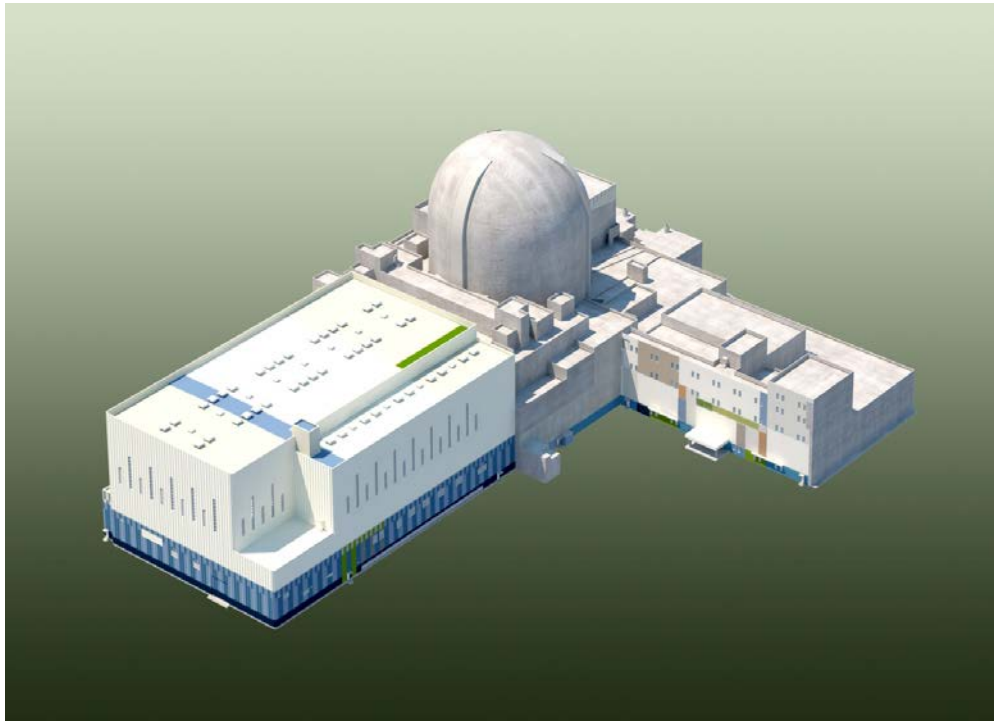
NON-PROPRIETARY

APR1400 Mitigation Strategies for Beyond Design Basis External Event



KEPCO/KHNP

Apr. 20~21. 2016

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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

❑ 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)
Core cooling with SGs available Mode 1,2,3,4,5 Representative case : full power	● Installed equipment & resources ● C1E DC(125V) available	● Installed + on-site equipment & resources ● A train of low voltage C1E buses is restored by a portable GTG (480V)	● Installed + on-site + off-site equipment & resources ● A train of high voltage C1E buses is restored by a portable GTG (4.16kV)
Core cooling with SGs not available Mode 5,6 Representative case : mid-loop	● Minimum operator actions	● Primary & secondary portable pumps are used (if necessary)	

2. Strategy for Core Cooling (full power)

2. Strategy for Core Cooling (full power)

❑ Strategy Summary

TS

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)

TS

2. Strategy for Core Cooling (full power)

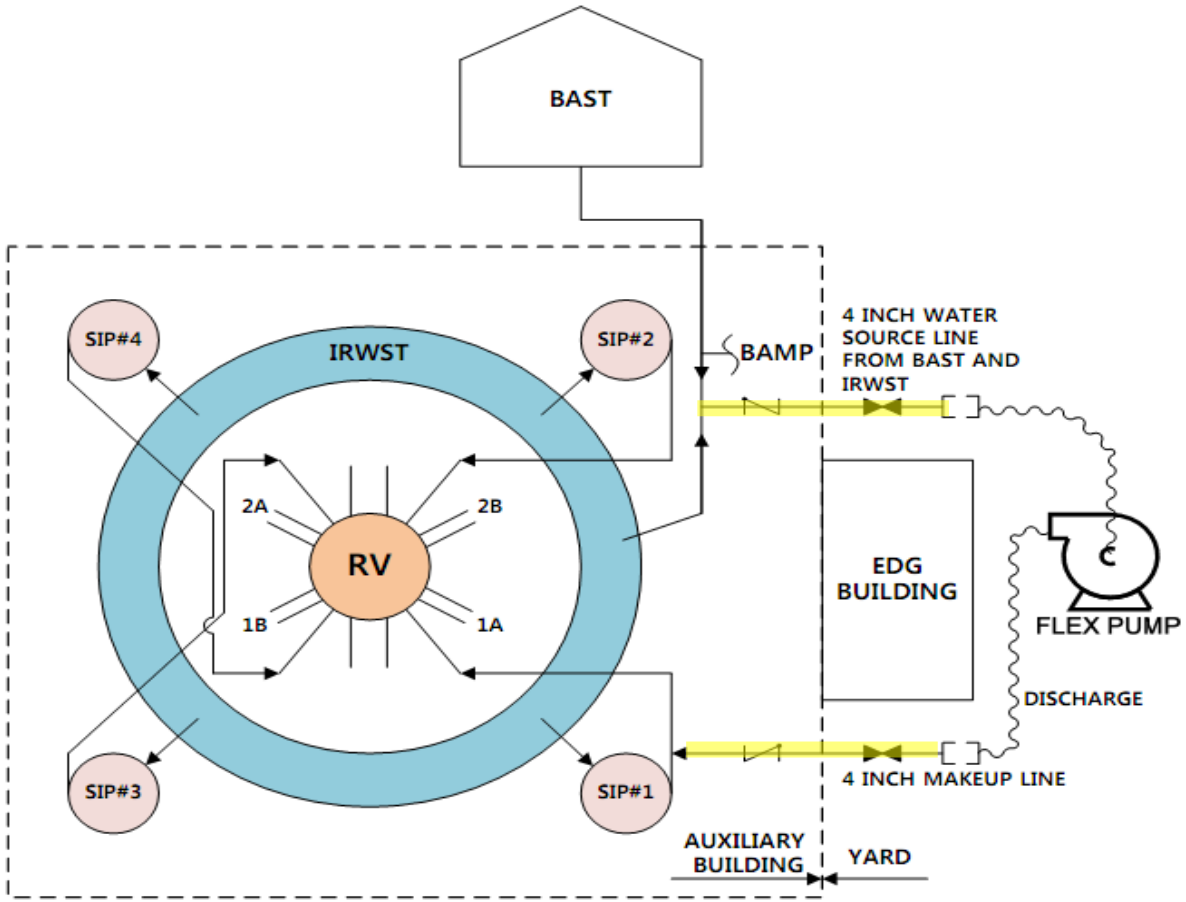
❑ Phase 2 (8 - 72 hrs)

