Probabilistic Modeling
Containment Filtration Strategies Rulemaking

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Objectives

- Provide input to regulatory analysis (cost-benefit) for each alternative:
  - Δperson-rem/y
  - Δoffsite cost/y
- Assess the balance between accident prevention and accident mitigation
- Assess the importance of operator actions
- Note: In general, filtration strategies (including an engineered containment vent filter) tend to affect the consequences of accident sequences, but not their frequencies.

Uses of a Portable Pump

- Review of licensee submittals:
  - Refill the CST
  - Core injection to prevent core damage
  - Isolation condenser refill (if applicable)
- Limited/no discussion of:
  - Core injection to prevent vessel breach
  - Drywell injection

RCIC Success Criteria

	Short Term	Intermediate Term	Long Term
Pump starts and runs	Yes Failure Mode: FTS	Yes Failure Mode: FTR	Yes Failure Mode: FTR
RPV depressurized to ~200 psig • Stop SRV cycling • Minimize RCIC pump room heatup Note: RCIC isolation on low steam line pressure (75 psig)	Yes Failure Mode: Stuck-open SRV	Yes Failure Modes: • RPV not depressurized • Inadvertent depressurization, leading to RCIC pump trip	Yes Failure mode: Stuck-open SRV
dc Power	Yes	Yes	Yes
Suction Conditions • High turbine exhaust pressure trip @ 50 psig • RCIC fails when SP temperature reaches 220 F (pump bearing cooling)	No	No	Yes Failure mode: containment not vented
Pump room cooling	No	No	Yes Failure mode: portable room cooling not aligned (Peach Bottom IPE – 10 h)
Suppression pool makeup	No	No	Yes Failure mode: No makeup aligned to CST or SP

Probability of Stuck-Open SRV

Source	SOARCA (Peach Bottom IPE)	SPAR (2010 Update)
Probability of Failure on Demand	3.7E-3/demand	8.56E-4/demand
100 demands	Pr{stuck-open SRV} = 0.31	Pr{stuck-open SRV} = 0.082
200 demand	Pr{stuck-open SRV} = 0.52	Pr{stuck-open SRV} = 0.16
300 demands	Pr{stuck-open SRV} = 0.67	Pr{stuck-open SRV} = 0.23
400 demands	Pr{stuck-open SRV} = 0.77	Pr{stuck-open SRV} = 0.29

