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.:	**418-8348**
SRP Section:	**SRP 19**
Application Section:	**19.1**
Date of RAI Issue:	**02/23/2016**

Question No. 19-49

10 CFR 52.47(a)(27) requires that a standard design certification applicant provide a description of the design specific PRA.

SRP Chapter 19.0, Revision 3 (Draft), Section "II. Acceptance Criteria," states that the staff determines whether, "…the technical adequacy of the PRA is sufficient to justify the specific results and risk insights that are used to support the DC or COL application.

Toward this end, the applicant's PRA submittal should be consistent with prevailing PRA standards, guidance, and good practices as needed to support its uses and applications and as endorsed by the NRC (e.g., RG 1.200)."

The staff noted that the PRA documentation (APR1400-K-P-NR-013503-P) considered flooding initiating events caused by inadvertent operation or erroneous operation of a plant component during maintenance.

The applicant concluded that these scenarios do not contribute significantly to the overall initiating event frequency. Please justify this conclusion in the DCD, for both at power and LPSD conditions.

Response

DCD Section 19.1.5.3.1.5 will be revised to include justification that maintenance-induced internal flooding events are considered to be negligible contributors to full power internal flooding risk (see Attachment 1).

DCD Section 19.1.6.4.1.3 will be revised to include justification that maintenance-induced internal flooding events are considered to be negligible contributors to LPSD internal flooding risk (see Attachment 2).

Impact on DCD

The DCD will be revised as stated in the response.

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.

piping penetrations, are assumed to be capable of withstanding the steam pressure transient.

j. Unless explicitly analyzed, failure of a pipe containing water above saturated conditions is assumed to actuate all fire protection systems in the room in which the break occurs as well as in any room where significant propagation occurs.

k. Significant propagation of steam is assumed to occur only through failed doors, open passageways, open stairwells, HVAC ducting, and open floor grating. While some propagation of steam would occur through open pipe and cable penetrations or EOL lines, this propagation is not considered significant and fire protection system actuation is not considered.

l. Failure of auxiliary steam (AS) or steam generator blowdown (SD) system piping in the auxiliary building is assumed to be incapable of resulting in pipe whip or unique jet impingement failures.

m. Lines that are not normally pressurized or charged, such as drain lines or abandoned in-place systems, are not considered as credible flood or spray sources. For example, relief lines downstream of a relief valve are not normally pressurized and are not included.

19.1.5.3.1.5 Initiating Event Analysis

The flooding-induced initiating events are divided into three categories of causes:

a. Tank rupture events causing flooding

b. Maintenance-related events causing flooding

c. System pipe rupture events causing flooding

No tank ruptures are identified as causing unique effects or contributing to internal flooding events. ~~Maintenance-induced flooding events are considered in the analysis, but a bounding analysis is performed to demonstrate that the maintenance-induced flooding event is a negligible contributor to the overall initiating event frequency.~~

New text is added as shown in A

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Maintenance-induced flooding events are considered in the analysis using a bounding analysis to estimate their frequency. The frequency of unisolated, maintenance-induced floods was calculated with the following equation:

$$F_T = F_m * P_f * P_I$$

where

F_T = Total frequency of unisolated, maintenance-induced floods while reactor is at power

F_m = Frequency of maintenance while reactor is at power

P_f = Probability that isolation fails initially and flood event is initiated

P_I = Probability that initiation of flooding is not detected immediately and flooding proceeds in the long term to adversely impact multiple systems

Maintenance unavailability values for fluid systems that could result in flooding events are shown in Table 6-1 of NUREG/CR-6928 (Reference 11).

The unavailability values are used as an annual frequency for maintenance events. Since no operational data exists for APR1400, a screening value of 5E-03 will be used to assess maintenance isolation failure. The probability that initiation of a flooding event is not immediately detected and the flooding event secured before causing subsequent equipment damage will use a screening value of 0.05.

