Docket No. 50-336
B15414

Attachment 1

Millstone Nuclear Power Station, Unit No. 2

Startup Test Report for Cycle 13

October 1995

Table of Contents

1. SUMMARY

The refueling outage preceding the Cycle 13 startup was approximately 304 days, starting on October 1, 1994 and ending on July 31, 1995.

The results of the Millstone 2, Cycle 13 low power physics testing and power ascension testing programs were in good agreement with the core design predictions and all measured parameters were within the acceptance criteria of the tests. One item is noteworthy of mention:

The measured rod worth for the "reference" CEA group was 8.52% *less than* the predicted value. While this measurement is within the ± 10% acceptance criteria, the low measurement is believed to have been caused by a signal bias from the excore detectors into the reactivity calculation. This theory was further confirmed upon reviewing the difference between the measured critical boron concentrations for the unrodded and rodded conditions. The measured difference was within 1 ppm boron of the predicted difference. The fact that the reference group rod worth value is used to calculate the rod worth parameters for the remaining CEA groups causes the measured rod worths to be less than the predicted values.

Two plant shutdowns and several downpowers during the power ascension testing program caused delays in the completion of these tests:

- On August 3, 1995, the reactor was shutdown from a power level of about 10% power due to a problem with a control rod power supply.
- On August 8, 1995, plant power was decreased from 80% to about 60% due to a problem with a pump seal in the secondary plant. At about 60% power, the reactor was manually tripped due to a secondary plant pipe rupture.
- On August 21, 1995, plant power was decreased from 100% to about 90% due to a problem with a valve leaking in the secondary plant.
- On August 22, 1995, plant power was decreased from 100% to about 90% due to a problem with pump vibration in the secondary plant.

2. INTRODUCTION

The Millstone 2 Cycle 13 fuel loading was completed on April 27, 1995. The attached core map (Figure 6.1) shows the final core loading. The subsequent operation/testing milestones were completed as follows:

Initial Criticality	July 31, 1995
Low Power Physics Testing Complete	August 2, 1995
Turbine On-Line	August 4, 1995
65% Power Testing Complete	August 6, 1995
96% Power Testing Complete	August 20, 1995
100% Power Testing Complete	August 29, 1995

The Millstone 2 Cycle 13 core is comprised of 217 Siemens Power Corporation manufactured fuel assemblies. The design of the 84 new fuel assemblies is slightly changed from the fuel design previously supplied by Siemens and was evaluated in accordance with 10CFR50.59. The new fuel assembly design changes were:

- Decreasing the thickness of the fuel rod cladding
- Increasing the diameter of the fuel pellet
- Decreasing the pellet-to-clad gap
- The high thermal performance spacer grid (used for debris protection) is replaced by a standard spacer grid and a longer fuel rod lower end plug
- Increasing the fuel rod fill gas pressure
- Increasing the uranium loading in each fuel assembly
- Increasing the exposure capability of the fuel assembly

3. LOW POWER PHYSICS TESTING RESULTS

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

3.1 Unrodded Critical Boron Concentration

The Critical Boron Concentration measured with CEA Group 7 at 143 steps withdrawn and an RCS temperature of 533.2°F was 1466 ppm.

Adjusted to the prediction conditions of Group 7 at 140 steps withdrawn and an RCS temperature of 532°F yields an adjusted, measured CBC of 1464 ppm.

Adjusted, measured unrodded CBC	=	1464 ppm
Predicted unrodded CBC	=	1452 ppm
Difference	=	12 ppm

Acceptance Criteria is ± 50 ppm of the predicted CBC.

Acceptance Criteria met? Yes

3.2 Moderator Temperature Coefficient

The Moderator Temperature Coefficient (MTC) measurements were performed at a boron concentration of 1466 ppm, an average RCS temperature of 529.6°F, and CEA Group 7 at 143 steps.

The measured MTC at these conditions was $+0.213 \times 10^{-4}$ Δρ/°F.

