Report No. NET-085-02-NP
Revision 1

Extended RPI Deviation Limits

and

On-Line Calibration of the RPI Channels

for

Indian Point Unit No. 2

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of

New York

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1.0 INTRODUCTION

The rod position indicator (RPI) system at Indian Point Unit No. 2 (IP2) provides the reactor operator with knowledge of the actual position (axial elevation) of each rod cluster control assembly (RCCA) relative to the bank demand position. The current Plant Technical Specification[1] (TS) for IP2 permits deviations of ±12 steps (± 7.5 inches) between the RPI channel output and the bank demand position over most of the range from fully inserted to fully withdrawn. Near the fully withdrawn position, the current TS allows an additional deviation of -12 to +17 steps as described in Section 2.0.

During plant startup, particularly from the cold condition, the RPI channels may be subject to instabilities and drift until the control rod drive assemblies come to thermal equilibrium at operating temperature. One consequence of these thermal instabilities can be spurious indications that RCCAs are misaligned from the bank demand position. Such deviations are termed spurious as there is no actual deviation between the actual RCCA position and the bank demand position.

Where such spurious deviations indicate that there is more than a ± 12 step misalignment between the indicated RCCA position and the bank demand position in more than one channel per RCCA group or two channels per RCCA bank, the current TS requires that the reactor be brought subcritical and the deviating RPI channels recalibrated. This process involves fully inserting RCCAs followed by withdrawal of the RCCAs with deviating RPIs. During withdrawal, the RPI signal (voltage) is measured and recorded as a function of RCCA position. This process can substantially delay the return to power operation and can impact the availability of the station. The costs, in terms of lost generating capacity are significant due to the current requirements for RPI calibration.

To mitigate this problem, a procedure has been developed to allow the on-line (at power levels below rated power) calibration of deviating RPI channels. A United States Patent has been granted to Dr. A. Ginsberg and Mr. J. Mooney, employees of Consolidated Edison[2], which sets forth a procedure allowing on-line calibration of the RPI channels. The patent further establishes a basis for extending the allowable deviation band of ±12 steps.

This report descibes analyses and evaluations which have been conducted to demonstrate the application of an extended RPI deviation band as well as on-line calibration of the RPI channels. Specifically, a NODE-P2 model of the IP2 core has been used to calculate the impact on core peaking factors with the RPI deviation band extended. The calculated core peaking factors are compared with limits imposed by the IP2 TS, and it is concluded that the RPI deviation band can be [.]

Similarly, the NODE-P2 model has been applied to calculate core peaking factors during on-line calibration of the RPI channels. The calculated values were then compared with the IP2 TS limits at the appropriate intermediate power level. This analyses demonstrates that on-line calibration exercises are acceptable provided they are initiated from [.]

To assure that on-line calibration activities will not adversely affect fuel reliability, fuel rod thermal mechanical duty during on-line calibration has been evaluated and assessed. This evaluation has used the FRAPCON computer code to model those fuel rods which are subject to the greatest power cycling during RCCA insertion and withdrawal. These analyses have demonstrated that on-line calibration of the RPI channels will have an insignificant impact on fuel rod thermal mechanical duty.

All postulated plant accidents and transients described in Chapter 14 of the IP2 FSAR have been reviewed and evaluated. This review focused on the potential consequences of each accident and transient in the event it were initiated during on-line RPI channel calibration. It has been concluded that on-line calibration of the RPI channels will not result in consequences of postulated transients and accidents more severe than those analyzed in Chapter 14 of the IP2 FSAR.

The following sections of this report describe the analyses and evaluation conducted in support of the license amendment request to permit the extended RPI deviation band, and on-line RPI channel calibration, at IP2. These analyses and evaluations demonstrate that the extended RPI deviation band and on-line RPI channel calibration will not result in any unreviewed safety questions.

The results are given for Cycle 11 and Cycle 12 of Indian Point 2. Limiting power levels have been established based on Cycle 12. Cycle 12 is considered typical of a long fuel cycle and hence it is believed that it is limiting. However, each reload must be evaluated to determine whether the power limits as specified in the Core Operating Limits Report (COLR) must be adjusted.

2.0 BACKGROUND

This section contains a brief description of the IP-2 rod position indicator system and the PTS limits which are potentially impacted by RPI deviations and on-line recalibration of the RPI channels. This material provides the reader with the required background for interpreting the methods and approaches discussed in subsequent sections of this report.

2.1 Rod Position Indicators and RCCA Configuration

The Rod Position Indicator (RPI) system at Indian Point Unit 2 is designed to indicate the actual position of each of the Rod Cluster Control Assemblies (RCCAs) in the core. When a RPI produces a signal indicating a RCCA is at 0 steps, the RCCA is fully inserted in the core. When the RPI registers an equivalent of 225 steps, the RCCA is fully withdrawn from the core.

The IP-2 core contains 53 RCCAs which are referred to as either RCCAs or control rods. The RCCAs are moved in and out of the core in symmetrically located groups or banks. Banks D, C, B, and A are called the control banks and they are used to control the reactor over the power range. The remaining banks S_A, S_B, S_C, and S_D are the shutdown banks which provide additional reactivity control to bring the reactor to a sufficiently subcritical condition following insertion of all control rods.

Each bank consists of 4, 8, or 9 individual RCCAs as shown in Figure 2-1. All RCCAs in a particular bank are generally moved in or out of the core simultaneously. The RPI signals from individual RCCAs are compared with the bank demand position to assure that all RCCAs are in alignment with their bank.

The Indian Point Unit 2 TS allows deviations between the RPI signal and the bank demand position within a fairly small tolerance range. Figure 2-2 illustrates the current range of permissible deviations between the bank demand position and the individual RPI signal for each RCCA. Over most of the range of RCCA travel (≤ 210 steps withdrawn) the maximum permissible deviation is ± 12 steps (± 7.5 inches). For RCCA positions ≥ 211 steps withdrawn the permissible positive deviation is extended to +17 steps. This allows for an error in the sensing electronics of +12 steps plus allowance for 5 steps which are not indicated due to the relationship of the RPI coil stack and the RCCA drive rod for indicated rod positions ≥ 211 steps withdrawn. The last five steps of travel (225 to 230 steps) are not indicated by the RPI because the drive rod and RCCA have been raised by three inches (+5 steps) from the rod bottom position in the OFA and LOPAR fuel types. The original HIPAR assemblies permitted RCCA withdrawal to 230 steps. (All HIPAR fuel has been permanently discharged from the core.)

2.2 Core Power Distribution Limits

2.2.1 Local Distributions and Peaking Factor Limits

The original bases for the allowable deviation shown in Figure 2-2 are the analyses of core power distributions under both steady state and anticipated transient conditions which are routinely performed as part of the reload safety analysis for each fuel cycle. These analyses demonstrate that core peaking factor limits will not be exceeded under all anticipated steady state operating conditions and normal operational transients as permitted by the operating mode specified in the PTS (ie., constant axial offset control) provided that no RCCA is misaligned from its bank by more than ± 12 steps. Compliance with the core peaking factor limits assures that the consequences of all postulated accidents as evaluated in the FSAR will be acceptable.

