



Kelvin Henderson
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April 30, 2013

U. S. Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, DC 20555-0001

Subject: Duke Energy Carolinas, LLC (Duke Energy)

Catawba Nuclear Station Unit 1
CNS Docket Nos. 50-413

Core Operating Limits Report (COLR)
Catawba Nuclear Station (CNS) Unit 1 Cycle 21, Revision 0

Attached, pursuant to Catawba Technical Specification 5.6.5, is an information copy and electronic copy of the Core Operating Limits Report for Catawba Unit 1 Cycle 21. This COLR is being submitted to update the limits of the Cycle 21 reload core.

The electronic copy of this COLR is included with the letter. The electronic copy includes the power distribution monitoring factors.

This letter, attached COLR, and computer disk do not contain any new commitments.

Please direct any questions or concerns to Randy Hart at (803) 701-3622.

Sincerely,

A handwritten signature in black ink, appearing to read 'Kel. Henderson', written in a cursive style.

Kelvin Henderson

Attachments

ADD
NRR

U.S. Nuclear Regulatory Commission

April 30, 2013

Page 2

xc w/Attachment only:

U.S. Nuclear Regulatory Commission

V.M. McCree, Region II Administrator
U.S. Nuclear Regulatory Commission
Marquis One Tower
245 Peachtree Center Avenue NE, Suite 1200
Atlanta, Georgia 30303-1257

Mr. J. Kim, NRC Project Manager
U.S. Nuclear Regulatory Commission
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Washington, D.C. 20555

Mr. G.A. Hutto, NRC Senior Resident Inspector
U.S. Nuclear Regulatory Commission
Catawba Nuclear Station

Catawba Unit 1 Cycle 21**Core Operating Limits Report
Revision 0****October 2012**

Calculation Number: CNC-1553.05-00-0582

		Date
Prepared By:	<u>Casey Kle</u>	<u>10/22/12</u>
Checked By:	<u>Laurie J. Abbey</u>	<u>10/23/2012</u>
Checked By:	<u>Nathan S. Hoffman</u> (Sections 1.1, 2.1, and 2.9 – 2.18)	<u>10/22/12</u>
Approved By:	<u>RC Harvey</u>	<u>10/23/2012</u>

QA Condition 1

The information presented in this report has been prepared and issued in accordance with Catawba Technical Specification 5.6.5.

Catawba 1 Cycle 21 Core Operating Limits Report**INSPECTION OF ENGINEERING INSTRUCTIONS**

Inspection Waived By:

RC Haney
(Sponsor)

Date:

10/23/2012CATAWBAInspection
Waived

MCE (Mechanical & Civil)

☒

Inspected By/Date: _____

RES (Electrical Only)

☒

Inspected By/Date: _____

RES (Reactor)

☒

Inspected By/Date: _____

MOD

☒

Inspected By/Date: _____

Other (_____)

☐

Inspected By/Date: _____

OCONEEInspection
Waived

MCE (Mechanical & Civil)

☐

Inspected By/Date: _____

RES (Electrical Only)

☐

Inspected By/Date: _____

RES (Reactor)

☐

Inspected By/Date: _____

MOD

☐

Inspected By/Date: _____

Other (_____)

☐

Inspected By/Date: _____

MCGUIREInspection
Waived

MCE (Mechanical & Civil)

☐

Inspected By/Date: _____

RES (Electrical Only)

☐

Inspected By/Date: _____

RES (Reactor)

☐

Inspected By/Date: _____

MOD

☐

Inspected By/Date: _____

Other (_____)

☐

Inspected By/Date: _____

Catawba 1 Cycle 21 Core Operating Limits Report

Implementation Instructions for Revision 0

Revision Description and PIP Tracking

Revision 0 of the Catawba Unit 1 Cycle 21 COLR contains limits specific to the reload core. There is no PIP associated with this revision.

Implementation Schedule

Revision 0 may become effective any time during No MODE between Cycles 20 and 21 but must become effective prior to entering MODE 6 which starts Cycle 21. The Catawba Unit 1 Cycle 21 COLR will cease to be effective during No MODE between Cycles 21 and 22.

Data files to be Implemented

No data files are transmitted as part of this document.

Catawba 1 Cycle 21 Core Operating Limits Report

REVISION LOG

<u>Revision</u>	<u>Effective Date</u>	<u>Pages Affected</u>	<u>COLR</u>
0	October 2012	1-32, Appendix A*	C1C21 COLR, Rev. 0

*Appendix A contains power distribution monitoring factors used in Technical Specification Surveillance. Appendix A is included only in the electronic COLR copy sent to the NRC.

Catawba 1 Cycle 21 Core Operating Limits Report

1.0 Core Operating Limits Report

This Core Operating Limits Report (COLR) has been prepared in accordance with the requirements of Technical Specification 5.6.5. The Technical Specifications that reference this report are listed below:

TS Section	Technical Specifications	COLR Parameter	COLR Section	COLR Page
2.1.1	Reactor Core Safety Limits	RCS Temperature and Pressure Safety Limits	2.1	9
3.1.1	Shutdown Margin	SDM	2.2	9
3.1.3	Moderator Temperature Coefficient	MTC	2.3	11
3.1.4	Rod Group Alignment Limits	SDM	2.2	9
3.1.5	Shutdown Bank Insertion Limit	SDM	2.2	9
		Rod Insertion Limits	2.4	11
3.1.6	Control Bank Insertion Limit	SDM	2.2	9
		Rod Insertion Limits	2.5	15
3.1.8	Physics Tests Exceptions	SDM	2.2	9
3.2.1	Heat Flux Hot Channel Factor	F _Q	2.6	15
		AFD	2.8	21
		OTΔT	2.9	24
		Penalty Factors	2.6	19
3.2.2	Nuclear Enthalpy Rise Hot Channel Factor	FAH	2.7	20
		Penalty Factors	2.6	19
3.2.3	Axial Flux Difference	AFD	2.8	21
3.3.1	Reactor Trip System Instrumentation	OTΔT	2.9	24
		OPΔT	2.9	25
3.3.9	Boron Dilution Mitigation System	Reactor Makeup Water Flow Rate	2.10	26
3.4.1	RCS Pressure, Temperature and Flow limits for DNB	RCS Pressure, Temperature and Flow	2.11	26
3.5.1	Accumulators	Max and Min Boron Conc.	2.12	26
3.5.4	Refueling Water Storage Tank	Max and Min Boron Conc.	2.13	28
3.7.15	Spent Fuel Pool Boron Concentration	Min Boron Concentration	2.14	28
3.9.1	Refueling Operations - Boron Concentration	Min Boron Concentration	2.15	28
5.6.5	Core Operating Limits Report (COLR)	Analytical Methods	1.1	6

The Selected License Commitments that reference this report are listed below:

SLC Section	Selected Licensing Commitment	COLR Parameter	COLR Section	COLR Page
16.7-9	Standby Shutdown System	Standby Makeup Pump Water Supply	2.16	29
16.9-11	Boration Systems – Borated Water Source – Shutdown	Borated Water Volume and Conc. for BAT/RWST	2.17	29
16.9-12	Boration Systems – Borated Water Source – Operating	Borated Water Volume and Conc. for BAT/RWST	2.18	30

Catawba 1 Cycle 21 Core Operating Limits Report

1.1 Analytical Methods

Analytical methods used to determine core operating limits for parameters identified in Technical Specifications and previously reviewed and approved by the NRC, as specified in Technical Specification 5.6.5, are as follows.

