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.:	**232-7864**
SRP Section:	**SRP 19**
Application Section:	**19.1.**
Date of RAI Issued:	**09/30/2015**

Question No. 19-8

10 CFR 52.47(27) requires that a standard design certification applicant provide a description of the design specific PRA and the results. Design Control Document Section 19.1.6, appears to be missing event trees for all plant operational states other than plant operational state 5, which represents mid-loop conditions. However, the plant response to a loss of decay heat removal (DHR) is significantly different if the reactor coolant system (RCS) is intact versus an open RCS. To provide an example of how the different plant operational states were modeled in the probabilistic risk assessment (PRA), the staff is requesting that the applicant add the event trees for all plant operational states for the initiating event, loss of the operating train of the shutdown cooling (SDC) system. The staff considers these low power shutdown (LPSD) event trees part of the PRA results. These event trees will allow the reader to understand the varying plant response to a shutdown initiating event given the different plant operational states.

10 CFR 52.47(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 noted that LPSD risk from POS 7 and POS 9 was screened from the average shutdown model. The staff understands the cavity is filled to the level necessary for core alterations in POS 7 and POS 9. The staff also acknowledges the flow limitations in the letdown line. However, the possibility of installed reactor internals could shorten the time to core boiling given limited communication between the RCS inventory around the core and inventory in the refueling cavity. In addition, losses of RCS inventory could be caused by operators (valve misalignments). To confirm appropriate screening of POS 7 and POS 9 from the LPSD PRA, the staff needs the following information documented in the DCD: (a) an evaluation documenting the time to core damage given an extended loss of the decay heat removal function with installed reactor internals, (b) an evaluation documenting the time to core damage given an extended loss of the decay heat removal function with the reactor internals removed, (c) an

evaluation that considers all possible drain paths from the refueling cavity including drain rates, (d) the availability of instrumentation and alarms to detect and mitigate each potential drain path, (e) the likelihood of the operator failing to terminate each potential leak path, and (f) the availability of pumps and a source of water to restore RCS inventory for each leak path.

Response – (Rev. 1)

All Low Power & Shutdown event trees, for all Plant Operating States, are provided in APR1400-K-P-NR-013702-P. This document is available on the Electronic Reading Room level “No_2,” in sublevel “10_All PRA notebooks.”

(a) RELAP calculations were performed to determine the time to core damage in POS 7. POS 9 differs from POS 7 only in that it is later in refueling and decay heat will be lower; therefore, the POS 7 result bounded POS 9. The results with the reactor internals installed are as follows.

Condition	POS 7	POS 9
Event time (Decay heat)	7 days after reactor trip (14.0 MWt)	16 days after reactor trip (10.3 MWt)
RCS Initial condition	Normal refueling level	Normal refueling level
Time to CD with reactor internals installed	63.1 hrs	Bounded by POS 7
Time to CD with reactor internals removed	68.6 hrs	

There are no temporary fuel racks in the cavity. DCD 9.1.4.2 will be revised as shown in Attachment 1.

The volume of the refueling cavity is 44450.6 ft^3(1258.7 m^3) which is applied to quantitative evaluation and calculated as 44450.6 ft^3(1258.7 m^3). DCD 9.1.4 will be revised as shown in Attachment 2.

(b) The RELAP results with the reactor internals removed are also listed in the table above.

(c) During cavity-flooded operations, the only potentially significant drainage path is via the suction lines for the Shutdown Cooling System (SCS). In this case, the discharge to the IRWST is opened, and the discharge back to the Reactor Coolant System (RCS) is closed. The letdown line is normally isolated in these states because there is insufficient pressure in the primary system to force flow through the letdown orifices. Instead, a portion of the SCS discharge, downstream of the SC heat exchangers, is diverted to shutdown purification.

Other potential discharge paths, such as the cross-tie to the Containment Spray system, are normally isolated during shutdown. The SCS discharge to the sampling system is only intermittently in service, and the 3/8” line will not divert a significant flow rate.

