REVISED RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

APR1400 Design Certification

Korea Electric Power Corporation / Korea Hydro & Nuclear Power Co., LTD

Docket No. 52-046

RAI No.:	**189-8057**
SRP Section:	**16 – Technical Specifications**
Application Section:	**16.3.1 Reactivity Control Systems**
Date of RAI Issue:	**09/01/2015**

Question No. 16-59

Justify deviation from the STS regarding Technical Specification (TS) 3.1.1. Shutdown Margin (SDM).

The STS has one TS (3.1.1) for SDM, applicable in MODES 3, 4, and 5. The applicant has proposed dividing the TS into two separate TS, 3.1.1. SHUTDOWN MARGIN (SDM) – T_{cold} > 99° C (210° F) and 3.1.2 SHUTDOWN MARGIN (SDM) – T_{cold} ≤ 99° C (210° F).

The deviation report, APR1400-K-O-NR-14001-NP, states that the SDM specifications are divided into 2 sections according to the applicable mode dependent shutdown margin in APR1400. This is reflected in the APPLICABILITY of the TS, with the proposed TS 3.1.1 being applicable in MODES 3 and 4 and the proposed TS 3.1.2 being applicable in MODE 5. Other than the difference in APPLICABILITY, the proposed TS 3.1.1 and 3.1.2 (LCO statements, ACTIONS, and SURVEILLANCE REQUIREMENTS) are identical.

This justification is required to ensure that the division of TS 3.1.1 into two TS is necessary, despite the fact that the new proposed TS are identical.

Response – (Rev.1)

KHNP will incorporate TS 3.1.2 and its associated Bases into TS 3.1.1 and its associated Bases. TS 3.1.2 and its Bases will be deleted. In addition, other Technical Specifications and Bases that reference the deleted information will be appropriately revised as shown in the Attachment. The re-numbering due to deletion of TS 3.1.2 which is not described in the Attachment will be performed when TS is revised to Rev.1 reflecting Global Editorial Comments raised at the meeting on Technical Specification on February 24 and 25, 2016.

Impact on DCD

Same as the changes described in Impact on Technical Specifications.

Impact on PRA

There is no impact on PRA.

Impact on Technical Specifications

- TS 3.1.1 and TS 3.1.2 including Bases 3.1.1 and Bases 3.1.2 will be revised as shown in the Attachment.
- TS 3.1.10, TS 3.3.13, TS 5.6.3, Bases 3.1.3, Bases 3.1.5, Bases 3.1.6, Bases 3.1.10 and Bases 3.9.1 will be also revised as shown in the Attachment.

Impact on Technical/Topical/Environmental Reports

There is no impact on any Technical, Topical, or Environment Report.

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3.1 REACTIVITY CONTROL SYSTEMS

3.1.1 SHUTDOWN MARGIN (SDM) ~~- T_{cold} > 99 °C (210 °F)~~ delete

LCO 3.1.1

a. SDM shall be within the limits specified in the COLR.

b. k_{N-1} shall be < 0.99.

c. With reactor trip circuit breakers (RTCBs) closed: Reactor criticality shall not be achieved with shutdown group CEA movement.

APPLICABILITY: ~~MODES 3 and 4.~~ MODES 3, 4 and 5.

ACTIONS

CONDITION	REQUIRED ACTION	COMPLETION TIME
A. SDM not within limits.	A.1 Initiate boration to restore SDM to within limit.	15 minutes
B. k_{N-1} not within limit. OR Reactor criticality can be achieved by shutdown group CEA movement when RTCBs are closed.	B.1 Vary CEA position to restore within limit. AND B.2 Initiate boration to restore within limit.	15 minutes 15 minutes

SURVEILLANCE REQUIREMENTS

SURVEILLANCE		FREQUENCY
SR 3.1.1.1	Verify SDM to be within the limits specified in the COLR.	24 hours
SR 3.1.1.2	Verify k_{N-1} < 0.99.	24 hours
SR 3.1.1.3	Verify criticality cannot be achieved with shutdown group CEA movement when RTCBs are closed.	24 hours

3.1 REACTIVITY CONTROL SYSTEMS

3.1.2 SHUTDOWN MARGIN (SDM) - T_{cold} ≤ 99 °C (210 °F)

LCO 3.1.2

a. SDM shall be within the limits specified in the COLR.

b. k_{N-1} shall be < 0.99.

c. With reactor trip circuit breakers (RTCBs) closed: Reactor criticality shall not be achieved with shutdown group CEA movement.

APPLICABILITY: MODE 5.

ACTIONS

CONDITION	REQUIRED ACTION	COMPLETION TIME
A. SDM not within limits.	A.1 Initiate boration to restore SDM to within limit.	15 minutes
B. k_{N-1} not within limit. OR Reactor criticality can be achieved by shutdown group CEA movement when RTCBs are closed.	B.1 Vary CEA position to restore within limit. AND B.2 Initiate boration to restore within limit.	15 minutes 15 minutes

SURVEILLANCE REQUIREMENTS

SURVEILLANCE		FREQUENCY
SR 3.1.2.1	Verify SDM to be within the limits specified in the COLR.	24 hours
SR 3.1.2.2	Verify k_{N-1} < 0.99.	24 hours
SR 3.1.2.3	Verify criticality cannot be achieved with shutdown group CEA movement when RTCBs are closed.	24 hours

3.1 REACTIVITY CONTROL SYSTEMS

~~3.1.10~~ 3.1.9 Special Test Exception (STE) – SHUTDOWN MARGIN (SDM)

LCO ~~3.1.10~~ 3.1.9 During performance of criticality test or measurement of CEA worth and SDM, the requirements of:

LCO 3.1.1, "SHUTDOWN MARGIN (SDM)~~: T_{cold} > 99 °C (210 °F)~~" delete

LCO ~~3.1.6~~ 3.1.5, "Shutdown Control Element Assembly (CEA) Insertion Limits"

LCO ~~3.1.7~~ 3.1.6, "Regulating Control Element Assembly (CEA) Insertion Limits"

LCO 3.3.1, "Reactor Protection System (RPS) Instrumentation - Operating" (Only applied to Trip Functions 2, 14, and 15 in Table 3.3.1-1)

LCO 3.3.2, "Reactor Protection System (RPS) Instrumentation - Shutdown" (Only applied to Trip Function 1 in Table 3.3.2-1)

may be suspended, provided shutdown reactivity equivalent to at least the highest estimated CEA worth (of those CEAs actually withdrawn) is available for trip insertion or the reactor is subcritical by at least the reactivity equivalent of the highest CEA worth.

APPLICABILITY: MODES 2 and 3 during PHYSICS TESTS.

-- NOTE --

Operation in MODE 3 shall be limited to 6 consecutive hours.

ACTIONS

CONDITION	REQUIRED ACTION	COMPLETION TIME
A. Any full strength CEA not fully inserted and less than the required shutdown reactivity available for trip insertion.	A.1 Initiate boration to restore required shutdown reactivity.	15 minutes

3.3 INSTRUMENTATION

3.3.13 Logarithmic Power Monitoring Channels

LCO 3.3.13 Two logarithmic power level monitoring instrumentation shall be OPERABLE.

APPLICABILITY: MODES 3, 4, and 5 with the reactor trip switchgears (RTSGs) open or control element assembly (CEA) drive system not capable of CEA withdrawal.

ACTIONS

CONDITION	REQUIRED ACTION	COMPLETION TIME
A. One or more required channel(s) inoperable.	A.1 ----- NOTE ----- Limited plant cooldown or boron dilution is allowed provided the change is accounted for in the calculated SDM. ----- Suspend all operations involving positive reactivity additions.	Immediately
	AND	
	A.2 Perform SDM verification in accordance with SR 3.1.1.1 ~~if~~ ~~T_{cold} > 99 °C (210 °F) or SR 3.1.2.1 if T_{cold} ≤ 99 °C (210 °F)~~. delete	4 hours AND Once per 12 hours thereafter

5.6 Reporting Requirements

5.6.3 CORE OPERATING LIMITS REPORT (COLR)

a. Core operating limits shall be established prior to each reload cycle, or prior to any remaining portion of a reload cycle, and shall be documented in the COLR for the following:

3.1.1, SHUTDOWN MARGIN (SDM) ~~– T_{cold} >99 °C (210 °F)~~ delete

~~3.1.2, SHUTDOWN MARGIN (SDM) – T_{cold} ≤ 99 °C (210 °F)~~ delete

3.1.3 ~~3.1.4~~, Moderator Temperature Coefficient (MTC)

3.1.4 ~~3.1.5~~, Control Element Assembly (CEA) Alignment

3.1.5 ~~3.1.6~~, Shutdown Control Element Assemblyu (CEA) Insertion Limits

3.1.6 ~~3.1.7~~, Regulating Control Element Assembly (CEA) Insertion Limits

3.1.7 ~~3.1.8~~, Part Strength Control Element Assembly (CEA) Insertion Limits

3.2.1, Linear Heat Rate (LHR)

3.2.4, Departure From Nucleate Boiling Ratio (DNBR)

3.2.5, AXIAL SHAPE INDEX (ASI)

3.9.1, Boron Concentration

b. The analytical methods used to determine the core operating limits shall be those previously reviewed and approved by the NRC, specifically those described in the following documents:

1. "CE Method for Control Element Assembly Ejection Analysis," CENPD-0190-A, (Methodology for Specification 3.1.6 ~~3.1.7~~, Regulating CEA Insertion Limits).

2. "The ROCS and DIT Computer Codes for Nuclear Design," CENPD-266-P-A, (Methodology for Specifications 3.1.1, Shutdown Margin(SDM); ~~3.1.2, Shutdown Margin(SDM);~~ delete 3.1.3 ~~3.1.4~~, Moderator Temperature Coefficient(MTC); 3.1.6 ~~3.1.7~~, Regulating CEA Insertion Limits and 3.9.1, Boron Concentration (Mode 6)).

3. "Modified Statistical Combination of Uncertainties," CEN-356(V)-P-A (Methodology for Specification 3.2.4, DNBR and 3.2.5, Axial Shape Index)

5.6 Reporting Requirements

5.6.3 CORE OPERATING LIMITS REPORT (COLR) (continued)

4. ”Realistic Evaluation Methodology for Large-Break LOCA of the APR1400,‘ APR1400-F-A-TR-12004-P Rev.0, December 2012, (Methodology for Specification 3.2.1, Linear Heat Rate).

5. ”Calculative Methods for the CE Small Break LOCA Evaluation Model,‘ CENPD-137-P, (Methodology for Specification 3.2.1, Linear Heat Rate).

3.1.1 3.1.4 3.1.3

6. ”CESEC Digital Simulation of a Combustion Engineering Nuclear Steam Supply System,‘ CENPD-107, (Methodology for Specifications 3.1.2, Shutdown Margin(SDM); ~~3.1.4~~, Moderator Temperature Coefficient; ~~3.1.5~~, Regulating CEA Insertion Limits; 3.1.7 ~~3.1.8~~, Part Strength CEA Insertion Limits).

c. The core operating limits shall be determined such that all applicable limits (e.g., fuel thermal mechanical limits, core thermal hydraulic limits, Emergency Core Cooling System (ECCS) limits, nuclear limits such as SDM, transient analysis limits, and accident analysis limits) of the safety analysis are met.

d. The COLR, including any midcycle revisions or supplements, shall be provided upon issuance for each reload cycle to the NRC.

