Florida Power & Light Company, 6501 S. Ocean Drive, Jensen Beach, FL 34957



March 26, 2008

L-2008-052 10 CFR 50.36

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

Re: St. Lucie Unit 2 Docket No. 50-389 Cycle 17 Startup Report

Pursuant to St. Lucie Unit 2 Technical Specification (TS) 6.9.1.1, Florida Power & Light Company (FPL) is submitting the Cycle 17 Startup Report. This report is required due to the replacement of the steam generators and the implementation of Startup Test Activity Reduction (STAR).

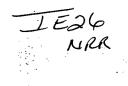
Please contact us if there are any questions regarding this submittal.

Very truly yours,

Gordon L. Johnston Site Vice President St. Lucie Plant

GLJ/KWF

Attachment



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# ST. LUCIE UNIT 2, CYCLE 17 REACTOR STARTUP PHYSICS TESTING REPORT

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#### I. Introduction

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 2 following the Cycle 17 refueling. The startup testing verifies that 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,
- 3) Power ascension testing, and,
- 4) Replacement Steam Generator Testing.

This Cycle 17 Startup Report is being submitted in accordance with Technical Specification 6.9.1.1 due to the replacement of the original steam generators during the refueling outage, which may have significantly altered the thermal and/or hydraulic performance of the unit.

The test data collected during startup and summarized in this report indicates that although key thermal-hydraulic parameters exhibited some changes there was no significant impact to the performance of the unit. The test data satisfied all acceptance criteria and demonstrated conformance to predicted performance.

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## II. Cycle 17 Fuel Design

The Cycle 17 reload consists entirely of fuel manufactured by Westinghouse. The primary design change to the core for Cycle 17 is the replacement of 77 irradiated fuel assemblies (4 Region P assemblies, 73 Region S assemblies) with 72 fresh fuel assemblies (Region X), and 5 irradiated Region S fuel assemblies from the spent fuel pool. The fuel in the Cycle 17 core is arranged in a low leakage pattern. The mechanical design of Region X fuel is essentially the same as that of Region U fuel, and consists of Value-Added<sup>TM</sup> fuel pellets and Guardian Grid<sup>TM</sup> design, first introduced in Cycle 11. The only significant difference is that Region X incorporates the use of ZIRLO<sup>TM</sup> cladding.

The safety analysis of this design was performed by Westinghouse and by FPL using NRC approved methodologies. The core design and the generation of physics inputs to safety are performed by FPL using the Westinghouse physics methodology.

The Cycle 17 reload is based on the Westinghouse WCAP-9272, Westinghouse Reload Safety Evaluation Methodology, first introduced in Cycle 15 for St. Lucie Unit 2. This approach uses a checklist format to assess cycle-specific core design and plant parameters for compliance with the existing safety analysis.

The Cycle 17 core map is represented in Figure 1. The assembly serial numbers and Control Element Assembly (CEA) serial numbers are given for each core location.

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## III. CEA Drop Time Testing

Following the core reload and prior to the approach to criticality, CEA drop time testing was performed. 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 2.91 seconds with maximum and minimum times of 3.02 seconds and 2.74 seconds, respectively (Reference 7). All drop times were within the 3.1 second requirement of Technical Specification 3.1.3.4 and within the safety analysis requirements supporting the reload PC/M 07004, "St. Lucie Unit 2 Cycle 17 Reload," requirements (Reference 6).

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## IV. Approach to Criticality

The approach to criticality involved diluting from a non-critical boron concentration of 1830 ppm to a predicted critical boron concentration of 1623 ppm. Inverse Count Rate Ratio (ICRR) plots were maintained during the dilution process using wide range channels C and D, and startup channels 1 and 2. Refer to Figures 2 through 5 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 2, Cycle 17, was achieved on January 4, 2008 at 0204 hours with CEA group 5 at 112 inches withdrawn and all other CEAs at the All-Rods-Out (ARO) position. The actual critical concentration was measured to be 1623 ppm (Reference 1).

#### V. Zero Power Physics Testing

To ensure that the operating characteristics of the Cycle 17 core were consistent with the design predictions, the following tests were performed:

- 1) Reactivity Computer Checkout;
- 2) All Rods Out Critical Boron Concentration; and,
- 3) Isothermal Temperature Coefficient Measurement

Proper operation of the reactivity computer is ensured by performing the "Reactivity Computer Checkout." This part of the testing determines the appropriate testing range and checks that reactivity changes are being correctly calculated by the reactivity computer's internal algorithms. The testing range is selected such that the signal to noise ratio is maximized and that testing is performed below the point of adding nuclear heat. The reactivity calculation is checked by performing a positive and negative reactor period test through respective introduction of a known amount of positive and negative reactivity. The results of the reactivity computer checkout were compared to the appropriate predictions supplied in the reload PC/M 07004 (Reference 6). Satisfactory agreement was obtained.

The measurement of the all-rods-out (ARO) critical boron concentration was performed. The measured value was 1627 ppm which compared favorably with the design value of 1628 ppm (Reference 2). 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 1.279 pcm/°F which fell well within the acceptance criteria of  $\pm 2.0$  pcm/°F of the design MTC of 1.63 pcm/°F. This complies with Unit 2 Technical Specification 3.1.1.4 requirements that the maximum upper limit shall be +5 pcm/°F at  $\leq$ 70% of Rated Thermal Power.

Rod worth measurements were not performed due to the implementation of the Startup Test Activity Reduction (STAR) program (Reference 9). Appendix A contains further information on the implementation of STAR for Unit 2 Cycle 17.

All acceptance criteria were met.

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#### VI. <u>Power Ascension Program</u>

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 greater than 98% rated thermal power.

A summary of the flux maps at the 30%, 45% and 98% power levels is provided in Figures 6, 7 and 8. These flux maps are used for comparing the measured power distribution with the predicted power distribution. For the purposes of power ascension, the acceptance criteria require the Root Mean Square (RMS) value of the power deviation to be less than or equal to 5%. The individual assembly powers should be within 10% of the predicted power for assembly powers greater than or equal to 0.9 (30% and 98% plateaus). In addition, for the 30% plateau the Relative Power Density (RPD) should be within 0.1 RPD units of predicted for assembly powers less than or equal to 0.9. These criteria were satisfied.

Additionally, calorimetric, nuclear, and delta T power calibrations were performed at each power plateau prior to advancing reactor power to the next higher level specified by procedure.

A determination of RCS flow by calorimetric parameters (Reference 8) was performed and the measured result of 404,128 gpm met the minimum acceptance criteria of 349,500 gpm (Technical Specification required flow of 335,000 gpm + uncertainties).

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#### VII. <u>Steam Generator Testing</u>

**Reactor Vessel Differential Pressure** 

-i 1

The Unit 2 Original Steam Generators (OSG) were replaced with new, equivalent steam generators supplied by AREVA, during the 2007 Steam Generator (SG) and Replacement and Refueling Outage. As a result of the steam generator replacement, return to service testing was performed.