DCD 19.1.6.1.1.5 will be revised as shown in Attachment 3. The potential drain down paths of SCS are shown in Attachment 4.

As per FSAR Table 5.4.7-1, the maximum Shutdown Cooling System flow is 6134 gpm. The normal SCS flow rate during High Water Level operation is >4800 gpm per Technical Specification Surveillance Requirement 3.9.4.1. Diversion flow is limited by an additional orifice on each discharge line to the IRWST.

Any other potential diversion scenarios will occur much more slowly, allowing the operators more time to identify and correct the configuration.

(d) The operators will have the Permanent Refueling Water Level Indication System (PWRLIS) for monitoring reactor cavity level. The IRWST also has redundant level transmitters that provide control room indication. In addition, they will have valve position indications, to identify an inventory diversion from the RCS to the IRWST. The IRWST temperature indicators will increase, confirming the inflow from the RCS. The PRWLIS provides low and low-low RCS water level alarms and was specifically designed to support safe draindown operation.

A radar-type level transmitter is installed in the refueling cavity to measure water level from the bottom to 12 inches below the top. The refueling cavity water level is indicated in the MCR and RSR. In addition, a temporary local level indicator is connected to the transmitter to measure the refueling cavity water level during refueling operation. The refueling cavity water level transmitter annunciates high water level (El. 154 ft 2 in) and low water level (El. 153 ft 10 in) to the MCR and RSR. DCD 9.1.3.5.4 will be revised as shown in Attachment 5.

(e) The probability of operator failure to isolate a potential drainage path has not been quantified, based upon the following considerations:

- The most rapid draindown scenario is an inadvertent diversion of the Shutdown Cooling System discharge to the IRWST. This evolution is normally performed in the draindown Plant Operating States but not in the cavity-flooded states (POS 7-9). Overdrain events are explicitly analyzed in the draindown states.
- There is no automatic function that performs this valve re-alignment. Thus an inadvertent draindown would require a simultaneous, spurious actuation of several series valves in the diversion flow path. The potential frequency of a multiple valve mis-position event is negligibly small.
- Even if an inadvertent diversion occurs at the maximum SCS system flow with one pump operating, the operators will still have sufficient time to identify the diversion and take corrective action before SCS suction is lost. The normal IRWST inventory is 652,800 gallons per the shutdown report, which will be used to flood the cavity for refueling. That inventory must be pumped out of the refueling cavity before SCS suction is lost. Several hundred thousand gallons must be removed from the cavity before SCS suction is lost, requiring a continuous, unmitigated diversion for at least an hour.
- Refueling levels are alarmed, and the operators are trained to identify and terminate a flow diversion, and initiate makeup. The recovery actions are simple and proceduralized.

This scenario was screened from the shutdown analyses and therefore no Human Error Probability was quantified. If the HEP were calculated, given the alarm cues, the available recovery time and the simplicity of the proceduralized recovery actions, a very small point estimate would be expected.

(f) As per the Shutdown Evaluation Report, Chapters 2.1 and 2.3, the Shutdown Cooling System pumps, the Safety Injection pumps and the Containment Spray pumps are all available to provide makeup during shutdown operation. The IRWST is the preferred source of inventory. In Modes 5 and 6, the charging system is also available as a backup for these pumps, using the boric acid storage tank as a makeup source.

Impact on DCD

DCD 9.1.4.2 will be revised as shown in Attachment 1 and 2
DCD 9.1.3.5.4 will be revised as shown in Attachment 2
DCD 9.1.6.1.1.5 will be revised as shown in Attachment 3
DCD 9.1.3.5.4 will be revised as shown in Attachment 5

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.

e. The components of the LLHS such as the bridges, trolleys, hoist units, hoisting cables, grapples, and hooks conform to the requirements of ASME NOG-1 (Reference 21).

f. The fuel handling equipment includes interlocks, travel-limiting features, and other protective devices to minimize the possibility of mishandling or equipment malfunction that could result in inadvertent damage to fuel assemblies and potential fission product release.

g. The equipment in the reactor containment building during plant operation is capable of withstanding, without damage, the containment building test pressure.

h. The seismic and quality group classifications for the LLHS are specified in Section 3.2. The LLHS is designed to meet the requirements of the seismic and quality group classifications.

i. No components in the LLHS are shared among nuclear power plants.

