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

September 24, 2018

Mr. Joseph W. Shea
Vice President, Nuclear Regulatory
Affairs and Support Services
Tennessee Valley Authority
1101 Market Street, LP 4A
Chattanooga, TN 37402

SUBJECT: BROWNS FERRY NUCLEAR PLANT, UNITS 1, 2, AND 3 – 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. MF0902, MF0903, MF0904; MF0881, MF0882, AND MF0883; EPID NOS. L-2013-JLD-0003; AND L-2013-JLD-0004)

Dear Mr. Shea:

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. ML13064A465), the Tennessee Valley Authority (TVA, the licensee), submitted its OIP for Browns Ferry Nuclear Plant, Units 1, 2, and 3 (BFN, Browns Ferry) in response to Order EA-12-049. At six month intervals following the submittal of the OIP, the licensee submitted reports on its progress in complying with Order EA-12-049. These reports were required by the order, and are listed in the attached safety evaluation. By letter dated August 28, 2013 (ADAMS Accession No. ML13234A503), the NRC notified all licensees and construction permit holders that the staff is conducting audits of their responses to Order EA-12-049 in accordance with NRC Office of Nuclear Reactor Regulation (NRR) Office Instruction LIC-111, "Regulatory Audits" (ADAMS Accession No. ML082900195). By letters dated April 6, 2015 (ADAMS Accession No. ML15069A358), and December 12, 2013 (ADAMS Accession No. ML13225A541), the NRC issued an audit report and Interim Staff Evaluation (ISE), respectively, on the licensee's progress. By letter dated May 31, 2018 (ADAMS Accession No. ML18166A086), TVA submitted a compliance letter and Final Integrated Plan (FIP) in response to Order EA-12-049. The compliance letter stated that the licensee had achieved full compliance with Order EA-12-049.

By letter dated February 28, 2013 (ADAMS Accession No. ML13063A437), the licensee submitted its OIP for Browns Ferry 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 November 14, 2013 (ADAMS Accession No. ML13274A657), and April 6, 2015 (ADAMS Accession No. ML15069A358), 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 February 26, 2016 (ADAMS Accession No. ML16060A175), TVA submitted a compliance letter for Browns Ferry in response to Order EA-12-051. The compliance letter stated that Browns Ferry had achieved full compliance with Order EA-12-051.

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

If you have any questions, please contact Milton Valentin, Browns Ferry Project Manager at the Beyond-Design-Basis Management Branch, at 301-415-2864 or at Milton.Valentin@nrc.gov.

Sincerely,

Brett Titus

Brett Titus, Acting Chief
Beyond-Design-Basis Management Branch
Division of Licensing Projects
Office of Nuclear Reactor Regulation

Docket Nos. 50-259, 50-260, and 50-296

Enclosure:
Safety Evaluation

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TENNESSEE VALLEY AUTHORITY

BROWNS FERRY NUCLEAR PLANT, UNITS 1, 2, AND 3

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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.

Enclosure

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 (ADAMS Accession No. ML12039A103), 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," 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.

The Nuclear Energy Institute (NEI) submitted document NEI 12-06, Revision 4, "Diverse and Flexible Coping Strategies (FLEX) Implementation Guide," (ADAMS Accession No. ML16354B421) 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. In a letter to NEI dated February 8, 2017 (ADAMS Accession No. ML17034A286), the NRC staff stated that Japan Lessons-Learned Division (JLD) Interim staff Guidance (ISG) JLD-ISG-2012-01, Revision 2 (ADAMS Package Accession No. ML17005A182) had been issued and had been made publicly available. This ISG revision endorsed NEI 12-06, Revision 4, with exceptions, clarifications and additions, as published in the *Federal Register* (83 FR 18089).

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.
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> 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 (ADAMS Accession No. ML12240A307), following several submittals and discussions in public meetings with NRC staff, the NEI submitted document NEI 12-02, Revision 1, "Industry Guidance for Compliance With NRC Order EA-12-051, To Modify Licenses With Regard to Reliable Spent Fuel Pool Instrumentation," to the NRC to provide specifications for an industry-developed methodology for compliance with Order EA-12-051. On August 29, 2012 (ADAMS Accession No. ML12221A339), the NRC staff issued its final version of JLD-ISG-2012-03, "Compliance with Order EA-12-051, Reliable Spent Fuel Pool Instrumentation", 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. ML13064A465), Tennessee Valley Authority (TVA, the licensee), submitted its OIP for Browns Ferry Nuclear Plant, Units 1 and 2 (BFN, Browns Ferry) in response to Order EA-12-049. By letters dated August 28, 2013 (ADAMS Accession No. ML13247A284), February 28, 2014 (ADAMS Accession No. ML14064A240), August 28, 2014 (ADAMS Accession No. ML14248A496), February 27, 2015 (ADAMS Accession No. ML15064A162), August 28, 2015 (ADAMS Accession No. ML15240A228), February 26, 2016 (ADAMS Accession No. ML16063A470), August 26, 2016 (ADAMS Accession No. ML16242A030), February 28, 2017 (ADAMS Accession No. ML17060A187), and August 31, 2017 (ADAMS Accession No. ML17243A299), 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 December 19, 2013 (ADAMS Accession No. ML13225A541), and April 6, 2015 (ADAMS Accession No. ML15069A358), the NRC issued an Interim Staff Evaluation (ISE) and an audit report on the licensee's progress. By letter dated December 23, 2014 (ADAMS Accession No. ML14281A198), the licensee requested a relaxation from the schedule requirements for Order EA-12-049 due to installation of the hardened containment ventilation system required by Order EA-13-109 (ADAMS Accession No. ML13143A321). By letter dated May 31, 2018 (ADAMS Accession No. ML18166A086), the licensee reported that full compliance with the requirements of Order EA-12-049 was achieved, and submitted a Final Integrated Plan (FIP).

3.1 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 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.

The Browns Ferry, Units 1, 2 and 3 are General Electric (GE) boiling-water reactors (BWR), Model 4, each with a Mark I containment. The licensee's three-phase approach to mitigate a postulated ELAP event, as described in the FIP, is summarized below.

At the initiation of the ELAP event, the reactors are assumed to trip from full power. The main steam isolation valves (MSIVs) automatically close, and the main steam relief valves (MSRVs) automatically cycle to control reactor pressure. For Phase 1 in each of the reactors, makeup to the reactor pressure vessel (RPV) is provided primarily by the reactor core isolation cooling (RCIC) system and the high pressure coolant injection (HPCI) system with suction from the condensate storage tank (CST). Because the CST is not robust for all postulated external events, the RCIC pump could take suction from the suppression pool to restore the RPV level. If the CST becomes unavailable, plant operators will manually transfer RCIC suction from the CST to the suppression pool and trip and manually lock out HPCI. All equipment needed to operate RCIC and HPCI is powered by Class 1E unit batteries and is protected from all external hazards. The reactor cooldown is initiated within 20 minutes of the event initiation at a rate near to the maximum allowable (100 degrees Fahrenheit (°F)/hour, per BFN technical specification). The cooldown is terminated when pressure is between 150-300 pounds per square inch gauge (psig) to maintain sufficient steam pressure for continued RCIC operation. Power (by the Class 1E batteries) and motive force (by the drywell control air system) for the MSRVs are maintained during the event. Cycling of the MSRVs and RCIC exhaust will increase temperature and pressure in the torus and drywell. To maintain pressure suppression capability, the licensee will vent the RCIC discharge through the containment vent path. For Phase 2, the strategy for reactor cooling uses portable, diesel-driven, high-capacity FLEX pump systems to draw water from the Wheeler Reservoir, which provides an unlimited supply of water fed by the Tennessee River. The licensee identified multiple connection points to transfer the RPV makeup from the RCIC system to the FLEX pump systems. The licensee has identified the containment integrated leak rate test (CILRT) FLEX pump system as the preferred Phase 2 core cooling strategy. The residual heat removal service water (RHRSW) FLEX pump system was identified as an additional core cooling strategy. Staging and preparation of the FLEX pump systems are expected to be completed in 8 hours from the event initiation or less. The Phase 3 strategy (if needed) for core cooling and decay heat removal will use additional equipment from the National Strategic Alliance for FLEX Emergency Response (SAFER) Response Center (NSRC) to provide backup to the FLEX pump systems.

To maintain containment integrity and to allow for continued RCIC operation, BFN will use the hardened containment vent system (HCVS). During Phase 1 and Phase 2, BFN will utilize anticipatory venting as needed to maintain containment pressure and temperature within acceptable limits. The strategy of Phase 3 is to continue venting supplemented by portable equipment delivered from the NSRC.

The BFN SFPs are located inside the reactor building. The SFP levels are monitored by equipment installed to meet the requirements of Order EA-12-051. After the initiating event, the SFPs will initially heat up due to the unavailability of the normal cooling system and could reach minimum shielding distance (8.5 feet above the top of the fuel) in 19 hours. According to the licensee's FIP, SFP cooling will be initiated in Phase 2 via makeup or spray by the FLEX pump systems through one of three possible SFP makeup strategies: (1) the preferred strategy is makeup from the skimmer surge tank makeup valve supplied with water from the CILRT FLEX pump system, (2) an additional strategy is to use the emergency equipment cooling water (EECW) FLEX pump system for makeup or to spray the refuel floor, and (3) another strategy uses the RHR fuel pool cooling capability to deliver water from the RHRSW FLEX pump system to the SFP cooling system and subsequently into the SFP. The Phase 3 strategy is to continue and support the Phase 2 activities using portable equipment from the NSRC as needed.

Following the initiating event, the operators will complete a load shed within 1 hour of event initiation to ensure safety-related battery life is extended up to approximately 12 hours. For Phase 2, the licensee indicated to have developed two strategies. The preferred strategy uses one 4160 Volt (V) FLEX generator that can connect to the 4160V safety-related distribution system at multiple points. This power will be transformed into 480V to supply power to battery chargers that can charge the unit batteries and power all equipment needed for the strategies. The additional strategy powers the battery chargers using 480V FLEX generators.

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 guidance in NEI 12-06, Revision 4.

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. In Phase 1, 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 DGs 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 which is used as needed.

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 units would have been operating at full power prior to the event. Therefore, the suppression pool may be credited as the heat sink for core cooling during the event. Maintenance of sufficient RPV inventory, while accommodating for steam release from the SRVs and ongoing system leakage expected under ELAP conditions, is accomplished through a combination of installed systems and FLEX equipment. The specific means used by the licensee to accomplish adequate core cooling are discussed in further detail below. The licensee's strategy for ensuring compliance with Order EA-12-049 for conditions where the units are shut down or being refueled is reviewed separately in Section 3.11 of this safety evaluation.

3.2.1 Core Cooling Strategy and RPV Makeup

3.2.1.1 Phase 1

Per the BFN FIP, the injection of cooling water into the RPV will be accomplished through the use of the HPCI and RCIC systems. Once water level is restored, HPCI will be secured and locked out but still available for use if necessary. The RCIC system will then be used to maintain water level. Because the turbine for the RCIC pump is driven by steam from the RPV, operation of the RCIC system further assists the MSRVs with RPV pressure control. The RCIC system suction is initially lined up to the CST and will pump water into the core from the CST, if it is available. The CSTs are not a fully protected source of water for the ELAP event. In the event that the CST is not available, the RCIC pump will take suction from the suppression pool. The BFN strategy assumes that only the water from the suppression pool is available. The RCIC pump is protected from all applicable hazards. More discussion on the CSTs and RCIC pump can be found in the subsections below.

Per the FIP, pressure control of the RPV is accomplished using the automatic depressurization system (ADS) SRVs, which are powered off of the Class 1E dc buses. Within 20 minutes after the initiation of the event, operators will utilize the MSRV's to depressurize at a rate of less than 100 °F per hour. After this point, the RPV pressure is lowered and maintained between 150 and 300 psig to allow for continued operation of the RCIC system. There is a backup nitrogen system in place that will be aligned to the MSRV's that provide nitrogen for at least 24 hours after the initiation of the ELAP event.

The licensee's FIP also stated that station batteries and the Class 1E dc distribution system will provide power to the RCIC system and instrumentation. Per FIP Section 2.18, "Sequence of Events," the dc load shedding begins concurrent with the declaration of a station blackout after the initiation of the ELAP event. An extended dc load shed is started within 15 minutes of the ELAP event, and is completed by 1 hour after event start. This load shedding will extend the battery capacity to power the Phase I systems and instrumentation to allow time for the FLEX DGs to be connected and run.

3.2.1.2 Phase 2

The licensee states in its FIP that RCIC will continue to be used until necessary to transfer to the FLEX pumps. The FLEX pumps are a tandem of a triton and dominator pump. The triton pump takes suction from the Tennessee River and provides suction to the dominator pump. The discharge of the dominator can be routed to various pathways for injection into the RPVs and SFPs. The FLEX pumps can provide 250 gallons per minute (gpm) to the RPV, as well as 150 gpm to the SFP for each unit. The triton pump is rated at 5,000 gpm and has a 50-foot suction lift. The dominator pump is rated for 5,000 gpm at 150 psig. The primary RPV injection strategy is using the CILRT FLEX pump system. This allows routing of water to inject into the RPV through the core spray (CS) system.

The BFN alternate core cooling strategy involves injecting into the RHRSW system. This combination of pipes and hoses will allow for injection into the RPV through the low pressure core injection (LPCI) system. This path provides a diverse injection path into the RPV.

As stated in its FIP, the licensee will use the BFN UHS for injection into the RPV and makeup to the SFP. The UHS is the Tennessee River. In the event of a downstream dam failure, the volume of water that is left in the intake canal pool can provide cooling of the RPV and the SFP for more than 72 hours. More discussion on water sources can be found below.

The licensee plans to open the hardened containment vent to maintain containment pressure and temperature within acceptable limits. The vent will be opened approximately 4-5 hours after the event start, when the containment pressure reaches 10-15 psig. .

3.2.1.3 Phase 3

According to the BFN FIP, the Phase 3 strategy is to maintain and supplement/replace the Phase 2 strategy with Phase 3 equipment. The Phase 3 equipment is expected to arrive from the NSRC within 24 hours of the NSRC notification and then can be connected to replace Phase 2 components. The Phase 2 connection points are compatible with the equipment that will be arriving from the NSRC.

3.2.2 Variations to Core Cooling Strategy for Flooding Event

In its FIP, the licensee stated to have a preferred 4160V electrical connection at either the 4160V Unit Board 1B (generators are deployed to Staging Area SA-A5) or 3B (generators deployed to Staging Area SA-A4). The FIP also provides details describing the plant shutdown boards each option should supply power to. Additional information about this variation to the electrical power strategies is provided in Section 3.7.3.2 of this evaluation. The licensee previously assessed the potential effects the reevaluated flooding hazard levels may have in implementing the mitigating strategies at BFN, as reported in its letter dated December 27, 2016 (ADAMS Accession No. ML16363A386). In this letter, the licensee reported that the FLEX strategies can be implemented without modification. The NRC staff assessment of this letter was completed in letter dated September 5, 2017 (ADAMS Accession No. ML17222A328). Additional information about flooding is provided in Section 3.5.2 of this evaluation.

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

Phase 1

Section 2.4.4.1 in the licensee's FIP described the RCIC system as consisting of a steam driven turbine pump and associated valves that takes suction from the CST or the suppression pool and utilizes reactor steam to drive the turbine, which is exhausted into the suppression pool. The RCIC system operates independently of ac power, plant service air, and an external cooling water system. It relies on dc power from the station's batteries for operation of valves and controls in the control room.