Adjusted to the prediction conditions for an RCS boron concentration of 1452 ppm and an RCS temperature of 532°F yields an adjusted, measured MTC of $+0.188 \times 10^{-4}$ Δρ/°F.

Adjusted, measured MTC	=	$+0.188 \times 10^{-4}$ Δρ/°F
Predicted MTC	=	$+0.213 \times 10^{-4}$ Δρ/°F
Difference	=	-0.025×10^{-4} Δρ/°F

Acceptance Criteria is $\pm 0.2 \times 10^{-4}$ Δρ/°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.

Technical Specification limit met? Yes

3.3 Control Element Assembly Rod Worth Parameters

Control Element Assembly (CEA) Rod Worth Parameters were measured using the "rod swap" method. Figure 6.2 shows the CEA group configuration.

CEA Group "A" was used as the "reference" group and its reactivity worth was measured using the "boron exchange" method (dilution results are shown below). The reactivity worth of the remaining CEA groups was measured by establishing a critical condition with the "test" group fully inserted and the "reference" group partially withdrawn.

The results of the CEA worth measurements were:

Group	Measured	Prediction	Difference	% Difference
A	1.020 %Δρ	1.115 %Δρ	-0.095 %Δρ	-8.52%
B	0.421 %Δρ	0.432 %Δρ	-0.011 %Δρ	-2.55%
1	0.679 %Δρ	0.746 %Δρ	-0.067 %Δρ	-8.98%
2	0.690 %Δρ	0.739 %Δρ	-0.049 %Δρ	-6.63%
3	0.447 %Δρ	0.536 %Δρ	-0.089 %Δρ	-16.60%
4	0.664 %Δρ	0.731 %Δρ	-0.067 %Δρ	-9.17%
5	0.312 %Δρ	0.323 %Δρ	-0.011 %Δρ	-3.41%
6	0.375 %Δρ	0.400 %Δρ	-0.025 %Δρ	-6.25%
7	0.692 %Δρ	0.784 %Δρ	-0.092 %Δρ	-11.73%
Total	5.300 %Δρ	5.806 %Δρ	-0.506 %Δρ	-8.72%

The Acceptance Criteria are:

1. The measured "reference" group worth is within ± 10% of the predicted worth.
2. The measured worth of the individual CEA groups is within ± 0.1%Δρ **or** ± 15% of the predicted worth, *whichever is larger*.
3. The sum of the measured CEA worths is within ± 10% of the sum of the predicted CEA worths.

Acceptance Criteria met for "reference" CEA group? Yes

Acceptance Criteria met for individual CEA groups? Yes, ± 15% of the predicted worth for CEA Group 3 is ± 0.080%$\Delta\rho$ (which is less than ± 0.1%$\Delta\rho$)

Acceptance Criteria met for sum of CEA group worths? Yes

The measured rod worth (dilution) for the "reference" CEA group was 8.52% *less than* the predicted value. The "reference" CEA group worth was also measured as it was withdrawn (boration), resulting in a measured value of 1.003 %$\Delta\rho$ (which is -10.07% *less than* the predicted value). While the average of these two measurements is within the ± 10% acceptance criteria, the low measurements are believed to have been caused by performing the rod worth tests with a signal bias from the excore detectors into the reactivity calculation. This theory was further confirmed upon reviewing the difference between the measured critical boron concentrations for the unrodded and rodded conditions. The measured difference was within 1 ppm boron of the predicted difference. The fact that the reference group rod worth value is used to calculate the rod worth parameters for the remaining CEA groups causes all of the measured rod worths to be less than the predicted values.

3.4 Rodded Critical Boron Concentration

The Critical Boron Concentration measured with CEA Group A at 6 steps withdrawn and an RCS temperature of 532°F was 1354 ppm.

Adjusted to the prediction conditions of Group A at 0 steps withdrawn and an RCS temperature of 532°F yields an adjusted, measured CBC of 1353 ppm.

