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

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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,

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

IE26

ST. LUCIE UNIT 1
CYCLE 16

St. Lucie Nuclear Plant

Sea Turtle Refuge

STARTUP PHYSICS TESTING REPORT

(D/RE/930584-R0)

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

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St. Lucie Unit 1, Cycle 16
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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 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 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

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_2 fuel rods and UO_2-Gd_2O_3 bearing rods (gadolinia burnable absorber fuel rods). UO_2 fuel rods have a central zone enrichment of 4.15 and 4.45 w/o U_{235}, whereas the UO_2-Gd_2O_3 rods have a central zone of 4 to 8 w/o Gd_2O_3 dispersed in a 2.6 to 3.5 w/o U_{235} carrier. The total batch burnable absorber requirement for fresh fuel is 992 Gd_2O_3 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_2) 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

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

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 ±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 ± 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 ± 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 ±15% or ±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.

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

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. References

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

9) St. Lucie Unit 1 Cycle 16 Reload PC/M #99016, Rev. 2, Attachment 1, Page 28 of 30.

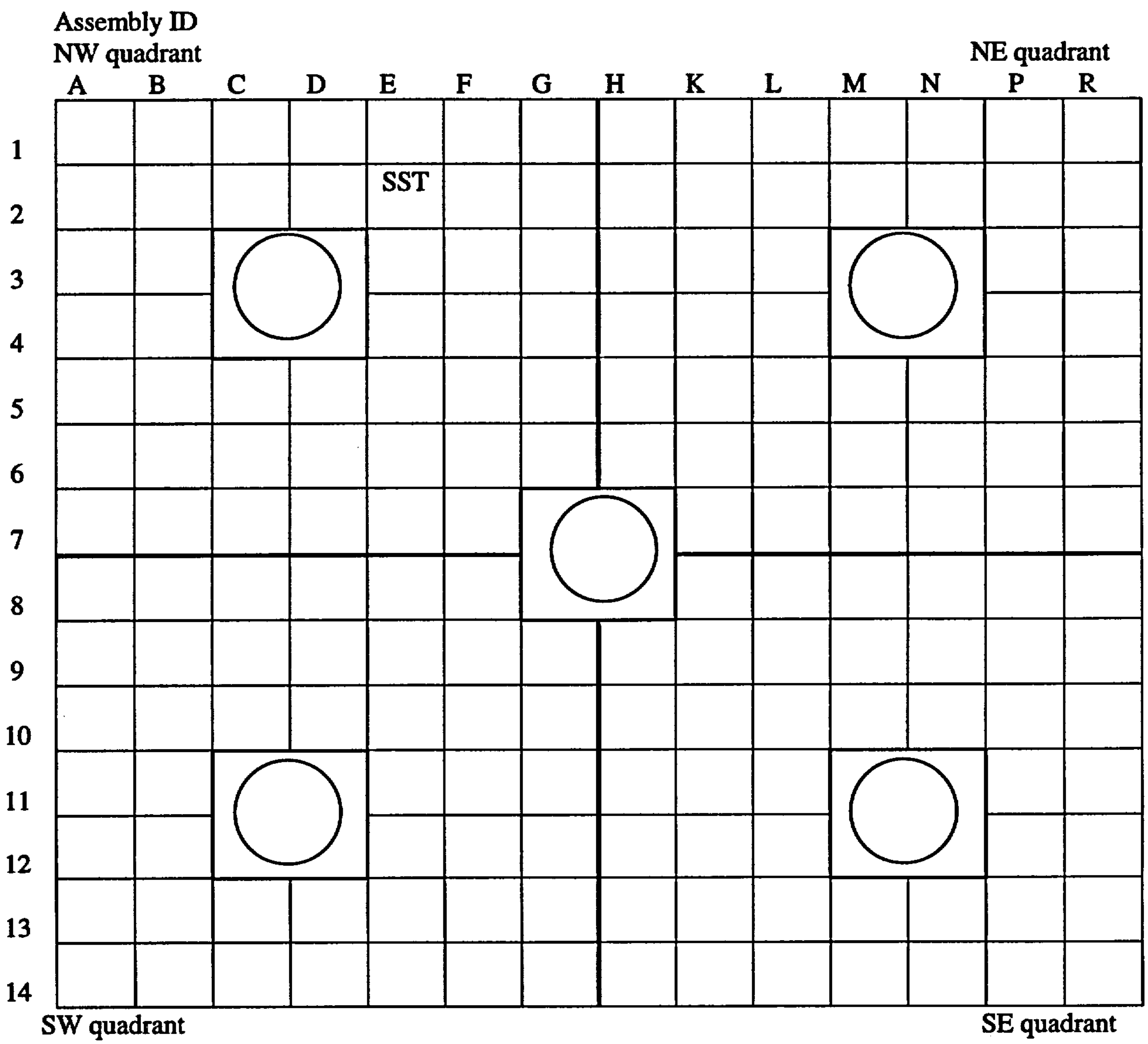
10) ENG Calculation PSL-1FJF-93-025, Revision 0, *"PSL1 CEA Drop Time Criteria for 90% Insertion"*

