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April 13, 2010

U. S. Nuclear Regulatory Commission
Attention: Document Control Desk
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VIRGINIA ELECTRIC AND POWER COMPANY
NORTH ANNA POWER STATION UNIT 2
CYCLE 21 CORE OPERATING LIMITS REPORT

Pursuant to North Anna Technical Specification 5.6.5.d, attached is a copy of the Virginia Electric and Power Company Core Operating Limits Report for North Anna Unit 2 Cycle 21 Pattern FRY.

If you have any questions regarding this submittal, please contact Mr. Thomas Shaub at (804) 273-2763.

Sincerely,

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for
C. L. Funderburk
Director - Nuclear Licensing and Operations Support
Dominion Resources Services, Inc.
for Virginia Electric and Power Company

Attachment: CORE OPERATING LIMITS REPORT, North Anna 2 Cycle 21 Pattern FRY

Commitments made in this letter: None

A001
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ATTACHMENT

CORE OPERATING LIMITS REPORT FOR NORTH ANNA UNIT 2
CYCLE 21 PATTERN FRY

NORTH ANNA POWER STATION UNIT 2
VIRGINIA ELECTRIC AND POWER COMPANY (DOMINION)

INTRODUCTION

The Core Operating Limits Report (COLR) for North Anna Unit 2 Cycle 21 has been prepared in accordance with North Anna Technical Specification 5.6.5. The technical specifications affected by this report are listed below:

TS 2.1.1	Reactor Core Safety Limits
TS 3.1.1	Shutdown Margin (SDM)
TS 3.1.3	Moderator Temperature Coefficient (MTC)
TS 3.1.4	Rod Group Alignment Limits
TS 3.1.5	Shutdown Bank Insertion Limit
TS 3.1.6	Control Bank Insertion Limits
TS 3.1.9	Physics Test Exceptions-Mode 2
TS 3.2.1	Heat Flux Hot Channel Factor
TS 3.2.2	Nuclear Enthalpy Rise Hot Channel Factor ($F^N_{\Delta H}$)
TS 3.2.3	Axial Flux Difference (AFD)
TS 3.3.1	Reactor Trip System (RTS) Instrumentation
TS 3.4.1	RCS Pressure, Temperature, and Flow DNB Limits
TS 3.5.6	Boron Injection Tank (BIT)
TS 3.9.1	Boron Concentration

In addition, a technical requirement (TR) in the NAPS Technical Requirements Manual (TRM) refers to the COLR:

TR 3.1.1 Boration Flow Paths – Operating

The analytical methods used to determine the core operating limits are those previously approved by the NRC and discussed in the documents listed in the References Section.

Cycle-specific values are presented **in bold.** Text in *italics* is provided for information only.

REFERENCES

1. VEP-FRD-42 Rev 2.1-A, Reload Nuclear Design Methodology, August 2003.

   (Methodology for TS 3.1.1 – Shutdown Margin, TS 3.1.3 – Moderator Temperature Coefficient, TS 3.1.5 – Shutdown Bank Insertion Limit, TS 3.1.4 – Rod Group Alignment Limits, TS 3.1.6 - Control Bank Insertion Limits, TS 3.1.9 – Physics Test Exceptions-Mode 2, TS 3.2.1 - Heat Flux Hot Channel Factor, TS 3.2.2 – Nuclear Enthalpy Rise Hot Channel Factor, TS 3.5.6 – Boron Injection Tank (BIT) and TS 3.9.1- Boron Concentration)

2. VEP-NE-2-A, Rev. 0, Statistical DNBR Evaluation Methodology, June 1987.

   (Methodology for TS 3.2.2 – Nuclear Enthalpy Rise Hot Channel Factor and TS 3.4.1 – RCS Pressure, Temperature and Flow DNB Limits)

3. VEP-NE-1- Rev. 0.1-A, Relaxed Power Distribution Control Methodology and Associated FQ Surveillance Technical Specifications, August 2003.

   (Methodology for TS 3.2.1 – Heat Flux Hot Channel Factor and TS 3.2.3 – Axial Flux Difference)

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

   (Methodology for TS 2.1.1 – Reactor Core Safety Limits and TS 3.3.1 – Reactor Trip System Instrumentation)

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

   (Methodology for TS 2.1.1 – Reactor Core Safety Limits, TS 3.1.1 – Shutdown Margin, TS 3.1.4 – Rod Group Alignment Limits, TS 3.1.9 – Physics Test Exceptions-Mode 2, TS 3.3.1 – Reactor Trip System Instrumentation, TS 3.4.1 – RCS Pressure, Temperature, and Flow DNB Limits, TS 3.5.6 – Boron Injection Tank (BIT) and TS 3.9.1 – Boron Concentration)

6. BAW-10227P-A, Rev. 0, "Evaluation of Advanced Cladding and Structural Material (M5) in PWR Reactor Fuel."

   (Methodology for TS 2.1.1 – Reactor Core Safety Limits, TS 3.2.1 - Heat Flux Hot Channel Factor)

7. EMF-2103 (P) (A), Rev. 0, "Realistic Large Break LOCA Methodology for Pressurized Water Reactors," April 2003.

   (Methodology for TS 3.2.1 - Heat Flux Hot Channel Factor)

8. EMF-96-029 (P) (A), Rev. 0 "Reactor Analysis System for PWRs," January 1997.

   (Methodology for TS 3.2.1 - Heat Flux Hot Channel Factor)

9. BAW-10168P-A, Rev. 3, "RSG LOCA - BWNT Loss-of-Coolant Accident Evaluation Model for Recirculating Steam Generator Plants," December 1996. Volume II only (SBLOCA models).