Adjusted, measured rodded CBC	=	1353 ppm
Predicted rodded CBC	=	1340 ppm
Difference	=	13 ppm

Acceptance Criteria is ± 50 ppm of the predicted CBC.

Acceptance Criteria met? Yes

3.5 Control Rod Drop Time Measurements

Control rod drop times were determined by measuring the time between the opening of the first reactor trip circuit breaker and the time when the 100% insertion position was reached ("dropped rod" limit switch). The Millstone 2 Technical Specifications require that all CEAs drop in ≤ 2.75 seconds to the 90% inserted position, with RCS conditions at ≥ 515°F and full flow (all reactor coolant pumps operating).

Control rod drop time testing was done at an RCS temperature of 534°F with all 4 reactor coolant pumps operating. The average control rod drop time was 2.48 seconds to 100% insertion, with the fastest and slowest drop times being 2.37 seconds and 2.64 seconds, respectively.

Technical Specification limits met? Yes

4. POWER ASCENSION TESTING RESULTS

4.1 Power Peaking, Linear Heat Rate and Incore Tilt Measurements

The following core power distribution parameters were measured during the power ascension to ensure compliance with the Technical Specifications:

- Total Unrodded Integrated Radial Peaking Factor (F_r^T) is the ratio of the peak fuel rod power to the average fuel rod power in an unrodded core. This value includes the effect of Azimuthal Power Tilt.
- Linear Heat Rate is the amount of power being produced per linear length of fuel rod.
- Azimuthal Power Tilt is the maximum difference between the power generated in any core quadrant (upper or lower) and the average power of all quadrants in that half (upper or lower) of the core divided by the the average power of all quadrants in that half (upper or lower) of the core.

The measurements of these parameters were:

Power Level	F_r^T	Peak Linear Heat Rate	Incore Tilt
65%	1.688	9.05 KW/ft	0.014
96%	1.638	12.92 KW/ft	0.012
100%	1.619	13.16 KW/ft	0.013

These measurements were obtained with all control rods fully withdrawn.

The corresponding Technical Specification limits for all power levels for these parameters are:

- $F_r^T \leq 1.69$ (Note - larger values of F_r^T are permissible at less than 100% power)
- Peak Linear Heat Rate ≤ 15.1 KW/ft
- Azimuthal Power Tilt ≤ 0.02

Technical Specification limits met? Yes

4.2 Critical Boron Measurements

Critical Boron Concentration (CBC) measurements were performed at 96% power and 100% power at equilibrium xenon conditions.

The CBC measured at 96% power with CEA Group 7 at 155 steps withdrawn and an RCS temperature of 570.2°F was 1017 ppm. The cycle average exposure at the time of this measurement was 195 MWD/MTU.

Adjusted to the prediction conditions of 96% power with CEA Group 7 at 155 steps withdrawn and an RCS temperature of 573.7°F yields an adjusted, measured CBC of 1020 ppm.

Adjusted, measured 96% power CBC = 1020 ppm

Predicted 96% power CBC = 1022 ppm

Difference = -2 ppm

Acceptance Criteria is ± 50 ppm of the predicted CBC

Acceptance Criteria met? Yes

The CBC measured at 100% power with CEA Group 7 completely withdrawn and an RCS temperature of 571.5°F was 990 ppm. The cycle average exposure at the time of this measurement was 473 MWD/MTU.

Adjusted to the prediction conditions of 100% power at an All Rods Out (ARO) condition and an RCS temperature of 572°F yields an adjusted, measured CBC of 991 ppm.

Adjusted, measured 100% power CBC	=	991 ppm
Predicted 100% power CBC	=	999 ppm
Difference	=	-8 ppm

Acceptance Criteria is ± 50 ppm of the predicted CBC

Acceptance Criteria met? Yes

4.3 Flux Symmetry Measurements

The core neutron flux symmetry was measured at approximately 30% power using the fixed incore detector monitoring system. The measured deviation between the highest and lowest values in operable symmetric incore detector locations ranged from 0.52% to 7.06%.

