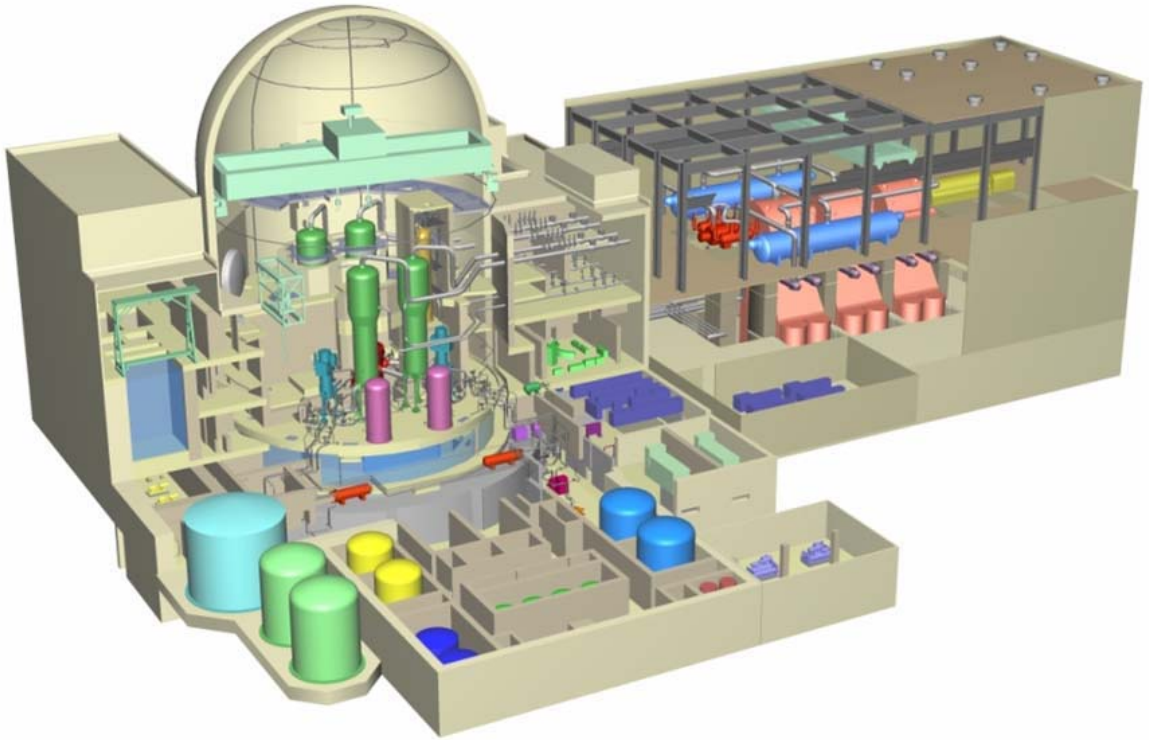
MITSUBISHI NUCLEAR ENERGY SYSTEMS, INC.

MITSUBISHI HEAVY INDUSTRIES, LTD.

US-APWR

MITSUBISHI US-APWR

System Design & Safety Features



June 29, 2007

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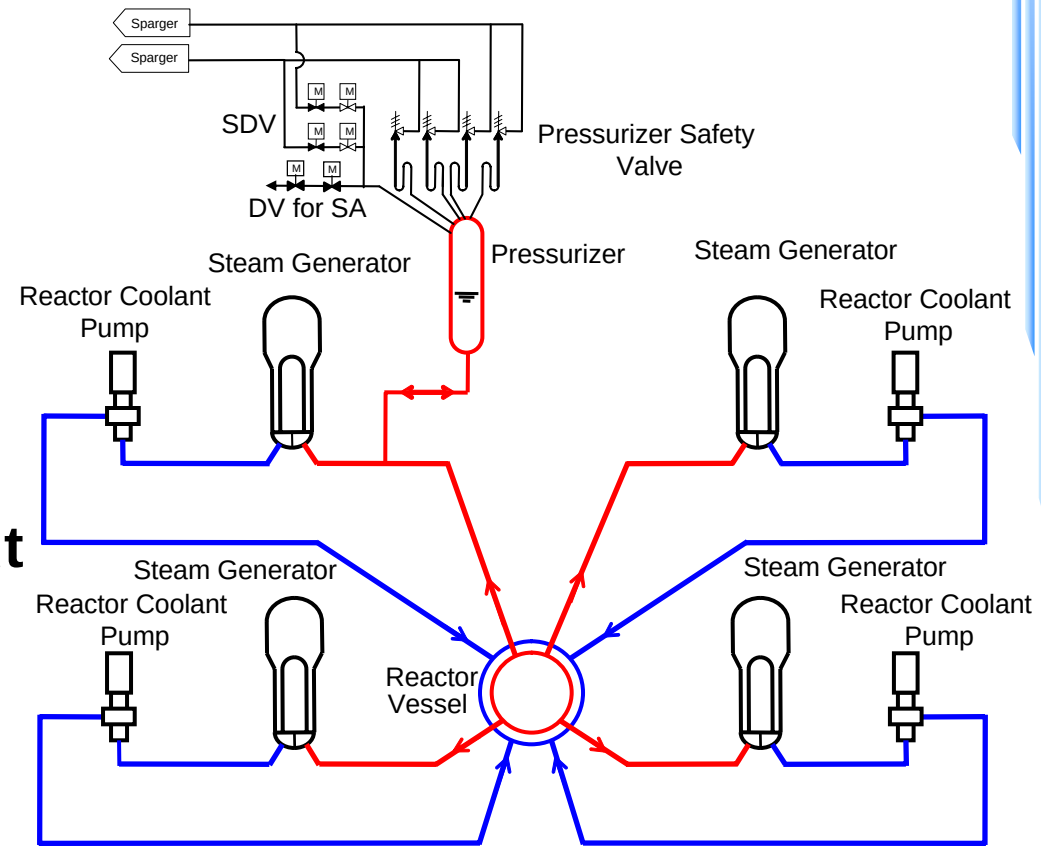
Reactor Coolant System

Design concept

- **Basic configuration is the same as current operating 4 loop plants proven by long term operating experience**
- **Enhanced reliability**
- **Large main components with large thermal output and high efficiency**
- **Enhanced plant controllability with large Pressurizer volume**



Reactor Coolant System (cont.)

Larger main components

- ✓ Larger diameter and height of Reactor Vessel with enhanced reliability
- ✓ Larger heat transfer area in SG contributes high efficiency due to high steam pressure
- ✓ Larger reactor coolant flow rate of RCP with 8000 HP motor

Enhanced plant control

- ✓ Larger Pressurizer volume assures greater margin for transients

Specifications	US-APWR	US Current 4 Loop Plant	Ratio
Core thermal output	4,451MWt	3,565MWt	1.25
SG Heat transfer area	91,500ft^2	55,000ft^2	1.66
Reactor Coolant Flow	112,000gpm	93,600gpm	1.20
Pressurizer Volume	2,900ft^3	1,800ft^3	1.61

Reactor Coolant System (cont.)

