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.:	**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 – (Rev. 2)

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.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.

Response to question 2.a, 2.b, 2.c, 3.b and 3.c:
All discussions regarding shutdown mitigating strategies are removed from DCD Tier 2 section 19.3 and Technical Report APR1400-E-P-NR-14005-NP and instead a COL item for the COL applicant to develop shutdown risk process and procedures consistent with NEI 12-06 guidance, revision 2 for shutdown modes is added, as indicated on the attached markup.

In the response to RAI 393-8432, question 19.03-13, revision 1, however, there are still references to using the SITs to keep the core covered during the shutdown operations with SGs not available. These references are removed as indicated on the attached markup.

The previous RAI responses (RAI 297-8309, Q.19.03-1, Rev.0; RAI 401-8402, Q.19.03-18, Rev.1; RAI 401-8402, Q.19.3-19, Rev.1; and RAI 401-8402, Q.19.3-20, Rev.1) had provided the information with markups for Subsections of Section 5.1.2.5 of Technical Report APR1400-E-P-NR-14005-NP, Rev.0. However, the Section 5.1.2.5 and its subsections are modified overall in the response to RAI 393-8432, Q.19.03-13, Rev.1 and the markups for the previous RAI responses (RAI 297-8309, Q.19.03-1, Rev.0; RAI 401-8402, Q.19.03-18, Rev.1; RAI 401-8402, Q.19.3-19, Rev.1; and RAI 401-8402, Q.19.3-20, Rev.1) was not incorporated in modified subsections. Therefore, the omitted information will be incorporated to proper subsections 5.1.2.5.2.3 and 5.1.2.5.3 in this revised RAI response (RAI 393-8432, Q.19.03-13, Rev.2) as indicated on the attached markup.

Impact on DCD

DCD Tier 2 section 19.3 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 will be revised as indicated on the attached markup.

RAI 393-8432 Q.19.03-13 Rev.1

19.3.2.3 Recommendations 4.1 and 4.2 – Station Blackout and Mitigation Strategies for Beyond Design Basis External Events

Recommendation 4.1 outlines minimum coping times for extended loss of alternating current (ac) power (ELAP) events. Recommendation 4.2 recommends that licensees provide reasonable protection from beyond design basis external events (BDBEEs) and add any additional equipment necessary to address the Fukushima event. Both Recommendations 4.1 and 4.2 are addressed through the baseline coping strategies described herein.

The APR1400 employs a three-phase approach for mitigating BDBEEs. The initial phase requires the use of installed equipment and resources to maintain or restore core cooling, containment function, and spent fuel pool (SFP) cooling capabilities. The transition phase requires providing sufficient, portable, onsite equipment and consumables to maintain or restore these functions until they can be accomplished with resources brought from offsite. The final phase requires obtaining sufficient offsite resources to sustain those functions indefinitely. Specifically, the following is incorporated into the APR1400 design:

a. Strategies to maintain or restore core cooling, containment function, and SFP cooling capabilities following a BDBEE capable of mitigating a simultaneous loss of all ac power and loss of normal access to the ultimate heat sink (LUHS)

b. Reasonable protection for the associated equipment from external events that demonstrates that there is adequate capacity to address challenges to core cooling, containment function, and SFP cooling capabilities

c. Strategies capable of being implemented in all modes of operations

Following is a brief synopsis of the mitigating measures to address these items:

The core cooling safety function includes maintaining core cooling, reactor coolant system (RCS) inventory, RCS boration, and key reactor instrumentation. The containment heat removal safety function includes maintaining containment pressure control, heat removal, and key containment instrumentation. The SFP cooling safety function includes maintaining SFP cooling and key SFP instrumentation. Each of the core cooling, containment ~~function~~, and SFP cooling strategies is described in detail in Reference 5.

cooling

RAI 393-8432 Q.19.03-13

RAI 393-8432 Q.19.03-13 Rev.1

The guidance for developing, implementing, and maintaining mitigation strategies from JLD-ISG-2012-01 (Reference 6) and the methodology to establish baseline coping capability from Nuclear Energy Institute (NEI) 12-06 (Reference 7) were considered in developing the APR1400 FLEX strategy. Each FLEX strategy follows a three-phase approach as required in the Order EA-12-049.

The three phases are:

a. Phase 1 – Initial response phase using installed equipment

b. Phase 2 – Transition phase using portable equipment and consumables

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.

This will be modified to "A" in following page.
[RAI 393-8432 - Question 19.03-13, Rev.0]

This will be modified as shown in following page.

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"A"

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.~~

[RAI 393-8432 - Question 19.03-13, Rev.0]

This paragraph in modification "A" will be deleted.

RAI 393-8432 Q.19.03-13

RAI 393-8432 Q.19.03-13 Rev.1

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^{2}A (625 psia) by virtue of LTOP valve operation. 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. Consequently, the full-power FLEX strategy can be also applied after the plant returns to hot standby condition.
[RAI 393-8432 - Question 19.03-13, Rev.0]

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

with SGs not available
[RAI 393-8432 - Question 19.03-13, Rev.0]

19.3.2.3.1.~~2~~ 3 ~~Mid-Loop Operation~~ Shutdown Conditions

~~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.~~

3
[RAI 393-8432 - Question 19.03-13, Rev.0]

RAI 393-8432 Q.19.03-13
RAI 393-8432 Q.19.03-13 Rev.1

Based on the analysis performed, the APR1400 will consider the following event sequence to address FLEX strategy for the shutdown operations with SGs not available:

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a. Phase 1: 0 to 3 hours

b. Phase 2: 3 to 72 hours

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.

"B" in following page will be added.
[RAI 393-8432 - Question 19.03-13, Rev.0]

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.

"C" in following page will be added.
[RAI 393-8432 - Question 19.03-13, Rev.0]

In Phase 3, the 4.16 kV mobile GTG, fuel, and cooling water are available for long-term coping for the event. The 4.16 kV mobile GTG will be used to restore Train A or Train B of the 4.16 kV Class 1E power system. If the SCS is operable when the 4.16 kV Class 1E power is restored, the plant will be cooled down or maintained by resuming the SCS operation. If not, the RCS inventory is maintained by the primary FLEX pump, as in Phase 2. In this case, the primary makeup water source and fuel oil for the mobile GTGs will be refilled from offsite resources.

19.3.2.3.2 Spent Fuel Pool Cooling

Based on the supporting analyses described in Reference 5, the following is the bulk SFP heatup time and boil-off rate for the worst-case full core offload:

"D" in following page will be added.
[RAI 393-8432 - Question 19.03-13, Rev.0]

RAI 393-8432 Q.19.03-13

RAI 393-8432 Q.19.03-13 Rev.1

RAI 393-8432 Q.19.03-13 Rev.2

These will be deleted.

"B"

The SIT isolation valves can be opened by local manual operator action and this can be simply pe[...] 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.

"C"

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.

"D"

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.

"E"

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, decay heat can be removed from the core by the RCS feed-and-bleed operation.

The APR1400 FLEX strategy follows a three-phase approach as required in the Order EA-12-049. Followings are general description of FLEX strategy for shutdown operation with SGs not available.

During Phase 1, decay heat is removed by the latent heat resulting from water boiloff in the core. The ~~At the same time, the SITs are used as a water source for gravity feed to the RCS. If it is determined that gravity feed is not effective to cool the RCS and prevent fuel damage, the~~ APR1400 will take actions to proceduralize administrative controls to pre-stage FLEX equipment prior to entering a condition where the SGs cannot provide adequate core cooling.

In Phase 2, the plant can be maintained at cold shutdown by the RCS feed-and-bleed operation using the FLEX pump which connected to a SIS injection line. The RCS inventory makeup is carried out by external injection using the primary side low-head FLEX pump with rated flow of 2,839.06 L/min (750 gpm), which is sufficient capacity for removing decay heat and flushing the RCS. Prior to core uncovery ~~loss of gravity feed from the SITs~~, the primary side low-head FLEX pump must be aligned to take suction from the acceptable coolant source and deliver the coolant to the vessel. A mobile GTG is prepared to connect to Train A or Train B 480 V Class 1E ac power system to supply power to Class 1E battery. Two primary low-head FLEX pumps are provided to meet the N+1 requirement. The COL applicant is to address the details of storage location for FLEX equipment (COL 19.3(4)).

In Phase 3, the 4.16 kV mobile GTG, fuel, and cooling water are available from offsite for long-term coping for the event. The 4.16 kV mobile GTG is used to restore Train A or Train B of 4.16 kV Class 1E power system. If the SCS is operable when the 4.16 kV Class 1E power is restored, the plant is cooled down to and maintained at cold shutdown by resuming the SCS operation. If not, the plant is maintained at the same safe shutdown state as in Phase 2, using the primary FLEX pump for RCS inventory makeup. In this phase, the primary and secondary makeup water sources and fuel oil for the mobile GTGs will be refilled from offsite resources.

The COL applicant is to develop shutdown risk processes and procedures, and verify ability to deploy FLEX equipment to provide core cooling in shutdown operation with SGs not available (COL 19.3(17)).

50.54(hh)(2). The self-powered (diesel-driven) FLEX 1,892.5 L/min (500 gpm), 757.1 L/min (200 gpm) SFP makeup pump, and SFP spray pump relied on to mitigate LOLA are therefore credited to mitigate the BDBEE.

Phase 3: after 72 hours

APR1400 continues to use the Phase 2 strategies to provide makeup to the SFP in Phase 3.

and Integrity

19.3.2.3.3 Containment Function

The containment isolation function can be accomplished with the containment isolation valves (CIVs), because containment penetrations that are required to be isolated for the BDBEE are designed to be isolated by either inside containment or outside containment isolation valves, as follows:

a. Normally closed motor-operated valve (fail as-is)

b. Air-operated valve (fail closed)

c. Check valve inside containment (automatic isolation)

The containment design incorporates a prestressed concrete containment with a steel liner to house the nuclear steam supply system. The containment and associated systems are designed to safely withstand environmental conditions that may be expected to occur during the life of the plant, including both short-term and long-term effects following a DBA and beyond DBA. ~~No special means are necessary for the APR1400 to maintain containment function during full-power operation, after a BDBEE with simultaneous loss of all ac power and LUHS. The emergency containment spray backup system (ECSBS) is used to maintain containment pressure and temperature during loss of RHR (Mode 5).~~

During the BDBEE, no major pipe break is postulated inside the containment, but RCP seal leakage is assumed with the leakage rate of 94.64 L/min (25 gpm) per RCP, a total of 378.5 m^3/min (100 gpm) for four RCPs. The containment pressure and temperature analyses are performed using the GOTHIC (Version 8.0) computer program. The containment pressure reaches the design pressure of 5.25 kg/cm^2 (74.7 psia) in 63 days from beginning of the event. The design temperature of 143 °C (290 °F) is reached in 71 days following the

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RAI 393-8432 Q.19.03-13 Rev.1

RAI 393-8432 Q.19.03-13 Rev.2

"F"

~~19.3.2.3.3 Containment Function and Integrity~~

The following acceptance criteria are applied to ensure the containment function and structural integrity throughout the BDBEE.

a. Containment pressure shall be less than the containment design pressure of 4.22 kg/cm^2 (60 psig).

b. Containment temperature shall be less than the environmental qualification (EQ) temperature limit of 182 ^{o}C (360 ^{o}F) that ensures the function of the safety-related equipment within containment.

The emergency containment spray backup system (ECSBS) is considered as a means to cool the containment atmosphere, thereby maintaining the containment pressure and temperature less than design limits.

In the supporting analyses described in Reference 5, the RCP seal LOCA at full-power operation is chosen as the representative case to demonstrate maintaining the containment pressure and temperature below the design limits through the FLEX strategy that uses the ECSBS. The analysis results shows that the containment pressure reaches the containment design pressure of 4.22 kg/cm^2 (60 psig) after approximately 16 days of the accident, then rapidly decreases and maintains at a low pressure by continuous spray through the ECSBS. The containment temperature reaches the highest temperature of 148 ^{o}C (298 ^{o}F), but which is well below the temperature limit of 182 ^{o}C (360 ^{o}F) for the environmental qualification of the safety related equipment within the containment.

From the analysis, it is noted that the containment pressure and temperature are maintained well below the design limits, thereby ensuring the function of safety-related equipment within containment as well as the containment structural integrity during the BDBEE.

The COL applicant is to develop the shutdown risk processes and procedures, and verify ability to deploy FLEX equipment to provide containment cooling in shutdown operation with SGs not available (COL 19.3(17)).

~~event. The technical report (Reference 5) provides the containment pressure and temperature analyses response for the full-power case with the assumed RCP seal leakage, and confirms that, during the course of the event for all phases, containment integrity is maintained.~~

~~Loss of RHR during mid-loop operation in Mode 5 is additionally assumed for the evaluation of containment capability. In this event, steam is assumed to be released from the RCS to the containment through the pressurizer manway due to the boiling of reactor coolant following the loss of RHR. The ECSBS is assumed to start spraying water into the containment atmosphere via a FLEX pump when the containment pressure reaches the UPC value of 12.9 kg/cm^2 (184 psia). After the initial operation, the ECSBS is assumed to be intermittently operated for 2 hours whenever the containment pressure reaches the UPC value. GOTHIC analyses are performed to confirm that the containment pressure and the temperature can be controlled within the UPC limit with the ECSBS operation following the loss of RHR in mode 5.~~

19.3.2.3.4 Supporting Systems

To mitigate the BDBEE, the following supporting systems have also been evaluated in Reference 5:

a. Electrical system (ac power and dc power)

b. Emergency lighting

c. Communication system

d. Water sources

e. Fuel oil

The design approach meets the NEI 12-06 in meeting the N+1 approach for the FLEX equipment, and primary and alternative connection points for fluids and electrical items. Regarding the storage of robust FLEX equipment and commodities, the N+1 philosophy has been adopted for the storage housing. Reference 5 describes the requirements in detail and the necessary design changes for APR1400 to meet the industry regulations. The

COL 19.3(17) The COL applicant is to develop shutdown risk processes and procedures, and verify the ability to deploy FLEX equipment to provide core cooling and containment cooling in shutdown operation with SGs not available.

