Severe Accident Analyses to Support Filtering Strategies Rulemaking

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Outline of Presentation

- Background
- Extended loss of AC Power (ELAP) event time lines
  - Phase 1: use installed plant equipment
  - Phase 2: use portable equipment already available on-site
  - Phase 3: use equipment and resources brought in from elsewhere
- Operator actions to prevent core damage during ELAP event and to mitigate consequences of ELAP core damage scenarios
  - RPV pressure control
  - Containment venting
  - Water addition
- Analytical approach
- Developing the regulatory basis for the Filtering Strategies Rule
- Some preliminary insights from simulating operator actions considered in developing filtering strategies

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Background

- Japan Lessons Learned Near Term Task Force Recommendations have led to new orders and rulemaking activities involving severe accident management
  - Order EA-12-049 on SBO Mitigation Strategies
    - Industry provided integrated plans on how core damage would be prevented during ELAP
    - Sequence of events time lines were provided, identifying elapsed times and time constraints required for various actions
  - Order EA-13-109 (superseding Order EA-12-050) on severe accident-capable hardened vents for BWR Mark I and Mark II plants
  - Rulemaking activities on SBO mitigation strategies, onsite emergency response capabilities, and filtering strategies for BWR Mark I and Mark II plants
- Filtering strategies rulemaking is a development from SECY-12-0157, in which the Staff recommended to the Commission that Severe accident-capable hardened vents and external filters be required for BWR Mark I and Mark II plants
  - The Commission's Staff requirements Memorandum (SRM) directed the Staff to prepare and issue Order EA-13-109 for severe accident-capable hardened vents, and to prepare a Regulatory Basis, including a Regulatory Analysis to support a rulemaking on Filtering Strategies

Background, cont.

- The Staff is currently developing the regulatory basis as an information paper to the Commission, that focuses on strategies and actions to provide RPV pressure control, wetwell and drywell venting, injection of water into the RPV, drywell flooding, and suppression pool makeup. External filters also being evaluated.
- On the Industry side,
  - EPRI has updated the Severe Accident Management Technical Basis Report
  - The PWR and BWR Owners Groups have revised their severe accident management guidance to accommodate lessons learned from Fukushima
  - The Nuclear Energy Institute (NEI) is preparing guidance documents for complying with Order EA-13-109, FLEX support guidelines in response to Order EA-12-049, and enhancing its emergency response capabilities and procedures for beyond design basis accidents and events
  - EPRI and the BWR Owners Group are also developing material to help develop the regulatory basis supporting what they believe are the proper venting and water addition strategies
- Many public meetings have taken place during this process
  - Public involvement continues

Sequence of Events Timeline During Extended Loss of AC Power (ELAP)

(From Peach Bottom Mitigation Strategies Integrated Plan)

Action (Phase 2 action in bold type)	Elapsed Time	Time Constraint	Remarks
Event starts	0	N/A	Plant at 100% power
Commence RPV cool down and depressurization, and DC load shedding	20 min	No	RPV could remain pressurized until heat capacity temp. limit (HCTL) approached. NRC begins at 10 min.
Align Nitrogen bottles to ADS SRVs, complete DC load shedding, and enter ELAP procedure	60 min	Yes	Approximation based on operating crew assessment of plant conditions. Load shed allows battery life of 5.5 hr.
Cool down at 80 ºF/hr and depressurize RPV to 200 psig	2.5 hr	No	EPG/SAG, Rev. 3 strategy will provide guidance on maintaining RPV pressure to allow continued RCIC operation
Open severe accident-capable hardened vent	4.8 hr	Yes	Limits torus temperature rise and provides heat sink Containment venting pressure is about 8 psig NRC analysis vents at 15 psig, and fails RCIC at 230 ºF.
Provide power to safety-related 480 VAC system	5 hr	Yes	Provide power by re-charging batteries
Commence lineup of FLEX pump	6 hr	No	Allows makeup to Torus and SFP
Complete lineup of FLEX pump and injection into Torus	12 hr	Yes	Provide makeup water to Torus to replenish inventory lost from venting

Operator Actions Considered in Developing Filtering Strategies
(when FLEX is not successful)

