Omaha Public Power District

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U. S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, DC 20555

References:
1. Docket No. 50-285
2. Letter from NRC (D. L. Wigginton) to OPPD (W. G. Gates) dated April 2, 1991.
3. Letter from NRC (D. L. Wigginton) to OPPD (W. G. Gates) dated April 22, 1992.

SUBJECT: Fort Calhoun Station (FCS) Cycle 20 Low Power Physics and Power Ascension Test Report

The FCS Cycle 20 core consists of 53 new fuel assemblies manufactured by Framatome ANP Richland, Inc. and 80 used fuel assemblies manufactured by Westinghouse Electric Company. Cycle 20 represents both a change in fuel suppliers and the first operating cycle using gadolinia as a burnable absorber. Therefore, in accordance with Technical Specification Section 5.9.1.a, Omaha Public Power District is submitting the attached report for the startup of Cycle 20.

The report includes a general description of the measured values obtained during the Cycle 20 startup test and evaluation phases. Also included is a comparison of the measured values with calculated design predictions.

If you should have any questions, please contact me.

Sincerely,

S. K. Gambhir
Division Manager
Nuclear Operations Division

SKG/RLJ/rlj

Attachment

IE26

c: E. W. Merschoff, NRC Regional Administrator, Region IV
A. Wang, NRC Project Manager
W. C. Walker, NRC Senior Resident Inspector
Winston & Strawn

CYCLE 20 LOW POWER PHYSICS AND POWER ASCENSION TEST PROGRAM

1.0 LOW POWER PHYSICS TESTS

1.1 Purpose

The purpose of the Cycle 20 Low Power Physics Tests (LPPT) was to obtain and confirm selected Cycle 20 core physics parameters. The physics parameters measured in the test included:

1. All rods out (ARO) Critical Boron Concentration (CBC),
2. Isothermal Temperature Coefficient of reactivity (ITC), and
3. Control Element Assemblies (CEAs) shutdown and regulating group worths using the Rod Group Exchange Technique.

1.2 Summary of Principal Results

Cycle 20 criticality was achieved at 1902 hours on April 27, 2001. Following criticality, zero-power physics testing was initiated to measure core physics parameters and validate the core design through comparison to predicted values. A summary of the primary results is described below:

ARO Critical Boron Concentration	1672 ppm
Isothermal Temperature Coefficient	-0.472×10^{-5} $\Delta\rho$/°F
Total Regulating and Shutdown Group Worth	5.648 %$\Delta\rho$

1.3 Discussion of Measurements and Results

1.3.1 Approach to Criticality

Prior to the Cycle 20 approach to criticality, Shutdown Groups A and B were fully withdrawn and the Reactor Coolant System (RCS) was diluted to the Estimated Critical Condition boron concentration for CEA Group 4 at 100 inches withdrawn.

The approach to criticality began by taking base count rates for each appropriate nuclear detector channel for use in the inverse count rate determination. The CEA Groups N, 1, 2, 3, and 4 were then withdrawn in increments, pausing to take the count rate for each channel to determine the inverse count rate and predict the point of criticality.

Initial criticality was achieved at 1902 hours on April 27, 2001. The boron concentration was approximately 1662 ppm with CEA Group 4 at about 100 inches withdrawn.

1.3.2 Zero Power Tests

Following Cycle 20 initial criticality, the reactivity computer was verified for correct operation. The following values of β and λ were set into the reactivity computer:

Group	ß	$\lambda(sec^{-1})$
1	0.000207	0.012773
2	0.001285	0.031669
3	0.001164	0.121335
4	0.002512	0.321948
5	0.000915	1.403397
6	0.000221	3.884056

β_{eff} 0.0063042

1.3.2.1 Validation of Power Range for LPPT and the ARO Critical Boron Concentration (CBC) Measurement

With the reactor at steady state after initial criticality, the boron concentration was 1662 ppm with Group 4 at about 100 inches. Group 4 was then withdrawn, thereby increasing reactor power. When reactor power approached 1×10^{-1} %, the power increase was terminated. There were no indications that sensible heat production occurred below 1×10^{-1} %. Also, the signal-to-noise ratio was deemed to be acceptable down to near 1×10^{-4} % power. Therefore, the power range for the LPPT was defined as 1×10^{-4} % to 5×10^{-2} %.