- 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)

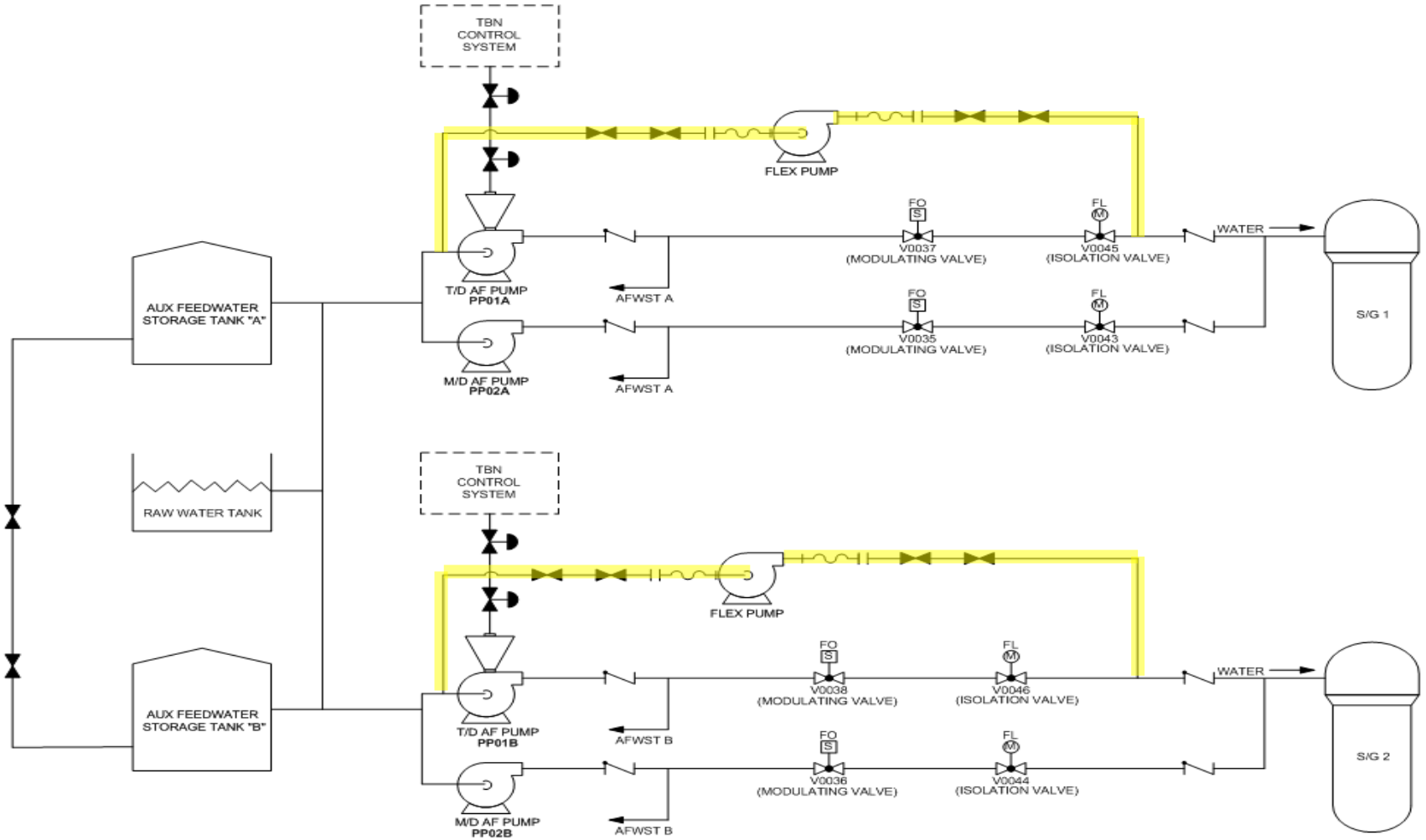
- External injection (Primary)



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 -)

