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Kewaunee Nuclear Power Plant
Cycle 20 Startup Report

In accordance with our practice of reporting the results of physics tests, enclosed is a copy of the Kewaunee Nuclear Power Plant Cycle 20 Startup Report.

Sincerely,

C. A. Schrock
Manager - Nuclear Engineering

BJD/san

cc - US NRC - Region III - w/o attach.
US NRC Resident Inspector - w/o attach.

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KEWAUNEE NUCLEAR POWER PLANT

CYCLE 20
STARTUP REPORT
JULY 1994

WISCONSIN PUBLIC SERVICE CORPORATION
WISCONSIN POWER & LIGHT COMPANY
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KEWAUNEE NUCLEAR POWER PLANT

STARTUP REPORT

CYCLE 20

JULY 1994

WISCONSIN PUBLIC SERVICE CORPORATION

GREEN BAY, WISCONSIN

KEWAUNEE NUCLEAR POWER PLANT

STARTUP REPORT

CYCLE 20

JULY 1994

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Approved By:	[signature] Vice President-Power Supply & Engineering	Date:	8-9-94

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1.0 INTRODUCTION, SUMMARY, AND CONCLUSION

1.1 Introduction

This report presents the results of the physics tests performed during startup of Kewaunee Cycle 20. The core design and reload safety evaluation were performed by Wisconsin Public Service Corporation (1) using methods previously described in WPS topical reports (2,3). The results of the physics tests were compared to WPS analytical results to confirm calculated safety margins. The tests performed and reported herein satisfy the requirements of the Reactor Test Program (4).

During Cycle 19-20 refueling, 36 of the 121 fuel assemblies in the core were replaced with fresh fuel assemblies. Twelve are Siemens Power Corporation design (5), enriched to 3.5 weight percent U235, and twenty-four are Siemens Power Corporation design (5), enriched to 3.7 weight percent U235. The Cycle 20 core consists of the following regions of fuel:

Region	ID	Vendor	Initial U235 W/O	Number of Previous Duty Cycles	Number of Assemblies
13	M	SPC	3.4	3	1
18	T	SPC	3.5	2	4
18	T	SPC	3.4	3	8
18	T	SPC	3.5	3	8
20	W	SPC	3.4	2	28
21	X	SPC	3.4	1	32
21	X	WES	3.1	1	4
22	Z	SPC	3.5	0	12 (Feed)
22	Z	SPC	3.7	0	24 (Feed)

The core loading pattern, assembly identification, RCCA bank identification, instrument thimble I.D., thermocouple I.D., and burnable poison rod configurations for Cycle 20 are presented in Figure 1.1.

On May 6, 1994, at 1739 hours, initial criticality was achieved on the Cycle 20 core. The schedule of physics tests and measurements is outlined in Table 1.1.

1.2 Summary

RCCA measurements are shown in Section 2. All RCCA drop time measurements were within Technical Specification limits. RCCA bank worths were measured using the rod swap reactivity comparison technique previously described (4,6). The reactivity comparison was made to the reference bank, Bank C, which was measured using the dilution technique. All results were within the established acceptance criteria (4), and thereby demonstrated adequate shutdown margin.

Section 3 presents the boron endpoint and boron worth measurements. The endpoint measurements for ARO and Bank C In core configurations were within the acceptance criteria (4). The available boron letdown data covering the first month of reactor operation is also shown. The agreement between measurements and predictions meets the review and acceptance criteria (4).

Section 4 shows the results of the isothermal temperature coefficient measurements. The differences between measurements and predictions were within the acceptance criteria (4).

Power distributions were measured via flux maps using the INCORE code for beginning of cycle (BOC) core conditions covering power escalation to 100 percent full power equilibrium xenon. The results indicate compliance with Technical Specification limits (7) and are presented in Section 5. Section 6 discusses the various calibrations performed during the startup of Cycle 20.

1.3 Conclusion

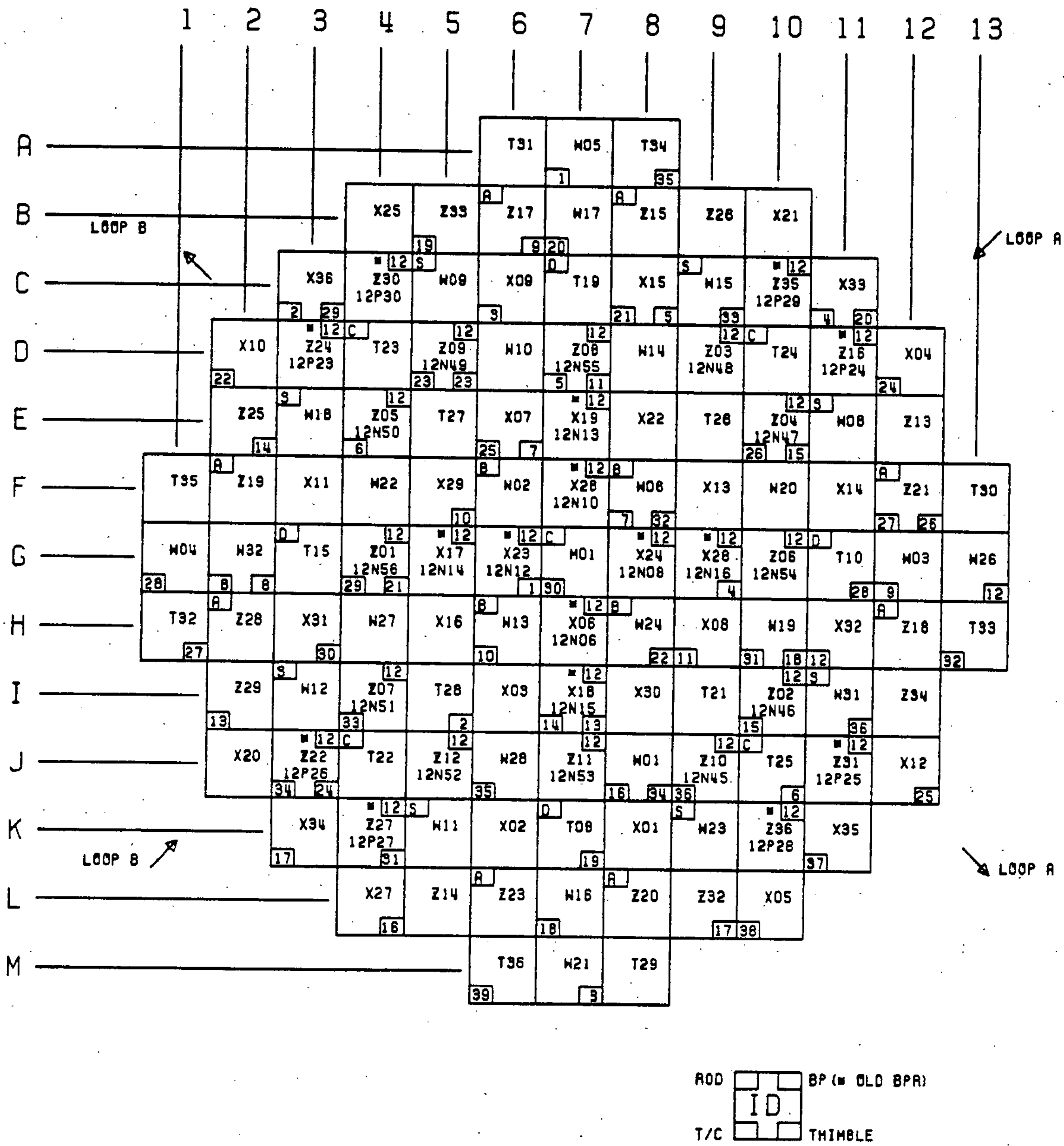
The startup testing of Kewaunee's Cycle 20 core verified that the reactor core has been properly loaded and the core characteristics satisfy the Technical Specifications (7) and are consistent with the parameters used in the design and safety analysis (1).

