Attachment 1

Safety Evaluation

for

Proposed Technical Specifications Change No. 28

North Anna Power Station Unit No. 1

8003140 236

SAFETY ANALYSIS FOR REVISED
CONTROL ROD INSERTION LIMITS FOR NORTH ANNA UNIT 1

1.0 Introduction and Summary

A quadrant power tilt and localized power distribution asymmetry was observed during the later portions of North Anna Unit 1, Cycle 1 operation. A safety assessment was made and no adverse impact on continued operations was predicted. The characterization of this quadrant power tilt and potential mechanisms causing the tilt were discussed with Nuclear Regulatory Commission Staff personnel on August 21, 1979. During the refueling for Cycle 2, the fuel, burnable poison, and control rods were inspected and no anomalies were observed. In addition, analytical investigations were undertaken to better understand and represent the observed end of Cycle 1 tilt and to assess any impact on Cycle 2. The result of these investigations was that no significant impact was predicted for Cycle 2.

However, during the low power physics testing of North Anna 1, Cycle 2, the local power distribution and reactivity in the southwest quadrant were determined to be significantly greater than those of the other quadrants in the core. Further, measurements of radial peaking factors at very low core power levels indicated that adjustments to the control rod insertion limits were needed in order to maintain $F_{\Delta H}$ within the limits required by the Technical Specifications.

Additional analytical simulation of the tilted condition in Cycle 2 was performed in order to a) provide a basis for revising the control rod insertion limits and b) generate core physics input required to support a safety evaluation of the impact of the power tilt on the postulated accidents presented in Chapter 15 of the FSAR. Based on this analytical simulation, a new and very conservative set of control rod insertion limits was developed and administratively imposed. These new limits were verified by measurement at several power levels during the unit startup physics testing program. In addition, these newly imposed limits were developed consistent with the commitment made in Reference 1.

The remaining sections present a summary of both the results of the analytical Cycle 2 flux tilt simulation, and the evaluation performed to assess the impact of the core tilt and the proposed control rod insertion limits on the conclusions stated in the FSAR regarding core safety. It has been concluded, based on this safety assessment, that the presence of the observed and predicted core tilt in Cycle 2 does not invalidate the conclusions presented in the FSAR. In addition, a company task force has been established to continue to investigate the basic underlying causes for the observed tilt.

2.0 Analytical Simulation of the North Anna Tilt

Analytical simulation of the quadrant burnup asymmetry which existed at the end of North Anna Unit 1, Cycle 1, indicates that this burnup asymmetry is the basic caure of the tilt observed in Cycle 2. This has been established by Cycle 2 full core calculations which are based on the actual TOTE measured burnups at the end of Cycle 1 and which show a quadrant tilt in Cycle 2 similar to the measured quadrant tilt.

This end of Cycle 1 burnup asymmetry can be accurately simulated by a full core depletion through Cycle 1 with a thermal imbalance between the reactor coolant loops (i.e., higher moderator temperature in Loop "A") represented in the depletion models. Table 1 compares the burnup tilt produced with an analytical simulation of a $6^{\circ}F$ thermal imbalance with the measured burnup asymmetry at the end of Cycle 1 (This analytical simulation also produces a quadrant power tilt). A thermal imbalance produces a quadrant reactivity and power imbalance which increases in magnitude with burnup due to the isothermal temperature coefficient becoming more negative. This type of phenomenon was generally observed in Cycle 1.

To represent the effect of the end of Cycle 1 burnup asymmetry on Cycle 2, a full core shuffle was made. Then, full core Cycle 2 calculations at various power and burnup conditions were made assuming that the thermal imbalance still existed. The quadrant power tilts calculated with this model are compared to the measured tilts during the Cycle 2 power ascension in Table 2. (Note that all of the values in Table 2 are average quadrant tilts. The maximum measured tilt values, which are compared to the Technical Specifications limits, are based on octants where the core is represented in radial quadrants and divided into octants by the core midplane).

The calculated quadrant power tilts during the Cycle 2 depletion at full power are presented in Table 3. As shown in this table, the full power tilts are less than 1% during the depletion through Cycle 2. This table also includes tilt values calculated during a power coastdown of Cycle 2 which is allowed for in the Cycle 2 reload safety evaluation (Reference 2).

