Entergy

Entergy Nuclear Northeast
Entergy Nuclear Operations, Inc.
Indian Point Energy Center
295 Broadway, Suite 1
P.O. Box 249
Buchanan, NY 10511-0249

July 9, 2002

Re: Indian Point Unit No. 2
Docket No. 50-247
NL-02-082

U. S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Mail Stop 0-P1-17
Washington, DC 20555-0001

SUBJECT: License Amendment Request (LAR No. 02-010) – Regarding Indian Point Energy Center, Unit No. 2 Technical Specifications Requirements for Control Rod Misalignment and Rod Position Indication.

References:
1. NRC letter to NYPA, Indian Point Unit 3 License Amendment No. 176, dated August 11, 1997
2. NRC letter to NYPA, Indian Point Unit 3 License Amendment No. 180, dated June 17, 1998
3. NRC letter to NYPA, Indian Point Unit 3 License Amendment No. 197, dated October 14, 1999
4. NYPA letter IPN-97-024 dated February 26, 1997, Proprietary and Non-Proprietary Versions of Westinghouse WCAP-14668, "Conditional Extension of the Rod Misalignment Technical Specification for Indian Point Unit 3, October, 1996"

Pursuant to 10CFR50.90, Entergy Nuclear Operations, Inc. (ENO) hereby requests an amendment to the Indian Point Nuclear Generating Unit 2 (IP2) Facility Operating License No. DPR-26, Appendix A, Technical Specifications (TS) Sections 3.10.4, "Rod Insertion Limits," 3.10.5, "Rod Misalignment Limitations," and 3.10.6, "Inoperable Rod Position Indicator Channels." The requested change would (1) remove the cycle specific allowances on rod insertion limits during individual rod position indicator channel calibrations and (2) revise the rod position indicator channel accuracy and rod misalignment requirements to be independent of the specific fuel cycle.

A001

The proposed changes are based on the analysis contained in WCAP-15902, "Conditional Extension of the Rod Misalignment Technical Specification for Indian Point Unit 2." Proprietary and non-proprietary versions of WCAP-15902 are included with this letter as Enclosures 1 and 2, respectively. Similar requests were approved by the NRC for Indian Point Nuclear Generating Unit 3 (IP3) in license amendments issued on August 11, 1997, June 17, 1998 and October 14, 1999 (Ref. 1, 2 and 3, respectively). The analysis in WCAP-15902 is similar to the analysis submitted in support of the IP3 amendment requests (Ref. 4). An application, pursuant to 10 CFR 2.790(b)(1), for withholding the information in the proprietary version of WCAP-15902 from public disclosure is included with Enclosure 1.

Attachment 1 to this letter provides the description and evaluation of the proposed changes. The revised TS pages and TS Bases pages are provided in Attachment 2 (strikeout and shaded format).

The onsite and the offsite safety review committees have reviewed the proposed change and both committees concur that the proposed change involves no significant hazards consideration as defined by 10 CFR 50.92(c).

Since this TS change will impact the restart from the next refueling outage at IP2, ENO requests approval of the proposed change by October 25, 2002 with an implementation date within 30 days of approval. There are no commitments contained in this submittal.

In accordance with 10 CFR 50.91, a copy of this submittal and the associated attachments are being submitted to the designated New York State official.

Should you or your staff have any questions regarding this submittal, please contact Mr. John F. McCann, Manager, Nuclear Safety and Licensing at (914) 734-5074.

I declare under penalty of perjury that the foregoing is true and correct.

Sincerely,

Executed on 7/9/02

Fred Dacimo
Vice President – Operations
Indian Point 2

Attachments
Enclosures
cc: See page 3

cc:

Mr. Hubert J. Miller
Regional Administrator-Region I
US Nuclear Regulatory Commission
475 Allendale Road
King of Prussia, PA 19406

Mr. Patrick D. Milano, Senior Project Manager, Section 1
Project Directorate I
Division of Licensing Project Management
US Nuclear Regulatory Commission
Mail Stop O-8-2C
Washington, DC 20555

NRC Senior Resident Inspector
US Nuclear Regulatory Commission
PO Box 38
Buchanan, NY 10511

Mayor, Village of Buchanan
236 Tate Avenue
Buchanan, NY 10511

Mr. Paul Eddy
NYS Department of Public Service
3 Empire Plaza
Albany, NY 12223

Mr. William F. Flynn
NYS ERDA
Corporate Plaza West
286 Washington Ave. Extension
Albany, NY 12223-6399

ATTACHMENT 1 TO NL-02-082

LICENSE AMENDMENT REQUEST

Revision to the IP2 Technical Specifications Requirements for Control Rod Misalignment and Rod Position Indication.

ENTERGY NUCLEAR OPERATIONS, INC
INDIAN POINT NUCLEAR GENERATING UNIT 2
DOCKET NO. 50-247

LICENSE AMENDMENT REQUEST

DESCRIPTION OF THE PROPOSED CHANGE

The proposed change revises the Indian Point Nuclear Generating Unit 2 (IP2) Facility Operating License No. DPR-26, Appendix A, Technical Specifications (TS) List of Tables, Section 3.10.4, "Rod Insertion Limits," Section 3.10.5, "Rod Misalignment Limitations," Section 3.10.6, "Inoperable Rod Position Indicator Channels," and the associated Bases to remove the cycle specific allowances on (1) rod insertion limits during individual rod position indicator channel calibrations and (2) rod position indicator channel accuracy requirements for operation at or below 50% power. The proposed change also permits increasing the indicated control rod misalignment from the current limits to an indicated misalignment of ± 24 steps when the core power is ≤ 85% of rated thermal power (RTP) and ± 12 steps when the core power is > 85% of RTP with variations (see proposed Table 3.10-1), which account for the control rod position being above the top of active fuel (TAF). The proposed change is based on the analysis documented in WCAP-15902. To perform the analysis of the possible rod misalignment, two distinct nuclear models of the IP2 core were used, as described in Section 3.2 of WCAP-15902. These models cover a large variation in cycle length, the number of feed assemblies, the feed enrichments and the number of burnable absorbers, and are expected to bound any current and future fuel management strategies for IP2. Based on these two models, the results of the rod misalignment analysis are considered to be cycle independent.

EVALUATION OF THE PROPOSED CHANGES

Westinghouse performed an analysis of the effects of increasing the allowed control rod indicated misalignment from 12 steps to an indicated misalignment of 24 steps when the core power is less than or equal to 85% of RTP and increasing the allowed misalignment to greater than 12 steps above 85% of RTP with the following additional considerations:

- When the group step counter demand position exceeds the TAF, the acceptable deviation on the negative side may increase by 1 step for every additional step of group step counter demand position;
- When the group step counter demand position is below the TAF by no more than 12 steps, the acceptable deviation on the positive side may extend to the fully withdrawn position.

The results of these analyses are reported in Westinghouse document WCAP-15902 and are summarized here. The number and type of rod misalignments were limited by the performance of an evaluation of the Failure Mode and Effects Analysis performed for the rod control system (Reference 1 of WCAP-15902). The evaluation was limited to single failures within the rod control system logic cabinets, power cabinets and the control rod drive mechanisms themselves. Multiple failures were not considered as reasonable precursors of rod misalignment since the surveillances of rod position are frequent enough to limit such occurrences.

The evaluation concluded that there were six categories of failure mechanisms that warranted investigation. These categories are described in Section 2.0 of WCAP-15902. As a result of these failure mode categories, eight different cases of misalignment were analyzed. Some cases involved single and multiple rod misalignments in a single group in either the insertion or withdrawal directions. These misalignments can be asymmetric.

The remaining cases involved all rods in a group misaligned from the group step counter demand position. While this type of misalignment did not result in a rod-to-rod deviation, either the group did not move in the correct direction or the correct group did not move which for the purpose of the analyses was considered a misalignment from the demand position. This type of misalignment is symmetric. The eight cases are described in detail in Section 3.3 of WCAP-15902.

The analyses concluded that below 85% of RTP, indicated rod misalignments of up to ±24 steps between the group step counter demand position and the position indicated by the analog rod position indicator (ARPI) may be allowed based on the magnitude of peaking factor margin that is introduced by the reduction in the power level.

The margin increases are provided by the equations of the Core Operating Limits Report, noted below for clarity:

$$F_Q(z) = \frac{[F_Q^{RTP}][K(z)]}{P} \text{ for } P > 0.5$$

$$F_Q(z) = \frac{[F_Q^{RTP}][K(z)]}{0.5} \text{ for } P \leq 0.5$$

$$F_{\Delta H}^{N} = [F_{\Delta H}^{RTP}][1.0+(PF_{\Delta H})(1-P)]$$

The margin requirements for a maximum indicated control rod misalignment of 24 steps are less than the increases in the limits for F_Q and $F_{\Delta H}$ for operation at or below 85% of RTP (for P = 85%, the quantity [1.0 + 0.3(1-P)] equals 1.045 or an increase of 4.5% in $F_{\Delta H}$ and 1/P equals 1.17 or an increase of 17% in F_Q). Therefore, the increase in allowed indicated misalignment is considered reasonable and acceptable. (See Section 3.5 of WCAP-15902)

For operation at power levels greater than 85% of RTP, the evaluation concludes that the degree of indicated misalignment is a function of the peaking factor margin present. The margin is determined by comparing the measured F_Q (z) and $F_{\Delta H}^{N}$ from the most recent, current cycle, full power incore flux map with their corresponding limits. However, for conservatism, IP2 will restrict the deviation to ±12 steps with the exceptions defined in Table 3.10-1 and explained below.

For group step counter demand positions greater than 209 steps withdrawn, it is acceptable for the ARPI to indicate misalignment greater than +12 steps without accounting for peaking factor margin. This is due to the TAF stack being at 221 steps withdrawn. Actual control rod positions above the TAF will not result in increased peaking factors for increased misalignments. Similarly, allowable negative deviation limits may increase by 1 step for every step the group step counter demand position is above the TAF.

TS 3.10.5.1 has been modified to allow up to one hour after control rod motion to verify control rod position. This time period is based on the time deemed necessary to allow the control rod drive shaft to reach thermal equilibrium. Due to changes in the magnetic permeability of the drive shaft as a function of temperature, the indicated position is expected to change with time as the drive shaft cools on withdrawal. The existing two hour time period to realign a misaligned rod is reduced to one hour after the completion of the thermal soak period to ensure an actual misalignment will be corrected within two hours of exceeding the limits. The one hour time period is consistent with NRC approved time extensions at other plants, specifically Salem Units 1 and 2; Turkey Points Units 3 and 4 and Indian Point Unit 3, and allows for the position indication to stabilize prior to taking action.

WCAP-15902, Section 3, identifies the effects of indicated rod misalignments greater than 12 steps on the normal operation peaking factors. Section 4 of WCAP-15902 identifies the effects on the applicable safety analyses. In summary, the increase in rod misalignment does not significantly affect any of the following: moderator or Doppler reactivity coefficients or defects, reactor kinetics data, boron worth or data generated for evaluation of boron dilution or boron system duty. Condition II transients, (rod out of position, dropped rod and single rod withdrawal) assume either all rods out (ARO) or rods at the insertion limit (RIL) as initial conditions. These are considered fully misaligned rod transients caused by a single failure of the control rod system. Therefore, one does not need to assume a rod misalignment from the ARO or RIL positions as a precondition to the Condition II rod misalignment transients. The proposed changes to the rod misalignment Technical Specifications do not have an adverse impact on the safety analysis inputs for these accidents or the DNB analysis results.

Another possible impact of the increase in the rod misalignment is an increase in the rod insertion allowance (RIA), the worth of the rods at their RIL. The RIA has a direct impact on the available trip reactivity and the shutdown margin (SDM) assumed in several transient analyses including steamline break. The maximum increase in the RIA, and hence largest reduction in the trip worth and SDM, would be due to an entire bank being misaligned in deeper than the RIL, consistent with failure category C described in Section 3.3 of WCAP-15902. However, the available trip reactivity and SDM also assume that the core is subcritical with an N-1 rod configuration, where the highest individual worth rod is stuck out of the core, consistent with failure category D described in Section 3.3 of WCAP-15902.

As stated above, only rod misalignments resulting from a single failure need to be considered, therefore, for the trip reactivity and SDM, one does not need to assume an increase in the RIA due to one misalignment and a worst stuck rod (WSR) due to another misalignment. In addition, the reduction in available SDM due to the WSR is much greater than the worth that would be lost due to an increase in the RIA. As such, the proposed changes to the rod misalignment TS do not have an adverse impact on the available trip reactivity or SDM.

Safety analyses parameters that are expected to be affected by the increased rod misalignment are the ejected rod $F_Q(z)$ and the ejected rod worth ($\Delta\rho_{EJ}$). To determine the ejected rod effects, reconditioning with the maximum allowed misalignment was assumed for single rod, a group of rods and entire banks. The subsequent effects on $F_Q(z)$ and $\Delta\rho_{EJ}$ for the two cycles were determined. Accordingly, increases in $F_Q(z)$ and $\Delta\rho_{EJ}$ must be included in the safety analyses to bound the projected effects when a cycle specific analysis is not performed, as described in Sections 4 and 5 of WCAP-15902.

The safety analysis of the rod ejection transient also assumes a certain amount of available trip worth following the rod ejection. Since the ejected rod is assumed to damage a neighboring Rod Cluster Control Assembly (RCCA) drive housing, the trip worth for this transient is defined as the change in core reactivity between the HZP, RIL condition and the HZP, all rods inserted (ARI) minus the ejected rod and the neighboring rod. Then, for the application of this TS, the available trip reactivity following a rod ejection accident that is calculated as part of the reload safety evaluation must be decreased, as described in Sections 4 and 5 of WCAP-15902, before comparing to the value assumed in the safety analysis.

NO SIGNIFICANT HAZARDS EVALUATION

ENO has determined that the proposed Technical Specification change involves no significant hazards consideration as defined by 10CFR50.92(c).

1. **Operation of the facility in accordance with the proposed amendment would not involve a significant increase in the probability of occurrence or consequences of an accident previously evaluated.**

The magnitude of control rod misalignment, allowed by the proposed changes to TS Section 3.10.5, is not a contributor to the mechanistic cause of an accident previously evaluated in the UFSAR. The functions of the Control Rod Drive System or the Analog Rod Position Indicator System are not being altered by the proposed changes. Therefore, the proposed increase in control rod misalignment will not result in an increase in the probability of a previously evaluated accident.

