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.:	**492-8614**
SRP Section:	**05.04.07 – Residual Heat Removal (RHR) System**
Application Section:	**Tier2 5.4.7 & Tier1 2.4.4**
Date of RAI Issue:	**05/26/2016**

Question No. 05.04.07-4

Gas Accumulation/Gas Entrainment

10 CFR 52.47(b)(1), which requires that a DC application contain the proposed ITAACs that are necessary and sufficient to provide reasonable assurance that, if the inspections, tests, and analyses are performed and the acceptance criteria met, a plant that incorporates the DC is built and will operate in accordance with the DC, the provisions of the Atomic Energy Act (AEA), and the U.S. Nuclear Regulatory Commission's (NRC's) regulations.

Prevention of potential gas accumulation in safety related systems, including emergency core cooling systems, are described in GL-2008-, "Managing Gas Accumulation In Emergency Core Cooling, Decay Heat Removal, and Containment Spray Systems". This includes, but is not limited to the Shutdown Cooling System (SCS), including potential gas entrainment during mid-loop operations from vortexing, the containment spray system (CSS), and the safety injection system (SIS).

NRC Regulatory Issue Summary 2013-09, endorses and recommends NEI 09-10, Revision 1a-A,
"Guidelines for Effective Prevention and Management of System Gas Accumulation" as an acceptable approach to managing gas accumulation (ML13136A129). The staff finds that the ITAACs submitted in response to RAI 42-7945 Question 19-2 do not adequately address the provisions in these documents. The staff is requesting KHNP to address GL-2008-01 and NEI 09-10, Revision 1a-A as they relate to SCS, SIS and CSS or provide and justify an alternate approach to managing gas accumulation.

ITAAC Gas Accumulation

The ITAAC below is representative of the standard ITAAC for gas accumulation.

Design Commitment	Inspections, Tests, Analyses	Acceptance Criteria
The decay heat removal function of the SCS, the emergency core cooling function of the SIS, and the containment heat removal function of the CSS will not be impaired by gas entrainment.	a. An analysis of the potential for gas entrainment will be performed to identify specific gas intrusion mechanisms that affect each local and system high point of the as-built configuration of the SCS, SIS, and CSS. The analysis will document the need for periodic monitoring and the monitoring interval based on design limits. b. An inspection will be performed to verify high point vents are installed in the as-built SCS, SIS, and CSS based on the analysis.	A report exist and concludes that the decay heat removal function of the SCS, the emergency core cooling function of the SIS, and the containment heat removal function of the CSS will not be impaired by gas entrainment The report identifies specific gas intrusion mechanisms that affect each local and system high point. The report will document the need for periodic monitoring and the monitoring interval based on design limits. b. High point vents are installed in the SCS, SIS, and CSS based on the analysis.

ITAAC Entrainment During Mid-Loop Operations

Section 5.4.7 discusses decay heat removal during mid-loop operation. An analysis will be performed to verify that the decay heat removal function of the SCS will not be impaired by gas entrainment during mid-loop operation while the system is operating at its maximum allowable flow rate and the reactor coolant hot leg level is at the lowest level allowable for decay heat removal.

The ITAAC below is representative of the standard ITAAC for gas entrainment during mid-loop operations.

Design Commitment	Inspections, Tests, Analyses	Acceptance Criteria
The decay heat removal function of the SCS will not be impaired by gas entrainment during mid-loop operation while the system is operating at its maximum allowable flow rate and the reactor coolant hot leg level is at the lowest level allowable for decay heat removal.	An analysis of the potential for gas entrainment during mid-loop operation will be performed of the as-built configuration of the SCS.	A report exist and concludes that the decay heat removal function of the SCS will not be impaired by gas entrainment during mid-loop operation while the system is operating at its maximum allowable flow rate and the reactor coolant hot leg level is at the lowest level allowable for decay heat removal.

Response

Gas Accumulation/Gas Entrainment

The SIS is designed to minimize the air accumulation in the pipe. The provision is made so that SIS piping locations susceptible to gas accumulation are sufficiently filled with water. Vent valves and Safety Injection Filling Tank (SIFT) provide the means for gravity filling of SIS piping. Detailed design features to address GL-2008-01 and NEI-09-10, Revision 1a-A are described in the DCD Tier 2 Subsections 6.3.2.1.2 and 6.3.2.2.6. DCD Tier 2 Figure 6.3.2-4 shows the SIS elevation diagram for gravity filling of SIS. TS SR 3.5.2.3 provides the surveillance requirements to verify the gas accumulation in SIS piping.

