NEI 13-02 [Rev. A3.2]

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INDUSTRY GUIDANCE FOR COMPLIANCE WITH ORDER EA-13-109

BWR Mark I & II Reliable Hardened Containment Vents Capable of Operation Under Severe Accident Conditions

July 2013

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Nuclear Energy Institute

INDUSTRY GUIDANCE FOR COMPLIANCE WITH ORDER EA-13-109:

BWR Mark I & II Reliable Hardened Containment Vents Capable of Operation Under Severe Accident Conditions

July 2013

Nuclear Energy Institute, 1776 I Street N. W., Suite 400, Washington D.C. (202.739.8000)

ACKNOWLEDGEMENTS

This report was prepared by the NEI Filtering Strategies Working Group and under the oversight of the industry Fukushima Response Steering Committee. This document would not have been possible without the engagement of the BWROG and the technical bases and rationale provided by EPRI.

NOTICE

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Industry Guidance for Compliance with Order EA-13-109: BWR Mark I & II Reliable Hardened Containment Vents Capable of Operation Under Severe Accident Conditions

1 INTRODUCTION

The nuclear energy industry and the NRC share a common challenge of providing prevention and mitigation strategies to maintain safety in the face of unlikely and extreme events. An approach that focuses on diverse and flexible mitigation capability will provide additional defense-in-depth safety enhancement against a range of extremes, some of which cannot be forecasted.

The importance of reliable operation of hardened vents during conditions involving loss of containment heat removal capability is well established and this understanding has been reinforced by the lessons learned from the accident at Fukushima Dai-ichi. Hardened vents have been in place in U.S. plants with BWR Mark I containments for many years but variance exists with regard to the capability of the vents for a broad spectrum of events. Generally, BWR Mark II containments do not currently have hardened vent paths. The NTTF 90-day report indicated hardened vent designs that were AC independent to operate with limited operator actions from the control room are necessary. Therefore, Order EA-12-050 required hardened containment venting systems in BWR facilities with Mark I and Mark II containments ~~are being required by the NRC~~ on the basis that they are needed to ~~ensure~~ provide reasonable assurance of adequate protection of public health and safety.

~~Prompted by Fukushima Dai-ichi accident, the NRC issued Order EA-12-050 requiring installation of a reliable hardened vents for Mark I and Mark II containments.~~ ~~As directed by the NRC, Commission th,e~~ Subsequently the original ~~Order~~ order was rescinded and replaced with a new order to ~~address~~ require severe accident capable containment vent ~~severe accident conditions~~s on the basis that it provides a cost-justified substantial safety improvement b~~. B~~eyond what is needed to provide reasonable assurance of adequate protection of public health and safety. Order EA-13-109 was issued to ~~maintain the same~~expand the set of design and quality requirements originally imposed by EA-12-050 ~~and included additional requirements~~ to ensure that venting functions are available during postulated severe accident conditions. Because EA-12-050 has been rescinded and its requirements are now reflected in Order EA-13-109, licensees are no longer expected to comply with the requirements of Order EA-12-050, including any applicable time lines for submission of integrated plans, or for complete implementation.

The new severe accident Hardened Containment Venting System (HCVS) Order contains historical information and decision making insights in sections I, II and III that provide useful information, but do not contain the legally binding actions which licensees are required to comply with, which are in sections IV and Attachment 2.

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Comment [N1]: Delete, does not appear pertinent to a design and quality requirements guidance document,

Comment [N2]: 050 did not require severe accident capability, 109 is the SA HCVS and this might be clearer if "new" were left out.

1.1 Purpose

The purpose of this guidance is to assist nuclear power reactor licensees with the identification of measures needed to comply with the requirements of Order EA-13-109, "Order Modifying Licenses with Regard to Reliable Hardened Containment Vents Capable of Operation Under Severe Accidents" [Ref. X]. This guidance provides an acceptable method for satisfying those requirements; however, licensees may propose other methods for satisfying these requirements.

Incorporation of the lessons learned and results from the March 11, 2011 Fukushima Dai-ichi~~2011~~ Accident is a key element in the foundation of requirements and guidance associated with the scope of work required in response to Order EA-13-109, which is prefaced by the following statement:

> *"The events at the Fukushima Dai-ichi nuclear power plant following the March 2011 earthquake and tsunami highlight the possibility that events such as rare natural phenomena could challenge the traditional defense-in-depth protections related to preventing accidents, mitigating accidents to prevent the release of radioactive materials, and taking actions to protect the public should a release occur. At Fukushima Dai-ichi, limitations in time and unpredictable conditions associated with the accident significantly hindered attempts by the operators to prevent core damage and containment failure. In particular, the operators were unable to successfully operate the containment venting system. These problems, with venting the containments under the challenging conditions following the tsunami, contributed to the progression of the accident from inadequate cooling of the core leading to core damage, to compromising containment functions from overpressure and over-temperature conditions, and to the hydrogen explosions that destroyed the reactor buildings (secondary containments)~~…~~ of three of the Fukushima Dai-ichi units. …The events at Fukushima reinforced the importance of reliable operation of hardened containment vents during emergency conditions, particularly for smaller containments such as the Mark I and Mark II designs.~~…~~"*

To address this event with the rest of the nuclear industry, there are many regulatory and industry recommendations and changes to be considered. ~~Among these currently~~Many of these are documented in the following:

- NRC Near Term Task Force 90 Day Report (Ref. X)
- NRC SRM/SECY 11-0124 - Recommended Actions to be taken Without Delay From The Near-Term Task Force Report (Ref. X)
- NRC SRM/SECY 11-0137 - Prioritization of Recommended Actions to be Taken in Response to Fukushima Lessons Learned (Ref. X)

The primary objectives of the Industry response scope of work derived from these documents resulted in NEI 12-06 [Rev. 0] DIVERSE AND FLEXIBLE COPING STRATEGIES (FLEX) IMPLEMENTATION GUIDE~~the Industry response to~~ for implementation of NRC Order EA-12-049, Mitigation Strategies for Beyond-Design-Basis External Events (FLEX) (Ref. X). Many of these cornerstones that will be utilized in this guidance

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document for addressing NRC Order EA-13-109 did not originally extend to venting capabilities under severe accident conditions.

The industry is committed to continuous improvement of nuclear safety. Some applicable continuous improvement work items from lessons learned from the Fukushima Daiichi event are listed below:

a) Confirm or establish effective coping measures to address the vulnerability of onsite and offsite AC power systems to common mode failures resulting from external and internal events, including beyond design basis events.

b) Confirm the external events that formed the basis for plant designs exceed credible hazards based on historical data and current models (floods, high winds, seismic events, etc.) or raise the design bases and change the plants, as necessary to accomplish the revised design bases.

c) Confirm or establish effective primary containment protective strategies that can manage post-accident conditions, including such factors as elevated pressures and hydrogen generation from fuel damage more extensive than original design bases, including use of hardened venting, etc. as appropriate.

d) Confirm or establish effective integrated strategies to provide for system based response for events and/or severe accidents involving multiple reactors at a site (i.e., integrate EOPs, SAMGs, AOIs, EDMGs, etc.).

e) Provide for support during extended emergencies involving infrastructure loss, including fuel supplies, coordination of offsite resources, communications, near site living requirements and transportation, and etc.

f) Share and participate with other stakeholders to co-develop responses, improve acceptance and consensus, and minimize development costs.

g) Establish Regional Response Centers with multiple sets of site response equipment and long term coping equipment for mitigating fuel damage from an ELAP event.

Comment [N3]: They are not meant for mitigating fuel damage.

Comment [N4]: This verbiage appears to wander a little far afield regarding EA-13-109 implementation and if it remains will likely be noted as not being endorsed by the ISG

1.2 HCVS Guiding Principles

Hardened vents have been in place in U.S. plants with BWR Mark I containments for many years but a variance exists with regard to the capability of the vents for a broad spectrum of events. BWR Mark II containments have containment venting capability but they typically are not hardened vent paths. Therefore, hardened containment venting systems in BWR facilities with Mark I and Mark II containments ~~are being~~were required by the NRC (Order EA-12-050) on the basis that they are needed to enhance protection of public health and ~~safety~~ safety.

On June 6, 2013, the US NRC rescinded Order EA-12-050 and issued a new order, EA-13-109, expanding the requirements of the original order to include requirements for the reliable hardened vent ~~for~~ to be capable of operation during severe accident conditions. The new ~~Order~~ order is applicable to all operating boiling water reactor (BWR) licensees with Mark I and Mark II containments issued under Title 10 of the Code of Federal Regulations (10 CFR), Part 50, "Domestic Licensing of Production and Utilization Facilities."

The original Order EA-12-050 [Ref. X] required that all boiling water reactor (BWR) Mark I and Mark II containments have a reliable hardened vent to remove decay heat from the containment and maintain ~~control of~~ containment pressure within acceptable limits following events that result in the loss of active containment heat removal capability or prolonged station blackout (SBO), i.e., Extended Loss of AC Power (ELAP). The original order did not include ~~explicit~~ requirements relating to severe accident service for the hardened containment venting system (HCVS); rather, the ~~focus of the~~ HCVS was ~~to~~ only required to be able to support strategies related to the prevention of core damage under a wide range of plant conditions. JLD-ISG-2012-02 (Ref. X) provided the Interim Staff Guidance (ISG) ~~to drive compliance to~~for implementation of Order EA-12-050.

All licensees subject to Order EA-12-050 provided integrated plans for the design and implementation of reliable hardened containment vents by February 28, 2013. In SRM-SECY-12-0157 [Ref. 3], the Commission directed the staff to revise Order EA-12-050 to require the upgrade or replacement of 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.

EA-13-109 requires that BWRs with Mark I or Mark II containments ensure that in addition to pre-core damage venting capability, the HCVS also provides a reliable hardened venting capability from the wetwell and drywell under severe accident conditions, including those involving a breach of the reactor vessel by molten core debris. A drywell strategy for alternate heat removal instead of the drywell vent requirement ~~is acceptable~~may be proposed for NRC staff review as an acceptable alternative. The severe accident capable HCVS is intended to keep the originally required function of the HCVS, which is to help prevent severe accidents from occurring, and to add the capability of ~~helping to mitigate the consequences of a~~operating during severe accident ~~should one occur~~conditions. The wetwell and drywell vent pathways are not required to be ~~in operation at the same time~~fully functional by the same implementation date. The development and implementation of the severe accident capable HCVS consists of two phases. The first phase consists of providing a venting system from the containment wetwell that meets the functional, quality, and programmatic requirements listed in subsequent sections of this guide. The second phase is associated with capabilities to vent from the drywell during severe accident conditions and involves either installing a venting system or developing a reliable strategy to limit the possible need to vent from the containment drywell during severe accident conditions. Thus the wetwell and drywell vent pathways will not be required to be installed concurrently. Appendix C outlines the methodology licensees can use to evaluate the viability of a drywell vent path.

1.3 PROCEDURE INTERFACE

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Comment [N5]: Severe accident service capability requirements were explicitly excluded, not happenstance or oversight.

Comment [N6]: To make matters clear, include a discussion of the relation between Phase 2 and rulemaking. The extension of Phase 2 implementation (drywell vent) is to converge with the rule making, so that need/no need for a drywell vent satisfies both Order EA-13-109 and rule making.

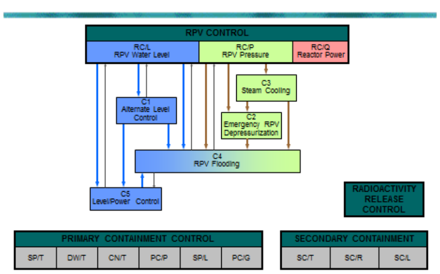
Comment [N7]: Does this imply that there is a real question as to the technical "viability" of a drywell vent?

