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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 23

Pursuant to Section 6.9.1.3 of the Millstone Power Station Unit 2 (MPS2) Technical Specifications, Dominion Nuclear Connecticut, Inc. hereby submits the enclosed Startup Test Report for Cycle 23.

If you have any questions or require additional information, please contact Mr. William D. Bartron at (860) 444-4301.

Sincerely,

Stephen E. Scace
Site Vice President – Millstone

Enclosure: (1)

Commitments made in this letter: None

cc: U.S. Nuclear Regulatory Commission
Region I Administrator
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IE26
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Action Plan/Commitments (Stated or Implied)

1. None

Required Changes to the UFSAR or QA Topical Report

1. None

*Verification of Accuracy

1. EN 21004K, "Cycle 23, Low Power Physics Test"
2. EN 21004J, "Cycle 23, Power Ascension Testing"
3. ETE-NAF-2014-0048, Rev. 0, Attachment A, "Millstone Unit 2, Cycle 23, Startup and Operations Report," April 2014 (Areva NP, Inc. Proprietary).
4. SP 21010, "CEA Drop Times"
5. WCAP-16011-P-A Revision 0, "Startup Test Activity Reduction Program," February 2005
6. ETE-MP-2014-1060, Rev 0, "Application of the Startup Test Activity Reduction (STAR) Program for Cycle 23," May 8, 2014

Enclosure

Millstone Power Station Unit 2
Startup Test Report for Cycle 23

Table of Contents

1. SUMMARY

The Millstone Power Station Unit 2 (MPS2) refueling outage preceding the Cycle 23 startup was approximately 42 days, starting on April 5, 2014 and ending on May 18, 2014.

The results of the MPS2, Cycle 23 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 Limiting Conditions of Operation (LCOs) were met.

Implementation of the Startup Test Activity Reduction (STAR) Program for MPS2 Cycle 23 has been accomplished in accordance with the steps outlined in WCAP-16011-A-P, Rev. 0 for (1) core design, (2) Control Element Assembly (CEA) lifetime, and (3) fuel and CEA fabrication. The STAR Applicability requirements for refueling have been accomplished for core verification, CEA coupling verification and startup testing. The application of the STAR Program allowed for the elimination of control rod worth measurements from the startup physics testing.

2. INTRODUCTION

The MPS2 Cycle 23 fuel loading was completed on May 6, 2014. The attached core map (Figure 6.1) shows the final core loading. The subsequent operation/testing milestones were completed as follows:

Initial Criticality	May 16, 2014
Low Power Physics Testing Complete	May 16, 2014
Turbine On-Line	May 18, 2014
30% Power Testing Complete	May 18, 2014
68% Power Testing Complete	May 19, 2014
100% Power Testing Complete	May 22, 2014

The MPS2 Cycle 23 core is comprised of 217 AREVA manufactured fuel assemblies.

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 CEA Group 7 at 168 steps withdrawn and a reactor coolant system (RCS) temperature of 529.0°F was 1510 ppm.

Adjusted to the prediction conditions of Group 7 at 180 steps withdrawn and an RCS temperature of 532°F yields an adjusted, measured CBC of 1525 ppm.

Adjusted, measured unrodded CBC	=	1525 ppm
Predicted unrodded CBC	=	1532 ppm
Difference	=	-7 ppm (-56 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 1510 ppm, an average RCS temperature of 529.9°F, and CEA Group 7 at 168 steps.

The measured ITC at these conditions was +0.67 pcm/°F.

Adjusted to the prediction conditions for an RCS boron concentration of 1532 ppm and an RCS temperature of 532°F yields an adjusted, measured ITC of +0.82 pcm/°F.

Adjusted, measured ITC	=	+0.82 pcm/°F
Predicted ITC	=	+0.45 pcm/°F
Difference	=	+0.37 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 $+0.23 \times 10^{-4}$ $\Delta\rho$/°F. The MPS2 Technical Specifications require the MTC 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

CEA Rod Worth Parameters were not measured as allowed by WCAP-16011-P-A, Revision 0, "Startup Test Activity Reduction Program."

3.4 Rodded Critical Boron Concentration

The CBC measured with CEA Group A inserted was not performed during Cycle 23 startup testing due to application of the STAR Program.

