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

June 21, 2019

Mr. Mano Nazar
President and Chief
Nuclear Officer
Nuclear Division
NextEra Energy Duane Arnold, LLC
Mail Stop: NT3/JW
15430 Endeavor Drive
Jupiter, FL 33478

SUBJECT: DUANE ARNOLD ENERGY CENTER – SAFETY EVALUATION REGARDING IMPLEMENTATION OF HARDENED CONTAINMENT VENTS CAPABLE OF OPERATION UNDER SEVERE ACCIDENT CONDITIONS RELATED TO ORDER EA-13-109 (CAC NO. MF4391; EPID NO. L-2014-JLD-0039)

Dear Mr. Nazar:

On June 6, 2013 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML13143A334), the U.S. Nuclear Regulatory Commission (NRC) issued Order EA-13-109, "Order to Modify Licenses with Regard to Reliable Hardened Containment Vents Capable of Operation Under Severe Accident Conditions," to all Boiling Water Reactor (BWR) licensees with Mark I and Mark II primary containments. The order requirements are provided in Attachment 2 to the order and are divided into two parts to allow for a phased approach to implementation. The order required each licensee to submit an Overall Integrated Plan (OIP) for review that describes how compliance with the requirements for both phases of Order EA-13-109 would be achieved.

By letter dated June 25, 2014 (ADAMS Accession No. ML14182A423), NextEra Energy Duane Arnold, LLC (NextEra, the licensee) submitted its Phase 1 OIP for Duane Arnold Energy Center (DAEC, Duane Arnold) in response to Order EA-13-109. At 6-month intervals following the submittal of the Phase 1 OIP, the licensee submitted status reports on its progress in complying with Order EA-13-109 at Duane Arnold, including the combined Phase 1 and Phase 2 OIP in its letter dated December 22, 2015 (ADAMS Accession No. ML15358A043). These status reports were required by the order and are listed in the enclosed safety evaluation. By letters dated May 27, 2014 (ADAMS Accession No. ML14126A545), and August 10, 2017 (ADAMS Accession No. ML17220A328), the NRC notified all BWR Mark I and Mark II licensees that the staff will be conducting audits of their implementation of Order EA-13-109 in accordance with NRC Office of Nuclear Reactor Regulation (NRR) Office Instruction LIC-111, "Regulatory Audits" (ADAMS Accession No. ML082900195). By letters dated February 11, 2015 (Phase 1) (ADAMS Accession No. ML15006A319), September 13, 2016 (Phase 2) (ADAMS Accession No. ML16248A001), and March 5, 2018 (ADAMS Accession No. ML18057B298), the NRC issued Interim Staff Evaluations and an audit report, respectively, on the licensee's progress. By letter dated December 19, 2018 (ADAMS Accession No. ML18360A170), the licensee reported that Duane Arnold is in full compliance with the requirements of Order EA-13-109, and submitted a Final Integrated Plan for Duane Arnold.

The enclosed safety evaluation provides the results of the NRC staff's review of Duane Arnold's hardened containment vent design and water management strategy for Duane Arnold. The intent of the safety evaluation is to inform Duane Arnold on whether or not its integrated plans, if implemented as described, appear to adequately address the requirements of Order EA-13-109. The staff will evaluate implementation of the plans through inspection, using Temporary Instruction 2515-193, "Inspection of the Implementation of EA-13-109: Order Modifying Licenses with Regard to Reliable Hardened Containment Vents Capable of Operation Under Severe Accident Conditions" (ADAMS Accession No. ML17249A105). This inspection will be conducted in accordance with the NRC's inspection schedule for the plant.

If you have any questions, please contact Dr. Rajender Auluck, Senior Project Manager, Beyond-Design-Basis Engineering Branch, at 301-415-1025, or by e-mail at Rajender.Auluck@nrc.gov.

Sincerely,

Nathan Sanfilippo, Chief
Beyond-Design-Basis Engineering Branch
Division of Licensing Projects
Office of Nuclear Reactor Regulation

Docket No. 50-331

Enclosure:
Safety Evaluation

cc w/encl: Distribution via Listserv

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NUCLEAR REGULATORY COMMISSION
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SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

RELATED TO ORDER EA-13-109

NEXTERA ENERGY DUANE ARNOLD, LLC

DUANE ARNOLD ENERGY CENTER

DOCKET NO. 50-331

1.0 INTRODUCTION

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

On June 6, 2013 [Reference 1], the NRC issued Order EA-13-109, "Order Modifying Licenses with Regard to Reliable Hardened Containment Vents Capable of Operation under Severe Accident Conditions". This order requires licensees to implement its requirements in two phases. In Phase 1, licensees of boiling-water reactors (BWRs) with Mark I and Mark II containments shall design and install a venting system that provides venting capability from the wetwell during severe accident conditions. In Phase 2, licensees of BWRs with Mark I and Mark II containments shall design and install a venting system that provides venting capability from the drywell under severe accident conditions, or, alternatively, those licensees shall develop and implement a reliable containment venting strategy that makes it unlikely that a licensee would need to vent from the containment drywell during severe accident conditions.

By letter dated June 25, 2014 [Reference 2], NextEra Energy Duane Arnold, LLC (NextEra, the licensee) submitted its Phase 1 Overall Integrated Plan (OIP) for Duane Arnold Energy Center (DAEC, Duane Arnold) in response to Order EA-13-109. By letters dated December 10, 2014 [Reference 3], June 18, 2015 [Reference 4], December 22, 2015 (which included the combined Phase 1 and Phase 2 OIP) [Reference 5], June 30, 2016 [Reference 6], December 22, 2016 [Reference 7], June 29, 2017 [Reference 8], December 19, 2017 [Reference 9], and June 26, 2018 [Reference 10], the licensee submitted 6-month updates to its OIP. By letters dated May 27, 2014 [Reference 11], and August 10, 2017 [Reference 12], the NRC notified all BWR Mark I and Mark II licensees that the staff will be conducting audits of their implementation of Order

Enclosure

EA-13-109 in accordance with NRC Office of Nuclear Reactor Regulation (NRR) Office Instruction LIC-111, "Regulatory Audits" [Reference 13]. By letters dated February 11, 2015 (Phase 1) [Reference 14], September 13, 2016 (Phase 2) [Reference 15], and March 5, 2018 [Reference 16], the NRC issued Interim Staff Evaluations (ISEs) and an audit report, respectively, on the licensee's progress. By letter dated December 19, 2018 [Reference 17], the licensee reported that full compliance with the requirements of Order EA-13-109 was achieved and submitted its Final Integrated Plan (FIP).

2.0 REGULATORY EVALUATION

Following the events at the Fukushima Dai-ichi nuclear power plant on March 11, 2011, the NRC established a senior-level agency task force referred to as the Near-Term Task Force (NTTF). The NTTF was tasked with conducting a systematic and methodical review of the NRC regulations and processes and determining if the agency should make improvements to these programs in light of the events at Fukushima Dai-ichi. As a result of this review, the NTTF developed a set of recommendations, documented in SECY-11-0093, "Near-Term Report and Recommendations for Agency Actions Following the Events in Japan," dated July 12, 2011 [Reference 18]. Following interactions with stakeholders, these recommendations were enhanced by the NRC staff and presented to the Commission.

On February 17, 2012 [Reference 19], the NRC staff provided SECY-12-0025, "Proposed Orders and Requests for Information in Response to Lessons Learned from Japan's March 11, 2011, Great Tohoku Earthquake and Tsunami", to the Commission. This paper included a proposal to order licensees to implement the installation of a reliable hardened containment venting system (HCVS) for Mark I and Mark II containments. As directed by the Commission in staff requirements memorandum (SRM)-SECY-12-0025 [Reference 20], the NRC staff issued Order EA-12-050, "Order Modifying Licenses with Regard to Reliable Hardened Containment Vents" [Reference 21], which required licensees to install a reliable HCVS for Mark I and Mark II containments.

While developing the requirements for Order EA-12-050, the NRC acknowledged that questions remained about maintaining containment integrity and limiting the release of radioactive materials if the venting systems were used during severe accident conditions. The NRC staff presented options to address these issues for Commission consideration in SECY-12-0157, "Consideration of Additional Requirements for Containment Venting Systems for Boiling Water Reactors with Mark I and Mark II Containments" [Reference 22]. In the SRM for SECY-12-0157 [Reference 23], the Commission directed the staff to issue a modification to Order EA-12-050, requiring licensees with Mark I and Mark II containments to "upgrade or replace the reliable hardened vents required by Order EA-12-050 with a containment venting system designed and installed to remain functional during severe accident conditions." The NRC staff held a series of public meetings following issuance of SRM SECY-12-0157 to engage stakeholders on revising the order. Accordingly, as directed by the Commission in SRM-SECY-12-0157, on June 6, 2013, the NRC staff issued Order EA-13-109.

Order EA-13-109 requires that BWRs with Mark I and Mark II containments have a reliable, severe-accident capable HCVS. Attachment 2 of the order provides specific requirements for implementation of the order. The order shall be implemented in two phases.

2.1 Order EA-13-109, Phase 1

For Phase 1, licensees of BWRs with Mark I and Mark II containments are required to design and install a venting system that provides venting capability from the wetwell during severe accident conditions. Severe accident conditions include the elevated temperatures, pressures, radiation levels, and combustible gas concentrations, such as hydrogen and carbon monoxide, associated with accidents involving extensive core damage, including accidents involving a breach of the reactor vessel by molten core debris.

The NRC staff held several public meetings to provide additional clarifications on the order's requirements and comments on the proposed draft guidance prepared by the Nuclear Energy Institute (NEI) working group. On November 12, 2013 [Reference 24], NEI issued NEI 13-02, "Industry Guidance for Compliance with Order EA-13-109," Revision 0, to provide guidance to assist nuclear power reactor licensees with the identification of measures needed to comply with the requirements of Phase 1 of Order EA-13-109. The NRC staff reviewed NEI 13-02, Revision 0, and on November 14, 2013 [Reference 25], issued Japan Lessons-Learned Project Directorate (JLD) interim staff guidance (ISG) JLD-ISG-2013-02, "Compliance with Order EA-13-109, 'Order Modifying Licenses with Regard to Reliable Hardened Containment Vents Capable of Performing under Severe Accident Conditions'", endorsing, in part, NEI 13-02, Revision 0, as an acceptable means of meeting the requirements of Phase 1 of Order EA-13-109, and on November 25, 2013, published a notice of its availability in the *Federal Register* (78 FR 70356).

2.2 Order EA-13-109, Phase 2

For Phase 2, licensees of BWRs with Mark I and Mark II containments are required to design and install a venting system that provides venting capability from the drywell under severe accident conditions, or, alternatively, to develop and implement a reliable containment venting strategy that makes it unlikely that a licensee would need to vent from the containment drywell during severe accident conditions.

The NRC staff, following a similar process, held several meetings with the public and stakeholders to review and provide comments on the proposed drafts prepared by the NEI working group to comply with the Phase 2 requirements of the order. On April 23, 2015 [Reference 26], NEI issued NEI 13-02, "Industry Guidance for Compliance with Order EA-13-109," Revision 1, to provide guidance to assist nuclear power reactor licensees with the identification of measures needed to comply with the requirements of Phase 2 of Order EA-13-109. The NRC staff reviewed NEI 13-02, Revision 1, and on April 29, 2015 [Reference 27], the NRC staff issued JLD-ISG-2015-01, "Compliance with Phase 2 of Order EA-13-109, 'Order Modifying Licenses with Regard to Reliable Hardened Containment Vents Capable of Performing under Severe Accident Conditions'", endorsing, in part, NEI 13-02, Revision 1, as an acceptable means of meeting the requirements of Phase 2 of Order EA-13-109, and on April 7, 2015, published a notice of its availability in the *Federal Register* (80 FR 26303).