The bounding design limitations of these systems will continue to be met and the integrity of the fuel cladding and the reactor coolant system pressure boundary will not be challenged by the proposed changes. The initial conditions and input assumptions employed in the calculation of the offsite radiological doses will remain valid. Therefore, the consequences of a previously evaluated accident will not be increased.

2. **Operation of the facility in accordance with the proposed amendment would not create the possibility of a new or different kind of accident from any accident previously evaluated.**

The pertinent licensing basis acceptance criteria will continue to be met and the margin of safety defined in the TS Bases will not be reduced in the IP2 licensing basis accident analyses. The magnitude of the allowed control rod misalignment is not a contributor to the mechanistic cause of any known accident and the functions of the Control Rod Drive System or the Analog Rod Position Indicator System are not being altered. Therefore, a new or different kind of an accident than any previously evaluated, will not be created.

3. **Operation of the facility in accordance with the proposed amendment would not involve a significant reduction in the margin of safety.**

Based on the changes to safety analyses input parameter values, the pertinent licensing basis acceptance criteria will continue to be met and the margin of safety, defined in the TS Bases, will not be reduced in the IP2 licensing basis accident analyses. Therefore, the proposed change will not involve a reduction in margin of safety.

CONCLUSIONS

Based on the above evaluation, ENO has concluded that the proposed change will not result in a significant increase in the probability or consequences of any accident previously analyzed; will not result in a new or different kind of accident from any accident previously analyzed, and will not result in a reduction in any margin of safety. Therefore, operation of IP2 in accordance with the proposed amendment involves no significant hazards considerations as defined in 10 CFR 50.92. In addition, the onsite and offsite safety review committees have reviewed the proposed change to the TS and both committees concur that the proposed change involves no significant hazards consideration.

ENVIRONMENTAL ASSESSMENT

An environmental assessment is not required for the proposed change because the requested change to the IP2 TS conforms to the criteria for "actions eligible for categorical exclusion," as specified in 10CFR51.22(c)(9). The requested change will have no impact on the environment. The proposed change involves no significant hazards consideration as discussed in the preceding section. The proposed change does not involve a significant change in the types or significant increase in the amounts of any effluents that may be released offsite. In addition, the proposed change does not involve a significant increase in individual or cumulative occupational radiation exposure.

ATTACHMENT 2 TO NL-02-082

TECHNICAL SPECIFICATION PAGES IN

STRIKEOUT/SHADED FORMAT

Deleted text is shown as ~~strikeout~~.

Added text is shown as shaded.

List of effective pages:

vii
3.10-5
3.10-6
3.10-9
3.10-13
3.10-14
3.10-15
3.10-16
3.10-17
3.10-18
Table 3.10-1 (page 1 of 1)

ENTERGY NUCLEAR OPERATIONS, INC
INDIAN POINT NUCLEAR GENERATING UNIT 2
DOCKET NO. 50-247

LIST OF TABLES

3.10.4.3 Control bank insertion shall be further restricted if:

a. The measured control rod worth of all rods, less the worth of the most reactive rod (worst case stuck rod), is less than the reactivity required to provide the design value of available shutdown,

b. A rod is inoperable (Specification 3.10.7).

3.10.4.4 Insertion limits do not apply during physics tests or during periodic exercise of individual rods. ~~*In addition, insertion limits do not apply when performing calibration of individual rod position indicator channels at or below a nominal 30% power not to exceed 35% power.~~ However, the shutdown margin indicated in Figure 3.10-1 must be maintained except for the low-power physics test to measure control rod worth and shutdown margin. For this test the reactor may be critical with all but one control rod inserted.

~~* For Cycle 15.~~

3.10.5 Rod Misalignment Limitations

3.10.5.1.~~1~~ Except for within one hour of control rod motion (to allow time for the control rod drive shaft to reach thermal equilibrium), the indicated misalignment between the group step counter demand position and the analog rod position indicator shall be maintained within the following limits:

a. For operation at or below 85% power, if a control rod is misaligned from its group step counter demand position by more than ± 24 steps ~~If a control rod is misaligned from its bank demand position by more than ±12 steps when indicated control rod position is less than or equal to 210 steps withdrawn~~, then realign the rod within one hour or determine the core peaking factors within 2 hours and apply Specification 3.10.2.

~~3.10.5.1.2~~ b. For operation greater than 85% power, if a control rod is misaligned from its group step counter demand position by more than the limits of Table 3.10-1, ~~If a control rod is misaligned from its bank demand position by more than +17, -12 steps when indicated control rod position is greater than or equal to 211 steps withdrawn,~~ then realign the rod within one hour or determine the core peaking factors within 2 hours and apply Specification 3.10.2.

3.10.5.2 If the restrictions of Specification 3.10.3 are determined not to apply and the core peaking factors have not been determined within two hours and the rod remains misaligned, the high reactor flux setpoint shall be reduced to less than or equal to 85% of its rated value.

3.10.5.3 If the misaligned control rod is not realigned within 8 hours, the rod shall be declared inoperable.

3.10.6 Inoperable Rod Position Indicator Channels

3.10.6.1 ~~A rod position indicator channel shall be capable of determining control rod position as follows: for operation at or below 50% power, within ±24 steps*; for operation above this power, within ±12 steps for indicated control rod position less than or equal to 210 steps withdrawn and +17, -12 steps for indicated control rod position greater than or equal to 211 steps withdrawn, or~~ If a rod position indicator channel is inoperable, then:

a. For operation between 50 percent and 100 percent of rating, the position of the control rod shall be checked indirectly by core instrumentation (excore detectors and/or movable incore detectors) every shift, or subsequent to rod motion exceeding 24 steps, whichever occurs first.

b. During operation below 50 percent of rating, no special monitoring is required.

3.10.6.2 Not more than one rod position indicator channel per group nor two rod position indicator channels per bank shall be permitted to be inoperable at any time. During calibration a rod position indication channel is not considered to be inoperable.

3.10.6.3 If a control rod, having an inoperable rod position indicator channel, ~~out of service~~ is found to be misaligned from Specification 3.10.6.1a, above, then Specification 3.10.5 will be applied.

~~* For Cycle 15.~~

3.10.7 Inoperable Rod Limitations

3.10.7.1 An inoperable rod is a rod which does not trip or which is declared inoperable under Specification 3.10.5, or which fails to meet the requirements of Specification 3.10.8.

3.10.7.2 Not more than one inoperable control rod shall be allowed any time the reactor is critical except during physics tests requiring intentional rod misalignment. Otherwise, the plant shall be brought to the hot shutdown condition.

3.10.7.3 If any rod has been declared inoperable, then the potential ejected rod worth and associated transient power distribution peaking factors shall be determined by analysis within 30 days. The analysis shall include due allowance for non-uniform fuel depletion in the neighborhood of the inoperable rod. If the

Measurements of the hot channel factors are required as part of startup physics tests at least each effective full-power month of operation, and whenever abnormal power distribution conditions require a reduction of core power to a level based on measured hot channel factors. The incore map taken following initial loading provides confirmation of the basic nuclear design bases, including proper fuel loading patterns. The periodic monthly incore mapping provides additional assurance that the nuclear design bases remain inviolate and identifies operational anomalies which would otherwise affect these bases.

For normal operation, it is not necessary to measure these quantities. Instead it has been determined that, provided certain conditions are observed, the hot channel factor limits will be met; these conditions are as follows:

1. At greater than 85% power, ~~C~~control rods in a single bank move together with no individual rod insertion differing by more than 15 inches from the group step counter ~~bank~~ demand position. An indicated misalignment limit of 12 steps precludes rod misalignment no greater than 15 inches with consideration of maximum instrumentation error. ~~for indicated rod position less than or equal to 210 steps withdrawn.~~ Additional misalignment per Table 3.10-1 is allowed near the fully withdrawn position, since the top of the active core (221 steps) is less than the fully withdrawn position.

   ~~For indicated control rod positions greater than or equal to 211 steps withdrawn, an indicated misalignment of +17 steps does not exceed the power peaking factor limits. The reactivity worth of a rod at this core height (211 + steps) is not sufficient to perturb power shapes to the extent that peaking factors are affected.~~

2. At or below ~~50~~85% power the allowed rod position indicator ~~capability~~ misalignment is less than or equal to 24 steps.

3. Control rod banks are sequenced with overlapping banks as described in Technical Specification 3.10.4.

4. The control rod bank insertion limits are not violated.

5. Axial power distribution control procedures, which are given in terms of flux difference control and control bank insertion limits, are observed. Flux difference refers to the difference in signals between the top and bottom halves of two-section excore neutron detectors. The flux difference is a measure of the axial offset which is defined as the difference in normalized power between the top and bottom halves of the core.

condition can be identified as due to rod misalignment, operation can continue at a reduced power (3% for each 1 percent the tilt ratio exceeds 1.0) for two hours to correct the rod misalignment.

Trip shutdown reactivity is provided consistent with plant safety analysis assumptions. One percent shutdown is adequate except for steam break analysis, which requires more shutdown if the boron concentration is low. Figure 3.10-1 is drawn accordingly.

Rod insertion limits are used to assure adequate trip reactivity, to assure meeting power distribution limits, and to limit the consequence of a hypothetical rod ejection accident. The available control rod reactivity, or excess beyond needs, decreases with decreasing boron concentration because the negative reactivity required to reduce the power level from full power to zero power is largest when the boron concentration is low.

~~Insertion limits do not apply during calibration of RPIs at or below a nominal 30% power not to exceed 35% power because performing these calibrations at this reduced power ensures that the power peaking factor limits are met.~~

The intent of the test to measure control rod worth and shutdown margin (Specification 3.10.4) is to measure the worth of all rods less the worth of the worst case for an assumed stuck rod, that is, the most reactive rod. The measurement would be anticipated as part of the initial startup program and infrequently over the life of the plant, to be associated primarily with determinations of special interest such as end-of-life cooldown, or startup of fuel cycles which deviate from normal equilibrium conditions in terms of fuel loading patterns and anticipated control bank worths. These measurements will augment the normal fuel cycle design calculations and place the knowledge of shutdown capability on a firm experimental as well as analytical basis.

Operation with abnormal rod configuration during low-power and zero-power testing is permitted because of the brief period of the test and because special precautions are taken during these tests.

The primary means of determining the position of individual control rods is the Analog Rod Position Indication system. The ARPI system consists of an individual rod position detector mounted on the pressure housing of each of the rod drive mechanisms, rack mounted electronic equipment and indicating equipment mounted on the flight panel. The rod position detector is a linear variable transformer consisting of primary and secondary coils alternatively stacked on a stainless steel support tube. The mechanism drive shaft serves as ~~a~~ the "movable core" of the transformer. With a constant AC source applied to the primary windings, the vertical position of the mechanism drive ~~rod~~ shaft changes the primary to secondary magnetic coupling and produces a unique AC secondary voltage. This output voltage is an analog signal which is proportional to the vertical position of the control rod. The magnetic permeability of the drive rod shaft is a function of temperature and the indicated position is expected to change with time as the drive shaft cools on withdrawal, therefore a soak period is provided to allow the drive shaft to reach thermal equilibrium prior to taking further action when the indicated control rod position exceeds the stated limits of misalignment from the group step counter demand position. The AC output from the secondary coils is fed to the signal conditioning circuit on the rod position chassis where ~~is~~ it is rectified to a DC signal and filtered. The resulting DC analog voltage, which is proportional to rod position, is fed to the following points.

a) Rod bottom bistable
b) Flight panel indicator
c) Position voltmeter on flight panel
d) Test points on front of chassis
e) Plant Computers

The axial position of shutdown rods and control rods is also indicated by the Bank Demand Position Indication System (commonly called group step counters). The Bank Demand Position Indication System counts the pulses from the rod control system that moves the rods. There is one step counter for each group of rods. Individual rods in a group all receive the same signal to move and should, therefore, all be at the same position as indicated by the group step counter for that group.

Technical Specification limits are established to ensure that the actual position of individual control rods match the group step counter demand position within an alignment limit that is established by analysis. These are:

a) ± 24 steps of the group step counter demand position (if the power level is less than or equal to 85% of rated thermal power);
b) to within the varying allowable deviations shown in Table 3.10-1 (if the power level is greater than 85% of rated thermal power);

~~A zero and span adjustment is provided to produce an output voltage signal proportional to rod travel between rods full in and rods full out. Because there is only a zero and span adjustment, a two point calibration is done.~~

~~The rod position indicator channel is sufficiently accurate to detect a rod ±7.5 inches away from its demand position for indicated control rod position less than or equal to 210 steps withdrawn. An indicated misalignment ≤ 12 steps does not exceed the power peaking factor limits. A misaligned rod of + 17 steps allows for an instrumentation error of 12 steps plus 5 steps that are not indicated due to the location relationship of the RPI coil stack and the control rod drive rod for indicated rod position greater than or equal to 211 steps withdrawn.~~ For power levels less than or equal to 85% of rated thermal power the allowable deviation may increase to ± 24 steps (± 15 inches). This is due to the rate of peaking factor margin increase (as power level decreases) being greater than the peaking factor margin loss (due to the increased control rod misalignment). This effect is described in Reference 2. These limits are applicable to all control rods (of all banks) over the range of 0 to 225 steps withdrawn inclusive. The analysis in Reference 2 was performed at a misalignment of ± 36 steps (± 22.5 inches) to account for ARPI design and calibration uncertainty of ± 12 steps (± 7.5 inches).