3.5 Control Rod Drop Time Measurements

The MPS2 Technical Specifications 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 529 °F with all four reactor coolant pumps operating. The average control rod drop time was 2.17 seconds to 90% insertion, with the fastest and slowest drop times being 2.06 seconds and 2.27 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 (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
68%	1.648	9.45 KW/ft	0.0049
100%	1.603	13.13 KW/ft	0.0047

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 limit for F_r^T met? Yes.

Technical Specification limit for LHR met? Yes.

Technical Specification 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 544.6°F was 1061 ppm. The cycle average exposure at the time of this measurement was 113 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 1061.4 ppm.

Adjusted, measured 100% power CBC	=	1061.4 ppm
Predicted 100% power CBC	=	1065.0 ppm
Difference	=	-3.6 ppm (-29 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 (HZP) to Hot Full Power (HFP) Critical Boron Concentration Difference

The difference in the adjusted measured CBC performed at HZP and HFP was determined and compared to the design prediction.

Predicted change in CBC from HZP to HFP	=	467.0 ppm
Adjusted, measured change in CBC from HZP to HFP	=	463.9 ppm
Difference	=	3.1 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 –0.019 to +0.032.

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 3.21%

Review Criteria is ± 10%.

Review Criteria met? Yes.

4.5 Moderator Temperature Coefficient

The ITC measurements were performed at a power level of 99.33 %, an RCS boron concentration of 1061 ppm, and an average RCS temperature of 569.32°F, and CEA Group 7 at 180 steps.

The measured ITC at these conditions was –7.526 pcm/°F.

The predicted ITC was determined for a power level of 100%, an RCS boron concentration of 1065 ppm, an average RCS temperature of 570.1°F, and at an ARO condition.

The predicted ITC at these conditions was –8.210 pcm/°F.

The predicted ITC adjusted for 99.33% power, an actual RCS boron concentration of 1061 ppm and an RCS temperature of 569.32°F yields an adjusted, predicted ITC of –8.162 pcm/°F.

Adjusted, Predicted ITC	=	–8.162 pcm/°F
Measured ITC	=	–7.526 pcm/°F
Difference	=	–0.636 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 Technical Specifications require the MTC be less than or equal to $+0.4 \times 10^{-4}$ $\Delta\rho$/°F for power levels greater than 70% power.

Technical Specification 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 389,874 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 376,874 GPM. This value is used to satisfy the technical specification surveillance requirement.

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

Technical Specification 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 68% power and 100% to determine if the measured and predicted core power distributions are consistent.

The core power distribution map for 68% power, cycle average exposure of 14 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 110 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 68% 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 2.0×10^{-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 23, Low Power Physics Test"

5.2 EN 21004J, "Cycle 23, Power Ascension Testing"

5.3 ETE-NAF-2014-0048, Rev. 0, Attachment A, "Millstone Unit 2, Cycle 23, Startup and Operations Report," April 2014 (Areva NP, Inc. Proprietary).

