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.:	**393-8432**
SRP Section:	**19.03 – Beyond Design Basis External Event (APR1400)**
Application Section:	**19.3**
Date of RAI Issue:	**02/02/2016**

Question No. 19.03-13

1. The KHNP Fukushima Technical Report, Section 5.1.2.3.2.2, "FLEX Strategy for Mode 4 and Mode 5 with SGs Available," states that the strategy includes RCS heat up and pressurization to hot standby conditions so that the full power core cooling strategy can be employed. Specifically, after the RCS temperature increases to the low temperature overpressure protection (LTOP) disable temperature (136.11 °C [277 °F]), the operator must manually isolate the RCS from the shutdown cooling system (SCS) by manually closing the SCS isolation valves. The operator must complete this action before the RCS temperature exceeds the SCS entry temperature 176.67 °C (350 °F). After that, a postulated RCS over pressurization can be protected by pilot-operated safety relief valves (POSRVs). The staff also understands that LTOP valves may be challenged during this core cooling strategy. To ensure that this core cooling strategy is feasible, the staff requests the following:

   a. This core cooling strategy for Modes 4 and 5 with the steam generators available needs to be documented in Section 19.3 of the DCD.

   b. The presence of alarms to indicate that the LTOP disable temperature has been exceeded needs to be documented in Section 19.3 of the DCD. The power for these alarms needs to be documented in Section 19.3 of the DCD.

   c. The time required for the operators to manually close the SCS isolation valves, the number of operators necessary to perform the task, and any necessary equipment to perform the task needs to be documented in Section 19.3 of the DCD.

   d. Given that the LTOP relief valves may be challenged during this scenario, the staff is requesting the applicant to update Section 19.3 of the DCD to evaluate the plant impact if the LTOP valves, which are spring operated, stick open.

2. The KHNP Fukushima Technical Report, Section 5.1.2.3, “FLEX Strategy for Shutdown Operation with SGs Not Available,” indicates in phase 1 that the safety injection tanks (SITs) are used as a water source for gravity feed to the RCS. To ensure that this core cooling strategy is feasible, the staff requests the following:

   a. Please document in Section 19.3 of the DCD how the safety injection tanks (SITs) can keep the core covered assuming the RCS is vented via the pressurizer given possible pressurizer surge line flooding. Surge line flooding following an extended loss of decay heat removal (DHR) may negate the elevation head necessary for SIT flow. Based on the shutdown evaluation report, the staff understands “With the earliest nozzle dam installation occurring at 4 days after shutdown, the decay heat present would require approximately 481 L/min (127 gpm)”.

   b. The number of operators and the time required for the operators to manually open the SIT isolation valves needs to be documented in Section 19.3 of the DCD.

   c. Any support systems or equipment necessary to manually open the SIT isolation valves needs to be documented in Section 19.3 of the DCD.

   d. Please document what alarms and instrumentation will be used to verify core coverage in Section 19.3 of the DCD. In this discussion, please document the impact of boiling through the pressurizer manway on the accuracy of the RCS level indication, including the midloop ultrasonic indication.

3. The KHNP Fukushima Technical Report, Section 5.1.2.3, “FLEX Strategy for Shutdown Operation with SGs Not Available,” indicates in phase 2 that the plant is expected to be maintained at cold shutdown by RCS feed-and-bleed operation using the FLEX pump. Decay heat is removed by boil off from the core, while the steam generated from the core is released through the pressurizer manway. In this feed-and-bleed operation, the RCS is expected to be maintained at the initial boron concentration because the rate of unborated water injection is expected to be balanced with the rate of steam discharge. The rate of injection flow is expected to be controlled to maintain the RCS water level between the core top and the hot leg center line. To ensure that this core cooling strategy is feasible, the staff requests the following:

   a. Please confirm whether any additional alarms and instrumentation will be used to maintain RCS level between the top of the core and the hot leg centerline beyond what is being credited in phase 1 in Section 19.3 of the DCD. In this discussion please document the impact of boiling through the pressurizer manway on the accuracy of the additional instrumentation and alarms.

   b. Please document in Section 19.3 of the DCD the plant impact if the operators raise RCS level above midloop conditions.

   c. In Table 3-2, “PWR FLEX Baseline Capability Summary, for Core Cooling,” the Method states, “All Plants Provide Means to Provide Borated RCS Makeup.” Please justify in Section 19.3 of the DCD why this approach of injecting unborated water is acceptable.

