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VIRGINIA ELECTRIC AND POWER COMPANY (DOMINION)
SURRY POWER STATION UNIT 2
CYCLE 24 STARTUP PHYSICS TESTS REPORT

As required by Surry Technical Specification 6.6.A.1, enclosed is the Virginia Electric and Power Company (Dominion) Engineering Technical Evaluation ETE-NAF-20110083, Rev. 0, "Surry Unit 2 Cycle 24 Startup Physics Tests Report." This report summarizes the results of the physics testing program performed prior to and following initial criticality of Cycle 24 on June 15, 2011. The results of the physics tests were within the applicable Technical Specification limits.

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

Sincerely,

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Enclosure

Commitments made in this letter: None

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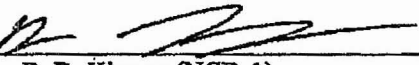
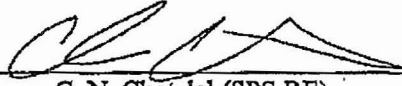
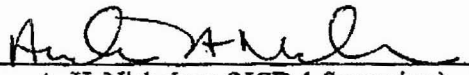
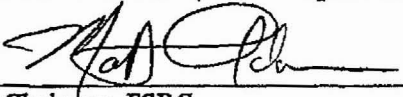
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ENGINEERING TECHNICAL EVALUATION
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SURRY UNIT 2 CYCLE 24
STARTUP PHYSICS TESTS REPORT

NUCLEAR ANALYSIS AND FUEL
NUCLEAR ENGINEERING & SERVICES
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August, 2011

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

The Surry Unit 2, Cycle 24 startup physics tests results and evaluation sheets are included as an appendix to provide additional information on the startup test results. Each data sheet provides the following information: 1) test identification, 2) test results, 3) acceptance criteria and whether it was met (if applicable), 4) date and time of the test, and 5) preparer/ reviewer initials. These sheets provide a compact summary of the startup test results in a consistent format. The entries for the design values were based on calculations performed by Dominion's Nuclear Analysis and Fuel Group. The acceptance criteria are based on design tolerances or applicable Technical Specification and COLR Limits.

SECTION 1 — INTRODUCTION AND SUMMARY

On April 16, 2011 at 18:49, Unit No. 2 of Surry Power Station tripped off line due to loss of offsite power. Unit 2 completed Cycle 23 at that time and began its Refueling Outage [Ref. 1]. During this refueling, 73 of the 157 fuel assemblies in the core were replaced with 9 twice burned assemblies from Batch S2/23 last irradiated during Surry 2 Cycle 22, 36 fresh Batch S2/26A assemblies, and 28 fresh Batch S2/26B assemblies. The Cycle 24 core consists of 9 sub-batches of fuel: two fresh batches (S2/26A and S2/26B), three once-burned batches (S2/25A, S2/25B, and S2/25C), and four twice-burned batches (S2/23B, S2/23D, S2/24A, and S2/24D) [Ref. 1]. S2C24 will be the first cycle to utilize the 15x15 Upgrade (Upgrade) Fuel Design. Therefore, all fresh fuel is the Upgrade fuel product and all reuse fuel is the Surry Improved Fuel (SIF/P+Z2) [Ref. 1].

For both fuel types, all fuel rods are supported by five structural ZIRLO grids and two Inconel-718 grids spaced along the axial length of the assembly. These grids are attached to the guide tubes, which are fixed to the upper and lower nozzles and thus provide structural support for the assembly. The Upgrade fuel design is similar to and compatible with the SIF/P+Z2 design. However, the Upgrade fuel also includes three additional ZIRLO Intermediate Flow Mixing (IFM) grids for improved thermal-hydraulic performance, ZIRLO (I-spring) structural mid grids with new balancing vane pattern, "tube-in-tube" guide thimbles, a shorter bottom end plug length, and the use of optimized ZIRLO fuel clad that improves corrosion resistance. The SIF/P+Z2 design includes debris resistant features that are part of Westinghouse's Performance+ design with ZIRLO cladding, intermediate structural grids, guide tubes, and instrumentation tubes [Ref. 1].

This cycle uses only 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].

Note that there are no thimble plugging devices or secondary sources inserted in Surry Unit 2 for this cycle. The cycle design report [Ref. 1] provides a more detailed description of the Cycle 24 core.

The S2C24 full core loading plan [Ref. 11] is given in Figure 1.1 and the beginning of cycle fuel assembly burnups [Ref. 6] are given in Figure 1.2. The available incore moveable detector locations used for the flux map analyses [Ref. 7] are identified in Figure 1.3. Figure 1.4 identifies the location and number of control rods in the Cycle 24 core [Ref. 1].

According to the Startup Physics logs, the Cycle 24 core achieved initial criticality on June 15, 2011 at 14:42 [Ref. 14]. Prior to and following criticality, startup physics tests were performed as outlined in Table 1.1. This cycle used the FTI Reactivity Measurement and Analysis System (RMAS) to perform startup physics testing. Note that RMAS v.6 [Ref. 9] was used for S2C24 Startup Physics Testing. The tests performed are the same as in previous cycles. A summary of the test results follows.

The measured drop time of each control rod was within the 2.4 second Technical Specification [Ref. 4] limit, as well as the Surry Unit 2 1.68 second administrative limit [Ref. 10].

Individual control rod bank worths were measured using the rod swap technique [Ref. 2]. For the purpose of this test, a bank was defined as 'fully inserted' when it was 2 steps off the bottom of the core [Ref. 13]. The sum of the individual measured control rod bank worths was within -3.8% of the design prediction. The reference bank (Control Bank B) worth was within -2.9% of its design prediction. Control rod banks with design predictions greater than 600 pcm were within $\pm 6.3\%$ of the design predictions. For individual banks worth 600 pcm or less (only Control Bank A fits this category), the difference was within 3.2 pcm of the design prediction. These results are within the design tolerances of $\pm 15\%$ for individual banks worth more than 600

pcm ($\pm 10\%$ for the reference bank worth), ± 100 pcm for individual banks worth 600 pcm or less, and $\pm 10\%$ for the sum of the individual control rod bank worths.

Measured critical boron concentrations for two control bank configurations, ARO and B-bank in, were within the design tolerances and the Technical Specification criterion [Ref. 4] that the overall core reactivity balance shall be within $\pm 1\% \Delta k/k$ of the design prediction. The boron worth coefficient measurement was within $+4.4\%$ of the design prediction, which is within the design tolerance of $\pm 10\%$.

The measured isothermal temperature coefficient (ITC) for the all-rods-out (ARO) configuration was within -0.228 pcm/ $^{\circ}\text{F}$ of the design prediction. This result is within the design tolerance of ± 2.0 pcm/ $^{\circ}\text{F}$.

Core power distributions were within established design tolerances. The measured assembly power distributions were within $\pm 4.40\%$ of the design predictions, where a $+4.40\%$ maximum difference occurred in the 28.7% power map in assembly B8. The heat flux hot channel factors, $F_Q(Z)$, and enthalpy rise hot channel factors, $F_{\Delta H}^N$, 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 total RCS Flow was successfully verified as being greater than 273,000 gpm and greater than the limit in the COLR (276,000 gpm), as required by Surry Technical Specifications [Ref. 4]. The total RCS Flow was measured as 295,495 gpm.

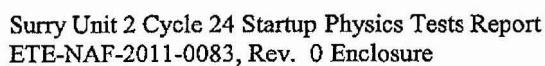
In summary, all startup physics test results were acceptable. Detailed results, specific design tolerances and acceptance criteria for each measurement are presented in the following sections of this report.

Table 1.1

SURRY UNIT 2 – CYCLE 24
CHRONOLOGY OF TESTS

Test	Date	Time	Power	Reference Procedure
Hot Rod Drop-Hot Full Flow	06/12/11	1837	HSD	2-NPT-RX-014
Reactivity Computer Checkout	06/15/11	1540	HZP	2-NPT-RX-008
Boron Endpoint – ARO	06/15/11	1540	HZP	2-NPT-RX-008
Zero Power Testing Range	06/15/11	1540	HZP	2-NPT-RX-008
Boron Worth Coefficient	06/15/11	1950	HZP	2-NPT-RX-008
Temperature Coefficient – ARO	06/15/11	1614	HZP	2-NPT-RX-008
Bank B Worth	06/15/11	1657	HZP	2-NPT-RX-008
Boron Endpoint – B in	06/15/11	1950	HZP	2-NPT-RX-008
Bank A Worth – Rod Swap	06/15/11	2015	HZP	2-NPT-RX-008
Bank C Worth – Rod Swap	06/15/11	2015	HZP	2-NPT-RX-008
Bank SA Worth – Rod Swap	06/15/11	2015	HZP	2-NPT-RX-008
Bank D Worth – Rod Swap	06/15/11	2015	HZP	2-NPT-RX-008
Bank SB Worth – Rod Swap	06/15/11	2015	HZP	2-NPT-RX-008
Total Rod Worth	06/15/11	2015	HZP	2-NPT-RX-008
Flux Map – less than 30% Power Peaking Factor Verification & Power Range Calibration	06/17/11	0337	28.7%	2-NPT-RX-002 2-NPT-RX-008 2-NPT-RX-005 2-GEP-RX-001
Flux Map – 65% - 75% Power Peaking Factor Verification & Power Range Calibration	06/18/11	0118	65.14%	2-NPT-RX-002 2-NPT-RX-008 2-NPT-RX-005 2-GEP-RX-001
Flux Map – 95% - 100% Power Peaking Factor Verification & Power Range Calibration	07/05/11	0853	99.81%	2-NPT-RX-002 2-NPT-RX-008 2-NPT-RX-005 2-GEP-RX-001
RCS Flow Measurement	6/28/11	1444	HFP	2-NPT-RX-009

SURRY UNIT 2 - CYCLE 24
FULL CORE LOADING PLAN
REVISION NO. 0



SURRY UNIT 2 – CYCLE 24
BEGINNING OF CYCLE FUEL ASSEMBLY BURNUPS (GWD/MTU)

Surry Unit 2 Cycle 24 Startup Physics Tests Report
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Figure 1.3