TABLE 1.1

BOC Physics Test

Test	Date Completed	Time Completed	Plant Conditions
Control Rod Operability Test	5/2/94	0300	Cold SD
Hot Rod Drops	5/4/94	1200	HSD
RPI Calibrations	5/5/94	2300	HSD
Initial Criticality	5/6/94	1739	HZP
Reactivity Computer Checkout	5/7/94	0250	HZP
ARO Endpoint	5/7/94	0412	HZP
Bank C Worth (Dilution)	5/7/94	0515	HZP
Bank C In-ORO Endpoint	5/7/94	0715	HZP
Bank C (Boration)	5/7/94	1152	HZP
ITC Determination	5/7/94	1400	HZP
Power Ascension Flux Map 2001	5/8/94	0446	25%
Power Ascension Flux Map 2002	5/10/94	1422	37%
Power Ascension Flux Map 2003	5/15/94	1537	74%
Power Ascension Flux Map 2004	5/18/94	0756	91%
Power Ascension Flux Map 2005	5/19/94	1349	100%
Power Ascension Flux Map 2006	5/24/94	1403	100%

Figure 1.1
Core Loading Map



CYCLE TWENTY

2.0 RCCA MEASUREMENTS

2.1 RCCA Drop Time Measurements

RCCA drop times to dashpot and rod bottom were measured at hot shutdown core conditions. The results of the hot shutdown measurements are presented in Table 2.1. The acceptance criterion (4) of 1.8 seconds to dashpot is adequately met for all fuel.

2.2 RCCA Bank Measurements

During Cycle 20 startup the reactivity of the reference bank (Bank C) was measured during dilution using the reactivity computer. The reactivity worth of the remaining banks was inferred using rod swap reactivity comparisons to the reference bank.

2.2.1 Rod Swap Results

The worth of the reference bank (Bank C) measured during dilution differed from the WPSC predicted Bank C worth by 5.3 pcm or 0.5 percent. A comparison of the measured to predicted reference bank integral and differential worth is presented in Figure 2.1.

Rod swap results for the remaining banks are presented in Table 2.2. The measured to predicted total rod worth difference is 0.6 percent which is within the acceptance criteria of 10.0 percent. All individual bank worths were within the 15.0 percent measured to predicted review criterion.

2.3 Shutdown Margin Evaluation

Prior to power escalation a shutdown margin evaluation was made to verify the existence of core shutdown capability. The minimum shutdown margins at beginning and end of cycle are presented in Table 2.3. A 10 percent uncertainty in the calculation of rod worth is allowed for in these shutdown margin analyses. Since the measured rod worths resulted in less than a 10 percent difference from predicted values, the analysis in Table 2.3 is conservative and no additional evaluations were required.

TABLE 2.1

Kewaunee Cycle 20

RCCA Drop Time Measurements

Hot Zero Power

	All Fuel
Average Dashpot Delta T (Sec)	1.258
Standard Deviation	0.026
Average Rod Bottom Delta T (Sec)	1.753
Standard Deviation	0.029

TABLE 2.2

Kewaunee Cycle 20

RCCA Bank Worth Summary

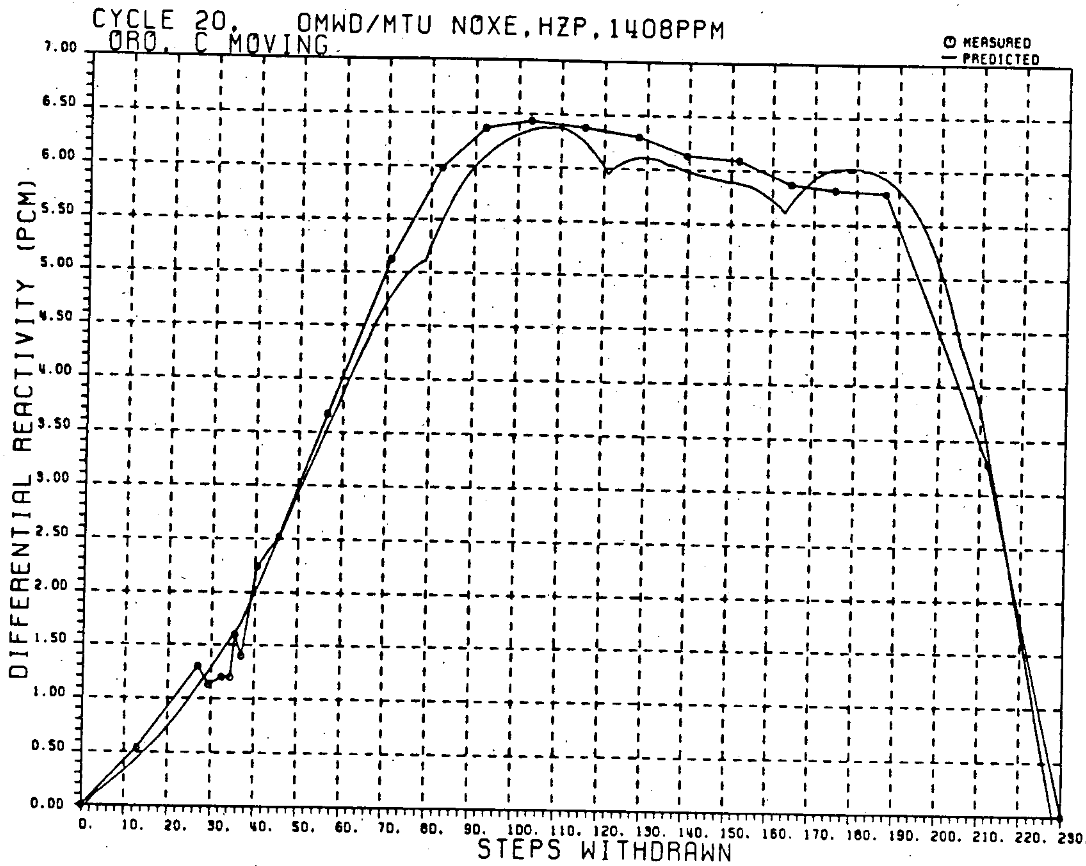
Reference Bank Measured by Dilution/Reactivity Computer

Rod Swap Method RCCA Bank	Measured Worth (PCM)	WPS Predicted Worth (PCM)	Difference (PCM)	Percent Difference
D	610.6	618	-7.4	-1.2
C*	1004.3	999	5.3	0.5
B	787.6	740	47.6	6.4
A	936.1	943	-6.9	-0.7
SA	635.0	644	-9.0	-1.4
SB	641.1	644	-2.9	-0.5
Total	4614.7	4588	26.7	0.6

