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

May 14, 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: LIMERICK GENERATING 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. MF4418 AND MF4419; EPID NO. L-2014-JLD-0051)

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. ML14181A418), Exelon Generation Company, LLC (the licensee) submitted its Phase 1 OIP for Limerick Generating Station, Units 1 and 2 (Limerick) 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 Limerick, including the combined Phase 1 and Phase 2 OIP in its letter dated December 15, 2015 (ADAMS Accession No. ML15364A014). 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. ML15082A433), August 2, 2016 (Phase 2) (ADAMS Accession No. ML16116A320), and May 29, 2018 (ADAMS Accession No. ML18135A436), the NRC issued Interim Staff Evaluations and an audit report, respectively, on the licensee's progress. By letter dated November 14, 2018 (ADAMS Accession No. ML18318A024), the licensee reported that Limerick is in full compliance with the requirements of Order EA-13-109 and submitted a Final Integrated Plan for Limerick.

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

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

Sincerely,

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

Docket Nos. 50-352 and 50-353

Enclosure:
Safety Evaluation

cc w/encl: Distribution via Listserv

TABLE OF CONTENTS

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

SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

RELATED TO ORDER EA-13-109

EXELON GENERATION COMPANY, LLC

LIMERICK GERNERATING STATION, UNITS 1 AND 2

DOCKET NOS. 50-352 AND 50-353

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 Limerick Generating Station, Units 1 and 2 (LGS, Limerick) in response to Order EA-13-109. By letters dated December 17, 2014 [Reference 3], June 30, 2015 [Reference 4], December 15, 2015 (which included the combined Phase 1 and Phase 2 OIP) [Reference 5], June 30, 2016 [Reference 6], December 15, 2016 [Reference 7], June 30, 2017 [Reference 8], December 15, 2017 [Reference 9], and June 29, 2018 [Reference 10], the licensee submitted 6-month updates to its OIP. By letters dated May 27, 2014 [Reference 11], and August 10, 2017 [Reference 12], the NRC notified all BWR Mark I and Mark II licensees that the staff will be conducting audits of their implementation of Order

EA-13-109 in accordance with NRC Office of Nuclear Reactor Regulation (NRR) Office Instruction LIC-111, "Regulatory Audits" [Reference 13]. By letters dated April 1, 2015 (Phase 1) [Reference 14], August 2, 2016 (Phase 2) [Reference 15], and May 29, 2018 [Reference 16], the NRC issued Interim Staff Evaluations (ISEs) and an audit report, respectively, on the licensee's progress. By letter dated November 14, 2018 [Reference 17], the licensee reported that full compliance with the requirements of Order EA-13-109 was achieved and submitted its Final Integrated Plan (FIP).

2.0 REGULATORY EVALUATION

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

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

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

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

2.1 Order EA-13-109, Phase 1

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

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

2.2 Order EA-13-109, Phase 2

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

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

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

Limerick is a General Electric BWR with a Mark II containment. Limerick installed an independent suppression pool vent system with two dedicated containment isolation valves routed to discharge above the reactor building roof for Units 1 and 2. The HCVS can be initiated via manual action from the main control room (MCR) or remote operating station (ROS) at the appropriate time based on procedural guidance in response to plant conditions from observed of derived symptoms. The vent utilizes containment parameters of pressure and suppression pool level from the MCR instrumentation to monitor effectiveness of the venting actions. Vent operation is monitored by HCVS valve position, temperature, and effluent radiation levels. The HCVS motive force is monitored and has the capacity to operate for 24 hours with installed equipment. Replenishment of the motive force will be by use of portable equipment once the installed motive force is exhausted. Venting actions are capable of being maintained for a sustained period of at least 7 days.

3.1 HCVS Functional Requirements

3.1.1 Performance Objectives

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

3.1.1.1 Operator Actions

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

In its FIP, the license indicated that the HCVS was designed to minimize reliance on operator actions in response to hazards identified in NEI 12-06, Revision 0 [Reference 28], which are applicable to the plant site. Operator actions to initiate the HCVS vent path can be completed by plant personnel and include the capability for remote-manual initiation from the ROS. A list of the remote-manual actions performed by plant personnel to open the HCVS vent path are listed in Table 3-1, "HCVS Operator Actions," of the FIP. An HCVS extended loss of alternating current (ac) power (ELAP) Failure Evaluation Table (FIP Table 3-2), which shows alternate actions that can be performed, is also provided in the FIP.

The licensee also stated that permanently-installed electrical power and pneumatic supplies are available to support operation and monitoring of the HCVS for a minimum of 24 hours. After 24 hours, available personnel will be able to connect supplemental electric power (FLEX portable generator) and pneumatic supplies (compressed gas bottles for valve operation and argon bottles for combustible gas inerting) for sustained operation of the HCVS for a minimum of 7 days.

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

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

3.1.1.2 Personnel Habitability – Environmental

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

In its FIP, the licensee stated that control of the HCVS is accomplished from the MCR. FLEX actions that may be taken to maintain the habitability of the MCR were developed in response to NRC Order EA-12-049. FLEX actions include opening MCR doors to the turbine enclosure and operating portable generators and fans to move air through the MCR (if required).

Alternate control of the HCVS is accomplished from the ROS, which is located at the emergency diesel generator (EDG) corridor, on the 217' elevation (same for both units), outside the reactor enclosure. Remote operating station habitability has been evaluated to be acceptable during the event and no action is required to keep the ROS habitable.

In the FIP, Table 2 contains a thermal evaluation of all the operator actions that may be required to support HCVS operation. The relevant evaluation, EC 622673, "Temperature, Humidity, and Radiological Evaluation of the HCVS and SAWA," demonstrates that the final design meets the requirements to minimize the plant operators' exposure to occupational hazards.

