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

February 2, 2017

Mr. Fadi Diya
Senior Vice President and Chief
 Nuclear Officer
Ameren Missouri
Callaway Plant
P.O. 620
Fulton, MO 65251

SUBJECT: CALLAWAY PLANT, UNIT 1 – SAFETY EVALUATION REGARDING IMPLEMENTATION OF MITIGATING STRATEGIES AND RELIABLE SPENT FUEL POOL INSTRUMENTATION RELATED TO ORDERS EA-12-049 AND EA-12-051 (CAC NOS. MF0772, AND MF0773)

Dear Mr. Diya:

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. ML13063A459), Union Electric Company (Union Electric, the licensee), doing business as Ameren Missouri, submitted its OIP for the Callaway Plant, Unit 1 (Callaway) 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 December 19, 2013 (ADAMS Accession No. ML13224A195), and March 31, 2016 (ADAMS Accession No. ML16077A353), the NRC issued an Interim Staff Evaluation (ISE) and audit report, respectively, on the licensee's progress. By letter dated July 6, 2016 (ADAMS Accession No. ML16189A304), Union Electric 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. ML13063A449), the licensee submitted its OIP for Callaway, in response to Order EA-12-051. At six month intervals following the submittal of the OIP, the licensee submitted reports on its progress in complying with Order EA-12-051. These reports were required by the order, and are listed in the attached safety evaluation. By letters dated December 19, 2013 (ADAMS Accession No. ML13224A195), and March 31, 2016 (ADAMS Accession No. ML16077A353), 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 July 6, 2016 (ADAMS Accession No. ML16189A309), Union Electric submitted a compliance letter in response to Order EA-12-051. The compliance letter stated that the licensee had achieved full compliance with Order EA-12-051.

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

If you have any questions, please contact Peter Bamford, Orders Management Branch, Callaway Project Manager, at 301-415-2833 or at Peter.Bamford@nrc.gov.

Sincerely,

Mandy K Halter

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

Docket No.: 50-483

Enclosure:
Safety Evaluation

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UNITED STATES
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SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

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

UNION ELECTRIC COMPANY

CALLAWAY PLANT, UNIT 1

DOCKET NO. 50-483

1.0 INTRODUCTION

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

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

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

2.0 REGULATORY EVALUATION

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

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

On February 17, 2012, the NRC staff provided SECY-12-0025, "Proposed Orders and Requests for Information in Response to Lessons Learned from Japan's March 11, 2011, Great Tohoku Earthquake and Tsunami," [Reference 2] to the Commission. This paper included a proposal to order licensees to implement enhanced BDBEE mitigation strategies. As directed by the Commission in staff requirements memorandum SRM-SECY-12-0025 [Reference 3], the NRC staff issued Orders EA-12-049 and EA-12-051.

2.1 Order EA-12-049

Order EA-12-049, Attachment 2, [Reference 4] requires that operating power reactor licensees and construction permit holders use a three-phase approach for mitigating BDBEEs. The initial phase requires the use of installed equipment and resources to maintain or restore core cooling, containment and SFP cooling capabilities. The transition phase requires providing sufficient, portable, onsite equipment and consumables to maintain or restore these functions until they can be accomplished with resources brought from off site. The final phase requires obtaining sufficient offsite resources to sustain those functions indefinitely. Specific requirements of the order are listed below:

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

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

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

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

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

On December 10, 2015, following submittals and discussions in public meetings with NRC staff, the Nuclear Energy Institute (NEI) submitted document NEI 12-06, Revision 2, "Diverse and

Flexible Coping Strategies (FLEX) Implementation Guide," [Reference 6] to the NRC to provide revised specifications for an industry-developed methodology for the development, implementation, and maintenance of guidance and strategies in response to the Mitigation Strategies order. The NRC staff reviewed NEI 12-06, Revision 2, and on January 22, 2016, issued Japan Lessons-Learned Directorate (JLD) Interim Staff Guidance (ISG) JLD-ISG-2012-01, Revision 1, "Compliance with Order EA-12-049, Order Modifying Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events," [Reference 7], endorsing NEI 12-06, Revision 2, with exceptions, additions, and clarifications, as an acceptable means of meeting the requirements of Order EA-12-049, and published a notice of its availability in the *Federal Register* (81 FR 10283).

2.2 Order EA-12-051

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

> All licensees identified in Attachment 1 to the order shall have a reliable indication of the water level in associated spent fuel storage pools capable of supporting identification of the following pool water level conditions by trained personnel: (1) level that is adequate to support operation of the normal fuel pool cooling system, (2) level that is adequate to provide substantial radiation shielding for a person standing on the spent fuel pool operating deck, and (3) level where fuel remains covered and actions to implement makeup water addition should no longer be deferred.
>
> 1. The spent fuel pool level instrumentation shall include the following design features:
>
> 1.1 Instruments: The instrumentation shall consist of a permanent, fixed primary instrument channel and a backup instrument channel. The backup instrument channel may be fixed or portable. Portable instruments shall have capabilities that enhance the ability of trained personnel to monitor spent fuel pool water level under conditions that restrict direct personnel access to the pool, such as partial structural damage, high radiation levels, or heat and humidity from a boiling pool.
>
> 1.2 Arrangement: The spent fuel pool level instrument channels shall be arranged in a manner that provides reasonable protection of the level indication function against missiles that may result from damage to the structure over the spent fuel pool. This protection may be provided by locating the primary instrument channel and fixed portions of the backup instrument channel, if applicable, to maintain instrument channel separation within the spent fuel pool area, and to utilize inherent shielding from missiles provided by existing recesses and corners in the spent fuel pool structure.
>
> 1.3 Mounting: Installed instrument channel equipment within the spent fuel pool shall be mounted to retain its design configuration during and

following the maximum seismic ground motion considered in the design of the spent fuel pool structure.

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

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

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

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

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

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

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

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

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

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

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

3.0 TECHNICAL EVALUATION OF ORDER EA-12-049

By letter dated February 28, 2013 [Reference 10], Union Electric Company (Union Electric, the licensee), doing business as Ameren Missouri, submitted an Overall Integrated Plan (OIP) for Callaway Plant, Unit 1 (Callaway) in response to Order EA-12-049. By letters dated August 29, 2013 [Reference 11], February 26, 2014 [Reference 12], August 28, 2014 [Reference 13], February 26, 2015 [Reference 14], August 27, 2015 [Reference 15], and February 23, 2016 [Reference 16], the licensee submitted six-month updates to the OIP. By letter dated August 28, 2013 [Reference 17], the NRC notified all licensees and construction permit holders that the staff is conducting audits of their responses to Order EA-12-049 in accordance with NRC Office of Nuclear Reactor Regulation (NRR) Office Instruction LIC-111, "Regulatory Audits" [Reference 36]. By letters dated December 19, 2013 [Reference 18], and March 31, 2016 [Reference 19], the NRC issued an Interim Staff Evaluation (ISE) and an audit report on the licensee's progress. By letter dated July 6, 2016 [Reference 20], 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.

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

At the onset of an ELAP the reactor is assumed to trip from full power. The reactor coolant pumps (RCPs) coast down and flow in the reactor coolant system (RCS) transitions to natural circulation. Operators will take prompt actions to minimize RCS inventory losses by isolating potential RCS letdown paths. Decay heat is removed by steaming to atmosphere from the steam generators (SGs) through the atmospheric steam dump valves (ASDs) or SG safety valves, and makeup to the SGs is initially provided by the turbine-driven auxiliary feedwater (TDAFW) pump taking suction from the (non-robust) condensate storage tank (CST), if it is not damaged during the event. If the CST is rendered unusable during the event, then the hardened condensate storage tank (HCST) provides an alternate robust source of water. Subsequently, the operators would begin a controlled cooldown and depressurization of the RCS by manually operating the SG ASDs. The SGs would be depressurized in a controlled manner to about 290 pounds per square inch gage (psig) over a period of several hours and then maintained at this pressure while the operators borate the RCS. Depressurizing the SGs reduces RCS temperature and pressure. The licensee plans to complete this cooldown within 12 hours of the start of the event. The reduction in RCS temperature will result in inventory contraction in the RCS. Ongoing RCS leakage, both assumed normal leakage and leakage from the RCP seals, would also contribute to the decrease in RCS liquid volume. However, during the cooldown RCS pressure should drop below the safety injection accumulator pressure and the injection of some quantity of borated water into the RCS from the accumulators would then occur.

The licensee expects to continue cooling the RCS using the TDAFW pump or a portable FLEX pump to feed the steam generators. In addition, as noted in the FIP, the licensee eventually expects to use equipment from the National Strategic Alliance for FLEX Emergency Response (SAFER) Response Center (NSRC) to restore the residual heat removal (RHR) system and supporting equipment. The operation of this system would allow RCS temperature to be reduced below 200 degrees Fahrenheit (°F). Prior to cooling the RCS to this level, operators would need to perform a number of supporting actions including injecting additional boric acid into the RCS to avoid the potential for re-criticality and isolating or venting the accumulators to avoid the potential for accumulator nitrogen cover gas injection into the RCS.

The operators will perform dc bus load stripping within the first hour following event initiation to ensure safety-related battery life is extended up to 12 hours. Following dc load stripping and prior to battery depletion, at least one (of two) 500-kilowatt (kW), 480 volt alternating current (Vac) generators will be deployed from the Hardened Storage Building (HSB). These portable generator(s) will be used to repower equipment needed to support the strategy, including: essential battery chargers, a FLEX air compressor, and an RCS makeup pump.

The RCS makeup and boration will be initiated within 26 hours of the ELAP to ensure that natural circulation, reactivity control, and boron mixing is maintained in the RCS. Operators will provide makeup using an electric-driven pump (described hereafter as the "FLEX boron" pump) to replenish RCS inventory and reestablish RCS level in the pressurizer. Procedures provide guidance for RCS inventory control and to establish the proper boration of the RCS to maintain subcritical conditions. The FLEX boron pump takes suction from one of the boric acid tanks (BATs), or the refueling water storage tank (RWST), and discharges into a preselected discharge path in the safety injection system. Power to the FLEX boron pump is supplied by the FLEX 480 Vac diesel generators (DGs).

The water supply for the TDAFW pump is initially from the CST if it is not damaged during the event. However, if the CST is rendered unusable during the event, then the HCST provides a suction source for the TDAFW pump. If the CST can be utilized it will provide approximately 24 hours of RCS decay heat removal, in addition to absorbing the latent heat associated with the planned RCS cooldown. The HCST will provide a suction source to the TDAFW pump for a minimum of 30 hours. According to the licensee's FIP, approximately 25 hours after the event, a mobile water purification unit from the NSRC will be available and could be placed in service prior to the depletion of the HCST.

In addition, the NSRC will provide high capacity pumps and large combustion turbine generators (CTGs), which could be used to restore access to the UHS and ultimately restore one RHR cooling train for long-term core cooling.

The SFP is located in the Fuel Building. Upon initiation of the ELAP event, the SFP will heat up due to the unavailability of the normal cooling system. The licensee has calculated that boiling could start as soon as 2.34 hours after the start of the event. To maintain SFP cooling capabilities, the licensee determined that it would take approximately 33 hours for SFP water level to drop to a level requiring the addition of makeup. Makeup water would be provided using a diesel-driven FLEX pump with a suction from the RWST, if available, or the (robust) HCST and discharging through a hose which will be connected to add water to the SFP. Ventilation of the generated steam is accomplished by manually opening the Fuel Building rollup door.

For Phases 1 and 2, the licensee's calculations demonstrate that for events starting in Modes 1-4, no actions are required to maintain containment pressure below design limits for a minimum of 72 hours. In its FIP, the licensee stated that no additional specific Phase 3 strategy is required for maintaining containment integrity. With the initiation of RHR to remove core heat, the licensee's FIP states that containment will depressurize without further action.

Below are specific details on the licensee's strategies to restore or maintain core cooling, containment, and SFP cooling capabilities in the event of a BDBEE, and the results of the staff's review of these strategies. The NRC staff evaluated the licensee's strategies against the endorsed NEI 12-06, Revision 2 guidance.

3.2 Reactor Core Cooling Strategies

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

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

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

3.2.1 Core Cooling Strategy and RCS Makeup

3.2.1.1 Core Cooling Strategy

3.2.1.1.1 Phase 1

As stated in Callaway's FIP, the heat sink for core cooling in Phase 1 is provided by the four SGs, which are fed simultaneously by the unit's TDAFW pump with inventory supplied from either the CST or the HCST. The HCST is designed to be robust against all applicable external hazards at the Callaway site. The licensee calculates that the HCST water volume, 366,544 gallons, is sufficient to remove residual heat from the reactor for a minimum of 30 hours, including the sensible heat associated with the RCS cooldown. Initially the source of feedwater would be the CST, if available. The TDAFW pump suction source will be transferred to HCST automatically, if the CST is depleted or otherwise unavailable. The TDAFW pump will start automatically on the initiation of the ELAP event. Should the TDAFW pump fail to start, approximately 50-60 minutes are available prior to SG dryout.

Following closure of the main steam isolation valves, as would be expected in an ELAP event, steam release from the SGs to the atmosphere would be accomplished via the main steam safety valves and/or the SG ASDs. The SG ASDs would typically be operated by the compressed air system. However, the compressed air system is not expected to be available following an ELAP. Callaway's FIP states that the ASD's can be operated using an installed backup nitrogen system which will provide motive force for 8 hours. The licensee has confirmed that the ASDs are robust for all applicable hazards. Power to the ASD controllers is provided by the Class 1E station batteries.

Callaway's Phase 1 strategy directs operators to commence a cooldown and depressurization of the RCS within 8 hours of the initiation of the ELAP/loss of normal access to the UHS event. Over a period of approximately 4 hours, the licensee will gradually cool down the RCS from post-trip conditions until a SG pressure of approximately 290 psig is reached. This corresponds to an RCS temperature of approximately 418°F. The minimum SG pressure of 290 psig is set to avoid the injection of nitrogen gas from the safety injection accumulators into the RCS.

Cooldown and depressurization of the RCS significantly extends the expected coping time under ELAP/loss of normal access to the UHS conditions because it allows coolant stored in the nitrogen-pressurized accumulators to inject into the RCS to offset system leakage and temperature related volume losses.

3.2.1.1.2 Phase 2

Callaway's FIP states that the primary strategy for core cooling in Phase 2 would be to continue using the SGs as a heat sink, with SG secondary inventory being supplied by the TDAFW pump. To support this function at least one FLEX 480 Vac diesel generator will be aligned and placed in service within 10 hours. This will provide necessary electrical power to the station batteries and will support the operation of the TDAFW pump, ASDs, and necessary instrumentation. Additionally, the licensee will align one of the two portable FLEX auxiliary feedwater (AFW) pumps that are capable of backing up the TDAFW pump.

In the event that the FLEX AFW pump is required to back up the TDAFW pump, two portable diesel driven pumps each rated for a capacity of 500 gallons per minute (gpm) at 500 psig are available and stored onsite in the HSB. Callaway's FIP describes the pump primary and alternate connection strategies. The primary connections for suction to the FLEX AFW pump are located on the HCST. Alternate suction points are located on the CST, the demineralized water storage tank, and the reactor makeup water storage tank. The FLEX AFW pump would be located near the suction source selected. This pump would discharge via hoses routed to primary or alternate connections. The primary connection point is in the non-safety auxiliary feedwater pump (NSAFP) discharge line. Alternate discharge connection paths are provided for the FLEX AFW pump. The first utilizes a combination of hoses and piping from the pump to FLEX connections in either the NSAFP discharge line or the "B" motor-driven AFW pump discharge line. The second utilizes running hoses from the pump through the Turbine Building and AFW corridor into the Auxiliary Building where it can be connected to FLEX connections on the discharge line of either the NSAFP or "B" motor-driven AFW pump.

According to Callaway's calculations, the HCST is capable of supplying SG makeup for a minimum of 30 hours. Additionally the CST normally contains a minimum volume of 396,544 gallons, although it is not missile protected and thus not credited for all scenarios.

To support the operation of the ASD's and TDAFW pump flow control valves compressed air will be provided by either a diesel-driven air compressor stored in the HSB or an electric motor-driven FLEX air compressor stored in the basement of the Auxiliary Building. The diesel-driven FLEX air compressor will be deployed "plant east" of the Turbine Building and an air hose run from the compressor through either the Turbine Building or the tendon access gallery to a distribution manifold. From this distribution manifold hoses can be run to four nitrogen accumulators which will provide air to the ASDs and the TDAFW pump flow control valves. In the event that the electric motor-driven FLEX air compressor is used, power will be provided by the FLEX DG. Air distribution will utilize the same hose and manifold setup described for the diesel-driven air compressor.

3.2.1.1.3 Phase 3

Per the Callaway FIP, the licensee's core cooling strategy for Phase 3 will continue with the Phase 2 strategy. Water processing units from the NSRC can be used for feeding the SGs with clean water. The NSRC will also provide backup equipment for the site's Phase 2 equipment.

The licensee's long-term strategy includes the repowering of one of the two 4160 Vac buses through the use of three NSRC provided 4160 Vac generators. These generators will provide adequate power to restore the RHR and component cooling water (CCW) systems and establish long-term shutdown cooling. Additional pumps provided by the NSRC include a high performance booster pump skid and a low pressure/high flow pump. In combination these pumps will be used to restore the UHS function by providing cooling water flow to one of the CCW heat exchangers.

3.2.1.2 RCS Makeup Strategy

3.2.1.2.1 Phase 1

Per the Callaway FIP, following the reactor trip at the start of the ELAP/loss of normal access to the UHS event, operators will isolate RCS letdown pathways and confirm the existence of natural circulation flow in the RCS. A small amount of RCS leakage will occur through the low-leakage RCP seals, but because the expected inventory loss would not be sufficient to drain the pressurizer prior to the RCS cooldown, its overall impact on the RCS behavior will be minor. Although the RCS cooldown planned to start at 8 hours into the event would be expected to drain the pressurizer and create a vapor void in the upper head of the reactor vessel, ample RCS volume should remain to support natural circulation flow throughout Phase 1. Likewise, there is no need to initiate boration during this period, since the reactor operating history assumed in the endorsed NEI 12-06 guidance implies that a substantial concentration of xenon-135 would be present in the reactor core. Nevertheless, as operators depressurize the RCS, some fraction of the borated inventory from the nitrogen-pressurized accumulators would be expected to passively inject. Following depressurization of the SGs to 290 psig, the licensee plans to isolate the accumulators to prevent the injection of nitrogen gas into the RCS.

