UNITED STATES NUCLEAR REGULATORY COMMISSION

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

January 15, 2019

Mr. Bryan C. Hanson
Senior Vice President
Exelon Generation Company, LLC
President and Chief Nuclear Officer
Exelon Nuclear
4300 Winfield Road
Warrenville, IL 60555

SUBJECT: QUAD CITIES NUCLEAR POWER STATION, UNITS 1 AND 2 - SAFETY EVALUATION REGARDING IMPLEMENTATION OF HARDENED CONTAINMENT VENTS CAPABLE OF OPERATION UNDER SEVERE ACCIDENT CONDITIONS RELATED TO ORDER EA-13-109 (CAC NOS. MF4460 AND MF4461; EPID NO. L-2014-JLD-0054)

Dear Mr. Hanson:

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 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 30, 2014 (ADAMS Accession No. ML14184A017), Exelon Generation Company, LLC (the licensee) submitted its Phase 1 OIP for Quad Cities Nuclear Power Station, Units 1 and 2 (Quad Cities) 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 Quad Cities, including the combined Phase 1 and Phase 2 OIP in its letter dated December 16, 2015 (ADAMS Accession No. ML15350A416). 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 Boiling Water Reactor 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 April 1, 2015 (Phase 1) (ADAMS Accession No. ML15089A421), April 28, 2017 (Phase 2) (ADAMS Accession No. ML17109A077), and June 15, 2018 (ADAMS Accession No. ML18162A017), the NRC issued Interim Staff Evaluations and an audit report, respectively, on the licensee's progress. By letter dated August 14, 2018 (ADAMS Accession No. ML18228A540), the licensee reported that Quad Cities is in full compliance with the requirements of Order EA-13-109, and submitted a Final Integrated Plan for Quad Cities.

The enclosed safety evaluation provides the results of the NRC staff's review of Quad Cities' hardened containment vent design and water management strategy for Quad Cities. The intent of the safety evaluation is to inform Quad Cities 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 T. Sanfilippo, Chief
Beyond-Design-Basis Engineering Branch
Division of Licensing Projects
Office of Nuclear Reactor Regulation

Docket Nos. 50-254 and 50-265

Enclosure:
Safety Evaluation

cc w/encl: Distribution via Listserv

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SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

RELATED TO ORDER EA-13-109

EXELON GENERATION COMPANY, LLC

QUAD CITIES NUCLEAR POWER STATION, UNITS 1 AND 2

DOCKET NOS. 50-254 AND 50-265

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 30, 2014 [Reference 2], Exelon Generation Company, LLC (the licensee) submitted a Phase 1 Overall Integrated Plan (OIP) for Quad Cities Nuclear Power Station, Units 1 and 2 (Quad Cities) in response to Order EA-13-109. By letters dated December 17, 2014 [Reference 3], June 30, 2015 [Reference 4], December 16, 2015 (which included the combined Phase 1 and Phase 2 OIP) [Reference 5], June 30, 2016 [Reference 6], January 26, 2017 [Reference 7], June 30, 2017 [Reference 8] and December 11, 2017 [Reference 9], the licensee submitted 6-month updates to its OIP. By letters dated May 27, 2014 [Reference 10], and August 10, 2017 [Reference 11], 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

Enclosure

NRC Office of Nuclear Reactor Regulation (NRR) Office Instruction LIC-111, "Regulatory Audits" [Reference 12]. By letters dated April 1, 2015 (Phase 1) [Reference 13], April 28, 2017 (Phase 2) [Reference 14], and June 15, 2018 [Reference 15], the NRC issued Interim Staff Evaluations (ISEs) and an audit report, respectively, on the licensee's progress. By letter dated August 14, 2018 [Reference 16], 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 17]. Following interactions with stakeholders, these recommendations were enhanced by the NRC staff and presented to the Commission.

On February 17, 2012 [Reference 18], 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 19], the NRC staff issued Order EA-12-050, "Order Modifying Licenses with Regard to Reliable Hardened Containment Vents" [Reference 20], 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 21]. In the SRM for SECY-12-0157 [Reference 22], 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 23], 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 24], 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 25], 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 26], 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

Quad Cities is a two unit General Electric BWR site with Mark I primary containment systems. To implement the Phase 1 requirements of Order EA-13-109, the licensee utilized existing wetwell vent system piping from the suppression chamber and attached new piping to route the HCVS effluent outside the reactor building and up to a point above the reactor building roof. The HCVS is initiated via manual action from either 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 ROS provides backup manual operation of the HCVS valves and purge system as required by the order. The containment parameters of pressure and level from the MCR instrumentation are used to monitor effectiveness of the venting actions. The vent operation is monitored using HCVS valve position, HCVS vent line temperature, HCVS vent line pressure, and effluent radiation levels. The HCVS motive force 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 will be capable of being maintained for a sustained period of up to 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 operator actions to initiate the HCVS vent path can be completed by plant personnel and it includes the capability for remote-manual initiation from the HCVS control station. After initial valve line-up at the ROS, the vent system is initiated, operated, and monitored from the MCR. The vent system can also be initiated and operated from the ROS located in the turbine building on the 619' elevation for Unit 1, and on the 611' elevation for Unit 2. A list of the remote manual actions for 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 3-2), which shows alternate actions that can be performed, is 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 portable equipment is needed 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/SAWA generators and nitrogen bottles provide this motive force. In all likelihood, these actions will be completed in less than 24 hours. However, the HCVS can be operated for at least 24 hours without any supplemental gas or electric power.

The NRC staff reviewed the HCVS Operator Actions Table and compared it with the information contained in the guidance document NEI 13-02 and determined that these actions should minimize the reliance on operator actions. The actions are consistent with the types of actions described in the guidance found 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 the actions described adequately address all the failure modes listed in the guidance provided by 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 (Non-Radiological)

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 system. 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 the MCR and ROS are protected from all external hazards and remain accessible during a range of plant conditions, including severe accident conditions. During the ELAP, as with the station blackout (SBO), normal ventilation systems are inoperable and non-vital equipment is not contributing to the area heat load. Therefore, area temperatures in the MCR will be higher than that for normal operation and likely more in line with that for SBO.

