Accident Progression and Critical Issues During Reactor Accidents - an End User Perspective

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Why are enhanced tools needed for EOP/SAG Implementation?

• Assistance in EOP/SAG implementation requires knowledge of:
  – Plant Procedures
  – Plant Responses
  – Available mitigative equipment and actions
  – Limitations on actions
  – Accident phenomena
  – Accident progression signatures
  – Accident progression timing

• Many decisions have introduced a substantial degree of Engineering evaluation to optimize the decisions

Perception of Accident Management
https://www.youtube.com/watch?v=wm-h7YR_410
Who activates the Emergency Response Organization (ERO)?

**Shift Manager (SM)**

- Licensed senior reactor operator
- Maintains command & control of the plant
- Makes initial emergency classification
  - If ≥ Alert, SM must activate ERO
  - SM is the Emergency Director (ED) until relieved by on-call ED (after which SM advises ED on matters regarding control of the reactor)
## Roles & Responsibilities for Accident Management After ERO Activation

### DECISION MAKERS

| The emergency response organization function responsible for assessing and selecting the accident mitigation strategy to be implemented |

### EVALUATORS

| The emergency response organization function responsible for evaluating plant symptoms in order to determine the damage condition(s) and recommending any potential strategies that may be used to mitigate the event |

### IMPLEMENTERS

| Plant personnel responsible for performing those steps necessary to accomplish the objectives of the accident mitigation strategies (e.g., hands-on control of valves, breakers, controllers) |

<table>
<thead>
<tr>
<th>EOP Realm - Operations Shift Managers</th>
<th>EOP Realm – Shift Technical Advisor</th>
<th>EOP Realm – Operating Crew</th>
</tr>
</thead>
<tbody>
<tr>
<td>Severe Accident Realm – ERO Emergency Director</td>
<td>Severe Accident Realm – ERO Staff:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• STA</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• TSC</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• EOF</td>
<td></td>
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<tr>
<td></td>
<td>Severe Accident Realm – ERO</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Operating Crew</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Additional Site Resources</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Additional Offsite Resources</td>
<td></td>
</tr>
</tbody>
</table>

### Position Types are defined in:

2. NEI 91-04, Rev 1, SEVERE ACCIDENT ISSUE CLOSURE GUIDELINES. December 1994
TSC Evaluations

- TSC Accident Assessment Team (AAT) performs evaluation functions for EOP/SAG decision making at US BWR Plants
- Subset of the larger TSC Staff

![Diagram showing TSC Evaluations roles and decision-making process]
Impetus for Technical Support Guidelines (TSGs) from Fukushima Daiichi Accident

- Data input is critical to support decision-making
- Trending assists in prioritization
- Understanding severe accident phenomena and timelines assist in recognizing critical events
- System operability assessment
  - Allows projection of time to future needs
  - Identifies support systems necessary
- Interpretation of EOP/SAG actions in light of current and projected plant conditions -- Examples:
  - Functional situations (containment impaired)
  - Core debris may not be retained in RPV
  - RPV breached
Technical Support Guideline (TSG) Overview
Technical Support Guideline (TSG) Development

- EPRI Technical Basis Report (TBR)

- TSG Products
  - EAAG
  - PSAG
  - SSAG
  - CPAG

- BWROG
  - EPG/SAG
  - Bases Document

- BWROG Generic Guideline

- Plant Specific TSG Development
  - Plant Specific Inputs:
    - Systems
    - Control Parameters
    - Limits
    - EOPs
    - SAGs
    - Other Procedures

- Severe Accident Scenario Analysis
  - Time Lines
  - Plant Response

- TSG Reference Manual And Training Tools
Technical Support Guidelines (TSG)

Purpose

- Developed by the US BWR Owner’s Group and BWR Plants
- Used by the Accident Assessment Team in the ERO Technical Support Center (TSC)
- Support execution of Emergency Operating Procedures (EOPs) and the Severe Accident Guidelines (SAGs)
- Specify engineering support activities
- Identify constraints and limitations of tools and capabilities used in assessment and prognosis, and uncertainties in the results
  - Instrument uncertainties
  - Core damage assessment
  - Assessment of resource limitations (can ERO effectively perform the expected actions – on-shift and after callout)
Relationship: Accident Management Guidelines and Plant Procedures

