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

January 3, 2019

Mr. Kevin Cimorelli
Site Vice President
Susquehanna Nuclear, LLC
769 Salem Boulevard
NUCSB3
Berwick, PA 18603-0467

SUBJECT: SUSQUEHANNA STEAM ELECTRIC 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. MF4364 AND MF4365; EPID NO. L-2014-JLD-0055)

Dear Mr. Cimorelli:

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 26, 2014 (ADAMS Package Accession No. ML14178A619), Susquehanna Nuclear, LLC (the licensee) submitted its Phase 1 OIP for Susquehanna Steam Electric Station, Units 1 and 2 (SSES, Susquehanna) 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 Susquehanna, including the combined Phase 1 and Phase 2 OIP in its letter dated December 23, 2015 (ADAMS Accession No. ML15362A528). 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. ML15090A300), August 25, 2016 (Phase 2) (ADAMS Accession No. ML16231A509), and October 5, 2017 (ADAMS Accession No. ML17272A733), the NRC issued Interim Staff Evaluations (ISEs) and an audit report, respectively, on the licensee's progress. By letter dated June 26, 2018 (ADAMS Accession No. ML18179A221), the licensee reported that Susquehanna, Units 1 and 2 are in full compliance with the requirements of Order EA-13-109 and submitted a Final Integrated Plan (FIP) for

Susquehanna, which was supplemented by letter dated November 27, 2018 (ADAMS Accession No. ML18332A263).

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

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

Sincerely,

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

Docket Nos. 50-387 and 50-388

Enclosure:
Safety Evaluation

cc w/encl: Distribution via Listserv

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SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

RELATED TO ORDER EA-13-109

SUSQUEHANNA NUCLEAR, LLC

SUSQUEHANNA STEAM ELECTRIC STATION, UNITS 1 AND 2

DOCKET NOS. 50-387 AND 50-388

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 26, 2014 [Reference 2], Susquehanna Nuclear, LLC (the licensee) submitted a Phase 1 Overall Integrated Plan (OIP) for Susquehanna Steam Electric Station, Units 1 and 2 (SSES, Susquehanna) in response to Order EA-13-109. By letters dated December 23, 2014 [Reference 3], June 23, 2015 [Reference 4], December 23, 2015 (which included the combined Phase 1 and Phase 2 OIP) [Reference 5], June 29, 2016 [Reference 6], December 19, 2016 [Reference 7], June 15, 2017 [Reference 8], and December 12, 2017 [Reference 9], the licensee submitted 6-month updates to its OIP. By letters dated May 27, 2014 [Reference 10], and August 10, 2017 [Reference 11], the NRC notified all BWR Mark I and Mark II licensees that the staff will be conducting audits of their implementation of Order EA-13-

109 in accordance with NRC Office of Nuclear Reactor Regulation (NRR) Office Instruction LIC-111, "Regulatory Audits" [Reference 12]. By letters dated April 1, 2015 (Phase 1) [Reference 13], August 25, 2016 (Phase 2) [Reference 14], and October 5, 2017 [Reference 15], the NRC issued Interim Staff Evaluations (ISEs) and an audit report, respectively, on the licensee's progress. By letter dated June 26, 2018 [Reference 16], the licensee reported that full compliance with the requirements of Order EA-13-109 was achieved and submitted its Final Integrated Plan (FIP), which was supplemented by letter dated November 27, 2018 [Reference 17].

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, "Order Modifying Licenses with Regard to Reliable Hardened Containment Vents," 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, NEI issued NEI 13-02, "Industry Guidance for Compliance with Order EA-13-109," Revision 0 [Revision 24] 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, 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'" [Reference 25], 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 <u>TECHNICAL EVALUATION OF ORDER EA-13-109, PHASE 1</u>

Susquehanna is a two unit General Electric BWR site with Mark II primary containment systems. To implement the Phase 1 requirements of Order EA-13-109, the licensee utilized existing spare penetrations in the wetwell. The HCVS discharge paths are routed separately and exits from the reactor building (RB) wall to an effluent release point more than 3 feet above the RB roof. The HCVS is initiated via manual action from either the main control room (MCR) primary operating station (POS), which will be treated as the main operating location for this order, or the remote operating station (ROS) at the appropriate time based on procedural guidance in response to plant conditions from observed or derived symptoms. The ROS provides backup manual operation of the HCVS valves as required by the order. The containment parameters of pressure and level from the MCR instrumentation are used to monitor effectiveness of the venting actions. The vent operation is monitored using HCVS valve position, temperature, and effluent radiation levels. The HCVS has the motive force to operate for 24 hours with installed equipment. Replenishment of the motive force will be by use of portable equipment once the installed motive force is exhausted. Venting actions will be capable of being maintained for a sustained period of up to 7 days.

3.1 HCVS Functional Requirements

3.1.1 Performance Objectives

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

3.1.1.1 Operator Actions

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

In its FIP, the licensee stated that operator actions to initiate the HCVS vent path can be completed by plant personnel and it includes the capability for remote-manual initiation from the HCVS control station. The HCVS is initiated via manual action from either the MCR (which serves as the POS) or the ROS at the appropriate time based on procedural guidance in response to plant conditions from observed or derived symptoms. A list of the remote manual actions for plant personnel to open the HCVS vent path is provided in FIP Table 1.1.1-1, HCVS Remote Manual Operator Actions, of the FIP. An HCVS extended loss of alternating current (ac) power (ELAP) Failure Evaluation (Table 1.1.1-2), which shows alternate actions that can be performed, is provided in the FIP.

The licensee also stated that from the MCR, the operators can operate the HCVS containment isolation valves (if electrical power is available), monitor HCVS vent valve position, drywell pressure, wetwell level, and pneumatic supply pressure. The indicators for the HCVS radiation monitor indication, vent pipe temperature, vent pipe pressure, and battery voltage are also located in the MCR area. The ROS consists of manual valves that directly port air to the valve actuators of the HCVS isolation valves. The ROS is equipped with instrumentation for the vent pressure, vent temperature, and vent radiation dose rate.

During an ELAP, electric power to operate the vent valves is provided by batteries with a capacity to supply required loads for at least the first 24 hours.

Before the batteries are depleted, the FLEX generators will supplement and recharge the batteries to support operation of the vent valves. The ROS is designated as the alternate control location and method. Since no electrical power is required to operate the HCVS containment isolation valves at the ROS, the valve solenoids do not need any additional backup electrical power.

Pneumatic power for the HCVS valve actuators is provided by the dedicated HCVS compressed air system. Pneumatic force is supplied from compressed gas bottles that are normally closed to isolate the air from the system. For the first 24 hours post-ELAP initiation, pneumatic force will be supplied from the dedicated HCVS compressed air system located in the ROS.