1. WCAP-9272-P-A, "WESTINGHOUSE RELOAD SAFETY EVALUATION METHODOLOGY," (W Proprietary).

Revision 0

Report Date: July 1985

Not Used

2. WCAP-10054-P-A, "Westinghouse Small Break ECCS Evaluation Model using the NOTRUMP Code," (W Proprietary).

Revision 0

Report Date: August 1985

3. WCAP-10266-P-A, "THE 1981 VERSION OF WESTINGHOUSE EVALUATION MODEL USING BASH CODE", (W Proprietary).

Revision 2

Report Date: March 1987

Not Used

4. WCAP-12945-P-A, Volume 1 and Volumes 2-5, "Code Qualification Document for Best-Estimate Loss of Coolant Analysis," (W Proprietary).

Revision: Volume 1 (Revision 2) and Volumes 2-5 (Revision 1)

Report Date: March 1998

5. BAW-10168P-A, "B&W Loss-of-Coolant Accident Evaluation Model for Recirculating Steam Generator Plants," (B&W Proprietary).

Revision 1

SER Date: January 22, 1991

Revision 2

SER Dates: August 22, 1996 and November 26, 1996.

Revision 3

SER Date: June 15, 1994.

Not Used

Catawba 1 Cycle 21 Core Operating Limits Report

1.1 Analytical Methods (continued)

6. DPC-NE-3000-PA, "Thermal-Hydraulic Transient Analysis Methodology," (DPC Proprietary).

Revision 5a

Report Date: October 2012

7. DPC-NE-3001-PA, "Multidimensional Reactor Transients and Safety Analysis Physics Parameter Methodology," (DPC Proprietary).

Revision 0a

Report Date: May 2009

8. DPC-NE-3002-A, "UFSAR Chapter 15 System Transient Analysis Methodology".

Revision 4b

Report Date: September 2010

9. DPC-NE-2004P-A, "Duke Power Company McGuire and Catawba Nuclear Stations Core Thermal-Hydraulic Methodology using VIPRE-01," (DPC Proprietary).

Revision 2a

Report Date: December 2008

10. DPC-NE-2005P-A, "Thermal Hydraulic Statistical Core Design Methodology," (DPC Proprietary).

Revision 4a

Report Date: December 2008

11. DPC-NE-2008P-A, "Fuel Mechanical Reload Analysis Methodology Using TACO3," (DPC Proprietary).

Revision 1a

Report Date: December 2008

Not Used

12. DPC-NE-2009-P-A, "Westinghouse Fuel Transition Report," (DPC Proprietary).

Revision 3a

Report Date: September 2011

13. DPC-NE-1004A, "Nuclear Design Methodology Using CASMO-3/SIMULATE-3P."

Revision 1a

Report Date: January 2009

Not Used

Catawba 1 Cycle 21 Core Operating Limits Report

1.1 Analytical Methods (continued)

14. DPC-NF-2010-A, "Duke Power Company McGuire Nuclear Station Catawba Nuclear Station Nuclear Physics Methodology for Reload Design."

Revision 2a

Report Date: December 2009

15. DPC-NE-2011-PA, "Duke Power Company Nuclear Design Methodology for Core Operating Limits of Westinghouse Reactors," (DPC Proprietary).

Revision 1a

Report Date: June 2009

16. DPC-NE-1005-P-A, "Nuclear Design Methodology Using CASMO-4 / SIMULATE-3 MOX", (DPC Proprietary).

Revision 1

Report Date: November 12, 2008

17. BAW-10231P-A, "COPERNIC Fuel Rod Design Computer Code" (Framatome ANP Proprietary)

Revision 1

SER Date: January 14, 2004

Not Used

Catawba 1 Cycle 21 Core Operating Limits Report

2.0 Operating Limits

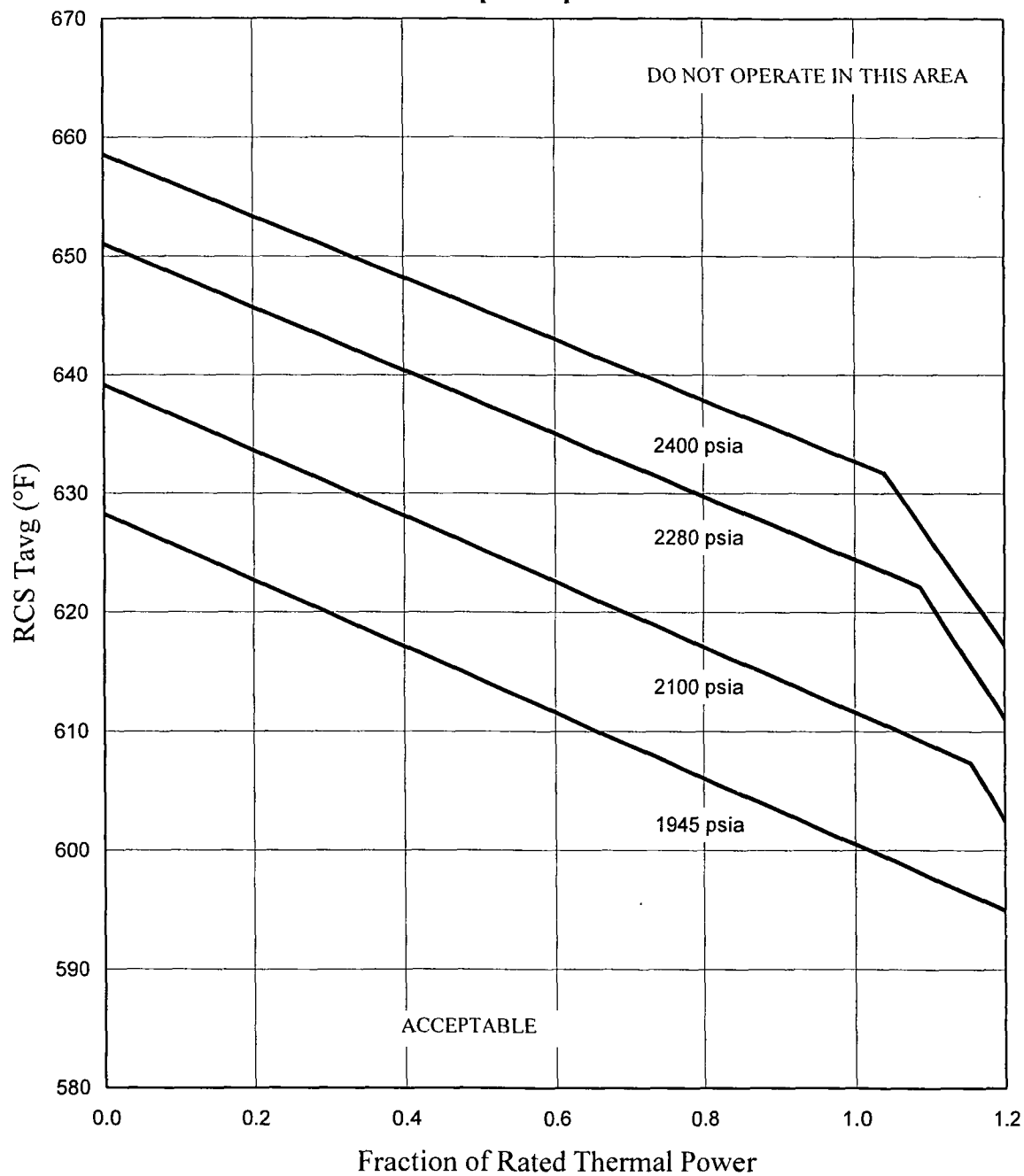
The cycle-specific parameter limits for the specifications listed in Section 1.0 are presented in the following subsections. These limits have been developed using NRC approved methodologies specified in Section 1.1.

2.1 Reactor Core Safety Limits (TS 2.1.1)

The Reactor Core Safety Limits are shown in Figure 1.

