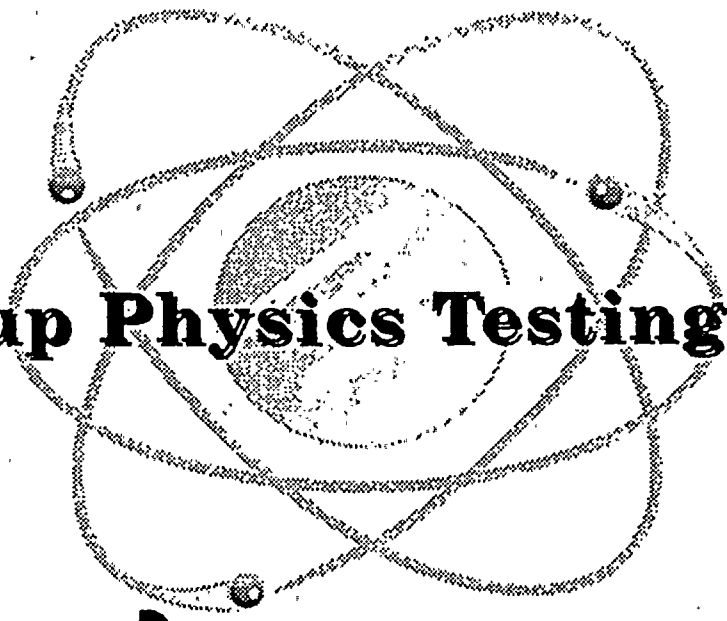


St. Lucie Unit 1, Cycle 12



Startup Physics Testing Report



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St. Lucie Unit 1, Cycle 12
Startup Physics Testing Report

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St. Lucie Unit 1, Cycle 12
Startup Physics Testing Report

Table of Contents

| <u>Section</u> | <u>Page</u> | <u>Title</u> |
|----------------|-------------|----------------------------|
| I | 4 | Introduction |
| II | 4 | Cycle 12 Fuel Design |
| III | 5 | Approach to Criticality |
| IV | 5 | Zero Power Physics Testing |
| V | 7 | Power Ascension Program |
| VI | 7 | Summary |
| VII | 8 | References |

List of Figures

| <u>Figure No.</u> | | <u>Titles</u> |
|-------------------|----|-------------------------------------|
| 1 | 9 | Cycle 12 Core Loading Pattern |
| 2 | 10 | Inverse Count Ratio Plot- Channel B |
| 3 | 10 | Inverse Count Ratio Plot- Channel D |
| 4 | 11 | RCS Boron Dilution Plot |
| 5 | 12 | Power Distribution- 25% Power |
| 6 | 13 | Power Distribution- 50% Power |
| 7 | 14 | Power Distribution- 100% Power |

List of Tables

| <u>Table No.</u> | | <u>Title</u> |
|------------------|----|---|
| 1 | 15 | Cycle-12 Reload Sub-Batch ID |
| 2 | 15 | Approach to Criticality |
| 3 | 16 | Comparison of SPCND Calculations with Measured Values |



St. Lucie Unit 1, Cycle 12
Startup Physics Testing Report

I. Introduction

The purpose of this report is to provide a description of the fuel design and core load, and to summarize the startup physics testing performed at St. Lucie Unit 1 following the Cycle 12 refueling. Startup physics testing verifies key core parameters are as predicted. The major parts of this testing program are:

- 1) Initial Criticality following reload,
- 2) Zero Power Physics Testing and,
- 3) Power Ascension Testing.

II. Cycle 12 Fuel Design

The Cycle 12 core consists entirely of fuel manufactured by Siemens Power Corporation Nuclear Division (SPCND). The 217 assemblies in the Cycle 12 core are comprised of fuel from three batches. Of these, 84 are fresh batch R assemblies consisting of natural uranium axial blanket assemblies, 84 are once burnt batch P assemblies consisting of 76 natural uranium axial blanket assemblies and 8 Vessel Fluence Reduction Assemblies (VFRAs), and 49 are twice burnt batch M assemblies. A further breakdown of the distinct sub-batches is contained in Table 1.

This is the sixth cycle of operation utilizing gadolinia, in the form of Gd_2O_3 , as a burnable absorber, coupled with the use of natural uranium blankets at the top and bottom of each fuel assembly. The batch R fuel is the fifth cycle of fuel provided by SPCND that uses long lower end-caps as a means of providing protection against debris fretting in the Lower End-Fitting region.

