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Dominion®

March 7, 2016

United States Nuclear Regulatory Commission
Regional Administrator – Region II
Marquis One Tower
245 Peachtree Center Ave., NE Suite 1200
Atlanta, Georgia 30303-1257

Serial No.: 16-071
NLOS/GDM
Docket No.: 50-281
License No.: DPR-37

VIRGINIA ELECTRIC AND POWER COMPANY
SURRY POWER STATION UNIT 2
CYCLE 27 STARTUP PHYSICS TESTS REPORT

As required by Surry Power Station (Surry) Technical Specification 6.6.A.1, enclosed is the Surry Unit 2 Cycle 27 Startup Physics Tests Report. This report summarizes the results of the physics testing program performed prior to and following initial criticality of Cycle 27 on December 1, 2015. The results of the physics tests were within the applicable Technical Specifications limits.

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

Sincerely,

T. R. Huber, Director
Nuclear Licensing and Operations Support
Dominion Resources Services, Inc. for
Virginia Electric and Power Company

Enclosure

Commitments made in this letter: None

IE26
NRR

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Serial No. 16-071
Docket No. 50-281

Enclosure

SURRY UNIT 2 CYCLE 27
STARTUP PHYSICS TESTS REPORT

February 2016

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

CLASSIFICATION/DISCLAIMER

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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 27 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, Rev. 2 [Ref. 12]. 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 27 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 October 19, 2015, Unit No. 2 of Surry Power Station completed Cycle 26 and began refueling [Ref. 1]. During this refueling, 64 of the 157 fuel assemblies in the core were replaced with fresh Batch S2/29 assemblies [Ref. 1]. The Cycle 27 core consists of 5 sub-batches of fuel: two fresh batches (S2/29A and S2/29B), two once-burned batches (S2/28A and S2/28B), and one twice-burned batch (S2/27B). Like S2C26, S2C27 will have a full core of the 15x15 Upgrade Fuel Design [Ref. 1].

The Westinghouse Upgrade fuel includes three ZIRLO Intermediate Flow Mixing (IFM) grids for improved thermal-hydraulic performance, ZIRLO (I-spring) structural mid grids with balanced mixing vane pattern, "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 Upgrade fuel used for batches S2/28 and S2/29 includes Westinghouse's Robust Protective Grid (RPG) and modified Debris Filter Bottom Nozzle (mDFBN), unlike the Upgrade fuel used for batch S2/27. S2C27 will be the first Surry Unit 2 cycle to utilize the Westinghouse Integral Nozzle (WIN) top nozzle design to reduce the potential for spring screw failures in the top nozzle [Ref. 1].

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].

Cycle 27 loads two Secondary Source Assemblies (SSAs) in core locations H-04 and H-12. Each assembly consists of six source rods containing antimony and beryllium pellets encapsulated in a double layer of stainless steel cladding. There are no thimble plugging devices in S2C27. The cycle design report [Ref. 1] provides a more detailed description of the Cycle 27 core.

Three reactor coolant pumps were replaced during the S2C26-S2C27 refueling outage. Further information on this replacement can be found in Reference 13.

The S2C27 full core loading plan [Ref. 2] is given in Figure 1.1, and the beginning of cycle fuel assembly burnups are given in Figure 1.2. The incore moveable detector locations used for the flux map analyses [Ref. 11] are identified in Figure 1.3. Figure 1.4 identifies the location and number of control rods in the Cycle 27 core [Ref. 1].

According to the Startup Physics logs, the Cycle 27 core achieved initial criticality on December 1, 2015 at 04:35 [Ref. 3]. 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.7 [Ref. 9] was used for S2C27 Startup Physics Testing. The tests performed are the same as in previous cycles. A summary of the test results follows.

After zero power physics testing, the reactor was shut down at 13:00 on December 1, 2015 for maintenance. The unit returned to critical at 16:35 on December 10, 2015, and reached full power on December 18, 2015 at 05:00.

The measured drop time of each control rod was within the 2.40 seconds Technical Specification [Ref. 6] limit, as well as the Surry Unit 2 1.68 seconds administrative limit [Ref. 8].

Individual control rod bank worths were measured using the rod swap technique [Ref. 4]. 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. 10]. The sum of the individual measured control rod bank worths was within –2.0% of the design prediction. The reference bank (Control Bank B) worth was within –1.9% of its design prediction. Control rod banks with design predictions greater than 600 pcm were within –5.2% of the design predictions. For individual banks worth 600 pcm or less (only Control Bank A fits this category), the difference was within +16.8 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, all-rods-out (ARO) and Reference Bank (B-bank) in, were within the design tolerances and the Technical Specification criterion [Ref. 6] that the overall core reactivity balance shall be within ±1% Δk/k of the design prediction. The boron worth coefficient measurement was within +0.8% of the design prediction, which is within the design tolerance of ±10%.

The measured isothermal temperature coefficient (ITC) for the ARO configuration was within +0.053 pcm/°F of the design prediction. This result is within the design tolerance of ±2.0 pcm/°F.

The zero power physics testing results were within the criteria established in Reference 20 permitting the first flux map to be performed up to 50% power (versus 30% power if the criteria were not met).

Core power distributions were all within established design tolerances. The measured assembly power distributions were within ±8.0% of the design predictions, where an 8.0% maximum difference occurred in the 45.40% power map. 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. 13]. None of the power ascension flux maps were within the maximum incore quadrant power tilt design tolerance of 2% (QPTR ≤ 1.02). The maximum incore quadrant power tilts ranged from 2.45% to 3.44% during the power ascension. NAF performed an additional assessment to confirm that the measured quadrant tilts were bounded by the current safety analysis. The larger than normal tilt is still under investigation at the time of this report [Ref. 18].

The total RCS Flow was successfully verified as being greater than 273,000 gpm and greater than the limit in the COLR (274,000 gpm), as required by Surry Technical Specifications [Ref. 6]. The total RCS Flow at nominal conditions was measured as 289,584 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 27
CHRONOLOGY OF TESTS

Test	Date	Time	Power	Reference Procedure
Hot Rod Drop-Hot Full Flow	11/30/15	17:45	HSD	2-NPT-RX-014
Reactivity Computer Checkout	12/01/15	05:45	HZP	2-NPT-RX-008
Boron Endpoint – ARO	12/01/15	05:45	HZP	2-NPT-RX-008
Zero Power Testing Range	12/01/15	05:45	HZP	2-NPT-RX-008
Boron Worth Coefficient	12/01/15	10:20	HZP	2-NPT-RX-008
Temperature Coefficient – ARO	12/01/15	05:48	HZP	2-NPT-RX-008
Bank B Worth	12/01/15	07:15	HZP	2-NPT-RX-008
Boron Endpoint – B in	12/01/15	10:20	HZP	2-NPT-RX-008
Bank A Worth – Rod Swap	12/01/15	09:55	HZP	2-NPT-RX-008
Bank C Worth – Rod Swap	12/01/15	09:55	HZP	2-NPT-RX-008
Bank D Worth – Rod Swap	12/01/15	09:55	HZP	2-NPT-RX-008
Bank SA Worth – Rod Swap	12/01/15	09:55	HZP	2-NPT-RX-008
Bank SB Worth – Rod Swap	12/01/15	09:55	HZP	2-NPT-RX-008
Total Rod Worth	12/01/15	09:55	HZP	2-NPT-RX-008
Flux Map – less than 50% Power*	12/12/15	04:59	45.40%	2-NPT-RX-002
Peaking Factor Verification				2-NPT-RX-008
& Power Range Calibration				2-NPT-RX-005
				2-GEP-RX-001
Flux Map – 65% - 75% Power	12/13/15	14:49	71.14%	2-NPT-RX-002
Peaking Factor Verification				2-NPT-RX-008
& Power Range Calibration				2-NPT-RX-005
				2-GEP-RX-001
Flux Map – 95% - 100% Power	12/21/15	08:36	99.88%	2-NPT-RX-002
Peaking Factor Verification				2-NPT-RX-008
& Power Range Calibration				2-NPT-RX-005
				2-GEP-RX-001
RCS Flow Measurement	12/18/15	05:00	HFP	2-NPT-RX-009

* Results of zero power physics testing permitted the first flux map to be performed up to 50% power (versus 30% power if specific criteria were not met).

