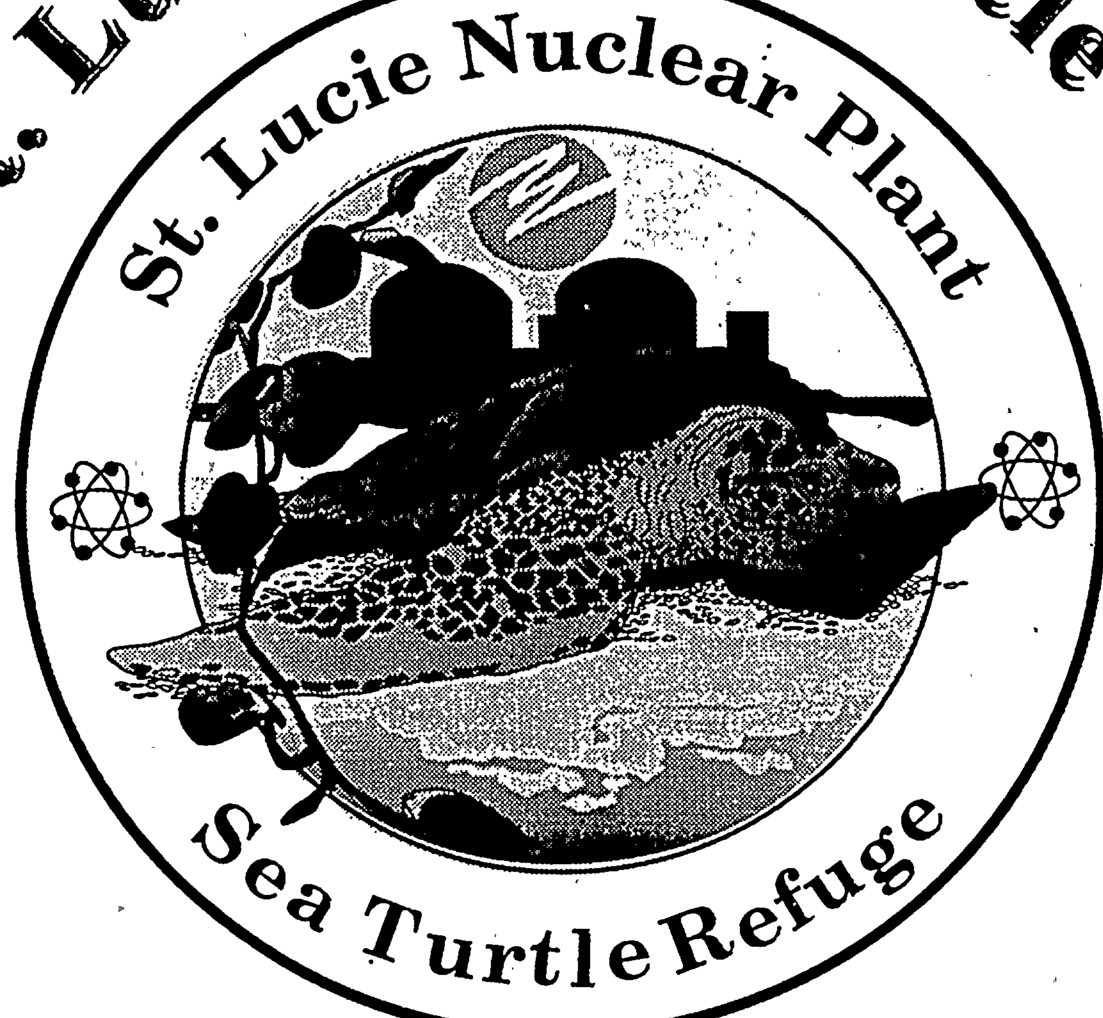
St. Lucie Unit 1, Cycle 12



Startup Physics Testing Report

(PRES/930584)

Author *Patricia Wachtel* Date *8-23-93*
Patricia Wachtel
Reactor Engineering, St. Lucie Plant

Reviewed *Walter D. Mead jr* Date *8-23-93*
Walter D. Mead, jr
Reactor Engineering, St. Lucie Plant

Reviewed *Modesto Jimenez* Date *8/30/93*
Modesto Jimenez
Reactor Support Supervisor, Nuclear Fuel

Approved *EWunderlich* Date *9/1/93*
Erwin J. Wunderlich
Reactor Engineering Supervisor
St. Lucie Plant

Table of Contents

List of Figures

List of Tables

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.