The highest value for maintenance unavailability shown in Table 6-1 of NURG/CR-6928 (Reference 11) that is potentially applicable to APR1400 is 3E-02. Using this value and the screening values above, the frequency of maintenance events causing an internal flooding initiating event is calculated as:

$$F_T = 3E\text{-}02/yr * 5.0E\text{-}03 * 0.05$$

$$F_T = 7.5E\text{-}06 \text{ per year}$$

This value would bound flood events because it considers that all maintenance unavailability involves activities that breach the fluid pressure boundary. In practice, it is expected that only about ten percent of maintenance events actually breach the pressure boundary which would result in a maintenance-induced flood frequency of 7.5E-07 per year. Comparing this frequency to the pipe break frequency calculated values calculated for the internal flooding analysis, it is concluded that maintenance-induced flooding events are negligible contributors to the overall initiating event frequency.

to recover the SCS via the standby train, if it is available. If this action is not successful, the operators must proceed to feed and bleed cooling.

New text is added as shown in A

19.1.6.4.1.4 Success Criteria

No changes to the success criteria are made for the internal flooding analysis, relative to the LPSD internal events PRA model. The same criteria for shutdown cooling (including supporting heat sinks), feed and bleed (including supporting heat sinks), and containment cooling are used throughout the evaluation.

19.1.6.4.1.5 Operator Actions

No changes are made to the LPSD internal events human error probabilities (HEPs) for the LPSD flood analysis. The operator actions for isolating LPSD pipe breaks involve similar timing and required similar actions as those operator actions for isolating at-power pipe breaks, so no new HEPs for LPSD are introduced.

19.1.6.4.1.6 Systems Analysis

No new systems are modeled for LPSD flooding, nor are any existing models expanded or revised for the LPSD flood analysis.

19.1.6.4.2 Results from Internal Flooding PRA for Low Power and Shutdown Operations

19.1.6.4.2.1 Risk Metrics

The CDF for LPSD flooding is 1.8×10^{-8}/year. This figure will be approximately two orders of magnitude less than LPSD internal events and internal fire, both of which are in the low 1×10^{-6}/year range for LPSD CDF. The LPSD flooding large release frequency (LRF) is not quantified. As an upper bound, it is assumed to be less than 1.8×10^{-8}/year. It should be noted that units for CDF and LRF are expressed in terms of “reactor calendar year” (shortened to “/year” when displayed in the text in this section).

A

Maintenance-induced flooding events are considered to be negligible contributors to LPSD internal flooding risk. As detailed in Section 19.1.5.3.1.5, the frequency of maintenance-induced flooding events was calculated using a bounding analysis to be less than 7.5E-07 per year, which is small in comparison to random system breaks. Furthermore, maintenance during shutdown is controlled on a divisional basis so that it is not likely that maintenance will be performed on the division of the operating shutdown cooling system if only one division is available. This practice further diminishes the potential for maintenance-induced floods to cause an initiating event during LPSD conditions.

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Question No. 19-50

10 CFR 52.47(a)(27) requires that a standard design certification applicant provide a description of the design specific PRA.

SRP Chapter 19.0, Revision 3 (Draft), Section “II. Acceptance Criteria,” states that the staff determines whether, “…the technical adequacy of the PRA is sufficient to justify the specific results and risk insights that are used to support the DC or COL application. Toward this end, the applicant’s PRA submittal should be consistent with prevailing PRA standards, guidance, and good practices as needed to support its uses and applications and as endorsed by the NRC (e.g., RG 1.200).”

According to the DCD, in cases where there is a potential for more than one fire-induced initiator to occur in a given fire compartment, the applicant established a hierarchy of initiating events “wherein perceived worst-case initiators were given preference over lesser initiators.” Please provide additional basis in the DCD for establishing this hierarchy and how this assumption may impact the PRA.

Response

DCD 19.1.6.3.1.3 will be revised to include additional information on the selection of fire-induced initiators.

