

Docket No. 50-336

MILLSTONE NUCLEAR POWER STATION

UNIT NO. 2

START-UP TEST REPORT

CYCLE 7

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1. SUMMARY

Low Power Physics Testing and Power Ascension Testing for Millstone 2 Cycle 7 identified no unusual situations or anomalies. All parameters measured were within their acceptance criteria and Technical Specification limits. One parameter is noteworthy of mention.

The most positive measured MTC at zero power was  $+0.553 \times 10^{-4} \Delta K/K/^{\circ}F$ , while the Technical Specification limit is  $+0.50 \times 10^{-4} \Delta K/K/^{\circ}F$ . While the measured value was in excess of the MTC limit, this condition was permitted by a Special Test Exception which allows the limit to be suspended in order to perform the MTC measurement. Administrative restrictions were established on CEA withdrawal and RCS average temperature in order to ensure that the MTC would be within the Technical Specification limits. This is a typical situation at initial startup conditions, given the large boron concentrations required following refueling.

2. INTRODUCTION

The Millstone 2, Cycle 7 fuel loading was completed on June 1, 1985. The attached core map (Figure 1) shows the final core configuration. Subsequent operation/testing milestones were completed as follows:

Initial Criticality	June 30, 1985
Low Power Physics Testing Completed	July 2, 1985
Main Turbine On-Line	July 4, 1985
50% Power Testing Completed	July 7, 1985
96% Power Testing Completed	July 11, 1985
100% Power Testing Completed	July 26, 1985

Cycle 7 operation is with 213 Westinghouse manufactured fuel assemblies and 4 Combustion Engineering manufactured fuel assemblies. The Safety Analysis is supplied by Westinghouse.

3. LOW POWER PHYSICS TESTING RESULTS

Low Power Physics Testing was performed at a power level of  $< 5 \times 10^{-2}\%$  power to avoid heat addition from the nuclear fuel.

3.1 Critical Boron Concentrations

Critical Boron Measurements were taken at two different Control Element Assembly (CEA) configurations, at All Rods Out (ARO) and with CEA Groups 7 through 2 inserted. See Figure 2, CEA and Excore Detector locations.

The Critical Boron Concentration (CBC) measured with CEA Group 7 at 145 steps was 1297 ppm. Adjusted to All Rods Out, the CBC is 1304 ppm. Therefore,

$$\begin{aligned}\text{Measured CBC @ BOL-HZP-ARO} &= 1304 \text{ ppm Boron} \\ \text{Predicted CBC @ BOL-HZP-ARO} &= \underline{1331 \text{ ppm}} \\ \Delta &= 27 \text{ ppm}\end{aligned}$$

The Acceptance Criteria is  $\pm 85$  ppm.

Acceptance Criteria met? Yes

The Critical Boron Concentration (CBC) measured with CEA Groups 7 through 3 inserted and Group 2 @ 18 steps was 927 ppm. Adjusted to CEA Groups 7-2 inserted, the CBC is 918 ppm. Therefore,

$$\begin{aligned}\text{Measured CBC @ BOL-HZP 2-7 CEA} &= 918 \text{ ppm Boron} \\ \text{Predicted CBC @ BOL-HZP 2-7 CEA} &= \underline{922 \text{ ppm}} \\ \Delta &= 4 \text{ ppm}\end{aligned}$$

The Acceptance Criteria is  $\pm 85$  ppm

Acceptance Criteria met? Yes

### 3.2 Control Element Assembly (CEA) Symmetry Checks

Millstone 2 performs rod swaps among all CEA's in a group of CEA's to verify that no serious tilts are present from either a core misloading, CEA problem, or other reactivity anomalies. 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 group.

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 assume the core is 1/8 core symmetric.

The results were:

	Maximum Value of Raw Deviation (¢)	Maximum Value of Corrected Deviation (¢)
Group 1 CEA's	0.99¢	0.56¢
Group 3 CEA's	1.11¢	0.83¢
Group A CEA's	0.93¢	0.43¢
Group B CEA's	0.61¢	0.47¢

The Acceptance Criteria is  $\pm 2.5¢$ .

Acceptance Criteria met? Yes

NOTE -  $\beta_{eff} = 0.6027\% \Delta K/K$

### 3.3 Moderator Temperature Coefficients

The Moderator Temperature Coefficients (MTC) were measured at two different CEA configurations, at All Rods Out and with CEA Groups 7 through 2 inserted.