5.4 SP 21010, "CEA Drop Times"

5.5 WCAP-16011-P-A Revision 0. "Startup Test Activity Reduction Program," February 2005

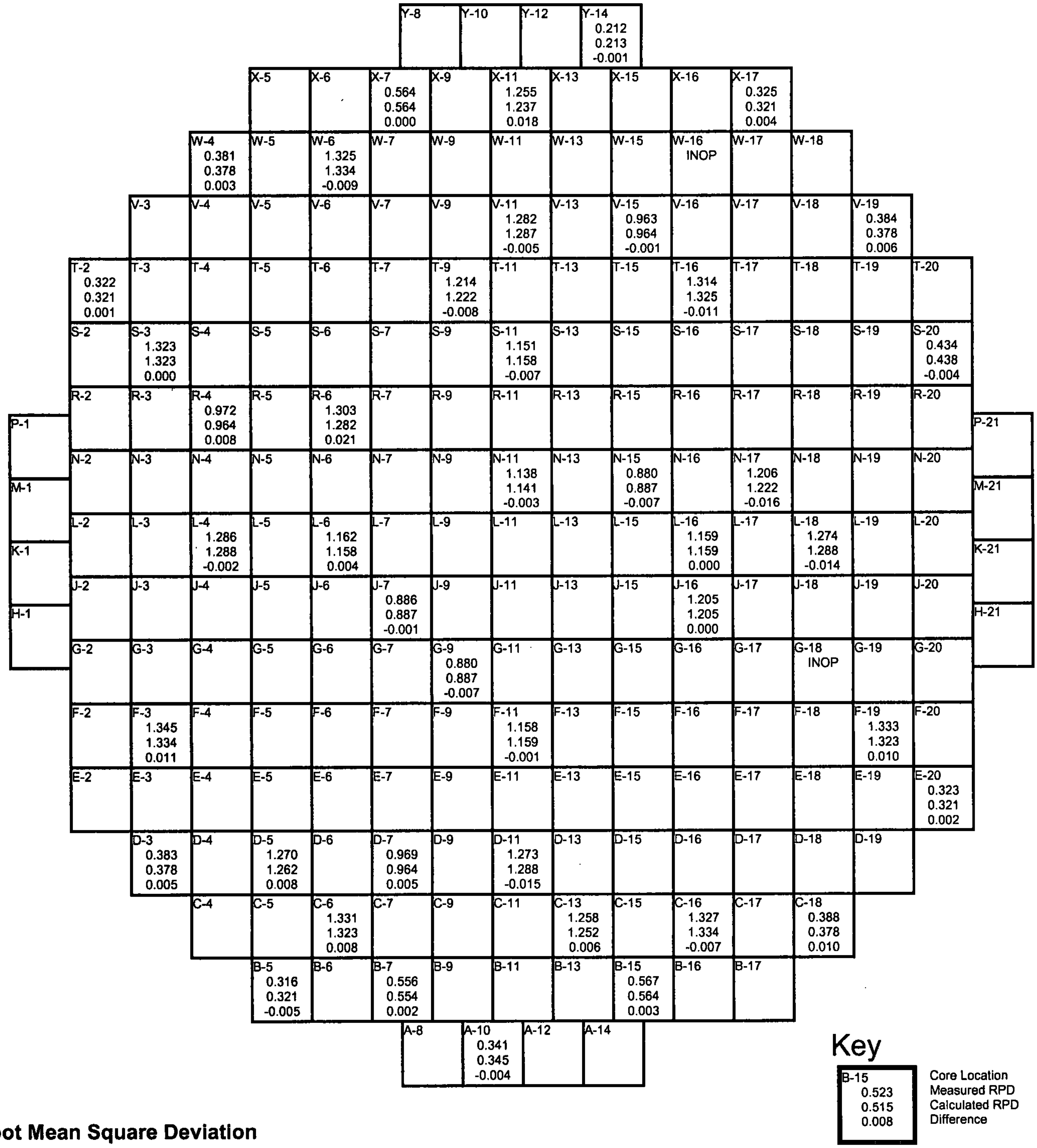
5.6 ETE-MP-2014-1060, Rev 0, "Application of the Startup Test Activity Reduction (STAR) Program for Cycle 23," May 8, 2014