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



Top View

	Legend
SST	Stainless Steel Filler Rod

Figure 2
Cycle 16 Core Loading Pattern

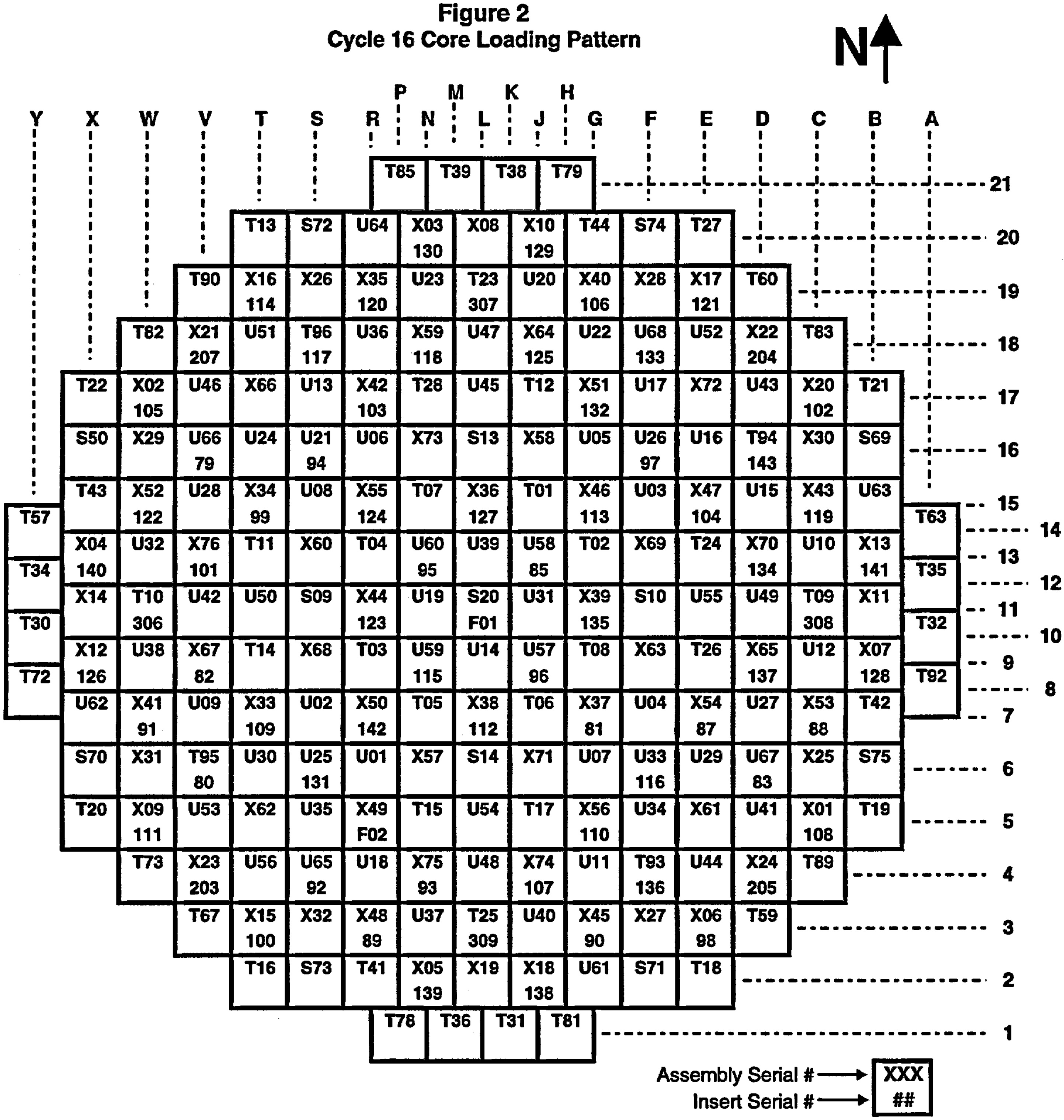


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Figure 3
Inverse Count Ratio Plot - Channel B

