Non-Proprietary

APR1400 Mitigation Strategies for BDB External Event

Pre-Application Review Meeting

May 28, 2014

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1. Introduction

A. Purpose of meeting

B. Status of APR1400 for Fukushima actions

A. Purpose of Meeting

- Basis for Fukushima actions for DC applicants : SECY 12-0025
  - For new DC applications not yet submitted, the staff expects those applications to address the Commission-approved Fukushima actions in their applications, prior to submittal, to the fullest extent practicable.
- Present APR1400 approaches and preliminary design to address the BDB external event to the staff.
  - Focus on the following Recommendations:
    - Recommendation 4.2 (Mitigation Strategies for BDBEE)
    - Recommendation 7.1 (SFP Instrumentation)
- KHNP expects staff's feedback on the APR1400 approaches and preliminary design.

B. Status of APR1400 for Fukushima actions

- KHNP has reviewed all NRC guidance including the following:
  - SECY 11- 0093 (NTTF Recommendations)
  - SECY 11-0137 (Prioritization of Recommended Actions)
  - SECY 12-0025 (Proposed Orders and RFI)
  - NRC Order EA-12-049 (Mitigation Strategies for BDBEE)
  - NRC Order EA-12-051 (Reliable SFP Instrumentation)

- KHNP has also reviewed other DC applicant's responses to the Fukushima actions as well as some of the operating US plant's responses.

- KHNP has completed preliminary analysis and design for the following:
  - Core cooling
  - SFP cooling
  - Containment pressure and temperature
  - Supporting systems

2. Strategy for Core Cooling

A. Overview

B. Core cooling with SGs available

- strategy summary
- phased approach (1, 2 & 3)
- supporting analysis

C. Core cooling with SGs not available

- strategy summary
- phased approach (1, 2 & 3)
- supporting analysis

A. Overview

❖ 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 - Minimum operator actions - C1E DC(125V) available	- Installed + on-site equipment & resources - A train of low voltage C1E buses is restored by a portable GTG (480V) - Primary & secondary portable pumps are used (if necessary)	- 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			

A. Overview

- Support analysis for the mitigation strategies
  - Assuming that RCP seal leakage is [ ]TS
  - Coping capability analysis in terms of safety functions
    - Core Cooling
    - RCS inventory
    - Reactivity control
    - Containment integrity (discuss in later part)

B. Core Cooling Strategy (SGs available)

TS

❖ Strategy Summary

B. Core Cooling Strategy (SGs available)

- Phase 1 (0 - 8 hrs)
  - Natural Circulation Cooling (NCC) operation
    - NCC operation starts automatically without operator action
    - SG feedwater injection : two T/D AFWPs
    - Steam release : MSSVs
    - Water source : two AFWSTs
  - RCP seal assumption [ ] TS
  - T/D AFWP control (automatic)
    - Control valves and instruments are powered by C1E 125V DC

B. Core Cooling Strategy (SGs available)

- Phase 1 (0 - 8 hrs)
  - 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)

B. Core Cooling Strategy (SGs available)

❖ Phase 2 (8 - 72 hrs)

- Natural Circulation Cooling (NCC) operation
  - RCS cooldown to hot shutdown using MSADVs
  - SG feedwater injection : two T/D AFWPs or portable pumps
  - Steam release : MSADVs
  - Water source : two AFWSTs
  - RCS inventory makeup : ACP or high head portable pump, SITs
  - 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

B. Core Cooling Strategy (SGs available)

❖ Phase 2 (8 - 72 hrs)

▪ Basic & Alternative strategy

- Basic Strategy (BS)
  - RCS cooldown : hot shutdown (350 ºF)
  - Primary make-up : ACP, SIT
  - Secondary cooling : T/D AFWPs and MSADVs

- Alternative Strategy (AS)
  - RCS cooldown : close to cold shutdown (210 ºF)
    ※ secondary portable pump maximum head allows around 15 bar, so SG should be depressurized with full opening of MSADVs
  - Primary make-up : high-head portable pump, SIT
  - Secondary cooling : portable pumps and MSADVs