Safety Depressurization Valve (SDV)

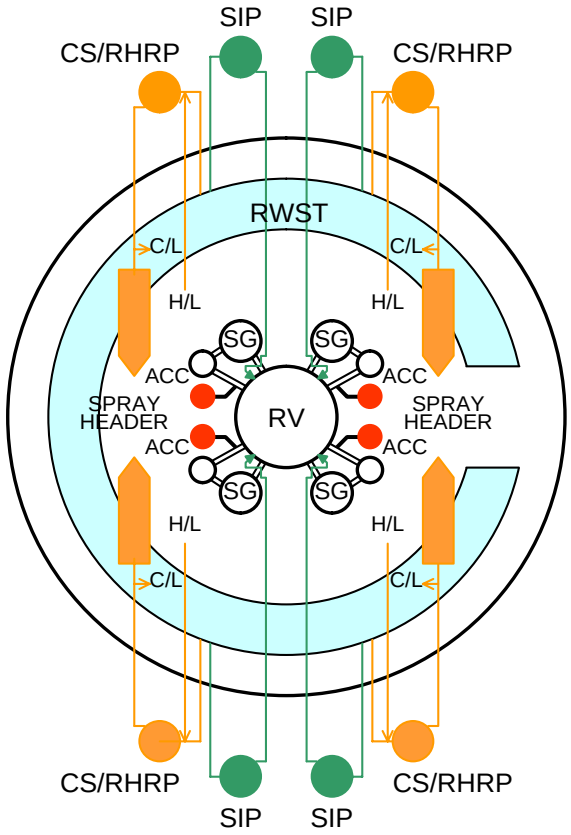
- ✓ SDVs are used to depress RCS in the case safe shutdown or SGTR

Depressurization Valve (DV)

- ✓ DV is installed for severe accident
- ✓ Pressurizer steam from this valve is directly discharged to containment

ECCS and CSS/RHRS

Design concept



➢ Basic design concept

- ✓ Achieve high reliability with simplified systems
- ✓ Introduce On Line Maintenance assuming single failure

➢ High Reliability

- ✓ 4 Train Configuration (50% x 4 for large break LOCA)
- ✓ In-containment RWSP (eliminate recirculation switchover)

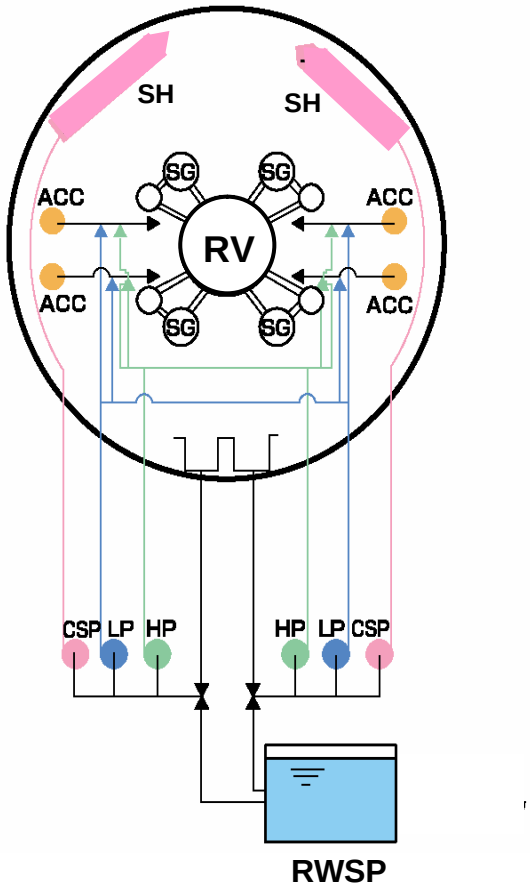
➢ Simplification

- ✓ Advanced accumulators (Integrated function of low head injection system)
- ✓ ECCS train includes only an accumulator and high head injection system
- ✓ Direct vessel injection (no inter-connection between trains)
- ✓ Common use of CSS and RHRS

ECCS and CSS/RHRS (cont.)

ECCS Configuration

Current 4 Loop PWR (2 train)

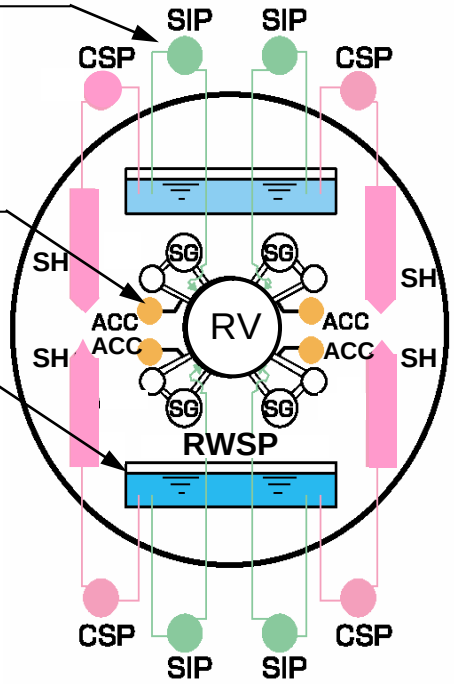


APWR (4 train)

◆**4 train (DVI)**
→ Higher Reliability
Simplified Pipe Routing

◆**Advanced Accumulator**
→ Elimination of LP

◆**In-containment RWSP**
→ Higher Reliability



ACC	: Accumulator
HP	: High Head SIP
LP	: Low Head SIP
SIP	: Safety Injection Pump
CSP	: Containment Spray Pump
SH	: Spray Header
RV	: Reactor Vessel
RWSP	: Refueling Water Storage Pit

ECCS and CSS/RHRS (cont.)

Components

- **Safety Injection Pump**

  Number : 4

- **Accumulator (with Flow Damper)**

  Number : 4

- **Containment Spray / Residual Heat Removal Pump**

  Number : 4

- **Containment Spray / Residual Heat Removal Heat Exchanger**

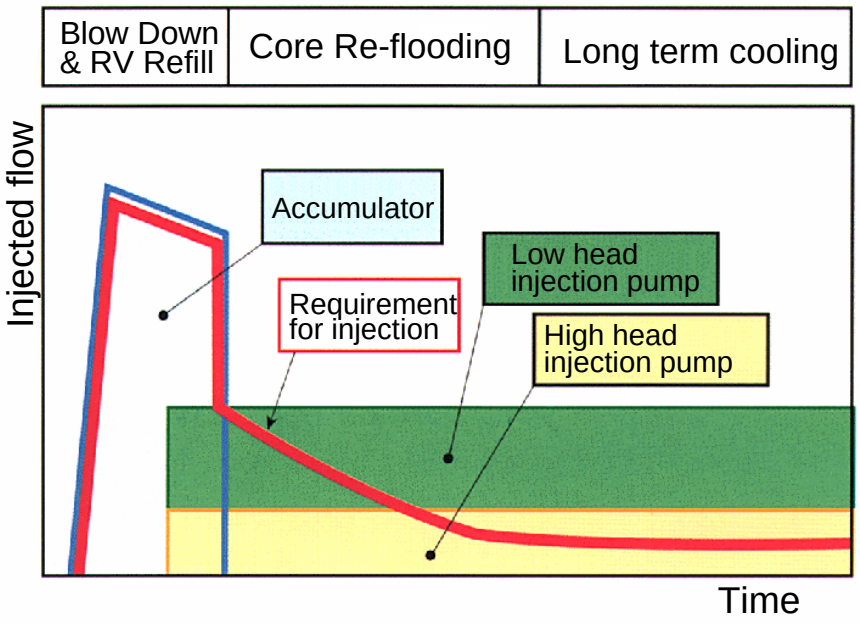
  Number : 4

ECCS and CSS/RHRS (cont.)

