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Dominion

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DOMINION NUCLEAR CONNECTICUT, INC.
MILLSTONE POWER STATION UNIT 2
STARTUP TEST REPORT FOR CYCLE 20

Pursuant to Section 6.9.1.3 of the Millstone Power Station Unit 2 Technical Specifications, Dominion Nuclear Connecticut, Inc. hereby submits the enclosed Startup Test Report for Cycle 20.

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

Very truly yours,

R. K. MacManus
Director – Nuclear Station and Licensing

Enclosure: (1)

Commitments made in this letter: None.

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ENCLOSURE

STARTUP TEST REPORT FOR CYCLE 20

DOMINION NUCLEAR CONNECTICUT, INC.
MILLSTONE POWER STATION UNIT 2

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1. SUMMARY

The refueling outage preceding the Cycle 20 startup was approximately 43 days, starting on October 6, 2009 and ending on November 18, 2009.

The results of the Millstone Power Station Unit 2 (MPS2), Cycle 20 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.

Implementation of the Startup Test Activity Reduction (STAR) Program for MPS2 Cycle 20 has been accomplished in accordance with the steps outlined in Westinghouse Commercial Atomic Power (WCAP)-16011-P-A, Rev. 0, "Startup Test Activity Reduction Program", February 2005, for (1) core design, (2) Control Element Assembly (CEA) lifetime, and (3) fuel fabrication. The STAR Applicability requirements for refueling have been accomplished for 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 20 fuel loading was completed on November 3, 2009. The attached core map (Figure 6.1) shows the final core loading. The subsequent operation/testing milestones were completed as follows:

Initial Criticality	November 17, 2009
Low Power Physics Testing Complete	November 17, 2009
Turbine On-Line	November 18, 2009
30% Power Testing Complete	November 18, 2009
69% Power Testing Complete	November 19, 2009
100% Power Testing Complete	November 24, 2009

The MPS2 Cycle 20 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 4×10^{-3} % power.

3.1 Unrodded Critical Boron Concentration

The Critical Boron Concentration (CBC) measured with CEA Group 7 at 148 steps withdrawn and a Reactor Coolant System (RCS) temperature of 529.0°F was 1615 parts per million (ppm).

Adjusted to the prediction conditions of Group 7 at 180 steps withdrawn and a RCS temperature of 532°F yields an adjusted, measured CBC of 1630 ppm.

Adjusted, measured unrodded CBC	=	1630 ppm
Predicted unrodded CBC	=	1614 ppm
Difference		16 ppm (130 percent millirho (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 1614 ppm, an average RCS temperature of 530.5°F, and CEA Group 7 at 148 steps.

The measured ITC at these conditions was +1.56 pcm/°F.

Adjusted to the prediction conditions for an RCS boron concentration of 1614 ppm and an RCS temperature of 532°F yields an adjusted, measured ITC of +1.49 pcm/°F.

Adjusted, measured ITC	=	+1.49 pcm/°F
Predicted ITC	=	+1.02 pcm/°F
Difference	=	+0.47 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 $+0.294 \times 10^{-4}$ change in reactivity per degree Fahrenheit ($\Delta\rho/°F$). 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 not measured as allowed by WCAP-16011-P-A, "Startup Test Activity Reduction Program."

3.4 Rodded Critical Boron Concentration

CBC measured with CEA Group A inserted was not performed during Cycle 20 startup testing due to application of the STAR Program.

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 530°F with all 4 reactor coolant pumps operating. The average control rod drop time was 2.22 seconds to 90% insertion, with the fastest and slowest drop times being 2.14 seconds and 2.30 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 the 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%	1.615	9.34 KW/ft	0.0032
100%	1.579	12.92 KW/ft	0.0029

KW/ft – (Kilowatt per foot)

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 less than 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 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 1154 ppm. The cycle average exposure at the time of this measurement was 166 Megawatt Days (MWD)/Metric Tons Uranium (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 1154 ppm.

Adjusted, measured 100% power CBC	=	1154 ppm
Predicted 100% power CBC	=	1134 ppm
Difference	=	20 ppm (157 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	=	466 ppm
Adjusted, measured change in CBC from HZP to HFP	=	476 ppm
Difference	=	-10 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 –0.017 to +0.022.

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 3.97%.

Review Criteria is ± 10%.

Review Criteria met? Yes.

4.5 Moderator Temperature Coefficient

ITC measurements were performed at a power level of 98.93%, an RCS boron concentration of 1154 ppm, and an average RCS temperature of 570.28°F, and CEA Group 7 at 180 steps.

