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.:	**418-8348**
SRP Section:	**SRP 19**
Application Section:	**19.1**
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Question No. 19-45

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, 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)."

It also states that, "…the applicant's uncertainty analysis identifies major contributors to the uncertainty associated with the estimated risks."

SRP Chapter 19.0, Revision 3, Section "III. Review Procedures," states:

"The staff will determine that the applicant has performed sensitivity studies sufficient to gain insights about the impact of uncertainties (and the potential lack of detailed models) on the estimated risk. The objectives of the sensitivity studies should include (1) determining the sensitivity of the estimated risk to potential biases in numerical values, such as initiating event frequencies, failure probabilities, and equipment unavailabilities, (2) determining the impact of the potential lack of modeling details on the estimated risk, and (3) determining the sensitivity of the estimated risk to previously raised issues (e.g., motor-operated valve reliability)."

It also states:

"…it is acceptable to make bounding-type assumptions consistent with the guidelines in RG 1.200. However, the risk models should still be able to identify vulnerabilities as well as design and operational requirements such as ITAAC and COL action items. In addition, the bounding assumptions should not mask any risk-significant information about the design and its operation."

To allow the staff to reach a reasonable assurance finding on the scope, level of detail, and technical adequacy of the APR1400 design certification PRA, the staff needs to understand how uncertainties in key assumptions impact risk quantification and risk insights. The staff notes that NUREG-1855, Revision 1, "Guidance on the Treatment of Uncertainties Associated with PRAs in Risk-Informed Decisionmaking," discusses the three types of uncertainty: completeness, parametric, and modeling. Based on review of the DCD, the staff finds that both the identification of key assumptions and the assessment of uncertainty in the stated key assumptions may not be complete. For low power and shutdown, the staff noted the statement in DCD Sections 19.1.6.1.2.7 and 19.1.6.3.2.4 that, "Modeling uncertainty is not represented in the shutdown model."

The staff reviewed Table 19.1-4 of the DCD which lists the key assumptions used in the PRA. However, Table 19.1-4 does not identify any key assumptions related to several PRA models (e.g., internal fire at power, internal flooding at power, as well as low power and shutdown). Furthermore, the staff finds that in some areas, the DCD does not document the evaluation of uncertainties associated with the key assumptions in Table 19.1 4. Identification of key assumptions in the DC application is important as the staff would need to validate this information for a future COL application referencing the DC.

Below are some example assumptions that should be evaluated for uncertainty:

- conditional core damage and large release probability associated with main control room abandonment scenarios
- fire ignition frequencies (e.g., consideration of more recent at-power and LPSD fire ignition frequency estimates)
- fraction of the room volume filled by equipment for internal flooding analysis
- RCP seal failure probability and model
- human error probabilities

To address the issues described above:

a) Update the DCD with a comprehensive assessment (not limited to these examples) of the impact of uncertainties in key assumptions:

    - risk insights, such as risk-significant equipment or operator actions, and important accident sequences, and
    - risk quantifications (of CDF and LRF)

b) Ensure that the uncertainty assessment considers all PRA models included in the APR1400 DC PRA (i.e., all operating modes, hazards, and PRA levels).

c) Ensure that any key assumptions related to any PRA model are identified in DCD Table 19.1-4.

Response – (Rev.2)

This response provides additional information associated with RAI 637-8664, Question 10.04.09-8, which is follow-up to RAI-86-8003, Question 10.04.09-6. The response to RAI 418-8348, Question 19-45 will be addressed with the response to RAI 434-8352, Question 19-92, which are closely related topics.

An AFWS reliability analysis was performed in accordance with Three Mile Island (TMI) Action Item II.E.1.1 of NUREG-0737. An acceptable AFWS should have unreliability in the range of 10^{-4} to 10^{-5} per demand as stated in Chapter 10.4.9 of NUREG-0800, Revision 3, "Standard Review Plan, Auxiliary Feedwater System (PWR), SRP Acceptance Criteria." The AFWS achieves this reliability target, as described in below:

1. The results of the AFWS reliability analysis are summarized in the DCD Section 19.1.7.6 (Attachment 1) and DCD Table 19.1-162 (Attachment 2).

2. See the response to Item 1 above.

3. The relationship between two columns in the table in Attachment 1 and an acceptable AFWS unavailability is discussed in the DCD Section 19.1.7.6 (see Attachment 1).

   Note that LOOP-GR scenario without the offsite power recovery has a system unreliability of $5.5x10^{-4}$ per demand (see Attachment 2). However, if the offsite power recovery is applied to this scenario the system reliability becomes $9.2x10^{-5}$ per demand which is in the range of 10^{-4} to 10^{-5} per demand. Crediting the offsite power recovery for LOOP-GR scenario is justified based on Chapter 10.4.9 of NUREG-0800 which states that compensating factors (e.g., other methods of accomplishing AFWS safety functions of the AFWS or other reliable methods for cooling the reactor core during abnormal conditions) may be considered to justify a larger AFWS unavailability.

