*Joint KINS-IAEA-ANNuR/ANSN/FNRBA
BPTC Course on Nuclear Safety,
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In-plant Accident Management:

Emergency Operating Procedure(EOP)
Severe Accident Management Guideline (SAMG)

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Contents

1. Concept of Accident Management

IAEA Safety Requirement


IAEA Safety Standards
for protecting people and the environment

Safety of
Nuclear Power Plants:
Commissioning and
Operation

Specific Safety Requirements
No. SSR-2/2 (Rev. 1)

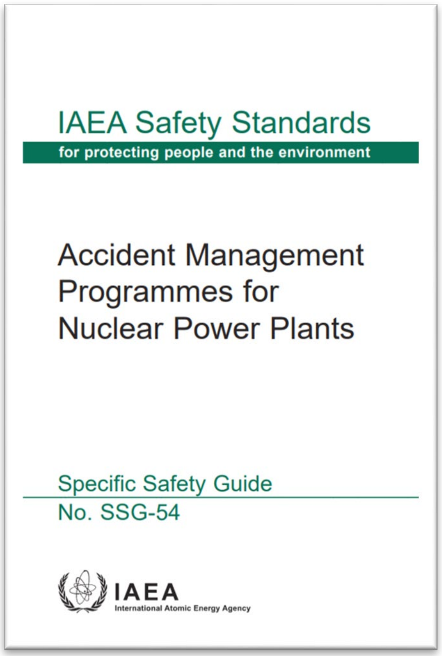
IAEA
International Atomic Energy Agency

Requirement 19: Accident management programme

The operating organization shall establish, and shall periodically review and as necessary revise, an accident management programme.

- To cover the preparatory measures, procedures and guidelines, and equipment that are necessary for preventing the progression of accidents, including accidents more severe than design basis accidents, and for mitigating their consequences.

IAEA Safety Guide



- An accident management programme encompasses plans and actions undertaken to ensure that the plant personnel and other operating organization personnel with responsibilities for accident management are adequately prepared to decide on and implement effective on-site actions.
- If an accident occurs at a nuclear power plant, to restore safety, two types of accident management guidance document are typically used: emergency operating procedures (EOPs) for preventing fuel rod degradation, and severe accident management guidelines (SAMGs) for mitigating significant fuel rod degradation when a severe accident is coming.

Objectives of Accident Management

- Accident management is actions to respond to and recover from an accident situation with an aim:
  - To prevent accident progression
  - To mitigate accident consequences
- **Preventive Actions**
  - To prevent the acceleration of the event into a severe accident so as to delay or prevent core damage
  - Examples:
    - primary system feed and bleed
    - depressurize RCS to inject water
- **Mitigatory Actions**
  - To mitigate consequence of core damage so as to:
    - To maintain the integrity of the containment, and
    - To minimize releases of radioactive material.
  - Examples:
    - vent containment (protect containment boundary integrity)
    - depressurize reactor system (prevent high pressure vessel failure

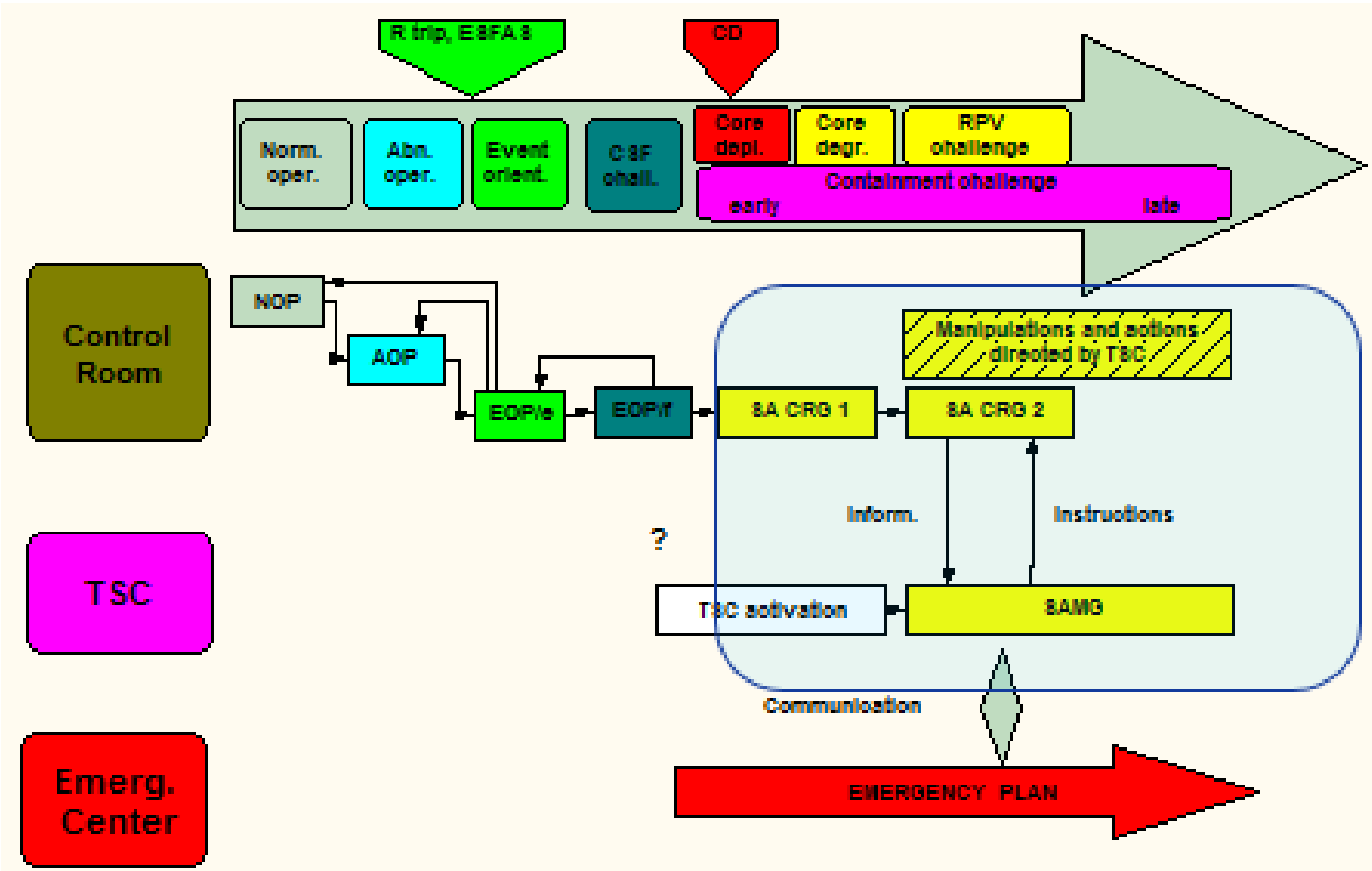
Operational Strategy in the plant states

<table>
<tr><th colspan="2">OPERATIONAL STATES</th><th colspan="3">ACCIDENT CONDITIONS</th></tr>
<tr><td>DiD level 1</td><td>DiD level 2</td><td colspan="2">DiD level 3</td><td>DiD level 4</td></tr>
<tr><td rowspan="2">Normal Operation (NO)</td><td rowspan="2">Anticipated Operational Occurrences (AOOs)</td><td rowspan="2">Design Basis Accidents (DBAs)</td><td colspan="2">Design Extension Conditions (DECs)</td></tr>
<tr><td>without significant core degradation</td><td>Severe Accidents (significant core degradation)</td></tr>
</table>

<table>
<tr><td rowspan="2">High quality equipment and LCOs</td><td rowspan="2">Safety systems and other surveillance features including SSCs
Safety analysis information (FSAR)</td><td colspan="2">Complementary measures to DECs
Severe accident analysis information (FSAR)</td></tr>
<tr><td>to prevent core melt</td><td>to mitigate consequence of core melt</td></tr>
</table>

<table>
<tr><td>Normal Operating Procedures</td><td>Abnormal Operating Procedures</td><td>Emergency Operating Procedures</td><td>Severe Accident Guidelines</td></tr>
</table>

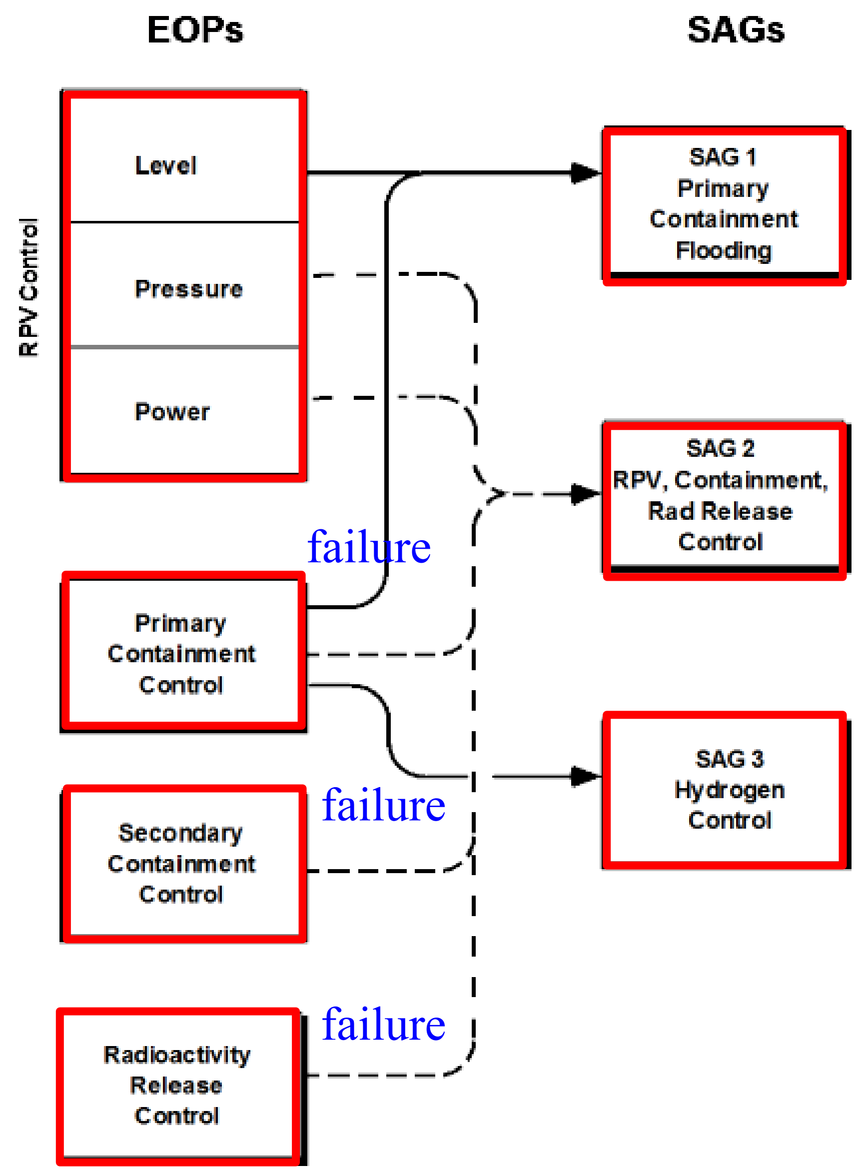
Operational Strategy (cont'd)