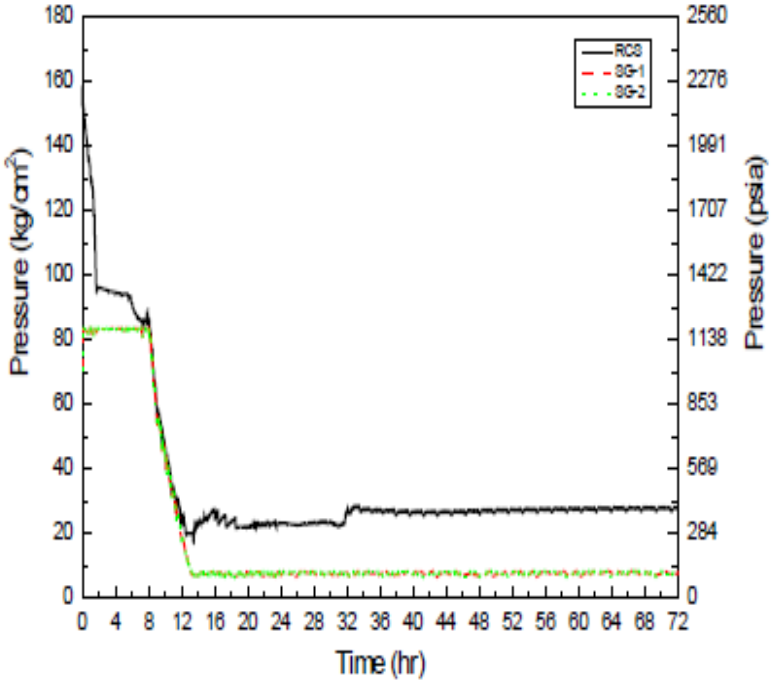
- NCC + forced cooling operation
  - RCS states
    1) hot shutdown (350 ºF)
    2) close to cold shutdown (210 ºF)
    3) cold shutdown (140 ºF)

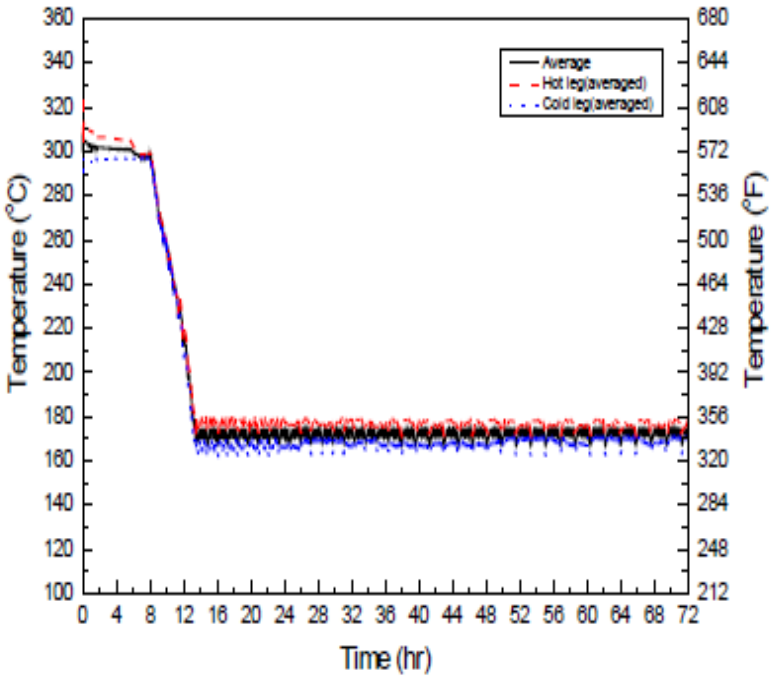
- 4.16 kV C1E (GTG) in-service
  - Before UHS is restored, M/D AFWP takes over T/D AFWPs
  - After UHS is restored, SCS operation takes over NCC operation
  - GTG fuel oil source : EDG fuel oil storage tank, off-site fuel oil sources