Comment [N8]: The material in this section provides a background of the SAMGs and devotes a lot of discussion to the SAMGs and how a drywell vent becomes even more unlikely to be used after a post Fukushima revision to the SAMGs. This verbiage ranges out beyond the scope of what the ISG will endorse as it goes far beyond what EA-13-109 deals with, the technical and quality requirements of severe accident capable vents. This section essentially argues a case against equipment requirements in the order. The industry is free to continue to present its case in the rule making and during the development of Appendix C (assessment of need for drywell vent) to this guidance document. Until a reliable venting strategy that does not require a reliable severe accident capable drywell venting system is agreed to, this section has no meaning and staff recommends that it be removed from the guidance document.

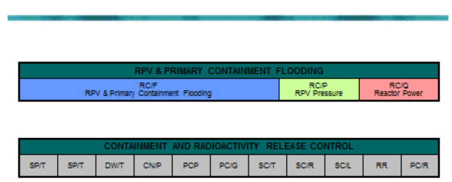
Command and Control for accident response is governed by the suite of Emergency Preparedness guidelines and procedures. Accident response is controlled by the plant specific Emergency Operating Procedures (EOPs), severe accident management guidelines (SAMGs), and Emergency Preparedness procedures. The EOPs provide direction to Operators for use of hardened vents (as well as other available venting) when adequate core cooling has been maintained for prevention of fuel damage. The SAMGs provide direction for use of hardened vents for the purpose of mitigation after adequate core cooling has been lost. The importance of reliable operation of hardened vents during conditions involving loss of containment heat removal capability is well established and this understanding has been reinforced by the lessons learned from the accident at Fukushima Dai-ichi. Understanding the procedural interface and direction is essential given the influence that severe accident conditions have on the design and operational use of the vent paths.

The plant specific procedures are based upon the BWROG generic Emergency Procedure Guidelines/Severe Accident Guidelines (EPGs/SAGs), whose organizational structure is diagramed below:

EPG Structure

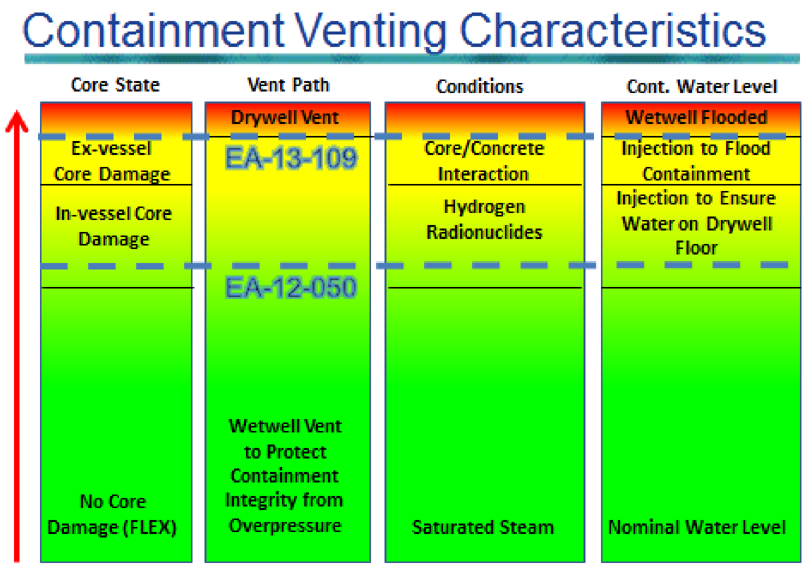


SAG Structure



Utilities currently have implemented Revision 2 of the EPG/SAGs, but Revision 3 has been published and includes the lessons learned from Fukushima Dai-ichi.

The BWROG standard emergency operating procedures and severe accident guides (EOP/SAG) (revision 2 and 3) both provide direction for BWR Mark I and II plants to leave EOP/SAG flowcharts at any point where adequate containment heat removal methods are in effect as on the following illustration of containment venting characteristics, i.e., they are not predisposed to have to use drywell venting.



Revision 3 of the EOP/SAG enhanced the flow of information from revision 2 using lessons learned from the Fukushima event. The information presented is representative of the structure in revision 3.

From the plant specific EOPs developed from the EPGs, use of a hardened vent is directed:

- before primary containment pressure reaches the primary containment overpressure limit defined by the Primary Containment Pressure Limit (PCPL),
- if lower containment pressure is necessary to provide RPV injection; if suppression pool approaches saturation conditions and can no longer effectively condense steam discharged from RCIC; or
- to limit total offsite dose by venting steam prior to experiencing fuel damage.

From the plant specific SAMGS developed from the SAGs, use of a hardened vent is directed:

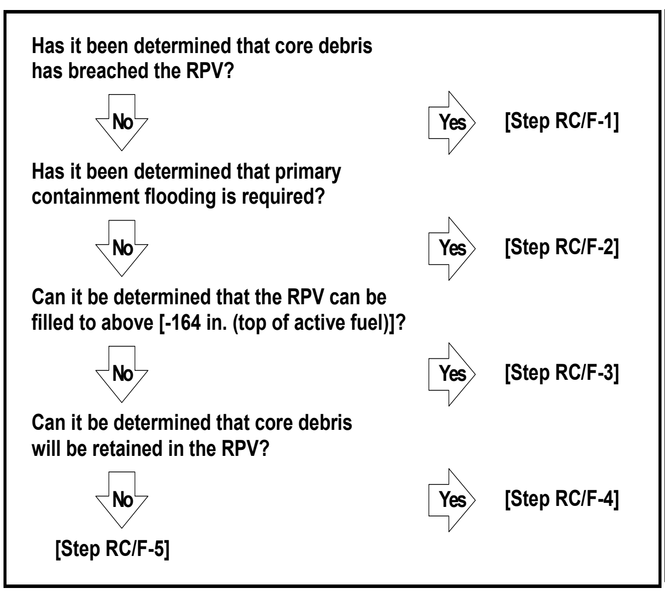
- Before primary containment pressure reaches the primary containment overpressure condition defined by (PCPL);
- To facilitate RPV injection or containment injection; or
- To remove combustible gases from primary and secondary containment.

Containment venting per the procedures and guidelines should be coordinated with evacuation procedures and timed to take advantage of favorable meteorological conditions. It should be coordinated to take advantage of suppression pool scrubbing as much as possible.

For venting from EOPs the wetwell vent is expected to be used to protect containment and will be venting mostly saturated steam, while Primary Containment Water level and pressure will be maintained to preserve the Pressure Suppression Capability of the Containment. This could include venting to protect steam driven systems being used to provide adequate core cooling or to limit the total offsite dose if it is expected that fuel damage has occurred.

Once fuel damage occurs and transfer to plant specific SAMGs is made containment venting will depend on what other plant conditions exist. Only two steps in plant specific SAMGs require containment flooding, steps RC/F-1 and RC/F-2. The remaining steps seek to maintain Pressure Suppression Capability (which means suppression pool water is maintained in an extended range but not flooding containment). Containment venting could be used to restore Pressure Suppression Capability by lowering containment pressure. The SAMGS do not mandate Drywell venting for all conditions.

The following graphic shows the SAMG decision block and briefly describes the conditions each step implements:



RC/F-1 RPV breached. Submerge debris and flood containment.

RC/F-2 Pressure Suppression Capability not maintained or Primary system break. Cool debris and flood containment.

RC/F-3 Re-flood RPV above TAF. Maintain Pressure Suppression Capability.

RC/F-4 Debris expected to remain in RPV. Cool debris and maintain Pressure Suppression Capability.

RC/F-5 Debris may melt through RPV. Containment may fail. Maximize RPV injection.

To summarize, containment venting is addressed in plant specific EOPs for prevention of core damage. After core damage cannot be prevented, plant specific SAMGs address mitigation of core damage. The basis for these actions is documented in the BWROG EPG/SAG Rev. 3 Appendix B, Technical Basis, and the Technical Support

Guidelines, Rev. 0. Hardened containment vent designs should include a review of the EPG/SAG Revision 3 directions for use of containment vents.

1.4 OVERVIEW

This industry guidance has been developed to provide an integrated set of considerations for the design and implementation of a severe accident capable hardened containment venting system (HCVS). This guidance is organized in the following manner:

Section 2:	Description of the boundary conditions to be applied to the design of HCVS including the applicable severe accident conditions, the design boundary conditions and operational assumptions, and the role of mitigation strategy capabilities implemented under EA-12-049 [Ref. X]
Section 3:	Guidance on the design considerations for the HCVS including vent path design, vent operation and monitoring, support systems for sustained operations, protection from flammable gas ignition, other design requirements such as environmental qualification, seismic and external hazard design and quality requirements.
Section 4:	Guidance on the operational considerations for the HCVS including procedural guidance and training related to the operator actions required for use of the HCVS and the testing and inspection of the HCVS and associated components.
Section 5:	Guidance on meeting the programmatic requirements associated with the revised order.
Section 6:	Operations consideration for the HCVS including environmental considerations, procedures, allowed out of service time, and testing.
Section 7:	Template for Overall Integrated Plan Submittal and six month status updates
Section 8:	References
Appendices:	Are provided to elaborate on specific aspects of the guidance including a glossary of key terms, a cross-reference roadmap of order requirements, FLEX interfaces, generic letter 89-16 interfaces, calculation methods for defining plant-specific severe accident operator doses and source terms, and design approaches to address control of flammable gases.

This industry guidance provides an acceptable method for satisfying those requirements. Licensees may propose other methods for satisfying these requirements. The NRC staff can review such methods and determine their acceptability on a case-by-case basis.

Comment [N9]: Method acceptable to NEI, an ISG will endorse specific provisions or not and in any event the NRC staff will review and determine acceptability of how licensee's will be implementing order EA-13-109.

2. WET WELL VENT BOUNDARY CONDITIONS FOR VENT DESIGN AND OPERATION

Boiling-Water Reactors (BWRs) with Mark I and Mark II containments shall have a reliable, severe accident capable hardened containment venting system (HCVS). The HCVS includes a severe accident capable wetwell venting system, and may also, depending on the approach taken for Phase 2 of Order EA-13-109, include a severe accident capable drywell venting system. Because ~~of~~ the ~~potential for~~ implementation is in two phases~~,~~ and the fact that the containment conditions that exist at the initiation of venting from the wetwell and drywell may be different, this document separates the boundary conditions for design and operation between wetwell and drywell into two separate sections. Boundary conditions used in design of HCVS shared components and piping is included in this Section and in Section 4.1.

Under Phase 1 of Order EA-13-109, Licensees with BWR Mark I and Mark II containments shall design and install a HCVS, using a vent path from the wetwell to remove decay heat, vent the containment atmosphere (including steam, hydrogen, carbon monoxide, non-condensable gases, aerosols, and fission products), and control containment pressure within acceptable limits. The HCVS shall be designed for those accident conditions (before and after core damage) for which containment venting is relied upon to reduce the probability of containment failure, including accident sequences that result in the loss of active containment heat removal capability during an extended loss of alternating current (AC) power (ELAP). The HCVS shall meet the requirements of Sections 4, 5, and 6 of this document.

Under Phase 2 of Order EA-13-109, Licensees with BWR Mark I and Mark II containments shall either, (1) design and install a HCVS, using a vent path from the containment drywell, that meet the requirements in Sections 3 through 6 or, (2) develop and implement a reliable containment venting strategy using the guidance provided in Appendix C of this document that demonstrates it is unlikely that a licensee would need to vent from the containment drywell before alternate reliable containment heat removal and pressure control is reestablished to meet the requirements in Section B.2 of the Order.

