27	17.65 17.56	31.16 31.24	24.70 25.11	30.62 30.78	30.72 30.89	23.39 23.58	10.43 10.20	8
9	22.44 22.36	14.61 14.65	29.90 29.96	17.03 17.09	35.98 35.88	17.44 17.66	31.26 31.45	17.63 17.56	31.64 31.45	17.44 17.66	35.48 35.88	17.00 17.09	29.82 29.96	14.86 14.65	22.81 22.36	9
10		13.00 12.92	16.80 16.65	30.17 30.11	36.84 36.95	26.18 26.60	17.27 17.66	31.10 31.24	17.61 17.66	26.33 26.60	36.93 36.95	30.03 30.11	16.66 16.65	12.99 12.92		10
11		28.34 28.23	14.96 14.70	16.45 16.49	25.88 26.33	36.65 36.95	35.70 35.88	24.58 25.11	35.85 35.88	36.96 36.95	26.11 26.33	16.61 16.49	14.97 14.70	28.21 28.23		11
12			17.75 17.46	28.40 28.17	16.18 16.49	29.68 30.11	16.72 17.09	30.38 30.78	16.87 17.09	30.25 30.11	16.59 16.49	28.37 28.17	17.64 17.46			12
13				17.91 17.46	15.58 14.70	17.00 16.65	29.56 29.96	30.29 30.89	29.70 29.96	16.84 16.65	14.95 14.70	17.71 17.46				13
14					28.61 28.23	13.63 12.92	14.70 14.65	23.30 23.58	14.61 14.65	12.99 12.92	28.45 28.23					14
15							22.69 22.36	10.41 10.20	22.16 22.36							15
	R	P	N	M	L	K	J	H	G	F	E	D	C	B	A	

FIGURE 2.5

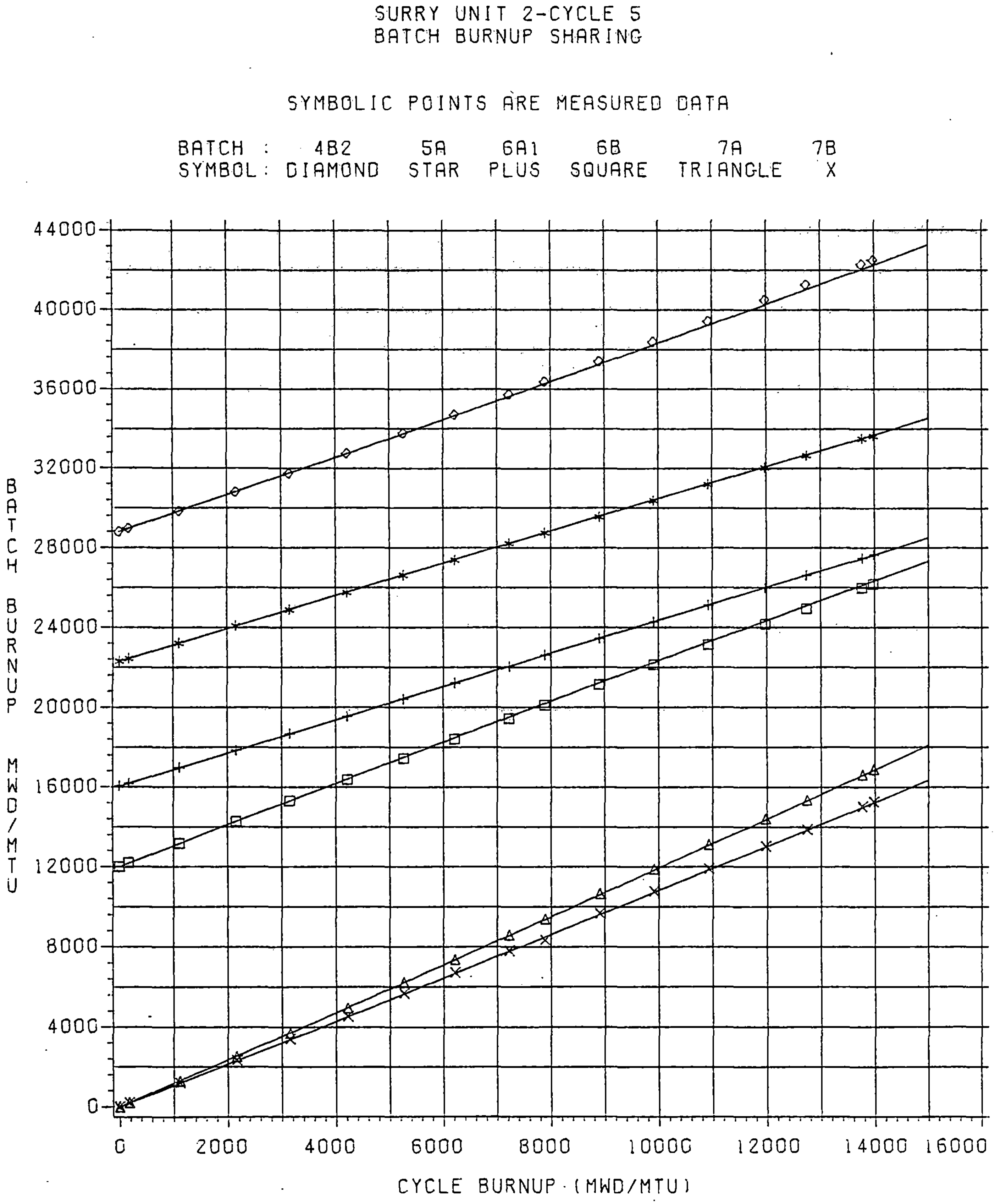

SURRY UNIT 2-CYCLE 5
BATCH BURNUP SHARING
SYMBOLIC POINTS ARE MEASURED DATA
BATCH : 4B2 5A 6A1 6B 7A 7B
SYMBOL : DIAMOND STAR PLUS SQUARE TRIANGLE X
BATCH BURNUP MWD/MTU
44000
40000
36000
32000
28000
24000
20000
16000
12000
8000
4000
0
0
2000
4000
6000
8000
10000
12000
14000
16000
CYCLE BURNUP (MWD/MTU)

FIGURE 2.4
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							22.51	10.09	22.21					MEASURED		1
							0.64	-1.08	-0.70					M/P % DIFF		
2					28.36	12.96	14.51	23.23	14.48	12.92	28.27					2
					0.46	0.31	-1.02	-1.49	-1.18	-0.04	0.15					
3				17.48	14.82	16.73	29.77	30.35	29.71	16.68	14.83	17.70				3
				0.12	0.85	0.46	-0.63	-1.73	-0.83	0.15	0.93	1.35				
4			17.59	28.11	16.38	29.85	16.99	30.59	16.92	29.92	16.48	28.23	17.71			4
			0.75	-0.19	-0.70	-0.88	-0.54	-0.61	-0.97	-0.63	-0.11	0.23	1.41			
5		28.48	14.75	16.36	25.98	36.88	35.90	24.99	35.69	36.62	26.20	16.50	15.19	28.60		5
		0.91	0.37	-0.83	-1.33	-0.18	0.05	-0.47	-0.51	-0.90	-0.47	0.04	3.37	1.30		
6		12.91	16.69	29.87	36.85	26.26	17.69	31.17	17.61	26.15	36.71	30.12	16.97	13.35		6
		-0.11	0.23	-0.81	-0.27	-1.28	0.19	-0.21	-0.27	-1.69	-0.65	0.03	1.92	3.27		
7	22.43	14.58	29.71	16.97	35.80	17.59	31.56	17.65	31.59	17.62	35.38	17.00	29.96	14.75	22.45	7
	0.31	-0.51	-0.83	-0.70	-0.22	-0.38	0.35	0.48	0.43	-0.25	-1.39	-0.49	-0.01	0.66	0.37	
8	10.12	23.30	30.72	30.64	24.71	31.16	17.75	42.51	17.65	31.16	24.70	30.62	30.72	23.39	10.43	8
	-0.74	-1.16	-0.55	-0.44	-1.57	-0.25	1.08	0.58	0.49	-0.24	-1.64	-0.50	-0.54	-0.81	2.31	
9	22.44	14.61	29.90	17.03	35.98	17.44	31.26	17.63	31.64	17.44	35.48	17.00	29.82	14.86	22.81	9
	0.33	-0.31	-0.22	-0.32	0.29	-1.23	-0.61	0.40	0.62	-1.28	-1.12	-0.51	-0.47	1.43	1.98	
10		13.00	16.80	30.17	36.84	26.18	17.27	31.10	17.61	26.33	36.93	30.03	16.66	12.99		10
		0.55	0.89	0.19	-0.31	-1.59	-2.22	-0.44	-0.27	-1.02	-0.05	-0.26	0.02	0.48		
11		28.34	14.96	16.45	25.88	36.65	35.70	24.58	35.85	36.96	26.11	16.61	14.97	28.21		11
		0.39	1.82	-0.27	-1.71	-0.80	-0.49	-2.11	-0.09	0.01	-0.83	0.70	1.84	-0.07		
12			17.75	28.40	16.18	29.68	16.72	30.38	16.87	30.25	16.59	28.37	17.64			12
			1.67	0.81	-1.92	-1.45	-2.14	-1.29	-1.27	0.45	0.59	0.71	0.99			
13				17.91	15.58	17.00	29.56	30.29	29.70	16.84	14.95	17.71				13
				2.59	6.05	2.10	-1.33	-1.93	-0.88	1.10	1.76	1.42				
14					28.61	13.63	14.70	23.30	14.61	12.99	28.45					14
					1.34	5.49	0.33	-1.18	-0.33	0.51	0.80					
15	STANDARD DEV						22.69	10.41	22.16					AVG ABS PCT		15
	= 0.86						1.46	2.03	-0.88					DIFF = 0.89		

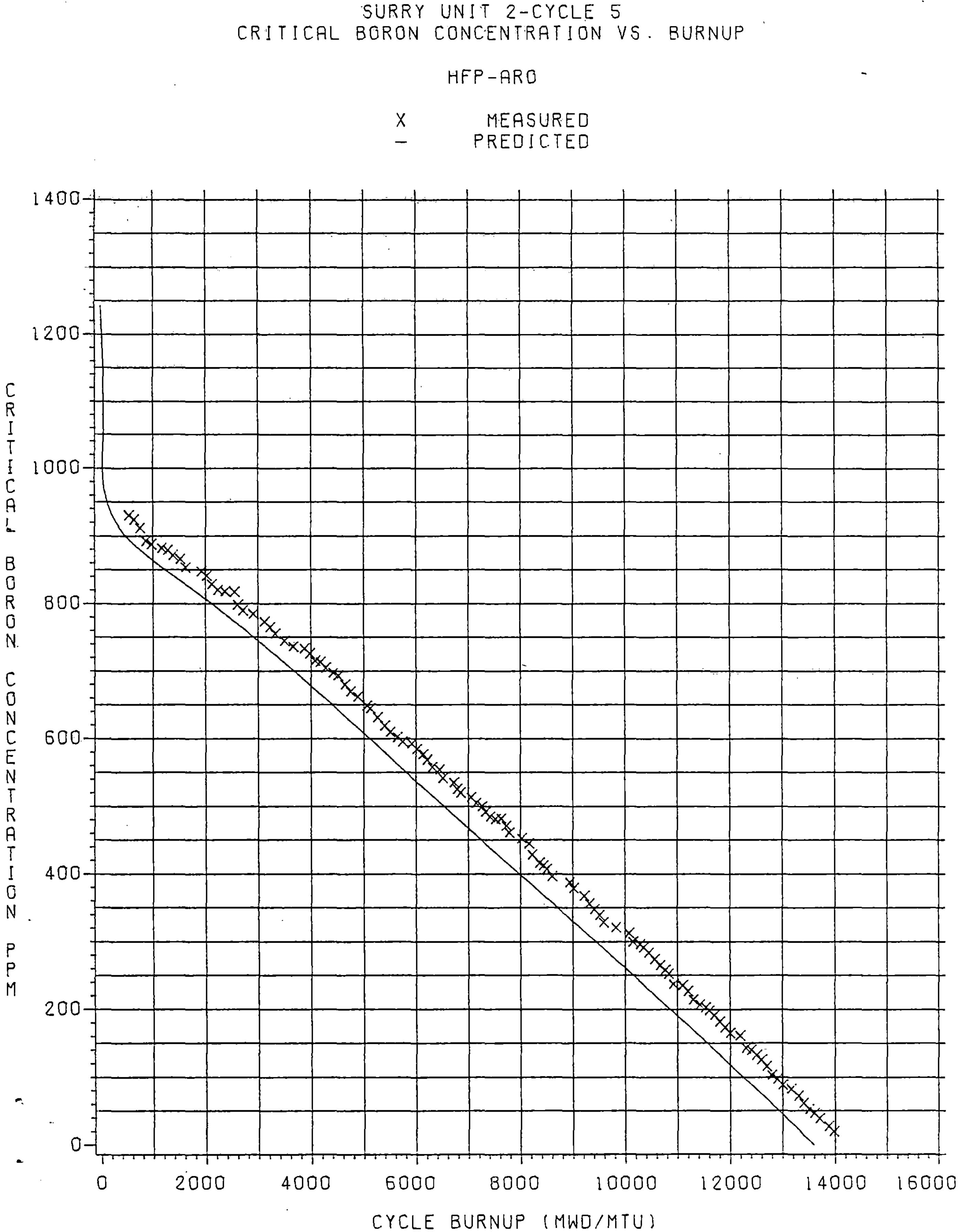
BURNUP SHARING
(10^3 MWD/MTU)

BATCH	CYCLE 2	CYCLE 3	CYCLE 4	CYCLE 5	TOTAL
4B2	7.28	6.61	14.91	13.71	42.51
5A	-	6.79	15.51	11.35	33.65
6A1	-	-	16.03	11.60	27.63
6B	-	-	11.93	14.24	26.17
7A	-	-	-	16.85	16.85
7B	-	-	-	15.25	15.25
CORE AVERAGE				13.97	

BURNUP TILT

NW- 0.9986
NE- 1.0000
SW- 1.0006
SE- 1.0008

FIGURE 3.1


SURRY UNIT 2-CYCLE 5
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 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 2, Cycle 5 core is shown in Figure 3.1. It can be seen that the measured data compare to within 50 ppm of the design prediction. This corresponds to less than ±0.5% delta K/K which is well within the ±1% delta K/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 5 core depleted as expected without any reactivity anomalies.

