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 Protection System (PS) 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 control cluster 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.

There are two systems that perform online monitoring of the core maximum LPD and minimum DNBR: the Protection System (PS) and the Reactor Control, Surveillance and Limitation (RCSL) system. The PS and the RCSL system are capable of verifying that the LPD and the DNBR do not exceed their limits. The PS and the RCSL system perform this

BASES

BACKGROUND (continued)

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 PS 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, but does not necessarily imply a violation of fuel design limits.

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

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.

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 calibrated 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 3.2.2 "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)").

BASES

BACKGROUND (continued)

The SPND signal gradually increases (conservative) and the gain constants must be periodically recalibrated to prevent unnecessary LPD penalties. Likewise, core burnup can produce power distribution changes that result in non-conservative SPND signals and also require periodic recalibration. 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:

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
- 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
- Insert RCCA bank signal (only for LPD LCO 2 signal in upper half of the core)

The surveillance setpoint corresponds to the first LPD LCO 1 threshold. 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 PS 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(d)(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 is critical. The power distribution LCOs, however, are only applicable in MODE 1 above 10% RTP. This LCO is not a concern 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 one 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 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.

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 PS 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.

REFERENCES

1. FSAR Chapter 15.

2. FSAR Chapter 6.

3. 10 CFR 50.36, Technical Specifications, August, 2007.

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. An 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 15 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 (API)," 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.

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

BASES

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 LOCA safety analysis indirectly models $F^N_{\Delta H}$ as an input parameter. The Nuclear Heat Flux Hot Channel Factor ($F_Q(Z)$) and the axial peaking factors are inserted directly into the LOCA safety analyses that 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(d)(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.

APPLICABILITY

MODE 1 with THERMAL POWER > 90% RTP.

Applicability in MODE 1 with THERMAL POWER ≤ 90% RTP is not required because this LCO applies only to LOCA analyses. LOCA events are limiting at HFP 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.

BASES

ACTIONS

A.1 and A.2

When $F^N_{\Delta H}$ 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 $F^N_{\Delta H}$ 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 $F^N_{\Delta H}$ 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 $F^N_{\Delta H}$ 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 1 with THERMAL POWER ≤ 90% RTP.

The allowed Completion Time of 2 hours is reasonable to reach MODE 1 with THERMAL POWER ≤ 90% RTP from full power operation in an orderly manner and without challenging plant systems.

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.

BASES

SURVEILLANCE REQUIREMENTS (continued)

Confirming $F^N_{\Delta H}$ in MODE 1 after an outage and before exceeding 98% power ensures that plant is operating within the limit given the major change in power distributions resulting from the core reload.

The 15 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 90% 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, August, 2007.

2. 10 CFR 50.36, Technical Specifications, August, 2007.

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 Protection System (PS) 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 Protection System (PS) and;
- The Reactor Control, Surveillance and Limitation (RCSL) system.

BASES

BACKGROUND (continued)

The PS and the RCSL system are capable of verifying that the LPD and the DNBR do not exceed their limits. The PS 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 PS 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, but does not necessarily imply a violation of fuel design limits.

The calculation of the minimum DNBR in the PS (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.

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 calibrated to the power density of the hot

BASES

BACKGROUND (continued)

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 gradually increases (conservative) with core burnup and the gain constants must be periodically recalibrated to prevent unnecessary DNBR penalties. Likewise, core burnup can produce power distribution changes that result in non-conservative SPND signals and also require periodic recalibration. Setpoint analyses account for the uncertainty inherent for a given AMS calibration frequency.

The PS 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

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 PS 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 PS division signals are derived using only one loops signals (rather than averaging them as is done in RCSL), the PS signal has a higher measurement uncertainty. This must be accounted for by monitoring to a higher DNB LCO limit as specified in the COLR.

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 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 minimum DNBR limit is typically established based on the Loss of Coolant Flow accident which is limiting relative to the maximum ΔDNBR assumed in safety analyses for all other AOOs. Therefore this LCO provides conservative limits for all other 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(d)(2)(ii) (Ref. 4).
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 PS. 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	<u>A.1</u> 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.

