UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

January 19, 2017

Mr. Peter P. Sena, III
President and Chief Nuclear Officer
PSEG Nuclear LLC – N09
P.O. Box 236
Hancocks Bridge, NJ 08038

SUBJECT: SALEM NUCLEAR GENERATING STATION, UNIT NOS. 1 AND 2 - SAFETY EVALUATION REGARDING IMPLEMENTATION OF MITIGATING STRATEGIES AND RELIABLE SPENT FUEL POOL INSTRUMENTATION RELATED TO ORDERS EA-12-049 AND EA-12-051 (CAC NOS. MF0868, MF0869, MF0913, AND MF0914)

Dear Mr. Sena:

On March 12, 2012, the U.S. Nuclear Regulatory Commission (NRC) issued Order EA-12-049, "Order Modifying Licenses with Regard to Requirements for Mitigation Strategies for Beyond Design-Basis External Events" and Order EA-12-051, "Order to Modify Licenses With Regard To Reliable Spent Fuel Pool Instrumentation," (Agencywide Documents Access and Management System (ADAMS) Accession Nos. ML12054A736 and ML12054A679, respectively). The orders require holders of operating reactor licenses and construction permits issued under Title 10 of the *Code of Federal Regulations* Part 50 to modify the plants to provide additional capabilities and defense-in-depth for responding to beyond-design-basis external events, and to submit for review Overall Integrated Plans (OIPs) that describe how compliance with the requirements of Attachment 2 of each order will be achieved.

By letter dated February 28, 2013 (ADAMS Accession No. ML13059A296), PSEG Nuclear LLC (PSEG, the licensee) submitted its OIP for Salem Nuclear Generating Station, Unit Nos. 1 and 2 (Salem), in response to Order EA-12-049. At six month intervals following the submittal of the OIP, the licensee submitted reports on its progress in complying with Order EA-12-049. These reports were required by the order, and are listed in the attached safety evaluation. By letter dated August 28, 2013 (ADAMS Accession No. ML13234A503), the NRC notified all licensees and construction permit holders that the staff is conducting audits of their responses to Order EA-12-049 in accordance with NRC Office of Nuclear Reactor Regulation (NRR) Office Instruction LIC-111, "Regulatory Audits" (ADAMS Accession No. ML082900195). By letters dated January 24, 2014 (ADAMS Accession No. ML13339A667), and October 10, 2014 (ADAMS Accession No. ML14258A308), the NRC issued an Interim Staff Evaluation (ISE) and audit report, respectively, on the licensee's progress. By letter dated September 28, 2016 (ADAMS Accession No. ML16273A349), the licensee submitted a compliance letter and Final Integrated Plan (FIP) in response to Order EA-12-049. The compliance letter stated that the licensee had achieved full compliance with Order EA-12-049.

By letter dated February 28, 2013 (ADAMS Accession No. ML13064A414), PSEG submitted its OIP for Salem in response to Order EA-12-051. At six month intervals following the submittal of the OIP, the licensee submitted reports on its progress in complying with Order EA-12-051. These reports were required by the Order, and are listed in the attached safety evaluation. By letters dated October 17, 2013 (ADAMS Accession No. ML13270A414), and October 10, 2014 (ADAMS Accession No. ML14258A308), the NRC staff issued an ISE and audit report, respectively, on the licensee's progress. By letter dated March 26, 2014 (ADAMS Accession No. ML14083A620), the NRC notified all licensees and construction permit holders that the staff is conducting audits of their responses to Order EA-12-051 in accordance with NRC NRR Office Instruction LIC-111, similar to the process used for Order EA-12-049. By letter dated January 25, 2016 (ADAMS Accession No. ML16026A024), PSEG submitted a compliance letter in response to Order EA-12-051. The compliance letter stated that the licensee had achieved full compliance with Order EA-12-051.

The enclosed safety evaluation provides the results of the NRC staff's review of PSEG's strategies for Salem. The intent of the safety evaluation is to inform PSEG on whether or not its integrated plans, if implemented as described, appear to adequately address the requirements of Orders EA-12-049 and EA-12-051. The staff will evaluate implementation of the plans through inspection, using Temporary Instruction 2515-191, "Implementation of Mitigation Strategies and Spent Fuel Pool Instrumentation Orders and Emergency Preparedness Communications/Staffing/ Multi-Unit Dose Assessment Plans" (ADAMS Accession No. ML15257A188). This inspection will be conducted in accordance with the NRC's inspection schedule for the plant.

If you have any questions, please contact John Boska, Orders Management Branch, Salem Project Manager, at 301-415-2901 or at John.Boska@nrc.gov.

Sincerely,

Mandy K Halter

Mandy K. Halter, Acting Chief
Orders Management Branch
Japan Lessons-Learned Division
Office of Nuclear Reactor Regulation

Docket Nos.: 50-272 and 50-311

Enclosure:
Safety Evaluation

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SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

RELATED TO ORDERS EA-12-049 AND EA-12-051

PSEG NUCLEAR LLC

SALEM NUCLEAR GENERATING STATION, UNIT NOS. 1 AND 2

DOCKET NOS. 50-272 AND 50-311

1.0 INTRODUCTION

The earthquake and tsunami at the Fukushima Dai-ichi nuclear power plant in March 2011 highlighted the possibility that extreme natural phenomena could challenge the prevention, mitigation and emergency preparedness defense-in-depth layers already in place in nuclear power plants in the United States. At Fukushima, limitations in time and unpredictable conditions associated with the accident significantly challenged attempts by the responders to preclude core damage and containment failure. During the events in Fukushima, the challenges faced by the operators were beyond any faced previously at a commercial nuclear reactor and beyond the anticipated design-basis of the plants. The U.S. Nuclear Regulatory Commission (NRC) determined that additional requirements needed to be imposed at U.S. commercial power reactors to mitigate such beyond-design-basis external events (BDBEEs).

On March 12, 2012, the NRC issued Order EA-12-049, "Order Modifying Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events" [Reference 4]. This order directed licensees to develop, implement, and maintain guidance and strategies to maintain or restore core cooling, containment, and spent fuel pool (SFP) cooling capabilities in the event of a BDBEE. Order EA-12-049 applies to all power reactor licensees and all holders of construction permits for power reactors.

On March 12, 2012, the NRC also issued Order EA-12-051, "Order Modifying Licenses With Regard to Reliable Spent Fuel Pool Instrumentation" [Reference 5]. This order directed licensees to install reliable SFP level instrumentation with a primary channel and a backup channel, and with independent power supplies that are independent of the plant alternating current (ac) and direct current (dc) power distribution systems. Order EA-12-051 applies to all power reactor licensees and all holders of construction permits for power reactors.

2.0 REGULATORY EVALUATION

Following the events at the Fukushima Dai-ichi nuclear power plant on March 11, 2011, the NRC established a senior-level agency task force referred to as the Near-Term Task Force (NTTF). The NTTF was tasked with conducting a systematic and methodical review of the NRC

regulations and processes and determining if the agency should make additional improvements to these programs in light of the events at Fukushima Dai-ichi. As a result of this review, the NTTF developed a comprehensive set of recommendations, documented in SECY-11-0093, "Near-Term Report and Recommendations for Agency Actions Following the Events in Japan," dated July 12, 2011 [Reference 1]. Following interactions with stakeholders, these recommendations were enhanced by the NRC staff and presented to the Commission.

On February 17, 2012, the NRC staff provided 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," [Reference 2] to the Commission. This paper included a proposal to order licensees to implement enhanced BDBEE mitigation strategies. As directed by the Commission in staff requirements memorandum (SRM)-SECY-12-0025 [Reference 3], the NRC staff issued Orders EA-12-049 and EA-12-051.

2.1 Order EA-12-049

Order EA-12-049, Attachment 2, [Reference 4] requires that operating power reactor licensees and construction permit holders use 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 and 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 off site. The final phase requires obtaining sufficient offsite resources to sustain those functions indefinitely. Specific requirements of the order are listed below:

1) Licensees or construction permit (CP) holders shall develop, implement, and maintain guidance and strategies to maintain or restore core cooling, containment, and SFP cooling capabilities following a beyond-design-basis external event.

2) These strategies must be capable of mitigating a simultaneous loss of all alternating current (ac) power and loss of normal access to the ultimate heat sink [UHS] and have adequate capacity to address challenges to core cooling, containment, and SFP cooling capabilities at all units on a site subject to this Order.

3) Licensees or CP holders must provide reasonable protection for the associated equipment from external events. Such protection must demonstrate that there is adequate capacity to address challenges to core cooling, containment, and SFP cooling capabilities at all units on a site subject to this Order.

4) Licensees or CP holders must be capable of implementing the strategies in all modes of operation.

5) Full compliance shall include procedures, guidance, training, and acquisition, staging, or installing of equipment needed for the strategies.

On August 21, 2012, following several submittals and discussions in public meetings with NRC staff, the Nuclear Energy Institute (NEI) submitted document NEI 12-06, "Diverse and Flexible Coping Strategies (FLEX) Implementation Guide," Revision 0 [Reference 6] to the NRC to provide specifications for an industry-developed methodology for the development, implementation, and maintenance of guidance and strategies in response to the Mitigation Strategies order. The NRC staff reviewed NEI 12-06 and on August 29, 2012, issued its final version of Japan Lessons-Learned Directorate (JLD) Interim Staff Guidance (ISG) 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" [Reference 7], endorsing NEI 12-06, Revision 0, with comments, as an acceptable means of meeting the requirements of Order EA-12-049, and published a notice of its availability in the *Federal Register* (77 FR 55230).

2.2 Order EA-12-051

Order EA-12-051, Attachment 2, [Reference 5] requires that operating power reactor licensees and construction permit holders install reliable SFP level instrumentation. Specific requirements of the order are listed below:

> All licensees identified in Attachment 1 to the order shall have 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 make-up water addition should no longer be deferred.
>
> 1. The spent fuel pool level instrumentation shall include the following design features:
>
> 1.1 Instruments: The instrumentation shall consist of a permanent, fixed primary instrument channel and a backup instrument channel. The backup instrument channel may be fixed or portable. Portable instruments shall have capabilities that enhance the ability of trained personnel to monitor spent fuel pool water level under conditions that restrict direct personnel access to the pool, such as partial structural damage, high radiation levels, or heat and humidity from a boiling pool.
>
> 1.2 Arrangement: The spent fuel pool level instrument channels shall be arranged in a manner that provides reasonable protection of the level indication function against missiles that may result from damage to the structure over the spent fuel pool. This protection may be provided by locating the primary instrument channel and fixed portions of the backup instrument channel, if applicable, to maintain instrument channel separation within the spent fuel pool area, and to utilize inherent shielding from missiles provided by existing recesses and corners in the spent fuel pool structure.

1.3 Mounting: Installed instrument channel equipment within the spent fuel pool shall be mounted to retain its design configuration during and following the maximum seismic ground motion considered in the design of the spent fuel pool structure.

1.4 Qualification: The primary and backup instrument channels shall be reliable at temperature, humidity, and radiation levels consistent with the spent fuel pool water at saturation conditions for an extended period. This reliability shall be established through use of an augmented quality assurance process (e.g., a process similar to that applied to the site fire protection program).

1.5 Independence: The primary instrument channel shall be independent of the backup instrument channel.

1.6 Power supplies: Permanently installed instrumentation channels shall each be powered by a separate power supply. Permanently installed and portable instrumentation channels shall provide for power connections from sources independent of the plant ac and dc power distribution systems, such as portable generators or replaceable batteries. Onsite generators used as an alternate power source and replaceable batteries used for instrument channel power shall have sufficient capacity to maintain the level indication function until offsite resource availability is reasonably assured.

1.7 Accuracy: The instrument channels shall maintain their designed accuracy following a power interruption or change in power source without recalibration.

1.8 Testing: The instrument channel design shall provide for routine testing and calibration.

1.9 Display: Trained personnel shall be able to monitor the spent fuel pool water level from the control room, alternate shutdown panel, or other appropriate and accessible location. The display shall provide on-demand or continuous indication of spent fuel pool water level.

2. The spent fuel pool instrumentation shall be maintained available and reliable through appropriate development and implementation of the following programs:

2.1 Training: Personnel shall be trained in the use and the provision of alternate power to the primary and backup instrument channels.

2.2 Procedures: Procedures shall be established and maintained for the testing, calibration, and use of the primary and backup spent fuel pool instrument channels.

2.3 Testing and Calibration: Processes shall be established and maintained for scheduling and implementing necessary testing and calibration of the primary and backup spent fuel pool level instrument channels to maintain the instrument channels at the design accuracy.

On August 24, 2012, following several NEI submittals and discussions in public meetings with NRC staff, the NEI submitted document NEI 12-02, "Industry Guidance for Compliance With NRC Order EA-12-051, To Modify Licenses With Regard to Reliable Spent Fuel Pool Instrumentation," Revision 1 [Reference 8] to the NRC to provide specifications for an industry-developed methodology for compliance with Order EA-12-051. On August 29, 2012, the NRC staff issued its final version of JLD-ISG-2012-03, "Compliance with Order EA-12-051, Reliable Spent Fuel Pool Instrumentation" [Reference 9], endorsing NEI 12-02, Revision 1, as an acceptable means of meeting the requirements of Order EA-12-051 with certain clarifications and exceptions, and published a notice of its availability in the *Federal Register* (77 FR 55232).

3.0 <u>TECHNICAL EVALUATION OF ORDER EA-12-049</u>

By letter dated February 28, 2013 [Reference 10], PSEG Nuclear LLC (PSEG, the licensee) submitted its Overall Integrated Plan (OIP) for Salem Nuclear Generating Station, Unit Nos. 1 and 2 (Salem or SGS) in response to Order EA-12-049. By letters dated August 25, 2013 [Reference 11], February 25, 2014 [Reference 12], August 26, 2014 [Reference 13], February 18, 2015 [Reference 14], August 26 , 2015 [Reference 48], and February 29, 2016 [Reference 49], the licensee submitted six-month updates to the OIP. By letter dated August 28, 2013 [Reference 15], the NRC notified all licensees and construction permit holders that the staff is conducting audits of their responses to Order EA-12-049 in accordance with NRC Office of Nuclear Reactor Regulation (NRR) Office Instruction LIC-111, "Regulatory Audits" [Reference 36]. By letters dated January 24, 2014 [Reference 16], and October 10, 2014 [Reference 17], the NRC issued an Interim Staff Evaluation (ISE) and an audit report on the licensee's progress. By letter dated September 28, 2016 [Reference 18], the licensee reported that full compliance with the requirements of Order EA-12-049 was achieved, and submitted a Final Integrated Plan (FIP).

3.1 <u>Overall Mitigation Strategy</u>

Attachment 2 to Order EA-12-049 describes the three-phase approach required for mitigating BDBEEs in order to maintain or restore core cooling, containment, and SFP cooling capabilities. The phases consist of an initial phase (Phase 1) using installed equipment and resources, followed by a transition phase (Phase 2) in which portable onsite equipment is placed in service, and a final phase (Phase 3) in which offsite resources may be placed in service. The timing of when to transition to the next phase is determined by plant-specific analyses.

While the initiating event is undefined, it is assumed to result in an extended loss of ac power (ELAP) with a loss of normal access to the UHS. Thus, the ELAP with loss of normal access to the UHS is used as a surrogate for a BDBEE. The initial conditions and assumptions for the analyses are stated in NEI 12-06, Section 3.2.1, and include the following:

1. The reactor is assumed to have safely shut down with all rods inserted (subcritical).

2. The dc power supplied by the plant batteries is initially available, as is the ac power from inverters supplied by those batteries; however, over time the batteries may be depleted.
3. There is no core damage initially.
4. There is no assumption of any concurrent event.
5. Because the loss of ac power presupposes random failures of safety-related equipment (emergency power sources), there is no requirement to consider further random failures.

Both units at Salem are Westinghouse pressurized-water reactors (PWRs) with dry ambient pressure containments. The licensee's three-phase approach to mitigate a postulated ELAP event, as described in the FIP, is summarized below. The approach is somewhat different if the plant receives warning of a pending flood, but the initial actions are similar.

At the onset of an ELAP both reactors are assumed to trip from full power. The reactor coolant pumps (RCPs) coast down and flow in the reactor coolant system (RCS) transitions to natural circulation. Operators will take prompt actions to minimize RCS inventory losses by isolating potential RCS letdown paths. Decay heat is removed by steaming to atmosphere from the steam generators (SGs) through the SG power-operated relief valves (PORVs) or SG safety valves, and makeup to the SGs is initially provided by the turbine-driven auxiliary feedwater (TDAFW) pump taking suction from the auxiliary feedwater storage tank (AFST), if available. The AFST is not tornado missile protected. If the AFST is not available, water to the TDAFW pump suction is provided from other available tanks or if necessary from the Hope Creek Generating Station (HCGS) fire protection tanks (FPTs) and diesel-driven fire pumps using a valve lineup and a temporary connection hose. Subsequently, the operators would begin a controlled cooldown and depressurization of the RCS by manually operating the SG PORVs. The SGs would be depressurized in a controlled manner to about 290 pounds per square inch gage (psig) and then maintained at this pressure while the operators borate the RCS. Depressurizing the SGs reduces RCS temperature and pressure. The licensee plans to complete this cooldown within four hours of the start of the event. The reduction in RCS temperature will result in inventory contraction in the RCS, with the result that the pressurizer would drain and a steam void would form in the reactor vessel upper head. The RCS leakage, particularly from the RCP seals, would also contribute to the decrease in RCS water volume. However, during the cooldown, RCS pressure should drop below the safety injection (SI) accumulator pressure of about 600 psig and the injection of some quantity of borated water into the RCS from the accumulators would then occur.

As discussed in its FIP, the licensee expects to use FLEX equipment from offsite response centers to restore shutdown cooling equipment (the residual heat removal (RHR) system and supporting equipment), the operation of which would allow RCS temperature to be reduced below 200 degrees Fahrenheit (°F). Prior to undertaking the additional cooling and depressurization of the RCS, operators would need to perform a number of supporting actions including injecting additional borated water into the RCS to avoid the potential for recriticality and isolating the accumulators using electrical power from FLEX generators to avoid the potential for excessive accumulator injection to the point that the nitrogen cover gas could enter the RCS.

Operators will ultimately transition the SG water supply from the TDAFW pump to portable FLEX pumps using water from the cleanest available source, or if need be, from the UHS, which is the Delaware River.

The operators will perform dc bus load stripping within the initial 2.5 hours following event initiation to ensure safety-related battery life is extended to at least 6 hours. Following dc load stripping and prior to battery depletion, 480 volt alternating current (Vac) FLEX diesel generators (DGs) will be started. Salem has four 480 Vac FLEX DGs, which includes one spare (N+1) DG. Three DGs are required to supply power to the units. Two FLEX DGs are staged at their point of use in the Salem Unit 2 canyon area located between the Salem Unit 2 fuel handling building (FHB) and the Unit 2 auxiliary building. Two FLEX DGs are stored in diverse outdoor FLEX storage areas (OFSAs), and one will be deployed to the canyon area during the event. The FLEX DGs will be used to repower essential battery chargers on both units within six hours of ELAP initiation, and to repower additional equipment as needed.

RCS makeup and boration will be initiated within 8 hours of the ELAP to ensure that natural circulation, reactivity control, and boron mixing is maintained in the RCS. Operators will provide reactor coolant makeup using a FLEX high-pressure charging pump (one per unit) to deliver borated water drawn from a FLEX connection on a boric acid storage tank (BAST) (there are two BASTs per unit, but only one is assumed to be available per unit).

The water supply for the TDAFW pump is initially from the AFST, if available. The AFST will provide a minimum of 9 hours of RCS decay heat removal, in addition to absorbing the latent heat associated with the planned RCS cooldown. Prior to emptying the AFST the operators will align another water source to the TDAFW pump suction.

In addition, a National Strategic Alliance for FLEX Emergency Response (SAFER) Response Center (NSRC) will provide high capacity pumps and large turbine-driven DGs which could be used to cool the reactors in the long-term by restoring one RHR cooling train per unit, or used to provide containment cooling. There are two NSRCs in the United States.

The SFP for each unit is located in the unit's FHB. Upon initiation of the ELAP event, the SFP will heat up due to the unavailability of the normal cooling system. To maintain SFP cooling capabilities, and using the conservative case of a full-core offload, the licensee determined that it would take approximately 44 hours for SFP water level to drop to a level requiring the addition of makeup to preclude fuel damage (water level at the top of the fuel racks). Makeup water would be provided using the diesel-driven FLEX service water (SW) pump with a suction from the UHS and discharging through a hose which will be connected to add water to the SFP. Ventilation of the generated water vapor and steam is accomplished by establishing a natural draft vent path and then by reenergizing the FHB exhaust fans using FLEX generators.

For Phases 1 and 2 the licensee's calculations demonstrate that no actions are required to maintain containment pressure below design limits for over 72 hours. During Phase 3, containment cooling and depressurization can be accomplished by operating one containment fan cooling unit, with service water for cooling supplied by a FLEX pump. The containment cooling fan would be powered by the 4160 Vac combustion turbine generators (CTGs) supplied by the NSRC.

Below are specific details on the licensee's strategies to restore or maintain core cooling, containment, and SFP cooling capabilities in the event of a BDBEE, and the results of the staff's

review of these strategies. The NRC staff evaluated the licensee's strategies against the endorsed NEI 12-06, Revision 0, guidance.

3.2 Reactor Core Cooling Strategies

Order EA-12-049 requires licensees to maintain or restore cooling to the reactor core in the event of an ELAP concurrent with a loss of normal access to the UHS (LUHS). Although the ELAP results in an immediate trip of the reactor, sufficient core cooling must be provided to account for fission product decay and other sources of residual heat. Consistent with endorsed guidance from NEI 12-06, Phase 1 of the licensee's core cooling strategy credits installed equipment (other than that presumed lost to the ELAP/LUHS event) that is robust in accordance with the guidance in NEI 12-06. In Phase 2, robust installed equipment is supplemented by onsite FLEX equipment, which is used to cool the core either directly (e.g., pumps and hoses) or indirectly (e.g., FLEX electrical generators and cables repowering robust installed equipment). The equipment available onsite for Phases 1 and 2 is further supplemented in Phase 3 by equipment transported from the NSRCs.

To adequately cool the reactor core under ELAP conditions, two fundamental physical requirements exist: (1) a heat sink is necessary to accept the heat transferred from the reactor core to coolant in the RCS and (2) sufficient RCS inventory is necessary to transport heat from the reactor core to the heat sink via natural circulation. Furthermore, inasmuch as heat removal requirements for the ELAP event consider only residual heat, the RCS inventory should be replenished with borated water in order to maintain the reactor in a subcritical condition as the RCS is cooled and depressurized.

As reviewed in this section, the licensee's core cooling analysis for the ELAP/LUHS event presumes that, per endorsed guidance from NEI 12-06, both units would have been operating at full power prior to the event. Therefore, the SGs may be credited as the heat sink for core cooling during the ELAP with loss of normal access to the UHS event. Maintenance of sufficient RCS inventory, despite ongoing system leakage expected under ELAP conditions, is accomplished through a combination of installed systems and FLEX equipment. The specific means used by the licensee to accomplish adequate core cooling during the ELAP/LUHS event are discussed in further detail below. The licensee's strategy for ensuring compliance with Order EA-12-049 for conditions where one or more units are shut down or being refueled is reviewed separately in Section 3.11 of this evaluation.

3.2.1 Core Cooling Strategy and RCS Makeup

3.2.1.1 Core Cooling Strategy

3.2.1.1.1 Phase 1

The licensee's FIP [Reference 18] states that immediately following the occurrence of an ELAP/LUHS event, the reactor will trip and the plant will initially stabilize at no-load reactor coolant system temperature and pressure conditions, with reactor decay heat removal via steam release to the atmosphere through the SG PORVs. Natural circulation of the reactor coolant system will develop to provide core cooling, and the TDAFW pump, with suction from the AFST, will provide water to the SGs to make up for steam release, assuming the AFST is available.

The TDAFW pump starts automatically upon the loss of offsite power, and no operator action is required for the pump to supply water from the AFST to the four SGs.

The AFSTs (one at each unit) each have a minimum available capacity of 200,000 gallons, representing sufficient volume for the first 9 hours of the event (which includes decay heat removal as well as the sensible heat associated with the initial RCS cooldown). They are fully robust to all applicable external hazards, except for tornado missile hazards. If an AFST is damaged and unavailable for SG makeup, then the TDAFW pump could take suction from any of the following tanks:

- Primary Water Storage Tank (PWST)
- Demineralized Water Storage Tank (DWST)
- Fire protection / fresh water storage tanks (FP/FWST)
- Hope Creek Generating Station (HCGS) fire protection tanks (FPTs)

None of these tanks is fully robust to a tornado missile strike. However, the licensee states that based on reasonable separation, either the AFST or HCGS FPTs can be credited to be available to supply the TDAFW pump. An underground cross-tie exists which would allow operators to align the volume of the HCGS FPTs to the Salem fire protection system. Operator action is required to align the HCGS FPTs to provide suction to the TDAFW pump; the licensee's FIP states that these actions can be completed before the expected worst-case time to SG dryout of 55 minutes. The timeline in Table 3 of the FIP indicates that operators identify the tornado missile damage to the AFST at 15 minutes after the start of the ELAP (Action Item 11). The licensee assumes that the AFST does not empty immediately, and that low level alarms alert the operators to the problem. Then the operators must align an alternate source of water in the next 55 minutes (Action Item 17). The validation document developed in support of the Salem FLEX strategy, Vendor Technical Document (VTD) 903021, "Salem Validation of FLEX Strategies," indicated that a time of 44 minutes was achievable for operators to recognize the loss of AFST inventory and align suction from the HCGS FPTs to the Salem AFW suction header and restore AFW flow to the SGs.