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

Acceptance Criteria met? Yes

4.4 Moderator Temperature Coefficient

The Moderator Temperature Coefficient (MTC) measurements were performed at a power level of 96%, an RCS boron concentration of 1017 ppm, an average RCS temperature of 566.7°F, and CEA Group 7 at 155 steps.

The measured MTC at these conditions was $-0.592 \times 10^{-4}\ \Delta\rho/°F$.

Adjusted to the prediction conditions for an RCS boron concentration of 1022 ppm and an RCS temperature of 573.7°F yields an adjusted, measured MTC of $-0.663 \times 10^{-4}\ \Delta\rho/°F$.

Adjusted, measured MTC	=	$-0.663 \times 10^{-4}\ \Delta\rho/°F$
Predicted MTC	=	$-0.600 \times 10^{-4}\ \Delta\rho/°F$
Difference	=	$-0.063 \times 10^{-4}\ \Delta\rho/°F$

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

Acceptance Criteria met? Yes

4.5 Reactor Coolant System Flow

The RCS flow rate was measured using the secondary calorimetric method, in which the RCS flow rate is inferred by performing a heat balance around the steam generators and RCS to determine reactor power, and measuring the differential temperature across the reactor core to determine the enthalpy rise.

The measured RCS flow rate at 100% power was 386,043 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 373,043 GPM. This value is used to satisfy the Technical Specification surveillance requirement.

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

The Millstone 2 Technical Specifications require the RCS flow rate to be greater than 360,000 GPM.

Technical Specification limit met? Yes

4.6 Core Power Distributions

The core power distribution measurements were inferred from the signals obtained by the fixed incore detector monitoring system. These measurements were performed at 65% power and 100% power at an All Rods Out (ARO) condition to determine if the measured and predicted core power distributions are consistent.

The core power distribution map for 65% power, cycle average exposure of 24 MWD/MTU, *non*-equilibrium xenon conditions is shown in Figure 6.3.

This map shows that there is good agreement between the measured and predicted values.

The core power distribution map for 100%, cycle average exposure of 446 MWD/MTU, equilibrium xenon conditions is shown in Figure 6.4. This map also shows that there is good agreement between the measured and predicted values.

The Acceptance Criteria for these measurements are:

1. The difference between the measured and predicted Relative Power Densities (RPDs) for core locations with an operable incore detector is less than 0.1.
2. The Root Mean Square (RMS) of all of the differences between the measured and predicted RPDs is less than 5%.

Acceptance Criteria met? Yes, for both 65% and 100% power

4.7 Reactor Coolant System Radiochemistry

RCS radiochemistry analysis during the power ascension testing program and during subsequent power operation indicate low activity levels with Iodine-131 values of about 8×10^{-4} μCi/ml. These low RCS activity levels are indicative of defect free fuel cladding.

