QUAD-CITIES NUCLEAR POWER STATION

UNIT 1 CYCLE 9

STARTUP TEST RESULTS

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PDR ADOCK 05000254
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1. Control Rod Scram Timing

Purpose

The purpose of this test is to demonstrate the scram capability of all of the operable control rods in compliance with Technical Specifications 4.3.C.1 and 4.3.C.2.

Criteria

A. The average scram insertion time, based on the de-energization of the scram pilot valve solenoids as time zero, of all operable control rods during reactor power operation shall be no greater than:

% INSERTED FROM FULLY WITHDRAWN	AVG. SCRAM INSERTION TIMES (sec)
5	0.375
20	0.900
50	2.000
90	3.500

The average of the scram insertion times for the three fastest control rods of all groups of four rods in a two by two array shall be no greater than:

% INSERTED FROM FULLY WITHDRAWN	AVG. SCRAM INSERTION TIMES (sec)
5	0.398
20	0.954
50	2.120
90	3.800

If these times cannot be met, the reactor shall not be made supercritical; if operating, the reactor shall be shutdown immediately upon determination that average scram time is deficient.

B. The maximum insertion time for 90% insertion of any operable control rod shall not exceed 7.00 seconds. If this requirement cannot be met, the deficient control rods shall be considered inoperable, fully inserted into the core, and electrically disarmed.

Results and Discussion

All 177 control rods were scram tested. The results are presented in Table 1. The maximum 90% insertion time was 2.95 seconds for control rod J-10(34-39). Both criteria A and B were met.

Table 1.

Control Rod Scram Results

NUMBER OF RODS	REACTOR CONDITIONS	AVERAGE TIMES FOR % INSERTED, SEC 5%	20%	50%	90%
177	Cold	0.26	0.49	0.96	1.66
177	Hot	0.29	0.68	1.46	2.58

Results and Discussion

Core power symmetry calculations were performed based upon computer program OD-1 data runs on April 11, 1986, at 98.5% power, and May 12, 1986, at 99.5% power. The average total TIP uncertainty from the two TIP sets was 4.312%. The random noise uncertainty was 3.181%. This yields a geometrical uncertainty of 2.911%. The total TIP uncertainty was well within the 9% limit.

Table 2 lists the symmetrical TIP pairs and their respective average deviations. Figure 1 shows the core location of the TIP pairs and the average TIP readings. The maximum deviation between symmetrical TIP pairs was 12.698% for pair 3-19. Thus, the second criterion, mentioned above, was also met.

The method used to obtain the uncertainties consisted of calculating the average of the nodal ratio of TIP pairs by:

$$\bar{R} = \frac{1@}{18n}\left[\sum_{j=1}^{n}\sum_{i=5}^{22} R_{ij}\right]$$

where Rij is the ratio for the ith node of TIP pair j, there being n such pairs, where n=18.

Next the standard deviation of the ratios is calculated by:

$$\sigma_{\bar{R}} = \left[\frac{\sum_{j=1}^{n}\sum_{i=5}^{22}(R_{ij} - \bar{R})^2}{(18n - 1)}\right]^{1/2}$$

σ_R is multiplied by 100 to express σ_R as a percentage of the ideal value of σ_R of 1.0.

$$\% \sigma_R = \sigma_R \times 100$$

The total TIP uncertainty is calculated by dividing % σ_R by $\sqrt{2}$ in order to account for data being taken at 3 inch intervals and analyzed on a 6 inch nodal basis.

In order to calculate random noise uncertainty the average reading at each node for nodes 5 through 22 is calculated by:

$$\overline{BASE}\ (K) = \frac{1}{NT\ .\ MT}\left[\sum_{M=1}^{MT}\sum_{N=1}^{NT} BASE\ (N, M, K)\right]$$

where NT = number of runs per machine = 4

MT = number of machines = 5

$\overline{BASE}$ (K) = average reading at nodal level K,

K = 5 through 22

2. Shutdown Margin Demonstration and Control Rod Functional Checks

Purpose

The purpose of this test is to demonstrate for this core loading in the most reactive condition during the operating cycle, that the reactor is subcritical with the strongest control rod full out and all other rods fully inserted.

Criteria

If a shutdown margin of 1.143% ΔK (=0.25% + R + B_4C settling penalty) cannot be demonstrated with the strongest control rod fully withdrawn, the core loading must be altered to achieve this margin. The core reactivity has been calculated to be at a maximum 6000 MWd/t into the cycle and R is given as 0.853% ΔK. The control rod B_4C settling penalty for Unit One is 0.04% ΔK.

