PROP

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Conditional Extension of the Rod Misalignment Technical Specification for Indian Point Unit 3

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Attachment II

Non-Proprietary Version

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ABSTRACT

This report proposes modifying the Technical Specification for allowable rod misalignment from the current ±12 steps indicated to a maximum of ±18 steps indicated for core powers greater than 85% rated thermal power (RTP) depending upon the minimum available peaking factor margin, and ±24 steps indicated for core powers less than or equal to 85%. Such a TS change is sought to minimize disruptions to normal plant operations due to erroneous indications of rod misalignment from the Analog Rod Position Indication system (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 relative changes in these peaking factors between similar cases with misalignments of ±12 indicated and cases with additional misalignment. These resulting required margins will be determined such that they are cycle independent for Indian Point 3. It will also be shown that plant safety is not compromised by this Technical Specification change.

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ACKNOWLEDGEMENTS

The author gratefully acknowledges the following individuals for their contributions to the completion of this report: M. E. Easter, S. B. Fowler, J. M. Freeland, B. J. Johansen and C. R. Tuley.

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1.0 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 For example, such fluctuations can occur after rod control cluster assemblies (RCCAs) are withdrawn from the core during startup.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.

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2.0 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.

3.0 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 3 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 3 core were used. The first model is the currently operating Cycle 9, and represents the current Indian Point 3 licensing basis for fuel products and peaking factor limits. The second model used is intended to represent a "bounding" future cycle; that is, higher enrichments, longer cycle, higher peaking factors, more burnable absorbers, etc. 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)	554	[ ]a,c
No. of Feed Assemblies	80	[ ]a,c
No. Feeds Under Lead Bank (No. @ w/o U235)	0	[ ]a,c
Feed Enrichments (No. @ w/o U235)	56 @ 4.00 24 @ 4.40	[ ]a,c
Axial Blankets (w/o U235)	0.74 Solid	[ ]a,c
Burnable Absorbers (No. / Type / Length)	6400 IFBA, 120" centered; 416 WABA, 120" centered	[ ]a,c
$F_{\Delta H}$ Limit	1.62	[ ]a,c
F_Q Limit	2.32	[ ]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 3 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:

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

$$F_Q^{LIMIT} = \frac{F_Q^{HFP}}{P}, P > 0.5 \quad (2)$$

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 as well as 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. 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 3, 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 Unit 3 Control and Shutdown Rod Configuration By Group and Power Cabinet