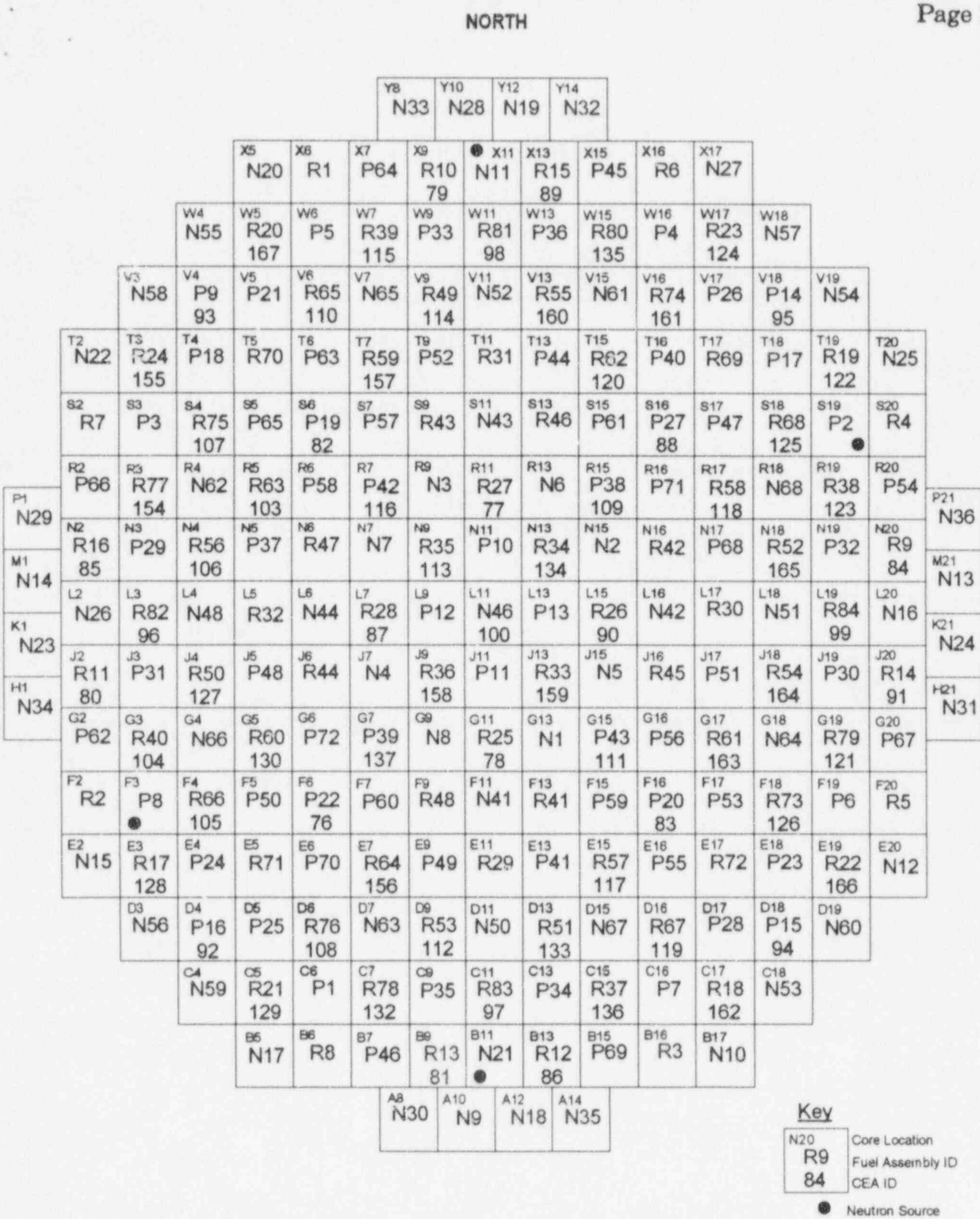
5. REFERENCES

5.1 In-Service Test T95-14, "Low Power Physics Tests - Cycle 13"

5.2 In-Service Test T95-16, "Power