국민에게 신뢰받는 안전 최우선의 **KINS**

Introduction to NPP system

System basic

Primary system summary

한국원자력안전기술원
KOREA INSTITUTE OF NUCLEAR SAFETY

Contents

I Primary System Outline

II RCS and Aux-primary system

III Plant Protection System(PPS)

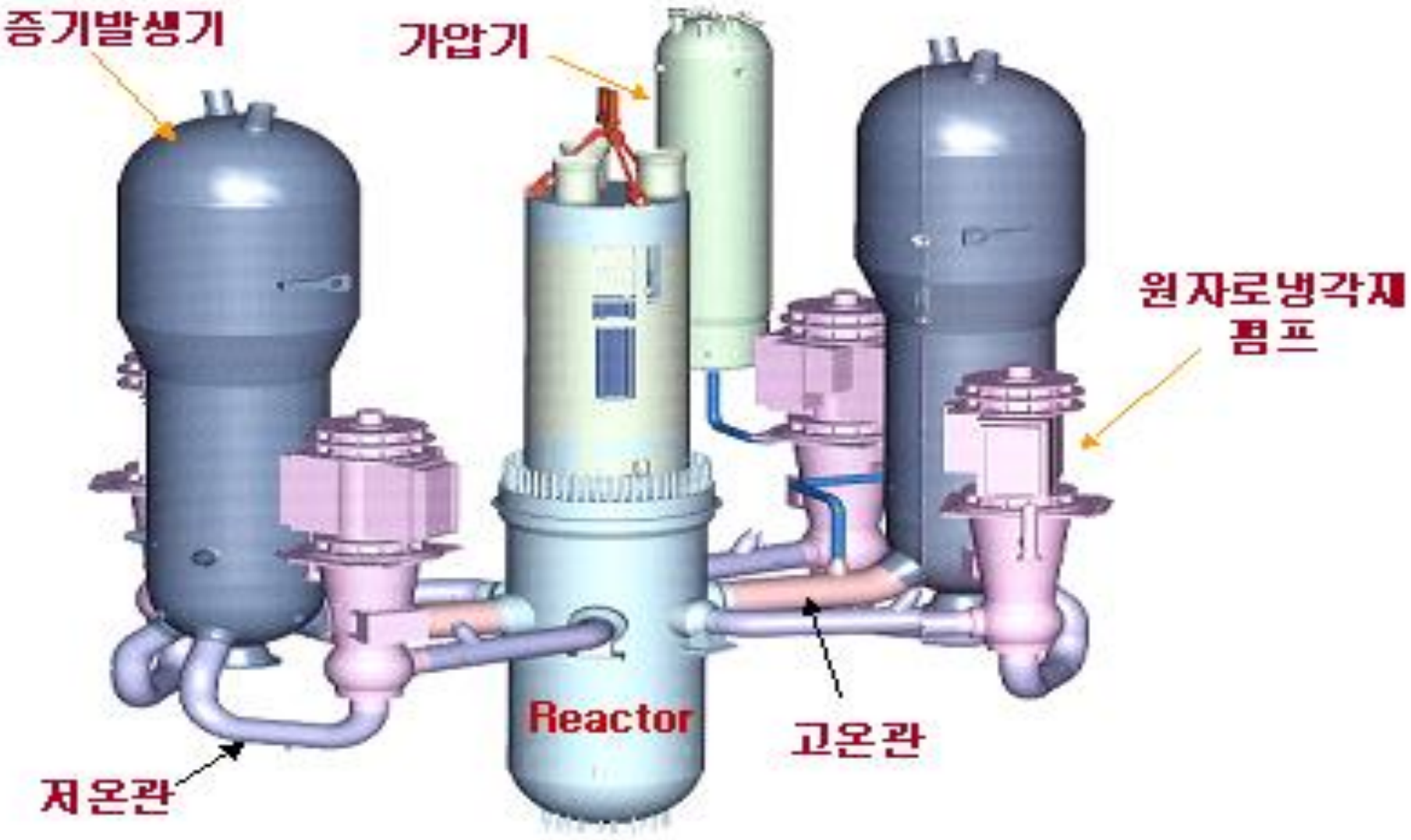
I. Primary System Outline

1. Primary System Outline

- **Primary System**
  - **Primary system: system related to primary coolant**
    - **Primary coolant: a fluid that directly absorbs heat from the reactor core**
- **Reactor Coolant System**
  - **Reactor, Steam Generator, PZR, RCP, Pipe such as hot/cold leg**
- **Primary Auxiliary System**
  - **CVCS, CCW system, ESW system, Shutdown cooling system**
- **Engineering safety facilities, etc.**
  - **Reactor building, Auxiliary systems of the reactor building (including the containment spray system), Emergency core cooling system, etc.**

II. RCS and Aux-primary system

2-1. Reactor Coolant System



2-1. RCS Composition

Rx vessel

- Support and protection of fuel assemblies and internal structures
- Provides power production area

Steam Generator

- Heat generated from fuel is transferred to the secondary side through U-tube
- Barrier to prevent diffusion of primary fission products into the environment

Reactor Coolant Pump

- Removes heat generated from the core by providing a forced circulation force to the reactor coolant

Pressurizer

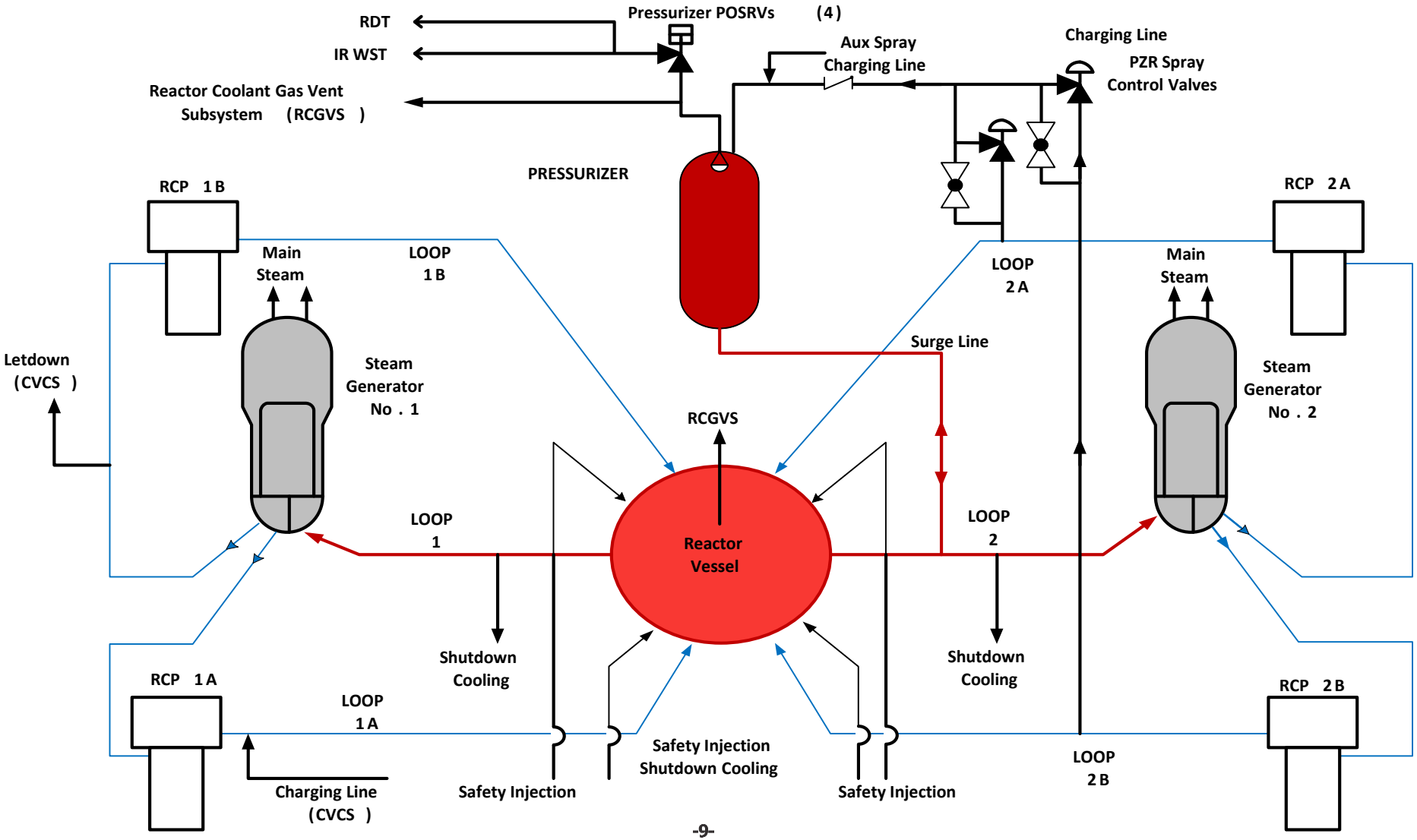
- RCS pressure and volume control means provided
  - Prevent pressure rise: reactor coolant pressure boundary integrity
  - Prevent pressure drop: pressure build-up to keep RCS supercooled

