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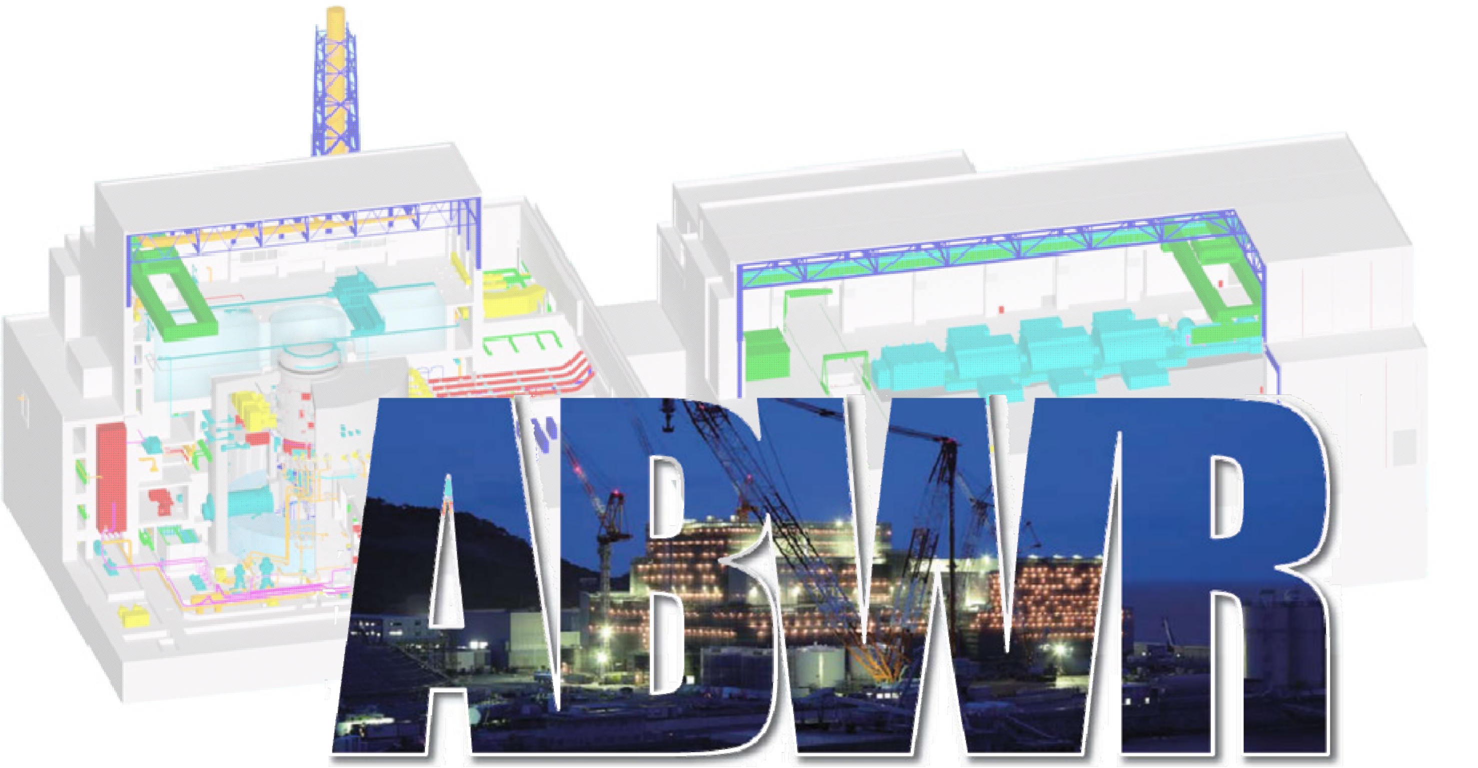
UK ABWR Generic Design Assessment

Generic PCSR Sub-chapter 16.5 : Severe Accident Management Systems



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16.5.1 Summary of Description

This section summarises the Severe Accident Management System in consideration of beyond design basis events. Against severe accidental events that potentially lead to multiple losses of the safety facilities (e.g. earthquake, flooding, aircraft crash, tornado terror attacks and so on), UK ABWR provisions for deploying the backup safety facilities for the Severe Accident Management. The backup safety facilities in UK ABWR are followings.

(1) Flooder System of Specific Safety Facility (FLSS)
(2) Flooder System of Reactor Building (FLSR)
(3) Filtered Containment Venting System (FCVS)
(4) Lower Drywell Flooder System (LDF)
(5) Alternate Heat Exchange Facility (AHEF)
(6) Reactor Depressurization Control Facility (RDCF)

16.5.2 Design Bases

16.5.2.1 Safety Function

The backup safety facilities are designed to meet the following safety functions.

(1) The backup safety facilities provide cooling water to the reactor core in order to prevent reactor core damage and to maintain reactor core cooling, in case of station blackout and/or loss of all function of digital Control and Instrumentation (C&I) equipment.
(2) The backup safety facilities supply water to the Primary Containment Vessel (PCV) spray header to provide for directly cooling the upper drywell atmosphere and scrubbing airborne fission products.
(3) The backup safety facilities provide water to the lower drywell under the severe accident condition of the vessel failure to remove decay heat from molten core and to prevent PCV breakage due to excess temperature.
(4) The backup safety facilities provide water to reactor well to prevent PCV flange breakage due to excess temperature.
(5) The backup safety facilities provide reactor vessel depressurisation control system to avoid rupture of the Reactor Pressure Vessel (RPV) at high pressure and to supply cooling water to the reactor core at low pressure.
(6) The backup safety facilities provide water to the Spent Fuel Storage Pool (SFP) to remove decay heat and to maintain the pool water level in an event of loss of makeup water function of SFP.

16.5.3 System Design Description

16.5.3.1 Flooder System of Specific Safety Facility

16.5.3.1.1 System Summary Description

This section is a general introduction to the Flooder System of Specific Safety Facility (FLSS) where the system roles, system functions, system configuration and modes of operation are briefly described.

16.5.3.1.1.1 System Roles

The main roles of the FLSS are to supply cooling water by pumps installed at Backup Building (B/B) to prevent serious damage to the core fuel and to prevent PCV breakage in the event of Severe Accident (SA) where the injection function to the RPV loses including where the core melts and causes a vessel failure to occur. FLSS also has the role of maintaining the SFP water level in the event of SA where the water supply function to the SFP loses.

16.5.3.1.1.2 Functions Delivered

The FLSS is designed to perform the following functions in the event of SA:
(1) The FLSS provides cooling water to the reactor core.
(2) The FLSS provides cooling water to the PCV spray header.
(3) The FLSS provides cooling water to the Lower Drywell (D/W)
(4) The FLSS provides cooling water to the reactor well.
(5) The FLSS provides cooling water to the SFP as necessary.

16.5.3.1.1.3 Basic Configuration

The FLSS consists of water source, pumps, piping, valves, instrumentations and controllers. Injection lines are provided for each destination described in 16.5.3.1.1.2**,** as shown on Figure 16.5-1.The main components are summarised as follows:
(1) FLSS is installed at B/B, which is totally independent from Reactor Building (R/B).
(2) Instrumentation, controllers, operation logic/circuit and control panels are in B/B.
(3) Piping and valves connecting to the Feedwater line
(4) Piping and valves connecting to the PCV spray line of Residual Heat Removal System (RHR)
(5) Piping and valves connecting to the Lower D/W supply line of Makeup Water Condensate System (MUWC)
(6) Piping and valves connecting to the reactor well supply line of Fuel Pool Cooling and Clean-up System (FPC)
(7) Piping and valves connecting to the SFP makeup water supply line of FPC

16.5.3.1.1.4 Modes of Operation

The FLSS can deliver the following operation modes by switching the position of the valves.

16.5.3.1.1.4.1 Plant normal operation condition

FLSS is on standby during normal plant operation.

16.5.3.1.1.4.2 Depressurisation and Injection Initiating Mode

In the event of an SA when all Emergency Core Cooling Systems (ECCSs) fail to cool the core, the FLSS is initiated to provide a cooling water flow path to RPV after depressurisation by Safety Relief Valves (SRVs).