The requirements of Order EA-12-050 addressed the use of the HCVS for both prevention of core damage and protection of the containment from overpressure failure during a Beyond Design Basis Event (BDBE). Unlike conditions resulting from postulated plant events, severe accidents, by their very nature, are an effectively unbounded class of events. Although reactors licensed under 10CFR52 have certain regulatory requirements related to severe accident capabilities, the extension of regulatory requirements to design features required for severe accident conditions is unique for existing reactors licensed under Part 50. This unique aspect of Order EA-13-109 calls for very clear definition of the boundary conditions to be applied to the design and operational considerations required to implement the HCVS. The purpose of this section is to clearly outline

Comment [N10]: Any thought to stating that venting just from the drywell with an external engineered filter could be an acceptable alternative, or is that left to the ISG to state?

Comment [JOB111]: that had not progressed to core damage and severe accident condition.

these boundary conditions and the key terms used in relation to the conditions associated with a severe accident capable vent.

Two key functional aspects of the HCVS involve the prevention of containment over-pressurization for events that do not result in core damage and for events where severe accident conditions exist.

A key guiding principle regarding the design of the HCVS is defining conditions that are consistent with~~match~~ the capability of the containment to withstand severe accidents. The HCVS is not required to be designed or have capability beyond those containment conditions (e.g. temperature, pressure, radionuclide, combustible gases) that have potential to challenge the containment boundary function.

2.1. HCVS Use for Design Basis

Use of the HCVS during design basis accidents or other design ~~licensing~~ basis events (DBE) is not assumed nor required. However, the EPGs provide directions on the use of the HCVS to support maintaining adequate core cooling and prevent core damage in response to containment conditions that progresses beyond plant design basis conditions.

Comment [N12]: The ISG for order EA-13-109 is not endorsing specific EPG content regarding venting and this fact will be noted in the ISG. See staff comment on Section 1.3

2.2. HCVS Use for Beyond Design Basis External Events (BDBEEs)

A spectrum of Beyond Design Basis Events (BDBE) or Beyond Design Basis External Events (BDBEE) may be postulated; however, in the context of the HCVS, the design and operation in response to such events is not intended to be constrained to a specific set of scenarios or timelines. Rather, the considerations for the HCVS are defined to provide a broad functional capability for the prevention of containment over-pressurization prior to core damage and mitigation of containment over-pressure conditions that may exist after core damage.

2.2.1. BDBE are events that involve assumptions and failures that exceed those associated with DBEs but may not be considered severe accidents.

2.2.2. Certain beyond design basis events such as an extended loss of AC power (ELAP) can result in the loss of active containment heat removal capability.

2.2.2.1. Plant actions to address an ELAP are contained in the plants response to NRC Order EA-12-049, commonly referred to as FLEX. An ELAP is not considered a severe accident since use of FLEX mitigates core damage.

Comment [N13]: The order states that core damage can result from loss of active containment heat removal capability or ELAP.

Comment [N14]: An ELAP is not considered a severe accident itself but may eventually result in core damage and severe accident conditions. The scope of EA-12-049 is prevention of core damage and does not address severe accident conditions.

2.2.3. The primary design objective of the HCVS is to provide sufficient venting capacity to prevent a long-term overpressure failure of the containment by keeping the containment pressure below the primary containment design pressure and the primary containment pressure limit (PCPL).

2.2.4. The HCVS venting pressure for a BDBE may be initiated below PCPL driven by other conditions created during BDBEs, such as to lower pressure to use a low pressure portable pump, or to control containment conditions to allow continued use of installed equipment during loss of containment cooling.

2.3. HCVS Use for Applicable Severe Accident Conditions

For the purpose of this order, the primary severe accident use of the HCVS is to protect the containment from over-pressure failure caused by the loss of active containment heat removal capability or ELAP. T~~t~~he increase in containment pressure is caused by~~from~~ steam or non-condensable gases, and elevated~~or~~ containment temperature ~~within containment~~ following severe core damage. The conditions include both scenarios in which all core debris is cooled in-vessel (similar to the accident at TMI-2) and scenarios in which core debris breaches the reactor coolant boundary and at least some core debris relocates into containment. Increased temperature resulting from severe accidents may impact the pressure retention capability of containment, particularly the drywell head gasket. The performance of the HCVS in response to a severe accident is intended to minimize, as far as reasonably practicable, releases of radionuclides to the environment by preventing containment over-pressure.

The HCVS would also be used as an element of the SAGs to maintain the Pressure Suppression Pressure function of the containment prior to RPV breach by controlling torus pressure and level. Additionally, venting of non-condensable gases from the drywell can reduce the challenge to containment integrity from stratified gas temperature effects on the drywell head.

2.3.1. The spectrum of severe accidents considered within the HCVS design are limited to those that do not compromise the containment integrity to reasonably retain radionuclides from being released to the environment given severe accident conditions.

2.3.2. Realistic assumptions (i.e. not bounding) may be used to determine the boundary conditions for design of the HCVS.

2.3.3. The integrity of the drywell head gasket should be considered to determine potential over-pressure margin to leakage from the head region.

2.4. Vent Design Boundary Conditions

The potential scope of possible severe accident conditions is essentially unbounded.   In some scenarios, severe accident containment conditions can compromise containment integrity for reasons other than over-pressurization, (e.g., drywell shell melt-through in Mark Is, extremely high temperatures or other postulated containment failure modes). The unbounded nature of severe accident conditions calls for a more reasonable design philosophy: the HCVS design should not exceed the current capability of the limiting containment components or the conditions under which it is required to operate. Four primary parameters are defined for use in defining the HCVS component capability; Pressure, Temperature, Radiation and Hydrogen/CO Concentration.

Order Reference: 1.2.10 – The HCVS shall be designed to withstand and

Comment [N15]: Any reason for not referencing specific installed equipment. The staff would like to know if equipment other than RCIC pumps or isolation condensers are included in the scope of this statement.

Comment [N16]: The early venting involves a policy issue that is currently under discussion within the NRC and between the industry and the NRC staff.

Comment [N17]: The ISG will not endorse specific SAG provisions directly or indirectly. See staff comment under Section 1.3.

Comment [N18]: Need clarification as to what is meant/intended here. Is it meant to capture the limitation of penetration seals, drywell head gasket or is it meant to address the water injection capability? The water injection capability for severe accidents is not in the scope of order EA-13-109, so the potential consequences of no injection could be excluded from the guidance document with the recognition that water injection requirements will be addressed during the rule making and Phase 2 guidance development.

Comment [N19]:

Comment [N20]: Staff agrees that head penetration is the focus but there may be other temperature limited penetration seals in the upper drywell.

Comment [N21]: Revise to state “meet or exceed” instead of “should not exceed’ 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.

2.4.1. Depending on the HCVS design, the HCVS may have three distinct portions.

2.4.1.1. a portion that only supports wetwell venting,

2.4.1.2. a portion that only supports drywell venting, and

2.4.1.3. a portion that is shared by both.

2.4.1.3.1. The drywell generally has the most limiting boundary conditions, so the drywell boundary condition parameters described below are recommended for the shared portions of the HCVS.

2.4.2. The use of the HCVS is directed by BWROG Emergency Procedure Guidelines/Severe Accident Guidelines (EPGs/SAGs) and adopted on a plant-specific basis through the use of flowcharts and procedures.

2.4.2.1. In the SAGs, the highest pressure used for venting to control (restore and maintain) pressure is based on the plant-specific Primary Containment Pressure Limit (PCPL).

2.4.2.1.1. The most bounding PCPL for design of components is PCPL-C, which is based on the pressure capability of containment.

2.4.2.1.2. PCPL-C is selected as the boundary condition for the design pressure of the HCVS components and piping. It is expected that the capability of HCVS components and piping will be greater than the design boundary conditions.

2.4.3. During a severe accident, temperature of gases in the wetwell and drywell will differ due to the high temperatures induced by core damage.

2.4.3.1. The suppression pool/wetwell of a BWR Mark I/II containment can generally be considered to be in a saturated condition.

2.4.3.2. The EPG/SAG guidance on determining the plant-specific PCPL provides a temperature range for the suppression pool of 70ºF to 350 ºF [Ref. 6].

2.4.3.3. Therefore, the design temperature for the wetwell vent portions of the HCVS are recommended to be based on either the 350 ºF upper bound of the EPG/SAG bases document which is above the saturation temperature corresponding to typical PCPL values.

2.4.4. For the drywell, the BWROG guidance on determining the plant-specific PCPL prescribes drywell temperature range for the drywell of 100ºF - 545ºF.

2.4.4.1. The maximum of this range, 545ºF, is recommended as the design temperature for the drywell and shared portions of the vent unless a lower number can be analytically justified.

2.4.5. Hydrogen gas (and other combustible gases) is a product of the core damage process as a result of chemical reactions involving zirconium and steam (or steel and steam) and Molten Corium Concrete Interaction (MCCI).

Comment [N22]: From entrained fission products

Comment [N23]: How about active voice, "…is required to meet or exceed…" Although not explicitly required by EA-13-109, meeting this requirement would appear to require identification of the limiting component(s) regarding the design parameters and their limiting parameter values. Staff's position was stated to the industry in several meetings. Full alignment not yet reached between the staff and industry.

Comment [N24]: Insufficient removal of decay heat from fission products resulting in superheat or non-saturated conditions in drywell.

Comment [N25]: Further discussions required to determine if a generic default design value is bounding and appropriate for all licensees. This is another item on which staff and industry are not in alignment.

2.4.5.1. Depending on the scenario and the timing of vent use, the volume fraction of hydrogen can vary widely.

2.4.5.2. Based on information in Appendix H, consideration of a hydrogen concentration range of 0% to 6% is recommended (see NUREG C/R-2475/NUREG C/R-6524, GE SIL 643, GE-NE-0000-003-1981-01)

2.4.5.2.1. Hydrogen is flammable at above 8% in many references and as low as 4% in other references.

2.4.5.2.1.1. The order drives two options, keep the hydrogen concentration below 8% by purging or to design for detonation.

2.4.5.2.1.1.1. Purging is an acceptable method for keeping the flammable concentration below 8%

2.4.5.2.1.1.2. Designing for detonation is addressed in Appendix H.

2.4.5.2.1.2. The exclusion of oxygen is an acceptable alternative to either inerting with steam or nitrogen or making the piping detonation/deflagration proof.

2.4.6. The recommended boundary conditions for the severe accident capable vent are summarized in Table 2-1 below.

Comment [N26]: Where and under what conditions, DW, WW, vent line? While venting with some condensation occurring in the flow, or after vent valve closed and steam condensation really commences. Staff reserves comment on this section, until completion of its review of the referenced documents. Will this guidance be included in Appendix H?

Table 2-1
Severe Accident Capable Vent Design Parameter Boundary Conditions

Boundary Parameter	Wetwell Vent Path	Drywell Vent/ Shared Paths
Containment Design Pressure	Containment Pressure at PCPL-C	
Containment Design Temperature	350 ºF	545ºF

Comment [N27]: See comment under section 2.4.5.2

2.4.6.1. Selection of values that are more conservative than the above recommended values is acceptable (i.e., higher design pressures and temperatures).

2.4.6.2. Less restrictive bases than the above recommended values require a plant-specific technical justification.

2.4.7. The piping, valves, and the valve actuators should be designed to withstand the dynamic loading resulting from the actuation of the system, including piping reaction loads from valve opening, potential for water hammer from accumulation of steam condensation, and hydrogen detonation, if applicable, during multiple venting cycles.

2.5. Vent Operation Assumptions

The vent must be capable of operation during an extended loss of AC power (ELAP) and under conditions that may exist during a severe accident.