The Shutdown Cooling System is designed to accommodate the recommendations addressed in GL-2008-01 and NEI 09-10, Revision 1a-A. The SCS piping is designed so that air trap is minimized. Vent valves and pipe arrangement design also provide system venting and reasonable assurance that maintenance can be performed on each component. Design features to prevent air entrainment during mid-operation are described in Subsection 5.4.7.2.6.f. SCS train piping locations susceptible to gas accumulation are periodically verified if those are sufficiently filled with water accordance with TS SRs 3.9.4.2 and 3.9.5.4.

The CSS is designed to minimize the air accumulation in the pipe. Continuous gas venting of the CSS suction lines is performed by continuous sloping of pipes. No flange on piping or equipment located above the minimum IRWST operating level (92.6 ft) to prevent gas entrainment in the discharge lines, and the vent lines are located at piping high points and an inspection will be performed to verify high point vents to accommodate the recommendations addressed in GL-2008-01 and NEI 09-10, Revision 1a-A.

ITAAC Gas Accumulation

DCD Tier 1 Subsection 2.4.3.1 and Table 2.4.3-4 will be revised as indicated in the attachments.

DCD Tier 1 Subsection 2.4.4.1 and Table 2.4.4-4 will be revised as indicated in the attachments.

DCD Tier 1 Subsection 2.11.2.1 and Table 2.11.2-4 will be revised as indicated in the attachments.

ITAAC Entrainment During Mid-Loop Operations

DCD Tier 1 Subsection 2.4.1.1 and Table 2.4.1-4 will be revised as indicated in the attachments.

Impact on DCD

DCD Tier 1 Subsections 2.4.1.1, 2.4.3.1, 2.4.4.1, 2.11.2.1 and Tables 2.4.1-4, 2.4.3-4, 2.4.4-4, 2.11.2-4 will be revised as indicated in attachment.

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 Environmental Report.

8.d All displays and alarms required by the design exist in the RSR as defined in Tables 2.4.3-2 and 2.4.3-3.

9.a The SIS provides RCS makeup, boration, and safety injection during design basis accidents.

9.b The pumps identified in Table 2.4.3-2 perform their safety function under expected ranges of fluid flow, pump head, electrical conditions, and temperature conditions up to and including design basis conditions.

9.c The SI pumps have sufficient net positive suction head (NPSH).

9.d The SI pumps deliver full flow to the reactor vessel within 40 seconds following receipt of a signal simulating ESF-SIAS or DPS-SIAS.

9.e The SI pumps can be tested at full flow during plant operation.

9.f The SIS can be manually realigned for simultaneous hot leg injection and direct vessel injection (DVI).

9.g The pumps identified in Table 2.4.3-2 start after receiving an ESF-SIAS or DPS-SIAS.

9.h A confirmatory-open interlock is provided to automatically open the SIT discharge valve upon receipt of an ESF-SIAS or DPS-SIAS.

10. The piping system qualified for LBB identified in Table 2.4.3-1 meets the LBB criteria

11. The emergency core cooling function of the SIS will not be impaired by gas entrainment.

2.4.3.2 <u>Inspections, Tests, Analyses, and Acceptance Criteria</u>

Table 2.4.3-4 specifies the inspections, tests, analyses, and acceptance criteria for the SIS.

Table 2.4.3-4 (8 of 8)

Design Commitment	Inspections, Tests, Analyses	Acceptance Criteria
9.f The SIS can be manually realigned for simultaneous hot leg injection and direct vessel injection (DVI).	9.f Testing will be performed with the system manually aligned for simultaneous DVI and hot leg injection.	9.f Each as-built SI pump injects no less than or equal to 3,195 L/min (1,034 gpm) and no more than or equal to 4,201 L/min (1,100 gpm) through each hot leg and DVI line with the RCS at atmospheric pressure.
9.g The pumps identified in Table 2.4.3-2 start after receiving an ESF-SIAS or DPS-SIAS.	9.g Tests will be performed on the as-built pumps in Table 2.4.3-2 using simulated signals.	9.g The as-built pumps in Table 2.4.3-2 start after receiving a simulated ESF-SIAS or DPS-SIAS.
9.h A confirmatory-open interlock is provided to automatically open the SIT discharge valve upon receipt of an ESF-SIAS or DPS-SIAS.	9.h Tests will be performed using simulated signals.	9.h The as-built SIT discharge valves in Table 2.4.3-2 automatically opens upon receipt of simulated ESF-SIAS or DPS-SIAS.
10. The piping system qualified for LBB identified in Table 2.4.3-1 meets the LBB criteria, or protection of dynamic effect from high energy line break is performed.	10. Inspections and analyses of the as-built piping system qualified for LBB identified in Table 2.4.3-1 will be performed, or inspections and analyses of the as-built high-energy piping including the protective features and safety-related SSCs will be performed.	10. For piping system qualified for LBB identified in Table 2.4.3-1, an LBB evaluation report exists which documents that the LBB acceptance criteria are met by the as-built piping system including the final detailed design parameters. For the piping not applied LBB, pipe rupture hazard analysis report exits and concludes that the as-built
11. The emergency core cooling function of the SIS will not be impaired by gas entrainment.	11.a. An analysis of the potential for gas entrainment will be performed to identify specific gas intrusion mechanisms that affect each local and system high point of the as-built configuration of the SIS. The analysis will document the need for periodic monitoring and the monitoring interval based on design limits. b. An inspection will be performed to verify high point vents are installed in the as-built SIS based on the analysis.	11. a. A report exists and concludes that the emergency core cooling function of the SIS will not be impaired by gas entrainment. The report identifies specific gas intrusion mechanisms that affect each local and system high point. The report will document the need for periodic monitoring and the monitoring interval based on design limits. b. High point vents are installed in the SIS based on the analysis.

