

**VIRGINIA ELECTRIC AND POWER COMPANY  
RICHMOND, VIRGINIA 23261**

January 23, 2003

United States Nuclear Regulatory Commission  
Attention: Document Control Desk  
Washington, D.C. 20555-0001

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Gentlemen:

**VIRGINIA ELECTRIC AND POWER COMPANY**  
**NORTH ANNA POWER STATION UNIT 2**  
**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's (Dominion) Core Operating Limits Report for North Anna Unit 2 Cycle 16 Pattern TP, Rev. 1.

No new commitments are intended by this letter. If you have any questions or require additional information, please contact us.

Very truly yours,



L. N. Hartz  
Vice President - Nuclear Engineering

Attachment

cc: U.S. Nuclear Regulatory Commission  
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IE24

**CORE OPERATING LIMITS REPORT Rev 1  
North Anna 2 Cycle 16 Pattern TP**

**January 2003**

## N2C16 CORE OPERATING LIMITS REPORT

### INTRODUCTION

The Core Operating Limits Report (COLR) for North Anna Unit 2 Cycle 16 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 3.1.5 Shutdown Bank Insertion Limit
- TS 3.1.6 Control Bank Insertion Limits
- TS 3.2.1 Heat Flux Hot Channel Factor
- TS 3.2.2 Nuclear Enthalpy Rise Hot Channel Factor ( $F_{\Delta H}^N$ )
- 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 3.9.1 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 for determining the core operating limits are those previously approved by the NRC and are discussed in the documents listed in the References Section. Cycle-specific values are presented in **bold**, while text in *italics* is provided for information only.

## REFERENCES

1. VEP-FRD-42 Rev 1-A, Reload Nuclear Design Methodology, September 1986; Supplement 1, November 1993; Supplement 2, September 1996.  
  
(Methodology for TS 3.1.1 – Shutdown Margin, TS 3.1.3 – Moderator Temperature Coefficient, TS 3.1.5 – Shutdown Bank Insertion Limit, TS 3.1.6 - Control Bank Insertion Limits, TS 3.2.1 - Heat Flux Hot Channel Factor, TS 3.2.2 – Nuclear Enthalpy Rise Hot Channel Factor and TS 3.9.1 – Boron Concentration)
2. WCAP-9220-P-A Rev1, Westinghouse ECCS Evaluation Model – 1981 Version, February 1982.  
  
(Methodology for TS 3.2.1 - Heat Flux Hot Channel Factor)
3. WCAP-9561-P-A Rev 1 Add. 3, BART A-1: A Computer Code for the Best Estimate Analysis of Reflood Transients – Special Report: Thimble Modeling in W ECCS Evaluation Model, July 1986.  
  
(Methodology for TS 3.2.1 - Heat Flux Hot Channel Factor)
4. WCAP-10266-P-A Rev 2, The 1981 Version of the Westinghouse ECCS Evaluation Model Using the BASH Code, March 1987.  
  
(Methodology for TS 3.2.1 - Heat Flux Hot Channel Factor)
5. WCAP-10054-P-A, Westinghouse Small Break ECCS Evaluation Model Using the NOTRUMP Code, August 1985.  
  
(Methodology for TS 3.2.1 - Heat Flux Hot Channel Factor)
6. WCAP-10079-P-A, NOTRUMP, A Nodal Transient Small Break and General Network Code, August 1985.  
  
(Methodology for TS 3.2.1 - Heat Flux Hot Channel Factor)
7. WCAP-12610-P-A, VANTAGE+ Fuel Assembly - Reference Core Report, April 1995.  
  
(Methodology for TS 3.2.1 - Heat Flux Hot Channel Factor)
8. VEP-NE-2-A, 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)

9. VEP-NE-3-A, Qualification of the WRB-1 CHF Correlation in the Virginia Power COBRA Code, July 1990.

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

10. VEP-NE-1-A, Virginia Power Relaxed Power Distribution Control Methodology and Associated FQ Surveillance Technical Specifications, March 1986; Supplement 1, September 1996.

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

11. WCAP-8745-P-A, Design Bases for the Thermal Overpower  $\Delta T$  and Thermal Overtemperature  $\Delta T$  Trip Functions, September 1986.

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

12. 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 3.3.1 – Reactor Trip System Instrumentation, TS 3.4.1 – RCS Pressure, Temperature, and Flow DNB Limits and TS 3.9.1 – Boron Concentration)

