11. POWER DISTRIBUTION COMPARISONS

Power distribution information contained in this section is presented to provide the perspective on the benchmarking of measured to predicted results. The predicted results are based on the PDQ07/EPRI-NODE-P models. Reference 28 presents the benchmarking results for the CASMO-3/SIMULATE-3 models.

11.1 Introduction and Summary

11.1.1 Introduction

The nuclear code employed in this section to calculate three dimensional assembly power calculations is EPRI-NODE-P. Additional two dimensional calculations are performed with PDQ07. The EPRI-NODE-P code has been benchmarked against McGuire Unit 1 Cycle 1 and part of Cycle 1A. It has also been benchmarked against TVA's Sequoyah Unit 1 Cycle 1.

This work encompassed: derivation of measured power distributions for the above cycles, simulations of the above cycles using EPRI-NODE-P, development of fitting procedures for the calculated assembly peak axial powers, and development of a statistical basis for estimating the calculational accuracy of EPRI-NODE-P.

11.1.2 Summary

A data base consisting of McGuire Unit 1 Cycle 1 and part of Cycle 1A, and TVA's Sequoyah Unit 1 Cycle 1, measured and EPRI-NODE-P calculated fuel assembly powers was assembled. Calculated and measured powers were statistically combined to derive 95/95 Observed Nuclear Reliability Factors (ONRF) for EPRI-NODE-P. ONRF's were calculated for assembly radial powers, assembly peak axial powers, and assembly normalized axial powers. The assembly radial power ($F_{\Delta H}$) is defined as the ratio of assembly average power to core average power. The assembly peak axial power (F_Q) is defined as the maximum assembly x-y planar average power along the fuel assembly length

relative to the core average power. The assembly axial power (F_Z) is defined as the ratio of the assembly peak axial power and the assembly radial power ($F_Q/F_{\Delta H}$).

ORNFs of 1.03 for the assembly radial powers, 1.06 for the assembly peak axial powers, and 1.05 for the assembly normalized axial powers were determined.

11.2 Measured Data

11.2.1 Measured Assembly Power Data

The measured power data base comprises assembly power data from McGuire Unit 1, Cycle 1 and part of Cycle 1A, and TVA's Sequoyah Unit 1, Cycle 1. All measured assembly power data are directly traceable to signals from the incore detector system.

11.2.2 Measurement System Description

The incore detector systems at McGuire and Sequoyah consist of 6 movable miniature fission chamber neutron detectors. The detectors are inserted into the bottom of the reactor vessel and driven up through the core to the top. They are then slowly withdrawn through the core. Incore flux maps are obtained by taking voltage signal readings from the detectors as they are withdrawn through the core. This data is then stored on the plant computer.

The detectors travel inside thimbles that are located in the Instrument Guide Tube of the fuel assemblies. There are 58 instrumented assemblies out of a total of 193 fuel assemblies. There are 61 voltage signals recorded axially along each of instrumented fuel assemblies. The instrumented fuel assemblies are shown on Figure 11-1.

The detectors are inter-calibrated by inserting each detector into one reference (calibration) fuel assembly. After each flux map the detector signals are processed by Shanstrom Nuclear Associates Code for Operating

Reactor Evaluation (SNA-CORE)[26]. SNA-CORE uses the 58 x 61 array of signals to calculate peaking factors, (radial powers and assembly peak axial powers) for each of the 193 assemblies. The 193 radial powers and assembly peak axial powers are then averaged into eighth core or quarter core, depending on the cycle. These peaking factors then make up the measured data base. All power measurements were taken at approximately equilibrium xenon conditions. Tables 11-1, 11-2, and 11-3 show the selected reactor state points.

11.3. EPRI-NODE-P Power Distribution Comparisons

11.3.1 EPRI-NODE-P Model

As noted previously, EPRI-NODE-P was used to calculate the three dimensional power distribution data presented in this section. This code can be used for all maneuvering analyses, core follow, and physics test data where three-dimensional core power distributions are required. In this section, comparisons of measured and EPRI-NODE-P calculated values will be shown for both radial powers and assembly peak axial powers. Comparisons were performed on a total of 37 reactor state points covering McGuire Unit 1, Cycle 1 and part of 1A, and Sequoyah Unit 1, Cycle 1.

McGuire Unit 1, Cycle 1 and Sequoyah Unit 1, Cycle 1 were modeled using eighth core symmetry. McGuire Unit 1, Cycle 1A was modeled using quarter core symmetry. Each fuel assembly was modeled with one radial and 12 equidistant axial nodes. The active stack height was set at 144 inches. Control rods could be positioned continuously in this model. Simulations of the McGuire and Sequoyah cores were performed using methods described in Section 3.5 and 5.2.

11.3.2 Fuel Cycle Simulations

Using the EPRI-NODE-P model described in section 11.3.1, McGuire Unit 1, Cycles 1 and part of 1A, and TVA's Sequoyah Unit 1, Cycle 1 were depleted

using thermal and hydraulic feedbacks. The depletions were performed in a core follow mode, utilizing critical boron searches at each exposure step.

McGuire Unit 1, Cycle 1 operated until 191.5 EFPD. Control and shutdown bank locations are shown on Figure 11-2. The core loading pattern is shown on Figure 11-3. During this time the unit was operated mostly at the 50% and 75% power plateaus because of power limitations imposed by steam generator flow impingement problems.

The EPRI-NODE-P radial powers were normalized to PDQ07 depletion at 25 EFPD for McGuire Unit 1, Cycle 1. There were 25 state points for this cycle. These are shown on Table 11-1. Figures 11-6 to 11-30 show comparisons of calculated and measured radial powers. Figure 11-31 to 11-55 show comparisons of calculated and measured assembly peak axial powers.

The data used for McGuire Unit 1, Cycle 1A was through 250 EFPD. Control and shutdown bank locations are the same as those for McGuire Unit 1, Cycle 1. The core loading pattern for cycle 1A was the same as the loading pattern for Cycle 1 except all but 2 burnable poison rods were removed. The two that remained were in core locations H-3 and H-13. The unit was operated mostly at 100% power during this time after the steam generator flow impingement problem was corrected.

The EPRI-NODE-P radial powers were normalized to PDQ07 depletion at 257 EFPD for McGuire Unit 1, Cycle 1A. There were 5 state points for the part of this cycle that was used. These are shown on Table 11-2. Figures 11-56 to 11-60 show comparison of calculated and measured radial powers. Figures 11-61 to 11-65 show comparisons of calculated and measured assembly peak axial powers.

TVA's Sequoyah Unit 1, Cycle 1 operated until the end of cycle which lasted 390 EFPD. Control and shutdown bank locations are shown on Figure 11-4. The core loading pattern is shown on Figure 11-5.

The EPRI-NODE-P radial powers were normalized to PDQ07 depletion at 25 EFPD

for Sequoyah Unit 1, Cycle 1. There were 7 state points for this cycle. These are shown on Table 11-3. Figures 11-66 to 11-72 show comparison of calculated and measured radial powers. Figures 11-73 to 11-79 show comparison of calculated and measured assembly peak axial powers.

11.3.3 Radial Power Methodology

The radial powers are radial peaking factors. Therefore, the radial peaking factors from SNA-CORE are compared directly to the normalized radial powers (P(I,J)) from EPRI-NODE-P.

11.3.4 Assembly Peak Axial Power Methodology

The assembly peak axial powers are peaking factors. There are 61 assembly axial powers for each fuel assembly calculated by SNA-CORE. Of these 61 assembly axial powers, the maximum is chosen for the "measured" assembly peak axial power. The EPRI-NODE-P model calculated 12 nodal axial powers per assembly. The assembly peak axial power could not be compared directly to the maximum nodal power.

Therefore, the nodal axial powers were curve fit using the following equation:

$$P(z) = \sum_{n=1}^{3} A_n \mathrm{Sin}(n\pi z) + B_n \mathrm{Cos}(n\pi z)$$

Where: A_n, B_n = Fourier series coefficients

z = normalized vertical axis variable

n = Fourier sequence number

The 12 level node powers were fit, yielding 61 assembly axial powers for each assembly at each state point. The assembly peak axial power was then selected from the 61 calculated assembly axial powers and the 12 nodal powers.

11.3.5 Conclusions

EPRI-NODE-P yielded consistently good power distributions when compared to measured power distributions. This conclusion applies for both radial and assembly peak axial power comparisons. Although the conclusions in this section are qualitative, quantitative statistical results of these comparisons will be shown in Section 11.5.

11.4 PDQ07 - Power Distribution Comparisons

Radial power distributions from the PDQ07 depletions of McGuire Unit 1, Cycle 1, Cycle 1A, and Sequoyah Unit 1, Cycle 1 were compared to measured radial power distributions from SNA-CORE at various burnups. The PDQ07 model employed a 2-dimensional geometry with two neutron energy groups. (For additional information concerning the use of this code, refer to Section 3.4). All power distributions from PDQ07 were performed at hot full power all rods out. Table 11-4 compares the state points of the measured data to that of PDQ07. Figures 11-80 to 11-86 show the comparisons of the radial powers.

11.5. Statistical Analysis

11.5.1 Observed Nuclear Reliability Factor Derivation

This section will address quantitatively statistics arising from Section 11.3. Normal distribution theory will be used in deriving calculational uncertainties.

In deriving the calculational uncertainty for EPRI-NODE-P, the algebraic difference between a calculated and a measured value forms a normally distributed (refer to Section 11.5.2) random variable.

The difference variable is defined:

$$D_i = C_i - M_i \qquad (11\text{-}1)$$

where: D is the i^{th} difference; $1 \le i \le N$

C is the i^{th} calculated value (radial or assembly peak axial power)

M is the i^{th} measured value (radial or assembly peak axial power)

The mean of the difference as defined in equation 11-2 is:

$$\bar{D} = \bar{C} - \bar{M} \qquad (11\text{-}2)$$

where: $$\bar{C} = \left(\sum_{i=1}^{n} C_i\right) \div n \qquad (11\text{-}2a)$$

$$\bar{M} = \left(\sum_{i=1}^{n} M_i\right) \div n \qquad (11\text{-}2b)$$

$$\bar{D} = \left(\sum_{i=1}^{n} D_i\right) \div n \qquad (11\text{-}2c)$$

n = number of observations in sample

Now a one sided upper bound factor is derived by employing One Sided Upper Tolerance Limit (OSUTL) methodology. For a normal random variable X with a sample mean X and standard deviation S, the OSUTL of X is defined by:

$$OSUTL(X) = \bar{X} + K \times S \qquad (11\text{-}3)$$

where: $$\bar{X} = \left(\sum_{i=1}^{n} X_i\right) \div n \qquad (11\text{-}4)$$

$$S = \left[\left(\sum_{i=1}^{n} (X_i - \bar{X})^2\right) \div (n-1)\right]^{1/2} \qquad (11\text{-}5)$$

In equation 11-3, K is the one-sided tolerance factor. Equation 11-3 is

formulated such that a predetermined proportion of the population (P) is below the OSUTL with a confidence factor (α)[25]. K is explicitly dependent on n, P, and α. Following industry practice, P = 95% and α = 95%.

The OSUTL is given for D by:

$$OSUTL(D) = \bar{D} + K \times S(D) \qquad (11\text{-}6)$$

C is a deterministic variable and does not have an OSUTL per se, but a reasonable upper limit to C can be defined by:

$$UL(C) = \bar{M} + OSUTL(D) \qquad (11\text{-}7)$$

$$UL(C) = \bar{M} + \bar{D} + K \times S(D) \qquad (11\text{-}7a)$$

If one substitutes equations 11-2 into equation 11-7 you obtain the following:

$$UL(C) = \bar{M} + \bar{C} - \bar{M} + K \times S(D) \qquad (11\text{-}8)$$

or $$UL(C) = \bar{C} + K \times S(D) \qquad (11\text{-}8a)$$

From equation (11-8a), it is more obvious that the upper limit is a function of the calculated parameter. Also, it is obvious that the standard deviation being associated with the calculated limit is that of the difference distribution. This means that any error in the measurement of the radial or assembly peak axial power as well as any calculational error will be included in the UL(C) parameter. While equation 11-7a and 11-8a are valid, the definition of $\bar{D} = \bar{C} - \bar{M}$ (equation 11-2) leads to UL(C) being smaller if the measured parameter is underpredicted. The conservative solution to this is to subtract $\bar{D}$ in equation 11-7a instead of adding it. This would yield the following equation:

$$UL(C) = \bar{M} + \bar{D} + K \times S(D) \qquad (11\text{-}9)$$

Finally, the Observed Nuclear Reliability Factor (ONRF) is defined as the quotient of UL(C) from equation 11-9 and the mean of the measurements:

$$\text{ONRF} = \frac{UL(C)}{\bar{\bar{M}}} \tag{11-10}$$

or

$$\text{ONRF} = \frac{\bar{M}-\bar{D}+K \times S(D)}{\bar{\bar{M}}} \tag{11-11}$$

The ONRF from equation 11-11 will be used as a multiplicative factor applied to EPRI-NODE-P calculated powers such that:

$$\text{ONRF} \times C \geq M \tag{11-12}$$

for 95% of the population and with a confidence factor of 95%. Separate ONRF's are derived for radial and assembly peak axial powers.

This procedure was employed in Reference 3 to statistically evaluate ORNFs for EPRI-NODE-P as part of the Oconee Reload Design Methodology.

11.5.2 Normality Test Results

In analyzing the normality of the difference distributions, C, M data were grouped into the following categories:

1) reactor cycle: McGuire 1, Cycle 1; McGuire 1, Cycle 1A; Sequoyah 1, Cycle 1
2) grouped cycles: All reactor cycles combined
3) type: radial powers or assembly peak axial powers

The difference distributions were analyzed for normality using the D' test from ANSI N15.15 - 1974.[27] Using the engineering judgment that only peaking factors greater than the core average are the area of concern, pairs of C,M where both are ≥ 1.0 will be treated. Table 11-5 displays the normality test results. The level of significance was chosen to be .05. Therefore, the D' statistic must be between the .025 and .975 percentage point D' values for normality. Here, 3 out of 4 assembly radial power distributions were normal and 4 assembly peak axial power distributions were normal. The remainder of

the difference distributions yielded D′ statistics that were close to the critical values and were therefore classified as nearly normal.

11.5.3 Observed Nuclear Reliability Factors (ONRF) for EPRI-NODE-P

In this subsection the statistical treatment developed in Section 11.5.1 will be utilized to develop ONRF's ($F^R_{\Delta H}$, F^R_Q, and F^R_Z) for McGuire Unit 1, Cycle 1 and part of Cycle 1A, and TVA's Sequoyah Unit 1, Cycle 1, combined.

All pairs of C, M $\geq$ 1.0 from all 37 state points of McGuire Unit 1, Cycle 1 and part of Cycle 1A, and Sequoyah Unit 1, Cycle 1, were obtained. The procedure was applied to radial powers, assembly peak axial powers, and assembly normalized axial powers. The variables shown in equation 11-11 were then derived and the ONRF's calculated.

As an example, for radial ORNF ($F^R_{\Delta H}$)

$\bar{M}$ = 1.131

$\bar{D}$ = 0.002

S(D) = 0.020

N = 846

K = 1.7343 (N = 846, 95%/95%)

Therefore, the ONRF would be:

$$\text{ONRF} = \frac{1.131 - 0.002 + (1.7343 \times 0.020)}{1.131} \qquad (11\text{-}13)$$

$$\text{ONRF} = 1.029 \qquad (11\text{-}13a)$$

Table 11-6 shows the calculated ORNF's and the data used to calculate them.

11.5.4 Quantitative Comparisons of EPRI-NODE-P to Measurement

By analyzing the variable D as defined in equation 11-1, the accuracy of EPRI-NODE-P can be assessed. Four important statistical properties of D are discussed.

$\bar{D}$ is the mean of the differences between EPRI-NODE-P and measured assembly powers. For McGuire Unit 1, Cycle 1 and part of 1A, and Sequoyah Unit 1, Cycle 1 $\bar{D}$ is 0.002 for radial powers and -0.031 for assembly peak axial powers. The above means were derived from all pairs of C, M $\geq$ 1.0 from all 37 state points. Subsequent statistics are also derived from this consideration.

S(D), the standard deviation of the differences, indicates the spread of the values of D about $\bar{D}$. For the above cycles, S(D) for radial powers is 0.020. S(D) for assembly peak axial powers is 0.028.

The mean of the absolute differences $\overline{ABS(D)}$ and its standard deviation can be combined to give limits on this variable. 95% confidence limits on the means were given by:

$$\overline{ABS(D)}_{U,L} = ABS(D) \pm \frac{t(.05,n) \times S(ABS(D))}{\sqrt{n}} \tag{11-14}$$

Equation 11-14 yields

$$\overline{ABS(D)}_{U,L} = 0.018 \pm 0.001$$

for radial powers for C, M pairs $\geq$ 1.0 for all 37 state points and:

$$\overline{ABS(D)}_{U,L} = 0.036 + 0.001$$

for assembly peak axial powers for all C, M pairs $\geq$ 1.0 for all 37 state points.

Tables 11-7 and 11-8 present summary D statistics for radial and assembly peak axial powers, respectively, where C, M $\geq$ 1.0 for all pairs considered.

11.5.5 Relative Percent Differences

The relative percent difference between EPRI-NODE-P calculated values and measured values will be defined:

$$\% \text{ Diff} = \frac{C-M}{M} \times 100 \qquad (11\text{-}15)$$

This section will address relative percent differences derived from:

a) the sample mean
b) the mean of the absolute value

Since negative percent differences represent calculational nonconservatisms, the minimum values will be more important. Relative percent differences for all C, M $\geq$ 1.0 will be discussed.

Combining data for McGuire Unit 1, Cycle 1, and part of Cycle 1A, and Sequoyah Unit 1, Cycle 1, the following results were obtained.

The average percent difference was 0.167 and the absolute 1.555 for radial powers. Also, the average percent difference was -2.195 and the absolute 2.392 for assembly peak axial powers.

Table 11-9 shows summary data for percent differences derived from calculated and measured radial powers. Values are presented by cycle and for all cycles combined. Table 11-10 is similar to Table 11-9 and provides data for assembly peak axial power percent differences.

11.5.6 Conclusions

A statistical analysis of EPRI-NODE-P calculated and plant measured power distributions has been performed. The resulting ONRF's for all C, M pairs $\geq$ 1.0 for all 37 state points are:

$(F^R_{\Delta H})$	(F^R_Q)	(F^R_Z)
Assembly Radial ONRF	Assembly Peak Axial ONRF	Assembly Normalized Axial Power ONRF
1.03	1.06	1.05

These values while based upon calculations and measurements performed on McGuire Unit 1, Cycles 1 and part of 1A, and Sequoyah Unit 1, Cycle 1 are applicable to all McGuire and Catawba units for the following reasons:

1. McGuire, Catawba, and Sequoyah have identical incore detector systems.

2. All units are manufactured by the same vendor and use similar fuel.

3. Calculations for all units were performed using the same calculational methods and procedures. Similarly, all calculations performed for McGuire and Catawba will use the same calculational methods and procedures.

As an additional verification of the conservatism in the 1.03 radial and 1.06 assembly peak axial ONRF's, all calculated maximum radial powers were multiplied by 1.03 and compared to measured. Similarly all calculated assembly peak axial powers were multiplied by 1.06 and compared to measured. 29 out of 843 (3.4%) radial powers exceeded the 1.03 x maximum calculated radial power. 43 out of 1038 (4.1%) assembly peak axial powers exceeded the 1.06 x maximum calculated assembly peak axial power. Therefore, the 1.03 radial factor was satisfactory for the entire population. The 1.06 assembly peak axial factor was also satisfactory for the entire population.

For pin power distributions, the uncertainty in the assembly power distribution is statistically combined with the uncertainty in the radial local factor (2% see Section 8.5) and the uncertainty for manufacturing tolerance (3%).

The pin total peak uncertainty factor (F_Q^{SCUF}) is calculated below.

$$F_Q^{SCUF} = 1+\frac{0.031}{1.375}+\sqrt{(0.03)^2+(0.035)^2+(0.02)^2} = 1.073$$

Similary, the pin radial peak uncertainty factor ($F_{\Delta H}^{SCUF}$) is calculated below, not including the bias term.

$$F_{\Delta H}^{SCUF} = 1+\sqrt{(0.03)^2+(0.03)^2+(0.02)^2} = 1.047$$

Finally, the assembly normalized axial peak uncertainty factor (F_Z^{SCUF}) is calculated below.

$$F_Z^{SCUF} = 1+\frac{0.032}{1.251}+\sqrt{(0.022)^2} = 1.048$$

TABLE 11-1

McGuire Unit 1 Cycle 1 State Points

Point #	EFPD	Power (%)	Control Bank D Position (Steps)	Axial Offset (Meas/Calc) (%)
1	1.28	30	213	-4.67 / -4.78
2	5.27	30	170	-10.68 / -9.20
3	7.70	48	200	-7.59 / -6.83
4	11.42	48	164	-11.90 /-11.07
5	37.10	50	186	-8.76 / -7.70
6	41.59	50	201	-5.56 / -6.30
7	48.75	50	201	-6.27 / -6.01
8	59.37	50	201	-5.06 / -5.83
9	75.38	50	198	-6.10 / -5.86
10	80.46	75	213	-8.57 / -6.94
11	91.54	75	213	-7.41 / -6.75
12	104.47	50	215	-4.07 / -3.58
13	112.05	50	215	-1.57 / -3.43
14	115.69	75	217	-5.61 / -6.52
15	118.71	50	180	-8.60 / -7.50
16	122.15	75	215	-5.58 / -6.36
17	130.59	75	215	-7.58 / -6.17
18	135.44	75	215	-5.77 / -5.99
19	139.82	50	180	-8.43 / -6.82
20	151.42	50	215	-0.54 / -2.52
21	146.01	75	215	-4.80 / -5.86
22	150.19	50	215	-0.70 / -2.32
23	162.76	50	215	-4.80 / -2.33
24	173.34	50	215	-0.29 / -2.27
25	185.58	50	215	-0.45 / -2.24

TABLE 11-2

McGuire Unit 1 Cycle 1A State Points

Point #	EFPD	Power (%)	Control Bank D Position (Steps)	Axial Offset (Meas/Calc) (%)
1	198.66	90	217	0.73 / -0.93
2	217.53	100	209	1.35 / -5.05
3	223.35	100	211	-3.51 / -4.92
4	236.23	100	211	-3.44 / -4.89
5	249.75	100	221	-2.51 / -3.77

TABLE 11-3

Sequoyah Unit 1 Cycle 1 State Points

Point #	EFPD	Power (%)	Control Bank D Position (Steps)	Axial Offset (Meas/Calc) (%)
1	71.82	100	200	-7.31 / -9.01
2	101.62	100	218	-4.36 / -6.19
3	133.29	100	216	-3.95 / -5.60
4	166.04	100	210	-2.68 / -5.51
5	231.70	100	216	-1.36 / -3.77
6	290.04	100	216	-1.51 / -3.40
7	378.92	100	222	-1.43 / -2.86

TABLE 11-4

McGuire Unit 1 Cycles 1 and 1A and Sequoyah Unit 1 Cycle 1
State Points for PDQ07 Calculated and Measured Data

			PDQ07 Calculated			Measured		
Pt #	Unit	Cycle	EFPD	Control Bank D Position (Steps)	Power (%)	EFPD	Control Bank D Position (Steps)	Power (%)
1	M1	1	52.2	228	100	48.8	200	50
2	M1	1	104.4	228	100	104.5	218	50
3	M1	1	156.7	228	100	150.2	216	50
4	M1	1A	208.9	228	100	198.7	210	90
5	S1	1	103.6	228	100	101.6	216	100
6	S1	1	155.5	228	100	133.3	216	100
7	S1	1	362.7	228	100	378.9	222	100

TABLE 11-5

Difference Distribution Normality Tests
for C, M ≥ 1.0 - 5% Level of Significance

Assembly Radial Powers

Unit/Cycle	N	D' (P=.025)	D'	D' (P=.975)	Remarks
M1/C1	510	3215.0	3274.7	3275.0	Normal
M1/C1A	190	725.9	746.0	748.1	Normal
S1/C1	146	487.6	491.9	504.6	Normal
All Combined	846	6886.7	7000.9	6986.2	Nearly Normal

Assembly Peak Axial Powers

Unit/Cycle	N	D' (P=.025)	D'	D' (P=.975)	Remarks
M1/C1	642	4546.4	4586.3	4621.7	Normal
M1/C1A	220	904.9	922.9	930.5	Normal
S1/C1	176	646.4	646.4	666.9	Normal
All Combined	1038	9345.5	9379.5	9489.8	Normal

TABLE 11-6

Calculated ONRFs and Associated Data

Assembly Radial Power ONRF ($F^R_{\Delta H}$)

$\bar{M}$	= 1.131
$\bar{D}$	= 0.002
S(D)	= 0.020
N	= 846
K	= 1.7343 (N = 846, 95%/95%)
ONRF($F^R_{\Delta H}$)	= 1.029

Assembly Peak Axial Power ONRF (F^R_Q)

$\bar{M}$	= 1.375
$\bar{D}$	= -0.031
S(D)	= 0.028
N	= 1038
K	= 1.7259 (N = 1038, 95%/95%)
ONRF(F^R_Q)	= 1.058

Assembly Axial Power ONRF (F^R_Z)

$\bar{M}$	= mean value of $(F_Q/F_{\Delta H})$meas.	= 1.251
$\bar{D}$	= mean value of $[(F_Q/F_{\Delta H})$meas. − $(F_Q/F_{\Delta H})$calc.]	= 0.032
S(D)	= 0.016	
N	= 846	
K	= 1.7343 (N = 846, 95%/95%)	
ONRF(F^R_Z)	= 1.048	

TABLE 11-7

Difference, Means, and Standard Deviations
for Assembly Radial Powers (C, M ≥1.0)

Unit/Cycle	N	$\overline{D}$	S(D)	$\overline{ABS}$	S(ABS(D))
M1/C1	510	-0.001	0.019	0.017	0.008
M1/C1A	190	-0.001	0.025	0.023	0.010
S1/C1	146	0.013	0.012	0.014	0.010
All Combined	846	0.002	0.020	0.018	0.010

TABLE 11-8

Difference, Means, and Standard Deviations
for Assembly Peak Axial Powers (C, M ≥1.0)

Unit/Cycle	N	$\overline{D}$	S(D)	$\overline{ABS}$	S(ABS(D))
M1/C1	642	-0.029	0.027	0.032	0.023
M1/C1A	220	-0.039	0.033	0.041	0.029
S1/C1	176	-0.028	0.026	0.031	0.023
All Combined	1038	-0.031	0.028	0.036	0.025

TABLE 11-9

Percent Difference Means

(C, M ≥1.0) - Assembly Radial Powers

Unit/Cycle	Mean % Difference	Mean Absolute % Difference
M1/C1	-0.058	1.452
M1/C1A	0.007	2.043
S1/C1	1.163	1.281
All Combined	0.167	1.555

TABLE 11-10

Percent Difference Means
(C, M $\geq$1.0) - Assembly Peak Axial Powers

Unit/Cycle	Mean % Difference	Mean Absolute % Difference
M1/C1	-2.001	2.196
M1/C1A	-2.838	3.031
S1/C1	-2.099	2.310
All Combined	-2.195	2.392