Operational Strategy (cont'd)

If EOP are no longer effective

→ transition to SAMG



2. Emergency Operation Procedure (EOP)

(1) Overview and strategy
(3) Optimal Recovery Guideline
(2) Functional Recovery Guideline

Overview (cont'd)

- EOP is **state-oriented procedures**
  - Operator can diagnose the state of the NSSS, and determine the actions.
- **Two EOP approaches**

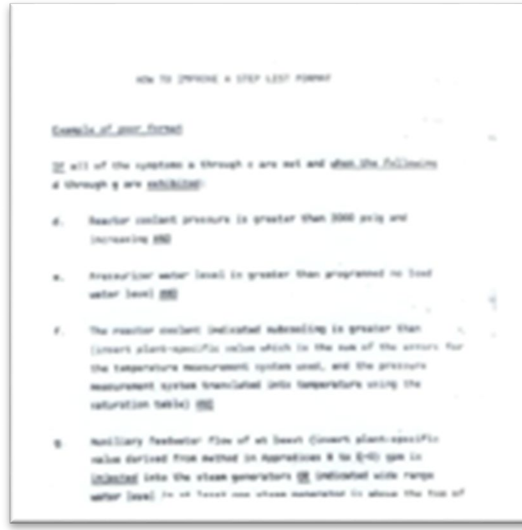
① **Event based procedures**
  - Procedures are based on the expected sequence of the incident or accident (e.g., LOCA, SGTR, etc.)
  - Applicable for a single initiating event

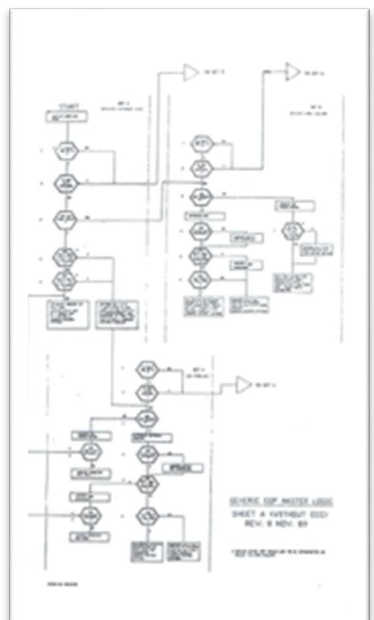
② **Symptom based procedures**
  - Strategies respond to any developing accident
  - Based on symptoms, deriving from the concept of recovery for critical safety function restoration.

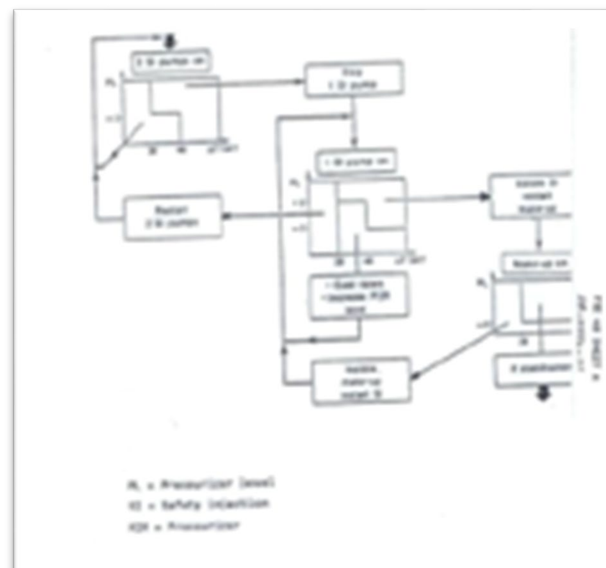
Overview (cont'd)

Format

- Sequential step list style :
- two column format style
- Flow Chart Format
- Block Diagram Format
- Logic Chart Format







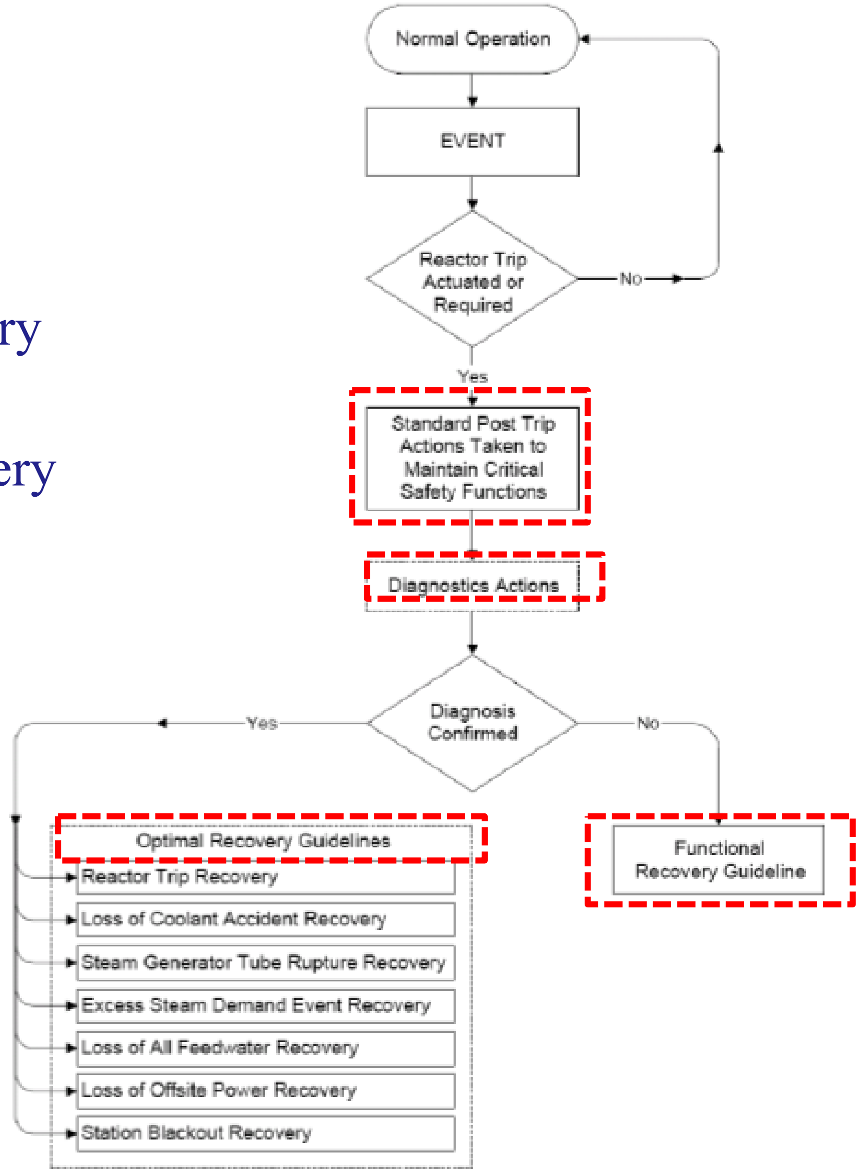
Strategy of EOP

① SPTA (Standard Post Trip Action)

→ ② DA (Diagnostic Action)

→ ③ ORG (Optimum Recovery Guideline)

→ ④ FRG (Functional Recovery Guideline)



(1) SPTA (Standard Post Trip Action) and DA(Diagnostic Action)

① SPTA

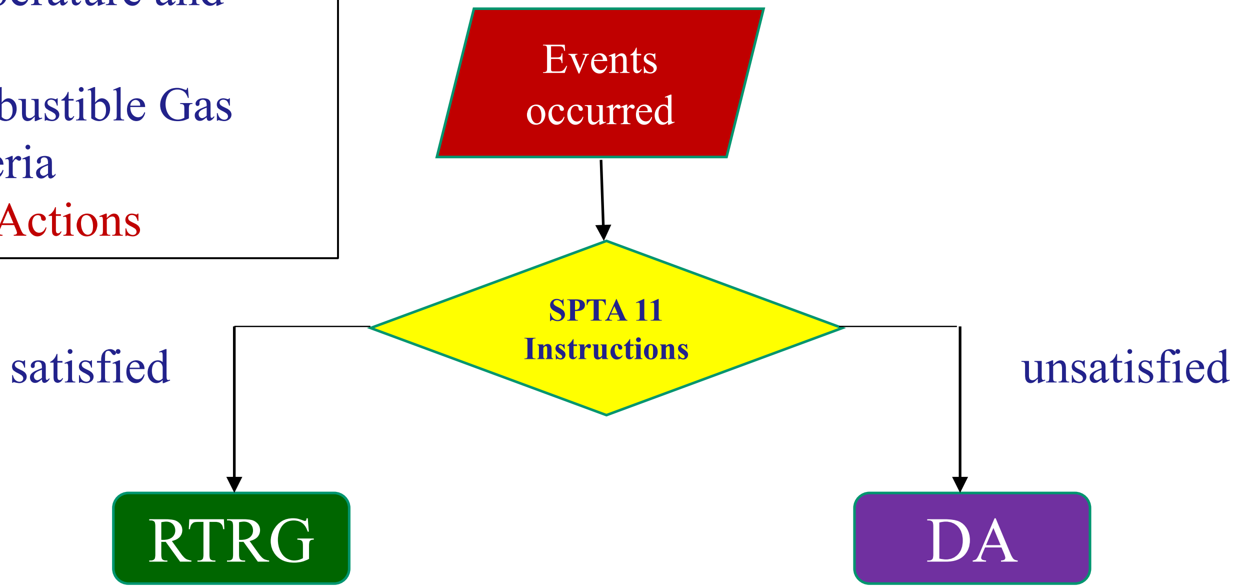
- Purpose
  - Check the safety functions against acceptance criteria
  - Restore the safety functions in jeopardy
- Safety Functions
  - Reactivity control
  - AC and DC electrical Power
  - RCS inventory control
  - RCS pressure control
  - Core heat removal
  - RCS heat removal
  - Containment isolation
  - Containment temperature and pressure control
  - Containment combustible gas control