The licensee's Phase 1 strategy directs the initiation of a cooldown and depressurization of the RCS at approximately 2 hours after the start of the ELAP event. Over a period of approximately 2 hours, operators would gradually cool down the RCS from post-trip conditions until SG pressure reaches 290 psig, which corresponds to an RCS cold-leg temperature of approximately 425 °F. Cooldown and depressurization of the RCS significantly extends the expected coping time under ELAP/LUHS conditions because it (1) reduces the potential for damage to RCP seals (as discussed in Section 3.2.3.3) and (2) allows borated water stored in the nitrogen-pressurized cold leg accumulators to passively inject into the RCS to offset system leakage and add negative reactivity. Stabilizing the RCS at these plant conditions allows steam pressure to remain high enough to support continued use of the TDAFW pump. To remove heat, operators will discharge steam through the SG PORVs, which would be operated remotely from the main control room using dc battery power and local backup nitrogen supply bottles.

By terminating the initial cooldown at an SG pressure of approximately 290 psig, the licensee has determined that injection of the nitrogen cover gas in the accumulators into the RCS will be

prevented. The NRC staff's audit found the licensee's calculational methods used in this determination to be appropriate.

3.2.1.1.2 Phase 2

The licensee's FIP states that the primary Phase 2 strategy for core cooling would be to continue using the SGs as a heat sink, with makeup water supplied by the AFST or any surviving high-quality water source listed in the previous section. The TDAFW pump is expected to remain in operation throughout Phase 2; a motor-driven FLEX AFW pump will also be deployed to provide long-term SG makeup in the event that SG pressure becomes insufficient for continued use of the TDAFW pump. Like the TDAFW pump, the FLEX AFW pump can be aligned to take suction from any surviving high-quality water source. The licensee stated that this FLEX pump has a capacity of 350 gallons per minute (gpm) at 350 psig.

Operators would preferably draw from the AFST for the first 9 hours of the event (the minimum time that the credited AFST volume can support) then align the TDAFW pump suction to the PWST, DWST or an FP/FWST. If none of these tanks is available due to damage from wind-borne missiles, the licensee credits the use of the HCGS FPTs. The licensee has calculated that the volume in the HCGS FPTs (approximately 263,120 gallons in each of two tanks) would adequately support SG makeup at both Salem units for over 11 hours. By 11 hours after the start of the ELAP event, the FIP states that operators will have deployed a portable, high capacity, diesel-driven FLEX SW pump to take suction from the Delaware River with the capability to supply the TDAFW pump or FLEX AFW pump, representing an essentially indefinite supply of SG makeup water. The FLEX SW pump has a nominal capacity of 1500 gpm, and would provide sufficient long-term flow for SG makeup, RCS makeup and SFP spray for both units simultaneously using the plant nuclear service water header.

The FIP also states that the 480 Vac FLEX DGs will be placed into service in Phase 2, within 6 hours of the initiating event, to provide electrical power to equipment supporting the core cooling strategy, including the FLEX AFW pumps and accumulator isolation valves. Following the isolation of the SI accumulators and the completion of RCS boration to satisfy shutdown margin requirements (as described in Section 3.2.1.2 of this safety evaluation (SE)), operators will conduct a second RCS cooldown, to a cold-leg temperature of less than 350 °F. Based on the licensee's timeline to add borated water to the RCS to establish shutdown margin, and to power the accumulator isolation valves from the FLEX generators and isolate the accumulators, the staff concludes that the licensee would be able to complete the second cooldown within 21 hours. Completing the second cooldown by 21 hours will limit the hydrothermal corrosion of the RCP #1 seal (see Sections 3.2.3.2 and 3.2.3.3 of this SE). It will also maintain the integrity of the RCP #2 seal, per the recommendations in Westinghouse Technical Bulletin (TB) 15-1.

3.2.1.1.3 Phase 3

According to the FIP, the initial Phase 3 core cooling strategy entails re-powering one 4 kilovolt (kV) vital bus at each unit from two 4.16 kV generators provided by the NSRC. This will allow operators to start an RHR pump and a component cooling water (CCW) pump at each unit; cooling water to the CCW heat exchangers would be supplied by the FLEX SW pump or by a high-capacity pump from the NSRC. The SG makeup would continue to be supplied from the Delaware River via either the TDAFW pump or the FLEX AFW pump for as long as required;

Salem will obtain water purification equipment from the NSRC to ensure a long-term source of purified water for makeup to the SGs.

3.2.1.2 RCS Makeup Strategy

3.2.1.2.1 Phase 1

Under ELAP conditions, RCS inventory will tend to diminish gradually due to leakage through RCP seals and other leakage points. Furthermore, the initial RCS cooldown starting at two hours into the event would result in a significant contraction of the RCS inventory, to the extent that the pressurizer would drain and a vapor void would form in the upper head of the reactor vessel. As is typical of operating PWRs, prior to implementing the Phase 2 FLEX strategy Salem does not have a fully robust capability for active RCS makeup. However, some passive injection from the nitrogen-pressurized accumulators would occur as the RCS is depressurized below the accumulator cover gas pressure, which would result in the addition of borated water to the RCS. As discussed further below, the licensee has determined that (1) sufficient reactor coolant inventory would be available throughout Phase 1 to support heat transfer to the SGs via natural circulation without crediting the active injection of RCS makeup, and (2) according to the core operating history specified in NEI 12-06, a sufficient concentration of xenon-135 should exist in the reactor core to ensure subcriticality throughout Phase 1, considering the planned cooldown profile.

3.2.1.2.2 Phase 2

In order to maintain sufficient borated RCS inventory in Phase 2, the licensee's FIP states that a motor-driven high-pressure FLEX charging pump is prestaged inside the auxiliary building at each unit to inject borated makeup water from the unit's two boric acid storage tanks (BASTs). The licensee will commence RCS makeup and boration no later than 8 hours after the start of the ELAP event, in order to ensure reactivity control and prevent the onset of reflux cooling.

Per UFSAR Section 9.3.4, each of the four BASTs (two per unit) has a nominal volume of 8000 gallons, and cross-tie capability exists between the two units. The licensee's analysis for the ELAP/LUHS scenario conservatively assumed that the administrative minimum volume of 5750 gallons in the BASTs would be available at each unit, at the nominal boron concentration of 6775 parts per million (ppm). The BASTs are located within the Seismic Class 1 auxiliary building, and are robust to all applicable external hazards. The licensee calculates that a maximum of 7870 gallons of makeup water at a boron concentration of 6775 ppm would be required to ensure long-term subcriticality, given the most restrictive core conditions (zero initial RCS boron concentration, xenon-free, RCS temperature of 200 °F). This maximum required volume (7870 gallons) applies to the limiting case of Unit 2 at core end-of-life, a scenario in which, per the licensee's calculations, some volume would be available via the cross-tie from Unit 1. (Unit 1 would have a reduced makeup volume requirement based on the time in its own operating cycle.) Still, some additional capability to refill the BASTs would be required in this most restrictive case.

Portable boric acid mixing tank skids are available to refill the BASTs or directly provide borated water to the suction of the FLEX charging pump. Operators would mix bags of powdered boric acid with non-borated dilution water, preferably from the PWST, or alternatively from any

available source of clean water, including the SW system. The licensee's calculations and the sequence of events timeline in the FIP state that operators would deploy and begin mixing borated water in the mixing tank at 7 hours after the initiating event, and that the first transfer of borated water from the mixing tank to the BASTs would occur at 9 hours after the initiating event. The licensee stated that each skid has the capability to produce 900 gallons of 7000-ppm borated water every 2 hours.

For long-term RCS inventory control (following the initial boration to ensure subcriticality) the FLEX charging pump would take suction from the refueling water storage tank (RWST), if available. However, the RWST is vulnerable to wind-borne missile hazards, and is not credited by the licensee for use in their FLEX strategy. If the RWST is unavailable, the FLEX charging pumps each have a two-valve suction manifold to permit blended borated makeup flow from both the BASTs and a source of non-borated makeup water, i.e. the PWST, DWST, FP/FWST, or SW header.

The primary path for borated makeup water to the RCS is via a connection on the chemical and volume control system, downstream of the installed charging pumps. Alternately, the FLEX charging pump can be connected to the SI system. Both of these connections are protected from all applicable hazards, and the two strategies represent independent flowpaths.

To prevent the injection of nitrogen cover gas from the SI accumulators into the RCS, operators will re-power and shut the accumulator isolation valves prior to commencing the second RCS cooldown to 350 °F.

3.2.1.2.3 Phase 3

In Phase 3, the RCS makeup strategy is a continuation of the Phase 2 strategy, supplemented as needed with equipment provided by the NSRC, including one 60-gpm high pressure injection pump and one 250-gpm mobile water treatment skid per unit. The NRC staff expects that the licensee would begin using purification equipment from the NSRC as soon as practical, considering the overall event response prioritization and the necessity to facilitate the use of higher quality water for RCS makeup. Additional boron injection to the RCS may be required prior to initiating the extended RCS cooldown below 350 °F (which is described in Section 3.2.1.1.3 of this SE).

3.2.2 Variations to Core Cooling Strategy for Flooding Event

The only design-basis flooding scenario of concern is the storm surge scenario, caused by a hurricane, which puts about 14 feet of water on the site. When the advance warning of a hurricane is received, the licensee will take action to move two additional FLEX generators into the canyon area (the area between the Unit 2 FHB and the Unit 2 auxiliary building). The licensee will build a 16 foot tall wall (sand and dirt in containers) which will seal the only outside entrance to the canyon and keep out the flood waters. In its FIP, the licensee stated that based on the location of the temporary wall relative to storm surge fetch lines, the height of the wall provides adequate protection against the design-basis storm surge flood depths. Therefore, FLEX generators will be available in case the emergency diesel generators (EDGs) fail. Also, submersible pumps will be staged in the turbine building, to take suction from the turbine

building floor. When the turbine building is flooded, water can be pumped to the FLEX pumps used to add water to the SGs, to the RCS, or to the SFP.

3.2.3 Staff Evaluations

3.2.3.1 Availability of Structures, Systems, and Components (SSCs)

Guidance document NEI 12-06 provides guidance that the baseline assumptions have been established on the presumption that other than the loss of the ac power sources and normal access to the UHS, installed equipment that is designed to be robust with respect to design basis external events is assumed to be fully available. Installed equipment that is not robust is assumed to be unavailable. Below are the baseline assumptions for the availability of SSCs for core cooling during an ELAP caused by a BDBEE.

3.2.3.1.1 Plant SSCs

Core Cooling

Phase 1

The licensee states that the TDAFW pump (1 for each unit) automatically starts and delivers AFW flow to the SGs from the AFST for all events except a tornado missile event, or from the HCGS FPTs and diesel-driven fire pumps following a tornado missile event which damages the AFST and the other nearby tanks. In Section 2.3.4.1 of its FIP, the licensee states that the TDAFW pump is located in the auxiliary building, a structure protected from all applicable design-basis external events. Furthermore, the Salem UFSAR Section 10.4.7.2.2, Rev 21, states that the auxiliary feedwater pumps, piping, tanks and valves are Seismic Category I. Salem procedure S1(2).OP-FS.FLX-0007(Q), "Loss of Vital Instrumentation or Control Power," Rev 0, directs operators to manually control the TDAFW pump and feed control valves if necessary. The NRC staff finds that the TDAFW pump is robust and is expected to be available at the start of an ELAP event consistent with NEI 12-06, Section 3.2.1.3. As discussed in Section 3.14 below, the NRC staff concludes that there is sufficient separation distance between the Salem AFSTs and the HCGS FPTs that one of these is expected to survive a tornado event.

The licensee plans to vent steam from the SGs by manually controlling the SG power operated relief valves (PORVs) and perform a controlled cooldown. As described in the FIP Section 2.3.4.2 the PORVs are safety-related, missile-protected, and seismically-qualified valves. The PORVs will be controlled remotely from the control room using battery supplied control power in Phase 1 and the 480 Vac FLEX generators during Phase 2 and 3. Remote operation of the PORVs requires backup nitrogen provided by FLEX nitrogen supply bottles. The backup nitrogen bottles are located in the penetration areas which are robust for all applicable hazards. During the audit, the licensee provided Design Change Package 80110341, Supplement 10, "Miscellaneous Information," Rev 2, which determined the backup nitrogen bottles will last approximately 72 hours. The NRC staff finds that the PORVs are robust and are expected to be available at the start of an ELAP event consistent with NEI 12-06, Section 3.2.1.3. Further explanation and the NRC staff's evaluation of the robustness and availability of water sources for an ELAP event is discussed in Section 3.10 of this SE.

Phase 2

The licensee's Phase 2 core cooling strategy continues to use the SGs as the heat sink. Salem will continue to use the TDAFW pump as long as possible, and then transition to using a portable FLEX AFW pump with the discharge connected to the AFW system to send water to the SGs. The licensee does not plan to rely on any installed plant SSCs other than installed systems with FLEX connection points and water sources discussed in SE Sections 3.7 and 3.10, respectively.

Phase 3

The licensee's Phase 3 core cooling strategy initially relies on Phase 2 strategies with the NSRC equipment providing backup to the onsite FLEX equipment. The licensee is also planning to receive the mobile purification unit from the NSRC so they can provide purified water from the UHS after the cleaner onsite sources have been depleted. Once the NSRC equipment arrives on site, the licensee's Phase 3 core cooling FLEX strategy can use RHR cooling to provide an alternate method of core cooling.

RCS Makeup

Phase 1

The licensee's Phase 1 RCS inventory control FLEX strategy credits some passive injection from the nitrogen-pressurized SI accumulators which would occur as the RCS is depressurized below the accumulator cover gas pressure, and result in the addition of borated water to the RCS. As discussed in section 3.2.1.2.1 above, the licensee has determined that sufficient reactor coolant inventory would be available throughout Phase 1 to support heat transfer to the SGs via natural circulation without crediting the active injection of RCS makeup. Per the Salem UFSAR, the SI accumulators are located in the containment and are Seismic Category I, and are therefore robust considering the postulated hazards.

Phase 2

The licensee's Phase 2 RCS makeup strategy for Salem will use a FLEX charging pump and does not rely on any installed plant SSCs other than installed systems with FLEX connection points and borated water sources discussed in Sections 3.7 and 3.10 respectively.

Phase 3

The licensee's Phase 3 RCS inventory strategy for Salem does not rely on any additional installed plant SSCs other than those discussed in Phase 2. However, the licensee also has procedures to establish shutdown cooling using RHR cooling as described in the Core Cooling – Phase 3 Section above.

3.2.3.1.2 Plant Instrumentation

According to the licensee's FIP, the following instrumentation would be relied upon to support its core cooling and RCS inventory control strategy:

- RCS cold-leg temperature (T_{cold})
- RCS hot-leg temperature (T_{hot})
- core exit thermocouple (CETC) temperature
- RCS wide-range pressure
- accumulator pressure
- accumulator level
- Reactor Vessel Level Indicating System (RVLIS)
- SG water level (wide-range and narrow-range)
- SG pressure
- AFST level
- RWST level
- pressurizer level
- pressurizer pressure
- AFW pump suction and discharge pressures
- ex-core neutron instruments

The instrumentation available to support the licensee's strategies for core cooling and RCS inventory during the ELAP event is consistent with and in some cases exceeds the recommendations specified in the endorsed guidance of NEI 12-06.

These instruments are initially powered by inverters powered from the vital station batteries. In Phase 2, long-term power is established for these essential instruments by recharging station batteries from a FLEX DG. The primary monitoring strategy for all of these parameters is to obtain readings from the main control room. Alternatively, FLEX support guideline (FSG)-7, "Loss of Vital Instrumentation or Control Power," provides guidance for operators to locally read instruments using portable equipment. Based on this information provided by the licensee, the NRC staff understands that indication for the above instruments would be available and accessible continuously throughout the ELAP event.

3.2.3.2 Thermal-Hydraulic Analyses

The licensee concluded that its mitigating strategy for reactor core cooling would be adequate based in part on a generic thermal-hydraulic analysis performed for a reference Westinghouse four-loop reactor using the NOTRUMP computer code. The NOTRUMP code and corresponding evaluation model were originally submitted in the early 1980s as a method for performing licensing-basis safety analyses of small-break loss-of-coolant accidents (LOCAs) for Westinghouse PWRs. Although NOTRUMP has been approved for performing small-break LOCA analysis under the conservative Appendix K paradigm and constitutes the current evaluation model of record for many operating PWRs, the NRC staff had not previously examined its technical adequacy for performing best-estimate simulations of the ELAP event. Therefore, in support of mitigating strategy reviews to assess compliance with Order EA-12-049, the NRC staff evaluated licensees' thermal-hydraulic analyses, including a limited review of the significant assumptions and modeling capabilities of NOTRUMP and other thermal-hydraulic codes used for these analyses. The NRC staff's review included performing confirmatory analyses with the NRC's TRACE code to obtain an independent assessment of the duration that reference reactor designs could cope with an ELAP event prior to providing makeup to the RCS.

Based on its review, the NRC staff questioned whether NOTRUMP and other codes used to analyze ELAP scenarios for PWRs would provide reliable coping time predictions in the reflux or boiler-condenser cooling phase of the event because of challenges associated with modeling complex phenomena that could occur in this phase, including boric acid dilution in the intermediate leg loop seals, two-phase leakage through RCP seals, and primary-to-secondary heat transfer with two-phase flow in the RCS. Due to the challenge of resolving these issues within the compliance schedule specified in Order EA-12-049, the NRC staff requested that industry provide makeup to the RCS prior to entering the reflux or boiler-condenser cooling phase of an ELAP, such that reliance on thermal-hydraulic code predictions during this phase of the event would not be necessary.

Accordingly, the ELAP coping time prior to providing makeup to the RCS is limited to the duration over which the flow in the RCS remains in natural circulation, prior to the point where continued inventory loss results in a transition to the reflux or boiler-condenser cooling mode. In particular, for PWRs with inverted U-tube SGs (such as Salem), the reflux cooling mode is said to exist when vapor boiled off from the reactor core flows out the saturated, stratified RCS hot legs and condenses in the SG tubes, with the majority of the condensate subsequently draining back into the reactor vessel through the hot legs in countercurrent fashion. Quantitatively, as reflected in documents such as the PWR Owners Group (PWROG) report PWROG-14064-P, Revision 0, "Application of NOTRUMP Code Results for Westinghouse Designed PWRs in Extended Loss of AC Power Circumstances," industry has proposed defining this coping time as the point at which the 1-hour centered time-average of the flow quality passing over the SG tubes' U-bend exceeds one-tenth (0.1). As discussed further in Section 3.2.3.4 of this evaluation, a second metric for ensuring adequate coping time is associated with maintaining sufficient natural circulation flow in the RCS to support adequate mixing of boric acid.

With specific regard to NOTRUMP, preliminary results from the NRC staff's independent confirmatory analysis performed with the TRACE code indicated that the coping time for Westinghouse PWRs under ELAP conditions could be shorter than predicted in Westinghouse Commercial Atomic Power (WCAP)-17601-P, "Reactor Coolant System Response to the Extended Loss of AC Power Event for Westinghouse, Combustion Engineering and Babcock & Wilcox NSSS Designs." Subsequently, a series of additional simulations performed by the staff and Westinghouse identified that the discrepancy in predicted coping time could be attributed largely to differences in the modeling of RCP seal leakage. (The topic of RCP seal leakage will be discussed in greater detail in Section 3.2.3.3 of this SE.) These comparative simulations showed that when similar RCP seal leakage boundary conditions were applied, the coping time predictions of TRACE and NOTRUMP were in adequate agreement. From these simulations, as supplemented by review of key code models, the NRC staff obtained sufficient confidence that the NOTRUMP code may be used in conjunction with the WCAP-17601-P evaluation model for performing best-estimate simulations of ELAP coping time prior to reaching the reflux cooling mode.

Although the NRC staff obtained confidence that the NOTRUMP code is capable of performing best-estimate ELAP simulations prior to the initiation of reflux cooling using the one-tenth flow-quality criterion discussed above, the staff was unable to conclude that the generic analysis performed in WCAP-17601-P could be directly applied to all Westinghouse PWRs, as the vendor originally intended. In PWROG-14064-P, Revision 0, the industry subsequently

recognized that the generic analysis would need to be scaled to account for plant-specific variation in RCP seal leakage. However, the staff's review, supported by sensitivity analysis performed with the TRACE code, further identified that plant-to-plant variation in additional parameters, such as RCS cooldown terminus, accumulator pressure and liquid fraction, and initial RCS mass, could also result in substantial differences between the generically predicted reference coping time and the actual coping time that would exist for specific plants.

As identified in the licensee's FIP, Salem relies upon the analysis methodology documented in PWROG-14015 and PWROG-14027 for a Category 1 Westinghouse four-loop plant. The PWROG generic analysis methodology and results included use of the four-loop Westinghouse reference plant identified in WCAP-17601. However, the licensee noted that some Salem plant parameters were not fully bounded by the parameters assumed in the generic analysis; therefore, the time of 15.6 hours to enter reflux cooling, which was determined by PWROG-14027 for the reference four-loop Category 1 plant, could not be assumed to apply to Salem. The licensee therefore applied the mass-balance methodology described in PWROG-14027 with unit-specific parameters for Salem Unit 1. (The licensee demonstrated that the relevant plant parameters of Salem Unit 2 were in all cases identical to, or bounded by, those of Unit 1.) This calculation incorporated plant-specific values for RCP seal leakage, which, due to the installation of seal leakoff flow restricting orifices in the RCP seal leakoff lines, are less than the leakage rates assumed in PWROG-14027 for a Category 1 plant. Their analysis, documented in Technical Evaluation 80111831-220, concluded that the time to enter reflux cooling is approximately 17.4 hours for Salem Unit 1, and that 17.4 hours would bound the time for Unit 2 to enter reflux cooling.

The NRC staff noted that the time to enter reflux cooling determined in PWROG-14027-P did not consider the potential for increased leakage due to seal faceplate degradation that is expected to occur in an ELAP event due to the loss of seal cooling. This hydrothermal corrosion phenomenon is discussed in greater detail in the subsequent section of this evaluation. The NRC staff performed confirmatory calculations to determine the expected impact, and concluded that Unit 1 could be expected to enter reflux cooling at approximately 13.2 hours, in the absence of FLEX RCS injection. Given the significant margin between this figure and the planned time of 8 hours to commence RCS injection, the NRC staff concluded that the licensee's FLEX strategy would be effective in preventing the onset of reflux cooling.

Therefore, based on the evaluation above, the NRC staff concludes that the licensee's analytical approach should appropriately determine the sequence of events for reactor core cooling, including time-sensitive operator actions, and evaluate the required equipment to mitigate the analyzed ELAP event, including pump sizing and cooling water capacity.

3.2.3.3 Reactor Coolant Pump (RCP) Seals

Leakage from RCP seals is among the most significant factors in determining the duration that a PWR can cope with an ELAP event prior to initiating RCS makeup. An ELAP event would interrupt cooling to the RCP seals, resulting in the potential for increased seal leakage and the failure of elastomeric o-rings and other components, which could further increase the leakage rate. As discussed above, as long as adequate inventory is maintained in the RCS, natural circulation can effectively transfer residual heat from the reactor core to the SGs and limit local imbalances in boric acid concentration. Along with cooldown-induced shrinkage of the RCS

inventory, cumulative leakage from RCP seals governs the duration over which natural circulation can be maintained in the RCS. Furthermore, the seal leakage rate at the depressurized condition can be a controlling factor in determining the flow capacity requirement for FLEX pumps to offset ongoing RCS leakage and recover adequate system inventory.

All four Model 93A RCPs installed at each Salem unit use standard three-stage Westinghouse seal packages. In accordance with analysis and testing documented in WCAP-10541-P, Revision 2, "Westinghouse Owners Group Report, Reactor Coolant Pump Seal Performance Following a Loss of All AC Power," the ELAP analysis in WCAP-17601-P assumed a leakage rate at nominal post-trip cold leg conditions (i.e., 2250 pounds per square inch absolute (psia) and 550 °F) of 21 gpm for each of the four RCPs, plus an additional 1 gpm of operational leakage. In the WCAP-17601-P analysis, both seal and operational leakage were assumed to vary according to the critical flow correlation modeled in the NOTRUMP code as the reactor was cooled down and depressurized.

Subsequent assessments of RCP seal leakage behavior under ELAP conditions by industry analysts and NRC staff identified several issues with the original treatment of seal leakage from standard Westinghouse seal packages. These concerns are documented in Westinghouse Nuclear Safety Advisory Letter (NSAL) 14-1, dated February 10, 2014, including (1) the initial post-trip leakage rate of 21 gpm does not apply to all Westinghouse pressurized-water reactors due to variation in seal leakoff line hydraulic configurations, (2) seal leakage does not appear to decrease with pressure as rapidly as predicted by the analysis in WCAP-17601-P, and (3) some reactors may experience post-trip cold leg temperatures in excess of 550 °F, depending on the lowest main steam safety valve lift setpoint. To address these issues, the PWROG performed additional analytical calculations using Westinghouse's seal leakage model (i.e., ITCHSEAL). These calculations included (1) benchmarking calculations against data from RCP seal leakage testing and (2) additional generic calculations for several groups of plants (categorized by similarity of first-stage seal leakoff line design) to determine the maximum leakage rates as well as the maximum pressures that may be experienced in the first-stage seal leakoff line piping.

During the audit review, the licensee indicated that Salem is deriving their seal leakage assumptions from plant-specific RCP seal leakage calculations that have been performed by the PWROG. The generic PWROG calculations audited by the staff, including proprietary reports PWROG-14015, "No. 1 Seal Flow Rate for Westinghouse Reactor Coolant Pumps Following Loss of All AC Power," and PWROG-14027, "No. 1 Seal Flow Rate for Westinghouse Reactor Coolant Pumps Following Loss of All AC Power, Task 3: Evaluations of Revised Seal Flow Rate on Time to Enter Reflux Cooling and Time at which the Core Uncovers," classify Salem in the fourth generic analysis category (Category 4, i.e., rotameter type flow meter plants) specified in NSAL 14-1. As noted above, the generic analysis category definitions used in these reports were established based on the hydraulic characteristics of the first-stage seal leakoff line. However, the licensee has performed a modification to both Salem units that increases the resistance in the seal leakoff lines, which effectively transitions Salem to a Category 1 plant. The Salem-specific calculation, performed by Westinghouse using the ITCHSEAL and NEWKFAC codes, demonstrates that the No. 1 seal leakoff flow rates for Salem are bounded by the seal leakoff flow rates for the generic Category 1 plant assumed by PWROG-14027.