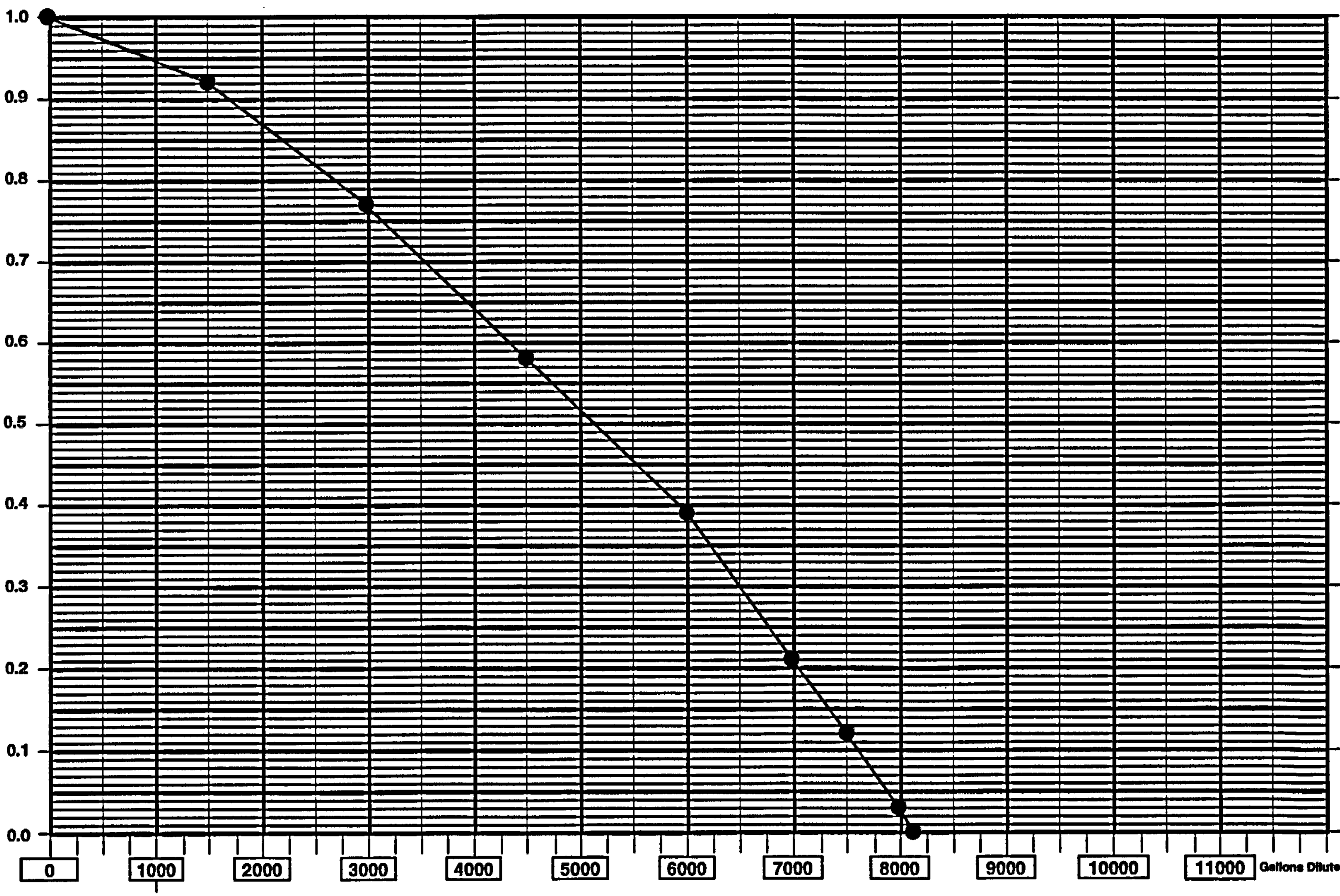

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Figure 4
Inverse Count Ratio Plot - Channel D