B. Core Cooling Strategy (SGs available)

❖ Phase 2 (8 - 72 hrs)

- RCS cooldown rate control
  - MSADVs control (MCR)
    - Power : 480V class 1E bus (A or B) connected to portable GTG
    - Cooldown rate : 50 ºF/hr (for BS & AS)
  - Secondary feedwater injection
    - T/D AFWP (same as phase 1) (for BS)
    - Portable secondary pumps (for AS)
- GTG fuel oil source
  - EDG fuel oil storage tanks and day tanks [ ] TS

B. Core Cooling Strategy (SGs available)

❖ Phase 2 (8 - 72 hrs)

- Feedwater source
  - Use AFWSTs first, then use RWTs
  - Required water for phase 1&2 : 752,809 gal

TS

B. Core Cooling Strategy (SGs available)

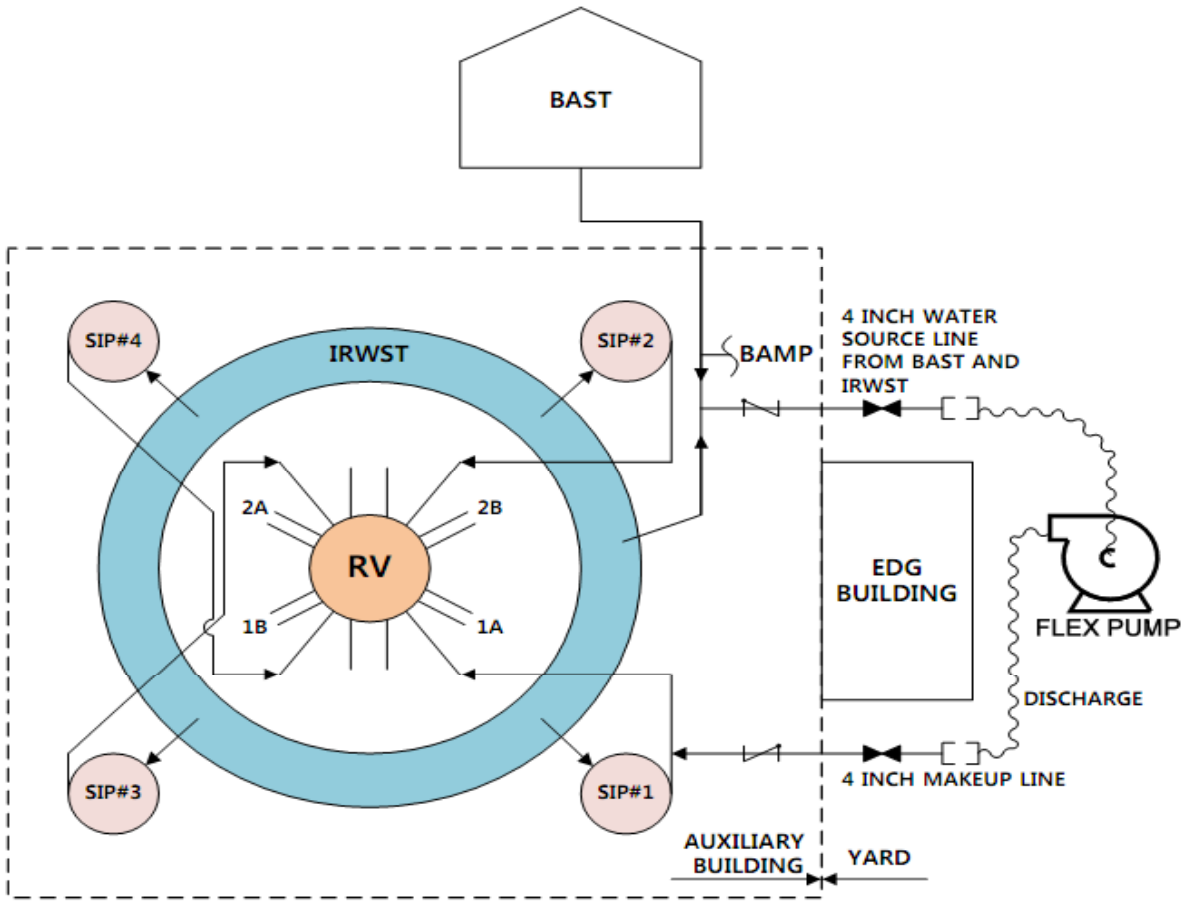
❖ Phase 2 (8 - 72 hrs)

