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DUKE POWER

October 13, 1994

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

Subject: Catawba Nuclear Station, Unit 2
Docket No. 50-414
Special Report
Unit 2 Cycle 7 Startup Report

Pursuant to Catawba Technical Specification 6.9.1 please find attached the Startup Report for Unit 2 Cycle 7 core design.

Very truly yours,

D. L. Rehn by William R. McCollum Jr.

D. L. Rehn

DT/

Attachment

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Duke Power Company
Catawba Nuclear Station
Unit 2 Cycle 7
STARTUP REPORT

October, 1994

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1.0 INTRODUCTION

Catawba Unit Two Cycle 7 includes a feed batch of 88 MkBW fuel assemblies manufactured by B&W Fuel Company (BWFC). The feed batch includes 48 fuel assemblies with axial blankets that were manufactured by BWFC for Trojan. The blankets consist of 0.71% w/o enrichment in the top and bottom 6 inches of the fuel rods. Of these 48 fuel assemblies 40 were enriched to 4.00% (w/o) and 8 to 3.60 % (w/o). The remaining 40 fuel assemblies were un-blanketed MkBW fuel assemblies enriched to 3.50% (w/o). Burnable poison rod assemblies used in the feed batch were also manufactured by BWFC.

Catawba Unit Two Cycle 7 core loading began at 1257 on May 28, 1994 and ended at 0237 on May 31, 1994. Initial criticality for cycle 7 occurred at 2359 on July 2, 1994. Zero Power Physics Testing ended at 2255 on March 31, 1993. The unit reached full power at 1005 on July 10, 1994. Power escalation testing, including testing at full power, was completed by July 21, 1994.

Table 1 contains some important characteristics of the Catawba 2 Cycle 7 core design.

TABLE 1
C2C7 CORE DESIGN DATA

1. C2C6 end of cycle burnup: 380 EFPD

2. C2C7 design length: 430 ± 10 EFPD

Region	Fuel Type	Number of Assemblies	Enrichment, w/o U^{235}	Loading, MTU**	Cycles Burned
7A (S)	OFA	29	3.75	12.2815	2
8A (T)	MkBW	76	3.75	34.6788	1
9A (U)	MkBW	40	4.00/0.71*	18.2520	0
9B(U)	MkBW	8	3.60/0.71*	3.6504	0
9C(U)	MkBW	40	3.50	18.2520	0
Totals		193		87.1147	

* Natural U blanketed fuel assemblies (0.71 w/o enrichment - 6 inches top and bottom)
** Design MTU loadings which were used in all design calculaations.

2.0 PRECRITICAL TESTING

Precritical testing includes:

- core loading
- preliminary calibration of nuclear instrumentation
- dilution of reactor coolant system to estimated critical boron concentration

Sections 2.1 through 2.3 describe results of precritical testing for Catawba 2 Cycle 7.

2.1 Total Core Reloading

The cycle 7 core was loaded under the direction of PT/0/A/4150/22, Total Core Reload. Plots of Inverse Count Rate Ratio (ICRR) versus number of fuel assemblies loaded were kept for each applicable source range and boron dilution mitigation system (BDMS) channel.

Core loading began at 1257 on May 28, 1994 and concluded at 0237 on May 31, 1994. Core loading was verified by PT/0/A/4150/03C, Core Verification, which was completed by 0830 on May 31, 1994.

Figure 1 shows the core loading pattern for Catawba 2 Cycle 7.

2.2 Preliminary NIS Calibration

Periodic test procedure PT/0/A/4600/05E, Preliminary NIS Calibration, is performed before initial criticality for each new fuel cycle. Intermediate range reactor trip and rod stop setpoints are adjusted using measured power distribution from the previous fuel cycle and predicted power distribution for the upcoming fuel cycle. Power range full power currents are similarly adjusted. Intermediate range calibration data is checked and revised as necessary during power escalation testing.

Table 2 shows the calibration data calculated by PT/0/A/4600/05E. Calculations were performed on June 13, 1994 and June 14, 1994. Calibrations were complete by July 2, 1994.

2.3 Reactor Coolant System Dilution

The reactor coolant system boron concentration was diluted from the refueling boron concentration to the estimated critical boron concentration per PT/0/A/4150/19A, NCS Dilution with Shutdown Banks Inserted. Inverse Count Rate Ratio (ICRR) was plotted versus gallons of demineralized water added.

Initial reactor coolant boron concentration was 2201 ppmB. The estimated critical boron concentration was calculated to be 1710 ppmB. The calculated volume of demineralized water required was 15340 gallons. This change in boron concentration was expected to decrease ICRR from 1.0 to 0.6.

Reactor coolant system dilution began at 1120 on July 2, 1994 and concluded at 1712 on July 2, 1994. The final reactor coolant system boron concentration, after allowing system to mix, was 1697 ppmB. Dilution was temporarily suspended after the addition of 10313 gallons demineralized water when the ICRR went outside (higher than predicted) the predicted ICRR behavior band. This ICRR behavior was conservative since it indicated that the reactivity of the core was being changed less than expected per gallon of demineralized water being added. Dilution was resumed after a procedure change was made to allow dilution to continue if the ICRR is more conservative than the predicted ICRR band. Figure 2 shows ICRR versus volume of water used.

FIGURE 1

CORE LOADING PATTERN, CATAWBA UNIT 2 CYCLE 7

North ^

180 (top) — FUEL TRANSFER CANAL ------> — 90 (left) — 270 (right) — 0 (bottom)