① Contents of SPTA

11 Instructions;

Check the safety functions

1.Verify Reactivity Control
→ 2. Verify Maintenance of Vital Auxiliaries
→ 3. Verify RCS Inventory Control
→ 4. Verify RCS Pressure Control
→ 5. Verify Core Heat Removal
→ 6. Verify RCS Heat Removal
→ 7. Verify Containment Isolation
→ 8. Verify Containment Temperature and Pressure Control
→ 9. Verify Containment Combustible Gas Control → 10. SFSC Exit Criteria
→ 11. Direction to Diagnostic Actions



SPTA (1)

1. ENTRY CONDITIONS
   - when ANY of the following symptom(s) of a Reactor Trip exist:
     - Reactor trip alarm
     - [CEA] bottom lights on
     - Rapid drop in reactor power
     - Reactor trip circuit [breakers] open
     - RPS trip setpoint exceeded

SPTA (2)

2. Verify Safety Function

4.0 INSTRUCTIONS/CONTINGENCY ACTIONS

INSTRUCTIONS		CONTINGENCY ACTIONS
1. **Verify Reactivity Control {spta}**		
Determine that Reactivity Control acceptance criteria are met:		
a. Verify that Reactor Power is lowering.	a.1	Perform the following as necessary to insert CEAs: 1) Manually trip the reactor. 2) De-energize the [CEA motor generator]. 3) Open the reactor trip breakers.
b. [Verify that Startup Rate is negative.]		
c. Verify that no more than [one full length CEA] is **NOT** inserted.	c.1	Borate the RCS to achieve [adequate shutdown margin].

SPTA (3)

INSTRUCTIONS		CONTINGENCY ACTIONS
5.	**Verify Core Heat Removal {spta}**	
	Determine that the Core Heat Removal acceptance criteria are met:	
	a. Verify that at least one RCP is operating.	
	b. Verify that Loop delta T is less than [maximum expected shutdown delta T with forced circulation].	
	c. Verify that RCS subcooling is greater than or equal to [minimum RCS subcooling].	
6.	**Verify RCS Heat Removal {spta}**	
	Determine that the RCS Heat Removal acceptance criteria are met:	
	a. Verify that at least one Steam Generator has **BOTH** of the following conditions met: • Level within [expected post-trip band] • Feedwater is available to restore level to [normal control band]	a.1 Ensure that feedwater is restoring level in at least one Steam Generator to [normal control band].

SPTA (4)

INSTRUCTIONS		CONTINGENCY ACTIONS
7.	**Verify Containment Isolation {spta}** Determine that the Containment Isolation acceptance criteria are met:	
a.	Verify that containment pressure is less than [maximum expected normal containment pressure].	a.1 **IF** containment pressure is greater than [CIAS setpoint], **THEN** ensure CIAS is initiated.
b.	Verify NO containment area radiation monitor [alarms], or unexplained rise.	
c.	Verify NO steam plant activity monitor [alarms], or unexplained rise.	

SPTA (5)

3.0 EXIT CONDITIONS

Standard SPTAs may be exited in one of two possible ways:

1. **IF** all safety function acceptance criteria are met,

   AND NO contingency actions were performed,

   THEN GO TO Reactor Trip Recovery procedure.

2. **IF ANY** safety function acceptance criteria are **NOT** met,

   OR ANY contingency action was taken,

   THEN GO TO Diagnostic Actions Guideline to diagnose the event.

SPTA (6)

11. Direction to Diagnostic Actions.

INSTRUCTIONS	CONTINGENCY ACTIONS
11. **Direction to Diagnostic Actions {spta}** **IF** any Safety Function Acceptance Criteria are **NOT** met, **OR** any contingency action was taken, **THEN** diagnose the event. REFER TO Diagnostic Actions Guideline.	

End of Section 4.0

2. Emergency Operation Procedure (EOP)

(1) Strategy

(2) Optimal Recovery Guideline

(2) Functional Recovery Guideline

ORG (Optimal Recovery Guideline)

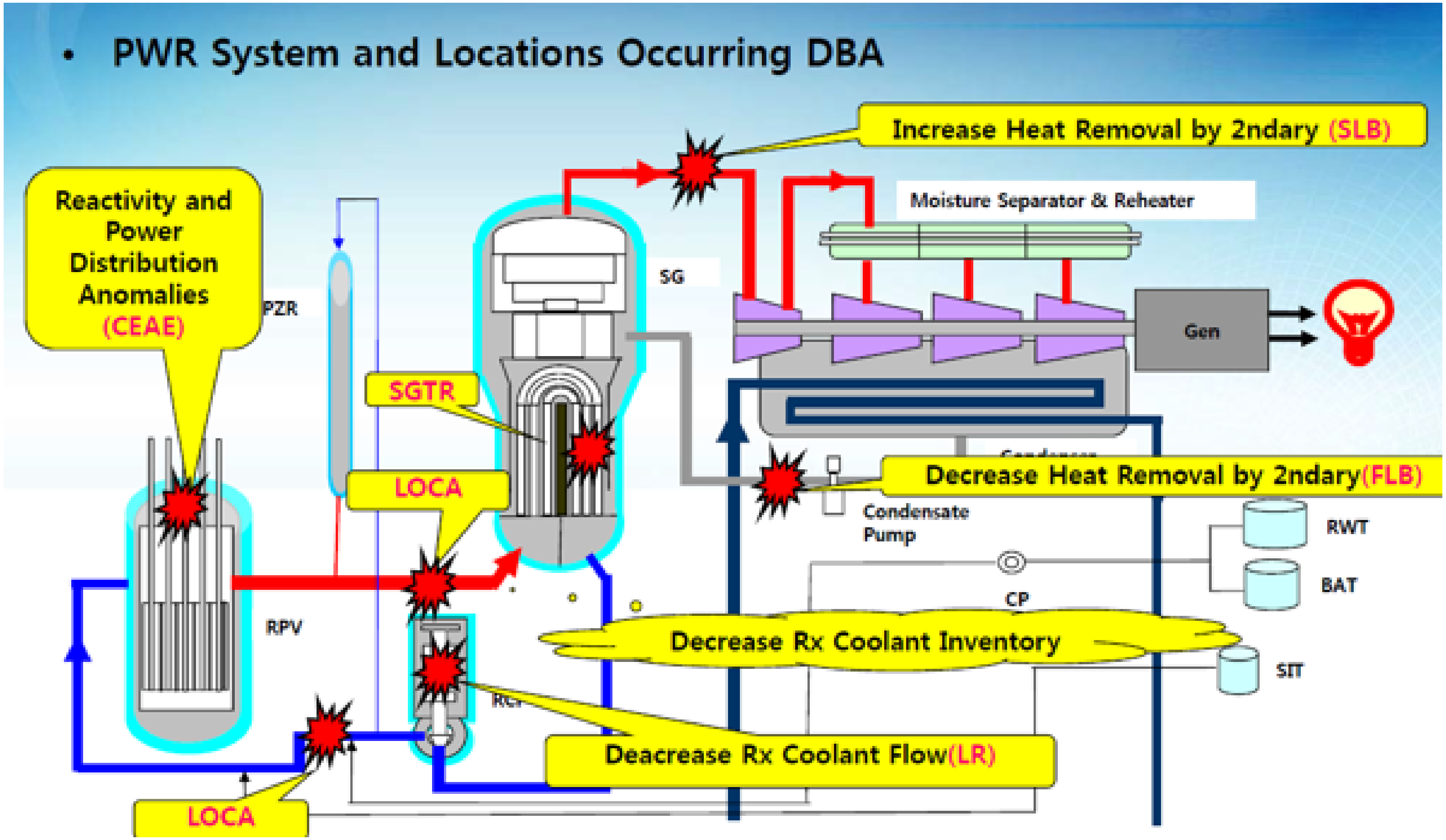
Purpose

- This guideline provides the operator actions which should be accomplished in the event.
- The actions in this guideline are necessary to ensure that the plant is placed in a stable, safe condition.

ORG (cont'd)

- **Grouped into 7 classes**
  1. Reactor Trip (RT) – Reactivity Induced Accidents
  2. Loss of Coolant Accident (LOCA) – Decrease in RCS Inventory
  3. Steam Generator Tube Rupture (SGTR) - Decrease in RCS Inventory and Containment Bypass
  4. Excess Steam Demand Event (ESDE) – Increase in heat removal through secondary side
  5. Loss of All Feedwater (LOAF) - Decrease in heat removal through secondary side
  6. Loss of Offsite Power (LOOP) – Decrease in RCS flow
  7. **Station Blackout (SBO) – Beyond Design Basis Accident**

Classification of Initiating Events



CEAE: Control Element Assembly Ejection
LOCA: Loss of Coolant Accident
SGTR: Steam Generator Tube Rupture
SLB: Steam Line Break
FLB: Feeder Line Break
LR: Reactor Coolant Pump Locked Roter

Case : SBO ORG

2.0 ENTRY CONDITIONS

IF a SBO is evident, as indicated by **ANY** of the following plant conditions:

- [Loss of control room lighting]
- Extensive loss of various indications

AND ONE of the following is true:

- The SPTA have been performed [Mode 1 or Mode 2]
- [SIAS has **NOT** been blocked] [Mode 3 or Mode 4]

THEN ENTER the SBO Recovery Guideline.