FIGURE 11-1

Instrumented Fuel Assemblies

McGuire and Sequoyah

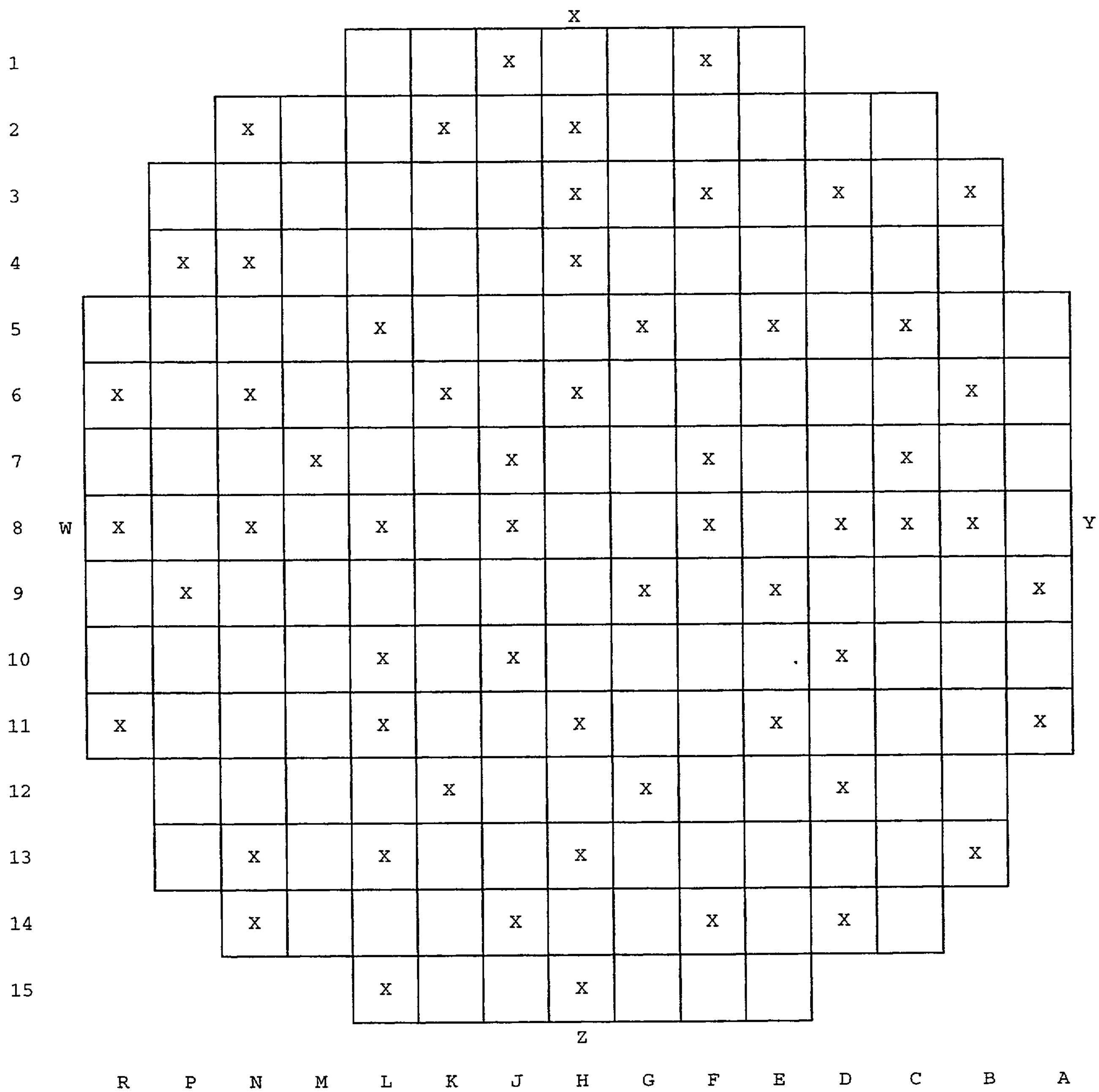

FIGURE 11-2

Control and Shutdown Bank Locations

McGuire 1 Cycle 1

X

		R	P	N	M	L	K	J	H	G	F	E	D	C	B	A	
1																	
2					SA		B		C		B		SA				
3						SD		SB		SB		SC					
4			SA		D				SE				D		SA		
5				SC										SD			
6			B				C		A		C				B		
7				SB										SB			
8	W		C		SE		A		D		A		SE		C		Y
9				SB										SB			
10			B				C		A		C				B		
11				SD										SC			
12			SA		D				SE				D		SA		
13						SC		SB		SB		SD					
14					SA		B		C		B		SA				
15																	

Z

FIGURE 11-3

Core Loading Pattern

McGuire 1 Cycle 1

X

	R	P	N	M	L	K	J	H	G	F	E	D	C	B	A
1					C	10 C	C	10 C	C	10 C	C				
2			9 C	C	12 C	A	20 C	A	19 C	A	12 C	C	9 C		
3		9 C	C	20 B	A	16 B	A	16 B	A	16 B	A	20 B	C	9 C	
4		C	20 B	B	20 B	A	16 B	A	16 B	A	20 B	B	20 B	C	
5	C	12 C	A	20 B	A	16 B	A	16 B	A	16 B	A	20 B	A	12 C	C
6	10 C	A	16 B	A	16 B	A	20 B	A	20 B	A	16 B	A	16 B	A	10 C
7	C	20 C	A	16 B	A	20 B	A	20 B	A	20 B	A	16 B	A	20 C	C
8 (W … Y)	10 C	A	16 B	A	16 B	A	20 B	A	20 B	A	16 B	A	16 B	A	10 C
9	C	20 C	A	16 B	A	20 B	A	20 B	A	20 B	A	16 B	A	20 C	C
10	10 C	A	16 B	A	16 B	A	20 B	A	20 B	A	16 B	A	16 B	A	10 C
11	C	12 C	A	20 B	A	16 B	A	16 B	A	16 B	A	20 B	A	12 C	C
12		C	20 B	B	20 B	A	16 B	A	16 B	A	20 B	B	20 B	C	
13		9 C	C	20 B	A	16 B	A	16 B	A	16 B	A	20 B	C	9 C	
14			9 C	C	12 C	A	20 C	A	19 C	A	12 C	C	9 C		
15					C	10 C	C	10 C	C	10 C	C				

Z

A — Region 1 (2.1 w/o)

B — Region 2 (2.6 w/o)

C — Region 3 (3.1 w/o)

Number indicates number of burnable poison rods

FIGURE 11-4

Control and Shutdown Bank Locations

Sequoyah 1 Cycle 1

X

	R	P	N	M	L	K	J	H	G	F	E	D	C	B	A	
1																
2				SA		B		C		B		SA				
3					SD		SB		SB		SC					
4		SA		D				D				D		SA		
5			SC										SD			
6		B				C		A		C				B		
7			SB										SB			
8 W		C		D		A		D		A		D		C		Y
9			SB										SB			
10		B				C		A		C				B		
11			SD										SC			
12		SA		D				D				D		SA		
13					SC		SB		SB		SD					
14				SA		B		C		B		SA				
15																

Z

FIGURE 11-5

<u>Core Loading Pattern</u>

<u>Sequoyah 1 Cycle 1</u>

X (top), Z (bottom), W (left, row 8), Y (right, row 8)

	R	P	N	M	L	K	J	H	G	F	E	D	C	B	A
1					C	10 C	C	10 C	C	10 C	C				
2			9 C	C	9 B	A	12 B	A	12 B	A	9 B	C	9 C		
3		9 C	C	16 B	A	16 B	A	20 B	A	16 B	A	16 B	C	9 C	
4		C	16 B	A	16 B	A	16 B	A	16 B	A	16 B	A	16 B	C	
5	C	9 B	A	16 B	A	20 B	A	20 B	A	20 B	A	16 B	A	9 B	C
6	10 C	A	16 B	A	20 B	A	20 B	A	20 B	A	20 B	A	16 B	A	10 C
7	C	12 B	A	16 B	A	20 B	A	12 B	A	20 B	A	16 B	A	12 B	C
8	10 C	A	20 B	A	20 B	A	12 B	A	12 B	A	20 B	A	20 B	A	10 C
9	C	12 B	A	16 B	A	20 B	A	12 B	A	20 B	A	16 B	A	12 B	C
10	10 C	A	16 B	A	20 B	A	20 B	A	20 B	A	20 B	A	16 B	A	10 C
11	C	9 B	A	16 B	A	20 B	A	20 B	A	20 B	A	16 B	A	9 B	C
12		C	16 B	A	16 B	A	16 B	A	16 B	A	16 B	A	16 B	C	
13		9 C	C	16 B	A	16 B	A	20 B	A	16 B	A	16 B	C	9 C	
14			9 C	C	9 B	A	12 B	A	12 B	A	9 B	C	9 C		
15					C	10 C	C	10 C	C	10 C	C				

A — Region 1 (2.1 w/o)

B — Region 2 (2.6 w/o)

C — Region 3 (3.1 w/o)

Number indicates number of burnable poison rods

FIGURE 11-6

McGuire-1 Cy-1 Assembly Radial Powers Calculated vs Measured

1.28 EFPD 30%FP Control Bank D at 213 Steps Withdrawn

	H	G	F	E	D	C	B	A
8	1.03 1.01	.94 .96	1.11 1.10	1.10 1.12	1.21 1.20	1.08 1.09	1.06 1.05	.73 .73
9		1.07 1.05	.99 1.01	1.18 1.16	1.11 1.14	1.17 1.15	1.01 1.03	.80 .79
10			1.15 1.14	1.10 1.13	1.19 1.17	1.06 1.10	1.04 1.01	.67 .68
11				1.18 1.18	1.04 1.06	1.12 1.12	1.02 1.01	.57 .58
12					1.27 1.24	.95 .95	.87 .87	
13						1.06 1.02	.50 .49	Calculated Measured

FIGURE 11-7

McGuire-1 Cy-1 Assembly Radial Powers Calculated vs Measured

5.27 EFPD 30%FP Control Bank D at 170 Steps Withdrawn

	H	G	F	E	D	C	B	A
8	.97 .97	.93 .97	1.12 1.12	1.12 1.15	1.23 1.22	1.10 1.12	1.07 1.07	.74 .74
9		1.08 1.06	1.01 1.03	1.20 1.18	1.13 1.16	1.19 1.17	1.02 1.05	.81 .80
10			1.17 1.15	1.11 1.14	1.19 1.17	1.07 1.10	1.04 1.01	.67 .68
11				1.18 1.17	1.02 1.04	1.11 1.09	1.01 .99	.57 .57
12					1.17 1.15	.92 .91	.85 .85	
13						1.03 .98	.49 .48	Calculated Measured

FIGURE 11-8

McGuire-1 Cy-1 Assembly Radial Powers Calculated vs Measured

7.70 EFPD 48%FP Control Bank D at 200 Steps Withdrawn

	H	G	F	E	D	C	B	A
8	1.05 1.05	.97 1.00	1.14 1.14	1.12 1.15	1.22 1.22	1.09 1.10	1.05 1.03	.72 .72
9		1.10 1.09	1.02 1.05	1.21 1.19	1.13 1.15	1.18 1.15	1.00 1.02	.79 .78
10			1.18 1.15	1.12 1.14	1.19 1.17	1.06 1.09	1.03 1.00	.66 .67
11				1.19 1.17	1.04 1.05	1.11 1.10	1.00 .99	.56 .57
12					1.23 1.22	.93 .93	.84 .85	
13						1.02 1.00	.48 .48	Calculated Measured

FIGURE 11-9

McGuire-1 Cy-1 Assembly Radial Powers Calculated vs Measured

11.42 EFPD 48%FP Control Bank D at 164 Steps Withdrawn

	H	G	F	E	D	C	B	A
8	.99 .99	.97 1.00	1.15 1.15	1.14 1.18	1.24 1.24	1.11 1.13	1.07 1.05	.73 .73
9		1.11 1.09	1.04 1.07	1.22 1.21	1.15 1.18	1.19 1.17	1.02 1.04	.80 .79
10			1.19 1.18	1.13 1.17	1.20 1.19	1.07 1.10	1.03 1.00	.66 .67
11				1.18 1.18	1.02 1.04	1.10 1.07	.99 .98	.56 .56
12					1.13 1.12	.90 .88	.83 .82	
13						.99 .94	.47 .46	Calculated Measured

FIGURE 11-10

McGuire-1 Cy-1 Assembly Radial Powers Calculated vs Measured

37.10 EFPD 50%FP Control Bank D at 186 Steps Withdrawn

	H	G	F	E	D	C	B	A
8	1.07 1.10	1.03 1.07	1.17 1.18	1.16 1.18	1.23 1.23	1.10 1.10	1.04 1.03	.71 .70
9		1.14 1.15	1.08 1.11	1.22 1.21	1.15 1.17	1.17 1.14	1.00 1.01	.77 .76
10			1.20 1.21	1.15 1.19	1.19 1.18	1.07 1.09	1.01 .98	.64 .65
11				1.19 1.20	1.05 1.05	1.09 1.06	.98 .97	.54 .55
12					1.17 1.15	.92 .90	.81 .81	
13						.98 .94	.47 .46	Calculated Measured

FIGURE 11-11

McGuire-1 Cy-1 Assembly Radial Powers Calculated vs Measured

41.59 EFPD 50%FP Control Bank D at 201 Steps Withdrawn

	H	G	F	E	D	C	B	A
8	1.10 1.10	1.04 1.08	1.18 1.18	1.16 1.21	1.22 1.22	1.10 1.11	1.03 1.01	.70 .70
9		1.15 1.15	1.08 1.12	1.22 1.21	1.15 1.18	1.14 1.14	1.00 1.01	.76 .75
10			1.20 1.19	1.15 1.19	1.19 1.18	1.07 1.09	1.00 .96	.64 .64
11				1.19 1.19	1.06 1.08	1.09 1.07	.97 .96	.54 .54
12					1.20 1.18	.93 .91	.81 .80	
13						.98 .94	.47 .46	Calculated Measured

FIGURE 11-12

McGuire-1 Cy-1 Assembly Radial Powers Calculated vs Measured

48.75 EFPD 50%FP Control Bank D at 201 Steps Withdrawn

	H	G	F	E	D	C	B	A
8	1.11 1.11	1.05 1.09	1.18 1.19	1.17 1.21	1.22 1.22	1.10 1.12	1.03 1.01	.70 .70
9		1.15 1.15	1.09 1.12	1.22 1.21	1.15 1.19	1.16 1.14	1.00 1.01	.76 .75
10			1.20 1.19	1.16 1.19	1.19 1.18	1.07 1.09	1.00 .96	.64 .64
11				1.19 1.19	1.07 1.08	1.09 1.07	.97 .95	.54 .54
12					1.20 1.18	.93 .91	.81 .80	
13						.98 .94	.47 .46	Calculated Measured

FIGURE 11-13

McGuire-1 Cy-1 Assembly Radial Powers Calculated vs Measured

59.37 EFPD 50%FP Control Bank D at 201 Steps Withdrawn

		H	G	F	E	D	C	B	A
8	Calculated	1.12	1.07	1.18	1.17	1.22	1.10	1.02	.69
	Measured	1.12	1.10	1.19	1.21	1.22	1.12	1.01	.70
9	Calculated		1.16	1.10	1.22	1.16	1.15	1.00	.75
	Measured		1.16	1.13	1.21	1.18	1.14	1.01	.75
10	Calculated			1.20	1.16	1.19	1.07	.99	.63
	Measured			1.19	1.19	1.17	1.09	.96	.64
11	Calculated				1.19	1.07	1.08	.97	.54
	Measured				1.18	1.07	1.06	.95	.54
12	Calculated					1.19	.93	.80	
	Measured					1.17	.92	.80	
13	Calculated						.97	.46	
	Measured						.95	.46	

FIGURE 11-14

McGuire-1 Cy-1 Assembly Radial Powers Calculated vs Measured

75.38 EFPD 50%FP Control Bank D at 198 Steps Withdrawn

	H	G	F	E	D	C	B	A
8	1.12 1.12	1.09 1.11	1.19 1.18	1.18 1.21	1.21 1.20	1.11 1.13	1.02 1.00	.69 .69
9		1.17 1.15	1.12 1.14	1.22 1.20	1.16 1.19	1.15 1.13	1.00 1.02	.75 .74
10			1.21 1.19	1.17 1.20	1.18 1.17	1.07 1.10	.98 .96	.63 .64
11				1.19 1.18	1.08 1.09	1.08 1.06	.96 .95	.53 .54
12					1.18 1.16	.93 .92	.80 .80	
13						.96 .94	.46 .46	Calculated Measured

FIGURE 11-15

McGuire-1 Cy-1 Assembly Radial Powers Calculated vs Measured

80.46 EFPD 75%FP Control Bank D at 213 Steps Withdrawn

	H	G	F	E	D	C	B	A
8	1.17 1.16	1.11 1.14	1.20 1.20	1.19 1.22	1.21 1.20	1.10 1.11	1.01 1.00	.68 .70
9		1.18 1.17	1.13 1.15	1.22 1.21	1.17 1.19	1.14 1.12	.99 1.01	.74 .74
10			1.21 1.19	1.18 1.19	1.18 1.17	1.07 1.09	.98 .95	.63 .64
11				1.19 1.18	1.09 1.09	1.07 1.05	.95 .95	.53 .53
12					1.19 1.17	.93 .92	.79 .80	
13						.95 .94	.46 .46	Calculated Measured

FIGURE 11-16

McGuire-1 Cy-1 Assembly Radial Powers Calculated vs Measured

91.54 EFPD 75%FP Control Bank D at 213 Steps Withdrawn

		H	G	F	E	D	C	B	A
8	Calculated	1.17	1.12	1.20	1.19	1.20	1.11	1.00	.68
	Measured	1.15	1.15	1.20	1.22	1.19	1.11	.99	.70
9	Calculated		1.19	1.14	1.22	1.17	1.14	.99	.73
	Measured		1.17	1.16	1.20	1.19	1.11	1.01	.73
10	Calculated			1.21	1.18	1.18	1.08	.97	.63
	Measured			1.19	1.21	1.16	1.10	.94	.63
11	Calculated				1.19	1.09	1.07	.95	.53
	Measured				1.18	1.11	1.05	.95	.53
12	Calculated					1.18	.94	.79	
	Measured					1.17	.93	.79	
13	Calculated						.94	.46	
	Measured						.93	.46	

FIGURE 11-17

McGuire-1 Cy-1 Assembly Radial Powers Calculated vs Measured

104.47 EFPD 50%FP Control Bank D at 215 Steps Withdrawn

	H	G	F	E	D	C	B	A
8	1.16 1.15	1.12 1.14	1.19 1.19	1.18 1.22	1.19 1.19	1.10 1.12	1.00 .99	.68 .69
9		1.17 1.17	1.13 1.15	1.20 1.19	1.16 1.19	1.13 1.11	1.00 1.02	.74 .73
10			1.20 1.18	1.18 1.19	1.17 1.16	1.08 1.10	.97 .95	.63 .64
11				1.18 1.16	1.10 1.10	1.07 1.06	.96 .95	.53 .53
12					1.20 1.18	.95 .94	.80 .80	
13						.96 .94	.46 .46	Calculated Measured

FIGURE 11-18

McGuire-1 Cy-1 Assembly Radial Powers Calculated vs Measured

112.05 EFPD 50%FP Control Bank D at 215 Steps Withdrawn

	H	G	F	E	D	C	B	A
8	1.16 1.14	1.12 1.14	1.19 1.18	1.18 1.21	1.19 1.19	1.10 1.12	1.00 .99	.68 .70
9		1.17 1.16	1.14 1.15	1.20 1.19	1.16 1.19	1.13 1.11	1.00 1.01	.74 .74
10			1.19 1.18	1.18 1.20	1.17 1.15	1.08 1.10	.97 .95	.63 .64
11				1.18 1.17	1.10 1.10	1.07 1.06	.97 .95	.53 .53
12					1.20 1.18	.96 .94	.80 .80	
13						.96 .95	.46 .47	Calculated Measured

FIGURE 11-19

McGuire-1 Cy-1 Assembly Radial Powers Calculated vs Measured

115.69 EFPD 75%FP Control Bank D at 217 Steps Withdrawn

	H	G	F	E	D	C	B	A
8	1.18 1.16	1.14 1.16	1.20 1.20	1.19 1.22	1.19 1.19	1.11 1.12	1.00 .99	.68 .69
9		1.19 1.18	1.15 1.16	1.21 1.19	1.17 1.19	1.13 1.11	1.00 1.01	.73 .73
10			1.20 1.19	1.18 1.20	1.17 1.15	1.08 1.10	.97 .95	.63 .64
11				1.18 1.17	1.10 1.10	1.07 1.05	.95 .95	.53 .53
12					1.18 1.17	.95 .94	.79 .80	
13						.94 .94	.46 .46	Calculated Measured

FIGURE 11-20

McGuire-1 Cy-1 Assembly Radial Powers Calculated vs Measured

118.71 EFPD   50%FP   Control Bank D at 180 Steps Withdrawn

	H	G	F	E	D	C	B	A
8	1.09 1.08	1.11 1.13	1.19 1.18	1.20 1.23	1.20 1.19	1.12 1.14	1.02 1.01	.70 .72
9		1.17 1.15	1.15 1.16	1.21 1.19	1.17 1.20	1.14 1.12	1.02 1.04	.75 .75
10			1.20 1.18	1.18 1.20	1.17 1.15	1.09 1.11	.98 .96	.63 .65
11				1.17 1.16	1.08 1.09	1.06 1.04	.96 .96	.53 .54
12					1.12 1.10	.93 .92	.79 .79	
13						.94 .92	.46 .46	Calculated Measured

FIGURE 11-21

McGuire-1 Cy-1 Assembly Radial Powers Calculated vs Measured

122.15 EFPD 75%FP Control Bank D at 215 Steps Withdrawn

	H	G	F	E	D	C	B	A
8	1.17 1.15	1.14 1.16	1.20 1.19	1.19 1.22	1.19 1.18	1.11 1.12	1.00 .99	.68 .70
9		1.19 1.17	1.15 1.17	1.20 1.18	1.17 1.19	1.13 1.10	1.00 1.02	.73 .73
10			1.20 1.18	1.18 1.21	1.17 1.15	1.08 1.10	.97 .94	.63 .64
11				1.18 1.17	1.10 1.11	1.07 1.05	.96 .95	.53 .53
12					1.18 1.17	.95 .94	.79 .79	
13						.94 .93	.46 .47	Calculated Measured

FIGURE 11-22

McGuire-1 Cy-1 Assembly Radial Powers Calculated vs Measured

130.59 EFPD 75%FP Control Bank D at 215 Steps Withdrawn

	H	G	F	E	D	C	B	A
8	1.17 1.16	1.15 1.16	1.19 1.18	1.19 1.22	1.18 1.17	1.11 1.13	1.00 .99	.68 .70
9		1.19 1.17	1.15 1.17	1.20 1.18	1.17 1.18	1.12 1.10	1.00 1.01	.73 .73
10			1.20 1.18	1.18 1.20	1.16 1.14	1.08 1.10	.97 .94	.63 .64
11				1.17 1.17	1.11 1.11	1.07 1.05	.96 .95	.53 .53
12					1.18 1.17	.96 .95	.79 .80	
13						.94 .94	.46 .47	Calculated Measured

FIGURE 11-23

McGuire-1 Cy-1 Assembly Radial Powers Calculated vs Measured

135.44 EFPD   75%FP   Control Bank D at 215 Steps Withdrawn

	H	G	F	E	D	C	B	A
8	1.17 1.16	1.15 1.17	1.19 1.19	1.19 1.22	1.18 1.17	1.11 1.12	1.00 .99	.68 .70
9		1.18 1.17	1.16 1.17	1.20 1.18	1.17 1.19	1.12 1.10	1.00 1.02	.73 .73
10			1.19 1.18	1.18 1.20	1.16 1.15	1.08 1.10	.97 .94	.63 .64
11				1.17 1.16	1.11 1.11	1.07 1.05	.96 .95	.53 .53
12					1.18 1.17	.96 .95	.79 .80	
13						.95 .94	.46 .47	Calculated Measured

FIGURE 11-24

McGuire-1 Cy-1 Assembly Radial Powers Calculated vs Measured

139.82 EFPD 50%FP Control Bank D at 180 Steps Withdrawn

	H	G	F	E	D	C	B	A
8	1.09 1.08	1.12 1.14	1.18 1.18	1.19 1.23	1.19 1.19	1.12 1.14	1.01 1.01	.70 .71
9		1.17 1.15	1.15 1.17	1.20 1.19	1.17 1.20	1.13 1.12	1.03 1.04	.75 .75
10			1.19 1.18	1.18 1.20	1.16 1.14	1.09 1.11	.98 .96	.64 .65
11				1.16 1.15	1.09 1.09	1.06 1.04	.97 .95	.54 .54
12					1.11 1.11	.94 .93	.79 .79	
13						.94 .92	.46 .46	Calculated Measured

FIGURE 11-25

McGuire-1 Cy-1 Assembly Radial Powers Calculated vs Measured

141.52 EFPD 50%FP Control Bank D at 215 Steps Withdrawn

	H	G	F	E	D	C	B	A
8	1.16 1.15	1.13 1.16	1.18 1.18	1.18 1.21	1.17 1.17	1.11 1.12	1.00 .99	.69 .70
9		1.17 1.16	1.14 1.16	1.19 1.17	1.16 1.18	1.12 1.10	1.01 1.02	.74 .74
10			1.18 1.17	1.18 1.20	1.16 1.14	1.08 1.10	.97 .95	.63 .64
11				1.17 1.16	1.11 1.11	1.07 1.06	.97 .96	.53 .53
12					1.19 1.17	.97 .96	.80 .81	
13						.96 .95	.47 .47	Calculated Measured

FIGURE 11-26

McGuire-1 Cy-1 Assembly Radial Powers Calculated vs Measured

146.01 EFPD 75%FP Control Bank D at 215 Steps Withdrawn

	H	G	F	E	D	C	B	A
8	1.17 1.16	1.15 1.18	1.19 1.18	1.19 1.22	1.17 1.17	1.11 1.12	1.00 .98	.68 .70
9		1.18 1.17	1.16 1.18	1.19 1.18	1.16 1.19	1.12 1.09	1.01 1.02	.74 .73
10			1.19 1.17	1.18 1.21	1.16 1.14	1.09 1.10	.97 .94	.63 .64
11				1.17 1.16	1.11 1.12	1.07 1.04	.96 .95	.53 .53
12					1.18 1.16	.96 .95	.79 .79	
13						.95 .93	.46 .47	Calculated Measured

FIGURE 11-27

McGuire-1 Cy-1 Assembly Radial Powers Calculated vs Measured

150.19 EFPD 50%FP Control Bank D at 215 Steps Withdrawn

	H	G	F	E	D	C	B	A
8	1.16 1.14	1.14 1.16	1.17 1.17	1.18 1.21	1.17 1.16	1.11 1.12	1.00 .99	.69 .71
9		1.17 1.15	1.15 1.16	1.18 1.16	1.16 1.19	1.12 1.10	1.01 1.03	.74 .74
10			1.18 1.16	1.17 1.20	1.15 1.14	1.09 1.11	.97 .95	.63 .65
11				1.16 1.16	1.11 1.12	1.07 1.05	.97 .96	.54 .54
12					1.19 1.17	.98 .97	.80 .80	
13						.97 .95	.47 .48	Calculated Measured

FIGURE 11-28

McGuire-1 Cy-1 Assembly Radial Powers Calculated vs Measured

162.76 EFPD 50%FP Control Bank D at 215 Steps Withdrawn

	H	G	F	E	D	C	B	A
8	1.15 1.14	1.14 1.17	1.17 1.17	1.18 1.21	1.16 1.16	1.11 1.13	1.00 .99	.69 .70
9		1.16 1.15	1.15 1.17	1.17 1.16	1.16 1.18	1.11 1.09	1.02 1.02	.74 .74
10			1.17 1.16	1.17 1.20	1.15 1.13	1.09 1.11	.97 .94	.64 .65
11				1.16 1.15	1.12 1.12	1.07 1.05	.97 .96	.54 .54
12					1.19 1.17	.98 .97	.80 .80	
13						.97 .95	.47 .48	Calculated Measured

FIGURE 11-29

McGuire-1 Cy-1 Assembly Radial Powers Calculated vs Measured

173.34 EFPD 50%FP Control Bank D at 215 Steps Withdrawn

Row		H	G	F	E	D	C	B	A
8	Calculated	1.15	1.14	1.16	1.17	1.15	1.11	1.00	.69
	Measured	1.13	1.17	1.16	1.21	1.14	1.13	.99	.71
9	Calculated		1.16	1.15	1.17	1.16	1.11	1.02	.74
	Measured		1.14	1.17	1.15	1.18	1.09	1.03	.74
10	Calculated			1.17	1.17	1.14	1.09	.97	.64
	Measured			1.15	1.19	1.12	1.11	.94	.65
11	Calculated				1.15	1.12	1.07	.98	.54
	Measured				1.14	1.12	1.05	.96	.54
12	Calculated					1.18	.99	.81	
	Measured					1.16	.98	.81	
13	Calculated						.97	.47	
	Measured						.95	.49	

FIGURE 11-30

McGuire-1 Cy-1 Assembly Radial Powers Calculated vs Measured

185.58 EFPD 50%FP Control Bank D at 215 Steps Withdrawn

	H	G	F	E	D	C	B	A
8	1.15 1.13	1.14 1.16	1.16 1.15	1.17 1.20	1.15 1.14	1.11 1.12	1.00 .99	.70 .72
9		1.16 1.14	1.15 1.16	1.16 1.14	1.15 1.18	1.11 1.09	1.03 1.04	.75 .74
10			1.16 1.14	1.17 1.19	1.14 1.12	1.09 1.11	.97 .95	.64 .66
11				1.15 1.14	1.12 1.13	1.07 1.06	.98 .97	.54 .54
12					1.18 1.17	.99 .99	.81 .81	
13						.97 .96	.48 .49	Calculated Measured

FIGURE 11-31

McGuire-1 Cy-1 Assembly Peak Axial Powers Calculated vs Measured

1.28 EFPD 30%FP Control Bank D at 213 Steps Withdrawn

	H	G	F	E	D	C	B	A
8	1.41 1.40	1.27 1.32	1.50 1.50	1.48 1.52	1.63 1.62	1.46 1.47	1.43 1.42	.99 1.00
9		1.45 1.43	1.34 1.38	1.60 1.57	1.50 1.54	1.59 1.55	1.36 1.40	1.09 1.08
10			1.56 1.55	1.49 1.54	1.61 1.59	1.43 1.49	1.41 1.37	.91 .92
11				1.60 1.60	1.42 1.45	1.52 1.52	1.38 1.37	.77 .78
12					1.74 1.71	1.29 1.29	1.18 1.18	
13						1.45 1.39	.68 .67	Calculated Measured