- RCS make-up
  - Water source : BAST ( ), IRWST ( ) TS TS
  - Required water for Phase 2 : TS
  - RCS & RCP seal injection
    - BS : ACP, SIT
    - AS : high-head portable pump, SIT
- RCS pressure control
  - RCGVS valves

B. Core Cooling Strategy (SGs available)

❖ Phase 2 (8 – 72 hrs)

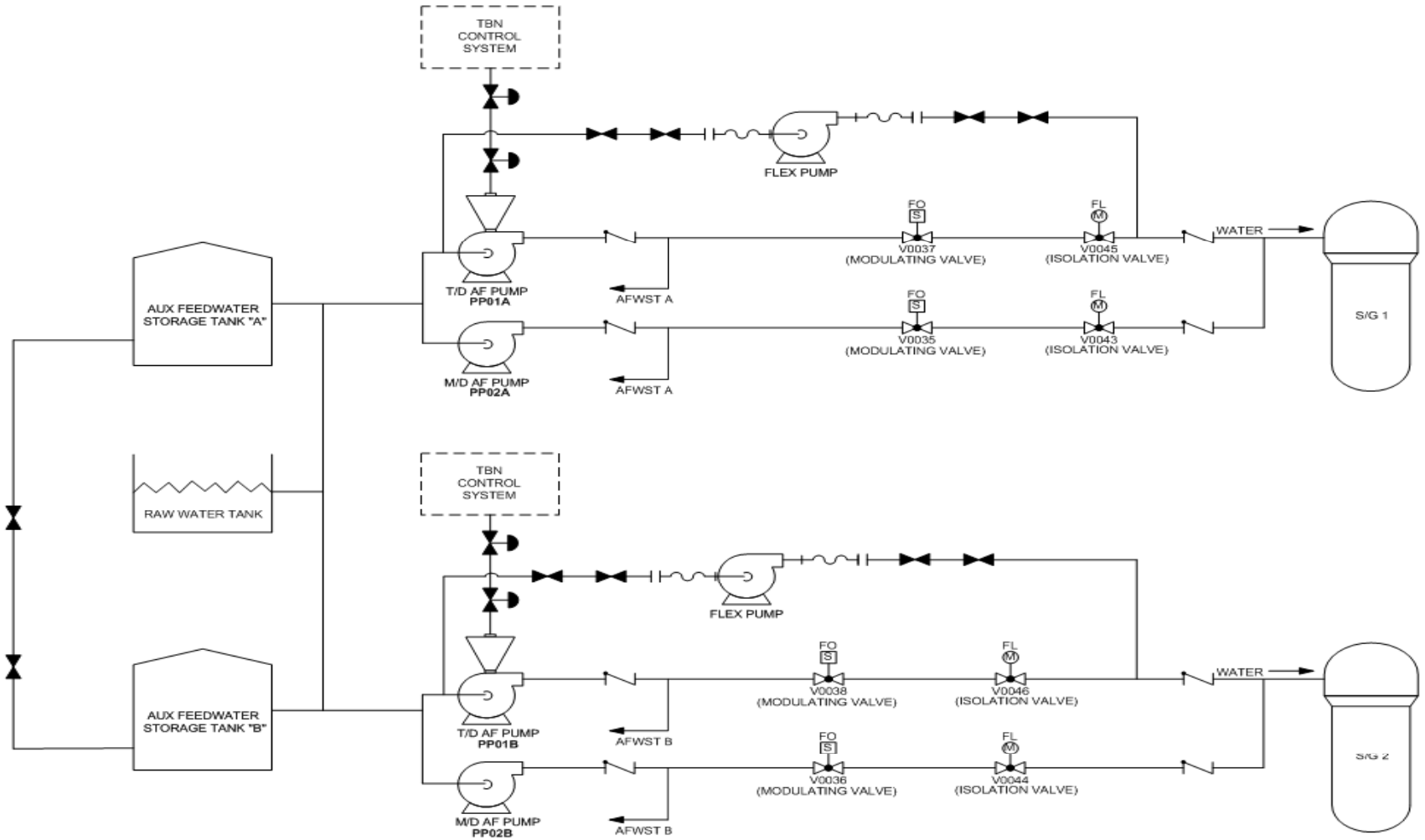
- External injection (Primary)