9.1.4.2 System Description

The LLHS is an integrated system of equipment, tools, and procedures for refueling, handling, and storage of fuel assemblies from receipt of the new fuel container to shipment of the spent fuel cask.

The equipment is designed to handle the fuel assemblies in dry or wet condition from the time they arrive at the site until they are placed in a cask for shipment from the site. Underwater transfer of fuel assemblies provides a transparent radiation shield, as well as a cooling medium for removal of decay heat. Boric acid is added to the SFP water in an amount that provides reasonable assurance of maintaining subcritical conditions.

The major components of the LLHS are the refueling machine (Figure 9.1.4-1), CEA change platform (Figure 9.1.4-2), fuel transfer system (Figures 9.1.4-3A and 9.1.4-3B), spent fuel handling machine (SFHM) (Figure 9.1.4-4), CEA elevator (Figure 9.1.4-5), and new fuel elevator (Figure 9.1.4-6). The fuel movement path for new fuel receipt and storage, reactor refueling operations, and spent fuel storage and shipment is shown in Figure 9.1.4-7. The fuel transfer system moves the fuel between the containment building

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and the fuel handling area in the auxiliary building through the transfer tube. The building layouts related to refueling operations are also shown in Figure 9.1.4-8 and Figure 9.1.4-9.

All of the LLHS equipment is classified as non-nuclear safety with the single exception of the double-blind flange assembly. In refueling pool, there is no temporary fuel rack to store a spent fuel assembly during refueling operations.

The two cavity fuel carriers are designed to meet the same criticality considerations as the spent fuel storage racks. The plant refueling cavity is equipped with devices that monitor the level of the refueling water in the refueling cavity. If the monitoring devices detect an inappropriate decrease in the level of refueling water during the refueling operation, the operator in the main control room (MCR) is alerted, and the operator takes immediate action to prevent water leakage. Makeup water is provided by plant procedures.

Tools and lift rigs are also used to disassemble reactor components.

The major tools and servicing equipment that are used for refueling are listed in Table 9.1.4-1.

In the design of fuel handling equipment, mechanical stops and positive locks are provided to prevent damage to or dropping of the fuel assemblies.

All machines in each refueling system are networked together to provide a simple method for communicating machine status and other pertinent information from one machine to another.

9.1.4.2.1 Components and Tools

9.1.4.2.1.1 Refueling Machine

The refueling machine is shown in Figure 9.1.4-1. The refueling machine is a traveling bridge and trolley that is located above the pool and rides on rails set in the concrete on each side of the refueling cavity. Motors on the bridge and trolley position the machine over each fuel assembly location within the reactor core or fuel transfer carrier. During withdrawal or insertion of a fuel assembly, the load on the hoist cable is monitored at the console to provide reasonable assurance that movement is not being restricted.

Locking between the grapple and the fuel assembly is provided by the engagement of the grapple actuator arm in axial channels running the length of the fuel hoist assembly.

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and the fuel handling area in the auxiliary building through the transfer tube. The building layouts related to refueling operations are also shown in Figure 9.1.4-8 and Figure 9.1.4-9.

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The volume of the refueling cavity is 44450.6 ft3 (1258.7 m3) which is applied to quantitative evaluation and calculated as 44450.6 ft3 (1258.7 m3)

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Locking between the grapple and the fuel assembly is provided by the engagement of the grapple actuator arm in axial channels running the length of the fuel hoist assembly.

c. Failure to begin secondary cooling before RCS level drops below the top of the hot leg is assumed to result in failure of secondary cooling.

d. One SG is assumed to be rendered unavailable by planned outage activities when the plant enters POS 4A.

e. The success criteria and time available for operator actions and events occurring in POS 3B is assumed to be the same as for events that occur in POS 3A. Since RCS temperature is lower in POS 3B, the timing for events is expected to take longer and, therefore, this assumption is conservative.

