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.:	**401-8402**
SRP Section:	**19.03 – Beyond Design Basis External Event (APR1400)**
Application Section:	
Date of RAI Issue:	**02/08/2016**

Question No. 19.03-16

NRC Commission paper SECY-12-0025 (February 17, 2012), “Proposed Orders and Requests for Information in Response to Lessons Learned from Japan’s March 11, 2011, Great Tohoku Earthquake and Tsunami,” stated that the NRC staff expected new reactor design certification or license applications (e.g., construction permit, operating license, and combined license) not yet then-submitted to address the Commission-approved Fukushima actions in their applications, prior to submittal, to the fullest extent practicable. In SECY-12-0025, the NRC staff outlined a three-phase approach regarding mitigation strategies to respond to beyond-designbasis external events (BDBEEs). The initial phase involved the use of installed equipment and resources to maintain or restore core cooling, containment, and spent fuel pool (SFP) cooling without alternating current power. The transition phase involved 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 involved obtaining sufficient offsite resources to sustain those functions indefinitely.

The NRC staff provided guidance for satisfying the Commission directives regarding BDBEE mitigation strategies in Japan Lesson-Learned Project Directorate (JLD)-ISG-2012-01, Revision 0, “Compliance with Order EA-12-049, Order Modifying Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events,” (ADAMS Accession No. ML12229A174). JLD-ISG-2012-01 endorsed with clarification the methodologies described in the industry guidance document Nuclear Energy Institute (NEI) 12–06, Revision 0, “Diverse and Flexible Coping Strategies (FLEX) Implementation Guide,” (ADAMS Accession No. ML12242A378). The guidance in JLD-ISG-2012-01 describes one acceptable approach for satisfying the Commission directives regarding BDBEE mitigation strategies.

APR1400 DCD, Tier 2, Section 19.3.2.3.3 describes use of the ultimate pressure capacity (UPC) as the acceptance criterion for assessing the APR1400 containment capabilities when steam generators (SG’s) are not available (mid-loop operation). The staff requests that the applicant provide justification that the selected acceptance criterion (i.e., UPC value of 184 psia) is appropriate to ensure containment capabilities during a beyond-design-basis external event. As part of the response,

1. Discuss how the selected acceptance criterion (i.e., UPC) accounts for uncertainty and margin to ensure containment capabilities.

2. Discuss the reasoning for selecting the design basis UPC limit provided in DCD Tier 2, Chapter 3.8, “Design of Category I Structures,” versus the UPC limits expressed in DCD Tier 2, Sections 19.1, “Probabilistic Risk Assessment,” or 19.2, “Severe Accident.”

3. Discuss how the containment UPC limit (12.9 kg/cm^2 or 184 psia) is determined and describe temperature assumptions associated with this determination.

4. Evaluate if the predicted temperature in containment (185 ºC or 365 ºF) is bounded by the temperature at which the UPC limit (12.9 kg/cm^2 or 184 psia) was determined.

5. Provide the basis for why the containment temperature criterion of 185 ºC (365 ºF) (temperature associated with maintaining containment at the UPC limit) isacceptable to ensure containment capabilities are maintained.

6. Provide justification that the instrumentation (e.g., pressure, temperature, level) credited with assisting the operators to maintain containment capabilities are qualified to function and provide reliable indication to the operator when exposed to these acceptance criteria. In addition, the staff requests that the applicant document the alarms, indications, and associated instrumentation that will direct the operator to initiate the emergency containment spray backup system (ECSBS).

7. Discuss how the uncertainty in the containment pressure displayed to the operator is considered in the analysis that provides the basis for operator actions to run the ECSBS in order to prevent the UPC limit from being exceeded.

8. Address if the containment configuration during lower modes could result in a lower or adjusted UPC when compared with power operation (Mode 1). If a lower or adjusted UPC is appropriate, discuss the impact on the mitigation strategy.

9. Given that EA 12-049 states, “Licensees or CP holders must provide reasonable protection for the associated equipment from external events,” the staff requests that the applicant justify plans to operate the ECSBS intermittently upon reaching the UPC limit, and not well before the UPC limit, to maintain the containment function.

Response

The UPC value has been changed from 184 psia (12.9 kg/cm^{2}A) to 158 psig (11.1 kg/cm^2) as addressed in the response for RAI 129-8085 Question 03.08.01-5.

The UPC value, which was used as the pressure limit for actuating the ECSBS at a beyond design basis external event (BDBEE) when steam generators are not available (mid-loop operation), does not include any margins relative to the uncertainties associated with the instrumentation or human errors. Further, the UPC value was originally chosen as the containment pressure limit in the analysis for the purpose of estimating the maximum allowable time for initial actuation of the ECSBS.

KHNP concluded that using the acceptance criterion, the UPC limit, as a setpoint for the ECSBS actuation is not appropriate for ensuring the containment structural integrity at a BDBEE that may causes containment pressurization. Also, the containment cooling through the ECSBS needs to be restricted to the cases that lead to the containment pressurization exceeding the design pressure based on the design-basis accident (DBA) among all containment pressurization cases following a BDBEE, since some cases that do not increase the containment pressure or those that increase the pressure but very slow such as the RCP Seal LOCA may not require the containment cooling due to having a sufficient time for plant recovery in low pressurized containment condition.

From the analysis to determine the appropriate containment pressure and initiation time for actuating the ECSBS, it is estimated that the spray actuation after 24 hours from reaching the containment design pressure maintains the containment highest pressure less than the UPC limit with a sufficient margin. The containment design pressure of 60 psig (4.2 kg/cm^2), which is determined as the allowable pressure limit to the DBA, is described in DCD Section 6.2.1.1.

In the previous scheme of the ECSBS, spraying is intermittent within the range up to the UPC limit, however with the new scheme, the ECSBS operates continuously. Logically, the continuous spray is more effective compared to the intermittent spray operation since the continuous spray will constantly maintain the containment atmosphere at a lower pressure, and thereby is clearly preferable in view of the operational safety of the ECSBS that requires manual operation in such a high containment pressure.

Thus, based on the analyses, the trigger for actuating the ECSBS will be changed to the time duration (24 hours after reaching the containment pressure of 54 psig) from the previous pressure limit, the UPC. In addition, the ECSBS will be operated to continuously spray external water supplied from the raw water tank (RWT) available in the phase 2. The RWT is designed to have a capacity (2,600,000 gal) capable enough of providing water for the containment cooling (1,080,000 gal) as well as for the core and the spent fuel pool cooling (750,000 gal).

Figure 1 and Figure 2 show the pressure and temperature transients of the case that uses the time duration of 24 hours after reaching the containment pressure of 54 psig (3.8 kg/cm^2) for the spray initiation in comparison to the case that uses the UPC value as the pressure limit.

As shown in Figure 1, the containment pressure rises up to 103.7psig (7.3 kg/cm^2) at 50 hours until the spraying begins. With the new scheme, the predicted highest pressure remains far less than the UPC limit, and which is even below the Factored Load Category (FLC) of 108 psig (7.6 kg/cm^2). Referring to figure 2, the containment temperature increases up to 326 $^\circ$F (163 $^\circ$C), however it is still bounded by the environmental qualification temperature of 360 $^\circ$F (182 $^\circ$C) for all of the safety related equipment within containment.

