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TS 5.6.5.d

U S Nuclear Regulatory Commission
ATTN: Document Control Desk
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Prairie Island Nuclear Generating Plant Unit 1
Docket 50-282
License No. DPR-42

Core Operating Limits Report (COLR) for Prairie Island Nuclear Generating Plant (PINGP) Unit 1, Cycle 27, Revision 1

Pursuant to the requirements of Technical Specification 5.6.5.d, the COLR for the PINGP Unit 1, Cycle 27, Revision 1, is attached. The limits specified in the attached COLR have been established using Nuclear Regulatory Commission (NRC) approved methodologies.

The COLR has been updated for the Unit 1 Cycle 27, Modes 1 through 6. The following sections have been revised with issuance of Revision 1:

- Added the information to item 1 and items 3 through 11 that was previously excluded from Revision 0, pending entering Modes 1 and 2.
- Revised the References section, reference 32, to update the 50.59 evaluation 1086 for Revision 1, "Unit 1 Cycle 27 Core Reload Modification."
- Revised Table 1, Minimum Required Shutdown Margin, to add the requirements for Modes 1 and 2.
- Added Tables 2 through 6 and Figures 1 and 6, which were previously excluded from Revision 0, pending entering Modes 1 and 2.

Summary of Commitments

This letter contains no new commitments and no revisions to existing commitments.

Mark A. Schimmel
Site Vice President, Prairie Island Nuclear Generating Plant
Northern States Power Company - Minnesota

Enclosure

cc: Administrator, Region III, USNRC
Project Manager, Prairie Island, USNRC
Resident Inspector, Prairie Island, USNRC
State of Minnesota

ENCLOSURE

PRAIRIE ISLAND NUCLEAR GENERATING PLANT
CORE OPERATING LIMITS REPORT
UNIT 1 – CYCLE 27
REVISION 1

Record of Revision (6 pages)

PINGP COLR Unit 1 – Cycle 27, Revision 1 (24 pages)

PRAIRIE ISLAND NUCLEAR GENERATING PLANT

Core Operating Limits Report

Record of Revision

Unit	Cycle	Revision No.	Approval Date	Remarks
2	13	0	3/22/90	Original Unit 2 Core Operating Limits Report, distributed with Technical Specification Revision 92.
1	14	0	3/22/90	Original Unit 1 Core Operating Limits Report, distributed with Technical Specification Revision 92.
		1	7/27/90	Incorporated expanded V(z) curves.
		2	9/27/90	Clarified rod insertion limit curve applicability.
		3	2/11/91	Incorporated revised F_Q of 2.45 as a result of NRC approval of Westinghouse Topical Report WCAP-10924-P-A, Volume 1, Addendum 4, October 1990.
2	14	0	-	Not used.
		1	9/27/90	Updated to Unit 2 Cycle 14, incorporated expanded V(z) curves and clarified rod insertion limit curve applicability.
		2	2/11/91	Incorporated revised F_Q of 2.45 as a result of NRC approval of Westinghouse Topical Report WCAP-10924-P-A, Volume 1, Addendum 4, October 1990.
1	15	0	6/25/91	Updated to Unit 1 Cycle 15.
2	15	0	3/9/92	Updated to Unit 2 Cycle 15 and clarified labeling of Figure 4. Clarified the actions to be taken if the nuclear enthalpy rise hot channel factor exceeds the Technical Specification limit.
1	16	0	12/28/92	Updated to Unit 1 Cycle 16, removed V(z) curves and replaced them with list of bounding V(z) values for three ranges of exposures.
2	16	0	12/8/93	Updated to Unit 2 Cycle 16. Removed the multiple V(z) curves and replaced them with a single figure with bounding V(z) curves for four ranges of exposures. Incorporated additional discussion related to V(z) and K(z).

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Record of Revision

Unit	Cycle	Revision No.	Approval Date	Remarks
2	16	1	11/3/94	The table containing the bounding V(z) values and Figure 2 updated to incorporate revised bounding V(z) values for the exposure range of 14-21.5 GWD/MTU. Figures 3 through 6 re-formatted.
1	17	0	6/17/94	Updated to Unit 1 Cycle 17. Removed the list of bounding V(z) values and replaced it with multiple V(z) curves. Incorporated additional discussion related to V(z) and K(z).
2	17	0	6/2/95	Updated to Unit 2 Cycle 17. Incorporated Table 1 and expanded Figure 2 with updated bounding V(z) values.
1	18	0	2/7/96	Updated to Unit 1 Cycle 18. Incorporated revised $F_{\Delta H}$ limit of 1.77. Incorporated Table 1 and updated Figure 2 with revised bounding V(z) values.
2	18	0	2/27/97	Updated to Unit 2 Cycle 18. Revised $F_{\Delta H}$ limit to 1.77. Updated Table 1 and Figures 2a through 2e with revised bounding V(z) values. Incorporated new Figures 2f and 2g with additional bounding V(z) values.
1	19	0	9/25/97	Updated to Unit 1 Cycle 19. Updated Table 1 and Figures 2a through 2f with revised bounding V(z) values.
2	19	0	12/17/98	Updated to Unit 2 Cycle 19. Updated Table 1 and Figures 2a through 2d with revised bounding V(z) values. Deleted Figures 2e, 2f and 2g.
1	20	0	5/13/99	Updated to Unit 1 Cycle 20. Updated Table 1 and Figures 2a through 2f with revised bounding V(z) values.
		1	8/4/00	Technical Specification Amendment 151: Relocate shutdown margin (SDM) requirements from Tech Specs and incorporate additional SDM requirements for Modes 3-6 from revised analysis of Uncontrolled Dilution event.

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Record of Revision

Unit	Cycle	Revision No.	Approval Date	Remarks
2	20	0	5/31/00	Updated to Unit 2 Cycle 20. Updated Table 1 and Figures 2a through 2d with revised bounding V(z) values. Added new Table 2 and Figures 2e, 2f and 2g with additional bounding V(z) values. Added references to Tables 1 and 2 and to Figures 2e, 2f and 2g to discussion of heat flux hot channel factor limits. Added discussion clarifying applicability of axial flux difference limits when using Tables 1 and 2 and Figures 2a through 2g. Added discussion of two tier V(z) curve presented in Table 2 and Figure 2g.
		1	8/4/00	Technical Specification Amendment 142: Relocate shutdown margin (SDM) requirements from Tech Specs and incorporate additional SDM requirements for Modes 3-6 from revised analysis of Uncontrolled Dilution event.
1	20	2	9/1/00	Revised to change axial flux difference target band.
1	21	0	1/31/01	Updated to support refueling activities associated with Unit 1 Cycle 21. Revision 0 of the Unit 1 Cycle 21 COLR had to be issued prior to confirming the applicability of the LOCA analysis. Therefore, Revision 0 of the Unit 1 Cycle 21 COLR does not contain all of the operating limits necessary to support operation of Unit 1 Cycle 21.
1	21	1	2/19/01	Updated to Unit 1 Cycle 21. Updated Tables 1 and 2 and Figures 2a through 2f with revised bounding V(z) values.
1	21	2	10/02/02	Revised to support License Amendment 158 changes, including revision of all references to TS, revision of F_Q symbols, addition of Table 4, ITC limits, DNB limits and refueling boron concentrations.
2	21	0	2/06/02	Updated to Unit 2 Cycle 21.

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Core Operating Limits Report

Record of Revision

Unit	Cycle	Revision No.	Approval Date	Remarks
2	21	1	10/02/02	Revised to support License Amendment 149 changes, including revision of all references to TS, revision of F_Q symbols, addition of Table 4, ITC limits, DNB limits and refueling boron concentrations. Also revised to include an additional V(z) curve to give greater F_Q margin between 13.0 and 16.0 GWd/MTU.
1	22	0	11/25/02	Updated to Unit 1 Cycle 22. Updated Tables 1 and 2 and Figures 2a through 2f with revised bounding V(z) values. Incorporated new Figure 2g with additional bounding V(z) values. Updated Table 3 with revised minimum shutdown margin limits. Deleted and revised text to eliminate duplication with the Technical Specifications and the Bases.
2	22	0	9/19/03	Updated to Unit 2 Cycle 22. Updated Tables 1 and 2. A reduced number of exposure ranges were calculated in Table 1, therefore new Figures 2a through 2e with revised bounding V(z) values replaced Figures 2a through 2f. New Figure 2f replaced Figure 2g for the 2 tier band bounding V(z) values. Updated Table 3 with revised minimum shutdown margin limits. Deleted and revised text to eliminate duplication with the Technical Specifications and the Bases.
1	22	1	7/6/04	Revision to incorporate Westinghouse Safety Analysis Transition per LA 162/153. Revision 1 contains transitional values for the OP/OT ΔT Trip setpoints that will be used while the physical changes are implemented.
2	22	1	7/6/04	Revision to incorporate Westinghouse Safety Analysis transition per LA 162/153. Revision 1 contains transitional values for the OP/OT ΔT Trip setpoints that will be used while the physical changes are implemented.
2	22	2	7/12/04	Revised Fq limit from 2.4 to 2.5. Removed OP and OT delta-T setpoints based on NMC methodology and replaced with Westinghouse developed setpoints.

