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.:	**42-7945**
SRP Section:	**19.2.2.2**
Application Section:	**19.2.2.2**
Date of RAI Issued:	**06/22/2015**

Question No. 19-2

10 CFR 52.47(a)(27) requires that a standard design certification applicant provide a description of the design specific PRA and the results. SRP Chapter 19, Revision 3 (Draft), “Design- Specific PRA (PRA for Non-Power Modes of Operation)” states that, “Given that shutdown risk may be highly outage-specific, the staff reviews the shutdown PRA insights to confirm that operational assumptions used to develop an average shutdown model (e.g., use of nozzle dams, outage schedule, containment status, procedural requirements) have been clearly documented in the FSAR.” Staff reviewed the Low Power Shutdown (LPSD) PRA results and found that the frequency of overdraining events (basic event, SO), which result in loss of the Shutdown Cooling System (SCS) pumps from air entrainment during midloop operations, to be key LPSD risk contributors. The staff then reviewed DCD Section 5.4.7 for design and operational details that support the frequency of overdraining used in the PRA. FSAR Section states that the Reactor Coolant System (RCS) level is maintained higher than the RCS low water level of [ ]TS above the loop center, and an SCS flow rate of [ ]TS [ ]TS is maintained. DCD Section 19.2.2.2, states “The shutdown cooling suction lines do not contain loop seals, thereby minimizing the potential to trap gas. The suction piping layout allows self-venting of accumulated gas (or air).” The staff also reviewed the Shutdown Evaluation Report, Section 2.3 “Reduced Inventory Operations and Generic Letter No. 88-17 Fixes” which states, “The APR1400 SCS suction lines do not contain any loop seals. The suction piping also has high point vents in order to release the gas accumulation. SCS pumps can be restarted with suitable venting procedures, providing reasonable assurance of an expedited reflood of the shutdown cooling pump suction.”

General Design Criteria 34 requires a residual heat removal (RHR) system designed to maintain specified acceptable fuel design limits and to meet design conditions that are not exceeded if a single failure occurs simultaneous with failure of specified electrical power systems. The enclosure to NRC Generic Letter (GL) 2008-01, “Managing Gas Accumulation in Emergency Core Cooling, Decay Heat Removal, and Containment Spray Systems” specifically addresses gas accumulation concerns in decay heat removal (DHR) piping. The Generic Letter covers both gas accumulation and vortexing from suction sources.

Consistent with General Design Criteria 34 (GDC 34) and GL 2008-01, the staff needs to determine that the potential for gas accumulation in the SCS was addressed. Also, the staff needs to determine that vortexing does not initiate at the specific hotleg levels and SCS flow rates specified above. There was insufficient information in the application to support both determinations. In accordance with SRP Chapter 19, the operational assumptions used to develop the LPSD PRA model should be clearly documented in the FSAR. Thus, the staff requests the following information be included in the FSAR:

1. The results of tests or analyses and key assumptions that conclude that vortexing does not initiate at the hot leg levels and the SCS flow rates specified above. This is needed because the staff could not find this information in the application.

2. The key design details that support the assumptions in Section 19.2.2.2 of the DCD that the SCS suction lines do not contain loop seals and the SCS suction piping allows self venting of accumulated gas or air. These key design details should be verified by an ITAAC (per SRP 14.3) and included in the APR1400 Risk Insights Table, or justification why these additions are not necessary should be provided.

3. An ITAAC verifying that decay heat removal can be maintained at the highest anticipated operational flow rate (4150 gpm) and the lowest anticipated hot leg level (3.28 inches above hot leg centerline) without indications of vortexing. This information is necessary to show conformance with GDC 34

Response

1. A test was performed to measure the hot leg levels and SCS flow rates where vortexing initiates in the mid-loop condition for the Ulchin NPP unit 3, the first OPR1000 plant. The test results show that vortexing started to initiate at the SCS flow rate of [ ]TS

   The mid-loop test results for an OPR1000 are applicable to the APR1400 design because the APR1400 geometries of the hot leg and SCS suction piping are identical to those of the OPR1000. Therefore, vortexing does not occur if the RCS water level is maintained [ ]TS is maintained.

2. The suction piping is arranged such that trapping of gases is precluded. The horizontal sections of the SCS piping on the pump suction side of the SCS piping are designed to slope continuously downward.

