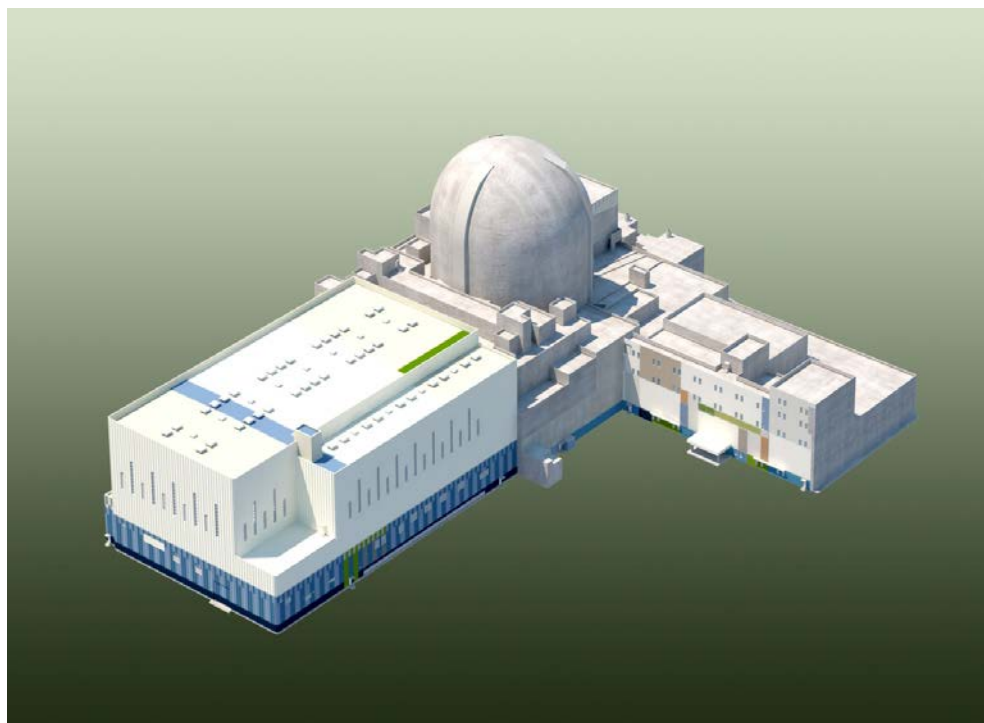


# APR1400 Mitigation Strategies for Beyond Design Basis External Event



**KEPCO/KHNP**  
**Apr. 20~21. 2016**

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# 1. Introduction

# 1. Introduction

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## □ NRC guidance

- SECY 11-0093 (NTTF Recommendations, 7/12/2011)
- SECY 11-0137 (Prioritization of Recommended Actions, 10/03/2011)
- NRC Order EA-12-049 (Mitigation Strategies for BDBEE, 03/12/2012)
- NRC Order EA-12-051 (Reliable SFP Instrumentation, 03/12/2012)
- NEI 12-06 (FLEX Implementation Guide, 08/21/2012)
- JLD-ISG-2012-01(Final endorsement of NEI 12-06)

# 1. Introduction

## □ Tier 1 Recommendations

- 2.1 - Seismic and flood hazard reevaluations (Request for Information (RFI))
- 2.3 - Seismic and flood walk-downs (RFI)
- 4.1 - Station blackout regulatory actions (Rulemaking)
- 4.2 - Mitigating strategies for beyond design basis events (Order)
- 5.1 - Reliable hardened vents for Mark I and Mark II containments
- 7.1 - Spent fuel pool instrumentation (Order)
- 8 - Strengthening and integration of emergency operating procedures, severe accident management guidelines, and extensive damage mitigation guidelines (Rulemaking)
- 9.3 - Emergency preparedness regulatory actions (RFI -staffing and communications)

**\* Applicable to new reactors : 2.1, 4.2, 7.1, 8, 9.3**

**\* Applicable to DC applicants : 4.2, 7.1**

# 1. Introduction

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## □ Three Phases Coping Approach

**(per order EA-12-049 and JLD-ISG-2012-01)**

- Phase 1 (Initial): requires the use of installed equipment and resources to maintain or restore core cooling, containment, and spent fuel pool (SFP) cooling capabilities
- Phase 2 (Transition): requires providing sufficient, portable, onsite equipment and consumables to maintain or restore these functions until they can be accomplished with resources brought from off site.
- Phase 3 (Final): requires obtaining sufficient offsite resources to sustain those functions indefinitely

# 1. Introduction

## □ Phased Approach for all operation modes

Operation Mode \ Coping Period	Phase 1 (initial)	Phase 2 (transition)	Phase 3 (final)
<b>Core cooling with SGs available</b> Mode 1,2,3,4,5 Representative case : full power	<ul style="list-style-type: none"> <li>● Installed equipment &amp; resources</li> <li>● C1E DC(125V) available</li> </ul>	<ul style="list-style-type: none"> <li>● Installed + on-site equipment &amp; resources</li> <li>● A train of low voltage C1E buses is restored by a portable GTG (480V)</li> </ul>	<ul style="list-style-type: none"> <li>● Installed + on-site + off-site equipment &amp; resources</li> <li>● A train of high voltage C1E buses is restored by a portable GTG (4.16kV)</li> </ul>
<b>Core cooling with SGs not available</b> Mode 5,6 Representative case : mid-loop	<ul style="list-style-type: none"> <li>● Minimum operator actions</li> </ul>	<ul style="list-style-type: none"> <li>● Primary &amp; secondary portable pumps are used (if necessary)</li> </ul>	

## 2. Strategy for Core Cooling (full power)



## 2. Strategy for Core Cooling (full power)

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### □ Strategy Summary

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## 2. Strategy for Core Cooling (full power)

### □ Phase 1 (0 - 8 hrs)

- Primary :
  - Natural Circulation Cooling (NCC) operation
  - RCP seal assumption : 25 gpm/RCP
- Secondary :
  - Turbine Driven Auxiliary Feedwater Pump control (automatic)
    - Control valves and instruments are powered by C1E 125V DC
- Preparations for Phase 2
  - Install a low voltage portable GTG to class 1E (480V) AC bus Train A or B
  - Open ACP room doors & Prepare to start ACP to inject cooling water to RCP seal
  - Install a high head portable pump to external injection line (primary)
  - Install two portable pumps to external injection line (secondary)

## 2. Strategy for Core Cooling (full power)

ACRS Meeting (Apr.20-21. 2016)

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## 2. Strategy for Core Cooling (full power)