2.2 Shutdown Margin - SDM (TS 3.1.1, TS 3.1.4, TS 3.1.5, TS 3.1.6, TS 3.1.8)

- 2.2.1** For TS 3.1.1, SDM shall be greater than or equal to 1.3% $\Delta K/K$ in MODE 2 with $K_{eff} < 1.0$ and in MODES 3 and 4.
- 2.2.2** For TS 3.1.1, SDM shall be greater than or equal to 1.0% $\Delta K/K$ in MODE 5.
- 2.2.3** For TS 3.1.4, SDM shall be greater than or equal to 1.3% $\Delta K/K$ in MODE 1 and MODE 2.
- 2.2.4** For TS 3.1.5, SDM shall be greater than or equal to 1.3% $\Delta K/K$ in MODE 1 and MODE 2 with any control bank not fully inserted.
- 2.2.5** For TS 3.1.6, SDM shall be greater than or equal to 1.3% $\Delta K/K$ in MODE 1 and MODE 2 with $K_{eff} \geq 1.0$.
- 2.2.6** For TS 3.1.8, SDM shall be greater than or equal to 1.3% $\Delta K/K$ in MODE 2 during PHYSICS TESTS.

Catawba 1 Cycle 21 Core Operating Limits Report**Figure 1****Reactor Core Safety Limits
Four Loops in Operation**

Catawba 1 Cycle 21 Core Operating Limits Report

2.3 Moderator Temperature Coefficient - MTC (TS 3.1.3)

2.3.1 The Moderator Temperature Coefficient (MTC) Limits are:

The MTC shall be less positive than the upper limits shown in Figure 2. The BOC, ARO, HZP MTC shall be less positive than $0.7\text{E-}04 \Delta\text{K/K/}^\circ\text{F}$.

The EOC, ARO, RTP MTC shall be less negative than the $-4.3\text{E-}04 \Delta\text{K/K/}^\circ\text{F}$ lower MTC limit.

2.3.2 The 300 ppm MTC Surveillance Limit is:

The measured 300 PPM ARO, equilibrium RTP MTC shall be less negative than or equal to $-3.65\text{E-}04 \Delta\text{K/K/}^\circ\text{F}$.

2.3.3 The 60 PPM MTC Surveillance Limit is:

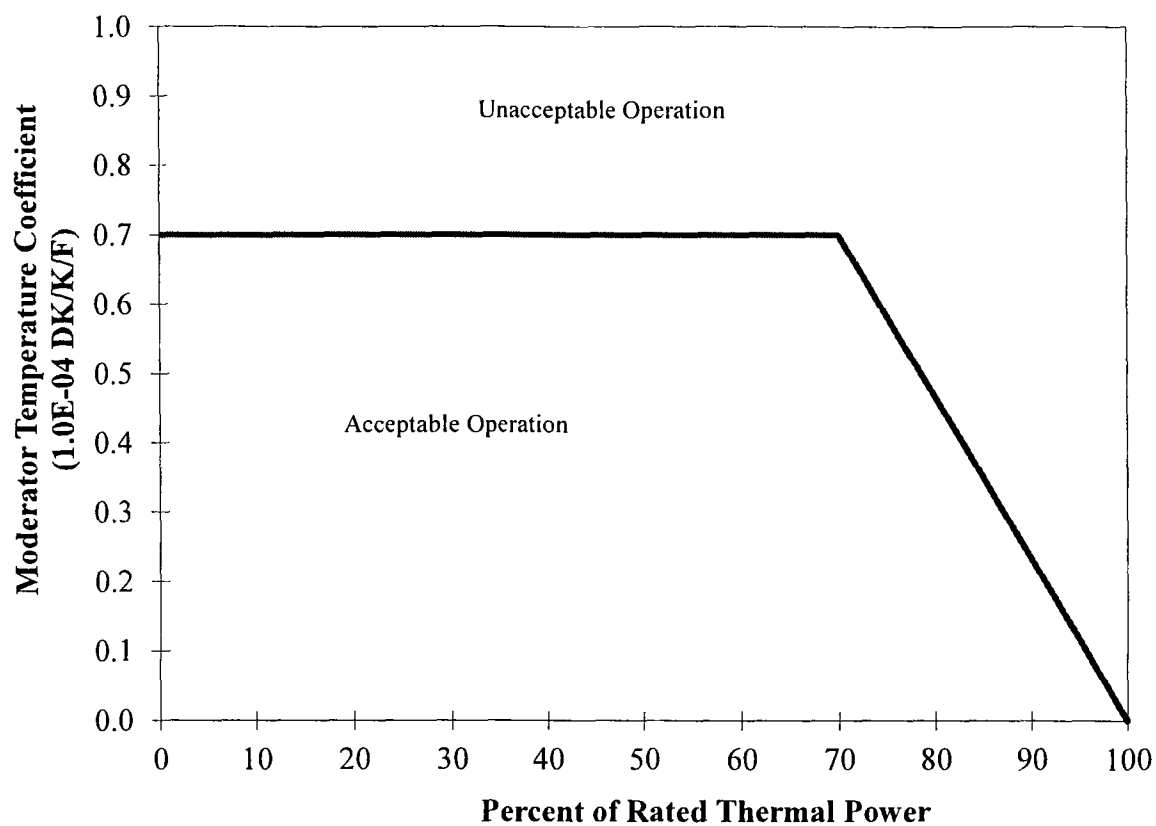
The 60 PPM ARO, equilibrium RTP MTC shall be less negative than or equal to $-4.125\text{E-}04 \Delta\text{K/K/}^\circ\text{F}$.

Where:

- BOC = Beginning of Cycle (burnup corresponding to most positive MTC)
- EOC = End of Cycle
- ARO = All Rods Out
- HZP = Hot Zero Thermal Power
- RTP = Rated Thermal Power
- PPM = Parts per million (Boron)

2.4 Shutdown Bank Insertion Limit (TS 3.1.5)

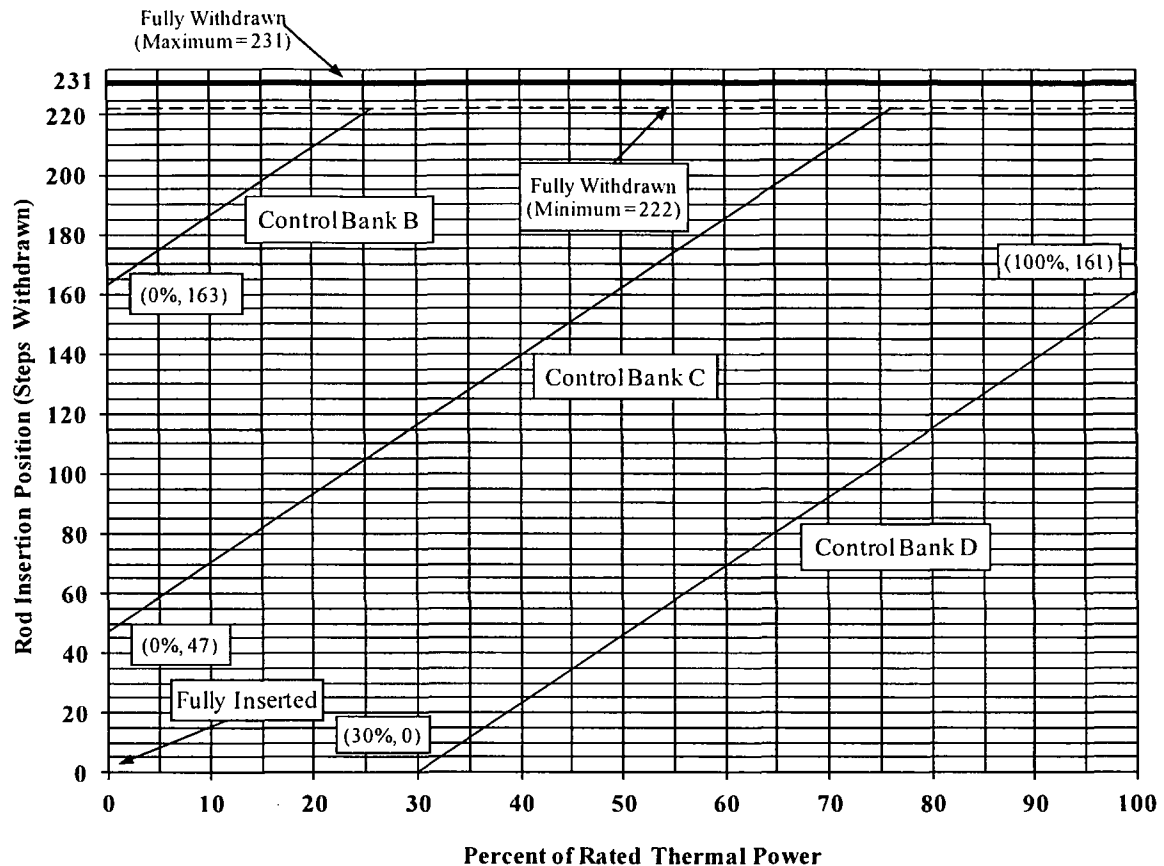
2.4.1 Each shutdown bank shall be withdrawn to at least 222 steps. Shutdown banks are withdrawn in sequence and with no overlap.

