Docket No. 50-336

MILLSTONE NUCLEAR POWER STATION
UNIT NO. 2

STARTUP TEST REPORT
CYCLE 6

March 1984

INDEX

1. SUMMARY - Cycle 6 Startup

The refueling outage preceeding the Cycle 6 Startup saw a number of unusual events for Millstone Unit 2. In particular the Thermal Shield was removed from the Core Support Barrel of the Reactor Vessel. Also, Millstone 2 experienced some fuel failure events during Cycle 5 and fuel sipping was performed for the first time during this outage to remove fuel pin leakers from the Cycle 6 core.

The results from this startup testing program were routine with 2 exceptions:

1. Identification of Some Fuel Failures

   Reactor Coolant System Iodine - 131 levels show that a small number of fuel pins are failed. Based on the Iodine 131 levels at the time of this report, the number of failed pins seem similar to the number failed in Cycle 5.

2. Power Distribution Radial Shift

   At-power measurements show that more power is being produced in the center of the core than what was expected/predicted. This shift in power towards the center of the core over what was predicted resulted in several problems. Higher Fxy^T peaking factors were measured than what was predicted, resulting in the inability to go higher than $\approx$ 85% power without a Technical Specification Change to allow higher Fxy^T limits. The shift in radial power to the center of the core is demonstrated in Figure 3. Also it is believed that the CEA worth disagreements that were identified during Low Power Testing were in part due to this power distribution shift.

2. INTRODUCTION

Millstone 2, Cycle 6 fuel loading was completed on December 12, 1983. The attached Core Map (figure 1) shows the final core geometry. Subsequent operation/testing milestones were completed as follows:

Initial Criticality	Jan. 5, 1984
Low Power Physics Testing Completion	Jan. 7, 1984
Turbine On-Line	Jan. 13, 1984
Complete 50% Power Testing	Jan. 20, 1984
Complete 83% Power Testing	Jan. 27, 1984
Complete 100% Power Testing	Feb. 3, 1984

Cycle 6 operation is with $\approx$ 90% Westinghouse fuel and 10% Combustion Engineering fuel. The Safety Analysis is supplied by Westinghouse.

During the outage preceeding this startup, the thermal shield was removed from the Core Support Barrel inside the Reactor Vessel. In addition the fuel loading plan was revised during the outage to eliminate failed fuel identified by sipping. These items were discussed with the NRC and docketed via other transmittals.

3. LOW POWER PHYSICS TESTING RESULTS

Low Power Physics Testing was conducted at a power level of $\approx 10^{-2}$% power.

3.1 Critical Boron Concentrations

Critical Boron Measurements were taken at 2 Control Element Assembly (CEA) configurations, all rods out (ARO) and with CEA banks 2 thru 7 inserted (See Figure 2, CEA MAP).

The Critical Boron Concentration (CBC) measured with CEA group 7 at 138 steps was 1262 ppm. Adjusted to all rods out, the CBC is 1271 ppm. ie,

Measured	@ BOL-HZP-ARO	1271 ppm Boron
Predicted	@ BOL-HZP-ARO	1275 ppm Boron
	Δ =	4 ppm

Acceptance Criteria ± 85 ppm

Acceptance Criteria Met? Yes

The Critical Boron Concentration (CBC) measured with CEA groups 7 thru 3 inserted and group 2 @ 10 steps was 908 ppm. Adjusted to CEA groups 7-2 inserted, the CBC is 907 ppm Boron. ie,

Measured CBC BOL-HZP-2-7 CEA	909 ppm
Predicted CBC BOL-HZP-2-7 CEA	895 ppm
Δ =	14 ppm

Acceptance Criteria = ± 85 ppm Boron
Acceptance Criteria Met? Yes

3.2 Control Element Assembly (CEA) Symmetry Checks

Millstone 2 performs rod swaps among CEA's in a bank of CEA's to verify that unexpected flux tilts are not present from either a core misloading, CEA problem or other reactivity anomaly. Results of the CEA symmetry checks are expressed as the largest deviation (in cents of reactivity) of any CEA from the average CEA for that CEA bank.

Two sets of values are given, raw values and corrected values. The corrected values take into account the slight design tilt, since the core is not exactly 1/8 core symmetric. The raw values are those values corrected for temperature but which assume the core is 1/8 core symmetric.