The NRC staff reviewed the HCVS Table 1.1.1-1, HCVS Remote Manual Operator Actions and Table 2 Operator Action Evaluations, compared them with the information contained in the guidance document NEI 13-02, and determined that these actions should minimize the reliance on operator actions. The actions are consistent with the types of actions described in the guidance found in NEI 13-02, Revision 1 as endorsed, in part, by JLD-ISG-2013-02 and JLD-ISG-2015-01, as an acceptable means for implementing applicable requirements of Order EA-13-109. The NRC staff also reviewed the HCVS Failure Evaluation Table and determined the actions described adequately address all the failure modes listed in the guidance provided by NEI 13-02, Revision 1, which include: loss of normal ac power; long-term loss of batteries; loss of normal pneumatic supply; loss of alternate pneumatic supply; and solenoid operated valve failure.

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

3.1.1.2 Personnel Habitability – Environmental (Non-Radiological)

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

In its FIP, the licensee indicated that primary control of the HCVS is accomplished from the main control room. FLEX actions that will maintain the MCR habitable were implemented in response to NRC Order EA-12-049. These actions include:

1. Opening selected doors (if required); and
2. Operating portable fans to move outside air through the MCR (if required).

The licensee updated existing calculation, EC-030-1006, "Control Structure Temperature Response to a Station Blackout or Fire Induced Loss of Control Structure HVAC," Revision 14 for ELAP conditions. Appendix L of this calculation addresses ELAP conditions. The calculation assumes an ambient temperature of 92 degrees Fahrenheit (°F) and a MCR heat load of 211,770 British thermal units an hour. The MCR heat load is based on normal operating conditions when ac power is available. Phase 2 of Susquehanna's mitigating strategies involves using the 4160 volt alternating-current (VAC) FLEX portable generators to repower MCR lighting and instrumentation, therefore the use of normal MCR heat loads should be conservative but representative of ELAP loads. The calculation predicts the MCR could exceed

110°F by 36 hours into the event. Procedure DC-FLEX-007, "Control Structure Ventilation Strategy," Revision 2 provides guidance for opening selected doors and use of a portable FLEX fan for establishing ventilation in the MCR.

The NRC staff audited the above calculation and the guidance in the procedure. The NRC staff also noted that the sizing of the portable fan was based on the higher, non-ELAP, heat load, which is conservative. The cooling provided by the ventilation established by opening doors and installing the portable FLEX fan assumes a constant outdoor temperature of 92°F, but conservatively does not credit diurnal temperature variations. The licensee also indicated that stay time in the MCR would be limited when the room temperature is high based on the guidance in NUMARC 87-00, "Guidelines and Technical Bases for NUMARC Initiatives Addressing Station Blackout at Light Water Reactors." The NRC staff also noted that for Phase 3 of mitigating strategies, as resources (off-site and on-site equipment along with personnel) become available, MCR cooling may be re-established as directed by the Technical Support Center. Based on the conservative assumptions, the mitigating actions, and the ability to rotate personnel out of the room, the temperature in the MCR should not inhibit the ability of operators to take their required actions.

Alternate control of the HCVS is accomplished from the ROS at the 686'-6" elevation of the control structure. The NRC staff audited the licensee calculation EC-030-1007, Appendix CC, "ROS Ventilation and Hydrogen Control," Revision 22. This calculation estimated the maximum ROS temperature to be less than 100°F (99.7°F). In the FIP, Table 2 contains a thermal evaluation of all the operator actions that may be required to support HCVS operation. The relevant ventilation calculations demonstrate that the final design meets the order requirements to minimize the plant operators' exposure to occupational hazards.

The NRC staff reviewed the information in Table 2 and audited the calculations referenced in the FIP and noted that the licensee referenced NUMARC 87-00 report for the habitability temperature limit as referenced in the guidance document NEI 12-06, "Diverse and Flexible Coping Strategies (FLEX) Implementation Guide" (endorsed by the NRC in JLD-ISG-2012-01 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML12229A174). For acceptance criteria at time greater than or equal to 36 hours, Susquehanna used the NUMARC habitability temperature limit of 110°F for personnel performing light work. NUMARC guidance states that "a drybulb temperature of 110°F is tolerable for light work for a 4-hour period while dressed in conventional clothing." The NRC staff noted that even though Susquehanna assumed an allowable stay time at 110°F, greater than the guidance in NUMARC 87-00, that operators will not be staying very long in areas with elevated temperatures. Work performed in these areas will be of limited time and effort. Existing plant procedures for hot area work will also provide protection for plant personnel. The NRC staff agrees that with the limited stay time, the absence of strenuous work tasks required to be performed, and existing procedures for working in elevated temperatures should not impede operators from completing their required tasks.

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

3.1.1.3 Personnel Habitability – Radiological

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

The licensee performed calculation EC-RADN-1180, "SSES HCVS Radiological Assessment," which documents the dose assessment for designated areas outside of containment caused by the sustained operation of the HCVS under the beyond-design-basis severe accident condition of an ELAP. Calculation EC-RADN-1180 was performed using NRC-endorsed HCVS-WP-02 [Reference 28] and HCVS-FAQ-12 [Reference 29] methodologies. Consistent with the definition of sustained operations in NEI 13-02, Revision 1, the integrated whole-body gamma dose equivalent[1] due to HCVS operation over a 7-day period was determined in the licensee's dose calculation and will not exceed 10 rem.[2] The calculated 7-day dose due to HCVS operation is a conservative maximum integrated radiation dose over a 7-day period with ELAP and fuel failure starting at reactor shutdown. For the sources considered and the methodology used in the calculation, the timing of HCVS vent operation or cycling of the vent will not create higher doses at personnel habitability and equipment locations (i.e., maximum doses determined in the calculation bound operational considerations for HCVS vent operation).

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

The licensee calculated the maximum dose rates and 7-day integrated whole body gamma dose equivalents for the MCR and the ROS. The calculation demonstrates that the integrated whole-body gamma dose equivalent to personnel occupying defined habitability locations (resulting from HCVS operation under beyond-design-basis severe accident conditions) will not exceed 10 rem.

The NRC staff notes that there are no explicit regulatory dose acceptance criteria for personnel performing emergency response actions during a beyond-design-basis severe accident. The Environmental Protection Agency (EPA) Protective Action Guides (PAG) Manual EPA-400/R-16/001, "Protective Action Guides and Planning Guidance for Radiological Incidents," provides emergency worker dose guidelines. Table 3.1 of EPA-400/R-16/001 specifies a guideline of 10 Roentgen equivalent man (rem) for the protection of critical infrastructure necessary for public welfare such as a power plant and a value of 25 rem for lifesaving or for the protection of large

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[1] For the purposes of calculating the personnel whole-body gamma dose equivalent (rem), it is assumed that the radiation units of Roentgen (R), radiation absorbed dose (rad), and Roentgen equivalent man (rem) are equivalent. The conversion from exposure in R to absorbed dose 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 millirem (100 mSv). https://www.nrc.gov/about-nrc/radiation/health-effects/rad-exposure-cancer.html

populations. The NRC further notes that during an emergency response, areas requiring access will be actively monitored by health physics personnel to ensure that personnel doses are maintained as low as reasonably achievable.

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

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

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.