3.2.1.2.2 Phase 2

In Phase 2, RCS injection is accomplished using either a FLEX boron pump staged in the Auxiliary Building or an alternative pump which is stored in the HSB. In the course of cooling and depressurizing the SGs to their target pressure, a portion of the accumulator liquid inventory will inject into the RCS. In order to ensure long-term sub-criticality as positive reactivity is added from the RCS cooldown and xenon decay, RCS boration will commence using a FLEX boron pump approximately 26 hours after the initiation of the ELAP event. With low-leakage Westinghouse SHIELD seals installed on all four RCPs, the licensee calculates that FLEX RCS makeup is not necessary to prevent the onset of reflux cooling for a minimum of 66.9 hours into the event.

The primary strategy utilizes the FLEX boron pump which is stored in the Auxiliary Building. The licensee's FIP describes this pump as having a capacity of 30 gpm at 1600 psig and 25 gpm at 2000 psig. The pump will be aligned to take suction from either of the two BATs (primary) or from the RWST (alternate). The BATs are robust for all applicable hazards. The RWST is seismically robust, but is not high wind (tornado) missile protected. The FLEX boron pump can be aligned to discharge to either a primary or alternate connection point. The primary discharge path would utilize hoses to connect to a connection on the boron injection header. The alternate would utilize hoses and intermediate piping connection points to align the discharge to a FLEX connection on the safety injection system.

The alternate strategy is utilized if the initiating event has resulted in flooding of the Auxiliary Building basement due to a seismically-induced tank/piping failure. In this case, the FLEX boron pump stored in the HSB will be deployed to the Auxiliary Building at a level not impacted by the postulated flooding and a suction hose will be connected to the RWST. This pump can be aligned to discharge to either a primary or alternate connection point. The primary discharge path would utilize hoses to connect to a connection on the safety injection header. The alternate path would utilize hoses and intermediate piping connection points to align the discharge to a FLEX connection on the boron injection header.

In both cases the FLEX boron pumps will be powered from 480 Vac power provided by the FLEX 480 Vac DGs. These generators are expected to be electrically aligned and in operation at approximately 10 hours after the initiation of the ELAP event.

The licensee's FIP states that the Callaway implementation of Order EA-12-049 is based on NEI 12-06, Revision 2, as endorsed by the NRC. Section 11.5.4.b of NEI 12-06 states that "The required FLEX equipment may be unavailable for 90 days provided that the site FLEX capability ("N") is met. If the site "N" capability is met but not protected for all of the site's applicable hazards, then the allowed unavailability is reduced to 45 days." This guidance is also reflected in the licensee's FIP, Section 2.18.7. Based on the information provided by the licensee, the NRC staff understands that in the event of a seismic event, flooding of the Auxiliary Building is assumed to occur, and thus the FLEX boron pump installed in the Auxiliary Building basement is not protected against a seismic event. This flooding will result in the loss of the primary means of providing the RCS injection function. Therefore, if the FLEX boron pump stored in the HSB is unavailable for any reason the licensee would not have "N" sets of equipment protected from a potential seismic event. Thus, the allowed unavailability for the FLEX boron pump stored in the HSB should be 45 days instead of 90 days. A similar logic would be applied to RCS makeup connections (electrical and mechanical) that are associated with the deployment of the FLEX boron pump stored in the HSB. Specifically, if only a singular connection is postulated to be available after a seismic event with the induced flooding, than that connection's allowed out-of-service time would be 45 days instead of 90 days.

3.2.1.2.3 Phase 3

Per the Callaway FIP, the licensee's core cooling strategy for Phase 3 begins with a continuation of the Phase 2 strategy with additional offsite equipment provided from the NSRC. The NSRC equipment provides a complete replacement set for the existing Callaway FLEX equipment including a high pressure injection pump rated for 60 gpm at 2000 psig. In addition, water purification equipment from the NSRC can be used to provide a source of high quality water for use in batching boron. One of two FLEX water heaters, stored in the HSB, can be used to heat incoming water to ensure the proper mixing of boric acid in the boric acid batch tank (BABT). A combination of FLEX and/or NSRC provided pumps can then be used to produce blended flows.

Callaway's long-term strategy in Phase 3 will include the repowering of one of the two 4160 Vac buses through the use of three NSRC-provided CTGs. These generators will provide adequate power to restore the RHR and CCW systems and establish long-term shutdown cooling. Additional pumps provided by the NSRC include a high performance booster pump skid and a low pressure/high flow pump. In combination, these pumps will be used to restore the UHS function by providing cooling water flow to one of the CCW heat exchangers.

3.2.2 Variations to Core Cooling Strategy for Flooding Event

In its FIP, the licensee stated that the Callaway site elevation is above the maximum plant site flood level, with the exception of the bottom slab of the RWST and the UHS. The licensee's compliance letter states that access to the RWST for FLEX strategy implementation is through the valve house, which is above the maximum flood level at the plant site. The licensee's compliance letter also states that deployment of FLEX equipment would not be impacted by a postulated flood and that the grading at the plant site is designed to prevent surface runoff or debris from flowing into the UHS retention pond. Therefore, the licensee's core cooling and makeup strategy implementation would remain the same should an ELAP and loss of normal access to the UHS associated with an external flooding event occur. Refer to Section 3.5.2 of this safety evaluation for further discussion on flooding.

3.2.3 Staff Evaluations

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

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

3.2.3.1.1 Plant SSCs

Core Cooling – Phase 1

According to the licensee's FIP, the TDAFW pump automatically starts and delivers AFW flow from the CST, if available, or the HCST to the SGs following an ELAP/loss of normal access to the UHS event. In Section 2.3.4.1 of its FIP, the licensee states that the TDAFW pump is located in a structure protected from all applicable design basis external events. Furthermore, the Callaway Final Safety Analysis Report (FSAR) [Reference 49] Table 3.2-1, states that the TDAFW pump and the motor-driven AFW pumps, piping and valves are Seismic Category I. Two steam admission valves, one from each of the "B" and "C" main steam headers, supply steam to the TDAFW pump. In the FIP, Section 2.3.4.1 states that in the event the TDAFW pump fails to start, procedures direct the operators to manually reset and start the pump. The operators will remotely adjust feed control valves to maintain SG level initially using compressed nitrogen from accumulator tanks and power from the 125 Volts-dc (Vdc) batteries. Based on the licensee's FIP and FSAR, the NRC staff finds that the TDAFW pump is robust and is expected to be available at the start of an ELAP event consistent with NEI 12-06, Section 3.2.1.3.

The licensee plans to vent steam from the SGs by manually controlling the steam generator ASDs and perform a controlled cooldown. As described in FIP Section 3.2.4.1, the ASDs are safety-related, missile protected and seismically qualified valves. The ASDs can be controlled from same backup nitrogen accumulators as TDAFW pump feed control valves that are fully protected. The ASDs require air or nitrogen for operation, so FLEX air compressors are relied on to provide pneumatic operation once the accumulators are exhausted. Control power will initially be provided by the station batteries and then the FLEX DGs. Based on the licensee's FIP, the NRC staff finds that the ASDs are robust and are expected to be available at the start of an ELAP event, consistent with NEI 12-06, Section 3.2.1.3. Further explanation and the NRC staff's evaluation of the robustness and availability of water sources for an ELAP event is discussed in Section 3.10 of this safety evaluation.

Core Cooling – Phase 2

The licensee's Phase 2 core cooling strategy continues to use the SGs as the heat sink. The operators will continue to use the TDAFW pump as long as possible, or the transition to using one of two portable FLEX AFW pumps discharging through a primary or alternate connection point to the SGs. For Phase 2 the licensee does not plan to rely on any plant SSCs other than the systems with FLEX connection points and water sources, as discussed in Sections 3.7 and 3.10 of this safety evaluation, respectively.

Core Cooling – Phase 3

The licensee's Phase 3 core cooling strategy initially relies on continuing with Phase 2 strategies with the NSRC equipment providing backup to the onsite FLEX equipment. The licensee is also planning to receive the mobile purification unit from the NSRC so they can provide clean water from the UHS to be used after the cleaner onsite sources have been depleted. Once the NSRC equipment arrives on site, the licensee plans to establish RHR cooling to provide a long term method of core cooling.

RCS Makeup - Phase 1

The licensee's Phase 1 RCS inventory control strategy relies on low leakage seals, and the licensee's analysis demonstrated that no RCS makeup is needed within 26 hours.

RCS Makeup - Phase 2

The licensee's Phase 2 RCS inventory strategy will use a FLEX boron pump and does not rely on any plant SSCs other than the systems with FLEX connection points and borated water sources discussed in Sections 3.7 and 3.10 of this safety evaluation, respectively.

RCS Makeup - Phase 3

The licensee's Phase 3 RCS inventory strategy does not rely on any additional installed plant SSCs other than those discussed in Phase 2.

3.2.3.1.2 Plant Instrumentation

According to the Callaway FIP, the following instrumentation will be relied upon to support the licensee's core cooling and RCS inventory control strategy. The following instruments are monitored from the control room and will be available throughout the event.

- SG level (wide range and narrow range)
- SG pressure
- RCS temperature (hot-leg and cold-leg)
- RCS pressure (wide range)
- Containment pressure (wide range)
- Reactor vessel level indicating system (RVLIS)
- AFW pump flow rate
- AFW pump suction pressure
- Core exit thermocouples (CETs)
- Pressurizer level
- Class 1E dc bus voltage

All of these instruments are powered by installed safety-related station batteries. To prevent a loss of vital instrumentation, operators will extend battery life to a minimum of 12 hours by shedding unnecessary loads. According to the licensee's FIP, the load shedding will be completed within 60 minutes from the initiation of the event. A FLEX 480 Vac DG will be deployed to repower the battery chargers within 10 hours from ELAP event initiation. This leaves a margin of at least 2 hours prior to depletion of the associated batteries.

The licensee's FIP states that, as recommended by Section 5.3.3 of NEI 12-06, procedures have been developed to read the above instrumentation locally using portable instruments, where applicable. The licensee has developed a FLEX Support Guideline (FSG) to provide instructions for obtaining alternate monitoring for the following parameters:

- RCS hot leg and cold leg temperatures
- RCS pressure
- SG level
- SG pressure
- AFW pump flow
- AFW suction pressure
- CETs
- Pressurizer level
- RWST level per local indication
- RVLIS
- Containment pressure
- Containment temperature
- Containment radiation

The licensee also stated in its FIP, that portable FLEX equipment credited in the mitigating strategies is supplied with the instrumentation necessary to support local equipment operation.

The NRC staff reviewed the licensee's instrument listing and the staff concludes that it is consistent with the recommendations specified in the endorsed guidance of NEI 12-06.

3.2.3.2 Thermal-Hydraulic Analyses

The licensee's mitigating strategy for reactor core cooling is based, in part, on a generic thermal-hydraulic analysis performed for a reference Westinghouse four-loop reactor using the NOTRUMP computer code. The NOTRUMP code and corresponding evaluation model were originally submitted in the early 1980s as a method for performing licensing-basis safety analyses of small-break loss-of-coolant accidents (LOCAs) for Westinghouse PWRs. Although NOTRUMP has been approved for performing small-break LOCA analysis under the conservative 10 CFR Appendix K paradigm and constitutes the current evaluation model of record for many operating PWRs, the NRC staff had not previously examined its technical adequacy for performing best-estimate simulations of the ELAP event. Therefore, in support of mitigating strategy reviews to assess compliance with Order EA-12-049, the NRC staff evaluated licensees' thermal-hydraulic analyses, including a limited review of the significant assumptions and modeling capabilities of NOTRUMP and other thermal-hydraulic codes used for these analyses. The NRC staff's review included performing confirmatory analyses with the TRACE code to obtain an independent assessment of the duration that reference reactor designs could cope with an ELAP event prior to providing makeup to the RCS.

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

Accordingly, the ELAP coping time prior to providing makeup to the RCS is limited to the duration over which the flow in the RCS remains in natural circulation, prior to the point where continued inventory loss results in a transition to the reflux or boiler-condenser cooling mode. In particular, for PWRs with inverted U-tube SGs, the reflux cooling mode is said to exist when vapor boiled off from the reactor core flows out the saturated, stratified hot leg and condenses on SG tubes, with the majority of the condensate subsequently draining back into the reactor vessel in countercurrent fashion. Quantitatively, as reflected in documents such as the PWR Owners Group (PWROG) report PWROG-14064-P, "Application of NOTRUMP Code Results for Westinghouse Designed PWRs in Extended Loss of AC Power Circumstances," Revision 0 [Reference 42], industry has proposed defining this coping time as the point at which the one-hour centered time-average of the flow quality passing over the SG tubes' U-bend exceeds one-tenth (0.1). As discussed further in Section 3.2.3.4 of this evaluation, a second metric for ensuring adequate coping time is associated with maintaining sufficient natural circulation flow in the RCS to support adequate mixing of boric acid.

With specific regard to NOTRUMP, preliminary results from the NRC staff's independent confirmatory analysis performed with the TRACE code indicated that the coping time for Westinghouse PWRs under ELAP conditions could be shorter than predicted in

WCAP 17601-P, "Reactor Coolant System Response to the Extended Loss of AC Power Event for Westinghouse, Combustion Engineering and Babcock & Wilcox NSSS Designs" [Reference 43]. Subsequently, a series of additional simulations performed by the staff and Westinghouse identified that the discrepancy in predicted coping time could be attributed largely to differences in the modeling of RCP seal leakage. These comparative simulations showed that when similar RCP seal leakage boundary conditions were applied, the coping time predictions of TRACE and NOTRUMP were in adequate agreement. From these simulations, as supplemented by review of key code models, the NRC staff obtained sufficient confidence that the NOTRUMP code may be used in conjunction with the WCAP-17601-P evaluation model for performing best-estimate simulations of ELAP coping time prior to reaching the reflux cooling mode.

Although the NRC staff obtained confidence that the NOTRUMP code is capable of performing best-estimate ELAP simulations prior to the initiation of reflux cooling using the one-tenth flow-quality criterion discussed above, the staff was unable to conclude that the generic analysis performed in WCAP-17601-P could be directly applied to all Westinghouse PWRs, as the vendor originally intended. In PWROG-14064-P, the industry subsequently recognized that the generic analysis would need to be scaled to account for plant-specific variation in RCP seal leakage. However, the staff's review, supported by sensitivity analysis performed with the TRACE code, further identified that plant-to-plant variation in additional parameters, such as RCS cooldown terminus, accumulator pressure and liquid fraction, and initial RCS mass, could also result in substantial differences between the generically predicted reference coping time and the actual coping time that would exist for specific plants.

During the audit process, the NRC staff evaluated a comparison of the generic analysis values from WCAP-17601-P and PWROG-14064-P to the Callaway plant-specific values. The NRC staff concurred with the licensee's evaluation that the generic plant parameters were bounding for the analyzed event. Callaway has installed low-leakage SHIELD shutdown seals; therefore, the seal leakage expected for Callaway is significantly less than assumed in the generic NOTRUMP analysis case. The NRC staff concluded, based on the licensee evaluation, that the licensee could maintain natural circulation flow in the RCS for approximately 45.1 hours for single-phase flow, and at least 66.9 hours for two-phase flow during the ELAP event without RCS makeup. The RCS makeup will be available per the licensee's mitigating strategy for shutdown margin at approximately 26 hours following initiation of ELAP, thus, the licensee's strategy for RCS makeup provides sufficient margin to the onset of reflux cooling.

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

3.2.3.3 Reactor Coolant Pump (RCP) Seals

Leakage from the RCP seals is among the most significant factors in determining the duration that a PWR can cope with an ELAP event prior to initiating RCS makeup. An ELAP event would interrupt cooling to the RCP seals, resulting in increased leakage and the potential for failure of elastomeric O-rings and other components, which could further increase the leakage rate. As discussed above, as long as adequate inventory is maintained in the RCS, natural circulation can effectively transfer residual heat from the reactor core to the SGs and limit local variations in boric acid concentration. Along with cooldown-induced contraction of the RCS inventory, cumulative leakage from RCP seals governs the duration over which natural circulation can be maintained in the RCS. Furthermore, the seal leakage rate at the depressurized condition can be a controlling factor in determining the flow capacity requirement for FLEX pumps to offset ongoing RCS leakage and recover adequate system inventory.

Per its FIP, the licensee credits Westinghouse Generation III SHIELD low leakage seals for FLEX strategies including RCS inventory control and boration. The low leakage seals limit the total RCS leak rate to no more than 5 gpm (1 gpm per RCP and 1 gpm of unidentified RCS leakage in accordance with Technical Specification 3.4.13).

To support the reviews of Order EA-12-049, the NRC issued an endorsement letter of a Westinghouse Technical Report, TR-FSE-14-1-P, "Use of Westinghouse SHIELD Passive Shutdown Seal for FLEX Strategies," [Reference 44] which outlines four conditions that must be met to credit the lower leakage rates associated with the SHIELD seals for Order EA-12-049 compliance. For Callaway, the NRC staff evaluated each condition as follows:

(1) Credit for the SHIELD seals is only endorsed for Westinghouse RCP Models 93, 93A, and 93A-1.

According to the licensee's compliance letter [Reference 20], this condition is satisfied because the Callaway RCPs are Westinghouse Model 93A-1.

(2) The maximum steady-state RCS cold-leg temperature is limited to 571°F during the ELAP (i.e., the applicable main steam safety valve setpoints result in an RCS cold-leg temperature of 571 °F or less after a brief post-trip transient).

According to the licensee's compliance letter, the maximum steady-state RCP seal temperature during an ELAP response is expected to be the RCS cold leg temperature corresponding to the lowest SG safety relief valve setting of 1200 psia [pounds per square inch absolute]. This results in a RCS cold leg temperature of approximately 567.2 °F.

(3) The maximum RCS pressure during the ELAP (notwithstanding the brief pressure transient directly following the reactor trip comparable to that predicted in the applicable analysis case from WCAP-17601-P) is as follows: For Westinghouse Models 93 and 93A-1 RCPs, RCS pressure is limited to 2250 psia.

According the Callaway FSAR Table 5.1-1, the normal operating RCS pressure is 2235 psig (approximately 2250 psia). Allowing for the possibility of a brief pressure transient directly following the reactor trip, the NRC staff concludes that the licensee's mitigating strategy of cooling the reactor core will maintain reactor pressure within the limiting value for Model 93A-1.

(4) Nuclear power plants that credit the SHIELD seal in an ELAP analysis shall assume the normal seal leakage rate before SHIELD seal actuation and a constant seal leakage rate of 1.0 gpm for the leakage after SHIELD seal actuation.