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Core Operating Limits Report

Record of Revision

Unit	Cycle	Revision No.	Approval Date	Remarks
1	22	2	7/16/04	Revised Fq limit form 2.4 to 2.5. Removed OP and OT delta-T setpoints based on NMC methodology and replaced with Westinghouse developed setpoints.
1	23	0	10/20/04	Updated to Unit 1 Cycle 23.
2	23	0	-	Not used due to core redesign.
2	23	1	5/19/05	Updated to Unit 2 Cycle 23 and to support redesign of Unit 2 Cycle 23 core.
1	23	1	7/11/05	Revised ITC upper limit from < 0 pcm/°F for power levels > 70% RTP to less than a line that slopes linearly from 0 pcm/°F at 70% RTP to -2.9 pcm/°F at 100% RTP. Revised the title of Figure 3 to reference T.S. 3.1.4 Condition B and revised the title of Figure 4 to reference T.S. 3.1.4 Condition A. Added references 24 and 25 to include the 50.59 screenings written to issue revision 1.
1	24	0	5/10/06	Updated to Unit 1 Cycle 24.
1	24	1	8/7/06	Updated Table 3 to reflect the correct $F_q^w(z)$ penalty factors.
2	24	0	11/26/06	Updated to Unit 2 Cycle 24 Modes 5 and 6.
2	24	1	12/6/06	Updated to Unit 2 Cycle 24 for Modes 1-6.
2	24	2	9/4/07	Revised to support LA-179/169. Revised reference 24 to include the revision number (revision 0) and the correct date of the report (January 2005). Revised references 6a, 6b, 6c, and 8 to say 'Deleted.' These references referred to the old LBLOCA methodology and model.
1	24	2	2/11/08	Updated Table 1 to reflect correct Shutdown Margin Requirements and added Figures 6A through 6H.

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Core Operating Limits Report

Record of Revision

Unit	Cycle	Revision No.	Approval Date	Remarks
2	24	3	2/11/08	Updated Table 1 to reflect correct Shutdown Margin Requirements and added Figures 6A through 6H.
1	25	0	2/24/08	Updated to Unit 1 Cycle 25
1	25	1	5/28/08	Updated Table 2 to reflect the correct W(z) at a burnup of 150 MWd/MTU and a core height of 6.20 feet
2	25	0	9/26/08	Updated for Unit 2 Cycle 25
1	26	0	9/24/09	Updated for Unit 1 Cycle 26
2	26	0	5/3/10	Updated for Unit 2 Cycle 26
2	26	1	5/17/10	Updated to include part power W(z) factors
1	26	1	9/2/10	Updated for second set of W(z) factors
2	26	2	9/30/10	Updated for Measurement Uncertainty Recapture power uprate to 1677 MWth and for a second set of W(z) factors
1	26	2	9/30/10	Updated for Measurement Uncertainty Recapture power uprate to 1677 MWth
1	26	3	12/17/10	Updated SDM in Table 1 for Mode 2 to say 1.9.
1	27	0	5/5/11	Updated for Unit 1 Cycle 27
1	27	1	6/2/11	Updated for Unit 1 Cycle 27 Modes 1 through 6

PRAIRIE ISLAND NUCLEAR GENERATING PLANT

CORE OPERATING LIMITS REPORT

UNIT 1 - CYCLE 27

REVISION 1

Reviewed By: _____ Date: 6-2-11
Lynn Johnson
Supervisor, NSSS

Reviewed By: _____ Date: 6/2/11
Hank Hoelscher
Supervisor, PWR Analyses

Approved By: _____ Date: 6/2/11
Tim Allen
Director, Site Engineering-Interim

Note: This report is not part of the Technical Specifications

This report is referenced in the Technical Specifications

PRAIRIE ISLAND NUCLEAR GENERATING PLANT
CORE OPERATING LIMITS REPORT
UNIT 1 - CYCLE 27
REVISION 1

This report provides the values of the limits for Unit 1 Cycle 27 as required by Technical Specification 5.6.5. These values have been established using NRC approved methodology and are established such that all applicable limits of the plant safety analysis are met. The Technical Specifications affected by this report are listed below:

1. 2.1.1 Reactor Core SLs
2. 3.1.1 Shutdown Margin (SDM)
3. 3.1.3 Isothermal Temperature Coefficient (ITC)
4. 3.1.5 Shutdown Bank Insertion Limits
5. 3.1.6 Control Bank Insertion Limits
6. 3.1.8 Physics Tests Exceptions - MODE 2
7. 3.2.1 Heat Flux Hot Channel Factor ($F_Q(z)$)
8. 3.2.2 Nuclear Enthalpy Rise Hot Channel Factor ($F^N_{\Delta H}$)
9. 3.2.3 Axial Flux Difference (AFD)
10. 3.3.1 Reactor Trip System (RTS) Instrumentation Overtemperature ΔT and Overpower ΔT Parameter Values for Technical Specification Table 3.3.1-1 (Note 1 and Note 2)
11. 3.4.1 RCS Pressure, Temperature, and Flow - Departure from Nucleate Boiling (DNB) Limits
12. 3.9.1 Boron Concentration

1. 2.1.1 Reactor Core Safety Limits

Reactor Core Safety Limits are shown in Figure 1.

Reference Technical Specification 2.1.1.

2. 3.1.1 Shutdown Margin Requirements

Minimum Shutdown Margin requirements are shown in Table 1.

Reference Technical Specification 3.1.1.

3. 3.1.3 Isothermal Temperature Coefficient (ITC)

ITC Upper limit:

a. < 5 pcm/°F for power levels < 70% RTP; and
b. a line which slopes linearly from
   i. 0 pcm/°F at a power level = 70% RTP to
   ii. -1.5 pcm/°F at a power level = 100% RTP

ITC Lower limit:

a. -43.15 pcm/°F

Reference Technical Specification 3.1.3.

4. 3.1.5 Shutdown Bank Insertion Limits

The shutdown rods shall be fully withdrawn.

Reference Technical Specification 3.1.5.

5. 3.1.6 Control Bank Insertion Limits

The control rod banks shall be limited in physical insertion as shown in Figures 2, 3, and 4.

The control rod banks withdrawal sequence shall be Bank A, Bank B, Bank C, and finally Bank D.

The control rod banks shall be withdrawn maintaining 128 step tip-to-tip distance.

Reference Technical Specification 3.1.6.

6. 3.1.8 Physics Tests Exceptions - MODE 2

Minimum Shutdown Margin requirements during physics testing are shown in Table 1.

Reference Technical Specification 3.1.8.

7. 3.2.1 Heat Flux Hot Channel Factor ($F_Q(Z)$)

The Heat Flux Hot Channel Factor shall be within the following limits:

CFQ = 2.50

K(Z) is a constant value = 1.0 at all elevations.

The HFP W(Z) values are provided in Table 2 and Table 4.

The W(Z) values in Table 2 are only applicable to Figure 5.

The W(Z) values in Table 4 are only applicable to Figure 6.

The data in Tables 2 and 4 should be used independently; cross interpolation or extrapolation between W(Z) sets is prohibited.

The Part Power W(Z) values for $75\% \leq P < 85\%$ and Part Power W(Z) values for $85 \leq P < 95\%$ are provided in Table 6.

The W(Z) values in Table 6 are only applicable to Figure 5.

The $F^W_Q(Z)$ Penalty Factors associated with Figure 5 and Table 2 are provided in Table 3.

The $F^W_Q(Z)$ Penalty Factors associated with Figure 6 and Table 4 are provided in Table 5.