Impact on DCD

DCD 19.1.6.3.1.3 will be revised as stated in the response 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 Environment Report.

SO – Overdrain events (POS 5 and 11 only)

JL – CVCS letdown line diversion LOCA

CC – Loss of operating component cooling train

KV – Loss of 4 kV bus on operating shutdown cooling train

LP – Loss of offsite power impacting operating shutdown cooling train

AS – Fire-induced main control room evacuation (alternate shutdown)

LPSD initiator fault tree models have been created for all systemic initiators, and any new equipment added to support these initiator fault trees has been included in Task 2. The flag files used during quantification to fail fire-damaged equipment in each fire compartment were updated to include any new equipment identified in Task 2 (included events added for LPSD initiator fault tree models), and any new cables added in Task 3.

During the development of the systemic initiator fault trees, it was identified that the spurious operations that could cause an SL event are the same that could cause an SO event. These two initiators are only applicable to POS 5 and 11, and are functionally the same initiator for fire scenarios since: 1) the flow diversion pathway is the same, 2) the mitigation scheme is identical, and 3) operator action timing is the same. For this analysis, the SL event is used to represent these failures.

b

Based on the potential for equipment damage in each fire compartment, ~~a list of potential fire-induced initiating events in each fire compartment has been developed.~~ Then, ~~F~~ f For each fire compartment, a single initiator is chosen for each POS based on the most likely fire in that compartment during that POS, ~~or engineering judgment~~. If there is the potential for more than one fire-induced initiator during a POS solely due to fire damage, engineering judgment is used to determine the representative initiator. A hierarchy was established wherein perceived worst-case initiators were given preference over lesser initiators. The hierarchy used is:

~~AS >~~ SL > LP > KV > S2 or CC ~~> JL~~ with JL included as described below

~~Note that AS is only applicable to fires involving the MCR and SL is only applicable to POS 5 and 11. Also, note that S2 and CC are functionally equivalent, since CC's only~~

Concerning MCR fires, all scenarios resulting in MCR evacuation are assumed to result in an AS event; no other event is applicable to fires involving MCR evacuation.
For all other fire scenarios, a list of potential fire-induced initiating events in each fire compartment has been developed

modeled function during LPSD is cooling the shutdown cooling heat exchangers, and direct fire-induced loss of shutdown cooling is functionally the same as fire-induced loss of CC (or SX).

new text is added as shown in A

Task 6, fire ignition frequency development, was accomplished in a two-step process. Step 1 involved updating the fire ignition frequency spreadsheet used in the FP-FPRA with the LPSD generic frequencies from Table 2 of NUREG/CR-7114. Step 2 involved updating the maintenance, occupancy, and storage transient fire influencing factors, using engineering judgment to identify fire compartments where these influencing factors will likely increase during the outage. The result of these two steps is a recalculation of the fire compartment initiating event frequencies for LPSD conditions. All assumptions or deviations from the NUREG/CR-6850 methodology for determining fire ignition frequencies taken in the FP-FPRA (see Subsection 19.1.5.2.1.3) are assumed applicable to the LPSD FPRA.

Task 7 screens fire compartments from further detailed analysis. Risk-significant fire compartments have been identified by inspection of preliminary CDF calculations, and resulted in the main turbine building area, fire compartment F000-TB, being the only fire compartment chosen for detailed analysis. Note that the MCR, fire compartment F157-AMCR analysis is performed in accordance with the NUREG/CR-6850, Task 11 methodology.

The Task 10 failure mode likelihood analysis conservatively sets all potential spurious operations have assumed to occur.

Task 8 fire scoping modeling and Task 11 detailed fire modeling have not been performed due to lack of sufficient data related to the relational location of the ignition sources and their targets (including intervening combustibles). Therefore, for single-compartment fire analyses, all unsuppressed fires are assumed to propagate throughout the entire compartment (damaging all PRA-credited equipment within the compartment). For multi-compartment scenarios, in addition to propagating throughout the exposing compartment (i.e., compartment in which the fire initiated), fire spread is assumed to propagate through barriers at the probabilities associated with the respective barriers under consideration. Generic barrier failure probabilities from NUREG/CR-6850 were used to calculate barrier failure probabilities between adjacent compartments.

