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.:	**517-8670**
SRP Section:	**19.03 – Beyond Design Basis External Event**
Application Section:	**19.3**
Date of RAI Issue:	**08/19/2016**

Question No. 19.03-41

10 CFR 52.47(a)(2) requires that a standard design certification applicant provide a description and analysis of the structures, systems, and components (SSCs) of the facility, with emphasis upon performance requirements, the bases, with technical justification therefor, upon which these requirements have been established, and the evaluations required to show that safety functions will be accomplished.

In light of recent RAI responses related to DCD Tier 2, Section 9.3.1, the staff found that some assumptions being used for mitigation strategies for the spent fuel pool (SFP) water level during beyond-design-basis-external events (BDBEEs) may need additional justifications.

In RAI 473-8582, Question 09.01.03-4, the staff requested the applicant to clarify the minimum safety water level credited to be retained in the SFP. The applicant's response stated that the minimum safety water level for the SFP is EL. 146 ft. under the worst postulated accident condition. In RAI 77-7991, Question 09.01.03-1, the staff requested the applicant to indicate the elevation of all pipes that interact with the SFP (pipes that penetrate the SFP wall and pipes that extend down into pool). The applicant's response stated that the SFP cleanup suction nozzle is at EL. 149'. In Technical Report APR1400-E-P-NR-14005-P, Rev.0, Appendix B for BDBEEs, one of the key assumptions used in the SFP time to boil and makeup analysis is to assume the initial SFP water level to be at normal water level, i.e. EL.154'. However, since the SFP cleanup suction nozzle is non-seismic, it could fail during a seismic BDBEE, causing the water in the SFP to drop to EL.149' instead of EL154' as assumed in the time to boil calculation mentioned above. A lower water level means less water inventory available for the pool boil-off and less time available for the operator actions to mitigate the event.

NEI 12-06, Section 3.2, "Performance Attributes," (ML12242A378) indicates that "installed equipment that is designed to be robust with respect to design basis external events is assumed to be fully available." The applicant is requested to justify/clarify the robustness of pipes that interact with the SFP that are located below the initial SFP water level assumption used in the calculation (i.e., 154’), or to revise the assumption of the initial SFP water level and re-do the SFP analysis for BDBEEs, and revise the Technical Report and DCD accordingly.

Response

The elevations of all pipes that penetrate the SFP are described in the response to RAI 77-7991, Question 09.01.03-1. The elevation of the SFP cleanup suction nozzle, which is located at the lowest elevation among the non-Seismic Category I pipes (Seismic Category II), is EL. 149’. Therefore, the EL. 149’ is assumed as the initial water level of the SFP during BDBEEs to conservatively calculate SFP boil-off time.

In addition to the change of the initial water level, the following input data are considered to calculate the SFP boil-off time.

- The top elevation of the Spent Fuel Rack (SFR) is changed from EL. 129’-6” to EL. 129’-8” based on the thermal hydraulic analysis which is mentioned in the response to RAI 497-8622, Question 09.01.03-6.
- The total water volume of the SFP is changed to the net water volume above the SFR based on the thermal hydraulic analysis. This assumption is more conservative since the net water volume provides the less cooling capability of SFP due to the less water volume and results in a shorter boiling time.
- The water density of the SFP is changed to the lowest water density that is expected during the analysis based on the response to RAI 497-8622, Question 09.01.03-6.
- The total heat load for modes 1 through 6 (with no full core offload) is changed. The total heat load is recalculated based on the maximum amount of one refueling batch, which is the same as the thermal hydraulic analysis. Therefore, this assumption is more conservative since the maximum amount of fuel provides more heat to the SFP and results in a shorter boiling time.

In addition, significant figures between the DCD and Technical Report APR1400-E-P-NR-14005-P/NP are corrected for the consistency as indicated in the Attachment.

Impact on DCD

DCD Tier 2, Subsection 9.1.3.3.2 and 19.3.2.3.2 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 will be revised as indicated in the Attachment.

GTGs is connected to the 480 V Class 1E power system Train A or B, and supplies power to the 125 Vdc battery charger, the 480 V load center, and the motor control center (MCC). With this Class 1E power, ACP, MSADVs, and essential I&C equipment are available during this phase. During this phase, additional cooling in MCR, electrical and I&C equipment rooms, TDAFWP rooms, and ACP room is not required based on heatup calculations.

ACP is used to provide makeup water for maintaining RCS inventory and provide RCP seal cooling. The suction source for ACP is the boric acid storage tanks (BASTs) and in-containment refueling water storage tank (IRWST). The water volume required for RCS inventory makeup during Phase 2 is approximately 643.52 m^3 (170,000 gal).

5.1.2.3.1.2.2 Contingency Plan

In the contingency plan strategy, installed plant equipment is assumed to be inoperable even after connection of 480 V mobile GTG. In this case, the RCS is further cooled down to around 110 °C (230 °F) with SGs fed by the two secondary side FLEX pumps instead of the plant installed TDAFWPs. RCS makeup is carried out by a primary side high-head FLEX pump instead of an ACP.

If the installed plant equipment, ACP, is inoperable, RCS inventory makeup can be provided by a primary side high-head FLEX pump 189.27 L/min (50 gpm) positive displacement pump with operating pressure of 105.46 kg/cm^2A (1,500 psia).

Two secondary FLEX pumps are also connected to the SG auxiliary feedwater (AFW) supply lines: one for each AFW line. The secondary FLEX pumps can be used to supply feedwater to SGs, when TDAFWPs are unavailable. If the SG pressure is under 6.33 kg/cm^2A (90 psia) during this phase, the TDAFWPs are inoperable. In this case, RCS is further cooled down to around 110 °C (230 °F) by depressurizing the SG to 1.03 kg/cm^2A (14.7 psia) using the MSADVs. During this time, the SG inventory is provided by the secondary side FLEX pumps (total dynamic head [TDH] of 17.01 kg/cm^2A [242 psia] at the rated flow rate of 1,173.48 L/min [310 gpm]) with suction from AFWST and RWT. The N+1 requirement for FLEX equipment is met by deploying two primary high-head FLEX pumps and three secondary FLEX pumps on site.