16.5.3.1.1.4.3 Injection Control Mode before vessel failure

After Depressurisation and Injection Initiating Mode the FLSS provides flow paths to RPV, the lower D/W and the reactor well in parallel. The supply flow rate is adjusted after confirmed the decrease in pressure of injection line.

16.5.3.1.1.4.4 Injection Control Mode after vessel failure

In an accidental condition of the vessel failure, the FLSS provides a flow path to RPV, the PCV spray, the lower D/W. The supply flow rate is adjusted after confirmed the decrease in pressure of injection line.

16.5.3.1.1.4.5 Test Mode

The FLSS functional tests are performed by manual operation in B/B to confirm that the FLSS delivers the required flow rate. In the test mode, water is taken from water source by FLSS Pumps, and then the water returns to the water source again via test piping.

16.5.3.1.2 Design Bases

Provisions for installing permanent and mobile safety facilities are put in place as countermeasures against severe accidental events that the safety facilities such as the ECCS, the Emergency Diesel Generators, etc. are unavailable due to beyond design basis of external hazards (e.g. earthquakes, flooding, aircraft crash, tornado and terror attacks). FLSS is designed as a permanent safety facility of UK ABWR and designed to meet the following Safety Function.

The FLSS provides cooling water to the reactor core in order to prevent reactor core damage and to maintain reactor core cooling until a condition equivalent to cold shutdown. From this perspective of safety function in SAs, the FLSS delivers a Category B safety function, and the components necessary to deliver this function as primary means are classified as Class 2 safety components according to the safety categorisation and classification of UK ABWR.

Part of the FLSS provides water to the PCV spray header to prevent PCV breakage due to excess pressure. From this perspective of safety function in SAs, the FLSS delivers a Category B safety function, and the components necessary to deliver this function as primary means are classified as Class 2 safety components according to the safety categorisation and classification of UK ABWR.

Part of the FLSS supplies water to the lower D/W to remove decay heat from molten core and to prevent PCV breakage due to excess temperature. From this perspective of safety function in SAs, the FLSS delivers a Category B safety function, and the components necessary to deliver this function as primary means are classified as Class 2 safety components according to the safety categorisation and classification of UK ABWR.

Part of the FLSS supplies water to reactor well to prevent PCV breakage due to excess temperature. From this perspective of safety function in SAs, the FLSS delivers a Category B safety function, and the components necessary to deliver this function as primary means are classified as Class 2 safety components according to the safety categorisation and classification of UK ABWR.

Part of the FLSS provides the SFP with water to remove decay heat and to maintain the pool water level in an event of loss of makeup water function of SFP. From this perspective of safety function in SAs, the FLSS delivers a Category B safety function, and the components necessary to deliver this function as primary means are classified as Class 2 safety components according to the safety categorisation and classification of UK ABWR.

Part of the FLSS forms the Primary Containment Vessel Boundary (PCV Boundary). Therefore, the components within the PCV boundary form a barrier to maintain the integrity of the boundary and thus prevent the dispersion of radioactive substances. From this perspective, the FLSS delivers a Category A safety function (containment) and the components necessary to deliver this function are classified as Class 1 safety components according to the safety categorisation and classification of UK ABWR.

This function is developed and justified in the section related to the Containment Isolation Function in PCSR chapter 13.

16.5.3.1.3 System Design

16.5.3.1.3.1 Overall Design and Operation

The purpose of FLSS is to supply cooling water to RPV, PCV, SFP, the lower D/W and the reactor well to prevent serious damage to the core fuel and fuel in SFP, to prevent PCV breakage by keeping the reactor core temperature low in the event of a SA. By switching the position of the valves, the FLSS is able to supply cooling water to each destination for heat removal. Every operation are manually operated and run until manually stopped.

16.5.3.1.3.1.1 Depressurisation and Injection Initiating Mode

The FLSS is manually initiated water injection after depressurisation operation with monitoring reactor pressure and reactor water level. The B/B water storage tanks are provided as a water source and supply water flows back to the B/B water storage tanks through a minimum flow line until injection valve opens.

16.5.3.1.3.1.2 Injection Control Mode before vessel failure

The FLSS maintains the water supply to RPV by adjusting control value. The FLSS also supplies water to the lower D/W and to reactor well in parallel with the reactor core injection operation.

16.5.3.1.3.1.3 Injection Control Mode after vessel failure

In the accidental condition of the vessel failure, the FLSS maintains the water supply to RPV after Depressurisation and Injection Initiating Mode. In parallel with the reactor core injection operation, water is also supplied to the lower D/W line, to the PCV spray line with the intermittent flow rate considering the conditions of instrumentations. The FLSS also supplies water to SFP for makeup.

16.5.3.1.3.2 Equipment Design and Operation

16.5.3.1.3.2.1 FLSS Pump

Two turbo type pumps driven by an induction motor with approximately 450m^3/h (provisional) of flow rate are provided in the FLSS. Each pump is installed in an injection line of the FLSS respectively. The two pump capacities satisfy the required flow rate to prevent remarkable damage of the reactor core according the SA analysis. The main specification of the FLSS Pump is described below.

(a)	Number:	2units
(b)	Pump Type:	Turbo
(c)	Capacity:	Approx. 450m^3/h

16.5.3.1.3.2.2 FLSS Water Source

Two water storage tanks with approximately 5000m^3 (provisional) are provided for B/B water source. These water tanks are dedicated tanks and installed as close as B/B. The total tank capacity meets the necessary amount of water which is determined based on the combination of water supply. The consideration of the combination cases are shown as follows;

(a) The amount of water supply for removal of the decay heat (including the amount of water for RPV injection and lower D/W injection)
(b) The amount of water supply to PCV spray
(c) The amount of water supply to reactor well
(d) The amount of water supply to the SFP

16.5.3.1.3.3 Main Support Systems

16.5.3.1.3.3.1 Instrumentation and Control

The main instrumentation and control provisions related to FLSS operation from the performance and reliability points of view are summarised as follows.

(1) Instrumentation
The instrumentation is provided to measure and monitor the operating conditions of the FLSS components necessary for the delivery of safety function. The status, measurements (and alarms) of the components and valves to be remotely operated are generally displayed in the B/B Control Room.
  (a) Installed in B/B
    (i) Flow-meters are mounted downstream the FLSS injection control valve to monitor system flow rate and to control minimum flow bypass valve.
    (ii) Water level instrumentations of the B/B water storage tanks are provided to monitor an appropriate water level.
  (b) Installed in R/B
  Reactor pressure and reactor water level instrumentations are monitored at B/B, which are separated from the instrumentations for principal ECCS.

(2) Control
The FLSS provides water injection by remotely and manually operated at the Control Room in the B/B after depressurisation and the FLSS operation is controlled by the Control Room in the B/B depending on accidental conditions.

16.5.3.1.3.3.2 Power Supply System

(1) The FLSS pumps and active components are supplied power by two independent Alternating Current (AC) and Direct Current (DC) power sources.
(2) The power sources written (1) are generated by the Alternative AC Generator System installed in B/B, which are different from the emergency power source installed in R/B.

