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U.S. Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, DC 20555

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DOMINION NUCLEAR CONNECTICUT, INC.
MILLSTONE POWER STATION UNIT 2
STARTUP TEST REPORT FOR CYCLE 25

Pursuant to Millstone Power Station Unit 2 Technical Specification 6.9.1.3, Dominion Nuclear Connecticut, Inc. hereby submits the enclosed Startup Test Report for Cycle 25.

If you have any questions or require additional information, please contact Jeffry Langan at (860) 444-5544.

Sincerely,

D. C. Lawrence
Director, Nuclear Station Safety and Licensing

Enclosure: (1)

Commitments made in this letter: None

1E26
NRR

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ENCLOSURE

STARTUP TEST REPORT FOR CYCLE 25

DOMINION NUCLEAR CONNECTICUT, INC.
MILLSTONE POWER STATION UNIT 2

Table of Contents

1. SUMMARY

The Millstone Power Station Unit 2 (MPS2) refueling outage preceding the Cycle 25 startup was approximately 33 days long, starting on April 1, 2017 and ending on May 5, 2017.

The results of the MPS2, Cycle 25 low power physics testing and power ascension testing programs were in good agreement with the core design predictions. All measured parameters were within the review and acceptance criteria of the tests. All Technical Specification (TS) Limiting Conditions of Operation (LCOs) were met.

2. INTRODUCTION

The MPS2 Cycle 25 fuel loading was completed on April 23, 2017. The attached core map (Figure 6.1) shows the final core loading. The subsequent operation/testing milestones were completed as follows:

Initial Criticality	May 4, 2017
Low Power Physics Testing Complete	May 4, 2017
Turbine On-Line	May 5, 2017
30% Power Testing Complete	May 5, 2017
69% Power Testing Complete	May 6, 2017
100% Power Testing Complete	May 12, 2017

The MPS2 Cycle 25 core is comprised of 217 AREVA manufactured fuel assemblies. Cycle 25 includes 68 fresh reload assemblies implementing the AREVA Standard CE-14 HTP fuel product with M5 Cladding.

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The Critical Boron Concentration (CBC) measured with Control Element Assembly (CEA) Group 7 at 178 steps withdrawn and a Reactor Coolant System (RCS) temperature of 529.5°F was 1537 ppm.

Adjusted to the prediction conditions of Group 7 at 180 steps withdrawn, RCS temperature of 532°F, and zero reactivity (residual rho correction), yields an adjusted, measured CBC of 1549 ppm.

Adjusted, measured unrodded CBC	=	1549 ppm
Predicted unrodded CBC	=	1540 ppm
Difference	=	+9 ppm (+75 pcm)

Review Criteria is ± 50 ppm of the predicted CBC.

Acceptance Criteria is ± 1000 pcm of the predicted CBC.

Review and Acceptance Criteria met? Yes.

3.2 Moderator Temperature Coefficient

The Isothermal Temperature Coefficient (ITC) measurements were performed at a boron concentration of 1537 ppm, an average RCS temperature of 530.2°F, and CEA Group 7 at 152 steps.

The measured ITC at these conditions was +0.648 pcm/°F.

The predicted ITC of +0.710 pcm/°F for an RCS boron concentration of 1540 ppm and an RCS temperature of 532°F, adjusted for measured conditions, yields an adjusted, predicted ITC of +0.759 pcm/°F.

Measured ITC	=	+0.648 pcm/°F
Adjusted, predicted ITC	=	+0.759 pcm/°F
Difference	=	-0.11 pcm/°F

Review Criteria is ± 2 pcm/°F of the predicted ITC.

Review Criteria met? Yes.

The Moderator Temperature Coefficient (MTC) was determined by subtracting the predicted Doppler Temperature Coefficient at the test conditions from the adjusted, measured ITC. The MTC at these conditions was $+0.21 \times 10^{-4}$ $\Delta\rho$/°F. The MPS2 TSs require the MTC be less positive than $+0.7 \times 10^{-4}$ $\Delta\rho$/°F for power levels less than 70% power.

TS limit met? Yes.