FIGURE 11-32

McGuire-1 Cy-1 Assembly Peak Axial Powers Calculated vs Measured

5.27 EFPD 30%FP Control Bank D at 170 Steps Withdrawn

	H	G	F	E	D	C	B	A
8	1.50 1.48	1.33 1.40	1.56 1.58	1.53 1.61	1.68 1.71	1.50 1.55	1.47 1.47	1.01 1.03
9		1.50 1.51	1.39 1.45	1.65 1.65	1.55 1.62	1.63 1.62	1.40 1.45	1.11 1.12
10			1.61 1.62	1.54 1.61	1.65 1.66	1.47 1.54	1.44 1.42	.93 .95
11				1.65 1.67	1.46 1.50	1.56 1.57	1.41 1.40	.79 .80
12					1.81 1.76	1.33 1.33	1.20 1.21	
13						1.47 1.43	.69 .69	Calculated Measured

FIGURE 11-33

McGuire-1 Cy-1 Assembly Peak Axial Powers Calculated vs Measured

7.70 EFPD 48%FP Control Bank D at 200 Steps Withdrawn

	H	G	F	E	D	C	B	A
8	1.46 1.47	1.33 1.38	1.54 1.56	1.52 1.58	1.65 1.66	1.47 1.50	1.42 1.40	.97 .99
9		1.49 1.50	1.38 1.43	1.63 1.62	1.52 1.58	1.58 1.57	1.35 1.39	1.06 1.07
10			1.59 1.58	1.52 1.57	1.62 1.61	1.43 1.49	1.39 1.36	.89 .91
11				1.61 1.62	1.42 1.45	1.51 1.51	1.35 1.35	.76 .77
12					1.71 1.71	1.27 1.28	1.14 1.16	
13						1.39 1.37	.66 .66	Calculated Measured

FIGURE 11-34

McGuire-1 Cy-1 Assembly Peak Axial Powers Calculated vs Measured

11.42 EFPD 48%FP Control Bank D at 164 Steps Withdrawn

	H	G	F	E	D	C	B	A
8	1.54 1.54	1.38 1.46	1.59 1.64	1.57 1.66	1.70 1.73	1.51 1.57	1.45 1.46	.99 1.01
9		1.55 1.57	1.43 1.51	1.67 1.70	1.57 1.65	1.63 1.63	1.38 1.45	1.09 1.10
10			1.64 1.67	1.56 1.65	1.66 1.68	1.47 1.55	1.42 1.41	.91 .94
11				1.66 1.69	1.47 1.52	1.54 1.56	1.38 1.39	.77 .80
12					1.76 1.75	1.30 1.32	1.16 1.19	
13						1.41 1.40	.67 .67	Calculated Measured

FIGURE 11-35

McGuire-1 Cy-1 Assembly Peak Axial Powers Calculated vs Measured

37.10 EFPD 50%FP Control Bank D at 186 Steps Withdrawn

	H	G	F	E	D	C	B	A
8	1.52 1.58	1.40 1.50	1.57 1.64	1.55 1.62	1.63 1.67	1.46 1.50	1.37 1.40	.93 .95
9		1.53 1.61	1.44 1.53	1.62 1.66	1.53 1.60	1.54 1.56	1.33 1.38	1.01 1.03
10			1.60 1.67	1.54 1.64	1.59 1.63	1.43 1.50	1.33 1.34	.85 .89
11				1.59 1.66	1.43 1.48	1.46 1.48	1.30 1.33	.72 .75
12					1.65 1.66	1.25 1.26	1.09 1.13	
13						1.32 1.32	.63 .64	Calculated Measured

FIGURE 11-36

McGuire-1 Cy-1 Assembly Peak Axial Powers Calculated vs Measured

41.59 EFPD 50%FP Control Bank D at 201 Steps Withdrawn

	H	G	F	E	D	C	B	A
8	1.50 1.55	1.39 1.49	1.55 1.61	1.53 1.64	1.60 1.65	1.44 1.51	1.35 1.37	.92 .95
9		1.52 1.57	1.43 1.52	1.60 1.64	1.52 1.60	1.52 1.53	1.31 1.37	1.00 1.01
10			1.58 1.62	1.52 1.61	1.57 1.60	1.41 1.48	1.31 1.30	.84 .86
11				1.57 1.62	1.42 1.48	1.44 1.45	1.28 1.29	.71 .73
12					1.62 1.64	1.24 1.25	1.07 1.09	
13						1.30 1.29	.62 .62	Calculated Measured

FIGURE 11-37

McGuire-1 Cy-1 Assembly Peak Axial Powers Calculated vs Measured

48.75 EFPD 50%FP Control Bank D at 201 Steps Withdrawn

	H	G	F	E	D	C	B	A
8	1.50 1.56	1.40 1.50	1.54 1.62	1.53 1.64	1.58 1.64	1.44 1.51	1.33 1.36	.91 .94
9		1.51 1.57	1.43 1.52	1.59 1.64	1.51 1.60	1.50 1.53	1.30 1.36	.99 1.01
10			1.57 1.62	1.52 1.61	1.55 1.59	1.40 1.47	1.29 1.30	.83 .86
11				1.56 1.61	1.41 1.47	1.42 1.44	1.27 1.28	.70 .72
12					1.60 1.63	1.23 1.25	1.06 1.09	
13						1.28 1.29	.61 .62	Calculated Measured

FIGURE 11-38

McGuire-1 Cy-1 Assembly Peak Axial Powers Calculated vs Measured

59.37 EFPD   50%FP   Control Bank D at 201 Steps Withdrawn

		H	G	F	E	D	C	B	A
8	Calculated	1.49	1.41	1.53	1.52	1.56	1.43	1.31	.89
	Measured	1.54	1.47	1.59	1.60	1.61	1.48	1.33	.92
9	Calculated		1.51	1.44	1.57	1.50	1.48	1.29	.97
	Measured		1.55	1.50	1.60	1.56	1.50	1.33	.99
10	Calculated			1.55	1.51	1.53	1.39	1.27	.82
	Measured			1.58	1.57	1.55	1.44	1.27	.84
11	Calculated				1.54	1.41	1.40	1.25	.69
	Measured				1.57	1.43	1.41	1.26	.71
12	Calculated					1.58	1.22	1.04	
	Measured					1.60	1.23	1.07	
13	Calculated						1.26	.60	
	Measured						1.27	.61	

FIGURE 11-39

McGuire-1 Cy-1 Assembly Peak Axial Powers Calculated vs Measured

75.38 EFPD 50%FP Control Bank D at 198 Steps Withdrawn

	H	G	F	E	D	C	B	A
8	1.48 1.51	1.41 1.46	1.51 1.54	1.51 1.57	1.53 1.55	1.41 1.46	1.28 1.29	.87 .90
9		1.49 1.51	1.43 1.48	1.54 1.56	1.48 1.53	1.45 1.46	1.27 1.31	.95 .96
10			1.53 1.54	1.50 1.55	1.50 1.51	1.37 1.42	1.24 1.24	.80 .83
11				1.51 1.53	1.40 1.42	1.37 1.38	1.23 1.24	.68 .69
12					1.54 1.56	1.21 1.22	1.02 1.05	
13						1.23 1.24	.59 .61	Calculated Measured

FIGURE 11-40

McGuire-1 Cy-1 Assembly Peak Axial Powers Calculated vs Measured

80.46 EFPD 75%FP Control Bank D at 213 Steps Withdrawn

	H	G	F	E	D	C	B	A
8	1.49 1.54	1.42 1.48	1.51 1.55	1.50 1.57	1.51 1.54	1.39 1.44	1.26 1.29	.86 .90
9		1.49 1.53	1.43 1.48	1.52 1.56	1.47 1.53	1.43 1.45	1.25 1.30	.93 .96
10			1.52 1.53	1.48 1.53	1.48 1.50	1.36 1.41	1.22 1.23	.79 .82
11				1.49 1.51	1.38 1.40	1.35 1.36	1.21 1.22	.67 .68
12					1.52 1.53	1.19 1.20	1.00 1.04	
13						1.20 1.22	.58 .60	Calculated Measured

FIGURE 11-41

McGuire-1 Cy-1 Assembly Peak Axial Powers Calculated vs Measured

91.54 EFPD 75%FP Control Bank D at 213 Steps Withdrawn

	H	G	F	E	D	C	B	A
8	1.47 1.50	1.41 1.47	1.49 1.52	1.48 1.56	1.48 1.50	1.38 1.41	1.25 1.26	.85 .89
9		1.47 1.50	1.43 1.48	1.50 1.52	1.45 1.51	1.41 1.41	1.24 1.28	.92 .93
10			1.50 1.51	1.47 1.53	1.46 1.47	1.34 1.39	1.21 1.20	.78 .80
11				1.47 1.49	1.37 1.40	1.33 1.33	1.19 1.20	.66 .67
12					1.50 1.50	1.19 1.19	.99 1.01	
13						1.19 1.19	.57 .59	Calculated Measured

FIGURE 11-42

McGuire-1 Cy-1 Assembly Peak Axial Powers Calculated vs Measured

104.47 EFPD 50%FP Control Bank D at 215 Steps Withdrawn

	H	G	F	E	D	C	B	A
8	1.43 1.47	1.38 1.44	1.44 1.49	1.45 1.53	1.44 1.48	1.35 1.40	1.22 1.24	.84 .86
9		1.43 1.46	1.39 1.45	1.45 1.49	1.42 1.48	1.37 1.39	1.23 1.27	.90 .92
10			1.45 1.46	1.44 1.48	1.41 1.44	1.32 1.38	1.18 1.19	.77 .79
11				1.43 1.44	1.36 1.38	1.31 1.33	1.18 1.19	.65 .66
12					1.47 1.49	1.18 1.18	.98 1.00	
13						1.18 1.18	.57 .58	Calculated Measured

FIGURE 11-43

McGuire-1 Cy-1 Assembly Peak Axial Powers Calculated vs Measured

112.05 EFPD   50%FP   Control Bank D at 215 Steps Withdrawn

	H	G	F	E	D	C	B	A
8	1.41 1.44	1.38 1.42	1.43 1.47	1.43 1.51	1.42 1.46	1.34 1.39	1.20 1.23	.83 .86
9		1.42 1.44	1.39 1.43	1.43 1.47	1.41 1.47	1.35 1.37	1.22 1.26	.90 .91
10			1.43 1.46	1.42 1.48	1.40 1.43	1.31 1.36	1.17 1.18	.77 .79
11				1.41 1.45	1.35 1.37	1.29 1.32	1.18 1.19	.65 .66
12					1.46 1.48	1.18 1.18	.97 1.00	
13						1.17 1.19	.57 .59	Calculated Measured

FIGURE 11-44

McGuire-1 Cy-1 Assembly Peak Axial Powers Calculated vs Measured

115.69 EFPD 75%FP Control Bank D at 217 Steps Withdrawn

	H	G	F	E	D	C	B	A
8	1.45 1.47	1.40 1.44	1.45 1.48	1.45 1.50	1.44 1.46	1.35 1.38	1.21 1.22	.83 .86
9		1.44 1.46	1.41 1.44	1.46 1.47	1.42 1.46	1.37 1.37	1.23 1.25	.90 .90
10			1.45 1.46	1.44 1.47	1.42 1.42	1.32 1.35	1.18 1.17	.77 .78
11				1.43 1.43	1.36 1.35	1.30 1.30	1.17 1.17	.65 .65
12					1.46 1.47	1.18 1.17	.97 .99	
13						1.16 1.17	.56 .58	Calculated Measured

FIGURE 11-45

McGuire-1 Cy-1 Assembly Peak Axial Powers Calculated vs Measured

118.71 EFPD 50%FP Control Bank D at 180 Steps Withdrawn

	H	G	F	E	D	C	B	A
8	1.46 1.48	1.41 1.47	1.46 1.50	1.46 1.54	1.45 1.48	1.37 1.43	1.23 1.26	.85 .89
9		1.45 1.47	1.42 1.47	1.47 1.49	1.44 1.50	1.38 1.40	1.25 1.30	.92 .94
10			1.46 1.48	1.45 1.52	1.43 1.45	1.34 1.40	1.20 1.20	.78 .82
11				1.44 1.47	1.37 1.41	1.32 1.34	1.20 1.21	.66 .68
12					1.49 1.51	1.20 1.22	.99 1.02	
13						1.20 1.21	.58 .60	Calculated Measured

FIGURE 11-46

McGuire-1 Cy-1 Assembly Peak Axial Powers Calculated vs Measured

122.15 EFPD 75%FP Control Bank D at 215 Steps Withdrawn

	H	G	F	E	D	C	B	A
8	1.44 1.45	1.40 1.44	1.44 1.46	1.44 1.49	1.42 1.43	1.34 1.38	1.21 1.21	.83 .86
9		1.43 1.44	1.40 1.44	1.44 1.45	1.41 1.45	1.36 1.35	1.22 1.24	.89 .90
10			1.44 1.44	1.43 1.47	1.40 1.40	1.32 1.35	1.17 1.15	.76 .78
11				1.42 1.42	1.35 1.36	1.29 1.28	1.17 1.16	.65 .65
12					1.45 1.45	1.18 1.17	.96 .98	
13						1.16 1.15	.56 .58	Calculated Measured

FIGURE 11-47

McGuire-1 Cy-1 Assembly Peak Axial Powers Calculated vs Measured

130.59 EFPD 75%FP Control Bank D at 215 Steps Withdrawn

	H	G	F	E	D	C	B	A
8	1.43 1.45	1.39 1.43	1.43 1.44	1.43 1.49	1.41 1.42	1.34 1.38	1.20 1.22	.83 .86
9		1.42 1.44	1.39 1.44	1.43 1.45	1.40 1.43	1.34 1.34	1.22 1.25	.89 .90
10			1.43 1.45	1.42 1.47	1.39 1.39	1.31 1.35	1.16 1.16	.76 .79
11				1.41 1.42	1.35 1.36	1.29 1.29	1.16 1.17	.64 .66
12					1.44 1.46	1.17 1.18	.96 .99	
13						1.15 1.17	.56 .58	Calculated Measured

FIGURE 11-48

McGuire-1 Cy-1 Assembly Peak Axial Powers Calculated vs Measured

135.44 EFPD 75%FP Control Bank D at 215 Steps Withdrawn

	H	G	F	E	D	C	B	A
8	1.42 1.44	1.39 1.43	1.42 1.45	1.42 1.48	1.40 1.41	1.33 1.36	1.19 1.20	.82 .85
9		1.41 1.43	1.39 1.42	1.42 1.43	1.40 1.43	1.34 1.34	1.22 1.23	.89 .89
10			1.42 1.42	1.42 1.45	1.38 1.38	1.31 1.33	1.16 1.14	.76 .77
11				1.40 1.40	1.34 1.34	1.28 1.27	1.16 1.15	.64 .64
12					1.44 1.43	1.17 1.16	.96 .97	
13						1.15 1.15	.56 .57	Calculated Measured

FIGURE 11-49

McGuire-1 Cy-1 Assembly Peak Axial Powers Calculated vs Measured

139.82 EFPD 50%FP Control Bank D at 180 Steps Withdrawn

	H	G	F	E	D	C	B	A
8	1.42 1.48	1.38 1.46	1.42 1.48	1.43 1.51	1.40 1.45	1.34 1.41	1.21 1.24	.84 .88
9		1.41 1.47	1.39 1.46	1.42 1.47	1.41 1.47	1.35 1.38	1.24 1.28	.91 .92
10			1.42 1.47	1.42 1.49	1.39 1.43	1.32 1.38	1.17 1.19	.77 .80
11				1.40 1.44	1.35 1.41	1.29 1.32	1.19 1.20	.65 .67
12					1.45 1.50	1.19 1.21	.98 1.01	
13						1.18 1.20	.57 .60	Calculated Measured

FIGURE 11-50

McGuire-1 Cy-1 Assembly Peak Axial Powers Calculated vs Measured

141.52 EFPD   50%FP   Control Bank D at 215 Steps Withdrawn

	H	G	F	E	D	C	B	A
8	1.37 1.43	1.35 1.42	1.37 1.44	1.38 1.48	1.36 1.42	1.30 1.37	1.16 1.20	.81 .85
9		1.37 1.42	1.35 1.42	1.38 1.44	1.36 1.44	1.30 1.34	1.20 1.24	.87 .90
10			1.38 1.43	1.38 1.46	1.35 1.39	1.28 1.34	1.13 1.16	.75 .78
11				1.36 1.41	1.32 1.35	1.25 1.29	1.14 1.17	.63 .66
12					1.41 1.45	1.16 1.18	.94 .99	
13						1.14 1.17	.56 .59	Calculated Measured

FIGURE 11-51

McGuire-1 Cy-1 Assembly Peak Axial Powers Calculated vs Measured

146.01 EFPD   75%FP   Control Bank D at 215 Steps Withdrawn

	H	G	F	E	D	C	B	A
8	1.41 1.43	1.38 1.44	1.40 1.43	1.41 1.47	1.38 1.40	1.32 1.36	1.19 1.19	.82 .85
9		1.40 1.42	1.38 1.43	1.40 1.42	1.39 1.43	1.32 1.32	1.21 1.23	.88 .89
10			1.40 1.41	1.40 1.45	1.37 1.37	1.30 1.33	1.15 1.14	.76 .78
11				1.38 1.39	1.34 1.35	1.27 1.26	1.16 1.15	.64 .64
12					1.43 1.42	1.17 1.16	.95 .97	
13						1.14 1.14	.56 .58	Calculated Measured

FIGURE 11-52

McGuire-1 Cy-1 Assembly Peak Axial Powers Calculated vs Measured

150.19 EFPD 50%FP Control Bank D at 215 Steps Withdrawn

	H	G	F	E	D	C	B	A
8	1.36 1.39	1.34 1.40	1.36 1.40	1.38 1.44	1.35 1.38	1.29 1.35	1.16 1.18	.81 .84
9		1.36 1.38	1.34 1.39	1.36 1.39	1.35 1.41	1.29 1.30	1.19 1.22	.87 .88
10			1.36 1.39	1.37 1.43	1.34 1.35	1.27 1.32	1.13 1.13	.74 .77
11				1.35 1.37	1.31 1.34	1.24 1.25	1.14 1.15	.63 .64
12					1.40 1.41	1.16 1.16	.94 .97	
13						1.13 1.14	.55 .58	Calculated Measured

FIGURE 11-53

McGuire-1 Cy-1 Assembly Peak Axial Powers Calculated vs Measured

162.76 EFPD 50%FP Control Bank D at 215 Steps Withdrawn

	H	G	F	E	D	C	B	A
8	1.35 1.39	1.33 1.39	1.35 1.39	1.36 1.43	1.33 1.36	1.28 1.33	1.15 1.17	.80 .83
9		1.34 1.37	1.33 1.38	1.35 1.38	1.34 1.39	1.28 1.29	1.18 1.21	.86 .87
10			1.35 1.37	1.36 1.42	1.32 1.34	1.26 1.31	1.12 1.12	.74 .77
11				1.34 1.36	1.30 1.32	1.23 1.24	1.13 1.14	.63 .64
12					1.38 1.40	1.15 1.15	.93 .96	
13						1.12 1.14	.55 .58	Calculated Measured

FIGURE 11-54

McGuire-1 Cy-1 Assembly Peak Axial Powers Calculated vs Measured

173.34 EFPD 50%FP Control Bank D at 215 Steps Withdrawn

	H	G	F	E	D	C	B	A
8	1.35 1.36	1.33 1.39	1.33 1.37	1.35 1.42	1.32 1.34	1.28 1.34	1.14 1.17	.80 .84
9		1.33 1.35	1.33 1.38	1.33 1.36	1.33 1.39	1.27 1.28	1.18 1.22	.86 .88
10			1.34 1.35	1.35 1.41	1.31 1.33	1.26 1.31	1.11 1.12	.74 .77
11				1.32 1.34	1.30 1.33	1.23 1.24	1.13 1.14	.62 .64
12					1.38 1.39	1.15 1.17	.93 .96	
13						1.12 1.14	.55 .58	Calculated Measured

FIGURE 11-55

McGuire-1 Cy-1 Assembly Peak Axial Powers Calculated vs Measured

185.58 EFPD 50%FP Control Bank D at 215 Steps Withdrawn

	H	G	F	E	D	C	B	A
8	1.34 1.35	1.32 1.37	1.32 1.35	1.34 1.40	1.30 1.33	1.27 1.32	1.13 1.16	.80 .84
9		1.32 1.34	1.32 1.36	1.32 1.34	1.32 1.38	1.26 1.27	1.18 1.21	.86 .87
10			1.32 1.34	1.34 1.39	1.30 1.31	1.25 1.30	1.11 1.11	.74 .77
11				1.31 1.33	1.30 1.32	1.22 1.24	1.13 1.14	.62 .64
12					1.37 1.39	1.15 1.17	.93 .96	
13						1.12 1.13	.55 .58	Calculated Measured

FIGURE 11-56

McGuire-1 Cy-1A Assembly Radial Powers Calculated vs Measured

198.66 EFPD 90%FP Control Bank D at 217 Steps Withdrawn

	H	G	F	E	D	C	B	A
8	1.12 1.08	1.20 1.22	1.11 1.08	1.16 1.18	1.07 1.05	1.13 1.18	1.00 .99	.76 .79
9	1.20 1.21	1.12 1.08	1.19 1.20	1.09 1.05	1.15 1.18	1.07 1.04	1.14 1.17	.76 .76
10	1.10 1.06	1.18 1.19	1.09 1.06	1.16 1.19	1.08 1.06	1.13 1.15	.96 .93	.70 .71
11	1.13 1.16	1.07 1.04	1.15 1.17	1.10 1.07	1.19 1.21	1.06 1.03	1.02 1.03	.54 .54
12	1.01 .99	1.11 1.13	1.06 1.04	1.18 1.20	1.18 1.16	1.12 1.13	.82 .83	
13	.96 .98	1.00 .98	1.09 1.13	1.04 1.02	1.11 1.11	1.01 1.01	.56 .57	
14	.92 .91	1.07 1.11	.93 .90	1.00 1.00	.81 .81	.56 .57		
15	.71 .73	.72 .72	.67 .69	.53 .52	Calculated Measured			

FIGURE 11-57

McGuire-1 Cy-1A Assembly Radial Powers Calculated vs Measured

217.53 EFPD 100%FP Control Bank D at 209 Steps Withdrawn

	H	G	F	E	D	C	B	A
8	1.10 1.06	1.19 1.21	1.10 1.08	1.15 1.18	1.07 1.05	1.13 1.17	1.00 .99	.76 .79
9	1.19 1.20	1.11 1.07	1.18 1.19	1.08 1.05	1.15 1.17	1.07 1.04	1.13 1.17	.76 .77
10	1.09 1.06	1.17 1.18	1.09 1.05	1.16 1.17	1.08 1.05	1.12 1.15	.96 .94	.71 .72
11	1.13 1.16	1.07 1.04	1.15 1.17	1.09 1.07	1.17 1.19	1.05 1.02	1.02 1.03	.55 .55
12	1.02 1.00	1.11 1.13	1.06 1.04	1.17 1.19	1.15 1.13	1.10 1.11	.82 .83	
13	.98 .99	1.01 .98	1.10 1.13	1.04 1.02	1.10 1.10	1.00 1.00	.57 .58	
14	.94 .93	1.09 1.12	.94 .92	1.01 1.02	.82 .82	.56 .57		
15	.73 .76	.74 .74	.69 .71	.54 .54	Calculated Measured			

FIGURE 11-58

McGuire-1 Cy-1A Assembly Radial Powers Calculated vs Measured

223.35 EFPD 100%FP Control Bank D at 211 Steps Withdrawn

	H	G	F	E	D	C	B	A
8	1.09 1.06	1.18 1.21	1.10 1.08	1.15 1.18	1.07 1.05	1.13 1.18	1.00 .99	.77 .79
9	1.18 1.20	1.11 1.07	1.17 1.19	1.08 1.05	1.14 1.17	1.07 1.05	1.13 1.17	.77 .77
10	1.09 1.07	1.17 1.19	1.09 1.05	1.15 1.17	1.08 1.05	1.12 1.14	.96 .93	.71 .72
11	1.13 1.17	1.07 1.04	1.14 1.17	1.09 1.07	1.17 1.19	1.05 1.02	1.02 1.02	.55 .55
12	1.02 1.01	1.11 1.13	1.06 1.04	1.17 1.19	1.16 1.14	1.10 1.11	.82 .82	
13	.99 .99	1.02 .99	1.10 1.13	1.04 1.01	1.10 1.10	1.00 .99	.57 .58	
14	.95 .93	1.09 1.12	.95 .92	1.01 1.02	.82 .82	.57 .57		
15	.74 .76	.74 .74	.69 .71	.54 .54	Calculated Measured			

FIGURE 11-59

McGuire-1 Cy-1A Assembly Radial Powers Calculated vs Measured

236.23 EFPD 100%FP Control Bank D at 211 Steps Withdrawn

	H	G	F	E	D	C	B	A
8	1.09 1.06	1.17 1.21	1.09 1.08	1.14 1.17	1.07 1.05	1.13 1.17	1.00 .99	.77 .80
9	1.17 1.20	1.10 1.07	1.16 1.18	1.07 1.05	1.14 1.16	1.07 1.04	1.13 1.17	.77 .77
10	1.08 1.06	1.16 1.18	1.08 1.05	1.15 1.17	1.07 1.05	1.12 1.14	.97 .94	.71 .73
11	1.13 1.16	1.06 1.04	1.14 1.16	1.08 1.06	1.17 1.18	1.05 1.02	1.02 1.02	.55 .56
12	1.03 1.01	1.11 1.13	1.06 1.04	1.16 1.18	1.15 1.13	1.10 1.10	.83 .82	
13	1.00 1.00	1.02 .99	1.10 1.13	1.04 1.01	1.10 1.10	1.00 .99	.57 .58	
14	.96 .94	1.10 1.12	.95 .93	1.01 1.02	.82 .82	.57 .58		
15	.75 .77	.75 .75	.70 .72	.55 .55	Calculated Measured			

FIGURE 11-60

McGuire-1 Cy-1A Assembly Radial Powers Calculated vs Measured

249.75 EFPD 100%FP Control Bank D at 221 Steps Withdrawn

	H	G	F	E	D	C	B	A
8	1.10 1.07	1.17 1.20	1.08 1.06	1.13 1.15	1.06 1.05	1.12 1.16	1.00 .99	.77 .80
9	1.17 1.19	1.09 1.06	1.15 1.17	1.07 1.05	1.13 1.17	1.06 1.04	1.13 1.15	.77 .77
10	1.08 1.06	1.15 1.17	1.07 1.05	1.14 1.17	1.07 1.05	1.12 1.14	.97 .93	.72 .72
11	1.12 1.17	1.06 1.04	1.13 1.15	1.08 1.05	1.17 1.18	1.05 1.03	1.02 1.03	.56 .55
12	1.03 1.03	1.11 1.14	1.06 1.02	1.17 1.17	1.17 1.14	1.10 1.11	.83 .83	
13	1.01 1.00	1.03 1.00	1.10 1.14	1.05 1.02	1.10 1.09	1.00 1.00	.58 .59	
14	.96 .95	1.10 1.13	.96 .94	1.02 1.03	.83 .81	.58 .58		
15	.76 .78	.76 .75	.71 .73	.55 .56	Calculated Measured			

FIGURE 11-61

McGuire-1 Cy-1A Assembly Peak Axial Powers Calculated vs Measured

198.66 EFPD 90%FP Control Bank D at 217 Steps Withdrawn

	H	G	F	E	D	C	B	A
8	1.34 1.34	1.41 1.51	1.30 1.33	1.35 1.44	1.25 1.27	1.29 1.41	1.13 1.19	.86 .94
9	1.41 1.50	1.32 1.33	1.38 1.47	1.27 1.29	1.33 1.42	1.23 1.25	1.30 1.40	.86 .91
10	1.29 1.31	1.37 1.46	1.28 1.30	1.35 1.45	1.26 1.29	1.29 1.39	1.09 1.11	.79 .86
11	1.32 1.43	1.25 1.27	1.34 1.43	1.28 1.32	1.37 1.47	1.21 1.25	1.17 1.24	.61 .65
12	1.18 1.21	1.28 1.37	1.23 1.26	1.36 1.45	1.37 1.41	1.28 1.36	.94 1.00	
13	1.11 1.19	1.15 1.17	1.25 1.36	1.19 1.22	1.27 1.34	1.15 1.21	.64 .69	
14	1.04 1.08	1.22 1.32	1.05 1.08	1.14 1.21	.92 .98	.64 .69		
15	.81 .87	.82 .86	.76 .83	.60 .63	Calculated Measured			

FIGURE 11-62

McGuire-1 Cy-1A Assembly Peak Axial Powers Calculated vs Measured

217.53 EFPD 100%FP Control Bank D at 209 Steps Withdrawn

	H	G	F	E	D	C	B	A
8	1.33 1.31	1.43 1.48	1.30 1.33	1.37 1.42	1.26 1.26	1.34 1.39	1.18 1.18	.90 .94
9	1.42 1.47	1.31 1.31	1.40 1.44	1.27 1.27	1.36 1.40	1.26 1.24	1.36 1.38	.90 .91
10	1.29 1.30	1.39 1.44	1.28 1.27	1.37 1.42	1.27 1.26	1.33 1.36	1.13 1.11	.83 .86
11	1.34 1.41	1.25 1.26	1.36 1.41	1.28 1.29	1.41 1.44	1.24 1.21	1.21 1.22	.64 .65
12	1.19 1.21	1.31 1.36	1.25 1.25	1.40 1.43	1.41 1.36	1.32 1.31	.97 .98	
13	1.14 1.19	1.18 1.17	1.30 1.34	1.23 1.21	1.32 1.31	1.19 1.18	.67 .68	
14	1.10 1.10	1.29 1.32	1.10 1.09	1.19 1.21	.97 .97	.67 .68		
15	.86 .90	.87 .87	.81 .84	.63 .64	Calculated Measured			

