Docket No. 50-336

MILLSTONE NUCLEAR POWER STATION
UNIT NO. 2

STARTUP TEST REPORT
CYCLE 12

MARCH 1993

INDEX

1. SUMMARY

The steam generators were replaced during the refueling outage preceding the Cycle 12 startup. The replacement of the original steam generators was necessary due to extensive damage and the subsequent repairs and plugging of defective tubes.

The results of the Millstone 2, Cycle 12 low power physics and power ascension testing programs were in good agreement with the core design predictions with one exception. The original acceptance criteria for the unrodded and rodded critical boron concentration was ± 50 ppm of the predicted value. During performance of the low power physics tests it was determined that the measured critical boron concentrations were approximately 65 ppm greater than the predicted value. The fuel supplier, Siemens Nuclear Power Corporation, was contacted to review these results for errors in the predictions and for potential impacts on the reload safety analyses. Siemens confirmed that no errors were revealed in the review of the startup physics calculations, and that there was no impact to the reload safety analyses due to the measurement differences.

2. INTRODUCTION

The Millstone 2 Cycle 12 fuel loading was completed on November 29, 1992. The attached core map (Figure 6.1) shows the final core loading. The subsequent operation/testing milestones were completed as follows:

Initial Criticality	January 10, 1993
Low Power Physics Testing Completion	January 12, 1993
Turbine On-Line	January 13, 1993
Completed 65% Power Testing	January 20, 1993
Completed 96% Power Testing	January 24, 1993
Completed 100% Power Testing	January 27, 1993

The Millstone 2 Cycle 12 core is comprised of 13 Westinghouse manufactured fuel assemblies and 204 Siemens Nuclear Power Corporation (SNPC) manufactured fuel assemblies. The Reload Safety Analysis is supplied by Siemens Nuclear Power Corporation.

3. LOW POWER PHYSICS TESTING RESULTS

Low Power Physics Testing was conducted at a power level of approximately 5×10^{-2}% power.

The reactivity computer was connected only to the Channel "X" upper and lower excore detectors, as the signal from the Channel "Y" upper detector was "noisy" and was not usable.

3.1 Unrodded Critical Boron Concentration

The Critical Boron Concentration (CBC) measured with CEA Group 7 at 156 steps withdrawn was 1332 ppm. Adjusted to an All Rods Out (ARO) condition, the measured CBC is 1339 ppm.

CBC Measured at BOL-HZP-ARO = 1339 ppm

CBC Predicted at BOL-HZP-ARO = 1276 ppm

Difference = 63 ppm

Acceptance Criteria is ± 94 ppm of the predicted Critical Boron Concentration.

Acceptance Criteria met? Yes

3.2 Unrodded Moderator Temperature Coefficient

The Moderator Temperature Coefficient (MTC) measurements were performed at a boron concentration of 1332 ppm, a temperature of 532.6°F and a CEA Group 7 position of 158 steps withdrawn.

The measured Moderator Temperature Coefficient at these conditions was $+0.224 \times 10^{-4}\Delta\rho/°F$. Adjusted to the prediction conditions, the measured MTC is $+0.132 \times 10^{-4}\Delta\rho/°F$.

Adjusted, MTC Measured at 532°F, 1263 ppm = $+0.132 \times 10^{-4}\Delta\rho/°F$

MTC Predicted at 532°F, 1263 ppm = $+0.263 \times 10^{-4}\Delta\rho/°F$

Difference = $-0.131 \times 10^{-4}\Delta\rho/°F$

Acceptance Criteria is $\pm 0.2 \times 10^{-4}\Delta\rho/°F$ of the predicted MTC.

Acceptance Criteria met? Yes

Additionally, per the Millstone 2 Technical Specifications, the MTC must be less positive than $+0.7 \times 10^{-4}\Delta\rho/°F$ for power levels less than 70% power.