For power levels greater than 85% of rated thermal power, the allowable deviation shown in Table 3.10-1 varies as a function of group step counter demand position allowing for the top of active fuel ending at a control rod position of 221 steps. For group step counter demand position greater than 209 steps withdrawn, it is acceptable for the analog rod position indicator to indicate misalignment greater than +12 steps. This is due to the top of active fuel stack being at 221 steps withdrawn. Actual control rod positions above the top of active fuel will not result in increased peaking factors for increased misalignments. Similarly, allowable negative deviation limits may increase by 1 step for every step of group step counter demand position over the top of active fuel. ~~The last five steps of rod travel are not indicated by the RPI because the drive rod and spider assembly have been raised three inches (≈5 steps) from rod bottom. The reactivity worth of a rod at this core height (210 + steps) is not sufficient to perturb power shapes to the extent that peaking factors are affected.~~

~~Experience at Indian Point 2 and at other plants with similar RPI systems has shown that the output signal of the RPI is not exactly linear with respect to vertical position of the control rod. Thus, there is some inherent error initially in the RPI indication. However, by calibrating the shutdown bank and control banks A, B and C at the fully withdrawn position, and control bank D at its normal operating position, the calibration will be most accurate at the position where the rods are usually found. In addition, experience has shown that the proportionality constant is sensitive to temperatures.~~

~~As a result of the above an additional uncertainty is added to the normal measurement uncertainty. To account for these uncertainties, data points can be collected and an individual graph for each RPI can be provided to the operator. As an alternative to individual graphs, a larger total uncertainty can be assumed for the RPI along with an equivalent assumed~~

~~misalignment of a rod from the bank demand position. Calculations have been done that demonstrate that a total of ±24 steps can be tolerated as an error at or below 50% power. Since at some power levels it is not possible to determine whether there is rod motion or the RPI has drifted or is inaccurate, the calculations have assumed in the worst case a misalignment of 48 steps between a D bank control rod and the remainder of its group (i.e., 24 steps due to the RPI indication and 24 steps misalignment). This was also done for the C Bank (both banks were nominally at their 100% power insertion limits). For conservatism the Technical Specifications on allowed rod misalignment has been kept at ±12 steps, that is, for power levels where the rod position can be determined more accurately. If the indicated misalignment of ±24 steps has been exceeded, and a check has shown that the control rod(s) are indeed misaligned by more than ±12 steps, then the rod would be returned to ±12 steps or additional action must be taken as prescribed in the Technical Specification.~~

It is recognized that during certain reactor conditions the actual rod position cannot be determined. For example, during startup (subcritical) when the shutdown banks are withdrawn there may be misalignment, but because the reactor is subcritical, no independent verification is possible. Therefore, the operator must rely on the RPI's. But, on the other hand, because there is no power, rod misalignment is of no significance. Therefore, the ± 24 steps criteria for the RPI indication, when applied to actual rod misalignment would have no affect on thermal margins because of higher peaking factors. No increase in power is allowed until all shutdown banks are out, Control Bank A is out and Control Banks B, C, and D are at or above the insertion limit.

Another situation where the actual rod position cannot be determined is when the reactor is being shutdown. Again for the control rods to be inserted beyond the insertion limit requires that the reactor be brought subcritical and again, rod misalignment would have no effect on thermal margins.

~~If it is determined that the RPI is out of calibration, on-line calibration of the instrumentation can be performed at or below a nominal 30% power not to exceed 35% power. Thermal margins are maintained by reducing power to or below the respective powers for extended RPI deviation limits and on-line calibration.~~

If the rod position indicator channel is not operable, the operator will be fully aware of the inoperability of the channel, and special surveillance of core power tilt indications, using established procedures and relying on excore nuclear detectors and/or movable incore detectors, will be used to verify power distribution symmetry. These indirect measurements do not have the same resolution if the bank is near either end of the core, because a 24-step misalignment would have no significant effect on power distribution. Therefore, it is necessary to apply the indirect checks following significant rod motion.

One inoperable control rod is acceptable provided that the power distribution limits are met, trip shutdown capability is available, and provided the potential hypothetical ejection of the inoperable rod is not worse than the cases analyzed in the safety analysis report. The rod ejection accident for an isolated fully-inserted rod will be worse if the residence time of the rod is long enough to cause significant non-uniform fuel depletion. The 4 week period is short compared with the time interval required to achieve a significant non-uniform fuel depletion.

The required drop time to dashpot entry is consistent with safety analysis.

References

1. UFSAR Section 14.3
2. WCAP-15902, "Conditional Extension of the Rod Misalignment Technical Specification for Indian Point Unit 2"

Table 3.10-1

Permissible Rod Misalignment vs. Group Step Counter Demand Position, >85% Power

Group Step Counter Demand Position (steps)	Maximum Positive Deviation (ARPIs reading greater than Group Step Counter Demand Position)	Maximum Negative Deviation (ARPIs reading less than Group Step Counter Demand Position)
≤ 209	12	-12
210 to 221	16	-12
222	16	-13
223	16	-14
224	16	-15
≥ 225	16	-16

ENCLOSURE 1 TO NL-02-082

Proprietary Version

WCAP-15902, "Conditional Extension of the Rod Misalignment Technical Specification for Indian Point Unit 2."

ENTERGY NUCLEAR OPERATIONS, INC
INDIAN POINT NUCLEAR GENERATING UNIT 2
DOCKET NO. 50-247

ENCLOSURE 2 TO NL-02-082

Non-Proprietary Version

WCAP-15902, "Conditional Extension of the Rod Misalignment Technical Specification for Indian Point Unit 2."

ENTERGY NUCLEAR OPERATIONS, INC
INDIAN POINT NUCLEAR GENERATING UNIT 2
DOCKET NO. 50-247

Westinghouse Non-Proprietary Class 3

WCAP-15902-NP
Revision 0

June 2002

Conditional Extension of the Rod Misalignment Technical Specification for Indian Point Unit 2

Westinghouse

WESTINGHOUSE NON-PROPRIETARY CLASS 3

WCAP-15902-NP

Conditional Extension of the Rod Misalignment Technical Specification for Indian Point Unit 2

June, 2002

R. J. Fetterman

Verified:________________
F. F. Cortazar

Approved:________________
E. J. Piplica, Manager
Core Analysis C

Westinghouse Electric Company LLC
Nuclear Fuel
4350 Northern Pike
Monroeville, Pennsylvania 15146-2886

ABSTRACT

This report proposes modifying the Technical Specification for allowable rod misalignment from the current ±12 steps indicated to a value up to a maximum of ±18 steps indicated, depending upon the minimum available peaking factor margin. Such a Technical Specifications change is sought to minimize disruptions to normal plant operations due to frequent and erroneous indications of rod misalignment from the Analog Rod Position Indicator (ARPI).

The required margins to the hot rod and hot spot peaking factor ($F_{\Delta H}$ and F_Q) limits will be determined by examining the changes in these peaking factors between similar cases with misalignments of ±12 and ±18 steps indicated. These resulting required margins will be determined such that they are cycle independent for Indian Point 2. It will also be shown that plant safety will not be compromised by this Technical Specifications change.

"This page intentionally blank."

ACKNOWLEDGEMENTS

The author gratefully acknowledges the following individuals for their contributions to the completion of this report: F. F. Cortazar and C. R. Tuley.

"This page intentionally blank."

TABLE OF CONTENTS

"This page intentionally blank."

LIST OF TABLES

"This page intentionally blank."

LIST OF FIGURES

1 INTRODUCTION

The current Westinghouse licensing basis supports an indicated rod misalignment of ±12 steps for any rod(s) within a bank from the bank demand position. As the analog rod position indication system (ARPI) has an uncertainty of 12 steps, the actual misalignment may be as large as ±24 steps. In most cases, these indicated misalignments are false readings caused by fluctuations in the temperature of the control rod drive shafts. For example, such fluctuations can occur after rod control cluster assemblies (RCCAs) are withdrawn from the core during startup. However, when an indication of a misalignment does occur, false or otherwise, the reactor operator must take corrective action per the Technical Specifications.

Increasing the maximum allowable indicated misalignment to ±18 steps (actual misalignment of ±30 steps) for core powers above 85% rated thermal power (RTP) and ±24 steps (actual misalignment of ±36 steps) for core powers less than or equal to 85% rated thermal power (RTP) will provide relief to the aforementioned conditions of false misalignment indications from the ARPI. For real misalignments, these misalignment increases generally yield small but acceptable increases in the hot rod and hot spot peaking factors, $F_{\Delta H}$ and F_Q. This report will briefly review the feasible single failures of the rod control system that could yield misalignments of single and multiple rods. These feasible single failures will then form the basis for the cases analyzed and documented in this report to support the increase in the misalignment permitted by the Technical Specifications.

“This page intentionally blank.”

2 DESCRIPTION OF ROD CONTROL SYSTEM FAILURES

To determine the misalignment cases to be analyzed for this Technical Specification change, an evaluation of the rod control system was performed, drawing from the Failure Mode and Effects Analysis (FMEA) documented in Reference 1. This evaluation considered single failures within the rod control system logic cabinets, power cabinets and the control rod drive mechanisms (CRDMs). This evaluation also considered the impacts of the revised current order timing previously documented in Reference 2.

This evaluation has determined that a single failure of the rod control system can result in six categories of failure mechanisms within the system:

A. [

]a,c.

B. [

]a,c.

C. [

]a,c.

D. [

]a,c.

E. [

]a,c.

F. [

]a,c.

3 ANALYSES SUPPORTING NORMAL OPERATION

For the remainder of this report, the failure mechanisms discussed in Section 2 will be referred to by the letter they are listed as; i.e. failures A through F. When analyzing these failure mechanisms for peaking factor impacts, the following cabinet configurations must be considered:

1. 1AC: groups CA1, CC1, SA1
2. 2AC: groups CA2, CC2, SA2
3. 1BD: groups CB1, CD1, SB1
4. 2BD: groups CB2, CD2, SB2
5. SCD: groups SC, SD

The above configurations are also illustrated in Figure 3.1. The group nomenclature used to describe the power cabinets is defined as follows: the first letter (C or S) refers to a control or shutdown bank; the second letter (A, B, C or D) refers to the bank; the number (1 or 2) refers to the group number. For example, power cabinet 1AC controls group CA1, which is group 1 of control bank A. Power cabinet 2BD controls group SB2, which is group 2 of shutdown bank B. Note that the Indian Point 2 plant does not have a shutdown bank E (SE), which would be the third group of rods in power cabinet SCD.

[

]a,c.

3.1 ANALYSIS METHODOLOGY

The failure mechanism categories described in Section 2 will be analyzed using the USNRC-approved PHOENIX-P/ANC core design system documented in References 3 and 4. For each failure analyzed, calculations are performed for misalignments of ±24 steps plus additional misalignments and compared to the corresponding non-misaligned reference case.

The $F_{\Delta H}$ and F_Q for these cases are calculated and compared [

]a,c.

3.2 CORE MODELS USED FOR ANALYSIS

To perform the analysis of the possible rod misalignments, two different ANC models of the Indian Point 2 core were used. The first model represents the planned design for 24 month cycle operation. The second model represents an 18 month transition cycle. These two models are summarized in Table 3.1 below:

Table 3.1 Design Models Used in Rod Misalignment Analyses

Design Parameter	Current Cycle	Future Cycle
Cycle Length (End of Full Power Capability, EFPD)	660	[ ]a,c
No. of Feed Assemblies	88	[ ]a,c
No. Feeds Under Lead Bank (No. @ w/o U235)	8 @ 4.95	[ ]a,c
Feed Enrichments (No. @ w/o U235)	32 @ 4.60 8 @ 4.80 48 @ 4.95	[ ]a,c
Axial Blankets (w/o U235)	8, 6" 2.6 w/o Annular 80, 8" 3.2 w/o Annular	[ ]a,c
Burnable Absorbers (No. / Type / Length)	848 IFBA, 120" centered 7664 IFBA, 128" centered 112 WABA, 132" centered 1040 WABA, 120" centered	[ ]a,c
$F_{\Delta H}$ Limit	1.70	[ ]a,c
F_Q Limit	2.50	[ ]a,c

3.3 MISALIGNMENT CASES ANALYZED

For the failure mechanism categories listed in Section 2, several distinct subsets of cases are analyzed in ANC. These cases are considered at [

]^{a,c}. Some cases are also examined at other cycle burnups, although these cases were found to generally yield less limiting increases in peaking factors from an increase in the rod misalignment. Most of the calculations are performed assuming the reference condition as hot full power (HFP) [

]^{a,c}; the Indian Point 2 RILs are illustrated in Figure 3.2. Several of these cases are repeated at other reference rod conditions above the RILs, and at part power conditions such as 85% and 50% rated thermal power. The subsets of cases analyzed are summarized below:

1. [

]^{a,c}.

2. [

]^{a,c}.

3. [

]^{a,c}.

4. [

]^{a,c}.

5. [

]^{a,c}.

6. [

]^{a,c}.

7. [

]^{a,c}.

8. [

]^{a,c}.

The basic analysis approach used in this report proposes dividing the rod misalignment Technical Specification into two modes of surveillance: operation at core powers greater than 85% rated thermal power (RTP); operation at core powers less than or equal to 85% RTP.

For the first mode of surveillance, the specific HFP cases analyzed for an additional 6 steps of misalignment are summarized in Table 3.3. The failure mechanisms listed in Table 3.3 are described in Section 2. Several of the limiting 6 step additional misalignment cases were repeated with only 3 steps of additional misalignment (±27 steps total) as listed in Table 3.4. The performance of the 3 step misalignment cases provide completeness and verify the bounding nature of the evaluation process utilized in this report. Results from these two tables are summarized in Table 3.2.

For the second mode of surveillance, additional cases were performed at part power conditions as listed in Tables 3.5 through 3.7 for additional misalignments of 6, 9 and 12 steps (30, 33 and 36 steps total). The results of the 12 additional step cases in Table 3.7 are used to determine an acceptable rod misalignment limit for core powers less than or equal to 85% RTP. The performance of the 6 and 9 step misalignment part-power cases provide completeness and verify the bounding nature of the evaluation process utilized in this report. Results from these three tables are also summarized in Table 3.2.

3.4 ANALYSIS RESULTS, POWER > 85% RTP

A complete description of all cases analyzed is presented in Tables 3.3 through 3.7. A summary of all cases analyzed and the limiting results to support the rod misalignment Technical Specifications change is given in Table 3.2. This data is presented as the change in the peak $F_{\Delta H}$ and F_Q for an increase in the rod misalignment beyond the current licensing basis of ±12 steps indicated (±24 steps actual).