* Reference bank

FIGURE 2.1

RCCA Bank C Integral and Differential Worth



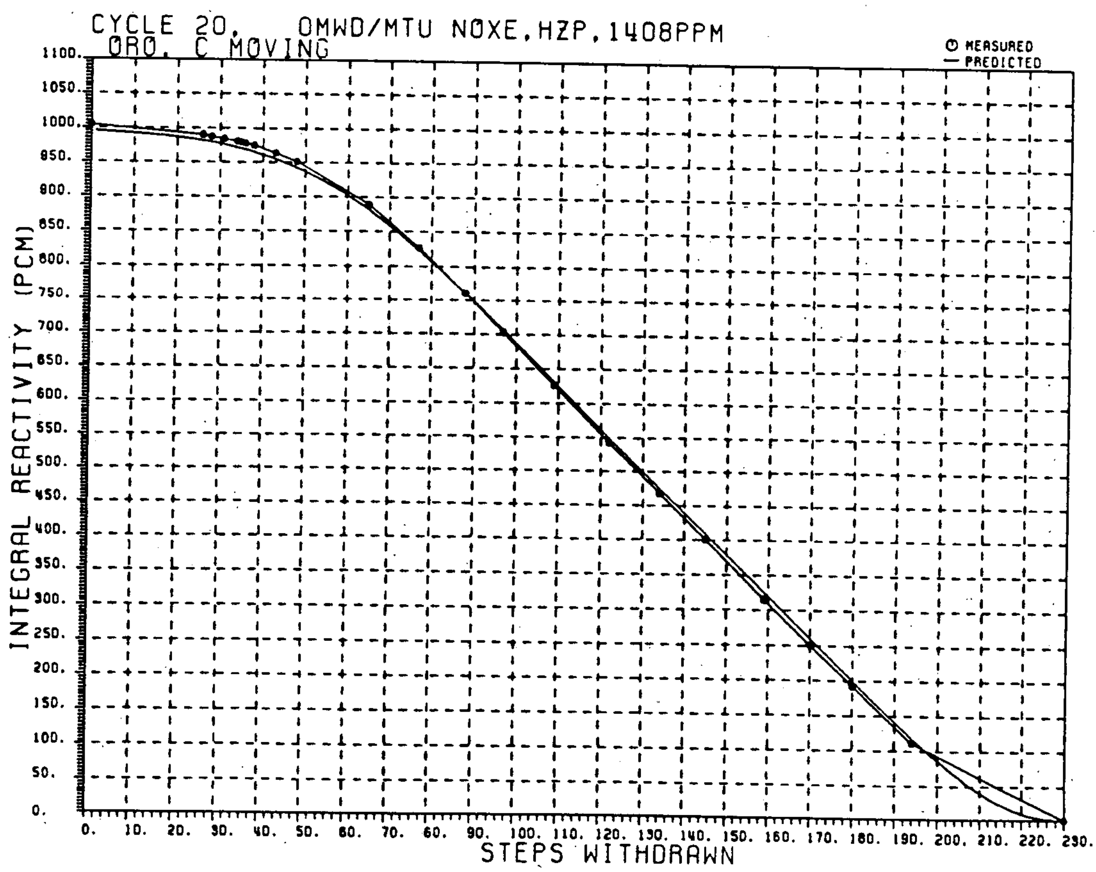


TABLE 2.3

Kewaunee Cycle 20

Minimum Shutdown Margin Analysis

RCCA Bank Worths (PCM)	BOC	EOC
N	6155	6265
N-1	5297	5496
Less 10 Percent	530	550
Sub Total	4767	4946
Total Requirements (Including Uncertainties)	2383	2151
Shutdown Margin	2384	2795
Required Shutdown Margin	1000	2000

3.0 BORON ENDPOINTS AND BORON WORTH MEASUREMENTS

3.1 Boron Endpoints

Dilution is stopped at the near ARO and at the Reference Bank nearly inserted core conditions. Boron concentration is allowed to stabilize. The critical boron concentration for these core configurations is then determined by boron endpoint measurement.

Table 3.1 lists the measured and WPSC predicted boron endpoints for the RCCA bank configurations shown. The results indicate a difference of -27 ppm and -23 ppm for the ARO and Bank C In conditions, respectively. The acceptance criterion on the all rods out boron endpoint is ±100 PPM, thus, the boron endpoint comparisons are considered acceptable.

3.2 Differential Boron Worth

The differential boron worth is calculated by dividing the worth of control Bank C by the difference in boron concentration of the corresponding bank out and bank in configuration. Table 3.2 presents a comparison between measured and predicted boron concentration change and differential boron worth. No acceptance criteria are applied to these comparisons.

3.3 Boron Letdown

The measured boron concentration data for the first month of power operation is corrected to nominal core conditions and presented versus cycle burnup in Figure 3.1. The predicted boron letdown curve is included for comparison.

TABLE 3.1

Kewaunee Cycle 20

RCCA Bank Endpoint Measurements

RCCA Bank Configuration	Measured Endpoint (PPM)	WPS Predicted Endpoint (PPM)	Difference (PPM)
All Rods Out	1441	1468	-27
Bank C In	1324	1347	-23