## **2.0 SAFETY LIMITS (SLs)**

### **2.1 SLs**

#### **2.1.1 Reactor Core SLs**

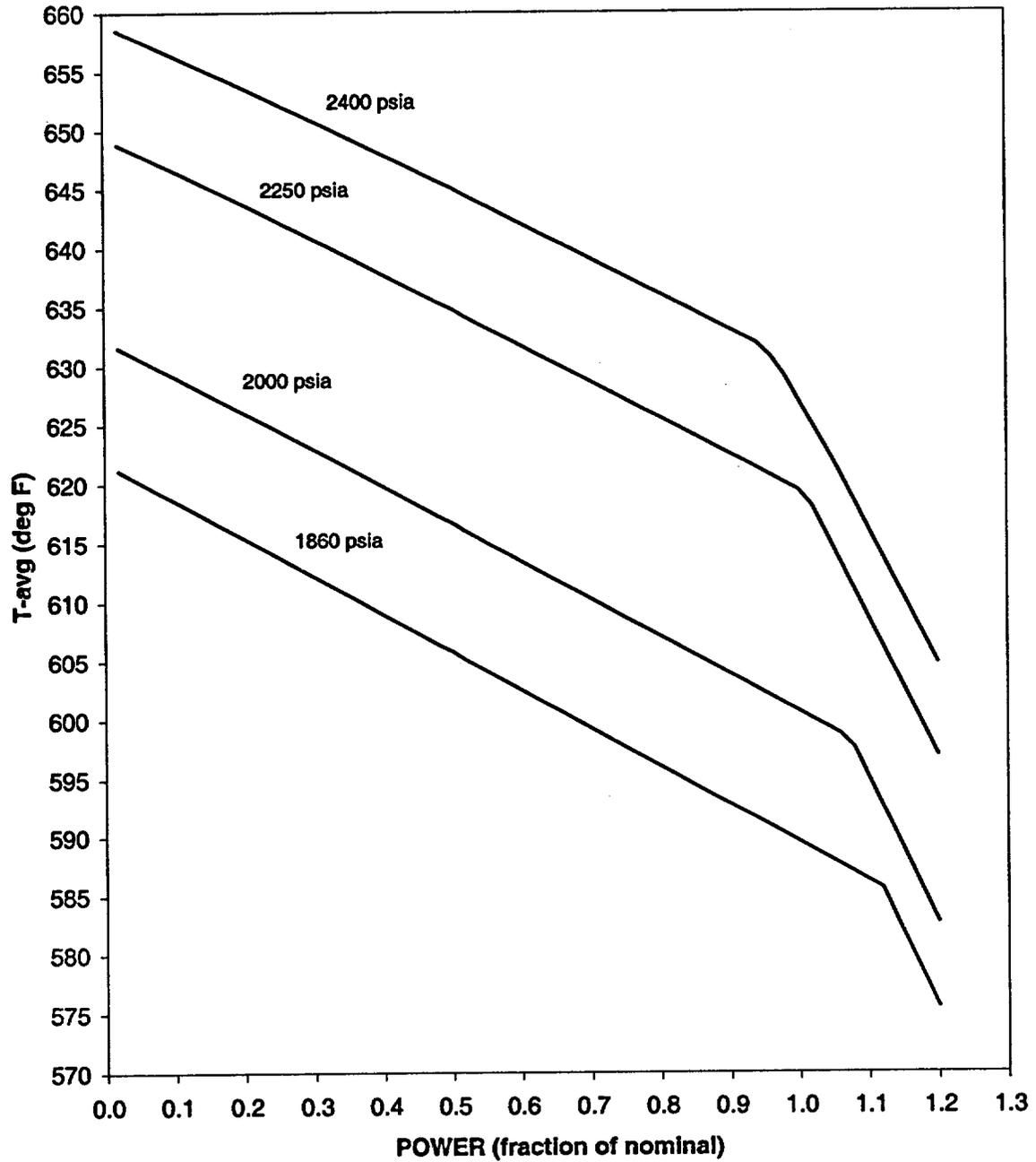
In MODES 1 and 2, the combination of THERMAL POWER, Reactor Coolant System (RCS) highest loop average temperature, and pressurizer pressure shall not exceed the limits specified in COLR Figure 2.1-1; and the following SLs shall not be exceeded.

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  $< 4700$  °F.

COLR Figure 2.1-1

**NORTH ANNA REACTOR CORE SAFETY LIMITS**



### 3.1 REACTIVITY CONTROL SYSTEMS

#### 3.1.1 SHUTDOWN MARGIN (SDM)

LCO 3.1.1 SDM shall be  $\geq 1.77\%$   $\Delta k/k$ .

#### 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  $+0.6 \times 10^{-4} \Delta k/k/^\circ F$ , when  $< 70\%$  RTP, and  $0.0 \Delta k/k/^\circ F$  when  $\geq 70\%$  RTP.

The BOC/ARO-MTC shall be  $\leq +0.6 \times 10^{-4} \Delta k/k/^\circ F$  (upper limit), when  $< 70\%$  RTP, and  $\leq 0.0 \Delta k/k/^\circ F$  when  $\geq 70\%$  RTP.

The EOC/ARO/RTP-MTC shall be less negative than  $-5.0 \times 10^{-4} \Delta k/k/^\circ F$  (lower limit).

The MTC surveillance limits are:

The 300 ppm/ARO/RTP-MTC should be less negative than or equal to  $-4.0 \times 10^{-4} \Delta k/k/^\circ F$  [Note 2].

The 60 ppm/ARO/RTP-MTC should be less negative than or equal to  $-4.7 \times 10^{-4} \Delta k/k/^\circ F$  [Note 3].

SR 3.1.3.2 Verify MTC is within  $-5.0 \times 10^{-4} \Delta k/k/^\circ F$  (lower limit).