The Cycle 12 core map is represented in Figure 1. The assembly serial numbers and Control Element Assembly (CEA) serial numbers are given for each core location. As in Cycle 11, the Cycle 12 reload employs a low-leakage design that relies on batch M fuel around the periphery, augmented with VFRAs in the core flats to further reduce the fluence on the reactor vessel welds for life extension purposes. Each VFRA is constructed to the design of a standard fuel assembly with the exception of the fuel pellets loaded in each fuel rod. The VFRA design utilizes depleted uranium instead of the standard reload enrichments. In addition, each of the outer four guide tube finger holes is loaded with a full-length hafnium insert to further suppress the flux at the vessel boundary.

St. Lucie Unit 1, Cycle 12
Startup Physics Testing Report

Following the fuel shuffle and prior to the approach to criticality, CEA drop time testing was performed. The objective of this test was to measure the time of insertion from the fully-withdrawn position (UEL) to the 90% inserted position under hot, full-flow conditions. The average CEA drop time was found to be 2.30 seconds with maximum and minimum times of 2.50 seconds and 2.14 seconds, respectively. All drop times were within the requirements of Technical Specifications 3.1.3.4 (i.e. less than or equal to 3.1 seconds).

III. Approach to Criticality.

The approach to criticality involved diluting from a non-critical boron concentration of 1633 ppm to a predicted critical boron concentration of 1408 ppm. The actual critical concentration was observed to be 1377 ppm. Inverse countrate ratio (ICRR) plots were maintained during the dilution process using wide range channels B and D. Refer to Figures 2 and 3 for ICRR information. Table 2 summarizes the dilution rates and times, as well as the beginning and ending boron concentrations.

Initial criticality for St. Lucie Unit 1, Cycle 12 was achieved on May 29, 1993 at 0421 with CEA group 7 at 60 inches withdrawn and all other CEA's at the all rods out (ARO) position.

IV. Zero Power Physics Testing

The purpose of the Zero Power Physics Testing program is to verify that the core operating characteristics are consistent with the design predictions and to provide assurance that the core can be operated as designed. The major tests performed for the startup of Cycle 12 were the following:

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

St. Lucie Unit 1, Cycle 12
Startup Physics Testing Report

The tests above were performed in accordance with approved procedures .

Zero Power Physics Testing started on May 29, 1993, following initial criticality. Following the Reactivity Computer Checkout, the CEA Symmetry Test commenced. The initial test showed indications of a possible unlatched CEA and the Unit was returned to cold shutdown conditions, the reactor was disassembled, and the CEA was relatched. Criticality was achieved, again, on June 11, 1993, and Zero Power Physics Testing was reinitiated on June 12, 1993.

Proper operation of the Reactivity Computer was verified for a second time 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 ascertained 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 by the fuel vendor. Satisfactory agreement was obtained.

Verification of proper CEA latching was confirmed through the use of the CEA Symmetry Test utilizing the Unit 1 Shutdown Groups A and B which contain dual CEAs. The prescribed acceptance criteria was that the reactivity measured for each dual CEA shall be within ± 15.0 pcm of the average reactivity measured for the entire group. There were no unlatched CEAs for either Shutdown Group.

The All Rod's Out Critical Boron concentration was performed. The measured value was 1418.7 ppm which compared favorably with the design value of 1456 ppm. This was within the acceptance limits of ± 100 ppm.

The measurement of the Isothermal Temperature Coefficient was performed and the resulting Moderator Temperature Coefficient (MTC) was obtained. The MTC was determined to be $+1.54$ pcm/ $^{\circ}$ F which fell well within the acceptance criteria of ± 2.0 pcm/ $^{\circ}$ F of the design MTC of $+1.38$ pcm/ $^{\circ}$ F (corrected). This agreed favorably with the Unit 1 Technical Specification 3.1.1.4 which states that the MTC shall be less positive than 7.0 pcm/ $^{\circ}$ F.

The final section of interest for low power physics testing is in the measurement of CEA Group Rod Worths. Rod worth measurements were performed using the Rod Swap methodology. This method involves exchanging the reference group, measured by the boration dilution technique, with each of the remaining test groups. A comparison of the measured and design CEA reactivity

St. Lucie Unit 1, Cycle 12
Startup Physics Testing Report

worths is provided in Table 3. The following acceptance criteria apply to the measurements made:

- 1) The measured value of each test group is within $\pm 15\%$ or ± 100 pcm of the design CEA worths, whichever is greater.
- 2) The measured 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 in that the Reference Group measured worth was within $\pm 10\%$ of design worth and each test group was within $\pm 15\%$ or ± 100 pcm of design worth.