TABLE 3.2

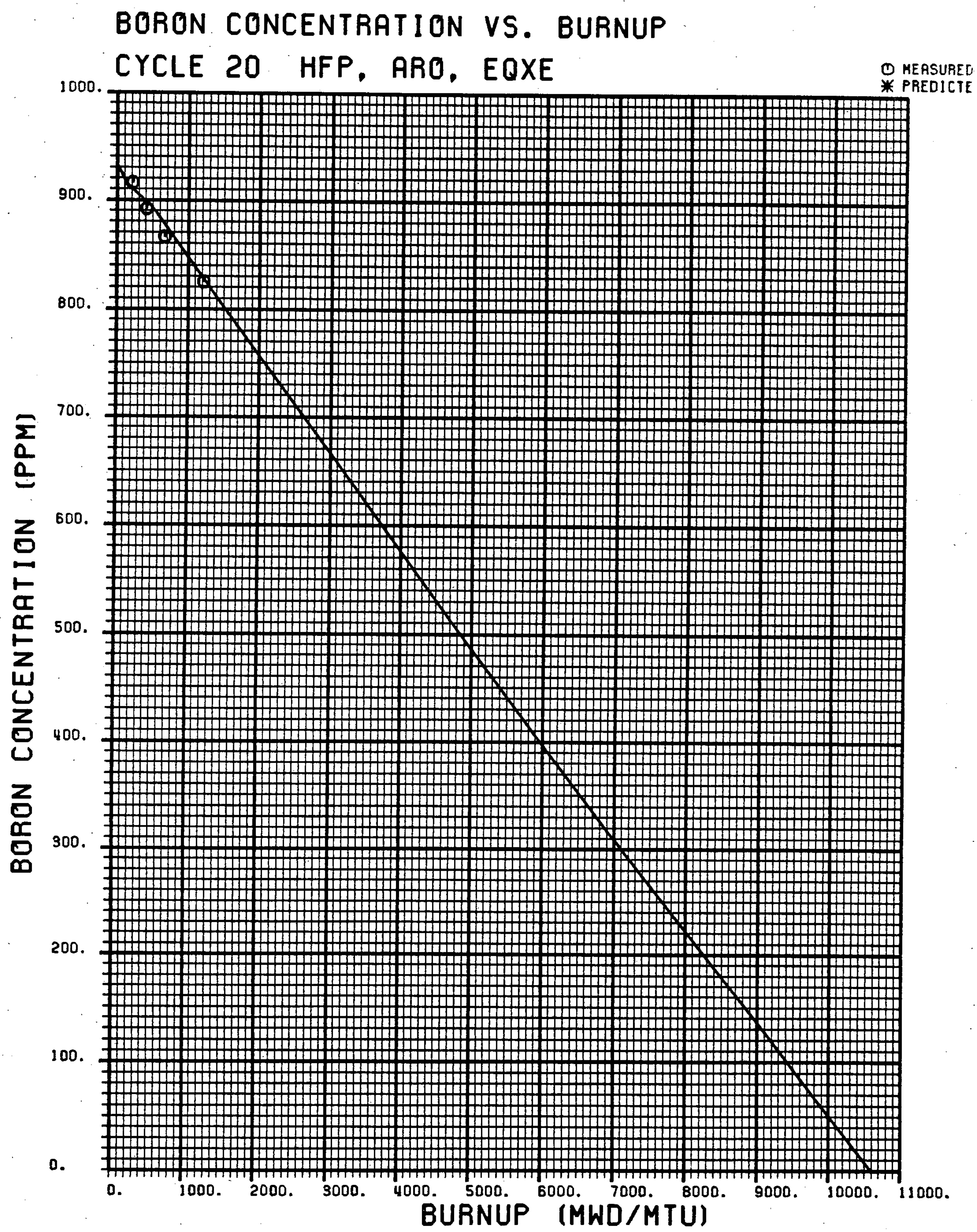
Kewaunee Cycle 20

Differential Boron Worth

RCCA Bank Configuration	CB Change Measured (PPM)	CB Change Predicted (PPM)	Percent Difference
ARO to C Bank In	117	121	-3.4

RCCA Bank Configuration	Measured Boron Worth (PCM/PPM)	Predicted Boron Worth (PCM/PPM)	Difference (PCM/PPM)
ARO/C Bank In	-8.6	-8.3	-0.3

FIGURE 3.1


BORON CONCENTRATION VS. BURNUP
CYCLE 20 HFP, ARO, EQXE
O MEASURED
✱ PREDICTE
1000.
900.
800.
700.
600.
500.
400.
300.
200.
100.
0.
BORON CONCENTRATION (PPM)
0.
1000.
2000.
3000.
4000.
5000.
6000.
7000.
8000.
9000.
10000.
11000.
BURNUP (MWD/MTU)

4.0 ISOTHERMAL TEMPERATURE COEFFICIENT

The measurement of the isothermal temperature coefficient was accomplished by monitoring reactivity while cooling down and heating up the reactor by manual control of the steam dump valves. The temperature and reactivity changes were plotted on an X-Y recorder and the temperature coefficient was obtained from the slope of this curve.

Core conditions at the time of the measurement were Bank D slightly inserted, all other RCCA banks full out, with a boron concentration of 1432 ppm. These conditions approximate the HZP, all rods out core condition which yields the most conservative (least negative) isothermal temperature coefficient measurement.

Table 4.1 presents the heatup and cooldown core conditions and compares the measured and predicted values for the isothermal temperature coefficient. The review criterion (4) of ±3 PCM/°F was met.

TABLE 4.1

Kewaunee Cycle 20

Isothermal Temperature Coefficient

Cooldown

Tave Start	-	546.0°F
Tave End	-	540.7°F
Bank D	-	202 Steps
Boron Concentration	-	1432 PPM

Measured ITC (PCM/°F)	WPSC Predicted ITC (PCM/°F)	Difference (PCM/°F)
-2.68	-4.41	1.73

Heat Up

Tave Start	-	540.1°F
Tave End	-	543.7°F
Bank D	-	194 Steps
Boron Concentration	-	1432 PPM

Measured ITC (PCM/°F)	WPSC Predicted ITC (PCM/°F)	Difference (PCM/°F)
-3.20	-4.20	1.00

5.0 POWER DISTRIBUTION

5.1 Summary of Power Distribution Criteria

Power distribution predictions are verified through data recorded using the incore detector system and processed through the INCORE computer code. The computer code calculates FQEQ and FDHN which are limited by technical specifications. These parameters are defined as the acceptance criteria on a flux map (4).

The review criterion for measurement is that the percent differences of the normalized reaction rate integrals of symmetric thimbles do not exceed 10 percent at low power physics test conditions and 6 percent at equilibrium conditions (4).

The review criterion for the prediction is that the standard deviation of the percent differences between measured and predicted reaction rate integrals does not exceed 5 percent.

The review criteria for the INCORE calculated quadrant powers are that the quadrant tilt is less than 4 percent at low power physics test conditions and less than 2 percent at equilibrium conditions (4).

5.2 Power Distribution Measurements

Table 5.1 identifies the reactor conditions for each flux map recorded at the beginning of Cycle 20.

Comparisons of measured to predicted power distributions for the flux maps are exhibited in Figures 5.1 through 5.6. As evidenced by the figures, the outer region of the core is initially overpredicted by approximately 5 percent and decreases with burnup to less than 4 percent.

Table 5.2 identifies flux map peak FDHN and minimum margin FQEQ. This table addresses acceptance criteria by verifying that technical specification limits are not exceeded. Table 5.2 also identifies FQW for the four Westinghouse assemblies and verifies that applied limits are reviewed. The Cycle 20 flux maps met all acceptance criteria.

Table 5.3 addresses the established review criteria for the flux maps. All review criteria were met for all the Cycle 20 flux maps.

TABLE 5.1

Flux Map Chronology and Reactor Characteristics

Map	Date	Percent Power	Xenon	Boron PPM	D Rods Steps	Exposure MDW/MTU
2001	5/8/94	25	NON-EQ.	1384	143	0
2002	5/10/94	37	NON-EQ.	1107	150	31
2003	5/15/94	74	NON-EQ.	1016	191	114
2004	5/18/94	91	NON-EQ.	965	204	195
2005	5/19/94	100	NON-EQ.	916	215	214
2006	5/24/94	100	EQ.	892	230	414

TABLE 5.2

Verification of Acceptance Criteria

Flux Map	Core Location	FQEQ	Limit
2001	L-06 ED,30	2.48	4.55
2002	L-06 ED,30	2.35	4.55
2003	B-06 EK,30	2.13	3.02
2004	B-06 EK,31	2.07	2.46
2005	B-06 GK,32	2.07	2.28
2006	F-02 KE,32	2.04	2.28

Flux Map	W Assembly Core Location	FQW	Limit
2001	C11	1.63	4.10
2002	C11	1.56	4.10
2003	C11	1.50	2.76
2004	K03	1.44	2.25
2005	K03	1.43	2.05
2006	K03	1.41	2.05

Flux Map	Core Location	FDHN	Limit
2001	H-09 EK	1.53	1.78
2002	E-08 KJ	1.51	1.74
2003	B-06 EK	1.50	1.63
2004	B-06 EK	1.50	1.58
2005	B-06 EK	1.50	1.55
2006	B-06 EK	1.49	1.55

FQEQ, FQW, and FDHN include appropriate uncertainties and penalties.