The measured ITC at these conditions was –7.844 pcm/°F.

The predicted ITC was determined for a power level of 100%, an RCS boron concentration of 1136 ppm, an average RCS temperature of 569.9°F, and at an ARO condition.

The predicted ITC at these conditions was –7.67 pcm/°F.

The predicted ITC adjusted for 98.93% power, an actual RCS boron concentration of 1154 ppm and an RCS temperature of 570.28°F yields an adjusted, predicted ITC of –7.458 pcm/°F.

Adjusted, Predicted ITC	=	–7.458 pcm/°F
Measured ITC	=	–7.844 pcm/°F
Difference	=	+0.386 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 -0.660×10^{-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 386,943 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 373,943 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 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 31 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 about 2.96×10^{-4} µCi/ml (microcuries per milliliter). These RCS activity levels show all failed fuel assemblies have been discharged from the core.

5. REFERENCES

5.1 EN 21004K, "Cycle 20, Low Power Physics Test"

5.2 EN 21004J, "Cycle 20, Power Ascension Testing"

5.3 "Millstone Unit 2, Cycle 20, Startup and Operations Report"

5.4 SP 21010, "CEA Drop Times,"

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

5.6 M2-EV-09-0008, Rev 0, "Application of the Startup Test Activity Reduction (STAR) Program for Cycle 20," November 13, 2009