V. Power Ascension Program

During Power Ascension, the fixed incore detector system is utilized to verify that the fuel is loaded properly and there are no abnormalities occurring in the various core parameters (core peaking factors, LHR, and Tilt) for power plateaus at 25%, 50%, and $\geq 98\%$ rated thermal power. Calorimetric, Nuclear, and ΔT power calibrations were performed at each of the plateaus prior to advancing reactor power to the next higher power level. A summary of the results of the flux maps at each power level is provided in Figures 5, 6, and 7.

Within seven days of attaining 100% power, the Hot Full Power (HFP) MTC test was performed by maintaining power constant and varying temperature. The center CEA, 7-1, was inserted to permit compensation of the resulting reactivity changes. The HFP MTC was measured to be -5.7772 pcm/ $^{\circ}\text{F}$ which was within ± 2.0 pcm/ $^{\circ}\text{F}$ of the design value of -4.2810 pcm/ $^{\circ}\text{F}$. This test also verified compliance with Technical Specification 3.1.1.4 which requires the measured MTC be less negative than -28.0 pcm/ $^{\circ}\text{F}$ and less positive than 2.0 pcm/ $^{\circ}\text{F}$ while thermal power is greater than 70%.

VI. Summary

A second rod drop test was performed prior to reaching criticality on June 11. The results of that test were consistent with the previous test conducted in May. The average CEA drop time was 2.36 seconds and the maximum and minimum times were 2.54 seconds and 2.22 seconds, respectively. Compliance with the applicable Technical Specifications was satisfactory for all tests.