In its FIP, the licensee indicated that primary control of the HCVS is accomplished from the MCR and that alternate control of the HCVS is accomplished from the ROS in the turbine building. FLEX actions that will maintain the MCR and turbine building (ROS location) habitable were implemented in response to NRC Order EA-12-049. The licensee will employ a "Toolbox Approach" for coping with extreme temperatures during FLEX implementation. Examples of acceptable toolbox actions to cope with extreme temperatures are:

- Opening doors when room temperatures become elevated;
- Rotation of personnel;
- Use of ice vests, etc. when tasks are in high heat and humidity;
- Utilizing small fans for air movement;
- Warming/cooling in available vehicles; and
- Utilizing firefighting turn-out gear to cope with extreme low temperatures.

Procedure QCOP 0050-11, "FLEX Control Room Ventilation," Revision 1, provides the primary means to ventilate the room, which will direct operators to open doors and panels and to utilize small generators, portable fans, and ductwork.

The licensee performed calculation QOA 5750-15, "Complete Loss of Control Room HVAC," Revision 13, which predicts the control room heat-up following a station blackout. The licensee's MCR heat-up analysis determined that the peak area temperature for the MCR is 100 degrees Fahrenheit (°F). The licensee also performed calculation EC-EVAL 398588, "QDC TB Temperature Assessment," Revision 0, which predicts the temperature profile in the turbine building following an ELAP. This calculation estimated the maximum temperature in the turbine building, where the ROS is located, to be approximately 120°F.

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 demonstrate that the final design meets the order requirements to minimize the plant operators' exposure to occupational hazards.

The NRC staff reviewed the information in Table 2, audited the calculations referenced in the FIP, and used NUMARC 87-00 as a basis for the habitability temperature limit as referenced in the guidance of NEI 12-06, "Diverse and Flexible Coping Strategies (FLEX) Implementation Guide," (endorsed by the NRC in JLD-ISG-2012-01 [Agencywide Documents Access and Management System (ADAMS) Accession No. ML12229A174]). The acceptance criteria in NUMARC 87-00 for the habitability temperature limit is 110°F for personnel performing light work as being acceptable. The NUMARC guidance states that "a drybulb temperature of 110°F is tolerable for light work for a four-hour period while dressed in conventional clothing." The NRC staff noted that even though Quad Cities predicted a maximum temperature of 120°F in the turbine building near the ROS location, which is greater than the guidance in NUMARC 87-00, that operators will not be staying long in areas with elevated temperatures. Most HCVS actions will take place in the MCR, which is predicted to remain well below the 110°F temperature limit. When manual actions are needed in the ROS, operators will use a "Toolbox Approach." In addition, existing plant procedures for hot area work will also provide protection for plant personnel. The NRC staff agrees that with the limited stay time, the absence of strenuous work tasks required to be performed, the use of ice vest, and existing procedures for working in elevated temperatures should not impede operators from completing their required tasks.

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 QDC-0000-M-2199, "HCVS 7 Day Dose Analysis [Phase I]," which documents the dose assessment for designated areas outside of containment caused by the sustained operation of the HCVS under the beyond-design-basis severe accident condition of an ELAP. Calculation QDC-0000-M-2199 was performed using NRC-endorsed HCVS-WP-02 [Reference 27] and HCVS-FAQ-12 [Reference 28] 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 was determined in the licensee's

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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.

dose calculation and will not exceed 10 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).

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 calculated the maximum dose rates and 7-day integrated whole-body gamma dose equivalents for the MCR and the ROS. The calculation 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) will 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 Roentgen equivalent man (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 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 and the expected integrated whole-body dose equivalent for expected actions 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.

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[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/radiation/health-effects/rad-exposure-cancer.html

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 Section III.B, Subsection 1.1.4 of the Quad Cities HCVS FIP, the licensee stated that primary control is accomplished from the MCR and alternate control is at the ROS on the mezzanine level of the turbine building. The licensee provided a complete list of the HCVS instrumentation and controls, including the location, local environmental conditions, and qualified environmental conditions in Table 1 of the FIP. The NRC staff reviewed the information in Table 1 of the FIP and confirmed the instrumentation and controls components are qualified for the anticipated local environmental conditions.

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 have 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 HCVS wetwell path is designed for venting steam/energy at a nominal capacity of 1 percent of 2957 megawatts thermal (MWt) thermal power at a pressure of 53 pounds per square inch gauge (psig). This pressure is the lower of the containment design pressure and the primary containment pressure limit (PCPL). The size of the wetwell portion of the HCVS is greater than 12 inches in diameter, which provides adequate capacity to meet or exceed the order criteria, as confirmed in the vent capacity calculation discussed below.

The licensee performed calculation QDC-1600-M-2188, "HCVS Vent Line Sizing Calculation (Unit 1)," Revision 0, and QDC-1600M-2247, "HCVS Vent Line Sizing Calculation (Unit 2)," Revision 0, to confirm the HCVS venting capacity. RELAP5 computer code was used to model the HCVS to perform this analysis. RELAP5 is a code to simulate transient two-phase flow conditions in piping systems. The RELAP5 program generates time-dependent thermal-hydraulic conditions within the piping at user-specified time increments. For Unit 1, the energy for 1 percent rated thermal power is calculated to be equivalent to a steam flow rate of approximately 110,465 pounds per hour (lbm/hr) at 47.9 psig PCPL (with torus filled with water up to the vent elevation). For Unit 2, the energy for 1 percent rated thermal power is calculated to be equivalent to a steam flow rate of approximately 110,453 lbm/hr at 47.7 psig PCPL (with the torus water level at the vent line opening). The design was evaluated considering pipe diameter, length, and geometry as well as vendor provided valve loss of coefficients (Cv). The licensee's RELAP5 calculations concludes that at the wetwell PCPL pressure, the HCVS can vent 167,000 lbm/hr of steam for Unit 1 and 173,000 lbm/hr for Unit 2, which provides margin to the minimum required flow rates. The NRC staff audited the licensee's evaluations and confirmed that the HCVS vent design will support the capacity to vent 1 percent of rated thermal power during ELAP and severe accident conditions.

Based on the evaluation above, the NRC staff concludes that the licensee's HCVS design characteristics, 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.

