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U.S. NUCLEAR REGULATORY COMMISSION

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TO: Mr. Benard C. Rusche

FROM: Duke Power Company, Charlotte, N. C., Mr. William O. Parker, Jr.

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PLANT NAME: (1-P)

Oconee Unit No. 3

ENCLOSURE

DUKE POWER COMPANY
OCONEE NUCLEAR STATION
UNIT 3, CYCLE 2
STARTUP TESTING SUMMARY

March 1, 1977 -

(15-P)

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2173 287 MA 2 60

NRC FORM 195 (2-76)

DUKE POWER COMPANY
STEAM PRODUCTION DEPT.
GENERAL OFFICES
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CHARLOTTE, N. C. 28242

P. O. BOX 2178

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373-4011

March 1, 1977

Mr. Benard C. Rusche, Director
Office of Nuclear Reactor Regulation
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

Attention: Mr. A. Schwencer, Chief
Operating Reactor Branch #1

Reference: Oconee Unit 3
Docket No. 50-287

Dear Sir:

In response to your letter of October 12, 1976, the attached summary of the startup testing performed for Oconee 3, Cycle 2 is provided.

Very truly yours,

W.O. Parker, Jr.

William O. Parker, Jr. By MST

MST:ge

Attachment

DUKE POWER COMPANY

OCONEE NUCLEAR STATION

UNIT 3, CYCLE 2

STARTUP TESTING SUMMARY

March 1, 1977

DUKE POWER COMPANY
OCONEE NUCLEAR STATION
UNIT 3, CYCLE 2
STARTUP TESTING SUMMARY

INTRODUCTION

The Cycle 2 Startup Test Program for Oconee Unit 3 consisted of pre-critical tests, zero power physics tests, and power escalation tests. This report provides a summary of the zero power and power escalation test results and includes, where appropriate, comparisons of measured and predicted values of important core parameters.

The zero power physics testing was initiated on October 29, 1976, and was completed on November 11, 1976. Testing was conducted with the reactor at Hot Zero Power conditions (532°F, 2155 psig, and 0% FP). The core parameters measured included all-rods-out critical boron concentration, isothermal temperature and moderate coefficients of reactivity, individual control rod groups and total group reactivity worths, and differential boron worth measurements. The measurements and results are further described in Section I.

Following satisfactory completion of zero power physics testing, the power escalation testing began on November 11, 1976, and was completed on December 3, 1976. The power escalation tests included core power distribution measurements at approximately 40% FP, 75% FP and 100% FP; power imbalance detector correlation tests; andmeasurements of reactivity coefficients at power. All tests met their respective acceptance criteria. Section II describes the individual tests in more detail and summarizes the results of these tests.

I. ZERO POWER PHYSICS TESTING

A. Initial Criticality

Cycle 2 initial criticality was achieved on Oconee 3 at 13:24 hours on November 7, 1976 by first withdrawing control rods (Group 70 to 75% withdrawn and Group 8 to 15% withdrawn) and initiating a continuous but regulated feed and bleed deboration of the Reactor Coolant System. Inverse multiplication plots versus boron concentration and time were maintained, and the feed and bleed was terminated when these plots reached a value of approximately 0.15. Criticality was then achieved by withdrawing Control Rod Group 7 from 75% to 81% withdrawn, with equilibrium conditions reached at 14:15 hours with Control Rod Group 7 at 84% withdrawn, and a Reactor Coolant System boron concentration of 1288 ppm.

This measured critical boron concentration of 1288 ppm met the acceptance criterion of 1200 ppm $\pm$100 ppm.

B. All Regulating Rods Out Boron Concentration

The all rods out configuration was achieved by boration of Control Rod Group 7 to approximately 95% withdrawn, and then achieving equilibrium boron conditions within the Reactor Coolant System. The Reactor Coolant System boron concentration at these equilibrium conditions was sampled and measured to be 1313 ppm. Control Rod Group 7 was then withdrawn to its out limit, and the resulting reactivity insertion corresponded to a 2 ppm increase in boron concentration. The measured All Rods Out Boron concentration with Control Rod Group 8 at 15% withdrawn was therefore 1315 ppm.

This value of 1315 ppm met the acceptance criterion of 1253 ppm $\pm$100 ppm.