3.0 TECHNICAL EVALUATION OF ORDER EA-13-109, PHASE 1

Duane Arnold is a single unit General Electric BWR site with a Mark I primary containment system. To implement Phase 1 requirements of Order EA-13-109, the HCVS at Duane Arnold uses a standalone piping system routed from the torus air space and discharges to the atmosphere. The HCVS is initiated via manual action from the main control room (MCR) or remote operating station (ROS) at the appropriate time based on procedural guidance in response to plant conditions from observed or derived symptoms.

The operators utilize containment parameters of pressure and level from the MCR instrumentation to monitor effectiveness of the venting actions. Vent operation is monitored by HCVS valve position, HCVS vent line temperature, and effluent radiation levels. The HCVS motive force is monitored and has the capacity to operate for 24 hours with installed equipment. Replenishment of the motive force will be by use of portable equipment once the installed motive force is exhausted. Venting actions are capable of being maintained for a sustained period of at least 7 days.

3.1 HCVS Functional Requirements

3.1.1 Performance Objectives

Order EA-13-109 requires that the design and operation of the HCVS shall satisfy specific performance objectives including minimizing the reliance on operator actions and plant operators' exposure to occupational hazards such as extreme heat stress and radiological conditions, and accessibility and functionality of HCVS controls and indications under a broad range of plant conditions. Below is the staff's assessment of how the licensee's HCVS meets the performance objectives required by Order EA-13-109.

3.1.1.1 Operator Actions

Order EA-13-109, Attachment 2, Section 1.1.1 requires that the HCVS be designed to minimize the reliance on operator actions. Relevant guidance is found in NEI 13-02, Section 4.2.6 and HCVS-FAQ [Frequently Asked Questions]-01.

In its FIP, the licensee stated that the HCVS was designed to minimize the reliance on operator actions in response to hazards identified in NEI 12-06, "Diverse and Flexible Coping Strategies (FLEX) Implementation Guide," Revision 2 [Reference 28], which are applicable to the plant site. Operator actions to initiate the HCVS vent path can be completed by plant personnel and include the capability for remote-manual initiation from the HCVS control station. A list of the remote manual actions performed by plant personnel to open the HCVS vent path are listed in Table 3-1, "HCVS Operator Actions," of the FIP. An HCVS extended loss of alternating current (ac) power (ELAP) Failure Evaluation Table (FIP Table 3-2), which shows alternate actions that can be performed, is also provided in the FIP.

The licensee also stated that permanently-installed electrical power and pneumatic supplies are available to support operation and monitoring of the HCVS for a minimum of 24 hours. No large portable equipment needs to be moved in the first 24 hours to operate the HCVS. After 24 hours, available personnel will be able to connect supplemental electric power and pneumatic supplies for sustained operation of the HCVS for a minimum of 7 days. The FLEX generators and replacement nitrogen bottles provide this motive force.

It is likely that these actions will be completed in less than 24 hours. However, the HCVS can be operated for at least 24 hours without any supplementation.

The NRC staff reviewed the HCVS Operator Actions Table, compared it with the information contained in NEI 13-02, and determined that these actions should minimize the reliance on operator actions. These actions are consistent with the type of actions described in NEI 13-02, Revision 1, as endorsed, in part, by JLD-ISG-2013-02 and JLD-ISG-2015-01, as an acceptable means for implementing applicable requirements of Order EA-13-109. The NRC staff also reviewed the HCVS Failure Evaluation Table and determined that the actions described adequately address all the failure modes listed in NEI 13-02, Revision 1, which include: loss of normal ac power; long-term loss of batteries; loss of normal pneumatic supply; loss of alternate pneumatic supply; and solenoid operated valve failure.

Based on the evaluation above, the NRC staff concludes that the licensee's HCVS design should minimize the reliance on operator actions, and, if implemented appropriately, appears to be consistent with NEI 13-02 guidance, as endorsed by JLD-ISG-2013-02 and JLD-ISG-2015-01, and should adequately address the requirements of the order.

3.1.1.2 Personnel Habitability – Environmental

Order EA-13-109, Attachment 2, Section 1.1.2 requires that the HCVS be designed to minimize plant operators' exposure to occupational hazards, such as extreme heat stress, while operating the HCVS. Relevant guidance is found in: NEI 13-02, Sections 4.2.5 and 6.1.1; NEI 13-02, Appendix I; and HCVS-FAQ-01.

In its FIP, the licensee stated that primary control of the HCVS is accomplished from the main control room. Alternate control of the HCVS is accomplished from the ROS, which is located in the 1A3 switchgear room on the 757' elevation in the control building. FLEX actions that may be taken to maintain the habitability of the MCR and ROS were developed in response to NRC Order EA-12-049. FLEX actions specified in abnormal operating procedure (AOP) 301.1, "Station Blackout," Revision 77, SAMP 724, "FLEX Damage Assessment and Portable Equipment Deployment," Revision 6, SAMP 726, "FLEX Adverse Environmental Conditions Guideline," Revision 1, and SAMP 729, "FLEX Ventilation of the Reactor Building without AC Power," Revision 1 include:

1. Restoring MCR ventilation via the FLEX diesel generator (DG). This load is considered in CAL-E13-001;
2. Opening MCR doors to establish natural circulation;
3. Operating portable generators and fans to move outside air through the MCR (if required);
4. Opening doors and a damper in the reactor building to establish natural circulation air flow in the reactor building;
5. Opening doors for the switchgear rooms to establish natural ventilation; and
6. Use of portable heaters staged inside the power block or in outside areas for continuously manned areas that are cold.

In the FIP, Table 2 contains a thermal evaluation of all the operator actions that may be required to support HCVS operation. The relevant ventilation calculations and evaluations (EC283904, "FLEX Evaluation," Revision 0, EVAL-16-M18, "Reactor Building Environmental Analysis for FLEX," Revision 0, and CAL-M06-007, "Room Heatup Analysis for Duane Arnold Energy During Station Blackout," Revision 1) demonstrate that the final design meets the order requirements to minimize the plant operators' exposure to occupational hazards. Procedure SA-AA-100-1008, "Heat Stress Control," provides DAEC administrative requirements for heat stress control.

The NRC staff audited the temperature response for the MCR under Order EA-12-049 compliance and documented in the NRC staff's safety evaluation [Reference 36] that the licensee has developed a plan that, if implemented appropriately, should maintain or restore equipment and personnel habitability conditions in the MCR following a BDBEE.

The NRC staff also audited building heat up calculations and guidance for heat stress control. The NRC staff concurred that based on the calculations and procedural guidance environmental conditions should not prevent operators from performing their required actions.

Based on the evaluation above, the NRC staff concludes that the licensee's HCVS design, with respect to personnel habitability during severe accident conditions, if implemented appropriately, appears to be consistent with NEI 13-02 guidance, as endorsed by JLD-ISG-2013-02 and JLD-ISG-2015-01, and should adequately address the requirements of the order.

3.1.1.3 Personnel Habitability – Radiological

Order EA-13-109, Attachment 2, Section 1.1.3 requires that the HCVS be designed to account for radiological conditions that would impede personnel actions needed for event response. Relevant guidance is found in: NEI 13-02, Sections 4.2.5 and 6.1.1; NEI 13-02, Appendices D, F, G and I; HCVS-FAQ-01, -07, -09 and -12; and HCVS-WP [White Paper]-02.

The licensee performed calculation CAL-R15-002, "Duane Arnold Hardened Containment Vent System Dose Assessment," which documents the dose assessment for designated areas inside the DAEC reactor building (outside of containment) and outside the DAEC reactor building caused by the sustained operation of the HCVS under the beyond-design-basis severe accident condition of an ELAP. Calculation CAL-R15-002 was performed using NRC-endorsed HCVS-WP-02 [Reference 29] and HCVS-FAQ-12 [Reference 30] methodologies. Consistent with the definition of sustained operations in NEI 13-02, Revision 1, the integrated whole-body gamma dose equivalent[1] due to HCVS operation over a 7-day period as determined in the licensee's dose calculation should not exceed 10 Roentgen equivalent man (rem).[2] The calculated 7-day dose due to HCVS operation is a conservative maximum integrated radiation dose over a 7-day period with ELAP and fuel failure starting at reactor shutdown. For the sources considered and the methodology used in the calculation, the timing of HCVS vent operation or cycling of the vent will not create higher doses at personnel habitability and equipment locations (i.e., maximum doses determined in the calculation bound operational considerations for HCVS vent operation).

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[1] For the purposes of calculating the personnel whole-body gamma dose equivalent (rem), it is assumed that the radiation units of Roentgen (R), radiation absorbed dose (rad), and Roentgen equivalent man (rem) are equivalent. The conversion from exposure in R to absorbed dose on in rad is 0.874 in air and < 1 in soft tissue. For photons, 1 rad is equal to 1 rem. Therefore, it is conservative to report radiation exposure in units of R and to assume that 1 R = 1 rad = 1 rem.

[2] Although radiation may cause cancer at high doses and high dose rates, public health data do not absolutely establish the occurrence of cancer following exposure to low doses and dose rates below about 10,000 mrem (100 mSv). https://www.nrc.gov/about-nrc/radialion/health-effects/rad-exposure-cancer.html

The licensee determined the expected dose rates in all locations requiring access following a beyond-design-basis ELAP. The licensee's evaluation indicates that for the areas requiring access in the early stages of the ELAP, the expected dose rates would not be a limiting consideration. For those areas where expected dose rates would be elevated at later stages of the accident, the licensee has determined that the expected stay times would ensure that operations could be accomplished without exceeding the emergency response organization (ERO) emergency worker dose guidelines.

The licensee evaluated the maximum dose rates and 7-day integrated whole-body gamma dose equivalents for the MCR, which is the primary control location, and the ROS. In its FIP, the licensee states that the ROS location and the travel path to the ROS have been evaluated for habitability and accessibility during a severe accident. The licensee further states that during an accident, the distance and shielding combined with the short duration of actions required at the ROS show the ROS to be an acceptable location for alternate control. The evaluation (as documented in CAL-R15-002) demonstrates that the integrated whole-body gamma dose equivalent to personnel occupying defined habitability locations (resulting from HCVS operation under beyond-design-basis severe accident conditions) should not exceed 10 rem.

The NRC staff notes that there are no explicit regulatory dose acceptance criteria for personnel performing emergency response actions during a beyond-design-basis severe accident. The Environmental Protection Agency (EPA) Protective Action Guides (PAG) Manual, EPA-400/R- 16/001, "Protective Action Guides and Planning Guidance for Radiological Incidents," provides emergency worker dose guidelines. Table 3.1 of EPA-400/R-16/001 specifies a guideline of 10 rem for the protection of critical infrastructure necessary for public welfare, such as a power plant, and a value of 25 rem for lifesaving or for the protection of large populations. The NRC staff further notes that during an emergency response, areas requiring access will be actively monitored by health physics personnel to ensure that personnel doses are maintained as low as reasonably achievable.

The NRC staff audited the licensee's calculation of the expected radiological conditions to ensure that operating personnel can safely access and operate controls and support equipment. Based on the expected integrated whole-body dose equivalent in the MCR and ROS during the sustained operating period, the NRC staff agrees that the mission doses associated with actions taken to protect the public under beyond-design-basis severe accident conditions will not subject plant personnel to an undue risk from radiation exposure.