   (Methodology for TS 3.2.1 - Heat Flux Hot Channel Factor)

10. DOM-NAF-2, Rev. 0.1-A, "Reactor Core Thermal-Hydraulics Using the VIPRE-D Computer Code," including Appendix A, "Qualification of the F-ANP BWU CHF Correlations in the VIPRE-D Computer Code," July 2009.

    (Methodology for TS 3.2.2 – Nuclear Enthalpy Rise Hot Channel Factor and TS 3.4.1 – RCS Pressure, Temperature and Flow DNB Limits)

2.0 SAFETY LIMITS (SLs)

2.1 SLs

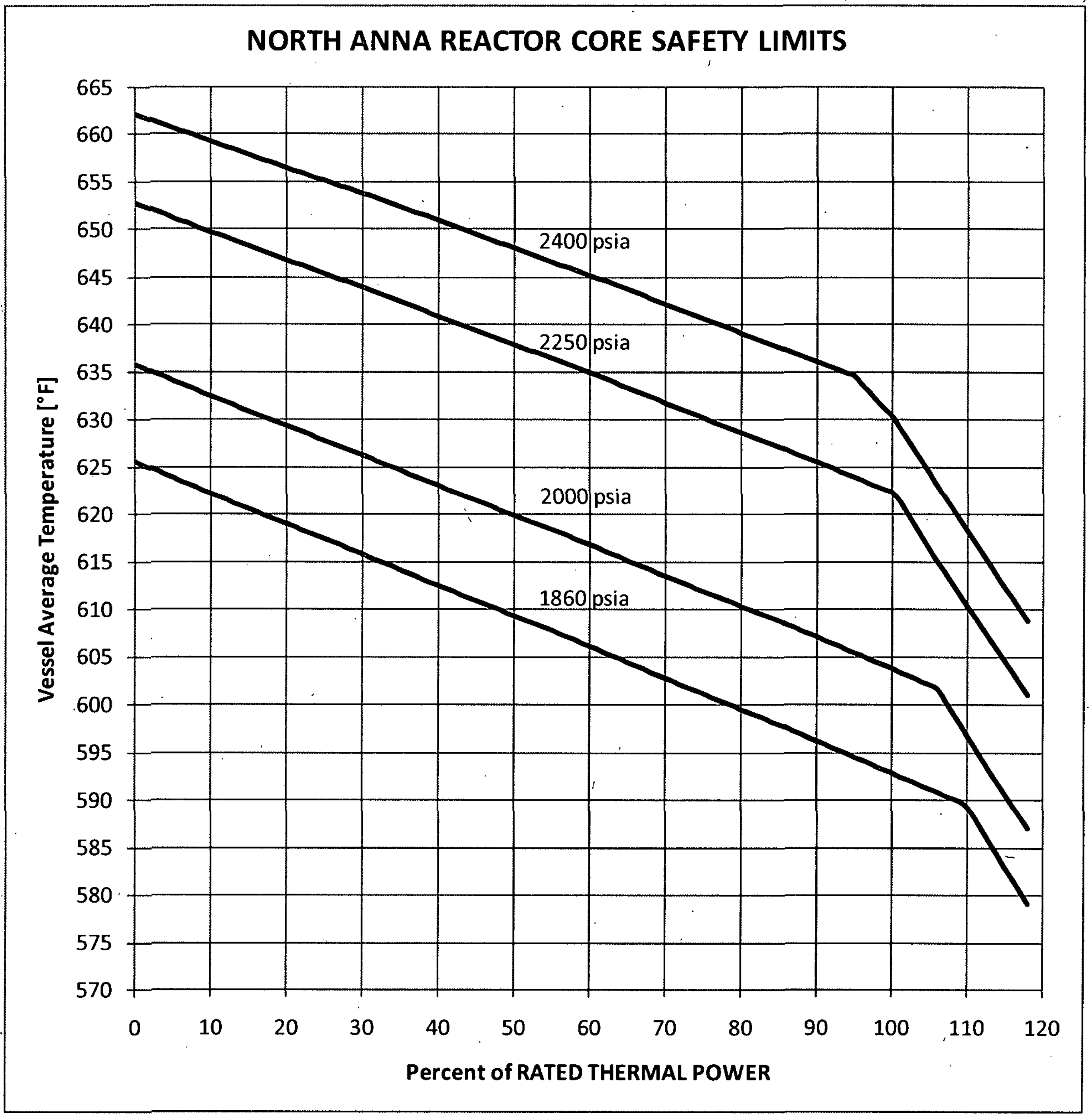
2.1.1 Reactor Core SLs

In MODES 1 and 2, the combination of THERMAL POWER, Reactor Coolant System (RCS) highest loop average temperature, and pressurizer pressure shall not exceed the limits specified in **COLR Figure 2.1-1**; and the following SLs shall not be exceeded.

