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UK ABWR

Document ID	:	GA91-9101-0101-16001
Document Number	:	SE-GD-0129
Revision Number	:	A

UK ABWR Generic Design Assessment

Generic PCSR Sub-chapter 16.1 : Water Systems

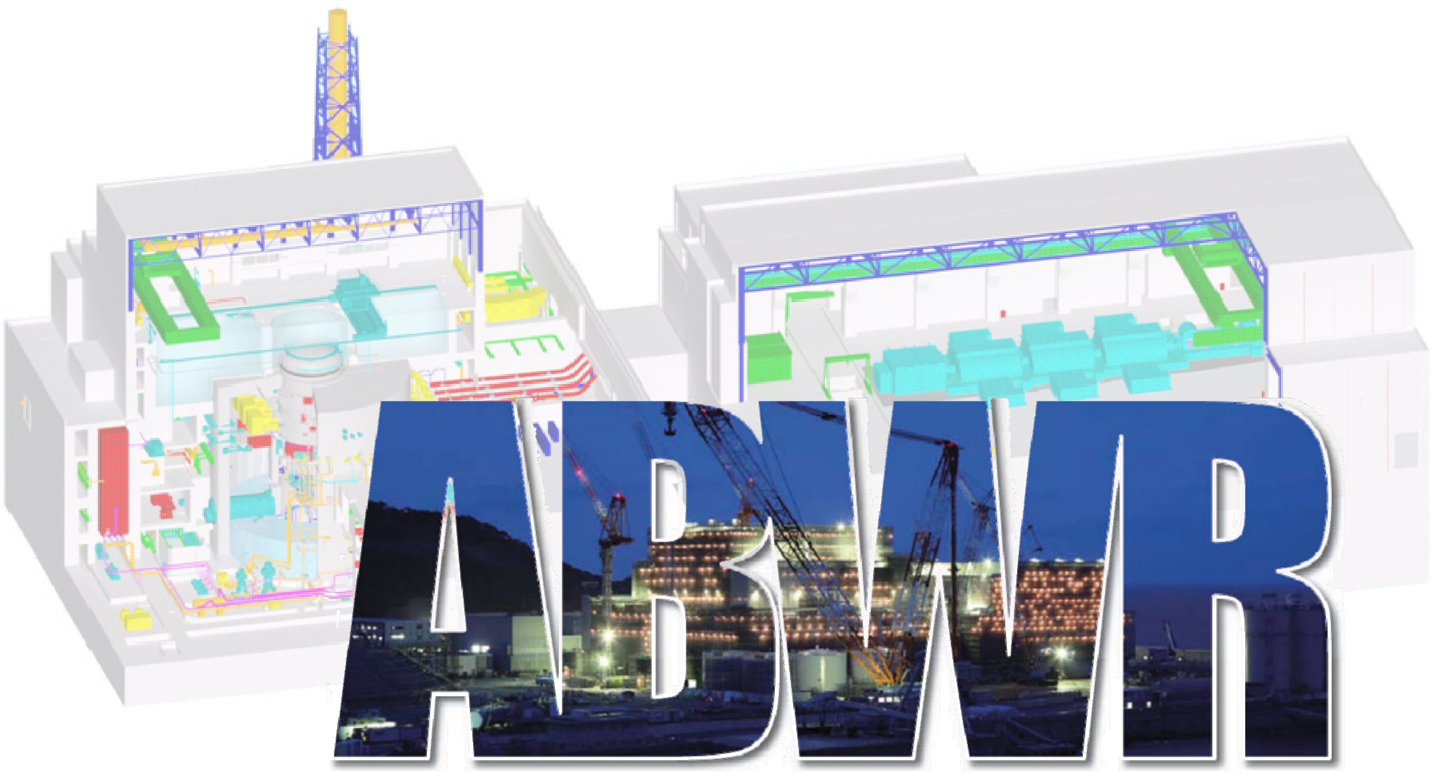

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Table of Contents

16.1.1 Ultimate Heat Sink

16.1.1.1 System Summary Description

This section is a general introduction to the conceptual design of the Ultimate Heat Sink (UHS) since the actual design depends on the site and therefore is site specific.

16.1.1.1.1 System Roles

The main role of the UHS is to provide cooling water and act as a heat sink for the Reactor Building Service Water System (RSW) during normal operation and accident conditions.

16.1.1.1.2 Functions Delivered

The UHS provides that an adequate source of cooling water is available at all times for reactor operation, shutdown cooling and accident mitigation. The RSW receives the cooling water from the UHS and returns the water to it. There are no other heat loads associated with the UHS in addition to the RSW.

16.1.1.1.3 Basic Configuration

The conceptual configuration of the SSCs related to the UHS is summarised as follows:

(1) UHS

(2) Water Intake Canal (refer to Generic PCSR chapter 10)

(3) Heat Exchanger Building (Hx/B)
The Hx/B is the structure housing the RSW Pumps, associated piping and valves. Refer to Generic PCSR chapter 10 for the design description of the Hx/B.

(4) Reactor Building Service Water System (RSW)
The RSW is divided into 3 independent and separated divisions A, B and C each one provided with the following main components.
- (a) Two RSW Pumps
- (b) Piping and valves
- (c) Instruments and controllers

(5) Reactor Building Cooling Water System (RCW)
The RCW is divided into 3 independent and separated divisions A, B and C each one provided with the following main components.
- (a) Two RCW Pumps per division
- (b) Two RCW Heat Exchangers per division
- (c) Piping and valves
- (d) Instruments and controllers

16.1.1.1.4 Modes of Operation

The UHS is designed to operate in conjunction with the RSW and RCW for the following principal modes.