C. Temperature Coefficients of Reactivity

With Control Rod Group 7 at 94% withdrawn and Control Rod Group 8 at 15% withdrawn, the Reactor Coolant System average temperature was varied from 532°F to 526°F, from 526°F to 536°F, and from 536°F to 532°F. A temperature coefficient was then calculated for each temperature ramp by dividing the reactivity changes by their corresponding temperature changes. The average value was calculated to be $-1.0 \times 10^{-5} (\Delta K/K)/°F$, which falls within the acceptance criterion limits of $-1.05 \times 10^{-5} (\Delta K/K)/°F \pm 0.4 \times 10^{-4} (\Delta K/K)/°F$ for that boron concentration.

By substracting the isothermal Doppler coefficient, the moderator coefficient of reactivity for each ramp was calculated and the average value was found to be $+1.1 \times 10^{-5} (\Delta K/K)/°F$. This measured moderator coefficient value is less than $0.5 \times 10^{-4} (\Delta K/K)/°F$, and therefore meets the acceptance criterion.

D. Control Rod Worth Measurements

Group integral and differential worths were obtained for Control Rod Groups 4 through 7 with Group 8 at 15% withdrawn by deboration from an all-rods-out configuration. In addition, Safety Rod Groups 1 through 3 were measured by a control rod drop. The measured reactivity worths of Control Rod Groups 6 and 7 met the acceptance criterion of predicted value ±20% of the measured value; however, the measured value of Control Rod Group 5, based upon an initial analysis of the experimental data, did not meet the acceptance criterion, and therefore the worth of Control Rod Group 4 was also measured.

A subsequent review of the experimental data indicated that there was a systematic error in the analysis of Control Rod Group 5, and upon correcting this error, the measured value of Control Rod Group 5 fell within the acceptance criteria. The measured value of Control Rod Group 4, however, did not meet the acceptance criterion, and its reactivity worth was again measured this time by boration, which yielded results consistent with the previous measurement.

The safety significance of the discrepancy between the measured and the predicted values of Control Rod Group 4 upon power operation of the unit was reviewed in detail, and it was concluded that since the measured values of each of the Control Rod Groups were less than the predicted values, the predicted values of the worst case stuck and ejected rods worths would be conservative. Since the total worth of the measured groups met the acceptance criterion, and since the calculated values of the beginning of cycle shutdown margin were much greater than the required margin, it was concluded that adequate shutdown margin would exist for power operation.

As an additional precaution, however, a rod drop measurement of safety rod groups 1 through 3 was performed. This reactivity, when combined with the worth of the other control rod groups already measured, yielded a value of measured total control rod worth within 4% of the predicted value, thus demonstrating an adequate shutdown margin.

Revised control rod worths were then obtained from Babcock and Wilcox utilizing their RISDM-PDQ-07, 2D, discrete model, which was not used for the previously generated control rod worths. Utilizing this revised predicted worth, the measured value of Control Rod Group 4 fell well within the acceptance criterion.

Table 1 illustrates the control rod worth measurement data as well as comparisons to pertinent predicted values.

E. Boron Worth Measurements

Initially, the measured differential boron worth showed a small deviation from the predicted value of 0.99%(ΔK/K)/100 ppm. A reanalysis of the boron samples indicated some inconsistencies in the initial sample measurements. Upon correcting the affected boron concentrations for this error, a differential boron worth of 1.038%ΔK/K/100ppm was obtained, and met the acceptance criterion.

F. Ejected Rod Worth Measurement

In order to measure the worst case ejected control rod worth, Rod 4 in Control Rod Group 6 (predicted to be the most reactive rod) was borated out of the core while Control Rod Group 5 was maintained at 0% withdrawn and Control Rod Group 8 at 15% withdrawn. The measured worst case ejected rod worth adjusted for all control rods inserted was 0.57%(ΔK/K). The error adjusted worst case ejected rod worth was calculated to be 0.60%(ΔK/K), which meets the acceptance criterion requiring the error adjusted worth to be less than 1.0%(ΔK/K).

II. POWER ESCALATION SEQUENCE TESTING

A. Core Power Distribution Results

Core power distribution measurements were performed at 40% FP, 75% FP, and 100% FP in order to verify that the measured power distribution is consistent with the predicted distribution. Corrected instrument readings from the incore instrumentation were taken from the process computer while the plant was operating at these power plateaus and were then compared to calculated power distributions at comparable burn-up, rod pattern, boron concentration, and power levels. The two power distributions were then compared, but no significant discrepancies were noted.

