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

August 1, 2017

Mr. George Lippard III, Vice President
Nuclear Operations
South Carolina Electric and Gas Company
Virgil C. Summer Nuclear Station
P. O. Box 88, Mail Code 800
Jenkinsville, SC 29065

SUBJECT: VIRGIL C. SUMMER NUCLEAR STATION, UNIT 1, 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. MF2338 AND MF1173)

Dear Mr. Lippard:

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. ML13063A150), South Carolina Electric and Gas Company, (SCE&G, the licensee), submitted its OIP for Virgil C. Summer Nuclear Station, Unit 1 (VCSNS) in response to Order EA-12-049. At six month intervals following the submittal of its 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 February 21, 2014 (ADAMS Accession No. ML14034A339), and September 16, 2015 (ADAMS Accession No. ML15253A721), the NRC issued an Interim Staff Evaluation (ISE) and audit report, respectively, on the licensee's progress. By letter dated October 31, 2016,(ADAMS Accession No. ML16307A390), SCE&G submitted a compliance letter and Final Integrated Plan (FIP) for VCSNS, Unit 1 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. ML13063A099), SCE&G submitted its OIP for VCSNS 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 December 5, 2013 (ADAMS Accession No. ML13305A100), and September 16, 2015 (ADAMS Accession No. ML15253A721), 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 22, 2016 (ADAMS Accession No. ML16028A196), SCE&G 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 SCE&G's strategies for VCSNS. The intent of the safety evaluation is to inform SCE&G 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 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 Milton Valentin-Olmeda, Orders Management Branch, VCSNS Project Manager, at 301-415-2864 or at Milton.Valentin-Olmeda@nrc.gov.

Sincerely,

Tony Brown, Acting Chief
Orders Management Branch
Japan Lessons-Learned Division
Office of Nuclear Reactor Regulation

Docket No.: 50-395

Enclosure:
Safety Evaluation

cc w/encl: Distribution via Listserv

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SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

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

SOUTH CAROLINA ELECTRIC AND GAS COMPANY

VIRGIL C. SUMMER NUCLEAR STATION, UNIT 1

DOCKET NO. 50-395

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" (Agencywide Documents Access and Management System (ADAMS) Accession No. ML12054A736). 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" (ADAMS Accession No. ML12054A679). 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 (ADAMS Accession No. ML11186A950). 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," (ADAMS Accession No. ML12039A103) 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 (ADAMS Accession No. ML120690347), the NRC staff issued Orders EA-12-049 and EA-12-051.

2.1 Order EA-12-049

Order EA-12-049, Attachment 2, (ADAMS Accession No. ML12054A736) 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 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 December 10, 2015, following submittals and discussions in public meetings with NRC staff, the Nuclear Energy Institute (NEI) submitted document NEI 12-06, Revision 2, "Diverse and Flexible Coping Strategies (FLEX) Implementation Guide," (ADAMS Accession No. ML16005A625) to the NRC to provide revised 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, Revision 2, and on January 22, 2016, issued Japan Lessons-Learned Directorate (JLD) Interim Staff Guidance (ISG) JLD-ISG-2012-01, Revision 1, "Compliance with Order EA-12-049, Order Modifying Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events," (ADAMS Accession No. ML15357A163), endorsing NEI 12-06, Revision 2, with exceptions, additions, and clarifications, as an acceptable means of meeting the requirements of Order EA-12-049, and published a notice of its availability in the *Federal Register* (81 FR 10283).

2.2 Order EA-12-051

Order EA-12-051, Attachment 2, (ADAMS Accession No. ML12054A679) 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 (ADAMS Accession No. ML12240A307) 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" (ADAMS Accession No. ML12221A339), 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 TECHNICAL EVALUATION OF ORDER EA-12-049

By letter dated February 28, 2013 (ADAMS Accession No. ML13063A150), South Carolina Electric and Gas Company (SCE&G, the licensee) submitted its Overall Integrated Plan (OIP) for Virgil C. Summer Nuclear Station, Unit 1 (VCSNS, V.C. Summer) in response to Order EA-12-049. By letters dated August 28, 2013 (ADAMS Accession No. ML13242A273), February 27, 2014 (ADAMS Accession No. ML14063A203), August 28, 2014 (ADAMS Accession No. ML14245A405), February 27, 2015 (ADAMS Accession No. ML15062A007), August 24, 2015 (ADAMS Accession No. ML15239A750), February 26, 2016 (ADAMS Accession No. ML16061A005), and August 29, 2016 (ADAMS Accession No. ML16243A464), the licensee submitted six-month updates to the OIP. 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 February 21, 2014 (ADAMS Accession No. ML14034A339), and September 16, 2015 (ADAMS Accession No. ML15253A721), the NRC issued an Interim Staff Evaluation (ISE) and an audit report on the licensee's progress. By letter dated October 31, 2016 (ADAMS Accession No. ML16307A390), the licensee reported full compliance with the requirements of Order EA-12-049 was achieved for VCSNS Unit 1, and submitted a Final Integrated Plan (FIP).

3.1 Overall Mitigation Strategy

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 concurrent 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.

V.C. Summer, Unit 1 is a 3-loop Westinghouse pressurized-water reactor (PWR) with a dry ambient pressure containment. The licensee's three-phase approach to mitigate a postulated ELAP event, as described in the FIP, is summarized below.

At the onset of an ELAP, the reactor trips from full power and initially stabilizes at no-load reactor coolant system (RCS) temperature and pressure conditions. Reactor decay heat is removed via steam release to the atmosphere through the steam generator (SG) power operated relief valves (PORVs) and/or the main steam safety valves (MSSVs). The reactor coolant pumps (RCPs) lose power and natural circulation of the RCS develops to provide core cooling. The turbine driven emergency feedwater (TDEFW) pump will provide flow from the condensate storage tank (CST) to the SGs to make up for steam release. For Phase 1, the licensee would commence a cooldown of the RCS and would continue feeding the SGs via the TDEWF pump for as long as there is sufficient CST inventory and sufficient SG pressure. For Phase 2, the RCS cooling strategy depends on the availability of equipment. If the CST is not available, the permanently installed FLEX alternate emergency feedwater (EFW) suction pumps would be aligned to transfer water from the UHS (service water (SW) pond) to the TDEFW pump suction to restore TDEFW flow within one hour. When the TDEFW becomes unavailable, the licensee would repower a motor-driven emergency feedwater (MDEFW) pump to continue pumping water from the CST or SW pond. Use of the MDEFW pump requires the operation of both of the FLEX combustion turbine generators (CTGs). If sufficient power is not available for the MDEFW pump, the licensee will use a portable FLEX SG feed pump for Phase 2. The Phase 3 RCS strategy would continue the Phase 2 coping strategy with the available pumps and systems, supplemented with offsite equipment as needed. The licensee has also identified other water sources, such as the demineralized water storage tank (DWST), the filtered water storage tank (FWST), the SW pond, or Lake Monticello (also refered to as Monticello Reservoir), as sources for SG makeup.

The electrical strategy for Phase 1 relies on the installed station batteries and the loads powered from it. The licensee sheds unnecessary loads to prolong battery life to greater than 15 hours. The licensee provides power to the station battery chargers before 15 hours from either a FLEX 7.2 kilovolt (kV) (1 megawatt (MW) CTG or a FLEX 480Volt (V) 80 kilowatt (kW)) portable diesel generator (DG). Load shedding of all non-essential ac and dc loads would commence at 3 hours and would be completed within 1 hour. Critical instrumentation is maintained throughout all phases.

As is typical of Westinghouse plants, there is no Phase 1 capability to make up to the RCS. The RCS cooldown 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 liquid volume. However, during the cooldown RCS pressure should drop below the safety injection accumulator pressure and some quantity of borated water from the accumulators would inject into the RCS. For Phase 2 the licensee initiates borated makeup to the RCS to maintain natural circulation and adequate shutdown margin. The RCS makeup and boration will be initiated by 20 hours using a FLEX RCS makeup pump taking suction from the refueling water storage tank (RWST), if available, or the boric acid tanks (BATs) and injecting via the safety injection (SI) system or the charging system.

The SFP is located in the fuel-handling building (FHB). Upon initiation of the ELAP event, the SFP will heat up due to the unavailability of the normal cooling system. The licensee has calculated that boiling could start as soon as 21 hours after the start of the event. To maintain SFP cooling capabilities, the licensee determined that it would take approximately 87 hours for SFP water level to drop to a level requiring the addition of makeup to preclude fuel damage. Makeup water would be provided in Phase 2 using one of the FLEX UHS pump systems from the SW pond, which is the site's UHS, or from the Monticello Reservoir. One makeup option uses fire hoses connected from the discharge of the FLEX pumps to a permanent FLEX connection on the safety-related SFP cooling system located in the safety-related auxiliary building (AB). Another option uses hoses connected to spray monitors located in the FHB. Natural circulation ventilation is established by opening the railroad bay doors and access penetrations in the roof. If additional ventilation is needed, destructive removal of panels in the walls of the FHB may be performed. Phase 3 would be a continuation of the Phase 2 approach using offsite equipment, as needed.

For the containment strategy, licensee calculations demonstrate that containment temperature and pressure will remain below design limits, and that key parameter instruments subject to the containment environment will remain functional for a minimum of 30 days. Therefore, actions to reduce containment temperature and pressure, and to ensure continued functionality of the instruments, are not immediately required. When desired to reduce containment temperature and pressure, portable CTGs provided by the National Strategic Alliance of FLEX Emergency Response (SAFER) Response Center (NSRC) can be used to energize a reactor building cooling unit fan, and cooling water to the reactor building cooling unit (RBCU) can be provided using a FLEX UHS pump system. Alternatively, containment temperature and pressure can be reduced by establishing spray within the containment using the FLEX UHS pump system to supply water to the reactor building (RB) spray header.

Equipment from one of the NSRCs will be used as needed. The NSRCs will provide high capacity pumps and large CTGs. There are two NSRCs in the United States.

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

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 states that immediately following the occurrence of an ELAP event concurrent with loss of normal access to the UHS, 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 MSSVs and SG PORVs. Natural circulation of the reactor coolant system will develop to provide core cooling, and the TDEFW pump, with suction from the CST, will provide water to the SGs to make up for steam release, assuming the CST is available. The TDEFW pump starts automatically upon the loss of offsite power, and the EFW system is normally aligned to supply water from the CST to the three SGs; no operator action is required to establish EFW flow to the SGs if the CST is available.

The licensee's Phase 1 strategy directs the initiation of a cooldown and depressurization of the RCS between 2-4 hours after the start of the ELAP event, at a nominal rate of 75 degrees Fahrenheit (°F) per hour. Over a period of approximately 2 hours, operators would gradually cool down the RCS from post-trip conditions until SG pressure reaches 260 pounds per square inch gauge (psig), which corresponds to an RCS cold-leg temperature of approximately 409 °F. Cooldown and depressurization of the RCS significantly extends the expected coping time under ELAP 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 SI 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 TDEFW pump. To remove heat, operators will discharge steam via manual control of the SG PORVs. If instrument air is available, the PORVs would be controlled remotely from the main control room (MCR); if instrument air is not available, operators would control the PORVs locally at the valve handwheels. The PORVs and upstream piping are safety-related and robust to all applicable external hazards, and are housed within robust, safety-related structures.

By terminating the initial cooldown at an SG pressure of approximately 260 psig, the licensee has determined that injection of the nitrogen cover gas from the SI 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.

The CST has a minimum usable capacity (per Technical Specifications) of 154,062 gallons, representing sufficient volume for at least the first 8.4 hours of the event, which includes decay heat removal as well as the sensible heat associated with the initial RCS cooldown. The CST is fully robust to all applicable external hazards, except for high wind (i.e., tornado) hazards. If the CST does not survive the initiating event, the licensee's credited core cooling strategy relies on the use of the SW system; therefore, it is discussed in the next section, Phase 2 Core Cooling Strategy.

3.2.1.1.2 <u>Phase 2</u>

If the CST is unavailable, operators would align the suction of the TDEFW pump to the SW system, which would be pressurized by FLEX Alternate EFW suction pumps taking suction from the seismically qualified SW pond. Two FLEX Alternate EFW suction pumps are permanently installed in the SW pump house, and are credited to be available for all applicable hazards. The pumps would be powered by either of two 80 kW DGs that are pre-installed in the DG building. The licensee stated that it has validated that the Alternate EFW suction flowpath can be aligned within one hour of the initiating event, which will prevent dryout of the SGs.

If the CST does survive the initiating event, its volume will eventually be depleted, potentially as early as 8.4 hours into the event per the licensee's calculations. Operators would refill the CST from any of the following sources of water, in order of preference based on water quality:

1. DWST
2. FWST
3. Lake Monticello
4. SW pond

The DWST and FWST are not seismically qualified, nor are they robust to wind-borne missile hazards. If available, however, they would contain a combined volume of over 600,000 gallons of water. One of two portable, diesel-driven FLEX booster/transfer pumps, with a minimum design flow rate of 800 gallons per minute (gpm), would be deployed to transfer water from the DWST or FWST to the CST if those tanks survive the initiating event.

Lake Monticello is not credited as an accessible source of water in the event of a beyond-design-basis seismic event. The SW pond, however, is fully robust to all applicable external hazards, and contains sufficient volume to represent an essentially unlimited supply of makeup water. Two trailer-mounted FLEX UHS pump systems are stored onsite for use when taking suction from Lake Monticello or the SW pond; one is stored in the FLEX Storage Building (FSB) and the other in the Emergency Response Building (ERB). Each system consists of two submersible hydraulic pumps and one diesel-driven booster pump, and each system has sufficient flow capacity to simultaneously support core cooling, the SFP and the reactor building cooling units. A FLEX UHS system could be aligned to refill the CST, to discharge to the suction of the FLEX SG feed pump (see below), or to feed the SGs directly.

The TDEFW pump is expected to be available throughout Phase 2, as long as SG pressure remains above 100 psig. If for any reason the TDEFW pump is no longer available, operators could re-power one of two MDEFW pumps using two trailer-mounted 1 MW FLEX CTGs. The MDEFW pump would then transfer water from the CST, or the Alternate EFW suction source, to the three SGs.

The FLEX SG feed pump is diesel-driven and rated for 500 gpm. The FLEX SG feed pump from the FSB, which could take suction from the CST or from the discharge of a FLEX UHS pump system (as discussed earlier in this section). Flexible hoses would connect the discharge of the FLEX SG feed pump to three connections on the main feed water lines, one for each SG. The licensee states that these connection points are protected from all applicable hazards.

When the SI accumulators have been isolated or vented (see Section 3.2.1.2 of this SE), operators will begin a second cooldown and depressurization of the RCS with a target RCS core inlet temperature of 350 °F.

3.2.1.1.3 <u>Phase 3</u>

The licensee's FIP states that Phase 3 will be a continuation of the Phase 2 coping strategy, with the TDEFW pump (or MDEFW pump if the TDEFW pump is not available), FLEX SG feed pump, FLEX UHS transfer system and/or FLEX Alternate EFW pump continuing to supply makeup water to the SGs. The NSRC will provide backup pumps, generators and diesel fuel to supplement the on-site Phase 2 equipment as needed. Also, the NSRC will furnish a mobile water treatment system to improve the quality of makeup water 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 2-4 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 VCSNS 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. 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 diesel-driven high-pressure FLEX RCS makeup pump will be deployed. Two of these pumps, each with a design capacity of 60 gpm at up to 2,000 psig, are stored onsite, one in the ERB and the other in the FSB. The pump can be aligned to take suction from either the BATs or the RWST. Per the licensee's FLEX Support Procedure (FSP) No. 8 (FSP-8), "Alternate RCS Boration", the two BATs are the preferred source for RCS makeup; they are fully robust to all applicable external hazards and would contain a minimum usable combined capacity of 14,000 gallons of water, borated to between 7,000 and 7,700 parts per million (ppm). The RWST has a minimum capacity of 453,800 gallons of water with a boron concentration of 2,300-2,500 ppm; it is robust to all hazards except for high winds.

The licensee will commence RCS makeup and boration no later than 20 hours after the start of the ELAP event, in order to ensure reactivity control and prevent the onset of reflux cooling. The licensee's thermal-hydraulic analysis and shutdown margin calculations are discussed in detail in Sections 3.2.3.2 and 3.2.3.4 of this SE.

The licensee's analyses and procedures for RCS inventory control and subcriticality take into account the possibility that the installed Alternate Seal Injection (ASI) pump and its dedicated DG survive the initial ELAP event, and start automatically. This positive-displacement (20 gpm) pump is not credited for FLEX, but if it does begin injecting into the RCS, FSP-8 directs operators to let the pump continue until boration time requirements are met. The ASI pump takes suction from the RWST and discharges to the installed seal water injection line. Operators may still deploy a FLEX RCS makeup pump for additional makeup capacity to the RCS.

Some injection of borated water from the SI accumulators is expected as the RCS is depressurized in Phase 1 and Phase 2. However, this passively injected volume is, conservatively, not credited by the licensee's thermal-hydraulic analysis. As noted in Section

3.2.1.1 above, the initial RCS cooldown will be arrested when SG pressure reaches 260 psig; the licensee states that this will prevent nitrogen cover gas from the accumulators from being injected into the RCS. In Phase 2, operators will re-power the accumulators' motor-operated isolation valves from either the FLEX CTGs or an 80-kW FLEX DG (FDG) and isolate the accumulators. After this action is completed, the subsequent RCS cooldown to 350 °F can begin.

3.2.1.2.3 Phase 3

The licensee calculates that the makeup water volume of the RWST and BATs will support RCS inventory and boration for weeks after the initiating event, given the presence of low-leakage RCP seals (see Section 3.2.3.3). The Phase 3 strategy, therefore, relies on continued use of the FLEX RCS makeup pump and on-site sources of borated water, as in Phase 2. The NSRC will provide backup pumps, which would be deployed if needed, as well as diesel fuel, water treatment equipment, and a mobile boration system. The NRC staff expects that the licensee would begin using water 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.

3.2.2 Variations to Core Cooling Strategy for Flooding Event

The licensee's FIP notes that VCSNS is equivalent to a dry site, as defined by Regulatory Guide (RG) 1.102, "Flood Protection for Nuclear Power Plants". Flooding from a local intense precipitation (LIP) event would be short-lived, and would not threaten the licensee's ELAP response strategy. Based on elevation and robust structure design, the FLEX storage locations will protect the equipment from flooding and ensure their accessibility. Therefore, there are no variations to the FLEX strategy for a beyond-design-basis flooding event.

3.2.3 Staff Evaluations

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

Guidance document NEI 12-06 provides baseline assumptions 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

The licensee provided descriptions in the FIP for the permanent plant SSCs to be used to support core cooling during Phase 1. The TDEFW pump provides feedwater to the three SGs. The TDEFW pump starts automatically and can draw water from the CST or SW system. The TDEFW pump is located in the Intermediate Building (IB), which is protected from all applicable external hazards. The licensee indicated that the existing procedures can be used during an

ELAP event to control TDEFW flow. During ELAP events, the SW system will not be available due to loss of power to the pumps, so the licensee stated that an alternative suction source from the SW Pond will be provided from the new permanently-installed FLEX Alternate EFW suction pumps in the SW Pump House. The licensee stated in the FIP that the use of the MDEFW pump will be the primary method during Phase 2 to supply SG makeup water from the CST or Alternate EFW source when the TDEFW pump becomes unavailable. One of the two available MDEFW pumps will be repowered from two FLEX CTGs. The MDEFW pumps are also located in the IB.

The CST supplies the EFW system and is described in the FIP and updated final safety analysis report (UFSAR) as being protected from all external events except for the tornado and high wind events. The available water volume in the CST is around 179,850 gallons. The SW Pond (the UHS) contains approximately 85 million gallons of water. The SW Pond is the credited water source for SG makeup during high winds and tornado ELAP events. For FLEX strategies, the licensee created a new suction connection in the SW pump house, where one of two (permanently installed) FLEX Alternate EFW suction pumps will provide water from the SW pond to the TDEFW or MDEFW pump for injection into the SGs. The SW pond and SW Pump House are both protected from all applicable external hazards.

The licensee also indicated that the SG PORVs will be used to support reactor core cooling and decay heat removal. The SG PORVs will be opened and throttled either remotely from the MCR (if instrument air is available) or by hand wheel locally (if instrument air is not available). The SG PORVs are protected from all applicable external hazards.

During the audit, the NRC staff reviewed the locations of the permanent SSCs described above to confirm that the SSCs will be protected from all applicable external hazards and have supporting procedures that will direct operators to take action as needed to support the core cooldown FLEX strategy. Based on the design and location of the protected water sources and the permanent and newly installed plant SSCs as described in the FIP, the staff finds that the licensee's strategy should be available to support core cooling during an ELAP caused by a BDBEE, consistent with Condition 4 of NEI 12-06, Section 3.2.1.3.