St. Lucie Unit 1, Cycle 12
Startup Physics Testing Report

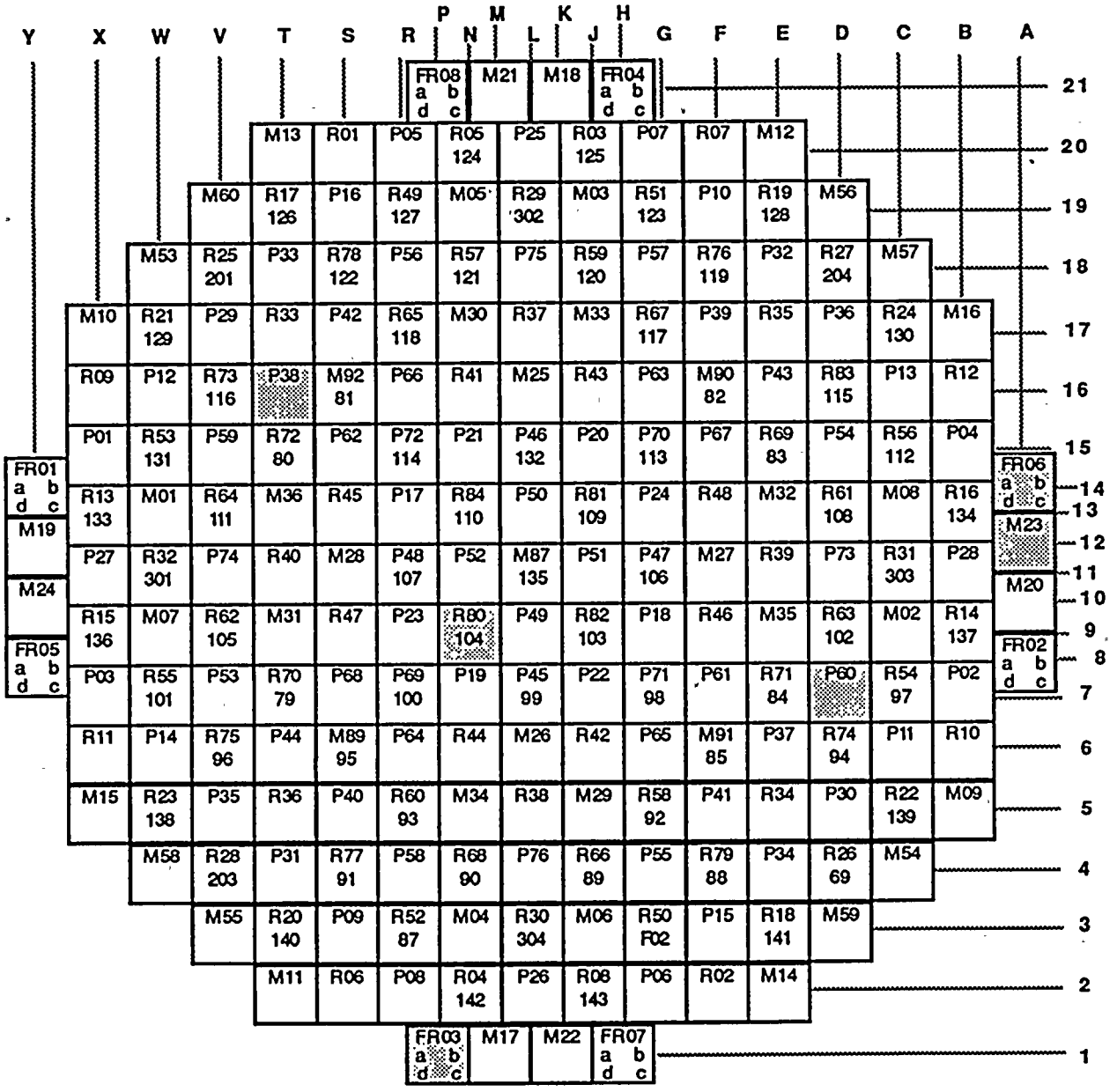
VII. References

- 1) "St. Lucie Unit 1, Cycle 12 Startup and Operations Report," EMF-93-076(P), .
dated April, 1993.
- 2) "Initial Criticality," Pre-Operational Test Procedure Number 1-3200088,
Revision 3.
- 3) "Reload Startup Physics Testing," Pre-Operational Test Procedure Number
3200091, Revision 1.
- 4) "Reactor Engineering Power Ascension Program," Pre-Operational Test
Procedure Number 3200092, Revision 3.
- 5) St. Lucie Unit 1 Technical Specifications.