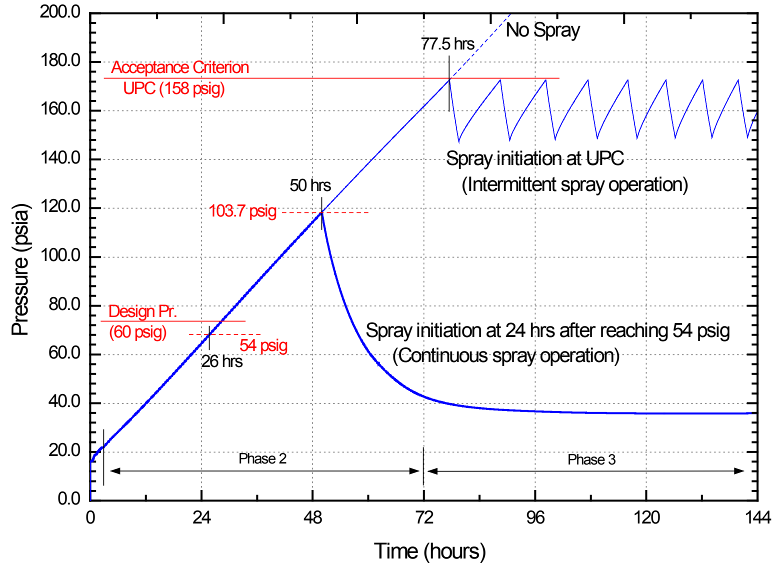

Figure 1. Pressure transients (loss of RHR at mid-loop operation)

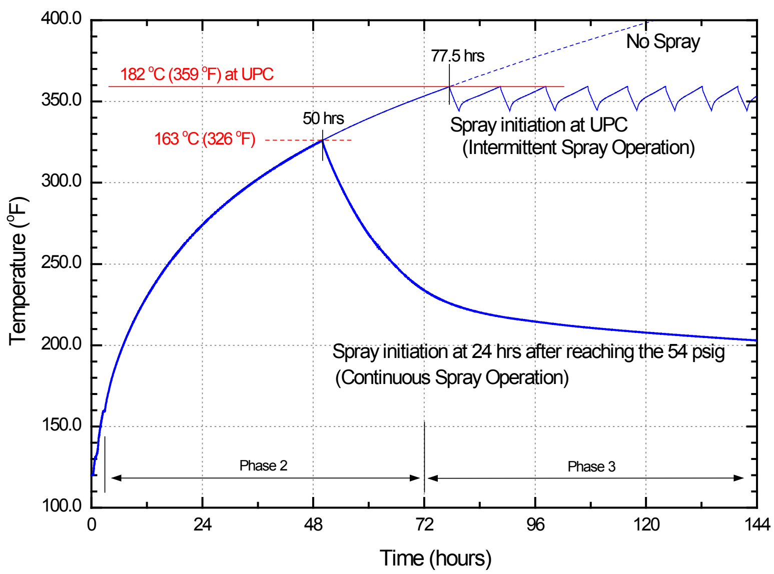

Figure 2. Temperature transients (loss of RHR at mid-loop operation)'

1. The APR1400 selects the UPC value as the acceptance criterion for ensuring the containment integrity to a BDBEE and no uncertainties and margins are taken into consideration for the acceptance criterion.

From the pressure transient of the improved ECSBS operation method (continuous spray after 24 hours from reaching containment design pressure), as shown in Figure 1, the predicted highest containment pressure (103.7 psig or 7.3 kg/cm^2) is far less than the UPC limit (158 psig or 11.1 kg/cm^2), which provides a margin enough not to need consideration of uncertainties associated with the instrumentation and human errors.

2. The UPC value described in DCD Tier 2 Section 19.3, which is chosen as the containment's acceptance criterion to a BDBEE, comes from the value provided in DCD Tier 2 Section 3.8 since the UPC is the maximum pressure capacity that is deterministically estimated for containment structural integrity including concrete, tendon and liner plate. The containment's UPC is the pressure value at the maximum strain of the liner plate, approximately 0.4 percent, in accordance with RG 1.216.

3. As described above, the ECSBS begins to spray at 24 hours after reaching the containment pressure of 54 psig (3.8 kg/cm^2), instead of using the UPC limit for the ECSBS actuation. The improved ECSBS operation maintains the containment pressure below the UPC limit with margin.

   The temperature assumptions associated with analysis are as described below;

   - The discharge flow from the RCS leakage is instantly mixed into the containment atmosphere and reaches in 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.

4. As shown in Figure 2, the predicted highest containment temperature at the time of spray initiation is estimated to 326 °F (163 °C), and which is less than the saturation temperature of 359 °F (181.7 °C) corresponding to the UPC limit.

5. Besides the pressure limit to protect the containment structures, the instrumentation for core monitoring needs to be additionally ensured in such a high coolant temperature following the containment pressurization.

   All the instruments relative to core monitoring including the CET sensors and cables are qualified for temperatures above 360 °F (182 °C) which is the maximum temperature for environmental qualification (EQ) of the safety related equipment within the RCS as well as the containment. The EQ temperature is sufficiently high compared to the predicted highest temperature of 326 °F (163 °C), consequently ensuring normal operation of all instruments for core monitoring.

6. The operator's pressure measurement for the ECSBS actuation is required only during the time that the containment pressure remains below the containment design pressure of 60 psig (4.22 kg/cm^2) and no instrumentation is credited thereafter.

   In the improved ECSBS operation, the pressure instruments for the CSS actuation at the design basis accident (DBA) are used to actuate the ECSBS at a BDBEE. The pressure measurement is accomplished by the operator through the containment pressure monitoring panel in the main control room (MCR) and completed prior to reaching the pressure of 54 psig (3.8 kg/cm^2).

In the APR1400, a total of four (4) pressure instruments are equipped in the containment building to actuate the containment spray system (CSS) against containment pressurization following the DBA and all of these instruments are qualified to function within the containment design pressure and temperature based on the environmental qualification (EQ) of safety related equipment. The pressure instruments (containment pressure protective WR transmitter, CM-PT-352A through CM-PT-352D) are included in the Table 3.11-3 of the DCD Tier 2 that lists the EQ equipment within the containment.

7. The containment pressure of 54 psig (3.8 kg/cm^2) is the value determined from consideration of 10 percent of negative margin on the containment design pressure of 60 psig (4.2 kg/cm^2) for the DBA. The negative pressure margin of 10 percent, which is considered in the analysis, provides the operator with a time duration of 3 hours prior to reaching the containment design pressure of 60 psig, consequently decreasing the peak pressure far less than the UPC limit.

8. The improved ECSBS operation that sprays at 24 hours after reaching the pressure of 54 psig (3.8 kg/cm^2) is commonly applied to all containment pressurization accidents concurrent with a BDBEE, without regard to the plant operation modes. There are no differences on the mitigation strategy for containment integrity to all containment pressurization accidents following a BDBEE.

9. The ECSBS will be operated in the manner of continuous spray with the external water supplied from the RWT. The continuous spray is accomplished through the continuous FLEX pump operation providing a constant flow rate of 750 gpm (2,893 L/min).

   The improved ECSBS operation is simple and does not need a specific operating procedure that may be required for the intermittent spray operation relying on the repetitive pressure measurements by operators. Further, the maximum containment pressure at the improved ECSBS operation remains well below the acceptance criterion, the UPC limit.

Impact on DCD

DCD Tier 2, Section 19.3 will be revised, as indicated in Attachment 1.