Catawba 1 Cycle 21 Core Operating Limits Report**Figure 2****Moderator Temperature Coefficient Upper Limit Versus Power Level**

NOTE: Compliance with Technical Specification 3.1.3 may require rod withdrawal limits. Refer to the Unit 1 ROD manual for details.

Catawba 1 Cycle 21 Core Operating Limits Report

Figure 3
Control Bank Insertion Limits Versus Percent Rated Thermal Power



The Rod Insertion Limits (RIL) for Control Bank D (CD), Control Bank C (CC), and Control Bank B (CB) can be calculated by:

$$\text{Bank CD RIL} = 2.3(P) - 69 \quad \{30 \leq P \leq 100\}$$

$$\text{Bank CC RIL} = 2.3(P) + 47 \quad \{0 \leq P \leq 76.1\} \text{ for CC RIL} = 222 \quad \{76.1 < P \leq 100\}$$

$$\text{Bank CB RIL} = 2.3(P) + 163 \quad \{0 \leq P \leq 25.7\} \text{ for CB RIL} = 222 \quad \{25.7 < P \leq 100\}$$

where $P = \% \text{Rated Thermal Power}$

NOTES: Compliance with Technical Specification 3.1.3 may require rod withdrawal limits. Refer to the Unit 1 ROD manual for details.

Catawba 1 Cycle 21 Core Operating Limits Report

Table 1
Control Bank Withdrawal Steps and Sequence

Fully Withdrawn at 222 Steps				Fully Withdrawn at 223 Steps			
Control Bank A	Control Bank B	Control Bank C	Control Bank D	Control Bank A	Control Bank B	Control Bank C	Control Bank D
0 Start	0	0	0	0 Start	0	0	0
116	0 Start	0	0	116	0 Start	0	0
222 Stop	106	0	0	223 Stop	107	0	0
222	116	0 Start	0	223	116	0 Start	0
222	222 Stop	106	0	223	223 Stop	107	0
222	222	116	0 Start	223	223	116	0 Start
222	222	222 Stop	106	223	223	223 Stop	107

Fully Withdrawn at 224 Steps				Fully Withdrawn at 225 Steps			
Control Bank A	Control Bank B	Control Bank C	Control Bank D	Control Bank A	Control Bank B	Control Bank C	Control Bank D
0 Start	0	0	0	0 Start	0	0	0
116	0 Start	0	0	116	0 Start	0	0
224 Stop	108	0	0	225 Stop	109	0	0
224	116	0 Start	0	225	116	0 Start	0
224	224 Stop	108	0	225	225 Stop	109	0
224	224	116	0 Start	225	225	116	0 Start
224	224	224 Stop	108	225	225	225 Stop	109

Fully Withdrawn at 226 Steps				Fully Withdrawn at 227 Steps			
Control Bank A	Control Bank B	Control Bank C	Control Bank D	Control Bank A	Control Bank B	Control Bank C	Control Bank D
0 Start	0	0	0	0 Start	0	0	0
116	0 Start	0	0	116	0 Start	0	0
226 Stop	110	0	0	227 Stop	111	0	0
226	116	0 Start	0	227	116	0 Start	0
226	226 Stop	110	0	227	227 Stop	111	0
226	226	116	0 Start	227	227	116	0 Start
226	226	226 Stop	110	227	227	227 Stop	111

Fully Withdrawn at 228 Steps				Fully Withdrawn at 229 Steps			
Control Bank A	Control Bank B	Control Bank C	Control Bank D	Control Bank A	Control Bank B	Control Bank C	Control Bank D
0 Start	0	0	0	0 Start	0	0	0
116	0 Start	0	0	116	0 Start	0	0
228 Stop	112	0	0	229 Stop	113	0	0
228	116	0 Start	0	229	116	0 Start	0
228	228 Stop	112	0	229	229 Stop	113	0
228	228	116	0 Start	229	229	116	0 Start
228	228	228 Stop	112	229	229	229 Stop	113

Fully Withdrawn at 230 Steps				Fully Withdrawn at 231 Steps			
Control Bank A	Control Bank B	Control Bank C	Control Bank D	Control Bank A	Control Bank B	Control Bank C	Control Bank D
0 Start	0	0	0	0 Start	0	0	0
116	0 Start	0	0	116	0 Start	0	0
230 Stop	114	0	0	231 Stop	115	0	0
230	116	0 Start	0	231	116	0 Start	0
230	230 Stop	114	0	231	231 Stop	115	0
230	230	116	0 Start	231	231	116	0 Start
230	230	230 Stop	114	231	231	231 Stop	115

Catawba 1 Cycle 21 Core Operating Limits Report

2.5 Control Bank Insertion Limits (TS 3.1.6)

2.5.1 Control banks shall be within the insertion, sequence, and overlap limits shown in Figure 3. Specific control bank withdrawal and overlap limits as a function of the fully withdrawn position are shown in Table 1.

2.6 Heat Flux Hot Channel Factor - $F_Q(X,Y,Z)$ (TS 3.2.1)

2.6.1 $F_Q(X,Y,Z)$ steady-state limits are defined by the following relationships:

$$\begin{aligned} F_Q^{RTP} * K(Z) / P & \quad \text{for } P > 0.5 \\ F_Q^{RTP} * K(Z) / 0.5 & \quad \text{for } P \leq 0.5 \end{aligned}$$

where,

$$P = (\text{Thermal Power}) / (\text{Rated Power})$$

Note: The measured $F_Q(X,Y,Z)$ shall be increased by 3% to account for manufacturing tolerances and 5% to account for measurement uncertainty when comparing against the LCO limit. The manufacturing tolerance and measurement uncertainty are implicitly included in the F_Q surveillance limits as defined for COLR Sections 2.6.5 and 2.6.6.

2.6.2 $F_Q^{RTP} = 2.70 \times K(BU)$

2.6.3 $K(Z)$ is the normalized $F_Q(X,Y,Z)$ as a function of core height. $K(Z)$ for Westinghouse RFA fuel is provided in Figure 4.

2.6.4 $K(BU)$ is the normalized $F_Q(X,Y,Z)$ as a function of burnup. F_Q^{RTP} with the $K(BU)$ penalty for Westinghouse RFA fuel is set to 1.0 at all burnups.

The following parameters are required for core monitoring per the Surveillance Requirements of Technical Specification 3.2.1:

2.6.5 $[F_Q^L(X,Y,Z)]^{OP} = \frac{F_Q^D(X,Y,Z) * M_Q(X,Y,Z)}{UMT * MT * TILT}$

where:

$[F_Q^L(X,Y,Z)]^{OP}$ = Cycle dependent maximum allowable design peaking factor that ensures $F_Q(X,Y,Z)$ LOCA limit is not exceeded for operation within the AFD, RIL, and QPTR limits.
 $F_Q^L(X,Y,Z)^{OP}$ includes allowances for calculational and measurement uncertainties.