2. Strategy for Core Cooling (full power)

❑ Supporting Analysis

- RCS pressure and temperature



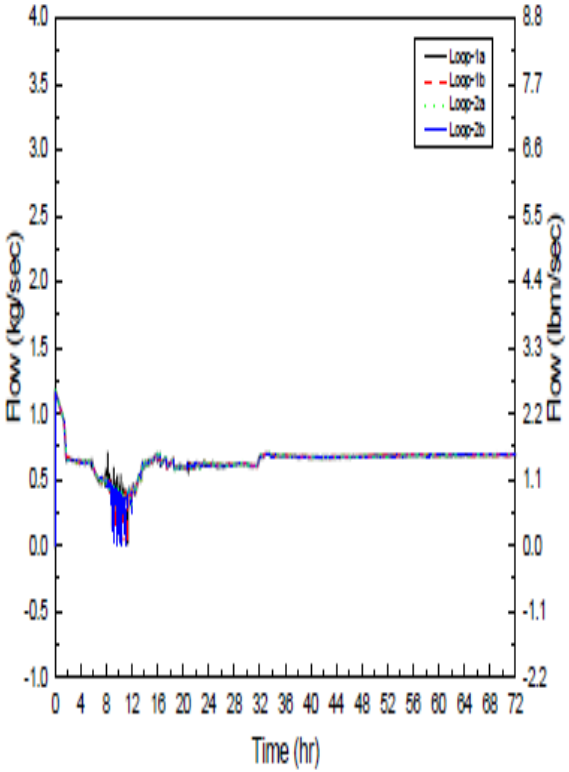


2. Strategy for Core Cooling (full power)

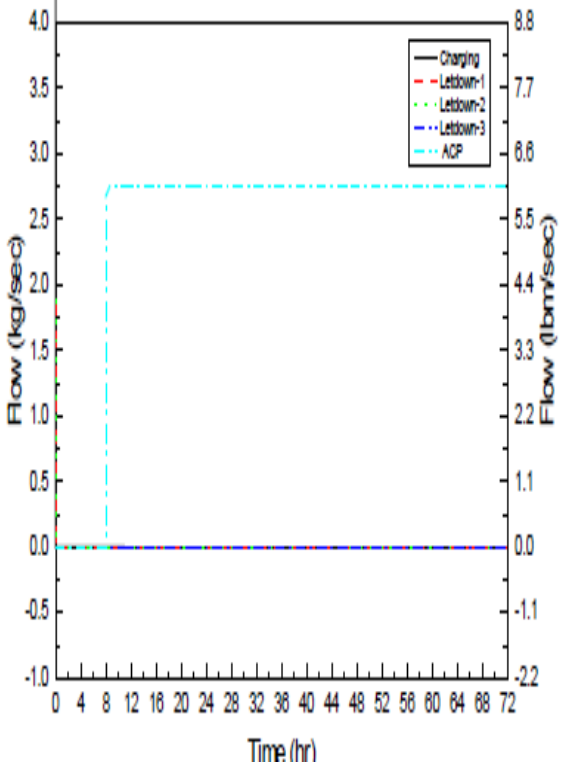
❑ Supporting Analysis

- RCS leak & make-up flow

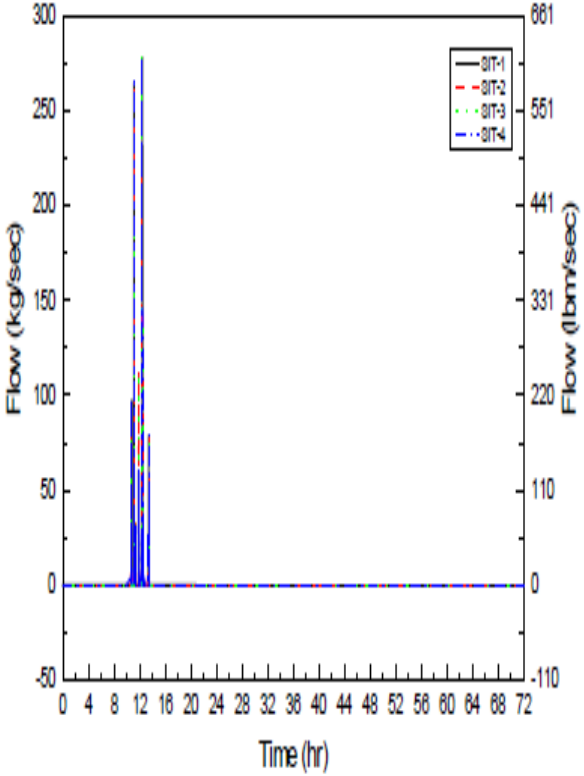
RCS Leak Flow(BS)



Aux Charging Flow(BS)



SIT Flow(BS)

