

Dominion Nuclear Connecticut, Inc.  
Rope Ferry Rd., Waterford, CT 06385  
Mailing Address: P.O. Box 128  
Waterford, CT 06385  
dom.com



**JUL 06 2016**

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

Serial No. 16-265  
MPS Lic/MLC R0  
Docket No. 50-423  
License No. NPF-49

**DOMINION NUCLEAR CONNECTICUT, INC.**  
**MILLSTONE POWER STATION UNIT 3**  
**STARTUP TEST REPORT FOR CYCLE 18**

Pursuant to Millstone Power Station Unit 3 Technical Specification 6.9.1.1, Dominion Nuclear Connecticut, Inc. submits the enclosed Startup Test Report for Cycle 18.

If you have any questions or require additional information, please contact Mr. Thomas G. Cleary at (860) 444-4377.

Sincerely,

B. L. Stanley  
Director, Nuclear Safety and Licensing – Millstone

Enclosure: (1)

Commitments made in this letter: None

IE26  
NRR

cc: U.S. Nuclear Regulatory Commission  
Region I Administrator  
2100 Renaissance Blvd, Suite 100  
King of Prussia, PA 19406-2713

R. V. Guzman  
Senior Project Manager – Millstone Power Station  
U.S. Nuclear Regulatory Commission  
One White Flint North, Mail Stop O8 C2  
11555 Rockville Pike  
Rockville, MD 20852-2738

NRC Senior Resident Inspector  
Millstone Power Station

**ENCLOSURE**

**STARTUP TEST REPORT FOR CYCLE 18**

**DOMINION NUCLEAR CONNECTICUT, INC.  
MILLSTONE POWER STATION UNIT 3**

## 1.0 SUMMARY

Pursuant to Millstone Power Station Unit 3 (MPS3) Technical Specification (TS) 6.9.1.1, a summary of the MPS3 Cycle 18 startup testing, performed following completion of the spring 2016 refueling outage, is provided.

## 2.0 INTRODUCTION

The MPS3 Cycle 18 fuel reload was completed on April 29, 2016. The attached core map (Figure 7.1) shows the final core configuration. Reference [6.3] documents that Cycle 18 uses a low leakage loading pattern (L3P) consisting of 85 new Region 20 fuel assemblies, 84 Region 19 once-burned fuel assemblies, and 24 Region 18 twice-burned fuel assemblies. All 193 fuel assemblies in the Cycle 18 core are the Westinghouse 17x17 robust fuel assembly (RFA-2) design.

The 85 new Region 20 fuel assemblies are comprised of 53 fuel assemblies enriched to 4.10 weight percent Uranium-235 (w/o  $U^{235}$ ) and 32 fuel assemblies enriched to 4.95 w/o  $U^{235}$ . The top and bottom regions of all fuel assemblies in the Cycle 18 core are comprised of a 6-inch annular blanket region enriched to 2.6 w/o  $U^{235}$ . Placement of the new fuel assemblies in the designated fresh fuel assembly locations was made in a random fashion in order to prevent power tilts across the core due to systematic deviations in the fresh fuel composition.

The 108 re-inserted fuel assemblies were ultrasonically cleaned during the spring 2016 refueling outage. The purpose of the ultrasonic fuel cleaning was to remove adhered crud (primarily nickel and iron-based deposits) from the surface of fuel rods that have previous core exposure in order to reduce the probability of occurrence of crud-induced power shift (CIPS).

Every fuel assembly in Cycle 18 contains an insert. The inserts consist of 61 rod cluster control assemblies (RCCAs), 128 thimble plugs, and 4 secondary source assemblies.

Subsequent operational and testing milestones were completed as follows:

Initial Criticality	May 12, 2016
Low Power Physics Testing completed	May 13, 2016
Main Turbine Online	May 13, 2016
49% Power Testing completed	May 14, 2016
74% Power Testing completed	May 15, 2016
100% Power Testing completed	May 24, 2016

### 3.0 FUEL DESIGN

All of the 193 assemblies in the Cycle 18 core are of the RFA-2 design. This fuel design is the same as that used in Cycle 17.

