B 3.2 POWER DISTRIBUTION LIMITS

B 3.2.1 Linear Power Density (LPD)

BASES

BACKGROUND

The purpose of this LCO is to limit the core power distribution to the initial values assumed in the accident analyses. Operation within the limits imposed by this LCO limits or prevents potential fuel cladding failures that could breach the primary fission product barrier and release fission products to the reactor coolant in the event of a Loss of Coolant Accident (LOCA), loss of flow accident, rod ejection accident, or other postulated accident requiring termination by a Distributed Control System (DCS) trip function. This LCO limits the damage to the fuel cladding during an accident by ensuring that the plant is operating within acceptable bounding conditions at the onset of the transient.

The core power distribution is controlled so that, in conjunction with other core operating parameters (e.g., rod cluster control assembly (RCCA) insertion and alignment limits), the power distribution does not result in violation of this LCO. The limiting safety system settings and this LCO are based on the accident analyses (Refs. 1 and 2), so that specified acceptable fuel design limits are not exceeded as a result of anticipated operational occurrences (AOOs), and the limits of acceptable consequences are not exceeded for other postulated accidents.

Limiting axial power redistribution over time also minimizes xenon distribution swings, which is a significant factor in controlling the axial power distribution.

The power distribution is a product of multiple parameters, various combinations of which may produce acceptable power distributions. Operation within the bounding conditions for power distribution is accomplished by maintaining the local LPD and the Departure from Nucleate Boiling Ratio (DNBR) within limits.

Proximity to the Departure from Nucleate Boiling (DNB) condition is expressed by the DNBR which is defined as the ratio of the cladding surface heat flux required to cause DNB to the actual cladding surface heat flux.

BASES

BACKGROUND (continued)

There are two systems that perform online monitoring of the core maximum LPD and minimum DNBR: the Distributed Control System (DCS) and the Reactor Control, Surveillance and Limitation (RCSL) System. The DCS and the RCSL System are capable of verifying that the LPD and the DNBR do not exceed their limits. The DCS and the RCSL System perform this function by continuously monitoring incore Self-Powered Neutron Detectors (SPND) measurements, thermal-hydraulic data, and RCCA insertion, and by calculating an actual value of DNBR and LPD, for comparison to:

- The respective trip setpoints in the DCS; and
- The limits for critical operation in the RCSL System.

Thus the RCSL System continuously indicates to the operator how far the core is from the operating LPD and DNBR limits, and provides an alarm in the Main Control Room if any limit is exceeded. Such a condition signifies a reduction in the capability of the plant to withstand an AOO or postulated accident. This does not necessarily imply a violation of fuel design limits because the DCS initiates a reactor trip when the High LPD reactor trip setpoint is reached..

The calculation of the maximum linear power density (in kW/ft) in the DCS (High Linear Power Density function) and in the RCSL System (High Linear Power Density Limitation function) is based on the readings of the SPNDs.

Twelve fuel assemblies are instrumented with SPND fingers which are distributed radially over the core such that their signals are representative of the key core parameters for different perturbation modes and fuel management schemes. Each of the twelve SPND fingers contains six detectors. In each finger, three SPNDs are located in the top core half and the other three in the bottom core half to detect the peak power density occurring in either the top or bottom halves. Thus they can cover all possible power distributions normal or transient. Axial locations are always situated between two grids to rule out the effect of flux depression in the vicinity of the grids.

BASES

BACKGROUND (continued)

Flux mapping is performed periodically with the Aeroball Measurement System (AMS), including reference heat balance, to provide an accurate image of the absolute (i.e., in kW/ft) 3D-power distribution. Based on this flux map, each SPND signal is adjusted by a unique calibration factor to the peak power density within its axial slice. After calibration, all twelve SPNDs within the same axial slice therefore provide the same value, which corresponds to the maximum linear power density value for that axial slice.

The SPND signals are also calibrated to reproduce the power distribution of the hot channel, for minimum DNBR calculation (see LCO 3.2.3 "Departure from Nucleate Boiling Ratio"), and to reproduce the average axial power of each core half, for AXIAL OFFSET calculation (see LCO 3.2.4 "AXIAL OFFSET (AO)").

The SPND signal to flux ratio gradually increases due to buildup of ^{60}Co and ^{61}Co. This effect is greater than the decrease in sensitivity due to ^{59}Co burnup. As a result, the SPND signal will always get more conservative with burnup.

From the time of calibration, a decreasing (non-conservative) SPND signal can result from changes in core power distributions due to core burnup. The signal variation due to power distribution changes can cause either a decreased or increased SPND signal. This variation in the SPND signal requires periodic recalibration to minimize uncertainties. The setpoint analyses account for the uncertainty inherent for a given AMS calibration frequency.

The maximum linear power density is monitored continuously by the "High Linear Power Density LCO" function of the RCSL System. Separate LCO setpoints exist for both the upper and lower half of the core. Violation of the linear power density operating limit initiates the following automatic and staggered countermeasures:

BASES

BACKGROUND (continued)

First High LPD LCO 1 level:

- Audible alarm in the control room;
- Prevent dilution signal (only for LPD LCO 1 signal in lower half of the core);
- RCCA bank withdrawal blocking signal;
- Turbine generator power increase blocking signal; and
- RCCA bank insertion blocking signal (only for LPD LCO 1 signal in lower half of the core).