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

The NRC staff also audited EC 423382, Revision 1 and EC 423281, Revision 1, which discuss the environmental conditions at the ROS. Table 2 of the FIP indicates that the maximum expected temperature at the ROS may be 121 degrees Fahrenheit (°F). During the audit, the NRC staff questioned the habitability for plant operators performing actions at the ROS. Limerick responded that the 121°F temperature is expected to occur due to a non-safety-related heating steam pipe rupturing during a seismic event. To mitigate this issue, the heating steam pipe was analyzed, and additional supports have been installed to ensure the piping will not rupture (EC 423333 and EC 423381). There are no additional process fluid piping or heat generating equipment that would add significant heat to this area. Therefore, the area will then be at outside ambient conditions that do not normally exceed 100 °F. In addition, operator stay time in the ROS is limited. If required, operating personnel working in high temperature areas will be protected using guidance in licensee procedure SA-AA-111, "Heat Stress Control." The NRC staff reviewed the information provided by the licensee and concurs that with protective measures and limited stay times, plant operators will not be prevented from taking the required actions in the ROS.

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 LM-0721, "Hardened Containment Vent System Dose Assessment," which documents the dose assessment for designated areas inside the LGS reactor enclosure (outside of containment) and outside the LGS reactor enclosure caused by the sustained operation of the HCVS under the beyond-design-basis severe accident condition of an ELAP. Calculation LM-0721 was performed using NRC-endorsed HCVS-WP-02 [Reference 29] and HCVS-FAQ-12 [Reference 30] methodologies. Consistent with the definition of sustained operations in NEI 13-02, Revision 1, the integrated whole-body gamma dose equivalent[1] due to HCVS operation over a 7-day period as determined in the licensee's dose calculation should not exceed 10 Roentgen equivalent man (rem).[2] The calculated 7-day dose due to HCVS operation is a conservative maximum integrated radiation dose over a 7-day period with ELAP and fuel failure starting at reactor shutdown. For the sources considered and the methodology used in the calculation, the timing of HCVS vent operation or cycling of the vent will not create higher doses at personnel habitability and equipment locations (i.e., maximum doses determined in the calculation bound operational considerations for HCVS vent operation).

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

The licensee evaluated the maximum dose rates and 7-day integrated whole-body gamma dose equivalents for the MCR which is the primary control location, and the remote operating station (ROS). In its FIP, the licensee states that the ROS location and the travel path to the ROS have been evaluated for habitability and accessibility during a severe accident. The licensee further states that during an accident, the distance and shielding combined with the short duration of actions required at the ROS show the ROS to be an acceptable location for alternate control. The evaluation (as documented in LM-0721) demonstrates that the integrated whole-body gamma dose equivalent to personnel

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

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

occupying defined habitability locations (resulting from HCVS operation under beyond-design-basis severe accident conditions) should not exceed 10 rem.

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

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

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

3.1.1.4 HCVS Controls and Indications

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

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

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

The NRC staff reviewed the FIP including the evaluation in Section 1.1.4 of the FIP and examined the information provided in Table 1. The NRC staff determined that the controls and indications appear to be consistent with the NEI 13-02 guidance. The NRC staff also confirmed the environmental qualification information in Table 1 of the FIP, as well as the seismic qualification of the controls and indications equipment through audit reviews of Limerick document EC 423333, Revision 4, "2R14MOD – Fukushima Hardened Vent – Online Elect/I&C Work." The NRC staff noted that the Regulatory Guide (RG) 1.97 instruments for drywell pressure (not including the indicators) and suppression pool level did not have qualification information listed in Table 1, but are considered acceptable, in accordance with the NEI 13-02 guidance, based on their design basis qualifications. The NRC staff also notes that the pressure indicators PI-042-170-1 and PI-042-270-1 qualification was considered separately and not part of the FAQ for RG 1.97 instruments.

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

3.1.2 Design Features

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

3.1.2.1 Vent Characteristics

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

The licensee performed calculation LM-709, "Limerick Hardened Containment Vent Capacity," Revision 0, which provides verification of 1 percent power flow capacity at design pressure for both Units 1 and 2. The calculation models all piping, elbows, valves, and other components using either specific or industry-standard flow coefficients to determine an equivalent length of piping. All of the 10" (Unit 1 only), 12", and 14" piping sections are modeled. The model is input into the Reactor Excursion and Leak Analysis Program version 5 (RELAP5) code, which is an industry-standard program for modeling compressible flow in piping. The minimum flow at design pressure to pass 1 percent rated thermal power was calculated to be 147,783 pounds mass per hour (lbm/hr). Calculation LM-709 verifies that the piping can pass greater than 1 percent flow.

The decay heat absorbing capacity of the suppression pool and the selection of venting pressure were made such that the HCVS will have sufficient capacity to maintain containment pressure at or below the containment design pressure (55 pounds per square gauge (psig)), which is lower than the primary containment pressure limit (PCPL) (60 psig). The calculation shows that containment is maintained below the design pressure once the vent is opened, even if it is not opened until PCPL is reached.

The NRC staff reviewed the information provided and audited calculation LM-709, Revision 1. The current licensed reactor thermal power is 3,515 megawatts thermal (MWt); however, LGS conservatively assumed the reactor thermal power to be 3,952 MWt. The calculation shows that 1 percent reactor power thermal energy is equivalent to 147,783 lbm/hr steam flow. The calculation also shows that the HCVS flow at 49.06 psig is 151,117 lbm/hr for Unit 1 and 149,540 lbm/hr for Unit 2. Based on the evaluation, the HCVS vent design appears to have the capacity to vent 1 percent of rated thermal power during ELAP and severe accident conditions with margin.

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

3.1.2.2 Vent Path and Discharge

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

The NRC staff evaluated the HCVS vent path and the location of the discharge. The HCVS is routed inside the reactor building until it exits to the South Stack structure. The South Stack structure also provides additional protection from wind-generated missiles. The 14" diameter HCVS vent pipe then runs vertically outside of the reactor enclosure above the South Stack and extends approximately 4' above the roof of the South Stack Instrument Room (elevation 426'). The NRC staff's review indicates that this appears to be consistent with the guidance provided in HCVS-FAQ-04. The routing of the vent pipe and location of the release point was established to minimize the radiological impact on plant operators and off-site help arriving at the plant. The release point along with the discharge velocity being greater than 8,000 feet per minute assures that the effluent plume will not be entrained into the recirculation zone of the reactor building, control enclosure or LGS, Units 1 and 2 ventilation systems, and the doors opened to establish natural ventilation during a BDBEE.