Acceptance Criteria met? Yes

3.3 Control Element Assembly Rod Worth Parameters

Control Element Assembly (CEA) Rod Worth Parameters were performed using the Rod Swap measurement technique. CEA Group A was used as the Reference CEA Group. All of the remaining CEA groups were then swapped with Group A. Figure 6.2 shows the CEA Group configuration. The results of the CEA measurements were:

Group	Measured	Prediction	Difference	% Difference
A	0.987% Δρ	1.024% Δρ	-0.037% Δρ	-3.61%
B	0.516% Δρ	0.484% Δρ	0.032% Δρ	+6.61%
1	0.804% Δρ	0.758% Δρ	0.046% Δρ	+6.07%
2	0.859% Δρ	0.806% Δρ	0.053% Δρ	+6.58%
3	0.452% Δρ	0.465% Δρ	-0.013% Δρ	-2.80%
4	0.670% Δρ	0.722% Δρ	-0.052% Δρ	-7.20%
5	0.405% Δρ	0.377% Δρ	0.028% Δρ	+7.43%
6	0.381% Δρ	0.380% Δρ	0.001% Δρ	+0.26%
7	0.781% Δρ	0.804% Δρ	-0.023% Δρ	-2.86%
TOTAL	**5.855% Δρ**	**5.820% Δρ**	**0.036% Δρ**	**+0.60%**

The Acceptance Criteria is that the Reference Group worth should be within ± 10% of the predicted value.

Acceptance Criteria met for the Reference Group? Yes

The Total CEA Worth should be within ± 10 % of the predicted value.

Acceptance Criteria met for the Total CEA Worth? Yes

The Acceptance Criteria for the remaining individual CEA Groups is that the Rod Worth Parameter of the remaining individual CEA Groups should be within ± 15% or ± 0.1%Δρ (whichever is greater) of the predicted value.

Acceptance Criteria met for the individual CEA Groups? Yes

3.4 Rodded Critical Boron Concentration

The Critical Boron Concentration (CBC) measured with CEA Group A fully inserted and CEA Group 7 at 175 steps withdrawn was 1234 ppm.

CBC Measured at BOL-HZP-Group A Inserted = 1234 ppm

CBC Predicted at BOL-HZP-Group A Inserted = 1169 ppm

Difference = 65 ppm

Acceptance Criteria is ± 94 ppm of the predicted Critical Boron Concentration.

Acceptance Criteria met? Yes

3.5 Control Rod Drop Time Measurements

Control rod drop time measurements were performed on all 61 CEA drive mechanisms.

The drop times from 0 to 100% insertion ranged from 2.33 to 2.58 seconds.

The Acceptance Criteria, per Millstone 2 Technical Specifications, is that all CEA's must drop from 0 to 90% insertion in less than 2.75 seconds.

Acceptance Criteria met? Yes

4. POWER ASCENSION TESTING RESULTS

4.1 Power Peaking, Linear Heat Rate and Incore Tilt Measurements

The measurements of these parameters were:

Power Level	F_r^T	Maximum Linear Heat Rate	Incore Tilt
65%	1.579	8.6 KW/ft	0.011
96%	1.556	12.1 KW/ft	0.011
100%	1.548	12.4 KW/ft	0.010

The corresponding Technical Specification limits for all power levels are:

$F_r^T \leq 1.690$

Maximum Linear Heat Rate $\leq$ 15.1 KW/ft

Azimuthal Power Tilt $\leq$ 0.02

Technical Specification limits met? Yes

4.2 Critical Boron Measurements

At 100% power, 339 MWD/MTU, CEA Group 7 at All Rods Out (ARO) and Equilibrium Xenon, the measured boron concentration was 885 ppm.

Adjusted, Measured boron concentration at
100% power, 339 MWD/MTU, ARO, Eq. Xenon = 866 ppm

Predicated, Measured boron concentration
at 100% power, 339 MWD/MTU,ARO, Eq. Xenon = 852 ppm

Difference = 14 ppm

Acceptance Criteria is $\pm$ 50 ppm of the predicted Critical Boron Concentration.

Acceptance Criteria met? Yes

4.3 Flux Symmetry Measurements

The flux symmetry was measured at approximately 28% power using the fixed incore detector monitoring system. The measured deviation between the highest and lowest values in operable symmetric detector locations ranged from 0% to 9.09%.

Acceptance Criteria is ± 10% (Deviation between the highest and lowest values in symmetric locations).

Acceptance Criteria met? Yes

4.4 Shape Annealing Factor Test

Data obtained during the measurement of an induced axial xenon oscillation was used to verify that the excore detector shape annealing factors (SAFs) remained valid. The shape annealing factors were last measured during the Cycle 6 startup testing program.

