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May 4, 1978

WILLIAM O. PARKER, JR.
VICE PRESIDENT
STEAM PRODUCTION

TELEPHONE: AREA 704
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Mr. Edson G. Case, Acting Director
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Washington, D. C. 20555

Attention: Mr. Robert W. Reid, Chief
Operating Reactors Branch No. 4

Reference: Oconee Unit 3
Docket No. 50-287

Dear Sir:

Attached for your information is the Startup Report for Oconee 3, Cycle 3.

Very truly yours,

William O. Parker, Jr.

William O. Parker, Jr.

GBS:scs

Attachment

781290047

A001 S 1/1

DUKE POWER COMPANY

OCONEE NUCLEAR STATION

UNIT 3, CYCLE 3

STARTUP TESTING SUMMARY

MAY 1978

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

I. INTRODUCTION

The Cycle 3 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 November 28, 1977, and was completed on December 3, 1977. 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 moderator coefficients of reactivity, individual control rod groups and total group reactivity worths, ejected rod worth measurements, and differential boron worth measurements. The measurements and results are further described in Section II.

Following satisfactory completion of zero power physics testing, the power escalation testing began on December 3, 1977, and was completed on February 5, 1978. The power escalation tests included core power distribution measurements at approximately 40% FP, 75% FP and 100% FP, power imbalance detector correlation tests, and measurements of reactivity coefficients at power. Section III describes the individual tests in more detail and summarizes the results of these tests.

II. ZERO POWER PHYSICS TESTING

A. Initial Criticality

Cycle 3 initial criticality was achieved on Oconee 3 at 9:45 hours on November 29, 1977 by first withdrawing control rods (Group 7 to 75% withdrawn and Group 8 to 37.5% withdrawn) and initiating a continuous but regulated feed and bleed deboration of the Reactor Coolant System.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 0.03. Criticality was achieved with equilibrium conditions reached at 9:45 hours with Control Rod Group 7 at 75% withdrawn and a Reactor Coolant System boron concentration of 1239 ppm.

This measured critical boron concentration of 1239 ppm met the acceptance criterion of 1236 ppm ±100 ppm.

B. All Regulating Rods Out Boron Concentration

The all rods out configuration was achieved by boration of Control Rod Group 7 to 100% withdrawn, and then achieving an equilibrium boron condition within the Reactor Coolant System. The Reactor Coolant System boron concentration at these equilibrium conditions was sampled and measured to be 1245 ppm.

This value of 1245 ppm met the acceptance criterion of 1261 ppm ±100 ppm.

C. Temperature Coefficients of Reactivity

The hot zero power temperature coefficients of reactivity were measured at two control rod configurations - all rods out (Group 8 inserted) and Groups 5-7 fully inserted. The test consisted of sequentially changing the RCS temperature by -5°F, +10°F, and -5°F and by measuring the associated changes in the core reactivity. The temperature coefficient was obtained by dividing the reactivity changes by the corresponding temperature changes. The moderator coefficient of reactivity was obtained by subtracting the predicted isothermal Doppler coefficient from the temperature coefficient.

The measured moderator and temperature coefficients of reactivity are shown in Table 1 along with their predicted values. The test satisfactorily met the acceptance criteria requiring the measured and predicted reactivity coefficients to agree within a tolerance of $\pm 0.4 \times 10^{-4}$ $(\Delta K/K)/°F$ and requiring the measured moderator coefficient to be less than $+0.5 \times 10^{-4}$ $(\Delta K/K)/°F$.

D. Control Rod Worth Measurements

Group integral and differential worths were obtained for Control Rod Groups 5 through 7 with Group 8 at 37.5% withdrawn by deboration from an all-rods-out configuration. The measured reactivity

worths of the Regulating Control Rod Groups 5 through 7 met the acceptance criteria requiring the predicted worth of the individual groups to be within ±15% of the measured value and the predicted total worth of the regulating groups to be within ±10% of the measured value. Table 2 illustrates the control rod worth measurement data as well as comparisons to pertinent predicted values.

E. Boron Worth Measurements

A measured differential boron worth of 1.13%(ΔK/K)/100ppm was obtained, which met the acceptance criterion of 1.02%(ΔK/K)/100ppmb ±10% of measured value.