The Axial Flux Difference (AFD) Band in Figure 6 is more restrictive than the AFD Band in Figure 5. Prior to switching from Figure 6 to Figure 5, $F^W_Q(Z)$ must be confirmed to meet Technical Specification requirements by one of the follow methods:

1. Confirm $F^W_Q(Z)$ meets the Technical Specification Limit with the Table 2 W(Z) values for the most recent surveillance performed.
2. Perform a new surveillance and confirm $F^W_Q(Z)$ meets the Technical Specification Limit with the Table 2 W(Z) values.

The HFP W(Z) values are generated assuming that they will be used for full power surveillance. When a part power surveillance is performed from BOC through 150 MWd/MTU and at a power level specified for Table 6, the W(Z) values provided in Table 6 should be used. When a part power surveillance is

performed after 150 MWD/MTU, or at a power level other than those specified for Table 6, the HFP W(Z) values in Table 2 or Table 4 should be used.

W(Z) values should be multiplied by the factor 1/P, when P > 0.5. When P is ≤ 0.5, the W(Z) values should be multiplied by the factor 1/(0.5), or 2.0. This is consistent with the adjustment in the $F_Q(Z)$ limit at part power conditions.

Reference 10 provides the basis for multiple sets of W(Z) curves.

Reference Technical Specification 3.2.1.

8. 3.2.2 Nuclear Enthalpy Rise Hot Channel Factor ($F_{\Delta H}^N$)

The Nuclear Enthalpy Rise Hot Channel Factor shall be within the following limits:

$F_{\Delta H} \leq 1.77 \times [1 + 0.3(1- P)]$ for all 422V+ type fuel assemblies, and

$F_{\Delta H} \leq 1.674 \times [1 + 0.3(1- P)]$ for all OFA type fuel assemblies

where: P is the fraction of RATED THERMAL POWER at which the core is operating.

Reference Technical Specification 3.2.2.

9. 3.2.3 Axial Flux Difference (AFD)

The indicated axial flux difference shall be maintained within the allowed operational space defined by Figure 5 or the more restrictive operational space as defined by Figure 6.

Both Figures 5 and 6 can be used any time during the cycle.

Prior to switching to the more restrictive AFD envelope (Figure 6), it should be confirmed that the plant is within the specified AFD envelope.

Reference Technical Specification 3.2.3.

10. 3.3.1 Reactor Trip System (RTS) Instrumentation

Overtemperature ΔT and Overpower ΔT Parameter Values for Technical Specification Table 3.3.1-1 (Note 1 and Note 2):

Overtemperature ΔT Setpoint

Overtemperature ΔT setpoint parameter values:

ΔT_0	=	Indicated ΔT at RATED THERMAL POWER, %
T	=	Average temperature, °F
T′	=	560.0 °F
P	=	Pressurizer Pressure, psig
P′	=	2235 psig
K_1	≤	1.17
K_2	=	0.014 /°F
K_3	=	0.00100 /psi
τ_1	=	30 seconds
τ_2	=	4 seconds
f(ΔI)	=	A function of the indicated difference between top and bottom detectors of the power range nuclear ion chambers. Selected gains are based on measured instrument response during plant startup tests, where q_t and q_b are the percent power in the top and bottom halves of the core respectively, and $q_t + q_b$ is total core power in percent of RATED THERMAL POWER, such that (a) For $q_t - q_b$ within –13, +8 % f(ΔI) = 0 (b) For each percent that the magnitude of $q_t - q_b$ exceeds +8% the ΔT trip setpoint shall be automatically reduced by an equivalent of 1.73 % of RATED THERMAL POWER. (c) For each percent that the magnitude of $q_t - q_b$ exceeds -13 % the ΔT trip setpoint shall be automatically reduced by an equivalent of 3.846 % of RATED THERMAL POWER.

Overpower ΔT Setpoint

Overpower ΔT setpoint parameter values:

ΔT_0	=	Indicated ΔT at RATED THERMAL POWER, %
T	=	Average temperature, °F
T′	=	560.0 °F
K_4	≤	1.11
K_5	=	0.0275/°F for increasing T; 0 for decreasing T
K_6	=	0.002/°F for $T > T'$; 0 for $T \leq T'$
τ_3	=	10 seconds

Reference Technical Specification 3.3.1.

11. 3.4.1 RCS Pressure, Temperature, and Flow - Departure from Nucleate Boiling (DNB) Limits

The DNB Limits are:
Pressurizer pressure limit = 2190 psia
RCS average temperature limit = 564°F
RCS total flow rate limit = 178,000 gpm

Reference Technical Specification 3.4.1.

12. 3.9.1 Refueling Boron Concentration.

The boron concentration of the reactor coolant system and the refueling cavity shall be sufficient to ensure that the more restrictive of the following conditions is met:

a) $K_{eff} \leq 0.95$
b) 2000 ppm
c) The Shutdown Margin specified in Table 1

Reference Technical Specification 3.9.1.

REFERENCES
(NRC Approved Methodologies for COLR Parameters)

1. NSPNAD-8101-A, "Qualification of Reactor Physics Methods for Application to Prairie Island," Revision 2, October 2000.

2. NSPNAD-8102-PA, "Prairie Island Nuclear Power Plant Reload Safety Evaluation Methods for Application to PI Units," Revision 7, July 1999.

3. NSPNAD-97002-PA, "Northern States Power Company's "Steam Line Break Methodology," Revision 1, October 2000.

4. WCAP-9272-P-A, "Westinghouse Reload Safety Evaluation Methodology," July, 1985.

5.a WCAP-10054-P-A, "Westinghouse Small Break ECCS Evaluation Model using the NOTRUMP Code," August, 1985.

5.b WCAP-10054-P-A, "Westinghouse Small Break ECCS Evaluation Model using the NOTRUMP Code," Addendum 2 Revision 1, July 1997.

6. Not used.

7. WCAP-10924-P-A, Volume 1, Revision 1, and Volume 2, Revision 2, "Westinghouse Large Break LOCA Best Estimate Methodology," September 2005.

8. XN-NF-77-57-(A), XN-NF-77-57, Supplement 1 (A), "Exxon Nuclear Power Distribution Control for Pressurized Water Reactors Phase II," May 1981.

9. WCAP-13677-P-A, "10 CFR 50.46 Evaluation Model Report: W-COBRA/TRAC 2-Loop Upper Plenum Injection Model Update to Support ZIRLO® Cladding Options," February 1994.

10. NSPNAD-93003-A, "Prairie Island Units 1 and 2 Transient Power Distribution Methodology," Revision 0, April 1993.

11. NAD-PI-003, "Prairie Island Nuclear Power Plant Required Shutdown Margin During Physics Tests," Revision 0, January 2001.

12. NAD-PI-004, "Prairie Island Nuclear Power Plant $F^{W}_{Q}(Z)$ Penalty With Increasing [$F^{C}_{Q}(Z)$ / K(Z) Trend," Revision 0, January 2001.

13. WCAP-10216-P-A, Revision 1A, "Relaxation of Constant Axial Offset Control/ FQ Surveillance Technical Specification," February 1994.

14. WCAP-8745-P-A, "Design Bases for the Thermal Overpower ΔT and Thermal Overtemperature ΔT Trip Functions," September 1986.

15. WCAP-11397-P-A, "Revised Thermal Design Procedure," April 1989.

16. WCAP-14483-A, "Generic Methodology for Expanded Core Operating Limits Report," January 1999.

17. WCAP-7588 Rev. 1-A, "An Evaluation of the Rod Ejection Accident in Westinghouse Pressurized Water Reactors Using Spatial Kinetics Methods," January 1975.

18. WCAP-7908-A, "FACTRAN – A FORTRAN IV Code for Thermal Transients in a UO_2 Fuel Rod," December 1989.

19. WCAP-7907-P-A, "LOFTRAN Code Description," April 1984.

20. WCAP-7979-P-A, "TWINKLE – A Multidimensional Neutron Kinetics Computer Code," January 1975.

21. WCAP-10965-P-A, "ANC: A Westinghouse Advanced Nodal Computer Code," September 1986.

22. WCAP-11394-P-A, "Methodology for the Analysis of the Dropped Rod Event," January 1990.

23. WCAP-11596-P-A, "Qualification of the PHOENIX-P/ANC Nuclear Design System for Pressurized Water Reactor Cores," June 1988.

24. WCAP-12910 Rev. 1-A, "Pressurizer Safety Valve Set Pressure Shift," May 1993.

25. WCAP-14565-P-A, "VIPRE-01 Modeling and Qualification for Pressurized Water Reactor Non-LOCA Thermal-Hydraulic Safety Analysis," October 1999.