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 31], provides a risk-informed approach to evaluate the threat posed to exposed portions of the HCVS by wind-borne missiles. The white paper concludes that the HCVS is unlikely to be damaged in a manner that prevents containment venting by wind-generated missiles coincident with an ELAP or loss of normal access to the ultimate heat sink (UHS) for plants that are enveloped by the assumptions in the white paper.

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

1. The exposed portion of vent pipe is greater than 30 feet above grade;

2. The target area of that portion of pipe not housed in a missile-protected structure is less than 300 ft^2;

3. The vent pipe is substantial and robust; and

4. There is no source of obvious potential missiles in the proximity.

The licensee's evaluation determined that the HCVS pipe is adequately protected from the tornado missile assumptions identified in HCVS-WP-04. The NRC staff reviewed the information provided and audited engineering change package EC 0423381 and agrees that supplementary protection is not required for the HCVS piping and components. The NRC staff noted that the HCVS pipe is mostly routed inside buildings which should provide protection for the vent from wind-borne missiles.

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 stated that the HCVS for Units 1 and 2 are fully independent of each other. The HCVS design uses two primary containment isolation valves (PCIVs) in series, in compliance with [Title 10 of the *Code of Federal Regulations* (CFR) Part 50, Appendix A, General Design Criteria (GDC)] GDC-56. The valves are located outside of primary containment as close to the suppression pool air space attached piping as practical and are normally held closed by their actuator spring. The vent pipe adjacent to the PCIVs has been designed with test connections to facilitate periodic 10 CFR Part 50, Appendix J, "Primary Reactor Containment Leakage Testing for Water-Cooled Power Reactors," Program [Reference 32] testing of the PCIVs, in compliance with GDC-54. The NRC staff reviewed the information provided and audited the engineering change package and agrees that the use of PCIVs appear to be acceptable to minimize unintended cross-flow of vented fluids between units and between other systems within the unit, and consistent with the guidance provided in NEI 13-02, HCVS-FAQ-05.

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

3.1.2.4 Control Panels

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

In its FIP, the licensee stated that the HCVS is normally operated and monitored from the MCR. In addition, the HCVS can be aligned by opening pneumatic and purge manual valves at the

ROS located in the diesel generator corridor on elevation 217', which is accessible from outside the reactor enclosure. Table 1 of the FIP contains a list of the HCVS instrumentation and controls components including their location and qualification information. The NRC staff reviewed Section III.B.1.2.4 and confirmed these statements by comparing the instrumentation and controls component locations provided in Table 1 of the FIP.

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

3.1.2.5 Manual Operation

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

In its FIP, the licensee stated that to meet the requirement for an alternate means of operation, the ROS is located in the diesel generator corridor. The pneumatic supply valves are readily accessible at the ROS. The ROS contains manually-operated valves that supply pneumatic force 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 improves system reliability.

The licensee further stated that the location for the ROS is in the respective unit's diesel generator corridor, south of the reactor enclosures. The ROS is located outside of the reactor enclosure and separated from the outside portion vent pipe by more than 100 feet and by concrete walls. The controls available at the ROS location are accessible and functional under a range of plant conditions, including severe accident conditions with due consideration to source term and dose impact on operator exposure, and loss of reactor enclosure ventilation.

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

The NRC staff also reviewed the information provided in Section 1.2.5 of the FIP. Attachment 2 of the FIP provides a one-line diagram of the HCVS vent path which demonstrates that pneumatic supply can be manually aligned directly to the PCIV actuator bypassing the solenoid valve. To close the PCIV, the actuator pneumatic supply can be manually aligned to the solenoid valve vent path.

As noted in Section 3.1.1.2, the maximum temperature at the ROS may reach 121°F if the heating steam pipe ruptures. Based on the licensee's reevaluation, additional pipe supports were added to minimize the likelihood of pipe rupture during a seismic event. The licensee believes that this modification should limit the ROS temperature to the outside ambient temperature. In addition, operator stay time in the ROS is also expected to be limited. If required, operating personnel working in high temperature areas will be protected using licensee procedural guidance in SA-AA-111, "Heat Stress Control." The NRC staff audited the information provided by the licensee and concurs that with protective measures and limited stay times, plant operators will not be prevented from taking the required actions in the ROS.

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 ELAP event, the motive force for the two HCVS PCIVs will be supplied by two compressed air bottles. The compressed air bottles are located in the ROS in each unit's EDG corridor. These bottles have been sized such that they can provide motive force for up to nine venting cycles, which include opening inboard PCIV HV-057V- 281 and outboard PCIV HV-057V-280. Additional gas bottles are readily available for installation to support sustained operation beyond the first 24 hours.

The licensee determined the required pneumatic supply storage volume and supply pressure set point required to operate the PCIVs for 24 hours following a loss of normal pneumatic supplies during an ELAP in calculation LM-0723, "HCVS PCIV Compressed Air Bottle Requirements," Revision 1. The required pressure for PCIV actuation is calculated at around 80 psig. This pressure includes an allowance for leakage. The NRC staff audited the calculation and confirmed that there should be sufficient pneumatic supply available to provide motive force to operate the PCIVs 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, Limerick would rely on a new HCVS battery and battery charger, which are separate for both Units 1 and 2, to provide power to HCVS components. The 125 volt (V) direct current (dc) HCVS battery and battery charger are located in its respective emergency diesel generator enclosure corridor on the 217' elevation. The HCVS battery and battery charger are installed where they are protected from applicable hazards. Exide Technologies manufactured the HCVS battery.

The HCVS battery can provide power for 24 hours without recharging with a nominal capacity of 208 ampere hours (Ah). During the audit period, the licensee provided the NRC staff an evaluation for the HCVS battery/battery charger sizing requirements including incorporation into the FLEX diesel generator (DG) loading calculation.

The NRC staff reviewed licensee calculation LE-0128, "HCVS Battery and Battery Charger Sizing," Revision 0, which verified the capability of the HCVS battery to supply power to the required loads during the first phase of the Limerick venting strategy for an ELAP. 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 calculation identified the required loads and their associated ratings (watts (W) and minimum system operating voltage). The licensee's battery sizing calculation showed that the maximum load per unit (Unit 1 or Unit 2) is 3.17 amperes (A) of continuous loading for a 24-hour duty period. Based on a continuous 3.17 A of loading for a 24-hour duty period, a 173.28 Ah (with correction factors applied) 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 208 Ah, which is more than the minimum required (173.28 Ah). Therefore, the Limerick HCVS battery should have sufficient capacity to supply power for at least 24 hours.