Second High LPD LCO 2 level:

- Reduce turbine generator power signal; and
- Insert RCCA bank signal (only for LPD LCO 2 signal in upper half of the core).

The surveillance setpoint corresponds to the First High LPD LCO 1 level. The objective of these staggered actions is to prevent operations leading to a further increase of linear power density so that the maximum LPD value can be quickly restored to below its limit.

During power operation with the RCSL System not in service, LPD signals from the DCS may be manually monitored to ensure LCO limits are maintained. In this case the automatic and staggered countermeasures described above will not occur and the operator must manually take action to control the LPD.

BASES

APPLICABLE SAFETY ANALYSES	The power distribution and RCCA insertion and alignment LCOs prevent core power distributions from reaching levels that violate acceptance criteria regarding fuel design and coolability. The power density at any point in the core must be limited to maintain the fuel design criteria. This is accomplished by maintaining the power distribution and reactor coolant conditions such that the peak power density and minimum DNBR are within operating limits supported by accident analyses (Ref. 1). Maximum LPD limit assumed in the LOCA analysis (Ref. 1) is typically limiting relative to the maximum LPD assumed in safety analyses for other AOO and postulated accidents. Therefore this LCO provides conservative limits for other AOOs such as uncontrolled RCCA bank withdrawal. Fuel cladding damage does not typically occur while the unit is operating at conditions outside the limits of this LCO during normal operation. Fuel cladding damage could result, however, if an AOO event occurs from initial conditions outside the limits of this LCO. The potential for fuel cladding damage exists because changes in the power distribution can cause increased power peaking during the transient. LPD satisfies Criterion 2 of 10 CFR 50.36(c)(2)(ii) (Ref. 3).
LCO	The LOCA safety analysis generally determines the maximum permitted linear power density for the upper half of the core. The LCO limit ensures that the post-LOCA fuel cladding temperature does not exceed a specified maximum limit of 2200°F. As a consequence the LCO ensures that the maximum LPD in the core is not exceeded in the event of a LOCA. A separate limit is also provided for the lower half of the core. This limit provides margin for those events that result in a axial redistribution of power towards the bottom of the core. Both limits ensure margin to fuel centerline melt and maintain clad strain < 1% during all AOOs. The LPD limits are provided in the COLR.
APPLICABILITY	Power distribution is a concern any time the reactor thermal power is greater than approximately 10% RTP. Therefore, the power distribution LCOs are applicable in MODE 1 above 10% RTP. This LCO is not a concern at or below 10% RTP because the core is operating well below its thermal limits.

BASES

ACTIONS

A.1

With the LPD exceeding its limit, excessive fuel damage could occur following an AOO or postulated accident. In this condition, prompt action must be taken to restore the LPD to within the specified limits.

The 1 hour limit to restore the LPD to within its specified limits is reasonable since the likelihood of an accident happening over this short period is negligible. The one hour Completion Time also allows the operator sufficient time for evaluating core conditions and confirming automatic actions have been effective or initiating proper corrective actions to restore the LPD to within its specified limits.

B.1

If the RCSL System is not available the OPERABLE LPD channels are monitored to ensure that the LPD limit is not exceeded. Operation within this limit ensures that no postulated accident results in consequences more severe than those described in the FSAR Chapter 15.

When operating with the RCSL System out of service there is a possibility of a slow undetectable transient that degrades the LPD slowly over a 1 hour period and is then followed by an AOO or an accident. To remedy this, the DCS calculated values of LPD are monitored every hour when the RCSL System is out of service. The 1 hour Frequency is adequate to allow the operator to identify an adverse trend in conditions that could result in an approach to the LPD LCO.

When the RCSL System is out of service and the LPD is not within a region of acceptable operation, immediate action is required to reduce power until the LPD is within the existing RCSL System out of service TS limits.

C.1

If the value of LPD is not restored to within its limits within the required Completion Time; the unit must be brought in a MODE or condition where the LCO is no longer applicable. This is done by placing the plant in at least MODE 1 with THERMAL POWER ≤ 10% RTP within 6 hours.

The allowed Completion Time of 6 hours is reasonable to reach MODE 1 with THERMAL POWER ≤10% RTP from full power operation in an orderly manner and without challenging plant systems.

BASES

SURVEILLANCE REQUIREMENTS

SR 3.2.1.1

The Surveillance requires the operator to verify that the LPD is within limits. This verification is in addition to the automatic checking performed by the RCSL System. The Surveillance can be performed by obtaining the current LPD generated by the RCSL System (providing the RCSL System is in service and has been properly calibrated) and verifying the value is within limits specified in the COLR. Alternately, the verification may also be performed by manually monitoring each OPERABLE DCS LPD division and verifying the value is within limits specified in the COLR. Since there are four different divisions based on individual loop conditions, it is necessary to monitor the most limiting LPD division. A 12 hour Frequency is sufficient to allow the operator to identify trends that would result in an approach to the LPD limits.

SR 3.2.1.2

With the RCSL System out of service, the operator must monitor the LPD with each OPERABLE LPD channel. A 1 hour Frequency is sufficient to allow the operator to identify trends that would result in an approach to the LPD limits.