B. Core Cooling Strategy (SGs available)

❖ Phase 2 (8 – 72 hrs)

- External Injection (Secondary)



B. Core Cooling Strategy (SGs available)

❖ Phase 3 (72 hrs -)

- NCC + forced cooling operation
  - RCS states
    1) hot shutdown (350 ºF) when BS of phase 2 continues
    2) close to cold shutdown (210 ºF) when AS of phase 2 continues
    3) cold shutdown (140 ºF) when cooldown with SCS
  - SG feedwater injection : portable pumps, AFWPs,
  - Steam release : MSADVs
  - SG cooling water source : Raw Water Tanks, Off-site water sources
  - RCS inventory makeup : ACP or high head portable pump
  - RCS makeup water source : IRWST

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

B. Core Cooling Strategy (SGs available)

❖ Supporting Analysis

- RCS pressure and temperature

TS

B. Core Cooling Strategy (SGs available)

❖ Supporting Analysis

- RCS leak & make-up flow

TS

B. Core Cooling Strategy (SGs available)

❖ Supporting Analysis

- PZR and Core level

TS

B. Core Cooling Strategy (SGs available)

❖ Supporting Analysis

- Secondary heat removals

TS

B. Core Cooling Strategy (SGs available)

❖ Supporting Analysis

- Reactivity control

TS

B. Core Cooling Strategy (SGs available)

❖ Instruments available for the operator

- PZR pressure
- PZR level
- Hot leg temperature
- Cold leg temperature
- SG pressure
- SG level
- Charging flow
- AFWST level
- RWT level(local)
- SIT level
- SIT pressure
- Containment pressure
- Etc.

C. Core Cooling Strategy (SGs not available)

❖ Low mode operation with SGs not available

- Mode 5 (Reduced Inventory Operation) or Mode 6 (Refueling)
- Feed and steaming operation strategy will be applied
- The most severe case is mid-loop operation during Mode 5
- The core cooling strategy is set up based on the plant condition for mid-loop operation

C. Core Cooling Strategy (SGs not available)

TS

❖ Strategy Summary

C. Core Cooling Strategy (SGs not available)

❖ Phase 1 (0 – 3 hrs)

- Decay heat is removed by coolant boil-off
- Gravity feed from SITs
  - 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
  - Open 1st SIT isolation valve
  - Open 2nd SIT isolation valve