Order Reference: 1.2.6 The HCVS shall 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 extended loss of AC power.

2.5.1. Severe accident conditions within the containment require consideration of accessibility and stay time issues using the methodologies in Appendix F and G. Sections 4.2.5 and 4.2.6 provide the requirements for design.

4. DESIGN CONSIDERATIONS

The purpose of the reliable HCVS is to enhance the capability of BWRs with Mark I and II containments to preserve containment capability~~integrity~~ in a wide spectrum of possible beyond design basis accident conditions including the presence of ex-vessel core debris, controlling containment pressure within acceptable limits by venting the containment atmosphere including steam, hydrogen, non-condensable gases, aerosols, and fission products. As described in Section 2, the HCVS will be designed for those accident conditions for which containment venting is relied upon to prevent containment failure; including accident sequences that result in the loss of active containment heat removal capability or extended loss of ac power (ELAP). This section describes the design considerations applicable to the design and implementation of a plant-specific HCVS.

4.1. Vent Design Criteria

4.1.1. Vent Thermal Design and Capacity

The primary design objective of the HCVS is to provide sufficient venting capacity to prevent a long-term overpressure failure of the containment by keeping the containment pressure below the PCPL and maintaining Pressure Suppression Capability such that the safety relief valves (SRVs) can be opened and closed as required by the plant conditions. Operational functionality of these valves will ensure the capability to depressurize the RPV to permit injection of low head injection systems and to maintain the containment pressure boundary.

Order Reference: 1.2.10 – The HCVS shall be designed consistent with containment pressures and temperatures during severe accident conditions as well as dynamic loading resulting from system actuation. The design is not required to exceed the current capability of the limiting containment components.

Comment [N28]: As stated in earlier staff comments, the HCVS is also not to be the weakest link, thus it is to be no less than the limiting containment component capability to be considered reliable.

Order Reference: 1.2.1 – The HCVS shall have the capacity to vent the steam/energy equivalent of 1 percent of licensed/rated thermal power (unless a lower value is justified by analyses), and be able to maintain containment pressure below the primary containment design pressure and the primary containment pressure limit (PCPL).

4.1.1.1. Key issues to be addressed in the Vent Thermal Design and Capacity requirements are:

4.1.1.1.1. Consideration of containment venting to support mitigation strategies

4.1.1.1.2. Ability of the vent system to operate under the expected pressures and temperatures of the containment.

4.1.1.1.2.1. The key consideration would be design temperature of the drywell vent components

4.1.1.1.3. Sizing considerations for the wetwell and drywell vent

4.1.1.1.3.1. A wet well vent sized under conditions of constant heat input at a rate equal to 1 percent of rated thermal power and containment pressure equal to the PCPL, the exhaust-flow through the wetwell vent would be sufficient to prevent the containment pressure from increasing.

4.1.1.1.3.2. The torus suppression capacity can be assumed to be sufficient to absorb the decay heat generated during at least the first three hours following the shutdown of the reactor with suppression pool as the source of injection

4.1.1.1.3.3. The decay heat can be assumed to be less than 1 percent of rated thermal power three hours following shutdown of the reactor, and that decay heat continues to decrease to well under 1 percent, thereafter.

4.1.1.1.3.4. If used for justification for less than 1 percent rated thermal power decay heat generation, an auditable engineering basis will be maintained for the decay heat absorbing capacity of the licensee's suppression pools

4.1.1.1.3.5. Licensees may also use a venting capacity sized under conditions of constant heat input at a rate lower than 1 percent of thermal power if it can be justified by analysis that primary containment design pressure and the PCPL would not be exceeded.

4.1.1.1.3.6. In cases where plants were granted, have applied, or plan to apply for power uprates, the 1 percent thermal power should corresponding to the uprated thermal power

4.1.1.1.3.7. The basis for the venting capacity should give appropriate consideration of where venting is being performed from (i.e., wetwell or drywell) and the difference in pressure between the drywell and the suppression chamber.

4.1.1.1.3.8. Vent sizing for multi-unit sites must take into consideration simultaneous venting from all the units, and ensure that venting on one unit does not negatively impact the ability to vent on the other units.

4.1.2. Multipurpose Penetration Use

Order Reference: 1.2.3 – The HCVS shall include design features to minimize unintended cross flow of vented fluids within a unit and between units on the site.
Order Reference: 2.1 – The HCVS vent path up to and including the second containment isolation barrier shall be designed consistent with the design basis of the plant. These items include piping, piping supports, containment isolation valves, containment isolation valve actuators and containment isolation valve position indication components.

4.1.2.1. Key issues to be addressed regarding multipurpose penetration use are:

4.1.2.1.1. Exception to GDC 56, 10 CFR 50.12 submittal

Comment [N29]: Unless all affected licensee's have a PCPL below and would remain below their containment design pressure, this should probably also include the design pressure limitation.

Comment [N30]: These should include a statement requiring confirmation by licensee calculations.

Comment [N31]: Those portions of the vent within the containment boundary are to be consistent with existing requirements/guidance for the purpose of design basis accidents.

4.1.2.1.1.1. Each HCVS containment penetration must have two in-series PCIVs as required by GDC 56.

4.1.2.1.1.1.1. Although GDC 56 stipulates that one valve should be inside containment and the other outside containment, both PCIVs on each HCVS containment penetration may be installed outside containment and as close as reasonably possible to the penetration.

4.1.2.1.1.1.2. Locating a power operated valve inside containment that must open and remain operable following a beyond design basis severe accident decreases the reliability of any valve and operator (including motive air and DC instrumentation and controls) located inside the containment.

4.1.2.1.2. The rational for locating the PCIVs as close as reasonably possible to the containment penetration is to comply with the applicable GDCs.

4.1.2.1.2.1. It limits the amount of the HCVS flow path that is part of the containment penetration boundary.

4.1.2.1.2.2. Minimizing the amount of new containment penetration piping limits the risks to containment integrity. Any piping that is part of the containment penetration boundary must be designed to the appropriate criteria (typically, protected from pipe whip, jet impingement, missiles, and be designed to ASME Section III class 2 with the added requirement for low stresses during design basis operation of the plant to preclude having to postulate pipe break or pipe cracks).

4.1.2.1.2.3. Locating the PCIVs close to the containment penetration ~~precludes any~~restricts the possibility for practical local-manual ~~operation,~~operation; section 4.2 discusses design features that will increase remote-manual operation.

4.1.2.1.3. GDC 56 stipulates that the valves must be either locked-closed or have automatic closure.

4.1.2.1.3.1. The intent of automatic isolation is to ensure that penetrations that may be open to the containment atmosphere during normal operation (e.g., nitrogen inerting, nitrogen purging) are closed when containment integrity is required.

4.1.2.1.3.2. Automatic isolation of the HCVS valves on a containment isolation signal is possible, but it would be redundant since these valves are required to be closed during all anticipated modes of operation that could require containment isolation. (except during the period required for operation when the containment isolation signals are to be defeated to allow HCVS operation)

4.1.2.1.3.3. Also, automatic isolation would unnecessarily complicate valve opening if HCVS is required.

Comment [N32]: NRC guidance allows for passive barriers like flanges (or even rupture disks) to serve in the place of a locked closed valve. The guidance should address the use of rupture disks in the vent lines.

Comment [N33]: Does not necessarily reflect vent designs with a rupture disk.

4.1.2.1.3.4. To support not providing locked-closed valves or automatic isolation, the new PCIVs are to be normally-closed valves that have a fail-closed mode (i.e., AOVs).

4.1.2.1.3.5. These valves shall have remote-manual operation, but with a key-lock on the control switch to prevent inadvertent opening.

4.1.2.1.4. As required by GDC 54, these penetrations "shall be designed with a capability to test periodically the operability of the isolation valves and associated apparatus and to determine if valve leakage is within acceptable limits."

4.1.2.1.4.1. The periodic PCIV testing frequency is dictated by the unit's Technical Specifications.

4.1.2.1.4.2. However, testing at any time may be required if a valve reliability issue arises.

4.1.2.1.4.3. Therefore, the HCVS flow path can be credited for being closed and remaining closed during all design basis transients and accidents.

4.1.3. Routing Considerations

Order Reference: 1.1.4 – The HCVS controls and indications shall be accessible and functional under a range of plant conditions, including a severe accident environment, extended loss of AC power, and inadequate containment cooling.

4.1.3.1. Key issues to be addressed regarding routing considerations are listed in Appendices F & G on source term and dose considerations and Section 4.2 for operator "residence time".

4.1.4. Multi-Unit Interfaces

System cross-connections or shared Unit vent exhaust flowpaths present a potential for steam, hydrogen, and airborne radioactivity leakage to other areas of the plant and to adjacent units at multi-unit sites if the units are equipped with common vent piping. At Fukushima, an explosion occurred in Unit 4, which was in a maintenance outage at the time of the event. Although the facts have not been fully established, a likely cause of the explosion in Unit 4 is that hydrogen leaked from Unit 3 to Unit 4 through a common venting system.

Order Reference: 1.2.3 – The HCVS shall include design features to minimize unintended cross flow of vented fluids within a unit and between units on the site."

4.1.4.1. HCVS design should provide design features to prevent the cross flow of vented fluids and migration to other areas within the plant or to adjacent units at multi-unit sites.

4.1.4.1.1. A design that is free of physical and control interfaces with other systems eliminates the potential for any cross-flow is one way to satisfy this requirement.

Comment [N34]: Does not necessarily reflect vent designs with a rupture disk.

Comment [N35]: By NRC guidance extension if a rupture disk is used as a penetration barrier, leak testing would also be appropriate.

4.1.4.1.2. Examples of acceptable means for minimizing cross flow are the use of valves, leak-tight dampers, and check valves.

4.1.4.1.3. Pressurizing with inert gas between system boundary valves could also be used (provided sufficient gas exists to support this during the required sustained operation period).

4.1.4.1.4. Other means are acceptable with a site specific justification based on the component parameters

4.1.4.1.5. Any HCVS flowpath interface should be designed to remain closed or automatically close upon the initiation of the HCVS and remain closed for as long as the HCVS is in operation

Comment [N36]: Position indication for those valves/dampers that would normally be open or local verification of shut position?

4.1.4.1.6. The environmental conditions (e.g. pressure, temperature) at the flowpath interface locations during venting operations should be evaluated to ensure that the interface will remain sufficiently leak-tight

4.1.4.1.7. If power is required for the interfacing valves to move to isolation position, it should be from power sources meeting the same standards and qualifications as the vent valves.

4.1.4.1.8. Leak tightness of any such barriers should be periodically verified by testing as described in section 6 of this document

4.1.5. Release Point

The HCVS release to outside atmosphere should be at an elevation higher than adjacent plant structures. (Refer to section 5 for discussion of qualification details)

Order Reference: 1.2.2 – The HCVS shall discharge the effluent to a release point above main plant structures.

4.1.5.1. Release through existing plant meteorological stack(s) is acceptable.

4.1.5.2. If the release from HCVS is through a stack different than the plant meteorological stack, the elevation of the stack should meet the following criteria:

4.1.5.2.1. Be higher than the nearest power block building or structure.

4.1.5.2.2. The release point should be situated away from ventilation system intake and exhaust openings.

Comment [N37]: Away from any entry point that might be expected to be opened during the event (to perhaps provide natural circulation ventilation)

4.1.5.2.3. The release stack or structure exposed to outside should be designed or protected to withstand missiles that could be generated by the external events that screen in for the plant site using the guidance in NEI 12-06 as endorsed by JLD-ISG-12-01 (See Section 5 for details).