As was discussed previously, a temperature imbalance was assumed for the calculations presented in Tables 1, 2 and 3. Calculations of the Cycle 2 tilt based on the Cycle 1 burnup asymmetry with no thermal imbalance are presented in Table 4. These results give a power tilt which was slightly larger at the beginning of Cycle 2 (1.7% at full power compared to 0.9% with the thermal imbalance), but which drops off rapidly in magnitude with depletion through Cycle 2.

The calculations presented in this section were performed with the Vepco one zone diffusion theory model (Reference 3). Independent calculations were also performed by Westinghouse and their analytical results were comparable to the Vepco model results. The methodolcgy used in the Westinghouse calculation was to determine the impact of the tilt with a full core nodal model and then apply the impact to the discrete symmetric diffusion theory analysis originally used to develop Reference 2. The major difference between the results generated with the Westinghouse and Vepco models was a larger tilt projected by Westinghouse at hot zero power, end of Cycle 2. The Westinghouse analytical model, which included the impact of this larger tilt, was used to evaluate the impact of the observed and projected tilt on the safety analysis parameters as discussed in the following sections. Westinghouse concluded, based on their review, that the use of their analytical representation of the tilt for the safety evaluation would bound the impact of results obtained with the Vepco model.

3.0 Impact on Core Safety

An explicit assessment of the impact of the observed (beginning of life) and analytically predicted (end of life) Cycle 2 core power tilt on all of the accidents postulated in Chapter 15 of the FSAR (Reference 4) has been made. This assessment assumes operation within the revised control rod insertion limits shown in Figure 1. In addition, the impact of a postulated coolant flow and temperature imbalance (a potential cause of the tilt) was determined.

3.1 Impact of Core Power Tilt

Core physics analyses have demonstrated that the observed and predicted flux asymmetry will have negligible impact on core average reactivity parameters (e.g., temperature coefficients and control rod bank worths). These conclusions have been confirmed by startup physics test results. Calculations have also indicated that core peaking factors associated with routine steady state operation over the power range will remain within appropriate design limits. This conclusion has been supported by all core power distribution measurements performed to date.

Since $F_{\Delta H}$ will be maintained within the Technical Specifications limits with the proposed control rod insertion limits, the basis assumed in the safety analysis for transients sensitive to $F_{\Delta H}$ (e.g., rod withdrawal and loss of flow) remains valid. The remaining potential core physics related impact of the tilt concerns the reactivity worth of postulated stuck, misaligned, dropped and ejected rods and their associated peaking factors. These parameters have a potential impact on core shutdown margin and the following accidents: all cases of the Rod Ejection Accident (i.e., from HZP and from HFP at BOL and EOL), Rod Misalignment, Dropped Rod, and the Main Steam Line Break Accident.

The stuck and ejected rod worths and their corresponding local peaking factors have been examined over the Cycle 2 range of power and core burnup. It has been concluded that even if the current rod insertion limits were used, the observed and predicted flux tilt will have negligible impact on the stuck and ejected rod worths and peaking factors in most cases. This results from the fact that the orientation of the flux tilt (which is along the S.W./N.E. core diagonal) is such that the limiting locations for stuck and ejected rods for this cycle (i.e., on the major core axes) are not significantly affected. While a potentially significant impact on the HZP, EOL ejected rod worth and peaking factors was identified with use of the current rod insertion limits, the revised rod insertion limits substantially reduce the magnitudes of both parameters for all cases. As a result, the currently applicable analyses of the Rod Ejection Accident remain limiting.

In a similar manner, it has been shown that the radial peaking factors associated with statically misaligned rods are negligibly impacted by the observed Cycle 2 flux tilt. Thus, the safety conclusions of the FSAR regarding this accident remain valid. In addition, an evaluation has been performed which determined that the Westinghouse interim generic position on the Dropped Rod Accident (Reference 5) remains valid.

The Main Steam Line break is potentially impacted by increased local peaking factors in the vicinity of the assumed stuck rod and by any decrease in the core shutdown margin. The orientation of the observed flux imbalance is such that the stuck rod worth and local peaking factors in the core location which are most limiting for the Main Steam Line Break accident are not significantly impacted. The Technical Specifications shutdown margin requirement has been confirmed for Cycle 2. Thus, all of the original core physics assumptions made and values of parameters used in the safety analysis for this accident remain valid.