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

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 CEA's. The prescribed acceptance criteria was that the reactivity measured for each dual CEA shall be within $\pm$ 15.0 pcm of the average reactivity measured for the entire group. There were no unlatched CEA's 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/°F which fell well within the acceptance criteria of ± 2.0 pcm/°F of the design MTC of +1.38 pcm/°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/°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 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 ±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 ±10% of the total design worth.

All acceptance criteria were met in that the Reference Group measured worth was within ±10% of design worth and each test group was within ±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 ≥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/°F which was within ±2.0 pcm/°F of the design value of -4.2810 pcm/°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/°F and less positive than 2.0 pcm/°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.

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.*

FIGURE 1
CYCLE 12 CORE LOADING PATTERN

	P	M	K	H
21	FR08 a b d c	M21	M18	FR04 a b d c

	X	W	V	T	S	R	N	L	J	G	F	E	D	C	B
20				M13	R01	P05	R05 124	P25	R03 125	P07	R07	M12			
19			M60	R17 126	P16	R49 127	M05	R29 302	M03	R51 123	P10	R19 128	M56		
18		M53	R25 201	P33	R78 122	P56	R57 121	P75	R59 120	P57	R76 119	P32	R27 204	M57	
17	M10	R21 129	P29	R33	P42	R65 118	M30	R37	M33	R67 117	P39	R35	P36	R24 130	M16
16	R09	P12	R73 116	P38	M92 81	P66	R41	M25	R43	P63	M90 82	P43	R83 115	P13	R12
15	P01	R53 131	P59	R72 80	P62	P72 114	P21	P46 132	P20	P70 113	P67	R69 83	P54	R56 112	P04
	R13 133	M01	R64 111	M36	R45	P17	R84 110	P50	R81 109	P24	R48	M32	R61 108	M08	R16 134
	P27	R32 301	P74	R40	M28	P48 107	P52	M87 135	P51	P47 106	M27	R39	P73	R31 303	P28
	R15 136	M07	R62 105	M31	R47	P23	R80 104	P49	R82 103	P18	R46	M35	R63 102	M02	R14 137
	P03	R55 101	P53	R70 79	P68	P69 100	P19	P45 99	P22	P71 98	P61	R71 84	P60	R54 97	P02
6	R11	P14	R75 96	P44	M89 95	P64	R44	M26	R42	P65	M91 85	P37	R74 94	P11	R10
5	M15	R23 138	P35	R36	P40	R60 93	M34	R38	M29	R58 92	P41	R34	P30	R22 139	M09
4		M58	R28 203	P31	R77 91	P58	R68 90	P76	R66 89	P55	R79 88	P34	R26 69	M54	
3			M55	R20 140	P09	R52 87	M04	R30 304	M06	R50 F02	P15	R18 141	M59		
2				M11	R06	P08	R04 142	P26	R08 143	P06	R02	M14			

	P	M	K	H
1	FR03 a b d c	M17	M22	FR07 a b d c

Y	A	
FR01 a b d c	FR06 a b d c	14, 13
M19	M23	12, 11
M24	M20	10
FR05 a b d c	FR02 a b d c	9, 8, 7