2-1. RCS function

- **Reactor core cooling**
  - The heat generated in the reactor is transferred to the steam generator.
- **Neutron slowing down**
  - Slowing neutrons to increase the possibility of nuclear fission
  - Acts as a reflector to reduce the loss of neutrons
- **Boron solvent**
  - Transport of Boron, a Soluble Neutron Absorbing Material
- **Keeping of fission products**
  - A secondary barrier that prevents periphery diffusion of fission products
- **Radiation shielding**
  - Reduction of external emission of radiation through attenuation

2-1. RCS

• RCS schematic diagram



2-2. CVCS

- RCS Inventory control(Excess coolant spillage, Insufficient coolant supplement, Automatic control of pressurizer level)
- Chemistry and Purity Maintenance (Dissolved oxygen removal, pH adjustment, Water purification)
- Reactor coolant system volume control
- Reactor control through boric acid concentration control
- RCS pressure control assistant
- RCP seal water supply
- RCS boron concentration measurement
- RCS fission product radiation monitoring

2-2. CVCS

Letdown

- RCP 1B Crossover Leg → Regenerative Hx → Letdown Hx → Back-pressure control V/V → Filter → BRM/PRM → Purification IX → VCT

Charging

- VCT → Charging P/P → Charging control V/V → Regenerative Hx → RCS 1A Cold Leg

RCP seal water injection

- VCT → Charging P/P → Charging control V/V → Seal water filter → RCP Seal → VCT

2-2. CVCS_Composition

- **Letdown Isolation V/V**

  - Maintaining inventory of reactor coolant and the integrity of the containment building in case of an accident

- **Purification and deborating ion exchanger**

  - Continuous removal of impurities and radionuclides from RCS

- **VCT**

  - Boric acid concentration mixing

- **Charging P/P**

  - Purified charge water supply to RCS and RCP

- **Charging Control V/V**

  - Control the pressurizer level by adjusting the charging flow

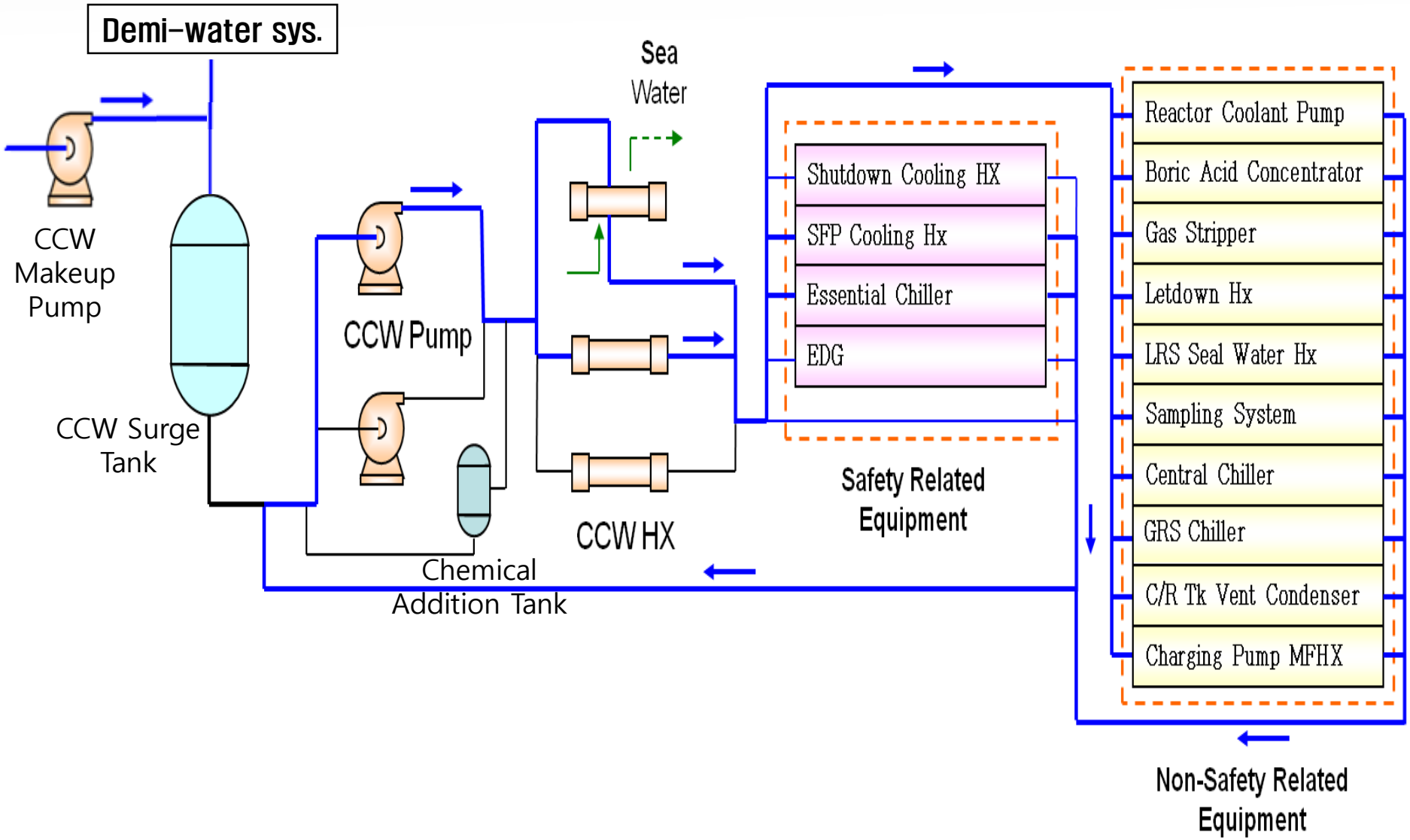
2-3. CCW(Component Cooling Water System)