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 Report

Technical Report “Evaluations and Design Enhancements to Incorporate Lessons Learned from Fukushima Dai-Ichi Nuclear Accident” APR1400-E-P-NR-14005-P/NP will be revised as indicated in the Attachment 2.

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.

Table 19.3-2 provides the specific details and summary of the various functions, mitigating strategies and capabilities to address: (1) core cooling, (2) SFP cooling and (3) containment integrity.

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.

Containment Function 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)

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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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The emergency containment spray backup system (ECSBS) is considered as a means necessary for the APR1400 to ensure the containment structural integrity from a BDBEE with simultaneous loss of all AC power and LUHS that may be followed by containment pressurization. The following acceptance criterion is applied for ensuring containment structural integrity during a BDBEE:

Containment pressure is maintained below the UPC limit at a BDBEE.

Containment pressure and temperature at a BDBEE are analyzed using the GOTHIC (Generation of Thermal-Hydraulic Information for Containments) computer code. In the supporting analyses to demonstrate the containment capability (Containment structural integrity), the RCP seal failure at full-power operation and loss of RHR at the mid-loop operation are chosen as two limiting accidents following a BDBEE that cause containment pressurization.

During the RCP seal failure following the 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 reaches the pressure of 4.0 kg/cm2 (57 psig) in about 15 days of the accident, then rapidly decreases and remains at low pressure condition due to the ECSBS operation. It is noted that the containment pressure is maintained well below the UPC limit at the RCP seal leakage following a BDBEE.

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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

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Loss of RHR at the mid-loop operation is additionally chosen as a representative limiting case among the accidents that may be postulated at Mode 5 and 6 with SGs not available. During the accident, steam is assumed to be continually released from the RCS to the containment through the pressurizer manway due to the boiling of reactor coolant following the loss of the RHR.

The containment pressure increases consistently from the beginning of the event and the ECSBS begins to spray at 24 hours after reaching the containment pressure of 3.8 kg/cm2 (54 psig). The ECSBS is operated in the manner of continuous spray with the RWT water supplied via a FLEX pump available in the phase 2. The FLEX pump provides the ECSBS with the flow rate of 2,839 L/min (750 gpm).

The containment pressure increases up to 7.3 kg/cm2 (103.7 psig) at 50 hours of the accident, however the predicted highest pressure remains far less than the UPC limit of 11.1 kg/cm2 (158 psig). The containment temperature reaches the highest temperature of 163 oC (326 oF), but which is also below the temperature limit of 182 oC (360 oF) for the environmental qualification of the safety related equipment within the containment.

From the analyses, it is noted that the containment integrity is ensured to all pressurization accidents following the BDBEE at the shutdown conditions as well as the full power operation.

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Figure 5-3 Containment Pressure for Full Power (RCP Seal LOCA)
Figure 5-4 Containment Temperature for Full Power (RCP Seal LOCA)

onsite SG cooling, RCS makeup water, and GTG fuel sources show the duration of Phase 2 can be extended up to 12 days. Hence, the operator has sufficient time margin to prepare for Phase 3.

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

5.1.2.3.1.3 Phase 3: Coping with both Installed and Offsite Resources in Addition to the Onsite Equipment (after 72 hours)

In Phase 3, offsite resources including a 4.16 kV mobile GTG, fuel, and cooling water can be assumed to be available for long-term coping with the BDBEE. The 4.16 kV mobile GTG is used to restore Train A or B of 4.16 kV Class 1E power system. The plant is brought to cold shutdown, using the shutdown cooling system (SCS) if the ultimate heat sink (UHS) is available after 4.16 kV Class 1E power is restored. If not, the plant is maintained at the same safe shutdown state as in Phase 2.

In this case, the primary and secondary makeup water sources and fuel oil for the mobile GTGs are refilled from offsite resources. The details for the offsite resources will be provided by the COL applicant.

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5.1.2.3.2 FLEX Strategy for Low-Power and Shutdown Operation with SGs Available

5.1.2.3.2.1 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 Mode 1 through Mode 3 operations.

5.1.2.3.2.2 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) (20 percent of the RCS hydraulic test pressure of 219.71 kg/cm^{2}A [3,125 psia]), because the LTOP relief valve installed in the SCS automatically opens at the opening setpoint (38.51 kg/cm^{2}A [530 psig]). After the RCS temperature increases to the LTOP disable temperature (136.11 °C [277 °F]), the operator tries to isolate the RCS from the SCS by manually closing the SCS isolation valves. The operator action for the 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 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.

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In this operation mode, the containment pressure increases consistently from the beginning of the event due to the RCP seal leakage. However the pressure is maintained far less than the ultimate pressure capacity (UPC) during more than two weeks even without containment cooling through the ECSBS actuation. Section 5.1.2.5.2.1 provides the containment pressure results to the RCP seal LOCA at full-power operation in detail.

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
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.

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

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~~ 3.6 days even if the water source is shared with ~~SFP~~ the SFP and the containment cooling (see Table B-3 in Appendix B). Hence, the operator has sufficient time margin for preparation of Phase 3.

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In this operation mode, the containment pressure increases consistently from the beginning of the event due to the mass and energy released from the RCS. However it can be maintained below the ultimate pressure capacity (UPC) by operating the emergency containment spray backup system (ECSBS) with the RWT water supplied via a FLEX pump available in the phase 2. Section 5.1.2.5.2.2 provides the containment pressure results to the loss of RHR at shutdown operation in detail.

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.

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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.

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.

Delete

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.

5.1.2.4.1 Strategy for SFP Cooling

Based on the supporting analyses (see Subsection 5.1.2.4.2) to determine the bulk SFP heatup time and boiloff rate, for a worst-case full core offload, these analyses concluded the following:

- Although sloshing may occur during a seismic event, the initial loss of SFP inventory does not preclude access to the refueling deck around the pool.

- SFP cooling system is lost; however, attached piping is intact.

- SFP heat load assumes the maximum design basis heat load as defined in Appendix B.

- Initial SFP water level is assumed at normal water level.

- SFP inventory makeup starts when the water level reaches Level 2 defined in NEI 12-02 (Reference 12).

- Water inventories:

  The water inventory above top of fuel: 1,034.4 m3 (36,529.5 ft3)

  The water inventory below top of fuel: 654.4 m3 (23,110.5 ft3)

  Total SFP inventory: 1,688.8 m3 (59,640 ft3)

5.1.2.4.2.2 Evaluation Results

From the detailed analysis presented in Appendix B, Table B-1, it can be seen that the worst-case SFP cooling load occurs in mode 6 with a full core offload.

5.1.2.4.2.3 Conclusions

Based on the SFP time to boil and makeup analysis provided above and in Appendix B, considering a worst-case full core offload, the conclusions are as follows:

- The operators have approximately 39.3 hours to restore cooling and/or makeup to the SFP in order to keep the spent fuel covered. Therefore, boiling of the SFP can be credited as the Phase 1 event mitigation method.

- To maintain at least 3.05 m (10 ft) of water inventory over the fuel assemblies, makeup to the SFP is provided within 25.03 hours.

- For Phase 2 and 3 event mitigation, an SFP makeup rate of 493.28 L/m (130.31 gpm) is needed to match the initial boiloff rate. The boiloff rate decreases over time as the spent fuel decay heat decreases.