SURRY UNIT 2 – CYCLE 24
AVAILABLE INCORE MOVEABLE DETECTOR LOCATIONS

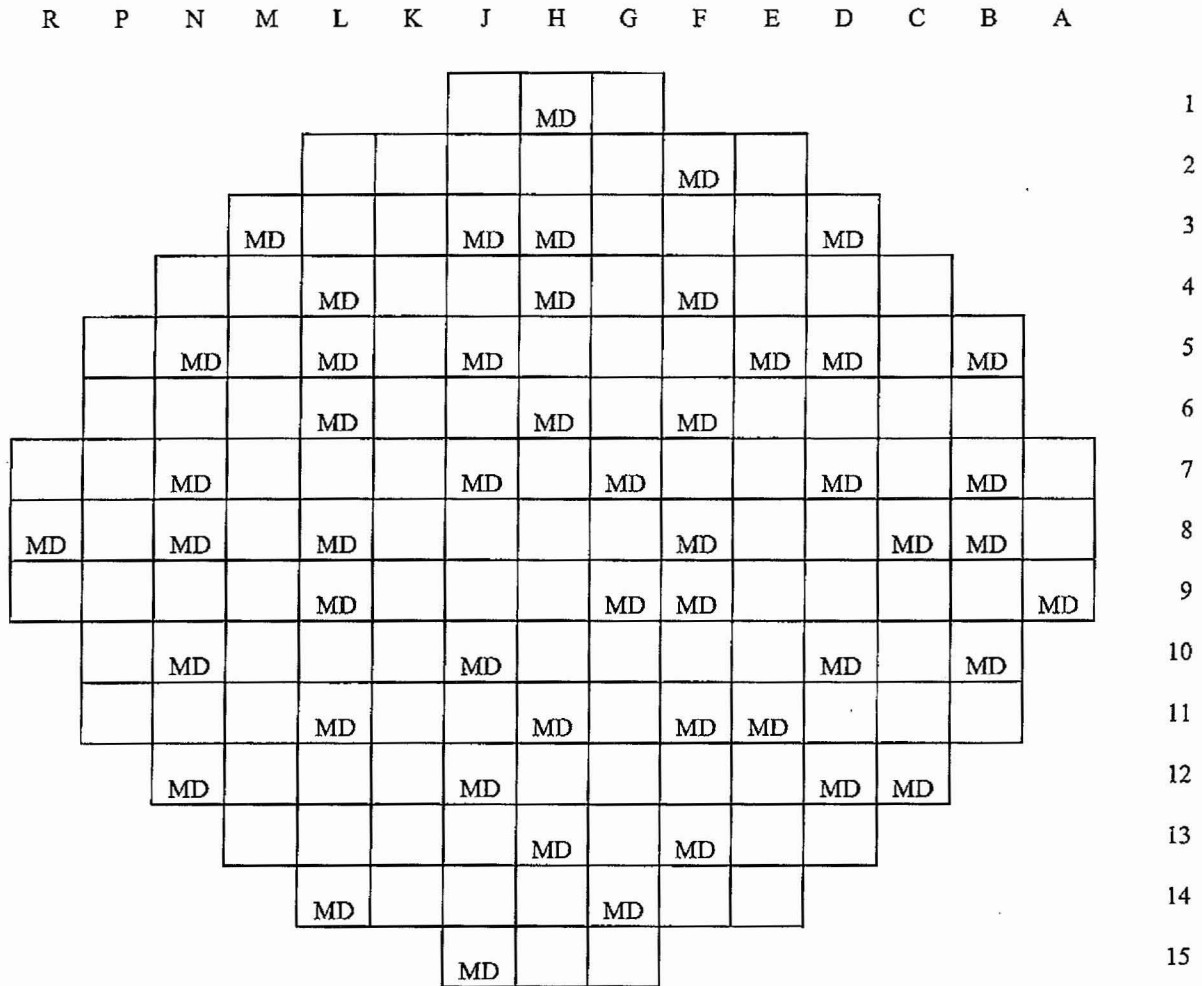
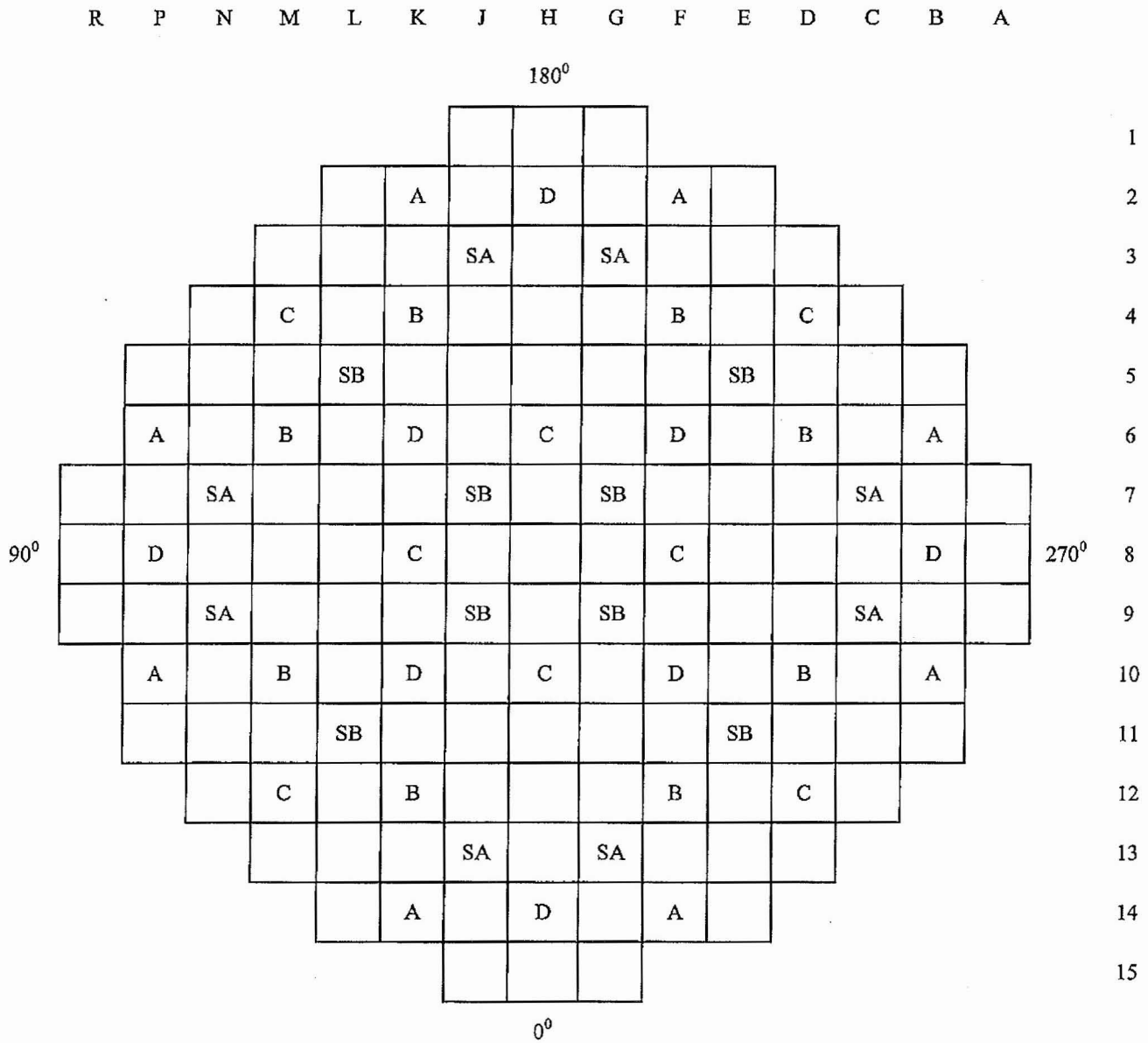


Figure 1.4

SURRY UNIT 2 – CYCLE 24
CONTROL ROD LOCATIONS



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

SB = Shutdown Bank SB
SA = Shutdown Bank SA

SECTION 2 — CONTROL ROD DROP TIME MEASUREMENTS

The drop time of each control rod was measured in hot shutdown with three reactor coolant pumps in operation (full flow) and with T_{ave} greater than 530 °F per 2-NPT-RX-014. This verified that the time to entry of a rod into the dashpot region was less than or equal to the maximum allowed by Technical Specification 3.12.C.1 [Ref. 4].

Surry Unit 2 Cycle 24 used the rod drop test computer (RDTC) in conjunction with the Computer Enhanced Rod Position Indication (CERPI) system. The CERPI system equipment replaced the Individual Rod Position Indication (IRPI) system. The rod drop times were measured by withdrawing all banks to their fully withdrawn position and dropping all of the 48 control rods by opening the reactor trip breakers. This allowed the rods to drop into the core as they would during a plant trip.

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

A typical rod drop trace for S2C24 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 20-24. Technical Specification 3.12.C.1 [Ref. 4] specifies a maximum rod drop time to dashpot entry of 2.4 seconds for all rods. These test results satisfied this technical specification limit as well as the administrative limit [Ref. 10] of 1.68 seconds. In addition, rod bounce was observed at the end of each trace demonstrating that no control rod stuck in the dashpot region.

Table 2.1

SURRY UNIT 2 – CYCLE 24 STARTUP PHYSICS TESTS
HOT ROD DROP TIME SUMMARY

ROD DROP TIME TO DASHPOT ENTRY

SLOWEST ROD	FASTEST ROD	AVERAGE TIME
F-06 1.39 sec.	P-8, L-5 1.25 sec	1.29 sec.