Ascension Tests - Cycle 13"

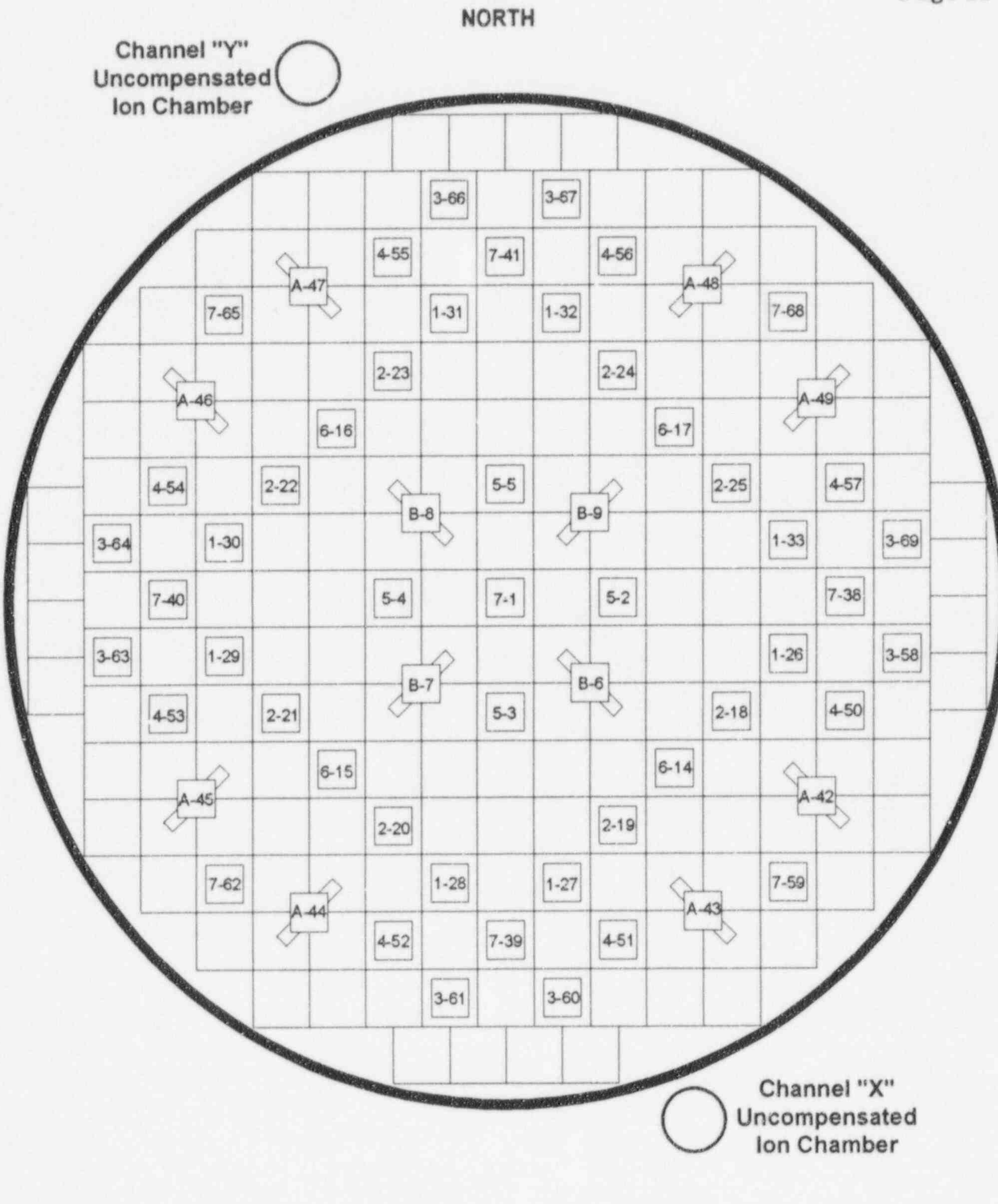
5.3 EMF-94-201(P), "Millstone Unit 2, Cycle 13, Startup and Operations Report"