Replace with B1

5.1.2.5 Containment Function

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:

B1

5.1.2.5 Containment Function and Integrity

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.

The emergency containment spray backup system (ECSBS) is considered as a means necessary for the APR1400 to ensure the containment structural integrity from a BDBEE with simultaneous loss of all AC power and LUHS that may be followed by containment pressurization.

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

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

c. Check valve inside containment (automatic isolation)

Replace with C1

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.

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.

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 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.

Replace with C2

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

C1

5.1.2.5.2 Containment Integrity

Containment pressure and temperature at a BDBEE are analyzed using the GOTHIC (Generation of Thermal-Hydraulic Information for Containments) computer code. In the supporting analyses to demonstrate the containment capability (Containment structural integrity), the RCP seal failure at full-power operation and loss of RHR at the mid-loop operation are chosen as two limiting accidents following a BDBEE that cause containment pressurization.

Acceptance Criteria

The following acceptance criterion is applied to the containment analysis for ensuring containment structural integrity during a BDBEE:

Containment pressure is maintained below the UPC limit at a BDBEE.

Analytical Methods

The GOTHIC containment model, which was developed for the containment response calculation to a LOCA and secondary system pipe ruptures described in DCD Tier 2, Section 6.2.1, is used to demonstrate the containment capability to cope with the BDBEE concurrent with loss of all AC power and LUHS. The GOTHIC containment model with analysis methodologies are described in the Technical Report "LOCA Mass and Energy Release Methodology" (Reference 17) in detail.

Key Assumptions

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

a. The ECSBS is assumed to be actuated at 24 hours after reaching the containment pressure of 3.8 kg/cm2 (54 psig) to all containment pressurization accident following a BDBEE.

b. 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.

c. Variance in local temperature within the containment is not assumed since the accident scenario is characterized by slow, but continuous containment pressurization.

C2

5.1.2.5.2.1 Containment Analysis for RCP Seal Failure (Full-Power Operation)

The RCP seal failure following a BDBEE is chosen as a representative accident for the full-power operation with SGs available (Section 5.1.2.3.4.2). During the accident, 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 pressure value of 4.0 kg/cm2 (57 psig) in about 15 days of the accident, then rapidly decreases and maintains low pressure condition due to the continuous ECSBS operation.

It is noted that the containment pressure is maintained well below the UPC limit at the RCP seal leakage following a BDBEE. Figure 5-3 and Figure 5-4 show the containment pressure and temperature transients to the RCP seal leakage, respectively.

5.1.2.5.2.2 Containment Analysis for loss of RHR (Mode 5 Operation)

The APR1400 shutdown operations with SGs not available include the mode 5 reduced inventory operation and the mode 6 refueling operation. The loss of RHR at the mid-loop operation following a BDBEE is chosen as a limiting case among the accidents that may be postulated at Mode 5 and 6 with SGs not available (Section 5.1.2.3.4.3). During the accident, steam is assumed to be continually released from the RCS to the containment through the pressurizer manway due to the boiling of reactor coolant following the loss of the RHR.

The containment pressure increases consistently from the beginning of the event and the containment cooling through the ECSBS begins at the 24 hours after reaching the containment pressure of 3.8 kg/cm2 (54 psig). The ECSBS is operated in the manner of continuous spray with the RWT water supplied via a FLEX pump available in the phase 2. The FLEX pump provides the ECSBS with the flow rate of 2,839 L/min (750 gpm).

The containment pressure increases up to 7.3 kg/cm2 (103.7 psig) at 50 hours of the accident, however the predicted highest pressure remains far less than the UPC limit, and which is also below the Factored Load Category (FLC) of 7.6 kg/cm2 (108 psig). The containment temperature reaches the highest temperature of 163 oC (326 oF), but which is well below the temperature limit of 182 oC (360 oF) for the environmental qualification (EQ) of the safety related equipment within the containment. Figure 5-5 and Figure 5-6 show the containment pressure and temperature results produced from the GOTHIC containment analysis.

From the analysis, it is noted that the containment integrity is ensured to the loss of RHR following a BDBEE at shutdown conditions.