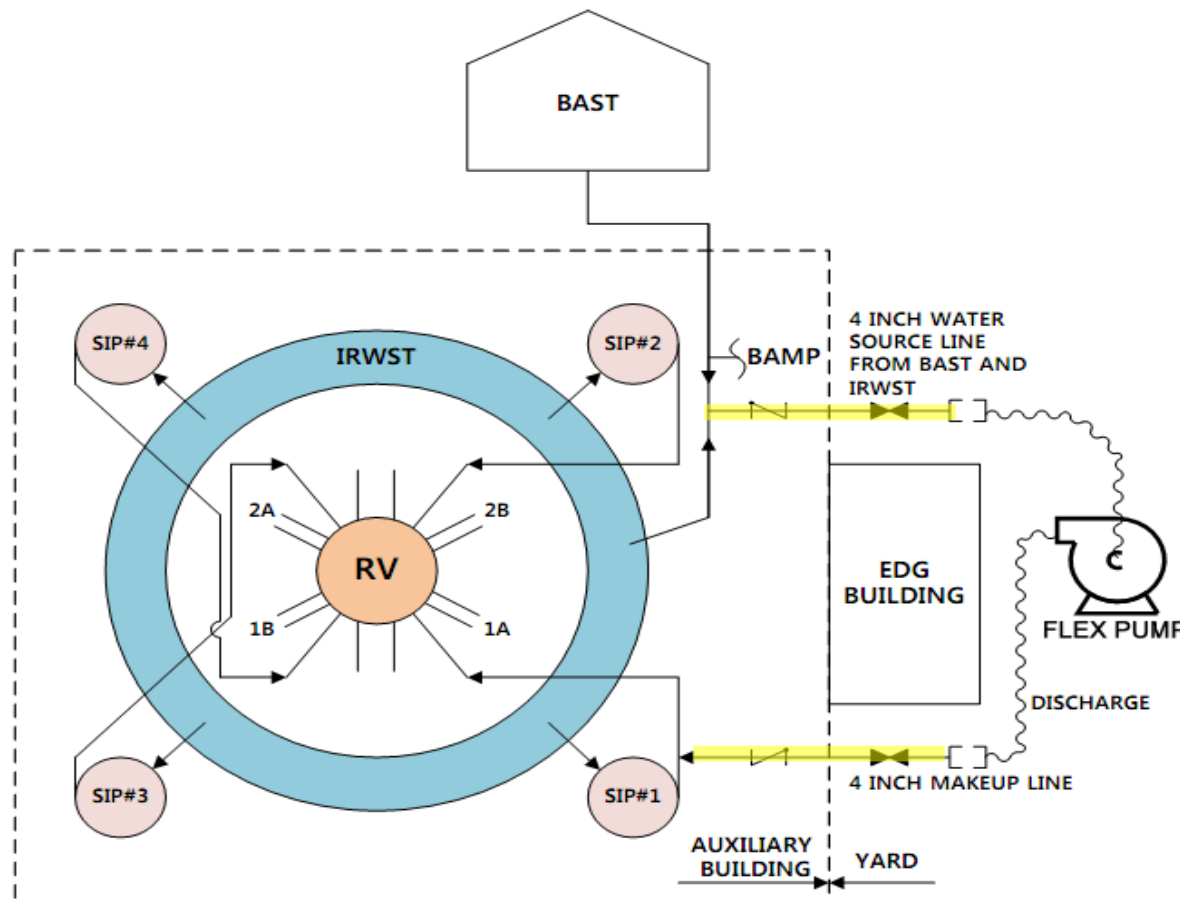
### □ Phase 2 (8 - 72 hrs)

- Primary :
  - Natural Circulation Cooling (NCC) operation
  - RCS inventory makeup : ACP or high head portable pump, SITs
- Secondary :
  - Turbine Driven Auxiliary Feedwater Pump control (automatic)
  - RCS cooldown to hot shutdown using MSADVs
  - Power
    - C1E 125V DC & 480V AC (A or B) power by GTG
    - C1E 125V DC (C and D) load shedding
- Preparations for Phase 3
  - Install a high voltage portable GTG to class 1E (4.16kV) AC bus
  - Restore ultimate heat sink

## 2. Strategy for Core Cooling (full power)

### □ Phase 2 (8 – 72 hrs)

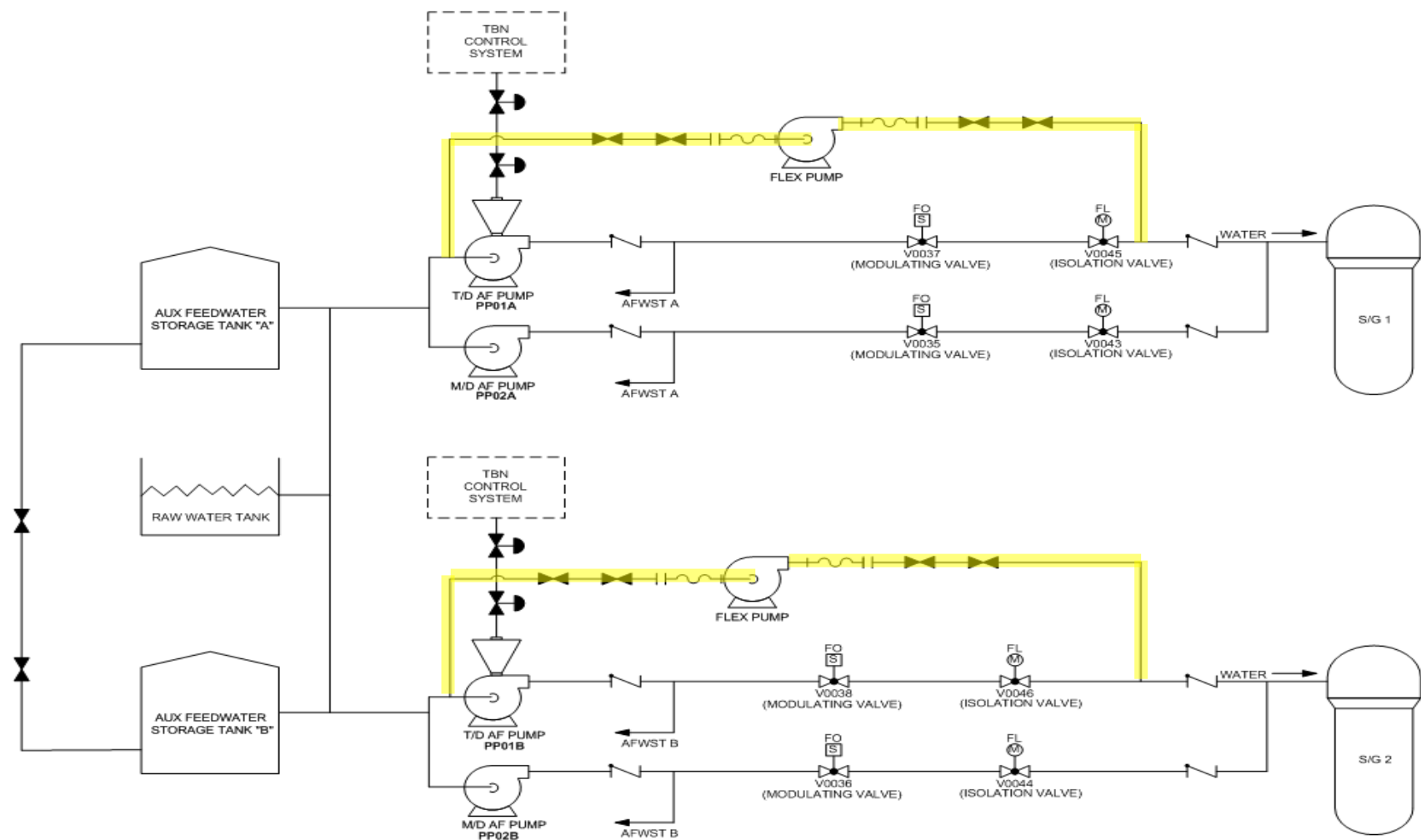
- External injection (Primary)



