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SURRY POWER STATION UNIT 1
CYCLE 23 STARTUP PHYSICS TESTS REPORT

As required by Surry Technical Specification 6.6.A.1, enclosed is the Virginia Electric and Power Company (Dominion) Technical Report NE-1578, Revision 0, entitled "Surry Unit 1 Cycle 23 Startup Physics Tests Report." This report summarizes the results of the physics testing program performed following initial criticality of Cycle 23 on May 11, 2009. The results of the physics tests were within the applicable Technical Specification limits.

If you have any questions or require additional information, please contact Mr. Gary Miller at (804) 273-2771.

Very truly yours,

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Enclosure

Commitments made in this letter: None

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TECHNICAL REPORT No. NE-1578 Rev. 0

SURRY UNIT 1 CYCLE 23 STARTUP PHYSICS TESTS REPORT

Surry Power Station Unit 1

Nuclear Analysis and Fuel

NUCLEAR ENGINEERING
DOMINION

July 2009

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PREFACE

This report presents the analysis and evaluation of the physics tests that were performed to verify that the Surry Unit 1, Cycle 23 core could be operated safely, and makes an initial evaluation of the performance of the core. It is not the intent of this report to discuss the particular methods of testing or to present the detailed data taken. Standard testing techniques and methods of data analysis were used. The test data, results and evaluations, together with the detailed startup procedures, are on file at Surry Power Station. Therefore, only a cursory discussion of these items is included in this report. The analyses presented include a brief summary of each test, a comparison of the test results with design predictions, and an evaluation of the results.

The Surry Unit 1, Cycle 23 startup physics tests results and evaluation sheets are included as an appendix to provide additional information on the startup test results. Each data sheet provides the following information: 1) test identification, 2) test results, 3) acceptance criteria and whether it was met (if applicable), 4) date and time of the test, and 5) preparer/ reviewer initials. These sheets provide a compact summary of the startup test results in a consistent format. The entries for the design values were based on calculations performed by Dominion's Nuclear Analysis and Fuel Group. The acceptance criteria are based on design tolerances or applicable Technical Specification and COLR Limits.

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SECTION 1 — INTRODUCTION AND SUMMARY

On 19 April 2009, Unit No. 1 of Surry Power Station completed Cycle 22 and began refueling [Ref. 1]. During this refueling, 65 of the 157 fuel assemblies in the core were replaced with 61 fresh Batch 25 assemblies and four twice-burned S1/22B assemblies. The Cycle 23 core consists of 12 sub-batches of fuel: four fresh batches (S1/25A, S1/25B, S1/25C, and S1/25D), four once-burned batches (S1/24A, S1/24B, S1/24C, and S1/24D), three twice-burned batches (S1/23A, S1/23D, and S1/23E) last irradiated in S1C22, and one twice-burned batch last irradiated in S1C21 (S1/22B). All batches are of the SIF/P+Z2 fuel type [Ref. 1, Ref. 8].

The Westinghouse SIF/P+Z2 fuel assembly design incorporates ZIRLO fuel cladding, intermediate grids, guide tubes, instrumentation tubes, and debris resistance features that are part of the Westinghouse PERFORMANCE+ design. SIF/P+Z2 assemblies are of the same basic design as SIF/P+Z, but use a slightly longer (0.2 inch) fuel pin and bottom end plug to enhance resistance to fretting wear, along with other small dimensional changes [Ref. 1].

This cycle uses only Westinghouse's Integral Fuel Burnable Absorber (IFBA) fuel product. All physical changes for IFBA are internal to the fuel rod cladding, with no apparent difference from discrete BP fuel assemblies in any external features. The IFBA design involves the application of a thin (0.0003125 inch) coating of ZrB_2 on the fuel pellet surface during fabrication. Pellets with the IFBA coating are placed in specific symmetric patterns in each fresh assembly, typically affecting from 16 to 148 rods per assembly. The top and bottom 6 inches of the fuel pellet stack in the IFBA rods will contain pellets that have no IFBA coating, and have a hole in the center (annular). This additional void space helps accommodate the helium gas that accumulates from neutron absorption in ZrB_2. IFBA rods generate more internal gas during operation because neutron absorption in the ZrB_2 coating creates helium gas in addition to the fission gas created during irradiation of the fuel. Therefore, the initial pressure is set lower so the internal pressure early in lifetime may be lower [Ref. 5].

Note that there are no thimble plugging devices or secondary sources inserted in Surry Unit 1 for this cycle. The cycle design report [Ref. 1] provides a more detailed description of the Cycle 23 core.

The S1C23 full core loading plan [Ref. 8 and Ref. 11] is given in Figure 1.1 and the beginning of cycle fuel assembly burnups [Ref. 6] are given in Figure 1.2. The available incore moveable detector locations used for the flux map analyses [Ref. 7] are identified in Figure 1.3. Figure 1.4 identifies the location and number of control rods in the Cycle 23 core [Ref. 1].

According to the Startup Physics logs, the Cycle 23 core achieved initial criticality on 11 May 2009 at 01:02 [Ref. 14]. Prior to and following criticality, startup physics tests were performed as outlined in Table 1.1. This cycle used the FTI Reactivity Measurement and Analysis System (RMAS) to perform startup physics testing. Note that RMAS v.6 [Ref. 9] was used for S1C23 Startup Physics Testing. The tests performed are the same as in previous cycles. A summary of the test results follows.

The measured drop time of each control rod was within the 2.4 second Technical Specification [Ref. 4] limit, as well as the 1.93 second administrative limit [Ref. 10].

Individual control rod bank worths were measured using the rod swap technique [Ref. 2]. For the purpose of this test, a bank was defined as 'fully inserted' when it was 2 steps off the bottom of the core [Ref. 13]. The sum of the individual measured control rod bank worths was within –2.3% of the design prediction. The reference bank (Control Bank B) worth was within –3.2% of its design prediction (corresponding to 41.8 pcm). The other control rod banks were within ±4.2% (-4.2% was recorded for Shutdown Bank B, which corresponds to a difference of 48.9 pcm) of the design predictions. For individual banks worth 600 pcm or less (only Control Bank A fits this category), the difference was within –0.7 pcm of the design prediction. These results are within the design tolerances of ±15% for individual banks worth more than 600 pcm (±10% for the reference bank worth), ±100 pcm for individual banks worth 600 pcm or less, and ±10% for the sum of the individual control rod bank worths.

Measured critical boron concentrations for two control bank configurations (ARO and B-bank in) were within +22 ppm of the design predictions. These results were within the design tolerances and also met the Technical Specification [Ref. 4] criterion that the overall core reactivity balance shall be within $\pm 1\%$ $\Delta k/k$ of the design prediction. The boron worth coefficient measurement was within -1.6% of the design prediction, which is within the design tolerance of $\pm 10\%$.

The measured isothermal temperature coefficient (ITC) for the all-rods-out (ARO) configuration was within -0.420 pcm/°F of the design prediction. This result is within the design tolerance of ± 2.0 pcm/°F.

Core power distributions were within established design tolerances. The measured assembly power distributions were within $\pm 5.1\%$ of the design predictions, where a +5.1% maximum difference occurred in the 26.1% power map in assembly B7. The heat flux hot channel factors, $F_Q(Z)$, and enthalpy rise hot channel factors, $F^N_{\Delta H}$, were within the limits of the COLR [Ref. 8]. All power flux maps were within the maximum incore power tilt design tolerance of 2% (QPTR ≤ 1.02).

The total RCS Flow was successfully verified as being greater than 273000 gpm as required by Surry Technical Specifications [Ref. 4]. The total RCS Flow was measured as 286190 gpm.

In summary, all startup physics test results were acceptable. Detailed results, specific design tolerances and acceptance criteria for each measurement are presented in the following sections of this report.

Table 1.1

SURRY UNIT 1 – CYCLE 23
CHRONOLOGY OF TESTS

Test	Date	Time	Power	Reference Procedure
Hot Rod Drop-Hot Full Flow	05/10/09	1057	HSD	1-NPT-RX-014
Reactivity Computer Checkout	05/11/09	0158	HZP	1-NPT-RX-008
Boron Endpoint – ARO	05/11/09	0158	HZP	1-NPT-RX-008
Zero Power Testing Range	05/11/09	0158	HZP	1-NPT-RX-008
Boron Worth Coefficient	05/11/09	0158	HZP	1-NPT-RX-008
Temperature Coefficient – ARO	05/11/09	0247	HZP	1-NPT-RX-008
Bank B Worth	05/11/09	0331	HZP	1-NPT-RX-008
Boron Endpoint – B in	05/11/09	0547	HZP	1-NPT-RX-008
Bank A Worth – Rod Swap	05/11/09	0550	HZP	1-NPT-RX-008
Bank SA Worth – Rod Swap	05/11/09	0550	HZP	1-NPT-RX-008
Bank C Worth – Rod Swap	05/11/09	0550	HZP	1-NPT-RX-008
Bank D Worth – Rod Swap	05/11/09	0550	HZP	1-NPT-RX-008
Bank SB Worth – Rod Swap	05/11/09	0550	HZP	1-NPT-RX-008
Total Rod Worth	05/11/09	0550	HZP	1-NPT-RX-008
Flux Map – less than 30% Power	05/11/09	2024	26.10%	1-NPT-RX-002
Peaking Factor Verification				1-NPT-RX-008
& Power Range Calibration				1-NPT-RX-005
Flux Map – 65% - 75% Power	05/13/09	0246	67.50%	1-NPT-RX-002
Peaking Factor Verification				1-NPT-RX-008
& Power Range Calibration				1-NPT-RX-005
Flux Map – 95% - 100% Power	05/15/09	1638	99.89%	1-NPT-RX-002
Peaking Factor Verification				1-NPT-RX-008
& Power Range Calibration				1-NPT-RX-005
RCS Flow Measurement	06/01/09	1400	HFP	1-NPT-RX-009