4.1.6. Leakage Criteria

The HCVS design should address the reduction of Hydrogen Gas flammability in the vent pipe through the use of steam suppression (Reference Appendix H and reference NUREG C/R-2475/NUREG C/R-6524, GE SIL 643, GE-NE-0000-003-1981-01)

Order Reference: 1.2.3 – The HCVS shall include design features to minimize unintended cross flow of vented fluids within a unit and between units on the site.
Order Reference: 1.2.12 – The HCVS shall be designed to minimize the potential for hydrogen gas migration and ingress into the reactor building or other buildings.

4.1.6.1. Design for Leakage during HCVS Operation:

4.1.6.1.1. HCVS line inerting

4.1.6.1.1.1. The HCVS up to the second containment isolation valve should be either nitrogen inerted or be "steam inerted" such that any hydrogen gases within the containment or vent pipe remain below the hydrogen gas flammability limit (See NUREG/CR-2475 and GE-NE-0000-003-1981-01).

4.1.6.1.1.2. The HCVS pipe beyond the isolation valves used to initiate/cease venting should be designed for deflagration/detonation due to potential for oxygen intrusion resulting from steam condensation following HCVS vent closure or have the capability of being purged prior to the vent drawing in oxygen.

4.1.6.1.2. HCVS line exclusion

4.1.6.1.2.1. The exclusion of oxygen as an acceptable alternative to either inerting with steam or nitrogen or making the piping detonation/deflagration proof. An example of this approach is maintaining the line pressure above atmosphere to the last isolation valve

4.1.6.1.2.2. The HCVS pipe beyond the isolation valves should be detonation/deflagration proof or have a purge system that would keep oxygen out of the system

4.1.6.2. Design for Leakage in interfacing piping to HCVS:

The HCVS pipe beyond the interfacing piping isolation valve should meet the provisions of section 4.1.4.1.

4.1.7. Protection from Flammable Gas Ignition

Protection from flammable gas ignition should utilize principles found in NUREG/CR-2475. Additional information is provided in Appendix H of this document. The evaluation of gas ignition is to document the capability of the HCVS piping to maintain integrity should deflagration or detonation occur. Deformation of the pipe is acceptable given the integrity and continued functional capability of the ~~pipe~~ vent system is shown to be maintained.

Order Reference: 1.2.11 – The HCVS shall 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.

4.1.7.1. Design for Deflagration/Detonation

Most plants have a UFSAR evaluation of the Offgas flow path for detonation potential that evaluates piping for this issue. This method can be similarly used to evaluate the HCVS design. Methods of designing the HCVS piping/components against flammable gas detonation/deflagration are discussed in Appendix H. Susceptible portions of the piping should be determined based on where oxygen can be drawn into the piping/interfacing piping.

4.1.7.2. Purge systems to reduce gas concentrations below flammability limits

Use of a purge system in sections of pipe susceptible to air intrusion from intermittent HCVS operation can also be used to minimize detonation/deflagration potential.

4.1.7.3. Design Systems to Prevent Detonation/Deflagration

Design of the HVCS may include features that prevent air/oxygen backflow into the discharge piping. Use of design features in sections of pipe susceptible to air intrusion from intermittent HCVS operation can also be used to minimize detonation/deflagration potential.

4.1.7.4. Combination of loads

The design of the HCVS is required to withstand the dynamic loading resulting from hydrogen deflagration/detonation. For design purposes, the HCVS is not required to consider assumed simultaneous loads that would not be present or occur during the venting of hydrogen (e.g. seismic loads).

4.1.8. Combined Drywell/Wetwell Vent pipe Design considerations

4.1.8.1. Depending on the HCVS design, the HCVS may have three distinct portions or flowpaths;

4.1.8.1.1. A portion that only supports wetwell venting,

4.1.8.1.2. A portion that only supports drywell venting, and

4.1.8.1.3. A portion that is shared by both.

4.1.8.2. The drywell generally has the most limiting boundary conditions, so the drywell boundary condition parameters described in Sections 2 and 3 are recommended for the shared portions of the HCVS.

4.1.9. Fault/Failure Evaluations

SAMPLE: Failure Evaluation Table

Functional Failure Mode	Failure Cause	Alternate Action	Failure with Alternate Action ~~Impact on~~Impact on Containment Venting?
Fail to Vent (Open) on Demand	Valves fail to open/close due to loss of normal AC power	Switch power supply to inverter backed AC power	No
	Valves fail to open/close due to loss of one train of inverter backed AC power	Align power supply to alternate inverter	No
	Valves fail to open/close due to complete loss of DC batteries (long term)	Recharge batteries with FLEX provided generators	No
	Valves fail to open/close due to loss of normal pneumatic air supply	No action needed, valves are provided with accumulator tanks which are sufficient for up to 5 actuations in a 24 hour period	No
	Valves fail to open/close due to loss of alternate pneumatic air supply (long term)	Recharge accumulator tanks with N_2 bottles and/or portable air compressors. Replace bottles as needed.	No
	Valve fails to open/close due to SOV failure	None	Yes

Comment [N38]: FLEX as in pre-core damage and not required to be able to setup and maintained after core damage.

Comment [N39]: Staff recognizes that this is a sample evaluation table. Since a SOV is a low cost item, will this represent a situation where design would consider redundancy n the SOVs to increase the reliability of the HCVS? Will this section include more details to show how the evaluations are intended to be used by the licensees?

Comment [N40]: No explicit requirement for full redundancy even though active components involved and may be required to repeatedly change position/state. If a single pipe, two valves in series gives redundancy to close but not to open.

4.2 Vent Operation and Monitoring

The importance of reliable operation of hardened vents during conditions involving loss of containment heat removal capability is well established and this understanding has been reinforced by the lessons learned from the accident at Fukushima Dai-ichi. This sub-section describes the design considerations relative to the HCVS operation and monitoring.

By nature, the ELAP creates a need to operate the vent manually (either locally or from remote stations) and the design concepts espoused in this document protect that operational capability. Due to the multiple functions provided by the vent path, a single set of passive features (e.g., Rupture Diaphragms) cannot achieve all of the operational functions, therefore operator actions are required. The challenges found in operating the vents at Fukushima have been addressed by this guidance as have the required actions to complete multiple functions (e.g. FLEX heat removal venting, normal plant venting, intermittent venting for source term control in severe accidents, post severe accident venting for combustible gas control). Based on this, the design elements proposed by this guidance (as listed below) do not require specific new requirements to minimize operator actions to address the ability to operate vents as required for ELAP and severe accident conditions.

Comment [N41]: Is this intended to preclude some "automatic" vent valve control system?

Comment [N42]: Where does this guidance provide for rupture disk use in the system design? There is agreement that a single vent path with a rupture disk may not be optimal, but in a parallel branch path it would appear to allow near elimination of valve failed shut or/operator not opening the vent to limit pressure near design values.

Comment [N43]: Delete, it is not in scope of order EA-13-109. Is this a filtration strategy?

4.2.1 Protection from Inadvertent Actuation

The design of the HCVS should incorporate features, such as control panel key-locked switches, locking systems, rupture discs, or administrative controls to prevent the inadvertent use of the vent valves.

Comment [N44]: How about just "...inadvertent opening of the vent…" Having a rupture disk with burst pressure at or probably somewhat above containment design pressure could allow the valve(s) in series to be normally open.

a. The system should be designed to preclude inadvertent actuation of the HCVS due to any single active failure.

b. The design should consider general guidelines such as single point vulnerability and spurious operations of any plant installed equipment associated with HCVS.

c. Use of Administrative controls on energizing the HCVS controls can also be a part of the acceptable plan to minimize impact on Current Licensing Basis (CLB) controls.

Order Reference: 1.2.7 - The HCVS shall include means to prevent inadvertent actuation.

4.2.1.1 One or more of the following criteria are acceptable approaches for inadvertent actuation features of the HCVS.

4.2.1.1.1 Rupture disc in flowpath

4.2.1.1.2 Key lock for valve switches

4.2.1.1.3 Administrative Controls for energizing components/controls

4.2.1.1.4 Interface with Technical Specification Components (such as current primary containment isolation valve (PCIV) controls).

4.2.1.2 Meeting design features and the above criteria will show compliance with separation of controls from CLB equipment and methods to demonstrate reasonable prevention of inadvertent actuation of the system.

4.2.1.3 Prevention of inadvertent actuation, while important for all plants, is essential for plants relying on containment accident pressure (CAP) to provide adequate net positive suction head to the emergency core cooling system (ECCS) pumps. Plants that rely on CAP should have an evaluation that specifically addresses the design considerations for minimizing inadvertent actuation interaction. This evaluation can include design features and administrative controls.

4.2.2 Required HCVS Controls {Primary Control and Monitoring Location}

The preferred location for remote operation and control of the HCVS is from the main control room. However, alternate locations to the control room are also acceptable.

Order Reference: 1.2.4 - The HCVS shall 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.

Order Reference: 1.2.8 - The HCVS shall include means to monitor the status of the vent system (e.g., valve position indication) from the control panel required by 1.2.4. The monitoring system shall be designed for sustained operation during an extended loss of AC power.

4.2.2.1 The control location should take into consideration the following:

4.2.2.1.1 The ability to open/close the valves multiple times during the event, i.e., sustained operations.

4.2.2.1.1.1 Licensees should determine the number of open/close cycles necessary during the first 24 hours of operation and provide supporting basis consistent with the plant-specific containment venting strategy.

4.2.2.1.1.2 Sustained operational requirements may continue beyond the capacity of the installed HCVS system motive force (air/nitrogen) make-up, power supply changes or both, i.e., beyond the first 24 hours.

4.2.2.1.1.3 Sustained operations provisions should continue until 7 days or until an alternative method of containment heat removal is put in place by using installed or portable equipment (e.g., a means of shutdown cooling aligned directly to the RPV, drywell or suppression pool).

4.2.2.1.1.4 During Sustained Operation, the containment barrier is manually controlled by the plant staff/ containment heat removal operations (either by containment venting or alternative measures) to prevent further fuel damage. This manual containment heat removal allows RPV injection by use of RCIC or external water supplies (reduced containment pressure may be required).

4.2.2.1.1.5 Severe accident venting to remove containment heat should be stopped as soon as possible to fully restore the containment function so that the containment source term barrier is available. Thus allowing design barriers to be maintained for potential degrading core conditions.

4.2.2.1.2 The temperature and radiological conditions that operating personnel may encounter both in transit and locally at the controls.

4.2.2.1.2.1 This should include the impacts on initial release of post severe accident source term and impacts of vent piping related heat up in areas with little or no ventilation on the controls/controlling station. Alternatives may be used, such as providing features to facilitate manual operation of valves from remote locations or relocating/reorienting containment vent valves.

4.2.2.1.3 Availability of permanently installed HCVS equipment, including any connections required to supplement the HCVS operation during an ELAP (e.g., electric power, N_2/air) consistent with the staff's guidance in JLD-ISG-2012-01 for Order EA-12-049.

4.2.2.1.4 The controls/control location design should preclude the need for operators to move temporary ladders or operate from atop scaffolding to access the HCVS valves or remote operating locations.

4.2.2.1.5 HCVS valve position indication should be available at the primary controlling location.

Comment [N45]: Needs further clarification. Does this mean sustained operations will be a minimum of seven days even if an alternate method of containment heat removal is put in place before then? As discussed in the meetings, clarify that alternate method of heat removal should not rely on the HCVS. For as long as releases and cross contamination due to interface leakages are a concern, the operation of HCVS will still be under sustained operations.

Comment [N46]: Does this indicate that any mention of automatic vent valve cycling/throttling for containment pressure control made during previous meetings is no longer being contemplated?