The current IP-2 PTS (through Amendment 167) imposes limits on the total core peaking factor $F_Q(z)$ and the enthalpy rise peaking factor, $F_{\Delta H}^N$. Paragraph 3.10.2.1 of the IP2 TS establishes these limits as:

$$F_{\Delta H}^{N} \leq 1.62 \{1 + 0.3 (1-P)\} \qquad (2\text{-}1)$$

$$F_Q(z) \leq \{2.32/P\} \times K(z), \quad \text{for } P > 0.5 \qquad (2\text{-}2)$$

$$F_Q(z) \leq \{4.64 \times K(z), \quad \text{for } P \leq 0.5$$

where P is the fraction of rated core power and K(z) is given by Figure 2-3. The relaxation afforded by Equation 2-1 at reduced power levels is extremely conservative. The limits on $F_{\Delta}H$ are designed to protect against departure from nucleate boiling and as such depends directly on the local power.

As part of the safety evaluation for a reload fuel cycle, $F_Q(z)$ is calculated as a function of core height by imposing various steady state and load follow transients on the core. These transients are initiated and controlled by insertion and withdrawal of control banks C and D and the results of subsequent redistribution of xenon on the local core power distributions calculated.

[

.] Figure 2-4 has been developed for Cycle 11 of operations (Reference 4) at IP2 and only the limiting values of $F_Q(z)$ have been plotted for each axial elevation. The calculated points have been synthesized from separate one dimensional axial calculations for F_z which are then combined with radial factors (F_{xy}^{N}) appropriate for the rodded and unrodded planes of the core. Alternatively, the analyses can be performed with a three dimensional nodal code thereby precluding the need for a synthesis step. The calculated values have been increased by a factor of 1.05 for conservatism and 1.03 to account for the engineering hot channel factor. Local power peaking effects due to fuel densification have not been included in Figure 2-4. [

.]

Implicit in the series of calculations which forms the basis for the flyspeck envelop curve (Figure 2-4), is the assumption that the control rods in a particular bank move simultaneously and that all rods within the bank are in alignment within ± 12 steps. Misalignments in excess of ± 12 steps have the potential to increase the radial peaking factor in the rodded plane of the core. This would tend to move the $F_Q(z)$ points in Figure 2-4 upward, reducing margin to the limiting operating envelope. An increase in the radial peaking factor can also increase the enthalpy rise peaking factor, $F_{\Delta H}^N$. Accordingly, any increase in the range of permissible deviation between RPI signals and the bank demand position would have to be assessed in terms of the limits imposed by Equations 2-1 and 2-2.

2.2.2 Global Core Power Distribution Limits

The local core peaking factors as described in the previous section are not routinely monitored during normal power operation. Instead, surveillance of core power distribution is via the excore detectors which provide the core axial flux difference (ΔI) and core quadrant tilt (QT). The axial flux difference is defined as:

$$\Delta I = AO \times (P_T + P_B) = P_T - P_B \qquad (2\text{-}3)$$

where

$AO = (P_T - P_B)/(P_T + P_B)$ = axial offset

P_T = power in the top half of the core

P_B = power in the bottom half of the core

The axial flux difference is measured by the excore detector system which consists of 4 upper and 4 lower ionization chambers located near the exterior surface of the reactor vessel. The output signals (current) from each detector is proportioned to P_T and P_B.

Section 3.10.2.6 of the IP-2 PTS requires that during power operation the axial flux difference be maintained within ± 5% of the target value. The target value depends on core power level and burnup. Figures 2-6 and 2-7 show how typically the flux difference depends on power and burnup. At power levels between 90% and 50% of rated power, the axial flux difference may vary from the target band as shown in Figure 2-8 for no more than one hour out of any 24 hour period. Below 50% power the flux difference may deviate from the target band within the envelope shown in Figure 2-8 without the 1 hour time restriction. However, the return to power levels above 50% is contingent on the flux difference not being outside the target band more than 2 hours out of the previous 24 hours.

The above operating strategy is termed constant axial offset control and is intended to preclude wide variations in the core axial offset. Such variations could initiate core xenon redistribution instabilities which would result in increased core peaking factors.

The core quadrant tilt is also monitored continuously during power operation with the excore detector system. The quadrant tilt is defined as:

$$QT = MAX \{4Q_1/P_T,\ 4Q_2/P_T,\ 4Q_3/P_T,\ 4Q_4/P_T,\ 4Q_5/P_B,\ 4Q_6/P_B,\ 4Q_7/P_B,\ 4Q_8/P_B \} \quad (2\text{-}4)$$

where

Q_1, Q_2, Q_3, Q_4 = fraction of power in the top four octants of the core

Q_5, Q_6, Q_7, Q_8 = fraction of power in the bottom four octants of the core

and P_T, P_B are as defined previously. The IP-2 PTS restricts the core quadrant tilt to $QT \leq 1.02$ for power operation at levels above 50%. If the quadrant tilt exceeds 1.02 and $1.02 < QT \leq 1.09$, the PTS requires a power reduction of 3% for every percent the quadrant tilt is greater than 1.0. In the event the core quadrant tilt exceeds 1.09 the PTS requires that the power level be reduced to 50 percent of rated or less.

2.3 Control Rod Insertion Limits and Shutdown Margin

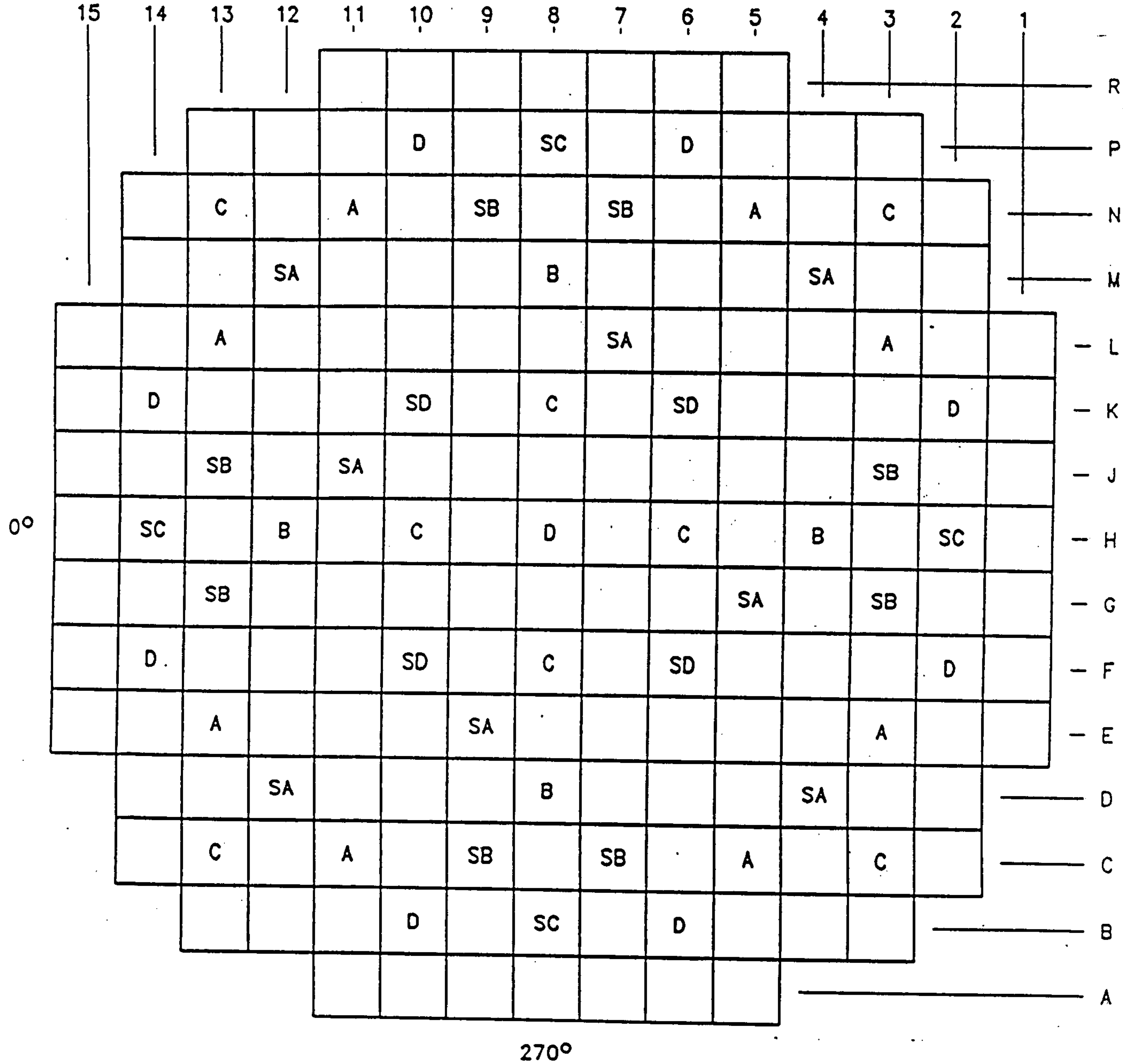
The IP2 Tech Spec Section 3.10.4 imposes limits on the depth of RCCA insertion permitted during power operation. These limits are intended to assure the availability of sufficient shutdown reactivity when all RCCAs are dropped into the core during a scram. The restrictions include:

a.) The shutdown banks shall be fully withdrawn when the reactor is critical or approaching criticality.

b.) When the reactor is critical, the control banks shall be limited in physical insertion to the insertion limits shown in Figure 2-9.

In practice, IP2 is brought to rated power conditions via chemical shim control and normally only D-bank is partially inserted (typically at the bite position) during the power ascension phase of operation.

In addition to control rod insertion limits, the PTS requires that a minimum hot shutdown margin is maintained. This assures that the reactor can be brought to and maintained subcritical under all postulated accidents and transients. The hot shutdown margin depends on the boron concentration in the reactor coolant system as shown in Figure 2-10. In practice, the hot shutdown margin is maintained by limiting the minimum soluble boron concentration in the coolant.



BANK IDENTIFIER	NUMBER OF LOCATIONS	BANK IDENTIFIER	NUMBER OF LOCATIONS
A	8	SA	8
B	4	SB	8
C	8	SC	4
D	9	SD	4

Figure 2-1: Control Rod Pattern and Bank Configuration

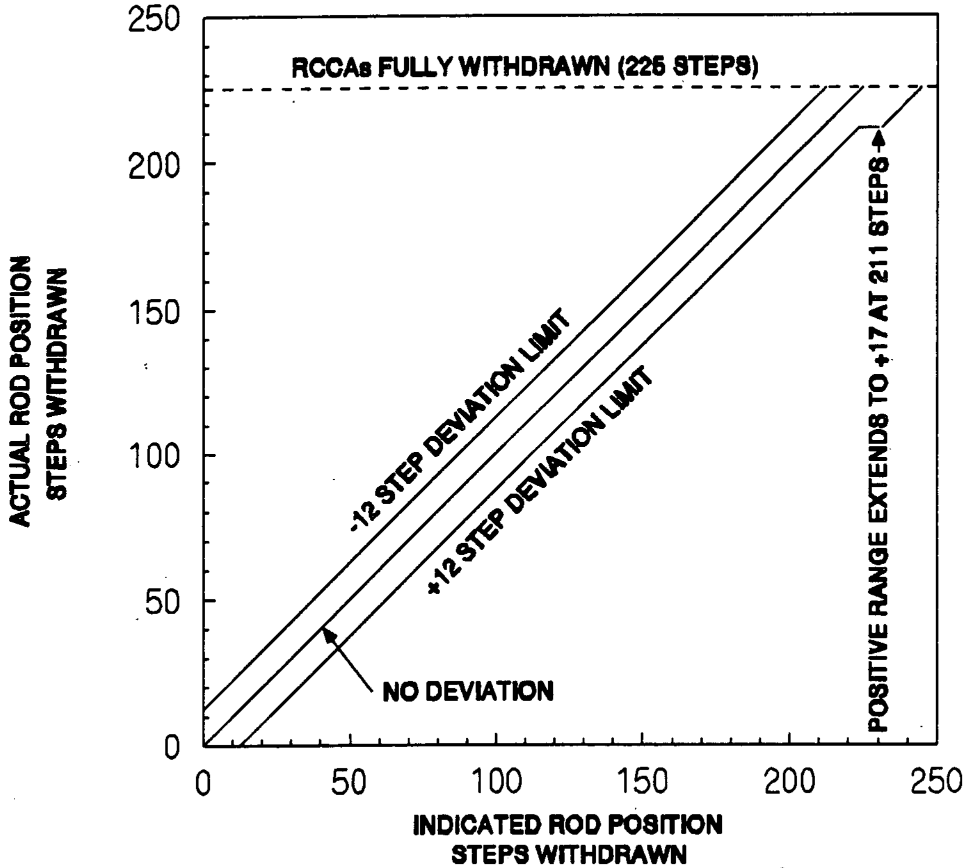


Figure 2-2: Current IP-2 RPI Deviation Limits

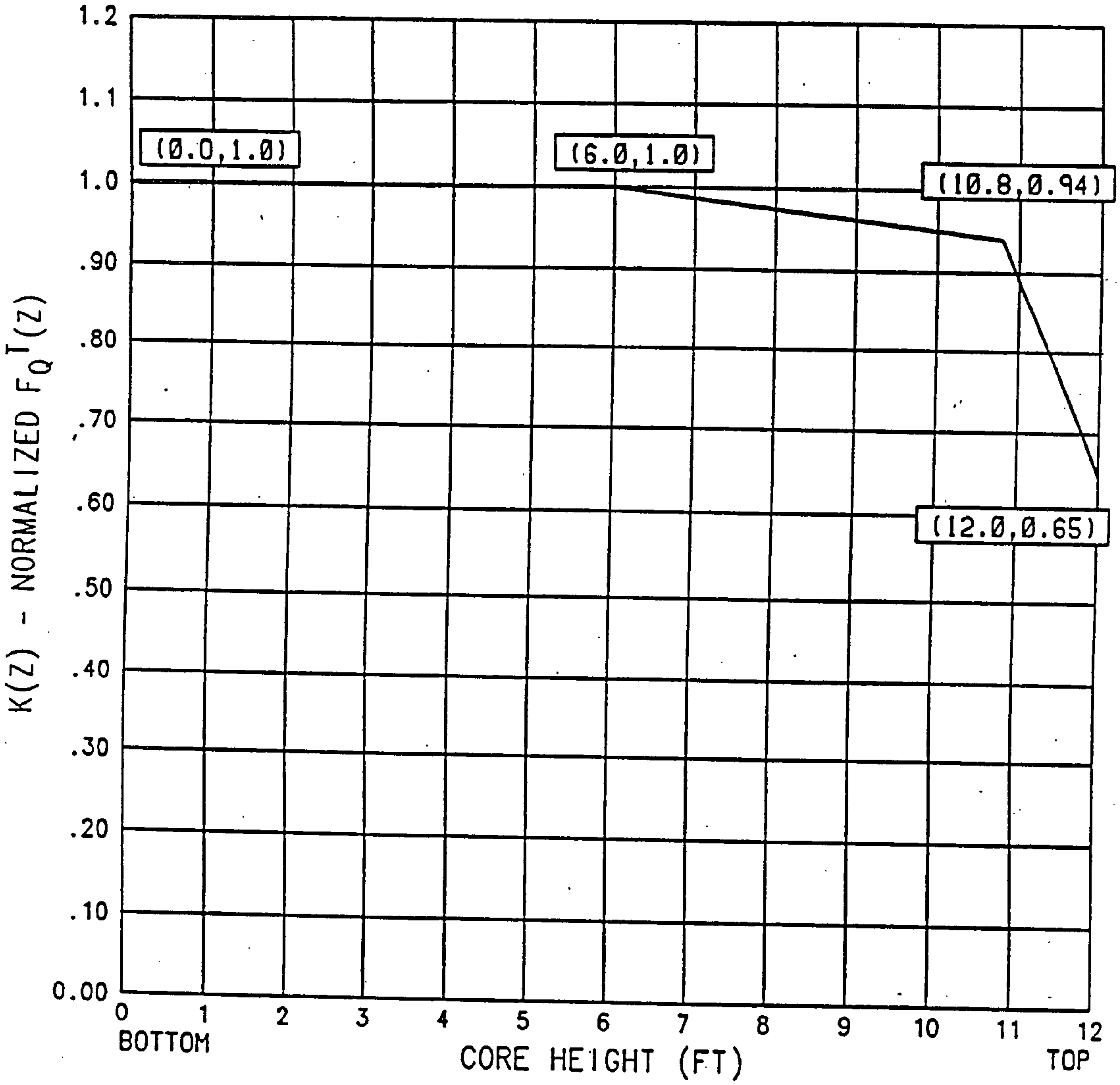


Figure 2-3: K(z) as a Function of Core Height .

Figure 2-4: [ ]

Figure 2-5: [ ]

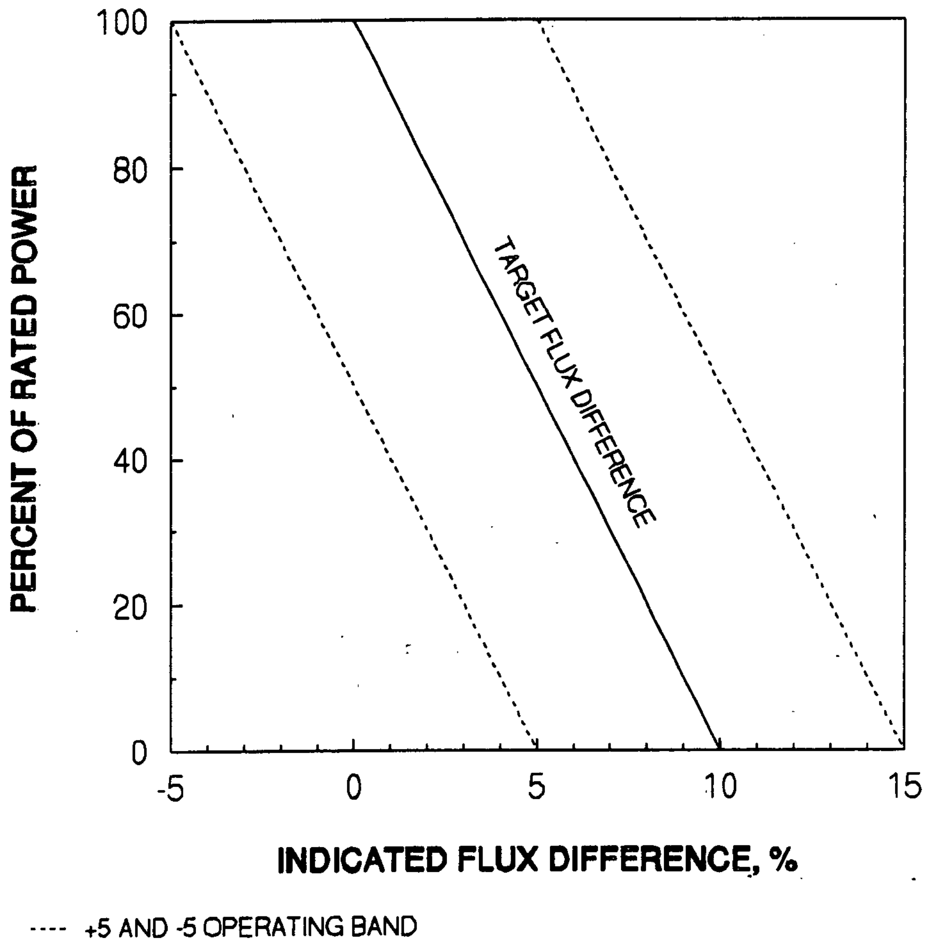


Figure 2-6: Typical Variation of Target Flux Difference with Core Power Level

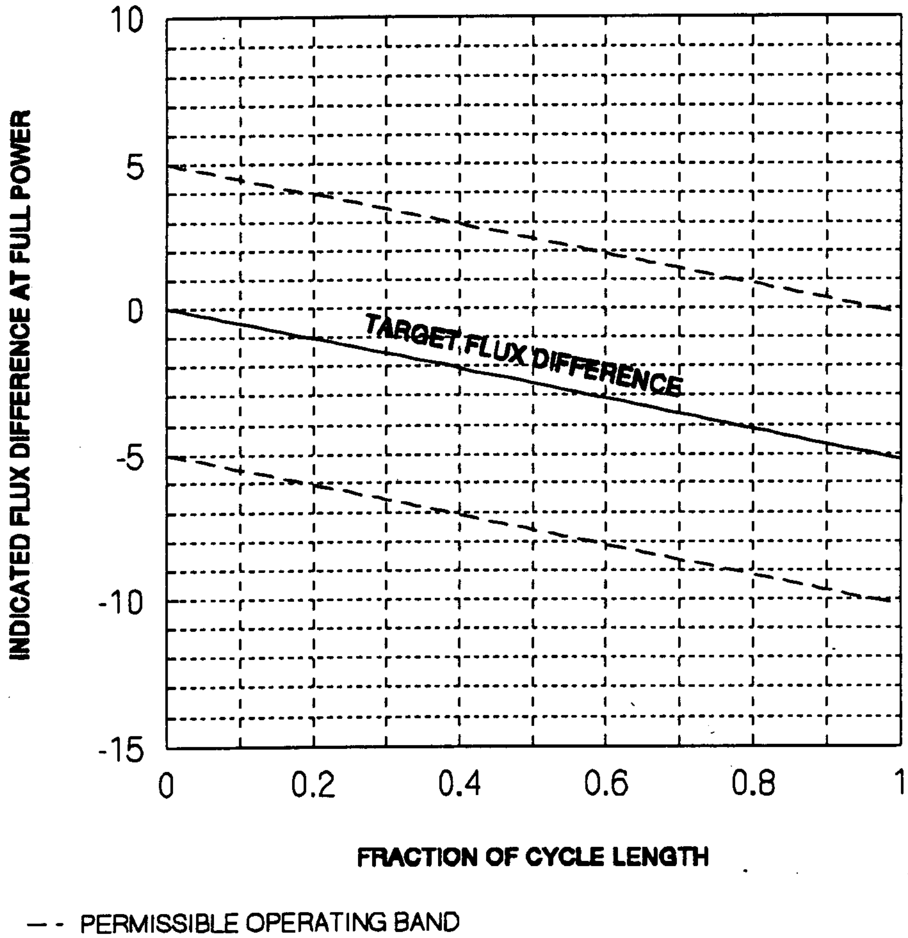


Figure 2-7: Typical Variation of the Target Flux Difference with Fuel Cycle Burnup