Figure 1.1

SURRY UNIT 1 – CYCLE 23
CORE LOADING MAP

SURRY UNIT 1 - CYCLE 23
FULL CORE LOADING PLAN
REVISION NO. 0

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VEP-NES-NAF

NORTH ↑

	A	B	C	D	E	F	G	H	J	K	L	M	N	P	R
15							42H	16H	43H						
14					48H	RCC 59H	40K	RCC 12K	38K	RCC 46H	58H				
13				39H	48K	34K	RCC 07K	12J	RCC 05K	30K	52K	34H			
12			36H	RCC 04K	18K	RCC 20J	38J	59J	43J	RCC 19J	20K	RCC 01K	40H		
11		50H	47K	24K	RCC 46J	51J	59K	25J	56K	55J	RCC 47J	17K	50K	45H	
10		RCC 57H	31K	RCC 14J	54J	RCC 26J	34J	RCC 09J	33J	RCC 24J	50J	RCC 13J	32K	RCC 52H	
9	59G	39K	RCC 15K	42J	55K	29J	RCC 29K	11J	RCC 28K	35J	60K	39J	RCC 13K	42K	44G
8	15H	RCC 16K	06J	52J	22J	RCC 07J	05J	25K	02J	RCC 08J	21J	53J	03J	RCC 06K	11H
7	54G	43K	RCC 10K	37J	58K	36J	RCC 26K	10J	RCC 27K	31J	61K	40J	RCC 14K	41K	31G
6		RCC 47H	33K	RCC 17J	57J	RCC 23J	32J	RCC 04J	30J	RCC 28J	60J	RCC 15J	37K	RCC 49H	
5		51H	49K	21K	RCC 48J	49J	54K	27J	57K	58J	RCC 45J	22K	51K	55H	
4			35H	RCC 03K	23K	RCC 16J	41J	56J	44J	RCC 18J	19K	RCC 02K	33H		
3				38H	53K	35K	RCC 09K	01J	RCC 08K	36K	46K	37H			
2					54H	RCC 60H	44K	RCC 11K	45K	RCC 56H	53H				
1							44H	12H	41H						

270° 180°

INCORE DEVICE DESCRIPTIONS:
RCC- FULL LENGTH CONTROL ROD

Prepared By: [signature] Date: 10/22/08
Reviewed By: [signature] Date: 10/29/08
Approved By: [signature] Date: 11/12/08

Concurrence By: [signature] Date: 11/12/08
Approved By: [signature] Date: 11/14/08

Figure 1.2

SURRY UNIT 1 – CYCLE 23
BEGINNING OF CYCLE FUEL ASSEMBLY BURNUPS (GWD/MTU)

	R	P	N	M	L	K	J	H	G	F	E	D	C	B	A	
1							36.80 / 36.42	40.85 / 40.79	36.15 / 36.39					MEASURED / PREDICTED		1
2					39.05 / 39.17	40.87 / 40.67	0.00 / 0.00	0.00 / 0.00	0.00 / 0.00	40.57 / 40.66	39.24 / 39.22					2
3				41.82 / 41.54	0.00 / 0.00	0.00 / 0.00	0.00 / 0.00	23.74 / 23.46	0.00 / 0.00	0.00 / 0.00	0.00 / 0.00	41.80 / 41.56				3
4			41.79 / 41.72	0.00 / 0.00	0.00 / 0.00	23.61 / 23.25	18.96 / 19.03	22.65 / 22.80	19.32 / 19.01	23.02 / 23.25	0.00 / 0.00	0.00 / 0.00	41.83 / 41.67			4
5		40.14 / 40.14	0.00 / 0.00	0.00 / 0.00	20.25 / 19.78	23.66 / 23.79	0.00 / 0.00	22.19 / 22.16	0.00 / 0.00	23.61 / 23.75	19.64 / 19.78	0.00 / 0.00	0.00 / 0.00	40.07 / 40.12		5
6		41.15 / 40.81	0.00 / 0.00	23.39 / 23.22	23.69 / 23.71	22.52 / 22.18	18.58 / 18.65	23.35 / 23.21	18.83 / 18.75	22.05 / 22.15	23.70 / 23.89	23.27 / 23.25	0.00 / 0.00	40.59 / 40.79		6
7	37.23 / 37.61	0.00 / 0.00	0.00 / 0.00	18.87 / 19.03	0.00 / 0.00	18.70 / 18.79	0.00 / 0.00	23.31 / 23.18	0.00 / 0.00	18.64 / 18.65	0.00 / 0.00	19.30 / 19.04	0.00 / 0.00	0.00 / 0.00	37.46 / 37.61	7
8	40.71 / 40.79	0.00 / 0.00	23.74 / 23.44	22.64 / 22.78	22.23 / 22.11	23.08 / 23.14	23.18 / 23.11	0.00 / 0.00	23.18 / 23.11	23.18 / 23.14	22.14 / 22.11	22.79 / 22.78	23.58 / 23.43	0.00 / 0.00	40.87 / 40.76	8
9	37.61 / 37.64	0.00 / 0.00	0.00 / 0.00	19.16 / 19.04	0.00 / 0.00	18.57 / 18.65	0.00 / 0.00	23.27 / 23.18	0.00 / 0.00	18.88 / 18.79	0.00 / 0.00	18.84 / 19.03	0.00 / 0.00	0.00 / 0.00	37.42 / 37.55	9
10		40.75 / 40.79	0.00 / 0.00	23.13 / 23.24	23.70 / 23.89	21.98 / 22.15	19.14 / 18.75	23.31 / 23.21	18.69 / 18.65	22.29 / 22.18	23.65 / 23.71	23.49 / 23.23	0.00 / 0.00	41.17 / 40.81		10
11		40.15 / 40.12	0.00 / 0.00	0.00 / 0.00	19.67 / 19.78	23.57 / 23.75	0.00 / 0.00	22.23 / 22.16	0.00 / 0.00	23.59 / 23.79	19.97 / 19.78	0.00 / 0.00	0.00 / 0.00	40.06 / 40.13		11
12			41.48 / 41.66	0.00 / 0.00	0.00 / 0.00	23.10 / 23.25	19.09 / 19.01	22.64 / 22.79	19.00 / 19.03	23.60 / 23.26	0.00 / 0.00	0.00 / 0.00	41.68 / 41.73			12
13				41.73 / 41.57	0.00 / 0.00	0.00 / 0.00	0.00 / 0.00	23.56 / 23.46	0.00 / 0.00	0.00 / 0.00	0.00 / 0.00	41.58 / 41.55				13
14					39.50 / 39.21	40.80 / 40.66	0.00 / 0.00	0.00 / 0.00	0.00 / 0.00	41.09 / 40.65	39.34 / 39.17					14
15							36.18 / 36.39	40.85 / 40.80	36.48 / 36.42							15

Figure 1.3

SURRY UNIT 1 – CYCLE 23
AVAILABLE INCORE MOVEABLE DETECTOR LOCATIONS

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

MD - Moveable Detector
* - Locations Not Used For Flux Map 1, 2, or 3 for S1C23

Figure 1.4

SURRY UNIT 1 – CYCLE 23
CONTROL ROD LOCATIONS

	R	P	N	M	L	K	J	H	G	F	E	D	C	B	A		
								180°									
1																	
2						A		D		A							
3							SA		SA								
4				C		B				B		C					
5					SB						SB						
6		A		B		D		C		D		B		A			
7			SA				SB		SB				SA				
8	90°	D				C				C				D		270°	
9			SA				SB		SB				SA				
10		A		B		D		C		D		B		A			
11					SB						SB						
12				C		B				B		C					
13							SA		SA								
14						A		D		A							
15																	
								0°									

D = Control Bank D
C = Control Bank C
B = Control Bank B
A = Control Bank A

SB = Shutdown Bank SB
SA = Shutdown Bank SA

SECTION 2 — CONTROL ROD DROP TIME MEASUREMENTS

The drop time of each control rod was measured in hot shutdown with three reactor coolant pumps in operation (full flow) and with T_{ave} greater than 530 °F as per 1-NPT-RX-014. This verified that the time to entry of a rod into the dashpot region was less than or equal to the maximum allowed by Technical Specification 3.12.C.1 [Ref. 4].

Surry Unit 1 Cycle 23 used the rod drop test computer (RDTC) in conjunction with the Computer Enhanced Rod Position Indication (CERPI) system. The CERPI system equipment replaced the Individual Rod Position Indication (IRPI) system. The rod drop times were measured by withdrawing all banks to their fully withdrawn position and dropping all of the 48 control rods by opening the reactor trip breakers. This allowed the rods to drop into the core as they would during a plant trip.

The current methodology acquires data using the secondary RPI coil terminals (/3 & /4) on the CERPI racks for each rod. Data is immediately saved to the rod drop test computer (RDTC) which computes the rod drop time automatically. Original data is also saved as an ASCII file and burned to a CD-R. Further details about the RDTC can be found in [Ref. 12].

A typical rod drop trace for S1C23 is shown in Figure 2.1. The measured drop times for each control rod are recorded on Figure 2.2. The slowest, fastest, and average drop times are summarized in Table 2.1. Technical Specification 3.12.C.1 [Ref. 4] specifies a maximum rod drop time to dashpot entry of 2.4 seconds for all rods. These test results satisfied this technical specification limit as well as the administrative limit [Ref. 10] of 1.93 seconds. In addition, rod bounce was observed at the end of each trace demonstrating that no control rod stuck in the dashpot region.

Table 2.1

SURRY UNIT 1 – CYCLE 23 STARTUP PHYSICS TESTS
HOT ROD DROP TIME SUMMARY

ROD DROP TIME TO DASHPOT ENTRY

SLOWEST ROD	FASTEST ROD		AVERAGE TIME
P-8 1.39 sec.	N-7, L-5, P-6, K-4, M-12	1.26 sec	1.29 sec.