(1) The UHS provides cooling water to the RSW and accepts the head load sent from the RSW as a result of the heat removal from the R/B auxiliaries operating during the modes indicated below by the RCW, which transfers the heat to the RSW through the RCW Heat Exchangers:
- (a) Normal Operation Mode
- (b) Reactor Shutdown Mode
- (c) LOCA Mode

(d) Hot Standby Mode (Offsite Power Available)
(e) Hot Standby Mode (Offsite Power Unavailable)

16.1.1.2 Design Bases

The UHS is the principal means to provide sufficient cooling water to the RSW to dissipate the heat from the plant auxiliaries required for normal operation, normal reactor shutdown, hot standby with off-site power and main condenser available, hot standby under LOOP and main condenser unavailable, and Loss of Coolant Accident (LOCA) accident conditions. From this perspective, the UHS delivers a Category A safety function, and as principal means, the components necessary to deliver this function are classified as Class 1 safety components according to the safety categorisation and classification of UK ABWR.

From the power generation perspective, the UHS provides sufficient cooling water to the RSW to dissipate the heat from the plant auxiliaries required for power generation during plant operation, though no safety requirements are put on the system from this perspective.

16.1.2 Reactor Building Cooling Water Systems

16.1.2.1 System Summary Description

16.1.2.1.1 System Roles

The main role of the RCW is to supply cooling water to the plant auxiliaries in order to preserve the specified functions. Plant auxiliaries consist of the equipment of low safety significance (reactor auxiliaries, radioactive waste system auxiliaries, some turbine auxiliaries containing fluids with radioactive substances) and the equipment of high safety significance (reactor auxiliaries, the emergency heating ventilation and air conditioning auxiliaries, etc.).

The main role of the RSW is to cool and remove the heat from the RCW by supplying service water from the Ultimate Heat Sink (UHS).

16.1.2.1.2 Functions Delivered

The RCW is designed to perform the following normal operation and safety functions:

(1) The RCW recirculates cooling water through the closed loop comprising the RCW Heat Exchanger and the equipment of low safety significance by the RCW Pump to remove the heat from each piece of equipment during normal plant operation, shutdown or hot standby (offsite power available) and transfer it to the RSW.

(2) The RCW recirculates cooling water through the closed loop comprising the RCW Heat Exchanger and the equipment of high safety significance by the RCW Pump to remove the heat from each piece of equipment after automatic initiation during plant abnormal conditions such as Loss of Offsite Power (LOOP) or Loss of Coolant Accident (LOCA) and transfer it to the RSW.

(3) With regard to the Fuel Pool Cooling and Clean-up System (FPC), the RSW and the HVAC Emergency Cooling Water System (HECW) auxiliaries, the RCW recirculates cooling water through the closed loop comprising the RCW Heat Exchanger and their auxiliaries by the RCW Pump to remove the heat from each one of their auxiliaries regardless of the plant operation conditions and transfer it to the RSW.
The RSW is designed to perform the following normal operation and safety functions:

(4) The RSW provides service water to the RCW Heat Exchangers from the water intake pit in order to remove the heat from RCW and discharge it into the water discharge pit.

16.1.2.1.3 Basic Configuration

The RCW consists of three independent divisions for cooling of all safety auxiliaries (RCW (A), RCW (B) and RCW (C)) provided with two RCW Pumps and two RCW Heat Exchangers each. In addition, each division is provided with one RCW Surge Tank to ensure the RCW Pump intake pressure and time margin against leakage of cooling water from the system. The RCW is provided with two RCW Chemical Addition Tanks (one tank is shared by two divisions) to inject corrosion inhibitor into the cooling water when necessary.

The main components are summarised as follows:

(1) Two RCW Pumps per division (A, B, C)
(2) Two RCW Heat Exchangers per division (A, B, C)
(3) One RCW Surge Tank per division (A, B, C)
(4) Two RCW Chemical Addition Tanks in the system (Division A and C share the tank)
(5) Piping and valves
(6) Instruments and controllers

The RSW consists of three independent divisions A, B and C corresponding to the RCW divisions. Each division consists of two independent trains comprising one RSW Pump, one RSW Strainer, piping, etc. and configured with a tie line at the outlet of each RSW Pump connecting them.
The main components are summarised as follows:
(1) Two RSW Pumps per division (A, B, C)
(2) Two RSW Strainers per division (A, B, C)
(3) Piping and valves
(4) Instruments and controllers
Figure 16.1-1 shows an outline of the RCW/RSW basic configuration.

16.1.2.1.4 Modes of Operation

The RCW and RSW can deliver the following operation modes.
(1) Normal Operation Mode
The RCW and RSW remove the heat from auxiliaries of low safety significance and some auxiliaries of higher safety during plant normal operation. This mode is initiated and controlled by remote manual operation from the Main Control Room (MCR). One RCW Pump, one RSW Pump and one Heat Exchanger are in service at each division during this mode while the remaining components are on standby.
(2) Reactor Shutdown Mode
The RCW and RSW remove decay heat from the RHR Heat Exchanger as well as the heat load of auxiliaries of low safety significance and some of higher safety significance during reactor shutdown. This mode is initiated and controlled by remote manual operation from the MCR and, two RCW Pumps, two RSW Pumps and two RCW Heat Exchangers are in service in each division during this mode.
(3) LOCA Mode
This mode is initiated automatically upon LOCA signal to remove decay heat from the RHR Heat Exchangers as well as the heat load of auxiliaries of high safety significance (Emergency Diesel Generator Facility, etc.) and some of low safety significance. The two RCW Pumps, two RCW Heat Exchangers and two RSW Pumps of each division are operated for this mode.
(4) Hot Standby Mode (Offsite Power Available)
This mode is manually operated from the MCR in conjunction with the Hot Standby Mode of the Turbine System to remove the heat load of auxiliaries of low safety significance and some of higher safety significance. One RCW Pump, one RCW Heat Exchanger and one RSW Pump per division are in service with the rest on standby.
(5) Hot Standby Mode (Offsite Power Unavailable)
This mode is initiated automatically upon LOOP signal to remove decay heat from the RHR Heat Exchangers as well as the heat load of auxiliaries of high safety significance (Emergency Diesel Generator Facility, etc.) and some of low safety significance by operating the two RCW pumps, the two RCW Heat Exchangers and the two RSW Pumps of each division. Power supply for this mode is supplied by the Emergency Diesel Generator System.
(6) Refuelling Outage Backup Mode
One of three divisions is shut off for maintenance while the other two divisions are in service during this mode. The cooling water for auxiliaries of high and low safety significance that are required to continuously operate in the division under maintenance is supplied by one of the operating divisions through the interconnecting tie lines. Two RCW Pumps, two RCW Heat Exchangers and two RSW Pumps are operating per available division. In this mode, remote manual operation is conducted from the MCR.