The Susquehanna HCVS instrumentation components are located in the reactor building, main control room, and the ROS. The severe accident water addition (SAWA) flow instrument is integral to the pumper truck located at the east end of the spray pond. Regarding the functionality of the HCVS controls and indications, the licensee evaluated the environmental conditions and impacts for the components (switches, control devices, instrumentation sensors, transmitters and indicators, etc.) required for HCVS venting operations. Susquehanna engineering change packages (ECPs) EC1881050, EC1881053, EC1881047, and EC1672825 for Unit 1 and EC1881014, EC1881029, EC1881034, and EC1672802 for Unit 2 were made available for NRC audit via the electronic portal (ePortal), which provided detailed design considerations for the HCVS system including instrumentation and controls and its seismic, temperature, and radiation environmental qualifications. The licensee also provided a complete list of the instrumentation components, their locations, the anticipated environmental conditions, and summary qualification details in Table 1 of its FIP [Reference 17].

The NRC staff reviewed the instrumentation and controls (I&C) configuration in Susquehanna's FIP and confirmed the qualification summary information provided in Table 1 for each channel based on an ePortal audit of Susquehanna documents DPA-16-DI-2015-23844, EC-030-1006, and EC-030-1007. The NRC staff reviewed the following channels that support HCVS operation: HCVS Effluent Temperature; HCVS Effluent Pressure; HCVS Gas Supply Pressure; HCVS Radiation Level; HCVS direct current (dc) Voltage; Reactor Pressure; Drywell Pressure; Wetwell Temperature; and Wetwell Level. The NRC staff notes that Reactor Pressure, Drywell Pressure, Wetwell Temperature, and Wetwell Level are declared Susquehanna post-accident monitoring (PAM) variables as described in Regulatory Guide (RG) 1.97, "Criteria for Accident

Monitoring Instrumentation for Nuclear Power Plants," 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 reviewed the licensee's evaluation and confirmed that the HCVS instrumentation should be adequate to support HCVS venting operations and capable of performing its intended function during ELAP and severe accident conditions.

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

3.1.2 Design Features

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

3.1.2.1 Vent Characteristics

Order EA-13-109, Attachment 2, Section 1.2.1 requires that the HCVS 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 HCVS suppression chamber vent path consists of 12-inch and 14-inch diameter piping. The HCVS is designed to permit venting the steam equivalent energy of one percent reactor thermal power at a containment design pressure of 53 pounds per square inch gauge (psig). 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 lower of the containment design pressure (53 psig) or the primary containment pressure limit (PCPL) (65 psig).

The licensee performed calculation EC-073-1019, "Flow Capacity of Unit 1 and Unit 2 Hardened Containment Vent System Under ELAP Conditions," Revision 3 to confirm the HCVS venting capacity. This calculation models all the piping elbows, valves, and other components using industry standard flow coefficients to determine an equivalent length of piping. The model consists of 12" and 14" sections. The model is input to the Transient Reactor Analysis Code and Modular Accident Analysis Program (MAAP) codes, which are industry standard programs for modeling compressible flow in piping. The codes also evaluate flow choking effects. The minimum flow to pass 1 percent rated thermal power at design pressure is 41.2 pound mass per second (lbm/sec).

The NRC staff audited EC-073-1019, Revision 3. The calculation assumes a rated core thermal power of 3952 megawatts thermal. The vent flow required to remove 1 percent of rated reactor power at containment design pressure of 53 psig is 41.2 lbm/sec. The Unit 1 vent is bounding for both units and the capacity at 53 psig is 46.3 lbm/sec. The flow from each vent is greater than the minimum of 41.2 lbm/sec.

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

3.1.2.2 Vent Path and Discharge

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

The NRC staff evaluated the HCVS vent path and the location of the discharge. The HCVS vent paths consist of a separate wetwell vent for each unit. The wetwell vent exits the primary containment suppression chamber through Penetration X-201B, through the normally closed inboard containment isolation valve (CIV) (HV1/257113) and the normally closed outboard CIV (HV1/257114). Downstream of outboard CIV, the 12" diameter wetwell vent flow path continues through a rupture disk and then exits the RB at elevation 707' (which is greater than 30' above the exterior grade elevation). Exterior to the RB, the wetwell vent pipe expands to 14" diameter, is supported from the RB wall, and then rises along the exterior of the RB. The vent line re-enters the RB at the skin area, passes through a check valve and then exits the RB roof at Elevation 870'. The vent pipe extends more than 3 feet above the parapet wall.

The wetwell vent line is equipped with a rupture disk (burst pressure of 43 psig) just downstream of the outboard CIV. The rupture disk serves as a secondary containment boundary to mitigate secondary containment bypass leakage considerations. The 43 psig burst pressure for the rupture disk was selected as being greater than the maximum loss of coolant accident (LOCA) wetwell pressure and less than the containment design pressure. The wetwell vent system and components downstream from the outboard CIV are designed for 65 psig and 350°F. The 350°F design temperature is based on the PCPL and the guidance in NEI 13-02.

All effluents are exhausted above each unit's RB. This discharge point is above each unit's RB parapet wall. There is a pipe end cover over the pipe discharge to prevent extraneous material from entering the pipe. Guidance in HCVS-FAQ-04 is provided to ensure that vented effluents are not drawn immediately back into any ELAP emergency ventilation intakes. The MCR emergency air intake in the ELAP event is at the 670 feet elevation, which is approximately 200 feet below the HCVS pipe outlet. Therefore, the vent pipe discharge point meets the guidance of HCVS-FAQ-04 for stack discharge relative to the ELAP air intake.

Guidance document NEI 13-02, Section 5.1.1.6 states 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 30], provides a risk-informed approach to evaluate the threat posed to exposed portions of the HCVS by wind-borne missiles. The white paper concludes that the HCVS is unlikely to be damaged in a manner that prevents containment venting by wind-generated missiles coincident with an ELAP or loss of normal access to the ultimate heat sink for plants that are enveloped by the assumptions in the white paper.

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

1. Susquehanna does not have any exposed HCVS pipe external to the RB below 30 feet above grade. At Susquehanna, the grade elevation near the HCVS pipe external to the RB is ~ 676 feet and the HCVS pipe penetrated the RB wall at ~ 707 feet. This results in an elevation difference of ~ 37 feet.

2. The exposed piping greater than 30 feet above grade has the following characteristics:

    a. The total vent pipe exposed area for Unit 2 is ~ 205 square feet which is less than the 300 square feet. The total vent pipe exposed area for Unit 1 is ~ 350 square feet which is greater than the 300 square feet and has been evaluated in AR/EWR-2016-18566, "HCVS Exceeds Target Area". The HCVS was determined to be acceptable.

    b. The vent pipe thickness is at least that of schedule 40 carbon steel pipe. The pipe is made of steel not plastic. The exposed pipe is at least 12" in diameter. The exposed pipe components have no small tubing susceptible to missiles.

    c. There are no obvious sources of missiles located in the proximity of the exposed HCVS components.

