US APPROACH TO ADDRESSING BWR MARK I AND MARK II CONTAINMENT ENHANCEMENTS

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PURPOSE OF BWR CONTAINMENT VENTING

- Provide containment pressure control under adverse conditions (Order 109)
- Maintain Suppression Pool Temperature at a level to keep RCIC functional (FLEX)
- Provide a decay heat removal pathway as a last resort (EPG/SAMG NRC SER Language)
- Provide controlled releases if core damage occurs by use of water/steam scrubbing inside containment (Land Contamination)

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NRC DIRECTIVES FOR BWR VENTING

- **Generic Letter 89-16**
  - Voluntary
  - WW and DW Vent
  - Rupture Disk
  - 18" Piping underground to Main Stack
  - AC Valves and Instruments
- **Extreme Mitigation (10CFR50.54(hh))**
  - Heroic Actions
  - Manual Actions and Valve Actuations
- **EA-12-050 – RHV Order (Rescinded)**
- **EA-13-109 – Severe Accident Capable HCVS**
  - Phase 1 Wetwell Vent
  - Phase 2 Strategy or Drywell Vent

TIER 1 NRC REGULATIONS FOLLOWING FUKUSHIMA ACCIDENT

4.2 Mitigating Strategies for Beyond Design Basis Events

- Develop, implement, and maintain strategies and equipment to mitigate the effects of beyond design basis challenges to core, containment, and spent fuel pool cooling functions