16.1.2.2 Design Bases

This section describes the design bases for the RCW/RSW.

16.1.2.2.1 Safety Functions

The RCW and RSW have been designed to meet the following safety functions:

(1) The RCW and RSW are the principal means to remove heat from plant Class 1 auxiliaries required for normal operation, normal reactor shutdown, hot standby, hot standby under LOOP with main condenser unavailable and infrequent faults such as LOCA. From this perspective, the RCW and RSW support the delivery of Category A safety functions, and as principal means, the components necessary to deliver heat removal are classified as Class 1 safety components according to the safety categorisation and classification of UK ABWR.

(2) The RCW and RSW are the principal means to remove heat from plant Class 2 auxiliaries required for normal operation, normal reactor shutdown, hot standby, hot standby under LOOP with main condenser unavailable and infrequent faults such as LOCA. From this perspective, the RCW and RSW support the delivery of Category A or Category B safety functions, and as principal means, the components necessary to deliver heat removal are classified as Class 2 safety components according to the safety categorisation and classification of UK ABWR.

(3) The RCW and RSW are the principal means to remove heat from plant Class 3 auxiliaries required for normal operation, normal reactor shutdown, hot standby, hot standby under LOOP with main condenser unavailable and infrequent faults such as LOCA. From this perspective, the RCW and RSW support the delivery of Category B or Category C safety functions, and as principal means, the components necessary to deliver heat removal are classified as Class 3 safety components according to the safety categorisation and classification of UK ABWR.

(4) Part of the RCW 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 RCW 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 safety function is developed and justified in the section related to the Primary Containment in Chapter 13.

16.1.2.2.2 Design Bases for Power Generation

From the power generation perspective, the RCW and RSW are the principal means to remove heat from plant auxiliaries required for power generation during plant operation, though no safety requirements are put on the system from this perspective.

16.1.2.3 System Design

This section describes the design of the RCW and RSW.

16.1.2.3.1 Overall Design and Operation

The RCW and RSW are composed of three electrical and mechanical independent divisions designated A, B, and C. Each division contains the necessary piping, pumps, valves and heat exchangers.

The RCW distributes cooling water to remove heat from the plant auxiliaries during normal operation, normal reactor shutdown, hot standby conditions (with off-site power and main condenser available conditions and under LOOP with main condenser unavailable conditions) and post-LOCA conditions and transfers it to the RSW through the heat exchangers, which removes heat from the RCW and transfers it to the UHS.

The auxiliaries to be supplied cooling water by RCW are assigned to the three divisions by considering equipment arrangement, heat loads, flow balance and the distribution of power supply to the loads.

During all plant operating modes, one RCW Pump and one heat exchanger are normally operating in each division. Therefore, if a LOCA occurs, the RCW required to shut down the plant safely are already in operation. The other pump and heat exchanger in each division are put in service if a LOCA occurs.

The RCW is provided with isolation valves to automatically separate the essential auxiliaries required during a LOCA from those non-essential, in order to assure the integrity and safety functions of the system during LOCA.

The RCW is configured as a closed loop and designed such that it automatically fills up cooling water to prevent cooling water insufficiency through the surge tanks. Makeup water is automatically added to the surge tanks from the MUWP.

There are interconnecting tie lines between the divisions, which will be used to supply cooling water to auxiliaries of the RCW division isolated for maintenance during refuelling outages. During refuelling outage backup mode, the auxiliaries supplied cooling water are limited so that the capacities of the RCW Pumps and heat exchangers in the supplying divisions are not exceeded. The tie lines are closed during the rest of operating modes.

16.1.2.3.2 Equipment Design and Operation

(1) RCW Pump
  (a) Configuration
  Divisions A and B of the RCW are designed to supply approximately 2,600m^3/h (provisional) of cooling water and division C of the RCW is designed to supply approximately 2,200m^3/h (provisional) of cooling water to satisfy the required flow of cooling water for all operating modes. Based on this, divisions A and B are provided with two 50%-capacity pumps of approx. 1,300m^3/h (provisional) of design flow rate per pump for each devision, and division C is provided with two 50%-capacity pumps of approx. 1,100m^3/h (provisional) of design flow rate per pump.
  (b) Performance
  The RCW Pump is designed to perform as follows:

Table 16.1-1 : RCW Pump Capacity

	RCW (A/B)	RCW(C)
Number	2 units/division (2 divisions)	2 units/division (1 division)
Rated Flow	Approx. 1,300m^3/h (per unit) (provisional)	Approx.1,100m^3/h (per unit) (provisional)

(2) RCW Heat Exchanger
  (a) Configuration
  The RCW is provided with two straight tubes/shell type (provisional) heat exchangers per division for heat removal from the RCW during all operating modes per division.