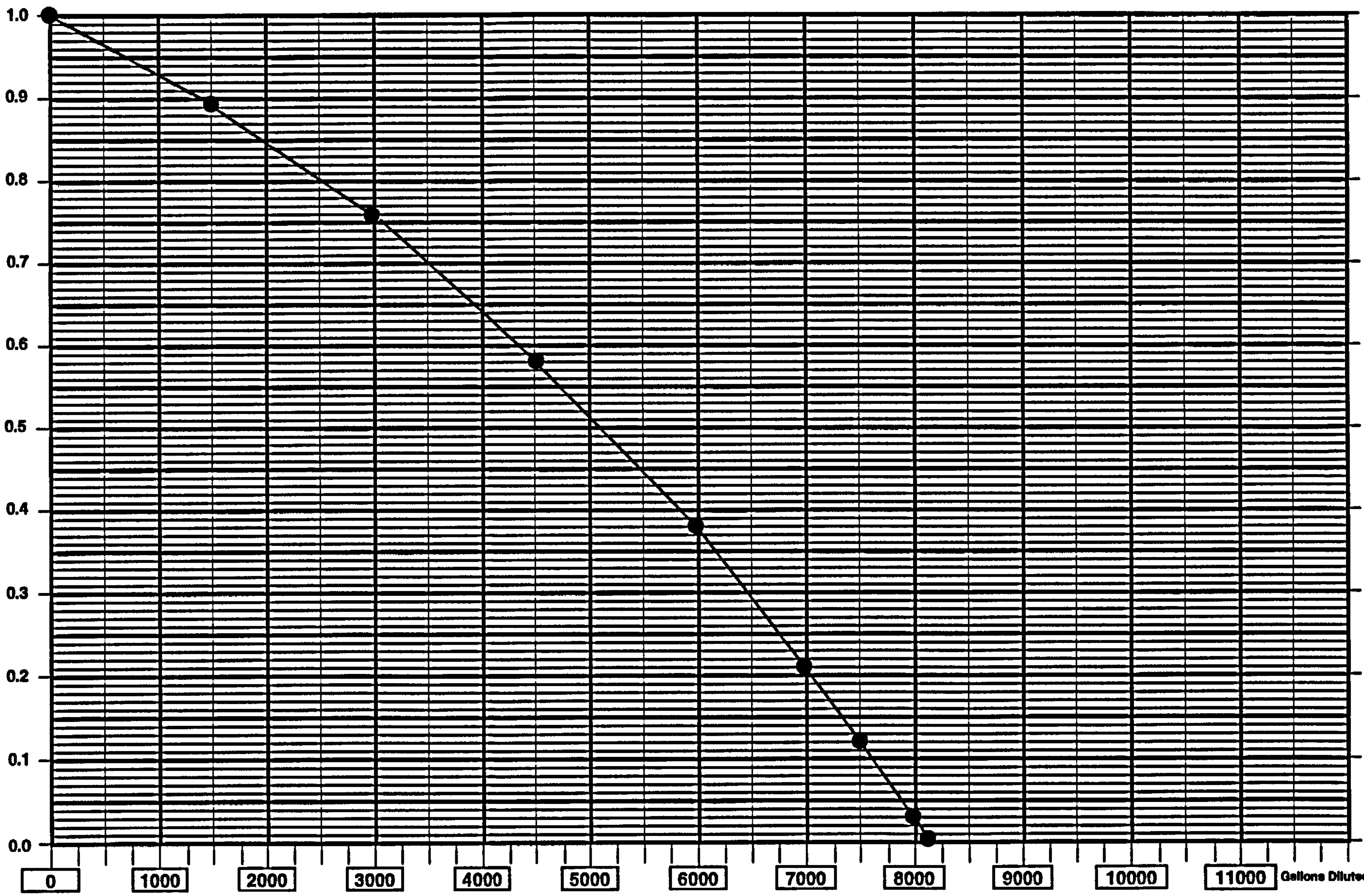

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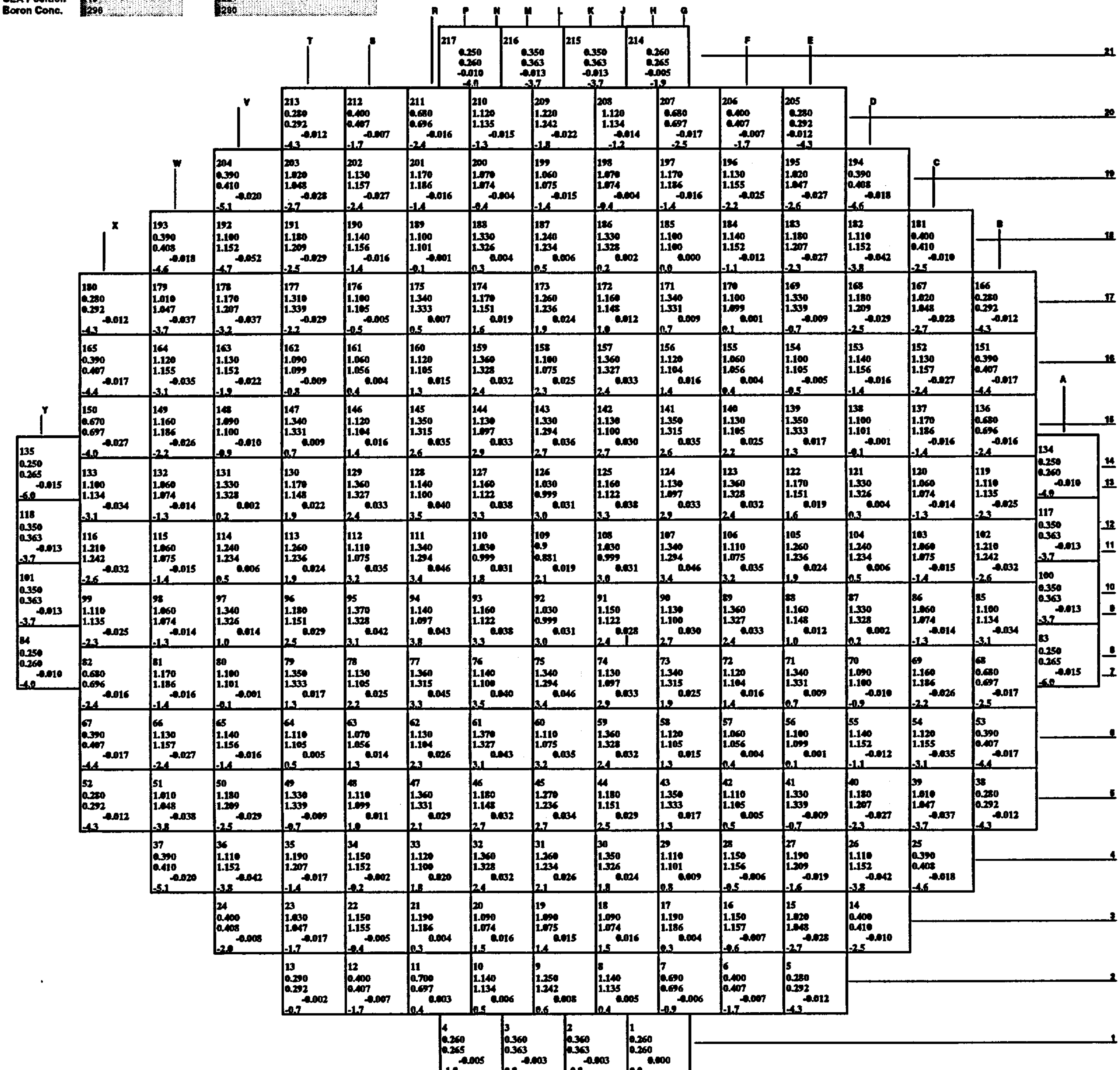
Figure 5

Power Distribution - 30% Power

	Measured:	Design:
	BEACON	
Source	S1_991020_0018	PCM 99016 Rev 2 Attachment 17
Power Level	29.6%	30.0%
Exposure	5.1	
CEA Position	119	122
Boron Conc.	1296	1280