Results and Discussion

On February 25, 1986, control rod E-5 (the rod which was calculated by General Electric to be of the highest worth) was fully withdrawn to demonstrate that the reactor would remain subcritical with the strongest rod full out. This maneuver was performed to allow cold control rod testing prior to the shutdown margin demonstration.

Control Rod functional subcritical checks were performed as part of the cold scram timing and control rod friction testing. No unexpected reactivity insertions were observed when any of the 177 control rods were withdrawn.

General Electric provided rod worth information for the two strongest diagonally adjacent rods F-6 and D-6 with rod E-5 full out. This method provided an adequate reactivity insertion to demonstrate the desired shutdown margin. On April 3, 1986, a diagonally adjacent shutdown margin demonstration was successfully performed. Using the G.E. supplied rod worth for E-5 (the strongest rod) and diagonally adjacent rods F-6 and D-6, it was determined that with E-5 and F-6 at position 48, and D-6 at position 20, a moderator temperature of 154°F, and the reactor subcritical, a shutdown margin of 1.380% ΔK was demonstrated. The G.E. calculated shutdown margin with E-5 withdrawn and 68°F reactor water temperature was 2.342% ΔK at the beginning of cycle 9.

At approximately 6000 MWd/t into cycle 9 a minimum calculated shutdown margin of 1.489% ΔK will occur with N-10 fully withdrawn. Note that the minimum shutdown margin shifts from rod E-5 at beginning of cycle to rod N-10 at 6000 MWd/t.

G.E.'s ability to determine rod worth was demonstrated by the accuracy of their in-sequence criticality prediction. The ΔK difference between the expected critical rod pattern and the actual critical rod pattern was determined to be 0.121% ΔK. This initial critical demonstrated that the actual shutdown margin at the beginning of cycle 9 was 2.463% ΔK and that 1.610% ΔK at 6000 MWd/t into cycle 9.

3. Initial Critical Prediction

Purpose

The purpose of this test is to demonstrate General Electric's ability to calculate control rod worths and shutdown margin by predicting the insequence critical.

Criteria

General Electric's prediction for the critical rod pattern must agree within 1% ΔK to actual rod pattern. A discrepancy greater than 1% ΔK in the non-conservative direction will be cause for an On-Site Review and investigation by Nuclear Fuel Services.

Results and Discussion

On April 4, 1986, at 1013 hours the reactor was brought critical with a reactor water temperature at the time of criticality of 162°F. The ΔK difference between the expected critical rod pattern at 68°F and the actual critical rod pattern at 162°F was 0.00331 from rod worth tables supplied by General Electric. The temperature effect was -0.0017 ΔK from General Electric-supplied corrections. The excess reactivity yielding the 156 second positive period was 0.0004 ΔK. These reactivities result in a 0.00121 ΔK difference (0.121% ΔK) between the expected critical rod pattern and the actual rod pattern. This is within the 1% ΔK required in the criteria of this test, and General Electric's ability to predict control rod worths is, therefore, successfully demonstrated.

4. Core Power Distribution Symmetry Analysis

Purpose

The purpose of this test was to determine the magnitude of indicated core power distribution asymmetries using data (TIP traces and OD-1) collected in conjunction with the P-1 update.

Criteria

A. The total TIP uncertainty (including random noise and geometric uncertainties obtained by averaging the uncertainties for all data sets) must be less than 9%.

B. The gross check of TIP signal symmetry should yield a maximum deviation between symmetrically located pairs of less than 25%.

The random noise is derived from the average of the nodal variances by:

$$\%\sigma \text{ noise} = \left[\frac{\sum_{K=5}^{22} \sum_{M=1}^{MT} \sum_{N=1}^{NT} \left[\frac{\text{BASE }(N, M, K) - \overline{\text{BASE}}\ (K)}{\text{BASE }(K)} \right]^2}{18\ (NT \times MT - 1)} \right]^{1/2} \times 100$$

Finally the TIP geometric uncertainty can be calculated by:

$$\%\ \sigma \text{ geometric} = (\%\ \sigma \text{ total}^2 - \%\ \sigma \text{ noise}^2)^{1/2}$$