Note 2: If the MTC is more negative than  $-4.0 \times 10^{-4} \Delta k/k/^\circ F$ , 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  $\leq 60$  ppm is less negative than  $-4.7 \times 10^{-4} \Delta k/k/^\circ F$ .

#### 3.1.4 Rod Group Alignment Limits

Required Action A.1.1 Verify SDM to be  $\geq 1.77\%$   $\Delta k/k$ .

Required Action B.1.1 Verify SDM to be  $\geq 1.77\%$   $\Delta k/k$ .

Required Action D.1.1 Verify SDM to be  $\geq 1.77\%$   $\Delta k/k$ .

### 3.1.5 Shutdown Bank Insertion Limits

**LCO 3.1.5** Each shutdown bank shall be withdrawn to at least 228 steps.

**Required Action A.1.1** Verify SDM to be  $\geq 1.77\% \Delta k/k$ .

**Required Action B.1** Verify SDM to be  $\geq 1.77\% \Delta k/k$ .

**SR 3.1.5.1** Verify each shutdown bank is withdrawn to at least 228 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  $\geq 1.77\% \Delta k/k$ .

**Required Action B.1.1** Verify SDM to be  $\geq 1.77\% \Delta k/k$ .

**Required Action C.1** Verify SDM to be  $\geq 1.77\% \Delta k/k$ .

**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.

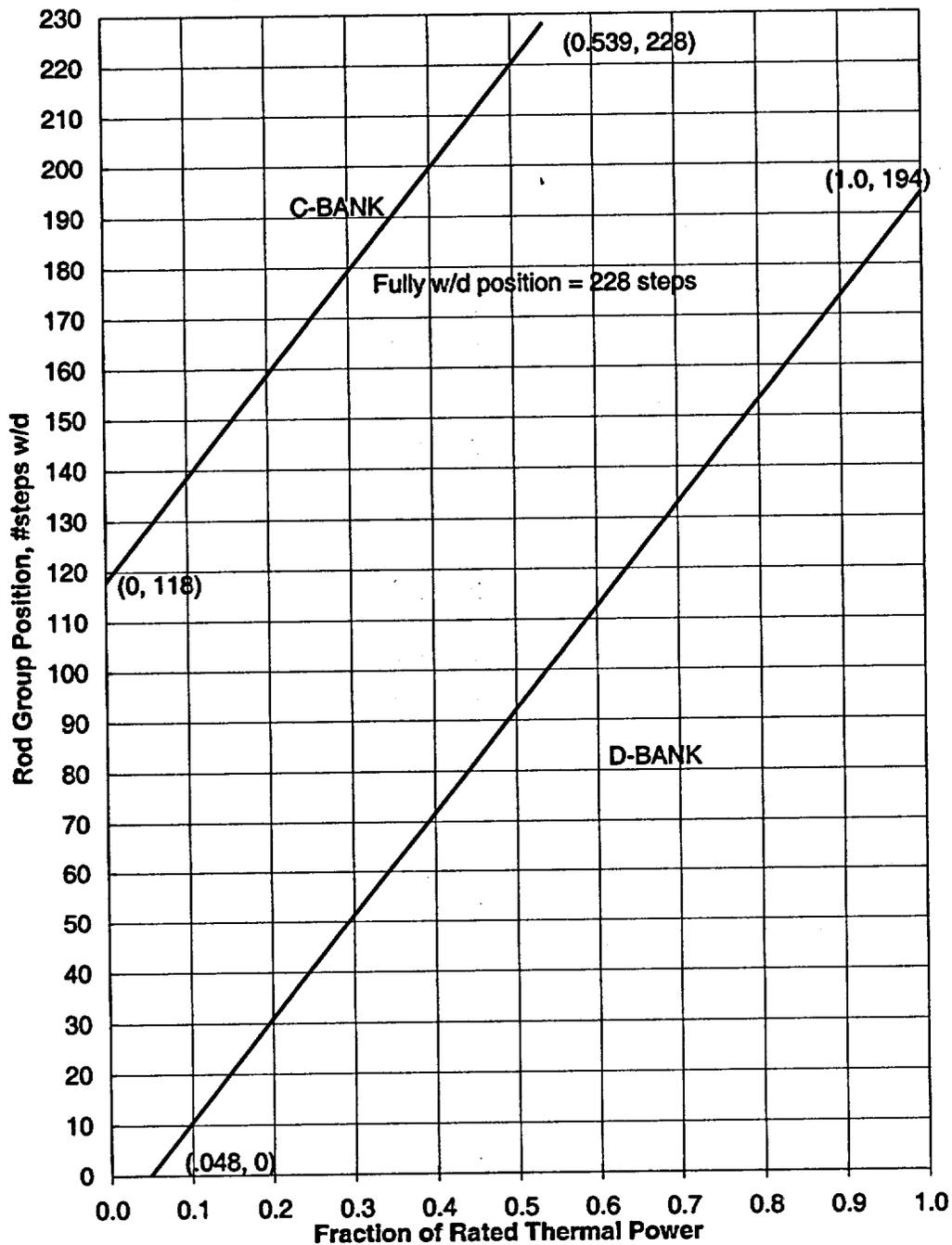
### 3.1.9 PHYSICS TESTS Exceptions – MODE 2

**LCO 3.1.9.b** SDM is  $\geq 1.77\% \Delta k/k$ .

**SR 3.1.9.4** Verify SDM to be  $\geq 1.77\% \Delta k/k$ .

COLR Figure 3.1-1

North Anna 2 Cycle 16  
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.