Section 4

POWER DISTRIBUTION FOLLOW

Analysis of core power distribution data on a routine basis is necessary to verify that the hot channel factors are within the Technical Specifications limits and to ensure that the reactor is operating without any abnormal conditions which could cause an "uneven" burnup distribution. Three-dimensional core power distributions are determined from movable detector flux map measurements using the INCORE[5] computer program. A summary of all monthly flux maps taken since the completion of startup physics testing for Surry 2, Cycle 5 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 5 life. Most of the radial power distributions were taken under equilibrium operating conditions with the unit at approximtely full power. In each case, the measured relative assembly powers were generally within 4% of the predicted values. 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 initial Cycle 5 Technical Specifications limit on the axially dependent heat flux hot channel factor, F-Q(Z), was 2.19 x K(Z), where K(Z) is the hot channel factor normalized operating envelope. On July 28, 1980, the Technical Specifications limit for F-Q(Z) was administratively reduced to 2.18 x K(Z)(6). The formal Technical Specifications implementation of the 2.18 limit for F-Q(Z) occurred with Technical Specifications Amendment No. 70, dated June 16, 1981(7). Figure 4.4 is a plot of the K(Z) curve associated with the 2.18 F-Q(Z) limit. This curve is representative of the K(Z) curves used throughout Cycle 5 since K(Z) changes only slightly with changes in the 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 5, the measured values of F-Q(Z) were within the Technical Specifications limit. A summary of the maximum values of all heat flux hot channel factors measured during Cycle 5 is given in Figure 4.8. As can be seen from this figure, there was approximately 27% margin to the limit at the beginning of the cycle, with the margin approximately constant throughout cycle operation.

The value of the enthalpy rise hot channel factor, F-delta H, which is the ratio of the integral of the power along the rod with the highest integrated power to that of the average rod, is routinely followed. The Technical Specifications limit for this parameter is set such that the critical heat flux (DNB) limit will not be violated. Additionally, the

F-delta H limit ensures that the value of this parameter used in the LOCA-ECCS analysis is not exceeded during normal operation. The Cycle 5 limit on the enthalpy rise hot channel factor was set at 1.55 x (1+0.2(1-P)), where P is the fractional power level. The values of the enthalpy rise hot channel factor parameters F-delta H(LOCA,Assy) and F-delta H(LOCA,Rod) were also routinely followed^{2}. F-delta H(LOCA,Assy) and F-delta H(LOCA,Rod) represent the enthalpy rise hot channel factor (F-delta H) evaluated for the peak assembly and peak rod in the core, respectively, between the 1.5 ft. and 10.5 ft. levels of the core. The full power limits for F-delta H(LOCA,Assy) and F-delta H(LOCA,Rod) were set at 1.476 and 1.550 respectively. Table 4.2 summarizes the F-delta H(LOCA,Assy) and F-delta H(LOCA,Rod) values measured during Cycle 5 operation. Figures 4.9 through 4.11 show that all measured values for F-delta H, F-delta H(LOCA,Assy) and F-delta H(LOCA,Rod) were within their respective Technical Specifications limits during Cycle 5. The necessity for monitoring F-delta H(LOCA,Assy) and F-delta H(LOCA,Rod) was deleted from the Technical Specifications on June 16, 1981 by Technical Specifications Amendment No. 70(7).

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

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*Delta Flux = (Pt-Pb) x 100 / 2441

where: Pt = Power in top of core(MW(th))

Pb = Power in bottom of core (MW(th))

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 4.12, shows the value of this parameter to have been approximately +1% at the beginning of Cycle 5. By the middle of the cycle, the value of delta flux had shifted to approximately -4%, and then returned to approximately -3% by the end of Cycle 5. This power shift can also be observed in the corresponding core average axial power distribution for a representative series of maps given in Figures 4.13 through 4.15. In Map S2-5-13 (Figure 4.13) taken at approximately 450 MWD/MTU, the axial power distribution had a flattened cosine shape with a peaking factor of 1.17. In Map S2-5-24 (Figure 4.14) taken at approximately 6,653 MWD/MTU, the axial power distribution had peaked slightly toward the bottom of the core with an axial peaking factor of 1.13. Finally, in Map S2-5-39 (Figure 4.15) taken at approximately 13,216 MWD/MTU, the axial power distribution remained slightly peaked toward the bottom of the core with an axial peaking factor of 1.13. The history of F-Z during the cycle can be seen more clearly in a plot of F-Z versus burnup given in Figure 4.16.

In conclusion, the Surry 2, Cycle 5 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
SURRRY UNIT 2 - CYCLE 5

SUMMARY OF FLUX MAPS FOR ROUTINE OPERATION

MAP NO.	DATE	BURNUP MWD/MTU	PWR (%)	BANK D STEPS	F-Q(T) HOT CHANNEL FACTOR 1				F-DH(N) HOT CHANNEL FACTOR 2			CORE F(Z) MAX		3 F(XY)	QPTR 4		AXIAL OFF SET (%)	NO. OF THIMBLES
					ASSY	PIN	AXIAL POINT	F-Q(T)	ASSY	PIN	F-DH(N)	AXIAL POINT	F(Z)		MAX	LOC		
13	9-12-80	450	100	215	B06	DE	34	1.716	D07	IH	1.387	23	1.171	1.352	1.0045	SE	+1.130	49
14	9-20-80	720	98	217	H09	HG	34	1.710	H09	HG	1.403	34	1.182	1.344	1.0035	NE	-1.519	42
17(5)	10-17-80	1690	100	217	J08	GH	23	1.709	J08	GH	1.394	23	1.166	1.339	1.0026	NE	+1.026	48
18	11-12-80	2540	100	214	J08	GH	23	1.695	J08	GH	1.402	34	1.158	1.344	1.0040	SE	-0.697	49
19	12-15-80	3660	100	212	D07	IH	21	1.702	J08	GH	1.412	33	1.146	1.356	1.0039	NE	-0.323	49
22(6)	1-14-81	4704	100	215	H09	HG	34	1.693	H09	HG	1.430	44	1.135	1.387	1.0030	SE	-0.753	48
23	2-11-81	5619	100	219	J08	GH	23	1.675	J08	GH	1.424	44	1.129	1.372	1.0030	SE	-0.488	49
24	3-13-81	6653	100	227	L13	MN	44	1.670	J08	GH	1.424	45	1.133	1.372	1.0025	SW	-0.963	47
27(7)	4-15-81	7666	100	225	G08	IH	45	1.691	J08	GH	1.429	45	1.135	1.381	1.0046	SE	-1.725	49
28	5-12-81	8258	100	228	L13	LL	46	1.773	L13	LL	1.451	45	1.144	1.409	1.0023	SW	-2.935	48
29	6-10-81	9230	100	227	J08	EH	46	1.710	J08	EH	1.428	45	1.147	1.383	1.0019	SE	-3.436	46
34(8)	7-19-81	10537	100	214	H09	LJ	47	1.720	J08	DI	1.425	46	1.154	1.377	1.0019	NE	-4.504	44
35	8-12-81	11320	100	220	H09	LJ	47	1.726	H09	LJ	1.424	46	1.147	1.383	1.0013	NW	-4.100	44
36	9-16-81	12210	100	216	F07	DG	46	1.705	F07	DG	1.421	46	1.136	1.372	1.0023	NE	-3.532	45
39(9)	10-15-81	13216	100	220	L13	LL	45	1.676	J06	ID	1.410	53	1.133	1.366	1.0011	NE	-2.808	47

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 OF THE CORE.

4. QPTR - QUADRANT POWER TILT RATIO.

5. MAPS 15 AND 16 WERE PARTIAL MAPS TAKEN FOR I/E CALIBRATION.

6. MAPS 20 AND 21 WERE PARTIAL MAPS TAKEN FOR I/E CALIBRATION.

7. MAPS 25 AND 26 WERE PARTIAL MAPS TAKEN FOR I/E CALIBRATION.

8. MAPS 30 AND 31 WERE PARTIAL MAPS TAKEN FOR I/E CALIBRATION BUT NOT USED.
MAPS 32 AND 33 WERE PARTIAL MAPS TAKEN FOR I/E CALIBRATION.

9. MAPS 37 AND 38 WERE PARTIAL MAPS TAKEN FOR I/E CALIBRATION.

TABLE 4.2

SURRY UNIT 2 - CYCLE 5

SUMMARY TABLE OF LOCA ENTHALPY RISE HOT CHANNEL FACTORS

MAP NUMBER	BURNUP (MWD/MTU)	$F_{\Delta H}^{N}/{}_{ASSY}^{LOCA}$*	LOCATION	$F_{\Delta H}^{N}/{}_{ROD}^{LOCA}$*	ASSEMBLY	PIN
S2-5-13	∿450	1.279	F-10	1.392	B-6	DE
S2-5-14	∿720	1.282	F-10	1.395	H-9	HG
S2-5-17	∿1690	1.263	F-10	1.393	H-9	HG
S2-5-18	∿2540	1.276	J-8	1.400	J-8	GH
S2-5-19	∿3660	1.299	J-8	1.409	J-8	GH
S2-5-22	∿4704	1.332	H-9	1.433	H-9	HG
S2-5-23	∿5619	1.334	J-8	1.425	J-8	GH
S2-5-24	∿6653	1.345	J-8	1.425	J-8	GH
S2-5-27	∿7666	1.357	J-8	1.434	J-8	GH
S2-5-28	∿8258	1.314	J-8	1.412	L-13	LL
S2-5-29#	∿9230	1.372	J-8	1.434	J-8	EH

*$F_{\Delta H}^{N}/{}_{ASSY}^{LOCA}$ and $F_{\Delta H}^{N}/{}_{ROD}^{LOCA}$ are measured between 1.5 feet and 10.5 feet of the core elevation and include an uncertainty of 1.04.

#The monitoring of $F_{\Delta H}^{N}/{}_{ASSY}^{LOCA}$ and $F_{\Delta H}^{N}/{}_{ROD}^{LOCA}$ was discontinued by Technical Specification Amendment No. 70, dated June 16, 1981.