3. Susquehanna maintains saws capable of cutting the HCVS pipe in the FLEX building as part of the FLEX equipment. These saws are capable of cutting an opening into the vent pipe should it become damaged such that it restricts flow to an unacceptable level.

4. Susquehanna maintains severe weather preparedness procedures that require the plant to consider reducing reactor power prior to the arrival of sustained hurricane force winds on site.

The NRC staff audited the referenced documents regarding the design of the HCVS and noted that procedure ES-1(2)273-007, "Venting Suppression Chamber Through the HCVS," provided guidance for the operation of the HCVS system. The procedure also provided guidance for compensatory actions if the HCVS stack should become damaged from wind-born missiles such that venting becomes obstructed.

The NRC staff also audited AR/EWR-2016-18566. The licensee used a risk-informed approach to address the additional HCVS stack area. The licensee performed a risk-informed review noting that the probability of an Enhanced Fujita (EF) 5 scale tornado is 70 percent to 80 percent lower in the eastern United States than in the central and western United States. The increase in HCVS stack area is only 17 percent. The licensee determined that for Susquehanna, the guidance in HCVS-WP-04 is bounding, even with the increased strike area. The licensee also noted that the HCVS is on the east side of the reactor buildings and that the land is either flat or slopes away from the buildings. The vent stacks are protected by the reactor buildings from the elevated source of wind-borne missile sources from the hills to the west. Based on the audit of referenced documents, the NRC staff agrees that the evaluation appears consistent with the NEI 13-02 guidance, including the associated white paper.

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

3.1.2.3 Unintended Cross Flow of Vented Fluids

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

In its FIP, the licensee described that the HCVS for both Units 1 and 2 for Susquehanna are fully independent of each other with separate discharge points. There are no HCVS piping connections to other systems (except for the primary containment) within the units.

To prevent leakage of vented effluent to other parts of the RB or other systems, Susquehanna uses dedicated piping systems from the wetwell penetration to the above the RB release point. There are no vent piping connections to other plant systems or to the other unit. The containment isolation valves are normally closed, fail closed, and are not required to change state in order to perform their safety-related containment isolation function; therefore, they can be assumed to be closed when required. Susquehanna CIVs HV1/257113 and HV1/257114 are part of the in-service testing (IST) program and are leak tested in accordance with 10 CFR Part 50, Appendix J [Reference 31].

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 describes initiation, operation, and monitoring of the HCVS from the POS at a control panel located in the MCR. The HCVS valves can also be opened from the ROS without any electrical power. The ROS for both units is only a short distance from the MCR and is located in the south west corner of the control structure 686'-6" elevation in an area shielded from the HCVS vent pipes by intervening structures, with a direct travel path from the ROS to between the ROS and the MCR.

The ROS contains manually operated valves that supply pneumatic pressure to the HCVS flow path valve actuators so that these valves may be opened without power to the valve actuator solenoids. Susquehanna's HCVS CIVs are normally closed, fail closed valves and require multiple actions from either the POS or the ROS to open and therefore do not receive any containment isolation signals. This provides a diverse method of valve operation improving system reliability. The NRC staff reviewed the licensee's HCVS design and agrees that the locations for operation (POS and ROS) of the HCVS appears to be acceptable and consistent with the guidance.

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 HCVS-FAQs-01, -03, -08, and -09.

In its FIP, the licensee described the ROS as a readily accessible alternate location with the means to operate HCVS valves via pneumatic motive force. The ROS for both units is located in the control structure. The ROS contains manually-operated valves that supply pneumatic pressure 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, thus improving system reliability.

Susquehanna's HCVS CIVs are air-operated valves (AOVs) that are normally closed and fail closed on loss of air. Pneumatic supply to the CIV actuators can be provided from the ROS. Manual operation of pneumatic supply and vent valves in the ROS allows manual operation of the HCVS CIVs when power is unavailable to the CIV solenoid valves.

In the FIP, Table 1 contains a summary of HCVS components, controls, and instruments that are required for severe accident response and notes that all these controls and instruments will be functional during a loss of ac power and severe accident. In the FIP, Table 2 contains a thermal and radiological evaluation of all the operator actions that may be required to support HCVS operation during a loss of ac power and severe accident and demonstrates that these actions will be possible without undue hazard to the operators.

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

3.1.2.6 Power and Pneumatic Supply Sources

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

Pneumatic Sources Analysis

For the first 24 hours following the event until 7 days post event, the motive supply for the AOVs will be three compressed air bottles that will be pre-installed and available. These bottles have been sized such that they can provide motive force for at least 17 cycles of a vent path, which includes opening for each of the two PCIVs (HV1/257113 and HV1/257114) and at least 16 openings of the outboard HCVS isolation valve (HV1/257114). The licensee performed calculation EC-073-1018, "HCVS Compressed Air Bottle Sizing Calculation," Revision 0, which determined the required pneumatic supply storage volume and supply pressure set point required to burst the rupture disk and operate the HCVS HV1/257113 and HV1/257114 for 24 hours following a loss of normal pneumatic supplies during an ELAP. The calculation also determined that three compressed air bottles filled to a minimum pressure of 2000 psig provide sufficient capacity for operation of the HCVS valves for 12 venting cycles for 24 hours following an ELAP. This minimum pressure includes an allowance for leakage. The licensee then determined through subsequent MAAP simulations that the vent would need to be cycled 6 times during the initial 24 hours following and a total of 17 times during the 7-day duration as described in the licensee's document titled, "Dispositions for DPA-04-DI-2015-23844, DPA-03-DI-2015-23844, and AR-2015-23588." The NRC staff audited the calculation and subsequent evaluation and confirmed that there should be sufficient pneumatic supply available to provide motive force to operate the HCVS AOVs for 24 hours following a loss of normal pneumatic supplies during an ELAP.

Power Source Analysis

During Phase 1, Susquehanna would rely on the Class 1E station batteries (to power containment instrumentation) and the new 125 Volt (V) HCVS dc battery to provide power to HCVS components. Each unit's HCVS system contains its own battery that is sized to provide a minimum of 24 hours of power to HCVS-related equipment. The HCVS batteries and battery chargers are permanently installed in the ROS where they are protected from applicable hazards. The NRC staff audited licensee calculation EC-002-1081, "Hardened Containment Vent System Battery Sizing," Revision 0, which evaluated the battery/battery charger sizing and device terminal voltages for the HCVS dc system. The results of the calculation showed that each HCVS battery, which is comprised of two strings of Enersys G70EP batteries (140 ampere hours (Ah) total), is adequately sized to supply power to the HCVS for at least 24 hours (129.6 Ah) following an ELAP. The required containment instrumentation is the same as that required by NRC Order EA-12-049. The capability and capacity of the Class 1E station batteries to supply power to the required containment instrumentation is addressed in the NRC's safety evaluation for NRC Order EA-12-049 [Reference 35].