Note that with the current $F_{\Delta H}$ and F_Q Technical Specifications, margins to the limits generally increase as power level decreases:

$$F_{\Delta H}^{LIMIT} = F_{\Delta H}^{HFP}[1 + 0.3(1 - P)] \tag{1}$$

$$F_Q^{LIMIT} = \frac{F_Q^{HFP}}{P}, P > 0.5 \tag{2}$$

Then, since $F_{\Delta H}$ and F_Q margins are usually a minimum at HFP, the amount of margin required to allow the permissible indicated misalignment to be increased from ±12 to ±18 steps will be determined based on the HFP data for the additional ±6 step misalignments from Table 3.3 and summarized in Table 3.2.

For all HFP ±6 step misalignment cases, the 95/95 increases in $F_{\Delta H}$ and F_Q are [ ]^{a,c} and [ ]^{a,c} respectively, and the maximum increases in $F_{\Delta H}$ and F_Q are [ ]^{a,c} and [ ]^{a,c} respectively. These results can be conservatively bounded by required $F_{\Delta H}$ and F_Q margins of [ ]^{a,c} and [ ]^{a,c}, respectively, for increased rod misalignment of ±6 steps. Note that these required margins are an increase of [ ]^{a,c} and [ ]^{a,c} respectively over the 95/95 values and an increase of [ ]^{a,c} and [ ]^{a,c} respectively over the observed maximum values for all HFP ±6 step cases.

Examining the ±3 step misalignments from Table 3.4, and summarized in Table 3.2, the 95/95 increases in $F_{\Delta H}$ and F_Q are [ ]^{a,c} and [ ]^{a,c} respectively, and the maximum increases in $F_{\Delta H}$ and F_Q are [ ]^{a,c} and [ ]^{a,c} respectively. These results can be conservatively bounded by required $F_{\Delta H}$ and F_Q margins of [ ]^{a,c} and [ ]^{a,c} respectively. Note that these required margins are an increase of [ ]^{a,c} and [ ]^{a,c} respectively over the 95/95 values and an increase of [ ]^{a,c} and [ ]^{a,c} respectively over the observed maximum values for all ±3 step cases. The analysis approach of the ±3 step cases is also conservative in that most of the cases analyzed [ ]^{a,c} were chosen based on which cases provided limiting results in the ±6 step analysis. [ ]^{a,c}.

Therefore, the proposed $F_{\Delta H}$ and F_Q margins for an additional 3 steps of misalignment are half of the limits proposed for an additional 6 steps. This would suggest that margin required for an increase in the permissible misalignment for core powers greater than 85% RTP can then be specified as a linear function of the available peaking factor margin, with the misalignment increase being determined from the minimum of the available $F_{\Delta H}$ or F_Q margin. The proposed rod misalignment limit for core powers greater than 85% RTP is illustrated in Figure 3.3.

3.5 ANALYSIS RESULTS, POWER ≤ 85% RTP

The ±6, ±9 and ±12 additional step part-power misalignment cases are listed in Table 3.5 through 3.7 respectively, and summarized in Table 3.2. The 95/95 increases in the ±6, ±9 and ±12 additional step $F_{\Delta H}$ and F_Q are [ ]^{a,c} and [ ]^{a,c}, [ ]^{a,c} and [ ]^{a,c}, and [ ]^{a,c} and [ ]^{a,c} respectively. The ±6 additional step part-power 95/95 $F_{\Delta H}$ and F_Q increases are only [ ]^{a,c} and [ ]^{a,c}, respectively, larger than the HFP-only ±6 additional step increases. However, by 85% power, the Technical Specification $F_{\Delta H}$ and F_Q limits have increased by 4.5% and 17%, respectively, as defined in Equations 1 and 2. [ ]^{a,c}, the proposed rod misalignment Technical Specification limit of ±18 steps indicated for core powers above 85% RTP can be increased for core powers less than or equal to 85% RTP. At 85% RTP, the peaking factor limit increases of 4.5% in $F_{\Delta H}$ and 17% in F_Q [ ]^{a,c} in F_Q due to the additional ±12 additional steps of rod misalignment. The analysis approach of the part-power misalignment cases is also conservative in that most of the cases analyzed [ ]a,c were chosen based on which cases provided limiting results in the ±6 step analysis. [

]a,c. Therefore, the proposed allowable indicated misalignment is ±24 steps for core powers of 85% RTP or less.

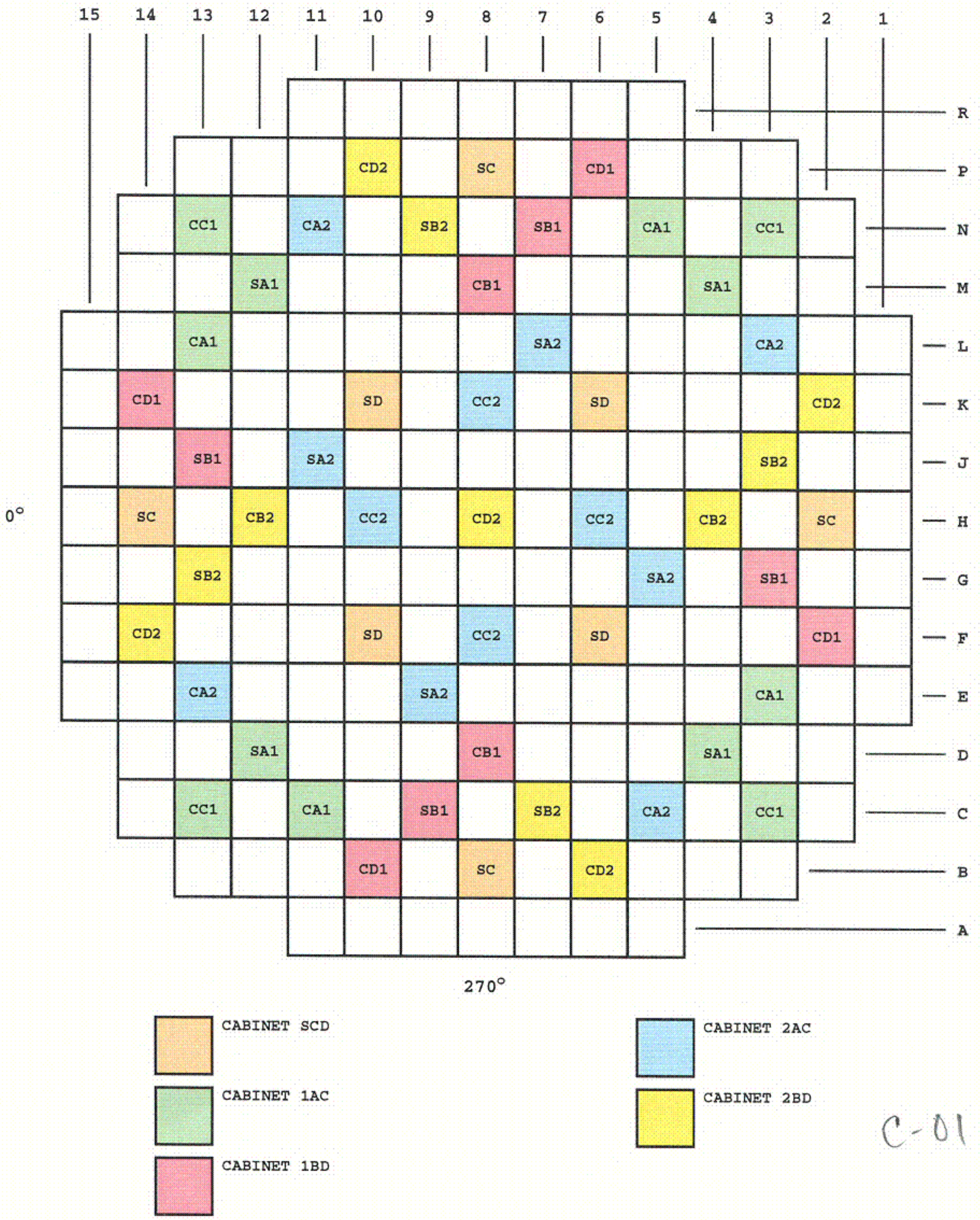
3.6 PROPOSED TECHNICAL SPECIFICATION CHANGES

A graphic representation of the proposed Technical Specification for core powers greater than 85% RTP discussed in Section 3.4 is shown in Figure 3.3. The amount of available margin must be determined at least once every 30 EFPD during normal incore flux map surveillance. For Indian Point 2, the amount of F_Q margin will be based on the F_Q surveillance methodology (Reference 6), which accounts for any transient and burnup effects on the measured steady-state F_Q. The required peaking factors margins for additional misalignments at core powers above 85% RTP are also summarized below:

Indicated Misalignment (Steps)	**Additional Misalignment (Steps)**	**Required Margin**	
		$F_{\Delta H}$	F_Q
12	0	[ ]a,c	[ ]a,c
13	1	[ ]a,c	[ ]a,c
14	2	[ ]a,c	[ ]a,c
15	3	[ ]a,c	[ ]a,c
16	4	[ ]a,c	[ ]a,c
17	5	[ ]a,c	[ ]a,c
18	6	[ ]a,c	[ ]a,c

For core powers of 85% RTP or less, as discussed in Section 3.5, the allowable indicated rod misalignment will be ±24 steps. At this amount of misalignment, the increase in the peaking factors relative to the current limit of ±12 steps is [ ]a,c as defined in Equations 1 and 2 of Section 3.4.

Figure 3.1 Indian Point 2 Control and Shutdown Rod Configuration By Subgroup and Power Cabinet



C-01

"This page intentionally blank."

Figure 3.2 Indian Point 2 Control Rod Insertion Limits

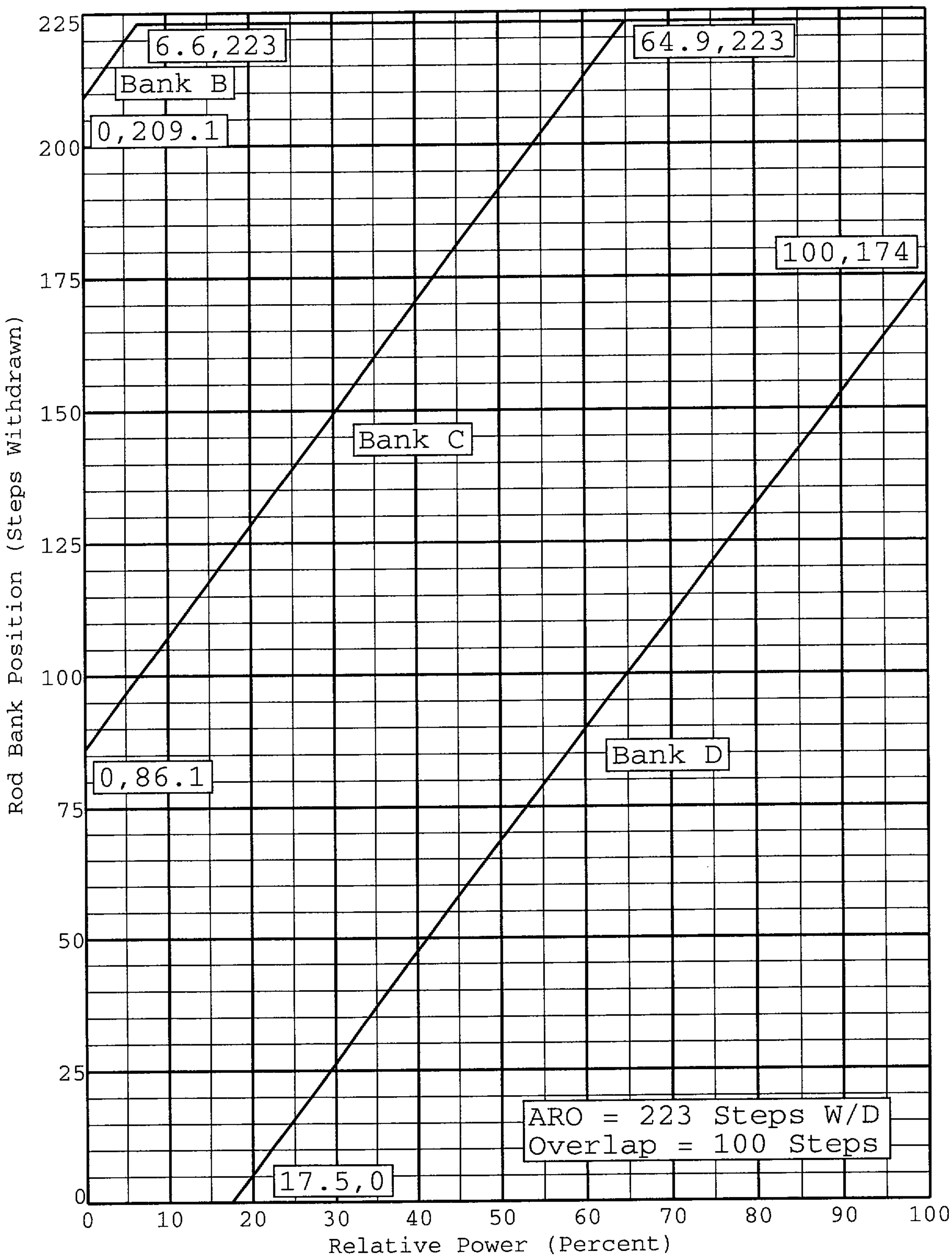


Figure 3.3 Permissible Increase in Rod Misalignment Vs. Available $F_{\Delta H}$ and F_Q Margin

a,c

Table 3.2 Summary of Misalignment Cases Analyzed; Change in Peak $F_{\Delta H}$ and F_Q for Increased Misalignment Beyond ±12 Steps Indicated