SBO ORG (cont'd)

3.0 EXIT CONDITIONS

1. The diagnosis of a Station Blackout is **NOT** confirmed.

   or

2. **ANY** of the Station Blackout Safety Function Status Check acceptance criteria are **NOT** satisfied.

   or

3. The Station Blackout guideline has accomplished its purpose by satisfying **ALL** of the following:
   - At least one vital [4.16 kV] electrical AC bus has been restored
   - All Safety Function status check acceptance criteria are being satisfied
   - An appropriate procedure, which has been provided and approved by the [Plant Technical Support Center or the Plant Operations Review Committee], can be implemented

SBO ORG (cont'd)

4.0 INSTRUCTIONS/CONTINGENCY ACTIONS

INSTRUCTIONS	CONTINGENCY ACTIONS
* 1. **Confirm Diagnosis {law1sbo}** Verify Safety Function Status Check Acceptance criteria are satisfied.	*.1 Re-diagnose the event and GO TO ONE of the following: • The appropriate Optimal Recovery Guideline • The Functional Recovery Guideline
* 2. **Classify the Event {law34sbo}** Ensure the Emergency Plan is implemented and the event is being classified.	
3. **Implement Placekeeping {law35sbo}** Open the placekeeper and note the time of the [event or EOP entry].	
4. **Protect Main Condenser {jc14sbo}** Isolate steam to the main condenser: [a. Ensure MSIVs are closed.] [b. Ensure steam generator blowdown is isolated.] [c. Ensure SG sampling is isolated.]	
* 5. **Minimize RCS Leakage {pk48sbo}** Minimize RCS leakage: a. Ensure letdown is isolated. [b. Ensure RCP controlled bleedoff is isolated.] c. Ensure RCS sampling is isolated	

* Continuously Applicable Step or Non-Sequential Step

INSTRUCTIONS	CONTINGENCY ACTIONS
* 6. **Ensure RCS temperature control {law21sbo}** Ensure RCS [Tave or Tcold] is less than [maximum expected post-trip temperature] **AND** controlled by operation of **ANY** of the following: • Atmospheric Dump Valves • Main Steam Safety Valves	
* 7. **Ensure SG Level being restored to Normal Control Band {law22sbo}** Ensure at least one steam generator has level being maintained or restored to the [normal control band].	
8. **Ensure De-energized Bus Breakers Open {law56sbo}** Ensure that all appropriate breakers on the de-energized buses [4.16 kV and 6.9 kV] are open.	
9. **Initiate AC Power restoration {pk25sbo}** Initiate actions to restore power to at least one vital [4.16kV] bus.	
10. **Reduce Battery Loads {sbo}** **IF** AC power has **NOT** been restored, **THEN** open supply breakers for all unnecessary DC loads.	

SBO ORG (cont'd)

INSTRUCTIONS	CONTINGENCY ACTIONS
* 11. **Ensure Equipment Ventilation {sbo}** **IF** AC power is **NOT** expected to be restored within [maximum required time], **THEN** ensure adequate ventilation or supplemental cooling is provided for all appropriate equipment.	
* 12. **Ensure Instrument Air {law48sbo}** [Ensure instrument air is available.]	
* 13. **Verify Single Phase Natural Circulation {pk21sbo}** Verify natural circulation flow in at least one loop by **ALL** of the following: • Loop delta T less than [normal full power delta T] • Hot and cold leg temperature constant or lowering • RCS subcooling greater than or equal to [minimum RCS subcooling] based on [representative] CET temperature • [NO abnormal difference] between Thot RTDs and [representative] CET temperature	13.1 Ensure proper control of steam generator feeding and steaming.
* 14. **Ensure Adequate Condensate Inventory {law6sbo}** Ensure the condensate inventory is greater than the minimum required. REFER TO Figure 13.14, Typical Feedwater capacity vs Time Remaining Until Shutdown Cooling and Figure 13.15, Typical Feedwater Required for Removal of Sensible Heat.	

INSTRUCTIONS	CONTINGENCY ACTIONS
15. **Maintain Subcooling w/SBO {pk27sbo}** **IF** AC power has **NOT** been restored, **THEN** perform a plant cooldown, as necessary, to maintain RCS subcooling within [allowable range of subcooling during SBO], based on [representative] CET temperature.	15.1 Ensure **BOTH** of the following conditions exist: • At least one steam generator has level being maintained or restored to [normal control band] • [Representative] CET temperature is [**NOT** superheated]
16. **Calculate Shutdown Margin w/SBO {pk29sbo}** At 50°F intervals, verify that the reactor will [remain shutdown] for 50°F less than indicated Tc and boron concentration at time of event initiation.	
17. **Stop Cooldown To Prevent Loss Of Reactivity Control w/SBO {pk30sbo}** **IF** the projected shutdown margin indicates that the reactor will **NOT** [remain shutdown], **THEN** stop the cooldown.	

SBO ORG (cont'd)

INSTRUCTIONS	CONTINGENCY ACTIONS
* 18. **Bypass automatic MSIS and SIAS Initiation {law12sbo}** As cooldown and depressurization proceed, lower or bypass automatic initiation setpoints: a. **IF** MSIS is **NOT** present, **THEN** lower or bypass the automatic initiation setpoint for MSIS. b. **IF** SIAS is **NOT** present, **THEN** lower or bypass the automatic initiation setpoint for SIAS.	
* # 19. **Restore Power w/SBO {pk31sbo}** **WHEN** at least one vital [4.16 kV] bus is energized, **THEN**: a. Ensure that vital [480 V, 240 V and 120 V] AC buses are energized. b. Restore power to at least one battery charger. c) Restore vital [125V] DC loads.	
* 20. **Restore vital equipment to service {pk32sbo}** Restore minimum required vital equipment to service, as necessary.	
* 21. **Borate the RCS {law27sbo}** Borate the RCS to maintain [adequate shutdown margin].	

INSTRUCTIONS	CONTINGENCY ACTIONS
22. **Ensure inventory control {law7sbo}** Ensure RCS inventory control is established by verifying **ALL** of the following: • Pressurizer level within [expected post-trip band], and can be controlled by charging [and letdown] • RCS subcooling greater than or equal to [minimum RCS subcooling] • Reactor vessel level greater than [top of hot the leg nozzles].	22.1 **IF** RCS inventory control is **NOT** established, **THEN**: a. Operate available charging pumps. b. Start HPSI pumps as necessary to ensure at least minimum SI flow within [SI flow delivery curves]. REFER TO Figure 13.13, Typical Acceptable SIS Flow versus RCS Pressure.

SBO ORG (cont'd)

INSTRUCTIONS	CONTINGENCY ACTIONS
23. **Maintain RCS within Post Accident PT Limits {pk7sbo}** Maintain the RCS less than the upper limits of the [Post Accident PT curves]: a. Operate main or auxiliary pressurizer sprays. b. **IF** HPSI throttle criteria are met, **THEN**: 1) Control charging and letdown. 2) Throttle HPSI flow as necessary.	23.1 **IF** the RCS is oversubcooled, **OR** pressurizer pressure exceeds the limits of [Post Accident PT curves], **THEN** take steps to restore subcooling or pressure to within the appropriate limit: a. Stop the cooldown. b. Depressurize the RCS using main or auxiliary pressurizer spray. c. **IF** HPSI throttle criteria are met, **THEN**: 1) Control charging and letdown. 2) Throttle HPSI flow as necessary. 23.2 **IF** the cooldown rate is greater than [Post Accident cooldown rate limit], **THEN** take steps to restore the cooldown rate to within its limit: a. Stop the cooldown as necessary. b. Maintain the plant in a stable pressure-temperature configuration. c. Continue the plant cooldown within [Post Accident cooldown rate limit].

INSTRUCTIONS	CONTINGENCY ACTIONS
* 24. **Ensure Operation of Ventilation Systems w/SBO {pk33sbo}** Ensure proper operation of **ALL** the following: • Containment ventilation fan coolers • Control room normal or emergency HVAC • Applicable building [HVAC] systems	
* 25. **Exit Blackout ORG {pk34sbo}** **WHEN** the Station Blackout exit conditions are satisfied, **THEN** exit this guideline and implement **ANY** of the following: • Loss of Offsite Power recovery guideline • An appropriate procedure as directed by the [Technical Support Center]	

The Station Blackout Recovery Guideline has accomplished its purpose if RCS conditions are being controlled in hot standby or hot shutdown, all of the SFSC acceptance criteria are being satisfied, and the entry conditions of an appropriate procedure are satisfied.

End of Section 4.0

Example: list of EOPs

E-0 Reactor Trip or Safety Injection

ES-0.0 Re-diagnosis
ES-0.1 Reactor Trip Response
ES-0.2 Natural Circulation Cooldown
ES-0.3 Natural Circulation Cooldown With Steam Void in Vessel

E-1 Less of Reactor or Secondary Coolant

ES-1.1 SI Termination
ES-1.2 Post-LOCA Cooldown and Depressurization
ES-1.3 Transfer to Cold Leg Recirculation
ES-1.4 Transfer to Hot Leg Recirculation

E-2 Faulted Steam Generator Isolation

E-3 Steam Generator Tube Rupture

ES-3.1 Post-SGTR Cooldown Using Backfill
ES-3.2 Post-SGTR Cooldown Using Blowdown
ES-3.3 Post-SGTR Cooldown Using Steam Dump

ECA-0.0 Loss of All AC Power (SBO)
ECA-0.1 Loss of All AC Power Recovery Without S.I. Required
ECA-0.2 Loss of All AC Power Recovery With S.I. Required
ECA-1.1 Loss of Emergency Coolant Recirculation
ECA-1.2 LOCA Outside Containment
ECA-2.1 Uncontrolled Depressurization

2. Emergency Operation Procedure (EOP)

(1) SPTA

(2) Optimal Recovery Guideline

(3) Functional Recovery Guideline

FRGs (Functional Recovery Guidelines)

Purpose

- This guideline provides operator actions for events in which a diagnosis is not possible, or for which an optimal recovery guideline is not sufficient.
- The actions of this guideline are necessary to ensure that the plant is placed in a stable, safe condition.

