SECY-12-0157
CONSIDERATION OF ADDITIONAL REQUIREMENTS FOR CONTAINMENT VENTING SYSTEMS FOR BWRs WITH MARK I AND MARK II CONTAINMENTS

Region II Counterparts Meeting

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Purpose

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- To discuss the staff's analysis and recommendations on imposing new requirements related to containment venting systems for boiling water reactors with Mark I and Mark II containments

C-10

Background - Tasking (1)

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- SRM on SECY-11-0137, "Prioritization of Recommended Actions to be Taken in Response to Fukushima Lessons Learned"
  - The staff should quickly shift the issue of "Filtration of Containment Vents" from the "additional issues" category and merge it with the Tier 1 issue of hardened vents for Mark I and Mark II containments such that the analysis and interaction with stakeholders needed to inform a decision on whether filtered vents should be required can be performed concurrently with the development of the technical bases, acceptance criteria, and design expectations for reliable hardened vents

Background - Tasking (2)

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- SRM from August 7, 2012 Commission Meeting on status of actions taken in response to lessons learned from the Fukushima Dai-ichi accident
  - In the forthcoming notation vote paper on filtered vents, the staff should include a discussion of accident sequences where the filters are and are not beneficial

Commission Paper

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- SECY Paper
  - Evaluation of Options
  - Design and Regulatory History
  - Foreign Experience
  - BWR Mark I & II Containment Performance During Severe Accidents
  - Technical Analyses (MELCOR/MACCS/PRA)
  - Stakeholder Interactions
  - Draft Orders

Main Paper

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- Discuss issues associated with severe accident containment venting and relevance to Mark I and II containments
- Identify potential options
- Basis for staff's recommendation
- Discuss role of quantitative analysis and qualitative analysis
- Provide concise writeups referencing enclosures for details

Options Considered

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1. No change (Reliable hardened vents - EA-12-050)
2. Severe accident capable vents order
3. Filtered vents order
4. Severe accident confinement strategy

Recommendation

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- Option 3 – Filtered Vents Order
  - The NRC staff finds that the combination of quantitative and qualitative factors best supports the installation of filtered venting systems at BWRs with Mark I and II containments

Option 3 - Filtered Vent

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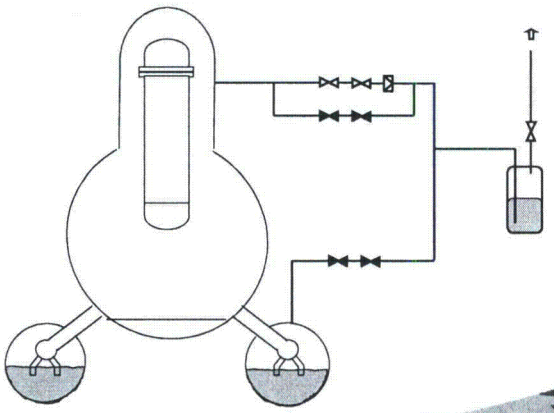

Basis for Proposed Recommendation

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- Cost-justified substantial safety enhancement
  - Quantitative analysis
  - Qualitative analysis
    - Enhances defense-in-depth (containment vulnerabilities and severe accident uncertainties)
    - Filter provides a fission product retention capability independent of plant accident response

Enclosure 1
Evaluation of Options

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- Summary of considerations in decision-making
- Consideration of adequate protection
- Decision on substantial safety enhancement
- Inclusion of qualitative arguments
- Presentation of results including sensitivity analysis

Cost-Benefit Analysis

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Quantitative Cost/Benefit Analysis Per Plant				
	Severe Accident Capable		Filtered	
Total Costs ($k)	(2,027)[1]		(16,127)	
Core Damage Frequency	$2x10^{-5}$yr	$2x10^{-4}$/yr	$2x10^{-5}$/yr	$2x10^{-4}$/yr
Total Benefits ($k)	938	9,380	1,648	16,480
Net Value (Benefits – Costs)	(1,089)	+7,353	(14,479)	+353

(1) As discussed in Enclosures 1 and 4, the costs for severe accident capable vents for Mark II containment designs will likely be higher. The higher cost reflects the likely need to modify the containments to prevent molten core debris in the lower drywell sump drain lines from causing a bypass of the suppression pool. Avoidance of wetwell bypass is needed to make the severe accident capable vents a viable option for the Mark II containment design.

