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.:	**5-7842**
SRP Section:	**19-0 – Probabilistic Risk Assessment and Severe Accident Evaluation**
Application Section:	**19.1**
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Question No. 19-1

10 CFR 52.47(a)(27) requires that a standard design certification applicant provide a description of the design-specific PRA. Item 10 of Section II, “Acceptance Criteria,” of the Standard Review Plan (SRP) 19.0 (Draft) Revision 3, states that, “The staff will determine that the technical adequacy of the PRA is sufficient to justify the specific results and risk insights that are used to support the DC application.” This SRP references RG 1.200 and the ASME/ANS PRA Standard “RA-Sa-2009.” In the ASME/ANS PRA Standard, Item (I) states, “Document the model integration process including… asymmetries in quantitative modeling to provide application users the necessary understanding of the reasons such asymmetries are present in the model.”

The staff reviewed APR1400 DCD Section 19.1, “Probabilistic Risk Assessment,” and found no information regarding the asymmetric configuration and modeling. Therefore, it is not clear whether the APR1400 PRA model is symmetric or not. Since the staff needs this information to make a reasonable assurance finding on the APR1400 PRA technical adequacy, they requested that the applicant address the following items a) through f) and include discussion of each in the DCD:

a) The assumption on the asymmetric configurations for analyzed initiating events (e.g., LOCA) and post-accident operations during power and low-power/shutdown conditions
b) The asymmetric configuration assumption relevant to the structure, system, or component (SSC) unavailability due to test/maintenance
c) The assessment of common cause failure (CCF) of components relative to the asymmetric configuration (e.g., CCF among standby and running components)
d) The modeling approach and impact of asymmetric configurations on internal fires, internal floods, seismic, and other external events
e) The effect of the asymmetry-related assumptions on component/train-specific importance measures and PRA results/insights/applications (i.e., RAP list)

f) A new COL information item to be added to the DCD to ensure that the asymmetric conditions due to modeling simplicity will be addressed or properly accounted for when the PRA is used for decision making.

Response

a) The assumption on the asymmetric configurations for analyzed initiating events (e.g., LOCA) and post-accident operations during power and low-power/shutdown conditions.

The APR1400 PRA full power internal events model uses point estimates from industry data for all initiating events including support system initiating events (e.g., loss of instrument air, total loss of component cooling water, etc.) Hence, there is no asymmetry introduced from support system initiators for the full power internal events model.

Note that the partial loss of component cooling water (CC) and essential service water (SX) are asymmetric in that they only occur on Train A. However, this is based on the plant design, and is not a PRA modeling issue. The “A” train of component cooling water system cools all four (4) reactor coolant pumps (RCPs); hence, a loss CC train A results in a plant trip, but loss of CC train B does not directly result in a plant trip. Therefore, the PRA models the plant design with respect to this initiator, and does not introduce any uncertainties with respect to model asymmetry.

Pipe break initiators (i.e., large LOCAs, SGTRs, feed line breaks and steam line breaks upstream of the MSIVs) are assumed to occur on a specific train, and therefore impact some model results. The main impact of the large LOCA break location is that it results in direct failure of a single safety injection tank (SIT), and one train of safety injection (SI) and shutdown cooling (SC) system. And the main impact of the feed and steam line break is that they preclude heat removal via the affected SG.

Regarding Large LOCA, the SITs, SI and SC inject directly into the vessel via direct vessel injection (DVI); therefore, breaks in the cold leg or hot leg do not result in failure of a train in these systems; however, DVI breaks can result in direct failure. In reality, it is equally likely that a DVI break would occur on any of the four (4) DVI lines, but in the APR1400 PRA model, the break is assumed in DVI line 2. Note that although all DVI lines are associated with a single train if SIT and SI, only DVI lines 1 and 2 are associated with an SC train. Therefore, by selecting DVI line 2, it is ensured that a worst case situation involving one (1) SIT, and one (1) train each of SI and SC are failed as a result of all DVI large LOCAs. The entire DVI Large LOCA IEF is assigned to DVI line 2 which results in all DVI LOCAs failing the “B” train of SC (as well as the “B” SIT and “B” train of SI); hence, the calculated CDF is conservative since, in reality, half of the DVI Large LOCA IEF (i.e., DVI large LOCAs in DVI lines 3 or 4) would not impact either SC train. In addition, the importance measures of the “A” train of SC are slightly increased. Note, however that the overall impact of large LOCA (LLOCA) is only about 0.2% of the total CDF mainly due to the low IEF. Therefore, the impact of asymmetric modeling on large LOCA is not significant to the APR1400 CDF results.