Power, Indicated Misalignment, No. Points, Summary Table No.	Peak	Distribution Function	Mean ($\bar{x}$), %	Std. Dev. (σ), %	95/95 Value, %	Max. % (Case No.)
HFP ±18 [ ]^{a,c} Table 3.3	$F_{\Delta H}$	Extreme Value	[ ]^{a,c}	[ ]^{a,c}	[ ]^{a,c}	[ ]^{a,c}
	F_Q	Beta	[ ]^{a,c}	[ ]^{a,c}	[ ]^{a,c}	[ ]^{a,c}
All Powers ±15 [ ]^{a,c} Table 3.4	$F_{\Delta H}$	Weibell	[ ]^{a,c}	[ ]^{a,c}	[ ]^{a,c}	[ ]^{a,c}
	F_Q	Beta	[ ]^{a,c}	[ ]^{a,c}	[ ]^{a,c}	[ ]^{a,c}
Part Power ±18 [ ]^{a,c} Table 3.5	$F_{\Delta H}$	Beta	[ ]^{a,c}	[ ]^{a,c}	[ ]^{a,c}	[ ]^{a,c}
	F_Q	Weibell	[ ]^{a,c}	[ ]^{a,c}	[ ]^{a,c}	[ ]^{a,c}
Part Power ±21 [ ]^{a,c} Table 3.6	$F_{\Delta H}$	Beta	[ ]^{a,c}	[ ]^{a,c}	[ ]^{a,c}	[ ]^{a,c}
	F_Q	Weibell	[ ]^{a,c}	[ ]^{a,c}	[ ]^{a,c}	[ ]^{a,c}
Part Power ±24 [ ]^{a,c} Table 3.7	$F_{\Delta H}$	Beta	[ ]^{a,c}	[ ]^{a,c}	[ ]^{a,c}	[ ]^{a,c}
	F_Q	Weibell	[ ]^{a,c}	[ ]^{a,c}	[ ]^{a,c}	[ ]^{a,c}

Table 3.3 Summary of 18 Step Indicated Hot Full Power Rod Misalignment Cases Analyzed (Sheet 1 of 16)

a,c

Case No.	Burnup	Power	Cycle	Failure Mechanism	Reference Bank Position	Rod(s) Misaligned	Peaking Factor % Increase for Additional 6 Steps	
							$F_{\Delta H}$	F_Q
1	BOL	HFP	Current	A	D at 174			
2	BOL	HFP	Current	D	D at 174			
3	BOL	HFP	Current	A	D at 186			
4	BOL	HFP	Current	D	D at 186			
5	BOL	HFP	Current	A	D at 198			
6	BOL	HFP	Current	A	D at 210			
7	BOL	HFP	Current	A	D at 174			
8	BOL	HFP	Current	D	D at 174			
9	BOL	HFP	Future	A	D at 174			
10	BOL	HFP	Future	D	D at 174			
11	BOL	HFP	Future	A	D at 186			
12	BOL	HFP	Future	D	D at 186			

Table 3.3 Summary of 18 Step Indicated Hot Full Power Rod Misalignment Cases Analyzed (Sheet 2 of 16)

Case No.	Burnup	Power	Cycle	Failure Mechanism	Reference Bank Position	Rod(s) Misaligned	Peaking Factor % Increase for Additional 6 Steps	
							$F_{\Delta H}$	F_Q
13	BOL	HFP	Future	A	D at 198			a,c
14	BOL	HFP	Future	A	D at 210			
15	BOL	HFP	Future	A	D at 174			
16	BOL	HFP	Future	D	D at 174			
17	MOL	HFP	Current	A	D at 174			
18	MOL	HFP	Current	D	D at 174			
19	MOL	HFP	Current	A	D at 174			
20	MOL	HFP	Current	D	D at 174			
21	MOL	HFP	Future	A	D at 174			
22	MOL	HFP	Future	D	D at 174			
23	MOL	HFP	Future	A	D at 174			
24	MOL	HFP	Future	D	D at 174			

Table 3.3 Summary of 18 Step Indicated Hot Full Power Rod Misalignment Cases Analyzed (Sheet 3 of 16)

Case No.	Burnup	Power	Cycle	Failure Mechanism	Reference Bank Position	Rod(s) Misaligned	Peaking Factor % Increase for Additional 6 Steps	
							$F_{\Delta H}$	F_Q
25	EOL	HFP	Current	A	D at 174			a,c
26	EOL	HFP	Current	D	D at 174			
27	EOL	HFP	Current	A	D at 186			
28	EOL	HFP	Current	D	D at 186			
29	EOL	HFP	Current	A	D at 198			
30	EOL	HFP	Current	A	D at 210			
31	EOL	HFP	Future	A	D at 174			
32	EOL	HFP	Future	D	D at 174			
33	EOL	HFP	Future	A	D at 186			
34	EOL	HFP	Future	D	D at 186			
35	EOL	HFP	Future	A	D at 198			
36	EOL	HFP	Future	A	D at 210			

Table 3.3 Summary of 18 Step Indicated Hot Full Power Rod Misalignment Cases Analyzed (Sheet 4 of 16)

Case No.	Burnup	Power	Cycle	Failure Mechanism	Reference Bank Position	Rod(s) Misaligned	Peaking Factor % Increase for Additional 6 Steps	
							$F_{\Delta H}$	F_Q a,c
37	BOL	HFP	Current	A	D at 174			
38	BOL	HFP	Current	D	D at 174			
39	BOL	HFP	Current	A	D at 174			
40	BOL	HFP	Current	D	D at 174			
41	BOL	HFP	Current	A	D at 174			
42	BOL	HFP	Current	D	D at 174			
43	BOL	HFP	Future	A	D at 174			
44	BOL	HFP	Future	D	D at 174			
45	BOL	HFP	Future	A	D at 174			
46	BOL	HFP	Future	D	D at 174			
47	BOL	HFP	Future	A	D at 174			
48	BOL	HFP	Future	D	D at 174			

Table 3.3 Summary of 18 Step Indicated Hot Full Power Rod Misalignment Cases Analyzed (Sheet 5 of 16)

Case No.	Burnup	Power	Cycle	Failure Mechanism	Reference Bank Position	Rod(s) Misaligned	Peaking Factor % Increase for Additional 6 Steps	
							$F_{\Delta H}$	F_Q
49	MOL	HFP	Current	A	D at 174			a,c
50	MOL	HFP	Current	D	D at 174			
51	MOL	HFP	Current	A	D at 174			
52	MOL	HFP	Current	D	D at 174			
53	MOL	HFP	Future	A	D at 174			
54	MOL	HFP	Future	D	D at 174			
55	MOL	HFP	Future	A	D at 174			
56	MOL	HFP	Future	D	D at 174			
57	EOL	HFP	Current	A	D at 174			
58	EOL	HFP	Current	D	D at 174			
59	EOL	HFP	Current	A	D at 174			
60	EOL	HFP	Current	D	D at 174			

Table 3.3 Summary of 18 Step Indicated Hot Full Power Rod Misalignment Cases Analyzed (Sheet 6 of 16)

Case No.	Burnup	Power	Cycle	Failure Mechanism	Reference Bank Position	Rod(s) Misaligned	Peaking Factor % Increase for Additional 6 Steps	
							$F_{\Delta H}$	F_Q
61	EOL	HFP	Current	A	D at 174			a,c
62	EOL	HFP	Current	D	D at 174			
63	EOL	HFP	Current	A	D at 198			
64	EOL	HFP	Current	A	D at 198			
65	EOL	HFP	Future	A	D at 174			
66	EOL	HFP	Future	D	D at 174			
67	EOL	HFP	Future	A	D at 174			
68	EOL	HFP	Future	D	D at 174			
69	EOL	HFP	Future	A	D at 174			
70	EOL	HFP	Future	D	D at 174			
71	EOL	HFP	Future	A	D at 198			
72	EOL	HFP	Future	A	D at 198			

Table 3.3 Summary of 18 Step Indicated Hot Full Power Rod Misalignment Cases Analyzed (Sheet 7 of 16)

Case No.	Burnup	Power	Cycle	Failure Mechanism	Reference Bank Position	Rod(s) Misaligned	Peaking Factor % Increase for Additional 6 Steps	
							$F_{\Delta H}$	F_Q
73	BOL	HFP	Current	A	D at 174			a,c
74	BOL	HFP	Current	D	D at 174			
75	BOL	HFP	Current	A	D at 174			
76	BOL	HFP	Current	D	D at 174			
77	BOL	HFP	Future	A	D at 174			
78	BOL	HFP	Future	D	D at 174			
79	BOL	HFP	Future	A	D at 174			
80	BOL	HFP	Future	D	D at 174			
81	EOL	HFP	Current	A	D at 174			
82	EOL	HFP	Current	D	D at 174			
83	EOL	HFP	Current	A	D at 174			
84	EOL	HFP	Current	D	D at 174			

Table 3.3 Summary of 18 Step Indicated Hot Full Power Rod Misalignment Cases Analyzed (Sheet 8 of 16)

a,c

Case No.	Burnup	Power	Cycle	Failure Mechanism	Reference Bank Position	Rod(s) Misaligned	Peaking Factor % Increase for Additional 6 Steps	
							$F_{\Delta H}$	F_Q
85	EOL	HFP	Current	A	D at 174			
86	EOL	HFP	Current	D	D at 174			
87	EOL	HFP	Current	A	D at 174			
88	EOL	HFP	Current	D	D at 174			
89	EOL	HFP	Future	A	D at 174			
90	EOL	HFP	Future	D	D at 174			
91	EOL	HFP	Future	A	D at 174			
92	EOL	HFP	Future	D	D at 174			
93	EOL	HFP	Future	A	D at 174			
94	EOL	HFP	Future	D	D at 174			
95	EOL	HFP	Future	A	D at 174			

Table 3.3 Summary of 18 Step Indicated Hot Full Power Rod Misalignment Cases Analyzed (Sheet 9 of 16)

Case No.	Burnup	Power	Cycle	Failure Mechanism	Reference Bank Position	Rod(s) Misaligned	Peaking Factor % Increase for Additional 6 Steps	
							$F_{\Delta H}$	F_Q
96	EOL	HFP	Future	D	D at 174			a,c
97	BOL	HFP	Current	A	D at 174			
98	BOL	HFP	Current	A	D at 174			
99	BOL	HFP	Current	A	D at 223 (ARO)			
100	BOL	HFP	Current	A	D at 174			
101	BOL	HFP	Current	A	D at 223 (ARO)			
102	BOL	HFP	Current	A	D at 174			
103	BOL	HFP	Current	A	D at 223 (ARO)			
104	BOL	HFP	Future	A	D at 174			

Table 3.3 Summary of 18 Step Indicated Hot Full Power Rod Misalignment Cases Analyzed (Sheet 10 of 16)

Case No.	Burnup	Power	Cycle	Failure Mechanism	Reference Bank Position	Rod(s) Misaligned	Peaking Factor % Increase for Additional 6 Steps	
							$F_{\Delta H}$	F_Q
105	BOL	HFP	Future	A	D at 174			a,c
106	BOL	HFP	Future	A	D at 223 (ARO)			
107	BOL	HFP	Future	A	D at 174			
108	BOL	HFP	Future	A	D at 223 (ARO)			
109	BOL	HFP	Future	A	D at 174			
110	BOL	HFP	Future	A	D at 223 (ARO)			
111	MOL	HFP	Current	A	D at 174			
112	MOL	HFP	Current	A	D at 174			
113	MOL	HFP	Current	A	D at 223 (ARO)			

Table 3.3 Summary of 18 Step Indicated Hot Full Power Rod Misalignment Cases Analyzed (Sheet 11 of 16)

Case No.	Burnup	Power	Cycle	Failure Mechanism	Reference Bank Position	Rod(s) Misaligned	Peaking Factor % Increase for Additional 6 Steps	
							$F_{\Delta H}$	F_Q
114	MOL	HFP	Future	A	D at 174			a,c
115	MOL	HFP	Future	A	D at 174			
116	MOL	HFP	Future	A	D at 223 (ARO)			
117	EOL	HFP	Current	A	D at 174			
118	EOL	HFP	Current	A	D at 174			
119	EOL	HFP	Current	A	D at 223 (ARO)			
120	EOL	HFP	Current	A	D at 174			
121	EOL	HFP	Current	A	D at 174			
122	EOL	HFP	Current	A	D at 174			
123	EOL	HFP	Current	A	D at 174			

Table 3.3 Summary of 18 Step Indicated Hot Full Power Rod Misalignment Cases Analyzed (Sheet 12 of 16)

Case No.	Burnup	Power	Cycle	Failure Mechanism	Reference Bank Position	Rod(s) Misaligned	Peaking Factor % Increase for Additional 6 Steps	
							$F_{\Delta H}$	F_Q
124	EOL	HFP	Current	A	D at 174			
125	EOL	HFP	Current	A	D at 174			
126	EOL	HFP	Current	A	D at 174			
127	EOL	HFP	Current	A	D at 174			
128	EOL	HFP	Future	A	D at 174			
129	EOL	HFP	Future	A	D at 174			
130	EOL	HFP	Future	A	D at 223 (ARO)			
131	EOL	HFP	Future	A	D at 174			
132	EOL	HFP	Future	A	D at 174			
133	EOL	HFP	Future	A	D at 174			
134	EOL	HFP	Future	A	D at 174			

a,c

Table 3.3 Summary of 18 Step Indicated Hot Full Power Rod Misalignment Cases Analyzed (Sheet 13 of 16)

Case No.	Burnup	Power	Cycle	Failure Mechanism	Reference Bank Position	Rod(s) Misaligned	Peaking Factor % Increase for Additional 6 Steps	
							$F_{\Delta H}$	F_Q
135	EOL	HFP	Future	A	D at 174			a,c
136	EOL	HFP	Future	AB	D at 174			
137	EOL	HFP	Future	A	D at 174			
138	EOL	HFP	Future	A	D at 174			
139	BOL	HFP	Current	B	D at 174			
140	BOL	HFP	Current	B	D at 174			
141	BOL	HFP	Current	B	D at 174			
142	BOL	HFP	Current	B	D at 174			
143	BOL	HFP	Future	B	D at 174			
144	BOL	HFP	Future	B	D at 174			
145	BOL	HFP	Future	B	D at 174			
146	BOL	HFP	Future	B	D at 174			

Table 3.3 Summary of 18 Step Indicated Hot Full Power Rod Misalignment Cases Analyzed (Sheet 14 of 16)

Case No.	Burnup	Power	Cycle	Failure Mechanism	Reference Bank Position	Rod(s) Misaligned	Peaking Factor % Increase for Additional 6 Steps	
							$F_{\Delta H}$	F_Q
147	EOL	HFP	Current	B	D at 174			a,c
148	EOL	HFP	Current	B	D at 174			
149	EOL	HFP	Future	B	D at 174			
150	EOL	HFP	Future	B	D at 174			
151	BOL	HFP	Current	C	D at 174			
152	BOL	HFP	Future	C	D at 174			
153	EOL	HFP	Current	C	D at 174			
154	EOL	HFP	Future	C	D at 174			
155	BOL	HFP	Current	E	D at 174			
156	BOL	HFP	Current	E	D at 186			
157	BOL	HFP	Future	E	D at 174			

Table 3.3 Summary of 18 Step Indicated Hot Full Power Rod Misalignment Cases Analyzed (Sheet 15 of 16)

Case No.	Burnup	Power	Cycle	Failure Mechanism	Reference Bank Position	Rod(s) Misaligned	Peaking Factor % Increase for Additional 6 Steps	
							$F_{\Delta H}$	F_Q
158	BOL	HFP	Future	E	D at 186			a,c
159	EOL	HFP	Current	E	D at 174			
160	EOL	HFP	Current	E	D at 174			
161	EOL	HFP	Current	E	D at 174			
162	EOL	HFP	Future	E	D at 174			
163	EOL	HFP	Future	E	D at 174			
164	EOL	HFP	Future	E	D at 174			
165	BOL	HFP	Current	F	D at 174			
166	BOL	HFP	Future	F	D at 174			

Table 3.3 Summary of 18 Step Indicated Hot Full Power Rod Misalignment Cases Analyzed (Sheet 16 of 16)

Case No.	Burnup	Power	Cycle	Failure Mechanism	Reference Bank Position	Rod(s) Misaligned	Peaking Factor % Increase for Additional 6 Steps	
							$F_{\Delta H}$	F_Q
167	EOL	HFP	Current	F	D at 174	[		] a,c
168	EOL	HFP	Future	F	D at 174			
(*)	Signifies that plots of peaking factors and increases due to additional steps of misalignment are included in the Appendix of this report.							