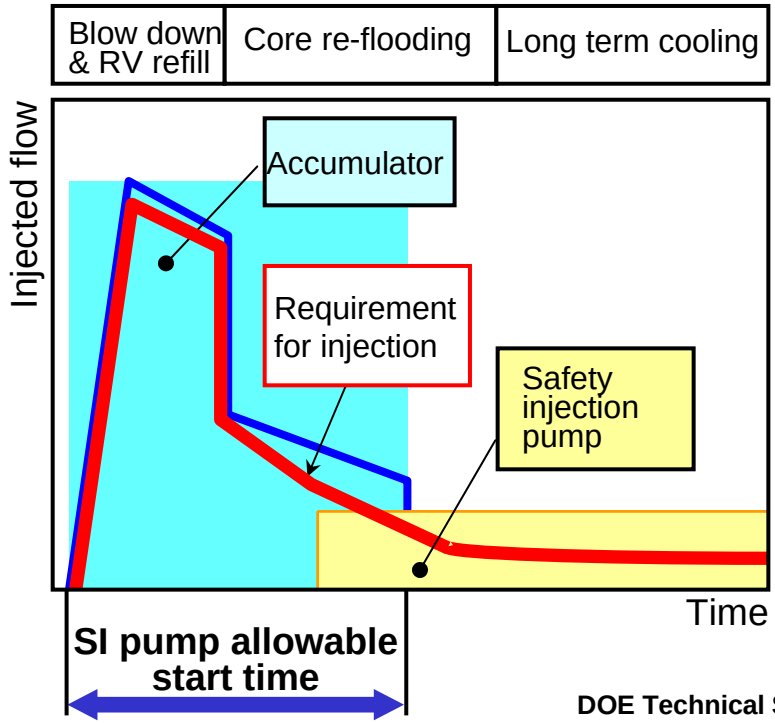
Advanced Accumulator (ACC)

- **Automatic switching of injection flow rate by flow damper**
- **Integrated function of low head injection system**
- **Long accumulator injection time allows more time for safety injection pump to start**

Current 4 Loop plant

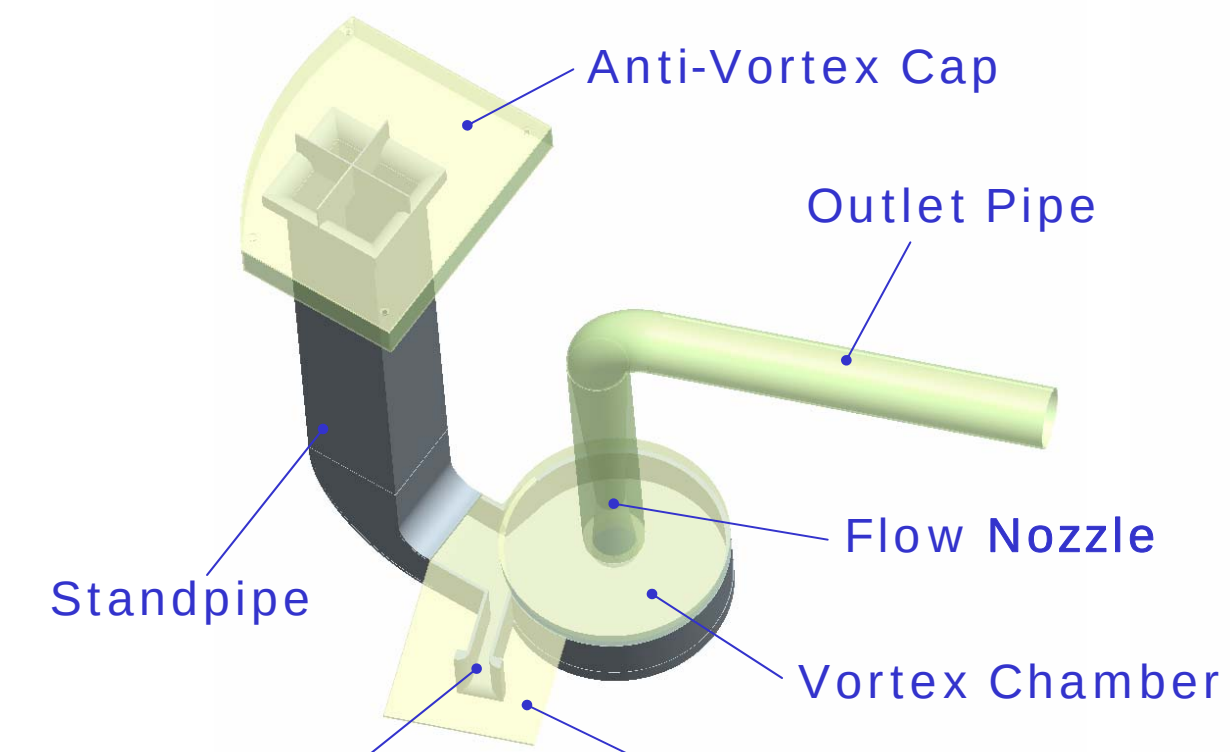


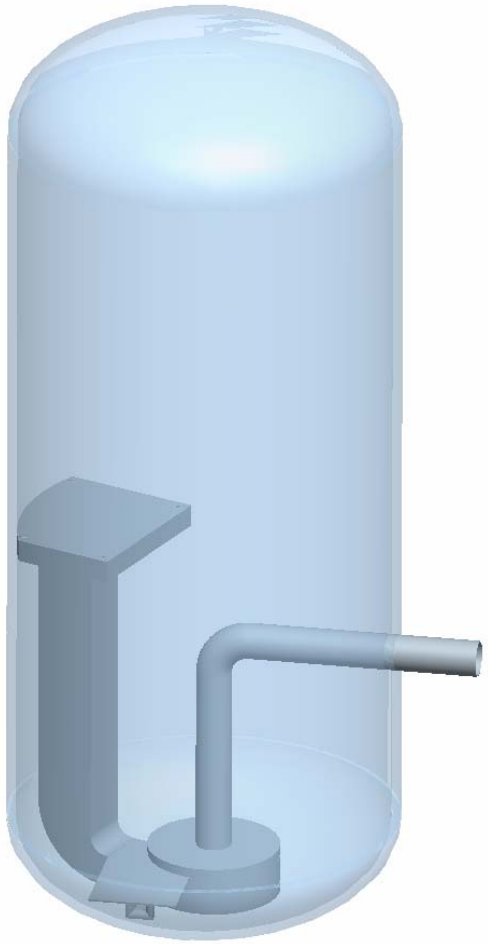
US-APWR



ECCS and CSS/RHRS (cont.)