The results of these comparisons are shown on the enclosed eighth core maps of radial and total peaking factors.

During the execution of the core power distribution test, the following parameters were checked:

1. SPND background readings and background corrections
2. Reactor Power Imbalance Values
3. Worst case extrapolated minimum DNBR
4. Quadrant power tilt
5. Extrapolated worst case maximum linear heat rate
6. Non-extrapolated worst case maximum linear heat rate
7. Tilt and imbalance values from back-up incore detectors.

All values checked were found to be reasonable and met the acceptance criteria applied to them. Table 2 provides the results of the minimum DNBR and maximum linear heat rate measurements and extrapolations and shows that all values, both extrapolated and measured, met the acceptance criteria.

B. Power Imbalance Detector Correlation Test Results

The power imbalance detector correlation test was performed at the 75% full power plateau to verify that the out-of-core detectors measure core offset within the tolerances assumed in the Safety Analysis (i.e., out-of-core offset = incore offset $\pm 3.5\%$). The test verified that all four out-of-core detectors satisfy the desired offset correlation. A comparison of incore detector imbalance to back-up recorder imbalance showed that for all values of imbalance measured, the maximum difference was 4.9% of imbalance, which is well within the $\pm 7.5\%$ acceptance criteria for incore to back-up incore calculated offset.

C. Reactivity Coefficient at Power

Both the temperature coefficient of reactivity and the power coefficient of reactivity were measured at the 100% full power plateau with no difficulties encountered. The temperature coefficient was measured to be $-0.6816 \times 10^{-4}(\Delta K/K)/°F$. This value met the acceptance criterion requiring the moderator temperature coefficient to be nonpositive. The measured power coefficient was $-0.719 \times 10^{-4}(\Delta K/K)/\%$ full power and met the acceptance criterion that it be less than or equal to $-0.55 \times 10^{-4}(\Delta K/K)/\%FP$.

TABLE 1

SUMMARY OF CONTROL ROD WORTH MEASUREMENTS

CONTROL ROD GROUP	BORON ENDPOINT (ppmB)	ORIGINAL PREDICTED WORTH (%ΔK/K)	REVISED PREDICTED WORTH (%ΔK/K)	MEASURED WORTH (%ΔK/K)	% DEVIATION FROM PREDICTED	
					ORIGINAL	REVISED
Group 7	1313(ARO) 1200	0.85	0.78	0.762	-10.35	-2.3
Group 6	1113	1.15	1.16	1.043	-9.30	-10.08
Group 5	1056	0.76	0.77	0.6666	-12.37	-13.51
Group 4	987	1.01	0.84	0.803	-20.50	-4.40
Group 1-3	N/A	6.01	5.61	6.10	+1.5	8.7
TOTAL 1-7	N/A	9.98	9.16	9.4	-3.9	+2.6

TABLE 2

TABULATED RESULTS OF MINIMUM DNBR AND MAXIMUM LINEAR HEAT RATE CALCULATIONS

POWER LEVEL %FP	WORST CASE MAXIMUM LINEAR HEAT RATE (KW/FT)	MAXIMUM ACCEPTABLE WORST CASE MAXIMUM LHR (KW/FT)	WORST CASE MINIMUM DNBR	EXTRA-POLATION POWER LEVEL	WORST CASE EXTRA-POLATED MAXIMUM LHR (KW/FT)	MAXIMUM ACCEPTABLE WORST CASE EXTRAP. MAXIMUM LHR (KW/FT)	WORST CASE EXTRA-POLATED MINIMUM DNBR	MINIMUM ACCEPTABLE WORST CASE EXTRA MINIMUM DNBR
39.68	5.18	15.5	8.31	85.5	11.00	20.15	2.38	1.30
74.48	9.17	15.5	4.20	105.5	12.48	20.15	2.31	1.30
99.07	13.645	15.5	2.97	105.5	13.98	20.15	2.25	1.30