This SR is modified by a Note that states that the SR is only required to be met when the LPD System is out of service. Continuous monitoring of the LPD is provided by the RCSL System, which calculates core power and core power operating limits based on the LPD and continuously displays these limits to the operator. A RCSL System margin alarm is annunciated in the event that the THERMAL POWER exceeds the core power operating limit based on the LPD.

REFERENCES

1. FSAR Chapter 15.

2. FSAR Chapter 6.

3. 10 CFR 50.36, Technical Specifications.

B 3.2 POWER DISTRIBUTION LIMITS

B 3.2.2 Nuclear Enthalpy Rise Hot Channel Factor ($F^N_{\Delta H}$)

BASES

BACKGROUND

The purpose of this LCO is to establish limits on the power density at any point in the core so that the fuel design criteria are not exceeded and the accident analysis assumptions remain valid specifically for the loss of cooling accident (LOCA) analyses. In addition this limit allows for further constraining the initial operating conditions assumed in other accident analyses. The design limits on local (pellet) and integrated fuel rod peak power density are expressed in terms of hot channel factors. Control of the core power distribution with respect to these factors ensures that local conditions in the fuel rods and coolant channels do not challenge core integrity at any location during either normal operation or a postulated accident analyzed in the safety analyses.

$F^N_{\Delta H}$ is defined as the ratio of the highest integrated linear power along any fuel rod to the average integrated fuel rod power. Therefore, $F^N_{\Delta H}$ is a measure of the maximum total power produced in a fuel rod.

$F^N_{\Delta H}$ is sensitive to fuel loading patterns, bank insertion, and fuel burnup. $F^N_{\Delta H}$ typically increases with control bank insertion and typically decreases with fuel burnup.

$F^N_{\Delta H}$ is not directly measurable but is inferred from a power distribution map obtained with the Aeroball Measurement System (AMS). Specifically, the results of a three dimensional power distribution map are analyzed by computer to determine $F^N_{\Delta H}$. This factor is calculated at least every 31 effective full power days (EFPD). However, during power operation, the global power distribution is continuously monitored by LCO 3.2.4, "AXIAL OFFSET (AO)," and LCO 3.2.5, "AZIMUTHAL POWER IMBLANCE (AZI)," which address directly and continuously measured process variables.

Since DNBR and LPD are monitored independently and protected with separate LCOs which specifically account for the 3D power distribution in the core, $F^N_{\Delta H}$ limits are used to verify the acceptability of the resulting limiting peak cladding temperatures that are used in the LOCA safety analyses.

BASES

BACKGROUND (continued)

Operation outside the LCO limits may produce unacceptable consequences if an anticipated operation occurrence (AOO) or other postulated accident occurs.

APPLICABLE SAFETY ANALYSES

This LCO provides limits on $F^N_{\Delta H}$ for the following purposes:

a. Restrict initial LPD to a value which ensures that during a LOCA the peak clad temperatures do not exceed 2200°F; and

b. Limit the scope of power distributions from which an accident may be initiated for all FSAR Chapter 15 events.

The nuclear enthalpy rise hot channel factor ($F^N_{\Delta H}$) is used directly in the LOCA analysis to verify the acceptability of the resulting peak cladding temperature (Ref. 1).

$F^N_{\Delta H}$ shall be maintained within the limits specified in the COLR. The $F^N_{\Delta H}$ limit identifies the coolant flow channel with the maximum enthalpy rise. This channel has the least heat removal capability and thus the highest probability for a departure from nucleate boiling (DNB). The limiting value of $F^N_{\Delta H}$, described by the equation contained in the COLR, is the design radial peaking factor used in the unit safety analyses.

$F^N_{\Delta H}$ satisfies Criterion 2 of 10 CFR 50.36(c)(2)(ii) (Ref. 2).

LCO

$F^N_{\Delta H}$ shall be maintained within the limits specified in the COLR. The $F^N_{\Delta H}$ limit identifies the coolant flow channel with the maximum enthalpy rise. This channel has the least heat removal capability and thus the highest probability for a DNB. The limiting value of $F^N_{\Delta H}$, described by the equation contained in the COLR, is the design radial peaking factor used in the unit safety analyses.

BASES

APPLICABILITY

Applicability in MODE 1 is required to limit the scope of power distributions from which an accident may be initiated for all FSAR Chapter 15 events. LOCA events are limiting at hot full power because at lower powers there is either insufficient stored energy in the fuel or insufficient energy being transferred to the reactor coolant to challenge licensing criteria.

ACTIONS

A.1 and A.2

When $F_{\Delta H}^{N}$ exceeds its limit there is little concern regarding DNBR or LPD since these parameters are independently monitored and protected with other trips. However, the LOCA analyses assume this limit at the initiation of the transient therefore exceeding it could result in peak clad temperatures in excess of the acceptance criteria.

The 1 hour limit to reduce power by 1% for each 1% that $F_{\Delta H}^{N}$ limit is exceeded by allows for an orderly power reduction that reduces the hot fuel rod integrated power to near its 100% limit.

The 4 hour limit then provides adequate time to confirm that $F_{\Delta H}^{N}$ has been restored or make necessary adjustments through control rod movements or further power reductions. This Completion Time also provides a reasonable limit on the amount of time which the plant may outside the $F_{\Delta H}^{N}$ limit.