The licensee's Phase 2 strategy is to deploy two 4160 Vac FLEX combustion turbine generators (CTGs) to provide power the 4160 Vac buses that would energize the battery chargers and supply dc loads. The 4160 Vac CTGs are rated for 1 megawatt and are sized to power all the 125 and 250 Vdc battery chargers, reactor core isolation cooling controls, MCR lighting, residual heat removal (RHR) motor operated valves, and other selected loads including the HCVS battery chargers and spent fuel pool (SFP) level instrumentation. Three 4160 Vac CTGs are available; however, only two CTGs are required to supply the power necessary to complete the licensee's FLEX strategies. While it cannot officially credit the FLEX CTGs until 24 hours from the onset of the event for HCVS electrical power, the licensee plans to repower the required equipment in approximately 6 hours.

The NRC staff audited licensee calculation EC-FLEX-0015, "Fukushima FLEX Generators - Phase 2 Load Flow Analysis," Revision 2, conceptual single line diagrams, and the separation and isolation of the FLEX CTGs from the EDGs. Based on the NRC staff's audit of EC-FLEX-0015, it appears that the FLEX CTGs would be loaded to approximately 86 percent of their 1250 kilo-Volt-Ampere (kVA) rating during the initial Phase 2 timeline. For alternative connections, the licensee showed that the CTGs would be loaded to approximately 94.5 percent of their 1250 kVA rating.

The NRC staff notes that the licensee took the FLEX cable lengths into consideration when sizing the FLEX CTGs (i.e., ensured that the voltage drop did not result in violating the minimum required voltage required at the limiting component). Based on its audit of the licensee's calculation, the NRC staff confirmed that two 4160 Vac FLEX CTGs appears to be adequate to support the electrical loads required for the licensee's Phase 2 strategies.

Electrical Connection Points

The licensee's strategy is to supply power to HCVS components using a combination of permanently installed and portable components. Staging and connecting the Phase 2 FLEX CTGs was addressed under Order EA-12-049 compliance and documented in the NRC staff's safety evaluation (Reference 35). The NRC staff audited licensee guidelines DC-FLEX-003, "Deployment for FLEX Strategies," Revision 4, and DC-FLEX-010, "4160 Vac Connection to E DG and ESS Busses," Revision 2, which provides direction for staging and connecting a FLEX CTGs to energize the electrical buses to supply required loads within the required timeframes.

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 that the HCVS is not to be used to defeat containment integrity during any design-basis transients and accidents. In addition, the HCVS was designed to include features to prevent inadvertent actuation due to equipment malfunction or operator error. Also, these protections are designed such that any credited containment accident pressure (CAP) that would provide net positive suction head to the emergency core cooling system (ECCS) pumps will be available (inclusive of a design basis loss-of-coolant accident, Susquehanna does not credit CAP for ECCS net positive suction head). However, the ECCS pumps will not have normal power available because of the ELAP.

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

- the key lock switch to energize the HCVS at panel 1/2C644 (the HCVS is normally deenergized) in the primary operating station (MCR);
- the ROS is locked closed;

- closed pneumatic supply valves in the locked closed ROS room; and
- separate key-lock switches for each unit's system.

These design features (isolated electrical and gas supply to the HCVS CIVs in access controlled rooms) meet the requirement to prevent inadvertent actuation of HCVS.

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

3.1.2.8 Monitoring of HCVS

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

In its FIP, the licensee stated that the HCVS monitoring parameters include indications for HCVS valve position, HCVS gas supply pressure, vent pipe pressure, temperature and radiation levels in the MCR and ROS, and HCVS dc battery voltage in the MCR. The licensee also stated that wetwell level and containment pressure indications are RG 1.97 variables and these components will be powered by station batteries. The station batteries are maintained via battery chargers supplied by the FLEX CTGs for sustained operation. The licensee further stated in its FIP that HCVS instruments have sufficient accuracy and range and are qualified for the environment as summarized in Table 1 of the FIP.

The NRC staff reviewed the information provided in the FIP and confirmed details of the qualification for the HCVS instruments in Susquehanna documents DPA-16-DI-2015-23844, EC-030-1006, and EC-030-1007. The NRC staff confirmed the RG 1.97 variables through its review of the Susquehanna Updated Final Safety Analysis Report (UFSAR).

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

3.1.2.9 Monitoring of Effluent Discharge

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

The HCVS design includes radiation monitors that are sufficient to monitor the effluent discharge during the operation of HCVS including severe accident conditions. The HCVS radiation monitoring system consists of an ion chamber detector mounted outside the vent pipe in the RB at the 683 foot elevation, coupled to a process and control module. The process and control module provides local indication and is mounted in the ROS panel 1/2D644 at control structure elevation 686'-6". The MCR has a radiation indicator on the 1/2C644 panel to verify venting operation. As discussed above in Section 3.1. 2.8, the radiation monitor detector is fully qualified for the expected vent pipe environment during accident conditions, and the process and control module is qualified for the environment in the control structure ROS. Both components are qualified for the applicable seismic requirements. The NRC staff reviewed the information provided in the FIP [Reference 17] and confirmed that it is consistent with the guidance.

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

3.1.2.10 Equipment Operability (Environmental/Radiological)

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

<u>Environmental</u>

The HCVS batteries and battery chargers are permanently installed at the ROS, in control building at the 686'-6" elevation. The NRC staff audited licensee calculations EC-030-1006, "Control Structure Temperature Response to a Station Blackout or Fire Induced Loss of Control Structure HVAC," Revision 14, and EC-030-1007, "Transient Temperature Response of the Control Structure Room with HCVS – Normal and Accident Conditions," Revision 22, which modeled the temperature response in the control structure with the HCVS in operation. The licensee's calculation assumed to size the ROS room vents to ensure that this temperature is not reached during an ELAP with HCVS in operation.

The licensee sized the HCVS batteries considering a minimum operating temperature of 60°F. This is the minimum ambient temperature of the room where the HCVS batteries are located as specified in calculation EC-002-1081. The licensee noted that the manufacturer's maximum design limit for the HCVS batteries when either charging or discharging is 140°F. Therefore, the HCVS batteries appear to be adequate to perform their design function under event temperatures. The operating temperature of the battery charger as specified by the vendor is -20°C to +50°C (-4°F to 122°F). Therefore, the battery charger appears to be adequate to perform its design function under event conditions (113°F).

The licensee evaluated hydrogen generation as a result of charging the HCVS batteries in calculation EC-030-1007, Appendix CC. For the ROS, the licensee determined the required flow rate based on a minimal room heat load of 50 watts. The ROS room has four fire protection dampers, as described in EC-030-1007 Appendix CC. Three (7"x7") dampers are installed at the ceiling elevation, 694'-10", while one (14"x14") damper is located at 687'-0". The natural air flow through these vents should remove both heat and hydrogen from the room. The NRC staff audited the licensee's calculation and confirmed that the ventilation strategy should be adequate to prevent hydrogen from accumulating to the point of combustion (4 percent).