Figure 2.1

SURRY UNIT 2 – CYCLE 24 STARTUP PHYSICS TESTS
TYPICAL ROD DROP TRACE

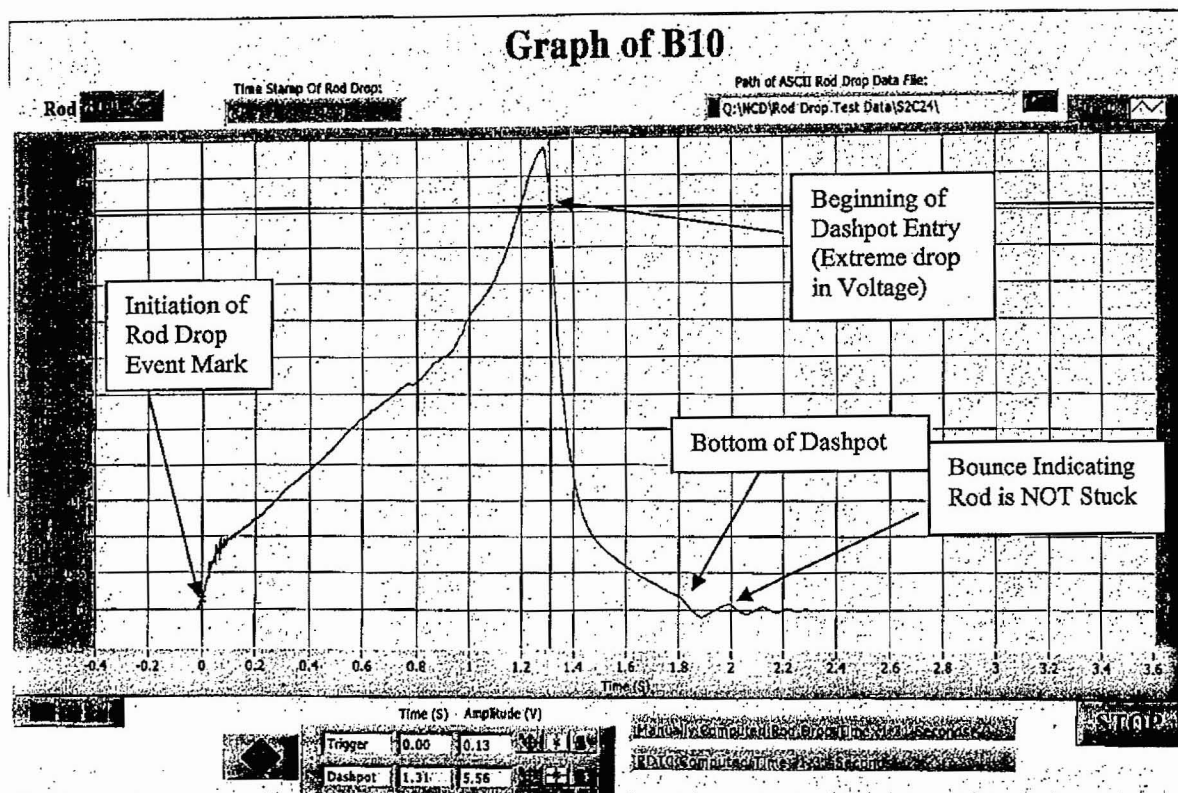


Figure 2.2

SURRY UNIT 2 – CYCLE 24 STARTUP PHYSICS TESTS
ROD DROP TIME – HOT FULL FLOW CONDITIONS

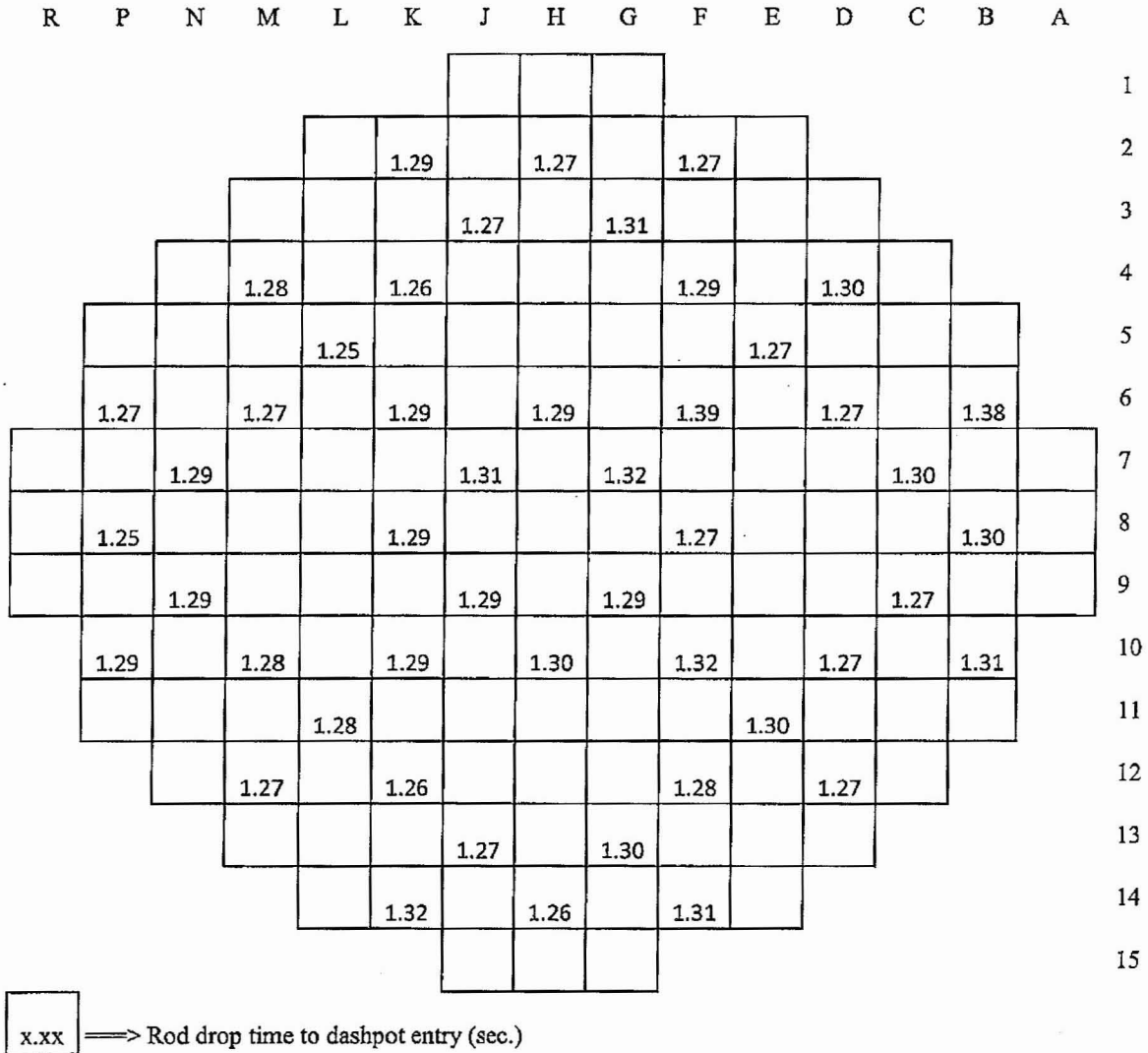
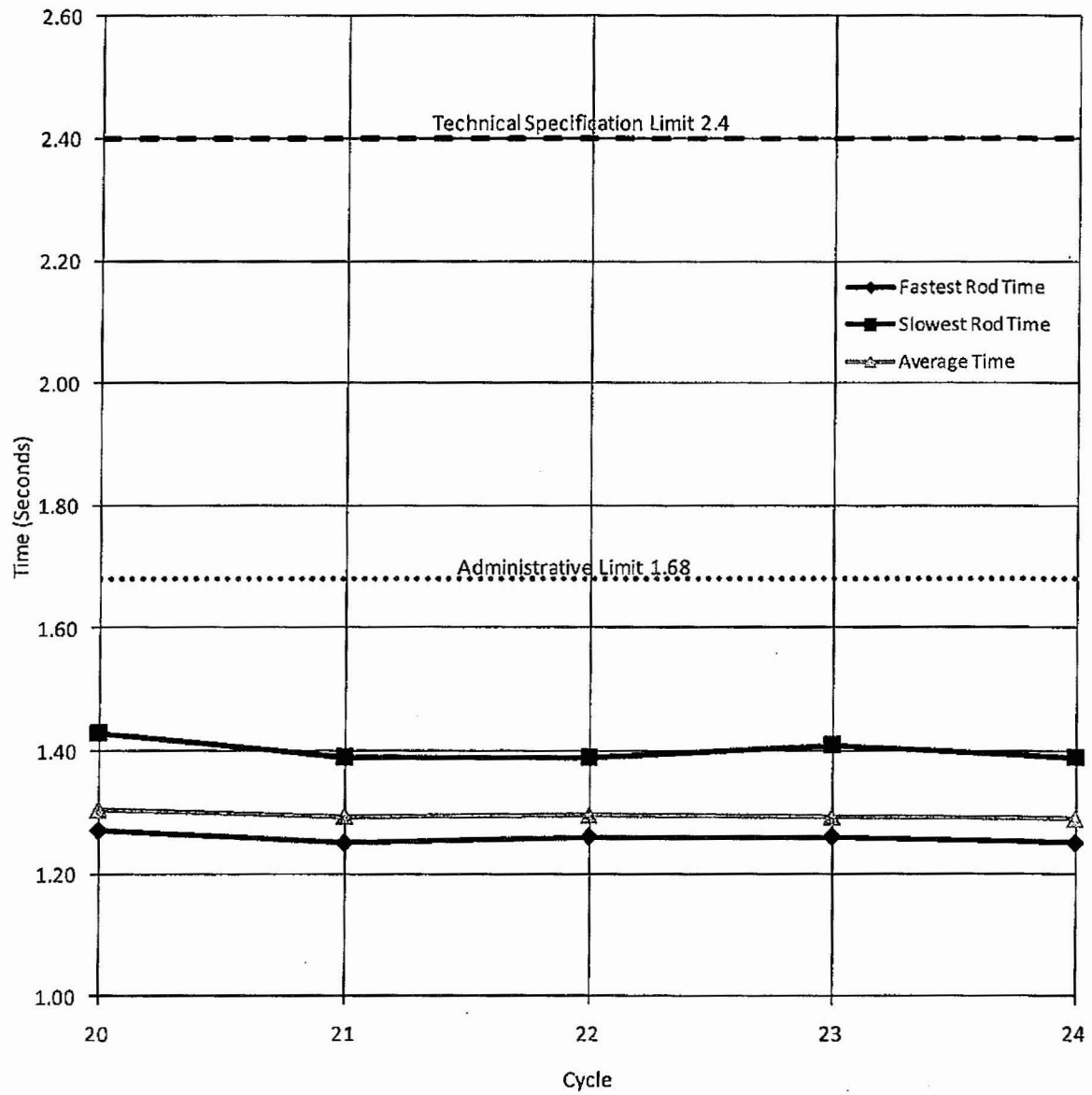


Figure 2.3

SURRY UNIT 2 – CYCLE 24 STARTUP PHYSICS TESTS
ROD DROP TIMES TRENDING



SECTION 3 — CONTROL ROD BANK WORTH MEASUREMENTS

Control rod bank worths were measured for the control and shutdown banks using the rod swap technique [Ref. 2]. The initial step of the rod swap method diluted the predicted most reactive control rod bank (hereafter referred to as the reference bank) into the core and measured its reactivity worth using conventional test techniques. The reactivity changes resulting from the reference bank movements were recorded continuously by the reactivity computer and were used to determine the differential and integral worth of the reference bank. For Cycle 24, Control Bank B was used as the reference bank. Surry 2's dilution rate was around 1000 pcm/hr for the reference bank measurement.