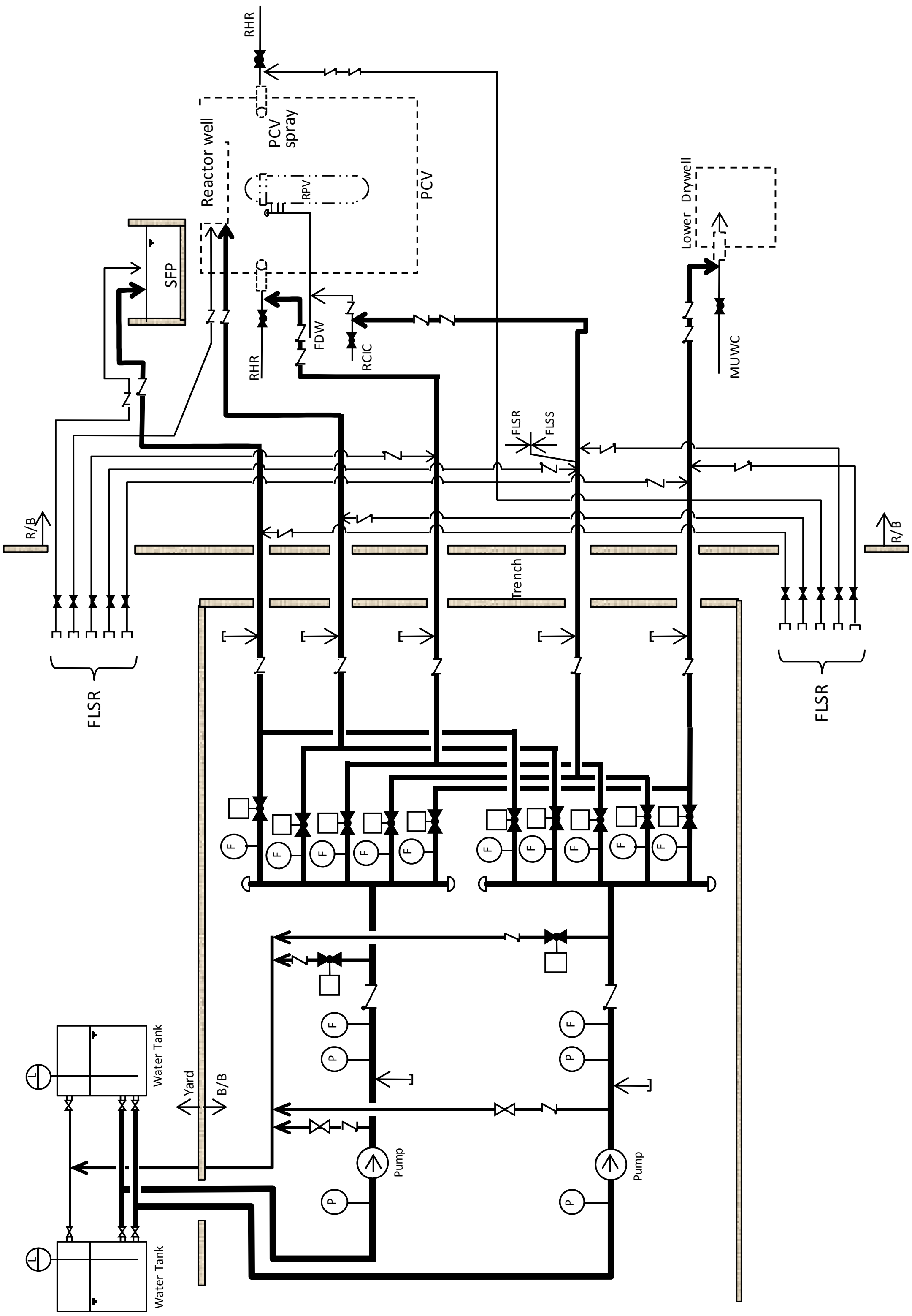

Figure 16.5-1 : Outline of the Flooder System of Specific Safety Facility

16.5.3.2 Flooder System of Reactor Building

16.5.3.2.1 System Summary Description

This section is a general introduction to the Flooder System of Reactor Building (FLSR) where the system roles, system functions, system configuration and modes of operation are briefly described.

16.5.3.2.1.1 System Roles

The main roles of the FLSR are to supply cooling water by Mobile Pumps to prevent serious damage to the core fuel, to prevent PCV breakage in the event of SA where the injection function to the RPV loses. FLSR also has the role of maintaining the SFP water level in the event of SA where the water supply functions to the SFP loses.

16.5.3.2.1.2 Functions Delivered

The FLSR is designed to perform the following functions in the event of a SA:
(1) The FLSR provides cooling water to the reactor core.
(2) The FLSR provides cooling water to the PCV spray header.
(3) The FLSR provides cooling water to the Lower D/W.
(4) The FLSR provides cooling water to the reactor well.
(5) The FLSR provides cooling water to the SFP as necessary.

16.5.3.2.1.3 Basic Configuration

The FLSR consists of Mobile Pumps, the necessary piping, valves and instrumentations. Two injection lines are provided for each destination as described in 16.5.3.2.1.2. Figure 16.5-2 illustrates the FLSR basic configuration. By connecting Mobile Pumps to a water source inside of the plant site boundary and to any injection piping, the FLSR supplies cooling water to the destination through FLSS line.

16.5.3.2.1.4 Modes of Operation

The FLSR can deliver the following operation modes by switching the position of the valves.

16.5.3.2.1.4.1 Plant normal operation condition

FLSR is on standby during normal plant operation.

16.5.3.2.1.4.2 Depressurisation and Injection Initiating Mode

In the event of an SA when all ECCSs, the Emergency Diesel Generators, etc. fail to cool the core, the FLSR is initiated to provide a flow path to RPV through the FLSS line after depressurisation by SRVs

16.5.3.2.1.4.3 Injection Control Mode before vessel failure

The FLSR provides flow paths to RPV, the lower D/W and the reactor well in parallel. The supply flow rate is adjusted after confirmed the decrease in injection pressure of injection line.

16.5.3.2.1.4.4 Injection Control Mode after vessel failure

In the case of the possibility of vessel failure, the FLSR provides a flow path to RPV, the PCV spray, the lower D/W. The supply flow rate is adjusted after confirmed the decrease in pressure of injection line.

16.5.3.2.1.4.5 Test Mode

The FLSR functional tests are performed with mobile pumps and injection piping to confirm water injection satisfies the required flow rate.

16.5.3.2.2 Design Bases

Provisions for installing permanent and mobile safety facilities are made as countermeasures against a severe accidental event that the safety facilities such as the ECCS, the Emergency Diesel Generators, etc. are unavailable due to beyond design basis of external hazards (e.g. earthquakes, flooding, aircraft crash, tornado and terror attacks). FLSR is designed as a mobile safety facility of UK ABWR and designed to meet the following Safety Functions.

The FLSR is the secondary means to provide coolant to the reactor core in order to prevent reactor core damage and to confirm reactor core cooling until a condition equivalent to cold shutdown. From this perspective of safety function in SAs, the FLSR delivers a Category B safety function, and the components necessary to deliver this function as secondary means are classified as Class 3 safety components according to the safety categorisation and classification of UK ABWR.

Part of the FLSR provides water to the PCV spray header to prevent PCV breakage due to excess pressure. From this perspective of safety function in SAs, the FLSR delivers a Category B safety function, and the components necessary to deliver this function as secondary means are classified as Class 3 safety components according to the safety categorisation and classification of UK ABWR.

Part of the FLSR supplies water to the lower D/W to remove decay heat from molten core and to prevent PCV breakage due to excess temperature. From this perspective of safety function in SAs, the FLSR delivers a Category B safety function, and the components necessary to deliver this function as secondary means are classified as Class 3 safety components according to the safety categorisation and classification of UK ABWR.

Part of the FLSR supplies water to reactor well to prevent PCV breakage due to excess pressure. From this perspective of safety function in SAs, the FLSR delivers a Category B safety function, and the components necessary to deliver this function as secondary means are classified as Class 3 safety components according to the safety categorisation and classification of UK ABWR.

Part of the FLSR provides the SFP with water to remove decay heat and to maintain the pool water level in an event of loss of makeup water function of SFP. From this perspective of safety function in SAs, the FLSR delivers a Category B safety function, and the components necessary to deliver this function as secondary means are classified as Class 3 safety components according to the safety categorisation and classification of UK ABWR.

16.5.3.2.3 System Design

16.5.3.2.3.1 Overall Design and Operation

The purpose of FLSR is to supply cooling water to the RPV, PCV, the SFP and the reactor well and to prevent serious damage to the core fuel and fuel in SFP, to prevent PCV breakage by keeping the reactor core temperature low in the event of a SA. By connecting Mobile Pumps to a water source inside of the plant site boundary and to any injection piping, the FLSR supplies cooling water to the destination as described as follows through FLSS line.

16.5.3.2.3.1.1 Depressurisation and Injection Initiating Mode

The FLSR is manually initiated water injection with after depressurisation operation with monitoring reactor pressure and reactor water level. Injection flow rate is adjusted with each throttle valves installed on injection piping outside the Reactor Building.

16.5.3.2.3.1.2 Injection Control Mode before vessel failure

The FLSR maintains the water supply to RPV by adjusting control value. The FLSR also supplies water to the lower D/W and to reactor well in parallel with the reactor core injection operation.