3.1.2.2 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 HCVS vent path consist of a separate wetwell vent for each unit. The wetwell vent exits the primary containment through the existing 18" vent valve 1(2)-1601-60 and associated 18" piping. The discharge is routed through the new 12" vent valve 1(2)-1699-98, located in the reactor building at elevation 632', and associated 12" piping then exiting the reactor building at elevation 644' where the pipe turns vertical to the release point at the top of the stack. A rupture disc has been added downstream of this control valve to serve as the secondary containment pressure boundary and to prevent secondary containment bypass leakage due to valve leakage during a design basis loss of coolant accident (LOCA). The 12" piping between the primary containment isolation valve (PCIV) and the rupture disc is normally vented to the reactor building via three-way valve, 1(2)-1605-14, to ensure any leakage past the PCIV does not burst the rupture disc. The three-way valve is normally locked in position and is manually unlocked and repositioned at the ROS to initiate HCVS operation. The vent pipe extends approximately 5 ft. above the parapet wall of the reactor building roof. This is consistent with the guidance provided for vent height in HCVS-FAQ-04.

For the seismic design of the outdoor HCVS stack, the licensee performed calculation AX-515B, "Pipe Stress Calculation for Vent'N R.B. Air Cool & Purge Piping Lines From Penetration Z-48 To Penetration Z-51," Revision 4, to determine seismic adequacy of the HCVS stack.

In its FIP, the licensee states that HCVS piping contains ASME Class 2, 3, and ANSI B31.1 piping and that the entire HCVS system has been evaluated to Seismic Category I requirements in pipe stress calculation AX-515B consistent with the plants seismic design basis to comply with NEI 13-02, Section 5.2 seismic design guidance

All effluents are exhausted above each unit's reactor building. The discharge point is above the unit's reactor building parapet wall. Guidance in HCVS-FAQ-04 is provided to ensure that vented effluents are not drawn immediately back into any ELAP emergency ventilation intake and exhaust pathways. 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 at the 628' elevation, which is approximately 117 feet below the HVCS pipe outlet. This requires 23.4 feet of separation. This MCR emergency intake is located on the service building roof and the HCVS vent is off the side of the reactor building and provides greater than 23.4 feet of separation. Therefore, the vent pipe discharge point meets the guidance of HCVS-FAQ-04 for stack discharge relative to the 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 29], 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 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 requirements contained in HCVS-WP-04. The evaluation demonstrated that the pipe was robust with respect to external missiles per HCVS-WP-04 in that:

1. There are no portions of exposed piping below 30 feet above grade. Considering that the plant is located at a low point of the surrounding area, a review of the area topographic map has been performed to verify that the 30-foot height requirement is met. As described in EC 392256, "Unit 1 Hardened Containment Vent System (Non-Outage Portion) as required by NRC Order EA-13-109," there are two areas located at grade elevation less than 30 feet from the pipe elevation (berm between ISFSI [Independent Spent Fuel Pool Storage Installation] Pad and Hydrogen Tank Farm and berm located near security shooting range). These areas remain under strict administrative control to eliminate placement of any large missiles within the vicinity.

2. The exposed piping greater than 30 feet above grade has the following characteristics:
    a. The total vent pipe exposed area is approximately 175 square feet for Unit 2 (less for Unit 1), which is less than 300 square feet.
    b. The pipe is made of schedule STD carbon steel versus 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.

3. Hurricanes are not a screened-in hazard for Quad Cities.

Due to actions taken to ensure there are no potential missiles within 0.5 miles of the vent pipe, crimping of the pipe due to tornado borne missiles is not credible. The evaluation concludes that Quad Cites meets all of the tornado missile assumptions identified in HCVS-WP-04. The NRC staff audited the information provided and finds that supplementary protection is not required for the HCVS piping and components.

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 that the HCVS for Units 1 and 2 for Quad Cities are fully independent of each other with separate discharge points. The only interfacing system with the HCVS is the standby gas treatment system (SGTS). There are two parallel interface isolation valves separating the SGTS and the HCVS discharge piping (valves 1(2)-1601-24 and 1(2)-1601-63).

The interface valves between the HCVS and the SGTS are normally-closed, fail-closed (spring and solenoid operated) valves. Upon initiation of an ELAP and associated loss of instrument air, the valves would automatically shut due to spring pressure or loss of power to the solenoid. Therefore, no additional power is necessary. When closed, leakage is minimized. These valves are part of the 10 CFR Part 50, Appendix J, "Primary Reactor Containment Leakage Testing for Water-Cooled Power Reactors," Program [Reference 30] and go through periodic surveillance testing to ensure the leak rates to be within the acceptable limits. The NRC staff audited the information provided and agrees that the use of primary containment isolation valves is acceptable for prevention of inadvertent cross-flow of vented fluids and meets the guidance provided in NEI 13-02, HCVS-FAQ-05, "HCVS Control and Boundary Valves."

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 operators unlock valves at the ROS and verify the rupture disc is burst for system initiation. Following initiation, the HCVS is designed for sustained manual operation from MCR panel 901 (2)-55. The ROS is readily accessible for system initiation and provides back-up controls as described and evaluated in the response under Order Element 1.2.5. The NRC staff confirmed these statements by comparing the instrumentation and controls component locations provided in Table 1 of the FIP.

The NRC staff also confirmed the statements by comparing the operator actions and locations provided in Table 2 of the FIP.

Based on the evaluation above, the NRC staff concludes that the licensee's location and design of the HCVS control panels, 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.

3.1.2.5 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 described the ROS as a readily accessible alternate location with the ability to operate HCVS valves via pneumatic motive force. The ROS contains manually-operated valves that supply pneumatics to the HCVS flow path valve actuators so that these valves may be opened without power to the valve actuator solenoids and regardless of any containment isolation signals. This provides a diverse method of valve operation and improving system reliability.

Following alignment of the three-way valve and gas isolation valves (Table 3-1 of the FIP) at the ROS, the HCVS has been designed to allow initiation, control, and monitoring of venting from the MCR and will be able to be operated from an installed ROS consistent with the requirements of the order. Both locations minimize plant operators' exposure to adverse temperature and radiological conditions, as discussed in Sections 3.1.1.2 and 3.1.1.3 and are protected from adverse natural phenomena and are sufficiently shielded.

Permanently installed electrical power, argon purge gas, and motive air/gas capability will be available to support operation and monitoring of the HCVS for the first 24 hours. Power will be provided by installed batteries for up to 24 hours before generators will be required to be functional. Operator actions required to extend venting beyond 24 hours includes replenishment of pneumatic supplies and argon purge system stored gases and recharging the electrical supply.

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.

