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United States Nuclear Regulatory Commission
Regional Administrator – Region II
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Atlanta, Georgia 30303-1257

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VIRGINIA ELECTRIC AND POWER COMPANY
SURRY POWER STATION UNIT 2
CYCLE 26 STARTUP PHYSICS TESTS REPORT

As required by Surry Power Station (Surry) Technical Specification 6.6.A.1, enclosed is the Surry Unit 2 Cycle 26 Startup Physics Tests Report. This report summarizes the results of the physics testing program performed prior to and following initial criticality of Cycle 26 on May 20, 2014. 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.

Sincerely,

Paul A. Blasioli

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Dominion Resources Services, Inc. for
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Enclosure

Commitments made in this letter: None

IE26
NRR

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Enclosure

SURRY UNIT 2 CYCLE 26 STARTUP PHYSICS TESTS REPORT

July 2014

Virginia Electric and Power Company (Dominion)
Surry Power Station Unit 2

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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 2, Cycle 26 core could be operated safely, and makes an initial evaluation of the performance of the core. This report was performed in accordance with DNES-AA-NAF-NCD-5007 [Ref. 17]. 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 2, Cycle 26 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.

SECTION 1 — INTRODUCTION AND SUMMARY

On April 20, 2014, Unit No. 2 of Surry Power Station completed Cycle 25 and began refueling [Ref. 1]. During this refueling, 61 of the 157 fuel assemblies in the core were replaced with 61 fresh Batch S2/28 assemblies. The Cycle 26 core consists of 6 sub-batches of fuel: two fresh batches (S2/28A and S2/28B), two once-burned batches (S2/27A and S2/27B), and two twice-burned batches (S2/26A and S2/26B). S2C26 is the first Surry cycle to load a full core of the 15x15 Upgrade (Upgrade) Fuel Design [Ref. 1].

The Westinghouse Upgrade fuel assembly design incorporates ZIRLO (I-spring) structural mid grids with balanced mixing vane pattern, ZIRLO Intermediate Flow Mixing (IFM) grids for improved thermal-hydraulic performance, "tube-in-tube" guide thimbles, and the use of optimized ZIRLO fuel clad that improves corrosion resistance and oxidation of the bottom portion of the fuel clad to improve debris resistance. The Surry 2 Batch 28 fuel is the first Unit 2 batch to utilize Westinghouse's Robust Protective Grid (RPG) and modified Debris Filter Bottom Nozzle (mDFBN). The RPGs were developed to mitigate grid failure mechanisms and the mDFBNs reduce the likelihood of debris bypass into the fuel bundles.

This cycle uses Westinghouse's Integral Fuel Burnable Absorber (IFBA) fuel product. 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].

Surry Unit 2 Cycle 26 implements the reinsertion of Secondary Source Assemblies (SSAs) to improve Source Range Detector indication. Cycle 26 loads SSAs in core locations

J-02 and G-14. Each assembly consists of six source rods containing antimony and beryllium pellets encapsulated in a double layer of stainless steel cladding. The SSAs are dimensionally similar to those loaded in prior Surry cycles, and are compatible with the 15 x 15 Upgrade Fuel Design. There are no thimble plugging devices in S2C26. The cycle design report [Ref. 1] provides a more detailed description of the Cycle 26 core.

The S2C26 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 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 26 core [Ref. 1].

According to the Startup Physics logs, the Cycle 26 core achieved initial criticality on May 20, 2014 at 18:33 [Ref. 14]. Prior to and following criticality, startup physics tests were performed as outlined in Table 1.1. This cycle used the Reactivity Measurement and Analysis System (RMAS) to perform startup physics testing. Note that RMAS v.6 [Ref. 9] was used for S2C26 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 2.40 second Technical Specification [Ref. 4] limit, as well as the Surry Unit 2 1.68 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 –4.6% of the design prediction. The reference bank (Control Bank B) worth was within -3.5% of its design prediction. Control rod banks with design predictions greater than 600 pcm were within -8.4% of their design predictions. For individual banks worth 600 pcm or less (only Control Bank A fits this category), the difference was within -3 pcm of the design prediction. These results are within the design tolerances of $\pm$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, all-rods-out (ARO) and Reference Bank (B-bank) in, were within the design tolerances and the Technical Specification criterion [Ref. 4] that the overall core reactivity balance shall be within ±1% Δk/k of the design prediction. The boron worth coefficient measurement was within -0.4% of the design prediction, which is within the design tolerance of ±10%.

The measured isothermal temperature coefficient (ITC) for the ARO configuration was within 0.190 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 ±5.3% of the design predictions, where a -5.3% maximum difference occurred in the 29.80% power map in assembly J10. 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 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 273,000 gpm and greater than the limit in the COLR (276,000 gpm), as required by Surry Technical Specifications [Ref. 4]. The total RCS Flow was measured as 294,349 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 2 – CYCLE 26
CHRONOLOGY OF TESTS

Test	Date	Time	Power	Reference Procedure
Hot Rod Drop-Hot Full Flow	05/20/14	1013	HSD	2-NPT-RX-014
Reactivity Computer Checkout	05/20/14	2011	HZP	2-NPT-RX-008
Boron Endpoint – ARO	05/20/14	2154	HZP	2-NPT-RX-008
Zero Power Testing Range	05/20/14	2011	HZP	2-NPT-RX-008
Boron Worth Coefficient	05/20/14	2357	HZP	2-NPT-RX-008
Temperature Coefficient – ARO	05/20/14	2045	HZP	2-NPT-RX-008
Bank B Worth	05/20/14	2155	HZP	2-NPT-RX-008
Boron Endpoint – B in	05/20/14	2357	HZP	2-NPT-RX-008
Bank A Worth – Rod Swap	05/21/14	0000	HZP	2-NPT-RX-008
Bank C Worth – Rod Swap	05/21/14	0000	HZP	2-NPT-RX-008
Bank SB Worth – Rod Swap	05/21/14	0000	HZP	2-NPT-RX-008
Bank SA Worth – Rod Swap	05/21/14	0000	HZP	2-NPT-RX-008
Bank D Worth – Rod Swap	05/21/14	0000	HZP	2-NPT-RX-008
Total Rod Worth	05/21/14	0000	HZP	2-NPT-RX-008
Flux Map – less than 30% Power Peaking Factor Verification & Power Range Calibration	05/21/14	1545	29.8%	2-NPT-RX-002 2-NPT-RX-008 2-NPT-RX-005 2-GEP-RX-001
Flux Map – 65% - 75% Power Peaking Factor Verification & Power Range Calibration	05/22/14	2129	71.10%	2-NPT-RX-002 2-NPT-RX-008 2-NPT-RX-005 2-GEP-RX-001
Flux Map – 95% - 100% Power Peaking Factor Verification & Power Range Calibration	05/27/14	0700	99.87%	2-NPT-RX-002 2-NPT-RX-008 2-NPT-RX-005 2-GEP-RX-001
RCS Flow Measurement	05/23/14	1800	HFP	2-NPT-RX-009

Figure 1.1

SURRY UNIT 2 – CYCLE 26
CORE LOADING MAP

SURRY UNIT 2 - CYCLE 26
FULL CORE LOADING PLAN
REVISION NO. 0

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VEP-NES-NAF

NORTH ↑

	R	P	N	M	L	K	J	H	G	F	E	D	C	B	A
1							27X	20X	22X						
2					13X	RCC 10X	SS9 649	RCC 651	632	RCC 08X	11X				
3				44X	638	659	RCC 607	37Y	RCC 604	661	635	50X			
4			38X	RCC 647	614	RCC 45Y	12Y	38Y	13Y	RCC 51Y	602	RCC 641	41X		
5		16X	643	610	RCC 18Y	28Y	01Y	619	04Y	25Y	RCC 20Y	611	639	01X	
6		RCC 14X	655	RCC 52Y	22Y	RCC 44Y	623	RCC 29Y	621	RCC 42Y	23Y	RCC 48Y	658	RCC 12X	
7	21X	630	RCC 601	11Y	06Y	627	RCC 55Y	57Y	RCC 54Y	629	08Y	09Y	RCC 613	644	25X
8	18X	RCC 650	39Y	36Y	617	RCC 40Y	53Y	625	60Y	RCC 35Y	618	41Y	30Y	RCC 653	19X
9	24X	633	RCC 606	16Y	03Y	624	RCC 58Y	56Y	RCC 59Y	626	02Y	10Y	RCC 608	637	23X
10		RCC 07X	660	RCC 49Y	26Y	RCC 31Y	628	RCC 43Y	622	RCC 33Y	21Y	RCC 47Y	656	RCC 15X	
11		05X	636	615	RCC 19Y	24Y	05Y	620	07Y	27Y	RCC 17Y	616	642	02X	
12			53X	RCC 645	612	RCC 50Y	14Y	32Y	15Y	RCC 46Y	605	RCC 646	55X		
13				45X	640	657	RCC 603	34Y	RCC 609	654	631	54X			
14					04X	RCC 06X	634	RCC 652	SS8 648	RCC 09X	03X				
15							26X	17X	28X						