Limit on FQEQ and FQW is a function of core power and axial location.

Limit on FDHN is a function of Core Power and Assembly Burnup.

TABLE 5.3

Verification of Review Criteria

Flux Map	(a) Maximum Percent Difference	(b) Standard Deviation	(c) Maximum Quadrant Tilt
2001	1.6	1.7	0.3
2002	2.1	1.3	0.2
2003	1.8	1.3	0.3
2004	1.6	1.4	0.3
2005	1.4	1.4	0.5
2006	1.2	1.5	0.4

(a) Maximum Percent Difference between symmetric thimbles for measured reaction rate integrals. Review criterion is 10 percent at low power. Review criterion is 6 percent at equilibrium power.

(b) Standard Deviation of the percent difference between measured and predicted reaction rate integrals. Review criterion is 5 percent.

(c) Percent Maximum Quadrant Tilt from normalized calculated quadrant powers. Review criteria are 4 percent at low power and 2 percent at equilibrium power.

Figure 5.1

Power Distribution for Flux Map 2001

	1	2	3	4	5	6	7	8	9	10	11	12	13
A						0.294 0.298 -1.34	0.322 0.329 -2.07	0.290 0.298 -2.78					
B				0.598 0.601 -0.63	1.043 1.057 -1.36	1.134 1.150 -1.36	0.720 0.736 -2.11	1.125 1.150 -2.19	1.034 1.057 -2.17	0.601 0.601 -0.12			
C			0.618 0.622 -0.63	1.247 1.250 -0.28	1.011 1.017 -0.62	1.117 1.119 -0.20	0.795 0.803 -0.92	1.107 1.119 -1.08	0.998 1.017 -1.87	1.249 1.250 -0.11	0.630 0.622 1.33		
D		0.597 0.600 -0.43	1.241 1.246 -0.43	1.113 1.116 -0.27	1.242 1.245 -0.23	1.038 1.037 0.06	1.191 1.198 -0.59	1.027 1.037 -0.99	1.232 1.245 -1.03	1.118 1.116 0.16	1.259 1.248 1.01	0.608 0.600 1.33	
E		1.051 1.053 -0.24	1.012 1.014 -0.24	1.244 1.242 0.16	1.172 1.173 -0.09	1.358 1.357 0.09	1.318 1.312 0.48	1.371 1.357 1.02	1.184 1.173 0.95	1.250 1.242 0.68	1.028 1.014 1.36	1.075 1.053 2.09	
F	0.298 0.297 0.37	1.149 1.145 0.37	1.120 1.112 0.68	1.038 1.030 0.79	1.357 1.349 0.60	1.195 1.190 0.39	1.334 1.324 0.73	1.206 1.190 1.34	1.364 1.349 1.13	1.042 1.030 1.18	1.128 1.112 1.41	1.151 1.145 0.47	0.296 0.297 -0.17
G	0.325 0.327 -0.52	0.726 0.732 -0.77	0.801 0.799 0.25	1.193 1.192 0.09	1.315 1.302 1.02	1.331 1.319 0.92	0.985 0.967 1.92	1.344 1.319 1.93	1.324 1.302 1.67	1.207 1.192 1.28	0.811 0.799 1.49	0.735 0.732 0.37	0.326 0.327 -0.34
H	0.295 0.297 -0.64	1.135 1.145 -0.86	1.114 1.112 0.15	1.031 1.030 0.07	1.363 1.349 1.07	1.200 1.190 0.84	1.347 1.324 1.71	1.211 1.190 1.76	1.374 1.349 1.82	1.035 1.030 0.51	1.114 1.112 0.17	1.134 1.145 -0.94	0.290 0.297 -2.39
I		1.043 1.053 -0.98	1.009 1.014 -0.46	1.240 1.242 -0.15	1.178 1.173 0.43	1.364 1.357 0.51	1.329 1.312 1.31	1.375 1.357 1.36	1.190 1.173 1.47	1.236 1.242 -0.46	1.007 1.014 -0.66	1.039 1.053 -1.35	
J		0.603 0.600 0.58	1.254 1.246 0.65	1.123 1.116 0.58	1.252 1.245 0.57	1.044 1.037 0.68	1.206 1.198 0.68	1.044 1.037 0.67	1.250 1.245 0.43	1.095 1.116 -1.85	1.229 1.246 -1.35	0.592 0.600 -1.32	
K			0.617 0.622 -0.85	1.240 1.250 -0.65	1.001 1.017 -1.57	1.131 1.119 1.05	0.809 0.803 0.76	1.117 1.119 -0.17	1.008 1.017 -0.86	1.224 1.250 -2.06	0.617 0.622 -0.65		
L				0.591 0.601 -1.78	1.039 1.057 -1.69	1.130 1.150 -1.71	0.723 0.736 -1.73	1.129 1.150 -1.83	1.035 1.057 -2.06	0.589 0.601 -2.06			
M						0.285 0.296 -4.46	0.314 0.329 -4.44	0.289 0.298 -3.28					

LOOP B (arrow at C1) · LOOP F (arrow at B13) · LOOP B (arrow at K2) · LOOP F (arrow at K13)

Legend (box, top to bottom): MEASURED FΔH · PREDICTED FΔH · PERCENT DIFFERENCE

FLUX MAP 2001

δ = 1.30

Figure 5.2

Power Distribution for Flux Map 2002

	1	2	3	4	5	6	7	8	9	10	11	12	13
A						0.306 0.306 0.07	0.336 0.339 -0.88	0.300 0.308 -1.80					
B				0.595 0.604 -1.44	1.059 1.058 0.06	1.156 1.157 0.06	0.740 0.750 -1.39	1.136 1.157 -1.81	1.039 1.058 -1.80	0.602 0.604 -0.25			
C			0.619 0.628 -1.45	1.235 1.239 -0.32	1.024 1.019 0.47	1.134 1.128 0.56	0.821 0.828 -0.57	1.116 1.128 -1.04	1.001 1.019 -1.77	1.236 1.239 -0.25	0.632 0.628 0.61		
D		0.596 0.602 -1.01	1.223 1.236 -1.05	1.106 1.109 -0.27	1.235 1.232 0.24	1.042 1.038 0.39	1.185 1.193 -0.65	1.028 1.038 -0.94	1.224 1.232 -0.63	1.114 1.109 0.42	1.250 1.236 1.14	0.606 0.602 0.60	
E		1.049 1.055 -0.63	1.010 1.018 -0.63	1.228 1.229 -0.06	1.164 1.166 -0.20	1.347 1.347 0.02	1.302 1.299 0.18	1.354 1.347 0.51	1.178 1.186 0.99	1.250 1.229 1.71	1.031 1.016 1.50	1.069 1.055 1.28	
F	0.308 0.304 1.12	1.166 1.153 1.10	1.136 1.122 1.27	1.034 1.031 0.32	1.340 1.340 0.03	1.179 1.184 -0.43	1.312 1.312 -0.02	1.190 1.184 0.52	1.352 1.340 0.93	1.043 1.031 1.13	1.136 1.122 1.27	1.164 1.153 0.98	0.307 0.304 1.02
G	0.342 0.337 1.39	0.751 0.747 0.52	0.829 0.821 0.93	1.184 1.187 -0.23	1.292 1.289 0.26	1.302 1.307 -0.35	0.971 0.966 0.57	1.318 1.307 0.81	1.298 1.289 0.72	1.195 1.187 0.70	0.828 0.821 0.85	0.754 0.747 0.96	0.341 0.337 1.01
H	0.308 0.304 1.28	1.157 1.153 0.37	1.131 1.122 0.77	1.030 1.031 -0.07	1.347 1.340 0.53	1.186 1.184 0.12	1.320 1.312 0.61	1.194 1.184 0.86	1.352 1.340 0.87	1.034 1.031 0.29	1.123 1.122 0.10	1.156 1.153 0.22	0.307 0.304 0.79
I		1.053 1.055 -0.22	1.013 1.018 -0.31	1.226 1.229 -0.25	1.165 1.166 -0.14	1.348 1.347 0.10	1.305 1.299 0.46	1.354 1.347 0.48	1.172 1.166 0.51	1.226 1.229 -0.26	1.012 1.016 -0.37	1.048 1.055 -0.71	
J		0.608 0.602 1.01	1.242 1.236 0.47	1.112 1.109 0.23	1.230 1.232 -0.15	1.041 1.038 0.32	1.198 1.193 0.26	1.041 1.038 0.25	1.229 1.232 -0.23	1.099 1.109 -0.95	1.227 1.236 -0.71	0.598 0.602 -0.68	
K			0.624 0.628 -0.67	1.230 1.239 -0.72	1.003 1.019 -1.53	1.137 1.128 0.75	0.628 0.826 0.30	1.125 1.128 -0.31	1.010 1.019 -0.88	1.221 1.239 -1.49	0.625 0.628 -0.46		
L				0.594 0.604 -1.64	1.041 1.058 -1.60	1.151 1.157 -0.53	0.746 0.750 -0.52	1.147 1.157 -0.86	1.042 1.058 -1.49	0.595 0.604 -1.49			
M						0.300 0.306 -1.80	0.333 0.339 -1.80	0.301 0.306 -1.64					