Based on the above, the NRC staff concurs with the licensee's calculations that show the ROS temperature will remain within the maximum temperature limit for the HCVS batteries (140°F) and the battery charger (122°F). Furthermore, based on temperatures remaining below 120°F (the temperature limit for electronic equipment to be able to survive indefinitely, identified in NUMARC-87-00, "Guidelines and Technical Bases for NUMARC Initiatives Addressing Station Blackout at Light Water Reactors," Revision 1, as endorsed by NRC RG 1.155), the NRC staff believes that other electrical equipment in 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 equipment located in the ROS appears to not be adversely impacted by the loss of ventilation as a result of an ELAP event with the HCVS in operation. The licensee's ventilation calculations included the added heat input of the HCVS on various plant areas that contain required equipment. In addition to the calculations audited during its review of the license's FIP for Order EA-12-049, the NRC staff audited licensee calculation EC-034-0512, "Cooling Loads – Reactor Building Zone 1 - Normal and Accident," Revision 7. This calculation notes that the pipe contains no process flow and assumes the entire pipe length is at the containment temperature. The piping upstream of the valves (towards the suppression pool) is insulated. The piping downstream of the valves is not insulated, however, the HCVS would only vent hot air intermittently. As a result, the net effect on the surrounding rooms appears to be minimal.

Radiological

The licensee's calculation EC-RADN-1180, "SSES HCVS Radiological 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 EC-RADN-1180 and noted that the licensee used conservative assumptions to bound the peak dose rates for the analyzed areas. For the sources considered and the methodology used in the dose calculation, the timing of HCVS vent operation or cycling of the vent will not create higher doses at personnel habitability and equipment locations (i.e., maximum doses determined in the calculation bound operational considerations for HCVS vent operation). The NRC staff's audit confirmed that the anticipated severe accident radiological conditions appear to not impact the operation of necessary equipment or result in an undue risk to personnel from radiation exposure.

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

3.1.2.11 Hydrogen Combustible Control

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

In NEI 13-02, Section 4.1.7 provides guidance for the protection from flammable gas ignition for the HCVS system. The NRC-endorsed NEI white paper, HCVS-WP-03, "Hydrogen /Carbon Monoxide Control Measures," Revision 1 [Reference 32], provides methods to address control of flammable gases. One of the acceptable methods described in the white paper is the installation of a check valve near or at the exhaust end of the vent stack (Option 5), which eliminates the ingress of air to the vent pipe when venting stops and the steam condenses.

In its FIP, the licensee stated that to reduce the probability of developing a detonable hydrogen mixture in the HCVS, a check valve is installed near the top of the pipe. This valve will open on venting, but will close to prevent air from migrating back into the pipe after a period of venting. The check valve is tested to ensure that it limits back-leakage to preclude a detonable mixture from occurring in case venting is stopped prior to the establishment of alternate reliable containment heat removal. The use of a check valve meets the requirement to ensure the flammability limits of gases passing through the vent pipe will not be reached. The NRC staff's review confirmed that the licensee's design appears to be consistent with the guidance and Option 5 of white paper HCVS-WP-03, and meets the design requirements to minimize the potential of hydrogen gas deflagration/detonation.

Based on the evaluation above, the NRC staff concludes that the licensee's HCVS design should ensure 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 RB 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 above in Section 3.1.2.3, there are no HCVS piping connections between the two units at Susquehanna. In addition, there are no HCVS piping connections to other systems (except the primary containment) within the units at Susquehanna.

Based on the evaluation above, the NRC staff concludes that the licensee's HCVS design should minimize 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 its FIP, the licensee stated that the primary and secondary containment required leakage testing is covered under existing design basis testing programs. The HCVS outside the containment boundary shall be tested to ensure that vent flow is released to the outside with minimal leakage, if any, through the interfacing boundaries with other systems or units.
In the FIP, Table 3-3 includes testing and inspection requirements for HCVS components. The NRC staff reviewed Table 3-3 and found that it appears to be consistent with Section 6.2.4 of NEI 13-02, Revision 1. Implementation of these testing and inspection requirements for the HCVS should ensure reliable operation of the systems.

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

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

3.2 HCVS Quality Standards

3.2.1 Component Qualifications

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

In its FIP, the licensee stated that the vent up to and including the outboard CIV is designed and installed consistent with the design basis of the plant (Safety-Related, ASME Section III Class 2, and Seismic Class 1). The wetwell vent system and components downstream from the outboard CIV are designed for 65 psig and 350 °F and to ASME Section III Class B.

The NRC staff audited engineering change EC 1881014, "U2 Reliable Hardened Containment Vent – Piping and Vent Stack Installation – Non-outage Work," Attachment I, "Design Inputs," and confirmed that the quality assurance requirements and qualifications for the HCVS components including piping, pipe supports, valves, etc. have been adequately identified.

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

3.2.2 Component Reliability and Rugged Performance

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

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

As noted earlier, as part of the audit review, the NRC staff audited engineering change EC 1881014, "U2 Reliable Hardened Containment Vent – Piping and Vent Stack Installation – Non-outage Work," Attachment I, "Design Inputs," and confirmed that the design inputs and qualifications for the HCVS components including piping, pipe supports, valves, etc. have been adequately identified.

The licensee also stated in its FIP that Table 1 contains a list of components, controls, and instruments required to operate HCVS, including their qualification and evaluation against the expected conditions. All instruments are fully qualified for the expected seismic conditions so that they will remain functional following a seismic event. The NRC staff reviewed the I&C configuration in the FIP and confirmed the qualification summary information provided in Table 1 for each channel based on an electronic portal audit of Susquehanna documents DPA-16-DI-2015-23844, EC-030-1006, and EC-030-1007.

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

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

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

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

As stated above in Section 2.2, Order EA-13-109 provides two options to comply with the Phase 2 order requirements. Susquehanna 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 portable, diesel-driven FLEX pumps to provide SAWA flow. The pumps discharge to the engineered safeguards service water pump house (ESSWPH) connection and then into the reactor pressure vessel (RPV). The licensee states in the FIP that the operator locations for deployment and operation of the SAWA equipment that are external to the RB 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. Operator actions required in the RB will be performed prior to 6 hours after loss of injection, prior to increased radiological dose rates. Once SAWA flow is initiated, operators will have to monitor and maintain SAWA flow and ensure refueling the diesel-driven equipment as necessary. Operators may also have to reduce flow as part of the SAWM strategy, if necessary, using one of the methods described below.

4.1.1 Staff Evaluation

4.1.1.1 Flow Path

The SAWA injection flow path starts from the FLEX suction at the spray pond, the ultimate heat sink (UHS), and goes through the SAWA (FLEX) pump. The discharge of the FLEX pump is routed to the ESSWPH where they are connected to the residual heat removal service water (RHRSW) system. The SAWA flow is then routed from the RHRSW to the RHR cross connect and then to the RPV via the RHR low-pressure coolant injection (LPCI) injection path. Once the SAWA components are deployed and connected, the SAWA flow rate is controlled by the pump discharge throttle valves and pump discharge pressure and flow rate. Backflow prevention is provided by check valves installed in the RHR LPCI system that are leak tested using existing leakage testing programs. Drywell pressure and suppression pool level will be monitored and flow rate will be adjusted by use of the FLEX (SAWA) pump control valve at the pump discharge, which also contains the SAWA flow indication.