90° (at left, row 8); 0° (at bottom, column H)

INCORE DEVICE DESCRIPTIONS:
RCC- FULL LENGTH CONTROL ROD
SS#- Secondary Source Assembly

Prepared By: D. R. Kinney Date: 10/9/13

Reviewed By: T. S. Psuik Date: 10/10/13

Approved By: A. H. Nicholson Date: 10/21/13

Concurrence By: A. L. Black Date: 10/16/13

Approved By: M. N. LaPlade Date: 10/18/13

Figure 1.2

SURRY UNIT 2 – CYCLE 26
BEGINNING OF CYCLE FUEL ASSEMBLY BURNUPS (GWD/MTU)

MEASURED PREDICTED

	R	P	N	M	L	K	J	H	G	F	E	D	C	B	A	
1							42.79 42.83	28.49 28.49	43.10 42.91							1
2					41.91 42.03	42.20 42.21	0.00 0.00	0.00 0.00	0.00 0.00	42.25 42.18	42.04 41.91					2
3				39.68 39.77	0.00 0.00	0.00 0.00	0.00 0.00	19.67 19.58	0.00 0.00	0.00 0.00	0.00 0.00	39.53 39.56				3
4			39.58 39.74	0.00 0.00	0.00 0.00	22.54 22.57	23.34 23.14	19.54 19.58	23.13 23.15	22.98 22.55	0.00 0.00	0.00 0.00	40.05 39.89			4
5		42.09 41.94	0.00 0.00	0.00 0.00	23.27 23.09	19.25 19.18	24.12 23.83	0.00 0.00	23.81 23.86	19.25 19.14	23.12 23.10	0.00 0.00	0.00 0.00	42.17 42.01		5
6		42.07 42.14	0.00 0.00	22.61 22.55	19.22 19.17	19.94 19.76	0.00 0.00	21.67 21.73	0.00 0.00	19.82 19.78	19.19 19.19	22.75 22.57	0.00 0.00	42.06 42.19		6
7	42.79 42.97	0.00 0.00	0.00 0.00	23.15 23.17	23.82 23.85	0.00 0.00	23.59 23.64	23.55 23.66	23.63 23.38	0.00 0.00	23.96 23.84	23.32 23.15	0.00 0.00	0.00 0.00	43.02 42.89	7
8	28.43 28.47	0.00 0.00	19.58 19.54	19.66 19.54	0.00 0.00	21.74 21.71	23.34 23.39	0.00 0.00	23.42 23.39	21.88 21.71	0.00 0.00	19.54 19.57	19.63 19.57	0.00 0.00	28.43 28.47	8
9	42.88 42.89	0.00 0.00	0.00 0.00	23.28 23.15	23.86 23.84	0.00 0.00	23.28 23.38	23.52 23.66	23.57 23.64	0.00 0.00	24.26 23.85	23.14 23.17	0.00 0.00	0.00 0.00	42.95 42.97	9
10		42.15 42.19	0.00 0.00	22.67 22.57	19.17 19.19	19.86 19.78	0.00 0.00	21.81 21.73	0.00 0.00	19.81 19.76	19.46 19.17	22.75 22.55	0.00 0.00	42.71 42.14		10
11		42.02 42.01	0.00 0.00	0.00 0.00	23.11 23.10	19.25 19.14	23.88 23.86	0.00 0.00	23.82 23.83	19.28 19.18	23.31 23.09	0.00 0.00	0.00 0.00	41.92 41.94		11
12			39.99 39.89	0.00 0.00	0.00 0.00	22.59 22.55	23.22 23.15	19.52 19.55	23.24 23.14	22.57 22.57	0.00 0.00	0.00 0.00	39.78 39.74			12
13				39.53 39.56	0.00 0.00	0.00 0.00	0.00 0.00	19.52 19.55	0.00 0.00	0.00 0.00	0.00 0.00	39.72 39.77				13
14					41.81 41.91	42.28 42.18	0.00 0.00	0.00 0.00	0.00 0.00	42.35 42.21	41.96 42.03					14
15							42.92 42.91	28.35 28.49	43.06 42.83							15

Figure 1.3

SURRY UNIT 2 – CYCLE 26
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

Figure 1.4

SURRY UNIT 2 – CYCLE 26
CONTROL ROD LOCATIONS

180°

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

90° (left, row 8) — 270° (right, row 8)

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 or equal to 530 °F per 2-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 2 Cycle 26 used the rod drop test computer (RDTC) in conjunction with the Computer Enhanced Rod Position Indication (CERPI) 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). Original data is also saved as an ASCII file and stored electronically. Further details about the RDTC can be found in [Ref. 12].

A typical rod drop trace for S2C26 is shown in Figure 2.1. The measured drop time for each control rod is recorded on Figure 2.2. The slowest, fastest, and average drop times are summarized in Table 2.1. Figure 2.3 shows slowest, fastest, and average drop times for Surry 2 cycles 20-26. 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 1.68 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 2 – CYCLE 26 STARTUP PHYSICS TESTS
HOT ROD DROP TIME SUMMARY

ROD DROP TIME TO DASHPOT ENTRY

SLOWEST ROD	FASTEST ROD	AVERAGE TIME
F-06 1.38 sec.	L-05 1.25 sec	1.29 sec.