Table 3.4 Summary of 15 Step Indicated Rod Misalignment Cases Analyzed (Sheet 1 of 7)

Case No.	Burnup	Power	Cycle	Failure Mechanism	Reference Bank Position	Rods Misaligned	Peaking Factor % Increase for Additional 3 Steps	
							$F_{\Delta H}$	F_Q
169	BOL	HFP	Current	A	D at 174			
170	BOL	HFP	Current	D	D at 174			
171	BOL	HFP	Future	A	D at 174			
172	BOL	HFP	Future	D	D at 174			
173	EOL	HFP	Current	D	D at 174			
174	EOL	HFP	Current	A	D at 186			
175	EOL	HFP	Current	D	D at 186			
176	EOL	HFP	Future	D	D at 174			
177	EOL	HFP	Future	A	D at 186			
178	EOL	HFP	Future	D	D at 186			
179	BOL	HFP	Current	A	D at 174			
180	BOL	HFP	Current	D	D at 174			

a,c

Table 3.4 Summary of 15 Step Indicated Rod Misalignment Cases Analyzed (Sheet 2 of 7)

Case No.	Burnup	Power	Cycle	Failure Mechanism	Reference Bank Position	Rods Misaligned	Peaking Factor % Increase for Additional 3 Steps	
							$F_{\Delta H}$	F_Q
181	BOL	HFP	Future	A	D at 174			a,c
182	BOL	HFP	Future	D	D at 174			
183	EOL	HFP	Current	A	D at 174			
184	EOL	HFP	Current	D	D at 174			
185	EOL	HFP	Future	A	D at 174			
186	EOL	HFP	Future	D	D at 174			
187	BOL	HFP	Current	A	D at 174			
188	BOL	HFP	Current	D	D at 174			
189	BOL	HFP	Future	A	D at 174			
190	BOL	HFP	Future	D	D at 174			
191	EOL	HFP	Current	A	D at 174			
192	EOL	HFP	Current	D	D at 174			

Table 3.4 Summary of 15 Step Indicated Rod Misalignment Cases Analyzed (Sheet 3 of 7)

Case No.	Burnup	Power	Cycle	Failure Mechanism	Reference Bank Position	Rods Misaligned	Peaking Factor % Increase for Additional 3 Steps	
							$F_{\Delta H}$	F_Q
193	EOL	HFP	Future	A	D at 174			a,c
194	EOL	HFP	Future	D	D at 174			
195	BOL	HFP	Current	A	D at 174			
196	BOL	HFP	Current	A	D at 174			
197	BOL	HFP	Current	A	D at 223 (ARO)			
198	BOL	HFP	Current	A	D at 174			
199	BOL	HFP	Current	A	D at 174			
200	BOL	HFP	Current	A	D at 223 (ARO)			
201	BOL	HFP	Future	A	D at 174			

Table 3.4 Summary of 15 Step Indicated Rod Misalignment Cases Analyzed (Sheet 4 of 7)

Case No.	Burnup	Power	Cycle	Failure Mechanism	Reference Bank Position	Rods Misaligned	Peaking Factor % Increase for Additional 3 Steps	
							$F_{\Delta H}$	F_Q
202	BOL	HFP	Future	A	D at 174			
203	BOL	HFP	Future	A	D at 223 (ARO)			
204	BOL	HFP	Future	A	D at 174			
205	BOL	HFP	Future	A	D at 174			
206	BOL	HFP	Future	A	D at 223 (ARO)			
207	MOL	HFP	Current	A	D at 174			
208	MOL	HFP	Current	A	D at 223 (ARO)			
209	MOL	HFP	Future	A	D at 174			
210	MOL	HFP	Future	A	D at 223 (ARO)			

a,c

Table 3.4 Summary of 15 Step Indicated Rod Misalignment Cases Analyzed (Sheet 5 of 7)

Case No.	Burnup	Power	Cycle	Failure Mechanism	Reference Bank Position	Rods Misaligned	Peaking Factor % Increase for Additional 3 Steps	
							$F_{\Delta H}$	F_Q
211	EOL	HFP	Current	A	D at 174			a,c
212	EOL	HFP	Current	A	D at 174			
213	EOL	HFP	Current	A	D at 223 (ARO)			
214	EOL	HFP	Current	A	D at 174			
215	EOL	HFP	Current	A	D at 174			
216	EOL	HFP	Current	A	D at 174			
217	EOL	HFP	Current	A	D at 174			
218	EOL	HFP	Current	A	D at 174			
219	EOL	HFP	Current	A	D at 174			
220	EOL	HFP	Future	A	D at 174			

Table 3.4 Summary of 15 Step Indicated Rod Misalignment Cases Analyzed (Sheet 6 of 7)

Case No.	Burnup	Power	Cycle	Failure Mechanism	Reference Bank Position	Rods Misaligned	Peaking Factor % Increase for Additional 3 Steps	
							$F_{\Delta H}$	F_Q
221	EOL	HFP	Future	A	D at 174			a,c
222	EOL	HFP	Future	A	D at 223 (ARO)			
223	EOL	HFP	Future	A	D at 174			
224	EOL	HFP	Future	A	D at 174			
225	EOL	HFP	Future	A	D at 174			
226	EOL	HFP	Future	A	D at 174			
227	EOL	HFP	Future	A	D at 174			
228	EOL	HFP	Future	A	D at 174			
229	EOL	HFP	Current	C	D at 174			
230	EOL	HFP	Future	C	D at 174			
231	BOL	HFP	Current	E	D at 186			

Table 3.4 Summary of 15 Step Indicated Rod Misalignment Cases Analyzed (Sheet 7 of 7)

Case No.	Burnup	Power	Cycle	Failure Mechanism	Reference Bank Position	Rods Misaligned	Peaking Factor % Increase for Additional 3 Steps	
							$F_{\Delta H}$	F_Q
232	BOL	HFP	Future	E	D at 186			[a,c]
233	BOL	HFP	Current	F	D at 174			
234	BOL	HFP	Current	F	D at 174			

Table 3.5 Summary of 18 Step Indicated Part-Power Rod Misalignment Cases Analyzed (Sheet 1 of 6)

Case No.	Burnup	Power	Cycle	Failure Mechanism	Reference Bank Position	Rods Misaligned	Peaking Factor % Increase for Additional 6 Steps	
							$F_{\Delta H}$	F_Q
235	BOL	85	Current	A	D at 174			a,c
236	BOL	85	Current	A	D at 142			
237	BOL	50	Current	A	D at 174			
238	BOL	50	Current	A	D at 68, C at 191			
239	BOL	50	Current	A	D at 223 (ARO)			
240	BOL	85	Current	A	D at 223 (ARO)			
241	BOL	85	Future	A	D at 174			
242	BOL	85	Future	A	D at 142			

Table 3.5 Summary of 18 Step Indicated Part-Power Rod Misalignment Cases Analyzed (Sheet 2 of 6)

Case No.	Burnup	Power	Cycle	Failure Mechanism	Reference Bank Position	Rods Misaligned	Peaking Factor % Increase for Additional 6 Steps	
							$F_{\Delta H}$	F_Q
243	BOL	50	Future	A	D at 174			a,c
244	BOL	50	Future	A	D at 68, C at 191			
245	BOL	50	Future	A	D at 223 (ARO)			
246	BOL	85	Future	A	D at 223 (ARO)			
247	MOL	85	Current	A	D at 174			
248	MOL	85	Current	A	D at 142			
249	MOL	85	Current	A	D at 223 (ARO)			
250	MOL	85	Future	A	D at 174			

Table 3.5 Summary of 18 Step Indicated Part-Power Rod Misalignment Cases Analyzed (Sheet 3 of 6)

Case No.	Burnup	Power	Cycle	Failure Mechanism	Reference Bank Position	Rods Misaligned	Peaking Factor % Increase for Additional 6 Steps	
							$F_{\Delta H}$	F_Q
251	MOL	85	Future	A	D at 142			a,c
252	MOL	85	Future	A	D at 223 (ARO)			
253	EOL	85	Current	A	D at 174			
254	EOL	85	Current	A	D at 142			
255	EOL	50	Current	A	D at 174			
256	EOL	50	Current	A	D at 68, C at 191			
257	EOL	50	Current	A	D at 223 (ARO)			
258	EOL	85	Current	A	D at 223 (ARO)			

Table 3.5 Summary of 18 Step Indicated Part-Power Rod Misalignment Cases Analyzed (Sheet 4 of 6)

Case No.	Burnup	Power	Cycle	Failure Mechanism	Reference Bank Position	Rods Misaligned	Peaking Factor % Increase for Additional 6 Steps	
							$F_{\Delta H}$	F_Q
259	EOL	85	Current	A	D at 174			a,c
260	EOL	85	Current	A	D at 174			
261	EOL	85	Current	A	D at 174			
262	EOL	85	Current	A	D at 142			
263	EOL	85	Current	A	D at 174			
264	EOL	85	Current	A	D at 142			
265	EOL	50	Current	A	D at 174			
266	EOL	50	Current	A	D at 68, C at 191			
267	EOL	85	Current	C	D at 142			
268	EOL	85	Current	C	D at 174			

Table 3.5 Summary of 18 Step Indicated Part-Power Rod Misalignment Cases Analyzed (Sheet 5 of 6)

Case No.	Burnup	Power	Cycle	Failure Mechanism	Reference Bank Position	Rods Misaligned	Peaking Factor % Increase for Additional 6 Steps	
							$F_{\Delta H}$	F_Q
269	EOL	85	Future	A	D at 174			a,c
270	EOL	85	Future	A	D at 142			
271	EOL	50	Future	A	D at 174			
272	EOL	50	Future	A	D at 68, C at 191			
273	EOL	50	Future	A	D at 223 (ARO)			
274	EOL	85	Future	A	D at 223 (ARO)			
275	EOL	85	Future	A	D at 174			
276	EOL	85	Future	A	D at 174			

Table 3.5 Summary of 18 Step Indicated Part-Power Rod Misalignment Cases Analyzed (Sheet 6 of 6)

Case No.	Burnup	Power	Cycle	Failure Mechanism	Reference Bank Position	Rods Misaligned	Peaking Factor % Increase for Additional 6 Steps	
							$F_{\Delta H}$	F_Q
277	EOL	85	Future	A	D at 174			a,c
278	EOL	85	Future	A	D at 142			
279	EOL	85	Future	A	D at 174			
280	EOL	85	Future	A	D at 142			
281	EOL	50	Future	A	D at 174			
282	EOL	50	Future	A	D at 68, C at 191			
283	EOL	85	Future	C	D at 142			
284	EOL	85	Future	C	D at 174			

Table 3.6 Summary of 21 Step Indicated Part-Power Rod Misalignment Cases Analyzed (Sheet 1 of 6)

Case No.	Burnup	Power	Cycle	Failure Mechanism	Reference Bank Position	Rods Misaligned	Peaking Factor % Increase for Additional 9 Steps	
							$F_{\Delta H}$	F_Q
285	BOL	85	Current	A	D at 174			
286	BOL	85	Current	A	D at 142			
287	BOL	50	Current	A	D at 174			
288	BOL	50	Current	A	D at 68, C at 191			
289	BOL	50	Current	A	D at 223 (ARO)			
290	BOL	85	Current	A	D at 223 (ARO)			
291	BOL	85	Future	A	D at 174			
292	BOL	85	Future	A	D at 142			

a,c

Table 3.6 Summary of 21 Step Indicated Part-Power Rod Misalignment Cases Analyzed (Sheet 2 of 6)

Case No.	Burnup	Power	Cycle	Failure Mechanism	Reference Bank Position	Rods Misaligned	Peaking Factor % Increase for Additional 9 Steps	
							$F_{\Delta H}$	F_Q
293	BOL	50	Future	A	D at 174			a,c
294	BOL	50	Future	A	D at 68, C at 191			
295	BOL	50	Future	A	D at 223 (ARO)			
296	BOL	85	Future	A	D at 223 (ARO)			
297	MOL	85	Current	A	D at 174			
298	MOL	85	Current	A	D at 142			
299	MOL	85	Current	A	D at 223 (ARO)			
300	MOL	85	Future	A	D at 174			

Table 3.6 Summary of 21 Step Indicated Part-Power Rod Misalignment Cases Analyzed (Sheet 3 of 6)