## 2. Strategy for Core Cooling (full power)

### □ Phase 2 (8 – 72 hrs)

- External Injection (Secondary)



## 2. Strategy for Core Cooling (full power)

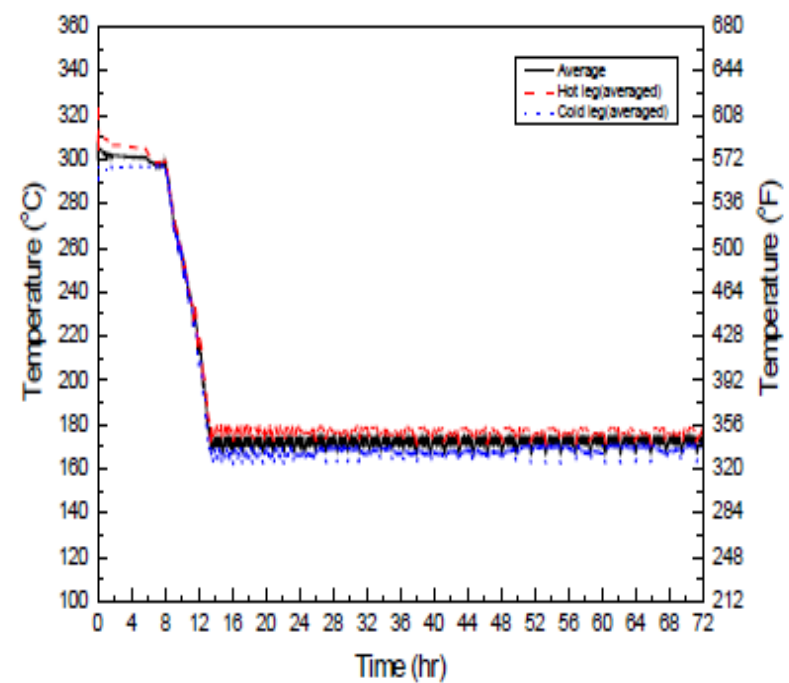
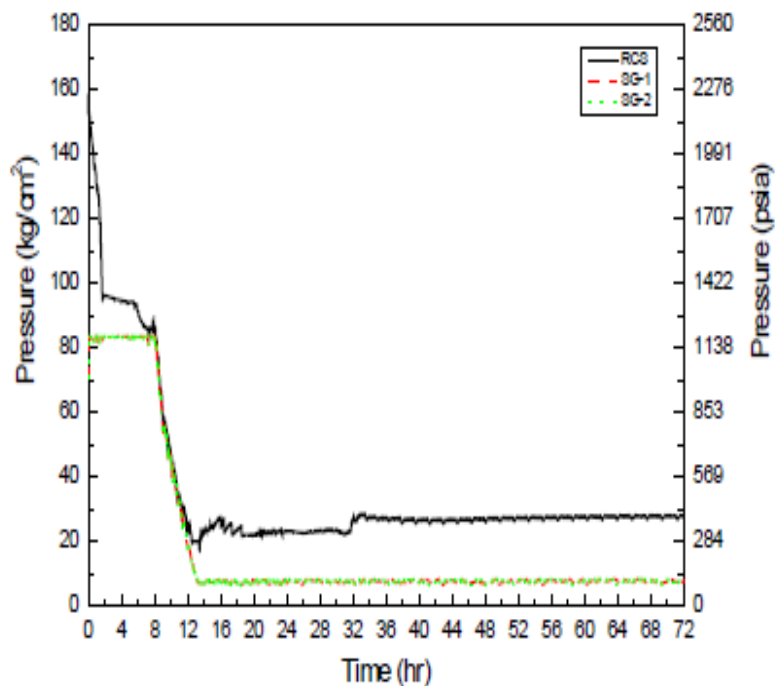
### □ Phase 3 (72 hrs - )

- NCC + forced cooling operation
  - RCS states
    - 1) hot shutdown (350 °F)
    - 2) close to cold shutdown (210 °F)
    - 3) cold shutdown (140 °F)
- 4.16 kV C1E (GTG) in-service
  - Before UHS is restored, M/D AFWP takes over T/D AFWPs
  - After UHS is restored, SCS operation takes over NCC operation
  - GTG fuel oil source : EDG fuel oil storage tank, off-site fuel oil sources