During the NIC19 startup physics testing campaign, a control rod became stuck on the bottom eventually forcing a reactor trip to fix the problem. A theorized potential cause of the stuck rod issue was the presence of debris near the upper core plate interfering with the rod grippers when the control rods were manually inserted to the fully inserted position of 0 steps withdrawn. A possible solution to this issue for startup physics testing was to avoid requiring control rods to be manually inserted to 0 steps. To accomplish this, an evaluation of the startup physics testing process was performed [Ref. 13], concluding that the definition of fully inserted for control rod positions used in startup physics testing could be changed from 0 steps withdrawn to a range of 0 to 2 steps withdrawn. The S2C24 startup physics testing campaign used 2 steps withdrawn for all conditions requiring control rods to be manually fully inserted.

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

Test bank swaps proceed in sequential order from the bank with the smallest worth to the bank with the largest worth. The second test bank should have a predicted worth higher than the first bank in order to ensure the first bank will be moved fully out before the second bank is fully inserted. The rod swap maneuver was performed by withdrawing the previous test bank (or reference bank for the first maneuver) several steps and then inserting the next test bank to

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

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

A summary of the test results is given in Table 3.1. As shown in this table and the Startup Physics Test Summary Sheets given in the Appendix, the individual measured bank worths for the control and shutdown banks were within the design tolerance of $\pm 10\%$ for the reference bank, $\pm 15\%$ for test banks of worth greater than 600 pcm, and ± 100 pcm for test banks of worth less than or equal to 600 pcm. The sum of the individual measured rod bank worths was within -3.8 % of the design prediction. This is well within the design tolerance of $\pm 10\%$ for the sum of the individual control rod bank worths.

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

Table 3.1

SURRY UNIT 2 – CYCLE 24 STARTUP PHYSICS TESTS
CONTROL ROD BANK WORTH SUMMARY

BANK	MEASURED WORTH (PCM)	PREDICTED WORTH (PCM)	PERCENT DIFFERENCE (%) (M-P)/P X 100
B - Reference	1442.64	1486	-2.9
D	1008.6	1050.9	-4.0
C	763.8	815.2	-6.3
A	332.1	335.3	-1.0*
SB	988.2	1045.9	-5.5
SA	912.9	927.9	-1.6
Total Bank Worth	5448.3	5661.1	-3.8

*Note: For Bank A, (M-P) = -3.2 pcm.

Figure 3.1

SURRY UNIT 2 – CYCLE 24 STARTUP PHYSICS TESTS
CONTROL BANK B INTEGRAL ROD WORTH - HZP
ALL OTHER RODS WITHDRAWN

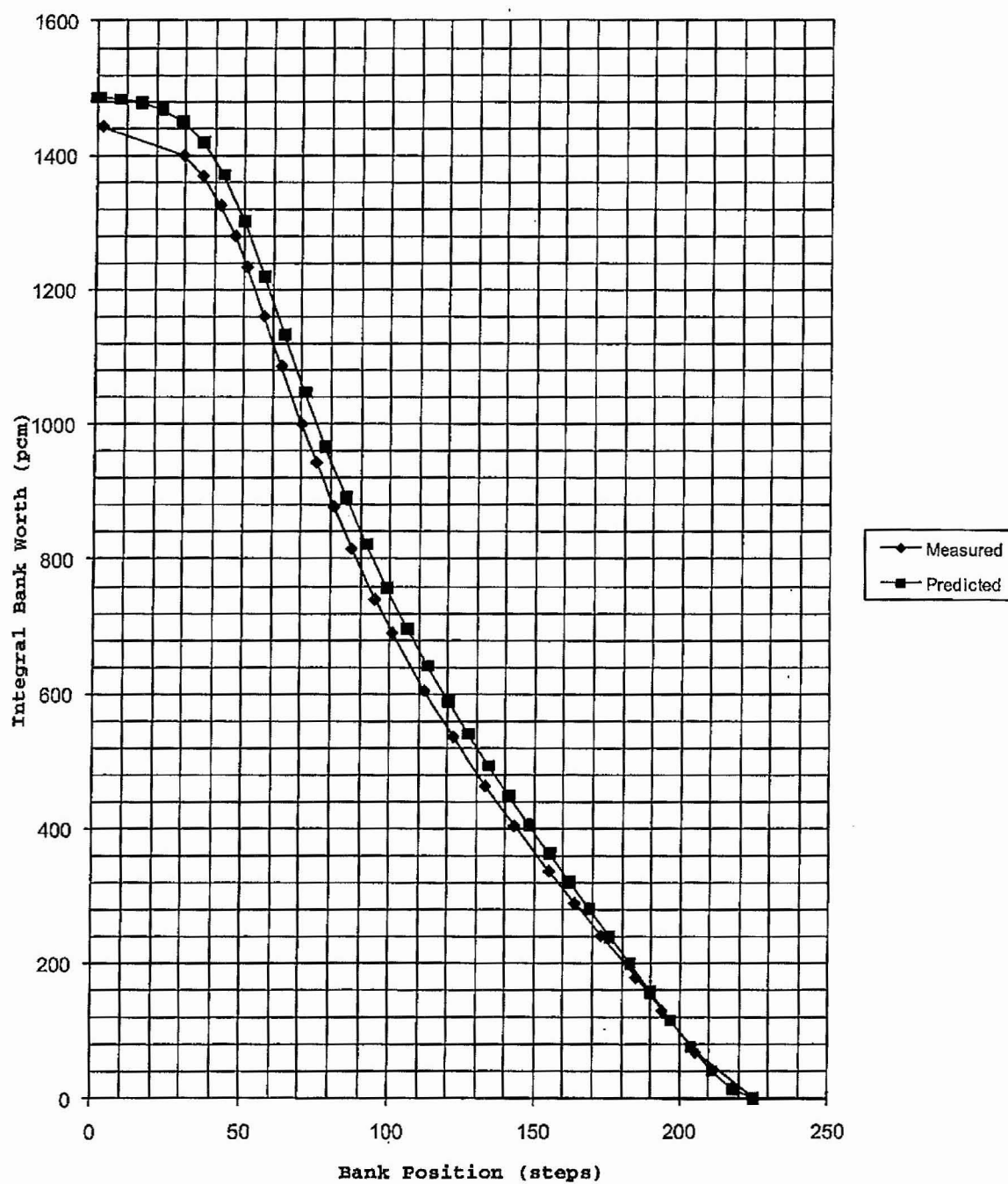
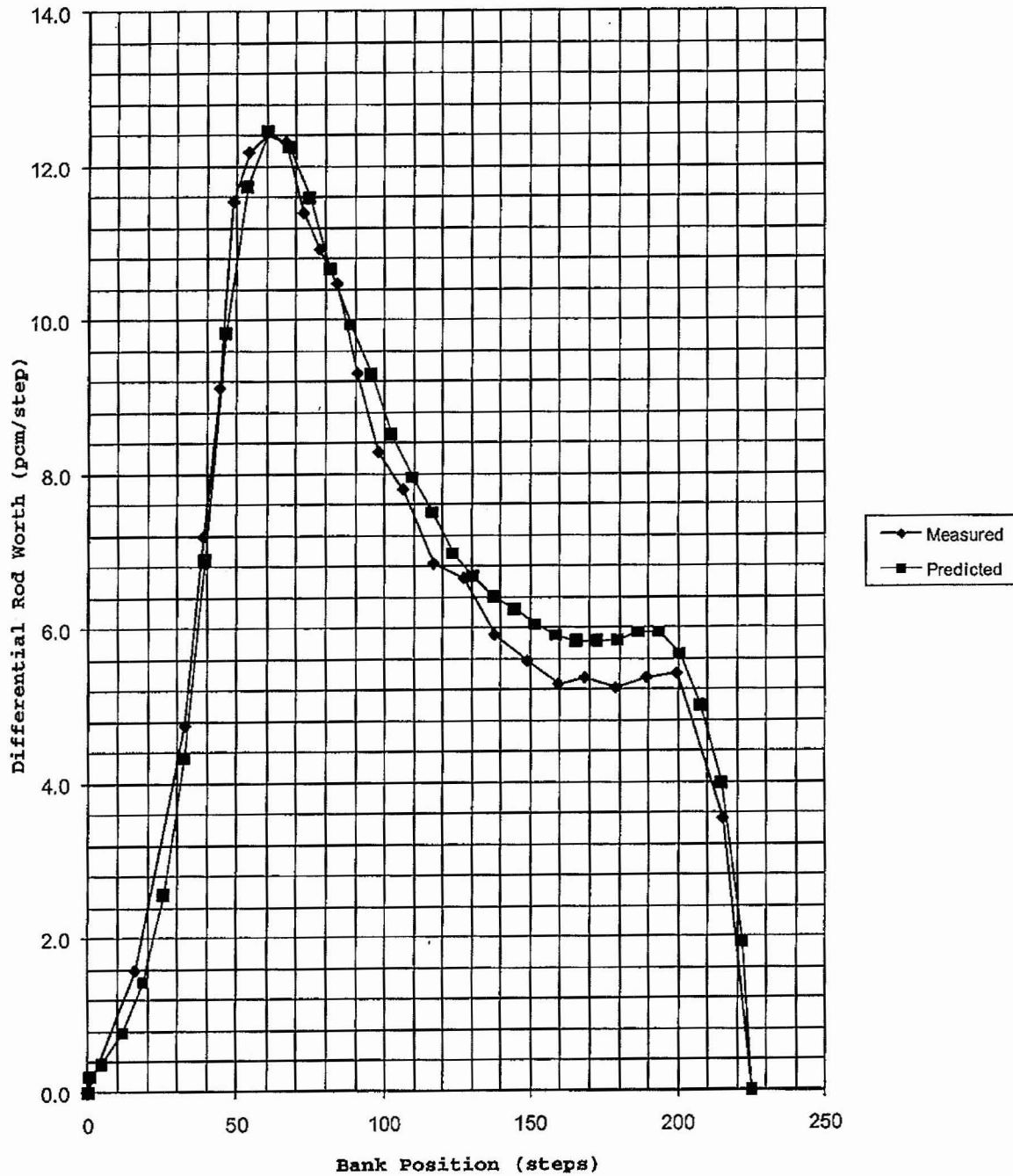