6. FIGURES

6.1 Cycle 20 Core Loading Map

6.2 69% Core Power Distribution Map

6.3 100% Core Power Distribution Map

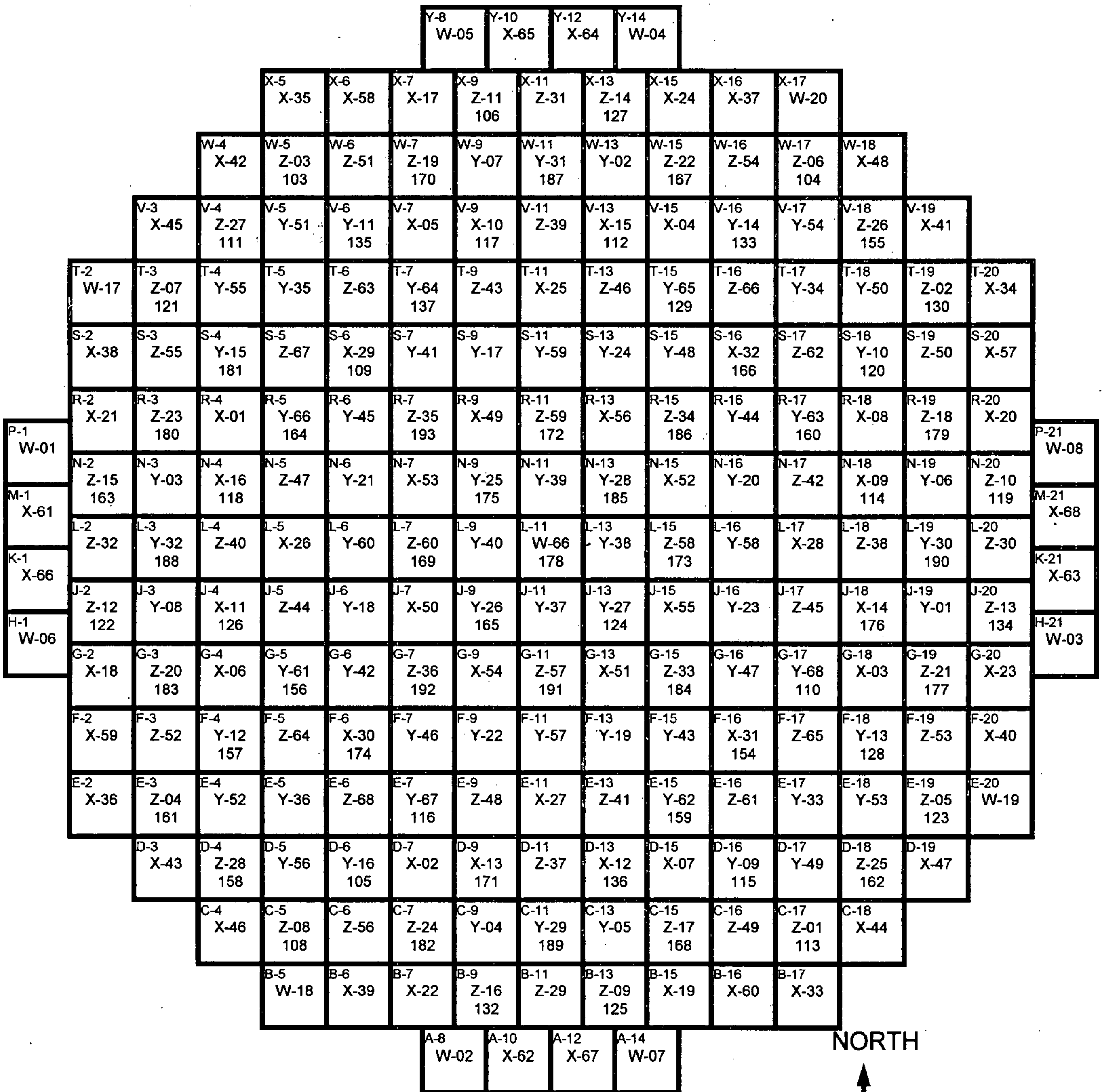
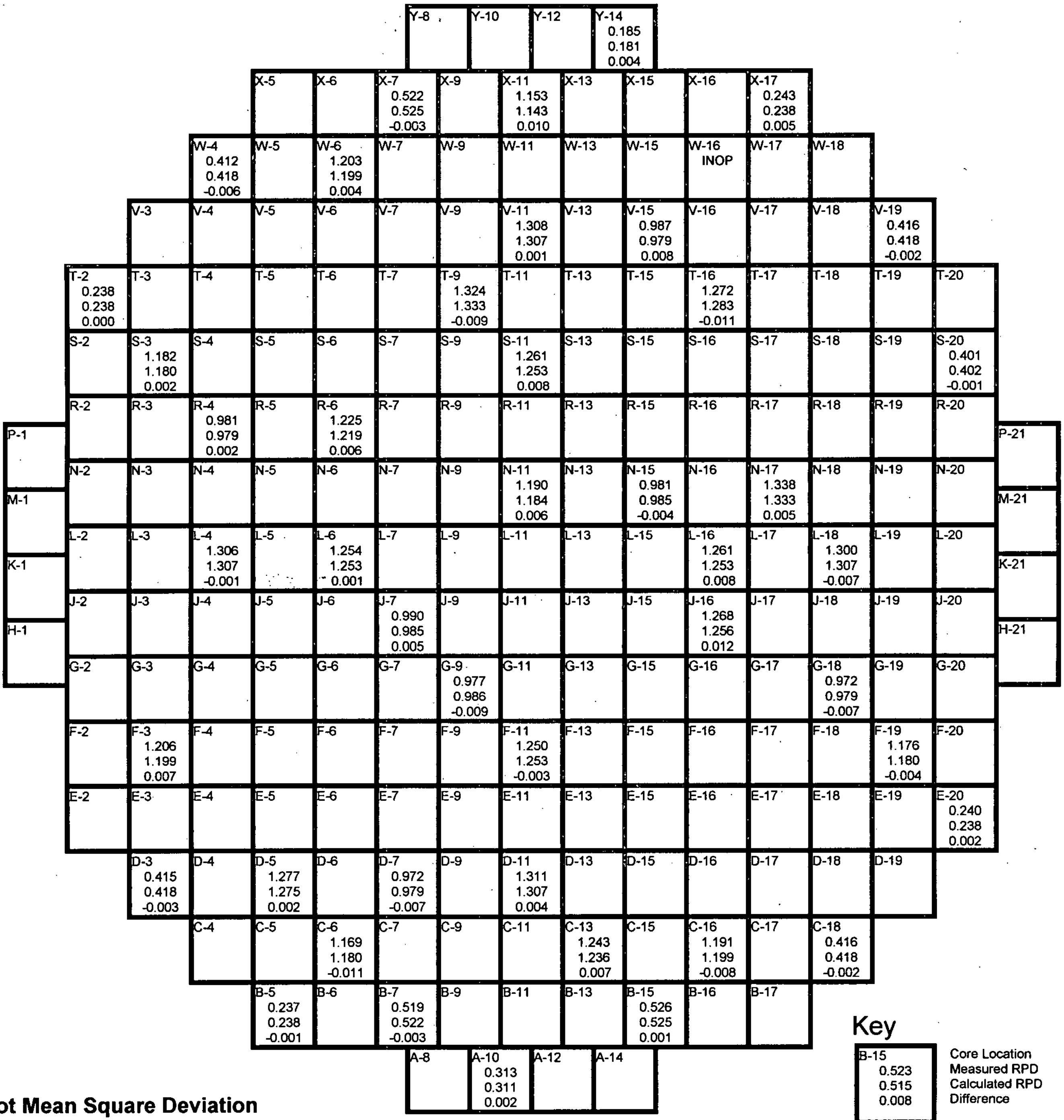


