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February 28, 2020

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

Serial No.: 20-067
NRA/GDM
Docket No.: 50-280
License No.: DPR-32

VIRGINIA ELECTRIC AND POWER COMPANY (DOMINION ENERGY VIRGINIA)
SURRY POWER STATION UNIT 1
CYCLE 30 STARTUP PHYSICS TESTS REPORT

Enclosed is the Surry Unit 1 Cycle 30 Startup Physics Tests Report. The report summarizes the results of the physics testing program performed prior to and following initial criticality of Cycle 30 on November 29, 2019. 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,

B E Standley

B. E. Standley, Director
Nuclear Regulatory Affairs
Dominion Energy Services, Inc. for
Virginia Electric and Power Company

Enclosure: Surry Unit 1 Cycle 30 Startup Physics Tests Report

Commitments made in this letter: None

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NRC Senior Resident Inspector
Surry Power Station

Serial No. 20-067
Docket No. 50-280

Enclosure

SURRY UNIT 1 CYCLE 30
STARTUP PHYSICS TESTS REPORT

February 2020

Virginia Electric and Power Company
(Dominion Energy Virginia)
Surry Power Station Unit 1

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 1 Cycle 30 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. 3 [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 1 Cycle 30 startup physics tests results and evaluation sheets are included in Appendix B 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 Energy's Nuclear Engineering and Fuel Group. The acceptance criteria are based on design tolerances or applicable Technical Specification and COLR Limits.

Per Surry Technical Specifications 6.6.A [Ref. 4], "the report shall address each of the tests identified in the FSAR and shall in general include a description of the measured values of the operating conditions or characteristics obtained during the test program, and a comparison of these values with design predictions and specifications." Per UFSAR Section 3.6.1.1 [Ref. 19], "a detailed series of start-up physics tests are performed", followed by references to core power distribution measurements, i.e., flux maps. The S1C30 Startup Physics Tests Report includes, as required, a description of measured values and a comparison of these values to design predictions of all of the tests performed during startup testing and the initial power ascension flux maps performed thereafter.

SECTION 1 — INTRODUCTION AND SUMMARY

On October 19, 2019, Unit No. 1 of Surry Power Station completed Cycle 29 and began refueling [Ref. 1]. During this refueling, 60 of the 157 fuel assemblies in the core were replaced with fresh Batch S1/32A and S1/32B assemblies [Ref. 8]. The Surry 1 Cycle 30 (S1C30) core consists of 8 sub-batches of fuel: two fresh batches (S1/32A and S1/32B), three once-burned batches (S1/31A, S1/31B and S2/30B), and three twice-burned batches (S1/30A, S1/30C and S2/29B). S1C30 utilizes the 15x15 Upgrade (Upgrade) Fuel Design for all but 4 of the fuel assemblies (which make up batch S1/30C). The remaining 4 assemblies are Lead Test Assemblies (LTAs) of the AREVA AGORA-5A-I (AGORA) design that are being loaded for their third cycle of irradiation [Ref. 1].

Fuel batches S1/30A, S1/31A, S1/31B, S1/32A, S1/32B, S2/29B and S2/30B are of the Westinghouse Upgrade fuel design which includes ZIRLO (I-spring) structural mid grids with balanced mixing vane pattern, three ZIRLO Intermediate Flow Mixing (IFM) grids, "tube-in-tube" guide thimbles, 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, Robust Protective Grids (RPG) and modified Debris Filter Bottom Nozzles (mDFBN). In addition, these batches of the Upgrade fuel design utilize the Westinghouse Integral Nozzle (WIN) top nozzle design [Ref. 8].

The fresh Upgrade fuel uses Westinghouse's Integral Fuel Burnable Absorber (IFBA) product as the burnable absorber. The IFBA design involves the application of a thin 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 to accommodate higher lifetime pressure increase from the IFBA coating [Ref. 5].

Surry 1 batch 30C is of the AREVA AGORA fuel design. The top grids of the assemblies are a High Thermal Performance (HTP) design fabricated from M5 material. The mid-grids are AFA-3G vaned mixing grids, which are bimetallic grids utilizing M5 strips and Inconel 718 springs. The mid-span mixing grids (MSMG) are M5 vaned mixing grids placed on spans 3 through 5 on the assembly. The MSMG are similar to the IFM grids used in the other batches of this cycle and are located at approximately the same elevations as the IFMs. The bottom grid is an Inconel 718 HMP (High Mechanical Performance) grid. The fuel rod cladding is composed of M5 material and the guide tubes and instrument tubes are composed of Q12 (zirconium alloy) and are of the MONOBLOC design [Ref. 1].

The AREVA AGORA LTAs utilize gadolinia (Gd_2O_3) as a burnable poison integral to the fuel. Each LTA contains 28 gadolinia rods, 12 at 2% and 16 at 6%, with 6 inch cutback regions at the top and bottom of the fuel. The cutback regions are the same enrichment as non-gadolinia rods. The gadolinia rods are subject to the 5:1 enrichment penalty (5% reduction in U-235 for each weight percent of gadolinia) from the nominal enrichment.

Cycle 30 loads Secondary Source Assemblies (SSAs) in core locations H04 and H12 to improve Source Range Detector response. 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 S1C30. The cycle design report [Ref. 1] provides a more detailed description of the Cycle 30 core.

The S1C30 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 30 core [Ref. 1].

According to the Startup Physics logs, the Cycle 30 core achieved initial criticality on November 29, 2019 at 01:20 [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.7.15.04 [Ref. 9] was used for S1C30 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 1.68 second 15x15 Upgrade Fuel administrative limit [Ref. 10]. No control rods are located in the four AGORA assemblies.

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 3.5% lower than the design prediction. The reference bank (Control Bank B) worth was 3.5% lower than its design prediction. Control rod banks with design predictions greater than 600 pcm were within ±3.0% of the design predictions except C-bank. The measured worth for C-bank was 622 pcm which was 6.1% below the design prediction. The larger percent difference is due to the relatively low worth of C-bank. For individual banks worth 600 pcm or less (only Control Bank A fits this category), the difference was 12 pcm below 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. 4] that the overall core reactivity balance shall be within ±1% Δk/k of the design prediction. The boron worth coefficient measurement (the differential boron worth, DBW) was 1.8% lower than the design prediction, which is within the design tolerance of ±10%.

The measured isothermal temperature coefficient (ITC) for the all-rods-out (ARO) configuration was 0.496 pcm/°F higher than the design prediction. This result is within the design tolerance of ±2.0 pcm/°F [Ref. 14].

Core power distributions were within established design tolerances. The measured assembly power distributions were within the design tolerance of ±15% for assemblies with power <0.9 and ±10% for assemblies with power ≥0.9. A 3.8% maximum difference occurred in the 28.53% 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. 8]. All power flux maps were within the maximum incore power tilt design tolerance of 2% (QPTR $\leq$ 1.02).

The Reactor Coolant Pump (RCP) start sequence is as follows: 'C' RCP started on 11/19 at 16:48, 'A' RCP started on 11/22 at 14:38, and 'B' RCP started on 11/26 at 00:01 [Appendix A].

All zero power physics testing results met the tighter criteria permitting the first flux map analysis to be performed as high as 50% power (versus 30% power).

The total RCS Flow was successfully verified as being greater than 273,000 gpm and greater than the limit in the COLR (274000 gpm), as required by Surry Technical Specifications [Ref. 4]. The total RCS Flow at nominal conditions was measured as 289,846 gpm.

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

Table 1.1

SURRY UNIT 1 – CYCLE 30
CHRONOLOGY OF TESTS

Test	Date	Time	Power	Reference Procedure
Hot Rod Drop-Hot Full Flow	11/28/19	12:24	HSD	1-NPT-RX-014
Reactivity Computer Checkout	11/29/19	02:25	HZP	1-NPT-RX-008
Boron Endpoint – ARO	11/29/19	02:25	HZP	1-NPT-RX-008
Zero Power Testing Range	11/29/19	02:25	HZP	1-NPT-RX-008
Boron Worth Coefficient	11/29/19	06:45	HZP	1-NPT-RX-008
Temperature Coefficient – ARO	11/29/19	02:53	HZP	1-NPT-RX-008
Bank B Worth	11/29/19	05:03	HZP	1-NPT-RX-008
Boron Endpoint – B in	11/29/19	06:45	HZP	1-NPT-RX-008
Bank A Worth – Rod Swap	11/29/19	07:35	HZP	1-NPT-RX-008
Bank C Worth – Rod Swap	11/29/19	07:35	HZP	1-NPT-RX-008
Bank SA Worth – Rod Swap	11/29/19	07:35	HZP	1-NPT-RX-008
Bank D Worth – Rod Swap	11/29/19	07:35	HZP	1-NPT-RX-008
Bank SB Worth – Rod Swap	11/29/19	07:35	HZP	1-NPT-RX-008
Total Rod Worth	11/29/19	09:20	HZP	1-NPT-RX-008
Flux Map – less than 50% Power* Peaking Factor Verification & Power Range Calibration	11/30/19	02:09	28.53%	1-NPT-RX-002 1-NPT-RX-008 1-NPT-RX-005 1-GEP-RX-001
Flux Map – 65% - 75% Power Peaking Factor Verification & Power Range Calibration	12/01/19	07:05	70.62%	1-NPT-RX-002 1-NPT-RX-008 1-NPT-RX-005 1-GEP-RX-001
Flux Map – 95% - 100% Power Peaking Factor Verification & Power Range Calibration	12/05/19	13:13	99.93%	1-NPT-RX-002 1-NPT-RX-008 1-NPT-RX-005 1-GEP-RX-001
RCS Flow Measurement	12/03/19	09:25	HFP	1-NPT-RX-009

* Results of zero power physics testing required the first flux map to be performed up to 50% power (versus 30% power if specified criteria were not met). The first flux map was performed below 30% power in anticipation of required chemistry hold.