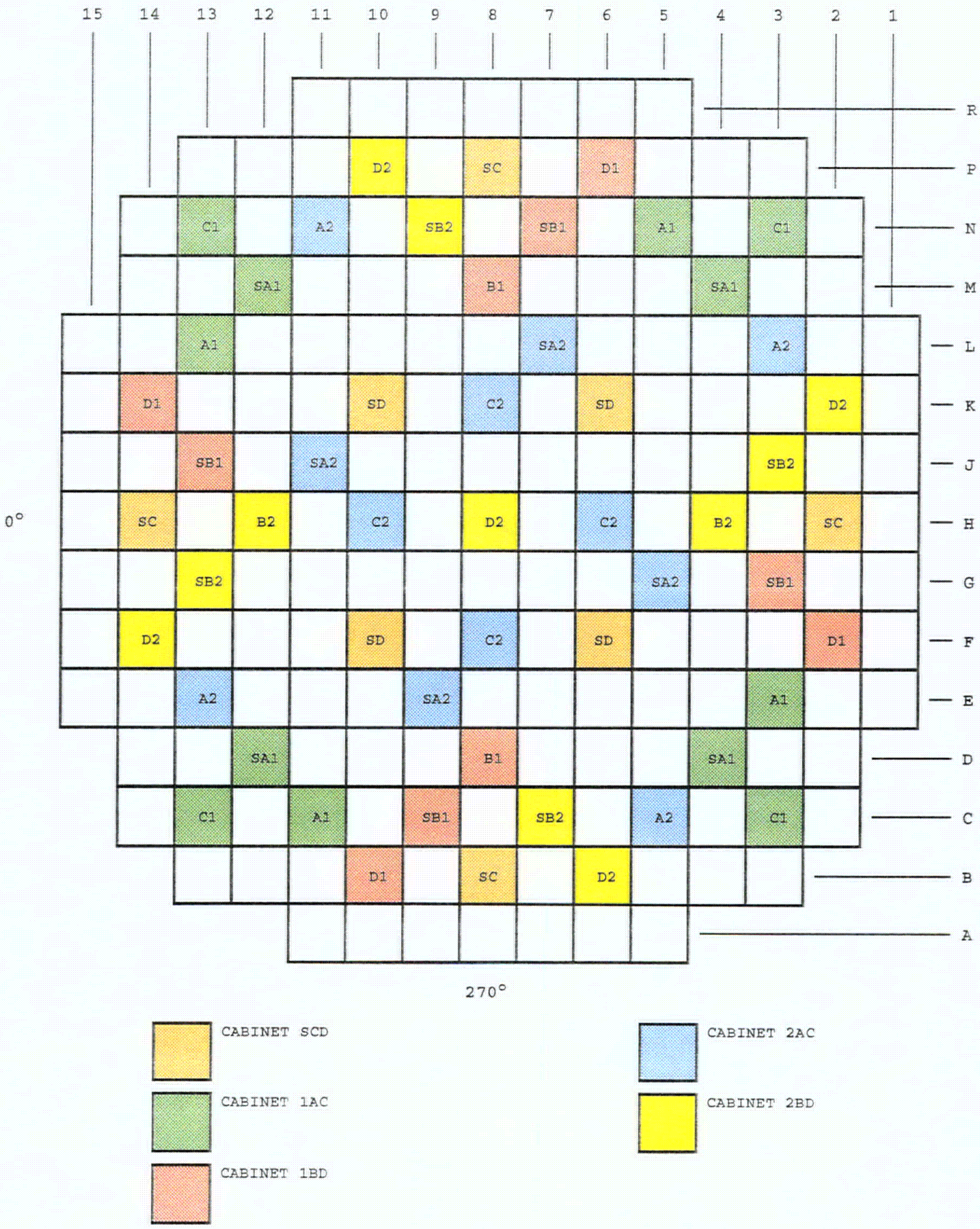

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Figure 3.2 Indian Point 3 Control Rod Insertion Limits

