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Florida Power & Light Company, 6351 S. Ocean Drive, Jensen Beach, FL 34957

January 12, 2000

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U. S. Nuclear Regulatory Commission Attn: Document Control Desk Washington, DC 20555

Re: St. Lucie Unit 1 Docket 50-335 Cycle 16 Startup Physics Testing Report

Pursuant to St. Lucie Unit 1 Technical Specification 6.9.1.1, the enclosed summary report of plant startup and power escalation testing for Cycle 16 is hereby submitted.

Should you have any questions, please contact us.

Very truly yours,

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J. A. Stall Vice President St. Lucie Plant

JAS/spt

Enclosure: St. Lucie Unit 1, Cycle 16 Reactor Startup Physics Testing Report

cc: Regional Administrator, USNRC, Region II Senior Resident Inspector, USNRC, St. Lucie Plant

# ST. LUCIE UNIT 1 CYCLE 16



# STARTUP PHYSICS TESTING REPORT

(D/RE/930584-R0)

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Reviewed

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SEE FOLLOWING PAGE. Reviewed\_ Date K. Nordmeyer for C. O'Farrill Nuclear Fuel, ENG

Approved\_

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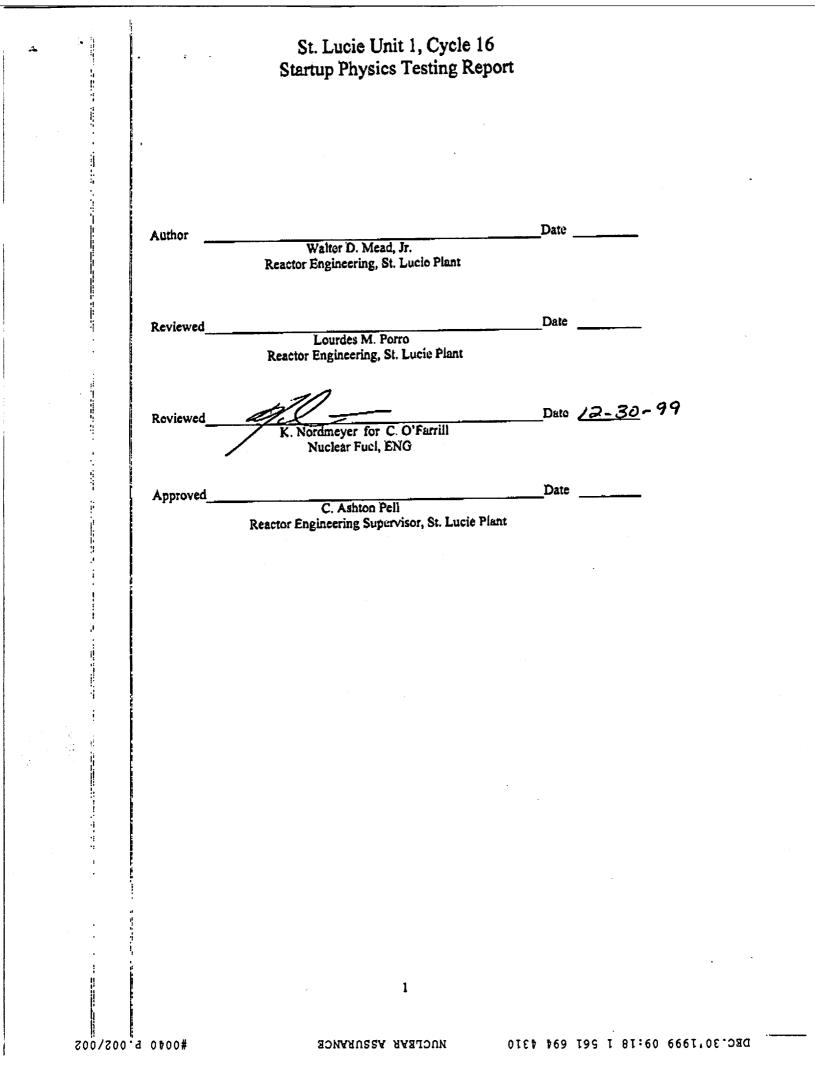
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Date 12/31/55

C. Ashton Pell Reactor Engineering Supervisor, St. Lucie Plant



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#### I. Introduction

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The purpose of this report is to provide a description of the fuel design and core load, and to summarize the startup testing performed at St. Lucie Unit 1 following the cycle 16 refueling outage. The Startup testing verifies key core and plant parameters are as predicted. The major parts of this testing program include:

- 1) Initial criticality following refueling,
- 2) Zero power physics testing, and
- 3) Power ascension testing

During cycle 15 operation, an increase in iodine chemistry trending indicated the failure of one or more fuel pins. Fuel sipping and ultrasonic inspections were performed during the cycle 16 refueling outage. This testing confirmed the presence of failed rods in fuel assemblies residing in very low power locations in the cycle 15 core. Of these failures, 7 of 8 assemblies with failed fuel rods were scheduled for discharge to the spent fuel pool. The remaining assembly with a failed fuel fuel rod was repaired for re-use in the cycle 16 loading pattern. The root cause of the failures was determined by the fuel vendor to be grid-to-rod fretting.

This Cycle 16 Startup Report is being submitted in accordance with Technical Specification 6.9.1.1 as the result of the use of:

- 1) a repaired and reconstituted, twice-burned fuel assembly that experienced a fuel pin breach near the end of cycle 15 operation and,
- 2) an assembly substituted for a fuel bundle that suffered grid strap damage in the spent fuel pool during fuel handling operations.

The test data collected during startup and summarized in this report indicates there were no observable changes in neutronic or thermal-hydraulic parameters and thus there was no significant impact to the performance of the unit. The test data satisfied all acceptance criteria and demonstrated general conformance to predicted performance.