Figure 3.2

SURRY UNIT 2 -- CYCLE 24 STARTUP PHYSICS TESTS
CONTROL BANK B DIFFERENTIAL ROD WORTH - HZP
ALL OTHER RODS WITHDRAWN



SECTION 4 — BORON ENDPOINT AND WORTH MEASUREMENTS

Boron Endpoint

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

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

Boron Worth Coefficient

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

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

Table 4.1

SURRY UNIT 2 – CYCLE 24 STARTUP PHYSICS TESTS
BORON ENDPOINTS SUMMARY

Control Rod Configuration	Measured Endpoint (ppm)	Predicted Endpoint (ppm)	Difference M-P (ppm)
ARO	1588.3	1620	-31.7
B Bank In	1387.5	1390.3*	-2.8

* 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 24 STARTUP PHYSICS TESTS
BORON WORTH COEFFICIENT

Measured Boron Worth (pcm/ppm)	Predicted Boron Worth (pcm/ppm)	Percent Difference (%) $(M-P)/P \times 100$
-7.18	-7.51	-4.39

SECTION 5 — TEMPERATURE COEFFICIENT MEASUREMENT

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

Reactivity was measured during the RCS heat up of $+3.51^{\circ}\text{F}$, followed by the RCS cool down of -3.15°F . Reactivity and temperature data were taken from the reactivity computer. Using the statepoint method, the temperature coefficient was determined by dividing the change in reactivity by the change in RCS temperature.

The predicted and measured isothermal temperature coefficient values are compared in Table 5.1. As can be seen from this summary and from the Startup Physics Test Summary Sheet given in the Appendix, the measured isothermal temperature coefficient value was within the design tolerance of $\pm 2 \text{ pcm}/^{\circ}\text{F}$. The calculated moderator temperature coefficient (MTC), which is calculated using a measured ITC of $-1.860 \text{ pcm}/^{\circ}\text{F}$, a predicted DTC of $-1.80 \text{ pcm}/^{\circ}\text{F}$, and a measurement uncertainty of $+0.5 \text{ pcm}/^{\circ}\text{F}$, is $+0.440 \text{ pcm}/^{\circ}\text{F}$. It thus satisfies the COLR criteria [Ref. 8] that indicates MTC at HZP be less than or equal to $+6.0 \text{ pcm}/^{\circ}\text{F}$.

Table 5.1

SURRY UNIT 2 – CYCLE 24 STARTUP PHYSICS TESTS
ISOTHERMAL TEMPERATURE COEFFICIENT SUMMARY

BANK POSITION (STEPS)	TEMPERATURE RANGE (°F)		BORON CONCENTRATION (ppm)	ISOTHERMAL TEMPERATURE COEFFICIENT (PCM/°F)				
	LOWER LIMIT	UPPER LIMIT		HEAT- UP	COOL- DOWN	AVG. MEAS	PRED	DIFFER (M-P)
D/205	545.96	549.47	1581	-1.743	-1.977	-1.860	-1.632	-0.228

SECTION 6 — POWER DISTRIBUTION MEASUREMENTS

The core power distributions were measured using the moveable incore detector flux mapping system. This system consists of five fission chamber detectors which traverse fuel assembly instrumentation thimbles in up to 50 core locations. Figure 1.3 shows the available locations monitored by the moveable detectors for the ramp to full power flux maps for Cycle 24. For each traverse, the detector voltage output is continuously monitored on a recorder, and scanned for 610 discrete axial points. Full core, three-dimensional power distributions are determined from this data using a Dominion-modified version of the Combustion Engineering computer program, CECOR [Ref. 3, 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.

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 28.7% power to verify the radial power distribution (RPD) predictions at low power. Figure 6.1 shows the measured RPDs from this flux map. Flux maps 2 and 3 were taken at 65.14% and 99.81% 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 +4.4% in the 28.7% power map, -3.5% in the 65.14% power map, and -3.7% in the 99.81% power map. The maximum average quadrant power tilts for the three power maps are +0.62 % (1.0062), +0.45 % (1.0045), and +0.65% (1.0065), respectively. These power tilts are within the design tolerance of 2% (1.02).

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

In conclusion, the power distribution measurement results are considered acceptable with respect to the design tolerances, the accident analysis acceptance criteria, and the COLR [Ref. 8]. It is therefore anticipated that the core will continue to operate safely throughout Cycle 24.

Table 6.1

**SURRY UNIT 2 – CYCLE 24 STARTUP PHYSICS TESTS
INCORE FLUX MAP SUMMARY**

Map Description	Map No.	Date	Burn up MWD/MTU	Power (%)	Bank D Steps	Peak $F_Q(Z)$ Hot Channel Factor (1)			F_{AH}^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_{AH}^N	Axial Point	F_Z	Max	Loc		
Low Power	1	06/17/11	2	28.66	168	D05	30	2.174	D05	1.521	30	1.328	1.0062	SE	-0.005	50
Int. Power (4)	2	06/18/11	17	65.14	198	D05	29	1.924	D05	1.477	26	1.208	1.0045	SE	+3.010	50
Hot Full Power	3	07/05/11	381	99.81	224	D05	31	1.836	D05	1.437	30	1.167	1.0065	SE	-0.212	50

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

(1) $F_Q(Z)$ includes a total uncertainty of 8.00%

(2) F_{AH}^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

SURREY UNIT 2 – CYCLE 24 STARTUP PHYSICS TESTS
COMPARISON OF MEASURED POWER DISTRIBUTION
PARAMETERS WITH THEIR CORE OPERATING LIMITS

Map	Peak $F_Q(Z)$ Hot Channel Factor				F_{AH}^N Hot Channel Factor		
No.	Meas.	Limit	Node	Margin ^s (%)	Meas.	Limit	Margin ^s (%)
1	2.174	5.000	30	56.5	1.521	1.894	19.69
2	1.924	3.838	29	49.9	1.477	1.723	14.28
3	1.836	2.505	31	26.7	1.437	1.561	7.94

The measured $F_Q(Z)$ hot channel factors include 8.00% total uncertainty. Measured F_{AH}^N data includes no uncertainty.

$$\text{\$ Margin (\%)} = 100 * (\text{Limit} - \text{Meas.}) / \text{Limit}$$

**Figure 6.1 — ASSEMBLYWISE POWER DISTRIBUTION,
MAP 01, 28.66% POWER**

Top value = Measured, middle value = Analytical, bottom value = % Delta
 $\% \text{ Delta} = (M - A) \times 100 / A$

R	P	N	M	L	K	J	H	G	F	E	D	C	B	A
1						0.287 0.266 0.23	0.338 0.335 0.81	0.265 0.265 0.18						
2				0.321 0.320 0.40	0.650 0.648 0.33	1.002 0.999 0.33	1.049 1.044 0.49	0.999 0.999 -0.04	0.638 0.648 -1.61	0.319 0.321 -0.50				
3			0.366 0.369 -0.81	1.043 1.038 0.46	1.228 1.226 0.17	1.216 1.214 0.14	1.126 1.111 1.38	1.219 1.216 0.21	1.227 1.229 -0.19	1.044 1.041 0.27	0.373 0.370 0.88			
4		0.366 0.369 -0.71	0.907 0.908 -0.06	1.305 1.293 0.92	1.361 1.360 0.09	1.203 1.206 -0.25	1.273 1.267 0.50	1.210 1.209 0.06	1.365 1.365 -0.01	1.305 1.298 0.55	0.921 0.911 1.10	0.376 0.371 1.46		
5	0.319 0.323 -1.12	1.030 1.046 -1.53	1.290 1.298 -0.58	1.183 1.189 -0.47	1.219 1.228 -0.72	1.292 1.177 -1.90	1.168 1.177 -0.74	1.311 1.320 -0.69	1.227 1.232 -0.44	1.211 1.196 1.23	1.323 1.302 1.60	1.066 1.048 1.73	0.330 0.324 1.87	
6	0.653 0.658 -0.74	1.228 1.239 -0.90	1.368 1.372 -0.27	1.241 1.233 0.63	1.124 1.132 -0.74	1.237 1.252 -1.23	1.097 1.108 -0.95	1.235 1.253 -1.43	1.104 1.134 -2.68	1.240 1.235 0.41	1.395 1.372 1.66	1.264 1.241 1.83	0.675 0.662 2.02	
7	0.287 0.288 -0.50	1.016 1.024 -0.74	1.218 1.231 -1.04	1.212 1.216 -0.29	1.324 1.325 -0.10	1.247 1.254 -0.56	1.094 1.108 -1.26	0.998 1.011 -1.28	1.092 1.109 -1.55	1.244 1.256 -0.93	1.334 1.325 0.64	1.250 1.216 2.81	1.257 1.232 2.06	1.052 1.029 2.27
8	0.351 0.351 -0.08	1.069 1.073 -0.36	1.134 1.128 0.53	1.276 1.277 -0.08	1.186 1.184 0.20	1.106 1.112 -0.56	1.003 1.012 -0.93	0.670 0.677 -1.02	1.000 1.012 -1.15	1.105 1.111 -0.52	1.192 1.184 0.67	1.298 1.277 1.62	1.144 1.128 1.44	1.120 1.073 4.40
9	0.293 0.294 -0.51	1.024 1.029 -0.47	1.226 1.233 -0.56	1.207 1.216 -0.77	1.300 1.325 -1.88	1.243 1.256 -1.07	1.101 1.109 -0.71	1.001 1.011 -0.96	1.096 1.108 -1.11	1.252 1.254 -0.18	1.332 1.324 0.63	1.234 1.216 1.49	1.254 1.231 1.88	1.055 1.024 3.06
10	0.657 0.662 -0.76	1.228 1.241 -1.05	1.360 1.372 -0.89	1.222 1.235 -1.05	1.121 1.134 -1.18	1.252 1.253 -0.06	1.099 1.108 -0.79	1.241 1.252 -0.91	1.124 1.132 -0.73	1.242 1.233 0.71	1.393 1.372 1.56	1.263 1.239 1.91	0.676 0.658 2.71	
11	0.322 0.324 -0.63	1.041 1.048 -0.68	1.292 1.302 -0.77	1.190 1.196 -0.54	1.220 1.232 -1.00	1.304 1.320 -1.23	1.157 1.177 -1.71	1.303 1.317 -1.03	1.215 1.228 -1.06	1.200 1.189 0.92	1.319 1.298 1.62	1.067 1.045 2.09	0.331 0.323 2.35	
12	0.373 0.371 0.60	0.905 0.911 -0.69	1.286 1.298 -0.95	1.348 1.365 -1.23	1.184 1.209 -2.04	1.255 1.267 -0.96	1.203 1.206 -0.28	1.364 1.360 0.30	1.306 1.293 1.00	0.928 0.908 2.25	0.383 0.369 3.75			
13	0.367 0.370 -0.84	1.030 1.042 -1.12	1.215 1.229 -1.16	1.203 1.216 -1.06	1.113 1.111 0.18	1.218 1.214 0.35	1.218 1.226 1.25	1.241 1.241 1.05	1.218 1.038 1.25	0.375 0.369 1.63				
14	0.315 0.321 -1.80	0.642 0.648 -0.94	0.992 1.000 -0.81	1.041 1.045 -0.35	1.003 0.999 0.39	0.655 0.648 1.01	0.324 0.320 1.21							
15						0.263 0.265 -0.73	0.335 0.335 -0.11	0.266 0.266 0.07						