The axial xenon oscillation measurements were performed at 65% power. This test utilizes both the ex-core detectors and the in-core detectors and the in-core analysis computer program, INPAX, to provide meaningful test results. Figure 6.3 shows the induced xenon oscillation.

Results of the test showed that the shape annealing factors decreased by approximately 10% when compared to the values measured in Cycle 6. The new shape annealing factors will be input into the Reactor Protection System. The table below shows the results for the four safety channels:

	Cycle 6 SAF	Cycle 12 SAF
Channel "A"	2.267	2.042
Channel "B"	1.783	1.612
Channel "C"	2.116	1.991
Channel "D"	1.870	1.777

The results of this test were acceptable.

4.5 **Moderator Temperature Coefficient**

The measured MTC value at 96% power, with CEA Group 7 at 150 steps, at an average RCS temperature of 567.87°F and an RCS boron concentration of 884 ppm was -0.681×10^{-4} $\Delta\rho$/°F.

Adjusting this measured value to the prediction conditions of 96% power, 572.6°F and an RCS boron concentration of 868 ppm yields an MTC value of -0.770×10^{-4} $\Delta\rho$/°F.

Comparing the Adjusted, Measured MTC value to the predicted value yields:

Adjusted, Measured MTC at 96% power,
868 ppm boron, and T_{ave} = 572.6°F = -0.770×10^{-4} $\Delta\rho$/°F

Predicted MTC at 96% power,
868 ppm boron, and T_{ave} = 572.6°F = $\underline{-0.661 \times 10^{-4}\ \Delta\rho/°F}$

Difference = -0.109×10^{-4} $\Delta\rho$/°F

Acceptance Criteria is $\pm 0.3 \times 10^{-4}$ $\Delta\rho$/°F of the predicted MTC.

Acceptance Criteria met? Yes

4.6 **Doppler Only Power Coefficient**

The measured Doppler Only Power Coefficient (DOPC) at 94.85% power, an average RCS temperature of 570.3°F, and an RCS boron concentration of 884 ppm was -1.304×10^{-4} $\Delta\rho$/% Power.

Comparing the measured DOPC value to the predicted value yields:

Measured DOPC at 94.85% power,
884 ppm boron, and T_{ave} = 570.3°F = -1.304×10^{-4} $\Delta\rho$/% Power

Predicted DOPC at 96% power,
868 ppm boron, and T_{ave} = 572.6°F = $\underline{-1.030 \times 10^{-4}\ \Delta\rho/\%\ \text{Power}}$

Difference = -0.274×10^{-4} $\Delta\rho$/% Power

Acceptance Criteria is $\pm 0.3 \times 10^{-4}$ $\Delta\rho$/% Power of the predicted DOPC.

Acceptance Criteria met? Yes

4.7 **Reactor Coolant System Flow**

The measured Reactor Coolant System Flow Rate at 100% power was 383,802 GPM.

When 13,000 GPM is subtracted from the measured flow rate to account for measurement uncertainties, the Minimum Guaranteed Safety Analysis RCS Flow Rate is 370,802 GPM.

The measurement uncertainty value of 13,000 GPM is 4% of the Design Flow Rate value of 324,800 GPM.

The Acceptance Criteria per Millstone 2 Technical Specifications, is that the RCS flow must be greater than 360,000 GPM.

Acceptance Criteria met? Yes

4.8 **Power Distributions**

The Radial Power Distribution map for 65% power, 71 MWD/MTU, All Rods Out, Equilibrium Xenon conditions is shown in Figure 6.4. The agreement between the measurements and the predictions is acceptable.

The Radial Power Distribution map for 100% power, 337 MWD/MTU, All Rods Out, Equilibrium Xenon conditions is shown in Figure 6.5. The agreement between the measurements and the predictions is acceptable.

The Acceptance Criteria is that the difference between the measured and predicted Relative Power Density (RPDs) for core locations with an operable incore detector is less than 0.10.

Acceptance Criteria met for 65% power? Yes

Acceptance Criteria met for 100% power? Yes

The Acceptance Criteria is that the Root Mean Square (RMS) of all the differences between the measured and calculated RPDs is less than 5%.

Acceptance Criteria met for 65% power? Yes

Acceptance Criteria met for 100% power? Yes

4.9 **Reactor Coolant System Radiochemistry**

Reactor Coolant System radiochemistry analyses during the power ascension testing program and subsequent power operation indicate low activity levels in the RCS with Iodine-131 values of about 1×10^{-3} μCi/ml.