Pneumatic Sources Analysis

For the first 24 hours following the event, the motive supply for the HCVS valves will be from the new nitrogen gas supply subsystems, with manual controls located at the ROS in the turbine building. The new nitrogen gas supply subsystem in each unit is comprised of two portable nitrogen bottles and it routes gas supply lines to the actuators of air-operated valve (AOV) 1(2)-1601-60 and AOV 1(2)-1699-98 in the reactor building. The licensee performed calculations QDC-1600-M-2212, "HCVS Nitrogen Bottle Sizing and Pressure Regulator Set Point Determination (Unit 1)," Rev. 0A, and QDC-1600-M-2249, "HCVS Nitrogen Bottle Sizing and Pressure Regulator Set Point Determination (Unit 2)," Revision 0, which determined the required pneumatic supply storage volume and supply pressure set point required to operate the HCVS valves (AOV 1(2)-1601-60 and AOV 1(2)-1699-98) for 24 hours following a loss of normal pneumatic supplies during an ELAP.

The licensee's calculation determined that two nitrogen bottles (per nitrogen gas supply subsystem - filled to a minimum pressure of 2000 psig each) can provide sufficient capacity for operation of the HCVS valves for 24 hours following an ELAP. The calculations also determined that twelve venting cycles are needed in the first 24 hours. The NRC staff audited the calculations in QDC-1600-M-2212 and QDC-1600-M-2249 and confirmed that there should be sufficient pneumatic supply available to provide motive force to operate the HCVS valves in both Units 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, Quad Cities would rely on the new dedicated 125-volt (V) direct current (Vdc) battery, with rack, battery charger, transfer switch, and distribution panel, to provide power to the HCVS. The HCVS battery supplies a common wall-mounted125 Vdc distribution panel for both units. The HCVS battery and battery charger are located on the turbine building mezzanine floor elevation 611'-6 where it is protected from screened-in hazards. Exide Technologies manufactured the HCVS battery.

The HCVS battery is GNB model MCX-9 with a nominal capacity of 344 ampere-hours (A-H). The HCVS battery is sized such that it can supply 125 Vdc to Unit 1 and Unit 2 for 24 hours (assuming simultaneous operation of the HCVS at both units) without recharging. During the audit period, the licensee provided an evaluation for the HCVS battery/battery charger sizing requirements including incorporation into the FLEX diesel generator (DG) loading calculation.

The NRC staff audited licensee calculation QDC-1600-E-2200, "125 VDC Battery Sizing Calculation for Hardened Containment Vent System for 24 Hour Duty Cycle," Revision 1, which verified the capability of the HCVS battery to supply power to the required loads during the first phase of the Quad Cities venting strategy for an ELAP event. The HCVS battery was sized in accordance with Institute of Electrical and Electronics Engineers (IEEE) Standard 485-2010, "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 2015. The licensee's evaluation identified the required loads and their associated ratings (ampere (A) and minimum required voltage). The licensee's battery sizing calculation showed that based on 8.8 A of loading for a 24-hour duty period, a 211.2 A-H battery is required to satisfy the necessary battery duty cycle and end-of cycle battery terminal voltage requirements. The battery selected by the licensee has a capacity of 344 A-H, which is more than the minimum required (211.2 A-H). Therefore, the Quad Cities HCVS battery appears to have sufficient capacity to supply power for at least 24 hours with margin available.

The licensee's strategy includes repowering the HCVS battery charger within 24 hours after initiation of an ELAP. The licensee's strategy also relies on one of two portable 500-kilowatt (kW) 480 V alternating current (Vac) FLEX DG. Only one of the FLEX DGs is required for the HCVS electrical strategy. The 480 Vac FLEX DG will provide power to the HCVS load in addition to loads addressed under Order EA-12-049.

The NRC staff audited licensee calculation QDC-7300-E-2099, "Unit 1(2) 480 VAC FLEX Diesel Generator and Cable Sizing for Beyond Design Basis FLEX Event," Revision 1, which incorporated the HCVS loads on the FLEX DG. The minimum required load for the Phase 2 500 kW FLEX DG incorporating the HCVS loads is 221 kW. Based on its audit of calculation QDC-7300-E-2099, the NRC staff confirmed that the FLEX DGs should have sufficient capacity and capability to supply the necessary loads during an ELAP event.

Electrical Connection Points

The licensee's strategy is to supply power to HCVS components using a combination of permanently installed and portable components. Staging and connecting the 500 kW FLEX DG to power the 480 Vac bus was addressed under Order EA-12-049 compliance and documented in an NRC staff safety evaluation [Reference 34]. Licensee procedure QCOP 1600-33, "Hardened Containment Vent System Lineup and Operation," Revision 1, provides guidance to power the HCVS battery charger from the 480 Vac bus.

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 provide clear guidance to operators that the HCVS is not to be used to defeat containment integrity during any design basis transients and accident. In addition, the HCVS was designed to provide features that prevent inadvertent actuation due to equipment malfunction or operator error. Also, 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 LOCA. However, the ECCS pumps will not have normal power available because of the ELAP.

The containment isolation valves must be opened to permit vent flow. The physical features that prevent inadvertent actuation are key-locked MCR panel 901(2)-55 switches (1(2)-1604-15, 1(2)-1604-10A, 1(2)-1604-10B), and locked-closed manual isolation valves at the ROS for the argon (1(2)-1605-14) and nitrogen subsystems (1(2)-1604-14 and 1(2)-1604-24). The NRC staff's review of the HCVS confirmed that the licensee's design is consistent with the guidance and appears to 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.

In Section III.B, Subsection 1.2.8 of the Quad Cities FIP, the licensee stated that the HCVS includes indications for HCVS valve position, vent pipe temperature, effluent radiation levels, and argon purge pressure in the MCR, and 125 Vdc HCVS battery voltage and nitrogen pressure at the ROS. The NRC staff confirmed these statements by reviewing the instrumentation and controls list in Table 1 of the FIP. The NRC staff notes that the valve position indications were not provided in the list, but the staff did identify them in the system schematic provided in Attachment 3a of the FIP.

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 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.

In Section III.B, Subsection 1.2.9 of the Quad Cities FIP, the licensee stated that the HCVS radiation monitoring system consists of an ion chamber detector coupled to a process and control module, 1(2)-1603-21. The process and control module is located at the ROS locations in the Unit 1 turbine building elevation 619' and the Unit 2 turbine building elevation 611'. The radiation monitor (RM) 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 ROS locations. Both components are qualified for the seismic requirements. The NRC staff reviewed the information provided in Table 1 of the FIP and confirmed that it is consistent with the guidance.