FIGURE 4.1

SURRY UNIT 2 - CYCLE 5

ASSEMBLYWISE POWER DISTRIBUTION

S2-5-13

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

        ................                  ......................                 ................
        .  PREDICTED   .                  . 0.43 . 0.75 . 0.43 .                 .  PREDICTED   .
        .  MEASURED    .                  . 0.43 . 0.75 . 0.42 .                 .  MEASURED    .             1
        .PCT DIFFERENCE.                  .  0.1 .  0.1 . -0.4 .                 .PCT DIFFERENCE.
        ................    ..................................................   ................
                            . 0.42 . 0.93 . 1.04 . 1.11 . 1.04 . 0.93 . 0.42 .
                            . 0.41 . 0.93 . 1.04 . 1.10 . 1.03 . 0.92 . 0.41 .                                2
                            . -0.2 . -0.6 . -0.7 . -0.8 . -1.0 . -1.3 . -0.7 .
                     ................................................................
                     . 0.56 . 1.01 . 1.14 . 1.18 . 1.18 . 1.18 . 1.14 . 1.01 . 0.56 .
                     . 0.56 . 1.01 . 1.13 . 1.17 . 1.16 . 1.16 . 1.12 . 1.00 . 0.56 .                         3
                     . -0.2 . -0.1 . -0.3 . -0.8 . -1.6 . -1.4 . -1.1 . -0.6 .  0.1 .
              ..............................................................................
              . 0.56 . 0.91 . 1.14 . 1.16 . 1.19 . 1.09 . 1.19 . 1.16 . 1.14 . 0.91 . 0.56 .
              . 0.56 . 0.90 . 1.13 . 1.15 . 1.17 . 1.08 . 1.17 . 1.15 . 1.13 . 0.91 . 0.57 .                  4
              .  0.4 . -0.5 . -0.4 . -1.1 . -1.3 . -1.5 . -1.4 . -0.9 . -0.4 .  0.2 .  2.7 .
       ............................................................................................
       . 0.42 . 1.01 . 1.14 . 1.23 . 1.03 . 1.04 . 1.20 . 1.04 . 1.03 . 1.23 . 1.14 . 1.01 . 0.42 .
       . 0.42 . 1.02 . 1.13 . 1.20 . 1.01 . 1.02 . 1.18 . 1.02 . 1.01 . 1.21 . 1.15 . 1.05 . 0.44 .           5
       .  0.9 .  0.9 . -0.7 . -2.3 . -1.4 . -1.5 . -1.5 . -1.5 . -1.6 . -1.1 .  0.9 .  4.0 .  6.3 .
       ............................................................................................
       . 0.93 . 1.14 . 1.16 . 1.03 . 1.23 . 1.21 . 1.12 . 1.21 . 1.23 . 1.03 . 1.16 . 1.14 . 0.93 .
       . 0.94 . 1.14 . 1.15 . 1.02 . 1.21 . 1.19 . 1.11 . 1.19 . 1.19 . 1.02 . 1.17 . 1.17 . 0.98 .           6
       .  0.3 .  0.3 . -0.6 . -0.6 . -1.1 . -1.0 . -1.2 . -1.2 . -2.5 . -0.5 .  0.8 .  3.4 .  5.3 .
..........................................................................................................
. 0.43 . 1.04 . 1.18 . 1.19 . 1.04 . 1.21 . 1.11 . 1.18 . 1.11 . 1.21 . 1.04 . 1.19 . 1.18 . 1.04 . 0.43 .
. 0.43 . 1.05 . 1.18 . 1.18 . 1.02 . 1.19 . 1.11 . 1.17 . 1.11 . 1.19 . 1.04 . 1.21 . 1.20 . 1.08 . 0.44 .    7
.  1.8 .  0.5 . -0.2 . -0.7 . -1.6 . -0.9 . -0.2 . -0.4 . -0.2 . -1.2 .  0.2 .  1.7 .  1.8 .  3.1 .  2.7 .
..........................................................................................................
. 0.75 . 1.11 . 1.18 . 1.09 . 1.20 . 1.12 . 1.18 . 0.91 . 1.18 . 1.12 . 1.20 . 1.09 . 1.18 . 1.11 . 0.75 .
. 0.76 . 1.11 . 1.18 . 1.08 . 1.17 . 1.11 . 1.18 . 0.92 . 1.18 . 1.12 . 1.20 . 1.11 . 1.19 . 1.12 . 0.78 .    8
.  1.8 .  0.6 .  0.3 . -0.8 . -2.6 . -1.3 . -0.1 .  0.2 .  0.1 . -0.1 .  0.5 .  1.0 .  0.7 .  1.4 .  4.0 .
..........................................................................................................
. 0.43 . 1.04 . 1.18 . 1.19 . 1.04 . 1.21 . 1.11 . 1.18 . 1.11 . 1.21 . 1.04 . 1.19 . 1.18 . 1.04 . 0.43 .
. 0.43 . 1.06 . 1.20 . 1.19 . 1.04 . 1.19 . 1.09 . 1.18 . 1.11 . 1.20 . 1.03 . 1.18 . 1.18 . 1.07 . 0.45 .    9
.  1.8 .  1.6 .  1.5 .  0.1 . -0.3 . -1.2 . -1.6 . -0.3 .  0.4 . -0.6 . -0.9 . -0.6 .  0.3 .  2.7 .  6.3 .
..........................................................................................................
       . 0.93 . 1.14 . 1.16 . 1.03 . 1.23 . 1.21 . 1.12 . 1.21 . 1.23 . 1.03 . 1.16 . 1.14 . 0.93 .
       . 0.96 . 1.16 . 1.16 . 1.01 . 1.20 . 1.18 . 1.10 . 1.19 . 1.22 . 1.02 . 1.15 . 1.13 . 0.95 .           10
       .  2.5 .  2.5 .  0.1 . -1.7 . -1.7 . -1.8 . -2.0 . -0.9 . -0.5 . -0.8 . -1.2 . -0.1 .  1.7 .
       ............................................................................................
       . 0.42 . 1.01 . 1.14 . 1.23 . 1.03 . 1.04 . 1.20 . 1.04 . 1.03 . 1.23 . 1.14 . 1.01 . 0.42 .
       . 0.43 . 1.03 . 1.14 . 1.18 . 1.00 . 1.02 . 1.15 . 1.02 . 1.02 . 1.22 . 1.15 . 1.02 . 0.42 .           11
       .  2.3 .  2.3 . -0.2 . -3.5 . -2.3 . -2.3 . -3.6 . -2.1 . -0.3 . -0.6 .  0.5 .  1.2 .  1.3 .
       ............................................................................................
              . 0.56 . 0.91 . 1.14 . 1.16 . 1.19 . 1.09 . 1.19 . 1.16 . 1.14 . 0.91 . 0.56 .
              . 0.57 . 0.91 . 1.10 . 1.14 . 1.17 . 1.06 . 1.18 . 1.17 . 1.15 . 0.93 . 0.57 .                  12
              .  2.2 . -0.1 . -3.5 . -2.1 . -1.6 . -2.7 . -0.9 .  1.0 .  1.2 .  2.5 .  1.8 .
              ..............................................................................
                     . 0.56 . 1.01 . 1.14 . 1.18 . 1.18 . 1.18 . 1.14 . 1.01 . 0.56 .
                     . 0.57 . 1.04 . 1.15 . 1.16 . 1.15 . 1.19 . 1.17 . 1.04 . 0.57 .                         13
                     .  2.9 .  3.7 .  1.3 . -2.0 . -2.4 .  0.4 .  3.0 .  3.1 .  2.5 .
                     ................................................................
                            . 0.42 . 0.93 . 1.04 . 1.11 . 1.04 . 0.93 . 0.42 .
                            . 0.43 . 0.97 . 1.06 . 1.11 . 1.05 . 0.95 . 0.43 .                                14
                            .  3.7 .  4.1 .  1.6 .  0.1 .  0.6 .  2.0 .  3.2 .
        ................    ..................................................   ................
        .   STANDARD   .                  . 0.43 . 0.75 . 0.43 .                 .    AVERAGE   .
        .  DEVIATION   .                  . 0.45 . 0.77 . 0.43 .                 .PCT DIFFERENCE.             15
        .   =1.226     .                  .  4.4 .  2.9 .  0.6 .                 .     = 1.4    .
        ................                  ......................                 ................
```

SUMMARY

```
MAP NO: S2-5-13          DATE:  9/12/80           POWER:  100%

CONTROL ROD POSITIONS:   F-Q(T)  = 1.716          QPTR:

D BANK AT 215 STEPS      F-DH(N) = 1.387          NW  0.995 | NE  1.002
                                                  ----------|----------
                         F(Z)    = 1.171          SW  0.998 | SE  1.005

                         F(XY)   = 1.352

                         BURNUP  =    450 MWD/MTU    A.O =  1.13(%)
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SURRY UNIT 2 - CYCLE 5

ASSEMBLYWISE POWER DISTRIBUTION

S2 - 5 - 24

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

        ................                        .........................                       ................
        .  PREDICTED   .                        .  0.43 .  0.72 .  0.43 .                       .  PREDICTED   .
        .  MEASURED    .                        .  0.43 .  0.72 .  0.43 .                       .  MEASURED    .        1
        .PCT DIFFERENCE.                        .  -0.8 .  -0.8 .  -0.6 .                       .PCT DIFFERENCE.
        ................        .........................................................       ................
                                .  0.44 .  0.92 .  1.04 .  1.04 .  1.04 .  0.92 .  0.44 .
                                .  0.44 .  0.93 .  1.04 .  1.02 .  1.03 .  0.92 .  0.44 .                                       2
                                .   0.8 .   0.7 .  -0.7 .  -1.1 .  -1.1 .  -0.3 .   0.5 .
                        .........................................................................
                        .  0.58 .  1.06 .  1.20 .  1.12 .  1.09 .  1.12 .  1.20 .  1.06 .  0.58 .
                        .  0.59 .  1.05 .  1.19 .  1.12 .  1.07 .  1.11 .  1.19 .  1.06 .  0.59 .                               3
                        .   0.5 .  -0.5 .  -0.3 .   0.2 .  -2.0 .  -1.3 .  -0.6 .   0.4 .   1.8 .
                ..........................................................................................
                .  0.58 .  0.91 .  1.19 .  1.13 .  1.22 .  1.04 .  1.22 .  1.13 .  1.19 .  0.91 .  0.58 .
                .  0.59 .  0.91 .  1.17 .  1.12 .  1.22 .  1.04 .  1.21 .  1.12 .  1.19 .  0.92 .  0.60 .                       4
                .   0.5 .  -0.6 .  -1.6 .  -0.9 .  -0.5 .  -0.7 .  -1.2 .  -0.8 .   0.1 .   0.8 .   2.4 .
        .........................................................................................................
        .  0.44 .  1.06 .  1.19 .  1.16 .  0.98 .  1.01 .  1.15 .  1.01 .  0.98 .  1.16 .  1.19 .  1.06 .  0.44 .
        .  0.44 .  1.06 .  1.18 .  1.14 .  0.97 .  1.01 .  1.14 .  1.00 .  0.97 .  1.15 .  1.19 .  1.09 .  0.46 .               5
        .   0.3 .   0.3 .  -0.8 .  -1.5 .  -1.0 .  -0.3 .  -0.4 .  -0.9 .  -1.1 .  -0.4 .   0.4 .   2.7 .   4.9 .
        .........................................................................................................
        .  0.92 .  1.20 .  1.13 .  0.98 .  1.18 .  1.27 .  1.11 .  1.27 .  1.18 .  0.98 .  1.13 .  1.20 .  0.92 .
        .  0.92 .  1.20 .  1.13 .  0.98 .  1.18 .  1.28 .  1.11 .  1.27 .  1.16 .  0.97 .  1.12 .  1.21 .  0.95 .               6
        .   0.3 .   0.3 .  -0.3 .  -0.3 .  -0.2 .   0.2 .  -0.1 .  -0.5 .  -1.6 .  -0.9 .  -0.4 .   1.2 .   2.8 .
.........................................................................................................................
.  0.43 .  1.04 .  1.12 .  1.22 .  1.01 .  1.27 .  1.13 .  1.28 .  1.13 .  1.27 .  1.01 .  1.22 .  1.12 .  1.04 .  0.43 .
.  0.42 .  1.04 .  1.12 .  1.21 .  0.99 .  1.27 .  1.14 .  1.28 .  1.13 .  1.26 .  1.00 .  1.21 .  1.12 .  1.05 .  0.43 .       7
.  -1.0 .  -0.3 .   0.2 .  -0.8 .  -1.8 .  -0.4 .   1.2 .   0.6 .   0.3 .  -0.7 .  -1.6 .  -1.3 .  -0.5 .   0.6 .   0.8 .
.........................................................................................................................
.  0.72 .  1.04 .  1.09 .  1.04 .  1.15 .  1.11 .  1.28 .  0.98 .  1.28 .  1.11 .  1.15 .  1.04 .  1.09 .  1.04 .  0.72 .
.  0.71 .  1.03 .  1.09 .  1.03 .  1.11 .  1.10 .  1.29 .  0.99 .  1.28 .  1.11 .  1.13 .  1.03 .  1.08 .  1.05 .  0.75 .       8
.  -1.0 .  -0.5 .  -0.3 .  -1.1 .  -3.0 .  -1.1 .   1.3 .   1.4 .   0.5 .  -0.1 .  -1.7 .  -1.2 .  -1.0 .   1.3 .   3.8 .
.........................................................................................................................
.  0.43 .  1.04 .  1.12 .  1.22 .  1.01 .  1.27 .  1.13 .  1.28 .  1.13 .  1.27 .  1.01 .  1.22 .  1.12 .  1.04 .  0.43 .
.  0.42 .  1.04 .  1.12 .  1.22 .  1.01 .  1.26 .  1.11 .  1.28 .  1.15 .  1.25 .  1.00 .  1.22 .  1.11 .  1.06 .  0.45 .       9
.  -1.0 .  -0.2 .   0.2 .  -0.6 .  -0.3 .  -1.4 .  -1.9 .   0.6 .   1.5 .  -1.5 .  -1.4 .  -0.7 .  -0.9 .   1.5 .   5.0 .
.........................................................................................................................
        .  0.92 .  1.20 .  1.13 .  0.98 .  1.18 .  1.27 .  1.11 .  1.27 .  1.18 .  0.98 .  1.13 .  1.20 .  0.92 .
        .  0.93 .  1.21 .  1.14 .  0.99 .  1.17 .  1.25 .  1.10 .  1.27 .  1.17 .  0.98 .  1.12 .  1.19 .  0.92 .               10
        .   0.9 .   0.9 .   0.7 .   0.3 .  -1.0 .  -2.0 .  -1.2 .  -0.5 .  -0.5 .  -0.8 .  -0.4 .  -0.7 .  -0.3 .
        .........................................................................................................
        .  0.44 .  1.06 .  1.19 .  1.16 .  0.98 .  1.01 .  1.15 .  1.01 .  0.98 .  1.16 .  1.19 .  1.06 .  0.44 .
        .  0.45 .  1.07 .  1.20 .  1.16 .  0.97 .  0.99 .  1.12 .  1.00 .  0.98 .  1.15 .  1.20 .  1.07 .  0.44 .               11
        .   1.5 .   1.5 .   1.5 .   0.3 .  -1.9 .  -2.1 .  -2.6 .  -1.6 .  -0.6 .  -0.3 .   1.0 .   1.3 .   0.7 .
        .........................................................................................................
                .  0.58 .  0.91 .  1.19 .  1.13 .  1.22 .  1.04 .  1.22 .  1.13 .  1.19 .  0.91 .  0.58 .
                .  0.59 .  0.93 .  1.24 .  1.11 .  1.20 .  1.02 .  1.20 .  1.13 .  1.19 .  0.93 .  0.60 .                       12
                .   2.1 .   2.1 .   4.5 .  -1.8 .  -2.1 .  -2.7 .  -1.6 .  -0.1 .   0.5 .   2.1 .   3.2 .
                ..........................................................................................
                        .  0.58 .  1.06 .  1.20 .  1.12 .  1.09 .  1.12 .  1.20 .  1.06 .  0.58 .
                        .  0.60 .  1.11 .  1.21 .  1.09 .  1.06 .  1.11 .  1.20 .  1.07 .  0.60 .                               13
                        .   3.3 .   4.5 .   1.3 .  -2.7 .  -3.1 .  -0.9 .   0.6 .   1.2 .   2.6 .
                        .........................................................................
                                .  0.44 .  0.92 .  1.04 .  1.04 .  1.04 .  0.92 .  0.44 .
                                .  0.46 .  0.96 .  1.06 .  1.04 .  1.04 .  0.93 .  0.44 .                                       14
                                .   4.5 .   4.6 .   1.5 .  -0.0 .   0.1 .   0.5 .   0.6 .
        ................        .........................................................       ................
        .  STANDARD    .                        .  0.43 .  0.72 .  0.43 .                       .    AVERAGE   .
        .  DEVIATION   .                        .  0.45 .  0.74 .  0.43 .                       .PCT DIFFERENCE.        15
        .   =1.078     .                        .   4.8 .   3.1 .   0.6 .                       .    = 1.2     .
        ................                        .........................                       ................
```

SUMMARY

```
MAP NO: S2-5-24            DATE:  3/13/81              POWER:  100%

CONTROL ROD POSITIONS:     F-Q(T)  = 1.670             QPTR:

D BANK AT 227 STEPS        F-DH(N) = 1.424             NW  .0997 | NE  1.000
                                                       ----------|----------
                           F(Z)    = 1.133             SW  1.002 | SE  1.001