	R	P	N	M	L	K	J	H	G	F	E	D	C	B	A
1					T64 PD	US42 PD	S10 PD	U51 PD	S29 PD	US44 PD	T62 PD				
2			S49 PD	T70 RCCA	U63 BP	T21 RCCA	U66 BP	T31 RCCA	U76 BP	T42 RCCA	U77 BP	T34 RCCA	S72 PD		
3		S27 PD	T59 PD	U50 BP	T33 RCCA	U85 BP	T71 RCCA	U56 BP	T50 RCCA	U71 BP	T30 RCCA	U72 BP	T25 PD	S68 PD	
4		T69 RCCA	U68 BP	T61 RCCA	US03 BP	T66 PD	US15 BP	S16 RCCA	US18 BP	T14 PD	US28 BP	T17 RCCA	U69 BP	T20 RCCA	
5	T60 PD	U62 BP	T38 RCCA	US29 BP	S59 PD	US02 BP	T04 PD	US37 BP	T73 PD	US08 BP	S25 PD	US23 BP	T44 RCCA	U65 BP	T12 SS
6	US45 PD	T08 RCCA	U49 BP	T37 PD	US24 BP	T53 RCCA	US20 BP	T75 RCCA	US21 BP	T05 RCCA	US14 BP	T56 PD	U75 BP	T39 RCCA	US46 PD
7	S02 PD	U61 BP	T41 RCCA	US17 BP	T01 PD	US01 BP	S63 PD	US27 BP	S01 PD	US13 BP	T46 PD	US10 BP	T54 RCCA	U58 12 BP	S20 PD
8	U82 PD	T51 RCCA	U80 BP	S24 RCCA	US34 BP	T22 RCCA	US32 BP	S36 RCCA	US26 BP	T11 RCCA	US40 BP	S33 RCCA	U74 BP	T68 RCCA	U88 PD
9	S76 PD	U73 BP	T72 RCCA	US25 BP	T45 PD	US22 BP	S26 PD	US31 BP	S44 PD	US09 BP	T26 PD	US36 BP	T35 RCCA	U70 BP	S62 PD
10	US47 PD	T67 RCCA	U79 BP	T65 PD	US07 BP	T48 RCCA	US16 BP	T16 RCCA	US30 BP	T47 RCCA	US19 BP	T07 PD	U57 BP	T23 RCCA	US41 PD
11	T29 SS	U84 BP	T63 RCCA	US33 BP	S06 PD	US35 BP	T15 PD	US39 BP	T52 PD	US04 BP	S40 PD	US38 BP	T74 RCCA	U55 BP	T19 PD
12		T76 RCCA	U64 BP	T32 RCCA	US05 BP	T09 PD	US11 BP	S75 RCCA	US06 BP	T10 BP	US12 BP	T13 RCCA	U78 BP	T28 RCCA	
13		S51 PD	T06 PD	U67 BP	T49 RCCA	U81 BP	T18 RCCA	U83 BP	T43 RCCA	U87 BP	T24 RCCA	U52 BP	T40 PD	S64 PD	
14			S54 PD	T03 RCCA	U86 BP	T55 RCCA	U53 BP	T58 RCCA	U59 BP	T57 RCCA	U54 BP	T36 RCCA	S30 PD		
15					T02 PD	US48 PD	S12 PD	U60 PD	S66 PD	US43 PD	T27 PD				

Legend:
- Fuel Assembly Region Reference Number
- Fuel component (PD = plugging device, BP = burnable poison rod assembly)

TABLE 2
PRELIMINARY NIS CALIBRATION DATA

Intermediate Range

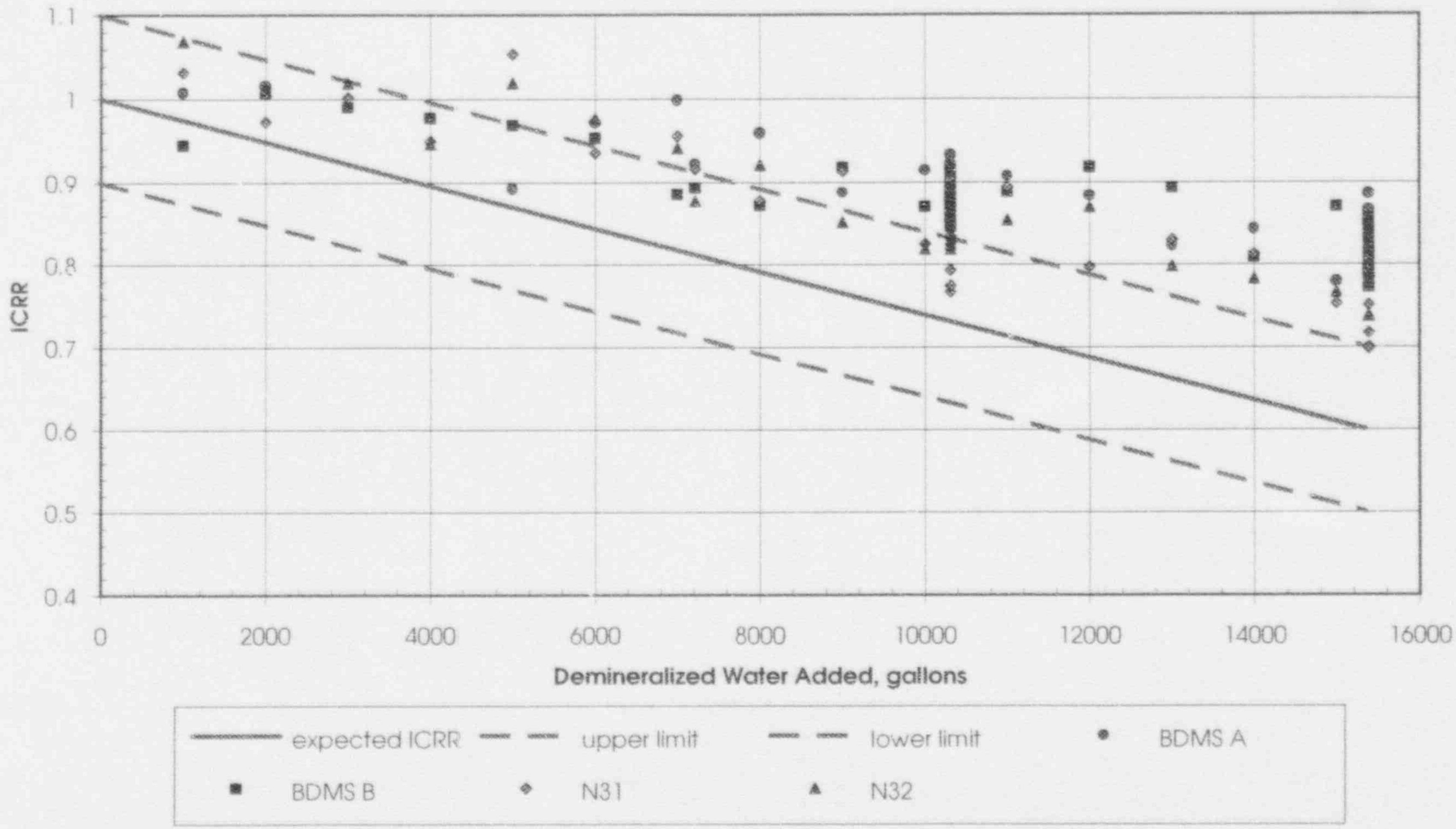
Channel	Ratio (BOC 7 ÷ Cycle 6)	Cycle 6 Reactor Trip Setpoint, µAmps	Cycle 6 Rod Stop Setpoint, µAmps	BOC 7 Reactor Trip Setpoint, µAmps	BOC 7 Rod Stop Setpoint, µAmps
N35	1.009	81	65	82	66
N36	1.008	70	56	71	57