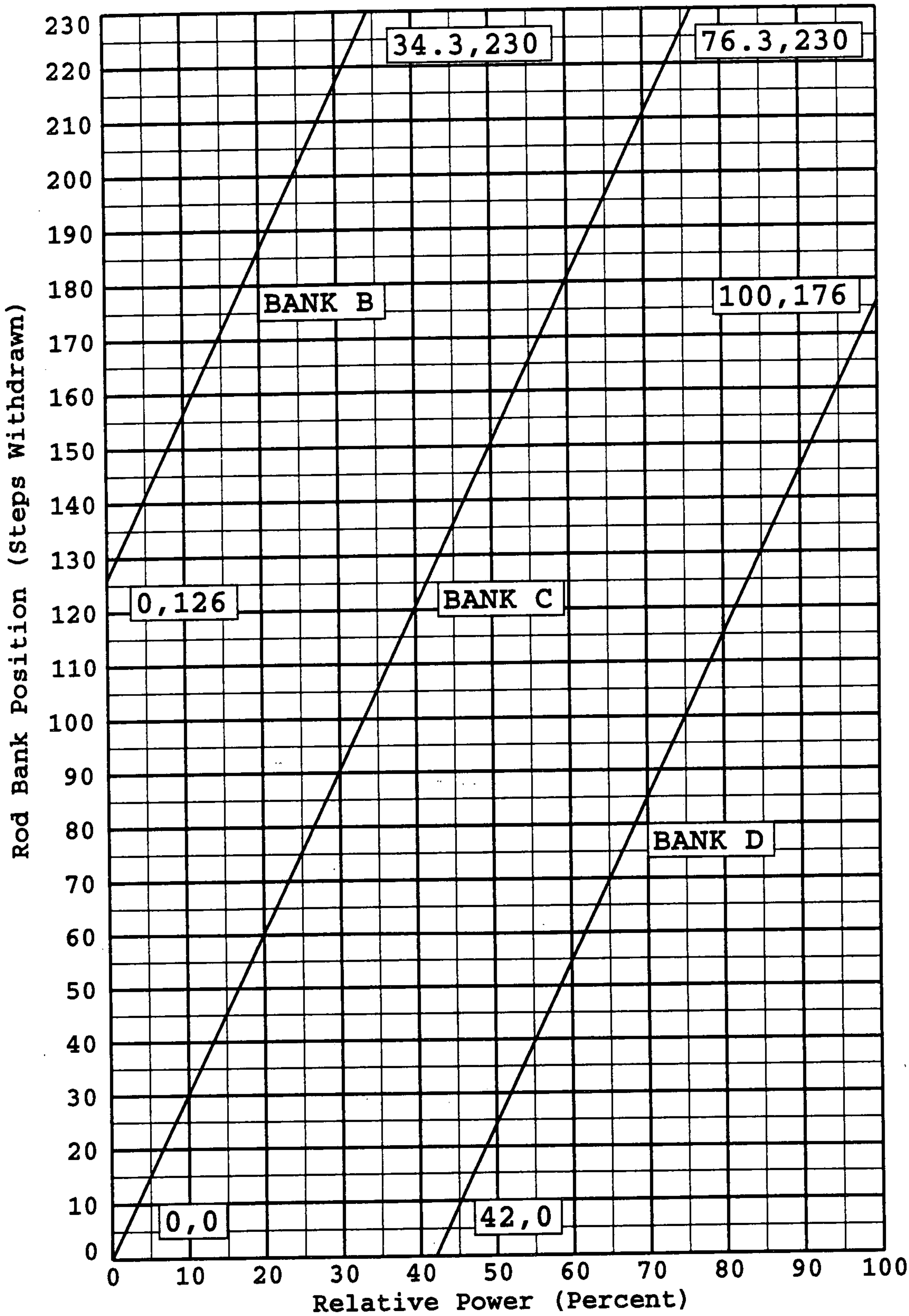

Figure 3.3 Permissible Increase in Rod Misalignment Vs. Available $F_{\Delta H}$ and F_Q Margin

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	Peak	Distribution Function	Mean ($\bar{x}$), %	Std. Dev. (σ), %	95/95 Value, %	Max. % (Case No.)
HFP ±18 [ ]a,c	$F_{\Delta H}$	Beta	[ ]a,c	[ ]a,c	[ ]a,c	[ ]a,c
	F_Q	Beta	[ ]a,c	[ ]a,c	[ ]a,c	[ ]a,c
All Powers ±15 [ ]a,c	$F_{\Delta H}$	Beta	[ ]a,c	[ ]a,c	[ ]a,c	[ ]a,c
	F_Q	Beta	[ ]a,c	[ ]a,c	[ ]a,c	[ ]a,c
Part Power ±18 [ ]a,c	$F_{\Delta H}$	Gamma	[ ]a,c	[ ]a,c	[ ]a,c	[ ]a,c
	F_Q	Beta	[ ]a,c	[ ]a,c	[ ]a,c	[ ]a,c
Part Power ±21 [ ]a,c	$F_{\Delta H}$	Beta	[ ]a,c	[ ]a,c	[ ]a,c	[ ]a,c
	F_Q	Beta	[ ]a,c	[ ]a,c	[ ]a,c	[ ]a,c
Part Power ±24 [ ]a,c	$F_{\Delta H}$	Beta	[ ]a,c	[ ]a,c	[ ]a,c	[ ]a,c
	F_Q	Beta	[ ]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 11)

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 176			
2	BOL	HFP	Current	D	D at 176			
3	BOL	HFP	Future	A	D at 176			
4	BOL	HFP	Future	D	D at 176			
5	BOL	HFP	Future	A	D at 188			
6	BOL	HFP	Future	D	D at 188			
7	BOL	HFP	Future	A	D at 200			
8	BOL	HFP	Future	A	D at 212			
9	BOL	HFP	Current	A	D at 176			
10	BOL	HFP	Current	D	D at 176			
11	BOL	HFP	Future	A	D at 176			
12	BOL	HFP	Future	D	D at 176			

Table 3.3: Summary of 18 Step Indicated Hot Full Power Rod Misalignment Cases Analyzed (Sheet 2 of 11)