#### II. Cycle 16 Fuel Inspection and Repair

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During the refueling outage, core-wide sipping of fuel used in cycle 15 was performed via a wet sipping system installed in the refueling machine mast. In this inspection campaign, eight fuel assemblies were identified with possible fuel failures; one twice-burned assembly (T-01) scheduled for reinsertion and seven thrice-burned assemblies scheduled to be discharged (S-30, S-32, S-34, S36, S-44, S-45, and S-48). The seven S-batch assemblies were all on the core periphery in low power locations during cycle 15 operation.

Ultrasonic inspections of these assemblies pinpointed fuel pins having the greatest probability of failure. These assemblies were reconstituted and the fuel pins subjected to further testing. Inspection of suspect rods using eddy-current and visual techniques resulted in identifying one failed rod out of four inspected in assembly T-01, four failed rods and two rods indicating wear out of nine rods inspected in assembly S-45, and one failed rod out of four inspected in assembly S-36.

Assembly T-01 was found to have one (1) leaking fuel pin in location E-2. The failed  $UO_2$  pin has been reconstituted with a stainless steel filler rod, as shown in Figure 1. The final as-built configuration of assembly T-01 is bounded by the calculations performed in Reference 1 and satisfies all of the requirements in the guidelines provided by the Nuclear Fuels department. The fuel vendor, Seimen's Power Corporation (SPC), has stated in Reference 2 that it is acceptable to return assembly T-01 to the reactor for continued service in Cycle 16. The S-batch assemblies were discharged to the spent fuel pool for storage.

The results of SPC's evaluation support the conclusion that the failures observed do not represent a reactor safety or a fuel operability concern. This conclusion is further strengthened by the knowledge that the rods at greatest risk for grid-to-rod fretting are high exposure, low power rods operating at the reactor core's edge and that the RCS activity of cycle 15 and prior cycles has remained at levels well below Technical Specification limits.

In addition to the repairs made to T-01, a second assembly, S-76, was replaced with fuel bundle S-50 subsequent to the original core design loading pattern. S-76 resided in the spent fuel pool during cycle 15 operation and was inspected prior to use in cycle 16. The inspection revealed damage to a spacer grid strap necessitating replacement of the assembly. The assembly S-50 is equivalent to the assembly S-76 in terms of physical dimension and neutronic characteristics. The impact on the core design parameters and the operational data was determined to be insignificant. All the reload analyses continued to remain applicable for the revised core loading pattern (Reference 12)

#### III. Cycle 16 Fuel Design

The cycle 16 reload consists entirely of fuel manufactured by Siemens Power Corporation (SPC). The 217 assemblies of the cycle 16 core are comprised of fuel from four batches. Of these, 76 are fresh assemblies (Batch X), 76 are once-burned batch T and Batch U assemblies, and 65 are twice-burned assemblies from batches T and S. Table 1 provides enrichment information for the cycle 16 reload sub-batches. The design supports a cycle length between 12,480 EFPH and 12,858 EFPH based on a cycle 15 exposure of 13,600 to 14,370 EFPH.

This is the tenth cycle of operation utilizing gadolinium in the form of  $Gd_2O_3$ , as a burnable neutron absorber. Batch X assemblies consist of enriched UO<sub>2</sub> fuel rods and UO<sub>2</sub>-Gd<sub>2</sub>O<sub>3</sub> bearing rods (gadolinia burnable absorber fuel rods). UO<sub>2</sub> fuel rods have a central zone enrichment of 4.15 and 4.45 w/o U<sub>235</sub>, whereas the UO<sub>2</sub>-Gd<sub>2</sub>O<sub>3</sub> rods have a central zone of 4 to 8 w/o Gd<sub>2</sub>O<sub>3</sub> dispersed in a 2.6 to 3.5 w/o U<sub>235</sub> carrier. The total batch burnable absorber requirement for fresh fuel is 992 Gd<sub>2</sub>O<sub>3</sub> rods. The mechanical design of Batch X fuel is essentially the same as that of Batches U & T (Cycle 15), Batch T (Cycle 14) and Batch S (Cycle 13) reload fuel. However the length of the axial blankets (UO<sub>2</sub>) rods and cutback regions (Gadolinia rods) have changed for Batch X. Also the fuel assembly design for Batch X fuel utilizes radial enrichment zoning.

The entire cycle 16 fuel load, batches S, T, U and X, consist of the debris resistant fuel assembly design first implemented in cycle 11. This design has long fuel rod lower end caps which provides protection against debris-induced-fretting in the lower end-fitting region.

The cycle 16 core map is represented in Figure 2. The assembly serial numbers and control element assembly (CEA) serial numbers are given for each core location. A low-leakage fuel management scheme similar to that of Cycle 15 is utilized in the Cycle 16 core design. There are no vessel fluence reduction assemblies (VFRA) in the Cycle 16 core, similar to Cycle 15 core design. The Cycle 16 core loading pattern is 90 degrees rotationally symmetric.

#### IV. CEA Drop Time Testing

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Following the core reload and prior to the approach to criticality, CEA drop time testing was performed. The purpose of this test is to demonstrate that the reactivity insertion as a function of time is bounded by the CEA scram worth curve assumed in the FSAR analysis.

The objective of this test is to measure the time of insertion from the fully withdrawn position (upper electrical limit) to the 90% inserted position under hot, full flow conditions. The average CEA drop time was found to be 2.28 seconds with maximum and minimum times of 2.52 seconds and 2.18 seconds, respectively. All drop times were within the 3.1 second requirement of Technical Specification 3.1.3.4 and the reload PC/M 99-016 requirements (References 10 & 13).

#### V. Approach to Criticality

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The approach to criticality involved diluting from a non-critical boron concentration of 1592 PPM to a predicted critical boron concentration of 1383 PPM. Inverse count rate ratio (ICRR) plots were maintained during the period of dilution using wide range Nuclear Instrument Channels B and D. Refer to Figures 3 and 4 for ICRR information. Table 2 summarizes the dilution rates and times, as well as beginning and ending boron concentrations.

Initial criticality for St. Lucie Unit 1, Cycle 16, was achieved on October 16, 1999 at 1000 with CEA group 7 at 60 inches withdrawn and all other CEAs at the all-rods-out (ARO) position. The actual critical concentration was measured to be 1393 PPM.