The results were:

	Maximum Value of Raw Deviation (¢)	Maximum Value of Corrected Deviation (¢)
Bank 1 CEA's	1.14¢	.56¢
Bank 3 CEA's	.73¢	.46¢
Bank A CEA's	1.14¢	.66¢
Bank B CEA's	1.01¢	.72¢

Acceptance Criteria ± 2.5¢

Acceptance Criteria Met? Yes

(Note B_{eff} = .608% ΔP)

3.3 Moderator Temperature Coefficients

Moderator Temperature Coefficients are measured at 2 critical CEA configurations. All rods out and with CEA banks 2-7 inserted.

All Rods Out Measurement

The measurement @ 528.1°F, CEA 7 @ 138 steps and a boron concentration of 1262 ppm was $+.447 \times 10^{-4}$ ΔP/°F.

Converting this measurement to its most positive value (All Rods Out) increases the MTC to $+.455 \times 10^{-4}$ ΔP/°F.

Measured value of MTC @ 528.1°F BOL-HZP/ARO $+.455 \times 10^{-4}$ ΔP/°F

Technical Specification MTC Limit/Must be no more positive than $+.50 \times 10^{-4}$ ΔP/°F

$$\Delta = \frac{+.50 \times 10^{-4} \text{ ΔP/°F}}{.045 \times 10^{-4} \text{ ΔP/°F}}$$

Acceptance Criteria Met? Yes

To compare the measurement to the prediction yields:

MTC measured value at 532°F, 1275 ppm Boron is: $-.43 \times 10^{-4}$ ΔP/°F

MTC predicted value at 532°F, 1275 ppm Boron is: $-.53 \times 10^{-4}$ ΔP/°F

$$\Delta = \frac{-.53 \times 10^{-4} \text{ ΔP/°F}}{.1 \times 10^{-4} \text{ ΔP/°F}}$$

Acceptance Criteria is ± $.3 \times 10^{-4}$ ΔP/°F

Acceptance Criteria Met? Yes

CEA 2-7 Inserted Measurement

The MTC measurement with CEA banks 7 thru 3 inserted & CEA bank 2 @ 10 steps, temperature = 527.6°F & a boron concentration 908 ppm was $-.39 \times 10^{-4}$ ΔP/°F. Adjusted to the vendor conditions @ Boron Concentration of 895 ppm and an average temperature of 532°F given a value of $-.44 \times 10^{-4}$ ΔP/°F. Therefore:

Predicted MTC @ 532°F, 895 ppm BOL/2-7 inserted CEA	$-.31 \times 10^{-4}$ ΔP/°F
Measured MTC @ 532°F, 895 ppm BOL/2-7 inserted CEA	$-.44 \times 10^{-4}$ ΔP/°F
Δ =	$.13 \times 10^{-4}$ ΔP/°F

Acceptance Criteria = $\pm.3 \times 10^{-4}$ ΔP/°F

Acceptance Criteria Met? Yes

3.4 Control Element Assembly Reactivity Worths

Reactivity worth measurements were performed twice on CEA banks 2 thru 7. All measurements were taken with each CEA bank moving alone with no overlap from other CEA banks.

RESULTS OF THE MEASUREMENTS WERE:

CEA BANK	MEASUREMENT	PREDICTION	(M-P/P) DELTA	% DIFFERENCE
7	.615% ΔP	.655% ΔP	-.040	- 6.1%
6	.297	.328	-.031	- 9.5%
5	.325	.276	+.049	-17.8%
4	.910	1.080	-.170	-15.7%
3	.612	.614	.002	- .3%
2	1.011	1.108	-.097	- 8.8%
2-7	3.77% ΔP	4.061% ΔP	-.291% ΔP	-7.2%

Acceptance Criteria on Total Worth CEA Groups 2-7 inserted is ± 10%

Acceptance Criteria Met? Yes

Acceptance Criteria on individual CEA banks is either ± 15% or within ± .1% ΔP.

Acceptance Criteria Met? Yes, on all banks except on Bank 4. Bank 4 does not meet acceptance criteria. It is slightly in excess of ± 15%.

Due to the disagreements found in the CEA worths, in particular CEA group 4, Westinghouse was consulted while Low Power Testing was in progress. Westinghouse reviewed CEA group 4 being slightly out of acceptance criteria to determine whether the safety analysis was affected. They concluded that the measured results of CEA group 4 worth was acceptable. This evaluation included shutdown margin, trip reactivity and power peaking factors.

3.5 Hot Rod Drops

Hot Rod Drops were performed on all 61 CEA drive mechanisms. The drop times from 0 to 90% insertion ranged from 2.02 to 2.31 seconds for all CEA's.