Response

1.a. DCD Tier 2, Subsection 19.3.2.3.1.2 describing “FLEX Strategy for Mode 4 and Mode 5 with SGs Available” will be added as indicated on the attached markup.

1.b. There is no alarm to indicate the LTOP disable temperature since the operator can continuously monitor the RCS temperature in MCR.

1.c. As shown in Figure A-23 of Technical Report APR1400-E-P-NR-14005-P, the operator shall close the SCS isolation valve to isolate the RCS from the SCS before the RCS temperature exceeds the SCS entry temperature (i.e., around 4 hours after the event initiation). During normal operation, the operator can manually control the SCS isolation valves through the operator console (operable with DC power) in MCR. However if the event of an ELAP concurrent with LUHS occurs, motor operated valves are inoperable because of the loss of all AC power. There are three SCS isolation valves at each train and these are arranged in a series. These valves are motor operated. But the middle one (SI-653/SI-654) at each train is battery backed up. Therefore this valve is manually operable when the DC battery is the only available power source. Only one reactor operator is enough to manually close the SCS isolation valve in MCR and this operator action can be finished before the RCS temperature exceeds the SCS entry temperature 176.67 °C (350 °F) (i.e., 4 hours after the event initiation) and there is no additional equipment needed to perform this task.

1.d. The possibility of stuck open LTOP valves in conjunction with the BDBEE is very remote. Even if the LTOP valve is stuck open, the operator can isolate the RCS from the SCS by closing the SCS isolation valve.

2.a. Before the midloop operation, the pressure of SITs is reduced by venting N_2 gas and maintained between 4.57 kg/cm^{2}A (65 psia) and 5.27 kg/cm^{2}A (75 psia). The slightly pressurized SITs with the elevation head can provide RCS with sufficient makeup water in spite of the head loss due to the pressurizer surge line flooding. In the support analysis of FLEX strategy for shutdown operation with SGs not available, the initial pressure of SITs is assumed to be 5.27 kg/cm^{2}A (75 psia). Figure A-26, A-27 and A-28 of Technical Report APR1400-E-P-NR-14005-P show the core is kept covered by the makeup water from the SITs during the midloop operation. The Technical Report APR1400-E-P-NR-14005-P section A.5.3 will be revised to clarify the initial pressure of SITs.

2.b. As described in section A.5.3 of Technical Report APR1400-E-P-NR-14005-P, if the operator manually opens the SIT isolation valve from the first SIT in approximately 1 hour and the second one in 2.5 hours, the time of core uncovery is extended to around 4 hours. The SIT isolation valves can be opened by local manual operator action and this can be simply performed by using handwheel installed in SIT isolation valves. Two operators are required to manually open the SIT isolation valves: supervisory reactor operator to monitor the plant status and to decide necessary operator actions in MCR and reactor operator to do the local manual action. This information will be included in DCD Tier 2 section 19.3.2.3.1.3.

2.c. There are no support systems or equipment needed to manually open the SIT isolation valves.

2.d. The operator can monitor the RCS level in MCR via flat panel display (FPD) from qualified indication and alarm system - P (QIAS-P). Coolant level during the reduced inventory operations is measured by the permanent refueling water level indication system (PRWLIS), the local refueling water level indication system (LRWLIS), and the ultrasonic level measurement system (ULMS). The PRWLIS consists of the wide range (WR) level instrument and the narrow range (NR) level instrument. Each of two trains provides the means of monitoring water level of each RCS loop to the MCR during reduced RCS inventory operations. The PRWLIS (WR) indicates coolant level between 10% level of the pressurizer and the bottom of the hot leg. It provides level indication to the MCR without alarm. The PRWLIS (NR) indicates coolant level between the top of the hot leg and 2 in above the bottom of the hot leg. It provides level indication and Low, Low-Low and High alarms to the MCR. The LRWLIS (Sight Glasses) indicates coolant level between 3 ft below the reactor vessel flange and the bottom of the hot leg. The LRWLIS provide level indication and Low and Low-Low alarms to the MCR. The ULMS is installed temporarily on both hot legs to monitor coolant level of hot leg during mid-loop operation. The ULMS provides indication, audible and visible alarms which consist of High, Low, and Low-Low alarms, and record functions to the MCR. Core exit temperature (CET) also can be monitored on FPD and the operator can verify core coverage by monitoring changes of this value. QIAS-P has high CET alarm. The channel accuracies of these instruments are not evaluated during the core boiling condition as of date. This information will be added to DCD Tier 2 section 19.3.2.3.1.3.