FIGURE 2
WIDERANGE CHANNEL B BORON DILUTION

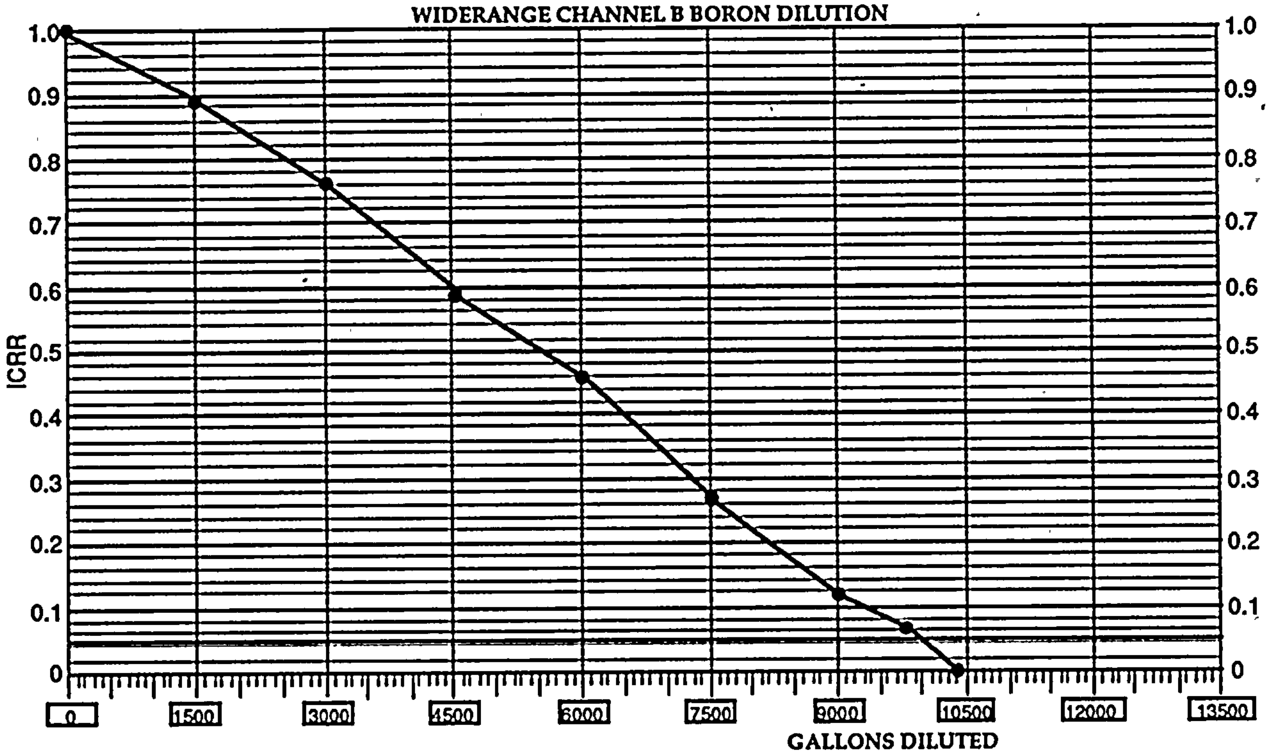


FIGURE 3
WIDERANGE CHANNEL D BORON DILUTION

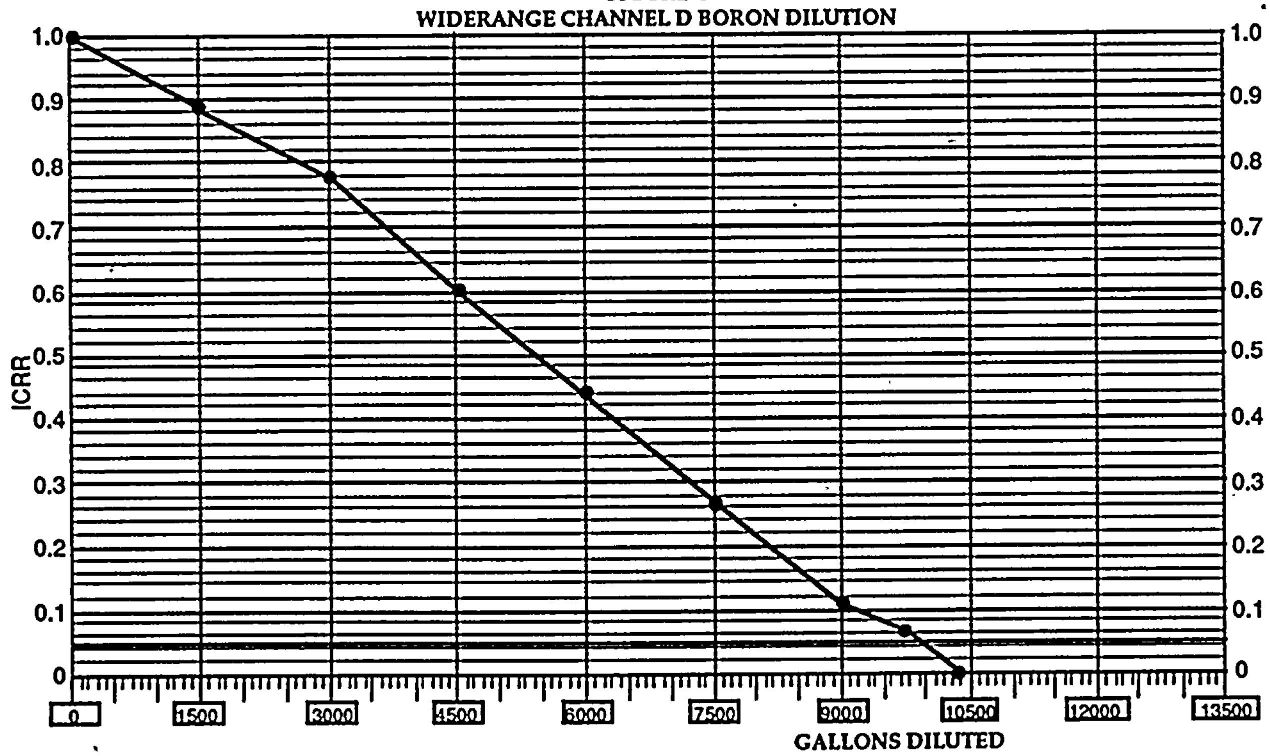


FIGURE 4
RCS BORON DILUTION

BORON CONCENTRATION VS. GALLONS DILUTED

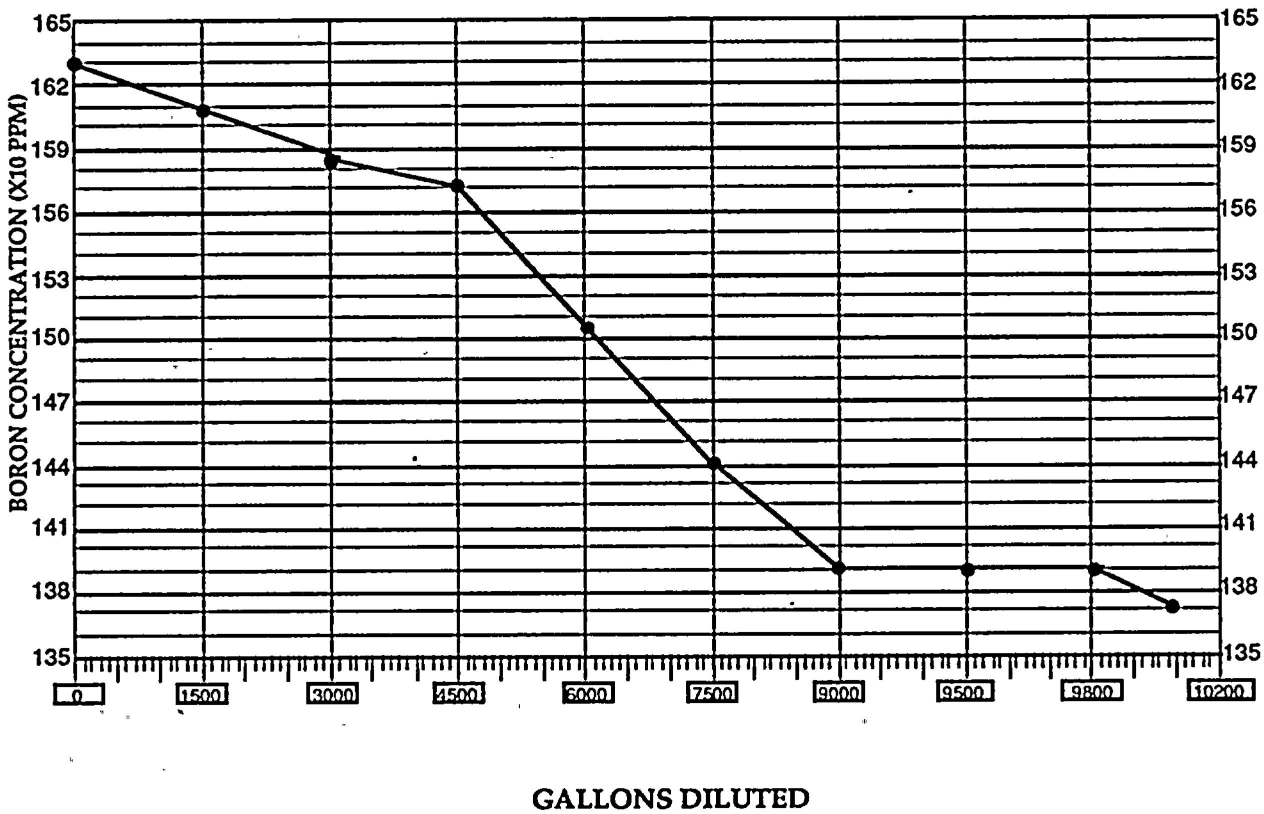


FIGURE 5
POWER DISTRIBUTION COMPARISON WITH DESIGN AT 25% POWER

MEASURE: (CECOR/INPAX)

UNIT 1

SNAPSHOT ID #	I0618936	
POWER LEVEL	25	%
EXPOSURE	4.6	EFPH
CEA POSITION	122.25	"
BORON CONC.	1381	PPM

DESIGN:

DATA SOURCE:	EMF-93-076(P)	