RMS Deviation: 2.26%

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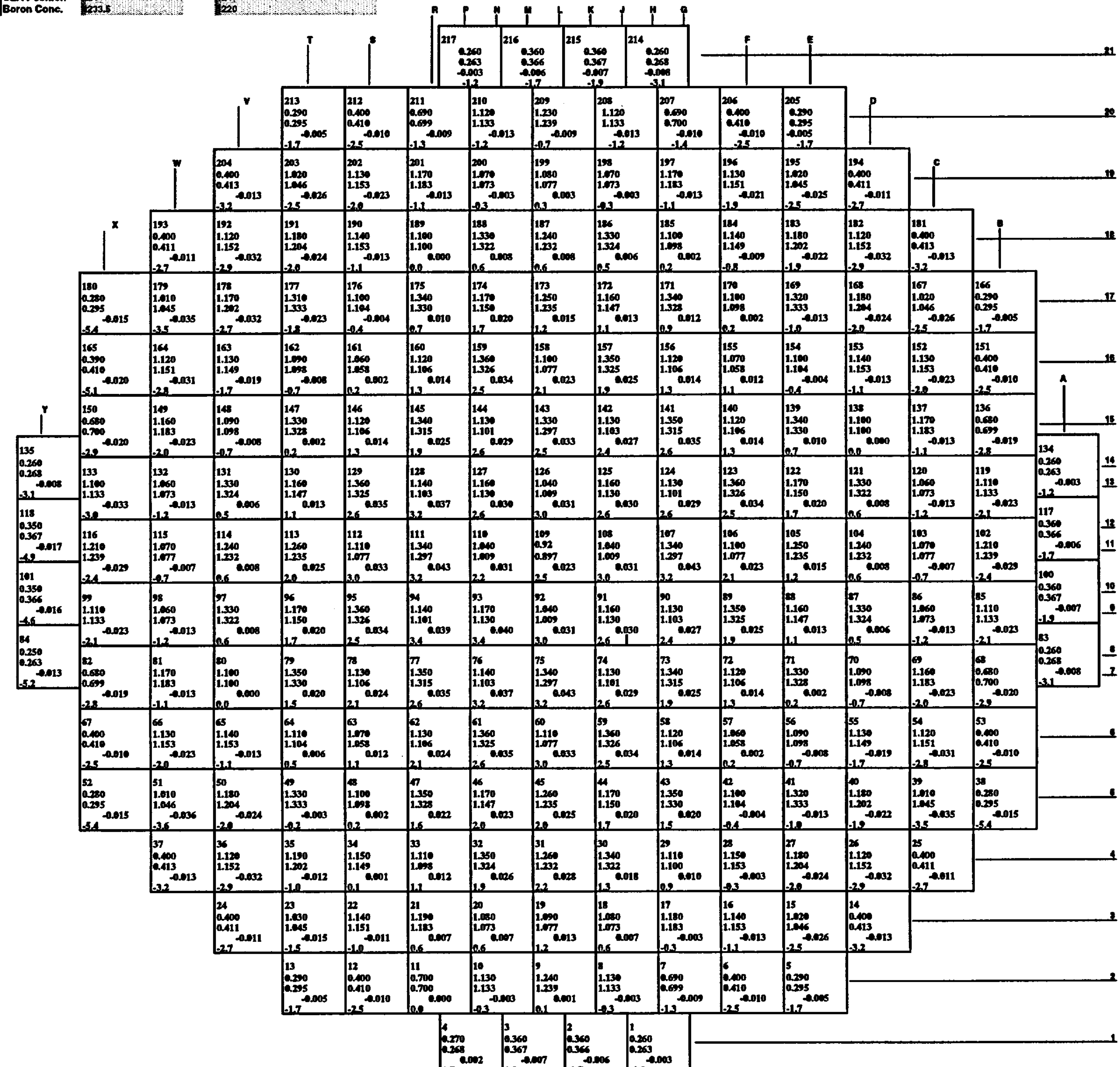
Figure 6

Power Distribution - 45% Power

	Measured:	Design:
	BEACON	
Source	s1_991020_1167	PCM 99016 Rev 2 Attachment 17
Power Level	45.0%	45.0%
Exposure	1.9	1
CEA Position	124	124
Boron Conc.	1233.5	1220