FIGURE 11-63

McGuire-1 Cy-1A Assembly Peak Axial Powers Calculated vs Measured

223.35 EFPD 100%FP Control Bank D at 211 Steps Withdrawn

	H	G	F	E	D	C	B	A
8	1.32 1.33	1.41 1.49	1.29 1.32	1.36 1.43	1.25 1.28	1.33 1.45	1.17 1.21	.90 .97
9	1.41 1.48	1.30 1.31	1.39 1.45	1.26 1.28	1.35 1.43	1.25 1.28	1.35 1.42	.90 .93
10	1.28 1.30	1.38 1.45	1.27 1.28	1.36 1.43	1.26 1.28	1.33 1.40	1.13 1.13	.83 .87
11	1.33 1.42	1.25 1.27	1.35 1.42	1.28 1.30	1.40 1.47	1.24 1.25	1.21 1.23	.64 .66
12	1.19 1.21	1.31 1.36	1.24 1.26	1.39 1.45	1.40 1.43	1.32 1.36	.97 .99	
13	1.14 1.19	1.18 1.19	1.29 1.37	1.22 1.24	1.31 1.35	1.19 1.21	.67 .69	
14	1.10 1.12	1.29 1.35	1.10 1.11	1.19 1.23	.96 .98	.66 .69		
15	.87 .91	.87 .88	.81 .85	.63 .65	Calculated Measured			

FIGURE 11-64

McGuire-1 Cy-1A Assembly Peak Axial Powers Calculated vs Measured

236.23 EFPD 100%FP Control Bank D at 211 Steps Withdrawn

	H	G	F	E	D	C	B	A
8	1.29 1.32	1.39 1.47	1.27 1.31	1.34 1.42	1.24 1.27	1.32 1.43	1.17 1.20	.90 .96
9	1.39 1.45	1.28 1.30	1.37 1.43	1.25 1.27	1.33 1.41	1.24 1.27	1.34 1.41	.90 .93
10	1.26 1.28	1.36 1.42	1.26 1.27	1.34 1.41	1.25 1.27	1.32 1.38	1.12 1.12	.83 .87
11	1.32 1.41	1.23 1.26	1.34 1.40	1.26 1.29	1.38 1.45	1.23 1.24	1.20 1.22	.64 .66
12	1.18 1.21	1.30 1.36	1.24 1.25	1.38 1.44	1.38 1.41	1.31 1.34	.97 .98	
13	1.15 1.19	1.18 1.19	1.29 1.36	1.22 1.23	1.30 1.34	1.18 1.20	.67 .69	
14	1.11 1.12	1.30 1.34	1.10 1.11	1.19 1.22	.96 .98	.67 .69		
15	.88 .91	.88 .89	.82 .86	.64 .65	Calculated Measured			

FIGURE 11-65

McGuire-1 Cy-1A Assembly Peak Axial Powers Calculated vs Measured

249.75 EFPD 100%FP Control Bank D at 221 Steps Withdrawn

	H	G	F	E	D	C	B	A
8	1.26 1.26	1.35 1.40	1.24 1.24	1.31 1.36	1.21 1.25	1.29 1.38	1.15 1.18	.89 .95
9	1.35 1.41	1.25 1.26	1.33 1.39	1.22 1.24	1.30 1.39	1.22 1.23	1.32 1.37	.89 .91
10	1.23 1.25	1.33 1.39	1.23 1.25	1.31 1.38	1.22 1.25	1.29 1.35	1.11 1.09	.83 .85
11	1.29 1.39	1.21 1.24	1.31 1.36	1.23 1.24	1.35 1.41	1.20 1.22	1.18 1.20	.64 .65
12	1.17 1.22	1.28 1.34	1.21 1.20	1.35 1.38	1.35 1.37	1.28 1.32	.95 .97	
13	1.15 1.18	1.17 1.18	1.27 1.35	1.20 1.22	1.28 1.30	1.16 1.17	.66 .68	
14	1.10 1.12	1.29 1.34	1.09 1.12	1.18 1.22	.95 .96	.66 .67		
15	.88 .91	.88 .88	.82 .86	.64 .66	Calculated Measured			

FIGURE 11-66

Sequoyah-1 Cy-1 Assembly Radial Powers Calculated vs Measured

71.82 EFPD 100%FP Control Bank D at 200 Steps Withdrawn

	H	G	F	E	D	C	B	A
8	1.14 1.12	1.09 1.05	1.19 1.17	1.12 1.11	1.16 1.15	1.05 1.05	1.01 1.01	.69 .71
9		1.18 1.16	1.12 1.11	1.20 1.19	1.16 1.16	1.14 1.13	1.00 1.01	.75 .77
10			1.20 1.18	1.13 1.12	1.19 1.18	1.09 1.09	.98 .98	.64 .66
11				1.19 1.18	1.13 1.13	1.10 1.08	.93 .92	.53 .56
12					1.10 1.09	.98 .99	.82 .86	
13						.98 1.02	.48 .51	Calculated Measured

FIGURE 11-67

Sequoyah-1 Cy-1 Assembly Radial Powers Calculated vs Measured

101.62 EFPD 100%FP Control Bank D at 218 Steps Withdrawn

	H	G	F	E	D	C	B	A
8	1.17 1.14	1.11 1.06	1.20 1.16	1.15 1.13	1.18 1.17	1.06 1.06	1.00 1.00	.69 .71
9		1.19 1.16	1.15 1.12	1.21 1.18	1.17 1.16	1.13 1.12	1.00 1.01	.74 .76
10			1.20 1.18	1.15 1.13	1.18 1.17	1.09 1.09	.97 .97	.63 .65
11				1.19 1.17	1.14 1.13	1.08 1.08	.92 .91	.53 .55
12					1.11 1.11	.99 1.00	.81 .85	
13						.97 1.02	.48 .51	Calculated Measured

FIGURE 11-68

Sequoyah-1 Cy-1 Assembly Radial Powers Calculated vs Measured

133.30 EFPD 100%FP Control Bank D at 216 Steps Withdrawn

	H	G	F	E	D	C	B	A
8	1.17 1.14	1.13 1.08	1.20 1.17	1.17 1.14	1.18 1.16	1.08 1.07	.99 .99	.68 .70
9		1.19 1.17	1.17 1.14	1.20 1.19	1.18 1.17	1.12 1.12	1.00 1.01	.73 .76
10			1.21 1.18	1.16 1.14	1.17 1.17	1.09 1.09	.96 .96	.63 .65
11				1.18 1.16	1.14 1.13	1.07 1.06	.91 .91	.53 .55
12					1.09 1.09	.99 1.00	.80 .84	
13						.96 1.01	.47 .51	Calculated Measured

FIGURE 11-69

Sequoyah-1 Cy-1 Assembly Radial Powers Calculated vs Measured

166.04 EFPD 100%FP Control Bank D at 210 Steps Withdrawn

	H	G	F	E	D	C	B	A
8	1.15 1.13	1.13 1.09	1.20 1.17	1.18 1.15	1.16 1.14	1.09 1.08	.99 .99	.69 .71
9		1.19 1.16	1.18 1.15	1.20 1.19	1.18 1.17	1.12 1.11	1.00 1.01	.74 .76
10			1.20 1.18	1.17 1.15	1.17 1.16	1.10 1.09	.96 .96	.63 .66
11				1.18 1.16	1.14 1.13	1.06 1.06	.91 .91	.53 .55
12					1.08 1.08	.99 1.00	.80 .84	
13						.96 1.00	.48 .51	Calculated Measured

FIGURE 11-70

Sequoyah-1 Cy-1 Assembly Radial Powers Calculated vs Measured

231.70 EFPD 100%FP Control Bank D at 216 Steps Withdrawn

	H	G	F	E	D	C	B	A
8	1.12 1.10	1.11 1.08	1.17 1.14	1.18 1.16	1.15 1.13	1.10 1.09	.99 .99	.71 .72
9		1.16 1.13	1.18 1.16	1.17 1.16	1.17 1.17	1.11 1.09	1.01 1.02	.75 .76
10			1.18 1.16	1.18 1.16	1.15 1.14	1.10 1.10	.96 .96	.65 .67
11				1.16 1.14	1.14 1.14	1.06 1.05	.92 .92	.54 .56
12					1.08 1.07	1.01 1.02	.81 .84	
13						.96 1.00	.49 .53	Calculated Measured

FIGURE 11-71

Sequoyah-1 Cy-1 Assembly Radial Powers Calculated vs Measured

292.04 EFPD 100%FP Control Bank D at 216 Steps Withdrawn

	H	G	F	E	D	C	B	A
8	1.08 1.07	1.09 1.07	1.14 1.12	1.17 1.15	1.13 1.11	1.11 1.10	1.00 .99	.73 .74
9		1.13 1.11	1.17 1.15	1.15 1.14	1.16 1.16	1.10 1.08	1.03 1.03	.76 .78
10			1.15 1.14	1.17 1.16	1.13 1.12	1.11 1.11	.97 .97	.67 .69
11				1.14 1.12	1.14 1.13	1.06 1.05	.94 .93	.56 .58
12					1.07 1.06	1.03 1.04	.82 .85	
13						.97 1.00	.50 .55	Calculated Measured

FIGURE 11-72

Sequoyah-1 Cy-1 Assembly Radial Powers Calculated vs Measured

378.92 EFPD 100%FP Control Bank D at 222 Steps Withdrawn

	H	G	F	E	D	C	B	A
8	1.06 1.02	1.06 1.04	1.10 1.08	1.14 1.14	1.11 1.09	1.12 1.10	1.01 1.00	.76 .77
9		1.09 1.07	1.14 1.13	1.12 1.10	1.14 1.14	1.09 1.07	1.04 1.05	.79 .80
10			1.12 1.10	1.14 1.14	1.11 1.09	1.11 1.11	.99 .98	.71 .73
11				1.11 1.09	1.13 1.13	1.06 1.05	.96 .96	.59 .60
12					1.08 1.06	1.05 1.06	.84 .87	
13						.98 1.02	.53 .58	Calculated Measured

FIGURE 11-73

Sequoyah-1 Cy-1 Assembly Peak Axial Powers Calculated vs Measured

71.82 EFPD 100%FP Control Bank D at 200 Steps Withdrawn

	H	G	F	E	D	C	B	A
8	1.48 1.55	1.40 1.42	1.51 1.57	1.45 1.50	1.51 1.60	1.35 1.42	1.26 1.33	.87 .93
9		1.50 1.56	1.44 1.48	1.53 1.59	1.48 1.56	1.44 1.51	1.27 1.34	.94 1.02
10			1.52 1.57	1.44 1.49	1.50 1.57	1.38 1.45	1.23 1.29	.80 .86
11				1.51 1.57	1.44 1.51	1.38 1.43	1.17 1.21	.67 .74
12					1.41 1.50	1.26 1.32	1.03 1.13	
13						1.25 1.36	.60 .67	Calculated Measured

FIGURE 11-74

Sequoyah-1 Cy-1 Assembly Peak Axial Powers Calculated vs Measured

101.62 EFPD 100%FP Control Bank D at 218 Steps Withdrawn

	H	G	F	E	D	C	B	A
8	1.44 1.46	1.37 1.35	1.46 1.48	1.41 1.44	1.45 1.50	1.30 1.36	1.20 1.26	.83 .88
9		1.45 1.47	1.41 1.42	1.47 1.50	1.43 1.47	1.37 1.42	1.21 1.27	.89 .96
10			1.47 1.48	1.41 1.42	1.43 1.48	1.32 1.37	1.16 1.22	.76 .82
11				1.44 1.48	1.39 1.43	1.31 1.35	1.11 1.14	.64 .69
12					1.35 1.40	1.21 1.25	.98 1.06	
13						1.18 1.27	.57 .64	Calculated Measured

FIGURE 11-75

Sequoyah-1 Cy-1 Assembly Peak Axial Powers Calculated vs Measured

133.30 EFPD 100%FP Control Bank D at 216 Steps Withdrawn

	H	G	F	E	D	C	B	A
8	1.40 1.42	1.35 1.33	1.43 1.44	1.40 1.41	1.41 1.45	1.29 1.33	1.17 1.21	.81 .85
9		1.42 1.43	1.40 1.40	1.43 1.46	1.40 1.44	1.32 1.37	1.18 1.23	.87 .92
10			1.43 1.44	1.39 1.39	1.39 1.42	1.30 1.33	1.13 1.17	.74 .79
11				1.40 1.42	1.36 1.38	1.26 1.29	1.08 1.10	.62 .66
12					1.30 1.34	1.18 1.22	.95 1.03	
13						1.14 1.23	.56 .62	Calculated Measured

FIGURE 11-76

<u>Sequoyah-1 Cy-1 Assembly Peak Axial Powers Calculated vs Measured</u>

<u>166.04 EFPD 100%FP Control Bank D at 210 Steps Withdrawn</u>

	H	G	F	E	D	C	B	A
8	1.37 1.37	1.33 1.29	1.40 1.39	1.39 1.38	1.38 1.39	1.28 1.29	1.15 1.17	.81 .84
9		1.39 1.38	1.40 1.37	1.40 1.42	1.39 1.40	1.30 1.32	1.17 1.20	.86 .90
10			1.40 1.40	1.38 1.36	1.36 1.38	1.28 1.30	1.11 1.13	.74 .78
11				1.37 1.36	1.34 1.34	1.24 1.25	1.06 1.08	.62 .66
12					1.28 1.30	1.17 1.19	.93 1.00	
13						1.12 1.19	.56 .61	Calculated Measured

FIGURE 11-77

Sequoyah-1 Cy-1 Assembly Peak Axial Powers Calculated vs Measured

231.70 EFPD 100%FP Control Bank D at 216 Steps Withdrawn

	H	G	F	E	D	C	B	A
8	1.27 1.28	1.26 1.24	1.32 1.31	1.35 1.34	1.31 1.31	1.26 1.26	1.12 1.13	.80 .83
9		1.31 1.30	1.35 1.33	1.33 1.33	1.34 1.35	1.25 1.26	1.15 1.17	.85 .88
10			1.33 1.33	1.34 1.33	1.29 1.30	1.26 1.27	1.08 1.10	.74 .77
11				1.30 1.30	1.30 1.30	1.19 1.21	1.05 1.06	.62 .65
12					1.23 1.25	1.16 1.18	.92 .98	
13						1.10 1.15	.56 .62	Calculated Measured

FIGURE 11-78

Sequoyah-1 Cy-1 Assembly Peak Axial Powers Calculated vs Measured

292.04 EFPD 100%FP Control Bank D at 216 Steps Withdrawn

	H	G	F	E	D	C	B	A
8	1.23 1.24	1.22 1.23	1.28 1.28	1.32 1.33	1.27 1.29	1.26 1.26	1.12 1.14	.82 .85
9		1.26 1.28	1.31 1.32	1.29 1.31	1.31 1.34	1.23 1.24	1.16 1.18	.87 .89
10			1.29 1.31	1.31 1.32	1.26 1.28	1.25 1.27	1.08 1.11	.76 .79
11				1.27 1.28	1.28 1.30	1.18 1.20	1.06 1.07	.64 .66
12					1.21 1.24	1.17 1.19	.92 .97	
13						1.10 1.15	.57 .63	Calculated Measured

FIGURE 11-79

Sequoyah-1 Cy-1 Assembly Peak Axial Powers Calculated vs Measured

378.92 EFPD 100%FP Control Bank D at 222 Steps Withdrawn

	H	G	F	E	D	C	B	A
8	1.19 1.22	1.20 1.22	1.24 1.27	1.30 1.34	1.26 1.28	1.27 1.29	1.15 1.17	.86 .90
9		1.23 1.26	1.29 1.33	1.26 1.30	1.30 1.34	1.23 1.25	1.19 1.22	.89 .93
10			1.26 1.29	1.30 1.33	1.25 1.28	1.26 1.30	1.11 1.14	.80 .84
11				1.26 1.28	1.28 1.32	1.20 1.23	1.09 1.11	.67 .69
12					1.22 1.26	1.19 1.24	.94 1.00	
13						1.11 1.19	.59 .67	Calculated Measured

FIGURE 11-80

McGuire-1 Cy-1 PDQ07 Assembly Radial Powers Calculated vs Measured

PDQ07 - 52.2 EFPD vs Core Meas - 48.8 EFPD

	H	G	F	E	D	C	B	A
8	1.16 1.12	1.10 1.09	1.20 1.19	1.20 1.21	1.23 1.23	1.12 1.12	1.01 1.01	.68 .71
9		1.18 1.15	1.12 1.13	1.23 1.22	1.18 1.19	1.15 1.14	1.00 1.02	.74 .75
10			1.22 1.20	1.19 1.19	1.20 1.18	1.09 1.10	.97 .97	.63 .64
11				1.20 1.19	1.08 1.08	1.08 1.07	.94 .96	.53 .54
12					1.22 1.18	.92 .92	.80 .81	
13						.96 .95	.46 .46	Calculated Measured

FIGURE 11-81

McGuire-1 Cy-1 PDQ07 Assembly Radial Powers Calculated vs Measured

PDQ07 - 104.4 EFPD vs Core Meas - 104.5 EFPD

	H	G	F	E	D	C	B	A
8	1.17 1.15	1.13 1.15	1.19 1.19	1.20 1.23	1.20 1.19	1.12 1.12	1.00 1.00	.69 .70
9		1.18 1.17	1.14 1.16	1.21 1.20	1.18 1.19	1.13 1.12	1.01 1.02	.74 .74
10			1.20 1.18	1.19 1.20	1.18 1.16	1.09 1.11	.96 .96	.64 .64
11				1.19 1.17	1.10 1.11	1.07 1.07	.94 .96	.54 .53
12					1.21 1.18	.94 .94	.80 .80	
13						.96 .94	.47 .47	Calculated Measured

FIGURE 11-82

McGuire-1 Cy-1 PDQ07 Assembly Radial Powers Calculated vs Measured

PDQ07 - 156.7 EFPD vs Core Meas - 150.2 EFPD

	H	G	F	E	D	C	B	A
8	1.17 1.15	1.15 1.17	1.18 1.17	1.19 1.21	1.17 1.17	1.12 1.13	1.00 1.00	.70 .71
9		1.17 1.15	1.15 1.17	1.18 1.17	1.17 1.19	1.12 1.10	1.02 1.03	.75 .74
10			1.18 1.16	1.18 1.20	1.16 1.14	1.10 1.11	.96 .95	.65 .65
11				1.17 1.16	1.11 1.12	1.07 1.06	.95 .96	.55 .54
12					1.20 1.17	.96 .97	.81 .81	
13						.96 .95	.49 .48	Calculated Measured

FIGURE 11-83

McGuire-1 Cy-1A PDQ07 Assembly Radial Powers Calculated vs Measured

PDQ07 - 208.9 EFPD vs Core Meas - 198.7 EFPD

	H	G	F	E	D	C	B	A
8	1.10 1.08	1.22 1.23	1.08 1.09	1.17 1.19	1.05 1.06	1.16 1.18	.99 .99	.78 .79
9	1.22 1.22	1.09 1.08	1.20 1.20	1.06 1.06	1.17 1.18	1.05 1.05	1.18 1.17	.76 .76
10	1.07 1.07	1.19 1.19	1.06 1.06	1.18 1.19	1.06 1.06	1.16 1.16	.95 .93	.72 .72
11	1.14 1.17	1.04 1.04	1.17 1.18	1.08 1.08	1.22 1.22	1.04 1.04	1.03 1.03	.54 .54
12	.98 .99	1.12 1.13	1.04 1.04	1.21 1.21	1.20 1.17	1.15 1.13	.83 .83	
13	.96 .99	.98 .98	1.12 1.14	1.03 1.02	1.14 1.12	1.02 1.01	.58 .58	
14	.91 .91	1.11 1.11	.91 .91	1.01 1.01	.82 .82	.58 .57		
15	.73 .74	.72 .72	.69 .70	.53 .53	Calculated Measured			

FIGURE 11-84

Sequoyah-1 Cy-1 PDQ07 Assembly Radial Powers Calculated vs Measured

PDQ07 - 103.6 EFPD vs Core Meas - 101.6 EFPD

	H	G	F	E	D	C	B	A
8	1.16 1.14	1.08 1.07	1.17 1.17	1.13 1.13	1.18 1.17	1.08 1.07	1.01 1.00	.71 .71
9		1.17 1.16	1.12 1.12	1.19 1.19	1.17 1.17	1.14 1.13	1.02 1.01	.77 .77
10			1.18 1.18	1.13 1.13	1.18 1.18	1.10 1.10	.97 .98	.65 .66
11				1.18 1.18	1.15 1.14	1.09 1.08	.91 .92	.55 .56
12					1.13 1.11	1.00 1.00	.84 .85	
13						1.01 1.02	.50 .51	Calculated Measured

FIGURE 11-85

Sequoyah-1 Cy-1 PDQ07 Assembly Radial Powers Calculated vs Measured

PDQ07 - 155.5 EFPD vs Core Meas - 133.3 EFPD

	H	G	F	E	D	C	B	A
8	1.17 1.13	1.11 1.09	1.18 1.18	1.16 1.16	1.17 1.15	1.09 1.08	1.00 .99	.71 .71
9		1.18 1.17	1.16 1.16	1.19 1.19	1.18 1.18	1.12 1.12	1.02 1.01	.76 .77
10			1.19 1.19	1.16 1.16	1.17 1.17	1.10 1.10	.96 .96	.65 .66
11				1.17 1.16	1.15 1.14	1.07 1.06	.90 .92	.55 .56
12					1.11 1.08	1.00 1.00	.82 .84	
13						.99 1.00	.50 .52	Calculated Measured

FIGURE 11-86

Sequoyah-1 Cy-1 PDQ07 Assembly Radial Powers Calculated vs Measured

PDQ07 - 362.7 EFPD vs Core Meas - 378.9 EFPD

	H	G	F	E	D	C	B	A
8	1.04 1.03	1.04 1.04	1.09 1.09	1.15 1.14	1.11 1.09	1.13 1.10	1.01 1.01	.77 .78
9		1.07 1.07	1.14 1.14	1.11 1.11	1.16 1.15	1.09 1.08	1.06 1.05	.80 .81
10			1.11 1.11	1.15 1.14	1.11 1.10	1.12 1.12	.98 .99	.72 .73
11				1.11 1.10	1.15 1.13	1.06 1.05	.95 .96	.60 .61
12					1.08 1.07	1.05 1.07	.85 .87	
13						1.01 1.03	.57 .59	Calculated Measured

12. REFERENCES

1. Nuclear Associates International Corp., "Advanced Recycle Methodology Program System Documentation", CCM-3, (EPRI Confidential), September, 1977.

2. Studsvik Energiteknik AB, "CASMO-2 A Fuel Assembly Burnup Program," Studsvik/NR-81/3, 1981.

3. Duke Power Company, "Oconee Nuclear Station Reload Design Methodology," NFS-1001, Rev. 4, June 1981.

4. Bettis Atomic Power Laboratory, C. J. Pfeiffer, "PDQ-7 Reference Manual II," WAPD-TM-947(L), February 1971.

5. Rothleder, B. M., Fisher, J. R., "EPRI-NODE-P," EPRI-ARMP System Documentation, CCM-3, Part II, Chapter 14, September 1977.

6. Not Used.

7. Not Used.

8. Cobb, W. R., Eich, W. J., Tivel, D. E., "EPRI-CELL Code Description," EPRI-ARMP System Documentation, CCM-3, Part II, Chapter 5, October 1978.

9. Edenius, M., Ekberg, K., Haggblom, H., "CASMO - THE DATA LIBRARY," Studsvik/K2-81/491, 1981.

10. Cobb, W. R., Tivel, D. E., "EPRI-CELL: GAM-THERMOS Library Descriptions," EPRI-ARMP System Documentation, CCM-3, Part II, Chapter 2, April 1976.

11. Rothleder, B. M., Poetschat, G. R., "NUPUNCHER Code Description," EPRI-ARMP System Documentation, CCM-3, Part II, Chapter 8, October 1975.

12. Duke Power Company, "MULTIFIT User Documentation," (Proprietary), February 1983.

13. Hebert, M. J., et. al., "PROGRAM C-HA-R-T CASMO to HARMONY Tableset Conversion Processor," YAEC-1313P, May 1982.

14. Rothleder, B. M. et. al., "PWR Core Modeling Procedures for Advanced Recycle Methodology Program," RP-976-1, August 1979.

15. Rothleder, B. M., Poetschat, G. R., "EPRI-FIT Code Description," EPRI-ARMP System Documentation, CCM-3, Part II, Chapter 10, October 14 1975.

16. Rothleder, B. M., Poetschat, G. R., "SUPERLINK-P Code Description," EPRI-ARMP System Documentation, CCM-3, Part II, Chapter 12, October 22 1975.

17. Smith, M. L., "PDQ7V2P7," (Proprietary), Virginia Electric and Power Company, December 1977.

18. McGuire Nuclear Station, Units 1 and 2, Updated Final Safety Analysis Report, Docket Nos. 50-369, 370.

19. Catawba Nuclear Station, Units 1 and 2, Updated Final Safety Analysis Report, Docket Nos. 50-413, 414.

20. Letter, W. O. Parker to H. R. Denton, "Oconee Reload Design Methodology Topical Report," Question 3, Docket Nos. 50-269,-270,-287, November 13 1980.

21. Duke Power Company, Quality Assurance Program Topical Report, Revision 26, September 13, 2000.

22. Not Used.

23. Not Used.

24. Not Used.

25. D. B. Owen, "Factors For One-Sided Tolerance Limits And For Variables Sampling Plans," SCR-607, Sandia Corporation Monograph, March 1963.

26. Shanstrom, R. T., et al, "CORE Codes for Operating Reactor Evaluation", SNA1617 (Proprietary), Shanstrom Nuclear Associates, April 1982.

27. American National Standards Institute, Inc., "Assessment of the Assumption of Normality (Employing Individual Observed Values)", ANSI N15.15-1974, 1974.

28. "Duke Power Company, Nuclear Design Methodology Using CASMO-3/SIMULATE-3P, DPC-NE-1004A, Rev. 1, SER dated April 26, 1996.

29. "Duke Power Company, Nuclear Design Methodology for Core Operating Limits of Westinghouse Reactors", DPC-NE-2011PA, March 1990.

30. "Duke Power Company, McGuire Nuclear Station, Catawba Nuclear Station, Multidimensional Reactor Transients and Safety Analysis Physics Parameters Methodology", DPC-NE-3001PA, November 1991.

31. "Duke Power Company, Westinghouse Fuel Transition Report", DPC-NE-2009-P-A, SER dated September 22, 1999.

32. "Duke Power Company, McGuire Nuclear Station, Catawba Nuclear Station, Nuclear Physics Methodology for Reload Design", DPC-NF-2010-PA, NRC Approved SER, March 13, 1985.

APPENDIX A

Code Summary

CASMO-2

CASMO-2 is a multi-group two-dimensional transport theory code for burnup calculations on BWR and PWR assemblies. This code has been developed by Studsvik Energiteknik AB and supported by EPRI.

CHART

CHART prepares cross section tables in HARMONY format from cross section data produced by CASMO-2. CHART reduces significantly the tedious task of hand transferring values from CASMO-2 printout to macroscopic and microscopic tables in card image HARMONY format. Two, three, and four group cross section data may be obtained with one-dimensional HARMONY interpolating tables.

CORE

CORE (Codes for Operating Reactor Evaluation), is a package of computer routines for the off-line evaluation of reactor performance. CORE uses as input: detailed reactor physics data, isotopics, and thermal-hydraulics data. Calculated values are: F_Q, $F_{\Delta H}^N$, assembly burnups, isotopics, reactivity, and core thermal-hydraulics information.

DELAY

DELAY calculates core averaged delayed neutron fractions for six energy groups, core averaged decay constants for six energy groups, core averaged delayed neutron fraction with and without importance factor, estimated prompt neutron lifetime, and reactivity versus period. Input consists primarily of isotopic fission fractions versus burnup and enrichment from PDQ07 calculations.

EPRI-CELL

EPRI-CELL computes the space, energy and burnup dependence of the neutron spectrum within cylindrical cells of Light Water Reactor fuel rods. Its primary output consists of broad group, microscopic, exposure dependent cross sections for subsequent use in multidimensional diffusion theory depletion analysis. EPRI-CELL utilizes three industry accepted subcodes; GAM-1, THERMOS, and CINDER.

EPRI-CPM

EPRI-CPM is a multi-group two-dimensional collision probability code for burnup calculations on BWR and PWR assemblies. The code handles a geometry consisting of cylindrical fuel rods of varying composition in a square pitch array with allowance for fuel rods loaded with gadolinium, burnable absorber rods, cluster control rods, in-core instrument channels, water gaps, boron steel curtains and cruciform control rods in the regions separating fuel assemblies.