Power Range

Channel	Ratio (BOC 7 ÷ Cycle 6)	Axial Offset, %	Cycle 6 Full Power Current, µAmps		BOC 7 Full Power Current, µAmps	
			Upper	Lower	Upper	Lower
N41	0.951	+20	386.6	294.4	367.7	280.0
		0	335.3	344.6	318.9	327.7
		-20	284.1	394.6	270.2	375.2
N42	0.964	+20	304.4	237.8	293.4	229.2
		0	265.8	278.6	256.2	268.5
		-20	227.3	319.2	219.1	307.6
N43	0.936	+20	349.9	269.5	327.4	252.2
		0	300.6	313.9	281.3	293.7
		-20	251.5	358.3	235.3	335.3
N44	0.933	+20	335.6	262.3	313.0	244.6
		0	291.0	305.0	271.4	284.4
		-20	246.2	347.7	229.6	324.2

FIGURE 2

ICRR vs. DEMIN WATER ADDED DURING REACTOR COOLANT SYSTEM DILUTION



3.0 ZERO POWER PHYSICS TESTING

Zero Power Physics Testing (ZPPT) is performed at the beginning of each cycle and is controlled by PT/0/A/4150/01, Controlling Procedure for Startup Physics Testing. Test measurements are made below the point of nuclear heat using the output of one power range detector connected to a reactivity computer. Measurements are compared to predicted data to verify core design. The following tests/measurements are included in the ZPPT program:

- 1/M Approach to Criticality
- Measurement of point of adding heat
- Reactivity computer checkout
- All Rods Out critical boron concentration measurement
- All Rods Out isothermal temperature coefficient measurement
- Measurement of reference bank worth by dilution
- Reference bank in critical boron concentration measurement
- Differential boron worth determination
- Control rod worths measurement by Rod Swap

Zero power physics testing for Catawba 2 Cycle 7 began at 2148 on July 2, 1994 with the beginning of rod withdrawal for approach to criticality. ZPPT ended at 0030 on July 4, 1994 following analysis of rod swap data. Table 3 summarizes results from ZPPT. All acceptance criteria were met.

Sections 3.1 through 3.10 describe ZPPT measurements and results.

3.1 1/M Approach to Criticality

Initial criticality for Catawba 2 Cycle 7 was achieved per PT/0/A/4150/19, 1/M Approach to Criticality. In this procedure, Estimated Critical Rod Position (ECP) is calculated based on latest available reactor coolant boron concentration. Control rods, beginning with shutdown banks in normal sequence, are withdrawn until Boron Dilution Mitigation System (BDMS) count rate doubles. Inverse Count Rate Ratio (ICRR) is plotted for each source range and BDMS channel. ICRR data is used to project critical rod position. If projected critical rod position is acceptable, rod withdrawal may continue.

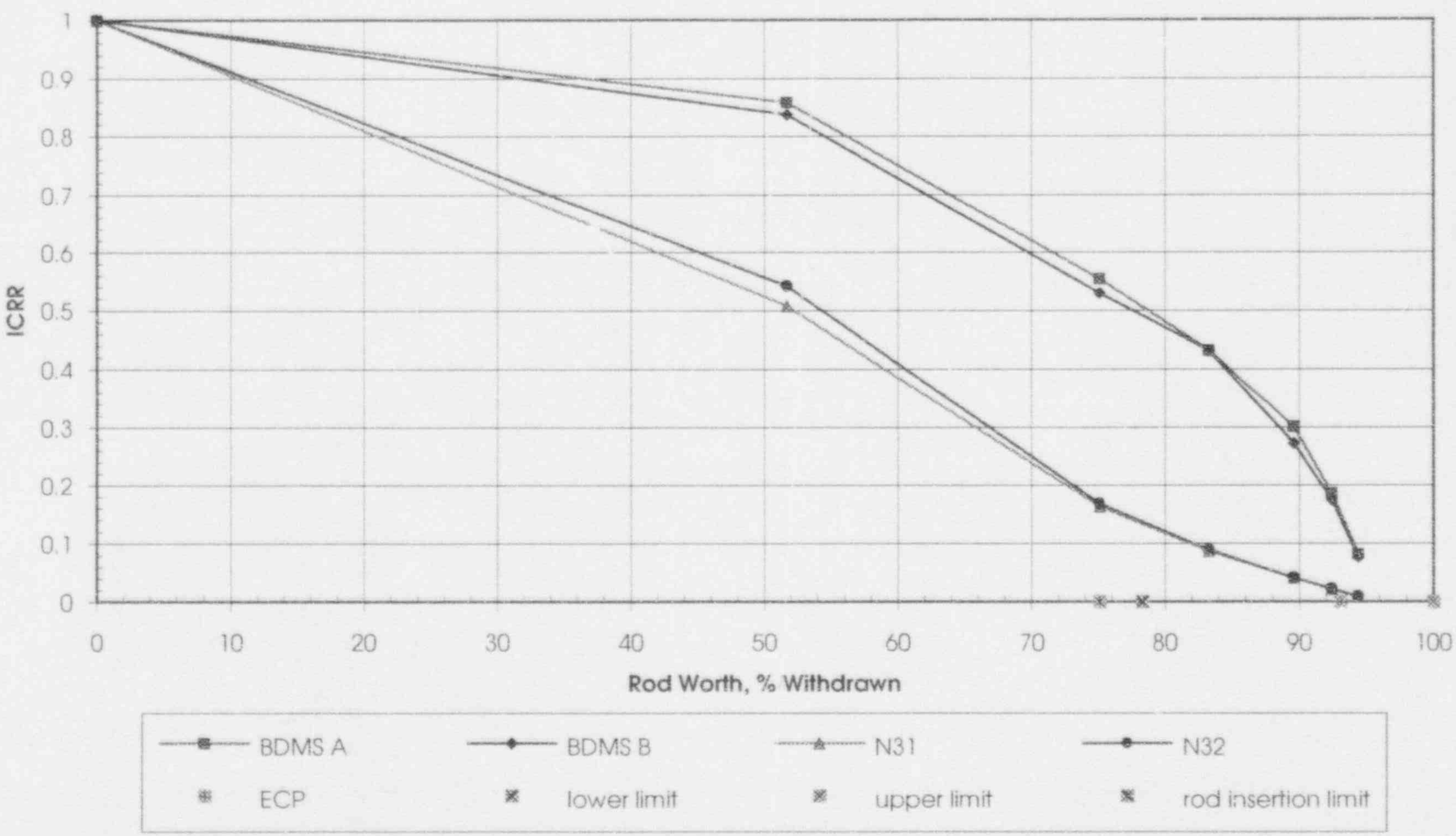
Rod withdrawal for the approach to criticality began at 2148 on July 2, 1994. Criticality was achieved at 0015 on July 3, 1994 with Control Bank D at 117 steps withdrawn.