AVERAGE ABSOLUTE PERCENT DIFFERENCE = 1.0

STANDARD DEVIATION = 0.819

Summary:

Map No: S2-24-01	Date: 06/17/2011	Power: 28.66%
Control Rod Position:	$F_Q(z) = 2.174$	QPTR: $\frac{0.9955}{0.9925} \mid \frac{1.0058}{1.0062}$
D Bank at 168 Steps	$F_{\Delta H}^N = 1.521$	
	$F_Z = 1.328$	
Burnup = 2 MWD/MTU	Axial Offset (%) = -0.005	

Figure 6.2 — ASSEMBLYWISE POWER DISTRIBUTION,
MAP 02, 65.14% POWER

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

R	P	N	M	L	K	J	H	G	F	E	D	C	B	A
1						0.287 0.286 0.21	0.367 0.365 0.45	0.286 0.286 -0.16						
2					0.327 0.328 -0.23	0.659 0.659 0.02	1.024 1.024 -0.01	1.109 1.107 0.18	1.020 1.024 -0.35	0.648 0.659 -1.64	0.326 0.329 -0.92			
3				0.365 0.374 -2.35	1.021 1.024 -0.27	1.205 1.207 -0.13	1.211 1.212 -0.11	1.130 1.121 0.76	1.212 1.213 -0.05	1.204 1.209 -0.39	1.024 1.026 -0.20	0.374 0.375 -0.21		
4			0.372 0.375 -0.83	0.894 0.899 -0.52	1.264 1.262 0.17	1.327 1.328 -0.06	1.192 1.192 -0.01	1.265 1.254 0.92	1.195 1.194 0.09	1.330 1.332 -0.15	1.266 1.266 0.03	0.907 0.901 0.64	0.379 0.376 0.91	
5	0.328 0.331 -0.77	1.021 1.030 -0.89	1.261 1.266 -0.38	1.170 1.172 -0.14	1.216 1.220 -0.36	1.295 1.307 -0.91	1.168 1.170 -0.19	1.301 1.309 -0.62	1.213 1.223 -0.80	1.179 1.178 0.05	1.288 1.269 1.46	1.044 1.031 1.22	0.331 0.331 0.10	
6	0.666 0.668 -0.26	1.213 1.217 -0.32	1.335 1.337 -0.16	1.224 1.224 0.04	1.173 1.178 -0.43	1.251 1.259 -0.63	1.108 1.114 -0.56	1.244 1.259 -1.22	1.147 1.180 -2.83	1.222 1.225 -0.25	1.351 1.336 1.09	1.233 1.219 1.18	0.681 0.671 1.42	
7	0.308 0.309 -0.43	1.043 1.045 -0.18	1.225 1.225 -0.04	1.199 1.199 -0.02	1.310 1.312 -0.15	1.256 1.261 -0.36	1.114 1.121 -0.58	1.021 1.030 -0.85	1.110 1.122 -1.06	1.248 1.262 -1.12	1.313 1.312 0.11	1.221 1.199 1.81	1.243 1.226 1.38	1.070 1.050 1.93
8	0.375 0.380 -1.44	1.130 1.133 -0.22	1.141 1.135 0.53	1.262 1.261 0.06	1.174 1.176 -0.14	1.115 1.116 -0.13	1.026 1.030 -0.42	0.698 0.701 -0.70	1.023 1.030 -0.76	1.107 1.116 0.28	1.179 1.176 0.98	1.273 1.261 0.81	1.144 1.135 0.81	1.169 1.133 3.18
9	0.312 0.315 -0.87	1.045 1.050 -0.46	1.221 1.226 -0.40	1.198 1.199 -0.12	1.315 1.312 0.24	1.261 1.262 -0.07	1.121 1.122 -0.12	1.026 1.030 -0.34	1.121 1.121 0.01	1.270 1.261 0.71	1.320 1.312 0.59	1.211 1.199 1.02	1.239 1.225 1.13	1.065 1.045 1.94
10	0.665 0.671 -0.86	1.202 1.219 -1.37	1.329 1.336 -0.55	1.223 1.225 -0.20	1.176 1.180 -0.30	1.260 1.259 0.09	1.111 1.114 -0.26	1.258 1.259 -0.08	1.181 1.178 0.26	1.230 1.224 0.51	1.352 1.337 1.11	1.231 1.217 1.13	0.677 0.668 1.28	
11	0.328 0.331 -0.80	1.022 1.031 -0.84	1.260 1.269 -0.68	1.172 1.178 -0.54	1.219 1.223 -0.35	1.304 1.309 -0.39	1.158 1.170 -1.00	1.304 1.307 -0.25	1.224 1.220 0.34	1.170 1.172 -0.19	1.277 1.266 0.85	1.041 1.030 1.09	0.334 0.331 1.04	
12		0.375 0.376 -0.25	0.895 0.901 -0.61	1.258 1.266 -0.60	1.327 1.332 -0.39	1.194 1.194 -0.03	1.252 1.254 -0.16	1.193 1.192 0.05	1.333 1.328 0.39	1.268 1.262 0.50	0.912 0.899 1.47	0.382 0.375 1.96		
13		0.373 0.375 -0.67	1.018 1.026 -0.83	1.203 1.209 -0.54	1.210 1.213 -0.24	1.126 1.121 0.41	1.213 1.212 0.07	1.214 1.207 0.59	1.030 1.024 0.60	0.378 0.374 1.07				
14			0.318 0.329 -3.49	0.654 0.659 -0.77	1.019 1.024 -0.47	1.104 1.107 -0.24	1.019 1.024 -0.53	0.661 0.659 0.23	0.329 0.328 0.39					
15						0.282 0.286 -1.24	0.363 0.365 -0.53	0.285 0.286 -0.43						

AVERAGE ABSOLUTE PERCENT DIFFERENCE = 0.7 STANDARD DEVIATION = 0.633

Summary:

Map No: S2-24-02 Date: 06/18/2011 Power: 65.14%
Control Rod Position: $F_Q(z) = 1.924$ QPTR: 0.9969 | 1.0021
D Bank at 198 Steps $F_{AH}^N = 1.477$ 0.9966 | 1.0045
 $F_Z = 1.208$
Burnup = 17 MWD/MTU Axial Offset (%) = +3.010

Figure 6.3 — ASSEMBLYWISE POWER DISTRIBUTION,
MAP 03, 99.81% POWER

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

R	P	N	M	L	K	J	H	G	F	E	D	C	B	A
1						0.296 0.297 -0.38	0.374 0.377 -0.75	0.295 0.297 -0.79						
2				0.328 0.330 -0.52	0.658 0.659 -0.17	1.023 1.024 -0.15	1.130 1.131 -0.10	1.018 1.024 -0.54	0.645 0.659 -2.15	0.327 0.331 -1.17				
3			0.368 0.376 -2.10	0.999 1.005 -0.57	1.187 1.191 -0.31	1.210 1.211 -0.10	1.127 1.120 0.60	1.212 1.212 -0.02	1.189 1.193 -0.34	1.005 1.007 -0.17	0.375 0.377 -0.49			
4		0.371 0.376 -1.25	0.884 0.892 -0.86	1.236 1.242 -0.50	1.296 1.299 -0.21	1.182 1.181 0.11	1.258 1.241 1.41	1.188 1.183 0.39	1.307 1.303 0.34	1.247 1.245 0.18	0.898 0.895 0.39	0.379 0.377 0.59		
5	0.329 0.332 -1.05	0.997 1.010 -1.32	1.236 1.245 -0.76	1.154 1.160 -0.50	1.213 1.218 -0.39	1.307 1.315 -0.64	1.171 1.171 -0.02	1.314 1.318 -0.33	1.216 1.221 -0.37	1.167 1.165 0.15	1.260 1.248 0.99	1.018 1.011 0.72	0.329 0.333 -1.08	
6	0.663 0.667 -0.67	1.191 1.200 -0.78	1.301 1.307 -0.46	1.220 1.236 -0.18	1.231 1.271 -0.42	1.265 1.271 -0.49	1.120 1.127 -0.64	1.261 1.272 -0.90	1.214 1.238 -1.97	1.222 1.223 -0.07	1.318 1.306 0.92	1.211 1.201 0.79	0.674 0.670 0.63	
7	0.316 0.320 -1.14	1.037 1.043 -0.59	1.216 1.223 -0.57	1.184 1.187 -0.29	1.317 1.320 -0.23	1.270 1.273 -0.26	1.139 1.143 -0.33	1.061 1.067 -0.55	1.136 1.143 -0.60	1.265 1.274 -0.70	1.324 1.320 0.30	1.208 1.187 1.77	1.235 1.224 0.90	1.057 1.048 0.85
8	0.384 0.392 -2.03	1.148 1.154 -0.48	1.135 1.131 0.37	1.246 1.247 -0.07	1.176 1.175 0.08	1.129 1.129 -0.02	1.066 1.068 -0.20	0.739 0.740 -0.15	1.064 1.068 -0.33	1.123 1.129 -0.51	1.181 1.175 0.54	1.259 1.247 0.98	1.137 1.131 0.51	1.184 1.154 2.63
9	0.321 0.325 -1.15	1.040 1.048 -0.74	1.216 1.224 -0.63	1.184 1.187 -0.25	1.323 1.320 0.20	1.275 1.274 0.07	1.145 1.143 0.22	1.068 1.067 0.11	1.148 1.143 0.48	1.291 1.273 1.39	1.333 1.320 0.98	1.202 1.187 1.26	1.236 1.223 1.05	1.059 1.043 1.57
10	0.662 0.670 -1.12	1.183 1.201 -1.54	1.298 1.306 -0.62	1.221 1.223 -0.14	1.237 1.238 -0.08	1.277 1.272 0.42	1.128 1.127 0.10	1.276 1.271 0.42	1.246 1.236 0.84	1.234 1.222 0.97	1.331 1.307 1.83	1.215 1.200 1.25	0.672 0.667 0.73	
11	0.329 0.333 -1.24	0.999 1.011 -1.17	1.238 1.248 -0.79	1.162 1.165 -0.29	1.219 1.221 -0.20	1.314 1.318 -0.28	1.162 1.171 -0.78	1.317 1.315 0.18	1.229 1.218 0.94	1.159 1.160 -0.05	1.258 1.245 1.03	1.023 1.010 1.31	0.336 0.332 1.08	
12	0.370 0.377 -1.73	0.887 0.895 -0.94	1.237 1.245 -0.61	1.297 1.303 -0.43	1.180 1.183 -0.28	1.240 1.241 -0.07	1.184 1.181 0.29	1.309 1.299 0.75	1.249 1.242 0.55	0.901 0.892 1.01	0.386 0.376 2.57			
13	0.373 0.377 -1.04	0.998 1.007 -0.94	1.185 1.193 -0.65	1.208 1.212 -0.31	1.125 1.120 0.45	1.214 1.211 0.22	1.203 1.191 0.98	1.013 1.005 0.78	0.379 0.376 0.73					
14	0.319 0.331 -3.71	0.653 0.659 -0.90	1.018 1.024 -0.56	1.128 1.131 -0.28	1.017 1.024 -0.69	0.661 0.659 0.36	0.332 0.330 0.51							
15						0.292 0.297 -1.80	0.375 0.377 -0.44	0.295 0.297 -0.69						