6. FIGURES



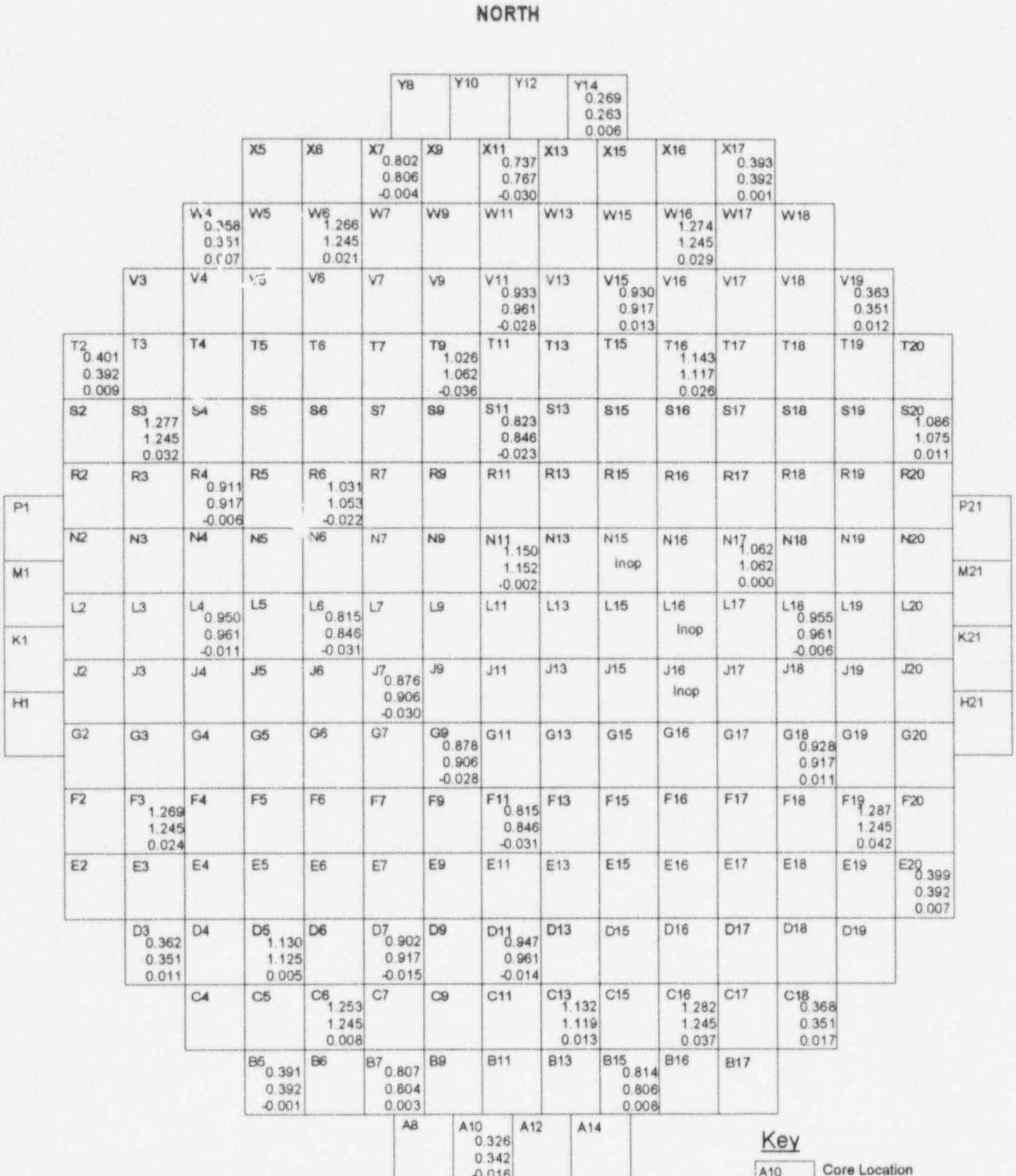
Cycle 13
Core Loading Map

FIGURE 6.1



CEA Group Configuration

FIGURE 6.2



Key

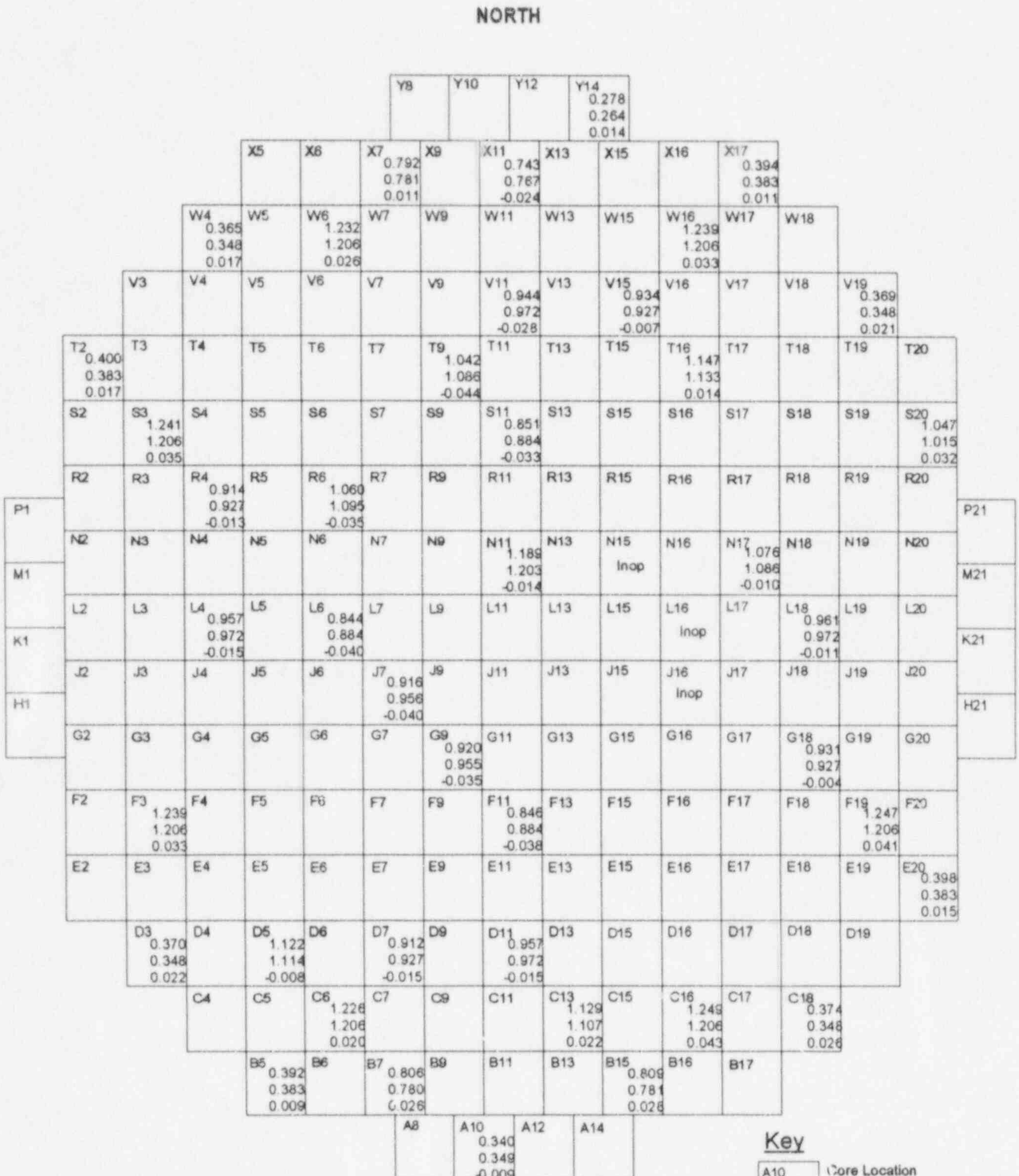
A10 Core Location
0.326 Measured RPD
0.342 Calculated RPD
-0.016 Difference

Inop = Inoperable Incore Detector Location

Root Mean Square of differences
for all core locations = 1.60%

65% Power Distribution Map
All Rods Out, Non-Equilibrium Xenon, 24 MWD/MTU

FIGURE 6.3



Key

A10	Core Location
0.340	Measured RPD
0.349	Calculated RPD
-0.009	Difference

Inop = Inoperable Incore Detector Location

Root Mean Square of differences
for all core locations = 2.01%

100% Power Distribution Map
All Rods Out, Equilibrium Xenon, 446 MWD/MTU

FIGURE 6.4