Figure 1.1

SURRY UNIT 1 – CYCLE 30
CORE LOADING MAP

SURRY UNIT 1 - CYCLE 30
FULL CORE LOADING PLAN
REVISION NO. 0

ETE-NAF-2019-0027 REV. 0
ATTACHMENT 1
PAGE 1 OF 1

VEP-NES-NAF

NORTH ↑

	A	B	C	D	E	F	G	H	J	K	L	M	N	P	R
15							747	AG2	744						
14					409	RCC 510	AA33	RCC AA46	AA40	RCC 508	407				
13				735	AA52	AA05	RCC AA16	530	RCC AA14	AA06	AA43	740			
12			738	RCC 750	AA55	RCC 547	533	SS10 517	539	RCC 545	AA59	RCC 756	733		
11		410	AA41	AA58	RCC 551	505	AA18	531	AA19	501	RCC 554	AA53	AA48	408	
10		RCC 502	AA08	RCC 543	504	RCC AA28	561	RCC AA29	562	RCC AA26	514	RCC 546	AA07	RCC 513	
9	743	AA36	RCC AA13	538	AA17	560	RCC 520	552	RCC 518	563	AA20	536	RCC AA09	AA39	748
8	AG3	RCC AA42	532	524	529	RCC AA32	553	858	550	RCC AA31	528	522	525	RCC AA45	AG5
7	745	AA37	RCC AA10	540	AA24	558	RCC 519	549	RCC 521	559	AA22	534	RCC AA11	AA38	742
6		RCC 511	AA04	RCC 544	506	RCC AA27	564	RCC AA30	557	RCC AA25	503	RCC 542	AA02	RCC 515	
5		405	AA44	AA60	RCC 556	509	AA21	526	AA23	516	RCC 555	AA56	AA51	412	
4			737	RCC 752	AA57	RCC 541	535	SS11 523	537	RCC 548	AA54	RCC 753	736		
3				739	AA49	AA01	RCC AA15	527	RCC AA12	AA03	AA50	734			
2					411	RCC 507	AA35	RCC AA47	AA34	RCC 512	406				
1							741	AG6	746						

270° (beside row 8, left side); 180° (below row 1, column H)

INCORE DEVICE DESCRIPTIONS:
RCC - FULL LENGTH CONTROL ROD
SS# - SECONDARY SOURCE ASSEMBLY

Prepared By: [signature] S. B. Rosenfelder Date: 02/18/18
Concurrence By: [signature] B. S. Williamson Date: 4/24/19
Reviewed By: [signature] D. B. Livingston Date: 4/15/19
Approved By: [signature] A. H. Nicholson Date: 4/22/19
Approved By: [signature] M. N. LaPrade Date: 4/24/19

Figure 1.2

SURRY UNIT 1 – CYCLE 30
BEGINNING OF CYCLE FUEL ASSEMBLY BURNUPS (MWD/MTU)

	R	P	N	M	L	K	J	H	G	F	E	D	C	B	A	
1							41024. 40869.	40578. 40398.	40900. 40827.							1
2					35704. 35882.	23927. 23745.	0. 0.	0. 0.	0. 0.	23855. 23740.	35997. 35882.					2
3				40764. 40263.	0. 0.	0. 0.	0. 0.	23462. 23608.	0. 0.	0. 0.	0. 0.	40282. 40220.				3
4			40263. 40275.	40938. 40295.	0. 0.	19353. 19355.	19748. 19708.	23954. 24349.	19803. 19712.	19338. 19313.	0. 0.	39757. 39884.	40315. 40224.			4
5		36141. 35894.	0. 0.	0. 0.	20385. 20512.	23703. 23988.	0. 0.	24028. 24004.	0. 0.	23679. 24007.	20475. 20512.	0. 0.	0. 0.	35929. 35903.		5
6		23829. 23747.	0. 0.	19196. 19374.	24074. 24070.	0. 0.	23072. 22889.	0. 0.	22980. 22896.	0. 0.	23935. 24058.	19327. 19399.	0. 0.	23655. 23748.		6
7	41290. 40814.	0. 0.	0. 0.	19808. 19719.	0. 0.	22635. 22872.	24394. 24407.	20598. 20617.	24563. 24452.	22592. 22859.	0. 0.	19925. 19718.	0. 0.	0. 0.	41000. 40829.	7
8	40503. 40411.	0. 0.	23725. 23587.	24519. 24433.	23894. 24001.	0. 0.	20397. 20695.	21421. 21402.	20641. 20696.	0. 0.	23911. 24001.	24330. 24433.	23670. 23587.	0. 0.	40614. 40411.	8
9	40808. 40830.	0. 0.	0. 0.	19704. 19717.	0. 0.	22869. 22859.	24491. 24452.	20191. 20616.	24639. 24407.	22981. 22873.	0. 0.	19693. 19719.	0. 0.	0. 0.	40755. 40815.	9
10		23929. 23748.	0. 0.	19292. 19398.	24195. 24059.	0. 0.	22911. 22896.	0. 0.	22804. 22888.	0. 0.	23997. 24069.	19397. 19374.	0. 0.	24018. 23747.		10
11		35745. 35903.	0. 0.	0. 0.	20703. 20512.	24063. 24008.	0. 0.	24194. 24004.	0. 0.	24001. 23988.	20626. 20512.	0. 0.	0. 0.	35834. 35894.		11
12			40428. 40284.	40091. 39933.	0. 0.	19032. 19312.	19597. 19712.	24223. 24349.	19523. 19708.	19037. 19354.	0. 0.	40296. 40292.	40476. 40283.			12
13				40330. 40285.	0. 0.	0. 0.	0. 0.	23609. 23608.	0. 0.	0. 0.	0. 0.	40170. 40247.				13
14					35961. 35881.	23534. 23740.	0. 0.	0. 0.	0. 0.	23666. 23744.	35702. 35882.					14
15							41270. 40833.	41061. 40398.	41126. 40865.							15
	R	P	N	M	L	K	J	H	G	F	E	D	C	B	A	

* MEASURED *
* PREDICTED *

Figure 1.3

SURRY UNIT 1 – CYCLE 30
AVAILABLE INCORE MOVEABLE DETECTOR LOCATIONS

	R	P	N	M	L	K	J	H	G	F	E	D	C	B	A
1								o 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					x MD
10			MD				MD					MD		MD	
11					MD			MD		MD	MD				
12			MD				MD					MD	MD		
13								+ MD		MD					
14					x MD				MD						
15							MD								

MD - Moveable Detector
\+ - Locations Not Used For Any Map
x - Location Not Used For Flux Map 1
* - Location Not Used For Flux Maps 2 and 3
o - Location Not Used For Flux Map 3

Figure 1.4

SURRY UNIT 1 – CYCLE 30
CONTROL ROD LOCATIONS

180^0

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

0^0

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 1-NPT-RX-014. This verified that the time to entry of a rod into the dashpot region was less than or equal to the maximum allowed by Technical Specification 3.12.C.1 [Ref. 4].

Surry Unit 1 Cycle 30 used the Rod Drop Measurement Instrument (RDMI) to gather and analyze the rod drop data. Secondary coil voltage data is acquired for each rod using the Computer Enhanced Rod Position Indication (CERPI) system. Data is immediately saved to a comma-separated value file. [Ref. 12, Section 1.0 and Section 2.8 of Att. B]

An annotated sample rod drop trace 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 1 cycles 18-30. 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 Westinghouse 15x15 Upgrade 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. Compared to the rod drop results from S1C29, the fastest rod drop time increased by 0.04 seconds, the average rod drop time increased by 0.01 seconds, and the slowest rod time increased by 0.01 seconds. This is within the normal cycle to cycle variation.

Table 2.1

SURRY UNIT 1 – CYCLE 30 STARTUP PHYSICS TESTS
HOT ROD DROP TIME SUMMARY

ROD DROP TIME TO DASHPOT ENTRY

SLOWEST ROD	FASTEST ROD	AVERAGE TIME
P-08 1.46 sec.	H-02 1.33 sec	1.36 sec.