> Callaway's FIP and supporting calculations assume a constant Westinghouse SHIELD RCP seal package leakage rate of 1 gpm per RCP, plus 1 gpm of unidentified RCS leakage, for a total RCS leakage of 5 gpm. As noted previously, the licensee's calculation indicates that reflux cooling would not be entered for a minimum of 66.9 hours into the event, even if FLEX RCS makeup flow were not provided as planned. Since Callaway's mitigating strategy directs RCS makeup to begin approximately 26 hours after event initiation, the NRC staff concludes that ample margin exists to accommodate any small additional volume of leakage that is expected to occur before actuation of the SHIELD seal.

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

3.2.3.4 Shutdown Margin Analyses

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

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

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

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

In the Callaway FIP, Section 2.3.9, and the shutdown margin calculation reviewed during the audit process (CN-SEE-I-12-32, "Callaway Reactor Coolant System Inventory, Shutdown Margin, and Mode 5/6 Boric Acid Precipitation Control Analysis to Support the Diverse and Flexible Coping Strategy (FLEX)," Revision 0), describe the strategy necessary to maintain shutdown margin following the initiation of the ELAP event. As described in both documents, the strategy would supply negative reactivity by injecting borated water into the RCS by employing the FLEX boron pump. This will guarantee that a shutdown margin of 1 percent is preserved following cooldown to the initial threshold (SG pressure of 290 psig) and while accounting for xenon decay. The safety injection accumulators provide an initial negative reactivity contribution during the RCS cooldown. During Phase 2, adequate shutdown margin requirements are provided either by a pre-installed FLEX boron pump taking suction from a BAT, or a portable FLEX boron pump with suction from the RWST. According to the licensee's FIP and the associated shutdown margin calculations, in order to confirm that acceptable boric acid concentration is supplied to the RCS, injection is required starting at approximately 26 hours following the initiation of the ELAP event. The licensee's analysis demonstrated that adequate shutdown margin would be provided at an injection rate of 10 gpm from the BAT injection source or 20 gpm from the RWST injection source. The licensee's shutdown margin calculations show that the injection of approximately 2700 gallons of water with a boric acid concentration minimum of 7000 parts per million (ppm) from the BAT, or the injection of approximately 8500 gallons of water, with a boric acid concentration minimum of 2350 ppm from the RWST would meet the shutdown margin requirement of 1 percent at limiting cycle conditions.

Toward the end of an operating cycle, when RCS boron concentration reaches its minimum value, some PWR licensees may need to vent the RCS to ensure that their FLEX strategies can inject a volume of borated coolant that is sufficient to satisfy shutdown margin requirements. The licensee's FIP concluded that, because the RCS volume shrinks as it cools down, the required volume of boric acid solution could be injected without having to vent the RCS.

The NRC staff's audit review of the licensee's shutdown margin calculation determined that credit was taken for uniform mixing of boric acid during the ELAP event. The NRC staff had previously requested that the industry provide additional information to justify that borated makeup would adequately mix with the RCS volume under natural circulation conditions potentially involving two-phase flow. In response, the PWROG submitted a position paper, dated August 15, 2013 (withheld from public disclosure due to proprietary content), which provided test data regarding boric acid mixing under single-phase natural circulation conditions and outlined applicability limits intended to ensure that boric acid addition and mixing during an ELAP would occur under conditions similar to those for which boric acid mixing data is available. By letter dated January 8, 2014 [Reference 45], the NRC staff endorsed the boron mixing position paper with three conditions. These conditions are restated below, followed by the licensee's compliance letter response:

> Condition 1: The required timing and quantity of borated makeup should consider conditions with no RCS leakage and with the highest applicable leakage rate.
>
> Licensee Response: CN-SEE-I-12-32 assumes highest RCS leakage for RCS Inventory control. Ameren Calculation XX-136, "FLEX EOP Action Value V.08 'Time to Initiate Alternate Boration'," Revision 0, assumes no RCS leakage for RCS Boration requirements.

Condition 2: Adequate borated makeup should be provided either: (1) prior to the RCS natural circulation flow decreasing below the flow rate corresponding to single-phase natural circulation, or (2) if provided later, then the negative reactivity from the injected boric acid should not be credited until one hour after the flow rate in the RCS has been restored and maintained above the flow rate corresponding to single-phase natural circulation.

Licensee Response: The pumped RCS makeup/boration strategy for Callaway Plant (per Ameren Calculation XX-136, Revision 0) includes providing RCS injection in excess of the maximum primary-system leak rate of 5 gpm (1 gpm per RCP plus 1 gpm unidentified leakage) starting no later than 26 hours following the loss of all ac power, which is well before the time when the RCS liquid inventory would be reduced to the minimum single phase natural circulation level (45.1 hours).

Condition 3: A delay period adequate to allow the injected boric acid solution to mix with the RCS inventory should be accounted for when determining the required timing for borated makeup. Provided that the flow in all loops is greater than or equal to the corresponding single-phase natural circulation flow rate, a mixing delay period of 1 hour is considered appropriate.

Licensee Response: The RCS boration timeline to maintain subcritical conditions when performing an RCS cooldown to 350°F as detailed in Ameren Calculation XX-136, Revision 0, includes one hour of mixing following addition of the borated volume for complete mixing.

The NRC staff's audit review considered whether the licensee had followed recommendations from the PWROG's position paper and the associated conditions imposed in the NRC staff's endorsement letter. Regarding the first condition, the NRC staff's review finds that the licensee's shutdown margin calculation had considered an appropriate range of RCS leakage rates in determining the limiting condition for the shutdown margin analysis. Furthermore, the NRC staff finds that the licensee's plan to initiate RCS makeup by 26 hours, including consideration of the inherent margin relative to when makeup is required, satisfies the second two conditions. Therefore, the NRC staff concludes that the licensee's calculation conforms to the intent of the PWROG position paper, including the additional conditions imposed in the NRC staff's endorsement letter.

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

3.2.3.5 FLEX Pumps and Water Supplies

The licensee relies on two different portable pumps during Phase 2. The licensee plans to use a FLEX AFW pump to feed the SGs from the CST or the HCST when the TDAFW pump can no longer be used. Also, the licensee plans to use a FLEX boron pump to provide high pressure, low flow RCS makeup from the BATs or the RWST. In Section 2.3.10 of its FIP, the licensee identified the performance criteria (e.g., flow rate, discharge pressure) for the Phase 2 portable pumps. See Section 3.10 of this safety evaluation for a detailed discussion of the availability and robustness of each water source.

During Phase 2, core cooling will be transferred to a portable diesel-driven centrifugal FLEX AFW pump when the TDAFW pump is no longer available. The FLEX AFW pump will take suction from the CST or HCST. A single pump provides full capability to feed all steam generators. In the FIP, Section 2.3.10.1 states that the FLEX AFW pump is nominally rated for 500 gpm at 500 psig. During the audit process, the NRC staff reviewed the licensee's calculation AMN-003-CALC-017, "AFW Hydraulic Calculation for FLEX Piping Configuration," Revision 2, which determined the fluid system hydraulic performance. The NRC staff review notes that this calculation assessed different possible lineups based on such variables as suction sources, connection points and hose paths to determine the flow to ensure that the FLEX AFW pump procured by the licensee would be adequate for providing injection into the SGs at the required flow rate and discharge pressure.

Additionally, the licensee relies on one of two available FLEX boron pumps to provide RCS makeup. The NRC staff reviewed the licensee's calculation, AMN-003-CALC-016, "FLEX RCS Inventory Control and Core Cooling Hydraulic Calculation for Callaway Energy Center Unit 1," Revision 4, which determined the fluid system hydraulic performance. This calculation assessed different possible lineups based on such variables as suction sources, connection points and hose paths to determine the flow to ensure that the FLEX boron pump would be adequate for providing injection into the RCS at the required flow rate and discharge pressure. The FLEX boron pumps can be powered by the FLEX DGs through one of two available receptacles in the Auxiliary Building.

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

Based on the staff's review of the FLEX pumping capabilities at Callaway, as described in the above hydraulic analyses and the FIP, the NRC staff concludes that the portable FLEX pumps 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 ELAP and loss of normal access to the UHS. The electrical strategies described in the FIP are practically identical for maintaining or restoring core cooling, containment, and SFP cooling, except as noted in Sections 3.3.4.4 and 3.4.4.4 of this safety evaluation. The NRC staff reviewed the licensee's FIP, conceptual electrical single-line diagrams, and summary of calculations for sizing the FLEX generators and station batteries. The staff also reviewed the licensee's evaluations that addressed the effects of temperature on the electrical equipment credited in the FIP as a result of the loss of heating, ventilation, and air conditioning (HVAC) systems caused by the event.

After an ELAP and loss of all access to the UHS, the plant's indefinite coping capability is attained through the implementation of pre-determined FLEX strategies that are focused on maintaining or restoring key plant safety functions. A safety function-based approach provides consistency with, and allows coordination with, existing plant emergency operating procedures (EOPs). The FLEX strategies are implemented in support of EOPs using FSGs.

During the first phase of the ELAP event, the licensee would rely on the Class 1E station batteries and Inverters to provide power to key instrumentation for monitoring parameters and power to controls for SSCs used to maintain the key safety functions (reactor core cooling, RCS inventory control, and containment integrity). The Class 1E station batteries, inverters and associated dc distribution systems are located within the Control Building and Auxiliary Building, which are Seismic Category I structures. As such, the Phase 1 electrical equipment should be appropriately protected during the BDEEE.

The safety-related batteries will be used to initially power required key instrumentation and other required loads. Licensee procedures ECA-0.0, "Loss of All AC Power," and FSG-004, "ELAP DC Bus Load Shed and Management," direct operators to conserve dc power during the event by stripping non-essential loads. Plant operators will strip or shed unnecessary loads to extend battery life until backup power is available. Plant operators would commence load shedding within 45 minutes of the initiating event and complete load shedding within 60 minutes of the initiating event.

Callaway has four independent Class 1E 125 Vdc station batteries: NK11, NK12, NK13, and NK14. The batteries contains 60 cells each and were manufactured by Exide Technologies (GNB model). The NK11 and NK14 batteries are model NCN-23 (1672 ampere – hour (A-H) at an 8-hour discharge rate to 1.81 volts per cell) and the NK13 and NK12 batteries are model NCN-13 (952 A-H at an 8-hour discharge rate to 1.81 volts per cell).

The NRC staff reviewed the summary of the licensee's dc system calculation Attachment O, "Fukushima Extended Loss of AC Power Load Shed Analysis," in calculation NK-05, "Class 1E Battery Capacity," Revision 10, to verify capacity of the dc system to supply dc power to the required loads during the first phase of the Callaway FLEX mitigation strategies plan. In the calculation, the licensee identified the required loads, their associated ratings (ampere and minimum required voltage) and the loads that would be shed within 60 minutes to ensure battery operation of at least 12 hours. This strategy provides sufficient margin to transition to Phase 2 as the licensee expects the onsite portable FLEX DG to be staged, deployed and energized within 10 hours after onset of an ELAP event. The staff reviewed FSG-4 to confirm that it provides operational guidance to load shed non-essential loads within the time assumed in the licensee's analysis.

In order to assess extended battery duty cycles, the guidance in NEI White Paper, "EA-12-049 Mitigating Strategies Resolution of Extended Battery Duty Cycles Generic Concern," [Reference 46] was developed by the nuclear industry. This paper was subsequently endorsed by the NRC [Reference 47]. 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 of 2015 [Reference 48]. The testing provided additional validation that the NEI white paper method was technically acceptable. During the audit process, the NRC staff reviewed the licensee's battery calculations and confirmed that they had followed the guidance in the NEI white paper.

Based on the above, the NRC staff concludes that the Class 1E station batteries have adequate capacity to supply the required loads until the Phase 2 equipment can be deployed and energize the Callaway vital buses.

During Phase 2, the licensee's strategy includes transition from installed equipment to the onsite FLEX equipment. In its FIP, the licensee discussed primary and alternate strategies for supplying power to equipment required to provide reactor core, containment, and SFP cooling using a combination of portable FLEX and permanently installed, seismically robust components. In its FIP, the licensee stated that Callaway will use two 480 Vac, 500 kW trailer mounted FLEX DGs to power the required Phase 2 loads. Both FLEX DGs are identical, thus ensuring electrical compatibility and sufficient electrical capacity in an instance where substitution is required. Since both FLEX DGs are identical and interchangeable, the NRC staff finds that the licensee has met the provisions of NEI 12-06 for spare equipment capability regarding the Phase 2 FLEX DGs. The FLEX 480 Vac FLEX DGs are stored in the HSB.

The licensee's document DAR-PEUS-12-3, "FLEX Electrical Conceptual Design for Callaway Energy Center," Revision 1, was reviewed by the NRC staff. In this document, the licensee determined that all four battery chargers will be connected to the FLEX DG at the same time and the total required Phase 2 loads would be approximately 196 kW. During the audit process, the NRC staff also reviewed the licensee's calculations, conceptual single line electrical diagrams, the separation and isolation of the FLEX DGs from the Class 1E emergency diesel generator (EDG), and procedures that direct operators how to align, deploy, connect, and protect associated systems and components. The staff notes that FSG-4 provides guidance on energizing battery chargers using the FLEX DGs to ensure that the critical plant instruments are continued to be powered, as well as providing guidance on staging, connecting and energizing FLEX 480 Vac FLEX DGs.

Based on its review, the NRC staff concludes that the Phase 2 FLEX DGs have adequate capability and capacity to power the loads needed for the analyzed ELAP event.

For Phase 3, the licensee plans to continue the Phase 2 coping strategy with additional assistance provided from offsite equipment/resources as needed. The offsite resources that will be provided by an NSRC includes three (3) 1-megawatt (MW), 4160 Vac CTGs, one (1) 480 Vac, 1100 kW CTG, a distribution center, and cables. The three (3) NSRC supplied 4160 Vac CTGs running in parallel will supply power to one of the two Class 1E 4160 Vac buses. Additionally, by restoring a Class 1E 4160 Vac bus, power can be restored to the Class 1E 480 Vac via the 4160/480 Vac step down transformers to power selected 480 Vac loads. The three 1-MW CTGs will provide power that should be sufficient for restoration of the RHR System and the needed portion of the CCW and essential service water systems to establish decay heat removal. The staff reviewed FSG-42, "Deployment of NSRC FLEX Generators," Revision 0, which provides guidance to the operators to stage, deploy and connect the NSRC 4160 Vac CTGs to the 4160 Vac buses and NSRC 480 Vac CTG to primary and alternate connection points. Procedure FSG-42 also provides guidance to the plant operators to verify proper phase rotation on the CTGs before electrical buses are energized to ensure it matches plant equipment (pumps motors etc.).

Based on its review of the licensee's summary calculation DAR-PEUS-12-3 and FSG-42, the NRC staff finds that the 4160 Vac and 480 Vac equipment being supplied from an NSRC should have sufficient capacity and capability to supply the required loads during Phase 3.

3.2.4 Conclusions

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

3.3 Spent Fuel Pool Cooling Strategies

In NEI 12-06, Revision 2, Table 3-2 and Appendix D summarize an approach consisting of two separate capabilities for the SFP cooling strategies. This approach requires a strategy to mitigate the effects of steam from the SFP, such as venting. It also uses a portable injection source to provide the capability for: (1) makeup via hoses on the refueling floor capable of exceeding the boil-off rate for the design basis heat load; and (2) makeup via connection to spent fuel pool cooling piping or other alternate location capable of exceeding the boil-off rate for the design-basis heat load. During the event, the licensee selects the SFP makeup method to use based on plant conditions. However, in JLD-ISG-2012-01, Revision 1 [Reference 7], the NRC staff did not fully accept the NEI-proposed approach, and added another requirement to either have the capability to provide spray flow to the SFP, or complete an SFP integrity evaluation which demonstrates that a seismic event would have a very low probability of inducing a crack in the SFP or its piping systems so that spray would not be needed to cool the spent fuel.

As described in NEI 12-06, Section 3.2.1.7, and JLD-ISG-2012-01, Section 1.1, strategies that must be completed within a certain period of time should be identified and a basis that the time can be reasonably met should be provided. In NEI 12-06, Section 3 provides the performance attributes, general criteria, and baseline assumptions to be used in developing the technical basis for the time constraints. Since the event is beyond-design-basis, the analysis used to provide the technical basis for time constraints for the mitigation strategies may use nominal initial values (without uncertainties) for plant parameters, and best-estimate physics data. All equipment used for consequence mitigation may be assumed to operate at nominal setpoints and capacities. In NEI 12-06, Section 3.2.1.2 describes the initial plant conditions for the at-power mode of operation; Section 3.2.1.3 describes the initial conditions; and Section 3.2.1.6 describes SFP initial conditions.

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

The ELAP causes a loss of cooling in the SFP. As a result, the pool water will heat up and eventually boil off. The licensee's response is to provide makeup water. The timing of operator actions and the required makeup rates depend on the decay heat level of the fuel assemblies in the SFP. The sections below address the response during operating, pre-fuel transfer or post-fuel transfer operations. The effects of an ELAP with full core offload to the SFP is addressed in Section 3.11. The licensee's plan incorporates the capability to provide SFP spray, consistent with the performance characteristics of JLD-ISG-2012-01, Revision 1 (250 gpm).

3.3.1 Phase 1

The licensee will monitor SFP water level using reliable SFP level instrumentation installed per Order EA-12-051. The licensee will route and connect certain SFP makeup hoses and vent the Fuel Building during this time period in preparation for providing SFP makeup water in Phase 2.

3.3.2 Phase 2

During Phase 2, FIP Section 2.4.2 states that operators will deploy a portable FLEX SFP pump to supply water from the RWST or HCST to the SFP. The primary connection for the pump discharge can be routed to a permanently installed pipe which is located in the Fuel Building and terminates on the refueling floor, spraying water into the pool through permanently installed nozzles. The alternate connection is also located in the Fuel Building. An intermediate pipe has been permanently installed from the alternate connection to a higher level in the Fuel Building where a hose is used to connect to the SFP cooling system. Lastly, the licensee has a third, permanently installed connection point to a separate spray header that terminates with two monitor spray nozzles spraying into the pool. Because the licensee does not route hose directly to the SFP and does not use portable monitor nozzles as outlined in NEI 12-06, Revision 2 as endorsed by the NRC in JLD-ISG-2012-01, Revision 1, the staff determined the licensee's SFP cooling strategy is an alternative to the guidance. However, the staff finds the alternative strategy to be acceptable. See Section 3.14 of this safety evaluation for a more detailed discussion of the NRC's evaluation of the alternative.

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 will be available during Phase 3 for SFP cooling and will provide an additional pump for defense-in-depth. The NSRC will also provide water purification equipment to maintain an indefinite clean water source.