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	2000	HFP	Future	A	D at 176			a,c
14	2000	HFP	Future	D	D at 176			
15	6000	HFP	Future	A	D at 176			
16	6000	HFP	Future	D	D at 176			
17	MOL	HFP	Current	A	D at 176			
18	MOL	HFP	Current	D	D at 176			
19	MOL	HFP	Future	A	D at 176			
20	MOL	HFP	Future	D	D at 176			
21	EOL	HFP	Current	A	D at 176			
22	EOL	HFP	Current	D	D at 176			
23	EOL	HFP	Current	A	D at 188			
24	EOL	HFP	Current	D	D at 188			

Table 3.3: Summary of 18 Step Indicated Hot Full Power Rod Misalignment Cases Analyzed (Sheet 3 of 11)

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
25	EOL	HFP	Current	A	D at 200			
26	EOL	HFP	Current	A	D at 212			
27	EOL	HFP	Future	A	D at 176			
28	EOL	HFP	Future	D	D at 176		(*)	(*)
29	EOL	HFP	Future	A	D at 188			
30	EOL	HFP	Future	D	D at 188			
31	EOL	HFP	Future	A	D at 200			
32	EOL	HFP	Future	A	D at 212			
33	BOL	HFP	Current	A	D at 176			
34	BOL	HFP	Current	D	D at 176			
35	BOL	HFP	Current	A	D at 176			
36	BOL	HFP	Current	D	D at 176			

Table 3.3: Summary of 18 Step Indicated Hot Full Power Rod Misalignment Cases Analyzed (Sheet 4 of 11)

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
37	BOL	HFP	Current	A	D at 176			a,c
38	BOL	HFP	Current	D	D at 176			
39	EOL	HFP	Current	A	D at 176			
40	EOL	HFP	Current	D	D at 176			
41	EOL	HFP	Current	A	D at 176			
42	EOL	HFP	Current	D	D at 176			
43	EOL	HFP	Current	A	D at 176			
44	EOL	HFP	Current	D	D at 176			
45	EOL	HFP	Current	A	D at 200			
46	EOL	HFP	Current	D	D at 200			
47	EOL	HFP	Current	A	D at 200			
48	EOL	HFP	Current	D	D at 200			

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Table 3.3: Summary of 18 Step Indicated Hot Full Power Rod Misalignment Cases Analyzed (Sheet 5 of 11)

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	BOL	HFP	Current	A	D at 176			a,c
50	BOL	HFP	Current	D	D at 176			
51	BOL	HFP	Current	A	D at 176			
52	BOL	HFP	Current	D	D at 176			
53	6000	HFP	Future	A	D at 176			
54	6000	HFP	Future	D	D at 176			
55	6000	HFP	Future	A	D at 176			
56	6000	HFP	Future	D	D at 176			
57	MOL	HFP	Future	A	D at 176			
58	MOL	HFP	Future	D	D at 176			
59	MOL	HFP	Future	A	D at 176			
60	MOL	HFP	Future	D	D at 176			

Table 3.3: Summary of 18 Step Indicated Hot Full Power Rod Misalignment Cases Analyzed (Sheet 6 of 11)

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 176			
62	EOL	HFP	Current	D	D at 176			
63	EOL	HFP	Current	A	D at 176			
64	EOL	HFP	Current	D	D at 176			
65	EOL	HFP	Future	A	D at 176			
66	EOL	HFP	Future	D	D at 176		(*)	(*)
67	EOL	HFP	Future	A	D at 176			
68	EOL	HFP	Future	D	D at 176		(*)	(*)
69	EOL	HFP	Future	A	D at 176			
70	EOL	HFP	Future	D	D at 176			
71	EOL	HFP	Future	A	D at 176			
72	EOL	HFP	Future	D	D at 176			

a,c

Table 3.3: Summary of 18 Step Indicated Hot Full Power Rod Misalignment Cases Analyzed (Sheet 7 of 11)

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	EOL	HFP	Future	A	D at 176	[		] a,c
74	EOL	HFP	Future	D	D at 176			
75	BOL	HFP	Current	A	D at 176			
76	BOL	HFP	Future	A	D at 176			
77	BOL	HFP	Future	A	D at 176			
78	BOL	HFP	Future	A	D at 224 (ARO)		(*)	(*)
79	BOL	HFP	Future	A	D at 224 (ARO)			
80	6000	HFP	Future	A	D at 176	]		