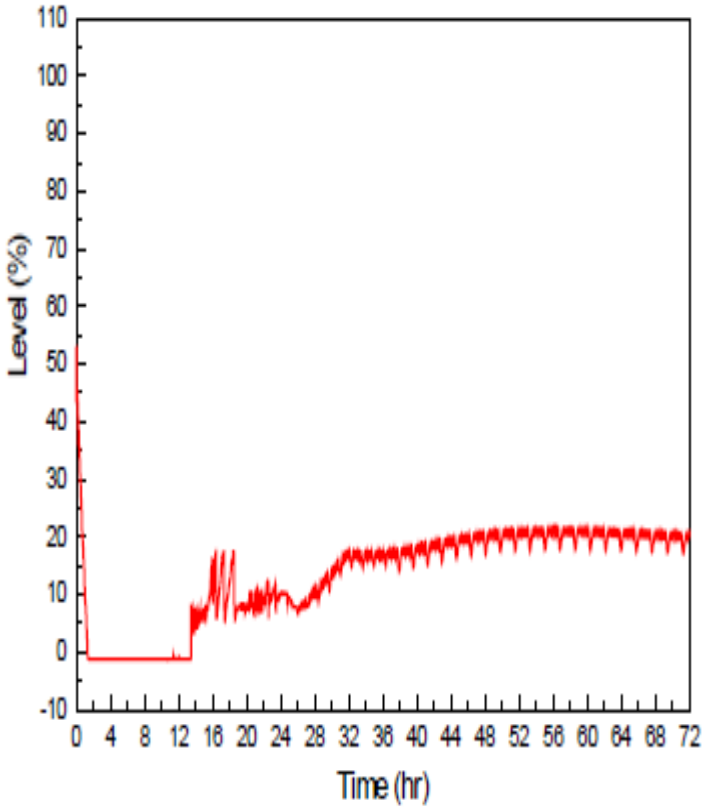


2. Strategy for Core Cooling (full power)

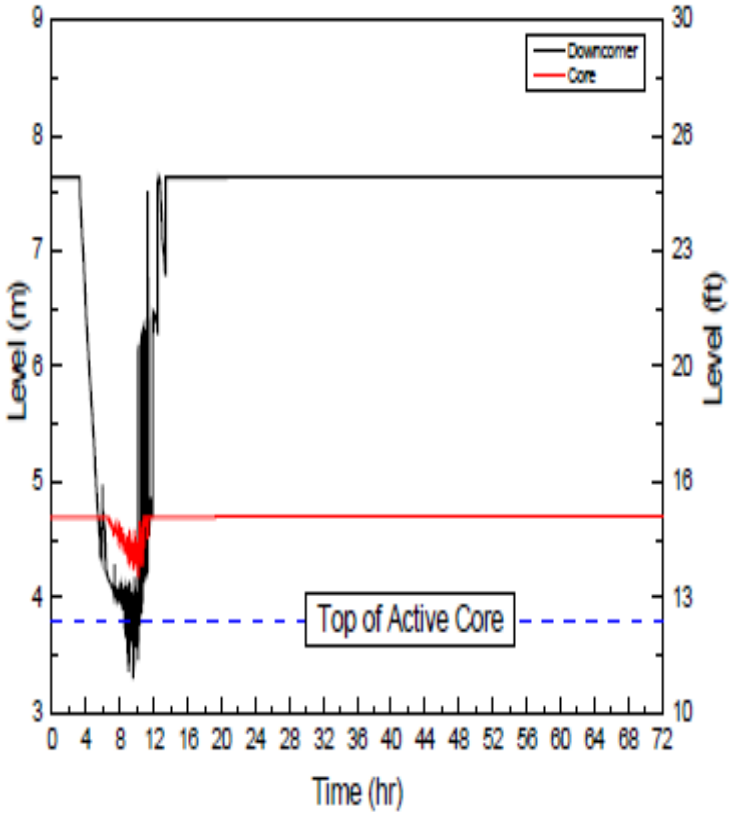
❑ Supporting Analysis

- PZR and Core level

PZR Level (BS)



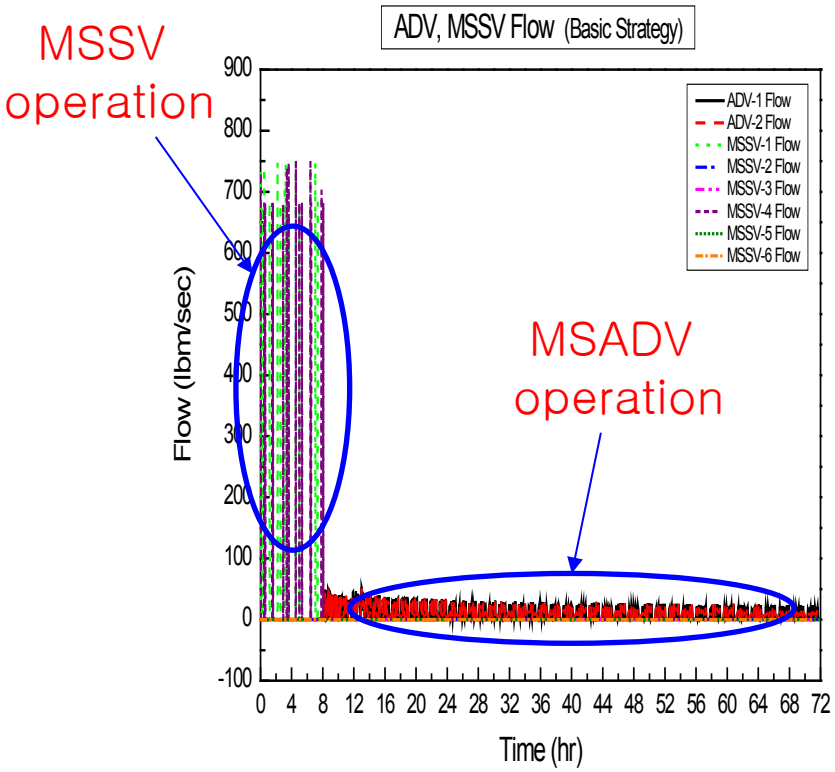
RV-DC, Core Level (BS)