Figure 2.1

SURRY UNIT 2 – CYCLE 26 STARTUP PHYSICS TESTS
TYPICAL ROD DROP TRACE

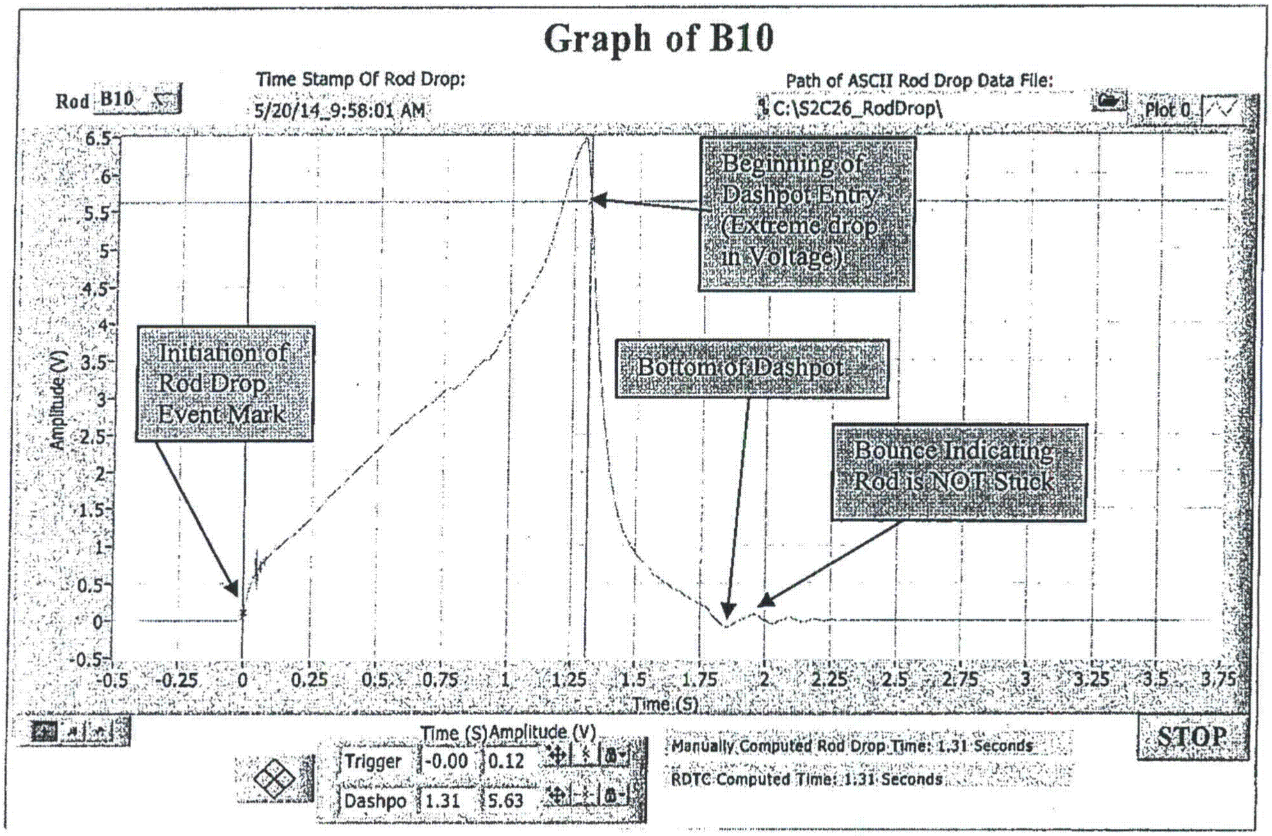


Figure 2.2

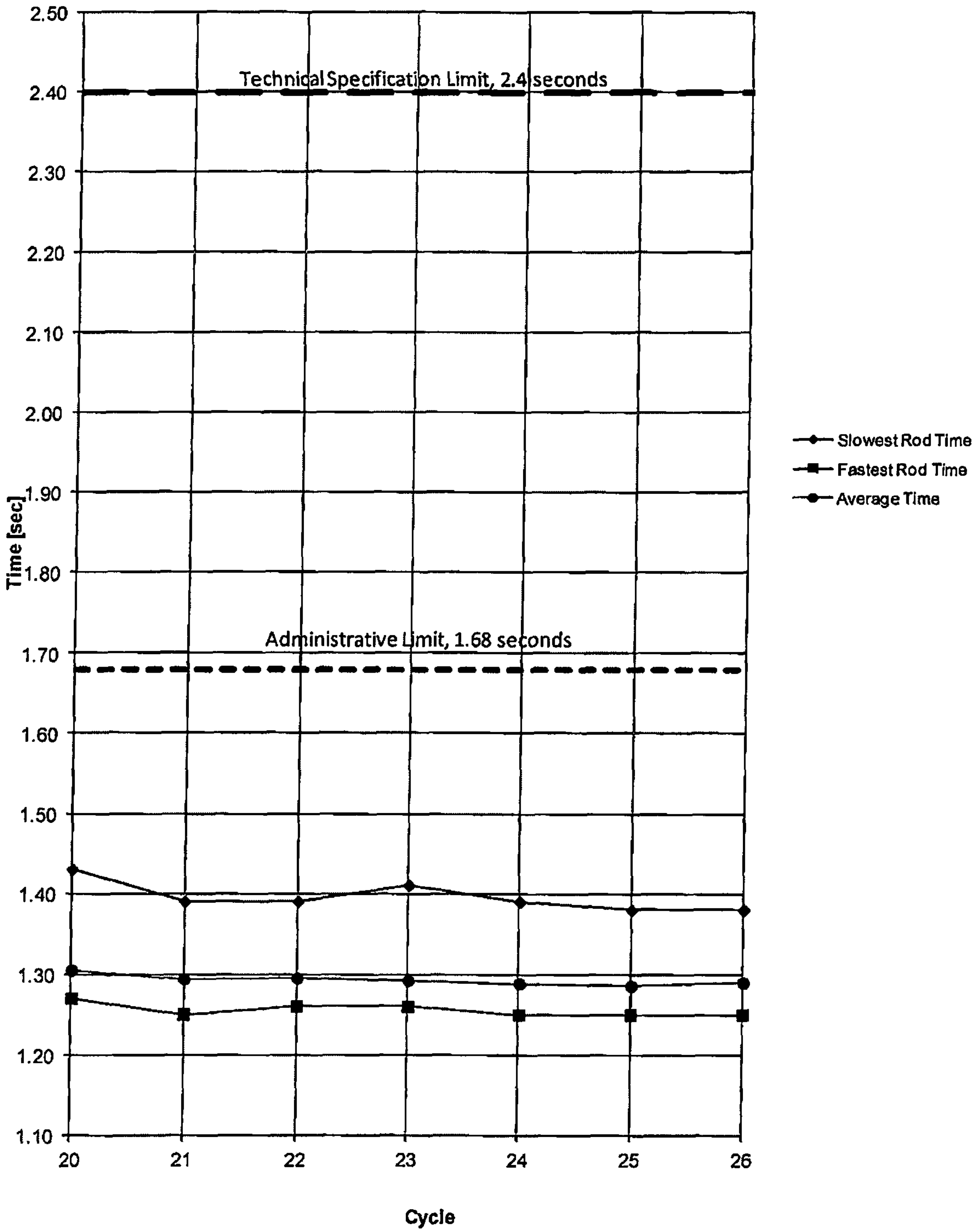
SURRY UNIT 2 – CYCLE 26 STARTUP PHYSICS TESTS
ROD DROP TIME – HOT FULL FLOW CONDITIONS

	R	P	N	M	L	K	J	H	G	F	E	D	C	B	A
1															
2						1.28		1.27		1.30					
3							1.27		1.28						
4				1.28		1.26				1.29		1.29			
5					1.25						1.28				
6		1.27		1.27		1.29		1.29		1.38		1.26		1.37	
7			1.28				1.28		1.30				1.28		
8		1.26				1.29				1.27				1.32	
9			1.28				1.28		1.28				1.26		
10		1.28		1.27		1.28		1.29		1.32		1.29		1.31	
11					1.27						1.31				
12				1.27		1.26				1.29		1.27			
13							1.26		1.29						
14						1.34		1.27		1.30					
15															

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

Figure 2.3

SURRY UNIT 2 – CYCLE 26 STARTUP PHYSICS TESTS
ROD DROP TIMES TRENDING



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 26, Control Bank B was used as the reference bank. Surry 2 targeted a dilution rate of 960 pcm/hr for the reference bank measurement.

During a previous startup physics testing campaign, a control rod became stuck on the bottom eventually forcing a reactor trip to fix the problem. The 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 S2C26 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 ±10% for the reference bank, ±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 -4.6% of the design prediction. This is well within the design tolerance of ±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 2 – CYCLE 26 STARTUP PHYSICS TESTS
CONTROL ROD BANK WORTH SUMMARY

BANK	MEASURED WORTH (PCM)	PREDICTED WORTH (PCM)	PERCENT DIFFERENCE (%) (M-P)/P X 100
B – Reference	1309	1357	-3.5%
A	200	203	-3 pcm*
C	845	905	-6.6%
D	1138	1188	-4.2%
SA	919	923	-0.5%
SB	1032	1127	-8.4%
Total Bank Worth	5443	5703	-4.6%

*Note: For bank worth < 600 pcm, worth difference = (M - P).