40% FP RADIAL PEAKING FACTORS

FIGURE 1

	8	9	10	11	12	13	14	15
H	1.00 1.15	0.958 1.09	0.963 1.07	1.056 1.06	1.205 1.22	0.89 0.85	0.809 0.80	0.705 0.64
K		1.118 1.23	1.295 1.21	1.15 1.15	1.327 1.35	0.644 0.62	0.665 0.71	0.6277 0.59
L			1.020 1.08	1.057 1.11	1.267 1.17	0.9642 0.98	0.9301 1.05	0.5538 0.52
M				1.389 1.41	1.416 1.34	1.2486 1.27	0.966 0.99	
N					1.061 1.09	1.2154 1.10	0.6902 0.70	
O					MEASURED PREDICTED	0.7677 0.74		

Largest Predicted Peak = 1.41
Largest Measured Peak = 1.416
Deviation = -0.4%

Core conditions for Predicted Peaking Factor

Group 6 = 90.3% wd

Group 7 = 12.9% wd

Group 8 = 38.4% wd

Imbalance = +0.25% FP

Offset = +0.62%

Core Burn-up = 2.0 EFPD

Core Conditions for Measured Peaking Factors

Group 6 = 92.7% wd

Group 7 = 16.6% wd

Group 8 = 37.6% wd

Axial Imbalance = 1.43% FP

Max. Quadrant Tilt = 1.44%

Core Burn-up = 2.0 EFPD

Core Power = 39.68%F

40% FP TOTAL PEAKING FACTORS

FIGURE 2

	8	9	10	11	12	13	14	15
H	1.384 1.48	1.34 1.41	1.37 1.35	1.27 1.32	1.56 1.50	1.063 1.01	1.005 0.93	0.822 0.74
K		1.635 1.60	1.848 1.57	1.572 1.47	1.668 1.69	0.825 0.70	0.802 0.82	0.778 0.68
L			1.397 1.35	1.282 1.39	1.6325 1.59	1.215 1.19	1.115 1.26	0.6565 0.61
M				1.79 1.75	1.861 1.68	1.52 1.54	1.203 1.18	
N					1.348 1.37	1.573 1.33	0.858 0.84	
O					MEASURED PREDICTED	0.969 0.90		

Largest Predicted Peak = 1.75
Largest Measured Peak = 1.861
Deviation = -6.3%

Core Conditions for Predicted Peaking Factors:

Group 6 = 90.3% wd

Group 7 = 12.9% wd

Group 8 = 38.4%

Imbalance = +0.25% FP

Offset = 0.62%

Core Burn-up = 2.0 EFPD

Core Conditions for Measured Peaking Factors:

Group 6 = 92.7% wd

Group 7 = 16.6% wd

Group 8 = 37.6% wd

Axial Imbalance = 1.43% FP

Max. Quadrant Tilt = 1.44%

Core Burn-up = 2.0 EFPD

Core Power = 39.68% FP

75% FP RADIAL PEAKING FACTORS

FIGURE 3

	8	9	10	11	12	13	14	15
H	0.987 1.13	0.938 1.08	0.928 1.03	1.055 1.05	1.184 1.21	0.896 0.86	0.818 0.82	0.723 0.67
K		1.099 1.21	1.268 1.19	1.129 1.14	1.333 1.34	0.642 0.63	0.681 0.73	0.652 0.62
L			0.995 1.07	1.068 1.10	1.213 1.15	1.004 0.98	0.919 1.07	0.571 0.54
M				1.373 1.38	1.391 1.31	1.310 1.25	0.991 1.00	
N					1.042 1.08	1.207 1.10	0.706 0.72	
O					MEASURED PREDICTED	0.784 0.75		

Largest Predicted Peaking Factor = 1.38
Largest Measured Peaking Factor = 1.391
Deviation = -0.8%