A(1/2)

The basis for the hierarchy starts with the fact that the LP, KV, S2 and CC events all result in failure of the running SC train which do not impact the RCS or reactor cavity water levels, whereas SL and JL also result in a decrease of the water level.

The SL event is only applicable by definition in reduced inventory POSs 5 and 11. In addition to restoration of SC, inventory make-up and isolation of the flow diversion is required, or else feed and bleed is required. The perceived relative severity of the SL event is due to the initial low RCS level in POS 5 and 11 resulting in relatively shorter operator action times. Hence, SL is deemed to be more severe than LP, KV, S2 or CC events during POS 5 and 11.

LP, KV, S2 and CC all deal with the failure of the operating train of SC, where S2 and CC are functionally equivalent. Since CC's only modeled function during LPSD is cooling the shutdown cooling heat exchangers, direct fire-induced loss of shutdown cooling is functionally the same as fire-induced loss of CC (or SX). The selection of CC or S2 is based on engineering judgement considering the failed equipment. For example, if CC fails due to direct fire damage to the CC pump and S2 fails due to spurious operation, then CC is selected since the fire damage is "guaranteed" whereas the S2 spurious operation is not a guaranteed failure (i.e., fire-induced spurious operation is usually represented as a probability).

Regarding KV, the 4 kV bus which fails the operating SC train, also fails other equipment powered by that bus; hence, the KV event would be more challenging than the S2 or CC events. Likewise, with LP, offsite power is lost to at least the entire division supporting the operating SC train (not just a single train), requiring the DGs to supply 4 kV power to the division. Additionally, if the LP event fails both divisions of offsite power, conditional failure of the DGs results in an SBO requiring power from the AAC. Therefore, LP is considered to be more challenging than the KV event. Finally, note that these four events are only applicable during the POSs in which the affected train is operating. Based on the LPSD assumed operating schedule, SC train A is operating during POS 3 – 7, and SC train B is operating during POS 9 – 13. Hence, if the fire only impacts SC train B during POS 5, there is no initiating event since SC train A is unaffected.

Regarding JL, there is many similarities with the SL event, except that the JL event can occur during any POS. Since SL is restricted to POS 5 and 11, for fire scenarios when both SL and JL are possible, the SL event is selected during POS 5 and 11, and the JL event is selected for all other POSs. Note that both the event tree structure and HRA of the SL and JL events is identical in POS 5 and 11 (Reference 7); hence, there is no CDF or LRF impact due to this use of engineering judgement, and the only impact is on the distribution of CDF and LRF between JL and SL.

A(2/2)

The application of the JL event in POSs other than 5 and 11 is based on the fact that the JL event can occur in any POS while the LP, KV, S2 and CC events only occur when the operating train is damaged. In addition, the JL event assumes an unrecoverable loss of RCS water outside containment. For fires, since fire-induced pipe break is not credible, the JL event can only be caused by equipment damage diverting the water from the RCS; hence, for POSs with higher initial water levels (i.e., POSs other than POS 5 and 11), the JL event may actually be recoverable if the operators re-route the water back to the RCS, and/or isolate the spurious operation causing the diversion; however, this is not credited. Additionally, although not credited, in reality, natural clearing of the hot short may isolate the JL event.

Hence, for fire scenarios when both JL and either LP, KV, S2 or CC occur, JL is assumed for the POSs where the LP, KV, S2 or CC event would not occur. For example, if a fire scenario results in damaging equipment which could both result in a JL event and fail the SC A train, the S2 event would be assumed during POS 3A – 6 (because the A train of SC is assumed to be the operating train in these POSs), and JL is modeled for POS 10 – 13.

