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October 23, 2009
BW090111

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

Braidwood Station, Unit 2
Facility Operating License No. NPF-77
NRC Docket No. STN 50-457

Subject: Core Operating Limits Report, Braidwood Unit 2 Cycle 15

The purpose of this letter is to transmit the Core Operating Limits Report (COLR) for Braidwood Unit 2 Cycle 15, in accordance with Technical Specification 5.6.5, "Core Operating Limits Report (COLR)." Braidwood Unit 2 Cycle 15 COLR, Revision 4 was implemented during Braidwood Unit 2 Refueling Outage 14 in support of Cycle 15 operation. Note that Revision 4 is the original version of the Braidwood Unit 2 Cycle 15 COLR implemented in support of Cycle 15 operation. The revision number is based on a numbering convention that continues from the previous revision of the Unit 2 COLR, i.e., Braidwood Unit 2 Cycle 14 COLR, Revision 3.

If you have any questions regarding this matter, please contact Mr. David Gullott, Regulatory Assurance Manager, at (815) 417-2800.

Sincerely,



Amir Shahkarami
Site Vice President
Braidwood Station

Attachment: Core Operating Limits Report, Braidwood Unit 2 Cycle 15, Revision 4

cc: NRC Regional Administrator, Region III
NRC Senior Resident Inspector – Braidwood Station

ATTACHMENT

Core Operating Limits Report

Braidwood Unit 2 Cycle 15

Revision 4

CORE OPERATING LIMITS REPORT (COLR)

FOR

BRAIDWOOD UNIT 2 CYCLE 15

EXELON TRACKING ID:

COLR BRAIDWOOD 2 REVISION 4

CORE OPERATING LIMITS REPORT (COLR) for BRAIDWOOD UNIT 2 CYCLE 15

1.0 CORE OPERATING LIMITS REPORT

This Core Operating Limits Report (COLR) for Braidwood Station Unit 2 Cycle 15 has been prepared in accordance with the requirements of Technical Specification 5.6.5 (ITS).

The Technical Specifications affected by this report are listed below:

- SL 2.1.1 Reactor Core Safety Limits (SLs)
- LCO 3.1.1 SHUTDOWN MARGIN (SDM)
- LCO 3.1.3 Moderator Temperature Coefficient (MTC)
- LCO 3.1.4 Rod Group Alignment Limits
- LCO 3.1.5 Shutdown Bank Insertion Limits
- LCO 3.1.6 Control Bank Insertion Limits
- LCO 3.1.8 PHYSICS TESTS Exceptions – MODE 2
- LCO 3.2.1 Heat Flux Hot Channel Factor ($F_Q(Z)$)
- LCO 3.2.2 Nuclear Enthalpy Rise Hot Channel Factor ($F_{\Delta H}^N$)
- LCO 3.2.3 AXIAL FLUX DIFFERENCE (AFD)
- LCO 3.2.5 Departure from Nucleate Boiling Ratio (DNBR)
- LCO 3.3.1 Reactor Trip System (RTS) Instrumentation
- LCO 3.3.9 Boron Dilution Protection System (BDPS)
- LCO 3.4.1 Reactor Coolant System (RCS) Pressure, Temperature, and Flow Departure from Nucleate Boiling (DNB) Limits
- LCO 3.9.1 Boron Concentration

The portions of the Technical Requirements Manual affected by this report are listed below:

- TRM TLCO 3.1.b Boration Flow Paths – Operating
- TRM TLCO 3.1.d Charging Pumps – Operating
- TRM TLCO 3.1.f Borated Water Sources – Operating
- TRM TLCO 3.1.g Position Indication System – Shutdown
- TRM TLCO 3.1.h Shutdown Margin (SDM) – MODE 1 and MODE 2 with $k_{eff} \geq 1.0$
- TRM TLCO 3.1.i Shutdown Margin (SDM) – MODE 5
- TRM TLCO 3.1.j Shutdown and Control Rods
- TRM TLCO 3.1.k Position Indication System – Shutdown (Special Test Exception)

CORE OPERATING LIMITS REPORT (COLR) for BRAIDWOOD UNIT 2 CYCLE 15

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 are applicable for the entire cycle unless otherwise identified. These limits have been developed using the NRC-approved methodologies specified in Technical Specification 5.6.5.

2.1 Reactor Core Safety Limits (SLs) (SL 2.1.1)

2.1.1 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 Figure 2.1.1.