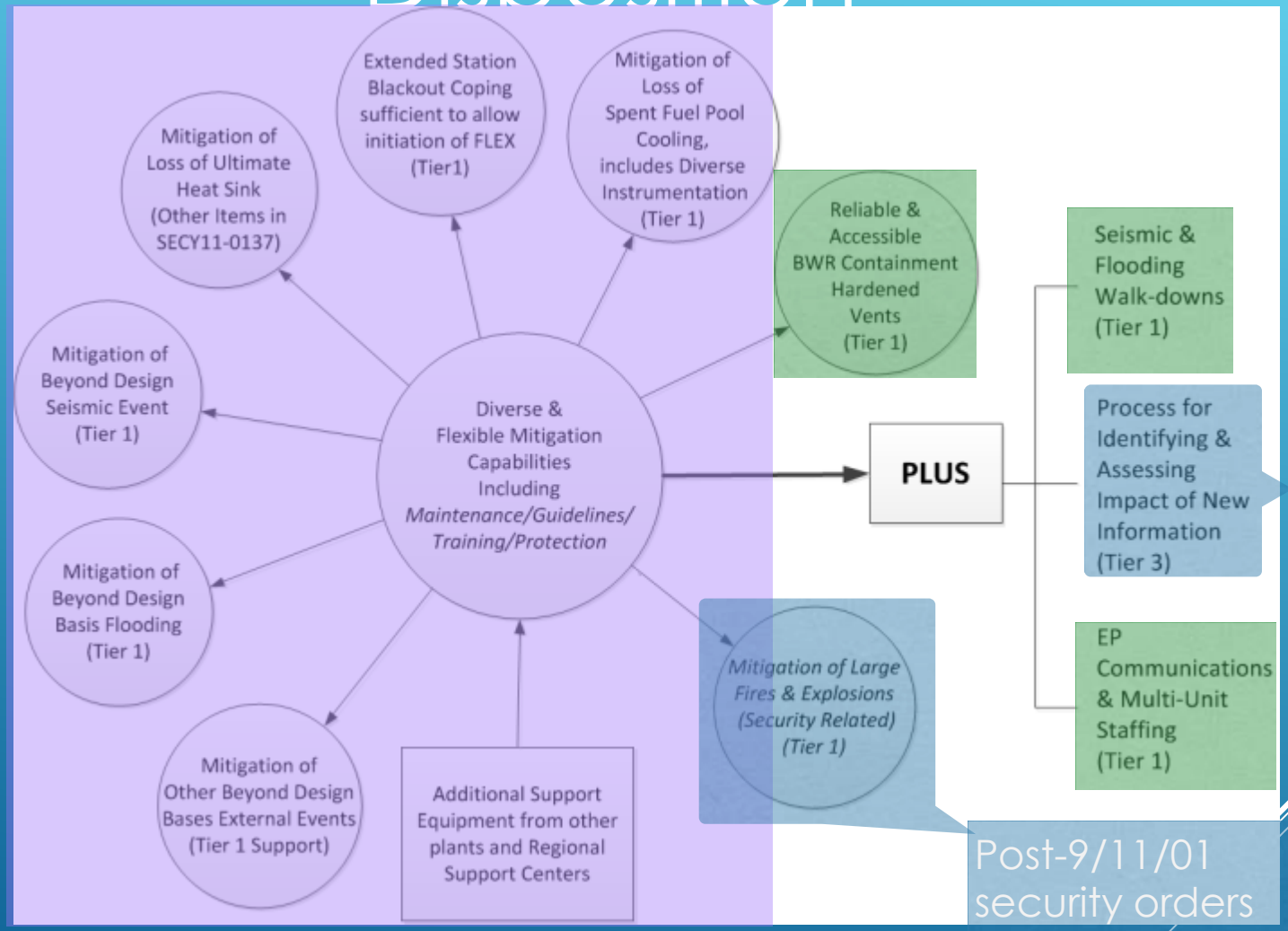
5.1 Reliable Hardened Vents

- Enhanced reliability during prolonged station blackout (SBO) conditions

7.1 Reliable Spent Fuel Pool Instrumentation

- For beyond design basis events instrumentation must support maintaining SFP inventory and adequate prioritization of event mitigation or recovery

Industry FLEX Approach & NRC Disposition



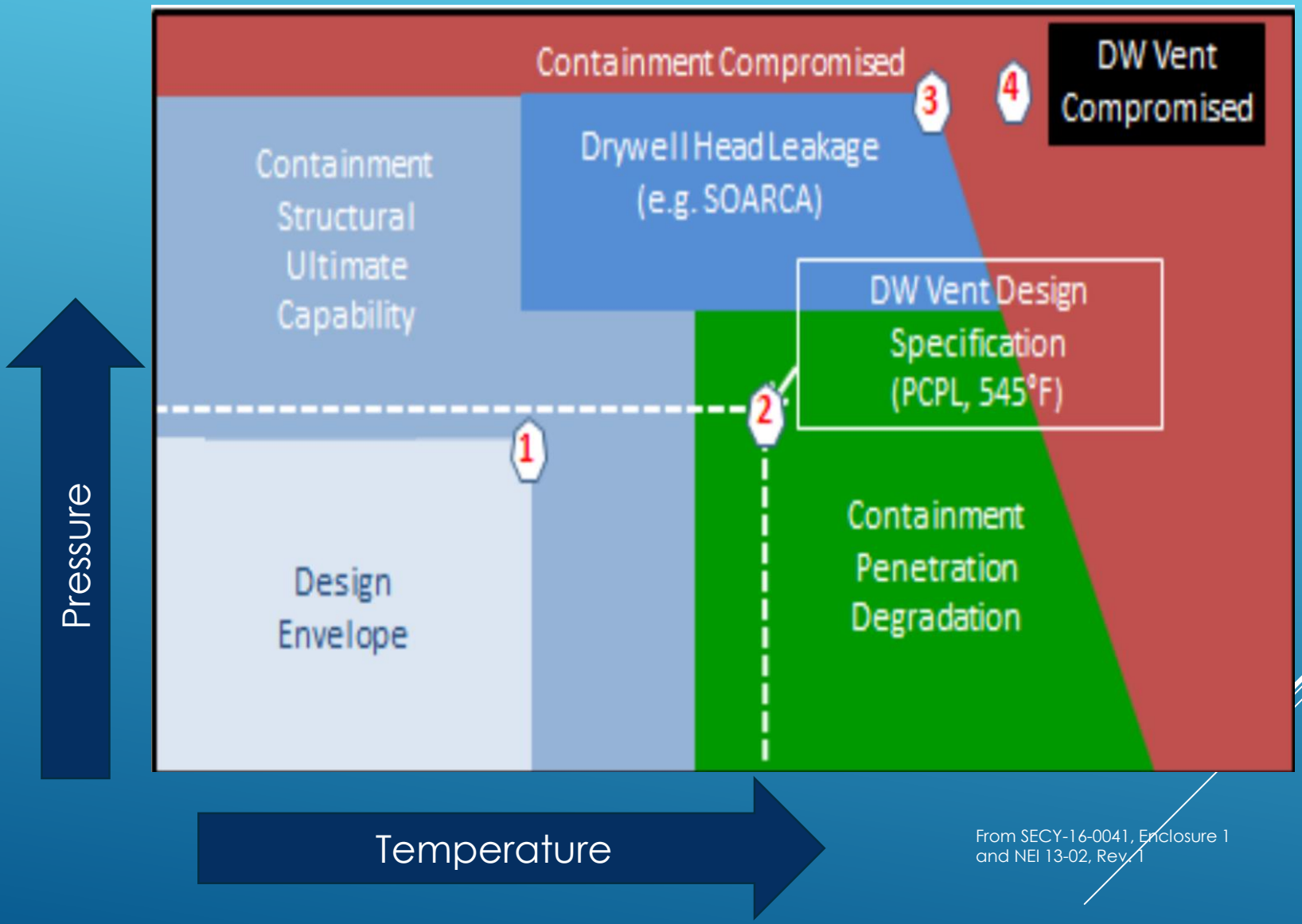
5.1 HARDENED CONTAINMENT VENT SYSTEM (ORDER EA-13-109)