Figure 3 shows the ICRR plots that were used during the approach to criticality. All acceptance criteria of PT/0/A/4150/19 were met.

TABLE 3
SUMMARY OF ZPPT RESULTS

PARAMETER	MEASURED VALUE	PREDICTED VALUE/ACCEPTANCE CRITERIA
Nuclear Heat	3.0×10^{-7} amps (N44)	N/A
ZPPT Test Band	10^{-8} to 10^{-7} amps (N44)	N/A
ARO Critical Boron	1749 ppmB	1776 ± 50 ppmB
ARO ITC	-3.07 pcm/°F	-3.36 ± 2 pcm/°F
ARO MTC	-1.181 pcm/°F	-1.49 pcm/°F
Reference Bank (Control Bank C) Worth	1009 pcm	951 ± 143 pcm
Ref. Bank in Critical Boron	1619 ppmB	1645 ppmB
Differential Boron Worth	-7.76 pcm/ppmB	-7.26 ± 1.27 pcm/ppmB
Control Bank D Worth	602 pcm	560 ± 200 pcm
Control Bank B Worth	717 pcm	645 ± 200 pcm
Control Bank A Worth	366 pcm	373 ± 200 pcm
Shutdown Bank E Worth	466 pcm	442 ± 200 pcm
Shutdown Bank D Worth	464 pcm	430 ± 200 pcm
Shutdown Bank C Worth	459 pcm	425 ± 200 pcm
Shutdown Bank B Worth	1004 pcm	917 ± 301 pcm
Shutdown Bank A Worth	315 pcm	284 ± 200 pcm
Total Rod Worth	5401 pcm	5027 ± 503 pcm

FIGURE 3
ICRR vs. CONTROL ROD WORTH DURING APPROACH TO CRITICALITY



3.2 Source Range/Intermediate Range Overlap Data

During the initial approach to criticality, source range and intermediate range data was obtained to verify that at least one decade of overlap existed. If one decade of overlap did not exist, intermediate range compensation voltage would have been adjusted to provide the overlap.

Overlap data for Cycle 7 was obtained per PT/0/A/4150/01, Controlling procedure for Startup Physics Testing, on July 3, 1994. Table 4 contains the overlap data. The acceptance criterion was met.

TABLE 4
SOURCE RANGE/ INTERMEDIATE RANGE OVERLAP DATA

	SOURCE RANGE		INTERMEDIATE RANGE	
	N31, cps	N32, cps	N35, amps	N36, amps
INITIAL DATA: NIS Meters	220	190	1×10^{-11}	1×10^{-11}
OAC	216	173	1.092×10^{-11}	1.065×10^{-11}
FINAL DATA: NIS Meters	11,000	8,000	1×10^{-10}	1×10^{-10}
OAC	12,600	9,896	1.055×10^{-10}	1.065×10^{-10}

3.3 Point of Nuclear Heat Addition

The point of nuclear heat addition is measured by trending reactor coolant system temperature, pressurizer level, flux level, and reactivity while slowly increasing reactor power. A slow, constant startup rate is initiated by rod withdrawal. An increase in reactor coolant system temperature and/or pressurizer level accompanied by a change in reactivity and/or rate of flux increase indicates the addition of nuclear heat. The measurement is repeated to ensure confidence in results.

For Cycle 7, the point of nuclear heat addition was determined per PT/0/A/4150/01, Controlling Procedure for Startup Physics Testing, on July 3, 1994. Table 5 summarizes the data obtained.

The zero power physics test band was set at 10^{-8} to 10^{-7} amps on power range channel N41 (connected to reactivity computer). This test band provided more than a factor of two margin to nuclear heat for zero power physics testing. Acceptance criterion was satisfied.

TABLE 5
NUCLEAR HEAT DETERMINATION

	Reactivity Computer (N44), amps	Intermediate Range Channel N35, amps	Intermediate Range Channel N36, amps
RUN #1	4.7×10^{-7}	1.384×10^{-7}	1.236×10^{-7}
RUN #2	3.0×10^{-7}	3.458×10^{-7}	3.381×10^{-7}

3.4 Reactivity Computer Checkout

The reactivity computer checkout was performed per PT/0/A/4150/01, Controlling Procedure for Startup Physics Testing, to verify that the power range channel connected to the reactivity computer can provide reliable reactivity data. Reactivity insertions of approximately +25, -30 and +40 pcm are made. The period is measured and used to determine the theoretical reactivity. The measured reactivity for each case is compared to the theoretical reactivity and verified to be within 4.0%.

The checkout was performed for Cycle 7 on July 3, 1994. The +40 pcm test was repeated since the reactivity addition was needed to build up flux. Table 6 lists the results of the 4 reactivity insertions. The acceptance criterion was met in all 4 cases.

TABLE 6
REACTIVITY COMPUTER CHECKOUT

Period, seconds	Theoretical Reactivity, pcm	Measured Reactivity, pcm	Absolute Error, pcm	Percent Error,%
154.39	40.73	39.69	1.04	2.56
309.57	22.15	21.64	0.51	2.30
-292.71	-29.81	-29.34	0.47	1.58
162.31	39.05	38.65	0.40	1.02

3.5 ARO Boron Endpoint Measurement

This test is performed at the beginning of each cycle to verify that measured and predicted total core reactivity are consistent. The test is performed near the all rods out (ARO) configuration. Reactor coolant system boron samples are obtained while control bank D is pulled to the fully withdrawn position. The reactivity difference from criticality to the ARO configuration is measured and converted to an equivalent boron worth using the predicted differential boron worth. The average measured boron concentration is adjusted accordingly to obtain the ARO critical boron concentration.