To further ensure that the generic Category 1 leakage rates are applicable to Salem, the NRC staff requested during the audit that the licensee confirm that applicable portions of the first-

stage seal leakoff line piping can withstand the maximum pressure experienced during an ELAP event. According to generic calculations performed by Westinghouse using the ITCHSEAL code, Category 1 plants would be expected to experience choked flow at the flow-measurement orifice in the first-stage seal leakoff line, even after completion of the initial RCS cooldown. Therefore, to support application of the generic Category 1 leakage rates, it is necessary for the licensee to demonstrate that a rupture in the pressure boundary of leakoff line piping or components upstream and inclusive of the flow orifice would not occur at Salem. During the audit, the licensee informed the NRC staff that the applicable portions of the leakoff line piping and components can tolerate pressures greater than or equal to RCS design pressure (i.e., 2500 psia). Thus, the licensee's analysis concluded that the functionality of the first-stage seal leakoff lines should not be challenged during an analyzed ELAP event and Category 1 leakage rates should be applicable to Salem.

In support of beyond-design-basis mitigating strategy reviews, the NRC staff performed an audit of the PWROG's generic effort to determine the expected seal leakage rates for Westinghouse RCPs under loss-of-seal-cooling conditions. A key audit issue was the capability of Westinghouse's ITCHSEAL code to reproduce measured seal leakage rates under representative conditions. Considering known testing and operational events according to their applicability to the thermal-hydraulic conditions associated with the analyzed ELAP event, the benchmarking effort focused on comparisons of ITCHSEAL simulations to data from WCAP-10541-P that documents an RCP seal leakage test performed in the mid-1980s at Électricité de France's Montereau facility. Comparisons of analytical results to the Montereau data indicated that, while the ITCHSEAL code could not simultaneously obtain good agreement with respect to RCS pressure, the leakage rate simulated by ITCHSEAL could be tuned to reproduce the measured seal leakage rate data. Subsequent to the benchmarking effort, data from an additional RCP seal leakage test at the Montereau facility that had not been documented in WCAP-10541-P was brought to the staff's attention. The leakage rate during this test was significantly higher than that of the test in WCAP-10541-P that had been used to benchmark the ITCHSEAL code. However, conservative margin was identified in the ITCHSEAL analyses (e.g., PWROG-14015-P, PWROG-14027-P), which the staff determined should offset the potential for increased leakage rates observed in the additional Montereau test.

In conjunction with the revised seal leakage analysis that Westinghouse performed for the first-stage seal, as described above, the PWROG's generic effort also sought to demonstrate that the second-stage seal will remain fully closed during the ELAP event. If the second-stage seal were to open, additional leakage past the second-stage seal could add to the first-stage seal leakoff line flow that has been considered in the licensee's evaluation. Previous calculations documented in WCAP-10541-P indicated that second-stage seal closure could be maintained under the set of station blackout conditions and associated assumptions analyzed therein. Recent calculations performed by Westinghouse and AREVA in support of PWR licensees' mitigating strategies indicated that both vendors also expected the second-stage seals essentially to remain closed throughout the ELAP event, even when the RCS is cooled down and depressurized in accordance with a typical strategy. Contrary to these analytical calculations, two recent RCP seal leakage tests performed as part of AREVA's seal development program (discussed further below) have indicated that the second-stage seals could open and remain open under ELAP conditions. This unexpected phenomenon occurred near the end of the tests and could not be fully understood and evaluated by the vendors or NRC staff, based upon the limited data available. While considering these limitations, the staff

observed that the opening of the second-stage seal did not appear to result in an increase in the total rate of leakage measured during the two AREVA tests.

On March 3, 2015, Westinghouse issued Technical Bulletin (TB) 15-1, "Reactor Coolant System Temperature and Pressure Limits for the No. 2 Reactor Coolant Pump Seal." Through TB 15-1, Westinghouse communicated to affected customers that long-term integrity of Westinghouse-designed second-stage RCP seals could not be supported by the available analysis, and recommended that affected plants execute an extended cooldown of the RCS to less than 350 °F and 400 psig by 24 hours into the ELAP event. Second-stage seal integrity appears necessary to ensure that leakage from Westinghouse-designed RCP seals can be limited to a rate that can be offset by the FLEX equipment typically available for RCS injection under ELAP conditions. The mitigating strategy documented in Salem's FIP satisfies Westinghouse's TB 15-1 guidance. The recommendation was amended by Revision 1 of TB 15-1, which was issued on August 29, 2016; Salem's strategy likewise satisfies the revised set of recommendations.

The seal leakoff analysis discussed above assumes no failure of the seal design, including the elastomeric o-rings. In some plant designs, such as those with no accumulator backing of the SG PORV actuators, the cold legs could experience temperatures as high as 580 °F before cooldown commences. This is beyond the 550 °F qualification temperature of 7228-B type o-rings used in RCP seals. During the audit review, the licensee noted the design changes at both units which installed high-pressure nitrogen bottles on each SG PORV. This robust backup nitrogen supply would permit operators to operate the SG PORVs automatically or manually from the main control room in the early minutes of an ELAP event, and thereby maintain RCS temperature within the qualification limits of the RCP o-rings. Therefore, the staff's audit review concluded that o-ring failure for Salem under analyzed ELAP event conditions would not be expected.

Licensee emergency operating procedures (EOPs) 1/2-EOP-LOPA-1, "Loss of All AC Power," Rev. 30, and 1/2-EOP-LOPA-4, "Extended Loss of All AC Power", Rev. 30, direct that, following the loss of seal cooling that results from the ELAP event, seal cooling would not be restored. The NRC staff considers this practice appropriate because it prevents thermal shock, which, as described in NRC Information Notice 2005-14, "Fire Protection Findings on Loss of Seal Cooling to Westinghouse Reactor Coolant Pumps," could lead to increased seal leakage.

In addition, the NRC staff audited information associated with the more recent RCP seal leakage testing performed by AREVA. The AREVA testing showed a gradual increase in the measured first-stage seal leakage rate, which post-test inspection and analysis tied to hydrothermal corrosion of silicon nitride (likely assisted by flow erosion). Silicon nitride ceramic is used to fabricate the first-stage seal faceplates currently in operation in Westinghouse-designed RCP seals. This material degradation phenomenon would not have been present in the Montereau testing because that test article's faceplates were fabricated from aluminum oxide (consistent with the seals of actual Westinghouse-designed RCPs of that era). However, hydrothermal corrosion of silicon nitride became an audit focus area because the test data indicated that the long-term seal leakage rate could exceed the values assumed in the licensee's analysis. Academic research reviewed by the industry and NRC staff associated with this general phenomenon indicated that the corrosion rate is temperature dependent.

From the limited information available regarding the recent AREVA tests, as well as several sensitivity calculations performed by the NRC staff during the audit, the NRC staff concluded that (1) the leakage rate for silicon-nitride RCP seals may be lower initially than had been predicted analytically by the PWROG's generic analysis using ITCHSEAL, (2) the RCP seal leakage rate during Phase 2 and/or Phase 3 of the ELAP event may increase beyond the long-term rate predicted analytically by the PWROG, and (3) certain aspects of the seal behavior observed in the AREVA tests did not appear consistent with the expected behavior based on models and theory that formed the basis for the WCAP and PWROG reports discussed above.

The licensee's FIP states that initiating RCS makeup no later than 8 hours would ensure that natural circulation can be maintained in the RCS. Each unit's initial RCS makeup flow capacity of 56 gpm exceeds the total rate of RCS leakage predicted by the PWROG's analysis following RCS depressurization, such that RCS inventory would begin to recover upon restoration of RCS makeup. However, in light of the potential for hydrothermal corrosion behavior, such as observed during the AREVA testing, the NRC staff determined that the mitigating strategy documented in the licensee's FIP could allow the RCP seal leakage rate to increase with time, potentially to the point of exceeding the available FLEX injection capacity. Due to the temperature-dependence of the hydrothermal corrosion reaction discussed above, the time and target temperature of the RCS cooldown have a significant impact on the long-term leakage rate from the RCP seals. At the time of developing the mitigating strategy documented in its FIP, the licensee was not fully aware of the influence of hydrothermal corrosion on the long-term seal leakage rate and had not specifically analyzed the potential impacts.

Therefore, during the audit the NRC staff performed confirmatory calculations that used empirical hydrothermal corrosion data to estimate the expected impact of faceplate degradation on the RCP seal leakage rate during the analyzed ELAP event. According to the staff's calculations for the cooldown profile described in the FIP, hydrothermal corrosion could result in greater RCS leakage for Salem than had been considered in the licensee's thermal-hydraulic analysis.

Based upon the current understanding of the hydrothermal corrosion phenomenon, the staff's calculations determined that reducing the RCS cold leg temperature below 350 °F by 21 hours into the event should be sufficient to terminate the hydrothermal corrosion reaction prior to the RCP seal leakage rate increasing beyond the long-term capability of Salem's FLEX RCS makeup strategy. Based on the licensee's timeline to add borated water to the RCS to establish shutdown margin, and to power the accumulator isolation valves from the FLEX generators and isolate the accumulators, the staff concludes that the licensee would be able to complete this second cooldown within 21 hours and thereby limit the hydrothermal corrosion of the #1 seal. As a result, the NRC staff concluded that the FLEX RCS makeup strategy for Salem should be capable of satisfying the requirement in Order EA-12-049 for indefinite coping.

Based upon the discussion above, the NRC staff concludes that the RCP seal leakage rates assumed in the licensee's thermal-hydraulic analysis may be applied to the beyond-design basis ELAP event for the site.

3.2.3.4 Shutdown Margin Analyses

In an analyzed ELAP event, the loss of electrical power to control rod drive mechanisms is assumed to result in an immediate reactor trip with the full insertion of all control rods into the core. The insertion of the control rods provides sufficient negative reactivity to achieve subcriticality at post-trip conditions. However, as the ELAP event progresses, the shutdown margin for PWRs is typically affected by several primary factors:

- the cooldown of the RCS and fuel rods adds positive reactivity
- the concentration of xenon-135, which (according to the core operating history assumed in NEI 12-06) would
  - initially increase above its equilibrium value following reactor trip, thereby adding negative reactivity
  - peak at roughly 12 hours post-trip and subsequently decay away gradually, thereby adding positive reactivity
- the passive injection of borated makeup from nitrogen-pressurized accumulators due to the depressurization of the RCS, which adds negative reactivity

At some point following the cooldown of the RCS, PWR licensees' mitigating strategies generally require active injection of borated coolant via FLEX equipment. In many cases, boration would become necessary to offset the gradual positive reactivity addition associated with the decay of xenon-135; but, in any event, borated makeup would eventually be required to offset ongoing RCS leakage. The necessary timing and volume of borated makeup depend on the particular magnitudes of the above factors for individual reactors and are determined by plant-specific analysis.

The specific values for these and other factors that could influence the core reactivity balance that are assumed in the licensee's current calculations could be affected by future changes to the core design. However, NEI 12-06, Section 11.8 states that "[e]xisting plant configuration control procedures will be modified to ensure that changes to the plant design ... will not adversely impact the approved FLEX strategies." Inasmuch as changes to the core design are changes to the plant design, the staff expects that any core design changes, such as those considered in a core reload analysis, will be evaluated to determine that they do not adversely impact the approved FLEX strategies, especially the analyses which demonstrate that recriticality will not occur during a FLEX RCS cooldown.

During the audit, the NRC staff reviewed the licensee's shutdown margin calculation. According to the FIP, borated water from the BASTs will be injected into the RCS no later than 8 hours into the event. The licensee's shutdown margin analysis conservatively determined that the injection of borated coolant should begin no later than 12 hours into the event to ensure that recriticality can be avoided as the core's xenon concentration decays away. The calculation of the time for initiating RCS boration was based upon an RCS temperature of 420 °F, which is the saturation temperature corresponding to the target SG pressure of the initial cooldown. The licensee further determined the required rate of injection to maintain the reactor subcritical by considering the boration rate necessary to counterbalance the rate of reactivity increase due to xenon decay. The licensee calculated that a FLEX RCS makeup rate of 40 gpm, in conjunction with RCS letdown via the reactor vessel head vent, would provide sufficient capacity to maintain

the reactor subcritical. The licensee's analysis considered several cases, the most restrictive case being conservative end of life (EOL) core conditions, with zero initial RCS boration, zero negative reactivity from core xenon, and no assumed RCS leakage. The licensee further calculated that a maximum of 7870 gallons of water from the BASTs or boric acid mixing tanks, borated to the nominal concentration of 6775 ppm, would be required to ensure long-term subcriticality at a conservatively low RCS temperature of 200 °F, and administrative controls ensure that this volume will remain valid for future core designs. This volume is within the combined minimum capacity of the BASTs, as supplemented by use of the boric acid mixing tanks (described in Section 3.2.1.2.2 of this SE).

Toward the end of an operating cycle, when the RCS boron concentration reaches its minimum value, some PWR licensees may need to vent the RCS to ensure that their FLEX strategies can inject a volume of borated coolant that is sufficient to satisfy shutdown margin requirements in cases where minimal RCS leakage occurs. During the audit, the licensee discussed Salem's capability to conduct RCS venting in the case that letdown from the RCS is necessary. The licensee stated that, in this case, operators would follow the direction of guideline FSG-8 to energize and open dc-powered reactor vessel upper head vent valves, which can be operated from the control room under ELAP conditions. The licensee indicated that the head vent path would be opened as required in response to high RCS pressure or pressurizer level, and closed again on indication of low pressurizer level or when operators have completed the required boron addition. As a backup to the reactor head vent path, operators can open a single pressurizer PORV to achieve the necessary letdown; use of a PORV in this way would only be done if the reactor vent valves were for some reason unavailable.

The NRC staff's audit review of the licensee's shutdown margin calculation further determined that credit was taken for uniform mixing of boric acid during the ELAP event. The NRC staff had previously requested that the industry provide additional information to justify that borated makeup would adequately mix with the RCS volume under natural circulation conditions potentially involving two-phase flow. In response, the PWROG submitted a position paper, dated August 15, 2013 (withheld from public disclosure due to proprietary content), which provided test data regarding boric acid mixing under single-phase natural circulation conditions and outlined applicability conditions intended to ensure that boric acid addition and mixing during an ELAP would occur under conditions similar to those for which boric acid mixing data is available. By letter dated January 8, 2014 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML13276A183), the NRC staff endorsed the above position paper with three conditions:

- The required timing and quantity of borated makeup should consider conditions with no RCS leakage and with the highest applicable leakage rate.
- Adequate borated makeup should be provided either (1) prior to the RCS natural circulation flow decreasing below the flow rate corresponding to single-phase natural circulation, or (2) if provided later, then the negative reactivity from the injected boric acid should not be credited until one hour after the flow rate in the RCS has been restored and maintained above the flow rate corresponding to single-phase natural circulation.
- A delay period adequate to allow the injected boric acid solution to mix with the RCS inventory should be accounted for when determining the required timing for borated

makeup. Provided that the flow in all loops is greater than or equal to the corresponding single-phase natural circulation flow rate, a mixing delay period of one hour is considered appropriate.

During the audit review, the licensee confirmed that Salem will comply with the August 15, 2013, position paper on boric acid mixing, including the conditions imposed in the staff's corresponding endorsement letter. The NRC staff verified that the licensee's analyses considered the appropriate range of RCS leakage rates. The NRC staff further confirmed that the licensee would provide RCS makeup prior to RCS loop flow decreasing below the single-phase natural circulation flow rate. Finally, the NRC staff also confirmed that the licensee's calculations adequately incorporated a one-hour delay to account for the mixing time of boric acid in the RCS.

Finally, the NRC staff's audit identified that, while the licensee's analyses demonstrate adequate shutdown margin for an RCS average temperature as low as 200 °F, the licensee may further cool the RCS to cold shutdown conditions. As a result, maintaining adequate shutdown margin would require the injection of additional boron into the RCS prior to reducing RCS average temperature below 200 °F. The staff's audit identified that the reactivity impacts of the additional cooldown to cold shutdown conditions had not been explicitly analyzed by the licensee. However, considering the time duration available prior to completing the additional cooldown, the NRC staff expects that (1) sufficient equipment (i.e., including both onsite and NSRC-supplied equipment, such as mobile boration units) and supplies of powdered boric acid should be available to prepare the required borated water, (2) sufficient time should be available to vent the RCS, if necessary, to allow injection of the volume of borated water required to ensure adequate shutdown margin, and (3) sufficient time should be available for the licensee's technical support personnel to determine the boron concentration required to ensure adequate shutdown margin.

Therefore, based on the evaluation above, the NRC staff concludes that the sequence of events in the proposed mitigating strategy should result in acceptable shutdown margin for the analyzed ELAP event.

3.2.3.5 FLEX Pumps and Water Supplies

The licensee relies on three different portable pumps during Phase 2. The licensee plans to use a 460 Vac motor-driven centrifugal FLEX AFW pump (one per unit) to feed the SGs if the TDAFW pump can no longer be used. Also, the licensee plans to use a 460 Vac motor-driven positive-displacement FLEX charging pump (one per unit) to provide high pressure, low flow RCS makeup from the BASTs, a portable boric acid mixing tank, or the RWST. The licensee also relies on a diesel-driven centrifugal FLEX SW pump (one pump serves both units) to provide water from the Delaware River (the UHS) to the suction of the TDAFW pumps, the FLEX AFW pumps, the FLEX charging pumps, or directly to the SFP, via the nuclear service water header. Lastly, during a flood scenario, the licensee uses a 460 Vac motor-driven FLEX submersible pump (one pump per unit, with one spare pump per unit) to supply water from the flooded turbine building. The FLEX AFW pumps and FLEX charging pumps are stored on the 84 foot elevation of the auxiliary building, and are moved into their operating location on that level when they are needed. The FLEX SW pumps are stored in outdoor storage locations. The FLEX submersible pumps are stored in the turbine building or in locations such that they

can be placed in the turbine building prior to the arrival of a hurricane storm surge at the site. In Section 2.3.9 of its FIP, the licensee identified the performance criteria (e.g., flow rate, discharge pressure) for the Phase 2 portable pumps. See Section 3.10 for a detailed discussion of the availability and robustness of each water source.

During Phase 2, SG makeup will be transferred to a FLEX AFW pump when the TDAFW pump is no longer available. The FLEX AFW pump will take suction from the AFST preferably, or any other available, purified water source, or as a last resort from the discharge of the FLEX SW pump, which is a robust source of water from Delaware Bay, but with significant salt content which can degrade the SGs over time. A single FLEX AFW pump provides full capability to feed all steam generators for one unit. In the FIP, Section 2.3.9.1 states that the FLEX AFW pump is nominally rated at 350 gpm at 380 pounds per square inch differential. The licensee performed calculation S-C-FLX-MDC-2338, "FLEX Hydraulic Analysis," Rev 0, to determine the fluid system hydraulic performance using the PROTO-FLO software package. The NRC staff noted that this calculation assessed different possible lineups based on such variables as suction sources, connection points and hose paths to determine the flow to ensure that the FLEX AFW pumps procured by the licensee would be adequate for providing injection into the SGs at the required flow rate and discharge pressure.

Additionally, the licensee relies on a FLEX charging pump to provide high pressure, low flow RCS makeup. The FLEX charging pumps are portable, motor-driven positive-displacement pumps that can provide 56 gpm at a discharge pressure of 1600 psi. The licensee calculation S-C-FLEX-MDC-2338 described above determined the FLEX charging pump fluid system hydraulic performance. This calculation assessed different possible lineups based on such variables as suction sources, connection points and hose paths to determine the flow to ensure that the FLEX charging pump would be adequate for providing injection into the RCS at the required flow rate and discharge pressure.

The licensee relies on a FLEX SW pump to provide water for long term AFW, SFP and possibly RCS makeup. The licensee relies on one FLEX SW pump for both units and the licensee has three pumps onsite, one for Salem, one for HCGS, and one to satisfy the NEI 12-06 guidance to have a spare (N+1). Section 2.3.9.3 of the FIP states that a FLEX SW pump can provide 1500 gpm (350 gpm AFW flow, 112 gpm for the RCS, and 500 gpm for the SFP). The calculation S-C-FLEX-MDC-2338 also analyzed the FLEX SW pump and found the pump would be able to provide the flow described above with at least 147 psia discharge pressure. The hydraulic model takes into account suction sources, different lineups and the manufacturer's capacity curves.

The last portable pump the licensee relies on is a FLEX submersible pump, one for each unit, which is only used in a flooding scenario. A spare submersible pump is also provided for each unit. When notified of the potential for flooding from storm surge, the licensee verifies that the submersible pumps are prestaged in the turbine buildings. The licensee uses this pump as a booster pump to supply the TDAFW pump, the FLEX AFW pump, or the FLEX charging pump. The submersible pumps are powered by the FLEX DGs in the canyon area and take a suction from the turbine building floor during a flooding scenario. The same calculation, S-C-FLEX-MDC-2338 determined the flow characteristics required and verified the purchased pumps were sufficient to provide the required flow. Section 2.3.2 states that the FLEX submersible pumps can provide 350 gpm at 43.3 psig.

The staff confirmed that flow rates and pressures evaluated in the hydraulic analyses were reflected in the FIP for the respective SG and RCS makeup strategies based upon the above FLEX pumps and the respective FLEX connections being made as directed by the FSGs. During the onsite audit, the staff conducted a walk down of the hose deployment routes for the above FLEX pumps to confirm the evaluations of the pump staging locations, hose distance runs, and connection points as described in the above hydraulic analyses and FIP. Also, the NRC staff noted that the performance criteria for the FLEX Phase 3 NSRC pumps are consistent with the FLEX Phase 2 portable pumps capacities.

Based on the staff's review of the FLEX pumping capabilities at Salem, as described in the above hydraulic analyses and the FIP, the licensee has demonstrated that its FLEX pumps should perform as intended to support core cooling and RCS makeup during an ELAP caused by an external event, consistent with NEI 12-06, Section 11.2.

3.2.3.6 Electrical Analyses

The licensee's electrical strategies in the Salem FIP provide power to the equipment and instrumentation used to mitigate the ELAP and LUHS. The electrical strategies described in the FIP are practically identical for maintaining or restoring core cooling, containment, and SFP cooling, except as noted in Sections 3.3.4.4 and 3.4.4.4 of this SE.

The NRC staff reviewed the licensee's FIP conceptual electrical single-line diagrams and summary of calculations for sizing the FLEX generators and station batteries. The staff also reviewed the licensee's evaluations that addressed the effects of temperature on the electrical equipment credited in the FIP as a result of the loss of heating, ventilation, and air conditioning (HVAC) caused by the event.

According to the licensee's FIP, operators would declare an ELAP following a loss of offsite power, loss of all emergency diesel generators, and the loss of any alternate alternating current (ac) power. The plant's indefinite coping capability is attained through the implementation of pre-determined FLEX strategies that are focused on maintaining or restoring key plant safety functions. A safety function-based approach provides consistency with, and allows coordination with, existing plant emergency operating procedures (EOPs). The FLEX strategies are implemented in support of EOPs using FLEX Support Guidelines (FSGs).

During the first phase of the ELAP event, Salem strategy would rely on Class 1E station batteries and inverters to provide power to key instrumentation for monitoring parameters and power to controls for SSCs used to maintain the key safety functions (reactor core cooling, containment, and SFP cooling). The Salem Class 1E station batteries, inverters and associated direct current (dc) distribution systems are located within the auxiliary building which is a Seismic Class I structure. These components are considered robust and protected with respect to applicable site external hazards since they are located within safety-related, Seismic Class I structures.

The Salem strategy relies on the safety-related batteries to initially power required key instrumentation and other required loads. Licensee procedures S1.OP-AB.LOOP-0001, "Loss of Off-Site Power," Revision 31, S2.OP-AB.LOOP-0001, "Loss of Off-Site Power," Revision 30,

1/2-EOPLOPA-1, "Loss of All AC Power," Revision 30, and FSG S1/S2 OP-FS.FLX-0004, "ELAP DC Bus Load Shed Management," Revision 0 (FSG-4), direct operators to take actions to prolong battery service time by stripping non-essential loads and to deploy FLEX equipment for plant recovery. In accordance with the FIP Table 3, "Sequence of Events Timeline," and procedure S1/S2.OP-AB.LOOP-0001, plant operators would commence load shedding within 10 minutes on 125 Volts direct current (Vdc) buses and complete it within 30 minutes after the onset of an ELAP/LUHS event. The licensee would perform a second load shed to strip additional non-essential loads on the 125 Vdc and 28 Vdc buses that would be completed within 2.5 hours into an ELAP event in accordance with guideline FSG-4. The load shedding would extend the battery service time to at least 6 hours.

Salem Units 1 and 2 each have three independent Class 1E 125 Vdc station batteries to supply power to the vital instruments and control power. Salem 125 Vdc Class 1E station batteries contain 60 cells each and were manufactured by C&D Technologies. They are model LCR-33 (2320 ampere – hour (A-H) capacity). In addition, each unit has two independent Class 1E 28 Vdc batteries containing 13 cells each, manufactured by C&D Technologies. They are model KCR-21 (800 A-H). The 28 Vdc batteries supply power to the main control room console.

In its FIP, the licensee stated that the Class 1E battery duty cycle of at least 6 hours was calculated in accordance with the Institute of Electrical and Electronic Engineers (IEEE) Standard 485-2010, "IEEE Recommended Practice for Sizing Lead-Acid Batteries for Stationary Applications," methodology using manufacturer discharge test data applicable to the FLEX strategy.