Figure 2.1

SURRY UNIT 1 – CYCLE 23 STARTUP PHYSICS TESTS
TYPICAL ROD DROP TRACE

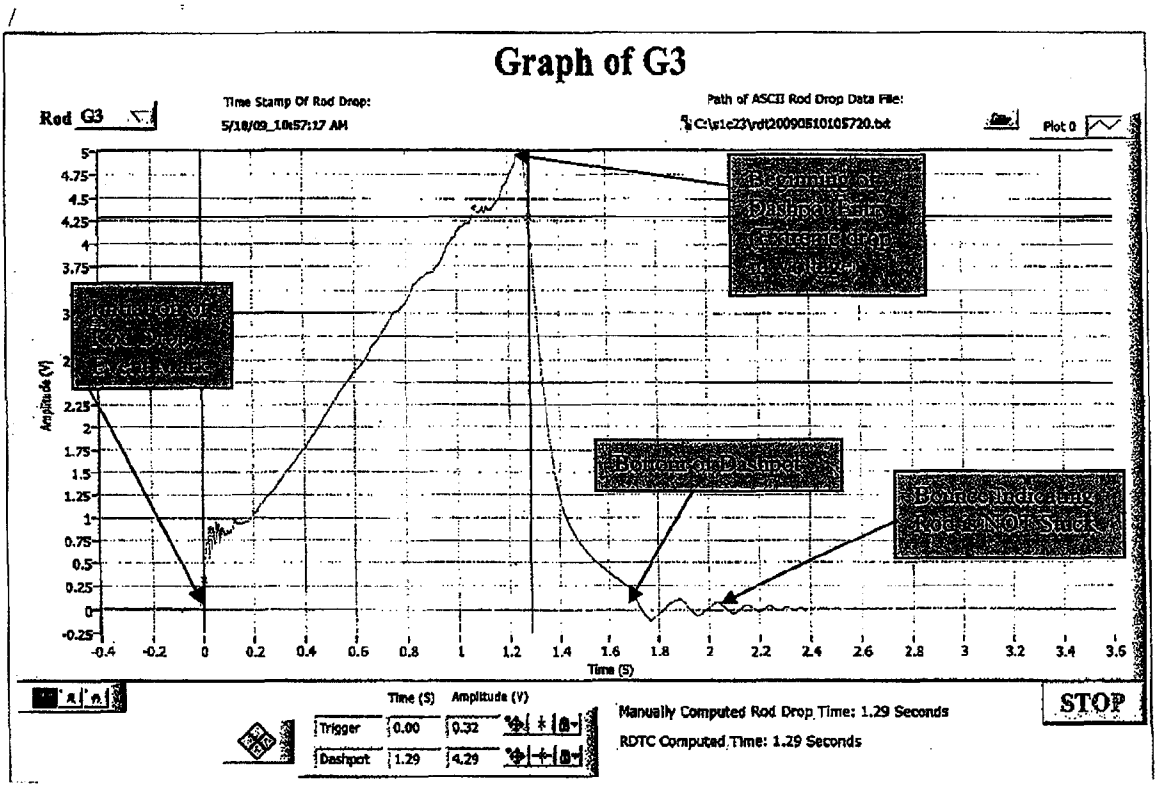


Figure 2.2

SURRY UNIT 1 – CYCLE 23 STARTUP PHYSICS TESTS
ROD DROP TIME – HOT FULL FLOW CONDITIONS

	R	P	N	M	L	K	J	H	G	F	E	D	C	B	A
1															
2						1.28		1.27		1.28					
3							1.29		1.29						
4				1.27		1.26				1.28		1.31			
5					1.26						1.29				
6		1.26		1.27		1.29		1.27		1.30		1.27		1.37	
7			1.26				1.32		1.29				1.29		
8		1.39				1.29				1.38				1.31	
9			1.32				1.28		1.32				1.28		
10		1.28		1.28		1.27		1.27		1.31		1.30		1.29	
11					1.27						1.28				
12				1.26		1.28				1.28		1.30			
13							1.29		1.29						
14						1.31		1.27		1.33					
15															

x.xx ==> Rod drop time to dashpot entry (sec.)

SECTION 3 — CONTROL ROD BANK WORTH MEASUREMENTS

Control rod bank worths were measured for the control and shutdown banks using the rod swap technique [Ref. 2]. The initial step of the rod swap method diluted the predicted most reactive control rod bank (hereafter referred to as the reference bank) into the core and measured its reactivity worth using conventional test techniques. The reactivity changes resulting from the reference bank movements were recorded continuously by the reactivity computer and were used to determine the differential and integral worth of the reference bank. For Cycle 23, Control Bank B was used as the reference bank. Surry 1 targeted a dilution rate of 1100 pcm/hr for the reference bank measurement.

During the N1C19 startup physics testing campaign, a control rod became stuck on the bottom eventually forcing a reactor trip to fix the problem. A theorized potential cause of the stuck rod issue was the presence of debris near the upper core plate interfering with the rod grippers when the control rods were manually inserted to the fully inserted position of 0 steps withdrawn. A possible solution to this issue for startup physics testing was to avoid requiring control rods to be manually inserted to 0 steps. To accomplish this, an evaluation of the startup physics testing process was performed [Ref. 13], concluding that the definition of fully inserted for control rod positions used in startup physics testing could be changed from 0 steps withdrawn to a range of 0 to 2 steps withdrawn. The S1C23 startup physics testing campaign used 2 steps withdrawn for all conditions requiring control rods to be manually fully inserted.

After completion of the reference bank reactivity worth measurement, the reactor coolant system temperature and boron concentration were stabilized with the reactor near critical and the reference bank near its full insertion. Initial statepoint data (core reactivity and moderator temperature) for the rod swap maneuver were next obtained with the reference bank at its fully inserted position and all other banks fully withdrawn.

Test bank swaps proceed in sequential order from the bank with the smallest worth to the bank with the largest worth. The second test bank should have a predicted worth higher than the first bank in order to ensure the first bank will be moved fully out before the second bank is fully

inserted. The rod swap maneuver was performed by withdrawing the previous test bank (or reference bank for the first maneuver) several steps and then inserting the next test bank to balance the reactivity of the reference bank withdrawal. This sequence was repeated until the previous test bank was fully withdrawn and the current test bank was nearly inserted. The next step was to swap the rest of the test bank in by balancing the reactivity with the withdrawal of the reference bank, until the test bank was fully inserted and the reference bank was positioned such that the core was near the initial statepoint condition. This measured critical position (MCP) of the reference bank with the test bank fully inserted was used to determine the integral reactivity worth of the test bank.

The core reactivity, moderator temperature, and differential worth of the reference bank were recorded with the reference bank at the MCP. The rod swap maneuver was repeated for all test banks. Note that after the final test bank was fully inserted, the test bank was swapped with the reference bank until the reference bank was fully inserted and the last test bank was fully withdrawn. Here the final statepoint data for the rod swap maneuver was obtained (core reactivity and moderator temperature) in order to verify the reactivity drift was within procedural limitations for the rod swap test.

A summary of the test results is given in Table 3.1. As shown in this table and the Startup Physics Test Summary Sheets given in the Appendix, the individual measured bank worths for the control and shutdown banks were within the design tolerance of $\pm 10\%$ for the reference bank, $\pm 15\%$ for test banks of worth greater than 600 pcm, and ± 100 pcm for test banks of worth less than or equal to 600 pcm. The sum of the individual measured rod bank worths was within -2.3% of the design prediction. This is well within the design tolerance of $\pm 10\%$ for the sum of the individual control rod bank worths.

The integral and differential reactivity worths of the reference bank (Control Bank B) are shown in Figures 3.1 and 3.2, respectively. The design predictions [Ref. 1] and the measured data are plotted together in order to illustrate their agreement. In summary, the measured rod worth values were found to be satisfactory.

Table 3.1

SURRY UNIT 1 – CYCLE 23 STARTUP PHYSICS TESTS
CONTROL ROD BANK WORTH SUMMARY

BANK	MEASURED WORTH (PCM)	PREDICTED WORTH (PCM)	PERCENT DIFFERENCE (%) (M-P)/P X 100
D	1073.2	1094.2	-1.9
B - Reference	1275.2	1317	-3.2
C	942.0	973.8	-3.3
A	229.3	230.0	-0.3*
SB	1108.0	1156.9	-4.2
SA	905.1	892.2	+1.4
Total Bank Worth	5532.6	5664.1	-2.3

*Note: For Bank A, (M-P) = -0.7 pcm.