Figure 6.1
Millstone Power Station Unit 2
Cycle 20 Core Loading Map



Root Mean Square Deviation for all Core Locations = 0.006

Figure 6.2
69% Core Power Distribution Map
All Rods Out, Non-Equilibrium Xenon, 14MWD/MTU

						Y-8	Y-10	Y-12	Y-14 0.188 0.185 0.003							
				X-5	X-6	X-7 0.526 0.529 -0.003	X-9	X-11 1.143 1.132 0.011	X-13	X-15	X-16	X-17 0.245 0.241 0.004				
			W-4 0.412 0.419 -0.007	W-5	W-6 1.192 1.185 0.007	W-7	W-9	W-11	W-13	W-15	W-16 INOP	W-17	W-18			
		V-3	V-4	V-5	V-6	V-7	V-9	V-11 1.307 1.305 0.002	V-13	V-15 0.987 0.982 0.005	V-16	V-17	V-18	V-19 0.416 0.420 -0.004		
	T-2 0.241 0.241 0.000	T-3	T-4	T-5	T-6	T-7	T-9 1.328 1.337 -0.009	T-11	T-13	T-15	T-16 1.267 1.277 -0.010	T-17	T-18	T-19	T-20	
	S-2	S-3 1.171 1.168 0.003	S-4	S-5	S-6	S-7	S-9	S-11 1.271 1.264 0.007	S-13	S-15	S-16	S-17	S-18	S-19	S-20 0.405 0.406 -0.001	
P-1	R-2	R-3	R-4 0.984 0.982 0.002	R-5	R-6 1.232 1.227 0.005	R-7	R-9	R-11	R-13	R-15	R-16	R-17	R-18	R-19	R-20	P-21
M-1	N-2	N-3	N-4	N-5	N-6	N-7	N-9	N-11 1.204 1.202 0.002	N-13	N-15 0.994 1.002 -0.008	N-16	N-17 1.341 1.337 0.004	N-18	N-19	N-20	M-21
K-1	L-2	L-3	L-4 1.304 1.305 -0.001	L-5	L-6 1.263 1.264 -0.001	L-7	L-9	L-11	L-13	L-15	L-16 1.271 1.264 0.007	L-17	L-18 1.298 1.305 -0.007	L-19	L-20	K-21
H-1	J-2	J-3	J-4	J-5	J-6	J-7 1.004 1.002 0.002	J-9	J-11	J-13	J-15	J-16 1.276 1.265 0.011	J-17	J-18	J-19	J-20	H-21
	G-2	G-3	G-4	G-5	G-6	G-7	G-9 0.991 1.002 -0.011	G-11	G-13	G-15	G-16	G-17	G-18 0.975 0.982 -0.007	G-19	G-20	
	F-2	F-3 1.193 1.185 0.008	F-4	F-5	F-6	F-7	F-9	F-11 1.262 1.264 -0.002	F-13	F-15	F-16	F-17	F-18	F-19 1.167 1.168 -0.001	F-20	
	E-2	E-3	E-4	E-5	E-6	E-7	E-9	E-11	E-13	E-15	E-16	E-17	E-18	E-19	E-20 0.242 0.241 0.001	
		D-3 0.417 0.420 -0.003	D-4	D-5 1.260 1.257 0.003	D-6	D-7 0.975 0.982 -0.007	D-9	D-11 1.310 1.305 0.005	D-13	D-15	D-16	D-17	D-18	D-19		
			C-4	C-5	C-6 1.160 1.168 -0.008	C-7	C-9	C-11	C-13 1.237 1.226 0.011	C-15	C-16 1.182 1.185 -0.003	C-17	C-18 0.417 0.420 -0.003			
				B-5 0.240 0.241 -0.001	B-6	B-7 0.525 0.526 -0.001	B-9	B-11	B-13	B-15 0.531 0.529 0.002	B-16	B-17				
						A-8	A-10 0.317 0.316 0.001	A-12	A-14							

Radial
Root Mean Square Deviation
for all Core Locations = 0.006

Axial
Root Mean Square Core Average
Deviation = 0.015

Key

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

Figure 6.3
100% Core Power Distribution Map
All Rods Out, Non-Equilibrium Xenon, 31MWD/MTU