Figure 1.1

SURRY UNIT 2 – CYCLE 27
CORE LOADING MAP

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VEP-NES-NAF

NORTH ↑

	R	P	N	M	L	K	J	H	G	F	E	D	C	B	A
1							49Y	656	47Y						
2					43Y	RCC 26Y	743	RCC 754	748	RCC 21Y	40Y				
3				41Y	735	758	RCC 708	648	RCC 713	762	740	32Y			
4			34Y	RCC 750	701	RCC 631	607	SS8 617	604	RCC 640	706	RCC 756	39Y		
5		44Y	738	716	RCC 646	624	723	644	720	626	RCC 645	710	733	42Y	
6		RCC 25Y	764	RCC 642	621	RCC 731	612	RCC 652	605	RCC 726	623	RCC 636	760	RCC 28Y	
7	51Y	747	RCC 705	601	718	611	RCC 654	729	RCC 657	610	724	613	RCC 703	744	45Y
8 (90°)	658	RCC 755	632	620	630	RCC 653	727	625	732	RCC 650	637	619	634	RCC 751	660
9	46Y	741	RCC 712	606	722	616	RCC 661	725	RCC 659	615	719	608	RCC 715	746	50Y
10		RCC 27Y	759	RCC 639	622	RCC 730	614	RCC 651	602	RCC 728	628	RCC 643	757	RCC 24Y	
11		31Y	737	714	RCC 641	627	717	633	721	629	RCC 647	709	736	33Y	
12			30Y	RCC 752	707	RCC 635	603	SS9 618	609	RCC 638	704	RCC 753	37Y		
13				38Y	739	761	RCC 702	649	RCC 711	763	734	36Y			
14					35Y	RCC 22Y	745	RCC 749	742	RCC 23Y	29Y				
15							52Y	655	48Y						

0°

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

Prepared By: [signature] B. R. Kinney Date: 4/17/15
Reviewed By: [signature] S. B. Rosenfelder Date: 04/20/15
Approved By: [signature] A. H. Nicholson Date: 4/22/15

Concurrence By: [signature] A. L. Black Date: 4/28/15
Approved By: [signature] M. N. LaPrade Date: 4/28/15

Figure 1.2

SURRY UNIT 2 – CYCLE 27
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							42.99 42.84	22.78 22.67	42.98 42.83							1
2					42.65 42.70	39.28 39.41	0.00 0.00	0.00 0.00	0.00 0.00	39.66 39.40	42.64 42.71					2
3				40.28 40.48	0.00 0.00	0.00 0.00	0.00 0.00	19.19 18.95	0.00 0.00	0.00 0.00	0.00 0.00	40.33 40.43				3
4			41.14 41.10	0.00 0.00	0.00 0.00	19.55 19.16	23.76 23.72	23.98 23.86	23.88 23.89	19.14 19.20	0.00 0.00	0.00 0.00	41.14 41.18			4
5		40.57 40.65	0.00 0.00	0.00 0.00	20.94 20.37	24.01 23.99	0.00 0.00	19.66 19.47	0.00 0.00	24.22 23.97	20.37 20.38	0.00 0.00	0.00 0.00	40.36 40.68		5
6		39.23 39.38	0.00 0.00	19.38 19.21	23.76 23.98	0.00 0.00	23.37 23.47	21.64 21.47	23.83 23.44	0.00 0.00	23.82 23.96	19.29 19.20	0.00 0.00	39.18 39.40		6
7	43.11 42.83	0.00 0.00	0.00 0.00	24.11 23.88	0.00 0.00	23.74 23.46	23.12 22.57	0.00 0.00	22.61 22.65	23.30 23.46	0.00 0.00	23.91 23.87	0.00 0.00	0.00 0.00	42.66 42.81	7
8	22.74 22.65	0.00 0.00	19.50 19.47	23.87 23.84	19.68 19.50	21.99 21.64	0.00 0.00	23.00 23.14	0.00 0.00	21.78 21.64	19.68 19.53	23.73 23.84	19.51 19.44	0.00 0.00	22.92 22.66	8
9	43.02 42.81	0.00 0.00	0.00 0.00	24.07 23.93	0.00 0.00	23.69 23.46	22.66 22.66	0.00 0.00	22.56 22.55	23.48 23.46	0.00 0.00	24.00 23.93	0.00 0.00	0.00 0.00	42.71 42.83	9
10		39.49 39.39	0.00 0.00	19.33 19.19	23.98 23.96	0.00 0.00	23.47 23.44	21.51 21.46	23.45 23.47	0.00 0.00	23.90 23.99	19.11 19.20	0.00 0.00	39.26 39.39		10
11		40.57 40.68	0.00 0.00	0.00 0.00	20.51 20.38	23.91 23.98	0.00 0.00	19.62 19.51	0.00 0.00	23.70 24.00	20.30 20.37	0.00 0.00	0.00 0.00	40.69 40.65		11
12			41.13 41.20	0.00 0.00	0.00 0.00	19.23 19.21	23.85 23.84	23.71 23.85	24.12 23.78	19.13 19.16	0.00 0.00	0.00 0.00	41.14 41.12			12
13				40.28 40.45	0.00 0.00	0.00 0.00	0.00 0.00	18.94 18.91	0.00 0.00	0.00 0.00	0.00 0.00	40.55 40.46				13
14					42.48 42.71	39.08 39.41	0.00 0.00	0.00 0.00	0.00 0.00	39.18 39.42	42.45 42.70					14
15							42.74 42.83	22.73 22.66	43.01 42.84							15

Figure 1.3

SURRY UNIT 2 – CYCLE 27
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 27
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 side, row 8) — 270° (right side, 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 at hot shutdown (HSD) 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. 6].

Surry Unit 2 Cycle 27 used the Rod Drop Measurement Instrument (RDMI) instead of the rod drop test computer (RDTC) [Ref. 7]. The rod drop times were measured by withdrawing all banks to their fully withdrawn position and dropping all 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 rod position indication (RPI) coil terminals (/3 & /4) on the Computer Enhanced Rod Position Indication (CERPI) racks for each rod. Data is immediately saved to a comma-separated value file. Further details about the RDMI can be found in Reference 7.

A typical rod drop trace for S2C27 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 20-27. Technical Specification 3.12.C.1 [Ref. 6] 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. 8] 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. The rod drop times were slower than S2C26 by an average of 0.06 seconds, which is attributed to use of the new RDMI (data analyzed for previous cycles with RDMI also gave similar slower rod drop times [Ref. 14]).

Table 2.1

SURRY UNIT 2 – CYCLE 27 STARTUP PHYSICS TESTS
HOT ROD DROP TIME SUMMARY

ROD DROP TIME TO DASHPOT ENTRY

SLOWEST ROD	FASTEST ROD	AVERAGE TIME
B-06 1.43 sec.	K-04 1.31 sec	1.35 sec.