#### VI. Zero Power Physics Testing

To ensure that the operating characteristics of the cycle 16 core were consistent with the design predictions, the following tests were performed:

- 1) Reactivity Computer Checkout;
- 2) Dual CEDM Symmetry Test;
- 3) All Rods Out Critical Boron Concentration;
- 4) Isothermal Temperature Coefficient Measurement; and
- 5) CEA Group Rod Worth Measurements.

Proper operation of the reactivity computer was verified through the performance of two tests. In the first, reactor power was elevated sufficiently high to ensure maximum sensitivity of the reactivity measuring system and at the same time preserve adequate margin to the point of adding heat. The second test ascertains the response to a known value of positive or negative reactivity by measuring the values of positive or negative reactor periods that result. The results of the reactivity computer checkout were compared to the appropriate predictions supplied in the reload PC/M 99-016. Satisfactory agreement was obtained.

Verification of proper CEA latching is confirmed through the use of a CEA symmetry test for those groups which contain dual CEAs (shutdown banks A&B). The prescribed acceptance criteria is that the reactivity measured for each dual CEA shall be within  $\pm 15.0$  pcm of the average reactivity measured all dual CEAs within the entire group. The acceptance criterion was satisfied and it was concluded there were no unlatched CEAs in either shutdown group.

The measurement of the all-rods-out (ARO) critical boron concentration was performed. The measured value was 1434 PPM which compared favorably with the design value of 1426 PPM (Reference 7). This was within the acceptance limits of  $\pm$  50 PPM.

The measurement of the isothermal temperature coefficient was performed and the resulting moderator temperature coefficient (MTC) was derived. The MTC was determined to be 1.15 pcm/°F which fell well within the acceptance criteria of  $\pm 2.0$  pcm/°F of the design MTC of 0.99 pcm/°F (corrected). This satisfies the Unit 1 Technical Specification which states that the MTC shall be less positive than 7.0 pcm/°F when reactor power is less than 70% power.

Rod worth measurements were performed using the rod swap methodology. This method involves exchanging a reference group, which is measured by the boration dilution technique, with each of the remaining test groups. A comparison of the measured and design CEA reactivity worths is provided in Table 3. The following acceptance criteria applies to the measurements made:

1) The measured value of each test group, or supergroup measured, is within  $\pm 15\%$  or  $\pm 100$  pcm of its corresponding design CEA worths, whichever is greater and,

2) The worth of the reference group and the total worth for all the CEA groups measured is within  $\pm 10\%$  of the total design worth.

All acceptance criteria were met.

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#### VII. Power Ascension Program

During power ascension, the fixed incore detector system is utilized to verify that the core is loaded properly and there are no abnormalities occurring in various core parameters (core peaking factors, linear heat rate, and tilt) for power plateaus at 30%, 45%, and 98% rated thermal power.

A summary of the flux maps at the 30%, 45% and 98% power plateaus is provided in Figures 5, 6 & 7. These flux maps are used for comparing the measured power distribution with the predicted power distribution. For the purposes of the power ascension, the acceptance criteria requires the root mean square (RMS) value of the power deviation be less than or equal to 5%. In addition, for the 30% and 98% plateaus, the individual assembly powers should be within 10% of the predicted power (both) and the relative power density (RPD) should be within 0.1 RPD units of predicted for the 30% power case. These criteria were satisfied.

When the unit reached full power, a calorimetric was performed in accordance with reference 8 for the purpose of calculating the RCS flow rate. The RCS flow rate was determined to have increased from 407,206 gpm (measured in cycle 15) to 409,240 gpm in cycle 16 (reference 8). This measured flow was well in excess of the Technical Specification minimum of 365,000 gpm and well within the flow measurement uncertainty.

Within seven effective full power days of attaining the equilibrium value of 100% power, a hot full power (HFP) MTC test was performed by maintaining power constant and varying temperature. The center CEA (7-1) was operated to permit compensation of the resulting reactivity changes. The HFP MTC was measured to be -6.21 pcm/°F. This satisfied the acceptance criteria to verify compliance with Technical Specification 3.1.1.4 to have a measured MTC less positive than +2.0 pcm/°F while thermal power is greater than 70%. The power coefficient was not measured.

#### VIII. Summary

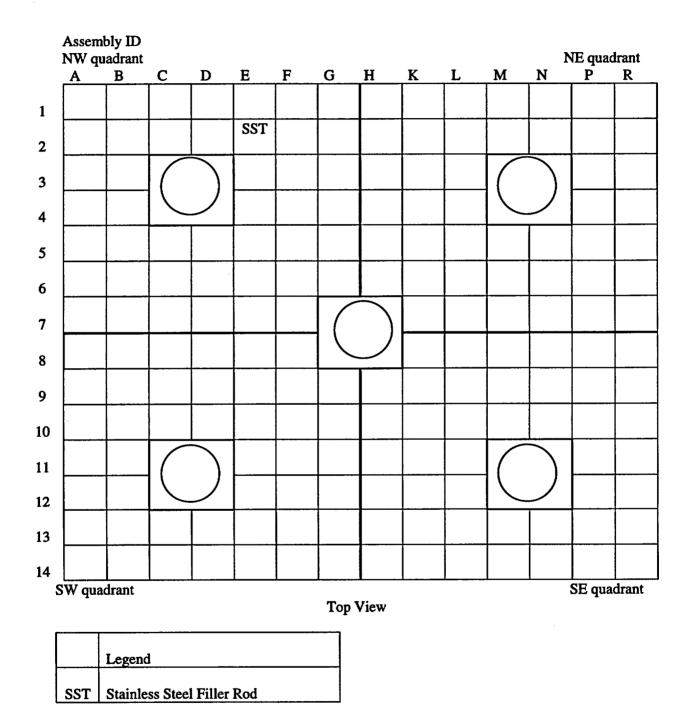
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Compliance with the applicable Unit 1 Technical Specifications was satisfactory and all acceptance criteria were met. The test data supports a conclusion that the repairs made to fuel assembly T-01 and the replacement of assembly S-76 with assembly S-50 had no significant effect on core behavior. The physics and thermal-hydraulic performance test data satisfied all acceptance criteria and demonstrated general conformance to predicted performance.