Figure 3.1

SURRY UNIT 1 – CYCLE 23 STARTUP PHYSICS TESTS
CONTROL BANK B INTEGRAL ROD WORTH - HZP
ALL OTHER RODS WITHDRAWN

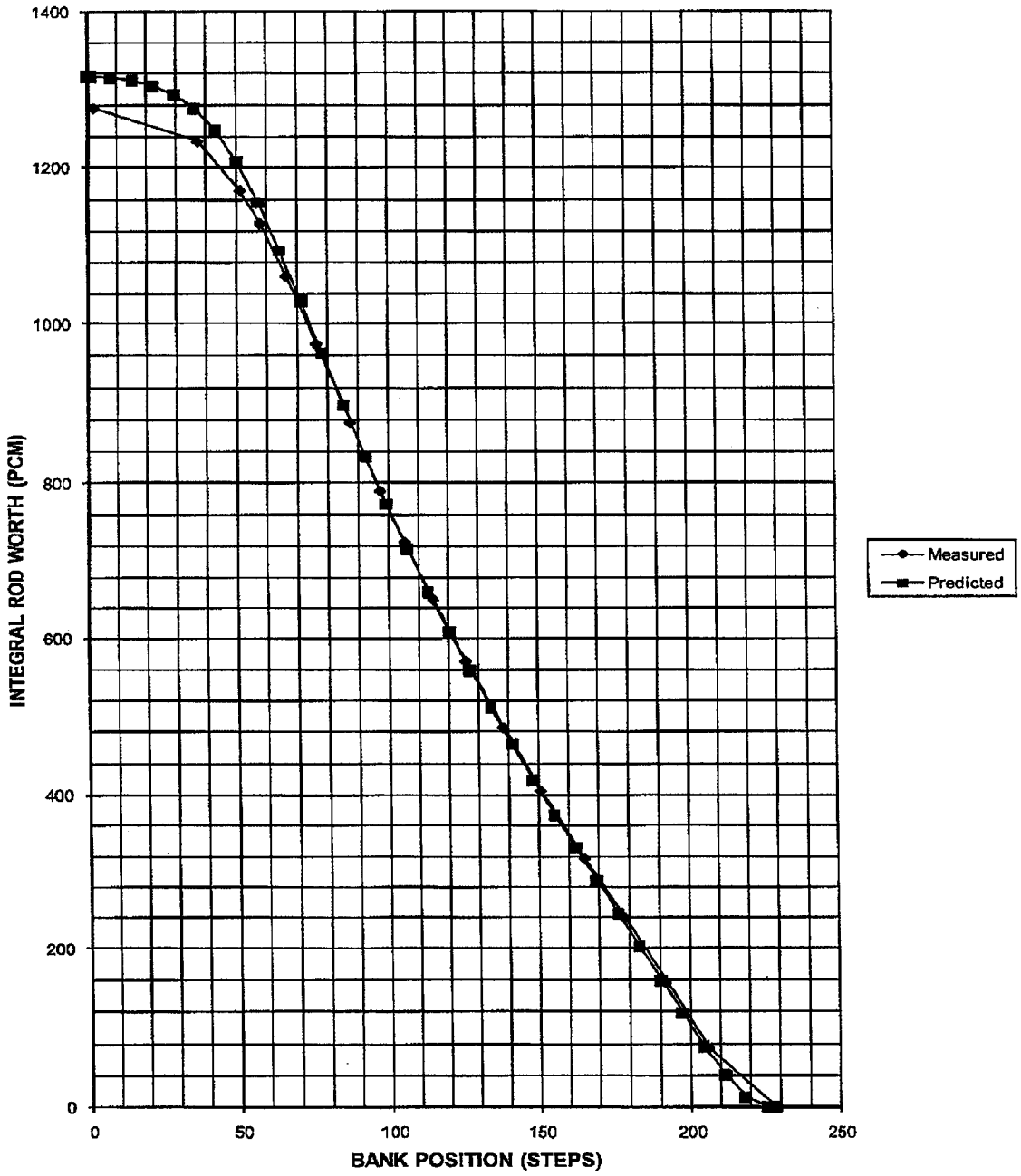
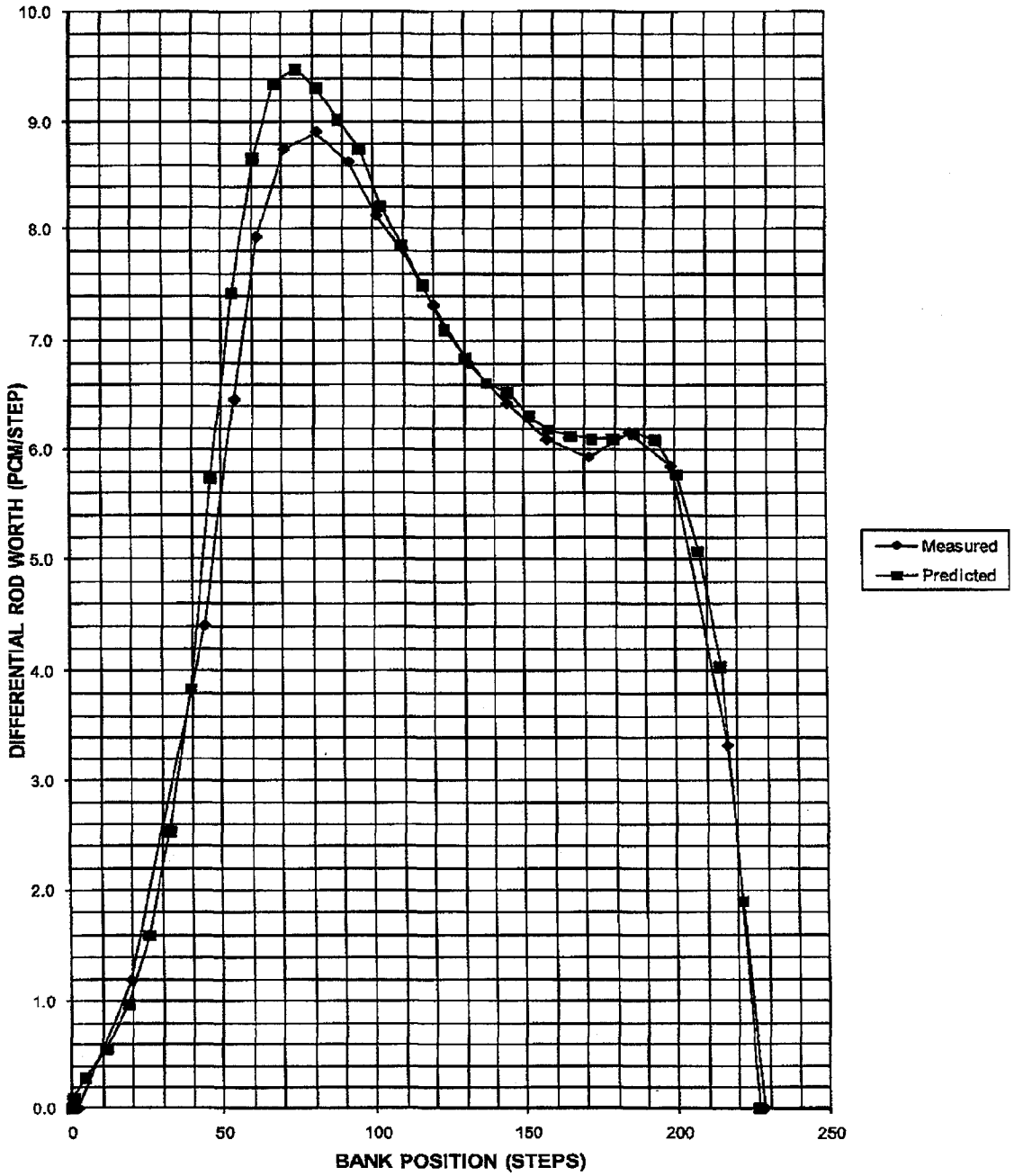


Figure 3.2

SURRY UNIT 1 – CYCLE 23 STARTUP PHYSICS TESTS
CONTROL BANK B DIFFERENTIAL ROD WORTH - HZP
ALL OTHER RODS WITHDRAWN



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SECTION 4 — BORON ENDPOINT AND WORTH MEASUREMENTS

Boron Endpoint

With the reactor critical at hot zero power, reactor coolant system (RCS) boron concentrations were measured at selected rod bank configurations to enable a direct comparison of measured boron endpoints with design predictions. For each critical boron concentration measurement, the RCS conditions were stabilized with the control banks at or very near a selected endpoint position. Adjustments to the measured critical boron concentration values were made to account for off-nominal control rod position and moderator temperature, as necessary.

The results of these measurements are given in Table 4.1. As shown in this table and in the Startup Physics Test Summary Sheets given in the Appendix, the measured critical boron endpoint values were within their respective design tolerances. The ARO endpoint comparison to the predicted value met the requirements of Technical Specification 4.10.A [Ref. 4] regarding core reactivity balance. In summary, the boron endpoint results were satisfactory.

Boron Worth Coefficient

The measured boron endpoint values provide stable statepoint data from which the boron worth coefficient or differential boron worth (DBW) was determined. By relating each endpoint concentration to the integrated rod worth present in the core at the time of the endpoint measurement, the value of the DBW over the range of boron endpoint concentrations was obtained.

A summary of the measured and predicted DBW is shown in Table 4.2. As indicated in this table and in the Appendix, the measured DBW was well within the design tolerance of $\pm 10\%$. In summary, the measured boron worth coefficient was satisfactory.

Table 4.1

SURRY UNIT 1 – CYCLE 23 STARTUP PHYSICS TESTS
BORON ENDPOINTS SUMMARY

Control Rod Configuration	Measured Endpoint (ppm)	Predicted Endpoint (ppm)	Difference M-P (ppm)
ARO	1645	1623	+22
B Bank In	1473	1470*	+3

* The predicted endpoint for the B Bank In configuration was adjusted for the difference between the measured and predicted values of the endpoint taken at the ARO configuration as shown in the boron endpoint Startup Physics Test Summary Sheet in the Appendix.

Table 4.2

SURRY UNIT 1 – CYCLE 23 STARTUP PHYSICS TESTS
BORON WORTH COEFFICIENT

Measured Boron Worth (pcm/ppm)	Predicted Boron Worth (pcm/ppm)	Percent Difference (%) (M-P)/P x 100
-7.41	-7.53	-1.6

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SECTION 5 — TEMPERATURE COEFFICIENT MEASUREMENT

The isothermal temperature coefficient (ITC) at the all-rods-out condition is measured by controlling the reactor coolant system (RCS) temperature with the steam dump valves to the condenser, establishing a constant heatup or cooldown rate, and monitoring the resulting reactivity changes on the reactivity computer.

Reactivity was measured during RCS heatup of +3.14°F, followed by RCS cooldown of -3.31°F. Reactivity and temperature data were taken from the reactivity computer. Using the statepoint method, the temperature coefficient was determined by dividing the change in reactivity by the change in RCS temperature.

The predicted and measured isothermal temperature coefficient values are compared in Table 5.1. As can be seen from this summary and from the Startup Physics Test Summary Sheet given in the Appendix, the measured isothermal temperature coefficient value was within the design tolerance of ±2 pcm/°F. The calculated moderator temperature coefficient (MTC), which is calculated using a measured ITC of -1.682 pcm/ °F, a predicted DTC of -1.80 pcm/ °F, and a measurement uncertainty of +0.5 pcm/ °F, is +0.62 pcm/ °F. It thus satisfies the COLR criteria [Ref. 8] that indicates MTC at HZP be less than or equal to +6.0 pcm/ °F.