The licensee's strategy includes repowering the HCVS battery charger within 24 hours after initiation of an ELAP. The licensee's strategy relies on one 500 kilowatt (kW) 480 Volt alternating current (Vac) FLEX DG per unit for the HCVS electrical strategy. The 480 Vac FLEX DG would provide power to the HCVS load in addition of loads addressed under Order EA-12-049.

The NRC staff also audited licensee engineering change documents EC 423381 (Section 3.35), "Part 1: 1R17 Mod – Fukushima Hardened Vent – Online Work 16-00130 / ECR-DCP," Revision 5" and EC 423333 (Section 3.35), "Part 1 of 6, 2R14 Mod – Fukushima Hardened Vent – Online Elect/I&C Work 16-00013 / ECR-DCP," Revision 4 which incorporated the HCVS battery charger on the FLEX DGs. The addition of 6.5 A (maximum load associated with the HCVS battery charger) to the FLEX DG loading is acceptable and the rated loading of the FLEX DG will not be exceeded. Based on the NRC staff's audit of engineering documents EC 423381 and EC 423333, it appears that the FLEX DGs should have sufficient capacity and capability to supply the necessary loads during an ELAP event.

<u>Electrical Connection Points</u>

The licensee's strategy to supply power to HCVS components requires using a combination of permanently installed and portable components. Staging and connecting the 500 kW FLEX DG were both addressed under Order EA-12-049. Licensee procedures T-334, "FLEX Generator Connection for Repowering Div. 2 Battery Charger (Unit 1)," Revision 2, and T-334, "FLEX Generator Connection for Repowering Div. 2 Battery Charger (Unit 2), Revision 3, provide guidance to place the HCVS battery charger in service and power them from the FLEX DG.

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

3.1.2.7 Prevention of Inadvertent Actuation

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

In its FIP, the licensee stated that the emergency operating procedures (EOPs) provide clear guidance to operators that the HCVS is not to be used to defeat containment integrity during any design-basis transients or accident. In addition, the HCVS was designed to provide features that prevent inadvertent actuation due to equipment malfunction or operator error.

At Limerick, inadvertent actuation prevention of the HCVS is accomplished by its passive design features. The two PCIVs are designed in series with the HCVS vent pipe, with each PCIV being able to isolate the HCVS vent line through its actuator spring. The PCIVs are isolated from their motive pneumatic supply by locked closed manual valves. A rupture disk is installed downstream of the PCIVs. The purge gas supply is isolated from the HCVS vent line by a locked-closed manual valve and a locked-closed manual valve to bypass the primary operating station. The licensee also indicated in its FIP that the control panel in the MCR has a key lock switch that controls power for the HCVS system and prevents power to the PCIV and argon purge valves. The NRC staff's audit of the HCVS confirmed that the licensee's design appears to be consistent with the guidance and should preclude inadvertent actuation.

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

3.1.2.8 Monitoring of HCVS

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

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

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

3.1.2.9 Monitoring of Effluent Discharge

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

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

In Section III.A.2 of its FIP, the licensee stated that the radiation monitor uses an ion chamber detector. In Section III.B.1.2.9 of its FIP, the licensee stated that the radiation monitor detector is fully qualified for the expected environment at the vent pipe during accident conditions, and the process and control module is qualified for the mild environment in the MCR. The NRC staff reviewed the qualification summary information provided in Table 1 of the FIP and finds that it appears to meet the guidance. The NRC staff also confirmed the summary information through audit reviews of Limerick document EC 423333, Revision 4, "2R14MOD – Fukushima Hardened Vent – Online Elect/I&C Work."

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

3.1.2.10 Equipment Operability (Environmental/Radiological)

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

Environmental

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

As discussed in Section 3.1.1.2, the licensee's evaluation included in EC 423333 and EC 423381 predicts the temperature profile at the ROS (diesel generator enclosure corridor) following an ELAP. The licensee determined that the peak temperature around the ROS will be close to outside ambient conditions that do not normally exceed 100°F.

The licensee sized the HCVS batteries considering a minimum operating temperature of 25°F. This is the minimum ambient temperature of the area where the HCVS batteries are located as specified in EC 423333 and EC 423381. The manufacturer's maximum design limit for the HCVS batteries and battery charger is 122°F. Therefore, the HCVS batteries and battery charger appear to be adequate to perform their design function under event conditions.

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

Radiological

The licensèe's calculation LM-0721, "Hardened Containment Vent System Dose Assessment," documents the dose assessment for both personnel habitability and equipment locations associated with event response to a postulated ELAP condition. The NRC staff audited calculation LM-0721 and notes that the licensee used conservative assumptions to bound the peak dose rates for the analyzed areas. For the sources considered and the methodology used in the dose calculation, the timing of HCVS vent operation or cycling of the vent will not create higher doses at personnel habitability and equipment locations (i.e., maximum doses determined in the calculation bound operational considerations for HCVS vent operation). The NRC staff's audit confirmed that the anticipated severe accident radiological conditions will not preclude the operation of necessary equipment or result in an undue risk to personnel from radiation exposure.

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

3.1.2.11 Hydrogen Combustible Control

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

In NEI 13-02, Section 4.1.7 provides guidance for the protection from flammable gas ignition for the HCVS system. The NEI issued a white paper, HCVS-WP-03, "Hydrogen /Carbon Monoxide Control Measures," Revision 1, endorsed by the NRC [Reference 33], which provides methods to address control of flammable gases. One of the acceptable methods described in the white paper is the installation of an active purge system (Option 3), which ensures the flammability limit of gases passing through the system is not reached.