The return to service testing comprised two discreet types of testing: post work testing and performance testing. Testing of many of the individual components impacted by the installation of the Replacement Steam Generators (RSGs) was performed and documented under the Post Maintenance program. Performance testing which required integrated plant conditions was performed using existing plant procedures, or specialized test procedures detailed in 2-PTP-35, "Unit 2 Cycle 17 Return to Service Testing and Performance Verification".

There were no adverse conditions identified during the performance of 2-PTP-35 affecting the thermal and hydraulic behavior of the reactor core. Performance of the RSGs was monitored throughout the power ascension. The data was reviewed at each power plateau and compared with design predictions, which were summarized in 2-PTP-35. The power plateaus were chosen to align with the normal power ascension procedure.

Figure 9 displays the measured primary side differential pressure at the power plateaus. As illustrated on the graph the average differential pressure decreased with rising power due the effects of decreasing fluid density with power. Reactor Vessel differential pressure was monitored throughout the power ascension and is shown on Figure 10. This parameter was used to estimate the RCS flow in Mode 3. Values for the measured and predicted differential pressures are provided in Table VII-1 below. Based on the various instrument uncertainties (e.g., RCS flow measurement uncertainty is  $\pm 14,500$  gpm) and accuracy of the analytical model, the differences are considered reasonable and the results acceptable.

ParameterMeasured ValuePredicted ValueSG Differential Pressure20.5 psid to 23.5 psid @27.6 psid @ measuredmeasured flow offlow of 402,814 gpm

404,128 gpm

of 404,128 gpm

47 psid @ measured flow

45.05 psid @ measured

flow of 409,193 gpm

Table VII-1: Differential Pressures for the SG and Reactor Vessel (Based on 100% Power, 1355 MWt per SG)

Figure 11 shows the RCS temperatures at the various power levels. T <sub>Cold</sub> was maintained per
procedures to approximately 549°F (actual measured was ~548.34°F). The measured $T_{Hot}$ and
consequently $\Delta T$ were higher than predicted due to the effects of Hot Leg Stratification Factor
(HLSF), which was determined to be approximately 5°F at 100% power.

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The parameters  $T_{Avg}$ ,  $T_{Ref}$  and predicted  $T_{Avg}$  are plotted on Figure 12. The Average Temperature,  $(T_{Avg})$ , based on primary temperature instruments and  $T_{Ref}$ , which is derived from turbine first stage pressure, are used as indication of primary to secondary power mismatch. At 100% power the predicted  $T_{Avg}$  was 572.26°F, the measured  $T_{Avg}$  was 575.8°F, and the measured  $T_{Ref}$  was 575.7°F. The measured values were reasonable compared to the predicted value taking into account the effect of HLSF. Also, with  $T_{Avg}$  and  $T_{Ref}$  being within 0.1°F of each other there was no indication of a primary to secondary power mismatch and the results are documented as acceptable.

The RCS low flow reactor trip is derived from SG differential pressure instrumentation. Differential pressure data is collected in Mode 3. The low flow trip setpoints were determined and implemented based on the Mode 3 differential pressure data. The Hot Zero Power flow rate of approximately 406,000 gpm calculated in Mode 3 determined that the low flow trip setpoints were set to cover a range of SG differential pressures of 20.0 psid to 28.5 psid as specified in 2-PTP-35.

At the 98% plateau, the RCS flow was determined as 404,128 gpm (202,064 gpm per SG) at a SG differential pressure of approximately 23 psid per SG. AREVA determined the best estimate primary flow to be 201,407 gpm per SG with a pressure loss along the tubes of 27.60 psid at this predicted flow rate. Considering the calculational uncertainties as well as the instrument uncertainties for both the flow measurement (i.e.,  $\pm 14,500$  gpm) and the differential pressure measurements, the calculated and measured values are within the measurement uncertainty and are considered acceptable.

In accordance with Technical Specification Table 3.2-2, the measured RCS flow rate (after accounting for uncertainties) is required to be  $\geq$  335,000 gpm and less than the PCM 05137 maximum design flow of 431,000 gpm. Accounting for a measurement uncertainty of 14,500 gpm, the actual RCS flow is between 389,628 gpm and 418,628 gpm. Therefore, the minimum flow requirement is met and the design flow rate is not exceeded.

Blowdown testing was performed in accordance with NOP-23.02. The acceptance criterion for the blowdown test is to achieve a blowdown rate of 1% (5.9 x  $10^4$  lb/hr/SG) of steam flow or meeting the maximum capacity of the system. As a blowdown capacity of 5.9 x  $10^4$  lb/hr/SG was achieved during the test the blowdown capacity measurement was documented as acceptable. In addition, there was no detectable primary to secondary leakage as verified by testing and by Chemistry daily sampling results.

As described above, RSG performance tests that could impact the thermal and hydraulic behavior of the reactor core, performed per RSG Return to Service procedure, were completed and it was concluded that there were no adverse impacts to the thermal and hydraulic behavior of the reactor core as a result of the installation of RSGs at St. Lucie Unit 2.

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## VIII. <u>Summary</u>

Compliance with the applicable Unit 2 Technical Specifications was satisfactory. The acceptance criteria for all the startup testing parameters were met.

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

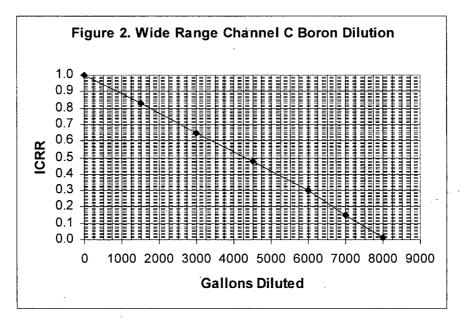
- "Unit 2 Initial Criticality Following Refueling," Pre-Operational Procedure 2-3200088, Rev. 27.
- 2) "Reload Startup Physics Testing," Pre-Operational Procedure 3200091, Rev. 27
- 3) "Reactor Engineering Power Ascension Program," Pre-Operational Procedure 3200092, Rev. 33.
- 4) St. Lucie Unit 2 Technical Specifications.
- 5) Engineering Evaluation PSL-ENG-SEMJ-08-011, "St. Lucie Unit 2 Replacement Steam Generator Return to Service Summary Report," Revision 0, February 2008.
- 6) St. Lucie Unit 2 Cycle 17 Reload PC/M #07004, Rev 1.
- 7) "Periodic Rod Drop Time and CEA Position Functional Test," Operating Procedure 2-0110054, Rev. 26C.
- 8) "RCS Flow Determination by Calorimetric," Operating Procedure 2-0120051, Rev. 16A.
- 9) WCAP- 16011-P-A, Rev. 0, "Startup Test Activity Reduction Program," February 2005.