                           F(XY)   = 1.372

                           BURNUP  =  6653 MWD/MTU    A.O =  -0.96(%)
```

FIGURE 4.3

SURRY UNIT 2 - CYCLE 5

ASSEMBLYWISE POWER DISTRIBUTION

S2-5-39

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

       ................                   ......................                    ................
       .  PREDICTED   .                   . 0.45 . 0.73 . 0.45 .                    .  PREDICTED   .
       .  MEASURED    .                   . 0.45 . 0.73 . 0.45 .                    .  MEASURED    .
       .PCT DIFFERENCE.                   .  0.1 .  0.1 .  0.2 .                    .PCT DIFFERENCE.
       ................     ..................................................      ................
                            . 0.47 . 0.92 . 1.06 . 1.01 . 1.06 . 0.92 . 0.47 .
                            . 0.48 . 0.92 . 1.05 . 1.00 . 1.05 . 0.93 . 0.47 .
                            .  1.9 .  0.1 . -0.7 . -1.0 . -0.6 .  0.3 .  0.2 .
                     ................................................................
                     . 0.61 . 1.09 . 1.24 . 1.10 . 1.06 . 1.10 . 1.24 . 1.09 . 0.61 .
                     . 0.62 . 1.10 . 1.24 . 1.10 . 1.03 . 1.09 . 1.24 . 1.09 . 0.61 .
                     .  1.7 .  1.0 .  0.1 . -0.3 . -2.2 . -1.0 .  0.2 .  0.2 .  0.1 .
              ..............................................................................
              . 0.61 . 0.92 . 1.20 . 1.11 . 1.25 . 1.02 . 1.25 . 1.11 . 1.20 . 0.92 . 0.61 .
              . 0.61 . 0.93 . 1.21 . 1.11 . 1.24 . 1.02 . 1.23 . 1.11 . 1.20 . 0.92 . 0.62 .
              . -0.3 .  0.1 .  0.2 . -0.1 . -0.6 . -0.9 . -1.0 . -0.0 . -0.3 . -0.4 .  1.6 .
       ............................................................................................
       . 0.47 . 1.09 . 1.20 . 1.12 . 0.96 . 0.99 . 1.10 . 0.99 . 0.96 . 1.12 . 1.20 . 1.09 . 0.47 .
       . 0.46 . 1.07 . 1.19 . 1.11 . 0.96 . 1.00 . 1.10 . 0.99 . 0.96 . 1.11 . 1.19 . 1.12 . 0.49 .
       . -1.8 . -1.8 . -0.7 . -0.6 . -0.1 .  0.2 .  0.2 . -0.0 . -0.4 . -0.6 . -0.8 .  2.4 .  5.7 .
       ............................................................................................
       . 0.92 . 1.24 . 1.11 . 0.96 . 1.13 . 1.28 . 1.08 . 1.28 . 1.13 . 0.96 . 1.11 . 1.24 . 0.92 .
       . 0.91 . 1.23 . 1.11 . 0.96 . 1.13 . 1.29 . 1.09 . 1.29 . 1.12 . 0.95 . 1.10 . 1.25 . 0.95 .
       . -0.9 . -0.9 . -0.4 .  0.3 .  0.5 .  1.2 .  1.2 .  0.9 . -0.5 . -0.8 . -1.0 .  0.8 .  2.8 .
..........................................................................................................
. 0.45 . 1.06 . 1.10 . 1.25 . 0.99 . 1.28 . 1.11 . 1.27 . 1.11 . 1.28 . 0.99 . 1.25 . 1.10 . 1.06 . 0.45 .
. 0.45 . 1.06 . 1.10 . 1.24 . 0.99 . 1.28 . 1.13 . 1.29 . 1.12 . 1.29 . 0.98 . 1.23 . 1.09 . 1.06 . 0.45 .
. -1.1 . -0.5 . -0.1 . -0.6 . -1.0 .  0.4 .  2.1 .  1.8 .  1.7 .  0.8 . -1.0 . -1.4 . -0.7 . -0.1 .  0.0 .
..........................................................................................................
. 0.73 . 1.01 . 1.06 . 1.02 . 1.10 . 1.03 . 1.27 . 0.98 . 1.27 . 1.03 . 1.10 . 1.02 . 1.06 . 1.01 . 0.73 .
. 0.72 . 1.00 . 1.05 . 1.02 . 1.08 . 1.03 . 1.30 . 1.00 . 1.29 . 1.09 . 1.08 . 1.01 . 1.04 . 1.01 . 0.74 .
. -1.1 . -0.7 . -0.1 . -0.7 . -1.9 . -0.1 .  2.2 .  2.4 .  1.3 .  0.5 . -1.7 . -1.3 . -1.0 .  0.1 .  2.2 .
..........................................................................................................
. 0.45 . 1.06 . 1.10 . 1.25 . 0.99 . 1.28 . 1.11 . 1.27 . 1.11 . 1.28 . 0.99 . 1.25 . 1.10 . 1.06 . 0.45 .
. 0.45 . 1.05 . 1.09 . 1.24 . 1.00 . 1.27 . 1.08 . 1.28 . 1.13 . 1.26 . 0.98 . 1.23 . 1.09 . 1.08 . 0.47 .
. -1.1 . -1.0 . -1.0 . -0.5 .  0.7 . -0.9 . -2.7 .  0.7 .  2.1 . -1.4 . -1.6 . -1.1 . -0.6 .  1.4 .  4.8 .
..........................................................................................................
       . 0.92 . 1.24 . 1.11 . 0.96 . 1.13 . 1.28 . 1.08 . 1.28 . 1.13 . 0.96 . 1.11 . 1.24 . 0.92 .
       . 0.91 . 1.22 . 1.11 . 0.96 . 1.11 . 1.24 . 1.08 . 1.29 . 1.13 . 0.96 . 1.10 . 1.23 . 0.93 .
       . -1.1 . -1.1 . -0.5 . -0.1 . -1.2 . -2.7 . -0.5 .  1.2 .  0.5 . -0.2 . -0.8 . -0.6 .  0.4 .
       ............................................................................................
       . 0.47 . 1.09 . 1.20 . 1.12 . 0.96 . 0.99 . 1.10 . 0.99 . 0.96 . 1.12 . 1.20 . 1.09 . 0.47 .
       . 0.47 . 1.10 . 1.20 . 1.10 . 0.94 . 0.97 . 1.07 . 1.01 . 0.98 . 1.12 . 1.21 . 1.10 . 0.47 .
       .  0.9 .  0.9 . -0.1 . -1.4 . -2.1 . -2.7 . -2.7 .  2.0 .  1.8 .  0.5 .  0.6 .  0.8 .  0.8 .
       ............................................................................................
              . 0.61 . 0.92 . 1.20 . 1.11 . 1.25 . 1.02 . 1.25 . 1.11 . 1.20 . 0.92 . 0.61 .
              . 0.63 . 0.94 . 1.19 . 1.09 . 1.21 . 0.99 . 1.24 . 1.12 . 1.21 . 0.94 . 0.62 .
              .  2.8 .  1.2 . -1.4 . -2.2 . -2.3 . -3.1 . -0.3 .  0.5 .  0.7 .  1.4 .  2.2 .
              ..............................................................................
                     . 0.61 . 1.09 . 1.24 . 1.10 . 1.06 . 1.10 . 1.24 . 1.09 . 0.61 .
                     . 0.64 . 1.15 . 1.26 . 1.07 . 1.02 . 1.08 . 1.23 . 1.09 . 0.62 .
                     .  4.3 .  5.9 .  1.6 . -3.1 . -3.1 . -1.7 . -1.0 . -0.1 .  1.7 .
                     ................................................................
                            . 0.47 . 0.92 . 1.06 . 1.01 . 1.06 . 0.92 . 0.47 .
                            . 0.49 . 0.98 . 1.09 . 1.01 . 1.05 . 0.91 . 0.46 .
                            .  5.9 .  5.9 .  2.3 . -0.1 . -0.9 . -0.8 . -1.0 .
       ................     ..................................................      ................
       .   STANDARD   .                   . 0.45 . 0.73 . 0.45 .                    .    AVERAGE   .
       .  DEVIATION   .                   . 0.48 . 0.75 . 0.45 .                    .PCT DIFFERENCE.
       .   =1.222     .                   .  6.0 .  3.4 . -0.6 .                    .    = 1.2     .
       ................                   ......................                    ................
```

SUMMARY

```
MAP NO: S2-5-39             DATE: 10/15/81           POWER:  100%

CONTROL ROD POSITIONS:      F-Q(T)   = 1.676         QPTR:

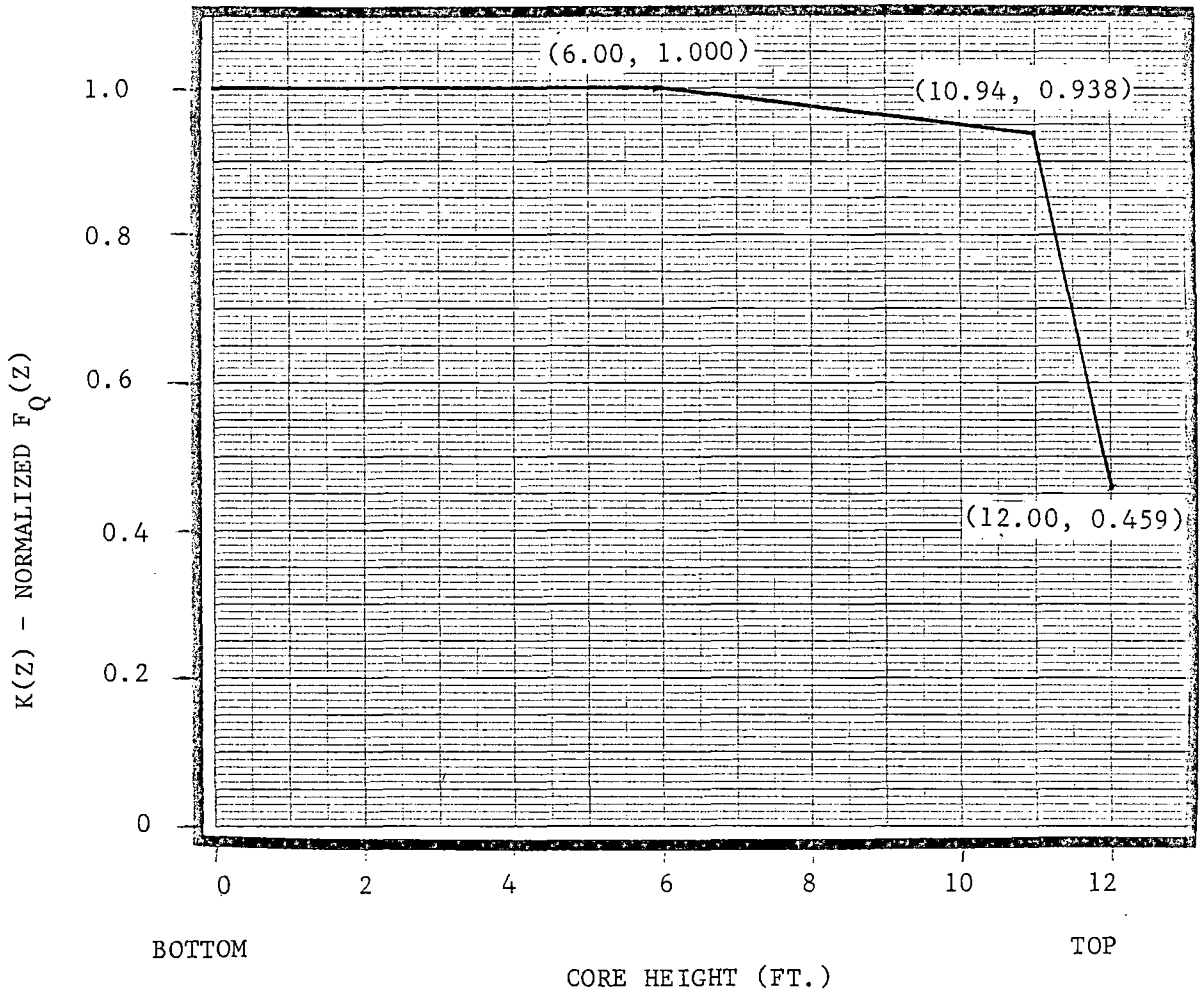
D BANK AT 220 STEPS         F-DH(N)  = 1.410         NW    0.999 | NE  1.001
                                                     ------------|----------
                            F(Z)     = 1.133         SW    0.999 | SE  1.001

                            F(XY)    = 1.366

                            BURNUP   = 13216 MWD/MTU   A.O =   -2.81(%)
```