26. WCAP-14882-P-A, "RETRAN-02 Modeling and Qualification for Westinghouse Pressurized Water Reactor Non-LOCA Safety Analyses," April 1999.

27. WCAP-16009-P-A, "Realistic Large-Break LOCA Evaluation Methodology Using the Automated Statistical Treatment Of Uncertainty Method (ASTRUM)," Revision 0, January 2005.

28. Caldon, Inc. Engineering Report-80P, "Improving Thermal Power Accuracy and Plant Safety While Increasing Operating Power Level Using the LEFM √™ System," Revision 0, March 1997.

29. Caldon, Inc. Engineering Report-157P, "Supplement to Topical Report ER-80P: Basis for a Power Uprate With the LEFM √™ Check or CheckPlus™ System," Revision 5, October 2001.

30. WCAP-12610-P-A, "VANTAGE+ Fuel Assembly Reference Core Report," April 1995.

31. WCAP-12610-P-A and CENPD-404-P-A, Addendum 1-A, "**Optimized ZIRLO™**," July 2006.

32. 50.59 Evaluation 1086, Revision 1, "Unit 1 Cycle 27 Core Reload Modification."

Table 1

Minimum Required Shutdown Margin, %Δρ

	Number of Charging Pumps Running**		
Mode 1*			
	0-1 Pump	**2 Pumps**	**3 Pumps**
0 – 20000 MWd/MTU	-	-	-

Mode 2*			
	0-1 Pump	**2 Pumps**	**3 Pumps**
0 – 20000 MWd/MTU	1.9	1.9	1.9

Physics Testing in Mode 2			
	0-1 Pump	**2 Pumps**	**3 Pumps**
0 – 20000 MWd/MTU	0.5	0.5	0.5

Mode 3	**Tave ≥ 520 °F (Most Reactive Rod Out)**		
	0-1 Pump	**2 Pumps**	**3 Pumps**
0 – 20000 MWd/MTU	2.0	2.0	2.0

Mode 3	**350 °F ≤ Tave < 520°F (Most Reactive Rod Out)**		
	0-1 Pump	**2 Pumps**	**3 Pumps**
0 MWd/MTU	2.0	2.0	2.5
12000 MWd/MTU	2.0	2.0	2.0
20000 MWd/MTU	2.0	2.0	2.0

Mode 4	**200 °F < Tave < 350°F (Most Reactive Rod Out)**		
	0-1 Pump	**2 Pumps**	**3 Pumps**
0 MWd/MTU	2.0	4.0	6.5
12000 MWd/MTU	2.0	3.0	4.5
20000 MWd/MTU	2.0	2.0	2.5

Operational Mode Definitions, as per TS Table 1.1-1.

* For Mode 1 and Mode 2 with $K_{eff} \geq 1.0$, the minimum shutdown margin requirements are provided by the Rod Insertion Limits.

** Charging pump(s) in service only pertains to steady state operations. It does not include transitory operations. For example, operations such as starting a second charging pump in order to secure the operating pump would fall under the one pump in service column.

Table 1, Continued

Minimum Required Shutdown Margin, %Δρ

	Number of Charging Pumps Running**		
Mode 5	**68°F ≤ Tave ≤ 200°F (Most Reactive Rod Out)**		
	0-1 Pump	**2 Pumps**	**3 Pumps**
0 MWd/MTU***	2.5	4.5	7.5
12000 MWd/MTU	2.0	3.0	5.0
20000 MWd/MTU	2.0	2.0	3.0

Mode 6	**68°F ≤ Tave < 200°F (ARI)**		
	0-1 Pump	**2 Pumps**	**3 Pumps**
0 MWd/MTU***	5.129	5.129	7.0
12000 MWd/MTU	5.129	5.129	5.129
20000 MWd/MTU	5.129	5.129	5.129

Mode 6	**68°F ≤ Tave < 200°F (ARO)**		
	0-1 Pump	**2 Pumps**	**3 Pumps**
0 MWd/MTU***	5.129	5.5	9.0
12000 MWd/MTU	5.129	5.129	7.0
20000 MWd/MTU	5.129	5.129	5.129

Operational Mode Definitions, as per TS Table 1.1-1.

** Charging pump(s) in service only pertains to steady state operations. It does not include transitory operations. For example, operations such as starting a second charging pump in order to secure the operating pump would fall under the one pump in service column.

*** These values are also applicable for the Unit 1 Cycle 26 end of cycle.

Table 2 - W(z) Values associated with Figure 5 (Top 10% and Bottom 8% excluded)*

	Height	BU [MWd/MTU]						
	[ft]	150	5000	9000	12000	14000	16000	18000
		AO = 0.38	AO = -1.89	AO = -3.59	AO = -4.17	AO = -2.17	AO = -0.82	AO = -1.01
[BOTTOM] 1	0.00	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
2	0.20	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
3	0.40	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
4	0.60	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
5	0.80	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
6	1.00	1.2899	1.1992	1.1874	1.1705	1.1949	1.2181	1.2138
7	1.20	1.2795	1.1916	1.1795	1.1626	1.1870	1.2093	1.2047
8	1.40	1.2673	1.1828	1.1704	1.1537	1.1782	1.1995	1.1947
9	1.60	1.2537	1.1731	1.1607	1.1444	1.1689	1.1893	1.1844
10	1.80	1.2391	1.1628	1.1506	1.1346	1.1593	1.1788	1.1739
11	2.00	1.2235	1.1520	1.1400	1.1246	1.1495	1.1680	1.1633
12	2.20	1.2074	1.1411	1.1293	1.1144	1.1396	1.1571	1.1526
13	2.40	1.1910	1.1296	1.1186	1.1044	1.1297	1.1462	1.1420
14	2.60	1.1745	1.1185	1.1080	1.0945	1.1200	1.1353	1.1314
15	2.80	1.1572	1.1131	1.0971	1.0844	1.1103	1.1241	1.1200
16	3.00	1.1468	1.1120	1.0896	1.0778	1.1014	1.1156	1.1159
17	3.20	1.1426	1.1116	1.0877	1.0769	1.0989	1.1148	1.1168
18	3.40	1.1401	1.1107	1.0884	1.0786	1.1026	1.1200	1.1231
19	3.60	1.1380	1.1104	1.0918	1.0838	1.1053	1.1236	1.1280
20	3.80	1.1370	1.1101	1.0968	1.0905	1.1083	1.1262	1.1321
21	4.00	1.1357	1.1114	1.1017	1.0968	1.1132	1.1307	1.1380
22	4.20	1.1335	1.1139	1.1057	1.1024	1.1185	1.1359	1.1445
23	4.40	1.1307	1.1154	1.1091	1.1073	1.1227	1.1397	1.1494
24	4.60	1.1273	1.1163	1.1123	1.1114	1.1261	1.1427	1.1533
25	4.80	1.1233	1.1165	1.1168	1.1156	1.1287	1.1445	1.1560
26	5.00	1.1190	1.1168	1.1210	1.1205	1.1304	1.1458	1.1579
27	5.20	1.1133	1.1179	1.1243	1.1252	1.1317	1.1452	1.1583
28	5.40	1.1092	1.1201	1.1269	1.1290	1.1332	1.1456	1.1586
29	5.60	1.1114	1.1231	1.1289	1.1326	1.1365	1.1544	1.1662
30	5.80	1.1147	1.1275	1.1344	1.1370	1.1479	1.1652	1.1777
31	6.00	1.1193	1.1342	1.1435	1.1455	1.1622	1.1755	1.1888
32	6.20	1.1242	1.1432	1.1544	1.1562	1.1753	1.1846	1.1984
33	6.40	1.1284	1.1532	1.1653	1.1653	1.1875	1.1927	1.2068
34	6.60	1.1346	1.1620	1.1752	1.1736	1.1986	1.1994	1.2138
35	6.80	1.1422	1.1699	1.1841	1.1809	1.2084	1.2048	1.2194
36	7.00	1.1493	1.1767	1.1917	1.1867	1.2167	1.2088	1.2235
37	7.20	1.1553	1.1824	1.1983	1.1919	1.2235	1.2118	1.2265

* **Linear extrapolation based on a line between 16,000 MWD/MTU and 18,000 MWD/MTU is adequate for addressing burnups beyond 18,000 MWD/MTU.**