## 2. Strategy for Core Cooling (full power)

### □ Supporting Analysis

- RCS pressure and temperature



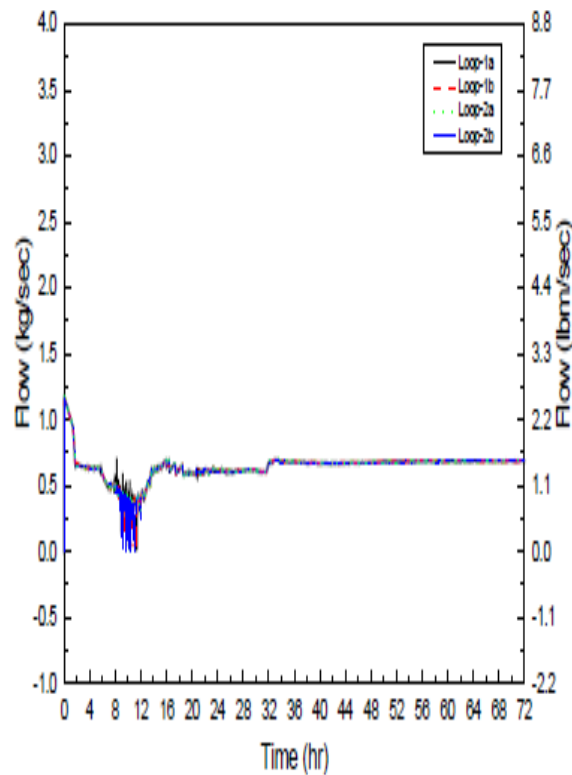


## 2. Strategy for Core Cooling (full power)

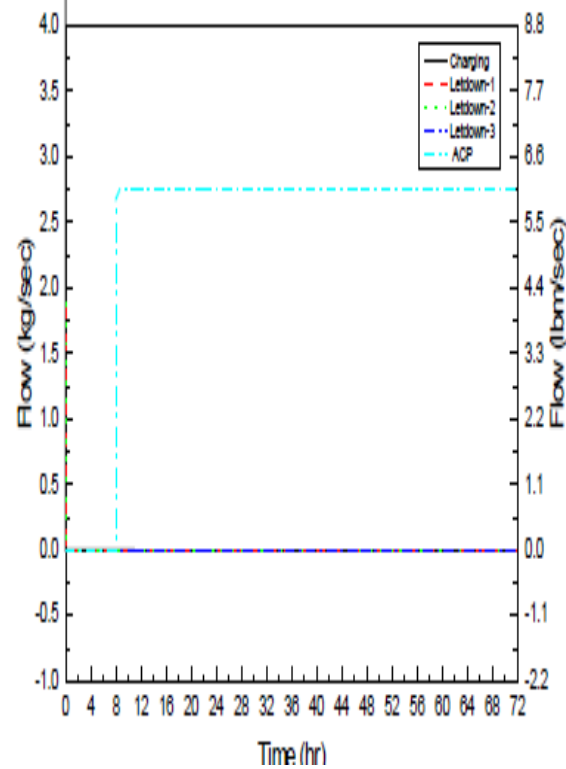
### □ Supporting Analysis

- RCS leak & make-up flow

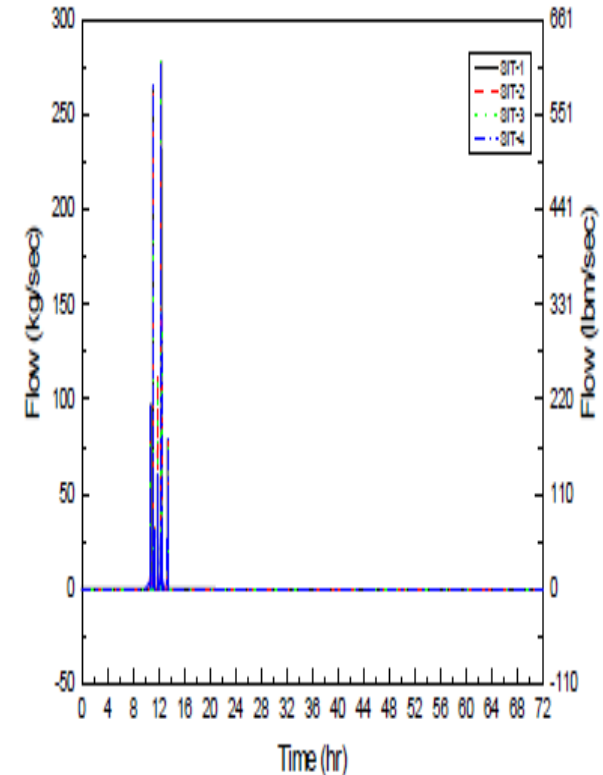
RCS Leak Flow(BS)



Aux Charging Flow(BS)



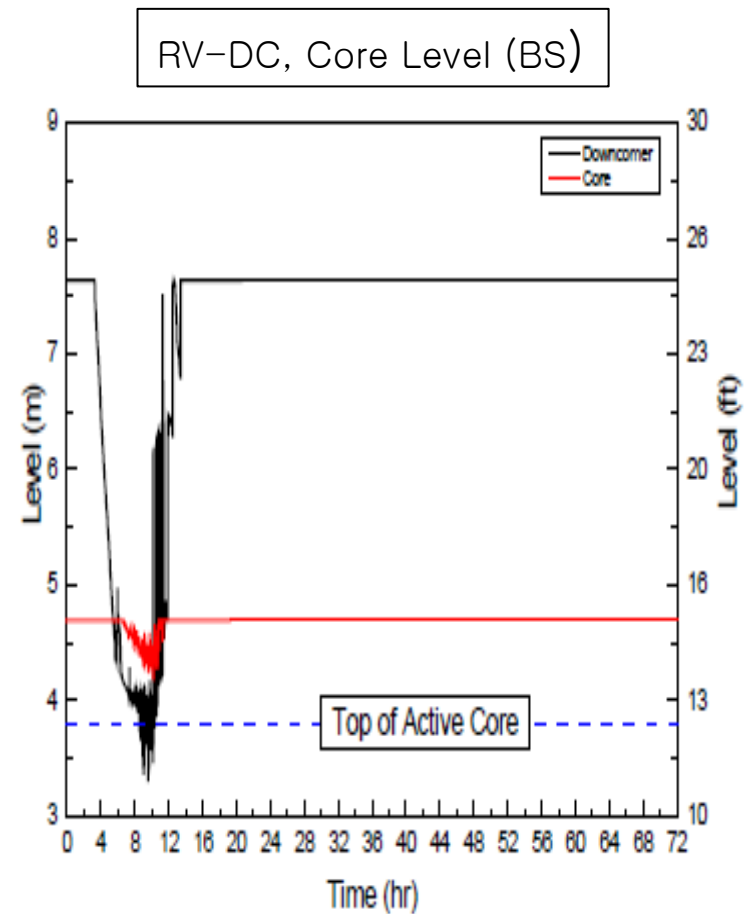
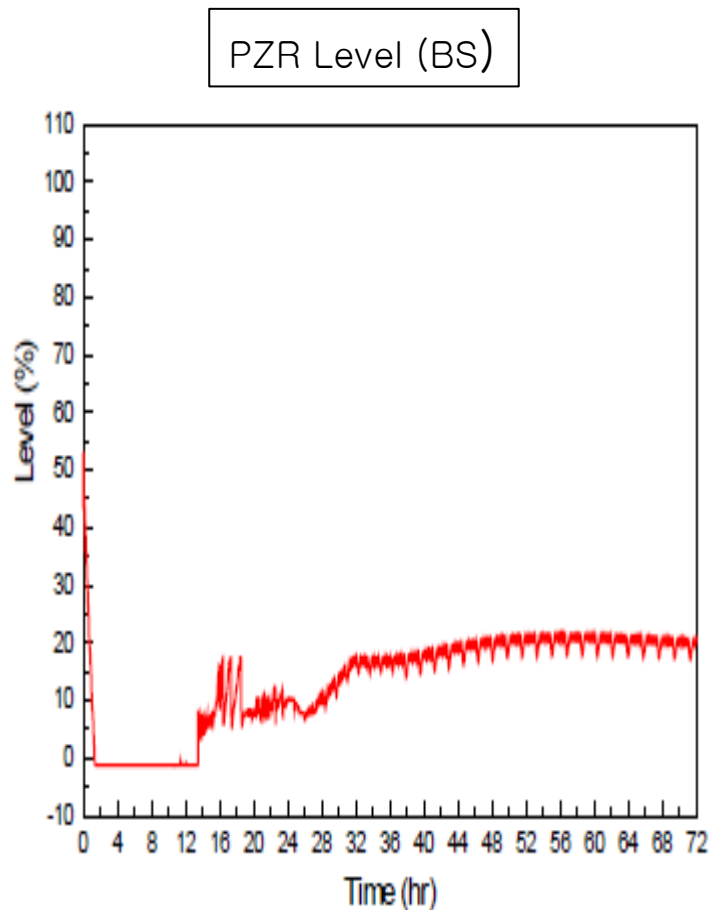
SIT Flow(BS)