RCS Inventory Control

The FIP states that one of two FLEX RCS makeup pumps draws suction from either the RWST or the BATs. The RWST is a stainless steel, seismically-qualified tank located outside of the AB. The RWST is protected from all applicable external hazards, except for tornado missiles. The FIP states that the RWST volume is maintained greater than 453,800 gallons at a boron concentration between 2,300 and 2,500 ppm in accordance with V.C. Summer Technical Specification 3.5.4. Two BATs are stainless steel, seismically qualified tanks located in the AB, which are protected from all applicable external hazards. The BATs are described in the FIP as having a combined borated water volume of greater than 14,000 at a boron concentration between 7,000 and 7,700 ppm.

During the audit, the NRC staff reviewed the locations of both the RWST and BATs to verify that the licensee will have at least one fully protected pathway for all applicable external events. Based on the location and the availability of the borated water sources, the staff finds the licensee's strategy should support RCS inventory control during an ELAP caused by a BDBEE, consistent with Condition 3 of NEI 12-06, Section 3.2.1.3.

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 temperature
- RCS pressure
- Reactor Vessel Level Instrumentation System (RVLIS)
- SG water level
- SG pressure
- EFW flow rate
- CST level
- BAT level
- RWST level
- nuclear 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.

The primary monitoring strategy for all of these parameters is to obtain readings from the main control room. Alternatively, FSP-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 based its mitigating strategy for reactor core cooling in part on a generic thermal-hydraulic analysis performed for a reference Westinghouse three-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 VCSNS), 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 one-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, VCSNS relies upon the analysis methodology documented in PWROG-14015 and PWROG-14027 for a Category 2 Westinghouse three-loop plant. The PWROG generic analysis methodology and results included use of the three-loop Westinghouse reference plant identified in WCAP-17601. The licensee applied the mass-balance methodology described in PWROG-14027 with unit-specific parameters for VCSNS. This calculation incorporated plant-specific values for RCP seal leakage, which, due to the installation of Flowserve N-9000 low-leakage RCP seals, are less than the leakage rates assumed in PWROG-14027 for a Category 2 plant. Their analysis concluded that the time to enter reflux cooling is approximately 39.5 hours for VCSNS whereas RCS makeup would be available per the licensee's mitigating strategy within 20 hours. Confirmatory calculations performed by the NRC staff using the same methodology, but assuming a more conservative value for the density of the RCS seal leakage (see Section 3.2.3.3), indicated that the time to reflux cooling would be 33.1 hours into the event, which is still bounded by the licensee's planned time to commence RCS injection.

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 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, potentially resulting in increased 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 variations in boric acid concentration. Along with cooldown-induced contraction 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.

As noted above, Flowserve N-9000 3-stage seals are installed on the RCPs at VCSNS, Unit 1. The N-9000 seal is a product in Flowserve's N-seal line of hydrodynamic seals that was developed in the 1980s. One of the design objectives for the N-9000 seal was to provide low-leakage performance under loss-of-seal-cooling conditions during events such as a station blackout. On August 5, 2015, in support of licensees using Flowserve RCP seals, the PWROG submitted a white paper to the NRC staff describing the response of the Flowserve N-Seal RCP Seal Package to a postulated ELAP (ADAMS Accession No. ML15222A366).

The N-Seal white paper contains information regarding the expected leakage rates over the course of an ELAP event for each PWR at which Flowserve N-Seals are currently installed. Leakage rates as a function of time were assigned based upon a comparison of plant-specific thermal profiles relative to the thermal margin demonstrated in a test of N-Seal performance under simulated station blackout conditions that was conducted by Flowserve in 1988. According to measured data from this test, following controlled bleedoff (CBO) isolation at 0.5 hours, over the course of the succeeding period of 6 to 7 hours during which CBO isolation was maintained, the average seal leakage rate was slightly less than 0.05 gpm. Although the NRC staff agreed that it is appropriate to allow credit for demonstrated performance, during its review of the Flowserve white paper, the staff questioned the extrapolation of evidence from a limited test period of 6-7 hours to the indefinite coping period associated with the ELAP event. While the NRC staff ultimately agreed with the credit Flowserve's N-Seal white paper allowed for CBO isolation in determining the short-term thermal exposure profile of seal elastomers, the staff did not endorse direct application of the average leakage rate measured with the CBO isolated in the 1988 test for an indefinite period in the absence of demonstrated long-term seal performance. By letter dated November 12, 2015 (ADAMS Accession No. ML15310A094), the staff endorsed the leakage rates described in the white paper for the beyond-design-basis ELAP event, subject to certain limitations and conditions.

During the audit, the NRC staff audited the applicable information from the Flowserve N-Seal white paper, and the limitations and conditions in the NRC endorsement letter, against the VCSNS plant design and the mitigating strategy and determined that they were generally consistent, with the exception of condition (4):

> In its white paper, Flowserve has generally specified leakage rates in volumetric terms. For converting the specified volumetric flow rates to mass flow rates, licensees should use a density of 62 lbm/ft^3 (approximately 993 kg/m^3) throughout the ELAP event. This condition reflects observations made during testing conducted by Flowserve that simulated a loss of seal cooling, wherein the seal leakage mass flow rate remained roughly constant as the test apparatus underwent a significant cooldown and depressurization.

Contrary to this condition, the licensee assumed density values based on the cooldown and depressurization profile of the RCS throughout the ELAP event, which is reasonable but nonconservative. However, the staff's confirmatory calculations confirm that the licensee's timeline for RCS inventory control and boration will effectively prevent reflux cooling in the RCS (see Section 3.2.3.2) and loss of shutdown margin (see Section 3.2.3.4).

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. The licensee's analysis was based on appropriately conservative assumptions, including end of life (EOL) core conditions, with zero initial RCS boration, zero negative reactivity from core xenon, and zero boration from passive accumulator injection. In its calculations, the licensee assumed RCS leakage of 2.5 gpm per RCP seal, which is non-conservative for shutdown margin purposes, since non-borated coolant is assumed to leave the RCS at a relatively high rate while borated makeup water is injected. However, the licensee did assume that the boron concentration of water leaving the RCS through the RCP seals was equal to the desired final RCS boron concentration, which the staff concurs is equivalent or conservative with compared to assuming zero RCS leakage, in terms of the equilibrium calculation.

According to the FIP and Emergency Operating Procedure (EOP) No. 6 (EOP-6.0), "ECA-0.0 Loss of All ESF AC Power," Revision 34, injection of borated water from the BATs or RWST to the RCS will begin no later than 20 hours into the event. The licensee's shutdown margin analysis determined that the reactor will remain subcritical at 409 °F, i.e., the saturation temperature corresponding to the target SG pressure of the first RCS cooldown, for up to 29 hours after the initiating event without boron injection. The licensee's procedures direct that RCS cooldown below this point will not be performed until the RCS boration is complete. Given the FLEX RCS makeup pump capacity of 60 gpm, and assuming the lowest boron concentration in either the BAT or RWST allowed by Technical Specifications, the required volume to ensure long-term subcriticality would take no longer than approximately 3.6 hours using the less-concentrated water in the RWST, or approximately 1 hour if the highly-concentrated BAT water is used (which is the licensee's preferred strategy). The required injection volume was calculated based on the final cooldown temperature of 350 °F.

As noted in Section 3.2.1.2 of this SE, the ASI pump and its associated DG may survive the initial event and start automatically, injecting makeup water from the RWST to the RCS via the RCP seals. The licensee included this case in its shutdown margin calculations, and concluded that up to 17.5 hours may be required for the ASI pump alone to inject the required boration volume from the RWST to ensure long-term subcriticality. However, FSP-8 directs operators to commence RCS makeup using the 60-gpm FLEX pump if required to supplement the injection from the ASI pump. Therefore, the staff concludes that starting RCS injection no later than 20 hours into the event will effectively maintain shutdown margin.

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 VCSNS'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 FSP-8 to energize and open ac-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.

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 (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 VCSNS will comply with the August 15, 2013, position paper on boric acid mixing, including the conditions imposed in the staff's corresponding endorsement letter. One exception is the consideration of conditions with zero RCS leakage, but as noted above, the assumptions in the licensee's analysis were in fact equivalent or conservative compared to assuming no RCS leakage. 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.

The NRC staff further performed confirmatory calculations to determine whether the initiation of RCS makeup would begin prior to RCS loop flow decreasing below the single-phase natural circulation flow rate, as the licensee claimed. The staff noted that the licensee's calculation assumed that the density of the leaking coolant would vary over time, following the RCS cooldown profile of the ELAP strategy. Although reasonable, this is contrary to condition (4) of the NRC endorsement letter regarding the Flowserve RCP seal (ADAMS Accession No. ML15310A094), namely that a constant density of 62 lbm/ft^3 be assumed throughout the ELAP event. Per the endorsement letter, "[t]his condition reflects observations made during testing conducted by Flowserve that simulated a loss of seal cooling, wherein the seal leakage mass flow rate remained roughly constant as the test apparatus underwent a significant cooldown and depressurization." Using this density value, the staff's calculations concluded that RCS natural circulation would decrease below the flow rate corresponding to single-phase natural circulation at 17 hours into the ELAP event. However, the flow rate in the RCS would be restored above the flow rate corresponding to single-phase natural circulation within 30 minutes of initiating RCS injection. Given the planned time to commence RCS injection no later than 20 hours into the event, then, the staff finds that per the second part of the condition in the boron mixing endorsement letter, negative reactivity from boron injection may be credited at 21.5 hours into the ELAP event (which includes the 1 hour delay). Therefore, the staff considers the licensee's ELAP strategy to comply with the limitations and conditions of the boric acid mixing position paper and corresponding NRC endorsement letter.

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 350 °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 350 °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 FIP states that the licensee has two FLEX UHS pump systems, one stored in the FSB and the other stored in the ERB. A FLEX UHS pump system is deployed on the FLEX UHS pump trailer to either the Monticello Reservoir or SW Pond. The FLEX UHS pump system simultaneously provides water for SG makeup, SFP makeup, and containment cooling. Two FLEX booster/transfer pumps (N and N+1) can also be used to transfer water from the DWST or FWST to provide makeup to the CST, if available. One FLEX booster/transfer pump is stored in the FSB and the other pump is stored in the ERB.

If the MDEFW pump is unavailable, the FLEX SG feed pump will be used to provide SG makeup. The FLEX SG feed pump is a portable trailer-mounted, diesel-driven centrifugal pump with a design flow of 500 gpm at 500 psig. The FLEX SG feed pump is stored in the FSB. The FLEX SG feed pump can take suction from the CST and inject into the SG directly. The FLEX SG feed pump can also be used in conjunction with the FLEX booster/transfer pump and FLEX UHS pump system to supply makeup water from the Monticello Reservoir or SW Pond.

The licensee also permanently installed two FLEX Alternate EFW suction pumps that would be used to provide SW water to either the TDEFW pump or one of the MDEFW pumps. Both FLEX Alternate EFW suction pumps (N and N+1) are located in the SW Pump House, which is protected from all applicable external hazards. One FLEX alternate EFW pump is used to transfer water from the SW pond to the SW pump discharge crosstie header located in the SW pump house. Each pump can provide 15 feet (ft.) head pressure, at a rated flow of 500 gpm, which is sufficient to prevent cavitation of the TDEFW pump or the MDEFW pumps. The two 80 KW FDGs (N and N+1) that power the FLEX alternate EFW pump are located in the DG building near the FSB.

For RCS makeup, the licensee has two FLEX RCS makeup pumps (N and N+1). One FLEX RCS makeup pump is stored in the FSB and other pump is stored in the ERB. The FLEX RCS makeup pumps are both capable of delivering a flow of 60 gpm at a discharge pressure of up to 2,000 psig.

During the audit review, the licensee provided for the NRC staff's review FLEX hydraulic calculations DC00080-001, "FLEX Flow Requirements for RBCU, S/G Feed, SFP Make-up and Tank Transfers," Revision 2, and DC00080-009, "FX System Flow Model Analysis Case," Revision 1. These calculations evaluated the FLEX pumps providing SG and RCS makeup strategies. The calculation DC00080-003, "FLEX Boration Requirements," Revision 2, provided RCS system requirements for boration. FSP-2, "Alternate EFW Suction Source," Revision 0, and the Engineering Change Request (ECR) 51003B, "FLEX Alternate EFW Suction Source," address how the TDEFW and MDEFW pumps will be connected to the new SW connection in the SW Pump House. The SW connection for this makeup strategy is discussed below in Section 3.7.3.1.

The NRC staff reviewed the above hydraulic calculations for SG and RCS makeup during the audit and later compared the flow rates and pressures to the values provided in the FIP for the above FLEX pumps. The NRC staff conducted a walkdown of the hose deployment routes for the above FLEX pumps deployment locations during the audit. The NRC staff confirmed that the FLEX pumps and associated hoses and fittings were stored in building locations that were separated at a significant distance to ensure availability of one set of FLEX equipment needed for makeup strategies.

The NRC staff finds that the licensee has developed strategies that have sufficient alternatives or redundancy to satisfy the criteria in Section 3.2.2 of NEI 12-06 for the FLEX pumps. Further, based on the NRC staff's review of the FLEX pumping capabilities at VCSNS, as described in the above hydraulic analyses, supporting engineering document, FSP, and the FIP, the NRC staff concludes that the portable and permanent FLEX pumps should perform as intended to support SG makeup, CST makeup, and RCS inventory control during an ELAP event, consistent with NEI 12-06, Section 11.2.

3.2.3.6 <u>Electrical Analyses</u>

The licensee's electrical strategies 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.

During the first phase of the ELAP event, the licensee would rely on the installed equipment and onsite resources such as Class 1E station batteries 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, RCS inventory control, and containment integrity). The VCSNS has two Class 1E station batteries that were manufactured by C&D Technologies. The Class 1E station batteries are model LCR-31 with 2,175 ampere-hours at an 8-hour discharge rate to 1.75 V per cell. The Class 1E station batteries, battery chargers, and inverters are located within the protected areas of the IB, which is a seismically qualified structure. As such, the Phase 1 electrical equipment should be appropriately protected during the BDEEE. Guidance in FSP-4.0, "ELAP DC Bus Load Shed/Management," directs operators to conserve dc power during the event by stripping non-essential loads. Plant operators will strip or shed unnecessary loads to extend battery life until backup power is available. Plant operators would commence load shedding within 3 hours and complete load shedding within 4 hours from the onset of an ELAP.

The NRC staff reviewed the licensee's dc coping calculations DC08320-019, "EOP-6/DMG Ultimate Battery Life," Revision 1, and DC08320-010, "Class 1E 125 Volt DC System Voltages & Voltage Drop," Revision 13, which verified the capability of the dc system to supply power to the required loads during the first phase of the VCSNS FLEX mitigation strategy plan for an ELAP as a result of a BDBEE. The licensee's evaluation identified the required loads and their associated ratings (ampere (A) and minimum required voltage (V)) and the non-essential loads that would be shed within 4 hours to ensure battery operation for at least 15 hours.

The NEI White Paper, "EA-12-049 Mitigating Strategies Resolution of Extended Battery Duty Cycles Generic Concern," (ADAMS Accession No. ML13241A186) provides guidance for calculating extended duty cycles of batteries (i.e., beyond 8 hours). This paper was endorsed by the NRC (ADAMS Accession No. ML13241A188). In addition to the White Paper, the NRC sponsored testing at Brookhaven National Laboratory that resulted in the issuance of NUREG/CR-7188, "Testing to Evaluate Extended battery Operation in Nuclear Power Plants," in May 2015. The testing provided additional validation that the NEI White Paper method was technically acceptable. The NRC staff reviewed the licensee's battery calculations and confirmed that they had followed the guidance in the NEI White Paper.

Based on its review of the licensee's analysis and procedures, the battery vendor's capacity and discharge rates for the Class 1E station batteries, the NRC staff finds that the VCSNS Class 1E station batteries have adequate capacity and capability to power the loads required to mitigate the consequences during Phase 1 of an ELAP provided that necessary load shedding is completed within the times assumed in the licensee's analysis.

The licensee's Phase 2 electrical strategies (primary, alternate, and defense-in-depth) propose repowering the battery chargers within 15 hours after initiation of an ELAP. The strategies will use two 1 MW 7.2 kV CTGs operated in parallel or a portable 80 kw 480 Vac FDG (three available for this purpose). The licensee can also use a 300 kW 480 Vac DG (one portable, one installed) as a defense-in-depth measure that is not credited for FLEX. The primary strategy would use the 7.2 kV CTGs to provide power to vital battery chargers, battery room supply and exhaust fans, MDEFW pumps, accumulator isolation valves, and RBCU fans (if necessary). One of the alternate strategies would use one of the 80 kW portable 480 Vac FDGs (three designated for use) to provide power to vital battery chargers or swing battery charger, and accumulator isolation valves. Another alternate strategy, not needed to meet the criteria in NEI 12-06, would use one of these three 80 kW portable 480 Vac FDGs to power the vital batteries using a portable battery charger and a second to power the accumulator isolation valves. For loss of the CST, the licencee would use a pre-installed 80 kW, 480 Vac DG (two designated for use) to provide power to one of the FLEX Alternate EFW pumps. The defense-in-depth strategy would use one of the 300 kW DGs to power the FLEX battery chargers and various other loads.

The NRC staff reviewed licensee calculations DC08260-001, Revision 0, "FLEX East Strategy Electrical Calculations," DC08260-002, Revision 0, "FLEX West Strategy Electrical Calculation," conceptual single line electrical diagrams, and the separation and isolation of the FDGs and CTGs from the Class 1E EDGs. Based on the NRC staff's review of the calculation (DC08260-001), the minimum required loads for the licensee's primary strategy on the Phase 2 CTGs is 1,226 kW. The minimum required loads for the licensee's alternate strategy on the Phase 2 80 kW FDG to repower a vital battery charger and accumulator isolation valves is 58 kW. The minimum required loads for the licensee's alternate strategy on the Phase 2 80 kW FDG to power the alternate EFW suction pump is 24 kW. Based on the NRC staff's review of the calculation (DC08260-002), the minimum required loads for the licensee's defense-in-depth strategy on the 300 kW DG is 132.8 kW. Based on the minimum required loads for the 1 MW CTG's, 80 kW FDGs, and 300 kW defense-in-depth DGs, the NRC staff finds they are adequate to support the electrical loads required for the licensee's Phase 2 strategies.

For Phase 3, the licensee plans to continue its Phase 2 coping strategy with additional assistance provided from offsite equipment/resources. The offsite resources that will be provided by an NSRC include two 1.0 MW 4160 Vac CTGs, one 1100 kW 480 Vac CTG, and distribution panels (including cables and connectors). Two 4160 Vac CTGs will be operated in parallel to provide a total of approximately 2 MW capacity which provides the same capacity as Phase 2 FLEX 7.2 kV CTGs. Therefore, the two NSRC supplied 4160 Vac, 1.0 MW CTGs can either replace or supplement the FLEX 7.2 kV CTGs. Connection to the plant will require use of a 4160 Vac to 7.2 kV step-up transformer which is maintained onsite as FLEX equipment. Based on the 4160 Vac CTGs replacing or supplementing the 7.2kV CTGs and the 480 Vac CTGs providing backup to the Phase 2 portable FDGs (1,100 kW versus 80 kW), the NRC staff finds that the 4160 Vac and 480 Vac equipment being supplied from an NSRC has sufficient capacity and capability to supply the electrical loads required for the Phase 3 strategies.

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

Table 3-2 and Appendix D of NEI 12-06 summarize an approach consisting of two 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; and 2) makeup via connection to SFP cooling piping or other alternate location capable of exceeding the boil-off rate for the design-basis heat load. However, in JLD-ISG-2012-01, Revision 1 (ADAMS Accession No. ML15357A163), the NRC staff did not fully accept this approach, and added another requirement to either have the capability to provide spray flow to the SFP, or complete an SFP integrity evaluation which demonstrates that a seismic event would have a very low probability of inducing a crack in the SFP or its piping systems so that spray would not be needed to cool the spent fuel. The evaluation must use the reevaluated seismic hazard described in Section 3.5.1 below if it is higher than the site's current safe shutdown earthquake (SSE). 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. In 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. The 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. The licensee has decided to provide the spray flow described in JLD-ISG-2012-01.

3.3.1 <u>Phase 1</u>

The licensee stated that no operator actions will be performed during Phase 1 other than creating a ventilation path for the FHB. The licensee will monitor SFP water level using reliable SFP level instrumentation installed per Order EA-12-051.

3.3.2 <u>Phase 2</u>

The FIP states that the Phase 2 strategy for SFP cooling/inventory is to initiate SFP makeup using one of the FLEX UHS pump systems taking suction from the SW pond or the Monticello Reservoir. One FLEX UHS pump system is stored in the FSB and the other is stored in the ERB, each with its respective track vehicle. Fire hoses will connect the discharge of the FLEX pumps to a permanent FLEX connection on the SFP system. The FLEX connection is located in the AB. The licensee also described that one of two fire pumper trucks can provide SFP makeup through a hose routed to the SFP deck, where it can be connected to the spray monitors or run directly into the SFP. One fire pumper truck is located in the FSB and the other fire pumper truck is located in the ERB. The spray monitors are stored in the FHB.