The NRC staff reviewed the summary of the licensee's dc system calculations ES-4.008, "125VDC Beyond Design Basis Event Battery Sizing Calculation," Revision 0, and ES-3.005, "28VDC Beyond Design Basis Event Battery Sizing Calculation," Revision 0, to verify the capacity of the dc system to supply power to the required loads during the first phase of the Salem FLEX mitigation strategies plan. In the calculations, the licensee identified the required loads, their associated ratings (amperes and minimum required voltage) and the loads that would be stripped within 2.5 hours to ensure battery operation lasts at least 6.0 hours. This strategy provides sufficient margin to transition to Phase 2 as the licensee expects the pre-staged Phase 2 FLEX DG to start powering the battery chargers within 6 hours after onset of an ELAP event and prior to batteries depleting to their minimum acceptable voltage. Based on the evaluation above, the NRC staff concludes that the licensee's load shedding strategy is adequate to ensure that the safety-related batteries will be available to supply power to the required loads until the Phase 2 equipment is aligned.

The licensee's Phase 2 strategy includes re-powering the battery chargers within 6 hours to maintain availability of instrumentation to monitor key parameters. Prior to the depletion of the 125 Vdc and 28 Vdc Class 1E station batteries, operators would repower the safety-related battery chargers using pre-staged 480 Vac, 600 kilowatt (kW) FLEX DGs. In its FIP, the licensee stated that three 480 Vac, 600 kW DGs are required to provide the FLEX power for both units. A total of four DGs are available onsite (one is a spare). Two of the four FLEX DGs (FLXE8 and FLXE9) are pre-staged in the Unit 2 canyon area while the remaining two (FLXE10 and FLXE11) are stored in diverse outdoor FLEX storage areas (OFSAs). Following an ELAP from any BDBEE other than a hurricane-induced flood, one of the two stored FLEX DGs would be moved from its outdoor storage location and deployed to the Unit 2 canyon area to provide

power to the FLEX 480 Vac motor control centers (MCCs). In the event that a flood from a hurricane is predicted, both of the two stored portable DGs will be moved to the Unit 2 canyon area which will be flood protected by construction of a watertight wall at the entrance to the canyon.

If one of the two pre-staged FLEX DGs becomes unavailable, the spare portable DG would be deployed to the canyon area and operated to supply the required loads. Guideline S1/S2.OP-FS.FLX-0005, "Initial Assessment and FLEX Equipment Staging," Revision 0, (FSG-5) provides operational guidance to the operators for the replacement 480 Vac DG. All Phase 2 DGs are electrically equivalent to each other, thus ensuring electrical compatibility and sufficient electrical capacity in an instance where substitution is required. Since all four FLEX DGs are electrically equivalent to each other, the NRC staff finds that the licensee has met the intent of NEI 12-06, Section 3.2.2, to have a spare generator (N+1) capable of substituting for a required generator.

In the licensee's design analysis ES-15.019, "FLEX Electrical System Analysis -Salem 1 & 2," Revision 1, the licensee stated that Salem will use 480 Vac, 600 kW, 0.8 power factor, trailer-mounted DGs to power the required Phase 2 loads for each unit. In the calculation (ES-15.019) the licensee determined that one 600 kW DG for each unit will supply an estimated total load of 515 kW for Unit 1 and 482 kW for Unit 2 while having adequate capacity to start the largest load (a 200 horsepower FLEX AFW pump). A steady-state margin of 85 kW for the Unit 1 DG and 118 kW for the Unit 2 DG will be available to power other loads, if necessary. One Phase 2 DG will supply power to a 750 kilovolt Ampere (kVA), 480-240 Vac, three phase transformer connected to a 240 Vac FLEX MCC common to both units. The total estimated loads that this DG would supply is 465 kW while supplying both Salem units. A steady-state margin of 135 kW will be available for the DG to power other loads, if necessary. The licensee also identified cautions and limitations on simultaneous starting of loads and other loading limitations on the Phase 2 FLEX DGs in the calculation (ES-15.019).

In its FIP, the licensee stated that the FLEX DGs pre-staged in the canyon area are not vulnerable to an external flooding event other than from a hurricane-driven storm surge event. A hurricane event is assumed to have greater than 48 hours of warning time and flooding is expected to persist above site grade for approximately 11 hours. As such, Salem plans to deploy the two DGs in outside storage to the canyon area (which already has two pre-staged DGs) and flood-protect all four FLEX DGs within the canyon area after a hurricane event that meets specified criteria is predicted and before the hurricane reaches Salem. Flood protection will be accomplished by the erection of a 16 foot high temporary flood barrier at the open end of the canyon area. Once the flood barrier is erected, the four FLEX DGs deployed in the canyon area, which includes the N+1 FLEX DG, will not be vulnerable to an external flooding event. Pumps to remove accumulated rainwater during the hurricane event will be located in the canyon area and will be powered by a FLEX DG or station power (if available).

The NRC staff reviewed calculations, single line electrical diagrams, the separation and isolation of the FLEX DGs from the Class 1E EDGs, and procedures that direct operators how to align, deploy, connect, and protect associated systems and components. Guideline FSG-5 provides guidance on how to deploy, connect, and energize loads from the FLEX DGs that will ensure that critical plant instruments and other required equipment continue to be powered during an

ELAP event. Based on the above, the NRC staff concludes that the Phase 2 FLEX DGs should have adequate capacity to power the loads required for the analyzed ELAP event.

For Phase 3, the licensee plans to continue the Phase 2 coping strategy with additional assistance provided from offsite equipment/resources as needed. The offsite resources that will be provided by an NSRC includes two (per unit) 1-megawatt (MW), 4160 Vac CTGs, one (per unit) 1100 kW, 480 Vac CTG, distribution panels, cables etc. In its FIP, the licensee stated that the Phase 3 strategy relies on two NSRC-supplied 4160 Vac CTGs running in parallel that will be connected to an NSRC-supplied 4160 Vac switchgear. Two 1-MW CTGs running in parallel per unit will provide approximately 2 MW of power for each unit. The 4160 Vac CTGs would be used to restore systems to establish decay heat removal. In calculation ES-15.019, the licensee determined that the expected loading on the two 4160 Vac CTGs running in parallel will be 1,871 kW (for Unit 1) and 1,851 kW (for Unit 2). The calculation also showed that the paralleled 4160 Vac CTGs have adequate capacity to start the largest load (a 400 horsepower RHR pump) with a steady state margin of 129 kW (for Unit 1) and 142 kW (for Unit 2) available for other loads, if necessary. In the calculation (ES-15.019), the licensee determined that if one of the two 4160 Vac CTGs fails, then the expected loading on one 4160 Vac CTG would be 919 kW (for Unit 1) and 910 kW (for Unit 2). The single 4160 Vac CTG has adequate capacity to only start a 300 horsepower CCW pump. Based on its review of the summary of the licensee's calculation, the NRC staff finds that the 4160 Vac equipment being supplied from an NSRC should have sufficient capacity and capability to supply the required loads.

Based on its review, the NRC staff finds that the plant batteries used in the strategy should have sufficient capacity to support the licensee's strategy, and that the FLEX DGs and CTGs that the licensee plans to use should have sufficient capacity and capability to supply the necessary loads during an ELAP event.

3.2.4 Conclusions

Based on this evaluation, the NRC staff concludes that the licensee has developed guidance that should maintain or restore core cooling and RCS inventory during an ELAP event consistent with NEI 12-06 guidance, as endorsed by JLD-ISG-2012-01, and should adequately address the requirements of the order.

3.3 Spent Fuel Pool Cooling Strategies

In NEI 12-06, Table 3-2 and Appendix D summarize an acceptable approach consisting of three separate capabilities for the SFP cooling strategies. This approach uses a portable injection source to provide the capability for 1) makeup via hoses on the refueling floor capable of exceeding the boil-off rate for the design basis heat load; 2) makeup via connection to spent fuel pool cooling piping or other alternate location capable of exceeding the boil-off rate for the design basis heat load; and 3) spray via portable monitor nozzles from the refueling floor using a portable pump capable of providing a minimum of 200 gpm per unit (250 gpm if overspray occurs). During the event, the licensee selects the SFP makeup method to use based on plant conditions. This approach also requires a strategy to mitigate the effects of steam from the SFP, such as venting.

As described in NEI 12-06, Section 3.2.1.7, and JLD-ISG-2012-01, Section 2.1, strategies that must be completed within a certain period of time should be identified and a basis that the time can be reasonably met should be provided. In NEI 12-06, Section 3 provides the performance attributes, general criteria, and baseline assumptions to be used in developing the technical basis for the time constraints. Since the event is beyond design basis, the analysis used to provide the technical basis for time constraints for the mitigation strategies may use nominal initial values (without uncertainties) for plant parameters, and best-estimate physics data. All equipment used for consequence mitigation may be assumed to operate at nominal setpoints and capacities. NEI 12-06, Section 3.2.1.2 describes the initial plant conditions for the at-power mode of operation; Section 3.2.1.3 describes the initial conditions; and Section 3.2.1.6 describes SFP initial conditions.

In NEI 12-06, Section 3.2.1.1 provides the acceptance criterion for the analyses serving as the technical basis for establishing the time constraints for the baseline coping capabilities to maintain SFP cooling. This criterion is keeping the fuel in the SFP covered with water.

The ELAP causes a loss of cooling in the SFP. As a result, the pool water will heat up and eventually boil off. The licensee's response is to provide makeup water. The timing of operator actions and the required makeup rates depend on the decay heat level of the fuel assemblies in the SFP. The sections below address the response during operating, pre-fuel transfer or post-fuel transfer operations. The effects of an ELAP with full core offload to the SFP is addressed in Section 3.11.

3.3.1 Phase 1

The licensee stated in its FIP that no actions are required during ELAP Phase 1 for SFP makeup because the time to boil is sufficient to enable deployment of Phase 2 equipment. The licensee will monitor SFP water level using reliable SFP level instrumentation installed per Order EA-12-051 and evaluated in section 4 of this SE.

3.3.2 Phase 2

During Phase 2, FIP Section 2.4.2 states that operators will deploy a portable pump (either the FLEX SW pump or FLEX AFW pump) to supply water from the any of the available onsite tanks or the UHS to the SFP. Either pump discharge can be routed to a connection to the SFP cooling system (not requiring refueling floor access), or connected to the portable SFP spray header.

3.3.3 Phase 3

The licensee will be able to repower the SFP cooling system using the NSRC 4160 Vac generators to reenergize vital 4160 Vac buses in each unit.

3.3.4 Staff Evaluations

3.3.4.1 Availability of Structures, Systems, and Components

3.3.4.1.1 Plant SSCs

Condition 6 of NEI 12-06, Section 3.2.1.3, states that permanent plant equipment contained in structures with designs that are robust with respect to seismic events, floods, and high winds, and associated missiles, are available. In addition, Section 3.2.1.6 states that the initial SFP conditions are: 1) all boundaries of the SFP are intact, including the liner, gates, transfer canals, etc., 2) 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 and 3) SFP cooling system is intact, including attached piping.

The staff reviewed the licensee's calculation on habitability on the SFP refuel floor. This calculation and the FIP indicate that boiling begins at approximately 6 hours during a normal, non-outage situation. The staff noted that the licensee's sequence of events timeline in the FIP indicates that operators will deploy hoses and spray nozzles as a contingency for SFP makeup within 3 hours from event initiation to ensure the SFP area remains habitable for personnel entry.

As described in the licensee's FIP, the licensee's Phase 1 SFP cooling strategy does not require any operator actions. However, the licensee does establish a ventilation path to cope with temperature, humidity and condensation from evaporation and/or boiling of the SFP. The operators are directed to use a FLEX 460 Vac generator to repower the 11 and 21 Fuel Handling Building exhaust fans.

The licensee's Phase 2 SFP cooling strategy involves the use of the FLEX SW or AFW pump, with suction from any available tank or the UHS, to supply water to the SFP. The staff's evaluation of the robustness and availability of FLEX connections points for the FLEX pump is discussed in Section 3.7.3.1 below. Furthermore, the staff's evaluation of the robustness and availability of the UHS for an ELAP event is discussed in Section 3.10.3.

3.3.4.1.2 Plant Instrumentation

In its FIP, the licensee stated that the instrumentation for SFP level will meet the requirements of Order EA-12-051. Furthermore, the licensee stated that these instruments will have initial local battery power with the capability to be powered from the FLEX DGs. The NRC staff's review of the SFP level instrumentation, including the primary and back-up channels, the display to monitor the SFP water level and environmental qualifications to operate reliably for an extended period are discussed in Section 4 of this SE.

3.3.4.2 Thermal-Hydraulic Analyses

As described in plant evaluation 80105702-0010, "IER 11-4 Reponses for Loss of SFP Cooling," the SFP will boil in approximately 6 hours and boil off to a level 10 feet above the top of fuel about 27 hours from initiation of the event with no operator action at the maximum design heat load.

Evaluation 80105702-0010 states that the bounding scenario analyzed is the maximum normal/emergency refueling heat load which includes a full core offload. The heat load, boil-off times, and makeup rates can be found in the table below.

	Heat Load	Time to boil to top of fuel	Makeup rate
Full Core Offload	45 million Btu/hr	44 hrs	95.5 gpm

Therefore, the licensee conservatively determined that a SFP makeup flow rate of 100 gpm will maintain adequate SFP level above the fuel for an ELAP occurring during normal power operation. Consistent with the guidance in NEI 12-06, Section 3.2.1.6, the staff finds the licensee has considered the maximum design-basis SFP heat load.

3.3.4.3 FLEX Pumps and Water Supplies

As described in the FIP, the SFP cooling strategy relies on either the FLEX SW or FLEX AFW pump to provide SFP makeup during Phase 2. In the FIP, section 2.3.9 describes the hydraulic performance criteria (e.g., flow rate, discharge pressure) for the FLEX pumps. The staff noted that the performance criteria of a FLEX pump supplied from an NSRC for Phase 3 would allow the NSRC pump to fulfill the mission of the onsite FLEX pump if the onsite FLEX pump were to fail. The SFP spray rate of 500 gpm exceeds the maximum SFP makeup requirements as outlined in the previous section of this SE.

3.3.4.4 Electrical Analyses

The licensee's basic FLEX strategy for maintaining SFP cooling is to monitor the SFP level and provide makeup water to the SFP sufficient to maintain substantial radiation shielding for a person standing on the SFP refueling floor and provide for cooling for the spent fuel due to boil-off of the water.

The licensee will monitor SFP level in all three phases by instrumentation installed in response to the NRC Order EA-12-051. The SFP level instruments are powered by Class 1E vital instrument buses, which are fed from uninterruptible power supply (UPS) backed inverters that are to be re-powered by FLEX DGs in the event of an ELAP. In addition, the dedicated, replaceable battery backup for the level instruments provides power for seven days of operation in minimum power mode, providing sufficient capacity to support instrument channel operation by battery power until FLEX equipment can reenergize the normal power supply.

The staff performed a comprehensive analysis of the licensee's electrical strategies, which includes the SFP makeup and cooling strategy. In its FIP, the licensee stated that the Phase 1 coping strategy for SFP cooling is to monitor SFP level using instruments installed as required by NRC Order EA-12-051 (the capability of this instrumentation is described in Section 4 of this SE). The licensee's Phase 2 SFP cooling strategy (besides the monitoring of SFP level) relies on the Phase 2 DGs to support the SFP makeup function of the motor-driven FLEX AFW pump. The licensee's Phase 3 SFP cooling strategy (besides the monitoring of SFP level) relies on two NSRC CTGs (per unit) operated in parallel to repower the 'B' 4160 Vac bus to supply power to the component cooling system and a SFP pump for SFP cooling functions.

The NRC staff reviewed the licensee analyses of the capacity and capability of Phase 2 FLEX DGs and the Phase 3 4160 Vac CTGs in Section 3.2.3.6 of this SE. Based on its review, the NRC staff finds that the Phase 2 DGs and Phase 3 CTGs are appropriately sized to support the licensee's FLEX strategies.

3.3.5 Conclusions

Based on this evaluation, the NRC staff concludes that the licensee has developed guidance that if implemented appropriately should maintain or restore SFP cooling following an ELAP consistent with NEI 12-06 guidance as endorsed by JLD-ISG-2012-01, and should adequately address the requirements of the order.

3.4 Containment Function Strategies

The industry guidance document, NEI 12-06, Table 3-2, provides some examples of acceptable approaches for demonstrating the baseline capability of the containment strategies to effectively maintain containment functions during all phases of an ELAP event. One such approach is for a licensee to perform an analysis demonstrating that containment pressure control is not challenged. The Salem units each have a dry ambient pressure containment.

The licensee performed several containment technical evaluations, including Technical Evaluation 80111831-0041, "MODE 1-4 MAAP Results – Westinghouse Flow Orifice Assessment Incorporated," which were based on the boundary conditions described in Section 2 of NEI 12-06. The calculation analyzed the strategy of monitoring containment parameters and concluded that the containment parameters of pressure and temperature remain well below the respective UFSAR Section 6.2 design limits of 47 psig and 271 °F for more than 96 hours. From its review of the evaluation, the NRC staff noted that the required actions to maintain containment integrity and required instrumentation functions have been developed, and are summarized below.

Eventual containment cooling and depressurization to normal values may utilize off-site equipment and resources during Phase 3 if onsite capability is not restored.

3.4.1 Phase 1

The Phase 1 coping strategy for containment involves verifying containment isolation and monitoring containment parameters using installed instrumentation. Emergency operating procedure 1/2-EOP-LOPA-4, "Extended Loss of All AC Power," provides guidance.

3.4.2 Phase 2

During Phase 2, the licensee continues monitoring containment parameters, as is done in Phase 1.

3.4.3 Phase 3

During Phase 3, the licensee continues monitoring containment parameters, as is done in Phase 1.

If required, Phase 3 containment cooling strategy relies on NSRC-provided generators to power a safeguards electrical bus. The installed containment fan coil units can be repowered from the safeguards bus. Cooling water to the fan coil unit cooler may be provided by the plant service

water system repowered from the safeguards bus, or the service water header may be pressurized by the NSRC-supplied high-capacity FLEX service water pumps or the plant FLEX service water pump.

3.4.4 Staff Evaluations

3.4.4.1 Availability of Structures, Systems, and Components

NEI 12-06 baseline assumptions have been established on the presumption that other than the loss of the ac power sources and normal access to the UHS, installed equipment that is designed to be robust with respect to design-basis external events is assumed to be fully available. Installed equipment that is not robust is assumed to be unavailable. Below are the baseline assumptions for the availability of SSCs for maintaining containment functions during an ELAP.

3.4.4.1.1 Plant SSCs

Reactor Containment

The reactor containment structure completely encloses the entire RCS and ensures that post-accident leakage from the containment is limited to a safe rate of 0.1 percent of the containment free volume per day at the design pressure of 47 psig. The reactor containment structure is a reinforced concrete vertical right cylinder with a flat base and a hemispherical dome. A welded steel liner with a minimum thickness of 1/4 inch is attached to the inside face of the concrete shell to ensure a high degree of leak tightness. The containment has a net free volume of 2,620,000 cubic feet. The design objective of the containment structure is to contain all radioactive material which might be released from the core following a loss-of-coolant accident (LOCA). The containment is a Seismic Category I structure designed to function during and after a safe shutdown earthquake. The structure serves as both a biological shield and a pressure container.

Containment Fan Coil Units

The containment fan coil units are part of the containment cooling system described in UFSAR Section 6.2.2.2. The containment cooling system is designed to recirculate and cool the containment atmosphere in the event of a LOCA and thereby ensure that the containment pressure will not exceed its design value of 47 psig at 271 °F (100-percent relative humidity). The cooling water requirements for the fan coil units during a LOCA and recovery are supplied by the service water system. The fan motor enclosures, electrical insulation, and bearings are designed for operation during accident conditions. Individual system components and their supports meet the requirement for Seismic Class I structures and are isolated from fan vibration.

Service Water System

The service water system (SWS) is described in USFAR Section 9.2.1. It is designed to supply an adequate supply of cooling water to the reactor safeguards and auxiliary equipment under all credible seismic, flood, drought, and storm conditions. The SWS is designed for Seismic Class I conditions except for the turbine area service water piping outside of the service water

intake structure, which is of non-Class I design. The Seismic Class I service water piping inside the service water intake structure which supplies the turbine area is provided with two motor-operated valves in series, to isolate the non-Class I portion of the system upon receipt of a SI signal or a loss of offsite power. The motor-operated valves can be closed locally if ac power is not available.

3.4.4.1.2 Plant Instrumentation

In NEI 12-06, Table 3-2 specifies that containment pressure is a key containment parameter which should be monitored by repowering the appropriate instruments. The licensee's FIP states that control room instrumentation would be available due to the coping capability of the station batteries and associated inverters in Phase 1, or the portable FLEX DGs deployed in Phase 2. If no ac or dc power was available, the FIP states that key credited plant parameters, including containment pressure, would be available using alternate methods.

Containment pressure indication is available in the main control room (MCR) throughout the event under all postulated environmental conditions. Should containment pressure indication be lost, alternate monitoring will be established per guideline S1/S2.OP-FS.FLX-0007, "Loss of Vital Instrumentation or Control Power" (FSG-7).

3.4.4.2 Thermal-Hydraulic Analyses

Technical Evaluation 80111831-0041 used the Modular Accident Analysis Program (MAAP) Version 4 computer program to determine the temperature and pressure response in the containment in various operating modes during an ELAP.

The technical evaluation for Modes 1-4 assumed all containment fan coil units de-energized at onset of the event (T=0 hours). The RCS cooldown is initiated at T=2 hours. Peak RCP seal leakage is 21 gpm. The evaluation stated the containment pressure will gradually increase to 2.25 psig with a temperature of roughly 142 °F at T=96 hours when it was assumed a containment fan coil unit could be placed in service. The containment remains below the design parameters of 47 psig and 271 °F.

3.4.4.3 FLEX Pumps and Water Supplies

The licensee intends to use NSRC-supplied pumps for Phase 3 containment cooling, if the plant service water pumps cannot be restored. FLEX pumps may be used to supplement the NSRC-supplied pumps as needed. The use of FLEX pumps is covered above in Section 3.2.3.5, "FLEX Pumps and Water Supplies".

3.4.4.4 Electrical Analyses

The licensee performed a containment evaluation based on the boundary conditions described in Section 2 of NEI 12-06. Based on the results of this analysis, the licensee developed required actions to ensure maintenance of containment integrity and functionality of required instrumentation. In its FIP, the licensee stated that with an ELAP initiated while in Modes 1-4, containment cooling for that unit is also lost for an extended period of time. Therefore, containment temperature and pressure will slowly increase. Structural integrity of the reactor

containment building due to increasing containment pressure will not be challenged during the first 72 hours of an ELAP/LUHS event. However, with no cooling in the containment, temperatures in the containment are expected to rise and could reach a point where continued reliable operation of key instrumentation and components might be challenged.

Based on the conclusions of Salem Technical Evaluation 80111831-0040, "Evaluation of Mode 1-4 MAAP Results Against NEI 12-06 Requirements," and 80111831-0041, "MODE 1-4 MAAP Results – Westinghouse Flow Orifice Assessment Incorporated," the licensee determined that containment pressure can be maintained substantially below the design pressure using only FLEX RCS cooldown via the steam generators (pending the results of the Westinghouse reassessment of RCP seal leak-off rates (Westinghouse NISL PSE-14-4 transmitted under letter PSE-14-4 Dated February 18, 2014).

During Phase 1, the Salem strategy relies on the 125 Vdc and 28 Vdc Class 1E batteries to power critical instruments within containment during Phase 1 and the 480 Vac, 600 kW FLEX DGs to repower battery chargers and instrumentation within 6 hours of the event during Phase 2. The licensee's strategy to power instrumentation using the Class 1E batteries and 480 Vac, 600 kW FLEX DGs is identical to what was described in Section 3.2.3.6 of this SE. Therefore, the capacity of the Class 1E batteries and Phase 2 FLEX DGs are adequate to ensure continued containment monitoring.

Salem Phase 3 coping strategy during plant Modes 1-4 relies on two 4160 Vac 1-MW CTGs (per unit) operating in parallel to provide electrical power to the required safeguards equipment. The CTGs will be used to re-power containment cooling through the use of the installed containment fan coil units (FCUs) and Delaware River water supplied to the FCU coolers through the SW system. In its FIP, the licensee stated that one 4160 Vac bus is required for each unit to repower the containment cooling options. The NRC staff reviewed the licensee's analysis of the 4160 Vac CTGs capacity and the expected loads in Section 3.2.3.6 of this SE. Based on its review, the NRC staff finds that the Phase 3 CTGs should have adequate capacity and capability to supply adequate power to the required instruments and loads required for containment temperature and pressure monitoring and cooling, if necessary.

Guidelines S1/2-OP-FS.FLX-00012, "Alternate Containment Cooling," Revision 0, provide guidance to the operators to monitor and maintain containment temperature and pressure below instrumentation design limits.

Based on the above, the NRC staff determined that the electrical equipment available onsite (i.e., 480 Vac, 600 kW FLEX DGs and other credited equipment) supplemented with the electrical equipment that will be supplied from the NSRCs (i.e., 4160 Vac CTGs) have sufficient capacity and capability to supply the required loads to reduce containment temperature and pressure to ensure that key components and instrumentation remain functional.

Based on the above, the NRC staff concludes that the Salem electrical strategy for restoring and maintaining containment integrity and cooling indefinitely during an ELAP as a result of a BDBEE is acceptable.

3.4.5 Conclusions

Based on this evaluation, the NRC staff concludes that the licensee has developed guidance that, if implemented appropriately, should maintain or restore containment functions following an ELAP event consistent with NEI 12-06 guidance, as endorsed by JLD-ISG-2012-01, and should adequately address the requirements of the order.

3.5 Characterization of External Hazards

Sections 4 through 9 of NEI 12-06 provide the methodology to identify and characterize the applicable BDBEEs for each site. In addition, NEI 12-06 provides a process to identify potential complicating factors for the protection and deployment of equipment needed for mitigation of applicable site-specific external hazards leading to an ELAP and loss of normal access to the UHS.

Characterization of the applicable hazards for a specific site includes the identification of realistic timelines for the hazard, characterization of the functional threats due to the hazard, development of a strategy for responding to events with warning, and development of a strategy for responding to events without warning.

The licensee reviewed the plant site against NEI 12-06 and determined that FLEX equipment should be protected from the following hazards: seismic; external flooding; severe storms with high winds; snow, ice and extreme cold; and extreme high temperatures.