Table 2 (cont.) - W(z) Values associated with Figure 5 (Top 10% and Bottom 8% excluded)*

	Height	BU [MWd/MTU]						
	[ft]	150	5000	9000	12000	14000	16000	18000
		AO = 0.38	AO = -1.89	AO = -3.59	AO = -4.17	AO = -2.17	AO = -0.82	AO = -1.01
38	7.40	1.1601	1.1875	1.2043	1.1980	1.2285	1.2138	1.2283
39	7.60	1.1637	1.1915	1.2086	1.2059	1.2315	1.2138	1.2280
40	7.80	1.1660	1.1939	1.2137	1.2123	1.2324	1.2119	1.2255
41	8.00	1.1667	1.1945	1.2186	1.2167	1.2310	1.2079	1.2209
42	8.20	1.1657	1.1934	1.2216	1.2195	1.2274	1.2020	1.2139
43	8.40	1.1631	1.1902	1.2225	1.2200	1.2212	1.1936	1.2047
44	8.60	1.1588	1.1848	1.2210	1.2183	1.2124	1.1824	1.1946
45	8.80	1.1511	1.1804	1.2184	1.2174	1.2035	1.1782	1.1889
46	9.00	1.1489	1.1784	1.2180	1.2184	1.1937	1.1770	1.1839
47	9.20	1.1566	1.1781	1.2207	1.2199	1.1831	1.1731	1.1745
48	9.40	1.1684	1.1790	1.2246	1.2188	1.1782	1.1670	1.1648
49	9.60	1.1785	1.1855	1.2268	1.2209	1.1859	1.1608	1.1676
50	9.80	1.1918	1.1945	1.2304	1.2213	1.1949	1.1603	1.1714
51	10.00	1.2020	1.2034	1.2350	1.2220	1.2021	1.1618	1.1730
52	10.20	1.2121	1.2115	1.2412	1.2252	1.2092	1.1635	1.1742
53	10.40	1.2232	1.2187	1.2492	1.2282	1.2155	1.1642	1.1743
54	10.60	1.2264	1.2250	1.2563	1.2334	1.2213	1.1670	1.1746
55	10.80	1.2206	1.2301	1.2621	1.2382	1.2256	1.1737	1.1771
56	11.00	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
57	11.20	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
58	11.40	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
59	11.60	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
60	11.80	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
[TOP] 61	12.00	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

* **Linear extrapolation based on a line between 16,000 MWD/MTU and 18,000 MWD/MTU is adequate for addressing burnups beyond 18,000 MWD/MTU.**

Table 3

$F^W_Q(Z)$ Penalty Factor associated with Figure 5 and Table 2

Cycle Burnup (MWD/MTU)	$F^W_Q(Z)$ Penalty Factor
0	1.0200
20000	1.0200

Linear interpolation is adequate for intermediate cycle burnups.

Table 4 - W(z) Values associated with Figure 6 (Top 10% and Bottom 8% excluded)*

	Height	BU [MWd/MTU]						
	[ft]	150	5000	9000	12000	14000	16000	18000
		AO = 0.38	AO = -1.89	AO = -3.59	AO = -4.17	AO = -2.17	AO = -0.82	AO = -1.01
[BOTTOM] 1	0.00	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
2	0.20	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
3	0.40	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
4	0.60	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
5	0.80	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
6	1.00	1.2315	1.1443	1.1263	1.1076	1.1283	1.1499	1.1747
7	1.20	1.2226	1.1378	1.1198	1.1013	1.1220	1.1425	1.1663
8	1.40	1.2120	1.1301	1.1124	1.0941	1.1149	1.1343	1.1571
9	1.60	1.2003	1.1218	1.1046	1.0866	1.1076	1.1260	1.1477
10	1.80	1.1877	1.1131	1.0965	1.0790	1.1002	1.1175	1.1381
11	2.00	1.1744	1.1040	1.0882	1.0713	1.0928	1.1088	1.1284
12	2.20	1.1606	1.0948	1.0799	1.0636	1.0855	1.1006	1.1187
13	2.40	1.1468	1.0857	1.0718	1.0562	1.0784	1.0933	1.1091
14	2.60	1.1328	1.0766	1.0639	1.0491	1.0716	1.0867	1.0995
15	2.80	1.1188	1.0670	1.0557	1.0417	1.0660	1.0803	1.0891
16	3.00	1.1075	1.0654	1.0529	1.0400	1.0613	1.0747	1.0846
17	3.20	1.1047	1.0679	1.0527	1.0408	1.0622	1.0761	1.0844
18	3.40	1.1060	1.0746	1.0569	1.0460	1.0681	1.0844	1.0859
19	3.60	1.1065	1.0816	1.0660	1.0564	1.0731	1.0909	1.0945
20	3.80	1.1065	1.0883	1.0746	1.0663	1.0818	1.0973	1.1020
21	4.00	1.1061	1.0944	1.0824	1.0754	1.0912	1.1054	1.1103
22	4.20	1.1050	1.1000	1.0898	1.0841	1.0994	1.1138	1.1194
23	4.40	1.1034	1.1049	1.0965	1.0921	1.1071	1.1210	1.1275
24	4.60	1.1016	1.1092	1.1025	1.0995	1.1140	1.1273	1.1346
25	4.80	1.1015	1.1128	1.1078	1.1060	1.1200	1.1328	1.1408
26	5.00	1.1013	1.1158	1.1127	1.1123	1.1252	1.1372	1.1457
27	5.20	1.1022	1.1179	1.1181	1.1191	1.1298	1.1409	1.1503
28	5.40	1.1073	1.1200	1.1238	1.1261	1.1332	1.1455	1.1566
29	5.60	1.1113	1.1231	1.1287	1.1324	1.1365	1.1544	1.1662
30	5.80	1.1147	1.1275	1.1344	1.1370	1.1465	1.1652	1.1777
31	6.00	1.1193	1.1342	1.1435	1.1455	1.1579	1.1755	1.1888
32	6.20	1.1242	1.1432	1.1544	1.1562	1.1678	1.1846	1.1984
33	6.40	1.1283	1.1532	1.1653	1.1653	1.1769	1.1927	1.2068
34	6.60	1.1317	1.1620	1.1752	1.1736	1.1850	1.1994	1.2138
35	6.80	1.1341	1.1699	1.1841	1.1808	1.1917	1.2048	1.2194
36	7.00	1.1365	1.1767	1.1917	1.1867	1.1972	1.2087	1.2233
37	7.20	1.1393	1.1823	1.1983	1.1917	1.2012	1.2109	1.2254

* **Linear extrapolation based on a line between 16,000 MWD/MTU and 18,000 MWD/MTU is adequate for addressing burnups beyond 18,000 MWD/MTU.**

Table 4 (cont.) - W(z) Values associated with Figure 6 (Top 10% and Bottom 8% excluded)*

	Height	BU [MWd/MTU]						
	[ft]	150	5000	9000	12000	14000	16000	18000
		AO = 0.38	AO = -1.89	AO = -3.59	AO = -4.17	AO = -2.17	AO = -0.82	AO = -1.01
38	7.40	1.1423	1.1865	1.2043	1.1965	1.2035	1.2113	1.2256
39	7.60	1.1449	1.1891	1.2086	1.2025	1.2039	1.2098	1.2237
40	7.80	1.1464	1.1900	1.2116	1.2072	1.2025	1.2062	1.2196
41	8.00	1.1465	1.1890	1.2125	1.2099	1.1989	1.2004	1.2131
42	8.20	1.1452	1.1861	1.2113	1.2107	1.1933	1.1927	1.2043
43	8.40	1.1425	1.1812	1.2081	1.2093	1.1853	1.1824	1.1931
44	8.60	1.1384	1.1743	1.2025	1.2055	1.1749	1.1692	1.1798
45	8.80	1.1310	1.1638	1.1953	1.2009	1.1651	1.1614	1.1679
46	9.00	1.1295	1.1590	1.1842	1.1986	1.1595	1.1564	1.1545
47	9.20	1.1343	1.1593	1.1770	1.1985	1.1565	1.1508	1.1401
48	9.40	1.1385	1.1639	1.1791	1.1994	1.1541	1.1463	1.1289
49	9.60	1.1495	1.1672	1.1854	1.2012	1.1587	1.1445	1.1190
50	9.80	1.1599	1.1741	1.1921	1.2017	1.1637	1.1439	1.1175
51	10.00	1.1699	1.1804	1.1979	1.2033	1.1671	1.1459	1.1179
52	10.20	1.1820	1.1849	1.2023	1.2092	1.1697	1.1520	1.1193
53	10.40	1.1898	1.1909	1.2055	1.2164	1.1711	1.1568	1.1232
54	10.60	1.1950	1.1909	1.2113	1.2226	1.1742	1.1612	1.1300
55	10.80	1.1905	1.1911	1.2168	1.2277	1.1762	1.1649	1.1485
56	11.00	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
57	11.20	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
58	11.40	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
59	11.60	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
60	11.80	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
[TOP] 61	12.00	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

* **Linear extrapolation based on a line between 16,000 MWD/MTU and 18,000 MWD/MTU is adequate for addressing burnups beyond 18,000 MWD/MTU.**

Table 5

$F^W_Q(Z)$ Penalty Factor associated with Figure 6 and Table 4

Cycle Burnup (MWD/MTU)	$F^W_Q(Z)$ Penalty Factor
0	1.0200
20000	1.0200

Linear interpolation is adequate for intermediate cycle burnups.