4.1.1.2 SAWA Pump

The licensee plans to use a portable pump to provide SAWA flow to both units. In its FIP, the licensee described the hydraulic analysis performed to demonstrate the capability of one of the two available portable FLEX pumps to provide the required 500 gallons per minute (gpm) of SAWA flow to one unit while providing SFP and RPV makeup to the other unit in an ELAP scenario. The staff audited calculations EC-013-1896, "Performance Requirements for Portable Diesel Driven Pump in Support of FLEX Mitigation Strategies (NRC Order EA-12-049)," Revision 0, and EC-016-1043, "Flow Model of UHS Cooling Water to Support Phase II and III FLEX Mitigation Strategy," Revision 4, which determined that the required SAWA flowrate of 500 gpm to each unit 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 at Units 1 and 2, as described in the above hydraulic analyses 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

In its FIP, the licensee states that Susquehanna's initial SAWA flow is 500 gpm, which is the same amount as assumed in the industry base case model noted in NEI 13-02, Section 4.1.1.2.1. The initial SAWA flow will be provided to the RPV within 8 hours of the loss of injection. After 4 hours of the initial 500 gpm injection, the flow rate can be throttled down to 100 gpm. Susquehanna calculation EC-073-1019, "Flow Capacity of Unit 1 and Unit 2 Hardened Containment Vent System under ELAP Conditions," Revision 3 and calculation EC-FLEX-0021, "Suppression Pool Water Level During Severe-Accident Coping Time," Revision 0, assume an initial SAWA flow of 500 gpm starting 8 hours after the loss of injection and demonstrate that the containment is protected at this initial flow rate and subsequent reduction in flow to 100 gpm.

The NRC staff audited calculation EC-073-1019, Revision 3. The calculation used the MAAP computer program and confirmed that the primary containment will remain below the design pressure of 53 psig.

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

4.1.2 Conclusions

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

4.2 Severe Accident Water Management (SAWM)

The strategy for Susquehanna 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. SAWM consists of flow control at or near the FLEX (SAWA) pump along with instrumentation and procedures to ensure that the wetwell vent is not submerged (SAWM). Procedures have been issued to implement this strategy including Revision 3 to the Severe Accident Management Guidelines. This strategy has been shown via MAAP analysis to protect containment without requiring a drywell vent for at least 7 days, which is the guidance from NEI 13-02 for the period of sustained operation.

The SAWM strategy consists of flow control at the SAWA (FLEX) pump along with wetwell level indication in the MCR to ensure that the wetwell vent is not submerged (SAWM). Water from the SAWA (FLEX) pump will be routed through the RHRSW system to the RHR system. This RHR connection allows the water to flow into the RPV. Throttling valves and flow meters will permit water flow to maintain wetwell availability. BWR Owners Group (BWROG) generic assessment, BWROG-TP-15-008 [Reference 33], provides the principles of SAWA to ensure protection of containment.

4.2.1 Staff Evaluation

4.2.1.1 Available Freeboard Use

As stated in the FIP, the suppression pool freeboard volume is the volume between the normal suppression pool level of 671 feet and the bottom of the HCVS wetwell vent penetration elevation of 686.4 feet (elevations are plant reference values). This provides a water volume over 560,000 gallons. Generic assessment BWROG-TP-15-011 [Reference 34] outlines a principle of SAWM is to preserve the wetwell vent for a minimum of 7 days. After containment parameters are stabilized with SAWA flow, SAWA flow will be reduced to a point where containment pressure will remain low while wetwell level is stable or very slowly rising. For Susquehanna, the SAWA flow rate is 500 gpm for first 4 hours followed by 100 gpm until an alternate means of removing reactor decay heat can be implemented. Licensee calculations EC-FLEX-0021 and EC-016-1043 demonstrate that the wetwell level will not reach the wetwell vent for at least 7 days.

The NRC staff audited Technical Evaluations EC-FLEX-0021 and EC-016-1043 and concurs that 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 above, the SAWA/SAWM strategy is based on the BWROG generic assessments in BWROG-TP-15-008 and BWROG-TP-15-011. The SAWA flow is based on the industry base model flow of 500 gpm to start at about 8 hours and will be reduced to 100 gpm after 4 hours. As stated in the FIP, calculations EC-073-1019 and EC-FLEX-0021 demonstrate that with these flow rates and controls, the containment will be protected. The NRC staff audited these calculations and agrees with the licensee's evaluation.

4.2.2 Conclusions

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

4.3 SAWA/SAWM Motive Force

4.3.1 Staff Evaluation

4.3.1.1 SAWA Pump Power Source

As described above, the licensee plans to use portable diesel-driven pumps to provide SAWA flow. Operators will refuel the pump and CTGs in accordance with Order EA-12-049 procedures using fuel oil from the installed underground DG fuel oil storage tanks. The licensee states in its FIP that refueling will be accomplished in areas that are shielded and protected from the radiological conditions during a severe accident scenario. The fuel tank on the SAWA pumps are sized such that the pumps can run for at least 4 hours prior to needing to be refueled. The licensee states in Section IV.C.9.6.1 that it will have enough onsite fuel supply to last more than 7 days.

4.3.1.2 CTG Loading Calculation for SAWA/SAWM Equipment

The licensee's FLEX strategies in response to NRC Order EA-12-049 are to restore the containment instruments, containment pressure, and wetwell level necessary to successfully implement the SAWA option. The licensee's strategy relies on the FLEX CTGs to repower the Class 1E and HCVS battery chargers before the Class 1E and HCVS batteries are depleted. The SAWA electrical loads are included in the FLEX CTG loading calculation (EC-FLEX-0015) used for EA-12-049 compliance (Reference 35). See Section 3.1.2.6 above for further details. The NRC staff audited the information provided on the ePortal and confirmed that the Class 1E station batteries, HCVS dc power system, and the FLEX CTGs 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 capability to implement the water management strategy 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, it 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

Guidance document NEI 13-02 provides specific guidance regarding the required instrumentation necessary to perform SAWA/SAWM operations, which includes indications of containment pressure, wetwell level, and water addition flow rate. In Section IV.C.10.1 of its FIP, the licensee states that Table 1 contains a listing of all the instruments needed for SAWA and SAWM implementation including the expected environmental parameters for each instrument, its qualification, and its power supply for sustained operation. The NRC staff reviewed Table 1 and noted that Susquehanna's SAWA/SAWM strategy relies on three instruments: wetwell level; containment pressure; and a SAWA flow meter to provide indication of the pump output flow rate. The drywell pressure and wetwell level are existing instrumentation and are declared Susquehanna PAM variables as described in RG 1.97. The NRC staff review determined that the proposed instruments are consistent with the guidance for SAWA/SAWM instruments.