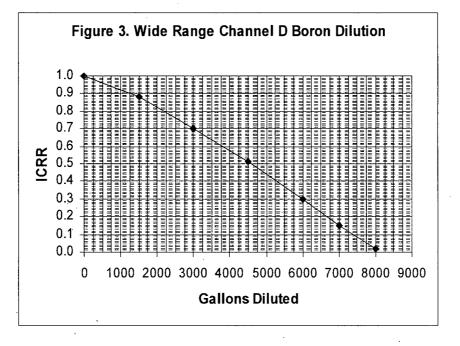
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# FIGURE 1 CYCLE 17 CORE LOADING PATTERN

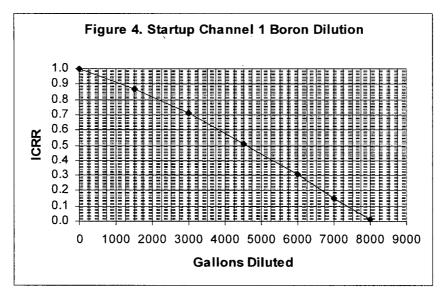
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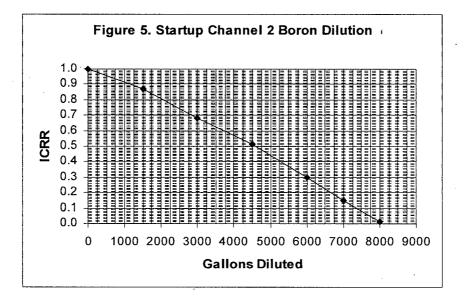
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> Key: Box # Measured Design Dett: % Diff.

## Figure 6

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1 1 1.

#### **POWER DISTRIBUTION COMPARISON WITH DESIGN - 30% POWER**

Measurod: Source Power Level Exposure CEA Position Boron Conc.	BEACON 52 010407 24.2% 1.4 EFP 121.3 1543 Measur	н		Design: PCM 07004, R 30.0% 8 EFP 122 1463	1	R	P N 1	, M L II	к ј 	н с	† ~					
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0.360 0.380 -0.020 <u>-5.6</u> 84	99 1.170 1.180 -0.010 -0.9	98 1.230 1.220 0.010 0.8	97 1.290 1.280 0.010 0.8	96 0.970 0.960 0.010 1.0	95 1.220 1.220 0.000 0.0	94 1.260 1.250 0.010 0.8	93 0.980 0.990 -0.010 -1.0	92 1.230 1.240 -0.010 -0.8	91 0.980 0.990 -0.010 -1.0	90 1.250 1.250 0.000 0.0	89 1.220 1.220 0.000 0.0	88 0.960 0.960 0.000 0.0	87 1.290 1.280 0.010 0.8	86 1.230 1.230 0.000 0.0	85 1.180 1.190 -0.010 -0.8	0.390 0.410 -0.020 -5.1 83
0.330 0.340 -0.010 - <u>3.0</u>	82 0.600 0.610 -0.010 -1.7	81 1.250 1.250 0.000 0.0	80 1.230 1.220 0.010 0.8	79 1.300 1.290 0.010 0.8	78 1.120 1.120 0.000 0.0	77 1.250 1.250 0.000 0.0	76 1.260 1.250 0.010 0.8	75 0.950 0.960 -0.010 -1.1	74 1.250 1.250 0.000 0.0	73 1.250 1.250 0.000 0.0	72 1.120 1.120 0.000 0.0	71 1.300 1.290 0.010 0.8	70 1.230 1.220 0.010 0.8	69 1.260 1.260 0.000 0.0	68 0.610 0.620 -0.010 -1.6	0.340 0.350 -0.010 -2.9
	67 0.400 0.410 -0.010 -2.5	66 1.200 1.200 0.000 0.0	65 1.270 1.270 0.000 0.0	64 1.180 1.170 0.020 0.8	63 1.300 1.290 0.010 0.8	62 1.120 1.120 0.000 0.0	61 1.220 1.220 0.000 0.0	60 1.100 1.100 0.000 0.0	59 1.220 1.220 0.000 0.0	58 1.120 1.120 0.009 0.0	57 1.300 1.290 0.010 0.8	56 1.190 1.180 0.010 0.8	55 1.280 1.270 0.010 0.8	54 1.200 1.210 -0.010 -0.8	53 0.400 0.410 -0.010 -2.5	
	52 0.270 0.280 -0.010 -3.7	51 0.610 0.620 -0.010 -1.6	50 1.240 1.240 0.000 0.0	49 1.390 1.390 0.000 0.0	48 1.180 1.180 0.000 0.0	47 1.300 1.290 0.010 0.8	46 0.960 0.960 0.000 0.000	45 1.150 1.150 0.000 0.0	44 0.960 0.960 0.000 0.0	43 1.290 1.290 0.000 0.0	42 1.180 1.170 6.010 0.8	41 1.390 1.390 0.000 0.0	40 1.240 1.240 0.000 0.0	39 0.610 0.620 -0.010 -1.6	38 0.270 0.280 -0.010 -3.7	
		37 0.330 0.340 -0.010 -3.0	36 1.110 1.130 -0.020 -1.8	35 1.240 1.240 0.000 0.0	34 1.270 1.270 0.000 0.0	33 1.230 1.220 0.010 0.8	32 1.290 1.280 0.010 0.8	31 1.180 1.180 0.000 0.0	30 1.280 1.280 0.000 0.0	29 1.220 1.220 0.000 0.0	28 1.270 1.270 0.000 0.0	27 1.240 1.240 0.000 0.0	26 1.110 1.130 -0.020 -1.8	25 0.330 0.340 -0.010 -3.0	]	
			24 0.330 0.340 -0.010 -3.0	23 0.610 0.620 -0.010 -1.6	22 1.190 1.210 -0.020 -1.7	21 1.250 1.260 -0.010 -0.8	20 1.220 1.230 -0.010 -0.8	19 1.310 1.320 -0.010 -0.8	18 1.210 1.220 -0.010 -0.8	17 1.240 1.250 -0.010 -0.8	16 1.180 1.200 -0.020 -J.7	15 0.610 0.620 -0.010 -1.6	14 0.330 0.340 -0.010 -3.0			
				13 0.270 0.280 -0.010 -3.7	12 0.400 0.410 -0.010 -2.5	11 0.600 0.620 -0.020 -3.3	10 1.170 1.190 -0.020 -1.7	9 1.230 1.250 -0.020 -1.6	8 1.150 1.180 -0.030 -2.6	7 0.590 0.610 -0.020 -3.4	6 0.390 0.410 -0.020 -5.1	5 0.260 0.280 -0.020 -7.7				
						4 0.330 0.350 -4 -6.1	0.410	0.380	0.340							
RMS Dev	viation:	1.18%														

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Key:

## Figure 7

#### POWER DISTRIBUTION COMPARISON WITH DESIGN – 45% POWER

easured: urce wer Level posure A Position ron Conc.	BEACON ts2_010508_ 43.4% 7.1 EFP 123 1421	H		Design: PCM 07004, R 45.0% 16 EFPI 124 1388	1 ·	R	P N 1	«	ر ب ا	H G	 N					
				т	5	- 11 č	1.340 (	0.38 (	.41	.350 0.35 :000 0.0	F	E				
				213 0.270 0.280 -0.010 -3.7	212 0.400 0.410 0.010 -2.5	211 0.610 0.620 -0.010 -1.6	210 1.170 1.170 0.000 0.0	209 1.240 1.240 0.000 0.0	208 1.180 1.190 -0.010 -0.8	207 0.610 0.620 -0.010 -1.6	206 0.410 0.420 -0.010 -2.4	205 0.280 0.280 0.000 0.0				
		w	204 0.340 0.350 -0.010 -2.9	203 0.620 0.630 -0.010 -1.6	202 1.190 1.200 -0.010 -0.8	201 1.250 1.250 0.000 0.0	200 1.220 1.220 0.000 0.0	199 1_320 1_320 0.000 0.0	198 1.230 1.220 0.010 0.8	197 1.260 1.250 0.010 0.8	196 1.200 1.200 0.000 0,0	195 0.620 0.630 -0.010 -1.6	194 0.340 0.350 -0.010 -2.9		_	
	x	193 0.340 0.350 -0.010 -2.9	192. 1.120 1.130 -0.010 -0.9	191 1.240 1.240 0.000 0.0	190 1.270 1.260 0.010 0.8	189 1.230 1.220 0.010 0.8	188 1.290 1.280 0.010 0.8	187 1.190 1.180 0.010 0.8	186 1.300 1.280 0.020 1.5	185 1.230 1.220 8.010 0.8	184 1.270 1.260 0.010 0.8	183 1.240 1.240 0.000 0.0	182 1.130 1.130 0.000 0.0	181 0.340 0.350 -0.010 -2.9	B	
	180 0.280 0.280 0.000 0.0	179 0.620 0.630 -0.010 -1.6	178 1.240 1.240 0.000 0.0	177 1.390 1.380 0.010 0.7	176 1.190 1.170 0.020 1.7	175 1.310 1.290 0.020 1.5	174 0.980 0.960 0.020 2.0	173 1.170 1.150 0.020 1.7	172 0.980 0.960 0.020 2.0	171 1.310 1.290 0.020 1.5	170 1.190 1.170 0.020 1.7	169 1.390 1.380 0.010 0.7	168 1.240 1.240 0.000 0.0	167 0.620 0.630 -0.010 -1.6	166 0.280 0.280 0.000 0.0	
	165 0.410 0.420 -0.010 -2.4	164 1.200 1.200 0.000 0.0	163 1.280 1.260 0.020 1.6	162 1.190 1.170 0.020 1.7	161 1.310 1.290 0.020 1.5	160 1.130 1.120 0.010 0.9	159 1.240 1.220 0.020 1.6	158 1.120 1.100 0.020 1.8	157 1.230 1.220 0.010 0.8	156 1.130 1.120 0.010 0.9	155 1_300 1.290 0.010 0.8	154 1.180 1.170 0.010 0.8	153 1.270 1.260 0.010 0.8	152 1.200 1.200 0.000 0.0	151 0.410 0.410 0.000 0.0	 î
Y 55 340	150 0.610 0.620 -0.010 -1.6	149 1.260 1.250 0.010 0.8	148 1.230 1.220 0.010 0.8	147 1.310 1.290 0.020 1.5	146 1.130 1.120 0.010 0.9	145 1.270 1.250 0.020 1.6	144 1.270 1.260 0.010 0.8	143 0.970 0.976 0.000 0.0	142 1.270 1.260 0.010 0.8	141 1.260 1.250 0.010 0.8	140 1.120 1.120 0.000 0.0	139 1.300 1.290 0.010 0.8	138 1.220 1.220 0.000 0.0	137 1.250 1.250 0.000 0.0	136 0.610 0.620 -0.010 -1.6	134
350 -0.010 :.9 18 .400	133 1.180 1.190 -0.010 -0.8	132 1.230 1.220 0.010 0.8	131 1.290 1.280 0.010 0.8	130 0.980 0.960 0.020 2.0	129 1.230 1.220 0.010 0.8	128 1.270 1.260 0.010 0.8	127 1.000 1.000 0.000 0.0	126 1.250 1.250 0.000 0.0	125 1.000 1.000 0.000 0.0	124 1.260 1.260 0.000 0.0	123 1.220 1.220 0.000 0.0	122 0.970 0.960 0.010 1.0	121 1.280 1.280 0.000 0.0	120 1.220 1.220 0.000 0.0	119 1.160 1.170 -0.010 -0.9	0.340 0.340 0.000 0.0 117 0.370
.410 -0.010 2.5 01 .370	116 1.230 1.240 -0.010 -0.8	115 1.320 1.320 0.000 0.0	114 1.190 1.180 0.010 0.8	113 1.160 1.150 0.010 0.9	112 1.110 1.110 0.000 0.0.	111 0.970 0.970 0.000 0.0	110 1.250 1.250 0.000 0.0	109 0.74 0.740 0.000 0.0	108 1.250 1.250 0.000 0.0	107 0.960 0.970 -0.010 -1.0	106 1.110 1.110 0.000 0.0	105 1.150 1.150 0.000 0.0	104 1.180 1.180 0.000 0.0	103 1.310 1.320 -0.010 -0.8	102 1.230 1.240 -0.010 -0.8	0.370 0.380 -0.010 -2.7 100 0.400
380 -0.010 2.7 4 340	99 1.360 1.170 -0.010 -0.9	98 1.220 1.220 0.000 0.0	97 1.290 1.280 0.010 0.8	96 0.970 0.960 0.010 1.0	95 1.230 1.220 0.010 0.8	94 1.270 1.260 0.010 0.8	93 1.000 1.000 0.000 0.0	92 1.250 1.250 0.000 0.0	91 1.000 1.000 0.000 0.0	90 1.260 1.260 0.000 0.0	89 1.220 1.220 0.000 0.0	88 0.970 0.960 0.010 1.0	87 1.290 1.280 0.010 0.8	86 1.220 1.220 0.000 0.0	85 1.170 1.190 -0.020 -1.7	0.400 0.410 -0.010 -2.5 83 0.340
.340 .340 0.000 .0	82 0.610 0.620 -0.010 -1.6	81 1.250 1.250 0.000 0.0	80 1.220 1.220 0.000 0.0	79 1.300 1.290 0.010 0.8	78 1.130 1.120 0.010 0.9	77 1.260 1.250 0.010 0.8	76 1.270 1.260 0.010 0.8	75 0.970 0.970 0.000 0.0	74 1.260 1.260 0.000 0.0	73 1.260 1.250 0.010 0.8	72 1.120 1.120 0.000 0.0	71 1.300 1.290 0.010 0.8	70 1.230 1.220 0.010 0.8	69 1.250 1.250 0.000 0.0	68 0.610 0.620 -0.010 -1.6	0.350 -0.010 -2.9
	67 0.410 0.410 0.000 0.0	66 1.190 1.200 -0.010 -0.8	65 1.270 1.260 0.010 0.8	64 1.180 1.170 0.010 0.8	63 1.300 1.290 0.010 0.8	62 1.130 1.120 0.010 0.9	61 1.230 1.220 0.010 0.8	60 1.110 1.110 0.000 0.0	59 1.230 1.220 0.010 0.8	58 1.120 1.120 0.000 0.0	57 1.300 1.290 0.010 0.8	56 1.180 1.170 0.010 0.8	55 1.270 1.260 0.010 0.8	54 1,200 1.200 0.000 0.0	53 0.410 0.420 -0.010 -2.4	
	52 0.280 0.280 0.000 0.0	51 0.620 0.630 -0.010 -1.6	50 1.230 1.240 -0.010 -0.8	49 1.380 1.380 0.000	48 1.180 1.170 0.010 0.8	47 1.300 1.290 0.010 0.8	46 0.970 0.960 0.010 1.0	45 1.160 1.150 0.010 0.9	44 0.970 0.960 0.010 1.0	43 1.290 1.290 0.000 0.0	42 1.170 1.170 0.000 0.0	41 1.380 1.380 0.000 0.0	40 1.230 1.240 -0.010 -0.8	39 0.620 0.630 -0.010 -1.6	38 0.280 0.280 0.000 0.0	
		37 0.340 0.350 -0.010 -2.9	36 1.110 1.130 -0.020 -1.8	35 1.230 1.240 -0.010 -0.8	34 1.260 1.260 0.000 0.0	33 1.220 1.220 0.000 0.0	32 1.280 1.280 0.000 0.0	31 1.180 1.180 0.000 0.0	30 1.280 1.280 0.000 0.0	29 1.210 1.220 -0.010 -0.8	28 1.260 1.260 0.000 0.0	27 1.230 1.240 -0.010 -0.8	26 1.110 1.130 -0.020 -1.8	25 0.340 0.350 -0.010 -2.9	,	
			24 0.340 0.350 -0.010 -2.9	23 0.610 0.630 -0.020 -3.3	22 1.190 1.200 -0.010 -0.8	21 1.240 1.250 -0.010 -0.8	20 1.220 1.220 0.000 0.0	19 1.310 1.320 -0.010 -0.8	18 1.210 1.220 -0.010 -0.8	17 1.230 1.250 -0.020 -1.6	16 1.180 1.200 -0.020 -1.7	15 0.610 0.630 -0.020 -3.3	14 0.340 0.350 -0.010 -2.9	]		
	,		e.	13 0.270 0.280 -0.010 -3.7	12 0.400 0.420 -0.020 -5.0	11 0.610 0.620 -0.010 -1.6	10 1.170 1.190 -0.020 -1.7	9 1.220 1.240 -0.020 -1.6	8 1.150 1.170 -0.020 -1.7	7 0.600 0.620 -0.020 -3.3	6 0.400 0.410 -0.010 -2.5	5 0.270 0.280 -0.010 -3.7				
						4 0.340 0.350 -2.9	3 0.400 0.410 0.010 -0 2.5	2 0.370 0.380 0.010 -0 -2.7	1 0.330 0.340 .010 -4 -3.0	0.010						