3.a. There are no additional alarms and instrumentation to use to maintain RCS level between the top of the core and the hot leg centerline beyond the answer of question 19.03-13.2.d.

3.b. In phase 2 of "FLEX Strategy for Shutdown Operation with SGs Not Available," the operator starts to makeup the RCS using the Primary Low-Head FLEX Pump (750 gpm). As described in the answer of question 19.03-13.2.d, the operator can monitor the whole hot leg level with alarms and control the pump flowrate. Therefore the RCS level can be maintained within the midloop condition. Even if the operator fails to control the pump flowrate and makeup the RCS using 100% flowrate, it takes about 33 minutes for the collapsed level of hot leg to increase from centerline to top. This is sufficient time that the operator performs adequate action to avoid significant impact on the plant.

3.c. DCD Tier 2, Subsection 19.3.2.3.1.2 will be revised to provide the injecting unborated water approach as indicated on the attached markup.

Impact on DCD

DCD Tier 2 section 19.3.2.3.1 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

Technical Report APR1400-E-P-NR-14005-NP section A.5.3 will be revised as indicated on the attached markup.

The guidance for developing, implementing, and maintaining mitigation strategies from

The APR1400 core cooling capability to cope with the BDBEE, ELAP concurrent with LUHS, is addressed for all of the following operation modes.

a. Full-power operation

b. Low-power operations and shutdown conditions with steam generators (SGs) available

c. Shutdown conditions with SGs not available

Among the above operation modes, full-power operation is selected as a representative case for setting up the FLEX strategy for the modes 1 through 4 (power operation, startup, hot standby, and hot shutdown), and mode 5 (cold shutdown) operation with SGs available. Mid-loop operation is selected as a representative case for setting up the FLEX strategy for the mode 5 and 6 operation with SGs not available. The specific operational strategies are described in the following subsections.

c. Phase 3 – Indefinite sustainment of these functions using offsite resources

19.3.2.3.1 Core Cooling

~~The APR1400 FLEX strategy can be divided into two sets of operational strategies, as follows:~~

~~a. FLEX strategy for Modes 1 through 4 (full-power operation, startup, hot standby, hot shutdown) and Mode 5 operation (cold shutdown) with steam generators (SGs) available~~

~~b. FLEX strategy for Modes 5 and 6 operations with SGs not available~~

~~Supporting analysis is performed to demonstrate the APR1400 baseline coping capability based on both of the FLEX strategies. In the support analysis, the full-power operation case is selected as a representative one for the operational strategy for the Modes 1 through 5 with SGs available. Mid-loop operation case is selected as a representative one for the operational strategy for Mode 5 and 6 with SGs not available.~~

The initiating event is assumed to be a loss of offsite power (LOOP) with concurrent loss of all ac power and LUHS during the full-power operation or mid-loop operation. Based on the analysis performed, the APR1400 will consider the three-phase approach as shown in Table 19.3-1 to address FLEX strategies for the various plant operations, namely, full-power operation, low-power, and shutdown operations, with and without SGs available.

approximately 98.89 °C (210 °F) with SGs fed by the secondary side FLEX pumps instead

19.3.2.3.1.2 Low-Power Operation with SGs available

Strategy for Mode 1 through Mode 3

The NCC analysis result for the full-power FLEX strategy is still valid for operation in modes 1 through 3, i.e., lower-power operation, startup, and hot standby conditions, because it covers various states of the plant, including full-power operation through hot shutdown condition. Therefore, the same FLEX strategy as in the full-power operation can be also applied to the modes 1 through 3 operations.