HOT CHANNEL FACTOR NORMALIZED

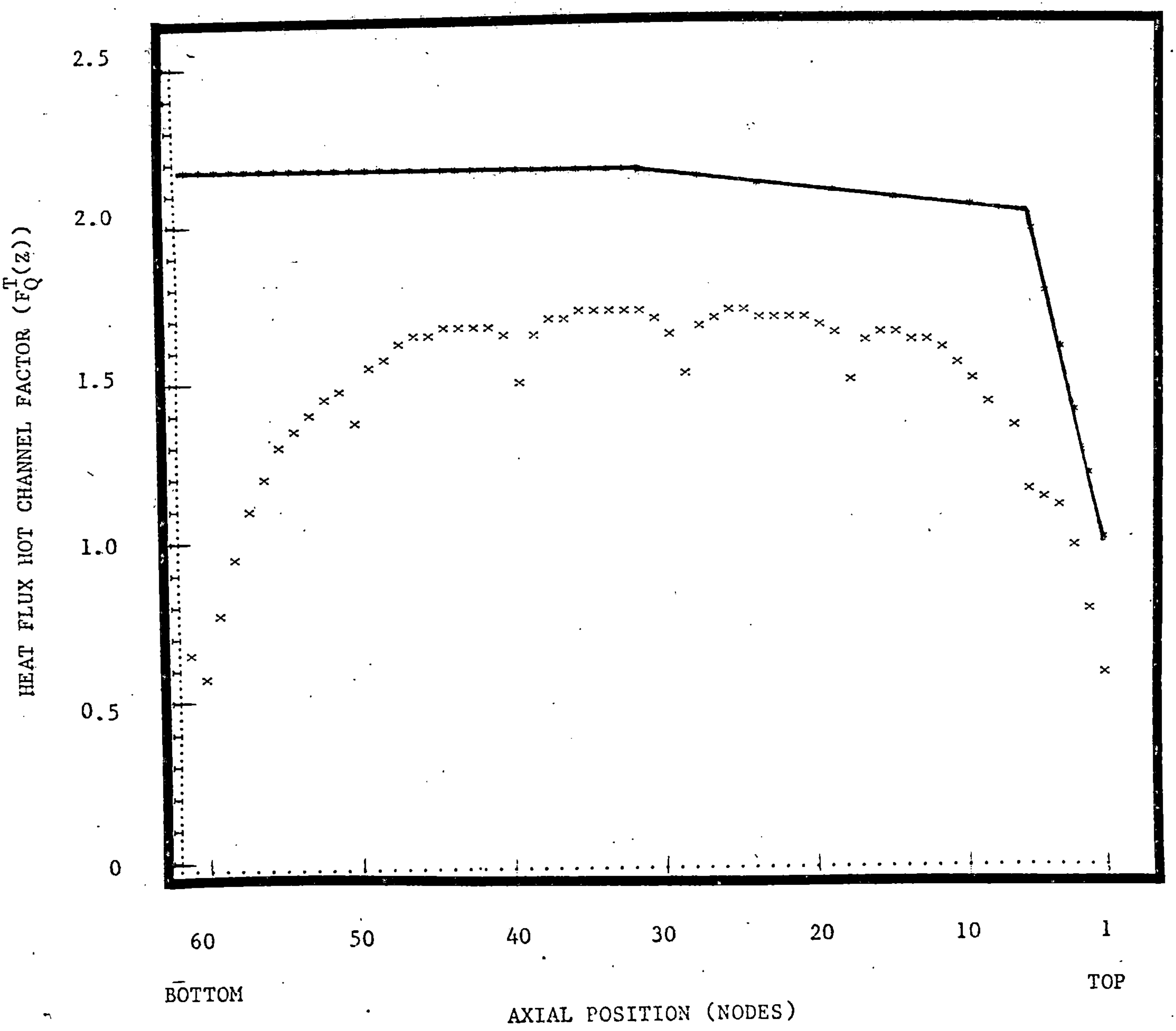
OPERATING ENVELOPE



SURRY UNIT 2 - CYCLE 5

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

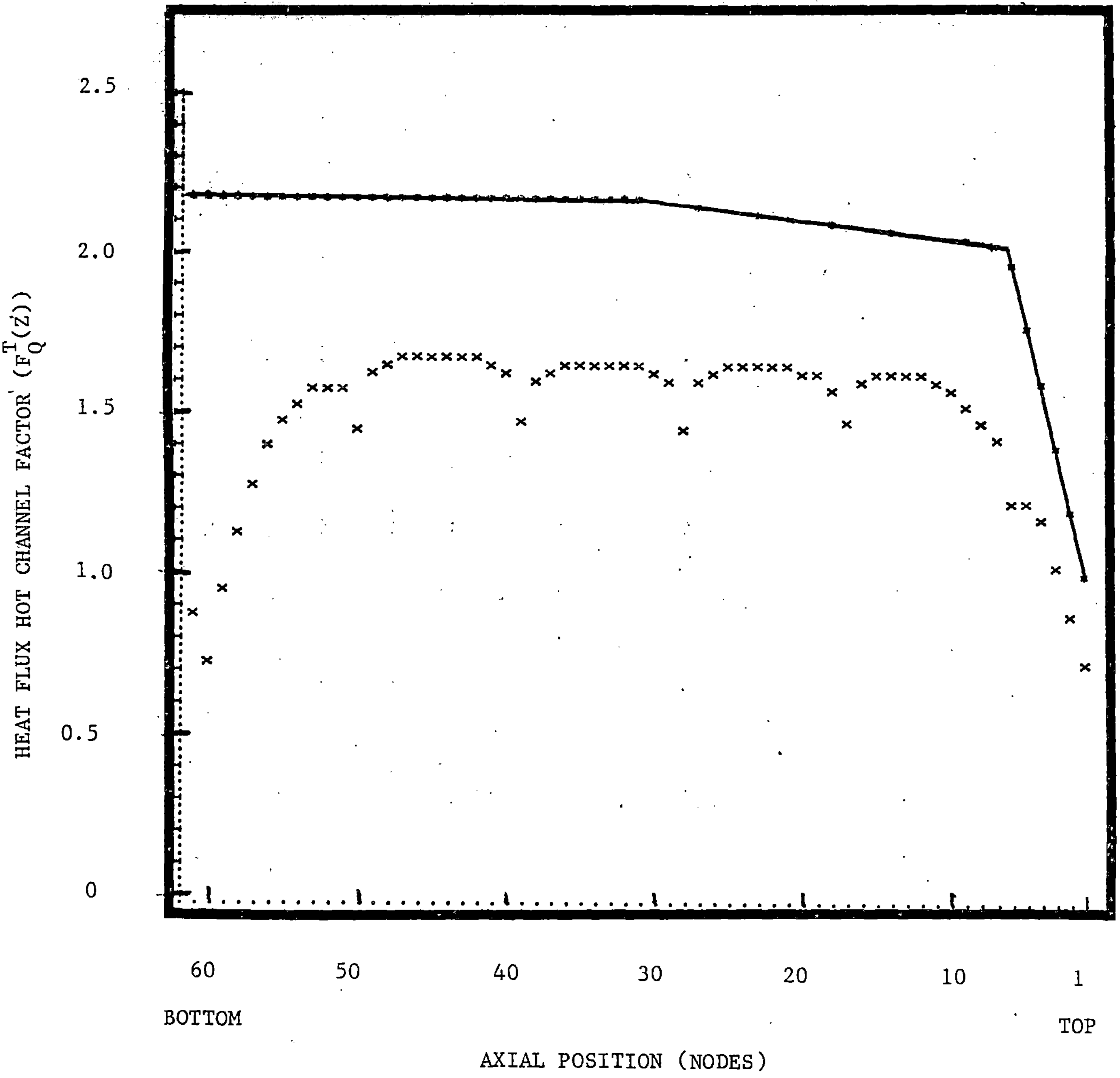
S2 - 5 - 13



SURRY UNIT 2 - CYCLE 5

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

S2 - 5 - 24



SURRY UNIT 2 - CYCLE 5

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

S2 - 5 - 39

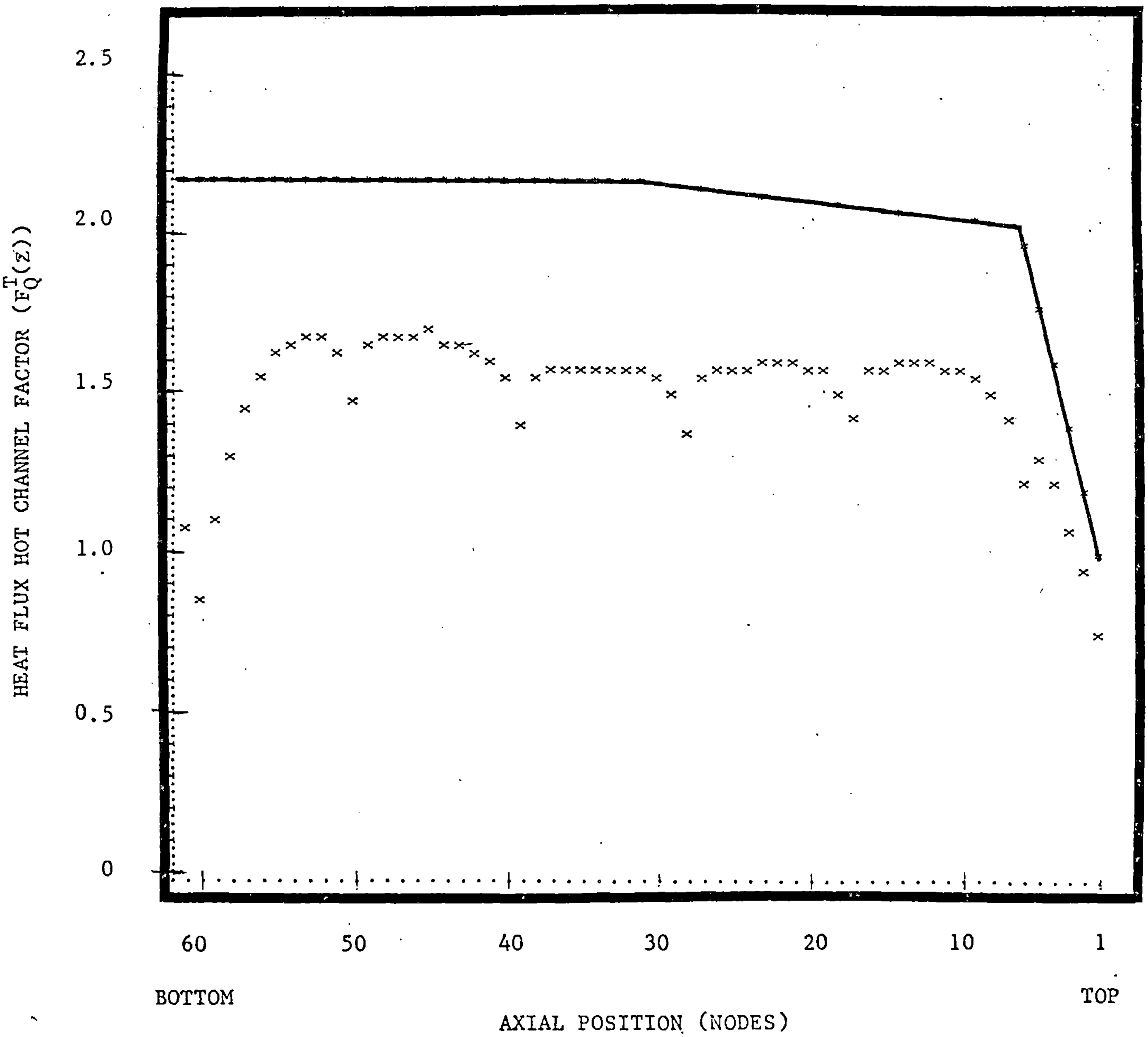


FIGURE 4.8

SURRY 2 CYCLE 5
MAXIMUM HEAT FLUX HOT CHANNEL FACTOR
VS
BURNUP

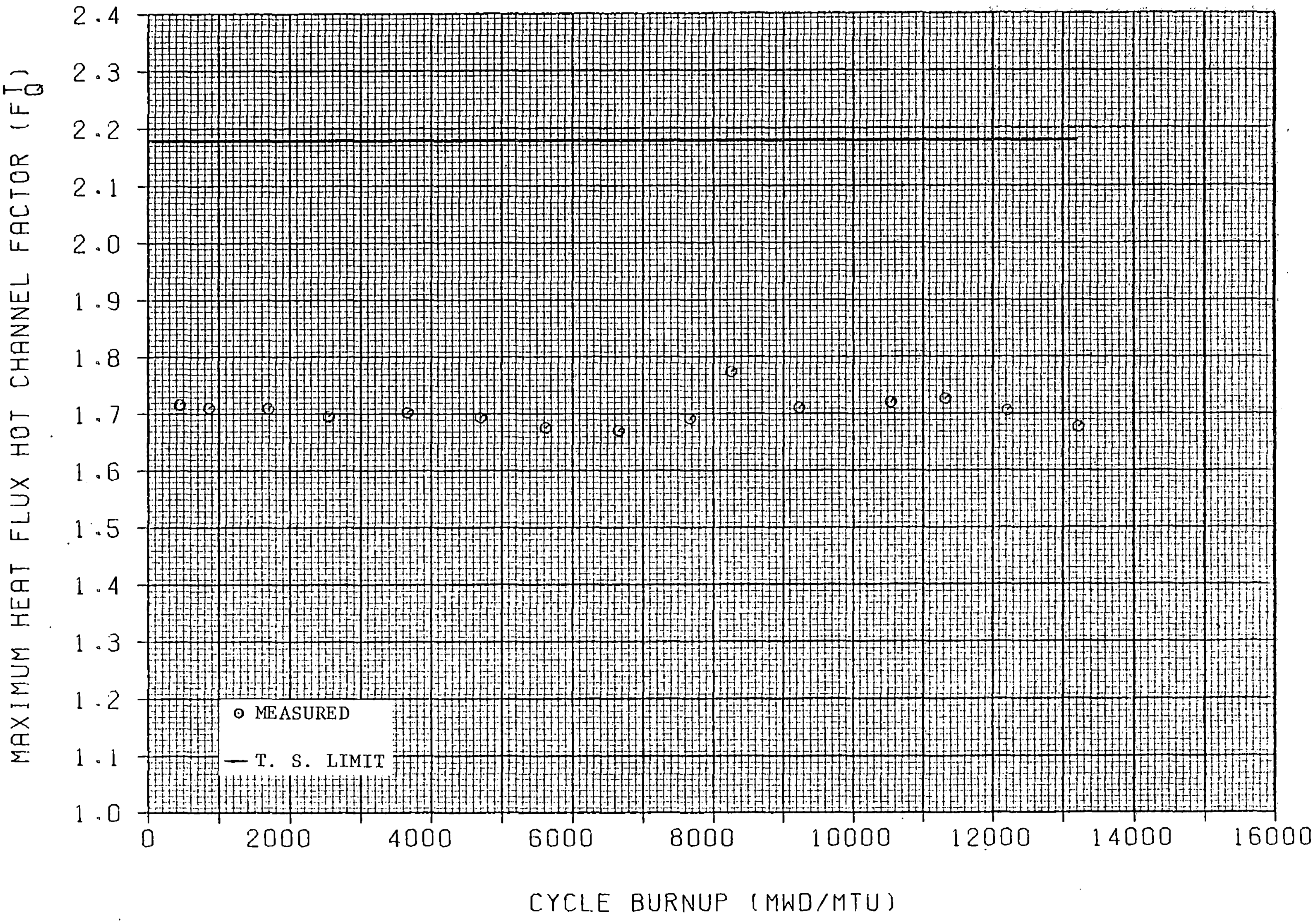
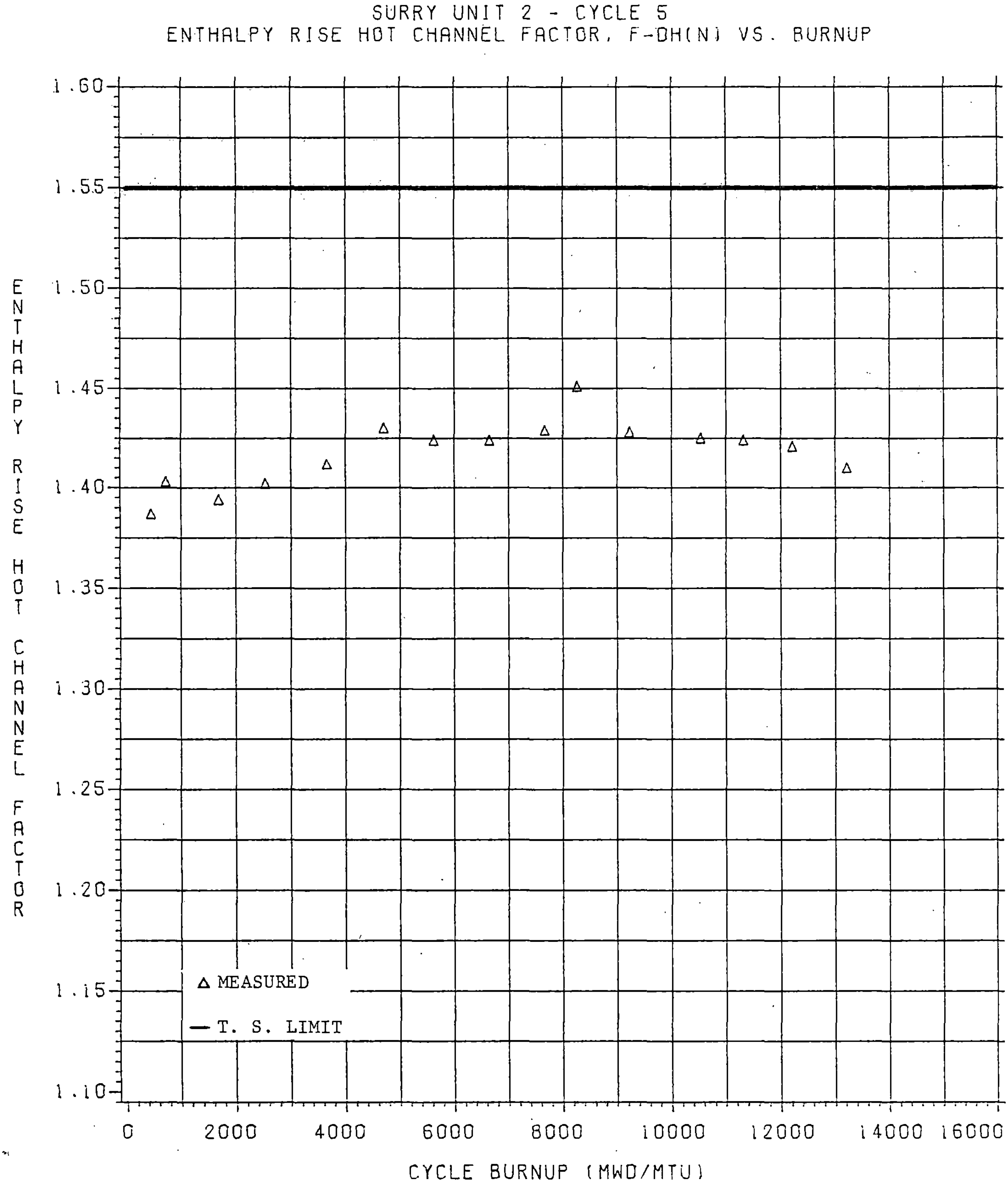
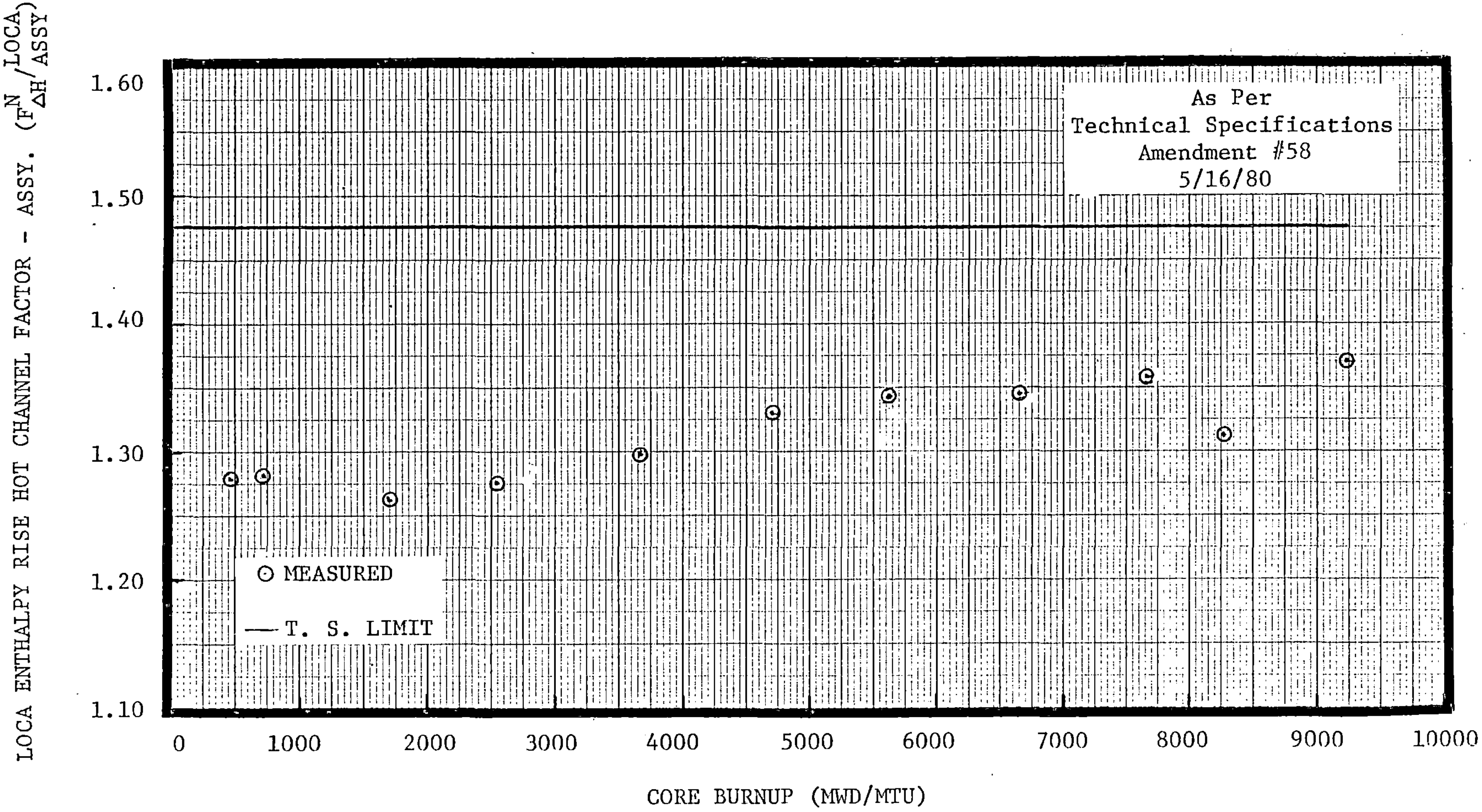


FIGURE 4.9


SURRY UNIT 2 - CYCLE 5
ENTHALPY RISE HOT CHANNEL FACTOR, F-DH(N) VS. BURNUP
ENTHALPY RISE HOT CHANNEL FACTOR
1.60
1.55
1.50
1.45
1.40
1.35
1.30
1.25
1.20
1.15
1.10
0
2000
4000
6000
8000
10000
12000
14000
16000
CYCLE BURNUP (MWD/MTU)
△ MEASURED
— T. S. LIMIT