The change in the  $F_Q(Z)$  limit for coastdown operation is accommodated by defining a variable quantity, CFQ as indicated below. Then, the following expressions apply to both normal operation and Tavg coastdown regimes.

**CFQ = 2.19, for normal operation at full power;**

**CFQ = 2.15, for flux map immediately preceding EOC temperature coastdown and during subsequent power coastdown operation.**

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

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

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

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

$K(Z)$  is provided in COLR Figure 3.2-1; and

$N(Z)$  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.

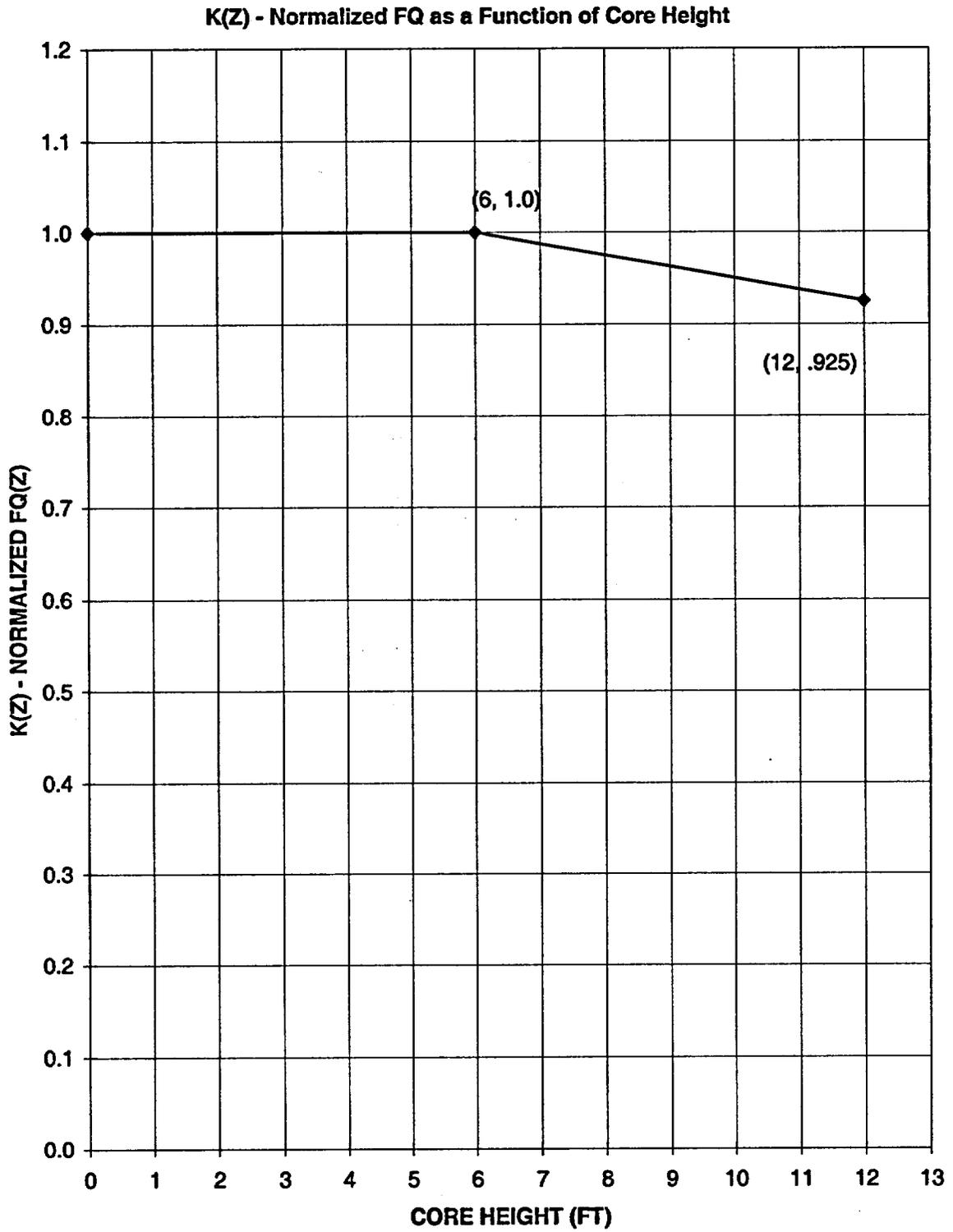
*The discussion in the Bases Section B 3.2.1 for this LCO requires the application of a cycle dependent non-equilibrium multiplier,  $N(Z)$ , to the measured peaking factor,  $F_Q^M(Z)$ , before comparing it to the limit.  $N(Z)$  accounts for power distribution transients encountered during normal operation. As function  $N(Z)$  is dependent on the predicted equilibrium  $F_Q(Z)$  and is sensitive to the axial power distribution, it must be 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  
N2C16 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 20400 MWD/MTU
10	10.2	1.112	1.112	1.148	1.148	1.148	1.148
11	10.0	1.111	1.111	1.148	1.148	1.148	1.148
12	9.8	1.110	1.110	1.146	1.146	1.146	1.146
13	9.6	1.109	1.109	1.146	1.146	1.146	1.145
14	9.4	1.108	1.108	1.147	1.147	1.147	1.146
15	9.2	1.110	1.110	1.151	1.151	1.151	1.150