Table 3.3: Summary of 18 Step Indicated Hot Full Power Rod Misalignment Cases Analyzed (Sheet 8 of 11)

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
81	6000	HFP	Future	A	D at 224	[		] a,c
82	MOL	HFP	Future	A	D at 176			
83	MOL	HFP	Future	A	D at 224			
84	EOL	HFP	Current	A	D at 176			
85	EOL	HFP	Future	A	D at 176			
86	EOL	HFP	Future	A	D at 176			
87	EOL	HFP	Future	A	D at 176			
88	EOL	HFP	Future	A	D at 176			]

Table 3.3: Summary of 18 Step Indicated Hot Full Power Rod Misalignment Cases Analyzed (Sheet 9 of 11)

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
89	EOL	HFP	Future	A	D at 176			a,c
90	EOL	HFP	Future	A	D at 176			
91	EOL	HFP	Future	A	D at 176			
92	EOL	HFP	Future	A	D at 176			
93	EOL	HFP	Future	A	D at 176			(*)
94	EOL	HFP	Future	A	D at 224			
95	BOL	HFP	Current	B	D at 176			
96	BOL	HFP	Current	B	D at 176			
97	BOL	HFP	Current	B	D at 176			
98	BOL	HFP	Current	B	D at 176			
99	BOL	HFP	Future	B	D at 176			

Table 3.3: Summary of 18 Step Indicated Hot Full Power Rod Misalignment Cases Analyzed (Sheet 10 of 11)

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
100	EOL	HFP	Future	B	D at 176			a,c
101	EOL	HFP	Future	B	D at 176			
102	BOL	HFP	Current	C	D at 176			
103	EOL	HFP	Future	C	D at 176			
104	BOL	HFP	Future	E	D at 176		(*)	
105	BOL	HFP	Future	E	D at 188			
106	EOL	HFP	Current	E	D at 176			
107	EOL	HFP	Future	E	D at 176			
108	EOL	HFP	Future	E	D at 176			
109	BOL	HFP	Future	F	D at 176		(*)	

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

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
110	EOL	HFP	Current	F	D at 176	[		] a,c
111	EOL	HFP	Future	F	D at 176	[		]
(*)	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 3)

Case No.	Burnup	Power	Cycle	Failure Mechanism	Reference Bank Position	Rods Misaligned	Peaking Factor % Increase for Additional 3 Steps	
							$F_{\Delta H}$	F_Q
112	BOL	HFP	Current	A	D at 176			a,c
113	BOL	HFP	Current	D	D at 176			
114	BOL	HFP	Current	A	D at 176			
115	BOL	HFP	Current	D	D at 176			
116	BOL	HFP	Current	A	D at 176			
117	BOL	HFP	Current	D	D at 176			
118	BOL	HFP	Future	A	D at 224 (ARO)			
119	BOL	HFP	Future	E	D at 176			
120	BOL	HFP	Future	F	D at 176			
121	MOL	HFP	Future	A	D at 224			

Table 3.4: Summary of 15 Step Indicated Rod Misalignment Cases Analyzed (Sheet 2 of 3)

Case No.	Burnup	Power	Cycle	Failure Mechanism	Reference Bank Position	Rods Misaligned	Peaking Factor % Increase for Additional 3 Steps	
							$F_{\Delta H}$	F_Q
122	EOL	HFP	Future	D	D at 176			a,c
123	EOL	HFP	Future	D	D at 176			
124	EOL	HFP	Current	A	D at 176			
125	EOL	HFP	Current	D	D at 176			
126	EOL	HFP	Current	A	D at 176			
127	EOL	HFP	Current	D	D at 176			
128	EOL	HFP	Current	A	D at 176			
129	EOL	HFP	Future	A	D at 176			
130	BOL	85%	Current	A	D at 176			
131	BOL	85%	Current	D	D at 176			
132	BOL	85%	Current	A	D at 130			