  TS, TS, TS
- Preparations for Phase 2
  - Install a low head portable pump

C. Core Cooling Strategy (SGs not available)

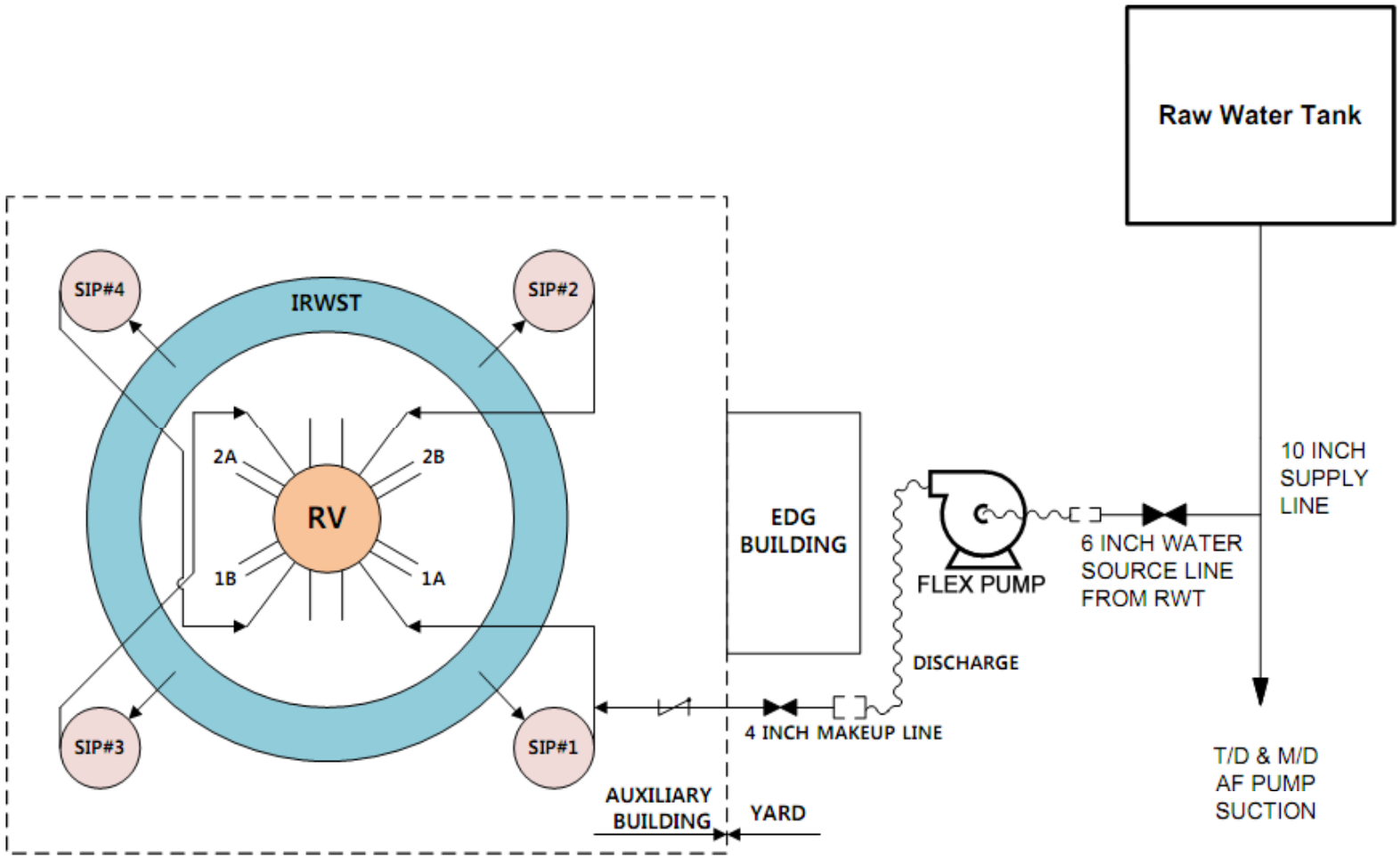
❖ Phase 2 (3 – 72 hrs)

- 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

C. Core Cooling Strategy (SGs not available)

❖ Phase 2 (3 – 72 hrs)

- External Injection (Primary)



C. Core Cooling Strategy (SGs not available)

- 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

C. Core Cooling Strategy (SGs not available)

❖ Supporting analysis

- Upper plenum/core liquid fraction, core/downcomer collapsed level depending on gravity feed from SITs

TS

C. Core Cooling Strategy (SGs not available)

❖ Supporting analysis

- RCS temperature, liquid fraction, SIT inventory depending on gravity feed from SITs

TS

C. Core Cooling Strategy (SGs not available)

- Instruments available for the operator
  - Hot leg temperature
  - Cold leg temperature
  - Portable pump flow(local)
  - RCS level
    - ULMS and Sight glass(local)
    - HJTC
  - SIT level
  - SIT pressure
  - Containment pressure
  - Etc.