2.1.1.1 The departure from nucleate boiling ratio (DNBR) shall be maintained greater than or equal to the 95/95 DNBR criterion for the DNB correlations and methodologies specified in the References Section.

2.1.1.2 The peak fuel centerline temperature shall be maintained < 5173°F, decreasing by 65°F per 10,000 MWD/MTU of burnup.

COLR Figure 2.1-1



3.1 REACTIVITY CONTROL SYSTEMS

3.1.1 SHUTDOWN MARGIN (SDM)

LCO 3.1.1 SDM shall be ≥ **1.77 % Δk/k.**

3.1.3 Moderator Temperature Coefficient (MTC)

LCO 3.1.3 The MTC shall be maintained within the limits specified below. The upper limit of MTC is +**0.6 x 10^{-4} Δk/k/°F**, when < 70% RTP, and **0.0 Δk/k/°F** when ≥ 70% RTP.

The BOC/ARO-MTC shall be ≤ **+0.6 x 10^{-4} Δk/k/°F** (upper limit), when < 70% RTP, and ≤ **0.0 Δk/k/°F** when ≥ 70% RTP.

The EOC/ARO/RTP-MTC shall be less negative than **–5.0 x 10^{-4} Δk/k/°F** (lower limit).

The MTC surveillance limits are:

The 300 ppm/ARO/RTP-MTC should be less negative than or equal to **–4.0 x 10^{-4} Δk/k/°F** [Note 2].

The 60 ppm/ARO/RTP-MTC should be less negative than or equal to **–4.7 x 10^{-4} Δk/k/°F** [Note 3].

SR 3.1.3.2 Verify MTC is within **–5.0 x 10^{-4} Δk/k/°F** (lower limit).

Note 2: If the MTC is more negative than **–4.0 x 10^{-4} Δk/k/°F,** SR 3.1.3.2 shall be repeated once per 14 EFPD during the remainder of the fuel cycle.

Note 3: SR 3.1.3.2 need not be repeated if the MTC measured at the equivalent of equilibrium RTP-ARO boron concentration of ≤ 60 ppm is less negative than **–4.7 x 10^{-4} Δk/k/°F.**

3.1.4 Rod Group Alignment Limits

Required Action A.1.1 Verify SDM to be ≥ **1.77 % Δk/k.**

Required Action B.1.1 Verify SDM to be ≥ **1.77 % Δk/k.**

Required Action D.1.1 Verify SDM to be ≥ **1.77 % Δk/k.**

3.1.5 Shutdown Bank Insertion Limits

LCO 3.1.5 Each shutdown bank shall be withdrawn to at least **226** steps.

Required Action A.1.1 Verify SDM to be ≥ **1.77 % Δk/k**.

Required Action B.1 Verify SDM to be ≥ **1.77 % Δk/k**.

SR 3.1.5.1 Verify each shutdown bank is withdrawn to at least **226** steps.

3.1.6 Control Bank Insertion Limits

LCO 3.1.6 Control banks shall be limited in physical insertion as shown in **COLR Figure 3.1-1**. Sequence of withdrawal shall be A, B, C and D, in that order; and the overlap limit during withdrawal shall be **98** steps.

Required Action A.1.1 Verify SDM to be ≥ **1.77 % Δk/k**.

Required Action B.1.1 Verify SDM to be ≥ **1.77 % Δk/k**.

Required Action C.1 Verify SDM to be ≥ **1.77 % Δk/k**.

SR 3.1.6.1 Verify estimated critical control bank position is within the insertion limits specified in **COLR Figure 3.1-1**.

SR 3.1.6.2 Verify each control bank is within the insertion limits specified in **COLR Figure 3.1-1**.

SR 3.1.6.3 Verify each control bank not fully withdrawn from the core is within the sequence and overlap limits specified in **LCO 3.1.6 above**.