- NRC Issued a Revised Order in June 2013
  - Revision requires vent use to mitigate ELAP event **and** Severe Accidents
- Overall Integrated Plan (OIP) for Revised Order
  - Phase I – Jun 2014
  - Phase II – Dec 2015
- Implementation
  - Phase 1(2 cycles after Phase 1 OIP)
    - Fall 2016 – June 2018
  - Phase 2 (1st start-up after June 2017)
    - Fall 2017 – June 2019

BWR MARK I AND MARK II CONTAINMENT

- US BWR Mark I and Mark II containments:
  - Use typical construction materials which establish margin from design to loss of function
  - Utilize a volume of water inside containment to absorb energy and scrub contaminates
  - Have the ability to maintain pressure limits via venting
  - Have piping connections to feed water to the vessel or containment

CONTAINMENT CAPABILITY



From SECY-16-0041, Enclosure 1 and NEI 13-02, Rev. 1

BWR CONTAINMENT VENTING

GL 89-16
Hardened Vent

Voluntary
Hardened flow path
AC instruments
Manual capability
Heroic Actions

EA-12-049*
FLEX

Anticipatory Venting
Prevent Core Damage
Remote ELAP 0 – 8 hrs
Power, Air, Accessible
Rupture Disc Reduction
Non-Heroic Actions

EA-13-109
Wet Well Vent with SAWA/SAWM

Assume Core Damage
Ex-Vessel Progression
Extended Operation(7d)
Redundant Control
Additional Instruments
Limited Actions <24 hrs
Protect response actions
Hydrogen/CO Control
Water Addition
Manage SAWA to Maintain Wet Well Vent

*NRC Order EA-12-050 proposed enhanced criteria for venting, but superseded by NRC Order EA-13-109

ANTICIPATORY BWR VENTING

- Anticipatory Venting supports extended RCIC Operation for Mitigating Strategies/FLEX
- Preferred choice for Containment/Core Decay heat removal.
  - Maximizes core cooling and containment function reliability
  - Minimizes support systems and operator actions,
  - Utilizes ≈10 times more efficient method of heat transfer
  - Uses installed equipment
- Venting capability will be enhanced with compliance with NRC order EA-13-109 in BWR MK I & MK II

PROCEDURE INTERFACE

- 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.
  - Most severe accident scenarios, which require venting and vent mostly steam, would occur in the preventive phase of the event (in EOP space) where adequate core cooling is maintained.
  - Mitigation would occur in SAMG space.
- 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 Daiichi.

STANDARD DEFINITION OF SEVERE ACCIDENT (ASME/ANS RA-SA-2009)

"An accident that involves extensive core damage and fission product release into the reactor vessel and containment with potential release to the environment."