The CST is not credited for FLEX strategies and plant procedures instruct operators to manually switch the suction source from the CST to the suppression pool for the RCIC system, if the CST becomes unavailable. The suppression pool also serves as the heat sink for reactor vessel MSRV discharges and RCIC turbine steam exhaust during the ELAP event. The suppression pool contains approximately 960,000 gallons of water and can provide over 16 hours of makeup to the RPV. The suppression pool is a safety-related seismically qualified structure, which is protected from all applicable external hazards. The RCIC system and suppression pool are located inside the reactor building, and it protects them from all applicable external hazards. After evaluating these systems and their protection against applicable external hazards, the NRC staff finds that the RCIC system and the suppression pool are robust and are expected to be available at the start of an ELAP event consistent with NEI 12-06, Section 3.2.1.3.

Section 2.4.4.2 of the licensee's FIP describes the primary strategy for reactor pressure control and decay heat removal as manual operation of the ADS MSRVs. For ELAP events, the ADS MSRVs require dc control power from the station's batteries and pneumatic nitrogen from the Drywell Control Air Receivers (DCARs) until the alternate nitrogen supply is aligned for manual operation in Phase 2. The ADS MSRVs and DCARs are located in the reactor building, which is protected from all applicable external hazards. Additionally, the ADS MSRVs are safety-related, so the NRC staff finds the ADS MSRVs and support systems are robust and are expected to be available at the start of an ELAP event consistent with NEI 12-06, Section 3.2.1.3.

Phase 2

The licensee's RPV makeup strategy for Phase 2 transitions from the RCIC system to the FLEX pump systems for each Unit. Operators are directed by FLEX Support Instructions (FSIs) to align the suction of the either the CILRT or RHRSW FLEX pump systems to the Tennessee River, which contains an unlimited amount of water for RPV and SFP makeup. The hoses from the CILRT FLEX pump system are aligned to the condensate storage and supply (CS&S) piping, which supplies charging water to the CS system. The CS injection valves are aligned to provide makeup water to the RPV for each of the units along with makeup water to the SFP. The alternative RPV makeup strategy utilizes the RHRSW pump system, which is aligned to RHRSW Header B (for Unit 3) and RHRSW Header D (for Units 1 and 2). These flow paths use the RHRSW/RHR Standby Coolant crosstie, with injection coming through the RHR LPCI piping. The RHRSW/RHR motor-operated valves are aligned to supply RPV makeup. The mechanical connections for the CILRT and RHRSW pump systems are described in Section 3.7.3.1 of this evaluation.

Phase 3

The licensee's Phase 3 RPV makeup strategy for BFN does not rely on any additional installed plant SSCs other than those discussed in Phase 1 and 2.

3.2.3.1.2 Plant Instrumentation

The licensee's plan for BFN is to monitor instrumentation in the control room and by alternate means to support the FLEX core cooling strategy. The instrumentation is powered by station batteries and will be maintained for indefinite coping via battery chargers powered by the FLEX diesel generators (DGs). A more detailed evaluation of the instrumentation power supply is contained in Section 3.2.2.6 of this evaluation.

As described in the FIP, the following instrumentation will be relied upon to support FLEX core cooling and inventory control strategy:

- RPV Level (Wide Range)
- RPV Pressure
- Drywell Pressure
- Drywell Temperature
- Suppression Chamber Pressure
- Suppression Pool Water Level
- Suppression Pool Water Temperature

These instruments can be monitored from the Main Control Room (MCR) or locally at instrument racks.

The instrumentation identified by the licensee to support its core cooling strategy is consistent with the recommendation specified in the endorsed guidance of NEI 12-06.

Per the FIP, instrumentation is normally powered by station batteries during the ELAP event. The batteries are charged by use of a FLEX generator which provides power to the battery chargers through emergency buses. Based upon the information provided by the licensee, the NRC staff understands that the locations of the instrument indications would be accessible continuously throughout the ELAP event.

In accordance with NEI 12-06, Section 5.3.3.1, guidelines for obtaining critical parameters locally are provided in an FSG (or FSI, in this case). The BFN procedure 1, 2, 3-FSI-6C, "Key Instrument Readings During Loss of DC Power," provides alternate methods for obtaining critical parameters if key parameter instrumentation is unavailable. The SFP level instruments are discussed in Section 4 below.

3.2.3.2 Thermal-Hydraulic Analyses

The licensee concluded that its mitigating strategy for reactor core cooling would be adequate based in part on thermal-hydraulic analysis performed using Version 4 of the Modular Accident Analysis Program (MAAP). Because the thermal-hydraulic analysis for the reactor core and containment during an ELAP event are closely intertwined, as is typical of BWRs, TVA has addressed both in a single, coupled calculation. This dependency notwithstanding, the NRC staff's discussion in this section focuses on the licensee's analysis of reactor core cooling. The NRC staff's review of the licensee's analysis of containment thermal-hydraulic behavior is provided subsequently in Section 3.4.4.2 of this evaluation.

The MAAP is an industry-developed, general-purpose thermal-hydraulic computer code that has been used to simulate the progression of a variety of light water reactor accident sequences, including severe accidents such as the Fukushima Dai-ichi event. Initial code development began in the early 1980s, with the objective of supporting an improved understanding of and predictive capability for severe accidents involving core overheating and degradation in the wake of the accident at Three Mile Island Nuclear Station, Unit 2. Currently, maintenance and development of the code is carried out under the direction of the Electric Power Research Institute (EPRI).

To provide analytical justification for their mitigating strategies in response to Order EA-12-049, a number of licensees for BWRs and pressurized-water reactors (PWRs) completed analyses of the ELAP event using Version 4 of the MAAP code (MAAP4). Although MAAP4 and predecessor code versions have been used by the industry for a range of applications, such as the analysis of severe accident scenarios and probabilistic risk analysis (PRA) evaluations, the NRC staff had not previously examined the code's technical adequacy for performing best-estimate simulations of the ELAP event. In particular, due to the breadth and complexity of the physical phenomena within the code's calculation domain, as well as its intended capability for rapidly simulating a variety of accident scenarios to support PRA evaluations, the NRC staff observed that the MAAP code makes use of a number of simplified correlations and approximations that should be evaluated for their applicability to the ELAP event. Therefore, in support of the reviews of licensees' strategies for ELAP mitigation, the NRC staff audited the capability of the MAAP4 code for performing thermal-hydraulic analysis of the ELAP event for both BWRs and PWRs. The NRC staff's audit review involved a limited review of key code models, as well as confirmatory analysis with the TRACE code to obtain an independent assessment of the predictions of the MAAP4 code.

To support the NRC staff's review of the use of MAAP4 for ELAP analyses, in June 2013, EPRI issued a technical report entitled "Use of Modular Accident Analysis Program (MAAP) in Support of Post-Fukushima Applications (ADAMS Accession No. ML13190A201)." The document provided general information concerning the code and its development, as well as an overview of its physical models, modeling guidelines, validation, and quality assurance procedures.

Based on the NRC staff's review of EPRI's June 2013 technical report, as supplemented by further discussion with the code vendor, audit review of key sections of the MAAP code documentation, and confirmation of acceptable agreement with NRC staff simulations using the TRACE code, the NRC staff concluded that, under certain conditions, the MAAP4 code may be used for best-estimate prediction of the ELAP event sequence for BWRs.
The NRC staff issued an endorsement letter dated October 3, 2013 (ADAMS Accession No. ML13275A318), which documented these conclusions and identified specific limitations that BWR licensees should address to justify the applicability of simulations using the MAAP4 code for demonstrating that the requirements of Order EA-12-049 have been satisfied.

During the audit process, the NRC staff verified that the licensee's MAAP4 calculation, along with an associated addendum, addressed the limitations from the NRC staff's endorsement letter. The licensee utilized the generic roadmap and response template that had been developed by EPRI to support consistency in individual licensee's responses to the limitations from the endorsement letter. In particular, based upon review of the MAAP4 calculation document, the staff concluded that appropriate inputs and modeling options had been selected for the code parameters expected to have a dominant influence for the ELAP event. The NRC staff further observed that the limitations imposed in the endorsement letter, particularly those concerning the RPV collapsed liquid level being maintained above the reactor core and the primary system cooldown rate being maintained within Technical Specification limits, were satisfied. Specifically, the licensee's analysis calculated that BFN would maintain the collapsed liquid level in the reactor vessel above the top of the active fuel region throughout the analyzed ELAP event. By maintaining the reactor core fully covered with water, adequate core cooling is assured for this event. Additionally, BFN fulfillment of the endorsement letter condition regarding the primary system cooldown rate signifies that thermally induced volumetric contraction and other changes in primary system thermal-hydraulic conditions should proceed relatively slowly with time, which supports the NRC staff's confidence in the predictions of the

MAAP4 code. Furthermore, that the licensee should be capable of maintaining the entire reactor core submerged throughout the ELAP event is consistent with the staff's expectation that the licensee's flow capacity for primary makeup (i.e., installed RCIC pump and, subsequently, FLEX pumps) should be sufficient to support adequate heat removal from the reactor core during the analyzed ELAP event, including potential losses due to expected primary leakage.

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 Recirculation Pump Seals

An ELAP event would result in the interruption of cooling to the recirculation pump seals, potentially resulting in increased leakage due to the distortion or failure of the seals, elastomeric O-rings, or other components. Sufficient primary make-up must be provided to offset recirculation pump seal leakage and other expected sources of primary leakage, in addition to removing decay heat from the reactor core.

During the audit, the NRC staff discussed recirculation pump seal leakage with the licensee and requested that the licensee justify the applicability of the assumed leakage rate to the ELAP event.

The licensee's calculations for BFN assumed a seal leakage rate of 61 gpm at full reactor pressure. This leakage rate is meant to bound 18 gpm per recirculation pump seal, in accordance with NRC Generic Letter 91-07, in addition to the licensee's additional primary system leakage rate equal to the Technical Specification limit of 25 gpm. This leakage rate will decrease as the reactor pressure decreases and as the reactor cools down. The RCIC pump capability makes up for the leakage rate plus steam removal with margin. The FLEX Pumps capability of 250 gpm to the RPV at a lower RPV pressure provides significant margin to the assumed leakage rates during the event.

In the MAAP analysis, the licensee discussed system response to the variation of seal leakage rate as a function of RPV pressure in the thermal hydraulic simulation. The initial seal leakage rate was assumed to be 61 gpm. As the RPV was depressurized (in the MAAP analysis), the seal leakage rate was reduced. After its analysis, the licensee concluded that the RPV water level continued to be above the top of the active fuel throughout the simulation period.

Considering the above factors, the NRC staff concludes that the leakage rate assumed at BFN is reasonable based the Generic Letter 91-07. The staff further notes that gross seal failures are not anticipated to occur during the postulated ELAP event. As is typical of the majority of U.S. BWRs, BFN has an installed steam-driven pump (i.e., RCIC) capable of injecting into the primary system at a flow rate well in excess of the primary system leakage rate expected during an ELAP, and the other pumps used for core cooling in its FLEX strategy have a similar functional capability and margin well above the expected leakage rate.

Based upon the discussion above, the NRC staff concludes that the recirculation pump 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

As described in the BFN Updated Final Safety Analysis Report (UFSAR), the control rods provide adequate shutdown margin under all anticipated plant conditions, with the assumption that the highest-worth control rod remains fully withdrawn. Section 1.1, "Definitions," of the BFN Technical Specification further clarifies that shutdown margin is to be calculated for a cold, xenon-free condition to ensure that the most reactive core conditions are bounded.
Based on the NRC staff's audit review, the licensee's ELAP mitigating strategy maintains the reactor within the envelope of conditions analyzed by the licensee's existing shutdown margin calculation. Furthermore, the existing calculation retains conservatism because the guidance in NEI 12-06 permits analyses of the beyond-design-basis ELAP event to assume that all control rods fully insert into the reactor core.

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

For Phase 2, the licensee utilizes a FLEX pump system comprised of triton and dominator pumps connected in series. The triton pump takes suction from the Tennessee River and provides suction to the dominator pump. The triton is a trailer-mounted, diesel-driven centrifugal pump that utilizes two floating submersible pumps. The licensee indicated that the triton pump is capable of supplying up to 5,000 gpm, has a 50 foot suction lift, and can supply a dominator pump up to 150 feet away and 50 feet above the triton. The dominator pump is also a trailer-mounted, diesel-driven centrifugal pump and is rated at 5,000 gpm at 150 psig. The BFN site has three FLEX pump system strategies. The fluid motive force portion of the BFN FLEX Plan is satisfied through the implementation of EECW and CILRT FLEX Pump System strategies. The RHRSW FLEX Pump System strategy provides an alternate connection point and pathway to the RPV and SFP. Even though BFN has four pump combinations available, only two pump combinations represent N with a third pump combination representing N+1. Three pump combinations are required to meet the N+1 FLEX requirements at BFN.

For RPV makeup, the licensee indicated in its FIP that either the CILRT or RHRSW FLEX pump systems are deployed and placed into operation within 8 hours of ELAP initiation. Either FLEX pump system is staged at the designated location near the Tennessee River and is connected with hoses outside that are routed to the designated connection points to supply RPV makeup water to all three units. Additionally, the licensee indicated in the FIP that, in the event of a failure of the downstream dam (Wheeler) were to occur, a pool of water containing a volume of approximately 69.6×10^6 cubic feet of water would be available to the FLEX pump systems at the BFN plant intake. Section 3.7.3.1 of this evaluation describes the connection points for RPV makeup using the CILRT or RHRSW FLEX pump systems. The EECW FLEX pump system can be used to supply cooling water to the RCIC oil coolers after Phase 1 operation, the control bay ventilation system, area coolers, and to the SFP. The FLEX pumps are stored in the FLEX Equipment Storage Building (FESB), which is protected from all applicable external hazards. Section 3.10 of this evaluation provides a detailed discussion of the availability and robustness of each water source for the FLEX pump systems. To verify that the FLEX pump systems capacities are within requirements, the licensee performed calculation MDN0003602014000233, Revision 3, "Hydraulic Analysis for Fukushima FLEX Connection Modifications," to verify the volumetric flow rate and head needed to remove decay heat following a BDBEE.

From the review of the hydraulic analysis performed by the licensee, the NRC staff confirmed that the FLEX pump systems are within the required capacity for RPV and SFP makeup. During the onsite audit, the NRC staff conducted a walkdown of the location of the FLEX pump systems and hoses storage locations and the CILRT, RHRSW, and EECW connection points as described in the hydraulic analyses and FIP. Based on the staff's review of the FLEX pumping capabilities at BFN, as described in the above hydraulic analysis and the FIP, the NRC staff concludes that the FLEX pump systems should perform as intended to support core cooling and RCS inventory control during an ELAP event, consistent with NEI 12-06, Section 11.2.

3.2.3.6 Electrical Analyses

The licensee's electrical strategies provide power to the equipment and instrumentation used to mitigate the postulated event. The electrical strategies described in the FIP are integrated for maintaining or restoring the critical functions of core cooling, containment, and SFP cooling. Any function-specific considerations for containment and SFP cooling are noted in Sections 3.3.4.4 and 3.4.4.4 of this safety evaluation.