Structure of Advanced Accumulator



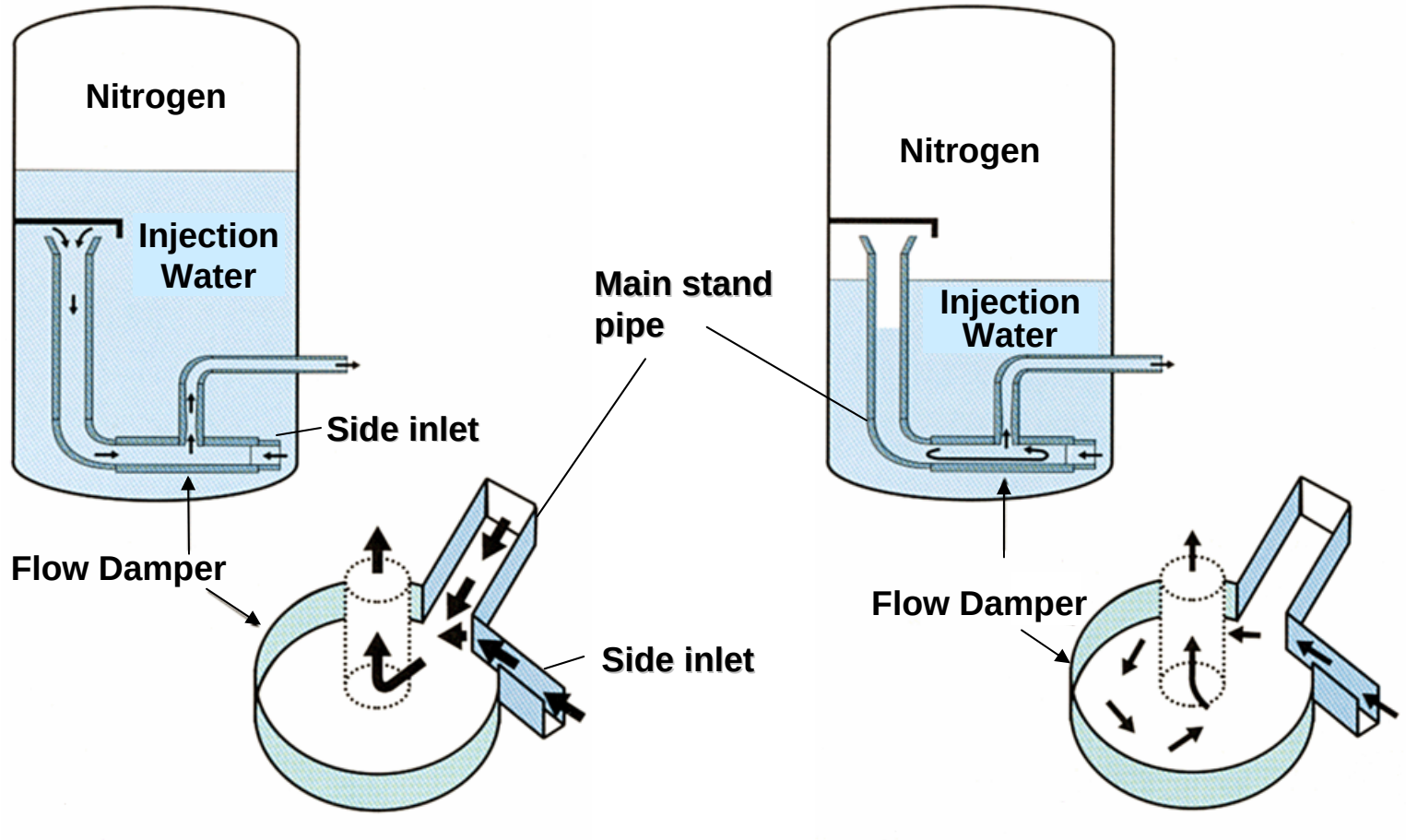


Flow Damper

ECCS and CSS/RHRS (cont.)

Mechanism of Advanced Accumulator

Flow damper passively switches the flow rate



Large Flow Rate

Reduced Flow Rate

ECCS and CSS/RHRS (cont.)

Verification Test Results of ACC

Visualization Test

- 1/5 Scale Flow Damper Model
- Low Pressure Test [Less than 128psig (0.88 MPa (gage))]
- Focus Points
  - ✓ During large flow, no vortex flow is occurring
  - ✓ During low flow, stable vortex flow is created, and flow rate decreases

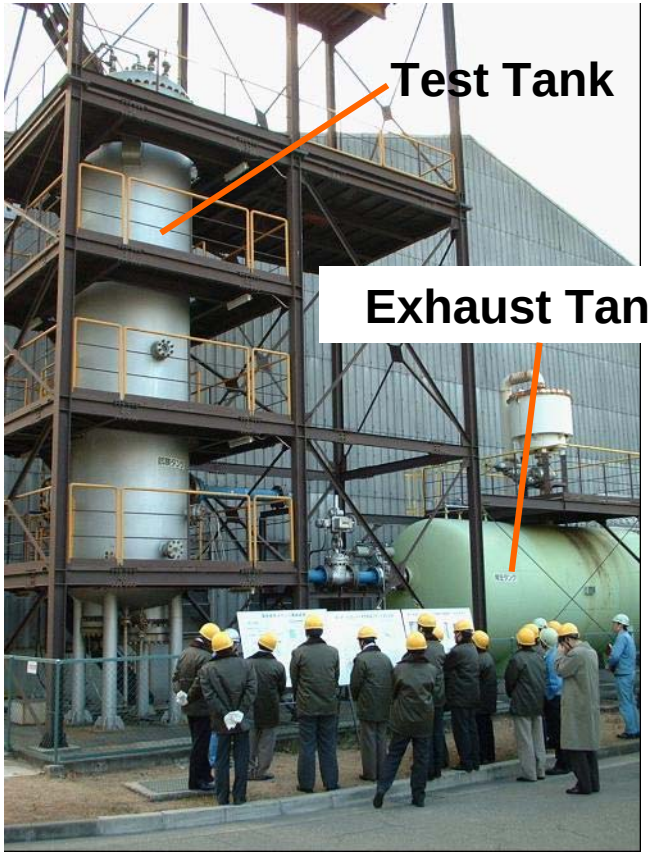
Large Flow | Switching Flow Rate | Small Flow

Flow in Vortex Chamber

ECCS and CSS/RHRS (cont.)

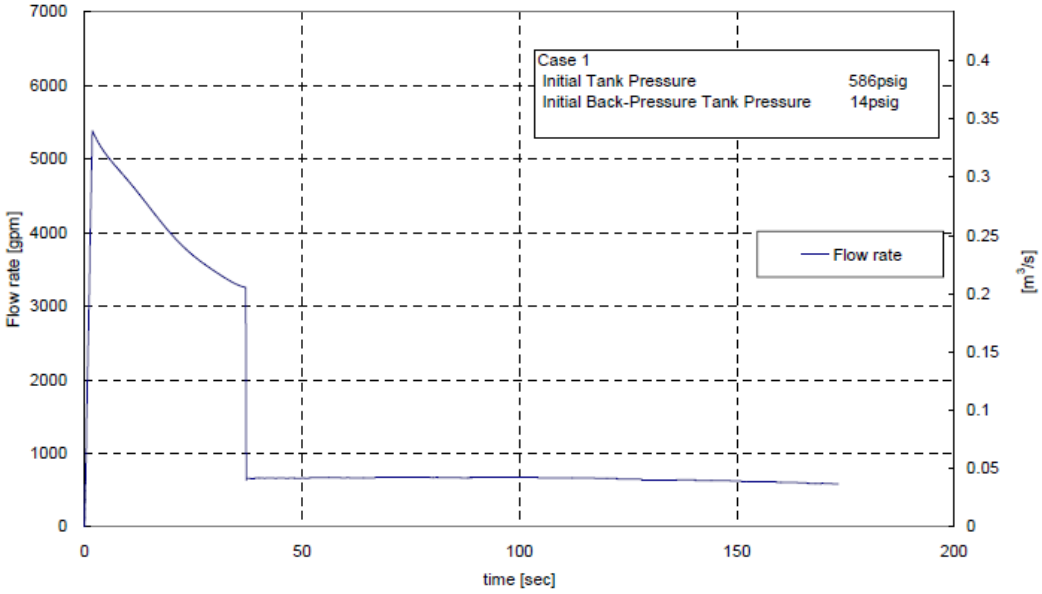
Verification Test Results of ACC (cont.)

Test at Design N_2 Pressure



Test Facility

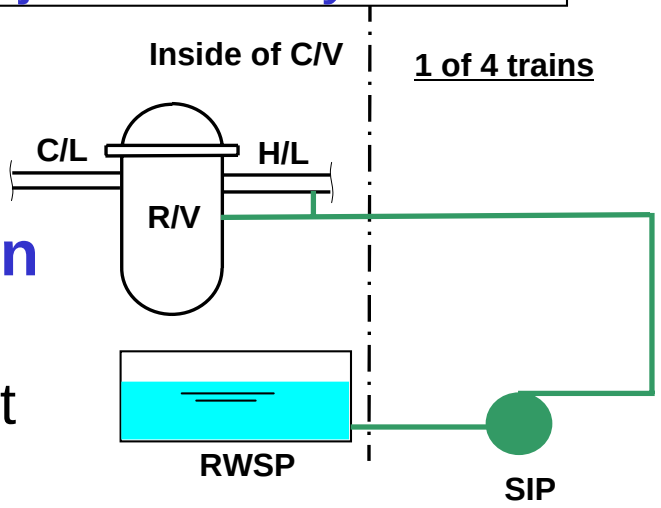
- **Full Height 1/2 Scale Test**
- **Test Pressure:**
  586 - 758 psig (4.04 - 5.23MPa (gage))



ECCS and CSS/RHRS (cont.)