Further details of AFWS reliability study will be added in the Auxiliary Feedwater System Notebook (APR1400-K-P-NR-013207-P) as an appendix.

Impact on DCD

The DCD Section 19.1.7.6 and 10.4.9.2.1 will be revised as discussed above.

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.

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4) Transmitting excessive loads to the containment pressure boundary

5) Compromising the function of the MCR

6) Precluding an orderly cooldown of the RCS

s. Each turbine-driven pump is supplied with steam from a single SG (i.e., the one to which it supplies AFW).

t. The AFW is delivered to the downcomer nozzles of the SGs.

u. A non-safety-grade source of condensate from the condensate storage tank (by gravity feed) can be aligned if the safety-related source is exceeded before shutdown cooling system entry conditions are reached.

v. The principal AFWS pressure-retaining materials are shown in Table 10.4.9-5.

w. The recommendations of NRC RG 1.28 (Reference 3) are applied during fabrication of the AFWS, and preheat guidelines in ASME Section III, Appendix D, Article D-1000 for carbon steel are applied to the AFWS components.

10.4.9.2 System Description

10.4.9.2.1 General Description

Table 10.4.9-7

The AFWS is shown in Figures 10.4.9-1. The AFWS consists of two 100 percent capacity motor-driven pumps, two 100 percent capacity turbine-driven pumps, two 100 percent auxiliary feedwater storage tanks (AFWSTs), valves, two cavitating flow-limiting venturis, and instrumentation. The SG makeup flow requirement is given in ~~Table 10.4.9-7~~.
~~Table 19.1-162 and discussed in Subsection 19.1.7.6.~~

Each pump takes suction from a respective AFWST and has a respective discharge header. Each pump discharge header contains a pump discharge check valve, flow-modulating valve, AFW isolation valve, and SG isolation check valve. One motor-driven pump and one turbine-driven pump are configured into one mechanical division and joined together inside containment to feed their respective SG through a common AFW header, which connects to the SG downcomer feedwater line. Each common AFW header contains a cavitating venturi to restrict the maximum AFW flow rate to each SG.

making the final determination of the RAP scope. Refer to Section 17.4 for a description of the Reliability Assurance Program. As stated in Subsection 19.1.1.4, the COL applicant is responsible for describing the uses of PRA in support of licensee programs such as RAP implementation during the operational phase.

19.1.7.5 PRA Input to the Regulatory Treatment of Non-Safety-Related Systems Program

The APR1400 design is an evolutionary ALWR, and the RTNSS is not applicable to this design.

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19.1.8 Conclusions and Findings

The APR1400 design has evolved from current PWR technology that incorporates features intended to make the plant safer and easier to operate as compared to currently operating plants. The PRA results and risk insights should confirm that the design incorporates features to reduce overall risk compared to operating plants. The phrase "risk insights" refers to the results and findings that come from PRA. Specifically, risk insights include information about:

a. Design features that are the highly effective in reducing risk with respect to operating plants

b. Major contributors to risk, including equipment failures and operator actions

c. Major contributors to the uncertainty associated with the risk results

Risk insights from each hazard evaluated for different operational modes are described in the subsections shown below:

19.1.4.1.2.8 – Level 1 Internal Events PRA for Operations at Power

19.1.4.2.2.8 – Level 2 Internal Events PRA for Operations at Power

19.1.5.1.2.3 – Seismic Risk Evaluation

19.1.5.2.2.5 – Internal Fire Risk Evaluation

19.1.5.3.2.4 – Internal Flooding Risk Evaluation

A (1/2)

19.1.7.6 AFWS Reliability Analysis

The AFWS reliability analysis was performed in accordance with Three Mile Island (TMI) Action Item II.E.1.1 of NUREG-0737 as stated in DCD Section 10.4.9.1.2 (o). The AFWS reliability was evaluated for four system scenarios:

- Loss of AFWS following initiation of a general transient event (GTRN)
- Loss of AFWS following initiation of a loss of main feedwater event (LOFW)
- Loss of AFWS following initiation of a grid related loss of offsite power event (LOOP-GR)
- Loss of AFWS following initiation of a grid related LOOP-GR event with offsite power recovered

The AFWS reliability models were developed using the existing at-power internal events PRA model for the AFWS trains A and B (i.e., one motor driven pump (MDP) and one turbine driven pump (TDP) per train) supplying their associated steam generators during the initial 24 hour period following the initiating event. The AFWS fault tree logic includes system/train independent failures, common cause failures, human action failures, test and maintenance events, and associated power and steam support systems failures.