In its FIP, the licensee stated that to prevent a detonable mixture from developing in the pipe, a purge gas (argon) supply system has been provided to displace potentially flammable/denotable mixtures of gases that may be present in the vent after system actuation. The vent pipe is routed with a continuously upward slope. The purge gas supply system is designed for four purge cycles during the first 24-hour period without the need to recharge. The argon purge system is utilized to provide pressure needed to burst the rupture disk when going to anticipatory venting. The volume of gas required to rupture the disk has been considered as part of the argon gas calculation. Therefore, considerations of dynamic loading, resulting from hydrogen deflagration and detonation of the vent piping is not required. The NRC staff audited the proposed design to purge the HCVS vent as the means to address the potential for combustible gas deflagration/detonation. 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 should meet the requirement to prevent a detonable mixture from developing in the pipe.

Based on the evaluation above, the NRC staff concludes that the licensee's HCVS design ensures that the flammability limits of gases passing through the system are not reached, and, if implemented appropriately, appears to be consistent with NEI 13-02 guidance, as endorsed by JLD-ISG-2013-02 and JLD-ISG-2015-01, and should adequately address the requirements of the order.

3.1.2.12 Hydrogen Migration and Ingress

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

As discussed in Section 3.1.2.3, the HCVS for Units 1 and 2 are fully independent of each other. The design effectively eliminated the cross flow of fluids and gases from the HCVS into other systems or buildings. The HCVS has been designed with two PCIVs in series that are located outside of the primary containment, as close to the suppression pool air space attached piping as practical. The vent pipe adjacent to the PCIVs has been designed with branch connections to facilitate periodic Appendix J leak rate testing of the PCIVs, ensuring leakage of flammable gases remains low. Purging the vent line following each cycle will eliminate the combustible gases and render the line free of any detonable gas mixture. As a result, oxygen infiltration resulting from steam collapse is not a concern. The portion between the PCIVs is steam inerted such that any combustible gas is below the flammability limit. The NRC staff reviewed the information provided and audited the engineering change package and 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 Limerick FIP, Table 3-3 includes testing and inspection requirements for the 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 LGS implemented operation, testing, and inspection requirements for the HCVS and SAWA that follows the existing plant procedures and process to ensure reliable operation of the systems. The existing plant maintenance program is applied to the HCVS and SAWA valves, instead of the maintenance frequency that has been listed in NEI 13-02, Section 6.2.4. The maintenance program uses PCM (Performance Centered Maintenance) templates, which are used to develop preventive LGS implemented operation, testing, and inspection requirements for the HCVS and SAWA that follows the existing plant procedures and process to ensure reliable operation of the systems. The existing plant maintenance program is applied to the HCVS and SAWA valves instead of the maintenance frequency that has been listed in NEI 13-02, Section 6.2.4. The maintenance program uses PCM templates, which are used to develop preventive maintenance tasks to maintain the plant's components. The NRC staff reviewed the information provided and confirmed that the licensee has implemented adequate programs for operation, testing, inspection, and maintenance of the HCVS.

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

3.2 HCVS QUALITY STANDARDS

3.2.1 Component Qualifications

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

In its FIP, the licensee states that the HCVS components were selected to ensure system reliability and functionality, through the quality of design and materials. The HCVS vent path up to and including the second containment isolation barrier is designed and procured as suitable for the BDBEE/severe-accident environmental and process conditions and HCVS mission time. The components incorporated in this portion of the system are designed to the seismic design requirements of the plant and are evaluated as a Seismic I system. All suppression pool air space attached piping, which includes a segment of the HCVS piping downstream of the second containment isolation barrier, is designed as ASME Section III, Class 2 piping. This is consistent with the existing design basis of the plant. Electrical power to the HCVS components is supplied from a dedicated battery and does not impact existing Class IE station battery system. The HCVS battery charger supplies electrical power from an existing Class IE motor control center (MCC) and will be shunt tripped on a loss of coolant accident signal. There is a minimal impact on Class 1D MCC loading during normal operation mode of the plant.

Guidance in NEI 13-02 suggest a 350° F value for HCVS design temperature based on the highest PCPL among the Mark I and II plants. In its FIP, the licensee states that the Unit 1 HCVS piping follows the guidance from NEI 13-02 for all the components and valves. For Unit 2, the HCVS has been designed to a PCPL of 60 psig and a minimum corresponding saturation temperature of 308° F. This lower HCVS design temperature is adequate for component qualifications, since it is acceptable (per the guidance in NEI 13-02) to assume saturation conditions in containment.

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

3.2.2 Component Reliability and Rugged Performance

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

The HCVS vent path up to and including the second containment isolation valve is designed consistent with the design basis of the current containment isolation systems. All other HCVS components have been procured and designed for reliable and rugged performance. All of the new HCVS components, solely dedicated to HCVS operation, including pneumatics supplies, batteries, and control panels were procured with augmented requirements, designed to the seismic design requirements of the plant and are evaluated as a Seismic Category I system. Vent piping beyond the second containment isolation valve (the outboard PCIV) is designed to American National Standards Institute/American Society of Mechanical Engineers (ANSI/ASME) B31.1 and Seismic Category I criteria. The application of ANSI/ASME B31.1 is consistent with the site design basis and the code of record. Table 1 of the FIP contains a list of components, controls, and instruments required to operate the HCVS, their qualification limits, and a summary of the expected environmental conditions. All instruments are fully qualified for the expected seismic conditions so that they will remain functional following a seismic event. The NRC staff reviewed this table and confirmed that the components required for HCVS venting are designed to remain functional following a design-basis earthquake.

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

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

- The strategy making it unlikely that a licensee would need to vent from the containment drywell during severe accident conditions shall be part of the overall accident management plan for Mark I and Mark II containments;
- The licensee shall provide supporting documentation demonstrating that containment failure, as a result of overpressure, can be prevented without a drywell vent during severe accident conditions; and,
- Implementation of the strategy shall include licensees preparing the necessary procedures, defining and fulfilling functional requirements for installed or portable equipment (e.g. pumps and valves), and installing the needed instrumentation.

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

4.1 Severe Accident Water Addition (SAWA)

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

4.1.1 Staff Evaluation

4.1.1.1 Flow Path

The SAWA injection flow path starts at the spray pond and goes to the FLEX pump through suction hoses to a flexible discharge hose. The SAWA flow path continues from the discharge hose to the residual heat removal service water (RHRSW) system and into the reactor enclosure, where it is connected to the RHR system through permanently-installed piping. The SAWA flow path is completed by the RHR piping being connected to the RPV through the RHR low pressure coolant injection (LPCI) valve. Drywell pressure and wetwell level will be monitored and flow rate will be adjusted by use of the SAWA pump control valve at the valve manifold that also contains the SAWA flow indication. The hoses and pumps used for SAWA flow are stored in the FLEX pump storage building (FPSB), which is protected from all hazards. This SAWA injection path is also protected from all external hazards in addition to severe accident conditions.

