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

January 15, 2016

Mr. David A. Heacock
President and Chief Nuclear Officer
Virginia Electric and Power Company
Innsbrook Technical Center
5000 Dominion Boulevard
Glen Allen, VA 23060-6711

SUBJECT: NORTH ANNA POWER STATION, UNITS 1 AND 2 – SAFETY EVALUATION REGARDING IMPLEMENTATION OF MITIGATING STRATEGIES AND RELIABLE SPENT FUEL POOL INSTRUMENTATION RELATED TO ORDERS EA-12-049 AND EA-12-051 (TAC NOS. MF0998, MF0999, MF0986, AND MF0987)

Dear Mr. Heacock:

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. ML13063A182), Virginia Electric and Power Company (Dominion, the licensee) submitted its OIP for North Anna Power Station, Units 1 and 2 (North Anna) in response to Order EA-12-049. By letters dated April 30, 2013, August 23, 2013, February 27, 2014, August 28, 2014, and March 2, 2015 (ADAMS Accession Nos. ML13126A207, ML13242A012, ML14069A012, ML14251A024, and ML15069A233 respectively), Dominion submitted a supplement and four six-month updates to the OIP. By letter dated August 28, 2013 (ADAMS Accession No. ML13234A503), the NRC notified all licensees and construction permit holders that the staff is conducting audits of their responses to Order EA-12-049 in accordance with NRC Office of Nuclear Reactor Regulation (NRR) Office Instruction LIC-111, "Regulatory Audits" (ADAMS Accession No. ML082900195). By letter dated January 29, 2014 (ADAMS Accession No. ML13338A448), the NRC issued an interim staff evaluation (ISE) on North Anna's progress. By letter dated September 24, 2014 (ADAMS Accession No. ML14259A458), the NRC issued an onsite audit regarding mitigating strategies and reliable spent fuel instrumentation related to Orders EA-12-049 and EA-12-051. By letter dated May 19, 2015 (ADAMS Accession No. ML15149A143), Dominion submitted a compliance letter and final integrated plan (FIP) in response to Order EA-12-049.

By letter dated February 28, 2013 (ADAMS Accession No. ML13063A017), Dominion submitted its OIP for North Anna in response to Order EA-12-051. By email dated May 28, 2013 (ADAMS Accession No. ML13177A194), the NRC staff sent a request for additional information (RAI) to the licensee. By letters dated July 2, 2013, August 23, 2013, February 27, 2014, and August 26, 2014 (ADAMS Accession Nos. ML13190A310, ML13242A015, ML14069A009, and ML14245A401, respectively), Dominion submitted its RAI responses and first three six-month updates to the OIP. The NRC staff's review to date led to the issuance of the North Anna ISE and RAI dated November 1, 2013 (ADAMS Accession No. ML13281A648). By letter dated March 26, 2014 (ADAMS Accession No. ML14083A620), the NRC notified all licensees and construction permit holders that the staff is conducting in-office and on-site 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 September 24, 2014 (ADAMS Accession No. ML14259A458), the NRC issued an on-site audit report regarding mitigating strategies and reliable spent fuel instrumentation related to Orders EA-12-049 and EA-12-051. By letter dated December 3, 2014 (ADAMS Accession No. ML14342B005), Dominion submitted its compliance letter in response to Order EA-12-051.

The enclosed safety evaluation (SE) provides the results of the staff's review of Dominion's strategies for North Anna. The intent of the SE is to inform Dominion on whether or not their integrated plans, if implemented as described, provide a reasonable path for compliance with Orders EA-12-049 and EA-12-051. The NRC staff will evaluate implementation of the plans through inspection Temporary Instruction 191, "Inspection of the Implementation of Mitigation Strategies and Spent Fuel Pool Instrumentation Orders and Emergency Preparedness Communications/Staffing/Multi-Unit Dose Assessment Plans" (ADAMS Accession No. ML14273A444). This inspection will be conducted in accordance with the NRC's inspection schedule for the plant.

If you have any questions, please contact Tony Brown, Orders Management Branch, North Anna Project Manager, at 301-415-1924 or at Tony.Brown@nrc.gov.

Sincerely,

Gregory Bowman, Chief
Orders Management Branch
Japan Lessons-Learned Division
Office of Nuclear Reactor Regulation

Docket Nos.: 50-338 and 50-339

Enclosure:
Safety Evaluation

cc w/encl: Distribution via Listserv

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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

VIRGINIA ELECTRIC AND POWER COMPANY

NORTH ANNA POWER STATION, UNITS 1 AND 2

DOCKET NOS. 50-338 AND 50-339

1.0 INTRODUCTION

The earthquake and tsunami at the Fukushima Dai-ichi nuclear power plant (Fukushima) 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. 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 to mitigate such beyond-design-basis external events (BDBEEs) at U.S. commercial nuclear power plants.

On March 12, 2012, the NRC issued Order EA-12-049, "Order Modifying Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events" (Agencywide Documents Access and Management System (ADAMS) Accession No. ML12054A736). This order directed licensees to develop, implement, and maintain guidance and strategies to maintain or restore core cooling, containment, and spent fuel pool (SFP) cooling capabilities in the event of a BDBEE. Order EA-12-049 applies to all power reactor licensees and all holders of construction permits for power reactors.

On March 12, 2012, the NRC also issued Order EA-12-051, "Order Modifying Licenses with Regard to Reliable Spent Fuel Pool Instrumentation" (ADAMS Accession No. ML12054A679). This order directed licensees to install reliable SFP level instrumentation with a primary channel and a backup channel, and with independent power supplies that are independent of the plant alternating current (ac) and direct current (dc) power distribution systems. Order EA-12-051 applies to all power reactor licensees and all holders of construction permits for power reactors.

2.0 REGULATORY EVALUATION

Following the events at Fukushima on March 11, 2011, the NRC established a senior-level agency task force referred to as the Near-Term Task Force (NTTF). The NTTF was tasked with conducting a systematic and methodical review of the NRC regulations and processes and determining if the agency should make additional improvements to these programs in light of the events at Fukushima. As a result of this review, the NTTF developed a comprehensive set of recommendations, documented in SECY-11-0093, "Near-Term Report and Recommendations for Agency Actions Following the Events in Japan," dated July 12, 2011 (ADAMS Accession No. ML11186A950). Following interactions with stakeholders, these recommendations were enhanced by the NRC staff and presented to the Commission.

On February 17, 2012, the NRC staff provided SECY-12-0025, "Proposed Orders and Requests for Information in Response to Lessons Learned from Japan's March 11, 2011, Great Tohoku Earthquake and Tsunami" (ADAMS Accession No. ML12039A103), to the Commission. This paper included a proposal to order licensees to implement enhanced BDBEE mitigation strategies. As directed by Staff Requirements Memorandum (SRM)-SECY-12-0025 (ADAMS Accession No. ML120690347), the NRC staff issued Orders EA-12-049 and EA-12-051.

2.1 Order EA-12-049

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

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

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

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

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

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

On August 21, 2012, following several submittals and discussions in public meetings with NRC staff, the Nuclear Energy Institute (NEI) submitted document NEI 12-06, "Diverse and Flexible Coping Strategies (FLEX) Implementation Guide," Revision 0 (ADAMS Accession No. ML12242A378), to the NRC to provide specifications for an industry-developed methodology for the development, implementation, and maintenance of guidance and strategies in response to Order EA-12-049. The NRC staff reviewed NEI 12-06 and on August 29, 2012, issued its final version of Japan Lessons-Learned Directorate (JLD) Interim Staff Guidance (ISG) JLD-ISG-2012-01, "Compliance with Order EA-12-049, Order Modifying Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events" (ADAMS Accession No. ML12229A174), endorsing NEI 12-06, Revision 0, with comments, as an acceptable means of meeting the requirements of Order EA-12-049, and published a notice of its availability in the *Federal Register* (77 FR 55230).

2.2 Order EA-12-051

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

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

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

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

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

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

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

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

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

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

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

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

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

On August 24, 2012, following several NEI submittals and discussions in public meetings with NRC staff, the NEI submitted document NEI 12-02, "Industry Guidance for Compliance With NRC Order EA-12-051, To Modify Licenses With Regard to Reliable Spent Fuel Pool Instrumentation," Revision 1 (ADAMS Accession No. ML12240A307), to the NRC to provide specifications for an industry-developed methodology for compliance with Order EA-12-051. On August 29, 2012, the NRC staff issued its final version of JLD-ISG-2012-03, "Compliance with Order EA-12-051, Reliable Spent Fuel Pool Instrumentation" (ADAMS Accession No. ML12221A339), endorsing NEI 12-02, Revision 1, as an acceptable means of meeting the requirements of Order EA-12-051 with certain clarifications and exceptions, and published a notice of its availability in the *Federal Register* (77 FR 55232).

3.0 TECHNICAL EVALUATION OF ORDER EA-12-049

By letter dated February 28, 2013 (ADAMS Accession No. ML13063A182), Virginia Power and Electric Company (Dominion, the licensee) submitted its Overall Integrated Plan (OIP) for North Anna Power Station, Units 1 and 2 (North Anna, NAPS) in response to Order EA-12-049. By letters dated April 30, 2013 (ADAMS Accession No. ML13126A207), August 23, 2013 (ADAMS Accession No. ML13242A012), February 27, 2014 (ADAMS Accession No. ML14069A012), August 28, 2014 (ADAMS Accession No. ML14251A024), and March 2, 2015 (ADAMS Accession No. ML15069A233), the licensee submitted a supplement and four six-month updates to the OIP. By letter dated August 28, 2013 (ADAMS Accession No. ML13234A503), the NRC notified all licensees and construction permit holders that the staff is conducting audits of their responses to Order EA-12-049 in accordance with NRC Office of Nuclear Reactor Regulation (NRR) Office Instruction LIC-111, "Regulatory Audits" (ADAMS Accession No. ML082900195). By letters dated January 29, 2014 (ADAMS Accession No. ML13338A448), and September 24, 2014 (ADAMS Accession No. ML14259A458), the NRC issued an Interim Staff Evaluation (ISE) and an audit report on the licensee's progress. By letter dated May 19, 2015 (ADAMS Accession No. ML15149A143), 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 loss of normal access to the ultimate heat sink (LUHS). This event 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.

North Anna, Units 1 and 2 are pressurized-water reactors (PWRs) with dry sub-atmospheric containment buildings. The FIP describes the licensee's three-phase approach to mitigate a postulated ELAP event.

At the onset of an ELAP, both reactors are assumed to trip from full power. The reactor coolant pumps (RCPs) coast down, and flow in the reactor coolant system (RCS) transitions to natural circulation. Decay heat is removed by steaming the steam generators (SGs) through the main steam safety valves or SG power-operated relief valves (PORVs), and makeup to the SGs is provided by the turbine-driven auxiliary feedwater pump (TDAFWP). Within 2 hours, the operators manually operate the PORVs to begin a controlled cooldown and depressurization of the RCS. The RCS makeup, to account for RCS leakage and inventory contraction, is initially provided from the safety injection cold leg accumulators. The initial RCS cooldown is controlled to prevent nitrogen in the accumulators from entering the RCS. Operators will further reduce RCS inventory loss by isolating other potential RCS letdown paths.

The water supply for the TDAFWP is initially the protected emergency condensate storage tank (ECST). The ECST will provide a minimum of 4.2 hours of RCS decay heat removal concurrent with a RCS cooldown to 290 psig steam generator pressure. Prior to emptying the ECST, the operators will align the TDAFWP suction to the protected fire protection (FP) system, which is pressurized by the protected diesel-driven fire pump (DDFP), taking suction from the protected Service Water (SW) reservoir (approximately 22.5 million gallons of usable water volume) to provide sufficient flowrate and pressure to support TDAFWP operation. In addition to the SW reservoir, a portable beyond-design-basis (BDB) high capacity pump can be used to draw water from Lake Anna to provide suction for the TDAFWP. A portable auxiliary feedwater (AFW) pump is available for SG injection though both primary and alternate connection locations.

The dc bus load stripping will be initiated within the first hour to ensure Class 1E battery life is extended to 8 hours. Portable generators will be used to repower instrumentation prior to battery depletion.

Following dc load stripping and prior to battery depletion, portable 120/240 volt alternating current (Vac) diesel generators will be deployed and connected to power several 120 Vac vital buses. As a backup to the 120/240 Vac diesel generators, 480 Vac diesel generators are available from the BDB storage building to also power the 120 Vac vital buses.

Borated RCS makeup will be initiated within 16 hours of the ELAP/LUHS event. Two portable diesel-driven BDB RCS injection pumps are being stored in the on-site BDB storage building and can be deployed (one to each unit). At least one of these pumps is assumed available and the licensee stated that a single pump can provide makeup for both units. In this case, the single available pump may be used to supply alternating borated makeup to both units, alternating every hour, using the normal charging header cross-tie lines so that the pump would not need to be repositioned. With only one available pump, according to the licensee's planned strategy, RCS injection to the first unit would begin by 15 hours to ensure makeup to the second unit by 16 hours. The available pump(s) would take suction from the portion of the refueling water storage tanks' (RWSTs) inventory that is available, or would take suction from portable boric acid mixing tanks.

During Phase 3 of the event, a National SAFER Response Center (NSRC) will provide pumps, generators, and other equipment to back up onsite FLEX equipment.

Licensee calculations conclude that containment temperature and pressure will remain below design limits and key parameter instrumentation subject to the containment environment will remain functional for a minimum of 7 days. Initial actions include verifying containment isolation and monitoring containment temperature and pressure using installed instrumentation. As necessary, the licensee will initiate actions to reduce containment temperature and pressure utilizing offsite equipment brought in from an NSRC in order to supply power to either of the Class 1E 4160 Vac buses on each unit, which will allow restoring the Class 1E buses to power selected 480 Vac loads. Several options are available for containment temperature reduction, including establishing containment air recirculation fan cooling, establishing control rod drive mechanism cooling, or spraying water into the containment using the containment recirculation spray system.

To maintain SFP cooling capabilities, the licensee determined that initially only monitoring the SFP level is required. Boiling will begin in approximately 9 hours and boil off to a level 10 feet above the top of fuel in 43 hours, and prior to that time, SFP makeup will be initiated using either the BDB high capacity pump connected to the permanent BDB SFP makeup connection or the existing Fire Protection (FP). Ventilation of the fuel building is accomplished by opening several rollup doors in the building to establish a natural circulation flowpath through which steam generated by boiling in the SFP can exit the fuel building. In addition, a spray strategy can be initiated by deploying a fire hose connected to spray monitors set up on the SFP deck, fed by the FP system or the BDB high capacity pump.

Below are specific details on the licensee's strategies to restore or maintain core cooling, containment, and SFP cooling capabilities in the event of an ELAP and the results of the staff's review of these strategies. The NRC staff evaluated the licensee's strategies against the endorsed NEI 12-06, Revision 0, guidance.

3.2 Reactor Core Cooling Strategies

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

The equipment available onsite for Phases 1 and 2 is further supplemented in Phase 3 by equipment transported from the NSRCs.

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

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

3.2.1 Core Cooling Strategy and RCS Makeup

3.2.1.1 Phase 1

As stated in the FIP, the heat sink for core cooling in Phase 1 would be provided by the three SGs at each unit, which would be fed simultaneously by the unit's TDAFWP with inventory supplied from the ECST. The TDAFWP is ac-independent and this pump, the ECST, and the associated flow path meet applicable criteria for robustness, per NEI 12-06. The ECST has a minimum usable volume of 96,000 gallons, which will support decay heat removal for up to 4.2 hours, accounting for the planned RCS cooldown. When the ECST has been depleted, operators will align the TDAFWP suction to the protected portion of the FP system, which is common to both units. The FP system will be pressurized by the installed DDFP taking suction from the SW reservoir.

North Anna's Phase 1 strategy directs the initiation of a cooldown and depressurization of the RCS within 2 hours of the initiation of the ELAP/LUHS event. Over a period of approximately 2 hours, Dominion would cool down the RCS at a maximum rate of 100°F/hr from post-trip conditions until a SG pressure of 290 per square inch gage (psig) is reached. A minimum SG pressure of 290 psig is set initially to prevent nitrogen gas from the safety injection accumulators from entering the RCS. Cooldown and depressurization of the RCS significantly extends the expected coping time under ELAP/LUHS conditions because it (1) reduces the potential for damage to RCP seals (as discussed in Section 3.2.3.3) and (2) allows coolant stored in the nitrogen-pressurized accumulators to inject into the RCS to offset system leakage.

Although operators would verify that isolation of normal letdown and other flowpaths out of the RCS has occurred automatically (due to the loss of ac power), some RCS leakage would nevertheless be expected to occur under ELAP conditions through RCP seals and other leakage points. Therefore, as the ELAP event progresses, RCS inventory tends to gradually diminish in the absence of RCS makeup. As is typical of operating PWRs, North Anna does not have installed ac-independent RCS makeup pumps. Therefore, the licensee has performed an analysis and concluded that sufficient RCS inventory will be available in Phase 1 to support heat transfer to the SGs via natural circulation.

3.2.1.2 Phase 2

The Phase 2 FLEX strategy for core cooling provides an indefinite supply of feedwater to the SGs using the DDFP with suction from the SW reservoir (approximately 22.5 million gallons of water), followed by a portable BDB high capacity pump with suction from Lake Anna if required. In the North Anna FIP, Dominion stated that potential debris at the suction screen of the DDFP would not prevent adequate flow to the pump. The trash screens on the SW reservoir Intake Bay are designed to pass the full design flow of a SW pump and the DDFP, and the SW pumps will not be operating due to the ELAP/LUHS. Since the 600 gallons per minute (gpm) required by the DDFP to provide a suction source for the TDAFW pump is a small fraction of the design flow rate of the trash screen, the calculated unblocked trash screen area required for passing the required flow rate appears justifiable.

Additionally, portable, diesel-driven BDB AFW pumps are available as a back-up to the TDAFWPs, with both primary and alternate connections. Both the BDB high capacity pump and the portable BDB AFW pump are stored in the BDB storage building, which was designed and constructed to prevent water intrusion and designed to protect equipment from seismic, flooding, high winds, and extreme temperatures. Haul paths have been pre-determined and documented in the FLEX Support Guidelines (FSGs) from the BDB storage building to the various deployment locations. The paths have been determined to be stable following a seismic event, and debris removal equipment (stored in the BDB storage building) will be available to clear the paths of obstructions if necessary.

RCS inventory makeup will be initiated within 16 hours of the ELAP/LUHS event, using a portable pump to replenish RCS inventory. The initiation of RCS inventory makeup from a borated water source also addresses the requirement to keep the reactor subcritical throughout the ELAP event; see Section 3.2.3.4 for details. To accomplish these functions, licensee procedures direct plant personnel to deploy the two portable, diesel-driven, 45-gpm BDB RCS injection pumps (one per unit) from the onsite BDB storage building. The licensee stated in the FIP that, in the event one pump is unavailable, the available BDB RCS injection pump may be used to supply RCS inventory makeup to both units by alternating RCS injection between the units. The preferred source of borated coolant for the BDB RCS injection pumps is the site's two refueling water storage tanks (RWSTs). The licensee stated that one BDB RCS injection pump and one RWST are sufficient to provide the needed makeup to both units during Phase 2. In the unlikely event that both RWSTs are unavailable or depleted, the licensee has developed a contingency strategy to utilize portable boric acid mixing tanks (BAMTs), deployed from the BDB storage building.

The primary RCS injection point is located in the safeguards building of each unit and provides a path to the RCS hot legs; the alternate connection is inside the hydrogen recombiner vault (in the basement of the auxiliary building) and provides a path to the charging system unit cross-connect piping. Both connections are protected against all design-basis external hazards.

3.2.1.3 Phase 3

According to its FIP, North Anna's core cooling strategy for Phase 3 is a continuation of the Phase 2 strategy with additional offsite equipment and resources.

As discussed above, the DDFP taking suction from the SW reservoir and the BDB high capacity pump drawing water from Lake Anna are capable of providing a long-term heat sink for an indefinite coping period. Additional equipment from a NSRC will be available in Phase 3 to provide backup to the BDB high capacity pump, BDB AFW pumps, and other equipment. Additionally, a reverse osmosis/ion exchanger water processing system will be provided from the NSRC to provide a method to remove impurities from alternate fresh water supplies to the TDAFW pump and the BDB AFW pumps. The Phase 3 strategy for re-powering the residual heat removal (RHR) system via portable 4160 V ac generators provides an alternate method for removing decay heat and/or RCS cooldown to cold shutdown.

The RCS makeup strategy is similarly supplemented by offsite resources. Equipment requested from the NSRC for RCS inventory control includes backup RCS injection pumps, mobile water treatment skids, and mobile boration skids.

3.2.2 Variations to Core Cooling Strategy for Flooding Event

In its FIP, in Section 2.6.2, the license states that the majority of the site grade is above the design-basis flood level, and the western portion of the Unit 2 turbine building is protected by a dike to prevent flooding during the design-basis flood. There is no deployment of FLEX equipment in the area west of the Unit 2 turbine building; consequently, there are no deployment limitations due to flooding from the design-basis flood. As a result, there are no variations to the core cooling strategy in the event of a flood. Refer to Section 3.5.2 of this SE 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 - SG - MODES 1-4 only

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. North Anna's core cooling FLEX strategies rely on its existing TDAFWP to remove heat from the RCS by providing cooling water to the three SGs, as described in North Anna's FIP. Operators relieve steam from the SGs through the PORVs, which are air-operated valves (AOVs) with control power from the Class 1E batteries. In addition, North Anna relies on its DDFP to supply water to the TDAFWP or portable AFW pump in Phases 2 and 3.

As described in the NAPS Updated Final Safety Analysis Report (UFSAR) Table 3.2-1, the TDAFWP is a seismic Category I component. The TDAFWP is located in the AFW pump house, which is a seismic Category I and tornado missile-protected structure (UFSAR Table 3.2-1). As described in North Anna's FIP, two air-operated steam supply trip valves (TVs), which are normally closed, supply steam to the TDAFWP turbine. If the dc solenoids that actuate the TVs de-energize, air is vented to open the valves and admit steam to the turbine. During an ELAP, procedures direct operators to ensure that the TVs are open by removing power from the solenoids to vent the actuators. The governor valve automatically controls TDAFWP turbine steam flow. In addition, operators can manually control the steam flow with the overspeed trip/throttle valve. In the event the TDAFW pump fails to start (or trips after start-up), procedures direct the operators to manually reset and start the pump. Manual reset, starting, and operation of the pump does not require electrical power for motive force or control. Operators would have approximately 50 minutes to manually start the pump and initiate cooling water flow before the steam generators dry out (ADAMS Accession No. ML13126A207). Based on the location and design of the TDAFWP and Dominion's control strategy, as described in the FIP and NAPS UFSAR, the TDAFWP should be available to support core cooling during an ELAP caused by a BDBEE, consistent with Condition 6 of NEI 12-06, Section 3.2.1.3.