Based on the evaluation above, the NRC staff concludes that the licensee's HCVS design, with respect to personnel habitability during severe accident conditions, if implemented appropriately, appears to be consistent with NEI 13-02 guidance, as endorsed by JLD-ISG-2013-02 and JLD-ISG-2015-01, and should adequately address the requirements of the order.

3.1.1.4 HCVS Controls and Indications

Order EA-13-109, Attachment 2, Section 1.1.4 requires that the HCVS controls and indications be accessible and functional under a range of plant conditions, including severe accident conditions, ELAP, and inadequate containment cooling. Relevant guidance is found in: NEI 13-02, Sections 4.1.3, 4.2.2, 4.2.3, 4.2.4, 4.2.5, and 6.1.1; NEI 13-02, Appendices F, G and I; and HCVS-FAQs-01 and -02.

Accessibility of the controls and indications for the environmental and radiological conditions are addressed in Sections 3.1.1.2 and 3.1.1.3 of this safety evaluation, respectively.

In its FIP, the licensee stated that primary control of the HCVS is accomplished from the MCR and that under the postulated scenarios of Order EA-13-109, the MCR is adequately protected from excessive radiation dose and no further evaluation of its use is required (HCVS-FAQ-06). The licensee further stated that the ROS is in the 1A3 switchgear room and is in an area evaluated to be accessible before and during a severe accident. The licensee also provided, In Table 1 of its FIP, a list of the controls and indications that are or may be required to operate the HCVS during a severe accident, including the locations, anticipated environmental conditions, and the environmental conditions (temperature and radiation) to which each component is qualified.

The NRC staff reviewed the FIP, including the evaluation in Section 1.1.4 of the FIP and examined the information provided in Table 1. The NRC staff determined that the controls and indications appear to be consistent with the NEI 13-02 guidance. The NRC staff also confirmed some of the environmental qualification information in Table 1 of the FIP through audit reviews of Duane Arnold document EC281991, "Reliable Hardened Containment Vent - Wetwell NRC Order EA-13-109," Revision 24. The NRC staff noted that the Regulatory Guide (RG) 1.97 instruments (including drywell pressure and wetwell level) did not have qualification information listed in Table 1, but are considered acceptable, in accordance with the NEI 13-02 guidance, based on their design basis qualifications. The NRC staff also noted that torus pressure, listed in Table 1, is not required for compliance and was not reviewed.

Based on the evaluation above, the NRC staff concludes that the licensee's HCVS design, with respect to accessibility and functionality of the HCVS controls and indications during severe accident conditions, if implemented appropriately, appears to be consistent with NEI 13-02 guidance, as endorsed by JLD-ISG-2013-02 and JLD-ISG-2015-01, and should adequately address the requirements of the order.

3.1.2 Design Features

Order EA-13-109 requires that the HCVS shall include specific design features, including specifications of the vent characteristics, vent path and discharge, control panel, power and pneumatic supply sources, inadvertent actuation prevention, HCVS monitoring, equipment operability, and hydrogen control. Below is the staff's assessment of how the licensee's HCVS meets the performance objectives required by Order EA-13-109.

3.1.2.1 Vent Characteristics

Order EA-13-109, Attachment 2, Section 1.2.1 requires that the HCVS has the capacity to vent the steam/energy equivalent of one percent of licensed/rated thermal power (unless a lower value is justified by analyses) and be able to restore and then maintain containment pressure below the primary containment design pressure and the primary containment pressure limit. Relevant guidance is found in NEI 13-02, Section 4.1.1.

The licensee performed calculation CAL-M15-013, "Duane Arnold Energy Center Hardened Containment Vent System Pipe Sizing Analysis," Revision 0, which provides verification of one percent power flow capacity at the lesser of the primary containment design pressure and the primary containment pressure limit (PCPL) based on a fully submerged wetwell.

This analysis was performed using a RELAP5 model created for the HCVS piping, valves, and fittings. Fitting losses were taken from Crane Technical Paper No. 410. To determine vent capacity, compressible flow was assumed with saturated steam only and the capacity was compared to one percent decay heat steam generation based on the latent heat of vaporization (h_{fg}) at the venting pressure. The required flow for one percent rated power (1,912 megawatts thermal (MWt)) is 71,750 pounds mass per hour (lbm/hr).

The design pressure of the wetwell is 56 pounds per square inch gauge (psig) and the PCPL for a fully submerged wetwell is 52.9 psig. The calculation conservatively assumed that the differential pressure between the wetwell and the drywell was 8.1 psi based on 60 degrees Fahrenheit (°F) water, and therefore a wetwell pressure of 44.8 psig was used for the vent sizing. At this conservative wetwell pressure, the HCVS has a capacity of 84,700 lbm/hr compared to the required capacity of 71,750 lbm/hr, which accounts for 118.0% of the required flow.

The NRC staff audited calculation CAL-M15-013. The NRC staff noted that the computer program RELAP5 was used to verify the HCVS sizing and that the Modular Accident Analysis Program (MAAP) Version 4.0.9 was used to model transient wetwell and drywell conditions based on the flowrates calculated by RELAP5. Based on the evaluation, the HCVS vent design appears to have the capacity to vent one percent of rated thermal power during ELAP and severe accident conditions with margin.

Based on the evaluation above, the NRC staff concludes that the licensee's HCVS design characteristics, if implemented appropriately, appear to be consistent with NEI 13-02 guidance, as endorsed by JLD-ISG-2013-02 and JLD-ISG-2015-01, and should adequately address the requirements of the order.

3.1.2.2 Vent Path and Discharge

Order EA-13-109, Attachment 2, Section 1.2.2 requires that the HCVS discharge the effluent to a release point above main plant structures. Relevant guidance is found in: NEI 13-02, Section 4.1.5; NEI 13-02, Appendix H; and HCVS-FAQ-04.

The NRC staff evaluated the HCVS vent path and the location of the discharge. The wetwell vent exits the primary containment through a dedicated penetration in the torus air space. The 10-inch vent pipe is routed through a wall in the torus room to the southwest corner room where it turns up and goes through the reactor building first floor and into the south stairwell. The piping is then routed vertically up until it penetrates a block wall and enters the refueling floor where it goes up and through the roof for an elevated release. The end of the vent pipe is approximately four feet above the reactor building roof parapet wall (elevation 898'-8") and terminates at an elevation of 902'-6". The NRC staff's review indicates that this appears to be consistent with the guidance provided in HCVS-FAQ-04.

Part of the HCVS-FAQ-04 guidance is designed to ensure that vented fluids are not drawn immediately back into any emergency ventilation intakes. Such ventilation intakes should be below a level of the pipe by 1 foot for every 5 horizontal feet. The MCR emergency intake in the ELAP event is approximately at elevation 812', which is approximately 90 feet below the HVCS pipe outlet. This intake is approximately 200 horizontal feet from the DAEC vent pipe, which would require the intake to be approximately 40 feet below the vent pipe. Therefore, the vent pipe discharge point appears to be consistent with the guidance of HCVS-FAQ-04 for stack discharge relative to ELAP air intake.

Guidance document NEI 13-02, Section 5.1.1.6, provides guidance that missile impacts are to be considered for portions of the HCVS. The NRC-endorsed NEI white paper, HCVS-WP-04, "Tornado Missile Evaluation for HCVS Components 30 Feet Above Grade," Revision 0 [Reference 32], provides a risk-informed approach to evaluate the threat posed to exposed portions of the HCVS by wind-borne missiles. The white paper concludes that the HCVS is unlikely to be damaged in a manner that prevents containment venting by wind-generated missiles coincident with an ELAP or loss of normal access to the ultimate heat sink (UHS) for plants that are enveloped by the assumptions in the white paper.

The licensee evaluated the vent pipe robustness with respect to wind-borne missiles against the assumptions contained in HCVS-WP-04. This evaluation demonstrated that the pipe was robust with respect to external missiles per HCVS-WP-04 in that:

1. For the portions of exposed piping below 30 feet above grade:
   The HCVS piping is located inside the reactor building from the torus, through the south stairwell, and then out through the reactor building roof. The reactor building is a substantially seismically-qualified building that was designed to withstand both the design-basis earthquake and tornado. The instrumentation for the HCVS is located inside the control building and the reactor building, both of which are designed to withstand the design-basis tornado (and earthquake). Any components located less than 30 feet above grade are adequately protected by the structure that houses them.

2. The exposed piping greater than 30 feet above grade has the following characteristics:
   a. The total vent pipe exposed area is about 63 square feet, which is less than 300 square feet.
   b. The pipe is made of schedule 40 carbon steel and is not plastic, and the pipe components have no small tubing susceptible to missiles.
   c. There are no obvious sources of missiles located in the proximity of the exposed HCVS components. Tornado missile hazard inspections are performed in OP-AA-102-1002 on the refueling floor to remove and/or tie down potential tornado missile hazards.

3. Due to the small exposed target area and the removal of tornado missiles in the area during season readiness inspections, it is unlikely that the HCVS pipe will crimp and thus a cutting tool is not required for DAEC. However, DAEC has saws available in the FLEX buildings that can cut steel.

4. Hurricanes are not screened in for DAEC.

The NRC staff reviewed the information provided and audited the calculations and evaluations. The NRC staff noted the reactor building stairwell was evaluated to demonstrate reasonable assurance that the HCVS pipe is adequately protected against seismic or tornado events. Based on the evaluation above, the NRC staff concludes that the licensee's location and design of the HCVS vent path and discharge, if implemented appropriately, appears to be consistent with NEI 13-02 guidance, as endorsed by JLD-ISG-2013-02 and JLD-ISG-2015-01, and should adequately address the requirements of the order.

3.1.2.3 Unintended Cross Flow of Vented Fluids

Order EA-13-109, Attachment 2, Section 1.2.3 requires that the HCVS include design features to minimize unintended cross flow of vented fluids within a unit and between units on the site. Relevant guidance is found in: NEI 13-02, Sections 4.1.2, 4.1.4, and 4.1.6; and HCVS-FAQ-05.

In its FIP, the licensee described DAEC as a single-unit site and the design of the HCVS is such that it is a completely independent system that runs from the torus to the roof of the reactor building. The HCVS design uses two primary containment isolation valves (PCIVs) in series, in compliance with [Title 10 of the *Code of Federal Regulations* (CFR) Part 50, Appendix A, General Design Criteria (GDC)] GDC-56. The primary containment isolation valves, CV4360 and CV4361, are located outside of primary containment as close to the suppression pool air space attached piping as practical and are nitrogen-operated valves. Nitrogen is provided from a common supply header that is normally isolated from nitrogen supply pressure by locked closed valve V43-0642 located at the ROS in the 1A3 switchgear room within the control building. Periodic 10 CFR Part 50, Appendix J, "Primary Reactor Containment Leakage Testing for Water-Cooled Power Reactors," Program [Reference 32] testing of the PCIVs will be performed in compliance with GDC-54. Redundant check valves are provided in the purge line to prevent backflow of potentially hazardous gases or steam. The NRC staff audited the information provided and agrees that the use of primary containment isolation valves appears to be acceptable for prevention of inadvertent cross-flow of vented fluids and consistent with the guidance provided in HCVS-FAQ-05.

Based on the evaluation above, the NRC staff concludes that the licensee's HCVS design limits the potential for unintended cross flow of vented fluids and, if implemented appropriately, appears to be consistent with NEI 13-02 guidance, as endorsed by JLD-ISG-2013-02 and JLD-ISG-2015-01, and should adequately address the requirements of the order.