The ARO CBC was determined by, first measuring the reactivity change caused by withdrawing the remainder of CEA Group 4 to determine the end of Group 4 reactivity worth. This reactivity worth was then translated into the equivalent boron concentration and added to the measured CBC with Group 4 partially inserted, resulting in the ARO CBC. Table 1 contains the measured and predicted ARO CBC. The ARO CBC was well within the acceptance and review criteria for the test.

1.3.2.2 Isothermal Temperature Coefficient of Reactivity Measurement

The ITC was measured by, first increasing the RCS inlet temperature by approximately 5°F, then decreasing the RCS inlet temperature by approximately 10°F, and then increasing the RCS inlet temperature by approximately 5°F. The reactivity changes associated with the temperature changes were measured and used to calculate the ITC.

Table 1 contains the measured and predicted ITC values. The reported value is the average of the three measurements taken during the three temperature swings. Since the temperature swings moved equally about the initial temperature (~532°F), the value reported is a true ITC at HZP (~532°F) and no adjustment is needed.

The Moderator Temperature Coefficient (MTC) of Reactivity, which is equal to the ITC minus the Fuel Temperature Coefficient of Reactivity (FTC), was verified to be less than the $+0.5 \times 10^{-4}\ \Delta\rho$ /°F Technical Specification limit. The most positive MTC, including uncertainties, was calculated to be $+0.159 \times 10^{-4}\ \Delta\rho$ /°F and is included in Table 1. The most positive MTC was well within the acceptance criteria for the test.

1.3.2.3 Shutdown and Regulating CEA Group Worths

The CEA group worths were measured using the rod group exchange technique, where individual rod groups (i.e., test groups) were measured by swapping them with a reference group whose worth was determined by the boration-dilution method. The reference group was determined from predictions to be the CEA group with the most worth. Therefore, the worth of the test groups is a function of the measured worth of the reference group.

For Cycle 20, Group A was used as the reference group for Groups B, 1, 2, 3 and 4. Groups 3 and 4 were combined into one super group. A super group is a combination of two or more test groups into a more worthy rod group to provide a more accurate measurement. Table 1 contains the measured and predicted CEA group worths. As shown, all group worths, as well as the total worth of all CEA groups, were within the acceptance and review criteria for the test.

1.4 Conclusions

Test personnel have concluded that the Low Power Physics Test program conducted for Cycle 20 yielded results that are as accurate as can be expected within the limitations of reasonable reactor safety, prudent use of plant equipment and accuracy of available instrumentation. The data collected during the Cycle 20 Low Power Physics Tests was analyzed by Omaha Public Power District - Nuclear Engineering. The results show excellent agreement with the 3-D SIMULATE-3 code predicted values, thus providing confirmation of the methods used in designing the Cycle 20 core and the associated analyses.

2.0 POWER ASCENSION

2.1 Purpose

The purpose of the Cycle 20 power ascension test program was to verify that the measured at-power core parameters were within the limits of the Technical Specifications/COLR, and to compare selected measured parameters with the calculated values. The power ascension test program consisted of:

1. Comparison of measured integrated radial peaking factors to the COLR limits,

2. Comparison of the measured excore and incore azimuthal power tilts to the Technical Specification limits, and

3. Comparison of measured and predicted radial power distributions.

2.2 Summary of Principal Results

Following zero-power physics testing, power ascension began and the turbine-generator was placed on-line at 0013 hours on April 29, 2001. A summary of the pertinent parameters measured during the power ascension is shown in Table 2. As shown, the integrated radial peaking factors and the power tilts are well within their corresponding limits. Additionally, radial power distribution comparisons indicate that the Cycle 20 core is operating as predicted.