As described in the FIP, the SG PORVs are safety-related, missile-protected, seismically-qualified valves. Dominion stated that these valves are powered from safety-related sources and supplied by back-up air bottles. Operators can control the SG PORVs from the Main Control Room (MCR), which will aid in minimizing field action and maximizing SG PORV control response. Operators will continue controlling the SG PORVs from the MCR until the air supply from the respective back-up air receiver is depleted. Following depletion of back-up air receivers, operators will initiate manual control via local manual hand wheels, or recharge the backup air receivers using a portable diesel driven air compressor stored in the BDB storage building. Based on the location and design of the SG PORVs and Dominion's control strategy, as described in the FIP and NAPS UFSAR, the SG PORVs should be available to support core cooling during an ELAP caused by a BDBEE, consistent with Condition 6 of NEI 12-06, Section 3.2.1.3.

As described in the NAPS UFSAR Section 8.3.2.1, the safety-related Class 1E batteries and associated dc buses are seismically mounted and located in missile-protected rooms inside the service building, which is a seismic Category I structure. Based on the location and design of the station batteries, as described in the FIP and NAPS UFSAR, the station batteries should be available to support core cooling during an ELAP caused by a BDBEE, consistent with Condition 6 of NEI 12-06, Section 3.2.1.3.

As described in the NAPS UFSAR Table 3.2.1, the DDFP is a seismic Category I component located inside the SW pump house, which is a seismic Category I and tornado missile-protected structure. In addition, as stated in North Anna's FIP, the fire protection piping from the DDFP to the suction of the TDAFW pump is also seismic Category I and tornado missile-protected. Based on the location and design of the DDFP and associated piping, as described in the FIP and NAPS UFSAR, the DDFP should be available to support core cooling during an ELAP caused by a BDBEE, consistent with Condition 6 of NEI 12-06, Section 3.2.1.3.

Condition 3 of NEI 12-06, Section 3.2.1.3, states that cooling and makeup water inventories contained in systems or structures with designs that are robust with respect to seismic events, floods, and high winds, and associated missiles are available. Dominion's core cooling FLEX strategies rely on its ECST. The ECST is the initial water source for the TDAFWP at the onset of an ELAP. However, in order to provide a suction source for portable pumps or the ability to refill the ECST, Dominion installed a suction/refill connection to the ECST. The connection includes a hose coupling suitable for easy connection of a fire hose supplying water from the BDB high capacity pump or one of the other sources of water to refill the ECST. The connection is seismically designed and located inside the AFW pump house. As described in the NAPS USFAR, Table 3.2.1, the ECST is a seismic Category I, tornado missile-protected tank. Based on the design of the ECST, as described in the FIP and NAPS UFSAR, the ECST should be available to support core cooling during an ELAP caused by a BDBEE, consistent with Condition 3 of NEI 12-06, Section 3.2.1.3.

Condition 4 of NEI 12-06, Section 3.2.1.3, states that normal access to the UHS is lost, meaning the motive force for UHS flow (i.e., pumps) is assumed to be lost with no prospect for recovery, but the water inventory in the UHS remains available and robust piping connecting the UHS to plant systems remains intact. As described in North Anna's FIP, following depletion of the usable volume in the ECST, operators will swap the suction of the TDAFWP to the seismic Category I portions of the FP system with the DDFP taking suction from the SW reservoir. As described in the NAPS USFAR, Table 3.2.1, the SW reservoir is a seismic Category I structure. If necessary, Dominion can provide make-up water to the SW reservoir (or directly to the TDAFWP) from Lake Anna via a portable pump. As described in NAPS UFSAR, Section 3.8.3.1, the dam that impounds Lake Anna is a Seismic Class I structure. Based on the design of the SW reservoir and Lake Anna dam, as described in the FIP and NAPS UFSAR, these water sources should be available to support core cooling during an ELAP caused by a BDBEE, consistent with Condition 4 of NEI 12-06, Section 3.2.1.3.

Primary and Alternate Connection Points for Core Cooling

Section 3.2.2 of NEI 12-06 states that the portable pumps for core and SFP cooling functions are expected to have a primary and an alternate connection or delivery point. At a minimum, the primary connection point should be an installed connection suitable for both the on-site and off-site equipment, but the secondary connection point can require reconfiguration if the licensee can show that adequate time and resources are available to support the reconfiguration. In addition, NEI 12-06, Table D-1 states that primary and alternate injection points are required to establish capability to inject through separate divisions/trains (i.e., should not have both connections in one division/train).

As described in North Anna's FIP, the primary connection to supply AFW to the SGs via a portable pump is located on the TDAFW pump discharge line located in the AFW pump house. As described in the NAPS UFSAR, Table 3.2-1, the TDAFW pump discharge line is seismic Category I piping from the discharge of the pump to the SG feed lines inside of containment. In addition, Table 3.2-1 lists the AFW pump house as a seismic Category I and tornado missile-protected structure.

As described in North Anna's FIP, the alternate AFW connection for SG injection is located on the main feedwater system in the mechanical equipment room located in the service building. The connection consists of a hose adapter that replaces the valve bottom flange connection on any of three main feedwater regulating bypass valves. The NAPS UFSAR, Section 10.4.3, describes only the AFW portion of the condensate and feedwater system as a seismic Category I system. In the NAPS UFSAR, Table 3.2-1 identifies only the SG feed lines inside containment to and including first isolation check valve outside containment as seismic Category I and missile-protected. In addition, Table 3.2-1 does not list the mechanical equipment room portion of the service building as seismic Category I or tornado missile-protected. However, NEI 12-06 Section 3.2.2, states that both the primary and alternate connection points do not need to be available for all applicable hazards, but the location of the connection points should provide reasonable assurance that one connection will be available to support core cooling during an ELAP following a BDBEE.

The main and auxiliary feedwater systems do share common piping depending on the chosen flow paths. However, operators can configure the system such that the primary and alternate connection points would provide independent flow paths to individual SGs. Based on the design and location of the primary and alternate AFW connection points, as described in the FIP and NAPS UFSAR, at least one of the connection points should be available to support core cooling via a portable pump during an ELAP caused by a BDBEE, consistent with NEI 12-06, Section 3.2.2 and Table D-1.

RCS Inventory Control - MODES 1-4 only

Condition 3 of NEI 12-06, Section 3.2.1.3, states that cooling and makeup water inventories contained in systems or structures with designs that are robust with respect to seismic events, floods, and high winds, and associated missiles are available. As described in North Anna's FIP, the primary supply of borated water to the BDB RCS injection pump is through a suction connection from the RWST via a permanent hose connection. The connection is installed in one of two quench spray pump's suction elbows for each unit, allowing borated water from the RWST to be supplied to a portable BDB RCS injection pump.

Table 3.2-1 of the NAPS UFSAR describes the RWST and quench spray subsystem piping, valves, and supports as seismic Category I, but not protected from tornado-generated missiles. Dominion stated in its FIP that if one unit's RWST is damaged, the suction hose to that unit's BDB RCS injection pump can be routed from the opposite unit's RWST to provide a borated water source to the BDB RCS injection pump. In addition, Dominion stated that if neither RWST is available, portable BAMTs are available to batch borated water and provide borated water to the suction of the BDB RCS Injection pumps. These portable BAMTs will be transported from the onsite BDB storage building and positioned near the BDB RCS Injection pump as a back-up suction source. Dilution water will be added to the mixing tank by either a portable transfer pump, the BDB AFW pump, or from the BDB high capacity pump header taking suction from a clean water source. As described below in Section 3.2.3.4, "Shutdown Margin Analyses," powdered boric acid will be mixed with dilution water to achieve the proper concentration for maintaining adequate shutdown margin while making up RCS inventory. Each tank is equipped with an agitator to facilitate mixing of the boric acid. Based on the design of the RWST, and the availability of portable BAMTs, as described in the FIP and UFSAR, a borated water source should be available to support RCS inventory control via a portable pump during an ELAP caused by a BDBEE, consistent with Condition 3 of NEI 12-06, Section 3.2.1.3.

Primary and Alternate Connection Points for RCS Inventory Control

Section 3.2.2 of NEI 12-06 states that the portable pumps for core and SFP cooling functions are expected to have a primary and an alternate connection or delivery point. At a minimum, the primary connection point should be an installed connection suitable for both the on-site and off-site equipment, but the secondary connection point can require reconfiguration if the licensee can show that adequate time and resources are available to support the reconfiguration. In addition, NEI 12-06, Table D-1, states that primary and alternate injection points are required to establish capability to inject through separate divisions/trains (i.e., should not have both connections in one division/train).

As described in North Anna's FIP, the primary connection for RCS makeup is located downstream of the low-head safety injection (LHSI) pump discharge motor-operated valves (MOVs) leading in to the RCS hot legs. The NAPS UFSAR, Table 3.2-1, describes the LHSI pumps and piping as well as the RCS piping as seismic Category I and tornado missile-protected systems.

As described in North Anna's FIP, the alternate RCS connection utilizes a connection to a standpipe located in the auxiliary building basement that extends to an accessible area in the hydrogen recombiner vault. A spectacle flange is attached to the standpipe outlet (lower end) to a connection located on the Unit 2 normal charging header. The BDB RCS injection pump can deliver borated water from the RWST or the portable boric acid mixing tank to the RCS via the normal charging header. The cross-ties in the normal charging system provide the capability to inject borated water into either unit from this location. The NAPS UFSAR, Table 3.2-1, describes the auxiliary building and the charging system piping as seismic Category I and tornado missile-protected. The location of the alternate connection point allows for an injection path that is independent of the primary RCS injection path.

Based on the design and location of the primary and alternate RCS injection connection points, as described in the FIP and NAPS UFSAR, at least one of the connection points should be available to support RCS injection via a portable pump during an ELAP caused by a BDBEE, consistent with NEI 12-06, Section 3.2.2 and Table D-1.

3.2.3.1.2 <u>Plant Instrumentation</u>

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

- feedwater (FW) flowrate
- SG water level
- SG pressure
- RCS temperature (hot-leg and cold-leg)
- RCS pressure
- core exit thermocouple temperature
- ECST level
- pressurizer level
- reactor vessel level indicating system (RVLIS)
- excore nuclear instruments

The primary indications for all parameters are located in the MCR. The FIP states that the Auxiliary Shutdown (ASD) panel provides alternate indication of SG water level, SG pressure, RCS temperatures, RCS pressure, ECST level, and pressurizer level. In the event that 125 Vdc and 120 Vac vital bus infrastructure is damaged, guidance for alternately obtaining SG water level, core exit thermocouple temperatures, RCS pressure, pressurizer level, and excore nuclear instruments locally is provided in FSG-7, "Loss of Vital Instrumentation or Control Power." Where applicable, guidance is provided for measuring key instrument readings using a portable instrument.

The SG pressure can be read locally in the main steam valve house. Hot-leg and cold-leg RCS temperatures ("A" and "B" loops only), RCS pressure, pressurizer level, and excore nuclear instruments will be indicated in the fuel building. The ECST level can be read locally at the ECST refill connection and pump suction gauges. Train "A" of RVLIS will be available on a recorder on the post-accident monitoring (PAM) panel. Portable BDB equipment is supplied with the local instrumentation needed to operate the equipment. The use of these instruments is detailed in the associated FSGs for use of the equipment.

3.2.3.2 Thermal-Hydraulic Analyses

Dominion concluded that its mitigating strategy for reactor core cooling would be adequate based in part on generic thermal-hydraulic analysis performed for a reference Westinghouse three-loop reactor using the NOTRUMP computer code. The NOTRUMP code and corresponding evaluation model were originally submitted in the early 1980s as a method for performing licensing-basis safety analyses of small-break loss-of-coolant accidents (LOCAs) for Westinghouse PWRs. Although NOTRUMP has been approved for performing small-break LOCA analysis under the conservative Appendix K paradigm and constitutes the current evaluation model of record for many operating PWRs, the NRC staff had not previously examined its technical adequacy for performing best-estimate simulations of the ELAP event. Therefore, in support of mitigating strategy reviews to assess compliance with Order EA-12-049, the NRC staff evaluated licensees' thermal-hydraulic analyses, including a limited review of the significant assumptions and modeling capabilities of NOTRUMP and other thermal-hydraulic codes used for these analyses. The NRC staff's review included performing confirmatory analyses with the 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. In the PWROG Core Cooling Position Paper, which was provided in a letter dated January 30, 2013, the PWROG recommended that the reflux or boiler-condenser cooling phase be avoided because of uncertainties in operators' ability to control natural circulation following reflux boiling and the impact of the diluted pockets of water on criticality. Due to the challenge of resolving the above issues within the compliance schedule specified in Order EA-12-049, the NRC staff requested that PWR 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 the Pressurized-Water Reactor Owners Group (PWROG)-sponsored Technical Report PWROG-14064-P, Revision 0, "Application of NOTRUMP Code Results for Westinghouse Designed PWRs in Extended Loss of AC Power Circumstances," industry has proposed defining this coping time as the point at which the one-hour centered time-average of the flow quality passing over the SG tubes' U-bend exceeds one-tenth (0.1). As discussed further in Section 3.2.3.4 of this evaluation, a second metric for ensuring adequate coping time is associated with maintaining sufficient natural circulation flow in the RCS to support adequate mixing of boric acid.

With specific regard to NOTRUMP, preliminary results from the NRC staff's independent confirmatory analysis performed with the TRACE code indicated that the coping time for Westinghouse PWRs under ELAP conditions could be shorter than predicted in WCAP-17601-P, "Reactor Coolant System Response to the Extended Loss of AC Power Event for Westinghouse, Combustion Engineering and Babcock & Wilcox NSSS Designs," and WCAP-17792-P, "Emergency Procedure Development Strategies for the Extended Loss of AC Power Event for all Domestic Pressurized Water Reactor Designs." Subsequently, a series of additional simulations performed by the staff and Westinghouse identified that the discrepancy in predicted coping time could be attributed largely to differences in the modeling of RCP seal leakage. (The topic of RCP seal leakage is discussed in greater detail in Section 3.2.3.3 of this SE.) These comparative simulations showed that, when similar RCP seal leakage boundary conditions were applied, the coping time predictions of TRACE and NOTRUMP were in adequate agreement. From these simulations, as supplemented by review of key code models, the NRC staff obtained sufficient confidence that the NOTRUMP code may be used in conjunction with the WCAP-17601-P evaluation model for performing best-estimate simulations of ELAP coping time prior to reaching the reflux cooling mode. Further discussion of the staff's review, including conditions and limitations regarding the application of the NOTRUMP code to analysis of the ELAP event, may be found in the NRC staff's endorsement letter on this subject, dated June 16, 2015 (ADAMS Accession No. ML15061A442).

Although the NRC staff obtained confidence that the NOTRUMP code is capable of performing best-estimate ELAP simulations prior to the initiation of reflux cooling using the one-tenth flow-quality criterion discussed above, the staff was unable to conclude that the generic analysis performed in WCAP-17601-P could be directly applied to all Westinghouse PWRs, as the vendor originally intended. In PWROG-14064-P, Revision 0, the industry subsequently recognized that the generic analysis would need to be scaled to account for plant-specific variation in RCP seal leakage. However, the staff's review, supported by sensitivity analysis performed with the TRACE code, further identified that plant-to-plant variation in additional parameters, such as RCS cooldown terminus, accumulator pressure and liquid fraction, and initial RCS mass, could also result in substantial differences between the generically predicted reference coping time and the actual coping times that would exist for specific plants.

During onsite audit discussion, licensee personnel indicated that the Westinghouse three-loop reference case was roughly based on the North Anna design. The NRC staff review of detailed information following the onsite audit confirmed that no major discrepancies exist between the generic analytical assumptions and the plant design and mitigation strategy for North Anna.

However, the leakage rate boundary condition assumed in the generic Westinghouse thermal-hydraulic analysis differs from the plant-specific condition for North Anna. Whereas the generic Westinghouse three-loop analysis assumed an RCS leakage rate commensurate with three Westinghouse-designed RCP seals, two of the three-seals at North Anna have been replaced by Flowserve N-9000 seals, which would have a lower leakage rate. On the other hand, the remaining Westinghouse-designed RCP seal at North Anna has been analyzed to have a higher leakage rate than assumed in the generic thermal-hydraulic analysis, due in large part to the less-restricted flow in the first-stage seal leakoff line at North Anna. According to calculations performed by the licensee, a calculated time limit of 16.7 hours for initiating FLEX RCS makeup is applicable to North Anna. The North Anna FIP states that FLEX RCS makeup will begin within 16 hours of initiation of the ELAP event, with a 45-gpm makeup capacity. In this case, the single available pump may be used to supply alternating borated makeup to both units, using the normal charging header cross-tie lines so that the pump would not need to be repositioned. With only one available pump, according to the licensee's planned strategy, RCS injection to the first unit would begin by 15 hours to provide makeup to the second unit by 16 hours. The licensee concluded that sufficient margin to reflux cooling would be available for North Anna.

Using the leakage rates determined from the ITCHSEAL code, the NRC staff performed confirmatory calculations that predicted a time (15.6 hours) that is on par with the 16-hour time by which the licensee currently plans to initiate RCS makeup. A key parameter in this evaluation is the RCP seal leakage rate, which is discussed further in Section 3.2.3.3.

The NRC staff's audit review found the licensee's thermal-hydraulic analysis to be in adequate conformance with applicable guidance documents (e.g., NEI 12-06, the NRC staff's endorsement letter regarding the NOTRUMP code, WCAP-17601-P, PWROG-14207-P). Furthermore, considering the uncertainty band associated with determining RCP seal leakage rates under ELAP conditions (see discussion below), reasonable agreement was generally found to exist between the licensee's analysis and confirmatory calculations performed by the NRC staff. Therefore, based on the evaluation above, the licensee's analytical approach should appropriately determine the sequence of events, including time-sensitive operator actions, and 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 pressurized-water reactor can cope with an ELAP event prior to initiating RCS makeup. An ELAP event would interrupt cooling to the RCP seals, potentially resulting in increased leakage and the failure of elastomeric o-rings and other components, which could further increase the leakage rate. As discussed above, as long as adequate inventory is maintained in the RCS, natural circulation can effectively transfer residual heat from the reactor core to the SGs and limit local imbalances in boric acid concentration. Along with cooldown-induced shrinkage of the RCS inventory, cumulative leakage from RCP seals governs the duration over which natural circulation can be maintained in the RCS. Furthermore, the seal leakage rate at the depressurized condition can be a controlling factor in determining the flow capacity requirement for FLEX pumps to offset ongoing RCS leakage and recover adequate system inventory.

North Anna Units 1 and 2 are three-loop Westinghouse pressurized-water reactors, with one Westinghouse RCP in each loop. The Model 93A RCPs at North Anna Units 1 and 2 originally used standard three-stage Westinghouse seal packages. All original RCP seals for both units were subsequently replaced with highly similar seals manufactured by AREVA to Westinghouse specifications. North Anna has since replaced two of the three AREVA-manufactured RCP seals on each unit with low-leakage Flowserve N-9000 seals with the Abeyance feature. Although they will not be installed prior to the required FLEX implementation date, the licensee stated in its FIP that it intends to install an additional N-9000 seal in place of the remaining AREVA RCP seal at each unit. The licensee plans to replace the remaining Unit 2 seal during the spring 2016 outage and the remaining Unit 1 seal during the spring 2018 outage (Reference 1).

Regarding the N-9000 seals, on August 3, 2015, Flowserve submitted its "White Paper on the Response of the N-Seal Reactor Coolant Pump (RCP) Seal Package to Extended Loss of All Power (ELAP)" (ADAMS Accession No. ML15222A366). The white paper contained information regarding the expected leakage rates for Flowserve N-Seals under loss-of-seal-cooling conditions that would exist during an ELAP event. By letter dated November 12, 2015 (ADAMS Accession No. ML15310A094), the NRC staff endorsed the leakage rates described in the white paper for the beyond-design-basis ELAP event, subject to certain limitations and conditions. The limitations and conditions have been discussed with the licensee, which has confirmed that they will be satisfied. Therefore, the NRC staff has confidence in the leakage rates the licensee has proposed for these seals for the analyzed ELAP event.

Regarding the AREVA-manufactured seals, the staff has been reviewing the performance of this type of seal (i.e., Westinghouse-designed) under ELAP conditions in support of its reviews of licensee's mitigating strategies. As noted in Section 3.2.3.2, Dominion is relying on thermal-hydraulic analysis performed with the NOTRUMP code to determine the time at which makeup would be required to maintain natural circulation flow in the RCS. In accordance with analysis and testing documented in WCAP-10541-P, "Westinghouse Owners Group Report, Reactor Coolant Pump Seal Performance Following a Loss of All AC Power," Revision 2, the ELAP analysis in WCAP-17601-P assumed a leakage rate at nominal post-trip cold leg conditions (i.e., 2250 psia and 550°F) of 21 gpm for each RCP, plus an additional 1 gpm of operational RCS leakage. In the WCAP-17601-P analysis, both seal and operational leakages were assumed to vary according to the critical flow correlation modeled in the NOTRUMP code as the reactor was cooled down and depressurized.

Recent assessments of RCP seal leakage behavior under ELAP conditions by industry analysts and NRC staff identified several issues with the original treatment of seal leakage from standard Westinghouse-designed seal packages. These issues, which the staff considers applicable to the remaining AREVA seals at North Anna, are documented in the Westinghouse Nuclear Safety Advisory Letter (NSAL) 14-1, dated February 10, 2014, and included (1) the initial post-trip leakage rate of 21 gpm does not apply to all Westinghouse pressurized-water reactors due to variation in seal leakoff line hydraulic configurations; (2) according to test data, seal leakage does not appear to decrease with pressure as rapidly as predicted by the analysis in

WCAP-17601-P; and (3) some reactors may experience post-trip cold leg temperatures in excess of 550 °F, depending on the lowest main steam safety valve lift setpoint. To address these issues, the PWROG performed additional analytical calculations using Westinghouse's seal leakage model (i.e., ITCHSEAL). These calculations included (1) benchmarking calculations against available test data and (2) additional generic calculations for several groups of plants (categorized by similarity of first-stage seal leakoff line design) to determine the maximum leakage rates, as well as the maximum pressures that may be experienced in the first-stage seal leakoff line piping.

During the audit review, Dominion indicated that North Anna is relying on the generic Westinghouse RCP seal leakage calculations that have been performed by the PWROG. The generic PWROG calculations audited by the staff, including proprietary reports PWROG-14015-P, "No. 1 Seal Flow Rate for Westinghouse Reactor Coolant Pumps Following Loss of All AC Power," and PWROG-14027-P, "No. 1 Seal Flow Rate for Westinghouse Reactor Coolant Pumps Following Loss of All AC Power, Task 3: Evaluations of Revised Seal Flow Rate on Time to Enter Reflux Cooling and Time at which the Core Uncovers," classify North Anna in the third generic analysis category (i.e., Category 3) specified in NSAL-14-1.