3.2 Impact of a Postulated Core Thermal/Hydraulic Imbalance

While a detailed review of plant performance data is underway, preliminary results indicate only a small loop thermal-hydraulic imbalance. However, the impact of a significant flow imbalance ($\sim$ 6%) and the associated temperature imbalance on the thermal-hydraulic bases of the safety analysis has also been evaluated. Thermal hydraulic imbalances have a potential impact on postulated transients which result from changes in primary coolant system flow rate (such as a Complete Loss of Flow, or Locked Rotor and the loss of offsite power Main Steam Line Break (MSLB) transient cases). The mixing assumptions for the MSLB are also potentially affected. In addition, the core thermal limit curves, which form the basis for some reactor protection system setpoints (in particular, the overpower and overtemperature ΔT trips), are potentially impacted by a thermal-hydraulic imbalance.

Studies of the Loss of Flow transients have shown that flow imbalances of $\sim$ 6% will result in no DNBR penalty relative to the limiting case, assuming the lowest loop flow is no less than the thermal design flow. The measured loop and total core flows at North Anna substantially exceed the thermal design value. In addition, the impact of an initial flow imbalance on the Locked Rotor transient has been investigated and determined to be negligible. In a similar fashion, the impact of a loop flow imbalance on the current core thermal limit curves has been assessed. It has been concluded that the thermal limits remain adequate and that the overtemperature and overpower ΔT trip setpoint calibration procedures remain valid.

The Main Steam Line Break transient could potentially be impacted by an initial flow imbalance due to changed flow coastdown characteristics and flow mixing assumptions. Both potential impacts have been assessed and found to be negligible and therefore, the current Main Steam Line Break analyses remain conservative.

These evaluations have demonstrated that the impact of a potential loop flow and temperature imbalance for North Anna Unit 1 does not invalidate the conclusions of the FSAR, provided the flow in all loops is equal to the thermal design flow or greater. As discussed previously, measurements indicate substantial margins to the thermal design flow rate in all loops.

4.0 Conclusions

It has been concluded that the presence of the observed and predicted core tilt in North Anna Unit 1, Cycle 2 does not invalidate the conclusions of the FSAR regarding core safety from either a physics or thermal-hydraulics standpoint. These conclusions have been based on the assumption that the actual tilt will not significantly exceed those measured to date or predicted to occur under various plant conditions with currently available models. The tilt will be monitored throughout Cycle 2 in order to confirm that the bases of this evaluation remain valid. Significant changes in the value of tilt will be detectable by the EXCORE and INCORE monitoring systems.

^c.0 References

1. Letter from C. M. Stallings (Vepco) to H. R. Denton (NRC), Serial No. 973. Docket Nos. 50-338 and 50-339, December 17, 1979.

2. Letter from C. M. Stallings (Vepco) to H. R. Denton (NRC), Serial No. 867, Docket No. 50-338, November 2, 1979.

3. Letter from W. N. Thomas (Vepco) to B. C. Rusche (NRC), Serial No. 011, January 25, 1977, (VEP-FRD-20, "The PDQ07 One Zone Model, Virginia Electric and Power Company").

4. North Anna Power Station Units 1 and 2, Final Safety Analysis Report, Docket Nos. 50-338 and 50-339, dated January 3, 1973, as amended.