16	9.0	1.111	1.111	1.153	1.153	1.153	1.156
17	8.8	1.115	1.115	1.156	1.156	1.156	1.162
18	8.6	1.119	1.119	1.160	1.160	1.160	1.167
19	8.4	1.126	1.126	1.163	1.163	1.163	1.170
20	8.2	1.133	1.133	1.167	1.167	1.167	1.172
21	8.0	1.139	1.139	1.170	1.170	1.170	1.174
22	7.8	1.142	1.142	1.172	1.172	1.172	1.177
23	7.6	1.142	1.142	1.172	1.172	1.172	1.181
24	7.4	1.139	1.139	1.170	1.170	1.170	1.187
25	7.2	1.137	1.137	1.167	1.167	1.167	1.191
26	7.0	1.134	1.134	1.162	1.162	1.162	1.191
27	6.8	1.131	1.131	1.157	1.157	1.157	1.189
28	6.6	1.126	1.126	1.152	1.152	1.152	1.184
29	6.4	1.121	1.121	1.146	1.146	1.146	1.177
30	6.2	1.114	1.114	1.141	1.141	1.141	1.168
31	6.0	1.106	1.106	1.137	1.137	1.137	1.162
32	5.8	1.098	1.098	1.132	1.132	1.132	1.156
33	5.6	1.091	1.091	1.125	1.125	1.125	1.152
34	5.4	1.088	1.088	1.117	1.117	1.117	1.145
35	5.2	1.087	1.087	1.107	1.108	1.108	1.134
36	5.0	1.091	1.091	1.103	1.103	1.103	1.124
37	4.8	1.096	1.096	1.104	1.105	1.105	1.120
38	4.6	1.106	1.106	1.110	1.109	1.109	1.120
39	4.4	1.119	1.119	1.120	1.111	1.111	1.124
40	4.2	1.132	1.132	1.131	1.115	1.115	1.126
41	4.0	1.144	1.144	1.144	1.120	1.120	1.127
42	3.8	1.156	1.156	1.156	1.124	1.124	1.127
43	3.6	1.167	1.167	1.167	1.128	1.128	1.128
44	3.4	1.178	1.178	1.177	1.130	1.130	1.129
45	3.2	1.187	1.187	1.187	1.134	1.134	1.133
46	3.0	1.196	1.196	1.196	1.141	1.141	1.140
47	2.8	1.204	1.204	1.204	1.151	1.151	1.150
48	2.6	1.212	1.212	1.212	1.159	1.159	1.158
49	2.4	1.218	1.218	1.218	1.167	1.167	1.166
50	2.2	1.225	1.225	1.225	1.174	1.174	1.173
51	2.0	1.231	1.231	1.231	1.182	1.182	1.182
52	1.8	1.237	1.237	1.237	1.191	1.191	1.193