3.3.4 Staff Evaluations

3.3.4.1 Availability of Structures, Systems, and Components

3.3.4.1.1 Plant SSCs

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

The staff reviewed the licensee's calculation of the time to boil for the SFP. This calculation and the FIP indicate that boiling begins at approximately 5.46 hours during a normal, non-outage (partial core offload) situation. The staff noted that the licensee's sequence of events timeline in its FIP indicates that operators will deploy hoses and spray nozzles as a contingency for SFP makeup within 5.4 hours from event initiation to ensure the SFP area remains habitable for personnel entry.

As described in the licensee's FIP, the licensee's Phase 1 SFP cooling strategy does not require immediate SFP makeup. However, the licensee does establish a ventilation path to cope with temperature, humidity and condensation from evaporation and/or boiling of the SFP. Specifically, the operators are directed to open the Fuel Building exterior roll-up door to establish the ventilation path. At this time the operators will also connect the SFP makeup and spray hoses inside the Fuel Building.

The licensee's Phase 2 and Phase 3 SFP cooling strategy involves the use of the FLEX pump (or possibly an NSRC-supplied pump for Phase 3), with suction from the HCST being refilled from the UHS, to supply water to the SFP. The staff's evaluation of the robustness and availability of FLEX connections points for the FLEX pump is discussed in Section 3.7.3.1 below. Furthermore, the staff's evaluation of the robustness and availability of the UHS for an ELAP event is discussed in Section 3.10.3.

3.3.4.1.2 Plant Instrumentation

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

3.3.4.2 Thermal-Hydraulic Analyses

As described in the licensee's FIP, Section 2.4.6, the SFP will boil in approximately 2.34 hours and boil off to a level 15 feet above the top of fuel in 35 hours from initiation of the event with no operator action at the maximum design heat load (full core offload).

Calculation CN-SEE-II-12-39, "Determination of the Time to Boil in the Callaway Spent Fuel Pool after an Earthquake," Revision 0, states that the two bounding scenarios analyzed are: (1) maximum normal operation heat load, and (2) the maximum normal/emergency refueling heat load. The heat loads, boil-off times, and makeup rates are listed below.

	Heat Load	Time to boil	Makeup rate
Case 1	27.15 million Btu/hr	5.46 hrs	58.08 gpm
Case 2	63.41 million Btu/hr	2.34 hrs	135.64 gpm

Therefore, the licensee conservatively determined the required SFP makeup flow rate that will maintain adequate SFP level (greater than 15 feet) for an ELAP occurring during normal power operation as well as for a full core offload. Consistent with the guidance in NEI 12-06, Section 3.2.1.6, the staff finds the licensee has considered the maximum design-basis SFP heat load.

3.3.4.3 FLEX Pumps and Water Supplies

As described in the FIP, the SFP cooling strategy relies on the FLEX SFP pump to provide SFP makeup during Phase 2. In the FIP, Section 2.4.7.1 describes the hydraulic performance criteria (e.g., flow rate, discharge pressure) for the FLEX SFP pump. The FIP states the FLEX SFP pump can provide nominally 250 gpm at 92 psig discharge pressure. The staff noted that the performance criteria of a FLEX pump supplied from an NSRC for Phase 3 would allow the

NSRC pump to fulfill the mission of the onsite FLEX pump if the onsite FLEX pump were to fail. As stated above, the FLEX SFP pump can provide SFP spray flow rate of 250 gpm which both meets and exceeds the maximum SFP makeup requirements. Furthermore, the staff review of the SFP analysis described above concludes that it is consistent with NEI 12-06, Section 11.2 and the FLEX equipment is capable of supporting the SFP cooling strategy.

3.3.4.4 Electrical Analysis

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

The NRC staff reviewed the licensee's electrical strategies, which includes the SFP cooling strategy. In the FIP, the licensee credited electrical components in addition to instrumentation used to monitor SFP level (which is addressed as part of the NRC Order EA-12-051). The licensee plans to use onsite FLEX portable generators to provide alternative power to the SFP instrumentation display panels and to recharge the backup battery within 72 hours of an ELAP event. During the audit process the NRC staff reviewed the licensee's plan, and concludes that there will be adequate capacity and capability to supply alternative power to the SFP instrumentation display panels and to recharge the backup battery, if necessary. No other electrical power is needed as part of the licensee's SFP cooling strategy.

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

3.3.5 Conclusions

Except for the SFP spray alternative evaluated separately in Section 3.14 of this safety evaluation, the NRC staff concludes that the licensee's strategy is consistent with NEI 12-06 guidance, as endorsed by JLD-ISG-2012-01, Revision 1, and the licensee's strategy should maintain or restore SFP cooling following an ELAP and should adequately address the requirements of the order.

3.4 Containment Function Strategies

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

The licensee performed a containment evaluation, CN-SCC-13-001, "Callaway ELAP Containment Environment Analysis," Revision 2, which was based on the boundary conditions described in Section 2 of NEI 12-06. The calculation analyzed the strategy and concluded that the containment parameters of pressure and temperature remain well below the respective FSAR [Reference 49], Table 6.2.1-2, design limits of 60 psig and 320°F during the first 72 hours. From its review of the evaluation, the NRC staff noted that the required actions to maintain containment integrity and the required instrumentation functions have been developed, and are summarized below.

3.4.1 Phase 1

The Phase 1 coping strategy for maintaining containment functions only involves verifying containment isolation and monitoring containment temperature and pressure using installed instrumentation. The FIP states that the containment pressure and temperature indication will be available in the control room for the duration of the ELAP.

3.4.2 Phase 2

During Phase 2, containment temperature and pressure are expected to remain below design limits; however, containment status will continue to be monitored. Phase 2 activities therefore are designed to maintain the monitoring function. Monitoring is accomplished via the licensee's electrical strategy (FLEX DG powering the required instrumentation).

3.4.3 Phase 3

The licensee stated in its FIP, that no additional specific Phase 3 strategy is required to maintain containment integrity. However, the licensee does plan to establish RHR cooling which will lower the heat input into containment and therefore minimize containment challenges to support indefinite coping. Additionally, during the audit process the NRC staff reviewed the licensee's procedure FSG-12, "Alternate Containment Cooling," Revision 0, which provides multiple methods to cool containment should it become necessary.

3.4.4 Staff Evaluations

3.4.4.1 Availability of Structures, Systems, and Components

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

3.4.4.1.1 Plant SSCs

Section 3.8.1 of the Callaway FSAR states that the containment consists of concrete and steel. It is a Seismic Category I cylindrical structure with a hemispherical dome constructed of a pre-stressed, reinforced concrete and a conventionally reinforced concrete base slab. A welded steel liner is attached to the inside face of the concrete. Being a Seismic Category I structure, the containment has been designed to maintain its function following a safe shutdown earthquake (SSE). Additionally, Sections 3.3 and 3.5 of the FSAR state that Seismic Category I structures are designed to withstand extreme wind phenomena including tornado effects. The staff finds that the containment building is robust and would be expected to be available at the start of an ELAP event consistent with NEI 12-06, Section 3.2.1.3.

Table 6.2.1-2 of the Callaway FSAR, shows that the net free volume of the containment is 2.50 million cubic feet. The addition of mass and energy to the containment atmosphere during an ELAP event is driven by the assumed leakage from the RCP seals. The relatively small amount of heat and mass being added to the containment atmosphere coupled with the very large net free volume of the containment results in a slow-moving response. As stated above, the licensee's calculation shows that even with no mitigating actions taken to remove heat from the containment, the containment parameters of pressure and temperature remain well below the respective design limits of 60 psig and 320°F for at least 72 hours.

3.4.4.1.2 Plant Instrumentation

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

3.4.4.2 Thermal-Hydraulic Analyses

During the audit process, the NRC staff reviewed calculation CN-SCC-13-001, "Callaway ELAP Containment Environment Analysis," Revision 2, which was based on the boundary conditions described in Section 2 of NEI 12-06. In this calculation, the licensee utilized the GOTHIC 7.2b code to model the containment response to an ELAP. The only additions of heat and mass to the containment atmosphere under ELAP conditions are the ambient heat losses from the surfaces of hot equipment and the leakage of reactor coolant from the RCP seals.

Using the input described above, the containment maximum pressure and temperature within the 72 hours were estimated to be approximately 21.5 psia and less than 200°F with no operator actions taken. The analysis did show some local temperatures in the lower reactor vessel cavity compartment peak at 560°F then slowly decrease. The licensee's compliance letter, Enclosure 2, Confirmatory Item 3.2.3.A, states that the steel and concrete structure in that area remains functional and has sufficient margin to the design limits. In FIP Section 2.5.6, the licensee states that the only instrumentation in that region that might fail are the nuclear instruments (NIs). The licensee therefore developed procedures to compensate for a loss of NIs. With the exception of the lower vessel cavity temperatures, the containment parameters are still far below the FSAR design parameters of 60 psig and 320°F, and thus the NRC staff concludes that the licensee has adequately demonstrated that there is significant margin before a containment limit would be reached.

3.4.4.3 FLEX Pumps and Water Supplies

The licensee does not plan to use any FLEX equipment to maintain containment integrity other than what has already been mentioned in other sections of this safety evaluation.

3.4.4.4 Electrical Analyses

During Phase 1, Class 1E batteries will supply power to the plant instruments through Class 1E inverters for at least 12 hours. The NRC staff has reviewed the Class 1E battery capacity and capability in Section 3.2.3.6 of this safety evaluation.

During Phase 2, a FLEX DG will supply power to recharge the depleted batteries via battery chargers, which will provide continuous power to the plant instruments. The NRC staff reviewed the licensee's analysis and concluded that the FLEX DG should have adequate capacity and capability to supply power to the required Phase 2 instruments for monitoring containment temperature and pressure.

During Phase 3, the three NSRC supplied 1-MW, 4160 Vac CTGs could provide power to the required Phase 2 loads (instruments) and Phase 3 loads (such as an RHR pump and CCW pump) to help maintain containment pressure and temperature within the equipment design limits via RCS cooling, if necessary. The NRC staff reviewed the licensee's calculations and procedures and concludes that the NSRC supplied CTGs running in parallel should provide adequate capacity and capability to supply power to the required Phase 3 loads that would support maintaining containment pressure and temperature control indefinitely.

Based on above, the NRC staff concludes that the licensee's electrical strategy regarding the containment safety function during an ELAP as a result of a BDBEE is acceptable.

3.4.5 Conclusions

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

3.5 Characterization of External Hazards

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

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

The licensee reviewed the plant site against NEI 12-06 and determined that FLEX equipment should be protected from the following hazards: seismic; 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 Request for Information pursuant to Title 10 of the *Code of Federal Regulations* Part 50, Section 50.54(f) [Reference 21] (hereafter referred to as the 50.54(f) letter), which requested that licensees reevaluate the seismic and flooding hazards at their sites using updated hazard information and current regulatory guidance and methodologies. Due to the time needed to reevaluate the hazards, and for the NRC to review and approve them, the reevaluated hazards were generally not available until after the mitigation strategies had been developed. The NRC staff has developed a proposed rule, titled "Mitigation of Beyond-Design-Basis Events," hereafter called the MBDBE rule, which was published for comment in the Federal Register on November 13, 2015 [Reference 39]. The proposed MBDBE rule would make the intent of Orders EA-12-049 and EA-12-051 generically applicable to all present and future power reactor licensees, while also requiring that licensees consider the reevaluated hazard information developed in response to the 50.54(f) letter.

The NRC staff requested Commission guidance related to the relationship between the reevaluated flooding hazards provided in response to the 50.54(f) letter and the requirements for Order EA-12-049 and the MBDBE rulemaking (see COMSECY-14-0037, Integration of Mitigating Strategies for Beyond-Design-Basis External Events and the Reevaluation of Flooding Hazards" [Reference 38]). The Commission provided guidance in an SRM to COMSECY-14-0037 [Reference 22]. The Commission approved the staff's recommendations that licensees would need to address the reevaluated flooding hazards within their mitigating strategies for BDBEEs, and that licensees may need to address some specific flooding scenarios that could significantly damage the power plant site by developing scenario-specific mitigating strategies, possibly including unconventional measures, to prevent fuel damage in reactor cores or SFPs. The NRC staff did not request that the Commission consider making a requirement for mitigating strategies capable of addressing the reevaluated flooding hazards be immediately imposed, and the Commission did not require immediate imposition. In a letter to licensees dated September 1, 2015 [Reference 37], the NRC staff informed the licensees that the implementation of mitigation strategies should continue as described in licensee's OIPs, and that the NRC safety evaluations and inspections related to Order EA-12-049 will rely on the guidance provided in JLD-ISG-2012-01, Revision 0, and the related industry guidance in NEI 12-06, Revision 0. The hazard reevaluations may also identify issues to be entered into the licensee's corrective action program consistent with the OIPs submitted in accordance with Order EA-12-049.

As discussed above, licensees are reevaluating the site seismic and flood hazards as requested in the NRC's 50.54(f) letter. After the NRC staff approves the reevaluated hazards, licensees will use this information to perform flood and seismic mitigating strategies assessments (MSAs) per the guidance in NEI 12-06, Revision 2, Appendices G and H [Reference 6]. The NRC staff endorsed Revision 2 of NEI 12-06 in JLD-ISG-2012-01, Revision 1 [Reference 7]. The licensee's MSAs will evaluate the mitigating strategies described in this safety evaluation using the revised seismic hazard information and, if necessary, make changes to the strategies or equipment. Licensees will submit the MSAs for NRC staff review.

The licensee developed its OIP for mitigation strategies by considering the guidance in NEI 12-06 and the site's design-basis hazards. Therefore, this 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 SSE. As described in FSAR Section 2.5.2.8, the SSE seismic criteria for the site is two-tenths of the acceleration due to gravity (0.20g) peak 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

In its FIP, the licensee described that the types of events evaluated to determine the worst potential flood including: (1) potential maximum flood (PMF) due to nearby water sources, and (2) flood due to local intense precipitation equal to the potential maximum precipitation (PMP) at the plant site.

The licensee stated that specific analysis of flood levels resulting from ocean front surges and tsunamis is not required because of the inland location of the plant. Flood waves from landslides into upstream reservoirs required no specific analysis due to the lack of topographic and geologic features conducive to landslide formation. The licensee also concluded that seiches pose no flood threats for the plant.

The maximum plant site flood level from any cause is elevation 840.16 feet (ft.) mean sea level (MSL). The grade level for all SSCs (except the UHS retention pond and RWST) is at an elevation of about 840.5 ft. MSL (this elevation correlates to plant elevation 2000 ft.), which is above the design basis flood level. Per NEI 12-06, plants that are considered “dry” (i.e., the plant is built above the design basis flood level) are not susceptible to the external flooding hazard; therefore, the licensee concludes that the external flood hazard is screened out for Callaway.

In its compliance letter [Reference 20], the licensee describes a potential seismic failure of piping in the auxiliary feedwater room that could drain the contents of the CST into the Auxiliary Building, flooding the 1974 ft. elevation with approximately 4 feet of water. This potential motivated the licensee’s strategy of storing one boron injection/RCS makeup pump in the HSB such that it can be deployed at a higher elevation in the Auxiliary Building than the pre-staged RCS boron pump.

As the licensee's flooding reevaluation activities are completed, the licensee is expected to assess the mitigation strategies to ensure they can be implemented under the reevaluated hazard conditions as will potentially be required by the proposed MBDBE rulemaking.

3.5.3 High Winds

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

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

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

A review of NEI 12-06 Figure 7-2, Recommended Tornado Design Wind Speeds for the 1E-6/year Probability Level indicates that the site is in Region 1 of this figure, where the tornado design wind speed exceeds 130 mph. Therefore, the plant screens in for an assessment for high winds and tornados, including missiles produced by these events. The site is beyond the range of high winds from a hurricane per NEI 12-06 Figure 7-1, thus, a hurricane hazard is not applicable.

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

3.5.4 Snow, Ice, and Extreme Cold

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

In its FIP, the licensee stated that the site is located at 38° 45' 40.7" north latitude and 91° 46' 50.5" west longitude. In addition, the site is located within the region characterized by the Electric Power Research Institute (EPRI) as ice severity level 3 (NEI 12-06, Figure 8-2, Maximum Ice Storm Severity Maps). Consequently, the site is subject to icing conditions that could cause low to medium damage to electrical transmission lines.

In its FIP, the licensee stated that the climate at the Callaway Plant site is temperate-continental with cold, snowy winters. Based on climatological data from nearby weather stations, the normal average temperature is 55°F in Columbia, Missouri. The extreme low temperature was -26°F in Fulton, Missouri. The licensee concludes that the plant screens in for an assessment for snow, ice, and extreme cold hazard.

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

3.5.5 Extreme Heat

In the section of its FIP regarding the determination of applicable extreme external hazards, the licensee stated that, as per NEI 12-06 Section 9.2, all sites are required to consider the impact of extreme high temperatures. The climate at the Callaway Plant site is temperate-continental with warm, humid summers. Based on climatological data from nearby weather stations, the extreme recorded local high temperature was 116°F in Fulton, Missouri. The licensee thus concludes that the plant site screens in for an assessment of the 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 NRC staff concludes that the licensee has appropriately screened in the high temperature hazard and characterized the hazard in terms of expected temperatures.

3.5.6 Conclusions

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

3.6 Planned Protection of FLEX Equipment

3.6.1 Protection from External Hazards

In its FIP, the licensee described the new HSB for storage of FLEX equipment. The HSB is a single, 7,200 square ft. concrete building that was constructed to meet the requirements of NEI 12-06, Revision 2, for seismic, flooding, high winds, snow, ice, extreme cold, and high temperatures for protection of FLEX equipment. The HSB is inside the protected area and is utilized to house most of the FLEX equipment. Some FLEX equipment is stored within the power block in Seismic Category I buildings (e.g., Auxiliary Building, Fuel Building).

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

3.6.1.1 Seismic

In its FIP, the licensee stated that the HSB was designed using American Society of Civil Engineers (ASCE) standard ASCE 7-10, "Minimum Design Loads for Buildings and Other Structures." The Callaway plant SSE was utilized as a design input for seismic design requirements. This should ensure that the portable FLEX equipment stored in this building will be protected from a seismic event. According to the licensee's FIP, analysis of the components stored in the HSB has been performed to determine appropriate measures to prevent seismic interaction.

3.6.1.2 Flooding

The Callaway FIP states that the limiting postulated flood hazard elevation is below the grade level of all plant SSCs, except for the UHS and the lower portion of the RWST.