5. REFERENCES

5.1 In-Service Test T92-75, Low Power Physics Tests - Cycle 12.

5.2 In-Service Test T92-76, Power Ascension Tests - Cycle 12.

5.3 Millstone Unit 2, Cycle 12, Startup and Operations Report, EMF-92-100(P), October 1992.

5.4 D. P. Austin (SNP) letter to J. A. Camp (NUSCo), "Millstone Unit 2 Startup Physics Tests", dated January 11, 1993.

6. FIGURES

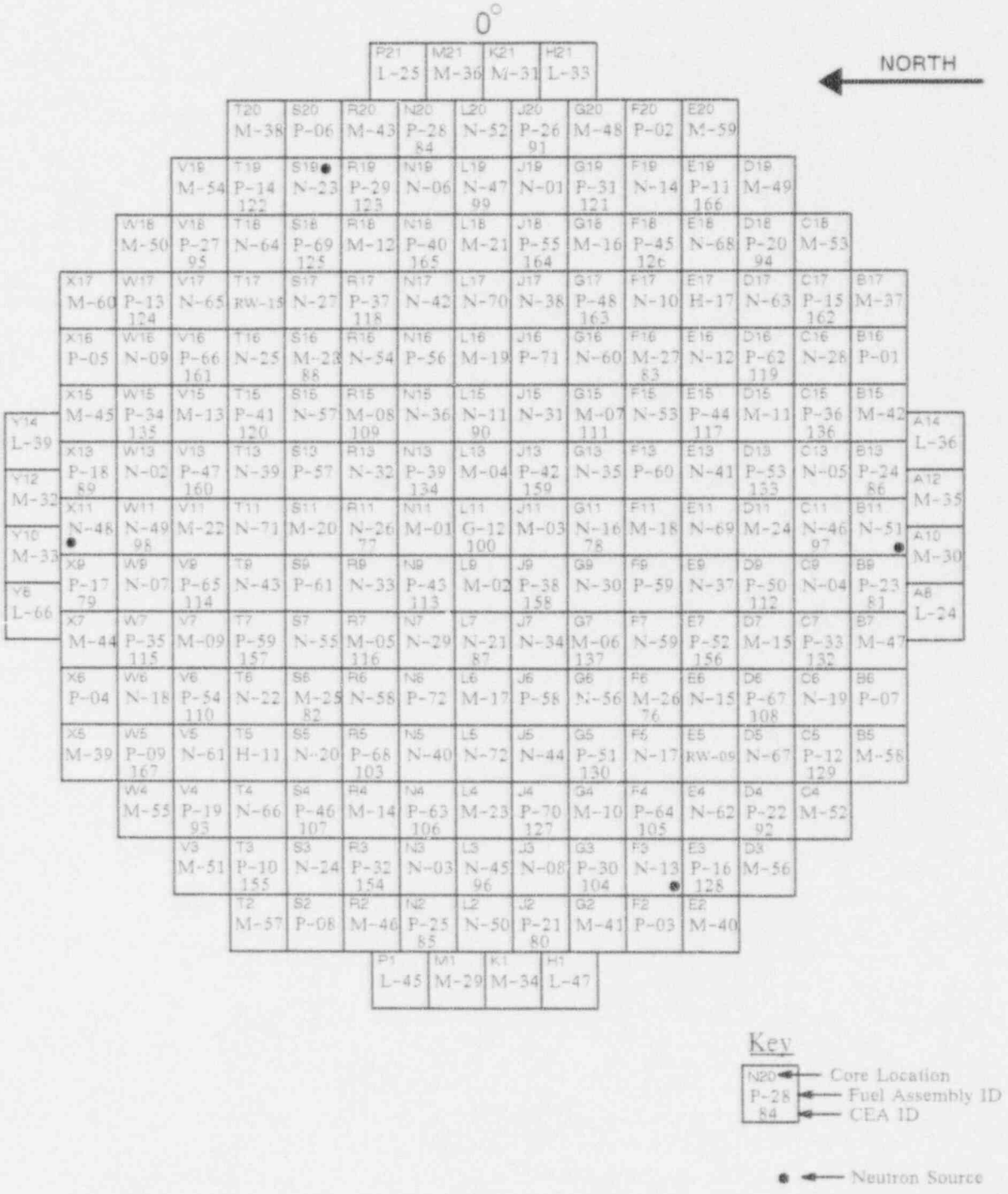
6.1 Cycle 12 Core Loading Map

6.2 CEA Group Configuration

6.3 Xenon Oscillation at 65% Power

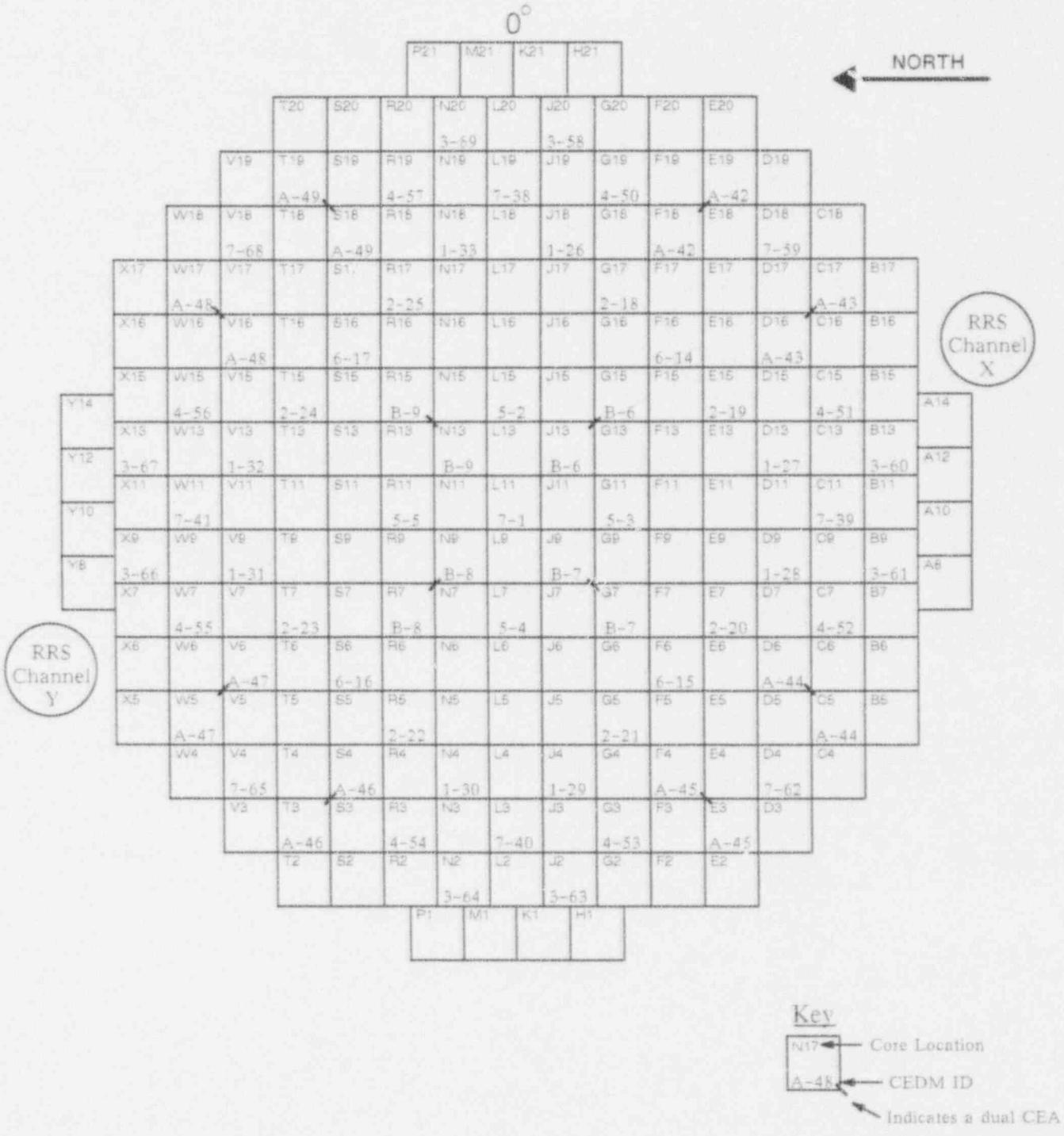
6.4 65% Power Distribution Map