These decks were generated for normal operation flux maps which are typically taken at full power. Additional N(z) decks may be generated if necessary, consistent with the methodology described in the RPDC topical.

COLR Figure 3.2-1



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

**LCO 3.2.2  $F_{\Delta H}^N$  shall be within the limits specified below.**

$$F_{\Delta H}^N \leq 1.49\{1 + 0.3(1 - P)\}$$

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

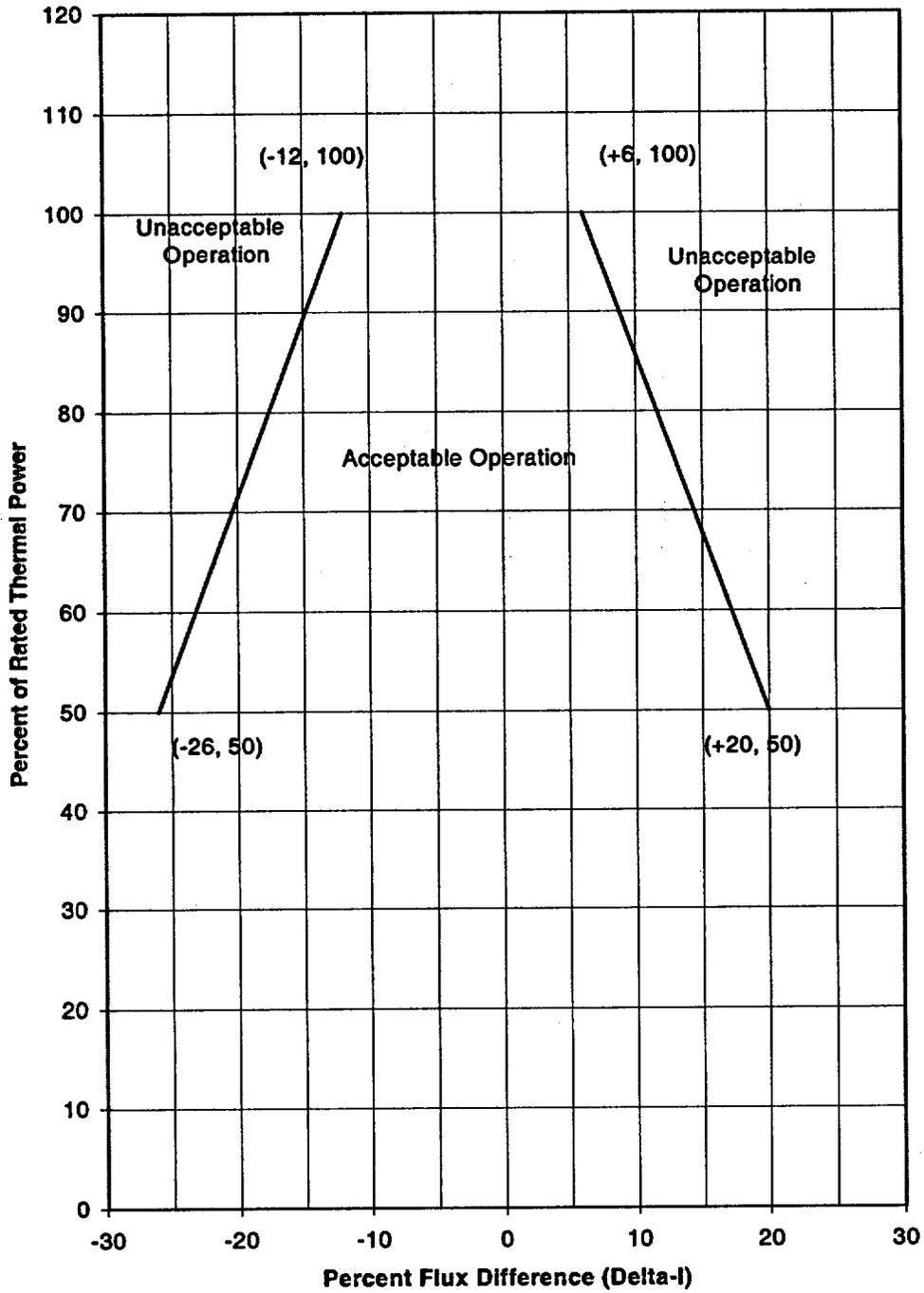
**SR 3.2.2.1 Verify  $F_{\Delta H}^N$  is within limits specified above.**