Figure 2.1

SURRY UNIT 2 – CYCLE 27 STARTUP PHYSICS TESTS
TYPICAL ROD DROP TRACE

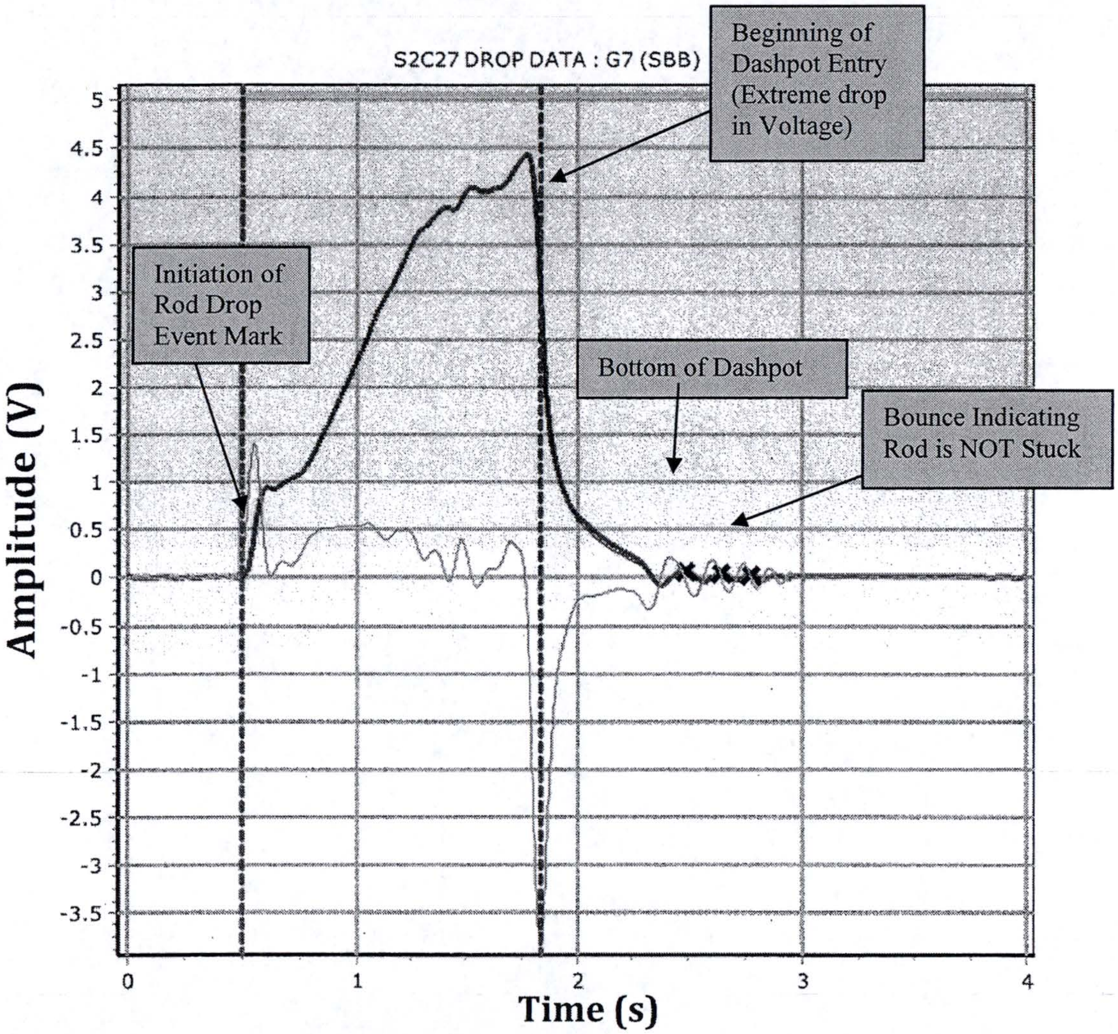


Figure 2.2

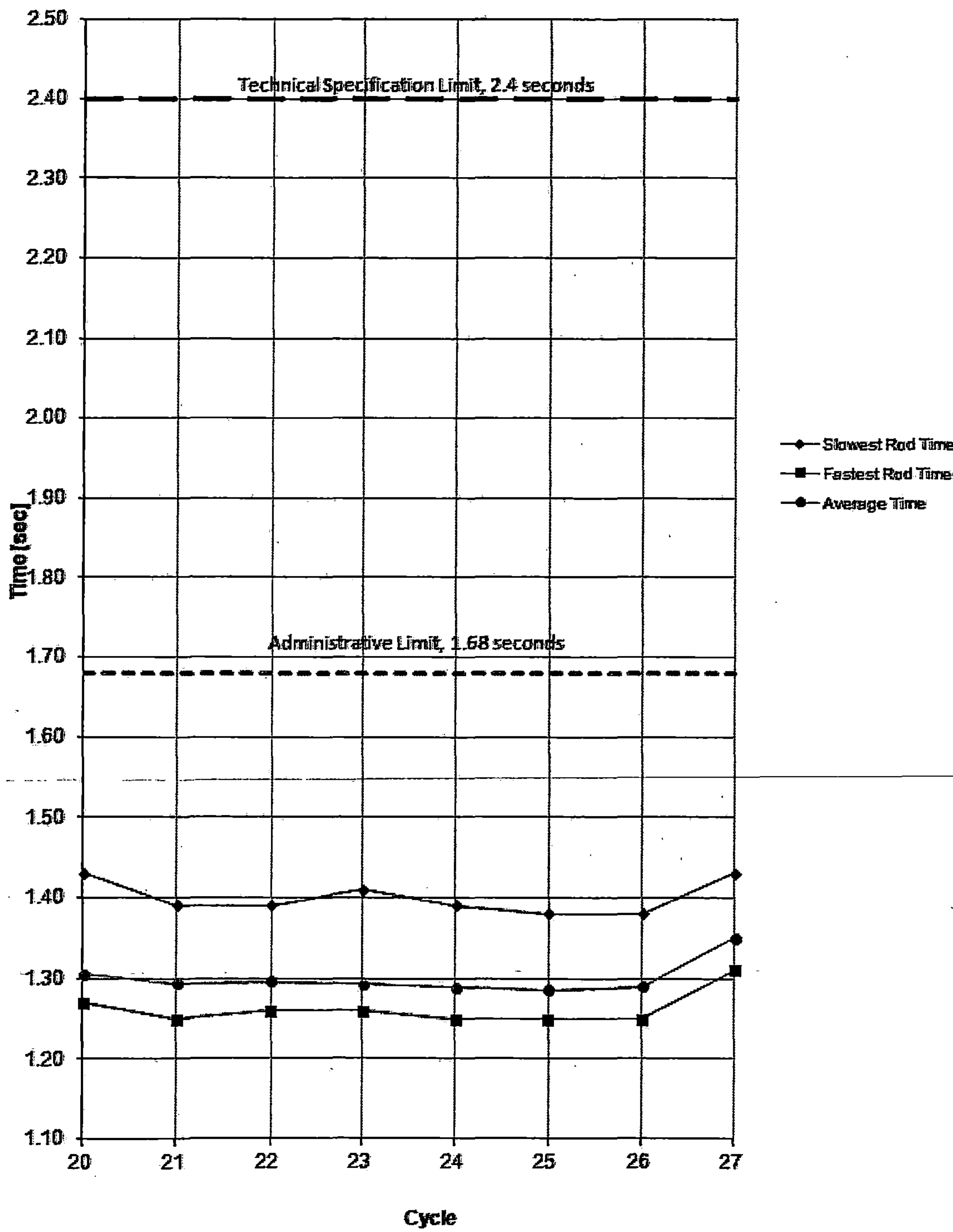
SURRY UNIT 2 – CYCLE 27 STARTUP PHYSICS TESTS
ROD DROP TIME – HOT FULL FLOW CONDITIONS

R	P	N	M	L	K	J	H	G	F	E	D	C	B	A	
															1
					1.348		1.340		1.344						2
						1.352		1.356							3
			1.340		1.312				1.364		1.360				4
				1.332						1.346					5
	1.326		1.336		1.342		1.350		1.426		1.326		1.432		6
		1.344				1.352		1.340				1.356			7
	1.330				1.332				1.328				1.368		8
		1.360				1.338		1.334				1.336			9
	1.348		1.330		1.348		1.350		1.372		1.342		1.366		10
				1.346						1.362					11
			1.340		1.330				1.332		1.338				12
						1.338		1.360							13
					1.386		1.338		1.364						14
															15

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

Figure 2.3

SURRY UNIT 2 – CYCLE 27 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. 4]. 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 27, Control Bank B was used as the reference bank. Surry 2 targeted a dilution rate of 1100 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. 10], 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 S2C27 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 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 -2.0% 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 27 STARTUP PHYSICS TESTS
CONTROL ROD BANK WORTH SUMMARY

BANK	MEASURED WORTH (PCM)	PREDICTED WORTH (PCM)	PERCENT DIFFERENCE (%) (M-P)/P X 100
B – Reference	1398.7	1426.3	-1.9%
A	218.9	202.1	+16.8 pcm*
C	872.7	919.8	-5.1%
D	941.4	960.8	-2.0%
SA	993.3	965.6	+2.9%
SB	1111.9	1173.4	-5.2%
Total Bank Worth	5536.9	5648.1	-2.0%