Table 5.1

SURRY UNIT 1 – CYCLE 23 STARTUP PHYSICS TESTS
ISOTHERMAL TEMPERATURE COEFFICIENT SUMMARY

BANK POSITION (STEPS)	TEMPERATURE RANGE (°F)		BORON CONCENTRATION (ppm)	ISOTHERMAL TEMPERATURE COEFFICIENT (PCM/°F)				
	LOWER LIMIT	UPPER LIMIT		HEAT-UP	COOL-DOWN	AVG. MEAS	PRED	DIFFER (M-P)
D/205	546.04	549.38	1636	-1.801	-1.563	-1.682	-1.262	-0.420

SECTION 6 — POWER DISTRIBUTION MEASUREMENTS

The core power distributions were measured using the moveable incore detector flux mapping system. This system consists of five fission chamber detectors which traverse fuel assembly instrumentation thimbles in up to 50 core locations. Figure 1.3 shows the available locations monitored by the moveable detectors for the ramp to full power flux maps for Cycle 23. For each traverse, the detector voltage output is continuously monitored on a recorder, and scanned for 610 discrete axial points. Full core, three-dimensional power distributions are determined from this data using a Dominion-modified version of the Combustion Engineering computer program, CECOR [Ref. 3]. CECOR couples the measured voltages with predetermined analytic power-to-flux ratios in order to determine the power distribution for the whole core.

A list of the full-core flux maps [Ref. 7] taken during the startup test program and the measured values of the important power distribution parameters are given in Table 6.1. A comparison of these measured values with their COLR limits is given in Table 6.2. Flux map 1 was taken at 26.1% power to verify the radial power distribution (RPD) predictions at low power. Figure 6.1 shows the measured RPDs from this flux map. Flux maps 2 and 3 were taken at 67.5% and 99.89% power, respectively, with different control rod configurations. These flux maps were taken to check at-power design predictions and to measure core power distributions at various operating conditions. The radial power distributions for these maps are given in Figures 6.2 and 6.3.

The radial power distributions for the maps given in Figures 6.1, 6.2, and 6.3 show that the measured relative assembly power values deviated from the design predictions by at most +5.1% in the 26.1% power map, -3.4% in the 67.5% power map, and +3.2% in the 99.89% power map. The maximum quadrant power tilts for the three power maps are +0.46 % (1.0046), +0.28 % (1.0028), and +0.30% (1.0030), respectively. These power tilts are within the design tolerance of 2% (1.02).

The measured $F_Q(Z)$ and $F^N_{\Delta H}$ peaking factor values for the at-power flux maps were within the limits of the COLR [Ref. 8]. Flux Maps 1, 2, and 3 were used for power range detector calibration or to confirm existing calibrations. The flux map analyses are documented in [Ref. 7].

In conclusion, the power distribution measurement results are considered acceptable with respect to the design tolerances, the accident analysis acceptance criteria, and the COLR [Ref. 8]. It is therefore anticipated that the core will continue to operate safely throughout Cycle 23.

Table 6.1

SURRY UNIT 1 – CYCLE 23 STARTUP PHYSICS TESTS
INCORE FLUX MAP SUMMARY

Map Description	Map No.	Date	Burn up MWD/ MTU	Power (%)	Bank D Steps	Peak $F_Q(Z)$ Hot Channel Factor (1)			$F^N_{\Delta H}$ Hot (2) Channel Factor		Core F_Z Max		Core Tilt (3)		Axial Offset (%)	No. Of Thimbles
						Assy	Axial Point	$F_Q(Z)$	Assy	$F^N_{\Delta H}$	Axial Point	F_Z	Max	Loc		
Low Power	1	05/11/09	1	26.1	173	L11	25	2.263	M7	1.521	26	1.375	1.0046	SE	+6.275	46
Int. Power (4)	2	05/13/09	19	67.5	195	J12	23	1.970	E11	1.493	21	1.234	1.0028	SE	+5.720	46
Hot Full Power	3	05/15/09	102	99.89	227	E11	33	1.866	E11	1.482	30	1.168	1.0030	SE	+3.281	46

NOTES: Hot spot locations are specified by giving assembly locations (e.g. H-8 is the center-of-core assembly) and core height (in the "Z" direction the core is divided into 61 axial points starting from the top of the core). Flux Maps 1, 2, and 3 were used for power range detector calibration or were used to confirm existing calibrations.

(1) $F_Q(Z)$ includes a total uncertainty of 8%

(2) $F^N_{\Delta H}$ includes no uncertainty.

(3) CORE TILT - defined as the average quadrant power tilt from CECOR. "Max" refers to the maximum positive core tilt (QPTR > 1.0000).

(4) Int. Power – intermediate power flux map.

Table 6.2

SURRY UNIT 1 – CYCLE 23 STARTUP PHYSICS TESTS
COMPARISION OF MEASURED POWER DISTRIBUTION
PARAMETERS WITH THEIR CORE OPERATING LIMITS

Map	Peak $F_Q(Z)$ Hot Channel Factor*			$F_Q(Z)$ Hot Channel Factor** (At Node of Minimum Margin)				$F^N_{\Delta H}$ Hot Channel Factor		
No.	Meas.	Limit	Node	Meas.	Limit	Node	Margin$ (%)	Meas.	Limit	Margin$ (%)
1	2.263	4.570	25	2.263	4.570	25	50.48	1.521	1.906	20.20
2	1.970	3.368	23	1.967	3.334	19	41.00	1.493	1.712	12.79
3	1.866	2.323	33	1.835	2.264	21	18.95	1.482	1.561	5.06

*The Core Operating Limit for the heat flux hot channel factor, $F_Q(Z)$, is a function of core height and power level. The value for $F_Q(Z)$ listed is the maximum value of $F_Q(Z)$ in the core. The COLR [Ref. 8] limit listed is evaluated at the plane of maximum $F_Q(Z)$.

**The value for $F_Q(Z)$ listed above is the value having the lowest margin to the limit. The minimum margin values listed above are the minimum percent difference between the measured values of $F_Q(Z)$ and the COLR limit for each map.

The measured $F_Q(Z)$ hot channel factors include 8% total uncertainty. Measured $F^N_{\Delta H}$ data includes no uncertainty.

$ Margin (%) = 100*(Limit – Meas.) / Limit

Figure 6.1 — ASSEMBLYWISE POWER DISTRIBUTION
26.1% POWER

R	P	N	M	L	K	J	H	G	F	E	D	C	B	A	
	PREDICTED MEASURED PCT DIFFERENCE					.265 .269 1.3	.275 .288 4.9	.261 .264 1.5			PREDICTED MEASURED PCT DIFFERENCE				1
				.288 .288 -.1	.478 .478 .0	1.045 1.049 .4	.870 .877 .8	1.040 1.047 .6	.477 .484 1.4	.287 .287 -.1					2
			.391 .389 -.5	1.015 1.015 .0	1.136 1.133 -.3	1.238 1.236 -.2	1.092 1.099 .6	1.239 1.236 -.2	1.137 1.131 -.5	1.015 1.008 -.7	.391 .391 .2				3
		.388 .389 .4	1.122 1.123 .1	1.295 1.299 .3	1.227 1.221 -.5	1.376 1.361 -1.1	1.350 1.322 -2.0	1.383 1.366 -1.2	1.229 1.215 -1.2	1.295 1.277 -1.3	1.121 1.114 -.6	.387 .386 -.4			4
	.282 .285 1.1	1.009 1.016 .7	1.293 1.292 -.1	1.390 1.372 -1.3	1.303 1.290 -1.0	1.323 1.302 -1.6	1.272 1.253 -1.5	1.333 1.314 -1.4	1.306 1.286 -1.6	1.388 1.354 -2.5	1.290 1.287 -.3	1.006 1.006 .0	.281 .279 -.5		5
	.471 .479 1.8	1.129 1.147 1.5	1.227 1.233 .5	1.307 1.305 -.2	1.187 1.175 -1.0	1.285 1.269 -1.3	1.117 1.106 -1.0	1.289 1.276 -1.0	1.187 1.169 -1.6	1.301 1.284 -1.3	1.221 1.214 -.6	1.125 1.130 .4	.469 .479 2.2		6
.247 .253 2.6	1.025 1.049 2.4	1.229 1.269 3.2	1.378 1.390 .9	1.331 1.327 -.2	1.290 1.279 -.9	1.112 1.094 -1.6	.976 .967 -.9	1.113 1.110 -.2	1.288 1.279 -.7	1.323 1.311 -.9	1.371 1.356 -1.1	1.225 1.240 1.2	1.020 1.072 5.1	.244 .255 4.4	7
.265 .275 3.7	.853 .863 1.1	1.083 1.086 .3	1.347 1.350 .2	1.273 1.265 -.6	1.119 1.108 -.9	.977 .965 -1.2	1.010 1.000 -1.1	.977 .970 -.7	1.119 1.115 -.3	1.272 1.269 -.3	1.347 1.347 .0	1.083 1.096 1.2	.853 .864 1.3	.265 .271 2.1	8
.244 .248 1.5	1.021 1.031 1.0	1.226 1.233 .6	1.371 1.370 -.1	1.324 1.306 -1.3	1.289 1.273 -1.2	1.113 1.096 -1.5	.976 .965 -1.1	1.112 1.097 -1.4	1.290 1.293 .2	1.331 1.331 .0	1.378 1.381 .2	1.229 1.236 .6	1.025 1.032 .8	.247 .252 1.9	9
	.469 .474 1.2	1.126 1.142 1.5	1.222 1.224 .2	1.301 1.292 -.7	1.188 1.171 -1.4	1.289 1.263 -2.0	1.117 1.108 -.8	1.285 1.277 -.7	1.187 1.180 -.6	1.307 1.309 .1	1.226 1.231 .4	1.129 1.133 .3	.471 .466 -.9		10
	.281 .283 .9	1.007 1.015 .8	1.290 1.291 .1	1.389 1.382 -.5	1.307 1.300 -.5	1.333 1.326 -.5	1.272 1.277 .3	1.323 1.320 -.2	1.303 1.290 -1.0	1.390 1.394 .3	1.292 1.301 .7	1.009 1.016 .7	.282 .282 .2		11
		.387 .391 .9	1.121 1.123 .2	1.295 1.294 -.1	1.229 1.230 .1	1.383 1.387 .3	1.350 1.362 .9	1.376 1.385 .7	1.227 1.233 .5	1.294 1.305 .8	1.122 1.140 1.6	.388 .395 2.0			12
			.391 .391 .1	1.015 1.017 .2	1.137 1.142 .5	1.239 1.253 1.1	1.092 1.119 2.5	1.238 1.256 1.5	1.136 1.154 1.6	1.015 1.028 1.2	.391 .396 1.4				13
				.287 .288 .2	.477 .482 .9	1.040 1.057 1.6	.870 .883 1.6	1.045 1.060 1.4	.478 .486 1.5	.288 .291 1.3					14
	STANDARD DEVIATION = .906					.261 .273 4.6	.275 .281 2.3	.265 .269 1.7			AVERAGE PCT DIFFERENCE = 1.0				15