3.1.2.4 Control Panels

Order EA-13-109, Attachment 2, Section 1.2.4 requires that the HCVS be designed to be manually operated during sustained operations from a control panel located in the main control room or a remote but readily accessible location. Relevant guidance is found in NEI 13-02, Sections 4.2.2, 4.2.4, 4.2.5, 5.1, and 6.1; NEI 13-02, Appendices A and H; and HCVS-FAQs-01 and -08.

In its FIP, the licensee stated that the wetwell vent will be initiated and then operated and monitored from a control panel located in the MCR for the sustained operating period. The licensee also described actions to be taken at the ROS, located in the control building on elevation 757', and provided a sketch in Attachment 6 of the FIP to establish the relative proximity of the two control locations. Table 1 of the FIP, contains a list of the HCVS instrumentation and controls components including their location and qualification information. The NRC staff reviewed Section III.B.1.2.4 and confirmed these statements by comparing the instrumentation and controls component locations provided in Table 1 of the FIP.

Based on the evaluation above, the NRC staff concludes that the licensee's location and design of the HCVS control panels, if implemented appropriately, appears to be consistent with NEI 13-02 guidance, as endorsed by JLD-ISG-2013-02 and JLD-ISG-2015-01, and should adequately address the requirements of the order.

3.1.2.5 Manual Operation

Order EA-13-109, Attachment 2, Section 1.2.5 requires that the HCVS, in addition to meeting the requirements of Section 1.2.4, be capable of manual operation (e.g., reach-rod with hand wheel or manual operation of pneumatic supply valves from a shielded location), which is accessible to plant operators during sustained operations. Relevant guidance is found in NEI 13-02, Section 4.2.3 and in HCVS-FAQs-01, -03, -08, and -09.

In its FIP, the licensee stated that to meet the requirement for an alternate means of operation of HCVS, opening valves using pneumatic motive force can be performed from the ROS. The ROS contains manually-operated valves that can supply nitrogen to the HCVS flow path valve actuators so that these valves may be opened without power to the actuator solenoid valves. Manual operation of the purge system from the ROS can also be performed by using manually-operated valves. This provides a diverse method of HCVS operation and improves system reliability.

The ROS is located on the ground floor of the control building on elevation 757'. The ROS is readily accessible from the MCR and turbine building. The controls available at the ROS location are accessible and functional under a range of plant conditions, including severe accident conditions, with due consideration to source term and dose impact on operator exposure, extended loss of ac power, inadequate containment cooling, and loss of reactor building ventilation.

Table 1 of the FIP contains an evaluation of the required controls and instruments that are required for severe accident response and demonstrates that all these controls and instruments will be functional during a loss of ac power and severe accident. Table 2 of the FIP contains a summary of thermal and radiological evaluation of the operator actions that may be required to support HCVS operation during a loss of ac power and severe accident. The licensee's evaluations conclude that these actions will be possible without undue hazard to the operators. These evaluations demonstrate that the design meets the requirement to be manually operated from a remote but readily accessible location during sustained operation. Attachment 6 to the FIP contains a site layout showing the location of these HCVS actions. The NRC staff audited the pertinent plant drawings and evaluation documents. The NRC staff's audit confirmed that the actions appear to be consistent with the guidance.

Based on the evaluation above, the NRC staff concludes that the licensee's HCVS design allows for manual operation, and, if implemented appropriately, appears to be consistent with NEI 13-02 guidance, as endorsed by JLD-ISG-2013-02 and JLD-ISG-2015-01, and should adequately address the requirements of the order.

3.1.2.6 Power and Pneumatic Supply Sources

Order EA-13-109, Attachment 2, Section 1.2.6 requires that the HCVS be capable of operating with dedicated and permanently installed equipment for at least 24 hours following the loss of normal power or loss of normal pneumatic supplies to air operated components during an ELAP. Relevant guidance is found in: NEI 13-02, Sections 2.5, 4.2.2, 4.2.4, 4.2.6, and 6.1; NEI 13-02, Appendix A; HCVS-FAQ-02; and HCVS-WPs-01 and -02.

<u>Pneumatic Sources Analysis</u>

For the first 24 hours following the ELAP event, the motive force for the actuation of the two PCIVs and purging of the HCVS vent piping will be supplied by eleven nitrogen air bottles.

The nitrogen air bottles are stationed on the first floor of the reactor building in the control rod drive repair room. These bottles have been sized such that they can provide motive force for eight cycles of the PCIVs and six purges of HCVS piping.

In calculation CAL-M15-014, "Nitrogen Supply for Hardened Containment Vent," Revision 0, the licensee determined the required pneumatic supply storage volume and supply pressure set point required to operate the PCIV actuation and HCVS piping purge for 24 hours following a loss of normal pneumatic supplies during an ELAP. The required pressure for HCVS operation is approximately 1920 psig. The licensee's calculation determined that 11 nitrogen bottles, each filled at the maximum capacity of 3275 psig, will provide sufficient capacity for 8 cycles of the HCVS valves and 6 purges of HCVS vent piping for 24 hours following an ELAP. This pressure includes an allowance for leakage. The NRC staff audited the calculation and confirmed that there should be sufficient pneumatic supply available to provide motive force to operate the HCVS system for 24 hours following a loss of normal pneumatic supplies during an ELAP.

Power Source Analysis

In its FIP, the licensee stated that during the first 24 hours of an ELAP event, Duane Arnold would rely on a dedicated uninterruptable power supply (UPS) to provide power to HCVS components. The HCVS UPS consist of a 125-volt (V) direct current (dc) battery (1D0990), battery charger (1D0991), and 125 Vdc panel (1D0992). The HCVS UPS is located in the 1A3 switchgear room in control building on elevation 757'. The HCVS UPS is installed where it is protected from applicable hazards. Exide Technologies manufactured the HCVS battery.

The HCVS battery is model GNB Absolyte GP 6-50G07 with a nominal capacity of 152 ampere hours (Ah). The HCVS battery has a minimum capacity capable of providing power for 24 hours without recharging. During the audit period, the licensee provided the NRC staff an evaluation for the HCVS battery/battery charger sizing requirements including incorporation into the FLEX DG loading calculation.

The NRC staff audited licensee calculation CAL-E15-002, "125VDC HCVS Battery / Battery Charger Sizing and Voltage Drop Calculation," Revision 0, which verified the capability of the HCVS battery to supply power to the required loads during the first phase of the Duane Arnold venting strategy for an ELAP. The HCVS battery was sized in accordance with Institute of Electrical and Electronics Engineers (IEEE) Standard 485-1997, "IEEE Recommended Practice for Sizing Lead-Acid Batteries for Stationary Applications," which is endorsed by RG 1.212, "Sizing of Large Lead-Acid Storage Batteries," published in 2008. The licensee's calculation identified the required loads and their associated ratings (minimum system operating voltage, and watts (W) or amperes (A)). The licensee's battery sizing calculation also showed that the minimum calculated terminal voltage at each device is above the minimum voltage required during the 24-hour discharge cycle. Therefore, the Duane Arnold HCVS battery should have sufficient capacity to supply power for at least 24 hours.

The licensee's strategy includes repowering the HCVS battery within 24 hours after initiation of an ELAP. The licensee's strategy relies on one of two 405-kilowatt (kW) 480 Volt alternating current (Vac) FLEX DGs. Only one of the FLEX DGs is required for the HCVS electrical strategy. The 480 Vac FLEX DG would provide power to the HCVS load in addition of loads addressed under Order EA-12-049.

The NRC staff also audited licensee calculation CAL-E13-001, "FLEX Electrical Equipment Sizing," Revision 0, which incorporates the HCVS loads on the FLEX DGs. Based on the NRC staff's audit of licensee calculation CAL-E13-001, it appears that the FLEX DG should have sufficient capacity and capability to supply the necessary loads during an ELAP event.

Electrical Connection Points

The licensee's strategy to supply power to HCVS components requires using a combination of permanently installed and portable components. Staging and connecting the 405 kW FLEX DG were addressed under Order EA-12-049. Licensee procedure SAMP 732, "FLEX Repowering the Containment Hard Pipe Vent UPS," Revision 0, provides guidance connecting the HCVS battery charger to the 480 Vac FLEX DG.

Based on the evaluation above, the NRC staff concludes that the licensee's HCVS design allows for reliable operation with dedicated and permanently installed equipment, and, if implemented appropriately, appears to be consistent with NEI 13-02 guidance, as endorsed by JLD-ISG-2013-02 and JLD-ISG-2015-01, and should adequately address the requirements of the order.

3.1.2.7 Prevention of Inadvertent Actuation

Order EA-13-109, Attachment 2, Section 1.2.7 requires that the HCVS include means to prevent inadvertent actuation. Relevant guidance is found in NEI 13-02, Section 4.2.1.

In its FIP, the licensee stated that the emergency operating procedures (EOPs) provide clear guidance to operators that the HCVS is not to be used to defeat containment integrity during any design-basis transients or accidents. In addition, the HCVS was designed to provide features to prevent inadvertent actuation due to equipment malfunction or operator error. These protections are designed such that any credited containment accident pressure (CAP) that would provide net positive suction head to the emergency core cooling system (ECCS) pumps will be available (inclusive of a design basis loss-of-coolant accident). However, the ECCS pumps will not have normal power available because of the ELAP.

The containment isolation valves must be open to permit vent flow. At Duane Arnold, the physical features that prevent inadvertent actuation are:

- The key lock switch for valves CV4360 and CV4361;
- The locked closed pneumatic supply isolation valve, V43-0642, located at the ROS that isolates nitrogen supply pressure from both the purge line and the HCVS valve operators; and
- The rupture disk, PSE4362, located downstream of CV4360 and CV4361, which also provides a zero-leakage barrier.

The NRC staff's audit of the HCVS confirmed that the licensee's design appears to be consistent with the guidance and should preclude inadvertent actuation.

Based on the evaluation above, the NRC staff concludes that the licensee's HCVS design, with respect to prevention of inadvertent actuation, if implemented appropriately, appears to be consistent with NEI 13-02 guidance, as endorsed by JLD-ISG-2013-02 and JLD-ISG-2015-01, and should adequately address the requirements of the order.

3.1.2.8 Monitoring of HCVS

Order EA-13-109, Attachment 2, Section 1.2.8 requires that the HCVS include means to monitor the status of the vent system (e.g. valve position indication) from the control panel required by Section 1.2.4. In addition, Order EA-13-109 requires that the monitoring system be designed for sustained operation during an ELAP. Relevant guidance is found in: NEI 13-02, Section 4.2.2; and HCVS-FAQs-01, -08, and -09.

The NRC staff reviewed the following channels documented in Table 1 of the FIP that support HCVS operation: HCVS temperature; HCVS radiation; drywell pressure; wetwell level; valve position indication; N2 supply pressure; and 125 Vdc uninterruptable power supply. The NRC staff notes that drywell pressure and wetwell level are declared Duane Arnold post-accident monitoring (PAM) variables as described in RG 1.97 and the existing qualification of these channels is considered acceptable for compliance with Order EA-13-109 in accordance with the guidance in NEI 13-02, Appendix C, Section C.8.1. The NRC staff also reviewed FIP Section III.B.1.2.8 and determined that the HCVS instrumentation appears to be adequate to support HCVS venting operations and can perform its intended function during ELAP and severe accident conditions.

Based on the evaluation above, the NRC staff concludes that the licensee's HCVS design allows for the monitoring of key HCVS instrumentation, and, if implemented appropriately, appears to be consistent with NEI 13-02 guidance, as endorsed by JLD-ISG-2013-02 and JLD-ISG-2015-01, and should adequately address the requirements of the order.

