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.:	**440-8551**
SRP Section:	**19 - Probabilistic Risk Assessment and Severe Accident Evaluation Application Section**
Application Section:	**19**
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Question No. 19-95

The staff reviewed the applicant’s response to RAI 7864, Question 19-5. In this RAI, staff requested 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 also requested KHNP to clarify in Chapter 19 of the DCD whether the 160 degree Fahrenheit (160F) 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, with vessel level above reduced inventory conditions.

In the RAI response, KHNP responded that the 160 degree temperature limit comes from NUREG 1449. However, Section 6.9.4.2 of NUREG-1449, "Radiological Considerations," states, “Boiling of coolant within an opened reactor system following a postulated loss of shutdown cooling would release dissolved fission products within the containment atmosphere.” In NUREG-1449, PWR equivalent doses are depicted in Figures 6.2 and 6.3. These calculations indicate that self-contained breathing apparatus would be required for an extended stay within the containment because of the dose and humidity, since the filtration type would not function adequately in high humidity above about 106F (41C). NUREG-1449 also states, “It may be difficult to perform containment closure operations in self-contained breathing apparatus because the air supply will limit how long personnel can stay on the job. In evaluating recovery actions following a potential loss of shutdown cooling, licensees should avoid plant conditions in which steaming could occur before the containment was closed, unless reduced coolant activities or limited requirements for personnel entry indicated that the associated risk was acceptable.”

The staff also reviewed NUMARC 91-06, Guidelines for Industry Actions to Assess Shutdown Management, dated December 1991. Section 4.1.1, Loss of Decay Heat Removal, Guideline 3, states, “Containment hatches (equipment and personnel) and other penetrations that communicate with the containment atmosphere (primary or secondary, as appropriate) should either be closed or capable of being closed prior to core boiling following a loss of DHR and should be addressed in procedures."

KHNP also responded that the low power and shut down (LPSD) Level 2 PRA assumed that the containment equipment hatch is closed during reduced inventory conditions as well as above reduced inventory conditions when reactor coolant system (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."

Based on this response, the staff reviewed the Basis for Technical Specification (TS), 3.6.7, which requires containment closure during reduced inventory operations. The KHNP TS states that Reduced RCS Inventory is defined as the plant condition when the RCS level is below the 38.72 m (127 ft 1/4 in) elevation and fuel is in the reactor vessel. The 38.72 m (127 ft 1/4 in) elevation corresponds to 91.44 cm (3 ft) below the reactor vessel flange.

Based on staff review of: (1) KHNP's response to RAI 19-5, (2) NUREG-1449, (3) KHNP TS 3.6.7, and (4) KHNP's proposed DCD Table 19.1-93, the staff has the following questions:

1. The applicant's proposed combined license (COL) action item for the development of containment closure procedures that will be in effect until containment temperatures reach 160F appear to be inconsistent with NUREG-1449 and NUMARC 91-06. The staff is requesting KHNP to revise this COL action item to be consistent with NUMARC 91-06 or explain the basis for not revising the item.

2. Based on the TS definition of reduced inventory, Plant Operational State (POS) 6, which is defined as having RCS vessel level at the vessel flange, may have the containment hatch open. According to TS, POS 4B and POS 10 may also have the containment hatch open. However, DCD Section 19.1.6.2.1.1, states that a single Containment Event Tree (CET) model is developed for evaluation of POS 4B, 5, 6, 10, 11, and 12A. DCD Section 19.1.6.2.1.1 also states, for each of these POSs, "the containment is closed per Technical Specifications and the pressurizer manway open, the accident progressions considered are similar and can be assessed with a single CET." The staff is requesting KHNP to resolve the technical inconsistency between Technical Specifications and DCD section 19.1.6.2.1.1.

Response – (Rev. 1)

1. The COL action item for containment closure procedures at a harsh environment during shutdown is provided only in the Shutdown Evaluation Report (SER). The NRC's question regarding the COL action item is not applicable since the SER is not incorporated by reference (IBR) to the DCD.

2. Applicability of TS 3.6.7 will be revised in the response to RAI 481-8546. Therefore, DCD Section 19.1.6.2.1.1 will not be revised.

Impact on DCD

There is no impact on the DCD.

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.