Figure 2.1

SURRY UNIT 1 – CYCLE 30 STARTUP PHYSICS TESTS
ANNOTATED SAMPLE ROD DROP TRACE

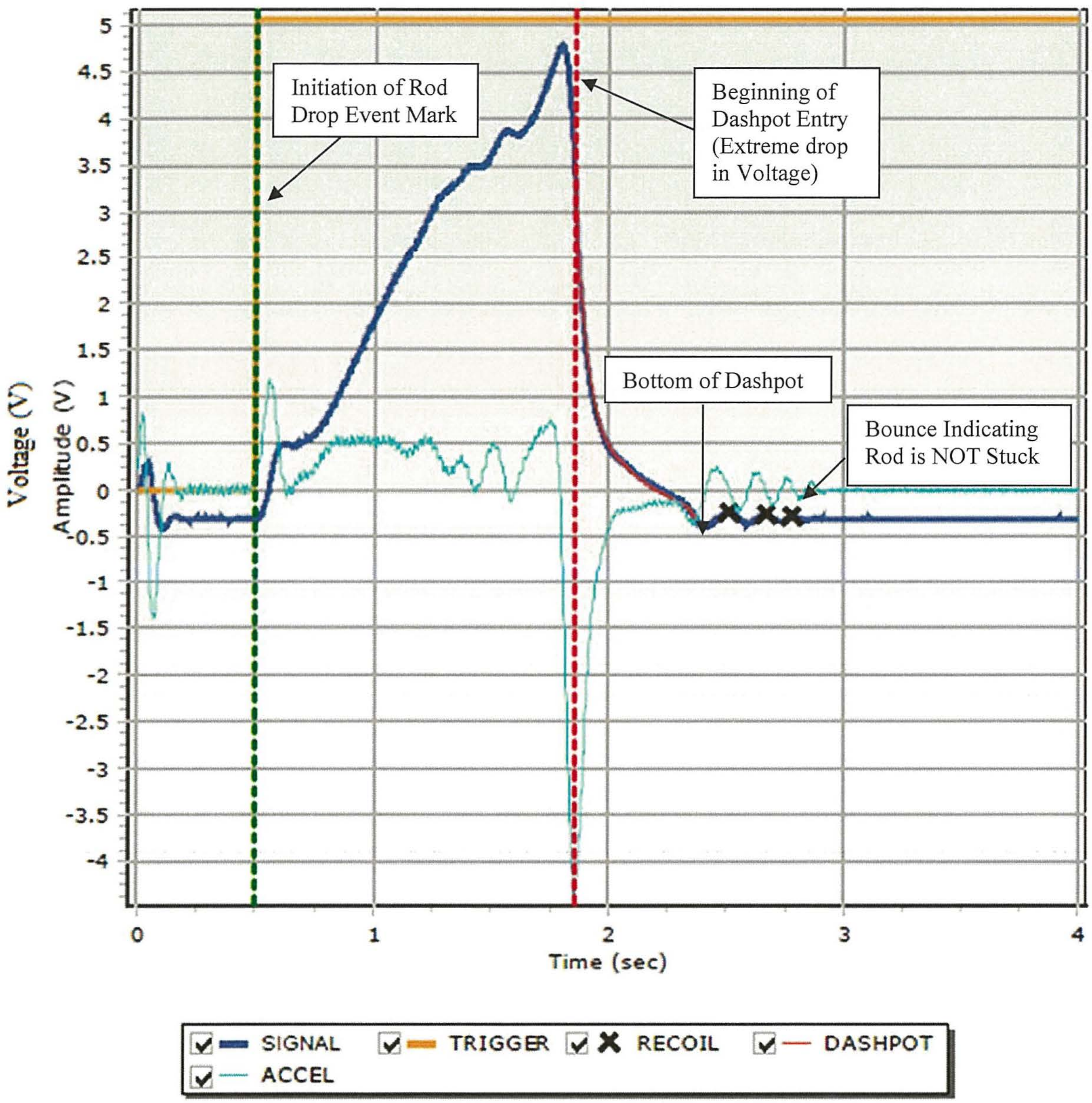


Figure 2.2

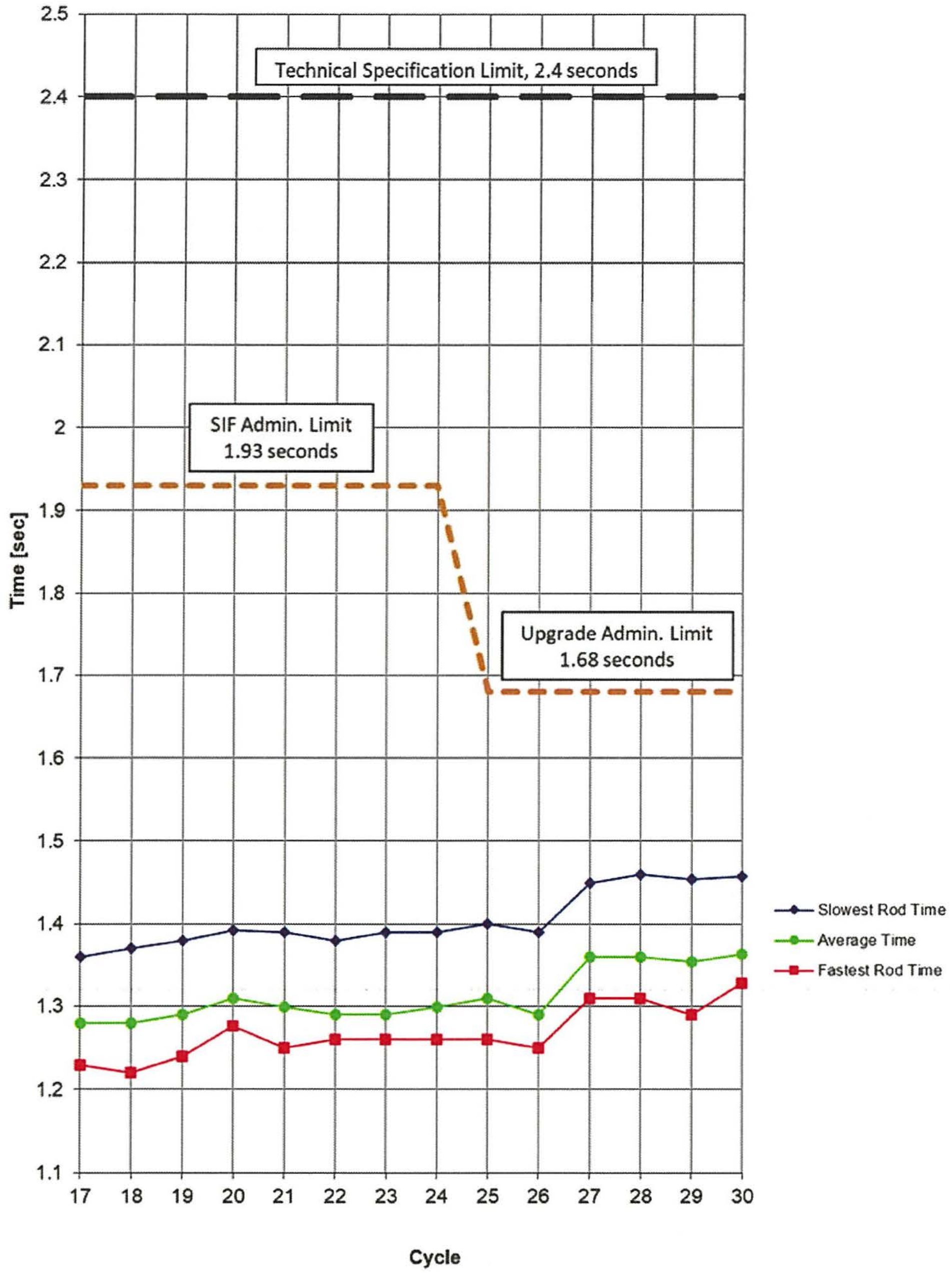
SURRY UNIT 1 – CYCLE 30 STARTUP PHYSICS TESTS
ROD DROP TIME – HOT FULL FLOW CONDITIONS

R	P	N	M	L	K	J	H	G	F	E	D	C	B	A	
															1
					1.356		1.328		1.348						2
						1.356		1.356							3
			1.368		1.330				1.332		1.406				4
				1.336						1.350					5
	1.336		1.340		1.338		1.356		1.356		1.342		1.444		6
		1.338				1.376		1.356				1.350			7
	1.458				1.376				1.438				1.374		8
		1.382				1.350		1.374				1.366			9
	1.358		1.354		1.346		1.388		1.364		1.354		1.384		10
				1.336						1.348					11
			1.338		1.338				1.346		1.400				12
						1.374		1.372							13
					1.398		1.332		1.404						14
															15

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

Figure 2.3

SURRY UNIT 1 – CYCLE 30 STARTUP PHYSICS TESTS
ROD DROP TIMES TRENDING[1]



[1] Step increase from Cycle 26 to Cycle 27 is concurrent with rod drop test computer change.

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 30, Control Bank B was used as the reference bank. Surry 1 targeted a dilution rate of 1100 pcm/hr for the reference bank measurement.

During 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 S1C30 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 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 zero reactivity. 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 and moderator temperature 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 Appendix B, 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 3.5% lower than 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 1 – CYCLE 30 STARTUP PHYSICS TESTS
CONTROL ROD BANK WORTH SUMMARY

BANK	MEASURED WORTH (PCM)	PREDICTED WORTH (PCM)	PERCENT DIFFERENCE (%) (M-P)/P X 100
B – Reference	1338	1386	-3.5%
A	287	299	-12 pcm*
C	622	662	-6.1%
SA	951	980	-3.0%
D	1033	1061	-2.7%
SB	1067	1100	-3.0%
Total Bank Worth	5298	5490**	-3.5%

* Note: For bank worth < 600 pcm, worth difference = (M - P).
** Total bank worth is calculated using individual bank worth with higher precision than reported.