Figure 3.1

SURRY UNIT 2 – CYCLE 26 STARTUP PHYSICS TESTS
CONTROL BANK B INTEGRAL ROD WORTH - HZP
ALL OTHER RODS WITHDRAWN

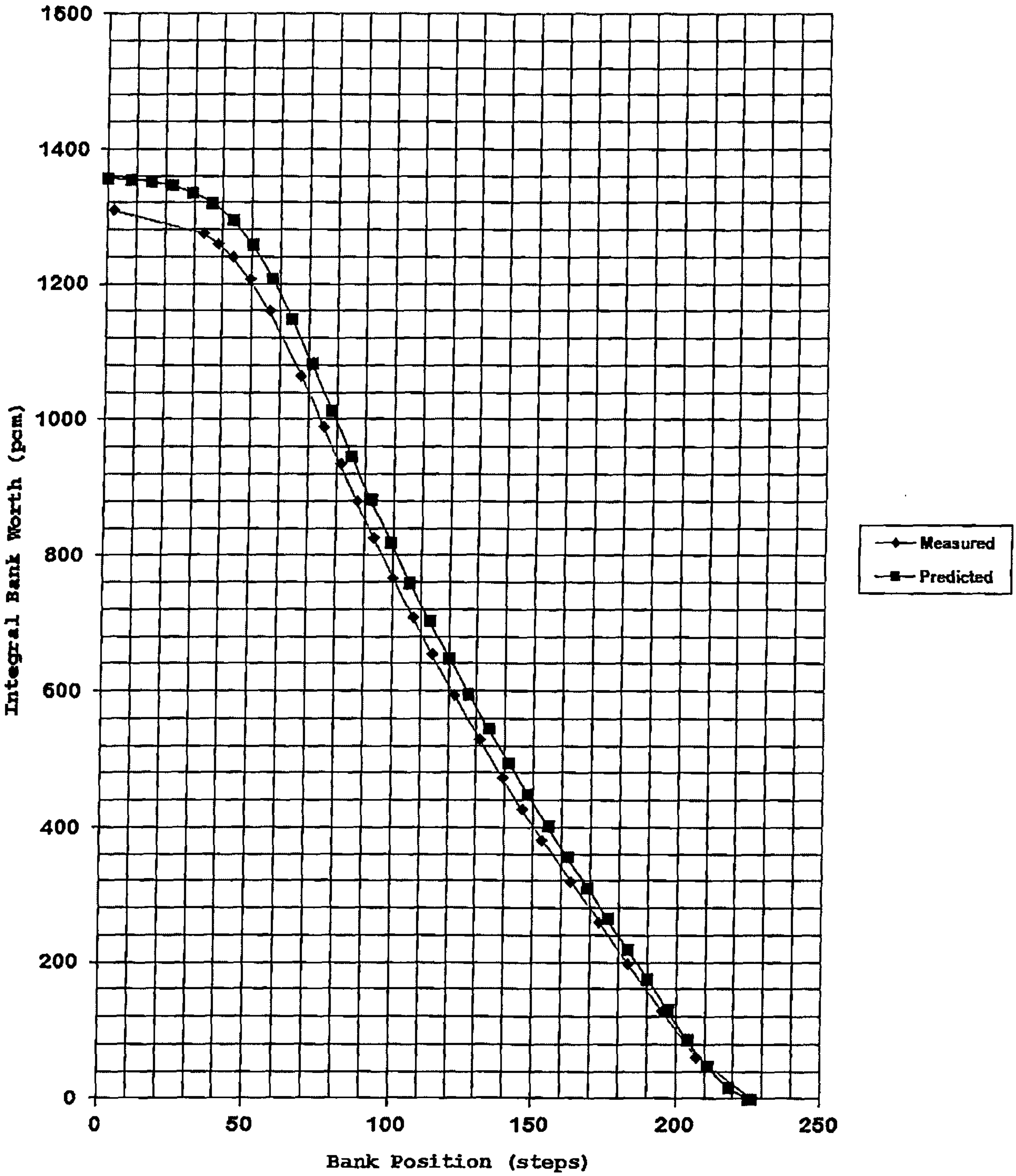
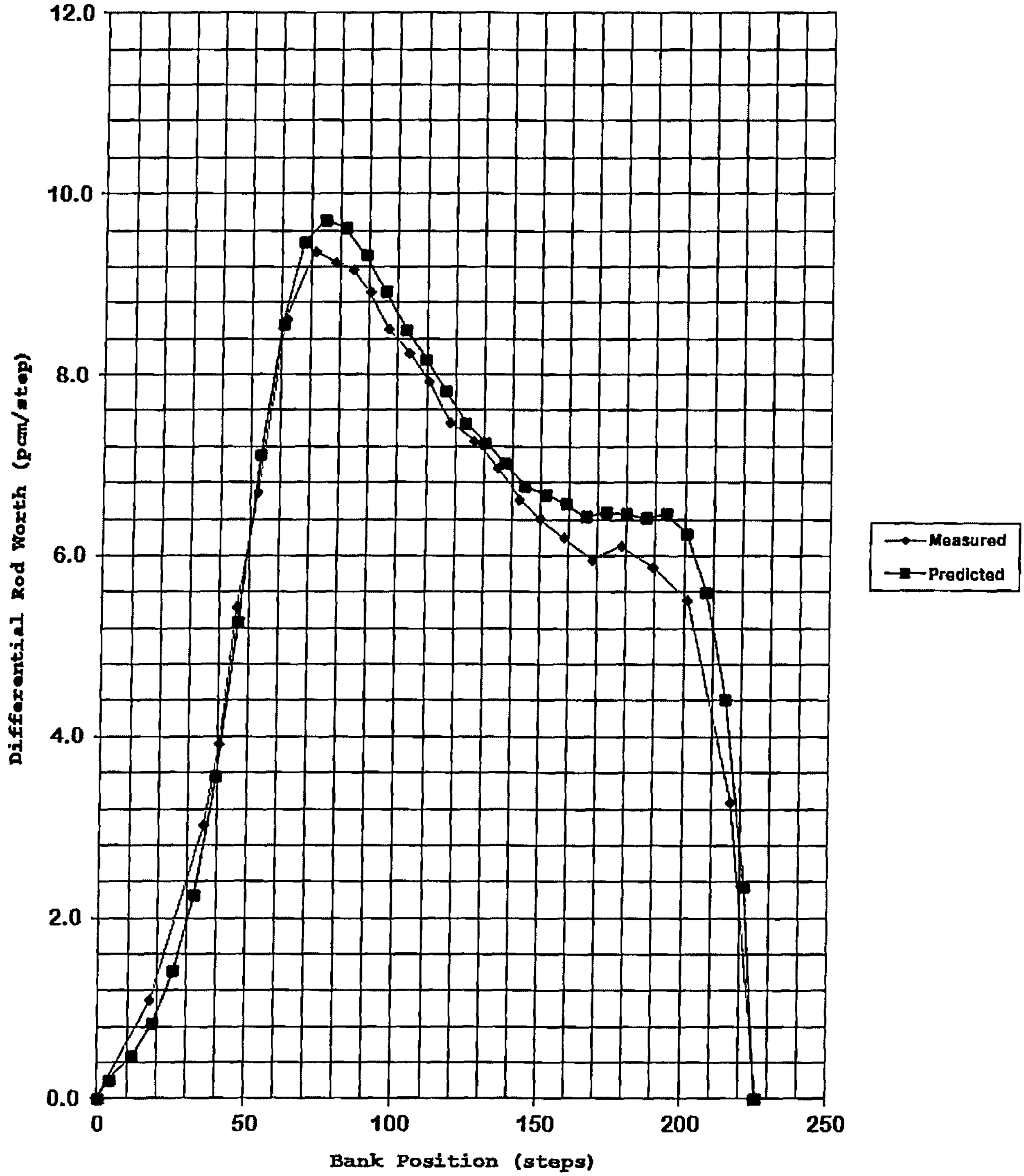


Figure 3.2

SURRY UNIT 2 – CYCLE 26 STARTUP PHYSICS TESTS
CONTROL BANK B DIFFERENTIAL ROD WORTH - HZP
ALL OTHER RODS WITHDRAWN



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 2 – CYCLE 26 STARTUP PHYSICS TESTS
BORON ENDPOINTS SUMMARY

Control Rod Configuration	Measured Endpoint (ppm)	Predicted Endpoint (ppm)	Difference M-P (ppm)
ARO	1602	1616	-14
B Bank In	1427	1421*	6

* 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 2 – CYCLE 26 STARTUP PHYSICS TESTS
BORON WORTH COEFFICIENT

Measured Boron Worth (pcm/ppm)	Predicted Boron Worth (pcm/ppm)	Percent Difference (%) (M-P)/P x 100
-7.47	-7.50	-0.4%

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 the RCS heat up of 2.99 °F, followed by the RCS cool down of 3.01 °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 ITC 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 ITC value was within the design tolerance of ±2 pcm/°F. The calculated moderator temperature coefficient (MTC), which is calculated using a measured ITC of -2.005 pcm/ °F, a predicted Doppler temperature coefficient (DTC) of -1.83 pcm/ °F, and a measurement uncertainty of +0.5 pcm/ °F, is +0.325 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 2 – CYCLE 26 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/208	546.17	549.22	1596	-2.195	-1.815	-2.005	-2.195	0.190

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 Cycle 26 power ascension flux maps. 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, CEBRZ/CECOR [Refs. 3, 15, 18]. CECOR couples the measured voltages with predetermined analytic power-to-flux ratios in order to determine the power distribution for the whole core. The CECOR GUI [Ref. 16] was used as an interface to CEBRZ and CECOR.