The incore detection system is operable per Appendix 1, RMS deviation should be less than or equal to 5.0% and meet the requirements of 4.7.1 if performed at the 25 and 98 percent power test plateaus during the power ascension test program.

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> Design Deita % Diff.

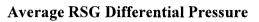
## Figure 8

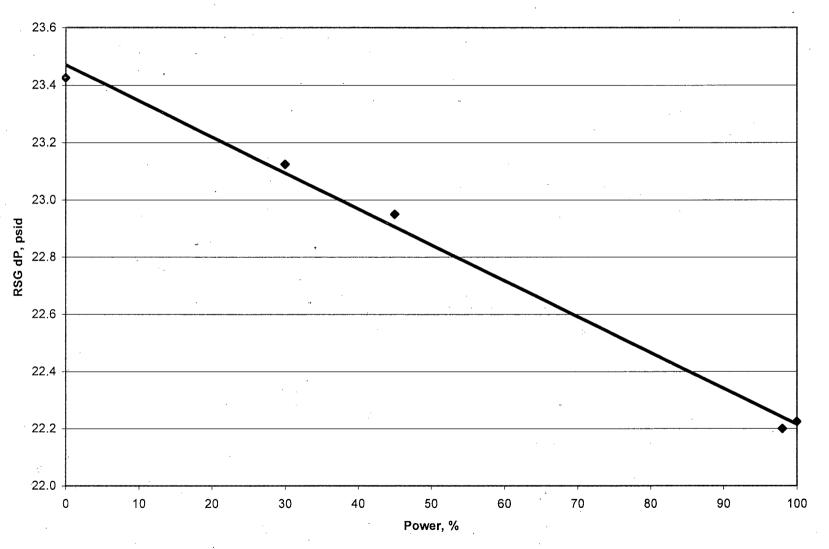
## POWER DISTRIBUTION COMPARISON WITH DESIGN - 98% POWER