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

Figure 3.1

SURRY UNIT 2 – CYCLE 27 STARTUP PHYSICS TESTS
CONTROL BANK B INTEGRAL ROD WORTH - HZP
ALL OTHER RODS WITHDRAWN

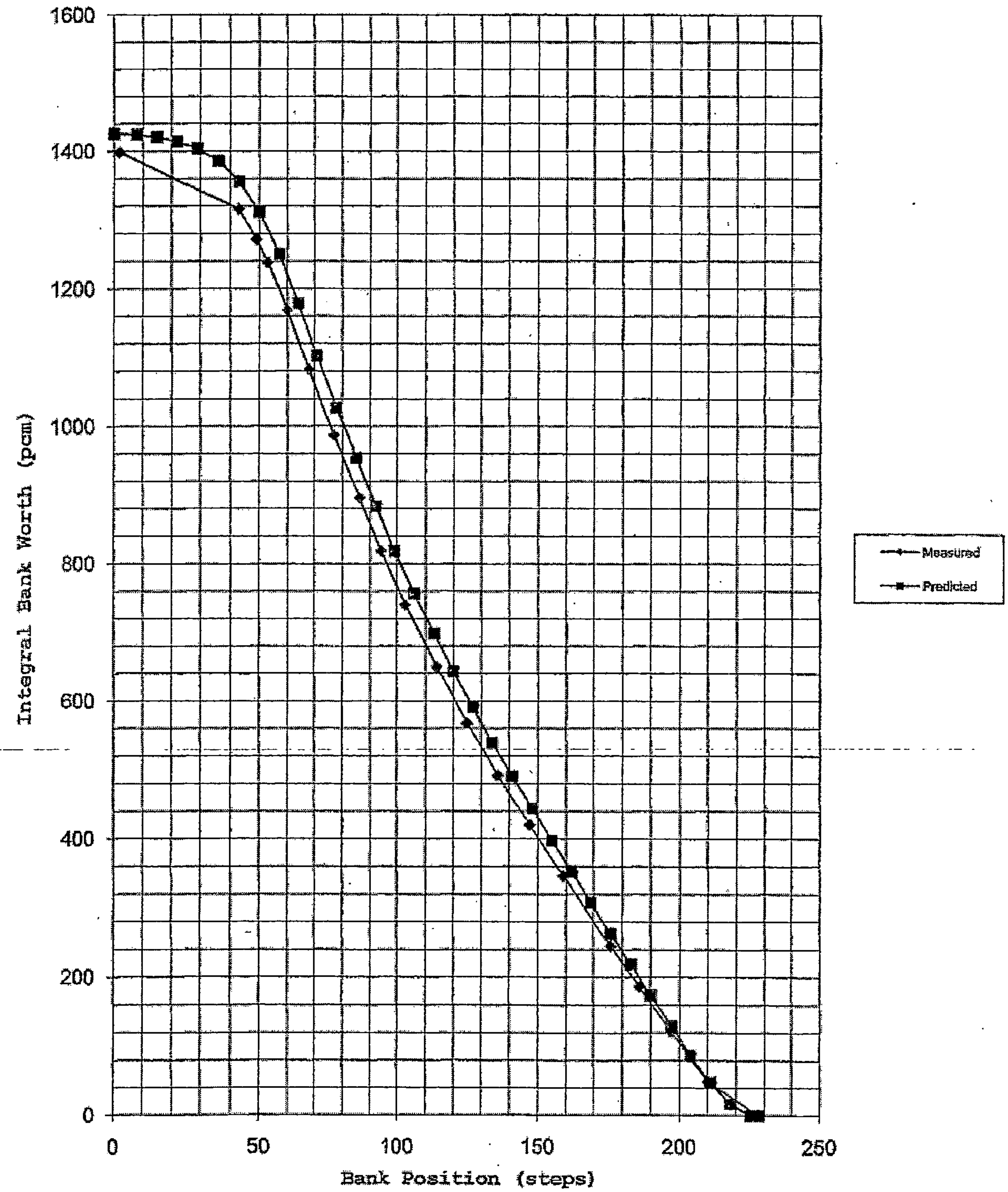
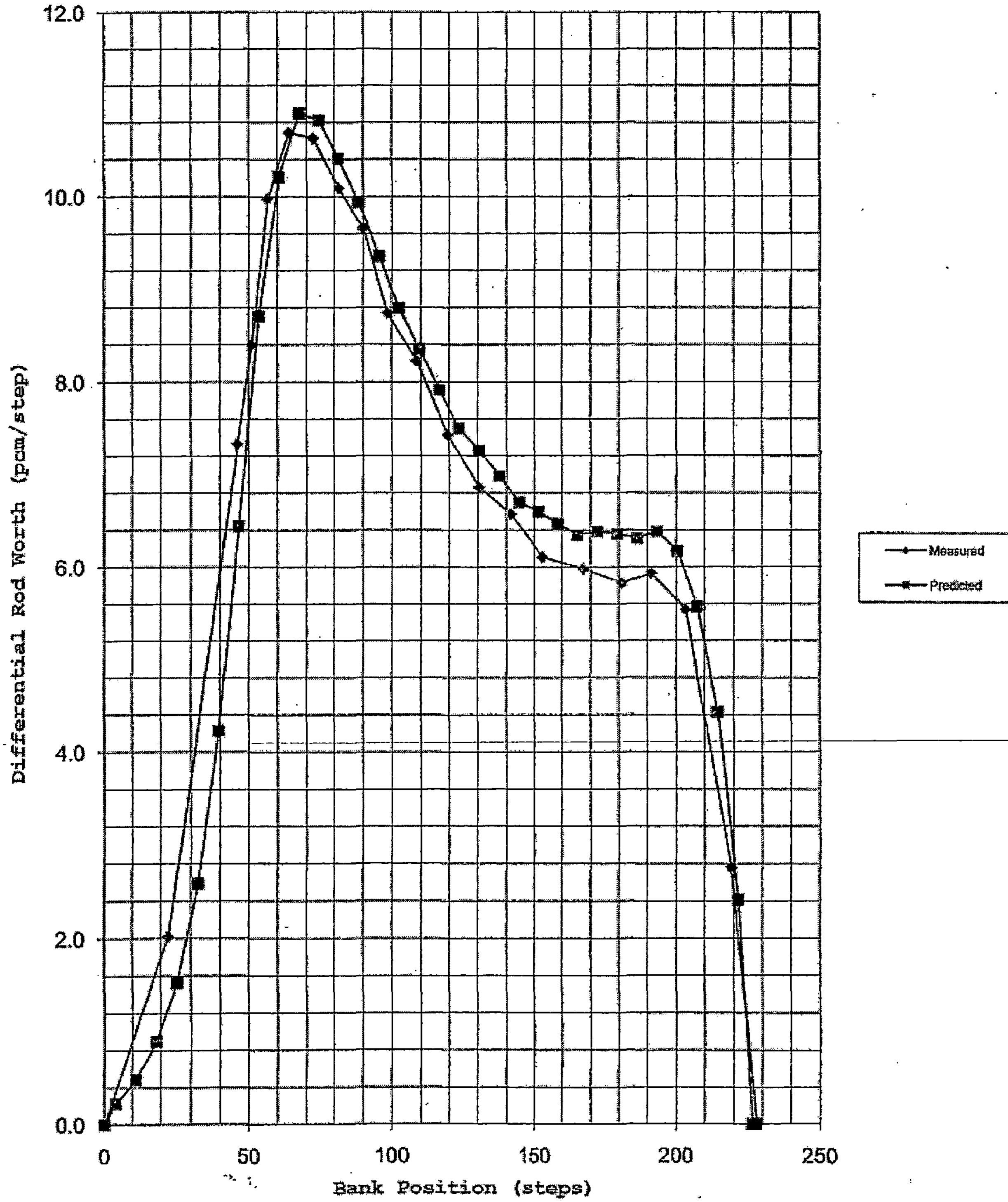


Figure 3.2

SURRY UNIT 2 – CYCLE 27 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 (HZP), 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. 6] 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 ±10%. In summary, the measured boron worth coefficient was satisfactory.

Table 4.1

SURRY UNIT 2 – CYCLE 27 STARTUP PHYSICS TESTS
BORON ENDPOINTS SUMMARY

Control Rod Configuration	Measured Endpoint (ppm)	Predicted Endpoint (ppm)	Difference M-P (ppm)
ARO	1554.1	1578	-23.9
B Bank In	1370.1	1365.1*	+5.0

* 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 27 STARTUP PHYSICS TESTS
BORON WORTH COEFFICIENT

Measured Boron Worth (pcm/ppm)	Predicted Boron Worth (pcm/ppm)	Percent Difference $\frac{(M-P)}{P} \times 100$ (%)
-7.60	-7.54	0.8

SECTION 5 — TEMPERATURE COEFFICIENT MEASUREMENT

The ITC at the ARO condition is measured by controlling the RCS temperature with the steam dump valves to the condenser, establishing a constant heatup or cooldown rate by adjusting feed and letdown flow rates, and monitoring the resulting reactivity changes on the reactivity computer.

Reactivity was measured during the RCS heat up of 3.26 °F, followed by the RCS cool down of 2.91 °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 -2.412 pcm/ °F, a predicted doppler temperature coefficient (DTC) of -1.83 pcm/ °F, and a measurement uncertainty of +0.5 pcm/ °F, is -0.082 pcm/ °F. It thus satisfies the COLR criteria [Ref. 13] which indicates MTC at HZP be less than or equal to +6.0 pcm/ °F.

Table 5.1

SURRY UNIT 2 – CYCLE 27 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/207	547.28	550.56	1547.3	-2.201	-2.624	-2.412	-2.465	0.053

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 27 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 [Ref. 15, Ref. 16]. 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. 17) was used as an interface to CEBRZ and CECOR.

A list of the full-core flux maps [Ref. 11] 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 45.40% 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 through 4 were taken at 71.14%, 73.14%, and 99.88% power, respectively, with different control rod configurations. Flux maps 2 and 4 were taken to check at-power design predictions and to measure core power distributions at various operating conditions. Map 3 is a full core map used for the maximum allowable power calculation, and incore average quadrant tilt verification after a down power. The RPDs for these maps are given in Figures 6.2 through 6.4.

The RPDs for the maps given in Figures 6.1, 6.2, 6.3, and 6.4 show that the measured relative assembly power values deviated from the design predictions by at most ±8.0% in the 45.40% power map, ±6.7% in the 71.14% power map, ±6.3% in the 73.14% power map, and ±6.1% in the 99.88% power map. The maximum average quadrant power tilt for the four maps were +3.44%, +2.96%, +2.95% and +2.45%, respectively. These power tilts are not within the design tolerance of 2%. The current safety analysis was examined and it was confirmed the measured tilt was bounded by the safety analysis. At the time of this report, this issue is still under investigation [Ref. 18] and being monitored [Ref. 19].

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. 13]. Flux Maps 1 through 4 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. 13]. It is therefore anticipated that the core will continue to operate safely throughout Cycle 27.