Case No.	Burnup	Power	Cycle	Failure Mechanism	Reference Bank Position	Rods Misaligned	Peaking Factor % Increase for Additional 9 Steps	
							$F_{\Delta H}$	F_Q
301	MOL	85	Future	A	D at 142			a,c
302	MOL	85	Future	A	D at 223 (ARO)			
303	EOL	85	Current	A	D at 174			
304	EOL	85	Current	A	D at 142			
305	EOL	50	Current	A	D at 174			
306	EOL	50	Current	A	D at 68, C at 191			
307	EOL	50	Current	A	D at 223 (ARO)			
308	EOL	85	Current	A	D at 223 (ARO)			

Table 3.6 Summary of 21 Step Indicated Part-Power Rod Misalignment Cases Analyzed (Sheet 4 of 6)

Case No.	Burnup	Power	Cycle	Failure Mechanism	Reference Bank Position	Rods Misaligned	Peaking Factor % Increase for Additional 9 Steps	
							$F_{\Delta H}$	F_Q
309	EOL	85	Current	A	D at 174			
310	EOL	85	Current	A	D at 174			
311	EOL	85	Current	A	D at 174			
312	EOL	85	Current	A	D at 142			
313	EOL	85	Current	A	D at 174			
314	EOL	85	Current	A	D at 142			
315	EOL	50	Current	A	D at 174			
316	EOL	50	Current	A	D at 68, C at 191			
317	EOL	85	Current	C	D at 142			
318	EOL	85	Current	C	D at 174			

a,c

Table 3.6 Summary of 21 Step Indicated Part-Power Rod Misalignment Cases Analyzed (Sheet 5 of 6)

Case No.	Burnup	Power	Cycle	Failure Mechanism	Reference Bank Position	Rods Misaligned	Peaking Factor % Increase for Additional 9 Steps	
							$F_{\Delta H}$	F_Q
319	EOL	85	Future	A	D at 174			a,c
320	EOL	85	Future	A	D at 142			
321	EOL	50	Future	A	D at 174			
322	EOL	50	Future	A	D at 68, C at 191			
323	EOL	50	Future	A	D at 223 (ARO)			
324	EOL	85	Future	A	D at 223 (ARO)			
325	EOL	85	Future	A	D at 174			
326	EOL	85	Future	A	D at 174			

Table 3.6 Summary of 21 Step Indicated Part-Power Rod Misalignment Cases Analyzed (Sheet 6 of 6)

Case No.	Burnup	Power	Cycle	Failure Mechanism	Reference Bank Position	Rods Misaligned	Peaking Factor % Increase for Additional 9 Steps	
							$F_{\Delta H}$	F_Q
327	EOL	85	Future	A	D at 174			a,c
328	EOL	85	Future	A	D at 142			
329	EOL	85	Future	A	D at 174			
330	EOL	85	Future	A	D at 142			
331	EOL	50	Future	A	D at 174			
332	EOL	50	Future	A	D at 68, C at 191			
333	EOL	85	Future	C	D at 142			
334	EOL	85	Future	C	D at 174			

Table 3.7 Summary of 24 Step Indicated Part-Power Rod Misalignment Cases Analyzed (Sheet 1 of 6)

a,c

Case No.	Burnup	Power	Cycle	Failure Mechanism	Reference Bank Position	Rods Misaligned	Peaking Factor % Increase for Additional 12 Steps	
							$F_{\Delta H}$	F_Q
335	BOL	85	Current	A	D at 174			
336	BOL	85	Current	A	D at 142			
337	BOL	50	Current	A	D at 174			
338	BOL	50	Current	A	D at 68, C at 191			
339	BOL	50	Current	A	D at 223 (ARO)			
340	BOL	85	Current	A	D at 223 (ARO)			
341	BOL	85	Future	A	D at 174			
342	BOL	85	Future	A	D at 142			

Table 3.7 Summary of 24 Step Indicated Part-Power Rod Misalignment Cases Analyzed (Sheet 2 of 6)

Case No.	Burnup	Power	Cycle	Failure Mechanism	Reference Bank Position	Rods Misaligned	Peaking Factor % Increase for Additional 12 Steps	
							$F_{\Delta H}$	F_Q
343	BOL	50	Future	A	D at 174			a,c
344	BOL	50	Future	A	D at 68, C at 191			
345	BOL	50	Future	A	D at 223 (ARO)			
346	BOL	85	Future	A	D at 223 (ARO)			
347	MOL	85	Current	A	D at 174			
348	MOL	85	Current	A	D at 142			
349	MOL	85	Current	A	D at 223 (ARO)			
350	MOL	85	Future	A	D at 174			

Table 3.7 Summary of 24 Step Indicated Part-Power Rod Misalignment Cases Analyzed (Sheet 3 of 6)

Case No.	Burnup	Power	Cycle	Failure Mechanism	Reference Bank Position	Rods Misaligned	Peaking Factor % Increase for Additional 12 Steps	
							$F_{\Delta H}$	F_Q
351	MOL	85	Future	A	D at 142			a,c
352	MOL	85	Future	A	D at 223 (ARO)			
353	EOL	85	Current	A	D at 174			
354	EOL	85	Current	A	D at 142			
355	EOL	50	Current	A	D at 174			
356	EOL	50	Current	A	D at 68, C at 191			
357	EOL	50	Current	A	D at 223 (ARO)			
358	EOL	85	Current	A	D at 223 (ARO)			

Table 3.7 Summary of 24 Step Indicated Part-Power Rod Misalignment Cases Analyzed (Sheet 4 of 6)

Case No.	Burnup	Power	Cycle	Failure Mechanism	Reference Bank Position	Rods Misaligned	Peaking Factor % Increase for Additional 12 Steps	
							$F_{\Delta H}$	F_Q
359	EOL	85	Current	A	D at 174			a,c
360	EOL	85	Current	A	D at 174			
361	EOL	85	Current	A	D at 174			
362	EOL	85	Current	A	D at 142			
363	EOL	85	Current	A	D at 174			
364	EOL	85	Current	A	D at 142			
365	EOL	50	Current	A	D at 174			
366	EOL	50	Current	A	D at 68, C at 191			
367	EOL	85	Current	C	D at 142			
368	EOL	85	Current	C	D at 174			

Table 3.7 Summary of 24 Step Indicated Part-Power Rod Misalignment Cases Analyzed (Sheet 5 of 6)

Case No.	Burnup	Power	Cycle	Failure Mechanism	Reference Bank Position	Rods Misaligned	Peaking Factor % Increase for Additional 12 Steps	
							$F_{\Delta H}$	F_Q
369	EOL	85	Future	A	D at 174			a,c
370	EOL	85	Future	A	D at 142			
371	EOL	50	Future	A	D at 174			
372	EOL	50	Future	A	D at 68, C at 191			
373	EOL	50	Future	A	D at 223 (ARO)			
374	EOL	85	Future	A	D at 223 (ARO)			
375	EOL	85	Future	A	D at 174			
376	EOL	85	Future	A	D at 142			

Table 3.7 Summary of 24 Step Indicated Part-Power Rod Misalignment Cases Analyzed (Sheet 6 of 6)

Case No.	Burnup	Power	Cycle	Failure Mechanism	Reference Bank Position	Rods Misaligned	Peaking Factor % Increase for Additional 12 Steps	
							$F_{\Delta H}$	F_Q
377	EOL	85	Future	A	D at 174			a,c
378	EOL	85	Future	A	D at 142			
379	EOL	85	Future	A	D at 174			
380	EOL	85	Future	A	D at 142			
381	EOL	50	Future	A	D at 174			
382	EOL	50	Future	A	D at 68, C at 191			
383	EOL	85	Future	C	D at 142			
384	EOL	85	Future	C	D at 174			
(*)	Signifies that plots of peaking factors and increases due to additional steps of misalignment are included in the Appendix of this report.							

4 SAFETY ANALYSIS IMPACTS

Section 3 discussed the effects of increased misalignment on the normal operation peaking factors. This section will address the effects on safety analysis inputs used for the reload safety evaluation (Reference 7).

An increase in rod misalignment does not have a significant impact on any of the [ ]^{a,c}. An increase in the rod misalignment also will not adversely effect the [ ]^{a,c} or data generated for the evaluation of [ ]^{a,c}.

Many of the Condition II transients, such as rod out of position, dropped rod and single rod withdrawal are based on the motion of a control rod or control bank. These are considered fully misaligned rod transients caused by a single failure of the rod control system. Recall from Section 3.0 that a key assumption of the analysis documented in this report is that rod misalignments resulting from a [ ]^{a,c} need be considered, consistent with the current Westinghouse licensing basis. Series of [ ]^{a,c} do not need to be considered. Therefore, one does not need to assume a rod misalignment from the [ ]^{a,c} as a precondition to one of the above mentioned Condition II rod misalignment transients; such an assumption would be beyond the [ ]^{a,c}. As such, the proposed changes to the rod misalignment Tech Spec do not have an adverse impact on the safety analysis inputs for these accidents, or the DNB analysis results.

Another possible impact of the increase in the rod misalignment is an increase in the rod insertion allowance (RIA), the worth of the rods at their insertion limits or RILs. The RIA has a direct impact on the available trip reactivity and the shutdown margin (SDM) assumed in several transient analyses including steamline break. The maximum increase in the RIA, and hence largest reduction in the trip worth and SDM, would be due to an entire bank being misaligned in deeper than the RIL, consistent with failure category C described in Section 3.3. However, the available trip worth and SDM also assume that the core is subcritical with an N-1 rod configuration, where the highest individual worth rod is stuck out of the core, consistent with failure category D. As stated above, rod misalignments resulting from a [ ]^{a,c}. Therefore, for the trip reactivity and SDM one does not need to assume an increase in the RIA due to [ ]^{a,c}. In addition, the reduction in available SDM due to the WSR is much greater than the worth that would be lost due to an increase in the RIA. As such, the proposed changes to the rod misalignment Tech Spec do not have an adverse impact on the available trip worth or SDM.

Safety analyses inputs that would be affected by an increase in the allowable misalignment are the rod ejection F_Q, the ejected rod worth $\Delta\rho_{EJ}$, and the available trip worth following a rod ejection.

The rod ejection parameters can be affected by an increased rod misalignment of the RIL rods at HZP prior to the ejection. Misalignments of individual rods, bank groups and entire banks were considered to determine the limiting effects on F_Q and $\Delta\rho_{EJ}$. Calculations were also performed for both cycles described in Section 2, assuming an additional 12 steps of rod misalignment at the HZP RIL. Results of these calculations show maximum increases of [ ]a,c in F_Q and [ ]a,c in $\Delta\rho_{EJ}$ for the current cycle and [ ]a,c in F_Q and [ ]a,c in $\Delta\rho_{EJ}$ for the future cycle. Note that these values are very similar for the two cycles, indicating that the results are reasonably independent of the cycle design. Then for application of this Technical Specification change, [ ]a,c.

The safety analysis of the rod ejection transient also assumes a certain amount of available trip worth following the rod ejection. Since the ejected rod is assumed to damage a neighboring RCCA drive housing, the trip worth for this transient is defined as the change in core reactivity between the HZP, RIL condition and the HZP, all rods inserted (ARI) minus the ejected rod and the neighboring rod. For this part of the rod ejection transient, the limiting misalignment will be the [ ]a,c. Inserting [ ]a,c. Then for application of this Technical Specification, the trip worth available following a rod ejection calculated as part of the reload safety evaluation [ ]a,c. The [ ]a,c pcm is approximately [ ]a,c than the maximum calculated value for either cycle.

5 CONCLUSIONS

An extension of the allowable indicated rod misalignment of ±12 steps to ±18 steps may be permitted for core powers above 85% RTP as long as it is demonstrated that sufficient peaking factor margin is available. To increase the allowable indicated misalignment by 6 steps for operation above 85% of rated thermal power, [ ]^{a,c} F_Q margin and [ ]^{a,c} $F_{\Delta H}$ margin must be available. The amount of required margin is also linearly dependent upon the amount of additional misalignment desired, as shown in Figure 3.3 and summarized below:

Indicated Misalignment (Steps)	Additional Misalignment (Steps)	Required Margin	
		$F_{\Delta H}$	F_Q
12	0	[ ]^{a,c}	[ ]^{a,c}
13	1	[ ]^{a,c}	[ ]^{a,c}
14	2	[ ]^{a,c}	[ ]^{a,c}
15	3	[ ]^{a,c}	[ ]^{a,c}
16	4	[ ]^{a,c}	[ ]^{a,c}
17	5	[ ]^{a,c}	[ ]^{a,c}
18	6	[ ]^{a,c}	[ ]^{a,c}

Indicated misalignments of up to 24 steps are also permitted for all powers of 85% RTP or less.

The analysis documented in this report has been performed such that the above mentioned excess peaking factor margin required for additional indicated rod misalignment is [ ]^{a,c}.

The analysis documented in this report is conservative and appropriate based on the following assumptions on rod insertion:

- The rod insertion limits (RILs) shown in Figure 3.2 determine the maximum bank demand position as a function of core power;
- The all rods out (ARO) demand position can be as deep as [ ]^{a,c}, which corresponds to the top of the active fuel stack for the Indian Point 2 Cycle 15 feed fuel assemblies.

The results of this report are also conservative and appropriate for any future change in the RILs that would reduce the maximum allowable rod insertion and for any ARO position above [ ]^{a,c}. Any future change to the RILs or the ARO position that would permit deeper rod insertion would also require an evaluation of the results of this report.

As part of the reload specific safety evaluation, design calculations will include the following additional conservatisms to bound the maximum increases in rod misalignment any time during the cycle:

- [ ]^{a,c}
- [ ]^{a,c}
- [ ]^{a,c}

6 REFERENCES

1. Shopsky, W. E., *Failure Mode and Effects Analysis (FMEA) of the Solid State Full Length Rod Control System*, WCAP-8976, Rev. 0 (Non-Proprietary Class 3), August 1977.

2. Baker, T., et. al., *Rod Control System Evaluation Program*, WCAP-13864, Revision 1-A (Non-Proprietary Class 3), November 1994.