Figure 3.1

SURRY UNIT 1 – CYCLE 30 STARTUP PHYSICS TESTS
CONTROL BANK B INTEGRAL ROD WORTH - HZP
ALL OTHER RODS WITHDRAWN

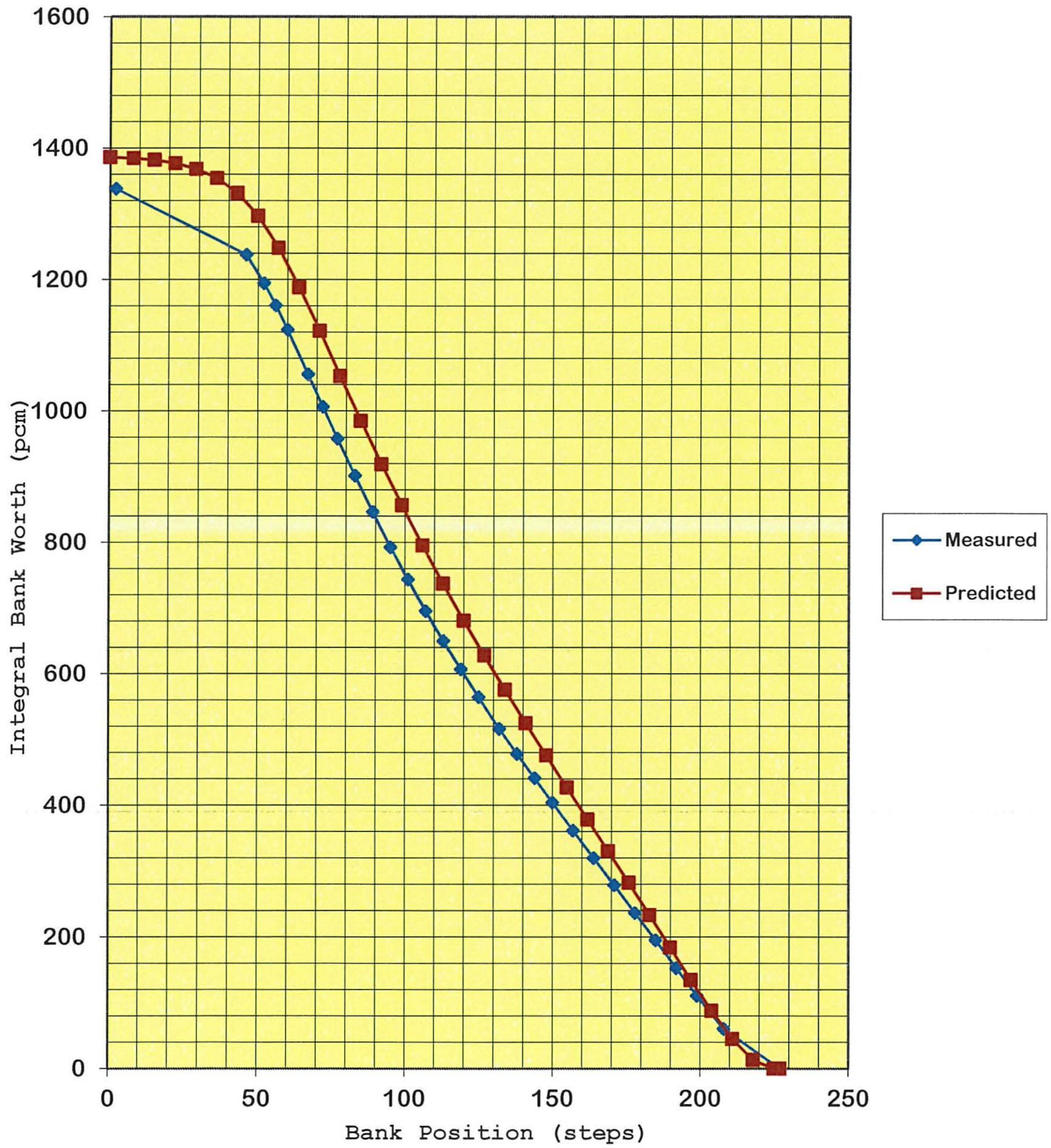
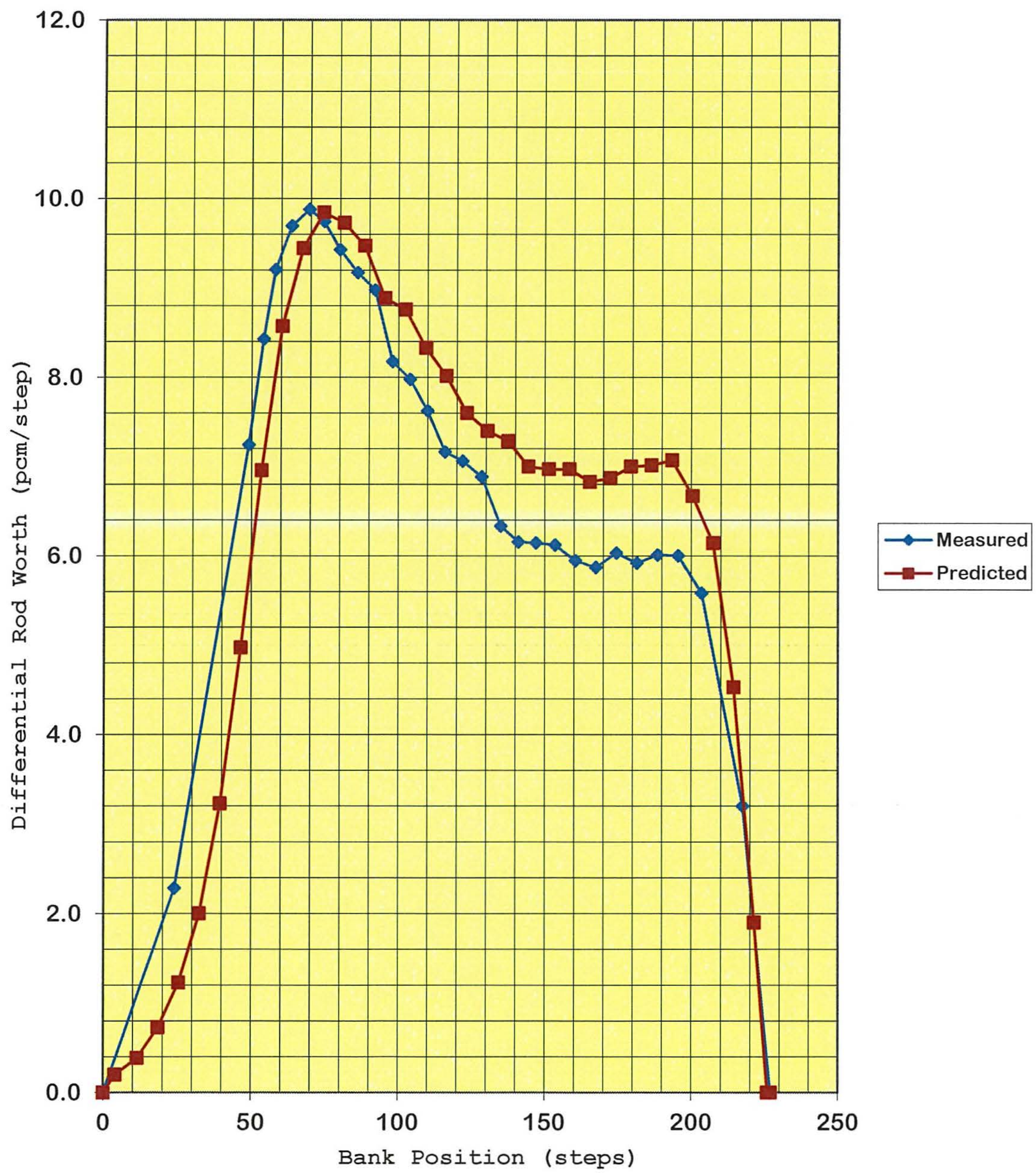


Figure 3.2

SURRY UNIT 1 – CYCLE 30 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 Appendix B, 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 Appendix B, the measured DBW was well within the design tolerance of $\pm$10%. In summary, the measured boron worth coefficient was satisfactory.