Divisions A and B are provided with two heat exchangers of approximately 17.4MW/unit each and division C is provided with two heat exchangers of approximately 16.3MW/unit. The tube side water is service water circulated by the RSW, whereas the shell side (RCW) is fresh cooling water.

(b) Performance
The RCW Heat Exchanger is designed to perform as follows:

Table 16.1-2 : RCW Heat Exchanger Capacity (Divisions A and B)

RCW Heat Exchanger (A)/(B)		
	Shell (provisional)	Tube (provisional)
Fluid	Fresh water	Service water
Flow rate (m^3/h per unit)	Approx.1,300 (provisional)	Approx.1,800 (provisional)
Capacity (MW/unit)	Approx.17.4 (provisional)	

Table 16.1-3 : RCW Heat Exchanger Capacity (Division C)

RCW Heat Exchanger (C)		
	Shell (provisional)	Tube (provisional)
Fluid	Fresh water	Service water
Flow rate (m^3/h per unit)	Approx.1,100 (provisional)	Approx.1,800 (provisional)
Capacity (MW/unit)	Approx.16.3 (provisional)	

(3) RSW Pump

(a) Configuration
Each division of the RSW is designed to supply approximately 3,600m^3/h (provisional) of service water to satisfy the required flow of cooling water for all operating modes. Based on this, each division is provided with two 50%-capacity pumps of approx. 1,800m^3/h (provisional) of design flow rate per pump with a total of six pumps.

(b) Performance
The RSW Pump is designed to perform as follows:

Table 16.1-4 : RSW Pump Capacity

RCW (A/B/C)	
Number	2 units/division (3 divisions)
Rated Flow	Approx. 1,800m^3/h (per unit) (provisional)

16.1.2.3.3 Main Support Systems

16.1.2.3.3.1 Instrumentation and Control

(1) Instrumentation
Instrumentation is provided to measure and monitor the operating conditions of the RCW and RSW components necessary for the delivery of the safety functions. The main provisions for instrumentation are described as follows.

(a) General Provisions

(i) As a general rule, all instruments are arranged so that monitoring and control of process variables (flow rate, pressure, etc.) as well as operation are performed from the Main Control Room (MCR).

(ii) Sampling points for determining cooling water quality and detecting any leakage of radioactive fluids from the auxiliaries (such as the RHR Heat Exchangers, the CUW Heat Exchangers, etc.) are provided.

(iii) The position of all motor-operated and pneumatic valves is indicated on the MCR.

(2) Control
The main control provisions related to the delivery of the safety functions by the RCW and RSW are summarised as follows.
(a) General Provisions
(i) The isolation valves separating non-essential low safety significance loads from those essential during LOCA are designed to close automatically upon the LOCA signal. These valves fully close if the control source of the valve is lost.
(ii) The RCW is designed to supply cooling water automatically to the RHR Heat Exchanger upon the LOCA signal.
(iii) The RCW Pumps on standby are designed to start automatically upon low operating pressure signal and/or failure of the operating the RCW Pump signal.
(iv) All the RCW Pumps, the RCW Heat Exchangers and the RSW Pumps are designed to start automatically upon the LOCA and the LOOP signals.

16.1.2.3.3.2 Power Supply System

(1) The normal AC power supply to the RCW and RSW electrical components is provided by an independent and reliable off-site source (external grid). In addition, RCW and RSW Class 1 components, valves, instruments and controllers are provided with emergency AC power supply and DC power supply.
(2) Each of the RCW and RSW divisions A, B and C is supplied power by independent divisions 1, 2 and 3 of the emergency power supply system respectively.

16.1.2.3.4 System Architecture

(1) Redundancy
The RCW and RSW consist of three redundant divisions A, B, and C with their respective pumps, heat exchangers, strainers, piping, valves, and instrumentation such that, single failure of any dynamic component does not prevent the delivery of the safety functions.
(2) Independence
The components forming the three divisions of the RCW and the RSW are independent and separately arranged in different locations within the Heat Exchanger Building (Hx/B) to prevent failure of a component in one of the divisions from leading to a common cause failure of all divisions.