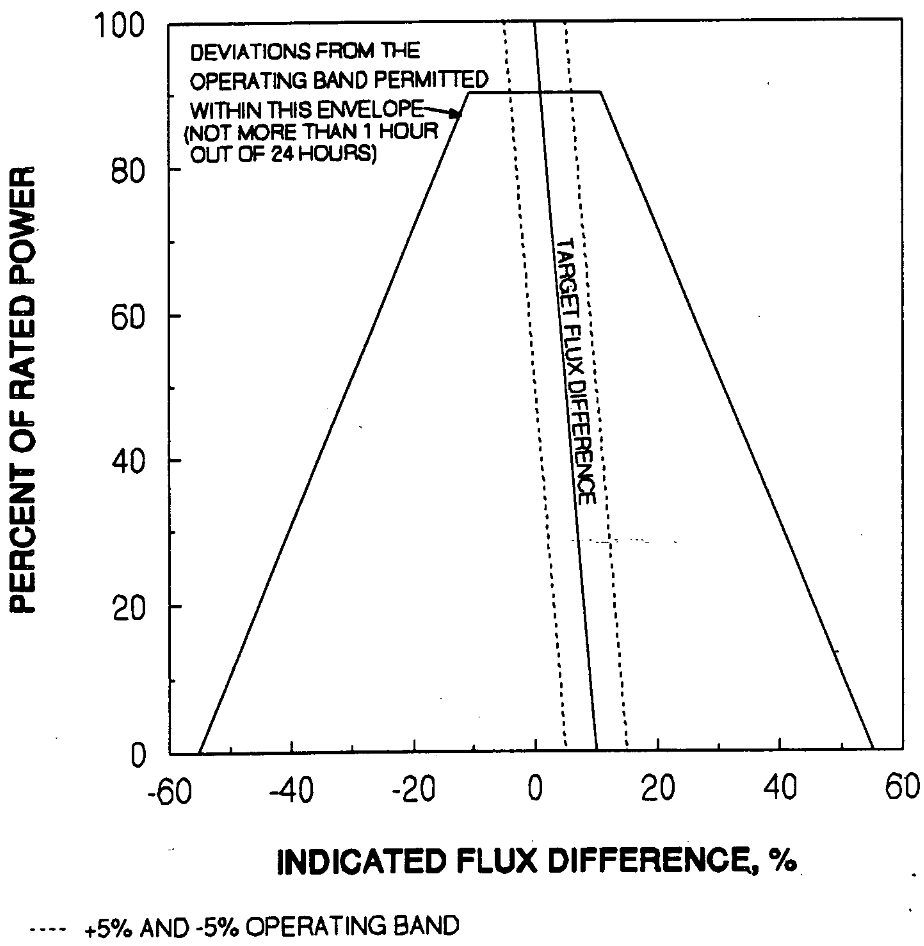


Figure 2-8: Flux Difference versus Core Operating Power Level

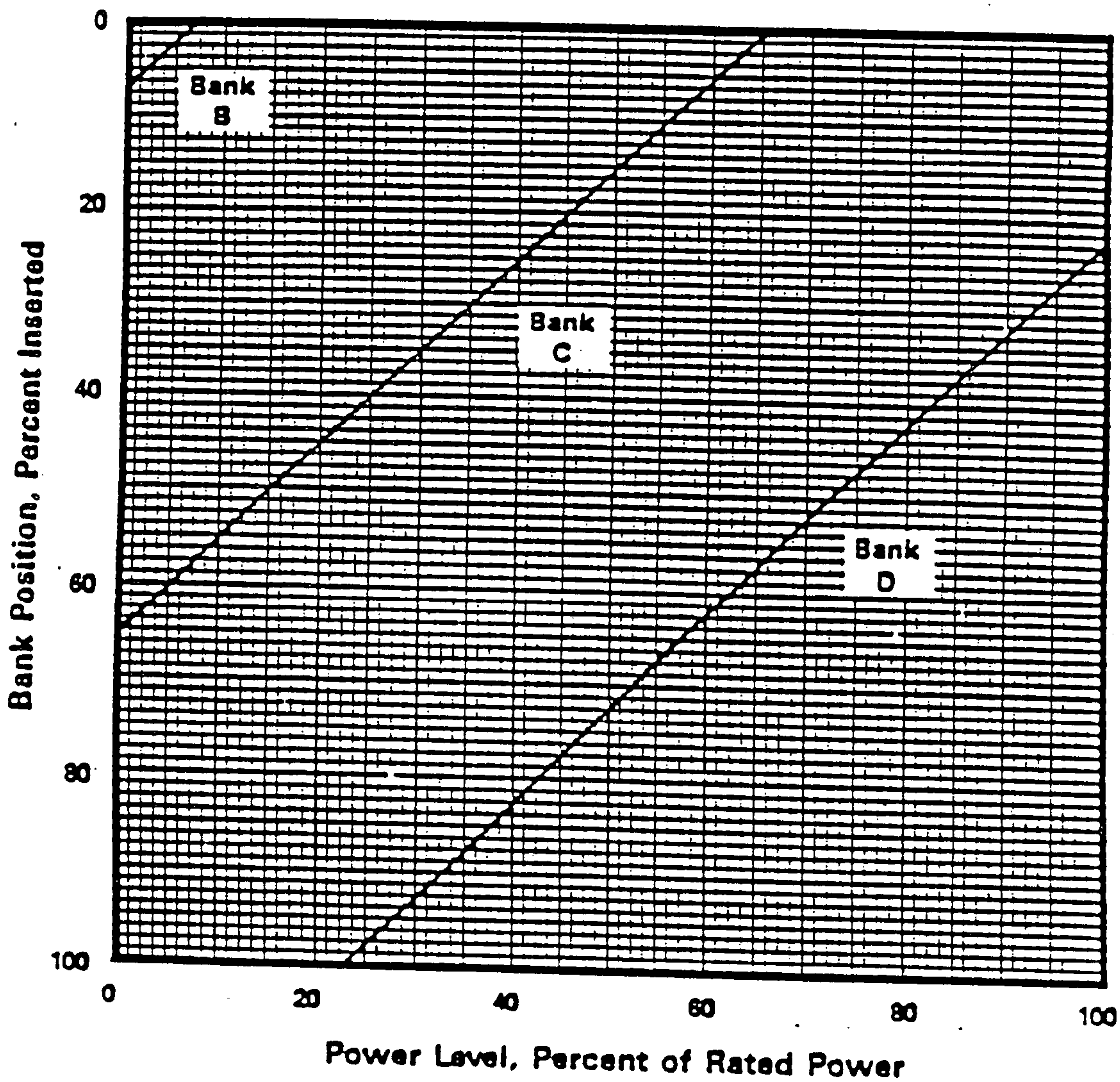


Figure 2-9: Control Rod Insertion Limits

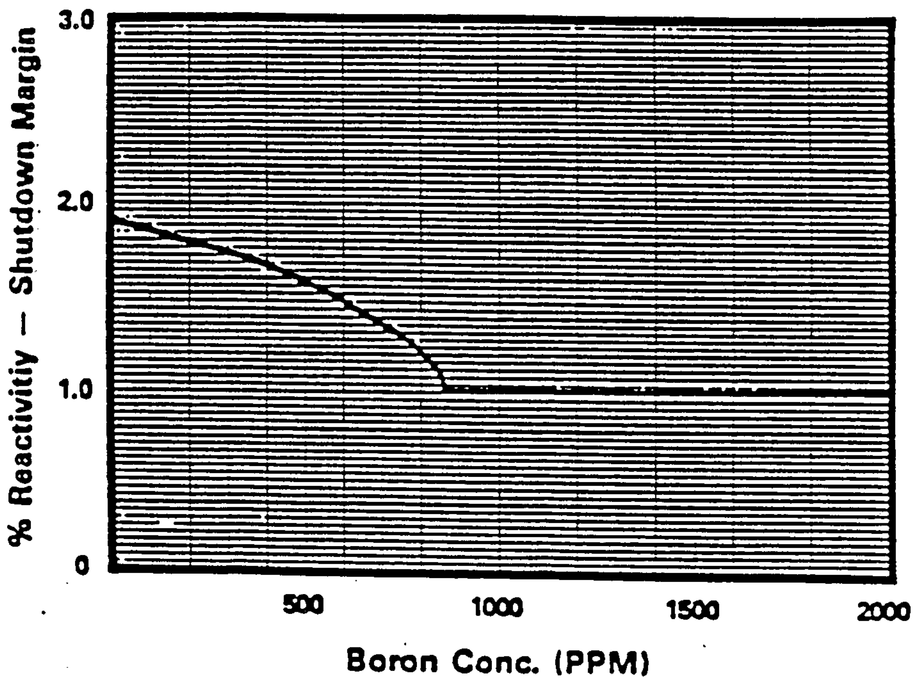


Figure 2-10: Hot Shutdown Margin versus Boron Concentration

3.0 ASSESSMENT OF RPI DEVIATION LIMITS

3.1 Scope of the Analyses

As noted in Section 1.0, RPI deviations from the bank demand position are generally not actual misalignments but are thermally induced instabilities in the instrumentation. This evaluation assumes the indicated misalignments represent actual rod misalignments and then calculates the resulting impact on core peaking factors and global core power distributions. In this manner it is demonstrated that, even if the misalignments are actual, the resulting impact on core peaking is small and can be accommodated by limiting core power levels.

Fuel Cycles 11 and 12 at IP2 have been evaluated with respect to allowing an extended RPI deviation band[3,4]. For these evaluations a full core NODE-P2[5] model of the IP2 core was employed. This model simulated the depletion of Fuel Cycles 11 and 12 and the effect of RCCA misalignment on core peaking factors was analyzed at beginning of cycle (BOC), mid cycle (MOC) and end of cycle (EOC). A large number of combinations of misaligned RCCAs were simulated at each of the three burnup points. RCCA misalignments of [

] were considered.

As described in Section 2.0, the IP2 core contains 53 individual RCCAs and the number of combinations of misaligned rods at discrete misalignments is very large. Accordingly, an analyses matrix was developed which included a large number of combinations of misaligned RCCAs but not all conceivable combinations. The combinations selected for the analyses are believed to be limiting with respect to the impact on core peaking factors and global core power distributions. The analyses matrix is shown in Table 3-1 and contains [

.]

[

]

The last three of these were analyzed as they tend to maximize the increase in core peaking and are therefore believed to be bounding.

3.2 Results of the RCCA Misalignment Analyses and Discussion

The results of the RCCA misalignment analyses have been summarized in Table 3-2. The table contains the maximum fractional change in nodal F_Q and pin $F_{\Delta H}$ from each of the [ ]of RCCA misalignments considered. It also contains the maximum values of core quadrant tilt and deviation from the target flux difference. It is noted that the maximum fractional change in nodal F_Q is [ ] with an associated change in $F_{\Delta H}$ of [.] This occurs for the [

.] Figures 3-1 and 3-2 illustrate the fractional change in nodal F_Q and $F_{\Delta H}$ versus steps of RCCA misalignment. The fractional change in both of these peaking factors in relation to the current TS limit of ±12 steps is shown. With such a high density of RCCAs at the top of the core, the axial power is forced to the lower half of the core and the flux difference deviates from the target value by [.] Accordingly, if the RCCAs were actually misaligned the operator would have indication via the excore instrumentation and could take remedial action.