COL 19.3(3) The COL applicant is to develop the details for offsite resou RAI 393-8432 Q.19.03-13 Rev.1

RAI 393-8432 Q.19.03-13 Rev.2

COL 19.3(4) The COL applicant is to address the details of storage location for FLEX equipment.

as per Section 3.2.3 of NEI 12-06, rev.2

COL 19.3(5) The COL applicant is to address site-specific strategies to mitigate BDBEEs as specified in the NRC Order EA-12-049.

COL 19.3(6) The COL applicant is to address SFP level instrumentation maintenance procedure development and perform training as specified in NRC Order EA-12-051.

COL 19.3(7) The COL applicant is to address development of EOPs, SAMGs, and EDMGs that incorporate lessons learned from TEPCO's Fukushima Dai-Ichi nuclear power plant accident as addressed in SECY-12-0025.

COL 19.3(8) The COL applicant is to address enhancement of the offsite communication system as specified in the NRC Request for Information pertaining to NTTF Recommendation 9.3.

COL 19.3(9) The COL applicant is to address staffing for large-scale natural events as specified in the NRC RFI pertaining to NTTF Recommendation 9.3.

19.3.5 References

1. SECY-12-0025, "Proposed Orders and Requests for Information in Response to Lessons Learned from Japan's March 11, 2011, Great Tohoku Earthquake and Tsunami," U.S. Nuclear Regulatory Commission, February 2012.

2. Order EA-12-049, "Order Modifying Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events," U.S. Nuclear Regulatory Commission, March 12, 2012.

3. Order EA-12-051, "Order Modifying Licenses with Regard to Reliable Spent Fuel Pool Instrumentation," U.S. Nuclear Regulatory Commission, March 12, 2012.

Table 19.3-1

Summary of Phase Approaches for Each of the Plant Operation Modes

Phase	Phase Description	Modes 1 through 4 and Mode 5 Operations with SGs Available	Modes 5 and 6 Operations with SGs Not Available
1	Coping with installed plant equipment	0 to 8 hours	0 to 3 hours
2	Coping with installed plant equipment and onsite portable (FLEX) equipment	8 to 72 hours	3 to 72 hours
3	Coping with both onsite portable (FLEX) equipment and offsite resources in addition to installed equipment	Indefinite time period following phase 2	Indefinite period following phase 2

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LIST OF FIGURES

Table 4-1 Post-Fukushima NRC Recommendations and Requirements (3 of 18)

NTTF Rec. No	NRC Recommendations/Requirements in SECY-11-0093, SECY-11-0137, SECY-12-0025, SECY-12-0095, EA-12-049, EA-12-051	APR1400 Design	Applicable DCD Section	COL Action	Note
2.3	**Flooding Walkdowns** • Perform flood protection walkdowns using an NRC-endorsed walkdown methodology, • Identify and address plant-specific degraded, non-conforming, or unanalyzed conditions as well as cliff-edge effects through the corrective action program and consider these findings in the Recommendation 2.1 hazard evaluations, as appropriate, • Identify any other actions taken or planned to further enhance the site flood protection, • Verify the adequacy of programs, monitoring and maintenance for protection features, and, • Report to the NRC the results of the walkdowns and corrective actions taken or planned.	NA	NA	NA	Request for information via 50.54(f) letter.
4.1	**Station Blackout (SBO)** **(NTTF Recommendations)** Initiate rulemaking to revise 10 CFR 50.63 to require each operating and new reactor licensee to (1) establish a minimum coping time of 8 hours for a loss of all ac power, (2) establish the equipment, procedures, and training necessary to implement an “extended loss of all ac” coping time of 72 hours for core and spent fuel pool cooling and for reactor coolant system and primary containment integrity as needed, and (3) preplan and prestage offsite resources to support uninterrupted core and spent fuel pool cooling, and reactor coolant system and containment integrity as needed, including the ability to deliver the equipment to the site in the time period allowed for extended coping, under conditions involving significant degradation of	See NTTF Recommendations 4.1 and 4.2 in Subsection 5.1.2	19.3.2.3	COL 19.3(3), 19.3(4), ~~and~~ 19.3(5) , and 19.3(17)	

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Table 4-1 Post-Fukushima NRC Recommendations and Requirements (4 of 18)

NTTF Rec. No	NRC Recommendations/Requirements in SECY-11-0093, SECY-11-0137, SECY-12-0025, SECY-12-0095, EA-12-049, EA-12-051	APR1400 Design	Applicable DCD Section	COL Action	Note
	offsite transportation infrastructure associated with significant natural disasters.				
4.2	**Mitigation Strategies for Beyond-Design-Basis External Events (EA-12-049)** (1) Licensees shall develop, implement and maintain guidance and strategies to maintain or restore core cooling, containment and SFP cooling capabilities following a beyond-design-basis external event. (2) These strategies must be capable of mitigating a simultaneous loss of all alternating current (ac) power and loss of normal access to the ultimate heat sink and have adequate capacity to address challenges to core cooling, containment, and SFP cooling capabilities at all units on a site subject to this Order. (3) Licensee must provide reasonable protection for the associated equipment from external events. Such protection must demonstrate that there is adequate capacity to address challenges to core cooling, containment, and SFP cooling capabilities at all units on a site subject to this order. (4) Licensee must be capable of implementing the strategies in all modes. (5) Full compliance shall include procedures, guidance, training, and acquisition, staging, or installation of equipment needed for the strategies.	See NTTF Recommendation 4.2 in Subsection 5.1.2	19.3.2.3	COL 19.3(3), 19.3(4), ~~and~~ 19.3(5), and 19.3(17)	

Table 4-1 Post-Fukushima NRC Recommendations and Requirements (12 of 18)

NTTF Rec. No	NRC Recommendations/Requirements in SECY-11-0093, SECY-11-0137, SECY-12-0025, SECY-12-0095, EA-12-049, EA-12-051	APR1400 Design	Applicable DCD Section	COL Action	Note
	SECY-11-0137, and identify actions that have been taken, or are planned, to address plant-specific issues associated with the updated seismic and flooding hazards in conjunction with the resolution of NTTF Recommendations 2.1 and 2.3.	NA	NA	COL 19.3(1) and 19.3(2)	
	2. Incorporate the loss of UHS as a design assumption in the resolution of station blackout rulemaking activities in conjunction with the resolution of NTTF Recommendation 4.1.	See NTTF Recommendation 4.2 in Subsection 5.1.2	19.3.2.3	COL 19.3(3), 19.3(4), ~~and~~ 19.3(5), and 19.3(17)	
	3. Provide mitigating measures for beyond-design-basis external events to also include a loss of access to the normal UHS in conjunction with the resolution of NTTF Recommendation 4.2.	See NTTF Recommendation 4.2 in Subsection 5.1.2	19.3.2.3	COL 19.3(3), 19.3(4), ~~and~~ 19.3(5), and 19.3(17)	
	4. Include UHS systems in the reevaluation of site-specific natural external hazards, and identify actions that have been taken, or are planned, to address plant-specific issues associated with the updated hazards in conjunction with the resolution of the new Tier 2 Recommendation 2.1 activity described in Enclosure 3, “Other Natural External Hazards.”	NA	NA	Refer to Tier 2 Recommendation	
Tier 2 (Actions do not require long-term study and can be initiated when sufficient technical information and applicable resources become available)					
2.1	**Other External Events Protections (SECY-12-0025)** 1. Continue stakeholder interactions to discuss the technical basis and acceptance criteria for conducting a reevaluation of site-specific	No Action	NA	NA	

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5.0 STRATEGIES TO ACTION ITEMS FROM FUKUSHIMA DAI-ICHI EVENTS

5.1 Tier 1 Items

5.1.1 Recommendation 2.1 – Seismic and Flooding Re-Evaluation

Seismic and flooding re-evaluation is the responsibility of COL applicant. The COL applicant will confirm that the site-specific design criteria for seismic and flood are met. It is expected that the APR1400 will satisfy the seismic requirements since it is designed to meet Central and Eastern United States (CEUS) seismic requirements. Also, for dry sites, the APR1400 will not have a problem in regard to flooding. However, for wet sites, flood protection may be necessary depending on the location of FLEX equipment. Therefore, the COL applicant will also address the flood requirements for wet sites.

5.1.2 Recommendations 4.1 and 4.2 – SBO and FLEX

5.1.2.1 Introduction

to ensure containment functions and structural integrity through containment cooling.

This subsection summarizes the APR1400 diverse and flexible coping (FLEX) strategies for the beyond-design-basis external event (BDBEE), extended loss of all ac power (ELAP) concurrent with loss of normal access to ultimate heat sink (LUHS). The purpose of establishing the FLEX strategies is to maintain core cooling, spent fuel pool (SFP) cooling, and ~~containment heat removal functions.~~

The core cooling safety function includes maintaining core cooling, reactor coolant system (RCS) inventory, RCS boration, and key reactor instrumentation. The ~~containment heat removal~~ safety function includes maintaining containment pressure control, ~~heat removal,~~ and key containment instrumentation. The SFP cooling safety function includes maintaining SFP cooling and key SFP instrumentation.

NTTF Recommendation 4 (Reference 1) recommends that all operating and new reactor designs enhance SBO mitigation capability for BDBEEs. Recommendation 4.1 outlines minimum coping times for SBO events. Recommendation 4.2 recommends that licensees provide reasonable protection from BDBEEs and add any additional equipment necessary to address multiunit events. This report addresses both Recommendation 4.1 and 4.2 through the baseline coping strategies.

5.1.2.2 Baseline Coping Capability

The guidance for developing, implementing, and maintaining mitigation strategies from JLD-ISG-2012-01 (Reference 7) and the methodology to establish baseline coping capability from NEI 12-06 (Reference 8) were considered in developing the APR1400 FLEX strategies and evaluating the resultant baseline coping capability after the BDBEE.

The APR1400 FLEX strategies follow a three-phase approach as required in the Order EA-12-049 (Reference 5). The three phases are:

- Phase 1 – Initial response phase using installed equipment
- Phase 2 – Transition phase using FLEX equipment and consumables
- Phase 3 – Indefinite sustainment of these functions using offsite resources.

containment cooling

The APR1400 baseline coping capability to maintain core cooling, SFP cooling, and ~~containment heat removal functions~~ after the BDBEE are addressed in the following sections, along with the FLEX strategies and supporting analyses.

5.1.2.3 Operational Strategy for Core Cooling

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.~~

5.1.2.3.1 FLEX Strategy for Full-Power Operation

The initiating event is assumed to be a loss of offsite power (LOOP) with concurrent loss of all ac power and LUHS during full-power operation. Based on the analysis performed, the APR1400 design includes consideration of the following event sequence to address FLEX strategy for full-power operation:

Phase 1: 0 to 8 hours

Phase 2: 8 to 72 hours

Phase 3: Indefinite time period following Phase 2

The timeline of the APR1400 FLEX strategy for full-power operation is shown in Figure 5-1 and the detailed sequence of events is tabulated in Table 5-1. The following are the operational strategies for each phase.

5.1.2.3.1.1 Phase 1: Coping with Installed Plant Equipment (0 to 8 hours)

5.1.2.3.1.1.1 Phase 1-a: 0 to 1 hour

The main control room (MCR) operators may require up to 1 hour to assess plant conditions, equipment and system availability, and to identify the event as an ELAP concurrent with LUHS.

During Phase 1-a, only the installed plant equipment is used for coping. Specifically, two turbine-driven auxiliary feedwater pumps (TDAFWPs) automatically start on an auxiliary feedwater actuation system (AFAS) signal to provide core cooling through the SGs. Auxiliary feedwater storage tanks (AFWSTs) are used to supply water to the TDAFWPs, and steam generated in the SGs is released through the main steam safety valves (MSSVs). Class 1E batteries supply dc power to essential instrumentation and control (I&C) equipment, and for the operation of the TDAFWPs. The RCS is maintained at hot standby condition by the natural circulation cooling (NCC) operation without any operator action during this phase.

The reactor coolant pump (RCP) seal integrity may be challenged, because both the seal injection water supply and component cooling water supply to the RCP thermal barrier heat exchanger are lost due to the event of ELAP concurrent with LUHS. The RCP seal leakage is assumed to be 94.64 L/min (25 gpm) per RCP, based on the evaluation report on the APR1400 KSB RCP seals (Reference 9).

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5.1.2.3.3 FLEX Strategy for Shutdown Operation 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, decay heat can be removed from the core by the RCS feed-and-bleed operation.

In developing the APR1400 baseline coping capability during shutdown operations with SGs not available, the mid-loop operation case is selected as a representative one, because this operation mode has the lowest RCS inventory and requires the earliest operator action for the feed-and-bleed operation.

Based on the analysis performed, the APR1400 design includes consideration of the following event sequence to address FLEX strategy for shutdown operations with SGs not available:

Phase 1: 0 to 3 hours

Phase 2: 3 to 72 hours

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Phase 3: Indefinite time period following Phase 2

The timeline of the APR1400 FLEX strategy for the shutdown operations with SGs not available is shown in Figure 5-2 and the detailed sequence of events is tabulated in Table 5-3. The following are the operational strategies for each phase.