Core Conditions for Predicted Peaking Factors

Group 6 = 90.3% wd

Group 7 = 12.9% wd

Group 8 = 32.3% wd

Imbalance = -0.28% FP

Offset = -0.37%

Core Burn-up = 4.0 EFPP

Core Conditions for Measured Peaking Factors

Group 6 = 92.7% wd

Group 7 = 16.6% wd

Group 8 = 37.6% wd

Axial Imbalance = 1.43%FP

Max. Quadrant Tilt = 1.4%

Core Burn-up = 4.03 EFPD

Core Power = 75% FP

75% FP TOTAL PEAKING FACTORS

FIGURE 4

	8	9	10	11	12	13	14	15
H	1.227 1.42	1.169 1.35	1.232 1.31	1.184 1.28	1.421 1.48	1.014 1.01	0.9726 0.96	0.82148 0.80
K		1.456 1.51	1.655 1.48	1.412 1.40	1.630 1.69	0.738 0.77	0.825 0.87	0.760 0.75
L			1.234 1.31	1.343 1.35	1.514 1.55	1.221 1.23	1.152 1.33	0.674 0.66
M				1.700 1.67	1.696 1.61	1.586 1.51	1.161 1.22	
N					1.250 1.32	1.442 1.31	0.828 0.85	
O						0.909 0.89		

MEASURED 0.909

PREDICTED 0.89

Largest Predicted PF = 1.67
Largest Measured PF = 1.70
Deviation = -1.8%

Core Conditions for Predicted Peaking Factors

Group 6 = 90.3% wd

Group 7 = 12.9% wd

Group 8 = 32.3% wd

Imbalance = -0.28 FP

Offset = -0.37%

Core Burn-up = 4.0 EFPD

Core Conditions for Measured Peaking Factors

Group 6 = 92.7% wd

Group 7 = 16.6% wd

Group 8 = 37.6% wd

Axial Imbalance = 1.43% FP

Max. Quadrant Tilt = 1.4%

Core Burn-up = 4.03 EFPD

Core Power = 75% FP

100% FP RADIAL PEAKING FACTORS

FIGURE 5

	8	9	10	11	12	13	14	15
H	0.986 1.13	0.933 1.08	0.923 1.03	1.053 1.05	1.163 1.20	0.916 0.86	0.816 0.83	0.744 0.68
K		1.092 1.20	1.258 1.19	1.121 1.13	1.328 1.33	0.653 0.64	0.702 0.74	0.67 0.63
L			0.984 1.07	1.052 1.10	1.18 1.15	1.01 0.98	0.93 1.08	0.58 0.56
M				1.359 1.36	1.37 1.30	1.32 1.25	0.997 1.01	
N					1.024 1.08	1.20 1.10	0.71 0.72	
O						0.82 0.82		

MEASURED
PREDICTED

Largest Predicted Peaking Factor = 1.36
Largest Measured Peaking Factor = 1.37
Deviation = -0.7%

Core Conditions for Predicted Peaking Factors

Group = 90.3% wd

Group 7 = 12.9%

Group 8 = 32.3% wd

Imbalance = -4.37% wd

Offset = -4.3%

Core Burn-up = 4.0 EFPD

Core Conditions for Measured Peaking Factors

Group 6 = 86.6% wd

Group 7 = 14% wd

Group 8 = 19.5% wd

Axial Imbalance = -2.74%FP

Maximum Quadrant Tilt = 1.25%

Core Burn-up = 6.52 EFPD

Core Power = 99.07% FP

100% FP TOTAL PEAKING FACTORS

FIGURE 6

	8	9	10	11	12	13	14	15
H	1.17 1.36	1.10 1.29	1.18 1.25	1.21 1.29	1.34 1.54	1.11 1.06	1.01 1.02	0.89 0.86
K		1.39 1.43	1.57 1.40	1.33 1.38	1.63 1.76	1.02 0.82	0.88 0.92	0.82 0.80
L			1.16 1.30	1.28 1.40	1.47 1.61	1.23 1.29	1.20 1.40	0.72 0.71
M				1.53 1.74	1.67 1.66	1.59 1.58	1.19 1.29	
N					1.26 1.37	1.42 1.37	0.86 0.91	
O					MEASURED PREDICTED	0.93 0.94		

Largest Predicted PF = 1.74
Largest Mearsured PF = 1.67
Deviation = 4.0%

Core Conditions for Predicted Peaking Factors

Group 6 = 90.3% wd

Group 7 = 12.9% wd

Group 8 = 32.3% wd

Imbalance = -4.37% FP

Offset = -4.37%

Core Burn-up: 4.0 EFPD

Core Conditions for Measured Peaking Factors

Group 6 = 86.6% wd

Group 7 = 14% wd

Group 8 = 19.5% wd

Axial Imbalance = -2.74% FP

Maximum Quadrant Tilt = 1.25%

Core Burn-up = 6.52 EFPD

Core Power = 99.07% FP