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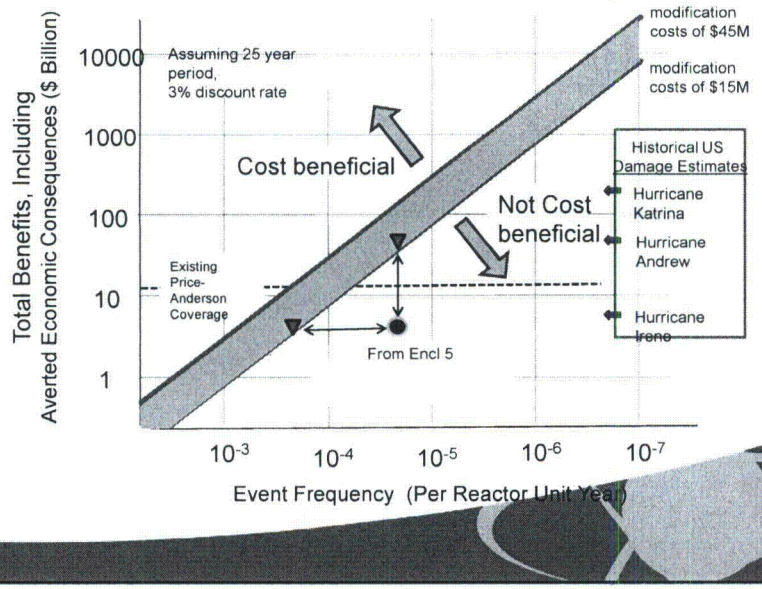
Break Even Cost/Benefit Considerations



Qualitative Arguments

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- Providing defense in depth
- Addressing significant uncertainties
- Supporting severe accident management and response
- Improving hydrogen control
- Addressing external events
- Addressing multi-unit events
- Considering independence of barriers
- Improving emergency planning
- Considering consistency between reactor technologies
- Considering severe accident policy statement
- Addressing international experience and practices

Enhances Defense-in-Depth

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- Containment is an essential element of defense-in-depth
- Addresses high conditional containment failure probability
- Filtering compensates for the loss of the containment barrier due to venting
- Filtering improves confidence to depressurize containment to address other severe accident challenges

Uncertainties

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- Uncertainties in prevention and mitigation of severe accidents
  - Event frequency
  - Severe accident progression
  - Radiological consequences
  - Economic consequences

Hydrogen

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- Improves operator confidence in a "clean" release for hydrogen control
  - Allows early operator intervention to vent hydrogen and control containment pressure
  - Sustained lower pressure reduces leakage of hydrogen thru penetration seals
  - Decreased leakage reduces threat from hydrogen explosion to reactor building, spent fuel pool, and emergency responders

Multi-unit Events

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- A concern highlighted by the Fukushima accident is conditions or events (e.g., external hazards) which challenge multiple units at a nuclear facility
- There is a significant advantage to having installed equipment and/or strategies in place to address such multi-unit events

Design and Regulatory History

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- Mark I Containments
  - WASH-1400 & NUREG-1150 found that Mark I containments could be severely challenged if a severe accident occurred
  - Relatively small volume
    - Gas and steam buildup affect pressure more dramatically
  - BWR cores have ~3 times the quantity of zirconium as PWRs
    - Potential for hydrogen gas and containment pressurization

Design and Regulatory History

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- Mark II Containments
  - Similar to Mark I, the most challenging severe accident sequences are station blackout and anticipated transients without scram
  - Risk profile dominated by early failure with a release that bypasses the suppression pool
  - Hardened venting was considered not beneficial because of unacceptable offsite consequences without an external filter like MVSS
  - Staff did not recommend generic backfit of hardened vent, but recommended a comprehensive evaluation as part of the IPE program

Design and Regulatory History

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- Mark I Containments
  - Containment Performance Improvement Program
    - Determine what actions, if any, should be taken to reduce the vulnerability to severe accidents
    - Staff recommended
      - Improve hardened vent
      - Improve RPV depressurization system
      - Provide alternate water supply to RPV and drywell sprays
      - Improve emergency procedures and training
    - Commission approved hardened vent
    - Other recommendations evaluated as part of IPE program

Foreign Experience

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- Staff visited Sweden, Switzerland, and Canada
- Insights from visits and public meetings consistent with previous findings
  - 1988 CSNI Report 156, Specialists' Meeting on Filtered Containment Venting Systems
- Together, FCVS and containment flooding scrub fission products from core debris and remove decay heat

Foreign Experience

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FCVS Status at Non-U.S. BWR Facilities