3.3 Control Element Assembly Rod Worth Parameters

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	988.6 pcm	923 pcm	65.6 pcm	-7.1 %
B	502.5 pcm	514 pcm	-11.5 pcm	2.2 %
1	654 pcm	638.8 pcm	15.2 pcm	-2.4 %
2	798 pcm	805.5 pcm	-7.5 pcm	0.9 %
3	410.9 pcm	393.3 pcm	17.6 pcm	-4.5 %
4	630 pcm	590 pcm	40 pcm	-6.8 %
5	373.7 pcm	383.5 pcm	-9.8 pcm	2.5 %
6	420.8 pcm	422.8 pcm	-2 pcm	0.5 %
7	898.3 pcm	855.4 pcm	42.9 pcm	-5 %
Total	5676.8 pcm	5526.3 pcm	150.5 pcm	-2.7 %

The Review and 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 ± 100 pcm 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.

Review Criteria met for "reference" CEA group? Yes.

Review Criteria met for individual CEA groups? Yes.

Acceptance Criteria met for sum of CEA group worths? Yes.

3.4 Rodded Critical Boron Concentration

The CBC measured with CEA Group A at 1 step withdrawn and an RCS temperature of 529.5°F was 1442 ppm.

Adjusted to the prediction conditions of Group A at 0 steps withdrawn, RCS temperature of 532°F and zero reactivity (residual rho correction), yields an adjusted, measured CBC of 1444 ppm.

Adjusted, measured rodded CBC	=	1444 ppm
Predicted rodded CBC	=	1429 ppm
Difference	=	+15 ppm (+130 pcm)

Review Criteria is ± 50 ppm of the predicted CBC.

Acceptance Criteria is ± 1000 pcm of the predicted CBC.

Review and Acceptance Criteria met? Yes.

3.5 Control Rod Drop Time Measurements

The MPS2 TSs require that all CEAs drop in less than or equal to 2.75 seconds to the 90% inserted position, with RCS conditions at greater than or equal to 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 four reactor coolant pumps operating. The average control rod drop time was 2.16 seconds to 90% insertion, with the fastest and slowest drop times being 2.04 seconds and 2.26 seconds, respectively.

TS 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 TSs:

- 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 (LHR) 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 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
69%	1.597	9.37 KW/ft	0.0083
100%	1.579	13.02 KW/ft	0.0082

The corresponding TS 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 < 100% power)

- Peak Linear Heat Rate ≤ 15.1 KW/ft

- Azimuthal Power Tilt ≤ 0.02

TS limit for F_r^T met? Yes.

TS limit for LHR met? Yes.

TS limit for Tilt met? Yes.

4.2 Critical Boron Concentration Measurements

CBC measurement was performed at 100% power at equilibrium xenon conditions.

The CBC measured at 100% power with CEA Group 7 at 180 steps withdrawn and an RCS cold leg temperature of 544.5°F was 1084 ppm. The cycle average exposure at the time of this measurement was 208 Megawatt Days per Metric Ton Uranium (MWD/MTU).

Adjusted to the prediction conditions of 100% power at an All Rods Out (ARO) condition and an RCS cold leg temperature of 545 °F yields an adjusted, measured CBC of 1084.5 ppm.

Adjusted, measured 100% power CBC	=	1084.5 ppm
Predicted 100% power CBC	=	1078.9 ppm
Difference	=	+5.6 ppm (+45 pcm)

Review Criteria is ± 50 ppm of the predicted CBC.

Acceptance Criteria is ± 1000 pcm of the predicted CBC.

Review and Acceptance Criteria met? Yes.

4.3 Hot Zero Power to Hot Full Power Critical Boron Concentration Difference

The difference in the adjusted measured CBC performed at Hot Zero Power (HZP) and Hot Full Power (HFP) was determined and compared to the design prediction.

Predicted change in CBC from HZP to HFP	=	461 ppm
Adjusted, measured change in CBC from HZP to HFP	=	464.3 ppm
Difference	=	-3.3 ppm

Review Criteria is ± 50 ppm of the predicted CBC difference.