Catawba 1 Cycle 21 Core Operating Limits Report

$F_Q^D(X,Y,Z)$ = Design power distribution for F_Q . $F_Q^D(X,Y,Z)$ is provided in Appendix Table A-1 for normal operating conditions and in Appendix Table A-4 for power escalation testing during initial startup operation.

$M_Q(X,Y,Z)$ = Margin remaining in core location X,Y,Z to the LOCA limit in the transient power distribution. $M_Q(X,Y,Z)$ is provided in Appendix Table A-1 for normal operating conditions and in Appendix Table A-4 for power escalation testing during initial startup operation.

UMT = Total Peak Measurement Uncertainty. (UMT = 1.05)

MT = Engineering Hot Channel Factor. (MT = 1.03).

TILT = Peaking penalty that accounts for allowable quadrant power tilt ratio of 1.02. (TILT = 1.035)

$$2.6.6 \quad [F_Q^L(X,Y,Z)]^{RPS} = \frac{F_Q^D(X,Y,Z) * M_C(X,Y,Z)}{UMT * MT * TILT}$$

where:

$[F_Q^L(X,Y,Z)]^{RPS}$ = Cycle dependent maximum allowable design peaking factor that ensures $F_Q(X,Y,Z)$ Centerline Fuel Melt (CFM) limit is not exceeded for operation within the AFD, RIL, and QPTR limits. $[F_Q^L(X,Y,Z)]^{RPS}$ includes allowances for calculational and measurement uncertainties.

$F_Q^D(X,Y,Z)$ = Design power distributions for F_Q . $F_Q^D(X,Y,Z)$ is provided in Appendix Table A-1 for normal operating conditions and in Appendix Table A-4 for power escalation testing during initial startup operations.

$M_C(X,Y,Z)$ = Margin remaining to the CFM limit in core location X,Y,Z from the transient power distribution. $M_C(X,Y,Z)$ is provided in Appendix Table A-2 for normal operating conditions and in Appendix Table A-5 for power escalation testing during initial startup operations.

Catawba 1 Cycle 21 Core Operating Limits Report

UMT = Total Peak Measurement Uncertainty. (UMT = 1.05)

MT = Engineering Hot Channel Factor. (MT = 1.03).

TILT = Peaking penalty that accounts for allowable quadrant power tilt ratio of 1.02. (TILT = 1.035)

2.6.7 KSLOPE = 0.0725

where:

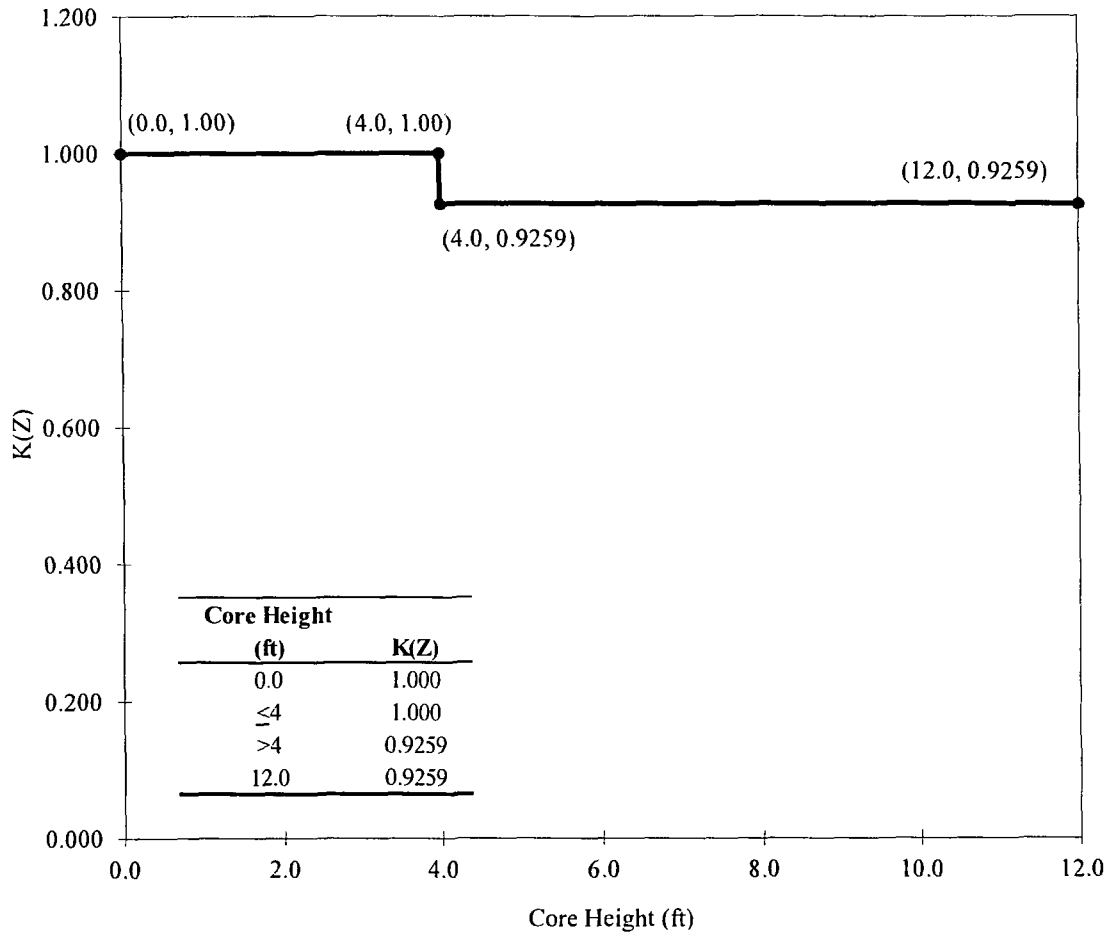
KSLOPE = Adjustment to K_1 value from OTΔT trip setpoint required to compensate for each 1% $F_Q^M(X,Y,Z)$ exceeds $F_Q^L(X,Y,Z)^{RPS}$.

2.6.8 $F_Q(X,Y,Z)$ Penalty Factors for Technical Specification Surveillances 3.2.1.2 and 3.2.1.3 are provided in Table 2.

Catawba 1 Cycle 21 Core Operating Limits Report

Figure 4

**$K(Z)$, Normalized $F_Q(X,Y,Z)$ as a Function of Core Height
for Westinghouse RFA Fuel**



Catawba 1 Cycle 21 Core Operating Limits Report

Table 2

$F_Q(X,Y,Z)$ and $F_{\Delta H}(X,Y)$ Penalty Factors
For Tech Spec Surveillances 3.2.1.2, 3.2.1.3 and 3.2.2.2

Burnup (EFPD)	$F_Q(X,Y,Z)$ Penalty Factor (%)	$F_{\Delta H}(X,Y)$ Penalty Factor (%)
4	2.00	2.00
12	2.00	2.00
25	2.00	2.00
50	2.00	2.00
75	2.00	2.00
100	2.00	2.00
125	2.00	2.00
150	2.00	2.00
175	2.00	2.00
200	2.00	2.00
225	2.00	2.00
250	2.00	2.00
275	2.00	2.00
300	2.00	2.00
325	2.00	2.00
350	2.00	2.00
375	2.00	2.00
400	2.00	2.00
425	2.00	2.00
450	2.00	2.00
460	2.00	2.00
475	2.00	2.00
485	2.00	2.00
490	2.00	2.00
500	2.00	2.00
510	2.00	2.00

Note: Linear interpolation is adequate for intermediate cycle burnups.
All cycle burnups outside the range of the table shall use a 2% penalty factor for both $F_Q(X,Y,Z)$ and $F_{\Delta H}(X,Y)$ for compliance with the Tech Spec Surveillances 3.2.1.2, 3.2.1.3 and 3.2.2.2.