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 pumps and FLEX DG will be staged outside so they will not be adversely impacted by a loss of ventilation.

The HCVS batteries and battery charger are permanently installed at the ROS, in the turbine building at the 611' elevation. As discussed above in Section 3.1.1.2, the licensee performed technical evaluation EC-EVAL-398588, which analyzed the temperature response in the turbine building. The licensee determined that the temperature on the 611' elevation (Unit 2 ROS and HCVS batteries/ battery charger) is expected to remain above 50°F and below 120°F. The licensee determined that the temperature on the 619' elevation (Unit 1 ROS) is expected to remain below 120°F. The licensee will employ a "Toolbox Approach" for coping with temperatures.

The licensee sized the HCVS batteries considering a minimum operating temperature of 50°F. This is the minimum ambient temperature of the room where the HCVS batteries are located as specified in calculation QDC-1600-E-2200. The manufacturer's maximum design limit for the HCVS batteries is 122°F. Therefore, the HCVS batteries appears to be adequate to perform their design function under event temperatures. The operating temperature of the battery charger as specified by the vendor is -18°C to +50°C (0°F to 122°F). Therefore, the battery charger also appears to be adequate to perform its design function under event conditions (120°F).

Based on the above, the NRC staff concurs with the licensee's calculations that show the ROS temperature will remain within the maximum temperature limit (122°F) for the HCVS batteries and the battery charger. Furthermore, based on temperatures 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 Regulatory Guide (RG) 1.155), the NRC staff agrees that other electrical equipment in the ROS appears to 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 agrees that the HCVS equipment located at the ROS in the turbine building appears to not be adversely impacted by the loss of ventilation resulting from an ELAP event.

Radiological

The licensee's calculation QDC-0000-M-2199, "HCVS 7 Day Dose Analysis," 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 QDC-0000-M-2199 and noted 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 appear to not impact 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 31], 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 pipe, a purge system is installed to purge hydrogen (and other combustibles) from the pipe with argon after a period of venting and to purge oxygen from the pipe prior to resuming venting. The supply for the purge system is argon bottles mounted at the ROS. The argon supply lines are then routed to the HCVS vent line via tubing and connected to the line between the new PCIV and rupture disc. Repositioning the 3-way valve 1(2)-1605-14 closes the leakoff line and enables argon injection into the main vent line for initial system lineup. The system is manually initiated by operators following vent closure either remotely from the MCR (via hand switches controlling the 1(2)-1605-25A purge solenoid-operated valve (SOV)) or from manual valves located at the ROS which bypass the purge SOV. The argon purge system is utilized to provide pressure needed to burst the rupture disc. The installed capacity for the argon purge system has been sized for at least 8 purges within the first 24 hours of the ELAP. Calculation QDC-1600-2190, "Hardened Containment System Design Calculation," Revision 0, determined that 16 argon bottles for each unit (32 total) maintained at a minimum pressure of 2350 at 70°F can provide necessary argon to purge the HCVS following 8 venting evolutions during a severe accident scenario. The NRC staff confirmed that the licensee's design appears to be consistent with Option 3 of white paper HCVS-WP-03. The NRC staff also audited the licensee's analysis and confirmed the installed purge system capacity is sufficient. 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 of the argon purge system in conjunction with the HCVS venting strategy meets 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 3.2.1.3, the only interfacing system with the HCVS is the SGTS and there are two parallel interface isolation valves (1(2)-1601-24 and 1(2)-1601-63) separating the SGTS and the HCVS discharge piping. The interface valves between the HCVS and the SGTS are normally closed, fail closed, and are not required to change state to perform their safety related containment isolation function; therefore, they can be assumed to be closed when required. Valves 1(2)-1601-24 and 1(2)-1601-63 are part of the in-service testing (IST) program, and are leak tested in accordance with 10 CFR 50, Appendix J. The NRC staff's review 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 Quad Cities FIP, Table 3-3 includes testing and inspection requirements for HCVS components. The NRC staff reviewed Table 3-3 and found 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 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 stated that the wetwell vent up to and including the second containment isolation barrier is designed and installed consistent with the design basis of primary containment including pressure, temperature, radiation, and seismic loads. These items include piping, piping supports, containment isolation valves, containment isolation valve actuators, and containment isolation valve position indication components. The hardened vent piping between the wetwell and the reactor building roof, including boundary isolation valve 1(2)-1699-98, is designed to the Updated Final Safety Analysis Report (UFSAR) system design pressure of 62 psig at 350°F.

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 that is 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 states 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. 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 has 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.

New components related to HCVS operation are required to be designed to operate following a seismic event. The licensee provided several qualification reports which demonstrate the seismic adequacy of the HCVS components. These seismic qualification reports indicate the HCVS piping, components, supports, and wall penetrations are based on the Quad Cities safe shutdown earthquake (SSE). Table 1 of the FIP contains a list of components and instruments required to operate the HCVS, their qualification and evaluation against the expected conditions. The NRC staff reviewed this table and confirmed that the components required for HCVS venting are designed to remain functional following a design basis earthquake.

The licensee performed evaluation QDC-0020-S-2192, "HCVS Steel Tower Structural Calculation," Revision 0, which analyzed the steel tower to support the Unit 1 and Unit 2 HCVS piping outside of the reactor building for beyond-design-basis conditions, which includes tornado and SSE events. The NRC staff audited the licensee's evaluation at the HCVS steel support tower, which is shown to be structurally adequate to withstand the beyond-design-basis loads. This calculation demonstrated that the HCVS tower adds insignificant mass to the reactor building and will have negligible impact on the seismic analysis of the reactor building. Additionally, there is no seismic interaction between the reactor building and HCVS tower during a seismic event.

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. Quad Cities 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 one of two portable diesel-driven FLEX pumps to provide SAWA flow for flooded and non-flooded conditions respectively. Both conditions take suction from their designated water sources and their pathways are aligned to lead into one train of the residual heat removal (RHR) system and then into the reactor pressure vessel (RPV). The portable FLEX pumps will be deployed prior to initiating SAWA flow. The licensee states in the FIP that the operator locations for deployment and operation of the SAWA equipment 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 emergency response organization (ERO) exposure guidelines. Once SAWA flow is initiated, operators will have to monitor and maintain SAWA flow and ensure refueling the FLEX pump as necessary.