4.1.1.2 SAWA Pump

In its FIP, the licensee states that the strategy is to use a portable diesel-driven pump for each unit to provide FLEX and SAWA flow. The FLEX pumps are capable of 500 gallons per minute (gpm) for RPV injection. The FLEX pumps are transported on trailer-mounted units and are stored in the FPSB, where they are protected from all applicable external hazards. The initial SAWA flow will be injected into the RPV within 8 hours of the loss of injection. In its FIP, the licensee described the hydraulic analysis performed to demonstrate the capability of each portable FLEX pump to provide the required 500 gpm of SAWA and SFP flow to its respective unit. The NRC staff audited calculation LM-0706, "Fukushima FLEX Hydraulic Analysis," Revision 3, which determined that the required SAWA flowrate of 500 gpm was within the capacity of the portable FLEX pumps.

The NRC staff audited the flow rates and pressures evaluated in the hydraulic analyses and confirmed that the equipment is capable of providing the needed flow. Based on the NRC staff's audit of the FLEX pumping capabilities, as described in the above hydraulic analysis and the FIP, it appears that the licensee has demonstrated that its portable FLEX 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 Limerick from the BWR Owners Group (BWROG) emergency procedure guidelines and severe accident guidelines (EPG/SAG) and NEI 13-02, Appendix I. The SAWA/SAWM [Severe Accident Water Management] implementing procedures are integrated into the LGS severe accident management procedures (SAMPs). In particular, EPG/SAG, Revision 3, when implemented with Emergency Procedures Committee Generic Issue 1314, allows throttling of SAWA valves in order to protect containment while maintaining the wetwell vent in service. The SAMP 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 industry-developed validation guidance to demonstrate that the FLEX/SAWA portable pump can be deployed and commence injection in less than 8 hours. The studies referenced in NEI 13-02, Revision 1, 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 Limerick will be approximately 500 gpm. After roughly 4 hours, during which the maximum flow rate is maintained, the SAWA flow will be reduced. The reduction in flow rate and the timing of the reduction will be based on stabilization of the containment parameters of drywell pressure and wetwell level.

The licensee performed calculation LG-MISC-018, "MAAP Analysis to Support HCVS Design," Revision 0, to demonstrate that SAWA flow could be reduced to 100 gpm after 4 hours of initial SAWA flow rate and that suppression pool level remains below the suppression pool vent pipe for greater than 7 days of sustained operation allowing significant time for restoration of alternate containment pressure control and heat removal. At some point, if the wetwell level begins to rise, indicating that the SAWA flow is greater than the steaming rate due to containment heat load, SAWA flow can be further reduced as directed by the SAMPs.

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. Limerick will follow the guidance (flow rate and timing) for SAWA/SAWM described in BWROG-TP-15-008, "Severe Accident Water Addition Timing," [Reference 34] and BWROG-TP-15-011 "Severe Accident Water Management" [Reference 35]. The wetwell vent will be opened prior to exceeding the design value of 55 psig. The licensee also referenced analysis included in BWROG-TP-15-008, which demonstrates adding water to the reactor vessel within 8 hours of the onset of the event will limit the peak containment drywell temperature, significantly reducing the possibility of containment failure due to temperature. Drywell pressure can be controlled by venting the containment from the suppression chamber.

The NRC staff audited the information referenced above. Guidance document NEI 13-02, uses an initial SAWA flow of 500 gpm reduced after four hours to 100 gpm. The NRC staff noted that Limerick used the same flow rates to that of the reference plant used in the EPRI Technical Report 3002003301, "Technical Basis for Severe-Accident Mitigating Strategies." This is consistent with NEI 13-02, Section 4.1.1.2.

4.1.2 Conclusions

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

4.2 Severe Accident Water Management (SAWM)

The licensee's strategy at Limerick to preclude the necessity for installing a hardened drywell vent is to implement the containment venting strategy utilizing SAWA and SAWM. This strategy consists of the use of the Phase 1 wetwell vent and SAWA hardware to implement a water management strategy that will preserve the wetwell vent path until alternate reliable containment heat removal can be established. The SAWA system consists of a FLEX (SAWA) pump injecting into the RPV. The overall strategy consists of flow control at the FLEX (SAWA) pump along with instrumentation and procedures to ensure that the wetwell vent is not submerged (SAWM). Water from the SAWA (FLEX) pump will be routed through the RHRSW piping to the RHR system. This RHR connection allows the water to flow into the RPV. Throttling valves and flow meters will be used to control water flow to maintain wetwell availability. Procedures have been issued to implement this strategy, including site specific implementation of the generic BWROG EPG/SAG Revision 3 with Emergency Procedures Committee Generic Issue 1314. The BWROG generic assessment, BWROG-TP-15-008 [Reference 34], provides the principles of SAWA to ensure protection of containment. 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 consistent with the guidance from NEI 13-02 for the period of sustained operation.

4.2.1 Staff Evaluation

4.2.1.1 Available Freeboard Use

As stated in the FIP, the licensee states that the freeboard between 23 feet (normal level) and 39 feet (bottom of suppression pool vent pipe) in the suppression pool provides approximately 1,104,572 gallons of water before the water level reaches the bottom of the vent pipe. Generic assessment BWROG-TP-15-011 [Reference 35] provides the principles of SAWM to preserve the suppression pool vent for a minimum of 7 days. After containment parameters are stabilized with SAWA flow, SAWA flow will be reduced to a point where containment pressure will remain low while suppression pool water level is stable or very slowly rising. For Limerick, the SAWA/SAWM design flow rates (500 gpm at 8 hours followed by 100 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. As shown in calculation LG-MISC-018, the suppression pool level will not reach the suppression pool vent for at least 7 days.