Summary:

Map No: S1-23-01	Date: 05/11/2009		Power: 26.1%	
Control Rod Position:	$F_Q(Z)$ = 2.263	QPTR:	0.9997	0.9957
D Bank at 173 Steps	$F^N_{\Delta H}$ = 1.521		1.0001	1.0046
	F_Z = 1.375			
	Burnup = 1 MWD/MTU		Axial Offset (%) = +6.275	

Figure 6.2 — ASSEMBLYWISE POWER DISTRIBUTION
67.5% POWER

R	P	N	M	L	K	J	H	G	F	E	D	C	B	A	
	PREDICTED MEASURED PCT DIFFERENCE					.287 .288 .4	.301 .304 .8	.283 .284 .6			PREDICTED MEASURED PCT DIFFERENCE				1
				.301 .301 .1	.497 .498 .1	1.069 1.073 .4	.922 .927 .5	1.065 1.070 .5	.496 .499 .6	.301 .301 .0					2
			.401 .395 -1.4	1.012 1.013 .1	1.130 1.130 .0	1.232 1.233 .1	1.097 1.106 .8	1.233 1.236 .3	1.131 1.131 .1	1.012 1.010 -.2	.400 .396 -1.0				3
		.398 .399 .3	1.107 1.108 .1	1.268 1.275 .6	1.205 1.203 -.1	1.344 1.340 -.3	1.318 1.327 .7	1.350 1.352 .1	1.207 1.206 -.1	1.267 1.263 -.3	1.107 1.105 -.2	.397 .397 -.2			4
	.295 .297 .5	1.007 1.013 .6	1.266 1.265 -.1	1.355 1.344 -.8	1.284 1.274 -.8	1.305 1.280 -2.0	1.253 1.247 -.5	1.314 1.309 -.4	1.287 1.283 -.4	1.354 1.346 -.6	1.264 1.266 .2	1.005 1.004 -.1	.295 .285 -3.4		5
	.490 .493 .5	1.125 1.130 .5	1.205 1.207 .2	1.288 1.292 .3	1.218 1.212 -.5	1.287 1.275 -1.0	1.122 1.116 -.5	1.290 1.284 -.5	1.219 1.211 -.6	1.283 1.279 -.3	1.201 1.201 .0	1.122 1.125 .3	.489 .493 .9		6
.269 .270 .4	1.052 1.058 .6	1.225 1.234 .7	1.347 1.348 .1	1.313 1.308 -.3	1.291 1.284 -.6	1.130 1.121 -.8	.999 .994 -.5	1.131 1.126 -.4	1.290 1.286 -.3	1.307 1.303 -.3	1.342 1.340 -.1	1.222 1.232 .8	1.048 1.080 3.0	.266 .273 2.3	7
.292 .292 .1	.907 .910 .3	1.090 1.094 .4	1.317 1.315 -.2	1.254 1.244 -.8	1.123 1.116 -.7	1.000 .994 -.6	1.040 1.033 -.7	1.000 .995 -.5	1.123 1.122 -.1	1.254 1.254 .0	1.317 1.319 .1	1.090 1.095 .4	.907 .911 .4	.292 .293 .3	8
.266 .267 .3	1.048 1.052 .4	1.222 1.225 .2	1.341 1.335 -.5	1.307 1.284 -1.8	1.290 1.278 -.9	1.131 1.124 -.6	.999 .993 -.6	1.130 1.117 -1.2	1.291 1.294 .2	1.313 1.314 .1	1.347 1.348 .1	1.225 1.224 -.1	1.052 1.047 -.5	.269 .264 -1.9	9
	.489 .491 .5	1.122 1.132 .9	1.201 1.198 -.2	1.283 1.273 -.8	1.219 1.213 -.5	1.290 1.290 .0	1.122 1.119 -.3	1.287 1.282 -.4	1.219 1.217 -.1	1.289 1.294 .4	1.205 1.208 .2	1.125 1.121 -.3	.490 .478 -2.6		10
	.295 .295 .1	1.005 1.004 -.1	1.264 1.258 -.5	1.354 1.344 -.7	1.287 1.285 -.2	1.314 1.315 .1	1.253 1.250 -.3	1.305 1.302 -.2	1.285 1.278 -.5	1.355 1.370 1.1	1.266 1.274 .6	1.007 1.007 .0	.296 .293 -.9		11
		.397 .389 -2.2	1.107 1.100 -.6	1.268 1.262 -.4	1.207 1.209 .2	1.350 1.364 1.0	1.318 1.329 .8	1.345 1.352 .5	1.205 1.211 .5	1.268 1.279 .9	1.108 1.121 1.2	.398 .395 -.6			12
			.400 .398 -.5	1.012 1.009 -.3	1.131 1.134 .3	1.233 1.245 1.0	1.098 1.117 1.8	1.232 1.245 1.1	1.130 1.141 .9	1.012 1.022 .9	.401 .405 1.0				13
				.301 .294 -2.0	.496 .497 .3	1.065 1.076 1.0	.922 .934 1.3	1.069 1.084 1.3	.498 .503 1.1	.301 .304 1.0					14
	STANDARD DEVIATION = .568					.283 .285 .9	.302 .305 1.3	.287 .291 1.3			AVERAGE PCT DIFFERENCE = .6				15

Summary:

Map No: S1-23-02	Date: 05/13/2009		Power: 67.5%	
Control Rod Position:	$F_Q(Z)$ = 1.970	QPTR:	0.9990	0.9997
D Bank at 195 Steps	$F^N_{\Delta H}$ = 1.493		0.9984	1.0028
	F_Z = 1.234			
	Burnup = 19 MWD/MTU		Axial Offset (%) = +5.720	

Figure 6.3 — ASSEMBLYWISE POWER DISTRIBUTION
99.89% POWER

R	P	N	M	L	K	J	H	G	F	E	D	C	B	A	
	PREDICTED MEASURED PCT DIFFERENCE					.296 .298 .8	.314 .321 2.0	.291 .294 .8			PREDICTED MEASURED PCT DIFFERENCE				1
				.303 .303 .1	.500 .501 .2	1.065 1.070 .4	.954 .960 .6	1.061 1.066 .5	.498 .499 .1	.302 .302 -.1					2
			.399 .392 -1.6	.991 .992 .1	1.112 1.112 .0	1.218 1.220 .2	1.099 1.107 .7	1.219 1.222 .3	1.112 1.112 .0	.991 .989 -.2	.399 .397 -.5				3
		.396 .398 .6	1.081 1.083 .2	1.240 1.248 .6	1.192 1.191 -.1	1.328 1.325 -.3	1.305 1.314 .7	1.334 1.335 .1	1.193 1.192 -.1	1.240 1.237 -.2	1.080 1.079 -.1	.396 .395 -.2			4
	.297 .300 1.0	.986 .997 1.1	1.239 1.241 .1	1.338 1.331 -.5	1.288 1.279 -.7	1.307 1.284 -1.8	1.255 1.249 -.5	1.315 1.309 -.5	1.290 1.284 -.5	1.337 1.332 -.4	1.237 1.239 .2	.985 .983 -.2	.297 .288 -2.8		5
	.493 .497 .8	1.107 1.116 .8	1.192 1.195 .3	1.292 1.291 -.1	1.279 1.271 -.6	1.309 1.296 -1.0	1.143 1.137 -.5	1.312 1.303 -.7	1.279 1.264 -1.2	1.287 1.279 -.6	1.188 1.184 -.4	1.104 1.105 .1	.492 .496 .9		6
.279 .281 .6	1.050 1.059 .9	1.213 1.227 1.2	1.331 1.333 .1	1.314 1.306 -.6	1.313 1.303 -.7	1.158 1.147 -.9	1.029 1.022 -.7	1.158 1.151 -.6	1.312 1.303 -.7	1.309 1.299 -.8	1.326 1.311 -1.2	1.210 1.216 .5	1.047 1.080 3.2	.277 .283 2.5	7
.306 .305 -.2	.941 .944 .4	1.093 1.095 .1	1.305 1.301 -.3	1.256 1.239 -1.4	1.144 1.134 -.9	1.030 1.022 -.8	1.070 1.062 -.8	1.030 1.023 -.7	1.144 1.141 -.3	1.257 1.253 -.3	1.305 1.302 -.2	1.094 1.098 .4	.941 .948 .7	.306 .308 .7	8
.276 .277 .2	1.047 1.051 .4	1.210 1.213 .3	1.326 1.322 -.3	1.309 1.294 -1.2	1.312 1.301 -.8	1.158 1.149 -.8	1.029 1.021 -.8	1.158 1.145 -1.1	1.313 1.318 .4	1.315 1.315 .0	1.331 1.332 .0	1.213 1.213 .0	1.050 1.048 -.2	.279 .276 -1.3	9
	.492 .495 .7	1.104 1.116 1.1	1.188 1.189 .0	1.287 1.281 -.4	1.279 1.273 -.5	1.312 1.304 -.6	1.143 1.136 -.6	1.309 1.301 -.7	1.279 1.274 -.3	1.292 1.297 .4	1.192 1.196 .3	1.107 1.106 -.1	.493 .483 -2.0		10
	.297 .298 .4	.985 .987 .3	1.237 1.235 -.2	1.337 1.332 -.4	1.291 1.290 -.1	1.315 1.315 .0	1.255 1.250 -.4	1.307 1.299 -.7	1.288 1.268 -1.5	1.338 1.355 1.3	1.239 1.251 .9	.986 .988 .2	.297 .296 -.6		11
		.396 .392 -1.0	1.080 1.078 -.2	1.240 1.239 -.2	1.194 1.198 .4	1.334 1.350 1.2	1.305 1.314 .6	1.329 1.333 .3	1.192 1.196 .3	1.240 1.255 1.2	1.081 1.102 2.0	.396 .393 -.7			12
			.399 .398 -.2	.991 .989 -.2	1.112 1.116 .4	1.219 1.230 .9	1.099 1.113 1.2	1.218 1.231 1.1	1.112 1.128 1.4	.991 1.005 1.4	.399 .405 1.7				13
				.302 .295 -2.3	.499 .500 .3	1.061 1.072 1.0	.954 .966 1.2	1.065 1.083 1.6	.500 .507 1.5	.303 .307 1.4					14
	STANDARD DEVIATION = .577					.291 .295 1.3	.315 .319 1.4	.296 .301 1.6			AVERAGE PCT DIFFERENCE = .7				15