Table 6 - W(z) Values Associated with Figure 5 for Part Power Surveillances*
(Top 10% and Bottom 8% excluded)

	Height	Part Power W(z) Functions (% of Hot Full Power)	
		80†	90††
	[ft]	D-Bank @ 194 Steps‡	D-Bank @ 203 Steps‡
		HFP AO = 0.38	HFP AO = 0.38
[BOTTOM] 1	0.00	1.0000	1.0000
2	0.20	1.0000	1.0000
3	0.40	1.0000	1.0000
4	0.60	1.0000	1.0000
5	0.80	1.0000	1.0000
6	1.00	1.3198	1.3023
7	1.20	1.3069	1.2906
8	1.40	1.2923	1.2772
9	1.60	1.2762	1.2624
10	1.80	1.2590	1.2465
11	2.00	1.2408	1.2297
12	2.20	1.2221	1.2127
13	2.40	1.2031	1.1954
14	2.60	1.1840	1.1779
15	2.80	1.1642	1.1595
16	3.00	1.1515	1.1481
17	3.20	1.1448	1.1427
18	3.40	1.1398	1.1390
19	3.60	1.1353	1.1357
20	3.80	1.1320	1.1336
21	4.00	1.1283	1.1310
22	4.20	1.1239	1.1278
23	4.40	1.1189	1.1238
24	4.60	1.1133	1.1193
25	4.80	1.1068	1.1141
26	5.00	1.1001	1.1088
27	5.20	1.0922	1.1020
28	5.40	1.0862	1.0972
29	5.60	1.0864	1.0985
30	5.80	1.0876	1.1006

* W(z) values only valid for core average burnups ≤ 150 MWd/MTU.

† 80% of full power W(z) values are applicable for powers 75% ≤ P < 85%.

†† 90% of full power W(z) values are applicable for powers 85% ≤ P < 95%.

‡ Rod insertion is given as a target value. Use control rods as necessary to control to target AO.

Table 6 (cont.) - W(z) Values Associated with Figure 5 for Part Power Surveillances*
(Top 10% and Bottom 8% excluded)

	Height	Part Power W(z) Functions (% of Hot Full Power)	
		80†	90††
	[ft]	D-Bank @ 194 Steps‡	D-Bank @ 203 Steps‡
		HFP AO = 0.38	HFP AO = 0.38
31	6.00	1.0900	1.1040
32	6.20	1.0929	1.1077
33	6.40	1.0951	1.1111
34	6.60	1.0995	1.1164
35	6.80	1.1055	1.1232
36	7.00	1.1111	1.1296
37	7.20	1.1160	1.1350
38	7.40	1.1205	1.1393
39	7.60	1.1242	1.1424
40	7.80	1.1269	1.1444
41	8.00	1.1291	1.1461
42	8.20	1.1294	1.1459
43	8.40	1.1271	1.1434
44	8.60	1.1219	1.1389
45	8.80	1.1172	1.1326
46	9.00	1.1195	1.1320
47	9.20	1.1318	1.1411
48	9.40	1.1470	1.1539
49	9.60	1.1637	1.1691
50	9.80	1.1818	1.1864
51	10.00	1.1942	1.1994
52	10.20	1.2005	1.2073
53	10.40	1.2100	1.2174
54	10.60	1.2174	1.2230
55	10.80	1.2172	1.2208
56	11.00	1.0000	1.0000
57	11.20	1.0000	1.0000
58	11.40	1.0000	1.0000
59	11.60	1.0000	1.0000
60	11.80	1.0000	1.0000
[TOP] 61	12.00	1.0000	1.0000

* W(z) values only valid for core average burnups ≤ 150 MWd/MTU.

† 80% of full power W(z) values are applicable for powers 75% ≤ P < 85%.

†† 90% of full power W(z) values are applicable for powers 85% ≤ P < 95%.

‡ Rod insertion is given as a target value. Use control rods as necessary to control to target AO.