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

4.2.1.2 Strategy Time Line

As noted in Section 4.1.1.3, "SAWA Analysis of Flow Rates and Timing," calculation LG-MISC-018 demonstrates that throttling SAWA flow after containment parameters have stabilized, in conjunction with venting containment through the suppression pool vent will result in a stable or slowly rising suppression pool water level. Calculation LG-MISC-018 demonstrates that for the scenario analyzed, suppression pool level will remain below the suppression pool vent pipe for greater than the 7 days of sustained operation allowing significant time for restoration of alternate containment pressure control and heat removal. The NRC staff concurs that the SAWM approach should provide operators sufficient time to reduce the water flow rate and to maintain wetwell venting capability. The strategy is based on BWROG generic assessments in BWROG-TP-15-008 and BWROG-TP-15-011.

4.2.2 Conclusions

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

4.3 SAWA/SAWM Motive Force

4.3.1 Staff Evaluation

4.3.1.1 SAWA Pump Power Source

As described in Section 4.1, the licensee plans to use portable diesel-driven FLEX pumps to provide SAWA flow. Operators will refuel the FLEX pump and DGs in accordance with Order EA-12-049 procedures using fuel oil from the installed EDG fuel oil storage tanks. Procedure T-369, "Transferring Diesel Fuel From Tank in Flex Pump Storage Building," directs operators to refuel the portable FLEX equipment from the onsite EDG fuel oil storage tanks. In its FIP, the licensee states that refueling will be accomplished in areas that are shielded and protected from the radiological conditions during a severe accident scenario.

4.3.1.2 DG Loading Calculation for SAWA/SAWM Equipment

In its FIP, the licensee list drywell pressure, suppression pool level and the SAWA flow meter as instruments required for SAWA and SAWM implementation. The drywell pressure and suppression pool level instruments are used for HCVS venting operation. These instruments are powered by the Class 1E station batteries until the FLEX DG is deployed and available. The SAWA flow meter is an electromagnetic flow meter mounted in the piping on the pumps skid and is powered by the SAWA pumps electrical system.

The NRC staff audited licensee calculation LE-0125, "Class 1E Battery Load Duty Cycle Determination ELAP Scenario," Revision 3, under Order EA-12-049, 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 Limerick FLEX mitigation strategy plan for an ELAP event. The NRC staff also audited licensee engineering change document ECR 14-00019 (EC 422939), "Fukushima FLEX – Electrical Engineering Modification," Revision 1, which verified that the 500kW FLEX DG is adequate to support the HCVS electrical loads. The NRC staff confirmed that the Class 1E 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 during severe accident conditions following an ELAP event, and, if implemented appropriately, appears to be consistent with NEI 13-02 guidance, as endorsed by JLD-ISG-2013-02 and JLD-ISG-2015-01, and should adequately address the requirements of the order.

4.4 SAWA/SAWM Instrumentation

4.4.1 Staff Evaluation

4.4.1.1 SAWA/SAWM Instruments

In Section IV.C.10.2 of its FIP, the licensee stated that the instrumentation needed to implement the SAWA/SAWM strategy is suppression pool level, drywell pressure, and SAWA flow. The NRC staff found that suppression pool level and drywell pressure are existing RG 1.97 instruments that were designed and qualified for severe accident conditions. The SAWA flow instrument range is 37 to 1246 gpm, which appears to be consistent with the licensee's strategy. The NRC staff reviewed Section IV.C.10.1, Section IV.C.10.2, and Table 1 of the FIP and found that the instruments appear to be consistent with the NEI 13-02 guidance.

4.4.1.2 SAWA Instruments and Guidance

In Section IV.C.10.2 of its FIP, the licensee stated that the drywell pressure and suppression pool level instruments, used to monitor the condition of containment, are qualified for post-accident use and that the LGS strategy may also make use of drywell temperature, read directly from a portable thermocouple reader, if available. The licensee also stated that these instruments are referenced in SAGs for control of SAWA flow to maintain the wetwell vent in service while maintaining containment protection and are powered initially by station batteries until the FLEX generator is deployed.

In Section IV.C.10.2 of its FIP, the licensee stated that the SAWA flow meter is an electromagnetic flow meter mounted in the piping on the pump's skid and powered by the pump's electrical system.

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

4.4.1.3 Qualification of SAWA/SAWM Instruments

In Section IV.C.10.3 of its FIP, the licensee stated that the drywell pressure and suppression pool level are declared Limerick PAM variables as described in RG 1.97 and the existing qualification of these channels is considered acceptable for compliance with Order EA-13-109 in accordance with the guidance in NEI 13-02, Appendix C, Section C.8.1. The NRC staff verified the RG 1.97 variables in the Limerick Final Safety Analysis Report. The staff notes that the licensee clarified in its FIP that the drywell pressure indicator in the MCR is not RG 1.97 qualified but is qualified for the mild environment in the MCR.

In its FIP, the licensee stated that the SAWA flow meter is rated for continuous use under the expected ambient conditions and so will be available for the entire period of sustained operation. Furthermore, since the pump is deployed outside the reactor building, and on the opposite end of the reactor building from the vent pipe, there is no concern for any effects of radiation exposure to the flow instrument. The licensee stated in Table 1 of the FIP that anticipated temperature at this location is 97°F and the qualification temperature is 120°F. The licensee further stated in Table 1 of the FIP that the flow meter is located outside and therefore radiation is not a concern. The NRC staff confirmed the proposed location of the SAWA flow meter relative to the vent in FIP Attachment 8 drawing. The NRC staff reviewed Table 1 of the FIP and determined that the SAWA flow meter appears to be qualified for the anticipated environment.

4.4.2 Conclusions

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

4.5 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 LM-0725, "FLEX Activity and HCVS Phase 2 Dose Assessment." This calculation analyzed the dose at different locations and times where operator actions will take place during FLEX/SAWA/SAWM activities. The analyzed locations include the MCR, ROS, travel paths for hose routing, and FLEX/SAWA pump locations.

In its FIP, the licensee stated that the FLEX hoses and pumps are stored in the FPSB where it is protected from screened-in hazards. The licensee further stated that the SAWA injection path is qualified for all the screened in hazards in addition to severe accident conditions. Therefore, there will be no issues with radiation dose rates at the FLEX pump control location and there will be no significant dose to the FLEX pump. Based on an audit of the licensee's evaluations, the staff agrees that it appears that there should be no significant issues with radiation dose rates at the SAWA pump control location and there should be no significant dose to the SAWA pump.