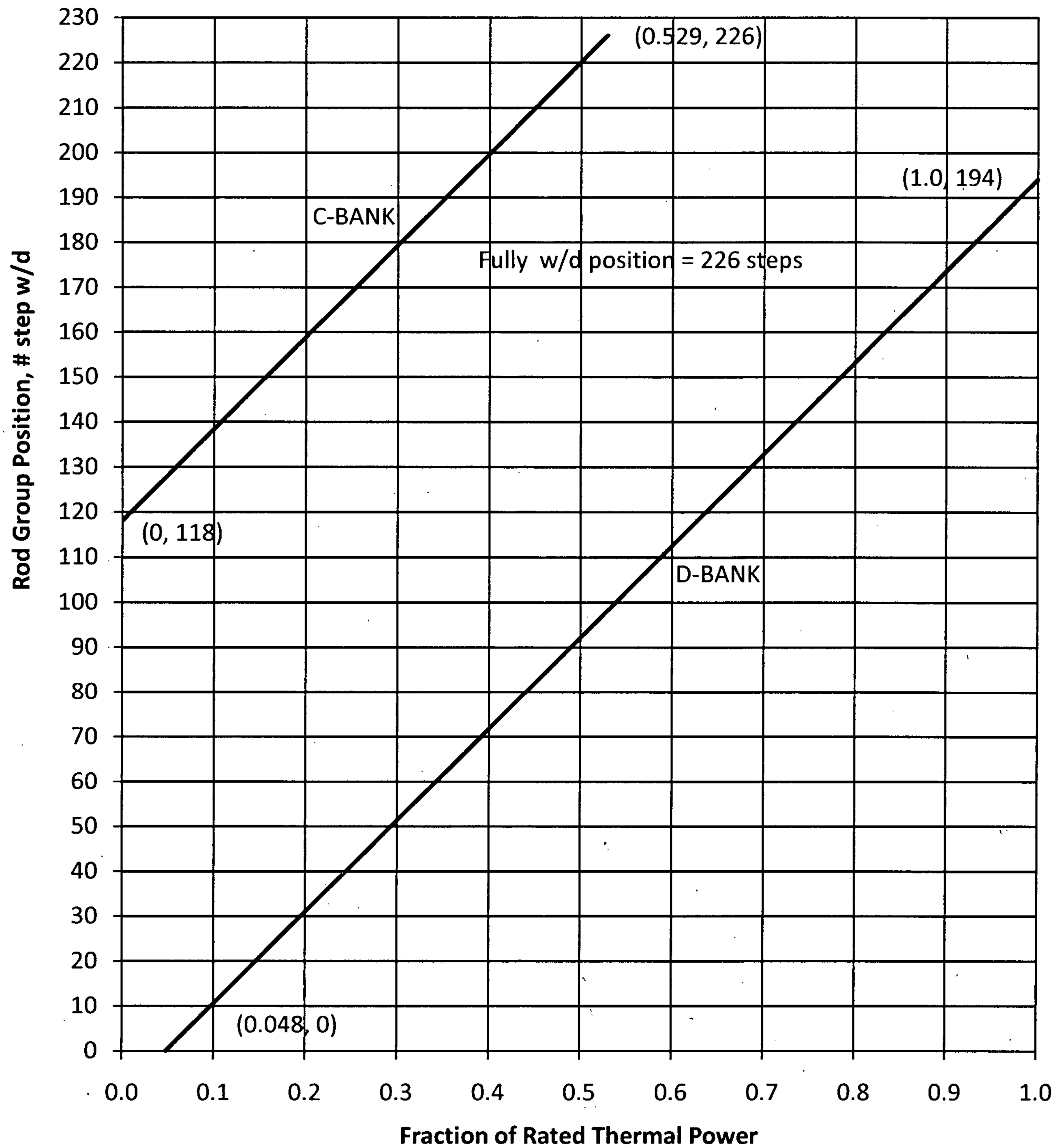
3.1.9 PHYSICS TESTS Exceptions – MODE 2

LCO 3.1.9.b SDM is ≥ **1.77 % Δk/k**.

SR 3.1.9.4 Verify SDM to be ≥ **1.77 % Δk/k**.

COLR Figure 3.1-1

North Anna 2 Cycle 21
Control Rod Bank Insertion Limits



3.2 POWER DISTRIBUTION LIMITS

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

LCO 3.2.1 $F_Q(Z)$, as approximated by $F_Q^M(Z)$, shall be within the limits specified below.

CFQ = 2.32

The Measured Heat Flux Hot Channel Factor, $F_Q^M(Z)$, shall be limited by the following relationships:

$$F_Q^M(Z) \leq \frac{CFQ}{P} \frac{K(Z)}{N(Z)} \qquad for\ P > 0.5$$

$$F_Q^M(Z) \leq \frac{CFQ}{0.5} \frac{K(Z)}{N(Z)} \qquad for\ P \leq 0.5$$

where: $P = \frac{THERMAL\ POWER}{RATED\ THERMAL\ POWER}$; and

K(Z) is provided in **COLR Figure 3.2-1,**
N(Z) is a cycle-specific non-equilibrium multiplier on $F_Q^M(Z)$ to account for power distribution transients during normal operation, provided in **COLR Table 3.2-1.**

The discussion in the Bases Section B 3.2.1 for this LCO requires the application of a cycle dependent non-equilibrium multiplier, N(Z), to the measured peaking factor, $F_Q^M(Z)$, before comparing it to the limit. N(Z) accounts for power distribution transients encountered during normal operation. As function N(Z) is dependent on the predicted equilibrium $F_Q(Z)$ and is sensitive to the axial power distribution, it is typically generated from the actual EOC burnup distribution that can only be obtained after the shutdown of the previous cycle. The cycle-specific N(Z) function is presented in **COLR Table 3.2-1.**

COLR Table 3.2-1

N2C21 Normal Operation N(Z)