Additionally, as RCS cooldown continues and RCS pressure decreases to the designed setpoint of safety injection tank (SIT) injection, the SITs automatically discharge 4,000 ppm borated water into the RCS for boration and inventory makeup.

5.1.2.3.1.2.3 Common Strategy to Both the Basic Strategy and Contingency Plan

As the TDAFWPs or the secondary FLEX pumps continue to feed the SG, the AFWST inventory is depleted. Then, the suction of the TDAFWPs is realigned to the RWTs. The fuel for the mobile GTG is supplied by gravity flow from the emergency diesel generator (EDG) fuel oil day tank(s). Once the mobile GTG is running, the existing diesel fuel oil transfer pump is used to make up day tanks from the underground EDG fuel oil storage tanks, each having a capacity of 7 days of EDG operation at its continuous rating. Connections are also provided to supply fuel from the EDG fuel oil day tank to the primary and secondary side FLEX pumps for operation during Phase 2.

Table 5-2 shows the water volumes available from the AFWST and RWT during Phase 2. Although the water source from the RWT should be shared with SFP cooling, the AFWST and RWT are evaluated to be sufficient for continuous NCC operation for up to ~~12~~ 11 days (see Table B-3 in Appendix B).

After the plant is brought to the safe shutdown state, i.e., hot shutdown or cold shutdown, the 4.16 kV mobile GTG and other resources, such as cooling water and fuel, will also be prepared by the end of Phase 2. All of the operator actions to prepare Phase 3 will be finished by 72 hours following the event. Even though Phase 2 is assumed to last until 72 hours in this core cooling strategy, the capacity of the onsite SG cooling, RCS makeup water, and GTG fuel sources show the duration of Phase 2 can be extended up to ~~12~~ 11 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.

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.

- The operators have approximately ~~39.3~~ 29.6 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 water to the SFP is provided within ~~25.03~~ 15.36 hours.
- For Phases 2 and 3 of event mitigation, an SFP makeup rate of ~~493.28 L/m (130.31 gpm)~~ 493.2 L/min (130.3 gpm) is needed to match the initial boiloff rate. The boiloff rate decreases over time as the spent fuel decay heat decreases.

Based on this information, an overview of the spent fuel cooling mitigation strategies is provided in Table 5-4. Specific details of the SFP mitigation strategies for each phase are provided in the following subsections.

5.1.2.4.1.1 Phase 1: SFP Cooling (0 to 8 hours)

In Phase 1, action is taken to open the rollup door to the fuel handling area truck bay on the El. 100′-0″ of the auxiliary building, prior to the onset of boiling, to establish a vent path from the area for steam generated from the SFP. Based on the analyses, SFP boiling is calculated to occur no sooner than ~~4.3~~ 2.0 hours after the ELAP event occurs, considering the most limiting plant condition, i.e., mode 6 with full core offload and failure of non-seismic Category I piping.

No makeup water to the SFP is required and the water level is monitored. ~~Also, there is no non-seismic piping connected to the SFP that could potentially drain water from the SFP during a seismic event.~~ During this phase, a FLEX pump with external makeup water connections to the RWT is established.

The vent path for the spent fuel area that is established in Phase 1 is maintained open in Phases 2 and 3.

5.1.2.4.1.2 Phase 2: SFP Cooling (8 to 72 hours)

For Phase 2 event mitigation, makeup is required to the SFP. Based on the analyses presented in Appendix B, a minimum flow rate of ~~493.28 L/min (130.31 gpm)~~ 493.2 L/min (130.3 gpm) is required to match the worst-case SFP boiloff rate. This SFP makeup flow requirement is bounded, however, by the SFP makeup flow requirement needed to mitigate the effect of loss of large area (LOLA) per 10 CFR 50.54(hh) (2). The self-powered (diesel-driven) FLEX, 1,893 L/min (500 gpm) and 757 L/min (200 gpm), SFP makeup pump and spray pump relied on to mitigate LOLA are therefore credited to mitigate the BDBEE. These pumps are provided to meet the N+1 requirement for a single-unit site and will meet 10 CFR 50 Appendix A, General Design Criterion (GDC) 2.

<u>SFP Makeup Water Source</u>

In all operating modes, the raw water tank (RWT) can be used as the water source for SFP makeup. The RWT contains sufficient water inventory for SFP makeup required for mode 6 operation (limiting), which is ~~1,390 m^3 (367,214 gal)~~ 1,676 m^3 (442,883 gal) as shown in Appendix B, Table B-3.

Flexible hoses, FLEX pump(s), fuel for FLEX pump(s), and any other equipment required for this strategy are normally located away from the auxiliary building (i.e., greater than 91.44 m [100 yards]), so that mobilization of the equipment for SFP makeup capability can occur within the most limiting time of ~~25.03~~ 15.36 hours for mode 6 operation (boiloff time to 3.05 m [10 ft] above fuel rack top water level).

<u>Makeup Water FLEX Pump Staging and Pump Discharge Connections</u>

In Phase 2, the FLEX pump described above is staged outside the auxiliary building.

The FLEX pump discharge hose is routed to one of the two permanent SFP makeup connections located outside the east wall of the auxiliary building, as shown in Figure 6-2. One primary connection location is mounted on the wall of auxiliary building adjacent to, and just south of, the emergency diesel generator (EDG) building, and the other connection is mounted on the wall of auxiliary building adjacent to, and just north of, the emergency diesel generator building. The alternate connection is close to the SFP makeup connections. An SFP spray connection is close to each SFP makeup connection.