LOOP B (upper left) · LOOP A (upper right) · LOOP B (lower left) · LOOP A (lower right)

Legend (values in each box, top to bottom):
- MEASURED FDHN
- PREDICTED FDHN
- PERCENT DIFFERENCE

FLUX MAP 2002

δ = 0.88

Figure 5.3

Power Distribution for Flux Map 2003

	1	2	3	4	5	6	7	8	9	10	11	12	13
A						0.320 0.317 0.95	0.356 0.359 -0.86	0.309 0.317 -2.58					
B				0.596 0.600 -0.63	1.051 1.041 0.95	1.164 1.153 0.95	0.774 0.784 -1.21	1.129 1.153 -2.06	1.020 1.041 -2.04	0.600 0.600 -0.05			
C			0.619 0.623 -0.63	1.198 1.200 -0.14	1.022 1.015 0.65	1.158 1.151 0.60	0.921 0.923 -0.24	1.139 1.151 -1.09	0.997 1.015 -1.75	1.200 1.200 -0.05	0.632 0.623 1.36		
D		0.598 0.599 -0.17	1.195 1.197 -0.19	1.088 1.089 -0.12	1.216 1.213 0.26	1.052 1.049 0.32	1.206 1.211 -0.44	1.038 1.049 -1.02	1.206 1.213 -0.56	1.096 1.089 0.62	1.216 1.197 1.60	0.607 0.599 1.37	
E		1.041 1.038 0.28	1.016 1.013 0.28	1.207 1.211 -0.36	1.155 1.157 -0.21	1.332 1.332 -0.04	1.294 1.289 0.37	1.339 1.332 0.50	1.171 1.157 1.22	1.234 1.211 1.87	1.031 1.013 1.79	1.056 1.038 1.70	
F	0.320 0.316 1.27	1.165 1.150 1.26	1.158 1.145 1.16	1.042 1.043 -0.06	1.325 1.325 -0.03	1.178 1.179 -0.30	1.300 1.297 0.26	1.189 1.179 0.83	1.341 1.325 1.18	1.054 1.043 1.02	1.158 1.145 1.17	1.154 1.150 0.31	0.317 0.316 0.38
G	0.359 0.357 0.50	0.781 0.781 0.00	0.924 0.919 0.59	1.200 1.205 -0.43	1.280 1.280 -0.02	1.287 1.293 -0.46	0.975 0.971 0.42	1.303 1.293 0.80	1.289 1.280 0.72	1.211 1.205 0.52	0.925 0.919 0.65	0.782 0.781 0.22	0.358 0.357 0.25
H	0.317 0.316 0.36	1.149 1.150 -0.14	1.151 1.145 0.48	1.044 1.043 0.07	1.333 1.325 0.58	1.182 1.179 0.21	1.300 1.297 0.22	1.186 1.179 0.59	1.335 1.325 0.75	1.044 1.043 0.12	1.142 1.145 -0.25	1.142 1.150 -0.72	0.313 0.316 -0.98
I		1.031 1.036 -0.67	1.009 1.013 -0.40	1.211 1.211 -0.03	1.165 1.157 0.67	1.336 1.332 0.27	1.291 1.289 0.12	1.334 1.332 0.14	1.161 1.157 0.32	1.207 1.211 -0.37	1.006 1.013 -0.69	1.026 1.038 -1.19	
J		0.602 0.599 0.60	1.204 1.197 0.57	1.096 1.089 0.60	1.220 1.213 0.60	1.049 1.049 0.02	1.208 1.211 -0.24	1.047 1.049 -0.24	1.212 1.213 -0.12	1.077 1.089 -1.15	1.183 1.197 -1.19	0.592 0.599 -1.19	
K			0.619 0.623 -0.74	1.191 1.200 -0.75	1.001 1.015 -1.43	1.146 1.151 -0.49	0.920 0.923 -0.31	1.148 1.151 -0.27	1.014 1.015 -0.16	1.198 1.200 -0.20	0.616 0.623 -1.22		
L				0.591 0.600 -1.58	1.025 1.041 -1.53	1.136 1.153 -1.49	0.772 0.784 -1.49	1.141 1.153 -1.04	1.039 1.041 -0.20	0.599 0.600 -0.18			
M						0.309 0.317 -2.49	0.350 0.359 -2.48	0.313 0.317 -1.35					

LOOP B (near B–C, columns 1–2) · LOOP A (near B, column 13) · LOOP B (near K, columns 1–2) · LOOP A (near K, column 13)

Legend (each box, top to bottom):
- MEASURED FDHN
- PREDICTED FDHN
- PERCENT DIFFERENCE