3.3.3 <u>Phase 3</u>

The FIP states that the Phase 3 SFP makeup strategy is a continuation of Phase 2. The NSRC will supply high capacity pumps to backup the FLEX pumps and a water treatment skid to remove water impurities as needed. The SW pond will serve as the makeup water source for SG, RCS, and SFP.

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.

As described in the licensee's FIP, the Phase 1 SFP cooling strategy does not require any 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 by FSP-11.0, "Alternate SFP Makeup and Cooling," to open railroad bay doors on the 436 ft. elevation of the FHB and at least 14 smoke detector access penetrations in the roof of the FHB. The licensee indicated in its FIP that additional ventilation in the FHB can be provided with the removal of translucent panels in the walls.

The licensee's SFP cooling strategy uses the FLEX UHS pump system to pump water from the SW pond or the Monticello Reservoir. The fire pumper truck with suction from the SW Pond or Monticello Reservoir is used as the alternate SFP makeup strategy. The staff's evaluation of the robustness and availability of FLEX connections points for the above pumps is discussed in Section 3.7.3.1 below. The staff's evaluation of the robustness and availability of the SW Pond and Monticello Reservoir for an ELAP event is discussed in Section 3.10.3 of this SE.

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 an external ac source. 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

In NEI 12-06, Section 3.2.1.6 states that SFP heat load assumes the maximum design basis heat load for the site. In accordance with NEI 12-06, the licensee performed a thermal-hydraulic analysis of the SFP as a basis for the inputs and assumption used in its FLEX equipment design requirements analysis. During the audit, the licensee provided calculation DC00020-244, "Spent Fuel Pool Time to Boil – Response to INPO IER L1-11-4," Revision 0, which described the thermal-hydraulic analysis of the SFP under ELAP conditions. The calculation concluded that the SFP heat load will reach maximum boiling temperature in approximately 21 hours and boil off to 10 ft. from the top of the active fuel in approximately 87 hours without any operator actions. The licensee also indicated in the FIP that the SFP makeup will begin around 18 hours into the ELAP event at a flow rate of 120 gpm, which is higher than the design requirement of 93 gpm to replenish the SFP water being boiled off.

The NRC staff reviewed the thermal-hydraulic calculation DC00020-244 during the audit and concluded that that the licensee has conservatively determined a SFP makeup flow rate of at least 93 gpm that will maintain adequate SFP level above the fuel for an ELAP occurring during normal power operation. Based on the information contained in the FIP and the thermal-hydraulic calculation, the NRC staff finds that the licensee has considered the maximum design-basis SFP heat load, consistent with NEI 12-06 Section 3.2.1.6.

3.3.4.3 FLEX Pumps and Water Supplies

During the audit, the licensee provided hydraulic calculation DC00080-001, which described the hydraulic analysis for the SFP makeup. One FLEX UHS pump system is capable of delivering 120 gpm of flow to the SFP (only 93 gpm is required for the SFP makeup strategy). Both fire pumper trucks are capable of providing greater than the 93 gpm flow requirement for SFP makeup. The NRC staff reviewed the hydraulic calculation of the FLEX UHS pump system and fire pumper trucks to confirm that they both can meet the makeup requirements for the SFP. Based on the NRC staff's review of the SFP makeup requirements, the licensee has demonstrated that the FLEX UHS pump systems and fire pumper trucks, if aligned and operated as described in the FSP-11 and the FIP, should perform as intended to support SFP cooling, consistent with NEI 12-06, Section 11.2.

3.3.4.4 Electrical Analyses

The basic FLEX strategy for maintaining SFP cooling is to monitor the SFP level and provide makeup water to the SFP for cooling for the spent fuel due to boil-off of the water.

The licensee's Phase 1, 2, and 3 electrical strategies are to continue to monitor SFP level using instrumentation installed by the NRC Order EA-12-051 to ensure adequate water level remains over the fuel. The capability of this instrumentation is described in other areas of this SE. Power to these instruments will be from dual selectable power supplies utilizing dedicated lithium ion batteries with back up batteries for replacement.

In its FIP, the licensee did not credit any additional electrical equipment beyond the SFP level instrumentation as part of its Phase 2 and 3 strategies.

Based on its review, the NRC staff finds that the licensee's strategy is acceptable to restore or maintain SFP cooling indefinitely during an ELAP as a result of a BDBEE.

3.3.5 Conclusions

Based on this evaluation, the NRC staff concludes that the licensee has developed guidance that, if implemented as described, 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. V.C. Summer has a dry ambient pressure containment.

The licensee performed a containment evaluation, DC0080-010, "VCSNS ELAP Containment Response Due to RCS Inventory Loss," Revision 1, which was based on the boundary conditions described in Section 2 of NEI 12-06. The calculation assumed the RCS was cooled down and depressurized within the first 6 hours and analyzed the strategy of containment isolation and monitoring containment pressure using installed instrumentation. The licensee concluded that, even with the licensee taking no mitigating actions related to removing heat from containment, the containment parameters of pressure and temperature remain well below the respective updated final safety analysis report (UFSAR) Table 6.2.1 design limits of 57 psig and 283 °F for more than 30 days. Eventual containment cooling and depressurization to normal values may utilize off-site equipment and resources during Phase 3 if onsite capability is not restored.

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.

3.4.1 Phase 1

The licensee's containment analysis shows that the structural integrity of the reactor containment building, due to increasing containment pressure, will not be challenged for a minimum of 30 days following a BDBEE ELAP event. For Modes 1 through 4, the analysis shows that with no operator actions, containment pressure will slowly increase to 17.1 psig over 30 days and the maximum containment temperature reached is 215.2 °F over the same 30 day period. Since 17.1 psig and 215.2 °F are below the containment design pressure and temperature limits (UFSAR Section 6.2.1), no mitigation actions are necessary to maintain or restore containment cooling during Phases 1 or 2.

The Phase 1 coping strategy for containment integrity involves verifying containment isolation per EOP-6.0 and monitoring containment temperature and pressure using installed instrumentation. The MCR indication for containment temperature and pressure will be retained for the duration of the ELAP.

3.4.2 Phase 2

The licensee's containment analysis shows that there are no mitigation actions necessary (and none are planned) to maintain or restore containment cooling during Phase 2 for Modes 1 through 4. Containment temperature and pressure are expected to remain below design limits for more than 30 days.

The Phase 2 coping strategy for containment integrity is to continue monitoring containment temperature and pressure using installed instruments. Phase 2 activities to repower installed instruments are required for continued monitoring of containment conditions.

3.4.3 Phase 3

The Phase 3 strategy for containment integrity involves monitoring containment conditions and reducing containment temperature and pressure as necessary to ensure continued functionality of instrumentation to monitor key parameters. Containment cooling can be accomplished using existing plant systems, Phase 2 and/or Phase 3 FLEX equipment. Containment temperature and pressure can be reduced using one of the options below:

Reactor Building Cooling Unit Option

The primary strategy is to provide cooling water to one RBCU in either train using a FLEX UHS pump system. Fire hose will connect the discharge of the FLEX UHS pump system to permanent pipe stub-outs on existing SW lines, which supply flow to the RBCUs. One RBCU fan can be repowered by one FLEX CTG via the 7.2 kV switchgear bus 1DA or 1DB. Alternately, the Phase 3 CTGs, supplied by the NSRC, can be used to power the fan motors. The associated fan will be placed in slow speed.

Defense-in-Depth Reactor Building Spray Option

An alternate strategy is to establish water spray within containment using the reactor building spray system. An existing 2.5 inch B.5.b connection on the 'B' reactor building spray header will be used to provide an alternate water supply to cool containment. Fire hose will connect the discharge of the FLEX UHS pump system to the existing B.5.b connection.

3.4.4 Staff Evaluations

3.4.4.1 Availability of Structures, Systems, and Components

Guidance document NEI 12-06 provides 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

Containment

In the UFSAR, Section 3.8.1.1 states that the reactor building is a post tensioned, reinforced concrete structure with an integral steel liner. The containment free volume is 1.84×10^6 ft^3 with a maximum internal design pressure of 57 psig and a design temperature of 283 °F. The reactor building consists of a cylindrical wall, a shallow dome roof and a foundation mat with a depressed in-core instrumentation pit under the reactor vessel. A retaining wall, extending approximately ¼ of the way around the reactor building, protects the below grade portions of the reactor building wall from the subgrade. Adjacent buildings surround the remaining three quarters of the reactor building.

The staff noted that the reactor building structure is safety related and seismically qualified to all applicable seismic criteria. It acts as a closed vessel, and is therefore not subject to external flooding issues. The site limited extreme temperatures will not have a significant effect on the containment as the containment is a large mass which will act as a heat sink to disperse any heating or cooling effects. It is therefore protected from all applicable hazards and is expected to be available during an ELAP event.

Reactor Building Cooling Units

The RBCUs are part of the reactor building cooling system. RBCUs receive cooling water from the SW system. During the postulated ELAP, the licensee can supply water via the FLEX UHS pump system. The cooling fans can be powered by the CTGs. Equipment that is required to remove post-accident heat is qualified to operate in the post-accident environment and are seismically qualified. The staff noted that reactor building cooling system is Seismic Category I and that the associated components are Safety Class 2b. It is therefore protected from all applicable hazards and is expected to be available during an ELAP event.

Service Water Pond

The SW pond, a seismically qualified impoundment of a portion of Lake Monticello, serves as the UHS. The SW pond contains approximately 85 million gallons of water at elevation of 416.5 ft. mean sea level. The portable FLEX UHS pump system is capable of transferring water from the SW pond to the RBCUs via SW supply lines. The FLEX UHS pump system can also be used to supply water to the reactor building spray system via a B.5.b connection.

Reactor Building Spray Headers and Nozzles

The reactor building spray headers and nozzles are part of the reactor building spray system which is used to remove thermal energy from containment following an accident. The FLEX UHS pump system will supply water to the reactor building spray headers. Equipment that is required to remove post-accident heat is qualified to operate in the post-accident reactor building environment and seismically qualified. The staff noted that reactor building spray system is Seismic Category I and that the associated components are Safety Class 2a. It is therefore protected from all applicable hazards and is expected to be available during an ELAP event.

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 instrumentation is available to monitor containment temperature and containment pressure during all phases of the containment integrity strategy. Indicators for the instruments are located in the MCR. Instruments used to monitor these parameters will be available after a required load striping of the dc buses.

In the unlikely event that the 120 Vdc and 120 Vac vital bus infrastructure is damaged, alternate procedures for obtaining local indication of critical parameters is provided in FSP-7.0, "Loss of Vital Instrumentation or Control Power," Revision 0, as required by NEI 12-06.

3.4.4.2 Thermal-Hydraulic Analyses

The NRC staff reviewed analysis DC0080-010, "VCSNS ELAP Containment Response Due to RCS Inventory Loss," Revision 1, which was based on the boundary conditions described in Section 2 of NEI 12-06. In this calculation, the licensee utilized the Generation of Thermal-Hydraulic Information for Containments (GOTHIC) version 8.0 code to determine the containment pressure and temperature response during an ELAP. The only additions of heat and mass to the containment atmosphere under ELAP conditions are the heat loads from the reactor coolant system and main steam system (e.g., from the surfaces of hot equipment and the leakage of reactor coolant from the RCP seals). Specifically, the licensee's engineering evaluation models the containment conditions for operating Modes 1 through 4 in which the SGs are available to remove RCS heat. The RCS heat sink is maintained in Phase 1, which relies on installed plant equipment and on-site resources, by feeding the SGs using the TDEFW pump while steaming to the atmosphere via the PORVs and/or the MSSVs. The steam generator pressure is controlled by the steam line safety valves until RCS cooldown commences. The first RCS cooldown (75 °F/hr to 260 psig steam generator pressure) commences four hours into the event and the second RCS cooldown (25 °F/hr to 170 psig steam generator pressure) commences thirty hours into the event. The licensee replaced the original Westinghouse RCP seals with Flowserve N-9000 seals. The seal leakage is assumed to be 2.5 gpm per each of the three RCPs and an unidentified leakage limit of 1 gpm, for a total RCS leakage rate of 8.5 gpm into containment.

Using the input described above (Case 2 – RCS leakage and RCP pump seal leakage with no reactor building cooling), the containment pressure reaches 17.1 psig at the end of the 30-day period and the maximum temperature reaches 215.2 °F over the same period of time. The maximum values calculated are well below the UFSAR design parameters of 57 psig and 283 °F, so the licensee has adequately demonstrated that there is significant margin before a limit would be reached.

3.4.4.3 FLEX Pumps and Water Supplies

FLEX UHS Pump Systems

The VCSNS site has two FLEX UHS pump systems. Each FLEX UHS pump system consists of two submersible hydraulic pumps and one diesel driven centrifugal booster pump. Each FLEX UHS pump system is stored on a FLEX UHS pump trailer, one system in the FSB and one system in the ERB. A FLEX UHS pump system is towed by one of two Prinoth Panther T8 track vehicles, which are also stored in the FLEX storage buildings, and a submersible pump deployed using the track vehicle's crane. Only one submersible pump is required to provide flow to the trailer mounted booster pump to obtain the design flow of 2,500 gpm (300 psig).

The FLEX UHS pump system is used in multiple strategies including core cooling, SFP cooling, and containment cooling. A hydraulic analysis of the flow paths from each water source to the delivery locations has confirmed that applicable performance requirements are met.

Monticello Reservoir

The Monticello Reservoir is a source of water for the SW pond. The SW pond is connected to the Monticello Reservoir by an interconnecting pipe. The interconnecting pipe is used to provide makeup from the Monticello Reservoir to the SW pond in order to maintain operating levels in both heat sinks.

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 its evaluation, the licensee developed required actions to ensure maintenance of containment integrity and required instrumentation continues to function. With an ELAP initiated, while VCSNS is in Modes 1-4, containment cooling would be lost for an extended period of time. Therefore, containment temperature and pressure will slowly increase.

The licensee's Phase 1 coping strategy for containment involves verifying containment isolation per EOP-6.0, and monitoring containment temperature and pressure using installed instrumentation. These installed containment instruments will be powered by the Class 1E station batteries. The NRC staff reviewed calculations DC08320-019 and DC08320-010, and find that the Class 1E station batteries have adequate capacity and capability for at least 15 hours to power the installed instruments as discussed in Section 3.2.3.6 of this SE.

The licensee's Phase 2 coping strategy is to continue monitoring containment temperature and pressure using installed instrumentation. Additionally, containment temperature and pressure will be reduced, if necessary, using an RBCU or RB spray. The NRC staff reviewed the summary of calculation DC08260-001 in Section 3.2.3.6 of this SE and finds that the 7.2 kV FLEX CTGs should have adequate capacity to repower the installed containment instruments, the RBCU, and other required loads. Based on this information, the NRC staff concludes that the licensee's Phase 2 electrical strategy to repower instruments and components is adequate to allow continued containment monitoring and ensure that required components remain within their associated temperature limits.

The licensee's Phase 3 coping strategy is to obtain additional electrical capability and redundancy for on-site equipment until such time that normal power to the site can be restored. In its FIP, the licensee stated that VCSNS will receive two 1.0 MW, 4160 Vac CTGs and one 1.1 MW, 480 Vac CTG from an NSRC to supply power to Phase 3 loads. The RBCU fan motors are 480 Vac loads with breakers fed from the 7.2 kV switchgear buses through a 7200/480 Vac step down transformer, which can be powered by the 4160 Vac CTGs supplied by an NSRC, via the step up transfer. The NRC staff's evaluation of the NSRC supplied 1.0 MW, 4160 Vac CTGs in Section 3.2.3.6 of this SE concluded that the NSRC supplied 4160 Vac CTGs have adequate capacity and capability to power the Phase 3 loads to restore containment cooling and thus maintain containment pressure and temperature control indefinitely.

Based on its review, the NRC staff determined that the electrical equipment available onsite supplemented with the equipment that will be supplied from an NSRC, there is sufficient capacity and capability to supply the required loads to reduce containment temperature and pressure, if necessary, to ensure that the key components including required instruments remain functional.

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; ice; extreme cold; and extreme high temperatures. The snow hazard was screened out.

References to external hazards within the licensee's mitigating strategies and this safety evaluation 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) (ADAMS Accession No. ML12053A340) (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 (80 FR 70610). 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" (ADAMS Accession No. ML14309A256)). The Commission provided guidance in an SRM to COMSECY-14-0037 (ADAMS Accession No. ML15089A236). 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 damage 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 (ADAMS Accession No. ML15174A257), 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 (ADAMS Accession No. ML16005A625). The NRC staff endorsed Revision 2 of NEI 12-06 in JLD-ISG-2012-01, Revision 1 (ADAMS Accession No. ML15357A163). The licensee's MSAs will evaluate the mitigating strategies described in this safety evaluation 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 to be the earthquake magnitude associated with the SSE. Per UFSAR Section 3.7.1, the maximum horizontal ground acceleration for the SSE is 0.15g at the competent rock foundation elevation and 0.25g for the soil foundation. 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 the seismic hazard and identified the hazard levels to be evaluated.

3.5.2 Flooding

In its FIP, the licensee described that VCSNS is the equivalent of a dry site as defined in RG 1.102, "Flood Protection for Nuclear Power Plants." The VCSNS site is susceptible to brief water build-up due to a local intense precipitation event. FLEX equipment is stored either within structures designed to protect the equipment from the flood elevations or above the flood elevation calculated by the site external flooding analysis. Local ponding onsite due to local intense precipitation (i.e. probable maximum precipitation (PMP)) event was a design consideration in selection of storage locations, equipment connections, and deployment routes. The licensee's FSP 5.0 states, in part, that the station has had experience with a loss of sump pump capability and ground water intrusion rate was not severe, allowing more than 24 hours to provide alternate pumping means for protection of critical areas.

In a letter dated March 22, 2017 (ADAMS Accession No. ML17072A259), the NRC documented its review of the VCSNS flooding MSA (ADAMS Accession No. ML16357A603). The letter states that the NRC staff confirmed the licensee's flood hazard MSA was in fact performed consistent with the guidance in Appendix G of NEI 12-06, Revision 2, as endorsed by JLD-ISG-2012-01, Revision 1. Based on the reevaluated flood parameters for LIP being equal to the FLEX design-basis, the NRC staff concluded that the licensee demonstrated that the mitigation strategies are reasonably protected from reevaluated flood hazards conditions. No more actions are pending to resolve the flooding hazard MSA at the VCSNS site.

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 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, Revision 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, "Design Basis Tornado for Nuclear Power Plants," Revision 1.

In its FIP, regarding the determination of applicable extreme external hazards, the licensee described VCSNS as being located at latitude 34° 17' 54.1" North and longitude 81° 18' 54.6" West. In NEI 12-06, Figures 7-1 show the VCSNS site in an area where the resulting frequency of recurrence of hurricanes with wind speeds in excess of 130 mph exceeds 1E-6 per year. In NEI 12-06, Figure 7-2 show the VCSNS site in an area where the recommended tornado design wind speed for a 1E-6/year probability exceeds 130 mph. Therefore, high-wind hazards are applicable to the site. The licensee stated in its FIP that plant design bases address high winds, hurricanes, and tornados. In the VCSNS UFSAR, Section 3.3 states a wind velocity of 100 mph is used for the analysis of seismic category I structures. Also, design parameters applicable to the design-basis tornado include a rotational wind speed of 290 mph, a translational wind speed of 70 mph, and an atmospheric pressure drop of 3 psi at the rate of 2 psi/second (sec).

As stated above, high-wind hazards are applicable to the VCSNS 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 NEI 12-06 Figure 8-2 should address the impact of ice storms.

In its FIP, regarding the determination of applicable extreme external hazards, the licensee stated that the site is located at latitude 34° 17' 54.1" North and longitude 81° 18' 54.6" West. For being below the 35^{th} latitude, the licensee does not expect significant amounts of snow, and screened out the snow hazard. The NRC staff agrees with this assessment. In addition, the site is located within the region characterized by EPRI as ice severity level 5 (NEI 12-06, Figure 8-2, Maximum Ice Storm Severity Maps). Consequently, the site is subject to severe icing conditions that could cause severe damage to electrical transmission lines. The licensee concludes that the plant screens in for an assessment for ice and extreme cold hazard. In its FIP, VCSNS considered the effects of extreme low temperatures and weather conditions.

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 ice; therefore, the hazard is screened in. The licensee has appropriately screened in the hazard and characterized the hazard in terms of expected damage.

3.5.5 Extreme Heat

In the section of its FIP regarding the determination of applicable extreme external hazards, the licensee stated that VCSNS considered the effects of high temperatures. In the region around VCSNS, the summer has approximately 50 days with temperatures of 90 °F or above and 6 days with temperatures of 100 °F or above.

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 portable beyond design-basis (BDB) equipment is stored in the ERB, FSB, and the Containment Access Ramp (CAR). These storage buildings are protected from all applicable hazards with the exception of design basis tornado winds and missiles; therefore, separation is used to minimize the probability that a single event would damage all FLEX equipment. The FSB is a structure made out of a steel roof frame, steel columns, and precast concrete walls. The ERB is also a steel roof frame with steel columns, but it has a combination of steel braced frames and masonry shear walls. The ERB is located southwest of the RB and the FSB is located East Southeast of the RB.