#### IX. <u>References</u>

- 1) FPL Calculation PSL-1FJF-99-141, Rev 1, "St. Lucie Unit 1 Cycle 16 Region T Bounding Fuel Pin Reconstitution"
- 2) SPC Letter RIW:99:220, "Acceptability of Repaired Assembly T01 for Use in St. Lucie Unit 1 Cycle 16" September 29, 1999.
- 3) "Initial Criticality," Pre-Operational Procedure 1-3200088
- 4) "Reload Startup Physics Testing," Pre-Operational Procedure 3200091
- 5) "Reactor Engineering Power Ascension Program," Pre-Operational Procedure 3200092
- 6) St. Lucie Unit 1 Technical Specifications.
- 7) St. Lucie Unit 1 Cycle 16 Reload PC/M #99016, CRN 99016-8628, Table 2.3.1
- 8) "RCS Flow Determination By Calorimetric Procedure," St. Lucie Unit 1 Operating Procedure 1-0120051
- St. Lucie Unit 1 Cycle 16 Reload PC/M #99016, Rev. 2, Attachment 1, Page 28 of 30.
- 10) ENG Calculation PSL-1FJF-93-025, Revision 0, "PSL1 CEA Drop Time Criteria for 90% Insertion"
- 11) "At Power Determination of Moderator Temperature Coefficient and Power Coefficient," Operating Procedure 3200051
- 12) St. Lucie Unit 1 Cycle 16 Reload PC/M #99016, Rev. 2, Page 18 of 62.
- 13) "Periodic Rod Drop Time Test and CEA Position Functional Test," Operating Procedure 1-0110054

Figure 1 As-built Reconstitution of Assembly T1



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# Figure 2 Cycle 16 Core Loading Pattern

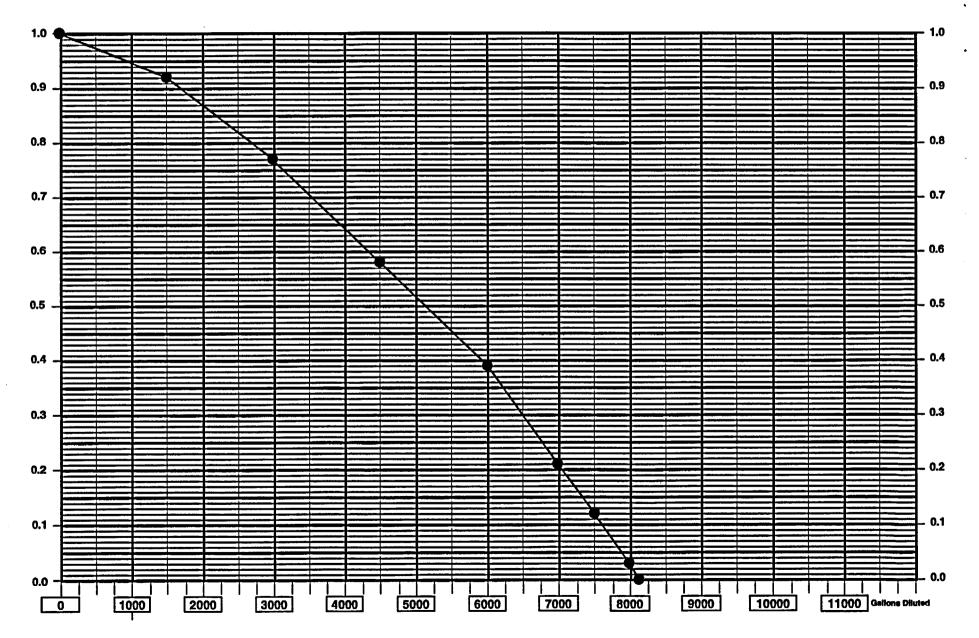
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#### St. Lucie Unit 1, Cycle 16 Startup Physics Testing Report Figure 3 Inverse Count Ratio Plot - Channel B

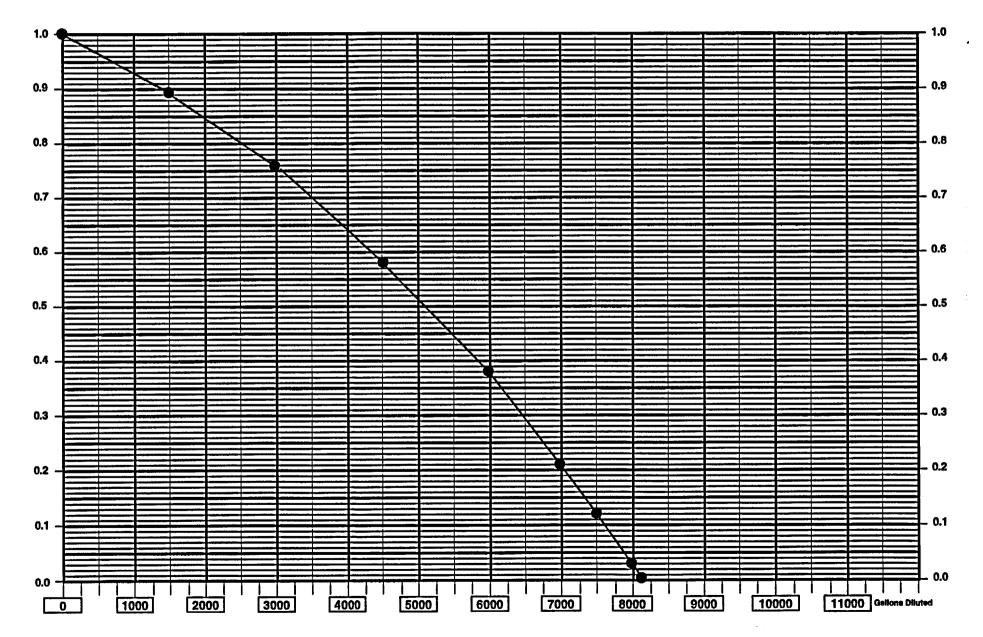
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#### St. Lucie Unit 1, Cycle 16 Startup Physics Testing Report Figure 4 Inverse Count Ratio Plot - Channel D