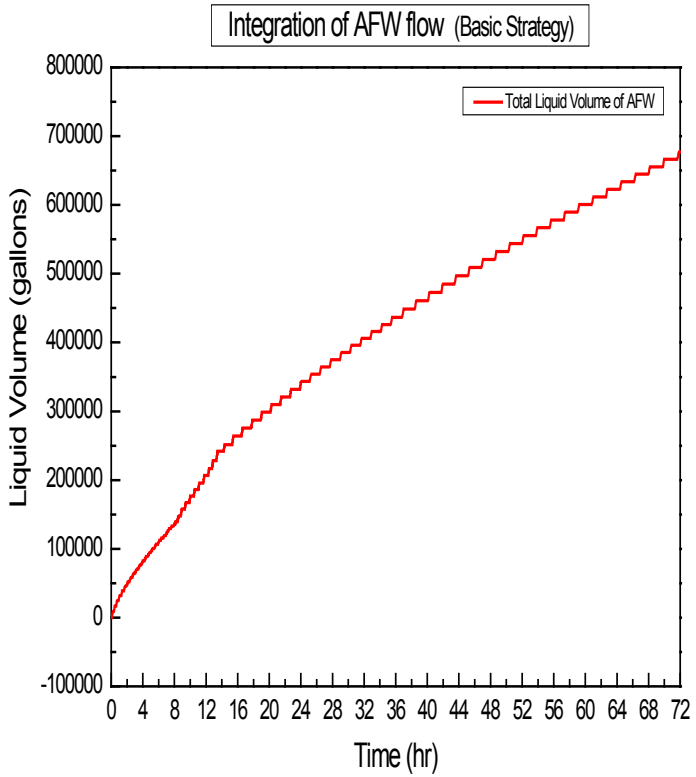


2. Strategy for Core Cooling (full power)

❑ Supporting Analysis

- Secondary heat removals



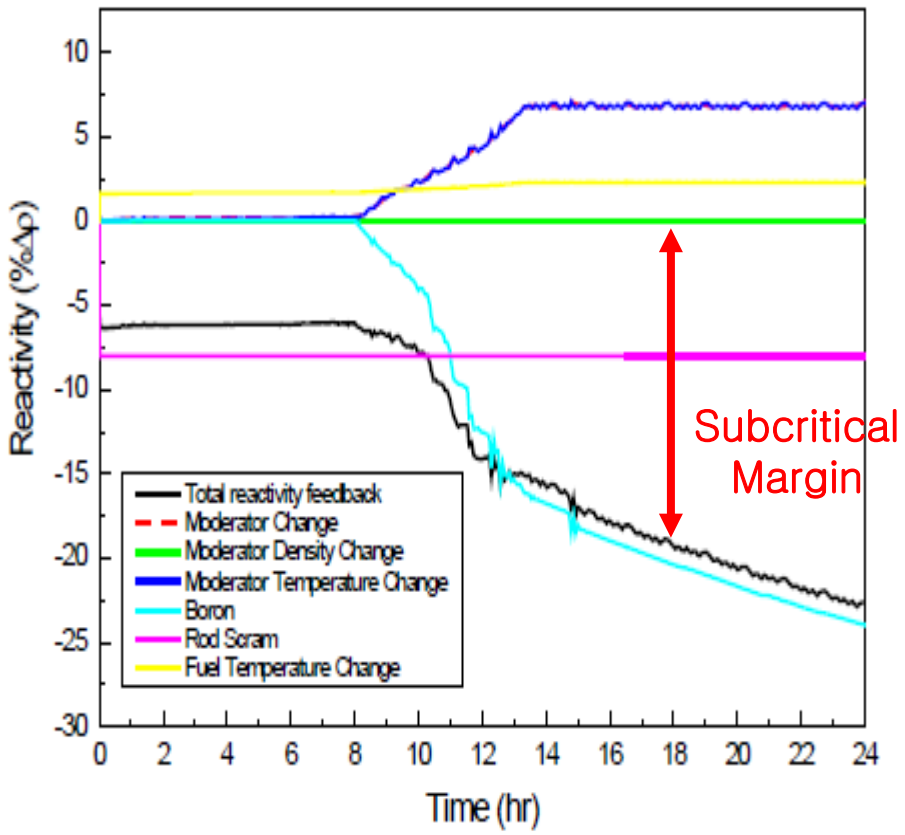


2. Strategy for Core Cooling (full power)

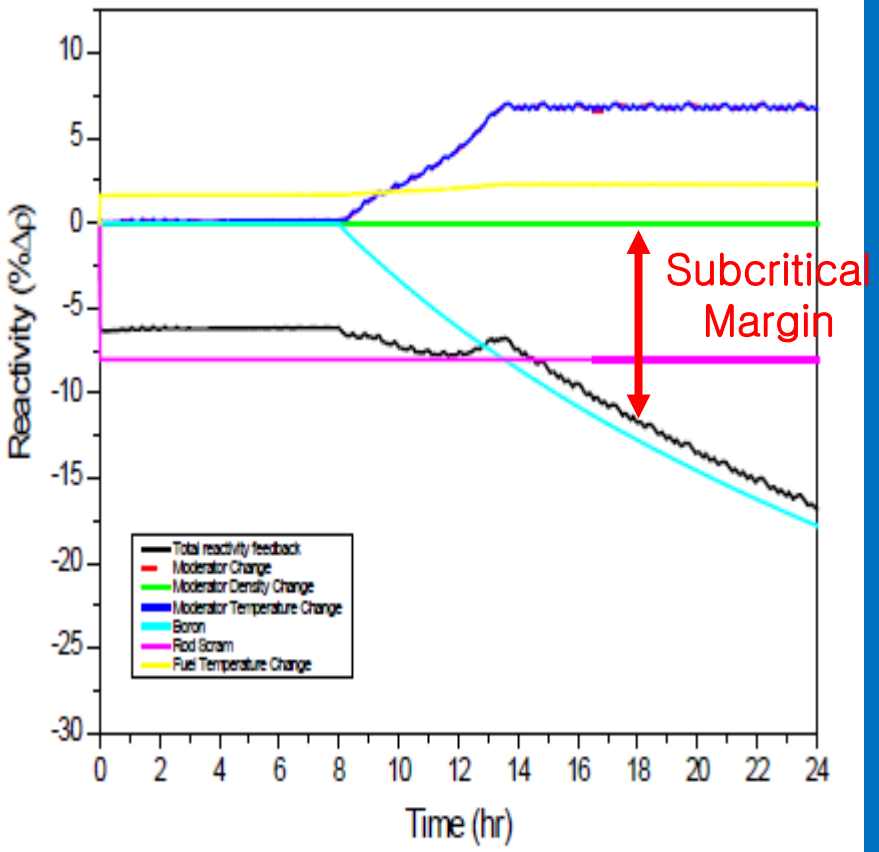
❑ Supporting Analysis

- Reactivity control

Reactivity (with RCP Leak)



Reactivity (No RCP Leak)



3. Strategy for Core Cooling (Mid-loop)

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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 uncovery time without operator action : 90 minutes
  - Core uncovery 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 1st SIT isolation valve (1 hour)
  - Open 2nd SIT isolation valve (2.5 hours)
- Preparations for Phase 2
  - Install a low head portable pump