According to the licensee's FIP, operators would enter the FSIs following a loss of offsite power and emergency diesel generators (EDGs) with a confirmation of no imminent return of any of those power sources. The plant's indefinite coping capability is attained through the implementation of pre-determined FLEX strategies that are focused on maintaining or restoring key plant safety functions. A safety function-based approach provides consistency with, and allows coordination with, existing plant emergency operating instructions (EOIs).

During the first phase of an ELAP event, the licensee would rely on the safety-related Class 1E batteries to provide power to key instrumentation and applicable dc components. The BFN Class 1E station batteries and associated dc distribution systems are located within safety-related structures designed to meet applicable design-basis external hazards. The safety related 250 Volt (V) dc (vdc) system for each unit consists of independent and redundant switchgear assemblies, a battery charger, two divisional inverters and a battery. There is also one spare battery charger, capable of supplying any of the three unit batteries. The licensee's procedures direct operators to conserve dc power during the event by stripping non-essential loads. Operators will strip or shed unnecessary loads to extend battery life until backup power is available (Phase 2). The plant operators would commence load shedding of the station batteries within 15 minutes and complete load shedding within 1 hour from the onset of the event. In its FIP, the licensee stated the station batteries could cope for at least 12 hours if the load shed is completed within 1 hour.

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.

During the audit process, the NRC staff reviewed the licensee's dc coping calculation EDQ000992013000202, Revision 1, "250V DC Batteries 1, 2, & 3 Evaluation for Beyond

Design Basis External Event (BDBEE) Extended Loss of AC Power (ELAP)," which verified the capability of the dc system to supply power to the required loads during the first phase of the licensee's FLEX mitigation strategy. The licensee's calculation identified the required loads and their associated ratings (ampere (A) and minimum required voltage) and the non-essential loads that would be shed within 1 hour to ensure battery operation for at least 12 hours. Based on its review of the licensee's calculation, the NRC staff found that the three Class 1E batteries should have sufficient capacity to supply power for at least 12 hours. Further, based on its review of the licensee's analyses and procedures, and the battery vendor's capacity and discharge rates for the Class 1E station batteries, the NRC staff finds that the BFN dc systems 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 analyses.

The licensee developed multiple strategies to provide electrical power during Phase 2. The preferred strategy uses one 4160 volts act (Vac) FLEX combustion turbine generator (CTG) that can be connected to the 4160 Vac safety-related distribution system at multiple points. The power is then transformed to 480 Vac to supply power to the 480 Vac shutdown boards A and B on each unit. The 480 Vac shutdown boards supply power to unit battery chargers 1, 2A, 2B, and 3, which charge the unit batteries and supply dc loads. The 480 Vac shutdown boards also supply the 480 Vac reactor motor operated valve (RMOV) boards, control bay vent boards, standby gas treatment (SGT) boards, and DG auxiliary boards. These boards supply power to equipment necessary for the performance of all strategies. The 4160 Vac CTGs are rated for 1 megawatt (MW) and are sized to power the 250 V dc battery chargers, RCIC controls, motor operated valves (MOVs), and other selected loads. Two 4160 Vac CTGs are available; however, only one CTG is required to supply the power necessary to complete the FLEX strategies. The primary staging area for the CTG is directly outside the Unit 3 DG rooms, with alternates available just outside the Turbine Building Breezeway area or directly outside the Units 1 and 2 DG rooms.

An additional strategy would power the 480 Vac battery chargers using a 480 Vac FLEX CTG. This strategy allows backfeed from the battery charger supply to selected MOVs needed for the FLEX strategies. The 480 Vac FLEX CTGs are rated for 850 kilowatts (kW) (825 kW at 130°C) and are sized to power the battery chargers, RCIC controls, MOVs, and other selected loads. Two 480 Vac CTGs are available, however, only one CTG is required to supply the power necessary to complete the FLEX strategies.

No matter which strategy is selected, the licensee plans to repower the required equipment in approximately 8 hours. Each of the licensee's strategies satisfy the "N+1" provision of NEI-12-06.

The NRC staff reviewed licensee calculations EDQ0003602015000325, Revision 1, "Electrical Evaluation for 4kV ac FLEX Turbine Generators," and EDQ0003602014000281, Revision 1, "Electrical Evaluation for Portable Power Supply for Unit Battery Chargers," conceptual single line diagrams, and the separation and isolation of the FLEX CTGs from the EDGs. Based on the NRC staff's review of calculation EDQ0003602015000325, the maximum expected loads in Phase 2 for the 4160 Vac FLEX CTG total approximately 690 kW. Based on the NRC staff's review of calculation EDQ0003602014000281, the maximum expected loads in Phase 2 for the 850 kW FLEX CTG total approximately 283 kW. The staff notes that the licensee took the FLEX cable lengths into consideration when sizing the FLEX CTGs (i.e., ensured that the voltage drop did not result in violating the minimum required voltage required at the limiting component). Based on its review of the licensee's calculations, the NRC staff finds that either a single 1 MW or a single 850 kW FLEX CTG is adequate to support the electrical loads required for the licensee's Phase 2 strategies. The NRC staff confirmed that licensee guidelines 0-FSI-3A, Revision 3, "480V FLEX Diesel Generator Setup and Operation," and 0-FSI-3C, Revision 4, "4kV FLEX Generator Setup and Operation," provide direction for staging and connecting a FLEX CTGs to energize the electrical buses to supply required loads within the required timeframes.

For Phase 3, the licensee plans to continue the Phase 2 coping strategy with additional assistance provided from offsite equipment/resources. The offsite electrical equipment that will be provided by the NSRC includes six 1-MW 4160 Vac CTGs, three 1-MW 480 Vac CTGs, and three distribution centers (including cables and connectors). Based on the margin available for the 4160 Vac and 480 Vac CTGs, the NRC staff finds that the CTGs being supplied from the NSRCs have sufficient capacity and capability to supply the required loads during Phase 3, if necessary. The licensee would stage the NSRC CTGs in the vicinity of the Phase 2 FLEX CTGs. The licensee would rely on Technical Support Center (TSC) personnel to connect and utilize the NSRC equipment for long-term coping or recovery.

Based on its review, the NRC staff finds that the Class 1E station batteries should have sufficient capacity to support the licensee's strategy, and that the FLEX CTGs and NSRC supplied CTGs should have sufficient capacity and capability to supply the necessary loads during an ELAP event while maintaining adequate separation and isolation of the FLEX CTGs from the EDGs.

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 RPV inventory during an ELAP event consistent with NEI 12-06 guidance, as endorsed by JLD-ISG-2012-01, and should adequately address the requirements of the order.

3.3 Spent Fuel Pool Cooling Strategies

In NEI 12-06, Revision 4, Table 3-1 and Appendix C 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 directly to the pool, and (2) makeup via connection to SFP makeup piping or other suitable means. 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 set points 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. This criterion is keeping the fuel in the SFP covered with water.

The ELAP causes a loss of cooling in the SFP and, 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 staff's assessment, presented in this safety evaluation section, primarily addresses the anticipated response during non-full core offload scenarios. The effects of a postulated event with a full core offload is addressed in Section 3.11 of this safety evaluation.

3.3.1 Phase 1

The licensee stated in its FIP that no operator actions are required during ELAP Phase 1 for SFP makeup because the time to boil is sufficient to enable deployment of Phase 2 equipment. Water level in the SFP will be maintained 17 feet above top of the stored fuel. The FSIs will direct operators to take action to setup SFP makeup within 8 hours of ELAP initiation. Operators will also be directed to open plant doors within the first hour of the event in order to provide a vent pathway for steam and condensate from the SFP. The licensee will calculate the SFP heatup rate and monitor SFP water level using reliable SFP level instrumentation installed per Order EA-12-051.

3.3.2 Phase 2

During Phase 2, the licensee described in its FIP that the CILRT FLEX pump systems will be deployed and staged within 8 hours and the FLEX pump systems for connection to the EECW header will be deployed and staged within 12 hours to take suction from the Tennessee River for SFP makeup. The FLEX pump systems will be stored in the FESB. The operators will be directed by the FSIs to set up SFP makeup equipment located near the refuel floor of the reactor building within 8 hours after ELAP event initiation in advance of high temperatures. The SFP makeup is provided by the CILRT FLEX pump system through the CS&S system to the skimmer surge tank makeup valve located on the refuel floor. For SFP makeup involving the EECW FLEX pump system, fire hoses and associated equipment are pre-staged for connection to the South EECW header if the CILRT connection is unavailable. An additional alternate SFP makeup is provided by the RHRSW FLEX pump system, which supplies the RHRSW headers and delivers to the SFP cooling system using the RHR Fuel Pool Cooling (FPC) assist valves. The mechanical connections for SFP makeup for all three FLEX pump systems are described in Section 3.7.3.1 of this safety evaluation.

3.3.3 Phase 3

The FIP states that SFP cooling can be maintained indefinitely using the makeup strategies described in Phase 2 above. However, NSRC equipment is available during Phase 3 for SFP cooling and provide additional defense-in-depth.

3.3.4 Staff Evaluations

3.3.4.1 Availability of Structures, Systems, and Components

3.3.4.1.1 Plant SSCs

Condition 6 of NEI 12-06, Section 3.2.1.3, states that permanent plant equipment contained in structures with designs that are robust with respect to seismic events, floods, and high winds, and associated missiles, are available. In addition, Section 3.2.1.6 states that the initial SFP conditions are: 1) all boundaries of the SFP are intact, including the liner, gates, transfer canals, etc., 2) although sloshing may occur during a seismic event, the initial loss of SFP inventory does not preclude access to the refueling deck around the pool, and 3) SFP cooling system is intact, including attached piping.

The NRC staff reviewed the licensee's calculation on habitability on the SFP refuel floor. Calculation MDQ00778880333, Revision 6, "Spent Fuel Pool Heatup Rate With No Cooling or Makeup," and the FIP indicated that the minimum shielding distance (8.5 feet above the top of the fuel racks) is reached approximately around 19 hours for maximum heat load conditions during full core offload. The NRC staff noted that the licensee's sequence of events timeline in the FIP indicates that operators will deploy SFP makeup equipment located from the FESB and stage onto the refuel floor of the reactor building within 8 hours after ELAP. The licensee described this as a contingency to ensure the SFP area remains habitable for personnel entry.

As described in the licensee's FIP, the licensee's Phase 1 SFP cooling strategy does not require any operator actions. However, the licensee does establish a ventilation path to cope with temperature, humidity and condensation from evaporation and/or boiling of the SFP. The security personnel are directed to open designated doors in the reactor building ground level, refuel floor, and reactor building roof within the first hour of ELAP event initiation to establish natural circulation flow path convective cooling.

The licensee's Phase 2 and Phase 3 SFP cooling strategy involves the use of the CILRT, RHRSW, or EECW FLEX pump systems (or NSRC supplied pumps for Phase 3), with suction from the Tennessee River, to supply water to the SFP. The FSIs direct operators to complete the designated FLEX pump system deployment with accompanying hose runs for SFP makeup in the reactor building within 8 hours of ELAP initiation. The NRC staff's evaluation of the robustness and availability of FLEX connections points for the FLEX pump systems is discussed in Section 3.7.3.1 of this evaluation. Furthermore, the NRC staff's evaluation of the robustness and availability of the Tennessee River for an ELAP event is discussed in Section 3.10 of this evaluation.

The licensee stated, in its FIP, that an additional strategy is to use the FLEX Pump System for spray to the Refuel Floor. As stated in NEI 12-06, Revision 4, Table C-3, SFP spray capability is not required for plants that demonstrate SFP integrity by performing a seismic SFP integrity evaluation for their mitigating strategies seismic hazard using EPRI 3002007148, "Seismic Evaluation Guidance: Spent Fuel Pool Integrity Evaluation," or other NRC endorsed guidance. The licensee has completed the SFP integrity analysis for the reevaluated seismic hazard, and the NRC staff evaluation can be found in letter dated January 27, 2017 (ADAMS Accession No. ML17024A164). Having the capability to spray the SFP is considered defense-in-depth.

3.3.4.1.2 Plant Instrumentation

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

3.3.4.2 Thermal-Hydraulic Analyses

As described in FIP Section 2.5.7, the SFP will boil in approximately 2.3 hours and boil off to a level of 8.5 feet above the spent fuel racks in 19 hours from initiation of the event, with no operator action at the maximum design heat load for full core offload conditions. Therefore, the licensee conservatively determined that a SFP makeup flow rate of at 150 gpm will make up or maintain adequate SFP level at above the fuel for an ELAP occurring during normal power operation. For the maximum heat load scenario, the licensee indicated that the FSIs will direct operators to take more expedient action to stage SFP makeup 8 hours after ELAP initiation. Consistent with this guidance in NEI 12-06, Section 3.2.1.6, the NRC staff finds the licensee has considered the maximum design-basis SFP heat load.

3.3.4.3 FLEX Pumps and Water Supplies

As described in the FIP, the SFP cooling strategy relies on the CILRT, RHRSW, or EECW FLEX pump systems to provide SFP makeup for all three units during Phase 2. In the FIP, Section 2.5.7 references Calculation MDN0003602014000233, Revision 3, "Hydraulic Analysis for Fukushima FLEX Connection Modifications," which provides the hydraulic performance criteria (e.g., flow rate, discharge pressure) for the FLEX pump systems. The CILRT and RHRSW FLEX pump systems are also used for RPV makeup for all three units as described above, and the licensee's calculation reflected simultaneous makeup to the RPV and SFP. The EECW FLEX pump system can also be used in place of either the CILRT or RHRSW FLEX pump systems to supply SFP makeup for all three units. The NRC staff noted that the performance criteria of a FLEX pump supplied from an NSRC for Phase 3 would allow the NSRC pump to fulfill the SFP makeup function if any of the FLEX pump systems were to fail.

3.3.4.4 Electrical Analyses

The licensee's mitigating strategy for SFP cooling does not rely on electrical power, except for power to SFP level instrumentation. The SFP water level is monitored by the instrumentation that was installed in response to Order EA-12-051. These instruments are located in the shutdown board rooms adjacent to each backup control panel. There are two independent, redundant channels of indication, and each channel includes an uninterruptible power system power supply and batteries capable of powering the instrument loops for a minimum of 4 days. The instrument loops are also capable of being powered from the FLEX CTGs when they become available. The capability of this instrumentation is described in Section 4 of this safety evaluation.

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

3.3.5 Conclusions

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

3.4 Containment Function Strategies

The industry guidance document, NEI 12-06, Table 3-1, 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.

Browns Ferry's three units are GE BWRs with Mark I containments. The licensee's strategy is to use anticipatory venting by means of the HCVS to maintain containment pressure and temperature within acceptable values such that the suppression pool temperature remains acceptable for RCIC operation. Operation of the containment venting system will utilize plant batteries and compressed gas systems supplemented/replaced by FLEX equipment as needed. This is consistent with the guidance provided by NEI 12-06.

The licensee performed a containment evaluation, captured in Report 06050-RPT-13406, Revision 1, "MAAP 4.0.7 Thermal Hydraulic Calculations to Support Extended Loss of AC Power FLEX Strategies," based on the boundary conditions described in Section 2 of NEI 12-06. The calculation analyzed the strategy of venting the suppression chamber when containment pressure reaches 15 psig to ensure the suppression pool temperature remains acceptable for RCIC operation. The FSAR Section 5.2, Table 5.2-1, "Principal Design Parameters and Characteristics of Primary Containment," design limits are 56 psig and 281 °F for both drywell and suppression chamber. The licensee's calculation concluded that employing this venting strategy enables containment conditions to remain within design limits for more than 120 hours except for the drywell temperature. A justification for exceeding this temperature limit is discussed in Section 3.4.4.1.1.