5. Letter from T. M. Anderson (Westinghouse) to A. T. Schwencer (NRC), NS-TMA-2167, November 28, 1979.

Figure 1

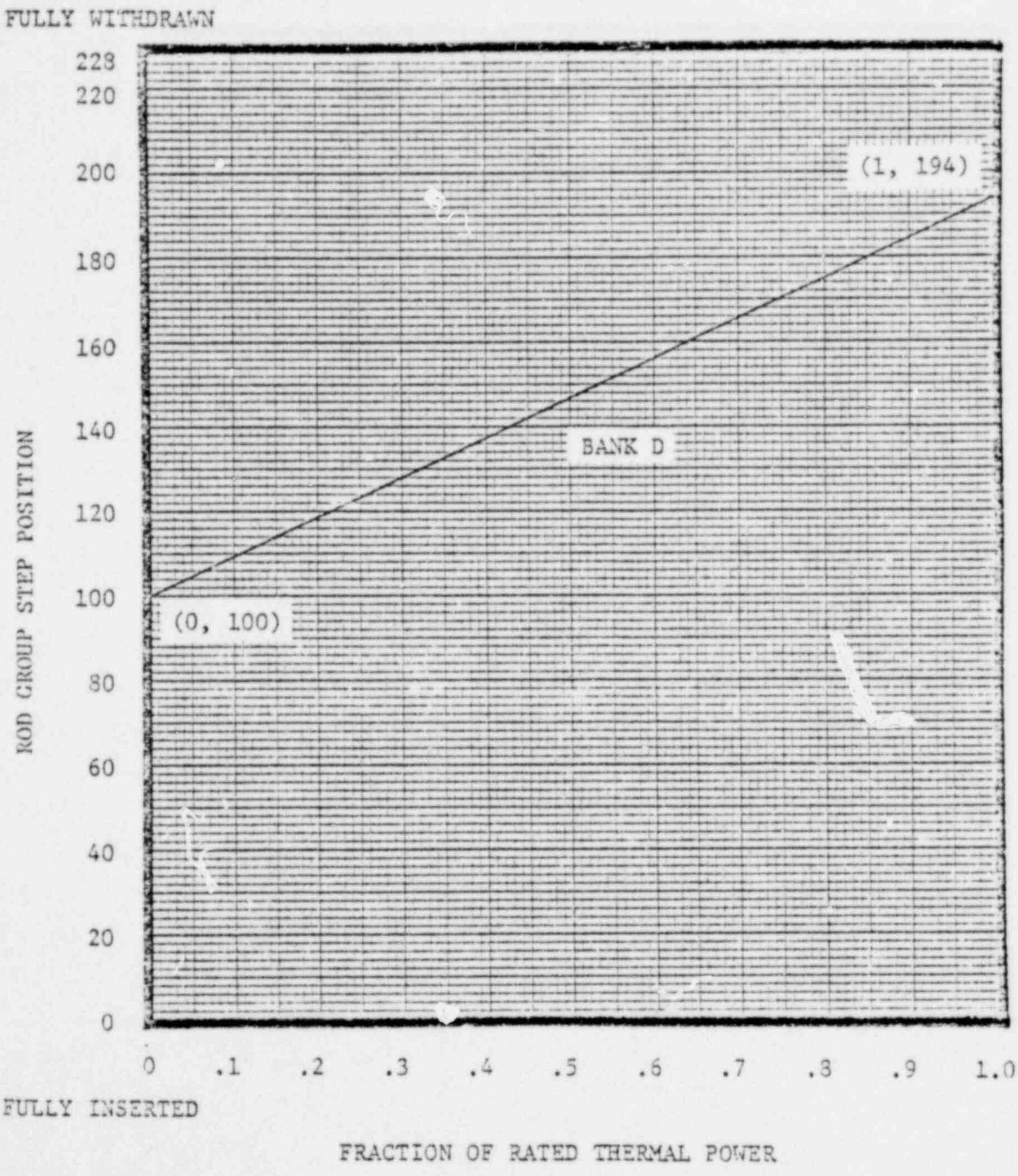

Figure 3.1-1 Rod Group Insertion Limits Versus Thermal Power

TABLE 1

CALCULATED AND MEASURED QUADRANT BURNUP TILT
NORTH ANNA UNIT NO. 1, CYCLE 1

Core Average Burnup	Quadrant	Measured Tilt (%)	Calculated Tilt (%) (Temperature Imbalance 6 F)
15900	SW	- 0.7	- 0.7
	NE	+ 0.8	+ 0.5
	NW	+ 0.1	+ 0.3
	SE	- 0.1	- 0.1