## 2. Strategy for Core Cooling (full power)

### □ Supporting Analysis

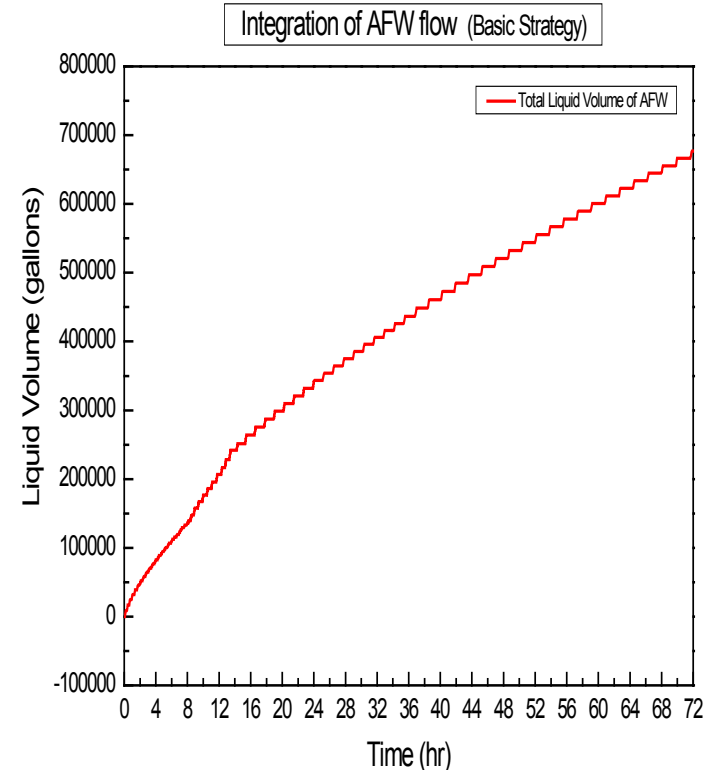
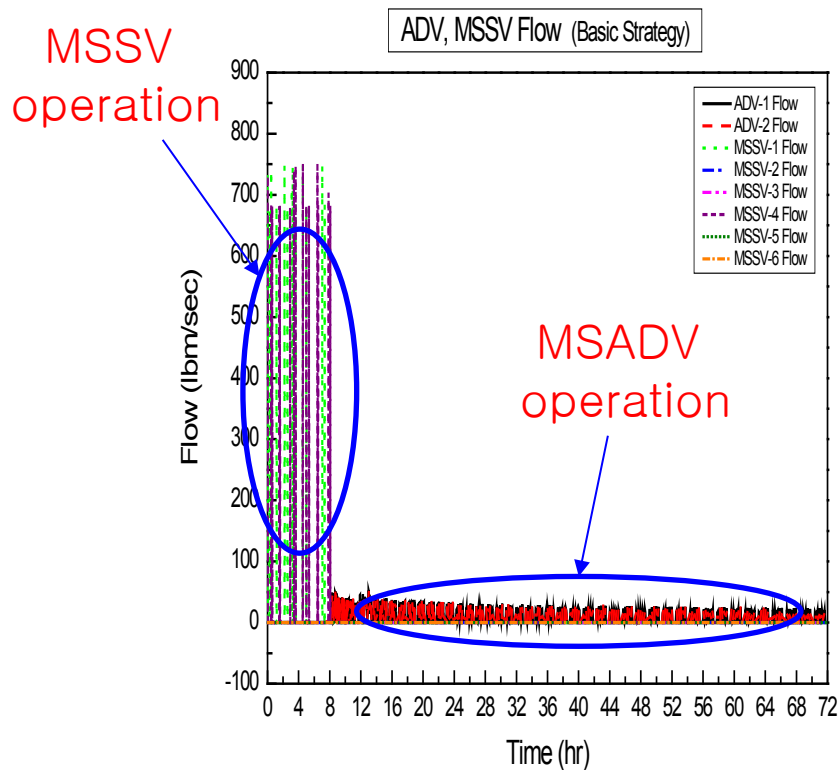
- PZR and Core level