4.1.1 Staff Evaluation

4.1.1.1 Flow Path

The normal SAWA injection flow path is initiated from the FLEX/SAWA portable pump staged at the Discharge Bay, which will serve as the water source. For local intense precipitation (LIP) flooding events, manhole 1-13, located west of the radwaste building, will be used as the water source if the Discharge Bay is unavailable (due to high flood waters preventing pump deployment at this location). Fire hoses are connected from the discharge portion from the FLEX/SAWA portable pump and routed to a distribution manifold staged inside the turbine building. The hoses are routed through the flow meter on the flow meter cart to wall penetrations at the reactor building. The SAWA injection pathway continues with fire hoses from the reactor building wall penetrations to the condensate transfer/fill system piping connections, which lead to the RHR system and eventual injection into the RPV. The FLEX/SAWA portable pump and hoses are stored in the FLEX storage building (FSB), which is protected from all applicable external hazards. Additional equipment to support SAWA injection are stored in areas within the turbine and reactor buildings and they are also protected from external hazards consistent with NRC Order EA-12-049 requirements. SAWA flow can be controlled within the range of 80 gallons per minute (gpm) to 400 gpm, consistent with the BWR Owner's Group (BWROG) reference plant analyses described in NEI 13-02, Rev. 1.

4.1.1.2 SAWA Pump

In its FIP, the licensee states that one of two diesel-driven FLEX/SAWA portable pumps will be deployed near the Discharge Bay to provide SAWA flow for normal SAWA injection. For LIP conditions, the FLEX/SAWA portable pump will be deployed near Manhole 1-13 on the westside of the radwaste building for the suction source. The licensee indicated in the FIP that the FLEX/SAWA portable pump would be deployed in time to meet the eight-hour RPV injection time constraint.

During the audit, the NRC staff audited calculation QDC-0000-M-2097, "PIPE FLO Analysis of FLEX and HCVS Phase II SAWA/SAWM Strategy," Revision 1, which determined that the required SAWA flowrate of 400 gpm to each unit was within the capacity of the FLEX/SAWA portable pump. The NRC staff audited the flow rates and pressures evaluated in the hydraulic analysis and confirmed that the equipment can provide the needed flow. Based on the NRC staff's audit of the FLEX pumping capabilities at Quad Cities, as described in the above hydraulic analyses and the FIP, it appears that the licensee has demonstrated that the FLEX/SAWA portable pump 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 Quad Cities from the BWROG emergency procedure guidelines and severe accident guidelines (EPG/SAG) and NEI

13-02, Appendix I. The SAWA/SAWM implementing procedures are integrated into the QCNPS severe accident management guidelines (SAMGs). In particular, EPG/SAG, Revision 3, when implemented with emergency procedures committee Generic Issue 1314, allows throttling of SAWA in order to protect containment while maintaining the wetwell vent in service. The SAMG flow charts direct the use of the hardened vent as well as SAWA/SAWM when the appropriate plant conditions have been reached.

The licensee used the validation guidance in Appendix E to NEI 12-06, Revision 2, and procedures QCOP 0050-05, "FLEX-SAW Fire Hose Deployment," Revision 3, and QCOP 0050-07, "FLEX Generator and Pump Power Cable Deployment," Revision 3, to demonstrate 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, demonstrate 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 Quad Cities will be approximately 400 gpm, which is based on the QCNPS reactor core isolation cooling (RCIC) flow rates per the guidance in NEI 13-02, Section 4.1.1.2.2. 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 referenced plant analysis included in NEI 13-02, Revision 1, EPRI Technical Report 3002003301, and the QCNPS specific parameters to demonstrate that SAWA flow could be reduced to 80 gpm after 4 hours of initial SAWA flow rate and containment would remain protected. At some point, as torus level begins to rise, indicating that the SAWA flow is greater than the steaming rate due to containment heat load, SAWA flow can be reduced as directed by SAMG guidelines.

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. Quad Cities will follow the guidance (flow rate and timing) for SAWA/SAWM described in BWROG-TP-15-008, "Severe Accident Water Addition Timing," [Reference 32] and BWROG-TP-15-011 "Severe Accident Water Management" [Reference 33]. The wetwell vent will be opened prior to exceeding the PCPL value of 53 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 suppression chamber through the suppression pool.

The NRC staff audited the information referenced above. The reference plant has a torus freeboard of 525,000 gallons and Quad Cities has a torus freeboard of 619,190 gallons. The reference plant assumes a SAWA flow of 500 gpm and Quad Cities assumes a SAWA flow of 400 gpm starting at 8 hours into the event. The reference plant reduces SAWA flow to 100 gpm at 12 hours into the event; Quad Cities reduces SAWA flow to 80 gpm at 12 hours into the event.

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.

4.1.2 Conclusions

Based on this evaluation, the NRC staff concludes that the licensee has developed SAWA guidance that, if implemented appropriately, will 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.

4.2 Severe Accident Water Management (SAWM)

The strategy for Quad Cities to preclude the necessity for installing a hardened drywell vent is to implement the containment venting strategy utilizing SAWA and severe accident water management (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 consists of a FLEX (SAWA) pump injecting into the RPV. SAWM consists of flow control at the FLEX (SAWA) along with instrumentation and procedures to ensure that the wetwell vent is not submerged (SAWM). Procedures have been issued to implement this strategy including Revision 3 to the SAMGs. This strategy has been shown via Modular Accident Analysis Program (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.

The SAWA system consists of a SAWA pump injecting into the RPV (discussed above). The SAWM system consists of flow control at the FLEX (SAWA) valve distribution manifold in the turbine building along with wetwell level indication in the MCR to ensure that the wetwell vent is not submerged (SAWM). Water from the SAWA (FLEX) pump will be routed through the FLEX (SAWA) valve distribution manifold to the RHR system. This RHR connection allows the water to flow into the RPV. Throttling valves and flow meters will permit water flow to maintain wetwell availability. BWROG generic assessment, BWROG-TP-15-008, provides the principles of SAWA to ensure protection of containment.

4.2.1 Staff Evaluation

4.2.1.1 Available Freeboard Use

As stated in the FIP, the freeboard between 14' and 29.5' elevation in the wetwell provides approximately 950,000 gallons of water volume based on the QCNPS torus with a 30' minor diameter and a 109' major diameter. This elevation is the bottom of the vent pipe at wetwell elevation 29.5'. Generic assessment BWROG-TP-15-011 [Reference 33], outlines a principal of SAWM is to preserve the wetwell 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 wetwell level is stable or very slowly rising. For Quad Cities, the SAWA/SAWM design flow rates (400 gpm starting at 8 hours into the event followed by 80 gpm from 12 hours to 168 hours) and above 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. The NRC staff audited the information provided and concurs that the flow of water added to the suppression pool can be controlled such that the wetwell vent remains operational.