3.1.2.9 Monitoring of Effluent Discharge

Order EA-13-109, Attachment 2, Section 1.2.9 requires that the HCVS include means to monitor the effluent discharge for radioactivity that may be released from operation of the HCVS. In addition, Order EA-13-109 requires that the monitoring system provide indication from the control panel required by Section 1.2.4 and be designed for sustained operation during an ELAP. Relevant guidance is found in: NEI 13-02, Section 4.2.4; and HCVS-FAQs-08 and -09.

The NRC staff reviewed the following channels documented in Table 1 of the FIP that support monitoring of HCVS effluent: HCVS valve position; HCVS temperature; and HCVS radiation. The NRC staff found that effluent radiation monitor provides sufficient range to adequately indicate effluent discharge radiation levels.

In Section III.B.1.2.9, the licensee stated that the radiation monitoring system consists of an ion chamber detector located at the ground floor of the reactor building (elevation 757') with a process and control module in the MCR. The radiation monitor detector is fully qualified for the expected environment at the vent pipe during accident conditions, and the process and control module is qualified for the mild environment in the MCR. The NRC staff reviewed the qualification summary information provided in Table 1 of the FIP and finds that it appears to meet the guidance. The NRC staff also confirmed the summary information through audit reviews of Duane Arnold document EC281991, "Reliable Hardened Containment Vent - Wetwell NRC Order EA-13-109," Revision 24.

Based on the evaluation above, the NRC staff concludes that the licensee's HCVS design allows for the monitoring of effluent discharge, and, if implemented appropriately, appears to be consistent with NEI 13-02 guidance, as endorsed by JLD-ISG-2013-02 and JLD-ISG-2015-01, and should adequately address the requirements of the order.

3.1.2.10 Equipment Operability (Environmental/Radiological)

Order EA-13-109, Attachment 2, Section 1.2.10 requires that the HCVS be designed to withstand and remain functional during severe accident conditions, including containment pressure, temperature, and radiation while venting steam, hydrogen, and other non-condensable gases and aerosols. The design is not required to exceed the current capability of the limiting containment components. Relevant guidance is found in: NEI 13-02, Sections 2.3, 2.4, 4.1.1, 5.1 and 5.2; NEI 13-02 Appendix I; and HCVS-WP-02.

Environmental

The FLEX diesel-driven severe accident water addition (SAWA) pump and FLEX DG will be staged outside so they will not be adversely impacted by a loss of ventilation.

As discussed above in Section 3.1.1.2, the licensee performed calculation CAL-M06-007, which determined the expected temperature at the ROS (1A3 Switchgear Room) following an ELAP. The licensee determined that performing compensatory ventilation actions (opening doors, restarting control building ventilation fans in Phase 2, and/or staging temporary fans) around the ROS will maintain the switchgear room temperatures below 120°F. In the case of extreme cold temperatures, licensee procedure SAMP 724, "FLEX Damage Assessment and Portable Equipment Deployment," Revision 0, directs operators to use portable heaters to maintain temperatures.

The HCVS UPS (battery, battery charger, and 125 Vdc panel) and supporting equipment are permanently installed in the battery room corridor in the control building on elevation 757'. The NRC staff reviewed licensee calculation CAL-M06-007, under Order EA-12-049, which determined the expected temperature in the battery room following an ELAP. The licensee determined that the temperature in the battery room corridor would remain less than 120°F. The licensee plans to open doors, restore normal ventilation, and establish portable ventilation after the FLEX DG is placed in service. Licensee procedures AOP 301.1, "Station Blackout," Revision 65 and SAMP 724, "FLEX Damage Assessment and Portable Equipment Deployment," Revision 0, directs operators to open doors, restore normal ventilation, and establish portable ventilation in the control building.

Based on the above, the NRC staff concurs with the licensee's calculations that show the battery room corridor will remain within the maximum temperature limit of 122°F for the HCVS batteries and battery charger. Furthermore, based on temperature remaining below 120°F (the temperature limit for electronic equipment to be able to survive indefinitely, identified in NUMARC-87-00, "Guidelines and Technical Bases for NUMARC Initiatives Addressing Station Blackout at Light Water Reactors," Revision 1, as endorsed by NRC RG 1.155), the NRC staff believes that other electrical equipment located at the ROS should not be adversely impacted by the loss of ventilation as a result of an ELAP event with the HCVS in operation. Therefore, the NRC staff concurs that the HCVS equipment should not be adversely impacted by the loss of ventilation as a result of an ELAP event.

Radiological

The licensee's calculation CAL-R15-002, "Hardened Containment Vent System Dose Assessment," documents the dose assessment for both personnel habitability and equipment locations associated with event response to a postulated ELAP condition.

The NRC staff audited calculation CAL-R15-002 and notes that the licensee used conservative assumptions to bound the peak dose rates for the analyzed areas. For the sources considered and the methodology used in the dose calculation, the timing of HCVS vent operation or cycling of the vent will not create higher doses at personnel habitability and equipment locations (i.e., maximum doses determined in the calculation bound operational considerations for HCVS vent operation). The NRC staff's audit confirmed that the anticipated severe accident radiological conditions will not preclude the operation of necessary equipment or result in an undue risk to personnel from radiation exposure.

Based on the evaluation above, the NRC staff concludes that the licensee's HCVS design, with respect to equipment operability during severe accident conditions, if implemented appropriately, appears to be consistent with NEI 13-02 guidance, as endorsed by JLD-ISG-2013-02 and JLD-ISG-2015-01, and should adequately address the requirements of the order.

3.1.2.11 Hydrogen Combustible Control

Order EA-13-109, Attachment 2, Section 1.2.11 requires that the HCVS be designed and operated to ensure the flammability limits of gases passing through the system are not reached; otherwise, the system shall be designed to withstand dynamic loading resulting from hydrogen deflagration and detonation. Relevant guidance is found in: NEI 13-02, Sections 4.1.7, 4.1.7.1, and 4.1.7.2; NEI 13-02, Appendix H; and HCVS-WP-03.

In NEI 13-02, Section 4.1. 7 provides guidance for the protection from flammable gas ignition for the HCVS system. The NEI issued a white paper, HCVS-WP-03, "Hydrogen /Carbon Monoxide Control Measures," Revision 1, endorsed by the NRC [Reference 33], which provides methods to address control of flammable gases. One of the acceptable methods described in the white paper is the installation of an active purge system (Option 3), which ensures the flammability limit of gases passing through the system is not reached.

In its FIP, the licensee stated that to prevent a detonable mixture from developing in the HCVS pipe, a purge system using nitrogen has been provided to displace potentially flammable/detonable mixtures of gases that may be present in the vent after system actuation. The purge system was evaluated in CAL-M15-014, "Nitrogen Supply for Hardened Containment Vent," Revision 0, and it is designed to provide a minimum velocity of 3.5 feet per second in the 10" HCVS pipe with a minimum required purge volume of 1.10 times the vertical pipe volume plus 1.50 times the horizontal pipe volume in accordance with the American Gas Association "Purging Principles and Practice." The purge system has been designed with a capacity to rupture the rupture disc and perform 6 pre/post vent valve cycle purges. The NRC staff reviewed the information provided and audited the referenced calculation. The NRC staff confirmed that the licensee's design appears to be consistent with Option 3 of white paper HCVS-WP-03 and that the use purge gas in conjunction with the HCVS venting strategy should meet the requirement to prevent a detonable mixture from developing in the pipe.

Based on the evaluation above, the NRC staff concludes that the licensee's HCVS design ensures that the flammability limits of gases passing through the system are not reached, and, if implemented appropriately, appears to be consistent with NEI 13-02 guidance, as endorsed by

JLD-ISG-2013-02 and JLD-ISG-2015-01, and should adequately address the requirements of the order.

3.1.2.12 Hydrogen Migration and Ingress

Order EA-13-109, Attachment 2, Section 1.2.12 requires that the HCVS be designed to minimize the potential for hydrogen gas migration and ingress into the reactor building or other buildings. Relevant guidance is found in NEI 13-02, Section 4.1.6; NEI 13-02, Appendix H; HCVS-FAQ-05; and HCVS-WP-03.

As discussed in Section 3.1.2.3, DAEC is a single unit site and the design of the HCVS is such that it is a completely independent system that runs from the torus to the roof of the reactor building. The design effectively eliminated the cross flow of fluids and gases from the HCVS into other systems or buildings. The HCVS has been designed with two PCIVs in series that are located outside of the primary containment, as close to the suppression pool air space attached piping as practical. Periodic Appendix J leak rate testing of the PCIVs ensures that leakage of flammable gases remains low. Purging the vent line following each cycle will eliminate the combustible gases and render the line free of any detonable gas mixture. As a result, oxygen infiltration resulting from steam collapse is not a concern. The portion between the PCIVs is steam inerted such that any combustible gas is below the flammability limit. The NRC staff's audit confirmed that the design appears to be consistent with the guidance and meets the design requirements to minimize the potential of hydrogen gas migration into other buildings.

Based on the evaluation above, the NRC staff concludes that the licensee's HCVS design minimizes the potential for hydrogen gas migration and ingress, and, if implemented appropriately, appears to be consistent with NEI 13-02 guidance, as endorsed by JLD-ISG-2013-02 and JLD-ISG-2015-01, and should adequately address the requirements of the order.

3.1.2.13 HCVS Operation/Testing/Inspection/Maintenance

Order EA-13-109, Attachment 2, Section 1.2.13 requires that the HCVS include features and provisions for the operation, testing, inspection and maintenance adequate to ensure that reliable function and capability are maintained. Relevant guidance is found in NEI 13-02, Sections 5.4 and 6.2; and HCVS-FAQs-05 and -06.

In the Duane Arnold FIP, Table 3-3 includes testing and inspection requirements for HCVS components. The NRC staff reviewed Table 3-3 and confirmed that it is consistent with Section 6.2.4 of NEI 13-02, Revision 1. Implementation of these testing and inspection requirements for the HCVS will ensure reliable operation of the systems.

In its FIP, the licensee stated that the maintenance program was developed using the guidance provided in NEI 13-02, Sections 5.4 and 6.2, and it utilizes the standard Electric Power Research Institute (EPRI) industry preventive maintenance process for the maintenance calibration and testing for the HCVS components. The NRC staff reviewed the information provided and confirmed that the licensee has implemented adequate programs for operation, testing, inspection, and maintenance of the HCVS.

Based on the evaluation above, the NRC staff concludes that the licensee's HCVS design allows for operation, testing, inspection, and maintenance, and, if implemented appropriately, appears to be consistent with NEI 13-02 guidance, as endorsed by JLD-ISG-2013-02 and JLD-ISG-2015-01, and should adequately address the requirements of the order.

3.2 HCVS QUALITY STANDARDS

3.2.1 Component Qualifications

Order EA-13-109, Attachment 2, Section 2.1 requires that the HCVS vent path up to and including the second containment isolation barrier be designed consistent with the design basis of the plant. Items in this path include piping, piping supports, containment isolation valves, containment isolation valve actuators, and containment isolation valve position indication components. Relevant guidance is found in NEI 13-02, Section 5.3.

In its FIP, the licensee states that the wetwell vent up to and including the second containment isolation valve is designed consistent with the design basis of the plant. These items include piping, piping supports, containment isolation valves, containment isolation valve actuators, and containment isolation valve position indication components. The piping system was designed to 350°F for a beyond-design-basis event and 65 psig. The 10" piping downstream of the second containment isolation barrier was also classified as safety-related since it penetrates secondary containment. All piping and pipe supports were designed to seismic Category 1 criteria. Piping above the fifth floor of the reactor building has been designed to withstand the design-basis wind loads. The nitrogen tubing and bottles have also been designed to seismic Category 1 criteria. Instrumentation and electrical equipment have either been seismically qualified by test or by similarity to substantially designed and previously seismically-tested equipment.