In order to ensure that the generic Category 3 leakage rates are applicable to North Anna, the NRC staff requested that Dominion confirm that applicable portions of the first-stage seal leakoff line piping can withstand the maximum pressure that may be postulated during an ELAP event. According to generic calculations performed by Westinghouse using the ITCHSEAL code, Category 3 plants would be expected to experience choked flow at the flow-measurement orifice in the first-stage seal leakoff line, even after completion of the RCS cooldown. Therefore, to support application of the generic Category 3 leakage rates, it is necessary for Dominion to confirm that a rupture in the pressure boundary of leakoff line piping or components upstream of the flow orifice would not occur at North Anna. During the audit process, Dominion informed the NRC staff that the applicable portions of the leakoff line piping and components can tolerate pressures greater than or equal to RCS design pressure (i.e., 2500 psia). Thus, the licensee's analysis concluded that the functionality of the No. 1 seal leakoff lines would not be expected to be challenged during an ELAP (Reference 2) and Category 3 leakage rates should be applicable to North Anna.

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

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

Westinghouse issued Westinghouse Technical Bulletin (TB) 15-1, "Reactor Coolant System Temperature and Pressure Limits for the No. 2 Reactor Coolant Pump Seal," dated March 3, 2015. Westinghouse notified Dominion of the TB on March 17, 2015 (Reference 3). The bulletin concluded that long-term integrity of Westinghouse-designed second-stage RCP seals could not be supported by the available analysis, and recommended that affected plants execute an extended cooldown of the RCS to less than 350°F and 400 psig by 24 hours into the ELAP event. Westinghouse stated that second-stage seal integrity is necessary to ensure that the leakage from Westinghouse-designed RCP seals can be limited to a rate that can be offset by the equipment available for FLEX RCS injection. In light of the design similarities noted above, the NRC staff considers the recommendations of TB 15-1 applicable to the AREVA-manufactured seals remaining at North Anna.

Dominion notified the NRC staff that the issue was entered into the corrective action program for further evaluation (ADAMS Accession No. ML15324A304). The PWROG is currently in the process of revising the cooldown limits in TB 15-1 due to concerns about potential unintended consequences with TDAFW operation. The licensee stated that it intends to implement the recommendations of the revised TB to ensure integrity of the RCP seal package while avoiding concerns with TDAFW pump operation. The NRC staff intends to review the revised recommendations in the revised TB 15-1 to ensure their adequacy.

During the audit review, Dominion confirmed that RCP seal cooling will not be restored after it is lost due to the ELAP event. The NRC staff considers this practice appropriate because it prevents thermal shock, which could lead to increased seal leakage, as described in Information Notice 2005-14, "Fire Protection Findings on Loss of Seal Cooling to Westinghouse Reactor Coolant Pumps" (ADAMS Accession No. ML051080499).

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

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

The licensee stated in its FIP that, based on its analysis, RCS inventory makeup will begin with sufficient time that the reflux cooling condition will be avoided. Assuming one Westinghouse-style RCP seal per unit and only one of the two BDB RCS injection pumps is available to provide makeup to both units, the total injection rate from this pump would be more than double the RCS leak rate initially per unit (following RCS depressurization). With injection starting 16 hours into the event, this would lead to a gradual increase in margin to reflux cooling conditions. However, as time passes, the RCP seal leakage rate may increase until RCS leakage exceeds the FLEX injection capacity. The staff estimates that this could occur approximately 24 hours into the event for the above scenario (although there is considerable uncertainty in extrapolating the related test data). In this scenario, RCS inventory would gradually diminish (unless additional sources of RCS makeup could be provided, e.g., via Phase 3 equipment). Were this to persist, it would lead to a termination of natural circulation in the RCS and entry into reflux cooling. The licensee's existing analysis for the ELAP event assumes that natural circulation will be maintained in the RCS.

The licensee's plan is to provide sufficient RCS makeup during all phases of an ELAP. The NRC staff continues to work with Westinghouse, AREVA, and the PWROG to fully understand all the available test data and address remaining questions and uncertainties. The following factors are also considered as part of the assessment of this issue:

- According to the validation of its staffing plan, with augmented staffing available at 6 hours into the ELAP event, North Anna expects to have the capability to establish RCS makeup within 8 hours of event initiation (Reference 4). The NRC staff expects the licensee to initiate FLEX RCS makeup without delay when it becomes available, provided such action is consistent with the overall event response prioritization.

- The licensee's procedures direct plant personnel to deploy both BDB RCS injection pumps (one per unit), including all hoses and fittings, even though only one (shared between units) is credited in their analysis.

- Additional RCS makeup pumps will be delivered 24 hours after initial notification to the NSRC. These pumps can provide additional RCS makeup capability before the onset of reflux cooling.

- North Anna currently has only one remaining standard Westinghouse-style RCP seal at each unit. As discussed in Section 3.2.3.3, the licensee plans to replace the remaining Westinghouse-style seals with low-leakage Flowserve N-9000 seals, which will provide a significant reduction in RCS leakage and will eliminate the long-term leakage increase.

- As documented in correspondence from the licensee dated November 19, 2015 (ADAMS Accession No. ML15324A304), the likelihood that both RWSTs are unavailable following a beyond-design-basis event is minimal. The RWSTs are located approximately 450 feet apart on opposite ends of the power block and separated by the Auxiliary buildings and the containment buildings. A portion of the Auxiliary building and the entire containment buildings are tornado generated missile-protected structures and the RWST top elevations are below the top elevations of the Auxiliary buildings and containments. The RWST are further shielded on three of four sides by other structures, most of which are protected from tornado generated missiles.

- The NRC staff understands that the PWROG is addressing the issue related to the potential gradual increase in leakage from Westinghouse-style RCP seals.The licensee is expected to evaluate any new information or recommendations, consistent with the provisions in NEI 12-06, to maintain FLEX strategies up to date considering plant changes and operational experience.

The staff notes that, based on its evaluations, there is the potential for the RCS to enter reflux cooling later in the event. However, the factors listed above provide reasonable assurance that this condition can be avoided and that the licensee's strategy should meet the order requirements to maintain or restore core cooling for the beyond-design-basis ELAP event.

3.2.3.4 Shutdown Margin Analyses

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

- the cooldown of the RCS and fuel rods adds positive reactivity
- the concentration of xenon-135:
  - initially increases above its equilibrium value following reactor trip, thereby adding negative reactivity
  - peaks at roughly 12 hours post-trip and subsequently decays away gradually, thereby adding positive reactivity
- the injection of borated makeup from passive accumulators due to the depressurization of the RCS, which adds negative reactivity

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

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 NRC staff requested that the industry provide additional information to justify that borated makeup would adequately mix with the RCS volume under natural circulation conditions potentially involving two-phase flow. In response, the PWROG submitted a position paper, dated August 15, 2013 (withheld from public disclosure due to proprietary content), which provided test data regarding boric acid mixing under single-phase natural circulation conditions and outlined applicability conditions intended to ensure that boric acid addition and mixing during an ELAP event would occur under conditions similar to those for which boric acid mixing data is available. By letter dated January 8, 2014 (ADAMS Accession No. ML13276A183), the NRC staff endorsed the above position paper with three conditions:

- The required timing and quantity of borated makeup should consider conditions with no RCS leakage and with the highest applicable leakage rate.
- Adequate borated makeup should be provided either (1) prior to the RCS natural circulation flow decreasing below the flow rate corresponding to single-phase natural circulation, or (2) if provided later, then the negative

reactivity from the injected boric acid should not be credited until one hour after the flow rate in the RCS has been restored and maintained above the flow rate corresponding to single-phase natural circulation.

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

During the audit review, Dominion confirmed that North Anna will comply with the August 15, 2013, position paper on boric acid mixing, including the conditions imposed in the staff's corresponding endorsement letter.

According to the FIP, RCS makeup will be initiated no later than 16 hours following an ELAP event. Dominion's shutdown margin (SDM) analysis for North Anna determined that at least 1 percent SDM is available up to 37 hours following a reactor trip from full power with all control rods inserted; after 37 hours, additional boration is necessary to maintain subcriticality as xenon decays with the plant in a cold condition. The licensee's calculations show that approximately 4600 gallons of 2600 ppm borated water from the RWST will be adequate to meet shutdown reactivity requirements for each unit at the limiting end-of-cycle condition with core inlet temperature as low as 366°F.

As noted previously in Section 3.2.1.2, the licensee plans to deploy both BDB RCS injection pumps, but stated that one pump can provide makeup to both units. In this case, the single available pump may be used to supply borated makeup to both units, alternating every hour, using the normal charging header cross-tie lines so that the pump would not need to be repositioned. With only one available pump, according to the licensee's planned strategy, RCS injection to the first unit would need to begin by 15 hours to provide makeup to the second unit by 16 hours. Considering the 4600-gallon volume to be injected per unit to satisfy shutdown margin requirements, adequate boration could be provided to both units using a single 45-gpm BDB RCS injection pump within approximately 4 hours. The licensee stated that the RCS can accommodate the required makeup volume without venting, due to volume shrink as the plant cools down.

According to the staff's current understanding of the licensee's RCS cooldown profile and the licensee's calculations showing that adequate boration can be achieved for both units within 4 hours of initiating RCS makeup, the NRC staff expects that the RCS would remain in natural circulation flow while the quantity of boric acid required to maintain adequate shutdown margin is injected. Thus, the borated coolant injected by the FLEX RCS makeup pumps should have sufficient opportunity for mixing, such that an even distribution can be achieved throughout the RCS at a concentration that would ensure adequate shutdown margin per the PWROG position paper, as modified by the conditions specified in the NRC staff's endorsement letter.

The RWSTs at North Anna are the preferred borated water source for RCS injection; they are seismically-qualified but not fully protected from wind-borne missiles. As discussed in Section 3.2.3.3, it is highly unlikely that both RWSTs are unavailable following a beyond-design-basis event is minimal. The staff expects that the available volume of borated water in a single RWST would be capable of supplying adequate RCS makeup to both units for multiple days.

In the event that both RWSTs are unavailable or become depleted, portable BAMTs will be transported from the onsite BDB storage building and positioned near the RCS Injection pump as a back-up suction source. Dilution water will be added to the mixing tank by either a portable transfer pump, the BDB AFW pump, or from the BDB high capacity pump header taking suction from a clean water source. Bags of powdered boric acid will be mixed with dilution water to achieve the proper concentration for maintaining adequate shutdown margin while making up RCS inventory. Each tank is equipped with an agitator to facilitate mixing of the boric acid. The maximum boron concentration that will be mixed is below the level at which precipitation concerns occur, even at temperatures down to 32°F; however, a heater is also available to prevent tank freezing, if necessary.

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

Section 11.2 of NEI 12-06 states that design requirements and supporting analysis should be developed for portable equipment that directly performs a FLEX mitigation strategy for core cooling, containment, and SFP cooling that provides the inputs, assumptions, and documented analysis that the mitigation strategy and support equipment will perform as intended. Section 2.3.10 of North Anna's FIP describes the hydraulic performance criteria (e.g., flow rate, discharge pressure) for its FLEX Phase 2 portable pumps. The performance criteria for the FLEX Phase 2 portable pumps is met or exceeded by the FLEX Phase 3 portable pump performance data, indicating that the pumps from the NSRC can substitute for the onsite Phase 2 pumps if necessary. During the audit review, Dominion provided FLEX hydraulic calculations (CALC-ME-0965, "Evaluate the BDB High Head Injection Pump for Beyond-Design-Basis (BDB) at the Primary and Alternate Supply Locations in Modes 1-4, and the BDB AFW Pump in Modes 5 and 6", Rev. 0 and CALC-ME-0966, Beyond Design Basis (BDB)-BDB High Capacity Pump and BDB AFW Pump Hydraulic Analysis for Spent Fuel Pool Makeup and AFW Injection at NAPS Units 1 and 2, Rev. 0), which demonstrate that the FLEX Phase 2 portable pumps identified in its revised OIP are capable of providing sufficient make-up to the SGs, RCS, and refilling the ECST. Calculation CALC-ME-0966 utilized Applied Flow Technology Fathom computer software to create an as-built hydraulic model which incorporated the FLEX strategies contained in its revised OIP and the purchased valve datasheets and pump curves for each FLEX valve and pump. Calculation CALC-ME-0965 employed hand calculations to verify that the BDB RCS Injection pump and BDB AFW pumps can provide the requisite flow, taking into account anticipated head losses. In addition, the calculations relied upon piping isometrics, FLEX valves and connections, and hose lengths and diameters (suction and discharge) to ensure the FLEX pumps can support each FLEX safety function. Dominion's calculations evaluated several different flow configurations to show that flow rates provided by the FLEX Phase 2 portable pumps meet or exceed the required flow rates for each of the FLEX safety functions. Based on the staff's review of the FLEX pumping capabilities at NAPS, as described in CALC-ME-0965, CALC-ME-0966, and North Anna's FIP, Dominion has demonstrated that its FLEX portable pumps should perform as intended to support core cooling, containment and SFP cooling during and ELAP caused by a BDBEE, consistent with NEI 12-06, Section 11.2.

Note: The available water sources for Phase 2 and 3 FLEX portable pumps are discussed in Section 3.10 of this SE.

Based on its review, the NRC staff concludes that, if implementation is performed as described, the licensee has demonstrated that its FLEX portable pumps are capable of supporting the water make-up to the SGs, RCS, and refilling the CST.

3.2.3.6 Electrical Analyses

The licensee's OIP and FIP define strategies capable of mitigating a simultaneous loss of all alternating current (ac) power and loss of normal access to the ultimate heat sink (LUHS) resulting from a BDBEE by providing the capability to maintain or restore core cooling (the licensee's strategy for RCS inventory control uses the same electrical strategy as for maintaining or restoring core cooling, containment, and SFP cooling) at all units on the North Anna site. Furthermore, the electrical coping strategies are the same for all modes of operation.

The NRC staff reviewed the licensee's OIP and FIP to determine whether the FLEX strategies, if implemented appropriately, should maintain or restore core cooling, containment, and spent fuel pool cooling following a BDBEE. As part of its review, the NRC staff reviewed conceptual electrical single-line diagrams, summaries of results and conclusion of calculations for sizing the FLEX diesel and turbine generators and station batteries, and summaries of calculations that addressed the effects of temperature on the electrical equipment credited in the OIP and FIP as a result of losing heating, ventilation, and air conditioning (HVAC) during an extended loss of ac power (ELAP) as a result of a BDBEE. According to the licensee's OIP and FIP, ELAP entry conditions can be verified by control room staff. As stated in the FIP, a transition to ECA-0.0, "Loss of All AC Power," will be made upon the diagnosis of the total loss of ac power. This step is time sensitive and must occur within 1 hour following the start of the ELAP event. This procedure directs isolation of RCS letdown pathways, verification of containment isolation, reduction of dc loads on the station Class 1E batteries, and establishes electrical equipment alignment in preparation for eventual power restoration. The operators re-align AFW flow to all steam generators, establish manual control of the SG PORVs, and initiate a rapid cool down of the RCS to minimize inventory loss through the RCP seals.

While the licensee's OIP and FIP identify specific strategies, due to the inability to anticipate all possible scenarios, the strategies are also diverse and flexible to encompass a wide range of possible conditions. According to the licensee, their OIP/FIP strategies have been incorporated into the site emergency operating procedures (EOPs) in accordance with established EOP change processes and their impact to the design-basis capabilities of the units evaluated under 10 CFR 50.59.

The NRC staff discussed the electrical portion of the NAPS mitigation strategy for an ELAP event with the licensee's staff and performed a walk-down of the licensee's OIP strategies during an onsite audit that was conducted May 19-22, 2014. The walk down focused on the areas where the electrical equipment will be stored, deployed, and operated; the connection points to the electrical distribution system; battery load shedding; and the cable runs from the staged and deployed FLEX diesel and turbine generators. The report that documents the result of the onsite audit was issued September 24, 2014 (ADAMS Accession No. ML14259A458).

As a part of ELAP mitigating strategy, the licensee plans to store 120/240 Vac Diesel Generators, 480 Vac Diesel Generators, cables, electrical connectors, switchgear, FLEX Pumps, hoses, etc. in the BDB storage building. The BDB storage building is designed as robust and protected from all applicable external hazards. See Section 3.6 of this evaluation for more detail.

North Anna's Phase 1 FLEX strategy involves relying on installed plant equipment and onsite resources, such as use of installed Class 1E station batteries, vital inverters, and the Class 1E dc electrical distribution system. This equipment is considered robust and protected with respect to applicable site external hazards. The dc power from the station batteries will be needed in an ELAP for loads such as shutdown system instrumentation, control systems, and dc-powered AOVs and MOVs. Procedure FSG–4, "ELAP DC Bus Load Shed and Management," Rev. 0, directs operators to conserve dc power during the event by stripping non-essential loads. The stripping, or load shedding, would begin within 1 hour after the occurrence of an ELAP/LUHS event and is expected to be completed within the next 30 minutes. The licensee noted and the staff confirmed that the useable station battery capacity can be extended up to 8 hours by load stripping non-essential loads for each unit.

During the onsite audit, the staff reviewed the summary of results and conclusion of the licensee's dc system analysis (Calculation EE-0009, "125 VDC System Analysis," Rev. 1, and ETE-CPR-2012-0012, "Beyond Design Basis – Flex Strategy Overall Integrated Plan Basis Document," Rev. 3) to verify the capability of the dc system to supply the required loads during the first phase of the North Anna FLEX mitigation strategies plan for an ELAP as a result of a BDBEE. The licensee's analysis identified the required loads and their associated ratings (amperage and minimum voltage) and non-essential loads that would be shed to ensure battery operation for at least 8 hours (power is expected to be restored to the vital 120 Vac buses by this time). Based on its review of FSG–4, "ELAP DC Bus Load Shed and Management," Rev. 0, and "125 Vdc System Analysis," Rev. 1, the NRC staff finds that the North Anna, Unit 1 and Unit 2 dc systems have adequate capacity and capability to power the loads required to mitigate the consequences during Phase 1 of an ELAP as a result of a BDBEE provided that necessary load shedding is completed within the times assumed in the licensee's analysis.

North Anna's Phase 2 strategy involves transitioning from installed plant equipment to the on-site FLEX equipment. The NAPS on-site electrical FLEX equipment includes three FLEX 120/240 Vac, 40 kilowatt (kW) portable diesel generators (DG) (for the primary electrical strategy), associated cables, electrical connectors, switchgear and two 480 Vac, 350 kW DGs (for the alternate electrical strategy), associated FLEX cables, connectors and switchgear. One FLEX 120/240 Vac DG will be deployed and operated in the alleyway east of the Unit 1 Auxiliary building and one FLEX 120/240 Vac DG will be deployed and operated in the alleyway west of the Unit 2 Auxiliary building within 5 hours after the ELAP initiation. These FLEX 120/240 Vac DGs will re-power each unit's vital 120 Vac buses within 6 hours to power required instruments. The 480 Vac DGs are available as an alternate power supply source if the 120/240 Vac DGs are not available.

The 120/240 Vac DGs each have two output circuits and each circuit includes an adjustable output breaker, weatherproof receptacle, and flexible and weatherproof cable with weatherproof connectors at both ends, which connects to a receptacle panel located in the associated unit's rod drive room. The connecting cables for both units are pre-staged in the hydrogen recombiner control panel vault and are, therefore, protected from the BDBEE hazards. If needed, the 480 Vac DGs will be deployed adjacent to the deployment locations of the 120/240 Vac DGs. The 480 Vac DGs each have a set of color coded cables which will be connected with proper phase rotation to the color coded mating receptacles in the receptacle panel located in the rod drive room. In addition to color coding, a phase rotation meter is provided in the receptacle panel for each 480 Vac circuit. The protection for the 480 Vac DG connections are the same as for the primary connections with the exception that the 480 Vac DG cables are stored in the BDB storage building with the generator and are also protected from site applicable BDBEE hazards.

The 480 Vac FLEX DGs will provide charging current to the 125 Vdc Vital Batteries and ensure that 125 Vdc vital battery power (control) and the 120 Vac Vital Instrument Power (instrument indication) remain available.

Based on its review of Calculation EE-0863, "Calculation for North Anna Power Station Beyond Design Basis – FLEX Electrical 480 Vac and 120 Vac System Loading Analysis for NAPS BDB FLEX DC NA-13-01017," Rev. 1 and Rev. 2, and Calculation EE-0865, "Calculation for North Anna Power Station Beyond Design Basis – FLEX Electrical 480 Vac and 120 Vac System Loading Analysis for NAPS BDB FLEX DC NA-13-01018," Rev. 0, conceptual single line electrical diagrams, station procedures, and interactions with the licensee's staff, the NRC staff finds that the licensee's approach is acceptable given the storage and staging locations of the FLEX DGs, the protection and diversity of the power supply pathways, the separation and isolation of the DGs from the Class 1E emergency diesel generators, and availability of procedures to direct operators how to align, connect, and protect associated systems and components. The NRC staff also finds that the station batteries and FLEX DGs have sufficient capacity and capability to supply the necessary loads following a BDBEE.

For Phase 3, North Anna plans to continue the Phase 2 coping strategy with additional assistance provided from offsite equipment/resources.

The offsite resources that will be provided by the NSRCs includes two 1-MW 4160 Vac turbine generators and a distribution panel (including cables and connectors) per unit. One of the two Class 1E 4160 Vac buses is required for each unit to repower the containment cooling. The staff reviewed a summary of results and conclusion of the calculation EE-0871, "Calculation for North Anna Power Station Beyond Design Basis – FLEX Electrical 4160 Vac System Loading Analysis," Rev. 0. The components necessary to implement the various containment cooling options and for continuation of the Phase 2 coping strategy have been included in the calculations to support the sizing of the 4160 Vac turbine generators. Based on its review, the NRC staff finds that the 4160 Vac equipment being supplied from the NSRCs will provide adequate power to enable North Anna to maintain or restore core cooling, spent fuel pool cooling, and containment indefinitely following a BDBEE.

3.2.4 Conclusions

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

3.3 Spent Fuel Pool Cooling Strategies

In NEI 12-06, Section 3.2.1.1 states that for PWRs, the requirement is to keep fuel in SFP covered. In NEI 12-06, Table 3-2 and Appendix D summarize one acceptable approach for the SFP cooling strategies. This approach uses a portable injection source to provide the capability for (1) makeup via hoses on the refueling floor capable of exceeding the boil-off rate for the design basis heat load; (2) makeup via connection to SFP cooling piping or other alternate location capable of exceeding the boil-off rate for the design basis heat load; and (3) spray via portable monitor nozzles from the refueling floor using a portable pump capable of providing a minimum of 200 gallons per minute (gpm) per unit (250 gpm to account for overspray). In conjunction with the SFP cooling strategies, each site should provide a strategy to establish a vent pathway to remove steam and condensate from the SFP area.