Table 4.1

SURRY UNIT 1 – CYCLE 30 STARTUP PHYSICS TESTS
BORON ENDPOINTS SUMMARY

Control Rod Configuration	Measured Endpoint (ppm)	Predicted Endpoint (ppm)	Difference M-P (ppm)
ARO	1588	1589	-1
B Bank In	1410	1407*	3

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

Table 4.2

SURRY UNIT 1 – CYCLE 30 STARTUP PHYSICS TESTS
BORON WORTH COEFFICIENT

Measured Boron Worth (pcm/ppm)	Predicted Boron Worth (pcm/ppm)	Percent Difference (%) (M-P)/P x 100
-7.52	-7.66	-1.8%

SECTION 5 — TEMPERATURE COEFFICIENT MEASUREMENT

The Isothermal Temperature Coefficient (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 3.66 °F, followed by the RCS cool down of 3.34 °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 Appendix B, 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 -1.771 pcm/ °F, a predicted doppler temperature coefficient (DTC) of -1.65 pcm/ °F, and a measurement uncertainty of +0.5 pcm/ °F, is -0.121 pcm/ °F. It thus satisfies the COLR criteria [Ref. 8] that indicates MTC at HZP be less than or equal to +6.0 pcm/ °F.

Table 5.1

SURRY UNIT 1 – CYCLE 30 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/199	546.13	549.79	1576.7	-1.583	-1.958	-1.771	-2.267	0.496

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 30 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. 3, Ref. 15]. 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 28.53% 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 70.62% and 99.93% power, respectively, with different control rod configurations. These flux maps were taken to check at-power design predictions and to measure core power distributions at various operating conditions. The radial power distributions for these maps are given in Figures 6.2 and 6.3.

The radial power distributions for the maps given in Figures 6.1, 6.2 and 6.3 show that the measured relative assembly power values deviated from the design predictions by at most ±3.8% in the 28.53% power map, ±3.1% in the 70.62% power map and ±2.8% in the 99.93% power map. The maximum positive quadrant power tilt for the three maps were 0.72%, 0.66% and 0.76%, respectively. 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.

As a best practice, transient $F_Q(Z)$ margin is being monitored starting in Surry 1 Cycle 30 for flux maps at greater than 90% power. The $F_Q(Z)$ margin is compared with conservative screening values from the design report [Ref. 1]. The $F_Q(Z)$ margin for the 99.93% flux map exceeds the conservative screening value of 10.6% from the design report.

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 30.

Table 6.1

SURRY UNIT 1 – CYCLE 30 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)			$F^N_{\Delta H}$ Hot (2) Channel Factor		Core F_Z Max		Core Tilt (3)		Axial Offset (%)	No. Of Thimbles
						Assy	Axial Point	$F_Q(Z)$	Assy	$F^N_{\Delta H}$	Axial Point	F_Z	Max	Loc		
Low Power	1	11/30/19	1.6	28.53	175	M-7	27	2.250	M-7	1.550	26	1.360	1.0072	NW	7.387	44
Int. Power (4)	2	12/01/19	20.8	70.62	191	M-7	27	1.956	M-9	1.506	26	1.219	1.0066	SW	1.733	45
Hot Full Power	3	12/05/19	153.0	99.93	226	M-9	27	1.864	M-9	1.485	27	1.168	1.0076	SW	1.934	44

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

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

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

Table 6.2

SURRY UNIT 1 – CYCLE 30 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	2.250	5.000	27	55.0	1.550	1.986	22.0
2	1.956	3.540	27	44.8	1.506	1.779	15.4
3	1.864	2.502	27	25.5	1.485	1.635	9.2

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
28.53% 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							0.261 0.260 0.42	0.296 0.286 3.53	0.262 0.260 0.92						
2					0.275 0.276 -0.41	0.610 0.613 -0.49	1.048 1.053 -0.47	1.068 1.071 -0.29	1.055 1.054 0.07	0.622 0.615 1.20	0.280 0.278 0.83				
3				0.279 0.282 -1.12	0.898 0.902 -0.44	1.157 1.162 -0.46	1.269 1.278 -0.70	1.222 1.242 -1.60	1.277 1.280 -0.27	1.172 1.166 0.50	0.915 0.908 0.75	0.285 0.285 0.06			
4			0.289 0.283 2.04	0.574 0.569 0.84	1.185 1.188 -0.28	1.346 1.350 -0.33	1.372 1.382 -0.72	1.257 1.269 -0.91	1.383 1.384 -0.05	1.364 1.355 0.63	1.210 1.195 1.28	0.593 0.582 1.84	0.291 0.286 1.91		
5		0.286 0.278 2.81	0.934 0.908 2.85	1.215 1.192 1.96	1.296 1.273 1.79	1.244 1.239 0.38	1.276 1.287 -0.85	1.225 1.231 -0.48	1.292 1.288 0.31	1.255 1.242 1.04	1.303 1.279 1.85	1.233 1.199 2.83	0.931 0.912 2.12	0.290 0.280 3.63	
6		0.634 0.619 2.35	1.200 1.173 2.32	1.385 1.358 2.02	1.265 1.242 1.85	1.141 1.128 1.14	1.214 1.208 0.48	1.156 1.161 -0.41	1.217 1.209 0.69	1.147 1.130 1.54	1.261 1.246 1.20	1.379 1.362 1.23	1.187 1.176 0.89	0.625 0.621 0.69	
7	0.269 0.263 2.26	1.088 1.066 2.07	1.326 1.295 2.37	1.426 1.400 1.87	1.319 1.297 1.66	1.230 1.212 1.49	1.247 1.221 2.12	1.323 1.312 0.81	1.240 1.221 1.53	1.223 1.214 0.78	1.305 1.299 0.47	1.405 1.403 0.13	1.294 1.297 -0.26	1.065 1.067 -0.18	0.263 0.264 -0.41
8	0.296 0.290 2.04	1.104 1.086 1.65	1.274 1.263 0.91	1.328 1.310 1.41	1.262 1.246 1.31	1.179 1.166 1.13	1.323 1.311 0.88	1.286 1.285 0.11	1.308 1.311 -0.21	1.165 1.167 -0.13	1.240 1.246 -0.48	1.299 1.311 -0.90	1.239 1.263 -1.90	1.079 1.086 -0.64	0.288 0.290 -0.74
9	0.269 0.264 1.90	1.088 1.067 1.98	1.321 1.297 1.87	1.422 1.402 1.45	1.311 1.299 0.89	1.221 1.213 0.63	1.223 1.221 0.17	1.300 1.312 -0.93	1.190 1.221 -2.51	1.189 1.212 -1.89	1.279 1.297 -1.38	1.383 1.400 -1.23	1.278 1.295 -1.30	1.057 1.066 -0.82	0.261 0.263 -0.62
10		0.637 0.621 2.60	1.215 1.176 3.34	1.382 1.362 1.50	1.253 1.245 0.61	1.133 1.130 0.26	1.213 1.209 0.30	1.144 1.161 -1.44	1.180 1.208 -2.31	1.100 1.128 -2.47	1.216 1.242 -2.07	1.338 1.358 -1.44	1.158 1.173 -1.27	0.619 0.620 -0.24	
11		0.285 0.279 2.32	0.929 0.912 1.83	1.207 1.198 0.79	1.273 1.278 -0.42	1.235 1.242 -0.59	1.274 1.288 -1.11	1.194 1.231 -3.02	1.251 1.287 -2.78	1.192 1.239 -3.75	1.235 1.273 -2.98	1.168 1.192 -2.05	0.893 0.908 -1.65	0.276 0.278 -0.87	
12			0.285 0.285 -0.12	0.581 0.581 0.08	1.188 1.195 -0.57	1.344 1.354 -0.77	1.368 1.384 -1.19	1.246 1.269 -1.85	1.354 1.382 -2.05	1.319 1.350 -2.27	1.161 1.188 -2.27	0.557 0.569 -2.07	0.278 0.283 -1.72		
13				0.283 0.284 -0.24	0.901 0.907 -0.69	1.155 1.166 -0.92	1.266 1.280 -1.12	1.226 1.242 -1.29	1.263 1.278 -1.18	1.153 1.162 -0.76	0.888 0.902 -1.51	0.277 0.282 -1.78			
14					0.275 0.278 -0.98	0.609 0.615 -1.03	1.043 1.054 -1.08	1.061 1.071 -0.92	1.047 1.053 -0.52	0.609 0.613 -0.69	0.273 0.276 -1.11				
15							0.256 0.260 -1.61	0.283 0.286 -0.95	0.258 0.260 -0.58						

AVERAGE ABSOLUTE PERCENT DIFFERENCE = 1.2
STANDARD DEVIATION = 0.833

ANALYTICAL AXIAL OFFSET = 9.394 %
MEASURED AXIAL OFFSET = 7.387 %

Summary:

QPTR:		
	1.0072	1.0071
	1.0032	0.9825

Figure 6.2

ASSEMBLYWISE POWER DISTRIBUTION
70.62% 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
							0.278	0.314	0.279						
1							0.279	0.310	0.280						
							-0.27	1.34	-0.37						
					0.288	0.626	1.058	1.094	1.061	0.634	0.292				
2					0.292	0.633	1.067	1.107	1.068	0.634	0.293				
					-1.28	-1.11	-0.89	-1.13	-0.69	0.01	-0.19				
				0.295	0.901	1.145	1.256	1.212	1.258	1.157	0.915	0.296			
3				0.298	0.912	1.157	1.267	1.237	1.268	1.160	0.916	0.301			
				-1.07	-1.22	-1.01	-0.85	-2.04	-0.83	-0.29	-0.11	-1.77			
			0.301	0.584	1.162	1.313	1.342	1.236	1.351	1.331	1.189	0.603	0.304		
4			0.299	0.586	1.179	1.326	1.355	1.250	1.357	1.330	1.184	0.598	0.301		
			0.72	-0.31	-1.47	-0.98	-0.98	-1.11	-0.43	0.08	0.41	0.77	0.97		
		0.297	0.931	1.188	1.260	1.227	1.260	1.213	1.276	1.244	1.275	1.205	0.929	0.300	
5		0.293	0.915	1.181	1.260	1.233	1.275	1.221	1.275	1.235	1.264	1.186	0.919	0.294	
		1.43	1.71	0.61	-0.04	-0.46	-1.15	-0.67	0.11	0.70	0.85	1.62	1.13	2.19	
		0.643	1.175	1.342	1.243	1.163	1.213	1.154	1.222	1.183	1.250	1.344	1.171	0.640	
6		0.637	1.164	1.332	1.235	1.160	1.212	1.161	1.213	1.162	1.238	1.334	1.166	0.638	
		0.87	0.97	0.78	0.69	0.27	0.05	-0.61	0.71	1.78	0.93	0.77	0.45	0.29	
	0.283	1.084	1.288	1.382	1.295	1.227	1.238	1.311	1.239	1.230	1.291	1.373	1.276	1.075	0.282
7	0.282	1.076	1.279	1.370	1.283	1.215	1.219	1.301	1.218	1.216	1.284	1.372	1.280	1.077	0.282
	0.53	0.77	0.74	0.87	0.95	0.98	1.57	0.75	1.76	1.13	0.53	0.06	-0.31	-0.17	-0.17
	0.313	1.124	1.257	1.299	1.250	1.176	1.312	1.277	1.301	1.170	1.232	1.279	1.231	1.113	0.312
8	0.312	1.117	1.253	1.287	1.234	1.164	1.300	1.273	1.300	1.164	1.234	1.287	1.253	1.117	0.312
	0.18	0.66	0.34	0.95	1.32	1.06	0.90	0.30	0.08	0.48	-0.16	-0.63	-1.73	-0.35	-0.14
	0.285	1.091	1.299	1.389	1.296	1.226	1.226	1.295	1.192	1.203	1.273	1.359	1.266	1.070	0.284
9	0.282	1.077	1.280	1.372	1.284	1.216	1.218	1.300	1.219	1.215	1.283	1.370	1.279	1.076	0.282
	1.11	1.34	1.52	1.20	0.95	0.86	0.68	-0.42	-2.23	-0.95	-0.76	-0.78	-1.00	-0.55	0.79
		0.652	1.202	1.355	1.248	1.171	1.230	1.153	1.193	1.142	1.221	1.322	1.153	0.632	
10		0.638	1.166	1.334	1.238	1.161	1.212	1.160	1.212	1.160	1.235	1.332	1.164	0.637	
		2.17	3.13	1.54	0.81	0.84	1.49	-0.64	-1.56	-1.58	-1.12	-0.78	-0.93	-0.82	
		0.300	0.934	1.197	1.265	1.237	1.272	1.194	1.252	1.202	1.240	1.167	0.905	0.290	
11		0.294	0.919	1.186	1.263	1.235	1.275	1.221	1.275	1.233	1.260	1.181	0.915	0.293	
		1.92	1.68	0.96	0.13	0.13	-0.25	-2.18	-1.83	-2.53	-1.58	-1.20	-1.11	-0.96	
			0.298	0.600	1.186	1.329	1.350	1.237	1.342	1.311	1.165	0.576	0.294		
12			0.301	0.597	1.184	1.330	1.357	1.249	1.355	1.326	1.179	0.586	0.299		
			-1.00	0.46	0.15	-0.08	-0.50	-0.96	-0.96	-1.11	-1.21	-1.78	-1.77		
				0.301	0.919	1.160	1.265	1.233	1.266	1.161	0.908	0.295			
13				0.300	0.916	1.159	1.268	1.237	1.267	1.157	0.912	0.298			
				0.44	0.35	0.06	-0.25	-0.31	-0.06	0.33	-0.47	-1.02			
					0.301	0.635	1.066	1.107	1.077	0.636	0.291				
14					0.293	0.634	1.068	1.106	1.067	0.632	0.292				
					2.67	0.17	-0.18	0.11	0.98	0.61	-0.18				
							0.274	0.309	0.281						
15							0.280	0.309	0.279						
							-2.17	-0.03	0.83						

AVERAGE ABSOLUTE PERCENT DIFFERENCE = 0.9 ANALYTICAL AXIAL OFFSET = 3.301 %
STANDARD DEVIATION = 0.610 MEASURED AXIAL OFFSET = 1.733 %

Summary:

QPTR:		
	0.9998	1.0033
	1.0066	0.9904

Figure 6.3

ASSEMBLYWISE POWER DISTRIBUTION
99.93% 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
							0.287	0.322	0.288						
1							0.290	0.325	0.290						
							-0.93	-0.96	-0.66						
					0.292	0.628	1.053	1.126	1.056	0.634	0.296				
2					0.296	0.635	1.064	1.137	1.064	0.636	0.297				
					-1.32	-1.11	-1.02	-0.98	-0.73	-0.38	-0.47				
				0.299	0.889	1.126	1.239	1.215	1.243	1.137	0.901	0.300			
3				0.303	0.901	1.139	1.251	1.230	1.252	1.141	0.904	0.306			
				-1.34	-1.38	-1.15	-0.96	-1.21	-0.70	-0.38	-0.29	-1.88			
			0.304	0.585	1.143	1.290	1.323	1.220	1.331	1.307	1.167	0.604	0.308		
4			0.303	0.590	1.161	1.304	1.337	1.237	1.338	1.308	1.166	0.601	0.306		
			0.38	-0.82	-1.55	-1.06	-1.07	-1.41	-0.53	-0.05	0.12	0.42	0.66		
		0.299	0.911	1.161	1.241	1.231	1.268	1.215	1.278	1.250	1.260	1.181	0.914	0.303	
5		0.297	0.904	1.163	1.250	1.240	1.277	1.223	1.278	1.241	1.254	1.167	0.907	0.298	
		0.72	0.77	-0.14	-0.74	-0.72	-0.68	-0.66	0.02	0.69	0.49	1.17	0.80	1.56	
		0.642	1.150	1.310	1.233	1.221	1.234	1.169	1.243	1.251	1.255	1.320	1.150	0.641	
6		0.639	1.145	1.310	1.241	1.223	1.234	1.176	1.234	1.225	1.243	1.312	1.146	0.639	
		0.49	0.40	-0.01	-0.67	-0.15	-0.04	-0.58	0.72	2.11	1.00	0.60	0.39	0.38	
	0.294	1.078	1.269	1.357	1.292	1.245	1.250	1.316	1.248	1.252	1.294	1.353	1.259	1.071	0.292
7	0.292	1.071	1.262	1.350	1.285	1.236	1.234	1.308	1.233	1.237	1.286	1.351	1.263	1.072	0.293
	0.57	0.63	0.52	0.53	0.51	0.73	1.32	0.61	1.25	1.24	0.61	0.17	-0.28	-0.11	-0.30
	0.327	1.155	1.252	1.287	1.255	1.192	1.320	1.282	1.309	1.190	1.237	1.269	1.227	1.144	0.327
8	0.327	1.146	1.244	1.274	1.235	1.180	1.308	1.279	1.308	1.180	1.235	1.274	1.244	1.146	0.327
	0.05	0.75	0.63	1.02	1.65	1.05	0.89	0.27	0.07	0.86	0.13	-0.42	-1.40	-0.18	-0.08
	0.295	1.085	1.281	1.369	1.302	1.251	1.245	1.304	1.208	1.231	1.279	1.342	1.252	1.067	0.293
9	0.292	1.072	1.263	1.351	1.286	1.237	1.233	1.308	1.234	1.236	1.285	1.350	1.262	1.071	0.292
	1.14	1.26	1.40	1.33	1.25	1.15	0.94	-0.30	-2.09	-0.37	-0.48	-0.59	-0.82	-0.39	0.32
		0.652	1.176	1.332	1.258	1.239	1.259	1.170	1.218	1.210	1.230	1.301	1.136	0.636	
10		0.639	1.146	1.311	1.243	1.224	1.234	1.176	1.234	1.224	1.241	1.310	1.145	0.639	
		2.01	2.65	1.57	1.20	1.22	2.01	-0.52	-1.33	-1.17	-0.92	-0.69	-0.79	-0.44	
		0.303	0.920	1.180	1.262	1.247	1.276	1.194	1.257	1.218	1.230	1.149	0.894	0.295	
11		0.297	0.906	1.167	1.253	1.241	1.278	1.223	1.277	1.240	1.250	1.163	0.904	0.297	
		1.95	1.58	1.13	0.73	0.47	-0.15	-2.40	-1.55	-1.81	-1.62	-1.20	-1.09	-0.77	
			0.302	0.604	1.170	1.309	1.330	1.225	1.326	1.294	1.149	0.579	0.299		
12			0.305	0.600	1.165	1.307	1.338	1.237	1.337	1.304	1.161	0.590	0.303		
			-0.97	0.64	0.47	0.14	-0.56	-0.96	-0.85	-0.74	-1.06	-1.86	-1.45		
				0.307	0.909	1.142	1.249	1.226	1.252	1.146	0.898	0.301			
13				0.305	0.904	1.141	1.252	1.230	1.251	1.138	0.901	0.303			
				0.58	0.53	0.07	-0.26	-0.30	0.07	0.73	-0.29	-0.78			
					0.304	0.638	1.062	1.138	1.073	0.639	0.296				
14					0.296	0.636	1.064	1.137	1.064	0.635	0.296				
					2.81	0.28	-0.15	0.12	0.88	0.69	0.08				
							0.285	0.324	0.292						
15							0.290	0.325	0.290						
							-1.88	-0.16	0.72						