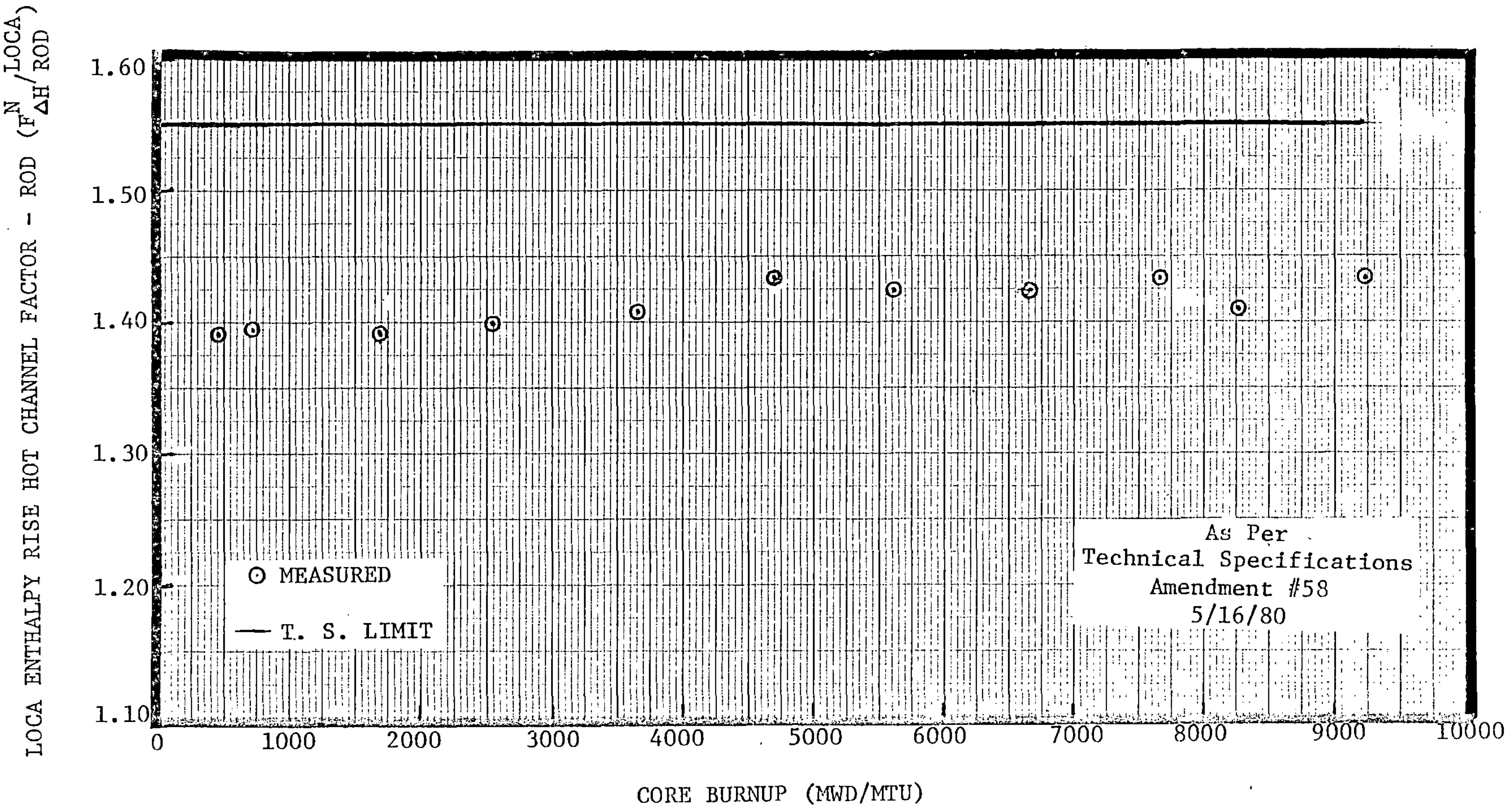
SURRY UNIT 2 - CYCLE 5

LOCA ENTHALPY RISE HOT CHANNEL FACTOR - ASSY. VS. BURNUP



SURRY UNIT 2 - CYCLE 5

LOCA ENTHALPY RISE HOT CHANNEL FACTOR - ROD
VS.
BURNUP

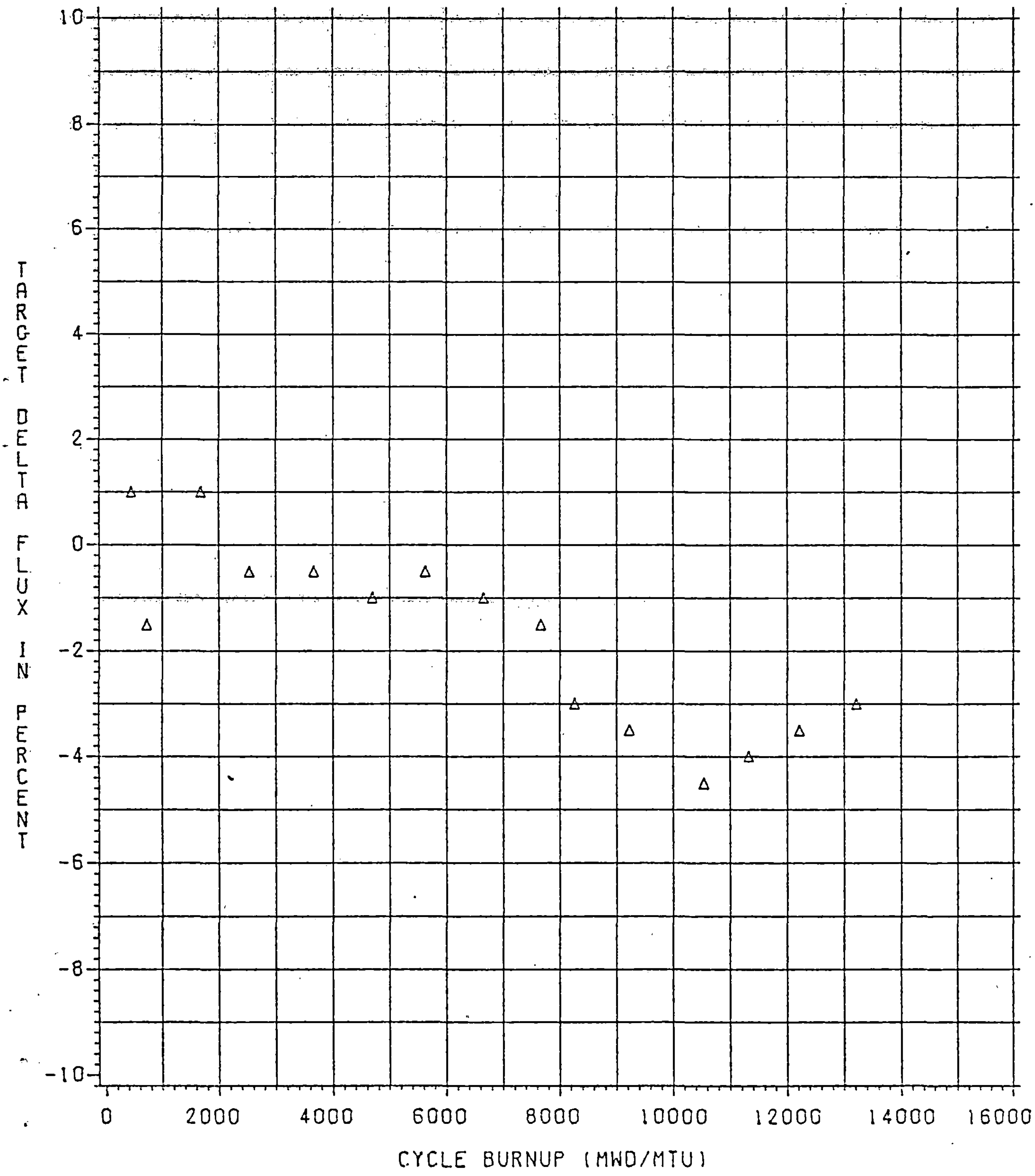


As Per
Technical Specifications
Amendment #58
5/16/80

FIGURE 4.12 .