### 4.0 LOW POWER PHYSICS TESTING

The low power physics testing program for Cycle 18 was completed using the procedure in Reference [6.1] which is based on the Westinghouse dynamic rod worth measurement (DRWM) technique described in Reference [6.4]. This program consisted of the following: control and shutdown bank worth measurements, critical boron endpoint measurements for all rods out (ARO), and ARO moderator/isothermal temperature coefficient measurements. Low power physics testing was performed at a power level below the point of nuclear heat to avoid nuclear heating reactivity feedback effects.

#### 4.1 Critical Boron Concentration

The critical boron concentration was measured for the ARO configuration. The measured values include corrections to account for differences between the measured critical rod configuration and the ARO configuration. The review and acceptance criteria of  $\pm 500$  and  $\pm 1000$  percent milliRho (pcm), respectively, were met for the ARO configuration.

#### Summary of Boron Endpoint Results

	Measured (ppm)	Predicted (ppm)	M-P (ppm)	Acceptance Criteria (pcm)
All Rods Out (ARO)	2060	2058	+2 (-14.7 pcm)	$\pm 1000$

#### 4.2 Moderator Temperature Coefficient

Isothermal temperature coefficient (ITC) data was measured with Control Bank D at 197 steps withdrawn. The review criteria of  $\pm 2$  pcm/degrees Fahrenheit ( $^{\circ}$ F) to the predictions were met.

The ARO moderator temperature coefficient (MTC) of  $+0.60$  pcm/ $^{\circ}$ F was calculated by subtracting the design Doppler temperature coefficient ( $-1.74$  pcm/ $^{\circ}$ F) from the measured ARO isothermal temperature coefficient of  $-1.70$  pcm/ $^{\circ}$ F, and adding the delta ( $\Delta$ ) ITC correction value of  $+0.56$  pcm/ $^{\circ}$ F ( $\Delta$ ITC corrects the MTC at the measurement conditions to the minimum temperature for

criticality value of 551°F). The TS limit of MTC < +5.0 pcm/°F at ARO hot zero power (HZP) was met.

**Isothermal/Moderator Temperature Coefficient Results**

	Measured (pcm/°F)	Corrected Predicted (pcm/°F)	M-P (pcm/°F)	Acceptance Criteria (pcm/°F)
ARO ITC	-1.70	-2.52	0.82	NA
ARO MTC	0.60	NA	NA	MTC < +5.0

**4.3 Control Rod Reactivity Worth Measurements**

The integral reactivity worths of all RCCA control and shutdown banks were measured using the DRWM technique. The review criteria of the measured worth is ±15% or 100 pcm of the individual predicted worth, whichever is greater and the sum of the measured worths is ±8% of the predicted worths. The DRWM rod worth acceptance criteria is defined as: the sum of the measured worths (M) of all banks shall be greater than or equal to 90% of the sum of their predicted worths (P).

**Control Bank Integral Worth Results**

	Measured (pcm)	Predicted (pcm)	M-P (pcm)	% Difference (M-P) / P
Control Bank A	774.0	769.4	4.6	0.6
Control Bank B	597.7	606.1	-8.4	-1.4
Control Bank C	784.5	828.1	-43.6	-5.3
Control Bank D	606.7	566.2	40.5	7.2
Shutdown Bank A	387.8	399.9	-12.1	-3.0
Shutdown Bank B	911.3	976.4	-65.1	-6.7
Shutdown Bank C	406.0	381.5	24.5	6.4
Shutdown Bank D	404.8	384.6	20.2	5.3
Shutdown Bank E	82.2	82.2	0	0
Total	4955.0	4994.4	-39.4	-0.8

The measured results of the individual bank worths and the total control bank worth showed excellent agreement with the predicted values. All individual and

total worth review criteria were met. The acceptance criteria for the sum of the measured rod worths (greater than or equal to 90% of the sum of the predicted worths), was met.

## 5.0 POWER ASCENSION TESTING

Testing was performed at specified power plateaus of approximately 49%, 74% and 100% Reactor Thermal Power (RTP). Power changes were governed by operating procedures and fuel preconditioning guidelines.