Strategy for Mode 4 and Mode 5 with SGs Available

In these operation modes, the SCS normally maintains the RCS between 176.67 °C (350 °F) (hot shutdown) and 54.44 °C (130 °F) (cold shutdown), while the SGs are still available. If the event an ELAP concurrent with LUHS occurs during these operation modes, the RCS is heated up and pressurized due to the loss of the SCS.

If the RCS temperature is initially below the maximum RCS temperature requiring low-temperature overpressurization protection (LTOP), i.e., 136.11 °C (277 °F), the RCS pressure can be maintained below the LTOP protection limiting pressure of 43.94 kg/cm^2A (625 psia). After the RCS temperature increases to the LTOP disable temperature, the operator tries to isolate the RCS from the SCS by manually closing the SCS isolation valves. There are three SCS isolation valves at each train and these are arranged in a series. One of the SCS isolation valve is battery backed up. Therefore this valve is manually operable when the DC battery is the only available power source. Only one reactor operator is enough to manually close the SCS isolation valve in MCR because one of the SCS isolation valve is battery backed up. This operator action can be finished before the RCS temperature exceeds the SCS entry temperature and there is no additional equipment needed to perform this task. After that, the RCS overpressurization can be protected by pilot-operated safety relief valves (POSRVs).

After closing of the SCS isolation valves, the RCS temperature and pressure continue to increase, and eventually return to the hot standby condition. Then, the SG side feed-and-bleed operation can start cooling down the RCS, as described in the baseline cooling capability for ELAP and LUHS at full-power operation.

In this phase, the primary and secondary makeup water sources and fuel oil for the mobile GTGs will be refilled from offsite resources.

19.3.2.3.1.~~2~~ 3 Mid-Loop Operation with SGs not available

In developing the APR1400 baseline coping capability for the shutdown operations with SGs not available, the mid-loop operation case is selected as a representative one. The reason is that the earliest operator action is required for the mid-loop operation case, because the operation mode has lowest RCS inventory.

Decay heat is removed by boiloff from the core, while the steam generated from the core is released through the pressurizer manway. The low-head FLEX pump takes suction from the RWT, and the rate of injection flow is controlled to maintain the RCS water level between the core top and the hot leg center line. In this feed-and-bleed operation, the RCS is maintained at the initial boron concentration, because the rate of unborated water injection is well balanced with the rate of steam discharge.

The SIT isolation valves can be opened by local manual operator action and this can be simply performed by using handwheel installed in SIT isolation valves. Two operators are required to manually open the SIT isolation valves: supervisory reactor operator to monitor the plant status and to decide necessary operator actions in MCR and reactor operator to do the local manual action.

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c. Phase 3: indefinite time period following the phase 2

During Phase 1, decay heat is removed as latent heat that developed during the water boil-off in the core. At the same time, the water source for gravity feed from the SITs is utilized to prevent core uncovery. Since the operator can easily identify the initiation of loss of residual heat removal (RHR), the operator can promptly initiate the necessary recovery action for keeping the core covered: manually opening the valves needed for gravity feed. Then, the operator prepares for the next phase. A primary low-head FLEX pump is connected to the SIS injection line. A mobile GTG is connected to Train A or Train B 480 V Class 1E ac power system. All of the operator actions will be finished within 3 hours following the event.

During Phase 2, the RCS inventory makeup is carried out by external injection using the primary side low-head FLEX pump, with a rated flow of 2,839.06 L/min (750 gpm), which is sufficient capacity for removing decay heat.