Acceptance Criteria: All CEA's must drop from 0 to 90% insertion in less than 2.75 seconds, per technical specifications.

Acceptance Criteria Met? Yes

4. POWER ASCENSION TESTING

4.1 Power Peaking, Linear Heat Rate and Incore Tilt Measurements were:

Power Level	Fxy^T	Fr^T	Max. Linear Heat Rate	Incore Tilt
50% Power	1.682	1.532	7.13 kws/ft	.008
83%	1.661	1.525	11.30 kws/ft	.008
100%	1.670	1.519	13.24 kws/ft	.006

Corresponding Technical Specification Limits Are:

Power Level	Fxy^T	Fr^T	Max. Linear Heat Rate	Incore Tilt
50%	1.836	1.705	15.6 kws/ft	.02
83%	1.785	1.605	15.6	.02
100%	1.719	1.565	15.6	.02

Techanical Specification Limits Met? Yes

NOTE: A Technical Specification change was processed for F_{xy}^T limits prior to plant power increasing above 83% power.

4.2 Boron Measurements

At 50% power, 50 MWD/MT, ARO, Equilibrium Xenon, the measured Boron Concentration was 1005 ppm.

Measured 50% Power, ARO, EQ Xe, 50 MWD/MT	1005 ppm Boron
Predicted 50% Power, ARO, EQ Xe, 50 MWD/MT	1019 ppm Boron
Δ =	14 ppm

Acceptance Criteria = ± 85 ppm Boron
Acceptance Criteria Met? Yes

At 100% power, 400 MWD/MT, ARO, Equilibium Xenon, the measured Boron Concentration was 880 ppm.

Measured 100% Power, ARO, EQ Xe, 400 MWD/MT	880 ppm Boron
Predicted 100% Power, ARO, EQ Xe, 400 MWD/MT	884 ppm Boron
Δ =	4 ppm

Acceptance Criteria = ± 85 ppm Boron
Acceptance Criteria Met? Yes

4.3 Moderator Temperature Coefficient @ 83% Power

The MTC measured at 83% power with CEA 7 at 150 steps, T_{ave} = 561°F, 915 ppm Boron was $-.14 \times 10^{-4}$ ΔP/°F. Adjusted to the predicted MTC conditions given;

Predicted MTC @ 563°F, 915 ppm, 83% power is	$-.22 \times 10^{-4}$ ΔP/°F
Measured MTC @ 563°F, 915 ppm, 83% power is	$-.17 \times 10^{-4}$ ΔP/°F
Δ =	$.05 \times 10^{-4}$ ΔP/°F

Acceptance Criteria is $\pm .3 \times 10^{-4}$ ΔP/°F

Acceptance Criteria Met? Yes

4.4 Doppler Only Power Coefficient

The doppler only power coefficient was measured at 81.5% power, T_{ave} = 566.5 and Boron = 915 ppm. The measured value at these conditions was $-.89 \times 10^{-4}$ ΔP/% Power.

Adjusting the measured value to the conditions of the prediction yields:

Measured Value	$-.89 \times 10^{-4}$ ΔP/% power
Predicted Value	$-.92 \times 10^{-4}$ ΔP/% power
Δ =	$.03 \times 10^{-4}$ ΔP/% power

Acceptance Criteria $\pm .3 \times 10^{-4}$ ΔP/% power

Acceptance Criteria Met? Yes

4.5 RCS Flow @ 100% Power

The measured RCS flow at 100% power was 378,800 gpm.

Acceptance Criteria is > 350,000 gpm

Acceptance Criteria Met? Yes

4.6 Power Distributions

A Power Distribution Map at 100% power, 500 MWD/MT is shown in Figure 3. This map shows the agreement between measured and predicted Relative Power Density for each assembly in an average 1/8 core octant. While acceptable, it does show an unexpected higher power core center region with corresponding lower power peripheral fuel assemblies.

Acceptance Criteria: All locations with ± 10%
Acceptance Criteria Met? Yes

4.7 Shape Annealing Factor Test

In response to the thermal shield removal, a Shape Annealing Factor Test was performed at 50% power. This test was designed to ensure that accurate constants were being used for Axial Shape Index (ASI) inputs to the Reactor Protection System.

Results of the test showed essentially no change in Shape Annealing Factor since they were measured during initial plant startup. The new Shape Annealing Factors were input to the Reactor Protection System. The table below shows the results for the 4 safety channels.