Design feature of high head injection system

- **4 independent trains without interconnections between trains**
- **Sufficient capacity of safety injection pumps**
  - ✓ Meets the safety injection requirement in core reflooding stage



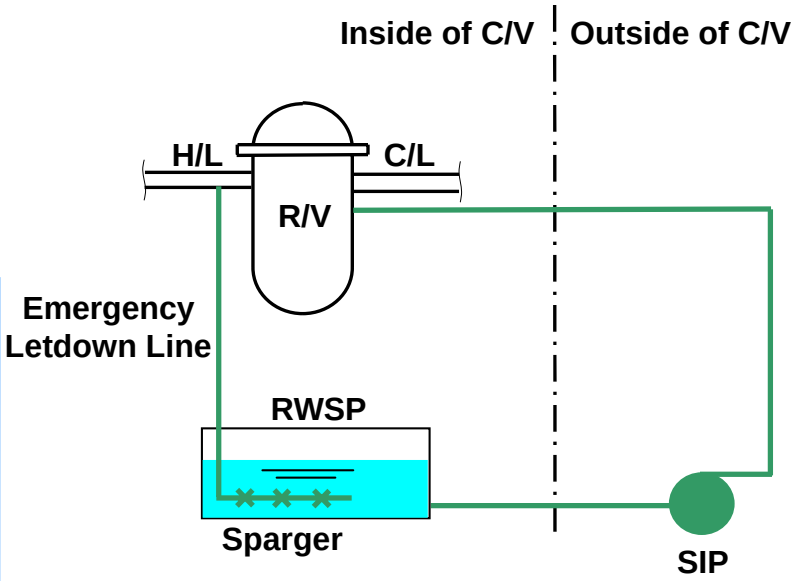
Item	US-APWR	US Current 4 Loop Plant	Reason and/or Advantage
Train	4 train	2 train	•Enhanced reliability •Achieve OLM under single failure
High head Injection	DVI 4 SIP	Loop injection 2 SIP + 2CH/SIP	•No interconnection between trains
Refueling Water Storage Pit	Inside CV	Outside CV	•Eliminate recirculation switchover

ECCS and CSS/RHRS (cont.)

Feed & Bleed in Safe Shutdown

➢ Design Features

Feed & Bleed in Safe Shutdown



- ✓ Emergency Letdown Lines are installed from H/L to RWSP
- ✓ In Safe Shutdown operation, emergency boration source is RWSP
- ✓ The borated water is injected by Safety Injection pump
- ✓ The volume control of RCS is achieved by Feed & Bleed with SIP and Emergency Letdown Line

ECCS and CSS/RHRS (cont.)

Common use of CSS/RHRS

- **CS pumps/Heat Exchangers used for RHR functions during shutdown**
  - ✓**In current PWR plants, RHRS functions as the low head safety injection system (Common use of RHR and LHSI)**
  - ✓**In US-APWR, the function of the low head safety injection (LHSI) is integrated into the Advanced Accumulator and safety injection pumps (SIP)**

Comparison of Systems

System	*US-APWR*	*Current PWR*
Containment Spray System	*CS/RHRS*	*CSS*
Residual Heat Removal System	*CS/RHRS*	*RHRS/LHSI*
Low Head Safety Injection System	*Advanced Accumulator and SIP*	*RHRS/LHSI*
Accumulator Injection System	*Advanced Accumulator*	*Accumulator*
High Head Safety Injection System	*SIP*	*SIP*

ECCS and CSS/RHRS (cont.)

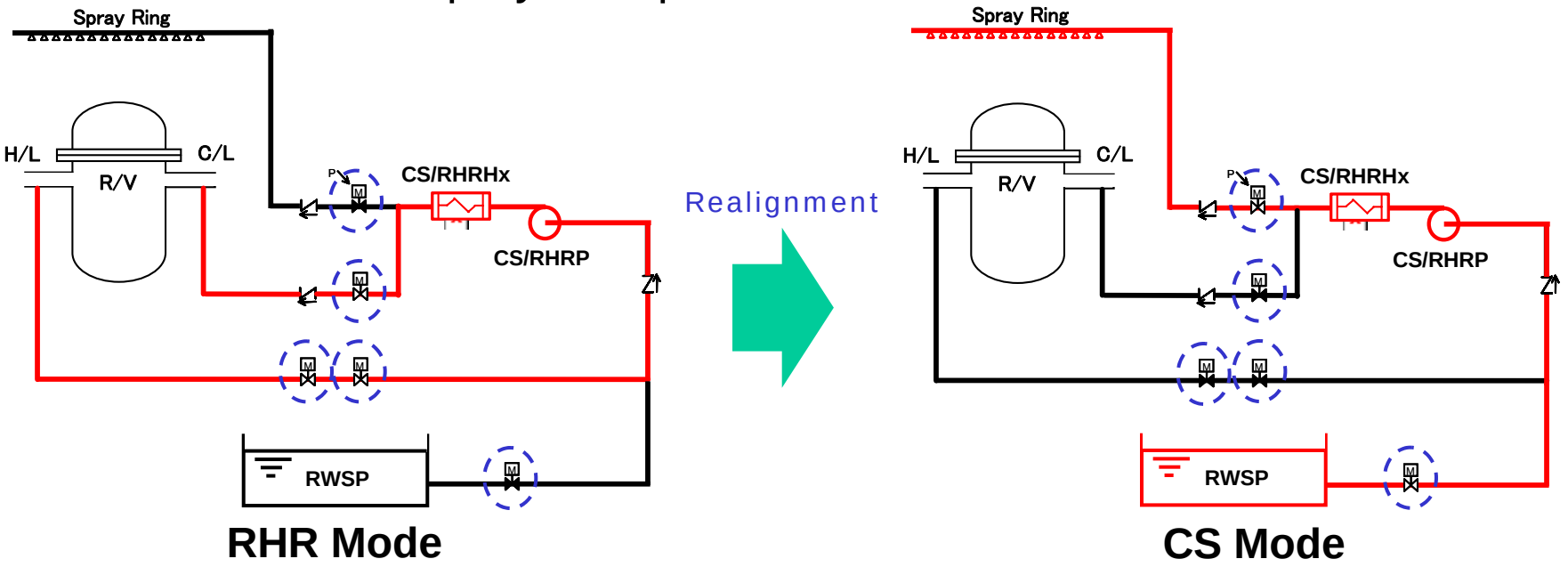
Common use of CSS/RHRS (cont.)

- **CS pumps / Heat Exchangers used for RHR functions during shutdown (Cont'd)**
  - ✓**During Power Operation**
    - •Available for CSS
  - ✓**During Shutdown Operation**
    - •Operating as RHRS
    - •Available for CSS (Manual)
  - ✓**During Accident Conditions**
    - •Operating as CSS
    - •Available for Long Term RWSP cooling

ECCS and CSS/RHRS (cont.)

Common use of CSS/RHRS (cont.)

- **CS pumps / Heat Exchangers used for RHR functions during shutdown (Cont'd)**
  - ✓ **During Shutdown Operation**
    - •Operating as RHRS
    - •Operators can realign from RHR mode to Containment Spray mode by changing motor operated valve positions when containment spray is required to initiate