FCVS Status	GE Mark I	GE Mark II	ABB Mark II	GE Mark III	Other	ABWR	Totals	
FCVS Operational	1	0	6	1	5	0	**13**	30%
Committed	6	7	0	5	4	3	**25**	57%
Considering	1	0	0	1	0	0	**2**	5%
No FCVS	2	2	0	0	0	0	**4**	9%
Non-U.S. Totals	**10**	**9**	**6**	**7**	**9**	**3**	**44**	

MELCOR

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- Based on SOARCA MELCOR modeling
- Accident sequences
  - Informed by SOARCA and Fukushima
  - Long-term SBO (base case 16 hr RCIC)
- Mitigation actions
  - B.5.b and/or FLEX provide core spray or drywell spray (300 gpm)
  - Containment venting
- Sensitivity analysis
  - Spray flow rate and timing, wetwell versus drywell venting, and RCIC duration

MELCOR Calculations

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- Water on the drywell floor is needed to prevent liner melt-through
  - Also scrubs fission products and reduces drywell temperature
- Venting prevents over-pressurization failure
  - Wetwell venting is preferable to drywell venting
- Need combination of venting and drywell flooding
  - More reduction in fission product release
  - Maintain reactor building integrity

MELCOR Results

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Event Timing (hr.)	Case 2 RCIC only	Case 3 RCIC + wetwell vent	Case 6 RCIC + core spray	Case 7 RCIC + core spray + wetwell vent
Station blackout	0.0	0.0	0.0	0.0
RCIC flow terminates	17.9	17.9	17.9	18.0
Core uncovery	22.9	22.9	22.9	22.9
Relocation of core debris to lower plenum	25.9	25.9	25.9	25.8
RPV lower head failure	37.3	34.3	36.7	33.8
Drywell pressure > 60 psig	22.8	22.8	23.3	23.2
Drywell head flange leakage (>80 psig)	25.5	---	25.4	---
Drywell liner melt-through	40.3	36.6	---	---
Calculation terminated	48	48	48	48

MELCOR Results

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Selected MELCOR Results	Case 2 RCIC only	Case 3 RCIC + vent	Case 6 RCIC + core spray	Case 7 RCIC + core spray + vent
Debris mass ejected (1000 kg)	286	270	255	302
In-vessel hydrogen generated (kg-mole)	525	600	500	600
Ex-vessel hydrogen generated (kg-mole)	461	708	276	333
Other non-condensable generated (kg-mole)	541	845	323	390
Cesium release fraction at 48 hrs.	1.32E-02	4.59E-03	3.76E-03	3.40E-03
Iodine release fraction at 48 hrs.	2.00E-02	2.81E-02	1.70E-02	2.37E-02

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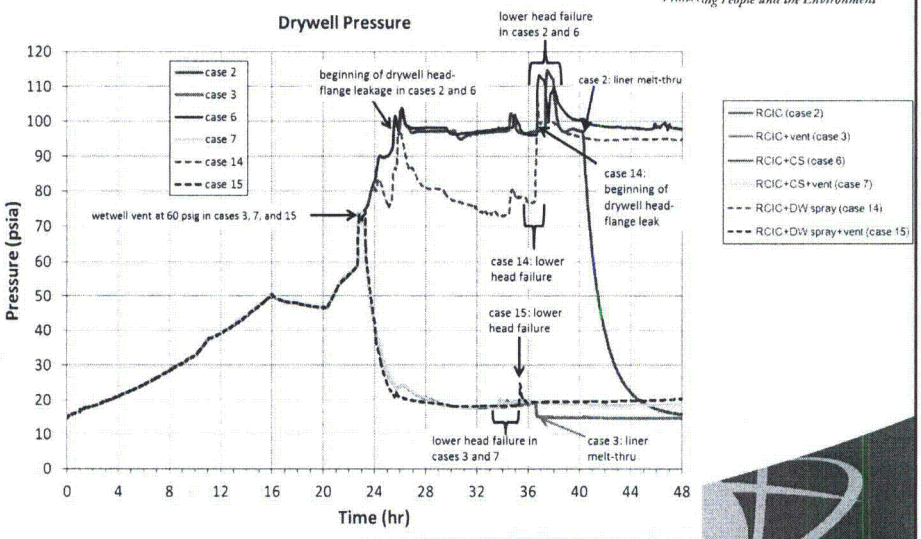

