

3.10.4.4 Except during physics testing, power operation with an inoperable control rod shall not be allowed if the inoperable rod has a potential reactivity insertion upon ejection greater than $0.365\% \Delta k/k$. The control bank insertion limits shown in Figure 3.10-1 shall be used until the potential reactivity insertion of the inoperable rod has been confirmed to be less than $0.365\% \Delta k/k$ at greater control bank insertion.

Basis:

The reactivity control concept is that reactivity changes accompanying changes in reactor power are compensated by control rod motion. Reactivity changes associated with xenon, samarium, fuel depletion, and large changes in reactor coolant temperature (operating temperature to cold shutdown) are compensated by changes in the soluble boron concentration. During power operation, the shutdown groups are fully withdrawn and control of reactor power is by the control groups. A reactor trip occurring during power operation will put the reactor into the hot shutdown condition.

The control rod insertion limits provide for achieving hot shutdown by reactor trip at any time, assuming the highest worth control rod remains fully withdrawn with sufficient margins to meet the assumptions used in the accident analysis.⁽¹⁾ In addition, they provide a limit on the maximum inserted rod worth in the unlikely event of a hypothetical

rod ejection, and provide for acceptable nuclear peaking factors.

The lines shown on Figure

3.10-1 meet the shutdown requirement. The maximum shutdown margin requirement occurs at end-of-cycle life and is based on the value used in analysis of the hypothetical steam break accident. Early in cycle life, less shutdown margin, is required, and Figure 3.10-2 shows the shutdown margin equivalent to 1.9% reactivity at end-of-life with respect to an uncontrolled cooldown. All other accident analyses are based on 1% reactivity shutdown margin. Part length rod insertion has been eliminated for this cycle to eliminate potential adverse power shapes and to preclude rapid local power changes caused by part length rod travel through the core.

The various control rod banks (shutdown banks, control banks A, B, C, D, and part-length rods) are each to be moved as a bank; that is, with all rods in the bank within one step ($5/8$ inch) of the bank position. Position indication is provided by two methods: a digital count of actuation pulses which shows the demand position of the banks and a linear position indicator (LVDT) which indicates the actual rod position. (2) The 15 inch permissible misalignment provides an

enforceable limit below which design distribution is not exceeded.

In the event that an LVDT is not in service, the effects of a mal-positioned control rod are observable on nuclear and process information displayed in the control room and by core thermocouples and in-core movable detectors. The two hours in 3.10.2.3 are acceptable since complete rod misalignment (Part-length or full-length control rod 12 feet out of alignment with its bank) does not result in exceeding core safety limits in steady state operation at rated power and is short with respect to probability of an independent accident. If the condition cannot be readily corrected, the specified reduction in power to 75% will ensure that design margins to core limits will be maintained under both steady state and anticipated transient conditions.

An upper bound envelope of 2.32 times the normalized peaking factor axial dependence of Figure 3.10-3 has been determined from extensive analyses considering operating maneuvers consistent with the technical specifications on power distribution control as given in Section 3.10. The results of the loss of coolant accident analyses based on this upper bound envelope demonstrate compliance with the Final Acceptance Criteria limit for Emergency Core Cooling Systems.

When an F_Q measurement is taken, both experimental error and manufacturing tolerance must be allowed for. Five percent is the appropriate allowance for a full core map taken with the movable incore detector flux mapping system and three percent is the appropriate allowance for manufacturing tolerance. When a measurement of $F_{\Delta H}^N$ is taken, experimental error must be allowed for and 4 percent is the appropriate allowance for a full core map with the movable incore detector flux mapping system.

Measurements of the hot channel factors are required as part of startup physics tests, at least each 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 pattern. The periodic incore mapping provides additional assurance that the nuclear design bases remain inviolate and identifies operational anomalies which might, 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. Control rods in a single bank move together with no individual rod insertion differing by more than 15 inches from the bank demand position.
2. Control rod banks are sequenced with overlapping banks as described in Specification 3.10.
3. The full length and part length control bank insertion limits are not violated.
4. Axial power distribution limits which are given in terms of flux difference limits and control bank insertion limits are observed. Flux difference is $q_T - q_B$ as defined in Specification 2.3.1.2d.

The permitted relaxation in $F_{\Delta H}^N$ with reduced power allows radial power shape changes with rod insertion to the insertion limits. It has been determined that provided the above conditions 1 through 4 are observed, these hot channel factors limits are met. In specification 3.10 F_0 is arbitrarily limited for $P < 0.5$ (except for low power physics tests).

The limits on axial power distribution referred to above are designed to minimize the effects of xenon redistribution on the axial power distribution during load-follow maneuvers. Basically, control of flux difference is required to limit the difference between the current value of Flux Difference (ΔI) and a reference value which corresponds to the full power equilibrium value of Axial Offset (Axial Offset = ΔI /fractional power). The reference value of flux difference varies with power level and burnup but expressed as axial offset it varies primarily with burnup.