Extreme Damage Mitigation Guidelines (EDMGs)
- Establish communications
- Perform notifications
- Actions to shutdown the reactor
- Actions to inject into the reactor
- Damage assessment
- Transition to other Ops Procedures when ERD manned

Emergency Management Guidelines (EMGs)
Integrated Response Plan for Large Scale events

Emergency Operating Procedures (EOPs)
- EOP 1 - RPV Control
- EOP 2 - Primary Containment Control
- EOP 3 - Secondary Containment Control
- EOP 4 - Radiation Release Control
- ALC - Alternate Level Control
- ED – Emergency RPV Depressurization
- ATWS RPV Control
- RPVF – RPV Flooding

Severe Accident Management Guidelines (SAMGs)
- SAG 1 - RPV and Primary Containment Flooding Severe Accident Guideline
- SAG 2 - Containment and Radioactivity Release Severe Accident Guideline
- SAG 3 - Hydrogen Control Guideline

Abnormal Operating Procedures

Support Procedures
- 100 - Rod Insertion Procedures (RIPs)
- 200 - EOP Defeats
- 300 - Supplemental Emergency Procedures (SEPs)
- 400 - Alternate Injection Procedures (AIPs)
- 500 - EOP Flowchart Supporting CALCs
- 600 - EOP Flowchart Supporting Graphs (GRAPHs)
- 700 - Severe Acc Mgmt Procedures (SAMPs)

Technical Support Guidelines
- Control Parameter Assessment Guideline (CPAG)
- System Status Assessment Guideline (SSAG)
- Plant Status Assessment Guideline (PSAG)
- EOP/SAG Action Assessment Guideline (EAAG)
## Structure of Technical Support Guidelines (TSGs)

<table>
<thead>
<tr>
<th>Guideline</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control Parameter Assessment Guideline (CPAG)</td>
<td>Identify best estimate value for each EOP and SAG control parameter</td>
</tr>
<tr>
<td>Plant Status Assessment Guideline (PSAG)</td>
<td>Forecast the future values of control parameters</td>
</tr>
<tr>
<td>Function (System) Status Assessment Guideline (SSAG)</td>
<td>Establish operability and reliability of plant systems</td>
</tr>
<tr>
<td>EOP/SAG Action Assessment Guideline (EAAG)</td>
<td>Priority and timing for actions directed by the EOPs/SAGs</td>
</tr>
</tbody>
</table>

**Flowchart:**
- Start
- Control Parameter Assessment
- Plant Status Assessment
- Function Status Assessment
- EPG/SAG Action Assessment
Control Parameter Assessment

- **Purpose of Control Parameter Assessment (CPA)** is to evaluate the availability of instrumentation used to determine the values of EOP/SAG control parameters.
- Under some conditions, indirect methods or calculation aids may be required.
- **Control Parameter Assessment helps determine:**
  - Condition of the plant based on the parameter indications
  - Whether or not indications are telling ‘truth’
  - Whether or not any are indicating ‘error’
Example: Torus Water Temperature