From its review of the evaluation, the NRC staff noted that 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 FIP states that, during Phase 1, BFN will depressurize the RPV to the range of 150-300 psig using the MSRVs, which direct steam into the suppression pool. This action will absorb the heat load in the primary containment, limiting the pressure rise and prolonging coping time. During Phase 1, reactor core cooling is maintained by the operation of the RCIC system. The licensee will utilize anticipatory venting using the installed HCVS to maintain containment pressure and temperature within acceptable values. The wetwell venting will commence when containment pressure reaches approximately 15 psig, which is predicted to occur approximately 4.5 hours into the event, according to the containment analysis. By venting at this pressure, containment pressure limits are not exceeded and suppression pool temperature should remain acceptable for RCIC operation.

3.4.2 Phase 2

The strategy to maintain containment integrity for Phase 2 is to maintain the Phase 1 strategy of providing cooling water to the RPV and venting the suppression chamber using the vent system. Monitoring of containment (drywell) pressure and temperature is available via permanently installed plant instrumentation. The containment analysis demonstrates that primary containment limits are not reached, except for the drywell temperature, and suppression pool temperature remains acceptable during the event.

3.4.3 Phase 3

The Phase 3 strategy is the continuation of the Phase 2 strategy supplemented by portable equipment delivered from off-site. Additional generators supplied by the NSRC will allow methods of containment cooling, such as drywell blowers, to be placed in service. Instructions for connection and utilization of NSRC equipment for long term coping or recovery will be provided by TSC personnel who will have assessed the condition of the plant and infrastructure, plant accessibility, and additional available off-site resources (both equipment and personnel) following the BDBEE.

3.4.4 Staff Evaluations

3.4.4.1 Availability of Structures, Systems, and Components

Baseline assumptions in NEI 12-06 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

Primary Containment

Section 5.2.3.1 of the Browns Ferry UFSAR, Amendment 27, describes a GE Mark I primary containment, which houses the RPV, reactor coolant recirculating loops, and other branch connections for the reactor coolant system. The pressure suppression system consists of a drywell, a pressure suppression chamber (alternatively referred to as the torus or wetwell), which stores a large volume of water (referred to as the suppression pool), a vent system between the drywell and pressure suppression chamber, and other service equipment. The drywell is a steel pressure vessel with a spherical lower portion 67 feet in diameter and a cylindrical upper portion 38 feet-6 inches in diameter. The overall height is approximately 115 feet. The drywell free volume is approximately 171,000 cubic feet. The drywell is designed for a maximum internal pressure of 62 psig coincident with a maximum design temperature of 281 °F, plus the dead, live, and seismic loads imposed on the shell. The UFSAR states that the drywell design pressure is in accordance with the ASME Boiler and Pressure Vessel Code, Section III.

As stated in Section 3.4 above, the UFSAR design limit for the drywell temperature is calculated to be exceeded. As part of the audit process, the licensee discussed that the drywell temperature limits are limiting only when the drywell pressure is also limiting. Since the drywell pressures in all analyzed cases were less than 50 percent of the design pressure, the exceedance of the drywell temperature limit does not threaten the drywell structure. In addition, the drywell air temperature does not exceed the environmental qualifications of the MSRVs for the duration of the event. Therefore, the drywell and components in containment are not expected to fail.

The pressure suppression chamber (wetwell or torus) is a steel pressure vessel in the shape of a torus below and encircling the drywell, with a centerline diameter of approximately 111 feet and a cross-sectional diameter of 31 feet. The pressure suppression chamber volume is approximately 250,000 cubic feet. The pressure suppression chamber is held by supports which transmit vertical and seismic loading to the reinforced concrete foundation slab of the Reactor Building. The pressure suppression pool is approximately 123,000 cubic feet of water contained within the pressure suppression chamber. It serves both as a heat sink for postulated transients and accidents and as a source of water for the emergency core cooling system. The UFSAR Table 5.2-1, states the pressure suppression chamber internal design pressure is 56 psig, and the design temperature of the pressure suppression chamber is 281 °F.
In accordance with NEI 12-06, the containment is assumed to be isolated following the initiating event. As the suppression pool heats up and begins to boil, the containment will begin to heat up and pressurize. Additionally, because it is necessary to ensure the capability of MSRVs to perform the pressure relief function and it is necessary to maintain containment integrity, the containment will be vented to reduce suppression pool inventory and containment pressure. The HCVS has been enhanced to ensure required vent operations. The HCVS will be operated with control from the MCR.

The primary containment and the HCVS valves are located within the Reactor Building, which is designed as a seismic Class I structure. The staff noted that being a seismic Category I structure, it has been designed to be robust with respect to the design-basis external events and therefore is assumed to be fully available.

Hardened Containment Vent System

Following an initiating event, which results in an ELAP concurrent with LUHS, the HCVS provides a means of relieving excessive containment pressure. The vent flow path utilizes a 14-inch line which taps off of the 20-inch torus vacuum breaker. Two 14-inch pneumatically-operated butterfly valves are located inside the Reactor Building. The piping penetrates the Reactor Building wall, and after exiting the Reactor Building, the piping turns up and travels vertically along the exterior wall of the Reactor Building. The piping continues up the wall of the Reactor Building until it reaches approximate elevation 665 feet where it turns and penetrates the siding of the Reactor Building superstructure. Once inside the superstructure, the piping is routed vertically adjacent to an existing steel column until it penetrates the roof of the superstructure, ultimately terminating at approximate elevation 741 feet-6 inches. Also, necessary equipment for operation of the HCVS is included: a HCVS nitrogen system, backup electrical power supplies, controls, monitoring instrumentation, and a remote operating station (ROS).

The HCVS nitrogen system includes a nitrogen bottle rack in the DG buildings, along with the ROS for the HCVS. The system provides enough motive air supplies to assure 24 hours of operation without bottle change out. The ROS includes pressure gauges to indicate system supply pressure both upstream and downstream of the pressure regulator and indicate when bottle change out is required.

The normal power supply for the HCVS solenoids is the Class 1E unit batteries, which remain available for the duration of the event. In the event of failure of the batteries, the HCVS system contains its own battery, which can be aligned to provide power to the HCVS solenoids. The HCVS batteries are sized to provide a minimum of 24 hours of power to HCVS related equipment.

The use of HCVS per EOIs is initiated to maintain containment parameters below design limits and within the limits that allow continued use of RCIC. These procedures include steps for HCVS valve operation, as well as alignment of the backup nitrogen bottles and battery when necessary. Anticipatory venting when containment pressure reaches 15 psig is performed. By venting at this pressure, containment pressure limits are not exceeded and suppression pool temperature remains acceptable for RCIC operation.

The DG buildings house the HCVS ROS, backup nitrogen supply, and backup batteries. The buildings are Seismic Category I and provide protection from all applicable hazards.

Based on these UFSAR qualifications, the containment, the HCVS, and the necessary support equipment credited in the strategy are robust, as defined by NEI 12-06, and would be available following an ELAP-inducing event.

3.4.4.1.2 Plant Instrumentation

Table 3-1 in NEI 12-06 specifies that containment pressure, suppression pool level, and suppression pool temperature are key containment parameters which should be monitored by repowering the appropriate instruments.

The licensee's FIP states that monitored parameters include drywell temperature and pressure, suppression pool temperature and level, and suppression chamber pressure. These instruments are located in the MCR and would be available due to the coping capability of the station batteries or inverters that maintain operation of the instrument during the ELAP. If no ac or dc power is available, the key credited plant parameters, including these containment parameters, would be available using alternate methods.

In the highly unlikely event these instruments are unavailable, procedures and equipment needed are available to provide methods for obtaining necessary instrument readings to support the implementation of the coping strategy. Procedure 1,2,3-FSI-6C includes control room and non-control room readouts and also provides guidance on how and where to measure key instrument readings as close to containment penetrations, as possible, using portable instruments (e.g., a Fluke meter).

Based on this information, the licensee should have the ability to appropriately monitor the key containment parameters as delineated in NEI 12-06, Table 3-1.

3.4.4.2 Thermal-Hydraulic Analyses

The licensee performed a containment evaluation, as documented in 06050-RPT-13406, Revision 1, "MAAP 4.0.7 Thermal Hydraulic Calculations to Support Extended Loss of AC Power FLEX Strategies," which was based on the boundary conditions described in Section 2 of NEI 12-06. This calculation utilized MAAP, Version 4.0.7, to perform numeric computations of the fundamental thermodynamic equations which predict the heat up and pressurization of the containment atmosphere under ELAP conditions. In order to establish an effective and robust mitigation strategy, a number of sensitivity cases were performed to provide the BFN decision-makers with a characterization of the margin associated with various assumptions regarding:

- Initial conditions
- Operator response actions
- Alternative approaches

Considering the general case (Case 1), the analysis assumes a total reactor coolant system (RCS) leakage of 61 gpm. RCIC is started automatically on low RPV level and provides vessel injection from the suppression pool. The wetwell venting is started when the wetwell gas space pressure reaches 15 psig.

The calculation shows that the containment reaches 15 psig at 4.5 hours when the wetwell vent was assumed to be opened. The peak containment pressure reached is 17.2 psig (31.9 per square inch absolute (psia)) at roughly 14.6 hours and the peak drywell temperature reached is 293 °F at 56.8 hours. The peak suppression chamber pressure is calculated to be 17.1 psig (31.8 psia) with an airspace temperature of 261 °F at approximately 14.3 hours, and a peak suppression pool temperature of 249 °F.

The NRC staff reviewed the calculation and verified that the maximum values calculated are below the UFSAR design parameters stated above in Section 3.4.4.1, except for the drywell temperature. A justification for exceeding the drywell temperature design limit is discussed in Section 3.4.4.1.1. Therefore, the drywell and suppression chamber are not expected to fail.

3.4.4.3 FLEX Pumps and Water Supplies

The FLEX pump systems and water supplies are described in detail in Section 3.2.3.5 of this evaluation. The FLEX pumps will provide any required make-up water to the suppression pool.

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 the maintenance of containment capability and ensure that the required instrumentation continues to function.

The licensee's Phase 1 coping strategy is to monitor containment pressure and temperature using installed instrumentation, and maintain containment capability using normal design features of the containment, such as the MSRVs, as well as the HCVS. The licensee's strategy to repower instrumentation using the Class 1E station batteries is described in Section 3.2.3.6 of this safety evaluation and is adequate to ensure continued containment monitoring.

The normal power supply for the HCVS solenoids is the Class 1E unit batteries, which should remain available for the duration of the event. In the event of failure of the Class 1E batteries, the HCVS system contains its own battery, which can be aligned to provide power to the HCVS solenoids. The HCVS batteries are sized to provide a minimum of 24 hours of power to HCVS-related equipment. The NRC staff reviewed licensee calculation EDQ0010642015000349, Revision 2, "Unit 1 HCVS Electrical Design & Equipment Sizing Analysis," which evaluated the battery/battery charger sizing and device terminal voltages for the HCVS dc system. The results of the calculation showed that the HCVS battery is adequately sized to supply power to the HCVS for at least 24 hours following an ELAP.

The licensee's Phase 2 coping strategy is to continue monitoring containment pressure and temperature using installed instrumentation and maintaining containment capability. The licensee's strategy to repower instrumentation using a FLEX CTG is identical to what was described in Section 3.2.3.6 of this safety evaluation and is adequate to ensure continued containment monitoring. The licensee also plans to recharge the HCVS battery utilizing the FLEX CTG. Based on its review of licensee calculation EDQ0010642015000349, the NRC staff finds that the FLEX CTG can support the addition of the HCVS battery charger. The licensee would transition to Phase 2 prior to depleting the HCVS battery (i.e., within 24 hours). The staff confirmed that 1, 2, 3-EOI- Appendix-13, "Emergency Venting Primary Containment," provides guidance to place the HCVS battery charger in service and power them from the FLEX CTG.

The licensee's Phase 3 strategy is to continue its Phase 2 strategy throughout the event. BFN will receive offsite resources and equipment as needed, including CTGs, from an NSRC. Given the capacity of these CTGs, the NRC staff finds that it is reasonable to expect that the licensee could utilize these resources to supply power to the HCVS components to maintain the containment function indefinitely. The licensee would stage the CTGs in the vicinity of the Phase 2 FLEX CTGs. The licensee would rely on TSC personnel to connect and utilize the NSRC equipment for long-term coping or recovery if needed.

Based on its review, the NRC staff determined that the electrical equipment available onsite (e.g., Class 1E batteries, HCVS battery, and FLEX CTGs), has sufficient capacity and capability to supply the required loads to maintain containment. The equipment from the NSRC will be utilized as needed to enhance the long-term coping capability.

3.4.5 Conclusions

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

3.5 Characterization of External Hazards

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

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

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

References to external hazards within the licensee's mitigating strategies and this 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 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. ML15089A236)). The Commission provided guidance in an SRM to COMSECY-14-0037 (ADAMS Accession No. ML14309A256). 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. By letter 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 SEs 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 4, Appendices G and H (ADAMS Accession No. ML16354B421). As previously mentioned, Revision 2 of JLD-ISG-2012-01 endorsed Revision 4 of NEI 12-06, with exceptions, clarifications and additions, as published in the *Federal Register* (83 FR 18089). The licensee's MSAs will evaluate the mitigating strategies described in this safety evaluation using the revised seismic and flood hazard information and make changes to the strategies or equipment, if necessary. The licensee has completed the MSA for flooding at BFN (ADAMS Accession No. ML16363A386) and plans to submit the MSA for seismic at a later time. The NRC staff has reviewed the flooding MSA and issued its corresponding assessment letter (ADAMS Accession No. ML17222A328).

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 safety evaluation makes a determination based on the licensee's OIP and FIP. The characterization of the applicable external hazards for the plant site is discussed below.

3.5.1 Seismic

In its FIP, the licensee described the current design-basis seismic hazard, the design-basis or maximum earthquake. For the purposes of this evaluation, the staff will use the current NRC term corresponding to this earthquake level, the safe-shutdown earthquake (SSE). According to the FIP, the SSE corresponds to an acceleration level of 0.20g (design-basis or maximum earthquake). This acceleration of up to 0.20g corresponds to a horizontal ground acceleration. For the design of Class I structures and equipment, the maximum horizontal acceleration and the maximum vertical acceleration were considered simultaneously. The vertical acceleration was taken as two-thirds of the horizontal ground acceleration. It should be noted that the actual seismic hazard involves a spectral graph of the acceleration versus the frequency of the motion. Peak acceleration in a certain frequency range, such as the numbers above, is often used as a shortened way to describe the hazard.

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

3.5.2 Flooding

The licensee's FIP stated that BFN is susceptible to flooding via local intense precipitation (LIP) and river flooding. The term "probable maximum flood" (PMF) is described in the FIP as the hypothetical flood which would result from the probable maximum precipitation failure of dams and earth embankments upstream. The PMF would result in a peak water elevation of approximately 578 feet (including wind wave run-up) at the site location, which is above the plant grade elevation of 565 feet. The licensee stated, in its FIP that, during the design inundation period, the flood waters are predicted to exceed the plant grade level for up to 7.4 days and to reach a maximum still water elevation of 572.5 feet, as stated in UFSAR Section 2.4, Appendix 2-4A. Plant structures at BFN housing equipment important for safety are designed to remain watertight by utilizing both permanently installed and temporary flood barriers. This site is considered a "wet site."