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B 3.1 REACTIVITY CONTROL SYSTEMS

delete

B 3.1.1 SHUTDOWN MARGIN (SDM) ~~– T_{cold} > 99 °C (210 °F)~~

BASES

BACKGROUND

The reactivity control systems must be redundant and capable of holding the reactor core subcritical when shutdown under cold conditions, in accordance with GDC 26 (Reference 1). Maintenance of the SHUTDOWN MARGIN (SDM) ensures that postulated reactivity events will not damage the fuel. SDM requirements provide sufficient reactivity margin to ensure that acceptable fuel design limits will not be exceeded for normal shutdown and anticipated operational occurrences (AOOs). As such, the SDM defines the degree of subcriticality which would be obtained immediately following the insertion of all full strength control element assemblies (CEAs), assuming the single CEA of highest reactivity worth is fully withdrawn.

The system design requires that two independent reactivity control systems be provided, and that one of these systems be capable of maintaining the core subcritical under cold conditions. These requirements are provided by the use of movable CEAs and soluble boric acid in the RCS. The CEA system provides the SDM during power operation and is capable of making the core subcritical rapidly enough to prevent exceeding acceptable fuel damage limits, assuming that the CEA of highest reactivity worth remains fully withdrawn.

The soluble boron system can compensate for fuel depletion during operation and all xenon burnout reactivity changes and maintain the reactor subcritical under cold conditions.

3.1.6

During power operation, SDM control is ensured by operating with the shutdown CEAs fully withdrawn and the regulating CEAs within the limits of LCO ~~3.1.7~~, "Regulating Control Element Assembly (CEA) Insertion Limits." When the unit is in the shutdown and refueling MODES, the SDM requirements are met by means of adjustments to the RCS boron concentration.

APPLICABLE SAFETY ANALYSES

The minimum required SDM is assumed as an initial condition in safety analysis. The safety analysis (Reference 2) establishes an SDM that ensures specified acceptable fuel design limits are not exceeded for normal operation and AOOs, with the assumption of the highest worth CEA stuck out following a reactor trip.
The acceptance criteria for the SDM are that specified acceptable fuel design limits are maintained. This is done by ensuring that:

a. The reactor can be made subcritical from all operating conditions, transients, and Design Basis Events.

b. The reactivity transients associated with postulated accident conditions are controllable within acceptable limits (departure from nucleate boiling ratio (DNBR), fuel centerline temperature limit for AOOs, and less than or equal to 230 cal/g energy deposition for the CEA ejection accident); and

c. The reactor will be maintained sufficiently subcritical to preclude inadvertent criticality in the shutdown condition.

The most limiting accident for the SDM requirements are based on a main steam line break (MSLB) as described in the accident analysis (Reference 2). The increased steam flow resulting from a pipe break in the main steam system causes an increased energy removal from the affected steam generator (SG), and consequently the RCS. This results in a reduction of the reactor coolant temperature. The resultant coolant shrinkage causes a reduction in pressure. In the presence of a negative moderator temperature coefficient, this cooldown causes an increase in core reactivity. As RCS temperature decreases, the severity of an MSLB decreases until the MODE 5 value is reached. The most limiting MSLB, with respect to potential fuel damage before a reactor trip occurs, is a guillotine break of a main steam line inside containment initiated at the end of core life. The positive reactivity addition from the moderator temperature decrease will terminate when the affected SG boils dry, thus terminating RCS heat removal and cooldown. Following the MSLB, a post trip return to power will not occur and THERMAL POWER will not violate the safety limit (SL) requirement of SL 2.1.1.

APPLICABLE SAFETY ANALYSES (continued)

In addition to the limiting MSLB transient, the SDM requirement for MODES 3, 4 and 5 ~~MODES 3 and 4~~ must also protect against:

a. Inadvertent boron dilution

b. An uncontrolled CEA withdrawal from a subcritical condition

c. Startup of an inactive reactor coolant pump (RCP)

d. CEA ejection

Each of these is discussed below:

In the boron dilution analysis, the required SDM defines the reactivity difference between an initial subcritical boron concentration and the corresponding critical boron concentration. These values, in conjunction with the configuration of the RCS and the assumed dilution flow rate, directly affect the results of the analysis. This event is most limiting at the beginning of core life when critical boron concentrations are highest. The withdrawal of CEAs from subcritical conditions adds reactivity to the reactor core, causing both the core power level and heat flux to increase with corresponding increases in reactor coolant temperatures and pressure. The withdrawal of CEAs also produces a time dependent redistribution of core power.

Depending on the system initial conditions and reactivity insertion rate, the uncontrolled CEA withdrawal transient is terminated by either a low DNBR trip, a high local power density trip, or a Logarithmic Power Level trip. In all cases, power level, RCS pressure, linear heat rate, and the DNBR do not exceed allowable limits.

The startup of an inactive RCP will not result in a “cold water” criticality, even if the maximum difference in temperature exists between the SG and the core. The maximum positive reactivity addition that can occur due to an inadvertent RCP start is less than ~~half~~ the minimum required SDM. An idle RCP cannot, therefore, produce a return to power from the hot standby condition.

delete

BASES

APPLICABLE SAFETY ANALYSES (continued)

The CEA ejection is the accident occurring during conditions allowed by the power dependent insertion limit (PDIL). This event will lead to a rapid positive reactivity addition resulting in a rapid power excursion. A reactor trip on high power is generated to terminate the accident. The CEA ejection can result in limited fuel damage with the subsequent release of radioactive material, so it may be necessary to evaluate the radiological consequence in accordance with the 10 CFR 50.34. SDM is an important parameter in this analysis.