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Power D			4.350 4.350 4.160 4.1	210 1.120 1.135 1.135 1.135 -0.015	200 11879 6.4 0.604	188 1.330 1.336 1.326 0.004	117 117 1151 151 151 151 151	159 1.346 1.125 1.	144 1.136 1.197 1.197 2.9	127 1160 1120 1120	110 1.400 0.999 0.999 1.8 0.403	93 1.160 1.122 1.122 3.3 6.035	74 1.140 1.106 1.106 1.5	61 1.370 1.1377 2.1	46 1.180 1.148 1.148 2.7 0.032	32 1.360 1.328 1.328 2.4		10 1.140 1.134 0.006	4 3 0.260 0.265 0.365 0.365 0.365 0.365 0.365	
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			•	2112 8.400 8.467 -0.807 -1.7	202 1.130 1.157 1.157 -0.027	190 1.140 1.156 1.156	176 1.100 1.105 -0.5	161 1.060 1.056 1.056 0.4	146 1.120 1.164 1.164 1.164	129 1.360 1.327 2.4	112 1.110 1.075 3.2 6.035	95 1.370 1.338 1.338 8.042	78 1.130 1.105 1.105 2.2 4.025	63 1.076 1.056 1.856 1.3	46 1.110 1.099 1.0			12 0.400 0.407 0.407 -1.7		
•	Her 2 Alterna		•	213 0.250 0.292 0.291 0.291		1	1210 1210 1210 1210	162 1.090 1.099 1.099 1.099	147 1.340 1.331 0.7 0.7	130 1.176 1.176 1.148 1.148	113 1.360 1.236 0.024 1.9	96 1.180 1.151 1.151 2.5 0.029	77 1.350 1.333 1.333 1.330 1.3000 1.3000 1.3000 1.3000 1.3000 1.3000 1.3000 1.30000000000	64 1.110 1.105 0.005	6 1.336 1.336 1.336 1.4566	35 1.190 1.207 1.40 1.4	23 1.430 1.447 1.447	13 0.290 0.292 0.292 0.292		
	Design: Pour paols	280		×	204 0.390 0.410 0.410	192 11400 11152 11152 11152	178 1.170 1.207	163 11130 11153 10 <b>-</b> 002	148 1480 1.100 1.100 1.100	131 1.330 1.338 0.002	11.140 11.240 1.124 1.124 1.124	77 1.340 1.326 1.0.0	80 1.190 1.101 -0.001 -0.001	65 11140 11156 11156 114	50 1.180 1.269 1.269 1.25	36 1.110 1.153 1.153 1.153	24 0.400 0.405 0.405 -2.006			
	8				¥	193 0.390 0.403 0.403		164 1.130 1.155	149 1.160 1.186 2.2 <b>-</b> 0.626	132 11060 11074 113	115 1160 11060 11075 114	98 11860 11874 11874 11874	81 1.170 1.186 1.186 -0.016	66 1.130 1.157 4.027	51 1.010 1.048 1.048 -3.8	37 6.390 0.419 0.419 0.419			2.26%	1
	BEACON BEACON BLANDER BLANDER BLANDER BLANDER BLANDER BLANDER BLANDER BLANDER BLANDER BLANDER BLANDER BEACON BEACO	200				×	190 8.280 8.292 8.292 4.3	165 0.390 0.467 0.467 0.467	150 0.67 0.697 0.697	11 1100 11100 11100	11 111 111 111 111 111 111 111 111 111	99 1.110 1.135 1.135 4.025	82 0.680 0.696 0.696 1.4	67 6.190 0.467 0.467 4.4	52 0.250 0.251 0.251 0.251				iation:	
	Measured: Source Power Lowel Exposure CFA Bosition	Boron Cone.							۲ ۱35	0.250 0.365 -0.015 5.0 118	0.350 0.363 -0.013 -0.0	0.350 0.963 -0.013 -3.7 -84	0.250 0.260 -8.810					•	RMS Deviation:	

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Box # Messured Design X DHf.