The Cycle 7 beginning of cycle, hot zero power, all rods out, critical boron concentration was measured on July 3, 1994 per PT/0/A/4150/10, Boron Endpoint measurement. The measured boron concentration (average of 5 samples) was 1747 ppmB. This value was adjusted by 2 ppmB to yield an ARO concentration of 1749 ppmB. Predicted ARO critical boron concentration was 1776 ppmB. The acceptance criterion, measured boron within 50 ppmB of predicted, was met.

3.6 ARO Isothermal Temperature Coefficient Measurement

The all rods out (ARO) isothermal temperature coefficient (ITC) is measured at the beginning of each cycle to verify consistency with predicted value. In addition, the moderator temperature coefficient (MTC) is obtained by subtracting the doppler temperature coefficient from the ITC. The MTC is used to ensure compliance with Technical Specification limits.

To measure the ITC, a slow (< 20°F/hour) reactor coolant system cooldown is initiated while trending reactivity versus temperature on an X-Y plotter. When sufficient data (approximately 5 °F) is obtained, a heatup is performed while again trending reactivity versus temperature. The slopes of the Reactivity versus temperature lines are used to determine the ITC. The cooldown/heatup cycle is repeated if additional data is required.

The beginning of cycle 7 ITC was measured per PT/0/A/4150/12A, Isothermal Coefficient of Reactivity Measurement, on July 3, 1994. No additional cooldown/heatup cycles were required because of good agreement between the heatup and cooldown results. Table 7 summarizes the data obtained during the measurement.

Average ITC was -3.07 pcm/°F. Predicted ITC was -3.36 pcm/°F. Measured ITC was within acceptance criterion of predicted ITC ± 2 pcm/°F.

The MTC was determined to be -1.18 pcm/°F. This value was used with procedure PT/0/A/4150/21, Temporary Rod Withdrawal Limits Determination, to ensure that MTC would remain within Technical Specification limits at all power levels. No rod withdrawal limits were required.

TABLE 7
ITC MEASUREMENT RESULTS

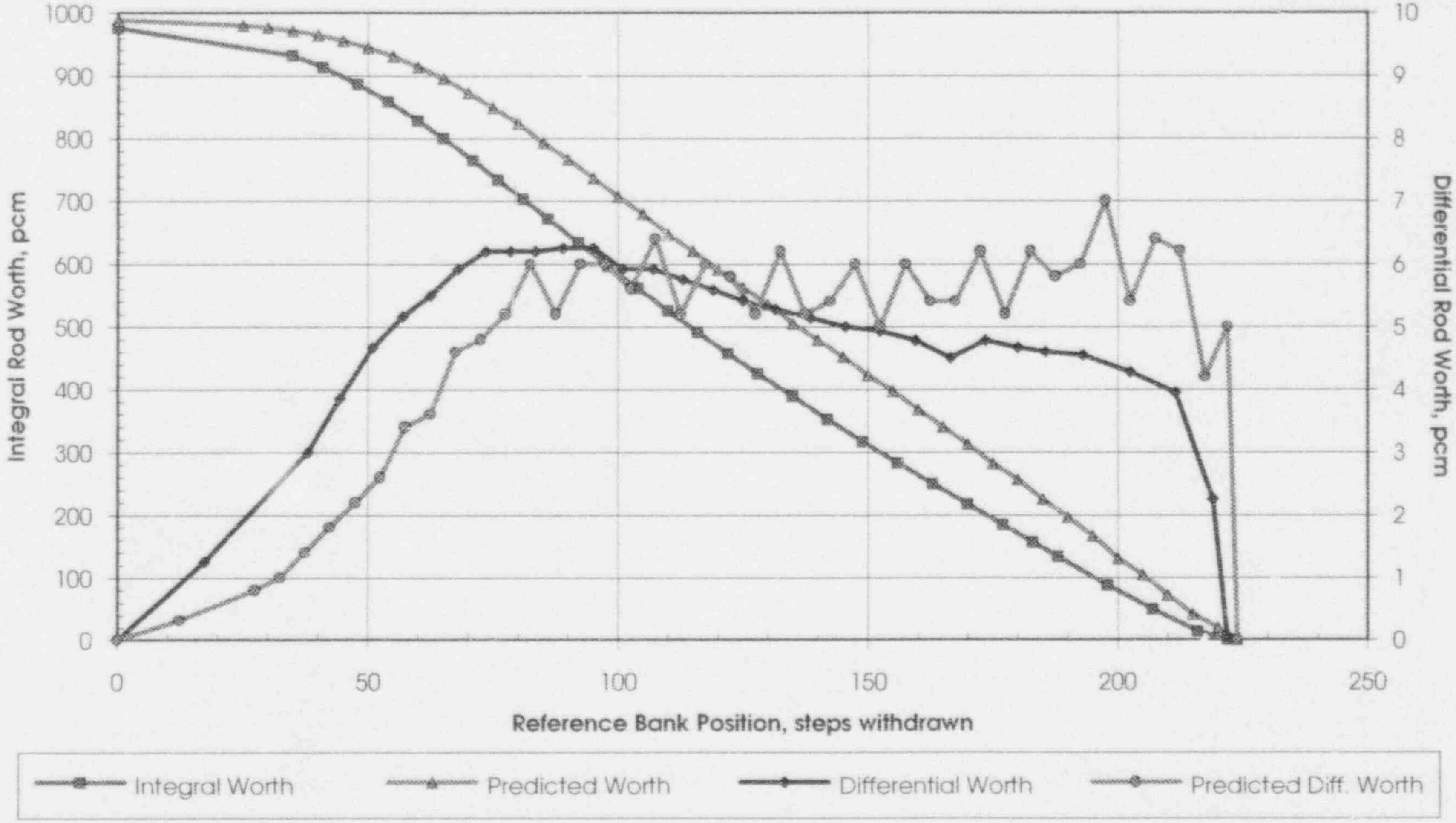
	ΔT, °F	$\Delta\rho$, pcm	T_{avg}, °F	ITC, pcm/°F	
				Uncorrected	Corrected to 557 °F
Cooldown	-5	+13.7	554.5	-2.74	-3.04
Heatup	+5	-14.0	554.5	-2.80	-3.10
				Average:	-3.07

3.7 Reference Bank Worth Measurement by Dilution

The control rod bank predicted to have the highest worth is designated the reference bank and is measured by inserting the bank (with all other rod banks fully withdrawn) in discrete steps while slowly diluting the reactor coolant boron concentration. The reactivity worths of the discrete steps of rod insertion are measured using the reactivity computer and summed to obtain the integral worth of the reference bank.