4.2.1.2 Strategy Time Line

As noted above, in Section 4.1.1.3, "SAWA Analysis of Flow Rates and Timing," the SAWA flow is based on the site-specific RCIC design flow rate of 400 gpm to start at about 8 hours and will be reduced to 80 gpm after 4 hours. The NRC staff concurs that the SAWM approach will 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 suppression chamber through the suppression pool. Assessment BWROG-TP-011 demonstrates that for a reference plant 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.

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 above, the licensee plans to use one of two FLEX/SAWA portable pumps to provide SAWA flow. The FLEX/SAWA pumps are commercial portable pumps rated for long-term outdoor use in emergency scenarios. The pumps are diesel-driven by an engine mounted on a trailer with the pump. The pumps will be refueled by the FLEX refueling equipment that has been qualified for long-term refueling operations per EA-12-049.

4.3.1.2 DG Loading Calculation for SAWA/SAWM Equipment

In its FIP, the licensee lists drywell pressure, suppression pool level, and SAWA/SAWM meters as instruments required for SAWA and SAWM implementation. The drywell pressure and suppression pool level are used for HCVS venting operation. These instruments are powered by the Class 1E station batteries, and from ac distribution systems that are powered from the FLEX DG. The SAWA/SAWM flow meters are battery powered and do not require electric power.

The NRC staff audited licensee calculation QDC-8300-E-2100, "Unit 1(2) 125 VDC Battery Coping Calculation For Beyond Design Basis FLEX Event – Corrected Copy," Revision 1, which verified the capability of the Class 1E station batteries to supply power to the required loads (e.g. drywell pressure and suppression pool level) during the first phase of the Quad Cities FLEX mitigation strategy plan for an ELAP event. The NRC staff also audited licensee calculation QDC-7300-E-2099, which verified that the 500 kW FLEX DG is adequate to support the addition of the HCVS electrical loads.

Based on its review, the NRC staff concludes that the Class 1E station batteries and 500 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, 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, Subsection 10.1 of the Quad Cities FIP, the licensee stated that Table 1 in the Quad Cities FIP contained a table that listed all HCVS instrumentation and controls. The NRC staff reviewed Table 1 and identified wetwell level, drywell pressure and SAWA flow instrument as the key indications for SAWA/SAWM control.

4.4.1.2 SAWA Instruments and Guidance

In Section IV.C.10.2 of the Quad Cities FIP, the licensee stated that 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. The licensee also stated that the SAWA flow meters are digital flow meters mounted on the flow meter cart, are battery powered, and do not require a power feed. The NRC staff reviewed the FIP Section IV.C.10.2 and Table 1 in the FIP and found it is consistent with the NEI 13-02 guidance.

The Quad Cities electrical strategy may repower other instrumentation. The licensee stated that the Quad Cities SAMG strategies will evaluate drywell temperature, if available. The NRC staff found this is consistent with the guidance in NEI 13-02, Section C.8.3.

4.4.1.3 Qualification of SAWA/SAWM Instruments

In Section IV.C.10.3 of the Quad Cities FIP, the licensee stated that the drywell pressure and wetwell level instruments are pressure and differential pressure detectors that are safety-related and qualified per RG 1.97, Revision 2 (UFSAR Section 7.5). The NRC staff reviewed the Quad Cities UFSAR to confirm the instruments were previously qualified for use as accident monitoring instruments per RG 1.97. 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.

In Section IV.C.10.3 of the Quad Cities FIP, the licensee stated that the SAWA flow meters are rated for continuous use under the expected temperature and radiation conditions. The NRC staff reviewed the FIP and identified the flow meter deployment location inside the turbine building. The NRC staff reviewed Table 1 of the FIP and confirmed the anticipated environmental conditions are within the qualified range for the flow meter.

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, 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 SAWA/SAWM Severe Accident Considerations

4.5.1 Staff Evaluation

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 QDC-0000-M-2223, "HCVS Phase II 7 Day Dose Analysis." 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, and travel paths for hose routing.

In its FIP, the licensee states that the SAWA pumps are stored in the FSB and will be operated from outside the reactor building, in a location that is shielded from the HCVS vent pipe by the off-gas building. The NRC staff audited the radiological analysis and concurs that, if implemented correctly, 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 licensee also states that the SAWA flow path inside the Reactor Building consists of piping that will be unaffected by the radiation dose and 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 concurs 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 Quad Cities SAWA strategy relies on three instruments: wetwell level; containment pressure; and SAWA flow. Containment pressure and wetwell level are declared QCNPS post-accident-monitoring (PAM) variables as described in R.G. 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 stated in Section 4.5.1.1, the SAWA pump will be operated outside the reactor building in a location that is shielded from the HCVS vent pipe by the off-gas building. This location ensures that there will be no adverse effects from radiation exposure to the flow instruments mounted on the SAWA pump trailer. The licensee has chosen low dose areas for the FLEX/SAWA manifold flowmeters to ensure that their operation will not be adversely affected by radiation exposure. 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 SAWA monitoring equipment can all be operated from the MCR and the SAWA pump is operated from outside the reactor building at ground level; therefore, there are no thermal concerns for operators. The MCR and ROS are expected to remain habitable with respect to temperature during the event. Environmental conditions in the MCR and the ROS were discussed previously in Section 3.1.1.2, Personnel Habitability – Environmental. Based on the above, the NRC staff concludes that environmental conditions will not prevent operators from implementing the SAWA or SAWM strategies.