FLUX MAP 2003

$\delta = 0.91$

Figure 5.4

Power Distribution for Flux Map 2004

	1	2	3	4	5	6	7	8	9	10	11	12	13
A						0.328 0.322 1.96	0.365 0.367 -0.46	0.313 0.322 -2.79					
B				0.594 0.600 -0.98	1.053 1.033 1.97	1.172 1.149 1.97	0.789 0.795 -0.76	1.126 1.149 -1.98	1.013 1.033 -1.96	0.599 0.600 -0.08			
C			0.617 0.623 -0.99	1.180 1.186 -0.53	1.024 1.015 0.94	1.166 1.157 0.79	0.957 0.955 0.23	1.146 1.157 -0.96	0.999 1.015 -1.56	1.185 1.186 -0.08	0.632 0.623 1.38		
D		0.597 0.598 -0.13	1.181 1.183 -0.18	1.078 1.083 -0.51	1.208 1.206 -0.03	1.055 1.054 0.11	1.212 1.216 -0.35	1.045 1.054 -0.90	1.201 1.208 -0.54	1.088 1.083 0.48	1.200 1.183 1.45	0.606 0.598 1.37	
E		1.038 1.031 0.68	1.019 1.012 0.67	1.203 1.205 -0.20	1.154 1.156 -0.14	1.327 1.327 -0.01	1.287 1.286 0.10	1.329 1.327 0.15	1.165 1.156 0.75	1.224 1.205 1.54	1.031 1.012 1.86	1.054 1.031 2.20	
F	0.326 0.321 1.56	1.163 1.145 1.55	1.165 1.152 1.16	1.047 1.047 0.03	1.321 1.321 -0.02	1.177 1.179 -0.14	1.292 1.293 -0.05	1.182 1.179 0.27	1.330 1.321 0.70	1.057 1.047 0.93	1.168 1.152 1.42	1.148 1.145 0.25	0.321 0.321 -0.06
G	0.367 0.365 0.36	0.792 0.792 0.04	0.956 0.951 0.58	1.207 1.211 -0.30	1.277 1.277 0.00	1.287 1.289 -0.19	0.977 0.976 0.10	1.294 1.289 0.36	1.261 1.277 0.32	1.217 1.211 0.45	0.960 0.951 0.94	0.793 0.792 0.14	0.364 0.365 -0.25
H	0.322 0.321 0.19	1.144 1.145 -0.11	1.158 1.152 0.49	1.047 1.047 0.00	1.326 1.321 0.35	1.181 1.179 0.18	1.294 1.293 0.11	1.183 1.179 0.36	1.327 1.321 0.43	1.048 1.047 0.09	1.151 1.152 -0.11	1.134 1.145 -0.93	0.313 0.321 -2.31
I		1.026 1.031 -0.51	1.013 1.012 0.08	1.208 1.205 0.28	1.164 1.156 0.68	1.331 1.327 0.29	1.285 1.286 -0.06	1.326 1.327 -0.08	1.156 1.156 0.00	1.200 1.205 -0.44	1.005 1.012 -0.68	1.020 1.031 -1.06	
J		0.605 0.598 1.20	1.197 1.183 1.16	1.094 1.083 1.00	1.219 1.208 0.89	1.051 1.054 -0.28	1.207 1.216 -0.71	1.047 1.054 -0.70	1.201 1.208 -0.60	1.072 1.083 -1.01	1.170 1.183 -1.06	0.592 0.598 -1.05	
K			0.623 0.623 -0.11	1.184 1.166 -0.13	1.007 1.015 -0.79	1.141 1.157 -1.43	0.945 0.955 -1.05	1.151 1.157 -0.51	1.015 1.015 -0.01	1.193 1.186 0.55	0.817 0.623 -1.11		
L				0.594 0.600 -0.95	1.024 1.033 -0.89	1.124 1.149 -2.17	0.777 0.795 -2.16	1.135 1.149 -1.23	1.039 1.033 0.54	0.603 0.600 0.55			
M						0.313 0.322 -2.69	0.356 0.367 -2.69	0.318 0.322 -1.21					

LOOP B (near B/C, columns 1–2) — LOOP A (near B/C, column 13) — LOOP B (near K/L, columns 1–2) — LOOP A (near K/L, column 13)

Legend (each cell, top to bottom):
MEASURED FDHN
PREDICTED FDHN
PERCENT DIFFERENCE

FLUX MAP 2004

$\delta = 1.01$

Figure 5.5
Power Distribution for Flux Map 2005

	1	2	3	4	5	6	7	8	9	10	11	12	13
A						0.332 0.325 2.06	0.370 0.372 -0.43	0.316 0.325 -2.77					
B				0.596 0.600 -0.73	1.052 1.031 2.05	1.172 1.148 2.05	0.797 0.802 -0.55	1.128 1.148 -1.77	1.013 1.031 -1.77	0.600 0.600 -0.06			
C			0.620 0.625 -0.74	1.177 1.180 -0.26	1.026 1.015 1.11	1.171 1.161 0.83	0.973 0.969 0.36	1.152 1.161 -0.82	1.002 1.015 -1.28	1.179 1.180 -0.08	0.633 0.625 1.34		
D		0.598 0.599 -0.20	1.174 1.177 -0.23	1.078 1.081 -0.24	1.206 1.204 0.18	1.057 1.055 0.16	1.214 1.217 -0.23	1.047 1.055 -0.79	1.200 1.204 -0.37	1.086 1.081 0.44	1.193 1.177 1.38	0.607 0.599 1.34	
E		1.032 1.029 0.30	1.015 1.012 0.31	1.198 1.201 -0.24	1.153 1.154 -0.13	1.322 1.323 -0.05	1.284 1.282 0.13	1.325 1.323 0.15	1.163 1.154 0.81	1.218 1.201 1.43	1.031 1.012 1.91	1.054 1.029 2.40	
F	0.328 0.324 1.42	1.161 1.145 1.40	1.169 1.155 1.19	1.049 1.049 0.03	1.318 1.317 0.03	1.175 1.177 -0.18	1.291 1.289 0.12	1.183 1.177 0.47	1.326 1.317 0.80	1.054 1.049 0.46	1.166 1.155 0.96	1.145 1.145 -0.03	0.325 0.324 0.19
G	0.373 0.370 0.70	0.801 0.799 0.34	0.973 0.965 0.83	1.209 1.211 -0.17	1.275 1.274 0.05	1.281 1.285 -0.29	0.979 0.977 0.24	1.291 1.285 0.49	1.278 1.274 0.33	1.210 1.211 -0.11	0.969 0.965 0.33	0.797 0.799 -0.19	0.370 0.370 0.00
H	0.326 0.324 0.56	1.148 1.145 0.21	1.164 1.155 0.74	1.052 1.049 0.27	1.325 1.317 0.56	1.179 1.177 0.18	1.290 1.289 0.07	1.181 1.177 0.33	1.322 1.317 0.36	1.046 1.049 -0.33	1.147 1.155 -0.72	1.130 1.145 -1.31	0.317 0.324 -2.01
I		1.027 1.029 -0.20	1.014 1.012 0.24	1.206 1.201 0.43	1.163 1.154 0.81	1.326 1.323 0.23	1.281 1.282 -0.09	1.322 1.323 -0.06	1.154 1.154 -0.03	1.194 1.201 -0.62	1.004 1.012 -0.83	1.018 1.029 -1.12	
J		0.606 0.599 1.24	1.192 1.177 1.24	1.093 1.081 1.10	1.216 1.204 1.02	1.054 1.055 -0.13	1.211 1.217 -0.51	1.050 1.055 -0.50	1.200 1.204 -0.35	1.070 1.081 -1.01	1.164 1.177 -1.11	0.592 0.599 -1.12	
K			0.622 0.625 -0.42	1.175 1.180 -0.43	1.002 1.015 -1.26	1.151 1.161 -0.84	0.963 0.969 -0.62	1.156 1.161 -0.41	1.013 1.015 -0.19	1.180 1.160 -0.03	0.617 0.825 -1.22		
L				0.591 0.600 -1.47	1.017 1.031 -1.39	1.125 1.148 -2.01	0.785 0.802 -2.02	1.133 1.148 -1.33	1.031 1.031 -0.04	0.600 0.600 -0.03			
M						0.315 0.325 -3.17	0.360 0.372 -3.17	0.320 0.325 -1.63					