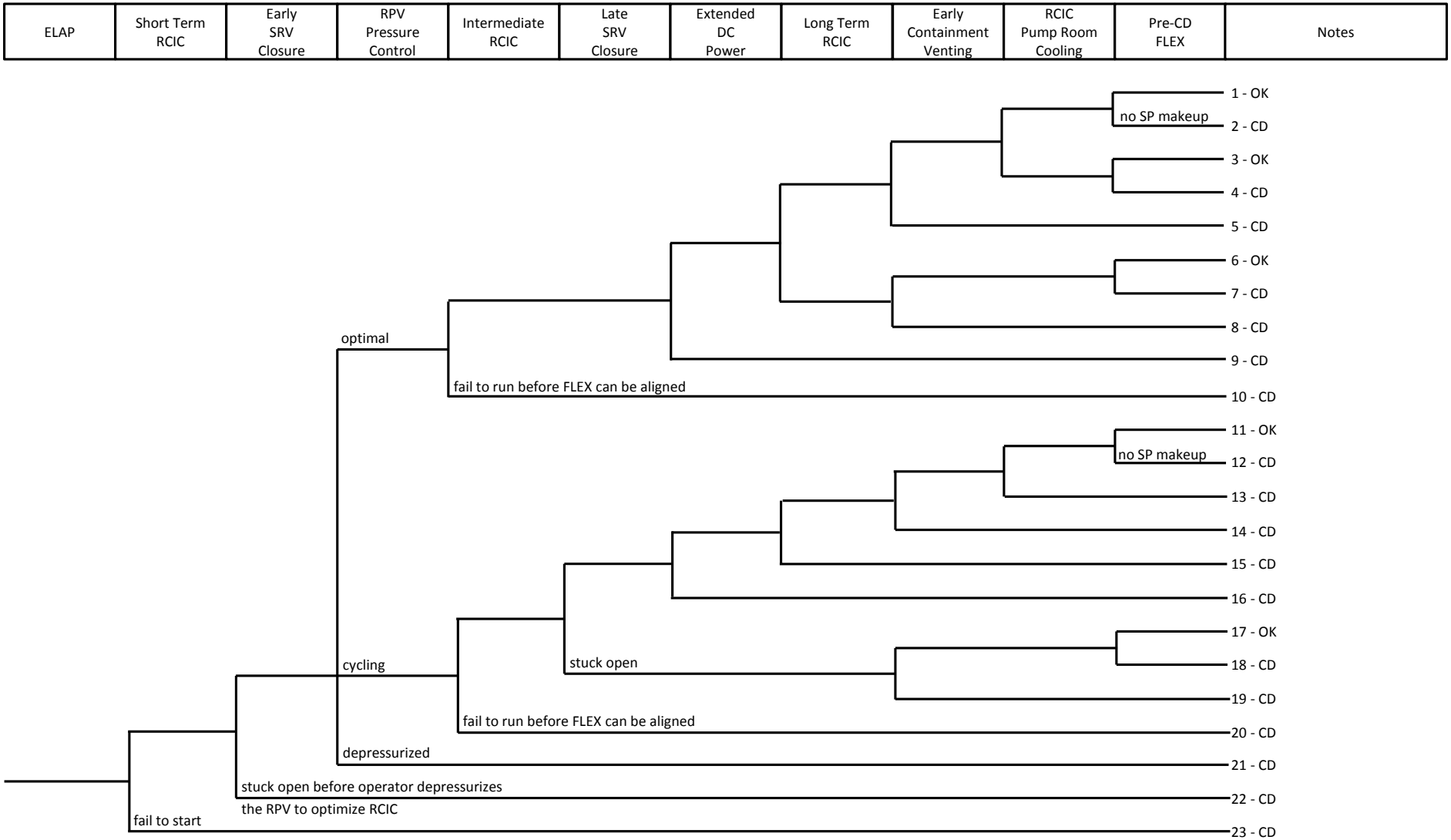
Portable Pump Success Criteria

Success Criteria	Before Core Damage		After Core Damage	
	CST or SP Makeup During Extended RCIC	RPV Injection to Prevent Core Damage	RPV Injection to Prevent Vessel Breach and Liner Melt-Through	DW Injection to Prevent Liner Melt-Through
Pump starts and runs	Yes	Yes	Yes	Yes
RPV depressurized as needed to ensure adequate pump flow	Yes	No	Yes	No
Containment vented as needed to remove decay heat and ensure adequate pump flow	• No for CST makeup • Yes for SP makeup	Yes	Yes	Yes
Inventory	Yes	Yes	Yes	Yes

Operator Actions Under Consideration

- dc power
  - Load shedding
  - Align portable generator
- Depressurize RPV to ~200 psig
- Depressurize RVP below portable pump shutoff head
- Align extra air or N_2 bottles to the SRVs
- RCIC blackstart and blackrun
- Containment venting
  - Before core damage
  - After core damage
- Align portable pump
  - CST refill during RCIC operation
  - Suppression pool refill during RCIC operation
  - Core injection (to prevent core damage)
  - Core injection (to prevent vessel breach)
  - Drywell injection (to prevent liner melt-through)

Delineation of Core-Damage Accident Sequences



MELCOR Analysis

August 14, 2013

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Technical Basis for Rulemaking

- Rulemaking focus
  - Filtering strategies with drywell filtration and severe accident management of BWR Mark I and II containments (SRM)
    - Severe accident distinct possibility; emphasis on mitigation
    - Base case: ELAP + HCVS + EPG/SAG
    - Alternatives: core injection (FLEX like), drywell injection, filter
  - Accident management rulemaking (industry's position)?
    - Accident management including core injection (FLEX) and early venting to avoid severe accident or delay it for a prolonged time (prevention); mitigation upon core damage
    - Base case: ELAP + HCVS + FLEX + EPG/SAG
    - Alternatives: modified FLEX for SA, drywell injection, filter

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Consideration of Analysis Options

- RCIC operation
  - RCIC duration: 16 hr., 4 hr., 0 hr.
  - Flow rate: 600 gpm (or EPG/SAG specification, if any)
- RPV depressurization and vessel injection (?)
  - Reliability of vessel injection under SA condition
  - Injection source, capacity, and effectiveness
- Drywell spray
  - Spray actuation time: @RCIC stop, @ vessel breach, other (?)
  - Spray flow rate: 500 gpm, variation (if any)
- Containment venting
  - Vent sizing: variable between wetwell and drywell, same
  - Vent cycling criteria: (PCPL)/(PCPL-15), other (if any)?
  - Transition from WW to DW venting: SP high water level, other (?)
  - Early venting option: criteria (?)
- Duration of transients: 72 hours, other (?)