5.1.2.3.3.1 Phase 1: Coping with Installed Plant Equipment ~~(0 to 3 hours)~~

During Phase 1, decay heat is removed by the latent heat resulting from water boiloff in the core. ~~At the same time, the SITs are used as a water source for gravity feed to the RCS.~~ Since the operator can easily identify the initiation of loss of residual heat removal, the necessary recovery action of manually opening the valves needed for gravity feed from SITs can promptly begin and the core remains covered. Then, the operator connects a primary low-head FLEX pump to the SIS injection line for preparation of the feed-and-bleed operation in Phase 2. The operator actions are finished by 3 hours following the event. The operator has a 1-hour margin for preparation of Phase 2, because the analysis result shows that the Phase 1 gravity feed and boiling operation can last for 4 hours.

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5.1.2.3.3.2 Phase 2: Coping with Installed Plant Equipment and Onsite Portable Resources ~~(3 to 72 hours)~~

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In Phase 2, the plant can be maintained at cold shutdown by the RCS feed-and-bleed operation using the FLEX pump. The RCS inventory makeup is carried out by external injection using the primary side low-head FLEX pump with rated flow of 2,839.06 L/min (750 gpm), which is sufficient capacity for removing decay heat. 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 raw water tank (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. In the meantime, a mobile GTG is connected to Train A or Train B 480 V Class 1E ac power system within 8 hours to supply power to Class 1E battery.

~~The Phase 2 feed-and-bleed operation using onsite water source is assumed to last for 72 hours in the timeline of the mid-loop operation FLEX strategy, but the capacity of the RWT is sufficient to extend the period of Phase 2 up to 6.4 days even if the water source is shared with SFP cooling (see Table B-3 in~~

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"G"

The APR1400 FLEX strategy follows a three-phase approach as required in Order EA-12-049 (Reference 5). The following sections are general descriptions of FLEX strategy for shutdown operation with SGs not available. Detailed procedures will be developed by the COL applicant. The APR1400 added a COL item in DCD Chapter 19.3 specifying that the COL applicant will develop shutdown risk processes and procedures, and verify the ability to deploy FLEX equipment to provide core cooling in shutdown operations with SGs not available.

The

"H"

~~If it is determined that gravity feed is not effective to cool the RCS and prevent fuel damage, the~~ APR1400 will take actions to proceduralize administrative controls to pre-stage FLEX equipment prior to entering a condition where the SGs cannot provide adequate core cooling.

"I"

In Phase 2, the plant can be maintained at cold shutdown by the RCS feed-and-bleed operation using the FLEX pump which is connected to a SIS injection line . The RCS inventory makeup is carried out by external injection using the primary side low-head FLEX pump with rated flow of 2,839.06 L/min (750 gpm), which is sufficient capacity for removing decay heat and flushing the RCS. Prior to ~~loss of gravity feed from the SITs~~, the primary side low-head FLEX pump must be aligned to take suction from the acceptable coolant source and deliver the coolant to the vessel. A mobile GTG is prepared to connect to Train A or Train B 480 V Class 1E ac power system to supply power to Class 1E battery.

core uncovery

Appendix B). Hence, the operator has sufficient time margin for preparation of Phase 3.

In Phase 3, the primary side feedwater sources and fuel oil for the mobile GTGs are refilled from offsite resources. If the SCS is successfully restored after the 4.16 kV GTG is connected, the plant can be brought to and maintained at the cold shutdown using the SCS instead of the RCS feed-and-bleed operation.

The specific storage location, mobilization, and other details for the FLEX pumps and mobile GTGs are COL items.

5.1.2.3.3.3 Phase 3: Coping with Both Installed Plant Equipment and Offsite Resources in Addition to Onsite Equipment ~~(after 72 hours)~~

In Phase 3, the 4.16 kV mobile GTG, fuel, and cooling water are available from offsite for long-term coping for the event. The 4.16 kV mobile GTG is used to restore Train A or Train B of 4.16 kV Class 1E power system. If the SCS is operable when the 4.16 kV Class 1E power is restored, the plant is cooled down to and maintained at cold shutdown by resuming the SCS operation. If not, the operator keeps the plant at the same safe shutdown state as in Phase 2, using the primary FLEX pump for RCS inventory makeup. The primary makeup water source and fuel oil for the mobile GTGs are refilled using offsite resources. ~~In this operation mode, containment pressure increases consistently from the beginning of the event due to the mass and energy released from the RCS, but it can be maintained below ultimate pressure capacity (UPC) by operating the emergency containment spray backup subsystem (ECSBS) intermittently after reaching UPC at around 3.5 days following the event (see Figure 5-4)~~. Details for the offsite resources will be provided by the COL applicant.

5.1.2.3.4 Supporting Analysis for Core Cooling

Supporting analyses have been performed using RELAP5/Mod 3.3 to confirm the APR1400 core cooling capability to cope with the BDBEE, ELAP concurrent with LUHS, according to the FLEX strategies. Specifically, the coping capability is evaluated for the following operation modes:

- Full-power operation
- Low-power operations and shutdown conditions with SGs available
- Shutdown conditions with SGs not available

Among the above operation modes, the full-power operation is selected as a representative case 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 the mode 5 and 6 operation with SGs not available. In the full-power operation case, the RCP seal leakage is assumed to be 94.64 L/min (25 gpm) per RCP.

5.1.2.3.4.1 Acceptance Criteria

The following acceptance criteria based on the NEI 12-06, Section 3.2.1 (Reference 8) are applied to the supporting analysis for the operational strategy for core cooling during the BDBEE:

- Core cooling is maintained.
- No fuel failures occur.

The fulfillment of above criteria is determined by evaluating RCS key parameters, such as RCS and SG pressures, RCS temperature, and collapsed levels in the reactor vessel, core, and SG.

5.1.2.3.4.2 Analysis Conditions ~~of the FLEX Strategy for Power Operation and Shutdown Condition with SGs Available~~

The following analysis conditions and assumptions are selected according to the requirements of NEI 12-06, Section 3.2.1. ~~The full power operation is selected as a representative case for the modes 1 through 4 and mode 5 operations with SGs available.~~

- The plant is assumed to operate at 100 percent rated power with no uncertainty for system parameters.
- The initiating event is assumed to be ELAP concurrent with LUHS.
- The reactor is assumed to be tripped automatically by the low RCP speed trip function of the RPS since the RCPs could not be provided with ac power.
- The MSSVs are assumed to actuate automatically when the SG pressure exceeds the MSSV setpoints.
- RCP seal leakage is assumed to be 94.64 L/min (25 gpm) per RCP. This causes loss of RCS inventory, which should be adequately compensated for preventing core uncovery.
- The TDAFWPs are assumed to start automatically on receipt of an AFAS signal.
- The decay heat conditions of ANSI/ANS-5.1-1979 are used for best-estimate simulation of the FLEX strategy.
- The operator is assumed to cool down the RCS by controlling MSADVs with a rate of 27.78 °C/hr (50 °F/hr) from 8 hours following the BDBEE.
- The auxiliary charging pump (ACP) is assumed to supply borated water at the constant value of 166.56 L/min (44 gpm) for RCS makeup after 8 hours following the event. If the ACP is unavailable for supplying water to RCS, a primary high-head FLEX pump is used for providing adequate water for maintaining RCS inventory.
- Four SITs inject 4,000 ppm borated water into RCS when RCS pressure decreases below the setpoints as designed.
- Normal feedwater flow to the SGs is assumed to stop at the initiation of the BDBEE. Auxiliary feedwater flow supplies water to the SGs and is controlled to maintain SG level within the control band of 25 to 40 percent.

~~5.1.2.3.4.3 Analysis Conditions of the FLEX Strategy for Shutdown Conditions with SGs Not Available~~

~~The following are the analysis conditions and assumptions of the FLEX strategy for shutdown conditions with SGs not available:~~

- ~~Mid-loop operation is selected as a representative case for the mode 5 and 6 operation with SGs~~

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~~not available.~~

- ~~The plant is assumed to be in mid-loop operation with the decay heat level of 3.5 days after reactor trip. The initiating event is assumed to be an ELAP concurrent with LUHS.~~

- ~~The decay heat conditions of ANSI/ANS-5.1-1979 are selected for best-estimate simulation of this FLEX strategy.~~

- ~~The operator is assumed to open first and second SIT isolation valves for gravity feed to the RCS at 1 hour and 2.5 hours, respectively.~~

- ~~The other two SITs are assumed to be in maintenance.~~

~~5.1.2.3.4.4~~ 5.1.2.3.4.3 Analysis Results and Conclusion ~~for Full-Power Operation~~

The APR1400 core cooling capability under the BDBEE, ELAP concurrent with LUHS, is analyzed using the RELAP5/Mod 3.3 code, according to the full-power operational strategy, consisting of the following three phases as described in Subsection 5.1.2.3.1.

- Phase 1: 0 to 8 hours

- Phase 2: 8 to 72 hours

- Phase 3: Indefinite time period following Phase 2

For the full-power operation case, two types of core cooling strategies, which are basic operational strategy and contingency plan, are analyzed. In the basic strategy, the RCS is cooled down to hot shutdown using both installed plant equipment (such as MSADV, TDAFWP, and ACP), and FLEX equipment (such as the mobile GTG). The contingency plan is prepared in case the installed plant equipment is inoperable even after connection of mobile ac power. In this case, the RCS is cooled down to cold shutdown using the secondary side FLEX pump. RCS makeup is carried out by the primary side high-head FLEX pump.

Based on the two types of cooling strategies employed, it is concluded that the plant can be maintained at hot standby condition during Phase 1 (0 to 8 hours following the BDBEE), and cooled down to hot shutdown or cold shutdown state during Phase 2 (8 to 72 hours), using onsite resources. The same safe shutdown state is also be maintained during Phase 3 (after 72 hours), by continuing NCC operation with the cooling water source (for FLEX pumps) and fuel oil (for mobile GTGs) supplied from offsite resources.

If SCS is successfully restored after the 4.16 kV GTG is connected, the plant can be brought to and maintained at cold shutdown using the SCS instead of SG cooling.

Appendix A provides further details of these analyses for the operational strategies – basic operational strategy and contingency plan – in the aspect of core cooling capability during this event.

~~The specific storage location, mobilization, and other details for the FLEX pumps and mobile GTGs are COL items.~~

~~5.1.2.3.4.5 Analysis Results and Conclusion for Low-Power Operation and Shutdown Conditions with SGs Available~~

Appendix A also shows the APR1400 coping capability against ELAP concurrent with LUHS during low-

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power operations and shutdown conditions. Based on the evaluation results for the operation modes 1 … s still valid for this

The specific storage location, mobilization, and other details for the FLEX pumps and mobile GTGs are COL items.

In the operation modes 4 and 5 with SGs available, 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 ELAP concurrent with LUHS occurs during these operation modes, the RCS is heated up and pressurized for a period due to the loss of the SCS. If the RCS temperature is initially below the maximum RCS temperature requiring the LTOP, i.e., 136.11 °C (277 °F), the RCS pressure can be maintained below the LTOP limiting pressure of 43.94 kg/cm^{2}A (625 psia), because the LTOP relief valve installed in the SCS automatically opens at the opening setpoint (38.51 kg/cm^{2}A [530 psig]). Once the RCS temperature reaches the LTOP disable temperature (136.11 °C [277 °F]), the operator isolates the RCS from the SCS by manually closing the SCS isolation valves. The operator action for isolation of the SCS is finished before the RCS temperature exceeds the SCS entry temperature (176.67 °C [350 °F]). After that, the RCS overpressurization can be protected by POSRVs. After closing the SCS isolation valves, the RCS temperature and pressure continue to increase, and eventually return to the hot standby condition. The full-power FLEX strategy can be also applied after the plant returns to hot standby.

5.1.2.3.4.6 Analysis Results and Conclusion for Shutdown Conditions with SGs not Available

Mid-loop operation is selected as a representative case for the analysis of the mode 5 and 6 operation with SGs not available. The FLEX strategy for the mid-loop operation consists the following three phases 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

Based on the analysis result for the mid-loop operation case, which is the most limiting case of the shutdown operation with SGs not available, it is concluded that the decay heat can be removed by RCS inventory boiling during Phase 1. The Phase 1 period can be extended to about 4 hours, using gravity feed from two SITs, even though the Phase 1 period is determined to be 3 hours in the timeline of the FLEX strategy. In Phase 2, the plant can be maintained at cold shutdown by the RCS feed-and-bleed operation using the FLEX pump. The Phase 2 feed-and-bleed operation using an onsite water source is assumed to last for 72 hours in the timeline of the mid-loop operation FLEX strategy, but the capacity of the RWT is sufficient to extend the period of Phase 2 up to 6.4 days even if the water source is shared with SFP cooling (see Table B-3 in Appendix B). Hence, the operator has sufficient time margin for preparation of Phase 3. In Phase 3, the primary side feedwater sources and fuel oil for the mobile GTGs are refilled from offsite resources. If SCS is successfully restored after the 4.16 kV GTG is connected, the plant can be brought to and maintained at the cold shutdown using SCS instead of the RCS feed-and-bleed operation.

In this operation mode, containment pressure increases consistently from the beginning of the event due to the mass and energy released from the RCS, but it can be maintained below UPC by operating the ECSBS intermittently after reaching UPC at around 3.5 days following the event (see Figure 5-4).

5.1.2.4 SFP Cooling

This subsection outlines the operational strategy to maintain the SFP water level at a safe condition throughout the BDBEE. The APR1400 SFP conditions are analyzed for a number of postulated scenarios for the ELAP event. The scenario with ELAP following a seismic event is found to be the most limiting case due to the higher SFP inventory loss.

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5.1.2.5 Containment Function

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There are no special means necessary for the APR1400 to maintain containment function during full-power operation, after a BDBEE with simultaneous loss of all ac power and LUHS. The ECSBS is used for controlling the containment pressure and temperature during loss of residual heat removal (mode 5).