- **Supply of cooling water to the main equipment of the primary system**
  - **Safety related system : CS, SC, EDG, ECW, SFP, SCS**
  - **Non-safety system : RCP, CV, PS, RMS, GRS, LRS, etc.**
  - **Supply of cooling water up to 35°C in normal condition and up to 43.3°C in case of accident**
- **The role of an intermediate barrier between the radioactive system and the seawater system (circulation closed circuit)**
- **Designed to keep the power plant safe by removing fuel decay heat and heat from safety facilities even in an emergency**
- **Consists of two independent channels for reliability**
- **Components(each ch.) : CCW PP 2 ea, Hx 3 ea, Surge Tk 1 ea, Make-up P/P 1 ea**

2-3. CCW_Composition

- **CCW P/P**
  - Circulating component cooling water
- **CCW Hx**
  - Maintaining a constant temperature through Hx with seawater
- **Surge Tank**
  - Provide pump suction head and control CCW inventory
- **Each heat exchangers**
  - Removal of heat from the primary system

2-3. CCW


Demi-water sys.
Sea Water
CCW Makeup Pump
CCW Surge Tank
CCW Pump
CCW HX
Chemical Addition Tank
Shutdown Cooling HX
SFP Cooling Hx
Essential Chiller
EDG
Safety Related Equipment
Reactor Coolant Pump
Boric Acid Concentrator
Gas Stripper
Letdown Hx
LRS Seal Water Hx
Sampling System
Central Chiller
GRS Chiller
C/R Tk Vent Condenser
Charging Pump MFHX
Non-Safety Related Equipment

2-4. ESW(Essential Service Water System)

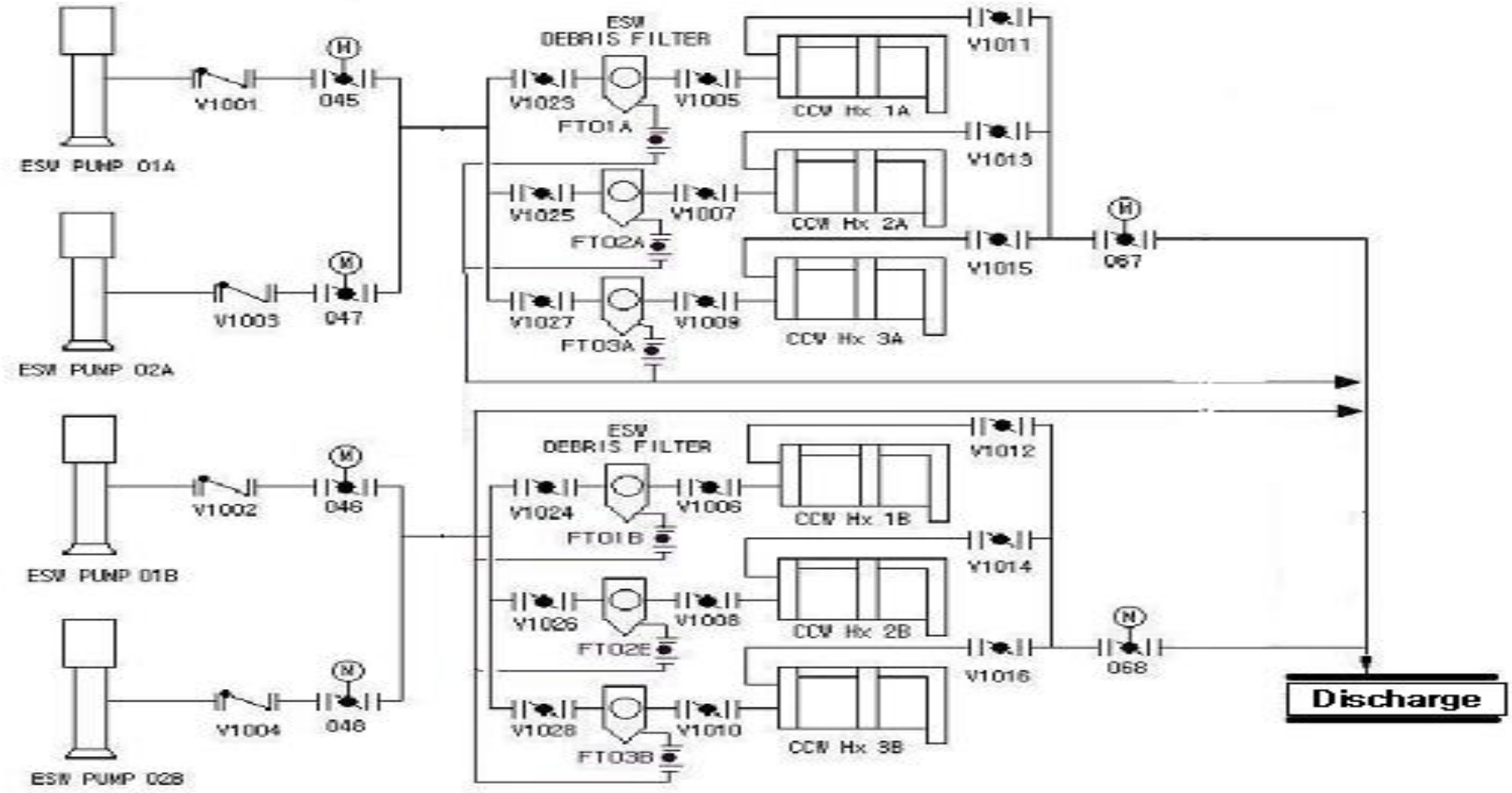
- To supply cooling seawater to the CCW heat exchanger to remove the heat load on the primary cooling water system in all operation modes of the power plant
- Operation range

  - Temperature: min. 0.4°C, max. 26.78°C in normal condition, maximum 31°C in accident

  - Sea level: min. -8.01m, max. +2.820m (0m: Incheon average sea level)

- The heat load transferred from the reactor auxiliary load is released to the final heat removal source (seawater)
- Designed as two independent ch.s for operational reliability
- Component(each ch.) : ESW PP 2 ea, Hx 3 ea, Filter 3 ea

2-4. ESW


ESW PUMP 01A
V1001
045
ESW PUMP 02A
V1003
047
ESW PUMP 01B
V1002
046
ESW PUMP 02B
V1004
048
ESW DEBRIS FILTER
V1023
FT01A
V1005
V1025
FT02A
V1007
V1027
FT03A
V1009
ESW DEBRIS FILTER
V1024
FT01B
V1006
V1026
FT02B
V1008
V1028
FT03B
V1010
CCW Hx 1A
CCW Hx 2A
CCW Hx 3A
CCW Hx 1B
CCW Hx 2B
CCW Hx 3B
V1011
V1013
V1015
V1012
V1014
V1016
067
068
Discharge

2-5. SCS(Shutdown Cooling System)

- Residual heat removal: core residual heat removal during power plant cooling and heating operation (@ 31.6kg/cm2, 177 °C below)
- IRWST cooling operation after accident
- Others
  - Refuelling tank filling/draining, CVCS purification oil connection during power plant shutdown period
  - RCS low temperature overpressure protection function (LTOP:Low Temperature Overpressure Protection)

2-5. SCS_Composition

- **Shutdown Cooling P/P**

  - Provides forced circulation power that sucks the coolant from the high-temperature tube and cools it through the heat exchanger