16.5.3.2.3.1.3 Injection Control Mode after vessel failure

In the accidental condition of the vessel failure, the FLSS maintains the water supply to RPV after Depressurisation and Injection Initiating Mode. In parallel with the reactor core injection operation, water is also supplied to the lower D/W line, to the PCV spray line with intermittent flow rate considering the conditions of instrumentations. The FLSS also supplies water to SFP for makeup.

16.5.3.2.3.2 Equipment Design and Operation

16.5.3.2.3.2.1 FLSR Pump

Mobile Pumps are provided to satisfy the required flow rate for each function in the FLSR to prevent remarkable damage of the reactor core according the SA analysis. The required flow rate is determined based on the combination of water supply.

16.5.3.2.3.3 Main Support Systems

16.5.3.2.3.3.1 Instrumentation and Control

The main instrumentation and control provisions related to FLSR operation from the performance and reliability points of view are summarised as follows.

(1) Instrumentation
Flow meters are installed on each Mobile Pump to measure water injection flow rate.

(2) Control
All operation of the FLSR is manual.

16.5.3.2.3.3.2 Power Supply System

The Mobile Pumps are designed to be powered by mobile power source facilities.

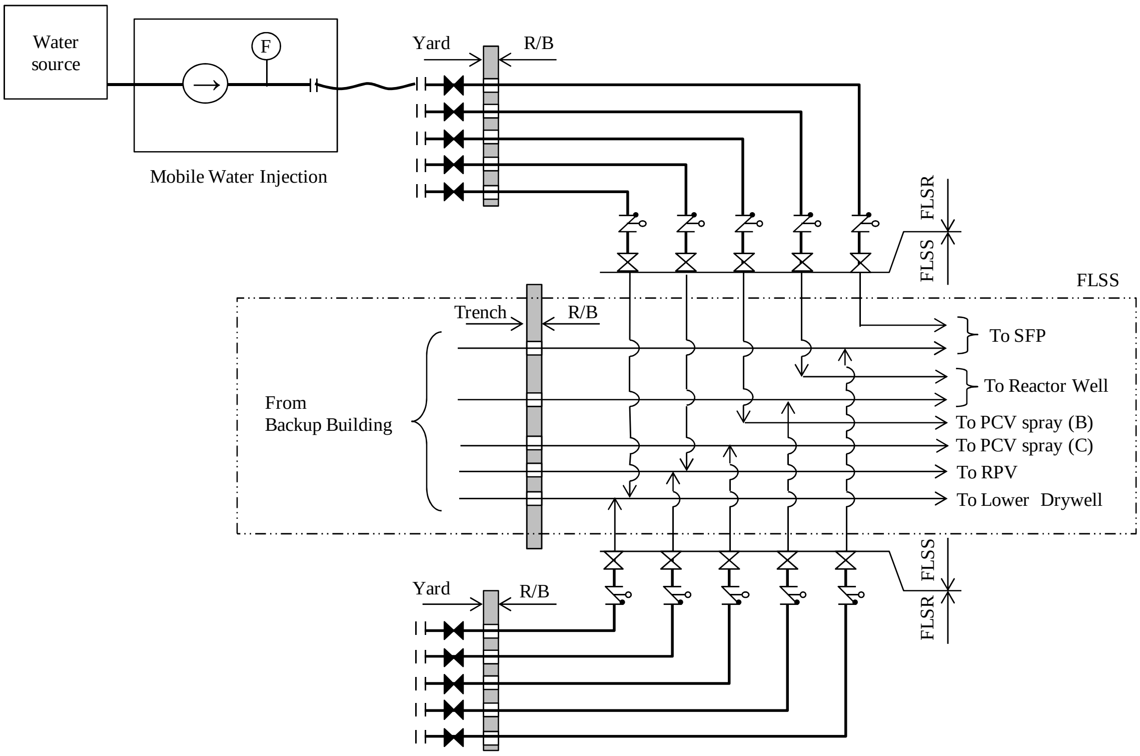

Figure 16.5-2 : Outline of the Flooder System of Reactor Building

16.5.3.3 Filtered Containment Venting System

16.5.3.3.1 System Summary Description

This section is a general introduction to the Filtered Containment Venting System (FCVS) where the system roles, system functions, system configuration and modes of operation are briefly described.

16.5.3.3.1.1 System Roles

The main roles of the FCVS are to prevent damage to the PCV for overpressure and to avoid the release of large quantities of fission products in the event of SA.

16.5.3.3.1.2 Functions Delivered

The FCVS is designed to perform the following functions in the event of SA:
(1) The FCVS filters the radioactive iodine and long-half life fission products (FPs) generated during SA in the PCV through the filter vent device.
(2) The FCVS releases non-condensable gases and steam through the main stack to prevent damage to the PCV for overpressure.

16.5.3.3.1.3 Basic Configuration

The FCVS consists of filter vent device, nitrogen gas purge facility, the necessary piping, valves, rupture disks, instrumentations and controllers. The main components are summarized as follows:

(1) Filter Vent Device
(2) Nitrogen Gas Purge Facility
(3) Piping, Valves and Rupture Disks
(4) Instrumentation and Controllers

16.5.3.3.1.4 Modes of Operation

The FCVS can deliver the following operation modes by switching the position of the valves.

16.5.3.3.1.4.1 Plant normal operation condition

The system is maintained on standby during the period in which PCV confinement function is expected. During standby, the system is kept under a nitrogen atmosphere to prevent the detonation due to the possible inflow of hydrogen gas from the PCV when system initiation. Thus, the system internal atmosphere is replaced by nitrogen gas before plant start up.

16.5.3.3.1.4.2 PCV vent operation

The emission of long-half life FPs is reduced by filtering the containment vessel gases containing fission products through the filter vent device before exhausting them into the atmosphere in the event there was the possibility of containment vessel damage due to overpressure (PCV design pressure exceeded) during SA.

16.5.3.3.2 Design Bases

The FCVS has been designed to meet the following Safety Functions (SFCs) when the safety facilities such as the ECCS and the Emergency Diesel Generators are not unavailable due to SAs caused by beyond design basis of external hazards (e.g. earthquakes, flooding, aircraft crash, tornado and terror attacks):

The FCVS is a principal means to limit the release of radioactive material from the PCV in the event of SAs. From this perspective, the FCVS delivers a Category B mitigation function, and as principal means, the components necessary to deliver this containment function are classified as Class 2 safety components according to the safety categorisation and classification of UK ABWR.

The FCVS is a principal means to deliver overpressure protection of the PCV Boundary under SA conditions that could put excessive pressure on the boundary. From this perspective, the FCVS delivers a Category B mitigation function, and as a principal means, the components necessary to deliver overpressure protection are classified as Class 2 safety components according to the safety categorisation and classification of UK ABWR.

Part of the FCVS forms the PCV Boundary. Therefore, the components within the PCV boundary form a barrier to maintain the integrity of the boundary and thus prevent the dispersion of radioactive substances. From this perspective, the FCVS delivers a Category B safety function (confinement) and the components necessary to deliver this function are classified as Class 2 safety components according to the safety categorisation and classification of UK ABWR.

This Function is developed and justified in the section related to Containment Function in PCSR chapter 13.

16.5.3.3.3 System Design

16.5.3.3.3.1 Equipment Design and Operation

(1) Vent Filter
   (a) One vent filter is located in the shielding wall.
   (b) The vent filter is designed to remove aerosol, iodine element and organic iodine.

(2) Containment Overpressure Protection System (COPS)
   COPS is designed to be capable of venting via rupture disk to prevent over pressurization of PCV without operator’s action (passive vent). COPS has the line which bypasses the rupture disk is provided for the purpose of carrying out a vent operation manually (controlled vent).

16.5.3.3.3.2 Main Support Systems

(1) Instrumentation and Control
   The main instrumentation and control provisions related to FCVS operation from the performance and reliability points of view are summarised as follows. The design of the Instrumentation and Control will be addressed in PCSR chapter 14 “Control and Instrumentation Systems”.
   (a) The instruments around the filter vent are designed to be capable of monitoring of the system status even if venting is implemented under loss of power supply.
   (b) The instruments around the filter vent are designed to be capable of monitoring of the system status from outside the shielding wall.