5.1.2.5.1 Containment Isolation Function

Containment isolation can be accomplished with the containment isolation valves (CIVs), because containment penetrations that are required to be isolated for the BDBEE are designed to be isolated by either inside-containment or outside-containment isolation valves, as follows:

a. Normally closed motor-operated valve (MOV) (fail as-is)

b. Air-operated valve (AOV) (fail closed)

This will be modified to "K" in following page.

c. Check valve inside containment (automatic isolation)

5.1.2.5.2 Containment Capability during Full-Power Operation

The containment design incorporates a prestressed concrete containment with a steel liner to house the nuclear steam supply system. The containment and associated systems are designed to safely withstand environmental conditions that may be expected to occur during the life of the plant, including both short-term and long-term effects following a design basis accident (DBA) and beyond DBA.

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During a BDBEE, no major pipe break is postulated inside the containment, but RCP seal leakage is assumed to be at a leak rate of 94.64 L/min (25 gpm) per RCP, a total of 378.5 L/min (100 gpm) for four RCPs. The containment pressure and temperature analyses are performed using the GOTHIC (Version 8.0) computer program. The containment pressure reaches the design pressure of 5.25 kg/cm^2 A (74.7 psia) in about 63 days from the beginning of the event. The design temperature of 143 °C (290 °F) is not exceeded until 71 days following the event. Figure 5-3 provides the containment pressure and temperature responses with the assumed RCP seal leakage. Therefore, containment integrity is maintained following full-power events through all phases.

5.1.2.5.3 Containment Capability during Mode 5 Operation

Loss of residual heat removal (RHR) during mid-loop operation in mode 5 is additionally assumed for the evaluation of containment capability. In the RCS mid-loop operation, SG nozzle dams are installed on the steam generator plena and the pressurizer manway remains opened. In this event, steam is assumed to be released from the RCS to the containment through the pressurizer manway due to the boiling of reactor coolant following the loss of RHR.

This will be modified to "M" in following page.

Due to the mass and energy released from the RCS, containment pressure increases consistently from the beginning of the event, but it can be maintained below UPC by operating the ECSBS intermittently after reaching UPC at around 83 hours. The ECSBS is assumed to start spraying water into the containment atmosphere via a FLEX pump when the containment pressure reaches the UPC value of 12.9 kg/cm^2 A (184 psia). After the initial operation, the ECSBS is assumed to be intermittently operated for 2 hours whenever the containment pressure reaches the UPC value. The FLEX pump provides the flow rate of 2,839 L/min (750 gpm) and the differential pressure of at least 2.8 kg/cm^2 (40 psi) at the ECSBS nozzle. The external water source for ECSBS operation is the RWT.

GOTHIC analyses are performed for evaluation of the containment pressure and temperature responses following loss of RHR in mode 5. Figure 5-4 shows that the containment pressure reaches the UPC value in about 3.5 days without ECSBS operation, but with the intermittent operation of ECSBS, containment

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5.1.2.5 Containment Function and Structural Integrity

This subsection presents the operational strategy for containment cooling to ensure the containment function and structural integrity throughout the BDBEE. The APR1400 containment cooling capability to cope with the BDBEE is addressed in ~~the section~~ this subsection.

"K"

5.1.2.5.1 Strategy for Containment Cooling

All of the containment heat removal systems are not credited to operate in the containment pressurization following mass and energy releases from the RCS during the BDBEE. However, even in that condition, the containment conditions need to be maintained within the containment design pressure and the environmental qualification (EQ) temperature that ensure functions of the safety related equipment within the containment as well as the containment structural integrity.

The emergency containment spray backup system (ECSBS) is considered as a means to cool the containment atmosphere, consequently decreasing the containment pressure and temperature below the design limits in such a case that the containment pressure increases following the BDBEE.

The ECSBS is manually actuated when the containment pressure reaches the design pressure. The RWT water is used as the water source for supplying to the ECSBS. The RWT has a sufficient capacity to provide water for the containment cooling including for the core and the SFP cooling ~~in phase 2. After phase 2, the RWT is filled with off-site water by fire vehicles that are infinitely available in phase 3~~.

"L"

5.1.2.5.2 Supporting Analyses for Containment Cooling

The containment design incorporates a prestressed concrete containment with a steel liner to house the nuclear steam supply system. The containment and associated systems are designed to safely withstand environmental conditions that may be expected to occur during the life of the plant, including both short-term and long-term effects following a DBA and beyond DBA.

In the supporting analysis for the containment cooling during the BDBEE, the RCP seal LOCA at full-power operation is chosen as the representative case of power operation and shutdown conditions with SGs available to demonstrate maintaining the containment pressure and temperature below the design limits through the FLEX strategy that using the ECSBS.

The APR1400 added a COL item in DCD Chapter 19.3 specifying that the COL applicant is to develop the shutdown risk processes and procedures, and verify the ability to deploy FLEX equipment to provide containment cooling in shutdown operation with SGs not available.

5.1.2.5.2.1 Acceptance Criteria

The following acceptance criteria are applied to ensure the containment function and structural integrity throughout the BDBEE.

・Containment pressure is maintained below the containment design pressure of 4.22 kg/cm^2 (60 psig) at a BDBEE.
・Containment temperature is maintained at a value less than the EQ temperature of 182 ^{o}C (360 ^{o}F).

5.1.2.5.2.2 Analytical Methods and Assumptions

Containment pressure and temperature at a BDBEE are analyzed using the GOTHIC (Generation of Thermal-Hydraulic Information for Containments) computer code. The GOTHIC containment model, which was developed for the containment response calculation to a LOCA described in DCD Tier 2 Section 6.2.1, is used to demonstrate the containment capability to cope with the BDBEE. The GOTHIC containment model with analysis methodology are described in Technical Report "LOCA Mass and Energy Release Methodology" (Reference 17) in detail.

The major assumptions used in the containment analysis are listed below:

・The ECSBS is actuated when the pressure reaches the containment design pressure in the containment pressurization following a BDBEE.
・The discharge flow from the RCS leakage is instantly mixed into the containment atmosphere and reaches thermal equilibrium within the containment volume during the transient.
・Variance in local temperature within the containment is not assumed since the accident scenario is characterized by slow, but continuous containment pressurization.

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5.1.2.5.2.3 Analysis Results and Conclusion

During the full-power operation, no major pipe break is postulated inside the containment, but RCP seal leakage is assumed to be at a leak rate of 94.64 L/min (25 gpm) per RCP, a total of 378.5 L/min (100 gpm) for four RCPs.

The containment pressure reaches the design pressure of 4.22 kg/cm^2 (60 psig) after approximately 16 days of the accident, then rapidly decreases and maintains at a low pressure by continuous spray through the ECSBS.

The containment temperature reaches the highest temperature of 148 ^{o}C (298 ^{o}F), but which is well below the temperature limit of 182 ^{o}C (360 ^{o}F) for the environmental qualification of the safety related equipment within the containment. Figure 5-3 and Figure 5-4 show the containment pressure and temperature transients to the RCP seal LOCA, respectively.

From the analysis, it is noted that the containment pressure and temperature are maintained well below the design limits, thereby ensuring the functions of safety-related equipment within containment as well as the containment structural integrity during the BDBEE.

The ECSBS FLEX pump provides the flow rate of 2,839 L/min (750 gpm) at a discharge pressure head of 200 m (656 ft).

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Connection line

The connection line to the FLEX pump runs inside the containment building through the auxiliary building from the Siamese connection to the ECSBS nozzles, which is designed to Seismic Category I standpipe. The connection line is divided into two Quality Groups. The line from the Siamese connection to the ECSBS isolation valve (V1013) is designed with Quality Group D and the line from V1013 to ECSBS nozzles is designed with Quality Group B.

A simplified drawing that identifies the flow path to deliver water to the ECSBS is schematically shown in Figure 6-7.

5.1.2.5.3

A

~~5.1.2.5.2.4~~ ECSBS operation for Containment Cooling

~~Preperation~~ for ECSBS operation

If the ECSBS operation needs to be used, the following tasks are established.

a. Mobilize ECSBS FLEX pump and connect the pump suction to the RWT outlet for water supply
b. Connect pump discharge to the Siamese connection of the ECSBS standpipe
c. Open the RWT isolation valve in yard and enter general access area in the AB and open ECSBS isolation valve (CS-V1013)

Preparation

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~~pressure can be maintained within the UPC limit. Figure 5-5 shows that the containment temperature is maintained well below 185 °C (365 °F), which is less than the upper limit temperature of 196 °C (385 °F) for ensuring the operability of RCS sensors.~~

5.1.2.6 Support Systems

5.1.2.6.1 Electrical Systems

This subsection describes the electrical strategies to support the FLEX items described above for NTTF 4.1 and 4.2.

As stated earlier, the BDBEE causes the unit to lose all ac power. The initial condition is assumed to be a LOOP at a plant site resulting from a BDBEE that affects the offsite power system either throughout the grid or at the plant with no prospect for recovery of offsite power for an extended period. All installed sources of emergency onsite ac power and alternate ac power sources are assumed to be unavailable and not imminently recoverable.

However, the installed electrical distribution system, including inverters and battery chargers, remain available provided they are protected in a manner consistent with current station design.

5.1.2.6.1.1 AC Power

The APR1400 has one 4.16 kVac, 5,000 kW and two 480 Vac, 1,000 kW mobile GTGs for the N+1 requirement, and those mobile GTGs are designed to meet the load requirements as stated in Table 5-5. (See Appendix C for a detailed breakdown of electrical loadings.) The 480 V mobile GTG is credited to power the Class 1E 480 V load centers during Phase 2, while the 4.16 kV mobile GTG is credited to power the Class 1E switchgear during Phase 3.

The 4.16 kV mobile GTG is connected to the 4.16 kV switchgear Train A (or B), and the 480 V mobile GTG is connected to 480 V load center Train A (or B). The provisions to connect these GTGs are incorporated in the APR1400 design. The 4.16 kV GTG powers the 4.16 kV switchgear, 480 V load center and MCC, 480 Vac / 125 Vdc battery charger, 125 Vdc battery, 125 Vdc / 120 Vac inverter, and 120 Vac distribution panel in Train A (or B). The 480 V mobile GTG powers the 480 V load center and MCC, 480 Vac / 125 Vdc battery charger, 125 Vdc battery, 125 Vdc / 120 Vac inverter, and 120 Vac distribution panel in Train A (or B).

During Phase 1, the APR1400 takes credit for Train C or D to which the TDAFWP is connected, while during Phases 2 and 3, the APR1400 takes credit for Train A or B. The ACP is designed to be powered from both Train A and Train B, and the MSADV is designed to be powered from either Train A or Train B. Therefore, during Phases 2 and 3, when the mobile GTG is connected to either Train A or Train B, the APR1400 can be maintained in a safe condition. During Phase 3, the shutdown cooling pump and heat exchanger are used to recover the plant.

5.1.2.6.1.2 DC Power

The APR1400 does not use mobile dc power supplies.

During an ELAP, Class 1E 125 Vdc power is required for operation of 4.16 kV switchgears, 125 Vdc loads, 480 Vac MOVs and AOVs that are backed up by 125 Vdc batteries, I&C panels and shutdown system instrumentation, and 120 Vac loads that are inverted from 125 Vdc batteries.

Both Train A and B batteries have a capacity of 2,800 Ah and can supply dc power up to 2 hours without load shedding and an additional 6 hours with load shedding. Train C and D batteries have a capacity of 8,800 Ah and can supply dc power up to 16 hours without load shedding. The first 8 hours (Phase 1) at least 32 days to sustain the demand for fuel oil during full-power mode operation. ~~During the low-power mode, the fuel oil storage tanks and their associated day tank can sustain the fuel oil demand for at least 33 days based on a total consumption of (31,343+2,873+750+379) = 35,343 L (9,337 gal) per Table 5-6.~~

5.1.2.7 Summary of APR1400 Mitigation Capability for FLEX

The APR1400 baseline capability is sufficient to support the safety functions of core cooling, containment function, and SFP cooling after BDBEE, with simultaneous loss of all ac power and LUHS. However, FLEX equipment stored onsite (or offsite) will be used to support the mitigation of a BDBEE resulting in an ELAP and LUHS. The APR1400 mitigation capability of the BDBEE is summarized in Table 5-7, which is based on the NEI 12-06 (Reference 8) FLEX capability matrix table. This table outlines baseline and FLEX capabilities of the APR1400 to maintain safety functions of core cooling, containment, and SFP cooling.

5.1.2.8 Conformance with NRC/NEI Recommendations

Conformance with JLD-ISG-2012-01 (Reference 7) is addressed in Table 5-8.

Conformance with NEI 12-06 (Reference 8) is addressed in Table 5-9.

Conformance with NEI 12-06, Tables D-1, D-2, and D-3 (Reference 8) is addressed in Table 5-10.

5.1.3 Recommendation 7.1 – SFP Instrumentation

5.1.3.1 Introduction

Recommendation 7.1 is a Tier 1 recommendation that resulted in the issuance of NRC Order EA-12-051 (Reference 6). The Order modified licenses to require a reliable indication of the water level in associated spent fuel storage pools capable of supporting identification of the following pool water level conditions by trained personnel: (1) level that is adequate to support operation of the normal fuel pool cooling system, (2) level that is adequate to provide substantial radiation shielding for a person standing on the spent fuel pool operating deck, and (3) level where fuel remains covered and actions to implement makeup water addition should no longer be deferred.

The APR1400 SFP water level instrumentation is consistent with the guidelines in NRC EA-12-051 (Reference 6), NEI 12-02 Rev. 1 (Reference 12), and JLD-ISG-2012-03 Rev. 0 (Reference 13) as described in the following subsection.

5.1.3.2 Basic Strategy

The strategy for addressing NTTF 7.1 SFP instrumentation is described below.