Standpipes to SFP Area

The FLEX pump connections are each connected to an independent, seismically qualified standpipe that runs inside the auxiliary building from the pump staging area to a location above the SFP at El. 156 ft. The two standpipes for the SFP makeup pump and the two standpipes for the SFP spray pump are located at diverse locations in the auxiliary building and extend from the ground elevation to the SFP elevation. The standpipes are suitably separated on the same side of the auxiliary building. The standpipes have connections at the bottom at ground elevation and the connections are external to the auxiliary building. Operators are able to connect flexible hoses to the standpipes, which are supplied by a FLEX pump. The standpipes for SFP makeup have hard-piped connections to the SFP edge to allow water makeup to the pool. The standpipes for SFP spray have hard-piped connections to the spray headers to allow spray into the pool. Each spray header is equipped with a number of spray nozzles to direct flow into SFP area. An isolation valve and a check valve are provided on each standpipe.

The simplified arrangements of these makeup and spray provisions are shown in Figures 6-2 and 6-3.

SFP Makeup FLEX Pumps

The diesel-driven FLEX pumps are provided to supply SFP makeup and SFP spray at a rate of at least 1,893 L/min (500 gpm) and 757 L/min (200 gpm), respectively.

FLEX Equipment Storage

The flexible hoses, FLEX pump, FLEX pump fuel supply, and any other FLEX equipment required for this strategy are stored away from the auxiliary building (i.e., greater than 91.44 m [100 yards] away) so that mobilization of the equipment for SFP makeup capability can occur within the ~~25.03-hour~~ 15.36 hours period identified above. The specific storage location, mobilization, and other details for the FLEX equipment are COL items.

5.1.2.4.1.3 Phase 3: SFP Cooling (after 72 hours)

The APR1400 continues operating with Phase 2 strategies to provide makeup to the SFP in Phase 3. In Phase 3, makeup to the RWT is provided from offsite water sources by the COL applicant.

5.1.2.4.2 Supporting Analyses for the Operational Strategy for SFP Cooling

SFP decay heat removal capacity has been evaluated to confirm that SFP cooling can be continued during and after the occurrence of a BDBEE resulting in an ELAP and LUHS.

5.1.2.4.2.1 Evaluation Conditions

NEI 12-06, Section 3.2.1.6 defines the following SFP conditions as general criteria and baseline assumptions for SFP conditions:

- All boundaries of the SFP are intact, including the liner, gates, transfer canals, etc.

- 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.~~ El. 149 ft 0 in (elevation of SFP cleanup suction nozzle).
- 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 rack: ~~1,034.4 m3 (36,529.5 ft3)~~ 816.3 m^3 (28,826 ft^3)

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

  Total SFP inventory: ~~1,688.8 m3 (59,640 ft3)~~ 816.3 m^3 (28,826 ft^3)

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~~ 29.6 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~~ 15.36 hours.
- For Phase 2 and 3 event mitigation, an SFP makeup rate of ~~493.28 L/m (130.31 gpm)~~ 493.2 L/min (130.3 gpm) is needed to match the initial boiloff rate. The boiloff rate decreases over time as the spent fuel decay heat decreases.

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:

5.1.2.6.1.3 Emergency Lighting

Emergency lighting in areas such as the MCR and technical support center (TSC) / operational support center (OSC) is provided from the Class 1E batteries during Phase 1, and from the mobile GTG during Phases 2 and 3.

Access to manual valves requires lighting, and access to instrumentation monitoring or equipment operation also requires lighting. Under this adverse condition, the APR1400 is designed to provide portable lighting (e.g., flashlights or headlamps) as necessary to perform essential functions.

5.1.2.6.1.4 Communications

Design features are incorporated into onsite plant communication system to enhance emergency preparedness for BDBEEs associated with simultaneous LUHS. These are described below.

The APR1400 communication subsystems provide an independent and diverse mode of communications. A failure of one subsystem does not affect the capability to communicate using the other system.

Electric power is provided to the communications subsystems from the non-Class 1E uninterruptible power system (UPS) with 1-hour capacity in normal operation. The wireless communication system is supplied from the dedicated emergency UPS with 16-hour capacity.

However, normal communications may be lost or hampered during an ELAP. In this condition, portable communication devices are provided to support interaction between personnel in the plant and those providing overall command and control. Communication gear (satellite phones and radios) are also provided for onsite and offsite communications. This system provides an alternate communication path for outside connections. The satellite telephone equipment includes a roof-mounted antenna and transceiver.

5.1.2.6.2 Water Supply System

The primary source of water for the core cooling function is the AFWST for the first 72 hours, and the RWT can be used thereafter for up to ~~12~~ days, if required (Table 5-2).

For the SFP makeup and spray function, the RWT is the source of water.

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5.1.2.6.3 Fuel Oil Supply System

EDG fuel oil day tank and the underground 7-day fuel oil storage tanks are used for running the diesel-driven FLEX pumps. During Phase 3, fuel oil is provided from an offsite source. Table 5-6 provides a summary of the fuel oil demands during the three phases of this event.

The existing onsite EDG fuel oil storage tanks and associated diesel fuel oil day tanks have a capacity of 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.

- Level 2: Level adequate to provide substantial radiation shielding for a person standing on the spent fuel pool operating deck

Indicated level on either the primary or backup instrument channel of greater than 3.05 m (+/-0.305 m) (10 ft [+/- 1 ft]) above the top of the fuel storage racks. The 3.05 m (10 ft) criterion is conservative with regard to dose, in that the APR1400 DCD Subsections 9.1.3.1 and 9.1.3.3.4 indicate that dose would remain at or below 0.025 mSv (2.5 mrem/hr) at the surface of the water. This monitoring level provides reasonable assurance that there is adequate water level to provide substantial radiation shielding for a person standing on the spent fuel pool operating deck. The elevation associated with this level is greater than ~~139 ft 6 in~~ 139 ft 8 in plus the accuracy of the SFP water level instrument channel, which is determined at the COL stage.