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

4.5.1.2 Severe Accident Effect on SAWA/SAWM Instruments

The LGS SAWA strategy relies on three instruments: wetwell level; containment pressure; and SAWA flow. Containment pressure and wetwell level are declared LGS 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 discussed above in Section 4.5.1.1, the SAWA pump is stored in the FPSB and will be operated from outside the reactor enclosure, on the opposite side of the reactor enclosure from the vent pipe. Therefore, there will be no issues with radiation dose rates at the FLEX pump control location and there will be no significant radiation exposure to the flow instruments mounted on the SAWA pump skid. Based on this information, the NRC staff agrees that the SAWA/SAWM instruments should not be adversely affected by radiation effects due to severe accident conditions.

4.5.1.3 Severe Accident Effect on Personnel Actions

According to the FIP, actions inside the reactor enclosure needed to support SAWA occur within 7 hours of a loss of injection per Procedures T-300 and T-301. In this event, core damage is not expected for at least 1 hour and vessel breach for another 6 hours, so that there will be no excessive radiation levels or heat related concerns in the reactor enclosure when the actions are performed.

After the SAWA flow path is aligned inside the reactor enclosure, the operators make all hose connections, control the SAWA pump to perform SAWA/SAWM operations, and observe the necessary instruments all from outside the reactor building. Therefore, the loss of ventilation inside the building will not impede these actions. Existing plant guidance will provide protection for operators performing outdoor work.

Table 2 of the FIP provides a list of SAWA/SAWM operator actions, as well as an evaluation of each for suitability during a severe accident. Attachment 6 of the FIP shows the approximate locations of the actions. All SAWA/SAWM controls and indications are accessible during severe accident conditions.

The SAWA pump and monitoring equipment can all be operated locally at the pump from outside the reactor enclosure at ground level. The LGS FLEX response ensures that the SAWA pump, FLEX generators, and other equipment can all be run for a sustained period by refueling. All the refueling locations are in shielded or protected areas so that there is no radiation hazard from core material during a severe accident. The monitoring instrumentation includes SAWA flow at the pump, and suppression pool level and containment pressure in the MCR.

The licensee performed calculation LM-0725, "FLEX Activity and HCVS Phase 2 Dose Assessment," which documents the dose assessment for designated areas inside the LGS reactor enclosure (outside of containment) and outside the LGS reactor enclosure caused by FLEX activities and the sustained operation of the HCVS under the beyond-design-basis severe accident condition of an ELAP. This assessment used conservative assumptions to determine the expected dose rates in all areas that may require access during a beyond-design-basis ELAP. As stated in Section 3.1.1.3, Personnel Habitability - Radiological, the NRC staff agrees, based on the audit of the licensee's detailed evaluation, that mission doses associated with actions taken to protect the public under beyond-design-basis severe accident conditions will not subject plant personnel to an undue risk from radiation exposure.

4.5.2 Conclusions

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

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

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

5.0 HCVS/SAWA/SAWM PROGRAMMATIC CONTROLS

5.1 Procedures

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

In its FIP, the licensee states that a site-specific program and procedures were developed following the guidance provided in NEI 13-02, Sections 6.1.2, 6.1.3, and 6.2.

They address the use and storage of portable equipment including routes for transportation from the storage locations to deployment areas. In addition, the procedures have been established for system operations when normal and backup power is available, and during ELAP conditions. The FIP also states that provisions have been established for out-of-service requirements of the HCVS and the compensatory measures. In the FIP, Section V.B provides specific time frames for out-of-service requirements for HCVS functionality.

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

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

5.2 Training

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

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

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

6.0 CONCLUSION

In June 2014, the NRC staff started audits of the licensee's progress in complying with Order EA-13-109. The staff issued an ISE for implementation of Phase 1 requirements on April 1, 2015 [Reference 14], an ISE for implementation of Phase 2 requirements on August 2, 2016 [Reference 15], and an audit report on the licensee's responses to the ISE open items on May 29, 2018 [Reference 16]. The licensee reached its final compliance date on November 14, 2018, and has declared in letter dated November 14, 2018 [Reference 17], that Limerick Generating 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 Limerick to NRC, "Limerick, 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. ML14181A418)

3. Letter from Limerick 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. ML14353A110)

4. Letter from Limerick 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. ML15181A016)

5. Letter from Limerick to NRC, "Limerick, 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 15, 2015 (ADAMS Accession No. ML15364A014)

6. Letter from Limerick 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. ML16182A011)

7. Letter from Limerick to NRC, "Fifth Six-Month Status Report For Phases 1 and 2 Overall Integrated Plan in Response to June 6, 2013 Commission Order Modifying Licenses with Regard to Reliable Hardened Containment Vents Capable of Operation Under Severe Accident Conditions (Order Number EA-13-109)," dated December 15, 2016 (ADAMS Accession No. ML16350A266)

8. Letter from Limerick 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 30, 2017 (ADAMS Accession No. ML17181A031)

9. Letter from Limerick 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 15, 2017 (ADAMS Accession No. ML17349A035)

10. Letter from Limerick to NRC, "Eighth Six-Month Status Report For Phases 1 and 2 Overall Integrated Plan in Response to June 6, 2013 Commission Order Modifying Licenses with Regard to Reliable Hardened Containment Vents Capable of Operation Under Severe Accident Conditions (Order Number EA-13-109)," dated June 29, 2018 (ADAMS Accession No. ML18180A029)

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

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

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

14. Letter from NRC to Limerick, "Limerick Generating 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. ML15082A433)

15. Letter from NRC to Limerick, "Limerick Generating 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 August 2, 2016 (ADAMS Accession No. ML16116A320)

16. Letter from NRC to Limerick, "Limerick Generating 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 May 29, 2018 (ADAMS Accession No. ML18135A436)

17. Letter from Limerick to NRC, "Limerick Generating 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 November 14, 2018 (ADAMS Accession No. ML18318A024)

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

19. 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)

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SUBJECT: LIMERICK GENERATING 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. MF4418 AND MF4419; EPID NO. L-2014-JLD-0051) DATED: May 14, 2019

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