5.1.3.2.1 Identification of Spent Fuel Pool Water Levels

The following are the key spent fuel pool water levels:

- Level 1: Level adequate to support operation of the normal SFP cooling system

Indicated water level on either the primary or backup instrument channel of greater than El. 144 ft 0in (based on ensuring the open end of the normal suction lines does not become uncovered) plus the accuracy of the SFP water level instrument channel.

TS

Table 5-3 Sequence of Events for Core Cooling (Mid-Loop Operation)

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Table 5-6 Summary of Fuel Oil Demand (most limiting) ~~(1 of 2)~~

Modes	Phase	Purpose	Fuel Oil Source	Equipment (Specification)	Fuel Oil Volume required Liters (gal)	Remark
Full Power	Phase 1	Core cooling	NA			
	Phase 2 (modes 1~4)	Power supply	EDG fuel oil storage tank and day tank	GTG (480 V/1,000 kW)	29,072 (7,680)	7.57 L/min (2.0 gpm)
		Core cooling		Two secondary FLEX pumps (each 1,174 L/min, 160 m [310 gpm, 525 ft])	2,764 (730)	0.36 L/min (0.095 gpm)
		RCS makeup		One primary high-head FLEX pump (190 L/min, 17 kg/cm^2 A [50 gpm, 243 psia])	2,060 (544)	0.54 L/min (0.142 gpm)
		SFP cooling (No full core offload)		- One SFP makeup FLEX pump (1,893 L/min [500 gpm]) - SFP spray (757 L/min [200 gpm])	174 (46) 379 (100)	An alternate means of SFP makeup FLEX pump
	Phase 3	RCS makeup SFP cooling	Resources external (COL)			
Low Modes	Phase 1	RCS makeup	NA	NA		
		SFP cooling	NA	NA		
	Phase 2	Power supply	EDG fuel oil storage tank and day tank	GTG (480 V/1,000 kW)	31,343 (8,280)	7.57 L/min (2.0 gpm)
	Phase 2 (Mode 5 and 6 w/o full core offload)	RCS cooling	RWT (water source)	One primary low-head FLEX pump (2,839 L/min, 17 kg/cm^2 A [750 gpm, 243 psia])	2,873 (759)	RCS feed-and-bleed operation
		SFP cooling (No full core offload)		- One SFP makeup FLEX pump (1,893 L/min [500 gpm]) - One SFP spray FLEX pump (757 L/min [200 gpm])	174 (46) 379 (100)	An alternate means of SFP-makeup FLEX pump
	Mid-loop operation in Mode 5	ECSBS	RWT (water source)	One ECSBS pump (2,839 L/min, 17 kg/cm^2 A [750 gpm, 243 psia])	750 (198)	Based on 69 hours (9 cycles) operation for every 2 hours operation followed by 6 hours off

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Table 5-6 Summary of Fuel Oil Demand (most limiting) (2 of 2)

Modes	Phase	Purpose	Fuel Oil Source	Equipment (Specification)	Fuel Oil Volume required Liters (gal)	Remark
	Phase 2 (mode 6 with full core offload)	SFP cooling	RWT (water source)	- One SFP makeup FLEX pump (1,893 L/min [500 gpm]) - One SFP spray FLEX pump (757 L/min [200 gpm])	174 (46) 379 (100)	An alternate means of SFP-makeup, FLEX pump
	Phase 3	RCS makeup SFP cooling	Resources external (COL)			

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Table 5-7 APR1400 FLEX Capability Summary (1 of 3)

Safety Function		Method	Capabilities	FLEX Equipment
Core Cooling and RCS Inventory	Core Cooling (SGs available): Modes 1 through 5	Phase 1: • NCC • TDAFWP-SG-MSSV-AFWST Phase 2: • NCC • TDAFWP-AFWST-SG-MSADV • ACP, SIT • FLEX pumps • Load shedding • 480 V mobile GTGs • IRWST, AFWST Phase 3: • Same as Phase 2 • RWT • Offsite resources • 4.16 kV mobile GTG	• Use of installed equipment (TDAFWP-SG-MSSV-MSADV, ACP, SIT, UHS, SCS) • Use of water supply (AFWST, RWT, IRWST) • Use of a primary side high-head FLEX pump if ACP is not available • Use of secondary side FLEX pumps if TDAFWPs are not available • Connection for FLEX pumps to supply water • Use of UHS/SCS instead of the NCC cooling with MSADVs and TDAFWPs after the 4.16 kV mobile GTG is connected, if UHS is restored	• Onsite self-powered primary high-head FLEX pump • Onsite self-powered secondary side FLEX pump to directly supply water to SG • 480 V onsite mobile GTG • 4.16 kV offsite mobile GTG
Available borated water source (COL 19.3(17))	Core Cooling (SGs unavailable): Modes 5 and 6	Phase 1 • Decay heat is removed by boiloff from the core ~~• SIT~~ Phase 2 • Feed-and-bleed by external injection using FLEX pump • ~~RWT~~ • 480 V mobile GTGs Phase 3 • 4.16kV mobile GTG~~Offsite resources~~UHS/SCS • ~~RWT~~ • Offsite resources	~~• Use of installed equipment (SIT)~~ • Use of water supply (~~RWT~~ IRWST) • Vent steam through PZR manway • Use of FLEX pump • RCS makeup connections for a FLEX primary side pump • Use of UHS/SCS instead of the NCC cooling with MSADVs and TDAFWPs after the 4.16 kV mobile GTG is connected, if UHS is restored	• Onsite self-powered primary side FLEX pump to make up RCS • 480 V onsite mobile GTG • 4.16 kV offsite mobile GTG

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Table 5-7 APR1400 FLEX Capability Summary (2 of 3)

Safety Function		Method	Capabilities	FLEX Equipment
	RCS Inventory/ Boration (SGs available): Modes 1 through 5	• Low-leakage RCP seals (leakage assumed to be 94.64 L/m [25 gpm] per RCP) • Provide borated RCS makeup	• Use of ACP or primary side high-head FLEX pump for RCS makeup with borated water • SIT for boration	• Onsite self-powered primary side FLEX • 480 V onsite mobile GTG • 4.16 kV offsite mobile GTG
	RCS Inventory/ Boration (SGs not available): Modes 5 and 6	• RCS feed and bleed • ~~Supply borated water from SIT to RCS~~ • ~~Supply water from RWT to RCS at the rate of core boiloff (feed-and-bleed)~~ • ~~RCS remains at constant boron concentration during feed-and-bleed operation~~	• ~~Use of SIT for RCS makeup and boration~~ • Use of primary side low-head FLEX pump for RCS makeup	• Onsite self-powered primary side FLEX pump
	Key Instrumentation	• SG water level and pressure • AFWST water level • ~~SIT level and pressure~~ • RCS hot leg (HL) and cold leg (CL) temperature • Pressurizer (PZR) water level and pressure • Core exit temperature	• Instruments powered by Class 1E dc bus	• Onsite mobile GTG
Containment Integrity	~~Containment Pressure Control / Heat Removal~~ Containment Cooling	• Containment Structure • ECSBS (for Mode 5 only) •	• Source of water (AFWST, RWT) • ECSBS spray	• ~~None~~ Onsite self-powered FLEX pumps to provide containment cooling, with hoses and couplings
	Key Containment Instrumentation	• Containment pressure •	• Key instruments powered by Class 1E dc bus	• None
SFP Cooling	SFP Cooling	• SFP makeup and SFP spray	• Use of installed equipment (RWT) • Use of FLEX pumps • SFP makeup lines and SFP spray lines from yard connections to SFP • Vent pathway for steam and condensed vapors from SFP area	• Onsite self-powered FLEX pumps to makeup SFP, with hoses and couplings

Table 5-8 Conformance with JLD-ISG-2012-01, Rev. 0 (1 of 5)

JLD-ISG-2012-01 Rev. 0			APR1400
Section		Summary	
1.0	Evaluation of External Hazards	NEI 12-06, Section 4 describes the overall methodology for evaluating the impact of the hazards, described in Sections 5.0 through 9.0, on the deployment of the strategies to meet the baseline coping capability.	COL applicants are responsible to assess the site-specific external hazards in accordance with the guidance.
2.0	Phased Approach	Order EA-12-049 requires a three-phase approach to mitigating beyond-design-basis events, with an initial response phase using installed equipment, a transition phase using portable equipment and consumables to provide core and spent fuel pool (SFP) cooling and maintain the containment functions, and a third phase of indefinite sustainment of these functions using offsite resources. Maintenance of core and SFP cooling and containment functions requires overlap between the initiating times for the phases with the duration for which each licensee can perform the prior phases. The NRC staff recognizes that for certain beyond-design-basis external events, the damage state could prevent maintenance of key safety functions using the equipment intended for particular phases. Under such circumstances, prompt initiation of the follow-on phases to restore core and SFP cooling and containment functions is appropriate. If fuel damage occurs, the Severe Accident Management Guidelines should be used as guidance.	The APR1400 FLEX strategy complies with the guidance. The APR1400 FLEX strategy to provide core and SFP cooling, and to maintain containment integrity when ELAP and LUHS are assumed to occur simultaneously, follows the three-phase approach as requested in Order EA-12-049. The three-phase operations consist of an initial response phase using installed equipment, a transition phase using FLEX equipment and consumables to provide core cooling, and a third phase of indefinite sustainment of these functions using offsite resources.
2.1	Initial Response Phase	The initial response phase will be accomplished using installed equipment. Licensees should establish and maintain current estimates of their capabilities to maintain core and SFP cooling and containment functions assuming a loss of alternate current (ac) electric power to the essential and nonessential switchgear buses except for those fed by station batteries through inverters. This estimate provides the time period in which the licensee should be able to initiate the transition phase and maintain or restore the key safety functions using portable onsite equipment. This estimate should be considered in selecting the storage locations for that equipment and the prioritization of resources to initiate their use.	The APR1400 FLEX strategy complies with the guidance. FLEX strategy for power operation and shutdown mode with SGs available: Initial phase ~~(0-8 hours)~~: During the initial response phase, it is assumed that all ac power and normal access to UHS are lost, but the dc battery is available. Train C and D Class 1E battery supplies dc power to essential I&C equipment, and TDAFWPs continue to feed SGs at least for 8 hours following the event. Also, the steam generated from SG is released though the passive safety valves, MSSVs. Therefore, NCC operation to maintain RCS at hot standby is possible without any operator action during this phase.

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Table 5-8 Conformance with JLD-ISG-2012-01, Rev. 0 (2 of 5)

JLD-ISG-2012-01 Rev. 0			APR1400
Section		Summary	
			FLEX strategy for shutdown mode with SGs not available: Initial phase ~~(0-3 hours)~~: Decay heat is removed by RCS inventory boiloff from the core ~~boiling with gravity feed from SITs. The only operator action is to manually open the valves needed for gravity feed from SITs during this phase.~~
2.2	Transition Phase	The transition phase will be accomplished using portable equipment stored onsite. The strategies for this phase must be capable of maintaining core cooling, containment, and spent fuel pool cooling capabilities (following their restoration, if applicable) from the time they are implemented until they can be supplemented by offsite resources in the final phase. The duration of the transition phase should provide sufficient overlap with both the initial and final phases to account for the time it takes to install equipment and for uncertainties.	The APR1400 FLEX strategy complies with the guidance. FLEX strategy for power operation and shutdown mode with SGs available: Transition phase ~~(8-72 hours)~~: During this phase, RCS is cooled down to around 176.67 °C (350 °F) using the installed plant equipment, such as TDAFWP, MSADV, ACP, SIT, and/or FLEX equipment, such as 480 V mobile GTG and primary FLEX pump. If installed plant equipment is inoperable even after connection of mobile ac power, RCS is further cooled down to around 98.89 °C (210 °F) using secondary side FLEX pump. RCS makeup is carried by the primary side FLEX pump. AFWST and RWT are consecutively used as onsite water sources to feed SGs. The transition phase can be extended to approximately 12 days. Therefore, the duration of the transition phase provides sufficient overlap with final phase. The initial phase overlaps for at least 8 hours with the transition phase, since dc battery is available until 16 hours following the event without load shedding. FLEX strategy for shutdown mode with SGs not available: Transition phase ~~(3-72 hours)~~: The plant is maintained at cold shutdown by the RCS feed-and-bleed operation using the primary side low-

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Table 5-8 Conformance with JLD-ISG-2012-01, Rev. 0 (3 of 5)

JLD-ISG-2012-01 Rev. 0			APR1400
Section		Summary	
			head FLEX pump. ~~The capacity of the RCS feedwater source, RWT, is sufficient to extend the period of the transition phase up to 6.4 days. Therefore, the duration of the transition phase has sufficient overlap with final phase. The initial phase overlaps for 1 hour with the transition phase, since the capacity of gravity feed from SITs prevent core uncovery for 4 hours. The overlap time is sufficient, because the operator action needed for the transition phase is only to connect a primary FLEX pump.~~
2.3	Final Phase	The final phase will be accomplished using the portable equipment stored onsite augmented with additional equipment and consumables obtained from offsite.	The APR1400 FLEX strategy complies with the guidance. Final phase ~~(after 72 hours)~~: 4.16 kV mobile GTG is connected to Train A or Train B Class 1E switchgear. Consumables such as cooling water and GTG fuel are supplied from offsite for long-term coping with the event.
3.0	Core Cooling Strategies	The first set of strategies necessary to meet the requirements of Order EA-12-049 addresses challenges to core cooling. Core cooling must be accomplished in all three phases described in the Order. The purpose of these strategies is to provide a means of cooling the core in order to prevent fuel damage.	The APR1400 FLEX strategy complies with the guidance. Supporting analysis for the operational strategy for core cooling were performed using RELAP5/Mod 3.3. It was shown from the analysis that even in the ELAP concurrent with LUHS, the plant is maintained at safe shutdown state (hot standby, hot shutdown, or cold shutdown, depending on the phase of the APR1400 core cooling FLEX strategy) without fuel damage.
4.0	Spent Fuel Pool Cooling Strategies	The second set of strategies necessary to meet the requirements of Order EA-12-049 addresses challenges to SFP cooling. SFP cooling must be accomplished in all three phases described in the Order. The purpose of these strategies is to provide alternate means of cooling the spent fuel in order to prevent fuel damage. Licensees must consider all loading conditions relevant to their SFP, including a maximum core offload.	The APR1400 FLEX strategy complies with this guidance. Alternate means for supplying both makeup water to the SFP and spray water are provided from the outside of the auxiliary building. Maximum core offload condition was considered in the SFP boiloff analysis.