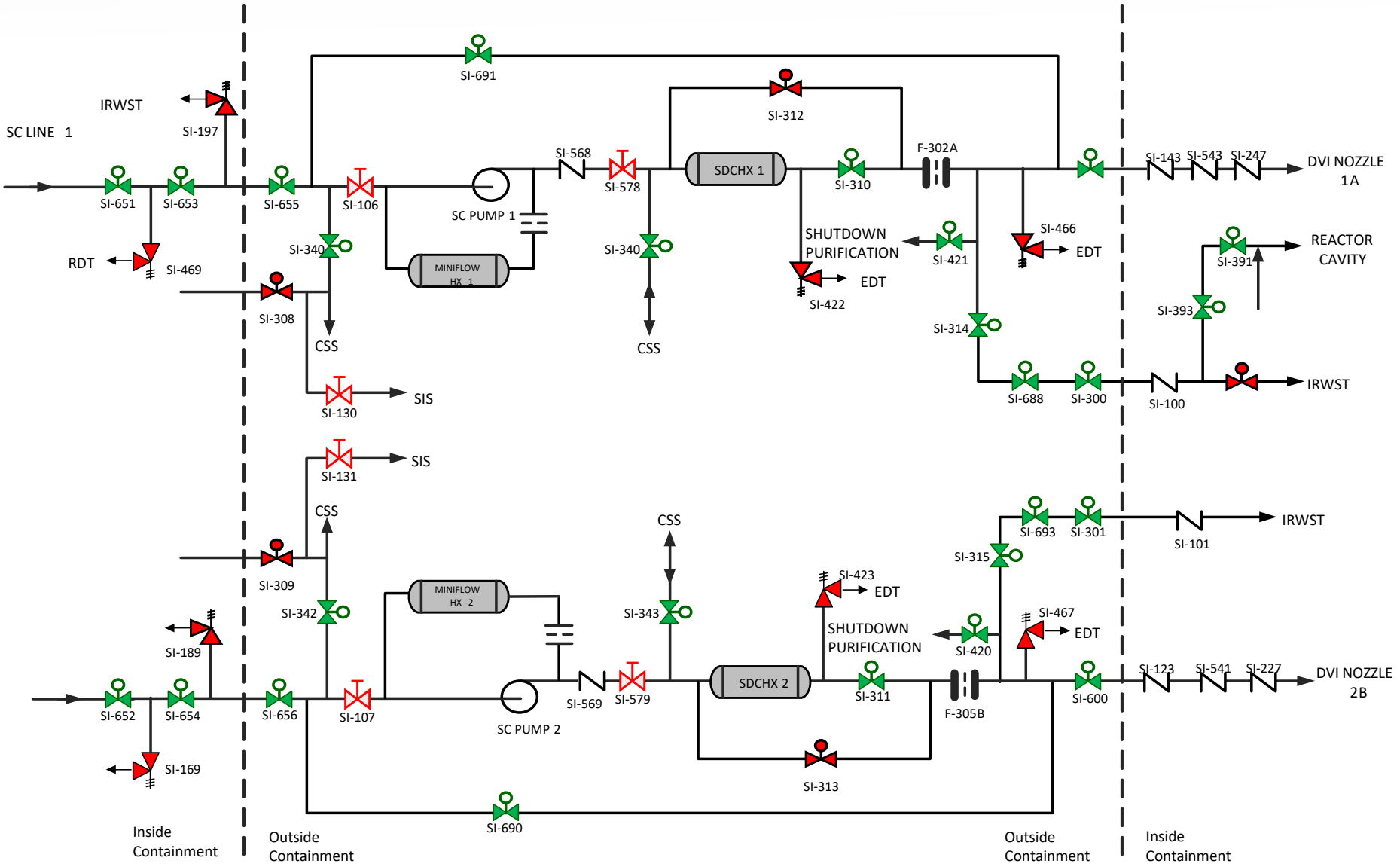
- **Shutdown Cooling Hx**

  - Remove heat from the high-temperature coolant with the CCW

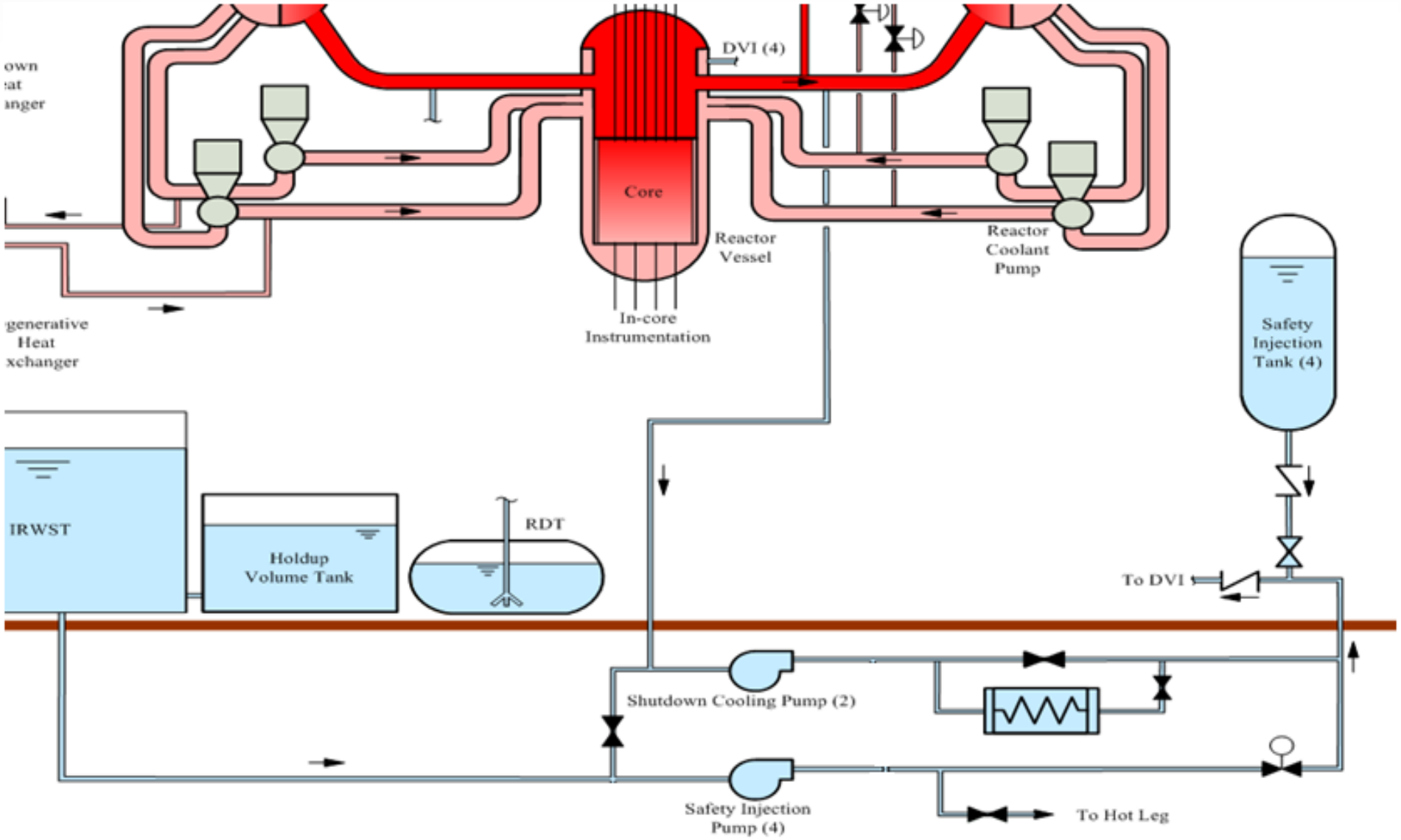
- **LTOP V/V**

  - Release the pressure to prevent damage to the reactor due to low temperature overpressure at the pressurizer full level.