The beginning of cycle 7 reference bank (Control Bank C) worth was measured on July 3, 1994 per PT/0/A/4150/11A, Control Rod Worth Measurement by Boration/Dilution. Figure 4 shows integral worth of reference bank versus bank position. The reference bank was measured to be worth 1009 pcm; predicted worth was 951 pcm. The acceptance criterion, measured worth within ± 15% of predicted, was met.

FIGURE 4
INTEGRAL AND DIFFERENTIAL WORTH OF REFERENCE BANK



3.8 Reference Bank in Boron Endpoint Measurement

This test is performed at the beginning of each cycle to measure the critical boron concentration with the reference bank fully inserted and all other control rod banks fully withdrawn. The measured boron concentration is used with the measured ARO critical boron concentration and the measured worth of the reference bank to calculate the differential boron worth. Reactor coolant system boron samples are obtained while control rods are inserted or withdrawn to the "Reference Bank in" configuration. The reactivity difference from criticality to the "Reference Bank in" configuration is measured and converted to an equivalent boron worth using the predicted differential boron worth. The average measured boron concentration is adjusted accordingly to obtain the "Reference Bank in" critical boron concentration.

The Cycle 7 beginning of cycle, hot zero power, reference bank in, critical boron concentration was measured on July 3, 1994 per PT/0/A/4150/10, Boron Endpoint measurement. The measured boron concentration (average of 5 samples) was 1617 ppmB. This value was adjusted by 2 ppmB to yield a "Reference Bank in" concentration of 1619 ppmB. Predicted "Reference Bank in" critical boron concentration was 1645 ppmB. There is no quantitative acceptance criteria directly associated with this test.

3.9 Differential Boron Worth Determination

The differential boron worth is calculated from the measured ARO critical boron concentration, Reference Bank in critical boron concentration, and total reactivity worth of reference bank. The calculated value is compared to predicted value to verify consistency. This calculation also provides an indirect check of measured reference bank worth and of the boron endpoint measurements.

The beginning of Cycle 7, hot zero power differential boron worth was calculated to be -7.76 pcm/ppmB per PT/0/A/4150/01, Controlling Procedure for Startup Physics Testing. The predicted value was -7.26 pcm/ppmB. The acceptance criterion (measured within ± 15% of predicted), was met.

3.10 Control Rod Worth Measurement by Rod Swap

The worths of all control rod banks except the reference bank are measured by inserting each bank while withdrawing the reference bank and/or previously measured bank to maintain near critical conditions. When the bank being measured is fully inserted, the reference bank is positioned to achieve critical conditions with all other rod banks fully withdrawn. The worth of the fully inserted bank is determined from the critical position of the reference bank. The measured worth is compared to predicted worth to verify consistency. The sum of the worths of all banks, including the reference bank, is also compared to predicted total.

The beginning of cycle 7 rod worth measurement by rod swap was performed on July 3, 1994 per PT/0/A/4150/11B, Control Rod Worth Measurement by Rod Swap. Table 8 summarizes the results. All acceptance criteria were met.

TABLE 8
CONTROL ROD WORTH MEASUREMENT DATA

Bank	Adjusted Reference Bank Worth	Critical Position of Ref. Bank	Remaining Worth of Ref. Bank	Alpha	Measured Worth, pcm	Predicted Worth, pcm	Difference (Predicted - Measured)	% Diff. (Pred - Meas)/Pred × 100	Acceptance Criteria
Control C (ref. bank)	N/A	N/A	N/A	N/A	1009	951	-58.0	-6.1	951 ± 143 (15%)
Shutdown A	1027.0	90	643	1.108	314.6	284	-30.6	-10.8	284 ± 200 pcm
Control A	1026.3	77	734	0.899	366.4	373	6.6	1.8	373 ± 200 pcm
Shutdown C	1025.6	108	520	1.090	459.0	425	-34.0	-8.0	425 ± 200 pcm
Shutdown D	1024.9	109	513	1.094	463.6	430	-33.6	-7.8	430 ± 200 pcm
Shutdown E	1024.1	97	594	0.940	465.5	442	-23.5	-5.3	442 ± 200 pcm
Control D	1023.4	129	382	1.103	602.1	560	-42.1	-7.5	560 ± 200 pcm
Control B	1022.7	144	294	1.042	716.9	645	-71.9	-11.1	645 ± 200 pcm
Shutdown B	1022.0	209	22	0.835	1003.9	917	-86.9	-9.5	917 ± 275 (30%)
				Total	5401.1	5027	-374.1	-7.4	>5027 - 503 pcm

4.0 POWER ESCALATION TESTING

Power escalation testing is performed during the initial power increase to full power for each cycle and is controlled by PT/0/A/4150/01, Controlling Procedure for Startup Physics Testing. Tests are performed from 0% through 100% power with major testing plateaus at 30%,65%, and 100% power.

Significant tests performed during power escalation are:

- •Core Power Distribution (at 30%, 65%, and 100% power)
- •One-Point Incore/Excore Calibration (at 30% power)
- •Reactor Coolant Delta Temperature Measurement (at 65% and 100% power)
- •Hot Full Power Critical Boron Concentration Measurement (at 100% power)
- •Reactor Coolant Flow Measurement by Precision Calorimetric (at 100% power)
- •Incore/Excore Calibration (at 100% power)

In addition to the tests listed above, PT/0/A/4150/01 performs checks on the incore detector system, on-line thermal power program, intermediate range setpoints, etc. The results of these checks are not included in this report.

Power escalation testing for Catawba 2 Cycle 7 began on July 4, 1994. Full power was reached on July 9, 1994. On July 9, 1994 the Reactor was manually tripped at 55% F. P. after a runback from 100% due to loss of CFPT 2A.. Full power was again achieved on July 15, 1994. Full power testing was completed on July 21, 1994.