	Cycle 1 S.A.F.	Cycle 6 S.A.F.
Channel A	2.195	2.267
Channel B	1.738	1.783
Channel C	2.142	2.116
Channel D	1.851	1.870

4.8 Reactor Coolant System Chemistry

Reactor Coolant System (RCS) Chemistry up to 83% power testing showed low activity levels in the RCS. Iodine 131 values were 10^{-3} μCi/ml or less up to and including the 83% power plateau.

Within a few days of reaching 100% power, RCS activity levels experienced significant increases in total activity as well as I-131 increases. After several weeks of operation, Iodine-131 levels as of this writing were stabilizing around a value of about .07 μCi/ml Iodine-131. This is indicative of a small number of failed fuel pins.

5. REFERENCES

5.1 Inservice Test T83-42, Low Power Physics Testing for Cycle 6

5.2 Inservice Test T83-43, Power Ascension Testing for Cycle 6

5.3 Westinghouse Nuclear Design Report - Cycle 6

JP:dlp

FIGURE 1

APPROVAL: Stephen E. Scace — REACTOR ENGINEER — DATE: 2-14-75

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Y							H37		H51		H26			H60							
X						H39	H46	H64	F58 31		•H14	F35 40		H72		H29	H52				
W					H36	A013 14	H87	A068 25	H22		F02 72	H04		A055 47		H83	F04 55	H57			
V				H67	H17 67	G71	A048 18	H12	F70 30		G02	F40 39		H24		A069 51	G45	H11 69		H56	
T			H44	F14 6	G72	G50 P	G11	F44 24	G12		G38 P	G18		F36 46		G01	G37 P	G69		A014 63	H32
S			H45	H75	A039 10	G20	F74 17	H85	F64		G59	F65		H74		B028 50	G21	A032 59		H81 •	H58
R			H62	A056 5	H20	F69 13	H84	F06 23	G36		F45 34	G31		F03 45		H88	F48 54	H16		A054 62	H35	
P		H43																				H33
N			F56 2	H19	F68 9	G08	F53	G65	F05 29		G42	F20 38		G48		F26	G13	F29 58		H18	F52 65	
M		H27																				H42
L			H06	F17 70	G19	G61 P	G52	F47 22	G28		F72 33	G44		F27 44		G49	G40 P	G17		F15 73	H09	
K		H66																				H50
J			F49 1	H03	F55 8	G03	F51	G34	F09 28		G25	F10 37		G54		F31	G16	F30 57		H08	F63 64	
H		H30																				H71
G			H25	A058 4	H21	F34 12	H79	F18 21	G53		F25 32	G46		F16 43		H82	F71 53	H10		A005 61	H40	
F			H68	H78 •	A041 7	G23	F19 16	H86	F54		G58	F57		H76		F13 49	G06	A015 56		H80	H63	
E			H65	A060 3	G29	G64 P	G15	F28 20	G14		G30 P	G07		F46 42		G09	G39 P	G43		F11 60	H34	
D				H41	H01 66	G27	A021 15	H07	F61 27		G22	F62 36		H02		A008 48	G70	H05 68		H69		
C					H31	F07 11	H73	A037 19	H15		F01 71	H13		A007 41		H77	A061 52	H59				
B						H53	H54	H47	F67 26		H23 •	F59 35		H55		H48	H70					
A								H38	H49		H28	H61										