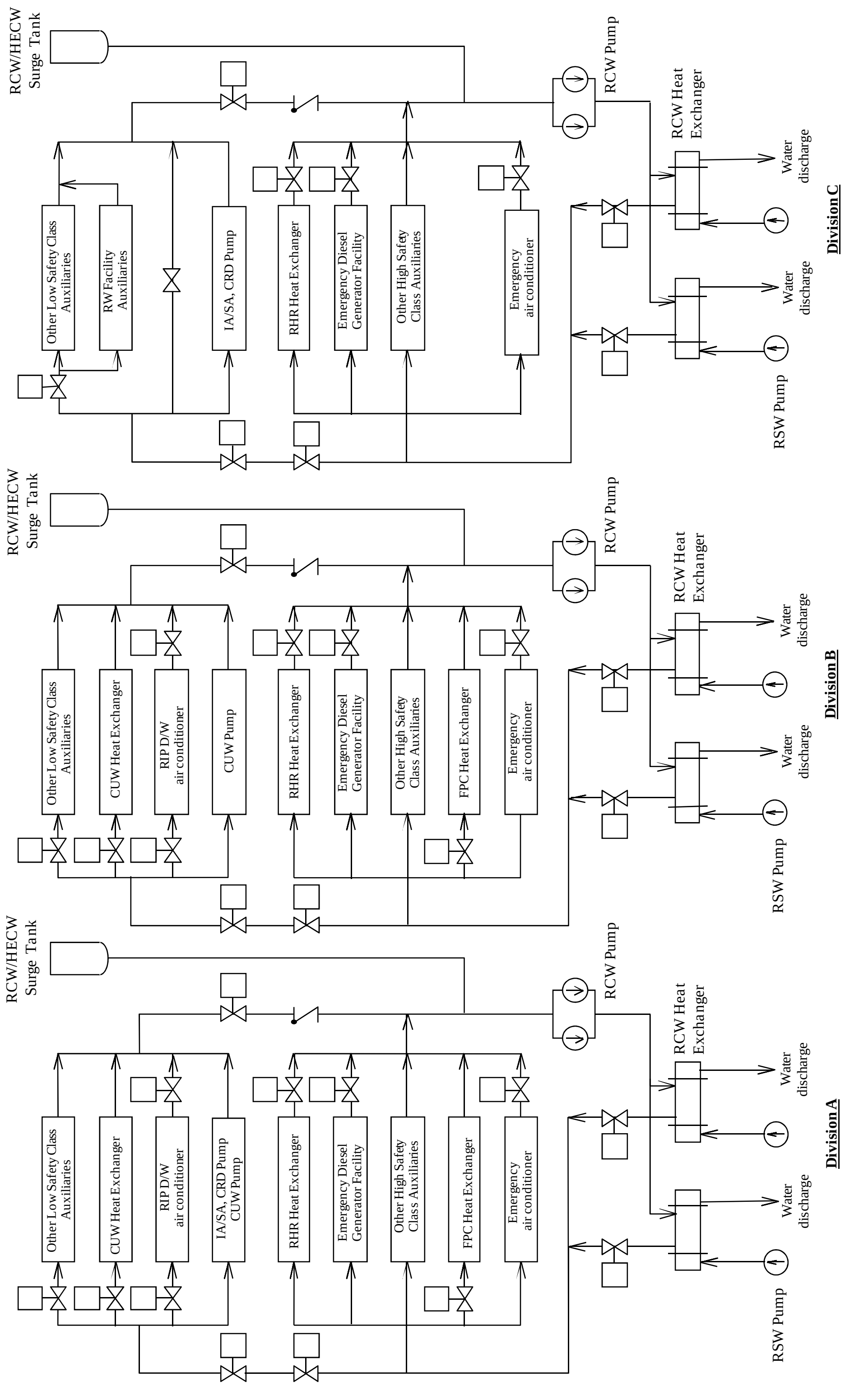

Figure 16.1-1 : Outline of the Reactor Building Cooling and Service Water System

16.1.3 Turbine Building Cooling Water Systems

16.1.3.1 Turbine Building Cooling Water System

16.1.3.1.1 System Summary Description

This section is a general introduction to the Turbine Building Cooling Water System (TCW) where the system roles, system functions, system configuration and modes of operation are briefly described.

16.1.3.1.2 System Roles

The purpose of The TCW is to supply cooling water to turbine auxiliary equipments to assure their functions.

16.1.3.1.3 Basic Configuration

The TCW consists of the following main components.

(1)	Turbine building cooling water pump (TCWP)	3 units (1 unit as standby)
(2)	Turbine building cooling water heat exchanger (TCW-HEX)	3 units (1 unit as standby)
(3)	TCW surge tank	1 unit

16.1.3.1.4 Modes of Operation

Modes of operation of the TCW are summarised as follows:

16.1.3.1.4.1 Normal operation

(1) During normal operation, the TCWPs circulate the cooling water through the TCW-HEXs shell side. The TCWP and TCW-HEX are composed of 3 × 50 % capacity with 1 unit as standby respectively.

(2) The TCWP suction is connected to the TCW surge tank to assure the required Net positive suction head (NPSH).

(3) The TCW surge tank is provided as a reservoir for small amounts of leakage from the TCW and for the expansion and contraction of the cooling water when the system temperature changes.

(4) When the nitrite concentration or pH in the cooling water drops below a low limit, an anti-corrosion chemical is injected to the TCWP suction from the RCW chemical addition tank where the anti-corrosion chemical is added manually.
In this injection system, the cooling water circulates from TCWP discharge header to TCWP suction header via RCW chemical addition tank by the TCWP head.

(5) The Temperature control valve (TCV) is located at the oil cooler inlet to reduce the cooling water pressure in the oil cooler so that the cooling water does not leak into oil as much as possible in case of tube leak.
In addition, regarding the Turbine electro hydraulic control system (EHC) oil cooler, titanium tube and double tube plate are adopted to prevent leakage.

(6) To protect the TCW surge tank downcomer corrosion, a recirculation line is connected between the TCW-HEX outlet and the TCW surge tank to supply anti-corrosion chemical.

16.1.3.1.4.2 Plant outage

(1) A small bypass valve is provided at the TCW-HEX outlet to fill it with cooling water for recovery after cleaning the unit.
(2) Basically, the cooling water drain is discharged to the Miscellaneous non-radioactive drain transfer system (MSC).

16.1.3.1.4.3 Transient conditions

The TCW surge tank hydrostatic head provides suction pressure for the TCWP. In case the TCW surge tank water level drops below the preset level, all TCWPs are stopped to prevent pump cavitations.

16.1.3.1.5 Design Bases

This section describes the design bases for the TCW.

16.1.3.1.5.1 Safety Functions

The TCW has been designed to meet the following Safety Function:
The TCW supplies cooling water to turbine auxiliary equipments. Failure of the TCW could demand Category A Safety Function. From this perspective, the TCW delivers a Category B preventive function, and therefore, the components necessary to deliver this function are classified as Class 3 safety components according to the safety categorisation and classification of UK ABWR.

16.1.3.1.5.2 Design Bases for Power Generation

From the power generation perspective, the TCW meets the following design bases:
The TCW supplies cooling water to turbine auxiliary equipments, such as oil coolers, motor coolers, shaft bearings, and HVAC normal cooling water system (HNCW) refrigerators.

16.1.3.1.6 System Design

This section describes the design of the TCW.

