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.:	**216-8221**
SRP Section:	**15.04.06 – Inadvertent Decrease in Boron Concentration in the Reactor Coolant(PWR)**
Application Section:	**15.04.06**
Date of RAI Issue:	**09/16/2015**

Question No. 15.4.6-2

10 CFR Part 50 Appendix A, GDC 10 requires that the reactor core and associated coolant, control and protection systems shall be designed with appropriate margin to assure that specified acceptable fuel design limits are not exceeded during any condition of normal operation, including the effects of anticipated operational occurrences. The inadvertent reactor coolant system (RCS) boron dilution event is classified as anticipated operational occurrence per SRP 15.4.6. SRP 15.4.6, Section III, “Review Procedures” states the reviewer confirms that analyses are included for a boron dilution incident during each of the plant initial conditions including power operation with rods in automatic.

In review of the DCD Tier 2, Section 15.4.6, staff could not find a mention of the plant response and time to re-criticality for Modes 1 and 2 (power operation) with rods in automatic. Justify the reason(s) for not including the discussion for control rods in automatic and update the DCD as necessary.

Response

If the boron dilution occurs during Mode 1 and Mode 2 in automatic rod control, the control rods begin to be inserted into the core to compensate for the power increase. As the dilution proceeds without any notification, the rods will reach the power dependent insertion limit (PDIL) and the PDIL alarm will alert the operator of the reactivity insertion. Without any operator action to stop the dilution, a reactor trip will occur and the subcritical reactivity of the core will be more than -5.5%Δρ due to the scram reactivity. In this case, operator action time is the time from the PDIL alarm to the return to re-criticality. This operator action time is at least the same or longer than the total dilution time during Mode 3. Therefore time to re-criticality for Mode 1 and Mode 2 with rods in automatic is bounded by the Mode 3 results.

Impact on DCD

There is no impact on DCD.

Impact on PRA

There is no impact on PRA.

Impact on Technical Specifications

There is no impact on Technical Specifications.

Impact on Technical/Topical/Environmental Reports

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

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Question No. 15.4.6-3

10 CFR Part 50 Appendix A, GDC 10 requires that the reactor core and associated coolant, control and protection systems shall be designed with appropriate margin to assure that specified acceptable fuel design limits are not exceeded during any condition of normal operation, including the effects of anticipated operational occurrences. The inadvertent reactor coolant system (RCS) boron dilution event is classified as anticipated operational occurrence per SRP 15.4.6. SRP 15.4.6 states that at least a 15 minute operator action time should be available to terminate a dilution during Modes 1 and 2 power operations.

In determining the time to re-criticality during power operations with control rods in manual it is unclear if the initial boron concentration assumed is the concentration at the start of the dilution or the value at the time of the reactor trip. Staff requests the applicant state what is the initial boron concentration assumed for power operations with control rods in manual and what is the time to re-criticality. If the boron concentration at the start of the dilution is used to determine the time of re-criticality provide an explanation why this is conservative. Update the DCD as necessary.

Response

The quantitative boron dilution analysis during power operations with control rods in manual was not performed. It is not necessary to perform the boron dilution analysis from the DNBR point of view, since the reactivity addition rate is lower than for the bank CEA withdrawal events. And the results of the boron dilution analysis after reactor trip are bounded by the results of the Mode 3 boron dilution.
If the boron dilution occurs during power operations in manual rod control, the power increases and eventually a reactor trip will occur. After a reactor trip, the subcritical reactivity of the core is more than -5.5%Δρ because of the scram reactivity. In this case, operator action time is the time from the reactor trip to the return to re-criticality. This operator action

time is at least the same or longer than the total dilution time during Mode 3. Therefore time to re-criticality for power operations with control rods in manual is bounded by the Mode 3 results.
The quantitative explanation for the boron dilution during Mode 1 in manual rod control is provided below:

TS

The quantitative explanation for the boron dilution during Mode 2 in manual rod control is provided below:

TS

The operator action time during power operations with control rods in manual is more than 2 hours.

Impact on DCD

There is no impact on DCD.

Impact on PRA

There is no impact on PRA.

Impact on Technical Specifications

There is no impact on Technical Specifications.