As described in NEI 12-06, Section 3.2.1.7 and JLD-ISG-2012-01, Section 2.1, strategies that have a time constraint to be successful should be identified and a basis provided that the time can be reasonably met. 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 ELAP may be the result of a BDBEE, 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.

Section 2.4 of North Anna's FIP states that the NAPS SFP is a common pool designed for both Unit 1 and Unit 2. The basic FLEX strategy for maintaining SFP cooling is to monitor SFP level and provide sufficient makeup water to the SFP to maintain the normal SFP level. The sections below describe the proposed strategies for each phase of mitigating the effects of a loss of SFP cooling during an ELAP for full power operations. The effects of a BDBEE with full core offload to the SFP will be addressed in Section 3.11.

3.3.1 Phase 1

As described in Section 2.4.1 of its FIP, Dominion's evaluations estimate that, with no operator action, following a loss of SFP cooling at the maximum design heat load, the SFP will reach 212°F in approximately 9 hours and boil off to a level 10 feet above the top of fuel in 43 hours from initiation of the event. The Phase 1 coping strategy for SFP cooling is to monitor SFP level using instrumentation installed as required by NRC Order EA-12-051. In addition, Dominion will establish a ventilation path whereby natural circulation will remove steam from the SFP area in order to inhibit the formation and buildup of condensation.

3.3.2 Phase 2

As described in Section 2.4.2 of North Anna's FIP, and Section E.2 of Dominion's OIP, transition from Phase 1 to Phase 2 requires initiation of SFP makeup using either the BDB high capacity pump through the BDB SFP makeup connection, the existing fire protection (FP) system, or directly to the SFP via hoses. The BDB high capacity pump is a towable, trailer mounted pump located in the BDB storage building. Vehicles capable of towing the pump and associated hoses and fitting are located within the protected BDB storage building. Licensee personnel will deploy the BDB high capacity pump, with its associated hoses and fittings, from the BDB storage building to an area near one of several available draft points. Licensee personnel would then connect this pump to the permanent, seismically designed external SFP makeup connection installed outside the fuel building. The FLEX strategy will support connection to the new permanent plant fitting using hoses and fittings to provide SFP makeup capabilities up to 500 gpm, which exceeds the boil off rate of 101 gpm. This connection and makeup strategy does not require entry into the fuel building.

As a secondary FLEX capability, the licensee can utilize the diesel-driven fire pump to pressurize the fire main which provides makeup to the SFP via the 6" emergency makeup line. This makeup strategy does not require entry into the fuel building or the deployment of pumps or hoses.

If necessary, the licensee has the capability to makeup to the SFP via hose directly into the SFP or via hose connected to a spray nozzle. The strategy provides makeup flow through either hose run over the side of the SFP or spray monitors set up on the SFP deck fed by the fire main or the BDB high capacity pump. When deployed, two spray monitors are connected via a wye that splits the pump supply into two 3-inch hoses. The two 3-inch spray monitor hoses will be routed from the new-fuel storage area to the SFP. The two oscillating spray monitors will be set up 30 feet apart and 16 feet back from the SFP to spray water into the SFP to maintain water level. Each method has the ability to supply 500 gpm of water to the pool, which exceeds the boil off rate of 101 gpm. The licensee concluded that the ability to deploy hoses and equipment for this strategy will not be hindered by environmental and radiological conditions in the fuel building (Reference 5).

3.3.3 Phase 3

Dominion indicated that the strategies described for Phase 2 SFP cooling can continue as long as there is sufficient inventory available. In addition, Dominion stated in Section 2.4.3 of its FIP that additional low pressure/high flow pumps will be available from the NSRC as a backup to the onsite BDB high capacity pumps.

3.3.4 Staff Evaluations

3.3.4.1 Availability of Structures, Systems, and Components

The baseline assumptions established in NEI 12-06 presume 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, in general, assumed to be fully available. Installed equipment that is not robust is, in general, assumed to be unavailable. Below are the baseline assumptions for the availability of SSCs for SFP cooling at NAPS during an ELAP.

3.3.4.1.1 <u>Plant SSCs</u>

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

As described in Section 2.4.4 of North Anna's FIP, NAPS relies on part of the FP system to supply water to the SFP via the SFP emergency makeup line. The strategy utilizes the FP pump and fire main piping which feeds the emergency SFP makeup line. As described in the NAPS UFSAR Table 3.2.1, the DDFP is a seismic Category I component located inside the service water pump house, which is a seismic Category I and tornado missile-protected structure. In addition, as stated in North Anna's FIP, the fire protection piping from the DDFP to the cross-tie to the SFP emergency piping is seismically-qualified, buried piping (i.e., protected from tornado generated missiles). The SFP makeup line is located within the fuel building, a Seismic Class 1, tornado missile-protected structure (NAPS UFSAR, Table 3.2-1). The emergency SFP makeup line extends above the SFP so that water can discharge directly into the pool. Based on the location and design of the DDFP and associated piping, and the SFP emergency makeup line as described in the FIP and NAPS UFSAR, the DDFP and associated piping, and SFP makeup line should be available to support SFP cooling during an ELAP/LUHS condition caused by a BDBEE, consistent with NEI 12-06, Section 3.2.1.3, Condition 6, and Section 3.2.1.6.

Primary and Alternate Connections

Section 3.2.2 of NEI 12-06 states that portable fluid connections for core and SFP cooling functions are expected to have a primary and an alternate connection or delivery point (e.g., the primary means to put water into the SFP may be to run a hose over the edge of the pool) and that at a minimum, the primary connection point should be an installed connection suitable for both the on-site and off-site equipment while the secondary connection point may require reconfiguration if it can be shown that adequate time and resources are available to support the reconfiguration. In addition, Section 3.2.2 states that both the primary and alternate connection points do not need to be available for all applicable hazards, but the location of the connection points should provide reasonable assurance that one connection will be available.

Section 2.4.4.1 of North Anna's FIP, states that the primary connection for SFP makeup will be a hose connection on the permanent, seismically designed BDB SFP makeup connection line located on the outside wall of the fuel building. The new BDB SFP makeup connection line is a 4-inch line that tees into the existing 6-inch emergency SFP makeup line. The existing line runs vertically along the south inside (concrete) wall of the fuel building between the 265-foot and the 270-foot elevations. The new seismically supported 4-inch line is routed from the new tee along and through the south inside wall to the exterior connection location. The new connection is supported from the outside wall of the fuel building at the 274-foot elevation near the Unit 1 containment above the vicinity where the buried emergency SFP makeup header from the FP system enters the fuel building at elevation 265-foot. A new check valve is installed inside the fuel building in the 6-inch line upstream of the tee to prevent back flow through the FP piping from the connection. A check valve in the new 4-inch line inside the fuel building will prevent flow out of the new connection line in the event that the existing emergency SFP makeup connection is in use (supplied from the FP header). The new connection is a standard fire hose connection and is located outside the fuel building at approximately the 274-foot elevation. Use of the primary BDB SFP makeup connection will not require entry into the fuel building.

The alternate Phase 2 strategy for providing makeup water to the SFP is to use the FP system and SFP emergency makeup line, which is existing plant equipment and does not require any additional connection points. An additional alternate strategy utilizes a portable hose directly into the SFP or connected to a spray monitor to achieve SFP cooling. Licensee personnel will run a hose from the fire main or the discharge of the BDB high capacity pump, through the fuel building door, and up to the SFP operating deck. From there, the hose may be run directly over the side of the pool or to portable spray monitors. When deployed, the two spray monitors will be connected via a wye that splits the pump discharge into two hoses. The two spray monitor hoses will be routed from the new fuel storage area to the SFP. The oscillating spray monitors will be set up approximately 30 feet apart and 16 feet back from the SFP. These spray monitors will spray water into the SFP to ensure cooling of the fuel assemblies.

Based on the location and design of the primary and alternate connections for SFP makeup, as described in the FIP and NAPS UFSAR, at least one connection should be available to support SFP cooling during an ELAP caused by a BDBEE, consistent with Section 3.2.2 of NEI 12-06.

Ventilation

Ventilation requirements to prevent excessive steam accumulation in the fuel building are included in an existing site abnormal procedure (AP). The AP directs operators to open several rollup doors in the fuel building to establish a natural circulation flowpath. Airflow through these doors provides adequate vent pathways through which steam generated by SFP boiling can exit the fuel building. The BDB FLEX Support Guidelines (FSGs) implement this method of ventilation for the fuel building.

Specifically, Attachment 2 of 0-FSG-5, "Initial Assessment and FLEX Equipment Staging," Rev. 0, identifies six doors which are to be opened to minimize steam build-up and condensation in the Fuel Handling Building. Although the procedure does not direct opening of these doors within a specific time constraint, as a part of the audit process the licensee provided calculation MISC-11792, "Extended Loss of AC Power, Spent Fuel Pool Heatup Times and Makeup Water for Dominion Nuclear Units," Rev. 0, which conservatively concluded that the SFP would not begin to boil for at least 9 hours following an ELAP-initiating event. Furthermore, the calculation concluded that the level in the SFP would not be less than 10 feet above the fuel racks for 43 hours following an ELAP-initiating event.

As stated in the "Primary and Alternate Connection" section above, and in the licensee's procedure, 0-FSG-11, "Alternate SFP Makeup and Cooling," Rev. 0, the preferred method of makeup to the SFP is through a hose connection external to the Fuel Handling Building, which then connects into permanently installed, seismically robust plant piping. In the event that one of the alternate methods that require manual actions in the vicinity of the SFP is needed in response to an ELAP, the licensee stated during the audit process that even under the most severe conditions without any credit for ventilation of the fuel handling building, a worker would have to be exposed to 69 continuous hours of an atmosphere postulated to have an instantaneous and complete release of all Xe-133 and I-131 from a full core offload before reaching a radiation exposure limit. Additionally, the licensee stated that self-contained breathing apparatus (SCBA) equipment would be available for the subject worker, if necessary.

Based on the administrative controls to establish ventilation in the fuel handling building before bulk boiling occurs, the relatively long time before the SFP level would approach the top of the fuel racks, the higher prioritization of the strategies, which do not require entry into the SFP area, and the availability of personal protective equipment if manual actions are needed, the proposed ventilation strategy should be sufficient to facilitate the maintenance of SFP cooling following an ELAP-initiating event.

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 480 V FLEX DGs. The NRC staff's review of the SFP level instrumentation, including the primary and back-up channels, the display to monitor the SFP water level and environmental qualifications to operate reliably for an extended period are discussed in Section 4 of this SE.

3.3.4.2 Thermal-Hydraulic Analyses

Section 11.2 of NEI 12-06 states, in part, that design requirements and supporting analysis should be developed for portable equipment that directly performs a FLEX mitigation strategy for core cooling, containment, and SFP cooling that provides the inputs, assumptions, and documented analysis that the mitigation strategy and support equipment will perform as intended. In addition, NEI 12-06, Section 3.2.1.6, Condition 4 states that SFP heat load assumes the maximum design-basis heat load for the site. In accordance with NEI 12-06, Dominion performed a thermal-hydraulic analysis of the SFP as a basis for the inputs and assumption used in its FLEX equipment design requirements analysis.

In Section 2.4.6 of its FIP, Dominion states that with the maximum expected SFP heat load immediately following a core offload, the SFP will reach a bulk boiling temperature of 212°F in approximately 9 hours and boil off to a level 10 feet above the top of fuel in 43 hours unless additional water is supplied to the SFP. Under these conditions, a flow rate of 101 gpm will replenish the water lost due to boiling. During the audit process, Dominion provided calculation MISC-11792, "Extended Loss of AC Power, Spent Fuel Pool Heatup Times and Water Makeup for Dominion Units," Rev. 0, which details the assumptions used to determine the heatup and boil off rates. According to the assumptions of calculation MISC-11792, the NAPS SFP temperature initially is 100°F. Using the most limiting SFP heat load of 53.1x10E6 BTU/hr (NAPS UFSAR, Rev. 48.02, pg 9.1-10), Dominion calculated the amount of time required to reach bulk boiling conditions in the SFP (i.e., 212°F), the amount of time until the water level would reach 10 feet above the fuel, and the associated volumetric flow rate of makeup water needed to maintain SFP level.

Based on the information contained in North Anna's FIP, calculation MISC-11792, and the NAPS UFSAR (via an analysis that considered maximum design-basis values, SFP heat load during operating, and pre-fuel transfer or post-fuel transfer operations), the staff finds that Dominion has provided a basis for assumptions and inputs used in determining the design requirements for FLEX equipment used in SFP cooling that are consistent with NEI 12-06, Section 3.2.1.6, Condition 4, and Section 11.2.

3.3.4.3 FLEX Pumps

Section 11.2 of NEI 12-06 states that design requirements and supporting analysis should be developed for portable equipment that directly performs a FLEX mitigation strategy for core cooling, containment, and SFP cooling that provides the inputs, assumptions, and documented analysis that the mitigation strategy and support equipment will perform as intended. Section 2.4.7.1 of North Anna's FIP describes the hydraulic performance criteria (e.g., flow rate, discharge pressure) for its FLEX Phase 2 portable pumps. The performance criteria for the FLEX Phase 2 portable pumps is met or exceeded by the FLEX Phase 3 portable pump performance data, indicating that the pumps from the NSRC can substitute for the onsite Phase 2 pumps if necessary. During the audit review, Dominion provided the FLEX hydraulic calculation CALC-ME-0966, "Beyond Design Basis (BDB)-BDB High Capacity Pump and BDB AFW Pump Hydraulic Analysis for Spent Fuel Pool Makeup and AFW Injection at NAPS Units 1 and 2," Rev. 0, which concluded that the FLEX Phase 2 portable pumps identified in its revised OIP are capable of providing sufficient make-up to SFP.

Calculation CALC-ME-0966 utilized Applied Flow Technology (AFT) Fathom computer software to create an as-built hydraulic model which incorporated the FLEX strategies contained in its revised OIP and the purchased valve datasheets and pump curves for each FLEX valve and pump. In addition, the calculations relied upon piping isometrics, FLEX valves and connections, and hose lengths and diameters (suction and discharge) to ensure the FLEX pumps can support each FLEX safety function. Dominion's calculations evaluated several different flow configurations to show that flow rates provided by the FLEX Phase 2 portable pumps meet or exceed the required flow rates for each of the FLEX safety functions. Based on the staff's review of the FLEX pumping capabilities at NAPS, Dominion has demonstrated that its FLEX portable pumps, if aligned and operated as described in CALC-ME-0966 and North Anna's FIP, should perform as intended to support SFP cooling during an ELAP caused by a BDBEE, consistent with NEI 12-06, Section 11.2.

3.3.4.4 Electrical Analyses

The licensee's OIP and FIP define strategies capable of mitigating a simultaneous loss of all ac power and LUHS, resulting from a BDBEE, by providing the capability to maintain or restore core cooling (the licensee's strategy for RCS inventory control uses the same electrical strategy as for maintaining or restoring core cooling, containment, and spent fuel pool cooling) at all units on the North Anna site. Furthermore, the electrical coping strategies are the same for all modes of operation.

The staff performed a comprehensive analysis of the licensee's electrical strategies, which includes the spent fuel pool cooling strategy. The staff's review is discussed in detail in Section 3.2.3.6.

3.3.5 Conclusions

Based on this evaluation, the NRC staff concludes that the licensee has developed strategies, guidance, and supporting evaluations that, if implemented appropriately, should maintain or restore SFP cooling during an ELAP following a BDBEE, consistent with the guidance in NEI 12-06, as endorsed by JLD-ISG-2012-01.

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/LUHS event. One such approach is for a licensee to perform an analysis demonstrating that containment pressure control is not challenged.

In accordance with this approach, the licensee performed a containment evaluation, MISC-11793, "Evaluation of Long Term Containment Pressure and Temperature Profiles Following Extended Loss of AC Power (ELAP)," Rev. 0, which was based on the boundary conditions described in Section 2 of NEI 12-06. The calculation concludes that, even with the licensee taking no mitigating actions related to removing heat from the primary containment following an ELAP-initiating event, the containment parameters of pressure and temperature remain well below the respective UFSAR Section 6.2.1.2 design limits of 45 psig and 280°F for more than 7 days. Specifically, the containment peak pressure at the end of the analyzed 7-day period is approximately 8 psig and the temperature rises to a maximum of approximately 185°F.

3.4.1 Phase 1

As stated on page 30 of the licensee's FIP, 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 at least one train of control room indication of containment wide range pressure and temperature will be available for the duration of the ELAP.

3.4.2 Phase 2

Pages 30 and 31 of the licensee's FIP state that continued monitoring of containment temperature and pressure necessitates using FLEX DGs to repower the station's 120 Vac vital buses because the station Class 1E batteries are calculated to be depleted 8 hours after an ELAP-initiating event. Action Item 13 on page 76 of the licensee's FIP shows that the FLEX DGs should be aligned and providing power to the 120 Vac vital buses approximately 6 hours after the ELAP-initiating event; thus, the ability to monitor the subject containment parameters is not expected to be lost.

3.4.3 Phase 3

Although the MISC-11793 analysis shows that, even without any active heat removal strategies from the primary containment, the parameters of temperature and pressure remain well below their design limits for a minimum of seven days, eventually equipment will be required to restore cooling to the containment. Action Item 23 on page 78 of the licensee's FIP directs the operations staff to restore containment temperature to less than 120°F within 7 days to prevent affecting the function of key parameter monitoring instrumentation. As such, the licensee has developed primary and alternate strategies to utilize the NSRC equipment to remove heat from containment.

The licensee's FIP states that the preferred method for containment heat removal is to restore 4160 Vac power to normal plant ventilation equipment. This capability will be provided by two, 1-MW 4160 Vac portable generators per unit from the NSRC. The portable 4160 Vac generators and a distribution panel for each unit will be brought in to supply power to either of the two Class 1E 4160 Vac buses on each unit. Additionally, by restoring the Class 1E 4160 Vac bus, power can be restored to the Class 1E 480 Vac buses via the 4160/480 Vac transformers to power selected 480 Vac loads.

The 4160 Vac generators from the NSRC will be aligned to provide power to the existing component cooling (CC) water system and the service water (SW) pumps (if available), an instrument air (IA) system compressor, and either the containment air recirculation fans (CARFs) or the control rod drive mechanism (CRDM) fan motors. If the SW pumps are not available, then low pressure/high flow diesel driven pumps from the NSRC will be available to provide flow to existing site heat exchangers to facilitate heat removal from the containment atmosphere.

As an alternative, the licensee's FIP states that the containment recirculation spray (RS) system pump motors could be powered by the NSRC 4160 Vac generators through the Class 1E 4160 Vac and 480 Vac buses on each unit. The containment sump must be filled with water to provide a suction source for the RS pumps, and the licensee identified several diverse potential water sources which, although not protected from all hazards, could be used to provide a sufficient sump inventory to accommodate spraying the containment. As the sprayed water collects in the containment sump, it will be recirculated through the RS heat exchangers which are typically cooled by the SW system. Similar to the method described above, if the SW pumps are available, they will be used to establish flow through the cooling side of the RS heat exchangers. In the event that the SW pumps are unavailable, cooling water flow will be provided by the low pressure/high flow diesel driven pumps from the NSRC.

3.4.4 Staff Evaluations

3.4.4.1 Availability of Structures, Systems, and Components

3.4.4.1.1 Plant SSCs

Sections 3.8.2 and 6.2.1.2 of North Anna's UFSAR state that the containment structure is a steel-lined, heavily reinforced concrete structure with a vertical cylindrical wall and hemispherical dome. It is supported on a flat base mat and is designed to withstand an internal pressure of 45 psig and temperature of 280°F. Table 3.2-1 of the UFSAR shows that the containment structure is a Seismic Category 1 structure which has been designed to resist the seismic forces of the design-basis earthquake. During normal plant operation, the containment is maintained at a sub-atmospheric pressure.

Note 'e' of UFSAR Table 6.2-2 states that the containment net free volume in the design-basis GOTHIC evaluation is 1.825 million cubic feet, and the addition of mass and energy to the containment atmosphere during an ELAP event is driven by the assumed leakage rate of 64 gpm from the RCP seals (see Section 3.4.4.2 for details). 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 to remove heat from the primary containment being taken, the containment parameters of pressure and temperature remain well below the respective design limits of 45 psig and 280°F for more than 7 days. The containment pressure at the end of the analyzed 7-day period is approximately 8 psig and the temperature rises to a maximum of approximately 185°F. Nonetheless, measures to remove heat from containment will eventually need to be taken, so the licensee has developed the strategies described in Section 3.4.3 above to utilize NSRC and installed equipment and provide this function.

Section 9.4.9 of the UFSAR states that the containment air recirculation system, which is used to cool the containment atmosphere during normal plant operation, has no engineered safety feature (ESF) functions. However, the system is equal to safety grade systems with respect to power supplies and cooling water (capable of being aligned to service water). The CARFs and associated motors are non-safety-related with special regulatory significance (NSQ). Each air cooler has its own seismic Category I cooling water supply and return lines penetrating the containment boundary. The containment isolation valves in the individual cooling water supply and return lines are safety grade and the cooling (SW) system piping is seismic category I design.

Section 6.2.2.1 of the UFSAR states that the CRDM cooling system also does not provide an ESF function. However, the licensee states in their FIP that restoration of the CRDM fan cooling involves essentially the same steps as the restoration of the CARF cooling capability.

Section 6.2.2 of the UFSAR describes the recirculation spray subsystem of the containment depressurization system. The entire containment depressurization system is an ESF system, and Section 6.2.2.1 specifically states the containment depressurization system is designed, fabricated, inspected, and installed to prevent and/or mitigate the consequences of accidents that could affect the public health and safety.

Given the above UFSAR information, and the amount of time before active containment heat removal is expected to be needed, there is reasonable assurance that at least one of the systems the licensee has identified will be available to support the strategy.

3.4.4.1.2 Plant Instrumentation

Table 3-2 of NEI 12-06, Rev. 0, states that the key containment response parameter to be monitored following an ELAP-initiating event is containment pressure. Page 34 of the licensee's FIP states that instrumentation providing containment pressure indication (Trains A and B) and containment wide range temperature indication (Train A only) will be available in the MCR throughout all Phases of the ELAP event.

Additionally, if the recirculation spray strategy is needed in Phase 3 to provide containment heat removal, the FIP states that containment sump level indication will be available in the MCR (Train B only) to support implementation.

3.4.4.2 Thermal-Hydraulic Analyses

During the audit process, the licensee provided the staff access to calculation MISC-11793, "Evaluation of Long Term Containment Pressure and Temperature Profiles Following Extended Loss of AC Power (ELAP)," Rev. 0, which was based on the boundary conditions described in

Section 2 of NEI 12-06. In this calculation, the licensee utilized the GOTHIC 7.2a code to model the containment response to an ELAP.