St. Lucie Unit 1, Cycle 12
Startup Physics Testing Report

FIGURE 1
CYCLE 12 CORE LOADING PATTERN



St. Lucie Unit 1, Cycle 12
Startup Physics Testing Report

FIGURE 2
WIDERANGE CHANNEL B BORON DILUTION

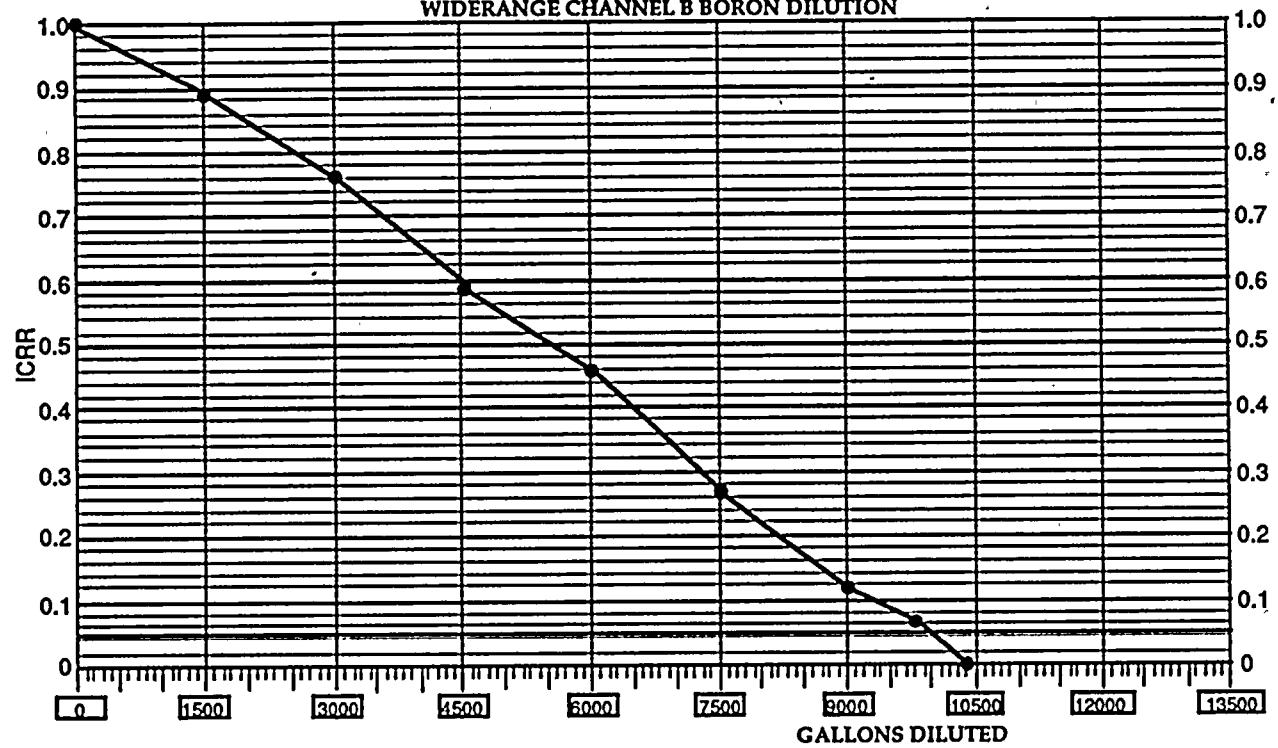
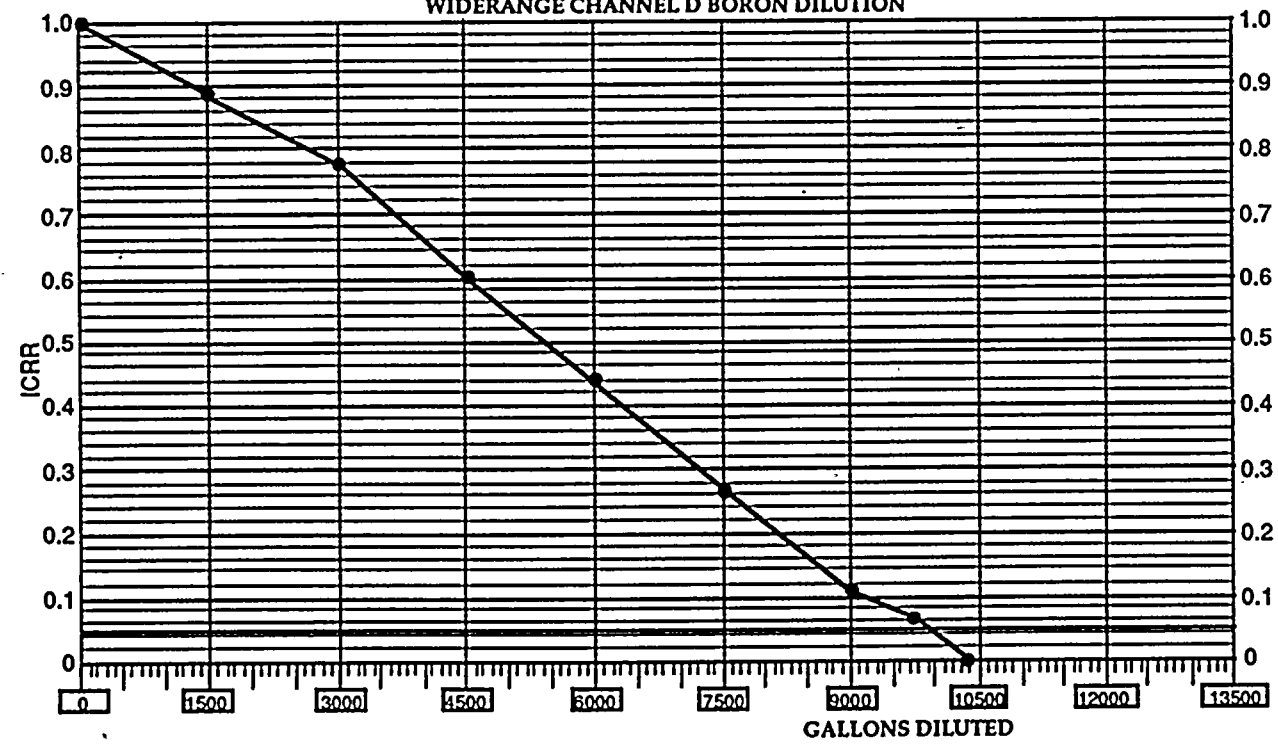