   DCD Tier 1, Table 2.4.4-4 will be revised to include an ITAAC to inspect the as-built SCS piping to ensure this downward slope is present and that piping from the RCS to the SCP has no loop seal, as shown in the attachment to this response.

3. Testing has shown that vortexing starts at an SCS flow rate of [ ]TS below the centerline of hot leg. Therefore, it is not necessary to include in the DCD an ITAAC which verifies there is no vortexing at the highest anticipated operational flow rate and the lowest anticipated hot leg level.

Impact on DCD

DCD Tier 1 Section 2.4.4.1 and Table 2.4.4-4 will be revised as indicated on the attached markup.

Impact on PRA

There is no impact on the PRA.

Impact on Technical/Topical/Environmental Reports

There is no impact on any Technical, Topical or Environmental Reports.

Impact on Technical Specifications

There is no impact on the Technical Specifications.

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

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.

9.g The piping of SCS contains no loop seals and maintains a horizontal or downward slope from the RCS to the SCP, with exception to the section of piping adjacent to the pump suction flange.

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.
9.g The piping of the SCS contains no loop seals and maintains a horizontal or downward slope from the RCS to the SCP, with exception to the section of piping adjacent to the pump suction flange.	9.g Inspection of the as-built piping will be conducted.	9.g SCS piping contains no loop seals and maintains a horizontal or downward slope from the RCS to the SCP, with exception to the section of piping adjacent to the pump suction flange, which has an upward section of piping.

RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

APR1400 Design Certification

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Docket No. 52-046

RAI No.: **No. 42-7945**

SRP Section: **SRP 19**

Application Section: **19.1.**

Date of RAI Issued: **06/08/2015**

Question No. 19-3

10 CFR 52.47(a)(27) requires that a standard design certification applicant provide a description of the design specific PRA and the results. SRP Chapter 19, Revision 3 (Draft), states, "The staff will determine that the applicant has performed risk importance studies at the system, train, and component level that adequately provide insights about (1) the systems that contribute the most in achieving the low risk level assessed in the PRA, (2) events (e.g., component failures or human errors) that contribute the most to decreases in the built-in plant safety level, and (3) events that contribute the most to the assessed risk." In this context, the tables reporting risk assessment worth (RAW) values for the low power shutdown (LPSD) PRA appear to have omitted risk significant initiating events, such as RCS overdraining at mid-loop, and PRA initiating event %SO, from the risk achievement analyses. Either add LPSD initiating events in the risk achievement worth analyses for the staff to determine which shutdown initiating events contribute most to the assessed risk, should they occur, or justify why this addition is not necessary.

Response

Table 1 lists the risk-significant initiating events for LPSD PRA. The events are ordered by their Fussell-Vesely importance.

Table 1
LPSD Internal Events PRA Initiating Events by FV (CDF)

No	Event	Description	FV	RAW	RRW
1	%SO	RCS Overdraining due to SCS	5.67E-01	1.96E+02	2.31E+00
2	%SL	Failure to Maintain Water Level at Reduced Inventory	9.74E-02	1.24E+00	1.11E+00
3	%SL1	Small LOCA at Reduced Inventory	5.38E-02	1.28E+00	1.06E+00