16.1.3.1.6.1 Overall Design and Operation

(1) The TCW is a closed system that circulates chemical-added cooling water by TCWP to cool turbine auxiliary equipments.
(2) In case of cooling water insufficiency, it is supplied from MUWP to the TCW surge tank.
(3) An anti-corrosion chemical is injected to the TCWP suction via the RCW chemical addition tank to protect piping and equipment in the system against corrosion.
(4) The TCW supplies cooling water to turbine auxiliary equipments, such as oil coolers, motor coolers, shaft bearings, refrigerators.
(5) The TCW supplies cooling water to only non-radioactive equipment to prevent radioactive pollution.

16.1.3.1.6.2 Equipment Design

16.1.3.1.6.2.1 TCWP

(1) Configuration
- (a) 3 TCWPs (50 % × 3) are installed (1unit as standby).
- (b) The shaft sealing is of a mechanical seal type to reduce the quantity of leakage.

(2) Performance
The TCWP is designed to perform as follows.

TCWP	Number:	3 units (1 unit as standby)
	Capacity:	to 3,700 m^3/h/unit

16.1.3.1.6.2.2 TCW-HEX

(1) Configuration
- (a) 3 TCW-HEXs (50 % × 3) are installed (1 unit as standby). The TCW water circulates on the shell side, and the TSW water circulates on the tube side.
- (b) If 1 of the active TCW-HEXs fails due to a tube leak or washing, the standby unit is placed in service manually.

(2) Performance
The TCW-HEX is designed to perform as follows.

TCW-HEX	Number:	3 units (1 unit as standby)
	Design heat duty:	to 22 MW/unit

16.1.3.1.6.3 Support Systems

The main systems supporting mechanical SSCs for the delivery of cooling water supply to turbine auxiliary equipments are described as follows:

16.1.3.1.6.3.1 Control and Instrumentation Systems

(1) Control
- (a) The air-operated TCV is locked at the current position (Fail As Is) in case of a loss of air supply, to prevent an extreme rise or drop in the temperature of the fluid being cooled (such as water, oil, air and hydrogen gas), except that the air-operated valve for supplying water to the TCW surge tank is fully open (Fail Open).
- (b) The cooling water temperature at the TCW-HEX outlet is maintained constant by controlling the TCW-HEX water flow rate and the bypass flow rate by using the air-operated TCW-TCV at its outlet.
- (c) The performance of the main turbine and the RFP-T are affected by the oil temperature variation, therefore, the TCVs are installed at the main turbine oil cooler and the RFP-T oil cooler supply lines respectively to regulate the cooling water flow rate in order to keep the oil temperature at the required value. The preset turbine oil temperature is changed in accordance with the turbine operation condition.
- (d) The cooling water flow rate to the EHC fluid cooler and the hydrogen coolers is regulated by TCV to keep the oil or hydrogen temperature at cooler outlet constant.
- (e) The cooling water flow rate to all of the other coolers is manually regulated by individual throttling valves located at cooler outlet.

(2) Interlocks
The TCWP has the following interlocks:
(a) In case of a drop in the TCWP discharge pressure, the alarms are transmitted to the Main control room (MCR) and the standby pump start automatically. After TCWP flow rate decreased and its discharge pressure recovered, 1 TCWP is shut down manually from the MCR.
(b) In case of the TCW surge tank water level “Low Low Low”, all TCWPs trip automatically.

16.1.3.1.6.3.2 Power Supply System

The TCW components are basically connected to the normal power supply.

16.1.3.1.6.3.3 Turbine Building Service Water System (TSW)

The TSW supplies cooling water to the TCW-HEX tube side to cool the TCW water.

16.1.3.1.6.3.4 Makeup water purified system (MUWP)

The MUWP supplies makeup water to the TCW surge tank.

16.1.3.2 Turbine Building Service Water System

16.1.3.2.1 System Summary Description

This section is a general introduction to the Turbine Building Service Water System (TSW) where the system roles, system functions, system configuration and modes of operation are briefly described.

16.1.3.2.2 System Roles

The purpose of the TSW is to supply sea water as cooling water to the Turbine building cooling water heat exchanger (TCW-HEX) and remove heat from the Turbine building cooling water system (TCW).

16.1.3.2.3 Basic Configuration

The TSW consists of the following main components.
(1) TSWP 3 units (1 unit as standby)
(2) TSW strainer 3 units (1 unit as standby)

16.1.3.2.4 Modes of Operation

Modes of operation of the TSW are summarised as follows:

16.1.3.2.4.1 Normal operation

(1) The TSW is equipped with 3 TSWPs of 50 % capacity (1 unit as standby) to assure normal plant operation and startup/shutdown operations.
(2) A TSW strainer is provided on each TCW-HEX inlet to protect the TCW-HEX and TSW piping by removing debris and aquatic organisms from the sea water.

The TSW strainer is able to perform self cleaning, changeover to the standby strainer and overhaul while the TSW is in service.
The TSW strainer self-cleaning starts automatically and periodically, or in the event of high differential pressure.

16.1.3.2.4.2 Start-up and shutdown operation

The residual air in the piping and the TCW-HEX during the TSW water filling is discharged by the discharge pressure of TSWP.

16.1.3.2.4.3 Abnormal conditions

The standby TSWP starts automatically in the event that a normally operating pump trips or the discharge pressure drops below a preset limit.

16.1.3.2.5 Design Bases

This section describes the design bases for the TSW.

16.1.3.2.5.1 Safety Functions

The TSW has been designed to meet the following Safety Function:
The TSW supplies sea water as cooling water to the TCW-HEX and remove heat from the TCW. Failure of the TSW could demand Category A Safety Function. From this perspective, the TSW delivers a Category B preventive function, and therefore, the components necessary to deliver this function are classified as Class 3 safety components according to the safety categorisation and classification of UK ABWR.