The HCVS downstream of the outboard containment isolation valve, including piping and supports, electrical power supply, valve actuator pneumatic supply, and instrumentation (local and remote) components, have been designed and analyzed to conform to the requirements consistent with the applicable design codes for the plant and to ensure functionality following a design-basis earthquake. This includes environmental qualification consistent with expected conditions at the equipment location.

Table 1 of the FIP contains a list of components and instruments required to operate HCVS, their qualification and evaluation against the expected conditions. All instruments are fully qualified for the expected seismic conditions so that they will remain functional following a seismic event. The NRC staff reviewed Table 1 and confirmed that the components required for HCVS venting are designed to remain functional following a design basis earthquake. The NRC staff also confirmed the instrumentation and control component qualifications through audit reviews of Duane Arnold document EC281991, "Reliable Hardened Containment Vent - Wetwell NRC Order EA-13-109," Revision 24.

Based on the evaluation above, the NRC staff concludes that the licensee's HCVS design, with respect to component qualifications, if implemented appropriately, appears to be consistent with NEI 13-02 guidance, as endorsed by JLD-ISG-2013-02 and JLD-ISG-2015-01, and should adequately address the requirements of the order.

3.2.2 Component Reliability and Rugged Performance

Order EA-13-109, Attachment 2, Section 2.2 requires that all other HCVS components be designed for reliable and rugged performance, capable of ensuring HCVS functionality following a seismic event. These items include electrical power supply, valve actuator pneumatic supply, and instrumentation (local and remote) components. Relevant guidance is found in NEI 13-02, Sections 5.2 and 5.3.

In its FIP, the licensee stated that the HCVS components downstream of the outboard containment isolation valve and components that interface with the HCVS are routed in seismically-qualified structures or supported from seismically qualified structures.

As part of the NRC staff's audit, the NRC staff requested information verifying that the new containment isolation valves, relied upon for the HCVS, will open under the maximum expected differential pressure during beyond-design-basis and severe accident wetwell venting. The licensee performed calculation CAL-M15-014, which discusses the valve/actuator information for the PCIVs. The NRC staff audited the calculation and confirmed that the PCIVs should open under the maximum expected differential pressure during beyond-design-basis and severe accident wetwell venting.

Based on the evaluation above, the NRC staff concludes that the licensee's HCVS design, with respect to component reliability and rugged performance, if implemented appropriately, appears to be consistent with NEI 13-02 guidance, as endorsed by JLD-ISG-2013-02 and JLD-ISG-2015-01, and should adequately address the requirements of the order.

3.3 Conclusions for Order EA-13-109, Phase 1

Based on its review, the NRC staff concludes that the licensee has developed guidance and a HCVS design that, if implemented appropriately, appears to be consistent with NEI 13-02 guidance, as endorsed by JLD-ISG-2013-02 and JLD-ISG-2015-01, and should adequately address the requirements of the order.

4.0 TECHNICAL EVALUATION OF ORDER EA-13-109, PHASE 2

As stated above in Section 2.2, Order EA-13-109 provides two options to comply with the Phase 2 order requirements. Duane Arnold has elected the option to develop and implement a reliable containment venting strategy that makes it unlikely the licensee would need to vent from the containment drywell before alternate reliable containment heat removal and pressure control is reestablished.

For this method of compliance, the order requires licensees to meet the following:

- The strategy making it unlikely that a licensee would need to vent from the containment drywell during severe accident conditions shall be part of the overall accident management plan for Mark I and Mark II containments;

- The licensee shall provide supporting documentation demonstrating that containment failure as a result of overpressure can be prevented without a drywell vent during severe accident conditions; and

- Implementation of the strategy shall include licensees preparing the necessary procedures, defining and fulfilling functional requirements for installed or portable equipment (e.g. pumps and valves), and installing the needed instrumentation.

Relevant guidance is found in NEI 13-02, Sections 4, 5 and 6; and Appendices C, D, and I.

4.1 Severe Accident Water Addition (SAWA)

The licensee plans to use the FLEX (SAWA) pump to provide SAWA flow into the reactor pressure vessel (RPV). Flow control for SAWA will be performed at the SAWA pump along with instrumentation and procedures to ensure that the wetwell vent is not submerged. Once SAWA flow is initiated, operators will have to monitor and maintain SAWA flow and ensure refueling of the diesel-driven equipment as necessary. In its FIP, the licensee states that the operator locations for deployment and operation of the SAWA equipment that are external to the reactor building are either shielded from direct exposure to the vent line or are a significant distance from the vent line so that dose will be maintained below ERO exposure guidelines.

4.1.1 Staff Evaluation

4.1.1.1 Flow Path

The SAWA injection flow path starts with the FLEX pump taking suction from the hotwell (flooded condition) or the circulating water pit (non-flooded condition). The water discharged from the FLEX pump through the hoses is supplied to the FLEX/SAWA connection in the heater bay of the turbine building. A portable in-line battery powered electromagnetic flow meter is placed in the hose run to provide indication of injection flow rate. The valves inside the reactor building will be lined-up so that water can be injected into the RPV through the low pressure coolant injection (LPCI) system. This LPCI connection ties into the RPV for SAWA injection. The hoses and pumps used for SAWA flow are stored in the two FLEX buildings, which is protected from all external hazards. This SAWA injection path is also protected from all external hazards in addition to severe accident conditions.

4.1.1.2 SAWA Pump

In its FIP, the licensee states that the strategy is to use two redundant portable diesel-driven fire pumps, in which one pump will be used for FLEX and SAWA strategies. The two FLEX pumps are trailer-mounted and are capable of withstanding seismic events. The two FLEX pumps are each capable of 1,000 gallons per minute (gpm) of total flow, which includes 272 gpm for RPV injection (for the first 4 hours of operation). The SAWA flow will be reduced to 55 gpm for the duration of the ELAP event. The FLEX pumps are stored in the FLEX buildings, where they are protected from all applicable external hazards. The initial SAWA flow will be injected into the RPV within 8 hours of the loss of injection. In its FIP, the licensee described the hydraulic analysis performed to demonstrate the capability of the two portable FLEX pumps to provide the required SAWA flow. The NRC staff audited calculation CAL-M13-005 DC-0367, "FLEX Diesel Pump Suction Hydraulic Analysis," Revision 1, which determined that the required SAWA flow rate of 272 gpm was within the capacity of at least one FLEX pump.

The NRC staff also audited the flow rates and pressures evaluated in the hydraulic analyses and confirmed that the equipment can provide the needed flow. Based on the NRC staff's audit of the FLEX pumping capabilities, as described in the above hydraulic analysis and the FIP, it appears that the licensee has demonstrated that the portable FLEX pumps should perform as intended to support SAWA flow.

4.1.1.3 SAWA Analysis of Flow Rates and Timing

The licensee developed the overall accident management plan for DAEC from the BWR Owner's Group (BWROG) emergency procedure guidelines and severe accident guidelines (EPG/SAG). The SAWA/SAWM [Severe Accident Water Management] implementing procedures are integrated into the DAEC severe accident management guidelines (SAMGs). In particular, EPG/SAG Revision 3, when implemented with Emergency Procedures Committee Generic Issue 1314, allows throttling of SAWA to protect containment while maintaining the wetwell vent in service. The SAMG flow charts direct use of the hardened vent, as well as SAWA/SAWM when the appropriate plant conditions have been reached.

The licensee used industry-developed validation guidance to demonstrate that the FLEX/SAWA portable pump can be deployed and commence injection in less than 8 hours. The studies referenced in NEI 13-02, Revision 1, demonstrated that establishing flow within 8 hours will protect containment. Guidance document NEI 13-02, Appendix I, establishes an initial water addition rate of 500 gpm based on EPRI Technical Report 3002003301, "Technical Basis for Severe-Accident Mitigating Strategies." The initial SAWA flow rate at DAEC will be at least 272 gpm. After roughly 4 hours, during which the maximum flow rate is maintained, the SAWA flow will be reduced. The reduction in flow rate and the timing of the reduction will be based on stabilization of the containment parameters of drywell pressure and wetwell level.

The licensee used the reference plant analysis included in NEI 13-02, Revision 1, and calculation CAL-M13-005, "FLEX Diesel Pump Suction Hydraulic Analysis," Revision 1, to demonstrate that SAWA flow could be reduced to 55 gpm after 4 hours of initial SAWA flow rate and that suppression pool level remains below the suppression pool vent pipe for greater than 7 days of sustained operation allowing significant time for restoration of alternate containment pressure control and heat removal. At some point, if the wetwell level begins to rise, indicating that the SAWA flow is greater than the steaming rate due to containment heat load, SAWA flow can be further reduced as directed by the SAMGs.

In its FIP, the licensee stated that the wetwell vent was designed and installed to meet NEI 13-02, Revision 1, guidance and is sized to prevent containment overpressure under severe accident conditions. DAEC will follow the guidance (flow rate and timing) for SAWA described in BWROG-TP-15-008, "Severe Accident Water Addition Timing," [Reference 34] and BWROG-TP-15-011 "Severe Accident Water Management" [Reference 35]. The wetwell vent will be opened prior to exceeding the PCPL value of 45 psig. The licensee also referenced analysis included in BWROG-TP-15-008, which demonstrates adding water to the reactor vessel within 8 hours of the onset of the event will limit the peak containment drywell temperature, significantly reducing the possibility of containment failure due to temperature. Drywell pressure can be controlled by venting the containment from the suppression chamber.

The NRC staff audited the information referenced above. Guidance document NEI 13-02, uses an initial SAWA flow of 500 gpm reduced to 100 gpm after four hours. The NRC staff noted that Duane Arnold determined plant-specific flow rates using the ratio of Duane Arnold licensed thermal power (1912 MWt) to that of the reference plant (3,514 MWt) used in the EPRI Technical Report 3002003301, "Technical Basis for Severe-Accident Mitigating Strategies." This is consistent with NEI 13-02, Section 4.1.1.2.

4.1.2 Conclusions

Based on this evaluation, the NRC staff concludes that the licensee has developed SAWA guidance that should ensure protection of the containment during severe accident conditions following an ELAP event, and, if implemented appropriately, appears to be consistent with NEI 13-02 guidance, as endorsed by JLD-ISG-2013-02 and JLD-ISG-2015-01, and should adequately address the requirements of the order.

4.2 Severe Accident Water Management (SAWM)

The licensee's strategy to preclude the necessity for installing a hardened drywell vent at Duane Arnold is to implement the containment venting strategy utilizing SAWA and SAWM. This strategy consists of the use of the Phase 1 wetwell vent and SAWA hardware to implement a water management strategy that will preserve the wetwell vent path until alternate reliable containment heat removal can be established. The SAWA system consist of a FLEX (SAWA) pump injecting into the RPV. The overall strategy consists of flow control (using local valves) at the FLEX (SAWA) pump along with instrumentation and procedures to ensure that the wetwell vent is not submerged (SAWM). Water from the SAWA (FLEX) pump will be routed through the LPCI system. The LPCI connection allows the water to flow in the RPV. Throttling cvalves and flow meters will be used to control water flow to maintain wetwell availability. Procedures have been issued to implement this strategy including revision 3 to the Severe Accident Management Guidelines (SAMGs). This strategy has been shown via MAAP analysis to protect containment without requiring a drywell vent for at least 7 days which is the guidance from NEI 13-02 for the period of sustained operation.