Catawba 1 Cycle 21 Core Operating Limits Report

2.7 Nuclear Enthalpy Rise Hot Channel Factor - $F_{\Delta H}(X,Y)$ (TS 3.2.2)

$F_{\Delta H}$ steady-state limits referred to in Technical Specification 3.2.2 are defined by the following relationship.

$$2.7.1 \quad [F_{\Delta H}^L(X,Y)]^{LCO} = \text{MARP}(X,Y) * \left[1.0 + \frac{1}{\text{RRH}} * (1.0 - P) \right]$$

where:

$[F_{\Delta H}^L(X,Y)]^{LCO}$ is the steady-state, maximum allowed radial peak and includes allowances for calculation/measurement uncertainty.

$\text{MARP}(X,Y) =$ Cycle-specific operating limit Maximum Allowable Radial Peaks. $\text{MARP}(X,Y)$ radial peaking limits are provided in Table 3.

$$P = \frac{\text{Thermal Power}}{\text{Rated Thermal Power}}$$

$\text{RRH} =$ Thermal Power reduction required to compensate for each 1% measured radial peak, $F_{\Delta H}^M(X,Y)$, exceeds the limit.
($\text{RRH} = 3.34, 0.0 < P \leq 1.0$)

The following parameters are required for core monitoring per the surveillance requirements of Technical Specification 3.2.2.

$$2.7.2 \quad [F_{\Delta H}^L(X,Y)]^{SURV} = \frac{F_{\Delta H}^D(X,Y) * M_{\Delta H}(X,Y)}{\text{UMR} * \text{TILT}}$$

where:

$[F_{\Delta H}^L(X,Y)]^{SURV} =$ Cycle dependent maximum allowable design peaking factor that ensures $F_{\Delta H}(X,Y)$ limit is not exceeded for operation within the AFD, RIL, and QPTR limits. $F_{\Delta H}^L(X,Y)^{SURV}$ includes allowances for calculational and measurement uncertainty.

$F_{\Delta H}^D(X,Y) =$ Design radial power distribution for $F_{\Delta H}$. $F_{\Delta H}^D(X,Y)$ is provided in Appendix Table A-3 for normal operation and in Appendix Table A-6 for power escalation testing during initial startup operation.

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$M_{\Delta H}(X,Y)$ = Margin remaining in core location X,Y relative to Operational DNB limits in the transient power distribution. $M_{\Delta H}(X,Y)$ is provided in Appendix Table A-3 for normal operation and in Appendix Table A-6 for power escalation testing during initial startup operation.

UMR = Uncertainty value for measured radial peaks (UMR = 1.0). UMR is set to 1.0 since a factor of 1.04 is implicitly included in the variable $M_{\Delta H}(X,Y)$.

TILT = Peaking penalty that accounts for allowable quadrant power tilt ratio of 1.02. (TILT = 1.035)

2.7.3 $RRH = 3.34$

where:

RRH = Thermal Power reduction required to compensate for each 1% measured radial peak, $F_{\Delta H}^M(X,Y)$ exceeds its limit. ($0 < P \leq 1.0$)

2.7.4 $TRH = 0.04$

where:

TRH = Reduction in $OT\Delta T K_1$ setpoint required to compensate for each 1% measured radial peak, $F_{\Delta H}^M(X,Y)$ exceeds its limit.

2.7.5 $F_{\Delta H}(X,Y)$ Penalty Factors for Technical Specification Surveillance 3.2.2.2 are provided in Table 2.

2.8 Axial Flux Difference – AFD (TS 3.2.3)

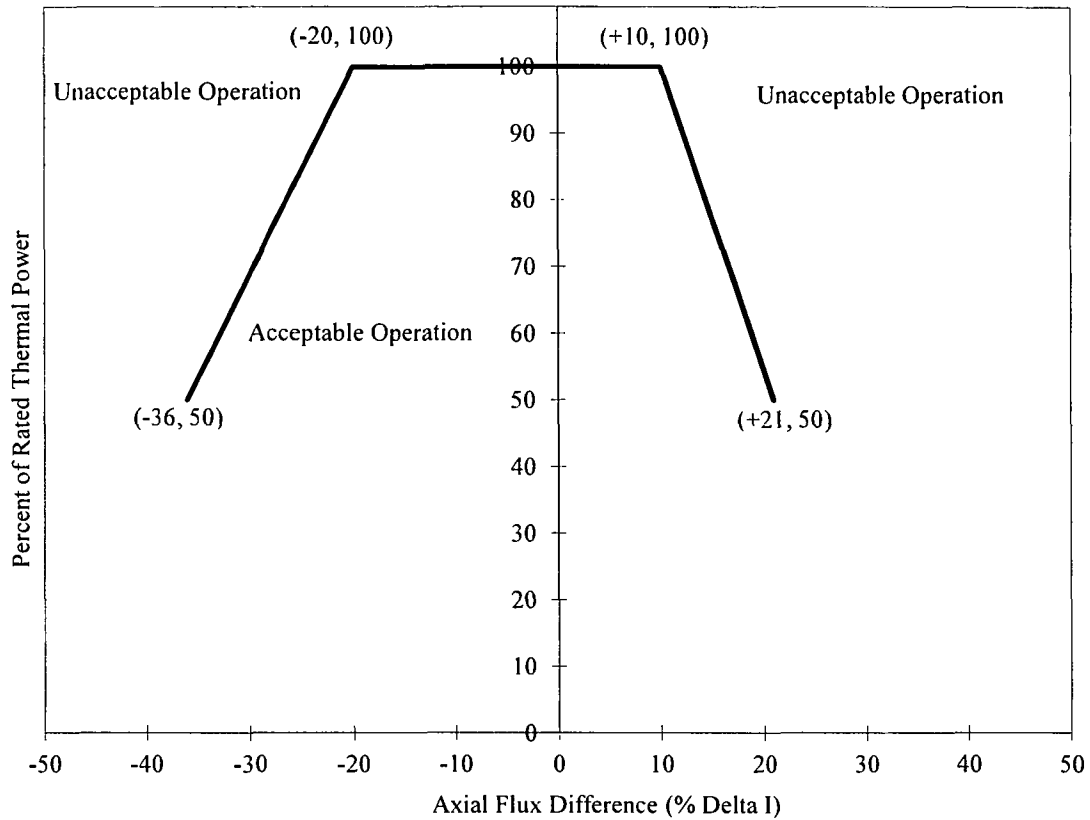
2.8.1 Axial Flux Difference (AFD) Limits are provided in Figure 5.