6. FIGURES

							Y-8 Y-37	Y-10 AA-24	Y-12 AA-19	Y-14 Y-48						
				X-5 AA-11	X-6 AA-42	X-7 AA-35	X-9 CC-23 177	X-11 CC-31	X-13 CC-26 205	X-15 AA-37	X-16 AA-49	X-17 AA-14				
			W-4 AA-69	W-5 CC-03 94	W-6 CC-35	W-7 CC-11 216	W-9 BB-03	W-11 BB-69 220	W-13 BB-07	W-15 CC-14 228	W-16 CC-38	W-17 CC-06 196	W-18 AA-73			
		V-3 AA-74	V-4 CC-19 195	V-5 BB-23	V-6 BB-53 188	V-7 AA-02	V-9 AA-55 226	V-11 CC-43	V-13 AA-59 175	V-15 AA-07	V-16 BB-60 230	V-17 BB-26	V-18 CC-18 92	V-19 AA-72		
	T-2 AA-15	T-3 CC-07 180	T-4 BB-27	T-5 BB-63	T-6 CC-59	T-7 BB-46 198	T-9 CC-51	T-11 AA-25	T-13 CC-54	T-15 BB-51 215	T-16 CC-62	T-17 BB-62	T-18 BB-22	T-19 CC-02 97	T-20 AA-10	
	S-2 AA-50	S-3 CC-39	S-4 BB-57 186	S-5 CC-63	S-6 Z-60 214	S-7 BB-09	S-9 BB-35	S-11 BB-44	S-13 BB-37	S-15 BB-13	S-16 Z-59 231	S-17 CC-58	S-18 BB-56 185	S-19 CC-34	S-20 AA-41	
P-1 Y-45	R-2 AA-38	R-3 CC-15 206	R-4 AA-08	R-5 BB-52 192	R-6 BB-14	R-7 CC-67 179	R-9 AA-67	R-11 CC-47 219	R-13 AA-62	R-15 CC-66 212	R-16 BB-12	R-17 BB-45 184	R-18 AA-01	R-19 CC-10 202	R-20 AA-34	P-21 Y-40
M-1 AA-20	N-2 CC-27 203	N-3 BB-08	N-4 AA-60 217	N-5 CC-55	N-6 BB-38	N-7 AA-63	N-9 BB-32 183	N-11 BB-65	N-13 BB-31 209	N-15 AA-66	N-16 BB-34	N-17 CC-50	N-18 AA-54 229	N-19 BB-02	N-20 CC-22 171	M-21 AA-23
K-1 AA-21	L-2 CC-32	L-3 BB-70 213	L-4 CC-44	L-5 AA-26	L-6 BB-41	L-7 CC-48 100	L-9 BB-66	L-11 AA-78 98	L-13 BB-68	L-15 CC-46 224	L-16 BB-43	L-17 AA-28	L-18 CC-42	L-19 BB-72 191	L-20 CC-30	K-21 AA-18
H-1 Y-38	J-2 CC-24 201	J-3 BB-04	J-4 AA-56 99	J-5 CC-52	J-6 BB-36	J-7 AA-68	J-9 BB-29 107	J-11 BB-67	J-13 BB-30 197	J-15 AA-61	J-16 BB-40	J-17 CC-53	J-18 AA-58 221	J-19 BB-06	J-20 CC-25 208	H-21 Y-47
	G-2 AA-36	G-3 CC-12 200	G-4 AA-03	G-5 BB-47 168	G-6 BB-10	G-7 CC-68 182	G-9 AA-64	G-11 CC-45 223	G-13 AA-65	G-15 CC-65 218	G-16 BB-16	G-17 BB-50 193	G-18 AA-06	G-19 CC-13 211	G-20 AA-40	
	F-2 AA-43	F-3 CC-36	F-4 BB-54 174	F-5 CC-60	F-6 Z-57 232	F-7 BB-15	F-9 BB-39	F-11 BB-42	F-13 BB-33	F-15 BB-11	F-16 Z-58 210	F-17 CC-61	F-18 BB-59 190	F-19 CC-37	F-20 AA-52	
	E-2 AA-12	E-3 CC-04 181	E-4 BB-24	E-5 BB-64	E-6 CC-64	E-7 BB-49 172	E-9 CC-56	E-11 AA-27	E-13 CC-49	E-15 BB-48 170	E-16 CC-57	E-17 BB-61	E-18 BB-25	E-19 CC-05 119	E-20 AA-13	
		D-3 AA-70	D-4 CC-20 95	D-5 BB-28	D-6 BB-58 187	D-7 AA-05	D-9 AA-57 225	D-11 CC-41	D-13 AA-53 233	D-15 AA-04	D-16 BB-55 189	D-17 BB-21	D-18 CC-17 222	D-19 AA-76		
			C-4 AA-75	C-5 CC-08 173	C-6 CC-40	C-7 CC-16 204	C-9 BB-05	C-11 BB-71 227	C-13 BB-01	C-15 CC-09 199	C-16 CC-33	C-17 CC-01 93	C-18 AA-71			
				B-5 AA-16	B-6 AA-51	B-7 AA-39	B-9 CC-28 207	B-11 CC-29	B-13 CC-21 96	B-15 AA-33	B-16 AA-44	B-17 AA-09				
							A-8 Y-46	A-10 AA-17	A-12 AA-22	A-14 Y-39						