As mentioned earlier, the licensee's flooding reevaluation activities are complete. The mitigation strategies have been assessed to determine that the reevaluated flooding hazard conditions should not challenge its implementation. The licensee has appropriately screened in this external hazard and identified the hazard levels to be evaluated.

3.5.3 High Winds

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

The screening for high wind hazard associated with tornadoes should be accomplished by comparing the site location to NEI 12-06, Figure 7-2, from U.S. NRC, "Tornado Climatology of the Contiguous United States," NUREG/CR-4461, 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 tornadoes or Regulatory Guide 1.76, Revision 1.

In its FIP, regarding the determination of applicable extreme external hazards, the licensee stated that the BFN site is located within Region 1 of NEI 12-06 Figure 7-2. Based on this location, the plant screens in for an assessment for high winds and tornadoes, including missiles produced by these events. The NRC staff notes that the site is within the 120-130 mph range of high winds from a hurricane per NEI 12-06, Figure 7-1.

Table 1.7-5 of the BFN UFSAR describes the wind design parameters for maximum sustained winds (100 mph) and tornadoes (300 mph). Section 12.2.2.9 of the BFN UFSAR provides information about wind loads and tornado-generated missiles used to design the reactor building.

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

3.5.4 Snow, Ice, and Extreme Cold

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

In its FIP, the licensee stated that the site is located below the 35th parallel and that snow and extreme cold events are unlikely. However, historical data shows snowfalls in excess of 6 inches are possible. Also, historical records in BFN UFSAR Section 2.3.5.1 show temperatures equal or less than 32 °F occur, typically, 57 days each year, with a record low of -12 °F.

Regarding ice and extreme cold, the NRC staff confirmed that BFN is located between ice severity region levels 4 and 5 of Figure 8-2 in NEI 12-06. These severity levels could produce severe damage or catastrophic destruction of power lines.

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

3.5.5 Extreme Heat

In its FIP, the licensee stated that, as per NEI 12-06 Section 9.2, all sites are required to consider the impact of extreme high temperatures. Summers at the site may bring periods of extremely hot weather, with the UFSAR, Section 2.3.5.1 describing a historical observed maximum of 108 °F and an average of 70 days per year with maximum temperatures equal to or greater than 90 °F. Thus, the plant site screens in for an assessment for an extreme high temperature hazard.

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

3.5.6 Conclusions

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

3.6 Planned Protection of FLEX Equipment

3.6.1 Protection from External Hazards

The licensee's FIP states that all the FLEX equipment is stored inside the FESB. The FESB is a structure made of reinforced concrete and steel elements. The FESB is the only FLEX storage facility at BFN and is described as capable of protecting the FLEX equipment from all hazards listed in Section 3.5 of this evaluation. Following the audit process, the NRC staff audited supporting calculations to confirm that the FESB was designed to meet the expectations in NEI 12-06 regarding protection of FLEX equipment. The licensee provided the staff access to calculation CDQ0003602013000136, "Flex Equipment Storage Building-Structural Calculations," where the design of the FESB is explained. Below are additional details on how FLEX equipment is protected from each of the applicable external hazards.

3.6.1.1 Seismic

Guidance in NEI 12-06 states that, to be considered robust, storage structures must either meet the plant's current design basis for the applicable hazard or be shown by analysis or test to meet or exceed the current design basis. During the audit process, the NRC staff audited calculation CDQ0003602013000136. In this document, the licensee explained that the seismic accelerations used for the design of the FESB are 0.24g and 0.38g, both higher than the SSE acceleration of 0.20g. Also, the licensee explained in its FIP that FLEX equipment is tied down to the FESB floor to prevent damage caused by seismic interaction. The NRC staff was able to confirm that the equipment is tied down during the onsite audit. Based on this analysis, the staff considers the FESB to meet the criteria in NEI 12-06, Section 5.3.1.

3.6.1.2 Flooding

During the audit process, the NRC staff confirmed that the FLEX equipment is protected from floods because the elevation of the FESB floor is well above expected flood elevations.

Additionally, the licensee has already completed its MSA for flooding (ADAMS Accession No. ML16363A386). The corresponding NRC staff assessment is available in a letter dated September 5, 2017 (ADAMS Accession No. ML17222A328).

3.6.1.3 High Winds

For high wind (tornado) conditions, calculation CDQ0003602013000136 states that the tornado wind used to design the FESB is 360 mph, which is higher than the current design basis tornado wind speed of 300 mph. The calculation also considers tornado translation and differential pressure caused by the tornado. The same calculation explains that the FESB was designed to withstand the impact of tornado generated missiles. The NRC staff also confirmed that the spectrum of tornado missiles used in the calculation bounds the one in the current licensing basis. In addition, the NRC staff noted that methods used for estimating the thickness of concrete and steel barriers are the same as those described in NUREG-0800 Section 3.5.3, "Barrier Design." For these reasons, the staff considers the FESB to meet the criteria in NEI 12-06, Section 7.3.1.

3.6.1.4 Snow, Ice, Extreme Cold and Extreme Heat

According to the licensee's FIP, the FESB HVAC system can maintain the internal building temperature between 50°F and 90°F. This ensures that equipment will work when called upon to function. Also, based on the description of the FESB, the structure is capable of withstanding snow and ice loads. For these reasons, the NRC staff does not consider the effects of snow, ice, extreme cold or heat on the FLEX equipment inside the FESB.

3.6.1.5 Conclusions

Based on this description, 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.

Each site should have N sets of FLEX hoses and cables. In addition, each site should have spare hose and cable in a quantity that meets either of the two methods described below:

- Method 1: Provide additional hose or cable equivalent to 10 percent of the total length of each type/size of hose or cable necessary for the "N" capability. For each type/size of hose or cable needed for the "N" capability, at least 1 spare of the longest single section/length must be provided.

- Method 2: Provide spare cabling and hose of sufficient length and sizing to replace the single longest run needed to support any single FLEX strategy.

In its FIP, the licensee stated that NEI 12-06 invokes an N+1 requirement for the FLEX equipment that directly performs a FLEX mitigation strategy for core cooling, containment, or SFP cooling in order to assure reliability and availability of the FLEX equipment required to meet the FLEX strategies. It is also stated in the FIP that sufficient equipment is available 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 pieces of equipment required by FLEX strategies for all units on-site. Table 1 of the FIP provides a list of the FLEX equipment available on-site. In addition, where multiple strategies to accomplish a function have been developed, the equipment associated with each strategy does not require N+1 capability.

The licensee further stated in its FIP, that the N+1 capability applies to the portable FLEX equipment that directly supports maintenance of the key safety functions identified in Table 3-2 of NEI 12-06. Other FLEX support equipment provided for mitigation of BDBEEs, but not directly supporting a credited FLEX strategy, is not required to have N+1 capability.

The licensee stated in its FIP, that the N+1 requirement does not apply to the FLEX support equipment, vehicles, and tools. However, these items are covered by an administrative procedure and are subject to inventory checks, requirements, and any maintenance and testing that are needed to ensure they can perform their required functions. The licensee provided a table in its FIP that listed the portable FLEX equipment, including quantity and performance criteria for the FLEX equipment.

Based on the number of portable FLEX pumps, FLEX DGs, and support equipment identified in Table 1 of the FIP, the NRC staff finds that, if implemented appropriately, the licensee's FLEX strategies include a sufficient number of portable FLEX pumps, FLEX DGs, and sufficient lengths of hoses and cables 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

3.7.1 Means of Deployment

According to the licensee's FIP, the Phase 2 FLEX strategies rely upon one heavy duty pickup truck and a track loader to accomplish deployment. This equipment will be used to: (a) transport FLEX equipment and site personnel, and (b) clear the deployment routes, staging areas, and paths for running hoses and cable. The licensee's FIP stated that tires for these vehicles and trailers are designed to withstand small debris punctures. One truck is equipped with a snow scraper blade, and both are equipped with tire chains. The transport vehicles and debris clearing equipment are stored in the FLEX storage building. Staging areas for FLEX and NSRC equipment are shown in Figure 1 of the licensee's FIP. For Phase 3 the NSRC equipment will be delivered by the SAFER group to Staging Area "B," located in the north-east vicinity of the site. Deployment and equipment check-out will be coordinated between SAFER and the site organization. Also, as part of the audit process, the licensee provided the site procedures for the NRC to confirm that there is guidance in place to support deployment after an external hazard event.

3.7.2 Deployment Strategies

According to the FIP, the licensee evaluated the deployment routes against the site hazards.

For seismic, TVA stated to have assessed the deployment routes for liquefaction. The evaluation concluded that areas outside the BFN site and potential routes to transport Phase 3 equipment to the site might not be available after an earthquake. However, the licensee has made arrangements for air transportation of Phase 3 equipment as part of the SAFER plan. In all other areas, displacements due to soil liquefaction were estimated no to exceed +/- 3 inches. These displacements are considered small and should not compromise deployment activities at the site.

For flooding, the licensee's FIP explains that some of the deployment routes might be affected by the flood waters. If flooding becomes an impediment for deployment, equipment could be transferred by air. Also, sufficient warning time will be available to make necessary arrangements and to pre-stage equipment away from the flood waters. The licensee explained to have a preferred electrical connection strategy for core cooling during floods and stated to have assessed it against the reevaluated flood hazard following the guidance in NEI 12-06, Revision 4.

According to the FIP, the licensee is prepared to address snow accumulation as one truck is equipped with a snow scraper blade, and both are equipped with tire chains. The FLEX strategy uses the Tennessee River ultimate source for makeup water in Phases 2 and 3. Because of its geographical location, this portion of the river is unlikely to have any significant ice buildup. Also, ice buildup is unlikely because the river is the discharge path for normal plant cooling operations.

3.7.3 Connection Points

3.7.3.1 Mechanical Connection Points

RPV Makeup

Sections 2.4.5.1 and 2.4.5.2 of the license's FIP describe the primary and alternate RPV makeup connection points involving the FLEX pump systems (the triton and dominator pumps connected in series) from the Tennessee River. As described above in Section 3.2.3.5 of this evaluation, each FLEX pump system is comprised of the triton pump taking suction from the Tennessee River and discharging to the suction portion of the dominator pump. The discharge of the dominator pump will be aligned with hose and adapters to the respective CILRT or RHRSW connection points for those FLEX pump systems.

The primary RPV makeup connection involving the CILRT has three flexible 5 inch hoses that come from the CILRT FLEX pump system and are connected to the CILRT connections that supply all three BFN units for Phase 2 Core Cooling. The CILRT connections are located in the RHRSW tunnel on the south end of the reactor building, and are protected from all applicable external hazards. The hoses are attached to the CILRT piping connections, which penetrate the reactor building walls, and are connected to the CS&S system piping. The CS&S supplies CS loops I and II, which is then injected to the RPV using the CS injection valves.

The alternate RPV connection involving the RHRSW has five 5-inch hoses that come from the RHRSW FLEX pump system. Two 5-inch hoses are connected to RHRSW Header B, which supplies Unit 3. The other three 5-inch hoses are connected to RHRSW Header D, which supplies Units 1 and 2. The RHRSW B and D header piping are located inside the Intake Structure pump rooms, and, as such, they are protected from the applicable external hazards. The RHRSW headers, which are cross tied with the RHR system, allow RPV injection using the LPCI injection valves.

SFP Cooling

Sections 2.5.5.1, 2.5.5.2, and 2.5.5.3 of the licensee's FIP describe the configuration for SFP makeup using the CILRT, RHRSW, and EECW FLEX pump systems. The FLEX pump systems utilize the CILRT, RHRSW, and EECW connection points to provide makeup water from the Tennessee River to the SFP. The CILRT FLEX pump system is indicated by the licensee as the preferred SFP makeup for all three units. The CILRT connection piping is located in the RHRSW tunnel in the reactor building and is protected from applicable external hazards except from a flood event. Due to having several days warning prior to a flood event, there will be sufficient time for operators to connect hoses to the CILRT connection points in the RHRSW tunnels as a part of the pre-stage flooding strategy. Three flexible 5-inch hoses are run from the CILRT FLEX pump system to the CILRT connection piping, which penetrate the reactor building walls and are connected to the CS&S system piping. The CS&S supplies makeup to the SFP skimmer surge tank, which overflows into the SFP. The alternate SFP makeup uses the RHRSW FLEX pump system to the RHRSW connection. Five flexible 5-inch hoses are connected to the RHRSW B and D header (as described above for RPV makeup) inside the intake structure pump rooms and are protected from all applicable external hazards. The hoses are connected into the RHRSW permanent piping, which is cross tied with the RHR system to allow SFP makeup using the FPC assist valves. An additional SFP makeup is provided by the EECW FLEX pump system to the EECW connections. Five flexible 5-inch hoses are connected to the existing EECW south header piping inside the intake structure valve pit, which is protected from all applicable external hazards. Water from the EECW header is then supplied to the SFP using hoses and nozzles pre-staged on the refuel floor.

3.7.3.2 Electrical Connection Points

During Phase 2, the licensee's FLEX strategy to re-power the station's battery chargers requires the use of a single 1 MW, 4160 Vac CTG for all three units. The preferred FLEX CTG connection point (non-flood) would use a 4160 Vac FLEX CTG that will be connected to 4160 Vac shutdown boards 3EB or 3ED. The CTG would be deployed to staging area SA-A6, and power cables would be routed from the CTG through the DG 3EA room or the cardox tank room and through designated wall penetrations into the 4160 Vac shutdown board room 3EB/3ED. The power cables are bolted to load carts that are racked in and connected to 4160 Vac shutdown boards 3EB or 3ED. These shutdown boards are electrically connected by plant breakers to the bus tie board that allows electrical power from the generators to be supplied to Unit 1 and 2 4160 Vac shutdown boards B and D. From the 4160 Vac shutdown boards, power is transformed to 480 Vac to supply power to the 480 Vac shutdown boards A and B on each unit. The 480 Vac shutdown boards supply power to Unit battery chargers 1, 2A, 2B, and 3, which charge the unit batteries and supply dc loads. The 480 Vac shutdown boards also energize the 480 Vac RMOV boards, control bay vent boards, SGT boards, and DG auxiliary boards. Operators would energize equipment required to cope with the event from these boards while monitoring generator loading.

For flood events, or if the preferred 4160 Vac electrical connection is not able to be used for any reason, the electrical connection can be made at either 4160 Vac Unit board 1B or 3B. The

CTG would be deployed to staging area SA-A5 to connect to Unit board 1B or staging area SA-A4 to connect to Unit board 3B. These connections also utilize load carts that the power leads from the FLEX CTG are bolted to, where they would then be racked in and connected to the Unit boards. If the Unit board 1B connection is selected, it would be electrically connected by plant breakers to shutdown bus 2, where they are used to supply 4160 Vac shutdown boards B and D, and the bus tie board. The bus tie board is electrically connected by plant breakers to 4160 Vac shutdown boards 3EB and 3ED. If the unit board 3B connection is selected, it is electrically connected by plant breakers to 4160 Vac shutdown board 3ED. This board is electrically connected to the bus tie board, and the bus tie board is electrically connected by plant breakers to 4160 Vac shutdown boards 3EB, B, and D via shutdown bus 2.

