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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 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.

3.10.5 Rod Misalignment Limitations

3.10.5.1 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, then realign the rod within one hour or determine the core peaking factors within 2 hours and apply Specification 3.10 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, 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 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 No 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, is found to be misaligned from Specification 3.10.6.1a, above, then Specification 3.10.5 will be applied

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, control rods in a single bank move together with no individual rod insertion differing by more than 15 inches from the group step counter demand position. An indicated misalignment limit of 12 steps precludes rod misalignment no greater than 15 inches with consideration of maximum instrumentation error. 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

2. At or below 85% power the allowed rod position indicator 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.

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 the "movable core" of the transformer. With a constant AC source applied to the primary windings, the vertical position of the mechanism drive 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 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);

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 approximately 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.

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 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
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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