It is also noted that for the first three classes of misaligned RCCAs [ ] the fractional change in nodal F_Q is [.] The maximum fractional change in $F_{\Delta H}$ for these cases is [.] Based on these results, it is concluded that power operation can be permitted with a RPI deviation limit of [ ] provided that the power level is limited to mitigate any potential increase in local peaking. Equations 2-1 and 2-2 provide the basis for specifying the core power level above which RPI deviations are restricted to the current ±12 steps band and below which deviations of [ ] steps are permitted. For the maximum change in F_Q [ ], Equation 2-2 limits core power to [.] For the maximum change in $F_{\Delta H}$ [ ], Equation 2-1 specifies a power level of [.] For this case, however, core power is restricted to [ ] as the control rods were inserted to the maximum depth as allowed by the insertion limits at [ ] power (see Figure 2-9). The next most limiting case results in a $F_{\Delta H}$ of [.] Equation 2-1 would limit power operations to [ ] for this case.

For conservatism the power level for operation with indicated RCCA misalignments of up to [ ] steps will be limited to the range of [ ] of rated power. For this power range, the permissible RPI deviation band would appear as shown in Figure 3-3. The proposed band allows deviation of up to [ ] over the entire range of rod travel except that above [ ] steps there is no limit on positive deviations. The basis for this is two fold. [

.]

For operating power levels above [ ] of rated power the applicable RPI deviation band is shown in Figure 3-4. This is identical to the current PTS band (Figure 2-2) with one exception. [

.]

Table 3-1

[ ]

[ ]

Table 3-1 (continued)

Table 3-2

[ ]

[ ]

Figure 3-1: [ ]

Figure 3-2: [ ]

Figure 3-3: [ ]

[

]

Figure 3-4: [ ]

4.0 ON-LINE CALIBRATION OF THE RPI CHANNELS

4.1 Scope of the Analyses

Calibration of the RPI channels is currently performed with the reactor at hot zero power. The analyses presented in this section demonstrate that at-power calibration is permissible at intermediate power levels. The procedure will involve [

.] It has been determined[3,4] that a suitable intermediate power level for on-line RCCA calibration is [.]

To assess the impact of on-line calibration of RCCAs on core safety limits, the NODE-P2 simulator model described previously was applied to fuel cycles 11 and 12[3,4]. Individual RCCAs were inserted in two node increments (of 24 axial nodes modeled in NODE-P2) to 0 steps withdrawn followed by withdrawal to 225 steps. At each insertion step the core peaking factors, axial flux difference, and quadrant tilt were calculated. [

.]