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 29.80% power to verify the radial power distribution (RPD) predictions at low power and to ensure there is no evidence that supports the possibility of a core misload or dropped rod. Figure 6.1 shows the measured RPDs from this flux map. Flux maps 2 and 3 were taken at 71.10% and 99.87% 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 RPDs 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 -5.3% in the 29.80% power map, -4.0% in the 71.10% power map, and +3.8% in the 99.87% power map. The maximum average quadrant power tilt for the three maps was +1.20% in the SE quadrant for the 29.80% power map. These power tilts are within the design tolerance of 2%.

The measured $F_Q(Z)$ and $F_{\Delta H}^N$ 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.

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 26.

Table 6.1

SURRY UNIT 2 – CYCLE 26 STARTUP PHYSICS TESTS
INCORE FLUX MAP SUMMARY

Map Description	Map No.	Date	Burnup MWD/MTU	Power (%)	Bank D Steps	Peak $F_Q(Z)$ Hot Channel Factor (1)			$F_{\Delta H}^N$ Hot (2) Channel Factor		Core F_Z Max		Core Tilt (3)		Axial Offset (%)	No. Of Thimbles
						Assy	Axial Point	$F_Q(Z)$	Assy	$F_{\Delta H}^N$	Axial Point	F_Z	Max	Loc		
Low Power	1	05/21/14	1.3	29.80	175	C8	25	2.276	C8	1.527	26	1.387	1.0120	SE	6.973	50
Int. Power (4)	2	05/22/14	22.0	71.10	197	F11	25	1.985	F11	1.483	26	1.227	1.0083	SE	4.104	50
Hot Full Power	3	05/27/14	166.0	99.87	225	F11	30	1.871	F11	1.467	29	1.179	1.0085	SE	2.271	50

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) $F_{\Delta H}^N$ 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 2 – CYCLE 26 STARTUP PHYSICS TESTS
COMPARISION OF MEASURED POWER DISTRIBUTION
PARAMETERS WITH THEIR CORE OPERATING LIMITS

Map No.	Peak $F_Q(Z)$ Hot Channel Factor				$F^N_{\Delta H}$ Hot Channel Factor		
	Meas.	Limit	Node	Margin* (%)	Meas.	Limit	Margin* (%)
1	2.276	5.000	25	54.5	1.527	1.889	19.1
2	1.985	3.516	25	43.5	1.483	1.695	12.5
3	1.871	2.503	30	25.3	1.467	1.561	6.0

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

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

Figure 6.1 — ASSEMBLYWISE POWER DISTRIBUTION
29.80% POWER

Top value = Measured, middle value = Analytical, bottom value = % Delta
% Delta = (M - A)x100/A

	R	P	N	M	L	K	J	H	G	F	E	D	C	B	A
1							0.236	0.370	0.243						
							0.232	0.359	0.238						
							1.93	3.12	2.12						
2					0.254	0.428	0.963	1.068	1.002	0.443	0.261				
					0.254	0.425	0.951	1.053	0.985	0.433	0.257				
					-0.16	0.69	1.26	1.46	1.69	2.39	1.39				
3				0.370	0.989	1.177	1.254	1.337	1.272	1.198	1.010	0.383			
				0.374	0.997	1.177	1.241	1.309	1.255	1.187	1.003	0.377			
				-1.14	-0.83	0.00	1.09	2.13	1.33	0.91	0.71	1.60			
4			0.370	1.060	1.223	1.272	1.246	1.376	1.249	1.286	1.248	1.090	0.381		
			0.376	1.078	1.242	1.281	1.239	1.349	1.238	1.285	1.246	1.080	0.375		
			-1.49	-1.65	-1.53	-0.68	0.52	2.02	0.90	0.07	0.16	0.97	1.48		
5		0.256	0.990	1.224	1.236	1.324	1.180	1.258	1.186	1.346	1.261	1.266	1.021	0.262	
		0.258	1.005	1.247	1.269	1.346	1.190	1.263	1.189	1.349	1.270	1.247	1.004	0.257	
		-0.95	-1.46	-1.87	-2.60	-1.63	-0.82	-0.41	-0.27	-0.26	-0.74	1.52	1.72	1.99	
6		0.436	1.185	1.271	1.310	1.182	1.162	1.169	1.175	1.214	1.355	1.310	1.215	0.444	
		0.436	1.194	1.290	1.351	1.216	1.192	1.203	1.193	1.217	1.350	1.289	1.191	0.435	
		-0.10	-0.75	-1.50	-3.02	-2.83	-2.50	-2.78	-1.52	-0.25	0.39	1.59	2.00	2.10	
7	0.244	1.001	1.271	1.242	1.173	1.164	1.125	1.132	1.137	1.184	1.203	1.278	1.292	1.016	0.246
	0.242	0.996	1.263	1.251	1.196	1.195	1.164	1.165	1.169	1.196	1.195	1.249	1.260	0.992	0.239
	0.66	0.52	0.60	-0.72	-1.94	-2.62	-3.36	-2.85	-2.76	-0.99	0.66	2.33	2.55	2.44	2.93
8	0.374	1.082	1.346	1.360	1.252	1.180	1.137	1.130	1.143	1.189	1.277	1.390	1.371	1.114	0.380
	0.368	1.078	1.330	1.363	1.271	1.209	1.171	1.163	1.170	1.207	1.269	1.359	1.326	1.075	0.367
	1.52	0.35	1.20	-0.23	-1.53	-2.39	-2.93	-2.83	-2.34	-1.51	0.59	2.31	3.40	3.66	3.50
9	0.243	1.007	1.279	1.244	1.171	1.163	1.130	1.132	1.133	1.182	1.204	1.275	1.303	1.029	0.247
	0.240	0.998	1.268	1.248	1.195	1.196	1.170	1.166	1.163	1.193	1.191	1.244	1.265	0.997	0.241
	1.32	0.85	0.85	-0.29	-2.01	-2.73	-3.45	-2.88	-2.60	-0.89	1.08	2.50	2.99	3.16	2.35
10		0.442	1.216	1.291	1.333	1.178	1.131	1.171	1.172	1.209	1.368	1.330	1.228	0.446	
		0.436	1.195	1.291	1.351	1.218	1.195	1.204	1.191	1.214	1.348	1.288	1.193	0.436	
		1.49	1.75	-0.03	-1.33	-3.25	-5.33	-2.73	-1.56	-0.41	1.51	3.29	2.95	2.35	
11		0.260	1.012	1.246	1.265	1.325	1.160	1.245	1.184	1.354	1.291	1.285	1.034	0.265	
		0.258	1.006	1.249	1.272	1.351	1.192	1.264	1.187	1.345	1.267	1.245	1.004	0.258	
		0.93	0.61	-0.21	-0.53	-1.92	-2.68	-1.54	-0.28	0.65	1.86	3.22	3.02	2.82	
12			0.374	1.074	1.235	1.267	1.214	1.346	1.245	1.305	1.277	1.130	0.385		
			0.376	1.081	1.248	1.287	1.244	1.352	1.236	1.280	1.241	1.077	0.375		
			-0.60	-0.64	-1.05	-1.53	-2.44	-0.45	0.75	1.94	2.89	4.96	2.73		
13				0.374	0.992	1.175	1.244	1.329	1.266	1.219	1.029	0.390			
				0.377	1.004	1.188	1.252	1.312	1.247	1.179	0.997	0.374			
				-0.80	-1.21	-1.13	-0.62	1.31	1.55	3.38	3.24	4.25			
14					0.250	0.429	0.982	1.057	0.964	0.437	0.263				
					0.257	0.432	0.983	1.055	0.955	0.426	0.255				
					-2.67	-0.68	-0.10	0.22	0.89	2.62	2.98				
15							0.241	0.362	0.235						
							0.238	0.359	0.233						
							1.19	0.73	0.89						

AVERAGE ABSOLUTE PERCENT DIFFERENCE = 1.7
STANDARD DEVIATION = 1.073

Summary:

Map No: S2-26-01
Control Rod Position:
D Bank at 175 Steps

Date: 05/21/2014

$F_Q(Z)$ = 2.276

$F^N_{\Delta H}$ = 1.527

F_Z = 1.387

Burnup = 1.3 MWD/MTU

Power: 29.80%

QPTR:

0.9890	1.0075
0.9915	1.0120

Axial Offset (%) = +6.973

Figure 6.2 — ASSEMBLYWISE POWER DISTRIBUTION
71.10% POWER

Top value = Measured, middle value = Analytical, bottom value = % Delta
% Delta = (M - A)x100/A