The licensee's FIP also states that the site is therefore considered to be "dry" and thus the external flood hazard screens out. During the audit process, the NRC staff questioned whether the UHS and RWST qualifiers could adversely impact the FLEX strategy. The licensee responded in its compliance letter stating that based on the site grading, the UHS would not be adversely impacted by debris associated with potential flood waters. Regarding the RWST, the licensee's compliance letter also states that access for FLEX strategies would be through the RWST valve house, which is above the maximum postulated site flood level and that deployment of FLEX equipment would not be impacted. In terms of equipment protection, the licensee's FIP states that the HSB was constructed to meet the requirements of NEI 12-06, Revision 2 for flooding. During the site audit, the NRC staff observed the location and elevation of the RWST valve house and HSB and concurred with the licensee's determination that these structures are protected from flooding and that deployment of any necessary FLEX equipment should not be adversely impacted by postulated flooding.

3.6.1.3 High Winds

In its FIP, the licensee stated that the HSB was designed to protect FLEX equipment against high wind conditions associated with a BDBEE, including tornado driven missiles as defined in NRC Regulatory Guide 1.76, Revision 1. The NRC staff review concludes that the use of NRC Regulatory Guide 1.76, Revision 1, for the HSB design provides reasonable assurance that he stored equipment should be available following a high wind event.

3.6.1.4 Snow, Ice, Extreme Cold and Extreme Heat

In its FIP, the licensee stated that the HSB was constructed to meet the requirements of NEI 12-06 Revision 2 for snow, ice, extreme cold, and high temperatures for protection of FLEX equipment. The HSB was designed to withstand extreme temperatures by using an installed ventilation system. The ventilation system will maintain temperatures below the upper operating temperatures of the FLEX equipment stored in the building. Installed heaters provide heat for the building to maintain the building warmer than 50°F. The licensee's compliance letter also states that the FLEX equipment not stored in the HSB is stored in the power block, which is also maintained at greater than 50°F.

3.6.2 Reliability 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.

Table 1 in the FIP lists the FLEX portable equipment stored onsite as well as the quantities, performance ratings, and functional uses, e.g., core, containment, SFP. This includes the major pumps and generators referred to in the descriptive portions of the FIP as well as associated hoses, cables, and fittings necessary to connect the equipment. It also includes tow and debris removal vehicles, light towers, and other miscellaneous support equipment.

Additionally, in its FIP the licensee stated that in the case of hoses and cables associated with FLEX equipment required for FLEX strategies, additional spares have been procured per the requirements of NEI 12-06, Section 3.2.2.16.

Based on the number of portable FLEX pumps, FLEX DGs, and support equipment identified in 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 equipment for RCS makeup and boration, SFP makeup, and maintaining containment consistent with the "N+1" recommendation in Section 3.2.2.16 of NEI 12-06, Revision 2.

3.6.3 Conclusions

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

3.7 Planned Deployment of FLEX Equipment

In its FIP, the licensee stated that pre-determined, preferred haul paths have been identified and documented in the FSGs. Figure 1 in the FIP shows the haul paths from the HSB to the various deployment locations.

3.7.1 Means of Deployment

Tow and debris removal vehicles are included in the Table 1 list of FLEX equipment in the FIP. The tow vehicle is a Freightliner truck with a service bed, which is stored in the HSB. This vehicle is capable of towing all FLEX equipment stored in the HSB. The debris removal equipment is a Case 590SN backhoe. The debris removal equipment is stored inside the HSB such that it remains functional and deployable to clear obstructions from the pathway between the HSB and the deployment location(s).

3.7.2 Deployment Strategies

In its FIP, the licensee stated that the deployment strategies from the HSB to each staging area are identified, as well as the debris removal concerns, security barriers, and lighting needs as they apply to each deployment path. To ensure the strategies can be implemented in all modes, areas adjacent to the equipment storage facilities and staging areas, as well as the deployment and routing paths will be kept normally accessible. Haul paths have been reviewed for potential soil liquefaction and have been determined to be stable following a seismic event.

The UHS retention pond would remain available as a water source during extreme cold conditions. In the event that the UHS retention pond was covered with a layer of ice, instructions are provided in an FSG for breaking through the ice to gain access to the water for the suction hoses and strainers.

3.7.3 Connection Points

3.7.3.1 Mechanical Connection Points

Core Cooling

The licensee's FIP, Section 2.3.5.1, states that the primary connection point for the FLEX AFW pump injects into the non-safety auxiliary feedwater pump discharge piping that feeds all four SGs. The connection is on an existing AFW line that contains a hose connection and two normally shut isolation valves. The primary AFW connection is located in the Auxiliary Building which is a Seismic Category I structure protected from all applicable hazards. The licensee's FIP, Section 2.3.5.1, also states that the alternate connection will connect to the discharge header of the "B" motor-driven auxiliary feedwater pump. This connection is also located in the Auxiliary Building. Additionally, the FLEX AFW pump will take suction from a connection to the HCST which the licensee stated in the FIP was fully protected from all applicable external hazards. During the audit process the NRC staff reviewed Callaway Modification Package MP-13-0024, "AFW Makeup for Core Cooling During BDBEE," Revision 3, to confirm that the primary and alternate connection points are seismically analyzed and high wind missile-protected, and therefore robust as defined by NEI 12-06.

In order to support long-term ASD and AFW flow control remote operation, the licensee developed a strategy to use either a diesel or electric-driven compressor to provide compressed air to the AFW/ASD accumulators. The four connections for the accumulators are located in the Auxiliary Building which is protected from all applicable hazards. The licensee has procedures to manually operate the AFW flow control valves and appropriate ASD valves, should remote operation be unavailable.

RCS Inventory Control/Makeup

Section 2.3.5.2 of the FIP, states that the discharge from the FLEX boron pump will be connected to the primary RCS tie-in on the boron injection header located in the Auxiliary Building on the 1974' elevation. In the FIP, Section 2.3.5.2 states that the alternate RCS connection is tied into the safety injection system via intermediate pipes and is also located in the Auxiliary Building on the 2000' level. The primary suction connections as stated in the FIP are one of two BATs. However, the licensee's compliance letter states that a seismic event could cause non-robust piping to fail, resulting in 4' of flooding of the Auxiliary Building basement (1974' elevation) which would make the FLEX boron pump stored on that level unavailable. If this scenario occurred, the FLEX boron pump stored in the HSB would be deployed to the 2000' level in the Auxiliary Building. The discharge of the pump would be routed to the safety injection system connection located on the 2000' level (the alternate connection described above). During this scenario based on a seismic event, the RWST would be used as a suction source. The licensee's FIP states that the RWST is Seismic Category I and thus would be available in this case.

SFP Makeup

In the licensee's FIP, Section 2.4.4.1, describes the SFP makeup strategy connections. The license has two independent flow paths for providing SFP makeup from the one of two available FLEX SFP pumps. The primary flow path utilizes a connection and permanently installed, seismically robust piping. The connection is located on ground level inside the Fuel Building and then the permanently installed pipe is routed up to the refueling floor where it ends at the pool level with two nozzles spray into the pool. The alternate flow path utilizes a separate connection on ground level of the Fuel Building and permanent piping routed up to the 2026' level where it terminates. A hose is then connected from the termination point to the SFP cooling system providing makeup to the pool. Lastly, the licensee has a third connection located on the ground floor of the Fuel Building. This connection and piping is routed up the wall of the fuel building above the pool and provides spray flow to the SFP via two monitor spray nozzles.

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

3.7.3.2 Electrical Connection Points

Electrical connection points are only applicable for Phases 2 and 3 of the licensee's mitigation strategies for a BDBEE. During Phase 2, the licensee has developed primary and alternate strategies for supplying power to equipment required to maintain or restore core cooling, containment, and SFP cooling using a combination of permanently installed and portable components.

In its FIP, the licensee discussed the primary and alternate strategies for Phase 2 operation for deployment and connections of the FLEX 480 Vac FLEX DGs to supply power to the Class 1E battery chargers. The primary strategy for repowering battery chargers is to deploy one of the two FLEX 480 Vac FLEX DGs and the cable trailer stored in the HSB to the staging area near the southwest side of the Auxiliary Building. Operators would then run cables through the selected emergency doors to a new Auxiliary Building FLEX 480 Vac DG connection panel. After the cable connections are complete, operators would align breakers and disconnect switches to restore power to the Class 1E battery chargers.

The alternate Phase 2 strategy for supplying power to the Class 1E battery chargers is to deploy the cable trailer and a FLEX 480 Vac FLEX DG to the staging area near the Engineered Safety Feature (ESF) Switchgear Room "B" doors. Operators would then run cables through these doors and to the selected Control Building FLEX 480V DG connection panel, located on the west wall of ESF Switchgear Room 3302. Operators would align breakers to restore power to the Class 1E 480 Vac Load Centers to provide power to the Class 1E battery chargers.

Auxiliary Building and Control Building FLEX 480V DG connection panels are seismically-designed, tornado missile protected, FLEX connection receptacles located within Seismic Category 1 buildings. The Auxiliary Building FLEX connection receptacle is connected to each 125 Vdc Vital Battery Charger via pre-installed cable and conduit. Disconnects provide appropriate electrical separation. The Control Building FLEX connection panel is connected to the Class 1E 480 Vac buses via pre-installed cable and conduit to Class 1E 480 Vac motor control center breakers. Callaway procedure FSG-4, "ELAP DC Bus Load Shed Management," provides guidance to the operators to deploy, stage and connect 480 Vac FLEX DGs to restore battery chargers to supply power to the critical instruments.

For Phase 3, three (3) 1-MW 4160 Vac CTGs supplied from an NSRC will be connected to a distribution panel (also provided from the NSRC) in order to meet the 4160 Vac load requirements. The 4160 Vac CTGs will be deployed outside the west wall of the Control Building. Operators would remove cables from a breaker on one of the Class 1E 4160 Vac buses and then connect cables from the distribution panel to the Class 1E 4160 Vac breaker. Primary and alternate strategies will allow the NSRC supplied 4160 Vac CTGs to supply power to one of the Class 1E 4160 Vac buses (NB01 or NB02) and will provide sufficient power for restoration of the RHR system and the needed portion of the CCW system. Additionally, by restoring a Class 1E 4160 Vac bus, power can be restored to the Class 1E 480 Vac via a 4160/480 Vac transformer to power selected 480 Vac loads. During the audit process, the NRC staff reviewed FSG-42, "Deployment of NSRC FLEX Generators," Revision 0, to verify the Phase 3 primary and alternate electrical strategies. The NRC staff review notes that phase rotation between NSRC CTGs and the installed plant equipment is checked before the plant equipment is energized.

All electrical connection points are located in either the Auxiliary or Control Building. These buildings are Seismic Category I structures providing protection of the connection points from all applicable external hazards at Callaway.

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

3.7.4 Accessibility and Lighting

With regard to lighting, in its FIP the licensee stated that the control room is served by emergency dc lighting powered by the Class 1E batteries. Prior to 12 hours after the event, the FLEX DG will be deployed to provide power to the Class 1E battery chargers. This will ensure continued operation of emergency dc lighting. Operators have flashlights available as necessary to provide lighting for operator actions outside the control room. Area lighting would be required for outside deployment of FLEX equipment during the night. FLEX light towers stored in the HSB provide this necessary lighting.

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. Specifically, the NRC staff reviewed FSG-5, "Initial Assessment and FLEX Equipment Staging," Revision 0, to confirm that contingencies are in place to provide access to areas required for the ELAP response if the normal access control systems are without power.

3.7.6 Fueling of FLEX Equipment

In its FIP, Section 2.9.5, the licensee states that all FLEX equipment stored in the HSB will be stored fueled. A fuel trailer is also stored in the HSB and is maintained full with approximately 1,140 gallons. Once the fuel in that tank is depleted the licensee has the ability to transfer fuel from the emergency fuel oil storage tanks to the fuel trailer. The fuel oil storage tanks (2 total) are located underground and protected from all applicable hazards. Each tank has a minimum supply of 80,900 gallons of fuel controlled by the plant technical specifications. The fuel trailer can be pulled by the FLEX tow vehicle or the debris removal vehicle, both of which are stored in the HSB. Based on the design and location of these EDG fuel tanks and protection, the staff finds the tanks are robust and the fuel oil contents should be available to support the licensee's FLEX strategies during an ELAP event.

As stated above, fuel oil storage tanks have approximately 160,000 gallons total. In the FIP, Section 2.9.5 states that the licensee calculated that the Phase 2 FLEX equipment consumption is 2,000 gallons per 12-hours. Fuel consumption increases significantly when the NSRC equipment is in operation. The licensee calculated that 26,000 gallons of fuel oil will be used in the first 72 hours and the usage after the NSRC equipment is operating will be approximately 13,000 gallons per day so the licensee calculates that one fuel oil storage tank should last for approximately 7 days. Given the information above, the NRC staff concludes that the licensee should have sufficient fuel onsite for diesel-powered equipment, and that diesel-powered FLEX equipment should be refueled to ensure uninterrupted operation to support the licensee's FLEX strategies.

In the Callaway compliance letter [Reference 20], the licensee stated that the trailer-mounted diesel driven equipment housed inside the HSB is equipped with automatic fuel oil purification systems that maintains the quality of the fuel oil inside the equipment tanks. Existing sampling requirements for the EDG fuel oil storage tanks are delineated in the Diesel Fuel Oil Testing Program as required by surveillance requirements contained in the plant technical specifications. Therefore, the diesel fuel oil onsite should be maintained such that the diesel-driven equipment will be available during an ELAP.

3.7.7 Conclusions

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 Callaway SAFER Plan

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

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

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

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

3.8.2 Staging Areas

In general, up to four staging areas for NSRC supplied Phase 3 equipment are identified in the SAFER Plans for each reactor site. There are multiple Staging Area "A's" for individual FLEX components inside the protected area. Staging Area "B" is immediately outside of the owner controlled area on the west side of the plant. Staging Area "C" (primary) and Staging Area "D" (alternate) are offsite areas (within about 25 miles of the plant) utilized for receipt of ground transported or airlifted equipment from the NSRCs. For Callaway, Staging Area "C" is the Ameren Missouri Columbia Gas Works Headquarters and Staging Area "D" is the Columbia Regional Airport. 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.

The Callaway SAFER Plan recognizes the potential need for helicopters to transport equipment from Staging Areas "C" and "D" to Staging Area "B" and provides instructions for accomplishing this option.

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 an external event and subsequent ELAP event at Callaway, ventilation that provides cooling to occupied areas and areas containing required equipment will be lost. The key areas identified for all phases of execution of the FLEX strategy activities are control room, Class 1E switchgear rooms, Class 1E battery rooms, and the TDAFW pump room.

TDAFW Pump Room

The licensee's Phase 1 core cooling FLEX strategy relies on the TDAFW pump as the motive force for providing cooling water to the SGs. During the audit, the licensee provided the staff with calculation M-GF-415, "Turbine Driven Aux Feed Pump GOTHIC Room Temperature Modeling," Revision 1. The calculation showed the maximum temperature of the TDAFW pump room will peak at 146°F, 30 days into the event if all ventilation is lost and no active or passive temporary ventilation is established. The Callaway FSAR [Reference 49], Table 8.3A-1, indicates that the components necessary for TDAFW pump operation are generally qualified to operate in a temperature environment up to at least 150°F, depending on the components. Further, the licensee relies on the TDAFW pump for the first 9 hours after event and after that, the FLEX AFW pump can provide makeup water to the SGs if necessary. The NRC staff also notes that the licensee's operational guidance instructs operators to establish additional ventilation, if necessary.

Based on the calculated room temperature staying below 150°F, the temperature that should ensure reliable operation, the NRC staff finds that the loss of ventilation during an ELAP should not have any adverse impact on the necessary equipment in the TDAFW pump room.

Control Room

In its FIP, the licensee stated that equipment functionality for instrumentation cabinets located in the control room will be assured by opening cabinet doors within 30 minutes after the onset of an ELAP event and that procedure ECA-0.0 provides this guidance. During the audit process the NRC staff reviewed Callaway Action Request (CAR) 201106180, Action 2.1.1.3, "Evaluate Control Room SBO Temperature Response," which modeled the control room temperature transient when all control room cooling is lost due to an ELAP event. This calculation determined that the expected maximum temperature in the control room will reach approximately 119°F and the maximum steady state temperature would be approximately 117°F. FSG-45, "Temporary Ventilation, Lighting and Power," Revision 0, provides guidance to the operators to monitor control room temperature and establish temporary ventilation (such as establishing a Control Building air flow exhaust path by opening or closing selected doors, installing blowers to direct hot air flow out of the building, etc.), if necessary to lower the temperature and to ensure that the control room temperature remains below equipment and component design temperature limits.

Based on control room 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 finds that the equipment in the control room will not be adversely impacted by the loss of ventilation as a result of an ELAP event.

Control Building Class 1E Battery Rooms

In the Callaway calculation GK-19, "Calculation of DC and ESF Switchgear Room Heat-up," Revision 0, the licensee determined that the maximum expected room temperature would be 113.3°F during a loss of offsite power (LOOP) scenario for vital battery rooms 1, 2, 3, and 4 with all air conditioning units lost. According to the licensee, the temperatures during a LOOP event will envelop temperatures during an ELAP event due to higher heat loads in the room during a LOOP event. Table 4 of FIP shows that the Class 1E battery room ventilation will be established within 12.5 hours into the event. FSG-45 provides guidance to the operator for actions to ventilate the battery rooms such as open/close selected battery doors, placing pedestal fans to direct air flow through the rooms for the Class 1E battery, dc switchboards, battery charger, inverters, ESF switchgear rooms using a blower (for hydrogen removal) when the battery charging is in progress.

Based on the licensee's analysis in calculation GK-19, the NRC staff finds that the Class 1E battery room temperature should remain below maximum temperature limit (120°F) of the batteries, as specified by the battery manufacturer Exide Technologies. Therefore, the NRC staff finds that the Callaway Class 1E batteries should perform their required functions at the expected temperatures as a result of loss of ventilation during an ELAP event.

Class 1E DC Switchboard Rooms (including Battery Chargers and Inverter) and ESF Switchgear Rooms

In Addendums 1 and 2 to calculation GK-19, the licensee determined that the maximum steady state temperature in the ESF switchgear rooms and Class 1E 125 Vdc switchboard rooms is expected to reach 156°F during a LOOP event. The environmental qualification evaluation in Addendum 1 of calculation GK-19 indicates that without opening room doors, the expected maximum room temperature for the LOOP condition does not exceed the equipment design qualification limit. Based on the calculation, the licensee concluded that the air conditioning units for Class 1E DC switchboard rooms and ESF switchgear rooms are not required for LOOP and non-LOOP conditions and that the room doors are not required to be opened under any condition for room cooling. However, the calculation stated that opening room doors is a conservative strategy to ensure room cooling and lower the room temperatures. FSG-45 includes guidance to implement ventilation for Class 1E DC switchboard and ESF switchgear rooms/areas by opening selected doors. Attachment D in FSG-45 shows the licensee's projected air flow passing through all Class 1E DC switchboard and ESF switchgear rooms and out of the Control Building. Based on above, the NRC staff finds that the equipment (DC switchboards, battery chargers and inverters and ESF switchgear) should remain functional in the expected room temperatures.