Replace with next two pages, D1, and D2

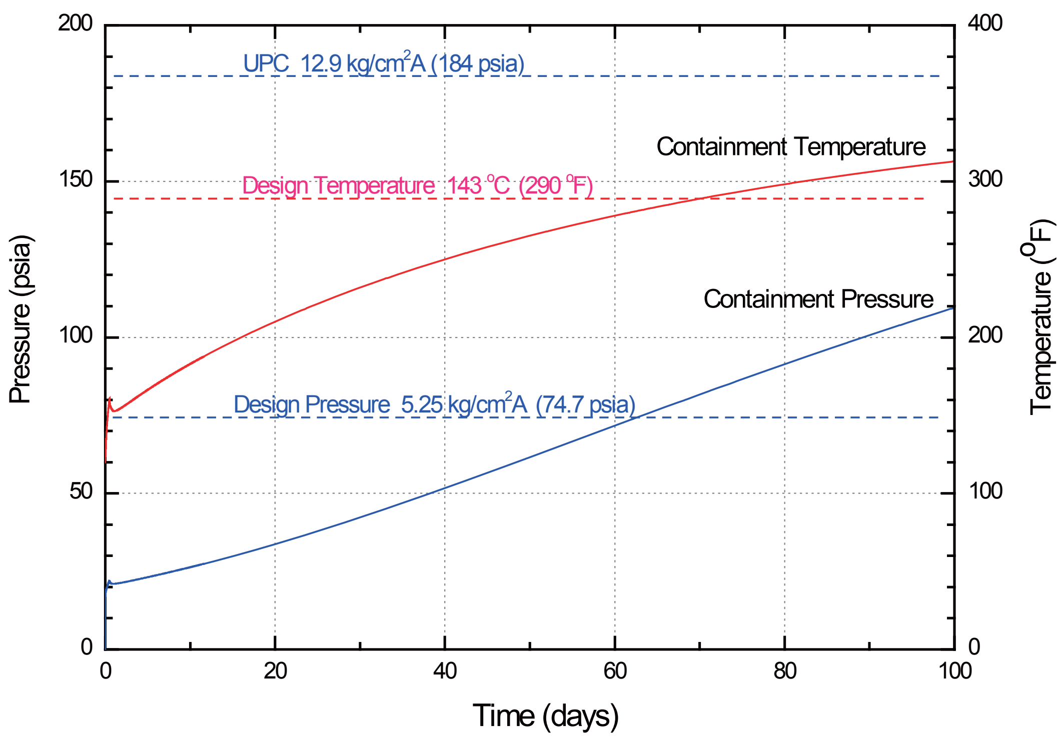

Figure 5-3 Containment Pressure and Temperature for Full Power

D1

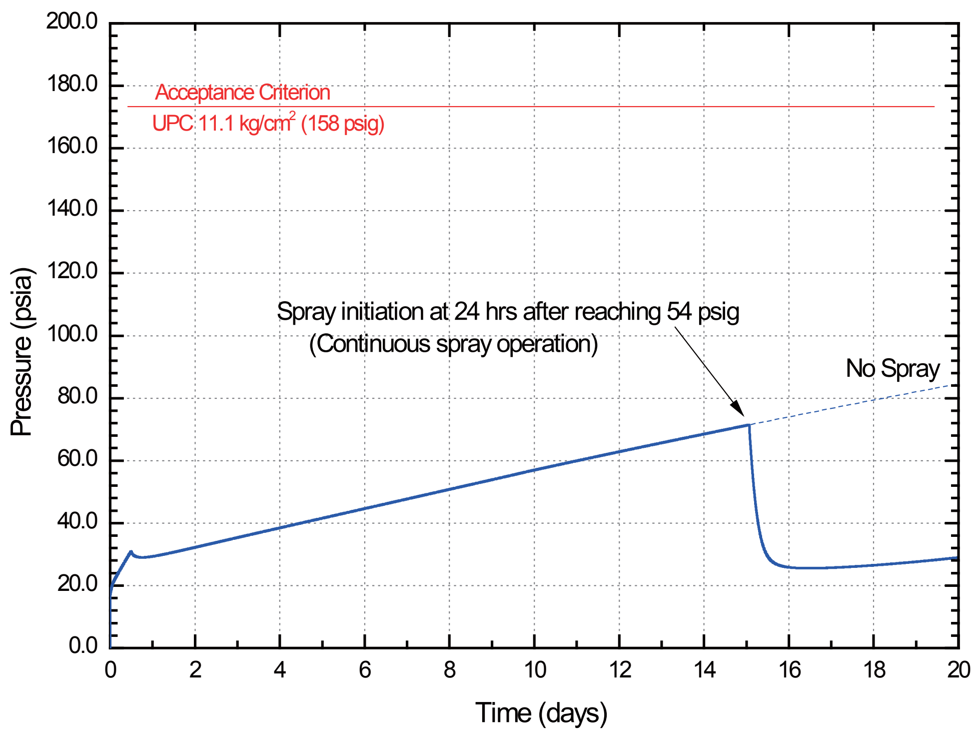

Figure 5-3 Containment Pressure for Full Power (RCP Seal LOCA)

D2

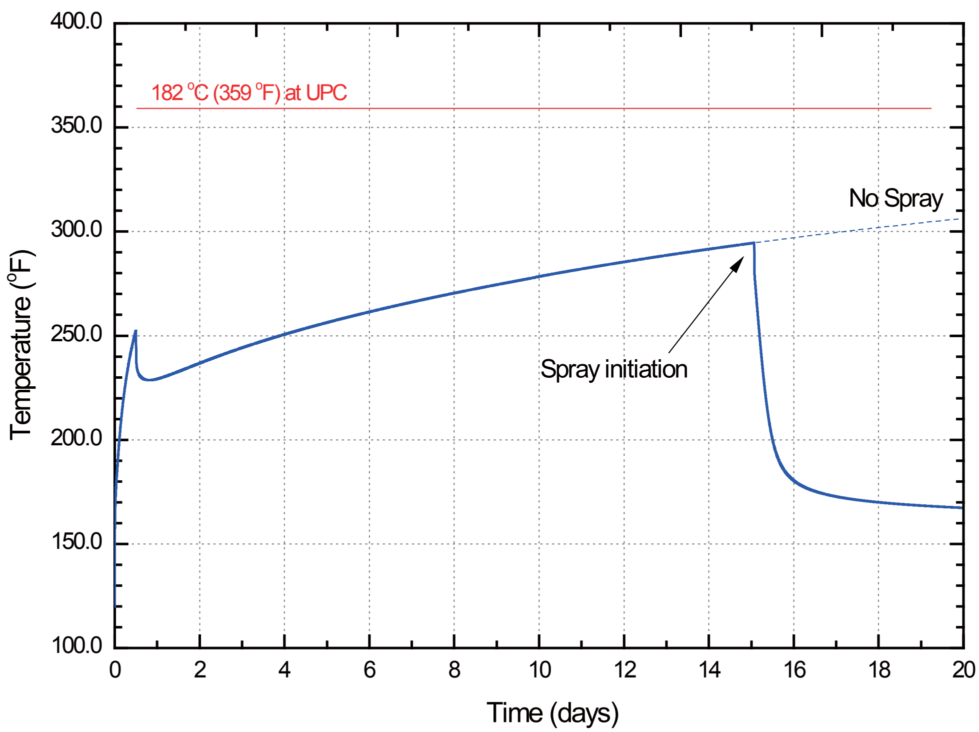

Figure 5-4 Containment Temperature for Full Power (RCP Seal LOCA)

Replace with D3

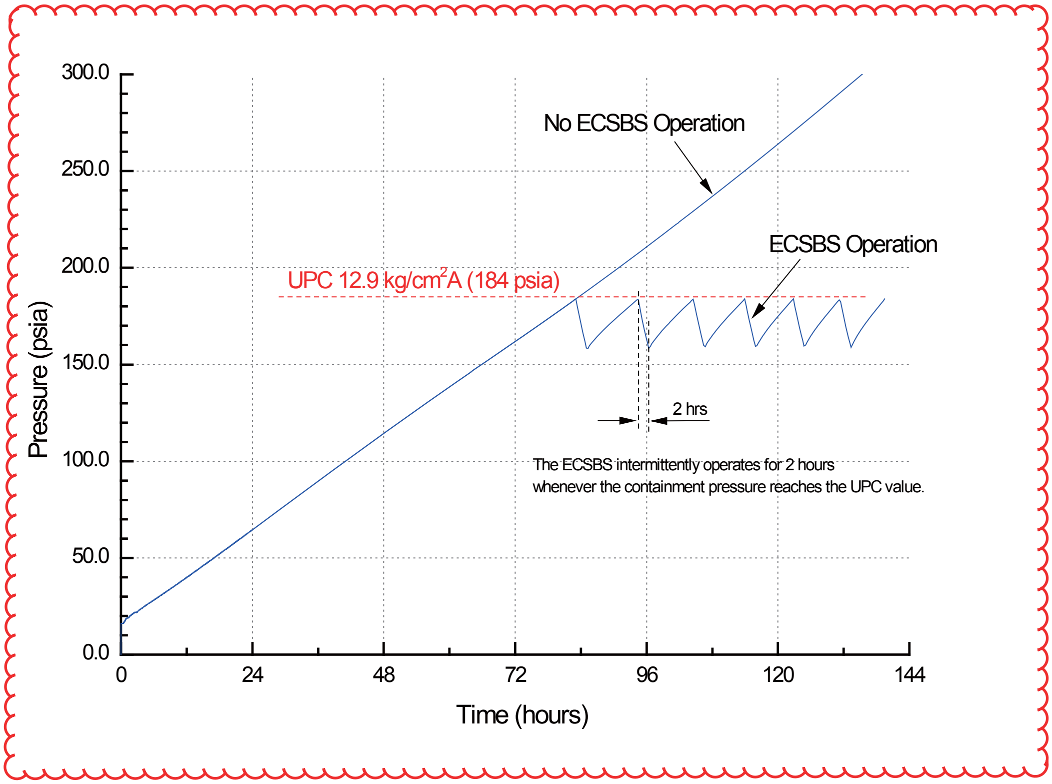

Figure 5-4 Containment Pressure for Loss of RHR (Mode 5)