2-5. SCS


SC LINE 1
IRWST
SI-197
SI-691
SI-312
SI-568
SI-578
SDCHX 1
SI-310
F-302A
SI-143
SI-543
SI-247
DVI NOZZLE 1A
SI-651
SI-653
SI-655
SI-106
SC PUMP 1
SI-340
MINIFLOW HX -1
SI-340
SHUTDOWN PURIFICATION
SI-421
SI-466
EDT
RDT
SI-469
SI-308
CSS
SI-422
EDT
SI-391
REACTOR CAVITY
SI-393
SI-314
SI-688
SI-300
SI-100
IRWST
SI-130
SIS
CSS
SI-131
SIS
SI-693
SI-301
SI-101
IRWST
SI-315
CSS
SI-309
SI-342
MINIFLOW HX -2
SI-343
SI-423
EDT
SHUTDOWN PURIFICATION
SI-420
SI-467
EDT
SI-189
SI-652
SI-654
SI-656
SI-107
SC PUMP 2
SI-569
SI-579
SDCHX 2
SI-311
F-305B
SI-600
SI-123
SI-541
SI-227
DVI NOZZLE 2B
SI-313
SI-169
SI-690
Inside Containment
Outside Containment
Outside Containment
Inside Containment

2-5. SCS


own
at
anger
generative
Heat
xchanger
DVI (4)
Core
Reactor
Vessel
In-core
Instrumentation
Reactor
Coolant
Pump
Safety
Injection
Tank (4)
IRWST
Holdup
Volume Tank
RDT
To DVI
Shutdown Cooling Pump (2)
Safety Injection
Pump (4)
To Hot Leg

2-6. SF(Spent Fuel Storage System)

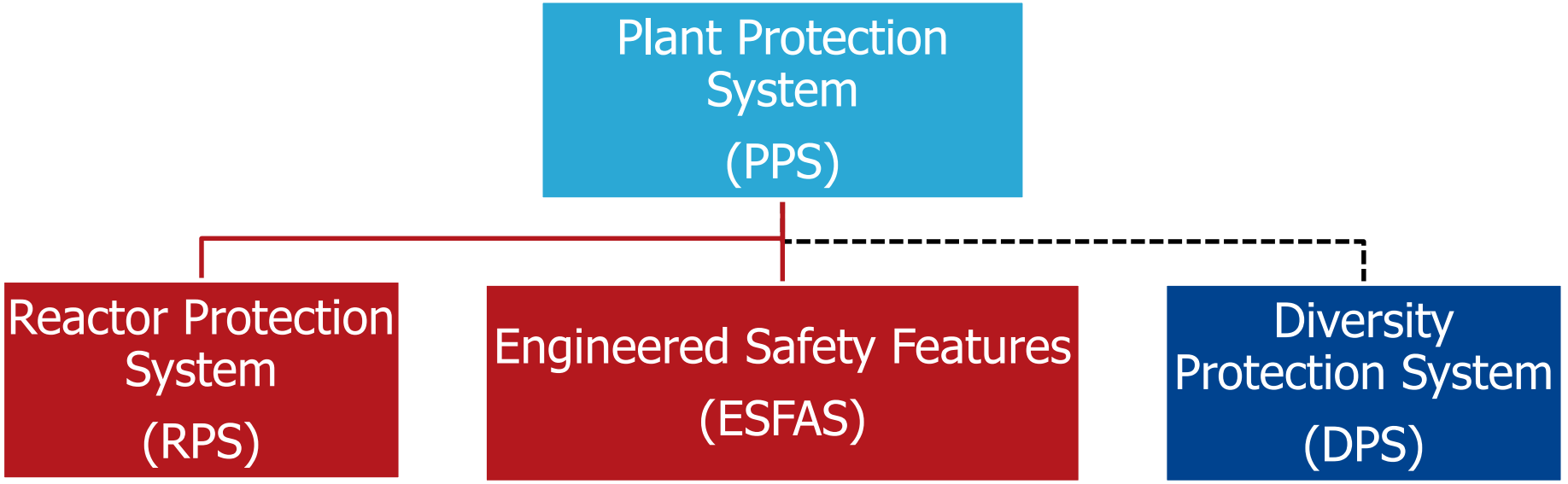
- Cooling of the spent fuel pool: Keep the pool temperature below 48.9°C
- Spent fuel pool purification
- Prevention of draining from the spent fuel pool: The cooling pump inlet is located high enough above the fuel
- Spent fuel pool make-up water: boric acid water, demineralized water

III. Plant Protection System(PPS)

PPS introduction & composition

Function

- **Maintaining anticipated operation occurence (AOO) and design-based accident (DBA) results within acceptable limits**
- **When safety-related power plant variables (pressurizer pressure, SG level, etc.) reach a set value, it automatically operates to ensure the integrity of the core and coolant system pressure boundary.**
- **Mitigating or preventing accidents so that the off-site dose rate does not exceed the 10 CFR 100 threshold in the event of an accident**



3-1. RPS Outline

Function

- In the event of an AOO, shut down the reactor quickly to prevent the safety threshold from being exceeded.
- Assisting ESFAS in the event of an accident to mitigate the consequences

Reactor Trip

- Manual trip: Circuit breaker open by selective 2/4 logic of circuit breaker installed in series/parallel
- When the target variable exceeds the set value, the reactor trip signal is generated by 2/4 logic
- Turbine trip signal generated by reactor shutdown
- One channel can be bypassed in case of a bistable or detector failure (simultaneous logic 2/4 ⇒ 2/3 conversion)
- In case of loss of input power of one M-G set, it is irrelevant to reactor trip

3-1. PPS Design Concept

- **Redundancy**
  - It consists of 4 channels A, B, C, D from sensor to initiation circuit
    - Use of 2/4 logic circuit
- **Diversity**
  - Protection function is performed through various facilities and signals
    - AFAS, PZR Hi Pr. : Generate trip signal by PPS, DPS
- **Independency**
  - Electrically and physically independent
    - Sensor, cable, power, cabinet channel, output card, etc.
- **Testability**
  - Test possible without loss of protection function during operation
    - Test 1 out of 4 channels
- **Fail-Safe**
  - Set in a safe direction in case of failure
    - Partial trip (1/4) occurs at 4 reactor shutdown circuit breaker in case of initiation circuit failure