Thermal-hydraulic parameters, nuclear parameters, and related instrumentation were monitored throughout the power ascension. Data was compared to previous cycle power ascension data and engineering predictions, as required, at each test plateau to identify calibration or system problems. The major areas analyzed were:

- Core Performance Evaluation: Flux mapping was performed at approximately 49%, 74% and 100% RTP using the moveable incore detector system. The resultant peaking factors and power distribution were compared to TS limits to verify that the core was operating within its design limits. All analysis limits were met and the results are summarized in Section 5.1.
- Nuclear Instrumentation Indication: Overlap data was obtained between the intermediate and power range nuclear instrumentation channels. Secondary plant heat balance calculations were performed to verify the nuclear instrumentation indications.
- Incore/Excore Calibration: Scaling factors were calculated from flux map data using the single point calibration methodology. The nuclear instrumentation power range channels were re-scaled at approximately 49% and 100% RTP.
- Reactor Coolant System (RCS) Flow: The RCS flow rate was measured at approximately 94% RTP using a secondary calorimetric heat balance for each loop with the steam generators as the control volumes. The calculated RCS flow rate met the TS requirements and is reported in Section 5.3.

### 5.1 Power Distribution, Power Peaking and Tilt Measurements

The core power distribution was measured through the performance of a series of flux maps during the power ascension, as specified in Reference [6.2]. The results from the flux maps were used to verify compliance with the power distribution TSs.

A low power flux map at approximately 49% RTP was performed to determine if any gross neutron flux abnormalities existed. At the 49% RTP plateau flux map and again at the 74% RTP plateau flux map, data necessary to perform an excore to incore calibration via the single point methodology was obtained. Per TS

Surveillance 4.3.1.1, Table 4.3-1, Functional Unit 2, Note 6, a flux map at approximately 100% RTP was performed for an excore to incore calibration. The 100% RTP map also verified core power distributions were within the design limits.

A summary of the measured axial flux difference (AFD) and incore tilt for the flux maps performed during the power ascension is provided below. Additional tables provide comparisons of the most limiting measured heat flux hot channel factor ( $F_Q$ ) and nuclear enthalpy rise hot channel factor ( $F_{\Delta h}$ ), including uncertainties, to their respective limits from each of the flux maps performed during the power ascension. The most limiting  $F_Q$  reported is based on minimum margin to the steady state limit that varies as a function of core height.

As shown below, all TS limits were met and no abnormalities in core power distribution were observed during power ascension.

**Summary of Measured Axial Flux Difference and Incore Tilt**

Power (%RTP)	Burnup (MWD/MTU)	Rod Position (steps)	AFD (%)	Incore Tilt
49.3	8.9	216	5.072	1.0188
73.6	27.2	216	3.821	1.0139
99.9	224.6	216	1.027	1.0107

**Comparison of Measured  $F_Q$  to  $F_Q^{RTP}$  Limit**

Power (%RTP)	Burnup (MWD/MTU)	Measured $F_Q$	$F_Q^{RTP}$ steady state limit	Margin to Transient Limit
49.3	8.9	N/A	N/A	N/A
73.6	27.2	1.8817	3.4075	8.9 %
99.9	224.6	1.8536	2.603	14.8 %

**Comparison of Measured  $F_{\Delta h}$  to  $F_{\Delta h}$  Limit**

Power (%RTP)	Burnup (MWD/MTU)	$F_{\Delta h}$	$F_{\Delta h}$ Limit
49.3	8.9	1.491	1.827
73.6	27.2	1.443	1.712
99.9	224.6	1.430	1.586

Presented in Figures 7.2, 7.3 and 7.4 are measured power distribution maps showing percent difference from the predicted power for approximately 49%, 74% and 100% RTP plateaus. These figures show there is good agreement between the measured and predicted assembly powers.

## 5.2 Boron Measurements

Hot full power ARO boron concentration measurements were performed after reaching equilibrium conditions. The measured ARO, hot full power, equilibrium xenon, boron concentration was 1412 ppm with a predicted value of 1439 ppm. The predicted to measured difference was -204 pcm which met the acceptance criteria of  $\pm 1000$  pcm.

## 5.3 Reactor Coolant System Flow Measurement

The RCS flow rate was determined using a secondary calorimetric heat balance for each loop with the steam generators as the control volumes. The following parameters were measured:

- RCS pressure
- Hot leg temperatures
- Cold leg temperatures
- Feedwater temperatures
- Feedwater flow rates
- Feedwater pressure
- Steam generator pressure

Steam generator blowdown was not isolated during the data acquisition period.

Per TS Surveillance 4.2.3.1.3, the RCS flow was measured within 24 hours after exceeding 90% RTP. The measured flow at 94.4% RTP was 402,787 gallons per minute (gpm) with a minimum required flow of 379,200 gpm. All TS limits were met.