D3

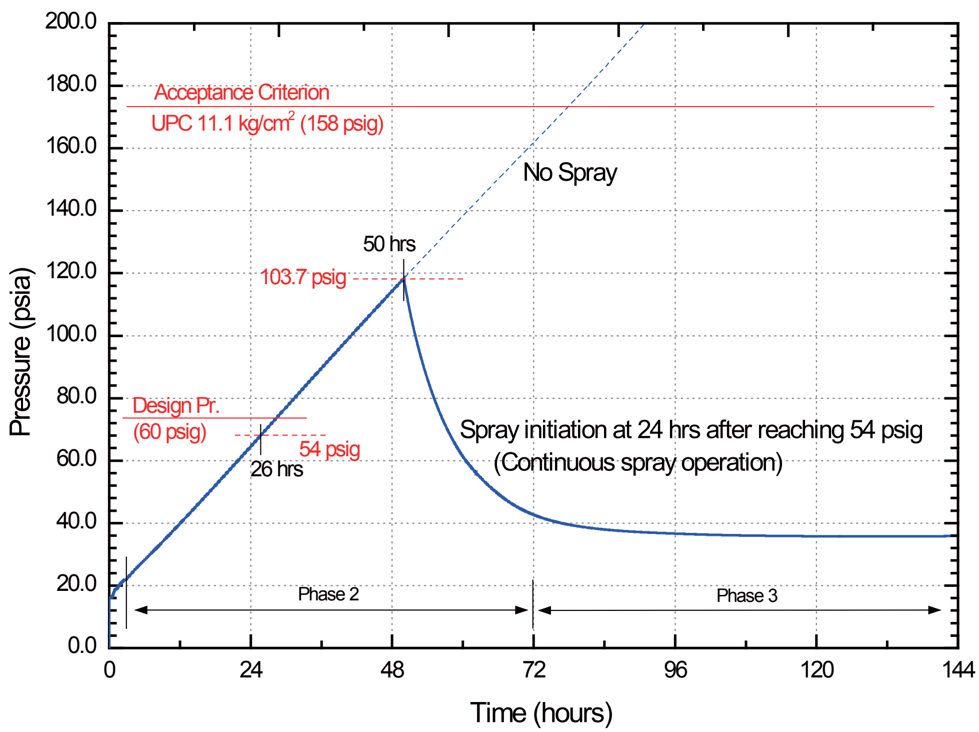

Figure 5-5

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

Replace with D4

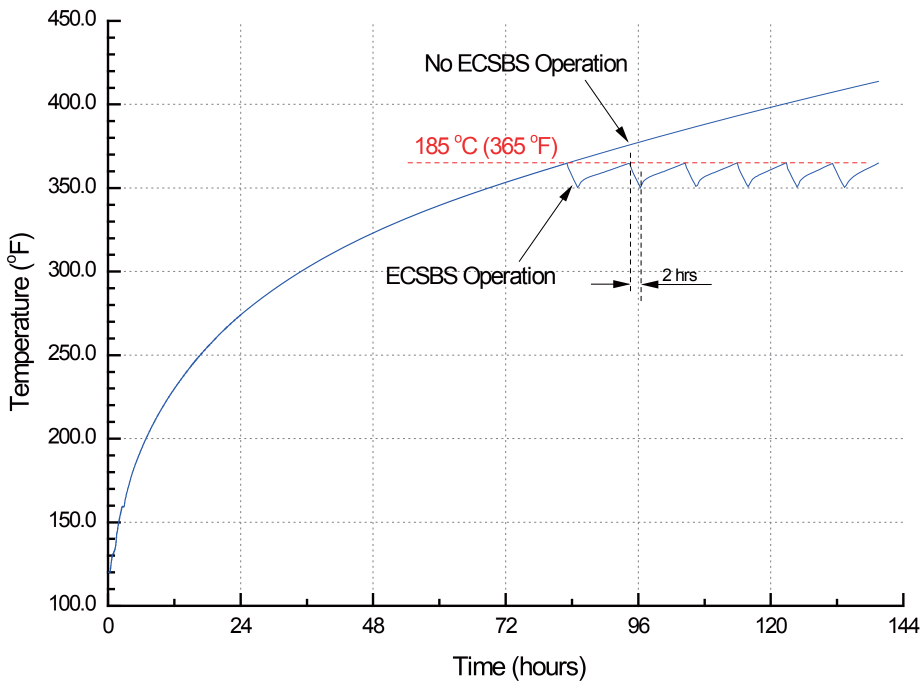

Figure 5-5 Containment Temperature for Loss of RHR (Mode 5)

D4

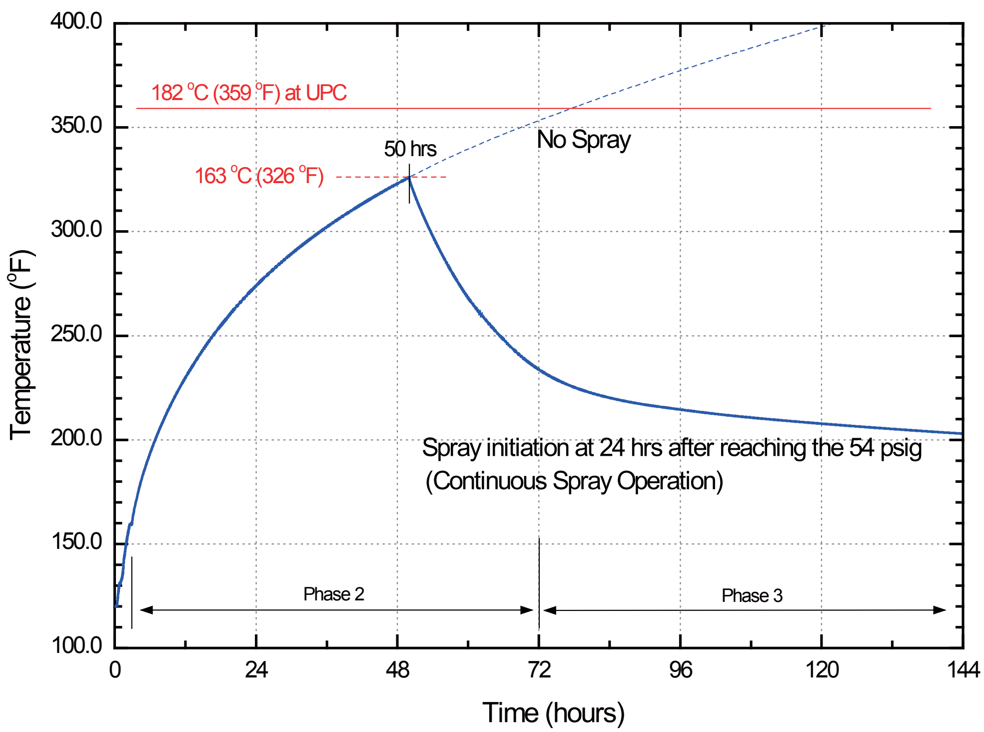

Figure 5-6

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

8.0 REFERENCES

1. SECY-11-0093, “Recommendations for Enhancing Reactor Safety in the 21st Century,” U.S. Nuclear Regulatory Commission, July 2011.

2. SECY-11-0137, “Prioritization of Recommended Actions to be Taken in Response to Fukushima Lessons Learned," U.S. Nuclear Regulatory Commission, October 2011.

3. 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.

4. SECY-12-0095, “Tier 3 Program Plans and 6-Month Status Update in Response to Lessons Learned from Japan’s March 11, 2011, Great Tohoku Earthquake and Subsequent Tsunami,” U.S. Nuclear Regulatory Commission, July 2012.

5. 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.

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

7. JLD-ISG-2012-01 “Compliance with Order EA-12-049, Order Modifying Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events,” Rev. 0, U.S. Nuclear Regulatory Commission, August 29, 2012.