3. Strategy for SFP Cooling

A. Key Assumptions

B. SFP cooling strategy

- strategy summary
- phased approach (1, 2 & 3)

C. SFP level instrumentation

A. Key Assumptions

❖ Key Assumptions

- Boil-off is credited to cool the SFP, provided the water level is maintained above the top of the spent fuel.
- Maximum number of SF assemblies are assumed to be in the SFP(20 years of fuel storage).
- Initial SFP water level is assumed to be at normal water level (Level 1).
- Three conditions are analyzed for the SFP decay heat load:
  - Mode 1 to Mode 4 without full core off-load
  - Mode 5 & Mode 6 without full core off-load
  - Mode 6 with full core off-load (Limiting Case)

B. SFP cooling strategy

❖ SFP Cooling Strategy Summary

TS

B. SFP cooling strategy

❖ Phase 1 (0 – 8 hrs)

- No action is needed for SFP makeup
- SFP water level is monitored.
- Open the rollup door to the fuel handling area truck bay on the EL.100'-0" of the Auxiliary Building.
- The vent path for the spent fuel area that is established in Phase 1 is maintained in Phase 2 and 3.
- Install a portable pump to external makeup connection and RWT connection line.

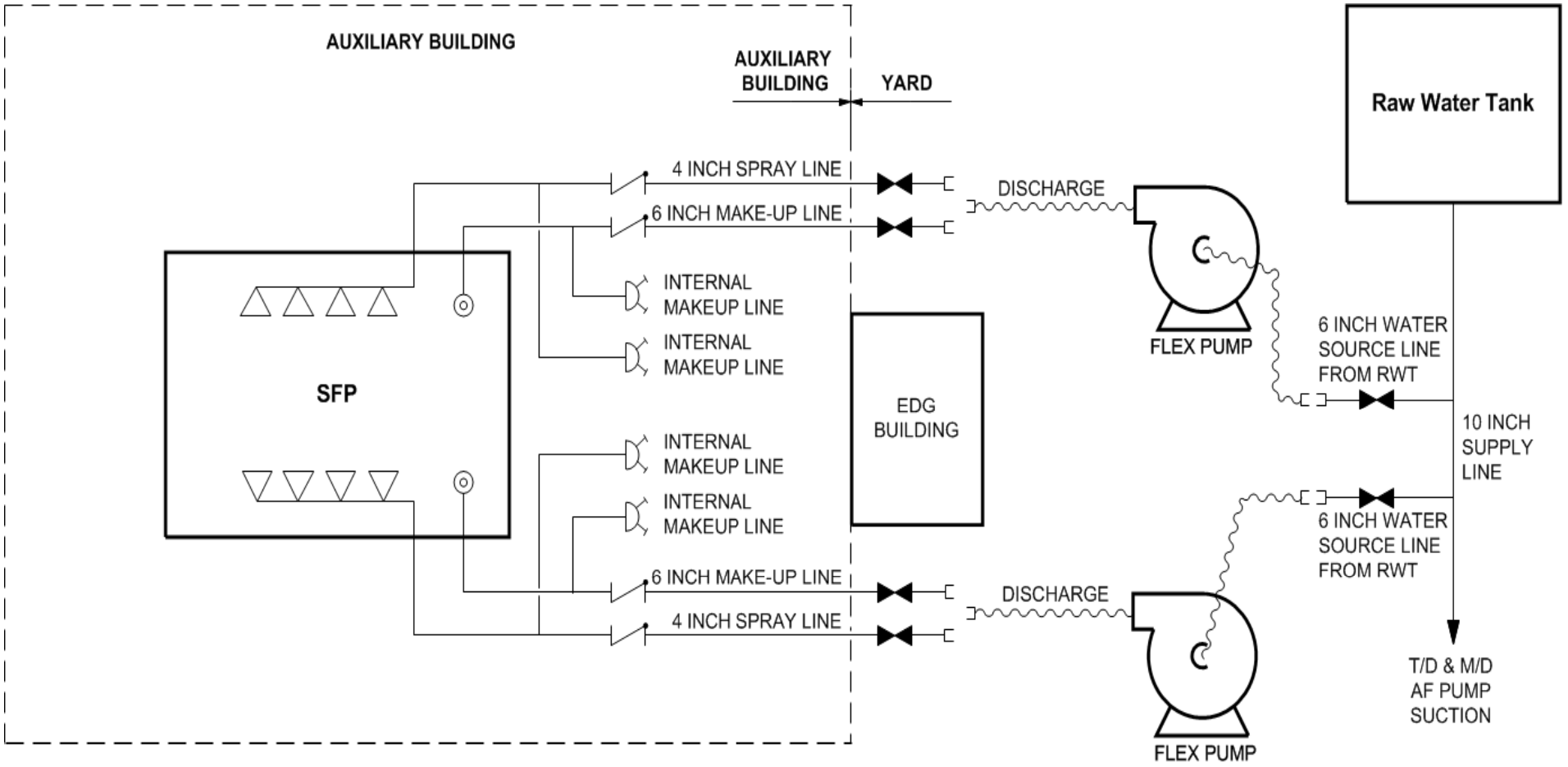
B. SFP cooling strategy

- Phase 2 (8 – 72 hrs)
  - Makeup : Portable pumps (SFP makeup or spray pump)
  - Water source : Raw Water Tank (RWT)
  - SFP water level is monitored

B. SFP cooling strategy

❖ Phase 2 (8 – 72 hrs)

- SFP Makeup and Spray Line diagram



B. SFP cooling strategy

- Phase 2 (8 – 72 hrs)
  - Makeup and Spray Source : Raw Water Tank (RWT)

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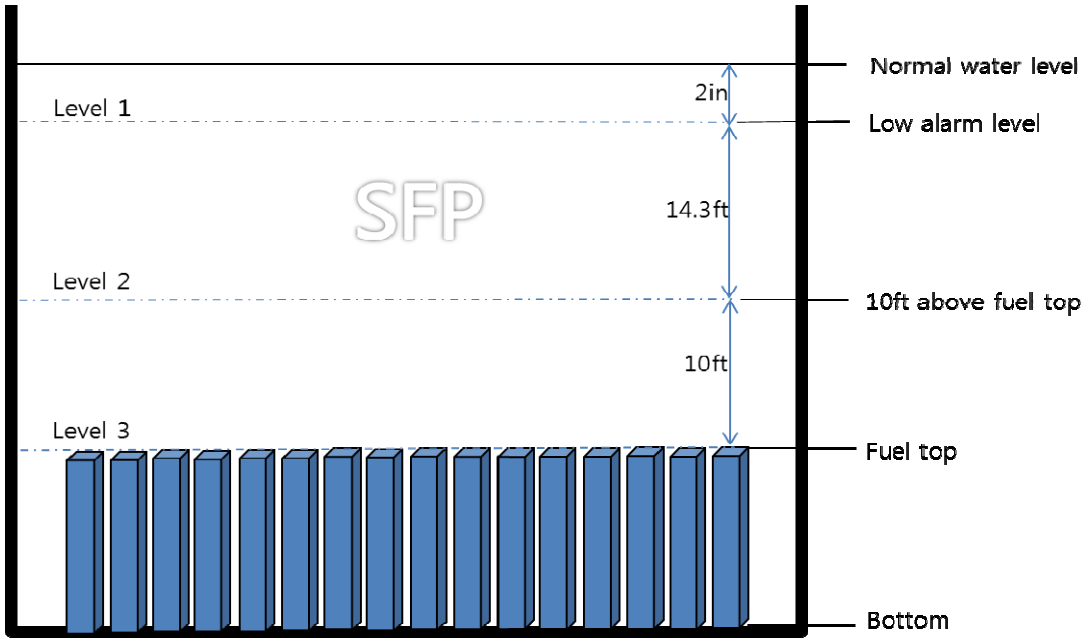
B. SFP cooling strategy