In the analysis of the CEA ejection event, SDM alone cannot prevent reactor criticality following a CEA ejection. The k_{N-1} requirement ensures the reactor remains subcritical and, therefore, satisfies the radially averaged enthalpy acceptance criterion considering power redistribution effects.

The function of k_{N-1} is to maintain sufficient subcriticality to preclude inadvertent criticality following ejection of a single control element assembly (CEA). k_{N-1} is a measure of the core's reactivity, considering a single malfunction resulting in the highest worth inserted CEA being ejected.

k_{N-1} requirements vary with the amount of positive reactivity that would be introduced assuming the CEA with the highest inserted worth ejects from the core. The k_{N-1} requirement ensures that a CEA ejection event while shutdown will not result in criticality.

The requirement prohibiting criticality due to shutdown group CEA movement is associated with the assumptions used in the analysis of uncontrolled CEA withdrawal from subcritical conditions. Due to the high differential reactivity worth of the shutdown CEA groups, the analysis assumes that the initial shutdown reactivity is such that the reactor will remain subcritical in the event of unexpected or uncontrolled shutdown group withdrawal.

SDM satisfies Criterion 2 of 10 CFR 50.36(c)(2)(ii).

LCO

The MSLB accident (Reference 2) and the boron dilution accident (Reference 3) are the most limiting analyses that establish the SDM value of the LCO. For MSLB accidents, if the LCO is violated, there is a potential to exceed the DNBR limit and to exceed 10 CFR 50.34 limits (Reference 4). For the boron dilution accident, if the LCO is violated, then the minimum required time assumed for operator action to terminate dilution may no longer be applicable.

SDM, k_{N-1}, and criticality due to shutdown CEA withdrawal are a core physics design condition that can be ensured through CEA positioning (regulating and shutdown CEAs) and through the soluble boron concentration.

APPLICABILITY

3, 4 and 5,

In MODES ~~3 and 4,~~ the SDM requirements are applicable to provide sufficient negative reactivity to meet the assumptions of the safety analyses discussed above.

3.1.5

3.1.6

In MODES 1 and 2, SDM is ensured by complying with LCO ~~3.1.6~~, "Shutdown Control Element Assembly (CEA) Insertion Limits," and LCO ~~3.1.7~~ "Regulating Control Element Assembly (CEA) Insertion Limits."

~~In MODE 5, the shutdown reactivity requirements are given in LCO 3.1.2, "SHUTDOWN MARGIN (SDM) – Tcold ≤ 99 °C (210 °F)."~~ In MODE 6, the shutdown reactivity requirements are given in LCO 3.9.1, "Boron Concentration."

delete

ACTIONS

A.1

If the SDM requirements are not met, boration must be initiated promptly. A Completion Time of 15 minutes is adequate for an operator to correctly align and start the required systems and components. It is assumed that boration will be continued until the SDM requirements are met.

In the determination of the required combination of boration flow rate and boron concentration, there is no unique requirement that must be satisfied. Since it is imperative to raise the boron concentration of the RCS as soon as possible (above 4,000 ppm boric acid and 109.8 L/min (29 gpm) flow rate), the boron concentration should be a highly concentrated solution, such as boric acid in the IRWST. The operator should borate with the best source available for the plant conditions.

ACTIONS (continued)

B.1 and B.2

If the k_{N-1} requirements are not met or reactor criticality is achievable by Shutdown Group CEA movement, boration must be initiated promptly and CEA position varied to restore k_{N-1} within limit or to ensure criticality due to Shutdown Group CEA movement is not achievable. A Completion Time of 15 minutes is adequate for an operator to correctly align and start the required systems and components and vary CEA position. It is assumed that boration will be continued and CEA position varied to return k_{N-1} to within limit or prevent reactor criticality due to Shutdown Group CEA movement. CEA movement is only required if the specific limit exceeded can be improved by taking this action.

SURVEILLANCE REQUIREMENTS

~~SR 3.1.1.1, 3.1.1.2, 3.1.1.3~~ SR 3.1.1.1, SR 3.1.1.2 and SR 3.1.1.3

SDM is verified by performing a reactivity balance calculation, considering the listed reactivity effects:

a. RCS boron concentration

b. CEA positions

c. RCS cold leg temperature

d. Fuel burnup based on gross thermal energy generation

e. Xenon concentration

f. Samarium concentration

g. Isothermal temperature coefficient (ITC)

Using the ITC accounts for Doppler reactivity in this calculation because the reactor is subcritical and the fuel temperature will be changing at the same rate as that of the RCS.

The Frequency of 24 hours is based on the generally slow change in required boron concentration, and it also allows sufficient time for the operator to collect the required data, which includes performing a boron concentration analysis, and complete the calculation.

BASES

REFERENCES

1. 10 CFR Part 50, Appendix A, GDC 26.
2. DCD Tier 2, Subsection 15.1.5.
3. DCD Tier 2, Subsection 15.4.6.
4. 10 CFR 50.34.