POWER LEVEL	25	%
EXPOSURE	5	EFPH
CEA POSITION	122	"
BORON CONC	960	PPM

					0.7260 0.7480 -0.0220 [1]
				1.1210 1.1440 -0.0230 [10]	0.9830 1.0150 -0.0320 [2]
			1.0720 1.0890 -0.0170 [18]	1.1340 1.1580 -0.0240 [11]	1.0200 1.0530 -0.0330 [3]
		0.8260 0.8390 -0.0130 [24]	1.0300 1.0410 -0.0110 [19]	1.1610 1.1790 -0.0180 [12]	0.8090 0.8440 -0.0350 [4]
	1.3080 1.3150 -0.0070 [29]	1.0780 1.0880 -0.0100 [25]	1.2030 1.2040 -0.0010 [20]	0.8090 0.8160 -0.0070 [13]	1.1120 1.1310 -0.0190 [5]
1.1470 1.1580 -0.0110 [33]	1.1320 1.1400 -0.0080 [30]	1.2330 1.2310 0.0020 [26]	1.1420 1.1280 0.0140 [21]	1.2300 1.2160 0.0140 [14]	1.1030 1.0940 0.0090 [6]
0.4000 0.4070 -0.0070 [34]	1.1830 1.1980 -0.0150 [31]	1.2280 1.2210 0.0070 [27]	1.3070 1.2870 0.0200 [22]	0.9980 0.9750 0.0230 [15]	1.2900 1.2500 0.0400 [7]
	0.4290 0.4680 -0.0390 [32]	1.1020 1.1060 -0.0040 [28]	1.0010 0.9830 0.0180 [23]	1.3040 1.2500 0.0540 [16]	1.0700 1.0060 0.0640 [8]
				0.1000 0.0970 0.0030 [17]	0.3490 0.3350 0.0140 [9]

KEY

MEASURED DESIGN DELTA [ID]