<table>
<thead>
<tr>
<th>ERIS</th>
<th>PIS Number</th>
<th>Readout</th>
<th>Power Supply</th>
<th>Other Limitations and Adjustments</th>
<th>Sensor Location</th>
<th>Transmitter Location</th>
<th>Environmental Limitations [°F]</th>
<th>Reading °F</th>
<th>Adjusted °F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>PRIMARY</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PT#259</td>
<td>T50N404A</td>
<td>T50-R800A</td>
<td>0-400°F</td>
<td>(SD-2861-2B)</td>
<td>TORUS Temp. DIV I AZ 270°</td>
<td>RB/BSmnt Grd 270° El. 551’04”</td>
<td>365</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>T50N405A</td>
<td>T50-R800A</td>
<td>0-400°F</td>
<td>(SD-2861-2B)</td>
<td>TORUS Temp. DIV I AZ 0°</td>
<td>RB/BSmnt Grd 0° El. 551’04”</td>
<td>365</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>T50N405B</td>
<td>T50-R800B</td>
<td>0-400°F</td>
<td>(SD-2861-2A)</td>
<td>TORUS Temp. DIV II AZ 90°</td>
<td>RB/BSmnt Grd 90° El. 551’04”</td>
<td>365</td>
<td></td>
<td></td>
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<tr>
<td>PT#111</td>
<td>T23N001</td>
<td>T23-R800 CH 1</td>
<td>0-100°F</td>
<td>(1-2860-9)</td>
<td>TORUS Wtr. Temp. AZ 22°</td>
<td>DW Grd 22° El. 551’01’</td>
<td>365</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>T23N002</td>
<td>T23-R800 CH 2</td>
<td>0-100°F</td>
<td>(1-2860-9)</td>
<td>TORUS Wtr. Temp. AZ 67°</td>
<td>DW Grd 67° El. 556’01’</td>
<td>365</td>
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</tr>
<tr>
<td></td>
<td>T23N003</td>
<td>T23-R800 CH 3</td>
<td>0-100°F</td>
<td>(1-2860-9)</td>
<td>TORUS Wtr. Temp. AZ 112°</td>
<td>DW Grd 112° El. 556’01’</td>
<td>365</td>
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</tr>
<tr>
<td></td>
<td>T23N004</td>
<td>T23-R800 CH 4</td>
<td>0-100°F</td>
<td>(1-2860-9)</td>
<td>TORUS Wtr. Temp. AZ 157°</td>
<td>DW Grd 157° El. 556’01’</td>
<td>365</td>
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<tr>
<td></td>
<td>T23N005</td>
<td>T23-R800 CH 5</td>
<td>0-100°F</td>
<td>(1-2860-9)</td>
<td>TORUS Wtr. Temp. AZ 202°</td>
<td>DW Grd 202° El. 556’01’</td>
<td>365</td>
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<tr>
<td></td>
<td>T23N006</td>
<td>T23-R800 CH 6</td>
<td>0-100°F</td>
<td>(1-2860-9)</td>
<td>TORUS Wtr. Temp. AZ 247°</td>
<td>DW Grd 247° El. 556’01’</td>
<td>365</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>T23N007</td>
<td>T23-R800 CH 7</td>
<td>0-100°F</td>
<td>(1-2860-9)</td>
<td>TORUS Wtr. Temp. AZ 292°</td>
<td>DW Grd 292° El. 556’01’</td>
<td>365</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>T23N008</td>
<td>T23-R800 CH 8</td>
<td>0-100°F</td>
<td>(1-2860-9)</td>
<td>TORUS Wtr. Temp. AZ 337°</td>
<td>DW Grd 337° El. 556’01’</td>
<td>365</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>ALTERNATE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E11N004A</td>
<td>E11-R601A</td>
<td>Red Pen</td>
<td>0-400°F</td>
<td>RRH HL XGHR “A” Inlet Temp. DIV I</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E11N004B</td>
<td>E11-R601B</td>
<td>Red Pen</td>
<td>0-400°F</td>
<td>RRH HL XGHR “B” Inlet Temp. DIV II</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Example: Torus Level Forecasting
(Wide Range)
The following restrictions apply to RPV water level instruments:

1. If drywell air temperature is above the RPV Saturation Temperature (Graph 1), water in the instrument legs may boil. If boiling is suspected:
   a. Subtract 23 inches from Fuel Zone and Narrow Range GEMAC indications.
   b. Do not use Floodup and Wide Range Yarway instruments.
2. Floodup and Wide Range instruments may not be used below the Minimum Indicated Level for the indicated drywell temperature.

### Table: Level Instrument Temperature

<table>
<thead>
<tr>
<th>Level Instrument</th>
<th>Temperature Instrument</th>
<th>Drywell Temp (°F)</th>
<th>MIL (in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wide Range Yarway</td>
<td>TR-4383A Channel 1</td>
<td>100-150</td>
<td>+8</td>
</tr>
<tr>
<td>LI-4539 (+8 to +218 in.)</td>
<td>Channel 1 (red)</td>
<td>151-200</td>
<td>+12</td>
</tr>
<tr>
<td></td>
<td></td>
<td>201-250</td>
<td>+16</td>
</tr>
<tr>
<td></td>
<td></td>
<td>251-300</td>
<td>+20</td>
</tr>
<tr>
<td></td>
<td></td>
<td>301-350</td>
<td>+25</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Upscale</td>
<td>+48</td>
</tr>
<tr>
<td>Wide Range Yarway</td>
<td>TR-4383B Channel 2</td>
<td>100-150</td>
<td>+168</td>
</tr>
<tr>
<td>LI-4540 (+8 to +218 in.)</td>
<td>Channel 2 (green)</td>
<td>151-200</td>
<td>+174</td>
</tr>
<tr>
<td></td>
<td></td>
<td>201-250</td>
<td>+181</td>
</tr>
<tr>
<td></td>
<td></td>
<td>251-300</td>
<td>+189</td>
</tr>
<tr>
<td></td>
<td></td>
<td>301-350</td>
<td>+199</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Upscale</td>
<td>+257</td>
</tr>
<tr>
<td>Floodup Range LI-4541</td>
<td>TR-4383A Channel 1</td>
<td>100-150</td>
<td>+168</td>
</tr>
<tr>
<td>(+158 to +458 in.)</td>
<td>Channel 1 (red)</td>
<td>151-200</td>
<td>+174</td>
</tr>
<tr>
<td></td>
<td></td>
<td>201-250</td>
<td>+181</td>
</tr>
<tr>
<td></td>
<td></td>
<td>251-300</td>
<td>+189</td>
</tr>
<tr>
<td></td>
<td></td>
<td>301-350</td>
<td>+199</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Upscale</td>
<td>+257</td>
</tr>
</tbody>
</table>
Purpose of Plant Status Assessment (PSA) is to:

• Forecast future values of EOP/SAG control parameters
  - Linear extrapolation of past values of the parameter
  - Calculation based on past values of the parameter or related parameters

• Specify the current state of the plant with respect to certain conditions = Identifying plant conditions
  - Status of plant parameters used to determine the condition of the core, RPV and containment
  - Some plant conditions are difficult to determine and require simultaneous comparison of several parameters and coincident parameter changes
    - RPV breach by core debris
    - Primary Containment Integrity Impairment
Critical Decision-Making In Plant Status Assessment

RPV Breach Signature

Steps
1. **RPV Water Level on Scale**
   - Yes, No, or Unknown

2. **RPV Water Level < BAF and RPV Injection < MDRIR**
   - Yes, No, or Indeterminant

3. **P_{RPV} - P_{PW} < 10 psig**
   - Yes, No, or Indeterminant

4. **H_2 Present**
   - Yes, No, or Indeterminant

CAUTION:
A single parameter cannot be used to determine RPV breach

Signature
- **DWT Increasing or Very High**
  - Yes, No, or Drywell Sprays Operating
- **RPV Bottom Head Metal Temperature >> Saturation**
  - Yes, Inconclusive

RPV Pressure Decrease Coincident with Drywell Pressure and Temperature Increase
- Yes, No, or Drywell Sprays Operating
- **H_2 Redistributed**
  - Yes, Inconclusive, or not applicable
- **Radiation Redistributed**
  - Yes, Inconclusive, or not applicable

**RPV Breached**

**Assume No RPV Breach**

Time _______  Time _______
Plant Status Assessment Tools

Drywell & Torus Volumes

- Free Volume of DW & Vent System = 972,465 gallons
- Free Volume of Torus Above Downcomer Opening = 899,156 gallons
- Free Volume of Torus above Min LCO Level = 724,636 gallons
- Volume of torus between 10.25 ft and 13.5 ft = 191,200 gallons
- Volume of torus between 10.25 ft and 16 ft = 322,300 gallons
- Volume of torus between 10.25 ft and 7.1 ft = 175,500 gallons
- Volume of Torus Flooded = 1,150,000 gallons
- Volume of Drywell & Torus Flooded = 2,120,000 gallons
Plant Status Assessment Tools