The technical specifications on power distribution assure that the F_0 upper bound envelope of 2.32 times Figure 3.10-3 is not exceeded and xenon distributions are not developed which, at a later time, could cause greater local power peaking even though the flux difference is then within the limits.

The target (or reference) value of flux difference is determined as follows. At any time that equilibrium xenon conditions have been established, the indicated flux difference is noted with part length rods withdrawn from the core and with control Bank D more than 190 steps withdrawn. This value, divided by the fraction of full power at which the core was operating is the full power value of the target flux difference. Values for all other core power levels are obtained by multiplying the full power value by the fractional power. Since the indicated equilibrium value was noted, no allowances for excore detector error are necessary and indicated deviation of ± 5 percent ΔI is permitted from the indicated reference value. During periods where extensive load following is required, it may be impossible to establish the required core conditions for measuring the target flux difference every month. For this reason, two methods are permissible for updating the target flux difference.

Strict control of the flux difference (and rod position) is not as necessary during part power operation. This is because xenon distribution control at part power is not as significant as the control at full power and allowance has been made in predicting the heat flux peaking factors for less strict control at part power.

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Strict control of the flux difference is not possible during certain physics tests, control rod exercises, or during the required periodic excore calibration which require larger flux differences than permitted. Therefore, the specifications on power distribution are not applicable during physics tests, control rod exercises, or excore calibrations; this is acceptable due to the extremely low probability of a significant accident occurring during these operations. Excore calibration includes that period of time necessary to return to equilibrium operating conditions.

In some instances of rapid plant power reduction automatic rod motion will cause the flux difference to deviate from the target band when the reduced power level is reached. This does not necessarily affect the xenon distribution sufficiently to change the envelope of peaking factors which can be reached on a subsequent return to full power within the target band, however to simplify the specification, a limitation of one hour in any period of 24 hours is placed on operation outside the band. This ensures that the resulting xenon distributions are not significantly

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different from those resulting from operation within the target band. The instantaneous consequence of being outside the band, provided rod insertion limits are observed, is not worse than a 10 percent increment in peaking factor for flux difference in the range +14 percent to -14 percent (+11 percent to -11 percent indicated) increasing by +1 percent of each 2 percent decrease in rated power. Therefore, while the deviation exists the power level is limited to 90 percent or lower depending on the indicated flux difference.

If, for any reason, flux difference is not controlled within the ± 5 percent band for as long a period as one hour, then xenon distributions may be significantly changed and operation at 50 percent is required to protect against potentially more severe consequences of some accidents.

As discussed above, the essence of the limits is to maintain the xenon distribution in the core as close to the equilibrium full power condition as possible. This is accomplished, without part length rods, by using the chemical volume control system to position the full length control rods to produce the required indication flux difference.

The effect of exceeding the flux difference band at or below half power is approximately half as great as it would be at 90% of rated power, where the effect of deviation has been evaluated.

The reason for requiring hourly logging is to provide continued surveillance of the flux difference if the normal alarm functions are out of service. It is intended that this surveillance would be temporary until the alarm functions are restored.

The quadrant power tilt ratio limit assures that the radial power distribution satisfies the design values used in the power capability analysis. Radial power distribution measurements are made during startup testing and periodically during power operation.

The limit of 1.02 at which corrective action is required provides DNB and linear heat generation rate protection with x-y plane power tilts. A limiting tilt of 1.025 can be tolerated before the margin for uncertainty in F_q is depleted. Therefore, the limiting tilt has been

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set as 1.02. To avoid unnecessary power changes the operator is allowed two hours in which to verify the tilt reading and/or to determine and correct the cause of the tilt. Should this action verify a tilt in excess of 1.02 which remains uncorrected, the margin for uncertainty in F_Q^N and $F_{\Delta H}^N$ is reinstated by reducing the power by 2% for each percent of tilt above 1.0, in accordance with the 2 to 1 ratio above, or as required by the restriction on peaking factors.

If instead of determining the hot channel factors, the operator decides to reduce power, the specified 75% power maintains the design margin to core safety limits for up to a 1.12 power tilt, using the 2 to 1 ratio. Reducing the overpower trip set point ensures that the protection system basis is maintained for sustained plant operation. A tilt ratio of 1.12 or more is indicative of a serious performance anomaly and a plant shutdown is prudent.

The specified rod drop time is consistent with safety analyses that have been performed. (1)

An inoperable rod imposes additional demands on the operator.

The permissible number of inoperable control rods is limited to one except during physics testing, in order to limit the magnitude of the operating burden, but such a failure would not prevent dropping of the operable rods upon reactor trip.

The reactivity worth limit for an inoperable control rod is consistent with the value found tolerable in the analysis of the hypothetical rod ejection accident. (3) The initial-core physics testing showed the maximum worth to be less than 0.365% when the controlling Group D

was more than 60% withdrawn, whereas larger worths were possible with the controlling bank fully inserted. (4)

References:

- (1) Technical Supplement Accompanying Application to Increase Power - Section 14
- (2) FSAR, Section 7.3
- (3) FSAR, Section 14.2.6
- (4) Technical Supplement - Appendix A, Pg. 120

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