AVERAGE ABSOLUTE PERCENT DIFFERENCE = 0.8   ANALYTICAL AXIAL OFFSET = 1.402 %
STANDARD DEVIATION = 0.563   MEASURED AXIAL OFFSET = 1.934 %

Summary:

QPTR:		
	0.9974	1.0026
	1.0076	0.9924

SECTION 7 — CONCLUSIONS

Table 7.1 summarizes the results associated with Surry Unit 1 Cycle 30 startup physics testing program. As noted herein, all test results were acceptable and within associated design tolerances, technical specification limits, or COLR limits. The AREVA AGORA LTAs show no signs of anomalous behavior and are performing as expected. It is anticipated, based on the results associated with the S1C30 startup physics testing program, that the Surry 1 core will continue to operate safely throughout Cycle 30.

Table 7.1

SURRY UNIT 1 – CYCLE 30 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	1588	1589	-1	±39
Critical Boron Concentration (HZP Ref Bank in), ppm	1410	1407	3	±28
Isothermal Temp Coefficient (HZP ARO), pcm/F	-1.771	-2.267	0.496	±2
Differential Boron Worth (HZP ARO), pcm/ppm	-7.52	-7.66	-1.8%	±10%
Reference Bank Worth (B-bank, dilution), pcm	1338	1386	-3.5%	±10%
A-bank Worth (Rod Swap), pcm	287	299	-12	±100
C-bank Worth (Rod Swap), pcm	622	662	-6.1%	±15%
SA-bank Worth (Rod Swap), pcm	951	980	-3.0%	±15%
D-bank Worth (Rod Swap), pcm	1033	1061	-2.7%	±15%
SB-bank Worth (Rod Swap), pcm	1067	1100	-3.0%	±15%
Total Bank Worth, pcm	5298	5490*	-3.5%	±10%
S1C30 Testing Time:		**8.0 hrs**		
[criticality 11/29/2019 @ 01:20 to end of testing 11/29/2019 @ 09:19]				
Last 5 Surry Startups:				
S2C29 testing time:		6.5 hrs		
S1C29 testing time:		8.0 hrs		
S2C28 testing time:		7.0 hrs		
S1C28 testing time:		5.8 hrs		
S2C27 testing time:		7.6 hrs		

* Total bank worth is calculated using individual bank worth with higher precision than reported.

SECTION 8 — REFERENCES

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15. S. R. Ehrensberger, "The CECOR Flux Map Analysis Code Version 3.4 Additional Software Requirements and Design", Engineering Technical Evaluation ETE-NAF-2018-0021, Rev. 0, March 2018.

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17. Nuclear Engineering Standard DNES-AA-NAF-NCD-5007, Rev. 3, "Startup Physics Tests Results Reporting".

18. 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.

19. Surry Units 1 and 2 Updated Final Safety Analysis Report, Revision 51.01.

APPENDIX A — RCP STARTUP ORDER

11/19/2019 03:27
Started 1-RC-P-1C1 (C RCP Aux oil Pump) IAW 1-OP-RC-001. White light (pressure) lit immediately.

0350 Cycled 1-EP-BKR-15C3 in Test IAW 1-OP-RC-001. All checks SAT. Secured 1-RC-P-1C1.

0416 1-EP-BKR-15C3 racked back to Disconnect. Awaiting installation of PRZR Safety Valve to remove breaker blocking device (T/O).
SPS Unit 1 Control Room Log HUMPHRIES, JOSHUA A

11/19/2019 11:19
Notified that 'B' PZR Safety Valve is installed. Verified TS 3.1.G remains met. Commenced PZR Fi
Solid conditions IAW 1-OP-RC-002. Pzr level is 57%, RWST level is 93.7%.

1-CH-311 previously closed. Opened 1-CH-MOV-1311 and closed 1-CH-MOV-1310A in preparati
for Hydrazine Addition to the PZR.

1131 Commenced 1 gal Hydrazine addition IAW 1-OP-CH-008.

Seal injection is in service with the following flowrates:
A RCP: 8.1 gpm
B RCP: 7.9 gpm
C RCP: 8.2 gpm

1204 Completed 1 gallon Hydrazine add to the PZR IAW 1-OP-CH-008 in preparation for filling th
PZR solid.

1205 Continuing to raise PZR level using the RWST. Pzr level is 74.3%, RWST level is 92.5%.

1209 1-CH-LCV-1115A is in Divert. 1-RC-FL-2 is bypassed.

1236 1-CH-LCV-1115A is in AUTO IAW 1-OP-CH-008. 1-RC-FL-2 is in service.

1239 1-CH-311 is open, 1-CH-MOV-1310A is open, 1-CH-MOV-1311 is closed.

1253 PZR level by 1-RC-LI-1460 (cold Cal Channel) is 102.5%. Continuing to fill the PZR solid.

1257 Unit 1 RCS is solid. PRZ level is 102.9% by 1-RC-LI-1460 (Cold Cal Channel). Level is rising in the PRT. Closed PZR PORV's and commenced raising RCS pressure to 100 psig. RWST Level is 91.0%.

1336 RCS pressure is stable at 105#. Pressure control band of 100-120#.

1456 I&C has vented 1-CH-PT-1156, -1155, -1154.

1544 Completed venting all RCP seals IAW 1-OP-RC-003. Commence raising RCS pressure to 300#

1620 RCS pressure is 300# and stable. Pressure control band of 290-320#

1645 0-OP-EP-004 Completed; Load shed system switch placed in NORM ENABLE.

1648 Started 1-RC-P-1C for continuous operation.
SPS Unit 1 Control Room Log MAJOR, SHATEEK RASON
11/19/2019 11:45: I concur with TS assessment. LONG, CLEON MAURICE

11/22/2019 02:28
A and B RCP Breaker cycling in TEST IAW 1-OP-RC-001:

Started 1-RC-P-1B1 (B RCP Aux oil Pump) IAW 1-OP-RC-001 Section 5.9. White light (pressure) lit immediately.

0234 Cycled 1-EP-BKR-15B3 in Test IAW 1-OP-RC-001. All checks SAT. Secured 1-RC-P-1B1.

0235 1-EP-BKR-15B3 remains racked to TEST due to personnel working nearby. Will rack to Connect when it will not impact ongoing work. 1-OP-RC-001 Section 5.9 remains open at step 5.9.11 to rack breaker as desired.

0300 Racked 1-EP-BKR-15A3 (A RCP Breaker) to Test. Started 1-RC-P-1A1 (A RCP Aux oil Pump) IAW 1-OP-RC-001 Section 5.8. White light (pressure) lit immediately.

0305 Cycled 1-EP-BKR-15A3 in Test IAW 1-OP-RC-001. All checks SAT. Secured 1-RC-P-1A1.

0308 1-EP-BKR-15A3 racked back to Disconnect. Breaker block remains installed for T/O 1-RCA-0009A.

0328 1-EP-BKR-15B3 has been racked to Connect for future start.
SPS Unit 1 Control Room Log HUMPHRIES, JOSHUA A

11/22/2019 14:38
Started 1-RC-P-1A IAW 1-OP-RC-001 and 1-GOP-1.7.

'A' RCP Vibrations are:

Shaft: 7mils/6mils
Frame: 1.2mils/0.8mils
SPS Unit 1 Control Room Log MAJOR, SHATEEK RASON

11/26/2019 00:01
The Security Diesel is in service IAW 0-OP-SE-002 section 6.1. Started 'B' RCP IAW 1-OP-RC-001.

Shaft Vibrations: 7.0 mils, Frame Vibrations: .5 mils

0023 Stabilizing RCS Temp at 190°F to support 1-NPT-RX-012, WR RTD Cross Calibration.

0042 RX Eng has completed data collection. Commenced RCS heatup. Heat up rate is approximately 20°F/hr

0056 Unit 1 RCS ('C' Hot Leg) has exceeded 200°F. Unit 1 is now in Intermediate Shutdown. Shutdown margin remains 1560 ppm.