#### All Rods Out MTC Measurement

The measured MTC value with CEA Group 7 at 145 steps, an average RCS temperature of 526.7°F, and an RCS boron concentration of 1297 ppm was  $+0.532 \times 10^{-4} \Delta K/K/^{\circ}F$ .

Comparing the adjusted MTC value to the predicted value yields:

$$\begin{aligned} \text{Adjusted, measured MTC @} \\ 532^{\circ}F, 1331 \text{ ppm, BOL, ARO} &= +0.553 \times 10^{-4} \Delta K/K/^{\circ}F \\ \text{Predicted MTC @ } 532^{\circ}F, \\ 1331 \text{ ppm, BOL, ARO} &= \frac{+0.544 \times 10^{-4} \Delta K/K/^{\circ}F}{\Delta = 0.009 \times 10^{-4} \Delta K/K/^{\circ}F} \end{aligned}$$

The Acceptance Criteria is  $\pm 0.3 \times 10^{-4} \Delta K/K/^{\circ}F$ .

Acceptance Criteria met? Yes

In addition to comparing the measured MTC value to the predicted value, it is also required to verify that the Technical Specification MTC limits are satisfied.

The Millstone 2 Technical Specification MTC limit states that the MTC shall be less positive than  $+0.50 \times 10^{-4} \Delta K/K/^{\circ}F$  whenever thermal power is less than or equal to 70% of rated thermal power.

While the measured MTC value exceeds the Technical Specification limit, this is permitted by a Special Test Exception which allows the MTC limit to be suspended in order to allow the MTC measurement to be performed.

Since the measure MTC value was in excess of the Technical Specification limit, it was necessary to establish administrative restrictions on CEA withdrawal and RCS average

temperature in order to ensure that the MTC would be less positive than  $+0.50 \times 10^{-4} \Delta K/K/^{\circ}F$ . These restrictions were only required until the critical boron concentration was reduced by fuel depletion.

#### CEA Groups 7-2 Inserted MTC Measurement

The measured MTC value with CEA Groups 7 through 3 inserted and CEA Group 2 at 20 steps, at an average RCS temperature of  $527.4^{\circ}F$ , and an RCS boron concentration of 927 ppm was  $-0.422 \times 10^{-4} \Delta K/K/^{\circ}F$ .

Adjusting this measured value to the prediction conditions of  $532^{\circ}F$  and 922 ppm yields an MTC value of  $-0.444 \times 10^{-4} \Delta K/K/^{\circ}F$ .

Comparing the adjusted MTC value to the predicted value yields:

Adjusted, measured MTC @

$532^{\circ}F$ , 922 ppm, BOL, CEA 7-2 Inserted  $= -0.444 \times 10^{-4} \Delta K/K/^{\circ}F$

Predicted MTC @  $532^{\circ}F$ ,

922 ppm, BOL, CEA 7-2 Inserted  $= \frac{-0.256 \times 10^{-4} \Delta K/K/^{\circ}F}{\Delta}$

$\Delta = 0.188 \times 10^{-4} \Delta K/K/^{\circ}F$

The Acceptance Criteria is  $\pm 0.3 \times 10^{-4} \Delta K/K/^{\circ}F$ .

Acceptance Criteria met? Yes

### 3.4 Control Element Assembly Reactivity Worths

Reactivity worth measurements were performed twice on CEA Groups 7 through 2. The first measurement involved measuring the reactivity worth of each CEA group individually. The second measurement involved measuring the reactivity worth of CEA Groups 2 and 3 individually, and CEA Groups 4 through 7 in their normal overlap mode of operation.

The results of the measurements were:

Individual CEA Group Measurements

CEA Group	Measured Worths(% $\Delta$ K/K)	Predicted Worths(% $\Delta$ K/K)	Delta (M-P)	% Difference [(M-P)/P]
7	0.752	0.727	0.025	3.4%
6	0.366	0.393	-0.027	-6.9%
5	0.225	0.267	-0.042	-15.7%
4	1.217	1.189	0.028	2.3%
3	0.573	0.503	0.070	13.9%
<u>2</u>	<u>1.240</u>	<u>1.168</u>	<u>0.072</u>	<u>6.2%</u>
Total	4.373	4.247	0.126	3.0%

CEA Overlap Measurements

CEA Group	Measured Worths(% $\Delta$ K/K)	Predicted Worths(% $\Delta$ K/K)	Delta (M-P)	% Difference [(M-P)/P]
2	1.251	1.168	0.083	7.1%
3	0.569	0.503	0.066	13.1%
<u>4-7</u>	<u>2.582</u>	<u>2.576</u>	<u>0.006</u>	<u>0.2%</u>
Total	4.402	4.247	0.155	3.6%

The Acceptance Criteria for the Total Worth of CEA Groups 7 through 2 inserted is  $\pm 10\%$ .