### RPV LEVEL CONTROL BREAKPOINTS

<table>
<thead>
<tr>
<th>Level (Inches)</th>
<th>Item of Interest</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>+211</td>
<td>High Level Trip, Main Turbine Trip</td>
<td>Loss of High Pressure Injection (FW, HPCI, RCIC)</td>
</tr>
<tr>
<td>+170</td>
<td>Low Level Scram PCIS Groups 2,3,4 Isolations</td>
<td>RPS Defeats needed in ATWS, Containment Isolation, Shutdown Cooling Valves Close</td>
</tr>
<tr>
<td>+19.5</td>
<td>High Pressure Injection, ARI, PCIS Group 5 Isol</td>
<td>HPCI/RCIC Auto Initiation, ARI Initiation &amp; Recirc Pump ATWS Trip, RWCU Isolations</td>
</tr>
<tr>
<td>+87</td>
<td>Two feet below Feedwater Spargers</td>
<td>During ATWS, if power is &gt;5% or unknown, lower level to 87 inches to reduce core inlet subcooling</td>
</tr>
<tr>
<td>+64</td>
<td>MSIV Closure, ECCS Auto Start, PCIS Group 1 Isol</td>
<td>Loss of Main Condenser, ADS Timers Start, MSIVs close</td>
</tr>
<tr>
<td>+15</td>
<td>Top of Active Fuel (See Note 1)</td>
<td>Loss of Adequate Core Cooling (ACC) from core submergence, Maximize Injection with Alternate Injection Systems in EOP 1</td>
</tr>
<tr>
<td>-25</td>
<td>Min Slim Cooling RPV Water Level</td>
<td>No guarantee that fuel cladding can be kept &lt;1500°F. ED required in EOP 1 before -25 in. If injection source available, Lower end of level control band in ATWS level/pump control, Loss of ACC in ATWS Slim Cooling and SAG entry required</td>
</tr>
<tr>
<td>-39</td>
<td>2/3 core height</td>
<td>RPV water level following DBA LOCA, SAG entry required in EOP 1 if can’t restore &amp; maintain above -35 in. while spray cooling</td>
</tr>
<tr>
<td>-40 (-43.8)</td>
<td>Min Zero Injection RPV Water Level (See Note 3)</td>
<td>No guarantee that fuel cladding temperature can be kept &lt;1500°F. Onset of metal-water reaction producing Hydrogen</td>
</tr>
<tr>
<td>-144 (-150)</td>
<td>Bottom of Active Fuel (See Note 2)</td>
<td>If level can be maintained above the bottom of active fuel, it is expected that core debris in the lower plenum will be submerged and will not breach the RPV</td>
</tr>
</tbody>
</table>
## Plant Status Assessment Tools

### Cumulative Time to Flood Containment to Various Heights

<table>
<thead>
<tr>
<th>Item</th>
<th>Height</th>
<th>Cumulative Time to Flood from Normal Level (minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Elevation</td>
<td>Distance Above Torus Bottom</td>
</tr>
<tr>
<td>Physical Feature</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal Water Level</td>
<td>729’8”</td>
<td>10’3”</td>
</tr>
<tr>
<td>Vacuum Breakers</td>
<td>733’</td>
<td>13’5”</td>
</tr>
<tr>
<td>Vent Lines Full</td>
<td>744’1”</td>
<td>24’8”</td>
</tr>
<tr>
<td>Drywell Sphere Equator</td>
<td>766’</td>
<td>46’7”</td>
</tr>
<tr>
<td>Bottom of RPV</td>
<td>772’5”</td>
<td>53’</td>
</tr>
<tr>
<td>Upper Drywell Spray</td>
<td>793’</td>
<td>74’</td>
</tr>
<tr>
<td>TAF</td>
<td>801’</td>
<td>82’</td>
</tr>
<tr>
<td>Drywell Vent</td>
<td>815’4”</td>
<td>95’</td>
</tr>
</tbody>
</table>
### MINIMUM TIMES TO RPV BREACH

<table>
<thead>
<tr>
<th>Accident Type</th>
<th>Approximate Time (Min.)</th>
<th>TAF to Breach</th>
<th>1/3 Core Height to Breach</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large LOCA with loss of make-up (LII-3C1)</td>
<td>40</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>Low pressure transient with loss of make-up (LII-1D1) (with ADS at TAF)</td>
<td>78</td>
<td>75</td>
<td></td>
</tr>
<tr>
<td>High Pressure Transient with loss of make-up (LII-1A1)&lt;sup&gt;(1)&lt;/sup&gt; (No Depressurization)</td>
<td>160&lt;sup&gt;(1)&lt;/sup&gt;</td>
<td>138&lt;sup&gt;(1)&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>High Pressure transient with loss of makeup (LII-1A2C)&lt;sup&gt;(2)&lt;/sup&gt;</td>
<td>93&lt;sup&gt;(2)&lt;/sup&gt;</td>
<td>72&lt;sup&gt;(2)&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>Loss of Makeup event initiated from High Pressure with SORV occurring when RPV level is below TAF (LII-1A4SRV)</td>
<td>102</td>
<td>84</td>
<td></td>
</tr>
</tbody>
</table>

**NOTE:** No injection to the RPV and no drywell sprays are operating in the above evaluations. Operation of either would result in increasing the observed time to RPV breach. In addition, other core melt progression models predict longer times to RPV breach by hours.
Function (System) Status Assessment

Purpose:

• Evaluate the availability of systems/components needed to implement EOPs/SAGs

Applies to:

• Systems/components identified in EOPs/SAGs
• Any support systems required by the identified systems/components
Function (System) Status Assessment

Is the system/component available to perform function?

