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:	**19 - Probabilistic Risk Assessment and Severe Accident Evaluation Application Section**
Application Section:	**19**
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Question No. 19-5

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 Shutdown Evaluation report (reference 22 in Section 5.4.7 of the DCD), Section 2.5.2 “Temperature Considerations”, states “In the analyses, the temperature of 71 degrees Celsius (160 degrees Fahrenheit) is used as the allowable upper limit, and the containment temperature should be maintained to be less than this value during the required time to close all containment openings including hatch or personal air locks at an accident.” The staff acknowledges that this statement concerns the Mode 5 LOCA analysis with water level in the pressurizer which is not reduced inventory operation. Since the safety injection pumps are assumed to be manually actuated at 32 minutes after the reactor trip by a pipe break, the staff understands no fuel damage is postulated for the Mode 5 LOCA with full inventory. However, the staff is requesting KHNP to justify reliable operator action for hatch closure in the Shutdown Evaluation Report, given the presence of (1) steam, (2) high humidity, (3) low visibility due to fog, and (4) high temperatures. The staff is requesting KHNP to clarify in Chapter 19 of the DCD whether the 160 degree Fahrenheit upper limit was used, when the hatch is permitted to be opened, to develop the likelihood of the operator failing to re-close the equipment hatch above reduced inventory conditions following a loss of decay heat removal.

Response

a) **Justify reliable operator action for hatch closure in the Shutdown Evaluation Report, given the presence of steam, high humidity, low visibility due to fog, and high temperatures.**

The 160 degrees Fahrenheit of the temperature, stated in the Shutdown Evaluation Report, Section 2.5.2 “Temperature Considerations”, is used as the allowable upper limit of temperature which does not damage personnel lungs and is based on the NUREG-1449.Thus this temperature value is chosen as the acceptance criteria to fulfill a minimum habitability that protects personnel health in a harsh environment.

In a LOCA and loss of decay heat removal event, the containment atmosphere is reached at high humid temperature condition in a short period of time after accident initiation even though the hatch remains opened. High humidity with low visibility due to fog as well as the high temperature aggravates the working environment, which results in shorting the work time required for plant personnel to close the containment hatch.

The COL applicant will determine the allowable safe working time for each plant personnel based on the time to reach the temperature limit estimated from the containment analysis, with consideration of the high relative humidity and low visibility in containment. The COL applicants will also develop the detailed plan and procedures for containment closure.

Followings are the description of each action for containment closure performed by DC and COL applicants. Subsection 2.5.3.4.4.2 of the Shutdown Evaluation Report (APR1400-E-N-NR-14005-P/NP) will be revised to include the following actions and the action items assigned to COL applicants will be summarized in Chapter 5 of the DCD.

DC applicant:

- Estimates the maximum allowable time for containment openings for radiation and temperature.
  - Identifies the limiting event with respect to core uncovery and radiation exposure
  - Verifies that the containment temperature is maintained less than 160 degrees Fahrenheit before completion of hatch closure.
- Provides a guidance to calculate allowable working time to personnel under harsh environment condition.
  - Identifies work and environmental factors being considered as the harsh environment to plant personnel.
  - Provides guidance on calculating heat stress that limits the safe working time in containment for personnel.

COL applicant:

- Estimates the actual time required for containment closure
  - Tests and verifies the required time for hatch closure by AC power at normal conditions.
  - Tests and verifies the required time for hatch closure by manual operation without AC power.

- Validates the actual time for hatch closure being less than the estimated allowable time for containment opening during an accident.