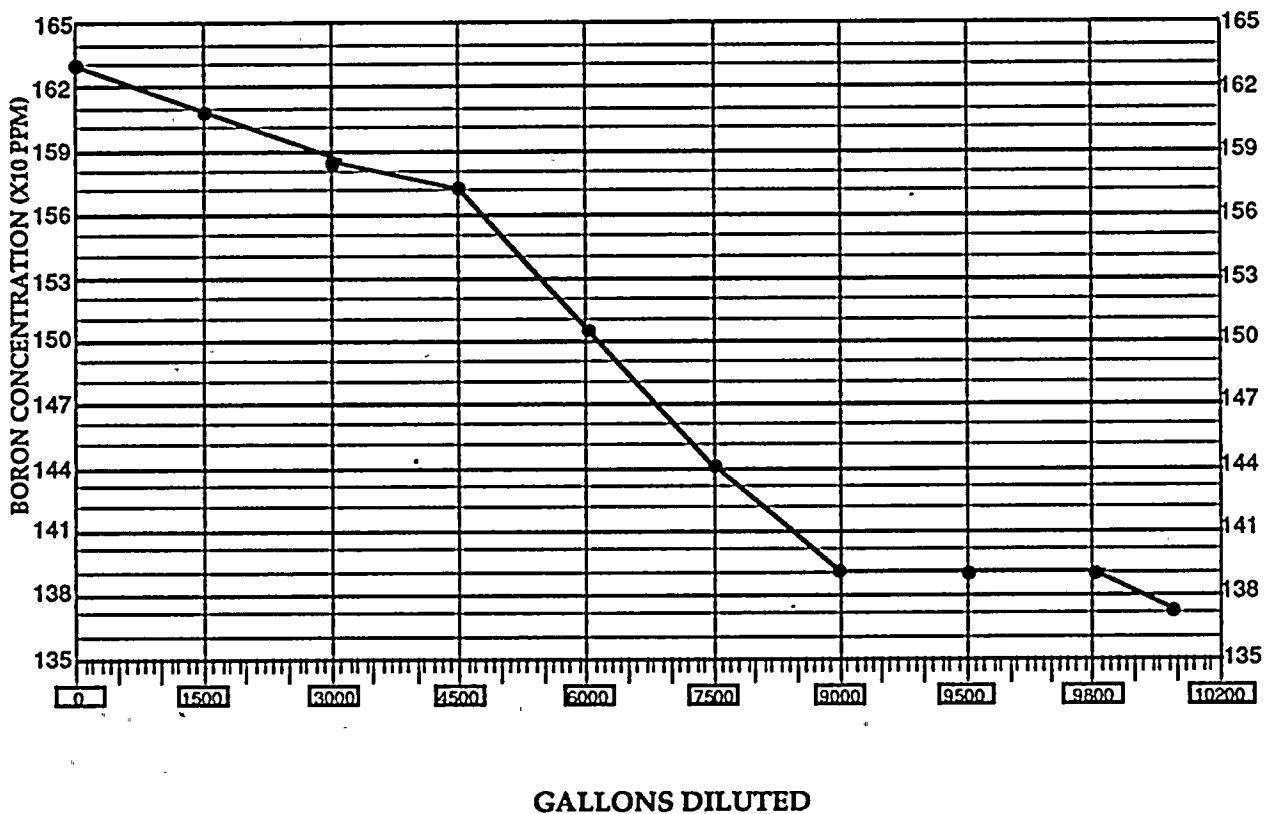
FIGURE 3
WIDERANGE CHANNEL D BORON DILUTION