The licensee performed calculations QDC-0000-M-2199, "HCVS 7 Day Dose Analysis [Phase I]," and QDC-0000-M-2223, "HCVS Phase II 7 Day Dose Analysis," in order to document the dose assessment for designated areas inside the Quad Cities reactor buildings (outside of containment) and outside the Quad Cities reactor buildings caused by the sustained operation of the HCVS under the beyond-design-basis severe accident condition of an ELAP. These assessments used conservative assumptions to access the expected dose rates in all areas that may require access during a beyond-design-basis ELAP. The NRC staff audited the licensee's evaluations and agrees, that if implemented correctly, 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, 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 reviewed 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 appears 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 systematic 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 systematic 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 April 1, 2015 [Reference 13], an ISE for implementation of Phase 2 requirements on April 28, 2017 [Reference 14], and an audit report on the licensee's responses to the ISE open items on June 15, 2018 [Reference 15]. The licensee reached its final compliance date on June 15, 2018, and has declared in letter dated August 14, 2018 [Reference 16], that Quad Cities Nuclear Power Station, Units 1 and 2 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 (ADAMS Accession No. ML13143A321)

2. Letter from Quad Cities to NRC, "Quad Cities, Units 1 & 2 – 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 30, 2014 (ADAMS Accession No. ML14184A017)

3. Letter from Quad Cities 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 17, 2014 (ADAMS Accession No. ML14351A433)

4. Letter from Quad Cities 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 30, 2015 (ADAMS Accession No. ML15181A330)

5. Letter from Quad Cities to NRC, "Quad Cities, Units 1 & 2 – 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 16, 2015 (ADAMS Accession No. ML15350A416)

6. Letter from Quad Cities 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. ML16182A013)

7. Letter from Quad Cities 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 January 26, 2017 (ADAMS Accession No. ML17026A366)

8. Letter from Quad Cities 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 27, 2017 (ADAMS Accession No. ML17178A079)

9. Letter from Quad Cities 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 11, 2017 (ADAMS Accession No. ML17345A778)

10. 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)

11. 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)

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

13. Letter from NRC to Quad Cities, "Quad Cities Nuclear Power Station, Units 1 and 2 – Interim Staff Evaluation Relating to Overall Integrated Plan in Response to Phase 1 of Order EA-13-109 (Severe Accident Capable Hardened Vents)," dated April 1, 2015 (ADAMS Accession No. ML15089A421)

14. Letter from NRC to Quad Cities, "Quad Cities Nuclear Power Station, Units 1 and 2 – Interim Staff Evaluation Relating to Overall Integrated Plan in Response to Phase 2 of Order EA-13-109 (Severe Accident Capable Hardened Vents)," dated April 28, 2017 (ADAMS Accession No. ML17109A077)

15. Letter from NRC to Quad Cities, "Quad Cities Nuclear Power Station, Units 1 and 2 – Report for The Audit of Licensee Responses to Interim Staff Evaluations Open Items Related to NRC Order EA-13-109 to Modify Licenses with Regard to Reliable Hardened Containment Vents Capable of Operation Under Severe Accident Conditions," dated June 15, 2018 (ADAMS Accession No. ML18162A017)

16. Letter from Quad Cities to NRC, "Quad Cities Nuclear Power Station, Units 1 and 2, Report of Full Compliance with Phase 1 and Phase 2 of 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 August 14, 2018 (ADAMS Accession No. ML18228A540)

17. SECY-11-0093, "Near-Term Report and Recommendations for Agency Actions Following the Events in Japan," dated July 12, 2011 (ADAMS Accession No. ML111861807)

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

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

20. Order EA-12-050, "Order Modifying Licenses with Regard to Reliable Hardened Containment Vents," March 9, 2012 (ADAMS Accession No. ML12054A694)

21. SECY-12-0157, "Consideration of Additional Requirements for Containment Venting Systems for Boiling Water Reactors with Mark I and Mark II Containments", November 26, 2012 (ADAMS Accession No. ML12325A704)

22. SRM-SECY-12-0157, "Staff Requirements - SECY-12-0157, "Consideration Of Additional Requirements For Containment Venting Systems For Boiling Water Reactors With Mark I And Mark II Containments", March 19, 2013 (ADAMS Accession No. ML13078A017)

23. NEI 13-02, "Industry Guidance for Compliance with Order EA-13-109," Revision 0, November 12, 2013 (ADAMS Accession No. ML13316A853)

24. Interim Staff Guidance JLD-ISG-2013-02, "Compliance with Order EA-13-109, Severe Accident Reliable Hardened Containment Vents," November 14, 2013 (ADAMS Accession No. ML13304B836)

25. NEI 13-02, "Industry Guidance for Compliance with Order EA-13-109," Revision 1, April 23, 2015 (ADAMS Accession No. ML15113B318)

26. Interim Staff Guidance JLD-ISG-2015-01, "Compliance with Phase 2 of Order EA-13-109, Severe Accident Reliable Hardened Containment Vents," April 29, 2015 (ADAMS Accession No. ML15104A118)

27. NEI Industry White Paper – HCVS-WP-02, "Sequences for HCVS Design and Method for Determining Radiological Dose from HCVS Piping," Revision 0, October 30, 2014 (ADAMS Accession No. ML14358A038)

28. Letter from NEI to NRC, "Hardened Containment Venting System (HCVS) Phase 1 and 2 Overall Integrated Plan Template," Revision 1, dated September 28, 2015, and Frequently Asked Questions (FAQs) 10, 11, 12, and 13 (ADAMS Accession No. ML15273A141)

29. NEI Industry White Paper – HCVS-WP-04, "Missile Evaluation for HCVS Components 30 Feet Above Grade," Revision 0, August 17, 2015 (ADAMS Accession No. ML15244A923)

30. Appendix J to 10 Code of Federal Regulations Part 50, "Primary Reactor Containment Leakage Testing for Water-Cooled Power Reactors"

31. NEI Industry White Paper – HCVS-WP-03, "Hydrogen/Carbon Monoxide Control Measures," Revision 1, October 2014 (ADAMS Accession No. ML14295A442)

32. BWROG-TP-15-008, "BWROG Fukushima Response Committee, Severe Accident Water Addition Timing," September 2015

33. BWROG-TP-15-011, "BWROG Fukushima Response Committee, Severe Accident Water Management Supporting Evaluations," October 2015

34. NRC Letter to Quad Cities, "Quad Cities Nuclear Power Station, Units 1 and 2 – Safety Evaluation Regarding Implementation of Mitigating Strategies And Reliable Spent Fuel Pool Instrumentation Related To Orders EA-12-049 And EA-12-051," December 13, 2018 (ADAMS Accession No. ML18333A016)

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Date: January 15, 2019

SUBJECT: QUAD CITIES NUCLEAR POWER STATION, UNITS 1 AND 2 - SAFETY EVALUATION REGARDING IMPLEMENTATION OF HARDENED CONTAINMENT VENTS CAPABLE OF OPERATION UNDER SEVERE ACCIDENT CONDITIONS RELATED TO ORDER EA-13-109 DATED: January 15, 2019

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