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Table 5-8 Conformance with JLD-ISG-2012-01, Rev. 0 (4 of 5)

JLD-ISG-2012-01 Rev. 0			APR1400
Section		Summary	
5.0	Containment Function Strategies	The third group of strategies and guidance necessary to meet the requirements of Order EA-12- 049 addresses challenges to the containment functions. Containment functions must be accomplished in all three phases described in the Order.	Upon loss of all ac power, all containment penetrations are isolated by either using dc power or mobile ac power. Also, for those penetrations needed to be opened for FLEX strategies, the isolation valves can be opened from the MCR.
5.1	Removal of Heat from Containment (Pressure Control)	Beyond-design-basis external events such as a prolonged SBO or loss of normal access to the ultimate heat sink could result in a long-term loss of containment heat removal. The goal of this strategy is to relieve pressure from the containment in such an event.	The APR1400 FLEX strategy complies with this guidance. The containment pressure and temperature can be maintained below the design basis value since the only source of energy imparted onto the containment building is the RCP seal leakage, which is 94.64 L/min (25 gpm) / RCP (a total of 378.54 L/min [100 gpm]). This is well below the mass and energy of the design basis accident, and the containment integrity can be maintained for the BDBEE conditions. ~~When the BDBEE occurs during the mid-loop operation, the containment pressure increases consistently due to the mass and energy released from the pressurizer manway, but it can be maintained below UPC by operating the ECSBS.~~
6.0	Programmatic Controls		
6.1	Equipment Protection, Storage, and Deployment	Storage locations chosen for the equipment must provide protection from external events as necessary to allow the equipment to perform its function without loss of capability. In addition, the licensee must provide a means to bring the equipment to the connection point under those conditions in time to initiate the strategy prior to expiration of the estimated capability to maintain core and spent fuel pool cooling and containment functions in the initial response phase. Staff Position: NEI 12-06 provides an acceptable method to provide reasonable protection, storage, and deployment of the equipment associated with Order EA-12-049.	COL applicant is responsible for the FLEX equipment protection, storage, and deployment.

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Table 5-10 Conformance with NEI 12-06, Rev. 0 – Tables D-1, D-2, and D-3 (1 of 4)

NEI 12-06, Rev. 0 – Tables D-1, D-2, and D-3			APR1400
Safety Function	**Method**	**Performance Attributes**	
Core Cooling and Heat Removal (SG available)	AFW/EFW	• Extend installed coping capability through procedural enhancements (e.g., load shedding), provision of portable battery chargers and other power supplies. • Objective is to provide extended baseline coping capability with installed equipment. • Procedures/guidance to include local manual initiation of ac-independent AFW/EFW pumps consistent with NEI 06-12.	• Train C/D dc battery is available for 16 hours without load shedding, and 480 V mobile GTG is prepared to charge Train A or Train B dc battery and to supply ac power to the installed safety components such as ACP. • ac-independent FLEX pumps provide the safety functions such as core cooling and RCS makeup, according to the APR1400 FLEX strategy.
Core Cooling and Heat Removal (SG available)	Depressurize SG for makeup with portable injection source	• Primary and alternate injection points are required to establish capability to inject through separate divisions/trains, i.e., should not have both connections in one division/train. • Makeup paths supply required SGs. • SG makeup rate should exceed decay heat levels at time of planned deployment in order to support restoring SG water level, e.g., 200 gpm.(1) • Analysis should demonstrate that the guidance and equipment for combined SG depressurization and makeup capability support continued core cooling.	• Rated flow of secondary FLEX pump is 1173.48 L/min (310 gpm), which is sufficient not only to remove decay heat but also to restore SG water level. •Supporting analysis for FLEX strategy shows that the APR1400 plant has capability for continued core cooling during ELAP concurrent with LUHS.
Core Cooling and Heat Removal (SG available)	Sustained source of water	• Water source sufficient to supply water indefinitely including consideration of concurrent makeup or spray of SFP	•Onsite water sources such as AFWST and RWT provide water to feed SG for approximately 2 weeks. When RWT inventory is shared with the SFP cooling water, the water source can feed SG at least for 12 days.
RCS Inventory Control / Long-Term Subcriticality	Low-leakage RCP seals and/or borated high-pressure RCS makeup required	• Makeup capability to maintain core cooling (1) • Sufficient letdown to support required makeup and ensure subcriticality (1)	•The APR1400 RCP adopts a three-stage seal design, which is similar to CE-KSB pump. •ACP provides RCS with borated water from IRSWT and BAST, after 480 V mobile GTG is connected. • SIT also provides RCS with borated water, when RCS pressure reduces to the setpoint during cooldown operation. • Primary FLEX pump is also able to make up RCS inventory with borated water in the long term.

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Figure 5-2 Timeline of the APR1400 FLEX Strategy for Mid-Loop Operation

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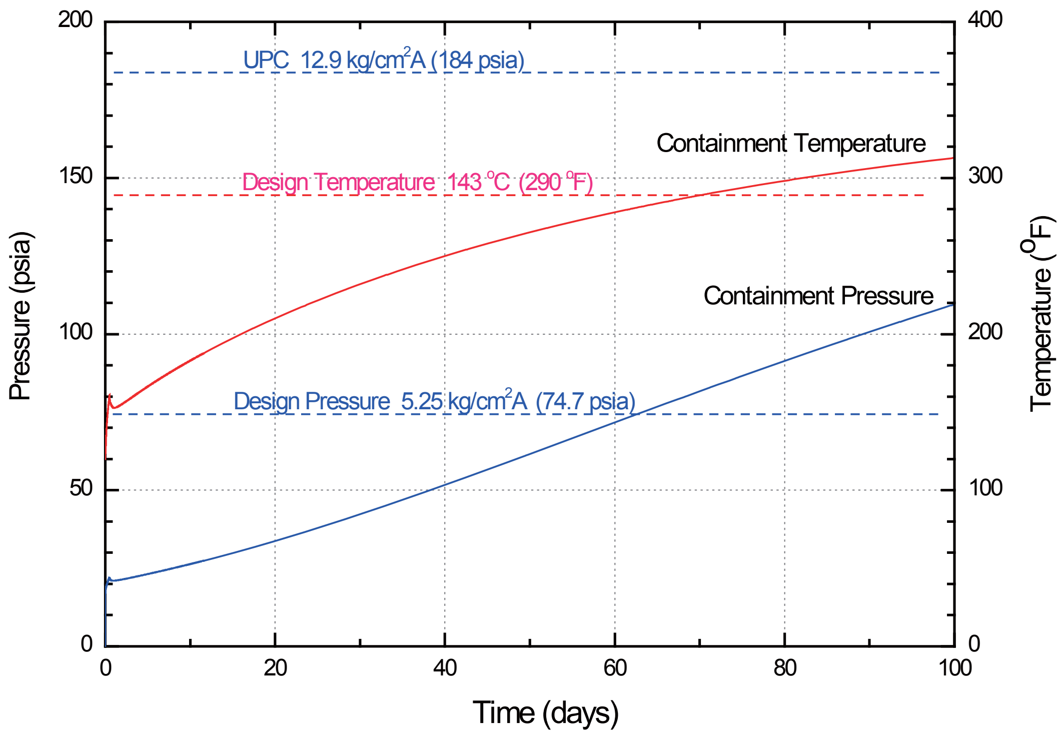

Figure 5-3 Containment Pressure and Temperature for Full Power

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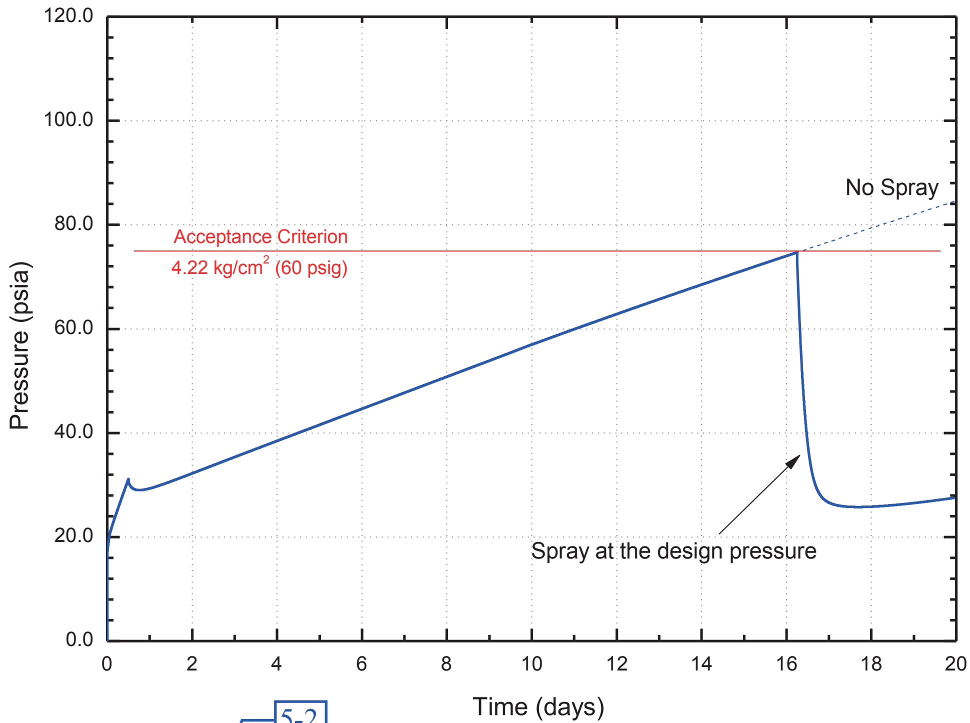

5-2

Figure 5-3 Containment Pressure for Full Power (RCP Seal LOCA)

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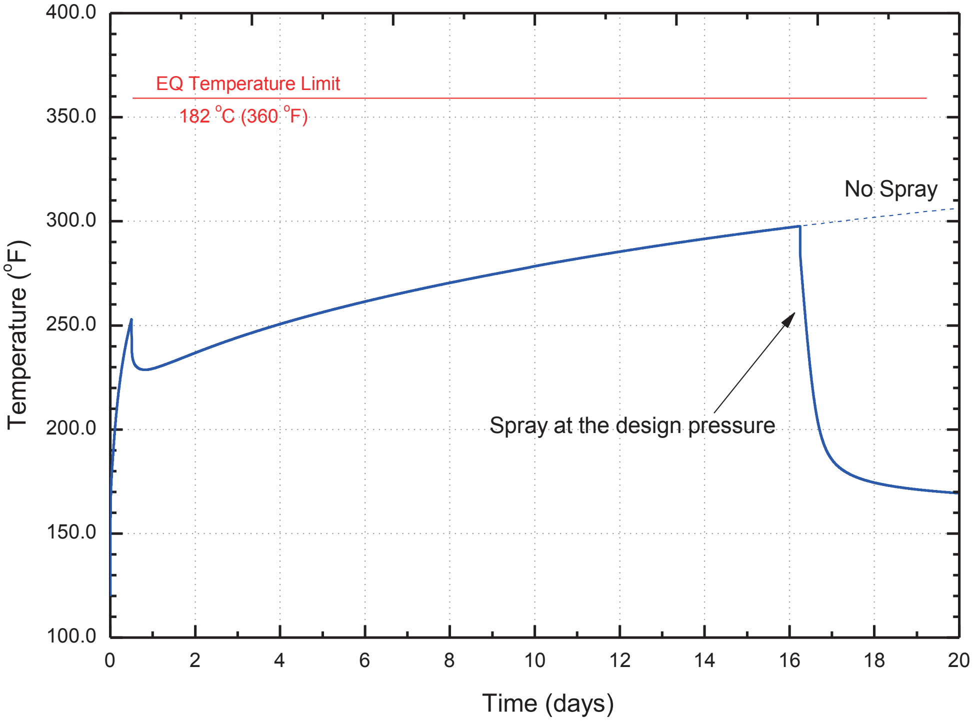

5-3

Figure 5-4 Containment Temperature for Full Power (RCP Seal LOCA)

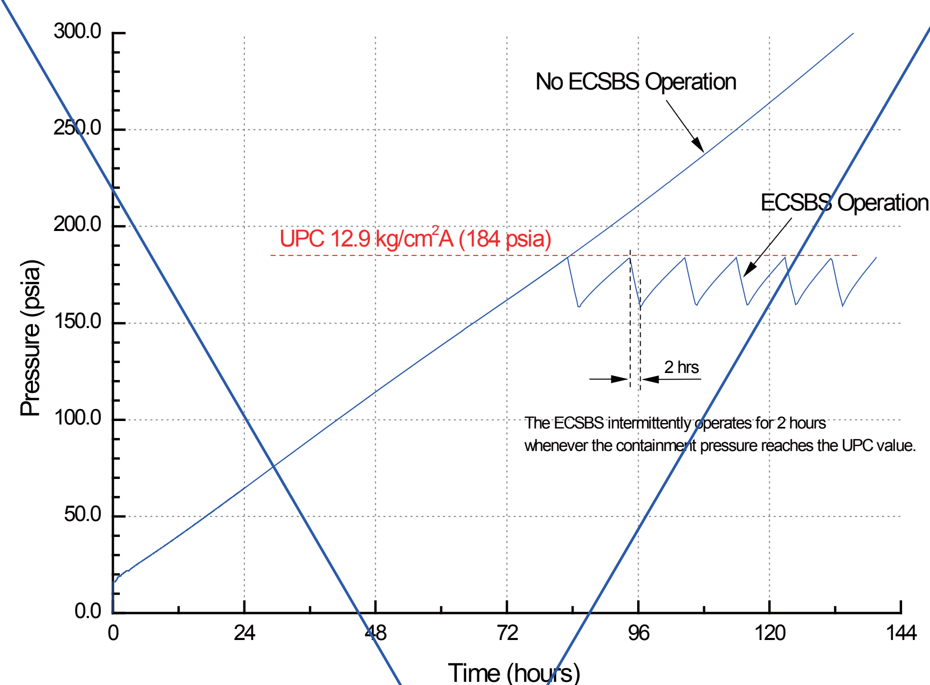

Figure 5-4 Containment Pressure for Loss of RHR (Mode 5)