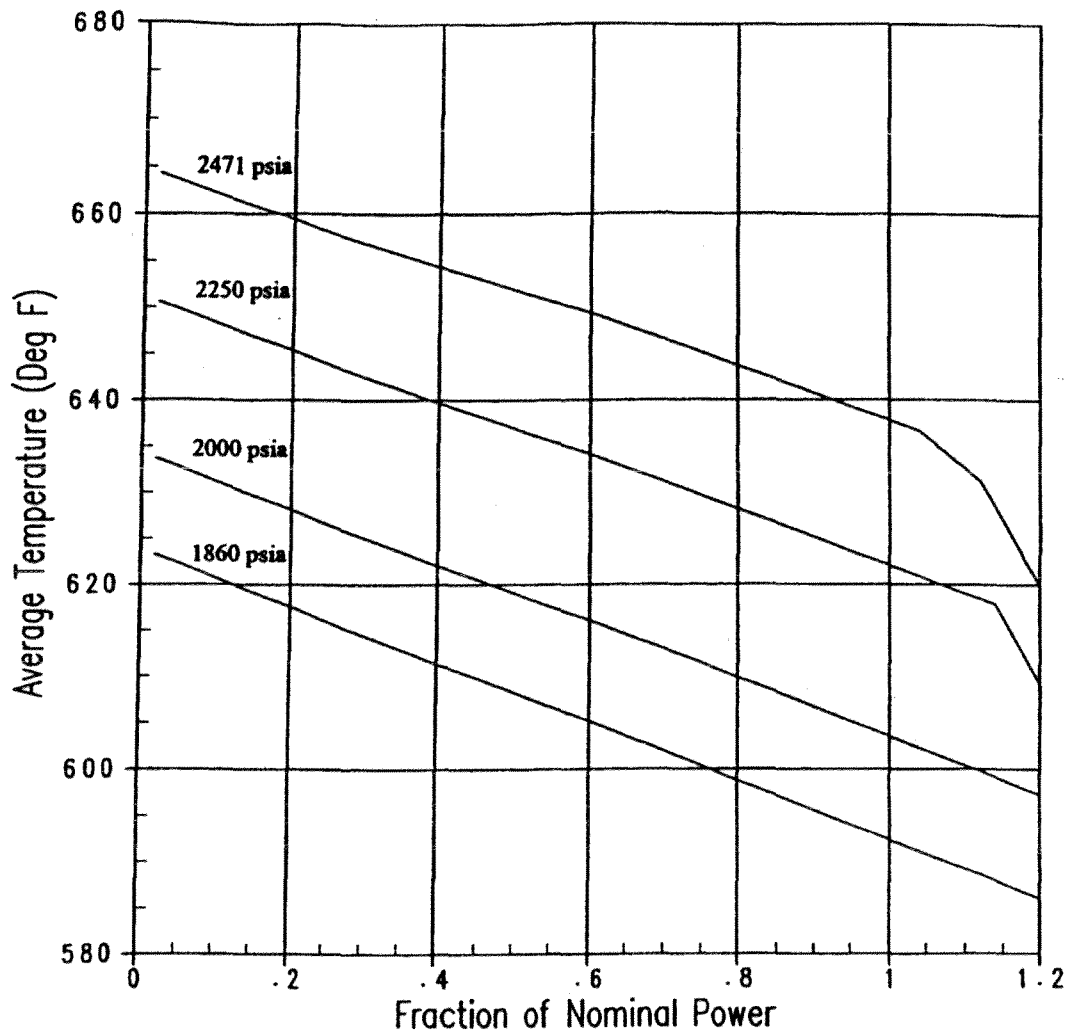


Figure 2.1.1: Reactor Core Limits

CORE OPERATING LIMITS REPORT (COLR) for BRAIDWOOD UNIT 2 CYCLE 15

2.2 SHUTDOWN MARGIN (SDM)

The SDM limit for MODES 1, 2, 3, and 4 is:

2.2.1 The SDM shall be greater than or equal to 1.3% $\Delta k/k$ (LCOs 3.1.1, 3.1.4, 3.1.5, 3.1.6, 3.1.8, 3.3.9; TRM TLCOs 3.1.b, 3.1.d, 3.1.f, 3.1.h, and 3.1.j).

The SDM limit for MODE 5 is:

2.2.2 SDM shall be greater than or equal to 1.3% $\Delta k/k$ (LCO 3.1.1, LCO 3.3.9; TRM TLCOs 3.1.i and 3.1.j).

2.3 Moderator Temperature Coefficient (MTC) (LCO 3.1.3)

The Moderator Temperature Coefficient (MTC) limits are:

2.3.1 The BOL/ARO/HZP-MTC upper limit shall be $+1.501 \times 10^{-5} \Delta k/k/^\circ F$.

2.3.2 The EOL/ARO/HFP-MTC lower limit shall be $-4.6 \times 10^{-4} \Delta k/k/^\circ F$.

2.3.3 The EOL/ARO/HFP-MTC Surveillance limit at 300 ppm shall be $-3.7 \times 10^{-4} \Delta k/k/^\circ F$.

2.3.4 The EOL/ARO/HFP-MTC Surveillance limit at 60 ppm shall be $-4.3 \times 10^{-4} \Delta k/k/^\circ F$.

where: BOL stands for Beginning of Cycle Life
ARO stands for All Rods Out
HZP stands for Hot Zero Thermal Power
EOL stands for End of Cycle Life
HFP stands for Hot Full Thermal Power

2.4 Shutdown Bank Insertion Limits (LCO 3.1.5)

2.4.1 All shutdown banks shall be fully withdrawn to at least 224 steps.

2.5 Control Bank Insertion Limits (LCO 3.1.6)

2.5.1 The control banks, with Bank A greater than or equal to 224 steps, shall be limited in physical insertion as shown in Figure 2.5.1.