AVERAGE ABSOLUTE PERCENT DIFFERENCE = 0.7

STANDARD DEVIATION = 0.581

Summary:

Map No: S2-24-03 Date: 07/05/2011 Power: 99.81%
Control Rod Position: $F_Q(Z) = 1.836$ QPTR: $\frac{0.9954}{0.9962} \quad \frac{1.0019}{1.0065}$
D Bank at 224 Steps $F_{AH}^N = 1.437$
 $F_Z = 1.167$
Burnup = 381.0 MWD/MTU Axial Offset (%) = -0.212

SECTION 7 — CONCLUSIONS

Table 7.1 summarizes the results associated with Surry Unit 2 Cycle 24 startup physics testing program. As noted herein, all test results were acceptable and within associated design tolerances, technical specification limits, or COLR limits. It is anticipated, based on the results associated with the S2C24 startup physics testing program, that the Surry 2 core will continue to operate safely throughout Cycle 24.

Table 7.1

STARTUP PHYSICS TESTING RESULTS SUMMARY

Parameter	Measured (M)	Predicted (P)	Diff (M-P) or (M-P)/P, %	Design Tolerance
Critical Boron Concentration (H2P ARO), ppm	1588	1620	-32	±50
Critical Boron Concentration (H2P Ref Bank in), ppm	1387.5	1390.3	-2.8	±30
Isothermal Temp Coefficient (H2P ARO), pcm/F	-1.860	-1.632	-0.228	±2
Differential Boron Worth (H2P ARO), pcm/ppm	-7.18	-7.51	+4.4%	±10%
Reference Bank Worth (B-bank, dilution), pcm	1443	1486	-2.9%	±10%
D-bank Worth (Rod Swap), pcm	1009	1051	-4.0%	±15%
SB-bank Worth (Rod Swap), pcm	988	1046	-5.5%	±15%
SA-bank Worth (Rod Swap), pcm	913	928	-1.6%	±15%
C-bank Worth (Rod Swap), pcm	764	815	-6.3%	±15%
Rod Worth ≤ 600 pcm:				
A-bank Worth (Rod Swap), pcm	332	335	-3	±100
Total Bank Worth, pcm	5448	5661	-3.8%	±10%
S2C24 testing time: 7.1 hrs				
[criticality 6/15/2011 @ 1442 to end of rod swap 6/15/2011 @ 2145]				
Recent Startups:				
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			
S2C21 testing time:	5.8 hrs			
S1C21 testing time:	5.0 hrs			

SECTION 8 — REFERENCES

1. D. T. Smith, "Surry Unit 2, Cycle 24 Design Report," Engineering Technical Evaluation ETE-NAF-2011-0055, Rev. 0, May, 2011.
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12. N. A. Yonker, "Validation of Rod Drop Test Computer for Hot Rod Drop Analysis," Calculation PM-1044, Rev. 0, November, 2004.
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14. B. R. Kinney, "Surry Unit 2 Cycle 24 Startup Physics Testing Logs and Results", Memorandum MEMO-NCD-20110046-0-0, June, 2011.
15. J. G. Miller, "The CECOR Flux Map Analysis Code for a Movable In-core Detector System," Technical Report NE-1582, Rev 0, September 2009.

APPENDIX — STARTUP PHYSICS TEST SUMMARY SHEETS

Surry Power Station Unit 2 Cycle 24 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 Reactor (ZPR) Background						
ZPTR= $\frac{2 \times 10^{-9}}{1 \times 10^{-7}}$ to amps	background < ZPTR < POAH background = 1.52×10^{-11} amps POAH = 2.227×10^{-7} amps	N/A	<input checked="" type="checkbox"/> Yes <input type="checkbox"/> No	N/A	6/15/11 @ 1540	JRY gum
Pre-Critical Bench Test Results						
$\rho_c = 55.48, -45.49$ pcm (measured reactivity) $\rho_t = 55.2, -45.77$ pcm (predicted reactivity) %D = $\{(\rho_c - \rho_t)/\rho_t\} \times 100\%$ %D = $0.51\%, -0.62\%$	$\{(\rho_c - \rho_t)/\rho_t\} \times 100\% \leq 4.0\%$ The allowable range is set to the larger of the measured results or the pre-critical bench test. Pre-critical Bench Test Results ± 123 pcm Allowable range ± 123 pcm	N/A	<input checked="" type="checkbox"/> Yes <input type="checkbox"/> No	N/A	6/15/11 @ 1540	JRY gum
Core Beta Asymmetry (CBA) Test						
$(C_B)_M = 1588.3$ ppm (Adj. To design conds.)	$(C_B)_{ARO} = 1620 \pm 50$ ppm $\Delta(C_B)_{ARO} = (C_B)_M - (C_B)_{ARO} = 31.7$ ppm	$ \alpha C_B \times \Delta(C_B)_{ARO} \leq 1000$ pcm [T.S. 4.10.A] $\alpha C_B = -7.42$ pcm/ppm	<input checked="" type="checkbox"/> Yes <input type="checkbox"/> No	<input checked="" type="checkbox"/> Yes <input type="checkbox"/> No	6/15/11 @ 1540	JRY gum
Asymmetry (ISO) Test						
$(\alpha_T)_{ARO}^M = -1.860$ pcm/F	$(\alpha_T)_{ARO} = -1.632 \pm 2$ pcm/F $(\alpha_T)_{ARO}^M - (\alpha_T)_{ARO} = -0.228$ pcm/F	$\alpha_T^{ISO} \leq \alpha_M^{lim} - \alpha_T^{mod} + \alpha_T^{DOP}$ $\alpha_T^{ISO} \leq 3.70$ pcm/F where: (α_M^{lim}) : 6.0 pcm/F [COLR 3.4] $(\alpha_T^{mod})^2$: 0.5 pcm/F $(\alpha_T^{DOP})^2$: -1.80 pcm/F	<input checked="" type="checkbox"/> Yes <input type="checkbox"/> No	<input checked="" type="checkbox"/> Yes <input type="checkbox"/> No	6/15/11 @ 1614	JRY gum
Reactivity Ratio (RR) Test						
$I_B^{REF,M} = 1442.64$ pcm	$I_B^{REF} = 1486 \pm 10\%$ $100 \times (\text{Meas.} - \text{Des.})/\text{Des.} = -2.9\%$	N/A	<input checked="" type="checkbox"/> Yes <input type="checkbox"/> No	N/A	6/15/11 @ 1657	JRY gum

- References
- ETE-NAF-2011-0055, Rev. 0
 - Memorandum from C.T. Snow to E.J. Lozito, dated June 27, 1980
 - Westinghouse Report WCAP-7905, Rev. 1
 - ETE-NAF-2011-0037, Rev. 0
 - Calculation PM-1435, Rev. 0