(c) The parameters to be monitored are as follows:
   (i) Vent Filter Pressure
   (ii) Vent Filter Temperature
   (iii) Pressure Downstream the Vent Filter
   (iv) Water Level of the Vent Filter
   (v) Radioactivity Concentration of the Exhausted Gases from the Vent Filter

(2) Power Supply System
The power sources are generated by the Alternative AC Generator System installed in B/B, which are different from the emergency power source installed in R/B.

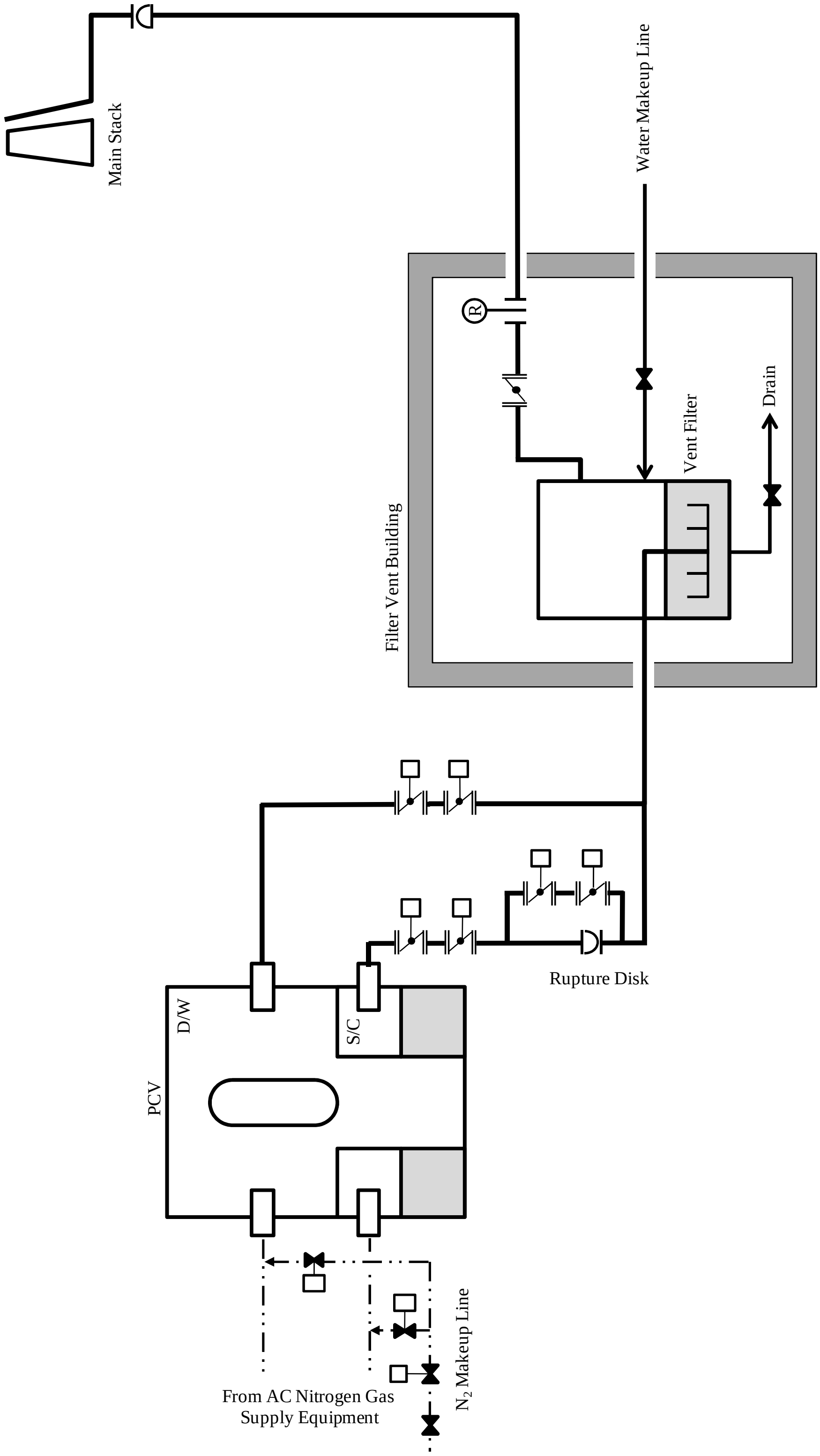

Figure 16.5-3 : Outline of the Filtered Containment Venting System

16.5.3.4 Lower Drywell Flooder System

16.5.3.4.1 System Summary Description

This section is a general introduction to the Lower Drywell Flooder System (LDF) where the system roles, system functions, system configuration and modes of operation are briefly described.

16.5.3.4.1.1 System Roles

The main roles of the LDF are to flood the lower D/W with water from the Suppression Pool (S/P) in the unlikely event of a SA where the core melts and causes a subsequent vessel failure to occur, and deposition of molten corium* on the lower D/W floor. The flooder covers molten corium with water for cooling and scrubbing any fission products released from the debris.

* Molten corium is a molten mixture of fuel, reactor internals, the vessel bottom head and control rod drive components.

16.5.3.4.1.2 Functions Delivered

The LDF provides water to the Lower D/W to remove the decay heat from molten corium for cooling and scrubbing any fission products released from the debris.

16.5.3.4.1.3 Basic Configuration

The LDF consists of water source, piping and fusible plugs (FPLGs) shown in Figure 16.5-4. The LDF has no pumps, no instrumentations and no controllers because the LDF operates automatically in a passive manner describes in 16.5.3.4.1.2.The main components are summarised as follows:

(1) LDF consists of ten pipes that run from the vertical pedestal vents into the lower D/W
(2) Each pipe contains a FPLG connected to the end of the pipe.
(3) The ten of LDF lines are arranged to distribute flow evenly around the circumference of the lower D/W.

16.5.3.4.1.4 Modes of Operation

LDF can deliver the following operation modes by opening FPLGs which are thermally activated.

16.5.3.4.1.4.1 Plant normal operation condition

LDF is on standby during normal plant operation.

16.5.3.4.1.4.2 Standby Mode

LDF is never expected to be needed for safety reasons because of the extensive array of water injection systems available to maintain core cooling. Namely, LDF is not expected to become a flow path from the S/P to the lower D/W during Design Basis Accidents (DBAs) such as Loss of Coolant Accidents (LOCAs).

16.5.3.4.1.4.3 Lower Drywell Flooder Mode

During SA that leads to core meltdown, vessel failure, and deposition of molten corium on the lower D/W floor, LDF provides a flow path for S/P water into the lower D/W and supplying a coolant to debris, by FPLG melting by an atmosphere temperature of lower D/W.

16.5.3.4.2 Design Bases

The LDF has been designed to meet the following Safety Functions when the safety facilities such as the ECCS and the Emergency Diesel Generators are unavailable due to SAs caused by beyond design basis of external hazards (e.g. earthquakes, flooding, aircraft crash, tornado and terror attacks).

The LDF is the secondary means to supply water to the lower D/W to remove decay heat from molten core and to prevent PCV breakage due to excess temperature. From this perspective, the LDF delivers a Category B safety function, and as secondary means, the components necessary to deliver this function are classified as Class 3 safety components according to the safety categorisation and classification of UK ABWR.

16.5.3.4.3 System Design

16.5.3.4.3.1 Overall Design and Operation

The purpose of LDF is to flood the debris by supplying cooling water to Lower D/W in the event of SAs that leads to core meltdown, vessel failure, and deposition of molten corium on the lower D/W floor. The flow path into the lower D/W area is opened when the lower D/W airspace temperature reaches about 260°C, by melting a fusible metal plug inside a FPLG, which enables to provide the flow with hydrostatic head.
The flow path is terminated when the water levels of vertical vents have reached the bottom end of flooder pipes inlet.

16.5.3.4.3.2 Equipment Design and Operation

16.5.3.4.3.2.1 FPLGs

(1) Configuration
LDF consists of ten lines that run from the vertical pedestal vents into the lower D/W to distribute flow evenly around the circumference of the lower D/W. FPLG is connected to each line at the end of the pipe that extends into the lower D/W by a flange.

(2) Performance
The FPLGs are designed such that they can be supply water to remove the heat from debris.

(a)	Type	Fusible Plug
(b)	Number:	10 units
(c)	Material:	mainly Stainless Steel

The flow path into the lower D/W area is opened when the lower D/W airspace temperature reaches about 260°C, by melting a fusible metal plug inside a FPLG, which enables to provide the cooling water flow with hydrostatic head.