## 6.0 REFERENCES

- 6.1 SP 31008, Rev. 008-00, "Low Power Physics Testing (ICCE)"
- 6.2 EN 31015, Rev. 004-00, "Power Ascension Testing of Millstone Unit 3"
- 6.3 ETE-NAF-2016-0041, Rev. 000, "Millstone Unit 3 Cycle 18 Nuclear Design Report"
- 6.4 WCAP-13360-P-A, Revision 1, "Westinghouse Dynamic Rod Worth Measurement Technique"

7.0 FIGURES

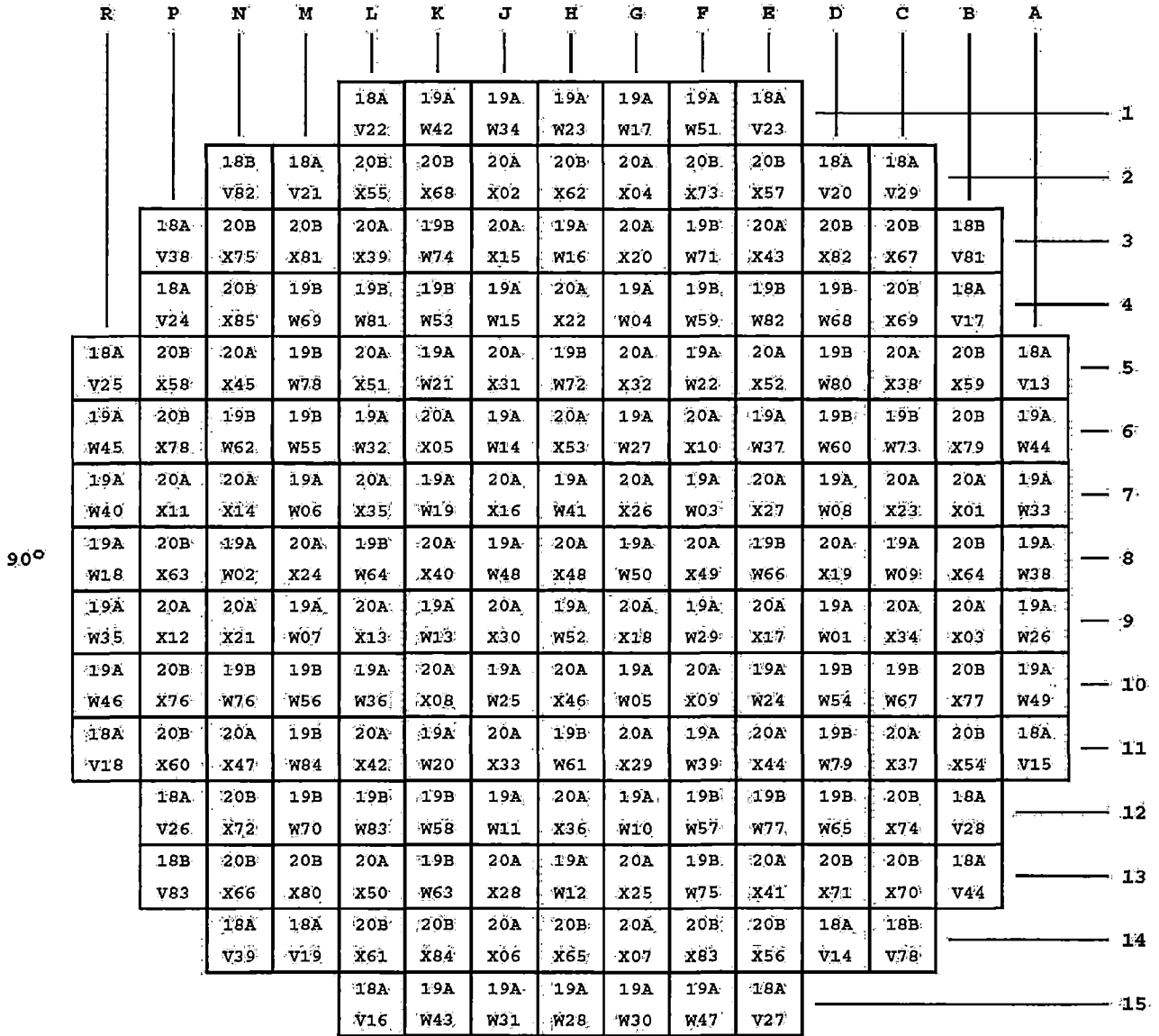
7.1 Core Loading Pattern, Millstone Unit 3 - Cycle 18