- Calculates allowable work time given to plant personnel in an accident
  - Determines type of work (heavy, moderate, light) and type of clothing while performing hatch closure.
  - Calculates allowable work time during accident conditions based on Heat Stress Management Program (EPRI NP-4453-L)
- Develops the procedure to protect plant personnel from harsh environment.
  - Uses a protective clothing equipped with self-breathing apparatus and safety glasses
  - Sets up the work plan to limit the allowable work time to each personnel during hatch closure.
  - A review of training for multiple crews to close the hatch in high humid temperature conditions that limit the allowable work time for each crew.
- Develops procedure to lengthen work time during hatch closure.
  - Use of fan coolers to decrease the maximum temperature, thus permitting longer work periods.
  - A review of training with the objective of reducing the closure time of containment hatch.
  - Improves design of the equipment hatch to reduce the time needed to close the containment.

b) Clarify in Chapter 19 of the DCD whether the 160 degree Fahrenheit upper limit was used, when the hatch is permitted to be opened, to develop the likelihood of the operator failing to re-close the equipment hatch above reduced inventory conditions following a loss of decay heat removal.

Shutdown Evaluation

The postulated accidents assuming containment openings include loss of shutdown cooling at above reduced inventory at mode 5, core alterations at mode 6 as well as LOCA at full inventory at mode 5. In the APR1400, all the events other than LOCA at full inventory are excluded from the LPSD analyses since times to reach coolant saturation and core uncovery of the loss of decay heat removal and core alterations are far longer (at least five times) than that of the LOCA at full inventory. The comparison was demonstrated on the System 80+ (Section 19.8A 2.5.3.3 of the CESSAR DC) which is the same PWR reactor type as the APR1400.

LPSD PRA

The 160 degree Fahrenheit upper limit was not used to develop the likelihood of the operator failing to re-close the equipment hatch in low power and shutdown (LPSD) Level 2 PRA. LPSD Level 2 PRA assumed that the containment equipment hatch is closed during reduced inventory conditions as well as above reduced inventory conditions which RCS is not intact for RCS fillup and drainout operation at mode 5. This assumption is based on procedure guidance of Shutdown Evaluation Report Table 2.1-1 “Administratively require containment integrity to remain intact during fillup and drainout in mode 5”.

Impact on DCD

The Subsection 5.4.16 of the DCD will be revised as indicated on the attached markup.

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

The Subsection 2.5.2.2 and 2.5.3.4.4.2 of the Shutdown Evaluation Report (APR1400-E-N-NR-14005-P/NP) will be revised as indicated on the attached markup.

COL 5.4(5) The COL applicant is to verify the as-built RV support material properties and 60-year neutron fluence.

COL 5.4(6) The COL applicant is to provide a procedure to protect the plant personnel from harsh environment and lengthen the work time within containment during hatch closure.

5.4.17 References

1. ASME Boiler and Pressure Vessel Code, Section III, "Rules for Construction of Nuclear Facility Components," The American Society of Mechanical Engineers, the 2007 Edition with the 2008 Addenda.

2. 10 CFR Part 50, Appendix A, "General Design Criteria for Nuclear Power Plants." U.S. Nuclear Regulatory Commission.

3. Regulatory Guide 1.14, "Reactor Coolant Pump Flywheel Integrity," Rev. 1, U.S. Nuclear Regulatory Commission, August 1975.

4. APR1400-A-M-NR-14001-P, "KHNP APR1400 Flywheel Integrity Report," KHNP, November 2014.

5. ASME Boiler and Pressure Vessel Code, Section XI, "Rules for Inservice Inspection of Nuclear Power Plant Components, The American Society of Mechanical Engineers, the 2007 Edition with the 2008 Addenda.

6. ASME PTC 8.2, "Centrifugal Pumps," The American Society of Mechanical Engineers, 1990.

7. NEMA MG-1, "Motors and Generators," National Electrical Manufacturers Association, 2009 (with 2010 Revision 1).

8. Regulatory Guide 1.121, "Bases for Plugging Degraded PWR Steam Generator Tubes," Revision 0, U.S. Nuclear Regulatory Commission, August 1976.

9. ASME Section III, Appendix N, "Dynamic Analysis Methods," The American Society of Mechanical Engineers, the 2007 Edition with the 2008 Addenda.

10. Bulletin 79-13, "Cracking in Feedwater System Piping," Rev. 1, U.S. Nuclear Regulatory Commission, August 30, 1979.

11. NEI 97-06, "Steam Generator Program Guidelines," Rev. 3, Nuclear Energy Institute, January 2011.

Equivalent (TEDE), which is applicable to LOCAs at full power as specified in 10 CFR 50.34(a)(1)(ii) (Reference 11).