B.1

When the Required Action cannot be met or completed within the required Completion Time; the unit must be brought in a MODE or condition where the LCO is no longer applicable. This is done by placing the plant in at least MODE 2

The allowed Completion Time of 6 hours is reasonable to reach MODE 2 from full power operation in an orderly manner and without challenging plant systems.

BASES

SURVEILLANCE REQUIREMENTS

SR 3.2.2.1

The value of $F^N_{\Delta H}$ is determined by taking an AMS flux map. A data reduction computer program (POWERTRAX™) then calculates the maximum value of $F^N_{\Delta H}$ from the measured flux distribution. The measured value of $F^N_{\Delta H}$ must be multiplied by the appropriate measurement uncertainty before making comparisons to the $F^N_{\Delta H}$ limit.

Confirming $F^N_{\Delta H}$ in MODE 1 after an outage and before exceeding 70% power ensures that plant is operating within the limit given the major change in power distributions resulting from the core reload.

The 31 EFPD Frequency between $F^N_{\Delta H}$ confirmations is also acceptable since power distributions change relatively slowly over this amount of fuel burnup. Accordingly, this Frequency is short enough that the $F^N_{\Delta H}$ limit cannot be exceeded for any significant period of operation.

This SR is modified by a Note that states the SR is not required to be performed until 24 hours after exceeding 40% power. This time period allows sufficient time to perform the required surveillance.

REFERENCES

1. 10 CFR 50.46, Acceptance Criteria for Emergency Core Cooling Systems for Light-Water Nuclear Power Reactors.

2. 10 CFR 50.36, Technical Specifications.

B 3.2 POWER DISTRIBUTION LIMITS

B 3.2.3 Departure from Nucleate Boiling Ratio (DNBR)

BASES

BACKGROUND

The purpose of this LCO is to limit the core power distribution to the initial values assumed in the accident analyses. Operation within the limits imposed by this LCO limits or prevents potential fuel cladding failures that could breach the primary fission product barrier and release fission products to the reactor coolant in the event of a Loss of Coolant Accident (LOCA), loss of flow accident including shaft break, rod ejection accident, or other postulated accident requiring termination by a Distributed Control System (DCS) trip function (Ref. 1). This LCO limits the damage to the fuel cladding during an accident by ensuring that the plant is operating within acceptable bounding conditions at the onset of a transient.

The core power distribution is controlled so that, in conjunction with other core operating parameters (e.g., RCCA insertion and alignment limits), the power distribution does not result in violation of this LCO. The limiting safety system settings and this LCO are based on the accident analyses (Refs. 1 and 2), so that specified acceptable fuel design limits are not exceeded as a result of anticipated operational occurrences (AOOs) and the limits of acceptable consequences are not exceeded for other postulated accidents.

Limiting axial power redistribution over time also minimizes the xenon distribution swings, which is a significant factor in controlling axial power distribution.

The power distribution is a product of multiple parameters, various combinations of which may produce acceptable power distributions. Operation within the design limits for power distribution is accomplished by maintaining the local Linear Power Density (LPD) and the DNBR within limits.

Proximity to the DNB condition is expressed by the DNBR, defined as the ratio of the cladding surface heat flux required to cause DNB to the actual cladding surface heat flux.

There are two systems that perform online monitoring of the core maximum LPD and minimum DNBR:

- The Distributed Control System (DCS); and
- The Reactor Control, Surveillance and Limitation (RCSL) System.

BASES

BACKGROUND (continued)

The DCS and the RCSL System are capable of verifying that the LPD and the DNBR do not exceed their limits. The DCS and the RCSL System perform this function by continuously monitoring incore Self-Powered Neutron Detectors (SPND) measurements, thermal-hydraulic data, and Rod Cluster Control Assemblies (RCCA) insertion, and by calculating an actual value of DNBR and LPD, for comparison to:

- The respective trip setpoints in the DCS; and
- The limits of acceptable operation in the RCSL System.

Thus the RCSL System indicates continuously to the operator how far the core is from the operating LPD and DNBR limits, and provides an alarm in the Main Control Room if any limit is exceeded. Such a condition signifies a reduction in the capability of the plant to withstand an AOO or postulated accident. This does not necessarily imply a violation of fuel design limits because the DCS initiates a reactor trip when the Low DNBR reactor trip setpoint is reached.

The calculation of the minimum DNBR in the DCS (Low DNBR trip function) and in the RCSL System (Low DNBR LCO function) is based for both systems on:

- The power density distribution in the hot channel, which is based on the readings of the SPND (reconstruction) fixed incore instrumentation;
- The inlet reactor coolant temperature;
- The pressurizer pressure; and
- The RCS flow rate.

Twelve fuel assemblies are instrumented with SPND fingers which are distributed radially over the core such that their signals are representative of the key core parameters for different perturbation modes and fuel management schemes. Each of the twelve SPND fingers contains six detectors. In each finger, three SPNDs are located in the top core half and the other three in the bottom core half to detect the peak power density occurring in either the top or bottom halves. Thus they can cover all possible power distributions normal or transient. Axial SPND locations are always situated between two grids to rule out the effect of flux depression in the vicinity of the grids.