SURRY UNIT 2 - CYCLE 5

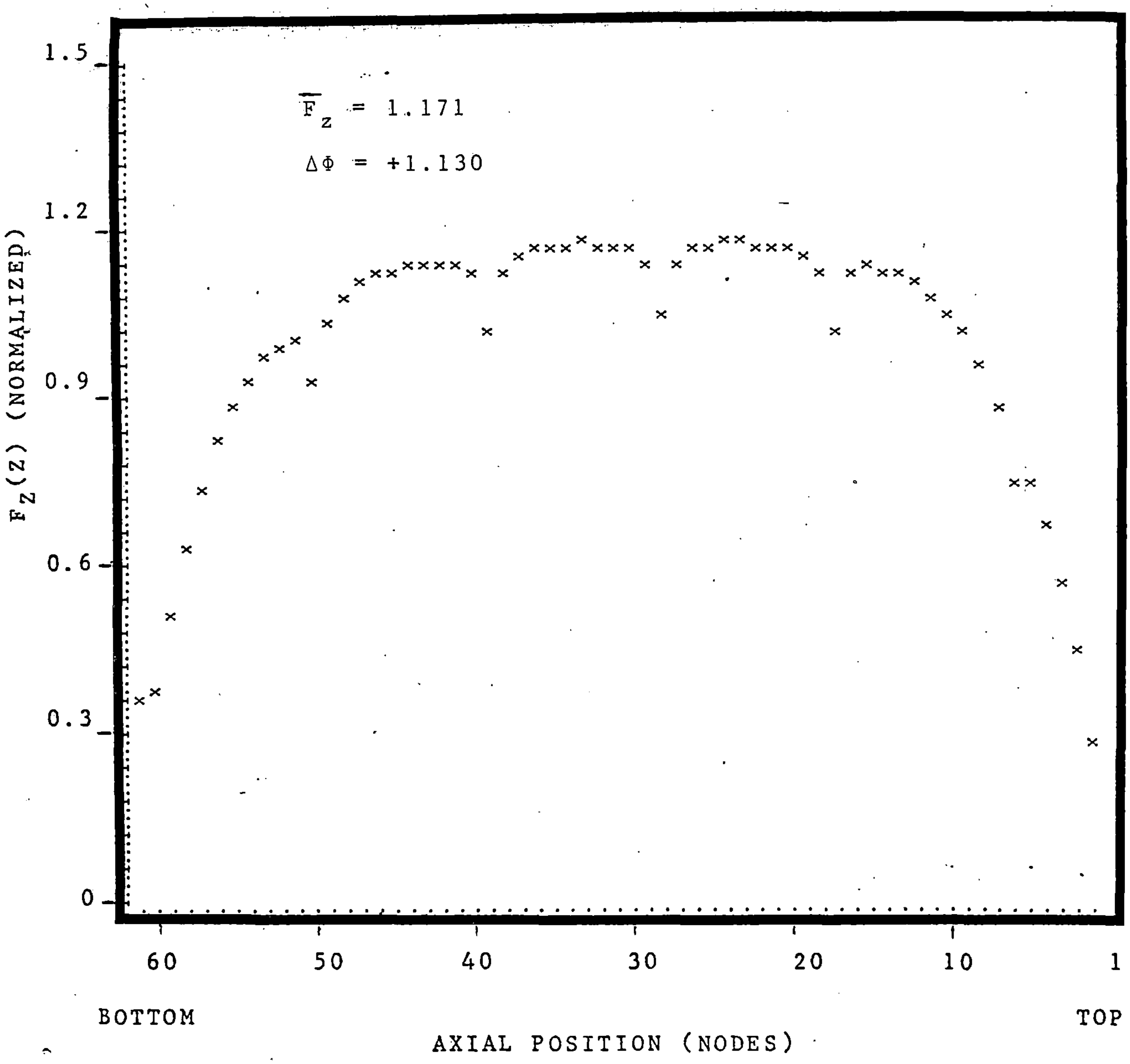
TARGET DELTA FLUX VS. BURNUP



SURRY UNIT 2 - CYCLE 5

CORE AVERAGE AXIAL POWER DISTRIBUTION

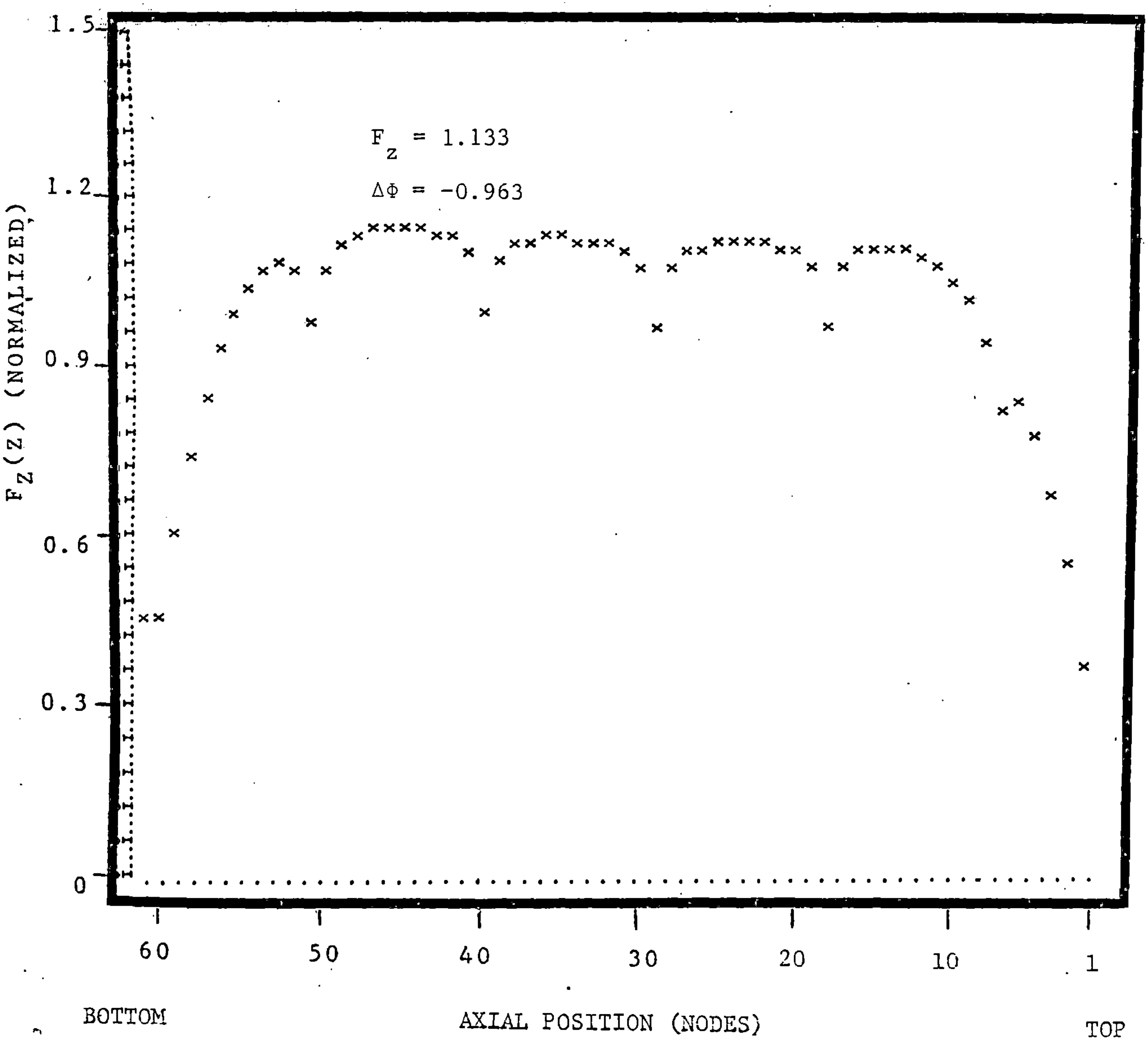
S2 - 5 - 13



SURRY UNIT 2 - CYCLE 5

CORE AVERAGE AXIAL POWER DISTRIBUTION

S2 - 5 - 24



SURRY UNIT 2 - CYCLE 5

CORE AVERAGE AXIAL POWER DISTRIBUTION

S2 - 5 - 39

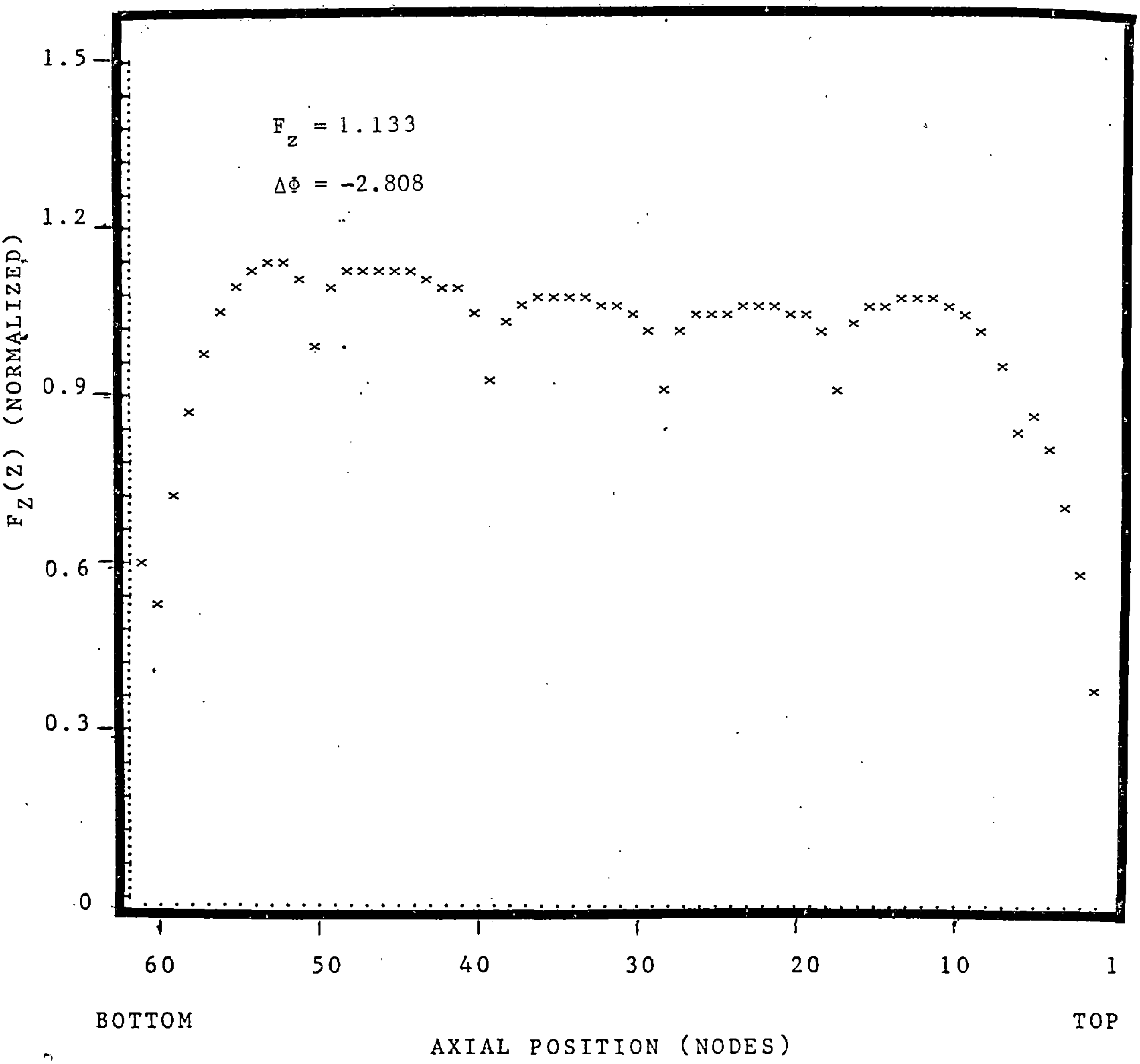
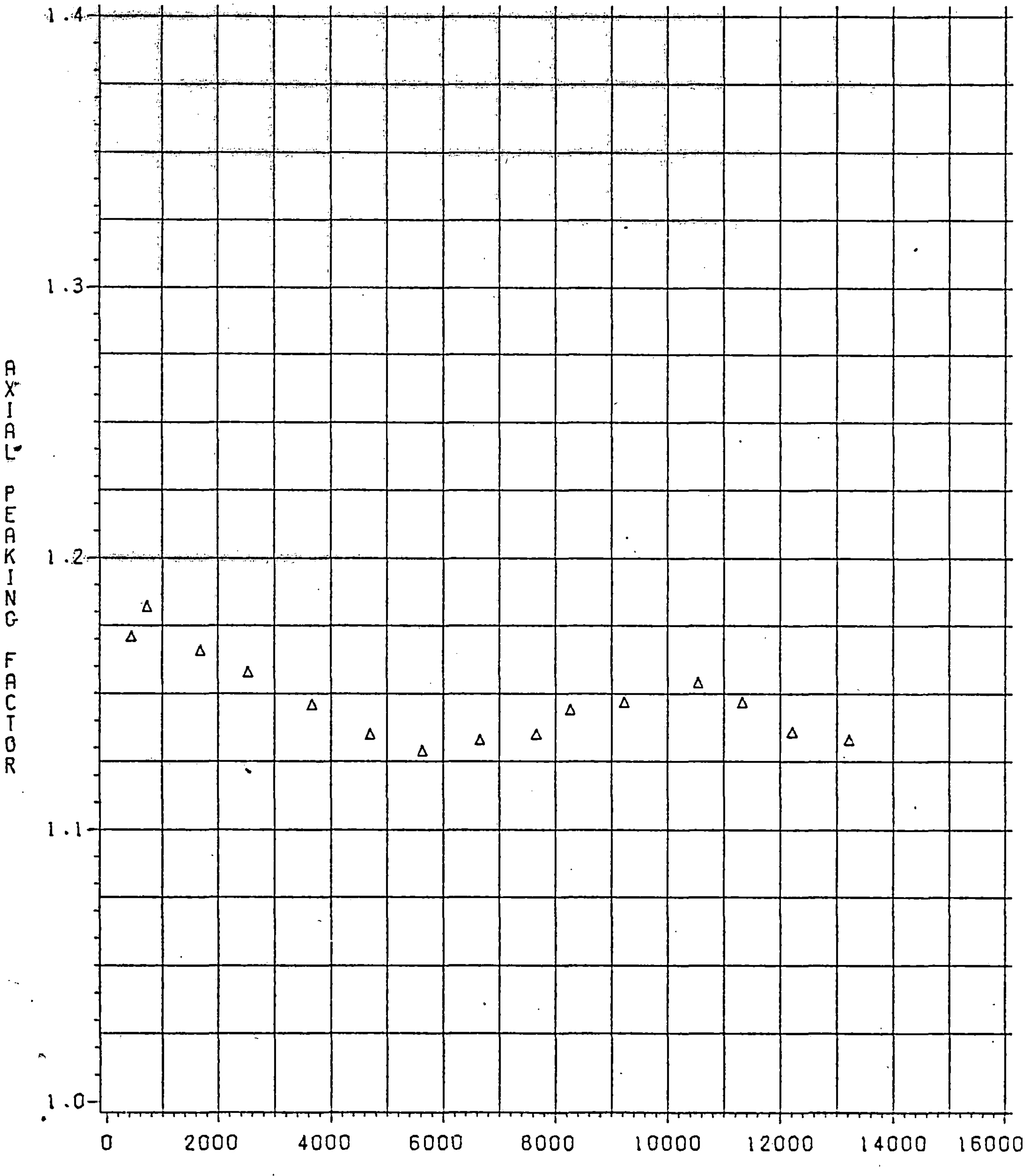


FIGURE 4.16


SURRY UNIT 2 - CYCLE 5
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
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 throught a breach in the cladding. As indicated in the Technical Specifications the dose equivalent I-131 concentration in the primary coolant was limited to 1.0 micro-Ci/gm for normal steady state operation during Cycle 5. Figure 5.1 shows the dose equivalent I-131 activity level history for the Surry 2, Cycle 5 core (the letdown flow rate averaged 105 gpm during power operation). The data demonstrates considerable scatter; however, the trend shows that during Cycle 5, the core operated substantially below the 1.0 micro-Ci/gm limit during steady state operation (the spike data is associated with power transients and unit shutdown). Specifically, the average dose equivalent I-131 concentration of 6.2 x 10^{-3} micro-Ci/gm is less than 1% 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 defect which may be present in a 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) so that 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 2, Cycle 5 core. These data indicate that any defects that may have been present during Cycle 5 are quite small.