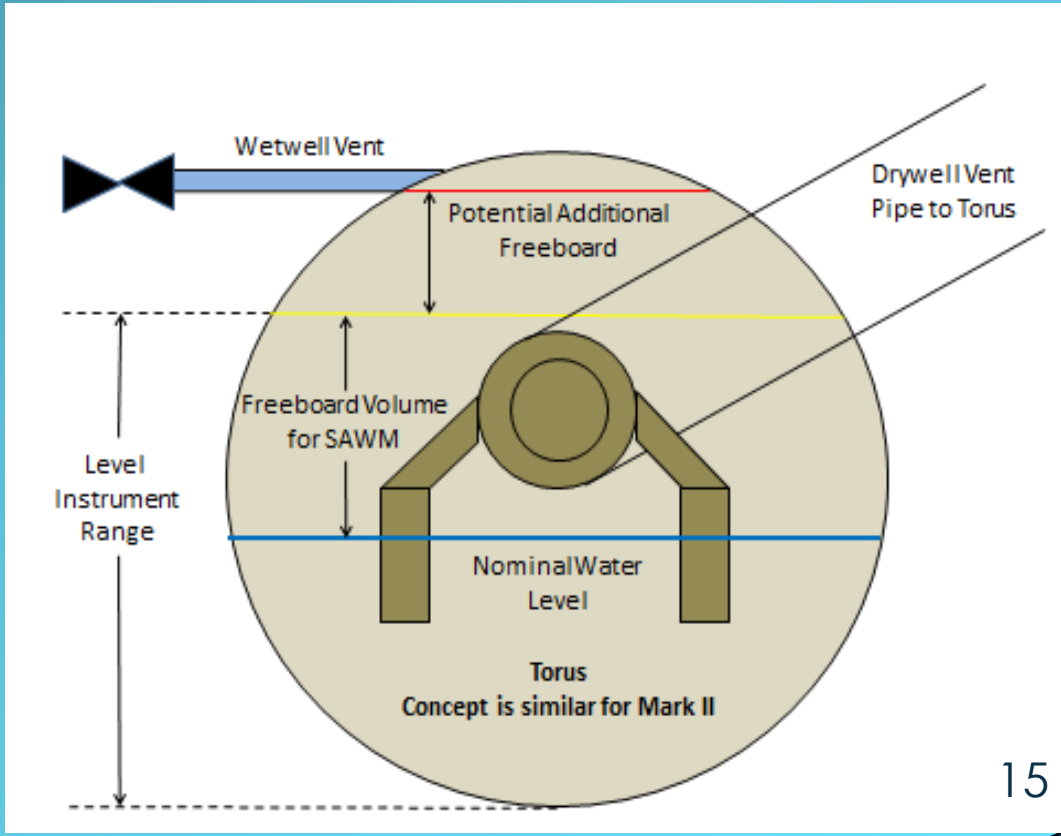
HARDENED CONTAINMENT VENTING SYSTEM (HCVS) GUIDING PRINCIPLES

- The severe accident capable HCVS function is to **help prevent severe accidents from occurring** and to add the capability of helping to mitigate the consequences of a severe accident should one occur.
  - Adding water such that the damaged core is cooled and the wet well vent is preserved, allows scrubbing within the suppression pool and containment to utilize the containment function which offers defense beyond FLEX for protecting from a beyond design basis event that progresses to a severe accident.