NODE	HEIGHT (FEET)	0 to 1000 MWD/MTU	1000 to 3000 MWD/MTU	3000 to 5000 MWD/MTU	5000 to 7000 MWD/MTU	7000 to 9000 MWD/MTU	9000 to 11000 MWD/MTU
10	10.2	1.093	1.119	1.130	1.131	1.132	1.151
11	10.0	1.092	1.117	1.128	1.130	1.131	1.149
12	9.8	1.094	1.115	1.126	1.129	1.129	1.145
13	9.6	1.099	1.114	1.125	1.129	1.129	1.143
14	9.4	1.101	1.111	1.124	1.127	1.128	1.141
15	9.2	1.105	1.112	1.129	1.129	1.129	1.142
16	9.0	1.119	1.122	1.143	1.143	1.136	1.142
17	8.8	1.133	1.133	1.158	1.158	1.145	1.145
18	8.6	1.138	1.137	1.163	1.163	1.149	1.148
19	8.4	1.139	1.139	1.164	1.164	1.152	1.152
20	8.2	1.141	1.141	1.167	1.167	1.157	1.157
21	8.0	1.141	1.141	1.168	1.168	1.161	1.161
22	7.8	1.140	1.140	1.168	1.168	1.163	1.162
23	7.6	1.139	1.139	1.170	1.169	1.166	1.164
24	7.4	1.137	1.137	1.172	1.172	1.171	1.167
25	7.2	1.136	1.136	1.174	1.174	1.173	1.169
26	7.0	1.137	1.137	1.173	1.173	1.173	1.171
27	6.8	1.138	1.138	1.173	1.174	1.174	1.172
28	6.6	1.138	1.138	1.172	1.173	1.173	1.172
29	6.4	1.136	1.136	1.168	1.170	1.171	1.170
30	6.2	1.132	1.132	1.161	1.164	1.166	1.166
31	6.0	1.131	1.130	1.159	1.163	1.166	1.165
32	5.8	1.126	1.126	1.151	1.157	1.161	1.162
33	5.6	1.113	1.113	1.132	1.139	1.145	1.156
34	5.4	1.102	1.106	1.116	1.125	1.132	1.150
35	5.2	1.097	1.110	1.113	1.123	1.127	1.147
36	5.0	1.098	1.118	1.117	1.127	1.129	1.143
37	4.8	1.102	1.123	1.122	1.128	1.133	1.137
38	4.6	1.107	1.128	1.127	1.130	1.136	1.135
39	4.4	1.112	1.130	1.130	1.131	1.138	1.137
40	4.2	1.118	1.133	1.133	1.129	1.137	1.136
41	4.0	1.126	1.136	1.136	1.127	1.134	1.134
42	3.8	1.136	1.137	1.138	1.126	1.130	1.130
43	3.6	1.145	1.138	1.139	1.129	1.128	1.128
44	3.4	1.152	1.141	1.137	1.130	1.128	1.129
45	3.2	1.158	1.148	1.137	1.134	1.133	1.134
46	3.0	1.164	1.157	1.141	1.139	1.140	1.142
47	2.8	1.173	1.169	1.149	1.149	1.148	1.151
48	2.6	1.183	1.180	1.154	1.155	1.152	1.152
49	2.4	1.196	1.194	1.165	1.165	1.159	1.156
50	2.2	1.213	1.212	1.181	1.182	1.173	1.170
51	2.0	1.224	1.224	1.193	1.193	1.182	1.179
52	1.8	1.227	1.228	1.195	1.195	1.184	1.180

These decks are generated for normal operation flux maps that are typically taken at full power ARO. Additional N(z) decks may be generated for the specific plant conditions at the time of the flux map, if necessary, consistent with the methodology described in the RPDC topical (Reference 3). EOR is defined as Hot Full Power End of Reactivity.