2.3 Discussion of Measurements and Results

2.3.1 Integrated Radial Peaking Factors

Measurements using incore detector signals and CECOR calculations indicate that the integrated radial peaking factors (F_R^T) at 50%, 66%, and 100% power were within the limits of the COLR. The results are presented in Table 2.

2.3.2 Azimuthal Power Tilts

Measurements using incore detector signals and CECOR calculations indicate that the excore azimuthal power tilts (T_{QE}) and the incore azimuthal power tilts (T_{QI}) at 50%, 66%, and 100% power, were within the limits of the Technical Specifications. The results are presented in Table 2.

2.3.3 Radial Power Distribution Comparison

Comparisons between the measured (CECOR) and calculated (SIMULATE-3) radial power distributions at 100% power show good agreement. The root mean squared error for the radial power distributions in instrumented assemblies are under 2%.

2.4 Conclusions

The measured radial peaking factors and azimuthal power tilts were found to be within the Technical Specification/COLR limits. Measurements of acceptable radial peaking factors demonstrate that the core is operating within the bounds of the safety analyses. The measured radial power distributions exhibit good agreement with those predicted by SIMULATE-3. These results provide confirmation of the core design methodology used for Cycle 20.

TABLE 1:CYCLE 20 COMPARISON OF PREDICTED AND MEASURED LOW POWER PHYSICS PARAMETERS
(Hot Zero Power, 2100 psia, 532°F)

Rod Worth by Rod Group Exchange Technique:

Group	Predicted Reactivity (%Δρ)	Measured Reactivity (%Δρ)	Predicted - Measured Reactivity (%Δρ)	Deviation from Measured (%)	Measured Value Acceptance and Review Criteria (%Δρ)	Measured Value Acceptance and Review Criteria (%Δρ)
1	0.77	0.75	0.02	2.7	±15	0.67 to 0.90
2	0.85	0.92	-0.07	-7.6	±15	0.74 to 1.00
3 + 4	1.27	1.28	-0.01	-0.8	±15	1.10 to 1.49
B	1.38	1.33	0.05	3.8	±15	1.20 to 1.62
A	1.39	1.37	0.02	1.5	±10	1.26 to 1.54
TOTAL	5.66	5.65	0.01	0.2	±10	5.15 to 6.28

ARO Critical Boron Concentration:

Predicted (ppm)	Measured (ppm)	Predicted - Measured (ppm)	Acceptance Criteria (ppm)	Review Criteria (ppm)
1667	1672	-5	±90 of predicted	±50 of predicted

Isothermal Temperature Coefficient:

Boron Concentration (ppm)	Temperature (°F)	Predicted (Δρ /°F)	Measured (Δρ /°F)	Most Positive MTC (Δρ /°F)	Acceptance Criteria (Δρ /°F)	Review Criteria (Δρ /°F)
1662	532	-0.055×10^{-4}	-0.047×10^{-4}	$+0.159 \times 10^{-4}$	MTC < Tech. Spec. Limit of $+0.50 \times 10^{-4}$	$\pm 0.20 \times 10^{-4}$ of predicted

TABLE 2
PHYSICS PARAMETERS MEASURED DURING POWER ASCENSION

Parameter	Thermal Power (%)	Measured Value	Technical Specification/COLR Limit
F_R^T	49.7	1.633	≤ 1.817
T_{QI}	49.7	0.86%	≤ 3
T_{QE}	49.7	1.18%	≤ 3
F_R^T	65.5	1.630	≤ 1.817
T_{QI}	65.5	0.78%	≤ 3
T_{QE}	65.5	0.20%	≤ 3
F_R^T	100.0	1.606	≤ 1.732
T_{QI}	100.0	0.99%	≤ 3
T_{QE}	100.0	0.23%	≤ 3
F_R^T	99.9	1.599	≤ 1.732
T_{QI}	99.9	0.92%	≤ 3
T_{QE}	99.9	0.53%	≤ 3