Regarding SGTR, feedwater line breaks (FWLB) and large steamline breaks upstream of the MSIVs (LSSB-U), the only impact on the PRA model is that it is assumed that the impacted SG is not available for secondary side heat removal. The APR1400 PRA assumes that all of these events are associated with SG2. In reality, there is an equally likely chance that these events are associated with either SG. Since the systems credited for secondary side heat removal are symmetric, and since the entirety of each of these IEFs is associated with SG2, there is no difference in the calculated CDF for these initiators. The only impact is in regards to the importance measures of the systems credited for secondary side cooling which include auxiliary feedwater (AF) or startup feedwater (SF) as a source of water for the SGs, and either the turbine bypass valves (TBVs), main steam safety valves (MSSVs) or main steam atmospheric dump valves (MSADVs) as a heat removal path. Note that the SF and TBVs are not credited for SGTR, FWLB or LSSB-U; hence, only the AF, MSSVs and MSADVs importance measures are impacted. However, note that these initiators combined result in less than 10% of the total CDF, so it is anticipated that their impact on the importance measures of these systems is small (see the discussion in response to question 19.1.e) on the use of importance measures).

In addition, the APR1400 PRA model uses an asymmetric model for normally operating systems with design redundancy (i.e., not all trains are required for successful operation).

Normally operating systems which do not require all trains operating include the:

- Component Cooling Water System (CC),
- Essential Service Water System (SX),
- Chemical and Volumetric Control System (CV),
- Essential Chilled Water System (WO),
- ESW Intake Structure/CC Heat Exchanger Building HVAC System (VG),
- Auxiliary Building Controlled Area HVAC System (VK),
- Auxiliary Building Clean Area HVAC System (VO), and
- Instrument Air System (IA)

The fault tree model for these systems makes assumptions regarding which trains are running and which are in standby. For example, the CC system, which consists of 4 trains with 2 trains per division, requires 1 train in each division be operating. It is assumed that pump 01A is running in the “A” division, and pump 01B is running in the “B”; pumps 02A and 02B are assumed to be in standby in the “A” and “B” divisions, respectively.

Failure modes only applicable to standby components (e.g., pump fails to start, component unavailable due to test or maintenance, check valve fails to open pre-initiator human failure events (HFEs), etc.) are always modeled for standby trains, when applicable. However, following a loss of offsite power (LOOP), the assumed running train needs to re-start; therefore, following LOOP events, failures such as failure to start, failure of check valves to open, etc., are included in the model as appropriate for the component. These model asymmetries tend to make the assumed standby train more “important” since the combined failure probability of their failure modes is larger than that of the operating train (see the discussion in response to question 19.1.e) on the use of importance measures). However, note that the impact on overall plant CDF is non-conservative since the test and maintenance unavailability of the assumed operating train is not accounted for in the model.

Regarding the asymmetry of normally operating systems, there were no pre-initiator HFEs which were not screened in the human reliability analysis (HRA). Therefore, model asymmetries are not further impacted from pre-initiator HFEs.

Normally operating systems can also be impacted by train specific initiating events loss of DC A and B (LODCA and LODCB). These events specifically model a loss of 125 VDC Bus MC01A and MC01B, respectively. For example, as previously discussed, it is assumed that CC pump 01A is running in the “A” division. Following a LODCA event, if the CC 01A pump fails to run, CC pump 02A has the ability to start because DC Bus MC01C is not impacted by the initiator. However, if CC pump 02A were assumed to be running at the start of the LODCA event, and subsequently failed, CC pump 01A could not start (without a local manual action to close the pump power supply breaker) since DC Bus MC01A is failed for LODCA events. Note, however, that both “B” train CC pumps would still be available. Therefore, the APR1400 PRA model is not conservative in this respect. Regardless, the impact on the APR1400 is small for LODCA and LODCB initiators (i.e., both 0.1% of the total CDF), and although it would increase if this model asymmetry were removed, it would not be expected to significantly impact the model due to the additional redundancy from the two (2) opposite trains.