Containment

In its FIP, the licensee stated that for Modes 1-4, peak pressure in the first 72 hours is expected to reach 21.5 psia which is lower than the containment design pressure of 60 psig and except for the lower reactor vessel cavity compartment, temperatures throughout containment will remain less than 200°F, well below the design temperature of 320°F. During the audit process the NRC staff reviewed the licensee's evaluation and analysis in CN-SCC-13-001, "ELAP Containment Environment Analysis," Revision 2, which determined that containment temperature and pressure during an ELAP will remain below containment design limits and that key instrumentation subject to the containment environment will remain functional except for the nuclear instrumentation, which is discussed later. Therefore, immediate actions to reduce containment temperature and pressure to ensure continued containment integrity will not be required. The staff also reviewed EQ-EV-200-SCP, "Comparison of ELAP Environmental Conditions to the Qualified Environmental Conditions for In-Containment Equipment and Cabling at Callaway Plant," Revision 1, where the licensee performed an analysis of the environmental qualifications of the key parameter instrumentation, which evaluated that key parameter instrumentation other than the nuclear instruments. For the nuclear instruments, the temperature in the containment sub-compartment where they are located exceeds the qualified temperature and thus may result in loss of indication. To compensate for this possibility, the licensee has revised its mitigation strategy such that the operations staff will utilize other instrumentation (e.g. RCS temperature and pressure) as an aid for determination that the reactor remains sub-critical. This guidance has been incorporated into FSG-7, "Loss of Vital Instrumentation or Control Power".

The staff also reviewed FSG-12, "Alternate Containment Cooling," Revision 0, which provides guidance to the operators to monitor and control containment temperature and pressure to ensure that equipment within the containment remains functional.

Based on review of licensee evaluation and procedures, the NRC staff finds that the strategies to monitor and control the containment temperature and pressure should ensure that the credited electrical equipment (solenoid valves, instruments etc.) within containment are expected to remain available indefinitely.

In summary, based on a review of the essential station equipment required to support the licensee's FLEX mitigation strategy, which are located in the TDAFW pump room, control room, Class 1E battery rooms, Class 1E DC switchboard and switchgear Rooms (includes Class 1E battery chargers and inverters), and containment, the NRC staff concludes that the electrical equipment relied on to mitigate the analyzed ELAP event should remain functional indefinitely.

3.9.1.2 Loss of Heating

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

During Phase 2, the licensee relies on the BAT and boric acid batching tank for RCS makeup. During the audit process, the licensee provided calculation NAI-1901-001, "GOTHIC Analysis of the Boric Acid Tank Rooms for Extended Loss of A/C Power," Revision 0. This calculation assumed a minimum external temperatures and modeled the room temperature of the BAT rooms (rooms 1116 and 1117) and the boric acid batching tank room (1407) during an ELAP event using the GOTHIC 8.0 software program. Although the temperature in all three rooms initially increases slightly, all three rooms drop below 59°F during the postulated event. The licensee states in its compliance letter that FSG-50, "Freeze Protection for ELAP Response," directs operators to place electric heaters in the Auxiliary Building to maintain all three rooms above 59°F to prevent boron precipitation. Additionally, operators are directed to heat the injection header room and the north piping penetration room to provide supplemental heating to selected areas that may house temporary piping/hoses needed for the FLEX equipment.

The licensee states in its FIP that the CST and HCST are adequately protected from extreme cold weather and the initial volume and temperature would preclude significant heat loss causing freezing during a loss of all ac power. In the FIP, Section 2.11.2 also states that FSG-50 directs operators to break through surface ice to access the UHS, if necessary. Additionally, the licensee states in its FIP, that heat tracing of equipment is not necessary. Procedures direct the operators to establish recirculation flow during cold temperatures to prevent hoses deployed outside from freezing and FSG-50 directs operators to deploy heaters to heat FLEX equipment placed outside. Additionally, the licensee's compliance letter, Enclosure 2, response to Confirmatory Item 3.2.4.3.A, states that the FLEX equipment operated outdoors is designed to operate with the outdoor temperature as low as -26°F. The licensee stated in the FIP that the

HSB is protected against extreme cold temperatures and is able to maintain the building warmer than 50°F, prior to the event.

The vital battery rooms are in the interior of the Control Building and are normally maintained at approximately 77°F. In calculation NAI-1871-001, "Minimum Vital Battery Room Temperatures during an ELAP Event using a Non-Safety-Related Callaway Control Building Gothic Model," Revision 0, the licensee determined that the minimum room temperature is expected to remain above 62°F at 12 hours with an upward trend. Given the upward trend of the battery room temperatures after 12 hours, the NRC staff concludes that the battery room temperatures should remain above minimum specified operating temperature of 60°F. Based on its review of the licensee's battery room assessment, the NRC staff finds that the Callaway Class 1E batteries should perform their required functions at the expected temperatures as a result of loss of heating during an ELAP event.

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

3.9.1.3 Hydrogen Gas Control in Vital Battery Rooms

An additional ventilation concern that is applicable to Phases 2 and 3, is the potential buildup of hydrogen in the Class 1E battery rooms as a result of loss of ventilation during an ELAP event. Off-gassing of hydrogen from batteries is only a concern when the batteries are charging. In its FIP, the licensee stated that under conditions where there is no ventilation, hydrogen concentration would reach 2 percent in 2.62 days in one of the Class 1E Battery Rooms (longer for the other three rooms). During the audit process, the NRC staff reviewed the licensee's calculation M-GK-370, "Post-Accident Battery Room H2 Concentration Level," Revision 1. In this calculation, the licensee verified that hydrogen gas accumulation in the vital battery rooms will not reach combustible levels while HVAC is lost during an ELAP. The calculation shows that a ventilation flow of 100 cubic feet per minute (cfm) of air would ensure that the hydrogen concentration would not reach the point of combustibility. The licensee would establish temporary ventilation for the Class 1E battery rooms well before the hydrogen concentration would reach 2 percent in accordance with FSG-45. In the FIP, the licensee stated that the blowers purchased for hydrogen removal have a minimum flow rate of 1842 cfm. The licensee's ventilation strategy provides guidance to the operators to monitor hydrogen level in the battery rooms, establish temporary ventilation such as opening selected doors in the battery rooms, and place pedestal fans to direct the air flow through and out of the battery rooms. Attachment "D" in FSG-45 shows the Control Building battery room ventilation configuration including the placement of supplemental pedestal fans, desired door status (open/closed), and direction of air flow during an ELAP event.

Based on its review of the FIP, licensee's calculation, and guidance in the licensee's FLEX guideline FSG-45, the NRC staff concludes that hydrogen accumulation in the Class 1E battery rooms should not reach the combustibility limit for hydrogen (4 percent) during an ELAP.

3.9.2 Personnel Habitability

3.9.2.1 Main Control Room

The licensee's FIP states that Ameren calculation BO-05, Addendum 19, "Revised Temperatures for 3601, 3605, and 3609 for Station Black Out," Revision 1, calculates the maximum control room temperature and determined that it does not exceed 120°F. As described in Section 3.9.1.1 of this safety evaluation the steady state temperature reaches approximately 117°F. The NRC staff notes that the licensee's calculation conservatively assumes that additional ventilation is not provided. During the audit process the staff reviewed FSG-45, "Temporary Ventilation, Lighting and Power," Revision 0, and confirmed that it provides detailed guidance to establish temporary ventilation, if necessary, in the control room. The licensee's FIP also states that habitability was evaluated in conjunction with the ventilation review and was determined to be acceptable. Based on the licensee's FIP statements, guidance for deployment of temporary ventilation, and the expected temperature response in the control room, the staff finds that the control room should remain habitable during an ELAP event.

3.9.2.2 Spent Fuel Pool Area

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

3.9.2.3 Other Plant Areas - TDAFW Pump Room

Although the TDAFW pump room gets as hot as 146°F, the licensee's strategy does not involved prolonged manual operation in the TDAFW pump room. In event that the TDAFW pump trips offline operators will have to enter the room temporarily to restart the pump. Since this is a short duration activity the NRC staff concludes that the calculated room temperatures should not inhibit a successful reset. Furthermore, as stated earlier, the licensee has procedures in place to establish temporary ventilation to reduce the temperature in the TDAFW pump room.

3.9.3 Conclusions

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

3.10 Water Sources

3.10.1 Steam Generator Makeup

In its FIP, the licensee described that the credited water sources for SG makeup are the CST (for non-missile hazards), HCST, and the UHS retention pond. The CST or the HCST would provide the initial inventory to the TDAFW pump at the initial onset of the event. The HCST provides a minimum of 30 hours of inventory to the TDAFW pump and is fully protected for all applicable external events. The CST can provide approximately 24 hours of inventory to the TDAFW pump for seismic or extreme temperature events, but is not missile protected. Table 3 in the FIP, provides a list of additional, potential water sources that may be used, their capacities, and an assessment of availability following the applicable hazards.

Approximately 25 hours after the event, a mobile water purification unit from the NSRC will be available. This unit could be placed in service prior to the depletion of the HCST. The mobile purification unit has sufficient capacity to be able to supply clean water for core cooling and SFP makeup and would be used to refill the HCST if SG makeup is still be used to provide core cooling.

In addition, the NSRC will provide high capacity pumps and CTGs which could be used to restore access to the UHS, and ultimately RHR system operation, so that SG makeup is no longer required.

3.10.2 Reactor Coolant System Makeup

In its FIP, the licensee described the two credited sources for borated water that are available onsite, the BATs and the RWST. The two BATs are located in the Auxiliary Building and store 4 percent by weight boric acid. The tanks are constructed of stainless steel, each having a minimum capacity of 17,658 gallons. The BATs are fully protected and qualified for all applicable external events.

The RWST is a Seismic Category I stainless steel tank vented to the atmosphere with a minimum contained borated water (2350 – 2500 ppm boron) volume of 394,000 gallons. However, the RWST is not missile protected; therefore, it is not credited for all external hazards.

The BABT is a non-seismic vertical stainless steel tank and is used to batch borated water for RCS makeup from the BATs. After completion of mixing, boric acid is gravity drained from the BABT to a BAT. Since the BABT is not seismically qualified, the licensee performed an evaluation that determined that the BABT and the piping from the BABT to the BAT are robust and will likely be available for implementation of FLEX strategies. The BABT and the piping from the BABT to the BAT are located in the Auxiliary Building, so they are fully protected from the other applicable external hazards. Clean water sources for use in batching borated water in the BABT would be used in the same order of preference provided in Table 3 of the FIP for the SG sources, dependent on availability.

3.10.3 Spent Fuel Pool Makeup

In its FIP, the licensee stated that water quality is not a significant concern for makeup to the SFP. The primary water source would be from the HCST via the FLEX SFP Pump. However, any of the water sources available would be acceptable for use as makeup to the SFP.

3.10.4 Containment Cooling

For Phases 1 and 2 the licensee's calculations demonstrate that no actions are required to maintain containment pressure below design limits for a minimum of 72 hours. In its FIP, the licensee stated that no additional specific Phase 3 strategy is required for maintaining containment integrity. With the initiation of RHR in Phase 3 to remove core heat, the containment will depressurize without further action. Thus, no direct water sources are required for containment cooling.

3.10.5 Conclusions

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

3.11 Shutdown and Refueling Analyses

Order EA-12-049 requires that licensees must be capable of implementing the mitigation strategies in all modes. In general, the discussion above focuses on an ELAP occurring during power operations. This is appropriate, as plants typically operate at power for 90 percent or more of the year. When the ELAP occurs with the plant at power, the mitigation strategy initially focuses on the use of the steam-driven TDAFW pump to provide the water initially needed for decay heat removal. If the plant has been shut down and all or most of the fuel has been removed from the reactor vessel 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, about 35 hours are available to implement makeup before boil-off results in the water level in the SFP dropping to point where there would be 15 feet of water above the top of the SFP storage racks. Given the concentration of efforts by the plant staff toward the SFP that would be available in a full core offload scenario, the NRC staff concludes that the licensee should be able to implement makeup prior to this time.

When a plant is in a shutdown mode in which steam is not available to operate the TDAFW pump and allow operators to release steam from the SGs (which typically occurs when the RCS has been cooled below about 300°F), another strategy must be used for decay heat removal. The NRC-endorsed strategy is described in NEI 12-06, Revision 2, Section 3.2.3. This 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 the shutdown risk assessment process would consider maintaining FLEX equipment necessary to support shutdown risk processes readily available and consider how FLEX equipment could be deployed or pre-deployed/pre-staged to support maintaining the key safety functions in the event of a loss of shutdown cooling.

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

3.12 Procedures and Training

3.12.1 Procedures

In its FIP, the licensee stated that the inability to predict actual plant conditions that require the use of FLEX equipment makes it impossible to provide specific procedural guidance. As such, the FSGs provide guidance that can be employed for a variety of conditions. Clear criteria for entry into FSGs ensures that FLEX strategies are used only as directed for BDBEE conditions, and are not used inappropriately in lieu of existing procedures. When FLEX equipment is needed to supplement existing strategies, the applicable EOP, Abnormal Operating Procedure (AOP), severe accident mitigation guideline, or extreme damage mitigation guideline directs the entry into and exit from the appropriate FSG.

According to the licensee, FSGs have been developed in accordance with PWROG guidelines. FSGs provide available, pre-planned FLEX strategies for accomplishing specific tasks in the EOPs or AOPs. The FSGs will be used to supplement (not replace) the existing procedure structure that establishes command and control for the event.

The licensee's FIP also states that procedural Interfaces are incorporated into procedure ECA-0.0, "Loss of All AC Power," to the extent necessary to include appropriate reference to FSGs and provide command and control for the ELAP. Additionally, procedural interfaces have been incorporated into a new off-normal procedure, OTO-NB-00005, "Loss of All AC Power While on RHR," to include appropriate reference to FSGs.

3.12.2 Training

In its FIP, the licensee stated that Initial training has been provided and periodic training will be provided to site emergency response leaders on BDB 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.

According to the licensee, the site nuclear training program assures that personnel proficiency in the mitigation of BDBEEs is adequate and maintained, and the necessary programs and controls were developed using the Systematic Approach to Training (SAT).

3.12.3 Conclusions

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

3.13 Maintenance and Testing of FLEX Equipment

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

In its FIP, the licensee stated that they would conduct maintenance and testing of the FLEX equipment in accordance with the site preventative maintenance (PM) program and utilize the EPRI PM basis database as an input in development of the specific Callaway Plant FLEX PM basis templates. In those cases where the EPRI templates were not available for the specific component types, PM actions were developed based on equipment manufacturer provided information/recommendations. Based on the FIP description, the NRC staff concludes that the Callaway Plant PM program for FLEX equipment follows the guidance of NEI 12-06, Section 11.5.

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

3.14 Alternatives to NEI 12-06, Revision 2

In NEI 12-06, Table 3-2 and Table D-3 summarize an acceptable 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 direct to pool capable of exceeding the boil-off rate for the design basis heat load; and (2) makeup via connection to spent fuel pool cooling piping or other alternate location capable of exceeding the boil-off rate for the design basis heat load. Additionally, JLD-ISG-2012-01 specifies that unless the site performs a seismic evaluation of their spent fuel pool, spray must be provided via portable nozzles from the refueling floor using a portable pump capable of providing a minimum of 200 gpm per unit (250 gpm if overspray occurs). Callaway did not perform such an evaluation; therefore, in order to meet NEI 12-06 Revision 2, as endorsed, the site would be subject to the spray flow requirements.

Because licensee's SFP cooling FLEX strategy does not use makeup hoses direct to the SFP, or "portable" nozzles for SFP spray, the staff determined the licensee's strategy is an alternative to NEI 12-06, Revision 2.

However, the NRC staff notes that the licensee's strategy involves:

- Three seismically qualified permanently installed makeup headers. Two provide SFP makeup and one provides spray.
- Each makeup header has sufficient capacity to provide SFP makeup in excess of the boil-off rate and the spray header can provide spray of 250 gpm to the pool.
- The FLEX pump discharge connection points to these redundant headers are robust and protected to such an extent that the staff concluded that at least one, and likely all, of the connections should be available during an ELAP event.

The NRC staff finds that the licensee's spray strategy provides a means to spray water into the SFP, consistent with the robust provisions of NEI 12-06. The staff also notes that the licensee's strategy utilizing an installed spray system would have an advantage of saving manpower resources during the event response, as compared to the deployment of hoses and portable nozzles. Therefore, even though the strategy does not use makeup hoses directly to the SFP and portable nozzles, it provides a means to deliver the required spray flow via a robust and diverse means and will maintain or restore SFP cooling following a BDBEE, as specified in Order EA-12-049. Based on this review, the staff finds that the licensee's lack of makeup hoses direct to the SFP, and the lack of "portable" nozzles for SFP spray is an acceptable alternative to NEI 12-06, Revision 2 as endorsed by JLD-ISG-2012-01.

In conclusion, the NRC staff finds that although the guidance of NEI 12-06 has not been met, if this alternative is implemented as described by the licensee, it will meet the requirements of the order.

3.15 Conclusions for Order EA-12-049

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

4.0 TECHNICAL EVALUATION OF ORDER EA-12-051

By letter dated February 28, 2013 [Reference 24], the licensee submitted an OIP for Callaway in response to Order EA-12-051. By letter dated June 7, 2013 [Reference 25] the NRC staff sent a request for additional information (RAI) to the licensee. The licensee provided a response by letter dated July 3, 2013 [Reference 26]. By letter dated November 25, 2013 [Reference 27], the NRC staff issued an ISE and RAI to the licensee.

By letters dated August 29, 2013 [Reference 28], February 26, 2014 [Reference 29], August 28, 2014 [Reference 30], February 26, 2015 [Reference 31], August 27, 2015 [Reference 32], and February 23, 2016 [Reference 33], the licensee submitted status reports for the Integrated Plan. The Integrated Plan describes the strategies and guidance to be implemented by the licensee for the installation of reliable SFP level instrumentation which will function following a BDBEE, including modifications necessary to support this implementation, pursuant to Order EA-12-051. By letter dated July 6, 2016 [Reference 35], the licensee reported that full compliance with the requirements of Order EA-12-051 was achieved.