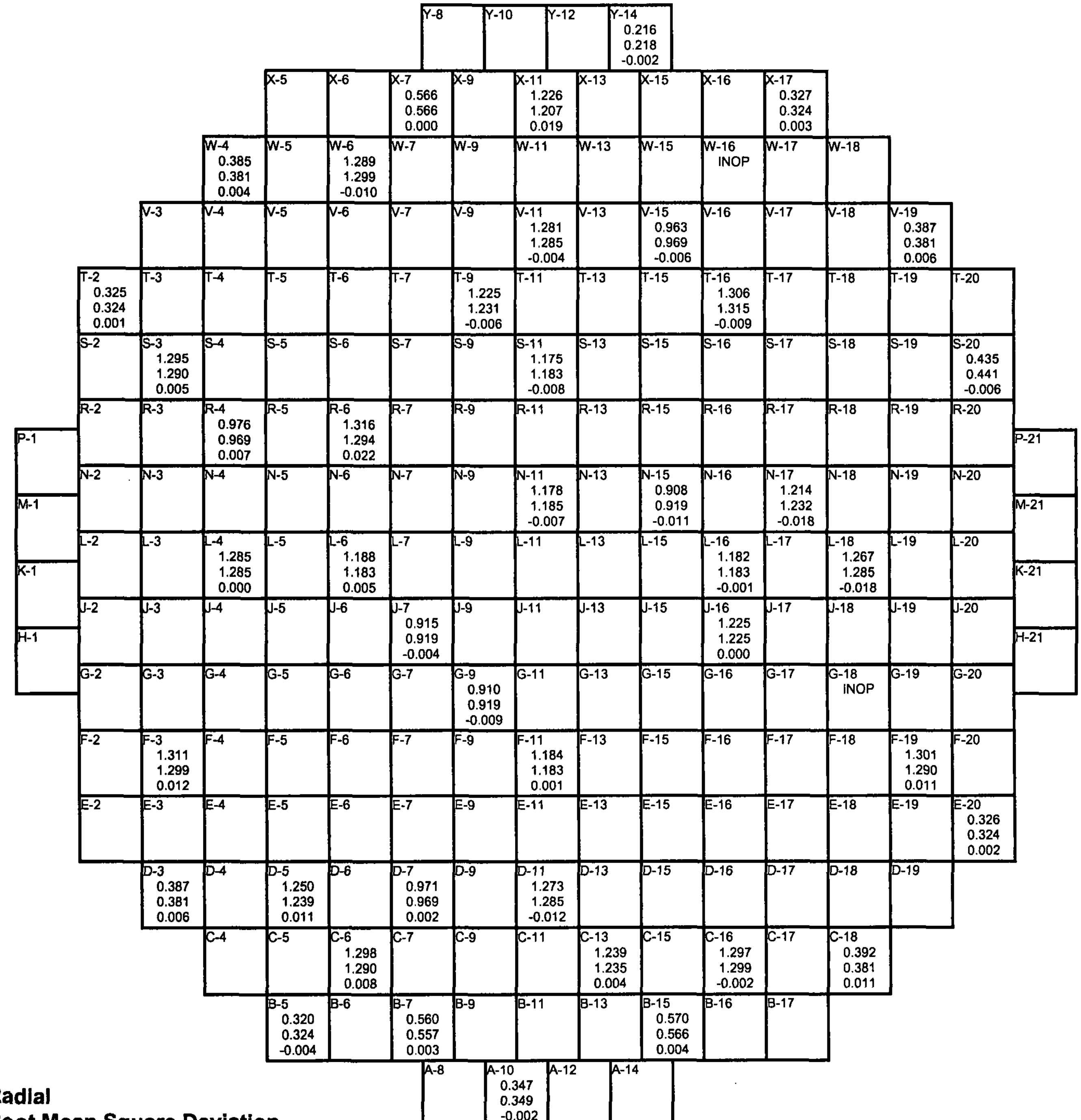
NORTH ↑

Figure 6.1
Millstone Unit No. 2
Cycle 23 Core Loading Map



Root Mean Square Deviation for all Core Locations = 0.015

Figure 6.2
68% Core Power Distribution Map
All Rods Out, Non-Equilibrium Xenon, 14 MWD/MTU



Radial
Root Mean Square Deviation
for all Core Locations = 0.009

Axial
Root Mean Square Core Average
Deviation = 0.015

Key

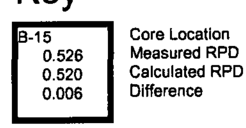


Figure 6.3
100% Core Power Distribution Map
All Rods Out, Non-Equilibrium Xenon, 110 MWD/MTU