Table 1 LPSD Internal Events PRA Initiating Events by FV (CDF)					
No	**Event**	**Description**	**FV**	**RAW**	**RRW**
4	%PL	POSRV Fails to Re-Close (*)	3.69E-02	1.10E+01	1.04E+00
5	%S1	Recoverable Loss of Shutdown Cooling	3.66E-02	1.22E+00	1.04E+00
6	%TC	Total Loss of Component Cooling Water	3.39E-02	1.46E+02	1.04E+00
7	%TS	Total Loss of Essential Service Water	3.39E-02	1.46E+02	1.04E+00
8	%LPSW	Switchyard-centered Loss of Offsite Power	2.76E-02	1.40E+00	1.03E+00
9	%SL2	Small LOCA above Reduced Inventory	2.35E-02	1.65E+00	1.02E+00
10	%LPWE	Weather-related Loss of Offsite Power	2.32E-02	1.61E+00	1.02E+00
11	%LPPL	Plant-centered Loss of Offsite Power	2.16E-02	1.39E+00	1.02E+00
12	%KV	Loss of Class 1E 4.16 kV Bus (SCS power)	1.06E-02	1.29E+00	1.01E+00
13	%ES	Partial Loss of Essential Service Water	7.34E-03	1.39E+00	1.01E+00
14	%S2	Unrecoverable Loss of Shutdown Cooling	6.91E-03	1.31E+00	1.01E+00
15	%LPGR	Grid-related Loss of Offsite Power (*)	5.48E-03	1.47E+00	1.01E+00
16	%JL	Unrecoverable LOCA (CVCS Letdown Line)	5.03E-03	2.00E+00	1.01E+00
17	%CC	Partial Loss of Component Cooling Water	2.65E-03	1.39E+00	1.00E+00
18	%MLOCA	Medium Loss of Coolant Accident (*)	1.86E-03	4.84E+00	1.00E+00
19	%ATWS	Anticipated Transient Without Scram (*)	1.13E-03	2.20E+02	1.00E+00
20	%RL	LTOP Relief Valve Fails to Re-Close (*)	9.53E-04	1.11E+00	1.00E+00
21	%LOOP-GR	Grid-Related LOOP (*)	4.53E-04	1.04E+00	1.00E+00
22	%SLOCA	Small Loss of Coolant Accident (*)	3.25E-04	1.16E+00	1.00E+00
23	%TLOESW	Total Loss of Essential Service Water (*)	3.05E-04	1.40E+00	1.00E+00
24	%LOOP-WE	Weather-Related LOOP (*)	2.39E-04	1.06E+00	1.00E+00
25	%TLOCCW	Total Loss of Component Cooling Water (*)	2.39E-04	1.40E+00	1.00E+00
26	%GTRN	General Transient (*)	1.49E-04	1.00E+00	1.00E+00
27	%SGTR	Steam Generator Tube Rupture (*)	1.47E-04	1.07E+00	1.00E+00
28	%RVR	Reactor Vessel Rupture (*)	9.79E-05	3.37E+03	1.00E+00
29	%LOOP-PL	Plant-Centered LOOP (*)	4.90E-05	1.03E+00	1.00E+00
30	%LOFW	Loss of Main Feedwater (*)	3.61E-05	1.00E+00	1.00E+00
31	%LOCV	Loss of Condenser Vacuum (*)	3.59E-05	1.00E+00	1.00E+00
32	%LSSB-D	Large Secondary Side Break (MSIV Downstream) (*)	2.00E-05	1.00E+00	1.00E+00
33	%LOIA	Loss of Instrument Air (*)	3.51E-06	1.00E+00	1.00E+00
(*) Transition mode events (>200^{o}F)					

Impact on DCD

DCD 19.1 will be revised to reflect the response of this RAI.

The table which is provided as the response of this RAI will be added between Table 19.1-105 and Table 19.1-106 in DCD 19.1 as shown in the 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

The table which is provided as the response of this RAI will be added between Table 1-105 and Table 1-106 in PRA Summary Report.

Table 19.1-105a

LPSD Internal Events PRA Key Initiating Events by FV (CDF)

Initiating Event	Description	FV
%SO	RCS Overdraining due to SCS	56.7%
%SL	Failure to Maintain Water Level at Reduced Inventory	9.7%
%SL1	Small LOCA at Reduced Inventory	5.4%
%PL	POSRV Fails to Re-Close (*)	3.7%
%S1	Recoverable Loss of Shutdown Cooling	3.7%
%TC	Total Loss of Component Cooling Water	3.4%
%TS	Total Loss of Essential Service Water	3.4%
%LPSW	Switchyard-centered Loss of Offsite Power	2.8%
%SL2	Small LOCA above Reduced Inventory	2.4%
%LPWE	Weather-related Loss of Offsite Power	2.3%
%LPPL	Plant-centered Loss of Offsite Power	2.2%
%KV	Loss of Class 1E 4.16 kV Bus (SCS power)	1.1%
%ES	Partial Loss of Essential Service Water	0.7%
%S2	Unrecoverable Loss of Shutdown Cooling	0.7%
%LPGR	Grid-related Loss of Offsite Power (*)	0.5%
%JL	Unrecoverable LOCA (CVCS Letdown Line)	0.5%
%CC	Partial Loss of Component Cooling Water	0.3%
%MLOCA	Medium Loss of Coolant Accident (*)	0.2%
%ATWS	Anticipated Transient Without Scram (*)	0.1%
%RL	LTOP Relief Valve Fails to Re-Close (*)	0.1%

(*) Transition mode events (>200 °F)