Table 6.1

SURRY UNIT 2 – CYCLE 27 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	12/12/15	7.0	45.40	177	E-12	26	2.134	D-10	1.571	26	1.268	1.0344	SE	4.397	50
Int. Power (4)	2	12/13/15	34.9	71.14	191	E-12	30	2.034	E-12	1.540	29	1.222	1.0296	SE	2.054	50
Int. Power (4)	3	12/16/15	115.0	73.14	197	E-12	30	2.005	E-12	1.528	29	1.210	1.0295	SE	2.506	50
Hot Full Power	4	12/21/15	262.3	99.88	227	E-12	30	1.909	E-12	1.497	29	1.169	1.0245	SE	1.779	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). These flux maps 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 27 STARTUP PHYSICS TESTS
COMPARISION OF MEASURED POWER DISTRIBUTION
PARAMETERS WITH THEIR CORE OPERATING LIMITS

	Peak $F_Q(Z)$ Hot Channel Factor				$F^N_{\Delta H}$ Hot Channel Factor		
Map No.	Meas.	Limit	Node	Margin* (%)	Meas.	Limit	Margin* (%)
1	2.134	5.000	26	57.3	1.571	1.816	13.5
2	2.034	3.514	30	42.1	1.540	1.695	9.1
3	2.005	3.418	30	41.3	1.528	1.686	9.4
4	1.909	2.503	30	23.7	1.497	1.561	4.1

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
45.40% POWER

ASSEMBLY RELATIVE POWER FRACTIONS
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							0.241 0.247 -2.56	0.401 0.410 -2.08	0.244 0.250 -2.38						
2					0.264 0.272 -2.85	0.449 0.462 -2.72	0.902 0.928 -2.81	0.962 0.998 -3.62	0.912 0.936 -2.59	0.464 0.465 -0.31	0.270 0.272 -0.79				
3				0.365 0.377 -3.29	0.972 1.004 -3.19	1.117 1.151 -2.94	1.240 1.272 -2.50	1.280 1.332 -3.87	1.248 1.283 -2.69	1.136 1.157 -1.83	0.997 1.007 -1.00	0.391 0.381 2.57			
4			0.365 0.372 -1.94	0.972 1.004 -3.17	1.246 1.290 -3.41	1.318 1.362 -3.24	1.211 1.244 -2.67	1.202 1.228 -2.11	1.222 1.252 -2.36	1.339 1.368 -2.09	1.277 1.295 -1.36	1.011 1.008 0.25	0.375 0.372 0.92		
5		0.281 0.283 -0.64	0.998 1.007 -0.88	1.248 1.292 -3.37	1.277 1.360 -6.13	1.157 1.206 -4.08	1.219 1.258 -3.07	1.311 1.349 -2.83	1.241 1.275 -2.67	1.185 1.212 -2.20	1.337 1.362 -1.83	1.307 1.292 1.19	1.018 1.008 1.02	0.285 0.283 0.54	
6		0.467 0.470 -0.74	1.150 1.163 -1.10	1.337 1.371 -2.46	1.163 1.212 -4.01	1.057 1.105 -4.36	1.105 1.147 -3.65	1.225 1.270 -3.58	1.120 1.154 -2.96	1.076 1.107 -2.83	1.200 1.211 -0.94	1.374 1.366 0.57	1.169 1.156 1.09	0.475 0.467 1.68	
7	0.249 0.251 -0.67	0.937 0.943 -0.68	1.293 1.292 0.05	1.242 1.259 -1.34	1.246 1.275 -2.31	1.118 1.152 -2.95	1.145 1.196 -4.22	1.123 1.162 -3.35	1.156 1.196 -3.34	1.132 1.151 -1.63	1.264 1.267 -0.27	1.260 1.250 0.82	1.291 1.273 1.44	0.959 0.933 2.78	0.258 0.249 3.65
8	0.409 0.414 -1.28	0.987 1.003 -1.64	1.306 1.323 -1.26	1.246 1.260 -1.08	1.343 1.355 -0.92	1.244 1.267 -1.81	1.136 1.165 -2.46	1.076 1.098 -1.99	1.146 1.165 -1.60	1.259 1.268 -0.69	1.366 1.356 0.71	1.282 1.262 1.59	1.347 1.327 1.54	1.057 1.005 5.21	0.436 0.415 5.16
9	0.246 0.248 -0.90	0.920 0.930 -1.06	1.257 1.268 -0.84	1.235 1.245 -0.83	1.245 1.264 -1.51	1.132 1.149 -1.47	1.176 1.194 -1.47	1.150 1.162 -1.03	1.192 1.196 -0.37	1.164 1.153 0.92	1.300 1.276 1.90	1.299 1.260 3.12	1.333 1.293 3.09	0.982 0.944 3.99	0.264 0.252 4.65
10		0.463 0.464 -0.32	1.148 1.150 -0.15	1.356 1.359 -0.25	1.200 1.206 -0.51	1.089 1.104 -1.40	1.137 1.152 -1.30	1.268 1.269 -0.05	1.157 1.146 0.92	1.121 1.105 1.42	1.251 1.212 3.21	1.446 1.371 5.46	1.213 1.163 4.27	0.485 0.470 3.17	
11		0.281 0.281 0.00	1.000 0.998 0.24	1.286 1.283 0.21	1.362 1.355 0.52	1.211 1.208 0.24	1.274 1.272 0.19	1.357 1.346 0.85	1.283 1.256 2.13	1.245 1.206 3.21	1.404 1.361 3.12	1.355 1.291 4.96	1.053 1.006 4.71	0.295 0.283 4.37	
12			0.371 0.366 1.30	1.004 0.998 0.64	1.295 1.285 0.80	1.376 1.362 1.00	1.263 1.249 1.09	1.257 1.227 2.48	1.288 1.242 3.71	1.427 1.362 4.75	1.356 1.291 5.06	1.075 1.005 7.01	0.389 0.368 5.83		
13				0.378 0.374 1.02	1.010 0.997 1.26	1.171 1.152 1.69	1.313 1.281 2.53	1.386 1.330 4.24	1.335 1.271 5.03	1.233 1.151 7.10	1.067 1.006 6.09	0.407 0.381 6.71			
14					0.274 0.269 1.83	0.475 0.463 2.54	0.967 0.934 3.51	1.036 0.996 4.05	0.980 0.928 5.65	0.492 0.462 6.59	0.290 0.272 6.50				
15							0.269 0.249 8.05	0.431 0.410 5.08	0.261 0.247 5.52						

AVERAGE ABSOLUTE PERCENT DIFFERENCE = 2.4
STANDARD DEVIATION = 1.756

Summary:

Map No: S2-27-01
Control Rod Position:
D Bank at 177 Steps

Date: 12/12/2015

$F_Q(Z)$ = 2.134

$F^N_{\Delta H}$ = 1.571

F_Z = 1.268

Burnup = 7.0 MWD/MTU

Power: 45.40%

QPTR:

0.9735	0.9926
0.9995	1.0344

Axial Offset (%) = +4.397

Figure 6.2 — ASSEMBLYWISE POWER DISTRIBUTION
71.14% POWER

ASSEMBLY RELATIVE POWER FRACTIONS
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							0.252	0.415	0.255						
							0.259	0.429	0.262						
							-2.82	-3.37	-2.69						
2					0.270	0.458	0.916	0.997	0.925	0.465	0.275				
					0.278	0.471	0.939	1.024	0.946	0.474	0.278				
					-2.85	-2.70	-2.44	-2.69	-2.19	-1.81	-1.03				
3				0.365	0.964	1.109	1.236	1.294	1.249	1.133	0.993	0.389			
				0.381	0.996	1.141	1.263	1.324	1.274	1.147	0.999	0.386			
				-4.24	-3.22	-2.85	-2.17	-2.26	-1.96	-1.25	-0.63	0.72			
4			0.368	0.964	1.228	1.300	1.197	1.180	1.218	1.339	1.269	1.003	0.380		
			0.376	0.996	1.270	1.343	1.235	1.220	1.242	1.349	1.275	0.998	0.377		
			-2.00	-3.17	-3.32	-3.20	-3.06	-3.26	-1.95	-0.72	-0.50	0.46	0.75		
5		0.287	0.988	1.236	1.284	1.161	1.208	1.301	1.243	1.194	1.337	1.287	1.009	0.289	
		0.289	0.999	1.272	1.344	1.206	1.256	1.340	1.272	1.211	1.346	1.272	1.000	0.289	
		-0.86	-1.11	-2.81	-4.44	-3.74	-3.85	-2.94	-2.28	-1.42	-0.65	1.19	0.92	-0.05	
6		0.474	1.140	1.322	1.169	1.094	1.119	1.238	1.137	1.107	1.203	1.355	1.157	0.483	
		0.479	1.153	1.352	1.211	1.136	1.157	1.270	1.164	1.138	1.210	1.347	1.146	0.475	
		-0.94	-1.16	-2.22	-3.46	-3.67	-3.27	-2.50	-2.36	-2.71	-0.61	0.58	0.96	1.70	
7	0.261	0.947	1.283	1.233	1.243	1.131	1.161	1.140	1.177	1.146	1.262	1.250	1.280	0.971	0.269
	0.263	0.953	1.283	1.250	1.273	1.162	1.203	1.169	1.203	1.160	1.265	1.241	1.265	0.944	0.261
	-0.90	-0.67	-0.03	-1.36	-2.32	-2.63	-3.48	-2.50	-2.18	-1.16	-0.24	0.73	1.18	2.90	3.21
8	0.426	1.016	1.298	1.237	1.327	1.245	1.148	1.092	1.162	1.265	1.354	1.266	1.330	1.072	0.450
	0.434	1.030	1.318	1.252	1.347	1.268	1.172	1.108	1.172	1.268	1.347	1.254	1.321	1.032	0.434
	-1.92	-1.39	-1.50	-1.23	-1.48	-1.78	-2.08	-1.42	-0.89	-0.21	0.50	0.93	0.66	3.85	3.63
9	0.257	0.932	1.251	1.229	1.251	1.146	1.187	1.162	1.209	1.169	1.289	1.273	1.307	0.980	0.270
	0.261	0.941	1.262	1.237	1.262	1.159	1.202	1.169	1.203	1.162	1.273	1.250	1.284	0.954	0.264
	-1.39	-0.94	-0.87	-0.68	-0.87	-1.11	-1.21	-0.61	0.54	0.61	1.28	1.82	1.81	2.71	2.15
10		0.472	1.142	1.340	1.203	1.125	1.147	1.269	1.169	1.154	1.243	1.390	1.183	0.491	
		0.473	1.141	1.342	1.206	1.136	1.162	1.269	1.156	1.136	1.211	1.352	1.153	0.479	
		-0.22	0.09	-0.14	-0.24	-0.94	-1.26	0.03	1.12	1.56	2.65	2.82	2.61	2.53	
11		0.287	0.995	1.268	1.347	1.211	1.272	1.345	1.279	1.244	1.402	1.326	1.034	0.299	
		0.287	0.992	1.265	1.341	1.208	1.269	1.337	1.255	1.205	1.345	1.272	0.998	0.289	
		0.17	0.28	0.25	0.42	0.29	0.22	0.62	1.95	3.22	4.24	4.21	3.60	3.43	
12			0.374	0.996	1.277	1.358	1.257	1.246	1.276	1.404	1.338	1.064	0.389		
			0.371	0.990	1.267	1.344	1.240	1.218	1.233	1.344	1.272	0.997	0.373		
			0.93	0.64	0.75	1.03	1.35	2.33	3.46	4.46	5.15	6.72	4.30		
13				0.382	1.002	1.161	1.303	1.373	1.321	1.212	1.056	0.410			
				0.379	0.990	1.142	1.272	1.324	1.263	1.142	0.998	0.386			
				0.80	1.20	1.64	2.44	3.74	4.56	6.17	5.82	6.20			
14					0.279	0.483	0.975	1.064	0.990	0.499	0.295				
					0.276	0.472	0.944	1.023	0.939	0.471	0.278				
					1.01	2.28	3.33	4.04	5.48	5.86	6.04				
15							0.277	0.449	0.272						
							0.261	0.429	0.259						
							6.12	4.65	5.12						

AVERAGE ABSOLUTE PERCENT DIFFERENCE = 2.1
STANDARD DEVIATION = 1.548

Summary:

Map No: S2-27-02
Control Rod Position:
D Bank at 191 Steps

Date: 12/13/2015
$F_Q(Z) = 2.034$
$F^N_{\Delta H} = 1.540$
$F_Z = 1.222$
Burnup = 34.9 MWD/MTU

Power: 71.14%

QPTR:		
	0.9751	0.9950
	1.0003	1.0296

Axial Offset (%) = +2.054

Figure 6.3 — ASSEMBLYWISE POWER DISTRIBUTION 73.14% POWER

ASSEMBLY RELATIVE POWER FRACTIONS
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							0.252 0.259 -2.63	0.418 0.430 -2.76	0.256 0.262 -2.33						
2					0.268 0.277 -3.22	0.456 0.469 -2.86	0.911 0.936 -2.65	1.001 1.028 -2.66	0.923 0.943 -2.13	0.466 0.472 -1.33	0.274 0.276 -0.72				
3				0.363 0.379 -4.10	0.954 0.988 -3.40	1.100 1.135 -3.11	1.226 1.259 -2.64	1.288 1.321 -2.48	1.244 1.269 -2.01	1.125 1.140 -1.28	0.984 0.990 -0.65	0.387 0.383 1.17			
4			0.365 0.374 -2.45	0.956 0.988 -3.25	1.219 1.263 -3.49	1.294 1.339 -3.33	1.196 1.234 -3.11	1.182 1.219 -3.06	1.216 1.241 -1.99	1.331 1.344 -0.96	1.259 1.267 -0.65	0.992 0.991 0.14	0.376 0.375 0.35		
5		0.284 0.288 -1.41	0.974 0.991 -1.72	1.227 1.265 -2.97	1.282 1.342 -4.45	1.165 1.209 -3.65	1.214 1.261 -3.70	1.305 1.343 -2.82	1.248 1.277 -2.29	1.196 1.215 -1.59	1.333 1.343 -0.78	1.273 1.265 0.67	0.998 0.992 0.58	0.289 0.288 0.27	
6		0.473 0.477 -0.84	1.134 1.146 -1.08	1.318 1.347 -2.13	1.174 1.215 -3.39	1.113 1.153 -3.46	1.130 1.166 -3.10	1.247 1.278 -2.43	1.147 1.173 -2.22	1.124 1.155 -2.70	1.204 1.213 -0.71	1.347 1.343 0.27	1.147 1.140 0.64	0.480 0.474 1.20	
7	0.262 0.264 -0.82	0.947 0.951 -0.46	1.285 1.279 0.44	1.235 1.250 -1.19	1.251 1.278 -2.12	1.142 1.172 -2.52	1.172 1.213 -3.35	1.151 1.179 -2.34	1.190 1.213 -1.92	1.156 1.170 -1.21	1.266 1.270 -0.33	1.247 1.241 0.52	1.273 1.261 0.92	0.962 0.941 2.25	0.268 0.262 2.40
8	0.428 0.435 -1.55	1.022 1.034 -1.17	1.296 1.316 -1.50	1.239 1.252 -1.07	1.335 1.350 -1.10	1.255 1.275 -1.55	1.159 1.182 -1.94	1.104 1.118 -1.28	1.173 1.182 -0.76	1.271 1.276 -0.38	1.356 1.351 0.40	1.265 1.254 0.89	1.327 1.319 0.62	1.073 1.036 3.61	0.450 0.436 3.22
9	0.258 0.261 -1.16	0.929 0.939 -1.03	1.246 1.258 -0.98	1.228 1.237 -0.73	1.257 1.267 -0.80	1.157 1.168 -0.94	1.199 1.212 -1.10	1.174 1.179 -0.45	1.222 1.213 0.77	1.180 1.172 0.68	1.295 1.278 1.31	1.273 1.250 1.86	1.304 1.280 1.89	0.978 0.952 2.70	0.271 0.264 2.81
10		0.469 0.472 -0.65	1.131 1.135 -0.39	1.334 1.338 -0.30	1.206 1.210 -0.29	1.144 1.152 -0.69	1.158 1.172 -1.23	1.279 1.277 0.15	1.180 1.166 1.22	1.172 1.152 1.73	1.247 1.215 2.63	1.389 1.347 3.09	1.179 1.146 2.86	0.492 0.477 3.23	
11		0.285 0.286 -0.26	0.984 0.984 0.03	1.260 1.258 0.14	1.343 1.338 0.39	1.217 1.211 0.49	1.280 1.274 0.49	1.353 1.341 0.87	1.286 1.260 2.05	1.247 1.209 3.12	1.397 1.342 4.09	1.317 1.265 4.12	1.026 0.990 3.63	0.298 0.288 3.51	
12			0.373 0.368 1.30	0.989 0.983 0.61	1.270 1.260 0.83	1.357 1.340 1.26	1.263 1.240 1.85	1.249 1.218 2.58	1.275 1.233 3.41	1.397 1.339 4.34	1.327 1.265 4.87	1.051 0.989 6.29	0.387 0.371 4.19		
13				0.380 0.376 1.02	0.995 0.982 1.33	1.157 1.136 1.86	1.303 1.267 2.81	1.373 1.321 3.96	1.315 1.258 4.51	1.202 1.135 5.88	1.044 0.990 5.44	0.406 0.383 5.93			
14					0.278 0.274 1.46	0.482 0.470 2.61	0.975 0.941 3.58	1.069 1.027 4.05	0.983 0.936 5.06	0.495 0.469 5.53	0.292 0.277 5.45				
15							0.279 0.262 6.62	0.450 0.430 4.77	0.272 0.259 5.03						

AVERAGE ABSOLUTE PERCENT DIFFERENCE = 2.1
STANDARD DEVIATION = 1.499

Summary:

Map No: S2-27-03
Control Rod Position:
D Bank at 197 Steps

Date: 12/16/2015
$F_Q(Z)$ = 2.005
$F^N_{\Delta H}$ = 1.528
F_Z = 1.210
Burnup = 115.0 MWD/MTU