EPRI-FIT

EPRI-FIT is a program which processes the PDQ07 integral file and calculates and edits values needed by the EPRI-NODE code. EPRI-FIT greatly reduces the hand calculation time needed to extract these values from the PDQ07 printout and improves the quality assurance. A data file under the local name of COLOR is written which contains the EPRI-FIT edited data and is used as input to the SUPERLINK program.

EPRI-NODE

EPRI-NODE is a multi-dimensional nodal code derived from FLARE. The EPRI-NODE program computes the core effective multiplication factor, the three-dimensional core power distribution, core coolant flow and temperature distribution, and fuel exposure distribution. The program includes the effects of partially inserted full-length control rods, part-length rods, and up to 13 different fuel assembly types with different enrichments and burnable absorber shim loadings. EPRI-NODE has a capacity to represent the core with 32 axial nodes for each fuel assembly and 30x30 nodes in the XY plane.

The program iterates to account for the interaction between power distribution and core nuclear properties which depend on coolant flow and coolant temperature distributions, fuel temperature distribution and xenon distribution. The program computes the time dependence of xenon following changes in power level and/or changes in power distribution. The program permits fuel shuffling from one location to another and fresh fuel insertion for burnup cycle calculations. Individual steps can by stacked for either xenon transient or fuel cycle burnup calculations. See Reference 5.

EPRI-NUPUNCHER

NUPUNCHER prepares cross section tables in HARMONY format from cross section data produced by EPRI-CELL and placed on the ECDATA file. NUPUNCHER reduces significantly the tedious task of hand transferring values from the EPRI-CELL printout to macroscopic and microscopic tables in card image HARMONY format. Two, three and four group cross section data may be obtained with one-dimensional HARMONY interpolating tables.

EPRI-PDQ07 MODIFICATIONS

PDQ07 is an industry accepted multi-group one, two, or three-dimensional diffusion depletion code. EPRI-ARMP uses PDQ07/Version II with minor modifications to allow options for improved removal treatment, peak power editing, and re-editing.

EPRI -SHUFFLE

The EPRI-SHUFFLE program will read a PDQ07 concentration file, make certain modifications to this file, and write a new updated concentration file. This procedure is accomplished by defining "assembly regions" in the program input. Assembly regions are square arrays of mesh points containing depletable nuclide concentrations and superimposed on the original PDQ07 geometry. These assembly regions are then used to describe the movement of existing nuclide concentrations by translation, reflection and/or rotation. In addition, new fuel concentrations can replace spent fuel concentrations in selected assembly regions described in the program's input.

EPRI - SUPERLINK

SUPERLINK accesses data on the files produced by EPRI-FIT and, together with relevant input information for file management and for data processing control, produces polynomial coefficients for use in EPRI-NODE.

MULTIFIT

MULTIFIT reads EPRI-CELL cross section files and generates HARMONY cross sections and g-factors. Both HARMONY masks and function tables can include the effects of up to three independent variables. MULTIFIT can perform almost all of the functions of EPRI-NUPUNCHER.

PDQ07

See EPRI-PDQ07 Modifications and Reference 4.

CASMO-3

CASMO-3 is a multi-group two-dimensional transport theory code for burnup calculations on BWR and PWR assemblies. This code develops cross-section data for use in SIMULATE-3. A full description of this code is contained in Reference 28.

SIMULATE-3P

SIMULATE-3 is a three-dimensional, two-group diffusion theory reactor simulator used for nuclear design calculations. A full description of this code is contained in Reference 28.

APPENDIX B

NRC/DPC Correspondence Regarding NRC Request for Additional Information

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

November 5, 1984

Docket Nos: 50-369, 50-370
and 50-413, 50-414

Mr. H. B. Tucker, Vice President
Nuclear Production Department
Duke Power Company
422 South Church Street
Charlotte, North Carolina 28242

Dear Mr. Tucker:

Subject: Request for Additional Information Regarding Topical Report on Physics Methodology for Reloads: McGuire and Catawba Nuclear Station

In response to your letter of July 18, 1984, the NRC staff, with the technical assistance of Brookhaven National Laboratory (BNL), is reviewing Duke Power Company topical report DPC-NF-2010 which describes the nuclear physics methodology for reload design at the McGuire and Catawba Nuclear Stations. We find that additional information identified in the enclosure is needed to complete this review.

A reply at your earliest opportunity and no later than November 30, 1984, is needed for the staff to meet your requested review completion date of January 1985. A copy of your reply should also be forwarded directly to BNL at the address below.

Should you have questions or need to meet with the staff regarding the enclosure, contact Darl S. Hood at (301) 492-8408.

Sincerely,

Elinor G. Adensam

Elinor G. Adensam, Chief
Licensing Branch No. 4
Division of Licensing

Enclosure:
As stated

cc: Dr. John Carew
Building 475 B
Brookhaven National Laboratory
Upton, Long Island, N.Y. 11973

See next page

CATAWBA

Mr. H. B. Tucker, Vice President
Nuclear Production Department
Duke Power Company
422 South Church Street
Charlotte, North Carolina 28242

cc: William L. Porter, Esq.
Duke Power Company
P.O. Box 33189
Charlotte, North Carolina 28242

J. Michael McGarry, III, Esq.
Bishop, Liberman, Cook, Purcell and Reynolds
1200 Seventeenth Street, N.W.
Washington, D. C. 20036

North Carolina MPA-1
P.O. Box 95162
Raleigh, North Carolina 27625

Mr. F. J. Twogood
Power Systems Division
Westinghouse Electric Corp.
P.O. Box 355
Pittsburgh, Pennsylvania 15230

NUS Corporation
2536 Countryside Boulevard
Clearwater, Florida 33515

Mr. Jesse L. Riley, President
Carolina Environmental Study Group
854 Henley Place
Charlotte, North Carolina 28208

Richard P. Wilson, Esq.
Assistant Attorney General
S.C. Attorney General's Office
P.O. Box 11549
Columbia, South Carolina 29211

North Carolina Electric Membership Corp.
3333 North Boulevard
P.O. Box 27306
Raleigh, North Carolina 27611

Saluda River Electric Cooperative, Inc.
P.O. Box 929
Laurens, South Carolina 29360

Senior Resident Inspector
Route 2, Box 179N
York, South Carolina 29745

James P. O'Reilly, Regional Administrator
U.S. Nuclear Regulatory Commission, Region II
101 Marietta Street, N.W., Suite 2900
Atlanta, Georgia 30323

Robert Guild, Esq.
P.O. Box 12097
Charleston, South Carolina 29412

Palmetto Alliance
2135 ½ Devine Street
Columbia, South Carolina 29205

Karen E. Long
Assistant Attorney General
N.C. Department of Justice
P.O. Box 629
Raleigh, North Carolina 27602

cc: Spence Perry, Esquire
Associate General Counsel
Federal Emergency Management Agency
Room 840
500 C Street, S.W.
Washington, D. C. 20472

Mark S. Calvert, Esq.
Bishop, Liberman, Cook,
Purcell & Reynolds
1200 17th Street, N.W.
Washington, D. C. 20036

Mr. Michael Hirsch
Federal Emergency Management Agency
Office of the General Counsel
Room 840
500 C Street, S.W.
Washington, DC 20472

Brian P. Cassidy, Regional Counsel
Federal Emergency Management Agency,
Region I
J. W. McCormach POCH
Boston, Massachusetts 02109

McGuire

Mr. H. B. Tucker, Vice President
Nuclear Production Department
Duke Power Company
422 South Church Street
Charlotte, North Carolina 28242

cc: Mr. A. Carr
Duke Power Company
P. O. Box 33189
422 South Church Street
Charlotte, North Carolina 28242

Mr. F. J. Twogood
Power Systems Division
Westinghouse Electric Corp.
P. O. Box 355
Pittsburgh, Pennsylvania 15230

Mr. Robert Gill
Duke Power Company
Nuclear Production Department
P. O. Box 33189
Charlotte, North Carolina 28242

J. Michael McGarry, III, Esq.
Bishop, Liberman, Cook, Purcell
and Reynolds
1200 Seventeenth Street, N.W.
Washington, D. C. 20036

Mr. Wm. Orders
Senior Resident Inspector
c/o U.S. Nuclear Regulatory Commission
Route 4, Box 529
Hunterville, North Carolina 28078

James P. O'Reilly, Regional Administrator
U.S. Nuclear Regulatory Commission,
Region II
101 Marietta Street, N.W., Suite 2900
Atlanta, Georgia 30323

R. S. Howard
Operating Plants Projects
Regional Manager
Westinghouse Electric Corporation - R&D 701
P. O. Box 2728
Pittsburgh, Pennsylvania 15230

REQUEST FOR ADDITIONAL INFORMATION ON DUKE POWER COMPANY
TOPICAL REPORT DPC-NF-2010

---

1. Please provide additional information regarding the NUC-MARGINS code and its use in the Dropped Rod Analysis. Provide short descriptions of the input, output, calculational models used, benchmark calculations performed and the conservatisms assumed in the analysis.

2. Identify the nominal and various off-nominal cross-section sets that are generated in order to evaluate the different reactivity coefficients and defects.

3. Provide a short description of the PDQEDIT code and describe the verification program that was undertaken to test data generated with PDQEDIT for use in SNA-CORE.

4. Comment on the reasons for the 3.1% non-conservative bias in the calculated peak axial powers (Section 11.5.4). Describe the model refinements, if any, that have been undertaken to reduce this bias.

5. Duke Power Company's contention that no uncertainty in calculated pin powers needs to be accounted for has not been adequately established. One possible way to establish the uncertainty is to perform a standard problem. A standard problem recently developed at Brookhaven National Laboratory for a licensee to assess its ability to calculate typical PWR fuel assemblies, is attached. A solution of this problem or other justification for the assumed uncertainty should be provided.

6. Please provide the updates to DPC-NF-2010, if any, that will make it consistent with the methodologies currently being used by Duke Power.

FUEL ASSEMBLY STANDARD PROBLEM

The standard problem is to be calculated in two dimensions in an iterated-source mode using reflecting boundary conditions in the horizontal plane neglecting axial leakage. The following series of assembly depletion and reactivity defect calculations are to be calculated.

I. DEPLETION CALCULATIONS

Provide the following edited quantities for an assembly with and without burnable poison rods at BOL, 500, 5000, 10000, 20000, 30000 and 40000 Mwd/MT*:

1. Relative pin powers

2. Assembly volume averaged fuel pellet isotopics; U^{235}, U^{238}, Pu^{239}, Pu^{240}, Pu^{241}, Pu^{242} and calculated fission product densities [atom/barn-cm]

3. Assembly total reaction rates (A-absorption, F-fission)

   a. Fuel

U^{235} (A)	Pu^{240} (A)
U^{235} (F)	Pu^{240} (F)
U^{238} (A)	Pu^{241} (A)
U^{238} (F)	Pu^{241} (F)
Pu^{239} (A)	Pu^{242} (A)
Pu^{239} (F)	Pu^{242} (F)

   b. Clad (A)
   c. Burnable Poison (A)
   d. Water (A)
   e. Control Rod (A)

4. Assembly Characteristics

   a. k_∞ - Infinite Multiplication Factor
   b. M^2 - Migration Area [cm^2]
   c. B_M^2 - Material Buckling [cm^{-2}]
   d. β - Delayed Neutron Fraction
   e. Two-Group Inverse Neutron Velocity† [cm/sec]

5. Two-Group Collapsed Assembly Averaged Cross Sections†

   D [cm], Σ_a[cm^{-1}], Σ_r[cm^{-1}],

   $\nu\Sigma_f$[cm^{-1}], $\kappa\Sigma_f$[watt/cm], Σ_f[cm^{-1}]

* These are editing points and do not necessarily correspond to the depletion steps.

† Thermal breakpoint assumed at 0.625 [eV]

II. REACTIVITY DEFECT CALCULATIONS

Provide the following reactivity defects (%Δ k/k) for an assembly with and without burnable poison rods at BOL and EOL (30,000 Mwd/MT):

	REACTIVITY DEFECT (%Δ k/k)*	UNPERTURBED CASE†	PERTURBED CASE
1.	Fuel Temperature (T_{fuel})	T_{fuel}^{base}	$T_{moderator}^{base}$
2.	Moderator Temperature ($T_{moderator}$)	$T_{moderator}^{base}$	$T_{moderator}^{base}$ -25°K
3.	Moderator & Fuel Temperature†† ($T_{Moderator}$ & T_{Fuel})	$T_{moderator}^{base}$	68°F
		T_{fuel}^{base}	68°F
4.	Moderator & Fuel Temperature†† ($T_{Moderator}$ & T_{Fuel})	$T_{moderator}^{base}$	300°F
		base fuel	300°F
5.	Boron Concentration (N_{boron})	N_{boron}^{base}	0 ppm
6.	Xenon Concentration (N_{xenon})	Equilibrium	0
7.	Control Rod #	Unrodded	Rodded

* It is recommended that a full flux solution be carried out for each state-point.

† Unperturbed parameters are at their base values indicated in the Standard Problem definition.

\# In the case of the W (17x17) assembly only the unpoisoned assembly is required.

†† Pressure is to be maintained at base value.

DATA FOR FUEL ASSEMBLY STANDARD PROBLEM

17 x 17 W Type Fuel Assembly

1. General Characteristics

Power density (W/Gm-U)	38.4
Average fuel temperature (°K)	968
Average clad temperature (°K)	600
Moderator temperature (°K)	560
Soluble boron concentration (ppm)	400
Average core pressure (psia)	2250
Xenon concentration	Equilibrium
Samarium concentration	Equilibrium

2. Configuration (1/8 assembly)

```
4
1 1
1 1 1
2 1 1 3
1 1 1 1 1
1 1 1 1 1 2
3 1 1 2 1 1 1
1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1
```

1 - Fuel Rod
2 - Burnable Poison Rod (BPR)
3 - Guide Thimble
4 - Instrument Thimble

Note: 1. For an unrodded or unpoisoned case replace all BPRs (2) with guide thimbles (3).

2. For a rodded case replace all BPRs (2) with control rods inserted in guide thimbles (3).

3. Fuel Assembly Data

Rod array	17 x 17
Fuel rods per assembly	264
Rod pitch (in)#	0.496
Assembly pitch (in)**	8.466 x 8.466
Assembly length (in)	151.0
Active fuel length (in)	144.0
Number of spacer grids†	8
Compositon of spacer grid	Inconel 718
Weight of spacer grids (lb)	12
Number of guide thimbles	24
Number of instrument thimbles	1

All dimensions are given at cold (68°F) conditions.
† Seven in active length.
** Center to center assembly pitch.

4. Fuel Rod Data

Clad O.D. (in)	0.374
Clad thickness (in)	0.0225
Diametral gap (in)	0.0065
Clad material	Zircaloy-4

5. Fuel Pellet Data

Material	UO_2 - Undished
Density (% of theoretical)	95
Enrichment (w/o)	2.6
Diameter (in)	0.3225

6. Burnable Poison Rod Data (See Figure 1)

Number per assembly	16
Material	Borosilicate Glass
Density (Borosilicate glass) (gm/cm^3)	2.28
Outside clad O.D. (in)	0.381
Outside Clad I.D. (in)	0.348
Absorber O.D. (in)	0.344
Absorber I.D. (in)	0.185
Inner-tube O.D. (in)	0.1805
Inner-tube I.D. (in)	0.170
Clad material	Stainless Steel
Inner-tube material	Stainless Steel
Boron loading (w/o B_2O_3 in glass rod)	12.5
Weight of Boron-10 (lb/ft)	0.000419

7. Guide Thimbles and Instrument Thimble Data

Number of guide thimbles	24
Number of instrument thimbles	1
Composition of thimbles	Zircaloy-4
Guide Thimble O.D. (in)	0.482
Guide Thimble I.D. (in)	0.450
Instrument Thimble O.D. (in)	0.482
Instrument Thimble I.D. (in)	0.450

8. Control Rod Data

Neutron absorber (w/o)	5% Cd, 15% In, 80% Ag
Absorber diameter (in)	0.341
Absorber density (lb/in^3)	0.367
Cladding material	304 Stainless Steel
Clad O.D. (in)	0.381
Clad thickness (in)	0.0185
Number of control rods	24

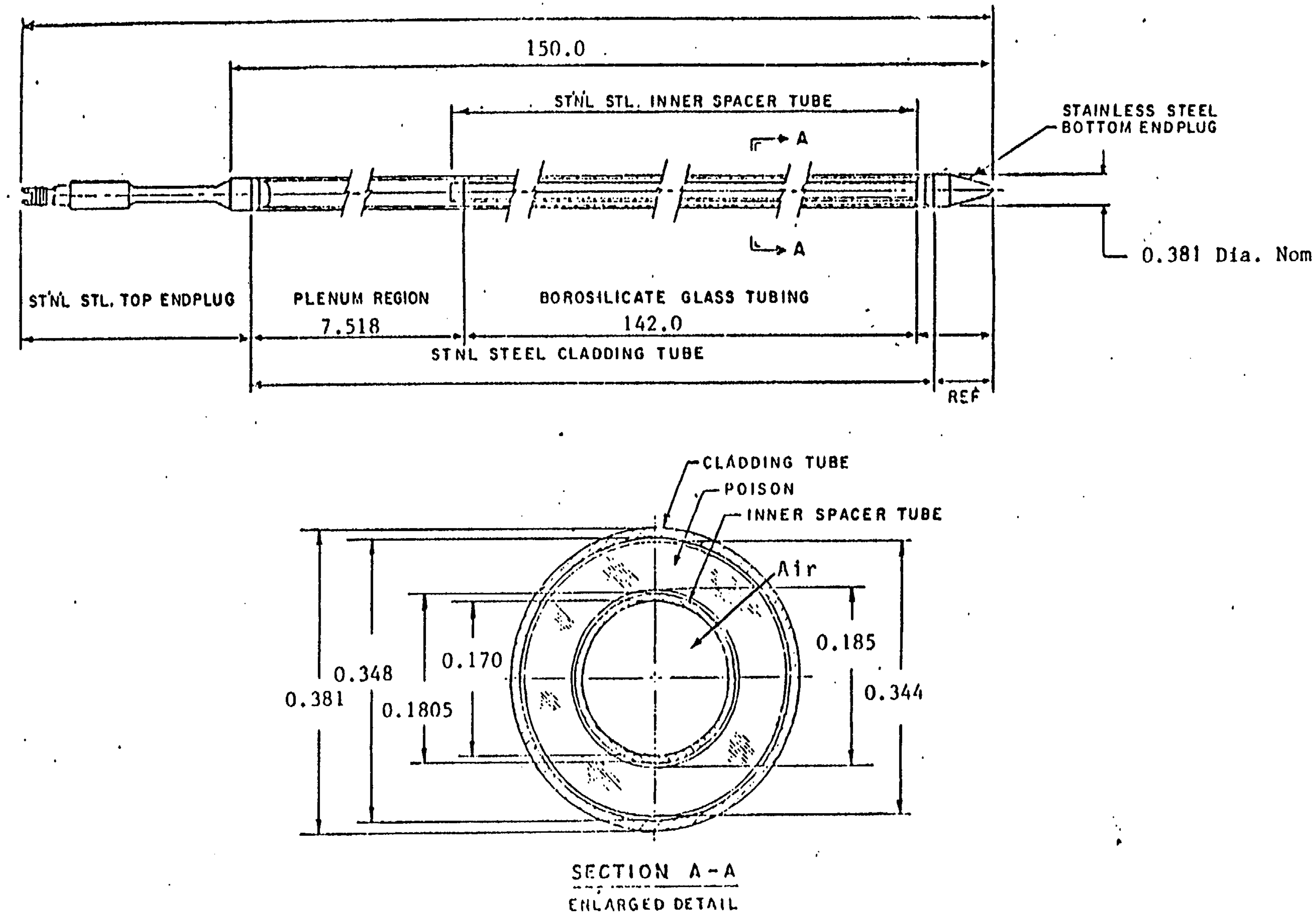

Figure 1. Burnable Poison Rod Configuration

DESCRIPTION OF CALCULATIONS AND METHODS

1. Name of code/code source/version
2. Reference for calculational method
3. Assembly solution method (Diffusion Theory, Collision Probability, Integral Transport, Monte Carlo, etc.)
4. Pin-cell solution method (if distinct from assembly solution method)
5. Spatial mesh assembly/pin-cell (nxm)
6. Neutron cross sections (ENDF/B or other identification)
7. Number of fast/thermal groups in assembly/pin-cell solution
8. Depletion steps

DUKE POWER COMPANY
P.O. BOX 33189
CHARLOTTE, N.C. 28242

HAL B. TUCKER
VICE PRESIDENT
NUCLEAR PRODUCTION

TELEPHONE
(704) 373-4531

December 19, 1984

Mr. Harold R. Denton, Director
Office of Nuclear Reactor Regulation
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

Attention: Ms. E. G. Adensam, Chief
Licensing Branch No. 4

Subject: McGuire Nuclear Station - Docket No. 50-369/370
Catawba Nuclear Station - Docket No. 50-413/414
Response Request for Additional Information Regarding
Topical Report DPC-NF-2010, "Nuclear Physics Metodology
for Reload Design"

In response to the request by telephone conference (between NRC, Duke and Brookhaven) on December 17, 1984 for additional information regarding the subject topical report, attached is Duke Power Company's revised answer to question number five, regarding pin power uncertainties.

If any additional information or discussion is desired, please feel free to call Scott Gewehr, Duke Power Licensing at (704) 373-7581.

Very truly yours,

Hal B. Tucker

Hal B. Tucker

SAG/mjf

Attachment

cc: Dr. John Carew
Building 475 B
Brookhaven National Laboratory
Upton, N. Y. 11973

Mr. Jesse L. Riley, President
Carolina Environmental Study Group
854 Henley Place
Charlotte, North Carolina 28208

James P. O'Reilly, Regional Administrator
U. S. Nuclear Regulatory Commission,
Region II
101 Marietta Street, N. W., Suite 2900
Atlanta, Georgia 30323

A001 1/1

121984
B97

DUKE POWER COMPANY
P.O. BOX 33189
CHARLOTTE, N.C. 28242

HAL B. TUCKER
VICE PRESIDENT
NUCLEAR PRODUCTION

TELEPHONE
(704) 373-4531

November 30, 1984

Mr. Harold R. Denton, Director
Office of Nuclear Reactor Regulation
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

Attention: Ms. E. G. Adensam, Chief
Licensing Branch No. 4

Subject: McGuire Nuclear Station - Docket No. 50-369/370
Catawba Nuclear Station - Docket No. 50-413/414
Response Request for Additional Information Regarding
Topical Report DPC-NF-2010, "Nuclear Physics Metodology
for Reload Design"

In response to your request (Reference Letter, E. G. Adensam to H. B. Tucker, November 5, 1984) for additional information regarding the subject topical report, attached are Duke Power Company's answers to the six questions in the request.

If any additional information or discussion is desired, please feel free to call Scott Gewehr, Duke Power Licensing at (704) 373-7581.

Very truly yours,

H.B. Tucker

Hal B. Tucker

SAG/mjf

Attachment

cc: Dr. John Carew
Building 475 B
Brookhaven National Laboratory
Upton, N. Y. 11973

Mr. Jesse L. Riley, President
Carolina Environmental Study Group
854 Henley Place
Charlotte, North Carolina 28208

James P. O'Reilly, Regional Administrator
U. S. Nuclear Regulatory Commission,
Region II
101 Marietta Street, N.W., Suite 2900
Atlanta, Georgia 30323

cc: Mr. Robert Guild, Esq.
P. O. Box 12097
Charleston, South Carolina 29412

Palmetto Alliance
2135 ½ Devine Street
Columbia, South Carolina 29205

Mr. W. T. Orders
Senior Resident Inspector
McGuire Nuclear Station

Senior Resident Inspector
Route 2, Box 179N
York, South Carolina 29745

Mr. F. J. Twogood
Power Systems Division
Westinghouse Electric Corp.
P. O. Box 355
Pittsburgh, Pennsylvania 15230

Mr. Harold R. Denton, Director
November 30, 1984
Page Three

bcc: William L. Porter, Esq.
Duke Power Company
P. O. Box 33189
Charlotte, North Carolina 28242

J. Michael McGarry, III, Esq.
Bishop, Liberman, Cook, Purcell
and Reynolds
1200 Seventeenth Street, N.W.
Washington, D. C. 20036

North Carolina MPA-1
P. O. Box 95162
Raleigh, North Carolina 27625

North Carolina Electric Membership Corp.
3333 North Boulevard
P. O. Box 27306
Raleigh, North Carolina 27611

Saluda River Electric Cooperative, Inc.
P. O. Box 929
Laurens, South Carolina 29360

N. A. Rutherford
R. L. Gill
K. S. Canady
L. H. Flores
R. H. Clark
H. T. Snead
P. M. Abraham

Q.1 Please provide additional information regarding the NUC-MARGINS code and its use in the Dropped Rod Analysis. Provide short descriptions of the input, output, calculational models used, benchmark calculations performed and the conservatisms assumed in the analysis.

A.1 Under the terms of the current fuel contract with Westinghouse, Duke Power will provide physics data for the rod drop transient to Westinghouse who will then perform the safety evaluation and/or reanalysis. This relationship will exist until Duke submits its thermal-hydraulic and safety analysis methodology reports to the NRC.

The physics methods described in Section 4.2.2.5, 6.2.2.4, and 9.1.3.3 will be further elaborated herein.

A. Initial conditions for analysis:

1. Control Bank D is inserted to the Rod Insertion Limit.
2. Core Power is 102% Full Power (2% calorimetric error included).
3. A full power xenon distribution is used which would produce a DNB limiting axial power profile.

B. Assumptions for system response upon rod drop:

1. No trip occurs.
2. Control bank D is withdrawn to compensate for the dropped rod.
3. A short duration reactor power overshoot will occur with the turbine-reactor control system eventually leveling out the reactor power to the initial power level.

Search cases are performed as described in Section 4.2.2.5 and 6.2.2.4. EPRI-NODE assembly average powers are converted to $F_{\Delta H}^{N}$ using the method described below. This method is employed for all $F_{\Delta H}^{N}$ evaluations. All physics codes employed are static, therefore, "before" and "after" rod drop power distributions are calculated.

The mathetical formulation of $F_{\Delta H}^{C}$ employs the Section 6.2.1.2 definitions as follows:

$$F_{\Delta H,j}^{C} = [\sum_{i=1}^{K} F_{i,j}^{node} \times RL_j^N + FR_j \times F_{K,j}^{node} \times RL_j^N + (1-FR_j) \times F_{K,J}^{node} \times RL_j^R + \sum_{i=N+1}^{M} F_{i,j}^{node} \times RL_j^R] \div M$$

and then:

$$F_{\Delta H}^{C} = \underset{j}{Max} (F_{\Delta H,j}^{C})$$

Where:

M = Number of axial nodes.

RL_j^N = Non-rodded radial local factor for assembly j.

$RL^R{}_j$ = Rodded radial local factor for assembly j.

FR_j = Linear fraction of assembly j which does not contain a control rod.

Radial local factors are edited by PDQ-EDIT using fine mesh PDQØ7 mesh average powers. The PDOØ7 cases are two-dimensional simulations with control bank(s) explicitly represented.

The nodal powers, $F_{i,j}^{node}$, are steady state three-dimensional calculations which explicitly model; control bank insertion, boron and xenon conditions, and other reactor state point variables necessary for a best estimate power distribution calculation.

$F_{\Delta H}^{C}$ is then evaluated by the NUC-MARGINS code or by hand calculations using the nodal powers from NODE-P and the RL from PDQ07. The NUC-MARGINS code has been independently verified to yield the correct $F_{\Delta H}^{N}$. $F_{\Delta H}^{T}$ is the ultimate output as defined by equation 6-2 for DNB analysis.

The system transient response and the transient DNB calculations would be performed by Westinghouse if the physics parameters exceeded the bounds of the previous analyses.

Q.2 Identify the nominal and various off-nominal cross-section sets that are generated in order to evaluate the different reactivity coefficients and defects.

A.2 The various fuel cross-section sets that are generated in order to evaluate different reactivity coefficients and defects are identified in Table 2.1. Nominal cross-sections are generated as a function of burnup at an average moderator temperature of 594°F and an average fuel temperature of 1250°F. The off-nominal cross-sections are generated at various burnups with varying moderator and fuel temperatures.

The cross-section representation in PDQØ7 differs between the quarter-core discrete pin and colorset models. The representation employed in the quarter-core model is discussed first and then the colorset discussion follows. All sets, except the baffle, use combined macroscopic and microscopic cross-sections.

Fuel cross-sections in quarter-core PDQØ7 are calculated according to the following relation:

$$\Sigma(T_M, T_F, Bu) = \Sigma_o(Bu) + \frac{\Delta\Sigma}{\Delta T_M} \times (T_M - T_M^{Ref}) + \frac{\Delta\Sigma}{\Delta\sqrt{T_F}} \times (\sqrt{T_F} - \sqrt{T_F}^{Ref})$$

where $\Sigma(T_M, T_F, Bu)$ = the total macroscopic cross-section as a function of moderator temperature, fuel temperature, and burnup.

$\Sigma_o(Bu)$ = the nominal macroscopic cross section as a function of burnup.