- Level 3: Level where fuel remains covered and actions to implement makeup water addition should no longer be deferred

Indicated level is on either the primary or backup instrument channel of greater than 0.305 m (1 ft) above the top of the fuel storage racks. The elevation associated with this level is greater than ~~129 ft 6 in~~ 129 ft 8 in plus the accuracy of the SFP water level instrument channel, which is determined at the COL stage. This monitoring level provides reasonable assurance that there is adequate water level above the stored fuel in the rack.

5.1.3.2.2 Instruments

The design of the instruments is consistent with the guidelines of NRC JLDISG-2012-03 Rev. 0 and NEI 12-02 Rev. 1. Specifically, the channels are designed as described below.

- Primary (fixed) instrument channel (Channel A)

The primary instrument channel provides level indication through the use of guided wave radar (GWR) technology using the principle of time domain reflectometry (TDR). The instrument provides a single continuous span from above Level 1 to within 0.305 m (1 ft) of the top of the spent fuel racks.

- Backup instrument channel (Channel B)

The backup instrument channel is identical to the primary channel and is a permanent, fixed channel. The backup instrument channel provides level indication through the use of GWR technology using the principle of TDR. The instrument provides a single continuous span from above Level 1 to within 0.305 m (1 ft) of the top of the spent fuel racks.

The primary and backup instrument channels provide continuous level indication over a minimum range from the high SFP alarm El. 154 ft 2 in plus the accuracy of the SFP water level instrument channel to the top of the spent fuel racks at El. ~~129 ft 6 in~~ 129 ft 8 in minus the accuracy of the SFP water level instrument channel.

5.1.3.2.3 Reliability

Conformance with the guidelines of NRC JLD-ISG-2012-03 Rev. 0 and NEI 12-02 Rev. 1 provides reasonable assurance of the reliability of the primary and backup instrument channels, as described in the subsections below. The GWR design was selected due to its reliability.

5.1.3.2.4 Instrument Channel Design Criteria

Instrument channel design is consistent with the guidelines of NRC JLD-ISG2012-03 Rev. 0 and NEI 12-02 Rev. 1.

Instrument channels consist of a corrosion- and radiation-resistant metal probe submerged in the pool and connected to a corresponding display/processor by coaxial cable. The probe spans the length of the measured range of pool levels.

The probe is seismically mounted. It is designed to operate in borated and non-borated water over the entire expected range of pool conditions from normal temperatures to boiling temperatures. Cables and connections are designed for expected radiation levels and environments of greater than 100 °C (212 °F) and 100 percent humidity. Probes, cables, connectors, and mounting hardware in the area of the SFP are designed to function after the effects of seismically induced sloshing.

In the SFP area, cables shall be routed in seismically mounted rigid metal conduit. Outside the pool

Table 5-2

Water Volume Source and Requirements for SG Feedwater

Tank	**Quantity**	**Tank Volume, m^3/tank (gal/tank)**	**Total Volume, m^3 (gal)**	**Phase 1 – Total Volume Required, m^3 (gal)**	**Phase 1 & 2 – Total Volume Required, m^3 (gal)**
Auxiliary Feedwater Storage Tank (AFWST)	2	1,819.61 (480,690)	3,639.22 (961,380)	529.96 (140,000)	2,849.69 (752,809) Primary source of water is AFWST for 72 hours. RWT can be used after depletion of AFWSTs for up to ~~12~~ 11 days following the event.
Raw Water Tank (RWT)	2	4,996.74 (1,320,000)	9,993.49 (2,640,000)	NA	

Table 5-4

FLEX Capability – Spent Fuel Pool Cooling Summary

Safety Function	Method	Phase 1	Phase 2 and 3
Spent Fuel Pool Cooling	Makeup through connection to SFP makeup piping or other suitable means (e.g., sprays)	Analysis demonstrates that spent fuel heats up slowly and remains cooled by water inventory above the top of the spent fuel. rack	Permanent connections for FLEX, self-powered SFP makeup pump and SFP spray pump. (FLEX connection locations and equipment are protected from the applicable hazards in NEI 12-06. They are designed to seismic Category I requirements. They either are located in seismic Category I structures or outside, above the ground).
	Makeup with FLEX injection source	Analysis demonstrates that spent fuel heats up slowly and remains cooled by water inventory above the top of the spent fuel.	Permanent connections to make up the SFP from RWT.
	Vent pathway for steam rack	Vent path from SFP area to environment established for removal of steam. (Rollup door to the fuel handling area truck bay is opened prior to earliest predicted spent fuel pool time to boil.)	Vent path established in Phase 1 is maintained open to provide a vent path for steam.
SFP Parameters	SFP level	Instruments powered by Class 1E MCC. The APR1400 design includes redundant, safety-related wide-range level sensors in SFP that fulfill EA-12-051 order.	On loss of normal 120 Vac power from the Class 1E 480 V MCC, each channel's internal UPS automatically transfers instrument power to a dedicated backup battery to support continuous monitoring of SFP level. If normal ac power is restored, the UPS will automatically transfer instrument power back to the normal ac power.

Table 5-8 (2 of 5)

JLD-ISG-2012-01 Rev. 0			APR1400
Section		Summary	
			Therefore, NCC operation to maintain RCS at hot standby is possible without any operator action during this phase. FLEX strategy for shutdown mode with SGs not available: Initial phase (0-3 hours): Decay heat is removed by RCS inventory 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. [11] 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-

Table 5-10 (1 of 4)

Conformance with NEI 12-06, Rev. 0 – Tables D-1, D-2, and D-3

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, 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.