Table 2

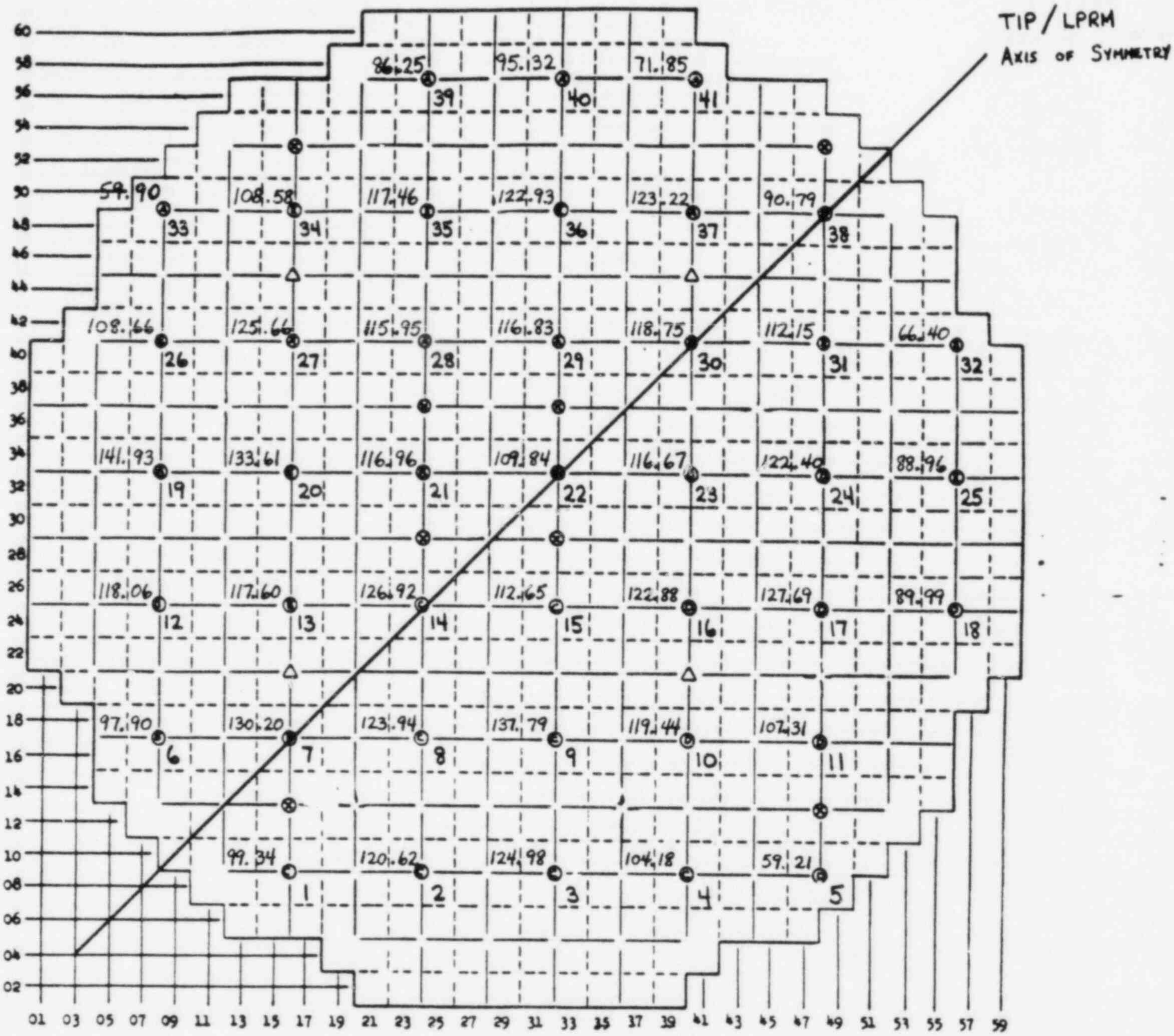
CORE SYMMETRY
Based on OD-1's From
04-11-86 (98.5% power) and 05-12-86 (99.5% power)

SYMMETRICAL TIP PAIR NUMBERS a-b	ABSOLUTE DIFFERENCE $T = T_a - T_b$	% DEVIATION $\% = 100 \times T / \frac{T_a + T_b}{2}$
1-6	1.443	1.468
2-12	2.564	2.158
3-19	16.948	12.698
4-26	4.484	4.207
5-33	0.690	1.162
8-13	6.336	5.248
9-20	4.178	3.080
10-27	6.228	5.088
11-34	1.262	1.155
15-21	4.310	3.751
16-28	6.937	5.800
17-35	10.224	8.354
18-39	3.724	4.242
23-29	0.673	0.578
24-36	0.530	0.430
25-40	6.366	6.917
31-37	11.067	9.404
32-41	5.454	7.896

$$T_i = \sum_{i=5}^{22} T_i(K) \quad /18$$

Average Deviation = 5.191

FIGURE 1



Ⓐ LPRM Location (Letter indicates TIP machine)

● LPRM Location (Common location for all TIP machines)

⊗ IRM Locations

△ SRM Locations

AVERAGE BASE

○

STRING NUMBER