6.5 100% Power Distribution Map



Cycle 12
Core Loading Map

FIGURE 6.1



CEA Group Configuration

FIGURE 6.2

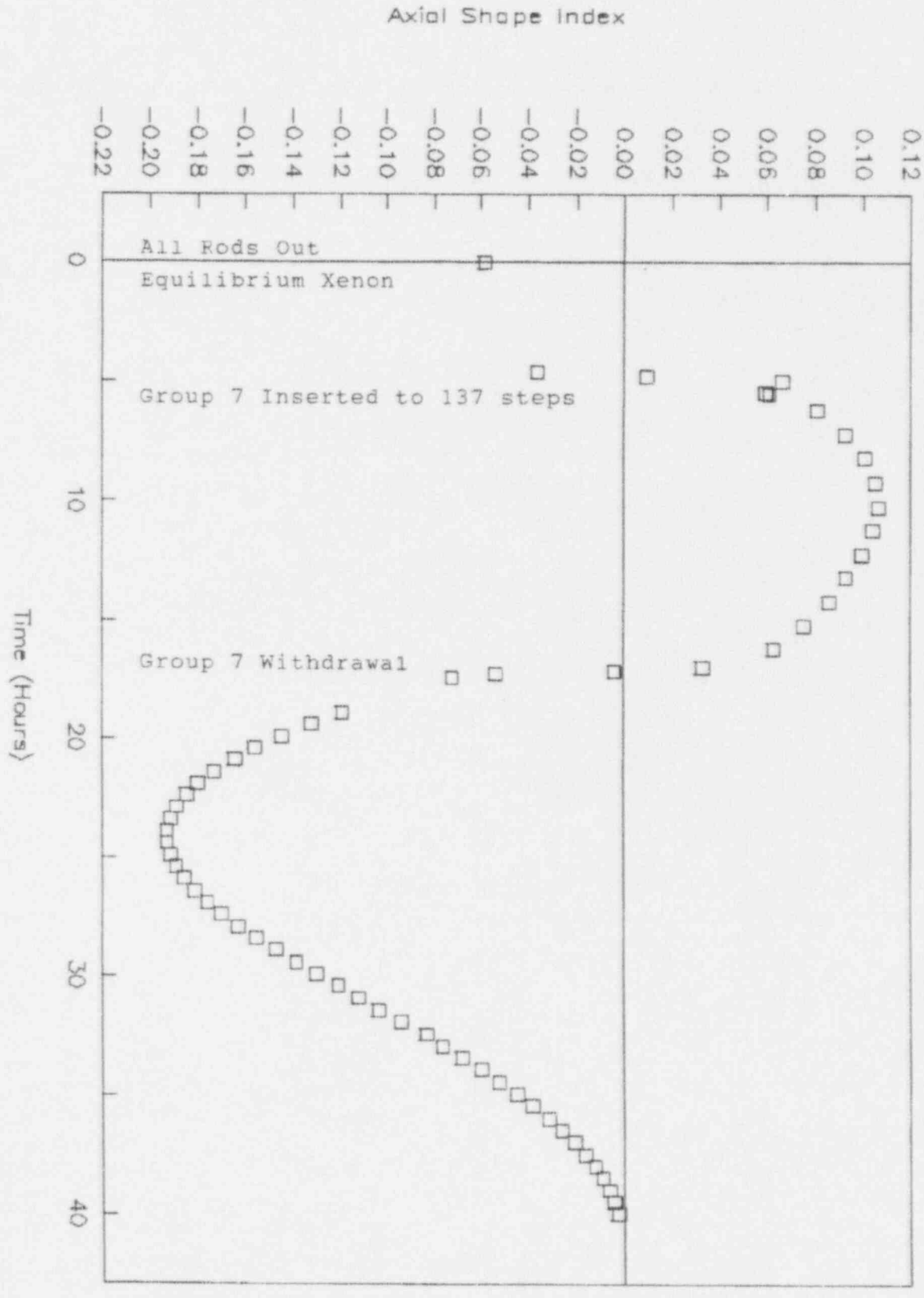
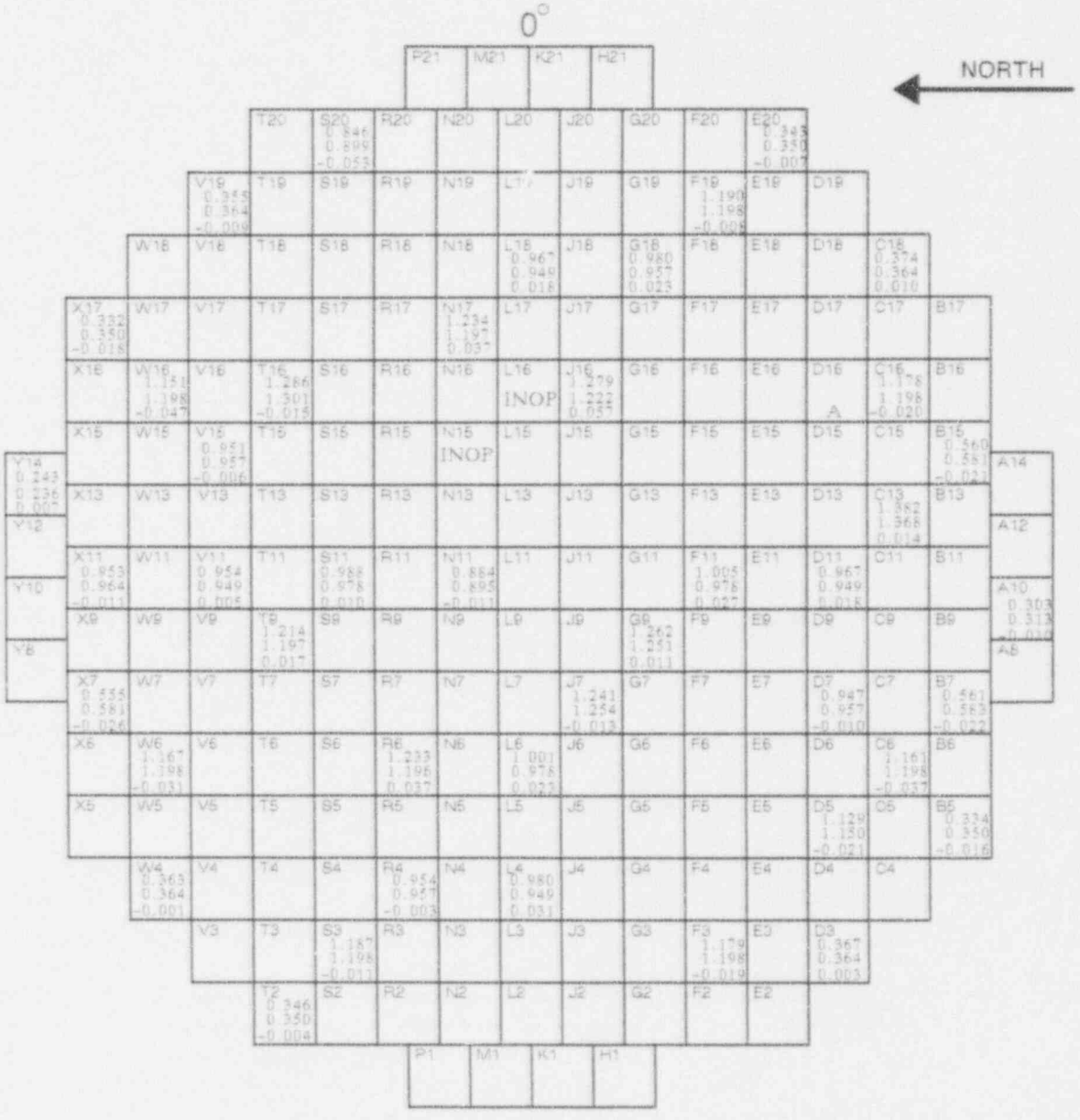