FRGs (cont'd)

- FRGs
  - 11 procedures have been developed.
    - Resources Assessment Tree (RAT)
    - Safety Functions Status Check (9 Functions)
      - Reactivity Control (RC)
      - Maintenance of Vital AC Power (MVA)
      - RCS Inventory Control (IC)
      - RCS Pressure Control (PC)
      - RCS and Core Heat Removal (HR)
      - Containment Isolation (CI)
      - Containment Temperature and Pressure Control (CTPC)
      - Containment Combustible Gas Control (CCGC)
      - Long Term Action (LTA)

FRGs (cont’d)

- Implemented in case an event cannot be diagnosed
- Checks safety functions against acceptance criteria
- Focuses on jeopardized safety functions to restore
- If CET (Core exit thermocouple temperature) exceeds 1200^{o}F, Operator terminate FRGs and start SAMGs.

Case : FRG (1)

2.0 ENTRY CONDITIONS of FRG

IF a FRG event is evident, as indicated by **ANY** of the following plant conditions:

ANY condition, or pattern of symptoms, for which abnormal or emergency guidance can **NOT** be identified

Actions taken in an Optimal Recovery Guideline are **NOT** satisfying the acceptance criteria in the Safety Function Status Check

Multiple events are in progress

AND ONE of the following is true:

The SPTA have been performed [Mode 1 or Mode 2]

[SIAS has NOT been blocked] [Mode 3 or Mode 4]

THEN ENTER the Functional Recovery Guideline.

Case : FRG (cont'd)

3.0 EXIT CONDITIONS of FRG

1. The acceptance criteria for <u>all success paths in use are being satisfied</u>.

   and

2. <u>An appropriate, approved procedure to implement exists </u>[or has been approved by the Plant Technical Support Center or the Plant Operations Review Committee].

Case : FRG (cont'd)

4.0 ENTRY PROCEDURE INSTRUCTIONS/CONTINGENCY ACTIONS

INSTRUCTIONS	CONTINGENCY ACTIONS
* 1. **Classify Event {law34locaentry}** Ensure the Emergency Plan is implemented and the event is being classified.	
2. **Implement Placekeeping {law35locaentry}** Open the placekeeper and note time of the [event or EOP entry].	
* 3. **RCP Trip Strategy {pk12locaentry}** **IF** pressurizer pressure is less than [SBLOCA plateau pressure], **AND** SIAS is actuated, **THEN**: a. Ensure **ONE** RCP in each loop is stopped. b. **IF** RCS subcooling is less than [minimum RCS subcooling], **THEN** ensure all RCPs are stopped.	
* 4. **Verify RCP Operating Limits {pk19locaentry}** **IF** RCPs are operating, **THEN** verify RCP operating limits are satisfied.	4.1 Stop RCPs which do **NOT** satisfy RCP operating limits.
5. **Sample steam generators {entry}** Sample both steam generators for activity and boron.	

INSTRUCTIONS	CONTINGENCY ACTIONS
6. **Place hydrogen monitors in service {pk42locaentry}** Relocated to CTPC Step 2A per CR 5048.	
* 7. **Identify Success Paths to be used {entry}** Identify success path(s) to be used to satisfy each safety function. REFER TO Figures 11-8 through 11-15, Resource Assessment Trees.	
* 8. **Perform Safety Function Status Checks for the selected Success Paths {entry}** Perform the Safety Function Status Checks. REFER TO Section 5.0, Safety Function Status Checks.	
* 9. **Perform Operator Instructions for each success path {entry}** Perform **ALL** the following in the order listed: • Instructions for success paths for safety functions that are in jeopardy are the first priority. • Instructions for success paths for safety functions that are challenged are second priority. • Instructions for all other success paths for safety functions are third priority.	

KINS

Case : FRG (5)

INSTRUCTIONS	CONTINGENCY ACTIONS
10. **Implement Long Term Actions {entry}**	
WHEN all Safety Function Status Check acceptance criteria are being satisfied, **THEN** PERFORM Long Term Actions. REFER TO Section 14.	

End of Section 4.0

10. Implement Long Term

Example: list of EOPs

F-0 The Critical Safety Function Status Trees

FR-S.1 Response to Nuclear' Power Generation /ATWS
FR-S.2 Response to Loss of Core Shutdown

FR-C.1 Response to Inadequate Core Cooling
FR-C.2 Response to Degraded Core Cooling
FR-C.3 Response to Saturated Core Cooling Condition

FR-H.1 Response to Loss of Secondary Heat Sink
FR-H.2 Response to Steam Generator Overpressure
FR-H.3 Response to Steam Generator High Level
FR-H.4 Response to Loss of Normal Steam Release Capabilities
FR-H.5 Response to Steam Generator Low Level

FR-P.1 Response to Imminent Pressurized Thermal Shock Conditions
FR-P.2 Response to Anticipated Pressurized Thermal Shock Conditions

FR-Z.1 Response to High Containment Pressure
FR-Z.2 Response to Containment Flooding
FR-Z.3 Response to High Containment Radiation Level

FR-I.1 Response to High Pressurizer Level
FR-I.2 Response to Low Pressurizer Level
FR-I.3 Response to Voids in Reactor Vessel

3. Severe Accident Management Guideline (SAMG)

(1) Overview of SAMG

(2) Technical Basis of SAMG

(2) Improvements since Fukushima

Overview of SAMGs

- Objectives of SAMG
  - return the core to a controlled, stable state
  - terminate fission product releases
  - maintain or return the containment to a controlled, stable state
- Principles of W SAMG
  - fully symptom based
  - does not require diagnosis of previous event progression
  - uses existing plant components and instrumentation
  - used by Technical Support Center (TSC)
  - enters when core damage begins
  - takes over from EOPs at core damage - no simultaneous use
  - exit when controlled stable state reached

Overview of WOG SAMG

Control Room

Severe Accident Control Room Guideline (**SACRG-1**) Initial Response

Severe Accident Control Room Guideline (**SACRG-2**) for Transients after the TSC is Functional

Technical Support Center

Diagnostic Flow Chart (DFC)

Severe Challenge Status Tree (SCST)

Severe Accident Guidelines

- SAG-1, - SAG-2, - SAG-3
- SAG-4, - SAG-5, - SAG-6
- SAG-7, - SAG-8

Severe Challenge Guidelines

- SCG-1
- SCG-2
- SCG-3
- SCG-4

Graphical Computation Aids

SAEG-1
TSC Long Term Monitoring Activities

SAEG-2
SAMG Termination

WOG : Westinghouse Owners Group

Korean SAMG

Westinghouse SAMG			KSNP/Kori 1 SAMG	
MCR	SACRG-1	Severe Accident Control Room Guildeline Initial Response	Emergency-01	Severe Accident Control Room Guildeline Initial Response
	SACRG-2	Severe Accident Control Room Guildeline For Transients After The TSC Is Functional		
TSC	SAG-1	Inject into the Steam Generator	Mitigation-01	Inject into the Steam Generator
	SAG-2	Depressurize the RCS	Mitigation-02	Depressurize the RCS
	SAG-3	Inject into the RCS	Mitigation-03	Inject into the RCS

Korean SAMG (cont'd)

Westinghouse SAMG			KSNP/Kori 1 SAMG	
TSC	SAG-4	Inject into Containment	Mitigation-04	Inject into Containment
	SAG-5	Reduce Fission Product Releases	Mitigation-05	Reduce Fission Product Releases
	SAG-6	Control Containment Conditions	Mitigation-06	Control of CV Condition
	SAG-7	Reduce Containment Hydrogen	Mitigation-07	Control of CV Hydrogen
	SAG-8	Flood Containment	N/A	For Ice Condenser Type
TSC	SCG-2	Depressurize Containment	N/A	For CFVS
	SCG-3	Control Hydrogen Flammability	N/A	Already considered in mitigation-07, Major action is the inerting process
	SCG-4	Control Containment Vacuum	N/A	For sub atmospheric containment
CAs	CA-1	RCS Injection to Recover Core	CA-01	Injection Rate For Long Term Decay Heat Removal
	CA-2	Injection Rate For Long Term Decay Hert Removal	CA-02	Hydrogen Flammability in CV

SAMG: Using US Methodology

Country	Plant	Type	SAMG Approach	Status
Belgium	Tihange Doel (some units)	PWR (W / Fra) PWR (W / Fra)	WOG WOG	Implemented Implemented
Netherlands	Borssele	PWR (Siemens)	WOG	Implemented
Spain	Vandellos Asco Almaraz Cofrentes	PWR (W) BWR	WOG BWROG	In progress In progress
Switzerland	Beznau Leibstadt	PWR (W) BWR (GE)	WOG BWROG	Implemented In planning
Sweden	Ringhals	PWR (W)	WOG	In progress (Mblacing BERG)
UK	Sizewell	PWR (W)	WOG - based	Implemented
South Africa	Koeberg	PWR (Fra)	WOG	Implemented
Slovenia	Krsko	PWR (W)	WOG	Implemented

Overview of WOG SAMG

Control Room

Severe Accident Control Room Guideline (**SACRG-1**) Initial Response

Severe Accident Control Room Guideline (**SACRG-2**) for Transients after the TSC is Functional

Technical Support Center

Diagnostic Flow Chart (DFC)

Severe Challenge Status Tree (SCST)

Severe Accident Guidelines

- SAG-1, - SAG-2, - SAG-3
- SAG-4, - SAG-5, - SAG-6
- SAG-7, - SAG-8

Severe Challenge Guidelines

- SCG-1
- SCG-2
- SCG-3
- SCG-4

Graphical Computation Aids

SAEG-1
TSC Long Term Monitoring Activities

SAEG-2
SAMG Termination

WOG : Westinghouse Owners Group

(1) Severe Accident Control Room Guidelines

- SACRG-1 Severe Accident Control Room Guideline Initial Response
  - use by control room staff until the TSC is functional and ready
  - limited to considerations and actions until TSC is staffed
- SACRG-2 Severe Accident Control Room Guideline for Transients After the TSC is Functional
  - Use by CR when the TSC is operated after core damage has occurred
  - purpose is to enhance communication between the CR and the TSC