f. If feed and bleed cooling is used in POS 3A, containment design pressure would be exceeded after 24 hours. Although containment ultimate pressure capability will not be exceeded within 24 hours, operator action to begin IRWST cooling is assumed to be required to provide reasonable assurance safe, stable conditions.

g. Success criteria for unrecoverable LOCA (JL) events are analyzed assuming that the maximum break is the 34.1 m^3/hr (150 gpm) flow rate of the CVCS letdown line that occurs at-power.

h. Success criteria for LTOP safety valve fails to reclose (RL) events are based on the relief capacity of one LTOP relief valve.

Tables for the success criteria for LPSD various initiating event categories and operating states are shown in Table 19.1-89 through Table 19.1-92.

Insert the new text from next page.

19.1.6.1.1.6 Human Reliability Analysis

The human reliability analysis (HRA) for the LPSD PRA is performed using the same methods as the at-power PRA described in Subsection 19.1.4.1.1.7.

Operator actions that respond to events that occur in Technical Specification Mode 2 or Mode 3 are assumed to be the same as the responses to events that occur at-power. Although the time available for response to an event in Mode 2 or Mode 3 is expected to be longer, thereby resulting in a lower HEP, this conservatism is considered to be negligible to overall risk because the time spent in these modes is short.

g. The LPSD risk in POS 7 and POS 9 is screened out, based on thermal hydraulic analysis results. The time to core damage in POS 7, with the reactor internals installed, is 63.1 hrs. This calculation does not credit an open path to the Spent Fuel Pool. A similar calculation, with the reactor internals removed, results in an even longer time to core damage. The time to core damage in POS 9 is bounded by POS 7.

Operation with Cavity Flooded

Operation with the refueling cavity flooded was screened from the LPSD analysis. This section provides the basis for screening these states.

- RELAP calculations were performed to determine the time to core damage in Plant Operating State 7. POS 9 differs from POS 7 only in that it is later in refueling and decay heat will be lower; therefore, the POS 7 result will bound POS 9. The results are as follows.

	POS 7	POS 9
Event time (Decay heat)	7 days after reactor trip (14.0 MWt)	16 days after reactor trip (10.3 MWt)
RCS Initial condition	Normal refueling level	Normal refueling level
Time to CD with reactor internals installed	63.1 hrs	Bounded by POS 7
Time to CD with reactor internals removed	68.6 hrs	

- During cavity-flooded operations, the only potentially significant drainage path is via the suction lines for the Shutdown Cooling System (SCS). In this case, the discharge to the IRWST is opened, and the discharge back to the Reactor Coolant System (RCS) is closed. The letdown line is normally isolated in these states because there is insufficient pressure in the primary system to force flow through the letdown orifices. Instead, a portion of the SCS discharge, downstream of the SC heat exchangers, is diverted to shutdown purification.

  Other potential discharge paths, such as the cross-tie to the Containment Spray system, are normally isolated during shutdown. The SCS discharge to the sampling system is only intermittently in service, and the 3/8" line will not divert a significant flow rate.

  As per FSAR Table 5.4.7-1, the maximum Shutdown Cooling System flow is 6134 gpm. The normal SCS flow rate during High Water Level operation is >4800 gpm per Technical Specification Surveillance Requirement 3.9.4.1. Diversion flow is limited by an additional orifice on each discharge line to the IRWST. Any other

potential diversion scenarios will occur much more slowly, allowing the operators more time to identify and correct the configuration.