Impact on Technical/Topical/Environmental Reports

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

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Question No. 15.4.6-4

10 CFR Part 50 Appendix A, GDC 10 requires that the reactor core and associated coolant, control and protection systems shall be designed with appropriate margin to assure that specified acceptable fuel design limits are not exceeded during any condition of normal operation, including the effects of anticipated operational occurrences. The inadvertent reactor coolant system (RCS) boron dilution event is classified as anticipated operational occurrence per SRP 15.4.6. SRP 15.4.6 states that at least a 15 minute operator action time should be available to terminate a dilution during Modes 3 through 5.

In DCD Tier 2, Section 15.4.6.3.1, “Evaluation Model,” the staff notes that equation 15.4-1 is ill-formed without an equals sign. Correct the equation by updating the DCD.

Response

Equation 15.4-1 in DCD Tier 2, Section 15.4.6.3.1 will be appropriately revised.

Impact on DCD

Equation 15.4-1 in DCD Tier 2, Section 15.4.6.3.1 will be revised as shown in the attached markup.

Impact on PRA

There is no impact on PRA.

Impact on Technical Specifications

There is no impact on Technical Specifications.

Impact on Technical/Topical/Environmental Reports

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

any ongoing deboration at least 30 minutes before the reactor achieves criticality. Therefore, Modes 1 and 2 do not have to be analyzed further with respect to an inadvertent decrease in reactor coolant boron concentration event.

For Modes 3, 4, 5, and 6, operation time is calculated from event initiation to loss of shutdown margin. For these modes, 30 minutes is conservatively subtracted from this time to determine the latest allowable time for alarm actuation. In these modes, it is calculated that at 30 minutes prior to loss of shutdown, the source range monitoring (SRM) ratio exceeds its setpoint. An operator response time of at least 30 minutes is demonstrated.

The operator can identify a boron dilution through a neutron flux alarm on the startup flux channel, reactor makeup flow rate, sampling or boric acid flow rate. The operator turns off the charging pump in order to stop further boron dilution. Next, the operator increases the RCS boron concentration by implementing the emergency boration procedure.

None of the single failures listed in Table 15.0-4 has any effect on this event in Modes 1 through 6.

15.4.6.3 Core and System Performance

15.4.6.3.1 Evaluation Model

Assuming complete mixing of boron in the RCS, the rate of change of boron concentration during dilution is described by the following equation.

$$M\frac{dC}{dt} = -WC \qquad \text{(Eq. 15.4-1)}$$

= -WC

Where:

M = RCS mass

C = time-dependent RCS boron concentration

W = charging mass flow rate of unborated water

dC/dt is maximized by maximizing W and minimizing M

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Application Section:	**15.04.06**
Date of RAI Issue:	**09/16/2015**

Question No. 15.4.6-5

10 CFR Part 50 Appendix A, GDC 10 requires that the reactor core and associated coolant, control and protection systems shall be designed with appropriate margin to assure that specified acceptable fuel design limits are not exceeded during any condition of normal operation, including the effects of anticipated operational occurrences. The inadvertent reactor coolant system (RCS) boron dilution event is classified as anticipated operational occurrence per SRP 15.4.6. SRP 15.4.6 states the minimum DNBR should be above the safety analysis DNBR limit for at power operations.

In DCD Tier 2, Section 15.4.6.6, “Conclusions,” the applicant states that the minimum DNBR is equal to or greater than the 1.29 limit. Staff could not find, in the DCD, a supporting basis for this conclusion. Staff request the applicant to update the DCD, as necessary, with supporting information which demonstrates the DNBR value remains above the limit.

Response

As stated in the response to Question 15.4.6-3, the reactivity insertion rate of the boron dilution during power operations is about 0.04 %Δρ/min and the reactivity insertion rates of the CEA withdrawal at HFP and HZP are 0.189 %Δρ/min and 0.705 %Δρ/min respectively. Because of this reason, the power increase due to the boron dilution is much slower than that of the CEA withdrawal events during power operations. Also the operator action time is more than 2 hours in power operations and sufficient time (more than 30 minutes) is available to take a corrective action during other operation Modes.

Impact on DCD

There is no impact on DCD.

Impact on PRA

There is no impact on PRA.

Impact on Technical Specifications

There is no impact on Technical Specifications.