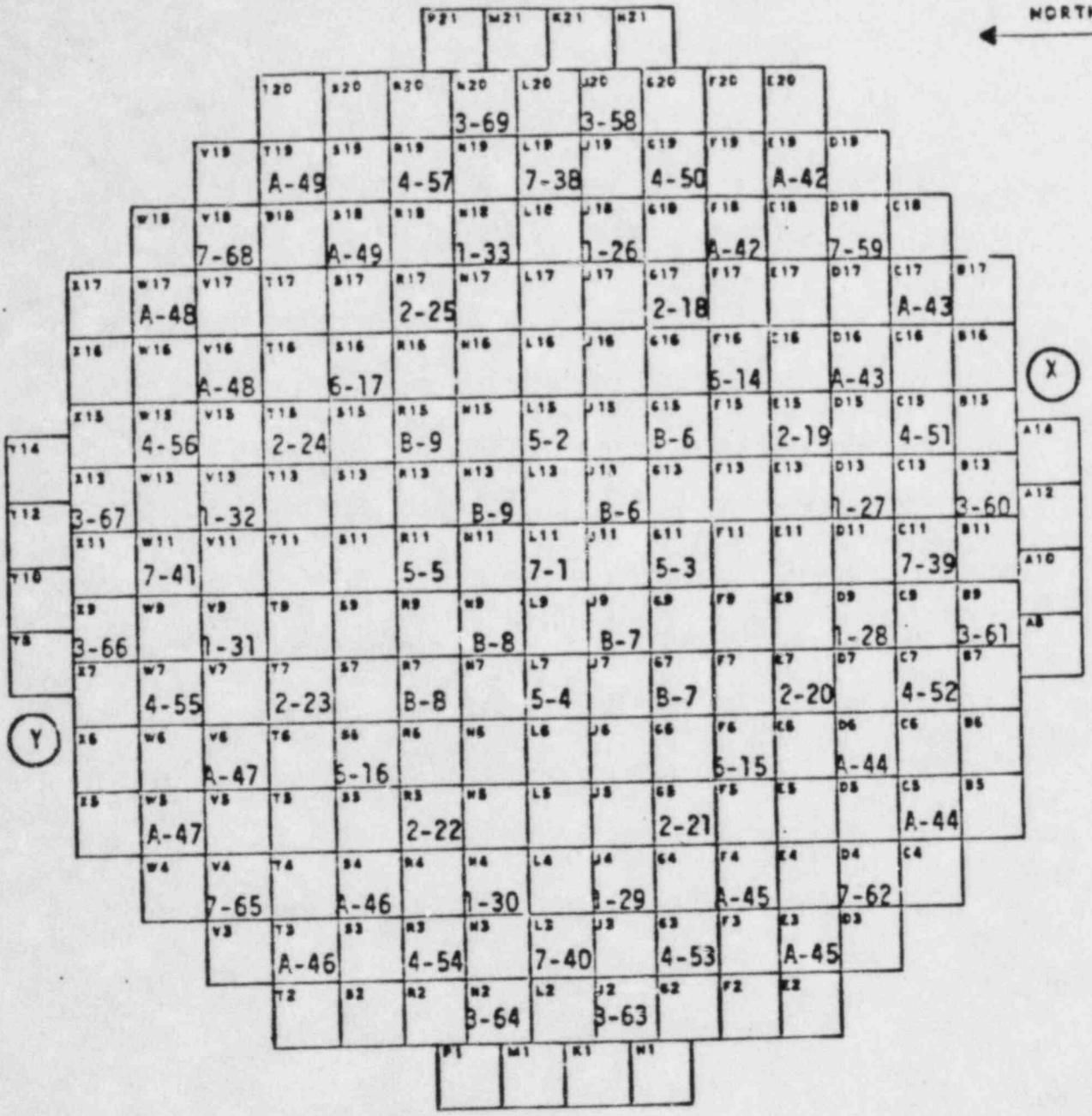
Cycle 6
CORE MAP

NORTH

Source locations		
1	X 11	NW
2	B 11	SW
3	F 3	SW
4	S 19	SE

2 - RE - A 4
REV. 0 2-14-74

FIGURE 2



REACTOR CORE

CEA AND EXCORE DETECTOR LOCATIONS

FIGURE 3
RADIAL POWER DISTRIBUTION MAP

100% Power, 500 MWD/MT Burnup
All Rods Out, EQ, Xenon
Millstone 2 Cycle 6

TOP - Predicted Relative Power Density
MIDDLE - Measured Relative Power Density
BOTTOM - % Difference (MEAS-PRED)/PRED

				1.113 1.096 -1.5%	.687 .685 -.3%		
			1.165 1.126 -3.3%	1.183 1.175 -.7%	.671 .683 +1.8%	.569 .576 +1.2%	
		.899 .903 +.4%	.975 .912 -6.5%	.835 .830 -.6%	1.140 1.125 -1.3%	.891 .867 -2.7%	
	.937 .980 +4.6%	1.241 1.263 +1.8%	1.035 1.037 +.2%	1.244 1.233 -.9%	.871 .880 +1.0%	1.069 1.046 -2.2%	.657 .638 -2.9%
.929 .984 +5.9%	1.165 1.202 +3.2%	1.056 1.058 +.2%	1.056 1.037 -1.8%	1.084 1.086 -.2%	1.245 1.238 -.6%	.945 .958 +1.4%	.880 .861 -2.2%
1.099 1.170 +6.5%	1.220 1.288 +5.6%	1.090 1.140 +4.6%	1.175 1.213 +3.2%	1.258 1.251 -.6%	1.040 1.012 -2.7%	.937 .949 +1.3%	1.198 1.191 -.6%