In its FIP, the licensee described that debris removal equipment is also stored inside the ERB and FSB in order to be reasonably protected from the applicable external events. The equipment is likely to remain functional and deployable to clear obstructions from the pathway between the BDB equipment's storage location and its deployment location(s).

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 the seismic protection provided by the buildings used to store FLEX equipment as follows:

The seismic design criteria and loadings for the ERB were developed in accordance with ASCE 7-10, "Minimum Design Loads for Buildings and Other Structures," as an Essential Facility (Category IV), which is the most conservative and robust of the potential options. To ensure conformance with the NRC expectation that the ERB supports fulfillment of FLEX mitigating strategies, Design Calculation DC02490-004, "Emergency Response Building Structural Calculation," Revision 1, has been developed, in part, to analyze the ERB with respect to the SSE. The calculation evaluated the seismic lateral force resisting system (LFRS) components of the structure, in high bay location of the ERB where the equipment is to be stored. The conclusion of the calculation is that the seismic LFRS of the ERB is expected to withstand the SSE seismic forces (soil foundation) and the ERB will remain accessible and will experience no catastrophic damage.

In addition, the FIP described that the seismic design criteria and loadings for the FSB were developed in accordance with ASCE 7-10 as an Essential Facility (Category IV). To ensure conformance with the NRC expectation that the FSB supports fulfillment of FLEX mitigating strategies, Design Calculation DC02490-005, "FLEX Storage Building Structural Calculations," Revision 0, has been developed, in part, to analyze the FSB with respect to the SSE. The FSB was designed to a wind speed in excess of the ASCE 7-10 wind speed requirements, in an attempt to demonstrate functionality during low intensity tornado events. Due to the increased wind speed used, the forces due to the design high wind of 188 mph bound the lateral SSE forces and therefore control the design of the lateral force resisting system design for the FSB. The conclusion of the licensee's calculation is that the seismic LFRS of the FSB is expected to withstand the SSE seismic forces and the FSB will remain accessible and will experience no catastrophic damage.

The FIP also described that the CAR storage area is a part of the IB east penetration area, and is a safety-related/seismic category 1 concrete structure which is integral with the IB structure. Therefore, the CAR concrete structure was designed to withstand the SSE event. As part of the FLEX response, a metal panel curtain wall and roll-up door were added to the CAR area to enclose the access opening for the storage area and provide a suitable FLEX equipment storage area. Design Calculation DC03440-004, "CAR Storage Area Enclosure Structural Design," Revision 0, was developed as part of the FLEX implementation to provide structural design of the enclosure wall and associated supports. The steel enclosure was designed for both the ASCE 7-10 wind and seismic loadings, and also the SSE loadings. Due to the light weight of the enclosure wall, the wind loadings controlled the design. The licensee concluded that the concrete and steel enclosures of the CAR storage area were both designed to withstand the SSE event.

The NRC staff looked at the design calculations to conclude that results seem to support the statements made by the licensee in its FIP, with regards to the structural capacity of the FSB, ERB, and CAR to withstand seismic loads equivalent to the SSE.

In its FIP, the licensee described that the alternate EFW DG, and supporting auxiliaries, are stored in the FDG. The FDG is described to be robust with respect to all applicable external hazards. The alternative EFW pumps are located within the service water pump house (SWPH). The SWPH is a safety-related, seismically category 1 structure and is robust with respect to all applicable external hazards. Given that the FDG and SWPH are seismic category I structures, these should be designed to withstand the SSE.

In its FIP, the licensee described that large portable BDB equipment such as pumps and power supplies are secured, if required by analysis, inside the ERB, FSB, and CAR to protect them during a seismic event. The buildings have tie downs integrated into the floor slab for this purpose. These tie downs are used to secure any equipment that is not considered stable to ensure the stored BDB equipment remains protected from damage during a seismic event. Additionally, the fire protection system is seismically installed. Floor tie downs were looked at during the onsite audit and its use might be subject of inspection.

3.6.1.2 Flooding

In its FIP, the licensee described that FLEX equipment is stored either within structures designed to protect the equipment from the flood elevations or above the flood elevation calculated by the site external flooding analysis. Local ponding onsite due to local intense precipitation (i.e. probable maximum precipitation or PMP) event was a design consideration in selection of storage locations, equipment connections, and deployment routes.

3.6.1.3 High Winds

In its FIP, the licensee described that storage locations (CAR, FSB, and ERB) for the portable FLEX equipment are protected from all hazards with the exception of design basis tornado winds and missiles; therefore, separation is used to minimize the probability that a single event would damage all FLEX equipment in these locations.

During the audit process, the licensee was requested to confirm that the analysis for local historical tornado data (width and path axis) was taken into account with regard to FLEX storage building locations. NEI 12-06, Section 7.3.1, describes that the axis of separation of the structure locations should consider the predominant path of tornados in the geographical location. In general, tornadoes travel from the West or West Southwesterly direction, diverse locations should be aligned in the North-South arrangement, where possible. Additionally, in selecting diverse FLEX storage locations, consideration should be given to the location of the DGs and switchyard such that the path of a single tornado would not impact all locations.

In the licensee's sixth 6-month update to the OIP (ADAMS Accession No. ML16061A005), the licensee described that VCSNS uses Option C as defined by NEI 12-06 Section 7.3.1 for protection of FLEX equipment from wind hazards. The FSB and the ERB are constructed to ASCE 7-10 and are designed to withstand design-basis hurricane winds. The buildings are not designed for the site design-basis tornado wind loads or for the site design-basis tornado generated missiles. The axis of orientation between the two FLEX storage buildings is similar to the West Southwesterly orientation described in NEI 12-06 Section 7.3.1 to be one of the generally predominant travel paths for tornadoes. This arrangement was deemed acceptable by the licensee, who stated the following:

- The location of the ERB is a compromise of proximity to Unit 1 and future Units 2 and 3. VCSNS staff and equipment located in this building are planned to respond to incidents at all units in the future.
- The location of the FSB is optimal to minimize the distance between the FLEX equipment storage location and the FLEX equipment deployment locations and to avoid transporting equipment over potentially downed high voltage power lines. The FSB location in relatively close proximity to the power block and credited water sources minimizes the debris clearing and

transit times for deployment of FLEX equipment. The location also minimizes the number of security barriers that are encountered during equipment deployment.
- The distance between the FSB and ERB is approximately 2,400 ft.

The licensee conducted a tornado analysis of the VCSNS site based upon the National Oceanic and Atmospheric Administration (NOAA) Storm Prediction Center information database. The licensee concluded that during the time period of 1962 – 2011, the distribution of tornado travel paths was random and did not favor any potential tornado path. Also in its tornado analysis, the licensee compared the average width of a tornado from the NOAA database, which is generally less than 1,320 ft., to the distance between the FSB and ERB stated above. The licensee concluded from the tornado analysis that a tornado would not impact both FLEX storage buildings at once due to the tornado size being less than separation distance between the FSB and ERB.

The NRC staff reviewed the licensee's tornado analysis along with the licensee's reasoning for placement of the FSB and ERB. The NRC staff also conducted its own tornado analysis. The NRC staff referred to the NOAA's Storm Prediction Center for 1950-2011 (which includes tornado data up to 2015). The data indicates that the average tornado width for South Carolina is about 121.5 yards (364.5 ft.). The closest tornado landing near the VCSNS site had a width of 400 yards (1,200 ft.). While some tornadoes did not follow the West or West Southwesterly direction, the NRC staff's position is that the tornado history in the vicinity of VCSNS is consistent with the basis for the guidance in NEI 12-06. Although the historical tornado data indicates that the average tornado width for South Carolina is significantly smaller than the distance between the FSB and ERB, the NRC staff concludes that a single tornado traveling in the predominant direction could impact both buildings. Furthermore, the electrical switchyard could be impacted by the same tornado. Therefore, the NRC staff considers the placement of the FSB and ERB to be an alternative to the NEI 12-06, Revision 2 guidance. The acceptability of this alternative is discussed in SE Section 3.14 of this SE.

3.6.1.4 <u>Snow, Ice, Extreme Cold and Extreme Heat</u>

As previously discussed, VCSNS does not experience significant snowfall or extreme low temperatures and are therefore not applicable to the site.

In its FIP, the licensee described that FLEX equipment is stored in structures which meet either the plant design basis for snow, ice, cold conditions or the guidance in ASCE 7-10. Strategies for the deployment of FLEX equipment considers impedances associated with ice accumulation.

In its FIP, the licensee stated that FLEX equipment is procured such that it is capable of functioning at the maximum design temperature for outdoor safety-related components. Per UFSAR Section 2.3.1, the maximum design temperature is 107 °F. Mechanical cooling systems are provided for safety-related equipment which is located in areas susceptible to sustained high temperatures.

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, and should adequately address the requirements of the order.

3.6.2 Availability of FLEX Equipment

Section 3.2.2.16 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.

In its FIP, the licensee provided a list (Table 5) of the portable FLEX equipment necessary for the implementation of the FLEX strategies in response to a BDBEE. The table listed the FLEX equipment, identified the storage locations, identified the credited strategy for the equipment, as well as performance criteria.

While the licensee only identified one FLEX SG feed pump to support the SG feed strategy in Table 5, the licensee has another method of feeding the SG, namely repowering a safety-related MDEFW pump with two portable FLEX CTGs. The FLEX SG feed pump is stored in the FSB and the FLEX CTGs are stored in the CAR, thus providing protection for at least one Phase 2 SG feed option.

Based on the number of FLEX pumps, FDGs, 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 should include a sufficient number of FLEX pumps, FDGs, and equipment for RCS makeup and boration, SFP makeup, and maintaining containment consistent with the N+1 recommendation in Section 3.2.2.16 of NEI 12-06.

3.7 Planned Deployment of FLEX Equipment

In its FIP, the licensee described that the FSB will be the preferred source of FLEX equipment to support Phase 2 actions following a BDBEE. The FSB is desired due to its proximity to vehicle access points in the protected area, and its position within the owner control area (OCA). The haul paths from the FSB to final deployment locations are much more direct than the haul paths from the ERB. There are two designated routes from the ERB to final deployment locations, as well as multiple equipment access paths to these routes. Routes from the ERB to final deployment locations, which involve entering the southern and western entrances through the OCA barrier, will involve movement of security features.

In its FIP, the licensee described that deployment of FLEX and debris removal equipment from the BDB storage buildings is not dependent on off-site power. All doors required to support

FLEX strategy deployment are designed for manual operation. In addition, strategies for the deployment of FLEX equipment considers impedances associated with ice accumulation.

3.7.1 Means of Deployment

In its FIP, the licensee described that the stored FLEX equipment includes two track vehicles which are equipped with front end blades and articulating arms that can be used to move or remove debris from the needed travel paths. A Caterpillar wheel loader is also available to deal with more significant debris conditions. The same debris removal equipment used for on-site pathways will be used to support debris removal to facilitate road access to the site.

3.7.2 Deployment Strategies

Preferred haul paths, over existing roads, have been identified and documented in the emergency response procedures (ERPs). Although haul paths are primarily over seismically prepared soil, diverse haul paths are utilized to address liquefaction concerns on the west side of the VCSNS site. The haul paths were selected such that areas with trees, power lines, and narrow passages were avoided, when possible. However, high winds can cause debris from distant sources to interfere with planned haul paths. Debris removal equipment is stored in the FSB and the ERB.

In its FIP, the licensee stated that water from the SW pond will be used to refill the CST or would be delivered to the portable FLEX SG feed pump by means of a FLEX UHS pump system. If the CST does not survive the BDBEE, an alternate EFW strategy will be deployed. This strategy utilizes water from the SW pond and a FLEX Alternate EFW suction pump which is installed in the SW pump house to provide water to the EFW system.

3.7.3 Connection Points

3.7.3.1 Mechanical Connection Points

Core Cooling (SG) Primary and Alternate Connections

The licensee described the primary connection for the SG makeup as one MDEFW pump using the CTGs deployed from the CAR when the TDEFW pump is no longer available. The MDEFW pump can take suction from the CST or the FLEX Alternate EFW suction pumps taking suction from the SW pond. The SW connection for the alternate EFW source is described as 4-inch discharge piping that is installed on the SW discharge crosstie header in the SW pump house. This connection is located in the SW pump house, which is protected from all applicable external hazards. The alternate SG makeup connection uses the FLEX SG feed pump, which can take suction from the CST or the discharge of the FLEX UHS pump system. The CST connections are protected from applicable hazards with the exception of the high wind hazard. The FLEX UHS pump system takes suction from the Monticello Reservoir or SW pond to supply the FLEX SG feed pump. Hose connections to the FLEX SG feed pump suction can be routed through two paths: the east feed connection (through the IB) and the west feed connection (through the AB). Both locations are fully protected from all applicable external hazards.

RCS Inventory Control Primary and Alternate Connections

The licensee described its primary connection for RCS makeup as a discharge connection installed on the SI line, which connects to a high pressure hose from the discharge of the FLEX RCS makeup pump for RCS makeup from the RWST or BATs. The primary RCS connection is located in the FHB, which is protected from all applicable external hazards. The alternate RCS makeup connection is described as the charging pump discharge hydro-test connection reconfigured for hose connections to deliver water from the discharge of the FLEX RCS makeup pump to the RCS. The alternate RCS makeup connection to the charging pump discharge is located in the AB, which is protected from all applicable external hazards. The licensee also described the RWST and BAT connections for the FLEX RCS pump in the FIP. The RWST connection consists of the RWST discharge to the SFP return piping. The BAT connection consists of a BAT discharge and pump suction crosstie piping. The RWST and BAT connections are located in the AB, which is protected from all applicable external hazards.

SFP Makeup Primary and Alternate Connections

The licensee described the primary connection for SFP makeup as a new SFP line that tees into the existing SFP system piping located in the AB. The AB is protected from all applicable external hazards. The licensee described the alternate connection for SFP makeup as using hoses routed from the fire pumper truck or FLEX UHS pump system to the SFP deck. The hoses can be run directly over the side of the pool or to the portable spray monitors, which would be set up on the deck next to the SFP. The FLEX equipment and hoses used for the alternate strategy are stored in FSB, FHB, and ERB.

3.7.3.2 Electrical Connection Points

Electrical connection points are only applicable for Phases 2 and 3 of the licensee's mitigation strategies for a BDBEE.

Phase 2

During Phase 2, the licensee has developed a primary, alternate, and defense-in-depth strategy for supplying power to equipment required to maintain or restore core cooling and containment cooling using a combination of permanently installed and portable components. There are two 1.0 MW 7.2 kV CTGs (operated in parallel for 2.0 MW), five 80 kW 480 Vac FDGs (three portable for battery chargers and two installed for FLEX alternate EFW function), and two 300 kW 480 Vac defense-in-depth DGs (only one is required).

Primary Connection Strategy

The licensee's primary connection strategy is to power the 7.2 kV buses (XSW1DA and/or XSW1DB) using the two 1.0 MW CTGs. The CTGs are stored on trailers within the CAR, and will be deployed outside the CAR for operation. The CTGs will be connected by temporary cable to a terminal box located inside the CAR. Permanent cable will transfer power from this terminal box to one located within the IB. Temporary cables are used within the IB to connect the intermediate terminal boxes to those which are permanently connected to the installed 7.2 kV switchgear bus (i.e., XSW1DA or XSW1DB). The licensee stated in its FIP that connection to the plant requires the use of a step-up transformer stored as FLEX equipment. The 7.2 kV switchgear buses supply power to the MDEFW Pump. Power is transferred from the 7.2 kV buses to the station battery chargers and RBCU fans via installed electrical distribution equipment (i.e., 7.2 kV/480 Vac transformer and selected 480 Vac MCCs). FSP-20.7, "FLEX Combustion Turbine Generator Operation," provides guidance for staging, deploying, and making electrical connections from the Phase 2 7.2 kV CTGs to the switchgear buses. Phase rotation checks were performed as part of post-modification testing.

Alternate Connection Strategy

One of the licensee's alternate connection strategies is to power the station vital battery chargers, or swing battery charger, and accumulator isolation valves using one of the 80 kW 480 Vac FDGs stored in the ERB or FSB. The FDG will be deployed to the turbine building or AB roll-up doors. Temporary cables are used to connect the FDG to an ac distribution panel. Temporary cables are also used to connect the AC distribution panel to the input of the station vital battery charger or swing battery charger. EMP-100.016, "Temporary Power from 80KW BDMG to XBC1A, XBC1B, OR XBC1A/1B Swing Battery Chargers," provides guidance for staging and making electrical connections between 80 kW 480 Vac FDGs and the vital station battery chargers or swing battery charger. Guidance in FSP-10.0, "Passive RCS Injection Isolation," covers powering the isolation valves and performing phase rotation checks on the 480 Vac FDGs.

Alternate Connection Strategy (Re-power vital station batteries via B.5.b diesel and B.5.b battery charger) –

The licensee's second alternate connection strategy utilizes the B.5.b portable DG power the stations vital batteries. The B.5.b DG would be staged near the turbine building bay area. Temporary cables are used to connect the B.5.b DG to the B5B battery charger that is also located in the turbine building bay area. Temporary cables are also used to connect the portable battery charger to vital station batteries. Guidance in EMP-100.013, "Temporary Power from B.5.b Diesel and B.5.b Battery Charger to supply Plant DC Power," addresses staging and making electrical connections from the B.5.b DG to the B.5.b battery charger to supply plant dc power. This alternate connection is considered defense–in-depth due to the use of B.5.b equipmpent.

Alternate Connection Strategy (FLEX Alternative EFW Suction Pumps)

The licensee's alternate connection strategy to power the EFW suction pumps utilizes one of the two 80 kW 480 Vac FDGs stored in the FDG. Guidance in FSP-2.0, "Alternate EFW Suction Source," Revision 0, covers operation of the 80kW FDG. Phase rotation checks were performed as part of post-modification testing.

Defense-in-Depth Connection Strategy

The licensee's defense-in-depth strategy is to power the station batteries and normal dc distribution system using one of the 300 kW 480 Vac DGs. The DG in the auxiliary electrical building (AEB) is portable, while the DG in the electrical building (EB) is permanently installed. A temporary cable connects the AEB DG to a generator docking station (GDS). The GDS is connected to the 480 Vac distribution panel via permanent cable. The EB DG connects to the 480 Vac distribution panel via permanent cable. The 480 Vac distribution panel connects to 2 FLEX battery chargers located in the EB via permanent cables. The FLEX battery chargers connects to disconnect switches and terminal boxes in the control building (CB) via temporary and permanent cables to power plant distribution panels (DPN1HA2 and DPN1HB2). The connection from this panel supplies the station batteries and normal dc distribution system. The licensee refers to FSP-5.0, "Initial Assessment and FLEX Equipment Staging," to repower the station batteries and normal dc distribution from the 300 kW 480 Vac DG located in the EB.

Phase 3

For Phase 3, the licensee will receive two 1.0 MW 4160 Vac and one 1100 kW 480 Vac CTGs from an NSRC. In its FIP, the licensee stated that the NSRC supplied 1.0 MW 4160 Vac and 480 Vac CTGs will serve as a backup to the FLEX 1 MW 7.2 kV CTGs and the 480 Vac FDGs located in the EB and AEB, respectively. The 480 Vac (300 kW) DGs in the EA and AEB have the capability and capacity to back up the Phase 2 power sources. The NSRC supplied 4160 Vac CTGs will be deployed near the Phase 2 7.2 kV CTGs staging location outside the CAR. Procedure VCS-ERP-0191,"ERU Deployment: NSRC 4160 CTG," provides guidance for deploying, making electrical connections to the 7.2 kV switchgear bus, and verifying proper phase rotation.

3.7.4 Accessibility and Lighting

The licensee described, in Section 2.8.2 of its FIP, that the ability to open doors for ingress and egress, ventilation, or routing of temporary cables and/or hoses is necessary to implement the FLEX coping strategies. Operators should have keys for emergency access to all areas required for equipment access and operator actions. Following a BDBEE and subsequent ELAP event, FLEX coping strategies require the routing of hoses and cables to be run through various barriers in order to connect equipment to station fluid and electric systems. For this reason, certain gates and doors will be opened and remain open. This violation of normal administrative controls is acknowledged and is acceptable during the implementation of FLEX coping strategies.

In Section 2.12 of its FIP, the licensee described that installed emergency lighting within structures built to withstand the site design basis external events should be initially available up to 8 hours following all BDBEEs except the BDB seismic event. With the exception of MCR lighting, these lights are assumed to be unanalyzed for seismic conditions. The licensee explained in its FIP, that the lighting for the control room, technical support center, debris removal equipment and vehicles, which consisted of flashlights, area-wide portable lighting devices, emergency lighting mounted on structures (adequate light up to 8 hours), and the essential lighting panels in the control room. Also, the licensee stated that light towers would be provided to support deployment of FLEX strategies around the site.