The GOTHIC model utilized mass and energy release rates taken from the PWROG Generic Evaluation Letter, LTR-LIS-11-657, "Transmittal of Mass and Energy Release Data for Westinghouse Designed NSSS to Support PWROG PA-ASC-0916 – Task 1 Station Blackout (SBO) Coping Study." The representative model utilized in the generic evaluation was a Westinghouse Standard 4-loop design. However, North Anna is a 3-loop plant; thus, the break mass and energy flow rates were multiplied by a factor of 0.75 to compensate.

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. In the PWROG generic evaluation, the RCP seals were assumed to leak at a rate of 21 gpm per pump. Additionally, 1 gpm of unidentified leakage at normal operating pressure was also assumed. The only heat removal mechanisms credited in the GOTHIC analysis were the passive heat sinks and the ambient heat loss from the containment structure to the outside atmosphere. Although 21 gpm is no longer considered by NRC staff to be a valid assumption for the leak rate of a Westinghouse RCP seal during an ELAP, two of three RCPs for each unit at North Anna have been fitted with low-leakage Flowserve N9000 seals, with a controlled bleedoff rate of 2.5 gpm per seal for the first several days of the ELAP event. Therefore, the assumptions of this PWROG generic evaluation are conservative with respect to the impact of RCP seal leakage on the containment atmosphere.

Using the input described above, the containment pressure and temperature parameters were calculated to be approximately 8 psig and 185°F, respectively, at the end of the 7-day analyzed period. As previously stated, the UFSAR limits are 45 psig and 280°F, so the licensee has adequately demonstrated that there is significant margin before a limit would be reached.

3.4.4.3 <u>FLEX Pumps and Water Supplies</u>

Although not needed for a minimum of 7 days, the North Anna long-term strategy for removing containment heat is to utilize offsite equipment to restore the CARFs, CRDM fans, or the RS system. The licensee's FIP states that the NSRC is providing a low pressure/high flow pump (nominal 5,000 gpm), which will be used as required to provide cooling loads to the SW system. A low pressure/medium flow (nominal 2,500 gpm) pump is also available from the NSRC, if needed. The licensee has also identified several water supplies in its FIP, with Lake Anna listed as the ultimate heat sink.

In the NAPS UFSAR, Section 9.2.1.2.1 states that one SW pump is normally used to supply water to one SW loop at a nominal rate of 11,500gpm. While the NSRC pump nominal capacity is roughly half of the nominal capacity of the SW pump, the number of heat load demands on the SW loop 7 days following an ELAP should be greatly reduced. By isolating non-essential equipment from the SW loop, the NSRC equipment should be sufficient to provide the necessary cooling flow to support containment heat removal.

3.4.4.4 <u>Electrical Analyses</u>

The licensee performed a containment evaluation analysis based on the boundary conditions described in Section 2 of NEI 12-06. Based on the results of this analysis, the licensee developed required actions to ensure maintenance of containment integrity and required instrumentation function. With an ELAP initiated, while either North Anna unit is in Modes 1-4, containment cooling for that unit is also lost for an extended period of time. Therefore, containment temperature and pressure will slowly increase. Structural integrity of the reactor containment building due to increasing containment pressure will not be challenged during the first several weeks of a BDB ELAP/LUHS event. However, with no cooling in the containment, temperatures in the containment are expected to rise and could reach a point where continued reliable operation of key instrumentation might be challenged. Conservative evaluations have concluded that containment temperature and pressure will remain below containment design limits and that key parameter instruments subject to the containment environment will remain functional for a minimum of seven days. Therefore, actions to reduce containment temperature and pressure and to ensure continued functionality of the key parameters will not be required immediately.

To reduce containment temperature and ensure continued functionality of the key parameters, the licensee will utilize existing plant systems that will be powered by offsite equipment during Phase 3. This capability will be provided by two 1 MW, 4160 Vac turbine generators and a distribution panel for each unit, which will be brought in from the NSRCs in order to supply power to either of the two Class 1E 4160 Vac buses on each unit. Additionally, by restoring the Class 1E 4160 Vac bus, power can be restored to the Class 1E 480 Vac buses via the 4160/480 Vac transformers to power selected 480 Vac loads.

The licensee evaluated several options to provide the operators with the ability to reduce the containment temperature for Phase 3, such as establishment of CARF cooling or CRDM cooling or containment spray options utilizing the RS system utilizing clean water from the casing cooling tank and the RWST. The licensee indicated that to implement containment cooling using CARF or CRDM options, the 4160 Vac turbine generators from the NSRC will need to be aligned to power a Class 1E 4160 Vac bus and a 480 Vac bus. The 4160 Vac turbine generators will provide power to the existing CC Water system and the SW pumps (if available), an IA system compressor, and either the CARF or the CRDM fan motors. For implementing containment cooling using the containment spray option, the 4160 Vac turbine generators will be aligned to power one of the Class 1E 4160 Vac and 480 Vac buses on each unit, which will provide power to the RS pump motor.

3.4.5 <u>Conclusions</u>

As shown above, even with the licensee taking no mitigating actions related to removing heat from the primary containment following an ELAP/LUHS-initiating event, the containment parameters of pressure and temperature remain well below the respective UFSAR Section 6.2.1.2 design limits of 45 psig and 280°F for more than 7 days.

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 a BDBEE consistent with NEI 12-06 guidance as endorsed by JLD-ISG-2012-01, and adequately addresses the requirements of the order.

3.5 Characterization of External Hazards

Sections 4 through 9 of NEI 12-06, Revision 0, provide the methodology to identify and characterize the applicable BDBEE 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 site-specific BDBEE leading to an ELAP and loss of normal access to the UHS.

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

The licensee reviewed the plant site against NEI 12-06 and determined that FLEX equipment should be protected from the following hazards: seismic, external flooding, severe storms with high winds, snow, ice, 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 interim staff guidance in JLD-ISG-2012-01. Coincident with the issuance of the order, on March 12, 2012, the NRC staff issued a request for information pursuant to Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50, Section 50.54(f) (ADAMS Accession No. ML12053A340) (hereafter referred to as the 50.54(f) letter), which requested that licensees reevaluate the seismic and flooding hazards at their sites using updated hazard information and current regulatory guidance and methodologies.

The NRC staff requested Commission guidance related to the relationship between the reevaluated flooding hazards provided in responses to the 50.54(f) letter and the requirements for Order EA-12-049 and related rulemaking to address BDBEE (see COMSECY-14-0037, "Integration of Mitigating Strategies for Beyond-Design-Basis External Events and the Reevaluation of Flooding Hazards," dated November 21, 2014). The Commission provided guidance in the SRM to COMSECY-14-0037 (ADAMS Accession No. ML15089A236). Specifically, the Commission approved the staff's recommendations that licensees need to address the reevaluated flooding hazards within their mitigating strategies for BDBEE, 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. The licensee has submitted its Flood Hazard Reevaluation Report (FHRR) (ADAMS Accession No. ML13074A925) and supplement (ADAMS Accession No. ML13242A017), and the staff completed its review of the report, as documented, by letter dated September 25, 2015 (ADAMS Accession No. ML15238A844), and discussed in Section 3.5.2 below. The licensee developed its OIP for mitigation strategies in February 2013 (ADAMS Accession No. ML13063A182) by considering the guidance in NEI 12-06 and its then-current design-basis hazards. Therefore, this SE makes a safety determination based on the OIP and FIP, and only notes the possibility of future actions by the licensee when the licensee's FHRR identifies a flooding hazard that exceeds the current design-basis flooding hazard.

Per the 50.54(f) letter, licensees were also asked to provide a seismic hazard screening and evaluation report to reevaluate the seismic hazard at their site. The licensee submitted its Seismic Hazard and Screening Report (SHSR) (ADAMS Accession No. ML14092A416) on March 31, 2014, and the staff completed its review of the SHSR, as documented by letter dated April 20, 2015 (ADAMS Accession No. ML15057A249), and discussed in Section 3.5.1 below. Therefore, this SE makes a determination based on the OIP and FIP, and only notes the possibility of future actions by the licensee when the licensee's SHSR identifies a seismic hazard that exceeds the current design-basis seismic hazard.

The characterization of the specific external hazards for the plant site is discussed below. In addition, Sections 3.5.1 and 3.5.2 summarizes the licensee's activities to address the 50.54(f) seismic and flooding reevaluations.

3.5.1 Seismic

The licensee stated in its FIP, that the seismic hazard is considered to be the earthquake magnitude associated with the design-basis seismic event. Per North Anna UFSAR Section 2.5.2.6, the design-basis earthquake for structures founded on rock is 0.12g for horizontal ground motion and 0.08g for vertical ground motion. For structures founded on soil, the design-basis earthquake is 0.18g for horizontal motion and 0.12g for vertical motion.

The licensee stated in its FIP, that a magnitude 5.8 earthquake occurred on August 23, 2011, with an epicenter approximately 11 miles from the site. The Peak Ground Acceleration (PGA) values developed from recorded motions as a result of this earthquake exceeded the horizontal and vertical design basis PGA values. However, evaluations performed following the earthquake have concluded that there was no significant physical or functional damage to seismically designed SSCs and only limited effects on non-seismic plant structures and equipment.

As previously discussed, the NRC issued a 50.54(f) letter that required facilities to reevaluate the site's seismic hazard (i.e., NTTF Recommendation 2.1). In addition, the 50.54(f) letter requested that licensees submit, along with the hazard evaluation, an interim evaluation and actions planned or taken to address the reevaluated hazard where it exceeds the current design basis.

Based on the results of the screening evaluation, North Anna screened-in for a risk evaluation, SFP evaluation, and a high frequency confirmation. The Electric Power Research Institute (EPRI) Report 3002000704 (ADAMS Accession No. ML13102A142), referred to as the Augmented Approach, was developed as the process for evaluating selected critical plant equipment prior to completing plant seismic risk evaluations. The NRC endorsed this report by letter dated May 7, 2013 (ADAMS Accession No. ML13114A949). The Augmented Approach outlines a process for responding to the seismic evaluation requested in the 50.54(f) letter under NTTF Recommendation 2.1, "Seismic." The process includes a near-term expedited seismic evaluation process (ESEP) followed by plant risk evaluations, in accordance with EPRI Report 1025287 (ADAMS Accession No. ML12333A170). This Augmented Approach ensures that FLEX-credited equipment (both currently installed and new) would retain function during and after a beyond-design-basis seismic event using seismic margins assessment criteria, by calculating a high confidence of low probability of failure (HCLPF) seismic capacity and comparing that to the seismic demand of a review level ground motion (RLGM), capped to two times the safe shutdown earthquake (SSE) from 1 to 10 Hertz (Hz). In accordance with this guidance, North Anna screened in for performance of the ESEP (ADAMS Accession No. ML14356A003).

The staff completed its review of North Anna's SHSR, as documented, by letter dated April 20, 2015 (ADAMS Accession No. ML15057A249). The staff concluded that the licensee conducted the hazard reevaluation using present-day methodologies and regulatory guidance, it appropriately characterized the site given the information available, and met the intent of the guidance for determining the reevaluated seismic hazard. The staff also concluded that Dominion's reevaluated seismic hazard for North Anna is suitable for other activities associated with the NTTF Recommendation 2.1, "Seismic." In reaching this determination, the NRC staff confirmed the licensee's conclusion that the licensee's ground motion response spectrum (GMRS) exceeds the SSE for North Anna Power Station, Units 1 and 2, over the frequency range of 4 to 100 Hz.

By letter dated December 17, 2014, the licensee submitted its ESEP report (ADAMS Accession No. ML14357A059). In the report, the licensee concluded that the SSCs have seismic factors of safety greater than unity and/or HCLPF capacities that are greater than the selected RLGM. Therefore, no upgrades to the plant or modifications to any SSC are required as a result of the ESEP. By letter dated July 7, 2015 (ADAMS Accession No. ML15182A392), the NRC staff completed its review of the ESEP report and stated that the licensee's implementation of the interim evaluation met the intent of the guidance.

By letter dated October 27, 2015 (ADAMS Accession No. ML15194A015), the NRC staff provided seismic probabilistic risk assessment (SPRA) submittal dates for sites that will submit an SPRA, including North Anna. North Anna's SPRA submittal date is March 31, 2018. As clarified in Footnote 2 of Table 1a, SPRAs will assess the effects of high frequency exceedance on plant equipment. Therefore, as indicated in Table 1a, North Anna will not perform an independent high frequency limited scope evaluation. North Anna will perform a limited scope evaluation of the spent fuel pool. The submittal date for the spent fuel pool evaluation is December 31, 2017.

As the license's seismic reevaluation activities are completed, the licensee will enter appropriate issues into the corrective action program. The licensee has appropriately screened in this external hazard and identified the hazard levels for reasonable protection of the FLEX equipment.

3.5.2 Flooding

The licensee stated in its FIP that North Anna is located on Lake Anna, which has a nominal water level at the 250 foot mean sea level (MSL) elevation. The watershed for Lake Anna is 343 square miles. The release of any upstream body of impounded water, due to a seismic event or dam failure, would not have a significant impact on lake level and thus would not cause flooding at the site (UFSAR Section 2.4.4). A potential cause of flooding at the site would be from high lake level due to runoff from an extreme precipitation event in the watershed. An evaluation was performed to determine the highest potential lake level due to runoff from extreme precipitation in the watershed. The resultant probable maximum flood still-water level is elevation 264.2 feet. When wind surge and wave run-up, due to a 40 mph wind blowing in the most critical direction, are added to this height, there is an increase of 2.9 feet, plus a backwater allowance of 0.2 feet. The resultant upper bound flood stage is at elevation 267.3, which is 3.7 feet below typical plant grade (UFSAR Section 2A. 2.1).

The licensee stated in its FIP that another potential source of flooding is the local accumulation of water due to precipitation. In UFSAR Section 2.4.2.2 it states: "The site is relatively flat, and no concentration of runoff is expected on the flat areas. The drainage area that will contribute to runoff on the site is not much larger than the site. The area west of the site will receive runoff from approximately 35 acres; however, the drainage facilities in this area have been designed for a 50-year storm." The licensee noted that in this discussion, the site refers to the area around the turbine buildings and reactor containments.

The licensee stated in its FIP that since the site is not located on an estuary or open coast, surge flooding is not a concern. Tsunami flooding is not a concern for the site because of its inland location. Seiche-related flooding is not addressed in the UFSAR and is not a design consideration. However, Section 2.4.5 of the North Anna Unit 3 early site permit does address a seiche event and concluded that since the power station site is not located on an estuary or open coast, surge or seiche flooding would not produce maximum water levels on the site. The North Anna, Unit 3 combined operating license (COL) is a more recent evaluation of flooding on the North Anna site and is applicable per NEI 12-06, Section 6.2.3.1.

The licensee stated in its FIP that per NEI 12-06, North Anna is considered a "wet" site because the site is maintained "dry" by a permanently installed dike. The design-basis flood level is based on the maximum potential lake level of 267.3 feet MSL resulting from a probable maximum precipitation (PMP) event over the Lake Anna watershed causing a significant rise in lake level. Although the majority of the site grade is above the design-basis flood level, the western portion of the Unit 2 turbine building is protected by a dike to prevent flooding during the design-basis flood. There is no deployment of FLEX equipment in the area west of the Unit 2 turbine building; therefore, there are no deployment limitations due to flooding from the design-basis flood.

As previously stated in this SE, the licensee completed and submitted its FHRR and a supplement, which represents the most current flooding analysis for North Anna. The licensee stated in its FIP that the reevaluation results were mostly bounded by the original North Anna UFSAR site flooding, vulnerabilities, and characteristics, in that the non-events such as seiche and dam failures continued to be non-events. The maximum flood levels due to elevated lake levels from a PMP event over the Lake Anna watershed exceeded the UFSAR value by 0.1 feet. This difference is insignificant since the plant grade is nearly 4 feet above this flood level.

The licensee stated in its FIP that the only significant difference identified during the reevaluation was a local intense precipitation (LIP) event. Using conservative drainage assumptions and current-day PMP rates, some areas of the site were subject to short-term flooding which required minimal protective actions.

The staff completed its review of North Anna's FHRR, as documented by letter dated September 25, 2015. The review concluded that the licensee conducted the hazard reevaluation using present-day methodologies and regulatory guidance used by the NRC staff in connection with ESP and COL reviews. The NRC staff confirmed that the licensee responded appropriately to Enclosure 2, Required Response 2, of the 50.54(f) letter, dated March 12, 2012. In reaching this determination, the staff confirmed the licensee's conclusions that (a) the reevaluated flood hazard results for LIP, streams and river flooding, and upstream dam failure flooding are not bounded by the current design-basis flood hazard, (b) additional assessments of plant response will be performed for the LIP, rivers and streams and dam failure flood-causing mechanisms, and (c) the reevaluated flood-causing mechanism information is appropriate input to the additional assessments of plant response as described in the 50.54(f) letter and COMSECY-15-0019 (NRC, 2015b).

As the licensee's flooding reevaluation activities are completed, the licensee will enter appropriate issues into the corrective action program.

The licensee has appropriately screened in this external hazard and identified the hazard levels for reasonable protection of the FLEX equipment.

3.5.3 High Winds

The licensee stated in its FIP that the plant design bases address the storm hazards of hurricanes, high winds, and tornadoes.

The licensee stated in its FIP that for hurricanes, a total of 51 tropical storms or hurricane centers were recorded between 1871 and 1987 as passing within 100 nautical miles of the North Anna site. North Anna UFSAR Section 2.3.1 stated that an average of approximately two tropical storms or hurricanes pass within 100 nautical miles of the North Anna plant site every 5 years. With the site being approximately 100 miles from the Atlantic Ocean, hurricanes and tropical storms tend to weaken before reaching the site.

The licensee stated in the FIP that for extreme straight winds, the extreme 1-mile wind speed at 30 feet above the ground, which is predicted to occur once in 100 years, is 80 mph. The extreme 1-mile wind speed is defined as the 1-mile passage of wind with the highest speed for the day. The fastest wind speed recorded at Richmond, based on the 1951-1987 period, was 68 mph from the southeast in October 1954. For tornadoes and tornado missiles, the North Anna UFSAR indicates that between January 1916 and December 1987, there were a total of 65 tornadoes reported within a 50-mile radius of the site (UFSAR Section 2.3.1). The tornado model used for design purposes has a 300 mph rotational velocity and a 60 mph translational velocity (UFSAR Section 3.3.2). 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

The licensee stated in its FIP that snowfalls of 4 inches or more occur, on average, once a year, and snow usually only remains on the ground from 1 to 4 days at a time. Richmond averages 14.6 inches of snow a year. The North Anna UFSAR stated that an examination of the period between 1977 and 1987 indicates that there were only six documented cases of ice storms in Louisa County and the immediately surrounding counties. Of these, two were reported to have caused serious damage (including damage to power lines and trees).

The licensee further stated that temperatures in the site region rarely fall below 10 degrees Fahrenheit (°F). The lowest temperature recorded in Richmond was minus 12 °F in January

1940 and the lowest recorded in Charlottesville was minus 9 °F in January 1985. Such low temperatures could adversely affect access to and the flow path from Lake Anna or the service water reservoir. Ice could form on the surface of Lake Anna or the Service water reservoir and impact FLEX strategies. However, capabilities are available to break through the ice, if needed, to provide access and a flow path.

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

3.5.5 Extreme Heat

The licensee stated in its FIP that temperatures in the site region rarely exceed 95 °F (UFSAR Section 2.3.1). The peak temperature recorded in Richmond was 105 °F in July 1977 and the peak temperature recorded in Charlottesville was 107 °F in September 1954 (UFSAR Table 2.3-2). The UFSAR information is limited to data prior to 1987. Therefore, the high and low temperature data presented above has been confirmed to be accurate based on published data for the southeast region of the United States through 2012.

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

3.5.6 Conclusions

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

3.6 Planned Protection of FLEX Equipment

3.6.1 Protection from External Hazards

The licensee stated in its FIP, that the BDB equipment is stored in a single 10,000 sq. ft. concrete building that meets the plant's design-basis for both seismic and tornado-missile protection. Portable equipment stored in the BDB storage building include: One BDB high capacity pump; three BDB AFW pumps; two BDB RCS injection pumps; associated hoses, strainers, and end fittings for the respective BDB pumps; three 120/240 Vac generators and associated cable, connectors, and switchgear; two 480 Vac generators and associated cables, connectors, and switchgear; three portable boric acid batching tanks; and miscellaneous support equipment, such as fuel carts with transfer pumps, debris removal equipment and extra generators.

The licensee stated in its FIP, that the 50.54(hh)(2) high capacity pump can meet the flow requirements for both the FLEX core cooling and SFP cooling strategies that credit the BDB high capacity pump and serves to meet the N+1 requirement. The 50.54(hh)(2) high capacity pump is stored in Warehouse 10, which is reasonably protected from flooding, extreme heat, and extreme cold hazards.

In a supplemental letter dated July 2, 2015 (ADAMS Accession No. ML15194A060), the licensee provided clarification on the storage of the 50.54(hh)(2) pump. The licensee identified that Warehouse 10, where the pump is stored, is vulnerable to seismic and high wind, tornado, and hurricane events. As such, the requirements of NEI 12-06 Sections 7.3.1 and 5.3.1 are not met, and the requirements of Section 11.3.3 will also not be met if one protected BDB high capacity pump is unavailable. The licensee acknowledge that the storage of this pump represents an alternative to the requirements of NEI 12-06, Sections 5.3.1, 7.3.1, and 11.3.3.

Accordingly, Dominion has implemented compensatory actions to support this alternative approach for stored BDB equipment. As stated in the letter, the unavailability requirements for FLEX equipment are prescribed by Dominion Fleet procedure ADM-CM-AA-BDB-102 and includes additional requirements to address the storage capability of FLEX equipment that is not fully protected. Specifically, the required FLEX equipment may be unavailable for 90 days provided that the site FLEX capability (N) is met. If the site FLEX (N) capability is met but not fully protected for the site's applicable hazards, the allowed unavailability is reduced to 45 days. Additionally, ADM-CM-AA-BDB-102 provides appropriate guidance for reasonable protection during forecast adverse external conditions as follows. Specifically, if FLEX equipment is likely to be unavailable during forecast site specific external events (e.g., hurricane), then appropriate compensatory measures should be taken to restore equivalent capability in advance of the event." Abnormal Procedure, 0-AP-41, "Severe Weather Conditions", accommodates this requirement as it invokes an evaluation of the availability of BDB equipment, which includes the 50.54(hh)(2) pumps, upon approaching severe weather.

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

3.6.1.1 <u>Seismic</u>

The licensee stated in its FIP that the portable FLEX equipment stored in the BDB storage building is protected against the hazard of a SSE. The BDB storage building was evaluated for the effect of local seismic ground motions consistent with the NAPS GMRS developed for the site as a result of the seismic hazard reevaluation and found to have adequate structural margin to remain functional (i.e., collapse is not expected and access to the interior retained).

The licensee stated in its FIP that analysis of components stored in the BDB storage building has been performed to determine appropriate measures to prevent seismic interaction. The fire protection and HVAC systems in the BDB storage building are seismically installed. The lighting, conduits, electrical, and fire detection components are not seismically installed, but are considered insignificant and not able to damage BDB equipment.