B 3.1 REACTIVITY CONTROL SYSTEMS

B 3.1.2 SHUTDOWN MARGIN (SDM) – T_{cold} ≤ 99 °C (210 °F)

BASES

BACKGROUND

The reactivity control systems must be redundant and capable of holding the reactor core subcritical when shutdown under cold conditions, in accordance with GDC 26 (Reference 1). Maintenance of the SDM ensures that postulated reactivity events will not damage the fuel. SDM requirements provide sufficient reactivity margin to ensure that acceptable fuel design limits will not be exceeded for normal shutdown and anticipated operational occurrences (AOOs). As such, the SDM defines the degree of subcriticality which would be obtained immediately following the insertion of all full strength control element assemblies (CEAs), assuming the single CEA of highest reactivity worth is fully withdrawn.

The system design requires that two independent reactivity control systems be provided, and that one of these systems be capable of maintaining the core subcritical under cold conditions. These requirements are provided by the use of movable CEAs and soluble boric acid in the reactor coolant system (RCS). The CEA system can compensate for the reactivity effects of the fuel and water temperature changes accompanying power level changes over the range from full load to no load. In addition, the CEAs, together with the boration system, provide the SDM during power operation and are capable of making the core subcritical rapidly enough to prevent exceeding acceptable fuel damage limits, assuming that the CEA of highest reactivity worth remains fully withdrawn. SDM is defined as the reactivity of the core with all CEAs inserted, assuming that the CEA of highest reactivity worth remains fully withdrawn.

The soluble boron system can compensate for fuel depletion during operation and all xenon burnout reactivity changes and maintain the reactor subcritical under cold conditions.

During power operation, SDM control is ensured by operating with the shutdown CEAs fully withdrawn and the regulating CEAs within the limits of LCO 3.1.7, “Regulating Control Element Assembly (CEA) Insertion Limits.” When the unit is in the shutdown and refueling MODES, the SDM requirements are met by means of adjustments to the RCS boron concentration.

BASES

APPLICABLE SAFETY ANALYSES

The minimum required SDM is assumed as an initial condition in safety analysis. The safety analysis (Reference 2) establishes an SDM that ensures specified acceptable fuel design limits are not exceeded for normal operation and AOOs, with the assumption of the highest worth CEA stuck out following a reactor trip.

The acceptance criteria for the SDM are that specified acceptable fuel design limits are maintained. This is done by ensuring that:

a. The reactor can be made subcritical from all operating conditions, transients, and Design Basis Events.

b. The reactivity transients associated with postulated accident conditions are controllable within acceptable limits (departure from nucleate boiling ratio (DNBR), fuel centerline temperature limit for AOOs, and less than or equal to 230 cal/g energy deposition for the CEA ejection accident); and

c. The reactor will be maintained sufficiently subcritical to preclude inadvertent criticality in the shutdown condition.

An inadvertent boron dilution is a moderate Frequency incident as defined in Reference 2. The core is initially subcritical with all CEAs inserted. A chemical and volume control system (CVCS) malfunction occurs which causes unborated water to be pumped to the RCS via one charging pump.

The reactivity change rate associated with boron concentration changes due to inadvertent dilution is within the capabilities of operator recognition and control. The high neutron flux alarm on the startup channel instrumentation will alert the operator of the boron dilution with a minimum of 30 minutes remaining before the core becomes critical.

SDM satisfies Criterion 2 of 10 CFR 50.36(c)(2)(ii). Even though it is not directly observed from the MCR, SDM is considered an initial condition process variable because it is periodically monitored to ensure that the unit is operating within the bounds of the accident analysis assumptions.

In the analysis of the CEA ejection event, SDM alone cannot prevent reactor criticality following a CEA ejection. The k_{N-1} requirement ensures the reactor remains subcritical and, therefore, satisfies the radially averaged enthalpy acceptance criterion considering power redistribution effects.

BASES

APPLICABLE SAFETY ANALYSES (continued)

The function of k_{N-1} is to maintain sufficient subcriticality to preclude inadvertent criticality following ejection of a single control element assembly (CEA). k_{N-1} is a measure of the core's reactivity, considering a single malfunction resulting in the highest worth inserted CEA being ejected.

k_{N-1} requirements vary with the amount of positive reactivity that would be introduced assuming the CEA with the highest inserted worth ejects from the core. The k_{N-1} requirement ensures that a CEA ejection event while shutdown will not result in criticality.

The requirement prohibiting criticality due to shutdown group CEA movement is associated with the assumptions used in the analysis of uncontrolled CEA withdrawal from subcritical conditions. Due to the high differential reactivity worth of the shutdown CEA groups, the analysis assumes that the initial shutdown reactivity is such that the reactor will remain subcritical in the event of unexpected or uncontrolled shutdown group withdrawal.

LCO

Chapter 15 accident analyses have shown that the required SDM is sufficient to avoid unacceptable consequences to the fuel or RCS as a result of the events addressed above.

The most limiting accident for the SDM requirements in MODE 5 is based on a boron dilution accident as described in the accident analysis (Reference 2). For the boron dilution accident, if the LCO is violated, then the minimum required time assumed for operator action to terminate dilution may no longer be applicable.

SDM, k_{N-1}, and criticality due to shutdown CEA withdrawal are a core physics design condition that can be ensured through CEA positioning (regulating and shutdown CEAs) and through the soluble boron concentration.

BASES

APPLICABILITY

In MODE 5, the SDM requirements are applicable to provide sufficient negative reactivity to meet the assumptions of the safety analyses discussed above. In MODES 1 and 2, SDM is ensured by complying with LCO 3.1.6, "Shutdown Control Element Assembly (CEA) Insertion Limits," and LCO 3.1.7 "Regulating Control Element Assembly (CEA) Insertion Limits." If the insertion limits of LCO 3.1.6 or LCO 3.1.7 are not being complied with, SDM is not automatically violated. The SDM must be calculated by performing a reactivity balance calculation (considering the listed reactivity effects in Bases Section SR 3.1.2.1).