3-1. PPS trip signal

Trip Siganl		Set-point	Input	Type	Background
Hi Log PWR		0.029 %	ENFMS (Safety)	stationary	Guarantee of fuel cladding and RCS pressure boundary integrity
VOPT	Max	110.4 %	ENFMS (Safety)	variable	Core protection in case of rapid positive reactivity insertion
	Slope	15.0 %/분			
	Step	14 %			
Lo DNBR		1.29		stationary	Avoid exceeding the DNBR limit
Hi LPD		689 W/cm (21 kW/ft)		stationary	Nuclear fuel integrity protection (prevention of exceeding the LDP)
PZR Hi Pr.		167.6 kg/cm^2_A	PZR Pr.(NR)	stationary	RCS pressure boundary integrity protection
PZR Lo Pr.		125.6 kg/cm^2_A	PZR Pr.(NR)	variable	RX trip and ESF operation in case of RCS decompression accident
S/G Lo LVL		45 %(WR)	SG LVL	stationary	Guaranteed running time of aux feedwater supply in case of water loss
S/G Lo Pr.		59.5 kg/cm^2_A	STM Pr.	variable	RCS overcooling protection
CV Hi Pr.		124.1 cmH_2O	CV Pr.	stationary	Maintaining the integrity of the CV
S/G Hi LVL		91 %(NR)	SG LVL	stationary	Prevent moisture ingress with TBN
RCS Lo Flow	Min	730.9 cmH_2O	SG DP	variable	Initiation of reactor trip when RCP shaft is stuck
	Slope	646.7 cmH_2O			
	Step	3 cmH_2O/초			

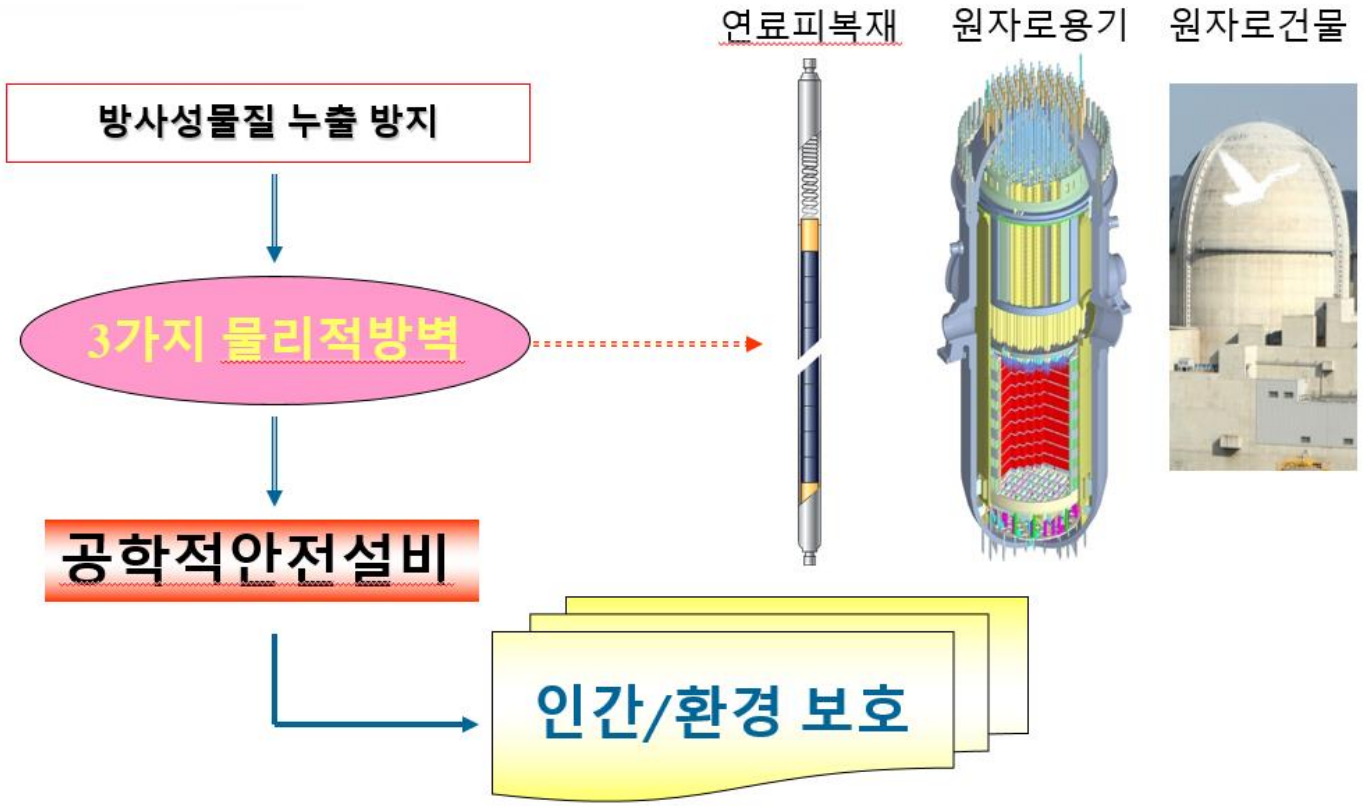
3-1. 원자로정지 가능 시나리오(예시)

VOPT	Boron dilution, controlled rod withdrawl, RCS subcooling
Hi Log Power	Unexpected power rise
Lo DNBR	CPC Aux Trip, RCP unexpected stop
Hi LPD	
PZR Hi Pressure	TBN stop when RPCS is disabled
PZR Lo Pressure	Open the pressurizer spray valve
SG Lo Level	Stopped the main feed water pump
SG Hi Level	Main feed water control valve failure open
SG Lo Pressure	Steam bypass control valve failure and open
CTMT Hi Pressure	LOCA, ESDE
RCS Lo Flow	RCP shaft stuck
Manual Trip	When requesting a manual shutdown of the reactor

3-2. ESF Outline

Function

- Provides protection against fission products emitted from the reactor coolant system
- Accident control, accident mitigation and accident closure
- Keep leaking radiation levels below the 10 CFR 100.11 limit.



3-2. ESF Outline

- **When the variable value reaches the set value, the following operation signal is generated.**

- **SIAS**
  - Supply of boric acid water in the core, protection of nuclear fuel cladding

- **CIAS**
  - Isolation of piping passing through the reactor building and prevention of external leakage of radioactive materials in the reactor building

- **CSAS**
  - Removing heat and radioactive iodine from inside the reactor building

- **MSIS**
  - Prevention of RCS overcooling, prevention of overpressure of reactor building, prevention of erosion of turbine blades due to moisture

3-2. ESF Outline

- **When the variable value reaches the set value, the following operation signal is generated.**

- **AFAS**
  - Supplying water to the steam generator, securing the primary heat removal source

- **FHEVAS**
  - Reduction of radiation levels in nuclear fuel buildings

- **CPIAS**
  - Prevention of external leakage of radioactive materials in the reactor building

- **CREVAS**
  - Securing the integrity of the main control room

3-2. ESF - Composition

- **Containment building system**
  - Containment building, Containment spray system, Containment isolation system, Containment building combustible gas control system
- **Satety injection system**
  - SIT, SIP, IRWST
- **Aux-feedwater system**
- **Fission product removal and control system**
  - MCR/FHB emergency ventilation system

※ Note: Auxiliary water supply systems are included in FSAR Chapter 10 (Steam and Power Conversion Systems)

Engineering safety equipment system: FSAR Chapter 6

3-3. Containment Building System

- **When the following design basis accident (DBA) occurs**

  - Loss of Coolant Accident
  - Excess Steam Demand Event
  - Loss of Feedwater Accident

  – **Keep within limits on the amount of radioactive material emitted**

  – **Withstand expected accident temperature and pressure**

  - Design Pr. : 60 psig, Design Temp. : 143 °C (290°F)