Additional connection points for the 4160 Vac FLEX CTGs are available at the B and D DG output terminals. In this case, a CTG would be deployed to staging area SA-A3. The permanent plant DG output leads would be lifted, and the temporary cables from the FLEX generators would be bolted to the output leads to the Unit 1 and 2 4160 Vac shutdown boards B and D. The shutdown boards are electrically connected to the bus tie board that allows electrical power from the CTG to be supplied to Unit 3 4160 Vac shutdown boards 3EB and 3ED.

Another connection point consists of powering the 480 Vac battery chargers directly from a 480 Vac FLEX CTG. In this case, a CTG would be deployed to staging area SA-A2. Temporary cables would connect the 480 Vac FLEX CTG to the FLEX distribution panel located on the control bay, elevation 586 feet. From the distribution panel, cables would be connected directly to the charger supply breaker on the front of each of the chargers that charge 250 V Unit batteries 1, 2, and 3. This connection point also allows back feed to selected MOVs needed for RPV injection.

The NRC staff confirmed that licensee guidelines 0-FSI-3A, Revision 3, "480V FLEX Generator Setup and Operation," and 0-FSI-3C, Revision 4, "4kV FLEX Generator Setup and Operation," provide direction for staging and connecting FLEX CTGs to energize the electrical buses to supply required loads within the required timeframes. According the licensee's FIP, the BFN FLEX CTGs were phase checked during factory acceptance testing and have also been phased-checked by BFN personnel via work orders. The BFN procedures 0-FSI-3C and 0-FSI-3A also contain steps to perform independent verification of the cable connections further ensuring that the proper phase rotation is established.

For Phase 3, the licensee plans to continue the Phase 2 coping strategy with additional assistance provided from offsite equipment/resources. The offsite electrical equipment that will be provided by the NSRC includes six 1-MW 4160 Vac CTGs, three 1-MW 480 Vac CTGs, and three distribution centers (including cables and connectors). Based on the margin available for the 4160 Vac and 480 Vac CTGs, the NRC staff finds that the CTGs being supplied from the NSRCs have sufficient capacity and capability to supply the required loads during Phase 3, if necessary. The licensee would stage the CTGs in the vicinity of the Phase 2 FLEX CTGs. The licensee would rely on TSC personnel to connect and utilize the NSRC equipment for long-term coping or recovery. The NRC staff expects that the TSC personnel would verify proper phase rotation when connecting any NSRC CTG to the BFN electrical distribution system.

3.7.4 Accessibility and Lighting

During the audit process, the licensee provided information regarding their ability to open doors for ingress and egress, ventilation, or temporary cables/hoses routing is necessary to implement the FLEX coping strategies. The licensee described contingencies to maintain access during loss of all ac/dc power, which are part of the BFN Security Plan. The contingencies consider access to buildings relied upon to implement the strategies, access to the protected area, and access to the FESB.

According to the licensee's FIP, flashlights are the primary means of lighting to accomplish FLEX actions. All plant Assistant Unit Operators (AUO) are required to have flashlights. Also, stocks of flashlights, batteries, and portable LED lights are stored in various locations within the Control Bay (i.e. the FLEX equipment room and the Relay Room Cage) and in the FESB. The licensee stated to have emergency lighting fixtures in areas for ingress and egress of FLEX equipment that should provide lighting for 8 hours. While not credited, the licensee reported that the large FLEX pumps and generators are outfitted with lights that can be powered from either their respective DGs or batteries in order to support connection and operation. In addition to the lights installed on the FLEX equipment, the FESB contains 6 generator-powered light towers and 10 portable LED light stands for use, as listed in Table 1 of the FIP.

3.7.5 Access to Protected and Vital Areas

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

3.7.6 Fueling of FLEX Equipment

Section 2.10 of the licensee's FIP states that fuel oil for the portable equipment can be obtained from the eight permanent plant DG 7-day Tanks. Each tank contains a Technical Specification minimum capacity of greater than 35,280 gallons, for a combined Technical Specification minimum volume of 282,240 gallons. The licensee will deploy two portable diesel engine-driven pumps to transfer fuel oil from the 7-day Tanks to the FLEX pump systems. For the FLEX generators, the licensee reported that pumps will take suction from the 7-day tanks. Based on the design and location of these tanks, the staff concludes that the day tanks are robust and the fuel oil contents should be available to support the licensee's FLEX strategies during an ELAP event.

The licensee stated, in its FIP, that the combined consumption rate of three FLEX Pump Systems, two 4kV FLEX generators, and one 480V FLEX generator is approximately 460 gallons per hour (gph), for a total 72-hour-consumption of approximately 33,120 gallons. Given that the fuel demand for the Phase 2 FLEX components cited above is well below the available fuel oil in the 7-day Tanks, the staff concludes that the licensee should have sufficient inventory of fuel for diesel-powered equipment required for the FLEX strategy until additional fuel arrives from off-site. Furthermore, the staff finds that the licensee should be able to refuel the diesel-powered equipment used in the FLEX strategy such that uninterrupted operation is ensured.

The licensee explained, in its FIP, that the 7-day Tanks will be inaccessible during a flood event. However, sufficient warning time is available for BFN offsite vendors to provide fuel oil trucks to support the Phase 2 and 3 FLEX fuel equipment requirements. The NRC staff inquired about the warning time and prediction method available to allow BFN site personnel to prepare the fuel tankers prior to the flood event. The licensee stated that the BFN site is projected to exceed the design basis flood in approximately 5 days. The licensee will rely on the local government meteorology for any rainfall that exceeds the current design elevation and will place the BFN site into cold shutdown within 12 hours after receiving the notification. This will include placing fuel tankers at designated locations, where a direct fill strategy can be deployed.

Section 2.19.7 of the licensee's FIP states that all FLEX equipment will be maintained in accordance with the preventative maintenance (PM) program. Section 2.10 of the FIP also states that the 7-day Tanks are tested monthly in accordance with BFN Technical Specification 3.8.3, "Diesel Fuel Oil, Lube Oil, and Starting Air," and Technical Specification 5.5.9, "Diesel Fuel Oil Testing Program." Fuel in the trailer mounted fuel oil storage tanks is tested at least annually in accordance with CI-404, "Miscellaneous Sampling and Chemical Addition Procedures." Based on the FIP description, the staff concludes that the licensee has demonstrated that fuel oil quality will be maintained to support the overall FLEX strategy.

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 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.

During the audit process, the NRC staff reviewed AREVA Document Number 38-9233739-000, "SAFER Response Plan for Browns Ferry Nuclear Plant," Revision 1, dated January 23, 2015. The staff noted that the 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. The staff also noted that the plan contains provisions for helicopter support, if it is required.

In its FIP, the licensee stated that, in the event of a BDBEE and subsequent ELAP/LUHS condition, equipment will be moved from an NSRC to a local assembly area established by the SAFER team.

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 (generally within about 25-45 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 BFN, Staging Area "C" is the Northwest Alabama Regional Airport in Muscle Shoals, Alabama, approximately 45 miles west of BFN. Staging Area "D" is the Pryor Field Regional Airport in Tanner, Alabama, approximately 15 miles southeast of BFN. Staging Area "B" is a large hard-surfaced area of approximately 2 to 3 acres in size. Staging Area "A" corresponds to the various deployment locations for each piece of FLEX equipment on the site, as shown in Figure 1 of the license's FIP.

The licensee's FIP states that deliveries will typically go by truck using preselected routes and with any necessary escort capabilities to ensure timely arrival at the plant site staging area "B" or to staging area "C". However, helicopter landing considerations are accounted for in selection of all these staging areas. The staff review of BFN's plan concludes that the helicopter provisions are appropriate.

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 Browns Ferry, ventilation that provides cooling to occupied areas and areas containing required equipment will be lost. Per the guidance given in NEI 12-06, FLEX strategies must be capable of execution under the adverse conditions (unavailability of installed plant lighting, ventilation, etc.) expected following a BDBEE resulting in an ELAP. In addition, NEI 12-06 states that a basis should be provided for the capability of the FLEX equipment to continue to function regarding the extreme environments that may be posed.

The primary concern with regard to ventilation is the heat buildup, which occurs with the loss of forced ventilation in areas that continue to have heat loads. 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 that the environmental conditions remain acceptable and within equipment qualification and design limits.

The key areas identified for all phases of execution of the FLEX strategy activities are the MCR, RCIC pump room, containment, battery and shutdown board rooms. The licensee evaluated these areas to determine the temperature profiles following the postulated event. The results of the licensee's room heat-up evaluations have concluded that temperatures remain within acceptable limits for all rooms/areas using passive and active means of ventilation.

Main Control Rooms

Licensee calculation MDQ0003602014000222, Revision 4, "BFN ELAP Transient Temperature Analysis," showed that portable fans alone will maintain the MCR temperature below 110 °F. The strategy for maintaining the environment of the MCR during Phase 2 will be by the employment of normal control bay ventilation area coolers as directed by licensee procedure 0-FSI-4A, "Control Bay/Reactor Building Lighting and Ventilation during ELAP Plant." This procedure includes provisions to install portable fans and ductwork, if necessary.

The licensee will receive offsite resources and equipment from an NSRC within 24 hours after the onset of an ELAP event. The NRC staff finds that it is reasonable to expect that the licensee could utilize these resources to reduce or maintain temperatures within the MCR to ensure that required electrical equipment survives indefinitely, if necessary.

The NRC staff concludes that the licensee's plan should maintain the MCR temperatures consistent with the analysis. 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), the NRC staff expects that the equipment in the MCR should not be adversely impacted by the loss of ventilation as a result of an ELAP event.

RCIC Pump Room

Licensee calculation MDQ0009992014000291, Revision 3, "Temperature Response of the Reactor Building Following an Extended Loss of AC Power," indicates that the RCIC room temperature will exceed 150°F, the RCIC electronic governor speed control module (EG-M) limit, in approximately 7 hours after the onset of an ELAP. In order to assure continued operation with high RCIC room temperatures, the licensee developed 2 EOI appendices to be performed during the event. The process in procedure 1,2,3-EOI Appendix-16K, Revision 1, "Bypassing RCIC High Temperature Isolations," is performed to bypass the RCIC area high temperature isolations. Also, the process in 1,2,3-EOI Appendix-20M, Revision 0, "RCIC Operation during Station Blackout," is performed, and it contains steps to disable the RCIC EG-M and control flow with the RCIC trip/throttle valve, FCV-71-9. These appendices are performed as soon as the event is entered and do not require entry into the RCIC room. With the compensatory actions in the two EOI Appendices, the licensee's calculation shows that the RCIC pump rooms should remain below the design limits for RCIC for at least 8 hours.

Beyond 8 hours, the licensee indicated that the CILRT pump system would be aligned and can provide RPV and SFP makeup. The function of core cooling could be transferred to FLEX equipment in this time period, thus eliminating the need for RCIC beyond 8 hours.

Based on the above, the NRC staff finds that the licensee's ventilation strategy should maintain the temperature of the RCIC pump rooms below the functional design limit of the RCIC pumps for at least 8 hours before RCIC is no longer needed due to the availability of the CILRT pump system to provide RPV and SFP makeup. Therefore, the NRC staff finds that the RCIC function will not be adversely impacted by the loss of ventilation as a result of an ELAP event.

Class 1E Battery and Shutdown Board Rooms

The licensee's analysis, MDQ0003602014000222, showed that none of the Class 1E battery rooms would exceed 110°F if the required doors are opened and ventilation is established. The analysis in document MDQ0003602014000222 also indicates that the shutdown board room temperatures at 72 hours are expected to range between 105 and 112°F. Licensee procedures 0-FSI-4A, Revision 1, "Control Bay/Reactor Building Lighting and Ventilation during ELAP," and SSI-16.1, Revision 17, "Compensatory Measures," direct operators to open doors and establish ventilation required by the calculation.

The NRC staff notes that the licensee will receive offsite resources and equipment from an NSRC within 24 hours after the onset of an ELAP event. The NRC staff finds that it is reasonable to expect that the licensee could utilize these resources to reduce or maintain temperatures within the battery and shutdown board rooms to ensure that required electrical equipment survives indefinitely, if necessary.

Based on the above, the NRC staff finds that the licensee's ventilation strategy (establishing ventilation and opening doors) should maintain battery and shutdown board room temperatures below the maximum temperature limit (122 °F) of the batteries, as specified by the battery manufacturer (C&D Technologies). This maximum temperature limit happens to be the temperature limit for electronic equipment to be able to survive indefinitely, identified in NUMARC-87-00, Revision 1, "Guidelines and Technical Bases for NUMARC Initiatives Addressing Station Blackout at Light Water Reactors," as endorsed by NRC Regulatory Guide 1.155, "Station Blackout." Therefore, the NRC staff finds that the electrical equipment located in the battery and shutdown board rooms will not be adversely impacted by the loss of ventilation as a result of an ELAP event. 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.

Battery Board Rooms

The temperature profile for the battery board rooms in licensee analysis MDQ0003602014000222 shows that the temperature in these rooms is expected to stay under 135 °F for at least the first 72 hours following the onset of an ELAP event. Licensee calculation GENSTP3-001, Revision 0, "Upper Boundary Temperature for Mild Environments Related to Environmental Qualification of Electrical Equipment," determined that electrical equipment in nuclear power plants can experience temperature excursions up to 140 °F for 24 hours followed by a period of 120 °F for an indefinite period or slow ramp to 135 °F followed by a period of 100 days at 135°F.

The NRC staff notes that the licensee will receive offsite resources and equipment from an NSRC within 24 hours after the onset of an ELAP event. The NRC staff finds that it is reasonable to expect that the licensee could utilize these resources to reduce or maintain temperatures within the battery board rooms to ensure that required electrical equipment survives indefinitely, if necessary.

Therefore, the NRC staff finds that the electrical equipment located in the battery board rooms will not be adversely impacted by the loss of ventilation as a result of an ELAP event.

Containment

The BFN FLEX strategy credits the use of the automatic depressurization system MSRVs. The licensee's analysis in MAAP 4.0.7, Report 06050-RPT-13406, Revision 1, provides analysis for eight different cases. Comparison of the MAAP analysis drywell temperature profiles of Report 06050-RPT-13406 to the test temperatures experienced during LOCA simulation testing documented in Environmental Qualification (EQ) Report 2199 (in Tab D-4 of EQ binder BFN0EQ SOL 009) reveals that the drywell temperatures do not exceed the EQ temperatures of the MSRVs during an ELAP event.

The MSRV solenoid test specimen was thermally aged at 342 °F for 56.5 days (EQ Report 5074, BFN0EQ SOL 009 Tab D-1) and later subjected to accident simulation testing involving temperatures up to 355 °F. The most thermally challenging ELAP case from Report 06050-RPT-13406, is Case 8 where a peak drywell temperature of 305 °F is reached at 62.1 hours. For conservatism, the licensee assumed that the temperature remains at the peak 305 °F for an additional 9.9 hours. The thermal aging performed at 342 °F followed by accident simulation testing at temperatures up to 355 °F provide assurance that the MSRV solenoid valves will perform their required function during an ELAP event.

To assess the long-term performance of the MSRVs, is important to remember that the licensee will receive offsite resources and equipment from an NSRC within 24 hours after the onset of an ELAP event. The NRC staff finds that it is reasonable to expect that the licensee would utilize these resources to reduce or maintain temperatures within containment to ensure that required electrical equipment survives indefinitely, if necessary. The staff also notes that plant operators will continue to monitor containment parameters and perform additional actions that may be required to reduce containment temperature and pressure as described in Section 2.6.4.2 of the licensee's FIP.