TABLE 2

CALCULATED AND MEASURED QUADRANT POWER TILT
RAMP UP TO POWER
NORTH ANNA UNIT NO. 1, CYCLE 2

Calculated Core Average Burnup	Power	Quadrant	Measured Tilt (%)	Calculated Tilt (%) (Temperature Imbalanc 6 F)
0	0	SW	+ 8.1	+ 6.0
		NE	- 8.6	- 5.4
		NW	+ 0.6	- 2.3
		SE	- 0.1	+ 1.7
0	3	SW	+ 7.4	+ 5.8
		NE	- 7.6	- 5.2
		NW	- 0.4	- 2.2
		SE	+ 0.6	+ 1.7
10 hrs	3	SW		+ 5.2
		NE		- 4.6
		NW		- 2.1
		SE		+ 1.5
30 hrs	30	SW		+ 3.4
		NE		- 3.0
		NW		- 1.4
		SE		+ 0.9
160 hrs	30	SW	+ 2.5	+ 2.0
		NE	- 2.3	- 1.7
		NW	- 0.5	- 0.8
		SE	+ 0.3	+ 0.5
200 hrs	50	SW	+ 2.1	+ 1.6
		NE	- 1.9	- 1.4
		NW	- 0.3	- 0.7
		SE	+ 0.1	+ 0.4
250 hrs	50	SW		+ 1.4
		NE		- 1.2
		NW		- 0.6
		SE		+ 0.4
300 hrs	100	SW	+ 0.9	+ 0.9
		NE	- 0.7	- 0.4
		NW	- 0.2	- 0.8
		SE	- 0.1	+ 0.3

TABLE 3

CALCULATED QUADRANT POWER TILT
DEPLETION THROUGH CYCLE 2
NORTH ANNA UNIT NO. 1, CYCLE 2

Core Average Burnup(MWD/MTU)	Power	Quadrant	Tilt (%) (Temperature Imbalannce 6 F)
1000	100	SW	+ 0.1
		NE	- 0.1
		NW	- 0.1
		SE	+ 0.1
2000	100	SW	+ 0.5
		NE	- 0.5
		NW	- 0.2
		SE	+ 0.2
4000	100	SW	- 0.5
		NE	+ 0.4
		NW	+ 0.2
		SE	- 0.1
6000	100	SW	- 0.1
		NE	+ 0.1
		NW	+ 0.1
		SE	+ 0.0
8000	100	SW	- 0.8
		NE	+ 0.6
		NW	+ 0.3
		SE	- 0.1
8900	100	SW	- 0.4
		NE	+ 0.2
		NW	+ 0.2
		SE	- 0.1
9400	100	SW	- 0.8
		NE	+ 0.6
		NW	+ 0.3
		SE	- 0.1

TABLE 3 (Continued)

Core Average Burnup(MWD/MTU)	Power	Quadrant	Tilt (%) (Temperature Imbalannce 6 F)
9600	96	SW	- 0.6
		NE	+ 0.4
		NW	+ 0.3
		SE	- 0.1
9800	87	SW	- 0.4
		NE	+ 0.3
		NW	+ 0.2
		SE	- 0.1
10000	81	SW	- 0.2
		NE	+ 0.1
		NW	+ 0.1
		SE	- 0.0
10200	75	SW	- 0.1
		NE	+ 0.0
		NW	+ 0.1
		SE	- 0.0
10400	70	SW	- 0.0
		NE	- 0.1
		NW	+ 0.0
		SE	- 0.0
10400	0	SW	+ 7.0
		NE	- 6.2
		NW	- 2.4
		SE	+ 1.6

TABLE 4

CALCULATED WITH NO TEMPERATURE IMBALANCE IN CYCLE 2
AND MEASURED QUADRANT POWER TILT
NORTH ANNA UNIT NO. 1, CYCLE 2

Calculated Core Average Burnup	Power	Quadrant	Measured Tilt (%)	Calculated Tilt (%)
0	3	SW	+ 7.4	+ 5.8
		NE	- 7.6	- 5.2
		NW	- 0.4	- 2.2
		SE	+ 0.6	+ 1.7
30 hrs	30	SW		+ 3.7
		NE		- 3.2
		NW		- 1.4
		SE		+ 1.0
200 hrs	50	SW	+ 2.1	+ 2.1
		NE	- 1.9	- 1.7
		NW	- 0.3	- 0.8
		SE	+ 0.1	+ 0.5
300 hrs	100	SW	+ 0.9	+ 1.7
		NE	- 0.7	- 1.4
		NW	- 0.2	- 0.7
		SE	- 0.1	- 0.4
4000 mwd/mtu	100	SW		+ 0.3
		NE		- 0.2
		NW		- 0.2
		SE		- 0.1
10400 mwd/mtu	100	SW		+ 0.4
		NE		- 0.4
		NW		- 0.2
		SE		+ 0.1