The license further indicated in its FIP that the need for a second BDB high capacity pump would be met by to the existing 10 CFR 50.54(hh)(2) high capacity pump, which is stored on-site in Warehouse 10. In NEI 12-06, Section 3.2.2 allows the use of the existing 10 CFR 50.54(hh)(2) pump and supplies provided it meets the functional and storage requirements outlined in this guideline, which includes protection against the hazards of a seismic event. The licensee stated that Warehouse 10 is reasonably protected from flooding, extreme heat, and extreme cold hazards, but did not state any protection from a seismic event. As discussed in Section 3.6.1, the licensee further clarified in a supplemental letter dated July 2, 2015, that Warehouse 10 is not protected from seismic and high wind, tornado, and hurricane events. The licensee implemented compensatory measures to limit the potential vulnerability of the pump as an acceptable alternative to the NEI 12-06 guidance.

Seismic (Electrical)

The 120/240 Vac, 480 Vac FLEX DGs, associated FLEX cables, electrical connectors and FLEX switchgears are stored inside the BDB storage building. The BDB storage building is designed and built to store the BDB FLEX equipment and meets the plant's design-basis for both seismic protection and seismic interactions. The installed FLEX 120/240 Vac and 480 Vac distribution systems are protected from seismic because they are located inside buildings that have been analyzed to survive two times the SSE for design-basis events. The electrical distribution from the FLEX DG deployment locations to the installed 120V/240 Vac and 480 Vac safety class electrical distribution system and electrical buses are housed in robust structures that are seismic and missile-protected consistent with the NEI 12-06 guidance or is located within a Class 1 structure.

3.6.1.2 Flooding

The licensee stated in its FIP that the portable FLEX equipment stored in the BDB storage building is protected against the hazard of flooding. This location is above the flood elevation from the most recent site flood analysis. The BDB storage building was designed and constructed to prevent water intrusion.

The licensee further stated in its FIP that the need for a second BDB high capacity pump would be met by the existing 10 CFR 50.54(hh)2 high capacity pump, which is stored on-site in a separate location from the BDB storage building. The licensee stated that the 10 CFR 50.54(hh)2 high capacity pump is also protected against a flooding event.

Flooding (Electrical)

The licensee stated in its FIP that the portable FLEX equipment including the 120/240 Vac and 480 Vac DGs, cables, connectors, and switchgear are stored in the BDB storage building, which is protected against the hazard of flooding. This location is above the flood elevation from the most recent site flood analysis. Furthermore, the BDB storage building is designed and constructed to prevent water intrusion. The licensee has appropriately provided flooding protection for the FLEX equipment by storing them above the analyzed flood level.

3.6.1.3 High Winds

The licensee stated in its FIP, that the portable FLEX equipment stored in the BDB storage building is protected against the hazard of high winds and associated missiles. However, the licensee stated in the FIP that the need for a second BDB high capacity pump would be met by the existing 10 CFR 50.54(hh)(2) high capacity pump, which is stored on-site in Warehouse 10. In NEI 12-06, Section 3.2.2 allows the use of the existing 10 CFR 50.54(hh)(2) pump and supplies provided it meets the functional and storage requirements outlined in this guideline, which includes protection against the hazards of high winds and associated missiles. The licensee stated that Warehouse 10 is reasonably protected from flooding, extreme heat, and extreme cold hazards. As discussed in Section 3.6.1, the licensee further clarified in a supplemental letter dated July 2, 2015, that Warehouse 10 is not protected from seismic and high wind tornado and hurricane events. The licensee implemented compensatory measures to limit the potential vulnerability of the pump as an acceptable alternative to the NEI 12-06 guidance.

Severe Storms with High Winds (Electrical)

The 120/240 Vac and 480 Vac FLEX DGs, cables, connectors, and switchgear are stored inside the BDB storage building. The BDB storage building is designed and built to withstand a 300 miles per hour (mph) tornado and 80 mph extreme straight wind and are designed to meet or exceed the licensing basis extreme high wind hazard for NAPS.

Based on the above, the licensee has appropriately provided high wind protection for the FLEX equipment by storing them in structures protected from high wind events or providing adequate compensatory measures as an acceptable alternative.

3.6.1.4 Snow, Ice, and Extreme Cold and Extreme Heat

The licensee stated in its FIP that the portable FLEX equipment stored in the BDB storage building is protected against the hazard of snow, ice, and extreme cold. The license further stated that need for a second BDB high capacity pump would be met by the existing 10 CFR 50.54(hh)(2) high capacity pump, which is stored on-site in a separate location from the BDB storage building, which is also protected against the hazards of snow, ice, and extreme cold.

The licensee stated in its FIP that the portable FLEX equipment stored in the BDB storage building is protected against the hazard of extreme heat. The license further stated that the need for a second BDB high capacity pump would be met by the existing 10 CFR 50.54(hh)(2) high capacity pump, which is stored on-site in a separate location from the BDB storage building and is protected against the hazard of extreme heat.

Snow, Ice, and Extreme Cold and Extreme Heat (Electrical)

The FLEX 120/240 Vac, 480 Vac DGs, cables, connectors, and switchgear are stored inside the BDB storage building. The BDB storage building is provided with a standalone seismically installed HVAC system to maintain acceptable internal environment to ensure FLEX equipment stored in the building will perform when called upon. The licensee designed the BDB storage building for snow, ice and extreme cold temperature conditions. Heating will be available to ensure no adverse effects on the FLEX equipment staged or stored within the BDB storage building. Equipment stored or staged in the auxiliary building is protected from these extremes in accordance with the licensing basis. The licensee has evaluated the BDB storage building for extreme high temperature effects. The licensee has evaluated the BDB storage building for extreme high temperatures to ensure no adverse effects on the stored FLEX equipment. Equipment stored or staged in the auxiliary building is protected from extreme high temperatures in accordance with the licensing basis. Based on the above, the licensee has appropriately provided snow, ice, extreme cold, and extreme heat protection for the FLEX equipment.

3.6.2 Reliability of FLEX Equipment

Section 3.2.2 of NEI 12-06 states, in part, that in order to assure reliability and availability of the FLEX equipment, the site should have sufficient equipment to address all functions at all units on-site, plus one additional spare (i.e., an N+1 capability, where "N" is the number of units on-site). It is also acceptable to have a single resource that is sized to support the required functions for multiple units at a site (e.g., a single pump capable of all water supply functions for a dual unit site). In this case, the N+1 could simply involve a second pump of equivalent capability. In addition, it is also acceptable to have multiple strategies to accomplish a function, in which case the equipment associated with each strategy does not require an additional spare. The existing 50.54(hh)(2) pump and supplies can be counted toward the N+1, provided it meets the functional and storage requirements outlined in NEI 12-06.

The licensee stated in its FIP that the 50.54(hh)(2) high capacity pump can meet the flow requirements for both the FLEX core cooling and SFP cooling strategies that credit the BDB high capacity pump and serves to meet the N+1 requirement. However, the 50.54(hh)(2) high capacity pump is stored in Warehouse 10, which is reasonably protected from flooding, extreme heat, and extreme cold hazards, but not a seismic hazard or the hazard of high winds and wind-borne missiles. As stated above, NEI 12-06 allows the existing 50.54(hh)(2) pump and supplies to be counted toward the N+1, provided it meets the functional and storage requirements outlined in NEI 12-06, which includes protection against a seismic event and high winds with wind-borne missiles. As discussed in Section 3.6.1, the licensee further clarified in a supplemental letter dated July 2, 2015, that Warehouse 10 is not protected from seismic and high wind tornado and hurricane events. The licensee implemented compensatory measures to limit the potential vulnerability of the pump as an acceptable alternative to the NEI 12-06 guidance.

Based on the number of portable FLEX pumps, FLEX DGs, and support equipment identified in the FIP and during the audit review, the staff finds that, if implemented appropriately, the licensee's FLEX strategies include a sufficient number of portable FLEX pumps, FLEX DGs and support equipment for core cooling, SFP makeup and RCS makeup strategies consistent with the N+1 recommendation in Section 3.2.2 of NEI 12-06. Additionally, based on the compensatory measures discussed in Section 3.6.1, storage of the 50.54(hh)(2) pump provides an acceptable alternative to NEI 12-06.

3.6.3 Conclusions

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

3.7 Planned Deployment of FLEX Equipment

3.7.1 Means of Deployment

In its FIP, the licensee indicated that the stored BDB debris removal equipment includes tow vehicles (tractors) equipped with front-end buckets and rear tow connections in order to move or remove debris from the needed travel paths. A front-end loader will also be available to deal with more significant debris conditions. Debris removal equipment is stored inside the BDB storage building and is protected from the severe storm and high wind hazards, such that the equipment remains functional and deployable to clear obstructions from the pathway between the BDB storage building and its deployment location(s).

The licensee stated that the deployment of the debris removal equipment and the Phase 2 BDB equipment from the BDB storage building is not dependent on offsite power. The building equipment doors are hydraulically operated with a battery backup and can also be opened manually.

3.7.2 Deployment Strategies

In its FIP, the licensee indicated that pre-determined, preferred haul paths have been identified and documented in the FSGs. These haul paths have been reviewed for potential soil liquefaction and have been determined to be stable following a seismic event. Additionally, the preferred haul paths minimize travel through areas with trees, power lines, narrow passages, etc., to the extent practical. However, high winds can cause debris from distant sources to interfere with planned haul paths. Debris removal equipment will be used to clear obstructions from the haul paths.

The licensee indicated in its FIP that major components for FLEX strategies are provided with cold weather packages and small electrical generators to protect the equipment from damage due to extreme cold weather and help assure equipment reliability as well as to power additional heat tape circuits, if necessary. In addition, the ECST refill connection pressure gauge instrument tubing credited for BDB and subject to freezing conditions in an ELAP event, will be protected with the use of portable heaters, which can be powered from small generators that have been procured and designated for FLEX strategies or from the small generators that are included as part of the large BDB pump skids.

The licensee stated in its FIP that Phase 3 of the FLEX strategies involves the receipt of equipment and various commodities, such as fuel and supplies, from offsite sources, including an NSRC. Delivery of this equipment can be through airlift or via ground transportation. An NSRC will deliver equipment to a staging area near the plant. Debris removal for the pathway between the site and the NSRC staging area and for the various plant access routes may be required. The same debris removal equipment used for onsite pathways may also be used to support debris removal to facilitate road access to the site once necessary haul routes and transport pathways onsite are clear.

The licensee stated in its OIP that ice might form on the surface of Lake Anna or the Service water reservoir. However, capabilities are available to break through the ice, if needed, to provide access and a flow path.

3.7.3 FLEX Connection Points

3.7.3.1 Mechanical Connection Points

BDB AFW Pump

As discussed in Section 3.2.3.1.1 of this evaluation, the primary connection to supply AFW to the SGs via a portable pump is located on the TDAFW pump discharge line located in the AFW pump house with the alternate connection located on the main feed water system inside the service building. The BDB AFW pump will discharge via portable hose connected to the primary or alternate connection points. The BDB AFW pump will draw suction via portable hose from a connection located on the ECST (discussed in Section 3.10 of this evaluation) or from the discharge of the BDB high capacity pump.

BDB High Capacity Pump

The BDB high capacity pump provides water for SFP and core cooling. For SFP cooling, the pump discharge connects via portable hose to the BDB SFP connection located outside of the fuel building (discussed in Section 3.3.4.11 of this evaluation). For core cooling, the pump discharge connects via portable hose to the BDB ECST refill connection (discussed in Section 3.10 of this evaluation) or directly to the suction of the BDB AFW pump. The BDB high capacity pump will draw a suction via portable hose connected to a suction strainer and placed directly into the SW reservoir or Lake Anna (discussed in Section 3.10 of this evaluation).

BDB RCS Injection Pump

As discussed in Section 3.2.3.1.1 of this evaluation, the primary RCS injection connection is located on the LHSI system with the alternate connection located on a standpipe in the auxiliary building, which connects via a spectacle flange to the normal charging system. The discharge of the pump connects via high pressure hose with threaded end connections to the primary or alternate connection points. The BDB RCS injection pump draws a suction via portable hose from the RWST through a connection on one of two quench spray pump's suction elbows for each unit (discussed in Sections 3.2.3.1.1 and 3.10 of this evaluation). In the event that both unit's RWSTs are unavailable, the pump can draw suction from a portable boric acid mixing tank, which is stored in the BDB storage building

3.7.3.2 Electrical Connection Points

In its FIP, the licensee stated that the primary electrical connection is a receptacle panel for the 120/240 Vac DG cable connections is located in the cable vault rod drive room which provides connections to repower essential instrumentation from a portable 120/240 Vac DG. The receptacle panel cables are installed in seismically mounted raceways to two BDB distribution panels, one for each of the 120/240 Vac DG output circuits. Each BDB distribution panel has branch circuit breakers sized to feed the required loads. The cables required to connect the 120/240 Vac DG to the receptacle panel are stored in the Hydrogen Recombiner control panel vault and are protected from seismic interactions, missiles, flood, snow and ice, and are operable within the outside temperature ranges applicable to the site.

In its FIP, the licensee stated that the alternate electrical connection is the receptacle panel for the 120/240 Vac DG connections located in the cable vault rod drive room. This receptacle panel also contains the 480 Vac DG cable connections to repower 480 Vac loads, including the battery chargers. From the receptacle panel, cables are installed in seismically mounted raceways to the Class 1E 480 Vac bus via preinstalled cable and conduit to Class 1E 480 Vac motor control center (MCC) breakers.

In its FIP, the licensee stated that two 1 MW 4160 Vac turbine generators delivered to the site from the NSRCs will be connected to a distribution panel (also delivered from the NSRC) in order to meet the required Phase 3 4160 Vac load requirements for each unit. Due to the size of the equipment, the 4160 Vac turbine generators will be deployed to areas either near the existing Emergency Diesel Generator (EDG) Rooms or by the large track bay openings in the Unit 1 and 2 turbine buildings. The area near the existing EDG rooms affords the simplest configuration to connect to one of the two Class 1E 4160 Vac buses for each unit, but space outside of these rooms is limited. Depending on the debris situation, the turbine building track bay openings may be the more viable option for deployment. In this case, either the Emergency Switchgear Room or the normal Switchgear Room would be used to tie the 4160 Vac Turbine Generators to one of the two Class 1E 4160 Vac buses for each unit.

3.7.4 Accessibility and Lighting

The licensee stated in its FIP that in order to validate the adequacy of supplemental lighting and the adequacy and practicality of using portable lighting to perform FLEX strategy actions, a lighting study was completed. Tasks evaluated included traveling to/from the various areas necessary to implement the FLEX strategies, making required mechanical and electrical connections, performing instrumentation monitoring, equipment operation, and component manipulation. Except for the Unit 1 and Unit 2 mechanical equipment rooms (MERs), the areas reviewed contain emergency lighting fixtures (Appendix "R" lighting) consisting of a battery, battery charger, and associated light fixtures. These emergency lights are designed and periodically tested to insure the battery pack will provide a minimum of eight (8) hours of lighting with no external ac power sources. Therefore, these currently installed emergency lighting fixtures provide adequate lighting to light pathways and implement the BDB strategies for Phase 1 mitigation strategy activities for 8 hours.

The licensee stated in its FIP that prior to the depletion of the Appendix "R" lighting (and in the MERs), portable battery powered remote area lighting systems (RALS) would be deployed to support the FLEX strategy tasks. These RALSs are rechargeable LED lighting systems designed to power the LED lights for a minimum of 7 hours at 6000 lumens or a maximum of 40 hours at 500 lumens.

The licensee indicated in its FIP that there are no emergency lighting fixtures in the yard outside of the protected area to provide necessary lighting in those areas where portable BDB equipment is to be deployed. Therefore, the large portable BDB pumps and diesel generators are outfitted with light plants that are powered from either their respective diesel generators or batteries in order to support connection and operation. In addition to the lights installed on the portable BDB equipment, portable light plants are included in the FLEX strategies. These portable diesel powered light plants can be deployed from the BDB storage building, as needed, to support nighttime operations. In addition to installed Appendix "R" lighting, the RALS, and the portable light plants, the BDB storage building also includes a stock of flashlights and headband lights to further assist the staff responding to a BDB event during low light conditions.

3.7.5 Access to Protected and Vital Areas

The ability to open doors for ingress and egress, ventilation, or temporary cables/hoses routing is necessary to implement the FLEX coping strategies. The licensee stated in its FIP that security doors and gates that rely on electric power to operate opening and/or locking mechanisms are barriers of concern. The security force will initiate an access contingency upon loss of the security diesel and all ac/dc power as part of the security plan. Access to the owner controlled area, site protected area, and areas within the plant structures will be controlled under this access contingency as implemented by security personnel. Access authorization lists are prepared daily and copies are protected from the various BDB external events for use post-ELAP event. The plant MCR contains a duplicate set of security keys for use by plant operations personnel in implementing the FLEX strategies.

Vehicle access to the protected area is via the double-gated sally-port at the security building. As part of the security access contingency, the licensee indicated in its FIP that the sally-port gates would be manually controlled to allow delivery of BDB equipment (e.g., generators, pumps) and other vehicles such as debris removal equipment into the protected area.

3.7.6 Fueling of FLEX Equipment

As stated in North Anna's FIP, FLEX equipment is stored in the fueled condition and the fuel tanks are typically sized to hold 24 hours of fuel. A fuel transfer truck with a tank capacity of 1000 gallons will be used to obtain fuel from on-site fuel oil tanks and refuel the FLEX equipment within the first 24 hours. The primary source of diesel fuel for portable equipment is the EDG fuel oil day tanks. These four tanks contain 800 gallons of diesel fuel each (a total of 3200 gallons) and are seismically mounted and housed in the tornado protected EDG cubicles (NAPS UFSAR, Table 3.2-1). A second source for diesel fuel is the two EDG underground diesel fuel oil storage tanks. Each tank has a 45,000-gallon capacity. These tanks are protected from high wind tornado missiles by virtue of the underground location and are also protected from seismic and flooding events (NAPS UFSAR, Table 3.2-1). A third source is the above ground diesel fuel oil storage tank that has a 275,000-gallon capacity. This tank is protected from flooding, but is not seismic or tornado protected. Diesel fuel in the fuel oil storage tanks is routinely sampled and tested via Technical Specification surveillance to assure fuel oil quality is maintained to American Society for Testing and Materials standards.

Dominion performed a fuel consumption study, which determined, at a conservative consumption rate of 120 gallons/hour, that the fuel transfer truck has sufficient capacity to support continuous operation of the major BDBEE equipment expected to be deployed and placed into service following a BDB external event. In addition, the fully protected sources of on-site diesel fuel have adequate capacity to provide on-site BDB equipment with diesel fuel for greater than 30 days. During the audit process, Dominion stated that if needed, its existing fuel oil supplier can supply fuel to provide an indefinite coping capability.

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 adequately addresses the requirements of the order.

3.8 Considerations in Using Offsite Resources

3.8.1 North Anna SAFER Plan

The licensee stated in its FIP, that the industry has established two NSRCs to support utilities during BDB events. Dominion has established contracts with the Pooled Equipment Inventory Company (PEICo) to participate in the process for support of the NSRCs, as required. Each NSRC will hold five sets of equipment, four of which will be able to be fully deployed when requested, the fifth set will have equipment in a maintenance cycle. In addition, onsite BDB equipment hose and cable end fittings are standardized with the equipment supplied from the NSRC. The plan is documented in Dominion's "SAFER Response Plan for North Anna Power Station," dated September 25, 2014.

By letter dated September 26, 2014 (ADAMS Accession No. ML14265A107), the NRC staff issued its staff 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.

3.8.2 Staging Areas

The licensee stated in its FIP that in the event of a BDB external event and subsequent ELAP/LUHS condition, equipment will be moved from an NSRC to a local assembly area established by the SAFER team. As described in the North Anna SAFER Response Plan, equipment can be taken to the North Anna site and staged at Staging Area B, located near the BDB storage building. Equipment can be delivered by helicopter if ground transportation is unavailable. Communications will be established between the North Anna plant site and the SAFER team via satellite phones and required equipment moved to the site as needed. First arriving equipment will be delivered to the site within 24 hours from the initial request. The order in which equipment is delivered is identified in the North Anna's SAFER Response Plan.

In addition, the staff confirmed in the North Anna SAFER Response Plan the locations of Staging Areas C and D. Specifically, Staging Area C is located approximately 65 miles from Staging Area B. The plan identifies primary and alternate driving routes. Staging Area D is located approximately 43 miles from Staging Area B. The plan also identifies primary and alternative driving routes from Staging Area D.

3.8.3 Conclusions

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

3.9 Habitability and Operations

3.9.1 Equipment Operating Conditions

As discussed in the FIP, the key areas impacted by a loss of ventilation are the MCR, emergency switchgear room (ESGR), main steam valve house (MSVH) (steam generator - PORV area), TDAFW pump room, quench spray pump house, auxiliary building, and the mechanical equipment room in the turbine building. These areas have been evaluated to determine the temperature profiles following an ELAP/LUHS event. With the exception of the TDAFW pump room, results of the calculation have concluded that temperatures remain within acceptable limits based on conservative input heat load assumptions for all areas with no actions being taken to reduce heat load or to establish either active or passive ventilation (e.g., portable fans, open doors, etc.). In the case of the TDAFW pump room, an alternate ventilation method will be initiated within 4 hours of the ELAP to ensure that the temperatures remain within the acceptable range for equipment and personnel habitability. The alternate ventilation method will be required to be in effect as long as the TDAFW pump is in service.

The licensee provided the staff with procedure FSG-5, "Initial Assessment and Equipment Staging," Rev. 0. The procedure directs operators to provide alternate cooling and ventilation by blocking open the TDAFWP room doors, establishing natural circulation ventilation of the fuel building, opening equipment room doors, opening energized cabinet doors, deploying portable fans, and checking to ensure battery room exhaust fans are in service once power is available.

3.9.1.1 Loss of Ventilation and Cooling

Following a BDBEE and subsequent ELAP event, plant HVAC in occupied areas and areas containing permanent plant and FLEX mitigation strategy equipment will be lost. Per NEI 12-06, FLEX mitigation strategies must be capable of execution under the adverse conditions (unavailability of normal plant lighting, ventilation, etc.) expected following a BDBEE resulting in an ELAP/LUHS. The primary concern with regard to ventilation is the heat buildup, which occurs with the loss of forced ventilation in areas that continue to have heat loads. The licensee performed a loss of ventilation analysis to quantify the maximum steady state temperatures expected in specific areas related to FLEX mitigation strategy implementation to ensure the environmental conditions remain acceptable for personnel habitability and within equipment qualification limits.