Acceptance Criteria met? Yes

The Acceptance Criteria for any individual CEA Group is either  $\pm 0.1\% \Delta K/K$  or  $\pm 15\%$  difference.

Acceptance Criteria met on all CEA Groups? Yes



### 3.5 Hot Rod Drops

Hot Rod Drops were performed on all 61 CEA drive mechanisms. The drop times from 0 to 100% insertion ranged from 2.19 to 2.45 seconds.

The Acceptance Criteria, per Millstone 2 Technical Specifications, is that all CEA's must drop from 0 to 90% insertion in less than 2.75 seconds.

Acceptance Criteria met? Yes

## 4. POWER ASCENSION TESTING RESULTS

### 4.1 Power Peaking, Linear Heat Rate and Tilt Measurements

The measurements of these parameters were:

<u>Power Level</u>	<u>T</u> <u>Fxy</u>	<u>T</u> <u>Fr</u>	<u>Max. Linear Heat Rate</u>	<u>Incore Tilt</u>
50%	1.570	1.473	6.91 KW/ft	0.002
96%	1.528	1.461	13.01 KW/ft	0.003
100%	1.521	1.466	13.12 KW/ft	0.003

The corresponding Technical Specification limits are:

<u>Power Level</u>	<u>T</u> <u>Fxy</u>	<u>T</u> <u>Fr</u>	<u>Max. Linear Heat Rate</u>	<u>Incore Tilt</u>
50%	1.836	1.705	15.6 KW/ft	0.02
96%	1.719	1.570	15.6 KW/ft	0.02
100%	1.719	1.565	15.6 KW/ft	0.02

Technical Specification limits met? Yes

### 4.2 Boron Measurements

At 50% power, 30 MWD/MTU, ARO and Equilibrium Xenon, the measured boron concentration was 1061 ppm.

Measured boron concentration 50% power,  
30 MWD/MTU, ARO, Eq. Xenon = 1061 ppm  
Predicted boron concentration 50% power,  
50 MWD/MTU, ARO, Eq. Xenon = 1071 ppm  
 $\Delta = 10$  ppm

The Acceptance Criteria is  $\pm 85$  ppm Boron.

Acceptance Criteria met? Yes

At 100% power, 275 MWD/MTU, ARO and Equilibrium Xenon, the measured boron concentration was 948 ppm.

Measured boron concentration 100% power  
275 MWD/MTU, ARO, Eq. Xenon = 948 ppm  
Predicted boron concentration 100% power  
275 MWD/MTU, ARO, Eq. Xenon = 951 ppm  
 $\Delta = 3$  ppm

The Acceptance Criteria is  $\pm 85$  ppm Boron.

Acceptance Criteria met? Yes

#### 4.3 Moderator Temperature Coefficient at 96% Power

The measured MTC value at 96% power, with CEA Group 7 at 150 steps, at an average RCS temperature of 567.25°F, and an RCS boron concentration of 948 ppm was  $-0.257 \times 10^{-4} \Delta K/K/^{\circ}F$ .

Adjusting this measured value to the prediction conditions of 96%, 567.2°F and 966 ppm yields an MTC value of  $-0.231 \times 10^{-4} \Delta K/K/^{\circ}F$ .

Comparing the adjusted MTC value to the predicted value yields:

Adjusted, measured MTC @ 96%,

966 ppm boron, and  $T_{ave} = 567.2^{\circ}\text{F} = -0.231 \times 10^{-4} \Delta\text{K/K/}^{\circ}\text{F}$

Predicted MTC @ 96%,

966 ppm boron, and  $T_{ave} = 567.2^{\circ}\text{F} = \frac{-0.215 \times 10^{-4} \Delta\text{K/K/}^{\circ}\text{F}}$

$$\Delta = 0.016 \times 10^{-4} \Delta\text{K/K/}^{\circ}\text{F}$$

The Acceptance Criteria is  $\pm 0.3 \times 10^{-4} \Delta\text{K/K/}^{\circ}\text{F}$ .