Impact on Technical/Topical/Environmental Reports

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

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.:	**216-8221**
SRP Section:	**15.04.06 – Inadvertent Decrease in Boron Concentration in the Reactor Coolant (PWR)**
Application Section:	**15.4.6**
Date of RAI Issue:	**09/16/2015**

Question No. 15.04.06-6

10 CFR Part 50 Appendix A, GDC 10 requires that the reactor core and associated coolant, control and protection systems shall be designed with appropriate margin to assure that specified acceptable fuel design limits are not exceeded during any condition of normal operation, including the effects of anticipated operational occurrences. The inadvertent reactor coolant system (RCS) boron dilution event is classified as anticipated operational occurrence per SRP 15.4.6. SRP 15.4.6 states that at least a 15 minute operator action time should be available to terminate a dilution during Modes 1 through 5.

The dilution rate is a function of the maximum charging flow rate. In review of DCD Tier 1, Table 2.4.6-4 (6 of 6), “Chemical and Volume Control System ITAAC”, ITAAC item 9.a, the staff noted that a minimum charging pump flow rate is established but no maximum value is provided. Staff needs to understand the basis for not establishing a maximum charging pump flow rate ITAAC item. The applicant is requested to provide the basis and update the DCD as appropriate.

Response

The limitation of the magnitude of a boron dilution source (i.e., charging flow rate) to prevent inadvertent RCS boron dilution will be added as an ITAAC item in DCD Tier 1 Section 2.4.6.1 and Table 2.4.6-4 as presented in Attachment 1. The maximum limit of charging flow rate, 567.8 L/min (150 gpm) specified as the acceptance criteria is consistent with the maximum charging flow rate used as an input in inadvertent RCS boron dilution event analysis for Operation Mode 5 (with the RCS partially drained) as provided in DCD Tier 2 Table 15.4.6-1. Other than this operation mode, maximum charging flow rate is limited by closing the charging restricting valve actuated by the high-high flow signal of the charging flow instrument (See DCD Tier 2 Section 9.3.4.5.4, Item d).

In relation to addition of this ITAAC item, DCD Tier 2 Table 14.3.4-1 will be revised as presented in Attachment 2.

Impact on DCD

DCD Tier 1 Section 2.4.6.1 and Table 2.4.6-4 will be revised as indicated in the Attachment 1. DCD Tier 2 Table 14.3.4-1 will be also revised as indicated in the Attachment 2.

Impact on PRA

There is no impact on the PRA.

Impact on Technical Specifications

There is no impact on the Technical Specifications.

Impact on Technical/Topical/Environmental Reports

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

8.d All displays and alarms required by the design exist in the RSR as defined in Tables 2.4.6-2 and 2.4.6-3.

9.a The CVCS provides makeup capability to maintain the RCS volume.

9.b The CVCS supplies seal water to the RCP seals.

9.c The CVCS provides pressurizer auxiliary spray water for depressurization.

10. The high-energy piping systems, including the protective features are reconciled with pipe rupture hazards analyses report to ensure that the safety-related SSCs are protected against or are qualified to withstand the dynamic effects associated with postulate failures of these piping systems.

2.4.6.2 Inspections, Tests, Analyses, and Acceptance Criteria

Table 2.4.6-4 specifies the ITAAC for the CVCS.

The ITAAC associated with the CVCS equipment, components, and piping that comprise a portion of the containment isolation system are described in Table 2.11.3-2.

9.d The CVCS limits the magnitude of a boron dilution source to the RCS to prevent inadvertent RCS boron dilution.

Table 2.4.6-4 (6 of 6)