Comment [N47]: What would be the conditions for this determination? Would these recognize the potential for gross leakage from over-heated penetrations if primary containment pressure is maintained elevated.

Comment [N48]: This is pre core-melt. Address severe accident conditions. That ISG was for that order and that order has been superseded, should deleted the "… consistent with…" portion.

4.2.2.1.6 HCVS valve position indicators should be capable of operating under the temperature/radiation conditions existing at the valve locations.

4.2.2.1.7 HCVS valve position indicators and indications should be powered from sources that will be available during the appropriate mission time of the HCVS system.

4.2.2.1.8 The HCVS system should include indications for the Containment Pressure and Wetwell level for determination of vent operation. These indications may be either at the controlling location for the HCVS or at another location with communication to the HCVS controlling location.

4.2.2.2 The following criteria are acceptable approaches for HCVS Primary Controls and Monitoring location:

4.2.2.2.1 Requirement for sustained operation

4.2.2.2.2 Requirements for assessment on temperature and radiological condition

4.2.2.2.3 Reasonable protection of required equipment

4.2.2.2.4 Required design criteria for indications

4.2.2.3 Meeting design features and the above criteria will show compliance with Primary Controls and Monitoring location requirements (including instrumentation).

4.2.3 Alternate Remote Operation {Alternate/Local Valve Control Location}

During an ELAP, manual operation/action from alternate control locations may become necessary to operate the HCVS. As demonstrated during the Fukushima event, the valves lost motive force including electric power and pneumatic air supply to the valve operators, and control power to solenoid valves.

a. If direct access and local operation of the valves is not feasible due to temperature or radiological hazards, licensees should include design features to facilitate remote manual operation of the HCVS valves. This could include means such as reach rods, chain links, hand wheels, alternative control locations, and portable equipment to provide motive force as needed (e.g., air/N_2 bottles, diesel powered compressors, and DC batteries).

Order Reference: 1.2.5 - The HCVS shall, in addition to the requirements of 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.

Comment [N49]: Is this during the "sustained operations", 24 hours or some other time frame?

Comment [N50]: Primary?

Comment [N51]: Primary?

Comment [N52]: This is after the installed equipment endurance period of 24 hours?

4.2.3.1 The HCVS design should consider the following elements to facilitate remote manual operation:

4.2.3.1.1 An assessment of temperature and radiological conditions that operating personnel may encounter both in transit and locally at the local or alternate control location.

4.2.3.1.1.1 Include radiological conditions associated with post severe accident source terms and impacts of vent piping related heat up in areas with little or no ventilation on the local or alternate control location.

4.2.3.1.1.2 Alternatives such as providing features to facilitate manual operation of valves from remote locations or relocating/reorienting the valves may be used.

4.2.3.1.1.3 Consider that local-manual access to PCIVs for an ELAP event may not be feasible due to high temperature or radiation levels in the Reactor Building since they will be located near a containment penetration.

4.2.3.1.1.4 Reach rods and chain-operators may not be credible except when located at a short distance from the valve and with limited turns which would not be the case for most of these valves.

Comment [N53]: This statement appears to be either primarily editorial or dismissive of potential mechanical linkage operation. This would not be NRC endorsed guidance verbiage.

4.2.3.1.1.5 The connections between the valves and portable equipment should be designed for quick deployment.

4.2.3.1.1.6 If a portable motive force (e.g., air or N_2 bottles, DC power supplies) is used in the design strategy, licensees should provide reasonable protection of that equipment consistent with the staff's guidance in JLD-ISG-2012-01 for Order EA-12-049.

Comment [N54]: This is for after the initial 24 hours? Also, referenced guidance is for prevention of core melt. Address severe accident conditions.

4.2.3.1.1.7 The Local Controls/Alternate Valve Control Location design should preclude the need for operators to move temporary ladders or operate from atop scaffolding to access the HCVS valves or remote operating locations.

Comment [N55]: As opposed to permanent platforms?

4.2.3.1.1.8 The HCVS system should include indications for the Containment Pressure and Wetwell level for determination of vent operation. These indications may be either at the local

Comment [N56]: Vented fluid temperature also?

controls/alternate control location for the HCVS systems or at another location with communication to the Local Controls/Alternate Valve Control Location.

4.2.3.2 The following criteria are acceptable approaches for HCVS Local Controls/Alternate Valve Control Location:

4.2.3.2.1 Supply an alternate method of HCVS valve operation

4.2.3.2.2 Assessment on temperature and radiological condition

4.2.3.2.3 Reasonable protection of required equipment

4.2.3.2.4 Required design criteria for indications

4.2.3.2.5 Criteria for manual opening of AOVs

4.2.3.2.6 Criteria for operation of MOVs

4.2.3.3 Meeting design features and the above criteria will show compliance with local controls/alternate control location requirements (including instrumentation).

4.2.4 Vent Monitoring

Plant operators must be able to readily monitor the radiological conditions that exist during venting operations of the HCVS at all times.

Order Reference: 1.2.9 - The HCVS shall include a means to monitor the effluent discharge for radioactivity that may be released from operation of the HCVS. The monitoring system shall provide indication from the control panel required by 1.2.4 and shall be designed for sustained operation during an extended loss of AC power.

Comment [N57]: Industry should consider an acceptable standard range of the monitor for all the Mark I and Mark II fleet. Is there any intent to include such information in Appendix G?

4.2.4.1 The HCVS design should provide a means to allow plant operators to readily determine, or have knowledge of, the following system parameters:

4.2.4.1.1 HCVS vent valves position (open or closed).

4.2.4.1.2 HCVS vent pipe radiation levels. The range of the instrument should be consistent with the dose rates anticipated during severe accident venting.

4.2.4.1.3 Other important information includes the status of supporting systems, such as availability of electrical power and pneumatic supply pressure.

4.2.4.1.3.1 Monitoring by means of permanently installed gauges or meters that are at, or nearby, the HCVS control panel or in the Control Room with communication to the HCVS control panel is acceptable.

4.2.4.1.3.2 Alternative approaches for system status instrumentation may be considered with appropriate ~~provided a~~ justification provided for alternative approaches ~~must be provided~~.

4.2.4.1.4 The HCVS system should include indications for the Containment Pressure and Wetwell level for determination of vent operation. These indications may be either at the local controls/alternate control location for the HCVS systems or at another location with communication to the Primary Controls location or local controls/alternate control location.

4.2.4.2 The means to monitor system status should support sustained operations during an ELAP, and be designed to operate under ~~potentially~~ environmental conditions that would be expected following a loss of containment heat removal capability and an ELAP. "Sustained operations" may include the use of portable equipment to provide an alternate source of power to components used to monitor HCVS status.

Comment [N58]: After 24 hours?

Note: Additional instrumentation required to comply with Order EA-12-049 as discussed in NEI 12-06 may be useful in support of HCVS operation, but are not required for HCVS functionality.

4.2.4.3 Instrument reliability should be demonstrated via an appropriate combination of design, analyses, operating experience, and/or testing of channel components for the conditions described in Section 2 of this guide.

4.2.4.4 The following criteria are acceptable approaches for HCVS monitoring:

4.2.4.4.1 Need to monitor HCVS vent pipe conditions including radiological releases, vent pipe pressure and temperature.

4.2.4.4.2 Sustained operation of HCVS vent pipe condition instrumentation and other required indications during an ELAP condition (limiting analysis).

4.2.4.4.3 Requirements for assessment of radiological, temperature and pressure conditions in the area of HCVS monitoring instruments.

4.2.4.5 Meeting design features and the above criteria will show compliance with HCVS monitoring.

4.2.5 Operational Hazards

Order Reference: 1.1.2 - The HCVS shall be designed to minimize plant operators' exposure to occupational hazards, such as extreme heat stress, while operating the HCVS system.

Order Reference: 1.1.3 - The HCVS shall also be designed to account for radiological conditions that would impede personnel actions needed for event response.

4.2.5.1 HCVS controls should be located in areas where sustained operation is possible accounting for expected temperatures and radiological conditions in the HCVS vent pipe and attached components without extreme heat stress or radiological over exposure to the operators.

4.2.5.1.1 HCVS operation must be possible without placing the operators in dose fields above those allowed by the ERO guidance to conduct local equipment operation.

4.2.5.1.2 HCVS operating locations (Primary/Alternate) must account for the expected lack of ventilation that is encountered during an ELAP event.

4.2.5.1.3 HCVS operating locations should not place the operators in areas above the safe entry points in the applicable plant safety manual/guidance.

4.2.5.1.4 HCVS controls should be located in areas where sustained operation is possible accounting for radiological conditions in the HCVS vent pipe and attached components within allowed doses per the ERO guidance to the operators for non-heroic actions. These conditions should include estimation of the impact during an ELAP event and following core damage required vent operations.

4.2.5.1.5 The HCVS vent pipe routing and shielding must be considered for other actions required of the plant staff/ERO during the event should venting be required during severe accident conditions. Guidance for the allowable dose fields/dose during required actions with the source term in the HCVS vent pipe would be the limits prescribed in the ERO guidance.

Note: Any deviation from the above can be considered provided justification is submitted.

Comment [N59]: Alternatively, additional shielding may provide acceptable radiation levels for operator access. 4.2.5.1.5 hints at this for "other actions".

4.2.5.2 The following criteria are acceptable approaches for HCVS operational hazards at local controls/primary and alternate control locations:

4.2.5.2.1 Temperature conditions at the HCVS proposed operating stations meet plant safety manual/guidance or justification is provided to the Staff.

4.2.5.2.2 Radiological conditions at the HCVS proposed operating stations meets ERO allowable dose guidance or justification is provided.

4.2.5.2.3 Other plant actions required by the plant staff/ERO should account for the expected radiological conditions caused by HCVS vent pipe routing with severe accident source term release through the HCVS vent pipe. The expected limits imposed on the dose/dose field from the ERO guidance should be used for these actions.

4.2.5.3 Meeting design features and the above criteria will show compliance with HCVS operational hazards at Primary Controls and Local/Alternate Valve Control Locations.

4.2.6 Designed to minimize Operator Actions

HCVS system should be designed to maximize the probability of successful operator action to operate vents when required.

Order Reference: 1.1.1 - The HCVS shall be designed to minimize the reliance on operator actions.

Comment [N60]: One consideration would be a parallel branch line with rupture disk and open valve(s).

4.2.6.1 Design features consistent with this approach include:

4.2.6.1.1 Environmental considerations

4.2.6.1.1.1 Heat stress impact on ability to vent

4.2.6.1.1.2 Radiological condition impact on ability to vent

4.2.6.1.2 Sustained operational capability

4.2.6.1.2.1 Independent 24 hour electrical and pneumatic supplies.

4.2.6.1.2.2 The system will be capable of multiple valve cycles during the first 24 hour period without the need to recharge pneumatic or electrical power supplies.

4.2.6.1.3 Ease of vent valve operation

4.2.6.1.3.1 Readily accessible under all operational conditions (e.g., accessible location without need for ladders or scaffolds)

4.2.6.1.3.2 Operation achievable at a localized location.

4.2.6.1.3.3 Operation does not require the use of jumpers or lifted leads to defeat valve interlocks.

4.2.6.1.3.4 System comprised of installed equipment. No need for system or component disassembly/reassembly.

4.2.6.2 The following criteria are acceptable approaches for HCVS minimize operator actions that could prevent vent operations when required:

4.2.6.2.1 Compliance with other sections of this guidance as listed above.

4.2.6.3 Meeting design features and the above criteria will show compliance with HCVS to minimize operator actions that could prevent vent operations when required.