8. NEI 12-06, “Diverse and Flexible Coping Strategies (FLEX) Implementation Guide,” Rev. 0, Nuclear Energy Institute, August 2012.

9. WCAP-17925-P, “Extended Loss of AC Power Capability for APR1400 KSB RCP Seals,” Rev. 0, Westinghouse Electric Company LLC, September 2014.

10. NEI White Paper, “Battery Life Issue,” Nuclear Energy Institute, August 2013.

11. NRC Letter dated September 2013 to NEI endorsing Reference 10 with clarifications.

12. NEI 12-02, “Industry Guidance for Compliance with NRC Order EA-12-051, ‘To Modify Licenses with Regard to Reliable Spent Fuel Pool Instrumentation,” Rev. 1, Nuclear Energy Institute, August 2012.

13. JLD-ISG-2012-03, “Compliance with Order EA-12-051, Reliable Spent Fuel Pool Instrumentation,” Rev. 0, U.S. Nuclear Regulatory Commission, August 2012.

14. IEEE Std 344-2004, “IEEE Recommended Practice for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations,” Institute of Electrical and Electronics Engineers, June 2005.

15. Enclosure 5 to "Request for Information Pursuant to Title 10 of the Code of Federal Regulations 50.54(f) Regarding Recommendations 2.1, 2.3, and 9.3 of the Near-Term Task Force Review of Insights from the Fukushima Dai-Ichi Accident," March 2012.

16. NEI 12-01, “Guideline for Assessing Beyond Design Basis Accident Response Staffing and Communication Capabilities,” Rev. 0, Nuclear Energy Institute, May 2012.

17. APR1400-Z-A-NR-14007-P(Proprietary) & (Non-Proprietary), "LOCA Mass and Energy Release Methodology," Rev. 0, KHNP, November 2014.

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.:	**401-8402**
SRP Section:	**19.03 – Beyond Design Basis External Event (APR1400)**
Application Section:	**19.3 - Fukushima**
Date of RAI Issue:	**02/08/2016**

Question No. 19.03-17

NRC Commission paper SECY-12-0025 (February 17, 2012), “Proposed Orders and Requests for Information in Response to Lessons Learned from Japan’s March 11, 2011, Great Tohoku Earthquake and Tsunami,” stated that the NRC staff expected new reactor design certification or license applications (e.g., construction permit, operating license, and combined license) not yet then-submitted to address the Commission-approved Fukushima actions in their applications, prior to submittal, to the fullest extent practicable. In SECY-12-0025, the NRC staff outlined a three-phase approach regarding mitigation strategies to respond to beyond-design basis external events (BDBEEs). The initial phase involved the use of installed equipment and resources to maintain or restore core cooling, containment, and spent fuel pool (SFP) cooling without alternating current power. The transition phase involved 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 involved obtaining sufficient offsite resources to sustain those functions indefinitely.

The NRC staff provided guidance for satisfying the Commission directives regarding BDBEE mitigation strategies in Japan Lesson-Learned Project Directorate (JLD)-ISG-2012-01, Revision 0, “Compliance with Order EA-12-049, Order Modifying Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events,” (ADAMS Accession No. ML12229A174). JLD-ISG-2012-01 endorsed with clarification the methodologies described in the industry guidance document Nuclear Energy Institute (NEI) 12?06, Revision 0, “Diverse and Flexible Coping Strategies (FLEX) Implementation Guide,” (ADAMS Accession No. ML12242A378). The guidance in JLD-ISG-2012-01 describes one acceptable approach for satisfying the Commission directives regarding BDBEE mitigation strategies.

Technical Report APR1400-E-P-NR-14005-P Section 5.1.2.5.3 provides performance requirements for portable equipment that sprays water (via emergency containment spray backup system (ECSBS)) into containment at 2,839 L/min (750 gpm) and a differential pressure of at least 2.8 kg/cm2 (40 psi). The ECSBS is assumed to operate intermittently for 2 hours whenever the containment pressure reaches the UPC value. The staff requests that the applicant provide the basis for selecting 40 psi as the minimum differential pressure performance requirement. Also, discuss the rationale for selecting intermittent spray operation versus continuous spray operation to maintain containment capabilities.

Response

The spray nozzles of ECSBS are identical to the main spray nozzles of the containment spray system. The differential pressure of 40 psi applied to the spray nozzles for the APR 1400 is based on the spray nozzle design which has been applied to the reference plant of SKN 3&4. The performance of the spray nozzle was tested and verified at a differential pressure of 40 psi by its vendor at the reference plant.

The ECSBS intermittent operation during containment pressurization accidents following the BDBEE will be changed to continuous spray operation as addressed in the response to RAI 401-8402 Question 19.03-16.

The APR1400 originally adopted the intermittent spray to reduce the amount of the water supplied into the containment building however this operation may threaten the containment integrity due to repetitive exposure of the containment structures to excessively high pressure that may yield the plastic deformation of structures within containment.

Additionally, the continuous spray is clearly preferable in view of the operational safety of the ECSBS since the continuous spray does not require repetitive pressure measurements for spray on/off control that are essentially required for intermittent spray operation.

Impact on DCD

DCD Tier 2, Section 19.3 will be revised, as indicated in the Attachment 1 associated with RAI 401-8402 Question 19.03-16

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 Report

Technical Report “Evaluations and Design Enhancements to Incorporate Lessons Learned from Fukushima Dai-Ichi Nuclear Accident” APR1400-E-P-NR-14005-P/NP will be revised as indicated in the Attachment 2 associated with RAI 401-8402 Question 19.03-16

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.:	**401-8402**
SRP Section:	**19.03 – Beyond Design Basis External Event**
Application Section:	**19.3**
Date of RAI Issue:	**02/08/2016**

Question No. 19.03-20

NRC Commission paper SECY-12-0025 (February 17, 2012), "Proposed Orders and Requests for Information in Response to Lessons Learned from Japan's March 11, 2011, Great Tohoku Earthquake and Tsunami," stated that the NRC staff expected new reactor design certification or license applications (e.g., construction permit, operating license, and combined license) not yet then-submitted to address the Commission-approved Fukushima actions in their applications, prior to submittal, to the fullest extent practicable. In SECY-12-0025, the NRC staff outlined a three-phase approach regarding mitigation strategies to respond to beyond-design basis external events (BDBEEs). The initial phase involved the use of installed equipment and resources to maintain or restore core cooling, containment, and spent fuel pool (SFP) cooling without alternating current power. The transition phase involved 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 involved obtaining sufficient offsite resources to sustain those functions indefinitely.