$\frac{\Delta\Sigma}{\Delta T_M}$ = the moderator temperature pseudo-microscopic cross-section which relates the change in macroscopic cross-section to change in moderator temperature.

$\frac{\Delta\Sigma}{\Delta\sqrt{T_F}}$ = the fuel temperature pseudo-microscopic cross-section which relates the change in macroscopic cross-section to a change in fuel temperature.

The macroscopic cross-sections given here may be of any type, e.g. transport, absorption, removal, or fission. The pseudo-microscopic cross-sections (or pseudo-micros) account for the change in the macroscopic cross-section as a result of a change from reference conditions. These pseudo-micros are input to PDQØ7 as a function of burnup. The moderator temperature pseudo-micros are determined from the cross-section sets at moderator temperatures of 630°F and 530°F (fuel temperature held constant at 1250°F).

The fuel temperature pseudo-micros are determined from the cross-section sets at fuel temperatures of 1250°F and 594°F (moderator temperature held constant at 594°F).

Most nonfuel cross-sections employed in quarter core calculations are evaluated as shown in Table 2.4, and are consistent with the core average moderator temperature of interest.

The reflector constants are evaluated at T_{inlet} (usually 557°F) and, at Hot Zero Power, are identical to the water gap constants. Baffle constants are evaluated using the method shown in Chapter 4 of EPRI NP-3642-SR (Few-Group Baffle and/or Reflector Constants for Diffusion Calculation Application, EPRI Special Report, August 1984).

Colorset PDQ07 calculations are performed which provide sufficient data to characterize operation from Hot Full Power (HFP) to Cold Zero Power (CZP) conditions. A breakpoint is designated at Hot Zero Power (HZP). Two sets of data (B-Constants) are then used in EPRI-NODE-P calculations:

1. Normal Operation - HFP to HZP

2. Low Temperature - HZP to CZP

B-Constants for the Normal Operation and Low Temperature models are generated following the sequence described in Section 3 of DPC-NF-2010.

Tables 2.1 and 2.4 describe conditions for fuel and non-fuel cross-section sets. The Normal Operation cross-sections input to colorset PDQ07 calculations are shown by the matrices in Table 2.2. Table 2.3 shows matrices of cross section sets for Low Temperature colorset calculations. Nonfuel cross-section sets (Table 2.4) are used which are consistent with the fuel moderator temperature.

Table 2.1

McGuire/Catawba
Fuel Cross-Section Sets

Cross-Section Set Type	T_{mod} (°F)	T_{fuel} (°F)	Power	Burnup Timesteps (GWD/MTU)	Application
P1	594	594	Zero	0.0	HFP → HZP
P2 (Nominal)	594	1250	Full	0.0	"
P3	630	1250	Full	0.0	"
P4	530	1250	Full	0.0	"
P8 (Nominal)	594	1250	Full	0.0, 0.1, 0.5, 1.0, 2.0, 4.0, 6.0, ..., 58.0, 60.0	"
P8B6	594	594	Full	"	"
P8B7	530	1250	Full	"	"
P8B8	630	1250	Full	"	"
P5	200	200	Zero	0.0	HZP → CZP
P9	200	200	Zero	0.0, 0.1, 0.5, 1.0, 2.0, 4.0, 6.0, ..., 58.0, 60.0	"
P6	557	557	Zero	0.0	"
P7	68	68	Zero	0.0	"

Table 2.2

Cross-Section Sets for Normal Operation
PDQØ7 Colorsets

BOL

Effect	P2(Nominal)	P1	P3	P4
	Cross-Section Set Type			
Soluble Boron	X			
K-inf vs. T_{mod}	X		X	X
Migration Area vs. T_{mod}	X		X	X
Doppler	X	X		

Depletion

Reactivity Effect	P8(Nominal)	P8B6	P8B7	P8B8
	Cross-Section Set Type			
Exposure	X			
Soluble Boron	X			
Control Rods	X			
Xenon	X			
Doppler	X	X		
Moderator			X	X

Table 2.3

Cross-Section Sets for Low Temperature
PDQØ7 Colorsets

BOL

Effect	Cross-Section Set Type P5	P6	P7
Soluble Boron	X		
K-inf. vs. T_{mod}	X	X	X
Migration Area vs. T_{mod}	X	X	X

DEPLETION

Reactivity Effect	Cross-Section Set Type P9
Exposure	X
Soluble Boron	X
Control Rods	X

Table 2.4

McGuire/Catawba
Non-fuel Cross-Section Sets

Material	Moderator Temperatures (°F)
Water Gap/Reflector	630, 594, 557, 530, 200, 68
Guide Tube/Inst. Tube	630, 594, 557, 530, 200, 68
Control Rod	594, 557, 200, 68
Burnable Poison Rod	594, 557, 200, 68
Baffle	EPRI NP-3642-SR

Q.3 Provide a short description of the PDQ-EDIT code and describe the verification program that was undertaken to test data generated with PDQ-EDIT for use in SNA-CORE.

A.3 PDQ-EDIT is a utility code written by Duke Power Company that is capable of reading Internal File Management (IFM) files written by PDQ07. This code is primarily used to develop theoretical factors for SNA-CORE, and to edit and process data contained on pointwise flux, power and concentration IFM files. PDQ-EDIT, like all Nuclear Design software used in safety related analysis, is quality assured as required by Duke Power Company's Administrative Policy Manual for Nuclear Stations.

SNA-CORE theoretical factors are generated from PDQ-EDIT in what is commonly known as theoretical factor sets. Each theoretical factor set is valid over a user defined burnup range. Theoretical factor sets consist of assembly average powers, assembly peak pin powers, and detector mesh average two-group fluxes.

Verification of theoretical factor sets is accomplished by the utility code SNAVER. SNAVER compares the symmetric assembly average and peak pin powers on either a 1/4-core or 1/8-core basis, and then calculates a percent difference for each power at a given location with respect to the average at that location. Percent differences greater than 0.1% are flagged by the program. The cognizant engineer must then verify whether these errors are justified. SNAVER also checks for consistancy between detector fluxes at symmetric locations, and for correct data format.

The formal benchmarking of theoretical factors developed from PDQ-EDIT was accomplished by comparing measured powers from Westinghouse's INCORE code, to those calculated from SNA-CORE for Sequoyah Unit 1 Cycle 1. All measured powers were inferred from plant supplied flux traces. Results from these comparisons are shown in Figures 1 thru 7. Good agreement between the two codes was observed. A summary of the average absolute relative error, and the standard deviation associated with these errors are presented in Table 1.

In conclusion, comparisons between measured data from Westinghouse's INCORE code and Duke's SNA-CORE code demonstrate the accuracy of the PDQ07, PDQ-EDIT, SNA-CORE code package. Also, in addition to the software quality assurance program employed at Duke, SNAVER provides an independent means of verifying the correctness of theoretical factor sets before they are used in a production environment.

Table 1

Statistical Summary of INCORE versus SNA-CORE
Measured Powers for Sequoyah 1 Cycle 1

CASE	Burnup EFPD	Average Absolute Relative Error (%)	Standard Derration %
1	71.82	1.34	1.84
2	101.62	1.06	1.43
3	133.30	1.14	1.48
4	166.04	1.28	1.64
5	231.70	1.21	1.48
6	292.04	1.20	1.51
7	378.92	1.05	1.34

Average Absolute Relative Error $(\overline{D}) \equiv \left|[(\text{SNA-CORE} - \text{INCORE})/\text{INCORE}]\right| * 100$

$$\overline{D} \equiv \sum_{i=1}^{N} D_i/N$$

FIGURE 1

SEQUOYAH 1 CYCLE 1 SNA-CORE VS. INCORE MEASURED POWERS
71.82 EFPD   100(%)FP   CONTROL BANK D AT 200 STEPS WITHDRAWN

Row		H	G	F	E	D	C	B	A
	SNA-CORE	1.12	1.05	1.17	1.11	1.15	1.05	1.01	.71
8	INCORE	1.17	1.08	1.17	1.14	1.18	1.07	1.01	.71
	SNA-CORE		1.16	1.11	1.19	1.16	1.13	1.01	.77
9	INCORE		1.17	1.13	1.19	1.17	1.13	1.03	.77
	SNA-CORE			1.18	1.12	1.18	1.09	.98	.66
10	INCORE			1.17	1.14	1.18	1.11	.97	.65
	SNA-CORE				1.18	1.13	1.08	.92	.56
11	INCORE				1.19	1.16	1.08	.92	.55
	SNA-CORE					1.09	.99	.86	
12	INCORE					1.12	.99	.83	
	SNA-CORE						1.02	.51	
13	INCORE						.99	.49	

FIGURE 2

SEQUOYAH 1 CYCLE 1 SNA-CORE VS. INCORE MEASURED POWERS
101.62 EFPD 100(%)FP CONTROL BANK D AT 218 STEPS WITHDRAWN

	H	G	F	E	D	C	B	A	
8	1.14	1.06	1.16	1.13	1.17	1.06	1.00	.71	
	1.16	1.09	1.17	1.15	1.17	1.08	1.00	.71	
9		1.16	1.12	1.18	1.16	1.12	1.01	.76	
		1.17	1.14	1.18	1.18	1.13	1.03	.76	
10			1.18	1.13	1.17	1.09	.97	.65	
			1.17	1.15	1.17	1.11	.96	.65	
11				1.17	1.13	1.08	.91	.55	
				1.18	1.16	1.08	.92	.55	
12					1.11	1.00	.85		
					1.11	1.00	.83		
13						1.02	.51		SNA-CORE
						.99	.50		INCORE

FIGURE 3

SEQUOYAH 1 CYCLE 1 SNA-CORE VS. INCORE MEASURED POWERS
133.30 EFPD 100(%)FP CONTROL BANK D AT 216 STEPS WITHDRAWN

	H	G	F	E	D	C	B	A
8	1.14 1.16	1.08 1.11	1.17 1.17	1.14 1.17	1.16 1.17	1.07 1.09	.99 .99	.70 .71
9		1.17 1.17	1.14 1.16	1.19 1.18	1.17 1.19	1.12 1.12	1.01 1.03	.76 .76
10			1.18 1.17	1.14 1.16	1.17 1.16	1.09 1.11	.96 .95	.65 .65
11				1.16 1.17	1.13 1.16	1.06 1.06	.91 .92	.55 .55
12					1.09 1.10	1.00 1.00	.84 .82	
13						1.01 .98	.51 .50	SNA-CORE INCORE

FIGURE 4

SEQUOYAH 1 CYCLE 1 SNA-CORE VS. INCORE MEASURED POWERS
166.04 EFPD 100(%)FP CONTROL BANK D AT 210 STEPS WITHDRAWN

	H	G	F	E	D	C	B	A	
	1.13	1.09	1.17	1.15	1.14	1.08	.99	.71	
8	1.16	1.11	1.17	1.18	1.15	1.10	.99	.71	
		1.16	1.15	1.19	1.17	1.11	1.01	.76	
9		1.17	1.18	1.18	1.19	1.11	1.03	.76	
			1.18	1.15	1.16	1.09	.96	.66	
10			1.17	1.18	1.15	1.11	.95	.65	
				1.16	1.13	1.06	.91	.55	
11				1.17	1.17	1.06	.92	.55	
					1.08	1.00	.84		
12					1.09	1.00	.82		
						1.00	.51		SNA-CORE
13						.97	.50		INCORE

FIGURE 5

SEQUOYAH 1 CYCLE 1 SNA-CORE VS. INCORE MEASURED POWERS
231.70 EFPD 100(%)FP CONTROL BANK D AT 216 STEPS WITHDRAWN

	H	G	F	E	D	C	B	A	
	1.10	1.08	1.14	1.16	1.13	1.09	.99	.72	
8	1.12	1.10	1.14	1.19	1.13	1.12	.99	.73	
		1.13	1.16	1.16	1.17	1.09	1.02	.76	
9		1.14	1.18	1.15	1.19	1.09	1.04	.77	
			1.16	1.16	1.14	1.10	.96	.67	
10			1.15	1.18	1.13	1.12	.95	.68	
				1.14	1.14	1.05	.92	.56	
11				1.14	1.17	1.05	.93	.56	
					1.07	1.02	.84		
12					1.08	1.02	.82		
						1.00	.53		SNA-CORE
13						.98	.52		INCORE

FIGURE 6

SEQUOYAH 1 CYCLE 1 SNA-CORE VS. INCORE MEASURED POWERS
292.04 EFPD 100(%)FP CONTROL BANK D AT 216 STEPS WITHDRAWN

		H	G	F	E	D	C	B	A
8	SNA-CORE	1.07	1.07	1.12	1.15	1.11	1.10	.99	.74
	INCORE	1.09	1.09	1.12	1.18	1.12	1.13	.99	.75
9	SNA-CORE		1.11	1.15	1.14	1.16	1.08	1.03	.78
	INCORE		1.11	1.18	1.13	1.18	1.08	1.05	.78
10	SNA-CORE			1.14	1.16	1.12	1.11	.97	.69
	INCORE			1.13	1.18	1.11	1.13	.96	.69
11	SNA-CORE				1.12	1.13	1.05	.93	.58
	INCORE				1.12	1.16	1.05	.94	.57
12	SNA-CORE					1.06	1.04	.85	
	INCORE					1.07	1.04	.83	
13	SNA-CORE						1.00	.55	
	INCORE						.98	.54	

FIGURE 7

SEQUOYAH 1 CYCLE 1 SNA-CORE VS. INCORE MEASURED POWERS
378.92 EFPD 100(%)FP CONTROL BANK D AT 222 STEPS WITHDRAWN

Row		H	G	F	E	D	C	B	A
8	SNA-CORE	1.02	1.04	1.08	1.14	1.09	1.10	1.00	.77
	INCORE	1.06	1.06	1.08	1.15	1.09	1.13	1.01	.79
9	SNA-CORE		1.07	1.13	1.10	1.14	1.07	1.05	.80
	INCORE		1.08	1.15	1.10	1.15	1.07	1.07	.81
10	SNA-CORE			1.10	1.14	1.09	1.11	.98	.73
	INCORE			1.09	1.15	1.09	1.13	.97	.74
11	SNA-CORE				1.09	1.13	1.05	.96	.60
	INCORE				1.10	1.15	1.05	.97	.60
12	SNA-CORE					1.06	1.06	.87	
	INCORE					1.07	1.06	.85	
13	SNA-CORE						1.02	.58	
	INCORE						1.00	.57	

Q.4. Comment on the reasons for the 3.1% non-conservative bias in the calculated peak axial powers (Section 11.5.4). Describe the model refinements, if any, that have been undertaken to reduce this bias.

A.4. The reason there is a -0.031 bias on the calculated peak axial powers (Section 11.5.4) is that the models used by Duke at the time of this report underpredicted the peak axial power. This -0.031 bias is the mean difference ($\overline{D}$) and is defined by equation 11-2. This value is a difference and not a percentage difference. The mean percent difference for all cases considered was -2.195% (Table 11-10). Again, it should be pointed out, that this number applies to all peak C, M pairs $\geq$ 1.0.

Although Dukes' models underpredict the peak axial power on an average of -2.195%, the Observed Nuclear Reliability Factor (ONRF) directly reflects this non-conservative prediction. This can be seen by examining equation 11-11. Because $\overline{D}$ is subtracted from $\overline{M}$, this equation is conservative for all cases of $\overline{D}$. (That is, $\overline{D}$ being positive, negative, or 0)

Consider the ONRF calculation of the peak axial power on Table 11-6. In this example if $\overline{D}$ were 0 the ONRF would be 1.035. With a $\overline{D}$ of -0.031 the ONRF is 1.058. This is a 2.2% increase in ONRF. The $\overline{D}$ of -0.031 represents a 2.195% underprediction of measured peak axial power. (Table 11-10). Therefore, it can be seen from this example, that there is a 1% increase in ONRF for each 1% that the model underpredicts the measured peak axial power.

In summary, even though the models used by Duke underpredict the peak axial power, the ONRF reflects this underprediction. As shown in the above example, there is a 1 to 1 correspondence in the percentage of the underprediction to the percentage increase in the ONRF.

The model refinements undertaken to reduce this underprediction are discussed in the answer to question 6 parts one and two. The refinements are; 1) normalization of EPRI-NODE-P to include unrodded M^2 adjustments, and 2) an increase in the number of axial nodes. Attached are the results of some maps compared to predictions using 12 levels and 18 levels of EPRI-NODE-P. Attached are the Difference Means and Standard Deviations for Assembly Peak Axial Powers (C, M $\geq$ 1.0), and Assembly Radial Powers. Also attached are Percent Difference Means (C, M $\geq$ 1.0) for Assembly Peak Axial Powers and Assembly Radial Powers.

Table 4-1

Difference Means and Standard Deviations for Assembly Radial Powers
(C, M $\geq$ 1.0)

Unit/Cycle	EPRI-NODE-P Model	N	$\overline{D}$	S($\overline{D}$)	$\overline{ABS(D)}$	S(ABS(D))
M1/C2	12 Level	144	-0.002	0.017	0.014	0.010
M1/C2	18 Level	144	-0.002	0.015	0.012	0.010

Difference Means and Standard Deviations for Assembly Peak Axial Powers
(C, M $\geq$ 1.0)

Unit/Cycle	EPRI-NODE-P Model	N	$\overline{D}$	S($\overline{D}$)	$\overline{ABS(D)}$	S(ABS(D))
M1/C2	12 Level	232	-0.004	0.031	0.025	0.018
M1/C2	18 Level	246	0.030	0.035	0.036	0.029

Percent Difference Means for Assembly Radial Powers
(C, M $\geq$ 1.0)

Unit/Cycle	EPRI-NODE-P Model	Mean % Difference	Mean Absolute % Difference
M1/C2	12 Level	-0.170	1.35
M1/C2	18 Level	-0.142	1.17

Percent Difference Means for Assembly Peak Axial Powers
(C, M $\geq$ 1.0)

Unit/Cycle	EPRI-NODE-P Model	Mean % Difference	Mean Absolute % Difference
M1/C2	12 Level	-0.407	2.039
M1/C2	18 Level	2.382	2.890

FIGURE 4.1

MCGUIRE-1 CYCLE-2 ASSEMBLY PEAK AXIAL POWERS - CALC (12 LEVEL) VS. MEAS

18 EFPD 100%FP CONTROL BANK D AT 207 STEPS WITHDRAWN

Row		H	G	F	E	D	C	B	A
8	CALC	.95	1.08	1.24	.97	.93	.80	1.09	1.28
	MEAS	.93	1.06	1.27	.98	1.00	.[illegible]5	1.19	1.27
9	CALC	1.10	1.27	1.25	1.03	.98	.93	1.50	1.30
	MEAS	1.09	1.27	1.25	1.03	1.02	.95	1.53	1.28
10	CALC	1.24	1.25	1.25	1.28	1.00	.96	1.13	1.19
	MEAS	1.28	1.27	1.27	1.32	1.03	1.00	1.19	1.16
11	CALC	.98	1.04	1.28	1.25	1.27	1.14	1.52	.92
	MEAS	1.00	1.04	1.32	1.28	1.29	1.15	1.48	.91
12	CALC	.94	.99	1.01	1.27	1.43	1.43	1.29	
	MEAS	1.02	1.04	1.02	1.30	1.40	1.41	1.26	
13	CALC	.81	.93	.97	1.14	1.43	.99	.79	
	MEAS	.88	.98	1.05	1.17	1.44	.98	.77	
14	CALC	1.10	1.51	1.14	1.52	1.30	.80		
	MEAS	1.12	1.46	1.14	1.44	1.26	.79		
15	CALC	1.28	1.31	1.19	.93				
	MEAS	1.27	1.26	1.15	.90				

FIGURE 4.2

MCGUIRE-1 CYCLE-2 ASSEMBLY PEAK AXIAL POWERS - CALC (12 LEVEL) VS. MEAS

30 EFPD 100%FP CONTROL BANK D AT 194 STEPS WITHDRAWN

	H	G	F	E	D	C	B	A
	.90	1.04	1.21	.95	.92	.82	1.12	1.30
8	.92	1.06	1.26	.98	1.02	.89	1.20	1.30
	1.05	1.24	1.22	1.00	.98	.95	1.53	1.33
9	1.08	1.26	1.25	1.03	1.04	1.00	1.53	1.29
	1.22	1.23	1.24	1.30	1.01	.98	1.16	1.21
10	1.27	1.26	1.26	1.32	1.04	1.04	1.21	1.19
	.95	1.01	1.30	1.26	1.28	1.15	1.54	.94
11	1.00	1.04	1.33	1.29	1.31	1.17	1.52	.94
	.92	.98	1.02	1.28	1.43	1.43	1.31	
12	1.03	1.05	1.04	1.31	1.42	1.44	1.29	
	.83	.96	.98	1.16	1.44	1.00	.80	
13	.90	1.01	1.08	1.19	1.46	1.01	.79	
	1.12	1.54	1.16	1.55	1.31	.81		
14	1.15	1.50	1.16	1.45	1.28	.81		
	1.31	1.33	1.21	.94	CALC			
15	1.30	1.30	1.16	.90	MEAS			

FIGURE 4.3

MCGUIRE-1 CYCLE-2 ASSEMBLY PEAK AXIAL POWERS - CALC (12 LEVEL) VS. MEAS

48 EFPD 100%FP CONTROL BANK D AT 228 STEPS WITHDRAWN

	H	G	F	E	D	C	B	A
	.94	1.08	1.22	.98	.95	.81	1.07	1.24
8	.92	1.04	1.23	.97	1.00	.86	1.16	1.25
	1.10	1.25	1.23	1.04	1.00	.92	1.46	1.27
9	1.07	1.24	1.22	1.01	1.01	.97	1.48	1.24
	1.23	1.24	1.24	1.26	1.01	.94	1.11	1.15
10	1.25	1.23	1.22	1.27	1.00	1.01	1.17	1.14
	.99	1.04	1.26	1.22	1.22	1.10	1.47	.90
11	.99	1.03	1.26	1.22	1.25	1.12	1.45	.90
	.96	1.01	1.01	1.22	1.35	1.36	1.24	
12	1.00	1.02	1.00	1.25	1.34	1.37	1.23	
	.82	.92	.94	1.10	1.36	.95	.77	
13	.87	.97	1.04	1.14	1.39	.96	.76	
	1.08	1.47	1.11	1.47	1.24	.78		
14	1.11	1.45	1.12	1.39	1.23	.78		
	1.24	1.27	1.16	.90	CALC			
15	1.26	1.25	1.12	.87	MEAS			

FIGURE 4.4

MCGUIRE-1 CYCLE-2 ASSEMBLY PEAK AXIAL POWERS - CALC (12 LEVEL) VS. MEAS

61 EFPD 100%FP CONTROL BANK D AT 220 STEPS WITHDRAWN

	H	G	F	E	D	C	B	A
	.92	1.05	1.19	.97	.94	.81	1.08	1.25
8	.91	1.03	1.23	.96	1.00	.86	1.15	1.24
	1.07	1.22	1.20	1.02	.99	.93	1.47	1.27
9	1.06	1.23	1.21	1.00	1.00	.96	1.47	1.24
	1.20	1.21	1.21	1.24	1.00	.95	1.12	1.16
10	1.24	1.22	1.21	1.26	1.00	1.01	1.17	1.14
	.97	1.02	1.24	1.20	1.22	1.11	1.47	.91
11	.99	1.03	1.26	1.22	1.24	1.12	1.45	.90
	.95	1.00	1.00	1.22	1.35	1.36	1.24	
12	1.01	1.02	1.00	1.24	1.33	1.35	1.22	
	.82	.93	.95	1.11	1.36	.95	.77	
13	.88	.98	1.04	1.14	1.38	.96	.75	
	1.09	1.48	1.12	1.48	1.24	.78		
14	1.10	1.44	1.12	1.38	1.22	.77		
	1.25	1.27	1.16	.91	CALC			
15	1.24	1.23	1.11	.87	MEAS			

FIGURE 4.5

MCGUIRE-1 CYCLE-2 ASSEMBLY PEAK AXIAL POWERS - CALC (12 LEVEL) VS. MEAS

101 EFPD 100%FP CONTROL BANK D AT 223 STEPS WITHDRAWN

	H	G	F	E	D	C	B	A
	.91	1.03	1.16	.96	.95	.83	1.08	1.22
8	.90	1.03	1.23	.97	1.01	.88	1.14	1.21
	1.04	1.19	1.17	1.00	.99	.94	1.46	1.25
9	1.04	1.21	1.19	1.00	1.01	.97	1.45	1.21
	1.17	1.17	1.17	1.23	.99	.96	1.11	1.14
10	1.22	1.20	1.19	1.25	1.00	1.01	1.15	1.13
	.96	1.01	1.23	1.19	1.20	1.09	1.45	.90
11	.99	1.02	1.25	1.21	1.23	1.10	1.41	.90
	.95	1.00	.99	1.20	1.31	1.32	1.21	
12	1.01	1.02	1.00	1.23	1.30	1.32	1.20	
	.84	.94	.96	1.09	1.32	.94	.77	
13	.89	.98	1.03	1.12	1.34	.95	.76	
	1.09	1.46	1.11	1.45	1.21	.77		
14	1.10	1.43	1.11	1.37	1.20	.77		
	1.22	1.25	1.14	.90	CALC			
15	1.21	1.20	1.10	.87	MEAS			

FIGURE 4.6

MCGUIRE-1 CYCLE-2 ASSEMBLY PEAK AXIAL POWERS - CALC (12 LEVEL) VS. MEAS

130 EFPD 100%FP CONTROL BANK D AT 216 STEPS WITHDRAWN

	H	G	F	E	D	C	B	A
	.90	1.02	1.18	.95	.95	.85	1.09	1.21
8	.93	1.04	1.23	.98	1.01	.89	1.14	1.20
	1.04	1.20	1.18	1.00	.99	.96	1.46	1.24
9	1.07	1.23	1.20	1.01	1.02	.98	1.45	1.20
	1.18	1.18	1.18	1.24	1.00	.97	1.12	1.14
10	1.23	1.22	1.20	1.26	1.01	1.02	1.14	1.11
	.95	1.00	1.24	1.19	1.20	1.10	1.44	.90
11	.99	1.03	1.26	1.22	1.24	1.11	1.41	.90
	.95	1.00	1.00	1.20	1.30	1.31	1.20	
12	1.03	1.04	1.02	1.24	1.31	1.32	1.19	
	.85	.96	.97	1.10	1.31	.95	.77	
13	.90	1.00	1.05	1.13	1.34	.95	.76	
	1.09	1.46	1.12	1.44	1.20	.78		
14	1.10	1.43	1.11	1.37	1.19	.77		
	1.21	1.24	1.14	.90	CALC			
15	1.19	1.20	1.10	.87	MEAS			

FIGURE 4.7

MCGUIRE-1 CYCLE-2 ASSEMBLY PEAK AXIAL POWERS - CALC (18 LEVEL) VS. MEAS

18 EFPD 100%FP CONTROL BANK D AT 207 STEPS WITHDRAWN

		H	G	F	E	D	C	B	A
8	CALC	.96	1.11	1.27	1.00	.96	.82	1.13	1.32
	MEAS	.93	1.06	1.27	.98	1.00	.85	1.19	1.27
9	CALC	1.13	1.30	1.28	1.06	1.01	.95	1.55	1.35
	MEAS	1.09	1.27	1.25	1.03	1.02	.95	1.53	1.28
10	CALC	1.27	1.28	1.29	1.32	1.03	.99	1.17	1.23
	MEAS	1.28	1.27	1.27	1.32	1.03	1.00	1.19	1.16
11	CALC	1.00	1.06	1.32	1.29	1.31	1.17	1.57	.95
	MEAS	1.00	1.04	1.32	1.28	1.29	1.15	1.48	.91
12	CALC	.97	1.02	1.03	1.31	1.47	1.47	1.33	
	MEAS	1.02	1.04	1.02	1.30	1.40	1.41	1.26	
13	CALC	.83	.96	.99	1.17	1.47	1.01	.82	
	MEAS	.88	.98	1.05	1.17	1.44	.98	.77	
14	CALC	1.13	1.56	1.17	1.57	1.34	.82		
	MEAS	1.12	1.46	1.14	1.44	1.26	.79		
15	CALC	1.33	1.35	1.23	.96				
	MEAS	1.27	1.26	1.15	.90				

FIGURE 4.8

MCGUIRE-1 CYCLE-2 ASSEMBLY PEAK AXIAL POWERS - CALC (18 LEVEL) VS. MEAS

30 EFPD 100%FP CONTROL BANK D AT 194 STEPS WITHDRAWN

	H	G	F	E	D	C	B	A
	.92	1.06	1.24	.97	.94	.84	1.15	1.34
8	.92	1.06	1.26	.98	1.02	.89	1.20	1.30
	1.08	1.27	1.26	1.03	1.01	.98	1.58	1.37
9	1.08	1.26	1.25	1.03	1.04	1.00	1.53	1.29
	1.25	1.26	1.27	1.34	1.04	1.01	1.19	1.25
10	1.27	1.26	1.26	1.32	1.04	1.04	1.21	1.19
	.98	1.04	1.34	1.30	1.32	1.19	1.59	.97
11	1.00	1.04	1.33	1.29	1.31	1.17	1.52	.94
	.95	1.01	1.04	1.32	1.47	1.48	1.35	
12	1.03	1.05	1.04	1.31	1.42	1.44	1.29	
	.85	.98	1.01	1.19	1.48	1.03	.83	
13	.90	1.01	1.08	1.19	1.46	1.01	.79	
	1.16	1.59	1.20	1.59	1.35	.84		
14	1.15	1.50	1.16	1.45	1.28	.81		
	1.35	1.38	1.25	.97	CALC			
15	1.30	1.30	1.16	.90	MEAS			