  – **Leakage limit after accident**

  - First 24hr : 0.1%/d

  - After 24hr : 0.05%/d

3-4. Containment Spray System

Function

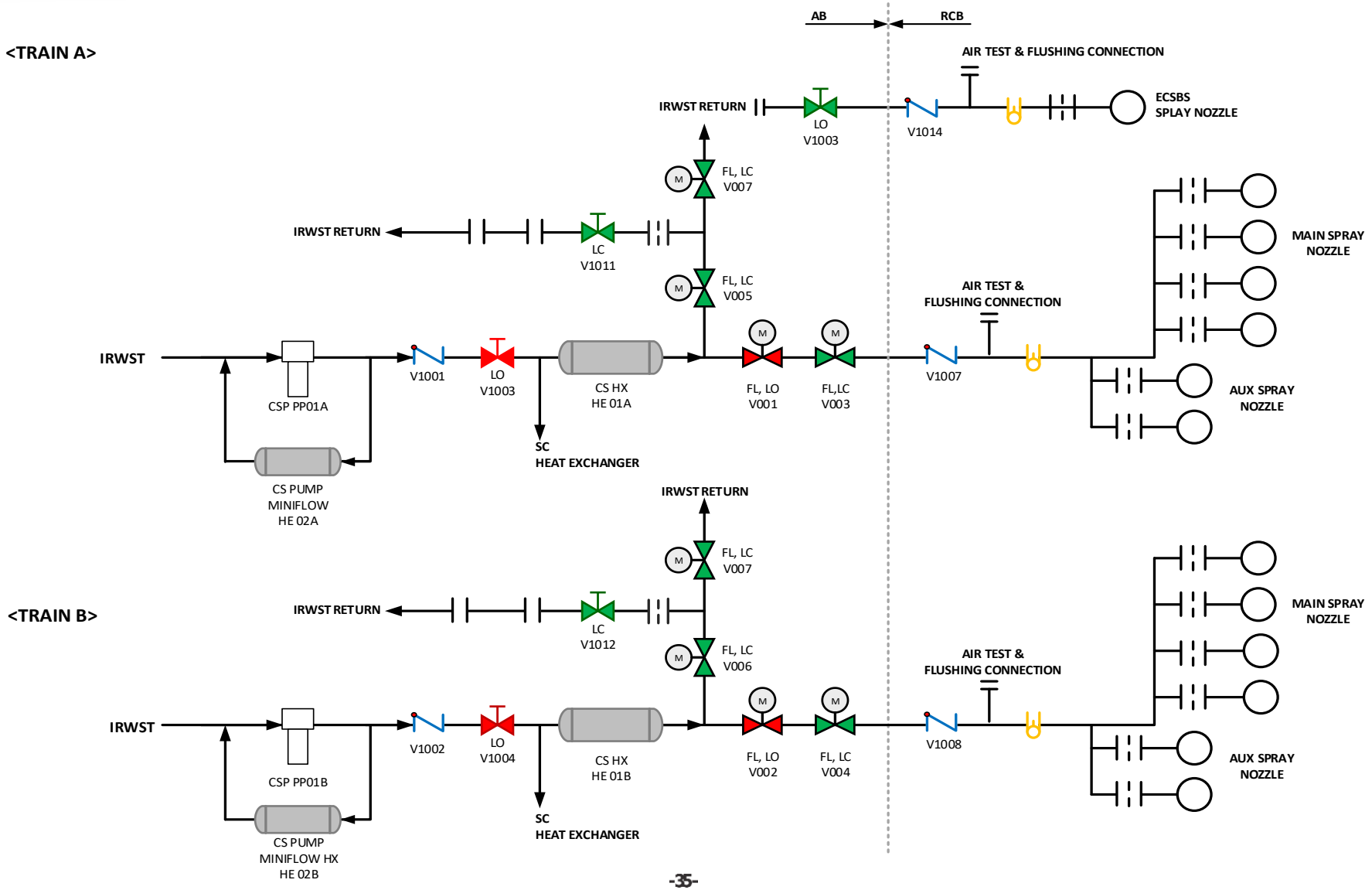
- After MSLR or LOCA, the pressure and temperature of the reactor building are lowered, and after LOCA, fission products are removed from the reactor building atmosphere.
- Maintain IRWST pH between 7 and 8.5 using sodium triphosphate (TSP) within 4 hours of accident
- Water spray located on the upper part of the reactor building
  - Watering condenses steam to reduce pressure and temperature
  - Auxiliary spray header and nozzle (131/150 ft) promotes atmospheric mixing

Composition

- CSP 2, CS Hx 2, Mini-flow Hx 2, Spray HDR and V/V
- External Spray Equipment
  - 2 CS P/P, SC P/P and IRWST unavailable
  - Connecting separate water to the outside of the auxiliary building and supplying it to the emergency spray header

3-4. Containment Spray System

[원자로건물살수계통 개략도]



3-4. Containment Spray System

3-5. Containment Isolation System

Function

- Isolation of non-safety-related fluid systems passing through the reactor building after DBA
- No specific systems for isolation

Design Concepts

- Double isolation of the reactor building penetration of a fluid system that does not require a function after a design-based accident
- Valves that are required to remain closed for the integrity of the reactor building are automatically closed and closed and sealed to minimize the release of radioactive materials.
- Capability for Periodic Reactor Building Isolation Valve Operability Testing

3-6. Combustion Gas Control System

- **Passive autocatalytic recombiner system**
  - Maintaining the hydrogen concentration in the CV below 4 v/o
  - Designed with 200% or more of the required capacity in case of a design basis event
- **Hydrogen purge system**
  - Air exhaust through the reactor building purge system at LOCA
- **Hydrogen control system**
  - Igniter(Power supplied from EDG)
- **Hydrogen monitoring system**
  - Provides continuous readings to MCR

3-7. ECCS

Function

- Restriction of nuclear fuel damage in case of loss of coolant
- Maintaining the original shape of the nuclear fuel bundle
- Limits the reaction between the fuel cladding and the coolant
- Removal of energy generated within the core
- Supply of boric acid water to maintain subcriticality
- Provision of long-term core cooling means after coolant loss accident
- Provision of alternative means for the removal of decay heat for accidents exceeding the design standard where steam generators are not available

  - RCS injection and discharge cooling operation in connection with the safety reduced pressure exhaust system