Acceptance Criteria met? Yes

#### 4.4 Doppler Only Power Coefficient

The measured Doppler only power coefficient at 94.1% power, an average RCS temperature of  $571.0^{\circ}\text{F}$ , and an RCS boron concentration of 948 ppm was  $-0.943 \times 10^{-4} \Delta\text{K/K/\% power}$ .

Adjusting this measured value to the prediction conditions yields a Doppler only power coefficient value of  $-0.947 \times 10^{-4} \Delta\text{K/K/\% power}$ .

Comparing the adjusted value to the predicted value yields:

Adjusted, measured value @

93% power, 966 ppm and  $572^{\circ}\text{F} = -0.947 \times 10^{-4} \Delta\text{K/K/\% Power}$

Predicted value @ 93% power

966 ppm and  $572^{\circ}\text{F} = \frac{-0.918 \times 10^{-4} \Delta\text{K/K/\% Power}}$

$$\Delta = 0.029 \times 10^{-4} \Delta\text{K/K/\% Power}$$

The Acceptance Criteria is  $\pm 0.3 \times 10^{-4} \Delta\text{K/K/\% Power}$ .

Acceptance Criteria met? Yes

#### 4.5 RCS Flow at 100% Power

The measured RCS flow at 100% power was 375,300 GPM.

The Acceptance Criteria is  $>350,000 \text{ GPM}$ .

Acceptance Criteria met? Yes

#### 4.6 Power Distributions

Power Distribution Maps are shown for 50% and 100% power conditions in Figures 3 and 4. The agreement between the measurements and the predictions is good.

The Acceptance Criteria is that all locations are within  $\pm 10\%$  of the predicted values.

Acceptance Criteria met? Yes

#### 4.7 Reactor Coolant System Radiochemistry

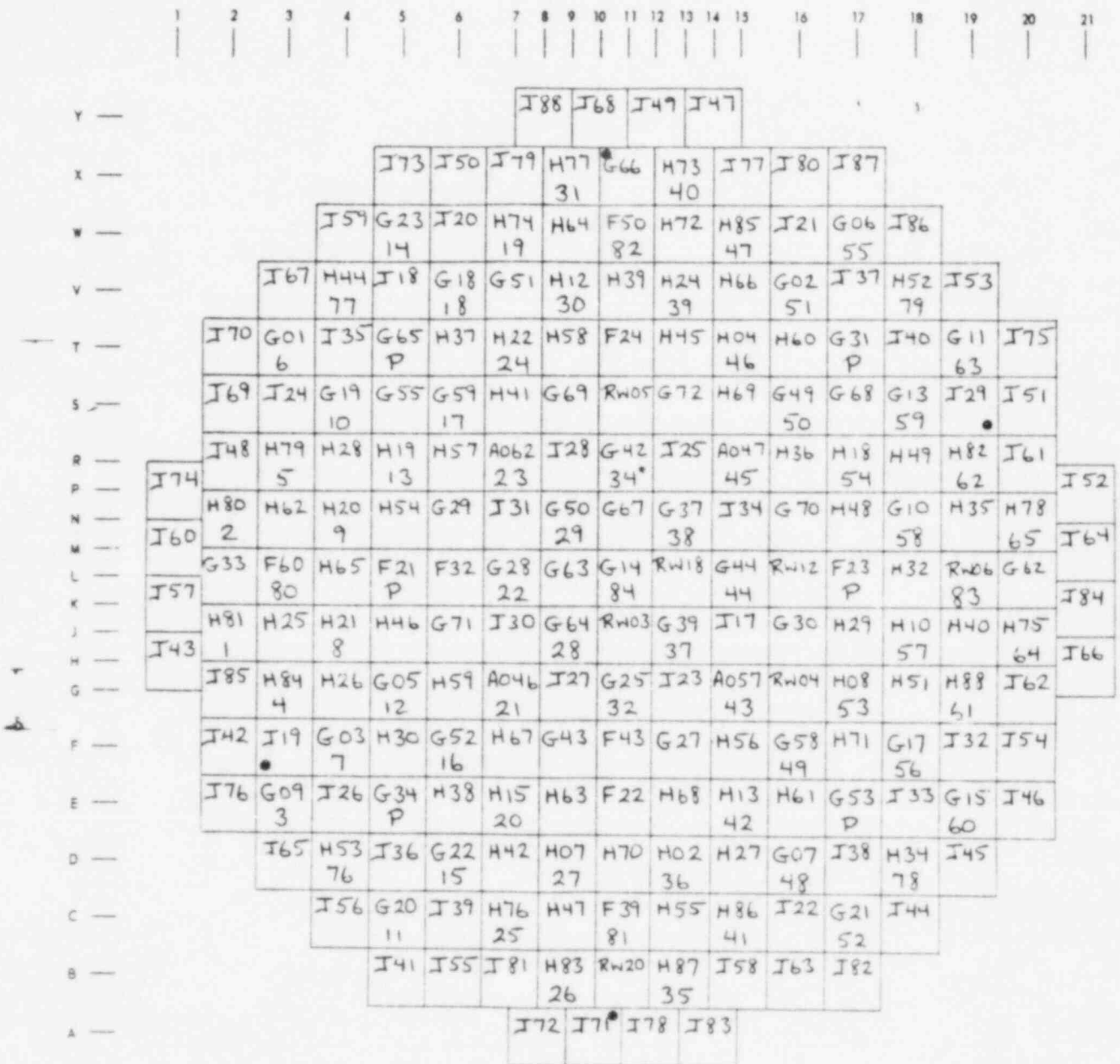
Reactor Coolant System (RCS) radiochemistry analyses during power ascension testing and subsequent power operation have showed low activity levels in the RCS. The Iodine - 131 values are typically  $2 \times 10^{-3}$   $\mu\text{Ci/ml}$  or less as of this writing, which indicates that the fuel integrity is sound. This is a factor of  $\approx 30$  lower than the previous 2 operating fuel cycles. With the core currently at  $\approx 1000$  MWD/MTU burnup, no iodine spiking at all has been observed, further substantiating that no fuel failures are present.