---

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

SURRY UNIT 2 - CYCLE 5

DOSE EQUIVALENT I-131 CONCENTRATION vs. TIME

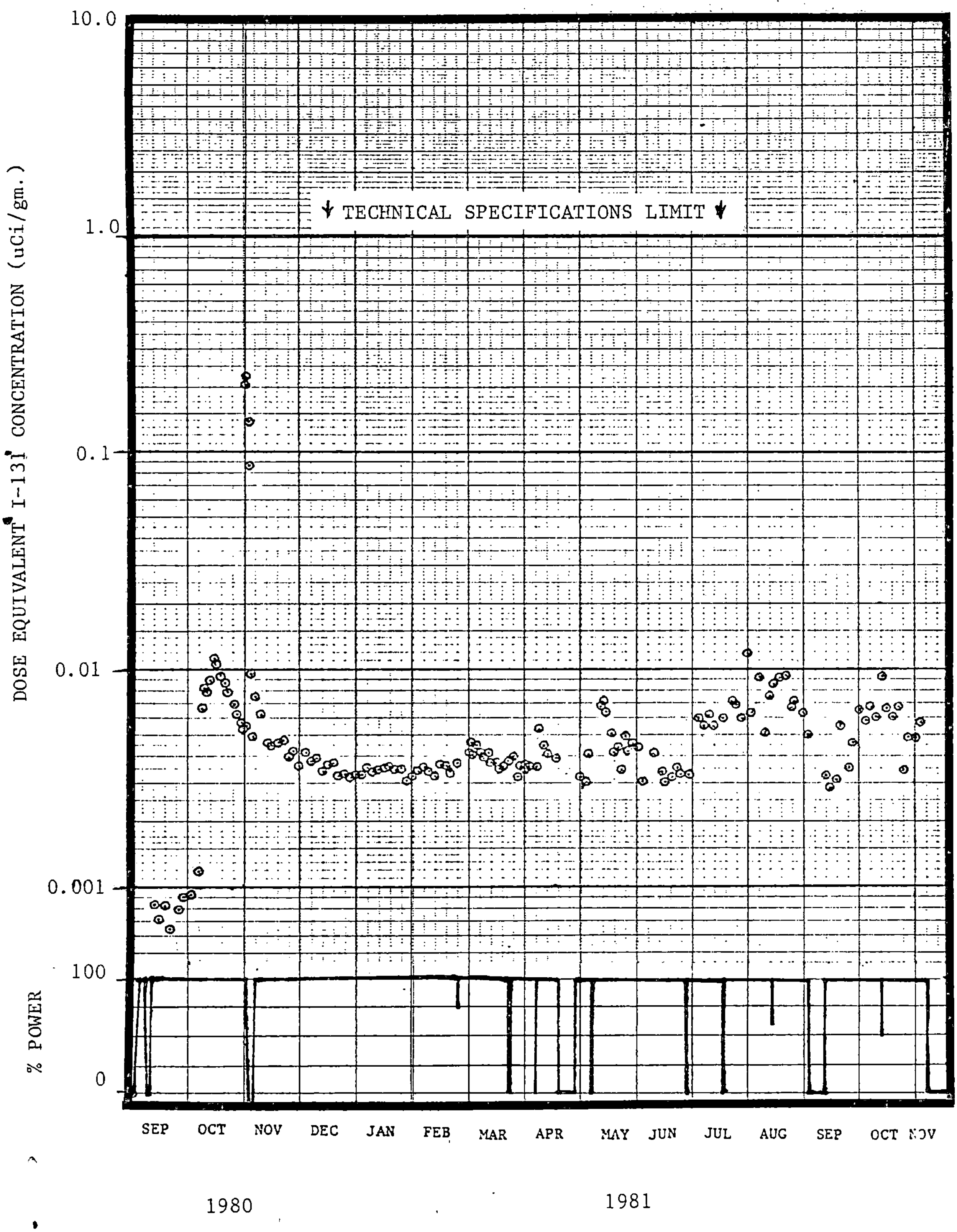
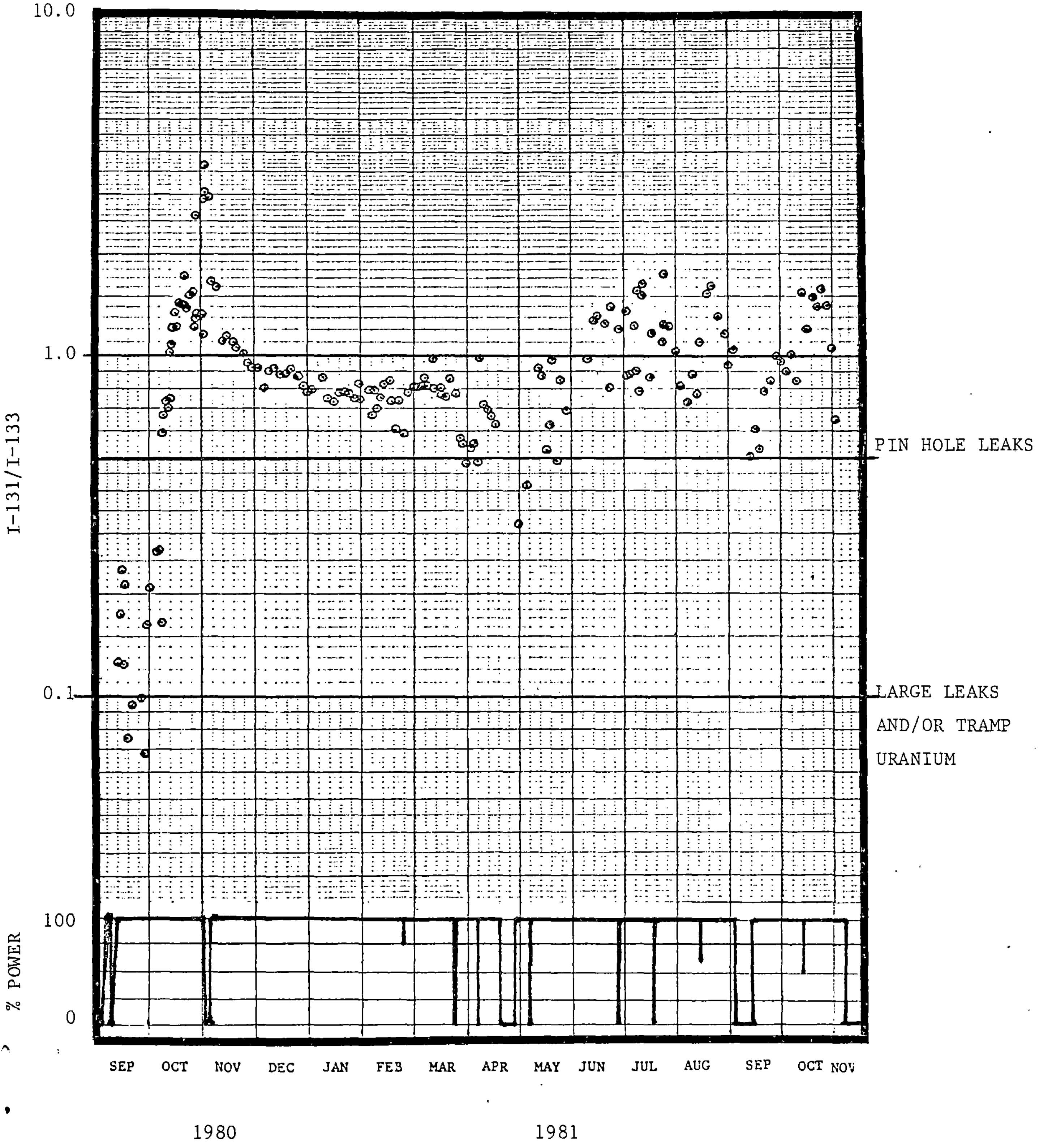


FIGURE 5.2

SURRY UNIT 2 - CYCLE 5

I-131/I-133 RATIO vs. TIME



Section 6

CONCLUSIONS

The Surry 2 core has completed Cycle 5 operation. Throughout this cycle, all core performance indicators compared favorably with the design predictions and all core related Technical Specifications limits were met with significant margin. No abnormalities in reactivity, power distribution, or burnup accumulation were detected. In addition, the excellent mechanical integrity of the fuel has not changed significantly throughout Cycle 5 as indicated by the radioiodine analysis.

REFERENCES

1) Mr. T. K. Ross and Mr. J. H. Leberstien, "Surry Unit 2, Cycle 5 Startup Physics Test Report," VEP-FRD-37, October, 1980.

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

3) Mr. T. K. Ross, "NEWTOTE Code", NFO-CCR-6, Revision 2, Vepco, July, 1981.

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.

6) Letter from Mr. B. R. Sylvia (Vepco) to Mr. H. R. Denton (NRC), "Supplemental Information Concerning Our Assessment of NUREG-0630", July 28, 1980 (Docket No. 50-281).

7) Surry Power Station Units 1 and 2, Technical Specifications Amendment Number 70, dated June 16, 1981.