In MODE 3 and 4, the shutdown reactivity requirements are given in LCO 3.1.1 "SHUTDOWN MARGIN (SDM) – T_{cold} > 99 °C (210 °F)." In MODE 6, the shutdown reactivity requirements are given in LCO 3.9.1, "Boron Concentration."

ACTIONS

A.1

If the SDM requirements are not met, boration must be initiated promptly. A Completion Time of 15 minutes is adequate for an operator to correctly align and start the required systems and components. It is assumed that boration will be continued until the SDM requirements are met.

In the determination of the required combination of boration flow rate and boron concentration, there is no unique requirement that must be satisfied. The operator should borate with the best source available for the plant conditions.

Since it is imperative to raise the boron concentration of the RCS as soon as possible (above 4,000 ppm boric acid and 109.8 L/min (29 gpm) flow rate), the boron concentration should be a highly concentrated solution, such as boric acid in the IRWST. The operator should borate with the best source available for the plant conditions.

B.1 and B.2

If the k_{N-1} requirements are not met or reactor criticality is achievable by Shutdown Group CEA movement, boration must be initiated promptly and CEA position varied to restore k_{N-1} within limit or to ensure criticality due to Shutdown Group CEA movement is not achievable. A Completion Time of 15 minutes is adequate for an operator to correctly align and start the required systems and components and vary CEA position. It is assumed that boration will be continued and CEA position varied to return k_{N-1} to within limit or prevent reactor criticality due to Shutdown Group CEA movement. CEA movement is only required if the specific limit exceeded can be improved by taking this action.

BASES

SURVEILLANCE REQUIREMENTS

SR 3.1.2.1, 3.1.2.2, 3.1.2.3

In MODE 5, SDM is verified by performing a reactivity balance calculation, considering the listed reactivity effects:

a. RCS boron concentration

b. CEA positions

c. RCS cold leg temperature

d. Fuel burnup based on gross thermal energy generation

e. Xenon concentration

f. Samarium concentration

g. Isothermal temperature coefficient (ITC)

Using the ITC accounts for Doppler reactivity in this calculation because the reactor is subcritical and the fuel temperature will be changing at the same rate as that of the RCS.

The Frequency of 24 hours is based on the generally slow change in required boron concentration, and it also allows sufficient time for the operator to collect the required data, which includes performing a boron concentration analysis, and complete the calculation.

REFERENCES

1. 10 CFR Part 50, Appendix A, GDC 26.

2. DCD Tier 2, Subsection 15.4.6.

B 3.1 REACTIVITY CONTROL SYSTEMS

B ~~3.1.3~~ 3.1.2 Reactivity Balance

BASES

BACKGROUND

According to GDC 26, 28, and 29 (Reference 1), reactivity shall be controllable, such that subcriticality is maintained under cold conditions and acceptable fuel design limits are not exceeded during normal operation and anticipated operational occurrences. Therefore, reactivity balance is used as a measure of the predicted versus measured core reactivity during power operation. The periodic confirmation of core reactivity is necessary to ensure that design basis accidents (DBA) and transient safety analyses remain valid. A large reactivity difference could be the result of unanticipated changes in fuel, control element assembly (CEA) worth, or operation at conditions not consistent with those assumed in the predictions of core reactivity, and could potentially result in a loss of SDM or violation of acceptable fuel design limits. Comparing predicted versus measured core reactivity validates the nuclear methods used in the safety analysis and supports the SDM demonstrations (LCO 3.1.1, "SHUTDOWN MARGIN (SDM) ~~– T_{cold} > 99 °C (210 °F)~~") in ensuring the reactor can be brought safely to cold, subcritical conditions. delete

When the reactor core is critical or in normal power operation, a reactivity balance exists and the net reactivity is zero. A comparison of predicted and measured reactivity is convenient under such a balance since parameters are being maintained relatively stable under steady state power conditions. The positive reactivity inherent in the core design is balanced by the negative reactivity of the control components, thermal feedback, neutron leakage, and materials in the core that absorb neutrons, such as burnable absorbers producing zero net reactivity. Excess reactivity can be inferred from the critical boron curve, which provides an indication of the soluble boron concentration in the reactor coolant system (RCS) versus cycle burnup. Periodic measurement of the RCS boron concentration for comparison with the predicted value with other variables fixed (such as CEA height, temperature, pressure, and power) provides a convenient method of ensuring that core reactivity is within design expectations and that the calculational models used to generate the safety analysis are adequate.

BASES

LCO

The limits on shutdown and regulating CEA alignments ensure that the assumptions in the safety analysis will remain valid. The requirements on CEA OPERABILITY ensure that upon reactor trip, the CEAs will be available and will be inserted to provide enough negative reactivity to shut down the reactor. The CEA OPERABILITY requirements (i.e., trippability) are separate from the alignment requirements that ensure the CEA banks maintain the correct power distribution and CEA alignment. The CEA OPERABILITY requirement is satisfied provided the CEA will fully insert in the required CEA drop time assumed in the safety analysis. CEA control malfunctions that result in the inability to move a CEA (e.g., CEA lift coil failures), but that do not impact trippability, do not result in CEA inoperability.

The requirement on OPERABILITY to maintain the CEA alignment to within 16.8 cm (6.6 in) between the highest and lowest CEAs in a subgroup is conservative. The minimum misalignment assumed in safety analysis is 48.3 cm (19 in), and in some cases, a total misalignment from fully withdrawn to fully inserted is assumed.