2.5.2 Each control bank shall be considered fully withdrawn from the core at greater than or equal to 224 steps.

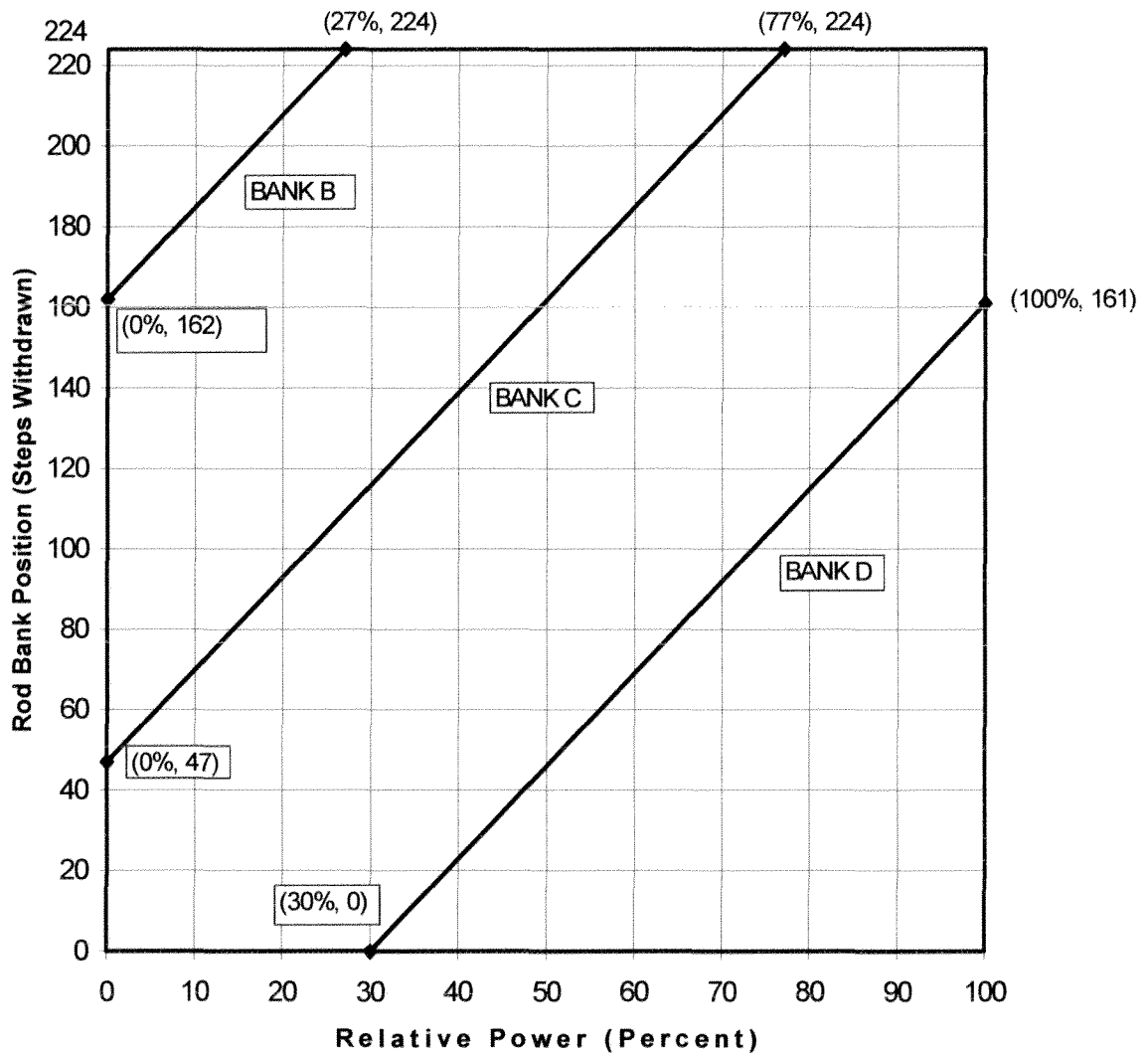
2.5.3 The control banks shall be operated in sequence by withdrawal of Bank A, Bank B, Bank C and Bank D. The control banks shall be sequenced in reverse order upon insertion.