4.4.1.2 SAWA Instruments and Guidance

Wetwell level (UR15776A/B and UR25776A/B) uses a differential pressure instrument to measure the wetwell level range from 4.5 to 49 feet (elevation 652.5' to 697'). This range extends from 4.5 feet off the bottom of the wetwell to approximately 10 feet above the bottom of the wetwell vent line, covering the full range of interest for SAWA operation. The wetwell level indicator is in the MCR.

The drywell pressure instrumentation (UR15701A/B and UR25701A/B) range is from -15 to 65 psig. The PCPL at Susquehanna is 65 psig. The drywell pressure indicator is in the MCR.

The flow meter is a mechanical paddle-wheel type instrument integral to the pumper truck with local indication and will be deployed outside the reactor building near the ESSWPH. The instrument range is 0 to 600 gpm. The anticipated range during use is 100 to 500 gpm. In Section IV.C.8 of its FIP, the licensee clarified that communication between the flow control operator at the pumper truck and operators at the MCR/ROS will be by radio, satellite phone, or runner.

4.4.1.3 Qualification of SAWA/SAWM Instruments

Drywell pressure and wetwell level are declared Susquehanna PAM variables as described in RG 1.97 and documented in Susquehanna UFSAR Section 7, Table 7.5-3. 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 flow meter is integral to the pumper truck and is an all-mechanical design. The NRC staff audited Susquehanna document EC-016-1043 Rev 3, Attachment 11 and confirmed that the operational temperature range of the flow instrument exceeds the site ambient extreme temperature conditions. The pumper truck is deployed on the opposite side of the reactor building from the vent, minimizing radiation exposure. The mechanical flow meter is not sensitive to radiation exposure.

The NRC staff reviewed the environmental conditions and instrument qualification information provided in Section IV.C.10.3 and Table 1 of the FIP and determined that the qualification of the SAWA/SAWM instruments is consistent with the guidance in NEI 13-02.

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 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.

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

4.5.1 <u>Staff Evaluation</u>

4.5.1.1 Severe Accident Effect on SAWA Pump and Flowpath

To address SAWA/SAWM severe accident dose considerations, the licensee performed a detailed radiological analysis documented as EC-RADN-1180, "SSES HCVS Radiological Assessment," Revision 1. This calculation analyzed the dose at different locations and times where operator actions will take place during FLEX/SAWA/SAWM activities. The analyzed locations include the MCR, ROS, and travel paths for hose routing.

In its FIP, the licensee states that manual actions required for SAWA inside the reactor building (RB) near the ESSWPH, where there could be a high radiation field due to a severe accident, will be performed before the dose is reaches unacceptable levels i.e., within 6 hours from the start of the ELAP. The licensee further states that other SAWA actions take place at locations that are shielded from the severe accident radiation levels by the thick concrete walls of the primary containment and the RB. The SAWA pump is stored in the flex storage building (FSB) and will be operated outside the RB. The SAWA pump will not be deployed on the same side of the RB as the vent pipe. The NRC staff audited the radiological analysis and concurs that, if implemented correctly, there should be no significant issues with radiation dose rates at the SAWA pump control location and there should be no significant dose to the SAWA pump.

In its FIP, the licensee states that the SAWA flow path inside the RB consists of stainless steel piping that will be unaffected by the radiation dose and that hoses will only be run in locations that are shielded from significant radiation dose or that have been evaluated for the integrated dose effects over the period of sustained operation. The NRC staff concurs that the SAWA flow path will not be adversely affected by radiation effects due to the severe accident conditions.

4.5.1.2 Severe Accident Effect on SAWA/SAWM Instruments

The licensee states that the drywell pressure and wetwell level instruments are safety-related and qualified for post-accident use and therefore are qualified for EA-13-109 events, in accordance with the guidance in NEI 13-02, Appendix C, Section C.8.1.

As stated in Section 4.5.1.1 above, the SAWA pump will be operated outside the RB, and will not be deployed on the side of the RB as the vent pipe. This location ensures that there will be no adverse effects from radiation exposure to the flow instruments mounted on the SAWA pump. The licensee has chosen low dose areas for the FLEX/SAWA manifold flowmeters to ensure that their operation will not be adversely affected by radiation exposure. Based on this information, the NRC staff concurs that the SAWA/SAWM instruments should not be adversely affected by radiation effects due to severe accident conditions.

4.5.1.3 Severe Accident Effect on Personnel Actions

The SAWA monitoring equipment can all be operated from the MCR, except the SAWA pump (the MCR personnel can communicate with the personnel operating the SAWA pump), and the SAWA pump are operated from outside the RB at ground level, therefore there is no thermal concerns for operators. Environmental conditions in the MCR and the ROS were discussed previously in Section 3.1.1.2, Personnel Habitability - Environmental.

Based on the above, the NRC staff agrees that, if implemented correctly, the environmental conditions should not prevent operators from implementing the SAWA or SAWM strategies.

The licensee performed calculation EC-RADN-1180, "SSES HCVS Radiological Assessment," which documents the dose assessment for designated areas outside of containment caused by the sustained operation of the HCVS under the beyond-design-basis severe accident condition of an ELAP. This assessment used conservative assumptions to assess 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 an audit of the licensee's detailed evaluation, that if implemented correctly, mission doses associated with actions taken to protect the public under beyond-design-basis severe accident condition should 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 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.

4.6 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, 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.

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 compensatory measures. In the FIP, Section V.B provides specific time frames for out-of-service requirements for HCVS functionality.

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

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

5.2 Training

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

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

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

6.0 CONCLUSION

In June 2014, the NRC staff started audits of the licensee's progress in complying with Order EA-13-109. The staff issued an ISE for implementation of Phase 1 requirements on April 1, 2015 [Reference 13], an ISE for implementation of Phase 2 requirements on August 25, 2016 [Reference 14], and an audit report on the licensee's responses to the ISE open items on October 5, 2017 [Reference 15]. The licensee reached its final compliance date on April 30, 2018 and has declared in letter dated June 26, 2018 [Reference 16] that Susquehanna Steam Electric Station, Units 1 and 2 are 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 Susquehanna to NRC, "Susquehanna, Units 1 and 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 26, 2014 (ADAMS Accession No. ML14178A619)

3. Letter from Susquehanna 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 23, 2014 (ADAMS Accession No. ML15040A155)

4. Letter from Susquehanna 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 23, 2015 (ADAMS Accession No. ML15174A052)

5. Letter from Susquehanna to NRC, "Susquehanna, Units 1 and 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 23, 2015 (ADAMS Accession No. ML15362A528)

6. Letter from Susquehanna 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 29, 2016 (ADAMS Accession No. ML16181A179)

7. Letter from Susquehanna 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 19, 2016 (ADAMS Accession No. ML16355A294)

8. Letter from Susquehanna 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 15, 2017 (ADAMS Accession No. ML17166A472)

9. Letter from Susquehanna 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 12, 2017 (ADAMS Accession No. ML17348A049)

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SUBJECT: SUSQUEHANNA STEAM ELECTRIC 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. MF4364 AND MF4365; EPID NO. L-2014-JLD-0055) DATED: January 3, 2019

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