Failure to meet the requirements of this LCO can produce unacceptable power peaking factors and LHRs, or unacceptable SDMs, all of which can constitute initial conditions inconsistent with the safety analysis.

APPLICABILITY

The requirements on CEA OPERABILITY and alignment are applicable in MODES 1 and 2. Because these are the only MODES in which neutron (or fission) power is generated and the OPERABILITY (i.e., trippability) and alignment of CEAs have the potential to affect the safety of the plant. In MODES 3, 4, 5, and 6, the alignment limits do not apply because the CEAs are bottomed, and the reactor is shut down and not producing fission power. In the shutdown MODES, the OPERABILITY of the shutdown and regulating CEAs has the potential to affect the required SDM, but this effect can be compensated for by an increase in the boron concentration of the RCS. See LCO 3.1.1, "SHUTDOWN MARGIN (SDM) ~~– T_{cold} > 99 °C (210 °F)" and LCO 3.1.2, "SHUTDOWN MARGIN (SDM) – T_{cold} ≤ 99 °C (210 °F)~~" for SDM in MODES 3, 4, and 5, and LCO 3.9.1 "Boron Concentration," for boron concentration requirements during refueling. delete

BASES

APPLICABLE SAFETY ANALYSES

Accident analysis assumes that the shutdown CEAs are fully withdrawn any time the reactor is critical. This ensures that:

a. The minimum SDM is maintained.

b. The potential effects of a CEA ejection accident are limited to acceptable limits.

CEAs are considered fully withdrawn at 367.7 cm (144.75 in) since this position places them outside the active region of the core.

On a reactor trip, all CEAs (shutdown and regulating CEAs), except the most reactive CEA, are assumed to insert into the core. The shutdown and regulating CEAs shall be at their insertion limits and available to insert the maximum amount of negative reactivity on a reactor trip signal. The regulating CEAs may be partially inserted in the core as allowed by LCO ~~3.1.7~~ 3.1.6, "Regulating Control Element Assembly (CEA) Insertion Limits." The shutdown CEA insertion limit is established to ensure that a sufficient amount of negative reactivity is available to shut down the reactor and maintain the required SDM (see LCO 3.1.1, "SHUTDOWN MARGIN (SDM) ~~– T_{cold} > 99 °C (210 °F)~~") following a reactor trip from full power. The combination of regulating CEAs and shutdown CEAs (less the most reactive CEA, which is assumed to be fully withdrawn) is sufficient to take the reactor from full power conditions at rated temperature to zero power and maintain the required SDM at rated no load temperature (Reference 3). The shutdown CEA insertion limit also limits the reactivity worth of an ejected shutdown CEA.

delete

The acceptance criteria for addressing shutdown CEA as well as regulating CEA insertion limits and inoperability or misalignment are that:

a. There be no violation of:

1. Specified acceptable fuel design limits(SAFDL)

2. Reactor coolant system (RCS) pressure boundary integrity

b. The core remains subcritical after accident transients.

The shutdown CEA insertion limits satisfy Criterion 2 of 10 CFR 50.36(c)(2)(ii).

BASES

LCO

The shutdown CEAs must be within their insertion limits any time the reactor is critical or approaching criticality. This ensures that a sufficient amount of negative reactivity is available to shut down the reactor and maintain the required SDM following a reactor trip.

APPLICABILITY

The shutdown CEAs must be within their insertion limits with the reactor in MODES 1 and 2. The Applicability in MODE 2 begins any time any regulating CEA is not fully inserted. This ensures that a sufficient amount of negative reactivity is available to shut down the reactor and maintain the required SDM following a reactor trip.

In MODE 3, 4, 5, and 6, the shutdown CEAs are fully inserted in the core and contribute to the SDM. Refer to LCO 3.1.1 "SHUTDOWN MARGIN (SDM) ~~– T_{cold} > 99 °C (210 °F)" and LCO 3.1.2 "SHUTDOWN MARGIN (SDM) – T_{cold} ≤ 99 °C (210 °F)~~" for SDM requirements in MODES 3, 4, and 5. LCO 3.9.1, "Boron Concentration," ensures adequate SDM in MODE 6.

delete

LCO ~~3.1.6~~ has been modified by a Note indicating the LCO requirement is suspended during SR ~~3.1.5.3~~, which verifies the freedom of the CEAs to move, and requires the shutdown CEAs to move below the LCO limits, which would normally violate the LCO.

3.1.5

3.1.4.3

ACTIONS

A.1

Prior to entering this Condition, the shutdown CEAs were fully withdrawn. If a shutdown CEA is then inserted into the core, its potential negative reactivity is added to the core as it is inserted. If the CEA(s) is not restored to within limits within 1 hour, then an additional 1 hour is allowed for restoring the CEA(s) to within limits. The 2 hour total Completion Time allows the operator adequate time to adjust the CEA(s) in an orderly manner and is consistent with the required Completion Times in LCO ~~3.1.5~~, "Control Element Assembly (CEA) Alignment."

3.1.4

BASES

BACKGROUND (continued)

PHYSICS TESTS are performed in accordance with these procedures and test results are approved prior to continued power escalation and long term power operation. Examples of PHYSICS TESTS include determination of critical boron concentration, CEA group worths, reactivity coefficients, flux symmetry, and core power distribution.

APPLICABLE SAFETY ANALYSES

It is acceptable to suspend certain LCOs for PHYSICS TESTS as long as fuel damage criteria are not exceeded. Even if an accident occurs during PHYSICS TESTS with one or more LCOs suspended, fuel damage criteria are preserved because adequate limits on power distribution and shutdown capability are maintained during PHYSICS TESTS.