STEP	ACTION/EXPECTED RESPONSE	RESPONSE NOT OBTAINED

Entry Conditions

This guideline is entered when [core exit thermocouple temperature is GREATER THAN 1200°F and actions to cool the core are not successful.][W,C] [fuel clad temperature is GREATER THAN OR EQUAL TO 1800°F.][B] The following procedures contain a transition to this guideline:

- [ECA-0.0][W]
- [FR-S.1][W]
- [FR-C.1][W]
- [SBCRG][W]
- [ARG-4][W]
- [EOP][C,B]

This guideline is entered when [plant specific indication that fuel damage has begun or actions in the abnormal operating procedure have not been successful.] The following procedures contain a transition to this guideline:

- [plant specific spent fuel pool abnormal operating procedures]

Transition to this guideline may also be made from other guidelines and procedures where a unique criteria for transition is not included, based on discretion of the licensed operators, including:

- [Extensive Damage Mitigation Guidelines]
- [plant specific shutdown procedures]
- [plant specific fire abnormal operating procedures]
- [sump blockage guidelines]

(2) SAGs Severe Accident Guidelines

- SAG-1 Inject into the Steam Generators
- SAG-2 Depressurize the RCS
- SAG-3 Inject into the RCS
- SAG-4 Inject into Containment
- SAG-5 Reduce Fission Product Releases
- SAG-6 Control Containment Conditions
- SAG-7 Reduce Containment Hydrogen
- SAG-8 Flood Containment

Notes

- The following guidance represents mitigation strategies based on previous events, extended analysis, and expected severe accident phenomena. The user may deviate from this guidance based on actual plant conditions. Additional information for deviating from this guidance is provided in the Supplemental Information sections and in TSG-4, BENEFIT CONSEQUENCE, Attachment A.
- The importance of SAG-3 may be impacted by plant states such as the reactor vessel head off or vents open, since the benefits of injecting into the SGs would be limited in those cases.
- TSG-1, INSTRUMENTATION, provides additional guidance for identifying alternate means of measuring or inferring a plant parameter or if confirmation of an indicated parameter is desired.

Entry Conditions

- [Steam generator level LESS THAN [Le01] (Orange)]^{W,C}
- Steam generator level LESS THAN [Le05]^{W,C} [Le04]^{B} (Yellow)

Purpose

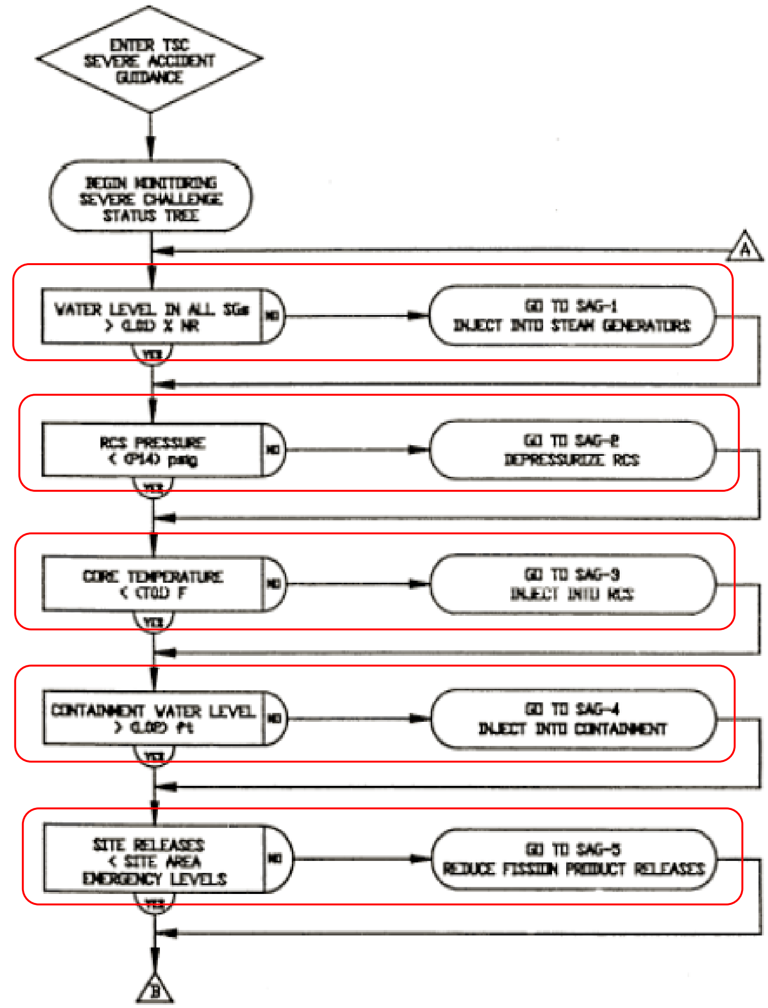
- To protect the steam generator tubes from creep rupture
- To provide a heat sink for the RCS
- To scrub fission products that enter the steam generators via tube leakage

(3) Diagnostic Flow Chart (DFC)

- Monitors key plant parameters
  - SG water level
  - RCS pressure
  - core temperature
  - containment water level
  - FP release
  - containment pressure
  - hydrogen concentration

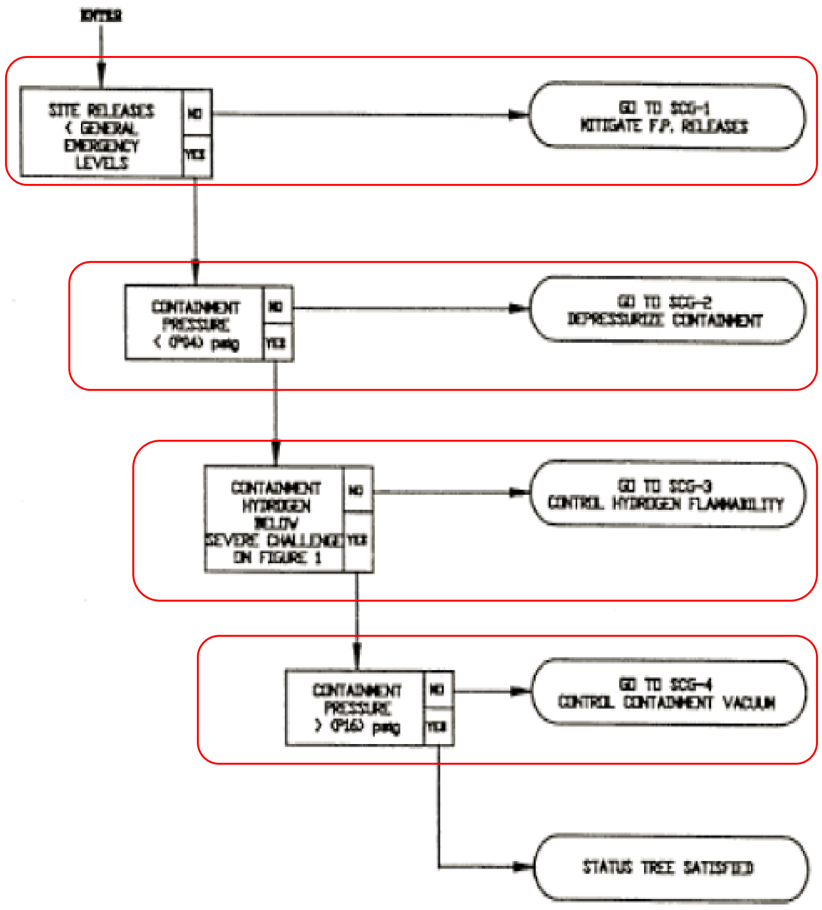
- If parameters are outside the range of stable controlled state, TSC is directed to the SAGs to implement the strategies

  - SAG-1 Inject into the Steam Generators
  - SAG-2 Depressurize the RCS
  - SAG-3 Inject into the RCS
  - SAG-4 Inject into Containment
  - SAG-5 Reduce Fission Product Releases
  - SAG-6 Control Containment Conditions
  - SAG-7 Reduce Containment Hydrogen
  - SAG-8 Flood Containment



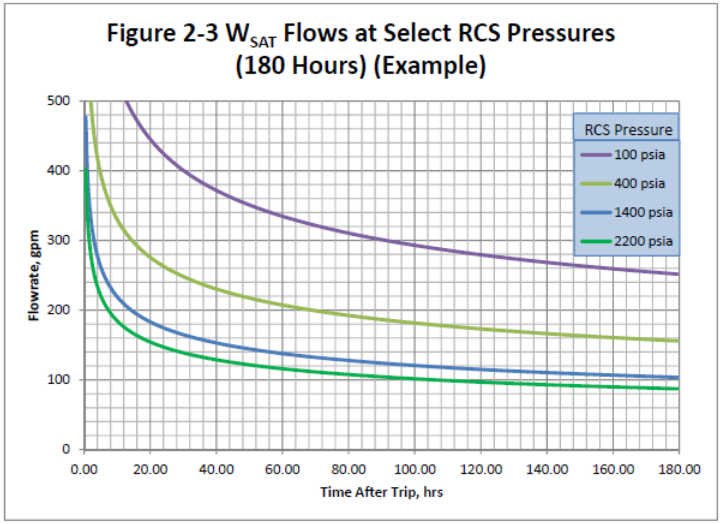
(4) Severe Challenge Status Tree (SCST)