## 2. Strategy for Core Cooling (full power)

### □ Supporting Analysis

- Secondary heat removals

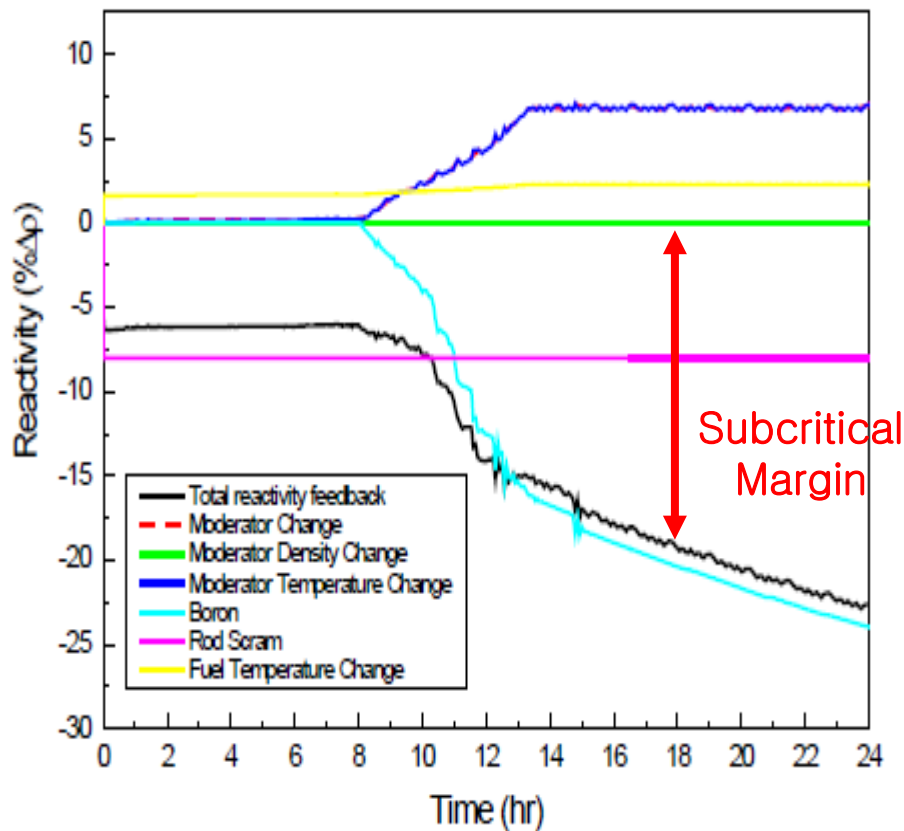


## 2. Strategy for Core Cooling (full power)

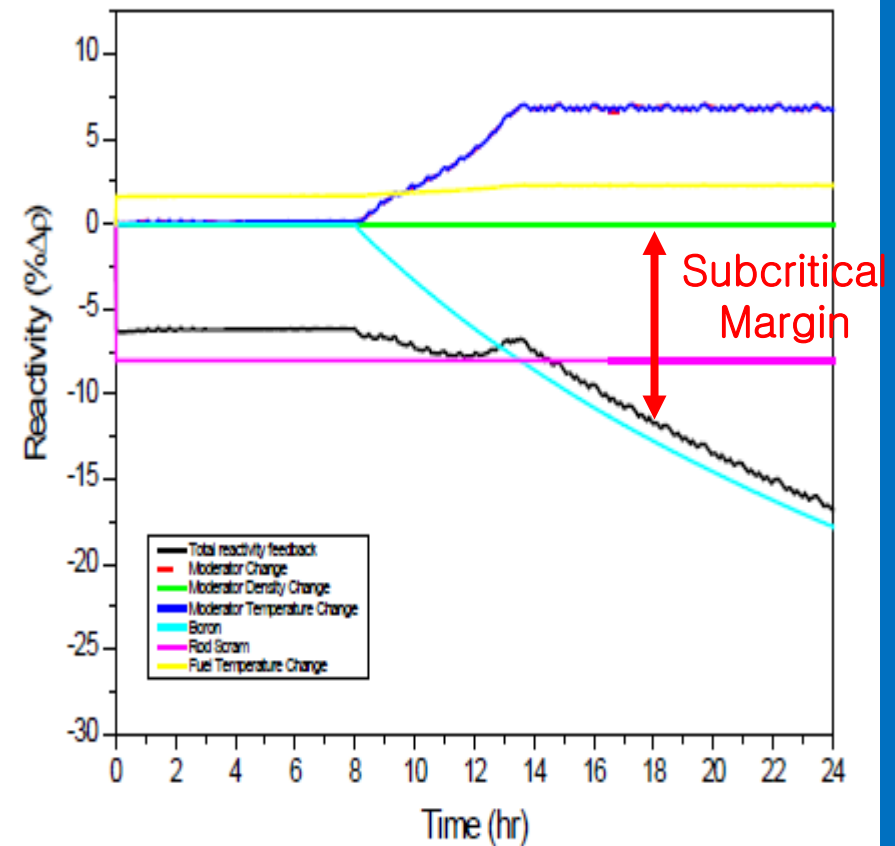
### □ Supporting Analysis

- Reactivity control

Reactivity (with RCP Leak)



Reactivity (No RCP Leak)



### **3. Strategy for Core Cooling (Mid-loop)**

### 3. Strategy for Core Cooling (mid-loop)

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#### □ Strategy Summary

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### 3. Strategy for Core Cooling (mid-loop)

#### □ Phase 1 (0 – 3 hrs)

- Decay heat is removed by coolant boil-off
- Gravity feed from Safety Injection Tanks
  - Core uncover time without operator action : 90 minutes
  - Core uncover time with gravity feed from two SITs : 4 hours
  - Two SITs are assumed to be in maintenance
- Required operator action
  - Open SIT gas vent valves (30 minutes)
  - Open 1<sup>st</sup> SIT isolation valve (1 hour)
  - Open 2<sup>nd</sup> SIT isolation valve (2.5 hours)
- Preparations for Phase 2
  - Install a low head portable pump