3.7.5 Access to Protected and Vital Areas

In its FIP, the licensee stated that security has established a protocol to permit access to the OCA, protected area and internal locked areas under ELAP conditions.

The licensee also described that other barriers that serve as protection for fires, floods, radiation, ventilation, tornados, and high energy line breaks may have to be opened to route hoses and cables in order to connect equipment to station fluid and electric systems.

3.7.6 Fueling of FLEX Equipment

In its FIP, the licensee described that FLEX support and transportation equipment (e.g., wheel loader and haul vehicles) will normally be maintained with sufficient fuel capacity to ensure their respective deployment functions. FLEX strategy mitigation equipment (e.g., UHS pumping systems pumps and SG feed pump) stored in either the ERB or the FSB will normally contain minimal fuel and thus require fueling prior to deployment and/or operation. The 1MW CTGs stored under the CAR do not have an integral fuel tank. The CTGs will be fueled by a dedicated Trans-Cube fuel trailer. This fuel trailer is maintained empty and will require initial fueling from the underground fuel oil storage tank (FOST) via a portable transfer pump up to 650 gallons. Two additional Trans-Cube fuel trailers are stored onsite; one is stored in the ERB and the other one in the FSB. These fuel trailers will be used to add fuel to FLEX equipment prior to deployment from the storage locations, as necessary. Subsequently, the fuel trailers will be hauled by pickup trucks to deliver fuel from the FOSTs, or other sources, to the various deployed diesel driven equipment locations.

In its FIP, the licensee described that based on a fuel consumption study, the amount of fuel consumed by major FLEX equipment over a 7 day period was estimated to be 49,504 gallons. The estimate conservatively assumes full loading and continuous operation of most equipment. According to the fuel consumption estimate, the two FOSTs, which are protected from all applicable hazards, have adequate capacity to provide the on-site FLEX equipment with diesel fuel for approximately 14 days. This time period could be extended based upon utilization of the auxiliary boiler tank or other available tanks on-site. Arrangements with fuel supply vendors ensure availability of fuel from off-site resources prior to depletion of fuel on-site. During the audit, the licensee indicated that the fuel oil quality requirements for the FLEX equipment would be made similar to existing site Technical Specifications and Chemistry Procedure CP-0401, "Diesel Fuel Oil Sampling Procedure," for administrative controls to govern the acceptability of the fuel oil for use in FLEX strategies.

3.7.7 Conclusions

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, and should adequately address the requirements of the order.

3.8 Considerations in Using Offsite Resources

3.8.1 VCSNS 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 (ADAMS Accession No. ML14265A107), 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 VCSNS, the Columbia Metropolitan Airport was identified as staging area C. The SCE&G Corporate Campus was identified as alternate staging area D. Staging areas A and B are located inside the VCSNS. Use of helicopters to transport equipment from Staging Area C to Staging Area B is recognized as a potential need within the VCSNS 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 VCSNS, ventilation that provides cooling to occupied areas and areas, containing required equipment will be lost. Per 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 following a BDBEE resulting in an ELAP. The primary concern with regard to ventilation is the heat buildup that occurs with the loss of forced ventilation in areas that continue to have heat loads. 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 within equipment limits.

The key areas identified for all phases of execution of the FLEX strategy activities are the control room (CR), relay room, TDEFW pump room, MDEFW pump area and EFW control valve mezzanine area, PORV area, Class 1E station battery rooms and battery charger rooms, ESF switchgear rooms, FHB, AB, and containment. The licensee evaluated these areas to determine the temperature profiles following an ELAP concurrent with loss of normal access to the UHS. With the exception of the CR, the licensee concluded in its calculations that temperatures remain within acceptable limits based on conservative input heat load assumptions for all areas with no immediate actions being taken to reduce heat load or to establish either active or passive ventilation (e.g., portable fans, open doors, etc.).

Control Room

The NRC staff reviewed TR00080-003, "FLEX Equipment Ventilation and Habitability Assessment," Revision 2, which, in part, evaluates the loss of cooling to the MCR during an ELAP event. Heat up in the MCR has previously been evaluated by the licensee for Station Blackout (SBO) in TR08200-003, "Compliance to NRC Rule 10CFR50.63 Station Blackout," Revision 8 and for loss of MCR HVAC in DC00020-227, "Control/TSC/Cable Spreading Separate Room Heat-Up Calculation – Complete Loss of HVAC," Revision 0. The SBO analysis evaluates the temperature response in the MCR in the absence of heat generated from MCR components powered from the plant AC electrical distribution. The loss of HVAC analysis considers the normal MCR heat load. The heat load for the ELAP scenario is somewhere in between the heat load analyzed in the two calculations. The ELAP MCR temperature response initially mimics the analyzed SBO response until plant personnel are able to energize the 7.2 kV safeguard bus, XSW1DA and XSW1DB, with two 1 MW CTGs. Even after the switchgear becomes energized, the MCR heat load remains much lower than normal operation due to the continued absence of non-safety related ac power, but the MCR heat load will increase above the SBO heat load.

Since it is difficult to predict when operators are able to energize XSW1DA and XSW1DB, the FLEX ventilation strategy for the MCR is based on the loss of HVAC analysis, which is much higher than the SBO heat load and bounds the ELAP heat load. Using the heat load from the loss of the MCR HVAC, the licensee determined that forced air ventilation by a fan with 15,560 cubic feet per minute (cfm) air flow is required in the MCR within 10 hours into an ELAP to maintain a MCR temperature of 115 °F. Initially, building doors and duct access doors will be opened to create natural stack ventilation. Afterward, forced flow will be established using portable fans powered by a portable DG. In addition, the MCR fan may be repowered and operated in the purge mode to add additional cooling. Guidance in FSP-20.1, "Vital Area Emergency Ventilation", instructs operators to open selected doors and to install temporary fans to establish outside air flow to the MCR within 10 hours.

Based on MCR 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, for electronic equipment to be able to survive indefinitely), with the mitigating actions described in FSP-20.1, as discussed above, the NRC staff finds that the equipment in the MCR should not be adversely impacted by the loss of ventilation as a result of an ELAP event.

Relay Room

The NRC staff reviewed TR00080-003, Revision 2, which also evaluates the loss of cooling to the relay room during an ELAP event. Heat up in the relay room has previously been evaluated by the licensee in DC00020-228, "Relay/Cable Spreading Room CB-425 Heat-Up Calculation," Revision 0. The heat loads in the Relay Room are powered from a variety of sources, including both ESF and non-ESF batteries, as well as safety-related ac power. Due to uncertainties regarding if and when particular loads are energized during an ELAP, the loss of HVAC analysis for the relay room from DC00020-228 is used as a bounding analysis.

Using the heat load from the loss of the relay room HVAC, the licensee determined that forced air ventilation by a fan with 5,993 cfm air flow is required in the relay room within 6 hours into an ELAP to maintain a relay room temperature below 120 °F, which is the acceptance criterion limit for the relay room due to equipment operability concerns. Initially, building doors will be opened (within 1 hour) to establish a flow path from the relay room to the 483 foot elevation of the control building. Afterward, various access doors and building doors will be opened and forced flow will be established (within 6 hours) using portable fans powered by a portable DG. Guidance in FSP-20.1 instructs operators to open selected doors and dampers within one hour, opening duct access doors, and deploying a portable FLEX diesel powered 6,000 cfm fan within 6 hours.

Based on the relay room expected temperatures remaining below the temperature limit (120 °F) with the mitigating actions described in FSP-20.1, as discussed above, the NRC staff finds that the equipment in the relay room will not be adversely impacted by the loss of ventilation as a result of an ELAP event.

TDEFW Pump Room

The NRC staff reviewed TR00080-003, Revision 2, which in part, evaluates the loss of cooling to the TDEFW pump room during an ELAP event. Heat up in the TDEFW pump room has previously been evaluated by the licensee in DC000020-2238, "EFW/TDEFW Pump Room Heat-Up Calculation," Revision 0. This analysis indicates that the room temperature reaches

132 °F quickly and reaches a steady-state temperature of 187 °F in 28 hours. The temperature limit for equipment operability in the TDEFW pump room is 180 °F.

DC00020-238 considers the normal (non-SBO) heat load, which is approximately 50 percent higher than the SBO heat load. It is expected that ambient temperature in the room during an ELAP will mimic the response to a SBO event, which has a lower heatup. To prolong availability of the equipment in the TDEFW pump room, the licensee determined that the doors to the room should be opened to provide natural ventilation and heat removal. There is also an 18" x 18" opening in the wall that allows air to escape. DC00020-238 shows that with these ventilation paths, the TDEFW and MDEFW rooms will act as a combined area, and this combined area will reach a steady-state temperature of 147 °F. Guidance in FSP-20.1 instructs operators to open the door within 4 hours.

Based on the TDEFW pump room expected temperatures remaining below the temperature limit (180 °F) with the mitigating actions described in FSP-20.1, as discussed above, the NRC staff finds that the equipment in the TDEFW pump room should not be adversely impacted by the loss of ventilation as a result of an ELAP event.

MDEFW Pump and EFW Control Valve Mezzanine Areas

The NRC staff reviewed TR00080-003, Revision 2, which in part, evaluates the loss of cooling to the MDEFW pump and EFW control valve mezzanine areas during an ELAP event. As discussed above, the MDEFW and TDEFW pump rooms will act as a combined room once the mitigation strategy for the TDEFW Pump Room is completed, and the combined area will conservatively reach a steady-state temperature of 147 °F. The temperature limit (NUMARC 87-00) for equipment operability in the MDEFW pump room is 180 °F. Since the temperature of the room will remain below the qualified temperature of the equipment in the room for the entirety of the ELAP event, no action is required for the MDEFW pump room. This room will also receive additional cooling due to the mitigation plan for the flow control valve (FCV) mezzanine area, as discussed below.

The EFW control valve mezzanine area is located on the 423 ft. 6 in level above the TDEFW and MDEFW pump rooms and is open to elevation 412 feet of the IB (the area containing the MDEFW pump). Heat will be added to this area from the MDEFW and TDEFW pump rooms due to the operating pumps. The air in this area will mix with the surrounding air and also continue to rise into the 436 foot elevation area, primarily through the reactor building buttress access opening and various openings in the ceiling. In TR00080-003, the licensee discusses that the FCV mezzanine floor also has a similar volume to that of the MDEFW pump room, and reasonably assumes that the steady-state temperature of this area will be similar, or approximately 147 °F. Since the FCVs and associated piping have a normal design temperature of 150 °F, the high temperature will have no effect on equipment functionality, as the temperature will remain below 147 °F, even when assuming conservative heat loads and not accounting for ventilation openings. Guidance in FSP-20.1 instructs operators to establish forced air ventilation powered by a 5kW portable DG.

PORV Areas

The NRC staff reviewed TR00080-003, Revision 2, which in part, evaluates the loss of cooling to the PORV areas during an ELAP event. One of three PORVs is located in the east penetration area, one in the west penetration area and one in the IB, all on the 436 feet grade elevation. These areas are normally ventilated by the penetration area systems and the IB system. During the initial phase of an ELAP, loss of ventilation to these areas will result in elevated temperatures in the areas of the PORVs. Based on historical temperature tests performed at the site, where the worst case peak ambient temperatures in the east and west penetration areas on the 436 ft. elevation with the HVAC fans turned off were determined, the licensee estimates that the "worse case" temperature in the areas of the PORVs will rise to approximately 150 °F. To account for the sources of radiant heat, the licensee determined that this temperature should be increased by an additional 13 °F. Even though flow through the main steam and feedwater pipes will be terminated during the event, there will be appreciable heat sources in the areas due to initial actuation of the safety valves and subsequent use of the PORVs.

In TR00080-003, the licensee described the FLEX strategy engineering control in the PORV areas. The licensee determined that in order to improve the local ambient conditions at the PORVs, actions to establish natural circulation should be performed in these areas to exhaust the heated air by opening doors, dampers, and pressure relief panels on the IB roof. The natural circulation path should be established prior to the initiation of the planned controlled RCS cooldown (2-4 hours). In addition to establishment of natural ventilation, forced ventilation should be employed for each of the PORV areas with use of FLEX portable, diesel powered supply fans. Forced ventilation should be established after the natural circulation path has been established. There is no time constraint for forced ventilation. Instead, forced ventilation should be established as soon as possible (as conditions warrant), when operators are locally manipulating SG PORVs. Guidance in FSP-20.1 tells operators to establish natural circulation and forced ventilation in the PORV areas powered by a 5kW portable DG.

The PORV equipment is qualified to operate in the expected environment, since the components are designed to operate at 600 °F. Special design requirements were specified that the equipment be certified to perform in 220 °F steam environment for three minutes, followed by three hours at 200 °F, therefore the NRC staff finds that the components in the PORV areas will not be adversely impacted by the loss of ventilation as a result of an ELAP event.

Class 1E Station Battery Rooms and Battery Charger Rooms

The NRC staff reviewed TR00080-003, Revision 2, which in part, evaluates the loss of cooling to the battery rooms and battery charger rooms during an ELAP event. Heat up in these rooms has previously been evaluated by the licensee in DC00020-233, "Battery and Charging Room Heat-Up Calculation," Revision 0, which determined that the expected steady state room temperature would remain at approximately 75 °F, assuming surrounding areas are maintained at the maximum environmental qualification (EQ) temperatures listed in the V. C. Summer Equipment Database, Revision 11, and all doors are assumed closed with no air circulation path. Calculation DC00020-233 showed that the analyzed steady state room temperature of 75 °F is lower than the VCSNS Technical Specification upper temperature limit of 118 °F and most limiting equipment temperature limit of 90 °F. However, since a loss of ventilation may cause hydrogen to accumulate within the battery rooms, the licensee's FLEX strategy is to open battery room doors and establish forced ventilation using a portable fan to ensure the "pocketing" of hydrogen is avoided. Because a flow path will be created to the surrounding rooms and out to the environment, the battery room will heat up if the surrounding area is hotter.

Guidance in FSP-20.1 instructs operators to restore battery room normal ventilation supply and exhaust fans (HVAC) when electrical power is available to the selected 7.2 kV switchgear buses from Phase 2 CTGs (within 15 hours) or from Phase 3 NSRC 4160 Vac CTGs, which should lower the temperature in the battery rooms and maintain room temperature below battery design temperature limit. Guidance in FSP-20.1 also directs operators to establish forced air ventilation using a portable exhaust fan at the battery room doors powered by a 5kW portable DG within 7 hours. Document TR00080-003 recommends use of only an exhaust fan without its corresponding supply fan if outdoor temperature is excessive high.

Since the battery room temperature is expected to remain lower than the 122 °F temperature limit recommended by the battery vendor (C&D Technologies), the NRC staff finds that there should not be any adverse impact on the batteries due to expected room temperatures. While the battery vendor's analysis shows that the batteries are capable of performing their function up to 122 °F, periodic monitoring of electrolyte level may be necessary to protect the battery since the battery may gas more at higher temperatures.

Regarding the battery charger rooms, calculation DC00020-233, shows the bounding temperature will reach 120 °F in approximately 7 hours and then increase to a steady-state temperature of approximately 137 °F within 20 hours. A conservative heat load was used in the loss of HVAC heat-up analysis. Each battery room has two 18" x 18" free-return openings in the ceiling allowing air to flow upward into the air handling unit areas and eventually to the roof of the IB. The licensee determined that opening doors will increase the effectiveness of the natural ventilation by creating another flow path to exhaust the heated air out through the ceiling which should ensure the room remains below 120 °F. Guidance in FSP 20.1 instructs operators to establishing natural circulation to the battery charger rooms within 7 hours. As defense-in-depth, TR00080-003 recommends staging a portable fan to direct air into the battery charger rooms for additional ventilation and cooling, if necessary.

The battery chargers qualification report and the vendor technical manual specify a maximum qualified environmental temperature of 140 °F. The chargers also have their own fan-powered, internal ventilation units, which draw air into the bottom of the chargers and out the top. Since the actions taken to establish natural ventilation should prevent the room temperature from exceeding 120 °F, the NRC staff finds that there should not be any adverse impact on the battery chargers due to expected room temperatures.

ESF Switchgear Rooms

The NRC staff reviewed TR00080-003, Revision 2, which in part, evaluates the loss of cooling to the switchgear rooms during an ELAP event. Heat rise in the rooms following a loss of chilled water to the air handling unit cooling coils has previously been evaluated by the licensee in DC00020-232, "Intermediate Building 436 and 463 Switchgear Rooms Heat-Up," Revision 0, which predicts a temperature increase to 135 °F in 10 hours for IB 36-01 and to 140 °F in 10 hours for IB 63-01. The assumed heat load in DC00020-232 is very conservative when compared to ELAP conditions, because the CTGs do not have the same power output as the EDGs and the HVAC fans would not be operating during an ELAP.

The 1DA switchgear qualification report documents the switchgear is qualified for an environmental temperature of 104 °F with a maximum operability limit of 134 °F. Switchgear room SBO temperature limits in NUMARC 87-00 are listed as 150 °F, so a maximum temperature of 140 °F and target temperature of 130 °F is acceptable for ensuring the electrical equipment functions properly. Using the heat load from Calculation DC00020-232, the licensee determined that forced air ventilation by a fan with 5,448 cfm air flow and 10,260 cfm air flow for IB 36-01 and IB 63-01, respectively, within 10 hours into an ELAP event should maintain the switchgear rooms temperature below 130 °F. Guidance in FSP-20.1 instructs operators to open selected doors and deploy forced ventilation within 10 hours.

Based on the switchgear rooms expected temperatures remaining below the equipment design temperature limits and with the mitigating actions described in FSP-20.1, as discussed above, the NRC staff finds that the equipment in the Switchgear Rooms will not be adversely impacted by the loss of ventilation as a result of an ELAP event.

<u>Fuel Handling Building</u>

See Section 3.3.4.1.1 for discussion related to the SFP area.

<u>Auxiliary Building</u>

The NRC staff reviewed TR00080-003, Revision 2, which in part, evaluates the loss of cooling to the AB during an ELAP event. Specifically, TR00080-003 evaluates the conditions at the 463 ft. elevation north stairway where one of the SFP level transmitters utilized in the FLEX SFP cooling strategy is mounted and also evaluates the location of the power control panel. In TR00080-003, the licensee calculated the heat load that would need to be removed from the 463 ft. elevation stairway to conservatively limit this area to 150 °F. Using this heat load, the licensee determined that a natural stack ventilation will be created to exhaust heated air in the stairwell by opening the outside stairwell door on the 436 ft. elevation and the stairwell door on the 485 ft. elevation of the AB. The required 180 cfm air flow is easily obtained by the established stack ventilation, so forced ventilation is not required. Guidance in FSP-20.1 tells operators to open selected doors to create natural stack ventilation.

Since the expected ventilation will limit the temperature in the stairwell where the sensor is located to 150 °F with the mitigating actions described in FSP-20.1, as discussed above, and thereby provide a 26 °F margin over its rated temperature of 176 °F, the NRC staff finds that the equipment in the AB will not be adversely impacted by the loss of ventilation as a result of an ELAP event.

The power control panel is located in environmental zone AB-71. According to environmental zone information, the maximum temperature for this area is 115 °F, and during an ELAP event, there are no sources of additional heat. The power control panel is qualified for temperatures up to 149 °F, therefore the control panel will not be adversely impacted by the loss of ventilation as a result of an ELAP event.

Containment

In its FIP, the licensee stated that the containment design pressure and temperature limits (57 psig and 283 °F) bound the expected containment pressure and temperature values (18.7 psig and 218 °F) calculated for the ELAP event for 30 days. The instruments, which monitor key parameters and are subject to the containment environment, are qualified to remain functional for a minimum of 45 days. The qualified equipment profile for the Reactor Head Vent Valves shows the valves are qualified for 315 °F (100 percent relative humidity) and 70 psig, which bounds the ELAP expected containment environment.

During the onsite audit, the licensee noted that all required instruments that are located in containment are environmentally qualified for the harsh containment environment. The licensee noted that all electrical equipment and instruments credited in the VCSNS ELAP mitigation strategies are located in environmental zone RB-04 through RB-11 and that document S-021-018 Sheet 7-9 contains an enveloping temperature profile for the containment equipment. In Calculation DC00080-010, "VCSNS ELAP Containment Response Due to RCS Inventory Loss," Revision 1, the licensee determined the expected temperatures in containment during an ELAP considering 5 different cases. The peak of the ELAP temperatures (maximum of 218 °F) are bounded by the EQ temperatures (maximum of 373 °F), which were used to qualify the existing equipment. Based on the temperature profile overlays, the EQ temperature profile bounds the ELAP containment profile for approximately 40 hours. Also, Calculation DC00080-010 showed that once the RBCU is restored using the Phase 2 or 3 CTGs and pumping systems, the ELAP containment temperature quickly decreases to approximately 130 °F, which is well within the equipment EQ temperature limit. Table 4 of the FIP shows that RB cooling is not required for greater than 30 days to prevent exceeding design temperature and pressure limits but will be established when ac power is available. According to the FIP, ac power should be available from the 7.2 kV CTGs within 15 hours into the ELAP event. Guidance in FSP-12.0, "Alternate Reactor Building Cooling," instructs operators to restore the RBCU.