Power: 71.14%

QPTR:		
	0.9753	0.9939
	1.0013	1.0295

Axial Offset (%) = +2.506

Figure 6.4 — ASSEMBLYWISE POWER DISTRIBUTION 99.88% POWER

ASSEMBLY RELATIVE POWER FRACTIONS
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							0.262 0.268 -2.21	0.433 0.446 -2.82	0.265 0.271 -2.09						
2					0.272 0.279 -2.45	0.463 0.474 -2.26	0.926 0.945 -2.03	1.040 1.063 -2.16	0.935 0.952 -1.80	0.471 0.477 -1.22	0.277 0.279 -0.64				
3				0.367 0.380 -3.54	0.951 0.978 -2.79	1.098 1.126 -2.44	1.229 1.253 -1.92	1.285 1.312 -2.06	1.241 1.263 -1.71	1.121 1.131 -0.89	0.977 0.980 -0.29	0.391 0.384 1.83			
4			0.367 0.375 -2.08	0.951 0.979 -2.81	1.212 1.247 -2.83	1.282 1.319 -2.79	1.190 1.222 -2.61	1.169 1.206 -3.04	1.208 1.228 -1.67	1.318 1.323 -0.42	1.247 1.251 -0.32	0.988 0.981 0.68	0.378 0.375 0.90		
5		0.287 0.290 -1.00	0.967 0.980 -1.32	1.214 1.249 -2.78	1.266 1.325 -4.44	1.171 1.209 -3.17	1.227 1.264 -2.91	1.299 1.331 -2.37	1.255 1.279 -1.90	1.199 1.214 -1.23	1.317 1.327 -0.74	1.264 1.249 1.16	0.989 0.981 0.81	0.289 0.290 -0.51	
6		0.479 0.482 -0.67	1.127 1.138 -1.00	1.301 1.327 -1.98	1.179 1.214 -2.92	1.169 1.203 -2.82	1.148 1.178 -2.56	1.252 1.276 -1.85	1.163 1.184 -1.77	1.177 1.205 -2.30	1.205 1.213 -0.62	1.328 1.322 0.45	1.139 1.132 0.66	0.485 0.479 1.30	
7	0.272 0.273 -0.41	0.957 0.960 -0.33	1.277 1.272 0.41	1.223 1.237 -1.10	1.255 1.280 -1.93	1.157 1.183 -2.20	1.186 1.222 -2.91	1.170 1.193 -1.95	1.205 1.222 -1.36	1.170 1.181 -0.96	1.268 1.272 -0.28	1.234 1.228 0.47	1.265 1.255 0.82	0.977 0.951 2.69	0.279 0.271 2.90
8	0.447 0.451 -0.78	1.060 1.070 -0.89	1.288 1.308 -1.52	1.226 1.239 -1.05	1.321 1.339 -1.31	1.256 1.274 -1.45	1.174 1.195 -1.73	1.117 1.130 -1.16	1.187 1.196 -0.72	1.271 1.275 -0.30	1.341 1.339 0.15	1.246 1.240 0.47	1.309 1.310 -0.05	1.111 1.072 3.66	0.467 0.452 3.40
9	0.269 0.270 -0.53	0.943 0.948 -0.55	1.245 1.252 -0.54	1.220 1.225 -0.39	1.268 1.271 -0.22	1.170 1.180 -0.81	1.207 1.221 -1.15	1.185 1.192 -0.57	1.226 1.222 0.33	1.183 1.183 0.03	1.289 1.280 0.74	1.251 1.237 1.11	1.289 1.273 1.23	0.984 0.961 2.43	0.281 0.273 2.93
10		0.477 0.477 0.05	1.133 1.127 0.56	1.318 1.318 0.02	1.208 1.210 -0.15	1.195 1.203 -0.68	1.166 1.183 -1.47	1.274 1.275 -0.09	1.187 1.177 0.87	1.218 1.203 1.28	1.238 1.214 1.96	1.352 1.326 1.95	1.161 1.138 1.98	0.496 0.482 2.81	
11		0.289 0.288 0.37	0.977 0.974 0.30	1.243 1.243 0.01	1.320 1.322 -0.14	1.212 1.211 0.11	1.277 1.277 0.01	1.337 1.329 0.58	1.284 1.263 1.63	1.241 1.209 2.67	1.371 1.325 3.47	1.291 1.248 3.41	1.008 0.980 2.90	0.299 0.290 3.04	
12			0.371 0.370 0.26	0.977 0.974 0.29	1.249 1.244 0.38	1.330 1.320 0.73	1.242 1.227 1.21	1.229 1.205 1.99	1.256 1.220 2.99	1.370 1.319 3.89	1.303 1.249 4.35	1.037 0.980 5.78	0.387 0.372 4.14		
13				0.380 0.377 0.71	0.981 0.972 0.93	1.143 1.128 1.30	1.288 1.261 2.11	1.353 1.312 3.13	1.302 1.252 4.03	1.191 1.127 5.65	1.029 0.979 5.16	0.405 0.384 5.41			
14					0.282 0.277 1.67	0.485 0.475 2.15	0.979 0.951 2.96	1.101 1.062 3.65	0.990 0.945 4.78	0.499 0.474 5.27	0.294 0.279 5.30				
15							0.288 0.271 6.13	0.465 0.446 4.32	0.281 0.268 4.68						

AVERAGE ABSOLUTE PERCENT DIFFERENCE = 1.8
STANDARD DEVIATION = 1.414

Summary:

Map No: S2-27-04
Control Rod Position:
D Bank at 227 Steps

Date: 12/21/2015
$F_Q(Z)$ = 1.909
$F^N_{\Delta H}$ = 1.497
F_Z = 1.169
Burnup = 262.3 MWD/MTU

Power: 99.88%

QPTR:		
	0.9789	0.9961
	1.0005	1.0245

Axial Offset (%) = +1.779

SECTION 7 — CONCLUSIONS

Table 7.1 summarizes the results associated with Surry Unit 2 Cycle 27 startup physics testing program. As noted herein, all test results were acceptable. The test results were within associated design tolerances, Technical Specifications limits, or COLR limits, except for the maximum positive incore quadrant power tilt exceeding the design criteria for all power ascension flux maps. Maximum incore quadrant power tilts ranged from 2.45% to 3.44% during the power ascension, exceeding the design criteria of 2%. It was confirmed that the measured tilt was bounded by the current safety analysis. As of the writing of this report, the larger than normal quadrant tilts remain under investigation and are being continuously monitored. Based on the results of the S2C27 startup physics testing program, it is anticipated that the Surry 2 core will continue to operate safely throughout Cycle 27.

Table 7.1

SURRY UNIT 2 – CYCLE 27 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	1554	1578	-24	±50
Critical Boron Concentration (HZP Ref Bank in), ppm	1370	1365	5	±29
Isothermal Temp Coefficient (HZP ARO), pcm/F	-2.412	-2.465	0.053	±2
Differential Boron Worth (HZP ARO), pcm/ppm	-7.60	-7.54	0.8%	±10%
Reference Bank Worth (B-bank, dilution), pcm	1399	1426	-1.9%	±10%
A-bank Worth (Rod Swap), pcm	219	202	17	±100
SA-bank Worth (Rod Swap), pcm	993	966	+2.9%	±15%
C-bank Worth (Rod Swap), pcm	873	920	-5.1%	±15%
D-bank Worth (Rod Swap), pcm	941	961	-2.0%	±15%
SB-bank Worth (Rod Swap), pcm	1112	1173	-5.2%	±15%
Total Bank Worth, pcm	5537	5648	-2.0%	±10%

S2C27 Testing Time:	**7.6**	**Hrs**
[criticality 12/01/2015 @ 04:35 to end of testing 12/01/2015 @ 12:08]		
Recent Startups:		
S1C27 testing time:	5.6	hrs
S2C26 testing time:	7.2	hrs
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. B. R. Kinney, "Surry Unit 2 Cycle 27 Full Core Loading Plan," Engineering Technical Evaluation ETE-NAF-20150005, Rev. 0, May 2015.
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14. A. T. Folkening, "Surry Rod Drop Measurement Instrument (RDMI) Data Comparison & Analysis Report," AREVA Document No. 5-9228549-000, Feb 2015.
15. 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.
16. 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.
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18. Condition Report CR1021297, "Unit 2 Incore QPTR greater than nominal RSAC limit," 14 December 2015.
19. Condition Report CR1024733, "Tracking of S2C27 Incore Tilt for review at 11,000 MWD/MTU," 21 January 2016.
20. T. S. Psuik, "Implementation of Changes to the Allowable Power Level for the Initial Startup Flux Map for Surry Units 1 and 2," Engineering Technical Evaluation ETE-NAF-2015-0007, Rev. 0, April 2015.