**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 Figures 3.2-2, 3.2-3 and 3.2-4.**

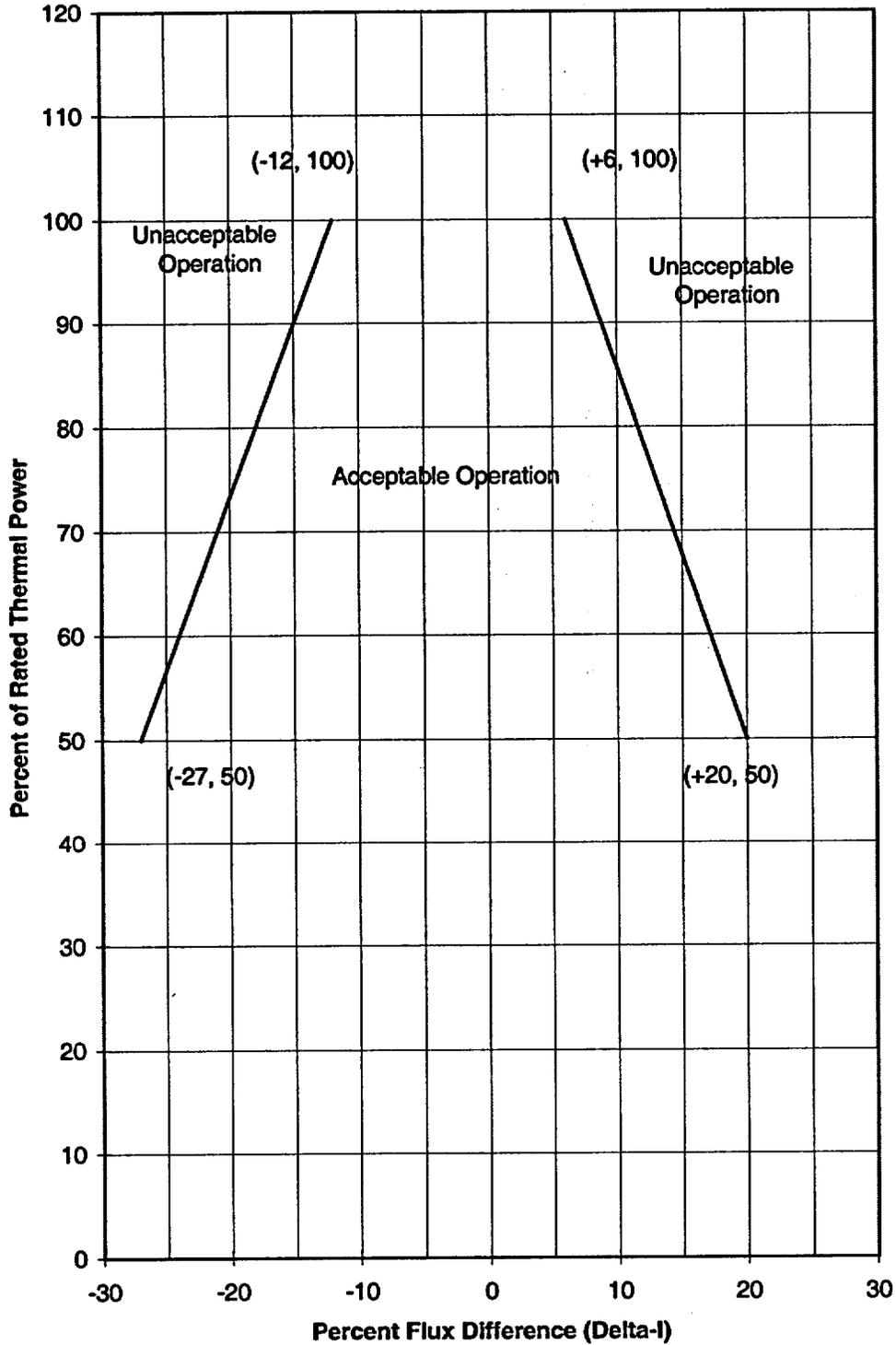
COLR Figure 3.2-2

N2C16 Axial Flux Difference Limits  
0 to 5000 MWD/MTU



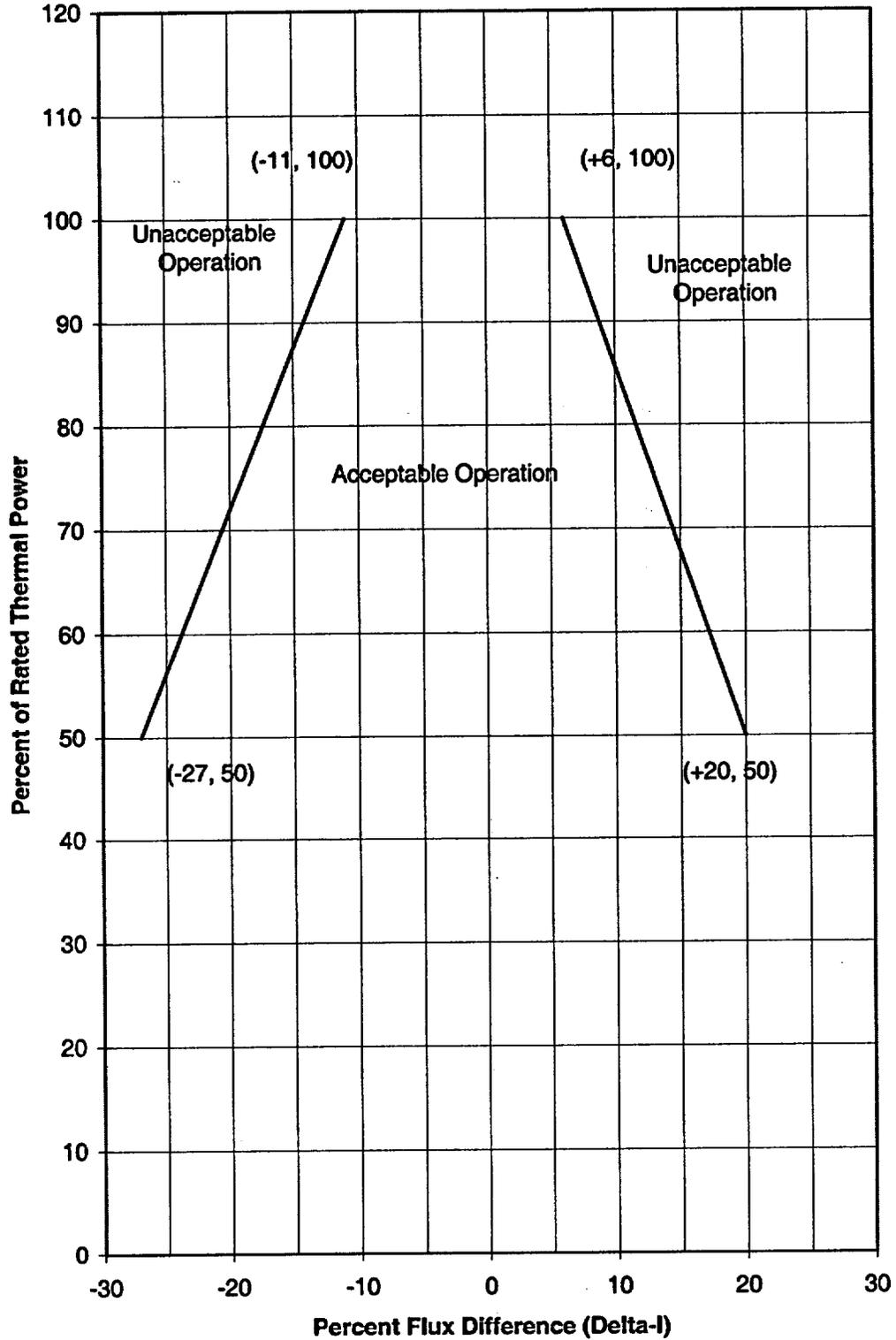
COLR Figure 3.2-3

**N2C16 Axial Flux Difference Limits  
5000 MWD/MTU to EOR**



COLR Figure 3.2-4

**N2C16 Axial Flux Difference Limits  
EOR to EOC (Coastdown)**



### 3.3 INSTRUMENTATION

#### 3.3.1 Reactor Trip System (RTS) Instrumentation

##### TS Table 3.3.1-1 Note 1: Overtemperature $\Delta T$

The Overtemperature  $\Delta T$  Function Allowable Value shall not exceed the following nominal trip setpoint by more than 2% of  $\Delta T$  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:  $\Delta T$  is measured RCS  $\Delta T$ ,  $^{\circ}\text{F}$ .

$\Delta T_0$  is the indicated  $\Delta T$  at RTP,  $^{\circ}\text{F}$ .

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

$T$  is the measured RCS average temperature,  $^{\circ}\text{F}$ .

$T'$  is the nominal  $T_{\text{avg}}$  at RTP,  $\leq 586.8$   $^{\circ}\text{F}$ .

$P$  is the measured pressurizer pressure, psig.

$P'$  is the nominal RCS operating pressure,  $\geq 2235$  psig.

$$K_1 \leq 1.2715$$

$$K_2 \geq 0.02172 \text{ } ^{\circ}\text{F}$$

$$K_3 \geq 0.001144 \text{ /psig}$$

$\tau_1, \tau_2 =$  time constants utilized in the lead-lag controller for  $T_{\text{avg}}$

$$\tau_1 \geq 23.75 \text{ sec}$$

$$\tau_2 \leq 4.4 \text{ sec}$$

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

$$f_1(\Delta I) \geq \begin{cases} 0.0165 \{-44 - (q_t - q_b)\} & \text{when } (q_t - q_b) < -44\% \text{ RTP} \\ 0 & \text{when } -44\% \text{ RTP} \leq (q_t - q_b) \leq +3\% \text{ RTP} \\ 0.0198 \{(q_t - q_b) - 3\} & \text{when } (q_t - q_b) > +3\% \text{ RTP} \end{cases}$$

[See footnote]<sup>#</sup>

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.