Based on temperatures remaining below the design limits of equipment and the availability of offsite resources after 24 hours, the NRC staff finds that the electrical equipment in the containment should not be adversely impacted by the loss of ventilation as a result of an ELAP event.

Based on its review of the essential station equipment required to support the FLEX mitigation strategy, which are primarily located in the RCIC pump rooms, battery and shutdown board rooms, MCR, and containment, the NRC staff finds that the electrical equipment should perform their required functions at the expected temperatures as a result of a loss of ventilation during the postulated event.

3.9.1.2 Loss of Heating

The BFN Class 1E station battery rooms are located inside safety-related structures and will not be directly exposed to extreme low temperatures. At the onset of the event, the Class 1E Battery Rooms would be at their normal operating temperature and the temperature of the electrolyte in the cells would build up due to the heat generated by the batteries discharging and during recharging. Temperatures in the battery rooms are not expected to be sensitive to extreme cold conditions due to their location, the concrete walls isolating the rooms from the outdoors, and lack of forced outdoor air ventilation during the early phases of an ELAP event.

Thus, the NRC staff concludes that the BFN Class 1E station batteries should perform their required functions as a result of loss of normal heating during an ELAP event.

The licensee stated in the FIP that heat tracing in general is not required for any plant equipment used for FLEX after the initiation of the ELAP event. This is due to the plant equipment being maintained in a dry condition until deployment and operation. The licensee also indicated that the FLEX strategy does not rely on plant or FLEX equipment that required heat tracing systems for extreme cold temperatures. The licensee did state during the audit process that some protective measures have been placed in the overall FLEX strategy for the implementation and operation of the FLEX pump systems. Documents 0-FSI-2A, "CILRT FLEX Pump System, 0-FSI-2B, "EECW FLEX Pump System," and 0-FSI-2C, "RHRSW FLEX Pump System," have considerations included for the respective FLEX pump system for operation during freezing temperatures. These considerations included isolation and drainage of all hose runs when not in use, use of antifreeze liquid in spray bottles for lubrication of hose and appliance threads, use of snow/ice pellets on walking surfaces, use of water bypass systems when the FLEX pump systems are in operation, and re-routing of hose runs to the forebay to prevent water exiting the hoses from becoming ice hazards. Additionally, the fuel oil to be used for the FLEX equipment is stored in the FESB, which is protected from freezing temperatures along with other applicable external hazards.

Based on the above, the NRC staff finds that the plant and FLEX equipment should perform their required functions during extreme cold temperatures during an ELAP event. The NRC staff's conclusion is based upon the provisions listed in the FSIs, which provide instructions to operators for prepping FLEX equipment for freeze protection. The NRC staff also finds that location of the fuel oil in the FESB will allow for FLEX equipment to function as expected during freezing temperatures.

3.9.1.3 Hydrogen Gas Control in Battery Rooms

An additional ventilation concern that is applicable to Phases 2 and 3, is the potential buildup of hydrogen in the battery rooms as a result of loss of ventilation during an ELAP event. Off-gassing of hydrogen from batteries is only a concern when the batteries are charging. According to the licensee calculation MDQ0-999-2004-0019, "Hydrogen Generation Rate in 250V Battery Rooms," Revision 0, each battery room's hydrogen concentration would reach 2 percent at 30 hours after the batteries are put on charge (conservatively assuming an equalizing charge of 2.33 V/cell at 92°F and that no ventilation is provided). Licensee calculation NDQ0031890069, "Hydrogen Concentration in the Control Bay 250-Volt Station Battery Rooms," Revision 1, determined the minimum ventilation that is needed to maintain hydrogen concentration below 2 percent in the battery rooms. Licensee procedure 0-FSI-4A, "Control Bay/Reactor Building Lighting and Ventilation during ELAP," Revision 1, provides guidance for establishing required ventilation to maintain hydrogen concentration below 2 percent in the battery rooms. The guidance directs operators to establish ventilation by opening doors and either re-energizing existing fans or deploying temporary fans and ducts.

Based on its review of the licensee's battery room ventilation strategy, the NRC staff finds that hydrogen accumulation in the BFN Class 1E 250 V battery rooms should not reach the combustibility limit for hydrogen (4 percent) during an ELAP event.

3.9.2 Personnel Habitability

3.9.2.1 Main Control Room

As described above in Section 3.9.1.1, the MCR temperature profiles were determined in calculation MDQ0003602014000222, which used the TMG modeling program. This calculation predicts that portable fans alone will maintain the MCR temperature below the upper habitability limit of 110 °F considering a loss of ventilation for 72 hours after the onset of the ELAP. The strategy for maintaining the environment of the MCR during Phase 2 will be by the employment of normal Control Bay ventilation area coolers as directed by licensee procedure 0-FSI-4A. This procedure includes provisions to install portable fans and ductwork, if necessary.

The licensee will receive offsite resources and equipment from the NSRC within 72 hours after the onset of an ELAP event. The NRC staff finds that it is reasonable to expect that the licensee could utilize these resources to reduce or maintain temperatures within the MCR to ensure that adequate personnel habitability.

Based on the expected temperature response in the MCR remaining below the limit of 110 °F (the temperature limit, as identified in NUMARC-87-00, Revision 1, "Guidelines and Technical Bases for NUMARC Initiatives Addressing Station Blackout at Light Water Reactors," for control room habitability), the staff finds it reasonable that operators can safely enter and occupy the MCR during an ELAP event. The staff finds the above strategies are consistent with NEI 12-06, Section 3.2.2 such that station personnel can safely enter and perform the necessary actions to support the FLEX mitigation strategies, during an ELAP event.

3.9.2.2 Spent Fuel Pool (SFP) Area

During the event, Reactor Building and Refuel Zone ventilation will be non-functional. Heat addition to the building will be from the SFP, RCIC operation, MSRV operation, and HCVS radiative heat. The SFP bulk boiling will create adverse temperature, humidity, radiation and condensation conditions in the SFP area, which requires a ventilation pathway. Procedures 0-FSI-4A and SSI-16.1, "Compensatory Measures," direct security to open doors within the first hour of the event. The doors are open on the Reactor Building roof, Refuel Floor, and Reactor Building ground level to establish a natural circulation flow path. Airflow through these doors provides adequate vent pathways through which steam generated by SFP boiling can exit the building.

3.9.2.3 Other Plant Areas

The area temperatures at every elevation of the Reactor Building are evaluated in MDQ0009992014000291, Revision 3, "Temperature Response of the Reactor Building Following an Extended Loss of AC Power." The results of that calculation demonstrate that all elevations of the Reactor Building will become very hot over the course of the event. All equipment deployment actions will be performed early in the event. Specific room heat-up calculations were performed for the RCIC pump room and the battery and shutdown board rooms, where there were equipment operability concerns. None of these rooms require personnel access during a FLEX event after the initial equipment setup and deployment.

Operator actions required later in the event in all buildings are subject to applicable site and fleet procedures, including but not limited to, 0-FSI-6E, "FLEX Strategies During Severe Hot and Cold Environments," in order to mitigate the risks of working in a hot/cold environment.

Following a BDBEE, 0-FSI-1, "FLEX Response Instruction," and current site conditions will be used to determine operator stay times and need for personnel protection such as ice vests.

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

Condition 3 of NEI 12-06, Section 3.2.2.5 states that cooling and makeup water inventories are considered available if they are contained in systems or structures with designs that are robust with respect to seismic events, floods, and high winds, and associated missiles. The NRC staff reviewed the licensee's planned water sources to verify that each water source was robust as defined in NEI 12-06.

3.10.1 RPV Makeup

Phase 1

The FIP indicated that, for Phase 1, the suppression pool provides makeup water to the RPV through the RCIC for about 8 hours after ELAP initiation. The suppression pool is described as near reactor quality water and contains about 960,000 gallons of water. As the event progresses, the licensee indicated that the RCIC will be secured and the FLEX pump systems will be deployed and placed into operation as discussed below for Phase 2. The licensee also indicated that the CST for each unit may also be used initially if available after the initiating event occurs. Each CST contains 135,000 gallons and will supply the RCIC automatically after the initiating event. Operators are directed to switch over to the suppression pool manually if the CSTs are not available.

Phase 2

During Phase 2, the CILRT or RHRSW FLEX pump systems are capable of being placed in service in approximately 8 hours to provide makeup to the RPV from the Tennessee River. The water provided from the Tennessee River can last throughout the entire ELAP event. In the event of a failure of the downstream dam (Wheeler) were to occur, a pool of water containing a volume of approximately 69.6×10^6 cubic feet of water would be available to the FLEX pumps at the plant intake.

Phase 3

For Phase 3, RPV makeup strategy is the same as the Phase 2 strategy with the usage of the NSRC equipment that arrives on site.

3.10.2 Suppression Pool Makeup

The FIP indicates that the suppression pool or torus, is part of primary containment and serves as the heat sink for reactor vessel MSRV discharges and RCIC turbine steam exhaust during the ELAP event. Although the suppression pool supplies the RCIC system during Phase 1, the licensee indicated that the FLEX strategy is to preserve the RCIC pumps and rely on the FLEX pump systems to continue RPV makeup. Therefore, the suppression pool is not required to have makeup water as part of the RPV makeup FLEX strategy. The suppression pool is a safety-related, seismically qualified structure which is protected from all applicable external hazards.

3.10.3 Spent Fuel Pool Makeup

No SFP makeup is required in Phase 1. Phase 2 and Phase 3 makeup to the SFP is from the Tennessee River, as described in Section 3.7.3.1 of this evaluation. The licensee indicated in the FIP that water quality is not a concern for water makeup to the SFP.

3.10.4 Containment Cooling

In its FIP, the licensee indicated that containment cooling is provided by the NSRC drywell blowers during Phase 3. No water sources are designated for containment cooling nor are needed for Phase 1, 2 or 3.

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. If an ELAP were to occur with the plant operating at power, the mitigation strategy initially focuses on the use of the steam-driven RCIC pump to provide the water initially needed for decay heat removal. If the plant has been shut down and all or most of the fuel has been removed from the RPV and placed in the SFP, there may be a shorter timeline to implement the makeup of water to the SFP. However, this is balanced by the fact that, if immediate cooling is not required for the fuel in the reactor vessel, the operators can concentrate on providing makeup to the SFP. The licensee's analysis shows that following a full core offload to the SFP, at least 19 hours are available to implement makeup before boil-off results in the water level in the SFP dropping far enough to reach minimum shielding distance of 8.5 feet above the fuel assemblies. The licensee has also stated to have the ability to implement makeup to the SFP within that time. During the audit process, the staff confirmed that the licensee's procedures would implement SFP makeup well before reaching a level that would uncover fuel assemblies.

When a plant is in a shutdown mode in which steam is not available to operate a steam-powered pump such as RCIC (which typically occurs when the RPV 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 of NEI 12-06 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 BFN utilized the NEI position paper entitled "Shutdown/Refueling Modes", as the basis for the BFN FLEX strategy in shutdown and refueling modes. Browns Ferry has also incorporated guidance from the BWR Owners Group (BWROG) technical paper BWROG-TP-15-019, "BWROG Fukushima Response Committee, BWR-Specific Shutdown Refueling Mode Guidance." According to the licensee, the BWROG paper expands upon the risk management concepts described in the NRC-endorsed in NEI position paper on shutdown and refueling mode conditions that have been incorporated into NEI 12-06, Revision 4, Section 3.2.3. Specifically, the BWROG paper defines certain shutdown/refueling conditions, and identifies actions that should be considered as part of the outage risk management program that are commensurate with the risk and applicable for a given plant state.

Based on the information above, 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

According the licensee's FIP, the overall plant response to an ELAP will be accomplished through normal plant command and control procedures and practices. Section 2.19.2 of the licensee's FIP stated that FSIs, provide guidance for deployment of FLEX equipment. The FSIs address a variety of post event conditions, and provide pre-planned strategies for accomplishing specific tasks associated with implementation of FLEX strategies. When FLEX equipment is needed to supplement Emergency or Abnormal Operating Procedure (EOP or AOP) strategies, the EOP or AOP directs the entry into and exit from the appropriate FSIs.

According to the licensee, the FSIs have been reviewed and validated by the involved groups to the extent necessary to ensure that implementation of the associated FLEX strategy is feasible. In addition, FSI maintenance is performed by the station procedures group.

During the audit process, the NRC staff was able to review some of the FSIs and found that those were in accordance with the descriptions provided by the license in the FIP.

3.12.2 Training

According to the licensee's FIP, TVA has developed and delivered training using the Systematic Approach to Training (SAT) Process to assure personnel proficiency in the mitigation of BDBEEs is adequate and maintained. The training consisted on courses from the National Academy for Nuclear Training e-Learning provided by the Emergency Response Training Development (ERTD) Working Group (facilitated by the Institute of Nuclear Power Operations, or INPO). Enclosure 3 of the licensee's FIP provided a list of completed training at BFN. Initial training has been provided and periodic training will be provided to site emergency response leaders on BDBEE emergency response strategies and implementing guidelines. Personnel assigned to direct the execution of mitigation strategies for BDBEEs have received the necessary training to ensure familiarity with the associated tasks, considering available job aids, instructions, and mitigating strategy time constraints.

3.12.3 Conclusions

Based on the description above, the NRC staff concludes that the licensee's procedure development, issuance, and control are in accordance with NEI 12-06, Section 11.4. In addition, based on the description above, the staff concludes that a training program for BDBEE mitigation has been established and should be maintained in accordance with NEI 12-06, Section 11.6.

3.13 Maintenance and Testing of FLEX Equipment

As a generic issue, NEI submitted a letter to the NRC dated October 3, 2013 (ADAMS Accession No. ML13276A573), which included EPRI Technical Report 3002000623, "Nuclear Maintenance Applications Center: Preventive Maintenance Basis for FLEX Equipment." By letter dated October 7, 2013 (ADAMS Accession No. ML13276A224), the NRC endorsed the use of the EPRI report and the EPRI database as providing a useful input for licensees to use in developing their maintenance and testing programs. In its FIP, the licensee stated that they would conduct maintenance and testing of the FLEX equipment in accordance with the industry letter.

In its FIP, the licensee described that FLEX equipment (including support equipment) is subjected to initial acceptance testing and to periodic maintenance and testing utilizing the guidance provided in INPO AP 913, "Equipment Reliability Process," to verify proper function. Maintenance and testing of FLEX equipment follows the EPRI Preventive Maintenance. According to the licensee, manufacturer's recommendations were used when templates were not available from EPRI.

The PM templates include activities such as:

- Functional Test and Inspection
- Fluid Filter Replacement
- Fluid Analysis
- Generator Load Test
- Component Operational Inspection
- Standby Walkdown

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 4

The NRC staff review of the licensee's FIP did not identify any alternatives to NEI 12-06, Revision 4.

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. ML13063A437), the licensee submitted an OIP for Browns Ferry in response to Order EA-12-051. By letter dated June 18, 2013 (ADAMS Accession No. ML13157A164), the NRC staff sent a Request for Additional Information (RAI) to the licensee. The licensee provided a response to the RAI by letter dated July 18, 2013 (ADAMS Accession No. ML13206A005). By letter dated September 27, 2013 (ADAMS Accession No. ML13266A389), the NRC staff issued an ISE and RAI to the licensee.