19.1.7.6.1 Loss of AFWS Following Initiation of a General Transient Event (GTRN)

The AFWS system reliability was evaluated for the conditions following the initiation of a general transient event (GTRN). The system fault tree model consists of failure of both Train A AFW MDP and TDP to provide sufficient flow to steam generator 1, and failure of both Train B AFW MDP and TDP to provide sufficient flow to steam generator 2. The GTRN initiating event is set to a 1.0 value, guaranteeing only GTRN conditions are evaluated. The AFWS unreliability following initiation of a GTRN event ($1.5x10^{-5}$/demand) is dominated by the common cause failure of all four AFWS pumps (two turbine driven and two motor driven) to run. Other top dominate failures are:

- Common cause failures of three AFWS pumps and a turbine driven pump to run
- Common cause failure of all four diesel generators to run
- Failure of all ESW debris filters due to plugging
- Common cause failure of all four ECW chillers to start

A startup feedwater system can be applied to a GTRN event case, which will improve the AFWS reliability.

19.1.7.6.2 Loss of AFWS Following Initiation of a Loss of Main Feedwater Event (LOFW)

The AFWS system reliability was evaluated for the conditions following initiation of a loss of main feedwater event (LOFW). The system fault tree model and the results are same as that of the GTRN event case described above, except a startup feedwater system is not available for a LOFW event case.

19.1.7.6.3 Loss of AFWS Following Initiation of a Grid Related Loss of Offsite Power Event (LOOP-GR)

The AFWS system reliability was evaluated for the conditions following initiation of a grid related loss of offsite power event (LOOP-GR). The system fault tree model is same as the GTRN event case above, but the LOOP-GR model includes the onsite power support system models (including EDGs). The system model associated with station blackout (SBO) condition is not credited.

The AFWS unreliability following initiation of a LOOP-GR ($4.8x10^{-4}$/demand) is dominated by the common cause failure of all four AFWS pumps (two turbine driven and two motor driven) to run. Other top dominate failures are:

- Failure of an AFW TDP isolation MOV to close and common cause failure of 3 of 4 EDGs to run
- Failure of an AFW TDP isolation MOV to open and common cause failure of 3 of 4 EDGs to run
- Failure of both AFW TDP isolation MOVs to close and failure of EDGs 1A and 1B to run

A (2/2)

19.1.7.6.4 Loss of AFWS Following Initiation of a Grid Related LOOP Event with Offsite Power Recovered

The AFWS system reliability was evaluated for the conditions following initiation of a LOOP-GR with offsite power recovery is considered. The system fault tree model is identical to that of LOOP-GR in Subsection 19.1.7.6.3. Key recovery rules applied are the offsite recovery at 4 hours, and the offsite recovery at 16 hours during LOOP condition. The AFWS unreliability following initiation of a LOOP-GR where offsite power recovery is considered ($9.2x10^{-5}$/ demand) is dominated by the common cause failure of all four AFWS pumps to run. Other top dominate failures are:

- Failure of an AFW TDP isolation MOV to close, common cause failure of 3 of 4 EDGs to run, and non-recovery of offsite power within 4 hours
- Failure of an AFW TDP isolation MOV to open, common cause failure of 3 of 4 EDGs to run, and non-recovery of offsite power within 4 hours
- Common cause failures of three AFWS pumps and a turbine driven pump failure to run

19.1.7.6.5 AFWS Reliability Analysis Conclusion

The results of the modeled scenarios are shown in Table 19.1-162, “AFWS Unreliability Results.” An acceptable AFWS should have unreliability in the range of 10^{-4} to 10^{-5} per demand exclusive of station blackout scenarios per NUREG-0800, Chapter 10.4.9 (Reference 6 of the DCD Section 10.4.12). NUREG-0800 also states that compensating factors (e.g., other methods of accomplishing AFWS safety functions of the AFWS or other reliable methods for cooling the reactor core during abnormal conditions) may be considered to justify a larger AFWS unavailability. Note that LOOP-GR scenario without the offsite power recovery has a system unreliability of $5.5x10^{-4}$ per demand. However, if the offsite power recovery is applied to this scenario the system reliability becomes $9.2x10^{-5}$ per demand which is in the range of 10^{-4} to 10^{-5} per demand.

The failure of AFWS scenarios evaluated for GTRN, LOFW, and LOOP-GR with power recover considered show that APR1400 AFWS reliability achieves this reliability target by having unreliability probabilities within the specified range, as summarized in Table 19.1-162.

Table 19.1-161

LPSD FPRA Source Term Category Frequencies and Contributions to LRF (POS 4B-12A)

Source Term Category	Description	Frequency (/yr)	% Total of LRF
RC-2-LPSD	Large, Early LPSD releases	2.69E-8	43.3
RC-3-LPSD	Large, Late LPSD releases	3.52E-8	56.7
Total		6.21E-8	100.0

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Table 19.1-162 AFWS Unreliability Results

AFW System Scenario	System Unreliability (per demand)
Failure of AFWS following initiation of a General Transient Event (GTRN)	1.5E-05
Failure of AFWS following initiation of a Loss of Main Feedwater Event (LOFW)	1.5E-05
Failure of AFWS following initiation of a Grid Related Loss of Offsite Power Event (LOOP-GR)	5.5E-04
Failure of AFWS following initiation of a LOOP-GR (with offsite power recovery)	9.2E-05