BASES

BACKGROUND (continued)

Flux mapping is performed periodically with the Aeroball Measurement System (AMS), including reference heat balance, to provide an accurate image of the absolute (i.e., in kW/ft) 3D-power distribution. In each finger, the six SPND signals are then adjusted by a unique calibration factor to the power density of the hot rod integrated on the length of the SPND. After calibration, all twelve SPND fingers therefore provide the same axial power shape representative of the power shape of the actual hot channel.

The SPND signal to flux ratio gradually increases due to buildup of ^{60}Co and ^{61}Co. This effect is greater than the decrease in sensitivity due to ^{59}Co burnup. As a result, the SPND signal will always get more conservative with burnup.

From the time of calibration, a decreasing (non-conservative) SPND signal can result from changes in core power distributions due to core burnup. The signal variation due to power distribution changes can cause either a decreased or increased SPND signal. This variation in the SPND signal requires periodic recalibration to minimize uncertainties. The setpoint analyses account for the uncertainty inherent for a given AMS calibration frequency.

The DCS and the RCSL System use these measurements and a proprietary algorithm to reconstruct the local thermal-hydraulic conditions at the minimum DNBR point in the core and apply the chosen Critical Flux Predictor (Ref. 3) to calculate the DNBR.

The minimum DNBR is monitored continuously by the "Low DNBR LCO" function of the RCSL System and indicated to the operator. Violation of the DNBR operating limit initiates the following automatic and staggered countermeasures:

First Low DNBR LCO 1 level:

- RCCA bank withdrawal blocking signal; and
- Turbine generator power increase blocking signal.

Second Low DNBR LCO 2 level:

- Reduce turbine generator power signal; and
- Insert RCCA bank signal.

BASES

BACKGROUND (continued)

The surveillance setpoint corresponds to the first Low DNBR LCO threshold. The objective of these staggered actions is to prevent operations leading to a further decrease of the DNBR such that the minimum DNBR value can be quickly restored to above its limit.

During power operation with the RCSL System out of service, DNBR signals from the DCS may be manually monitored to ensure LCO limits are maintained. In this case the automatic and staggered countermeasures described above will not occur and the operator must manually take action to control the LPD. In addition, since each the DCS division signals are derived using only one loops signals (rather than averaging them as is done in RCSL), the DCS signal has a higher measurement uncertainty. This must be accounted for by monitoring to a higher DNB LCO limit as specified in the COLR.

APPLICABLE SAFETY ANALYSES

The power distribution and RCCA insertion and alignment LCOs prevent core power distributions from reaching levels that violate acceptance criteria regarding fuel design and coolability. The DNBR at any point in the core must be limited to maintain the fuel design criteria. This is accomplished by maintaining the power distribution and reactor coolant conditions such that the peak power density and minimum DNBR are within operating limits supported by accident analyses.

The maximum change in the Departure from Nucleate Boiling Ratio (ΔDNBR) is evaluated for FSAR Chapter 15 Safety Analyses that utilize the methodology described in Reference 5. From the FSAR Chapter 15 Safety Analyses, the Complete Loss of Flow event typically provides the maximum ΔDNBR (based upon core loading characteristics). As described in Reference 5, the DNB LCO established with the maximum ΔDNBR in conjunction with the Low DNBR trip function assures protection from DNB for all AOOs.

Fuel cladding damage does not normally occur while the unit is operating at conditions outside the limits of this LCO during normal operation. Fuel cladding damage could result, however, if an AOO event occurs from initial conditions outside the limits of this LCO. The potential for fuel cladding damage exists because changes in the power distribution can cause a reduction in DNB margin at the initiation of a fast transient such that other plant trips can no longer respond in time to protect the fuel design limits.

DNBR satisfies Criterion 2 of 10 CFR 50.36(c)(2)(ii) (Ref. 4).

BASES

LCO

The Loss of Flow accident generally establishes the DNB LCO limits as this transient is too fast to be protected by the Low DNBR trip in the DCS. The DNB LCO therefore ensures that the plant operates far enough away from the DNBR design limit that in the event of a very fast transient sufficient time exists for other plants trips to intervene prior to exceeding the DNBR design limit. The DNBR limits are provided in the COLR.

APPLICABILITY

The DNB LCO is only applicable in MODE 1 above 10% RTP. This LCO is not a concern below 10% RTP and for lower operating MODES because the stored energy in the fuel and the energy being transferred to the reactor coolant are sufficiently low that DNBR is no longer a concern.

ACTIONS

A.1

With the DNBR exceeding its limit, excessive fuel damage could occur following an AOO or postulated accident. In this condition, prompt action must be taken to restore the DNBR to within the specified limits.

The 1 hour limit to restore the DNBR to within its specified limits is reasonable since the likelihood of an accident happening over this short period is negligible. The 1 hour Completion Time also allows the operator sufficient time for evaluating core conditions and either confirm automatic actions have been effective or initiating proper corrective actions to restore the DNBR to within its specified limits.

B.1

If the RCSL System is not available the OPERABLE DNBR channels are monitored to ensure that the DNBR limit is not exceeded. Operation within this limit ensures that no postulated accident results in consequences more severe than those described in the FSAR Chapter 15.