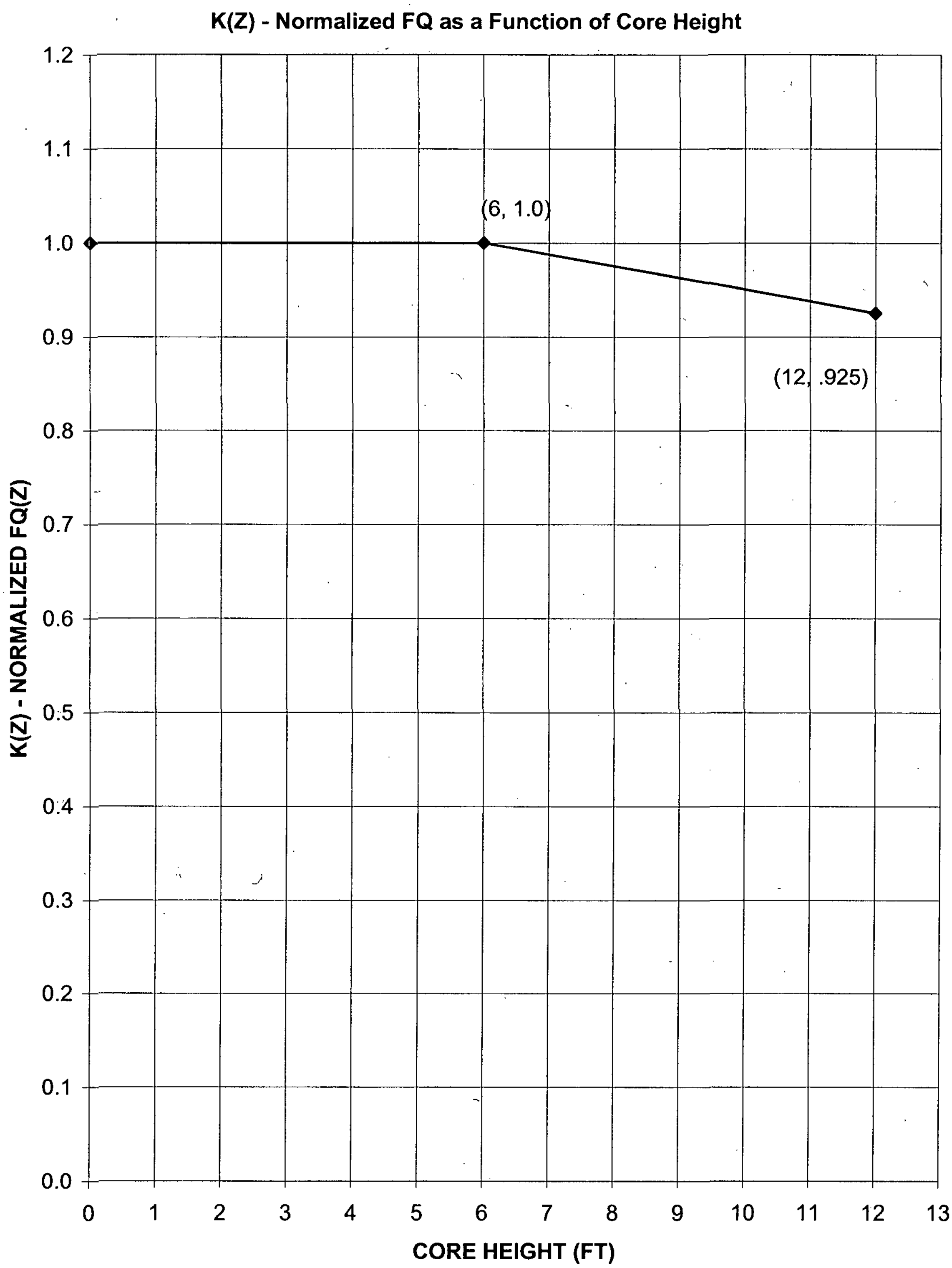
COLR Table 3.2-1 (continued)

N2C21 Normal Operation N(Z)

NODE	HEIGHT (FEET)	11000 to 13000 MWD/MTU	13000 to 15000 MWD/MTU	15000 to 17000 MWD/MTU	17000 to EOR MWD/MTU
10	10.2	1.151	1.119	1.119	1.119
11	10.0	1.149	1.117	1.118	1.118
12	9.8	1.145	1.115	1.117	1.116
13	9.6	1.143	1.115	1.116	1.116
14	9.4	1.141	1.110	1.112	1.110
15	9.2	1.142	1.113	1.114	1.113
16	9.0	1.140	1.126	1.122	1.134
17	8.8	1.143	1.143	1.135	1.159
18	8.6	1.148	1.150	1.140	1.166
19	8.4	1.158	1.158	1.149	1.172
20	8.2	1.171	1.172	1.165	1.187
21	8.0	1.181	1.181	1.176	1.197
22	7.8	1.184	1.184	1.180	1.200
23	7.6	1.188	1.189	1.186	1.203
24	7.4	1.194	1.197	1.196	1.209
25	7.2	1.197	1.202	1.203	1.214
26	7.0	1.197	1.204	1.204	1.216
27	6.8	1.197	1.206	1.206	1.218
28	6.6	1.195	1.206	1.206	1.220
29	6.4	1.190	1.207	1.207	1.222
30	6.2	1.182	1.204	1.204	1.221
31	6.0	1.177	1.205	1.205	1.224
32	5.8	1.170	1.199	1.199	1.218
33	5.6	1.159	1.183	1.183	1.205
34	5.4	1.149	1.168	1.168	1.191
35	5.2	1.146	1.161	1.161	1.188
36	5.0	1.145	1.156	1.156	1.180
37	4.8	1.142	1.151	1.151	1.165
38	4.6	1.139	1.149	1.149	1.150
39	4.4	1.136	1.149	1.149	1.138
40	4.2	1.132	1.145	1.145	1.140
41	4.0	1.129	1.139	1.139	1.152
42	3.8	1.127	1.139	1.139	1.160
43	3.6	1.129	1.143	1.143	1.165
44	3.4	1.130	1.144	1.144	1.168
45	3.2	1.134	1.146	1.146	1.169
46	3.0	1.142	1.146	1.148	1.168
47	2.8	1.151	1.148	1.152	1.167
48	2.6	1.151	1.149	1.153	1.164
49	2.4	1.157	1.157	1.162	1.171
50	2.2	1.172	1.174	1.180	1.190
51	2.0	1.183	1.187	1.194	1.207
52	1.8	1.185	1.190	1.198	1.214

These decks are generated for normal operation flux maps that are typically taken at full power ARO. Additional N(z) decks may be generated for the specific plant conditions at the time of the flux map, if necessary, consistent with the methodology described in the RPDC topical (Reference 3). EOR is defined as Hot Full Power End of Reactivity.