2.5.4 Each control bank not fully withdrawn from the core shall be operated with the following overlap limits as a function of park position:

| Park Position (step) | Overlap Limit (step) |
|----------------------|----------------------|
| 226 | 111 |
| 227 | 112 |
| 228 | 113 |
| 229 | 114 |

CORE OPERATING LIMITS REPORT (COLR) for BRAIDWOOD UNIT 2 CYCLE 15

Figure 2.5.1:
Control Bank Insertion Limits Versus Percent Rated Thermal Power



CORE OPERATING LIMITS REPORT (COLR) for BRAIDWOOD UNIT 2 CYCLE 15

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

2.6.1 Total Peaking Factor:

$$F_Q(Z) \leq \frac{F_Q^{RTP}}{0.5} \times K(Z) \quad \text{for } P \leq 0.5$$

$$F_Q(Z) \leq \frac{F_Q^{RTP}}{P} \times K(Z) \quad \text{for } P > 0.5$$

where: P = the ratio of THERMAL POWER to RATED THERMAL POWER

$$F_Q^{RTP} = 2.60$$

K(Z) is provided in Figure 2.6.1.

2.6.2 W(Z) Values:

a) When PDMS is OPERABLE, W(Z) = 1.00000 for all axial points.

b) When PDMS is inoperable, W(Z) is provided in Table 2.6.2.a.

The normal operation W(Z) values have been determined at burnups of 150, 6000, 14000, and 20000 MWD/MTU.

Table 2.6.2.b shows the $F_Q^C(z)$ penalty factors that are greater than 2% per 31 Effective Full Power Days (EFPD). These values shall be used to increase the $F_Q^W(z)$ as per Surveillance Requirement 3.2.1.2. A 2% penalty factor shall be used at all cycle burnups that are outside the range of Table 2.6.2.b.

2.6.3 Uncertainty:

The uncertainty, U_{FQ} , to be applied to the Heat Flux Hot Channel Factor $F_Q(Z)$ shall be calculated by the following formula

$$U_{FQ} = U_{qu} \cdot U_e$$

where:

U_{qu} = Base F_Q measurement uncertainty = 1.05 when PDMS is inoperable
(U_{qu} is defined by PDMS when OPERABLE.)

U_e = Engineering uncertainty factor = 1.03

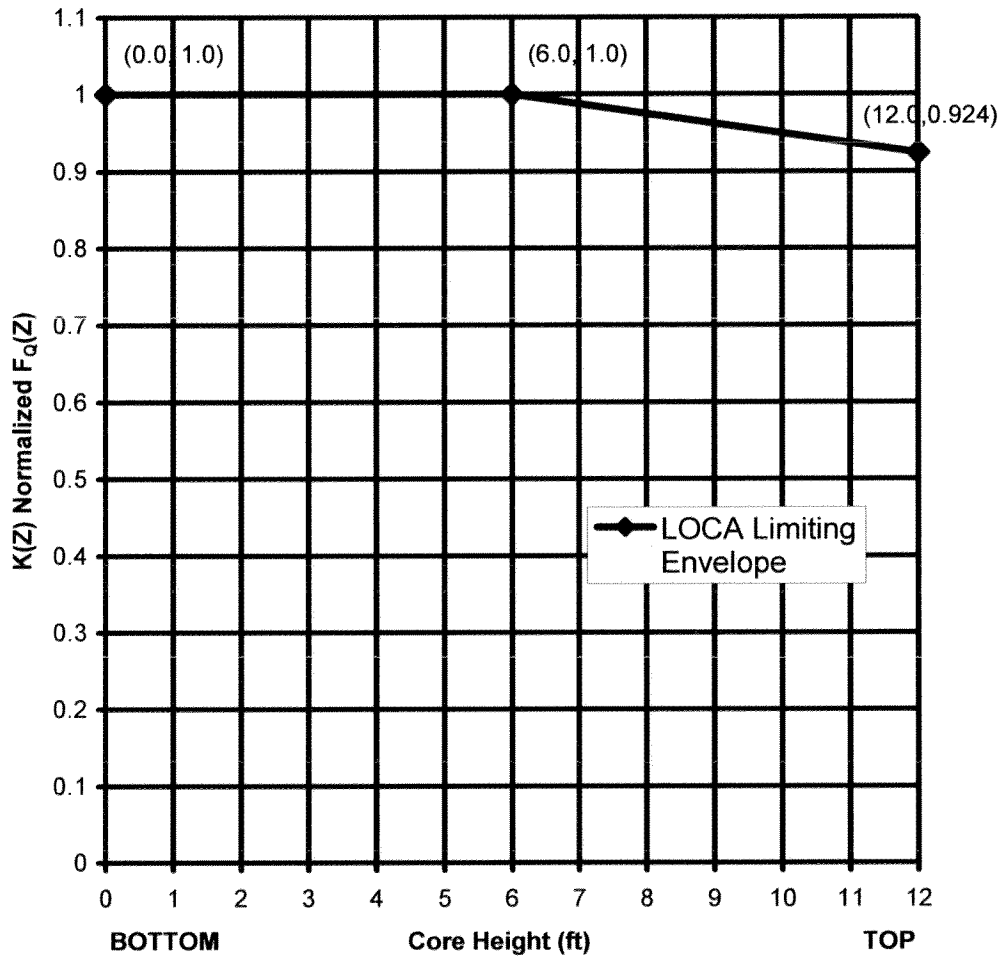
2.6.4 PDMS Alarms:

$F_Q(Z)$ Warning Setpoint = 2% of $F_Q(Z)$ Margin

$F_Q(Z)$ Alarm Setpoint = 0% of $F_Q(Z)$ Margin

CORE OPERATING LIMITS REPORT (COLR) for BRAIDWOOD UNIT 2 CYCLE 15

Figure 2.6.1
K(Z) - Normalized $F_q(Z)$ as a Function of Core Height



CORE OPERATING LIMITS REPORT (COLR) for BRAIDWOOD UNIT 2 CYCLE 15

| Table 2.6.2.a | | | | |
|---|-------------|--------------|---------------|---------------|
| W(Z) versus Core Height | | | | |
| (Top and Bottom 8% Excluded per WCAP-10216) | | | | |
| Height (feet) | 150 MWD/MTU | 6000 MWD/MTU | 14000 MWD/MTU | 20000 MWD/MTU |
| 0.00 (core bottom) | 1.2899 | 1.4576 | 1.4652 | 1.3512 |
| 0.20 | 1.2742 | 1.4271 | 1.4373 | 1.3481 |
| 0.40 | 1.2648 | 1.4103 | 1.4203 | 1.3390 |
| 0.60 | 1.2580 | 1.3955 | 1.4043 | 1.3342 |
| 0.80 | 1.2536 | 1.3734 | 1.3803 | 1.3287 |
| 1.00 | 1.2503 | 1.3558 | 1.3637 | 1.3233 |
| 1.20 | 1.2314 | 1.3356 | 1.3349 | 1.3141 |
| 1.40 | 1.2358 | 1.3289 | 1.3186 | 1.3056 |
| 1.60 | 1.2411 | 1.3107 | 1.3015 | 1.2924 |
| 1.80 | 1.2383 | 1.2865 | 1.2884 | 1.2815 |
| 2.00 | 1.2237 | 1.2630 | 1.2723 | 1.2686 |
| 2.20 | 1.2067 | 1.2417 | 1.2553 | 1.2492 |
| 2.40 | 1.1911 | 1.2180 | 1.2380 | 1.2345 |
| 2.60 | 1.1743 | 1.1967 | 1.2254 | 1.2155 |
| 2.80 | 1.1694 | 1.1897 | 1.2157 | 1.1992 |
| 3.00 | 1.1630 | 1.1850 | 1.2074 | 1.1873 |
| 3.20 | 1.1559 | 1.1790 | 1.1992 | 1.1726 |
| 3.40 | 1.1478 | 1.1743 | 1.1905 | 1.1629 |
| 3.60 | 1.1419 | 1.1677 | 1.1797 | 1.1674 |
| 3.80 | 1.1364 | 1.1615 | 1.1698 | 1.1707 |
| 4.00 | 1.1323 | 1.1550 | 1.1640 | 1.1740 |
| 4.20 | 1.1337 | 1.1459 | 1.1587 | 1.1750 |
| 4.40 | 1.1352 | 1.1383 | 1.1532 | 1.1778 |
| 4.60 | 1.1350 | 1.1279 | 1.1461 | 1.1884 |
| 4.80 | 1.1347 | 1.1189 | 1.1390 | 1.1980 |
| 5.00 | 1.1330 | 1.1091 | 1.1299 | 1.2055 |
| 5.20 | 1.1294 | 1.1028 | 1.1321 | 1.2092 |
| 5.40 | 1.1255 | 1.0989 | 1.1350 | 1.2139 |
| 5.60 | 1.1247 | 1.0950 | 1.1369 | 1.2230 |
| 5.80 | 1.1319 | 1.0971 | 1.1524 | 1.2427 |
| 6.00 | 1.1381 | 1.1056 | 1.1666 | 1.2578 |
| 6.20 | 1.1436 | 1.1121 | 1.1787 | 1.2699 |
| 6.40 | 1.1481 | 1.1195 | 1.1901 | 1.2777 |
| 6.60 | 1.1506 | 1.1248 | 1.1977 | 1.2822 |
| 6.80 | 1.1522 | 1.1291 | 1.2045 | 1.2840 |
| 7.00 | 1.1530 | 1.1342 | 1.2085 | 1.2814 |
| 7.20 | 1.1524 | 1.1412 | 1.2097 | 1.2720 |
| 7.40 | 1.1557 | 1.1502 | 1.2086 | 1.2630 |
| 7.60 | 1.1594 | 1.1579 | 1.2036 | 1.2485 |
| 7.80 | 1.1636 | 1.1668 | 1.1976 | 1.2327 |
| 8.00 | 1.1717 | 1.1742 | 1.1896 | 1.2155 |
| 8.20 | 1.1779 | 1.1791 | 1.1787 | 1.1924 |
| 8.40 | 1.1838 | 1.1860 | 1.1670 | 1.1728 |
| 8.60 | 1.1879 | 1.1958 | 1.1526 | 1.1577 |
| 8.80 | 1.1961 | 1.2063 | 1.1411 | 1.1462 |
| 9.00 | 1.2056 | 1.2246 | 1.1397 | 1.1356 |
| 9.20 | 1.2111 | 1.2417 | 1.1388 | 1.1533 |
| 9.40 | 1.2114 | 1.2569 | 1.1370 | 1.1808 |
| 9.60 | 1.2160 | 1.2711 | 1.1599 | 1.2245 |
| 9.80 | 1.2195 | 1.2804 | 1.1952 | 1.2624 |
| 10.00 | 1.2238 | 1.2863 | 1.2254 | 1.2965 |
| 10.20 | 1.2276 | 1.2874 | 1.2585 | 1.3265 |
| 10.40 | 1.2311 | 1.2887 | 1.2793 | 1.3519 |
| 10.60 | 1.2332 | 1.2858 | 1.2991 | 1.3714 |
| 10.80 | 1.2394 | 1.2873 | 1.3071 | 1.3887 |
| 11.00 | 1.2484 | 1.2957 | 1.3058 | 1.4047 |
| 11.20 | 1.2438 | 1.3185 | 1.3027 | 1.3987 |
| 11.40 | 1.2473 | 1.3199 | 1.3047 | 1.3936 |
| 11.60 | 1.2496 | 1.3367 | 1.2869 | 1.3904 |
| 11.80 | 1.2549 | 1.3464 | 1.2746 | 1.3860 |
| 12.00 (core top) | 1.2632 | 1.3605 | 1.2763 | 1.3873 |