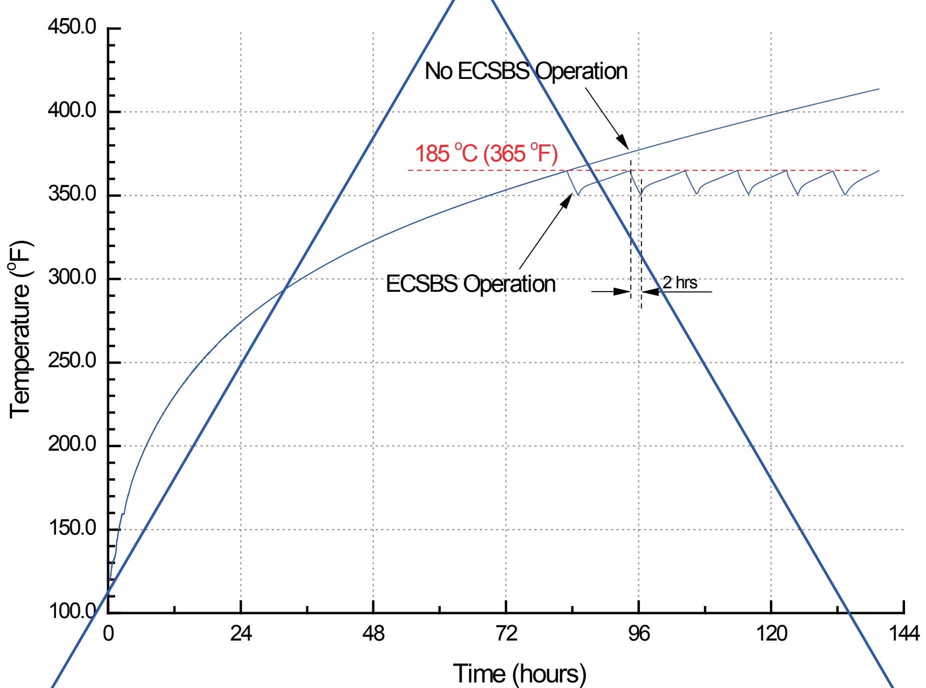

Figure 5-5 Containment Temperature for Loss of RHR (Mode 5)

6.0 DESIGN FEATURES AND PROGRAMS TO ADDRESS BDBEE

This chapter compiles design enhancements and programs that are incorporated into the APR1400 design to cope with the lessons learned from the accidents at TEPCO's Fukushima Dai-ichi Nuclear Power Station, and satisfy the requirements/recommendations issued after the disaster by the U.S. NRC. Design features and program descriptions, design basis, and compliance with NRC recommendations are described herein.

6.1 Overall Description

The following is the overall description:

- Fukushima issues are described in DCD Chapter 19.3.
- Compliance with NRC guidance is described in DCD Tier 2, Section 1.9.
- COL information is described in DCD Chapter 19.3.
- Connection points for FLEX equipment are incorporated in the system figures along with Table 6-1, which identifies the external connection components.

6.2 Specific Design Enhancements and Programs

6.2.1 Beyond Design Basis Seismic and Flood Protection

BDB seismic and flood protection is a COL item.

6.2.2 Primary Side FLEX Pump(s) and Connections

6.2.2.1 Design Description

One primary side FLEX pump connection has been provided into the SIS, downstream of the safety injection pump (SIP) no. 1 discharge line connection to the direct vessel injection (DVI) nozzle on the reactor vessel (RV) in the RCS, as shown in Figure 6-1. The primary side FLEX pump connection can be used by the high-head or low-head FLEX pump, depending on their necessity. The primary side high-head FLEX pump suction is the IRWST, while the low-head FLEX pump suction ~~is the RWT~~ will be determined by the COL applicant depending on the site specific FLEX strategy for low mode operations with SGs not available. The connector size to the hose screw connector upstream of the primary FLEX pump suction is designed as 6.35 cm(2.5 in) diameter in accordance with the fire industry standard, while the primary FLEX pump suction line is designed as 10.16 cm (4 in) diameter. The connection for FLEX pump will not introduce new failure during normal plant operation by keeping the RCS pressure boundary through manual isolation (Safety Class 1) and blind flange.

6.2.2.2 Design Basis

The IRWST is used as the water source for the ACP, and the primary side high-head FLEX pump. The water volume required for RCS inventory makeup during Phase 2 is approximately 643.52 m^3 (170,000 gal). The onsite water sources are sufficient to maintaining the plant in hot standby or hot shutdown condition for 2 weeks of full-power operation without considering consumption for the SFP cooling.

The primary side high-head FLEX pump is designed to supply 189.25 L/min (50 gpm) constantly, regardless of RCS pressure, in order to maintain the RCS inventory and remain in the hot shutdown

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condition, if the event occurs during full-power operation or lower mode
Alternatively, the low-head FLEX pump is designed to have a TDH of 160.02 m (525 ft) (17 kg/cm^2 A [243 psia] approximately) at 2,839 L/min (750 gpm) in order to maintain the RCS inventory and keep the cold shutdown condition by feed-and-bleed at lower modes of operation with SGs not available.

The FLEX pump is designed to meet the requirements of 10 CFR 50, Appendix A, General Design Criterion (GDC) 2, and is therefore classified as a “robust design.” The FLEX pump and the piping associated with this design are also classified as “robust design.” All equipment is commercial grade.

6.2.2.3 Compliance with NRC Recommendation

The primary side FLEX pump will be designed, manufactured, tested and installed in accordance with the applicable commercial codes and standards such as hydraulic institute pump standard, and with the design, storage, maintenance, testing as outlined in the NEI 12-06, Rev 0 Section 11.0. The primary side FLEX pump will be not designed as Seismic Category I, but will be stored in structures which are designed to satisfy GDC 2 to ensure meeting functional requirements for external environments such as seismic, flooding, wind, etc. for the specific site. The installed non-safety related in-line valves for the safety injection system are designed as Quality Group D and seismic Category I requirements. Since these are in-line valves, there is no specific regulating performance requirement for these components. The applicable codes and standards for valves are ASME B31.1 and B16.34.

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in Subsection 5.1.2
RCS water invento
References 5, 7, a

6.2.3 Spent Fue

6.2.3.1 Design I

As part of the FLE
configuration to ma
the following desig
lines and SFP spray lines to cope with BDBEEs:

The SFP spray pump and SFP makeup pump will be designed, manufactured, tested and installed in accordance with the applicable commercial codes and standards such as hydraulic institute pump standard, and with the design, storage, maintenance, testing as outlined in the NEI 12-06, Rev 0 Section 11.0. The SFP spray pump and SFP makeup pump will be not designed as Seismic Category I, but will be stored in structures which are designed to satisfy GDC 2 to ensure meeting functional requirements for external environments such as seismic, flooding, wind, etc. for the specific site. The installed non-safety related in-line valves for the SFP external makeup water system are designed as Quality Group D and seismic Category I requirements. Since these are in-line valves, there is no specific regulating performance requirement for these components. The applicable codes and standards for valves are ASME B31.1 and B16.34.

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6.2.3.2 Design Basis

The FLEX pump is designed to meet the requirements of 10 CFR 50, Appendix A, GDC 2, and is therefore classified as a “robust design.” The FLEX pump and the piping associated with this design are also classified as “robust design.” All equipment is commercial grade.

The SFP diverse makeup and spray lines are 15.24 cm (6 in) and 10.16 cm (4 in) pipes, respectively, to accommodate the 1,893 L/min (500 gpm) of makeup flow and 757 L/min (200 gpm) of spray flow. Since a flow rate of 493.28 L/min (130.31 gpm), approximately, is required to restore SFP inventory during SFP boiling (see Subsection 5.1.2.4), pipe sizes for the SFP makeup and spray lines are sufficient to provide the necessary flow rate during BDBEE.

These seismically qualified SFP makeup and SFP spray lines are connected to an onsite source of water, namely, the RWT. ~~These enhanced design features enable the plant to cope for up to 6.4 days (in consideration of ECSBS actuation at the same time) without offsite resources.~~

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RAI 393-8432 Q.19.03-13 Rev.2

Table 6-3 (1 of 2)

List of On-Site FLEX Equipment for BDBEE

Item No	Description	Quantity	Interface Design Parameters (Note)	Functional Requirements	Reference
1	Primary side high-head FLEX pump	Two (2)	• Diesel driven • Flowrate: 189.25 L/min (50 gpm) • Operating Pressure: 105.46 kg/cm^2A (1,500 psia) • Water Source: IRWST	Supply makeup water to RCS when ACP is not available.	DCD Tier 2 Subsection 19.3.2.3.1.1 TeR Sections 5.1.2.3.1.2.2 & 6.2.2.2
2	Primary side low-head FLEX pump	Two (2)	• Diesel driven • Flowrate: 2,839 L/min (750 gpm) • TDH: 160 m (525 ft) • ~~Water Source: RWT~~ Available borated water source (COL 19.3(17))	Supply makeup water to RCS during Phase 2 when SGs are not available.	DCD Tier 2 Subsection 19.3.2.3.1.~~2~~ 3 TeR Sections 5.1.2.3.3.2 & 6.2.2.2
3	Secondary side FLEX pump	Three (3)	• Diesel driven • Flowrate: [illegible] • TDH: 160 m (525 ft) • Water Source: AFWST and RWT	Supply cooling water to SGs [illegible] TDAFWP is not available.	DCD Tier 2 Subsection 19.3.2.3.1.1 TeR Sections 5.1.2.3.1.2.2 & 6.2.5.2
4	SFP Makeup FLEX pump	One (1)	• Diesel driven • Flowrate: 1,893 L/min (500 gpm) • Discharge Pressure: 32 m (105 ft) • Water Source: RWT	Supply makeup water to SFP.	DCD Tier 2 Subsection 19.3.2.3.2 TeR Sections 5.1.2.4.1.2 & 6.2.3.2
5	SFP Spray FLEX pump	One (1)	• Diesel driven • Flowrate: 757 L/min (200 gpm) • Discharge Pressure: 32.6 m (107 ft) • Water Source: RWT	Supply makeup water to SFP.	DCD Tier 2 Subsection 19.3.2.3.2 TeR Sections 5.1.2.4.1.2 & 6.2.3.2

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Table 6-3 (2 of 2)

Item No	Description	Quantity	Interface Design Parameters (Note)	Functional Requirements	Reference
6	ECSBS FLEX Pump	One (1)	• Diesel driven • Flowrate: 2,839 L/min (750 gpm) • Discharge Pressure: 200 m (656 ft) • Water Source: RWT	Supply water to containment atmosphere to prevent containment overpressurization during low mode operation.	DCD Tier 2 Subsection 19.3.2.3.3 TeR Sections 5.1.2.5
7	480 V mobile GTG	Two (2)	• 1000 kW each	Supply power to 480 V load center, motor control center, and 125 Vdc battery charger via 480 V Class 1E power system Train A or B during Phase 2.	DCD Tier 2 Subsection 19.3.2.3.1.1 TeR Sections 5.1.2.6.1.1, 6.2.6, and Table 5-5

(Note) The COL applicant is responsible for determining the final FLEX pump design head considering site conditions.

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APPENDIX.A Supporting Analysis Results for the Operational Strategy for Core Cooling

A.1 Introduction

This appendix provides the supporting analyses and their results for the APR1400 core cooling capability to cope with the BDBEE, ELAP concurrent with LUHS. Specifically, the coping capability is evaluated according to the FLEX strategies described in the Subsection 5.1.2.3, for the following operation modes:

- Full-power operation
- Low-power operations and shutdown conditions with SGs available
- ~~Shutdown conditions with SGs not available~~

~~Among the above operation modes, the full-power operation is selected as a representative case for the analysis of 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 the mode 5 and 6 operation with SGs not available. In the full-power operation case, the RCP seal leakage is assumed to be 94.64 L/min (25 gpm) / RCP.~~

A.2 Computer Code

A best-estimate computer code, named RELAP5/Mod 3.3, is used for the supporting analyses for the APR1400 operational strategy for core cooling. The RELAP5 code was approved by the NRC and has been widely used for the safety analysis of nuclear power plants of all over the world. The RELAP5 code is based on a non-equilibrium separated two-phase flow model and has other additional models to properly describe the thermal-hydraulic behavior of components of reactor systems including heat conduction in the core and reactor coolant system, reactor kinetics, control systems and trips.

A.3 Acceptance Criteria

The following acceptance criteria based on NEI 12-06, Section 3.2.1 are applied to the supporting analysis for the operational strategy for core cooling during the ELAP concurrent with LUHS.

- Core cooling is maintained
- No fuel failures

The fulfillment of these criteria is determined by evaluating RCS key parameters such as RCS and SG pressures, RCS temperature, collapsed levels in reactor vessel, core, and SG.