- TEDE less than 250 mSv for a pipe break during shutdown cooling operation

The radiological acceptance criteria due to an event resulting from a loss of DHR are determined to meet a small fraction of the dose limits in 10 CFR 50.34(a)(1)(ii). A fraction of 10 percent is selected taking into consideration the higher event frequency. Therefore, a 25 mSv TEDE at the EAB for any 2 hours is applied to the loss of DHR during shutdown cooling operation.

- TEDE less than 25 mSv for a loss of DHR during shutdown cooling operation

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2.5.2.2 Temperature Considerations

Other than the radiation levels, environmental condition such as temperature or relative humidity influence the allowable working time to close all containment openings. NUREG-1449 describes the allowable environmental condition to protect the personnel health at work inside the containment. It notes an upper temperature limit of 71 °C (160 °F) to avoid burning the lungs.

In the analyses, the temperature of 71 °C (160 °F) is used as the allowable upper limit and the containment temperature should be maintained to be less than this value during the required time to close all containment openings including hatch or personal air locks at an accident.

2.5.2.3 Airborne Radioactivity Concentrations

The emergency operators, who take action to close the containment, should also be protected from radiological exposure from the airborne radioactivity that is released from the RCS to the containment atmosphere. According to the scoping analyses performed by NRC staff in NUREG-1449, the internal dose rates may not be a serious issue if there is no fuel cladding leak and the RCS is cleaned up prior to start of shutdown cooling operation. In addition, the operators would be expected to wear breathing apparatus, and the inhalation doses would be much lower than the estimated values in NUREG-1449. Therefore, the airborne concentrations are not addressed in this analysis.

2.5.3 Description

2.5.3.1 Problem Formulation

The concern of interest is whether the pre-determined radiological dose limits are exceeded due to shutdown and low-power events while the containment is open. The amount of radioactive release depends on factors such as the events that are considered, containment integrity and the Technical Specifications and procedures for closing the containment.

Assumptions used in the analysis are chosen conservatively so the time required to close the containment prior to exceeding the offsite dose limit is minimized. Factors affecting the time to close the containment include radiological and environmental conditions, number and location of closure bolts, provision for loss of ac power, keeping tools needed for closing the equipment hatch near at hand and training and rehearsing personnel in the closure procedure. The analysis focuses on the temperature condition within the containment following the initiation of the event since the other factors are handled by the operational program.

The results of the analyses are used to support recommended changes to Technical Specifications and/or procedures.

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2.5.2.2 Temperature Considerations

NUREG-1449 notes an upper limit on temperature of 160 ˚F for personnel health, and EPRI-NP4453 LRI establishes guidelines for time limits in which work can be performed in high temperature humid environments.

A combination of environmental conditions (temperature, relative humidity) and work related factors (type of clothing, type of work) influences the staying time duration within containment. The safe work time recommended is based on the wet bulb globe temperature (WBGT) adjusted by the clothing type and level of work (light, moderate or heavy). At the containment initial conditions of 100 ˚F and 50% relative humidity without protective clothing, maximum work times for moderate work is longer than two hours.

Acceptance limits on temperature will be assumed based on the maximum times needed to close containment openings in each of the modes and events considered. In the APR1400, the temperature evaluation is limited to a loss of DHR initiated by loss of coolant accident at Mode 5, which has the potential for open containment. For Mode 5 LOCA, a minimum time of 60 minutes of moderate work is assumed to close the equipment hatch.

flashing fraction of 10 percent is used to be consistent with RG 1.183.

The 2-hour χ/Q value of 1.0E-03 sec/m^3 is used to calculate the potential offsite dose at the EAB.

2.5.3.4.4 Results

The thermodynamic and radiological analyses were performed assuming that the equipment hatch and personnel airlock areas remain closed or open throughout the progress of the event sequences.