Review Criteria met? Yes.

4.4 Flux Symmetry Measurements

The core neutron flux symmetry was measured at approximately 30% power using the fixed incore detector monitoring system. The differences between measured and calculated signals in operable incore detector locations ranged from –0.031 to +0.030.

Review Criteria is ± 0.10.

Review Criteria met? Yes.

The maximum azimuthal asymmetry in the neutron flux from measurements of the variation in incore detector signals from symmetric incore detectors was 3.04%

Review Criteria is ± 10%.

Review Criteria met? Yes.

4.5 Moderator Temperature Coefficient

The ITC measurements were performed at a power level of 99.02 %, an RCS boron concentration of 1084 ppm, and an average RCS temperature of 569.53°F, and CEA Group 7 at 180 steps.

The measured ITC at these conditions was –7.569 pcm/°F.

The predicted ITC was determined for a power level of 100%, an RCS boron concentration of 1085 ppm, an average RCS temperature of 570.0°F, and at an ARO condition.

The predicted ITC at these conditions was –7.80 pcm/°F.

The predicted ITC adjusted for 99.02% power, an actual RCS boron concentration of 1084 ppm and an RCS temperature of 569.53°F yields an adjusted, predicted ITC of –7.802 pcm/°F.

Adjusted, Predicted ITC	=	–7.802 pcm/°F
Measured ITC	=	–7.569 pcm/°F
Difference	=	–0.233 pcm/°F

Review Criteria is ± 2 pcm/°F of the predicted ITC.

Review Criteria met? Yes.

The MTC was determined by subtracting the predicted Doppler Temperature Coefficient at the test conditions from the measured ITC. The MTC at these conditions was -0.63×10^{-4} $\Delta\rho$/°F. The MPS2 TSs require the MTC be less than or equal to $+0.4 \times 10^{-4}$ $\Delta\rho$/°F for power levels greater than 70% power.

TS limit met? Yes.

4.6 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 391,936 gallons per minute (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 378,936 GPM. This value is used to satisfy the TS surveillance requirement.

The MPS2 TSs require the RCS flow rate to be greater than 360,000 GPM.

TS limit met? Yes.

4.7 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 69% power and 100% to determine if the measured and predicted core power distributions are consistent.

The core power distribution map for 69% power, cycle average exposure of 15.6 MWD/MTU, non-equilibrium xenon conditions is shown in Figure 6.2. 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 16.5 MWD/MTU, non-equilibrium xenon conditions is shown in Figure 6.3. This map also shows that there is good agreement between the measured and predicted values.

The review 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) deviation for radial and axial power distributions between the measured and predicted values is less than 0.05.

Review Criteria met? Yes, for both 69% and 100% power.

4.8 Reactor Coolant System Radiochemistry

RCS radiochemistry analysis during the power ascension testing program and during subsequent power operation indicate activity levels with Iodine-131 values of approximately 1.9×10^{-4} µCi/ml. These RCS activity levels show there are no failed fuel assemblies resident in the core.

5. REFERENCES

5.1 EN 21004K, "Cycle 25, Low Power Physics Test"

5.2 EN 21004J, "Cycle 25, Power Ascension Testing"

5.3 EN 21004F, "Control Rod Worth Measurements (ICCE)"

5.4 ETE-NAF-2017-0054, Rev. 0, Attachment A, "Millstone Unit 2, Cycle 25, Startup and Operations Report," April 2017 (Areva NP, Inc. Proprietary).