FIGURE 4.9

MCGUIRE-1 CYCLE-2 ASSEMBLY PEAK AXIAL POWERS - CALC (18 LEVEL) VS. MEAS

48 EFPD 100%FP CONTROL BANK D AT 228 STEPS WITHDRAWN

	H	G	F	E	D	C	B	A
	.96	1.10	1.25	1.00	.98	.84	1.11	1.28
8	.92	1.04	1.23	.97	1.00	.86	1.16	1.25
	1.12	1.28	1.26	1.06	1.03	.95	1.51	1.31
9	1.07	1.24	1.22	1.01	1.01	.97	1.48	1.24
	1.26	1.27	1.27	1.30	1.04	.97	1.14	1.19
10	1.25	1.23	1.22	1.27	1.00	1.01	1.17	1.14
	1.01	1.07	1.30	1.26	1.26	1.14	1.52	.93
11	.99	1.03	1.26	1.22	1.25	1.12	1.45	.90
	.98	1.03	1.04	1.26	1.39	1.40	1.28	
12	1.00	1.02	1.00	1.25	1.34	1.37	1.23	
	.84	.95	.97	1.14	1.40	.98	.79	
13	.87	.97	1.04	1.14	1.39	.96	.76	
	1.11	1.52	1.15	1.52	1.28	.80		
14	1.11	1.45	1.12	1.39	1.23	.78		
	1.29	1.31	1.20	.93	CALC			
15	1.26	1.25	1.12	.87	MEAS			

FIGURE 4.10

MCGUIRE-1 CYCLE-2 ASSEMBLY PEAK AXIAL POWERS - CALC (18 LEVEL) VS. MEAS

61 EFPD 100%FP CONTROL BANK D AT 220 STEPS WITHDRAWN

	H	G	F	E	D	C	B	A
	.95	1.08	1.23	.99	.97	.84	1.12	1.29
8	.91	1.03	1.23	.96	1.00	.86	1.15	1.24
	1.10	1.25	1.24	1.05	1.02	.96	1.52	1.31
9	1.06	1.23	1.21	1.00	1.00	.96	1.47	1.24
	1.23	1.24	1.25	1.28	1.03	.98	1.15	1.20
10	1.24	1.22	1.21	1.26	1.00	1.01	1.17	1.14
	1.00	1.05	1.28	1.24	1.26	1.14	1.52	.93
11	.99	1.03	1.26	1.22	1.24	1.12	1.45	.90
	.98	1.02	1.03	1.26	1.39	1.40	1.28	
12	1.01	1.02	1.00	1.24	1.33	1.35	1.22	
	.85	.96	.98	1.14	1.40	.98	.80	
13	.88	.98	1.04	1.14	1.38	.96	.75	
	1.12	1.53	1.16	1.52	1.28	.80		
14	1.10	1.44	1.12	1.38	1.22	.77		
	1.29	1.31	1.20	.94	CALC			
15	1.24	1.23	1.11	.87	MEAS			

FIGURE 4.11

MCGUIRE-1 CYCLE-2 ASSEMBLY PEAK AXIAL POWERS - CALC (18 LEVEL) VS. MEAS

101 EFPD 100%FP CONTROL BANK D AT 223 STEPS WITHDRAWN

	H	G	F	E	D	C	B	A
	.93	1.05	1.20	.98	.97	.85	1.12	1.26
8	.90	1.03	1.23	.97	1.01	.88	1.14	1.21
	1.07	1.23	1.21	1.03	1.02	.97	1.51	1.29
9	1.04	1.21	1.19	1.00	1.01	.97	1.45	1.21
	1.21	1.21	1.21	1.27	1.02	.99	1.15	1.18
10	1.22	1.20	1.19	1.25	1.00	1.01	1.15	1.13
	.98	1.03	1.27	1.23	1.24	1.13	1.49	.93
11	.99	1.02	1.25	1.21	1.23	1.10	1.41	.90
	.98	1.02	1.02	1.24	1.35	1.36	1.25	
12	1.01	1.02	1.00	1.23	1.30	1.32	1.20	
	.86	.98	.99	1.13	1.36	.97	.79	
13	.89	.98	1.03	1.12	1.34	.95	.76	
	1.12	1.51	1.15	1.49	1.25	.80		
14	1.10	1.43	1.11	1.37	1.20	.77		
	1.26	1.29	1.18	.93	CALC			
15	1.21	1.20	1.10	.87	MEAS			

FIGURE 4.12

MCGUIRE-1 CYCLE-2 ASSEMBLY PEAK AXIAL POWERS - CALC (18 LEVEL) VS. MEAS

130 EFPD 100%FP CONTROL BANK D AT 216 STEPS WITHDRAWN

	H	G	F	E	D	C	B	A
8	.93	1.05	1.21	.98	.97	.88	1.13	1.25
	.93	1.04	1.23	.98	1.01	.89	1.14	1.20
9	1.07	1.24	1.22	1.03	1.02	.99	1.50	1.27
	1.07	1.23	1.20	1.01	1.02	.98	1.45	1.20
10	1.22	1.22	1.22	1.27	1.03	1.00	1.15	1.17
	1.23	1.22	1.20	1.26	1.01	1.02	1.14	1.11
11	.98	1.03	1.27	1.23	1.24	1.13	1.48	.93
	.99	1.03	1.26	1.22	1.24	1.11	1.41	.90
12	.98	1.03	1.03	1.24	1.34	1.35	1.24	
	1.03	1.04	1.02	1.24	1.31	1.32	1.19	
13	.88	.99	1.00	1.13	1.35	.98	.80	
	.90	1.00	1.05	1.13	1.34	.95	.76	
14	1.13	1.50	1.15	1.48	1.24	.80		
	1.10	1.43	1.11	1.37	1.19	.77		
15	1.25	1.27	1.17	.93	CALC			
	1.19	1.20	1.10	.87	MEAS			

Q.5 Duke Power Company's contention that no uncertainty in calculated pin powers needs to be accounted for has not been adequately established. One of a set of standard problems, recently developed at Brookhaven National Laboratory for a licensee to assess its ability to calculate typical PWR fuel assemblies, is attached. The licensee's solution using PDQ07 will be an important means of determining the uncertainty in the calculated pin peaking factors.

Re: A.5 Based upon the Duke solution to the BNL benchmark assembly problem, BNL has identified an underprediction of the peak pin power after about 15,000 MWD/MTU which increases to about 1% at 40,000 MWD/MTU. As a result of a conference call held December 11, 1984 between BNL, NRC and Duke, it was determined that a two percent radial local uncertainty was conservative and would be applied in a statistical combination with the reliability factors and engineering hot channel factor.

The three factors to be statistically combined to determine the $F_{\Delta H}^{SCUF}$ factor to multiply the calculated $F_{\Delta H}$ are:

1. $F_Q{}^E$, Engineering Heat Flux Hot Channel Factor, is the allowance on heat flux for manufacturing tolerances. This factor allows for local variations in enrichment, pellet density, and diameter. It's numeric value is 1.03.

2. $F_{\Delta H}^R$, the Observed Nuclear Reliability Factor for $F_{\Delta H}$. This factor is developed in Section 11.5 and is 1.03. It represents the ability of EPRI-NODE-P to calculate assembly average power.

3. RL^R, Radial Local Uncertainty or pin power uncertainty. It represents the ability of EPRI-CELL/PDQ07 to calculate the pin power in an assembly. Determined to be 2%.

These factors are statistically combined as follows:

$$F_{\Delta H}^{SCUF} \equiv 1+\sqrt{(.03)^2 + (.03)^2 + (.02)^2} = 1.047.$$

Where SCUF is the statistically combined uncertainty factor.

These factors are statistically independent because they are calculated using different codes and represent different phenomena. The NRC has previously reviewed and approved the statical combination of the radial local uncertainty factor and the $F_{\Delta H}^R$ factor in Northern States Power's report "Qualification of Reactor Physics Methods for Application to Prairie Island Units NSPNAD-8101NP", December 1981. In addition, the NRC has previously reviewed and approved the statistical combination of all three factors in Westinghouse's "Improved Thermal Design Procedure", WCAP-8576, July 1975.

The three factors to be statistically combined to determine the F_Q^{SCUF} factor to multiply the calculated F_Q by are:

1. F_Q^E, Engineering Heat Flux Hot Channel Factor, 1.03.

2. F_Q^R, Assembly Peak Axial Observed Nuclear Reliability Factor. This factor is developed in Section 11.5 and consists of a bias of $(\frac{0.031}{1.375})$ and a $K\sigma$ of 0.048.

3. RL^R, Radial Local Uncertainty or pin power uncertainty, 2%.

The factors are combined to determine the F_Q^{SCUF} factor, where SCUF is the statistically combined uncertainty factor, as follows:

$$F_Q^{SCUF} \equiv 1 + \frac{.031}{1.375} + \sqrt{(.03)^2 + (.048)^2 + (.02)^2} = 1.083$$

$F_{\Delta H}^{SCUF}$ will replace $F_{\Delta H}^R$ in equation 6-2 and F_Q^{SCUF} will replace $F_Q^R \times F_Q^E$ in equation 6-3.

Table 5.1

Benchmark Problem

EPRI-CELL/PDQØ7 Analysis

Maximum Rod Power Summary

Exposure (MWD/MT)	Non-BP Assembly	16-BP Assembly
0	1.060	1.107
500	1.059	1.104
5000	1.054	1.073
10000	1.046	1.041
20000	1.028	1.021
30000	1.014	1.016
40000	1.008	1.010

Table 5.2

Benchmark Problem

Reactivity Defect Calculations

No BP's

Case	Description	0 MWD/MTU K-Infinity	0 MWD/MTU % Δρ	30000 MWD/MTU K-Infinity	30000 MWD/MTU % Δρ
0	Base	1.183699	--	0.896243	-
1	Doppler	1.194852	-0.789	0.907013	-1.325
2	MTC	1.186067	-0.169	0.897301	-0.132
3	68°F	1.211947	-1.969	0.898143	-0.236
4	300°F	1.204695	-1.472	0.904724	-1.046
5	SOLB	1.241994	-3.965	0.937659	-4.928
6	Xe	1.223867	-2.773	0.921068	-3.007
7	Rods	0.789700	42.149	0.605476	53.583

16 BP's

Case	Description	0 MWD/MTU K-Infinity	0 MWD/MTU % Δρ	30000 MWD/MTU K-Infinity	30000 MWD/MTU % Δρ
0	Base	1.020581	--	0.901031	--
1	Doppler	1.030387	-0.932	0.912429	-1.386
2	MTC	1.025619	-0.481	0.903525	-0.306
3	68°F	1.069628	-4.493	0.912266	-1.367
4	300°F	1.053687	-3.079	0.916026	-1.817
5	SOLB	1.060567	-3.694	0.938213	-4.398
6	Xe	1.049333	-2.685	0.926059	-3.000

Table 5.2
(Continued)

Additional Xenon Defect Data

No BP's

	0 MWD/MTU	30,000 MWD/MTU
Xenon Defect (% $\Delta\rho$)	-2.773	-3.007
Xenon Concentration (Atoms/cm^3)[1]	2.1337×10^{15}	1.8623×10^{15}
Xenon Defect (% $\Delta\rho$/atoms/cm^3)[2]	-1.300×10^{-15}	-1.615×10^{-15}

16 BP's

	0 MWD/MTU	30,000 MWD/MTU
Xenon Defect (%	-2.685	-3.000
Xenon Concentration (atoms/cm^3)[1]	2.1334×10^{15}	2.0056×10^{15}
Xenon Defect (% /atoms/cm^3)[2]	-1.259×10^{-15}	1.496×10^{-15}

1. Value averaged over entire assembly volume. Fuel to Assembly volume ratio = .90459.
2. Defect per unit volume evaluated over entire assembly.

Table 5.3

1. Name of Codes - PDQØ7; EPRI-CELL[1]
   Code Sources EPRI; EPRI[1]
   Version 2; RAM112[1]

2. Reference for Calculational Method - DPC-NF-2010

3. Assembly Solution Method - Two Group Diffusion Theory

4. Pin-Cell Solution Method - Transport Theory [1]

5. Spatial Mesh Assy/Pin-Cell

   Assembly - One mesh interval per pin

   Pin-Cell[1] - Four Mesh intervals in fuel pin
   One mesh interval in clad
   Five mesh intervals in moderator
   Two mesh intervals in extra region

6. Neutron Cross Section Library - ENDF/B4[1]

7. Number of Fast/Thermal Groups

	No. Fast Groups	No. Thermal Groups
Assembly	1	1
Pin Cell[1]	62	35

8. Depletion Steps -

   Assembly (hrs) - 0, 150, 500, 1000, 2000, 3000, 4000, 5000, 6000, 8000, 10000, 12000, 14000, 16000, 18000, 20000, 22000, 24000, 26000, 28000, 30000, 32000, 34000, 36000, 38000, 40000

   Pin/Cell(MWD/MTU)[1] 0, 0.001, 100, 500, 1000, 2000, 4000, 6000, 8000, 10000, 12000, 14000, 16000, 18000, 20000, 22000, 24000, 26000, 28000, 30000, 32000, 34000, 36000, 38000, 40000

1 _ All cross-section sets for benchmark problem except CRA and BP were calculated with EPRI-CELL.

Table 5.3 (Continued)

1. Name of Codes - CASMO2E[2]
   Code Sources STUDSVIK
   Version 5

2. Reference for Calculational Method - DPC-NF-2010

3. Assembly Solution Method - Two Group Diffusion Theory

4. Pin-Cell Solution Method - Transport Theory[2]

5. Spatial Mesh Assy/Pin-Cell

   Assembly - One mesh interval per pin[1]

   Pin-Cell - One mesh interval per pin[2]

6. Neutron Cross Section Library - ENDF/B3[2]

7. Number of Fast/Thermal Groups

	No. Fast Groups	No. Thermal Groups
Assembly	4	3
Pin-Cell	9	16

8. Depletion Steps

   Assembly - See Table 5.3 page 1

   Pin-Cell (MWD/MTU)[2] - 0, 150, 500, 1000, 2000, 3000, 5000, 7500, 10000, 12500, 15000, 20000, 25000, 30000, 35000, 40000

[2] - Refers to Burnable Poison and Control Rod Data

Figure A-3. Comparisons of Measured and Predicted Normalized Relative Power Densities for Core 1

INCORE DETECTOR	1.018 1.038 .020	1.011 .997 -.014	.987 .979 -.008	.981 .975 -.006	.997 .978 -.019	.966 .958 -.008	.945 .936 -.009
	1.019 1.035 .016	1.067 1.069 .002	1.012 1.015 .003	1.009 1.012 .003	1.058 1.054 -.004	.999 .988 -.011	.945 .941 -.004
		WATER	1.081 1.087 .006	1.090 1.089 -.001	WATER	1.032 1.045 .013	.953 .947 -.006
			1.054 1.070 .016	1.104* 1.117* .013	1.086 1.100 .014	.989 .994 .005	.945 .939 -.006
				WATER	1.059 1.062 .003	.965 .957 -.008	.934 .928 -.006
					.988 .986 -.002	.938 .937 -.001	.923 .919 -.004
					Measured RPD Calculated RPD ΔRPD	.925 .921 -.004	.914 .911 -.003
							.903 .903 .000

RMS(ΔRPD) = 0.008

Max (ABS(ΔRPD)) = 0.020

*Maximum power fuel rod predicted or measured.

FIGURE 5.1

Figure A-4. Comparisons of Measured and Predicted Normalized Relative Power Densities for Core 5

INCORE DETECTOR	1.005 1.026 .021	.913 .886 -.027	.170 .196 .026	.932 .903 -.029	1.036 1.045 .009	1.063 1.077 .014	1.072 1.090 .018
	.999 1.021 .022	1.017 1.012 -.005	.931 .901 -.030	1.007 .997 -.010	1.125 1.135 .010	1.094 1.112 .018	1.089 1.096 .007
		WATER	.988 .962 -.026	1.087 1.073 -.014	WATER	1.158* 1.174* .016	1.100 1.102 .002
			.181 .203 .022	1.050 1.035 -.015	1.131 1.158 .027	1.088 1.105 .017	1.086 1.090 .004
				WATER	1.048 1.018 -.030	1.035 1.018 -.017	1.070 1.070 .000
					.187 .211 .024	.963 .939 -.024	1.054 1.058 .004
					Measured RPD Calculated RPD ΔRPD	1.018 1.009 -.009	1.060 1.069 .009
							1.070 1.083 .013

Legend: UO_2-Gd_2O_3

RMS(ΔRPD) = 0.018
Max (ABS(ΔRPD)) = 0.030

*Maximum power fuel rod predicted or measured.

FIGURE 5.2

PDQØ7 CALCULATED
ROD POWERS

	PDQ-7
PPMB	400
NUMBER BA	0
K-INFINITY	1.18377
BURNUP	0
*MAX. ROD POWER	1.060

0.								
1.035	1.013							
1.038	1.013	1.015						
0.	1.029	1.032	0.					
1.037	1.014	1.018	1.044	1.051				
1.035	1.011	1.015	1.043	1.060 *	0.	PDQØ7		
0.	1.019	1.023	0.	1.042	1.014	0.975		
1.012	0.991	0.993	1.006	0.989	0.961	0.942	0.932	
0.975	0.971	0.970	0.972	0.964	0.951	0.942	0.939	0.949

FIGURE 5.3

PDQØ7 CALCULATED
ROD POWERS

	PDQ-7
PPMB	400
NUMBER BA	0
K-INFINITY	1.17560
BURNUP	500
*MAX. ROD POWER	1.059

PDQØ7

0.								
1.035	1.013							
1.037	1.013	1.014						
0.	1.028	1.032	0.					
1.037	1.013	1.017	1.043	1.051				
1.034	1.011	1.015	1.043	1.059 *	0.			
0.	1.018	1.022	0.	1.041	1.014	.975		
1.012	.992	.993	1.006	.989	.962	.943	.933	
.976	.971	.971	.972	.964	.952	.942	.940	.950

FIGURE 5.4

PDQØ7 CALCULATED
ROD POWERS

	PDQ-7
PPMB	400
NUMBER BA	0
K-INFINITY	1.12604
BURNUP	5000
*MAX. ROD POWER	1.054

0.								
1.032	1.012							
1.034	1.012	1.014						
0.	1.026	1.029	0.					
1.034	1.013	1.016	1.040	1.047				
1.031	1.010	1.014	1.039	1.054 *	0.	PDQØ7		
0.	1.017	1.021	0.	1.038	1.013	.977		
1.011	.992	.993	1.006	.990	.965	.947	.938	
.978	.974	.973	.974	.967	.955	.947	.944	.954

FIGURE 5.5

PDQØ7 CALCULATED
ROD POWERS

	PDQ-7
PPMB	400
NUMBER BA	0
K-INFINITY	1.06962
BURNUP	10,000
*MAX. ROD POWER	1.046

0.								
1.028	1.012							
1.030	1.012	1.013						
0.	1.023	1.026	0.					
1.029	1.012	1.015	1.034	1.040				
1.027	1.010	1.013	1.034	1.046 *	0.	PDQØ7		
0.	1.015	1.018	0.	1.032	1.010	.980		
1.009	.994	.995	1.005	.991	.969	.954	.945	
.981	.978	.977	.978	.971	.961	.953	.950	.958

FIGURE 5.6

PDQØ7 CALCULATED
ROD POWERS

	PDQ-7
PPMB	400
NUMBER BA	0
K-INFINITY	0.97482
BURNUP	20,000
*MAX. ROD POWER	1.028

0.								
1.019	1.010							
1.019	1.010	1.011						
0.	1.016	1.018	0.					
1.019	1.010	1.012	1.023	1.026				
1.017	1.008	1.010	1.022	1.028 *	0.	PDQØ7		
0.	1.010	1.012	0.	1.019	1.006	.986		
1.005	.997	.997	1.002	.994	.980	.969	.962	
.988	.986	.986	.986	.981	.973	.967	.965	.969

FIGURE 5.7

PDQØ7 CALCULATED
ROD POWERS

	PDQ-7
PPMB	400
NUMBER BA	0
K-INFINITY	0.89624
BURNUP	30.000
*MAX. ROD POWER	1.014

0.								
1.010	1.007							
1.011	1.007	1.007						
0.	1.009	1.010	0.					
1.011	1.007	1.008	1.013	1.014				
1.010	1.006	1.007	1.012	1.014 *	0.	PDQØ7		
0.	1.005	1.006	0.	1.009	1.002	.992		
1.002	.999	.999	1.001	.997	.989	.982	.978	
.994	.993	.993	992	.989	.985	.981	.979	.98

FIGURE 5.8

PDQØ7 CALCULATED
ROD POWERS

	PDQ-7
PPMB	400
NUMBER BA	0
K-INFINITY	0.83305
BURNUP	40.000
*MAX. ROD POWER	1.008

0.								
1.005	1.003							
1.005	1.003	1.004						
0.	1.005	1.005	0.					
1.005	1.004	1.004	1.007	1.008 *				
1.005	1.003	1.004	1.006	1.008 *	0.	PDQØ7		
0.	1.003	1.003	0.	1.005	1.001	.996		
1.001	.999	.999	1.000	.998	.994	.991	.988	
.997	.996	.996	.996	.995	.992	.990	.988	.989

FIGURE 5.9

PDQØ7 CALCULATED
ROD POWERS

	PDQ-7
PPMB	400
NUMBER BA	16
K-INFINITY	1.02062
BURNUP	0
*MAX. ROD POWER	1.107

0.								
1.054	1.027							
0.954	0.986	1.029						
0.	0.964	1.046	0.					
0.957	0.986	1.021	1.022	0.959				
1.064	1.030	0.975	0.925	0.883	0.	PDQØ7		
0.	1.060	0.957	0.	0.882	0.906	0.954		
1.107 *	1.062	0.989	0.942	0.950	0.980	1.008	1.038	
1.083	1.066	1.035	1.013	1.013	1.027	1.046	1.067	1.092

FIGURE 5.10

PDQØ7 CALCULATED
ROD POWERS

	PDQ-7
PPMB	400
NUMBER BA	16
K-INFINITY	1.01969
BURNUP	500
*MAX. ROD POWER	1.104

0.								
1.053	1.027							
0.957	0.987	1.028						
0.	0.966	1.046	0.					
0.959	0.987	1.021	1.023	0.962				
1.063	1.030	0.976	0.929	0.888	0.	PDQØ7		
0.	1.059	0.959	0.	0.887	0.910	0.955		
1.104 *	1.059	0.989	0.944	0.952	0.980	1.006	1.034	
1.080	1.063	1.033	1.012	1.012	1.025	1.042	1.062	1.087

FIGURE 5.11

PDQØ7 CALCULATED
ROD POWERS

	PDQ-7
PPMB	400
NUMBER BA	16
K-INFINITY	1.02749
BURNUP	5.000
*MAX. ROD POWER	1.073

0.								
1.046	1.023							
0.983	0.997	1.024						
0.	0.987	1.040	0.					
0.984	0.996	1.019	1.027	0.987				
1.052	1.024	0.989	0.963	0.938	0.	PDQØ7		
0.	1.045	0.979	0.	0.933	0.941	0.961		
1.073 *	1.038	0.991	0.964	0.964	0.975	0.988	1.005	
1.047	1.035	1.014	1.000	0.998	1.003	1.012	1.025	1.044

FIGURE 5.12

PDQØ7 CALCULATED
ROD POWERS

	PDQ-7
PPMB	400
NUMBER BA	16
K-INFINITY	1.02278
BURNUP	10,000
*MAX. ROD POWER	1.041

PDQØ7

0.								
1.036	1.018							
1.007	1.005	1.018						
0.	1.006	1.031	0.					
1.007	1.004	1.016	1.027	1.008				
1.038	1.016	1.000	0.995	0.986	0.			
0.	1.029	0.998	0.	0.978	0.972	0.970		
1.041 *	1.017	0.994	0.984	0.977	0.973	0.974	0.979	
1.017	1.009	0.998	0.990	0.986	0.984	0.986	0.992	1.006

FIGURE 5.13

PDQØ7 CALCULATED
ROD POWERS

	PDQ-7
PPMB	400
NUMBER BA	16
K-INFINITY	0.97150
BURNUP	20,000
*MAX. ROD POWER	1.021

0.								
1.020	1.010							
1.018	1.009	1.010						
0.	1.015	0.017	0.					
1.018	1.008	1.010	1.020	1.020				
1.019	1.008	1.007	1.017	1.021 *	0.	PDQØ7		
0.	1.012	1.010	0.	1.012	1.000	0.984		
1.010	1.000	0.997	1.000	0.991	0.978	0.971	0.968	
0.994	0.991	0.988	0.987	0.982	0.976	0.973	0.973	0.97[illegible]

FIGURE 5.14

PDQØ7 CALCULATED
ROD POWERS

	PDQ-7
PPMB	400
NUMBER BA	16
K-INFINITY	0.90103
BURNUP	30,000
*MAX. ROD POWER	1.016

0.								
1.011	1.006							
1.013	1.007	1.006						
0.	1.011	1.010	0.					
1.012	1.007	1.007	1.012	1.014				
1.010	1.005	1.006	1.013	1.016 *	0.			
0.	1.005	1.007	0.	1.010	1.002	0.991		
1.003	1.000	1.000	1.001	1.000	0.987	0.981	0.978	
0.995	0.993	0.992	0.991	0.988	0.984	0.981	0.980	0.983

PDQØ7

FIGURE 5.15

PDQØ7 CALCULATED
ROD POWERS

	PDQ-7
PPMB	400
NUMBER BA	16
K-INFINITY	0.84163
BURNUP	40.000
*MAX. ROD POWER	1.010

0.								
1.005	1.003							
1.007	1.004	1.004						
0.	1.006	1.005	0.					
1.007	1.004	1.004	1.007	1.008				
1.005	1.003	1.004	1.008	1.010 *	0.	PDQØ7		
0.	1.003	1.004	0.	1.007	1.002	0.995		
1.001	0.999	0.999	1.001	0.998	0.993	0.989	0.987	
0.996	0.996	0.995	0.995	0.993	0.990	0.988	0.988	0.989

FIGURE 5.16

Q.6 Please provide the updates to DPC-NF-2010, if any, that will make it consistent with the methodologies being used by Duke Power.

A.6 The following sections address updates to the methods described in DPC-NF-2010.

1. EPRI-NODE-P Normalization:

In addition to adjusting radial albedoes, small M^2 adjustments are made for various fuel types (usually only fresh fuel) to attain better agreement with PDQØ7 radial power calculations. Fugures 6.1 and 6.2 show the improvement for assembly radial powers with respect to measurement. Figures 6.3 and 6.4 address assembly peak power improvements. The data in figures 6.1 through 6.4 represent McGuire Unit 1 Cycle 2.

2. Axial Nodal Modeling:

Section 11 of DPC-NF-2010 presents a benchmark analysis which employed twelve axial nodes per assembly. Core-specific axial modeling would conform to the physics requirements of the core. Answer 4 addressed the calculated-to-measured improvement shown by employing eighteen axial nodes per assembly. Should future fuel assemblies become non-uniform, i.e., axial blankets or part length burnable absorbers, the Duke Power version of EPRI-NODE-P can adequately model the core.

Since the upgrades described in parts 1 and 2 have significantly improved calculated-to-measured agreement, the ONRF values for F_Q and $F_{\Delta H}^N$ in DPC-NF-2010 are considered conservative. Therefore, even though the upgraded methods have demonstrated improved agreement, Duke Power will still employ previously derived ONRFs.

3. EPRI-NODE-P Enhancements:

EPRI-NODE-P has received several major enhancements which are discussed below. This enhanced version was used throughout the analyses shown in DPC-NF-2010. These enhancements are:

a. Partial reactivity formulations due to xenon, moderator temperature, and doppler temperature have been revised to include third order burnup dependent multipliers.

b. Fuel assemblies can be axially modeled as containing up to three different fuel types.

c. Rodded M^2 is linearly adjusted according to the fraction of node length occupied by a control rod.

d. The full power volumetric average fuel temperature has been revised to a burnup dependent fourth order polynomial.

f. The nodal source convergence routine has been modified to use the Gauss-Seidel iterative method with the inclusion of an optional acceleration parameter.

g. Minor enhancements have also been made which allow more user-friendly input and output features.

Likewise, Duke Power's fitting code EPRI-SUPERLINK has been modified to provide compatibility with EPRI-NODE-P. All codes are rigorously tested and certified before production usage in conformance with Duke Power's Q/A procedures.