BASES

ACTIONS (continued)

When operating with the RCSL System out of service there is a possibility of a slow undetectable transient that degrades the DNBR slowly over a 1 hour period and is then followed by an AOO or an accident. To remedy this, the DCS calculated values of DNBR are monitored every hour when the RCSL System is out of service. The 1 hour Frequency is adequate to allow the operator to identify an adverse trend in conditions that could result in an approach to the DNBR LCO.

When the RCSL System is out of service and the DNBR is not within a region of acceptable operation, immediate action is required to reduce power until the DNBR is within the existing RCSL System out of service TS limits.

C.1

If the value of DNBR is not restored within its specified limits within the required Completion Time; the unit must be brought in a MODE or condition where the LCO is no longer applicable. This is done by placing the plant in at least MODE 1 with THERMAL POWER ≤ 10% RTP within 6 hours.

The allowed Completion Time of 6 hours is reasonable to reach MODE 1 with THERMAL POWER ≤ 10% RTP from full power operation in an orderly manner and without challenging plant systems.

SURVEILLANCE REQUIREMENTS

SR 3.2.3.1

The Surveillance requires the operator to verify that the DNBR is within limits. This verification is in addition to the automatic checking performed by the RCSL System. The Surveillance can be performed by obtaining the current DNBR generated by the RCSL System (providing the RCSL System is in service and has been properly calibrated) and verifying the value is within limits specified in the COLR. Alternately, the verification may also be performed by manually monitoring each OPERABLE DCS DNBR division and verifying the value is within limits specified in the COLR. Since there are four different divisions based on individual loop conditions, it is necessary to monitor the most limiting DNBR division. A 12 hour Frequency is sufficient to allow the operator to identify trends that would result in an approach to the DNBR limits.

BASES

SURVEILLANCE REQUIREMENTS (continued)

SR 3.2.3.2

With the RCSL System out of service, the operator must monitor the DNBR with each OPERABLE DNBR channel. A 1 hour Frequency is sufficient to allow the operator to identify trends that would result in an approach to the DNBR limits.

This SR is modified by a Note that states that the SR is only required to be met when the RCSL System is out of service. Continuous monitoring of the DNBR is provided by the RCSL System, which calculates core power and core power operating limits based on the DNBR and continuously displays these limits to the operator. A RCSL System margin alarm is annunciated in the event that the THERMAL POWER exceeds the core power operating limit based on the DNBR.

REFERENCES

1. FSAR Chapter 15.
2. FSAR Chapter 6.
3. ANP-10269P-A, “The ACH-2 CHF Correlation for the U.S. EPR Topical Report,” AREVA NP Inc, 2008.
4. 10 CFR 50.36, Technical Specifications.
5. ANP-10287P, Revision 0, “Incore Trip Setpoint and Transient Methodology for U.S. EPR Topical Report,” AREVA NP Inc, 2007.

B 3.2 POWER DISTRIBUTION LIMITS

B 3.2.4 AXIAL OFFSET (AO)

BASES

BACKGROUND

The purpose of this LCO is to limit the core power distribution to the initial values assumed in the anticipated operational occurrences (AOOs) and postulated accident analysis. Operation within the limits imposed by this LCO either limits or prevents potential fuel cladding failures that could breach the primary fission product barrier and release fission products to the reactor coolant in the event of a loss of coolant accident (LOCA), loss of flow accident, ejected rod cluster control assembly (RCCA) accident, or other postulated accident requiring termination by a Distributed Control System (DCS) trip function. This LCO limits the amount of damage to the fuel cladding during an accident by ensuring that the plant is operating within acceptable conditions at the onset of a transient (Ref. 2).

AXIAL OFFSET (AO) is a measure of the axial power distribution in the core. The purpose for a limit on AO is to limit the axial power distributions to initial values assumed in the AOOs and postulated accident analyses. Extreme shifts in power towards either the top or bottom of the core can have adverse impacts during an accident. In general, top-peaked power shapes have lower minimum departure from nucleate boiling ratio(s) (MDNBRs) to start with while bottom-peaked shapes tend to result in more significant DNBR degradation during a transient. Significant shifts in either direction can lead to increased linear power densities (LPDs). Minimizing power distribution skewing over time also minimizes xenon distribution skewing, which is a significant factor in controlling axial power distribution.

The reactor control, surveillance and limitations (RCSL) System continuously monitors the AXIAL OFFSET based on evaluations of the core power distribution using the incore self-powered neutron detectors (SPNDs). Twelve fuel assemblies are instrumented with SPND fingers which are distributed radially over the core such that their signals are representative of the key core parameters for different perturbation modes and fuel management schemes. Each of the twelve SPND fingers contains six detectors. In each finger, three SPNDs are located in the top core half and the other three in the bottom core half to detect power density occurring in top and bottom halves. Thus they can cover all possible power distributions, normal or accidental. Axial locations are always between two grids to rule out the effect of flux depression in the vicinity of the grids.

BASES

BACKGROUND (continued)

The SPND signal to flux ratio gradually increases due to buildup of ^{60}Co and ^{61}Co. This effect is greater than the decrease in sensitivity due to ^{59}Co burnup. As a result, the SPND signal will always get more conservative with burnup.