### 3. Strategy for Core Cooling (mid-loop)

#### □ Phase 2 (3 – 72 hrs)

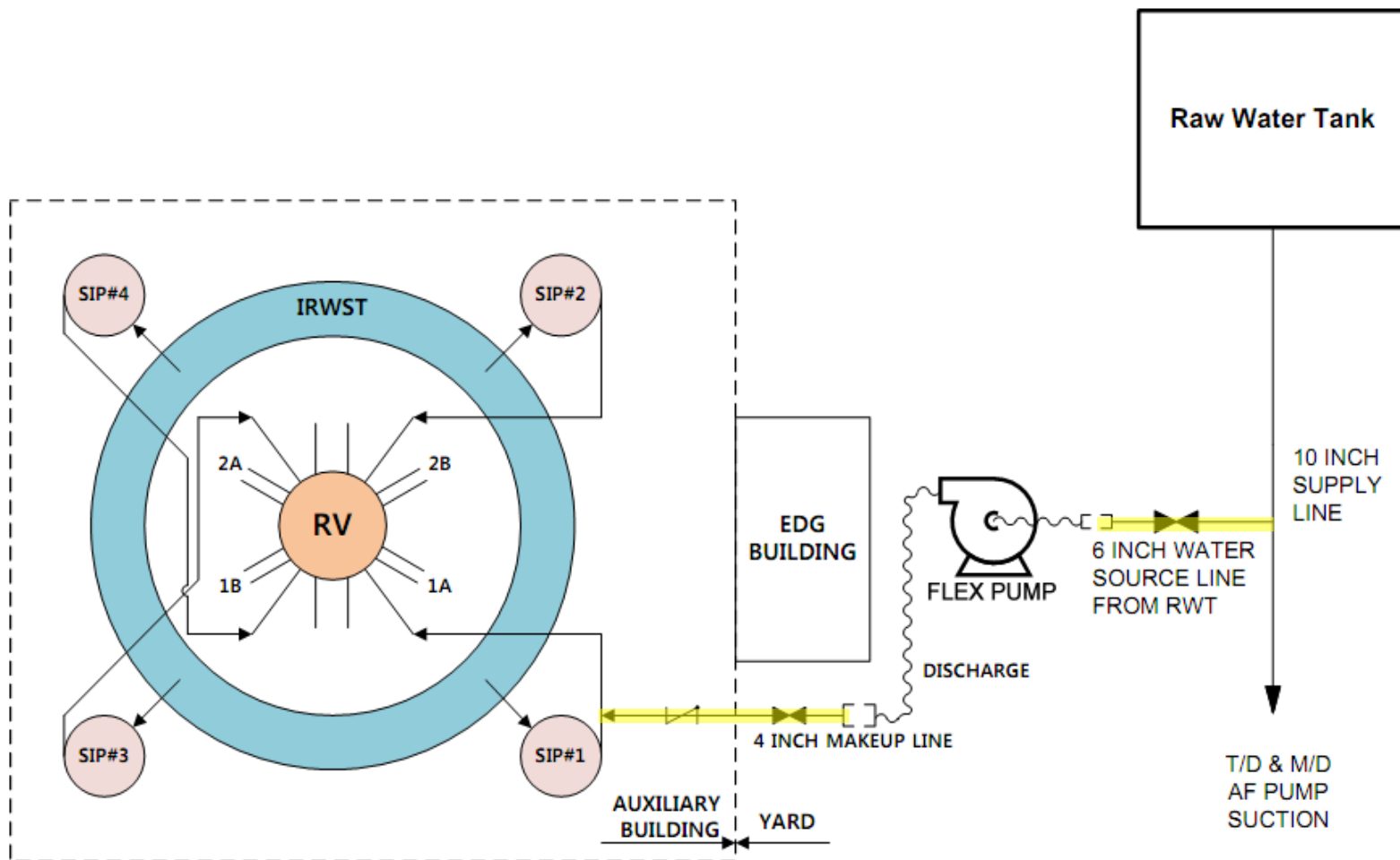
- Feed and steaming operation using portable pump
- RCS feed : primary side low head portable pump
- Steam vent : PZR Manway
- RCS cooling water source : RWT
- Required operator action
  - On/off control of the portable pump to maintain RCS level
  - Install & start a low voltage(480 V) AC portable GTG (within 8 hours)
- Preparations for Phase 3
  - Install a high voltage(4.16kV) portable GTG to 4.16kV class 1E AC bus
  - Restore ultimate heat sink



### 3. Strategy for Core Cooling (mid-loop)

#### □ Phase 2 (3 – 72 hrs)

- External Injection (Primary)



### 3. Strategy for Core Cooling (mid-loop)

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#### □ Phase 3 (72 hrs - )

- A 4.16 kV GTG provides power to a train of class 1E switchgear
  - If UHS is restored, SCS operation will take over the feed & steaming operation
  - Off-site resources will be used for maintaining the same strategy as in Phase 2
  - Fuel oil for GTGs are refilled by the off-site resources

## 4. Containment Capability

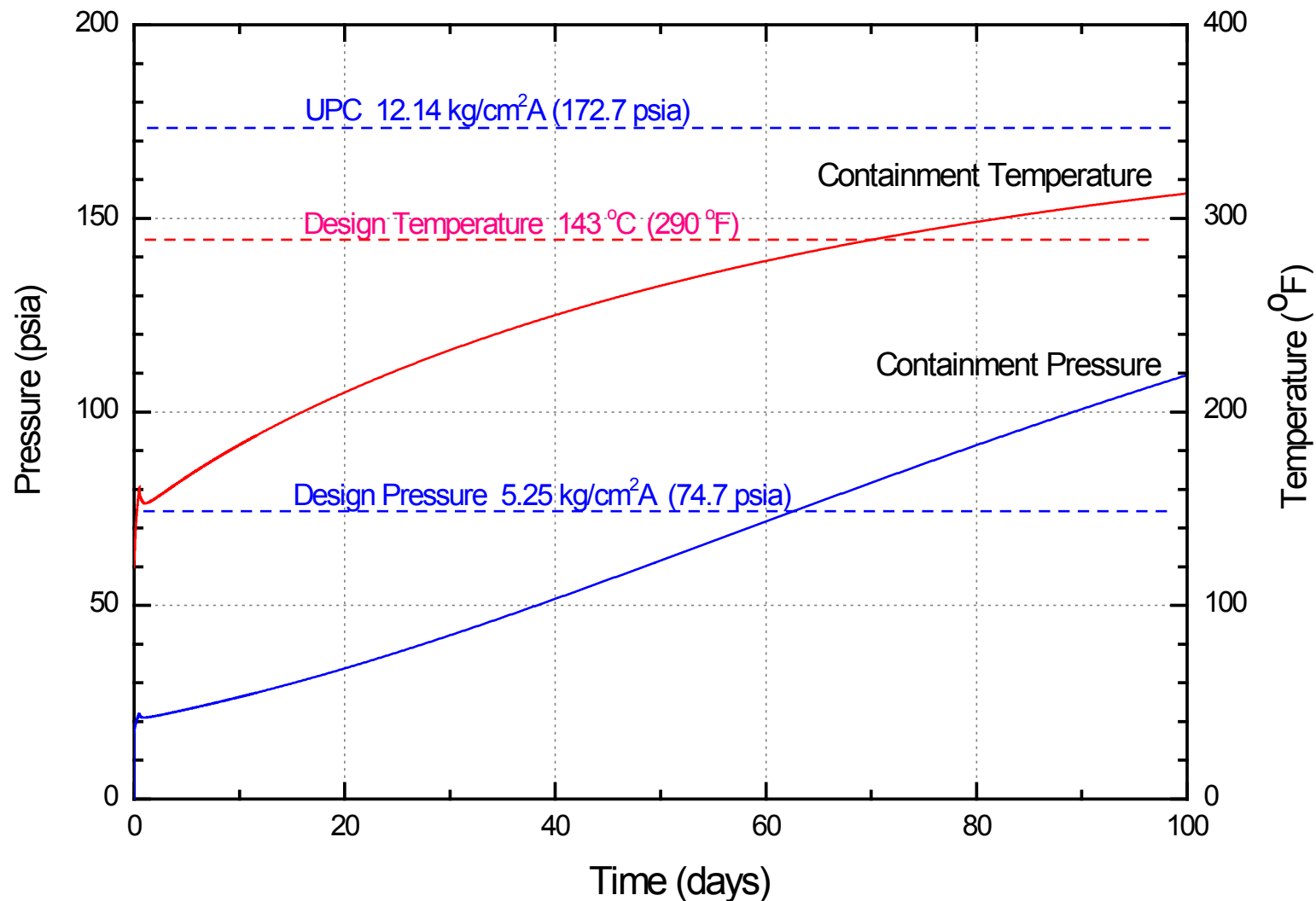
## 4. Containment Capability (full power)