8.c All displays and alarms required by the design exist in the MCR as defined in Tables 2.4.4-2 and 2.4.4-3.

8.d All displays and alarms required by the design exist in the RSR as defined in Tables 2.4.4-2 and 2.4.4-3.

9.a The SCS cools the reactor by removing decay heat and other residual heat from the reactor core and the RCS during the normal plant shutdown and cool down conditions.

9.b The SCS suction line relief valves provide RCS low temperature overpressure protection (LTOP).

9.c The pumps identified in Table 2.4.4-2 perform their safety function under expected ranges of fluid flow, pump head, electrical conditions, and temperature conditions up to and including design-basis conditions.

9.d Each SCP has sufficient net positive suction head (NPSH) in each operating configuration.

9.e Each SCP has a full flow test capability during a normal plant operating condition when the pump suction is aligned to the IRWST and the discharge is aligned to the IRWST.

9.f A containment spray actuation signal (CSAS) or engineered safety features-safety injection actuation signal (ESF-SIAS) starts SCP only when SCP is aligned for containment spray pump (CSP) function.

10. The piping system qualified for LBB identified in Table 2.4.4-1 meets the LBB criteria

11. The decay heat removal function of the SCS will not be impaired by gas entrainment.

2.4.4.2 Inspections, Tests, Analyses, and Acceptance Criteria

Table 2.4.4-4 specifies the inspections, tests, analyses, and acceptance criteria for the SCS.

Table 2.4.4-4 (7 of 7)

Design Commitment	Inspections, Tests, Analyses	Acceptance Criteria
9.e Each SCP has a full flow test capability during a normal plant operating condition when the pump suction is aligned to the IRWST and the discharge is aligned to the IRWST.	9.e Testing of SCP will be performed when the pump suction is aligned to the IRWST and the discharge is aligned to the IRWST.	9.e SCP delivers flow to IRWST of 18,927 L/min (5,000 gpm) when it takes suction from the IRWST.
9.f A containment spray actuation signal (CSAS) or engineered safety features-safety injection actuation signal (ESF-SIAS) starts SCP only when SCP is aligned for containment spray pump (CSP) function.	9.f Testing of simulated CSAS or ESF-SIAS when SCP is aligned for CSP function will be performed.	9.f SCP starts when receiving CSAS or ESF-SIAS when SCP is aligned for CSP function.
10. The piping system qualified for LBB identified in Table 2.4.4-1 meets the LBB criteria, or protection of dynamic effect from high energy line break is performed.	10. Inspections and analyses of the as-built piping system qualified for LBB identified in Table 2.4.4-1 will be performed, or inspections and analyses of the as-built high-energy piping including the protective features and safety-related SSCs will be performed.	10. For piping system qualified for LBB identified in Table 2.4.4-1, an LBB evaluation report exists which documents that the LBB acceptance criteria are met by the as-built piping system including the final detailed design parameters. For the piping not applied LBB, 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.
11. The decay heat removal function of the SCS will not be impaired by gas entrainment.	11.a An analysis of the potential for gas entrainment will be performed to identify specific gas intrusion mechanisms that affect each local and system high point of the as-built configuration of the SCS. The analysis will document the need for periodic monitoring and the monitoring interval based on design limits.	11.a A report exists and concludes that the decay heat removal function of the SCS will not be impaired by gas entrainment. The report identifies specific gas intrusion mechanisms that affect each local and system high point. The report will document the need for periodic monitoring and the monitoring interval based on design limits.
	11.b An inspection will be performed to verify high point vents are installed in the as-built SCS based on the analysis.	11.b High point vents are installed in the SCS based on the analysis.