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 81% withdrawn and Control Rod Group 8 at 37.5% withdrawn. The measured worth of rod 6-4 was 0.83% ΔK/K which met the acceptance criteria requiring the ejected rod worth to be less than or equal to 1% ΔK/K and to be within ±20% of measured of the predicted value of 0.73% ΔK/K.

A second set of ejected rod worth measurements were performed by individually swapping rod 6-2, 6-4, 6-6 and 6-8 out of the core and compensating by moving Control Rod Group 5. These four rods are in ¼ core symmetry and are predicted to be the highest worth rods and also of equal magnitude due to core symmetry. The test is designed to assure that the maximum worth ejected rod was indeed measured and also to give an indication of any asymmetric radial power distribution. The results of this test indicated that an asymmetric power distribution did exist. At this time the control rod drive power supplies for rods 6-4 and 6-6 were checked and verified to be in order. Since all zero power physics testing met the acceptance criteria, it was decided to begin power escalation in order to further characterize the power distribution asymmetry.

III. POWER ESCALATION SEQUENCE TESTING

A. Evaluation of the Asymmetric Power Distribution

The asymmetric power distribution identified by the deviation among measured symmetric ejected rod worths during zero power physics testing developed into a power tilt as power was escalated to 25% FP. At 25% FP Control Rod Groups 5 and 6 were borated to 100% withdrawn and Group 7 to 80% withdrawn in order to determine the effects of all-rods-out, but the tilt did not decrease. Group 8 rods were then exercised and it was determined that rod 8-3 was unlatched. The reactor was shut down to allow recoupling of the rod. Ejected rod worth measurements at zero power were repeated with the maximum worth rod meeting the acceptance criteria. Power was increased to the 40% FP power escalation sequence testing plateau and the measured tilt had decreased to within the Technical Specification limit. Normal power escalation sequence testing then continued.

B. 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 results of these comparisons are shown on the enclosed eighth core maps of radial and total peaking factors. (Figures 1-6). The following acceptance criteria were used at the three power level testing plateaus.

40% FP Acceptance Criteria

The largest measured radial peak $\leq$ 110% of the largest predicted radial peak.

The largest measured total peak $\leq$ 115% of the largest predicted total peak.

75% FP and 100% FP Acceptance Criteria

The largest measured radial peak $\leq$ 105% of the largest predicted radial peak.

The largest measured total peak $\leq$ 107.5% of the largest predicted total peak.

These acceptance criteria for the core power distribution measurements at 40% FP, 75% FP, and 100% FP were met.

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.

Table 3 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.

C. Power Imbalance Detector Correlation Test Results

The Power Imbalance Detector Correlation Test was performed initially at the 40% testing plateau in order to verify that the out-of-core detectors measurement of offset was sufficiently conservative with respect to the incore measured offset to assure that the tolerance assumed in the safety analysis would be met during full power operation. All four out-of-core detectors were verified to satisfy the desired offset correlation.

Following several days operation at full power, the power imbalance detector correlation test at 75% FP was performed 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 well within the $\pm$7.5% acceptance criteria for incore to back-up incore calculated offset.

D. Reactivity Coefficient at Power

The temperature coefficient of reactivity and the power coefficient of reactivity were measured at the 100% FP testing plateau. The measured temperature coefficient was -1.84×10^{-4} (ΔK/K)/°F which met the acceptance criterion of being less than -0.143×10^{-4} (ΔK/K)/°F for power levels above 95% FP. A maximum negative temperature coefficient limit of -1.54×10^{-4} (ΔK/K)/°F was established for the beginning of this fuel cycle in order to assure that the end-of-cycle moderator temperature coefficient value is not more negative than the value used in the FSAR steamline break analysis. When this limit is extrapolated from beginning-of-cycle for which it is specified to 43 EFPD at which time the measurement was made, the maximum negative temperature coefficient limit becomes -1.72×10^{-4} (ΔK/K)/°F. The measured value exceeded this acceptance criterion. It should be

recognized that although the acceptance criterion was exceeded when the temperature coefficient was measured at 43 EFPD, the test only determines if a limiting value might be approached later in the cycle. There currently exists a large margin between the existing temperature coefficient and the limit. The situation is under evaluation to determine if and when the maximum negative limit will be approached.