Based on the above, the NRC staff concludes that electrical equipment and instruments credited for the success of the licensee's FLEX strategy within the containment should function when exposed to the expected pressure and temperatures during an ELAP event.

3.9.1.2 Loss of Heating

The licensee indicated in its FIP, that FLEX equipment stored in the FSB and ERB will be protected from low temperatures due to the infrared space heaters used to maintain temperatures well above freezing. The CTGs staged in the CAR also have heaters to protect from extreme cold temperatures. The licensee did not identify any other areas that would be impacted by extreme cold temperatures due to the durability of the FLEX equipment procured for functioning in cold weather.

Class 1E Station Battery Rooms

In the event of an ELAP, HVAC in the Class 1E station battery rooms will be lost. The equipment and concrete walls of the building that houses the Class 1E station batteries provide a large thermal mass at initial ambient temperature. Without any outside air flow, the insulating value of thick exterior walls and heat input into the battery rooms from the batteries discharging will cause the room temperature to slowly rise. Adequate operability conditions will be monitored by the licensee.

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

3.9.1.3 Hydrogen Gas Control in Vital Battery Rooms

An additional ventilation concern 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. The NRC staff reviewed licensee calculations TR00080-003 and DC07290-001, "Hydrogen Evolution Rates Intermediate Building Battery Rooms," Revision 2, to verify that hydrogen gas accumulation in the 125 Vdc Vital Battery rooms will not reach combustible levels while HVAC is lost during an ELAP. Off-gassing of hydrogen from batteries is only a concern when the batteries are charging. Based on the calculations, the licensee concluded that it will take approximately 77 hours to reach 2 percent hydrogen concentration in the battery rooms when ventilation in the battery rooms is lost. Guidance in FSP-20.1 instructs to repower the normal Battery Room supply and exhaust fans (if power to any one of the two vital 7.2 kV switchgear buses (XSW1DA or XSW1DB is available)) or establish ventilation using a portable exhaust fan powered by a 5 kW portable DG.

Based on the above and mitigation actions in FSP-20.1, the NRC staff concludes that hydrogen accumulation in the safety-related battery rooms should not reach the combustibility limit for hydrogen (4 percent) during an ELAP as a result of BDBEE.

3.9.2 Personnel Habitability

3.9.2.1 Main Control Room

As described above in Section 3.9.1.1, heat up in the MCR has previously been evaluated by the licensee for SBO and for loss of MCR HVAC. The heat load for the ELAP scenario is somewhere in between the heat load in those two calculations. In TR00080-003, the licensee determined that temperatures are maintained in acceptable ranges by establishing natural circulation followed by forced ventilation in order to ensure habitability and equipment operations. Initially, building doors and duct access doors will be opened to create natural stack ventilation. Afterward, forced flow will be established using portable fans powered by a portable diesel generator. In addition, the MCR fan may be repowered and operated in the purge mode to add additional cooling. The licensee's evaluation TR00080-003, determined that a forced air ventilation by a fan with 15,560 cfm is sufficient to maintain the CR temperature below 115 °F. Guidance in FSP-20.1 instructs operators to open selected doors and to install temporary fans to establish outside air flow to the MCR within 10 hours. The licensee's maximum target CR temperature is slightly higher than the 110 °F temperature limit, as identified in NUMARC-87-00, for personnel habitability. However, based on the conservatism used in the licensee's evaluation, along with the capability of cycling operators in and out of the MCR as needed to monitor plant parameters, in conjunction with other heat stress counter measures, the NRC staff finds that personnel in the MCR should not be adversely impacted by the loss of ventilation as a result of an ELAP event.

3.9.2.2 Spent Fuel Pool Area

See Section 3.3.4.1.1 above for the detailed discussion of ventilation and habitability considerations in the SFP Area. In general, the licensee plans to establish natural circulation to ensure habitability and equipment operations, and deploy hoses before the SFP boiling affects habitability. The licensee also has the ability to add water to the SFP from the installed SFP cooling piping without accessing the refueling floor.

3.9.2.3 Other Plant Areas

In areas of the plant where operator actions are needed as part of the FLEX strategy, the licensee stated in TR00080-003, "FLEX Equipment Ventilation and Habitability Assessment," Revision 2, that in addition to ventilation established for habitability concerns, heat stress is addressed through providing ice vests, limiting stay times in hot areas, providing drinking water, and plant modifications designed to make operator actions easier to accomplish.

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

In its FIP, the licensee described that the CST would be the primary source of makeup water to the SGs. The CST is protected against all the applicable hazards with the exception of high winds. The CST volume is maintained greater than or equal to 179,850 gallons, to provide a minimum volume of 154,062 gallons to the EFW system. The DWST and the FWST would be used to supply makeup to the CST prior to depletion. The DWST and FWST are not seismically qualified or protected against extreme wind hazard, but if available, they normally contain more than 600,000 gallons of water to refill the CST. Water makeup from the available water sources is required around 8 hours after declaration of ELAP. If the CST is not available after the ELAP event, the operators would need to align makeup water from the Monticello Reservoir or the SW Pond within 1 hour to supply the suction of the TDEFW pump using the FLEX Alternate EFW suction pumps located in the SW Pump House. The FLEX Alternate EFW suction pumps can be connected to the TDEFW pump or one of the two MDEFW pumps powered by the CTGs. Straining of pond water would be provided as part of the FLEX UHS pump system. Using water from the SW pond for feeding SGs is part of the present licensing basis (UFSAR Section 10.4.9). The SW pond contains approximately 85 million gallons of water at Technical Specifications minimum and is protected against all applicable external hazards.

3.10.2 Reactor Coolant System Make-Up

In its FIP, the licensee described that makeup to the RCS would be from either the RWST (minimum volume of 453,800 gallons) or the BATs (minimum volume of 14,000 gallons). The RWST is not protected against missiles or high winds. The BATs are protected against all applicable hazards due to their location inside the AB. A boration skid from the NSRC can be used with the FLEX pumps to supply borated water for RCS makeup for Phase 3.

3.10.3 Spent Fuel Pool Make-Up

In its FIP, the licensee described that the SW pond or the Monticello Reservoir would provide the makeup water for the SFP. The SW pond contains approximately 85 million gallons of water at Technical Specifications minimum and is protected against all applicable hazards.

3.10.4 Containment Cooling

In its FIP, the licensee described that no water sources were needed for containment cooling during Phases 1 and 2. For Phase 3, the licensee described that the SW pond (UHS) or the Monticello Reservoir would provide the water for either cooling a repowered RBCU fan, or providing spray flow for the RB spray system. The SW pond contains approximately 85 million gallons of water at Technical Specifications minimum and is protected against all applicable hazards.

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, 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 TDEFW 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, if no actions are taken, it would take 87 hours for SFP water to boil-off dropping 10 ft. above fuel assemblies. The licensee has stated that they have the ability to implement makeup to the SFP within that time.

When a plant is in 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. The

NRC-endorsed strategy is described in NEI 12-06. Section 3.2.3 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. In its FIP, the licensee stated that it would follow this guidance. 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 FSPs will provide guidance that can be employed for a variety of conditions. Clear criteria for entry into FSPs will ensure that FLEX strategies are not used inappropriately in lieu of existing procedures. When FLEX equipment is needed to supplement strategies within EOPs or abnormal operating procedures (AOPs), the EOP or AOP, severe accident management guidelines (SAMGs), or beyond-design-basis mitigation guidelines (BDMGs) will direct the entry into and exit from the appropriate FSP.

The FIP also described that FSPs have been developed in accordance with PWROG guidelines to provide available, pre-planned FLEX strategies for accomplishing specific tasks in the EOPs or AOPs. The FSPs will be used to supplement, not replace, the existing procedure structure that establishes command and control for the event. Procedural interfaces have been incorporated into EOP-6.0 to include appropriate reference to FSPs and provide command and control for the ELAP. Additionally, procedural interfaces have been incorporated into the following AOPs to include appropriate reference to FSPs:

- AOP-123 series, SFP
- AOP-304.4, Loss of All ESF AC Power while on RHR Cooling

The FIP described that FSP maintenance will be performed by the station's procedures group. NEI 96-07, Revision 1, and NEI 97-04, Revision 1, are to be used to evaluate changes to procedures to determine the need for prior NRC approval.

3.12.2 Training

In its FIP, the licensee stated that training plans were developed for plant groups such as the Emergency Response Organization, Security, Operations, Engineering, Mechanical Maintenance, and Electrical Maintenance. The training plan development was done in accordance with licensee procedures using the Systematic Approach to Training (SAT).

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 and will be maintained in accordance with NEI 12-06, Section 11.6.

3.13 Maintenance and Testing of FLEX Equipment

In its FIP, the licensee described that NEI 12-06 provides guidance for the unavailability of equipment and connections that directly perform a FLEX mitigation strategy for core cooling, SFP cooling, and containment integrity. Allowed outage times are a function of the protection against site applicable hazards for the remaining available FLEX strategies. When a FLEX strategy is impaired due to equipment unavailability, the allowed outage time is reduced from 90 days to 45 days. Where VCSNS uses separation as a protection mechanism for the high wind hazard, allowed outage times for equipment necessary to implement a FLEX strategy is 45 days. Equipment outage times will be managed as follows:

- The required FLEX equipment may be unavailable for 90 days provided that the site FLEX capability (N) is met. If the site FLEX (N) capability is met but not protected for all of the site's applicable hazards, then the allowed unavailability is reduced to 45 days.

- One of the connections to plant equipment required for FLEX strategies can be unavailable for 90 days provided the remaining connection remains available such that the site FLEX strategy is available.

- If FLEX equipment or connections become unavailable such that the site FLEX capability (N) is not maintained, initiate actions within 24 hours to restore the site FLEX capability (N) and implement compensatory measures (e.g., use of alternate suitable equipment or supplemental personnel) within 72 hours.

- If FLEX equipment or connections to permanent plant equipment required for FLEX strategies are unavailable for greater than 45/90 days, restore the FLEX capability or implement compensatory measures (e.g., use of alternate suitable equipment or supplemental personnel) prior to exceedance of the 45/90 days.

Also, during the audit process, the licensee mentioned that maintenance and testing would follow EPRI Technical Report 3002000623, "Nuclear Maintenance Applications Center: Preventive Maintenance Basis for FLEX Equipment." 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 2

The staff identified the protection of the FLEX equipment from tornado winds and missiles as an alternative to the guidance in NEI 12-06, Revision 2. As explained by the licensee in its FIP, the

FSB and ESB are not designed to withstand tornado winds and missiles. The buildings are aligned with the predominant tornado path, and they collectively store the two portable FLEX RCS makeup pumps, one portable FLEX SG makeup pump, pumps and fire trucks used for SFP makeup, three portable 80 kW generators, one fuel trailer, two pumper trucks, fuel oil transfer pumps, cable trailers, hose trailers and supporting equipment for debris clearing, communications, ventilation, and lighting. To assess the implications of the selected storage configuration, the NRC staff evaluated the licensee's ability to provide core cooling, containment, and spent fuel pool cooling in the unlikely event of both FLEX storage buildings being affected by the same tornado.

The staff's primary concern was the RCS makeup strategy because all of the credited RCS makeup pumps are in the FLEX storage buildings (FSB and ESB) and RCS makeup is assumed to begin within 20 hours of an event. During the audit, the licensee identified that the ASI system, although not credited as part of the overall FLEX strategy (it is described in the FIP as defense in depth), would be available to provide the RCS makeup function. This system is designed to deliver 20 gpm to the RCP seals, is independent of the electrical grid, and starts injection within 4 minutes of an ELAP. The ASI pumps are located within the AB and are protected from tornado winds and missiles. The associated DG is installed west of the power block and is protected by distance and intervening structures such that it would not be affected by a tornado that impacts the FSB and ESB. The system draws water from the RWST, which is approximately 1,200 ft. perpendicular to the path between the FSB and ESB, and is expected to survive the tornado of interest. The licensee considers ASI to be defense in depth, so it is not subject to FLEX administrative controls. The staff audited the licensee's administrative controls for the system. The licensee considers the ASI system to be highly risk significant for a loss of offsite power event. Thus, the ASI system is considered "protected equipment" that is not removed from service when the VCSNS site is under a tornado watch. The maintenance activities for the ASI pumps and DG are controlled by the station's Maintenance Rule Program. The ASI system is limited to no more than 200 hours unavailability per rolling 36 months, which is more restrictive than FLEX components' allowed outage times. The ASI DG is tested weekly for 15 minutes and the ASI pumps are run quarterly for 10 minutes, meeting or exceeding the FLEX equipment test frequencies. Thus, while the ASI system is not controlled by the FLEX program administrative controls, the NRC staff has high confidence that the system should be available following the tornado event of interest.

The SG feed pump is stored in the FSB, and SG makeup is required when the TDEFW pump becomes unavailable. However, the licensee also credits the MDEFW pump, powered by the CTGs, for this function. The MDEFW pump takes suction from the CST or from the FLEX Alternate EFW suction pumps, which in turn take suction from the SW pond. The MDEFW pump is located in the IB, which is protected from all applicable external hazards. The CTGs are located in the CAR, which is protected by distance and intervening structures from the tornado event of interest. The FLEX Alternate EFW suction pumps are installed in the SW pump house, which is protected from all applicable external hazards. The DGs for the FLEX Alternate EFW suction pumps are located in the FDG Building, which is also protected from all applicable external hazards. Therefore, the location and protection for the MDEFW pump, the CTGs, and the FLEX Alternate EFW suction pumps and associated DGs provide assurance that the SG makeup function will be available following the tornado event of interest.

The SFP makeup portable pumps are stored in the FSB and ESB, as are the fire trucks that can also be used for this function. However, the SFP makeup function is designated to begin around 87 hours after the initiation of the ELAP event. The NSRC equipment is expected to be on site well before this time and can be used to provide this function. Therefore, if both FLEX storage buildings are impacted by the tornado, the licensee maintains the ability to support this function when need.

In conclusion, the NRC staff finds that although the guidance of NEI 12-06 was not fully met, if this alternative is implemented as described, the requirements of the order should be met.

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 (ADAMS Accession No. ML13063A099), the licensee submitted its OIP for VCSNS in response to Order EA-12-051. By letter dated July 29, 2013 (ADAMS Accession No. ML13203A180), the NRC staff sent a request for additional information (RAI) to the licensee. The licensee provided a response by letter dated August 28, 2013 (ADAMS Accession No. ML13247A338). By letter dated December 5, 2013 (ADAMS Accession No. ML13305A100), the NRC staff issued an ISE and RAI to the licensee. The licensee provided a response by letter dated October 29, 2014 (ADAMS Accession No. ML14304A538).

By letters dated August 28, 2013 (ADAMS Accession No. ML13242A272), February 27, 2014 (ADAMS Accession No. ML14063A201), August 28, 2014 (ADAMS Accession No. ML14245A404), February 27, 2015 (ADAMS Accession No. ML15062A008), and August 20, 2015 (ADAMS Accession No. ML15237A041), 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 (SFPLI), which will function following a BDBEE, including modifications necessary to support this implementation, pursuant to Order EA-12-051. By letter dated January 22, 2016 (ADAMS Accession No. ML16028A196), the licensee reported that full compliance with the requirements of Order EA-12-051 was achieved.

The licensee has installed a SFPLI system designed by AREVA. The NRC staff reviewed the vendor's SFPLI system design specifications, calculations and analyses, test plans, and test reports. The staff issued an audit report on September 15, 2014 (ADAMS Accession No. ML14203A326).

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 September 16, 2015 (ADAMS Accession No. ML15253A721), the NRC issued an audit report on the licensee's progress. Refer to Section 2.2 above for the regulatory background for this section.

4.1 Levels of Required Monitoring

In its letter dated August 28, 2013 (ADAMS Accession No. ML13247A338), the licensee stated that:

> The normal SFP water level to support SFP cooling pump operation is the 461.5 ft.Elevation. Abnormal Operating Procedures for a decreasing SFP water level requires restoration to the 460.5 ft. elevation before returning to normal operation. The NEI 12-02 "Level 1" datum is considered to be 461.5 ft. elevation. Per existing design basis calculations, Net Positive Suction Head (NPSH) margin exists with the SFP level at a Technical Specification minimum level, with the pool at saturated conditions, and a bounding high pump-flow-rate. Therefore, the chosen Level 1 datum of 461.5 ft. is greater than a SFP level that would cause loss of NPSH at saturated conditions and also greater than the elevation where the anti-siphoning holes are located.

The NRC staff noted that Level 1 at 461.5 ft. is adequate for normal SFP cooling system operation; it is also sufficient for NPSH and represents the higher of the two points described in NEI 12-02 for this level.

In its OIP, the licensee stated that:

> Level 2 is an indicated level on either the primary or backup instrument channel of greater than elevation 447.5 ft. This elevation is approximately 11 ft. above the top of the fuel assemblies stored in the racks. This level would allow radiation shielding protection for personnel on the spent fuel operating deck by limiting the dose rates to approximately 210 mrem/hr. However, it is desirable to limit the dose rates to less than 100 mrem/hr which would require the level to be maintained at greater than elevation 455.5 ft. or approximately 19 ft. above the top of the fuel assemblies stored in the racks. This monitoring level ensures there is adequate margin in the water level to provide substantial radiation shielding for personnel to respond tBeyond-Design-Basis External Events and to initiate SFP makeup strategies.

In its letter dated August 28, 2013, the licensee provided a sketch depicting the plant elevations corresponding to Levels 1, 2, and 3, and the top of the fuel rack. Level 2 is identified in this sketch as elevation of 455.5 ft., which is 18.5 ft. above the top of the fuel racks. Level 3 was initially identified in the sketch at an elevation of 437.0 ft., which is the top of spent fuel storage rack seated in the SFP. A later revision of this sketch (ADAMS Accession No. ML17087A146) was provided with a new elevation of 437.6 ft. (437 ft. 7 in.) for Level 3, as further discussed in SE section 4.2.1 below.

The NRC staff found the licensee selection of the SFP measurement levels adequate based on the following:

- Level 1 is adequate for normal SFP cooling system operation; it is also sufficient for NPSH and represents the higher of the two points described in NEI 12-02 for this level.
- Level 2 meets first option described in NEI 12-02 for Level 2, which is more than 10 ft. above the top of the fuel rack seated in the SFP.
- Level 3 is the highest point of any fuel storage rack seated in the SFP. This level allows the licensee to initiate water make-up with no delay meeting the NEI 12-02 specifications of the highest point of the fuel racks seated in the SFP. Meeting the NEI 12-02 specifications of the highest point of the fuel racks conservatively meets the Order EA-12-051 requirement of a level where the fuel remains covered.

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 Order EA-12-051.

4.2 Evaluation of Design Features

Order EA-12-051 required that the SFPLI 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 SFPLI.

4.2.1 Design Features: Instruments

In its OIP, the licensee stated that measured range will be continuous from the normal pool level elevation 461 ft. 5 in. to the top of the spent fuel seated in the racks at elevation 437 ft. 5 in. In its letter dated August 30, 2013, the licensee provided a sketch depicting the elevations identified as Levels 1, 2, and 3, and the top of the fuel rack. The staff reviewed this sketch and noted Level 3 is identified at an elevation of 437.3 ft. (the top of fuel rack). The instrument range specified for the licensee's instrumentation will not cover Level 3. In an email dated January 12, 2017 (ADAMS Accession No. ML17032A316), the staff requested the licensee to explain how the instrument range covers Level 3.

By email dated March 28, 2017 (ADAMS Accession No. ML17087A146), the licensee stated that the information included in Figure 1 of the August 30, 2013, letter to the NRC (ADAMS Accession No. ML13242A272) was intended to be preliminary information, as noted in the information provided with the asterisk. The actual top of the fuel racks is elevation 437.3 ft, which is also the 0 percent range of the calibration for the SFPLI system. Guidance document NEI 12-02 states Level 3 is to be +/- 1ft. from the top of the racks, to account for the instrument inaccuracies during the emergency conditions the final Level 3 level must be adjusted to approximate elevation of 437.6 ft. In this email, the licensee also provided a revised sketch. In this sketch, the licensee revised Level 3 to 437.6 ft. (437 ft. 7 in.). The staff finds the licensee's response acceptable. With the revised Level 3 of 437.6 ft. (437 ft. 7 in.), the instrument range will cover Levels 1, 2, and 3 as discussed in Section 4.1 of this SE.

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 the intent of NEI 12-02 guidance, as endorsed by JLD-ISG-2012-03, and should adequately address the requirements of Order EA-12-051.