4.2 Results of On-line RCCA Calibration Analyses

To illustrate the impact of single rod insertion on core peaking factors and global core power distributions, the NODE-P2 results are first presented for a "worst case" RCCA. A "worst case" RCCA is one which has [

.] For Cycle 12, this RCCA is in [

.] During calibration, the insertion of this RCCA results in [

.] Figure 4-1 is a plot of core axial flux difference during the calibration. The calculated flux difference is compared with the target value and the ± 5% operating band specified by the TS. [

.]

The core quadrant tilt during calibration is shown in Figure 4-2. When this RCCA is fully inserted, the core quadrant tilt reaches [ ] which can be compared with the alarm limit of 1.02 for power operation. The implications of a single RCCA calibration on core quadrant tilt limits are discussed subsequently.

Figure 4-3 contains a plot of the fractional change in nodal F_Q during calibration. The calculated values of F_Q are compared to the TS limits as defined by Equation 2-2. [

.]

Fuel Cycle 12 is the most limiting with respect to local core peaking and the composite results for all simulated RCCA calibrations are reported for this fuel cycle. The analyses includes some [

.] Figures 4-5, 4-6, and 4-7 contain plots of core axial flux difference during RCCA calibration initiated at [ ] power at [

.] The plots also show the target value and the ± 5% operating band. As noted in Section 2.2.2, below [ ] power the flux difference may deviate within the envelope shown in Figure 2-8. While some of the [

,] all are well within the envelope. It is noted, however, that the return to power levels above [ ] is contingent on the flux difference not being outside the target band more than 2 hours out of the previous 24 hours.

The core quadrant tilt for these cases is shown in Figure 4-8. The calculated values are compared with the nominal operating TS tilt limit of 1.02 and the maximum TS limit of 1.09. It is noted that quadrant tilts [ ] have been calculated. Under certain conditions the TS permits reduced power operation with quadrant tilt in the range of 1.02 to 1.09 and greater for limited periods of time. This will be discussed subsequently.

The fractional change in nodal peaking and $F_{\Delta H}$ are compared with the TS limits in Figures 4-9 and 4-10, respectively. [

.] From Equation 2-2 the permitted fractional change in the TS total peaking factor upon reduction of power [ ] is 1.0. It is noted that the maximum fractional increase in calculated peaking is [.] Figure 4-10 compares the calculated enthalpy rise peaking factor with the limit as imposed by Equation 2-2. It is clear that the $F_{\Delta H}$ limits are not exceeded during on-line calibration of the RPI channels.

4.3 Discussion

The calculated results described in Section 4.2 have been summarized in Table 4-1. In this table the maximum fractional changes in F_Q and $F_{\Delta H}$ are given as well as the maximum values of core quadrant tilt and flux difference. The results contained in Table 4-1 lead to the following conclusions:

[

.]

Section 3.10.3 of the IP-2 TS limits the core quadrant tilt to 1.02 for operation above [ ] of power. If the tilt exceeds 1.02 but is less than or equal to 1.09, core power level must be restricted three percent of rated value for every one percent the tilt exceeds 1.0 within 2.0 hours. Also, the power range high flux setpoint must be restricted in a similar manner. If the tilt cannot be restored within 24 hours, the power level must be reduced to [ ] of rated power and the power range high flux setpoint reduced to [ ] of rated power.

If the tilt exceeds 1.09 and there is simultaneous indication of a misaligned RCCA (which would be the case for RCCA calibration), immediate power reduction of 3 percent of rated for every percent the tilt exceeds 1.0 or to a level less than [ ] is required. If the tilt persists for more than 2 hours the power level must be restricted to less than [.] Within the next 4 hours, the power range high flux setpoint must be reduced to [ ] in the event the tilt condition is not corrected.

For the "worst case" RCCA in Table 4-1 the peak tilt approaches [.] By paragraph 3.10.3.2a of the TS, the maximum core power level would therefore need to be restricted to [ ] of rated. If the RCCA calibration required more than two hours, or if several RCCAs needed to be calibrated requiring more than 2 hours, the power level would have to be reduced to [ ] of rated. In the event the calibration procedures were to require more than 4 hours, paragraph 3.10.3.2a requires that the power range high flux trip setpoint be reset at 55% of rated thermal power.

[

.]

Table 4-1

[ ]

Figure 4-1: [ ]

Figure 4-2: [ ]

Figure 4-3: [ ]

Figure 4-4: [

]

Figure 4-5: [ ]

Figure 4-6: [ ]

Figure 4-7: [ ]

Figure 4-8: [ ]

Figure 4-9: [ ]

Figure 4-10: [ ]

5.0 ASSESSMENT OF FUEL THERMAL/MECHANICAL DUTY DURING ON-LINE RPI CALIBRATION

On-line calibration of the RPI channels will require the insertion of RCCAs from the fully withdrawn position to the fully inserted position followed by subsequent RCCA withdrawal. This will be carried out [.] As individual RCCAs are inserted, the core power distribution is shifted away from the RCCA. [.] In addition, the fuel rods in the assembly in which the RCCA is inserted will be subjected initially to a large power suppression followed by a power increase.

In order to assess the effect of such power cycling on the fuel rod thermal mechanical duty, a FRAPCON[6] model of the IP2 [ ] fuel rod was developed. Three cycle fuel rod power exposure histories were generated using NODE-P2 for the limiting fuel rods as described in Section 4.0. The limiting fuel rods are those which experience the greatest power cycle during on-line calibration exercises. These rods were identified by examining the NODE-P2 simulated calibration exercises.

5.1 Description of the Fuel Thermal/Mechanical Analyses

The limiting fuel rod from a [ ] fuel assembly with initial enrichment of [ ] was selected for evaluation. The limiting fuel rod is defined as the rod which experiences the largest nodal power increase during on-line calibration exercises. This corresponds to a fuel rod in fuel assembly [ ] in the diametrically opposed core quadrant is inserted and withdrawn. Table 5-1 contains a summary of the relevant fuel rod design parameters used as input to the FRAPCON model.

For this limiting fuel rod, a three cycle power/exposure history was developed for input to FRAPCON. [

.] For the peak power rod, on-line calibration was simulated at [

.] The [ ] case occurs at the highest nodal and rod average burnup and is therefore considered to be limiting. Figure 5-1 shows the local relative fuel rod nodal power as a function of axial elevation for the EOC case as the RCCA is moved into the core and withdrawn. All nodes experience an increase in relative power during rod insertion which [

.]

In addition to analyzing the peak power node during calibration, the limiting fuel rod in the [

.] The FRAPCON model was used to determine whether this power cycling would [

.] Figure 5-2 contains plots of the fuel rod axial power shape as the RCCA is inserted and withdrawn during calibration. This figure serves to illustrate the [

.]

5.2 Results of the FRAPCON Thermal Mechanical Analyses

Select results of the base case three cycle depletion analyses for the limiting fuel rod are shown in Figures 5-3 and 5-4. These results are for a rod with the peak nodal linear heat generation rate (LHGR) as shown in the Figure 5-4. Figure 5-3 also shows the location of the peak power node. This base case analysis does not include the simulation of on-line RCCA calibration and will be the reference condition against which calibration effects will be measured.

The limiting case [

.]

The effect of RCCA insertion with the limiting fuel rod located in the fuel assembly receiving the RCCA has also been analyzed. The fuel rod response during calibration at [ ] is shown in Figure 5-6. [

.]