Action	Phase	Core Uncov.?	Vessel Failed?	Remarks
Early depressurization of RPV	1	No	No	Cooldown at 80 ºF /hr
Control RPV pressure (200 to 400 psi)	1	No	No	Maximizes time for RCIC operation
Early venting	1	No	No	Allows a heat removal path
Add water to SP (plant specific)	2	Maybe	No	SP makeup replenishes water lost from venting and keeps SP cool
Further depressurize RPV at MSCL	2	Yes	No	Allows for injection into RPV
Close vent at MSCL	2	Yes	No	Minimize fission product releases
Inject into RPV after RCIC fails, or, flood DW after core damage	2	Yes	No	Inject up to VF and beyond. May include ceasing direct SP makeup
Re-open vent at PSP (perhaps)	2	Yes	Maybe	Retain pressure suppression function; possible vent cycling
Re-open vent at PCPL	2	Yes	Probably	Maintain containment integrity; possible vent cycling
Reduce flow and/or close WW vent at high WW water level (21 ft. PB)	2	Yes	Yes	Top of level instrument range. Prevent flooding WW vent
Open DW vent at PCPL	2	Yes	Yes	Maintain containment integrity; possible vent cycling
Turn off water at high DW level	2	Yes	Yes	Four feet from DW floor in PB. Not likely in first 72 hr

Analytical Approach

- Based on Time Lines, develop core damage and accident progression event trees
  - Quantify trees using HRA and accident progression calculations
- Develop matrix of (about 40) scenarios to be analyzed
  - Scenarios associated with the most risk-significant tree branches
  - MELCOR 2.1 used for accident progression and source term determination for the various scenarios
  - MELCOR results used to evaluate options considered to develop the regulatory basis for the rulemaking
- MACCS2 is used to determine off-site consequences for the various sequences
- Compare results using performance measures
- A Regulatory Analysis is used to determine cost-benefit

Some Options Considered in Developing the Regulatory Basis

1. Base Case: FLEX injection to RPV (consistent with Orders EA-12-49 and EA-13-109, and BWROG EPG/SAG Rev. 3)
2. External RPV Water Injection Point
   A. Option 1 plus external injection to RPV
   B. Option 2A plus wetwell/drywell (WW/DW) vent cycling
   C. Option 2B plus water management to prevent the need for DW venting
3. External Drywell (DW) Water Injection Point
   A. Option 1 plus external injection to DW
   B. Option 3A plus WW/DW vent cycling
   C. Option 3B plus water management to prevent the need for DW venting
4. Small Filter (not based on DF)
   A. Option 3A plus small filter
5. Large Filter
   A. Option 3A plus large filter

Possible Failures During the Accident and Phenomenological Issues

- Loss of DC power, either at the beginning or due to battery depletion
- RCIC pump failure to start or run
- RCIC failure from high suppression pool temperature or low RPV pressure or other means
- Stochastic failure of SRV to re-seat
- SRV seizure at high temperature
- Thermally-induced main steam line creep rupture
- Drywell liner melt-through
- High suppression pool temperature leading to reduced fission product scrubbing
- Cesium Hydroxide revaporization

Off-site Consequences and Performance Measures

- Results obtained using MACCS2
  - Latent cancer fatality risk
  - Prompt fatality risk
  - Land contamination
  - Population dose
  - Economic costs
- Possible performance measures (absolute and reductions relative to case with FLEX, wetwell venting, and no RPV or DW injection)
  - Cesium release fraction and/or decontamination factor
  - Latent cancer fatality risk
  - Population dose risk
  - Margin to QHO
  - Equipment and procedure availability similar to 10 CFR 50.54(hh)
  - Other

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Preliminary Results and Insights to Inform MELCOR Analyses

- Using the FLEX strategy and equipment, adequate core cooling can be maintained as long as RCIC is operational. It can be assured long-term once external injection into the RPV is established
- Early RPV depressurization, RPV pressure control, and Wetwell venting, increase the likelihood of RCIC to survive
- Most severe accident sequences result from RCIC failure due to excessive suppression pool temperature, not from battery depletion
- Injecting into RPV at or before vessel failure is more effective in reducing Cs release than flooding the drywell
- Lengthening the time to core damage and/or vessel failure increases the suppression pool temperature and hence Cs release
- Early battery depletion cause the RPV to re-pressurize and increases likelihood of main steam line creep rupture.
- Main steam line creep rupture causes an increase in Cs release
- Reducing flow to avoid opening DW vent minimizes Cs release
- Cs release directly proportional to CsOH release, showing impact of CsOH revaporization