The time to close the containment is determined to meet the dose limit of 250 mSv TEDE at the EAB, as described in Subsection 2.5.2.1. The temperature inside the containment for personnel to conduct containment closure is limited to 71 °C (160 °F), as described in Subsection 2.5.2.2.

2.5.3.4.4.1 Offsite Dose at EAB

The radiological consequences due to a Mode 5 LOCA are presented in Table 2.5-7 and Figure 2.5-4. The results show that the offsite dose is 150 mSv which is within the dose limit of 250 mSv. As shown in Figure 2.5-4, the minimum closure time is greater than 2 hours.

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2.5.3.4.4.2 Containment Temperature

The transient behaviors of containment temperatures are shown on Figure 2.5-5. For the case that 2 SIPs are in operation, the containment temperature is always maintained at less than 71 °C (160 °F). Although, for the case of 1 SIP operation, the containment temperature increases with time as the mass and energy release to the containment continues, the temperature is maintained at less than 71 °C (160 °F) during approximately more than 70 minutes after accident initiation. This satisfies the requirement that the containment temperature be maintained at less than 71 °C (160 °F) during the time required to close the equipment hatch.

2.5.4 Resolution

Analyses have been performed to provide reasonable assurance that the public radiation dose limit is not exceeded during the shutdown and low power operation modes. Through a qualitative evaluation on a variety of DBEs, a Mode 5 LOCA with full inventory was selected as the representative event to be quantitatively analyzed. Following a set of thermal-hydraulic analyses and radiological consequence analysis, it is concluded that the offsite dose at the EAB conforms with the acceptance limits of 250 mSv. In addition, the containment temperature is maintained less than the upper temperature limit of 71 °C (160 °F) for sufficient time to close the equipment hatch.

2.5.3.4.4.2 Containment Temperature

The transient behaviors of containment temperatures are shown on Figure 2.5-5. For the case that 2 SIPs are in operation, the containment temperature is always maintained at less than 71 °C (160 °F). Although, for the case of 1 SIP operation, the containment temperature increases with time as the mass and energy release to the containment continues, the temperature is maintained at less than 71 °C (160 °F) during approximately more than 70 minutes after accident initiation.

With consideration of safe work environment in containment, high humid temperature could limit the time available for utility personnel to close the containment within one hour. The use of multiple crews would be help if high humid condition limits the safe work time for each crew. Followings are the description of the actions for containment closure performed by DC and COL applicants respectively,to protect the plant personnel from harsh environment and lengthen the work time within containment.

DC applicant:
○ Estimates the maximum allowable time for containment openings in view of the radiation and temperature.
. Identifies the limiting event with respect to core uncovery and radiation exposure
. Verifies that the containment temperature is maintained less than 160 degrees Fahrenheit before completion of hatch closure.
○ Provides a guidance to calculate allowable working time to personnel under harsh environment condition.
. Identifies work and environmental factors being considered as the harsh environment to plant personnel.
. Provides a guidance to calculate heat stress to a personnel that limits the safe working time in containment.

COL applicant:
○ Estimates the actual time required for containment closure
. Tests and verifies the required time for hatch closure by AC power at a normal condition
. Tests and verifies the required time for hatch closure by manual operation without AC power.
. Validates the actual time for hatch closure being less than the estimated allowable time for containment opening at an accident.
○ Calculates allowable work time given to plant personnel in an accident
. Determines type of work (heavy, moderate, light) and type of clothing while performing hatch closure.
. Calculates allowable work time in an accident condition based on Heat Stress Management Program (EPRI NP-4453-L)
○ Develops the procedure to protect plant personnel from harsh environment.
. Uses a protective clothing equipped with self-breathing apparatus and safety glasses
. Setups the work plan to limit the allowable work time to each personnel during hatch closure.
. A review of training for multiple crews to close the hatch in the high humid temperature condition that limits the allowable work time for each crew.

○ Develops procedure to lengthen work time during hatch closure.
. Use of fan coolers to decrease the maximum temperature, thus permitting longer work periods.
. A review of training with the objective of reducing the closure time of containment hatch.
. Improves design of the equipment hatch to reduce the time needed to close the containment.