Table 5-10 (3 of 4)

NEI 12-06, Rev. 0 – Tables D-1, D-2, and D-3			APR1400
Safety Function	**Method**	**Performance Attributes**	
Containment Function	Containment spray	Due to the long-term nature of this function, the connection does not need to be a permanent modification. However, if a temporary connection is necessary, e.g., via valve bonnet, then this should be pre-identified.	The emergency containment spray backup system (ECSBS) is provided for long-term maintenance of containment function. The ECSBS is supplied water by FLEX pump through connections located outside the exterior wall of the auxiliary building.
Key Containment Parameters	Containment pressure	Identify instruments to be relied upon, including control room and field instruments.	The following containment pressure instruments are available in MCR for operators to monitor plant condition and carry out operator action according to the APR1400 FLEX strategy: - Containment pressure: high alarm indicator - Containment pressure: high-high alarm indicator
Spent Fuel Cooling	Makeup with portable injection source (makeup via hoses on refuel floor)	Minimum makeup rate must be capable of exceeding boiloff rate for the boundary conditions described in Subsection 3.2.1.6.	The APR1400 strategy complies with this guidance. The hose stations on the operating floor of the SFP area can provide the makeup capacity of 1,893 L/min (500 gpm), which exceeds the maximum boiloff rate (~~493.28 L/min [130.31 gpm]~~ 493.2 L/min [130.3 gpm]).
	Makeup with portable injection source (makeup via connection to SFP cooling piping or other alternate location)	Minimum makeup rate must be capable of exceeding boiloff rate for the boundary conditions described in Subsection 3.2.1.6.	The APR1400 strategy complies with this guidance. The FLEX makeup capacity (1,893 L/min [500 gpm]) exceeds the maximum boiloff rate (~~493.28 L/min [130.31 gpm]~~ 493.2 L/min [130.3 gpm]).
	Makeup with portable injection source (vent pathway for steam and condensate from SFP)	Plant-specific strategy should be considered as needed.	The rollup door at fuel handling area truck bay in the auxiliary building can be opened to provide a vent path for steam and condensate from SFP.

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

By incorporating this design into the APR1400, an alternate strategy of providing RCS inventory makeup is available when the ACP is not available. This core cooling strategy is described as the contingency plan in Subsection 5.1.2.3 of this report. This design change increases the reliability of the IRWST to maintain RCS water inventory after a BDBEE. This design feature complies with the requirements specified in References 5, 7, and 8.

6.2.3 Spent Fuel Pool – Makeup Line and Spray Line Enhancements

6.2.3.1 Design Description

As part of the FLEX strategy to address Recommendation 4.2, Figures 6-2, 6-3, and 6-4 depict the SFP configuration to maintain SFP cooling by providing SFP makeup and SFP spray capabilities. Therefore, the following design is provided in the APR1400 to enhance the capability of the SFP diverse makeup lines and SFP spray lines to cope with BDBEEs:

- Primary Connection: Permanently installed suction connection from the RWT for FLEX pump suction.

  RWT is used as the suction water source of the FLEX pumps. Two seismically qualified, 15.24 cm(6 in) diameter lines are installed downstream of RWT in the yard. The primary and secondary piping connections with isolation valves are located outside building and hose connector are located in the yard. A 15.24 cm(6 in) flexible hose is connected between the water supply line and the FLEX pump suction.

- Hose connections are provided for the FLEX pump connections for the SFP spray lines and SFP diverse makeup standpipes at the exterior of the auxiliary building.

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)~~ 493.2 L/min (130.3 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.

6.2.3.3 Compliance with NRC Recommendations

By incorporating this design into the APR1400, diverse and reliable sources of makeup water to the SFP are available to cope with BDBEE. This SFP cooling strategy is described in Subsection 5.1.2.4 of this report. These design features comply with the requirements specified in References 5, 7, and 8.

6.2.4 SFP Level Instrumentation

6.2.4.1 Design Description

The key SFP water levels associated with this design are described in Subsection 5.1.3. The specific design description is as follows:

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 0 in (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.

Level 2: Level adequate to provide substantial radiation shielding for a person standing on the spent fuel pool operating deck

The indicated level on either the primary or backup instrument channel of greater than 3.05 m (+/-0.305 m) (10 ft [+/-1 ft]) above the top of the fuel storage racks. The 3.05 m (10 ft) criterion is conservative with regard to dose, in that the APR1400 DCD Subsections 9.1.3.1 and 9.1.3.3.4 indicate that dose would remain at or below 0.025 mSv (2.5 mrem/hr) at the surface of the water. This monitoring level provides reasonable assurance there is adequate water level to provide substantial radiation shielding for a person standing on the SFP operating deck. The elevation associated with this level is greater than ~~139 ft 6 in~~ 139 ft 8 in plus the accuracy of the SFP water level instrument channel, which will be determined at the COL stage.

Level 3: Level where fuel remains covered and actions to implement makeup water addition should no longer be deferred

The indicated level is on either the primary or backup instrument channel of greater than 0.305 m (1 ft) above the top of the fuel storage racks. The elevation associated with this level is greater than ~~129 ft 6 in~~ 129 ft 8 in plus the accuracy of the SFP water level instrument channel, which will be determined at the COL stage. This monitoring level provides assurance that there is adequate water level above the stored fuel seated in the rack.

The following instruments are provided at the SFP to address the requirements of NRC JLD-ISG-2012-03 Rev. 0 and NEI 12-02 Rev. 1. Specifically, the channels are designed as described below:

- Primary (fixed) Instrument Channel (Channel A)

The primary instrument channel provides level indication through the use of guided wave radar (GWR) technology using the principle of TDR. The instrument provides a single continuous span from above Level 1 to within 0.305 m (1 ft) of the top of the spent fuel racks.

- Backup Instrument Channel (Channel B)

The backup instrument channel is identical to the primary channel and is a permanent, fixed channel. The backup instrument channel provides level indication through the use of GWR technology using the principle of TDR. The instrument provides a single continuous span from above Level 1 to within 0.305 m (1 ft) of the top of the spent fuel racks.

The primary and backup instrument channels provide continuous level indication over a minimum range from the high SFP alarm El. 154 ft 2 in plus the accuracy of the SFP water level instrument channel to the top of the spent fuel racks at ~~El 129 ft 6 in~~ El. 129 ft 8 in minus the accuracy of the SFP water level instrument channel.