YES

How long can it be expected to be available?

NO

How much time would be required to make it available?

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Function (System) Status Assessment

FSA involves knowing the following:

- Component location
- Power availability
- System lineup
- Support systems (cooling water, pneumatics, etc.)
- Motive force (steam, air, etc.)
- Environmental qualifications
- Interlocks
- Possible damage
## Function (System) Status Assessment

### System Dependency Matrix

<table>
<thead>
<tr>
<th>Support System</th>
<th>Reactivity Control</th>
<th>High Pressure Coolant Makeup</th>
<th>RPV Depressurization</th>
<th>Low Pressure Coolant Makeup</th>
<th>Containment Pressure/ Temperature Control</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RPS A B</td>
<td>HPCI A</td>
<td>CRD A B</td>
<td>LPCI A B</td>
<td>MSTW Remain Open</td>
</tr>
<tr>
<td>125 VDC Panel 1D13</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>125 VDC Panel 1D14</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>125 VDC Panel 1D21</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>125 VDC Panel 1D23</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>250 VDC MCC 1D41</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GSW</td>
<td></td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>RBCCW</td>
<td></td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>ESW (A)</td>
<td></td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>ESW (B)</td>
<td></td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>RHRSW (A)</td>
<td></td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>RHRSw (B)</td>
<td></td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Stilling Basin</td>
<td></td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>River Water</td>
<td></td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Well Water</td>
<td></td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Keep Full Pump</td>
<td></td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>
INPO IER 13-10 Rec. 4 (WANO SOER 2013-02 Rec. 4) - Verify that training programs prepare licensed operators and selected emergency response personnel to anticipate, recognize, and respond to core cooling system isolations that may occur during an event.
# RCIC Response to Loss of Control Power

## Table X.1.3-1

<table>
<thead>
<tr>
<th>System</th>
<th>Initial Configuration</th>
<th>Control Logic Power Supply</th>
<th>Resulting Condition</th>
<th>Guidance for Restoration / Operation</th>
</tr>
</thead>
</table>
| RCIC     | Standby Readiness     | Control Logic ‘A’ 1D13, 117  | • No auto-initiation at lo-lo RPV water level  
• No high RPV water level trip  
• No remote trip capability with pushbutton at 1C04  
• No auto-isolation of MO-2401  
(1) | 0150 for manual operation |
| RCIC     |                       | Control Logic ‘B’ 1D23, 107  | • No high level trip  
• No auto-isolation of MO-2400  
(1) | 0150 for manual operation  
(if required) |
| RCIC     |                       | Control Logic ‘A’ & ‘B’ 1D13, 117 1D23, 107 | • No auto-initiation at lo-lo RPV water level  
• No high RPV water level trip  
• No remote trip capability with pushbutton at 1C04  
• No auto-isolation capability  
• No auto-isolation for RCIC steam line (MO-2400 and MO-2401)  
(1) | 0150 for manual operation |
| Injecting|                       | Control Logic ‘A’ 1D13, 117  | • No auto-initiation at lo-lo RPV water level  
• No high RPV water level trip  
• No remote trip capability with pushbutton at 1C04  
• No auto-isolation of MO-2401  
(1) | 0150 for manual operation |
| RCIC     |                       | Control Logic ‘B’ 1D23, 107  | • No auto-initiation at lo-lo RPV water level  
• No high RPV water level trip  
• No remote trip capability with pushbutton at 1C04  
• No auto-isolation of MO-2400  
(1) | 0150 for manual operation  
(if required) |
| RCIC     |                       | Control Logic ‘A’ & ‘B’ 1D13, 117 1D23, 107 | • No auto-initiation at lo-lo RPV water level  
• No high RPV water level trip  
• No remote trip capability with pushbutton at 1C04  
• No auto-isolation capability  
• No auto-isolation for RCIC steam line (MO-2400 and MO-2401)  
(1) | 0150 for manual operation |

**NOTES TO TABLE X.1.3-1:**

(1) With DC supplied motive power available to MO-2401, Outboard Steam Line Isolation, RCIC steam line can be manually isolated from the Control Room.
**RCIC Critical “Pinch Point” Accident Management Actions**