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Question No. 19-51

10 CFR 52.47(a)(27) requires that a standard design certification applicant provide a description of the design specific PRA.

SRP Chapter 19.0, Revision 3 (Draft), Section "II. Acceptance Criteria," states that the staff determines whether, "…the technical adequacy of the PRA is sufficient to justify the specific results and risk insights that are used to support the DC or COL application. Toward this end, the applicant's PRA submittal should be consistent with prevailing PRA standards, guidance, and good practices as needed to support its uses and applications and as endorsed by the NRC (e.g., RG 1.200)."

The PRA documentation (APR1400-K-P-NR-013759-P) indicates that subjects such as flood area definition, identification of flood sources and propagation paths, and plant operating states are largely unchanged from the at-power internal flooding analysis. To ensure that the potential flood propagation paths for LPSD conditions have been properly evaluated, please describe in the DCD, how flood barriers assumed to be intact during at-power conditions that may not necessarily be intact during LPSD conditions are addressed in the LPSD analysis.

Response

DCD Section 19.1.6.4.1.2 will be revised to clarify how flooding barriers are evaluated in the LPSD analysis.

Impact on DCD

The DCD will be revised as stated in the response 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 Environment Report.

19.1.6.4.1.2 Initiating Events

The at-power flood analysis was reviewed to identify all floods that can submerge either of the SC pumps or their power supplies. In some cases, floods are identified that could submerge both pumps.

The flooding initiating events are verified to determine that the representative flow rates from the at-power model remained applicable for LPSD analysis. When necessary, some flow rates are adjusted (e.g., by expanding to include a wider range of potential flow rates). In addition, very low flood flow rates in the SC pump rooms are considered, in order to include potential spray vulnerability for the pump motors.

The volume of water necessary to cause submergence failure of the SC pumps was calculated and found to be different than the volume of water required to cause a reactor trip during power operations. This submergence volume is used to screen flooding sources that contained insufficient volume to damage the SC pumps. Additionally, this new volume is used to calculate a minimum flow rate required to result in submergence failure of the SC pumps within a time period in which the operators are expected to always be able to successfully isolate the break. A number of initiators are requantified using this new minimum flow rate.

Ruptures of the heat sinks for the SCS (component cooling and service water) are subsumed into general failures of the SCS and are not reanalyzed. Some CC system ruptures are retained because they could potentially fail a power supply and thus posed a broader threat than the loss of an SC train.

New text is added as shown in A

19.1.6.4.1.3 Accident Sequence

The AS development for LPSD flooding uses the loss of shutdown cooling sequences in the LPSD internal events analysis. While there are many initiating events (i.e., many floods that can fail one or both trains of SC), each unique IE use the same, basic loss of shutdown cooling (LOSC) event tree for the subsequent accident analysis.

Since the initiating events are failures of the running train of shutdown cooling, the sequences include the same potential recovery actions. First, the operators would attempt

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Consistent with the assumption one SDC train is operating during the first part of the outage and other SDC train is operating during the second part of the outage, the LPSD internal flooding analysis assumes that flood barriers separating the two divisions of the auxiliary building are maintained consistent with the internal flooding design basis during POS that SDC is required. Therefore, the propagation analysis developed for the at-power internal flooding analysis should be applicable to the LPSD flooding analysis when considering events that could cause failure of the operating SDC train.

Outage work is conducted on a train basis. That is, while work on train A equipment is planned, no maintenance is performed on any train B equipment and vice versa. This assumption regarding maintenance includes flood barriers separating the two divisions.

Additionally, the analysis assumes that auxiliary building flood barriers separating trains within a division are maintained consistent with the internal flooding design basis for the normallyoperating SDC train. The normally-operating SDC train is from the Division which is not scheduled for maintenance during that portion of the outage. Therefore, the propagation analysis developed for the at-power internal flooding analysis should be applicable to the LPSD flooding analysis when considering events that could cause failure of the operating SDC train.