4.2.2 Design Features: Arrangement

In a letter dated January 22, 2016 (ADAMS Accession No. ML16028A196), the licensee provided the following statements:

> The primary and backup trains of level instrumentation are mounted in the southwest and northwest corners of the Spent Fuel Pool (SFP) respectively, providing separation by the distance of the width of the SFP. The primary channel, horn, and waveguide pipe are located and mounted in the southwest corner of the SFP (463 ft. elevation). The primary waveguide pipe is routed due west into the north stairwell of the Auxiliary Building (AB), where the remote transmitter is located. The power control panel, auxiliary battery panel, and display for the primary channel are located due south of the remote transmitter and are mounted on a column due south of the AB lift. ...
>
> ... The backup level channel horn and waveguide pipe are mounted in the northwest corner of the SFP (463 ft. elevation). The backup waveguide pipe is routed northwest through the west wall of the Fuel Handling Building (FHB). The backup waveguide pipe is routed down along the outside wall of the FHB and the remote transmitter is mounted on the 458 ft. 9 inch (in.) elevation. ...
>
> ... The backup power control unit, auxiliary battery panel, and display are mounted roughly 5 ft. from the ground elevation of approximately 436 ft, which is above the site's maximum flood elevation of 437 ft. 8 in. (VCSNS design calculation, DC00080-002, "Site Hazards Design Parameters for FLEX").

Guidance document NEI 12-02 recommends mounting the sensors on opposite site or corners of the pool area, if practical, and separated by a distance comparable to the shortest length of a side of the pool. During the walkdown, the NRC staff noted that the locations for the level sensors are physically separated by a distance comparable to the shortest length of a side of the pool. The NRC staff finds that there is sufficient channel separation within the SFP area between the primary and back-up level instruments, sensor electronics, and routing cables 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.

With regard to the arrangement of the SFP level instrument outside of the FHB, the NRC staff noted that the backup channel equipment is located on the yard outside the FHB. This arrangement of the equipment does not meet the guidance of NEI 12-02. Section 3.2 of NEI 12-02, Revision 1, states, in part, that the reasonable protection guidance outlined in NEI 12-06 to meet Order EA-12-049 should be used to provide protection for installed primary and portable channels from external hazards.

During the onsite audit, the NRC staff raised the concern that the backup channel equipment located outdoors would not be protected from external hazards. In response to the staff's concern, in a letter dated January 22, 2016 (ADAMS Accession No. ML16028A196), the licensee stated, in part, that for the backup channel, the backup power control unit, auxiliary battery panel, and display are mounted roughly 5 ft. from the ground elevation of approximately 436 ft, which is above the site's maximum flood elevation of 437 ft. 8 in. as stated in VCSNS design calculation DC00080-002. The licensee also stated that the display, battery panels, transmitter, conduit, and related instrument waveguide pipe for the backup instrument channel are all located outside on the west wall of the FHB and are not protected against the high winds hazard. The outdoor channel display location is considered an alternative approach from NEI 12-02, Revision 1. To compensate for the lack of protection for backup instrument channel equipment against the high winds hazard, the allowable outage time (AOT) for the primary instrument channel equipment is reduced from 90 days to 30 days to minimize the likelihood that a high winds event could damage backup instrument channel equipment while the primary instrument channel is out of service. The licensee stated that VCSNS has implemented additional controls for the SFPLI. The controls include reducing the AOT for either channel to 30 days, maintaining a set of replacements parts, and providing procedural guidance to maintain the SFP level within the normal narrow range indication level during an ELAP event.

The NRC staff finds the licensee's response to the staff's concern with respect to the hazards protection for the backup instrument channel reasonable based on the following:

- The backup channel equipment is located above the license design basis flood level and the access to the backup channel would be through the AB, which is a safety related structure and is considered to survive all FLEX hazards.

- The licensee will reduce the AOT for the primary SFPLI channel from 90 days to 30 days to minimize the likelihood of the backup channel being damaged by an external event while the primary channel is out of service.

- The licensee will maintain a set of replacement parts to replace the backup channel equipment in a timely manner.

Thus, the staff views the licensee's proposed alternative as being an acceptable method of compliance with the order. The staff finds that, if implement as described, the licensee's proposed arrangement for the SFPLI should adequately address the requirements of Order EA-12-051.

4.2.3 Design Features: Mounting

In its letter dated January 22, 2016 (ADAMS Accession No. ML16028A196), the licensee stated the following on page 3 of 19 (Enclosure 2):

> Applicable hydrodynamic (wave impact) forces are included with seismic inertial and static loads in the radar horn/pipe qualification and mounting qualification load combinations.

> The primary and backup channels consisting of the remote transmitter, horn, and waveguide piping are mounted seismically. The mounting designs for the remote transmitter support and horn support were qualified considering the total weight of the waveguide piping and its components and the seismic accelerations for the building structure. To meet the seismic design criteria contained in NEI 12-02, the loading for the mounting supports was generated considering Safe Shutdown Earthquake (SSE) seismic accelerations.

The licensee also stated, in the same letter, the following information on page 5 of 19:

> The potential SFP sloshing effects due to a postulated seismic event have been evaluated for the primary and backup channels in VCSNS design calculation DC00080-004, "Spent Fuel Pool Sloshing Evaluation for SFPLI Equipment." The maximum seismic induced wave height in the SFP as well as maximum hydrodynamic (convective mode) pressures which are potentially imparted upon FLEX SFPLI installed by Engineering Change Request (ECR) 51001 were calculated. The maximum calculated wave height of 2.56 ft. and associated hydrodynamic pressure of 1.1 psi is presented as input to design and calculation of the applicable FLEX SFPLI components installed atop the SFP walls in the FHB.
>
> The Required Response Spectra (RRS) used for seismic testing of the SFP primary and backup level instrumentation and the electronics units envelop the VCSNS design basis seismic spectra for the location where the equipment will be installed.
>
> The remote transmitter mounting support is qualified by a generic calculation using a simple C-channel steel section that is welded centrally on a steel base plate mounted on the outside west wall of the FHB (backup) and the east wall of the north AB stairwell (primary).

In the same letter (pages 3 and 4 of 19), the licensee provided the following statements:

> The generic sensor mounting support was designed for generic enveloping seismic accelerations of 10g (horizontal) and 6.67g (vertical), which envelope the site seismic response spectra. The calculation further assumed an enveloping sensor cantilevered length. VCSNS calculation FX003, "Piping Analysis" and VCSNS calculation FXH5042, "Pipe Support", compare the site specific loadings to the vendor supplied generic calculations and determine the site specific loading is bounded by the generic calculation. ...
>
> ... The horn mounting support is qualified similarly to the remote transmitter support. It is qualified by a generic calculation which has been verified to bound site specific geometry and seismic loadings. The generic design of the horn mounting support conservatively uses generic seismic accelerations of 10g (horizontal) and 6.67g (vertical). VCSNS calculation FX003 and VCSNS calculation FXH5043, "Pipe Support," compare the site specific loadings to the

> vendor supplied generic calculations and determine the site specific loading is bounded by the generic calculation. ...
>
> ... The mounting design for the power control panels and auxiliary battery panels are qualified considering the total weight of the panel and its associated components and the seismic accelerations for the building structure. To meet the seismic design criteria contained in NEI 12-02, the loading for the panels were generated considering beyond design basis seismic accelerations.

During the onsite audit, the staff reviewed the mounting specifications and seismic analyses for the SFPLI, including the methodology and design criteria used to estimate the total loading on the mounting devices. The staff also reviewed the design inputs and the methodology used to qualify the structural integrity of the affected structures for each of the SFPLI mounting attachments. Based on the review, the staff found the criteria established by the licensee adequately account for the appropriate structural loading conditions, including seismic and hydrodynamic loads.

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 Order EA-12-051.

4.2.4 <u>Design Features: Qualification</u>

4.2.4.1 <u>Augmented Quality Process</u>

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 OIP, the licensee stated that augmented quality requirements, similar to those applied to fire protection, would be applied to this project.

Based on the statement in its OIP, 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 Order EA-12-051.

4.2.4.2 <u>Instrument Channel Reliability</u>

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 will not experience failures during beyond-design-basis conditions of temperature, humidity, emissions, surge, and radiation, and (2) to verify those tests envelope the plant-specific requirements.

The NRC staff reviewed the AREVA SFPLI's qualification and testing during the vendor audit for temperature, humidity, radiation, shock and vibration, and seismic (ADAMS Accession No. ML14203A326). The staff further reviewed the anticipated VCSNS's environmental conditions during the onsite audit (ADAMS Accession No. ML15253A721). Below is the staff's assessment of the equipment reliability of VCSNS SFP level instrumentation.

4.2.4.2.1 Shock and Vibration

On page 10 of 19 (Enclosure 2) of its letter dated January 22, 2016 (ADAMS Accession No. ML16028A196), the licensee stated the following:

> The VEGAPULS 62 ER through air radar sensor is similar in form, fit, and function to the VEGAPULS 66 including PLICSOM indicator that was shock tested in accordance with MIL-S- 901D, and vibration tested in accordance with MIL STD 167-1. The test report is contained in AREVA Document 38-9193058-000, "Report of Shock and Vibration Test on Two (2) 3" Navy Flange Mount Level Indicators and One (1) 3" Triclamp, 1½" Navy Flange Mount Level Indicator for Ohmart/VEGA Corporation Cincinnati, Ohio." Differences in construction are mainly in the smaller size of the VEGAPULS 62 ER. The shape of the housing, its material construction (precision cast stainless steel), the mass and form factor for the electronics modules, the materials and method for mounting the electronics into the sensor housing are the same between the VEGAPULS 66 and the VEGAPULS 62 ER. The incoupling and antennas for VEGAPULS 62 ER are smaller and lighter than for VEGAPULS 66 and therefore less susceptible to shock and vibration. Therefore, the shock and vibration testing is considered to be applicable to the VEGAPULS 62 ER sensor and the PLICSCOM indicator.
>
> The MIL-S-901D test consisted of a total of nine (9) shock blows, three (3) through each of the three (3) principal axes of the sensor, delivered to the anvil plate of the shock machine. The heights of hammer drop for the shock blows in each axis were one (1) foot, three (3) ft. and five (5) ft.
>
> The MIL STD 167-1 vibration test procedure applies to equipment found on Navy ships with conventional shafted propeller propulsion. The test frequencies ranged from 4 Hz to 50 Hz with amplitudes ranging from 0.048 inch at the low frequencies to 0.006 inch at the higher frequencies. This procedure is not applicable to high-speed or surface effect ships that are subject to vibrations for

> high-speed wave slap, which produce vibration amplitudes and frequencies in excess of the levels on conventional Navy ships. The potential vibration environment around the SFP and surrounding building structure might contain higher frequencies than were achieved in the testing discussed above. However, in addition to the MIL Standard testing above, the VEGAPULS 62 ER sensor has been shock tested in accordance with EN 60068-2-27 (100g, 6 ms), and vibration tested in accordance with EN 60068-2-6, Method 204 (except 4g, 200Hz).
>
> The VEGADIS 61 and VEGADIS 62 displays feature housings that are similar in size, materials, and form factor to the VEGAPULS 62 ER sensor, contain a terminal base attached with two screws similar to the electronics module in the VEGAPULS 62 ER, and contain a LCD display module that installs into the housing similar to the PLICSCOM in the VEGAPULS 62 ER. Therefore, these devices are considered to have the same resistance to shock and vibration as the VEGAPULS 62 ER and PLICSCOM.

The NRC staff performed an audit at AREVA facility for shock and vibration testing of the SFPLI sensors, electronic enclosures and transmitters. The staff found them acceptable. The staff issued an audit report on September 15, 2014 (ADAMS Accession No. ML14203A326).

4.2.4.2.2 <u>Seismic</u>

On page 12 of 19 (Enclosure 2) of its letter dated January 22, 2016 (ADAMS Accession No. ML16028A196), the licensee stated the following:

> The sensor, indicator, power control panel, horn end of the waveguide, standard pool end and sensor end mounting brackets, and waveguide piping were successfully seismically tested in accordance with the requirements of IEEE [Institute of Electrical and Electronics Engineers] standard 344-2004. The system was monitored for operability before and after the resonance search and seismic tests. The required response spectra used for the five OBEs and the single SSE in the test were taken from EPRI TR- 107330, Figures 4-5. The test response spectra from EPRI TR-107330, Figures 4-5, bound the building required response spectrum at all the locations where equipment will be located. Section 2.1 of AREVA Document 51-9202556-004, "*Qualification Analysis of VEGAPULS 62 ER Through Air Radar*," contains a summary of seismic qualification.

The NRC staff performed an audit at AREVA facility for seismic testing of the SFPLI sensors, electronic enclosures and transmitters. The staff found them acceptable. The staff issued an audit report on September 15, 2014 (ADAMS Accession No. ML14203A326). Further seismic qualifications of the SFPLI mounting is addressed in Subsection 4.2.3, "Design Features: Mounting," of this SE.

4.2.4.2.3 Radiation, Temperature, and Humidity

On page 7 and 8 of 19 (Enclosure 2) of its letter dated January 22, 2016 (ADAMS Accession No. ML16028A196), the licensee stated, in part, that:

> The area above and surrounding the pool will be subject to radiation dose in the event that the water levels are lowered and even potentially higher levels if the fuel becomes uncovered. The only parts of the instrument channels in the pool radiation environment are the metallic waveguide, horn, and fused silica glass horn cover which are not susceptible to the expected levels of radiation, and silicone elastomer moisture seal for the horn cover, which has associated radiation test data from the manufacture (AREVA Document 51-9202556-004, "Qualification Analysis of VEGAPULS 62 ER Through Air Radar"). The silicon elastomer seal has been tested for up to 7x108 rad, although above 1.6x108 rad the elastic modulus began to increase substantially. Nevertheless, even considering the conservative scenario above, the silicon elastomer test data demonstrates that the silicon is acceptable for the expected radiation dose for this application. VCSNS design calculation, DC00030-057, "Operator Dose as a Function of SFP Water Level," contains dose rates for multiple receiver points located in the SFP Building, in the area immediately surrounding the SFP (i.e., Table 7 of Section 8). Receiver Point 3 is the bounding location in the area surrounding the pool, and the dose rate for 1 foot of water cover, is calculated to be 8.30x106 mr/hr. The Total Integrated Dose, calculated over a 7 day period, is 1.39x106 Rad, which is below the point at which the elastic modulus of the elastomer begins to increase and also below the tested limit of the elastomer.
>
> The electronics are located in areas that are shielded from the direct shine from the fuel, and bounce and scatter effects above the pool. As noted in AREVA Document 51-9202556-004, Table C-1 of USNRC Bulletin 79-01B, Environmental Qualification of Class 1E Equipment, contains a listing of radiation thresholds for various materials. The most susceptible material, and therefore having the lowest threshold, was NMOS electronics with a threshold of 1x103 rad. For current generation operating reactors, the NRC staff's definition of a mild radiation environment for electronic components, such as semiconductors, or any electronic component containing organic materials as a total integrated dose of less than 1x103 rad (NUREG 1793, Section 3.11.3.2.1). Based on the information provided in the references listed above, the electronics in the VEGAPULS 62 ER sensor, displays, and power control panel are considered to be qualified for 1x103 rad.
>
> VCSNS Unit 1 has developed dose calculations (i.e., VCSNS design calculation, DC00030-057) for the areas in which the electronics of the systems will be located (AB 463 ft. north stairwell, AB 463 ft. General Area south of the equipment hatch, and at the AB Column). The calculation results contain dose rate and total integrated dose (TID) for each area. The calculation results conclude that the dose in these areas is below the radiation threshold for the electronics outlined in AREVA Document 51-9202556-004. The maximum TID for the bounding location was calculated to be 8.75 x 101 rad. The TID was

> calculated over a time period of 7 days. The calculation modeled SFP boil-off and calculated doses considering level decreases from normal operating level to 1 foot of water cover above the fuel. The calculation considered the 1 foot of water remained constant until the end of the evaluated time period.

Per AREVA Document 01-9225772-002, "Through Air Radar Spent Fuel Pool Level Instrument (SFPLI) Instruction Manual for V.C. Summer," the continuous duty temperature ranges for the system electronics are as follows:

- VEGAPULS 62 ER Sensor is -40 to 176° F
- VEGADIS 61 Indications and Adjustment Unit -4 to 158° F
- Power Control Panel -13 to 160° F
- Auxiliary Battery Panel -13 to 160° F

Per AREVA Document 51-9202556-004, "Qualification Analysis of VEGAPULS 62 ER through Air Radar," the remote transmitter has been tested in accordance with IEC 60068-2-30 which varies the temperature from room temperature to elevated temperature at high humidity conditions, to verify that the test item withstands condensation that can occur due to the changing conditions. The sensor has been tested to EN 60529:2000 to achieve the rating IP66/IP68, which signifies totally dust tight housing, protection against water jets and waves, and protection against prolonged effects of immersion under 0.2 bar pressure. The VEGADIS 61 indicating and adjustment module has a housing which is similar to the VEGAPULS 62 ER remote transmitter and are therefore considered equally covered by the two tests.

The power control panel and auxiliary battery panel is rated for a maximum temperature of at least 158 °F. Allowing for 9 °F heat rise in the panel, the overall panel maximum ambient temperature for operation is 149 °F. The power control panel and auxiliary battery panels enclosures are rated NEMA 4X and provides protection to the internal components from the effects of high humidity environments.

In its letter dated January 22, 2016 (page 9 of 19, Enclosure 2), the licensee stated the following:

> Per VCSNS Technical Report TR00080-003, "FLEX Equipment Ventilation and Habitability Assessment," the maximum temperature expected in the north stairwell of the AB is 150 °F. The only electronic equipment mounted in this area is the primary remote transmitter (VEGAPULS 62 ER Sensor). On the 463 ft. elevation of the AB, south of the AB equipment lift, the maximum temperature range is 105-115 °F. The electronic equipment mounted in this location is the VEGADIS 61 indications and adjustment unit, the power control panel for the primary channel, and the auxiliary battery panel for the primary channel. Per VCSNS design calculation DC00080-002, "Site Hazard Design Parameters for FLEX," the maximum outdoor temperature for components located outside is 107 °F.

Further down on the same letter page in response to RAI #7, the licensee stated the following:

> The maximum humidity postulated for the SFP area is 100 percent relative humidity, saturated steam. The radar sensor electronics will be located outside of the spent fuel pool room in an area away from the steam atmosphere. The waveguide pipe can tolerate condensation formation on the inner wall surface, provided condensate pooling does not occur within the waveguide pipe. Condensate pooling is prevented by installing a weep hole(s) at the low point(s) in the waveguide pipe. The system electronics for the system are contained in the power control panel, which is sealed and gasket. The power control panel is a NEMA 4X enclosure; it is designed for indoor or outdoor use to provide a degree of protection with respect to harmful effects on the equipment due to the ingress of moisture and condensation (e.g. rain, sleet, snow, splashing water, and hose directed water). The NEMA 4X power control panel enclosure provides protection to the internal components from the effects of high humidity environments (see Section 2.3 of AREVA Document 51-9202556-004, "Qualification Analysis of VEGAPULS 62 ER Through Air Radar," for further information)..

During the onsite audit at VCSNS, the NRC staff reviewed Calculations DC00030-057, "Spent Fuel Pool Instrumentation Dose Calculation," Revision 1, and TR00080-003, "FLEX Equipment Ventilation and Habitability Assessment," Revision 1. The staff verified that the environment qualification of SFPLI components are bounded by those in AREVA test reports.

4.2.4.2.4 Electromagnetic Compatibility

During the onsite audit, the NRC staff inquired about an assessment of potential susceptibilities of Electromagnetic Interferences (EMI) and Radio-Frequency Interference (RFI) in the areas where the SFP instruments are located and how to mitigate those susceptibilities. The licensee responded in the email dated January 31, 2017 (ADAMS Accession No. ML17032A316) that:

> The primary system in located in the AB-463 North Stairwell and the column near the AB Lift. The secondary system is located on the West outside wall of the Fuel Handling Building. ...
>
> Susceptibility testing was performed by the manufacturer to EN 61000-4 to achieve their CE rating. The test descriptions are summarized below:
>
> * EN 61000-4-2, Resistance against electrostatic discharge
> * EN 61000-4-4, Resistance against conducted fast transients (Burst)
> * EN 61000-4-5, Resistance against conducted slow transients (Surge)
> * EN 61000-4-6, Resistance against conducted high frequency interference
> * EN 61000-4-20, Resistance against high-frequency electromagnetic fields
>
> Section 5, "Equipment Susceptibility and Emissions Testing Guidance" of TR-102323 states that testing guidance provided in the guide applies to safety and non-safety related components whose operation can affect safety-related systems or component functions, or those deemed important to power production.

> Electronic Equipment installed by ECR51001 will be located on the 463 ft. Elevation of AB by the AB Lift and on the 436 ft. Elevation of the outside west wall of the Fuel Handling Building. This equipment is not located near any equipment that may affect the Spent Fuel Instrumentation for EMI/RFI concerns.
>
> Table 5-1 of TR-102323 requires that conducted and radiated emissions testing or evaluation be performed at low and high frequencies. Additionally, Table 5-2 provides the accepted testing standards to meet these requirements. Review of the testing provided by the vendor indicates the sensor, indicators, and power control panels were all tested to the Military Specifications listed in TR-102323; therefore, the EMI/RFI testing requirements have been met.
>
> A Condition Report (CR), CR-15-03207, was written after the NRC FLEX Auditor requested a site specific test to determine potential impacts from handheld radios, cell phones or other radio frequency interferences on the SFP instrumentation.
>
> CR-15-03027, Action 001, states the following:
>
> Design Engineering to work with Plant Support Engineering to develop a test plan to determine potential impacts of handheld radios, cell phones, and other radio frequency interferences on FLEX SFP instrumentation and document the results.