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

Case No.	Burnup	Power	Cycle	Failure Mechanism	Reference Bank Position	Rods Misaligned	Peaking Factor % Increase for Additional 3 Steps	
							$F_{\Delta H}$	F_Q
133	BOL	85%	Current	D	D at 130			
134	EOL	85%	Current	A	D at 176			
135	EOL	85%	Current	D	D at 176			
136	EOL	85%	Current	A	D at 176			
137	EOL	85%	Current	D	D at 176			

a,c

Table 3.5: Summary of 18 Step Indicated Part-Power Rod Misalignment Cases Analyzed (Sheet 1 of 4)

Case No.	Burnup	Power	Cycle	Failure Mechanism	Reference Bank Position	Rods Misaligned	Peaking Factor % Increase for Additional 6 Steps	
							$F_{\Delta H}$	F_Q
138	BOL	85%	Current	A	D at 176			
139	BOL	85%	Current	D	D at 176			
140	BOL	85%	Current	A	D at 130			
141	BOL	85%	Current	D	D at 130			
142	BOL	85%	Future	A	D at 224 (ARO)			
143	BOL	85%	Future	E	D at 176			
144	BOL	85%	Future	E	D at 130			
145	BOL	85%	Future	F	D at 176			
146	BOL	85%	Future	F	D at 130			

a,c

Table 3.5: Summary of 18 Step Indicated Part-Power Rod Misalignment Cases Analyzed (Sheet 2 of 4)

Case No.	Burnup	Power	Cycle	Failure Mechanism	Reference Bank Position	Rods Misaligned	Peaking Factor % Increase for Additional 6 Steps	
							$F_{\Delta H}$	F_Q
								a,c
147	MOL	85%	Future	A	D at 224 (ARO)			
148	EOL	85%	Current	A	D at 200			
149	EOL	85%	Current	D	D at 200			
150	EOL	85%	Current	A	D at 176			
151	EOL	85%	Current	D	D at 176			
152	EOL	85%	Current	A	D at 130			
153	EOL	85%	Current	D	D at 130			
154	EOL	85%	Future	A	D at 176			
155	EOL	85%	Future	D	D at 176			
156	EOL	85%	Future	A	D at 130			
157	EOL	85%	Future	D	D at 130			

Table 3.5: Summary of 18 Step Indicated Part-Power Rod Misalignment Cases Analyzed (Sheet 3 of 4)

Case No.	Burnup	Power	Cycle	Failure Mechanism	Reference Bank Position	Rods Misaligned	Peaking Factor % Increase for Additional 6 Steps	
							$F_{\Delta H}$	F_Q
158	EOL	50%	Current	A	D at 176			a,c
159	EOL	50%	Current	D	D at 176			
160	EOL	50%	Current	D	D at 24, C at 150			
161	EOL	50%	Current	A	D at 24, C at 150			
162	EOL	50%	Current	D	D at 24, C at 150			
163	EOL	50%	Current	A	D at 24, C at 150			
164	EOL	50%	Current	D	D at 24, C at 150			
165	EOL	85%	Current	A	D at 176			
166	EOL	85%	Current	D	D at 176			
167	EOL	85%	Current	A	D at 130			

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

Case No.	Burnup	Power	Cycle	Failure Mechanism	Reference Bank Position	Rods Misaligned	Peaking Factor % Increase for Additional 6 Steps	
							$F_{\Delta H}$	F_Q
168	EOL	85%	Current	D	D at 130			a,c
169	EOL	85%	Future	D	D at 176			
170	EOL	85%	Future	D	D at 176			
171	EOL	85%	Future	D	D at 130			
172	EOL	85%	Future	D	D at 130			
173	EOL	85%	Future	A	D at 176			
174	EOL	85%	Future	A	D at 130			

Table 3.6: Summary of 21 Step Indicated Part-Power Rod Misalignment Cases Analyzed (Sheet 1 of 4)

Case No.	Burnup	Power	Cycle	Failure Mechanism	Reference Bank Position	Rods Misaligned	Peaking Factor % Increase for Additional 9 Steps	
							$F_{\Delta H}$	F_Q
175	BOL	85%	Current	A	D at 176			a,c
176	BOL	85%	Current	D	D at 176			
177	BOL	85%	Current	A	D at 130			
178	BOL	85%	Current	D	D at 130			
179	BOL	85%	Future	A	D at 224 (ARO)			
180	BOL	85%	Future	E	D at 176			
181	BOL	85%	Future	E	D at 130			
182	BOL	85%	Future	F	D at 176			
183	BOL	85%	Future	F	D at 130			