6.2.4.2 Design Basis

The SFP instruments selected are seismically mounted. The probe is designed to operate in borated water and non-borated water over the entire expected range of pool conditions from normal water temperatures to boiling temperatures. Cables and connections are designed for expected radiation levels and environments of greater than 100 °C (212 °F) and 100 percent humidity.

6.2.4.3 Compliance with NRC Recommendations

The requirements and guidelines of NEI 12-02, Rev. 1 and NRC's JLD-ISG-2012-03, Rev. 0 are met.

6.2.5 AFWS Secondary Side FLEX Pump Connection

6.2.5.1 Design Description

Two secondary side diesel-driven FLEX pump connections are provided to the auxiliary feedwater system (AFWS) supply lines. One FLEX pump is connected to the train of the TDAFWP PP01A and the other to the TDAFWP PP001B. The FLEX pump suction and discharge pipes are 15.24 cm (6 in) diameter with Siamese connection. The suction and discharge connections are provided at the upstream of the auxiliary feedwater pump (AFWP) suction and the upstream of the AFW modulating valve, respectively. The RWT is an alternate water source that is independent, seismically qualified, and is connected to the AFWP suction. The piping sections connected at the AFW supply lines are classified as Safety Class 3, seismic Category I. The piping section downstream of the isolation valve at the exterior of the auxiliary building up to the connector is non-safety class and designed as seismic Category I. The specific features are depicted in Figure 6-5. Also, Figure 6-6 depicts the fuel oil connection for the secondary side FLEX pumps.

6.2.5.2 Design Basis

The AFWSTs are used as the water source for the TDAFWP and the secondary side FLEX pumps. Before water in the AFWST depletes, the suction of the TDAFWP is switched to the RWT. The onsite water sources are sufficient to keep the hot shutdown condition and for continuous NCC operation for at least ~~12~~ 11 days.

Each secondary side FLEX pump is designed to remove decay heat and keep the hot shutdown condition. The fuel for secondary side FLEX pump is supplied from the EDG fuel oil storage tank A/B as shown in Figure 6-6.

The secondary side 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. Each secondary side FLEX pump is designed for 1,174 L/min (310 gpm) at a TDH of 160 m (525 ft).

The COL applicants are responsible to determine the final FLEX pump design head considering site conditions.

6.2.5.3 Compliance with NRC Recommendations

By incorporating this design into the APR1400, alternative water makeup sources to the TDAFWP are available to supplement the water source to the SG and provide RCS cooldown. This design increases

APPENDIX B Spent Fuel Pool Time to Boil and Makeup Analysis

The APR1400 SFP conditions are analyzed for the BDBEE concurrent with LUHS.

B.1 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 SFP cooling during the ELAP:

- Fuel in the SFP remains covered.

B.2 Key Assumptions

The SFP time to boil and makeup analysis is performed using the following key assumptions and inputs:

- During an ELAP event, spent fuel cooling function by the spent fuel pool cooling system (SFPCS) heat exchangers is lost. Heatup of the SFP and boiling can be credited to cool the spent fuel, provided the water level is maintained above the top of the spent fuel [rack].
- A conservative number of rack spaces are assumed with all rack spaces.
- Heat losses from the SFP are conservatively neglected.
- Three conditions analyzed for the SFP decay heat load are:
  - SFP decay heat load during mode 1 to mode 4 without full core offload. This is defined as the decay heat generated by one refueling batch offloaded from core after 100 hours following shutdown, plus the spent fuel assemblies accumulated from the previous refueling operations.
  - SFP decay heat load during mode 5 and mode 6 without full core offload.
  - SFP decay heat during mode 6 with full core offload (limiting case), which is defined as the decay heat generated by one full core offloaded after 100 hours following shutdown, plus the spent fuel assemblies accumulated from the previous refueling operations.
- Initial SFP temperature is assumed at the maximum as follows:

  SFP decay heat during mode 1 to mode 6 with full core not offloaded: 48.9 ℃(120 °F)

  SFP decay heat during mode 6 with full core offload: 60 ℃ (140 °F)
- Initial SFP water level is assumed at ~~normal water level.~~ [El. 149 ft 0 in (elevation of SFP cleanup suction nozzle).]
- SFP inventory makeup starts when the water level reaches Level 2 defined in NEI 12-02 and shown in Figure B-1.
- Water inventories
  - The water inventory above top of fuel [rack]: ~~1034.4 m^3 (36,529.5 ft^3)~~ [816.3 m^3 (28,826 ft^3)]
  - ~~The water inventory below top of fuel: 654.4 m^3 (23,110.5 ft^3)~~

- Total SFP inventory: ~~1,688.8 m^3 (59,640 ft^3)~~ 816.3 m^3 (28,826 ft^3)

- Monitoring water level

  Based on Figure B-1, the following are the definitions of the water levels:

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

  Level 2: Level adequate to provide substantial radiation shielding for a person standing on the SFP operating floor

  Level 3: Level where fuel remains covered, but actions to implement makeup water addition should no longer be deferred

B.3 Methodology

The SFP time to boil and makeup analysis was performed to determine the bulk SFP heatup time and boiloff rate.

The SFP bulk heatup time is conservatively calculated using $\Delta t = MCp\Delta T/Q$,

where,

M (lbm) is the mass of water in the SFP.

Cp (Btu/lbm°F) is the specific heat.

ΔT (°F) is the temperature rise.

Δt (hr) is the time to complete the temperature rise.

Q (Btu/hr) is the heat added to the SFP from the spent fuel stored in the pool.

The boiloff rate is calculated using: Boiloff Rate = Q / h_{fg},

where,

Q (Btu/hr) is the heat added to the SFP from the spent fuel stored in the pool.

h_{fg} (Btu/lbm) is the latent heat of evaporation.