rce er Level Sure Position en Conc.	95.1% 25.6 EFP 137 1254	2220 H		PCM 07004, F 100.0% 40 EFP 137 1223		R	P N 1	4 L P	( _ )   	н с	N					
				Ť	s	11 0	.350 0	).39 0	.42 0		F	E		•		
			ľ	213 0.280 0.290 -0.010	212 0.410 0.420 -0.010	211 0.610 0.620 -0.010	210 1.150 1.160 -0.010	209 1.210 1.220 -0.010	208 1.160 1.170 -0.010 -0.9	207 0.620 0.620 0.000 0.0	206 0.420 0.420 0.000 0.0	205 0.290 0.290 0.000 0.0	] <u> </u>			
		<b>w</b>	204 0.350 0.360 -0.010	203 0.620 . 0.630 0.010	202 1.170 1.180 -0.010 -0.9	201 1.230 1.230 0.000	200 1.218 1.200 0.010 0.8	199 1.310 1.300 0.010	198 1.210 1.210 0.000	197 1.230 1.230 0.000	196 1.180 1.180 0.000	195 0.630 0.630 0.000	194 0.350 0.350 0.000 0.0		· · ·	
	×	193 0.350 0.350 0.000	-2.9 192 1.110 1.120 -0.010	-1.6 191 1.220 1.220 0.000	190 1.250 1.250 0.000	189 1.210 1.210 0.000	188 1.280 1.270 0.010	187 1.180 1.180 0.000	186 1.280 1.270 0.010	185 1.220 1.210 0.010	184 1.250 1.250 0.000	183 1.220 1.220 0.000	182 1.120 1.120 0.000	181 0.350 0.360 -0.010		
	180 0.290 0.290 0.000	179 0.630 0.630 0.000 0.0	178 1.220 1.220 0.000	0.0 177 1.360 1.350 0.010 0.7	0.0 176 1.170 1.160 0.010	175 1.300 1.280 0.020	0.8 1174 0.980 0.980 0.000	0.0 173 1.170 1.160 0.010 0.9	0.8 172 0.980 0.980 0.000 0.000	171 1_300 1.280 0.020	170 1.170 1.170 0.000	169 1.360 1.350 0.010	168 1.220 1.220 0.000	-2-9 167 0.630 0.630 0.000 0.0	166 0.290 0.290 0.000	]
	0.0 165 0.420 0.420 0.000	164 1.190 1.180 0.010 0.8	163 1.260 1.250 0.010	162 1.180 1.170 0.010	161 1.310 1.290 0.020	1.5 160 1.140 1.130 0.010 0.9	159 1.250 1.230 0.020	158 1.130 1.120 0.010 0.9	157 1.240 1.230 0.010	1.5 156 1.140 1.130 0.010	155 1.300 1.290 0.010	0,7 154 1.170 1.160 0.010 0.9	153 1.250 1.250 0.000 0.0	152 1.180 1.180 0.000	151 0.410 0.420 -0.010	 •
Y 35	0.0 150 0.620 0.620 0.000 0.0	1.240 1.230 0.010 0.8	0.8 148 1.220 1.210 0.010	147 1.300 1.280 0.020	146 1.140 1.130 0.010	145 1.290 1.270 0.020	144 1.290 1.280 0.010	143 1.000 0.990 0.010	142 1.290 1.280 0.010	1.280 1.270 0.010	1.40 1.140 1.130 0.010	139 1.290 1.280 0.010	138 1.210 1.210 0.000	137 1.230 1.230 0.000	136 0.610 0.620 -0.010 -1.6	134
.350 .360 -0.010 2.9	133 1.160 1.170 -0.010	132 1.210 1.210 0.000	131 1.280 1.270 0.010	130 0.990 0.980 0.010	129 1.250 1.230 0.020	128 1.290 1.280 0.010	127 1.030 1.030 0.000	126 1.290 1.290 0.000	125 1.030 1.030 0.000	124 1.280 1.280 0.000	123 1.240 1.230 0.010	122 0.980 0.980 0.000	121 1.280 1.270 0.010	120 1.200 1.200 0.000	119 1.150 1.160 -0.010	0.340 0.350 -0.010 -2.9
.400 .420 .0.020 5.0	116 1.210 1.220 -0.010	0.0 115 1.300 1.300 0.000	0.8 114 1.180 1.180 0.000	113 1.170 1.160 0.010	112 1.130 1.120 0.010	111 1.600 0.990 0.010	110 1.290 1.290 0.000	109 0.78 0.780 0.000	108 1.290 1.290 0.000	107 0.990 0.990 0.000	0.8 106 1.130 1.120 0.010 0.9	105 1.160 1.160 0.000	104 1.180 1.180 0.000	103 1.300 1.300 0.000	102 1.210 1.220 -0.010	0.380 0.390 -0.010 -2.6
380 390 -0.010 2.6 4	-0.8 99 1.150 1.160 -0.010	0.0 98 1.200 1.200 0.000	97 1.280 1.270 0.010	96 0.980 0.980 0.000	95 1.240 1.230 0.010	94 1.290 1.280 0.010	93 1.030 1.030 0.000	92 1.290 1.290 0.000	0.0 91 1.030 1.030 0.000 0.0	90 1.280 1.280 0.000	89 1.240 1.230 0.010	88 0.980 0.980 0.980 0.000	0.0 87 1.280 1.270 0.010	0.0 86 1.210 1.210 0.000	40.8 85 1.160 1.170 -0.010	0.410 0.420 -0.010 -2.4 83
340 350 -0.010 1.9	-0.9 82 0.610 0.620 -0.010 -1.6	81 1.230 1.230 0.000	0.8 80 1.210 1.210 0.000 0.0	79 1.300 1.280 0.020	78 1.140 1.130 0.010	77 1.280 1.270 0.010	76 1.290 1.280 0.010	75 0.990 0.990 0.000	74 1.280 1.280 0.000	73 1.280 1.270 0.010	72 1.140 1.130 0.010 0.9	71 1.300 1.280 0.020	0.8 70 1.220 1.210 0.010 0.8	69 1.240 1.230 0.010	-0.9 68 0.620 0.620 0.000	0.350 0.360 -0.010 -2.9
	67 0.410 0.420 -0.010	66 1.180 1.180 0.000	65 1.250 1.250 0.000	64 1.170 1.160 0.010	63 1.300 1.290 0.010 0.8	62 1.140 1.130 0.010	61 1.240 1.230 0.010 0.8	60 1.130 1.120 0.010	59 1.240 1.230 0.010 0.8	58 1.130 1.130 0.000	57 1.290 1.290 0.000	56 1.170 1.170 0.000	55 1.250 1.250 0.000	54 1.180 1.180 0.000	53 0.420 0.420 0.000	
	52 0.290 0.290 0.000	51 0.630 0.630 0.000 0.000	50 1.220 1.220 0.000	49 1.350 1.350 0.000	48 1.170 1.170 0.000 0.0	47 1.290 1.280 0.010	46 0.980 0.980 0.000	45 1.160 1.160 0.000	44 0.980 0.980 0.000 0.0	43 1.290 1.280 0.010 0.8	42 1.160 1.160 0.000	41 1.350 1.350 0.000 0.0	40 1.210 1.220 -0.010	39 0.620 0.630 -0.010	38 0.290 0.290 0.000	
		37 0.350 0.360 -0.010 -2.9	36 1.110 1.120 -0.010 -0.9	35 1.210 1.220 -0.010 -0.8	34 1.240 1.250 -0.010 -0.8	33 1.210 1.210 0.000	32 1.280 1.270 0.010 0.8	31 1.170 1.180 -0.010 -0.9	30 1.270 1.270 0.000 0.0	29 1.200 1.210 -0.010 -0.8	28 1.240 1.259 -0.010 -0.8	27 1.210 1.220 -0.010 -0.8	26 1.100 1.120 -0.020 -1.8	25 0.340 0.350 -0.010 -2.9		<b>-</b> .
			24 0.340 0.350 -0.010 -2.9	23 0.620 0.630 -0.010 -1.6	22 1.170 1.180 -0.010 -0.9	21 1.230 1.230 0.000 0.0	20 1.200 1.210 -0.010 -0.8	19 1.290 1.300 -0.010 -0.8	18 1.190 1.200 -0.010 -0.8	17 1.210 1.230 -0.020 -1.7	16 1.160 1.180 -0.020 -1.7	15 0.620 0.630 -0.010 -1.6	14 0.340 0.360 -0.020 -5.9			
				13 0.280 0.290 -0.010 -3.6	12 0.410 0.420 -0.010 -2.4	1] 0.610 0.620 -0.010 -1.6	10 1.150 1.170 -0.020 -1.7	9 1.200 1.220 -0.020 -1.7	8 1.130 1.160 -0.030 -2.7	7 · 0.600 0.620 -0.020 -3.3	6 0.410 0.420 -0.010 -2.4	5 0.280 0.290 -0.010 -3.6				
						4 0.350 0.360 -4 -2.9	0.420	0.390	1 0.340 0.350 -0 -2.9	0.010					-	
IS Dev	riation:	0.96%														·