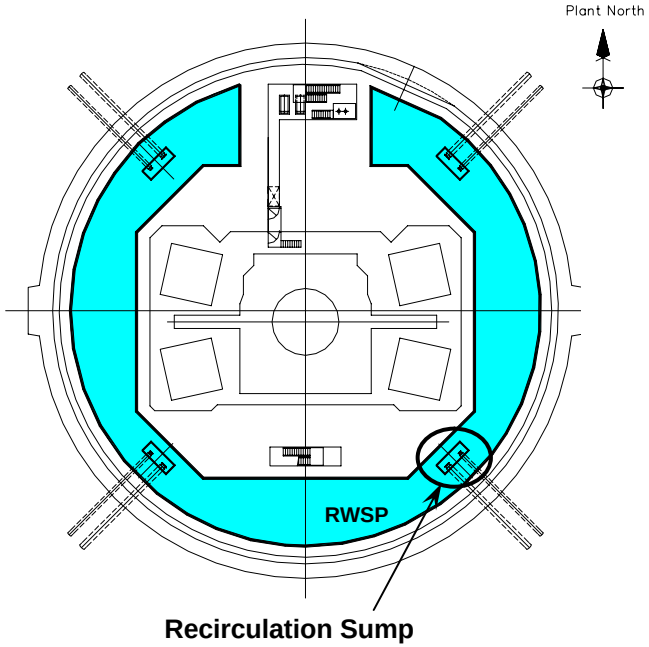


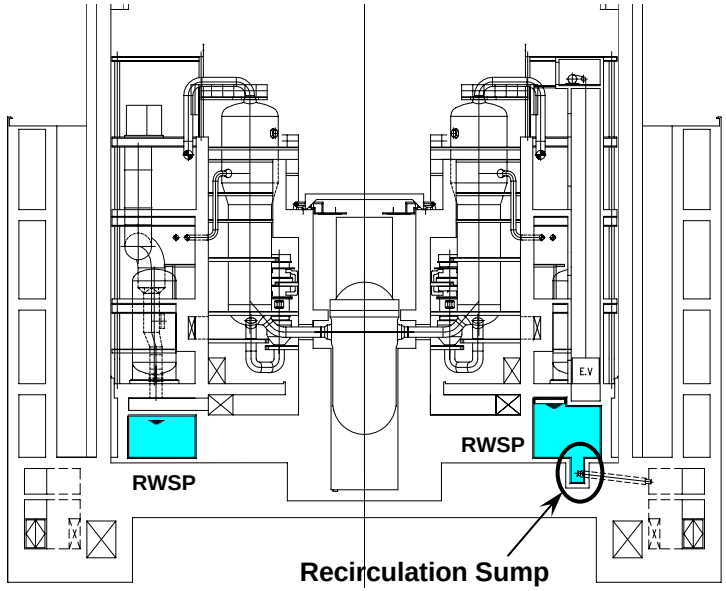
RHR Mode **CS Mode**

ECCS and CSS/RHRS (cont.)

In-containment Refueling Water Storage Pit

- Located at the lowest part of containment
- Provides a continuous suction source for both safety injection and CS/RHR pumps
  (Eliminates switchover of suction source)
- 4 recirculation sumps are installed

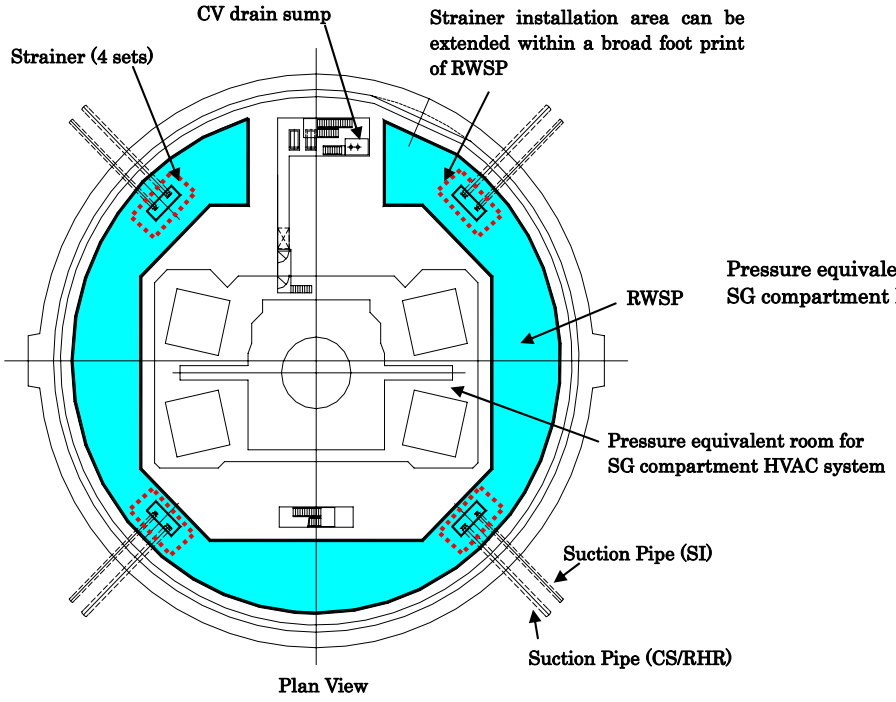


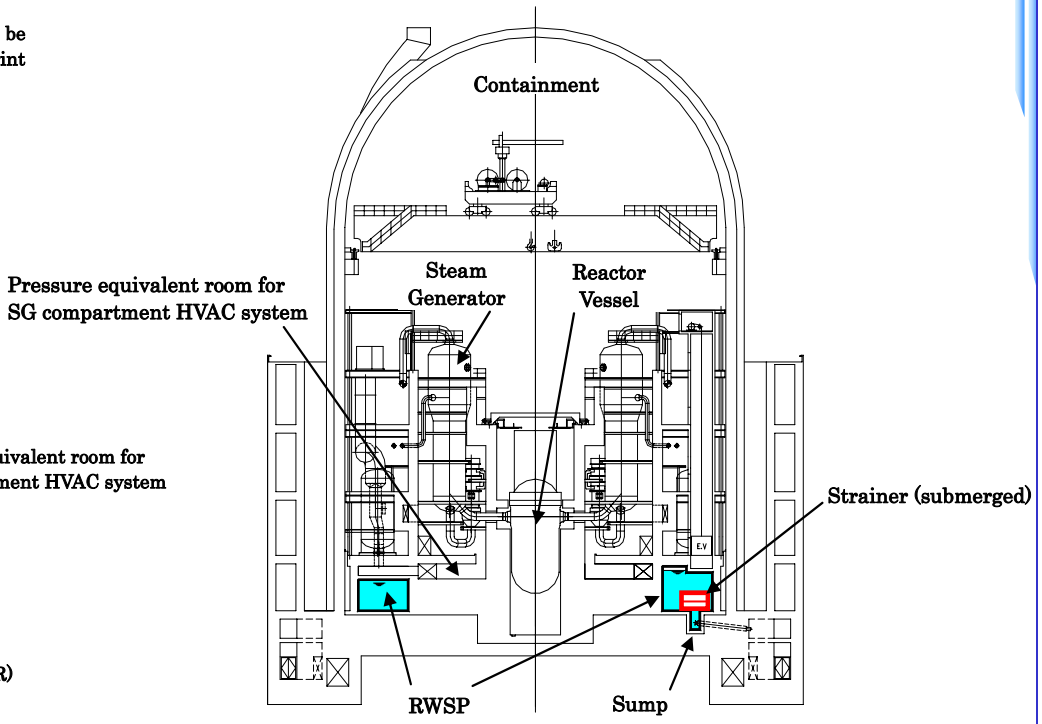


ECCS and CSS/RHRS (cont.)

Conservative Countermeasures for GSI-191

- Sufficient water head for Net Positive Suction Head (NPSH)
- Sufficient surface area for strainer
- Appropriate selection of insulation material
- Appropriate selection of pH control buffer