5. PROGRAMMATIC CONTROLS

5.1. Environmental Conditions

The HVCS is required to be capable of functioning during severe accidents in which the containment function is not compromised by the severe accident conditions. The HCVS equipment is designed to provide reasonable assurance of operation in the severe accident environment for which they are intended to function and over the time span for which they are needed. However, the environmental requirements of 10CFR50.49 are design basis regulatory requirements and as such are not applicable under severe accident conditions.

Order Reference: 1.2.10 – The HCVS shall be designed consistent with containment pressures and temperatures during severe accident conditions as well as dynamic loading resulting from system actuation. The design is not required to exceed the current capability of the limiting containment components.

Comment [N61]: However, being the "weakest link" or being less capable than the limiting containment component would be considered lacking sufficient reliability. Are the subsequently provided values of temperature and pressure established to ensure this is the case with all affected reactor containments, or does each licensee have to confirm this with identification of the limiting containment component(s). Also, see staff's comments elsewhere on this matter of "limiting containment components."

5.1.1. The resultant design conditions for the HCVS equipment to provide reasonable protection to assure functionality may be different for the wetwell vent and/or the drywell vent, thus the following environmental conditions should be considered in the design of the system:

5.1.1.1. The limiting wetwell conditions are assumed to be 350°F and 80 psig based on the saturation temperature at the drywell failure pressure.

5.1.1.2. The drywell conditions are assumed to be 545°F and 80 psig corresponding to the temperature and pressure at which the drywell head may exhibit some leakage. Although some range of temperatures above this may be encountered due to stratification in areas in the drywell, the HCVS equipment should be designed using a temperature of 545°F consistent with the boundary conditions as detailed in Section 2 of this document.

Comment [N62]: NRC staff has not taken a position on whether 545 degF is the appropriate generic, default or bounding value.

5.1.1.3. Drywell radiological conditions should be consistent with the conditions assumed in the plant's current licensing basis (CLB) for a major accident. (i.e., the most severe design basis accident during or following which the equipment is required to remain functional, including the radiation resulting from recirculating fluids for equipment located near the recirculating lines and including dose-rate effects.)

Comment [N63]: If this is what would be present or would be expected to bound the radiation conditions should the core relocate to the drywell floor. Is this a statement of analytical results?How would the DBA radiological condition in the drywell differ from that of a severe accident with ex-vessel core debris?

5.1.1.3.1. Such accidents have generally been assumed to result in substantial meltdown of the core with subsequent release of appreciable quantities of fission products (e.g., Technical Information Document (TID) 14844, "Calculation of Distance Factors for Power and Test Reactor Sites (March 1962)," or NUREG-1465, "Accident Source Terms for Light-Water Nuclear Power Plants" consistent with the current design basis of the plant.)

5.1.1.3.2. The evaluation of HCVS functionality should consider the potential conditions resulting from accidental events, whether postulated, hypothesized or otherwise identified, that do not exceed the conditions resulting from any credible accident as identified in the plant's CLB.

5.1.1.4. If the drywell vent and wetwell vent are interconnected, interaction between the two vent flowpaths should be considered although only one flowpath is required to be operated at any one time.

5.1.1.5. Environmental effects of the areas traversed by the system should be considered in both standby and operating conditions.

5.1.1.6. Tornado and wind loading and missile impacts are required to be considered for portions of the HCVS.

5.1.1.6.1. Current design of the structure is acceptable regarding wind and missile protection for portions of the HCVS enclosed within a seismic category 1 (or equivalent) building/enclosure or through the plants existing elevated release point (e.g., meteorological stack)

5.1.1.6.2. Reasonable protection evaluations per the guidance in NEI 12-06 as endorsed by JLD-ISG-12-001 for Order EA-12-049 should be performed for portions of the HCVS not covered in 5.1.1.6.1 above.

5.1.1.7. The system should be designed to provide reasonable assurance of operation for up to 7 days consistent with the sustained operation definition.

5.2. Seismic and External Hazard Conditions

Order Reference: 2.1 – The HCVS vent path up to and including the second containment isolation barrier shall be designed consistent with the design basis of the plant. These items include piping, piping supports, containment isolation valves, containment isolation valve actuators and containment isolation valve position indication components.

Order Reference: 2.2 – All other HCVS components shall 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.

5.2.1. HCVS components should be designed, as a minimum, to meet the seismic design requirements of the plant.

5.2.2. Components that are not required to be seismically designed by the design basis of the plant should be designed for reliable and rugged performance that is capable of ensuring HCVS functionality following a seismic event.

5.2.3. The components external to a seismic category 1 (or equivalent building or enclosure should be designed to meet the external hazards that screen in for the plant as defined in guidance NEI 12-06 as endorsed by JLD-ISG-12-001 for Order EA-12-049.

5.3. Quality Requirements

Order Reference: 2.1 – The HCVS vent path up to and including the second containment isolation barrier shall be designed consistent with the design basis of the plant. These items include piping, piping supports, containment isolation valves, containment isolation valve actuators and containment isolation valve position indication components.

Order Reference: 2.2 – All other HCVS components shall 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.

5.3.1. HCVS components should, as minimum, meet the quality design requirements of the plants ensuring HCVS functionality.

Comment [N64]: Is this already something established and agreed upon elsewhere? This is too broad a statement. Needs clarification as to which portions of the vent are under Appendix B and which are not.

5.4. Maintenance Requirements

Order Reference: 1.2.13 – The HCVS shall include features and provision for the operation, testing, inspection and maintenance adequate to ensure that reliable function and capability are maintained.

5.4.1. HCVS equipment should be initially tested or other reasonable means used to verify performance conforms to the design and operational requirements.

5.4.2. Validation of source manufacturer quality is not required.

5.4.3. The HCVS maintenance program should ensure that the FLEX equipment reliability is being achieved. Standard industry templates (e.g., EPRI) and associated bases will be developed to define specific maintenance and testing

5.4.3.1. Periodic testing and frequency should be determined based on equipment type and expected use (further details are provided in Section 6 of this document).

5.4.3.2. Testing should be done to verify design requirements and/or basis. The basis should be documented and deviations from vendor recommendations and applicable standards should be justified.

5.4.3.3. Preventive maintenance should be determined based on equipment type and expected use. The basis should be documented and deviations from vendor recommendations and applicable standards should be justified

5.4.3.4. Existing work control processes may be used to control maintenance and testing

5.4.4. HCVS permanent installed equipment should be maintained in a manner that is consistent with assuring that it performs its function when required.

5.4.4.1. HCVS permanently installed equipment should be subject to maintenance and testing guidance provided in INPO AP 913, Equipment Reliability Process, to verify proper function.

Comment [N65]: Does this specifically speak to severe accident service equipment or is it assumed adequate/appropriate.

5.4.5. HCVS non-installed equipment should be stored and maintained in a manner that is consistent with assuring that it does not degrade over long periods of storage and that it is accessible for periodic maintenance and testing.

OPERATIONAL CONSIDERATIONS

6.1 OPERATOR ACTIONS

During the extended loss of AC power condition at the Fukushima Dai-ichi units, operators faced many challenges while attempting to restore adequate core cooling in addition to complications associated with controlling containment pressure via the containment venting system. The difficulties faced by the operators related to operation of the containment venting system included the location of their vent valves, ambient temperatures and radiological conditions, loss of all alternating current electrical power, loss of motive force to open the vent valves, and exhausting DC battery power. The use of a hardened containment vent provides an important method of containment heat removal which can become necessary for an ELAP/loss of UHS event. Indirectly, an elevated containment pressure may prevent the injection from a low head water supply to the RPV. Operator actions are a vital part of normal and off-normal plant activities and are expected to play an important role in mitigation of beyond design basis external events. It is fully recognized that operator actions will be needed to implement the EA-13-109 severe accident capable HCVS; however, the licensees should consider design features for the system that will minimize the need and reliance on operator actions to the extent possible during a variety of plant conditions, as further discussed in this guideline.

The HCVS should be designed to be operated from a control panel located in the main control room or a remote but readily accessible location. The HCVS should be designed to be fully functional and self-sufficient with permanently installed equipment in the plant, without the need for portable equipment or connecting thereto, until such time that on-site or off-site personnel and portable equipment become available. At least one method of operation of the HCVS should be capable of operating with permanently installed equipment for at least 24 hours during the extended loss of AC power, unless a shorter period is justified by the licensee. The system should be deigned to function in this mode with permanently installed equipment providing electrical power (e.g., DC power batteries) and valve motive force (e.g., N_2/air cylinders). The HCVS operation in this mode depends on a variety of conditions, such as the cause for the extended loss of AC power (e.g., seismic event, flood, tornado, high winds), severity of the event, and time required for additional help to reach the plant, move portable equipment into place, and make connections to the HCVS. The system should be designed to function in this mode for a minimum duration of 24 hours with no operator actions required or credited to replenish electrical power and pneumatic supplies. Operator action is expected to perform system alignment and monitoring functions as needed for event mitigation. Durations of less than 24 hours will be considered if justified by adequate supporting information from the licensee. To ensure continued operation of the HCVS beyond 24 hours, licensees may credit manual actions, such as moving portable equipment to supplement electrical power and valve motive power sources.

For justifying periods less than 24 hours, the licensee should consider the number and complexity of actions and the cumulative demand on personnel resources that are needed to maintain hardened vent functionality (e.g., installation of portable equipment during the first 24 hours to restore power to the HCVS controls and/or instrumentation) as a result of design limitations. The use of supplemental portable power sources may be acceptable if the

Comment [N66]: Not acceptable. The HCVS must be capable of operating in the first 24 hours with permanently installed equipment by operator action at a control panel (i.e. switches, push buttons, etc.). Shorter than 24 hours in this mode is not allowed.

Comment [N67]: Clarify? Does it mean that operator actions are required for system alignment. The system shall align itself into the venting mode by simple operator actions at a control panel.

Comment [N68]: Delete. Less than 24 hours not acceptable.

supplemental power was readily available, could be quickly and easily moved into place, and installed through the use of pre-engineered quick disconnects, and the necessary human actions were identified along with the time needed to complete those actions. Conversely, supplemental power sources located in an unattended warehouse that require a qualified electrician to temporarily wire into the panel would not be considered acceptable because its installation requires a series of complex, time-consuming actions in order to achieve a successful outcome. There are similar examples that could apply to mechanical systems, such as pneumatic/compressed air systems.

Comment [N69]: Delete any reference to less than 24 hours. However, retain and include additional requirements for supplemental connection/design of pre-engineered disconnects for electrical power and mechanical systems (compressed air, etc.) for operation beyond 24 hours.

6.1.1 Feasibility and Accessibility

During an extended loss of AC power, the drywell, wetwell (torus or suppression pool), and nearby areas in the plant where HCVS components are expected to be located will likely experience elevated temperatures due to inadequate containment cooling combined with loss of normal and emergency building ventilation systems. In addition, installed normal and emergency lighting in the plant may not be available. Licensees should take into consideration plant conditions expected to be experienced during applicable beyond design basis external events when locating valves, instrument air supplies, and other components that will be required to safely operate the HCVS system. Components required for manual operation should be placed in areas that are readily accessible to plant operators, and not require additional actions, such as the installation of ladders or temporary scaffolding, to operate the system.

The design strategy should evaluate potential plant conditions and use acquired knowledge of these areas to provide input to system operating procedures, training, the choice of protective clothing, required tools and equipment, and portable lighting. The evaluation should include considerations such as, how temperatures would elevate due to extended loss of AC power conditions and the lighting that would be available following beyond design basis external events.