The staff finds the response acceptable because the licensee performed an assessment of potential susceptibilities of EMI and RFI in the areas where the SFP instruments are located. In addition, the licensee will perform a site specific test to determine the potential impacts of EMI/RFI where the SFP instrumentation equipment is located.

Based on the evaluation above, the NRC staff finds the licensee's proposed instrument qualification process appears to be with NEI 12-02 guidance, as endorsed by JLD-ISG-2012-03, and should adequately addresses the requirements of Order EA-12-051.

4.2.5 <u>Design Features: Independence</u>

In its OIP (ADAMS Accession No. ML13063A099), the licensee stated, in part, that:

> The primary instrument channel will be redundant to and independent of the backup instrument channel. The power sources for the primary and backup channels will be independent through the utilization of standalone battery power. The channels will be separated by a distance commensurate with the shortest length of a side of the spent fuel pool as defined by NEI 12-02 Section 3.2.

The staff notes that with the licensee's proposed power arrangement, the electrical functional performance of each level measured channel would be considered independent of the other channel, and the loss of one power supply would not affect the operation of other independent channel under BDB event conditions. The instrument channel physical separation is discussed in Section 4.2.2 of this evaluation.

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 Order EA-12-051.

4.2.6 Design Features: Power Supplies

As a common practice, the power for the SFPLI's normal operation is continuously provided by the site's ac/dc power distribution systems. The normal power for both channels of VCSNS SFPLI, however, is provided by the built-in batteries provided by the vendor, and the power for instrument is energized only as demanded. During the onsite audit, the staff raised the concerns of this power source configuration with regard to potential impact of the battery shelf life, battery discharge rates during the standby conditions, and battery power drainage to the equipment availability.

In response to the staff's concern, in its letter dated January 22, 2016 (ADAMS Accession No. ML16028A196), the licensee stated that both the primary and backup channels are powered from dual selectable power supplies utilizing dedicated lithium ion batteries with backup batteries available for easy replacement. The minimum expected battery life for each battery provides for 7 days of continuous service. Spare batteries will be readily available to maintain power to the system for the entire period of the FLEX response.

Related to preventive maintenance (PM), in the same letter, the licensee stated that activities for the SFPLI system and spare batteries have been created in accordance with VCSNS Procedure, SAP-0143, "Preventive Maintenance Program." The PM tasks draw on input from AREVA, VCSNS maintenance best practices, EPRI templates, and industry operating experience (OE). The following PM activities will verify the SFP level indication function, verify battery capability, and replace Lithium C-cell batteries every six months. These PM activities ensure continued proper functioning of the SFP level instrument:

Table 1: SFPI Preventive Maintenances

Equipment #	Equipment name	PM summary	PM Frequency
ILT09780	FLEX SFPLI Primary Remote Transmitter	Verify SFP Level Indication Function, Verify Battery Capability, and Replace Lithium C- Cell Batteries	6 Months
ILT09781	FLEX SFPLI Backup Remote Transmitter	Verify SFP Level Indication Function, Verify Battery Capability, and Replace Lithium C- Cell Batteries	6 Months
XPN6075	FLEX SFPLI Primary Power Control Panel (PCP)	Verify SFP Level Indication Function, Verify Battery Capability, and Replace Lithium C- Cell Batteries	6 Months

XPN6077	FLEX SFPLI BACKUP PCP	Verify SFP Level Indication Function, Verify Battery Capability, and Replace Lithium C- Cell Batteries	6 Months

Regarding the impact of the battery discharge rates on the battery capacity, in its letter dated January 22, 2016 (ADAMS Accession No. ML16028A196), the licensee stated that the power control panel and auxiliary battery panel contain eight Tadiran Model TL-5920 C-cell lithium batteries each that provide power. The battery storage life is reported by the manufacturer to be up to 20 years. However, the replacement interval recommended by AREVA is coincident with mandated surveillance of the level instrument. The battery life for worst case condition of 20 mA discharge rate is derived from the manufacturer technical data sheet in AREVA Document 51-9202556-004, "Qualification Analysis of VEGAPULS 62 ER Through Air Radar." Vendor analyses support the battery capacity (at 20mA continuous discharge) can sustain approximately 130 hours at negative 22 °F and approximately 230 hours at 32 °F. The lifetime increases significantly at lower discharge rates or at higher temperatures. Lifetimes at the temperatures from AREVA Document 51-9202556-004 for a 20 mA discharge rate are summarized in the table below:

Table 2: Backup Battery Lifetimes vs. Temperature

Temperature	Ampere-Hours to 2.0 volts	Lifetime to 2.0 volts @ 20 mA (hours)	Lifetime at full voltage @ 20mA (hours)
-30 °C (-22 °F)	2.7	135	131
0 °C (32 °F)	4.8	240	233
25 °C (77 °F)	6.8	340	330
55 °C (131 °F)	7.2	360	349
75 °C (167 °F)	4.3	215	209

During the onsite audit the NRC staff raised the concern that the licensee proposal of weekly channel check may drain the battery in addition to the self-discharge. The fully charged battery is only last 131 hours. Without the normal ac power source to fully charge the battery, the stand alone battery might not be able to perform its intended function during the ELAP event because of battery self-discharge and the power drainage due to weekly channel checks.

In response to the staff's concern, in letter dated January 22, 2016 (ADAMS Accession No. ML16028A196), the licensee stated that the SFPLI system is planned to be energized weekly for a channel check, the check is expected to take less than 1 minute, so 2 minutes will be used as a conservative estimate. The worst case current draw from AREVA Document 51-9202556-004 is 20mA. Since the extreme temperature of negative 22 °F is not a reasonable assumption for normal operations when the channel check will be performed, a more realistic temperature of 77 °F is used for estimation purposes. Therefore, using the above inputs, as well as vendor supplied battery information, the battery usage is estimated below:

Weekly: 20mA x (2/60) hrs. = 0.667mA-hrs

Yearly: 52 x 0.667 mA-hrs. = 34.67 mA-hrs.

<u>Or</u>

Reduction of rated life: 34.67/ 6600 = 0.53 percent
(Approximately 1.7 hours at nominal case environmental conditions)

The licensee further stated that the batteries are expected to be changed out every 6 months during calibration, but even if calibration is extended to 1 year, the weekly channel checks will have minimal impact on battery life of the primary batteries. Both the primary and the backup batteries are maintained in standby mode, and switched off/open. The circuit is open and there is no battery discharge while the instrument is switched off. The backup batteries will retain full qualified life as they will be maintained in the standby mode for the entire batteries will retain replacement cycle.

The NRC staff noted that loss of battery life due to weekly channel check is approximately 1.74 hrs. (2 min/week x 52 weeks x 20 mA = 0.0173 Ah/0.02 A = 1.74 hr.). This calculation and AREVA's calculation showed that the remaining life of the primary and back up channel is well above the 72 hours operating life required in NRC Order EA-12-051 (131 hrs. – 1.74 hrs. = 129.6 hrs.). Based on this information, the staff finds that the primary and backup batteries will have enough capability to power the SFPLI channels for at least 72 hours until additional off-site power can be obtained. In addition, the SFPLI power control panel has a 120 VAC outlet for portable generator connection. The staff finds that the licensee adequately addressed the staff's concerns.

Based on the evaluation above, the NRC staff finds that the licensee's proposed power supply design appears to be consistent with the intent of NEI 12-02 guidance, as endorsed by JLD-ISG-2012-03, and should adequately address the requirements of Order EA-12-051.

4.2.7 Design Features: Accuracy

On page 15 of 19 in response to RAI #14 (Enclosure 2) of its letter dated January 22, 2016 (ADAMS Accession No. ML16028A196), the licensee stated the following:

> The system is expected to retain the demonstrated accuracy following a loss of power and subsequent restoration. The system is normally de-energized and is only energized during an ELAP event, or other loss of normal spent fuel pool indication event. The loss of site power and sub-sequent restoration of power will have no impact on the SFPLI system, as the system is electrically isolated from normal plant power sources.
>
> Post modification and the vendor site acceptance test where conducted at the same time. With the horn in the normal operating position, the actual water level was calculated by measuring' the distance from the centerline of the waveguide pipe with a tape measure and then subtracting that distance from the known elevation of the centerline of the waveguide pipe. The minimum and maximum parameters were adjusted. A baseline for the sensor was then created. After this was done a small metal target was placed in the radar beam path to verify

the system responded in the correct direction. The horn was then rotated 180 degrees to the calibration position and a metal target was placed above the horn in the radar beam path at a different distance than the distance to the water level when the horn was in the normal operating position. The indicated level was then compared to the expected level as measured from the centerline of the waveguide pipe including the offset in the calibration position as defined in the factory acceptance test report from the vendor, AREVA. The horn was then returned to the normal operation position, and the indicated level was verified to be within tolerance. The results for the primary SFPLI (Southwest) was an error of negative 0.04 ft. with a measurement reliability of 36 dB. The results for the backup SFPLI (Northwest) was an error of 0.00 feet with a measured reliability of 60 dB systems. See AREVA Document 51-9241803-000, "Through Air Radar Spent Fuel Pool Level Instrument (SFPLI) Site Acceptance Test Report for VCS Unit 1." Both errors above fall within the vendors supplied accuracy of plus/minus 0.083 ft. and are acceptable.

Also as part of this test, a power verification test was performed. This test verified the system functionally ran from each independent power source. While each battery source was tested, the other was removed from the circuit.

The staff noted that licensee's analysis verified that channels will retain the accuracy performance values while each battery source was test and other was removed from the circuit. The accuracy in the SAT report for VCSNS was within the vendor specified accuracy and was within one foot as recommended in NEI 12-02.

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 Order EA-12-051.

4.2.8 Design Features: Testing

On page 16 of 19, in response to RAI #15 (Enclosure 2), of its letter dated January 22, 2016 (ADAMS Accession No. ML16028A196), the licensee stated that:

The primary SFP level channel has multi-point testing capability, in that the radar horn antenna can be rotated away from the SFP water surface and aimed at a movable metal target that is positioned at known distances from the horn. This allows checking for correct readings at various points across the instrument measurement range and validates the functionality of the installed system.

The backup SFP level channel design readily supports periodic calibration across its monitoring range. The instrument is equipped with a calibration test tee and can be isolated from the process for routine calibrations.

Site maintenance procedure ICP-390.012, "Spent Fuel Pool Level ILT09780 and ILT09781 Calibration," details in-situ calibration process that will result in channel calibration being maintained at its design accuracy.

During the onsite audit, the staff reviewed site maintenance procedure ICP-390.012 and found it acceptable. The staff found the licensee adequately described the calibration process that will result in channel calibration being maintained at its design accuracy.

Based on the evaluation above, the NRC staff finds that the licensee's proposed SFP instrumentation design allows for testing appears to be consistent with NEI 12-02 guidance, as endorsed by JLD-ISG-2012-03, and should adequately address the requirements of Order EA-12-051.

4.2.9 Design Features: Display

In its letter dated January 22, 2016 (ADAMS Accession No. ML16028A196), the licensee stated that the display, battery panels, transmitter, conduit, and related instrument waveguide pipe for the backup instrument channel are all located outside on the west wall of the FHB and are not protected against the high winds hazard. Regarding the environmental and radiological conditions of the locations of the level displays with respect to the habitability of these locations, in page 17 of 19 (Enclosure 2) of its letter dated January 22, 2016, the licensee stated that:

> Per ECR-51001, "FLEX Spent Fuel Pool Level Indication," local indication of SFP level from the primary channel of the FLEX SFPLI system is located on the 463 ft. elevation of the AB, on a column near the AB equipment lift. This area is outside of the FHB and not subject to adverse radiological, heat, or humidity conditions which would be expected inside the FHB. Per TR00080-006, "FLEX Timeline Constraints Basis," temperature ranges in this area are expected to be no more than 105-115 °F, provided that actions are taken within 14 hours to promote natural circulation ventilation. These actions are incorporated into FSP-20.1, "Vital Area Emergency Ventilation," and have been validated per Attachment 10 of TR00080-007, "FLEX Validation Document." Per the EQ Zone Database (for Zone AB-71), the maximum expected relative humidity is 90 percent. These conditions allow continued equipment operation and intermittent personnel access without further action.
>
> Per ECR-51001, local indication of SFP level from the backup channel of the FLEX SFPLI system is located in the yard, at the 436 ft. elevation, on the outside west wall of the FHB. This area is outside of the FHB and not subject to adverse radiological, heat, or humidity conditions which would be expected inside the FHB. Per Section 4.6 of TR00080-006, maximum ambient temperature during an ELAP event is 107 °F, which will allow continued equipment operation and intermittent personnel access without further action.
>
> Design calculation DC00030-057, "Operator Dose as a Function of SFP Water Level," Revision 1, calculates the dose rates at the location of the SFPLI sensors and displays. Table A4 of DC00030-357 contains a summary of dose rates at the desired locations. Location 2 is the display location for the primary channel (in the AB 463 General Area) and Location 3 is the location for the secondary channel (on the exterior wall of the FHB). The maximum dose rate is calculated considering 1 foot of SFP water above the top of the spent fuel, or elevation

> 436.5 ft. The maximum dose rate for Location 2 is 1.55x103 mr/hr and the maximum dose rate for Location 3 is 1.20x103 mr/hr.

Regarding the accessibility of the display locations, in the same letter, the licensee stated that:

> Use of the FLEX SFPLI system is directed from FSP-11, "Alternate SFP makeup and Cooling," which is entered from EOP-6.0, "Loss of all ESF AC Power," when SFP Level decreases less than 460.5 ft. Normal level in the SF Pool is 461.5 ft, with a low level alarm from design basis instrumentation at 461 ft. (Refer to ARP-001-XCP-608, "Annunciator Response Procedure," Window 1-2 SFP LVL HI/LO). While use of the FLEX SFPLI system is not specifically considered a time sensitive action (TSA), it is placed in service in the course of accomplishing SFP makeup, which is considered a TSA and must be performed within 87 hours per Section 4.5 of TR00080-006. Performance times are documented in TR00080-007, Attachment 22 (i.e., Perform SFP Makeup).
>
> Access to either channel of SFPLI would be through the AB, which is a safety related structure and is considered to survive all FLEX hazards. Normal access may be impeded somewhat, but it is expected that no significant obstacles would exist to access either channel of indication. Travel times to the location are expected to be less than 15 minutes for the control room or AB operators. An operator will not be continuously stationed at either location. Those operators performing SFP makeup strategies will periodically monitor level on these indications to gauge the success of their makeup/pumping actions. As SFP makeup operations are performed well into Phase 2, it is expected that additional personnel are available, if necessary. EPP-020, "Emergency Personnel Exposure Control," Revision 12, is used to control radiation exposure to plant personnel during emergencies. EPP-20, Attachment III, allows for up to 25 REM of dose to workers performing emergency activities to prevent large offsite dose releases that would be expected for the dose rates considered at the locations.

The NRC staff noted that the licensee adequately addressed the habitability and accessibility of the SFP level display. However, the backup channel display location does not meet the NEI 12-02 guidance with respect to the external hazard protection. The NRC staff finds that the backup instrument channel display location is an alternative method of conforming to NEI 12-02 as the external hazard protection is not provided in this location. The staff's evaluation of this alternative method, with respect to the external hazards protection for the backup instrument channel, is discussed in Subsection 4.2.2, "Design Features: Arrangement," of this SE. Thus, the staff views the licensee's proposed alternative as being an acceptable method of compliance with the order. In conclusion, the staff finds that, if additional controls described in Subsection 4.2.2 implemented appropriately, the licensee's proposed location and design of the SFP level instrumentation display should adequately address the requirements of Order EA-12-02.

4.3 Evaluation of Programmatic Controls

Order EA-12-051 specified that the SFP 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 SFP instrumentation.

4.3.1 Programmatic Controls: Training

In its OIP(ADAMS Accession No. ML13063A099), the licensee stated 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. Training will consist of the use of the level instrumentation system as well as the deployment of the portable components of the backup channel. Training will be completed prior to placing the instrumentation in service.

Guidance document NEI 12-02 specifies that the SAT process can be used to identify the population to be trained, and also to determine both the initial and continuing elements of the required training.

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 Order EA-12-051.

4.3.2 Programmatic Controls: Procedures

In its letter dated January 22, 2016 (ADAMS Accession No. ML16028A196), the licensee provided a list of procedures addressing operation, calibration, testing, maintenance and inspection for use of the SFP instrumentation. These procedures include:

> ICP-390.012, "Spent Fuel Pool Level ILT09780 and ILT09781 Calibration"
> This is a maintenance procedure for periodic calibration and testing of SFPLI.
>
> FSP-11, "Alternate SFP Makeup and Cooling"
> This procedure directs use of the system prior to makeup operations to monitor SFP level. It enables operators to determine if makeup operations are successfully being implemented if/when normal indication is unreliable.

The following AOPs have been revised to include use of this system:

> AOP-123.1, "Decreasing Level in the Spent Fuel Pool or Refueling Cavity During Refueling"
> AOP-123.4, "Loss of Spent Fuel Cooling"
> AOP-123.5, "Decreasing Level in the Spent Fuel Pool with the Transfer Tube Valve Closed"

During the onsite audit, the NRC staff reviewed a sample of procedures and noted that they were developed using the guidelines and vendor instructions to address the testing, calibration, maintenance, and operation and abnormal response, in accordance with the provisions of NEI 12-02.

Based on the evaluation 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 Order EA-12-051.

4.3.3 Programmatic Controls: Testing and Calibration

On page 19 of 19, in response to RAI #18 (Enclosure 2) of its letter dated January 22, 2016 (ADAMS Accession No. ML16028A196), the licensee stated that:

> New PM activities for the SFPLI system and spare batteries have been created in accordance with VCSNS Procedure SAP-0143, "Preventative Maintenance Program." The PM tasks draw on input from AREVA, VCSNS maintenance best practices, EPRI templates, and industry OE. The PM activities will verify SFPlevel indication function, verify battery capability, and replace Lithium C-cell batteries every six months. The PMs ensure continued proper functioning of the VEGAPULS 62 ER through Air Radar spent fuel pool level instrument.
>
> CR-15-03206 has been initiated to document the need for a channel check. Operations has agreed to perform a weekly channel check on trend rounds. Operations has revised OAP-106.1, "Operator Rounds," to include this channel check.
>
> Chapter 9 of the Beyond Design Basis (BDB) Program Document describes the elements managing availability of BDB equipment, including the reliable wide-range SFPLI. The program document will state that a failure to meet the N capability (i.e., the minimum required equipment to implement a strategy) due to unavailable equipment requires initiation of actions within 24 hours of discovery to restore the N capability and the establishment of a compensatory measure(s) within 72 hours.
>
> VCS-ERP-0012 contains guidance for necessary actions if one or more of the SFP level indicators are not available.
>
> Unavailability of the SFP level indicators is managed with VCS-ERP-0012. This procedure captures the requirement to initiate actions if one or both of the instrument channels cannot be restored to functional status within the allotted timeframe. The AOT for LI09781and LI09780 is 30 days. The AOTs are reduced because LI09781 is located outside and the channel is not protected from the high winds hazard. VCS-ERP-0012 provides guidance for the development of compensatory measures if the allowable outage times are exceeded.
>
> Necessary compensatory measures include, but are not limited to the following:
>
> - Increase Emergency Response Unit available staffing if a tornado watch is issued
> - Initiate action to verify location of spare battery for the operable level indicator

- Initiate action to provide refresher training to Emergency Response Unit staff to review actions necessary for the dewatering strategy
- Initiate action to defer maintenance on the operable level indicator

The NRC staff finds that the licensee has adequately described maintenance, testing, channel checks, and functional tests. These maintenances and tests are consistent with AREVA recommendations. The staff also finds that compensatory measures and the reduced AOT will minimize the SFPLI channel from out of service due to the backup channel located outside FHB.

Based on the evaluation 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 Order EA-12-051.

4.4 Conclusions for Order EA-12-051

In its letter dated January 22, 2016 (ADAMS Accession No. ML16028A196), 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 taken an alternative approach compared to NEI 12-02 but has met the requirements of the order. In addition, the NRC staff concludes that if the SFP level instrumentation is installed at VCNSN 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 July 13, 2015 (ADAMS Accession No. ML15253A721). The licensee reached its final compliance date on September 19, 2016 (ADAMS Accession No. ML16307A390), and has declared that the reactor is 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.

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Date: August 1, 2017

VIRGIL C. SUMMER NUCLEAR STATION, UNIT 1 - SAFETY EVALUATION REGARDING IMPLEMENTATION OF MITIGATING STRATEGIES AND RELIABLE SPENT FUEL POOL INSTRUMENTATION RELATED TO ORDERS EA-12-049 AND EA-12-051, DATED August 1, 2017

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