16.5.3.4.3.3 Main Support Systems

16.5.3.4.3.3.1 Instrumentation and Control

The control provisions related to the delivery of safety function is not needed because the LDF operate totally automatically in a passive manner. The operation of LDF is confirmed by the D/W temperature reduction and the lowering of S/P water level.

(1) Control
No operator action is required; therefore, no instrumentation for control is placed upon the system.

(2) Instrumentation
The instrumentation is provided to measure and monitor the operating conditions of the LDF components necessary for the delivery of safety function and thus ensure their performance and reliability. The statuses, measurements of the components are displayed in the B/B Control Room.

16.5.3.4.3.3.2 Power Supply System

No Power Supply System to actuate the FPLGs is required.

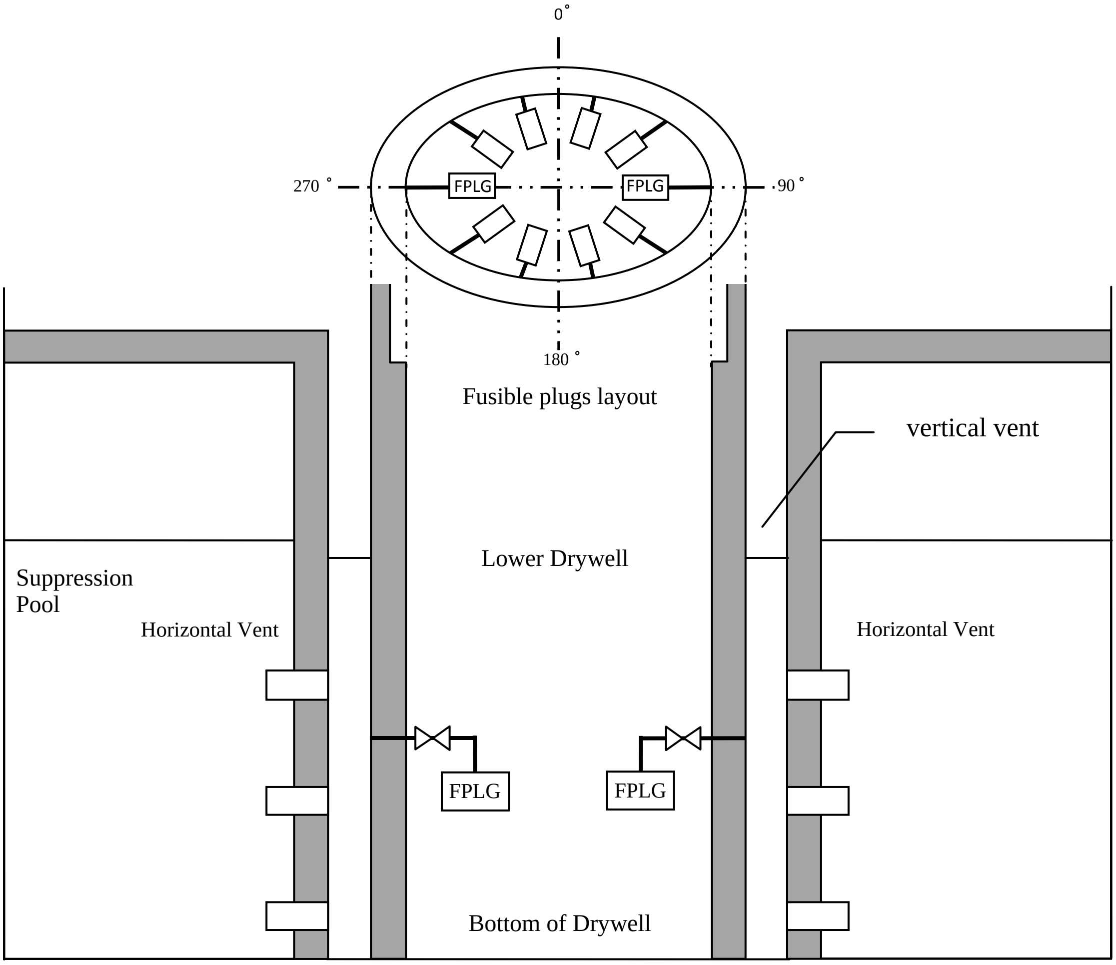

Figure 16.5-4 : Outline of the Lower Drywell Flooder

16.5.3.5 Alternate Heat Exchange Facility

16.5.3.5.1 System Summary Description

This section is a general introduction to the Alternate Heat Exchange Facility (AHEF) where the system roles, system functions, system configuration and modes of operation are briefly described.

16.5.3.5.1.1 System Roles

The main roles of the AHEF is to recover cooling capacity of any one division of RHR by connecting the mobile alternate cooling unit after having moved it beside the R/B, in case that the functions of Reactor Building Cooling Water System (RCW) or Reactor Building Service Water System (RSW) are lost.

16.5.3.5.1.2 Functions Delivered

The AHEF is designed to perform the following functions in the event of SA. The AHEF removes heat of a RHR Heat Exchanger by supplying cooling water from the Mobile AHEF Cooling Unit, which has AHEF Cooling Water Pumps and AHEF Heat Exchangers.

16.5.3.5.1.3 Basic Configuration

The AHEF consists of a Mobile AHEF Cooling Unit and AHEF Service Water Pumps. The main components are summarized as follows:

(1) The Mobile AHEF Cooling Unit consists of the following components:
- (a) AHEF Cooling Water Pumps: 2 units (50%-capacity/unit)
- (b) AHEF Heat Exchangers: 2 units (50%-capacity/unit)
- (c) Piping and Valves: 1 set
- (d) Instruments and Controllers: 1 set

(2) The AHEF Service Water Pumps and accompanied components are as follows:
- (a) AHEF Service Water Pumps: 2 units (50%-capacity/unit)
- (b) AHEF Strainers: 2 units (50%-capacity/unit)
- (c) Piping and Valves: 1 set
- (d) Temporary hoses: 1 set

16.5.3.5.1.4 Modes of Operation

The AHEF can deliver the following operation modes by switching the position of the valves.

16.5.3.5.1.4.1 Plant normal operation condition

The AHEF is on standby during normal plant operation.

16.5.3.5.1.4.2 AHEF operation

The AHEF supplies cooling water to one of the RHR Heat Exchangers to maintain cooling function of RHR in case that the functions of RCW or RSW are lost.

16.5.3.5.2 Design Bases

Provisions for installing permanent and mobile safety facilities are put in place as countermeasures against severe accidental events that the safety facilities such as the ECCS, the Emergency Diesel Generators, etc. are unavailable due to beyond design basis of external hazards (e.g. earthquakes, flooding, aircraft crash, tornado and terror attacks). AHEF is designed as a mobile safety facility of UK ABWR and designed to meet the following Safety Functions:

The AHEF is the secondary means to provide water to one of the RHR Heat Exchangers to maintain cooling function of RHR in order to prevent reactor core damage and to confirm reactor core cooling until a condition equivalent to cold shutdown. From this perspective of safety function in SAs, the AHEF delivers a Category B safety function, and as secondary means, the components necessary to deliver this function are classified as Class 3 safety components according to the safety categorisation and classification of UK ABWR.

Part of the AHEF provides water to one of the RHR Heat Exchangers to maintain cooling function of RHR in case that the functions of RCW or RSW are lost. From this perspective of safety function in SAs, the AHEF delivers a Category B safety function, and as secondary means, the components necessary to deliver this function are classified as Class 3 safety components according to the safety categorisation and classification of UK ABWR.

16.5.3.5.3 System Design

16.5.3.5.3.1 Overall Design and Operation

The purpose of AHEF is to remove decay heat of a RHR heat exchanger in the event of a SA. By supplying cooling water from the Mobile AHEF Cooling Unit, which has AHEF Cooling Water Pumps and AHEF Heat Exchangers. The AHEF Heat Exchangers are cooled with sea water driven by Mobile AHEF Service Water Pumps.