LOOP B (upper left) · LOOP A (upper right) · LOOP B (lower left) · LOOP A (lower right)

Legend (each cell, top to bottom):
- MEASURED FDHN
- PREDICTED FDHN
- PERCENT DIFFERENCE

FLUX MAP 2005

δ= 1.01

Figure 5.6

Power Distribution for Flux Map 2006

	1	2	3	4	5	6	7	8	9	10	11	12	13
A						0.332 0.326 1.93	0.373 0.374 -0.21	0.318 0.326 -2.24					
B				0.594 0.598 -0.69	1.045 1.025 1.93	1.167 1.145 1.94	0.799 0.804 -0.63	1.125 1.145 -1.80	1.007 1.025 -1.79	0.599 0.598 0.13			
C			0.618 0.623 -0.69	1.174 1.174 -0.03	1.027 1.014 1.28	1.175 1.163 1.01	0.984 0.982 0.18	1.152 1.163 -0.95	0.998 1.014 -1.55	1.176 1.174 0.13	0.633 0.623 1.67		
D		0.596 0.597 -0.12	1.169 1.171 -0.15	1.079 1.079 0.01	1.204 1.204 0.02	1.059 1.058 0.10	1.215 1.222 -0.61	1.049 1.058 -0.90	1.200 1.204 -0.32	1.088 1.079 0.84	1.194 1.171 1.92	0.607 0.597 1.68	
E		1.028 1.023 0.43	1.015 1.011 0.43	1.196 1.202 -0.32	1.149 1.154 -0.47	1.321 1.324 -0.27	1.282 1.285 -0.26	1.324 1.324 -0.02	1.165 1.154 0.92	1.229 1.202 2.20	1.038 1.011 2.61	1.054 1.023 3.05	
F	0.329 0.325 1.32	1.156 1.141 1.33	1.173 1.158 1.30	1.052 1.052 -0.03	1.313 1.317 -0.31	1.169 1.178 -0.77	1.283 1.289 -0.48	1.177 1.178 -0.07	1.326 1.317 0.68	1.058 1.052 0.57	1.175 1.158 1.43	1.144 1.141 0.26	0.327 0.325 0.62
G	0.374 0.372 0.56	0.803 0.802 0.11	0.986 0.978 0.78	1.214 1.217 -0.30	1.275 1.276 -0.11	1.276 1.285 -0.75	0.975 0.978 -0.30	1.284 1.285 -0.08	1.275 1.276 -0.09	1.214 1.217 -0.25	0.983 0.978 0.55	0.803 0.802 0.10	0.374 0.372 0.40
H	0.326 0.325 0.43	1.141 1.141 -0.01	1.166 1.158 0.66	1.052 1.052 -0.04	1.320 1.317 0.24	1.175 1.178 -0.30	1.285 1.289 -0.26	1.177 1.178 -0.08	1.317 1.317 -0.01	1.048 1.052 -0.41	1.150 1.158 -0.68	1.127 1.141 -1.22	0.319 0.325 -1.82
I		1.023 1.023 -0.06	1.016 1.011 0.46	1.205 1.202 0.22	1.151 1.154 -0.23	1.320 1.324 -0.31	1.281 1.285 -0.33	1.320 1.324 -0.32	1.151 1.154 -0.27	1.195 1.202 -0.57	1.004 1.011 -0.67	1.014 1.023 -0.87	
J		0.609 0.597 2.06	1.193 1.171 1.90	1.092 1.079 1.20	1.213 1.204 0.72	1.053 1.058 -0.48	1.216 1.222 -0.53	1.052 1.058 -0.53	1.199 1.204 -0.40	1.069 1.079 -0.92	1.161 1.171 -0.87	0.591 0.597 -0.85	
K			0.625 0.623 0.34	1.178 1.174 0.31	1.009 1.014 -0.55	1.154 1.163 -0.81	0.976 0.982 -0.62	1.160 1.163 -0.22	1.015 1.014 0.10	1.181 1.174 0.56	0.618 0.623 -0.82		
L				0.594 0.598 -0.74	1.018 1.025 -0.66	1.121 1.145 -2.10	0.788 0.804 -2.11	1.132 1.145 -1.19	1.031 1.025 0.56	0.601 0.598 0.57			
M						0.315 0.326 -3.38	0.361 0.374 -3.40	0.321 0.326 -1.44					

LOOP B (arrow near B-1, upper left); LOOP A (arrow near B-13, upper right); LOOP B (arrow near K-1, lower left); LOOP A (arrow near K-13, lower right)

Legend (each cell, top to bottom): MEASURED FDHN / PREDICTED FDHN / PERCENT DIFFERENCE

FLUX MAP 2006

δ = 1.06

6.0 REACTOR STARTUP CALIBRATIONS

6.1 Rod Position Calibration

The rod position indicators are calibrated each refueling in accordance with an approved surveillance procedure. The calibration includes the following:

a) The position signal output is checked at 20 and 200 steps for all rods.

b) The rod bottom lamps are checked to assure that they light at the proper rod height.

c) The control room rod position indicators are calibrated to read correctly at 20 and 200 steps.

d) The pulse-to-analog convertor alignment is checked.

e) The rod bottom bypass bi-stable trip setpoint is checked.

The calibration was performed satisfactorily during the Cycle 20 startup; no problems or abnormalities were encountered and site procedure acceptance criteria were met. At full power an adjustment was made to selected RPI channels to compensate for the temperature increase associated with power ascension.

6.2 Nuclear Instrumentation Calibration

The nuclear instrumentation (NI) calibration was performed in accordance with the Kewaunee Reactor Test Program during the Cycle 20 startup (4). A flux map was performed at approximately 75 percent power. The incore axial offset was determined from the data collected during the map. The NI's were then calibrated with a conservative incore axial offset-to-excore axial offset ratio of 1.7.

7.0 REFERENCES

(1) "Reload Safety Evaluation for Kewaunee Cycle 20," Wisconsin Public Service Corporation, February 1994.

(2) "Qualification of Reactor Physics Methods for Application to Kewaunee," Wisconsin Public Service Corporation, October 1978.

(3) "Reload Safety Evaluation Methods for Application to Kewaunee", WPSRSEM-NP-A, Revision 2, October 1988.

(4) "Reactor Test Program, Kewaunee Nuclear Power Plant," Wisconsin Public Service Corporation, May 1979. (Revision 3, March 1987)

(5) "Generic Mechanical and Thermal Hydraulic Design for Exxon Nuclear 14 x 14 Reload Assemblies with Zircaloy Guide Tubes for Westinghouse 2-Loop Pressurized Water Reactors," Exxon Nuclear Corporation, November 1978.

(6) "Rod Exchange Technique for Rod Worth Measurement" and "Rod Worth Verification Tests Utilizing RCC Bank Interchange," Westinghouse Corporation, May 12, 1978.

(7) "Kewaunee Nuclear Power Plant Technical Specifications," Wisconsin Public Service Corporation, Docket 50-305.