Reference 5 defines the requirements for initial testing of the facility, including PHYSICS TESTS. Requirements for reload fuel cycle PHYSICS TESTS are defined in ANSI/ANS-19.6.1-2005 (Reference 4). PHYSICS TESTS for reload fuel cycles are given in Table 1 of ANSI/ANS-19.6.1-2005. Although these PHYSICS TESTS are generally accomplished within the limits of all LCOs, conditions could occur when one or more LCOs must be suspended to make completion of PHYSICS TESTS possible or practical. This is acceptable as long as the fuel design criteria are not violated. As long as the linear heat rate (LHR) and the departure from nucleate boiling ratio (DNBR) remain within their limits, fuel design criteria are preserved.

In this test, the following LCOs are suspended:

delete

a. LCO 3.1.1, "SHUTDOWN MARGIN (SDM)~~: T_{cold} > 99 °C (210 °F)~~"

b. LCO ~~3.1.6~~ 3.1.5, "Shutdown Control Element Assembly (CEA) Insertion Limits"

c. LCO ~~3.1.7~~ 3.1.6, "Regulating Control Element Assembly (CEA) Insertion Limits"

d. LCO 3.3.1, "Reactor Protection System (RPS) Instrumentation – Operating" (Only applied to Trip Functions 2, 14 and 15 in Table 3.3.1-1)

e. LCO 3.3.2, "Reactor Protection System (RPS) Instrumentation – Shutdown" (Only Applied to Trip Function 1 in Table 3.3.2-1).

BASES

BACKGROUND (continued)

The SCS is kept in service during the refueling period to assist in maintaining the boron concentration in the RCS, the refueling canal, and the refueling pool above the COLR limit and to remove core decay heat and provide forced circulation in the RCS. (Refer to LCO 3.9.4, ”Shutdown Cooling System (SCS) and Coolant Circulation ƒ High Water Level‘ and LCO 3.9.5, ”Shutdown Cooling System (SCS) and Coolant Circulation ƒ Low Water Level‘).

APPLICABLE SAFETY ANALYSES

During refueling operations the reactivity condition of the core is consistent with the initial conditions assumed for the boron dilution accident in the accident analysis and is conservative for MODE 6. The magnitude of the boron concentration specified in the COLR is based on the nuclear design of each fuel cycle. It is further based on the core reactivity at the beginning of each fuel cycle (the end of refueling) and includes an uncertainty allowance.

The required boron concentration and the unit refueling procedures that demonstrate the correct fuel loading plan (including full core mapping) ensure the k_{eff} of the core will remain less than or equal to 0.95 during the refueling operation.

During refueling, the water volume in the spent fuel pool, the transfer canal, the refueling pool, the refueling canal and the reactor vessel form a single mass. As a result, the soluble boron concentration is the same in each of these volumes.

~~The limiting boron dilution accident occurs in MODE 5 (Reference 2). A detailed discussion of this event is provided in LCO Basis 3.1.2, ”SHUTDOWN MARGIN (SDM) ƒ T~~$_{cold}$ ~~≤ 99 °C (210 °F).”~~

The inadvertent boron dilution accident is discussed in DCD Tier 2, Section 15.4.6 (Reference 2).

The RCS boron concentration satisfies Criterion 2 of 10 CFR 50.36(c)(2)(ii).

LCO

The LCO 3.9.1 requires that a minimum boron concentration be maintained while in MODE 6. The boron concentration limit specified in the COLR during fuel handling operations ensures a k_{eff} of less than or equal to 0.95 is maintained. Violation of the LCO could lead to possible inadvertent criticality during MODE 6.

BASES

APPLICABILITY

This LCO is applicable in MODE 6 to ensure that the fuel in the reactor vessel will remain subcritical. The required boron concentration ensures a k_{eff} of less than or equal to 0.95. Above MODE 6, LCO 3.1.1, "SHUTDOWN MARGIN (SDM) ~~– T_{cold} > 99 °C (210 °F)," and LCO 3.1.2, "SHUTDOWN MARGIN (SDM) – T_{cold} ≤ 99 °C (210 °F)~~," ensures that an adequate amount of negative reactivity is available to shut down the reactor and to maintain the reactor subcritical.

delete

The Applicability is modified by a Note. The Note states that the limits on boron concentration are only applicable to the refueling canal and the refueling cavity when those volumes are connected to the RCS. When the refueling canal and the refueling cavity are isolated from the RCS, no potential path for boron dilution exists.

ACTIONS

A.1

Continuation of positive reactivity additions (including actions to reduce boron concentration) is contingent upon maintaining the plant in compliance with the LCO. If the boron concentration of any of the filled portions of the RCS, the refueling canal, or the refueling cavity is less than its limit, all operations involving or positive reactivity additions must be suspended immediately. Operations that individually add limited positive reactivity (e.g., temperature fluctuations from inventory addition or temperature control fluctuations), but when combined with all other operations affecting core reactivity (e.g., intentional boration)result in overall net negative reactivity addition, are not precluded by this action.

Suspension of positive reactivity additions shall not preclude completion of actions to establish a safe condition.

A.2

In addition to immediately suspending positive reactivity additions, boration to restore the concentration must be initiated immediately. In the determination of the required combination of boration flow rate and boron concentration, there is not a unique design basis event which must be satisfied. The only requirement is to restore the boron concentration to its required value as soon as possible. In order to raise the boron concentration of the RCS as soon as possible, the operator should begin boration with the best source available for unit conditions.

Once boration is initiated, it must be continued until the boron concentration is restored. The Completion Time depends on the amount of boron which must be injected to reach the required concentration.