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Table 3
Maximum Allowable Radial Peaks (MARPS)

RFA Fuel MARPs
 100% Full Power

Core Height (ft)	Axial Peak												
	1.05	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.1	3.0	3.25
0.12	1.8092	1.8553	1.9489	1.9953	1.9741	2.1073	2.0498	2.0090	1.9333	1.8625	1.7780	1.3151	1.2461
1.20	1.8102	1.8540	1.9401	1.9953	1.9741	2.1073	2.0191	1.9775	1.9009	1.8306	1.7852	1.3007	1.2235
2.40	1.8093	1.8525	1.9312	1.9779	1.9741	2.0735	1.9953	1.9519	1.8760	1.8054	1.7320	1.4633	1.4616
3.60	1.8098	1.8514	1.9204	1.9641	1.9741	2.0495	1.9656	1.9258	1.8524	1.7855	1.6996	1.4675	1.3874
4.80	1.8097	1.8514	1.9058	1.9449	1.9741	2.0059	1.9441	1.9233	1.8538	1.7836	1.6714	1.2987	1.2579
6.00	1.8097	1.8514	1.8921	1.9212	1.9455	1.9336	1.8798	1.8625	1.8024	1.7472	1.6705	1.3293	1.2602
7.20	1.8070	1.8438	1.8716	1.8930	1.8872	1.8723	1.8094	1.7866	1.7332	1.6812	1.5982	1.2871	1.2195
8.40	1.8073	1.8319	1.8452	1.8571	1.8156	1.7950	1.7359	1.7089	1.6544	1.6010	1.5127	1.2182	1.1578
9.60	1.8072	1.8102	1.8093	1.7913	1.7375	1.7182	1.6572	1.6347	1.5808	1.5301	1.4444	1.1431	1.0914
10.80	1.7980	1.7868	1.7611	1.7163	1.6538	1.6315	1.5743	1.5573	1.5088	1.4624	1.3832	1.1009	1.0470
11.40	1.7892	1.7652	1.7250	1.6645	1.6057	1.5826	1.5289	1.5098	1.4637	1.4218	1.3458	1.0670	1.0142

Catawba 1 Cycle 21 Core Operating Limits Report**Figure 5****Percent of Rated Thermal Power Versus Percent Axial Flux Difference Limits**

NOTE: Compliance with Technical Specification 3.2.1 may require more restrictive AFD limits. Refer to the Unit 1 ROD manual for operational AFD limits.

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2.9 Reactor Trip System Instrumentation Setpoints (TS 3.3.1) Table 3.3.1-1

2.9.1 Overtemperature ΔT Setpoint Parameter Values

<u>Parameter</u>	<u>Nominal Value</u>
Nominal T_{avg} at RTP	$T' \leq 585.1 \text{ }^{\circ}\text{F}$
Nominal RCS Operating Pressure	$P' = 2235 \text{ psig}$
Overtemperature ΔT reactor trip setpoint	$K_1 = 1.1978$
Overtemperature ΔT reactor trip heatup setpoint penalty coefficient	$K_2 = 0.03340/^{\circ}\text{F}$
Overtemperature ΔT reactor trip depressurization setpoint penalty coefficient	$K_3 = 0.001601/\text{psi}$
Time constants utilized in the lead-lag compensator for ΔT	$\tau_1 = 8 \text{ sec.}$ $\tau_2 = 3 \text{ sec.}$
Time constant utilized in the lag compensator for ΔT	$\tau_3 = 0 \text{ sec.}$
Time constants utilized in the lead-lag compensator for T_{avg}	$\tau_4 = 22 \text{ sec.}$ $\tau_5 = 4 \text{ sec.}$
Time constant utilized in the measured T_{avg} lag compensator	$\tau_6 = 0 \text{ sec.}$
$f_1(\Delta I)$ "positive" breakpoint	$= 19.0 \text{ } \%\Delta I$
$f_1(\Delta I)$ "negative" breakpoint	$= \text{N/A}^*$
$f_1(\Delta I)$ "positive" slope	$= 1.769 \text{ } \%\Delta T_0 / \%\Delta I$
$f_1(\Delta I)$ "negative" slope	$= \text{N/A}^*$

- * The $f_1(\Delta I)$ negative breakpoints and slopes for OT ΔT are less restrictive than the OP ΔT $f_2(\Delta I)$ negative breakpoint and slope. Therefore, during a transient which challenges the negative imbalance limits the OP ΔT $f_2(\Delta I)$ limits will result in a reactor trip before the OT ΔT $f_1(\Delta I)$ limits are reached. This makes implementation of an OT ΔT $f_1(\Delta I)$ negative breakpoint and slope unnecessary.

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2.9.2 Overpower ΔT Setpoint Parameter Values

<u>Parameter</u>	<u>Nominal Value</u>
Nominal T_{avg} at RTP	$T'' \leq 585.1 \text{ }^{\circ}\text{F}$
Overpower ΔT reactor trip setpoint	$K_4 = 1.0864$
Overpower ΔT reactor trip penalty	$K_5 = 0.02 \text{ }^{\circ}\text{F}$ for increasing T_{avg} $K_5 = 0.00 \text{ }^{\circ}\text{F}$ for decreasing T_{avg}
Overpower ΔT reactor trip heatup setpoint penalty coefficient (for $T > T''$)	$K_6 = 0.001179/^{\circ}\text{F}$ for $T > T''$ $K_6 = 0.0 \text{ }^{\circ}\text{F}$ for $T \leq T''$
Time constants utilized in the lead-lag compensator for ΔT	$\tau_1 = 8 \text{ sec.}$ $\tau_2 = 3 \text{ sec.}$
Time constant utilized in the lag compensator for ΔT	$\tau_3 = 0 \text{ sec.}$
Time constant utilized in the measured T_{avg} lag compensator	$\tau_6 = 0 \text{ sec.}$
Time constant utilized in the rate-lag controller for T_{avg}	$\tau_7 = 10 \text{ sec.}$
$f_2(\Delta I)$ "positive" breakpoint	$= 35.0 \text{ } \%\Delta I$
$f_2(\Delta I)$ "negative" breakpoint	$= -35.0 \text{ } \%\Delta I$
$f_2(\Delta I)$ "positive" slope	$= 7.0 \text{ } \%\Delta T_0 / \%\Delta I$
$f_2(\Delta I)$ "negative" slope	$= 7.0 \text{ } \%\Delta T_0 / \%\Delta I$

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2.10 Boron Dilution Mitigation System – BDMS (TS 3.3.9)

2.10.1 Reactor Makeup Water Pump combined flow rate limits:

<u>Applicable MODE</u>	<u>Limit</u>
MODE 3	≤ 110 gpm
MODE 4 or 5	≤ 70 gpm

2.11 RCS Pressure, Temperature and Flow DNB Limits (TS 3.4.1)

The RCS pressure, temperature and flow limits for DNB are shown in Table 4.

2.12 Accumulators (TS 3.5.1)

2.12.1 Boron concentration limits during MODES 1 and 2, and MODE 3 with RCS pressure >1000 psi:

<u>Parameter</u>	<u>Applicable Burnup</u>	<u>Limit</u>
Accumulator minimum boron concentration.	0 - 200 EFPD	2,500 ppm
Accumulator minimum boron concentration.	200.1 - 250 EFPD	2,400 ppm
Accumulator minimum boron concentration.	250.1 - 300 EFPD	2,341 ppm
Accumulator minimum boron concentration.	300.1 - 350 EFPD	2,273 ppm
Accumulator minimum boron concentration.	350.1 - 400 EFPD	2,206 ppm
Accumulator minimum boron concentration.	400.1 - 450 EFPD	2,139 ppm
Accumulator minimum boron concentration.	450.1 - 500 EFPD	2,073 ppm
Accumulator minimum boron concentration.	500.1 - 510 EFPD	2,007 ppm
Accumulator maximum boron concentration.	0 - 510 EFPD	3,075 ppm

Catawba 1 Cycle 21 Core Operating Limits Report**Table 4**

Reactor Coolant System DNB Parameters

PARAMETER	INDICATION	No. Operable CHANNELS	LIMITS
1. Indicated RCS Average Temperature	meter	4	≤ 587.2 °F
	meter	3	≤ 586.9 °F
	computer	4	≤ 587.7 °F
	computer	3	≤ 587.5 °F
2. Indicated Pressurizer Pressure	meter	4	≥ 2219.8 psig
	meter	3	≥ 2222.1 psig
	computer	4	≥ 2215.8 psig
	computer	3	≥ 2217.5 psig
3. RCS Total Flow Rate			$\geq 388,000$ gpm

Catawba 1 Cycle 21 Core Operating Limits Report**2.13 Refueling Water Storage Tank - RWST (TS 3.5.4)****2.13.1 Boron concentration limits during MODES 1, 2, 3, and 4:**

<u>Parameter</u>	<u>Limit</u>
RWST minimum boron concentration.	2,700 ppm
RWST maximum boron concentration.	3,075 ppm

2.14 Spent Fuel Pool Boron Concentration (TS 3.7.15)**2.14.1** Minimum boron concentration limit for the spent fuel pool. Applicable when fuel assemblies are stored in the spent fuel pool.