B.4 Evaluation Results

The evaluation results for the SFP time to boil and makeup water analysis are summarized in Tables B-1 through B-3. Based on Tables B-1 and B-2, the following inference can be drawn:

- For modes 1 to mode 6 with full core not offloaded, SFP boiling occurs approximately ~~13.5~~ 5.4 hours after an ELAP. As a result of boiling, SFP level reaches 3.05 m (10 ft) of water above the irradiated fuel assemblies in approximately ~~63.7~~ 33.1 hours after an ELAP. Within ~~63.7~~ 33.1 hours, Phase 2 actions should be initiated to provide makeup water to the SFP from the RWT using the portable pump.

- For mode 6 with maximum SFP heat loads due to a full core offload, the time to boil is reduced to ~~4.3~~ 2.0 hours after an ELAP. As a result of boiling, SPF level reaches 3.05 m (10 ft) of water above the irradiated fuel assemblies in approximately ~~25.03~~ 15.36 hours after an ELAP. Within ~~25.03~~ 15.36 hours, Phase 2 actions should be initiated to provide makeup water to the SFP from the RWT using the portable pump.

- In a postulated ELAP, the required SFP makeup flow rate to match the boiloff for modes 1 through 6 with core not offloaded is ~~203.5 L/m (53.76 gpm)~~ 237.7 L/min (62.79 gpm), and the SFP makeup flow rate for mode 6 with the full core offload is ~~493.28 L/min (130.31 gpm)~~ 493.2 L/min (130.3 gpm).

Table B-1

Time to Reach SFP Bulk Boiling and Input Parameters

Parameter \ MODE	Mode 1~6 (with no full core offload)	Mode 6 (with full core offload)
Initial water temperature, °C (°F)	48.9 (120)	60 (140)
Water density, kg/m^3 (lbm/ft^3)	~~988.48 (61.709)~~ 958.4 (59.83)	~~983.15 (61.376)~~ 958.4 (59.83)
Water volume, m^3 (ft^3)	~~1,688.8 (59,640)~~ 816.3 (28,826)	~~1,688.8 (59,640)~~ 816.3 (28,826)
Specific heat, kcal/kg-°C (Btu/lb-°F)	1.0 (1.0)	1.0 (1.0)
Heat load, MW (MBtu/hr)	~~7.32 (25)~~ 8.55 (29.2)	17.75 (60.6)
Temperature increase rate, hr/°C (hr/°F)	~~0.41 (0.15)~~ 0.11 (0.06)	~~0.19 (0.06)~~ 0.05 (0.03)
Temp. difference to boiling, °C (°F)	~~33.3~~ 51.1 (92.00)	~~22.2~~ 40.0 (72.00)
Time to boiling (hours)	~~***13.5***~~ 5.4	~~***4.3***~~ 2.0

Table B-2

Time to Reach SFP Water Level 2 and Level 3

Parameter \ MODE	Mode 1~6 (with no full core offload)	Mode 6 (with full core offload)
Density at 100 °C (212 °F), kg/m^3 (lb/ft^3)	958.4 (59.83)	958.4 (59.83)
Latent heat of water, kJ/kg (Btu/lb)	2,252 (969)	2,252 (969)
Boiloff rate, kg/hr (lb/hr)	~~11,703 (25,799.79)~~ 13,669 (30,134)	~~28,367 (62,538.70)~~ 28,367 (62,539)
Boiloff rate, L/min (gpm)	~~203.5 (53.76)~~ 237.7 (62.79)	~~493.28 (130.31)~~ 493.2 (130.3)
Time to Level 2 (3.05 m [10 ft] above ~~fuel~~ rack top), (hours)	~~***63.7***~~ 33.1	~~***25.03***~~ 15.36
Time to Level 3 (above ~~fuel~~ rack top), (hours)	~~***98.3***~~ 62.7	~~***39.3***~~ 29.6

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, during total coping time, m^3 (gal)		Mode 1 to 4(Note 1): ~~2,793 (737,851)~~ 3,443 (909,654); 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 rack top), (hours)	~~8.32~~ 38.95	~~46.97~~ 56.64
	Required makeup volume, m^3 (gal)	~~101.46 (26,827)~~ 555.46 (146,737)	~~1,390 (367,214)~~ 1,676 (442,883)
Makeup during ~~12 days (288 hours)~~ 11 days (264 hours)	Time for makeup (~~12~~ 11 days minus time to 3.05 m [10 ft] above fuel rack top), (hours)	~~224.32~~ 230.95	~~262.97~~ 248.64
	Required makeup volume, m^3 (gal)	~~2,739(723,538)~~ 3,294(870,114)	~~7,783(2,056,041)~~ 7,359(1,944,138)
Total copying Time		Modes 1 to 4: ~~12.2~~ 11.4 days Modes 5 and 6: 6.4 days	Mode 6: ~~15.1~~ 14.7 days

(Note 1): RWT can be used as the water source for NCC operation through TDAFWP and SFP makeup.