	R	P	N	M	L	K	J	H	G	F	E	D	C	B	A
1							0.254 0.251 1.07	0.393 0.388 1.32	0.260 0.257 1.01						
2					0.266 0.266 -0.17	0.443 0.442 0.33	0.978 0.972 0.63	1.104 1.096 0.73	1.012 1.005 0.66	0.453 0.449 0.93	0.270 0.269 0.37				
3				0.372 0.385 -3.49	0.987 0.993 -0.60	1.166 1.167 -0.05	1.241 1.232 0.71	1.314 1.299 1.12	1.251 1.245 0.48	1.177 1.175 0.15	0.999 0.998 0.13	0.390 0.387 0.70			
4			0.384 0.386 -0.63	1.056 1.067 -1.08	1.216 1.221 -0.40	1.255 1.259 -0.29	1.228 1.224 0.31	1.341 1.327 1.09	1.226 1.223 0.27	1.258 1.263 -0.40	1.222 1.224 -0.20	1.076 1.068 0.78	0.389 0.385 1.09		
5		0.270 0.269 0.24	0.997 0.999 -0.20	1.211 1.225 -1.15	1.222 1.250 -2.22	1.319 1.334 -1.13	1.181 1.188 -0.61	1.252 1.256 -0.31	1.181 1.187 -0.51	1.327 1.336 -0.66	1.240 1.251 -0.92	1.244 1.225 1.56	1.011 0.999 1.18	0.268 0.269 -0.22	
6		0.454 0.451 0.64	1.181 1.179 0.19	1.259 1.266 -0.57	1.316 1.337 -1.58	1.235 1.254 -1.50	1.186 1.203 -1.44	1.194 1.206 -1.02	1.187 1.204 -1.41	1.243 1.255 -0.92	1.333 1.337 -0.28	1.276 1.265 0.89	1.192 1.178 1.16	0.457 0.450 1.66	
7	0.262 0.260 0.78	1.020 1.012 0.83	1.266 1.249 1.35	1.233 1.232 0.12	1.183 1.192 -0.79	1.187 1.205 -1.48	1.144 1.171 -2.27	1.146 1.169 -1.94	1.141 1.176 -2.94	1.188 1.206 -1.48	1.189 1.191 -0.14	1.244 1.231 1.03	1.265 1.247 1.47	1.033 1.009 2.42	0.265 0.258 2.60
8	0.397 0.396 0.25	1.119 1.114 0.44	1.321 1.314 0.51	1.339 1.337 0.13	1.258 1.261 -0.22	1.197 1.210 -1.11	1.154 1.174 -1.67	1.146 1.168 -1.85	1.152 1.174 -1.91	1.190 1.209 -1.58	1.258 1.259 -0.07	1.346 1.334 0.90	1.331 1.312 1.43	1.154 1.113 3.66	0.407 0.395 2.95
9	0.260 0.259 0.35	1.017 1.013 0.42	1.258 1.253 0.36	1.230 1.229 0.11	1.189 1.190 -0.11	1.191 1.206 -1.22	1.155 1.176 -1.76	1.152 1.169 -1.49	1.154 1.171 -1.43	1.209 1.204 0.40	1.196 1.188 0.66	1.240 1.227 1.09	1.269 1.252 1.35	1.033 1.014 1.88	0.259 0.260 -0.21
10		0.454 0.452 0.38	1.186 1.180 0.49	1.263 1.266 -0.20	1.327 1.337 -0.74	1.235 1.255 -1.57	1.170 1.205 -2.92	1.192 1.206 -1.18	1.197 1.202 -0.40	1.261 1.253 0.63	1.347 1.335 0.89	1.280 1.264 1.26	1.193 1.179 1.19	0.454 0.452 0.40	
11		0.269 0.269 0.16	0.997 1.000 -0.28	1.217 1.226 -0.71	1.238 1.251 -1.04	1.321 1.338 -1.25	1.175 1.189 -1.21	1.254 1.256 -0.14	1.193 1.186 0.63	1.358 1.333 1.85	1.261 1.249 0.94	1.244 1.224 1.64	1.014 0.999 1.48	0.273 0.269 1.33	
12			0.380 0.386 -1.48	1.059 1.069 -0.98	1.211 1.225 -1.12	1.252 1.264 -0.97	1.217 1.228 -0.93	1.332 1.329 0.20	1.233 1.221 1.02	1.281 1.259 1.79	1.245 1.221 1.97	1.103 1.066 3.50	0.393 0.386 1.77		
13				0.383 0.387 -1.03	0.986 0.999 -1.29	1.165 1.175 -0.83	1.238 1.242 -0.31	1.312 1.301 0.83	1.251 1.237 1.16	1.194 1.168 2.25	1.016 0.993 2.28	0.396 0.385 2.83			
14					0.258 0.269 -3.99	0.445 0.449 -0.81	1.003 1.003 -0.05	1.101 1.097 0.36	0.981 0.975 0.64	0.450 0.443 1.69	0.272 0.267 2.02				
15							0.259 0.257 0.92	0.391 0.388 0.70	0.254 0.252 0.70						

AVERAGE ABSOLUTE PERCENT DIFFERENCE = 1.0
STANDARD DEVIATION = 0.785

Summary:

Map No: S2-26-02
Control Rod Position:
D Bank at 197 Steps

Date: 05/22/2014
$F_Q(Z)$ = 1.985
$F^N_{\Delta H}$ = 1.483
F_Z = 1.227
Burnup = 22.0 MWD/MTU

Power: 71.10%

QPTR:

0.9942	1.0024
0.9950	1.0083

Axial Offset (%) = +4.104

Figure 6.3 — ASSEMBLYWISE POWER DISTRIBUTION
99.87% POWER

Top value = Measured, middle value = Analytical, bottom value = % Delta
% Delta = (M - A)x100/A

	R	P	N	M	L	K	J	H	G	F	E	D	C	B	A
1							0.261	0.406	0.267						
							0.259	0.400	0.264						
							0.81	1.52	1.21						
2					0.267	0.446	0.978	1.129	1.011	0.455	0.272				
					0.268	0.445	0.971	1.119	1.003	0.452	0.271				
					-0.25	0.26	0.68	0.93	0.77	0.74	0.27				
3				0.372	0.970	1.148	1.230	1.303	1.240	1.160	0.984	0.389			
				0.384	0.976	1.150	1.222	1.289	1.234	1.158	0.981	0.386			
				-3.23	-0.58	-0.15	0.65	1.06	0.50	0.18	0.27	0.82			
4			0.381	1.035	1.198	1.238	1.216	1.330	1.219	1.245	1.206	1.056	0.388		
			0.385	1.047	1.203	1.244	1.217	1.315	1.216	1.247	1.206	1.049	0.385		
			-1.08	-1.17	-0.38	-0.52	-0.10	1.14	0.27	-0.19	0.02	0.66	0.71		
5		0.269	0.972	1.189	1.213	1.314	1.174	1.257	1.189	1.329	1.238	1.222	0.991	0.270	
		0.271	0.982	1.206	1.240	1.335	1.196	1.262	1.195	1.336	1.241	1.206	0.981	0.270	
		-0.67	-0.99	-1.41	-2.19	-1.54	-1.82	-0.42	-0.47	-0.49	-0.23	1.29	0.99	-0.06	
6		0.454	1.157	1.239	1.314	1.286	1.209	1.214	1.213	1.292	1.334	1.258	1.171	0.459	
		0.454	1.161	1.250	1.337	1.306	1.227	1.220	1.228	1.306	1.337	1.249	1.160	0.453	
		0.07	-0.38	-0.90	-1.72	-1.51	-1.47	-0.52	-1.21	-1.06	-0.24	0.73	0.91	1.38	
7	0.269	1.015	1.246	1.221	1.188	1.213	1.169	1.167	1.165	1.214	1.197	1.233	1.250	1.029	0.271
	0.267	1.010	1.238	1.224	1.199	1.229	1.190	1.185	1.195	1.230	1.199	1.223	1.236	1.007	0.265
	0.62	0.50	0.64	-0.25	-0.89	-1.34	-1.75	-1.55	-2.54	-1.31	-0.20	0.80	1.13	2.20	2.24
8	0.410	1.143	1.309	1.325	1.262	1.212	1.173	1.169	1.172	1.209	1.264	1.330	1.313	1.163	0.416
	0.407	1.137	1.302	1.324	1.267	1.224	1.190	1.187	1.189	1.223	1.266	1.322	1.300	1.135	0.407
	0.69	0.50	0.55	0.05	-0.37	-0.97	-1.39	-1.53	-1.46	-1.13	-0.16	0.59	0.98	2.51	2.11
9	0.267	1.016	1.247	1.224	1.202	1.219	1.179	1.171	1.178	1.230	1.202	1.228	1.253	1.027	0.269
	0.266	1.011	1.241	1.221	1.198	1.230	1.195	1.185	1.190	1.228	1.196	1.219	1.240	1.012	0.267
	0.56	0.52	0.50	0.22	0.31	-0.87	-1.37	-1.20	-1.00	0.18	0.46	0.75	1.02	1.45	0.60
10		0.457	1.171	1.249	1.329	1.292	1.201	1.207	1.222	1.312	1.346	1.259	1.173	0.459	
		0.454	1.161	1.250	1.337	1.307	1.229	1.220	1.226	1.305	1.335	1.249	1.161	0.455	
		0.71	0.84	-0.08	-0.58	-1.18	-2.29	-1.04	-0.30	0.56	0.84	0.77	1.02	0.93	
11		0.271	0.980	1.198	1.225	1.322	1.184	1.255	1.199	1.354	1.258	1.227	0.997	0.275	
		0.271	0.982	1.207	1.242	1.337	1.197	1.263	1.194	1.333	1.239	1.205	0.982	0.271	
		0.06	-0.18	-0.74	-1.34	-1.09	-1.10	-0.62	0.42	1.54	1.50	1.81	1.52	1.38	
12			0.378	1.038	1.193	1.238	1.213	1.319	1.225	1.266	1.230	1.087	0.394		
			0.385	1.049	1.207	1.249	1.220	1.317	1.214	1.243	1.203	1.047	0.385		
			-1.92	-1.05	-1.18	-0.88	-0.57	0.15	0.95	1.86	2.23	3.79	2.43		
13				0.382	0.970	1.150	1.229	1.300	1.243	1.179	1.001	0.396			
				0.386	0.981	1.157	1.231	1.290	1.226	1.151	0.976	0.384			
				-1.03	-1.08	-0.64	-0.14	0.79	1.36	2.44	2.54	3.14			
14					0.262	0.449	1.003	1.129	0.987	0.455	0.275				
					0.271	0.452	1.001	1.120	0.974	0.446	0.268				
					-3.14	-0.56	0.25	0.79	1.38	2.10	2.52				
15							0.266	0.404	0.263						
							0.264	0.400	0.259						
							0.77	0.99	1.36						