The measured power-Doppler coefficient was -1.59×10^{-4} $(\Delta K/K)/\%FP$. This value is more negative than the upper limit of -0.55×10 $(\Delta K/K)/\%FP$, and therefore, met the acceptance criterion.

Table 1 also contains the values of the reactivity coefficients measured at the 100% FP testing plateau.

TABLE 1
SUMMARY OF REACTIVITY COEFFICIENTS

	CONDITIONS	MEASURED VALUE	PREDICTED VALUE	ACCEPTANCE CRITERION
HOT ZERO POWER TEMPERATURE COEFFICIENT #1	GPS 5&6@100%WD GP 7@87.7%WD 1245 ppmb	$+0.034 \times 10^{-4} (\Delta K/K)/°F$	$-0.15 \times 10^{-4} (\Delta K/K)/°F$	Predicted $\pm 0.4 \times 10^{-4} (\Delta K/K)/°F$
HOT ZERO POWER MODERATOR COEFFICIENT #1	GPS 5&6@100%WD GP 7@87.7%WD 1245 ppmb	$+0.22 \times 10^{-4} (\Delta K/K)/°F$	$+0.04 \times 10^{-4} (\Delta K/K)/°F$	Predicted $\pm 0.4 \times 10^{-4} (\Delta K/K)/°F$ Less than $\mp 0.5 \times 10^{-4} (\Delta K/K)/°F$
HOT ZERO POWER TEMPERATURE COEFFICIENT #2	GPS 6&7@0%WD GP 5@5.13%WD GP 8@37.5%WD 992 ppmb	$-0.71 \times 10^{-4} (\Delta K/K)/°F$	$-0.85 \times 10^{-4} (\Delta K/K)/°F$	Predicted $\pm 0.4 \times 10^{-4} (\Delta K/K)/°F$
HOT ZERO POWER MODERATOR COEFFICIENT #2	GPS 6&7@0%WD GP 5@5.13%WD GP 8@37.5%WD 992 ppmb	$-0.52 \times 10^{-4} (\Delta K/K)/°F$	$-0.66 \times 10^{-4} (\Delta K/K)/°F$	Predicted $\pm 0.4 \times 10^{-4} (\Delta K/K)/°F$ Less than $\mp 0.5 \times 10^{-4} (\Delta K/K)/°F$
HOT FULL POWER TEMPERATURE COEFFICIENT	43 EFPD	$-1.84 \times 10^{-4} (\Delta K/K)/°F$	N/A	Less than $-0.143 \times 10^{-4} (\Delta K/K)/°F$ Greater than $-1.72 \times 10^{-4} (\Delta K/K)/°F$
HOT FULL POWER POWER-DOPPLER COEFFICIENT	43 EFPD	$-1.59 \times 10^{-4} (\Delta K/K)/\%FP$	N/A	Less than $-0.55 \times 10^{-4} (\Delta K/K)/\%FP$

TABLE 2

SUMMARY OF CONTROL ROD WORTH MEASUREMENTS

CONTROL ROD GROUP	PREDICTED WORTH (%ΔK/K)	MEASURED WORTH (%ΔK/K)	% DEVIATION FROM MEASURED
Group 7	0.68	0.71	- 4.2%
Group 6	0.98	1.08	- 9.2%
Group 5	0.98	0.98	0.0%
TOTAL 5-7	2.64	2.77	- 4.7%

TABLE 3

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-[1] POLATION POWER LEVEL	WORST CASE EXTRA-POLATED MAXIMUM LHR (KW/FT)	MAXIMUM ACCEPTABLE WORST CASE EXTRAP. MAXIMUM LHR (KW/FT)	WORST[2] CASE EXTRA-POLATED MINIMUM DNBR	MINIMUM ACCEPTABLE WORST CASE EXTRAP. MINIMUM DNBR
38.9	4.87	15.5	9.23	85.0	10.64	20.15	3.20	1.30
74.8	8.97	15.5	4.53	105.5	12.65	20.15	2.60	1.30
100.0	11.34	15.5	3.44	105.5	11.96	20.15	2.97	1.30

1-The extrapolation power level is the overpower trip setpoint of the next power level plateau in the escalation sequence.