References to external hazards within the licensee's mitigating strategies and this SE are consistent with the guidance in NEI-12-06 and the related NRC endorsement of NEI 12-06 in JLD-ISG-2012-01. Guidance document NEI 12-06 directed licensees to proceed with evaluating external hazards based on currently available information. For most licensees, this meant that the OIP used the current design-basis information for hazard evaluation. Coincident with the issuance of Order EA-12-049, on March 12, 2012, the NRC staff issued a Request for Information pursuant to Title 10 of the *Code of Federal Regulations* Part 50, Section 50.54(f) [Reference 19] (hereafter referred to as the 50.54(f) letter), which requested that licensees reevaluate the seismic and flooding hazards at their sites using updated hazard information and current regulatory guidance and methodologies. Due to the time needed to reevaluate the hazards, and for the NRC to review and approve them, the reevaluated hazards were generally not available until after the mitigation strategies had been developed. The NRC staff has developed a proposed rule, titled "Mitigation of Beyond-Design-Basis Events," hereafter called the MBDBE rule, which was published for comment in the *Federal Register* on November 13, 2015 [Reference 53]. The proposed MBDBE rule would make the intent of Orders EA-12-049 and EA-12-051 generically applicable to all present and future power reactor licensees, while also requiring that licensees consider the reevaluated hazard information developed in response to the 50.54(f) letter.

The NRC staff requested Commission guidance related to the relationship between the reevaluated flooding hazards provided in response to the 50.54(f) letter and the requirements for Order EA-12-049 and the MBDBE rulemaking (see COMSECY-14-0037, "Integration of Mitigating Strategies for Beyond-Design-Basis External Events and the Reevaluation of Flooding Hazards" [Reference 47]. The Commission provided guidance in an SRM to COMSECY-14-0037 [Reference 20]. The Commission approved the staff's recommendations that licensees would need to address the reevaluated flooding hazards within their mitigating

strategies for BDBEEs, and that licensees may need to address some specific flooding scenarios that could significantly impact the power plant site by developing scenario-specific mitigating strategies, possibly including unconventional measures, to prevent fuel damage in reactor cores or SFPs. The NRC staff did not request that the Commission consider making a requirement for mitigating strategies capable of addressing the reevaluated flooding hazards be immediately imposed, and the Commission did not require immediate imposition. In a letter to licensees dated September 1, 2015 [Reference 37], the NRC staff informed the licensees that the implementation of mitigation strategies should continue as described in licensee's OIPs, and that the NRC safety evaluations and inspections related to Order EA-12-049 will rely on the guidance provided in JLD-ISG-2012-01, Revision 0, and the related industry guidance in NEI 12-06, Revision 0. The hazard reevaluations may also identify issues to be entered into the licensee's corrective action program consistent with the OIPs submitted in accordance with Order EA-12-049.

As discussed above, licensees are reevaluating the site seismic and flood hazards as requested in the NRC's 50.54(f) letter. After the NRC staff approves the reevaluated hazards, licensees will use this information to perform flood and seismic mitigating strategies assessments (MSAs) per the guidance in NEI 12-06, Revision 2, Appendices G and H [Reference 54]. The NRC staff endorsed Revision 2 of NEI 12-06 in JLD-ISG-2012-01, Revision 1 [Reference 55]. The licensee's MSAs will evaluate the mitigating strategies described in this SE using the revised seismic hazard information and, if necessary, make changes to the strategies or equipment. Licensees will submit the MSAs for NRC staff review.

The licensee developed its OIP for mitigation strategies by considering the guidance in NEI 12-06 and the site's design-basis hazards. Therefore, this SE makes a determination based on the licensee's OIP and FIP. The characterization of the applicable external hazards for the plant site is discussed below.

3.5.1 Seismic

In its FIP, the licensee described the current design-basis seismic hazard, the safe shutdown earthquake (SSE). As described in UFSAR Section 2.5.2, "Vibratory Ground Motion," the SSE seismic criteria for the site is two-tenths of the acceleration due to gravity (0.20g) peak horizontal ground acceleration at the foundation level and 0.133g peak ground acceleration acting vertically. It should be noted that the actual seismic hazard involves a spectral graph of the acceleration versus the frequency of the motion. Peak acceleration in a certain frequency range, such as the numbers above, is often used as a shortened way to describe the hazard.

As the licensee's seismic reevaluation activities are completed, the licensee is expected to assess the mitigation strategies to ensure they can be implemented under the reevaluated hazard conditions as will potentially be required by the proposed MBDBE rulemaking. The licensee has appropriately screened in this external hazard and identified the hazard levels to be evaluated.

3.5.2 Flooding

In its FIP, the licensee described that the Salem plant area has a nominal grade elevation of 99.5 feet Public Service Datum (PSD). In its March, 11, 2014, letter [Reference 21], the

licensee states that 99.5 feet PSD is equal to 10.5 feet above mean sea level (MSL). In its FIP, the licensee stated that current design basis maximum flood levels result from the hurricane storm surge event, with a still water elevation of 113.8 feet PSD, which means the site would be flooded with 14.3 feet of water above grade level. The licensee stated that maximum design basis flood levels due to storm surge wave run-up are 120.4 feet PSD at the power block (auxiliary building) and 127.3 feet PSD at the service water intake structure (SWIS). By letter dated September 10, 2015 [Reference 53], the NRC staff agreed with the licensee's conclusion that the reevaluated storm surge flood levels are bounded by the design basis flood levels. The current design basis does not include an expected flooding event due to local intense precipitation (LIP). The licensee stated in its FIP that a hurricane event is assumed to have greater than 48 hours of warning time and flooding is expected to persist above site grade for approximately 11 hours.

As the licensee's flooding reevaluation activities are completed, the licensee is expected to assess the mitigation strategies to ensure they can be implemented under the reevaluated hazard conditions as will potentially be required by the proposed MBDBE rulemaking. The licensee has appropriately screened in this external hazard and identified the hazard levels to be evaluated.

3.5.3 High Winds

In NEI 12-06, Section 7, provides the NRC-endorsed screening process for evaluation of high wind hazards. This screening process considers the hazard due to hurricanes and tornadoes.

The screening for high wind hazards associated with hurricanes should be accomplished by comparing the site location to NEI 12-06, Figure 7-1 (Figure 3-1 of U.S. NRC, "Technical Basis for Regulatory Guidance on Design Basis Hurricane Wind Speeds for Nuclear Power Plants," NUREG/CR-7005, December, 2009). If the resulting frequency of recurrence of hurricanes with wind speeds in excess of 130 miles per hour (mph) exceeds 1E-6 per year, the site should address hazards due to extreme high winds associated with hurricanes using the current licensing basis for hurricanes.

The screening for high wind hazard associated with tornadoes should be accomplished by comparing the site location to NEI 12-06, Figure 7-2, from U.S. NRC, "Tornado Climatology of the Contiguous United States," NUREG/CR-4461, Rev. 2, February 2007. If the recommended tornado design wind speed for a 1E-6/year probability exceeds 130 mph, the site should address hazards due to extreme high winds associated with tornadoes using the current licensing basis for tornados or Regulatory Guide 1.76, Rev. 1.

The Salem UFSAR describes the current licensing basis for hurricanes for Category I buildings as a wind load of 30 pounds per square foot, equivalent to 108 mph. The UFSAR describes the current licensing basis for tornados as a peripheral wind velocity of 300 mph and a translational velocity of 60 mph, and an atmospheric pressure drop of 3 psig simultaneous with wind loading. The UFSAR describes the current licensing basis for tornado missiles for Category I buildings as 1) a wooden utility pole, 40 feet long, 12 inches in diameter, weighing 50 pounds per cubic foot, traveling in a vertical or horizontal direction at 150 mph; 2) a steel rod, 1 inch in diameter, 3 feet long, weighing 8 pounds, traveling horizontally at 316 feet per second and vertically at 252 feet per second; and 3) a utility pole, 35 feet long, 13.5 inches in diameter, weighing 1490

pounds, traveling horizontally at 211 feet per second and vertically at 169 feet per second, at all elevations less than 30 feet above grade within 0.5 miles of the facility structures, and 4) a passenger car missile.

In its FIP, regarding the determination of applicable extreme external hazards, the licensee stated that the site is located at 39° 27' 46" North latitude and 75° 32' 08" West longitude. As described in its FIP, using Figures 7-1 and 7-2 from NEI 12-06, PSEG determined that Salem could experience hurricane winds of approximately 160 mph (Figure 7-1), and could experience tornado force winds of approximately 166 mph (Region 2 in Figure 7-2), with a 1E-6/year probability. Therefore, the plant screens in for an assessment for high winds from hurricanes and tornados, including missiles produced by these events.

Therefore, high-wind hazards are applicable to the plant site. The licensee has appropriately screened in the high wind hazard and characterized the hazard in terms of wind velocities and wind-borne missiles.

3.5.4 Snow, Ice, and Extreme Cold

As discussed in NEI 12-06, Section 8.2.1, all sites should consider the temperature ranges and weather conditions for their site in storing and deploying FLEX equipment consistent with normal design practices. All sites outside of Southern California, Arizona, the Gulf Coast and Florida are expected to address deployment for conditions of snow, ice, and extreme cold. All sites located north of the 35th Parallel should provide the capability to address extreme snowfall with snow removal equipment. Finally, all sites except for those within Level 1 and 2 of the maximum ice storm severity map contained in Figure 8-2 should address the impact of ice storms.

In its FIP, regarding the determination of applicable extreme external hazards, the licensee described that the site is located at 39° 27' 46" North latitude and 75° 32' 08" West longitude. In addition, the site is located within the region characterized by EPRI as ice severity level 3 (NEI 12-06, Figure 8-2, Maximum Ice Storm Severity Maps). Consequently, the site is subject to low to medium damage to power lines and/or existence of considerable amount of ice. The licensee concludes that the plant screens in for an assessment for snow, ice, and extreme cold hazard. The FIP described that Technical Evaluation 80112074-0025, "Outdoor Storage of FLEX Equipment in Extreme Cold and Hot Weather," established the minimum outdoor temperature of -4 °F. A review of UFSAR Table 2.3-5, Distribution of Hourly Temperatures, does not show any site temperature data below 0 °F.

In summary, based on the available local data and Figures 8-1 and 8-2 of NEI 12-06, the plant site does experience significant amounts of snow, ice, and extreme cold temperatures; therefore, the hazard is screened in. The licensee has appropriately screened in the hazard and characterized the hazard in terms of expected temperatures.

3.5.5 Extreme Heat

In the section of its FIP regarding the determination of applicable extreme external hazards, the licensee stated that, as per NEI 12-06, Section 9.2, all sites are required to consider the impact of extreme high temperatures. Summers at the site may bring periods of extremely hot weather.

As described in the FIP, an evaluation of outdoor FLEX equipment in extreme temperature conditions considered a high temperature of 100 °F based on UFSAR Table 2.3-5. A review of UFSAR Table 2.3-5 does not show any site temperature data above 100 °F. The plant site screens in for an assessment for extreme high temperature hazard.

In summary, based on the available local data and the guidance in Section 9 of NEI 12-06, the plant site does experience extreme high temperatures. The licensee has appropriately screened in the high temperature hazard and characterized the hazard in terms of expected temperatures.

3.5.6 Conclusions

Based on the evaluation above, the NRC staff concludes that the licensee has developed a characterization of external hazards that is consistent with NEI 12-06 guidance, as endorsed by JLD-ISG-2012-01, and should adequately address the requirements of the order in regard to the characterization of external hazards.

3.6 Planned Protection of FLEX Equipment

3.6.1 Protection from External Hazards

In its FIP, the licensee described that the FLEX equipment required to mitigate a BDBEE at Salem is stored at its point of deployment in a robust structure (e.g., the new electrical distribution equipment and pumps stored in the auxiliary building), pre-staged in the canyon area, or stored in locations separated by sufficient distance to minimize the probability that a single event would damage all of the FLEX equipment needed to mitigate the event.

Below are additional details on how FLEX equipment is protected from each of the applicable external hazards.

3.6.1.1 Seismic

In its FIP, the licensee described that FLEX equipment is stored at locations designed or evaluated to withstand the effects of a seismic event, including potential liquefaction. FLEX charging pumps, auxiliary feedwater pumps, and new electrical distribution equipment are located in the Seismic Category I auxiliary buildings. The submersible pumps stored in the turbine building are only credited for the flooding event and are not required for the FLEX response to a seismic event.

In addition, the FIP described that two FLEX DGs are pre-staged outdoors in the canyon area. The canyon area is between the Unit 2 auxiliary building and FHB, which are Seismic Category I. There are no non-seismically robust components or structures positioned to interact with pre-staged FLEX DGs in the canyon area. The pre-staged FLEX DGs are restrained to prevent damage from a seismic event. Access to the canyon area through the seismically robust Salem Unit 2 auxiliary building ensures access to the FLEX DGs for control capability, and to the connection points for the FLEX DGs.

The FIP described that some Phase 2 FLEX equipment is stored outdoors at two locations within the protected area, and one location outside the protected area. Equipment stored in these areas will withstand the effects of a seismic event. Large portable FLEX equipment is secured for a seismic event and located so that it is not damaged by other items in a seismic event.

In its FIP, the licensee described that installed FLEX equipment credited following a seismic event is seismically robust, consistent with Salem's current seismic design practices. Installed FLEX equipment has been evaluated and protected from seismic interactions based on its location within the auxiliary building to ensure that unsecured or non-seismic components do not damage the equipment.

In its FIP, the licensee described how they addressed the potential for seismically induced internal flooding hazards. The licensee reviewed large internal flooding sources that are not seismically robust and do not require ac power, e.g., gravity drainage from lake or cooling basins for non-safety-related cooling water systems. The licensee determined that there are no internal flooding sources of this type that are within the Salem flood protected boundary.

3.6.1.2 Flooding

In the UFSAR, Section 2.4.1.1, "Site and Facilities," describes the auxiliary building as watertight up to elevation 115 feet PSD. All doors in the outer auxiliary building walls below elevation 120.4 feet PSD are watertight. In addition, UFSAR Section 2.4.1.1 describes that the portion of the SWIS enclosing the service water pumps, motors, and vital switchgear is watertight up to elevation 126 feet PSD with wave run-up protection to elevation 128 feet PSD.

In its FIP, the licensee described that the FLEX DGs pre-staged in the canyon area are above LIP flood depths and are not vulnerable to an external flooding event other than from a hurricane-driven storm surge event. The licensee stated that a hurricane event is assumed to have greater than 48 hours of warning time and flooding is expected to persist above site grade for approximately 11 hours. The licensee will deploy and flood-protect four FLEX DGs within the canyon area after a hurricane event that meets specified criteria is predicted and before the hurricane reaches Salem. Flood protection will be accomplished by the erection of a 16 foot high temporary flood barrier to completely close the open end of the canyon area. The licensee stated that based on the location of the temporary wall relative to storm surge fetch lines, the height of the wall provides adequate protection against the design-basis storm surge flood depths. Once the flood barrier is erected, the four FLEX DGs deployed in the canyon area, which includes the N+1 FLEX DG, will not be vulnerable to an external flooding event. Pumps to remove accumulated rainwater during the hurricane event will be located in the canyon area and will be powered by a FLEX DG or station power (if available).

The two FLEX SW pumps (one is a spare) are stored in the same outside locations as two of the FLEX DGs, and those locations are susceptible to flooding. In its FIP, the licensee stated that these pumps will be moved to the flood-protected HCGS Unit 2 reactor building before the arrival of the hurricane. During onsite flooding, if the water supply tanks are damaged the licensee will rely on water supplied by submersible pumps located in the flooded turbine building. Once the flooding subsides, the FLEX SW pumps will be deployed to provide a water supply from the Delaware River.

The FIP also described that FLEX equipment storage locations outside of flood-protected structures were evaluated for the potential impact of failure of large, non-seismic tanks. The largest non-seismic tanks are the two demineralized water storage tanks (DWSTs), each with a 500,000 gallon capacity. The DWSTs are greater than 400 feet away from the closest outdoor FLEX equipment storage area and significant open areas exist between the storage sites and non-seismic tanks. Considering the separation distances, open spaces and intervening structures, the licensee stated that it is unlikely that significant flooding and equipment damage will occur at the storage locations.

The FIP described that Salem FLEX strategies do not rely on ac power for ground water mitigation within the plant flood-protected areas.

In its FIP, the licensee described that prior to an anticipated hurricane event, actions are taken to move equipment and restock supplies in accordance with site severe weather procedures and FSGs.

3.6.1.3 High Winds

In its FIP, the licensee described that Salem is using an alternative to the criteria of NEI 12-06 Section 7.3.1, "Protection of FLEX Equipment," which recommends protection of FLEX equipment from high wind hazards via storage in a structure or in diverse locations. FLEX equipment required to mitigate a BDBEE at Salem is stored at its point of deployment in a robust structure (e.g., new FLEX electrical distribution equipment and FLEX pumps located in the auxiliary building), pre-staged in the canyon area (two FLEX DGs), or stored in outside locations separated by sufficient distance to minimize the probability that a single event would damage all of the FLEX equipment needed to mitigate the event.

The FIP described that two FLEX DGs, electrical connections, and distribution equipment are located in the canyon area. These FLEX DGs, electrical connections and distribution equipment are installed or stored in the eastern most area of the canyon, towards the service water accumulator building, surrounded on all four sides by the fuel handling and auxiliary buildings. FLEX equipment and connections located in the sheltered canyon area are designed for a wind speed of 200 mph.

As described in the FIP, the equipment stored in the canyon area is protected from missiles with a maximum height of 30 feet above grade by its location between the robust Seismic Category I auxiliary building and the Seismic Category I FHB. The locations for stored equipment were chosen so that they are protected by Category I structures in all horizontal trajectory line directions. There is no straight line trajectory for an automobile or utility pole type of missile to impact the stored equipment. A tornado missile evaluation was completed specifically for the canyon configuration based on the Salem design basis. The two FLEX DGs pre-staged in the canyon area are hardened to provide protection from this missile impact and are secured to protect against tornado wind speeds. The two FLEX DGs, the two FLEX SW pumps, and associated FLEX equipment which are stored outside of the canyon area are not missile protected but are separated by 1,200 feet or greater to ensure a single tornado does not impact more than one FLEX DG in outside storage, in accordance with NEI 12-06, Section 7.3.1.1.c.

Therefore, at least one of the two FLEX DGs and one of the two FLEX SW pumps in outside storage should be available following a tornado event.

For a hurricane event, the two FLEX DGs stored outside of the canyon area will be deployed to the canyon area prior to the event. They are not designed with inherent missile protection but they will be secured for protection from hurricane wind speeds. These two FLEX DGs will be moved to an area inside the canyon where protective actions will be taken to reduce the potential for wind impacts. This area of the canyon is protected on three sides by the Unit 2 auxiliary building (approximately 40 feet above grade) and the Unit 2 FHB (approximately 80 feet above grade). The western side will have an earthen-based flood wall sealing the entrance to the canyon and constructed to an elevation of 16 feet above grade (after the two FLEX DGs are moved inside the canyon) that will stop a hurricane missile.

The NRC staff considers the hurricane and tornado protection for the two FLEX DGs pre-staged in the canyon area to be an alternative to NEI 12-06, Section 7.3.1, as they are not protected to the plant licensing basis or have backup equipment stored in diverse locations. However, the NRC staff considers this to be an acceptable alternative as the storage configuration provides significant shelter from hurricanes and tornadoes, and the two FLEX DGs located in the canyon are hardened and secured to provide reasonable protection from high winds and small missiles. Refer to Section 3.14 below for additional information.

3.6.1.4 Snow, Ice, Extreme Cold and Extreme Heat

In its FIP, the licensee described that the Salem plan for storage locations includes either storage inside robust structures, storage in the canyon area, or storage at three outside locations (without storage buildings) with enough separation so that only one outside storage area would be impacted by a tornado. The licensee established the minimum outdoor temperature as -4 °F and the highest outdoor temperature as 100 °F.

The FIP described that Salem is using an alternative to the criteria of NEI 12-06, Section 8.3.1, "Protection of FLEX Equipment," which recommends storage of the N FLEX equipment within a structure to provide protection against snow, ice and extreme cold hazards. The licensee stated that equipment stored outdoors is designed for outdoor storage in cold environments consistent with normal design practices, e.g., using diesel engine block heaters and space heaters. In addition, the FIP described that the licensee integrated the FLEX capabilities into existing site cold weather procedures and established periodic FLEX equipment status checks that include diesel keep-warm systems and verification that access to equipment is not impaired by snow or ice. The NRC staff finds this to be an acceptable alternative, as the licensee has taken steps to ensure that the FLEX equipment will be functional if it is needed. For further discussion on this, refer to Section 3.14 below.

The licensee stated that FLEX strategies include providing power for installed heat tracing for water sources required for the strategies (AFST and RWST).

In its FIP, the licensee described that all FLEX equipment has been procured to be suitable for use at the peak temperature. Therefore, high temperature does not impact the functionality of FLEX equipment.

3.6.1.5 Conclusions

Based on this evaluation, the NRC staff concludes that the licensee has developed guidance that, if implemented appropriately, should protect the FLEX equipment during a BDBEE consistent with NEI 12-06 guidance, as endorsed by JLD-ISG-2012-01, with approved alternatives, and should adequately address the requirements of the order.

3.6.2 Availability of FLEX Equipment

Section 3.2.2 of NEI 12-06 states, in part, that in order to assure reliability and availability of the FLEX equipment, the site should have sufficient equipment to address all functions at all units on-site, plus one additional spare (i.e., an N+1 capability, where "N" is the number of units on site). It is also acceptable to have a single resource that is sized to support the required functions for multiple units at a site (e.g., a single pump capable of all water supply functions for a dual unit site). In this case, the N+1 could simply involve a second pump of equivalent capability. In addition, it is also acceptable to have multiple strategies to accomplish a function, in which case the equipment associated with each strategy does not require an additional spare. Table 1 of the FIP provides a listing of FLEX equipment stored on-site.

In its FIP, the licensee described that they have purchased sufficient equipment to address all functions at all three units on-site, plus one additional spare, i.e., an N+1 capability, where "N" is the number of equipment required by FLEX strategies for all three units on-site. Salem Units 1 and 2 and HCGS Unit 1 and the partially constructed HCGS Unit 2 are co-located on a common site (i.e., the units are in a common protected area, use a common emergency plan, security plan, etc.). For major FLEX equipment common to all units (FLEX DGs and diesel-driven FLEX SW pumps), the N+1 requirement is met by providing at least one spare in addition to the minimum set of equipment needed for all three operating reactors.

In addition, the FIP described that for the hoses and cables associated with FLEX equipment required for FLEX strategies, the licensee is using the NRC-endorsed alternative to NEI 12-06, Section 3.2.2, rather than have a complete extra set of hoses and cables. The basic premise of the alternative is that an extra 10 percent of hoses and cables would be sufficient, with certain qualifiers. This alternative is more fully explained in Section 3.14 below.

Based on the number of portable FLEX pumps, FLEX DGs, and support equipment identified in the FIP and during the audit review, the NRC staff finds that, if implemented appropriately, the licensee's FLEX strategies include a sufficient number of portable FLEX pumps, FLEX DGs, and equipment for RCS makeup and boration, SFP makeup, and maintaining containment consistent with the N+1 recommendation in Section 3.2.2 of NEI 12-06, with an approved alternative for spare hoses and cables.

3.7 Planned Deployment of FLEX Equipment

In its FIP, the licensee described that pre-determined, preferred haul paths have been identified and documented in the FSGs. Figure 4 of the FIP provides guidance related to the haul paths from the storage locations to the various deployment locations. Deployment pathways for FLEX equipment were selected to avoid the potential for debris from failed non-seismically designed structures.

The FIP described that Phase 3 of the FLEX strategies involves the receipt of equipment from offsite sources including an NSRC and the receipt of various commodities such as fuel and supplies. Delivery of this equipment can be through airlift (helicopter) or via ground transportation. Debris removal from the pathway between the site and the NSRC receiving locations (staging areas) and from the various plant access routes may be required. The same debris removal equipment used for onsite pathways may also be used to support debris removal to facilitate road access to the site once necessary haul routes and transport pathways onsite are clear.

3.7.1 Means of Deployment

In its FIP, the licensee described that towing and debris removal equipment are stored so that one set of equipment (one towing vehicle, one debris removal vehicle, and one forklift) will survive all hazards. Onsite debris removal equipment is available to clear pathways. In addition, snow removal is a normal activity at the plant site because of the climate. Reasonable access to FLEX equipment will be maintained throughout a snow event in accordance with plant procedure MA-AA-716-002-1002, "Facilities Maintenance Guidelines." Ice management will be performed as required such that large FLEX equipment can be moved by vehicles. Debris removal equipment can move through moderate snow accumulation and can also be used to move FLEX equipment.

3.7.2 Deployment Strategies

In the event of a hurricane, the FIP described that the two FLEX DGs in outside storage will be deployed to the canyon area and secured against hurricane wind speeds and the entrance to the canyon will be sealed by building a 16 foot high wall. In addition, FLEX equipment other than the diesel-driven FLEX SW pumps will be deployed prior to the hurricane. The diesel-driven FLEX SW pumps, including the N+1 pump, will be moved from the normal outdoor storage locations to the flood-protected HCGS Unit 2 reactor building (Unit 2 was never operational) before the arrival of a hurricane and deployed after flood waters recede.

The FIP also described that two 100 percent capacity submersible pumps with integral strainers will be staged in each Salem unit (i.e., the N and N+1 pumps) in the turbine building prior to the arrival of flooding due to hurricane storm surge. The turbine building basements will be flooded, and the submersible pumps will be used to provide makeup water if needed due to tank depletion or failure. A discharge hose will be routed from a submersible pump to the demineralized water pipe that feeds the TDAFW pump at Unit 1 and another submersible pump will discharge to the FP/FWST backup supply pipe that feeds the TDAFW pump at Unit 2. These pipes are routed below grade in the turbine building and are not susceptible to hurricane wind induced missiles. The pumps would then take suction from the flooded turbine building.

A liquefaction analysis of the outdoor storage locations demonstrated that the FLEX equipment can be deployed to the point of use. All areas adjacent to Class I structures around the Salem site have highly compacted backfill.