A.4 Analysis Condition and Assumption

The following analysis conditions and assumptions are selected according to the requirements of NEI 12-06, Section 3.2.1.

A.4.1 Power Operation and Shutdown Operations with SGs Available

- The full-power operation is selected as a representative case for setting up the APR1400 FLEX strategy of the modes 1 through 4 and mode 5 operation with SGs available.
- The plant is assumed to operate at 100 percent power with no uncertainty for system parameters.

The initiating event is assumed to be an ELAP concurrent with LUHS.

- The reactor is assumed to be tripped automatically by the low reactor coolant pump speed trip of the RPS since the RCPs could not be provided with ac power.
- The MSSVs are assumed to actuate automatically when the SG pressure exceeds the MSSV setpoints.
- RCP seal leakage is assumed to be 94.64 L/min (25 gpm) per RCP at the initial RCS pressure of 158.19 kg/cm^{2}A (2,250 psia) and naturally reduce as the RCS pressure decreases during the event. This causes loss of RCS inventory, which should be adequately maintained for preventing core uncovery leading to core failure.
- The TDAFWPs are assumed to start automatically on receipt of AFAS signal.
- The decay heat conditions of ANSI/ANS-5.1-1979 are used for best-estimate simulation of the FLEX strategy.
- Operator is assumed to cool down the RCS by controlling MSADVs with a rate of 27.78 °C/hour (50 °F/hour) from 8 hours following the BDBEE.
- The auxiliary charging pump (ACP) is assumed to supply borated water at the constant value of 166.56 L/min (44 gpm) for RCS makeup after 8 hours following the event. If ACP is unavailable, a primary high-head FLEX pump is used for providing adequate water to maintain RCS inventory.
- Four safety injection tanks (SITs) inject 4,000 ppm borated water into the RCS when the RCS pressure decreases below the setpoints as designed.
- Normal feedwater flow to SGs is assumed to stop at the initiation of the BDBEE. Auxiliary feedwater flow supplies water to SGs and is controlled to maintain SG level within the control band of 25 percent to 40 percent.

A.4.2 Shutdown Operations with SGs not Available

The following are the analysis conditions and assumptions of the FLEX strategy for shutdown conditions with SGs not available:

- Mid-loop operation is selected as a representative case for the mode 5 and 6 operation with SGs not available.
- The plant is assumed to be in mid-loop operation with the decay heat level of 3.5 days after reactor trip. The initiating event is assumed to be an ELAP concurrent with LUHS.
- The decay heat conditions of ANSI/ANS-5.1-1979 are selected for best-estimate simulation of this FLEX strategy.
- Operator is assumed to open first and second SIT isolation valves for gravity feed to the RCS at 1 hour and 2.5 hours, respectively.
- The other two SITs are assumed to be in maintenance.

A.5 Analysis Results

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kept at the SCS entry pressure of 31.64 kg/cm^{2}A (450 psia). The initial R 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^{2}A (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^{2}A (65 psia) and 5.27 kg/cm^{2}A (75 psia) [RAI 393-8432 - Question 19.03-13, Rev.0]

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 mid-loop operation. Each figure contains the two cases, loss of shutdown cooling system (LOSCS) and LOSCS with SIT operation, to evaluate the benefit of the gravity feed operation by SITs. In this analysis, it is assumed that SG nozzle dams are installed while the pressurizer manway is open. All the steam generated in the core is released through the pressurize manway. SIT injection is carried out in such a strategic way that the core is kept uncovered and the injected water is not spilled over.

Figure A-26 shows the liquid fractions of the core top and upper plenum below the top of the fuel alignment plate. The liquid of the upper plenum is saturated at about 450 sec. The liquid fraction in the upper plenum and core top drops to zero at around 100 minutes without gravity feed from the SIT. However, if the operator opens consecutively the discharge valves from the first SIT in around 1 hour and the second one in 2.5 hours, the time of core uncovery is extended to around 4 hours. The collapsed liquid levels of the core and downcomer in Figure A-27 also show the same trend as the liquid fraction in the upper plenum and core top. The saw-toothed wave that appeared after 1 hour reflects the consecutive water discharge from the first and second SITs. As a result, the time to core uncovery is extensively increased from 100 minutes to 4 hours by using two SITs for gravity feed. The fuel cladding temperature at the core top shown in Figure A-28 indicates that this temperature starts to increase rapidly at around 10 minutes after core uncovery. Based on the analysis results, it is concluded that the preparation for Phase 2 in the FLEX strategy for this operation should be finished within 3 hours after the event in order to have enough time margin before core uncovery. Therefore, the period of Phase 1 for this reduced inventory operation mode is determined to be 0 to 3 hours, while the end time of Phase 2 is still 72 hours, which is the same as in the other operational modes.

During Phase 1, the operator should prepare for Phase 2 by connecting the primary side low-head FLEX pump to the RCS and or the 480 kV mobile GTG to the 1E ac power system. Then, the RCS feed-and-bleed operation can be continued for Phase 2.

During the feed-and-bleed operation of Phase 2, 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.

Since the decay heat level during shutdown operations is much lower than that right after reactor shutdown, the required volume of water for removing decay heat is far less than that required for full-power case. In addition, since the suction of the primary side low-head FLEX pump is RWTs and the volume of each tank can fully cover the Phase 2 of full-power case, the water source for feeding the RCS is sufficient for Phase 2 operation of this reduced inventory operation mode.

In Phase 3, the primary side feedwater sources and fuel oil for the mobile GTGs are refilled from offsite resources. The details for the offsite resources will be developed by the COL applicant.

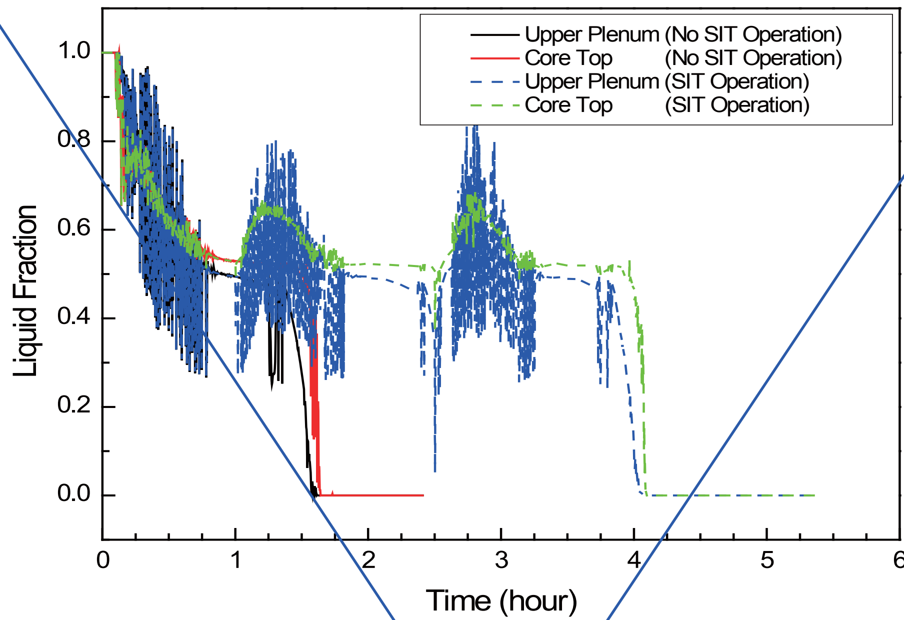

Figure A-26 Liquid Fractions of Upper Plenum and Core Top

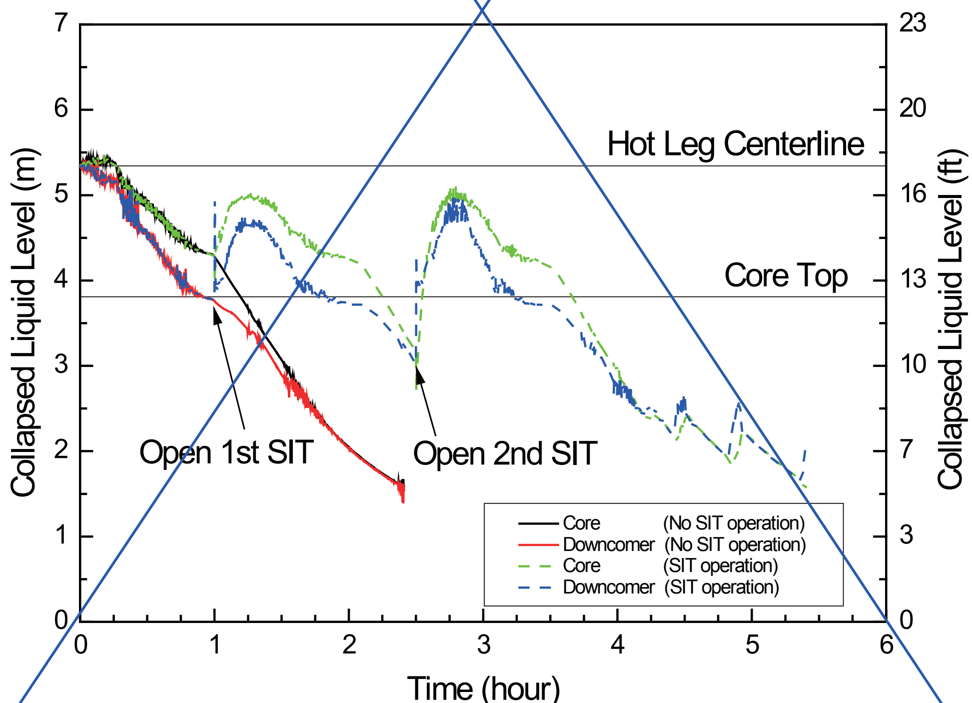

Figure A-27 Collapsed Downcomer and Core Level

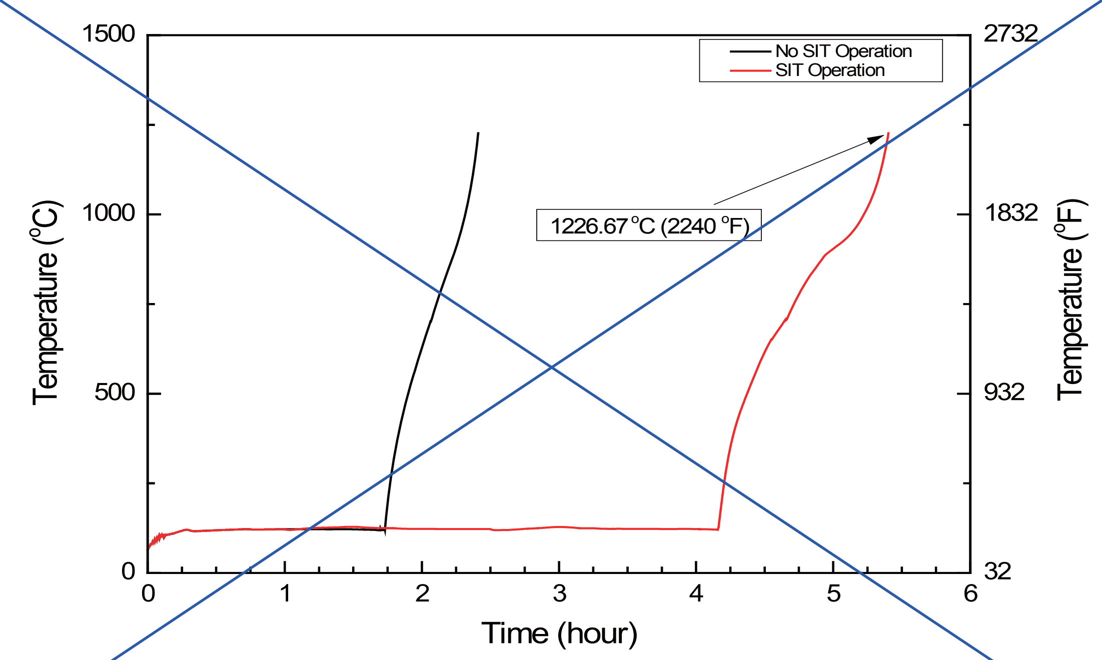

Figure A-28 Hot Rod Fuel Cladding Temperature at Core Top

(Note 1) RAI 393-8432 Q.19.03-13 Rev.1

Table B-3 Required Makeup Volume and Water Source

Parameter \ MODE		Mode 1~6 (with no full core offload)	Mode 6 (with no full core offload)
Water source Total volume, m^3 (gal)		RWT 9,993.49 (2,640,000)	RWT 9,993.49 (2,640,000)
Available volume for SFP makeup, m^3 (gal)		~~Mode 1 to 4(Note 1):~~ 2,793 (737,851); ~~Mode 5 and 6(Note 2):~~ ~~1,124 (296,800)~~	9,993.49 (2,640,000)
Makeup during 72 hours	Time for makeup (72 hours minus time to 3.05 m [10 ft] above fuel top), (hours)	8.32	46.97
	Required makeup volume, m^3 (gal)	101.46 (26,827)	1,390 (367,214)
Makeup during 12 days (288 hours)	Time for makeup (12 days minus time to 3.05 m [10 ft] above fuel top), (hours)	224.32	262.97
	Required makeup volume, m^3 (gal)	2,739(723,538)	7,783(2,056,041)
Total ~~copying~~ coping Time		~~Modes 1 to 4:~~ 12.2 days ~~Modes 5 and 6: 6.4 days~~	~~Mode 6:~~ 15.1 days

(Note 1): RWT can be used as the water source for NCC operation through TDAFWP and SFP makeup during modes 1 through 5 operation with SGs available. However, COL applicants are responsible to determine the available volume for SFP makeup and coping time during modes 5 and 6 with SGs unavailable.

~~(Note 2): RWT can be used as the water source for RCS makeup through primary low-head FLEX pump, SFP makeup, and ECSBS operation.~~