RMS DEVIATION = 2.3628 %

FIGURE 6
POWER DISTRIBUTION COMPARISON WITH DESIGN AT 50% POWER

UNIT 1

MEASURE: (CECOR/INPAX)

SNAPSHOT ID#	I0619931
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

					0.7570 0.7770 -0.0200 [1]
				1.1390 1.1710 -0.0320 [10]	1.0120 1.0440 -0.0320 [2]
			1.0870 1.1110 -0.0240 [18]	1.1500 1.1850 -0.0350 [11]	1.0400 1.0800 -0.0400 [3]
		0.8470 0.8550 -0.0080 [24]	1.0460 1.0640 -0.0180 [19]	1.1710 1.2070 -0.0360 [12]	0.8160 0.8680 -0.0520 [4]
	1.3080 1.3030 0.0050 [29]	1.1000 1.0950 0.0050 [25]	1.2190 1.2180 0.0010 [20]	0.8300 0.8360 -0.0060 [13]	1.1380 1.1480 -0.0100 [5]
1.1350 1.1350 0.0000 [33]	1.1420 1.1260 0.0160 [30]	1.2570 1.2240 0.0330 [26]	1.1540 1.1300 0.0240 [21]	1.2470 1.2230 0.0240 [14]	1.1330 1.1010 0.0320 [6]
0.3810 0.4000 -0.0190 [34]	1.2080 1.1730 0.0350 [31]	1.2790 1.2030 0.0760 [27]	1.3240 1.2740 0.0500 [22]	1.0040 0.9790 0.0250 [15]	1.2820 1.2450 0.0370 [7]
	0.4790 0.4620 0.0170 [32]	1.1380 1.0820 0.0560 [28]	1.0040 0.9670 0.0370 [23]	1.2760 1.2430 0.0330 [16]	1.0290 1.0010 0.0280 [8]
				0.1010 0.0990 0.0020 [17]	0.3470 0.3410 0.0060 [9]

KEY

MEASURED
DESIGN
DELTA [ID]

RMS DEVIATION = 3.0921 %

FIGURE 7
POWER DISTRIBUTION COMPARISON WITH DESIGN AT 100% POWER

MEASURE: (CECOR/INPAX)

UNIT 1

SNAPSHOT ID #	I0623931
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

					0.8290 0.8520 0.0040 [1]
				1.1910 1.2240 -0.0330 [10]	1.0760 1.1050 -0.0290 [2]
			1.1290 1.1540 -0.0250 [18]	1.2010 1.2310 -0.0300 [11]	1.0960 1.1310 -0.0350 [3]
		0.8770 0.8850 -0.0080 [24]	1.0760 1.0990 -0.0230 [19]	1.2080 1.2450 -0.0370 [12]	0.8640 0.9140 -0.0500 [4]
	1.2860 1.2830 0.0030 [29]	1.0930 1.1020 -0.0090 [25]	1.2060 1.2300 -0.0240 [20]	0.8480 0.8680 -0.0200 [13]	1.1480 1.1790 -0.0310 [5]
1.1080 1.1030 0.0050 [33]	1.0950 1.1020 -0.0070 [30]	1.1970 1.2030 -0.0060 [26]	1.0970 1.1280 -0.0310 [21]	1.2080 1.2280 -0.0200 [14]	1.1040 1.1180 -0.0140 [6]
0.3850 0.3850 -0.0000 [34]	1.1200 1.1210 -0.0010 [31]	1.1860 1.1620 0.0240 [27]	1.2460 1.2400 0.0060 [22]	0.9780 0.9810 -0.0030 [15]	1.2440 1.2500 -0.0060 [7]
	0.4230 0.4440 -0.0210 [32]	1.0400 1.0270 0.0130 [28]	0.9540 0.9260 0.0280 [23]	1.2150 1.2090 0.0060 [16]	0.9550 0.9940 -0.0390 [8]
				0.1010 0.1010 0.0000 [17]	0.3310 0.3470 -0.0160 [9]

KEY

MEASURED DESIGN DELTA [ID]

RMS DEVIATION = 2.2174 %

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

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