With respect to LPSD modeling, the model is asymmetric in that it assumes configurations for systems normally operating in each plant operating state (POS). However, the choice of which trains are operating and which are in standby is not a random choice, but rather based on the operating and maintenance schedule assumed for each POS. For example, in POS 3A ~ 6, the “A” train of SC is, by schedule, the operating train, and during POS 10 ~ 13, the “B” train of SC is, by schedule, the operating train. The model allows for changes in the schedule by changing the value of alignment flags, thereby making the model useful for any number of outage schedules. So although the LPSD model contains systemic asymmetries, they are as a result of the assumed outage schedule, and not a random process. Regardless, it will result in differences in the importance of trains of operating systems for each POS, but does not significantly impact the resultant CDF of each POS.

One additional asymmetry exists, and it is in regards to the use of the alternate AC (AAC) power source. The AAC is sized such that it can power a single full division (i.e., two trains). The APR1400 PRA model assumes that the operators align the AAC to Division 1 (Train A and C) since the preferred power source for the auxiliary charging pump (used to re-establish RCP seal cooling) is from the “A” train (the operators can also align alternate power from Train “B”). Note that the AAC is only credited in the APR1400 PRA model for station blackout (SBO) sequences where the AAC successfully starts and runs. This asymmetry is partially accounted for in the PRA model by adding a recovery action during cutset post-processing which has the operators align the AAC to Division 2 (Train B and D) for select cutsets. The overall impact of this modeling is conservative with respect to CDF as it does not take full credit of the AAC.

In conclusion, APR1400 PRA model asymmetry exists in some initiating events and normally operating systems. In most cases, the asymmetry has little to no impact on the plant CDF, and mainly impacts the importance measures of events. One exception is the modeling of TM only for the standby train which under-predicts CDF; this will be accounted for by doubling the TM events in the standby trains in the PRA model and DCD 19.1 in the next periodic upgrade.

b) The asymmetric configuration assumption relevant to the structure, system, or component (SSC) unavailability due to test/maintenance.

As previously stated in the answer to a), model asymmetries only impact normally operating systems. Test and maintenance (TM) unavailability is modeled for the assumed standby trains in the normally operating systems, and no unavailability is modeled for the assumed operating trains. This is non-conservative as it dismisses the annual unavailability of the assumed operating train. However, this will be accounted for by adjusting the TM events in the standby trains to ensure the entire unavailability time for the system is incorporated into the PRA model and DCD 19.1 in the next periodic upgrade.

c) The assessment of common cause failure (CCF) of components relative to the asymmetric configuration (e.g., CCF among standby and running components).

As previously stated in the answer to a), model asymmetries only impact normally operating systems. With respect to CCF modeling, the number of components in the common cause group (CCG) does not change regardless of whether the train is assumed running or in standby. For example, the CC system, which consists of four (4) trains with two (2) trains per division, requires one (1) train in each division be operating. It is assumed that pump 01A is running in the “A” division, and pump 01B is running in the “B”; pumps 02A and 02B are assumed to be in standby in the “A” and “B” divisions respectively. The CCG includes all four (4) pumps (01A, 02A, 01B, 02B) regardless of the failure mode, and the CCF modes are applied whenever the failure mode is applicable.

Since, for all conditions, fail to run is an applicable failure mode, all pumps include failure to run CCF events which include applicable failures of 2/4, 3/4 and 4/4 pumps. For LOOP scenarios, all CC pumps must start, so all pumps include failure to start CCF events which include applicable failures of 2/4, 3/4 and 4/4 pumps. For non-LOOP scenarios, only pumps 02A and 02B may need to start (given failure of pump 01A and 01B, respectively), so pump fail to start CCF events are only applied to pumps 02A and 02B; however, the fail to start CCF events include applicable failures of 2/4, 3/4 and 4/4 pumps. Note that if the model were symmetric there would be fail to start CCF events included in the non-LOOP failures for pumps 02A and 02B; however, there would also be a 50% probability applied to the standby CC pump failure to start failure modes to account for the estimated annual standby time, so the overall CDF impact would not be affected. Again, the importance measures would differ (see the discussion in response to question 19.1.e) on the use of importance measures).