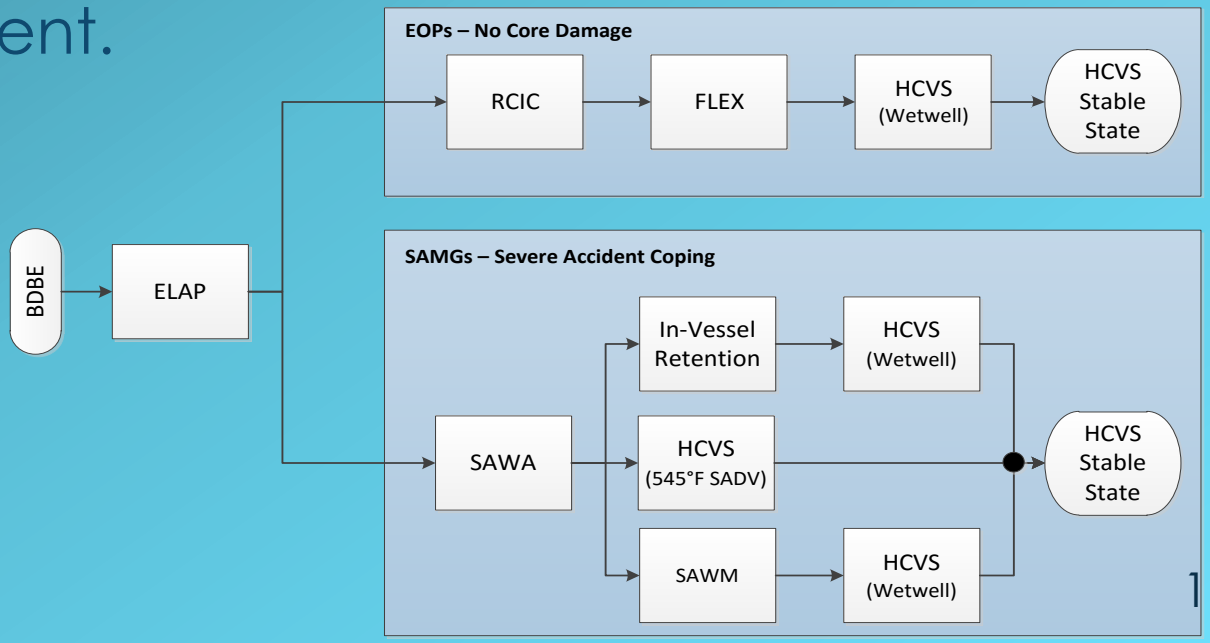
DEFINITIONS FROM NEI 13-02, REV 1

- **Severe Accident Water Addition (SAWA):** "The ability to provide water to the reactor pressure vessel or drywell under Severe Accident conditions. SAWA is predominately hardware related and consists of a water addition path, motive force, instrumentation and control as defined in this guide."
- **Severe Accident Water Management (SAWM):** "A strategy to manage SAWA in such a way that the use of the HCVS wetwell vent is preserved as defined in this guide. SAWM is predominately related to procedures and training."

Freeboard: Freeboard volume is defined as volume available for water addition that will not result in the loss of the wetwell vent path. This volume may be limited by the wetwell level instrument range or the elevation of the wetwell vent line.



Severe Accident Coping ends when containment pressure control using alternate containment heat removal is established. To achieve this objective, the alternate containment heat removal method must have sufficient capacity to remove all of the heat input to the containment so that containment pressure can be managed below PCPL without the use of the containment vent.