5.5 SP 21010, "CEA Drop Times"

6. FIGURES

6.1 Cycle 25 Core Loading Map

6.2 Cycle 25 CEA Group Configuration

6.3 69% Core Power Distribution Map

6.4 100% Core Power Distribution Map

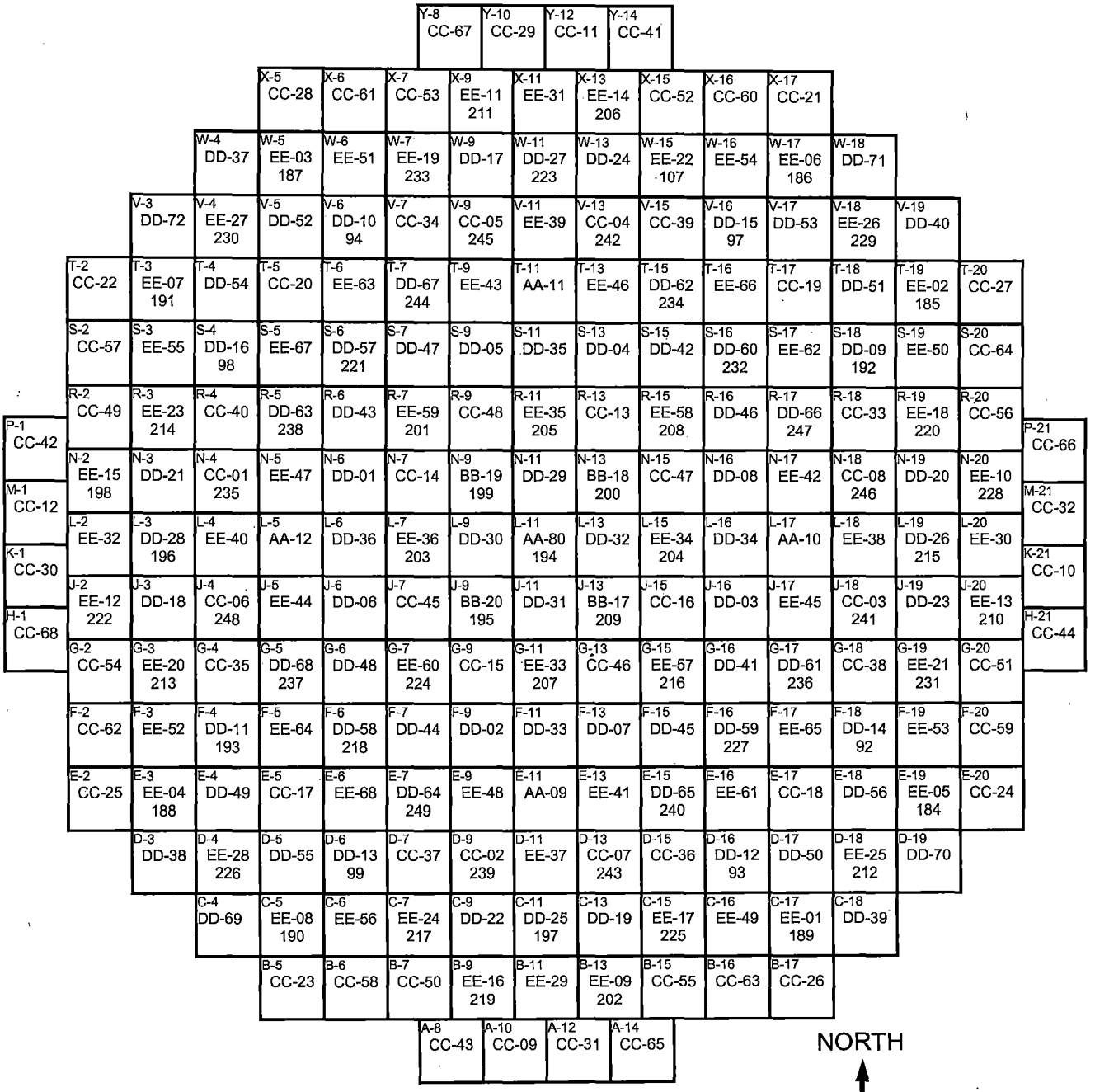


Figure 6.1