5.3 Discussion

The limiting fuel with respect to fuel thermal mechanical duty has been evaluated under the operating conditions imposed by on-line calibration. Both the fuel rod which is subjected to the highest nodel LHGR as well as the limiting rod in an assembly in which the RCCA is inserted have been assessed. [

.]

The analysis completed with the FRAPCON computer code has led to the following conclusions with respect to on-line calibration exercises:

[

.]

It is, therefore, concluded that on-line calibration of the RPI channels will be acceptable with respect to fuel thermal mechanical duty. It is not expected that on-line calibration activities will lead to an increased probability for fuel rod failures.

Table 5-1

Indian Point Unit 2 Region 12B Fuel Rod

and Assembly Design Parameters

Parameter	Value
Fuel enrichment (% U-235)	[ ]
Fuel density (%T.D. geometric)	[ ]
Fuel rod internal pressure (psig helium)	[ ]
Fuel rod length (inches)	[ ]
Fuel stack length (inches)	[ ]
Fuel loading (MTU)	[ ]
Fuel pellet diameter (inches)	[ ]
Fuel rod diameter (inches)	0.422
Fuel/cladding diametral gap (mils)	[ ]
Cladding wall thickness (mils)	[ ]
Fuel assembly length (inches)	159.765
Fuel assembly envelope (inches per side)	[ ]
Lattice configuration	[ ]
Lattice pitch (inches)	[ ]
No. of fuel rods per assembly	204
No. of control rod guide thimbles/assembly	20
No. of instrumentation thimbles/assembly	1

Figure 5-1: [ ]

Figure 5-2: [ ]

Figure 5-3: [ ]

[

]

Figure 5-4: [

]

Figure 5-5: [ ]

Figure 5-6: [ ]

6.0 THE IMPACT OF ON-LINE RCCA CALIBRATION ON POSTULATED PLANT TRANSIENTS AND ACCIDENTS

The analyses presented in Section 4.0 have served to illustrate that on-line calibration of individual RCCAs will not result in established core peaking factor limits being exceeded. Notwithstanding compliance with core peaking limits, all postulated plant transients and accidents have been evaluated to assure that on-line calibration of RCCAs will not present any unreviewed safety questions.

For these purposes, all postulated plant transients and accidents addressed in Section 14 of the Indian Point Unit No. 2 FSAR[10] have been reviewed and evaluated. This review is based on the assumption that each of the plant transients and accidents in Chapter 14 is initiated during the calibration of the RCCA at the point of RCCA insertion at which peaking factors are at their maximum values. It is noted that RCCA calibration is initiated at power levels of 50% of rated or less and the reduced power operation would generally be expected to mitigate any increase in core peaking.

Table 6-1 contains the results of this review for those accidents classified as core and coolant boundary protection analyses. For these accidents, the reactor control and protection system is relied upon to protect the core and reactor coolant boundary from damage under the postulated accident scenario and have no offsite radiation consequences. The results of this review shows that the consequences of any of these postulated accidents occurring during on-line calibration at 50% power or less is no more severe than the bounding analyses documented in the FSAR.

Table 6-2 contains the results of this review for those postulated accidents which rely on the engineered standby safety systems and features for mitigation. These accidents are more severe and may cause the release of radioactive material to the environment. The standby engineered safety features limit potential exposure of the public to below the limits of 10 CFR100 for situations that could conceivably involve uncontrolled releases of radioactive material to the environment. Table 6-2 shows that some of these accidents (fuel-handling accidents and accidental release of either liquid or gaseous wastes) are completely independent of reactor operation and therefore on-line RCCA calibration is of absolutely no consequence. For those accidents which are initiated with the reactor at power, Table 6-2 shows that on-line RCCA calibration would have no impact provided TS requirements for control rod shutdown margin are maintained.

The rupture of primary coolant pipes represent the "worst-case" accident(s) and are the primary basis for the design of the engineered safety features. Table 6-3 shows that for both the spectrum of small-break and large-break loss of coolant accidents (LOCA), on-line RCCA calibration will not cause the consequences to be any more severe than the bounding cases analyzed in Chapter 14 of the FSAR. This is the case since the core hot spot transient is primarily determined by the fuel stored thermal energy just prior to the accident. Since peaking limits are maintained during on-line RCCA calibration, the stored thermal energy is maintained and the hot spot thermal response is no more limiting than the bounding analyses presented in Chapter 14.

The final classification of accidents reviewed are the anticipated transients with scram (ATWS). These accidents are assumed to occur without reactor trip and an acceptable consequence is that gross fuel damage does not occur. The consequences of the ATWS events are sensitive to the peaking factors $F_{\Delta H}$ and F_Q and the core moderator coefficient. The results presented in Section 5.0 demonstrate that peaking limits on F_Q^N and $F_{\Delta H}$ are not exceeded for single RCCA calibrations initiated from power levels of 50% of rated or less. In addition, since boron concentration limits will, at all times, be maintained, the design moderator coefficient used in the ATWS analyses will not be violated during on-line calibration. Accordingly, on-line RCCA calibrations will not result in the consequences of any of the nine ATWS events from being any more severe than the bounding analyses presented in Chapter 14 of the IP2 FSAR.

It is therefore concluded that the on-line calibration of RCCAs when performed at 50% of rated power or less does not present any unreviewed safety questions.

Table 6-1

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Table 6-1 (continued)

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Table 6-2

[ ]

[ ]

Table 6-3

[ ]

7.0 Conclusions

The analyses and evaluations completed for IP2[3,4] for Fuel Cycles 11 and 12 and presented in this report clearly demonstrate the RPI deviation band can be extended to [ ] for operation at power levels [.] The analyses further demonstrate that on-line calibration of individual RPI channels can be conducted provided the reactor power is limited [.] The results of these evaluations and analyses show the core peaking factors will be maintained within acceptable limits during on-line calibration of the RPI channels. Further, on-line RPI calibration will have no significant impact on fuel rod thermal mechanical duty. A review of all postulated transients and accidents addressed in the FSAR has been completed. It has been determined that on-line calibration activities conducted at 50% power or less will not result in consequences of the transients and accidents being more severe than those reported in the FSAR. It is therefore concluded that this proposed amendment to the IP2 Plant Technical Specification does not present any unreviewed safety issues.

8.0 REFERENCES

1. Indian Point 2 Plant Technical Specification, through Amendment 168.

2. United States Patent No. 5,011,649 "Calibration of Rod Position Indicators", Granted to A. Ginsberg and J. Mooney, April 30, 1991.

3. "Evaluation and Demonstration of Extended RPI Deviation Limits and On-line Recalibration of the RPI Channels," NET-074-01. Northeast Technology Corp: Kingston, NY; May 1993.

4. "Extended RPI Deviation Limits and On-line Calibration of the RPI Channels for Indian Point Unit No. 2 Fuel Cycle 12," NET-085-01. Northeast Technology Corp: Kingston NY; December 1993.

5. "ARMP-02 Documentation: Part 11, Chapter 11 - NODE-P2 Computer Manuals Volume 2: User's Manual," EPRI NP-4574-CCM. Electric Power Research Institute: Palo Alto, CA; October 1988.

6. "FRAPCON-2: A Computer Code for the Calibration of Steady State Thermal-mechanical Behavior of Oxide Fuel Rods," NUREG/CR-1845R3. EG&G Idaho, Inc.; January 1981.