St. Lucie Unit 1, Cycle 12
Startup Physics Testing Report

FIGURE 4
RCS BORON DILUTION

BORON CONCENTRATION VS. GALLONS DILUTED





St. Lucie Unit 1, Cycle 12
Startup Physics Testing Report

**FIGURE 6
POWER DISTRIBUTION COMPARISON WITH DESIGN
AT 50% POWER**

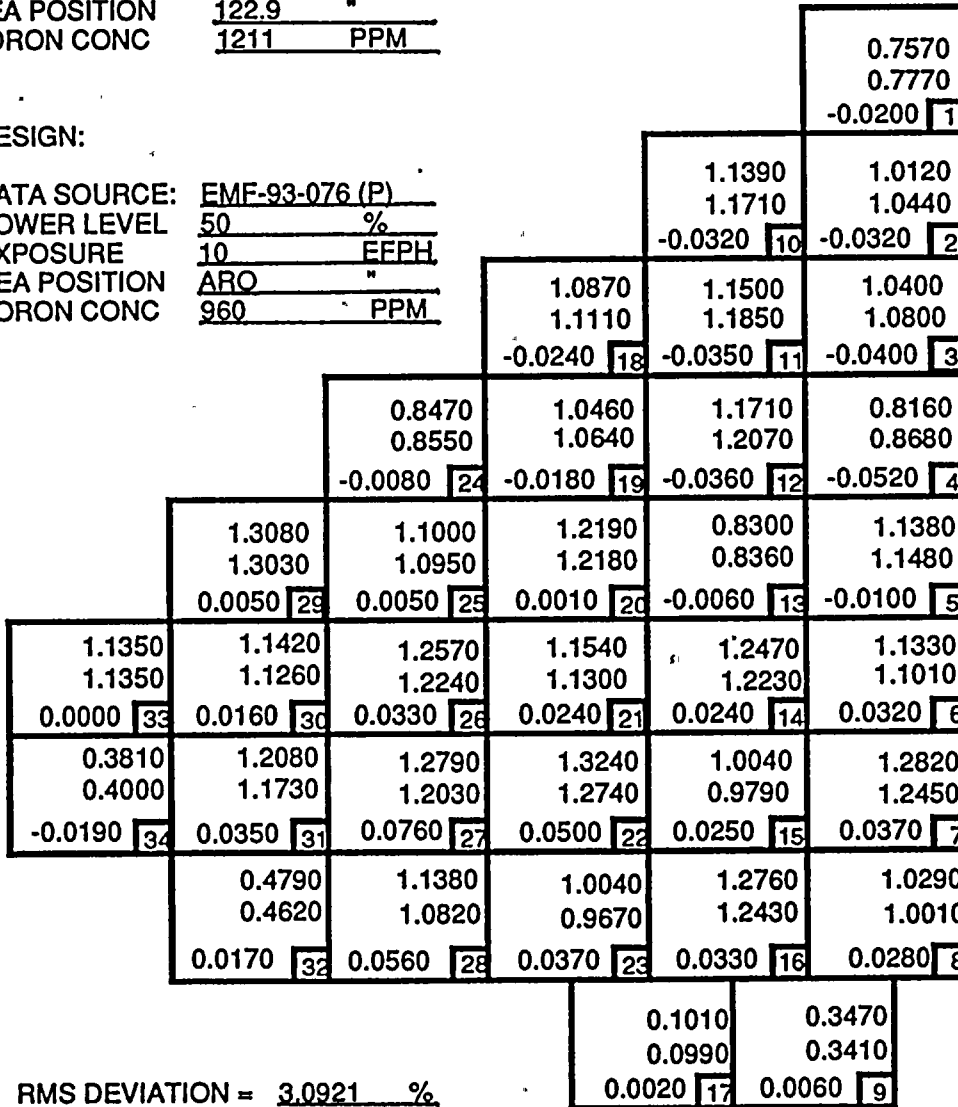
UNIT 1

MEASURE: (CECOR/INPAX)

SNAPSHOT ID# 10619931
POWER LEVEL 50 %
EXPOSURE 9.59 EFPH
CEA POSITION 122.9 "
BORON CONC 1211 PPM

DESIGN:

DATA SOURCE: EMF-93-076 (P)
POWER LEVEL 50 %
EXPOSURE 10 EFPH
CEA POSITION ARO "
BORON CONC 960 PPM



RMS DEVIATION = 3.0921 %

| |
|------------|
| KEY |
| MEASURED |
| DESIGN |
| DELTA [ID] |

St. Lucie Unit 1, Cycle 12
Startup Physics Testing Report

**FIGURE 7
POWER DISTRIBUTION COMPARISON WITH DESIGN
AT 100% POWER**

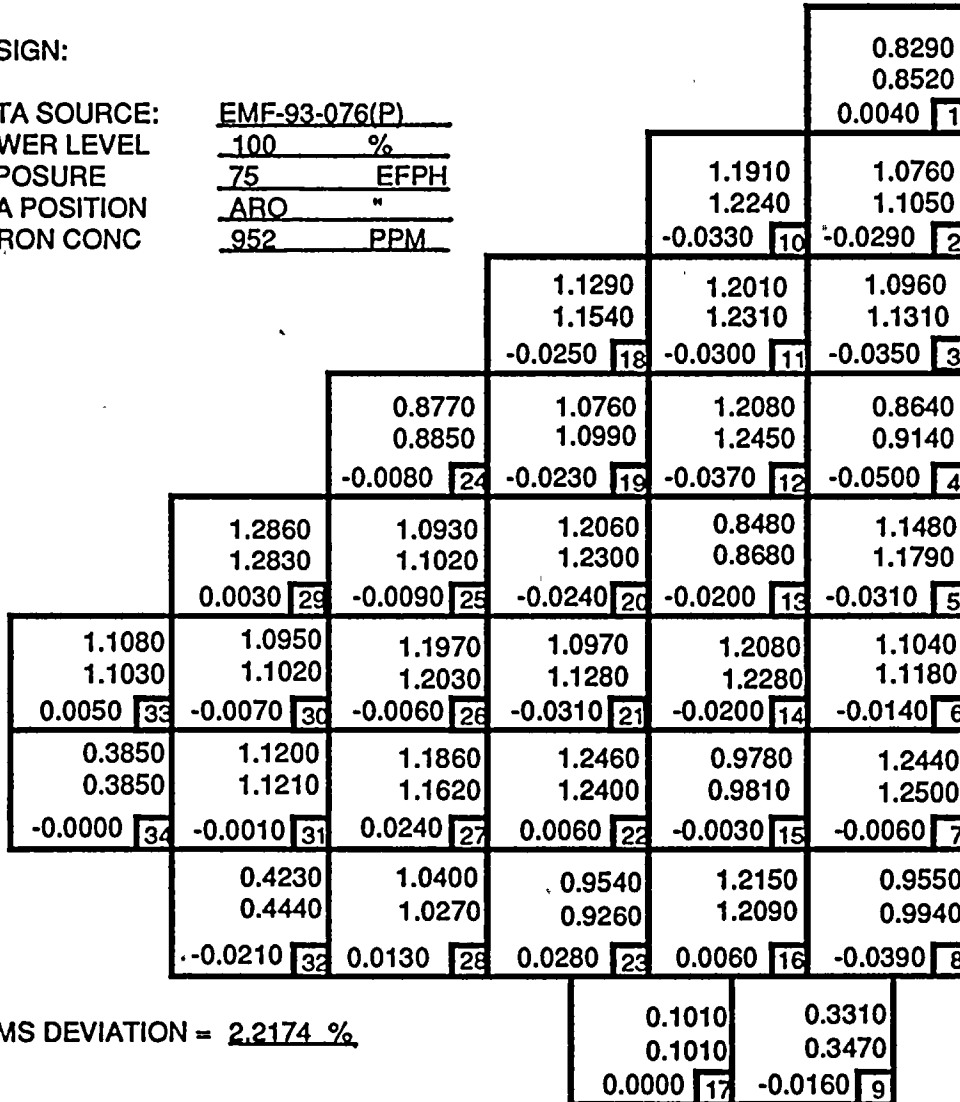
MEASURE: (CECOR/INPAX)