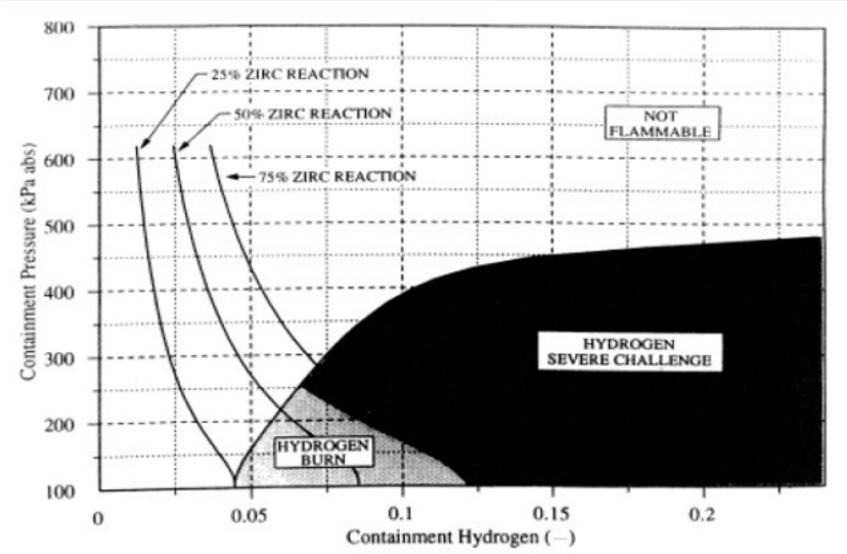
- Monitors key plat state
  - State exceed the set point, all other actions are stopped and the SCGs should be implemented
  - Key parameters monitored are
    - FP release
    - containment pressure
    - containment hydrogen



(5) CAs Computational Aids

- CA-1 RCS Injection to Recover Core
- **CA-2 Injection Rate for Long Term Decay Heat Removal**
- CA-3 Hydrogen Flammability in Containment
- CA-4 Volumetric Release Rate from Vent
- CA-5 Containment Water Level and Volume
- CA-6 RWST Gravity Drain
- CA-7 Hydrogen Impact when Depressurizing Containment



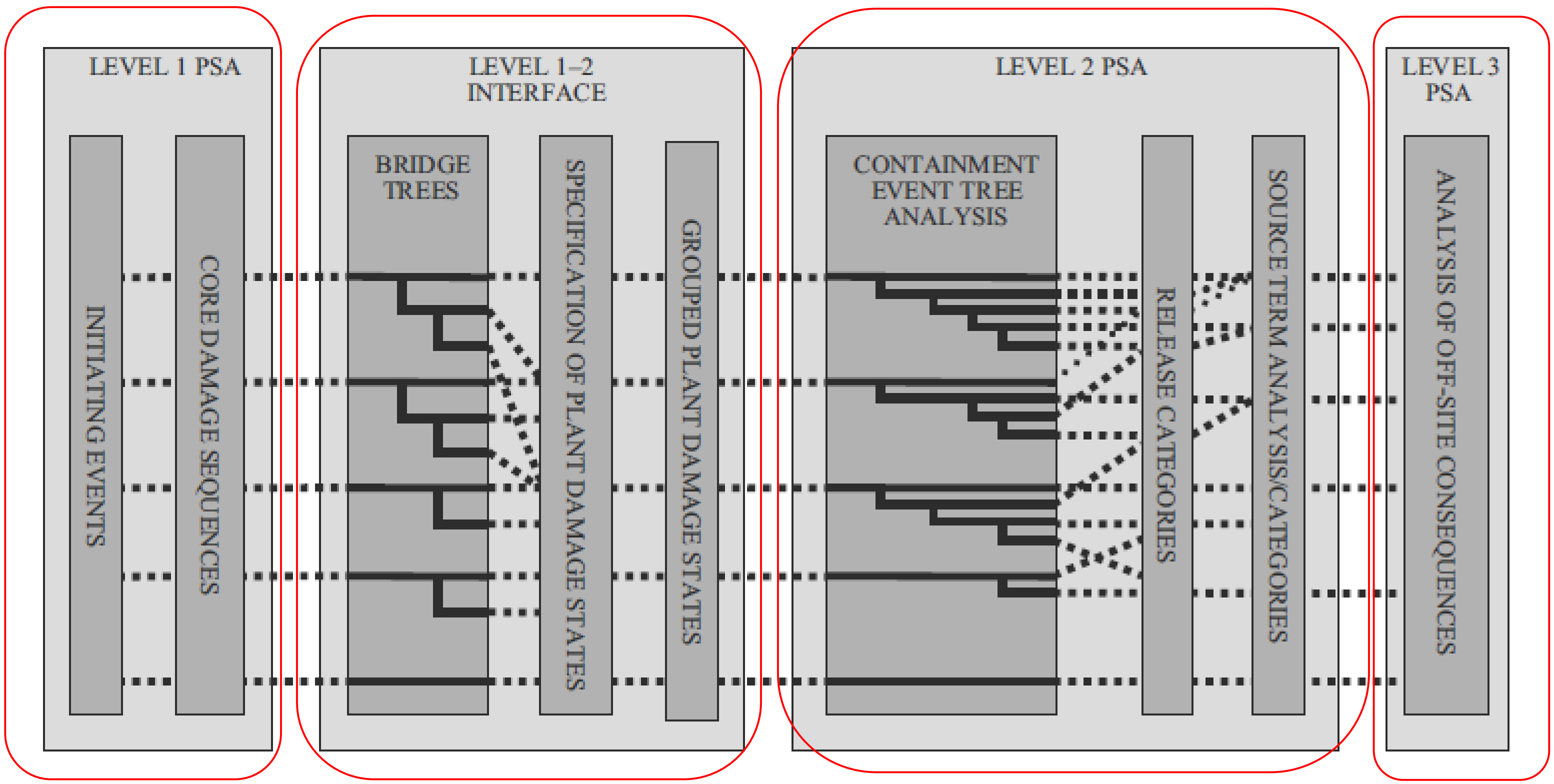


2. Technical Basis of SAMG

Identification of accident sequences leading to core damage

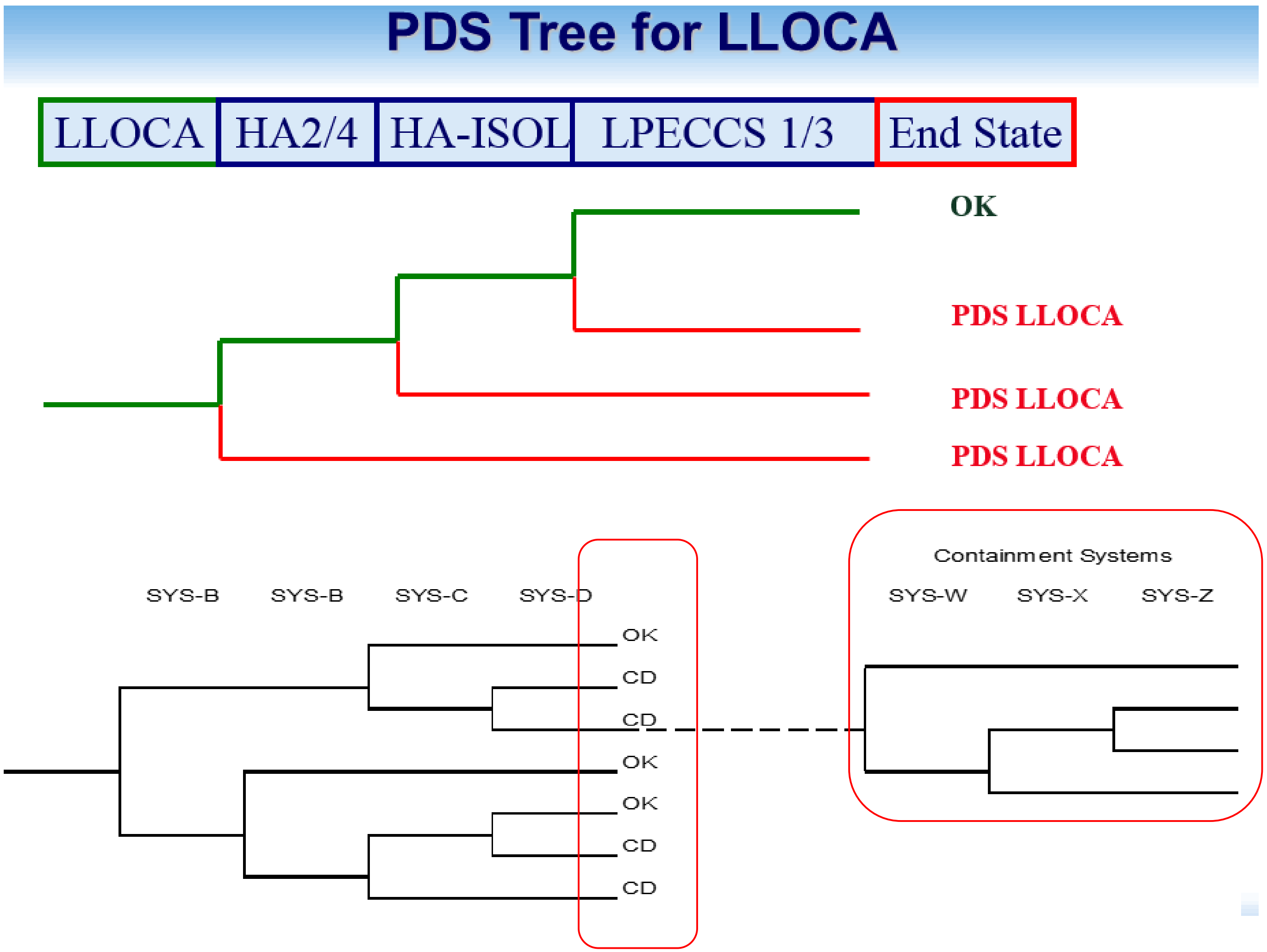
- Level 1 PSA provides information on the accident sequences that lead to core damage.
- Level 2 PSA provides the progression of severe accidents and to identify plant specific challenges and vulnerabilities of the containment
- Containment event tree analysis is where the accident progression is modelled to identify the accident sequences that lead to challenges to the containment and releases of radioactive material to the environment

Identification of accident sequences leading to core damage (cont'd)



Difficult to identify plant specific challenges and vulnerabilities of the containment