Summary:

Map No: S1-23-03	Date: 05/15/2009		Power: 99.89%	
Control Rod Position:	$F_Q(Z)$ = 1.866	QPTR:	0.9994	0.9983
D Bank at 227 Steps	$F^N_{\Delta H}$ = 1.482		0.9992	1.0030
	F_Z = 1.168			
	Burnup = 102 MWD/MTU		Axial Offset (%) = +3.281	

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SECTION 7 — CONCLUSIONS

Table 7.1 summarizes the results associated with Surry Unit 1 Cycle 23 startup physics testing program. As noted herein, all test results were acceptable and within associated design tolerances, technical specification limits, or COLR limits. It is anticipated, based on the results associated with the S1C23 startup physics testing program, that the Surry 1 core will continue to operate safely throughout Cycle 23.

The Programs Review Checklist (PRC) and Controlled Documents Summary (CDS) were reviewed as a part of this technical report in accordance with NDCM 3.11, Rev. 12. No impact to any programs or controlled documents was identified as a result of the review; therefore a PRC and CDS will not be attached to this technical report or to any associated engineering transmittal.

The data herein is simply intended to summarize the S1C23 startup physics testing program for information only and meet the requirements of Surry Technical Specification 6.6.A.1. This report does not have any impact on the Surry Operating License, Technical Specifications, or the design, the function, or any calculation associated with a SSC. Furthermore, this report does not perform or involve any test or temporary modification. Activity screening (in the form of an Activity Checklist) is thus not required. Because the PRC and CDS review did not flag any programs or controlled documents as impacted by the data herein, no Activity Checklist will be attached to this technical report or any associated engineering transmittal per NDCM 3.11, Rev. 12.

Table 7.1

STARTUP PHYSICS TESTING RESULTS SUMMARY

Parameter	Measured (M)	Predicted (P)	Diff (M-P) or (M-P)/P,%	Design Tolerance
Critical Boron Concentration (HZP ARO), ppm	1645	1623	22	±50
Critical Boron Concentration (HZP Ref Bank in), ppm	1473	1470	3	±27
Isothermal Temp Coefficient (HZP ARO), pcm/F	-1.682	-1.262	-0.420	±2
Differential Boron Worth (HZP ARO), pcm/ppm	-7.41	-7.53	-1.6%	±10%
Reference Bank Worth (B-bank, dilution), pcm	1275	1317	-3.2%	±10%
SB-bank Worth (Rod Swap), pcm	1108	1157	-4.2%	±15%
SA-bank Worth (Rod Swap), pcm	905	892	1.4%	±15%
D-bank Worth (Rod Swap), pcm	1073	1094	-1.9%	±15%
C-bank Worth (Rod Swap), pcm	942	974	-3.3%	±15%
Rod Worth ≤ 600 pcm:				
A-bank Worth (Rod Swap), pcm	229	230	-1.0	±100
Total Bank Worth, pcm	5533	5664	-2.3%	±10%
S1C23 testing time:		**6.2 hrs**		
[criticality 05/11/09 @ 0102 to end of rod swap 05/11/09 @ 0715]				
Recent Startups:				
S2C22 testing time:		6.2 hrs		
S1C22 testing time:		8.0 hrs		
S2C21 testing time:		5.8 hrs		
S1C21 testing time:		5.0 hrs		
S2C20 testing time:		8.0 hrs		
S1C20 testing time:		7.6 hrs		

SECTION 8 — REFERENCES

1. D. B. Livingston, "Surry Unit 1, Cycle 23 Design Report," Technical Report NE-1568, Rev. 0, May 2009

2. R. W. Twitchell, "Control Rod Reactivity Worth Determination By The Rod Swap Technique," Topical Report VEP-FRD-36-Rev. 0.2-A, September 2004

3. D. A. Pearson, "The Virginia Power CECOR Code Package," Technical Report NE-0831, Rev. 8, August 2004

4. Surry Units 1 and 2 Technical Specifications, Sections 3.12.C.1, 3.12.F.1, 4.10.A.

5. R. W. Twitchell, "Operational Impact of the Implementation of Westinghouse Integral Fuel Burnable Absorber (IFBA) and the Removal of Flux Suppression Inserts (FSIs) for Surry Unit 1 Cycle 21," Technical Report NE-1466, Rev. 0, January 2006

6. C. D. Roecker, "Surry Unit 1 Cycle 23 TOTE Calculations and Detailed Isotopics," Calculation PM-1303, Rev. 0, May, 2009

7. J. L. Meszaros et al, "Surry Unit 1 Cycle 23 Flux Map Analysis," Calculation PM-1304, Rev. 0, and Addenda A - B, May 2009

8. R. K. Fawls, "Reload Safety Evaluation Surry 1 Cycle 23 Pattern NXS," EVAL-ENG-RSE-S1C23, Rev. 0, March, 2009

9. S. B. Rosenfelder and S. S. Kere, "RMAS v6 Verification," Calculation PM-1075, Rev. 0, May, 2005

10. W. R. Kohlroser, "Administrative Limits on Hot Rod Drop Time Testing for Use as Acceptance Criteria in 1/2-NPT-RX-014 and 1/2-NPT-RX-007," Engineering Transmittal ET-NAF-97-0197, Rev. 0, August, 1997

11. J. L. Meszaros, "Surry Unit 1 Cycle 23 Full Core Loading Plan," Engineering Transmittal ET-NAF-08-0099, Rev. 0, November, 2008

12. N. A. Yonker, "Validation of Rod Drop Test Computer for Hot Rod Drop Analysis," Calculation PM-1044, Rev. 0, November, 2004

13. A. H. Nicholson, "Justification For Defining 0 To 2 Steps Withdrawn As Fully Inserted When Measuring Control And Shutdown Banks During The Surry Startup Physics Testing Program," Engineering Transmittal ET-NAF-06-0046, Rev. 0, April, 2006.

14. J. L. Meszaros, "Surry Unit 1 Cycle 23 Startup Physics Testing Logs and Results", Memorandum MEMO-NCD-20090034, Rev. 0, May 2009

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APPENDIX — STARTUP PHYSICS TEST SUMMARY SHEETS

Surry Power Station Unit 1 Cycle 23 Startup Physics Test Summary Sheet - Formal Tests (Page 1 of 6)

Measured Value	Design Criteria	Acceptance Criteria	Design Criteria Met	Acceptance Criteria Met	Date/ Time of Test	Prepared/ Reviewer
ZPTR= 2.0×10^{-9} to 1.0×10^{-7} amps	background < ZPTR < POAH background = 1.56×10^{-11} (NSS) amps POAH= 2.058×10^{-7} amps	N/A	✓ Yes No	N/A	05/11/09 01:58	SBR / MEH.
ρ_c= 59.36, -50.92 pcm (measured reactivity) ρ_t= 59.78, -52.19 pcm (predicted reactivity) %D = {(ρc - ρt)/ρt} x 100% %D = -0.71, -2.43	$\lvert(\rho_c - \rho_t)/\rho_t\rvert \times 100\% \le 4.0\ \%^3$ The allowable range is set to the larger of the measured results or the pre-critical bench test. Pre-critical Bench Test Results +/- 109 pcm Allowable range +/- 100 pcm	N/A	✓ Yes No	N/A	05/11/09 01:58	SBR / MEH.
$(C_B)^M_{ARO}$= 1645 ppm (Adj. To design conds.)	$(C_B)_{ARO}$=[1] 1623 ± 50 ppm $\Delta(C_B)_{ARO}=(C_B)^M_{ARO} - (C_B)_{ARO}$ = +22 ppm	$\lvert\alpha C_B \times \Delta(C_B)_{ARO}\rvert \le 1000$ pcm [T.S. 4.10.A] αC_B=[1] -7.45 pcm/ppm	✓ Yes No	✓ Yes No	05/11/09 01:58	SBR / MEH.
$(\alpha_T^{ISO})^M_{ARO}$ = -1.682 pcm/F	$(\alpha_T^{ISO})_{ARO}$ =[1] -1.262 ± 2 pcm/F $(\alpha_T^{ISO})^M_{ARO} - (\alpha_T^{ISO})_{ARO}$ = -0.42 pcm/F	$\alpha_T^{ISO} \le \alpha_M^{lim} - \alpha_T^{mod} + \alpha_T^{DOP}$ $\alpha_T^{ISO} \le 3.7$ pcm/F where: (α_M^{lim}); 8.0 pcm/F [COLR 3.1.1] (α_T^{mod})[2]; 0.5 pcm/F (α_T^{DOP})[4]; -1.8 pcm/F	✓ Yes No	✓ Yes No	05/11/09 02:47	SBR / MEH.
$I_B^{REF,M}$= 1275 pcm	I_B^{REF}=[1] 1317 ± 10% 100x(Meas. - Des.)/Des. = -3.2 %	N/A	✓ Yes No	N/A	05/11/09 03:31	SBR / MEH.