3.7.3 Connection Points

3.7.3.1 Mechanical Connection Points

Core Cooling

In the FIP, Section 2.3.5.1 and Figure 1 show that the primary connection point for the discharge of the FLEX AFW pump injects into the cross-connect line connecting the discharge headers of the two motor-driven AFW (MDAFW) pumps. UFSAR Section 10.4.7.2 states that each MDAFW pump normally feeds two of the four SGs. The FLEX connection is on the cross-connect line but is isolated from each discharge header by a normally shut isolation valve. By opening the two normally shut isolation valves (as directed by guideline FSG-3), the FLEX AFW pump can feed all four SGs. As described in SE Section 3.2.3.1.1, the AFW system pumps and piping are Seismic Category I. In its FIP, the licensee stated that the primary AFW discharge connection is located in the auxiliary building which is a Seismic Category I structure protected from all applicable hazards. However, the licensee did not identify an alternate discharge connection point for the FLEX AFW pump as specified in NEI 12-06, Section 3.2.2. The NRC staff has accepted this as an alternative to the guidance in NEI 12-06 due to the following reasons: 1) the FLEX AFW pump, the spare pump, and the discharge connection to the AFW system are located below ground level (84 foot elevation) inside a robust plant building (the auxiliary building), 2) the FLEX AFW pump and the spare pump are secured to protect against a seismic event, and 3) the FLEX AFW pump and its discharge connection are fully protected from external hazards. Refer to Section 3.14 below for additional discussion.

RCS Inventory Control/Makeup

Section 2.3.5.4 of the FIP states that the discharge from the FLEX charging pump can be connected to the discharge header of the plant charging pumps in the chemical volume and control system (CVCS) located in the auxiliary building on the 84' elevation. In the FIP, Section 2.3.5.5 states that the alternate FLEX charging pump discharge connection will be to the SI pump discharge header located in the auxiliary building. The suction of the FLEX charging pump can be aligned to several sources. The credited source is the fully robust BASTs, located in the auxiliary building. One alternate source is the RWST using connections on the CVCS changing pump suction header, or on the SI pump suction header. Another alternate source is the portable boric acid mixing tank located in the auxiliary building (mixing would be done locally prior to transfer). The auxiliary building is protected from all applicable hazards.

SFP Makeup

In the FIP, Section 2.4.4.1 describes the licensee's SFP makeup strategy connections. The licensee has two independent flow paths for providing SFP makeup from either of two available FLEX pumps, the FLEX AFW pump or the FLEX SW pump. The makeup water does not have to be borated, as the evaporation/boiling process does not remove significant amounts of boron

from the SFP. The primary flow path utilizes a 4-inch line that tees into the existing 6-inch SFP makeup line, which is permanently installed, seismically robust piping. The connection is located in the auxiliary building. The alternate FLEX connection is to the SFP spray header and is located in the auxiliary building. The SFP spray rig will be installed at each SFP before conditions degrade in the FHB.

Given the design and location of the primary and alternate connection points, as described in the above paragraphs, the staff finds that connection points should be available to support core, SFP, and containment cooling via a portable pump during an ELAP caused by an external event, consistent with NEI 12-06 Section 3.2.2, with an approved alternative for the core cooling function.

3.7.3.2 Electrical Connection Points

Electrical connection points are available for Phases 2 and 3 of the licensee's mitigation strategies for a BDBEE. During Phase 2, two pre-staged 480 Vac DGs and one DG (two are available) moved from its outdoor storage location will be used to power the necessary equipment. The licensee has developed a primary and alternate strategy for supplying power to the Phase 2 equipment required to maintain or restore core cooling, containment, and SFP cooling using a combination of permanently installed and portable components. The two pre-staged 480 Vac FLEX DGs are located in the eastern section of the Unit 2 canyon area, shielded on all four sides by the Unit 2 fuel handling building and auxiliary building. The licensee plans to move the other required FLEX DG from storage and place it next to the pre-staged DGs for an ELAP event as shown in Figure 2 of the FIP.

Primary Electrical Connection Points

Two of the three DGs located in the canyon area will each power a unit-specific 480 Vac FLEX MCC. Missile-protected receptacles are installed on the Unit 2 auxiliary building exterior wall to provide connection points for the 480 Vac FLEX DGs.

One pre-staged 480 Vac FLEX DG will feed a 480 Vac/240 Vac transformer permanently installed in the Salem Unit 2 auxiliary building. Missile-protected receptacles are installed on the Unit 2 auxiliary building exterior wall to provide a connection point for this 480 Vac FLEX DG. Cable in conduit is installed from the receptacles to the transformer and from the transformer to a permanently installed 240 Vac FLEX MCC common to both units. This primary connection is protected from all external hazards.

Alternate Electrical Connection Points

Alternate connections are available via transfer switches located in the Waste Evaporator Room in the Unit 2 auxiliary building to feed either the 240 Vac FLEX MCC or one of the 480 Vac FLEX MCCs. These connections are protected from all external hazards.

In its FIP, the licensee stated that correct phase rotation of the Phase 2 DGs was verified during the modification acceptance process.

Phase 3 4160 Vac Electrical Connection (Primary Connection Points)

The licensee's Phase 3 coping strategy is to establish the necessary long-term electrical capacity to meet all FLEX strategy needs until such time that normal power to the site can be restored. Two 4160 Vac portable CTGs per unit (with an outdoor synchronizing switchgear) will be provided by an NSRC and will be deployed to an area just outside the rollup door to the solid radwaste truck bay in the Unit 1 auxiliary building. These 4160 Vac CTGs will be used to power the Salem Unit 1 "B" 4160 Vac vital bus and the Salem Unit 2 "A" 4160 Vac vital bus via connections in the auxiliary building. Two 4160 Vac FLEX receptacle enclosures are used for each unit. One is next to the unit's vital bus at elevation 64 feet in the auxiliary building, and the second is in the drum storage area near the solid radwaste truck bay at elevation 100 feet (ground elevation). These connections are protected from all applicable site external hazards. The cables stored on site or supplied from an NSRC are compatible with the receptacle connections. Guideline FSG-5 provides direction for staging, connecting, and loading the NSRC 4160 Vac CTGs. The CTGs are connected to the receptacle near the truck bay, and that receptacle is connected using portable FLEX cables to the receptacle near the vital bus. The receptacle near the vital bus is hard wired to one of the switchgear cubicles on the vital bus, through a safety-related circuit breaker which is then closed to energize the vital bus. Guideline FSG-5 also provides guidance to the operators to verify the direction of motor rotation on a selected or available component to verify proper phase rotation before energizing any vital plant equipment to ensure that the NSRC-supplied CTG phase rotation is consistent with the plant installed equipment.

Phase 3 4160 Vac Electrical Connection (Alternate Connection Points)

The licensee did not install an alternate connection point for the 4160 Vac CTGs as specified in NEI 12-06, Section 3.2.2. The lack of an alternate connection point is an alternative to NEI 12-06. The NRC staff finds this alternative acceptable, as the primary 4160 Vac electrical connection points are located inside the auxiliary building. This building is a Seismic Class I structure providing protection of the connection points from all applicable site external hazards. Refer to Section 3.14 below for additional discussion.

Based on its review of conceptual single line electrical diagrams and station procedures, the NRC staff finds that the licensee's approach is acceptable given the protection and diversity of the power supply pathways, the separation and isolation of the FLEX generators from the Class 1E EDGs, and availability of procedures to direct operators how to align, connect, and protect associated systems and components.

3.7.4 Accessibility and Lighting

As described in the FIP, lighting is required for operator actions and access in the plant to implement actions associated with the station blackout (SBO) procedure. Emergency lighting is provided by local battery-powered emergency lighting. The availability of this lighting is at least 8 hours. The MCR and other areas of the auxiliary building have emergency lighting available from the 125 Vdc system via the emergency lighting inverters. The 125 Vdc system will last for at least 6 hours after load shed, and then power will be supplied to the battery chargers from the FLEX DG.

In addition, the FIP described that portable battery-powered lights will also be available for use in areas that require operator access to perform Phase 2 equipment connections.

3.7.5 Access to Protected and Vital Areas

During the audit process, the licensee provided information describing that access to protected areas will not be hindered. The licensee has contingencies in place to provide access to areas required for the ELAP response if the normal access control systems are without power.

3.7.6 Fueling of FLEX Equipment

In FIP Section 2.9.1, the licensee states that all Phase 2 FLEX equipment will be stored fueled with at least 9 hours of fuel. Once the fuel in the equipment's tank is depleted the licensee has the ability to transfer fuel from the emergency fuel oil storage tanks to a portable fuel trailer. The portable fuel trailer will then be used to refuel the FLEX equipment. The safety-related fuel oil storage tanks (2 per unit) are located underground and protected from all applicable hazards. Each tank has a nominal supply of about 30,000 gallons of fuel with a required minimum of 23,000 gallons and is a Class I structure as detailed in Section 3.2 of the Salem UFSAR. The licensee stated in its FIP that an existing diesel fuel oil transfer pump will be repowered from the FLEX MCC to pump fuel oil from these tanks. Based on the design and location of these EDG fuel tanks and the fuel oil transfer pumps, the staff finds the tanks and pumps are robust and the fuel oil contents should be available to support the licensee's FLEX strategies during an ELAP event.

As stated above, using the minimum required fuel storage, the fuel oil storage tanks have approximately 92,000 gallons total. In the FIP, Section 2.9.1 states that the licensee calculated that the onsite fuel oil storage tanks should last for approximately 5 days, as calculated by Technical Evaluation 80111831-0060. Given the information above, the licensee should have sufficient fuel onsite for diesel-powered equipment, and that diesel-powered FLEX equipment can be refueled to ensure uninterrupted operation to support the licensee's FLEX strategies.

In the Salem compliance letter [Reference 18], the licensee stated that periodic maintenance and testing falls under the preventive maintenance process, with site procedure OP-SA-108-115-1001, "Operability Assessment and Equipment Control Program," providing administrative controls on availability of equipment. The NRC staff finds that the FLEX equipment should be maintained, including the fuel oil quantity and quality, to ensure it will be available during an event.

3.7.7 Conclusion

Based on this evaluation, the NRC staff concludes that the licensee has developed guidance that, if implemented appropriately, should allow deploying the FLEX equipment following a BDBEE consistent with NEI 12-06 guidance as endorsed by JLD-ISG-2012-01, with approved alternatives, and should adequately address the requirements of the order.

3.8 Considerations in Using Offsite Resources

3.8.1 Salem SAFER Plan

The industry has collectively established the needed off-site capabilities to support FLEX Phase 3 equipment needs via the SAFER Team. The SAFER team consists of the Pooled Equipment Inventory Company (PEICo) and AREVA Inc. and provides FLEX Phase 3 management and deployment plans through contractual agreements with every commercial nuclear operating company in the United States.

There are two NSRCs, located near Memphis, Tennessee and Phoenix, Arizona, established to support nuclear power plants in the event of a BDBEE. Each NSRC holds five sets of equipment, four of which will be able to be fully deployed to the plant when requested. The fifth set allows removal of equipment from availability to conduct maintenance cycles. In addition, the plant's FLEX equipment hose and cable end fittings are standardized with the equipment supplied from the NSRC.

By letter dated September 26, 2014 [Reference 23], the NRC staff issued its assessment of the NSRCs established in response to Order EA-12-049. In its assessment, the staff concluded that SAFER has procured equipment, implemented appropriate processes to maintain the equipment, and developed plans to deliver the equipment needed to support site responses to BDBEEs, consistent with NEI 12-06 guidance; therefore, the staff concluded in its assessment that licensees can reference the SAFER program and implement their SAFER Response Plans to meet the Phase 3 requirements of Order EA-12-049.

The NRC staff noted that the licensee's SAFER Response Plan contains (1) SAFER control center procedures, (2) NSRC procedures, (3) logistics and transportation procedures, (4) staging area procedures, which include travel routes between staging areas to the site, (5) guidance for site interface procedure development, and (6) a listing of site-specific equipment (generic and non-generic) to be deployed for FLEX Phase 3.

3.8.2 Staging Areas

In general, up to four staging areas for NSRC-supplied Phase 3 equipment are identified in the SAFER plans for each reactor site. These are a Primary (Area C) and an Alternate (Area D), if available, which are offsite areas (within about 25 miles of the plant) utilized for receipt of ground transported or airlifted equipment from the NSRCs. From Staging Areas C and/or D, the SAFER team will transport the Phase 3 equipment to the on-site Staging Area B for interim staging prior to it being transported to the final location in the plant (Staging Area A) for use in Phase 3. For Salem, Alternate Staging Area D is Atlantic City International Airport. Staging Area C is the Millville Municipal Airport. Staging Area B is at the end of Buttonwood Road in Hancocks Bridge, New Jersey (a large laydown area north of the learning and development center and east of the HCGS cooling tower). Staging Area A is the point-of-use for the FLEX response equipment.

Use of helicopters to transport equipment from Staging Area C to Staging Area B is recognized as a potential need within the Salem SAFER Plan and is provided for.

3.8.3 Conclusions

Based on this evaluation, the NRC staff concludes that the licensee has developed guidance that, if implemented appropriately, should allow utilization of offsite resources following a BDBEE consistent with NEI 12-06 guidance, as endorsed by JLD-ISG-2012-01, and should adequately address the requirements of the order.

3.9 Habitability and Operations

3.9.1 Equipment Operating Conditions

3.9.1.1 Loss of Ventilation and Cooling

Following a BDBEE and subsequent ELAP event at Salem, ventilation that provides cooling to occupied areas and areas containing required equipment will be lost. The primary concern with regard to ventilation is the heat buildup which occurs with the loss of forced ventilation in areas that continue to have heat loads. Per the guidance given in NEI 12-06, FLEX strategies must be capable of execution under the adverse conditions (unavailability of installed plant lighting, ventilation, etc.) expected during an ELAP event. The licensee performed a loss of ventilation analysis to quantify the maximum steady state temperatures expected in specific areas related to FLEX implementation to ensure the environmental conditions remain acceptable for personnel habitability and within equipment qualification limits. The key areas identified for all phases of execution of the FLEX strategy activities are the TDAFW Pump Room, FHB, MCR, Class 1E Battery Rooms, Relay Rooms, Class 1E Battery Charger and Inverter Rooms, and Containment.

TDAFW Pump Room

In Technical Evaluation 80111831-0020, "Updated Unit 1 and 2 Evaluation of Salem Gothic Results," the licensee stated that the components in the TDAFW pump room are qualified for high temperature (149 °F) in accordance with Calculations S-C-AF-MEE-1749, "Effect of Loss of Room Cooler for Turbine Driven Auxiliary Feedwater Pump Room," Revision 0, and S-C-ABV-MEE-1472, Revision 1. The calculations showed that the expected peak temperature in the TDAFW pump area will be 145 °F and then decreases to 120 °F once doors are opened 30 minutes after initiation of an ELAP event and a temporary fan is installed 10 hours into an ELAP event.

Procedures S1/S2.OP-AB.LOOP-0001 provide guidance to the operators to block open doors in the TDAFW pump room within 30 minutes after an ELAP event. Guideline FSG-5 provides guidance for installing a portable fan 10 hours into an ELAP event. Based on temperatures remaining below the design limits of the TDAFW pump, the NRC staff finds that the electrical components and controls in the TDAFW pump room should remain functional during an ELAP event.

Fuel Handling Building

In Technical Evaluation 80111831-0020, the licensee stated that the only active components in the FHB during an ELAP event is the SFP level indication system. Equipment in this area consists of level probe and cabling. The SFP level system is designed to 212 °F for a period exceeding 7 days. By this time, the licensee will be capable of restoring FHB and SFP cooling

using NSRC-supplied equipment. Additionally, the number 11 and 21 FHB exhaust fans will be available within 7 hours after initiation of an ELAP to cool the area. Guideline FSG-5 provides guidance to implement and install number 11 and 21 FHB exhaust fans for cooling to ensure that the SFP level indication system remains functional during an ELAP.

Based on this information, the NRC staff finds that the electrical equipment in the FHB should remain functional during an ELAP event.

MCR including Electronic Equipment Room (EER) area

In Technical Evaluation 80111831-0020, the licensee determined that temperature in the MCR is expected to reach 104 °F (peak) at approximately 72 hours and the EER area to reach 103 °F at 72 hours. The licensee stated that electrical equipment in the MCR and EER area is designed for 110 °F. Therefore, the electrical equipment will remain functional and no compensatory actions are required. In the evaluation, the licensee stated that although actions such as opening MCR doors, placement of temporary fans, or repowering control area ventilation fans in the MCR area are not credited in the Gothic analysis, these actions are available to lower the MCR temperatures further. Procedures S1/S2.OP-AB.LOOP-0001 provide direction to the operators to block open doors in the MCR within 30 minutes after an ELAP event for room cooling.

Based on MCR and EER temperatures remaining below 120 °F (the temperature limit, as identified in NUMARC-87-00, "Guidelines and Technical Bases for NUMARC Initiatives Addressing Station Blackout at Light Water Reactors," Revision 1), the NRC staff finds that the equipment in the MCR and EER will not be adversely impacted by loss of ventilation as a result of an ELAP event.

Battery Rooms, Relay Room, Battery Charger and Inverter Rooms

The licensee's evaluation in Technical Evaluation 80111831-0020 showed that the peak temperature in these rooms is expected to be less than 95 °F and the equipment is designed for 122 °F. Therefore, equipment in this area is expected to operate as designed during an ELAP. The batteries are discharged during the initial 6 hours of the event and then they will be placed on charge. At that time, the temperature in the battery will be about 80 °F which is lower than the battery temperature upper limit (120 °F) recommended by the battery vendor (C&D Technologies).

Based on the expected room temperature remaining lower than the maximum battery design temperature, the NRC staff finds that there will not be any adverse impact on the batteries due to a loss of ventilation during an ELAP and batteries will remain functional considering the expected room temperature.

Although not required for temperature consideration, guideline FSG-5 provides guidance to the operators to re-power the battery room exhaust fans from the FLEX DGs at approximately the 6 hour mark for hydrogen control. That will also remove hot air from the battery rooms. The licensee stated that the Class 1E battery room temperatures are monitored two times per shift by Control Room Logs (Procedure S1/S2.OP-DL-ZZ-0003, "Control Room Logs," Revision 74).

Based on above, the NRC staff finds that equipment in the Class 1E Battery Rooms, Relay Room, Battery Charger and Inverter Rooms should remain functional during an ELAP.

Containment

In the licensee's containment analysis (Technical Evaluation 80111831-0040), the licensee determined that the peak pressure would be 2.25 psig using a containment fan coil unit (FCU) with a maximum temperature of approximately 142 °F at 96 hours after initiation of an ELAP event. The peak pressure and temperature are significantly lower than the containment design pressure of 47 psig and temperature of 271 °F. As such, no immediate action is required except to continue monitoring pressure and temperature during Phases 1 and 2. Expected temperature and pressure would be higher during a LOCA event due to higher heat loads than during an ELAP condition and therefore environmental conditions (temperature and pressure) during an ELAP would be less severe than the environmental conditions during a LOCA. As such, electrical equipment including valves qualified for LOCA would also be qualified for an ELAP environmental conditions (temperature and pressure). Based on this evaluation, the licensee determined that the equipment credited for ELAP (SJ54 valves for accumulator isolation, process instrumentation (RCS level, pressurizer level, and PR1 and PR2 position limit switches)) are qualified for a LOCA environment and thus should be available for an ELAP event.

The Phase 3 coping strategy for containment cooling relies on two 4160 Vac 1-MW CTGs (per unit) operating in parallel to provide power (approximately 2 MW) to the required safeguards equipment. The CTGs will be used to repower installed containment FCUs and the FCU coolers will be supplied using FLEX pumps pumping through the SW piping for containment cooling. Salem will implement resources received from an NSRC to establish the capability to provide power to the containment ventilation system thereby ensuring pressure control in containment after 72 hours from initiation of the ELAP event. Guidelines S1/2.OP-FS.FLX-0012, "Alternate Containment Cooling," Revision 0, provide guidance to the operators to implement actions to monitor and maintain containment temperature and pressure (such as venting or using RHR or the FCUs) to remain within credited equipment and instrument design limits to ensure they remain functional.

In the FIP the licensee stated that Technical Evaluation 80111831-0020 evaluated functionality of the SG PORVs (MS10 valves). Based on its review of the licensee's comparison of the temperature results from the Gothic analysis and the component data, the NRC staff determined that operation of the SG PORVs should not be challenged during an ELAP. Guidelines S1/S2.OP-FS.FLX- 0007, "Loss of Vital Instrumentation or Control Power," Revision 0, (FSG-7) addresses power supply to the SG PORVs in the event that control power is lost. The NRC staff finds that the SG PORV controllers should also be available during an ELAP.

The NRC staff reviewed the capacity of Class 1E batteries for Phase 1 loads, Phase 2 FLEX DGs, and the two NSRC-supplied 4160 Vac 1-MW CTGs (per unit) operating in parallel in Section 3.2.3.6 above and finds that this equipment should have adequate capacity and capability to supply power to the required loads to maintain or restore containment cooling during all 3 phases.

Based on its review of the essential station equipment required to support the FLEX mitigation strategy, which is primarily located in the TDAFW Pump Room, FHB, MCR, Class 1E Battery Rooms, Relay Rooms, Class 1E Battery Charger and Inverter Rooms, and Containment, the NRC staff finds that the equipment should perform their required functions at the expected temperatures as a result of loss of ventilation during an ELAP/LUHS event.

3.9.1.2 Loss of Heating

In Technical Evaluation 80111831-0080, "Effect of a Severe Low Outside Ambient Temperature on Station Batteries," the licensee used 65 °F (Gothic Analysis (VTD 902832, "Salem Unit 1 and 2 Control Room Gothic Model Extended Loss of AC Power Heat-up Analysis," Revision 1) to assess the impact of the loss of ventilation (heating) on station batteries during extreme low outside ambient temperature (-20 °F). The evaluation assumed that the Class 1E batteries are at a design charge level for at least 6 hours and the temperature in any of the Class 1E battery rooms is at the procedural minimum temperature of 65 °F at the time an ELAP occurs. Using the results of the above Gothic analysis, the licensee determined that the temperature in the Class 1E battery rooms should not decrease below the initial 65 °F during the time required for battery operation.

The licensee's Class 1E 28 Vdc and 125 Vdc battery sizing calculations (ES-3.005 and ES-4.008) assumed a 65 °F initial room (electrolyte) temperature. Since the calculated Class 1E battery room temperature does not decrease below the 65 °F assumed in the battery calculation, no decrease in battery capacity is expected. Once the FLEX DGs start supplying power to the battery chargers to provide the necessary dc power within 6 hours, the batteries will be placed on charge. With batteries on charge, the energized battery chargers will generate heat, moderating the room temperatures. Battery room temperatures are monitored two times per shift by Control Room Logs (Procedure S1/S2.OP-DL-ZZ-0003, "Control Room Logs," Revision 74).

Based on its review of the licensee's battery room assessment, the NRC staff finds that the Class 1E batteries should perform their required functions at the expected temperatures as a result of loss of heating during an ELAP event.

Operation of the TDAFW pump involves steam flow through the turbine and associated piping. The TDAFW pump is located in a temperature-controlled area of the auxiliary building and is relied upon immediately at the start of ELAP event. The staff finds it reasonable that low outside temperatures would not have an adverse effect on the TDAFW pump because of its location in an initially temperature-controlled area, steam flow through the components provides a heat load, and the components are in use early in the ELAP event.

The licensee states in its FIP that the installed heat tracing for the AFST and RWST will be repowered using the Phase 2 generators. Additionally, the licensee stated in Section 2.6.4 of its FIP that the FLEX equipment stored outdoors is designed for outdoor storage in cold environments and will be available during an ELAP event. Additionally, the licensee stated that FLEX equipment status checks have been incorporated into the existing cold weather procedures and provided a list of the procedures in Section 2.6.4 of the FIP.

Based on the information above, the NRC staff finds the station equipment required to support the FLEX mitigation strategy should perform the required functions at the expected temperatures as a result of loss of heating during an ELAP event consistent with NEI 12-06 Sections 3.2.2.12 and 8.3.2.

3.9.1.3 Hydrogen Gas Control in Vital Battery Rooms

An additional ventilation concern that is applicable to Phases 2 and 3 is the potential buildup of hydrogen in the battery rooms as a result of loss of ventilation during an ELAP event. Off-gassing of hydrogen from batteries is only a concern when the batteries are charging.

In its FIP, the licensee stated that its Phase 2 FLEX strategy requires re-energizing the battery room exhaust fans when energizing the battery chargers (i.e., placing the batteries on charge). Attachment 1 of guideline FSG-5 includes operator actions to reenergize the battery chargers and the battery room exhaust fans.

Based on its review of the licensee's FIP and FSG-5, the NRC staff finds that the licensee's strategy is sufficient to prevent hydrogen accumulation in the Class 1E battery rooms from reaching the combustibility limit for hydrogen (4 percent) during an ELAP.

3.9.2 Personnel Habitability

The licensee ran a series of GOTHIC models to determine the temperatures in various areas of the plant. The basis for habitability is the PSEG Safety Manual and plant procedure SA-AA-111, "Heat Stress Control." Procedure SA-AA-111 provides guidance for work performed under elevated air temperatures. The evaluation addressed "moderate" work level such as pulling and connecting hose or cables, maneuvering equipment into place, and opening or closing valves. Once FLEX equipment is in place, many work activities become "light" work, such as monitoring running equipment.

3.9.2.1 Main Control Room

Technical Evaluation 80111831-0020 stated that the MCR is continuously occupied during the event. Temperatures in the MCR are estimated to reach 94 °F at 12 hours and peak at 104 °F at 72 hours. The evaluation assumes restoring control area ventilation fan number 12 at 24 hours. Guidance for re-powering the number 12 control area ventilation fan and its operation are covered in guideline S1/S2.OP-FLX-0005, "Initial Assessment and FLEX Equipment Staging", Attachment 4. Plant procedure SA-AA-111, "Heat Stress Control," provides guidance for work performed under elevated air temperatures.