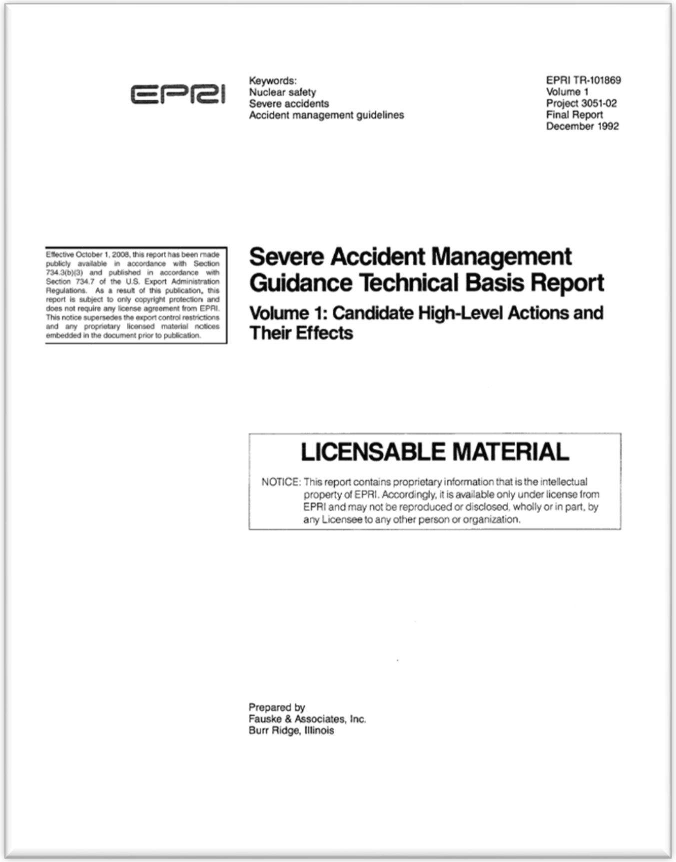
Identification of accident sequences leading to core damage (cont'd)



Identification of accident sequences leading to core damage (cont'd)

EPRI Technical Basis Report (PBR)

- Describes:
  - potential damage states
  - potential AM actions
  - impacts of potential actions
  - physics of severe accident processes
- Describes benefits & negative impacts of each potential action for each damage state combination


EPRI

Keywords:
Nuclear safety
Severe accidents
Accident management guidelines

EPRI TR-101869
Volume 1
Project 3051-02
Final Report
December 1992

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Severe Accident Management Guidance Technical Basis Report

Volume 1: Candidate High-Level Actions and Their Effects

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Identification of accident sequences leading to core damage (cont'd)

EPRI TBR (continued)

Conditions	CC	CH	I	B
BD	BD/CC	BD/CH	BD/I	BD/B
EX	EX/CC	EX/CH	EX/I	EX/B

EXAMPLE OF A MATRIX OF PLANT DAMAGE STATES

Damage States:

- RCS:
  - OX – oxidised fuel
  - BD – badly damaged fuel
  - EX – core ex-vessel
- Containment:
  - CC – closed and cooled
  - CH – challenged
  - I – impaired
  - B – bypassed

Overview of Candidate High Level Actions

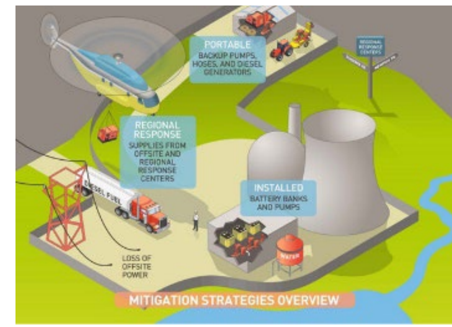
No	Candidate High Level Action
1	Inject into (makeup to) reactor pressure vessel/reactor coolant system
2	Depressurize the RPV/RCS
3	Depressurize steam generators
4	Inject into (feed) the steam generators
5	Spray into containment
6	Inject into containment
7	Operate fan coolers
8	Operate recombiners
9	Operate igniters
10	Vent the primary containment
11	Spray the secondary containment
12	Flood the secondary containmen

SAG-1 Inject into the Steam Generators
SAG-2 Depressurize the RCS
SAG-3 Inject into the RCS
SAG-4 Inject into Containment
SAG-5 Reduce Fission Product Releases
SAG-6 Control Containment Conditions
SAG-7 Reduce Containment Hydrogen
SAG-8 Flood Containment

3. Improvements since Fukushima

Addressing Fukushima Lessons Learned

- Extended Station Blackout
  - Implementation of FLEX and corresponding FLEX Support Guidelines (FSG)



- Loss of instrumentation and control
  - FSG-7 and SACRG-0.0 for loss of d.c.
- One unit was in shutdown – no SAMG for shutdown
  - Extension of generic SAMG to cover shutdown states (PSC-1081)
- Spent Fuel Pool cooling was lost – no SAMG for SFP cooling
  - FSG and FLEX equipment to makeup to SFP
  - Extension of generic SAMG to cover spent fuel pool accidents

Addressing Fukushima Lessons Learned (cont'd)

- Use of seawater – potential precipitation issues
  - EPRI TBR update and WOG SAMG rev. 2 guidance
- Multi-unit accident
  - TSGs for Decision Maker
  - N+1 FLEX equipment
- Site disruption – TSC unavailable/late
  - Restructuring of control room SAGs – some actions systematic by operators
  - EDMG for loss of command and control

WOG/PWROG SAMG Comparison

SACRGs	**Severe Accident Control Room Guidelines**		
SACRG-1	Severe Accident Control Room Guideline Initial Response		
SACRG-2	Severe Accident Control Room Guideline for Transients After the TSC is Functional		
DFC	**TSC Diagnostic Flow Chart**		
SAGs	**Severe Accident Guidelines**	SAG-1	Inject into the Steam Generators
		SAG-2	Depressurize the RCS
		SAG-3	Inject into the RCS
		SAG-4	Inject into Containment
		SAG-5	Reduce Fission Product Releases
		SAG-6	Control Containment Conditions
		SAG-7	Reduce Containment Hydrogen
		SAG-8	Flood Containment
SCST	**TSC Severe Challenge Status Tree**		
SCGs	Severe Challenge Guidelines	SCG-1	Mitigate Fission Product Releases
		SCG-2	Depressurize Containment
		SCG-3	Control Hydrogen Flammability
		SCG-4	Control Containment Vacuum
SAEGs	**Severe Accident Exit Guidelines**	SAEG-1	TSC Long Term Monitoring Activities
		SAEG-2	SAMG Termination
CAs	**Computational Aids**	CA-1	RCS Injection to Recover Core
		CA-2	Injection Rate for Long Term Decay Heat Removal
		CA-3	Hydrogen Flammability in Containment
		CA-4	Volumetric Release Rate from Vent
		CA-5	Containment Water Level and Volume
		CA-6	RWST Gravity Drain
		CA-7	Hydrogen Impact when Depressurizing Containment

WOG SAMG Rev. 0
1994

Figure 1: Main Components of the PWROG SAMG (DRAFT)

Control Room

- SAG-1 : Initial Response
- SAG-2 : TSC Recommending Strategies

Technical Support Center

- DPG – Diagnostic Process Guideline
  - SAG-3 : Inject into SGs
  - SAG-4 : Depressurize RCS
  - SAG-5 : Inject into RCS
  - SAG-6 : Inject into Containment
  - SAG-7 : Reduce Containment Hydrogen
  - SAG-8 : Control Containment Pressure
  - SAG-9 : Mitigate Fission Product Release
  - SAG-10 : Control SFP Level (independent entry possible)

- TSG-1: Instrumentation
- TSG-2: Decision Maker Guideline (UDM/SED)
- TSG-3: Site Capabilities
- TSG-4: Benefit Consequence Information
- TSG-5: Calculational Aids
  - CA-1 Injection Rate to Recover the Core
  - CA-2 Injection Rate for Long Term Decay Heat Removal
  - CA-3 Hydrogen Flammability in Containment
  - CA-4 Volumetric Release Rate from Vent
  - CA-5 Containment Water Level
  - CA-6 [RWST/BWST] Draindown
  - CA-7 Spent Fuel Pool

PWROG SAMG
Rev. 0 (draft)
2015

4. Concluding remarks

Concluding remarks (Recapping)

This lecture shares on the *Accident Management*

- Concept of Accident Management
- Emergency Operation Procedure (EOP)
  - Over view
  - Strategy
  - Functional Recovery Guidelines
  - Case: Station Blackout ORG
- Severe Accident Management Guidelines (SAMG)
  - Severe Accident Management Guidelines
  - Technical Basis
  - Improvements since Fukushima

Concluding remarks

- The objectives of accident management are:
  - Prevention of the accident from leading to core damage;
  - Termination of the progression of core damage once it has started;
  - Maintaining the capability of the containment for a long as possible;
  - Minimizing on-site and off-site radioactivity releases and their consequences; and
  - Returning the plant to a long-term controlled and safe state, ensuring subcriticality, core cooling and containment integrity.
- To achieve the objectives, operating staffs use the emergency operating procedures (EOPs) and severe accident management guidelines (SAMGs), to achieve accident management objectives.
- Following Fukushima, PWROG programs were revised SAMGs and provides for a comprehensive accident management capability.

Concluding remarks (Recapping)

Lectures also shares on the *Safety Analysis*

1. Introduction of Safety Analysis: DSA
   1) Purpose
   2) Safety Requirements
   3) Analysis in the Plate Sates
2. Safety analysis approaches
   1) Classification of Initiating Events (IEs)
   2) Overview of Deterministic Safety Analysis
   3) Acceptance Criteria for DBAs
   4) Verification and Validation of Codes

Concluding remarks (Recapping)

Lecture also shares on the *Severe Accident Analysis*

1. Experiences of severe accident
2. Concept of core degradation events
3. Safety accident phenomena
    1) In-vessel phenomena
    2) Ex-vessel phenomena
    3) Hydrogen combustion

Concluding remarks (Recapping)

Lecture also shares on the *Safety approach and engineering aspects*

1. Safety approach
   1) Defence-in-depth and multiple barriers
   2) Safety margin
2. Engineering aspects
   1) Proven engineering practices
   2) Engineering Design Rules
   3) Safety function
      - Redundancy
      - Diversity
      - Fail-safe design
      - Physical separation and independence of safety systems
   4) Single Failure Criteria
   5) Safety classification
   6) Equipment qualification

Thanks and all the best!

I wish you all the best for staying in Korea and hope every days will bring you happy memories when you get back home!

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