2-All cases extrapolated to 105.5%FP

FIGURE 1

40% FP RADIAL PEAKING FACTORS

	8	9	10	11	12	13	14	15
	0.82	0.90	0.79	0.98	1.53	0.88	0.47	0.72
H	0.82	0.97	0.77	0.96	1.40	0.87	0.48	0.69
		1.40	1.05	1.11	1.05	0.96	0.76	0.73
K		1.41	0.95	1.08	0.98	0.95	0.78	0.78
			0.77	1.22	1.06	1.03	1.16	0.73
L			0.67	1.14	0.99	0.98	1.33	0.75
				1.36	1.31	1.05	1.10	
M				1.36	1.29	1.06	1.15	
					1.23	1.17	0.79	
N					1.29	1.14	0.80	
						0.91	Measured	
O						0.91	Predicted	

Largest Measured Peak = 1.53
Largest Predicted Peak = 1.41

Deviation From Predicted = +8.51%

Core Conditions for Predicted Peaking Factors

Group 6 = 87.1% wd

Group 7 = 15.8% wd

Group 8 = 35.3% wd

Imbalance = +0.89% FP

Core Burnup = 2 EFPD

Core Conditions for Measured Peaking Factors

Group 6 = 86.3% wd

Group 7 = 12.6% wd

Group 8 = 25.5% wd

Imbalance = -0.14% FP

Core Burnup = 0.6 EFPD

FIGURE 2

40% FP TOTAL PEAKING FACTORS

		8	9	10	11	12	13	14	15
	Measured	1.00	1.06	0.94	1.11	1.81	1.02	0.52	0.90
H	Predicted	0.99	1.17	0.97	1.18	1.71	1.06	0.55	0.86
	Measured		1.68	1.21	1.34	1.22	1.12	0.84	0.84
K	Predicted		1.66	1.14	1.34	1.25	1.19	0.96	0.98
	Measured			0.89	1.46	1.36	1.19	1.33	0.84
L	Predicted			0.77	1.46	1.43	1.23	1.63	0.95
	Measured				1.60	1.54	1.20	1.30	
M	Predicted				1.73	1.69	1.34	1.43	
	Measured					1.47	1.23	0.94	
N	Predicted					1.70	1.45	1.03	
	Measured						1.08		
O	Predicted						1.17		

Largest Measured Peak = 1.81
Largest Predicted Peak = 1.73
Deviation From Predicted = +4.62%

Core Conditions for Predicted Peaking Factors

Group 6 = 87.1% wd

Group 7 = 15.8% wd

Group 8 = 35.3% wd

Imbalance = +0.89% FP

Core Burnup = 2 EFPD

Core Conditions for Measured Peaking Factors

Group 6 = 86.3% wd

Group 7 = 12.6% wd

Group 8 = 25.5% wd

Imbalance = -0.14% FP

Core Burnup = 0.6 EFPD

FIGURE 3

75% FP RADIAL PEAKING FACTORS

	8	9	10	11	12	13	14	15
	0.87	0.95	0.84	1.02	1.38	0.91	0.49	0.78
H	0.82	0.96	0.78	0.96	1.38	0.87	0.49	0.70
		1.33	1.04	1.14	1.08	0.98	0.78	0.76
K		1.38	0.94	1.08	0.98	0.96	0.79	0.79
			0.81	1.25	1.04	1.04	1.12	0.74
L			0.68	1.14	0.99	0.98	1.31	0.75
				1.39	1.33	1.08	1.11	
M				1.35	1.29	1.06	1.14	
					1.27	1.19	0.80	
N					1.29	1.14	0.81	
						0.93	Measured	
O						0.92	Predicted	