16.1.3.2.5.2 Design Bases for Power Generation

From the power generation perspective, the TSW meets the following design bases:
The TSW supplies the sea water from intake pool to the TCW-HEX via the TSW strainer and draws off the water to the discharge pool by Turbine building service water pump (TSWP).

16.1.3.2.6 System Design

This section describes the design of the TSW.

16.1.3.2.6.1 Overall Design and Operation

The TSW supplies the sea water from intake pool to the TCW-HEX via the TSW strainer and draws off the water to the discharge pool by TSWP.
The TSW operating pressure is lower than the TCW to prevent sea water from leaking into the TCW.

16.1.3.2.6.2 Equipment Design

16.1.3.2.6.2.1 TSWP

(1) Configuration
- (a) 3 TSWPs (50 % × 3) are installed (1unit as standby).
- (b) The TSWP is a vertical type.

(2) Performance
The TSWP is designed to perform as follows.

TSWP	Number:	3 units (1 unit as standby)
	Capacity:	to 3,800 m^3/h/unit

16.1.3.2.6.3 Support Systems

The main systems supporting mechanical SSCs for the delivery of cooling water supply to TCW-HEXs are described as follows:

16.1.3.2.6.3.1 Control and Instrumentation Systems

When 2 TSWPs are in operation, signals of the outlet pressure drop or the pump trip make standby pump start automatically.
The TSW strainer self-cleaning starts automatically and periodically, or in the event of high differential pressure.

16.1.3.2.6.3.2 Power Supply System

The TSW components are basically connected to the normal power supply.

16.1.3.2.6.3.3 Turbine Building Cooling Water System (TCW)

The TSW supplies sea water as cooling water to the TCW-HEX and remove heat from the TCW.
Makeup Water System.

16.1.4 Makeup Water Systems

16.1.4.1 Makeup Water Condensate System

16.1.4.1.1 System Summary Description

This section is a general introduction to the Makeup Water Condensate System (MUWC) where the system roles, system functions, system configuration and modes of operation are briefly described.

16.1.4.1.2 System Roles

The purpose of the MUWC is to supply condensate required for each component.

16.1.4.1.3 Basic Configuration

The MUWC consists of the following main components.

(1)	Condensate storage tank (CST)	1 unit
(2)	Makeup water condensate pump (MUWCP)	3 units

16.1.4.1.4 Modes of Operation

Modes of operation of the MUWC are summarised as follows:

16.1.4.1.4.1 Normal operation

(1) At least 1 of 3 MUWCPs is in operation. A minimum flow pipe is provided to continuously supply even when the makeup water flow rate is very low.
A pressure transmitter is provided at the pump discharge header to detect drops in pressure and automatically start the standby pump.

(2) The MUWC supplies purging, scramming and filling water to the CRD from the condensate spillover line at the normal operation, and the excess water is recovered to the CST. When the condensate spillover line is not available, the makeup water for CRD is supplied from the CST.

(3) The Makeup water purified system (MUWP) supplied purified makeup water to the CST, and the makeup water valve is remotely operated in the Main control room (MCR).

16.1.4.1.4.2 Start-up and shutdown operation

The returned water to the condenser at plant shutdown is recovered to the CST via the condensate spillover line.

16.1.4.1.4.3 Plant Outage

The water stored for emergency in the normal operation is able to be used as a part of the water required for such as the fuel pool filling in the reactor building during the outage.

16.1.4.1.5 Design Bases

This section describes the design bases for the MUWC.

16.1.4.1.5.1 Safety Functions

The MUWC has been designed to meet the following Safety Function:

The MUWC supplies required condensate to each component. Failure of the MUWC could demand Category A Safety Function. From this perspective, the MUWC delivers a Category B preventive function, and therefore, the components necessary to deliver this function are classified as Class 3 safety components according to the safety categorisation and classification of UK ABWR.

16.1.4.1.5.2 Design Bases for Power Generation

From the power generation perspective, the MUWC meets the following design bases:
The MUWC supplies required water such as filling water and water for washing purpose during the plant outage.

16.1.4.1.6 System Design

This section describes the design of the MUWC.

16.1.4.1.6.1 Overall Design and Operation

(1) The MUWC supplies required condensate at plant startup, shutdown and normal operation to each component which may potentially have radioactive contamination.
(2) The MUWC is used as a water source for the Reactor core isolation cooling system (RCIC), High pressure core flooder system (HPCF), Suppression pool clean-up system (SPCU) and Control rod drive system (CRD), and also receives water from the LCW.
(3) The CST holds the quantity of condensate for the HPCF or RCIC at the plant operation. Accordingly, the ejection nozzles for the HPCF and RCIC are installed lower than the nozzles for the other systems.
(4) The CST is equipped with a level switch to use the suppression pool water for supplying to the HPCF and RCIC in case the CST water level drops below a preset level.

16.1.4.1.6.2 Equipment Design

16.1.4.1.6.2.1 CST

(1) Configuration
    (a) The CST stores condensate as a water source for the HPCF, RCIC, SPCU and CRD. The CST usually stores the water from the LCW.
    (b) The CST stores the water for the Emergency core cooling system (ECCS) and the water used for makeup, filling, sealing, wash of equipment and decontamination. Since a water source for the ECCS must always be reserved, its suction nozzle is installed lower than the other nozzles.
    (c) A vacuum relief valve and a pressure relief valve are provided on the CST.
    (d) To detect leaks from the CST as early as possible, leaking water is collected into a pit equipped with a leak detector.
    (e) The drain pipes and overflow pipes of the CST are connected to the LCW collection tank. To prevent the air in the LCW collection tank from flowing into the MUWC through the pipe, an adequate countermeasure, such as U-seal or dipping the pipe end in the water in the LCW collection tank, is taken.