3-7. ECCS

Composition

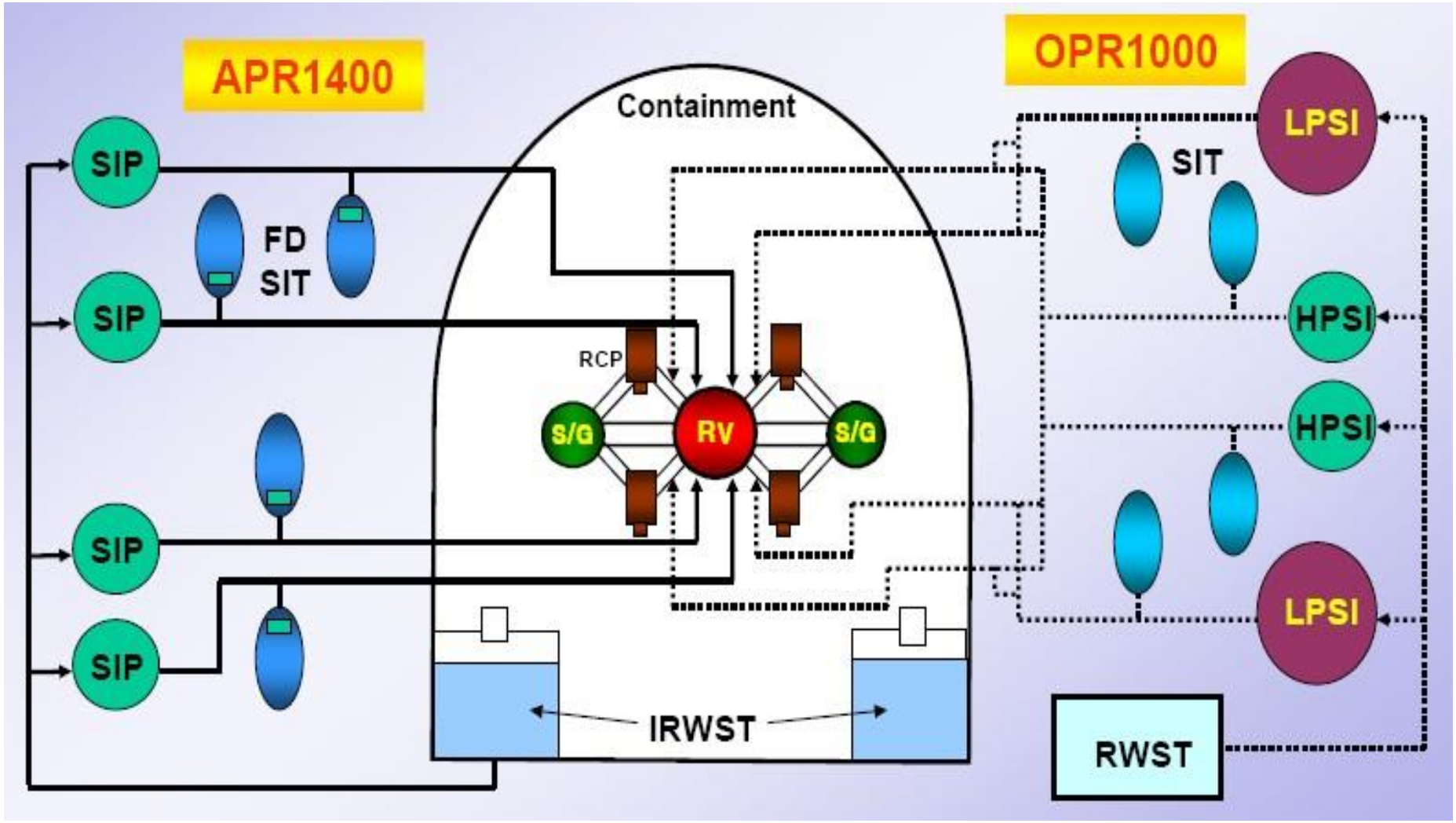
- Safety injection pump(SIP) 4ea
- In-containment refueling water storage tank(IRWST)
- Safety injection tank(SIT) 4ea
- Valve
- DVI injection

※ Note: OPR safety injection system configuration

- SIP : HPSI PP 2ea, LPSI PP 2ea
- RWT, location in fuel building
- Cold Leg injection

3-7. ECCS

- **Comparison of emergency core cooling system (APR & OPR)**



3-8. IRWST

- Boric acid water source of the SI/CS
- Boric acid water source in the reloading tank during nuclear refueling operation
- Primary heat removal source of pressurizer POSRV discharge water
- Cooling water source of the reactor common immersion system
- Overpressure protection equipment: 3 swing panels

3-9. CV Purge & HVAC

- Air temperature control in the reactor building: RCFC, CEDMCS, Rx Cavity Fan, etc.
- CV Purge : Lo Vol Purge, Hi Vol Purge, Post-LOCA Purge

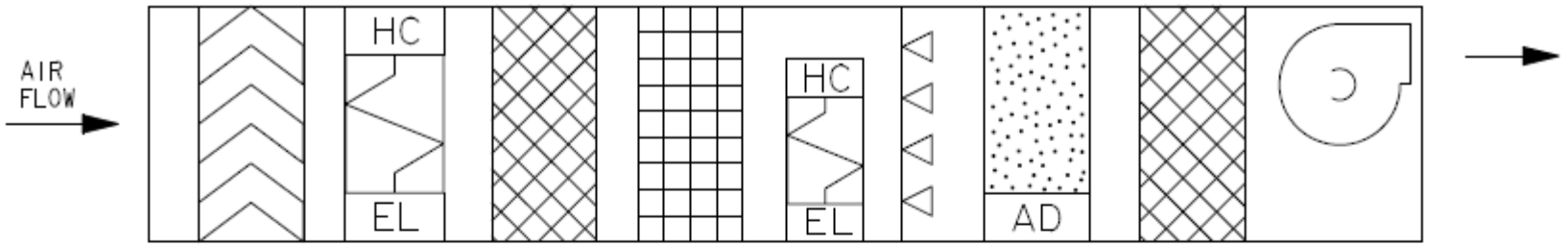
3-10. Fission product removal and control system (engineered safety facility filtration system)

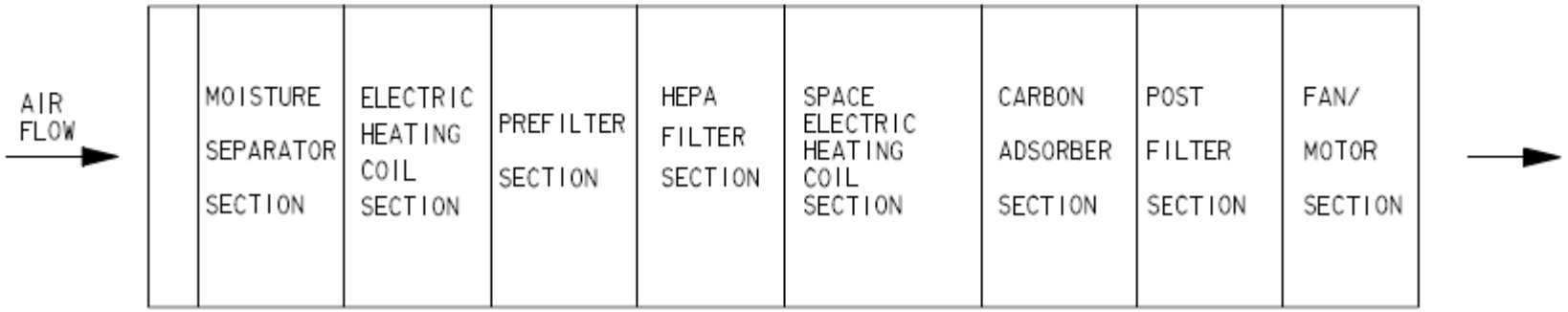
- **Main control room area emergency supplement system**
  - Purification of iodine and particles contained in outdoor air supplemented by MCR HVAC after LOCA

- **Auxiliary building emergency exhaust system**
  - Purification of iodine and particles that may be contained in the air exhausted from the Auxiliary Building Management Area

- **Fuel handling building emergency exhaust**
  - Purification of iodine and particles that may be contained in the air exhausted from the nuclear fuel handling area after a nuclear fuel handling accident

3-10. Fission product removal and control system (engineered safety facility filtration system)





Summary

- **Primary System**
  - Primary coolant related systems (primary coolant flow, cooling, control, etc.)
- **Reactor coolant system and auxiliary system**
  - Fission Control and Removal of Generated Heat
- **Plant Protection System(PPS)**
  - Stop reactors and protect operation barriers for power plant safety

Thank You

KINS 한국원자력안전기술원
KOREA INSTITUTE OF NUCLEAR SAFETY