Design Commitment	Inspections, Tests, Analyses	Acceptance Criteria
9.a The CVCS provides makeup capability to maintain the RCS volume.	9.a A test of as-built CVCS will be performed to measure the makeup flow rate.	9.a Each as-built CVCS charging pump delivers a flow rate to the RCS of greater than or equal to 586.7 L/min (155 gpm) at normal operating pressure of RCS.
9.b The CVCS supplies seal water to the RCP seals.	9.b A test of as-built CVCS will be performed by aligning a flow path to each RCP.	9.b Each as-built CVCS charging pump provides a flow rate of greater than or equal to 99.9 L/min (26.4 gpm) to four RCPs.
9.c The CVCS provides pressurizer auxiliary spray water for depressurization.	9.c A test of the as-built CVCS will be performed by aligning a flow path to the pressurizer auxiliary spray.	9.c The as-built CVCS charging pump provides spray flow to the pressurizer.
10. The high-energy piping systems, including the protective features are reconciled with pipe rupture hazards analyses report to ensure that the safety-related SSCs are protected against or are qualified to withstand the dynamic effects associated with postulate failures of these piping systems.	10. Inspections and analyses of the as-built high-energy piping including the protective features and safety-related SSCs will be performed.	10. Pipe rupture hazard analysis report exits and concludes that the as-built safety-related SSCs are protected against or are qualified to withstand the effects of postulated pipe failures of the as-built high-energy piping system.
9.d The CVCS limits the magnitude of a boron dilution source to the RCS to prevent inadvertent RCS boron dilution.	9.d A test of as-built CVCS will be performed to measure the charging flow rate through the charging restricting orifices .	9.d The as-built charging restricting orifices limit the charging flow rate to less than or equal to 567.8 L/min (150 gpm) at atmospheric pressure of RCS with the charging restricting orifice bypass valves closed.

Table 14.3.4-1 (4 of 4)

Item #	Tier 1 Reference	Design Features	Tier 2 Reference
1-25	2.5.1 Table 2.5.1-2, ITACC #4.a	A reactor trip occurs on high containment pressure.	Table 7.2-4
1-26	2.5.1 Table 2.5.1-2, ITACC #4.a	A reactor trip occurs on low reactor coolant flow.	Table 7.2-4
1-27	2.5.1 Table 2.5.1-3, ITACC #4.a	The safety injection actuation signal is initiated on low pressurizer pressure or high containment pressure.	Table 7.3-5A
1-28	2.5.1 Table 2.5.1-3, ITACC #4.a	The containment isolation actuation signal is initiated on high containment pressure or low pressurizer pressure.	Table 7.3-5A
1-29	2.5.1 Table 2.5.1-3, ITACC #4.a	The containment spray actuation signal is initiated on high high containment pressure.	Table 7.3-5A
1-30	2.5.1 Table 2.5.1-3, ITACC #4.a	The main steam isolation signal is initiated on low steam generator pressure, high containment pressure or high steam generator level.	Table 7.3-5A
1-31	2.5.1 Table 2.5.1-3, ITACC #4.a	The auxiliary feedwater actuation signal-1 is initiated on low steam generator 1 level.	Table 7.3-5A
1-32	2.5.1 Table 2.5.1-3, ITACC #4.a	The auxiliary feedwater actuation signal-2 is initiated on low steam generator 2 level.	Table 7.3-5A
1-33	2.4.6 ITAAC #9.d	The as-built charging restricting orifices limit the charging flow rate to less than or equal to 567.8 L/min (150 gpm) at atmospheric pressure of RCS with the charging restricting orifice bypass valves closed.	Table 15.4.6-1

(Added)

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Question No. 15.4.6-7

10 CFR Part 50 Appendix A, GDC 10 requires that the reactor core and associated coolant, control and protection systems shall be designed with appropriate margin to assure that specified acceptable fuel design limits are not exceeded during any condition of normal operation, including the effects of anticipated operational occurrences. The inadvertent reactor coolant system (RCS) boron dilution event is classified as anticipated operational occurrence per SRP 15.4.6. SRP 15.4.6 states that at least a 30 minute operator action time should be available to terminate a dilution during Mode 6, "Refueling."

In DCD Tier 2, Section 15.4.6.2(e), the applicant states that administrative controls are used to prevent dilution during Mode 6, "Refueling," therefore no evaluation of the time to reach criticality was performed. Staff needs a basis for using administrative controls instead of an explicit note in an existing Technical Specification or a new Technical Specification Limiting Condition of Operation prohibiting dilution, as administrative controls are controlled by the licensees. The applicant is requested to provide the basis and update the DCD as appropriate.

Response

KNHP has planned to reflect the administrative controls into the operating procedure of APR1400 enabling a relative valve to be closed during Mode 6 to block the flow paths that could allow unborated makeup to reach the RCS. But KHNP will add TS 3.9.7 and its associated Bases to TS 3.9.7 to prohibit dilution during Mode 6.