<sup>#</sup> Footnote: The units for  $f_1(\Delta I) = 0$  in the North Anna TS and NUREG-1431 are incorrectly specified as "% of RTP."  $f_1(\Delta I)$  being dimensionless should have no units. This discrepancy is being addressed by the North Anna Corrective Action System.

TS Table 3.3.1-1 Note 2: Overpower  $\Delta T$

The Overpower  $\Delta T$  Function Allowable Value shall not exceed the following nominal trip setpoint by more than 2% of  $\Delta T$  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:  $\Delta T$  is measured RCS  $\Delta T$ ,  $^{\circ}\text{F}$ .

$\Delta T_0$  is the indicated  $\Delta T$  at RTP,  $^{\circ}\text{F}$ .

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

$T$  is the measured RCS average temperature,  $^{\circ}\text{F}$ .

$T'$  is the nominal  $T_{\text{avg}}$  at RTP,  $\leq 586.8$   $^{\circ}\text{F}$ .

$$K_4 \leq 1.0865$$

$$K_5 \geq 0.0197 \text{ } ^{\circ}\text{F} \text{ for increasing } T_{\text{avg}}$$

$$0 \text{ } ^{\circ}\text{F} \text{ for decreasing } T_{\text{avg}}$$

$$K_6 \geq 0.00162 \text{ } ^{\circ}\text{F} \text{ when } T > T'$$

$$0 \text{ } ^{\circ}\text{F} \text{ when } T \leq T'$$

$\tau_3$  = time constant utilized in the rate lag controller for  $T_{\text{avg}}$

$$\tau_3 \geq 9.5 \text{ sec}$$

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

$$f_2(\Delta I) = 0, \text{ for all } \Delta I.$$

**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  $\geq 1.77$  %  $\Delta k/k$  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  $\geq 2600$  ppm.

*Note: The refueling boron concentration satisfies the more restrictive of the following conditions: (a)  $k_{eff} \leq 0.95$ , or (b) boron concentration  $\geq 2600$  ppm.*

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

**NAPS TECHNICAL REQUIREMENTS MANUAL**

**TRM 3.1 REACTIVITY CONTROL SYSTEMS**

**TR 3.1.1 Boration Flow Paths – Operating**

**Required Action E.2      Borate to a SHUTDOWN MARGIN  $\geq 1.77\%$   $\Delta k/k$  at 200 °F,  
after xenon decay.**