Figure 1

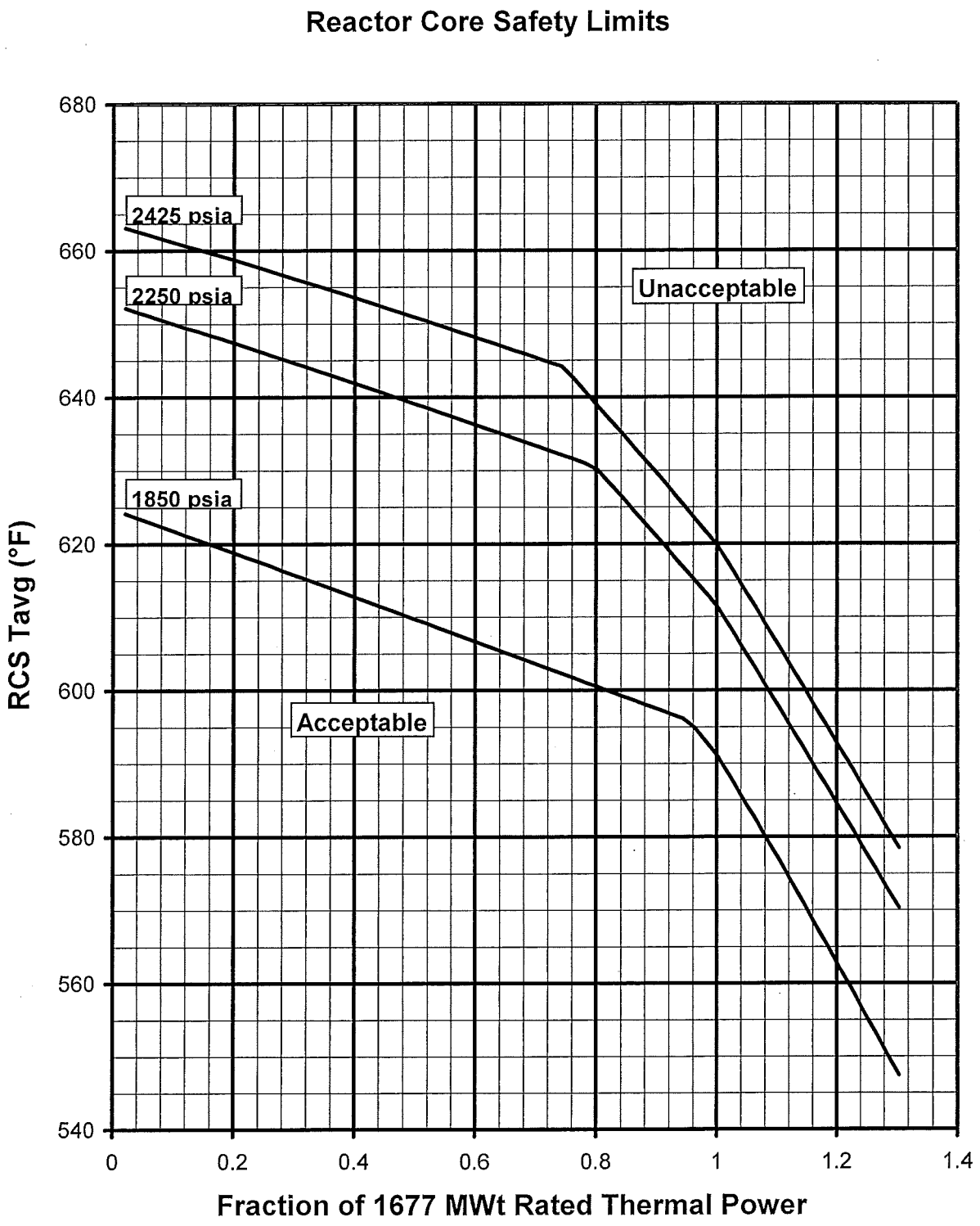
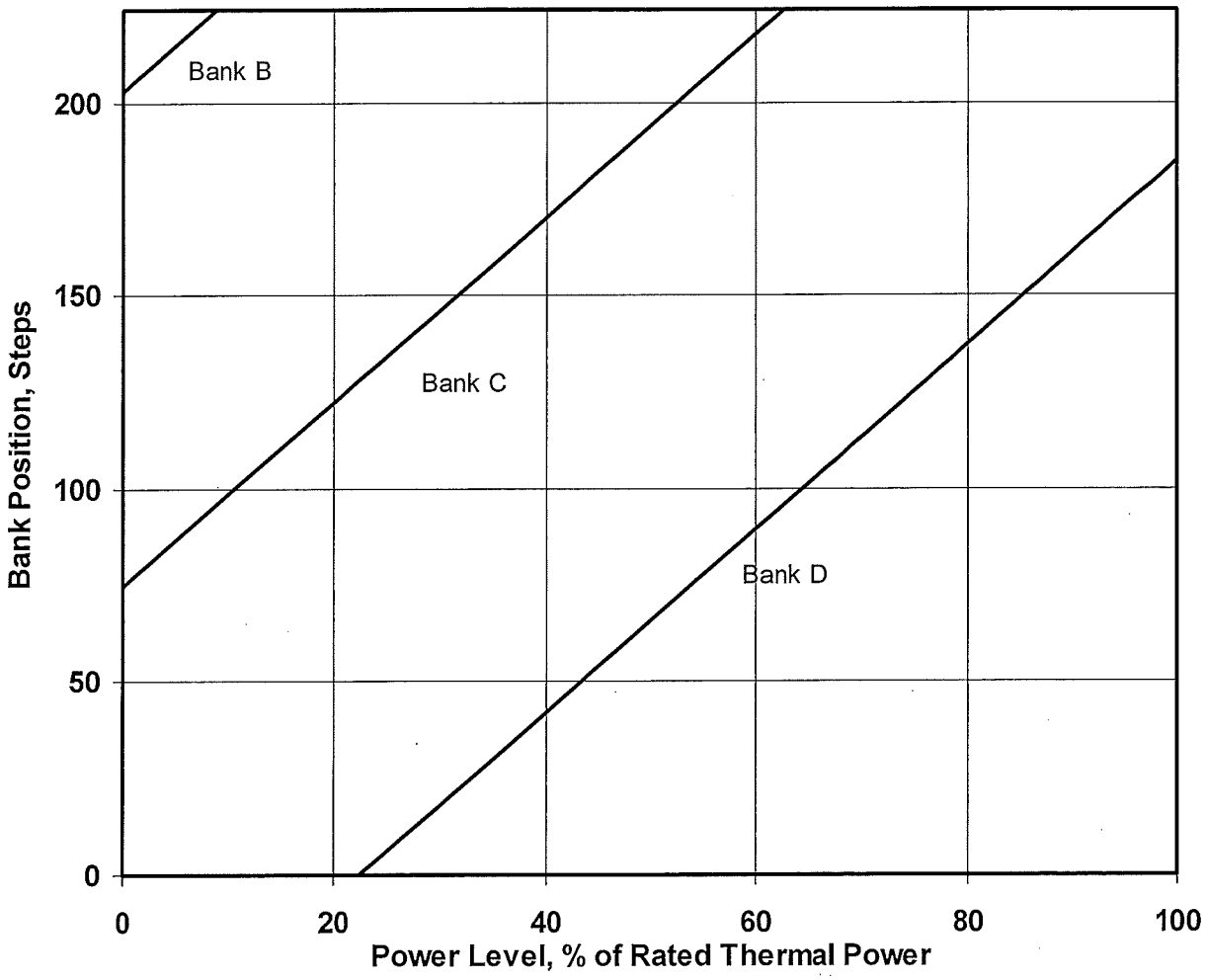

Reactor Core Safety Limits
680
660
640
620
600
580
560
540
RCS Tavg (°F)
2425 psia
2250 psia
1850 psia
Unacceptable
Acceptable
0
0.2
0.4
0.6
0.8
1
1.2
1.4
Fraction of 1677 MWt Rated Thermal Power

Figure 2
Rod Insertion Limit, 128 Step Tip-to-Tip

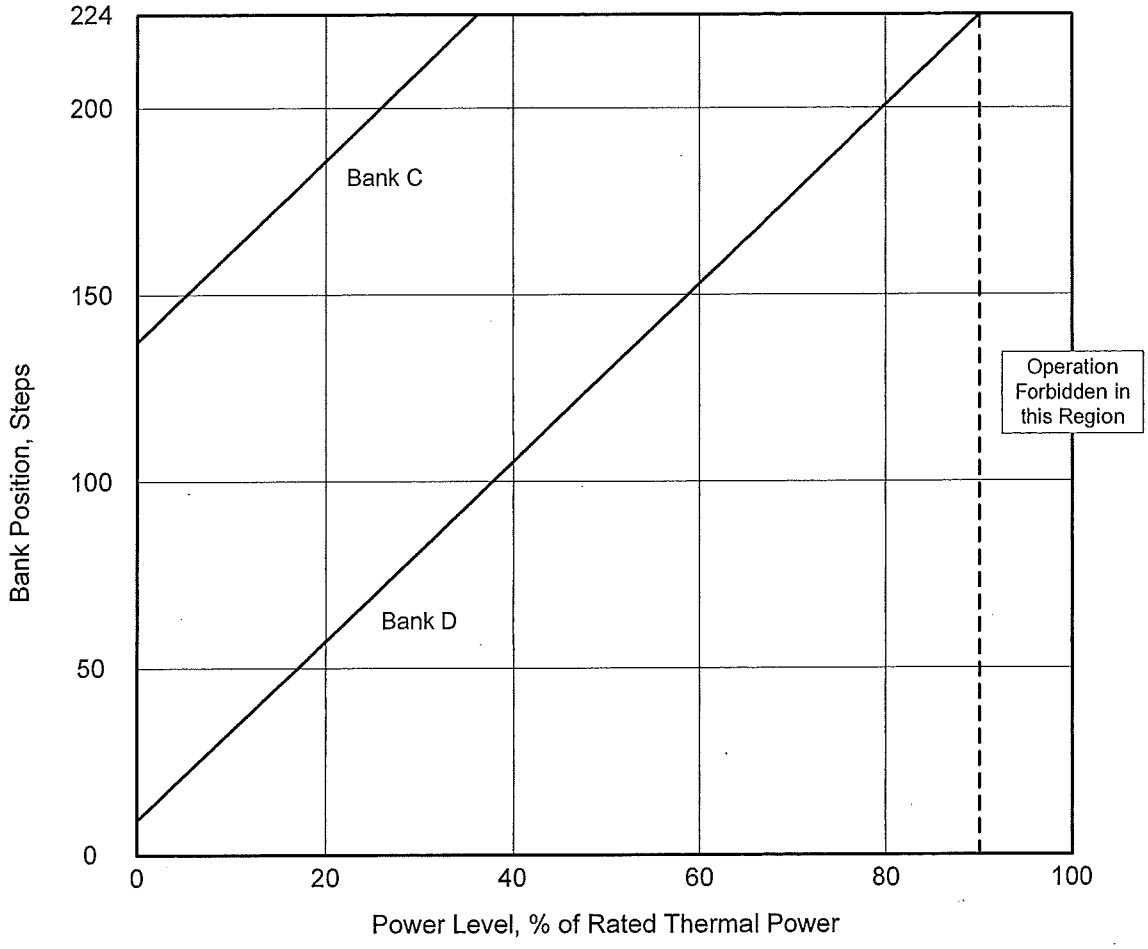


Bank Positions Given By:

- Bank D = (150 / 63) * (P – 100) + 185
- Bank C = (150 / 63) * (P – 100) + 185 + 128
- Bank B = (150 / 63) * (P – 100) + 185 + 128 + 128

NOTE: The top of the active fuel height corresponds to 224 steps. The ARO parking position may be any position above 224 steps.