<table>
<thead>
<tr>
<th>Maintain DC Power</th>
<th>Maintain Adequate Lube Oil Cooling via the Working Fluid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perform DC load shed</td>
<td>Prefer CST as the suction source (see Attachment YA)</td>
</tr>
<tr>
<td>Install portable generator</td>
<td>Replenish CST if necessary</td>
</tr>
<tr>
<td>Recover AC power (offsite/EDG)</td>
<td>Cool torus</td>
</tr>
<tr>
<td>Cross tie TSC EDG</td>
<td>Anticipatory vent to minimize the maximum torus temperature</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Maintain Adequate RPV Pressure</th>
<th>Maintain high RPMs on turbine to ensure adequate lubrication if high temperature water source is being used. (&gt;3500 RPM at suction temperatures &gt;200°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maintain Adequate NPSH</td>
<td>Control torus water level</td>
</tr>
<tr>
<td></td>
<td>Make up for vented non-condensables with non-combustibles</td>
</tr>
<tr>
<td></td>
<td>Minimize torus temperature increase</td>
</tr>
</tbody>
</table>
### Accident Mgmt Actions to Prolong RCIC Operation

#### Under ELAP Conditions: Example of Pinch Points

<table>
<thead>
<tr>
<th>RCIC Critical “Pinch Point”</th>
<th>Accident Management Actions</th>
</tr>
</thead>
</table>
| **Ensure Adequate Room Cooling and Prevent High Room Temperature Trips**                       | • Open door on the RCIC room  
• Provide portable gas powered fan  
• Bypass high room temperature trips                                                                                                                                                                                                                                                                  |
| **Prevent High Steam Line Temperature Trip**                                                  | • Insert temperature isolation interlock override                                                                                                                                                                                                                                                                                                          |
| **Prevent RCIC Room Flooding**                                                               | • ARP 1C14A<A-4> and, <B-4> (above max safe, above max normal, respectively) direct monitoring and refer operators to EOP-3.  
• EOP-3 to verify that all available sump pumps are operating to lower water level.  
• There is no installed equipment that could be used to limit flooding or arrest the rate of water level rise besides the sump pump.                                                                                                                                                                     |
| **Prevent High Turbine Exhaust Pressure Trip**                                               | • Provide a set point change that permanently increases the high pressure trip to ~100 psig as recommended by GEH                                                                                                                                                                                                                                                                                          |
| **Implement Authorized Bypasses of RCIC Protective Isolations and Trips**                    | • Bypass the high RPV water level trip (Defeat 8)(1)  
• Bypass the low RPV pressure isolation (Defeat 1)  
• Bypass the high room temperature isolation                                                                                                                                                                                                                                                                  |
Purpose:

- **Determine priority for returning systems to service**
  - What systems are needed to perform EOP/SAG functions?
  - How can resources be applied to ensure needed systems are available? (…and thus be successful in performing EOP/SAG functions)

- **Identify timing for actions directed by the EOPs/SAGs**
  - When to start performing actions?
  - How long to perform them?
Key Areas of EOP/SAG Action Assessment Guidelines

- Verification of Plant Response
  - Section 6.4
- Resource Allocation
  - Section 6.2
- Prioritization
  - Section 6.3
- Timing of Actions
- Systems
  - HPCI
  - RCC
  - Core Spray
  - LPCI
  - RHRSW

Figure 6.0-1 Key Areas of Expertise Available from the EOP Action Assessment Guideline
Timing of Actions

EPG/SAG decision

Does the type of decision allow flexibility in timing the action?

YES

- Control parameter status (CPA)
- Plant status and trends (PSA)
- System status and availability (FSA)

Evaluate window for taking action:
- What is earliest time?
- What is latest time?

Weigh pros/cons and formulate a recommendation for the time to perform action

NO

Perform action now!
Why is Venting Being Considered?