- Phase 3 (72 hrs -)
  - Strategy is the same as phase 2
  - Water source : RWT & off-site resources

C. SFP level instrumentation

❖ SFP Monitoring Water Level

- Level 1: Level adequate to support operation of the normal SFP cooling system
- Level 2: Level adequate to provide substantial radiation shielding for a person standing on the spent fuel pool operating floor
- Level 3: Level where fuel remains covered, but actions to implement make-up water addition should no longer be deferred



C. SFP level instrumentation

❖ SFP level instrumentation

- Two safety-related level instrumentation : train A and B
- Type : Guided Wave Radar (GWR)
- Range : Level 1 to level 3 (wide range)
- Arrangement :
  - Each instrument is arranged on opposite sides or corners of the pool area to provide reasonable protection against falling debris and structural damage.
- Mounting : Designed as Safety Class 3 and Seismic Category I
- Accuracy : Better than ± 1 ft (NEI 12-02)
- Display : Continuously displayed in the MCR and RSR
- Independence : Each instrument channel has different power source and is physically separated to the extent practicable.

4. Containment Capability

A. Containment Capability - Full Power

❖ Containment analysis for full power

- Assumption : RCP seal leakage of [ ]TS per RCP (total [ ])TS
- Containment analysis (GOTHIC 8.0)

[ ]TS

- Containment Integrity is maintained for RCP seal leakage case.

A. Containment Capability - Full Power

❖ Containment analysis for full power

TS

B. Containment Capability – Mode 5

❖ Containment analysis for mid-loop operation

- Assumption : inventory boil-off for loss of residual heat removal during mid-loop operation
- Containment analysis (GOTHIC 8.0)

[ ] TS

B. Containment Capability – Mode 5

❖ Containment Analysis for mid-loop operation

TS

5. Support Systems

A. Cooling water

B. Fuel oil

C. Electrical system

A. Cooling Water

❖ Summary of cooling water demand

TS

A. Cooling Water

❖ Summary of cooling water demand (Cont.)

TS

A. Cooling Water (Full Power)

TS

❖ Water source capacity

A. Cooling Water (Low Mode)

TS

A. Cooling Water

❖ Portable Equipment Connections

TS

B. Fuel Oil

❖ Summary of fuel oil demand

TS

B. Fuel Oil

❖ Summary of fuel oil demand (Cont.)

TS

B. Fuel Oil (Full Power)

❖ Fuel oil source capacity

- Existing on-site EDG fuel oil storage tanks and its associated diesel fuel oil day tanks (Train A and B)

[ ] TS

- APR1400 has the fuel oil source capacity of at least [ ] TS for full power mode

B. Fuel Oil (Low Mode)

- Fuel oil source capacity
  - Existing on-site EDG fuel oil storage tanks and its associated diesel fuel oil day tanks (Train A and B)

[ ] TS

- APR1400 has the fuel oil source capacity of at least [ ] TS for low mode

B. Fuel Oil

❖ Fuel oil supply connections

TS

C. Electrical System

❖ Electric Power Resources to cope with BDBEE

TS

C. Electrical System

TS

C. Electrical System

❖ Communication System

- Phase 1
  - Wireless system is powered from a dedicated UPS
- Phase 2
  - Wireless system is powered from a dedicated UPS
  - Wireless system is powered from train A or B 480Vac LC
- Phase 3
  - Wireless system is powered from a dedicated UPS
  - Wireless system is powered from train A or B 4.16kVac Switchgear

C. Electrical System

❖ Lighting System

- Phase 1
  - Emergency dc lighting system is powered from trains C or D 125Vdc buses
  - Individual fixed emergency lighting units equipped with self-contained battery pack are available for 8(eight) hours
- Phase 2
  - Emergency dc lighting system is powered from train A or B 125Vdc buses
  - Emergency ac lighting system is powered from train A or B 480Vac LC
- Phase 3
  - Emergency ac lighting system is powered from train A or B 4.16kVac Switchgear

* Portable light apparatuses are provided in all phases for access to areas with emergency lighting fixtures not installed

6. Discussion

Thank you