- The operators will have the Permanent Refueling Water Level Indication System (PWRLIS) for monitoring reactor cavity level, ~~as noted in the Shutdown Risk Evaluation, Table 2.1-1~~. The IRWST also has redundant level transmitters that provide control room indication. In addition, they will have valve position indications, to identify an inventory diversion from the RCS to the IRWST. The IRWST temperature indicators will increase, confirming the inflow from the RCS. The PRWLIS provides low and low-low RCS water level alarms and was specifically designed to support safe draindown operation. ~~Shutdown Report section 2.8.3.2.5.2 also notes the inclusion of the low refueling cavity level alarm.~~

- The probability of operator failure to isolate a potential drainage path has not been quantified, based upon the following considerations:

  a) The most rapid draindown scenario is a diversion of the Shutdown Cooling System discharge to the IRWST. This evolution is normally performed after onload, when the operators are ready to drain the refueling cavity for reactor head replacement.

  b) There is no automatic function that performs this valve re-alignment. Thus it would require a simultaneous, spurious actuation of several valves in the associated flow paths.

  c) Even if an inadvertent diversion occurs at the maximum SCS system flow with one pump operating, the operators will still have sufficient time to identify the diversion and take corrective action before SCS suction is lost. The normal IRWST inventory is 652,800 gallons ~~per the shutdown report,~~ which will be used to flood the cavity for refueling. That inventory must be pumped out of the refueling cavity before SCS suction is lost. Several hundred thousand gallons must be removed from the cavity before SCS suction is lost, requiring a continuous, unmitigated diversion for at least an hour.

  d) Refueling levels are alarmed, and the operators are trained to identify and terminate a flow diversion, and initiate makeup. The recovery actions are

simple and proceduralized. This scenario was screened from the shutdown analyses and no Human Error Probabilities were quantified.

- As per the Shutdown Evaluation Report, Chapters 2.1 and 2.3, the Shutdown Cooling System pumps, the Safety Injection pumps and the Containment Spray pumps are all available to provide makeup during shutdown operation. The IRWST is the preferred source of inventory. In Modes 5 and 6, the charging system is also available as a backup for these pumps, using the boric acid storage tank as a makeup source.

The potential drain down paths of SCS are as follow.

TS

Figure. RCS Drain Paths through SCS Train 1 (page 1 of 5)

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Figure. RCS Drain Paths through SCS Train 1 (page 2 of 5)

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Figure. RCS Drain Paths through SCS Train 1 (page 3 of 5)

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Figure. RCS Drain Paths through SCS Train 1 (page 4 of 5)

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Figure. RCS Drain Paths through SCS Train 1 (page 5 of 5)

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9.1.3.5.2 Pressure

Instrumentation is provided to measure and give indication of the pressures in the SFPCCS pump discharge lines. A deviation from normal pressure in the SFP cooling pump discharge lines is alarmed in the MCR. Instrumentation is also provided upstream and downstream of each cleanup filter, demineralizer, and demineralizer filter to measure the pressure differential across the filters, demineralizers, and demineralizer filters.

9.1.3.5.3 Flow

Instrumentation installed downstream of the SFP heat exchanger measures the SFP cooling portion flow and shows local indication of the SFP cooling portion flow. This instrument is used to check whether the flow rate of the cooling water returning to the SFP via the SFP heat exchanger is maintained at the specified value. Alarms that indicate a loss of cooling function are provided to the MCR to detect low flow rates.

A local flow indicator for measuring the purification flow is installed at the outlet of each purification line.

9.1.3.5.4 Water Level

Two safety-related SFP water level transmitters are installed in the SFP to measure the SFP water level from a 100 percent water level to the top level of the spent fuel assemblies. The SFP water level transmitters annunciate high water level, low water level, and low-low water level of the SFP to the MCR, RSR, and locally.

A level transmitter is installed in the refueling cavity to measure water level from the bottom to 12 inches below the top. The refueling cavity water level is indicated in the MCR and RSR. In addition, a temporary local level indicator is connected to the transmitter to measure the refueling cavity water level during refueling operation. The refueling cavity water level transmitter annunciates high water level (El. 154 ft 2 in) and low water level (El. 153 ft 10 in) to the MCR and RSR.

The SFP cooling pump and cleanup pump are interlocked with SFP water level to stop the pumps automatically as the SFP water level is decreased to a predetermined setpoint. The interlock prevent the pumps from cavitation and failure.

9.1.3.5.5 Radiation

Gamma radiation is continuously monitored in the fuel handling area. A high-level signal is alarmed locally and annunciated in the MCR.