APPENDIX — STARTUP PHYSICS TEST SUMMARY SHEET

Surry Power Station Unit 2 Cycle 27 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 E-9 to 1E-7 amps	background < ZPTR < POAH background = 3.91 E-11 amps POAH= 2.267E-7 amps	N/A	✓ Yes ___ No	N/A	12/1/15 0545	BTM/ BRK
Reactivity Computer Checkout						
ρ_c= 50.392/-36.420 pcm (measured reactivity) ρ_t= 50.693/-37.295 pcm (predicted reactivity) %D = {(ρc - ρt)/ρt} x 100% %D = -0.594/-2.171	$\lvert[(\rho_c - \rho_t)/\rho_t]\rvert \times 100\% \leq 4.0\%$[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/-100 pcm Allowable range +120/-100 pcm	N/A	✓ Yes ___ No	N/A	12/1/15 0545	BTM/ BRK
Critical Boron Concentration - ARO						
$(C_B)^M_{ARO}$= 1554.1 ppm (Adj. To design conds.)	$(C_B)_{ARO}$=[2] 1678 ± 50 ppm $\Delta(C_B)_{ARO}=(C_B)^M_{ARO} - (C_B)_{ARO}$ = -124 ppm	$\lvert\alpha C_B \times \Delta(C_B)_{ARO}\rvert \leq 1000$ pcm [T.S. 4.10.A] αC_B=[2] -7.47 pcm/ppm	✓ Yes ___ No	✓ Yes ___ No	12/1/15 0545	BTM/ BRK
Isothermal Temperature Coefficient - ARO						
$(\alpha_T^{ISO})^M_{ARO}$ = -2.412 pcm/°F	$(\alpha_T^{ISO})_{ARO}$ =[2] -2.465 ± 2 pcm/°F $(\alpha_T^{ISO})^M_{ARO} - (\alpha_T^{ISO})_{ARO}$ = +0.053 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	12/01/15 0548	SRG/ KLK
Control Bank B Worth Measurement, Rod Swap Reference Bank						
$I_B^{REF,M}$= 1398.746 pcm	I_B^{REF}=[2] 1426 ± 10% 100x(Meas. - Des.)/Des. = -1.9 %	N/A	✓ Yes ___ No	N/A	12/01/15 0715	SRG/ KLK

References
1.) DNES-AA-NAF-NCD-4015, Rev. 2
2.) ETE-NAF-2015-0118, Rev. 0
3.) ETE-NAF-2015-0117, Rev. 0

Surry Power Station Unit 2 Cycle 27 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						
$(C_B)^M{}_B$= 1370.1 ppm	$(C_B)_B$=[2] 1389 + $\Delta(C_B)_{ARO}$ = 29 ppm $\Delta(C_B)_{ARO}$= -23.9 ppm (from above) $(C_B)_B$= 1365.1 ± 29 ppm $(C_B)^M{}_B - (C_B)_B$= +5.0 ppm	N/A	✓ Yes ___ No	N/A	12/01/15 1020	SSR / KLK
HZP Boron Worth Coefficient Measurement						
$(\alpha C_B)^M$= -7.60 pcm/ppm	αC_B =[2] -7.54 ± 0.754 pcm/ppm $\Delta\alpha C_B=(\alpha C_B)^M - (\alpha C_B)$ = -.06 pcm/ppm	N/A	✓ Yes ___ No	N/A	12/01/15 1020	SSR / KLK
Control Bank A Worth Measurement, Rod Swap						
$I_A{}^{RS}$= 218.9 pcm	$(I_A{}^{RS})^3$= 202.1 ± 100 pcm Meas. - Des. = +16.8 pcm	N/A	✓ Yes ___ No	N/A	12/01/15 0955	SSR / KLK
Control Bank C Worth Measurement, Rod Swap						
$I_C{}^{RS}$= 872.7 pcm	$(I_C{}^{RS})^3$= 919.8 ± 15% 100x(Meas. - Des.)/Des. = -5.1 %	N/A	✓ Yes ___ No	N/A	12/01/15 0955	SSR / KLK
Shutdown Bank A Worth Measurement, Rod Swap						
$I_{SA}{}^{RS}$= 993.3 pcm	$(I_{SA}{}^{RS})^3$= 965.6 ± 15% 100x(Meas. - Des.)/Des. = +2.9 %	N/A	✓ Yes ___ No	N/A	12/01/15 0955	SSR / KLK
Control Bank D Worth Measurement, Rod Swap						
$I_D{}^{RS}$= 941.4 pcm	$(I_D{}^{RS})^3$= 960.8 ± 15% 100x(Meas. - Des.)/Des. = -2.0 %	N/A	✓ Yes ___ No	N/A	12/01/15 0955	SSR / KLK
Shutdown Bank B Worth Measurement, Rod Swap						
$I_{SB}{}^{RS}$= 1111.9 pcm	$(I_{SB}{}^{RS})^3$= 1173.4 ± 15% 100x(Meas. - Des.)/Des. = -5.2 %	N/A	✓ Yes ___ No	N/A	12/01/15 0955	SSR / KLK
Total Rod Worth, Rod Swap						
I_{Total}= 5534.9 pcm	$(I_{Total})^3$= 5648.1 ± 10% 100x(Meas. - Des.)/Des. = -2.0 %	N/A	✓ Yes ___ No	N/A	12/01/15 0955	SSR / KLK

References 1.) DNES-AA-NAF-NCD-4015, Rev. 2
2.) ETE-NAF-2015-0118, Rev. 0
3.) ETE-NAF-2015-0117, Rev. 0

Surry Power Station Unit 2 Cycle 27 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 ≤ 50%						
Map Power Level (% Full Power) = 45.40						
Max Relative Assembly Power, %DIFF (M-P)/P					12/14/15 04:59	[initials]
%DIFF= 7.1 % for Pi≥0.9 8.0 % for Pi<0.9	±10% for P_i ≥0.9 ±15% for P_i<0.9 (P_i = assy power)[1,2]	N/A	X Yes ___ No	N/A		
Nuclear Enthalpy Rise Hot Channel Factor, FΔH(N)						
FΔH(N)= 1.571	N/A	FΔH(N)≤1.56{1+0.3(1-P)} [COLR 3.7]	N/A	X Yes ___ No		
Total Heat Flux Hot Channel Factor, FQ(Z)						
Peak F_Q(Z) Hot Channel Factor= 2.154	N/A	F_Q(Z)≤5*K(Z) [COLR 3.7]	N/A	X Yes ___ No		
Maximum Positive Incore Quadrant Power Tilt						
Tilt= 1.0344	≤ 1.02[1]	N/A	___ Yes X No	N/A		

References 1.) DNES-AA-NAF-NCD-4015, Rev. 2
2.) ETE-NAF-2015-0118, Rev. 0
3.) ETE-NAF-2015-0117, Rev. 0

Surry Power Station Unit 2 Cycle 27 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) = 71.14						
Max Relative Assembly Power, %DIFF (M-P)/P					12/13/15 1449	SBR / RAH
%DIFF= 6.7 % for $P_i \geq 0.9$ 6.2 % for $P_i < 0.9$	±10% for $P_i \geq 0.9$ ±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)= 1.540	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= 2.034	N/A	$F_Q(Z) \leq [2.5/P]*K(Z)$ [COLR 3.7]	N/A	✓ Yes ___ No		
Maximum Positive Incore Quadrant Power Tilt						
Tilt= 2.96 % (1.0296)	≤ 1.02[1]	N/A	___ Yes ✓ No	N/A		

References 1.) DNES-AA-NAF-NCD-4015, Rev. 2
2.) ETE-NAF-2015-0118, Rev. 0
3.) ETE-NAF-2015-0117, Rev. 0

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Measured Value	Design Criteria	Acceptance Criteria	Design Criteria Met	Acceptance Criteria Met	Date/ Time of Test	Preparer/ Reviewer
I/D Flux Map 95% ≤ Power ≤ 100%						
Map Power Level (% Full Power) = 99.88						
Max Relative Assembly Power, %DIFF (M-P)/P					12/21/15 0236	T... 12/21/15 KLK 12/21/15
%DIFF= 5.3 % for Pi ≥ 0.9 6.1 % for Pi<0.8	±10% for $P_i \geq 0.9$ ±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)= 1.497	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= 1.909	N/A	$F_Q(Z) \leq (2.5/P)^*K(Z)$ [COLR 3.7]	N/A	✓ Yes ___ No		
Maximum Positive Incore Quadrant Power Tilt						
Tilt= 1.0245	≤ 1.02[1]	N/A	___ Yes ✓ No	N/A		

References 1.) DNES-AA-NAF-NCD-4015, Rev. 2
2.) ETE-NAF-2015-0118, Rev. 0
3.) ETE-NAF-2015-0117, Rev. 0

Surry Power Station Unit 2 Cycle 27 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}= 289,584 gpm	N/A	$F_{total} \geq$ 274000 gpm [COLR 3.8]	N/A	✓ Yes ___ No	10/16/15 0500	KK / DTA

References 1.) DNES-AA-NAF-NCD-4015, Rev. 2
2.) ETE-NAF-2015-0118, Rev. 0
3.) ETE-NAF-2015-0117, Rev. 0