As part of the audit process, the NRC staff reviewed Calculation ME-0972, "Evaluation of Room Air Temperatures Following Extended Loss of AC Power (ELAP)," Rev. 0, and Addendum A, "Analysis with Doors Open," to verify that electrical equipment relied upon as part of the North Anna mitigation strategy for an ELAP will not be adversely affected by increases in temperature as a result of loss of HVAC. The calculation also included a separate analysis of the TDAFW pump rooms. Calculation ME-0972 concluded that, since the steady state temperature in the TDAFW pump room remains below 130 °F, the temperature in this room is not expected to adversely affect the performance or reliability of the pump or pump motor. The licensee indicated that compensatory actions, such as opening the AFW pump house door, will be included in the FLEX coping procedures to ensure acceptable temperatures following an ELAP event and no other operator action to deploy portable ventilation equipment is expected to be necessary during the plant response to an ELAP.

The staff also walked down the battery rooms at North Anna to confirm the adequacy of the battery room ventilation. Two battery rooms are in the ESGR, and two are in the cable spreading room above the MCR. The ventilation for the battery rooms in the ESGR flows from the ESGR into the battery room, and then outside through the normal exhaust fan. For the battery rooms above the MCR, air is drawn from the MCR and exhausted back to the MCR. The battery rooms are not modeled in the loss of ventilation transient analysis model; however, Calculation ME-0972 determined that the expected loss of ventilation transient temperatures in the ESGR and in the MCR are expected to remain below 120 °F while relying on installed plant equipment (Phase 1) of an ELAP event. Therefore, the temperatures in the battery rooms above and below the MCR are expected to be approximately the same as the temperatures of the ESGR and the CR, respectively, during Phase 1. As a result of its review, the NRC staff did not identify any issues with ventilation of the battery rooms.

The licensee's Phase 3 strategy is to repower a MCR chiller for each unit and thus re-establish normal HVAC cooling capacity for the MCR envelope. The NRC staff's review of the licensee's assessment is that the impact of extreme low temperatures is not expected to be significant due to the continuous connection with the MCR and ESGR spaces and the heat storage capacity of the battery room concrete walls/floors/ceilings. However, if decreasing battery room temperatures become a concern, the FSGs provide for the use of portable heating equipment. The NRC staff's review focused on whether the licensee's mitigating strategies will ensure that neither high nor low temperature extremes will challenge the equipment design limits in the North Anna battery rooms.

Based on its review, the NRC staff did not identify any issues with the licensee's ability to ensure that the electrical equipment relied upon as part of the North Anna mitigation strategy will not be adversely affected by increases in temperature as a result of loss of HVAC.

3.9.1.2 Loss of Heating

In its FIP, the licensee stated that the major components for FLEX strategies are provided with cold weather packages and small electrical generators to protect the equipment from damage due to extreme cold weather and help assure equipment reliability as well as to power additional heat tape circuits, if necessary. In addition, the ECST refill connection pressure gauge instrument tubing credited for BDB and subject to freezing conditions in an ELAP event, will be protected with the use of portable heaters which can be powered from small generators that have been procured and designated for FLEX strategies or from the small generators that are included as part of the large BDB pump skids.

3.9.1.3 Hydrogen Gas Control in Vital Battery Rooms

An additional ventilation concern applicable to Phase 2 is the potential buildup of hydrogen in the battery rooms. The licensee's FIP stated that off-gassing of hydrogen from batteries is only a concern when the batteries are charging. Once a 480 Vac power supply is restored in Phase 2 and the station Class 1E batteries begin re-charging, power is also restored to the battery room ventilation exhaust fans which will prevent any significant hydrogen accumulation in the battery rooms.

Based on its review, the NRC staff finds that the licensee's evaluation demonstrated that hydrogen accumulation in the 125 Vdc vital battery rooms will not be a concern during an ELAP as a result of a BDBEE since it is reasonable to assume that when a 480 Vac power supply is restored in Phase 2 and the station Class 1E batteries begin re-charging, power will also be restored to the vital battery room HVAC exhaust fans that will maintain hydrogen concentration below combustibility limits in the battery rooms.

3.9.2 Personnel Habitability

It its FIP, the licensee stated that habitability considerations were evaluated in conjunction with equipment operability and determined to be acceptable.

3.9.2.1 Main Control Room

During the audit process, the licensee provided the staff access to calculation ME-0972, "Evaluation of Room Air Temperatures Following Extended Loss of AC Power (ELAP)," Rev. 0. Case 3 of this calculation performed a GOTHIC analysis of the MCR under ELAP conditions to predict the temperature response to the loss of active cooling. The results of Case 3 showed that, with no actions taken by the operations staff (e.g., opening doors, placing temporary fans), the temperatures in the MCR remain well below the 120°F occupancy threshold of Nuclear Management and Resources Council (now NEI) (NUMARC) 87-00, "Guidelines and Technical Bases for NUMARC Initiatives Addressing Station Blackout at Light Water Reactors," Rev. 1, throughout the ELAP event.

3.9.2.2 Spent Fuel Pool Area

For the evaluation of habitability in SFP area, see Sections 3.3.2 and 3.3.4.1.1.

3.9.3 Conclusions

Based on the evaluation above, 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 adequately addresses the requirements of the order.

3.10 Water Sources

Condition 3 of NEI 12-06, Section 3.2.1.3, states that cooling and makeup water inventories contained in systems or structures with designs that are robust with respect to seismic events, floods, and high winds, and associated missiles, are available. The staff reviewed Dominion's planned water sources to verify that each water source was robust as defined in NEI 12-06.

3.10.1 Steam Generator Make-Up

Phase 1

Dominion stated in its FIP that the ECST provides cooling water to the SGs in Phase 1. Table 3.2-1 in the NAPS UFSAR lists the ECST as a Seismic Category 1 and tornado missile-protected structure. The tank has a minimum usable capacity of approximately 96,000 gallons and will provide a cooling source to the SGs via the TDAFW pump for a minimum of 4.2 hours. After depletion of the usable ECST inventory, the TDAFW pump suction will be aligned to the seismic Category I, tornado missile-protected portion of the FP system (NAPS UFSAR, Table 3.2-1). The FP system, which is common to both units, will be pressurized by the DDFP, which provides water from the SW reservoir. The SW reservoir is impounded by a Seismic Category 1

(NAPS UFSAR, Table 3.2-1) earthen structure and provides approximately 22.5 million gallons of useable water. The available water in the ECST and SW reservoir should provide sufficient time for operators to begin deploying and staging Phase 2 FLEX equipment consistent with the sequence of events timeline documented in Table 4 of North Anna's FIP.

Based on the design of the ECST and SW reservoir, as described in the FIP and UFSAR, the licensee should have water sources available during the Phase 1 core cooling strategies for SG inventory makeup, consistent with NEI 12-06, Section 3.2.1.3.

Phase 2

Dominion stated in its FIP that the Phase 2 FLEX strategy uses a portable pump to draw water from the ECST, which can be refilled via the BDB high capacity pump from the SW reservoir or Lake Anna. In addition, the high capacity pump can discharge directly to the suction of AFW portable pump. As discussed above, the ECST is a Seismic Category 1 and tornado missile-protected structure. As stated in North Anna's FIP, a suction and/or refill connection to the ECST is installed to provide a suction source to portable equipment or to facilitate refill of the ECST. The connection is seismically designed and located inside the AFW pump house, a Seismic Category 1 and tornado missile-protected structure (NAPS UFSAR, Table 3.2-1). The SW reservoir is impounded by a Seismic Category 1 (NAPS UFSAR, Table 3.2-1) earthen structure and provides approximately 22.5 million gallons of useable water. Lake Anna is maintained by a seismically-qualified dam and provides an indefinite source of water. Therefore, reactor core cooling and heat removal have an indefinite supply of water for feeding the SGs using the installed DDFP with suction from the Service water reservoir followed by use of a portable BDB high capacity pump capable of drawing water from Lake Anna. Both of these sources of water will remain available for any of the external hazards. The available water in the SW reservoir and Lake Anna should provide sufficient time for operators to begin deploying and staging Phase 3 FLEX equipment consistent with the sequence of events timeline documented in Table 4 of North Anna's FIP.

Based on the design of the ECST, SW reservoir, and Lake Anna, as described in the FIP and UFSAR, the licensee should have water sources available during the Phase 2 core cooling strategies for SG inventory makeup, consistent with NEI 12-06, Section 3.2.1.3.

Phase 3

The licensee indicated in its FIP that the same water sources would be utilized during Phase 3 for reactor core cooling and heat removal as was used during Phase 2. Additionally, a reverse osmosis/ion exchanger water processing system will be provided from the NSRC to provide a method to remove impurities from alternate fresh water supplies to the TDAFW pump and the BDB AFW pumps.

Based on the design of the ECST, SW reservoir, and Lake Anna as described in the FIP and UFSAR, the licensee should an indefinite water source available during the Phase 3 core cooling strategies for SG inventory makeup, consistent with NEI 12-06, Section 3.2.1.3.

3.10.2 Reactor Coolant System Make-Up

Phase 1

In its FIP, the licensee stated that in general, the FLEX strategy for RCS inventory control/reactivity management relies on RCP seal leakage being sufficiently low for initial control of RCS inventory, isolation of the RCS as directed by the emergency procedure, and cooldown limitations to limit reactivity addition. With these controls in place, no RCS makeup or boration is required for the first 17 hours of an ELAP/LUHS event, at which point reflux cooling is conservatively assumed to occur in the RCS. The RCS makeup and boration will be initiated within 16 hours of the event, during Phase 2, to prevent the entry into reflux cooling.

The licensee indicated in its FIP that the emergency procedure also directs the operators to minimize RCS inventory loss through potential RCS letdown paths by closing or verifying closed RCS letdown isolation valves, pressurizer PORVs, excess letdown valves, RCS sample valves, loop drain valves, reactor vent valves, pressurizer vent valves, and RCP seal injection/return valves.

Therefore, the Phase 1 strategy for ensuring adequate RCS inventory and reactivity control consists of performing the RCS letdown path isolations directed by the emergency response procedures and cooling down to a SG pressure of 290 psig (approximately corresponding to a core inlet temperature of 419°F).

If implemented appropriately and consistent with the FIP, the licensee's approach should conserve RCS inventory to preclude the necessity for RCS system makeup during Phase 1.

Phase 2

The licensee stated in its FIP that during Phase 2, the primary supply of borated water for RCS injection will be from the RWST via quench spray supply piping to the suction of a portable diesel-driven BDB RCS injection pump. During normal power operation, each RWST has a minimum Technical Specification volume of 466,200 gallons of borated water at a concentration between 2600 and 2800 ppm. The RWST is the preferred borated water source and each unit's RWST is capable of supplying RCS makeup to the other unit by use of a BDB RCS injection pump. However, according to NAPS UFSAR, Table 3.2-1, each unit's RWST is Seismic Category 1 but not protected from tornado missiles. If both RWSTs are damaged by tornado missiles, the licensee can provide RCS makeup by use of portable boric acid mixing tanks, which are stored in the protected BDB storage building. The tank is used to mix dilution water via a hose connected to the BDB AFW pump or BDB high capacity pump providing water from the SW reservoir or Lake Anna with bags of powdered boric acid. The SW reservoir is impounded by a Seismic Category 1 (NAPS UFSAR, Table 3.2-1) earthen structure and provides approximately 22.5 million gallons of useable water. Lake Anna is maintained by a seismically-qualified dam and provides an indefinite source of water.

Based on the design of the RWST, SW reservoir, and Lake Anna and the storage location of the boric acid mixing tanks, as described in the FIP and UFSAR, the licensee should have water sources available during the Phase 2 core cooling strategies for RCS makeup, consistent with

NEI 12-06, Section 3.2.1.3.

Phase 3

The licensee indicated in its FIP that the same water sources would be utilized during Phase 3 for RCS injection as was used during Phase 2. Additionally, a reverse osmosis/ion exchanger water processing system will be provided from the NSRC to provide a method to remove impurities from alternate fresh water supplies to the BDB RCS injection pumps.

Based on the design of the RWST, SW reservoir, Lake Anna, and the storage location of the boric acid mixing tanks, as described in the FIP and UFSAR, the licensee should have an indefinite water source available during the Phase 3 core cooling strategies for RCS makeup, consistent with NEI 12-06, Section 3.2.1.3.

3.10.3 Spent Fuel Pool Make-Up

The licensee stated in its FIP that any water source available is acceptable for use as makeup to the SFP; however, the primary source would be from Lake Anna via the BDB high capacity pump or the SW reservoir via the DDFP. Water quality is not a significant concern for makeup to the SFP. Likewise, boration is not a concern since boron is not being removed from the SFP when boiling. The SW reservoir is impounded by a Seismic Category 1 (NAPS UFSAR, Table 3.2-1) earthen structure and provides approximately 22.5 million gallons of useable water. Lake Anna is maintained by a seismically-qualified dam and provides an indefinite source of water.

Based on the design of the SW reservoir and Lake Anna, as described in the FIP and UFSAR, the licensee should have an indefinite water source available during Phases 1, 2, and 3 for SFP makeup and cooling, consistent with NEI 12-06, Section 3.2.1.3.

3.10.4 Containment Cooling

The licensee indicated in its FIP that the water source for restoration of containment cooling would be from the CC system and SW system (repowering pumps) or from the SW reservoir using the DDFP. The SW reservoir is impounded by a Seismic Category 1 (NAPS UFSAR, Table 3.2-1) earthen structure and provides approximately 22.5 million gallons of useable water. If needed, makeup can be provided to the SW reservoir via a high capacity pump from the NSRC, which can also be used to deliver water directly to the SW system from the SW reservoir or Lake Anna. In addition, water for spray is available using clean water from the casing cooling tank and the RWST if available.

Based on the design of the SW reservoir, and Lake Anna, as described in the FIP and UFSAR, the licensee should have an indefinite water source available during the Phase 3 for containment cooling, consistent with NEI 12-06, Section 3.2.1.3.

3.10.5 Conclusion

Based on the above, if FLEX strategies are implemented appropriately and consistent with the FIP, the licensee should have water sources available for SG makeup, RCS makeup, SFP makeup, and containment cooling during an ELAP following a BDBEE consistent with NEI 12-06 guidance, as endorsed by JLD-ISG-2012-01, and 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 a BDBEE occurring during power operations. This is appropriate, as plants typically operate at power for 90 percent or more of the year. When the BDBEE occurs with the plant at power, the mitigation strategy initially focuses on the use of a pump coupled to a steam-powered turbine 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 pressure vessel (RPV) and placed in the SFP, there may be a shorter timeline to implement the makeup of water to the SFP. However, this is balanced by the fact that if immediate cooling is not required for the fuel in the reactor vessel, the operators can concentrate on providing makeup to the SFP. The licensee's analysis shows that following a full core offload to the SFP, about 43 hours are available to implement makeup prior to boil off to a level 10 feet above the top of the fuel, and the licensee has stated that they have the ability to implement makeup to the SFP within that time.

When a plant is in a shutdown mode in which steam is not available to operate the TDAFW pump (which typically occurs when the RCS has been cooled below about 300 °F), another strategy must be used for decay heat removal. On September 18, 2013, NEI submitted to the NRC a position paper entitled "Shutdown/Refueling Modes" (ADAMS Accession No. ML13273A514), which described methods to ensure plant safety in those shutdown modes. By letter dated September 30, 2013 (ADAMS Accession No. ML13267A382), the NRC staff endorsed this position paper as a means of meeting the requirements of the order. On December 8, 2014, Dominion submitted a compliance letter for North Anna, Unit 2 (ADAMS Accession No. ML14349A320), which stated that North Anna Power Station will abide by the NEI position paper entitled "Shutdown / Refueling Modes."

The position paper provides guidance to licensees for meeting the requirements of the order to be able to implement appropriate strategies in all modes. This is done by incorporating FLEX equipment in the existing plant process to manage safety functions when in shutdown modes. Considerations in the shutdown safety process include maintaining necessary FLEX equipment readily available and potentially pre-deploying/pre-staging equipment to support maintaining or restoring key safety functions in the event of a loss of shutdown cooling. The NRC staff concludes that the position paper provides an acceptable approach for demonstrating that the licensees are capable of implementing mitigating strategies in shutdown and refueling modes of operation.

In addition to the position paper requirements, the licensee developed specific core cooling strategies for Modes 5 and 6, as described in the FIP. Should an ELAP occur in this window, the immediate response to a loss of shutdown cooling will be to dispatch an operator to initiate gravity feed to the RCS cold legs from the outage unit's RWST. Unit shutdown procedures require the pre-deployment of a BDB AFW pump with supply and discharge hoses to serve as a low pressure RCS Injection pump, which will provide a means to establish forced feed of borated water to the RCS cold legs from the RWST during an ELAP event with a unit in either Modes 5 or 6. When forced RCS injection is established by the BDB AFW pump, gravity feed to the RCS cold legs will no longer be necessary.

The licensee states in its FIP that the RWST is not protected from all hazards (i.e., tornado missiles). If a tornado missile damages the RWST, procedures will direct the operators to use the opposite unit's RWST. If both RWSTs are damaged, the procedures will direct injection of available clean water sources in the order specified in Table 3 of the FIP. In this case, the flowrate will be reduced to match the boil-off rate of the RCS to minimize dilution of the RCS when adding unborated water. The water supply from the ECST would be available following a tornado event, thus providing a method for restoring core cooling for all hazards during Modes 5 and 6. Direction is also provided for operators to evacuate and establish closure of containment, and operate the containment purge system to prevent containment overpressurization during this event.

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

3.12 Procedures and Training

Procedures

The licensee stated in its FIP that the inability to predict actual plant conditions that require the use of BDB equipment makes it impossible to provide specific procedural guidance. As such, the FLEX Support Guidelines (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 BDB external event conditions, and are not used inappropriately in lieu of existing procedures. When BDB equipment is needed to supplement EOPs or abnormal procedures (APs) strategies, the EOP or AP directs the entry into and exit from the appropriate FSG procedure.

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

The licensee stated in its FIP that procedural interfaces have been 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 the following APs to include appropriate reference to FSGs:

- 0-AP-27, "Malfunction of Spent Fuel Pit System"
- 0-AP-10, "Loss of Electrical Power"
- 0-AP-11, "Loss of Residual Heat Removal (RHR)"

The licensee stated in its FIP that a new abnormal procedure, 0-AP-10.1, "Loss of All AC Power While on RHR," was prepared to provide the command and control function for the ELAP while on RHR, since ECA-0.0 does not apply in this operating mode.

The licensee stated in its FIP that FSGs have been reviewed and validated by the involved groups to the extent necessary to ensure that implementation of the associated FLEX strategy is feasible. Specific FSG validation was accomplished via table top evaluations and walk-throughs of the guidelines when appropriate.

Training

The licensee stated in its FIP that the Nuclear Training Program has been revised to assure personnel proficiency in utilizing FSGs and associated BDB equipment for the mitigation of BDB external events is adequate and maintained. These programs and controls were developed and have been implemented in accordance with the Systematic Approach to Training (SAT) Process.

The licensee stated in its FIP 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 the FLEX mitigation strategies for BDB external events have received the necessary training to ensure familiarity with the associated tasks, considering available job aids, instructions, and mitigation strategy time constraints. Care has been taken to not give undue weight (in comparison with other training requirements) to operator training for BDB external event accident mitigation. The testing/evaluation of operator knowledge and skills in this area has been similarly weighted.

The licensee stated in its FIP that in accordance with Section 11.6 of NEI 12-06, "ANSI/ANS [American Nation Standards Institute/American Nuclear Society] 3.5, Nuclear Power Plant Simulators for use in Operator Training," certification of simulator fidelity is considered to be sufficient for the initial stages of the BDB external event scenario until the current capability of the simulator model is exceeded. Full scope simulator models will not be upgraded to accommodate FLEX training or drills.

Conclusions

The NRC staff finds that the licensee has adequately addressed the procedures and training associated with FLEX because the procedures have been issued 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

The licensee stated in its FIP that initial component level testing, consisting of factory acceptance testing and site acceptance testing, was conducted to ensure the portable FLEX equipment can perform its required FLEX strategy design functions. The portable equipment that directly performs a FLEX mitigation strategy for the core cooling, containment, or SFP cooling is subject to periodic maintenance and testing in accordance with NEI 12-06 and INPO AP 913, "Equipment Reliability Process," to verify proper function. Additional FLEX support equipment that requires maintenance and testing will have preventive maintenance to ensure it will perform its required functions during a BDB external event.

As a generic issue, NEI submitted a paper dated October 3, 2013 (ADAMS Accession No. ML13276A573), which included EPRI Technical Report 3002000623, "Nuclear Maintenance Applications Center: Preventive Maintenance Basis for FLEX Equipment." By letter dated October 7, 2013, 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. Preventative maintenance (PM) templates for the major FLEX equipment including the portable diesel pumps and generators have also been issued.

The PM templates include activities such as:

- Periodic Static Inspections - Monthly walkdown
- Fluid analysis – Annually
- Periodic operational verifications
- Periodic performance tests

The licensee stated in its FIP that PM procedures and test procedures are based on the templates contained within the EPRI Preventive Maintenance Basis Database, or from manufacturer provided information/recommendations when templates were not available from EPRI. The corresponding maintenance strategies were developed and documented. The performance of the PMs and test procedures are controlled through the site work order process. FLEX support equipment not falling under the scope of Institute of Nuclear Power Operations (INPO) AP 913 will be maintained as necessary to ensure continued reliability. Performance verification testing of FLEX equipment is scheduled and performed as part of the Dominion PM process. A fleet procedure was established to ensure the unavailability of equipment and applicable connections that directly perform a FLEX mitigation strategy for core cooling, containment, and SFP cooling will be managed such that risk to mitigation strategy capability is minimized. Maintenance/risk guidance conforms to the guidance of NEI 12-06 as follows:

- Portable FLEX equipment may be unavailable for 90 days provided that the site FLEX capability (N) is available.
- If portable equipment becomes unavailable such that the site FLEX capability (N) is not maintained, initiate actions within 24 hours to restore the site FLEX capability (N) and implement compensatory measures (e.g., use of alternate suitable equipment or supplemental personnel) within 72 hours.

3.14 Alternatives to NEI 12-06, Revision 0

As discussed in Section 3.6.1, in a supplemental letter dated July 2, 2015 (ADAMS Accession No. ML15194A060), the licensee provided clarification on the storage of the 50.54(hh)(2) pump. The 50.54(hh)(2) pump is used as a backup (N+1 equipment) to the BDB high capacity pump. The licensee identified that Warehouse 10, where the pump is stored, is vulnerable to seismic and high wind tornado and hurricane events. As such, the requirements of NEI 12-06 Sections 7.3.1 and 5.3.1 are not met, and the requirements of Section 11.3.3 will also not be met if one protected BDB high capacity pump is unavailable. The licensee acknowledged that the storage of this pump in a non-robust structure represents an alternative to the requirements of NEI 12-06, Sections 5.3.1, 7.3.1, and 11.3.3.