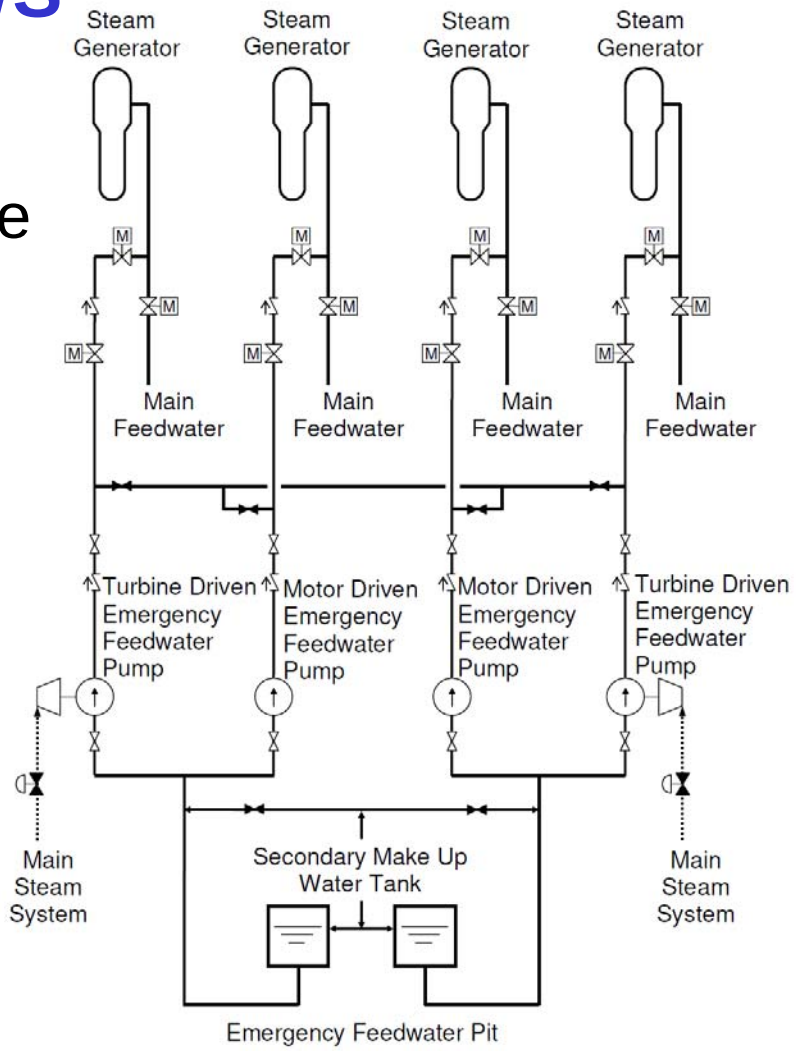
Emergency Feedwater System

➢Design concept of the EFWS

- ✓ Achieve high reliability with simplified systems
- ✓ Introduce On Line Maintenance assuming single failure

➢Feature of the EFWS

- ✓ Independent 4 train system
- ✓ 2 safety grade water sources
- ✓ Diverse power sources for the pumps
- ✓ Cross connections in the inlet and outlet of the pumps (normally isolated)



Emergency Feedwater System (cont.)

➢ 4 train configuration

- ✓ 4 pumps with diverse power sources
  - 2 motor-driven emergency feedwater pumps (50% x 2)
  - 2 turbine-driven emergency feedwater pumps (50% x 2)
- ✓ Cross connected discharge of the pumps allows On Line Maintenance (OLM)

➢ 2 safety grade independent feedwater sources

- ✓ Two emergency feedwater pits(50 % x 2)
- ✓ Cross connected inlet of the pumps backs up each feedwater source

Item	US-APWR	US Current 4 Loop Plant	Reason and/or Advantage
System Configuration	4 train	2 train	A pump is allowed OLM under the single failure
Emergency Feedwater Pump	M/D EFWP: 2 T/D EFWP: 2	M/D EFWP: 2 T/D EFWP: 1	Diverse power sources
Emergency Feedwater Source	2	1	2 independent pits (backup available)

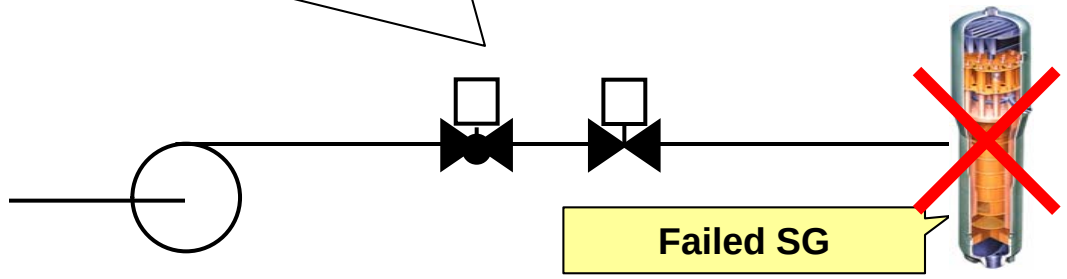
Emergency Feedwater System (cont.)

➢ Automatic isolation of EFW

- ✓ After detecting a failed SG (MSLB, FLB), the SG will be isolated automatically by EFW isolation signals (e.g. Isolated with low steam pressure signal)
- ✓ After detecting a failed SG (SGTR), the SG will be isolated automatically by EFW isolation signals (e.g. Isolated with high SG water level signal) in order to prevent SG over filling

Automatic isolation of EFW
- •High water level
- •Low steam line pressure

etc.



CCWS & ESWS

(Component Cooling Water System & Essential Service Water System)

➢ Design concept

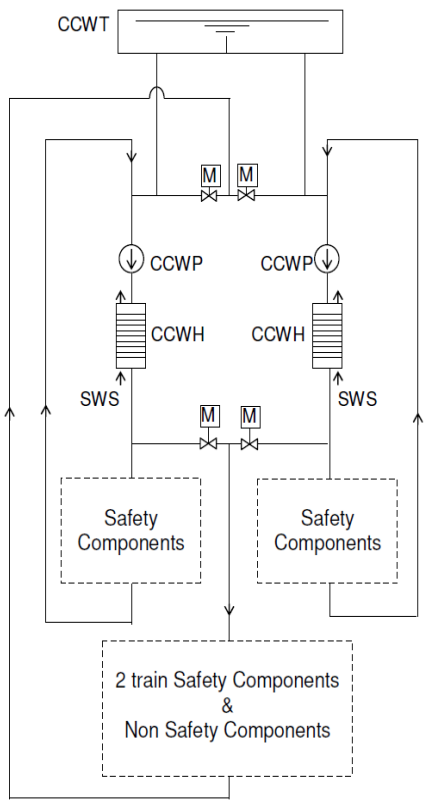
- ✓ CCWS and ESWS constitute a safety cooling chain
- ✓ 4 Train configuration
- ✓ Achieve high independence and high reliability
- ✓ Allows On Line Maintenance assuming single failure

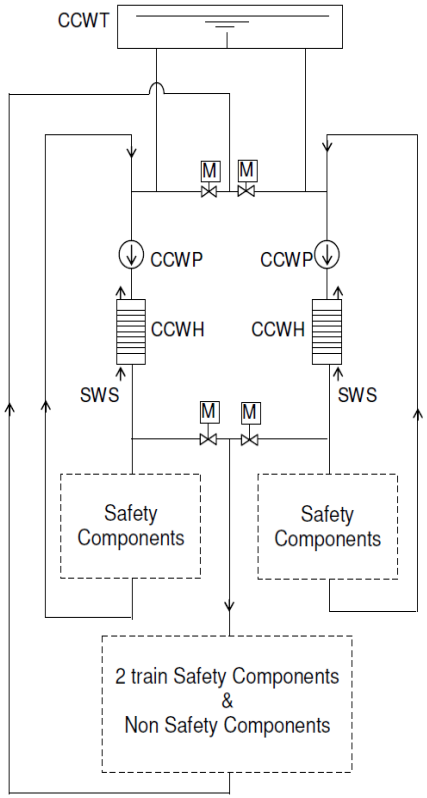
CCWS & ESWS (cont.)

➢Component Cooling Water System

- ✓ 4 safety train configuration
  (Each train consists of 1 CCWP and 1 CCW Hx)
- ✓ Completely separated into 2 independent sections even in normal operation
  (Each section has 1 CCWT)

- Achieve OLM under single Failure
- 2 train safety components (e.g.;SFP Hx.) are supplied with cooling water from 2 of 4 safety trains