The NRC staff provided guidance for satisfying the Commission directives regarding BDBEE mitigation strategies in Japan Lesson-Learned Project Directorate (JLD)-ISG-2012-01, Revision 0, "Compliance with Order EA-12-049, Order Modifying Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events," (ADAMS Accession No. ML12229A174). JLD-ISG-2012-01 endorsed with clarification the methodologies described in the industry guidance document Nuclear Energy Institute (NEI) 12–06, Revision 0, "Diverse and Flexible Coping Strategies (FLEX) Implementation Guide," (ADAMS Accession No. ML12242A378). The guidance in JLD-ISG-2012-01 describes one acceptable approach for satisfying the Commission directives regarding BDBEE mitigation strategies. NEI 12-06 Section 3.2.1.9, "Personal Accessibility," states that areas requiring personnel access should be evaluated to ensure the conditions will support the actions required by the plant specific strategy for responding to the event. Technical Report APR1400-E-P-NR-14005-P, Table 5-9, "Conformance with NEI 12-06, Rev. 0," indicates conformance to NEI 12-06 Section 3.2.1.9. The Technical Report does not describe plant areas requiring personnel access and the actions needed to maintain or restore the containment capabilities. The staff requests that the applicant provide a listing of the areas requiring personnel access, the actions required (e.g., opening a valve, making a connection), and an evaluation of those areas to ensure the conditions will support the actions required by the plant-specific strategy for responding to the event. In addition, the staff requests that the applicant document the specific tasks required to initiate the emergency containment spray backup system (ECSBS) and the required time to establish ECSBS.

Response

The ECSBS is used to maintain the containment pressure below the ultimate pressure capacity (UPC) limit during a BDBEE.

If the ECSBS FLEX mitigation needs to be used, the following operator actions are required to be initiated:

1. The ECSBS FLEX pump should be located close to the ECSBS Siamese connection in the east side of auxiliary building (AB). The suction of the pump is connected to a pipe line that is connected to the RWT using a flexible hose. The pump discharge is connected to the Siamese connection using the flexible hose.

2. The operator opens the RWT isolation valve to provide water to the pump. Then, the operator opens the ECSBS isolation gate valve (CS-V1013) on the ECSBS piping inside the mechanical penetration room 120-A16A at 120'-0" elevation in the AB, to provide water to the spray nozzles. The mechanical penetration room is normally designated radiation zone 6. The valve is opened with a reach rod from the general access area (120-A20A). The general access area (120-A20A) is accessible through the door ways, the corridor, and the stair as indicated in the table below.

3. The ECSBS spray is manually initiated 24 hours after the containment pressure reaches 3.8 kg/cm^2 (54 psig).

The details for the initiation time of ECSBS will be discussed in the response to RAI 401-8402, Question 19.03-16.

The specific tasks required to initiate the ECSBS and required time to establish ECSBS will be added to Technical Report APR1400-E-P-NR-14005-P/NP Subsection 5.1.2.5.2.3 as indicated in the Attachment. In addition, the DCD Tier 2 Figure 6.2.2-1 will be revised to incorporate the reach rod design of the ECSBS isolation gate valve (CS-V1013) which is to prevent the operator from entering the high radiation zone (see Attachment).

Table. The condition of operator access area in order to open the V1013

Location	Building	Room Number	Radiation Zone (normal)
Lobby	Compound BLDG	100-P41	1
Vestibule	Compound BLDG	100-P50	1
Access area	Compound BLDG	100-P24	1
Corridor	Compound BLDG	100-P54	2
Corridor	Compound BLDG	100-P14	2
Stair	Compound BLDG	063-P18	2

Corridor	Compound BLDG	120-P07	2
General access area	Auxiliary BLDG	120-A20A	2

Impact on DCD

DCD Tier 2 Figure 6.2.2-1 will be revised as indicated in the Attachment.

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-P/NP, Subsection 5.1.2.5.2.3 will be revised as indicated in the Attachment.

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

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

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.

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.

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.

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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 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

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5.1.2.5.2.3 ECSBS operation for Containment Integrity

Preperation for ECSBS operation

The following tasks for ECSBS are established within 24 hours after the containment pressure reaches 3.8 kg/cm2 (54 psig).

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)

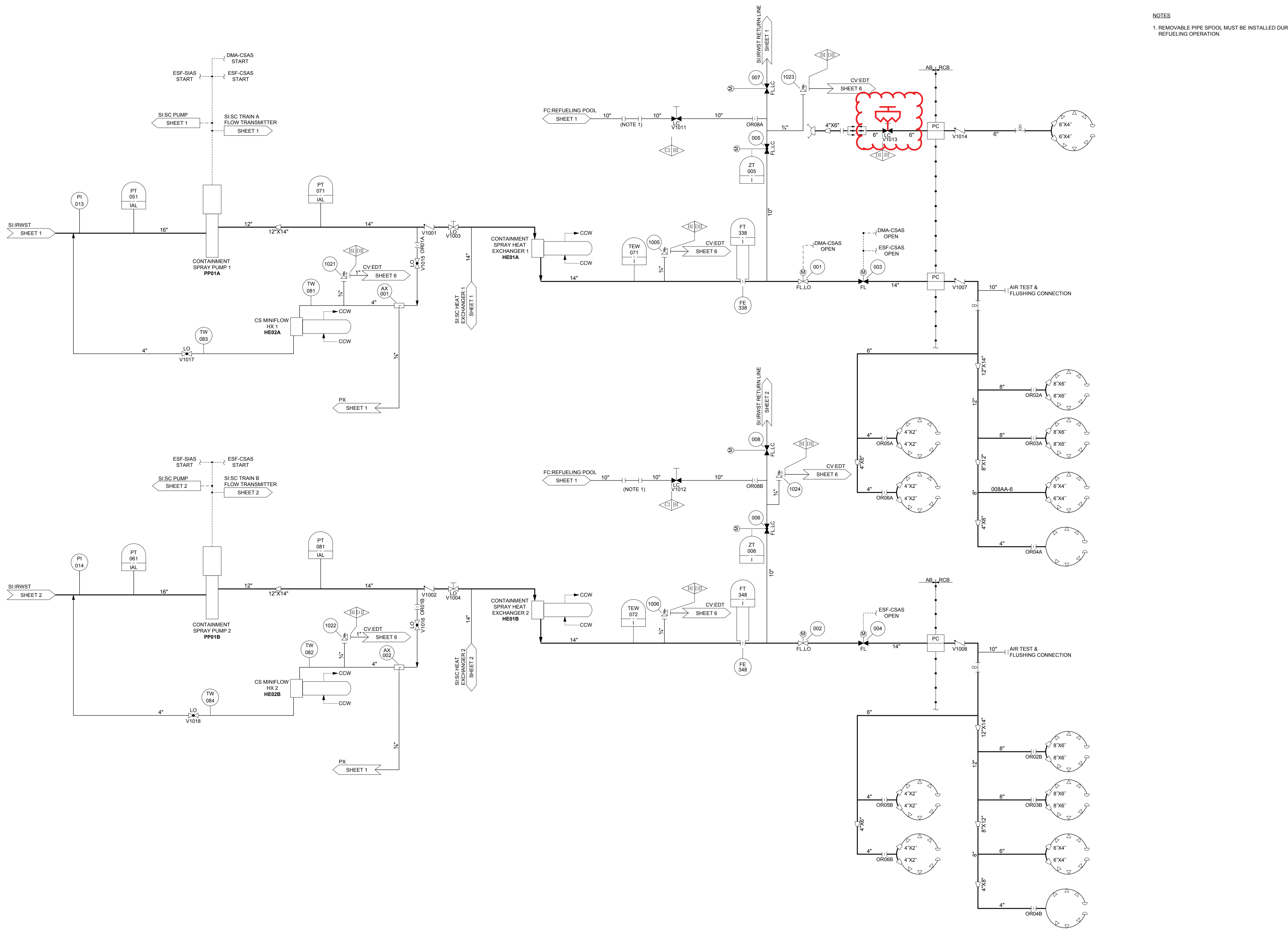

Figure 6.2.2-1   Containment Spray System Flow Diagram