Millstone Unit No. 2
Cycle 25 Core Loading Map

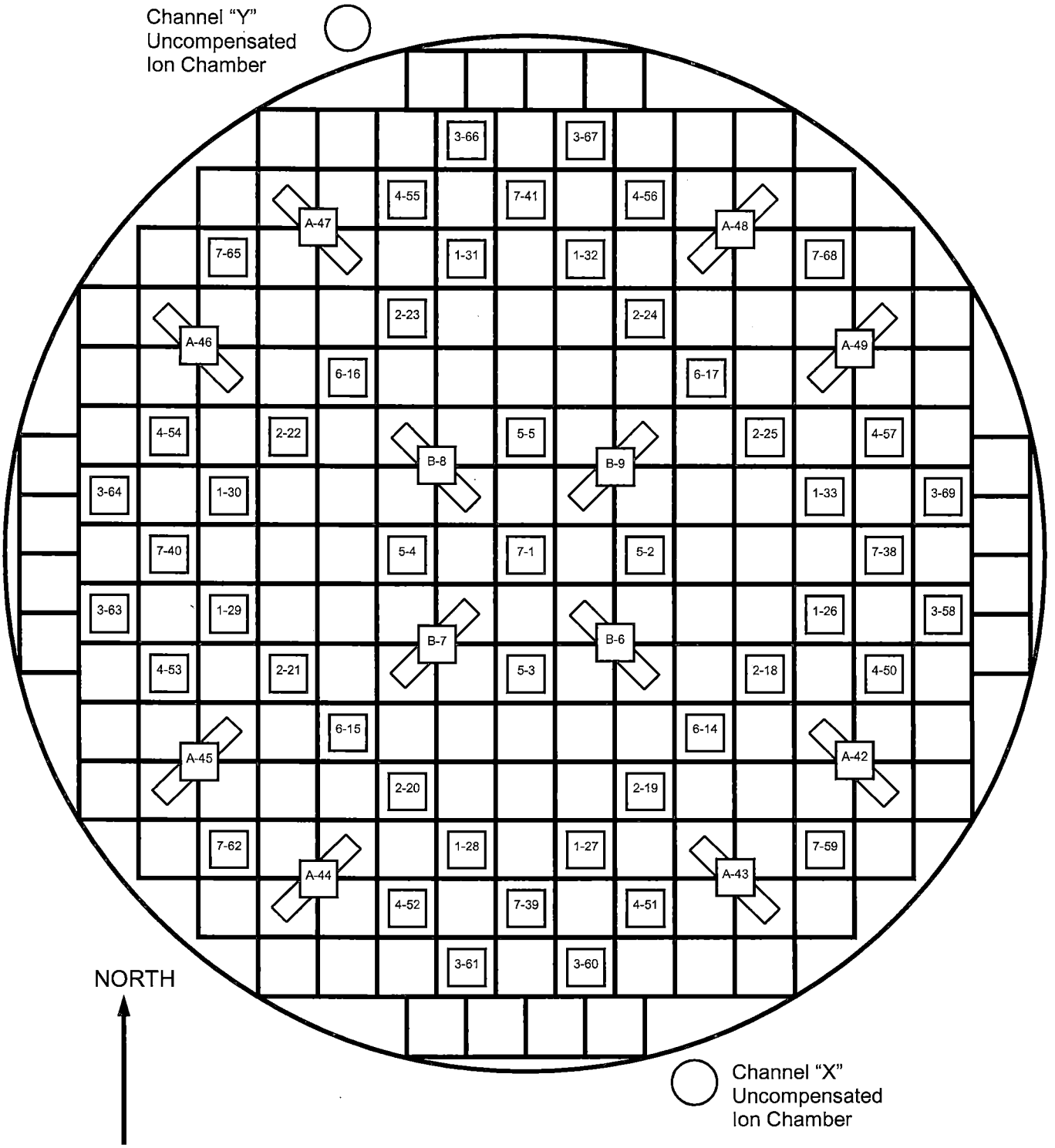
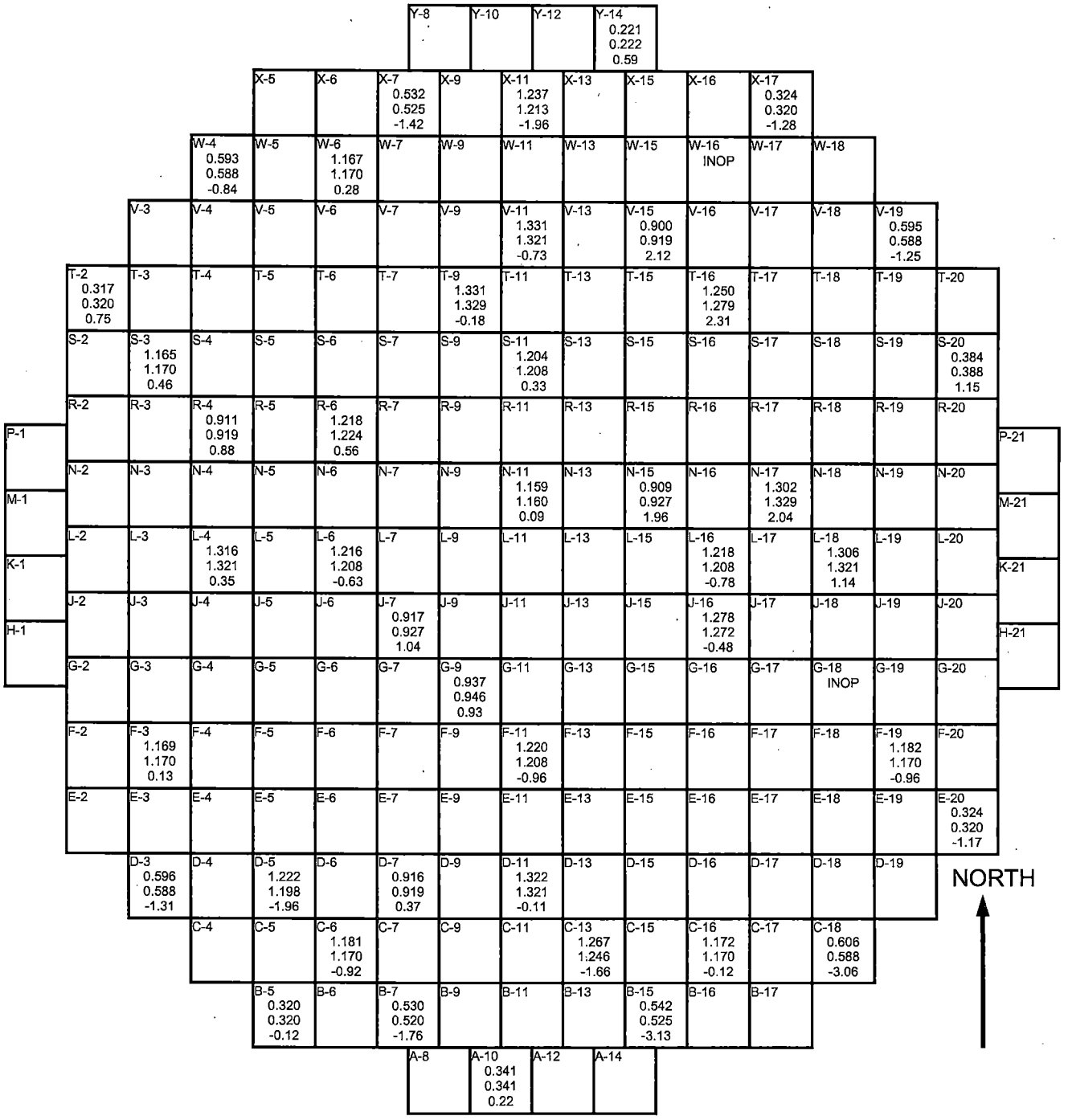