Sections 4.1 through 4.6 describe the significant tests performed during power escalation and their results.

4.1 Core Power Distribution

Core power distribution measurements are performed during power escalation at low power (approximately 30%), intermediate power (approximately 65%), and full power. Measurements are made to verify flux symmetry and to verify core peaking factors are within limits. Data obtained during this test are also used to check calibration of power range channels and to calibrate them if required (see sections 4.2 and 4.6). Measurements are made using the moveable incore detector system and analyzed using Duke Power's CORE and MONITOR codes (adapted from Shangstrom Nuclear Associates' CORE package and BWFC's MONITOR code, respectively).

The Catawba 2 Cycle 7 core power distribution measurements were performed on July 5, 1994 (30% power), July 7, 1994 (65% power), and July 17, 1994 (100% power). Table 9 through 11 summarize the results. All acceptance criteria were met.

TABLE 9
CORE POWER DISTRIBUTION RESULTS
30% POWER

Plant Data

Map ID:	FCM/2/07/01
Date of Map:	July 5, 1994
Cycle Burnup:	0.166 EFPD
Power Level:	29.64%
Control Rod Position:	Control Bank D at 218 steps withdrawn
Reactor Coolant System Boron Concentration:	1550 ppmB

CORE Results

Core Average Axial Offset:	12.504%
Tilt Ratios for Entire Core Height: Quadrant 1:	0.99657
Quadrant 2:	1.00250
Quadrant 3:	0.99176
Quadrant 4:	1.00916
Maximum F_Q (nuclear):	1.987
Maximum $F_{\Delta H}$ (nuclear):	1.481
Maximum Error between Pred. and Meas $F_{\Delta H}$:	7.57%
Average Error between Pred. and Meas. $F_{\Delta H}$:	2.67%
Maximum Error between Expected and Measured Detector Response:	5.80%
RMS of Errors between Expected and Measured Detector Response:	3.4%

MONITOR Results

Minimum F_Q Operational Margin:	71.26%
Minimum F_Q RPS Margin:	25.64%
Minimum F_Q LCO Margin:	53.42%
Minimum $F_{\Delta H}$ Surveillance Margin:	42.41%
Minimum $F_{\Delta H}$ LCO Margin:	20.29%

TABLE 10
CORE POWER DISTRIBUTION RESULTS
65% POWER

Plant Data

Map ID:	FCM/2/07/02
Date of Map:	July 7, 1994
Cycle Burnup:	0.963 EFPD
Power Level:	63.67%
Control Rod Position:	Control Bank D at 215 steps withdrawn
Reactor Coolant System Boron Concentration:	1380ppmB

CORE Results

Core Average Axial Offset:	4.272 %
Tilt Ratios for Entire Core Height: Quadrant 1:	1.00221
Quadrant 2:	0.99825
Quadrant 3:	0.99277
Quadrant 4:	1.00676
Maximum F_Q (nuclear):	1.794
Maximum $F_{\Delta H}$ (nuclear):	1.414
Maximum Error between Pred. and Meas $F_{\Delta H}$:	6.0%
Average Error between Pred. and Meas. $F_{\Delta H}$:	1.40%
Maximum Error between Expected and Measured Detector Response:	6.10%
RMS of Errors between Expected and Measured Detector Response:	2.00%

MONITOR Results

Minimum F_Q Operational Margin:	32.30%
Minimum F_Q RPS Margin:	24.29%
Minimum F_Q LCO Margin:	46.73%
Minimum $F_{\Delta H}$ Surveillance Margin:	35.33%
Minimum $F_{\Delta H}$ LCO Margin:	20.04%

TABLE 11
CORE POWER DISTRIBUTION RESULTS
100% POWER

Plant Data

Map ID:	FCM/2/07/03
Date of Map:	July 17, 1994
Cycle Burnup:	7.852 EFPD
Power Level:	99.79%
Control Rod Position:	Control Bank D at 212 steps withdrawn
Reactor Coolant System Boron Concentration:	1149 ppmB

CORE Results

Core Average Axial Offset:	-3.616%
Tilt Ratios for Entire Core Height: Quadrant 1:	0.99972
Quadrant 2:	1.00379
Quadrant 3:	0.98695
Quadrant 4:	1.00954
Maximum F_Q (nuclear):	1.791
Maximum $F_{\Delta H}$ (nuclear):	1.416
Maximum Error between Pred. and Meas $F_{\Delta H}$:	3.28%
Average Error between Pred. and Meas. $F_{\Delta H}$:	1.13%
Maximum Error between Expected and Measured Detector Response:	3.4%
RMS of Errors between Expected and Measured Detector Response:	1.5%

MONITOR Results

Minimum F_Q Operational Margin:	2.66 %
Minimum F_Q RPS Margin:	22.20%
Minimum F_Q LCO Margin:	16.69%
Minimum $F_{\Delta H}$ Surveillance Margin:	5.21%
Minimum $F_{\Delta H}$ LCO Margin:	12.17%

4.2 One-Point Incore/Excore Calibration

PT/0/A/4600/05D, One-Point Incore/Excore Calibration, is performed using results of power range data taken at 30% power and the incore axial offset measured at 30%. Power ranges are calibrated before exceeding 50% in order to have valid indications of axial flux difference and quadrant power tilt ratio for subsequent power increase. The calibration is checked at 65% power. If necessary, power ranges are calibrated again per PT/0/A/4600/05D or PT/0/A/4600/05A, Incore/Excore Calibration.

Data for Catawba 2 Cycle 7 was obtained on July 5, 1994 and all power range calibrations were completed on July 6, 1994. Results are listed in Table 12. All acceptance criteria were met.