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Docket No. 52-046

RAI No.:	**No. 42-7945**
SRP Section:	**SRP 19**
Application Section:	**19.1.**
Date of RAI Issued:	**06/08/2015**

Question No. 19-4

10 CFR 52.47(a)(27) requires that a standard design certification applicant provide a description of the design specific PRA and the results. SRP Chapter 19, Revision 3 (Draft), "Design-Specific PRA (PRA for Non-Power Modes of Operation)" states that, "Given that shutdown risk may be highly outage-specific, the staff reviews the shutdown PRA insights to confirm that operational assumptions used to develop an average shutdown model (e.g., use of nozzle dams, outage schedule, containment status, procedural requirements) have been clearly documented in the FSAR." The staff reviewed the applicant's definitions of Plant Operational States (POSs) defined in Table 19.1-81, LPSD Plant Operating States. The staff notes that POS development is a high level requirement in the ANS LPSD PRA standard issued for trial use. POS development is also necessary to perform a shutdown PRA since POS definitions are used to define success criteria for core cooling and timing for containment closure for each assessed shutdown plant operational state. The timing for core boiling and core uncovery is needed to confirm the numerical estimates for operator recovery, which drives shutdown risk. The staff needs more information regarding the POS definitions used to develop the average shutdown model. For each POS provide the following information in the FSAR:

1. The anticipated decay heat level and the associated time post shutdown
2. The size and locations of any RCS vents
3. The assumed RCS water level
4. The time to RCS boiling given a loss of the decay heat removal function
5. The time to core unrecovery
6. The thermal-hydraulic code used to assess the POS and a discussion of the acceptability of the code to assess that POS

Response

The responses are as follows:

- Table 2 provides the additional information on each plant operating state (POS) for items # 1, 3, 4 and 5. (Note: No. 5 is taken to be "The time to core uncover")
- Table 3 provides the additional information on the RCS vents for item #2.
- The response to item #6 is provided following Table 3.

Table 2
Summary of Result for Plant Operating States and Analysis

POS	Description	Anticipated Decay Heat Level (MWt)	Associated Time Post Shutdown (hrs)	Size and Locations of any RCS Vents	Minimum RCS Water Level During POS	Cases	Time to RCS Boiling	Time to Core Uncover
03A	Cooldown with Shutdown Cooling System to 212°F	24.6	32.9	RCS is intact and LTOP valves are in auto protection mode	Normal operation level	Base	16801 sec (4.67 hrs)	19943 sec (5.54 hrs)
						LTOP B Stuck-open at t=0	190 sec (0.05 hrs)	3061 sec (0.85 hrs)
						LOCA through CVCS Letdown line	13103 sec (3.64 hrs)	19837 sec (5.51 hrs)
03B	Cooldown with Shutdown Cooling System to 140°F	24.6	37.5	RCS is intact and LTOP valves are in auto protection mode	Normal operation level	N/A	N/A	N/A
04A	Reactor Coolant System drain-down (pressurizer manway closed)	18.6	75.1	RCGVS (Reactor Coolant System Gas Vent System) is open and LTOP valves are in auto protection mode	Normal operation level	Base	10728 sec (2.98 hrs)	48146 sec (13.37 hrs)
						LOCA through CVCS Letdown line	9724 sec (2.70 hrs)	47646 sec (13.24 hrs)
04B	Reactor Coolant System drain-down (pressurizer manway open)	18.5	76.4	Pressurizer manway open. RCGS (Reactor Coolant System Gas Vent System) open and LTOP valves are in auto protection mode	Hot leg top level	Base	134 sec (0.04 hrs)	5599 sec (1.56 hrs)
						LOCA through CVCS Letdown line	38 sec (0.01 hrs)	5502 sec (1.53 hrs)