Note: W(Z) values at 20000 MWD/MTU may be applied to cycle burnups greater than 20000 MWD/MTU to prevent W(Z) function extrapolation

CORE OPERATING LIMITS REPORT (COLR) for BRAIDWOOD UNIT 2 CYCLE 15

| Table 2.6.2.b Penalty Factors in Excess of 2% per 31 EFPD | |
|--|-------------------------------------|
| Cycle Burnup (MWD/MTU) | Penalty Factor $F^C_{\alpha}(z)$ |
| 323 | 1.0200 |
| 496 | 1.0242 |
| 669 | 1.0320 |
| 842 | 1.0393 |
| 1015 | 1.0435 |
| 1187 | 1.0452 |
| 1360 | 1.0454 |
| 1533 | 1.0434 |
| 1706 | 1.0404 |
| 1879 | 1.0364 |
| 2052 | 1.0320 |
| 2225 | 1.0277 |
| 2398 | 1.0238 |
| 2571 | 1.0206 |
| 2744 | 1.0200 |

Notes:

Linear interpolation is adequate for intermediate cycle burnups.

All cycle burnups outside the range of the table shall use a 2% penalty factor for compliance with the 3.2.1.2 Surveillance Requirements.

CORE OPERATING LIMITS REPORT (COLR) for BRAIDWOOD UNIT 2 CYCLE 15

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

2.7.1 $F_{\Delta H}^N \leq F_{\Delta H}^{RTP} [1.0 + PF_{\Delta H}(1.0 - P)]$

where: P = the ratio of THERMAL POWER to RATED THERMAL POWER

$F_{\Delta H}^{RTP} = 1.70$

$PF_{\Delta H} = 0.3$

2.7.2 Uncertainty when PDMS is inoperable

The uncertainty, $U_{F_{\Delta H}}$, to be applied to the Nuclear Enthalpy Rise Hot Channel Factor $F_{\Delta H}^N$ shall be calculated by the following formula:

$U_{F_{\Delta H}} = U_{F_{\Delta Hm}}$

where:

$U_{F_{\Delta Hm}} = \text{Base } F_{\Delta H}^N \text{ measurement uncertainty} = 1.04$

2.7.3 PDMS Alarms:

$F_{\Delta H}^N$ Warning Setpoint = 2% of $F_{\Delta H}^N$ Margin

$F_{\Delta H}^N$ Alarm Setpoint = 0% of $F_{\Delta H}^N$ Margin

2.8 AXIAL FLUX DIFFERENCE (AFD) (LCO 3.2.3)

2.8.1 When PDMS is inoperable, the AXIAL FLUX DIFFERENCE (AFD) Acceptable Operation Limits are provided in Figure 2.8.1 or the latest valid PDMS Surveillance Report, whichever is more conservative.

2.8.2 When PDMS is OPERABLE, no AFD Acceptable Operation Limits are applicable.

2.9 Departure from Nucleate Boiling Ratio (DNBR) (LCO 3.2.5)

2.9.1 $DNBR_{APSL} \geq 1.536$

The Axial Power Shape Limiting DNBR ($DNBR_{APSL}$) is applicable with THERMAL POWER $\geq 50\%$ RTP when PDMS is OPERABLE.