3. Nguyen, T. Q., et. al., *Qualification of the PHOENIX-P/ANC Nuclear Design System for Pressurized Water Reactor Cores*, WCAP-11596-P-A (Westinghouse Proprietary), June 1988.

4. Liu, Y. S., et. al., *ANC: A Westinghouse Advanced Nodal Computer Code*, WCAP-10965-P-A (Westinghouse Proprietary), December 1985.

5. Morita, T. et. al., *Topical Report - Power Distribution Control and Load Following Procedures*, WCAP-8385 (Westinghouse Proprietary), September 1974.

6. Miller, R. W. et. al., *Relaxation of Constant Axial Offset Control - FQ Surveillance Technical Specification*, WCAP-10216-P-A, Revision 1, February 1994.

7. Davidson, S. L., et. al., *Westinghouse Reload Safety Evaluation Methodology*, WCAP-9272-P-A, July, 1985.

"This page intentionally blank."

A APPENDIX

This section provides some additional detail to the cases highlighted in Tables 3.3 and 3.7. These cases yielded the limiting increase in $F_{\Delta H}$, F_Q or both. The following figures provide the misaligned peaking factors compared to the reference non-misaligned case, and the percent differences relative to 24 steps of total misalignment (±12 steps indicated). Data in these figures are provided as a function of axial offset, covering the maximum expected range for Indian Point 2. The data summarized in Tables 3.3 through 3.7 represents the maximum points from these figures.

"This page intentionally blank."

Figure A.1: Case 99; BOL HFP Current Cycle F_Q Versus Axial Offset, Control Bank D at 223 (ARO) and Cabinet 2AC Misaligned In Except for Rods C-05 and G-05

a,c

Figure A.2: Case 99; BOL HFP Current Cycle F_Q Difference Relative to 12 Step Indicated Misalignment Versus Axial Offset, Control Bank D at 223 (ARO) and Cabinet 2AC Misaligned In Except for Rods C-05 and G-05

a,c

Figure A.3: Case 106; BOL HFP Future Cycle $F_{\Delta H}$ Versus Axial Offset, Control Bank D at 223 (ARO) and Cabinet 2AC Misaligned In Except for Rods C-05 and G-05

a,c

Figure A.4: Case 106; BOL HFP Future Cycle $F_{\Delta H}$ Difference Relative to 12 Step Indicated Misalignment Versus Axial Offset, Control Bank D at 223 (ARO) and Cabinet 2AC Misaligned In Except for Rods C-05 and G-05

a,c

Figure A.5: Case 116; MOL HFP Future Cycle $F_{\Delta H}$ Versus Axial Offset, Control Bank D at 223 (ARO) and Cabinet 2AC Misaligned In Except for Rods C-05 and G-05

a,c

Figure A.6: Case 116; MOL HFP Future Cycle $F_{\Delta H}$ Difference Relative to 12 Step Indicated Misalignment Versus Axial Offset, Control Bank D at 223 (ARO) and Cabinet 2AC Misaligned In Except for Rods C-05 and G-05

a,c

Figure A.7: Case 116; MOL HFP Future Cycle F_Q Versus Axial Offset, Control Bank D at 223 (ARO) and Cabinet 2AC Misaligned In Except for Rods C-05 and G-05

a,c

Figure A.8: Case 116; MOL HFP Future Cycle F_Q Difference Relative to 12 Step Indicated Misalignment Versus Axial Offset, Control Bank D at 223 (ARO) and Cabinet 2AC Misaligned In Except for Rods C-05 and G-05

a,c

Figure A.9: Case 117; EOL HFP Current Cycle F_Q Versus Axial Offset, Control Bank D at 174 and Cabinet 2AC Misaligned In Except for Rod C-05

a,c

Figure A.10: Case 117; EOL HFP Current Cycle F_Q Difference Relative to 12 Step Indicated Misalignment Versus Axial Offset, Control Bank D at 174 and Cabinet 2AC Misaligned In Except for Rod C-05

a,c

Figure A.11: Case 118; EOL HFP Current Cycle F_Q Versus Axial Offset, Control Bank D at 174 and Cabinet 2AC Misaligned In Except for Rods C-05 and G-05

a,c

Figure A.12: Case 118; EOL HFP Current Cycle F_Q Difference Relative to 12 Step Indicated Misalignment Versus Axial Offset, Control Bank D at 174 and Cabinet 2AC Misaligned In Except for Rods C-05 and G-05

a,c

Figure A.13: Case 119; EOL HFP Current Cycle $F_{\Delta H}$ Versus Axial Offset, Control Bank D at 223 (ARO) and Cabinet 2AC Misaligned In Except for Rods C-05 and G-05

a,c

Figure A.14: Case 119; EOL HFP Current Cycle $F_{\Delta H}$ Difference Relative to 12 Step Indicated Misalignment Versus Axial Offset, Control Bank D at 223 (ARO) and Cabinet 2AC Misaligned In Except for Rods C-05 and G-05

a,c

Figure A.15: Case 124; EOL HFP Current Cycle F_Q Versus Axial Offset, Control Bank D at 174 and Cabinet 2AC Misaligned In

[ ]a,c

Figure A.16: Case 124; EOL HFP Current Cycle F_Q Difference Relative to 12 Step Indicated Misalignment Versus Axial Offset, Control Bank D at 174 and Cabinet 2AC Misaligned In

a,c

Figure A.17: Case 128; EOL HFP Future F_Q Versus Axial Offset, Control Bank D at 174 and Cabinet 2AC Misaligned In Except for Rod C-05

a,c

Figure A.18: Case 128; EOL HFP Future Cycle F_Q Difference Relative to 12 Step Indicated Misalignment Versus Axial Offset, Control Bank D at 174 and Cabinet 2AC Misaligned In Except for Rod C-05

a,c

Figure A.19: Case 129; EOL HFP Future Cycle $F_{\Delta H}$ Versus Axial Offset, Control Bank D at 174 and Cabinet 2AC Misaligned In Except for Rods C-05 and G-05

a,c

Figure A.20: Case 129; EOL HFP Future Cycle $F_{\Delta H}$ Difference Relative to 12 Step Indicated Misalignment Versus Axial Offset, Control Bank D at 174 and Cabinet 2AC Misaligned In Except for Rods C-05 and G-05

a,c

Figure A.21: Case 129; EOL HFP Future Cycle F_Q Versus Axial Offset, Control Bank D at 174 and Cabinet 2AC Misaligned In Except for Rods C-05 and G-05

a,c

Figure A.22: Case 129; EOL HFP Future Cycle F_Q Difference Relative to 12 Step Indicated Misalignment Versus Axial Offset, Control Bank D at 174 and Cabinet 2AC Misaligned In Except for Rods C-05 and G-05

a,c

Figure A.23: Case 130; EOL HFP Future Cycle $F_{\Delta H}$ Versus Axial Offset, Control Bank D at 223 (ARO) and Cabinet 2AC Misaligned In Except for Rods C-05 and G-05

a,c

Figure A.24: Case 130; EOL HFP Future Cycle $F_{\Delta H}$ Difference Relative to 12 Step Indicated Misalignment Versus Axial Offset, Control Bank D at 223 (ARO) and Cabinet 2AC Misaligned In Except for Rods C-05 and G-05

a,c

Figure A.25: Case 339; BOL 50% RTP Current Cycle F_Q Versus Axial Offset, Control Bank D at 223 (ARO) and Cabinet 2AC Misaligned In Except for Rods C-05 and G-05

a,c

Figure A.26: Case 339; BOL 50% RTP Current Cycle F_Q Difference Relative to 12 Step Indicated Misalignment Versus Axial Offset, Control Bank D at 223 (ARO) and Cabinet 2AC Misaligned In Except for Rods C-05 and G-05

a,c

Figure A.27: Case 345; BOL 50% RTP Future Cycle $F_{\Delta H}$ Versus Axial Offset, Control Bank D at 223 (ARO) and Cabinet 2AC Misaligned In Except for Rods C-05 and G-05

a,c

Figure A.28: Case 345; BOL 50% RTP Future Cycle $F_{\Delta H}$ Difference Relative to 12 Step Indicated Misalignment Versus Axial Offset, Control Bank D at 223 (ARO) and Cabinet 2AC Misaligned In Except for Rods C-05 and G-05

a,c

Figure A.29: Case 345; BOL 50% RTP Future Cycle F_Q Versus Axial Offset, Control Bank D at 223 (ARO) and Cabinet 2AC Misaligned In Except for Rods C-05 and G-05

a,c

Figure A.30: Case 345; BOL 50% RTP Future Cycle F_Q Difference Relative to 12 Step Indicated Misalignment Versus Axial Offset, Control Bank D at 223 (ARO) and Cabinet 2AC Misaligned In Except for Rods C-05 and G-05

a,c

Figure A.31: Case 351; MOL 85% RTP Future Cycle $F_{\Delta H}$ Versus Axial Offset, Control Bank D at 142 and Cabinet 2AC Misaligned In Except for Rods C-05 and G-05

a,c

Figure A.32: Case 351; MOL 85% RTP Future Cycle $F_{\Delta H}$ Difference Relative to 12 Step Indicated Misalignment Versus Axial Offset, Control Bank D at 142 and Cabinet 2AC Misaligned In Except for Rods C-05 and G-05

a,c

Figure A.33: Case 357; EOL 50% RTP Current Cycle $F_{\Delta H}$ Versus Axial Offset, Control Bank D at 223 (ARO) and Cabinet 2AC Misaligned In Except for Rods C-05 and G-05

a,c

Figure A.34: Case 357; EOL 50% RTP Current Cycle $F_{\Delta H}$ Difference Relative to 12 Step Indicated Misalignment Versus Axial Offset, Control Bank D at 223 (ARO) and Cabinet 2AC Misaligned In Except for Rods C-05 and G-05

a,c

Figure A.35: Case 357; EOL 50% RTP Current Cycle F_Q Versus Axial Offset, Control Bank D at 223 (ARO) and Cabinet 2AC Misaligned In Except for Rods C-05 and G-05

a,c

Figure A.36: Case 357; EOL 50% RTP Current Cycle F_Q Difference Relative to 12 Step Indicated Misalignment Versus Axial Offset, Control Bank D at 223 (ARO) and Cabinet 2AC Misaligned In Except for Rods C-05 and G-05

a,c

Figure A.37: Case 370; EOL 85% RTP Future Cycle $F_{\Delta H}$ Versus Axial Offset, Control Bank D at 142 and Cabinet 2AC Misaligned In Except for Rods C-05 and G-05

a,c

Figure A.38: Case 370; EOL 85% RTP Future Cycle $F_{\Delta H}$ Difference Relative to 12 Step Indicated Misalignment Versus Axial Offset, Control Bank D at 142 and Cabinet 2AC Misaligned In Except for Rods C-05 and G-05

a,c

Figure A.39: Case 371; EOL 50% RTP Future Cycle $F_{\Delta H}$ Versus Axial Offset, Control Bank D at 174 and Cabinet 2AC Misaligned In Except for Rods C-05 and G-05

a,c

Figure A.40: Case 371; EOL 50% RTP Future Cycle $F_{\Delta H}$ Difference Relative to 12 Step Indicated Misalignment Versus Axial Offset, Control Bank D at 174 and Cabinet 2AC Misaligned In Except for Rods C-05 and G-05

a,c

Figure A.41: Case 371; EOL 50% RTP Future Cycle F_Q Versus Axial Offset, Control Bank D at 174 and Cabinet 2AC Misaligned In Except for Rods C-05 and G-05

a,c

Figure A.42: Case 371; EOL 50% RTP Future Cycle F_Q Difference Relative to 12 Step Indicated Misalignment Versus Axial Offset, Control Bank D at 174 and Cabinet 2AC Misaligned In Except for Rods C-05 and G-05

a,c

Figure A.43: Case 372; EOL 50% RTP Future Cycle $F_{\Delta H}$ Versus Axial Offset, Control Banks D/C at 68/191 and Cabinet 2AC Misaligned In Except for Rods C-05 and G-05

a,c

Figure A.44: Case 372; EOL 50% RTP Future Cycle $F_{\Delta H}$ Difference Relative to 12 Step Indicated Misalignment Versus Axial Offset, Control Banks D/C at 68/191 and Cabinet 2AC Misaligned In Except for Rods C-05 and G-05

a,c

Figure A.45: Case 372; EOL 50% RTP Future Cycle F_Q Versus Axial Offset, Control Bank D/C at 68/191 and Cabinet 2AC Misaligned In Except for Rods C-05 and G-05

a,c

Figure A.46: Case 372; EOL 50% RTP Future Cycle F_Q Difference Relative to 12 Step Indicated Misalignment Versus Axial Offset, Control Bank D/C at 68/191 and Cabinet 2AC Misaligned In Except for Rods C-05 and G-05

a,c

Figure A.47: Case 373; EOL 50% RTP Future Cycle $F_{\Delta H}$ Versus Axial Offset, Control Bank D at 223 (ARO) and Cabinet 2AC Misaligned In Except for Rods C-05 and G-05

a,c

Figure A.48: Case 373; EOL 50% RTP Future Cycle $F_{\Delta H}$ Difference Relative to 12 Step Indicated Misalignment Versus Axial Offset, Control Bank D at 223 (ARO) and Cabinet 2AC Misaligned In Except for Rods C-05 and G-05

a,c

Figure A.49: Case 373; EOL 50% RTP Future Cycle F_Q Versus Axial Offset, Control Bank D at 223 (ARO) and Cabinet 2AC Misaligned In Except for Rods C-05 and G-05

a,c

Figure A.50: Case 373; EOL 50% RTP Future Cycle F_Q Difference Relative to 12 Step Indicated Misalignment Versus Axial Offset, Control Bank D at 223 (ARO) and Cabinet 2AC Misaligned In Except for Rods C-05 and G-05

a,c

Figure A.51: Case 376; EOL 85% RTP Future Cycle F_Q Versus Axial Offset, Control Bank D at 142 and Cabinet 2AC Misaligned In Except for Rods C-05

a,c

Figure A.52: Case 376; EOL 85% RTP Future Cycle F_Q Difference Relative to 12 Step Indicated Misalignment Versus Axial Offset, Control Bank D at 142 and Cabinet 2AC Misaligned In Except for Rod C-05

a,c