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## Figure 9





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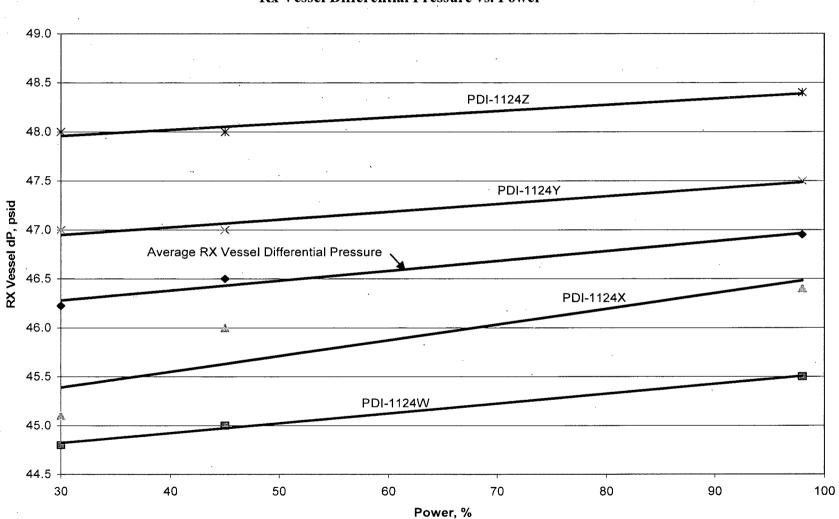


Figure 10 Rx Vessel Differential Pressure vs. Power

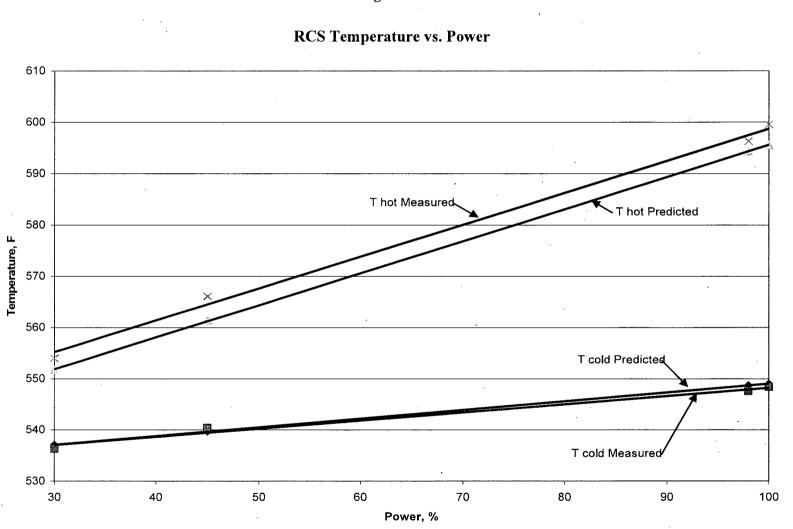
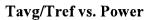
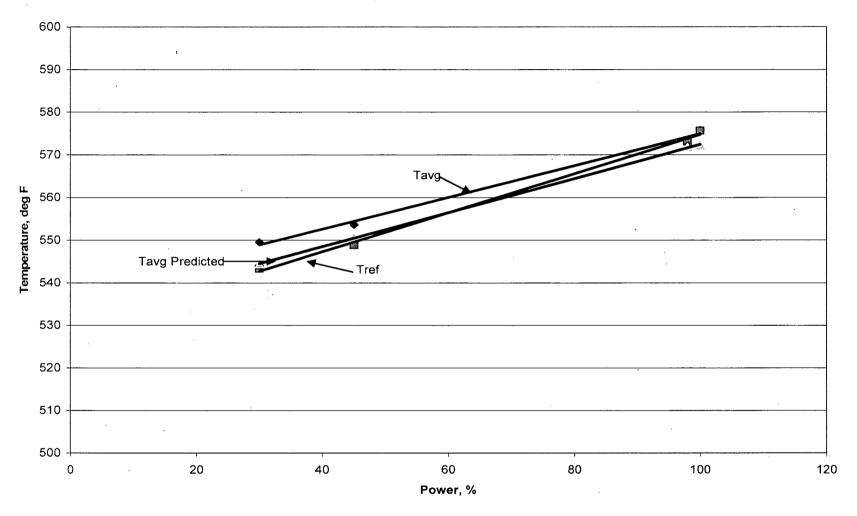


Figure 11

## Figure 12





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Sub-Batch	Number of Assemblies
S4	4
\$5	. 1
, T1	20 .
T2	8
Т3	16
T4	8
Τ5	20
U1	8
U2	28
U3 .	8
U4	4
U5	20
X1	8
X2	24
X3	12
X4	. 4
X5	16 .
X6	8

Table 1Cycle 17 Reload Sub-Batch ID\*

\*Reference 6

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# Table 2Approach to Criticality

Dilution Rate	Initial Boron	Final Boron	Approximate Dilution
	Concentration (ppm)	Concentration (ppm)	Time (minutes)
132 gpm	1830	1787	20
88 gpm	1787	1661	62
44 <sub>.</sub> gpm	1661	1623	96

#### Appendix A

#### Summary of Implementation on the First Application of STAR for St. Lucie Unit 2, Cycle 17

#### Background

The St. Lucie Unit 2, Cycle 17 startup from refueling successfully utilized the Startup Test Activity Reduction (STAR) Program in accordance with Westinghouse Topical Report, WCAP-16011-P-A, Rev. 0 (Reference A-1). This was the first application of the STAR Program at St. Lucie Unit 2. The current implementation eliminates the CEA worth measurement only and there is no change to the MTC testing requirements. The conditions and limitations of the NRC safety evaluation for the STAR Program topical report (Reference A-1) requires that "each licensee using STAR to submit a summary report following the first application, either successful or not, of STAR to its plant. The report should (a) identify the core design method used, (b) compare the measured and calculated values and the differences between these values to the corresponding core design method uncertainties and (c) show compliance with the STAR applicability requirements. If the application of STAR is unsuccessful, identify the reasons why the STAR application failed."

This summary report provides the NRC with the required information specified in the Conditions and Limitations section of the NRC safety evaluation for the STAR topical report.

#### Core Design Method Used

The core design method used for St. Lucie Unit 2 Cycle 17 reload core was the PHOENIX-P/ANC code design package described in Reference A-2. The CASMO-4/SIMULATE-3 (CS) code package described in Reference A-3 was used for the alternate method calculations.

#### Cycle 17 STAR Program Test Results (Comparison of Measured and Calculated Values)

A comparison of the last measured cycle values (Cycle 16) and the corresponding calculated values for the key physics parameters is provided in Table 3 along with the design method/analysis uncertainties.