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 3.9.7 including Bases 3.9.7 will be added as shown in the attached markup.

Impact on Technical/Topical/Environmental Reports

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

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3.9 REFUELING OPERATIONS

3.9.7 Unborated Water Source Isolation Valves

LCO 3.9.7 Each valve used to isolate unborated water sources shall be secured in the closed position.

APPLICABILITY: MODE 6.

ACTIONS

CONDITION	REQUIRED ACTION	COMPLETION TIME
A. One or more valves not secured in closed position.	A.1 Suspend CORE ALTERATIONS. AND A.2 Initiate actions to secure valve in closed position. AND A.3 Perform SR 3.9.1.1.	Immediately Immediately 4 hours

SURVEILLANCE REQUIREMENTS

SURVEILLANCE			FREQUENCY
SR	3.9.7.1	Verify each valve that isolates unborated water sources is secured in the closed position.	7 days

Insert

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B 3.9 REFUELING OPERATIONS

B 3.9.7 Unborated Water Source Isolation Valves

BASES

BACKGROUND

During MODE 6 operations, all isolation valves for reactor makeup water source containing unborated water that are connected to the Reactor Coolant System(RCS) must be closed to prevent unplanned boron dilution of the reactor coolant. The isolation valves must be secured in the closed position.

The Chemical and Volume Control System is capable of supplying borated and unborated water to the RCS through various flow paths. Since a positive reactivity addition made by reducing the boron concentration is inappropriate during MODE 6, isolation of all unborated water sources prevents an unplanned boron dilution.

APPLICABLE SAFETY ANALYSES

The possibility of an inadvertent boron dilution event (Reference 1) occurring during MODE 6 refueling operations is precluded by adherence to this LCO, which requires that potential dilution sources be isolated. Closing the required valves during refueling operations prevents the flow of unborated water to the filled portion of the RCS. The valves are used to isolate unborated water sources. These valves have the potential to indirectly allow dilution of the RCS boron concentration in MODE 6. By isolating unborated water sources, a safety analysis for an uncontrolled boron dilution accident is not required for MODE 6.

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

LCO

This LCO requires that flow paths to the RCS from unborated water sources be isolated to prevent unplanned boron dilution during MODE 6 and thus avoid a reduction in SDM.

Insert

BASES (continued)

APPLICABILITY

This LCO is applicable in MODE 6 to prevent an inadvertent boron dilution event by ensuring isolation of all sources of unborated water to the RCS.

ACTIONS

A.1

Continuation of CORE ALTERATIONS is contingent upon maintaining the unit in compliance with this LCO. With any valve used to isolate unborated water sources not secured in the closed position, all operations involving CORE ALTERATIONS must be suspended immediately. The Completion Time of "immediately" for performance of Required Action A.1 shall not preclude completion of movement of a component to a safe position

A.2

Preventing inadvertent dilution of the reactor coolant boron concentration is dependent on maintaining the unborated water isolation valves secured closed. Securing the valves in the closed position ensures that the valves cannot be inadvertently opened. The Completion Time of "immediately" requires an operator to initiate actions to close an open valve and secure the isolation valve in the closed position immediately. Once actions are initiated, they must be continued until the valves are secured in the closed position.

A.3

Due to the potential of having diluted the boron concentration of the reactor coolant, SR 3.9.1.1(verification of boron concentration) must be performed. The Completion Time of 4 hours is sufficient to obtain and analyze a reactor coolant sample for boron concentration.

Insert

BASES (continued)

SURVEILLANCE REQUIREMENTS

SR 3.9.7.1

These valves are to be secured closed to isolate possible dilution paths. The likelihood of a significant reduction in the boron concentration during MODE 6 operations is remote due to the large mass of borated water in the refueling cavity and the fact that all unborated water sources are isolated, precluding a dilution. This Surveillance demonstrates that the valves are closed through a system walkdown. The 7 day frequency is based on engineering judgment and is considered reasonable in view of other administrative controls that will ensure that the valve opening is an unlikely possibility.

REFERENCES

1. DCD Tier 2, Subsection 15.4.6.

Insert