Figure 6.2
Millstone Unit No. 2
CEA Group Configuration



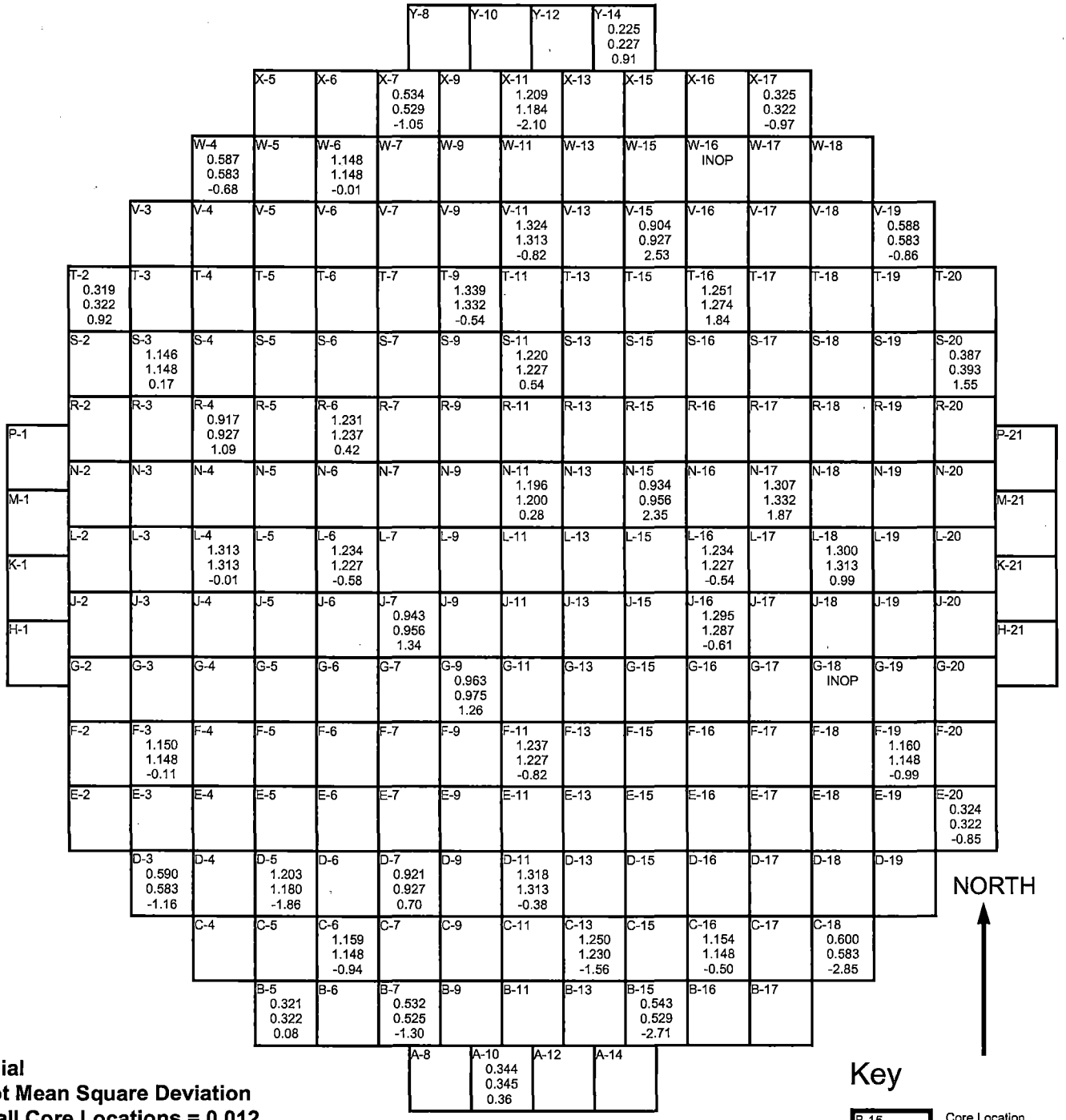
Key

B-15
0.523
0.515
0.008

Core Location
Measured RPD
Calculated RPD
Difference

Root Mean Square Deviation for all Core Locations = 0.017

Figure 6.3
69% Core Power Distribution Map
All Rods Out, Non-Equilibrium Xenon, 15.6 MWD/MTU



Radial
Root Mean Square Deviation
for all Core Locations = 0.012

Axial
Root Mean Square Core Average
Deviation = 0.007

Key

B-15	Core Location
0.526	Measured RPD
0.520	Calculated RPD
0.006	Difference

Figure 6.4
100% Core Power Distribution Map
All Rods Out, Non-Equilibrium Xenon, 16.5 MWD/MTU