By letters dated March August 28, 2013 (ADAMS Accession No. ML13247A290), February 28, 2014 (ADAMS Accession No. ML14174A041), August 28, 2014 (ADAMS Accession No. ML14247A430), February 27, 2015 (ADAMS Accession No. ML15064A188), August 28, 2015 (ADAMS Accession No. ML15240A391), the licensee submitted status reports for the Integrated Plan and the RAI in the ISE. The Integrated Plan describes the strategies and guidance to be implemented by the licensee for the installation of reliable SFP level instrumentation which will function following a BDBEE, including modifications necessary to support this implementation, pursuant to Order EA-12-051. By letter dated February 26, 2016 (ADAMS Accession No. ML16060A175), the licensee reported that full compliance with the requirements of Order EA-12-051 was achieved.

The licensee has installed a SFP level instrumentation system designed by Westinghouse. The NRC staff reviewed the vendor's SFP level instrumentation system design specifications, calculations and analyses, test plans, and test reports. The staff issued an audit report on August 18, 2014 (ADAMS Accession No. ML14211A346).

The staff performed an onsite audit to review the implementation of SFP level instrumentation related to Order EA-12-051 at Browns Ferry. The scope of the audit included verification of whether the: (a) site's seismic and environmental conditions are enveloped by the equipment qualifications, (b) equipment installation met the order requirements and vendor's recommendations, and (c) program features met the order requirements. By letter dated April 6, 2015 (ADAMS Accession No. ML15069A358), the NRC issued an audit report on the licensee's progress.

4.1 Levels of Required Monitoring

In its July 18, 2013, RAI response letter, the licensee identified Levels 1, 2, and 3 for Units 1, 2, and 3 and provided a sketch. The licensee identified Level 1 as 663 feet for Units 1, 2, and 3. The NRC staff noted that 663 feet is the same elevation as the weir for each SFP and is adequate for normal SFP operation and sufficient to provide net positive suction head (NPSH) for the BFN spent fuel cooling pumps, consistent with the NEI 12-02 guidance. The licensee identified Level 2 as 650 feet 4 inches for Units 1, 2, and 3. The NRC staff noted that 650 feet 4 inches is 10 feet (+/- 1 foot) above the top of the stored fuel seated in the storage racks, consistent with the NEI 12-02 guidance. The licensee identified Level 3 as 641 feet 4 inches for Units 1, 2, and 3. The NRC staff noted that 641 feet 4 inches is 1 foot above the top of the fuel in the storage racks, consistent with the NEI 12-02 guidance. The NRC staff previously reviewed and accepted Levels 1, 2, and 3 in the BFN ISE. The staff confirmed from the sketch provided in the July 18, 2013, RAI response letter that Level 3 is at the top of the SFP racks consistent with the guidance. Level 2 is 10 feet above the top of the racks and is sufficient to provide adequate shielding for persons standing at the edge of the pool deck. Consistent with the guidance, no shielding calculation was required for Level 2 elevations 10 feet or greater above the top of active fuel.

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

4.2 Evaluation of Design Features

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

4.2.1 Design Features: Instruments

In its OIP, the licensee stated that the primary and backup instruments will be located and permanently installed in each SFP. The OIP also states that both the primary and backup instrument channels will provide a continuous level indication over a minimum range from the normal pool level (663 feet for all units) to within 1 foot of the top of the spent fuel racks.

The licensee also clarified in its July 18, 2013 letter, that the measurement range of the installed instruments is 663 feet to 640 feet 10 inches which encompasses Level 1 and is within 1 foot of the top of the fuel rack (Level 3) at 640 feet 4 inches.

The NRC staff notes that the range specified for the licensee's instrumentation will cover Levels 1, 2, and 3 as described in Section 2.2 above. The licensee's proposed plan, with respect to the number of channels and the range of the instrumentation for both of its SFPs, appears to be consistent with NEI 12-02, as endorsed by the ISG.

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

4.2.2 Design Features: Arrangement

In its February 26, 2016, compliance letter, the licensee provided sketches showing the primary and backup instruments for Unit 1 near the North and South corners of the Unit 1 SFP. The Unit 2 sketch shows primary and backup instruments near the West and East corners of the Unit 2 SFP. The Unit 3 sketch shows primary and backup instruments near the West and East corners of the Unit 3 SFP. Cable routing for all units, also depicted in the sketches, maintained good separation of the primary and backup cables in the SFP areas.

The NRC staff noted 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.

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

4.2.3 Design Features: Mounting

The licensee for BFN uses a cantilever style mounting bracket bolted to the deck of the refueling floor. The mounting bracket supports a launch plate which provides mounting points for the cable conduit and the probe. The licensee provided a sketch and description of the qualification in its February 26, 2016, compliance letter, as part of BFN's RAI number 2 response. During an on-site audit walkdown of the BFN Unit 2 SFP, the NRC staff confirmed the design and mounting of the installed poolside bracket for were consistent with Revision 2 of Westinghouse Drawing 10067E25, "Browns Ferry Nuclear Plant Units 1, 2, & 3 Spent Fuel Pool Mounting Bracket Plans, Sections and Details." The staff also confirmed the seismic mounting of the other SFP level instrumentation components for Unit 2 during the walkdown.

During the on-site audit, the NRC staff reviewed Revision 1 of Westinghouse document CN-PEUS-14-11, "Seismic Analysis of the SFP Primary-Mounting Bracket at Browns Ferry Nuclear Plant," to confirm the plant-specific sloshing analysis was completed and that the anticipated loading from wave impingement was appropriately considered in the design of the mounting bracket.

The staff reviewed qualification of the SFP level instrumentation during the Westinghouse vendor audit. The staff also reviewed BFN calculation CDQ0000782014000219, "Seismic Qualification for the Mounting of Spent Fuel Pool Level Instrumentation at BFN" and Revision 3 of Document CDQ0000782014000252, "Seismic Qualification and Anchorage Design of the BFN Spent Fuel Pool Level Element Support Bracket," which ensure the Westinghouse qualification adequately addresses seismic demand as installed at BFN.

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

4.2.4 Design Features: Qualification

4.2.4.1 Augmented Quality Process

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

In its OIP, the licensee stated that instrument channel reliability shall be established by use of an augmented quality assurance process similar to that described in NEI 12-02.

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

4.2.4.2 Instrument Channel Reliability

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

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

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

The NRC staff reviewed vendor (Westinghouse) qualification testing and results during the vendor audit which is documented in the NRC letter dated August 18, 2014. The BFN configuration has only passive components in the SFP area. These components contain no electronic devices. The transmitters for each unit are Seismic Category I mounted outside the SFP area in the Reactor Building, elevation 639 feet. The display electronics are Seismic Category I mounted in the Reactor Building elevation 621 feet. The specific locations are the 4 KV Shutdown Board Room A (Unit 1), 4 KV Shutdown Board Room C (Unit 2), and the Electric Board Room (Unit 3), near the control room for each unit.

Following the on-site audit, the staff reviewed the BFN SFP level instrumentation FIP and, using an electronic reading room (or e-portal) provided by the licensee, the staff audited Revision 0 of BFN calculation MDQ0009992014000291, "Temperature Response of the Reactor Building Following an Extended Loss of AC Power", BFN calculation CDQ0000782014000219, "Seismic Qualification for the Mounting of Spent Fuel Pool Level Instrumentation at BFN", Revision 3 of CDQ0000782014000252, "Seismic Qualification and Anchorage Design of the BFN Spent Fuel Pool Level Element Support Bracket", and Revision 1 of NDQ0000782014000216, "Beyond Design Basis Dose Evaluation for Spent Fuel Pool Level Instrumentation" to confirm the qualification and anticipated post-event ELAP conditions for each location where SFP level instrumentation equipment is installed. The staff noted that the equipment in the SFP area contains no active components and their performance is not susceptible to the anticipated radiological conditions. The vendor provided testing documentation where the coaxial signal cable met the radiation aging criteria of 1 E7 RAD. Shielding provided by the concrete walls for the electronic components outside the SFP area limits exposure to less than 1 E3 RAD.

Temperature and humidity conditions in the pool area, per NEI 12-02, are assumed to be 212 °F and 100 percent relative humidity. Westinghouse testing confirmed that temperature does not impact the performance of the equipment in the SFP area. The condensing steam conditions, however, may have minor impact to the instrument accuracy, but as determined in the vendor audit, the impact is less than the accuracy criteria in NEI 12-02. The staff confirmed the anticipated maximum temperature of the SFP level instrumentation locations during ELAP are within the 150 °F qualification temperature of the transmitter and display. The staff noted the equipment locations did not contain significant heat sources during ELAP conditions.

Seismic qualification was discussed in Section 4.2.3 above. The staff notes the peak ground acceleration for BFN is relatively low and this NRC staff review of BFN SFP level instrumentation qualification, combined with the earlier review of qualification testing during the vendor audit, confirm the seismic qualification is consistent with the NEI 12-02 guidance.

Based on its on-site audit walkdown of installed instruments, the NRC determined that the as-installed configuration is consistent with the guidance for shock and vibration.

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

4.2.5 Design Features: Independence

As noted in Section 4.2.2 above, the licensee provided sketches showing adequate separation of the installed primary and secondary instruments for each unit's SFP's including the conduit routing paths inside the SFP areas. The staff also observed the separation of the completed Unit 2 installation during the on-site audit. The staff found the installed configuration at BFN appears to meet the guidance for physical separation.

The NRC staff observed, during the on-site audit, that the licensee powered the Unit 2 primary and secondary SFP level instrumentation from separate electrical busses, supporting the electrical separation criteria. The licensee also stated in RAI Number10 response, that, "Power to the primary channel is supplied from the 120 volt ac I&C buses, which are powered from the 480V Shutdown Boards. Power to the backup channel is also supplied from 120 volt ac I&C buses and the 480V Shutdown Boards from the opposite train. The 480V Shutdown Boards have the capability of being powered from the 4kV FLEX turbine generators once the 4KV shutdown boards are energized."

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

4.2.6 Design Features: Power Supplies

The licensee stated in its response to RAI Number 10 that, "Power to the primary channel is supplied from the 120 volt AC I&C buses, which are powered from the 480V Shutdown Boards. Power to the backup channel is also supplied from 120 volt AC I&C buses and the 480V Shutdown Boards from the opposite train. The 480V Shutdown Boards have the capability of being powered from the 4kV FLEX turbine generators once the 4KV shutdown boards are energized."

The NRC staff notes that the internal backup battery supply was qualified by the vendor to power the system for up to 72 hours. The staff reviewed the qualification and battery hold-up calculation during the vendor audit. Details are available in the August 18, 2014, vendor audit report.

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

4.2.7 Design Features: Accuracy

The NRC staff reviewed the accuracy of the Westinghouse SFP level instrumentation system during the vendor audit and found that it met the guidance. Details are available in the August 18, 2014, vendor audit report. The licensee stated, in part, in its February 26, 2015, compliance letter that accuracy and accuracy following a power interruption were confirmed on the installed systems during the site acceptance test.

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

4.2.8 Design Features: Testing

The NRC staff reviewed the testing and calibration of the Westinghouse SFP level instrumentation system during the vendor audit and found that it met the guidance. Details are available in the August 18, 2014, vendor audit report. The Westinghouse system's probe is detachable and can be placed in a separate fixture with a movable depth simulator for the calibration process.

In its FIP, as part of its RAI Number 15 response, the licensee provided a complete list of the procedures including those used for test and calibration. The NRC staff reviewed the draft BFN test and calibration procedures during the on-site audit. The NRC staff noted, as part of its audit findings, that draft BFN document LCI-2-L-78-042, "Spent Fuel Pool Wide Range Level Loop 1 Calibration" did not include the Westinghouse test fixture that should be used when the "lift the probe" two point test fails. The licensee indicated that the e-portal response was correct and the final updated version of the draft document was corrected. The staff closed the item based on the e-portal response.

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

4.2.9 Design Features: Display

In the FIP, as part of its RAI Number 14 response, the licensee stated, in part, that the channel displays for both primary and backup are located in the 4 KV Shutdown Board Room A (Unit 1), 4 KV Shutdown Board Room C (Unit 2), and Electric Board Room 3A (Unit 3), which is in close proximity to the Backup Control Panel. The displays are physically separated utilizing Class 1E train separation criteria to maintain channel independence. The licensee also stated, in part, that the backup channel displays and paths from the MCRs are a mild environment during ELAP, are promptly accessible (2 minute walk) by MCR personnel, are not subject to the environmental conditions associated with boiling in the SFP and communication by radio is available if needed. The route to the Backup Control Panel area from the MCR will be the same route that is utilized during design basis events because the route is within safety-related, seismic structures (Control Building and Reactor Building).

The pathway is expected to remain intact following a seismic event. In its FIP, the licensee detailed the backup locations and the operator pathways in Sketch 4 of Enclosure 2.

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

4.3 Evaluation of Programmatic Controls

Order EA-12-051 specified that the 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

The licensee stated, in part, in its OIP that the systematic approach to training will be used to evaluate and develop personnel training for the SFP level instrumentation. In its fifth six-month update letter, the licensee stated that all training had been completed.

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

4.3.2 Programmatic Controls: Procedures

In its compliance letter, as part of its RAI Number 15 response, the licensee provided a list of 20 procedures that had been created or modified for the operation, test, calibration, and maintenance of the SFP level instruments. Also in its compliance letter, as part of its RAI Number 16 response, the licensee stated that it had used the Westinghouse manuals to develop the BFN procedures for the SFP level instrumentation. The NRC staff had previously reviewed the Westinghouse manuals as part of the vendor audit and also reviewed a limited number of the draft BFN procedures that were available during the on-site audit.

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 the order.

4.3.3 Programmatic Controls: Testing and Calibration

In its compliance letter, as part of its RAI Number 16 response, the licensee stated, in part,

> BFN will implement a critical spare parts program for the system, taking into account the lead time and availability of spare parts, to provide assurance that a channel can be restored to service within 90 days. If one or both channels cannot be restored to service within 90 days, or if both channels become non-functioning, as a compensatory measure BFN will utilize 1-AOI-78-1, 2-AOI-78-1, or 3-AOI-78-1, "Fuel Pool Cleanup System Failure" during any loss of spent fuel pool level or cooling event. This instruction requires the dispatch of operators to

determine the spent fuel pool level and cooling system status and investigate the cause of leakage and take appropriate actions to restore the spent fuel pool level and cooling.

The NRC staff reviewed the above information provided by the licensee and found that it is consistent with the guidance.

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 the order.

4.4 Conclusions for Order EA-12-051

In its letter dated February 28, 2013 (ADAMS Accession No. ML13063A437), the licensee stated that they would meet the requirements of Order EA-12-051 by following the guidelines of NEI 12-02, as endorsed by JLD-ISG-2012-03. In the evaluation above, the NRC staff finds that, if implemented appropriately, the licensee has conformed to the guidance in NEI 12-02, as endorsed by JLD-ISG-2012-03. In addition, the NRC staff concludes that if the SFP level instrumentation is installed at BFN 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 January 2015. The licensee reached its final compliance date on May 31, 2018, for Order EA-12-049, and February 26, 2016, for Order EA-12-051, 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 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: September 24, 2018

SUBJECT: BROWNS FERRY NUCLEAR PLANT, UNITS 1, 2, AND 3 – 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. MF0902, MF0903, MF0904; MF0881, MF0882, AND MF0883; EPID NOS. L 2013-JLD-0003; AND L-2013-JLD-0004) DATED September 24, 2018

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