3.9.2.2 Spent Fuel Pool Area

Technical Evaluation 80111831-002 analyzed the conditions in the FHB. The operating deck (130 foot elevation) needs to be accessed to install the SFP spray header. For the extreme case of a recent full core offload and with the SFP initially at a procedural limit of 149 °F, the operating deck area temperature reaches 140 °F at approximately 3 hours and quickly rises to 212 °F as the SFP water reaches the boiling point. For the expected at-power case, with the SFP at a normal initial temperature of 110 °F, the operating deck area temperature remains

below 120 °F for 10 hours. Spray headers will be installed within the first 3 hours. The estimated time to install the spray headers is 15 minutes for each unit. Technical Evaluation 80111831-0020 also assumes an FHB exhaust fan is re-energized to provide a vent path from the SFP area. This is performed using guideline S1/S2.OP-FS.FLX-0005, "Initial Assessment and FLEX Equipment Staging."

3.9.2.3 Other Plant Areas

Turbine Driven Auxiliary Feedwater Pump Room

The TDAFW pump room is expected to reach 142 °F after 4 hours. Under these conditions the allowed stay time is 15 minutes. The licensee considers this sufficient time to establish initial pump conditions. After 10 hours, portable fans will be available to provide temperature moderation for personnel as needed.

Inner and Outer Steam Penetration Rooms

The SG PORVs (MS10 valves) are located in these rooms. The evaluation indicates the 100 foot elevation may reach 130 °F at 8 hours with a maximum temperature of 150 °F at 72 hours. The calculated temperature for the 115 foot elevation is 133 °F at 8 hours and a maximum of 156 °F at 72 hours. No personnel actions are required in these areas.

3.9.3 Conclusions

The NRC staff concludes that the licensee has developed guidance that, if implemented appropriately, should maintain or restore equipment and personnel habitability conditions following a BDBEE consistent with NEI 12-06 guidance, as endorsed by JLD-ISG-2012-01, and should adequately address the requirements of the order.

3.10 Water Sources

3.10.1 Steam Generator Make-Up

As described in the FIP, the TDAFW pumps (one per unit) and the AFSTs (one per unit) would be used initially if available. The AFSTs are not tornado missile protected. If an AFST is not available, water to the TDAFW pump suction could be aligned from one of the following sources:

- demineralized water storage tank (DWST) (two at the site),
- primary water storage tank (PWST) (one per unit),
- Salem fire protection/fresh water storage tanks (FP/FWSTs) (two at the site),
- HCGS fire protection tanks using the HCGS diesel-driven fire pumps (two at the site), or
- Delaware River using a FLEX service water pump

The FIP states that the DWSTs, Salem FP/FWSTs and HCGS FPTs are non-seismic, non-safety related tanks. UFSAR Section 3.2.1.1 states that the PWSTs are non-safety related but are designed to Seismic Class II. UFSAR Section 3.2.1.3 states that the difference between

Class I and Class II is that for Class I components dynamic methods of qualification or conservative static equivalents were used, while for Class II components only static methods were used. PSEG Specification S-C-1970-DSP-7148, "Detail Specification No. 70-7148, Auxiliary Feedwater Storage Tanks, Primary Water Storage Tanks, Refueling Water Storage Tanks, Units No. 1 and 2, Salem Nuclear Generating Station," shows that these tanks have the same design specification requirements. Since the PWSTs were qualified to the safe shutdown earthquake, the NRC staff accepts that the PWSTs should be available following a seismic event. The licensee credits the PWSTs as a supply source to the TDAFW pumps during a seismic event when the AFST water runs out after 9 hours and the FLEX SW pump is not yet in service.

The strategy for maintaining AFW sources available following a tornado event is based on the adequate separation of the AFSTs and the HCGS FPTs. A conservative plant-specific tornado evaluation has been performed (VTD 903078, "FLEX Water Storage Tornado Wind Hazard Evaluation") and the separation distance between Salem AFSTs and the HCGS FWSTs is approximately 2,240 feet. The NRC staff approved this as an alternative to NEI 12-06, Section 3.2.1.3(3). See Section 3.14 below for more detail.

The licensee maintains three diesel-driven FLEX SW pumps in outdoor storage areas that have sufficient separation that at least two pumps should survive a tornado event. One pump is designated for Salem and the other for Hope Creek. The Salem FLEX SW pump is placed at the Delaware River near the service water intake structure and hoses are connected so that river water can be supplied to both Salem units using the service water nuclear header. In case of surface ice on the river, chop saws and chain saws are maintained as part of the FLEX equipment inventory and periodically checked via SC.OP-PM.FLX-0002, "FLEX Equipment Inventory."

The above sources of water are listed in order of preference. Once the Phase 2 FLEX equipment is aligned for use, the SGs can also be fed using an electric-driven FLEX AFW pump.

3.10.2 Reactor Coolant System Make-Up

In its FIP, the licensee described that the sources of borated water have been evaluated for use during a BDBEE. Each borated water source is discussed in order of usage preference.

The FIP described that the BASTs (two per unit) are located within the auxiliary building and are protected against all external events. A maximum required boration of 7,870 gallons of 6,775 ppm boron would be required from each unit's BASTs.

As described in the FIP, in the event that the BASTs become depleted, two portable boric acid mixing tank skids are available to provide a suction source for the FLEX charging pumps. One portable mixing tank skid is capable of supporting long term boration of both units. The mixing tanks are staged in the auxiliary building for protection against external hazards. Dilution water will be added to the mixing tank from the unit's PWST using the unit's primary water pump and a hose connection (preferred) or another available water source (DWST, Salem FP/FWSTs, HCGS FPTs or SW) should the PWST be unavailable. The mixing tanks are each equipped with a heater to improve solubility and prevent tank freezing, if necessary.

The FIP also described that the RWSTs (one per unit) are seismically qualified, but located outside and vulnerable to externally generated missiles. Each unit's RWST would be used if available but it is not credited for any FLEX strategy.

3.10.3 Spent Fuel Pool Make-Up

In its FIP, the licensee described that any of the above water sources that are available are acceptable for use as makeup to the SFP. Each water source is discussed in order of usage preference in the FIP.

The FIP also described that a diesel-driven FLEX SW pump can be deployed to the Delaware River and pump river water through the SW header to provide makeup to the SFP. Procedure S1(2).OP-FS.FLX-0011, "Alternate Spent Fuel Pool Makeup and Cooling," Rev 0, directs operators to use the cleanest water sources available.

3.10.4 Containment Cooling

In its FIP, the licensee described that no water sources are needed for containment cooling during phases 1 and 2. During Phase 3, the coping strategy relies on two NSRC-supplied 1.0 MWe CTGs per unit operating in parallel to provide enough electrical power to the required safeguards equipment. The CTGs will be capable of powering containment cooling equipment, allowing the use of the installed containment fan coil units cooled by Delaware River water supplied through the SW system using the diesel-driven FLEX SW pumps. In addition to the Phase 2 diesel-driven FLEX SW pumps, supplemental pumping capability will be supplied from the NSRC to support this function. Salem will implement resources received from the NSRC to provide power to the containment ventilation system thereby ensuring pressure control in containment.

3.10.5 Conclusions

Based on the evaluation above, the NRC staff concludes that the licensee has developed guidance that, if implemented appropriately, should maintain satisfactory water sources following a BDBEE consistent with NEI 12-06 guidance, as endorsed by JLD-ISG-2012-01, with approved alternatives, and should adequately address the requirements of the order.

3.11 Shutdown and Refueling Analyses

Order EA-12-049 requires that licensees must be capable of implementing the mitigation strategies in all modes. In general, the discussion above focuses on an ELAP occurring during power operations. This is appropriate, as plants typically operate at power for 90 percent or more of the year. When the ELAP occurs with the plant at power, the mitigation strategy initially focuses on the use of the steam-driven TDAFW pump to provide the water initially needed for decay heat removal. If the plant has been shut down and all or most of the fuel has been removed from the RPV and placed in the SFP, there may be a shorter timeline to implement the makeup of water to the SFP. However, this is balanced by the fact that if immediate cooling is not required for the fuel in the reactor vessel, the operators can concentrate on providing makeup to the SFP. The licensee's analysis shows that following a full core offload to the SFP,

at least 44 hours are available to implement makeup before boil-off results in the water level in the SFP dropping far enough to uncover fuel assemblies, and the licensee has stated that they have the ability to implement makeup to the SFP within that time.

When a plant is in a shutdown mode in which steam is not available to operate the TDAFW pump and allow operators to release steam from the SGs (which typically occurs when the RCS has been cooled below about 300 °F), another strategy must be used for decay heat removal. On September 18, 2013, NEI submitted to the NRC a position paper entitled "Shutdown/Refueling Modes" [Reference 38], which described methods to ensure plant safety in those shutdown modes. By letter dated September 30, 2013 [Reference 39], the NRC staff endorsed this position paper as a means of meeting the requirements of the order.

The position paper provides guidance to licensees for reducing shutdown risk by incorporating FLEX equipment in the shutdown risk process and procedures. Considerations in the shutdown risk assessment process include maintaining necessary FLEX equipment readily available and potentially pre-deploying or pre-staging equipment to support maintaining or restoring key safety functions in the event of a loss of shutdown cooling. The NRC staff concludes that the position paper provides an acceptable approach for demonstrating that the licensees are capable of implementing mitigating strategies in shutdown and refueling modes of operation. In its FIP, the licensee stated that it would abide by the guidance in this position paper. During the audit process, the NRC staff observed that the licensee had made progress in implementing this guidance.

Based on the licensee's incorporation of the use of FLEX equipment in the shutdown risk process and procedures, the NRC staff concludes that the licensee has developed guidance that if implemented appropriately should maintain or restore core cooling, SFP cooling, and containment following a BDBEE in shutdown and refueling modes consistent with NEI 12-06 guidance, as endorsed by JLD-ISG-2012-01, and should adequately address the requirements of the order.

3.12 Procedures and Training

3.12.1 Procedures

In its FIP, the licensee described that the inability to predict actual plant conditions that require the use of FLEX equipment makes it not feasible to provide specific procedural guidance. The FSGs provide guidance that can be employed for a variety of conditions. Clear criteria for entry into FSGs ensures that FLEX strategies are used only as directed for BDBEE conditions, and are not used inappropriately in lieu of existing procedures. When FLEX equipment is needed to supplement EOPs or abnormal operating procedures (AOPs), the EOP or AOP directs the entry into and exit from the appropriate FSG. The existing command and control procedure structure will be used to transition to severe accident mitigation guidelines (SAMGs) if FLEX mitigation strategies are not successful.

The FIP described that FSGs have been developed in accordance with PWROG guidelines. The FSGs provide instructions for implementing available, pre-planned FLEX strategies to accomplish specific tasks in the EOPs or AOPs. The FSGs are used to supplement (not replace) the existing procedure structure that establishes command and control for the event. If

plant systems are restored, exiting the FSGs and returning to normal plant operating procedures will be addressed by the plant's emergency response organization and operating staff dependent on the actual plant conditions at the time.

As described in the FIP, procedural Interfaces have been incorporated into 1/2-EOP-LOPA-1, "Loss of All AC Power," and 1/2-EOP-LOPA-4, "Extended Loss of All AC Power," to the extent necessary to include appropriate reference to FSGs and provide command and control for the ELAP. Additionally, procedural interfaces have been incorporated into existing AOPs to include appropriate references to FSGs.

The FIP also described that FSG maintenance is performed as described in procedure EM-AA-100-1002. The FSGs have been reviewed and validated to the extent necessary to ensure that implementation of the associated FLEX strategy is feasible.

3.12.2 Training

In its FIP, the licensee described that their training program has been revised to assure personnel proficiency in utilizing FSGs and associated FLEX equipment for the mitigation of BDBEEs is adequate and maintained. These programs and controls were developed and have been implemented in accordance with the Systematic Approach to Training (SAT) Process.

The FIP described that initial training has been provided and periodic training will be provided to site emergency response leaders on beyond-design-basis (BDB) emergency response strategies and implementing guidelines. Personnel assigned to direct the execution of the FLEX mitigation strategies for BDBEEs have received the necessary training to ensure familiarity with the associated tasks, considering available job aids, instructions, and mitigation strategy time constraints.

The FIP described that certification of the training simulator fidelity using ANSI/ANS 3.5, "Nuclear Power Plant Simulators for use in Operator Training," is considered to be sufficient to simulate the initial stages of the BDBEE scenario until the current capability of the simulator model is exceeded. Full scope simulator models will not be upgraded to accommodate FLEX training or drills.

The FIP also described that performance enhancing activities (which may include drills, exercises, tabletop drills, out-of-sequence focused drills, etc.) to provide knowledge and skill development for FLEX responses will be incorporated into the overall PSEG drill and exercise program. PSEG follows the training requirements set forth in 10 CFR 50.47(b)(14) and 10 CFR 50 Appendix E Section F.2.j.

3.12.3 Conclusions

Based on the description above, the NRC staff finds that the licensee has adequately addressed the procedures and training associated with FLEX. The procedures have been issued in accordance with NEI 12-06, Section 11.4, and a training program has been established in accordance with NEI 12-06, Section 11.6.

3.13 Maintenance and Testing of FLEX Equipment

As a generic issue, NEI submitted a letter to the NRC dated October 3, 2013 [Reference 40], which included EPRI Technical Report 3002000623, "Nuclear Maintenance Applications Center: Preventive Maintenance Basis for FLEX Equipment." By letter dated October 7, 2013 [Reference 41], the NRC endorsed the use of the EPRI report and the EPRI database as providing a useful input for licensees to use in developing their maintenance and testing programs. In its FIP, the licensee stated that they would conduct maintenance and testing of the FLEX equipment in accordance with the industry letter.

The FIP described that FLEX equipment can be used for other purposes as long as controls are put in place to ensure equipment is able to be deployed to the proper locations within the time requirements of the FLEX strategies. Connecting FLEX equipment to plant systems outside of a BDB ELAP may require the Shift Manager/Emergency Coordinator to invoke 10CFR50.54(x) and/or 10CFR73.55(p). The equipment must be returned to the proper storage area if severe weather is predicted or when not in use. Use of portable diesel equipment must be used in accordance with New Jersey Department of Environmental Protection (NJDEP) air permits. FLEX equipment must be tracked when alternate use of equipment and connections is permitted using the tracking form contained in OP-SA-108-115-1001.

The exception to this tracking requirement is the debris removal equipment and towing equipment. This equipment is maintained by the site services group and the requirements to separate this equipment by 1200 feet during severe weather and when not in use is controlled by MA-AA-716-002-1002, "Facilities Maintenance Guidelines."

The NRC staff finds that the licensee has adequately addressed equipment maintenance and testing activities associated with FLEX equipment because a maintenance and testing program has been established in accordance with NEI 12-06, Section 11.5.

3.14 Alternatives to NEI 12-06, Revision 0

3.14.1 Reduced Set of Hoses and Cables As Backup Equipment

In its FIP, the licensee took an alternative approach to the NEI 12-06 guidance for hoses and cables. In NEI 12-06, Section 3.2.2 states that in order to assure reliability and availability of the FLEX equipment required to meet these capabilities, the site should have sufficient equipment to address all functions at all units on-site, plus one additional spare, i.e., an N+1 capability, where "N" is the number of units on-site. Thus, a single-unit site would nominally have at least two portable pumps, two sets of portable ac/dc power supplies, two sets of hoses and cables, etc. The NEI on behalf of the industry submitted a letter to the NRC [Reference 48] proposing an alternative regarding the quantity of spare hoses and cables to be stored on site. The alternative proposed was that that either a) 10 percent additional lengths of each type and size of hoses and cabling necessary for the N capability plus at least one spare of the longest single section/length of hose and cable be provided or b) that spare cabling and hose of sufficient length and sizing to replace the single longest run needed to support any FLEX strategy. The licensee has committed to following the NEI proposal. By letter dated May 18, 2015 [Reference 49], the NRC agreed that the alternative approach is reasonable, but that the licensees may need to provide additional justification regarding the acceptability of various cable and hose

lengths with respect to voltage drops, and fluid flow resistance. The NRC staff approves this alternative as being an acceptable method of compliance with the order.

3.14.2 Outside Water Supplies (Tanks) are not Robust For Plant Hazards

Guidance document NEI 12-06 [Reference 6], Section 3.2.1.3(3), states that cooling and makeup water inventories contained in systems or structures with designs that are robust with respect to seismic events, floods, and high winds and associated missiles are available to use in the FLEX strategies. The Salem site has no outside tanks that are qualified to withstand tornado missiles. The licensee has proposed an alternative to credit water sources in outside tanks based on tank separation. For example, the suction of each unit's TDAFW pump is normally aligned to the unit's AFST. In case of damage to an AFST, Salem has evaluated the use of the HCGS FPTs as a water supply to the TDAFW pump based on tank separation distance much larger than the expected tornado diameter. During the audit the licensee provided evaluation VTD 903078, "FLEX Water Storage Tornado Wind Hazard Evaluation," and the separation distance between the Salem AFSTs and the HCGS FPTs is approximately 2,240 feet. This is considerably larger than the expected width of a tornado in this locale. The NRC staff reviewed this evaluation and accepted this alternative. The Hope Creek FPTs are not credited for use at Hope Creek. Note that the Salem procedures also discuss the use of other tanks to supply water to the TDAFW pumps if those tanks are available, such as the Salem DWSTs and FWSTs, although there is insufficient separation from the AFSTs to credit them. Use of water supplies that survive the event is certainly permissible, but the credited alternative to the AFSTs is the Hope Creek FPTs.

3.14.3 Two FLEX Generators Permanently Staged in Unit 2 Canyon Area

Guidance document NEI 12-06 [Reference 6], Section 7.3.1, states that there are three configurations that could be used to protect FLEX equipment from a high wind hazard such as tornadoes. The Salem configuration for the two pre-staged FLEX generators does not meet any of these configurations. The licensee presented the following information in attachment 2 of Reference 18 to justify the Salem configuration.

> As described in the most recent six-month update [Reference 49], Salem is using an alternative to the criteria of NEI 12-06 Section 7.3.1, "Protection of FLEX Equipment," which recommends protection of FLEX equipment from high wind hazards via storage in a structure or in diverse locations. The two pre-staged DGs in the Canyon Area are in the eastern most area of the canyon, surrounded on all four sides by the Fuel Handling Building and Auxiliary Building. FLEX equipment in the Canyon Area, including the DGs, are designed for a site specific wind speed of 200 mph that has an exceedance probability of 10^{-7} for this location.
>
> Design Change Package (DCP) 80111494, Supplement 7, "Salem Generating Station Canyon Area High Wind Hazard FLEX Equipment Storage and Deployment," includes a tornado missile evaluation specifically for the Canyon Area configuration. Based on this evaluation, a 1" solid steel rod traveling at 26 feet/sec is used to design the hardened protection of FLEX equipment and connections located in the sheltered Canyon Area. The FLEX DGs pre-staged in

the Canyon Area are hardened to provide protection from this missile impact and are secured to protect against tornado wind speeds. The two FLEX DGs stored outside of the Canyon Area are not missile protected but are separated by 1200 feet or greater to ensure a single tornado does not impact more than one stored FLEX DG. Therefore, at least one of the unprotected FLEX DGs will be available for deployment to the canyon area following a tornado event.

Pre-staging the two FLEX DGs in the Canyon Area is an alternative to NEI 12-06 Revision 0, which describes the use of portable equipment. The FLEX DGs in the Canyon Area are shown in Figure 2 of the enclosed FIP. They are protected from all NEI 12-06 external hazards. The pre-staged FLEX DGs are hardened ("armored" as shown on FIP Figure 2) with missile protection on the top and all sides, and are provided with bracing systems to resist seismic and wind loads.

DCP 80111494, "Salem FLEX Generator Deployment (Canyon)," included the restraint and evaluation of gas bottles stored on the Auxiliary Building roof, to ensure that they would not become tornado missiles.

The NRC staff finds that this configuration is an acceptable alternative to NEI 12-06 based on meeting the order requirement to provide reasonable protection for the associated equipment from external events.

3.14.4 Outdoor Storage of FLEX Equipment (Outside the Canyon Area)

Guidance document NEI 12-06 [Reference 6], Section 8.3.1, states that there are two configurations that could be used to protect FLEX equipment from snow, ice, and extreme cold. Both of these configurations involve storage inside a building. As previously discussed in Section 3.6.1.4 above, for some FLEX equipment the licensee is using outdoor storage without a building. The licensee stated that equipment stored outdoors is designed for outdoor storage in cold environments consistent with normal design practices, e.g., using diesel engine block heaters and space heaters. In addition, the FIP described that the licensee integrated the FLEX capabilities into existing site cold weather procedures and established periodic FLEX equipment status checks that include diesel keep-warm systems and verification that access to equipment is not impaired by snow or ice. The NRC staff finds this to be an acceptable alternative, as the licensee has provided reasonable protection for the associated equipment from snow, ice, and extreme cold. In its FIP, the licensee stated that the FLEX equipment stored outdoors is secured for a seismic event and located so it is not damaged by other items in a seismic event in accordance with NEI 12-06, Section 5.3.1. The licensee also stated in its FIP, that the outdoor storage areas are not protected from tornado missiles, but that the storage locations for necessary FLEX equipment and the spare (N+1) FLEX equipment such as the FLEX DGs and FLEX SW pumps are separated by 1200 feet or greater to ensure a tornado does not impact both sets at the same time, in accordance with NEI 12-06, Section 7.3.1.1.c.

3.14.5 Alternate FLEX Fluid Connection for Core Cooling Is Not Available

In NEI 12-06, Section 3.2.2, it states that the portable fluid connection for the core cooling function is expected to have a primary and alternate connection or delivery point. The core cooling function is provided by pumping water into the SGs to boil off for core decay heat

removal. As described in Section 3.7.3.1 above, the Salem units each have only a single discharge connection point for the FLEX AFW pump. The philosophy of two connection points is mainly based on bringing a diesel-powered pump from a storage location, and maneuvering it to where it could be connected to a plant system. Debris from the event could result in obstructing a connection point. However, the Salem FLEX AFW pumps are motor-driven, and are prestaged inside the auxiliary building. The discharge connection point to the AFW system is close to where the pumps are prestaged. For these reasons, and the reasons given in Section 3.7.3.1 above, the NRC staff accepts the Salem configuration as an alternative to NEI 12-06, and finds that it meets the order requirement to implement a strategy to maintain or restore core cooling following a BDBEE.

3.14.6 Alternate FLEX Electrical Connection for NSRC CTGs Is Not Available

In NEI 12-06, Section 3.2.2, it states that the electrical connections are expected to have a primary and alternate connection point. It also states that both the primary and alternate connection points do not have to be available for all applicable hazards, but the location of the connection points should provide reasonable assurance of at least one connection being available. As discussed in Section 3.7.3.2 above, the licensee does not have an alternate connection point for the NSRC CTGs. However, the primary connection point is inside the auxiliary building and is protected from all applicable hazards. Further, the staff reviewed the plant layout and the applicable hazards and concludes that there is reasonable assurance the licensee can access the connection point following a BDBEE. Therefore, the staff finds the alternative to NEI 12-06 to be acceptable.

3.14.7 Conclusion

In conclusion, the NRC staff finds that although the guidance of NEI 12-06 has not been met, if these alternatives are implemented as described by the licensee, they will meet the requirements of the order.

3.15 Conclusions for Order EA-12-049

Based on the evaluations above, the NRC staff concludes that the licensee has developed guidance to maintain or restore core cooling, SFP cooling, and containment following a BDBEE which, if implemented appropriately, should adequately address the requirements of Order EA-12-049.

4.0 TECHNICAL EVALUATION OF ORDER EA-12-051

By letter dated February 28, 2013 [Reference 24], the licensee submitted its OIP for Salem in response to Order EA-12-051. By letter dated July 11, 2013 [Reference 25] the NRC staff sent a request for additional information (RAI) to the licensee. The licensee provided a response by letter dated August 12, 2013 [Reference 26]. By letter dated October 17, 2013 [Reference 27], the NRC staff issued an ISE and RAI to the licensee. The licensee provided a response to the RAI by letter dated January 25, 2016 [Reference 35].

By letters dated August 25, 2013 [Reference 29], February 25, 2014 [Reference 30], August 26, 2014 [Reference 31], February 18, 2015 [Reference 32], and August 26, 2015 [Reference 33],

the licensee submitted status reports for the Integrated Plan. The Integrated Plan describes the strategies and guidance to be implemented by the licensee for the installation of reliable SFP level instrumentation which will function following a BDBEE, including modifications necessary to support this implementation, pursuant to Order EA-12-051. By letter dated January 25, 2016 [Reference 35] the licensee reported that full compliance with the requirements of Order EA-12-051 was achieved.

The licensee has installed a SFP level instrumentation system designed by Mohr Test and Measurement, LLC. The NRC staff reviewed the vendor's SFP level instrumentation system design specifications, calculations and analyses, test plans, and test reports. The staff issued a vendor audit report on August 27, 2014 [Reference 34].

The staff performed an onsite audit to review the implementation of SFP level instrumentation related to Order EA-12-051. The scope of the audit included verification of (a) site's seismic and environmental conditions enveloped by the equipment qualifications, (b) equipment installation met the requirements and vendor's recommendations, and (c) program features met the requirements. By letter dated October 10, 2014 [Reference 17], the NRC issued an audit report on the licensee's progress. Refer to Section 2.2 above for the regulatory background for this section.

Salem Units 1 and 2 each have their own SFP, located in each unit's fuel handling building. Each pool is approximately 37 feet long by 28 feet 6 inches wide, and 44 feet deep.

4.1 Levels of Required Monitoring

Attachment 2 of Order EA 12 051 states in part:

> All licensees identified in Attachment 1 to this Order shall have 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 [Level 1], (2) level that is adequate to provide substantial radiation shielding for a person standing on the SFP operating deck [Level 2], and (3) level where fuel remains covered and actions to implement make-up water addition should no longer be deferred [Level 3].