BASES

ACTIONS (continued)

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 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 PS 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

REFERENCES

1. FSAR Chapter 15.

2. FSAR Chapter 6.

3. ANP-10269P and Supplement 1, Rev. 0, August, 2007.

4. 10 CFR 50.36, Technical Specifications, August, 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 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 Protection System (PS) 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 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 nuclear 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.

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BASES

BACKGROUND (continued)

The SPND signal gradually increases (conservative) with core burnup and the gain constants must be periodically recalibrated to prevent unnecessary AO penalties. Likewise, core burnup can produce power distribution changes that result in non-conservative SPND signals and also require periodic recalibration. 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 PS 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(d)(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 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.

BASES

SURVEILLANCE REQUIREMENTS

SR 3.2.4.1

The Surveillance requires the operator to verify that the AO 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 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 PS 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 (POWERTRAX™) then calculates the core wide assembly nodal power distribution from the measured flux distribution.

REFERENCES

1. 10 CFR 50.46, Acceptance Criteria for Emergency Core Cooling Systems for Light-Water Nuclear Power Reactors, August, 2007.

2. FSAR Chapter 15.

3. 10 CFR 50.36, Technical Specifications, August, 2007.

B 3.2 POWER DISTRIBUTION LIMITS

B 3.2.5 AZIMUTHAL POWER IMBALANCE (API)

BASES

BACKGROUND

The purpose of this LCO is to limit the core power distribution to those 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 Protection System (PS) trip function (Ref. 1). This LCO limits 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.

API > 1.04 are not expected during normal operation. If they do occur then actions must be taken since calculation of many core parameters (e.g. rod worths, moderator temperature coefficient (MTC), etc) do not explicitly account for azimuthal power asymmetries. Core API that are too large could invalidate the uncertainties assumed for these parameters. In addition, a large API indicates the existence of potential adverse phenomena in the core which warrant further evaluation.

APPLICABLE SAFETY ANALYSES

This LCO precludes power distributions that violate the following design criteria:

- The post-LOCA fuel cladding temperature does not exceed a specified maximum limit of 2200°F.
- There will be at least a 95% probability with 95% confidence that the hot rod in the core will not experience a DNB condition.
- The energy deposition to the fuel during a rod ejection accident will not exceed the limits specified in Reference 3.
- Control rods must be capable of shutting down the reactor with a minimum required SDM with the highest worth control rod fully withdrawn.

The LCO limits on the AO, API, 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 increased power peaking during the transient as well as changes in parameters such as rod worths which affect SDM.

BASES

APPLICABLE SAFETY ANALYSES (continued)

The API 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 API are within operating limits supported by accident analyses.

API satisfies Criterion 2 of 10 CFR 50.36(d)(2)(ii) (Ref. 3).

LCO

Since the PS and RCSL sense power distributions from the incore SPNDs, they both are able to account for the effects of core radial power asymmetries. The PS automatically provides for reductions in the Low Departure from Nucleate Boiling (DNBR) trip, whenever a significant API is detected. Most analytical parameters generated for safety analyses though are determined assuming symmetric core radial power distributions. Asymmetries in these distributions can impact parameters such as stuck rod worths and SDM. An API limit of ≤ 1.04 is sufficient to ensure the validity of these assumptions and therefore the licensing analyses.

APPLICABILITY

The API 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 API exceeding its limit, action must be taken to restore API within its limit within 2 hours. Restoring the API to within its specified limit of ≤ 1.04 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 API problem.

BASES

ACTIONS (continued)

B.1

If API 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.

SURVEILLANCE REQUIREMENTS

SR 3.2.5.1

The Surveillance requires the operator to verify that the API 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 API 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 PS API 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 API division. A 12 hour Frequency is sufficient to allow the operator to identify trends that would result in an approach to the API limits.

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

REFERENCES

1. FSAR Chapter 15.

2. 10 CFR 50.36, Technical Specifications, August, 2007.