Indication of Core Coverage

The operator can monitor the RCS level in MCR via flat panel display (FPD) from qualified indication and alarm system - P (QIAS-P). Coolant level during the reduced inventory operations is measured by the permanent refueling water level indication system (PRWLIS), the local refueling water level indication system (LRWLIS), and the ultrasonic level measurement system (ULMS). The PRWLIS consists of the wide range (WR) level instrument and the narrow range (NR) level instrument. Each of two trains provides the means of monitoring water level of each RCS loop to the MCR during reduced RCS inventory operations. The PRWLIS (WR) indicates coolant level between 10% level of the pressurizer and the bottom of the hot leg. It provides level indication to the MCR without alarm. The PRWLIS (NR) indicates coolant level between the top of the hot leg and 2 in above the bottom of the hot leg. It provides level indication and Low, Low-Low and High alarms to the MCR. The LRWLIS (Sight Glasses) indicates coolant level between 3 ft below the reactor vessel flange and the bottom of the hot leg. The LRWLIS provide level indication and Low and Low-Low alarms to the MCR. The ULMS is installed temporarily on both hot legs to monitor coolant level of hot leg during mid-loop operation. The ULMS provides indication, audible and visible alarms which consist of High, Low, and Low-Low alarms, and record functions to the MCR. Core exit temperature (CET) also can be monitored on FPD and the operator can verify core coverage by monitoring changes of this value. QIAS-P has high CET alarm.

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kept at the SCS entry pressure of 31.64 kg/cm^2A (450 psia). The initial RCS pressure and temperature are selected as a conservative combination in the cold shutdown operation range with respect to LTOP. The initial pressurizer level is 30 percent, which is the normal operating level during the low-mode operation.

Figure A-23 and A-24 show the analysis result for the RCS pressure and temperature during the event, respectively. After the shutdown cooling pump (SCP) stops at time zero, RCS pressure and temperature increase due to loss of residual heal removal function of SCS. However, the increasing rate of the RCS pressure becomes much slower at around 30 minutes, when the LTOP valve opens to mitigate the low-temperature overpressurization (Figure A-25). On the other hand, RCS temperature continues to increase, and reaches the LTOP disable temperature of 136.11 °C(277 °F) at around 2.3 hours. It can be seen that RCS pressure is maintained well below the LTOP limiting pressure of 43.94 kg/cm^2A (625 psia) until the RCS temperature reaches the LTOP disable temperature. RCS pressure increases rapidly again at around 4 hours when the operator is assumed to isolate the SCS from the RCS.

Based on the analysis result, it is concluded that the RCS overpressurization is well protected by the LTOP valve installed in the SCS, until the SCS is isolated by the operator after the RCS temperature exceeds the LTOP disable temperature. The RCS returns to the hot standby condition (above 176.67 °C [350 °F]) at around 4 hours following the event, so that the operator can isolate the SCS from the RCS and conduct the cooldown operation according to the full-power FLEX strategy. Although the operator action for RCS cooldown is delayed, the RCS overpressurization is successfully limited by the cyclic opening of POSRVs.

A.5.3 Shutdown Condition with SGs not Available

The APR1400 shutdown operations with SGs not available include the mode 5 reduced inventory operation and the mode 6 refueling operation. If the ELAP concurrent with LUHS occurs during the reduced inventory operation or refueling, the plant can be maintained at the cold shutdown state by the RCS feed-and-bleed operation.

In developing the APR1400 baseline coping capability for the shutdown operations with SGs not available, the mid-loop operation case is selected as a representative one. The reason is that the earliest operation action is required for the mid-loop operation case, because the operation mode has the lowest RCS inventory.

The mitigating strategy for this situation also involves the three-step approach as described in Subsection 5.1.2.3.3.

- Phase 1: 0 to 3 hours
- Phase 2: 3 to 72 hours
- Phase 3: Indefinite time period following Phase 2

to maintain the SIT between 4.57 kg/cm^2A (65 psia) and 5.27 kg/cm^2A (75 psia)

Gravity feed inventory addition via the plant-installed SITs can be utilized as the Phase 1 strategy for shutdown operations with SGs not available. The core uncovery time is about 100 minutes after the SCS fails to operate at mid-loop operation, while it is much longer in refueling operation.

Since the operator can easily identify the initiation of loss of residual heat removal, prompt action can be taken for gravity feed from the SIT. Nitrogen is vented from the SIT and discharge valves of the SITs are opened to prevent core uncovery.

Figures A-26 through A-28 show the analysis results of the loss of residual heat removal function during