0142 RCS temperature is 225°F (by Thot on "C" Loop, highest indicated). Current heat-up rate is ~37°F/Hr.

0242 RCS temperature is 261°F (by Thot on "C" Loop, highest indicated). Current heat-up rate is ~32°F/Hr.
SPS Unit 1 Control Room Log GRAY, ED

APPENDIX B — STARTUP PHYSICS TEST SUMMARY SHEETS

Surry Power Station Unit 1 Cycle 30 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= 1E-9 to 1E-7 amps	Background < ZPTR < POAH Background = 2.1E-11 amps (W...) POAH= 2.477E-7 amps	N/A	✓ Yes ___ No	N/A	11/29/19 02:25	TSP / KAH
Reactivity Computer Checkout						
ρ_c= +85.347 / -38.725 pcm (measured reactivity) ρ_t= +85.968 / -39.066 pcm (predicted reactivity) %D = ((ρc - ρt)/ρt) x 100% %D = -0.72% / -0.87 %	|((ρc - ρt)/ρt)| x 100% ≤ 4.00%[1] Pre-critical Bench Test Results +120 / -100 pcm The allowable range is set to the larger of the measured results or the pre-critical bench test. Allowable range +120 / -100 pcm	N/A	✓ Yes ___ No	N/A	11/29/19 02:25	TSP / KAH
Critical Boron Concentration - ARO						
$(C_B)^M_{ARO}$= 1588 ppm (Adjust to design conditions)	$(C_B)_{ARO}$=[2] 1589 ± 39 ppm or 300 pcm TSP 11/29/19 SRK 11/29/19 $\Delta(C_B)_{ARO}=(C_B)^M_{ARO} - (C_B)_{ARO}$ = -1 ppm	$\|\alpha C_B \times \Delta(C_B)_{ARO}\| \le 1000$ pcm [TS 4.10.A] αC_B=[2] -7.57 pcm/ppm	✓ Yes ___ No	✓ Yes ___ No	11/29/19 02:25	TSP / KAH
Isothermal Temperature Coefficient - ARO						
$(\alpha_T^{ISO})^M_{ARO}$ = -1.771 pcm/°F	$(\alpha_T^{ISO})_{ARO}$ =[2] -2.267 ± 2 pcm/°F $(\alpha_T^{ISO})^M_{ARO} - (\alpha_T^{ISO})_{ARO}$ = 0.496 pcm/°F	$\alpha_T^{ISO} \le \alpha_M^{lim} - \alpha_T^{unc} + \alpha_T^{DOP}$ $\alpha_T^{ISO} \le$ 3.85 pcm/°F where: (α_M^{lim}); 6 pcm/°F [COLR 3.4] (α_T^{unc})[1]; 0.5 pcm/°F (α_T^{DOP})[2]; -1.65 pcm/°F	✓ Yes ___ No	✓ Yes ___ No	11/29/19 02:53	TSP / KAH
Control Bank B Worth Measurement, Rod Swap Reference Bank						
$I_B^{REF,M}$= 1338 pcm	I_B^{REF}=[2] 1386 ± 10% 100x(Meas. - Des.)/Des. = -3.5 %	N/A	✓ Yes ___ No	N/A	11/29/19 05:03	SRK / MRN

References 1.) DNES-AA-NAF-NCD-4015
2.) ETE-NAF-2019-0119
3.) ETE-NAF-2019-0120

Surry Power Station Unit 1 Cycle 30 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						
$(C_B)^M_B$ = 1410 ppm	$(C_B)_B$ =[2] 1408 + $\Delta(C_B)_{ARO}$ ± 28 ppm $\Delta(C_B)_{ARO}$ = -1 ppm (from above) $(C_B)_B$ = ~~1408~~ 1407 ± 28 ppm $(C_B)^M_B - (C_B)_B$ = 3 ppm	N/A	✓ Yes ___ No	N/A	06:45 11/29/19	SBR MRM
HZP Boron Worth Coefficient Measurement						
$(\alpha C_B)^M$ = -7.52 pcm/ppm	αC_B =[2] -7.66 ± 0.77 pcm/ppm $\Delta\alpha C_B = (\alpha C_B)^M - (\alpha C_B)$ = 0.14 pcm/ppm	N/A	✓ Yes ___ No	N/A	11/29/19 06:45	SBR MRM
Control Bank A Worth Measurement, Rod Swap						
I_A^{RS} = 287 pcm	$(I_A^{RS})^3$ = 299 ± 100 pcm Meas. - Des. = -12 pcm	N/A	✓ Yes ___ No	N/A	11/29/19 07:35	SBR MRM
Control Bank C Worth Measurement, Rod Swap						
I_C^{RS} = 622 pcm	$(I_C^{RS})^3$ = 662 ± 15% 100x(Meas. - Des.)/Des. = -6.1 %	N/A	✓ Yes ___ No	N/A	11/29/19 07:35	SBR MRM
Shutdown Bank SA Worth Measurement, Rod Swap						
I_{SA}^{RS} = 951 pcm	$(I_{SA}^{RS})^3$ = 980 ± 15% 100x(Meas. - Des.)/Des. = -3.0 %	N/A	✓ Yes ___ No	N/A	11/29/19 07:35	SBR MRM
Control Bank D Worth Measurement, Rod Swap						
I_D^{RS} = 1033 pcm	$(I_D^{RS})^3$ = 1061 ± 15% 100x(Meas. - Des.)/Des. = -2.7 %	N/A	✓ Yes ___ No	N/A	11/29/19 07:35	SBR MRM
Shutdown Bank SB Worth Measurement, Rod Swap						
I_{SB}^{RS} = 1067 pcm	$(I_{SB}^{RS})^3$ = 1100 ± 15% 100x(Meas. - Des.)/Des. = -3.0 %	N/A	✓ Yes ___ No	N/A	11/29/19 07:35	SBR MRM
Total Rod Worth, Rod Swap						
I_{Total} = 5298 pcm	$(I_{total})^3$ = 5490 ± 10% 100x(Meas. - Des.)/Des. = -3.5 %	N/A	✓ Yes ___ No	N/A	11/29/19 09:20	SBR MRM

References 1.) DNES-AA-NAF-NCD-4015
2.) ETE-NAF-2019-0119
3.) ETE-NAF-2019-0120

Surry Power Station Unit 1 Cycle 30 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) = 29.53					11/30/19 0130	PHS KLK
Max Relative Assembly Power, %DIFF (M-P)/P						
%DIFF= -3.8 % for Pi≥ 0.9; 3.6 % for Pi < 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)= 1.550	N/A	FΔH(N) ≤ 1.635*{1+0.3*(1 - P)} [COLR 3.7.2]	N/A	✓ Yes ___ No		
Peak Total Heat Flux Hot Channel Factor, $F_Q(Z)$						
$F_Q(Z)$= 2.250	N/A	FQ(Z) ≤ 5.0 * K(z) [COLR 3.7.1]	N/A	✓ Yes ___ No		
Maximum Positive Incore Quadrant Power Tilt						
Tilt= 1.0072	≤ 1.02[1]	N/A	✓ Yes ___ No	N/A	↓	

References 1.) DNES-AA-NAF-NCD-4015
2.) ETE-NAF-2019-0119
3.) ETE-NAF-2019-0120

Surry Power Station Unit 1 Cycle 30 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) = 70.62					12/1/19 04:40	KLK / MFM
Max Relative Assembly Power, %DIFF (M-P)/P						
%DIFF= 3.1 % for Pi≥ 0.9; 2.7 % for Pi < 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)= 1.506	N/A	FΔH(N) ≤ 1.635*{1+0.3*(1 - P)} [COLR 3.7.2]	N/A	✓ Yes ___ No		
Peak Total Heat Flux Hot Channel Factor, $F_Q(Z)$						
$F_Q(Z)$= 1.956	N/A	FQ(Z) ≤ {2.5 / P} * K(z) [COLR 3.7.1]	N/A	✓ Yes ___ No		
Maximum Positive Incore Quadrant Power Tilt						
Tilt= 1.0066	≤ 1.02[1]	N/A	✓ Yes ___ No	N/A		

References 1.) DNES-AA-NAF-NCD-4015
2.) ETE-NAF-2019-0119
3.) ETE-NAF-2019-0120

Surry Power Station Unit 1 Cycle 30 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) = 99.93 ✓					12/5/19 0830	MH/MAC
Max Relative Assembly Power, %DIFF (M-P)/P						
%DIFF= 2.6 ✓ % for Pi ≥ 0.9; 2.8 ✓ % for Pi < 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)= 1.485 ✓	N/A	FΔH(N) ≤ 1.635*(1+0.3*(1 - P)) [COLR 3.7.2]	N/A	✓ Yes ___ No		
Peak Total Heat Flux Hot Channel Factor, $F_Q(Z)$						
$F_Q(Z)$= 1.864 ✓	N/A	FQ(Z) ≤ (2.5 / P) * K(z) [COLR 3.7.1]	N/A	✓ Yes ___ No		
Maximum Positive Incore Quadrant Power Tilt						
Tilt= 1.0076 ✓ 0.76% (AVE) 0.95% N44 UPPER	≤ 1.02[1]	N/A	✓ Yes ___ No	N/A		

References 1.) DNES-AA-NAF-NCD-4015
2.) ETE-NAF-2019-0119
3.) ETE-NAF-2019-0120

Surry Power Station Unit 1 Cycle 30 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} = 289845.8 gpm	N/A	$F_{total} \geq$ 274000 gpm [COLR 3.8]	N/A	✓ Yes ___ No	12/8/19 09:25	DJA / MJH

References 1.) DNES-AA-NAF-NCD-4015
2.) ETE-NAF-2019-0119
3.) ETE-NAF-2019-0120