References 1.) NE-1568, Rev. 0
2.) Memorandum from C.T. Snow to E.J. Lozito, dated June 27, 1980
3.) WCAP-7905, Rev. 1
4.) ET-NAF-09-0039, Rev. 0

Surry Power Station Unit 1 Cycle 23 Startup Physics Test Summary Sheet - Formal Tests (Page 2 of 6)

Measured Value	Design Criteria	Acceptance Criteria	Design Criteria Met	Acceptance Criteria Met	Date/ Time of Test	Preparer/ Reviewer
$(C_B)^M_B$= 1473 ppm	$(C_B)_B$=[1] 1448+$\Delta(C_B)_{ARO}$ ± 27 ppm $\Delta(C_B)_{ARO}$= +22 ppm (from above) $(C_B)_B$= 1470 ± 27 ppm $(C_B)^M_B$ - $(C_B)_B$ = +3 ppm	N/A	✓ Yes No	N/A	05/11/09 06:35	SGR/ MEH
$(\alpha C_B)^M$= -7.41 pcm/ppm	αC_B=[1] -7.53 ± 0.75 pcm/ppm $\Delta\alpha C_B$=$(\alpha C_B)^M$ - (αC_B) = +0.12 pcm/ppm	N/A	✓ Yes No	N/A	05/11/09 01:58	SGR/ MEH
I_A^{RS}= 229.3 pcm	$(I_A^{RS})^4$= 230.0 ± 160 pcm Meas. - Des. = -0.7 pcm	N/A	✓ Yes No	N/A	05/11/09 05:50	SGR/ MEH
I_{SA}^{RS}= 905.1 pcm	$(I_{SA}^{RS})^4$= 892.2 ± 15% 100x(Meas. - Des.)/Des. = +1.4 %	N/A	✓ Yes No	N/A	05/11/09 05:50	SGR/ MEH
I_C^{RS}= 942.0 pcm	$(I_C^{RS})^4$= 973.8 ± 15% 100x(Meas. - Des.)/Des. = -3.3 %	N/A	✓ Yes No	N/A	05/11/09 05:50	SGR/ MEH
I_D^{RS}= 1073.2 pcm	$(I_D^{RS})^4$= 1094.2 ± 15% 100x(Meas. - Des.)/Des. = -1.9 %	N/A	✓ Yes No	N/A	05/11/09 05:50	SGR/ MEH
I_{SB}^{RS}= 1108.0 pcm	$(I_{SB}^{RS})^4$= 1156.9 ± 15% 100x(Meas. - Des.)/Des. = -4.2 %	N/A	✓ Yes No	N/A	05/11/09 05:50	SGR/ MEH
I_{total}= 5532.6 pcm	$(I_{total})^4$= 5664.1 ± 10% 100x(Meas. - Des.)/Des. = -2.3 %	N/A	✓ Yes No	N/A	05/11/09 05:50	SGR/ MEH

References 1.) NE-1568, Rev. 0
2.) Memorandum from C.T. Snow to E.J. Lozito, dated June 27, 1980
3.) WCAP-7905, Rev. 1
4.) ET-NAF-09-0039, Rev. 0

Surry Power Station Unit 1 Cycle 23 Startup Physics Test Summary Sheet - Formal Tests (Page 3 of 6)

Measured Value	Design Criteria	Acceptance Criteria	Design Criteria Met	Acceptance Criteria Met	Date/ Time of Test	Preparer/ Reviewer
Map Power Level (% Full Power) = 26.1						
Max Relative Assembly Power, %DIFF (M-P)/P						
%DIFF= 5.1 % for Pi ≥0.9 4.9 % for Pi<0.9	±10% for P_i ≥0.9 ±15% for P_i<0.9 (P_i = assy power)[1,3]	N/A	✓ Yes ___ No	N/A	5/11/09 20:24	Kay [illegible]
Nuclear Enthalpy Rise Hot Channel Factor, FΔH(N)						
FΔH(N)= 1.521	N/A	FΔH(N)≤1.56(1+0.3(1-P)) [COLR 3.4]	N/A	✓ Yes ___ No		
Total Heat Flux Hot Channel Factor, FQ(Z)						
Peak $F_Q(Z)$ Hot Channel Factor= 2.263	N/A	$F_Q(Z)$≤4.64*K(Z) [COLR 3.3] Minimum Margin to COLR Limit= 50.5%	N/A	✓ Yes ___ No		
Maximum Positive Incore Quadrant Power Tilt						
Tilt= 1.0046	≤1.02[2]	N/A	✓ Yes ___ No	N/A		
Rodded Flux Map Criterion (If either criterion is met, a rodded flux map ≤30% power with rods at the insertion limit is not required)[5]						
Max RPD %DIFF= 5.1 % for P>0.9	N/A	≤ 20.6%	N/A	✓ Yes ___ No	5/11/09 20:24	Kay [illegible]
OR Synthesized FdH at limiting power[5] N/A	N/A	FΔH ≤1.56(1+0.3(1-P)) [COLR 3.4]				

References
1.) NE-1568, Rev. 0
2.) Memorandum from C.T. Snow to E.J. Lozito, dated June 27, 1980
3.) WCAP-7905, Rev. 1
4.) ET-NAF-09-0039, Rev. 0
5.) PM-1300 Rev. 0

Surry Power Station Unit 1 Cycle 23 Startup Physics Test Summary Sheet - Formal Tests (Page 4 of 6)

Measured Value	Design Criteria	Acceptance Criteria	Design Criteria Met	Acceptance Criteria Met	Date/ Time of Test	Preparer/ Reviewer
Map Power Level (% Full Power) = 67.5%						
Max Relative Assembly Power, %DIFF (M-P)/P					05/13/09 0246	SAR TSP
%DIFF= +3.0 % for Pi ≥0.9 -3.4 % for P_i<0.9	±10% for P_i≥0.9 ±15% for P_i<0.9 (P_i = assy power)[1,2]	N/A	✓ Yes ___ No	N/A		
Nuclear Enthalpy Rise Hot Channel Factor, FΔH(N)						
FΔH(N)= 1.493	N/A	FΔH(N)≤1.56(1+0.3(1-P)) [COLR 3.4]	N/A	✓ Yes ___ No		
Total Heat Flux Hot Channel Factor, FQ(Z)						
Peak $F_Q(Z)$ Hot Channel Factor= 1.970	N/A	$F_Q(Z)$≤(2.32/P)*K(Z) [COLR 3.3] Minimum Margin to COLR Limit= 41.0%	N/A	✓ Yes ___ No		
Maximum Positive Incore Quadrant Power Tilt						
Tilt= 1.0028	≤1.02[3]	N/A	✓ Yes ___ No	N/A		

References 1.) NE-1568, Rev. 0
2.) Memorandum from C.T. Snow to E.J. Lozito, dated June 27, 1980
3.) WCAP-7905, Rev. 1
4.) ET-NAF-09-0039, Rev. 0

Surry Power Station Unit 1 Cycle 23 Startup Physics Test Summary Sheet - Formal Tests (Page 5 of 6)

Measured Value	Design Criteria	Acceptance Criteria	Design Criteria Met	Acceptance Criteria Met	Date/ Time of Test	Preparer/ Reviewer
Mid Flux Map, 95% ≤ Power ≤ 100%						
Map Power Level (% Full Power) = 99.89						
Max Relative Assembly Power, %DIFF (M-P)/P					5/18/09 1638	Ady CNC
%DIFF= 3.2 % for $P_i \geq 0.9$ -2.8 % for $P_i < 0.9$	±10% for $P_i \geq 0.9$ ✓ ±15% for $P_i < 0.9$ ✓ (P_i = assy power)[1,3]	N/A	✓ Yes ___ No	N/A		
Nuclear Enthalpy Rise Hot Channel Factor, FΔH(N)						
FΔH(N)= 1.482	N/A	FΔH(N)≤1.56(1+0.3(1-P)) [COLR 3.4]	N/A	✓ Yes ___ No		
Total Heat Flux Hot Channel Factor, FQ(Z)						
Peak $F_Q(Z)$ Hot Channel Factor= 1.866	N/A	$F_Q(Z) \leq (2.32/P)*K(Z)$ [COLR 3.3] Minimum Margin to COLR Limit= 24.49 %	N/A	✓ Yes ___ No		
Maximum Positive Incore Quadrant Power Tilt						
Tilt= 0.53%	≤ 1.02[3]	N/A	✓ Yes ___ No	N/A		

References 1.) NE-1568, Rev. 0
2.) Memorandum from C.T. Snow to E.J. Lozito, dated June 27, 1980
3.) WCAP-7905, Rev. 1
4.) ET-NAF-09-0039, Rev. 0

Surry Power Station Unit 1 Cycle 23 Startup Physics Test Summary Sheet - Formal Tests (Page 6 of 6)

Measured Value	Design Criteria	Acceptance Criteria	Design Criteria Met	Acceptance Criteria Met	Date/ Time of Test	Preparer/ Reviewer
F_{total}[4] 286190 gpm	N/A	$F_{total} \geq 273000$ gpm [T.S. 3.12.F.1]	N/A	✓ Yes No	6/1/09 1400	[illegible] / CNC

References 1.) NE-1568, Rev. 0
2.) Memorandum from C.T. Snow to E.J. Lozito, dated June 27, 1980
3.) WCAP-7905, Rev. 1
4.) ET-NAF-09-0039, Rev. 0