### □ Containment response to RCP seal leakage

- Assumption
  - RCP seal leakage of 25 gpm per RCP (total 100 gpm)
  - ECSBS sprays when pressure reaches UPC (158 psig)
- Analysis
  - Use GOTHIC containment model for DBA LOCA analysis
  - Pressure rises to design pressure (60 psig) : 63 days
  - Temperature rises to design temperature (290 °F) : 71 days
- Result
  - Containment integrity is maintained for RCP seal leakage

## 4. Containment Capability (full power)

### □ Containment analysis for RCP seal leakage



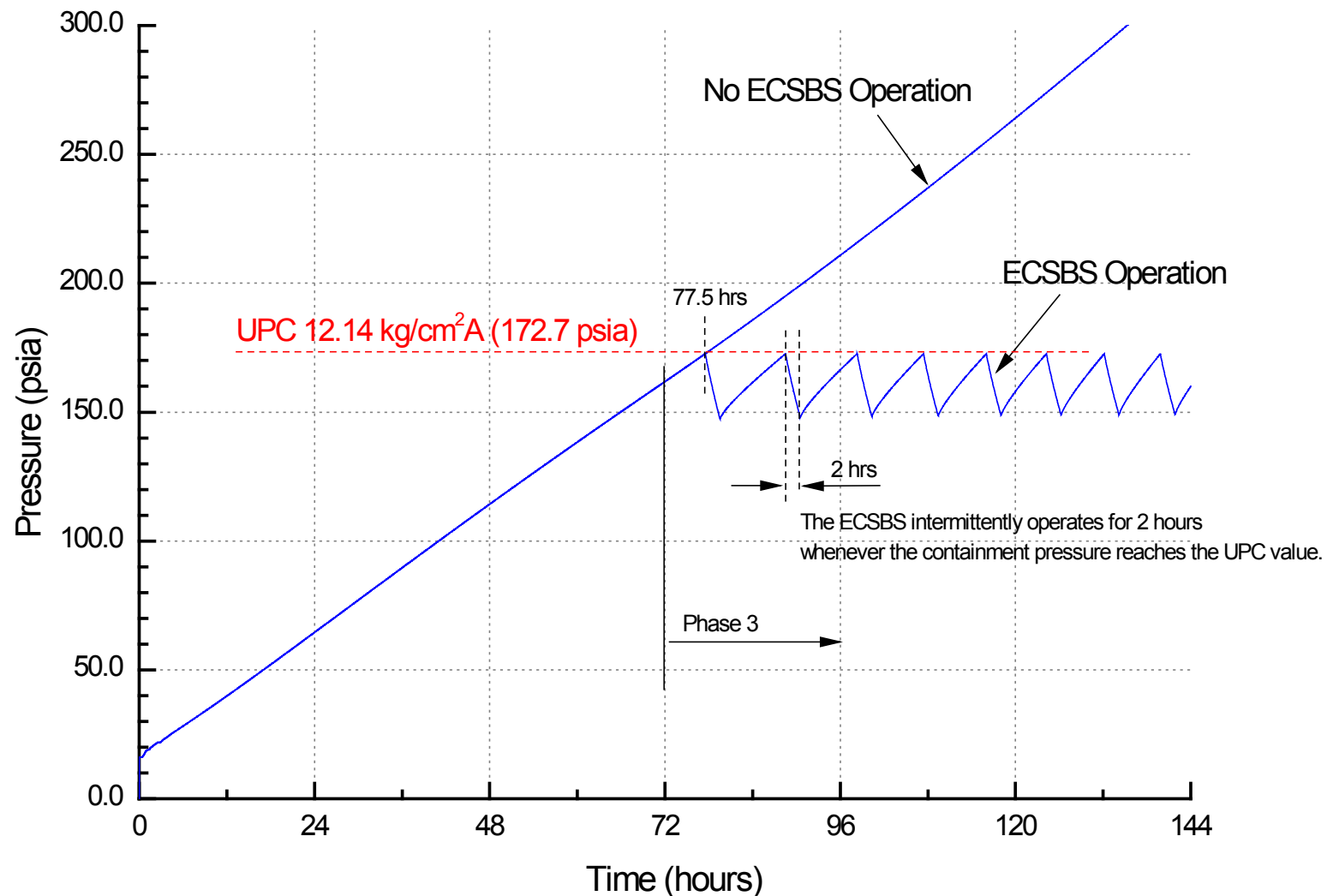
## 4. Containment Capability (mid-loop)

### □ Containment analysis for loss of RHR

- Assumption :
  - Steam releases to containment through pressurizer manway following loss of RHR at mid-loop operation
  - ECSBS sprays intermittently for 2 hours whenever pressure reaches the UPC(172.7 psia)
- Analysis
  - GOTHCI containment model used in DBA LOCA analysis
  - Initial peak pressure reaches the UPC at 3.5 days (phase 3)
  - Temperature is maintained below the limit value for ensuring RCS sensors operability
- Result
  - Containment pressure is controlled below the UPC with ECSBS

## 4. Containment Capability (mid-loop)

### □ Containment response to loss of RHR



## 5. Conclusion



## 5. Conclusion

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### ❑ Core cooling strategy under BDBEE

- Full power : strategy and supporting analysis are presented
- Mid-loop : strategy and required operator actions are presented

### ❑ Design enhancements

- Design enhancements to accommodate mobile equipment are presented and implemented to enhance mitigation capability to BDBEE

### ❑ Containment capability

- Containment capability and associated supporting analysis for BDBEE are presented

# Acronym

- ACP : Auxiliary Charging Pump
- AFWST : Auxiliary Feedwater Storage Tank
- AS : Alternative Strategy (Contingency Strategy)
- BAMP : Boric Acid Make-up Pump
- BAST : Boric Acid Storage Tank
- BDB : Beyond Design Basis
- BS : Basic Strategy
- C1E : Class 1E
- EDG : Emergency Diesel Generator
- GTG : Gas Turbine Generator
- IRWST : In-Refueling Water Storage Tank
- MSADV : Main Steam Air Dump Valve
- MSSV : Main Steam Safety Valve
- NTTF : Near Term Task Force
- PZR : Pressurizer
- RCP : Reactor Coolant Pump
- RCS : Reactor Coolant System
- RV-DC : Reactor Vessel Downcomer
- RWT : Raw Water Tank
- SCS : Shutdown Cooling System
- SFP : Spent Fuel Pool
- SG : Steam Generator
- SIP : Safety Injection Pump
- SIT : Safety Injection Tank
- T/D AFWP : Turbine Driven Auxiliary Feedwater Pump
- UHS : Ultimate Heat Sink
- UPC : Ultimate Pressure Capacity

# Thank you