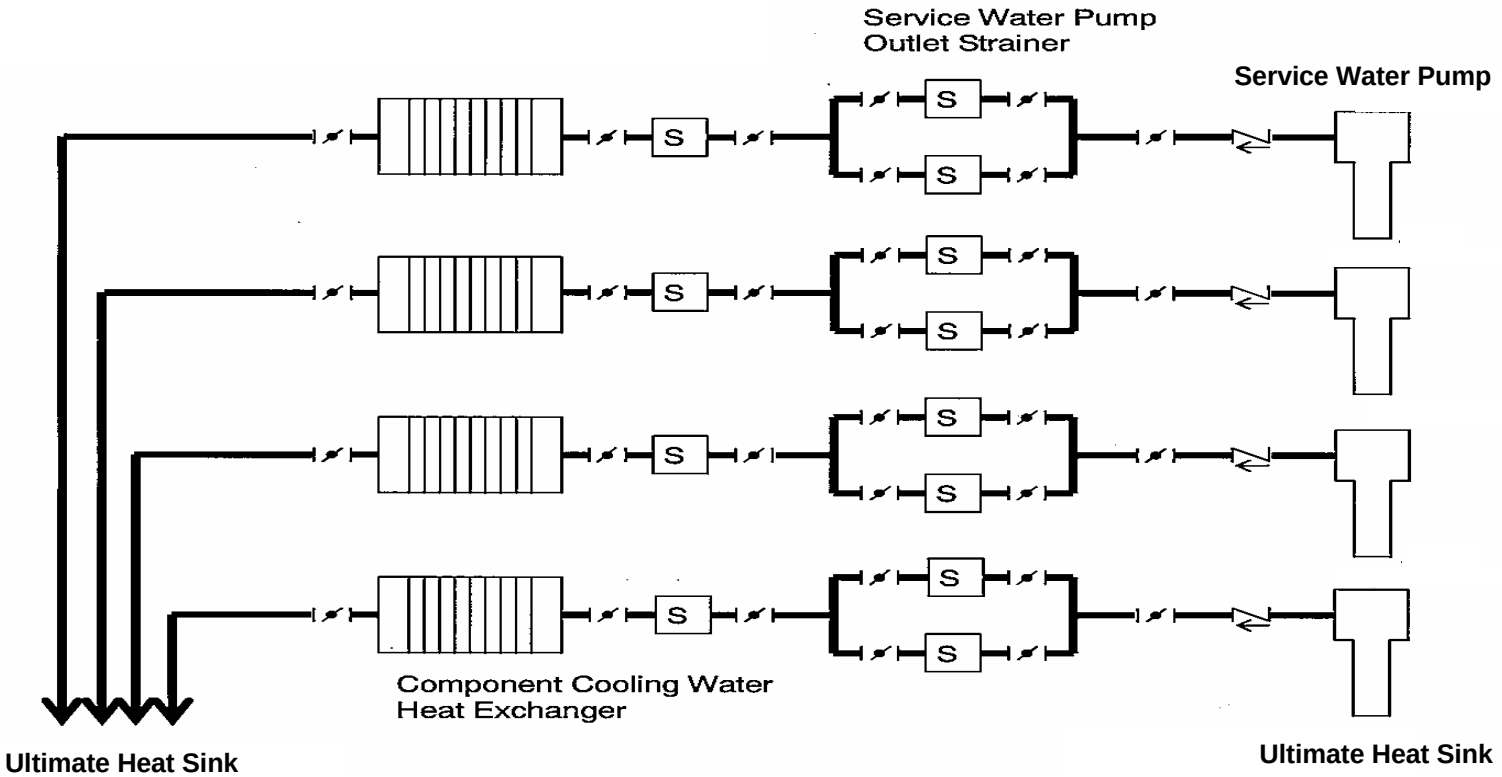




CCWS & ESWS (cont.)

➢Essential Service Water System

- ✓ Completely independent 4 train configuration
  (Each train consists of 1 ESWP)
- ✓ Raw water cooling for the CCW Hx

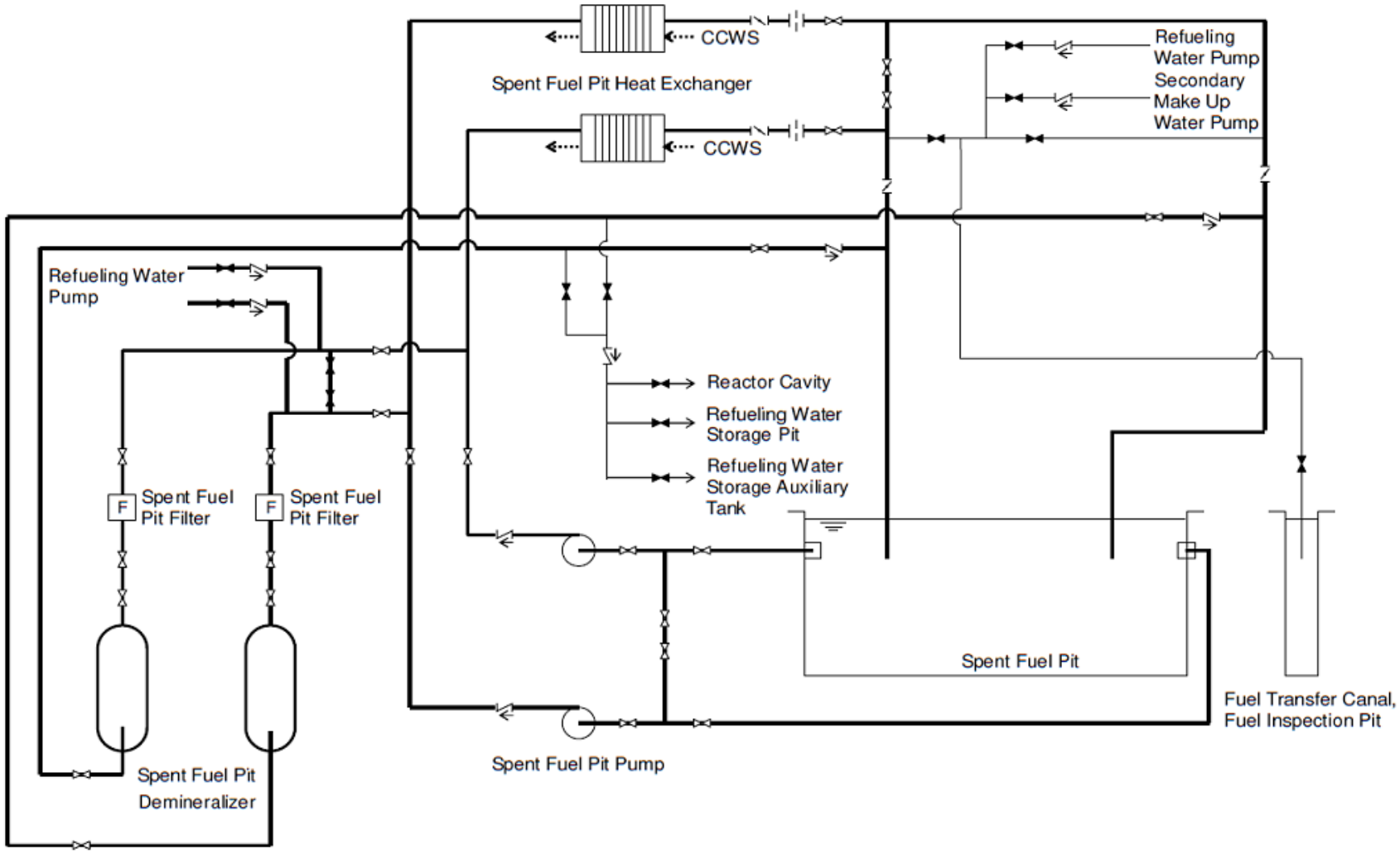


Spent Fuel Pit Purification and Cooling System

- **2 train configuration**
  - ✓ **Components**
    - **2 spent fuel pit pumps**
    - **2 spent fuel pit heat exchangers**
    - **2 spent fuel pit demineralizers**
    - **2 spent fuel pit filters**
  - ✓ **On line maintenance is available since the thermal load in the SFP during power operation is low enough for cooling with 1 train**

- **Safety related system**
  - ✓ **Power source for each SFP pump is from safety power buses**
  - ✓ **Cooling water for each SFP Hx. is selectable from 2 of 4 safety CCW trains**

Spent Fuel Pit Purification and Cooling System (cont.)



Chemical and Volume Control System

- **The CVCS is designed to perform the following functions in support of the reactor coolant system:**
  - ✓ **RCS inventory control and makeup**
  - ✓ **Reactor coolant purification**
  - ✓ **Reactivity control**
  - ✓ **Chemical additions for corrosion control**
  - ✓ **RCP Seal water injection**
- **The CVCS does not have requirements for mitigation of design basis accidents**
- **The CVCS includes the boron recycle system for the reuse of boric acid and primary makeup water**

Chemical and Volume Control System (cont.)