AVERAGE ABSOLUTE PERCENT DIFFERENCE = 1.0
STANDARD DEVIATION = 0.721

Summary:

Map No: S2-26-03
Control Rod Position:
D Bank at 225 Steps

Date: 05/27/2014
$F_Q(Z)$ = 1.871
$F^N_{\Delta H}$ = 1.467
F_Z = 1.179
Burnup = 166.0 MWD/MTU

Power: 99.87%

QPTR:

0.9927	1.0024
0.9964	1.0085

Axial Offset (%) = +2.271

SECTION 7 — CONCLUSIONS

Table 7.1 summarizes the results associated with Surry Unit 2 Cycle 26 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 S2C26 startup physics testing program, that the Surry 2 core will continue to operate safely throughout Cycle 26.

Table 7.1

SURRY UNIT 2 – CYCLE 26 STARTUP PHYSICS TESTS
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	1602	1616	-14	±50
Critical Boron Concentration (HZP Ref Bank in), ppm	1427	1421	6	±28
Isothermal Temp Coefficient (HZP ARO), pcm/F	-2.005	-2.195	0.190	±2
Differential Boron Worth (HZP ARO), pcm/ppm	-7.47	-7.50	-0.4%	±10%
Reference Bank Worth (B-bank, dilution), pcm	1309	1357	-3.5%	±10%
A-bank Worth (Rod Swap), pcm	200	203	-3	±100
C-bank Worth (Rod Swap), pcm	845	905	-6.6%	±15%
SB-bank Worth (Rod Swap), pcm	1032	1127	-8.4%	±15%
SA-bank Worth (Rod Swap), pcm	919	923	-0.5%	±15%
D-bank Worth (Rod Swap), pcm	1138	1188	-4.2%	±15%
Total Bank Worth, pcm	5443	5703	-4.6%	±10%

S2C26 Testing Time:	7.2	hrs
[criticality 05/20/2014 @ 18:33 to end of testing 05/21/2014 @ 01:42]		
Recent Startups:		
S1C26 testing time:	7.8	hrs
S2C25 testing time:	6.1	hrs
S1C25 testing time:	5.7	hrs
S2C24 testing time:	7.1	hrs
S1C24 testing time:	7.0	hrs
S2C23 testing time:	9.4	hrs
S1C23 testing time:	6.2	hrs
S2C22 testing time:	6.2	hrs
S1C22 testing time:	8.0	hrs

SECTION 8 — REFERENCES

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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. C. J. Wells and J. G. Miller, "The CEBRZ Flux Map Data Processing Code for a Movable In-core Detector System," Engineering Technical Evaluation ETE-NAF-2011-0004, Rev. 0, March 2011.
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14. B. R. Kinney, "Surry Unit 2 Cycle 26 Startup Physics Testing Logs and Results," Memorandum MEMO-NCD-20140016, Rev. 0, May 2014.
15. J. G. Miller, "The CECOR Flux Map Analysis Code for a Movable In-core Detector System," Engineering Technical Evaluation ETE-NAF-2011-0011, Rev 0, May 2011.
16. A. M. Scharf, "Qualification and Verification of the CECOR-GUI," Engineering Technical Evaluation ETE-NAF-2013-0081, Rev. 0, November 2013.
17. Nuclear Engineering Standard DNES-AA-NAF-NCD-5007, Rev. 1, "Startup Physics Tests Results Reporting."
18. A. M. Scharf, "The CECOR Flux Map Analysis Code Version 3.3 Additional Software Requirements and Design," Engineering Technical Evaluation ETE-NAF-2013-0088, Rev. 0, November 2013.

APPENDIX — STARTUP PHYSICS TEST SUMMARY SHEETS

Surry Power Station Unit 2 Cycle 26 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	Preparer/ Reviewer
Zero Power Testing Range Determination						
ZPTR= 2.0×10^{-8} to 1.0×10^{-7} amps	background < ZPTR < POAH background = 1.4×10^{-11} amps POAH= 2.458×10^{-7} amps	N/A	✓ Yes ___ No	N/A	5/20/14 20:11	BRK/ NWW
Reactivity Computer Checkout						
ρ_c= 49.61 / -48.18 pcm (measured reactivity) ρ_t= 50.00 / -48.35 pcm (predicted reactivity) %D = {(ρc - ρt)/ρt} x 100% %D = -0.77 / -0.34 %	$\lvert\{(\rho_c - \rho_t)/\rho_t\}\rvert \times 100\% \leq 4.0\ \%$[1] The allowable range is set to the larger of the measured results or the pre-critical bench test. Pre-critical Bench Test Results ±120 pcm Allowable range ±120 pcm	N/A	✓ Yes ___ No	N/A	5/20/14 20:11	BRK/ NWW
Critical Boron Concentration - ARO						
$(C_B)^M_{ARO}$= ~~2.005~~ 1602 ppm (BRK NWW 5/20/14 5/21/14) (Adj. To design conds.)	$(C_B)_{ARO}$=[2] 1616 ± 50 ppm $\Delta(C_B)_{ARO}=(C_B)^M_{ARO} - (C_B)_{ARO}$ = -14 ppm	$\lvert\alpha C_B \times \Delta(C_B)_{ARO}\rvert \leq 1000$ pcm [T.S. 4.10.A] αC_B=[2] -7.430 pcm/ppm	✓ Yes ___ No	✓ Yes ___ No	5/20/14 21:54	BRK/ NWW
Isothermal Temperature Coefficient - ARO						
$(\alpha_T^{ISO})^M_{ARO}$ = -2.005 pcm/°F	$(\alpha_T^{ISO})_{ARO}$ =[2] -2.195 ± 2 pcm/°F $(\alpha_T^{ISO})^M_{ARO} - (\alpha_T^{ISO})_{ARO}$ = 0.190 pcm/°F	$\alpha_T^{ISO} \leq \alpha_M^{lim} - \alpha_T^{mod} + \alpha_T^{DOP}$ $\alpha_T^{ISO} \leq$ 3.670 pcm/°F where: (α_M^{lim}); 6.0 pcm/°F [COLR 3.4] (α_T^{mod})[1]; 0.5 pcm/°F (α_T^{DOP})[2]; -1.83 pcm/°F	✓ Yes ___ No	✓ Yes ___ No	5/20/14 20:45	BRK/ NWW
Control Bank B Worth Measurement, Rod Swap Reference Bank						
$I_B^{REF,M}$= 1309 pcm	I_B^{REF}=[2] 1357 ± 10% 100x(Meas. - Des.)/Des. = -3.5 %	N/A	✓ Yes ___ No	N/A	5/20/14 21:55:12	BRK/ NWW