St. Lucie Unit 1, Cycle 16 Startup Physics Testing Report

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		·			•	166 0.290 0.295 0.295 -1.7 -1.7	151 0.400 0.410 0.410 -0.010	136 0.680 0.699 0.699 -2.8	119 1.110 1.111 1.111 1.111 1.111 1.111 1.111	102 1.210 1.239 1.239 2.4	85 1.110 1.133 4.023	68 0.480 0.700 	53 0.400 0.410 -4.010 -2.5	38 6.280 6.295 4.015 -5.4				
	← z			°	181 6.400 6.413 6.413 .4.2	167 1.020 1.046 -0.026	152 1.130 1.153 -0.023 -2.0	137 1.170 1.183 1.183 -0.013	120 1.060 1.073 1.073 -0.013 -1.2	103 1.076 1.077 1.077 -0.007	86 11860 11873 -4013	69 1.160 1.183 -0.023	54 1.120 1.151 1.151 -2.8	39 1.010 1.045 1.045 -3.5	25 0.400 0.411 -4.611			
			•	194 0.400 111.0.1 11.0.0 1.2.7	182 1.120 1.151 -4.032	1 1 1 1 1	153 1140 1.153 1.15 1.1-	138 1.100 1.100 1.100 0.000	121 1.330 1.332 0.005 0.6	104 1.240 1.232 1.232 0.005	#7 1.330 1.324 1.324 8.8006	70 1.090 1.095 -0.006	55 1.130 1.145 1.145 1.7		26 1.120 1.152 1.152 -0.802 -2.9	14 0.400 0.413 4.413 3.2		
		<b>u</b>	205 0.295 0.295 0.17 2.1.7	195 186 100.0 20.0 20.0 20.0 20.0 20.0 20.0 20.	183 1.180 1.202 1.302 4.022	169 1.320 1.333 1.013 1.0	154 1.180 1.184 1.184 0.4	139 1.340 1.330 1.330 1.330	122 1.170 1.150 1.150 1.170	105 1.150 1.135 1.135 4.015	1140 1147 1147 1147	71 1.330 1.325 0.002 0.2	56 1.090 1.095 -0.008	41 0.52.0 1.333 0.01.0 0.1.0	27 1.1940 1.204 -0.824	15 1.1020 1.1020 1.1026 - 4.126	s 0.290 0.295 -0.065 -1.7	
		•	206 6.400 6.416 -4.010 -2.5	21 121 1211 1211 1200 12	1140 11140 11140 11140 11140 11140	176 1.190 1.095 0.002 0.2	155 1.070 1.058 1.058 4.012 1.1	140 1.120 1.196 1.196 1.3	123 1.360 1.326 1.326 0.034 2.5	106 1.100 1.077 1.072 2.1	8 9251 9251 9125 91	72 1.120 1.106 1.106 1.106	57 11.860 11.858 0.2 0.2	42 1.180 1.184 -0.904	25 1.159 1.153 4.003 4.3	16 1.140 1.153 4.013	• •.400 •.410 •.410 •.410	
	Ģ-		207 9.690 8.700 8.700 1.4	197 11.170 11.1.1.1.1.1.1.1.1.1.1.1.1.1.1.1.1.1.1			156 1.126 1.106 1.106 1.3		124 1.130 1.101 2.6 2.6	167 1.340 1.297 3.2 3.2	90 1.130 1.103 1.103 2.4	73 1.340 1.315 0.025	58 1.120 1.106 1.3	43 1.350 1.330 1.330 1.5	29 1.116 1.100 0.910 0.9	17 1.180 1.183 0. <b>4</b> .003	6.090 6.099 -1.3 -0.009	599
45% Power	I- 	214	206 1.120 1.133 -4.613	198 1.070 1.070 1.070 1.070 1.040	186 1130 11324 11324 11324	172 1.160 1.167 1.167 1.1	157 1.360 1.325 0.625 1.9	142 1.130 1.103 1.103 2.4	125 1.160 1.136 0.030 2.6	106 1.640 1.640 1.009 3.0	91 1.160 1.130 0.030 2.6	74 11130 11191 8.029 2.6	59 1.360 1.326 1.326 2.5	44 1.170 1.150 1.7 0.020	30 1.340 1.322 1.322 1.3	18 1.080 1.073 0.6 4.007	1.139 1.133 -0.803	117 <b>- 1</b> 2
Figure 6 istribution -	-د بد بو	1366 1366 1366 137 137 137 137 137 137 137 137 137 137	209 1.230 1.230 1.230 1.230 1.230	199 1.080 1.077 1.077 1.077	187 1.240 1.232 2.6008	173 1.250 1.235 1.135 1.1	158 1.160 1.077 0.023 2.1	143 1.330 1.297 1.297 2.5	126 1.040 1.069 1.069 3.0	109 0.92 0.897 2.5	92 1.840 1.809 3.0	75 1.240 1.297 3.2 0.043	60 1.110 1.077 3.0 3.0	45 1.260 1.235 0.025 2.0	31 1.260 1.232 1.232 2.2	1000 11 1000 11000 11 1000 110000 110000 11000 11000 110000 1100000 1100000 11000000	11240 11239 81 8401	2 0.560 0.560 0.360 0.360
Figure 6 Power Distribution	2.	216 216 4.0000 4.00000 4.0000 4.0000 4.00000 4.00000 4.00000 4.00000000	210 1.126 1.126 1.13 2.1- 2.1-	200 1.079 1.073 1.073 -0.3	I	,			127 1.160 1.160 1.130 2.6 0.000	118 1.840 1.809 1.809 2.2	93 1.170 1.130 8.840	76 1.140 1.103 8.007 3.2	61 1360 1325 0.035 2.6	46 1.170 1.147 1.147 2.0		5	1130 1133 1133 1133 1133 1133 1133 1133	1.002 0.360 1.002 0.367 1.0 4
	٤,	A .	211 6.690 0.699 0.699 0.699	201 271.1 1.183 1.183 1.1.	11: 11:00 11:100	6.010	160 1.120 1.196 1.196 1.3		128 1.140 1.163 1.163 3.2	111 1.340 1.297 1.297 3.3	94 1.140 1.161 3.4				33 1.110 1.1996 1.1 0.012	21 1.136 0.6 1.135	11 6.700 0.700 0.0	
			212 0.400 0.410 0.410 0.410	202 1.136 1.153 1.153 1.023	061 06411 153 1400-11-	176 1.100 1.104 1.104	161 1.860 1.853 0.802 0.802	146 11126 11126 11106	129 1.360 1.325 0.035 2.6	112 1.110 1.077 0.033 3.0	95 1.360 1.336 1.336 2.5 0.034	78 1.136 1.106 2.1 2.1	63 1.876 1.858 1.1 1.1				12 0.400 0.410 -2.5	
Ň	w 2 Alacha	►	213 0.290 0.295 0.295 -1.7	203 1.000 1.000 1.006 2.5.	191 10111 2004 0.51	17 1510 1511 1500 15							64 1.110 1.104 0.5 0.006				13 6.295 	
	Centrol Control Contro		<b>&gt;</b>	204 0.400 0.413 0.413 0.413	191 1.130 1.132 1.152	178 1.170 1.362 1.362	163 1130 1149 11.7 1.7	148 148 11.090 11.098 1.098 1.098	131 1.330 1.324 0.5 0.406	114 1.240 1.230 1.232 0.008	97 1.330 1.322 1.322 0.608	80 1.190 1.190 0.0 0.0	65 1.140 1.153 4.013	50 1.180 1.204 1.204 2.0-224	36 1.126 1.152 1.152 2.0032	E		
	6			¥	193 8.400 8.411 8.411	179 1.010 1.045 3.5	164 1.120 1.151 1.151 -28	149 1.160 1.183 1.183 2.0	132 1.060 1.073 1.073 1.1.2	115 1.670 1.677 1.677 4.7	98 1.460 1.673 1.673 -1.2	81 1.170 1.183 1.183 -1.1	66 1.130 1.153 	51 1.010 1.046 1.046 1.046 .3.6	37 0.400 0.413 0.013 .0.013			1.97%
	BEACON 5.0% 15.0% 124 124 124 124				×	180 0.250 0.255 0.255 0.255	165 0.390 0.410 0.410 4.020	150 0.680 0.780 0.780	113 1.100 1.113 4.0	116 1.210 1.239 2.4	99 1110 1133 1133 2.1	12 0.650 0.699 0.69 0.69 0.69 0.69 0.69 0.69 0.	67 0.400 0.410 0.410 0.410 0.410	0.015				lation:
	Measured: Source Power Level Expoeure CEA Position Boron Conc.							۲ <u>.</u>	0.260 0.263 	0.350 0.367 49.017 191	0.350 0.366 - 4.016 - 4.016	0.250 0.263 - 4.013 - 5.2						RMS Deviation:

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St. Lucie Unit 1, Cycle 16 Startup Physics Testing Report

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Key: Box & Design Deta X DHI.

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						•	166 0.290 0.303 4.5 4.013	151 0.410 0.419 -4.009	136 0.690 0.703 0.703 1.9		182 1.200 1.214 - 4.014	85 1.160 1.117 -1.5	68 0.690 0.704 0.704 - 4.014 - 2.0	53 8.400 8.419 4.7 4.7	38 0.290 0.302 -4.012				
	<b>←</b> 2				°	181 0.418 0.419 0.419 -2.2	167 1.010 1.010 1.031 -0.021 -2.1	152 1.120 1.135 1.135 4.015	137 1.166 1.165 -0.006	120 1.660 1.663 4.006	163 1.070 1.077 1.077 4.007	86 1.060 1.068 -0.008	69 1.150 1.167 -4.017 -1.5	54 1.110 1.133 -4.023	39 1.000 1.030 -0.030 -3.0	25 0.400 0.417 -4.317 -4.3			
			_	•	194 0.400 0.417 -4.2	182 1.120 1.136 1.138 0.018	168 1.176 1.183 -0.013 -1.1	153 1.136 1.144 1.144 1.12	138 1.090 1.098 -0.7 -0.7	121 1.320 1.316 1.316 0.616	194 1.236 1.217 0.003 0.003	27 1.310 1.310 0.000	70 1.090 1.096 0.806	55 1.126 1.141 -0.021 -1.9	40 1.160 1.182 -0.022	26 1.110 1.138 1.138 -0.028	14 0.400 0.419 -4.7 -0.019		
		-		205 6.290 6.201 4.012 4.1	195 1.010 1.030 1.030 -2.0	11 11 11 11 11 12 11	169 1.300 1.213 1.0.013	154 1.100 1.100 1.109 -0.809	139 1.330 1.324 1.324 0.5	122 1.170 1.153 1.5 0.017	105 1.250 1.237 1.237 1.0 1.0	22 1.160 1.149 0.9 0.9	71 1.330 1.322 1.322 0.6 0.6	56 1.100 1.103 -0.003	41 1.300 1.313 0.013 -0.013	27 1.160 1.183 -0.023	15 1.016 1.031 -0.021 -2.1	5 6.296 0.303 -0.013	
		•+		206 8.4100 8.4100 8.4100 8.4100 8.4100 8.4100 8.41000000000000000000000000000000000000	196 1.120 1.133 1.13 1.13 1.13	194 1139 1141 1140- 1100-	170 1.190 1.193 -0.903	155 11809 11875 0.5 0.5 0.5	140 1.130 1.119 1.0 4.011	111 111 111 111 111 111 111 111 111 11	106 1.110 1.001 1.7 4.019	89 1.350 1.317 1.7 1.7	72 1.130 1.118 1.118 0.012	57 1.060 1.075 0.405 0.5	42 1.180 1.180 1.180 1.180 1.180	28 1.140 1.144 0.804	16 1.120 1.120 1.120 1.120 1.130	6 8.410 8.419 - <b>3.3</b> 00	
		 	27 7 7 7 7 7 7 7	207 4.6%0 4.7%4 4.014 -2.0	197 1.160 1.167 -0.067	185 1.890 1.896 1.896 -8.006	171 1.330 1.322 1.322 0.008 n.6	156 1,130 1,118 1,118 1,1	141 1.350 1.323 1.323 0.027	124 1.150 1.119 1.119 2.7 0.001	167 1.350 1.312 1.312 0.038	90 1.150 1.122 8.828	73 1.360 1.323 0.027 2.0	58 1.130 1.119 1.0 0.011	43 1.340 1.324 1.324 1.2	29 1.100 1.898 0.802 0.2	17 1.170 1.166 1.166 0.202	7 8.890 8.703 -0.813	
	- Full Power			208 1.116 1.117 -0.807	198 1.060 1.063 4.005	186 1.320 1.310 1.310 0.8	172 1.160 1.149 1.149 0.9	157 1.360 1.327 1.327 1.7	142 1.150 1.122 1.122 2.4	125 1,190 1,161 1,161 2,4	106 1.870 1.067 2.1 0.623	91 1.190 1.161 1.161 2.4	74 1.150 1.119 0.031 2.7	5) 1.360 1.328 1.328 2.4	44 1.1.170 1.153 1.153 1.15	30 1.330 1.310 1.50 0.020	18 1.070 1.068 0.002	s 1.110 1.116 -0.5	
Figure 7	Power Distribution -			209 1.216 1.214 1.214 1.214	199 1.080 1.077 1.077 0.3 0.3 0.3	187 1.236 1.227 0.003 0.3	173 1.256 1.237 1.237 1.8	158 1.110 1.401 1.7	143 1.359 1.312 0.038 2.8	126 1.076 1.047 2.1	189 6.97 6.949 2.2 6.021	52 070.1 130.1 210.0 21	75 1.350 1.312 6.035 2.8	60 1.120 1.091 2.6 2.6	45 1.240 1.237 1.237 1.8	31 1.240 1.227 0.013 1.0	19 1.860 1.877 1.800 0.3 0.3	9 1.226 1.214 1.214 0.5 0.5	2 2 2 2 2 7 4 1 1 4
μi i	Power Di			210 1.110 1.116 1.116 1.116	200 1.em0 1.ecs 0.2	185 1.320 1.310 1.310 8.610	174 1.170 1.153 1.153 1.15	159 1.360 1.328 1.328 2.4	144 1.159 1.119 1.119 2.7	127 1.196 1.161 2.4	110 1.070 1.047 2.0 2.0	93 1.190 1.161 0.4029 2.4	76 1.150 1.122 0.025 2.4	61 1.360 1.327 1.327 0.003	46 1.176 1.149 1.149 1.12	32 1.336 1.316 1.316 0.620	20 1.876 1.868 8.802 8.402	10 1.120 1.117 0.3 0.3	3 9 9 9 1 1 9 1 1 9
				211 0.690 0.703 0.713 -1.9	201 1.170 1.168 0.2 0.2	189 1.100 1.095 0.2 0.2	175 1.330 1.324 0.006 0.5	160 1.130 1.119 1.119 1.0	145 1.360 1.323 0.027 2.0	128 1.150 1.122 0.028 2.4	111 1.350 1.312 0.038 2.8	94 1.150 1.119 1.119 2.7	77 1.360 1.323 0.037 2.7	62 1.140 1.118 1.9 1.9	47 1.340 1.322 1.322 1.3	33 1.160 1.096 0.4	zi 1.170 1.167 0.3 0.3	11 0.780 0.704 0.804 -0.804	
	E	•		212 0.410 0.419 0.419 -1.1	202 1.120 1.135 -0.015 -1.3	190 1.130 1.144 1.144 1.2	176 1.100 1.109 -0.809	161 1.076 1.075 1.075 4.005	146 1.136 1.118 1.118 0.012	129 1.360 1.377 0.003	112 1.120 1.491 0.4729 2.6	95 1.360 1.325 0.033 2.4	78 1.140 1.119 1.18 0.021	63 1.080 1.075 0.5 0.5	48 1.100 1.103 -0.403	34 1.140 1.141 -0.101	22 1136 1133 1133 1030 1030	12 0.419 0.419 	
	v2 <b>X134</b>		_[	213 0.250 0.303 0.303 4.013	203 1.010 1.031 1.031 -2.1		177 1.300 1.313 .4.013	162 1.090 1.103 -0.013 -1.2	147 1.330 1.322 1.322 0.608	130 1.160 1.169 1.109	113 1.260 1.217 1.8 0.023	96 1.170 1.153 1.153 1.15		64 1.110 1.105 1.105 0.101	49 1.310 1.313 1.313 1.313 1.310		13 1.016 1.016 1.026 -0.020	13 0.290 0.302 0.3012	
	Design: PCU becign: PCU becign	3		<b>&gt;</b>	204 0.400 0.419 0.419 4.7	261 820.0- 821.1 821.1 821.1	178 1.150 1.110 1.182 1.182 1.182	163 1.126 1.141 1.141 4.021	148 1.096 1.096 1.096	131 1.320 1.310 0.51 0.510	114 1.130 1.127 1.127 0.003	97 1.310 1.310 1.310 0.8.8	80 1.100 1.698 0.802 0.2	63 1.140 1.144 1.144 -0.4	50 1.170 1.183 1.183 1.143	36 1.120 1.136 1.136 -1.6	24 8-490 8-417 8-417 -4.017		
	<b>S</b>				×	193 8.480 8.417 8.417 -4.2	179 1.030 1.030 1.030 1.030	164 1.110 1.133 		132 1.060 1.061 1.068 1.008 1.008	115 1.070 1.077 1.077 -0.7		81 1.160 1.168 -0.08 -0.7	66 1.120 1.135 1.135 1.135	51 1.010 1.01 1.021 2.1	37 0.416 0.419 -4.009			1.73%
	BEACON M.D					×	180 0.290 0.302 0.812 -41	165 0.400 0.419 0.419 -4.7		1201	116 1.200 1.214 4.014	99 1.100 1.116 1.116 1.15	82 0.690 0.783 0.783 0.783	60078	1013				riation:
	Measured: Source Power Level Exposure	Boron Conc.							<u>اتع</u>	0.260 0.776 	0.374 0.374 . <b>0.0</b> 14 .3.9 101	0.360 0.374 - <b>0.0</b> 14 - <b>3.9</b>	0.270 0.271 .0.011						RMS Deviation:

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RMS Deviation: 1.73%

Key: Box # Messured Deta S Diff.

# Table 1Cycle 16 Reload Sub-Batch ID\*

Sub-Batch	Number of Assemblies	Avg. Enrichment
S1	4	3.9
S2	1	3.88
S4	1	3.79
<b>S</b> 6	7	3.76
T1	8	4.43
T2	20	4.41
Т3	12	4.33
T5	20	4.30
U1	8	3.98
U2	32	3.95
U3	16	4.38
U4	4	4.36
U5	4	4.33
U6	4	4.30
X1	24	4.34
X2	8	4.29
X3	24	4.26
X4	20	4.21

\*Reference (9)

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# Table 2Approach to Criticality

Dilution Rate	Initial Boron Concentration	Final Boron Concentration	Dilution Time (minutes)
132 gpm	1592	1533	18
88 gpm	1533	1433	48
44 gpm	1433	1393	46

CEA Group	Measured Worth (pcm)	Design * Worth (pcm)	Percent Difference
Reference Group A	826.05	860.00	-4.10
6	354.95	340.00	4.21
7	576.64	570.00	1.15
5 & B	662.98	595.00	10.25
1	773.97	771.00	0.38
3 & 4	761.00	780.00	-2.42
2	878.05	833.00	5.13
Total	4834.25	4749.00	1.76

Table 3CEA Group Worth Summary

\*Reference 7

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Percent difference = (Measured-Design)/(Measured) \*100