From the time of calibration, a decreasing (non-conservative) SPND signal can result from changes in core power distributions due to core burnup. The signal variation due to power distribution changes can cause either a decreased or increased SPND signal. This variation in the SPND signal requires periodic recalibration to minimize uncertainties. The setpoint analyses account for the uncertainty inherent for a given AMS calibration frequency.

The AXIAL OFFSET is monitored continuously by the "Axial Power Shape LCO" function of the RCSL System. The Axial Power Shape LCO function aims at informing the operator if the AO limit is violated. The AO setpoint is function of the core THERMAL POWER level. Violation of the AO operating limits initiates an alarm in the main control room and an automatic signal blocking any turbine generator power increase. Active countermeasures are not initiated so as not to interfere with those automatic actions initiated by the "AXIAL OFFSET Control" function in RCSL, which will tend to restore the AO to within limits.

During power operation with the RCSL System out of service, SPND signals from the DCS may be manually monitored to determine AO and verify the LCO limit is maintained.

APPLICABLE SAFETY ANALYSES

The maximum AO limit is established for the following purposes:

a. Restrict initial AO to a value which ensures that during a LOCA the peak clad temperatures do not exceed 2200°F (Ref. 1); and

b. Restrict the scope of power distributions assumed as initial conditions in analyzing anticipated operational occurrences (AOOs) and postulated accidents.

Fuel cladding damage does not typically occur while the unit is operating at conditions outside the limits of this LCO during normal operation. Fuel cladding damage could result, however, if an AOO event occurs from initial conditions outside the limits of this LCO. The potential for fuel cladding damage exists because changes in the power distribution can cause increased power peaking during the transient.

AO satisfies Criterion 2 of 10 CFR 50.36(c)(2)(ii) (Ref. 3).

BASES

LCO

The positive AO limit is generally established to minimize or eliminate the consequences of the rod ejection or uncontrolled RCCA withdrawal transient. The negative AO limit is generally established by The Loss of Flow transient. The limits are established around a target AO that is a function of the core management scheme. The AO limits are provided in the COLR.

Violation of this LCO could produce unacceptable consequences if an AOO or postulated accident occurs while the AO is outside its specified limits.

APPLICABILITY

The AO LCO is only applicable in MODE 1 above 50% RTP. This LCO is not a concern below 50% RTP and for lower operating MODES because xenon transients generated within the lower power level range are not severe. In addition, significant margin to thermal limits exists at lower power levels and therefore thermal limits are not significantly challenged.

ACTIONS

A.1

With the AO exceeding its limit, excessive fuel damage could occur following an AOO or postulated accident. In this condition, prompt action must be taken to restore the AO to within the specified limit.

The 1 hour time period to restore the AO to within its specified limit is reasonable and ensures that the core does not continue to operate in this Condition. The 1 hour Completion Time also allows the operator sufficient time for evaluating core conditions and confirming automatic actions have been effective or initiating proper corrective actions to restore the AO to within its specified limit.

B.1

If the RCSL System is not available the OPERABLE AO channels are monitored to ensure that the AO limit is not exceeded. Operation within this limit ensures that no postulated accident results in consequences more severe than those described in the FSAR Chapter 15.

When operating with the RCSL System out of service there is a possibility of a slow undetectable transient that degrades the AO slowly over a 1 hour period and is then followed by an AOO or an accident. To remedy this, the DCS calculated values of AO are monitored every hour when the RCSL System is out of service. The 1 hour Frequency is adequate to allow the operator to identify an adverse trend in conditions that could result in an approach to the AO LCO.

BASES

ACTIONS (continued)

When the RCSL System is out of service and the AO is not within a region of acceptable operation, immediate action is required to reduce power until the AO is within the existing RCSL System out of service TS limits.

C.1

If the value of AO is not restored to within its specified limit within the required Completion Time; the unit must be placed in a MODE or condition where the LCO is no longer applicable. This is done by placing the plant in a least MODE 1 with THERMAL POWER to < 50% RTP within 4 hours.

The allowed Completion Time of 4 hours is reasonable to reach MODE 1 with THERMAL POWER < 50% RTP from full power operation in an orderly manner and without challenging plant systems.

SURVEILLANCE REQUIREMENTS

SR 3.2.4.1

The Surveillance requires the operator to verify that the AO is within limits about the target AO. This verification is in addition to the automatic checking performed by the RCSL System. The Surveillance can be performed by obtaining the current AO generated by the RCSL System (providing the RCSL System is in service and has been properly calibrated) and verifying the value is within limits specified in the COLR. Alternately, the verification may also be performed by manually monitoring each OPERABLE DCS AO division and verifying the value is within limits specified in the COLR. Since there are four different divisions based on individual loop conditions, it is necessary to monitor the most limiting AO division. A 12 hour Frequency is sufficient to allow the operator to identify trends that would result in an approach to the AO limits.

Another option is to monitor the AO through the generation of an AMS flux map. A data reduction computer program (POWERTRAXTM) then calculates the core wide assembly nodal power distribution from the measured flux distribution.

BASES

SURVEILLANCE REQUIREMENTS (continued)

SR 3.2.4.2

Target AO is determined at equilibrium xenon conditions in conjunction with a full core flux map.