Accordingly, Dominion has implemented compensatory actions to support this alternative approach for stored BDB equipment. As stated in the letter, the unavailability requirements for FLEX equipment are prescribed by Dominion Fleet procedure ADM-CM-AA-BDB-102 and includes additional requirements to address the storage capability of FLEX equipment that is not fully protected. Specifically, the required FLEX equipment may be unavailable for 90 days provided that the site FLEX capability (N) is met. If the site FLEX (N) capability is met but not fully protected for the site's applicable hazards, the allowed unavailability is reduced to 45 days. Additionally, ADM-CM-AA-BDB-102 provides appropriate guidance for reasonable protection during forecast adverse external conditions as follows. Specifically, if FLEX equipment is likely to be unavailable during forecast site specific external events (e.g., hurricane), then appropriate compensatory measures should be taken to restore equivalent capability in advance of the event." Abnormal Procedure, 0-AP-41, "Severe Weather Conditions," accommodates this requirement as it invokes an evaluation of the availability of BDB equipment, which includes the 50.54(hh)(2) pump, upon approaching severe weather.

Additionally, the licensee stated in Section 2.18.6 of its FIP that in the case of hoses and cables associated with FLEX equipment required for FLEX strategies, an alternate approach to meet the N+1 capability has been selected. These hoses and cables are passive components being stored in a protected facility. The +1 capability is accomplished by having sufficient hoses and cables to satisfy the N capability + 10 percent spares or at least 1 backup for the longest length of hose and cable. This 10 percent margin capability ensures that failure of any one of these passive components would not prevent the successful deployment of a FLEX strategy. The staff endorsed this approach by letter dated May 18, 2015 (ADAMS Accession No. ML15125A442). In the letter, the staff agreed that damage to all sections of FLEX hose and cable for a single unit during storage or deployment is unlikely. Therefore, the proposed alternate method described is reasonable.

The NRC staff finds that although the guidance of NEI 12-06 has not been met for storage of the 50.54(hh)(2) pump, if these alternatives are implemented as described by the licensee, they will meet the requirements of the order.

3.15 Conclusions for Order EA-12-049

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

4.0 TECHNICAL EVALUATION OF ORDER EA-12-051

By letter dated February 28, 2013 (ADAMS Accession No. ML13063A017), the licensee submitted its OIP for North Anna in response to Order EA-12-051. By e-mail dated May 28, 2013 (ADAMS Accession No. ML13177A194), the NRC staff sent a Request for Additional Information (RAI) to the licensee. The licensee provided a response by letter dated July 2, 2013 (ADAMS Accession No. ML13190A310). By letter dated November 1, 2013 (ADAMS Accession No. ML13281A648), the NRC staff issued an Interim Staff Evaluation and RAI to the licensee. By letter dated September 24, 2014 (ADAMS Accession No. ML14259A458), the NRC issued an audit report on the licensee's progress.

By letters dated August 23, 2013 (ADAMS Accession No. ML13242A015), February 27, 2014 (ADAMS Accession No. ML14069A009), August 26, 2014 (ADAMS Accession No. ML14245A401), the licensee submitted status reports for the OIP. The OIP 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 December 3, 2014 (ADAMS Accession No. ML14342B005), 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, LLC. The NRC staff reviewed the vendor's SFP level instrumentation system design specifications, calculations and analyses, test plans, and test reports. The staff issued a vendor audit report on August 18, 2014 (ADAMS Accession No. ML14211A346).

4.1 Levels of Required Monitoring

Attachment 2 of Order EA-12-051 states in part:

> All licensees identified in Attachment 1 to this Order shall have a reliable indication of the water level in associated spent fuel storage pools capable of supporting identification of the following pool water level conditions by trained personnel: (1) level that is adequate to support operation of the normal fuel pool cooling system [Level 1], (2) level that is adequate to provide substantial radiation shielding for a person standing on the SFP operating deck [Level 2], and (3) level where fuel remains covered and actions to implement make-up water addition should no longer be deferred [Level 3].

In its letter dated February 27, 2014, the licensee provided clarification on the proposed Level 1. The licensee stated that the correct elevation associated with Level 1 is 286.6 ft., as provided in calculation MISC-11798, "Dominion Fleet Spent Fuel Pool Levels to Provide Adequate NPSH [net positive suction head] to the Cooling Pumps with a Saturday Pool," Rev. 0. In its OIP, the licensee stated that the elevation associated with Level 2 is 274 ft. 2 in., which corresponds to approximately 10 ft. above the top of the SFP fuel storage rack. The licensee designated Level 3 at an elevation of 264 ft. 2 in., above the highest point of any spent fuel storage rack seated in the SFP. In its letter dated July 2, 2013, the licensee provided a figure of the SFP with the approximate locations identified as Levels 1, 2, and 3, consistent with the licensee's proposed elevations. The licensee later revised the levels. The NRC staff noted that Revision 1 of MISC-11798 redefined Level 1 as 289 ft. 4 in. and the licensee redefined Level 2 as 274 ft. 5 in. and Level 3 as 265 ft. 5 in. (1 foot above the spent fuel racks) (Reference 5).

Based on the discussion above, the NRC staff finds that, if implemented appropriately, the licensee's proposed Levels 1, 2, and 3 are consistent with NEI 12-02 guidance, as endorsed by JLD-ISG-2012-03, and adequately address the requirements of the order.

4.2 Evaluation of Design Features

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

4.2.1 Design Features: Instruments

In its OIP, the licensee stated that the spent fuel is stored in the SFP in the fuel building, which is shared by Units 1 and 2. The primary and back-up channels will use guided wave radar (GWR) based level measurement technology based on the time domain reflectometry principal. The licensee also stated that the channels will use a fixed instrument providing continuous level measurement over the entire range. The instruments will provide primary and backup level indication over the entire span of the SFP from the top of the fuel racks (264'5") to the normal operating level of 289'10" (Reference 5).

Based on the discussion above, the NRC staff finds that, if implemented appropriately, the licensee's proposed design, with respect to the number of channels and measurement range for its SFP, is consistent with NEI 12-02 guidance, as endorsed by JLD-ISG-2012-03, and adequately addresses the requirements of the order.

4.2.2 Design Features: Arrangement

In its OIP, the licensee stated that the primary and back-up channel level sensor probes will be installed on opposite sides of the SFP to maintain adequate channel separation. The primary instrument channel level sensing components will be located on the east wall of the SFP and the back-up instrument channel level sensing components will be located in the southwest corner of the SFP. The licensee also stated that existing barriers and physical separation will be used to provide a level of protection for the sensor and interconnecting cable. These physical barriers will protect the instrument sensors and cables from potential missiles generated by an event. The licensee also stated that the final sensor mounting design and cable routing will maintain a low profile to ensure that there is no interference with the existing fuel handling equipment.

In its letter dated February 27, 2014, the licensee provided a plan view sketch of the SFP area depicting the SFP inside dimensions, planned locations/placement of the primary and back-up level sensors, and the proposed routing of cables that extend from the sensors to the location of the electronics.

During the onsite audit visit, the NRC staff walked down the SFP area and the primary and back-up cable route. The walkdown started at the MCR, where licensee staff indicated the locations for the SFPI display cabinet, the electrical power sources, and the connections for the displays. From the MCR, the staff visited the cable spreading room and then the SFP area which is the proposed location for the SFPI sensor probe and the exit point from the SFP area to the auxiliary building.

The NRC staff noted that there is sufficient channel separation within the SFP area between the primary and back-up level instruments, sensor electronics, and routing cables to provide reasonable protection against loss of indication of SFP level due to missiles that may result from damage to the structure over the SFP.

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

4.2.3 Design Features: Mounting

In its letter dated February 27, 2014, the licensee stated that the mounting device (mounting bracket) for the SFPI is designated as Quality Classification NSQ (non-safety-related, with special quality requirements) in accordance with the Dominion Nuclear Quality Assurance Program. The licensee also stated that the mounting bracket design will meet the NAPS design and licensing basis requirements for seismic Category I components. The analysis method that will be used to qualify the mounting bracket for the loading conditions will include the design basis maximum seismic loads and the hydrodynamic loads that could result from pool sloshing.

During the onsite audit, the staff walked down the proposed location for the mounting brackets on the east and west ends on the refueling deck. The licensee showed the NRC staff the location (indicated by a mark-up on the refueling floor) where the base of the mounting bracket and anchor bolts on the east end would be located. The staff reviewed licensee documentation and drawings describing the mounting bracket and anchor bolt dimensions, materials, and the seismic and hydrodynamic loads applicable to the mounting bracket configuration. As part of the audit, the staff reviewed calculation, CEM-0139, "Mounting details for Spent Fuel Pool Monitoring," Rev. 0; CN-PEUS-14-3, "Seismic Analysis of the Spent Fuel Pool Mounting Bracket for Surry Power Station, Millstone Power station Unit 3 & North Anna Power Station," Rev. 1; drawing 10121079, "North Anna Spent Fuel Pool Instrumentation System Level Sensor Assembly," Rev .1, sheets 1, 3 and 4; drawing 10121079, "North Ana Spent Fuel Pool Instrumentation System Level Sensor Assembly," Rev. 0, sheet 2; and drawing 10067E16, "North Anna, Surry and Millstone Unit 3 Nuclear Generating Stations Spent Fuel Pool Mounting Bracket Plan, Sections, and Details," Rev. 2.

Based on the discussion above, the NRC staff finds that, if implemented appropriately, the licensee's proposed mounting design is consistent with NEI 12-02 guidance, as endorsed by JLD-ISG-2012-03, and adequately addresses 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.

In its OIP, the licensee stated that augmented quality requirements consistent with NEI 12-02, Appendix A-1, will be applied to this project.

If implemented appropriately, this approach is consistent with NEI 12-02 guidance, as endorsed by JLD-ISG-2012-03 and adequately addresses the requirements of the order.

4.2.4.2 Instrument Channel Reliability

NEI 12-02 states:

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

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

During the Westinghouse, LLC audit, the NRC staff reviewed vendor documents associated with testing conducted to demonstrate equipment reliability under BDB conditions. The staff reviewed the test results related to environmental qualification for the coaxial cable, probe, coupler, and pool-side bracket located inside the SFP area and outside where the level sensor electronics, sensor electronics bracket, indicators, and the electronics enclosure will be located. The staff included a summary of the SFPI environmental qualification and reliability design documents reviewed in the audit report dated August 18, 2014.

By letter dated February 27, 2014, the licensee provided its evaluation of the BDB environmental conditions at the site areas where the SFPI will be located. The NRC staff reviewed the licensee's dose rate analysis, RA-0048, "Radiological Evaluation following Beyond Design Basis NAPS SFP Draindown for NEI 12-02," Rev. 0. The staff also reviewed the room temperatures and humidity which were analyzed utilizing GOTHIC computational code and the results documented in calculation NA-CALC-MEC-ME-0972, "Evaluation of Room Air Temperatures Following Extended Loss of AC Power (ELAP)," Rev. 0. The SFPI displays, control box, and uninterruptable power supplies (UPS) are located in the MCR where habitability will be maintained as part of the FLEX strategies and, therefore, will not be subject to excessive environmental conditions.

The Westinghouse, LLC SFPI sensor consists of a stainless steel braided cable probe attached to a permanently installed mounting bracket anchored to the SFP deck. The probes will not be subject to shock and vibration loading conditions other than those induced by seismic motions. Seismic testing and analysis was conducted by Westinghouse, LLC. The test strategy included seismic response spectra that envelope the design basis maximum seismic loads and included applicable hydrodynamic loading that could result from conditions such as seismic-induced sloshing effects. In accordance with Westinghouse document WNA-PT-00188-GEN, "Spent Fuel Pool Instrumentation System (SFPIS) Standard Product Test Strategy," Rev. 1, the seismic adequacy of the SFPI equipment was demonstrated following the applicable guidance in Sections 7, 8, 9, and 10 of Institute of Electrical and Electronics Engineers (IEEE) Standard 344-2001, "IEEE Recommended Practice for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations."

The NRC staff notes that the SFPI, as designed, will envelope the environmental conditions for the SFPI installed locations for all the instrument components.

Based on the discussion above, the NRC staff finds that, if implemented appropriately, the licensee's proposed instrument qualification process is consistent with NEI 12-02 guidance, as endorsed by JLD-ISG-2012-03, and adequately addresses the requirements of the order.

4.2.5 Design Features: Independence

The primary and back-up channel level sensor probes are installed on opposite sides of the SFP to maintain adequate channel separation. During the onsite audit visit, the NRC staff walked down the SFP area and the route for the primary and back-up cables. The walkdown started at the MCR where licensee staff indicated the locations for the SFPI display cabinets, the electrical power sources, and the connections for the displays. The NRC staff walked the complete cable routing from the SFP to the MCR for the primary and back-up SFPI. Additionally, each instrument channel is normally powered by 120 Vac distribution panels powered by different 480 Vac buses to support continuous monitoring of the SFP level.

Based on the discussion above, the NRC staff finds that, if implemented appropriately, the licensee's proposed design, with respect to instrument channel independence, is consistent with NEI 12-02 guidance, as endorsed by JLD-ISG-2012-03, and adequately addresses the requirements of the order.

4.2.6 Design Features: Power Supplies

In its letter dated February 27, 2014, the licensee stated that each SFPI instrument channel is normally powered by 120 Vac distribution panels powered by different 480 Vac buses. On loss of normal 120 Vac power, each channel is equipped with a separate UPS that will automatically transfer to a dedicated 72-hour back-up battery. If normal power is restored, then the instrument channels will automatically transfer back to the normal 120 Vac power source. Westinghouse, LLC document WNA-CN-00300-GEN, "Spent Fuel Pool Instrumentation System Power Consumption Calculation," Rev. 0 concluded that with an initial full charge, the battery will maintain the level indication function without ac power for 101.21 hours (approximately 4 days). The licensee also stated in its letter dated February 27, 2014 that, with an additional remote display connected to the SFPI, the battery can maintain the level indication function for 3 days. The backup batteries are maintained in a charged state by the associated UPS.

During the onsite audit, the NRC staff reviewed the SFPI loop diagrams and observed the locations of the display cabinets, normal and auxiliary power sources and cable routing.

Based on the discussion above, the NRC staff finds that, if implemented appropriately, the licensee's proposed power supply design is consistent with NEI 12-02 guidance, as endorsed by JLD-ISG-2012-03, and adequately addresses the requirements of the order.

4.2.7 Design Features: Accuracy

Westinghouse, LLC performed the analysis to evaluate the accuracy of the SFPI. During the vendor audit, the NRC staff reviewed documents, WNA-CN-00301-GEN, "Spent Fuel Pool Instrumentation System Channel Accuracy Analysis," Rev. 0, which provides the SFPI channel accuracy analysis and WNA-DS-02957-GEN, "Spent Fuel Pool Instrumentation System Design Specification," Rev. 2, which provides the required display accuracy of the level indication as within ± 3 in. of the entire range. The test results documented in Westinghouse, LLC document EQ-QR-269, "Westinghouse Design Verification Testing Summary Report," Rev. 0, concluded that the channels retained the design accuracy at the completion of each test including loss of power and subsequent restoration of power. The staff included a summary of the SFPI accuracy evaluation and documents reviewed in the audit report dated August 18, 2014.

Based on the discussion above, the NRC staff finds that, if implemented appropriately, the licensee's proposed instrument accuracy is consistent with NEI 12-02 guidance, as endorsed by JLD-ISG-2012-03, and adequately addresses the requirements of the order.

4.2.8 Design Features: Testing

In its letter dated July 2, 2013, the licensee indicated that calibration of the SFPI will be performed in-situ. In-situ calibration is performed at the transmitter enclosure using internal displays. The GWR determines pool depth by measuring the time of flight of a pulse from the transmitter to the water interface and back to the transmitter's receiver. A calibration device, provided by the Westinghouse, LLC, incorporates time of flight delays equal to various pool levels. The device is connected to the transmitter and is exercised for each level. Following calibration certification, the depth indication for both pool level sensors is compared as a final functional check of the level measurement capabilities. The two independent channels of the SFPI will be cross-checked against each other. Since the two wide range level channels are independent, a channel check tolerance based on the design accuracy of each channel will be applied for cross comparison between the two channels.

During the Westinghouse, LLC audit the NRC staff reviewed document WNA-TP-04709-GEN, "Calibration Procedure," Rev. 3, which describes the two types of SFPI bracket designs and their method for calibration. By letter dated February 27, 2014, the licensee stated that calibration checks are intended to be performed within 60 days of a planned refueling outage, but not more frequently than once per 12 months. The licensee will use WNA-TP-04709-GEN, which specifies the allowed deviation from the instrument channel required accuracy that initiates a required adjustment to within the normal condition design accuracy. This procedure also provides the instructions for routine calibration of the SFPI to ensure that instrument performance is consistent with accuracy requirements during operation.

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

4.2.9 Design Features: Display

Section 3.9 of NEI 12-02 states that the intent of the guidance is to ensure that information is promptly available to the plant staff and decision makers. Ideally, there will be an indication from at least one channel of instrumentation in the MCR.

By letter dated August 23, 2013, the licensee stated that the display units would be located within the boundary of the MCR. During the onsite audit, the NRC staff visited the MCR where the licensee indicated the locations for the SFPI display cabinets, the electrical power sources, and connections for the display; all within the MCR envelope.

Based on the discussion above, the NRC staff finds that, if implemented appropriately, the licensee's proposed location and design of the SFP instrumentation displays is consistent with NEI 12-02 guidance, as endorsed by JLD-ISG-2012-03, and adequately addresses 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 SFPI.

4.3.1 Programmatic Controls: Training

Guidance document NEI 12-02 specifically addresses the use of SAT for training personnel in the use and the provision of alternate power to the primary and backup SFP instrument channels. In its OIP, the licensee indicated that the SAT will be used to identify the population to be trained and to determine both the initial and continuing elements of the required training.

During the onsite audit, the NRC staff met with the licensee staff and discussed Dominion's SAT program as it applies to FLEX and SFPI. The NRC staff reviewed administrative procedures and observed a portion of the FSG training class to North Anna non-licensed operators. The staff also inquired about operator training related to testing and calibration of new technology and/or components at the site such as the SFPI. The licensee indicated that North Anna personnel visited the SFPI vendor facility to witness and train on the processes for operation, testing, and calibration of the SFPI and development of testing and calibration procedures.

Based on the discussion above, the NRC staff finds that, if implemented appropriately, the licensee's proposed plan to train personnel in the use and the provision of alternate power to the primary and backup instrument channels, including the approach to identify the population to be trained is consistent with NEI 12-02 guidance, as endorsed by JLD-ISG-2012-03, and adequately addresses the requirements of the order.

4.3.2 Programmatic Controls: Procedures

In its letter dated February 27, 2014, the licensee stated that site-specific procedures would be developed for system inspection, calibration and test, maintenance, repair, operation, and normal and abnormal responses in accordance with NAPS procedural controls and will be based on recommended operation and maintenance procedures provided by Westinghouse, LLC. The licensee also provided a list of the procedures that will govern the use of the SFPI. The list included procedures for system inspection, calibration and testing, maintenance, repair, operation, and FSGs. Additionally, the licensee stated that preventive maintenance procedures to include tests, inspection, and periodic replacement of the backup batteries will be developed based on Westinghouse, LLC's recommendations.

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

4.3.3 Programmatic Controls: Testing and Calibration

In its letter dated February 27, 2014, the licensee indicated that consistent with the guidance provided in NEI 12-02, Section 4.3, the periodic calibration verification will be performed within 60 days of a refueling outage considering normal testing scheduling allowances (e.g. 25 percent). Calibration verification will not be required to be performed more than once per 12 months. The licensee also stated that if the plant staff determined a need to confirm the two channels are performing as expected, the two channels may be read in the MCR. While the SFP is operating within the design parameters and at normal level, the indicators may be compared to fixed marks within the SFP by visual observation to confirm indicated level.

Provisions associated with out of service (OOS) or non-functional equipment including allowed outage times and compensatory actions will also be consistent with the guidance provided in Section 4.3 of NEI 12-02. If one OOS channel cannot be restored to service within 90 days, appropriate compensatory actions, including the use of alternate suitable equipment, will be taken. If both channels become OOS, actions would be initiated within 24 hours to restore one of the channels to operable status and to implement appropriate compensatory actions, including the use of alternate suitable equipment and/or supplemental personnel, within 72 hours. The licensee stated that NAPS will maintain sufficient spare parts for the SFPI, taking into account the lead time and availability of spare parts, in order to expedite maintenance activities, when necessary, to provide assurance that a channel can be restored to service within 90 days. Additionally, if both channels are OOS, a condition report will be initiated and addressed through the Dominion's corrective action program.

Based on the discussion above, the NRC staff finds that, if implemented appropriately, the licensee's proposed testing and calibration plan is consistent with NEI 12-02 guidance, as endorsed by JLD-ISG-2012-03, and adequately addresses the requirements of the order.

4.4 Conclusions for Order EA-12-051

By letter dated February 28, 2013, 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 North Anna Power Station according to the licensee's proposed design, it should adequately address the requirements of Order EA-12-051.

5.0 CONCLUSION

In August 2013, the NRC staff started audits of the licensee's progress on these two orders. The staff conducted an onsite audit in May 2014. The licensee reached its final compliance date for Order EA-12-051 on October 8, 2014, and for Order EA-12-049 on March 27, 2015, and has declared that both of the NAPS reactors are in compliance with the orders. The purpose of this safety evaluation is to document the strategies and implementation features that the licensee has committed to and which NRC staff has evaluated to be satisfactory for compliance with these orders. 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. Based on the evaluations above, the NRC staff concludes that the licensee has developed guidance and proposed designs which, if implemented appropriately, will adequately address the requirements of Orders EA-12-049 and EA-12-051.

6.0 ADDITIONAL REFERENCES

1. ETE-NAF-2012-0150, "Evaluation of Core Cooling Coping for Extended Loss of AC Power (ELAP) and Proposed Input for Dominion's Response to NRC Order EA-12-049 for Dominion Fleet," Rev. 3

2. ETE-CPR-2015-1005, "Evaluation of RCP No. 1 Seal Leakoff Line for Potential Over-Pressure Conditions during an ELAP," Rev. 0

3. VRA-15-17, "Dominion Generation North Anna Units 1 and 2 – Surry Units 1 and 2 Transmittal of TB-1 'Reactor Coolant System Temperature and Pressure Limits for the No. 2 Reactor Coolant Pump Seal,'" March 17, 2015

4. ETE-CPR-2014-1004, "North Anna Power Station Beyond Design Basis FLEX Validation for Time Sensitive Actions (TSAs)," Rev. 0

5. ETE-CPR-2012-0012, "Beyond Design Basis – FLEX Strategy Basis Document and Final Integrated Plan," Rev. 8

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Sincerely,

/RA/

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Japan Lessons-Learned Division
Office of Nuclear Reactor Regulation

Docket Nos.: 50-338 and 50-339

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