Largest Measured Peak = 1.39
Largest Predicted Peak = 1.38

Deviation From Predicted = +0.72%

Core Conditions for Predicted Peaking Factors

Group 6 = 87.1% wd

Group 7 = 15.8% wd

Group 8 = 25.5% wd

Imbalance = +2.22% FP

Core Burnup = 3 EFPD

Core Conditions for Measured Peaking Factors

Group 6 = 87.0% wd

Group 7 = 13.0% wd

Group 8 = 18.0% wd

Imbalance = -2.3% FP

Core Burnup = 3.3 EFPD

FIGURE 4

75% FP TOTAL PEAKING FACTORS

	8	9	10	11	12	13	14	15
	1.01	1.08	0.97	1.15	1.56	1.04	0.58	0.81
H	0.99	1.17	0.97	1.18	1.71	1.06	0.54	0.86
		1.55	1.15	1.32	1.20	1.10	0.89	0.88
	K	1.66	1.14	1.34	1.25	1.19	0.96	0.98
			1.01	1.41	1.32	1.18	1.32	0.87
		L	0.77	1.46	1.46	1.23	1.63	0.95
				1.60	1.56	1.23	1.30	
			M	1.73	1.69	1.34	1.43	
					1.52	1.39	0.95	
				N	1.70	1.45	1.03	
						1.09	Measured	
					0	1.17	Predicted	

Largest Measured Peak = 1.60
Largest Predicted Peak = 1.73

Deviation From Predicted = -7.51%

Core Conditions for Predicted Peaking Factors

Group 6 = 87.1% wd

Group 7 = 15.8% wd

Group 8 = 25.5% wd

Imbalance = +2.22% FP

Core Burnup = 3 EFPD

Core Conditions for Measured Peaking Factors

Group 6 = 87.0% wd

Group 7 = 13.0% wd

Group 8 = 18.0% wd

Imbalance = -2.3% FP

Core Burnup = 3.3 EFPD

FIGURE 5

100% FP RADIAL PEAKING FACTORS

	8	9	10	11	12	13	14	15
	0.85	0.94	0.84	1.00	1.35	0.91	0.52	0.71
H	0.81	0.95	0.78	0.96	1.36	0.87	0.49	0.72
		1.31	1.04	1.11	1.05	0.96	0.77	0.77
K		1.35	0.94	1.07	0.98	0.96	0.80	0.80
			0.85	1.21	1.00	1.01	1.01	0.74
L			0.68	1.14	1.00	0.99	1.30	0.77
				1.34	1.29	1.05	1.08	
M				1.33	1.28	1.06	1.14	
					1.32	1.15	0.79	
N					1.28	1.14	0.83	
						0.93	Measured	
O						0.92	Predicted	

Largest Measured Peak = 1.35
Largest Predicted Peak = 1.36

Deviation From Predicted = -0.73%

Core Conditions for Predicted Peaking Factors

Group 6 = 87.1% wd

Group 7 = 15.8% wd

Group 8 = 19.1% wd

Imbalance = -0.1% FP

Core Burnup = 4 EFPD

Core Conditions for Measured Peaking Factors

Group 6 = 88.0% wd

Group 7 = 14.0% wd

Group 8 = 10.6% wd

Imbalance = -1.95% FP

Core Burnup = 3.3 EFPD

FIGURE 6

100%FP TOTAL PEAKING FACTORS

	8	9	10	11	12	13	14	15
H	0.98	1.06	0.96	1.09	1.53	1.02	0.61	0.82
	0.96	1.14	0.96	1.17	1.69	1.06	0.56	0.90
	K	1.54	1.14	1.27	1.24	1.08	0.88	0.86
		1.63	1.11	1.32	1.24	1.21	1.00	1.02
		L	1.05	1.39	1.30	1.18	1.32	0.84
			0.77	1.45	1.43	1.30	1.68	0.99
			M	1.60	1.56	1.23	1.29	
				1.71	1.66	1.37	1.48	
				N	1.45	1.38	0.94	
					1.70	1.49	1.08	
					O	1.10	Measured	
						1.21	Predicted	

Largest Measured Peak = 1.60
Largest Predicted Peak = 1.71

Deviation from Predicted = -6.43%

Core Conditions for Predicted Peaking Factors

Group 6 = 87.1% WD

Group 7 = 15.8% WD

Group 8 = 19.1% WD

Imbalance = -0.1% FP

Core Burnup = 4 EFPD

Core Conditions for Measured Peaking Factors

Group 6 = 88.0% WD

Group 7 = 14.0% WD

Group 8 = 10.6% WD

Imbalance = -1.95% FP

Core Burnup = 3.3 EFPD