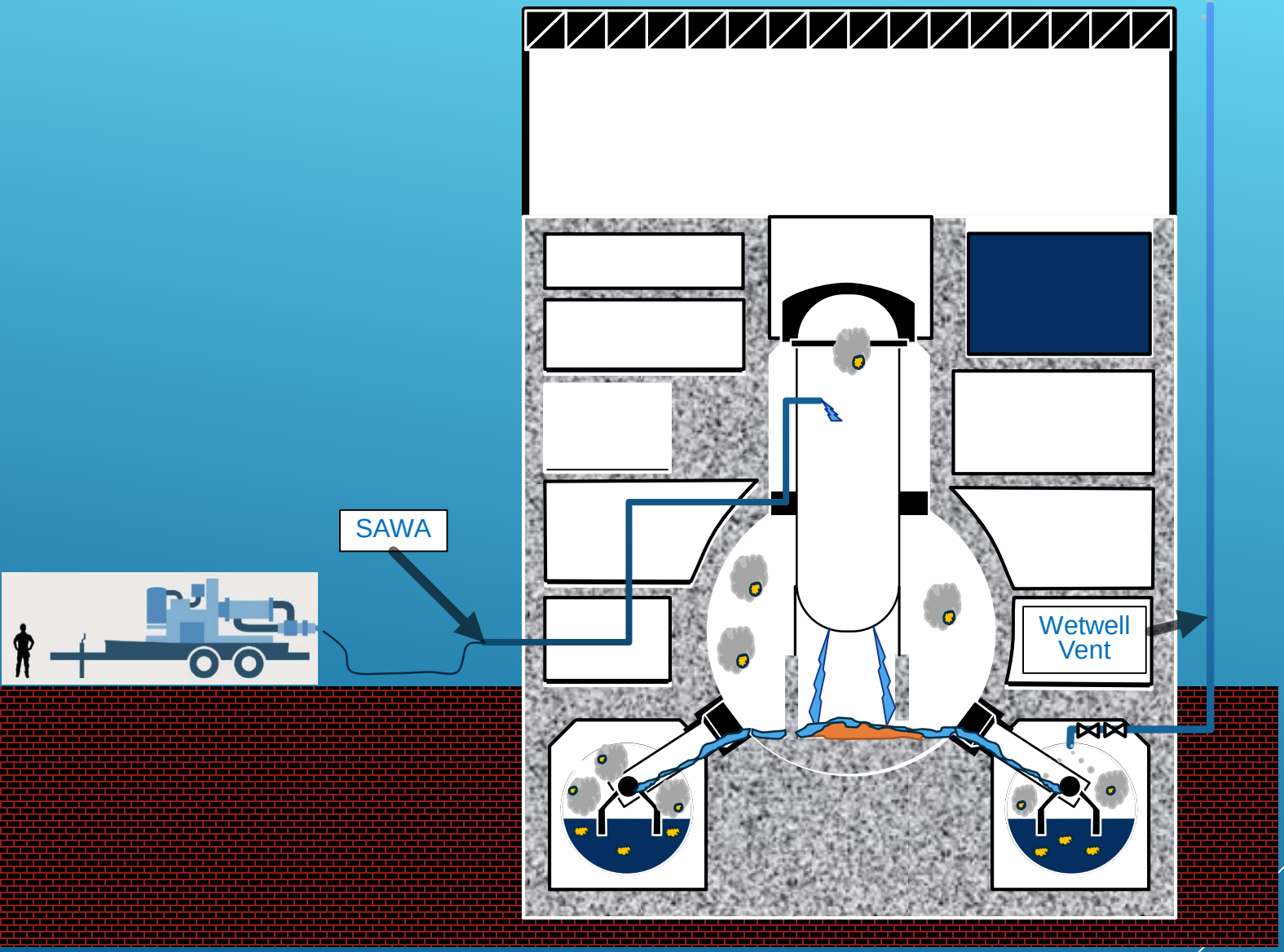
SEVERE ACCIDENT WATER ADDITION

- Severe accident considerations for water addition are the thermal and radiological impacts on operator actions that may exist under severe accident conditions
- The water addition source, whether to RPV or drywell, should be capable of the flow rate and pressures needed for water addition. An EPRI Technical Report validated that 500 gpm (the reference plant FLEX flow rate) was sufficient for SAWA
  - Electrical generators satisfying the requirements of EA-12-049 may be credited for powering components and instrumentation needed to establish a flow path from the water source to the addition point provided the actions necessary to deploy and maintain equipment can be performed under the thermal and radiological conditions associated with a severe accident.
  - Diesel or electric driven installed or portable pumps used to implement Order EA-12-049 (FLEX) may be used as water sources provided the actions necessary to deploy and maintain equipment can be performed under the thermal and radiological conditions associated with a severe accident.