16.5.3.5.3.1.1 AHEF Operation Mode

The Mobile AHEF Cooling Unit composed of the AHEF Cooling Water Pumps, the AHEF Heat Exchangers and other related components are mounted a trailer vehicle. The system flow rate of primary side (freshwater side) is about 600 m^3/h and a flow control valve is installed on the discharge side of the Mobile AHEF Cooling Unit. The system flow rate of secondary side (sea water side) is about 840 m^3/h and a flow control valve is installed on the discharge side of AHEF Service Water Pump.

16.5.3.5.3.2 Equipment Design and Operation

16.5.3.5.3.2.1 AHEF Cooling Water Pump

(1) Configuration
The AHEF Cooling Water Pumps are designed to satisfy the required flow rate and discharge head. The rated discharge head of the AHEF Cooling Water Pump is determined by considering the pressure losses due to water flow through the equipment, the friction losses of closed loops including RCW line, etc. The AHEF Cooling Water Pumps are mounted on a trailer vehicle composing the Mobile AHEF Cooling Unit.

(2) Performance
The AHEF Cooling Water Pumps are designed to perform as follows in order to satisfy the safety functions.
(a) Number: 2 units
(b) Flow rate: Approx. 300 m^3/h/unit (provisional)

16.5.3.5.3.2.2 AHEF Heat Exchanger

(1) Configuration
The AHEF Heat Exchangers are designed to remove decay heat of the reactor core. The AHEF Heat Exchangers are mounted on a trailer vehicle composing the Mobile AHEF Cooling Unit.

(2) Performance
The AHEF Heat Exchangers are designed to perform as follows in order to satisfy the safety functions.

Table 16.5-1: AHEF Heat Exchanger Capacity

AHEF Heat Exchanger		
	Primary side (provisional)	Secondary side (provisional)
Fluid	Fresh water	Service water
Flow rate (m^3/h per unit)	Approx. 300 (provisional)	Approx. 420 (provisional)
Capacity (MW/unit)	Approx. 12 (provisional)	

16.5.3.5.3.2.3 AHEF Service Water Pump

(1) Configuration
The AHEF Service Water Pumps are designed to satisfy the required flow rate and discharge head. The AHEF Service Water Pumps are designed to be capable of performing the required functions at the design sea water level. The total rated head of the AHEF Service Water Pumps is determined by considering the piping, hose and valves friction losses, the hydrostatic head between sea water and discharge, etc.

(2) Performance
The AHEF Service Water Pumps are designed to perform as follows in order to satisfy the safety functions.
(a) Number: 2 units
(b) Flow rate: Approx. 420 m^3/h /unit (provisional)

16.5.3.5.3.2.4 AHEF Strainer

(1) Configuration
The AHEF Strainers are mounted on the inlet of the AHEF Heat Exchangers to prevent the instruction of foreign material such as shellfish into the heat transfer piping, which causes blocking the piping.

(2) Performance
(a) Number: 2 units
(b) Flow rate: Approx. 420 m^3/h /unit (provisional)

16.5.3.5.3.3 Main Support Systems

16.5.3.5.3.3.1 Instrumentation and Control

The main instrumentation and control provisions related to AHEF operation from the performance and reliability points of view are summarised as follows.

(1) Instrumentation
(a) The AHEF is locally operated with monitoring local indicators of its instruments.
(b) Detection of leakage on AHEF is performed by monitoring the water level in the surge tank of design-based RCW.
(c) Detection of radioactivity exposure to AHEF is performed by regular sampling inspection of the cooling water.
(2) Control
All operation of the AHEF is manual.

16.5.3.5.3.3.2 Power Supply System

The Mobile Pumps are designed to be powered by mobile power source facilities in the case that normal and emergency power source are unavailable.

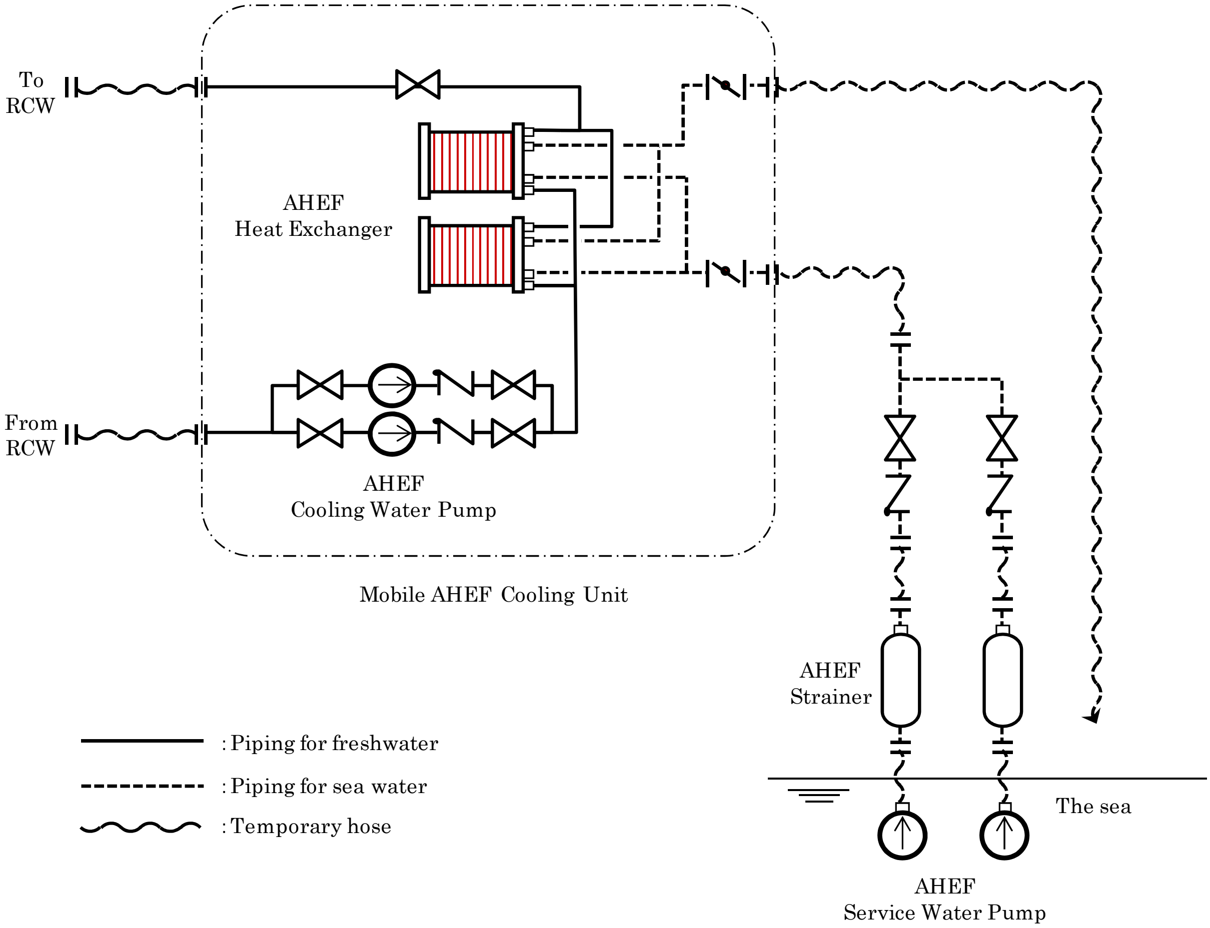

Figure 16.5-5 : Outline of the Alternate Heat Exchange Facility

16.5.3.6 Reactor Depressurization Control Facility

16.5.3.6.1 System Summary Description

This section is a general introduction to the Reactor Depressurization Control Facility (RDCF) where the system roles, system functions, system configuration and modes of operation are briefly described.

16.5.3.6.1.1 System Roles

The main role of the RDCF is to depressurization the RPV at the event of SA, and to enable water supply for the RPV to cool reactor core.

16.5.3.6.1.2 Functions Delivered

The RDCF depressurises the RPV under SA conditions in which the ADS or SRV manual operation at Main Control Room (MCR) is unavailable, to enable water supply for the RPV with the low-pressure RPV injection mode of FLSS or FLSR to cool reactor core. The SRVs without ADS function are opened by manually control at B/B to reduce RPV pressure, and to enable the water supply to RPV with the low-pressure RPV injection mode of FLSS or FLSR described in 16.5.3.1and16.5.3.2.

16.5.3.6.1.3 Basic Configuration

The RDCF consists of dedicated solenoid valves for SRV, power source, the necessary instrumentations and nitrogen feeder to operate the SRVs without ADS function. The main components are summarized as follows.