RMS Deviation: 1.97%

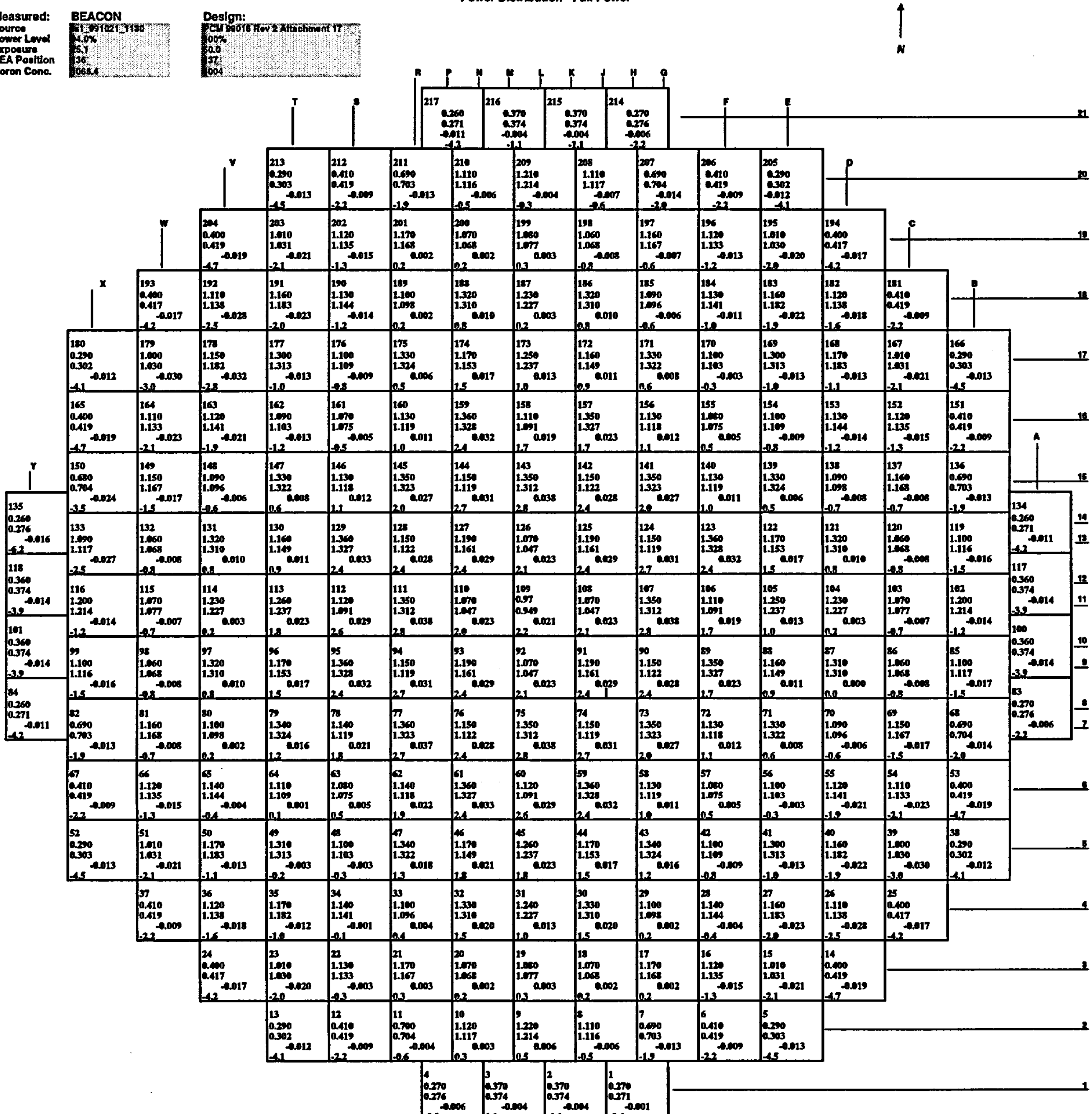
Key:

Box #
Measured
Design
Delta
% Diff.

Figure 7

Power Distribution - Full Power

	Measured: BEACON	Design:
Source	s1_991021_1130	PCM 99016 Rev 2 Attachment 17
Power Level	4.0%	00%
Exposure	5.1	0.0
CEA Position	136	137
Boron Conc.	068.4	004



RMS Deviation: 1.73%

Key:

Box #
Measured
Design
Delta
% Diff.

Table 1
Cycle 16 Reload Sub-Batch ID*

Sub-Batch	Number of Assemblies	Avg. Enrichment
S1	4	3.9
S2	1	3.88
S4	1	3.79
S6	7	3.76
T1	8	4.43
T2	20	4.41
T3	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)

Table 2
Approach 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

Table 3
CEA Group Worth Summary

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

*Reference 7

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