4.2.1 Staff Evaluation

4.2.1.1 Available Freeboard Use

In its FIP, the licensee states that the freeboard between 10'-5" (normal level) and 8'-3" (bottom of suppression pool vent pipe) in the suppression pool provides approximately 678,119 gallons of water before the water level reaches the bottom of the vent pipe. Generic assessment BWROG-TP-15-011 [Reference 35] provides the principles of SAWM to preserve the suppression pool vent for a minimum of 7 days. After containment parameters are stabilized with SAWA flow, SAWA flow will be reduced to a point where containment pressure will remain low while suppression pool water level is stable or very slowly rising. For Duane Arnold, the SAWA/SAWM design flow rates (272 gpm at 8 hours followed by 55 gpm from 12 hours to 168 hours) and available freeboard volume (described above) are bounded by the values utilized in the BWROG-TP-15-011 reference plant analysis that demonstrates the success of the SAWA/SAWM strategy. As shown in calculation EVAL-16-M01, "Determination of Suppression Pool Volume at Specific Water Levels to Support Severe Accident Water Management (SAWM) Strategies," Revision 0, the suppression pool level will not reach the suppression pool vent for at least 7 days.

The NRC staff audited the information provided including the calculation and the Technical Paper. Generic assessments in BWROG-TP-011 demonstrate that starting water addition at a high rate of flow and throttling after approximately 4 hours will not increase the suppression pool level to that which could block the suppression chamber HCVS. The NRC staff concurs that the flow of water added to the suppression pool can be controlled such that the suppression pool remains operational.

4.2.1.2 Strategy Time Line

As noted in Section 4.1.1.3, "SAWA Analysis of Flow Rates and Timing," the SAWA flow is based on the site-specific, scaled flow rate of 272 gpm to start at about 8 hours. Calculation CAL-M13-005 demonstrated that SAWA flow could be reduced to 55 gpm after 4 hours and containment would be protected. The NRC staff concurs that the SAWM approach should provide operators sufficient time to reduce the water flow rate and to maintain wetwell venting capability. The strategy is based on BWROG generic assessments in BWROG-TP-15-008 and BWROG-TP-15-011.

As noted above, BWROG-TP-15-008 demonstrates adding water to the reactor vessel within 8-hours of the onset of the event will limit the peak containment drywell temperature significantly, reducing the possibility of containment failure due to temperature. Drywell pressure can be controlled by venting the containment from the suppression chamber. Technical Paper BWROG-TP-011 demonstrates that, for a reference plant, starting water addition at a higher rate of flow and throttling after approximately 4-hours will not increase the suppression pool level to a point that could block the suppression chamber HCVS.

4.2.2 Conclusions

Based on this evaluation, the NRC staff concludes that the licensee has developed SAWM guidance that should make it unlikely that the licensee would need to vent from the containment drywell during severe accident conditions following an ELAP event, and, if implemented appropriately, appears to be consistent with NEI 13-02 guidance, as endorsed by JLD-ISG-2013-02 and JLD-ISG-2015-01, and should adequately address the requirements of the order.

4.3 SAWA/SAWM Motive Force

4.3.1 Staff Evaluation

4.3.1.1 SAWA Pump Power Source

As described in Section 4.1, the licensee plans to use one of two portable diesel-driven FLEX pumps to provide SAWA flow. Operators will refuel the FLEX pump and DGs in accordance with Order EA-12-049 procedures using fuel oil from the installed emergency diesel generator (EDG) fuel oil storage tanks. Procedure SAM 719, "Emergency Refueling of Diesel Powered Equipment," Revision 0, directs operators to refuel the portable FLEX pumps from the onsite EDG fuel oil storage tanks. In its FIP, the licensee states that refueling will be accomplished in areas that are shielded and protected from the radiological conditions during a severe accident scenario.

4.3.1.2 DG Loading Calculation for SAWA/SAWM Equipment

In its FIP, the licensee lists portable SAWA flow meters, wetwell level, drywell pressure, and torus pressure as instruments required for SAWA and SAWM implementation. The wetwell level, drywell pressure, and torus pressure are used for HCVS venting operation. These instruments are powered by the Class 1E station batteries until the FLEX DG is deployed and available. The SAWA flow meter is an electromagnetic flow meter that has a battery life of 6 to 10 years.

The NRC staff audited licensee dc sizing calculations E08-007, "250 VDC System Battery Sizing, Voltage Drop, Short Circuit, Coordination, and Charger Sizing," Revision 0 and E08-008, "125 VDC System Battery Sizing, Voltage Drop, Short Circuit, Coordination, and Charger Sizing," Revision 1, under Order EA-12-049, which verified the capability of the Class 1E station batteries to supply power to the required loads (e.g. wetwell level, drywell pressure, and torus pressure) during the first phase of the Duane Arnold FLEX mitigation strategy plan for an ELAP event. The NRC staff also audited licensee calculation CAL-E13-001, which verified that the 405 kW is adequate to support the addition of the HCVS electrical loads. The NRC staff confirmed that the Class 1E station batteries and 405 kW FLEX DGs should have sufficient capacity and capability to supply the necessary SAWA/SAWM loads during an ELAP event.

4.3.2 Conclusions

Based on this evaluation, the NRC staff concludes that the licensee has established the necessary motive force capable to implement the water management strategy during severe accident conditions following an ELAP event, and, if implemented appropriately, appears to be consistent with NEI 13-02 guidance, as endorsed by JLD-ISG-2013-02 and JLD-ISG-2015-01, and should adequately address the requirements of the order.

4.4 SAWA/SAWM Instrumentation

4.4.1 Staff Evaluation

4.4.1.1 SAWA/SAWM Instruments

In Section IV.C.10 of its FIP, the licensee stated that the instruments credited for SAWA/SAWM are the portable flow meters, the wetwell level indicators (LI4396A/B and LI4397 A/B), drywell pressure indicators (PI4396C/D), and the torus pressure indicators (PI4395A/B). The NRC staff found that wetwell level and drywell pressure are existing RG 1.97 instruments that were designed and qualified for severe accident conditions. The SAWA flow instrument range is 55 to 1761 gpm, which appears to be consistent with the licensee's strategy. The NRC staff reviewed Section IV.C.10.1, Section IV.C.10.2, and Table 1 of the FIP and found that the instruments appear to be consistent with the NEI 13-02 guidance.

4.4.1.2 SAWA Instruments and Guidance

In Section IV.C.10.2 of its FIP, the licensee stated that the drywell pressure and wetwell level instruments, used to monitor the condition of containment, are pressure and differential pressure detectors that are safety-related and qualified for post-accident use. These instruments are referenced in SAGs for control of SAWA flow to maintain the wetwell vent in service while maintaining containment protection and are powered initially by batteries until the FLEX generator is deployed and connected, and then by FLEX generator systems for the sustained operating period.

In Section IV.C.10.2 of its FIP, the licensee stated that the SAWA flow meter is an electromagnetic flow meter provided with 5" Storz connections that may be placed anywhere along the hose run. It is powered by internal batteries capable of providing power for much greater than 7 days (6 years minimum).

In Section IV.C.10.2 of its FIP, the licensee stated that FLEX electrical strategies repower other containment instruments that include drywell temperature, which may provide information for the operations staff to evaluate plant conditions under a severe accident and to provide confirmation for adjusting SAWA flow rates.

The NRC staff reviewed the FIP, including Table 1 and Section IV.C.10.2 and found the licensees response appears to be consistent with the guidance. The NRC staff notes that NEI 13-02, Revision 1, Section C.8.3 clarifies that drywell temperature is not required but may provide further information for the operations staff to evaluate plant conditions under severe accident and provide confirmation to adjust SAWA flow rates.

4.4.1.3 Qualification of SAWA/SAWM Instruments

In Section IV.C.10.3 of its FIP, the licensee stated drywell pressure and wetwell level instruments are pressure and differential pressure detectors that are safety-related and qualified for post-accident use. The NRC staff confirmed that drywell pressure and wetwell level were declared RG 1.97 variables and considered acceptable by the HCVS guidance as noted in Section 3.1.2.8 above.

In its FIP, the licensee stated that the SAWA flow meter is rated for continuous use under the expected ambient conditions and will be available for sustained operation. The licensee also stated that in extreme cold conditions, the flow meter will be in the turbine building and portable heaters are available to provide area heating if needed. The licensee provided qualification and anticipated conditions data in Table 1. The NRC staff confirmed the proposed locations of the SAWA flow meter relative to the vent pipe in FIP Attachment 6b drawing. The NRC staff reviewed Table 1 of the FIP and determined the SAWA flow meter appears to be qualified for the anticipated environment.

4.4.2 Conclusions

Based on this evaluation, the NRC staff concludes that the licensee has in place, the appropriate instrumentation capable to implement the water management strategy during severe accident conditions following an ELAP event, and, if implemented appropriately, appears to be consistent with NEI 13-02 guidance, as endorsed by JLD-ISG-2013-02 and JLD-ISG-2015-01, and should adequately address the requirements of the order.

4.5 <u>SAWA/SAWM Severe Accident Considerations</u>

4.5.1 <u>Staff Evaluation</u>

4.5.1.1 Severe Accident Effect on SAWA Pump and Flowpath

To address SAWA/SAWM severe accident dose considerations, the licensee performed a detailed radiological analysis documented as CAL-R15-002, "Duane Arnold Hardened Containment Vent System Dose Assessment." This calculation analyzed the dose at different locations and times where operator actions will take place during FLEX/SAWA/SAWM activities. The analyzed locations include the MCR, ROS, travel paths for hose routing, and FLEX/SAWA pump locations.

In its FIP, the licensee stated that the FLEX pumps are stored in the FLEX buildings located at the North and South ends of the DAEC site that are protected from screened-in hazards. The licensee further states that the SAWA pumps will be operated from outside the reactor building, either at the pump-house or in the turbine building. Therefore, there will be no issues with radiation dose rates at the FLEX pump control location and there will be no significant dose to the FLEX pump. The NRC staff agrees that there should be no significant issues with radiation dose rates at the SAWA pump control location, and there should be no significant dose to the SAWA pump.

The SAWA flow path inside the reactor building consists of steel piping that will be unaffected by the radiation dose. The licensee analyzed the radiological conditions along the SAWA flow path to ensure that hoses will only be run in locations that are shielded from significant radiation dose or that have been evaluated for the integrated dose effects over the period of sustained operation. The NRC staff audited the information and agrees that the SAWA flow path will not be adversely affected by radiation effects due to the severe accident conditions.

4.5.1.2 Severe Accident Effect on SAWA/SAWM Instruments

The DAEC SAWA strategy relies on three instruments: wetwell level; containment pressure; and SAWA flow. Containment pressure and wetwell level are declared DAEC PAM variables as described in RG 1.97 and the existing qualification of these channels is considered acceptable for compliance with Order EA-13-109 in accordance with the guidance in NEI 13-02, Appendix C, Section C.8.1.

As discussed above in Section 4.5.1.1, the SAWA pump is stored in the FLEX buildings and will be operated from outside the reactor building, either at the pump-house or in the turbine building. In its FIP, the licensee states that the SAWA flow meter is rated for continuous use under the expected ambient conditions and will be available for sustained operation. Therefore, there will be no issues with radiation dose rates at the FLEX pump control location and there will be no significant radiation exposure to the flow instruments mounted on the SAWA pump skid. Based on this information, the NRC staff agrees that the SAWA/SAWM instruments should not be adversely affected by radiation effects due to severe accident conditions.