(1) RDCF is designed to operate seven SRVs without ADS function.
(2) RDCF controls dedicated three-way solenoid valve connecting to the SRV installed on the Main steam line.
(3) Two solenoid valves are installed are per one SRV which ADS function is not with.
(4) Controllers, operation logic/circuit and control panels of RDCF are in B/B which is totally independent from R/B.
(5) RDCF uses the SRV Accumulator of Nuclear Boiler System (NB) for supplying nitrogen gas to operate the SRV.
(6) The outline of RDCF is shown in Figure 16.5-6.

16.5.3.6.1.4 Modes of Operation

The RDCF can deliver the following operation modes by switching the position of the valves.

16.5.3.6.1.4.1 Plant normal operation condition

RDCF is on standby during normal plant operation.

16.5.3.6.1.4.2 RPV Depressurization Mode

In the event of SA when all ECCSs including ADS fail to cool the core, RDCF is initiated to control dedicated solenoid valves in order to RPV depressurisation by SRV and maintain RPV low pressure to enable water supply for the RPV with the low-pressure RPV injection mode of FLSS or FLSR to cool reactor core.

16.5.3.6.2 Design Bases

The RDCF is designed to meet the following Safety Functions against severe accidental events that the safety facilities such as the ECCS, the Emergency Diesel Generators, etc. are unavailable due to beyond design basis of external hazards (e.g. earthquakes, flooding, aircraft crash, tornado and terror attacks).

The RDCF provides to RPV depressurization in order to prevent reactor core damage by the water supply to RPV with the low-pressure cooling water injection. From this perspective of safety function in SAs, the RDCF delivers a Category B safety function, and the components necessary to deliver this function are classified as Class 2 safety components according to the safety categorisation and classification of UK ABWR.

16.5.3.6.3 System Design

16.5.3.6.3.1 Overall Design and Operation

The RDCF depressurises the RPV under SA conditions in which the ADS or SRV manual operation at MCR is unavailable, to enable water supply for the RPV with the low-pressure RPV injection mode of FLSS or FLSR to cool reactor core. The SRVs without ADS function are opened by manually control at B/B to reduce RPV pressure, and to enable the water supply to RPV with the low-pressure RPV injection mode of FLSS or FLSR. All operations are performed manually. Operation is continued until it carries out manually stopping. The nitrogen is supplied from SRV Accumulator of NB or Emergency nitrogen gas cylinder of High Pressure Nitrogen Gas Supply System (HPIN).

16.5.3.6.3.2 Equipment Design and Operation

16.5.3.6.3.2.1 SRV Controlled by RDCF

(1) Configuration
- (i) For RPV depressurisation, RDCF controls seven of nine SRVs which ADS function is not with.
- (ii) Each SRV is provided with two alternative solenoid valves and with one accumulator which already exists for SRV relief function.
- (iii) RDCF uses the SRV Accumulator which the accumulator capacity is sufficient to provide one SRV actuation.
- (iv) Two solenoid valves are dedicated and independent from solenoid valve for SRV relief function.
- (v) The SRVs with two alternative solenoid valves are connected to the HPIN which supplies all the accumulators with nitrogen from HPIN nitrogen gas cylinder to keep them charged.
- (vi) RDCF is designed to provide control of the solenoid valve for depressurisation operation remotely and independently from B/B Control Room.

(2) Performance
The SRVs are needed to decompress RPV without core damage from accident analysis. The RDCF is provided seven SRVs to have enough capacities for RPV depressurisation to facilitate cooling water injection from FLSS or FLSR under SA.

16.5.3.6.3.3 Main Support Systems

16.5.3.6.3.3.1 Instrumentation and Control

(1) Instrumentation is provided to measure and monitor the operating conditions of the RDCF components necessary for the delivery of safety functions. The status, measurements and alarms of the components and valves to be remotely operated are generally displayed in the B/B Control Room.
(2) Control
The RDCF provides RPV depressurization by remotely and manually operated at the Control Room in the B/B.

16.5.3.6.3.3.2 Power Supply System

(1) The solenoid valves for SRV of RDCF are supplied power by Alternative AC Generator System.
(2) The power sources described above are generated by an alternative power supply system installed in B/B, which are different from the emergency power source installed in R/B.

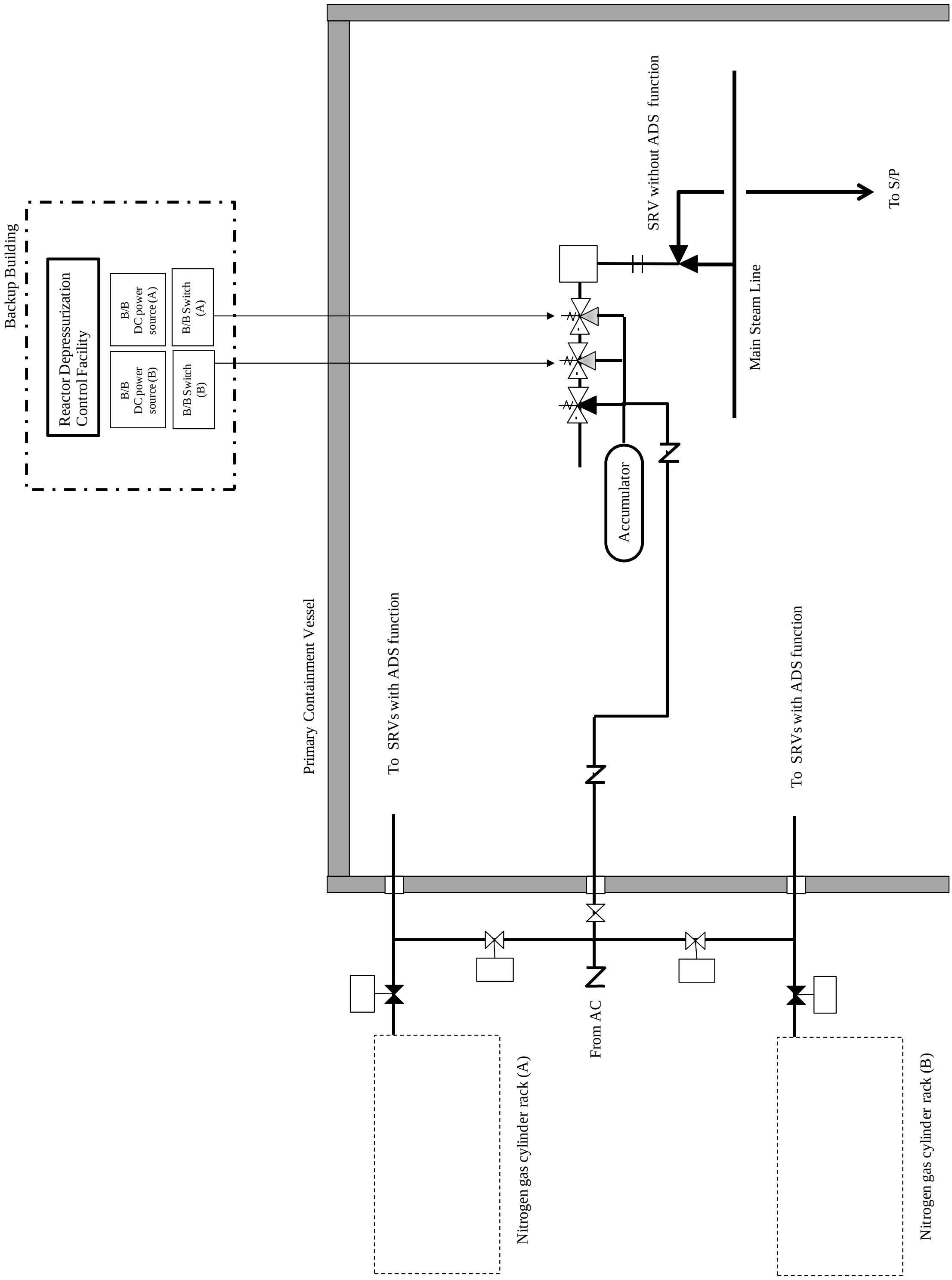

Figure 16.5-6 : Outline of the Reactor Depressurization Control Facility