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MELCOR Calculation Matrix

(06/11/2013 version)

Case Description	Input Parameters	Case 1	Case 2	Case 3	Case 4	Case 5
Main Steam Line Creep Rupture	RCIC failure (hr.)	16	4	0	16	4
	Drywell spray actuation	@ RCIC failure	@ RCIC failure	@ vessel breach	@ vessel breach	@ vessel breach
	Drywell spray flow rate (gpm)	500	500	500	500	500
	Wetwell vent cycling	(PCPL)/ (PCPL-15)	(PCPL)/ (PCPL-15)	(PCPL)/ (PCPL-15)	(PCPL)/ (PCPL-15)	(PCPL)/ (PCPL-15)
	Drywell vent cycling	(PCPL)/ (PCPL-15)	(PCPL)/ (PCPL-15)	(PCPL)/ (PCPL-15)	(PCPL)/ (PCPL-15)	(PCPL)/ (PCPL-15)
	Run time (hr.)	72	72	72	72	72

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MELCOR Calculation Matrix

(06/11/2013 version)

Case Description	Input Parameters	Case 6	Case 7	Case 8		
Main Steam Line Creep Rupture	RCIC failure (hr.)	16	16	16		
	Drywell spray actuation	16	16	@ vessel breach		
	Drywell spray flow rate (gpm)	500	500	500		
	Wetwell vent cycling	(PCPL)/ (PCPL-15)	Early venting	Early venting		
	Drywell vent cycling	No cycling	(PCPL)/ (PCPL-15)	(PCPL)/ (PCPL-15)		
	Run time (hr.)	72	72	72		

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Potential Industry Alternatives to Analyze
(industry presentation 07/22/2013)

1. Base Case
   - FLEX injection to RPV, EA-13-109, Rev. 3 EPG/SAGs
2. External RPV Water Injection Point
   - 2A. Option 1 plus external injection point to RPV
   - 2B. Option 2A plus WW/DW vent cycling
3. External DW Water Injection Point
   - 3A. Option 1 plus external injection point to DW
   - 3B. Option 3A plus WW/DW vent cycling
   - 3C. Option 3B plus water management to prevent the need for DW venting
4. Small Filter
   - Option 3A plus small filter
5. Large Filter
   - Option 3A plus large filter

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MELCOR Calculation Matrix

(revised 08/09/2013)

Case Description	Input Parameters	Case 1	Case 2	Case 3	Case 4	Case 5
Main Steam Line Creep Rupture	RCIC failure (hr.)	16	16	16	16	16
	WW venting	@ PSP	@PCPL	@PSP	@PSP	@PSP
	RPV injection (gpm) – pre-core damage	500	500	500	500	500
	RPV injection (gpm) – post-core damage	no	no	500	500	no
	WW vent cycling	no	no	no	(PCPL)/ (PCPL-15)	no
	DW venting	@??	@??	@??	@??	@??
	DW vent cycling	no	no	no	no	no
	DW spray actuation	no	no	no	no	@ vessel breach
	Run time (hr.)	72	72	72	72	72

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MELCOR Calculation Matrix

(revised 08/09/2013)

Case Description	Input Parameters	Case 6	Case 7	Case 8	Case 9	Case 10
Main Steam Line Creep Rupture	RCIC failure (hr.)	16	16	4	0	16
	WW venting	@ PSP	@PSP	@ PSP	@ PCPL	@PSP
	RPV injection (gpm) – pre-core damage	500	500	500	500	500
	RPV injection (gpm) – post-core damage	no	no	no	no	no
	WW vent cycling	(PCPL)/ (PCPL-15)	(PCPL)/ (PCPL-15)	no	no	no
	DW venting	@??	no	@??	@??	@??
	DW vent cycling	no	no	no	no	no
	DW spray actuation	@ vessel breach	no	no	no	@ RCIC failure
	Run time (hr.)	72	72	72	72	72

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Mapping of MELCOR Cases to Industry Alternatives and SRM Requirements
(MSL Creep Rupture Example)

Industry Alternatives	SRM Requirements/Guidance	Revised (8/9/13) MELCOR Cases*
Option 1 (base case)	Benefits of EA-13-109 (HCVS); 10CFR50.54 procedure availability + early venting	Case 1
Option 2A	Above + additional industry measures to maintain core in-vessel	Case 3
Option 2B	Above + modified operational procedure	Case 4
Option 3A	Maintain core coolability and containment integrity	Case 5
Option 3B	Maintain core coolability and containment integrity	Case 6
Option 3C	Above + modified venting strategy	Case 7
Option 4	External filtration	All MELCOR cases w/small DF filter
Option 5	External filtration	All MELCOR cases w/large DF filter

*** MELCOR Case 2 is without early venting (no comparable industry option); Cases 8 and 9 are sensitivities of RCIC duration; Case 10 is variation of the base case (Case 1) with drywell injection at RCIC failure.**

Industry options 4 and 5 are included for all MELCOR cases (Option 4 w/small DF filter, Option 5 w/large DF.

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Questions/Discussion