References 1.) DNES-AA-NAF-NCD-4015, Rev. 0
2.) ETE-NAF-2014-0036, Rev. 0
3.) ETE-NAF-2014-0039, Rev. 0
4.) Calculation PM-1652 Rev. 0

Surry Power Station Unit 2 Cycle 26 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
Critical Boron Concentration - B Bank In						
$(C_B)^M{}_B$= 1426.7 ppm	$(C_B)_B$=[2] 1435 +$\Delta(C_B)_{ARO}$ ± 28 ppm $\Delta(C_B)_{ARO}$= -14 ppm (from above) $(C_B)_B$= 1421 ± 28 ppm $(C_B)^M{}_B - (C_B)_B$ = 5.7 ppm	N/A	✓ Yes ___ No	N/A	5/20/14 23:57	BRK/ NWW
HZP Boron Worth Coefficient Measurement						
$(\alpha C_B)^M$ = -7.47 pcm/ppm	αC_B =[2] -7.50 ± 0.75 pcm/ppm $\Delta\alpha C_B=(\alpha C_B)^M - (\alpha C_B)$ = 0.03 pcm/ppm	N/A	✓ Yes ___ No	N/A	5/20/14 23:57	BRK/ NWW
Control Bank A Worth Measurement - Rod Swap						
I_A^{RS}= 200.2 pcm	$(I_A^{RS})^3$= 203.1 ± 100 pcm Meas. - Des.. = -2.9 pcm	N/A	✓ Yes ___ No	N/A	5/21/14 0:00	BRK/ NWW
Control Bank C Worth Measurement - Rod Swap						
I_C^{RS}= 844.9 pcm	$(I_C^{RS})^3$= 904.5 ± 15% 100x(Meas. - Des.)/Des. = -6.6 %	N/A	✓ Yes ___ No	N/A	5/21/14 0:00	BRK/ NWW
Shutdown Bank A Worth Measurement - Rod Swap						
I_{SA}^{RS}= 918.8 pcm	$(I_{SA}^{RS})^3$= 923.4 ± 15% 100x(Meas. - Des.)/Des. = -0.5 %	N/A	✓ Yes ___ No	N/A	5/21/14 0:00	BRK/ NWW
Shutdown Bank B Worth Measurement - Rod Swap						
I_{SB}^{RS}= 1031.8 pcm	$(I_{SB}^{RS})^3$= 1126.8 ± 15% 100x(Meas. - Des.)/Des. = -8.4 %	N/A	✓ Yes ___ No	N/A	5/21/14 0:00	BRK/ NWW
Control Bank D Worth Measurement - Rod Swap						
I_D^{RS}= 1138.1 pcm	$(I_D^{RS})^3$= 1188.2 ± 15% 100x(Meas. - Des.)/Des. = -4.2 %	N/A	✓ Yes ___ No	N/A	5/21/14 0:00	BRK/ NWW
Total Rod Worth - Rod Swap						
I_{Total}= 5443.3 pcm	$(I_{total})^3$= 5702.9 ± 10% 100x(Meas. - Des.)/Des. = -4.6 %	N/A	✓ Yes ___ No	N/A	5/21/14 0:00	BRK/ NWW

References 1.) DNES-AA-NAF-NCD-4015, Rev. 0
2.) ETE-NAF-2014-0036, Rev. 0
3.) ETE-NAF-2014-0039, Rev. 0
4.) Calculation PM-1652 Rev. 0

Surry Power Station Unit 2 Cycle 26 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
M/D Flux Map, Power ≤ 30%						
Map Power Level (% Full Power) = 29.8%						
Max Relative Assembly Power, %DIFF (M-P)/P					05/21/14 1545	SBR / RAu
%DIFF= -5.3 % for Pi ≥0.9 +4.2 % 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)= 1.527	N/A	FΔH(N)≤1.56(1+0.3(1-P)) [COLR 3.7]	N/A	✓ Yes ___ No		
Total Heat Flux Hot Channel Factor, FQ(Z)						
Peak F_Q(Z) Hot Channel Factor= 2.276	N/A	F_Q(Z)≤5*K(Z) [COLR 3.7]	N/A	✓ Yes ___ No		
Maximum Positive Incore Quadrant Power Tilt						
Tilt= 1.0120	≤ 1.02[1]	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) [4]					05/21/14 1545	SBR / RAu
Max RPD %DIFF= 5.3 % for P > 0.9	N/A	≤ 22.6%	N/A	✓ Yes ___ No		
OR Synthesized FdH at limiting power[4] N/A	N/A	FΔH ≤ 1.56(1+0.3(1-P)) [COLR 3.7]	N/A			

References 1.) DNES-AA-NAF-NCD-4015, Rev. 0
2.) ETE-NAF-2014-0036, Rev. 0
3.) ETE-NAF-2014-0039, Rev. 0
4.) Calculation PM-1652 Rev. 0

Surry Power Station Unit 2 Cycle 26 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
M/D Flux Map, 65% ≤ Power ≤ 75%						
Map Power Level (% Full Power) = 71.1						
Max Relative Assembly Power, %DIFF (M-P)/P					5/22/14 21:29	RAH / HS 5/23/14
%DIFF= 3.7 % for Pi ≥0.9 -4.0 % 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)= 1.483	N/A	FΔH(N)≤1.56(1+0.3(1-P)) [COLR 3.7]	N/A	✓ Yes ___ No	↓	↓
Total Heat Flux Hot Channel Factor, FQ(Z)					↓	↓
Peak F_Q(Z) Hot Channel Factor= 1.985	N/A	F_Q(Z)≤(2.5/P)*K(Z) [COLR 3.7]	N/A	✓ Yes ___ No	↓	↓
Maximum Positive Incore Quadrant Power Tilt						
Tilt= 1.0083	≤ 1.02[1]	N/A	✓ Yes ___ No	N/A		

References 1.) DNES-AA-NAF-NCD-4015, Rev. 0
2.) ETE-NAF-2014-0036, Rev. 0
3.) ETE-NAF-2014-0039, Rev. 0
4.) Calculation PM-1652 Rev. 0

Surry Power Station Unit 2 Cycle 26 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
M/D Flux Map; 95% ≤ Power ≤ 100%						
Map Power Level (% Full Power) = 99.87						
Max Relative Assembly Power, %DIFF (M-P)/P					5/23/14 07:00	DJA / [illegible]
%DIFF= 3.8 % for Pi ≥0.9 -3.2 % 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)= 1.467	N/A	FΔH(N)≤1.56(1+0.3(1-P)) [COLR 3.7] 1.561	N/A	✓ Yes ___ No		
Total Heat Flux Hot Channel Factor, FQ(Z)						
Peak F_Q(Z) Hot Channel Factor= 1.871	N/A	F_Q(Z)≤(2.5/P)*K(Z) [COLR 3.7] 2.503	N/A	✓ Yes ___ No		
Maximum Positive Incore Quadrant Power Tilt						
Tilt= 1.0085	≤ 1.02[1]	N/A	✓ Yes ___ No	N/A		

References 1.) DNES-AA-NAF-NCD-4015, Rev. 0
2.) ETE-NAF-2014-0036, Rev. 0
3.) ETE-NAF-2014-0039, Rev. 0
4.) Calculation PM-1652 Rev. 0

Surry Power Station Unit 2 Cycle 26 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
RCS Flow Measurement						
F_{Total}= ✓ 294,349 gpm	N/A	$F_{total} \geq$ 276000 gpm ✓ [COLR 3.8]	N/A	✓ Yes ___ No	5/03/14 1800	[illegible] / [illegible]

References 1.) DNES-AA-NAF-NCD-4015, Rev. 0
2.) ETE-NAF-2014-0036, Rev. 0
3.) ETE-NAF-2014-0039, Rev. 0
4.) Calculation PM-1652 Rev. 0