Surry Power Station Unit 2 Cycle 24 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
<i>Control Rods - Control Rods (CR) - Test 1</i>						
$(C_B)^M_B =$ <u>1387.5</u> ppm	$(C_B)_B = 1422 + \Delta(C_B)_{ARO} \pm 30$ ppm $\Delta(C_B)_{ARO} = \underline{-31.7}$ ppm (from above) $(C_B)_B = \underline{1390.3} \pm 30$ ppm $(C_B)^M_B - (C_B)_B = \underline{-2.8}$ ppm	N/A	<input checked="" type="checkbox"/> Yes <input type="checkbox"/> No	N/A	19:50 6/15/11	BLH SAR
<i>Control Rods - Control Rods (CR) - Test 2</i>						
$(\alpha C_B)^M =$ <u>-7.18</u> pcm/ppm	$\alpha C_B = -7.51 \pm 0.75$ pcm/ppm $\Delta \alpha C_B = (\alpha C_B)^M - (\alpha C_B) = \underline{0.33}$ pcm/ppm	N/A	<input checked="" type="checkbox"/> Yes <input type="checkbox"/> No	N/A	19:50 6/15/11	BLH SAR
<i>Control Rods - Control Rods (CR) - Test 3</i>						
$I_A^{RS} =$ <u>332.1</u> pcm	$(I_A^{RS})^4 = \underline{335.3} \pm 100$ pcm Meas. - Des. = <u>-3.2</u> pcm	N/A	<input checked="" type="checkbox"/> Yes <input type="checkbox"/> No	N/A	20:15 6/15/11	BLH SAR
<i>Control Rods - Control Rods (CR) - Test 4</i>						
$I_C^{RS} =$ <u>763.8</u> pcm	$(I_C^{RS})^4 = \underline{815.2} \pm 15\%$ $100 \times (\text{Meas.} - \text{Des.}) / \text{Des.} = \underline{-6.3}\%$	N/A	<input checked="" type="checkbox"/> Yes <input type="checkbox"/> No	N/A	20:15 6/15/11	BLH SAR
<i>Control Rods - Control Rods (CR) - Test 5</i>						
$I_{SA}^{RS} =$ <u>912.9</u> pcm	$(I_{SA}^{RS})^4 = \underline{927.9} \pm 15\%$ $100 \times (\text{Meas.} - \text{Des.}) / \text{Des.} = \underline{-1.6}\%$	N/A	<input checked="" type="checkbox"/> Yes <input type="checkbox"/> No	N/A	20:15 6/15/11	BLH SAR
<i>Control Rods - Control Rods (CR) - Test 6</i>						
$I_D^{RS} =$ <u>1008.6</u> pcm	$(I_D^{RS})^4 = \underline{1050.9} \pm 15\%$ $100 \times (\text{Meas.} - \text{Des.}) / \text{Des.} = \underline{-4.0}\%$	N/A	<input checked="" type="checkbox"/> Yes <input type="checkbox"/> No	N/A	20:15 6/15/11	BLH SAR
<i>Control Rods - Control Rods (CR) - Test 7</i>						
$I_{SB}^{RS} =$ <u>988.2</u> pcm	$(I_{SB}^{RS})^4 = \underline{1045.9} \pm 15\%$ $100 \times (\text{Meas.} - \text{Des.}) / \text{Des.} = \underline{-5.5}\%$	N/A	<input checked="" type="checkbox"/> Yes <input type="checkbox"/> No	N/A	20:15 6/15/11	BLH SAR
<i>Control Rods - Control Rods (CR) - Test 8</i>						
$I_{Total}^{RS} =$ <u>5448.3</u> pcm	$(I_{Total}^{RS})^4 = \underline{5661.1} \pm 10\%$ $100 \times (\text{Meas.} - \text{Des.}) / \text{Des.} = \underline{-3.8}\%$	N/A	<input checked="" type="checkbox"/> Yes <input type="checkbox"/> No	N/A	20:15 6/15/11	BLH SAR

References 1.) ETE-NAF-2011-0055, Rev. 0

2.) Memorandum from C.T. Snow to E.J. Lozito, dated June 27, 1980

3.) Westinghouse Report WCAP-7905, Rev. 1

4.) ETE-NAF-2011-0037, Rev. 0

5.) Calculation PM-1435, Rev. 0

Surry Power Station Unit 2 Cycle 24 Startup Physics Test Summary Sheet - Formal Tests (Page 3 of 6)

Measured Value	Design Criteria	Acceptance Criteria	Design Criteria Met	Acceptance Criteria Met	Date/Time of Test	Preparer/Reviewer		
Map Power Level (% Full Power) = <u>28.7</u>								
Max Relative Assembly Power, %DIFF (M-P)/P								
%DIFF = <u>4.4</u> % for $P_1 \geq 0.9$ <u>4.3</u> % for $P_1 < 0.9$	$\pm 10\%$ for $P_1 \geq 0.9$ $\pm 15\%$ for $P_1 < 0.9$ ($P_1 = \text{assy power}$) ^{1,2}	N/A	<input checked="" type="checkbox"/> Yes <input type="checkbox"/> No	N/A	4/17/11 03:37	BRH		
Nuclear Enthalpy Rise Hot Channel Factor, FAH(N)								
FAH(N) = <u>1.521</u>	N/A	$FAH(N) \leq 1.56(1+0.3(1-P))$ [COLR 3.7]	N/A	<input checked="" type="checkbox"/> Yes <input type="checkbox"/> No				
Total Heat Flux Hot Channel Factor, FQ(Z)								
Peak $F_Q(Z)$ Hot Channel Factor = <u>2.174</u>	N/A	$F_Q(Z) \leq 5 \cdot K(Z)$ [COLR 3.7] Minimum Margin to COLR Limit = <u>56.5%</u>	N/A	<input checked="" type="checkbox"/> Yes <input type="checkbox"/> No				
Maximum Positive Incore Quadrant Power Tilt								
Tilt = <u>1.0062</u>	$\leq 1.02^3$	N/A	<input checked="" type="checkbox"/> Yes <input type="checkbox"/> No	N/A				
Rodded Flux Map Criterion (If either criterion is met, a rodded flux map $\leq 30\%$ power with rods at the insertion limit is not required) ⁵								
Max RPD %DIFF = <u>4.4</u> % for $P > 0.9$ OR Synthesized FdH at limiting power = <u>N/A</u>	N/A	$\leq 20.3\%$ $FAH \leq 1.56(1+0.3(1-P))$ [COLR 3.7]	N/A	<input checked="" type="checkbox"/> Yes <input type="checkbox"/> No	4/17/11 03:37	BRH		

- References 1.) ETE-NAF-2011-0055, Rev. 0
 2.) Memorandum from C.T. Snow to E.J. Lozito, dated June 27, 1980
 3.) Westinghouse Report WCAP-7905, Rev. 1
 4.) ETE-NAF-2011-0037, Rev. 0
 5.) Calculation PM-1435, Rev. 0

Surry Power Station Unit 2 Cycle 24 Startup Physics Test Summary Sheet - Formal Tests (Page 4 of 6)

Measured Value	Design Criteria	Acceptance Criteria	Design Criteria Met	Acceptance Criteria Met	Date/Time of Test	Preparer/Reviewer		
Map Power Level (% Full Power) = <u>65.14</u>								
Max Relative Assembly Power, %DIFF (M-P)/P								
%DIFF = <u>3.2</u> % for $P_1 \geq 0.9$ <u>-3.5</u> % for $P_1 < 0.9$	$\pm 10\%$ for $P_1 \geq 0.9$ $\pm 15\%$ for $P_1 < 0.9$ (P_1 = assy power) ^{1,3}	N/A	<input checked="" type="checkbox"/> Yes <input type="checkbox"/> No	N/A	4/12/11 0818 RAH 4/12/11 JBL 4/12/11			
Nuclear Enthalpy Rise Hot Channel Factor, F _{ΔH} (N)								
F _{ΔH} (N) = <u>1.477</u>	N/A	$F_{\Delta H}(N) \leq 1.56(1+0.3(1-P))$ [COLR 3.7]	N/A	<input checked="" type="checkbox"/> Yes <input type="checkbox"/> No				
Total Heat Flux Hot Channel Factor, F _Q (Z)								
Peak F _Q (Z) Hot Channel Factor = <u>1.924</u>	N/A	$F_Q(Z) \leq (2.5/P)^{0.5} K(Z)$ [COLR 3.7] Minimum Margin to COLR Limit = <u>49.9%</u>	N/A	<input checked="" type="checkbox"/> Yes <input type="checkbox"/> No				
Maximum Positive Incore Quadrant Power Tilt								
Tilt = <u>1.0045</u>	$\leq 1.02^3$	N/A	<input checked="" type="checkbox"/> Yes <input type="checkbox"/> No	N/A				

- References 1.) ETE-NAF-2011-0055, Rev. 0
 2.) Memorandum from C.T. Snow to E.J. Lozito, dated June 27, 1980
 3.) Westinghouse Report WCAP-7905, Rev. 1
 4.) ETE-NAF-2011-0037, Rev. 0
 5.) Calculation PM-1435, Rev. 0

Surry Power Station Unit 2 Cycle 24 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
Min. Heat Flux Map $\geq 15\%$ Power $\leq 100\%$						
Map Power Level (% Full Power) = <u>99.81</u>					7/5/11 0853	CNC/DJA
Max Relative Assembly Power, %DIFF (M-P)/P						
%DIFF = <u>2.6</u> % for $P_i \geq 0.9$ <u>-3.7</u> % for $P_i < 0.9$	$\pm 10\%$ for $P_i \geq 0.9$ $\pm 15\%$ for $P_i < 0.9$ (P_i = assy power) ^{1,3}	N/A	<input checked="" type="checkbox"/> Yes <input type="checkbox"/> No	N/A		
Nuclear Enthalpy Rise Hot Channel Factor, FAH(N)						
FAH(N) = <u>1.437</u>	N/A	FAH(N) $\leq 1.56(1+0.3(1-P))$ [COLR 3.7]	N/A	<input checked="" type="checkbox"/> Yes <input type="checkbox"/> No		
Total Heat Flux Hot Channel Factor, FQ(Z)						
Peak $F_q(Z)$ Hot Channel Factor = <u>1.836</u>	N/A	$F_q(Z) \leq (2.5/P)^{1/4} K(Z)$ [COLR 3.7] Minimum Margin to COLR Limit = <u>26.7%</u>	N/A	<input checked="" type="checkbox"/> Yes <input type="checkbox"/> No		
Maximum Positive Incore Quadrant Power Tilt						
Tilt = <u>1.0065</u>	$\leq 1.02^3$	N/A	<input checked="" type="checkbox"/> Yes <input type="checkbox"/> No	N/A		

- References 1.) ETE-NAF-2011-0055, Rev. 0
 2.) Memorandum from C.T. Snow to E.J. Lozito, dated June 27, 1980
 3.) Westinghouse Report WCAP-7905, Rev. 1
 4.) ETE-NAF-2011-0037, Rev. 0
 5.) Calculation PM-1435, Rev. 0

Surry Power Station Unit 2 Cycle 24 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
ROSI Flow Measurement						
F_{Total} 295,495 gpm	N/A	$F_{Total} \geq 276000$ gpm [COLR 3.8] ≥ 273500 gpm TS. 3.12	N/A	<input checked="" type="checkbox"/> Yes <input type="checkbox"/> No	6/28/11 1444	AP / CNC

- References
- 1.) ETE-NAF-2011-0055, Rev. 0
 - 2.) Memorandum from C.T. Snow to E.J. Lozito, dated June 27, 1980
 - 3.) Westinghouse Report WCAP-7905, Rev. 1
 - 4.) ETE-NAF-2011-0037, Rev. 0
 - 5.) Calculation PM-1435, Rev. 0