The licensee has installed a SFP level instrumentation system designed by 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 for the Westinghouse-designed system on August 18, 2014 [Reference 34].

The staff also performed an onsite audit to review the implementation of SFP level instrumentation related to Order EA-12-051 at Callaway. The scope of the audit includes verification of: (a) site's seismic and environmental conditions enveloped by the equipment qualifications, (b) equipment installation met the requirements and vendor's recommendations, and (c) program features met the requirements. By letter dated March 31, 2016 [Reference 19], the NRC issued an audit report on the licensee's progress toward implementation of Order EA-12-051.

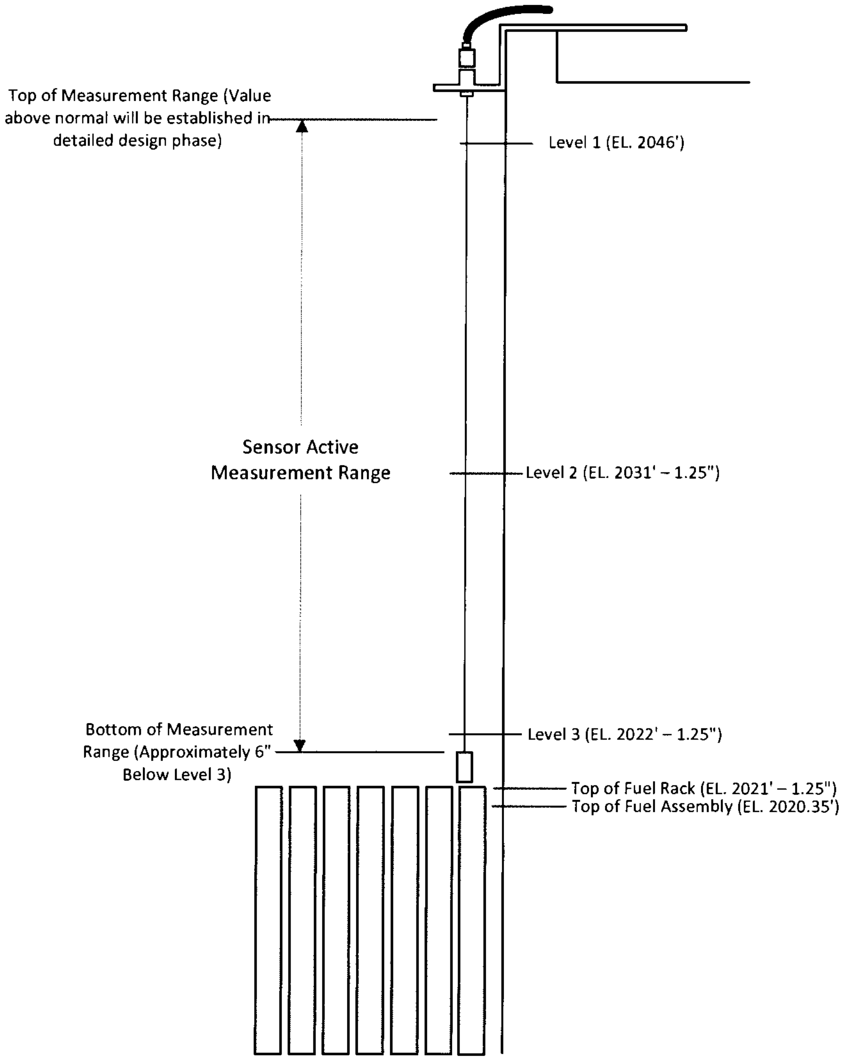
4.1 Levels of Required Monitoring

By letter dated July 3, 2013 [Reference 26], the licensee identified the SFP levels of monitoring as follows:

- Level 1 is at the plant elevation of 2046 feet (24 feet, 10.75 inches above the top of the fuel racks).
- Level 2 is at the plant elevation of 2031 feet, 1.25 inches (10 feet (+/- 1 foot) above the top of the fuel storage racks).
- Level 3 is at the plant elevation of 2022 feet, 1.25 inches (1 foot above the top of the fuel storage racks).

In its compliance letter dated July 6, 2016 [Reference 35], the licensee further provided the basis for the designated Level 1 as follows: Calculation M-EC-48, "Minimum Safety Limit for LSL 57 & 58," Revision 0, concludes that the SFP water elevation that is sufficient for the pump's required NPSH [Net Positive Suction Head] is elevation 2043' 6". Level 1 indication is at the normal SFP water operating level of elevation 2046' 0". This confirms that Level 1 has sufficiently covered the calculated level to maintain the pump's required NPSH. In the same letter, the licensee also provided a sketch depicting Levels 1, 2, and 3 and SFP level measurement range as shown in the figure below (Figure 1 - Callaway SFP Levels of Monitoring).

Figure 1 - Callaway SFP Levels of Monitoring



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

- Level 1 is the level at which the water height, assuming saturated conditions, above the centerline of the cooling pump suction provides the required NPSH specified by the pump manufacturer or engineering analysis. Thus, the designated Level 1 setpoint would allow the licensee to identify a level in the SFP adequate to support operation of the normal SFP cooling system and represents the higher of the options described in NEI 12-02.

- Level 2 meets first option described in NEI 12-02 for Level 2, which is 10 feet (+/- 1 foot) above the highest point of any fuel rack seated in the SFPs. The designed Level 2 represents the range of water level where any necessary operations in the vicinity of the SFP can be completed without significant dose consequences from direct gamma radiation from the SFP consistent with NEI 12-02.

- Level 3 is 1 foot above the highest point of any fuel storage rack seated in the SFP. This level meets the NEI 12-02 specifications of the highest point of any fuel rack seated in the SFP, thus establishing a level below which actions to implement makeup water addition should no longer be deferred. Meeting the NEI 12-02 specifications of the highest point of the fuel racks conservatively meets the Order EA-12-051 requirement of a level where the fuel remains covered.

Based on the evaluation above, the staff finds that the licensee's selection of Levels 1, 2, and 3 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 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. 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 Callaway SFP Instrumentation (SFPI) system will utilize fixed primary and backup guided wave radar (GWR) sensors. The GWR technology uses the principle of time domain reflectometry to detect the SFP water level. A microwave signal is sent down the cable probe sensor, and when it reaches the water, it is reflected back to the sensor electronics. This is due to the difference between the dielectric constants of air and water. Using the total signal travel time, the sensor electronics embedded firmware computes the level of the water in the SFP. The probe, which is located in the SFP, is separated from the sensor electronics, and connected by an interconnecting cable that is routed into an adjacent building. By placing the sensor electronics outside of the SFP area they are not subject to the harsh environment resulting from the boiling or loss of water in the pool during a postulated loss of inventory event that creates high humidity, steam and/or radiation. The primary and backup instrument channels will provide continuous level indication over a range of 23 feet 10.75 inches, from 12 inches above the top of the fuel storage racks (plant elevation 2,022 feet 1.25 inches) to the normal pool level elevation (plant elevation 2,046 feet).

The NRC staff noted that Callaway SFP level instrumentation consists of a permanent, fixed primary instrument channel and a backup instrument channel. The specified measurement range will cover Levels 1, 2, and 3 as described in Section 4.1 above. The staff finds that the licensee's design, with respect to the number of channels and measurement range for its SFP, appears to be consistent with the 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 compliance letter, the licensee described the SFP level instrument channel arrangement as follows. Physical separation of the primary and backup instrument channel signal cables is the used to provide reasonable protection of the level indication function against missiles that may result from the damage to the structure over the SFP. The sensors are located close to the side walls of the SFP and below the floor elevation to utilize the pool walls as inherent protection. The primary instrument channel sensor is mounted near the plant northeast corner of the SFP. From the primary sensor, the primary signal cable, contained in metal conduit, runs plant west approximately 17 feet above the floor along the plant north wall of the Fuel Building. The primary signal cable is then routed along this wall and then around the wall and ceiling of the fuel transfer canal until it penetrates the west wall into the Auxiliary Building. The backup instrument channel sensor is mounted near the plant northwest corner of the SFP. From the backup sensor, the backup signal cable, contained in metal conduit, runs plant north near the floor to the plant east wall of the fuel transfer canal. The backup signal cable is then routed around the walls of the fuel transfer canal until it penetrates the west wall into the Auxiliary Building. This separates the sensors by a distance that is practical and comparable to the shortest length of a side of the pool. The routed signal cables and couplers are contained in metal conduits, within the Fuel Building, and are separated along a shared wall by a distance of approximately 17 feet or more. The SFP walls and corners provide inherent missile protection for the level sensor signal cables. Physical separation of the primary and backup instrument channel signal cables and power cables is maintained through the Auxiliary Building in accordance with site guidelines for Class 1E and non-Class 1E raceway.

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

4.2.3 Design Features: Mounting

In its compliance letter the licensee stated that the mounting attachments are qualified by analysis. With the exception of the level sensor probe mounting bracket, all of the system equipment is seismically qualified by testing. The outputs of the seismic test for all equipment were used as the design input for the qualification of the mounting for that specific equipment. The mounting bracket for the sensing probe was designed according to the plant design basis for a SSE seismic hazard curve at the pool deck elevation. Loads that were considered in the evaluation of the bracket and its mounting are: (a) static loads including the dead weight of the mounting bracket in addition to the weight of the level sensing instruments, pipe guard and cabling; and (b) dynamic loads including the seismic load due to excitation of the instruments dead weight in addition to the hydrodynamic effects resulting from the excitation of the SFP water. A response spectra analysis was performed for the seismic evaluation of the mounting bracket using structural design and analysis software, GTSTRUDL. Hydrodynamic effects on the mounting bracket were evaluated using TID-7024, "Nuclear Reactors and Earthquakes, dated 1963," and added to the GTSTRUDL model. Plant acceptance criteria and applicable codes were used for the design of the bracket and its anchorage. All members' results were shown to be adequate for the loads and load combinations used in the analysis. Welded and bolted connections were evaluated and were shown to be adequate with significant margin.

Base plate of the mounting bracket and anchorage to concrete were evaluated using Plate Wizard in GTSTRUDL and designed to meet the plant criteria for base plates and anchors.

During the onsite audit, the NRC staff inquired about design information for electronics equipment and cable conduit mountings and supports. In response, the licensee stated that calculation CN-PEUS-14-15, "Seismic Qualification of the Electronics Enclosure and Transmitter Enclosure," and the owner's review show that electronic enclosures and transmitter enclosures are seismically mounted. Inline condulets were utilized in the Fuel Building in-lieu of mounting pull boxes and a seismic evaluation was performed on them. A single pull box used in Room 1507 in the Auxiliary Building is mounted in a manner that is approved for use at Callaway in safety related applications. The transmitters and mounting are seismically qualified and the test response spectra used for this qualification was obtained from Westinghouse Report EQLR-281, "Seismic Design Verification Test Report for the Spent Fuel Pool Instrumentation System," Revision 0. This test spectra was also used for seismic qualification of the SFPI transmitter enclosure as documented in CN-PEUS-14-15.

The NRC review of Section 4.6.1.3 and 5.1 of CN-PEUS-14-15, Revision 0, confirms that the test spectra envelopes twice the magnitude of the Callaway SSE response spectra. The transmitter and transmitter enclosure are both seismically mounted to the wall with 4-3/8" diameter Hilti Kwik Bolt 3 expansion anchors. Calculation CN-PEUS-14-15, Section 5.2 confirms that the mounting configuration is acceptable for the transmitter enclosure considering a weight of 57.185 pounds and twice the Callaway SSE seismic loading. The weight of the transmitter and associated components is approximately 15 pounds. As the mounting of the two components is the same with the transmitter weighing significantly less and seismic accelerations identical, the staff concludes that the transmitter mounting is acceptable by comparison.

The NRC staff reviewed the licensee's mounting design documentation and concludes that it 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 is not already covered by existing quality assurance requirements. Per 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.

By letter dated July 6, 2016 [Reference 35], the licensee stated that Westinghouse followed their Quality Management System to meet the augmented quality requirements identified in the order as applicable to the non-safety augmented quality classification of the SFPI system. The SFPI system specific requirements are identified by the Spent Fuel Pool Instrumentation Systems Project Plan and the Spent Fuel Pool Instrumentation System Design Specification. The SFPI system's augmented quality program includes the following activities:

- Design Control and Procurement Document Control
- Instructions, Procedures and Drawings

- Control of Purchased Material, Equipment and Services
- Inspection
- Testing and Test Control
- Inspection, Test, and Operating Status
- Nonconforming Items
- Corrective Action
- Records
- Audits

The NRC staff reviewed the licensee's augmented quality program for the SFPI system and notes that it contains all of the attributes listed in Appendix A-1 of NEI 12-02. Therefore, if implemented appropriately, the licensee's approach appears to be consistent with NEI 12-02 guidance, and should adequately address the requirements of the order.

4.2.4.2 Equipment Reliability

The NRC staff reviewed the Westinghouse SFP level instrumentation's qualification and testing for temperature, humidity, radiation, shock and vibration, and seismic considerations during a vendor audit. Results of this audit are documented in an NRC audit report dated August 18, 2014 [Reference 34]. The staff further reviewed the anticipated site-specific environmental conditions during an on-site audit at the Callaway site and the review is summarized below.

4.2.4.2.1 Temperature, Humidity, and Radiation

For the expected temperature conditions at Callaway and SFP level instrument qualifications, in its OIP, the licensee stated that SFPI system materials and components were selected and specified by design to meet or exceed the temperature and humidity in the Fuel Building and other buildings during the ELAP event for the locations of sensor and system electronics. In its compliance letter dated July 6, 2016 [Reference 35], the licensee further stated that components in the Fuel Building (level sensors and their respective cables) are qualified for conditions of 212°F at atmospheric pressure. For components in the Auxiliary Building, the sensor electronics are rated for 140°F at atmospheric pressure. Other components located in the Auxiliary and Control Buildings are rated for 140°F at atmospheric pressure. Two GOTHIC thermo-hydraulic models were created for the rooms within the Auxiliary Building where the sensor electronics will be located. The results of these models show that the rooms see a temperature rise of less than 5°F during the course of a 3-day ELAP event. The maximum expected temperature for the Electrical Penetration Room (#1409) is 109.8°F. No formal analysis was performed for Auxiliary Building Hallway (Room 1408) temperature. According to the licensee, due to lack of safety related heat loads and large volume, it is assumed that Room 1408 to remain near the initial temperature of 60 to 104°F and not to exceed 120°F. The equipment in the Room 1409 and 1408 location is qualified for 140°F.

With regard to the expected humidity conditions at Callaway, the licensee's compliance letter states that qualitatively, due to the lack of water sources in the rooms, the increasing temperatures in the rooms will cause the relative humidity of the rooms to decrease. The licensee's letter further provides a qualitative discussion of various factors that could influence humidity and concludes that the impact of increased humidity during an ELAP in Rooms 1408 and 1409 will be negligible, thus ensuring that the equipment qualifications as cited below are not exceeded for the sensor electronics or the main electronics. Components in the Fuel Building (level sensors and their respective cables) are qualified for 100 percent humidity (saturated steam). For components in the Auxiliary Building Room 1409, the sensor electronics are rated for humidity of 0-100 percent (non-condensing). Other components located in the Auxiliary Building Room 1408, the main electronics are rated for humidity of 0-95 percent (non-condensing).

Related to the expected radiological conditions at Callaway and equipment qualifications, in its compliance letter the licensee stated that the results of vendor tests and analysis demonstrating the qualification of the equipment to be installed are detailed in two Westinghouse proprietary documents. The coaxial cable, the coupler, the pool-side bracket, and the probe in the SFP area are required to operate reliably in the service environmental conditions specified in the table below [Table 1 – Spent Fuel Pool Area Radiological Conditions].

Table 1 – Spent Fuel Pool Area Radiological Conditions

Parameter	Normal	Beyond Design Basis
Radiation TID (above pool)	1E03 Rads γ	1E07 Rads γ
Radiation TID (12" above top of fuel rack)	1E07 Rads γ (probe & weight only)	1E09 Rads γ

The level sensor electronics, sensor electronics bracket, indicators, and the electronics enclosures outside of the SFP area are required to operate reliably in the service environmental conditions specified in the table below [Table 2 – Outside of Spent Fuel Pool Area Radiological Conditions].

Table 2 – Outside of Spent Fuel Pool Area Radiological Conditions

Parameter		Normal	Beyond Design Basis
Radiation TID		≤ 1E03 Rads γ	≤ 1E03 Rads γ

There are no active electronics in the Fuel Building. The transmitter electronics are physically located within the Auxiliary Building and therefore, are not subjected to the same post-event (Beyond-Design-Basis) radiological conditions as identified in Section 3.4, "Qualifications" of NEI 12-02, Revision 1. During a BDB event, the expected radiological conditions (dose rate and total integrated dose) in the Auxiliary Building are consistent with normal operating conditions identified in Callaway FSAR Table 3.11(b)-1 based on the following:

- During a BDB event, the RCS remains intact and the mitigating strategies employed per EA-12-049 will maintain core cooling.
- SFP makeup capability (>250gpm) exceeds the calculated full core offload boil-off rate of ~136 gpm.

Based on the licensee's OIP, FSAR, and compliance letter, supplemented by the audit review of the licensee's calculations, test information, and site documentation, the NRC staff review concludes that the equipment qualification, envelops the expected Callaway radiation, temperature, and humidity conditions during a postulated BDBEE.

4.2.4.2.2 Shock and Vibration

For the equipment's shock and vibration qualifications, in its compliance letter dated July 6, 2016 [Reference 35], the licensee stated that no portable hand-held devices are used in the SFPI system. Components of both the primary and backup SFP measurement channels are permanently installed and fixed to rigid, structural walls or floors of Seismic Category 1 structures, and will not be subject to anticipated shock or vibration inputs. Furthermore shock and vibration are not postulated for design basis event conditions in the area of instrument channel components. The level sensor electronics are enclosed in a [National Electrical Manufacturers Association] NEMA-4X housing. The electronics enclosure utilizes a NEMA-4X rated stainless steel housing. These housings mounted to a seismically qualified wall and contain the active electronics and aid in protecting the internal components from vibration induced damage. Vibration forces applied in testing were those intrinsic to seismic testing at sinusoidal frequencies from 1-100 Hertz and accelerations reaching nearly 10g [10 times the force of gravity]. No additional shock tests or vibration tests were performed. The probe, the coaxial cable, and the mounting brackets are inherently resistant to shock and vibration loadings.

The NRC staff review concludes that the equipment test parameters envelop the Callaway's expected shock and vibration conditions during a postulated BDBEE and that the licensee's shock and vibration evaluation and installation features should ensure equipment reliability.