COLR Figure 3.2-1



3.2.2 Nuclear Enthalpy Rise Hot Channel Factor ($F^N_{\Delta H}$)

LCO 3.2.2 $F^N_{\Delta H}$ shall be within the limits specified below.

$$\mathbf{F^N_{\Delta H} \leq 1.587\{1 + 0.3(1 - P)\}}$$

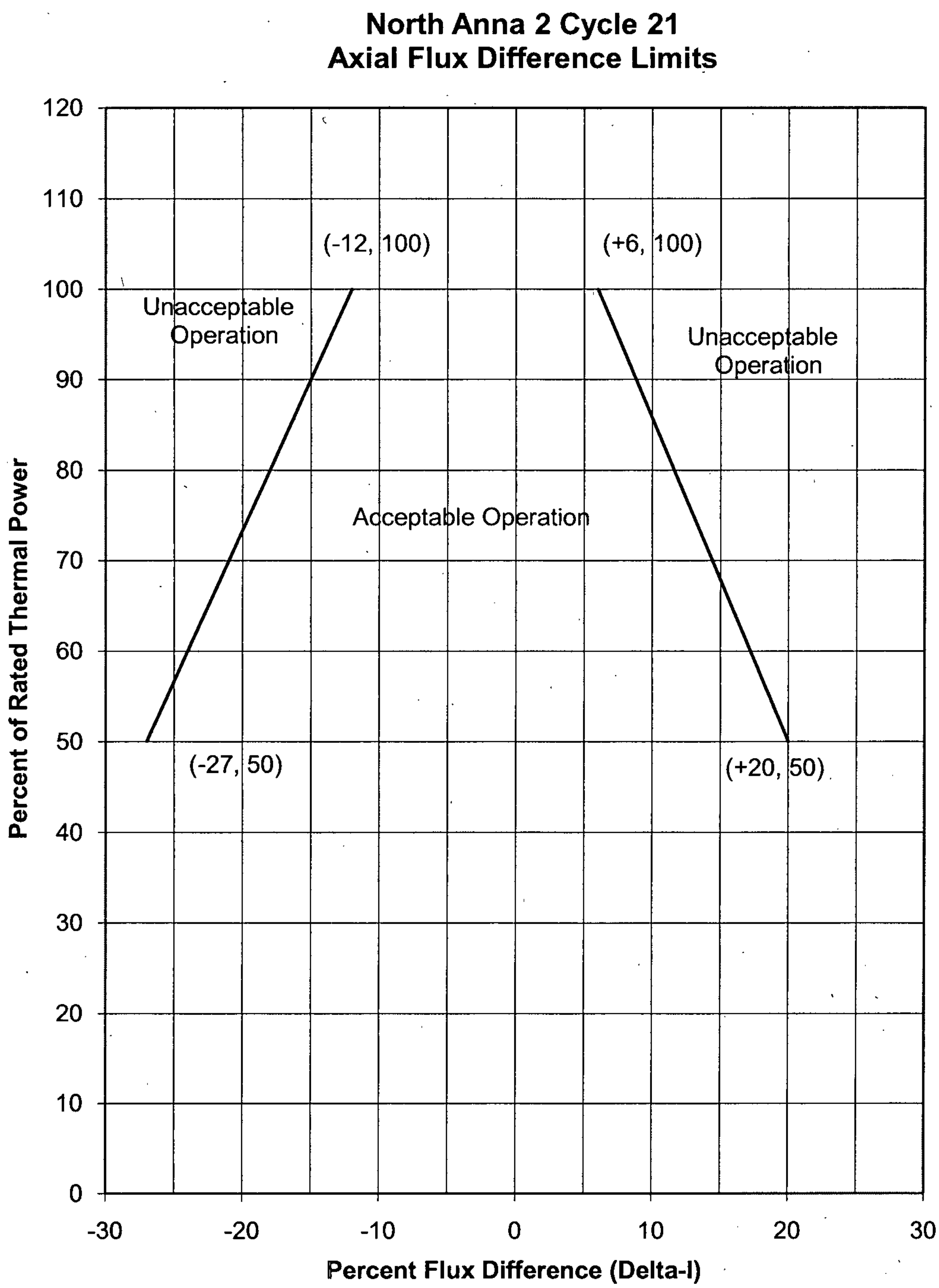
where: $P = \dfrac{THERMAL\ POWER}{RATED\ THERMAL\ POWER}$

SR 3.2.2.1 Verify $F^N_{\Delta H}$ is within limits specified above.