Parameter	Measured (Cycle 16)	Predicted (Cycle 16)	Safety Analysis / Design Method Uncertainty	Within Criteria?
BOC HZP CBC	1570	1567	100 ppm (minimum)	Yes
BOC HZP CEA WORTH (Bank B)	1513.49	1528.00	15%	Yes
BOC HZP CEA WORTH (Bank 1/3/5)	1433.63	1415.00	15%	Yes
BOC HZP CEA WORTH (Bank 2/4)	1354.64	1299.00	15%	Yes
BOC HZP CEA WORTH (Bank A)	1696.70	1690.00	15%	Yes
BOC HZP CEA WORTH (Total)	5998.47	5932.00	10%	Yes
BOC HZP ITC	-0.864	-1.301	1.8 pcm/°F	Yes
Power Distribution (RMS, 30%)	2.46		±5.00% *	Yes
Power Distribution (RMS, 45%)	1.56		±5.00% *	Yes
Power Distribution (RMS, 98%)	1.37		±5.00% *	Yes

Table 3:	Comparison	of Key	Parameters

\*Procedural limit based on guidance in ANSI Standard 19.6.1 – 1997.

The measured to predicted values for Cycle 16 were all within the acceptance criteria and design method/safety analysis uncertainties. This demonstrates compliance with Applicability Requirements of Table 3.4 for "Core Design", Items 1 and 2 in the STAR Topical.

Table 4 provides a summary of tests performed during the startup of the current Cycle 17.

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## Table 4: Summary of Tests Performed for Cycle 17

TEST	POWER	Location	Within Test Criteria
CEA Drop Time	Shutdown	Test results located in Section III of this document.	YES
CEA Drop Characteristics	Shutdown	CEA coupling verified by CEA drop characteristics	YES
CBC	HZP	Test results located in Sections IV and V of this document.	YES
ITC	HZP	Test results located in Section V of this document.	YES
MTC Surveillance	HZP	Test results located in Section V of this document.	YES
Incore Flux Symmetry	Low (30%)	Test results located in Section VI and Figure 4 of this document.	YES
Incore Power Distribution	Intermediate (45%)	Test results located in Section VI and Figure 5 of this document.	YES
Incore Power Distribution	HFP (98%)	Test results located in Section VI and Figure 6 of this document.	YES
ΔCBC HZP-HFP	HFP	The difference in boron concentration was within 21.0 ppm of prediction.	YES

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#### Compliance with STAR Applicability Requirements

STAR Applicability Requirements are conditions that must be satisfied to use the STAR Program. The STAR Applicability Requirements are provided in Table 3-4 of Reference A-1 and provide assurance that the core can be operated as designed when used in conjunction with the proposed tests. The STAR Applicability Requirements involve the following areas:

- Core Design
- Fabrication
- Refueling
- Startup Testing
- CEA Lifetime

Conformance with the STAR Applicability Requirements is documented in accordance with plant processes and procedures. Demonstration of compliance with each of the STAR applicability requirements was documented in STAR Cycle Specific Startup Test Checklists that were completed during the core design and startup testing for Cycle 17. The completed STAR Cycle Specific Startup Test Checklists verify the applicability requirements of Reference A-1 are satisfied.

#### References

A-1. WCAP- 16011-P-A, Rev. 0, "Startup Test Activity Reduction Program," February 2005.

A-2. WCAP-11596-P-A, "Qualification of the PHOENIX-P/ANC Nuclear Design System for Pressurized Water Reactor Cores," June 1988.

A-3. CASMO-4 Methodology, SSP-95/02 Revision 0, September 1995 & SIMULATE-3 Methodology, SSP-95/18 Revision 0, October 1995.

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#### **Core Design Applicability Requirements**

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The core design for Cycle 17 (cycle for STAR implementation) consists of the following:

- A cycle length ~of 16.1 EFPM
- An average enrichment of 3.83 w/o U-235
- A maximum enrichment of 4.17 w/o U-235
- A reload of 72 fresh assemblies
- A burnable absorber type of Gd<sub>2</sub>O<sub>3</sub>
- A CEA absorber type of B<sub>4</sub>C
- A low leakage fuel management scheme

#### Requirements from Table 3.4, "Core Design" section (Pages 3-9 and 3-10) in WCAP-16011-P-A

STAR Topical Applicability Requirement	Requirement	Requiremen t Satisfied Yes / No
Core Design Item 1	See Table 3	YES
Core Design Item 2	See Table 3	YES
Core Design Item 3 (first bullet)	Cycle Length	YES
Core Design Item 3 (second bullet)	Average Enrichment	YES
Core Design Item 3 (second bullet)	Maximum Enrichment	YES
Core Design Item 3 (third bullet)	Fraction of Core Reloaded	, YES
Core Design Item 3 (fourth bullet)	Fuel Type	YES
Core Design Item 3 (fifth bullet)	Burnable Absorber Type	YES
Core Design Item 3 (sixth bullet)	CEA Absorber Type	YES
Core Design Item 3 (seventh bullet)	Fuel Management	YES
Core Design Item 4 (first bullet)	CEA Worth Reconciliation	YES – Within 5%

# **CEA Lifetime Applicability Requirements**

#### Requirements from Table 3.4, "CEA Lifetime" section (Page 3-11) in WCAP-16011-P-A

STAR Topical Applicability Requirement	Requirement	Requirement Satisfied Yes / No
CEA Lifetime Items 1, 2, 3	CEA lifetime requirements are consistent with the St. Lucie Unit 2 CEA lifetime management program/evaluation, which adheres to the STAR Topical criteria on CEA Lifetime?	YES

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## **Fabrication Applicability Requirements**

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#### Requirements from Table 3.4, "Fabrication" section (Page 3-11) in WCAP-16011-P-A

STAR Topical Applicability Requirement	Requirement	Requirement Satisfied Yes / No
Fabrication ltem 1.a	FPL final core design/burnable absorber letter is in agreement with the final manufacturing document to ensure STAR Topical Applicability Requirements Fabrication Item 1.a?	YES
Fabrication Item 1.b, 1.c	The STAR Topical Applicability Requirements Fabrication Items 1.b and 1.c are consistent between FPL final core design/burnable absorber letter and the final manufacturing document (for each rod type)?.	YES
Fabrication Item 1.c (2)	STAR Topical Fabrication Item 1.c (2) is consistent with the fuel design requirements (fuel assembly orientation)?	YES
Fabrication Item 1.d	The STAR Topical Applicability Requirements Fabrication Item 1.d for each fuel assembly is correct per the requirements of the FPL final core design/burnable absorber letter?	YES
Fabrication Items 2.a, 2.b, 2.c, 2.d	For new CEAs, is the final manufacturing document consistent with the design specifications for STAR Topical Applicability Requirements Fabrication Items 2.a, 2.b, 2.c, and 2.d.	YES

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# **Refueling Applicability Requirements**

#### Requirements from Table 3.4, "Refueling" section (Page 3-11) in WCAP-16011-P-A

STAR Topical Applicability Requirement	Requirement	Requirement Satisfied Yes / No
Refueling Item 1	Core verification	YES
Refueling Item 2	CEA coupling	YES

# **Startup Testing Applicability Requirements**

#### Requirements from Table 3.4, "Startup Testing" section (Page 3-11) in WCAP-16011-P-A

The measured to predicted value for the ARO HZP CBC difference was < 10 ppm for Cycle 17.

STAR Topical Applicability Requirement	Requirement	Requirement Satisfied Yes / No
Startup Testing Item 1	Measured to Predicted ARO HZP CBC	YES