TABLE 12
ONE-POINT INCORE/EXCORE CALIBRATION RESULTS

Reactor Power = 29.64%   Axial Offset = 12.504%

Measured Power Range Currents, µAmps

	N41	N42	N43	N44
Upper	80.7	65.3	74.8	68.0
Lower	72.8	61.0	70.2	63.5

Ratio, Extrapolated (from measured) Currents to "Expected" (from last calibration) Currents

	N41	N42	N43	N44
Upper	0.8456	0.8457	0.8391	0.8290
Lower	0.8900	0.8911	0.8919	0.8782

New Calibration Currents, µAmps

Axial Offset, %	N41		N42		N43		N44	
	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower
+20	286.5	230.9	231.3	193.4	266.4	223.1	241.5	201.9
0	248.5	270.2	202.0	226.5	228.9	259.8	209.4	234.8
-20	210.6	309.5	172.7	259.6	191.5	296.6	177.2	267.7

4.3 Reactor Coolant Loop Delta Temperature Measurement

Reactor coolant system (NC) hot leg and cold leg temperature data is obtained between 50% and 80% power and at 100% power per PT/0/A/4600/26, NC Temperature Calibration, to ensure that full power delta temperature constants (ΔT_0) are valid. ΔT_0 is used in the overpower and overtemperature delta temperature reactor protection functions.

PT/0/A/4600/26 was performed at 64% power on 7/7/94 and at 100% power on 7/17/94. No adjustments were required based on results obtained at 64% power. Loops A, B, and D were calibrated using full power results. Table 13 summarizes the test results.

TABLE 13
REACTOR COOLANT DELTA TEMPERATURE DATA

Reactor Power = 63.96%

	Loop A	Loop B	Loop C	Loop D
Meas. T_{HOT}, °F	594.5	596.0	595.1	596.0
Meas. T_{COLD}, °F	556.2	556.8	556.6	557.2
Calc. Δh, BTU/lb	50.50	51.87	50.91	51.39
Calc. Δh_0, BTU/lb	78.96	81.09	79.59	80.35
Calc. ΔT_0, °F	57.0	58.4	57.4	57.9
Current ΔT_0, °F	56.8	58.8	57.9	56.6
Difference, °F	+0.2	-0.4	-0.5	+1.3

Reactor Power = 99.89%

	Loop A	Loop B	Loop C	Loop D
Meas. T_{HOT}, °F	617.9	620.6	618.6	620.6
Meas. T_{COLD}, °F	560.1	560.8	560.6	561.6
Calc. Δh, BTU/lb	79.94	83.26	80.42	82.19
Calc. Δh_0, BTU/lb	80.03	83.35	80.51	82.28
Calc. ΔT_0, °F	57.9	59.9	58.1	59.0
Current ΔT_0, °F	56.8	58.8	57.9	56.6
Difference, °F	+1.1	+1.1	+0.2	+2.4

4.4 Hot Full Power Critical Boron Concentration Measurement

The hot full power critical boron concentration is measured using PT/0/A/4150/04, Reactivity Anomaly Calculation. Reactor coolant boron concentration is measured (average of three samples) with reactor at essentially all rods out, hot full power, equilibrium xenon conditions. The measured boron is corrected for any off-reference condition (e.g. inserted rod worth, temperature error, difference from equilibrium xenon) and compared to predicted value.

For the purposes of Startup Physics testing, the predicted critical boron concentration is adjusted for the difference between predicted and measured critical boron concentration measured at zero power. The difference between measured boron concentration and adjusted predicted value is used to compare to acceptance criterion(±50 ppmB).

For Catawba 2 Cycle 7, the hot full power critical boron concentration was measured on July 20, 1994. The measured critical boron concentration was 1152.8 ppmB. Predicted critical boron concentration was 1158.4 ppmB; when adjusted for difference at zero power, the adjusted predicted critical boron concentration was 1131 ppmB. The difference between measured and adjusted predicted critical boron concentration was -21.7 ppmB, which met the acceptance criterion.

4.5 Calorimetric Reactor Coolant Flow Measurement

Reactor coolant flow is measured using a precision calorimetric based on secondary side parameters (feedwater flow, feedwater temperature, steam pressure) with reactor coolant temperature data. Pressure drop data for each of the reactor coolant elbow taps is also obtained. Measured reactor coolant flow is used with pressure drop data to obtain a correction factor for each elbow tap to convert pressure drop to mass and volumetric flow rate. Reactor coolant flow as measured by elbow taps is used to perform Technical Specification surveillances on reactor coolant flow and in the primary side calculation of thermal power.

For Catawba 2 Cycle 7, the calorimetric flow measurement was performed on July 20, 1994, per PT/2/A/4150/13B, Calorimetric Reactor Coolant Flow Measurement. Three test runs were performed; the average of the results was used for comparison to Technical Specification flow limit and for elbow tap correction factors. Table 14 summarizes the results. All acceptance criteria were met.

TABLE 14
CALORIMETRIC REACTOR COOLANT FLOW MEASUREMENT DATA

Test Run Number	Reactor Power, %	Calculated Reactor Coolant Flow Rate, gpm					% of Tech Spec Flow
		Loop A	Loop B	Loop C	Loop D	Total	
1	99.460	95,031	96,843	98,677	98,413	388,963	101.024
2	99.104	95,018	96,824	98,648	98,372	388,862	101.003
3	99.095	95,037	96,788	98,611	98,414	388,850	101.000

Average of total reactor coolant flow for the three test runs is 388,892 gpm.

Reactor Coolant Flow Channel	Elbow Tap Correction Factor			
	Loop A	Loop B	Loop C	Loop D
1	0.298220	0.297966	0.309416	0.296364
2	0.286113	0.281457	0.291395	0.294453
3	0.294320	0.297773	0.298145	0.295479

4.6 Incore/Excore Calibration

Excore power range channels are calibrated at full power per PT/0/A/4600/05A, Incore/Excore Calibration. Incore data (flux maps) and power range currents are obtained at various axial power distribution. A least squares fit of the output of each detector (upper and lower chambers) as a function of measured incore axial offset is determined. The slopes and intercepts of the fit for the upper and lower chamber for each channel are used to determine calibration data for that channel.

This test was performed for Catawba 2 Cycle 7 on July 18 and July 19, 1994. All power range calibrations were completed on July 21, 1994. Eight flux maps, with axial offset ranging from -10.333% to +1.728% were used. Table 15 summarizes the results. All acceptance criteria were met.

TABLE 15
INCORE/EXCORE CALIBRATION RESULTS

Full Power Currents, Microamps

Axial Offset, %	N41		N42		N43		N44	
	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower
+20%	331.5	259.2	268.4	217.5	313.2	251.3	282.0	227.8
0%	291.5	305.2	236.8	253.8	271.5	292.7	246.2	264.8
-20%	251.5	351.1	205.3	290.0	229.7	334.1	210.4	301.8

Correction (M_J) Factors

N41	N42	N43	N44
1.389	1.450	1.355	1.403