MCGUIRE-1 CYCLE-2 ASSEMBLY RADIAL POWERS - CALC (NO MSQUARE ADJ) VS. MEAS

48 EFPD 100%FP CONTROL BANK D AT 228 STEPS WITHDRAWN

	H	G	F	E	D	C	B	A
	.84	.97	1.15	.88	.88	.73	.91	1.03
8	.83	.94	1.11	.87	.90	.77	.98	1.06
	.99	1.18	1.16	.93	.90	.83	1.25	1.04
9	.97	1.12	1.10	.91	.91	.85	1.26	1.05
	1.16	1.16	1.16	1.20	.92	.86	.93	.96
10	1.13	1.11	1.11	1.16	.91	.89	.99	.97
	.88	.94	1.20	1.16	1.15	.97	1.23	.76
11	.89	.93	1.16	1.11	1.12	.98	1.23	.77
	.89	.91	.92	1.15	1.23	1.16	1.05	
12	.91	.92	.91	1.13	1.19	1.19	1.06	
	.74	.84	.86	.97	1.16	.79	.65	
13	.79	.87	.91	.99	1.20	.83	.66	
	.91	1.25	.93	1.24	1.05	.65		
14	.98	1.26	.97	1.20	1.05	.67		
	1.03	1.05	.96	.76	CALC			
15	1.06	1.05	.95	.75	MEAS			

FIGURE 6.1

MCGUIRE-1 CYCLE-2 ASSEMBLY RADIAL POWERS - CALCULATED VS. MEASURED

48 EFPD 100%FP CONTROL BANK D AT 228 STEPS WITHDRAWN

		H	G	F	E	D	C	B	A
8	Calculated	.83	.96	1.10	.88	.86	.75	.95	1.03
	Measured	.83	.94	1.11	.87	.90	.77	.98	1.06
9	Calculated	.98	1.13	1.12	.93	.91	.85	1.24	1.04
	Measured	.97	1.12	1.10	.91	.91	.85	1.26	1.05
10	Calculated	1.11	1.12	1.13	1.16	.93	.88	.97	.96
	Measured	1.13	1.11	1.11	1.16	.91	.89	.99	.97
11	Calculated	.88	.94	1.16	1.13	1.13	1.00	1.23	.75
	Measured	.89	.93	1.16	1.11	1.12	.98	1.23	.77
12	Calculated	.86	.91	.93	1.13	1.22	1.19	1.04	
	Measured	.91	.92	.91	1.13	1.19	1.19	1.06	
13	Calculated	.76	.86	.88	1.00	1.19	.85	.66	
	Measured	.79	.87	.91	.99	1.20	.83	.66	
14	Calculated	.96	1.24	.98	1.23	1.05	.66		
	Measured	.98	1.26	.97	1.20	1.05	.67		
15	Calculated	1.03	1.05	.96	.75				
	Measured	1.06	1.05	.95	.75				

FIGURE 6.2

MCGUIRE-1 CYCLE-2 ASSEMBLY RADIAL POWERS - CALCULATED VS. MEASURED

48 EFPD 100%FP CONTROL BANK D AT 228 STEPS WITHDRAWN

	H	G	F	E	D	C	B	A
8	.83 .83	.96 .94	1.10 1.11	.88 .87	.86 .90	.75 .77	.95 .98	1.03 1.06
9	.98 .97	1.13 1.12	1.12 1.10	.93 .91	.91 .91	.85 .85	1.24 1.26	1.04 1.05
10	1.11 1.13	1.12 1.11	1.13 1.11	1.16 1.16	.93 .91	.88 .89	.97 .99	.96 .97
11	.88 .89	.94 .93	1.16 1.16	1.13 1.11	1.13 1.12	1.00 .98	1.23 1.23	.75 .77
12	.86 .91	.91 .92	.93 .91	1.13 1.13	1.22 1.19	1.19 1.19	1.04 1.06	
13	.76 .79	.86 .87	.88 .91	1.00 .99	1.19 1.20	.85 .83	.66 .66	
14	.96 .98	1.24 1.26	.98 .97	1.23 1.20	1.05 1.05	.66 .67		
15	1.03 1.06	1.05 1.05	.96 .95	.75 .75	CALCULATED MEASURED			

FIGURE 6.2

MCGUIRE-1 CYCLE-2 ASSEMBLY PEAK AXIAL POWERS - CALC (NO MSQUARE ADJ) VS. MEAS

48 EFPD 100%FP CONTROL BANK D AT 228 STEPS WITHDRAWN

Row	Calc./Meas.	H	G	F	E	D	C	B	A
8	CALCULATED	.97	1.11	1.29	1.00	1.00	.81	1.06	1.30
	MEASURED	.92	1.04	1.23	.97	1.00	.86	1.16	1.25
9	CALCULATED	1.13	1.32	1.30	1.06	1.02	.93	1.54	1.32
	MEASURED	1.07	1.24	1.22	1.01	1.01	.97	1.48	1.24
10	CALCULATED	1.30	1.31	1.31	1.33	1.03	.95	1.09	1.20
	MEASURED	1.25	1.23	1.22	1.27	1.00	1.01	1.17	1.14
11	CALCULATED	1.01	1.07	1.33	1.28	1.28	1.10	1.53	.94
	MEASURED	.99	1.03	1.26	1.22	1.25	1.12	1.45	.90
12	CALCULATED	1.01	1.02	1.03	1.28	1.41	1.37	1.30	
	MEASURED	1.00	1.02	1.00	1.25	1.34	1.37	1.23	
13	CALCULATED	.82	.93	.95	1.10	1.37	.92	.78	
	MEASURED	.87	.97	1.04	1.14	1.39	.96	.76	
14	CALCULATED	1.06	1.55	1.10	1.54	1.30	.79		
	MEASURED	1.11	1.45	1.12	1.39	1.23	.78		
15	CALCULATED	1.30	1.32	1.21	.95				
	MEASURED	1.26	1.25	1.12	.87				

FIGURE 6.3

MCGUIRE-1 CYCLE-2 ASSEMBLY PEAK AXIAL POWERS - CALC (18 LEVEL) VS. MEAS

48 EFPD 100%FP CONTROL BANK D AT 228 STEPS WITHDRAWN

		H	G	F	E	D	C	B	A
8	CALC	.96	1.10	1.25	1.00	.98	.84	1.11	1.28
	MEAS	.92	1.04	1.23	.97	1.00	.86	1.16	1.25
9	CALC	1.12	1.28	1.26	1.06	1.03	.95	1.51	1.31
	MEAS	1.07	1.24	1.22	1.01	1.01	.97	1.48	1.24
10	CALC	1.26	1.27	1.27	1.30	1.04	.97	1.14	1.19
	MEAS	1.25	1.23	1.22	1.27	1.00	1.01	1.17	1.14
11	CALC	1.01	1.07	1.30	1.26	1.26	1.14	1.52	.93
	MEAS	.99	1.03	1.26	1.22	1.25	1.12	1.45	.90
12	CALC	.98	1.03	1.04	1.26	1.39	1.40	1.28	
	MEAS	1.00	1.02	1.00	1.25	1.34	1.37	1.23	
13	CALC	.84	.95	.97	1.14	1.40	.98	.79	
	MEAS	.87	.97	1.04	1.14	1.39	.96	.76	
14	CALC	1.11	1.52	1.15	1.52	1.28	.80		
	MEAS	1.11	1.45	1.12	1.39	1.23	.78		
15	CALC	1.29	1.31	1.20	.93				
	MEAS	1.26	1.25	1.12	.87				

FIGURE 6.4

APPENDIX C

Original Issue NRC SER

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

March 13, 1985

Docket Nos: 50-369, 50-370
and 50-413, 50-414

Mr. H. B. Tucker, Vice President
Nuclear Production Department
Duke Power Company
422 South Church Street
Charlotte, North Carolina 28242

Dear Mr. Tucker:

Subject: Topical Report on Physics Methodology for Reloads: McGuire and Catawba Nuclear Station

In response to your letter of July 18, 1984, with its supplemental information provided on November 30, and December 19, 1984, the NRC staff and its contractor, Brookhaven National Laboratory (BNL), have reviewed Duke Power Company Topical Report DPC-NF-2010, entitled "McGuire Nuclear Station/Catawba Nuclear Station Nuclear Physics Methodology for Reload Design," dated April 1984. This topical report is the first of a sequence of topical reports planned in regards to reload design at these stations. It describes the fuel, physics codes, fuel cycle design methods, and derivation of core physics parameters. It also presents statistical benchmarks which quantify reactivity and power distribution uncertainties.

Enclosed is our Safety Evaluation Report (SER) for this review. The SER notes in Section 3 that Section 6.3 and Chapter 7 of the Topical Report were excluded in our evaluation. Section 6.3 discusses the systematic application of safety related physics parameters for reload safety evaluation and, therefore, is outside the scope of the methodology described in the report. Chapter 7 discusses application of the physics methods to power peaking analysis and will be reviewed following a future submittal on three-dimensional power peaking analysis. Apart from these exclusions, we find that the methodology in the report, as modified by Duke's supplemental information, is acceptable for referencing in licensing actions involving nuclear physics calculations for reload design for the McGuire and Catawba Nuclear Stations.

We do not intend to repeat our review of the matters described in the report and found acceptable when the report appears as a reference in license applications, except to assure that the material presented is applicable to the specific plant involved. Our acceptance applies only to the matters described in the report.

In accordance with procedures established in NUREG-0390, it is requested that you publish the accepted version of this report within three months of receipt of this letter. The accepted version shall incorporate this letter and the enclosed evaluation between the title page and the abstract. The accepted version shall include an -A (designating accepted) following the report identification symbol.

Should our criteria or regulations change such that our conclusions as to the acceptability of the report are invalidated, you will be expected to revise and resubmit the report or submit justification for the continued effective applicability of the topical report.

Sincerely,

Cecil O. Thomas

Cecil O. Thomas, Chief
Standardization and Special Projects Branch
Division of Licensing

Enclosure:
As stated

cc: See next page

McGuire

Mr. H. B. Tucker, Vice President
Nuclear Production Department
Duke Power Company
422 South Church Street
Charlotte, North Carolina 28242

cc: Mr. A. Carr
Duke Power Company
P. O. Box 33189
422 South Church Street
Charlotte, North Carolina 28242

Mr. F. J. Twogood
Power Systems Division
Westinghouse Electric Corp.
P. O. Box 355
Pittsburgh, Pennsylvania 15230

Mr. Robert Gill
Duke Power Company
Nuclear Production Department
P. O. Box 33189
Charlotte, North Carolina 28242

J. Michael McGarry, III, Esq.
Bishop, Liberman, Cook, Purcell
and Reynolds
1200 Seventeenth Street, N.W.
Washington, D. C. 20036

Mr. Wm. Orders
Senior Resident Inspector
c/o U.S. Nuclear Regulatory Commission
Route 4, Box 529
Hunterville, North Carolina 28078

J. Nelson Grace, Regional Administrator
U.S. Nuclear Regulatory Commission,
Region II
101 Marietta Street, N.W., Suite 2900
Atlanta, Georgia 30323

R. S. Howard
Operating Plants Projects
Regional Manager
Westinghouse Electric Corporation - R&D 701
P. O. Box 2728
Pittsburgh, Pennsylvania 15230

CATAWBA

Mr. H. B. Tucker, Vice President
Nuclear Production Department
Duke Power Company
422 South Church Street
Charlotte, North Carolina 28242

cc: William L. Porter, Esq.
Duke Power Company
P.O. Box 33189
Charlotte, North Carolina 28242

J. Michael McGarry, III, Esq.
Bishop, Liberman, Cook, Purcell
and Reynolds
1200 Seventeenth Street, N.W.
Washington, D. C. 20036

North Carolina MPA-1
P.O. Box 95162
Raleigh, North Carolina. 27625

Mr. F. J. Twogood
Power Systems Division
Westinghouse Electric Corp.
P.O. Box 355
Pittsburgh, Pennsylvania 15230

NUS Corporation
2536 Countryside Boulevard
Clearwater, Florida 33515

Mr. Jesse L. Riley, President
Carolina Environmental Study Group
854 Henley Place
Charlotte, North Carolina 28208

Richard P. Wilson, Esq.
Assistant Attorney General
S.C. Attorney General's Office
P.O. Box 11549
Columbia, South Carolina 29211

North Carolina Electric Membership
Corp.
3333 North Boulevard
P.O. Box 27306
Raleigh, North Carolina 27611

Saluda River Electric Cooperative,
Inc.
P.O. Box 929
Laurens, South Carolina 29360

Senior Resident Inspector
Route 2, Box 179N
York, South Carolina 29745

J. Nelson Grace, Regional Administrato
U.S. Nuclear Regulatory Commission,
Region II
101 Marietta Street, N.W., Suite 2900
Atlanta, Georgia 30323

Robert Guild, Esq.
P.O. Box 12097
Charleston, South Carolina 29412

Palmetto Alliance
2135 ½ Devine Street
Columbia, South Carolina 29205

Karen E. Long
Assistant Attorney General
N.C. Department of Justice
P.O. Box 629
Raleigh, North Carolina 27602

cc: Spence Perry, Esquire
Associate General Counsel
Federal Emergency Management Agency
Room 840
500 C Street, S.W.
Washington, D. C. 20472

Mark S. Calvert, Esq.
Bishop, Liberman, Cook,
Purcell & Reynolds
1200 17th Street, N.W.
Washington, D. C. 20036

Mr. Michael Hirsch
Federal Emergency Management Agency
Office of the General Counsel
Room 840
500 C Street, S.W.
Washington, DC 20472

Brian P. Cassidy, Regional Counsel
Federal Emergency Management Agency,
Region I
J. W. McCormach POCH
Boston, Massachusetts 02109

SAFETY EVALUATION REPORT

Report Title:	McGuire Nuclear Station/Catawba Nuclear Station Nuclear Physics Methodology for Reload Design
Report Number:	DPC-NF-2010
Report Date:	April 1984
Originating Organization:	Duke Power Company
Reviewed By:	Core Performance Branch, BNL, and Core Performance Branch, NRC

1. Introduction

This report describes the methodology adopted by Duke Power Company for the physics analysis of the McGuire and Catawba nuclear reactors. The physics analysis (also referred to as the nuclear design process in the topical report) is intended to determine the values of safety related parameters including those describing the core power distribution, reactivity worths and coefficients, and the reactor kinetics characteristics. These values of the physics parameters are then intended to serve as input to the reload safety analysis.

2. Summary of Report

In this methodology the main computational tools used for the physics analysis are the EPRI-ARMP code system and the CASMO-2[2] code. The fuel performance codes COMETHE-IIIK[3] and TACO-2[4] are used for fuel performance analyses. CASMO-2, using a processed version of the ENDF/B-3 library in either 69 or 25 groups, and EPRI-CELL, using a 97-group library derived from ENDF/B-4, are used for cross section generation. Strong absorbers are modeled with CASMO-2, and equivalent diffusion theory parameters are generated by matching reaction rates calculated with CASMO-2 and PDQ07.[5] An assembly colorset PDQ07 model is used to generate k_∞ and M^2 data for the EPRI-NODE-P 3-D simulator, while a quarter core PDQ07 model is used for the calculation of x-y power distributions,

control bank worths, boron and xenon worths, and temperature coefficients. The NODE-P model is used for 3-D power distributions, ejected rod worths, differential rod worths, and xenon transient calculations.

The report describes the procedures used to calculate integral and differential control rod worths, shutdown margins, ejected and dropped rod worths, trip reactivity, critical boron concentrations, boron worth, xenon worth, reactivity coefficients, kinetics parameters, radial power peaking, and local power peaking. Measured parameters for the first cycles of McGuire Units 1 and 2, and Sequoyah Unit 1 have been compared with calculated values. Measured and calculated power distributions have been analyzed statistically and 95/95 Observed Nuclear Reliability Factors (ONRF) have been extracted.

3. Summary of Evaluation

The nuclear physics methodology described in Topical Report DPC-NF-2010 is the first part of a reload safety evaluation methodology to be submitted by the licensee, which is expected to also include fuel performance analysis, thermal-hydraulics analysis and transient and accident analysis. The licensee has indicated that this reload methodology will include Reload Safety Analysis Checklist (RSAC) comparisons which will be submitted first in collaboration with the fuel vendor, and later independently by the licensee. The licensee has also indicated that a 3-D Power Peaking Analysis will be submitted separately and, consequently, Sections 7.1, 7.2, 7.3, 7.4 and 7.4.1 will be reviewed after this analysis has been submitted. Although the application of the physics parameters has been briefly discussed in Section 6.3, the systematic application of safety related physics parameters for reload safety evaluation is outside the scope of the methodology described in the topical report and, consequently, has also been excluded from this review. The focus of the present evaluation has been on the adequacy of the methodology for calculating safety related physics parameters for use in reload safety analyses. The reload design methods are discussed in the following sections.

A. Nuclear Code System and Calculational Procedures

The Duke Power nuclear methodology is based on the well known and benchmarked EPRI-ARMP system, CASMO-2 and PDQ07 codes. Additionally, the use of a similar system of nuclear codes has been approved[6] by the NRC for use by Duke Power in the design of reload cores for the Oconee Nuclear Station.[7] The fuel performance codes COMETHE-IIIK and TACO-2, which are used for generating fuel properties related input data for the nuclear codes, are also well known and widely used in the industry. The cross section libraries used with EPRI-CELL and CASMO-2 have been derived from either the ENDF/B-3 or the ENDF/B-4 library, and contain a sufficiently detailed energy structure to enable an accurate determination of safety related physics parameters. EPRI recommended procedures[8] are followed in the use of the nuclear code system. A sufficient number of branch calculations are performed with the PDQ07 colorset model (both at beginning of life (BOL) and at selected burnup points, varying moderator and fuel temperature, soluble boron concentration, control rod insertion and xenon concentration) to allow proper determination of boron, xenon, Doppler and control rod worths and the relevant reactivity coefficients.[11] Sufficiently small steps are taken during the depletion calculations with the quarter core PDQ07 model to properly account for the effects of exposure. Measured values of critical boron concentrations, control rod worths, ejected rod worths, and isothermal temperature coefficients for Cycle 1 of both McGuire Unit 1 and Unit 2 have been compared with predictions. The measured critical boron concentrations are reproduced to within about 60 ppm with a standard deviation of about 15 ppm. Control rod bank worths are reproduced with a standard deviation of less than 8%. The isothermal temperature coefficients are reproduced to within about 5 pcm/°F, with a standard deviation of 1.87 pcm/°F. The quality of agreement between measured and predicted values of these physics parameters is acceptable provided the uncertainties are properly considered in the safety analysis.

B. Safety Related Parameters and Their Application

Calculation and application of the safety related physics parameters are described in chapter 6 of the report. A list of selected reload safety

related physics parameters is given in Table 6-1. It should be noted however, that parameters such as fuel temperature, fuel rod pressure, core DNB limits, fuel census data, maximum critical boron concentration, maximum shutdown boron concentration, which are used in the reload safety analyses of Westinghouse reactors[9], do not appear in Table 6-1. The criteria for evaluating the safety of a reload core design are not specified in sufficient detail. Duke Power should include this information in future topical reports.

C. Kinetics Parameters

Kinetics parameters are calculated using PDQ07 and the DELAY code. The calculated kinetics parameters include the six group delayed neutron fractions and effective yields, the total effective delayed neutron fraction, the prompt neutron generation time, and reactivity versus positive and negative doubling time. PDQ07 is used to obtain spatially averaged isotopic fission rates as a function of burnup, and DELAY is used to calculate kinetics parameters and to relate the reactor period to the inserted reactivity. The kinetics parameters are generated for both beginning of cycle (BOC) hot zero power (HZP) and hot full power (HFP) conditions with all rods out (ARO). A second set of delayed neutron parameters is generated for end of cycle (EOC).

The codes and methodology employed for the determination of these parameters have been previously reviewed and approved[10] by the staff.

D. Radial Local Power Peaking Analysis

A quadrant symmetric EPRI-NODE model is used to calculate nodal power distributions. A full core EPRI-NODE model is used to evaluate non-symmetric power distributions such as those encountered in the dropped rod configuration. The nodal powers are multiplied by the corresponding assembly radial local factor to yield the calculated total peaking factor:

$$F_Q^C = \text{Max}\,\{F_{i\ell}^{\text{Node}} \times RL_\ell\}\ , \qquad (1)$$

where RL_ℓ is the radial local factor for assembly ℓ, and $F_{i\ell}^{\text{Node}}$ is the nodal

power calculated at the axial location i for the assembly ℓ. The reliability factor for F_Q, F_Q^R, is calculated such that 95% of the calculated powers will be greater than the measured powers at a confidence level of 95%. Applying an additional multiplier, F_Q^E, to account for manufacturing tolerance, the total peaking factor, F_Q^T is defined as

$$F_Q^T = F_Q^R \times F_Q^E \times F_Q^C. \qquad (2)$$

Duke Power Company has presented comparisons between PDQ07 and CASMO-2 predictions of pin powers for 10 fuel assemblies at HFP, BOL, and no xenon conditions. In addition, measured pin powers in cold critical assemblies have been compared to PDQ07 predictions in two cases[7]. None of the measured or calculated lattices had any control rods inserted. On the basis of these results, Duke Power concluded that the PDQ07 prediction of the peak pin power is always conservative with respect to CASMO-2 calculations and to measurement; therefore, no uncertainty in the calculated radial local power is required. In response to a request for additional information, Duke Power has provided (1) results from two cold critical measurements that Duke Power made as prime contractor to DOE (Report DOE/ET/34212-41) and (2) a comprehensive solution to a standard problem recently developed at BNL to evaluate calculations of typical PWR fuel assemblies. The thorough and detailed nature of the solution, supplied in a relatively short period of time, is clearly an indication of the resources available to Duke Power in making physics calculations and their familiarity with the methods and procedures applicable in these analyses.

Comparison of EPRI-CELL/PDQ07 predictions of peak pin powers to measurements for the two criticals in the DOE study show that the EPRI-CELL/PDQ07 predictions of peak pin power are conservative by ≈1%. Duke Power believes that the overprediction of pin powers near the water holes is attributable to the use of Mixed Number Density (MND) thermal cross sections. It should be noted, however, that the use of MND cross sections does not necessarily lead to an overprediction of peak pin powers.[12] Comparison of the Duke Power solution to the standard problem with the benchmark solutions shows that at

BOL the Duke Power methods do indeed overpredict the peak pin power by just over 1%. However, the Duke Power methods underpredict the peak pin power by approximately 1% at 40,000 MWD/MTU with the "cross over" occurring smoothly at approximately 15,000 MWD/MTU. The Duke Power predictions are expected to have a similar exposure dependence relative to measurement. Any conservatism that might be present in the methodology used by Duke Power at BOL is not expected to persist at all exposures.

The basic methods used by Duke Power to calculate local radial peaking factors are in wide use, and the uncertainties associated with them have been published.[12,13] A review of the literature indicates that the appropriate uncertainty is a standard deviation of 2% between measured local radial power peaking factors and those calculated with a fine mesh diffusion theory code. In an amendment[14] to DPC-NF-2010 Duke Power has accounted for a 2% uncertainty in the calculation of the local peaking factor. The corresponding revised values of F_Q^R and $F_{\Delta H}^R$ are discussed in Section 3F.

E. Assembly Axial Power Analysis

The EPRI-NODE-P model with 12 axial nodes underpredicts the axial power peaking by an average of 2.2%. This deficiency of the model has been discussed with the licensee, who has noted that the agreement of model prediction to measurement is improved if (1) the number of axial nodes is increased from 12 to 18, and (2) the rodded M^2 is linearly adjusted according to the control fraction in the node. Despite the underprediction of the axial peaking using the EPRI-NODE-P model with 12 axial nodes, the total peaking factor F_Q^T (Equation 2) is not underestimated since the observed nuclear reliability factor (ONRF), F_Q^R, accounts for the bias between measurement and prediction.

While the 12 node model is acceptable, it is recommended that the Duke Power Company use the EPRI-NODE-P model with 18 axial nodes per assembly in all calculations. The enhanced accuracy of the model will improve the representation of non-uniform axial effects in the fuel assemblies.

F. Statistical Analysis

In deriving the calculational uncertainty of the models, the difference between measured and calculated power peaking factors has been assumed to be a normally distributed random variable. The D'Test has been applied to the difference distributions to establish their normality. The one-sided upper tolerance limit (OSUTL) on the difference variable, D, is

$$\mathrm{OSUTL}(\overline{D}) = D + K \times S(D), \qquad (3)$$

where $\overline{D}$ is the mean value of the difference variable, S(D) is the standard deviation, and K is the (sample size dependent) one-sided tolerance factor for the 95% probability at the 95% confidence level.

Using Equation (3), an upper limit to the calculated parameter can be defined as

$$\mathrm{UL}(C) = \overline{M} - \overline{D} + K \times S(D), \qquad (4)$$

where $\overline{M}$ is the mean of the measured variable. Finally, the observed nuclear reliability factor (ONRF) is defined

$$\mathrm{ONRF} = \mathrm{UL}(C)/\overline{M}. \qquad (5)$$

Utilizing 1038 observations (i.e., comparisons between measurements and predictions), the assembly peak axial ONRF (F_Q^R) has been determined by Duke Power to be 1.058, using the values; $\overline{M}$ = 1.375, $\overline{D}$ = -0.031, S (D) = 0.028 and K = 1.7259.

As noted in Section 3D, this value of F^R_Q assumes that there is no uncertainty in the calculation of the local power peaking factor. If, as indicated in reference 14, a fractional uncertainty of .02 is assumed for the local peaking, then by statistically combining the uncertainties for manufacturing tolerance (.03), assembly axial peaking (0.035), and local peaking (.02) the following

reliability factor for the total peaking, F_Q^{SCUF}, is obtained

$$F_Q^{SCUF} = 1 + (.031/1.375) + [(.03)^2 + (.035)^2 + (.02)^2]^{1/2} = 1.073. \qquad (6)$$

The corresponding Duke Power analysis for the radial ONRF ($F_{\Delta H}{}^R$) using $\bar{M}$ = 1.131, $\bar{D}$ = 0.002, S(D) = 0.02 and K = 1.7343 (846 Observations) results in an ONRF ($F_{\Delta H}{}^R$) of 1.029. As in the case of the F_Q^{SCUF}, combining the uncertainties due to manufacturing tolerance (.03), the radial assembly peaking (.03) and the radial local peaking (.02) yields

$$F_{\Delta H}^{SCUF} = 1 + [(.03)^2 + (.03)^2 + (.02)^2]^{1/2} = 1.047. \qquad (7)$$

These values for F_Q^{SCUF} and $F_{\Delta H}^{SCUF}$ include a 2% allowance for uncertainty in the calculation of the local peaking factor and are acceptable.

4. CONCULSION

The Duke Power Company Topical Report on Nuclear Physics Methodology for Reload Design (DPC-NR-2010) has been reviewed. As noted in Section 3 above, Sections 6.3, 7.1, 7.2, 7.3, 7.4, and 7.4.1 of the Topical Report were excluded from this evaluation.

Apart from these exclusions the methodology described in DPC-NF-2010 and modified in Reference 14 is found to be acceptable for referencing in licensing documents for the McGuire and Catawba Nuclear Stations.

References

1. "Advanced Recycle Methodology Program System Documentation," Nuclear Associates International, CCM-3, September 1977.

2. "CASMO-2 A Fuel Assembly Burnup Program," Studsvik Energiteknik AB, Studsvik /NR-81/3, 1981.

3. "COMETHE-IIIK-A Computer Code for Predicting Mechanical and Thermal Behavior of a Fuel Pin," Belgonuclear S.A., BN7609.1, March 1977.

4. "TACO2-Fuel Pin Performance Analysis," Babcock & Wilcox, BAW-10411, Lynchburg, Virginia, August 1979.

5. "PDQ-7 Reference Manual II," Bettis Atomic Power Laboratory, WAPD-TM-947(L), February 1971.

6. Letter from P. Wagner, NRC, to W. O. Parker, Jr., providing results of review of Duke Power Company Technical Report NSF-1001 on Oconee Nuclear Station Reload Design Methodology, July 29, 1981.

7. "Duke Power Company/Oconee Nuclear Station/Reload Design Methodology" Technical Report NFS-1001," Duke Power Company, NFS-1001, Rev. 1, May 1980.

8. B. M. Rothleder, et al., "PWR Core Modeling Procedures for Advanced Recycle Methodology Program," RP-976-1, August 1979.

9. "Westinghouse Reload Safety Evaluation Methodology (WCAP-9272)," F. M. Boredelön et al., Westinghouse Electric Corporation, March 1978.

10. Letter, W. O. Parker to H. R. Denton, "Oconee Reload Design Methodology Topical Report," Question 3, Docket Nos. 50-269, 270, 287, November 13, 1980.

11. Letter, H. B. Tucker (Duke Power) to H. R. Denton (NRC), "Response Request for Additional Information Regarding Topical Report DPC-NF-2010," Docket Nos., 50-369/370, 50-413/414, November 30, 1984.

12. R. D. Mosteller and R. S. Borland, "COPHIN Code Description," EPRI NP-1385, Electric Power Research Institute, April 1980.

13. P. L. Langford Jr., and R. J. Nath, "Evaluation of Nuclear Hot Channel Factor Uncertainties," WCAP-7398-L, Westinghouse Electric Corporation, April 1969.

14. Letter, H. B. Tucker (Duke Power) to H. R. Denton (NRC), "Response Request for Additional Information Regarding Topical Report DPC-NF-2010, "Docket Nos., 50-369/370, 50-413/414, December 19, 1984.