### 5. REFERENCES

- 5.1 In-Service Test T85-18, Initial Criticality/Low Power Physics Test - Cycle 7.
- 5.2 In-Service Test T85-19, Power Ascension Test - Cycle 7.
- 5.3 Westinghouse Nuclear Design Report - Cycle 7.

RB:dlp

FIGURE 1



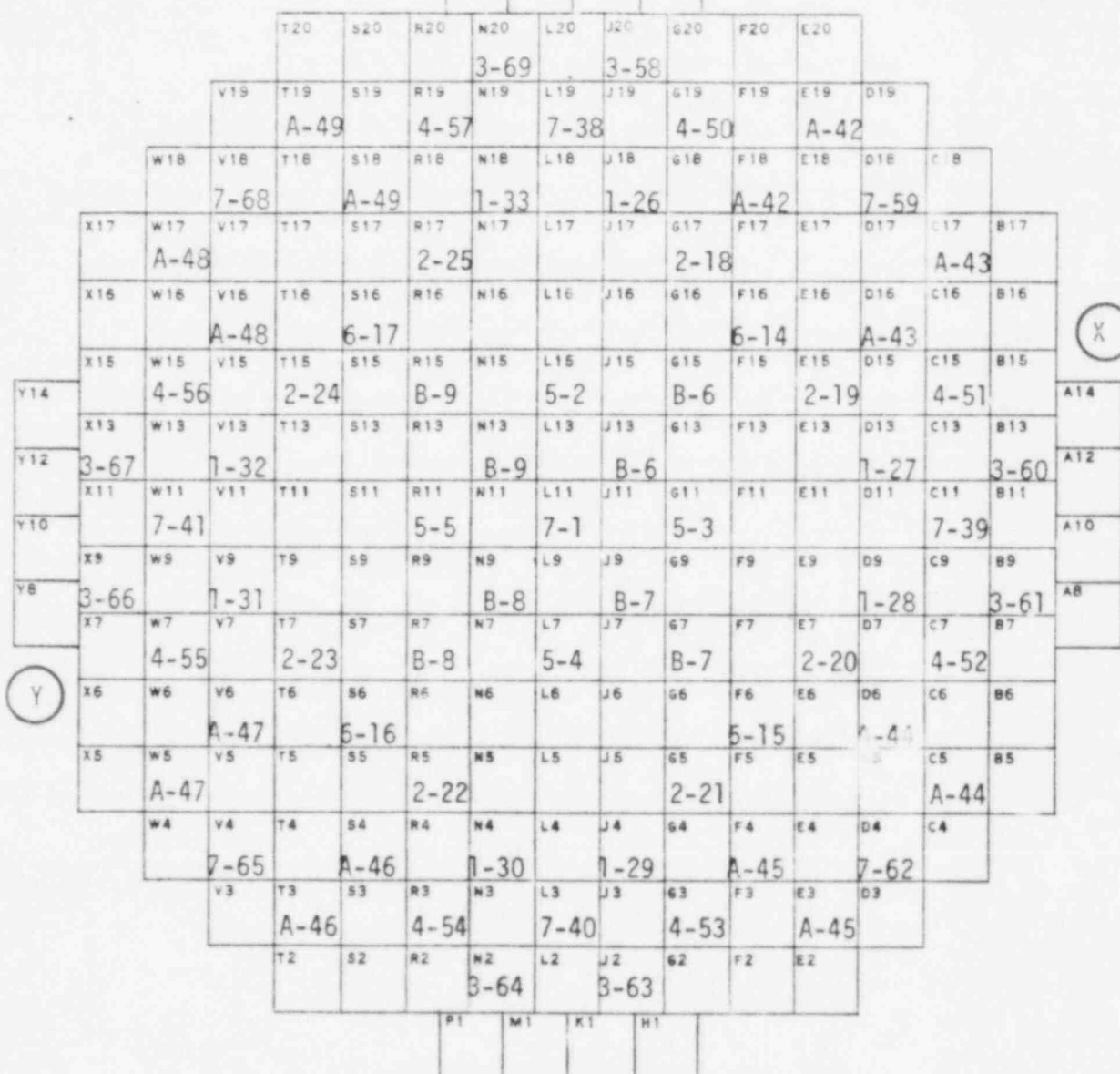
CYCLE 7  
CORE MAP

\* CEA 34 rotated CW 90°, S/N in NE web

SOURCE LOCATIONS

Source	Core location	Guide tube
S3	F-3	SW
S4	S-19	SE
S5	X-11	NW
S6	A-10	NE

P21	M21	K21	H21
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## CEA AND EXCORE DETECTOR LOCATIONS

## 50% POWER-BOC 7

XXX	Predicted RPD, 50% power, ARO, Equilibrium Xenon, 50 MWD/MTU		
YYY	INCA Measured RPD, 50% power, ARO, Equilibrium Xenon, 50 MWD/MTU		
ZZZ	% Difference [(M-P)/P]	33	34

[illegible]

FIGURE 3

# RELATIVE POWER DENSITIES

100% POWER-BOC 7

XXX

Predicted RPD, 100% power, ARO, Equilibrium Xenon, 150 MWD/MTU

YYY

INCA Measured RPD, 100% power, ARO, Equilibrium Xenon, 500 MWD/MTU

ZZZ

% Difference [(M-P)/P]