UNIT 1

SNAPSHOT ID # 10623931
POWER LEVEL 98.80 %
EXPOSURE 88.41 EFPH
CEA POSITION 135 "
BORON CONC. 987 PPM

DESIGN:

DATA SOURCE: EMF-93-076(P)
POWER LEVEL 100 %
EXPOSURE 75 EFPH
CEA POSITION ARO "
BORON CONC 952 PPM



RMS DEVIATION = 2.2174 %

| |
|------------|
| KEY |
| MEASURED |
| DESIGN |
| DELTA [ID] |

St. Lucie Unit 1, Cycle 12
Startup Physics Testing Report

TABLE 1
CYCLE 12 RELOAD SUB-BATCH ID

| Sub-Batch | # of Assemb | Enrich. |
|-----------|-------------|---------|
| M1 | 16 | 4.00 |
| M2 | 12 | 3.97 |
| M3 | 8 | 3.90 |
| M4 | 9 | 3.89 |
| M5 | 4 | 3.87 |
| P1 | 16 | 3.75 |
| P2 | 12 | 3.73 |
| P3 | 40 | 3.65 |
| P4 | 4 | 3.64 |
| P5 | 4 | 3.62 |
| P6 | 8 | 0.30 |
| R1 | 16 | 3.90 |
| R2 | 12 | 3.88 |
| R3 | 20 | 3.81 |
| R4 | 24 | 3.79 |
| R5 | 12 | 3.76 |

TABLE 2
APPROACH TO CRITICALITY

| Dilution Rate | Init. Boron Conc. | Final Boron Conc. | Dilution Time(min) |
|---------------|-------------------|-------------------|--------------------|
| 88 gpm | 1633 ppm | 1444 ppm | 151 |
| 44 gpm | 1444 ppm | 1377 ppm | 78 |

St. Lucie Unit 1, Cycle 12
Startup Physics Testing Report

**TABLE 3
COMPARISONS OF SPCND CALCULATIONS WITH
MEASURED VALUES**

CEA Group Worth Summary

| CEAGroup | Measured | Design | % Diff. |
|----------|----------|--------|----------|
| B/5 | 509 | 570 | 11.98 % |
| 7 | 654 | 591 | - 9.63 % |
| 2 | 699 | 674 | - 3.58 % |
| 1 | 759 | 689 | - 9.22 % |
| 4 | 824 | 714 | -13.35 % |
| 6/3 | 929 | 825 | -11.19 % |
| A | 1099 | 1059.2 | -3.62 % |
| Total | 5473 | 5122.2 | -6.41% |

Note: All worths in pcm
% Diff = (D/M-1)100

HZP Critical Boron

| Condition | Measured | Design(Adj) | Difference (M-D) |
|-----------|------------|-------------|------------------|
| ARO | 1418.7 ppm | 1456 ppm | -37.3 ppm |

Moderator Temperature Coefficient

| Condition | Measured | Design(Adj) | Difference(M-D) |
|-----------|--------------|--------------|-----------------|
| ARO | +1.56 pcm/°F | +1.38 pcm/°F | +0.18 pcm/°F |