Figure 3
Rod Insertion Limit, 128 Step Tip-to-Tip, One Bottomed Rod
(Technical Specification 3.1.4, Condition B)

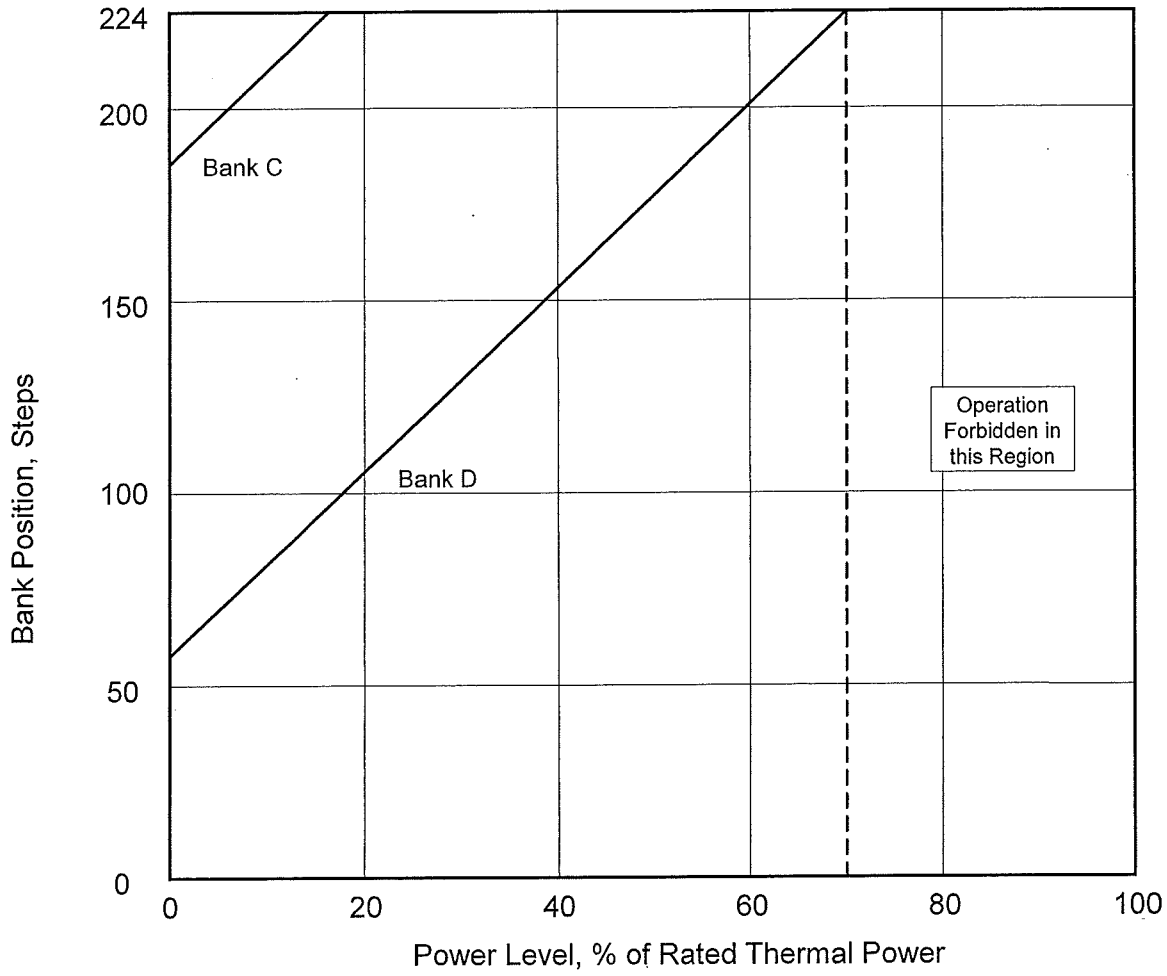


Bank Positions Given By:

- Bank D = (150 / 63) * (P – 90) + 224
- Bank C = (150 / 63) * (P – 90) + 224 + 128

NOTE: The top of the active fuel height corresponds to 224 steps. The ARO parking position may be any position above 224 steps.

Figure 4
Rod Insertion Limit, 128 Step Tip-to-Tip, One Inoperable Rod
(Technical Specification 3.1.4, Condition A)



Bank Positions Given By:

- Bank D = (150 / 63) * (P – 70) + 224
- Bank C = (150 / 63) * (P – 70) + 224 + 128

NOTE: The top of the active fuel height corresponds to 224 steps. The ARO parking position may be any position above 224 steps.

Figure 5
Flux Difference Operating Envelope associated with Table 2 and Table 6

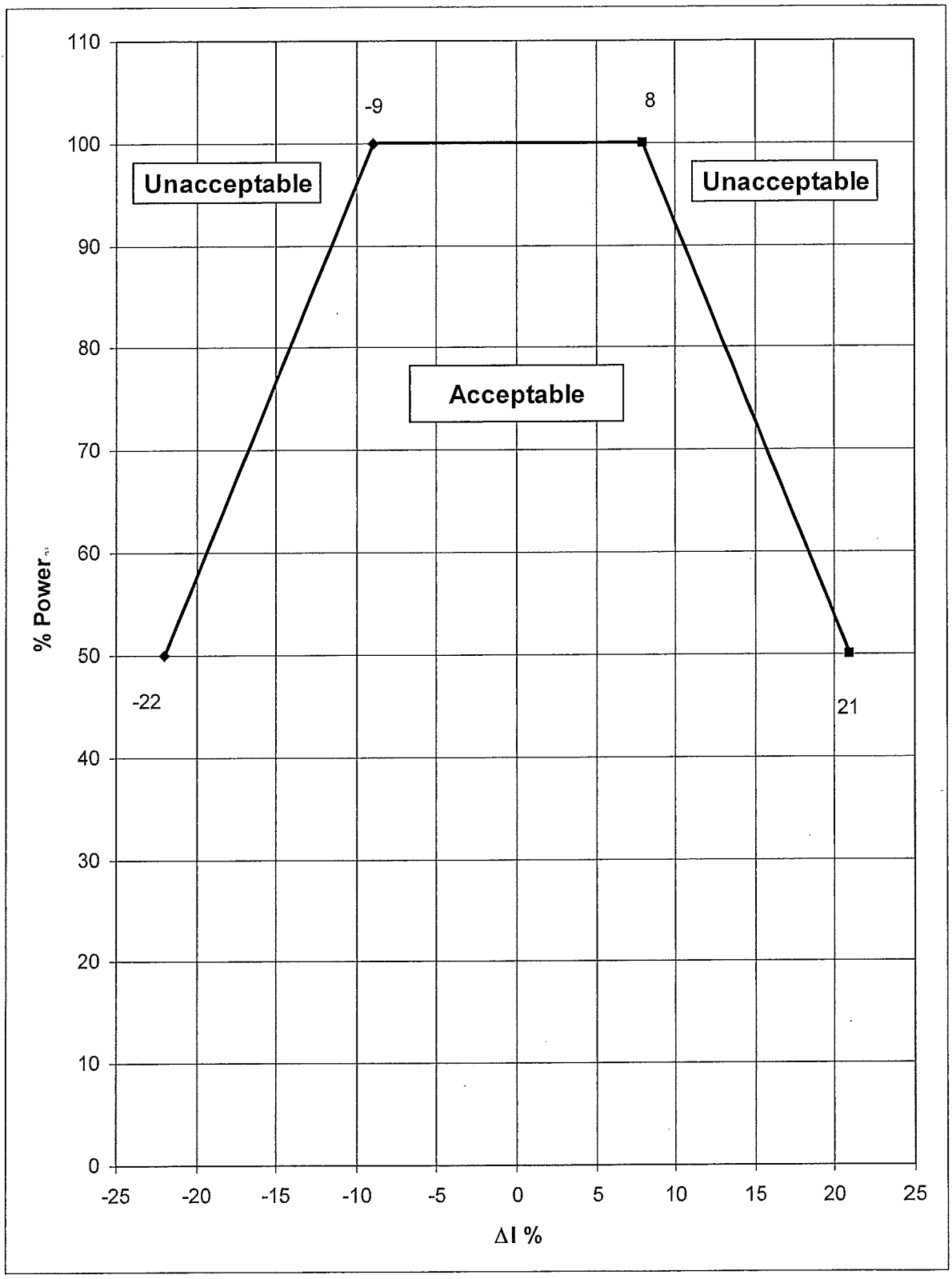


Figure 6
Flux Difference Operating Envelope associated with Table 4