10. The CSS pumps have sufficient net positive suction head (NPSH).

11. The CSS has heat removal capacity to control the containment atmosphere temperature and pressure.

12. The moderate-energy piping systems are reconciled with pipe rupture hazards analyses report to ensure that the safety-related SSCs are protected against or are qualified to withstand the environmental effects associated with postulate failures of these piping systems.

13. The containment heat removal function of the CSS will not be impaired by gas entrainment.

2.11.2.2 Inspections, Tests, Analyses, and Acceptance Criteria

The inspection, tests, analyses, and associated acceptance criteria for the CSS are specified in Table 2.11.2-4.

The ITAAC related to the CIVs and the piping between the CIVs of the CSS are described in Table 2.11.3-2.

Table 2.11.2-4 (6 of 6)

Design Commitment	Inspections, Tests, Analyses	Acceptance Criteria
11. The CSS has heat removal capacity to control the containment atmosphere temperature and pressure.	11.a Analyses will be performed to determine the heat removal capacities of the as-built CS heat exchanger.	11.a A report exists and concludes that the product of the overall heat transfer coefficient and the effective heat transfer area, UA, of each CS heat exchanger identified in Table 2.11.2-2 is greater than or equal to 7.793 × 105 cal/hr-°C (1.718 × 106 Btu/hr-°F).
	11.b A test of the as-built CS pump will be performed to measure the flow rate to the CS heat exchanger.	11.b The as-built CS pump identified in Table 2.11.2-2 delivers at least 18,927 L/min (5,000 gpm) to the CS heat exchanger.
12. The moderate-energy piping systems are reconciled with pipe rupture hazards analyses report to ensure that the safety-related SSCs are protected against or are qualified to withstand the environmental effects associated with postulate failures of these piping systems.	12. Inspections and analyses of the as-built moderate-energy piping and safety-related SSCs will be performed.	12. 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 moderate-energy piping system.
13. The containment heat removal function of the CSS will not be impaired by gas entrainment.	13. a. An analysis of the potential for gas entrainment will be performed to identify specific gas intrusion mechanisms that affect each local and system high point of the as-built configuration of the CSS. The analysis will document the need for periodic monitoring and the monitoring interval based on design limits. b. An inspection will be performed to verify high point vents are installed in the as-built CSS based on the analysis.	13. a. A report exists and concludes that the containment heat removal function of the CSS will not be impaired by gas entrainment. The report identifies specific gas intrusion mechanisms that affect each local and system high point. The report will document the need for periodic monitoring and the monitoring interval based on design limits. b. High point vents are installed in the CSS based on the analysis.

10. The RV is equipped with holders for at least six capsules for accommodating material surveillance specimens.

11. RV material specimens taken from materials actually used in fabrication of the beltline region are inserted in the capsules and include Charpy V-notch specimens of base metal, weld metal and heat-affected zone material and tensile and 1/2T compact tension specimens from base metal and weld metal.

12. CEDMs release the CEAs upon termination of electrical power to the CEDM.

13. The piping system qualified for LBB identified in Table 2.4.1-1 meets the LBB criteria

14. The decay heat removal function of the SCS will not be impaired by air entrainment into the SCS suction nozzle.

2.4.1.2 Inspections, Tests, Analyses, and Acceptance Criteria

Table 2.4.1-4 specifies the inspections, tests, analyses, and associated acceptance criteria for the reactor coolant system.

Table 2.4.1-4 (7 of 7)

Design Commitment	Inspections, Tests, Analyses	Acceptance Criteria
12. CEDMs release the CEAs upon termination of electrical power to the CEDMs.	12. Tests are performed on the as-built CEDMs to confirm scramability.	12. Maximum drop time for 90 % insertion of the CEA is 4.0 seconds.
13. The piping system qualified for LBB identified in Table 2.4.1-1 meets the LBB criteria.	13. Inspections and analyses of the as-built piping system qualified for LBB identified in Table 2.4.1-1 will be performed.	13. For piping system qualified for LBB identified in Table 2.4.1-1, an LBB evaluation report exists which documents that the LBB acceptance criteria are met by the as-built piping system including the final detailed design parameters.
14. The decay heat removal function of the SCS will not be impaired by gas entrainment during mid-loop operation while the system is operating at its maximum allowable flow rate and the reactor coolant hot leg level is at the lowest level allowable for decay heat removal.	14. Analyses or tests of the potential for gas entrainment during mid-loop operation will be performed on the as-built configuration of the SCS.	14. A report exists and concludes that the decay heat removal function of the SCS will not be impaired by gas entrainment during mid-loop operation while the system is operating at its maximum allowable flow rate and the reactor coolant hot leg level is at the lowest level allowable for decay heat removal.