In conclusion, the APR1400 PRA model asymmetries do not impact the CCG size for any affected components, and CCFs are applied to all components within the CCG whenever the underlying failure mode is applicable.

d) <u>The modeling approach and impact of asymmetric configurations on internal fires, internal floods, seismic, and other external events.</u>

The internal fires and internal flooding analyses utilize the internal events models as their base models; hence, they inherently include the same asymmetric configurations with the exception of those associated with the internal events initiating events. Since the initiating events in the external events are caused by the external initiator (e.g., fire or flood event), the random internal events initiators are not part of the external events model. Hence, only the impact of the mitigating system asymmetries are applicable to external events.

The systemic asymmetries impact the fire analysis in the same manner as in the internal events. Given a fire induced initiator, applicable mitigating systems must properly function in order to prevent core damage. SSCs in the mitigating systems can fail due to random failures, or directly as a result of the fire. The fire impacts are directly related to the location of the fire (i.e., fire compartment), and the equipment and cables passing through that compartment. The main impact that the model asymmetries have on the fire analysis is that fires which only fail the control power cables for an asymmetrically modeled component, only impacts that component if it is in standby. For example, in the case of the CC pumps, the 01A pump is assumed running and the 02A pump is in standby. If a fire damages the control power cables for CC pump 01A, there is no impact on the model since the pump is already assumed to be running, and does not require control power. However, if a fire damages the control power cables for CC pump 02A, there is an impact since the pump will not start (without local manual action to close the pump power supply breaker). This is not applicable to fire compartments which contain the pump, or fire compartments which contain both motive power and control power cables since the pump fails regardless of the availability of control power. Therefore, these type scenarios are limited to fire compartments which only contain control cables for the component in question.

In reality, these situations are only applicable to that portion of the year when the pump is in standby (i.e., 50% on average for the CC pumps). This results in a situation where certain fire compartments have an artificially high CDF (those which contain only control cable for the standby pump), and other fire compartments have an artificially low CDF (those which contain only control cable for the running pump). The combined impact of these compartments on the overall fire CDF is unknown, but it is anticipated to be small since it only impacts failure to start failure modes, and at least some of the CDF from scenarios with artificially higher CDF will be cancelled out by that from scenarios with artificially lower CDF. The main impact is on the risk ranking of the individual fire scenarios.

The seismic analysis is a seismic margins analysis, and the other external events use a screening analysis; neither of these analyses are probabilistic, and not impacted by the pre-defined configurations used in the internal events models.

In conclusion, modeling asymmetries have no impact on the Seismic Margins analysis, or the Other External Events screening analysis, and little impact on the internal fire and flooding PRAs.

e) The effect of the asymmetry-related assumptions on component/train-specific importance measures and PRA results/insights/applications (i.e., RAP list).

When reviewing importance measures of SSCs in support of PRA results, insights or applications, the impact of asymmetric modeling is accounted for by using the largest importance measure for the group of SSCs. For example, in the development of the RAP list, the importance measures of all four (4) Component Cooling Water (CC) pumps are compared, and the highest RAW and F-V importance measures of the four CC pumps are assigned to all four CC pumps.

f) A new COL information item to be added to the DCD to ensure that the asymmetric conditions due to modeling simplicity will be addressed or properly accounted for when the PRA is used for decision making.

The following COL action item will be added to the APR1400 DCD Section 19.1.9 to ensure that the COL applicant or holder referencing the certified APR1400 design will, as a minimum, in conformance with the guidance provided in the SRP 19.0 and RG 1.206, address model asymmetry:

- "The COL applicant is to ensure that asymmetric conditions due to modeling simplicity will be addressed or properly accounted for when the PRA is used for decision making."

Impact on DCD

There is an impact on the DCD 19.1, so the DCD 19.1 will be revised to reflect the responses to a) and b). But the DCD 19.1 will be revised in the next periodic upgrade.

DCD 19.1.9 and Table 1.8.2 will be revised as stated in the response to f) as shown in the attachment.