Table 3.6: Summary of 21 Step Indicated Part-Power Rod Misalignment Cases Analyzed (Sheet 2 of 4)

Case No.	Burnup	Power	Cycle	Failure Mechanism	Reference Bank Position	Rods Misaligned	Peaking Factor % Increase for Additional 9 Steps	
							$F_{\Delta H}$	F_Q
184	MOL	85%	Future	A	D at 224 (ARO)			a,c
185	EOL	85%	Current	A	D at 200			
186	EOL	85%	Current	D	D at 200			
187	EOL	85%	Current	A	D at 176			
188	EOL	85%	Current	D	D at 176			
189	EOL	85%	Current	A	D at 130			
190	EOL	85%	Current	D	D at 130			
191	EOL	85%	Future	A	D at 176			
192	EOL	85%	Future	D	D at 176			
193	EOL	85%	Future	A	D at 130			
194	EOL	85%	Future	D	D at 130			

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Table 3.6: Summary of 21 Step Indicated Part-Power Rod Misalignment Cases Analyzed (Sheet 3 of 4)

Case No.	Burnup	Power	Cycle	Failure Mechanism	Reference Bank Position	Rods Misaligned	Peaking Factor % Increase for Additional 9 Steps	
							$F_{\Delta H}$	F_Q
195	EOL	50%	Current	A	D at 176			a,c
196	EOL	50%	Current	D	D at 176			
197	EOL	50%	Current	D	D at 24, C at 150			
198	EOL	50%	Current	A	D at 24, C at 150			
199	EOL	50%	Current	D	D at 24, C at 150			
200	EOL	50%	Current	A	D at 24, C at 150			
201	EOL	50%	Current	D	D at 24, C at 150			
202	EOL	85%	Current	A	D at 176			
203	EOL	85%	Current	D	D at 176			
204	EOL	85%	Current	A	D at 130			

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

Case No.	Burnup	Power	Cycle	Failure Mechanism	Reference Bank Position	Rods Misaligned	Peaking Factor % Increase for Additional 9 Steps	
							$F_{\Delta H}$	F_Q
205	EOL	85%	Current	D	D at 130			
206	EOL	85%	Future	D	D at 176			
207	EOL	85%	Future	D	D at 176			
208	EOL	85%	Future	D	D at 130			
209	EOL	85%	Future	D	D at 130			
210	EOL	85%	Future	A	D at 176			
211	EOL	85%	Future	A	D at 130			

a,c

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Table 3.7: Summary of 24 Step Indicated Part-Power Rod Misalignment Cases Analyzed (Sheet 1 of 4)

Case No.	Burnup	Power	Cycle	Failure Mechanism	Reference Bank Position	Rods Misaligned	Peaking Factor % Increase for Additional 12 Steps	
							$F_{\Delta H}$	F_Q a,c
212	BOL	85%	Current	A	D at 176			
213	BOL	85%	Current	D	D at 176			
214	BOL	85%	Current	A	D at 130			
215	BOL	85%	Current	D	D at 130			
216	BOL	85%	Future	A	D at 224 (ARO)			
217	BOL	85%	Future	E	D at 176		(*)	
218	BOL	85%	Future	E	D at 130			(*)
219	BOL	85%	Future	F	D at 176		(*)	
220	BOL	85%	Future	F	D at 130			

Table 3.7: Summary of 24 Step Indicated Part-Power Rod Misalignment Cases Analyzed (Sheet 2 of 4)

Case No.	Burnup	Power	Cycle	Failure Mechanism	Reference Bank Position	Rods Misaligned	Peaking Factor % Increase for Additional 12 Steps	
							$F_{\Delta H}$	F_Q
221	MOL	85%	Future	A	D at 224 (ARO)			a,c
222	EOL	85%	Current	A	D at 200			
223	EOL	85%	Current	D	D at 200			
224	EOL	85%	Current	A	D at 176			
225	EOL	85%	Current	D	D at 176			
226	EOL	85%	Current	A	D at 130			
227	EOL	85%	Current	D	D at 130			
228	EOL	85%	Future	A	D at 176			
229	EOL	85%	Future	D	D at 176		(*)	(*)
230	EOL	85%	Future	A	D at 130			
231	EOL	85%	Future	D	D at 130			