3.2.3 AXIAL FLUX DIFFERENCE (AFD)

LCO 3.2.3 The AFD in % flux difference units shall be maintained within the limits specified in **COLR Figure 3.2-2.**

COLR Figure 3.2-2



3.3 INSTRUMENTATION

3.3.1 Reactor Trip System (RTS) Instrumentation

TS Table 3.3.1-1 Note 1: Overtemperature ΔT

The Overtemperature ΔT Function Allowable Value shall not exceed the following nominal trip setpoint by more than 2% of ΔT span, with the numerical values of the parameters as specified below.

$$\Delta T \leq \Delta T_0 \left\{ K_1 - K_2 \frac{(1+\tau_1 s)}{(1+\tau_2 s)} [T - T'] + K_3 (P - P') - f_1(\Delta I) \right\}$$

where: ΔT is measured RCS ΔT, °F.

ΔT_0 is the indicated ΔT at RTP, °F.

s is the Laplace transform operator, sec^{-1}.

T is the measured RCS average temperature, °F.

T' is the nominal T_{avg} at RTP, **≤ 586.8 °F.**

P is the measured pressurizer pressure, psig.

P' is the nominal RCS operating pressure, **≥ 2235 psig.**

K_1 ≤ **1.2715** K_2 ≥ **0.02172 /°F** K_3 ≥ **0.001144 /psig**

τ_1, τ_2 = time constants utilized in the lead-lag controller for T_{avg}

τ_1 ≥ **23.75 sec** τ_2 ≤ **4.4 sec**

$(1+\tau_1 s)/(1+\tau_2 s)$ = function generated by the lead-lag controller for T_{avg} dynamic compensation

$f_1(\Delta I) \geq$ **0.0165{–35 – ($q_t - q_b$)}**	when ($q_t - q_b$) < **–35%** RTP
0	when **–35%** RTP ≤ ($q_t - q_b$) ≤ **+3%** RTP
0.0198{($q_t - q_b$) – 3}	when ($q_t - q_b$) > **+3%** RTP

Where q_t and q_b are percent RTP in the upper and lower halves of the core, respectively, and $q_t + q_b$ is the total THERMAL POWER in percent RTP.

TS Table 3.3.1-1 Note 2: Overpower ΔT

The Overpower ΔT Function Allowable Value shall not exceed the following nominal trip setpoint by more than 2% of ΔT span, with the numerical values of the parameters as specified below.

$$\Delta T \leq \Delta T_0 \left\{ K_4 - K_5 \left[\frac{\tau_3 s}{1+\tau_3 s} \right] T - K_6 [T - T'] - f_2(\Delta I) \right\}$$

where: ΔT is measured RCS ΔT, °F.

ΔT_0 is the indicated ΔT at RTP, °F.

s is the Laplace transform operator, sec^{-1}.

T is the measured RCS average temperature, °F.

T' is the nominal T_{avg} at RTP, **≤ 586.8 °F.**

K_4 **≤ 1.0865**

K_5 **≥ 0.0197 /°F** for increasing T_{avg}

0 /°F for decreasing T_{avg}

K_6 **≥ 0.00162 /°F** when T > T'

0 /°F when T ≤ T'

τ_3 = time constant utilized in the rate lag controller for T_{avg}

τ_3 **≥ 9.5 sec**

$\tau_3 s/(1+\tau_3 s)$ = function generated by the rate lag controller for T_{avg} dynamic compensation

$f_2(\Delta I)$ = **0, for all ΔI.**

3.4 REACTOR COOLANT SYSTEM (RCS)

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

LCO 3.4.1 RCS DNB parameters for pressurizer pressure, RCS average temperature, and RCS total flow rate shall be within the limits specified below:

a. Pressurizer pressure is greater than or equal to **2205 psig**;

b. RCS average temperature is less than or equal to **591 °F**; and

c. RCS total flow rate is greater than or equal to **295,000 gpm**.

SR 3.4.1.1 Verify pressurizer pressure is greater than or equal to **2205 psig**.

SR 3.4.1.2 Verify RCS average temperature is less than or equal to **591 °F**.

SR 3.4.1.3 Verify RCS total flow rate is greater than or equal to **295,000 gpm**.

SR 3.4.1.4 -----------------------------NOTE---
Not required to be performed until 30 days after ≥ 90% RTP.

Verify by precision heat balance that RCS total flow rate is ≥ **295,000 gpm**.

3.5 EMERGENCY CORE COOLING SYSTEMS (ECCS)

3.5.6 Boron Injection Tank (BIT)

Required Action B.2 Borate to an SDM ≥ **1.77 % Δk/k at 200 °F**.

3.9 REFUELING OPERATIONS

3.9.1 Boron Concentration

LCO 3.9.1 Boron concentrations of the Reactor Coolant System (RCS), the refueling canal, and the refueling cavity shall be maintained ≥ **2600 ppm**.

SR 3.9.1.1 Verify boron concentration is within the limit specified above.

TRM 3.1 REACTIVITY CONTROL SYSTEMS

TR 3.1.1 Boration Flow Paths – Operating

Required Action D.2 Borate to a SHUTDOWN MARGIN ≥ **1.77 % Δk/k at 200 °F,** after xenon decay.