Axial Shape Index
-0.22
-0.20
-0.18
-0.16
-0.14
-0.12
-0.10
-0.08
-0.06
-0.04
-0.02
0.00
0.02
0.04
0.06
0.08
0.10
0.12
All Rods Out
Equilibrium Xenon
Group 7 Inserted to 137 steps
Group 7 Withdrawal
Time (Hours)
0
10
20
30
40
Xenon Oscillation at 65% Power

FIGURE 6.3

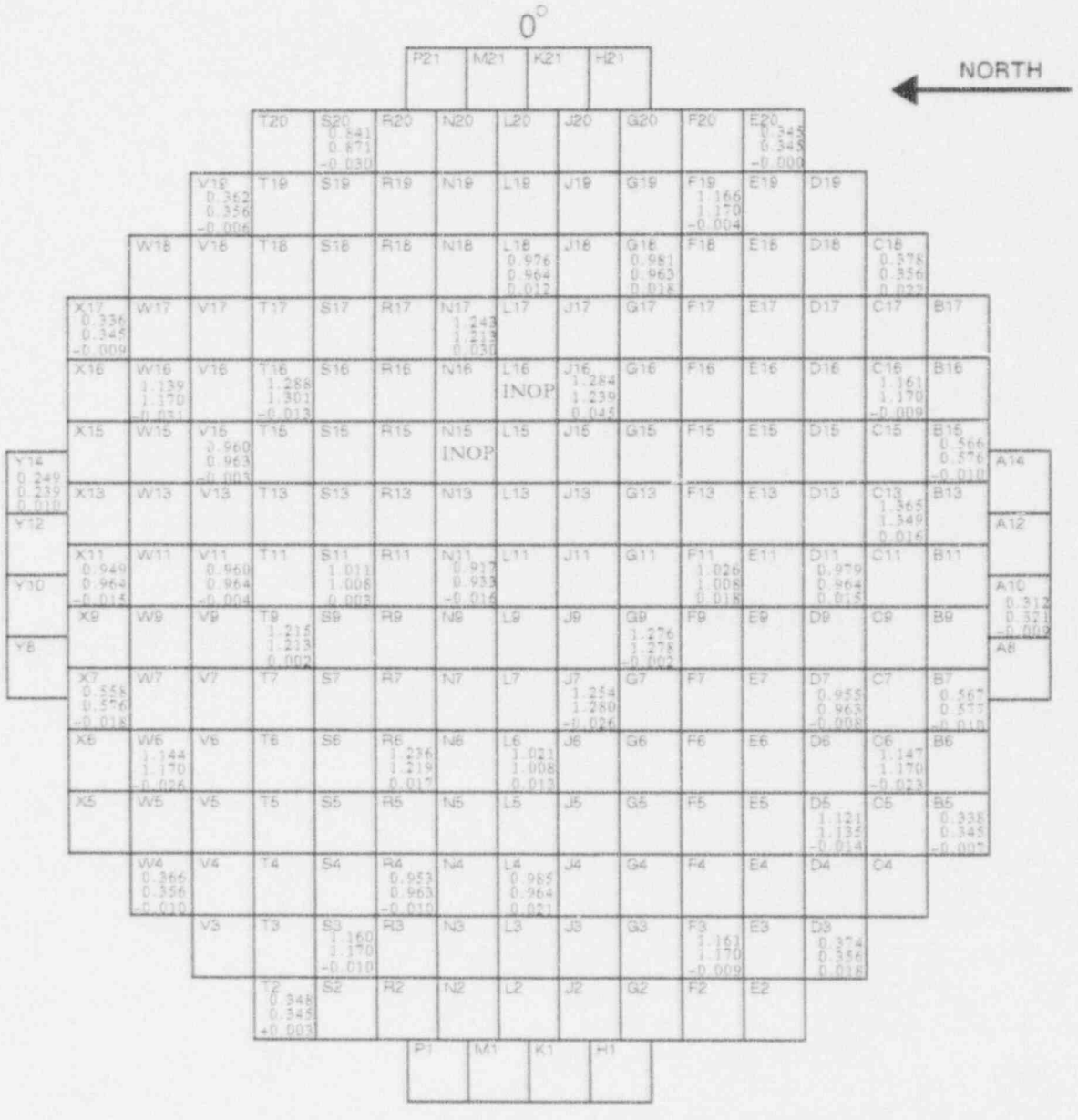


Root Mean Square of differences
for all core locations = 1.59%

INOP = Inoperable Incore Detector Location

65% Power Distribution Map
All Rods Out, Equilibrium Xenon, 71 MWD/MTW

FIGURE 6.4



Root Mean Square of differences
for all core locations = 1.12%

INOP = Inoperable Incore Detector Location

100% Power Distribution Map
All Rods Out, Equilibrium Xenon, 337 MWD/MTW

FIGURE 6.5