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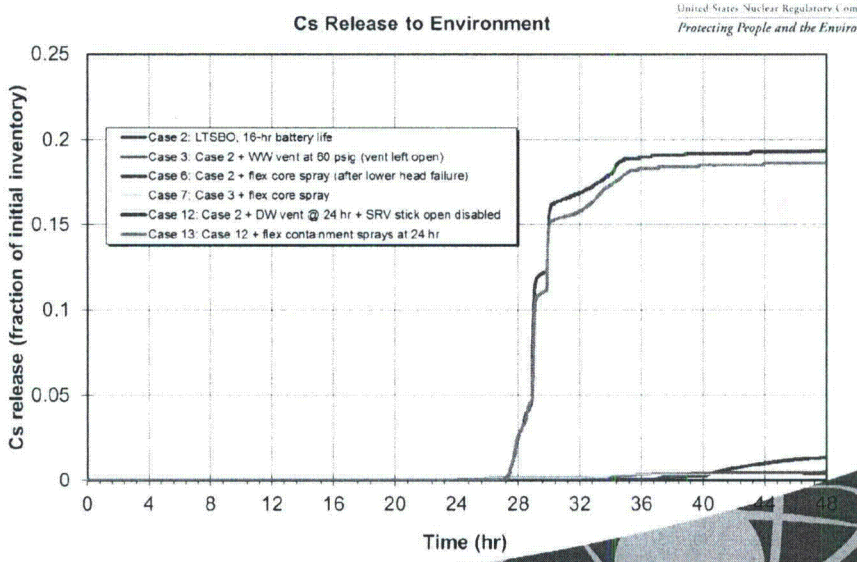

MACCS2

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- Offsite population doses, including doses to off-site decontamination workers
- Individual latent cancer fatality risk and prompt fatality risk
- Land contamination
- For different thresholds of Cs-137 concentration in soil (Ci/km2)
- Economic costs

MACCS2

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- The health effect of interest is latent cancer fatality risk, which is controlled in part by the habitability (return) criterion
  - Essentially no prompt fatality risk
- In terms of long-term radiation, the most important isotope is Cs-137, and most of the doses are from ground shine
- There is a non-linear relationship between decontamination factor and both land contamination area, health effects, and economic consequences

MACCS2 Results

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Event	Base case Case 2	Base case with WW venting Case 3 Unfiltered Filtered DF = 10	Base case with core spray Case 6	Base case with WW venting and core spray Case 7 Unfiltered Filtered DF = 10
Population dose 50 mile radius *per event* (rem)	**510,000**	400,000 180,000	**310,000**	240,000 37,000
Population weighted latent cancer fatality (LCF) risk 50 mile radius *per event*	**4.8E-05**	3.3E-05 1.3E-05	**2.5E-05**	1.6E-05 2.2E-06
Contaminated area (km^2) with level exceeding 15 $\mu Ci/m^2$ *per event*	**280**	54 8	**72**	34 0.4
Total economic cost 50 mile radius *per event* ($M)	**1,900**	1,700 270	**850**	480 18

MACCS2 Results

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Event	Base case with drywell venting Case 12 Unfiltered Filtered 1 DF=1,000 Filtered 2 DF=5,000	Base case with DW venting and DW spray Case 13 Unfiltered Filtered DF=1,000	Base case with drywell spray Case 14	Base case with WW venting & drywell spray Case 15 Unfiltered Filtered DF = 10
Population dose 50 mile radius *per event* (rem)	3,800,000 230,000 210,000	3,900,000 60,000	86,000	280,000 43,000
Population weighted latent cancer fatality (LCF) risk 50 mile radius *per event*	3.2E-04 1.6E-05 1.4E-05	3.3E-04 3.7E-06	6.4E-06	2.1E-05 2.7E-06
Contaminated area (km^2) with level exceeding 15 μCi/m2 *per event*	9,200 28 25	8,800 2	10	28 0.3
Total economic cost 50 mile radius *per event* ($M)	33,000 390 370	33,000 38	116	590 20

PRA

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- Conditional containment failure probability
- Insights from Severe Accident Mitigation Alternatives (SAMA) Analyses
- Technical approach
- Results
- Uncertainties

PRA

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- Estimated the risk reduction resulting from installation of a severe accident containment vent for use in regulatory analysis
  - 50-mile population dose (Δperson-rem/ry)
  - 50-mile offsite cost (Δ$/ry)
  - Onsite worker dose risk (Δperson-rem/ry)
  - Onsite cost risk (Δ$/ry)
  - Land contamination (Δconditional contaminated land area)

Draft Proposed Orders

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- Considerations
  - Proposed implementation date
  - Technical requirements
  - Detailed guidance document to be developed with consideration of stakeholder input
  - Options
    - Option 2 – Severe accident capable
    - Option 2 as part of Option 4
    - Option 3 – Engineered filtered vent

Next Steps

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- Commission Meeting
  - January 9, 2012
- Commission Decision
  - TBD