<u>Parameter</u>	<u>Limit</u>
Spent fuel pool minimum boron concentration.	2,700 ppm

2.15 Refueling Operations - Boron Concentration (TS 3.9.1)**2.15.1** Minimum boron concentration limit for filled portions of the Reactor Coolant System, refueling canal, and refueling cavity for MODE 6 conditions. The minimum boron concentration limit and plant refueling procedures ensure that core K_{eff} remains within the MODE 6 reactivity requirement of $K_{eff} \leq 0.95$.

<u>Parameter</u>	<u>Limit</u>
Minimum Boron concentration of the Reactor Coolant System, the refueling canal, and the refueling cavity.	2,700 ppm

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2.16 Standby Shutdown System - (SLC-16.7-9)

2.16.1 Minimum boron concentration limit for the spent fuel pool required for Standby Makeup Pump Water Supply. Applicable for MODES 1, 2, and 3.

<u>Parameter</u>	<u>Limit</u>
Spent fuel pool minimum boron concentration for TR 16.7-9.3.	2,700 ppm

2.17 Boration Systems Borated Water Source – Shutdown (SLC 16.9-11)

2.17.1 Volume and boron concentrations for the Boric Acid Tank (BAT) and the Refueling Water Storage Tank (RWST) during MODE 4 with any RCS cold leg temperature $\leq 210^{\circ}\text{F}$, and MODES 5 and 6.

<u>Parameter</u>	<u>Limit</u>
BAT minimum boron concentration	7,000 ppm
Volume of 7,000 ppm boric acid solution required to maintain SDM at 68°F	2,000 gallons
BAT Minimum Shutdown Volume (Includes the additional volumes listed in SLC 16.9-11)	13,086 gallons (14.9%)

NOTE: When cycle burnup is ≥ 471 EFPD, Figure 6 may be used to determine the required BAT Minimum Level.

RWST minimum boron concentration	2,700 ppm
Volume of 2,700 ppm boric acid solution required to maintain SDM at 68°F	7,000 gallons
RWST Minimum Shutdown Volume (Includes the additional volumes listed in SLC 16.9-11)	48,500 gallons (8.7%)

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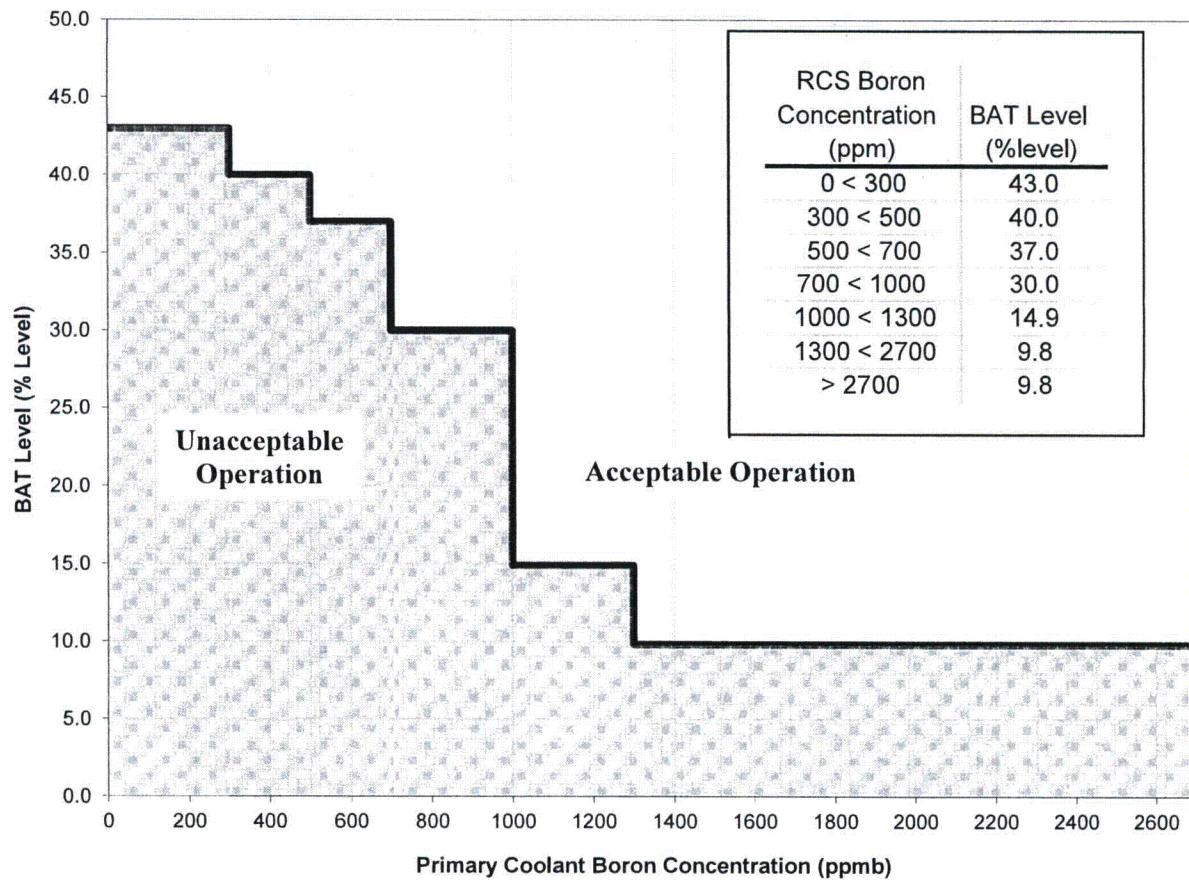
2.18 Boration Systems Borated Water Source - Operating (SLC 16.9-12)

2.18.1 Volume and boron concentrations for the Boric Acid Tank (BAT) and the Refueling Water Storage Tank (RWST) during MODES 1, 2, and 3 and MODE 4 with all RCS cold leg temperatures > 210°F.

<u>Parameter</u>	<u>Limit</u>
BAT minimum boron concentration	7,000 ppm
Volume of 7,000 ppm boric acid solution required to maintain SDM at 210°F	13,500 gallons
BAT Minimum Shutdown Volume (Includes the additional volumes listed in SLC 16.9-12)	25,200 gallons (45.8%)

NOTE: When cycle burnup is ≥ 471 EFPD, Figure 6 may be used to determine the required BAT Minimum Level.

RWST minimum boron concentration	2,700 ppm
Volume of 2,700 ppm boric acid solution required to maintain SDM at 210 °F	57,107 gallons
RWST Minimum Shutdown Volume (Includes the additional volumes listed in SLC 16.9-12)	98,607 gallons (22.0%)

Catawba 1 Cycle 21 Core Operating Limits Report**Figure 6****Boric Acid Storage Tank Indicated Level Versus
Primary Coolant Boron Concentration****(Valid When Cycle Burnup is ≥ 471 EFPD)****This figure includes additional volumes listed in SLC 16.9-11 and 16.9-12**

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Appendix A

Power Distribution Monitoring Factors

Appendix A contains power distribution monitoring factors used in Technical Specification Surveillance. This data was generated in the Catawba 1 Cycle 21 Maneuvering Analysis calculation file, CNC-1553.05-00-0579. Due to the size of the monitoring factor data, Appendix A is controlled electronically within Duke and is not included in the Duke internal copies of the COLR. The Catawba Reactor and Electrical Systems Engineering Section controls this information via computer files and should be contacted if there is a need to access this information.

Appendix A is included in the COLR copy transmitted to the NRC.