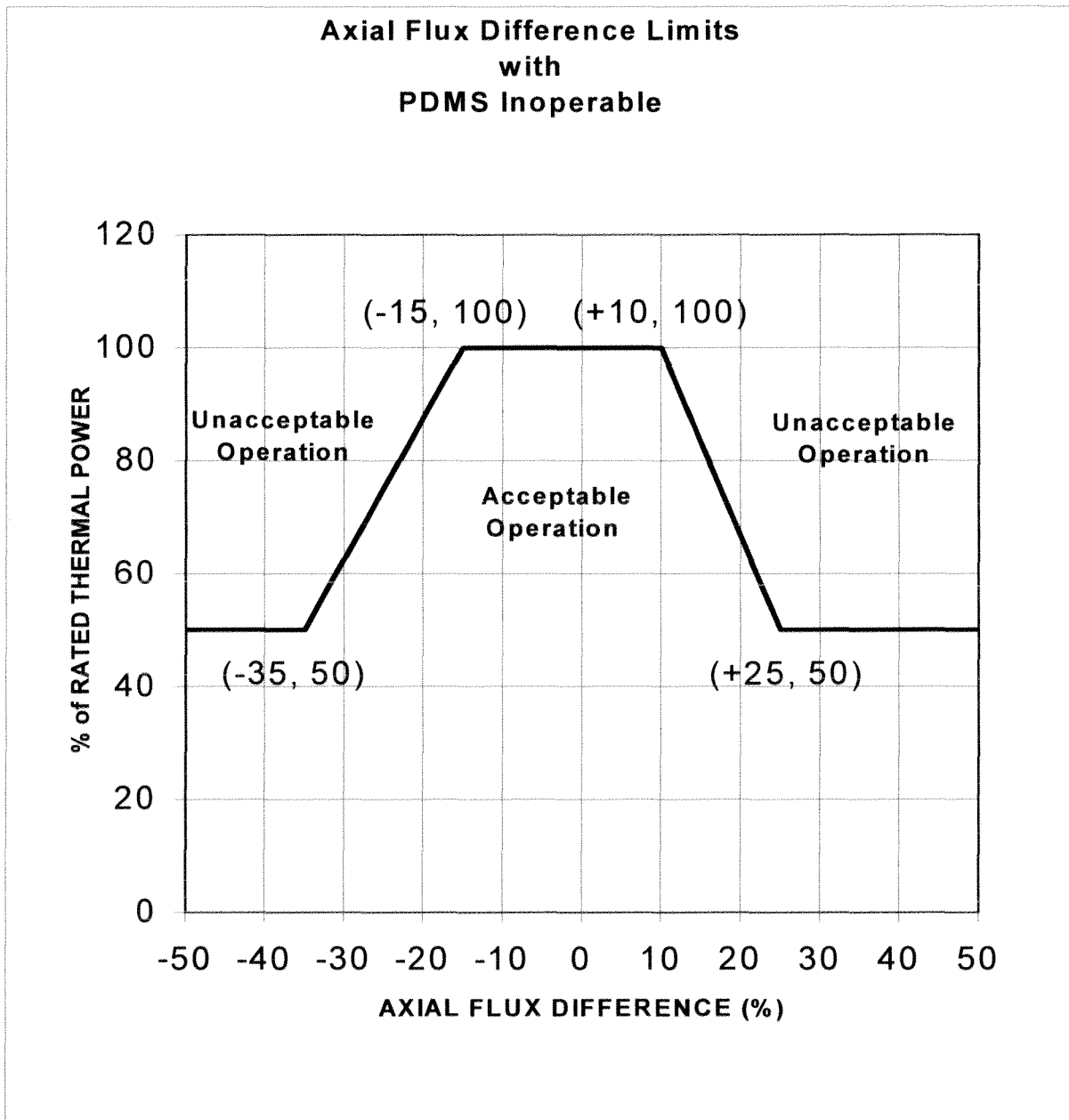
2.9.2 PDMS Alarms:

DNBR Warning Setpoint = 2% of DNBR Margin

DNBR Alarm Setpoint = 0% of DNBR Margin

CORE OPERATING LIMITS REPORT (COLR) for BRAIDWOOD UNIT 2 CYCLE 15

Figure 2.8.1 Axial Flux Difference Limits as a Function of Rated Thermal Power



CORE OPERATING LIMITS REPORT (COLR) for BRAIDWOOD UNIT 2 CYCLE 15

- 2.10 Reactor Trip System (RTS) Instrumentation (LCO 3.3.1) - Overtemperature ΔT Setpoint Parameter Values
- 2.10.1 The Overtemperature ΔT reactor trip setpoint K_1 shall be equal to 1.325.
 - 2.10.2 The Overtemperature ΔT reactor trip setpoint T_{avg} coefficient K_2 shall be equal to 0.0297 / °F.
 - 2.10.3 The Overtemperature ΔT reactor trip setpoint pressure coefficient K_3 shall be equal to 0.00181 / psi.
 - 2.10.4 The nominal T_{avg} at RTP (indicated) T' shall be less than or equal to 588.0 °F.
 - 2.10.5 The nominal RCS operating pressure (indicated) P' shall be equal to 2235 psig.
 - 2.10.6 The measured reactor vessel ΔT lead/lag time constant τ_1 shall be equal to 8 sec.
 - 2.10.7 The measured reactor vessel ΔT lead/lag time constant τ_2 shall be equal to 3 sec.
 - 2.10.8 The measured reactor vessel ΔT lag time constant τ_3 shall be less than or equal to 2 sec.
 - 2.10.9 The measured reactor vessel average temperature lead/lag time constant τ_4 shall be equal to 33 sec.
 - 2.10.10 The measured reactor vessel average temperature lead/lag time constant τ_5 shall be equal to 4 sec.
 - 2.10.11 The measured reactor vessel average temperature lag time constant τ_6 shall be less than or equal to 2 sec.
 - 2.10.12 The $f_1 (\Delta I)$ "positive" breakpoint shall be +10% ΔI .
 - 2.10.13 The $f_1 (\Delta I)$ "negative" breakpoint shall be -18% ΔI .
 - 2.10.14 The $f_1 (\Delta I)$ "positive" slope shall be +3.47% / % ΔI .
 - 2.10.15 The $f_1 (\Delta I)$ "negative" slope shall be -2.61% / % ΔI .

CORE OPERATING LIMITS REPORT (COLR) for BRAIDWOOD UNIT 2 CYCLE 15

- 2.11 Reactor Trip System (RTS) Instrumentation (LCO 3.3.1) - Overpower ΔT Setpoint Parameter Values
- 2.11.1 The Overpower ΔT reactor trip setpoint K_4 shall be equal to 1.072.
 - 2.11.2 The Overpower ΔT reactor trip setpoint T_{avg} rate/lag coefficient K_5 shall be equal to 0.02 / °F for increasing T_{avg} .
 - 2.11.3 The Overpower ΔT reactor trip setpoint T_{avg} rate/lag coefficient K_5 shall be equal to 0 / °F for decreasing T_{avg} .
 - 2.11.4 The Overpower ΔT reactor trip setpoint T_{avg} heatup coefficient K_6 shall be equal to 0.00245 / °F when $T > T''$.
 - 2.11.5 The Overpower ΔT reactor trip setpoint T_{avg} heatup coefficient K_6 shall be equal to 0 / °F when $T \leq T''$.
 - 2.11.6 The nominal T_{avg} at RTP (indicated) T'' shall be less than or equal to 588.0 °F
 - 2.11.7 The measured reactor vessel ΔT lead/lag time constant τ_1 shall be equal to 8 sec.
 - 2.11.8 The measured reactor vessel ΔT lead/lag time constant τ_2 shall be equal to 3 sec.
 - 2.11.9 The measured reactor vessel ΔT lag time constant τ_3 shall be less than or equal to 2 sec.
 - 2.11.10 The measured reactor vessel average temperature lag time constant τ_6 shall be less than or equal to 2 sec.
 - 2.11.11 The measured reactor vessel average temperature rate/lag time constant τ_7 shall be equal to 10 sec.
 - 2.11.12 The $f_2(\Delta I)$ "positive" breakpoint shall be 0 for all ΔI .
 - 2.11.13 The $f_2(\Delta I)$ "negative" breakpoint shall be 0 for all ΔI .
 - 2.11.14 The $f_2(\Delta I)$ "positive" slope shall be 0 for all ΔI .
 - 2.11.15 The $f_2(\Delta I)$ "negative" slope shall be 0 for all ΔI .

CORE OPERATING LIMITS REPORT (COLR) for BRAIDWOOD UNIT 2 CYCLE 15

2.12 Reactor Coolant System (RCS) Pressure, Temperature, and Flow Departure from Nucleate Boiling (DNB) Limits (LCO 3.4.1)

2.12.1 The pressurizer pressure shall be greater than or equal to 2209 psig.

2.12.2 The RCS average temperature (T_{avg}) shall be less than or equal to 593.1 °F.

2.12.3 The RCS total flow rate shall be greater than or equal to 386,000 gpm.

2.13 Boron Concentration

2.13.1 The refueling boron concentration shall be greater than or equal to the value given in the Table below (LCO 3.9.1). The reported value also bounds the end-of-cycle requirements for the previous cycle.

2.13.2 To maintain $keff \leq 0.987$ with all shutdown and control rods fully withdrawn in MODES 3, 4, or 5 (TRM TLCO 3.1.g Required Action B.2 and TRM TLCO 3.1.k.2), the Reactor Coolant System boron concentration shall be greater than or equal to the values given in the Table below.

| COLR Section | Conditions | Boron Concentration (ppm) |
|--------------|---------------------------------|---------------------------|
| 2.13.1 | Refueling | 1682 |
| 2.13.2 | a) prior to initial criticality | 1730 |
| 2.13.2 | b) all other times in life | 1968 |