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Table 3.7: Summary of 24 Step Indicated Part-Power Rod Misalignment Cases Analyzed (Sheet 3 of 4)

Case No.	Burnup	Power	Cycle	Failure Mechanism	Reference Bank Position	Rods Misaligned	Peaking Factor % Increase for Additional 12 Steps	
							$F_{\Delta H}$	F_Q
232	EOL	50%	Current	A	D at 176			
233	EOL	50%	Current	D	D at 176			(*)
234	EOL	50%	Current	D	D at 24, C at 150			
235	EOL	50%	Current	A	D at 24, C at 150			
236	EOL	50%	Current	D	D at 24, C at 150			
237	EOL	50%	Current	A	D at 24, C at 150			
238	EOL	50%	Current	D	D at 24, C at 150			
239	EOL	85%	Current	A	D at 176			
240	EOL	85%	Current	D	D at 176			
241	EOL	85%	Current	A	D at 130			

a,c

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

Case No.	Burnup	Power	Cycle	Failure Mechanism	Reference Bank Position	Rods Misaligned	Peaking Factor % Increase for Additional 12 Steps	
							$F_{\Delta H}$	F_Q
242	EOL	85%	Current	D	D at 130			
243	EOL	85%	Future	D	D at 176			
244	EOL	85%	Future	D	D at 176			(*)
245	EOL	85%	Future	D	D at 130			
246	EOL	85%	Future	D	D at 130			
247	EOL	85%	Future	A	D at 176			(*)
248	EOL	85%	Future	A	D at 130		(*)	
(*)	Signifies that plots of peaking factors and increases due to additional steps of misalignment are included in the Appendix of this report.							

a,c

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4.0 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.

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.

To evaluate the effects of an increased rod misalignment on the rod ejection accident, a cycle depletion with [ ]^{a,c}. This is a conservative assumption since Indian Point 3 historically does not load follow nor operate with D bank deeply inserted.

The rod ejection parameters can be affected by an increased rod misalignment in two ways: a misalignment of any number of RIL rods during the last 30 effective full power days (EFPD) of the rodded depletion; or a misalignment of the RIL rods at HZP prior to the ejection. For the first scenario, [ ]^{a,c}. For both scenarios, 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 either an additional 6 steps of rod misalignment during the last 30 EFPD of the HFP rodded depletion or 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. Again, recall that the future cycle has a feed assembly under all 9 of the RCCAs in the lead control bank D and the current cycle has none. As such, the future cycle yields larger non-misaligned values for the ejected rod F_Q and $\Delta\rho_{EJ}$. Both cycles also yield similar absolute increases in the ejected rod F_Q and $\Delta\rho_{EJ}$. Since the factors of conservatism to address the impacts of increased rod misalignment on rod ejection are multiplicative, or relative increases, the cycle with the lower absolute values will tend to yield the larger increases. 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}; recall from Figure 3.2 that the HZP RILs permit both control banks D and C to be fully inserted. 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.

5.0 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 3 Cycle 9 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}

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

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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 3. The data summarized in Tables 3.3 through 3.7 represents the maximum points from these figures.

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Figure A.1

a,c

Figure A.2

a,c

Figure A.3

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Figure A.4

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Figure A.5

a,c

Figure A.6

a,c

Figure A.7

a,c

Figure A.8

a,c

Figure A.9

a,c

Figure A.10

a,c

Figure A.11

a,c

Figure A.12

a,c

Figure A.13

a,c

Figure A.14

a,c

Figure A.15

[ ]a,c

Figure A.16

a,c

Figure A.17

a,c

Figure A.18

a,c

Figure A.19

a,c

Figure A.20

a,c

Figure A.21

a,c

Figure A.22

a,c

Figure A.23

a,c

Figure A.24

a,c

Figure A.25

a,c

Figure A.26

a,c

Figure A.27

a,c

Figure A.28

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Figure A.29

a,c

Figure A.30

a,c

Figure A.31

a,c

Figure A.32

a,c

Figure A.33

a,c

Figure A.34

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Figure A.35

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Figure A.36

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Figure A.37

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Figure A.38

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Figure A.39

a,c

Figure A.40

a,c

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