Table 2
Summary of Result for Plant Operating States and Analysis

POS	Description	Anticipated Decay Heat Level (MWt)	Associated Time Post Shutdown (hrs)	Size and Locations of any RCS Vents	Minimum RCS Water Level During POS	Cases	Time to RCS Boiling	Time to Core Uncover
05	Reduced Inventory operation and nozzle dam installation	16.8	96.7	Pressurizer manway open. Steam generators manway open. RCGVS (Reactor Coolant System Gas Vent System) open and LTOP valves are in auto protection mode	Mid-loop Operation level	Base	400 sec (0.11 hrs)	4582 sec (1.27 hrs)
						LOCA through CVCS Letdown line	398 sec (0.11 hrs)	4161 sec (1.16 hrs)
06	Fill for refueling	15.7	113.5	Pressurizer manway open. ICI tubes open. RCGVS (Reactor Coolant System Gas Vent System) open and LTOP valves are in auto protection mode. Nozzle dam installed	Reactor vessel flange level	Base	364 sec (0.10 hrs)	6020 sec (1.67 hrs)
						LOCA through CVCS Letdown line	362 sec (0.10 hrs)	5924 sec (1.65 hrs)
10	Reactor Coolant System drain-down to Reduced Inventory after refueling	9.3	435.9	Pressurizer manway open. ICI tubes open. RCGVS (Reactor Coolant System Gas Vent System) open and LTOP valves are in auto protection mode. Nozzle dam installed	Reactor vessel flange level	Base	861 sec (0.24 hrs)	10248 sec (2.85 hrs)
						LOCA through CVCS Letdown line	850 sec (0.24 hrs)	10133 sec (2.81 hrs)

Table 2
Summary of Result for Plant Operating States and Analysis

POS	Description	Anticipated Decay Heat Level (MWt)	Associated Time Post Shutdown (hrs)	Size and Locations of any RCS Vents	Minimum RCS Water Level During POS	Cases	Time to RCS Boiling	Time to Core Uncover
11	Reduced Inventory operation with steam generator manway closed	8.7	521.7	Pressurizer manway open. Steam generators manway open. RCGVS (Reactor Coolant System Gas Vent System) open and LTOP valves are in auto protection mode.	Mid-loop operation level	Base	1258 sec (0.35 hrs)	9874 sec (2.74 hrs)
						LOCA through CVCS Letdown line	1233 sec (0.34 hrs)	9914 sec (2.75 hrs)
12A	Refill Reactor Coolant System (pressurizer manway open)	8.6	534.9	Pressurizer manway open. LTOP valves are in auto protection mode	Hot leg center +13" level	Base	455 sec (0.13 hrs)	20094 sec (5.58 hrs)
						LOCA through CVCS Letdown line	451 sec (0.13 hrs)	19579 sec (5.44 hrs)
12B	Refill Reactor Coolant System (manway closed)	8.6	539.1	RCGVS (Reactor Coolant System Gas Vent System) open and LTOP valves are in auto protection mode.	28.2% Pressurizer level	Base	37176 sec (10.33 hrs)	No core uncovery (simulation time 25.0 hrs)
						LOCA through CVCS Letdown line	16713 sec (4.64 hrs)	85395 sec (23.72 hrs)
13	Reactor Coolant System heat-up with Shutdown Cooling System isolation at 350°F	8.4	562.3	RCS is intact and LTOP valves are in auto protection mode.	Normal operation level	Base	53063 sec (14.74 hrs)	60661 sec (16.85 hrs)
						LOCA through CVCS Letdown line	13703 sec (3.81 hrs)	59294 sec (16.47 hrs)

Table 3 Description of RCS Vents		
RCS Openings	**Size**	**Location**
RV Head RCGVS nozzle (D-HC-11162-C01)	0.75 inch	RV Head
POSRV RCGVS nozzle (D-HC-22162-C01)	0.75 inch	PZR Top
Pressurizer manway (D-HC-22162-C01)	16 inch	PZR Top
Steam generator A and B manway (E-3L186-220-001, D-HC-21154-C01)	21 inch	117ft 4 inch (same as SG outlet nozzle)
ICI tubes (3L186-ME-DS824-00)	1.023 inch (61 total)	RV bottom head

The following response of the thermal-hydraulics code used to analyze each POS is provided in response to item #6.

- Analysis code: RELAP5/MOD3.3 Patch 4

- Discussion: RELAP5/MOD3.3 is a best estimate thermal-hydraulic analysis code. It can analyze reactor accident response during the full range from power operation to mid-loop operations while shutdown. Separate analyses were performed for each Plant Operating State (POS). The POS were defined, consistent with the draft shutdown ASME standard, to establish an appropriate set of unique combinations of plant temperature, pressure, water level, mode of decay heat removal, and RCS configuration (e.g., whether the RCS is intact or not). The results of these analyses were used to establish success criteria for the accident mitigation functions in each POS.

Impact on DCD

There is no impact on the DCD.

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.