4.2.4.2.3 Seismic

In its compliance letter dated July 6, 2016 [Reference 35], the licensee stated that the SFPI system, including the pool-side bracket, is qualified as Seismic Category I per the Institute of Electrical and Electronics Engineers (IEEE) standard IEEE 344-2004. The objective of the testing and analysis was to demonstrate that the SFPI system meets the seismic performance requirements of Westinghouse proprietary design specification. The Required Response Spectra for this program includes the 10 percent margin recommended by IEEE 323-2003. The seismic test and analysis results are documented in two proprietary Westinghouse test reports.

During the audit process the NRC staff reviewed the licensee's seismic test and analysis results and concluded that the seismic design features should ensure that the equipment will remain functional after a postulated seismic event. Further evaluation of the SFP level instrument mounting is discussed in Subsection 4.2.3, "Design Features: Mounting".

In summary, based on the licensee's compliance letter, supplemented by the staff's audit review, the NRC staff finds the licensee's instrument qualification process appears to be consistent with NEI 12-02 guidance, as endorsed by JLD-ISG-2012-03, and should adequately address the requirements of the order.

4.2.5 Design Features: Independence

In its OIP, the licensee stated that the backup instrument channel will be redundant to and independent of the primary instrument channel. Independence of the two systems includes:

location, mounting, power sources, power and signal wiring, and indications, to prevent any failure of one system from affecting the other system.

By letter dated July 3, 2013 [Reference 26], the licensee stated that each channel will be installed using completely independent cabling structures, including routing of the interconnecting cable within the SFP area in separate hard-pipe conduits. Power sources will be routed to the electronics enclosures from electrically separated sources ensuring the loss of one train or bus will not disable both channels. Primary and backup channels will be completely independent of each other, having no shared components. As identified during the audit process, the system displays will be installed in separate qualified NEMA 4X or better enclosures, in the Auxiliary Building 2026' level corridor, Room 1408.

During the onsite audit, the NRC staff inquired about the normal power sources to verify the SFP level instrument channels independence. In its compliance letter dated July 6, 2016 [Reference 35], the licensee provided a response, in which it stated that the primary and backup SFPI system channels are powered by independent non-Class 1E electrical AC buses PA01 and PA02. The buses are not normally cross tied. They are fed from the same transformer source but from separate windings ("X" or "Y" winding on the 13.8kV side).

The NRC staff noted, and verified during the audit walk down, that with the licensee's design there is sufficient independence such that the failure of one instrument channel should not affect the operation of the other channel under BDB event conditions. Further evaluation of instrument channel's physical separation is discussed in Subsection 4.2.2, "Design Features: Arrangement".

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

4.2.6 Design Features: Power Supplies

In its compliance letter dated July 6, 2016 [Reference 35], the licensee stated that the primary and backup SFPI system channels are powered by independent non-Class 1E electrical ac buses PA01 and PA02. Each SFPI system channel of equipment has an independent uninterruptible power supply with 24V battery backup that ensures at least 72 hours of battery power without ac power. Additionally, an interface is provided for an alternate power supply such as a FLEX generator. The SFP level can be continuously monitored for at least 3 days under station blackout conditions with battery power only and at least for the required 7 days with an alternate power supply. According to the licensee, calculation J-2048-00051, "Power Consumption Calculation," demonstrates that the SFPI system will last greater than 3 days assuming a fully charged battery after AC power loss. The calculation includes design and aging margin. The strategy of providing power to the SFPI equipment during an ELAP prior to depletion of the batteries is contained in FSG-45, "Temporary Ventilation, Lighting and Power".

Based on the licensee's compliance letter, the NRC staff concludes that the licensee's SFPI should have sufficient battery capability to provide indication for at least 72 hours without ac power and that an alternate power supply capability is provided for longer term monitoring. Therefore, the staff finds the licensee's 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

In its compliance letter dated July 6, 2016 [Reference 35], the licensee stated that the channel accuracy for each SFPI system instrument channel is ± 3 inches for the full level measurement range. This covers the normal SFP surface level or higher to within six inches of the top of the fuel rack under both normal and BDB conditions. Both SFP primary and backup sensor electronics require periodic calibration verification to check that the channel's measurement performance is within the specified tolerance (± 3 inches). If the difference is larger than the allowable tolerance during the verification process, an electronic output verification/calibration will be required. If the electronic output verification/calibration does not restore the performance, a calibration adjustment will be required. The electronic output verification/calibration will verify electronics are working properly using simulated probe signals. The calibration adjustment is performed to restore level measurement accuracy within the acceptance criteria at 0 percent, 25 percent, 50 percent, 75 percent, and 100 percent points of the full span.

The NRC staff evaluated Westinghouse' s SFPLI system design during the vendor audit and noted that the accuracy of the SFPI is ± 3 inch for BDB conditions. The SFPI is designed to maintain its accuracy after a power interruption without recalibration. During the onsite audit, the NRC staff reviewed site acceptance testing report J-2048-00050, "Spent Fuel Pool Instrumentation System Site Acceptance Testing, June 2014 to November 2014," and post change test plan report MP13-0027, "SFP Instrumentation for NRC Order EA-12-051," Revision 1, and noted that the as-found instrument accuracy is within the design accuracy. The NRC staff concludes that the licensee has demonstrated that the instrument channels' accuracy is not significantly affected by BDB conditions. If implemented properly, the instrument channels should maintain the designed accuracy following a power source change or interruption without the need of recalibration.

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

4.2.8 Design Features: Testing

In its compliance letter dated July 6, 2016 [Reference 35], the licensee stated that the calibration verification is performed by utilizing the sliding pool-side bracket design to raise the sensor probe for calibration verification. This is performed by loosening the hold down bolts and raising the sensor assembly until it hits the top stop (at a pre-defined distance above the normal bracket level) and verifying that the indicator responds with a corresponding change in reading. Upon completion of measurement, the technician will lower the mounting bracket and re-torque the slide assembly hold down bolts. If the calibration verification indicates that the channel being checked is operating out of specification or an anomaly is observed, an electronic output verification/calibration is performed on the level sensor electronics outside of the SFP area. If the electronic output verification/calibration does not restore performance, a calibration adjustment will need to be performed. The calibration adjustment uses a portable test kit that attaches at the sensor electronics mounting, allowing the full calibration to be performed outside of the SFP area without removing installed SFPI system components from the SFP area. The test kit will consist of equipment specifically paired with the installed equipment in order to properly verify calibration of the sensor electronics. The calibration verification, electronic output verification/calibration, and the calibration adjustments are performed per plant procedures and detailed maintenance instructions.

The NRC staff noted that by comparing the levels in the instrument channels and the maximum level allowed deviation for the instrument channel design accuracy, the operators could determine if recalibration or troubleshooting is needed. The staff finds the licensee's 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

By letter dated July 3, 2013 [Reference 26], the licensee stated that the primary and backup displays would be located in the Control Room A/C Unit & Filtration Units Rooms "A" and "B", respectively. By letter dated August 28, 2014 [Reference 30], the licensee notified the NRC that the SFP displays would be located in the MG [motor-generator] Set Room (Room 1403 of the Auxiliary Building). The licensee's compliance letter dated July 26, 2016 [Reference 35], states that the displays are in an accessible location. During the audit process, the NRC staff was able to confirm that the installed location of both display units (primary and backup), is in Room 1408 of the Auxiliary Building, as documented in FSG-11, "Alternate SFP Makeup and Cooling," Revision 1. Based on a review of site drawings and procedures, with confirmation during the onsite audit walk down, the NRC staff was able to confirm that the displays are in a location readily accessible to the operators, with multiple pathways to reach the display location from the control room.

The NRC staff notes that per NEI 12-02 guidance, an acceptable location for SFP level instrumentation displays is one that is promptly accessible to the appropriate plant staff, outside the area surrounding the SFP, inside a structure providing protection against adverse weather, and outside of any very high radiation area or locked high radiation area during normal operation. Based on the licensee's compliance letter, the staff's FSAR review of the Auxiliary Building's design features, and the audit walk down, the NRC staff concludes that the licensee's selected location meets these provisions.

The NRC staff review finds that if implemented properly, the displays will provide continuous indication of SFP water level. The displays are located in a seismically qualified building and the accessibility of the displays following an ELAP event is considered acceptable. The staff concludes that the licensee's location and design of the SFP instrumentation displays 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 Evaluation of Programmatic Controls

Order EA-12-051 specified that the SFPI 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 spent fuel pool instrumentation.

4.3.1 Programmatic Controls: Training

In its OIP, the licensee stated that the SAT will be used to identify the population to be trained and to determine both the initial and continuing elements of the required training. Training will be completed prior to placing the instrumentation in service.

The NRC staff finds that the use of SAT to identify the training population and to determine both the elements of the required training is acceptable. The licensee's plan to train personnel in the operation, maintenance, calibration, and surveillance of the SFPI and the provision of alternate power to the primary and backup instrument channels, 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

With regard to Callaway procedures related to the SFP level instrumentation, in its letter dated July 3, 2013 [Reference 26], the licensee stated that procedures for inspection, maintenance, repair, operation, and abnormal response associated with the SFP level instrumentation will be developed consistent with Appendix A-1 of [NEI 12-02]. Site procedures will be prepared, reviewed and approved in accordance with Callaway Plant administrative controls, using the vendor technical manual and other documentation. The vendor technical manual and documentation will include principles of operation, inspection and maintenance recommendations, drawings and technical documentation, individual component manufacturer manuals and documentation and recommended spare parts. Additional procedures for abnormal response will be developed in conjunction with FLEX implementation. In its compliance letter dated July 6, 2016 [Reference 35], the licensee provided a list of Callaway procedures related to SFP level instrumentation.

Based on the licensee's OIP and compliance letter, the NRC staff notes that the licensee has developed procedures for the testing, surveillance, calibration, operation, and maintenance of the primary and backup SFP level instrument channels. The staff finds that the licensee's procedures appear to be consistent with NEI 12-02, 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 dated July 6, 2016 [Reference 35], the licensee stated that the maintenance and testing program will ensure that regular testing and calibration is performed and verified. Calibration and testing for the instruments will be based on Westinghouse "Spent Fuel Pool Instrumentation System Calibration Procedure", WNA-TP-04709-GEN (J-2048-00030) as adapted to specific site procedures. The periodic testing recommended to validate the functionality of the installed instrument channel will be performed within 60 days of a planned refueling outage with a normal testing allowance of 25 percent but not more than once per 12 month period. A verification of channels is performed each shift as part of Primary Operator Rounds. OOA-EC-00002-"Operator Aid For Spent Fuel Pool Level Indications" is used for the guide for verifying the values of each independent channel (EC-LI-59A and EC-LI-60A) against the other and against EC LI-39A, which is the other permanently-installed SFP level instrumentation.

Regarding to the compensatory measures for the SFP level instrument out-of-service, in its compliance letter, the licensee stated that non-functioning SFP level instrumentation will be tracked by Operations Procedure ODP-ZZ-00002, "Equipment Status Control". Appendix 1 of Emergency Response Matrix KDP-ZZ-00013 identifies compensatory actions. Operator Aid OOA-EC-00002 defines the values to identify expected SFP water levels. The primary operator rounds log describes required actions if unsatisfactory conditions are discovered, which generates a corrective action request. I&C procedures ITL-EC-00L59 and ITL-EC-00L60 provide methods for returning equipment to service. The primary or back-up instrument channel can be out of service for testing, maintenance and/or calibration for up to 90 days provided the other channel is functional. The non-functioning instrument shall be returned to service within the 90 day period. In the event that one instrument channel is not functional and is not expected to be restored within 90 days, compensatory actions will be taken. If both instrument channels are determined to be non- functioning, actions will be initiated within 24 hours to restore one of the instrument channels to full functionality within 72 hours prior to implementing compensatory actions. If one of the instrument channels cannot be restored within this period, then enhanced monitoring of the existing SFP level instrumentation will be performed each shift. In its compliance letter dated July 6, 2016 [Reference 35], the licensee also provided a list of Callaway preventive maintenance activities related to the SFP level instrumentation.

The NRC staff noted that the licensee's plan for testing and calibration appears to be consistent with the vendor recommendations. Additionally, the compensatory actions for instrument channel(s) out-of-service appear to be consistent with guidance in NEI 12-02. Therefore, the NRC staff concludes that the licensee's testing and calibration of the primary and backup SFP level instrument channels should maintain the instrument channels at the design accuracy.

Based on the evaluation above, the NRC staff finds that the licensee's 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 compliance letter dated July 6, 2016 [Reference 35], 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 guidelines of 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 Callaway according to the licensee's 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 2016 [Reference 19]. The licensee reached its final compliance date May 9, 2016, and has declared that the reactor is in compliance with the orders [References 20 and 35]. The purpose of this safety evaluation is to document the strategies and implementation features that the licensee has committed to. Based on the evaluations above, the NRC staff concludes that the licensee has developed guidance and proposed designs that if implemented appropriately should adequately address the requirements of Orders EA-12-049 and EA-12-051. The NRC staff will conduct an onsite inspection to verify that the licensee has implemented the strategies and equipment to demonstrate compliance with the orders.

6.0 REFERENCES

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

2. SECY-12-0025, "Proposed Orders and Requests for Information in Response to Lessons Learned from Japan's March 11, 2011, Great Tohoku Earthquake and Tsunami," February 17, 2012 (ADAMS Accession No. ML12039A103)

3. SRM-SECY-12-0025, "Staff Requirements – SECY-12-0025 - Proposed Orders and Requests for Information in Response to Lessons Learned from Japan's March 11, 2011, Great Tohoku Earthquake and Tsunami," March 9, 2012 (ADAMS Accession No. ML120690347)

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

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

6. Nuclear Energy Institute document NEI 12-06, "Diverse and Flexible Coping Strategies (FLEX) Implementation Guide," Revision 2, December 31, 2015 (ADAMS Accession No. ML16005A625)

7. JLD-ISG-2012-01, "Compliance with Order EA-12-049, Order Modifying Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events," Revision 1, January 22, 2016 (ADAMS Accession No. ML15357A163)

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

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

10. Union Electric letter ULNRC-05962, "Overall Integrated Plan in Response to March 12, 2012 Commission Order Modifying Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events," February 28, 2013 (ADAMS Accession No. ML13063A459)

11. Union Electric letter ULNRC-06024, "First Six-Month Status Report in Response to March 12, 2012 Commission Order Modifying Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events (Order Number EA-12-049)," August 29, 2013 (ADAMS Accession No. ML13242A239)

12. Union Electric letter ULNRC-06087, "Second Six-Month Status Report in Response to March 12, 2012 Commission Order Modifying Licenses with Regard to Requirements for

Mitigation Strategies for Beyond-Design-Basis External Events (Order Number EA-12-049)," February 26, 2014 (ADAMS Accession No. ML14057A770)

13. Union Electric letter ULNRC-06135, "Third Six-Month Status Report in Response to March 12, 2012 Commission Order Modifying Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events (Order Number EA-12-049)," August 28, 2014 (ADAMS Accession No. ML14241A665)

14. Union Electric letter ULNRC-06184, "Fourth Six-Month Status Report in Response to March 12, 2012 Commission Order Modifying Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events (Order Number EA-12-049)," February 26, 2015 (ADAMS Accession No. ML15057A303)

15. Union Electric letter ULNRC-06240, "Fifth Six-Month Status Report in Response to March 12, 2012 Commission Order Modifying Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events (Order Number EA-12-049)," August 27, 2015 (ADAMS Accession No. ML15239B402)

16. Union Electric letter ULNRC-06282, "Sixth Six-Month Status Report in Response to March 12, 2012 Commission Order Modifying Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events (Order Number EA-12-049)," February 23, 2016 (ADAMS Accession No. ML16054A836)

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

18. Letter from Jeremy S. Bowen (NRC) to Senior Vice President and Chief Nuclear Officer, Union Electric Company, Ameren Missouri, "Callaway Plant, Unit 1 - Interim Staff Evaluation Relating to Overall Integrated Plan in Response to Order EA-12-049 (Mitigation Strategies)," December 19, 2013 (ADAMS Accession No. ML13224A195)

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29. Union Electric letter ULNRC-06088, "Second Six-Month Status Report in Response to March 12, 2012 Commission Order Modifying Licenses with Regard to Reliable Spent Fuel Pool Instrumentation (Order Number EA-12-051)," February 26, 2014 (ADAMS Accession No. ML14057A773)

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40. Letter from Nicholas Pappas (NEI) to Jack R. Davis (NRC) regarding FLEX Equipment Maintenance and Testing, October 3, 2013 (ADAMS Accession No. ML13276A573)

41. Letter from Jack R. Davis (NRC) to Joseph E. Pollock (NEI), regarding NRC endorsement of the use of the EPRI FLEX equipment maintenance report, October 7, 2013 (ADAMS Accession No. ML13276A224)

42. PWROG-14064-P, Revision 0, "Application of NOTRUMP Code Results for PWRs in Extended Loss of AC Power Circumstances," (ADAMS Accession No. ML14276A099) (transmittal letter only, report is proprietary).

43. WCAP 17601-P, "Reactor Coolant System Response to the Extended Loss of AC Power Event for Westinghouse, Combustion Engineering and Babcock & Wilcox NSSS Designs," Revision 1 (ADAMS Accession No. ML13042A010) (transmittal letter only, report is proprietary)

44. NRC Endorsement Letter for TR-FSE-14-1-P, "Use of Westinghouse SHIELD Passive Shutdown Seal for FLEX Strategies," dated May 28, 2014 (ADAMS Accession No. ML14132A128)

45. Letter from Jack R. Davis (NRC) to Jack Stringfellow (PWROG), regarding Boron Mixing, dated January 8, 2014 (ADAMS Accession No. ML13276A183)

46. Letter from Nicolas Pappas (NEI) to Jack R. Davis (NRC), "EA-12-049 Mitigating Strategies Resolution of Extended Battery Duty Cycles Generic Concern," dated August 27, 2013 (ADAMS Accession No. ML13241A186)

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48. NUREG/CR-7188, "Testing to Evaluate Extended Battery Operation in Nuclear Power Plants," May 2015 (ADAMS Accession No. ML15148A418)

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Date: February 2, 2017

CALLAWAY PLANT, UNIT 1 – SAFETY EVALUATION REGARDING IMPLEMENTATION OF MITIGATING STRATEGIES AND RELIABLE SPENT FUEL POOL INSTRUMENTATION RELATED TO ORDERS EA-12-049 AND EA-12-051 DATED February 2, 2017:

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RidsNrrPMCallaway Resource

ADAMS Accession No. ML17010A332 ***via email**

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