3. Strategy for Core Cooling (mid-loop)

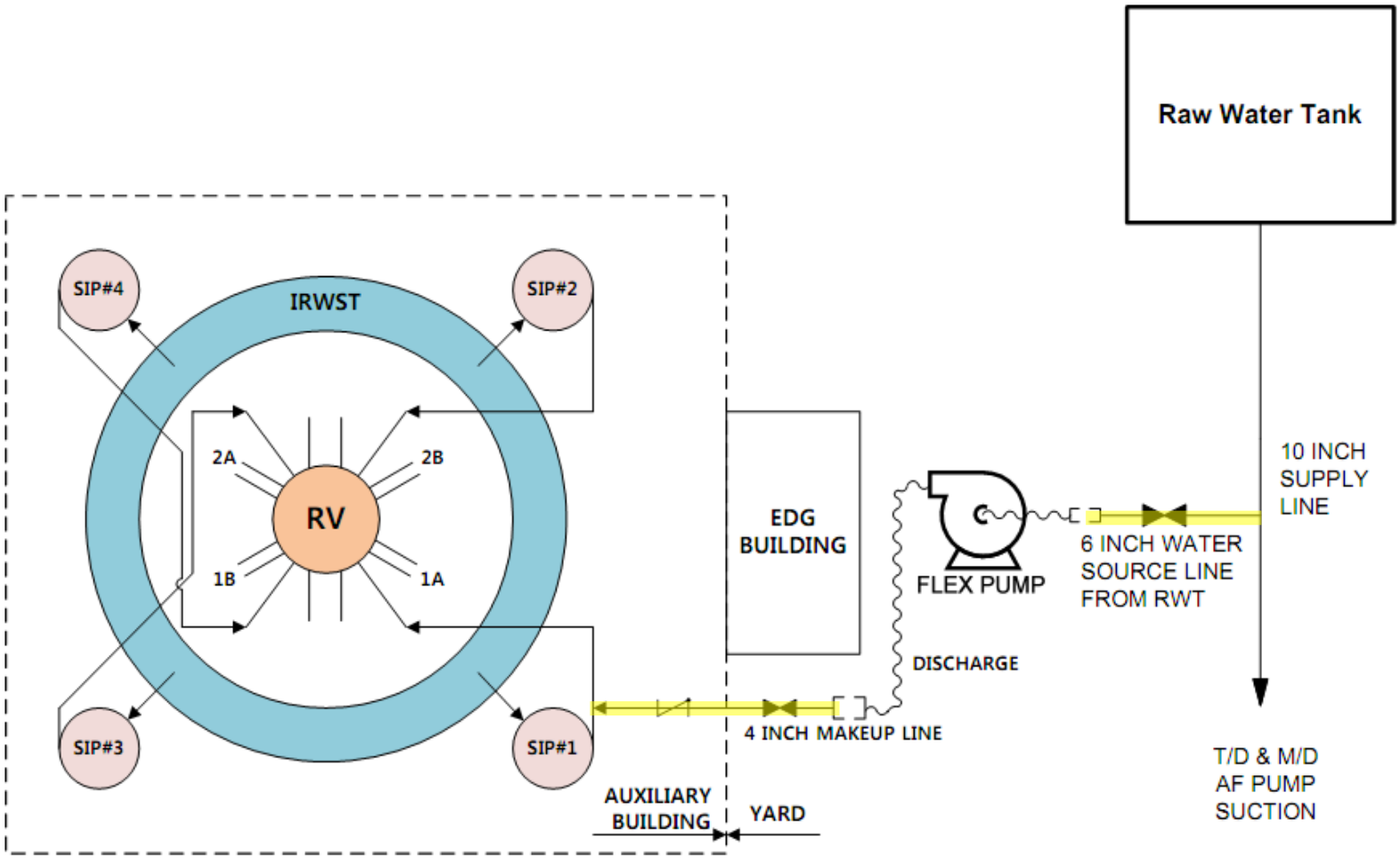
❑ Phase 2 (3 – 72 hrs)

- 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)

❑ 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

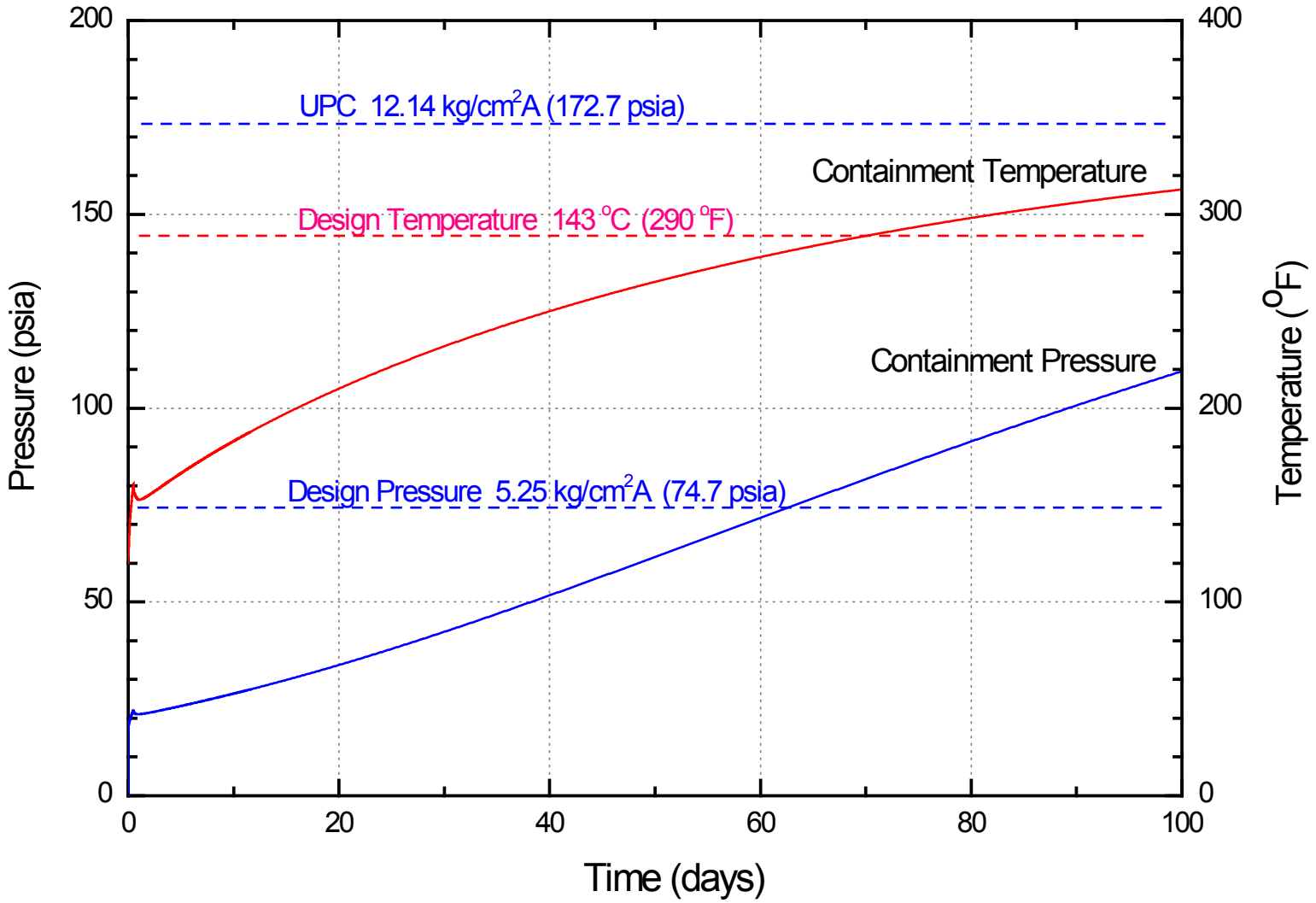
- Assumption
  - RCP seal leakage of 25 gpm per RCP (total 100 gpm)
  - ECSBS sprays when pressure reaches UPC (158 psig)

