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 Issue: **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

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	

(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.

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, 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.

(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 19.1.6.1.1.5 will be revised as shown 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.

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.