								33		34																	
								1.03 1.060 +2.9%		0.62 0.652 +5.2%																	
								29		30		31		32													
								1.03 1.042 +1.2%		1.18 1.172 -0.7%		0.68 0.719 +5.7%		0.54 0.567 +5.0%													
								24		25		26		27		28											
								0.99 0.988 -0.2%		1.19 1.191 0%		0.89 0.902 +1.3%		1.17 1.171 0%		0.90 0.920 +2.2%											
								18		19		20		21		22		23									
								0.88 0.878 -0.2%		1.20 1.179 -1.7%		1.06 1.047 -1.2%		1.18 1.184 +0.3%		1.08 1.073 -0.6%		1.11 1.110 0%									
								10		11		12		13		14		15		16		17					
								0.96 0.960 0%		1.24 1.221 -1.5%		1.01 0.963 -4.6%		1.14 1.129 -1.0%		1.07 1.056 -1.3%		1.16 1.118 -3.6%		1.00 1.002 +0.2%		0.66 0.686 +3.9%					
								1		2		3		4		5		6		7		8					
								0.76 0.749 -1.4%		1.01 0.994 -1.6%		1.01 1.003 -0.7%		0.97 0.938 -3.2%		0.85 0.850 0%		1.23 1.226 -0.3%		1.03 1.025 -0.5%		1.16 1.176 +1.4%					
																						9					
																						0.87 0.875 +0.6%					

FIGURE 4