7.2 INCORE Power Distribution – 49.3%, Millstone Unit 3 - Cycle 18

7.3 INCORE Power Distribution – 73.6%, Millstone Unit 3 - Cycle 18

7.4 INCORE Power Distribution – 99.9%, Millstone Unit 3 - Cycle 18

FIGURE 7.1  
 CORE LOADING PATTERN  
 MILLSTONE UNIT 3 - CYCLE 18



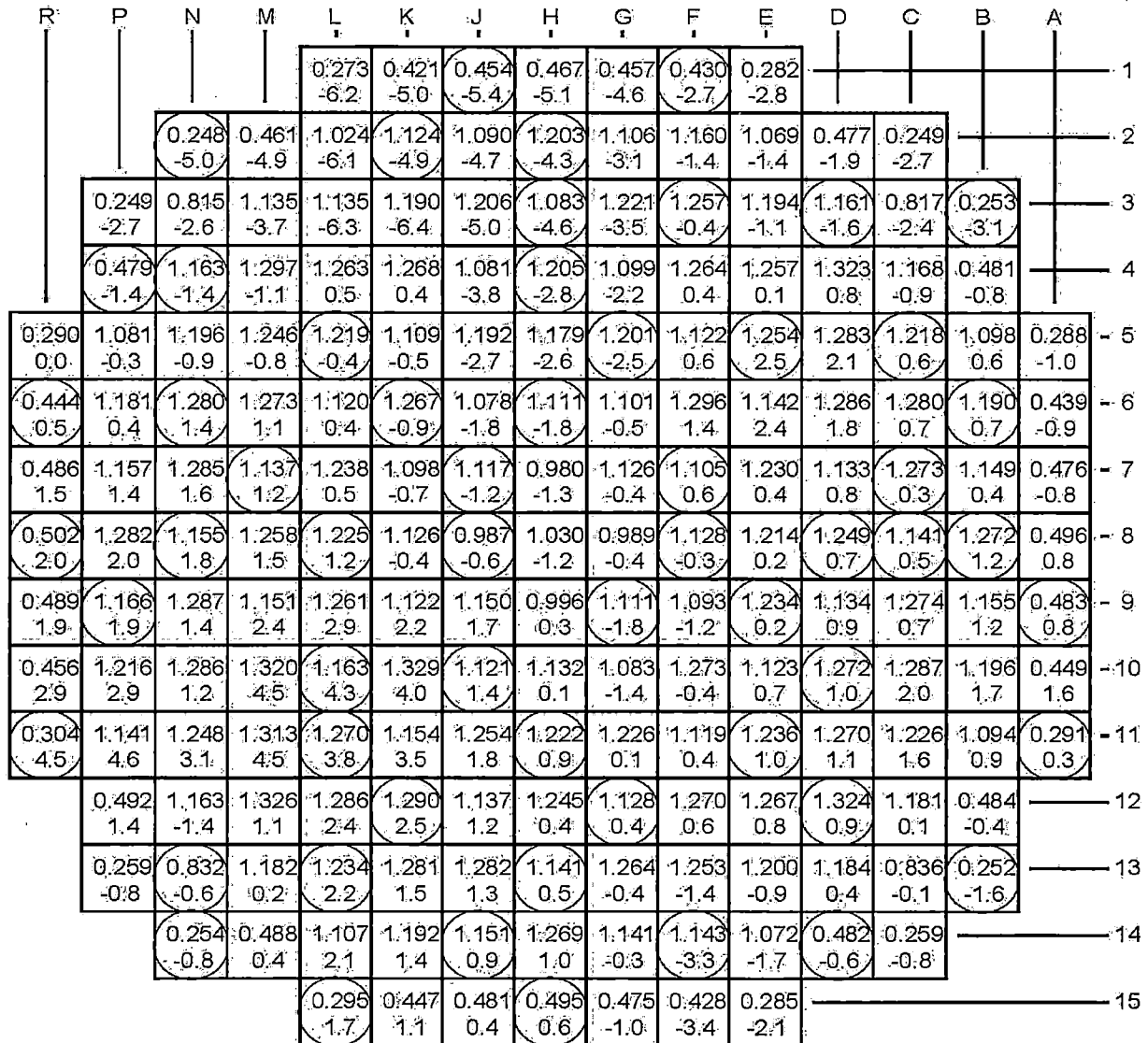
LEGEND