SR 3.2.4.3

With the RCSL System out of service, the operator must monitor the AO with each OPERABLE DCS AO division. A 1 hour Frequency is sufficient to allow the operator to identify trends that would result in an approach to the AO limits.

This SR is modified by a Note that states that the SR is only required to be met when the RCSL System is out of service. Continuous monitoring of the AO is provided by the RCSL System, which calculates core power and core power operating limits based on the AO and continuously displays these limits to the operator. A RCSL System margin alarm is annunciated in the event that the THERMAL POWER exceeds the core power operating limit based on the AO.

REFERENCES

1. 10 CFR 50.46, Acceptance Criteria for Emergency Core Cooling Systems for Light-Water Nuclear Power Reactors.

2. FSAR Chapter 15.

3. 10 CFR 50.36, Technical Specifications.

B 3.2 POWER DISTRIBUTION LIMITS

B 3.2.5 AZIMUTHAL POWER IMBALANCE (AZI)

BASES

BACKGROUND

The purpose of this LCO is to provide an indication to the operator that the core has an asymmetry and to limit the core power distribution asymmetry to those assumed in the accident analyses. Operation within the limit imposed by this LCO limits or prevents the amount of excessive asymmetric peaking that could occur due to unexpected power shifts from quadrant to quadrant. Excessive peaking prior to accident initiation can lead to unanalyzed conditions in the event of a Loss of Coolant Accident (LOCA), loss of flow accident, rod ejection accident, or other postulated accident requiring termination by a Distributed Control System (DCS) trip function (Ref. 1). This LCO limits the initial conditions so that the plant is operating within acceptable conditions at the onset of an accident.

APPLICABLE SAFETY ANALYSES

The LCO limits on the AO, AZI, Nuclear Enthalpy Rise Hot Channel Factor ($F^N_{\Delta H}$), and control bank insertion are established to preclude core power distributions from occurring which would exceed the safety analyses limits or invalidate assumptions used in deriving core analytical parameters. Fuel cladding damage could result if an AOO event occurs from initial conditions outside the limits of this LCO. The potential for fuel cladding damage exists because changes in the power distribution can cause higher initial peaking prior to the transient.

The AZI in the core must be limited to maintain the fuel design criteria. This is accomplished by maintaining the power distribution and reactor coolant conditions such that the peak power density and AZI are within operating limits supported by accident analyses.

AZI satisfies Criterion 2 of 10 CFR 50.36(c)(2)(ii) (Ref. 3).

BASES

LCO

Since the DCS and Reactor Control, Surveillance, and Limitation (RCSL) System sense power distributions from the incore SPNDs, they both are affected by core radial power asymmetries. The DCS automatically provides for reductions in the Low Departure from Nucleate Boiling (DNBR) trip, whenever a significant asymmetry is detected during an accident. An AZI limit is established in the COLR to ensure the validity of these assumptions for each cycle. At each Aeroball Measurement System (AMS) flux map, a data reduction computer program (POWERTRAX™) then calculates the core wide assembly nodal power distribution from the measured flux distribution. From this information, the measured peaking conditions will be verified to be within applicable limits and the AZI will be set to zero. The AZI is monitored to limit the amount of asymmetry allowed prior to the next AMS flux map.

APPLICABILITY

The AZI LCO is only applicable in MODE 1 above 50% RTP. This LCO is not a concern below 50% RTP and for lower operating MODES because the effect of radial power asymmetries is reduced as power levels are reduced and therefore become insignificant at these lower power levels. In addition, the stored energy in the fuel and the energy being transferred to the reactor coolant are low at these lower power levels.

ACTIONS

A.1

With AZI exceeding its limit, action must be taken to restore AZI within its limit within 2 hours. Restoring the AZI to within its specified limit contained in the COLR in 2 hours is reasonable since the likelihood of an accident happening over this short period is negligible and it ensures that the core does not continue to operate in this condition. The 2 hour Completion Time also allows the operator sufficient time for evaluating core conditions and determining the cause of the AZI problem.

B.1

If AZI is not restored to within its limit within the required Completion Time; the unit must be placed in a MODE or condition where the LCO is no longer applicable. This is done by placing the plant in a least MODE 1 with THERMAL POWER to < 50% RTP within 4 hours.

The allowed Completion Time of 4 hours is reasonable to reach MODE 1 with THERMAL POWER < 50% RTP from full power operation in an orderly manner and without challenging plant systems.

BASES

SURVEILLANCE REQUIREMENTS

SR 3.2.5.1

The Surveillance requires the operator to verify that the AZI is within limit. This verification is in addition to the automatic checking performed by the RCSL System. The Surveillance can be performed by obtaining the current AZI generated by the RCSL System (providing the RCSL System is in service and has been properly calibrated) and verifying the value is within limits specified in the COLR. A 12 hour Frequency is sufficient to allow the operator to identify trends that would result in an approach to the AZI limits.

If the RCSL System is out of service, the verification can be performed by manually monitoring the nuclear power from QN measurements in the Distributed Control System and calculating the AZI. A 1 hour Frequency is required for the operator to confirm that AZI is within its limit.

REFERENCES

1. FSAR Chapter 15.
2. 10 CFR 50.36, Technical Specifications.