Impact on PRA

There is an impact on the PRA model, so the PRA model will be revised to reflect the responses to a) and b) in the next periodic upgrade.

Impact on Technical Specifications

There is no impact on the Technical Specifications.

Impact on Technical/Topical/Environmental Reports

There is an impact on the PRA Summary Report, so the PRA Summary Report will be revised to reflect the revisions to the PRA model and DCD 19.1.

bolts (versus the 40 bolts used to secure the hatch during at-power operation); four bolts are sufficient to secure the hatch so that no visible gap can be seen between the seals and the sealing surface. See Subsection 19.1.6.2.

COL 19.1(15) The COL applicant is to develop a configuration control program requiring that, during Modes 4, 5, and 6, the watertight flood doors and fire doors be maintained closed in at least one quadrant. Furthermore, the COL applicant is to incorporate, as part of the aforementioned configuration control program, a provision that if the flood or fire doors to this designated quadrant must be opened for reasons other than normal ingress/egress, a flood or fire watch must be established for the affected doors.

COL 19.1(15) The COL applicant is to develop outage management procedures that limit planned maintenance that can potentially impair one or both SC trains during the shutdown modes.

COL 19.1(16) The COL applicant is to develop procedures and a configuration management strategy to address the period of time when one SC train is unexpectedly unavailable (including the termination of any testing or maintenance that can affect the remaining train and restoration of all equipment to its nominal availability).

COL 19.1(17) The COL applicant is to ensure that asymmetric conditions due to modeling simplicity will be addressed or properly accounted for when the PRA is used for decision making.

19.1.1

1. A
Probabilistic Risk Assessment for Nuclear Power Plant Applications" (Revision 1 RA-S-2002), American Society of Mechanical Engineers, April 2008.

2. ASME/ANS RA-Sa-2009, "Addenda to ASME/ANS RA-S-2008," American Society of Mechanical Engineers, February 2009.

3. Regulatory Guide 1.200, "An Approach for Determining the Technical Adequacy of Probabilistic Risk Assessment Results for Risk-Informed Activities," Rev. 2, U.S. Nuclear Regulatory Commission, March 2009.

Table 1.8-2 (28 of 29)

Item No.	Description
COL 19.1(11)	The COL applicant is to develop the fire barrier management procedures that direct the appropriate use of a fire watch and use of the isolation devices with a quick-disconnect mechanism for hose and cables that bleach a fire barrier.
COL 19.1(12)	The COL applicant is to develop procedures and operator training for reliance (during fire response) on undamaged instrumentation (when the location of the fire is known).
COL 19.1(13)	The COL applicant is to develop procedures specifying that a fire watch be present when hot work is being performed.
COL 19.1(14)	The COL applicant is to establish procedures for closing the containment hatch (after being opened during during LPSD operations) to promptly re-establish the containment as a barrier to fission product release. This guidance must include steps that allow for sealing of the hatch with four bolts (versus the 40 bolts used to secure the hatch during at-power operation); four bolts are sufficient to secure the hatch so that no visible gap can be seen between the seals and the sealing surface.
COL 19.1(15)	The COL applicant is to develop a configuration control program requiring that, during Modes 4, 5, and 6, the watertight flood doors and fire doors be maintained closed in at least one quadrant. Furthermore, the COL applicant is to incorporate, as part of the aforementioned configuration control program, a provision that if the flood or fire doors to this designated quadrant must be opened for reasons other than normal ingress/egress, a flood or fire watch must be established for the affected doors.
	The COL applicant is to develop outage management procedures that limit planned maintenance that can potentially impair one or both SC trains during the shutdown modes.
COL 19.1(16)	The COL applicant is to develop procedures and a configuration management strategy to address the period of time when one SC train is unexpectedly unavailable (including the termination of any testing or maintenance that can affect the remaining train and restoration of all equipment to its nominal availability).
COL 19.2(1)	The COL applicant is to perform and submit site-specific equipment survivability assessment in accordance with 10 CFR 50.34(f) and 10 CFR 50.44.
COL 19.2(2)	The COL applicant is to develop and submit an accident management plan.

COL 19.1(17) The COL applicant is to ensure that asymmetric conditions due to modeling simplicity will be addressed or properly accounted for when the PRA is used for decision making.