In its final compliance letter [Reference 35], the licensee provided Figure 1 (from PSEG drawing 606366) which shows Level 1 at 124 feet-8 inches (124'-8"), Level 2 at 114'-11¾", and Level 3 at 104'-11¾". In its final compliance letter the licensee states that the selection of Level 1 is based on the level at which reliable suction loss occurs for the SFP cooling pumps. The NRC staff's review indicates that water levels above Level 1 will support operation of the normal SFP cooling system. Guidance document NEI 12-02 [Reference 8] states that an acceptable level for Level 2 is 10 feet (plus or minus 1 foot) above the highest point of any fuel rack seated in the SFP. In its OIP [Reference 24], the license stated that its Level 2 value of 114'-11¾" is approximately 10 feet above the top of the fuel racks. The NRC staff notes that this value corresponds to an acceptable value for Level 2 from NEI 12-02. Guidance document NEI 12-02 states that an acceptable level for Level 3 is the highest point of any fuel rack seated in the SFP (plus or minus 1 foot). The licensee provided a sketch of the SFP in its letter dated August 12,

2013 [Reference 26]. This sketch shows that the top of the fuel racks is at 104'-11¾". Therefore, the licensee's value for Level 3 corresponds to an acceptable value for Level 3 as stated in NEI 12-02. The NRC staff notes that per this sketch the bottom of the level sensor is at 104'-11¾", and the staff notes that the sensor cannot sense water levels below that level. The NRC staff reviewed plant procedures for adding water to the SFPs, and notes that procedure 1/2-EOP-LOPA-4, "Extended Loss of All AC Power," Rev. 30, directs that actions be taken to add water to the SFPs when level drops below the low level alarm setting, which is set at 128'-2". Therefore, actions to add water will be taken well before reaching the level of 104'-11¾".

Based on the evaluation above, the NRC staff finds that the licensee's proposed Levels 1, 2 and 3 appear to be consistent with NEI 12-02 guidance, as endorsed by JLD-ISG-2012-03, and should adequately address the requirements of the order.

4.2 Evaluation of Design Features

Order EA-12-051 required that the SFP level instrumentation shall include specific design features, including specifications on the instruments, arrangement, mounting, qualification, independence, power supplies, accuracy, testing, and display. Refer to section 2.2 above for the requirements of the order in regards to the design features. Below is the staff's assessment of the design features of the SFP level instrumentation.

4.2.1 Design Features: Instruments

The licensee is using fixed instruments for both the primary and backup channels, which provide continuous level measurement over the entire range. In its letter dated August 12, 2013 [Reference 26], the licensee stated that the sensor is capable of continuously monitoring level from the high level alarm at elevation 129'-2" down to the top of the fuel racks at elevation 104'-11¾".

Based on the evaluation above, the NRC staff finds that the licensee's design, with respect to the number of channels and measurement range for its SFP, appears to be consistent with NEI 12-02 guidance, as endorsed by JLD-ISG-2012-03, and should adequately address the requirements of the order.

4.2.2 Design Features: Arrangement

In its letter dated August 12, 2013 [Reference 26], the licensee provided a plan view of the location of the sensors, cable routing, and sensor electronics and displays. The sensors are located near the end of each SFP, separated by the distance across the short side of the pool. As noted in the NRC staff's audit report [Reference 17], during the onsite audit the staff walked down the location of the level sensors in the SFP, the routing of the cables, and the locations of the instrument displays and backup batteries in the auxiliary building relay room. The NRC staff noted that there is sufficient channel separation within the SFP area between the primary and back-up level instruments, with cable routing in separate metal conduits with shielding provided by existing duct work to provide reasonable protection against loss of indication of SFP level due to missiles that may result from damage to the structure over the SFP.

Based on the evaluation above, the NRC staff finds that, if implemented appropriately, the licensee's proposed arrangement for the SFP level instrumentation appears to be consistent with NEI 12-02 guidance, as endorsed by JLD-ISG-2012-03, and should adequately address the requirements of the order.

4.2.3 Design Features: Mounting

In its letter dated August 12, 2013 [Reference 26], the licensee stated that the total loading, including static and dynamic loads, seismic and hydrodynamic, is in accordance with PSEG Technical Standards "Salem Structural Design Criteria". The Salem Structural Design Criteria provide both the design criteria and the methodology used for determining total loading. The licensee also stated that the Salem SFP Level Instrumentation Guided Wave Radar (GWR) sensor design does not include a stilling well. The low sensor mass and the sensor's reaction to seismic loading permit the sensor assembly mount to be very simple, lightweight, and require a very small footprint. The sensor is designed to mount in close proximity to the liner without penetrating it. Therefore, there are no points of attachment to the SFP liner.

By letters dated January 15, 2015 [Reference 28], and January 25, 2016 [Reference 35], the licensee further explained that for each unit's mounting attachment used to affix SFP level equipment to plant structures, the seismic response spectra bounding the Salem design maximum seismic loads applicable to the installed locations were used as the design input to perform the analysis. The SFP level probe assembly is supported by a bracket bolted to the edge of the SFP. Salem calculation 6S0-2345 demonstrates that the mounting configuration is structurally adequate to meet seismic design requirements, including structural adequacy of the bracket when subjected to seismic and hydrodynamic loads. The electronics, power supply enclosure, and battery boxes are column mounted and the mounting is shown to be structurally adequate in Salem calculation 6S0-2346.

During the week of May 26, 2014, the NRC staff conducted an audit of the design and qualification of Mohr's SFPI. The staff issued an audit report dated August 27, 2014 [Reference 34]. During this audit the staff reviewed the seismic test results for the SFPI signal processing unit and the extended battery documented in Mohr's document No. 1-4010-6, "Seismic Test Report" Rev. 1, dated February 6, 2014. These tests were conducted on a triaxial shake table using the IEEE guidance of standard IEEE 344- 2004, Sections 7, 8, 9, and 10 as recommended in the NRC's document JLD-ISG-2012-03 [Reference 9]. In its compliance letter [Reference 28], the licensee stated that an analytic modeling performed by the instrument vendor in accordance with IEEE 344-2004 used a detailed computational SFP hydrodynamic model. The computational model accounts for multi-dimensional fluid motion, pool sloshing, and loss of water from the pool. Seismic loading response of the probe and mount was separately modeled using finite element modeling software.

Based on the evaluation above, the NRC staff finds that the licensee's proposed mounting design appears to be consistent with NEI 12-02 guidance, as endorsed by JLD-ISG-2012-03, and should adequately address the requirements of the order.

4.2.4 Design Features: Qualification

4.2.4.1 Augmented Quality Process

Appendix A-1 of the guidance in NEI 12 02 describes a quality assurance process for non-safety systems and equipment that are not already covered by existing quality assurance requirements. In JLD-ISG-2012-03, the NRC staff found the use of this quality assurance process to be an acceptable means of meeting the augmented quality requirements of Order EA 12 051.

In its final compliance letter [Reference 35], the licensee stated that the SFP level instruments are designed to provide reliable indication at temperature, humidity and radiation levels consistent with beyond design basis conditions using the NRC-endorsed guidance of NEI 12-02, and are subject to the Salem augmented quality process.

Based on the discussion above, the NRC staff finds that, if implemented appropriately, this approach appears to be consistent with NEI 12-02 guidance, as endorsed by JLD-ISG-2012-03, and should adequately address the requirements of the order.

4.2.4.2 Instrument Channel Reliability

Section 3.4 of NEI 12-02 states, in part:

> The instrument channel reliability shall be demonstrated via an appropriate combination of design, analyses, operating experience, and/or testing of channel components for the following sets of parameters, as described in the paragraphs below:
>
> - conditions in the area of instrument channel component use for all instrument components,
> - effects of shock and vibration on instrument channel components used during any applicable event for only installed components, and
> - seismic effects on instrument channel components used during and following a potential seismic event for only installed components.

Equipment reliability performance testing was performed to (1) demonstrate that the SFP instrumentation (SFPI) will not experience failures during BDB conditions of temperature, humidity, emissions, surge, and radiation, and (2) to verify those tests envelope the plant-specific requirements.

During the Mohr audit, the NRC staff performed a review of the SFPI technical and design information. Activities that were performed in support of this vendor audit included detailed analysis and calculation discussions, equipment demonstration, and discussions with the vendor staff on specific topics. The staff also attended a presentation by vendor staff on the technical attributes and testing results of the instrumentation and witnessed a hands-on demonstration of vendor staff operating the equipment. The staff included a summary of the SFPI environmental qualification and reliability design documents reviewed in the audit report dated August 27, 2014 [Reference 34].

In its letter dated August 12, 2013 [Reference 26], the licensee stated that all equipment located in the FHB would be certified for use by the manufacturer for survivability under post-event

conditions including temperatures of at least 212 °F, 100 percent condensing atmosphere, submerged operation for components located in the SFP at elevated chemical concentrations, and exposure to postulated radiation levels with the SFP water levels at the top of the fuel storage racks for an extended period of time. The licensee also stated that the new electronics enclosures will be installed in the auxiliary building relay room, which is considered a mild environment. During the staff's review, the staff noted that the SFPI testing parameters envelope the expected BDB conditions at the site for the sensors in the fuel handling building and the electronics in the mild environment of the auxiliary building relay room.

In its letters dated January 15, 2015, and January 25, 2015, the licensee stated that for both units, a radiation dose rate analysis was performed to support the radiological assessment requirements defined by NEI 12-02 for the SFP area. The results from the dose rate analysis (dose rate and total integrated dose) were used as the design criteria supplied to the vendor as part of the PSEG Procurement Specification. In addition, information supplied from the vendor in a material qualification report was compared to the radiation, temperature and humidity conditions at the site and used as the basis to demonstrate reliability of the permanently installed equipment located in the SFP and surrounding area under the BDB conditions.

In 2015, Mohr identified that a component (a filter coil, also known as a choke) on one of the electronic circuit boards was experiencing a high rate of failure. Mohr selected a better replacement component, and Salem returned the circuit boards to Mohr for repairs. The NRC staff has evaluated this component replacement and found it acceptable. The component replacements by Mohr for Unit 1 are documented in the licensee's corrective action program, notifications 20694109 and 20700647. The component replacements for Unit 2 are documented in Revision 4 to design change package DCP-80108861, "Salem Unit 1 and 2 Spent Fuel Pool Level Instrumentation Modification."

Based on the evaluation above, the NRC staff finds that the licensee's proposed instrument qualification process appears to be consistent with NEI 12-02 guidance, as endorsed by JLD-ISG-2012-03, and should adequately address the requirements of the order.

4.2.5 Design Features: Independence

In its letter dated August 12, 2013 [Reference 26], the licensee stated that the SFP level instrumentation system is designed to provide two completely independent channels of level instrumentation. Each channel is comprised of the GWR sensor assembly, the sensor mount, and an electronics enclosure (transmitter, signal conditioning, communications circuitry, display panel, and internal battery). Each channel's electronics is equipped with appropriate connections to provide a signal to the remote displays. The normal power supply for each channel will be provided via separate 115 Vac, from battery-backed inverter vital power supplies, such that loss of one power source will not result in the loss of both channels.

The licensee stated that primary and back-up level sensors are located in different corners of the SFP with the electronics enclosures located in the relay room within the auxiliary building. The licensee further stated that the FHBs and auxiliary buildings are Seismic Class 1 structures designed to withstand seismic, flooding and wind events and therefore provide reasonable protection in accordance with assumptions used for Order EA-12-049 and outlined in NEI 12-06. The licensee also stated that that the Salem "Technical Standard for Physical Separation

Requirements (Electrical)" for instrument cabling would be applied to the SFP level instrumentation design.

Based on the evaluation above, the NRC staff finds that the licensee's proposed design, with respect to instrument channel independence, appears to be consistent with NEI 12-02 guidance, as endorsed by JLD-ISG-2012-03, and should adequately address the requirements of the order.

4.2.6 Design Features: Power Supplies

In its final compliance letter [Reference 35], the licensee stated that the power supply for each channel uses separate 115 Vac vital instrument buses. For Unit 1 the buses are 1B and 1C. For Unit 2, the buses are 2B and 2C. These buses are powered from uninterruptible power supplies (UPSs). Each UPS receives normal power from separate 230 Vac vital power. In the event of a loss of 230 Vac power, independent 125 Vdc vital station batteries will automatically supply power to the UPS's inverter in order to keep the 115 Vac vital instrument buses energized. If the 115 Vac vital instrument buses become deenergized, each SFP level channel has a local backup battery that is sized by the vendor. Mohr Test and Measurement, LLC, document 1-0410-7, "MOHR EFP-IL Spent Fuel Pool Instrumentation System Battery Life Report," concluded that the battery has sufficient capacity to maintain the level indication function for longer than 7 days. Mohr Document No. 1-0410-10, "MOHR EFP-IL SFPI System Power Interruption Report," Rev. 1, dated January 10, 2014, describes power interruption testing on the EFP-IL signal processing unit and battery. Test results indicate that no deficiencies were identified with respect to maintenance of reliable function, accuracy, or calibration as a result of power interruption.

Based on the discussion above, the NRC staff finds that the licensee's proposed power supply design appears to be consistent with NEI 12-02 guidance, as endorsed by JLD-ISG-2012-03, and should adequately address the requirements of the order.

4.2.7 Design Features: Accuracy

During the vendor audit the NRC staff reviewed the results from testing performed on the probe at 500 °F in saturated steam (100 percent relative humidity) that showed a system accuracy of approximately 0.5 inches. MOHR Document No. 1-0410-15, "MOHR EFP-IL-SFPI System Uncertainty Analysis," states, in part, that the EFP-IL-SFPI MOHR system, configured with a maximum length of transmission cable of 1000 feet, stays within the level measurement accuracy of ± 3 inches. Regarding the effects of the environmental conditions on the instrument, MOHR document No. 1-0410-3, "MOHR EFP-IL SFPI Proof of Concept Report," Rev. 0, states that the effects of temperature and humidity are insignificant with regard to measurement accuracy.

In its letters dated January 15, 2015, and January 25, 2015, the licensee re-stated the accuracy showed by vendor testing and further explained that the instrument vendor also identified that the presence of boric acid precipitate on the probe's active electrode surfaces above the water level produces a fixed measurement error with characteristic lowering of the apparent water level. The worst-case level measurement error due to this effect is estimated to be 2.5 inches, still within the ± 3 inches accuracy demonstrated during the factory acceptance test.

Based on the evaluation above, the NRC staff finds that the licensee's proposed instrument accuracy appears to be consistent with NEI 12-02 guidance, as endorsed by JLD-ISG-2012-03, and should adequately address the requirements of the order.

4.2.8 Design Features: Testing

In its letter dated August 12, 2013 [Reference 26], the licensee stated that the two independent channels of the SFP level instrumentation system will be cross-checked against each other. Since the two wide range level channels are independent, a channel check tolerance based on the design reference accuracy of each channel will be applied for cross comparison between the two channels. The overall channel tolerance will be determined using the Salem Instrument Setpoint Technical Standard and instrument reference accuracy information provided by the manufacturer.

In its letters dated January 15, 2015 and January 25, 2015, the licensee also stated that standard measurement and test equipment (M&TE) is used to confirm normal operation of the signal processor using a calibration procedure provided by the vendor. During planned periodic calibration checks, time-domain reflectometry (TDR) is used to demonstrate the impedance waveform through the transmission cable and connectors from the signal processor to the probe is unchanged when compared with the as-installed configuration. During normal operation, the level instrument automatically monitors the integrity of its level measurement system. All testing is performed using in-situ capability.

Further, MOHR documents, 1-0410-12, "MOHR EFP-IL Signal Processor Operator's Manual," 1-0410-13, "MOHR EFP-IL Signal Processor Technical Manual," and 1-0410-14, "MOHR SFP-1 Level Probe Assembly Technical Manual", reviewed by NRC staff, provide the testing and calibration procedures for the SFPI. MOHR's SFPI design can be calibrated in-situ without removal from its installed location. The system is calibrated using a CT-100 device and processing of vendor scanned files. Vendor documents also provide recommended calibration intervals to be followed by users of this instrumentation.

Based on the evaluation above, the NRC staff finds that the licensee's proposed SFP instrumentation design allows for testing consistent with NEI 12-02 guidance, as endorsed by JLD-ISG-2012-03, and should adequately address the requirements of the order.

4.2.9 Design Features: Display

Section 3.9 of NEI 12-02 states that the intent of the guidance is to ensure that information is promptly available to the plant staff and decision makers. In its final compliance letter [Reference 35], the licensee stated that:

> a) The primary and backup instrument channel displays are located in the Auxiliary Building Relay Room which is located one elevation below the MCR [main control room] and is easily accessible. Displays are also located in the MCR but the MCR displays are not provided with battery backup power and are therefore not credited for compliance with NRC Order EA-12-051.

b) The displays can be promptly accessed and viewed by emergency response staff using a stairwell located immediately outside the MCR. The display location was selected due to its proximity to other equipment that would require manual operation or require operator actions in support of BDB mitigating strategy implementation and anticipated BDB mitigating strategy access paths. Radiological habitability at this location has been evaluated against the Salem Unit 1 and 2 Environmental Design Criteria for postulated DBA [design basis accident] radiological events and used as a basis to determine radiological conditions for this location. The estimated doses obtained from SFP drain down conditions at Level 3 and exposure to personnel monitoring SFP levels from this location are bounded by the DBA radiological conditions. Heat and humidity have been evaluated for this location, and the location of the displays in the Auxiliary Building Relay Room, one elevation below the MCR, is sufficiently separated from the SFP and therefore heat and humidity from a boiling SFP will not compromise habitability.

Due to the location of the displays, the design can accommodate either periodic or continuous monitoring based on the requirements of the implementing BDB mitigating strategy. Travel time from the control room to the level displays is less than 5 minutes based on an informal walk through. Radiological, heat and humidity for the transit route has been evaluated and habitability is not compromised.

Communication remains available between the display location and the MCR or other emergency response locations within the power block where decision makers are located.

Based on the discussion above, and walkdowns conducted by the NRC staff during the onsite audit, the staff finds that the licensee's proposed location and design of the SFP instrumentation displays appear to be consistent with NEI 12-02 guidance, as endorsed by JLD-ISG-2012-03, and should adequately address the requirements of the order.

4.3 Evaluation of Programmatic Controls

Order EA-12-051 specified that the spent fuel pool instrumentation shall be maintained available and reliable through appropriate development and implementation programmatic controls, including training, procedures, and testing and calibration. Below is the NRC staff's assessment of the programmatic controls for the SFPI.

4.3.1 Programmatic Controls: Training

Guidance document NEI 12-02 specifically addresses the use of a Systematic Approach to Training (SAT) for training personnel in the use and the provision of alternate power to the primary and backup SFP instrument channels. In its final compliance letter [Reference 35], the licensee indicated that the SAT will be used to identify the population to be trained and to determine both the initial and continuing elements of the required training. In its final compliance letter, the licensee stated that:

> A systematic approach to training (SAT) was used for the new SFPLI equipment as part of the PSEG design change process. Training of on-site staff by PSEG training personnel was determined via SAT for the Operations and Maintenance training populations, in accordance with the SAT model of Analysis, Design, Development, Implementation, and Evaluation (ADDIE). The Analysis process of SAT identifies the population to be trained and the Design process determines the initial and continuing elements of the training. These processes are governed by station approved training procedures as a part of the National Academy for Nuclear Training accredited training programs.

Based on the discussion above, the NRC staff finds that the licensee's plan to train personnel in the operation, maintenance, calibration, and surveillance of the SFP level instrumentation, including the approach to identify the population to be trained, appears to be consistent with NEI 12-02 guidance, as endorsed by JLD-ISG-2012-03, and should adequately address the requirements of the order.

4.3.2 Programmatic Controls: Procedures

In its final compliance letter [Reference 35], the licensee described the procedures that have been developed for use with the SFP level instrumentation. The licensee stated that the procedures address operation (both normal and abnormal response), calibration, test, maintenance, and inspection, and that vendor documents that provide guidance for preventive and corrective maintenance have been approved for use at Salem. FSGs have been developed that use the SFP level indications to guide operator actions to maintain the water level in the SFPs.

Based on the discussion above, the NRC staff finds that the licensee's procedure development appears to be consistent with NEI 12-02 guidance, as endorsed by JLD-ISG-2012-03, and should adequately address the requirements of the order.

4.3.3 Programmatic Controls: Testing and Calibration

In its final compliance letter [Reference 35], the licensee described the maintenance and testing program that has been developed for use with the SFP level instrumentation. The licensee stated that:

> The SFP level instrument channel maintenance and testing program requirements to ensure design and system readiness are established in accordance with PSEG process and procedures, with consideration of vendor recommendations. The program ensures appropriate testing, channel checks, functional checks, periodic calibration and maintenance are performed.
>
> Provisions associated with out of service or inoperable equipment including out of service times and compensatory actions are in accordance with NEI 12-02 Section 4.3, "Testing and Calibration."

Based on the discussion above, the NRC staff finds that the licensee's proposed testing and calibration plan appears to be consistent with NEI 12-02 guidance, as endorsed by JLD-ISG-2012-03, and should adequately address the requirements of the order.

4.4 Conclusions for Order EA-12-051

In its letter dated February 28, 2013 [Reference 24], the licensee stated that they would meet the requirements of Order EA-12-051 by following the guidelines of NEI 12-02, as endorsed by JLD-ISG-2012-03. In the evaluation above, the NRC staff finds that, if implemented appropriately, the licensee has conformed to the guidance in NEI 12-02, as endorsed by JLD-ISG-2012-03. In addition, the NRC staff concludes that if the SFP level instrumentation is installed at Salem according to the licensee's proposed design, it should adequately address the requirements of Order EA-12-051.

5.0 CONCLUSION

In August 2013 the NRC staff started audits of the licensee's progress on Orders EA-12-049 and EA-12-051. The staff conducted an onsite audit in August 2014 [Reference 17]. The licensee reached its final compliance date on July 28, 2016, and has declared that both of the reactors are in compliance with the orders. The purpose of this safety evaluation is to document the strategies and implementation features that the licensee has committed to. Based on the evaluations above, the NRC staff concludes that the licensee has developed guidance and proposed designs that if implemented appropriately should adequately address the requirements of Orders EA-12-049 and EA-12-051. The NRC staff will conduct an onsite inspection to verify that the licensee has implemented the strategies and equipment to demonstrate compliance with the orders.

6.0 REFERENCES

1. SECY-11-0093, "Recommendations for Enhancing Reactor Safety in the 21st Century, the Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident," July 12, 2011 (ADAMS Accession No. ML11186A950)

2. 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," February 17, 2012 (ADAMS Accession No. ML12039A103)

3. SRM-SECY-12-0025, "Staff Requirements – 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," March 9, 2012 (ADAMS Accession No. ML120690347)

4. Order EA-12-049, "Order Modifying Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events," March 12, 2012 (ADAMS Accession No. ML12054A736)

5. Order EA-12-051, "Order Modifying Licenses with Regard to Reliable Spent Fuel Pool Instrumentation," March 12, 2012 (ADAMS Accession No. ML12054A679)

6. Nuclear Energy Institute document NEI 12-06, "Diverse and Flexible Coping Strategies (FLEX) Implementation Guide," Revision 0, August 21, 2012 (ADAMS Accession No. ML12242A378)

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," August 29, 2012 (ADAMS Accession No. ML12229A174)

8. Nuclear Energy Institute document NEI 12-02, "Industry Guidance for Compliance with NRC Order EA-12-051, To Modify Licenses with Regard to Reliable Spent Fuel Pool Instrumentation," Revision 1, August 24, 2012 (ADAMS Accession No. ML12240A307)

9. JLD-ISG-2012-03, "Compliance with Order EA-12-051, Order Modifying Licenses with Regard to Reliable Spent Fuel Pool Instrumentation," August 29, 2012 (ADAMS Accession No. ML12221A339)

10. Letter from PSEG to NRC, "PSEG Nuclear LLC's Overall Integrated Plan for the Salem Generating Station in Response to March 12, 2012 Commission Order Modifying Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events (Order Number EA-12-049)," February 28, 2013 (ADAMS Accession Nos. ML13059A296 and ML13059A297)

11. Letter from PSEG to NRC, "PSEG Nuclear LLC's First Six Month Status Report for the Salem Generating Station In Response to March 12, 2012 Commission Order Modifying Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-

Basis External Events (Order Number EA-12-049)," August 25, 2013 (ADAMS Accession No. ML13239A097)

12. Letter from PSEG to NRC, "PSEG Nuclear LLC's Second Six Month Status Report for the Salem Generating Station In Response to March 12, 2012 Commission Order Modifying Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events (Order Number EA-12-049)," February 25, 2014 (ADAMS Accession No. ML14058A230)

13. Letter from PSEG to NRC, "PSEG Nuclear LLC's Third Six Month Status Report for the Salem Generating Station In Response to March 12, 2012 Commission Order Modifying Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events (Order Number EA-12-049)," August 26, 2014 (ADAMS Accession No. ML14240A265)

14. Letter from PSEG to NRC, "PSEG Nuclear LLC's Fourth Six Month Status Report for the Salem Generating Station In Response to March 12, 2012 Commission Order Modifying Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events (Order Number EA-12-049)," February 18, 2015 (ADAMS Accession No. ML15051A267)

15. Letter from Jack R. Davis (NRC) to All Operating Reactor Licensees and Holders of Construction Permits, "Nuclear Regulatory Commission Audits of Licensee Responses to Mitigation Strategies Order EA-12-049," August 28, 2013 (ADAMS Accession No. ML13234A503)

16. Letter from Jeremy S. Bowen (NRC) to Thomas Joyce (PSEG), "Salem Nuclear Generating Station, Unit Nos. 1 and 2 – Interim Staff Evaluation and Audit Report Relating to Overall Integrated Plan in Response to Order EA-12-049 (Mitigation Strategies)," January 24, 2014 (ADAMS Accession No. ML13339A667)

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Date: January 19, 2017

SALEM NUCLEAR GENERATING STATION, UNIT NOS. 1 AND 2 - SAFETY EVALUATION REGARDING IMPLEMENTATION OF MITIGATING STRATEGIES AND RELIABLE SPENT FUEL POOL INSTRUMENTATION RELATED TO ORDERS EA-12-049 AND EA-12-051 DATED January 19, 2017

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