R	Region Identifier
ID	Fuel Assembly Identifier

REGION ASSEMBLIES ENRICHMENT

18A	20	4.10
18B	4	4.95
19A	52	4.10
19B	32	4.95
20A	53	4.10
20B	32	4.95

**FIGURE 7.2**  
**INCORE Power Distribution - 49.3%**  
**MILLSTONE UNIT 3 - CYCLE 18**





 Measured Power  
% Difference: (M-P)/P  
 Measured Location

FIGURE 7.3  
INCORE Power Distribution - 73.6%  
MILLSTONE UNIT 3 - CYCLE 18

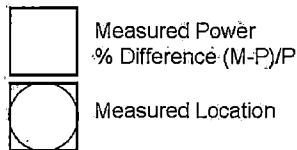
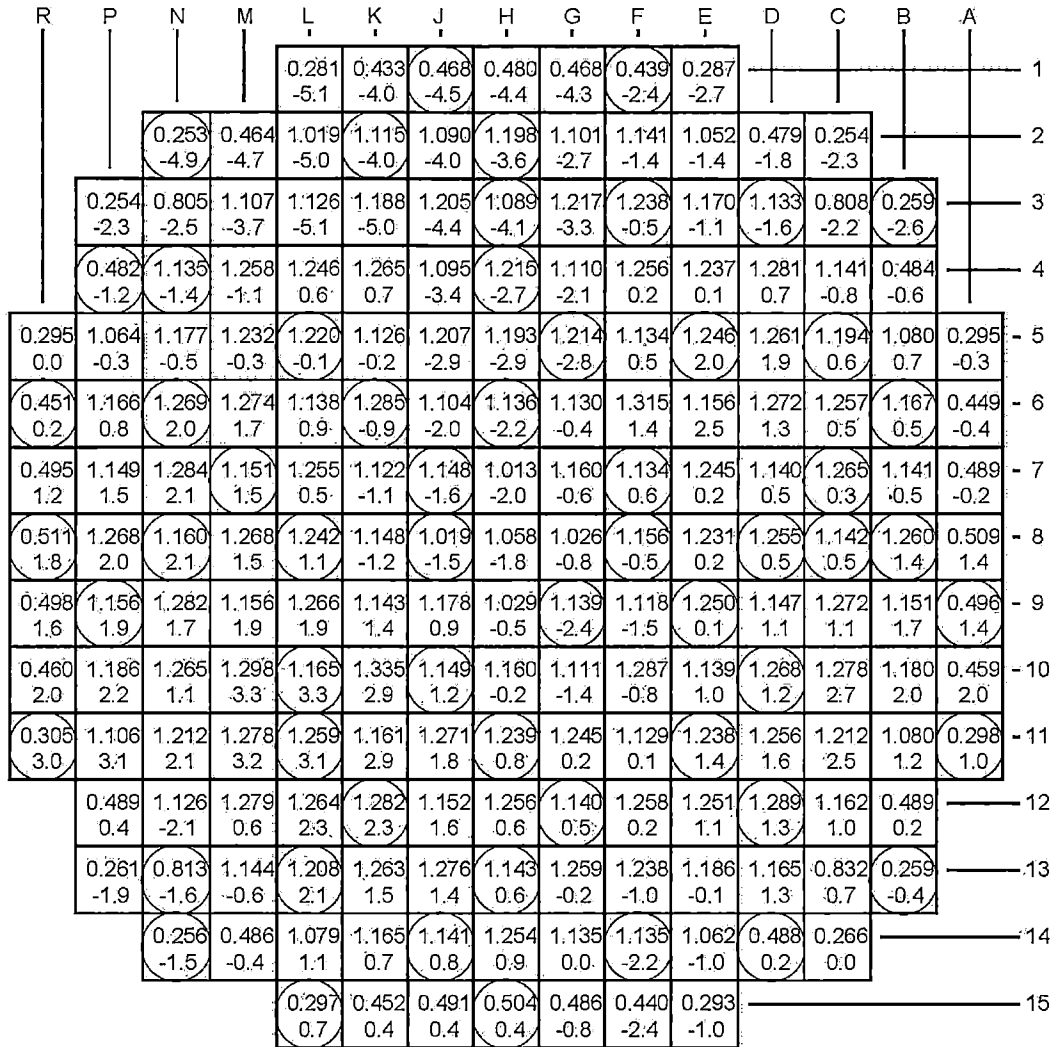
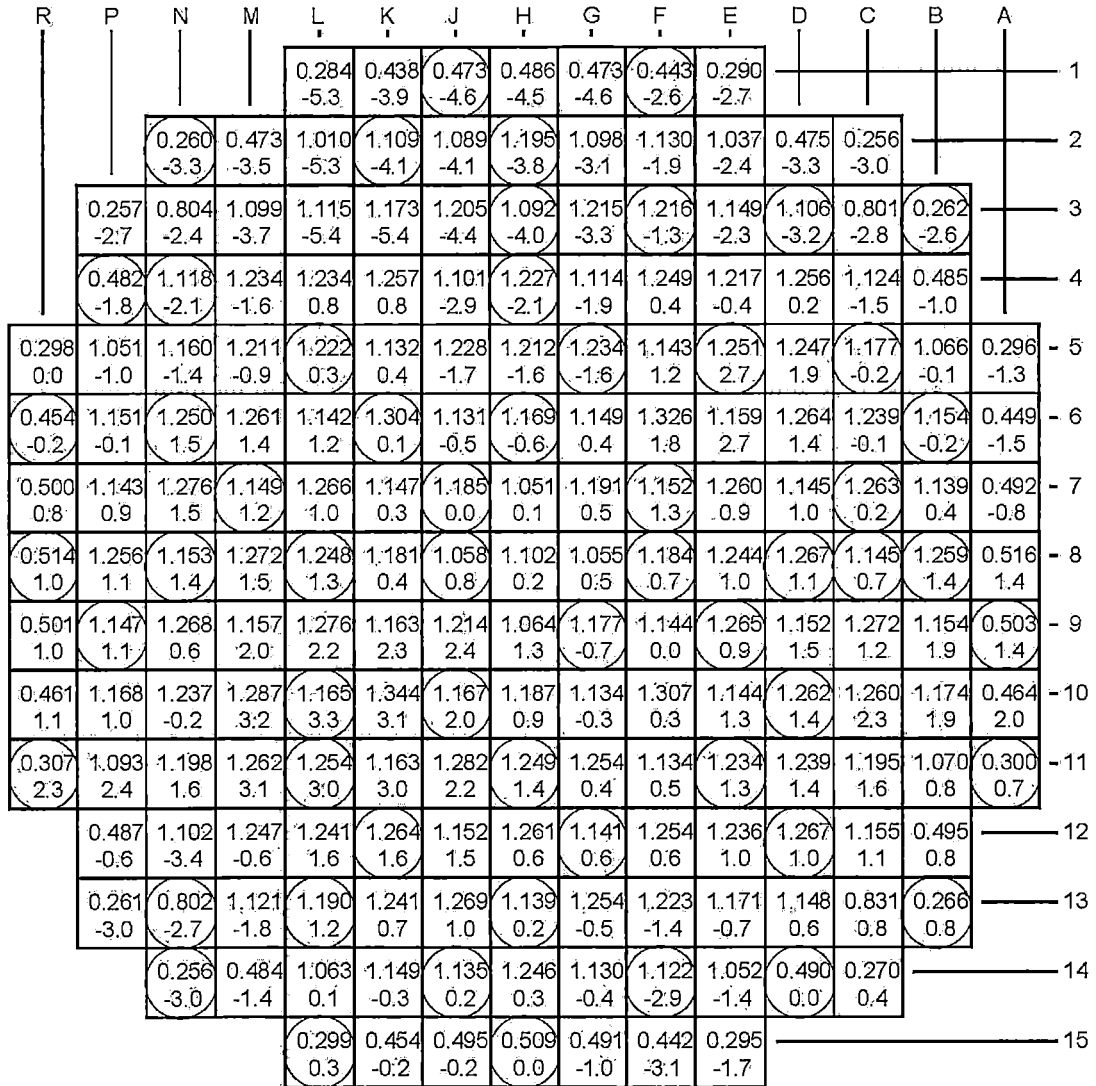




FIGURE 7.4  
 INCORE Power Distribution - 99.9%  
 MILLSTONE UNIT 3 - CYCLE 18



 Measured Power  
 % Difference (M-P)/P  
 Measured Location