- Torus Pressure Approaches or Exceeds PCPL
- Control of Oxygen/Hydrogen
- Control Torus Pressure below PSP

CONSIDERATIONS

- O2 concentrations assumed equal to those existing prior to event unless:
  - Containment Failure
  - Rx Bldg. to Torus Vacuum Breaker open
  - Containment isolation failure
  - Break in instrument air line
- Introduction of Hydrogen into containment usually accompanied by high radionuclide release into containment under severe accident conditions and potential for exceeding release limits.
- Venting is effective over a range of relatively high containment pressures
- Reduce Torus Pressure
- Could be used to anticipate RPV breach and provide added margin

CONSIDERATIONS

- If current injection is adequate DO NOT VENT only to enhance injection.
- If either RPV or containment injection is not adequate and will be increased by more than 25% VENT

CONSIDERATIONS

- Use Smallest Path
- Preserve Pool Scrubbing
- Avoid Release to Reactor Building

TIME = _____________

OFF-site and On-site Personnel Safety Maximized
High Airborne Radioactivity (e.g., RPV Breach)
Containment Structural Capability Adequate
Containment Vent Valve Capability Adequate
Preserve System Operability
Depletion of Non-condensibles
Habitability and Accessibility, and Equipment Operability Adverse Impact
Vent early through Torus Under Containment Flood Conditions to Reduce Need for Drywell Vent

CONCLUSION

*Additional considerations included in pro/con table if time permits

DESIRED FEATURES OF PATHWAY

- Use Smallest Path
- Preserve Pool Scrubbing
- Avoid Release to Reactor Bldg.
- Reduce Combustible Mixture Rapidly
- Use Smallest Path
- Preserve Pool Scrubbing
- Avoid Release to Reactor Building
- Use Smallest Path
- Preserve Pool Scrubbing
- Avoid Release to Reactor Bldg.
Containment Venting Considerations
EOP/SAG Action Assessment Using MAAP Models
EOP/SAG Action Assessment Using MAAP Models

High Pressure Transient with loss of make-up (LII-1A1) (No Depressurization)

These deterministic calculations are for accidents with:
- 100% Initial Power
- Scram Success
- No Injection after Scram
- NO DW Sprays
- No Containment Flooding

MAAP may be used to identify the accident sequence and provide insights on timing of actions.
Using MAAP with desk-top and full-scope simulators is very useful for training and can provide insights on the timing of actions.
Lessons-learned from the event at Fukushima illustrate the need for tools for Accident Assessment Team Members that are:

- Fully developed to the extent practical
- Attune to current understanding of accidents
- In line with and support sound decision making
- Will working conditions during an accident be amenable to accurate and timely decision making?

Severe accident conditions do not lend to simple, easy to understand instrument readings

While operators have much training, they do little training on SAM

Engineers who support operations do not have same degree of training and have little training on SAM
Voices from the Field – a Reminder of our Call to Action

“At that time, I was conjuring up faces of fellow colleagues who would die with me.” (Masao Yoshida, Site Superintendent)

“I was determined to stay behind to my death; however I was resolved to send my men back home alive.” (Ikuo Izawa, Shift Manager)

“Let me go and vent the containment. I know where the valve is and I can run fast. Let me protect the unit that I love.” (Kazuhiro Yoshida, Deputy Shift Manager)

“On the Brink: The Inside Story of Fukushima Daiichi”

“Book reveals human drama in Fukushima No. 1 crisis” The Japan Times 12/11/2012

http://amzn.com/4902075547
http://www.japantimes.co.jp/news/2012/12/11/national/book-
BWR Owners Group (BWROG)
TSG Workshops

Contact for participation in Training:
Phil Ellison, GE BWROG Project Manager,
phillip.Ellison@ge.com
Workshop will consist of the following:

- Introduction to Severe Accident Management (SAM)
- Phenomenology of Severe Accidents
- Review of Technical Support Guidelines from EPG/SAG R3 Workshop
- Case studies of 1F1, 1F2, and 1F3 using simple flowcharts and spreadsheets
- TEPCO discussion of findings since the accidents
- Key plant features which influence event progression

TSG Skill Set Workshop is planned to be held at the request of International members:

- Tokyo, Japan
- Taipei, Taiwan
- Vera Cruz, Mexico
- Europe (Madrid or Bad Zurzach)
- Multiple locations in the United States
Where Will the Workshop Be? (cont.)

Initial TSG Skill Set Workshop 2015 schedule:

- September 22-25: Taipei, Taiwan
- September 28 – October 1: Tokyo, Japan
TSG Development Contacts

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- Phil Ellison, GE BWROG Project Manager, phillip.Ellison@ge.com, 910-508-8772
- Jeff Gabor, Vice President, ERIN Engineering and Research Inc., jrgabor@erineng.com, 610-431-8260
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