4.5.1.3 Severe Accident Effect on Personnel Actions

The operation of SAWA and SAWM will not alter the environmental conditions evaluated in Section 3.1.1.2, "Personnel Habitability – Environmental," for the main control room or for the ROS. As part of the response to Order EA-12-049, DAEC used the results of EVAL-M16-18, "Reactor Building Environmental Analysis for FLEX," Revision 0, and CAL-M06-007, "Room Heatup Analysis for Duane Arnold Energy During Station Blackout," Revision 1, for determining expected temperatures in the reactor building and control building. These evaluations provide temperature response of the reactor and control buildings during a FLEX event and a station blackout event respectively. Since, in the severe accident, the core materials are contained inside the primary containment, the temperature response of the reactor and control buildings is driven by the loss of ventilation and ambient conditions and therefore will not change. Thus, the FLEX and station blackout calculations are bounding and acceptable for severe accident use.

Table 2 of the FIP provides a list of SAWA/SAWM operator actions as well as an evaluation of each for suitability during a severe accident. Attachment 6 of the FIP shows the approximate locations of the actions. The NRC staff audited the evaluations and noted that the results appear reasonable for the given inputs.

The licensee performed calculation CAL-R15-002, "Duane Arnold Hardened Containment Vent System Dose Assessment," which documents the dose assessment for designated areas inside the DAEC reactor building (outside of containment) and outside the DAEC reactor building caused by FLEX activities and the sustained operation of the HCVS under the beyond-design-basis severe accident condition of an ELAP. This assessment used conservative assumptions to determine the expected dose rates in all areas that may require access during a beyond-design-basis ELAP. As stated in Section 3.1.1.3, Personnel Habitability - Radiological, the NRC staff agrees, based on the audit of the licensee's detailed evaluation, that mission doses associated with actions taken to protect the public under beyond-design-basis severe accident conditions will not subject plant personnel to an undue risk from radiation exposure.

4.5.2 Conclusions

Based on this evaluation, the NRC staff concludes that the licensee has considered the severe accident effects on the water management strategy and that the operation of components and instrumentation should not be adversely affected, and the performance of personnel actions should not be impeded, during severe accident conditions following an ELAP event. The NRC staff further concludes that the water management strategy, if implemented appropriately, appears to be consistent with NEI 13-02 guidance, as endorsed by JLD-ISG-2013-02 and JLD-ISG-2015-01, and should adequately address the requirements of the order.

4.6 Conclusions for Order EA-13-109, Phase 2

Based on its review, the NRC staff concludes that the licensee has developed guidance and a water management strategy that, if implemented appropriately, appears to be consistent with NEI 13-02 guidance, as endorsed by JLD-ISG-2013-02 and JLD-ISG-2015-01, and should adequately address the requirements of the order.

5.0 HCVS/SAWA/SAWM PROGRAMMATIC CONTROLS

5.1 Procedures

Order EA-13-109, Attachment 2, Section 3.1 requires that the licensee develop, implement, and maintain procedures necessary for the safe operation of the HCVS. Furthermore, Order EA-13-109 requires that procedures be established for system operations when normal and backup power is available, and during an ELAP. Relevant guidance is found in NEI 13-02, Sections 6.1.2 and 6.1.2.1.

In its FIP, the licensee states that a site-specific program and procedures were developed following the guidance provided in NEI 13-02, Sections 6.1.2, 6.1.3, and 6.2. They address the use and storage of portable equipment including routes for transportation from the storage locations to deployment areas. In addition, the procedures have been established for system operations when normal and backup power is available, and during ELAP conditions. The FIP also states that provisions have been established for out-of-service requirements of the HCVS and the compensatory measures. In the FIP, Section V.B provides specific time frames for out-of-service requirements for HCVS functionality.

The FIP also provides a list of key areas where either new procedures were developed, or existing procedures were revised. The NRC staff audited the overall procedures and programs developed, including the list of key components included, and noted that they appear to be consistent with the guidance found in NEI 13-02, Revision 1. The NRC staff determined that procedures developed appear to be in accordance with existing industry protocols. The provisions for out-of-service requirements appear to reflect consideration of the probability of an ELAP requiring severe accident venting and the consequences of a failure to vent under such conditions.

Based on the evaluation above, the NRC staff concludes that the licensee's procedures for HCVS/SAWA/SAWM operation, if implemented appropriately, appear to be consistent with NEI 13-02 guidance, as endorsed by JLD-ISG-2013-02 and JLD-ISG-2015-01, and should adequately address the requirements of the Order.

5.2 Training

Order EA-13-109, Attachment 2, Section 3.2 requires that the licensee train appropriate personnel in the use of the HCVS. Furthermore, Order EA-13-109 requires that the training include system operations when normal and backup power is available, and during an ELAP. Relevant guidance is found in NEI 13-02, Section 6.1.3.

In its FIP, the licensee stated that all personnel expected to perform direct execution of the HCVS/SAWA/SAWM actions will receive necessary training. The training plan has been developed per the guidance provided in NEI 13-02, Section 6.1.3, and will be refreshed on a periodic basis as changes occur to the HCVS actions, systems, or strategies. In addition, training content and frequency follows the systems approach to training process. The NRC staff reviewed the information provided in the FIP and confirmed that the training plan is consistent with the established systems approach to training process.

Based on the evaluation above, the NRC staff concludes that the licensee's plan to train personnel in the operation, maintenance, testing, and inspection of the HCVS design and water management strategy, if implemented appropriately, appears to be consistent with NEI 13-02 guidance, as endorsed by JLD-ISG-2013-02 and JLD-ISG-2015-01, and should adequately address the requirements of the order.

6.0 CONCLUSION

In June 2014, the NRC staff started audits of the licensee's progress in complying with Order EA-13-109. The staff issued an ISE for implementation of Phase 1 requirements on February 11, 2015 [Reference 14], an ISE for implementation of Phase 2 requirements on September 13, 2016 [Reference 15], and an audit report on the licensee's responses to the ISE open items on March 5, 2018 [Reference 16]. The licensee reached its final compliance date on September 25, 2018, and has declared in letter dated December 19, 2018 [Reference 17], that Duane Arnold is in compliance with the order.

Based on the evaluations above, the NRC staff concludes that the licensee has developed guidance that includes the safe operation of the HCVS design and a water management strategy that, if implemented appropriately, should adequately address the requirements of Order EA-13-109.

7.0 REFERENCES

1. Order EA-13-109, "Order Modifying Licenses with Regard to Reliable Hardened Containment Vents Capable of Operation Under Severe Accident Conditions," June 6, 2013 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML13143A321)

2. Letter from Duane Arnold to NRC, "NextEra Energy Duane Arnold LLC's Phase 1 Overall Integrated Plan in Response to June 6, 2013, Commission Order Modifying Licenses with Regard to Reliable Hardened Containment Vents Capable of Operation Under Severe Accident Conditions Phase 1 (Order Number EA-13-109)," dated June 25, 2014 (ADAMS Accession No. ML14182A423)

3. Letter from Duane Arnold to NRC, "First Six-Month Status Report For Phase 1 Overall Integrated Plan in Response to June 6, 2013 Commission Order Modifying Licenses with Regard to Reliable Hardened Containment Vents Capable of Operation Under Severe Accident Conditions (Order Number EA-13-109)," dated December 10, 2014 (ADAMS Accession No. ML14349A324)

4. Letter from Duane Arnold to NRC, "Second Six-Month Status Report For Phase 1 Overall Integrated Plan in Response to June 6, 2013, Commission Order Modifying Licenses with Regard to Reliable Hardened Containment Vents Capable of Operation Under Severe Accident Conditions (Order Number EA-13-109)," dated June 18, 2015 (ADAMS Accession No. ML15170A333)

5. Letter from Duane Arnold to NRC, "Duane Arnold Energy Center – Phase 1 (Updated) and Phase 2 Overall Integrated Plan in Response to June 6, 2013, Commission Order Modifying Licenses with Regard to Reliable Hardened Containment Vents Capable of Operation Under Severe Accident Conditions (Order EA-13-109)," dated December 22, 2015 (ADAMS Accession No. ML15358A043)

6. Letter from Duane Arnold to NRC, "Fourth Six-Month Status Report For Phases 1 and 2 Overall Integrated Plan in Response to June 6, 2013, Commission Order Modifying Licenses with Regard to Reliable Hardened Containment Vents Capable of Operation Under Severe Accident Conditions (Order Number EA-13-109)," dated June 30, 2016 (ADAMS Accession No. ML16187A261)

7. Letter from Duane Arnold to NRC, "Fifth Six-Month Status Report For Phases 1 and 2 Overall Integrated Plan in Response to June 6, 2013 Commission Order Modifying Licenses with Regard to Reliable Hardened Containment Vents Capable of Operation Under Severe Accident Conditions (Order Number EA-13-109)," dated December 22, 2016 (ADAMS Accession No. ML16362A211)

8. Letter from Duane Arnold to NRC, "Sixth Six-Month Status Report For Phases 1 and 2 Overall Integrated Plan in Response to June 6, 2013 Commission Order Modifying Licenses with Regard to Reliable Hardened Containment Vents Capable of Operation Under Severe Accident Conditions (Order Number EA-13-109)," dated June 29, 2017 (ADAMS Accession No. ML17180A217)

9. Letter from Duane Arnold to NRC, "Seventh Six-Month Status Report For Phases 1 and 2 Overall Integrated Plan in Response to June 6, 2013 Commission Order Modifying

Licenses with Regard to Reliable Hardened Containment Vents Capable of Operation Under Severe Accident Conditions (Order Number EA-13-109)," dated December 19, 2017 (ADAMS Accession No. ML17353A668)

10. Letter from Duane Arnold to NRC, "Eighth Six-Month Status Report For Phases 1 and 2 Overall Integrated Plan in Response to June 6, 2013 Commission Order Modifying Licenses with Regard to Reliable Hardened Containment Vents Capable of Operation Under Severe Accident Conditions (Order Number EA-13-109)," dated June 26, 2018 (ADAMS Accession No. ML18177A261)

11. Nuclear Regulatory Commission Audits of Licensee Responses to Phase 1 of Order EA-13-109 to Modify Licenses With Regard To Reliable Hardened Containment Vents Capable of Operation Under Severe Accident Conditions, dated May 27, 2014 (ADAMS Accession No. ML14126A545)

12. Nuclear Regulatory Commission Audits of Licensee Responses to Phase 2 of Order EA-13-109 to Modify Licenses With Regard To Reliable Hardened Containment Vents Capable of Operation Under Severe Accident Conditions, dated August 10, 2017 (ADAMS Accession No. ML17220A328)

13. Nuclear Regulatory Commission Office of Nuclear Reactor Regulation Office Instruction LIC-111, "Regulatory Audits" (ADAMS Accession No. ML082900195)

14. Letter from NRC to Duane Arnold, "Duane Arnold Energy Center – Interim Staff Evaluation Relating to Overall Integrated Plan in Response to Phase 1 of Order EA-13-109 (Severe Accident Capable Hardened Vents)," dated February 11, 2015 (ADAMS Accession No. ML15006A319)

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Date: June 21, 2019

SUBJECT: DUANE ARNOLD ENERGY CENTER – SAFETY EVALUATION REGARDING IMPLEMENTATION OF HARDENED CONTAINMENT VENTS CAPABLE OF OPERATION UNDER SEVERE ACCIDENT CONDITIONS RELATED TO ORDER EA-13-109 (CAC NO. MF4391; EPID NO. L-2014-JLD-0039) DATE: June 21, 2019

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