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

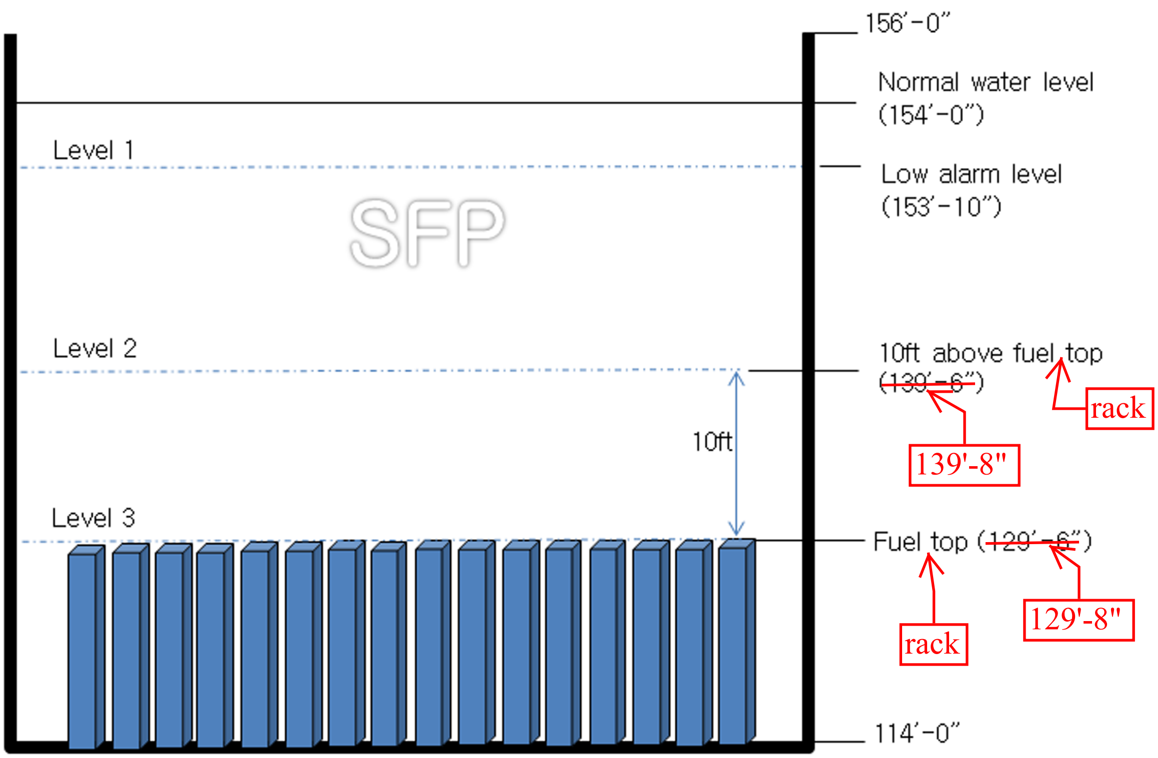

Figure B-1 Spent Fuel Pool Monitoring Water Level

is reactivated to resume SFP cooling, thereby precluding boiling. Furthermore, the SFP water volume allows an approximately 3.7-hour margin prior to SFP water boiling during a total loss of cooling condition or SBO at full core offloads. The SFP initial maximum boil-off rate for a worst case of full core off-load is approximately 579.17 L/min (153 gpm). The boil-off rate decreases over time as the spent fuel decay heat decreases. Based on the SFP boil-off and makeup analysis, a minimum flow rate of approximately 579.17 L/min (153 gpm) is required to match the SFP boil-off rate for the worst case. The SFP makeup flow rate is selected with a value that can exceed the boil-off rate of 579.17 L/min (153 gpm).

The SFP receives normal borated makeup water from the BAST, which is seismic Category I, safety Class 3, via the BAMP. The BAST is able to supply 643.52 L/min (170 gpm) of boric acid water through a seismic makeup line to the SFP.

The seismic Category I backup makeup water sources are also provided for SFP water makeup. The AFWSTs, as seismic Category I backup water sources, are able to supply 946.35 L/min (250 gpm) of non-borated water to the SFP via a CCW makeup pump. Non-borated water from a non-seismic category makeup water source is used to make up for the normal evaporation losses of the SFP from the DWST, and the makeup water is delivered via a manually operated valve in the connecting line.

Two makeup lines and two spray lines from outside the building are installed to establish a flexible means. Makeup water flow of ~~1,892 L/min~~ 1,893 L/min (500 gpm) and spray water flow of 757 L/min (200 gpm) from an external water source can be injected into the SFP. The makeup lines and spray lines are provided as dry pipes located on opposite corners of the SFP and are designed to withstand a safe shutdown earthquake. A portable makeup pump such as a fire truck can be used to supply SFP makeup water and spray water through these connection lines.

9.1.3.3.3 Spent Fuel Pool Dewatering

The SFPCCS is designed to prevent the reduction in spent fuel pool coolant inventory under accident conditions. To prevent the SFP cooling water loss, the pool is designed to maintain a minimum of approximately 3 m (10 ft) of water above the top of the spent fuel for proper cooling and shielding in accordance with NRC RG 1.13 (Reference 11). All piping that penetrates the pool is located at approximately 3 m (10 ft) above the top of the

29.6

a. 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.

b. To maintain at least 3.05 m (10 ft) of water inventory over the fuel assemblies, makeup water to the SFP is provided within ~~25.03~~ 15.36 hours.

493.2 L/min (130.3 gpm)

c. For Phases 2 and 3 of event mitigation, an SFP makeup rate of ~~493 L/min (130.31gpm)~~ is needed to match the initial boil-off rate. The boil-off rate decreases over time as the spent fuel decay heat decreases.

Specific details of the SFP mitigation strategies for each phase are provided below:

Phase 1: 0 to 8 hours

In Phase 1, action is taken to open the rollup door to the fuel handling area truck bay at El. 30.5 m (100′-0″) of the auxiliary building, prior to the onset of boiling to establish a vent path from the area for steam generated from the SFP. Based on the analyses, SFP boiling is calculated to occur no sooner than ~~4.3~~ 2.0 hours after the ELAP event occurs, considering the most limiting plant condition, i.e., Mode 6 with full core offload and failure of non-seismic Category I piping.

No makeup water to the SFP is required and the water level is monitored. ~~Also, there is no non-seismic piping connected to the SFP that could potentially drain water from the SFP during a seismic event.~~ During this phase, a FLEX pump with external makeup water connections to the RWT is established.

The vent path for the spent fuel area that is established in Phase 1 is maintained open in Phases 2 and 3.

Phase 2: 8 hours to 72 hours

493.2 L/min (130.3 gpm)

For Phase 2 event mitigation, makeup water is required to the SFP. Based on the analyses provided in Reference 5, a minimum flow rate of approximately ~~493.22 L/min (130.31 gpm)~~ is required to match the worst-case SFP boil-off rate. These SFP makeup and SFP spray flow requirements are bounded, however, by the SFP makeup and SFP spray flow requirements needed to mitigate the effect of loss of large area (LOLA) per 10 CFR

1,893 L/min 757 L/min

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.

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