The design of the HCVS should account for radiological conditions resulting from the beyond design basis external event. During the Fukushima event, personnel actions to manually operate the containment vent valves were impeded due to the location of the valves in the torus rooms. The HCVS should be designed to be placed in operation by operator actions at a control panel, located in the main control room or in a remote location. The design of the severe accident capable HCVS system will take into account the radiological conditions that may be encountered during system operation. The use of shielding and locating components having significant source term away from system control stations where the system will be operated are the primary means available to control operational dose. Additional means of minimizing potential radiological dose to the operators may include, but are not limited to:

- Simplification of operator actions needed to initiate, control and isolate the system including replenishment of electrical power and pneumatics during the sustained operational period
- Minimizing the time operators need to spend at the vent controls during system operation during severe accident conditions
- Minimizing the number of operators needed to operate and maintain the system

functional during severe accident conditions

- Developing a strategy to rotate operators through the various venting actions to minimize the dose received by any one operator

In response to Generic Letter (GL) 89-16, a number of facilities with Mark I containments installed vent valves in the torus room, near the drywell, or both. Licensees may continue to use these venting locations or select new locations, provided that the requirements of this guidance document are satisfied. The HCVS in conjunction with active core debris cooling improves the chances of mitigating a core damage accident by removing heat from containment and lowering containment pressure. Leakage from the HCVS within the plant and at the location of the external release could impact the event response from on-site operators and off-site help arriving at the plant. An adequate strategy to minimize radiological consequences that could impede personnel actions should include the following:

Comment [N70]: Not in the scope of the current severe accident capable vent order. They will be determined as part of the rule making and Phase 2 portion of the order.

1. Provide permanent radiation shielding where necessary to facilitate personnel access to valve controls that allow manual operation of the valves at a remote manual location. Other alternatives to facilitate personnel access besides radiation shielding can be utilized, such as:

   - providing features to facilitate manual operation of valves from remote locations, as discussed further in this guidance
   - locating the vent valves in areas that are significantly less challenging to operator access/actions

2. In accordance with Requirement 1.2.10, the HCVS should be designed for pressures that are consistent with the higher of the primary containment design pressure <u>and</u> the primary containment pressure limit (PCPL), as well as including dynamic loading resulting from system actuation and hydrogen deflagration or detonation if the gases passing through the system cannot be maintained below flammability limits. In addition, the system should minimize leakage. As such, ventilation duct work (i.e., sheet metal) should not be utilized in the design of the HCVS. Licensees should perform appropriate testing, such as hydrostatic or pneumatic testing, to establish the leak-tightness of the HCVS.

Comment [N71]: Also requirement 1.2.11. This discussion should include piping reaction loads from HCVS valve opening and for wetwell HCVS, concurrent hydrodynamic loads from SRV discharges.

3. The HCVS release to outside atmosphere should be at an elevation higher than adjacent power block plant structures. Release through existing plant metrological stacks is considered acceptable, provided the guidance under Requirements 1.2.3 and 1.2.11 are satisfied. If the release from HCVS is through a vent stack different than the plant metrological stack, the elevation of the stack should be higher than the nearest power block building or structure. The routing should be such that radiological conditions resulting from operation of the HCVS would not negatively impact on-site personnel response.

4. The required Operator actions to operate the HCVS under the design conditions required by Order items 1.1.2 and 1.1.3 at the plant specified operating locations would need to be evaluated. The operations should be feasible for the control locations for conducting the operations under the beyond design basis external event conditions. These expected conditions can be obtained from available generic or plant-specific accident analysis. The timing of the operations should be taken into consideration (e.g., operation of the equipment

during the worst source term release is not required if the station could be accessed prior to the release and after the release for control) for this accessibility/feasibility evaluation. Guidance is supplied in Appendix E of this guide for this evaluation. Elements of the evaluations can utilize NUREG 1921/1852 guidance and/or procedural controls.

6.1.2 Procedural Guidance

Procedures to operate, test, and maintain the severe accident capable HCVS should include the following elements:

- HCVS system operation including startup, shutdown and off-normal conditions
- HCVS system standby status verification
- System out of service controls
- location of system components and equipment lineups (may be part of other plant system procedures)
- instrumentation available during ELAP conditions that supports HCVS operation, including that used for detection/confirmation of vessel breach by core melt.
- directions for sustained operation using portable equipment and supplies,
- storage location of portable equipment
- equipment testing and maintenance
- If applicable, the nexus between containment accident pressure (CAP) and ECCS pump net positive suction head during a DBLOCA and how an inadvertent opening of the vent valve could have an adverse impact.

HCVS procedures should be developed and implemented in the same manner as other plant procedures necessary to support the execution of the Emergency Operating Procedures (EOPs) and the severe accident guidelines (SAGs).

HCVS procedures for operation need to be validated for operator feasibility/accessibility and should address the following functional operations:

- With power on normal power sources (no ELAP)
- With backup power and from local manual location/alternate remote location during conditions of ELAP/loss of UHS with no core damage for containment heat removal AND containment pressure control (PCPL). (FLEX)
- With backup power and from local manual location/alternate remote location during conditions of ELAP/loss of UHS with core damage and vessel breach for containment heat removal AND containment pressure control (PCPL). (Severe Accident Capable Vent)

6.1.2.1 Coordination with guidance and procedures

The Licensee should verify that the procedures for HCVS operation are coordinated with other procedures. The following relationships should be evaluated to address this coordination:

- Coordinate EOPs and SAGs with hardened containment vent operation on normal power sources (no ELAP)
- Coordinate EOPs, SAGs and FLEX Support Guidelines (FSGs) with hardened containment vent operation on normal and backup power and from primary and alternate locations during conditions of ELAP/loss of UHS with no core damage. System use is for containment heat removal AND containment pressure control
- Coordinate SAGs with HCVS operation on normal and backup power and from primary and alternate locations during conditions of ELAP/loss of UHS with core damage and vessel breach. System use is for containment heat removal AND containment pressure control (PCPL) with potential for combustible gases.
- Coordinate administrative controls for FLEX and HCVS equipment allowed outage times and compensatory actions

6.1.2.2 Demonstration with other Post Fukushima measures

The Licensee should demonstrate procedures for HCVS operation as follows:

- Hardened containment vent operation on normal power sources (no ELAP) – demonstrate use in simulator drills AND/OR ERO drills.
- Hardened containment vent operation on backup power and from primary or alternate location during conditions of ELAP/loss of UHS with no core damage. System use is for containment heat removal AND containment pressure control – demonstrate by use in simulator drills AND/OR ERO drills during FLEX demonstrations (as required by EA-12-049).
- HCVS operation on backup power and from primary or alternate location during conditions of ELAP/loss of UHS with core damage. System use is for containment heat removal AND containment pressure control with potential for combustible gases – demonstration by use in simulator drills AND/OR ERO drills and may be in conjunction with SAG change.

6.1.3 Training

All personnel expected to operate the HVCS should receive initial and continuing training in the use of plant procedures developed for system operations when either normal or backup power is available and during ELAP/loss of UHS conditions consistent with the plants systematic approach to training. The training should be refreshed on a periodic basis consistent with the procedure control process at the plant site or when procedural related changes occur to the HCVS.

Training should also ensure that specific guidance and procedures that direct HCVS Operation is referenced and used in formulation of the training (e.g., EOPs, FSGs, SAGs,).

6.2 TESTING AND INSPECTION OF HCVS

The HCVS design should provide a means (e.g., drain valves, pressure and temperature gauge connections) to periodically test system components, including exercising (opening and closing) the vent valve(s).

The HCVS outboard of the containment boundary should 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. The testing method can either individually leak test interfacing valves or test the overall leakage of the HCVS volume by conventional leak rate testing methods. The test volume should envelope the HCVS between the outer primary containment isolation barrier and the vent exit from the plant buildings, including the volume up to the interfacing valves. The test pressure should be based on the HCVS design pressure. Methods for testing system boundary leakage should be consistent with the licensee's design basis for these tests (e.g., permissible leakage rates for the interfacing valves should be within the requirements of American Society of Mechanical Engineers Operation and Maintenance of Nuclear Power Plants Code (ASME OM) – 2009, Subsection ISTC – 3630 (e) (2), or later edition of the ASME OM Code.) When testing the HCVS volume, allowed leakage should not exceed the sum of the interfacing valve leakages as determined by the licensee's test program (e.g., ASME OM Code). Allowable leakage through a barrier is to include determination as to the potential consequences of the leaked radioactivity and combustible gasses through that barrier (does it disperse readily, could it accumulate). If all interfacing boundaries are leak tested simultaneously, the entire leakage should be attributed to the most limiting barrier regarding potential adverse consequences.

Licensees should implement the following operation, testing and inspection requirements for the HCVS to ensure reliable operation of the system.

Testing and Inspection Requirements

Description	Frequency
Cycle the HCVS valves and the interfacing system valves not used to maintain containment integrity during operations.	Once per operating cycle
Perform visual inspections and a walkdown of HCVS components.	Once per operating cycle
Test and calibrate the HCVS radiation monitors.	Once per operating cycle
Leak test the HCVS.	(1) Prior to first declaring the system functional; (2) Once every five years thereafter; and, (3) After restoration of any breach of system boundary within the buildings.
Validate the HCVS operating procedures by conducting an open/close test of the HCVS control logic from its control panel and ensuring that all interfacing system valves move to their proper (intended) positions.	Once per every other operating cycle

Comment [JOB172]: This regime would allow for maintenance and restoration of suspect barriers. Wording needed regarding inspection/assessment of any barrier breach for signs of potential inability to meet leakage limits.

6.3 Allowed out of service time for HCVS

The unavailability of equipment and applicable connection that directly performs an HCVS function should be managed such that risk to HCVS capability is minimized. The primary (1.2.4) and alternate (1.2.5) method of HCVS operation will normally be functional in Modes 1, 2 and 3.

1. If the primary or alternate method of HCVS operation is non-functional, the primary or alternate HCVS controls/indications may be out of service for periods of up to 90 days.

2. If the primary and alternate methods of HCVS operation are non-functional, the primary and alternate HCVS controls/indications may be out of service for periods of up to 30 days.

3. If the allowed out of service times described in 1 and/or 2 above are exceeded, then through the plant corrective action program determine:

    a. The cause(s) of the non-functionality,

    b. The actions to be taken and the schedule for restoring the system to functional status and prevent recurrence, and

    c. Initiate action to implement appropriate compensatory actions.

The HCVS system is functional when piping, valves, instrumentation and controls including motive force necessary to support system operation are available. Since the system is designed to allow a primary and alternate means of operation by Order criteria 1.2.4 or 1.2.5, allowing for a longer out of service time with either of the functional capabilities maintained is justified. A shorter length of time when both primary and alternate means of system operation are unavailable is needed to restore system functionality in a timely manner while at the same time allowing for component repair or replacement in a time frame consistent with most high priority maintenance scheduling and repair programs.

Comment [JOB173]: 30 days or less considered high priority?

The system functionality basis is for coping with beyond design basis events and therefore plant shutdown to address non-functional conditions is not warranted. However, such conditions should be addressed by the corrective action program and compensatory actions to address the non-functional condition should be established. These compensatory actions may include alternative containment venting strategies needed to ensure fission product cladding integrity during design basis and beyond design basis events even though the severe accident capability of the vent system is degraded or non-functional.

Examples of non-functional equipment conditions expected to be resolved in a 30 or 90 day timeframe include pneumatic or electrical motive force, instrumentation and controls located outside the primary containment. Examples on non-functional equipment conditions that may require longer out of service times include piping and valve issues that may challenge primary containment operability that will require repair when the primary containment system is not required to be operable.

The applicability for system functional requirements is limited to startup, power operation and hot shutdown conditions when primary containment is required to be operable and containment integrity may be challenged by decay heat generation.