SEVERE ACCIDENT WATER MANAGEMENT

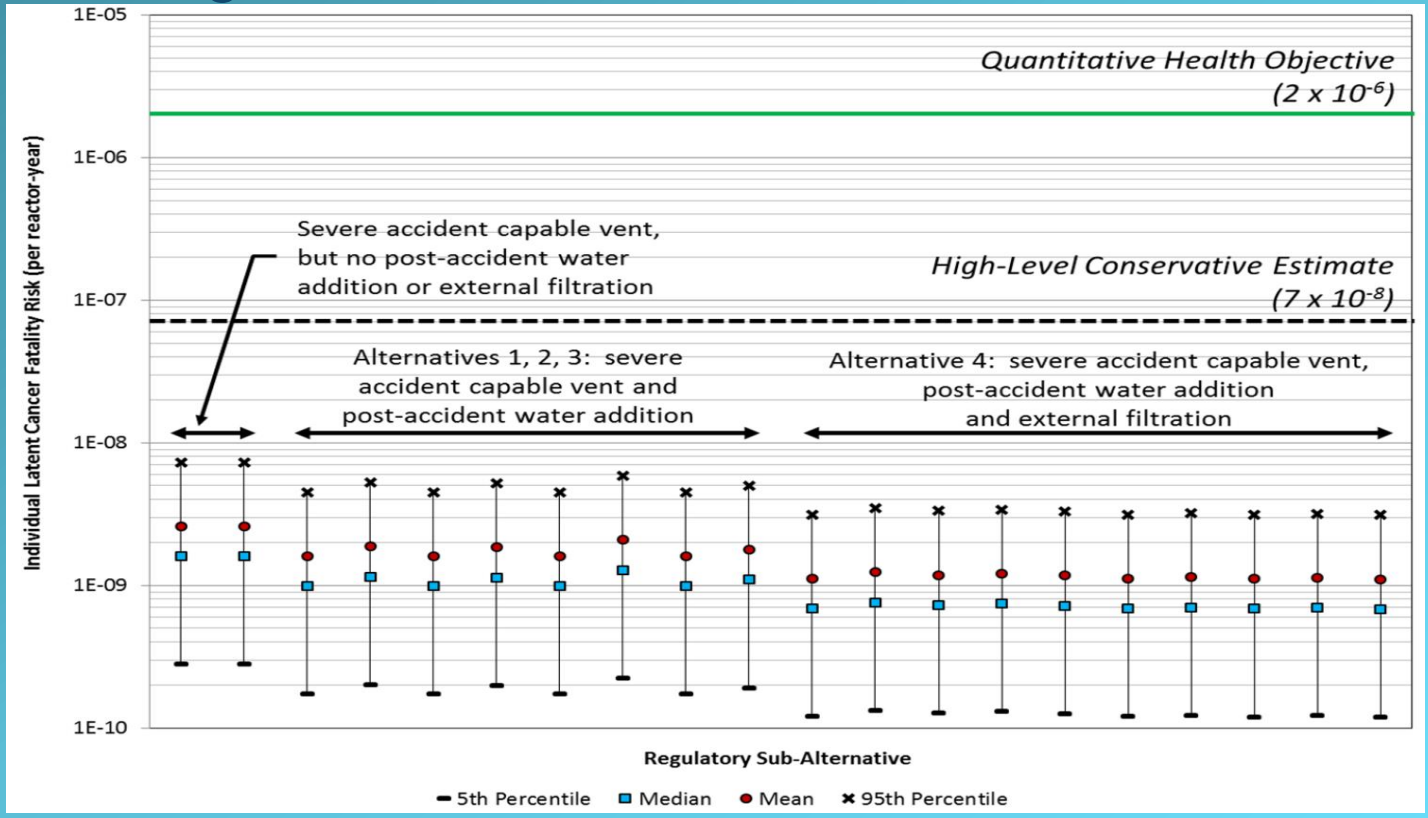
- SAWM defines how to use the hardware provided by SAWA to extend the use of the wetwell vent path, and will primarily be implemented through procedures and training. Under this water management strategy sufficient water flow must be supplied to reduce thermal challenges to the containment so that the containment capability remains intact, but water flow can be optimized, when appropriate, in order to avoid compromising the wetwell vent path.
  - Prior to vessel breach, the initial source of water on the drywell floor comes from a combination of Reactor Recirculation pump seal leakage and condensation caused by containment heat sinks in contact with the steam environment. When present, this water provides an initial quenching mechanism for the core debris as it exits the RPV, if RPV breach occurs after SAWA has been initiated water is expected to follow the core debris from the RPV and provide additional quenching.
- SAWA flow control and freeboard volume are the primary factors that impact long term use of the wetwell vent path for containment heat removal and pressure control. Due to the relative volume of the Torus (Suppression Pool) and SAWA flow rates, the change in Torus (Suppression Pool) level will be slow moving such that rapid, fine control of SAWA flow rate will not be required.

SAWA TO RPV VISUALIZATION



RADIOLIGICAL RELEASE STRATEGIES

- Very small safety benefit and no cost-benefit from external filter is consistent between NRC and industry studies
  - Actions from FLEX and Venting influence results
  - Water management is critical



From SECY-16-0041, Enclosure 1

SUMMARY

- For venting from EOPs, the wetwell vent is expected to be used to protect containment and will be venting mostly saturated steam.
- If fuel damage occurs and transfer to plant specific SAMGs is made, containment venting will depend on what other plant conditions exist.