Many of the LPSD Level 2 phenomenological considerations are the same as in the at-power analysis. Examples include containment isolation (without credit for automatic SI signals, which are not functional in some POS) and containment overpressurization. Some at-power phenomena are not relevant in some POS. However, some LPSD POS present accident progression challenges are unique to LPSD and therefore require evaluation. For example, in some POS, the containment equipment hatch can be open, which must be considered as a potential release path. When the hatch is closed (as is the case in many POS), it is secured with fewer bolts than in at-power conditions, meaning a lower containment ultimate pressure can be tolerated. In addition, a severe accident in POS with the RCS open results in hydrogen releases from the RCS that differ from at-power, so consideration must be given to the potential for hydrogen "pocketing." The most significant differences between the at-power and the LPSD Level 2 analysis occur in those POS in which the RCS is open, so the Level 2 analysis evaluates these in more detail, with additional consideration given to the POS in which the containment equipment hatch may be open.

The approach to the LPSD Level 2 is similar to the at-power Level 2 analysis in Subsection 19.1.4.2. The following subsections present material that differs from the at-power analysis. References to the at-power analysis are often made in the description of the LPSD Level 2 approach.

Unlike the at-power Level 2 analysis, the LPSD Level 2 does not group Level 1 sequences into PDSs. Relevant Level 1 sequence characteristics and system evaluations are considered directly in the LPSD containment event tree (CET). The top logic fault tree is used for the CET quantification, allowing Level 2 system fault trees and the CETs to be directly linked to the Level 1 system models without the need for the creation of PDSs.

A single CET model is developed for evaluation of POS 4B, 5, 6, 10, 11, and 12A. Since, for each of these POS, the containment is closed per ~~Technical Specifications~~ and the pressurizer manway open, the accident progressions considered are similar and can be assessed with a single CET. Differences in timing are evaluated for HEPs, but these are evaluated at the fault tree level and do not alter the CET structure.

~~is~~ ~~the Shutdown Evaluation Report~~

No change from original sentence

For POS 1, 2, 3A, 13, 14, and 15, the containment integrity is required by Technical Specifications, and the RCS is intact. Therefore, the accident progression of these POS can conservatively be estimated using the at-power conditional probability of a large

2.5.3.4.3.2 Input Parameters and Initial Conditions

The radiological consequences of the Mode 5 LOCA are analyzed using a conservative set of assumptions and the APR1400 design inputs. Input parameters values used in the analysis are presented in Table 2.5-6.

The RCS isotopic iodine concentrations are based on the Technical Specification for RCS equilibrium activity, and the noble gas concentrations are based on 1 percent fuel defect. Consistent with RG 1.183, iodine spiking is not considered.

The RCS mass release rates shown in Table 2.5-6 are determined to envelop the two cases in Table 2.5-4 because there is no difference in the resultant radiological consequences for the two cases.

The flashing fraction is determined based on the enthalpy difference under the circumstance of coolant leakage by assuming the leakage to be a constant enthalpy process. For all of the radionuclides released into the containment through the pipe break, the flashing fraction is conservatively assumed to be 1. For ESF leakage, the IRWST water is conservatively assumed to remain at less than 100 °C (212 °F), and the 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.

No change from original sentence

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.

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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 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:

A COL applicant should consider the following action items during TS mode 5 with the Pressurizer manway closed.

○ Validate the time required for containment closure.
  . Test and verify the required time for hatch closure with AC power.
  . Test and verify the required time for manual hatch closure without AC power.
  . Confirm that the actual time for hatch closure is less than the estimated allowable time following an accident.
○ Determine the allowable work time available for plant personnel in an accident.
  . Evaluate the work (heavy, moderate, light), and the type of clothing in use, when closing the hatch.
  . Determine the allowable work time during accident conditions, based on the Heat Stress Management Program (EPRI NP-4453-L).
○ Protect plant personnel from a harsh environment.
  . Utilize protective clothing, including a self-contained breathing apparatus and safety glasses.
  . Limit the allowable work time during hatch closure due to high temperature, humidity and dose, in compliance with ALARA.
  . Review training practices to ensure that the staff can complete the hatch closure, in a potentially harsh environment, within the required time.
○ Optimize the work environment while reducing the required work time.
  . Utilize fan coolers to reduce the maximum temperature, thus permitting longer work periods.
  . Review training practices to minimize the hatch closure time.
  . Improve the equipment hatch design to minimize closure time.