- 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



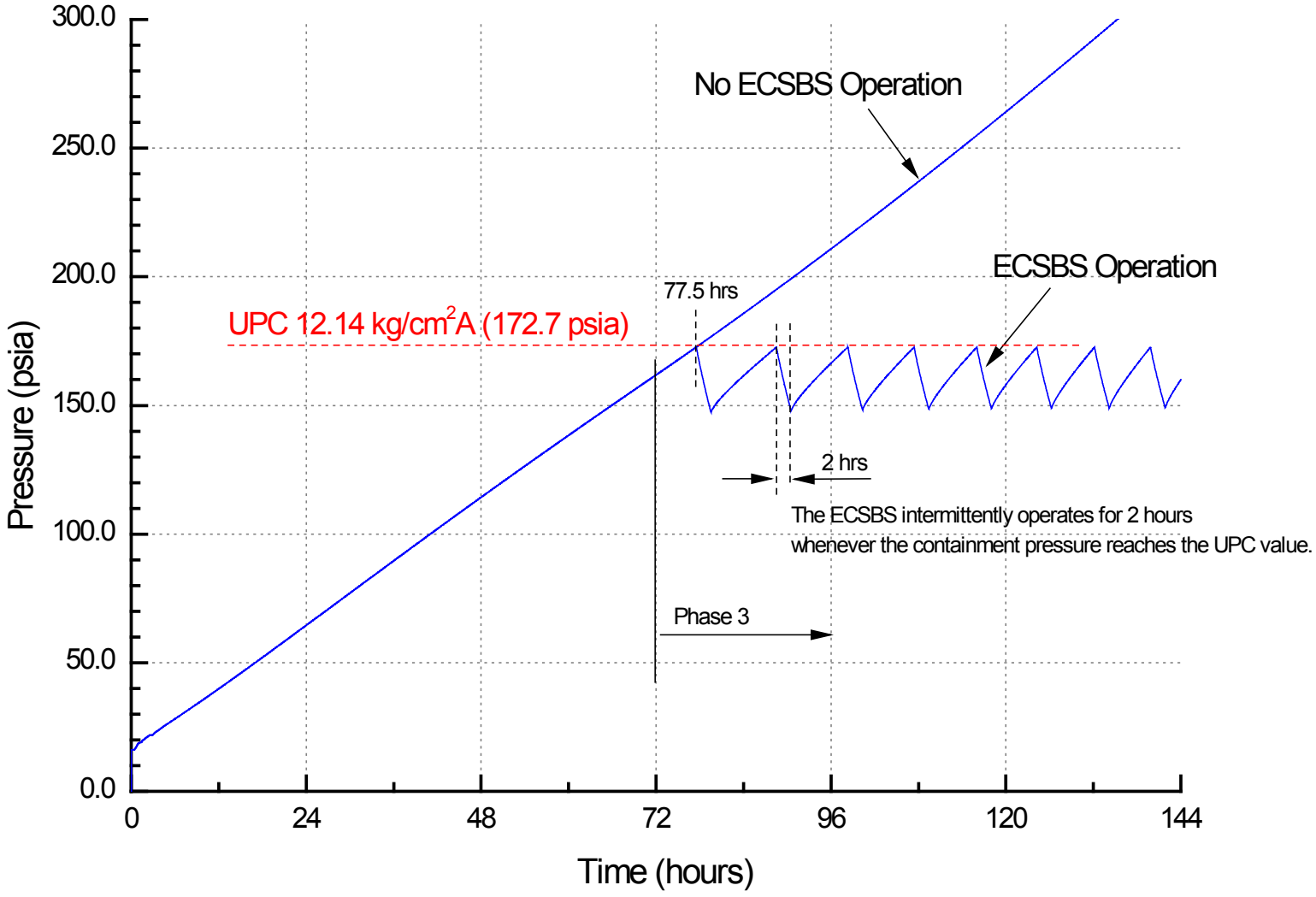
4. Containment Capability (mid-loop)

❑ 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

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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