(2) Performance
The CST is designed to perform as follows.

CST	Number:	1 unit
	Nominal Capacity:	to 2,400 m^3

16.1.4.1.6.2.2 MUWCP

(1) Configuration
   (a) This pump transfers condensate water from the CST to equipments.
   (b) The MUWCPs are connected to the emergency power for ensuring the water supply even when the loss of power accident.
   (c) 3 MUWCPs are installed. 1 pump is normally operated.
   (d) All 3 pumps are used to supply a large amount of condensate water, such as for filling of the reactor well.
(2) Performance
   The MUWCP is designed to perform as follows.

MUWCP	Number:	3 units
	Capacity:	to 130 m^3/h/unit

16.1.4.1.6.3 Support Systems

The main systems supporting mechanical SSCs for the delivery of makeup water supply are described as follows:

16.1.4.1.6.3.1 Control and Instrumentation Systems

(1) The purified water is automatically supplied to the CST by an automatic interlock which controls the makeup valve by the CST water level High/Low switch. Water level High/Low alarms are set for the purpose to notice the CST abnormal water levels.
(2) The CST makeup valve is able to be switched open/close manually also at the MCR.
(3) In case of a MUWCP discharge pressure “Low”, 1 standby pump starts automatically.
(4) The standby MUWCP is stopped by manual after confirming the increase of pump discharge pressure and the decrease of system flow rate.
(5) The CST is equipped with a water level transmitter to detect water levels, to run and stop the MUWCP and to control the Level control valve (LCV) for the purified water makeup. These operations are able to be controlled also by manual.
(6) To prevent the MUWCP cavitations due to lower water level of the CST, interlocks are provided to automatically trip the pump at a preset level for normal operation and for outage respectively.
   To prevent the MUWCP from frequent start and stop, interlocks are provided to prevent standby pump startup in case the CST water level is below preset levels for normal operation and for outage respectively.

16.1.4.1.6.3.2 Power Supply System

The MUWCP components are not required to be connected to the emergency power in safety perspective..

16.1.4.1.6.3.3 Reactor core isolation cooling system (RCIC)

The MUWC supplies makeup water through the RCIC to the Reactor pressure vessel (RPV) as the primary water source, supported by the Suppression Pool (S/P), which is the final water source of the RCIC.

16.1.4.1.6.3.4 High pressure core flooder system (HPCF)

The MUWC supplies makeup water through the HPCF to the Reactor pressure vessel (RPV) as the primary water source, supported by the Suppression Pool (S/P), which is the final water source of the HPCF.

16.1.4.1.6.3.5 Suppression pool clean-up system (SPCU)

The MUWC supplies makeup water through the SPCU to the spent fuel storage pool as the primary water source, supported by the Suppression Pool (S/P), which is the final water source of the SPCU.

16.1.4.1.6.3.6 Control rod drive system (CRD)

The MUWC supplies purge water through the CRD to the Fine motion control rod drive (FMCRD), Reactor Internal Pumps (RIPs) and the Reactor Water Clean-up System (CUW) when the condensate spillover line is not available.

16.1.4.1.6.3.7 Low conductivity waste system (LCW)

The MUWC receives water from LCW. The drain pipes and overflow pipes of the CST are connected to the LCW collection tank.

16.1.4.1.6.3.8 Turbine Gland Steam System (TGS)

The MUWC supplies the makeup water for steam generation in the Gland steam evaporator (GSE).

16.1.4.1.6.3.9 Condenser

The MUWC supplies makeup water to the condenser to control the condenser hotwell water level.

16.1.4.1.6.3.10 Makeup water purified system (MUWP)

The MUWP supplies purified makeup water to the CST.

16.1.5 HVAC Cooling Water System

16.1.5.1 HVAC Emergency Cooling Water System (HECW)

16.1.5.1.1 System Summary Description

This section is a general introduction to the HECW where the system roles, system functions, system configuration and modes of operation are briefly described.

16.1.5.1.1.1 System Roles

HECW is designed for achieving following purpose.

Providing chilled water as a cooling medium to each cooling coil of Supply Air Treatment Facilities within Normal/Emergency Heating Ventilating and Air Conditioning System (HVAC) [Main Control Room (MCR) HVAC, ED/G (Emergency Diesel Generator) Electrical Equipment Zone (DGEE/Z) HVAC and Control Building Electrical Equipment Zone (CBEEE/Z) HVAC] during the plant normal operation (normal operation of the reactor, or when operation of the reactor is shutdown) and the plant emergency operation [such as “Loss of Coolant Accident (LOCA)”, “rapture of the Main Steam (MS) piping”, and “Loss of Off-site Power (LOOP)”].

16.1.5.1.1.2 Function Delivered

HECW is designed for providing following function.

Stabilizing the cooling function for the MCR HVAC, DGEE/Z HVAC and CBEEE/Z HVAC during the plant normal operation and the plant emergency operation are to be maintained.

16.1.5.1.1.3 Basic Configuration

HECW consists of 3 divisions of A, B and C all of which are provided individually. The system main components are summarized as follows:

- (a) HECW Chillers (hereinafter Chiller)
  - (i) Divisions A and B
    2 units [per division] (divisions A and B shares single stand-by unit)
  - (ii) Division C
    2 units (one stand-by unit)
- (b) HECW Chilled Water Pumps (hereinafter Chilled Water Pump)
  - (i) Divisions A and B
    2 units [per division] (divisions A and B shares single stand-by unit)
  - (ii) Division C
    2 units (one stand-by unit)
- (c) HECW Chemical Addition Tank (hereinafter Chemical Addition Tank)
  1 unit [per division A, B and C each]
- (d) Surge Tank [Sharing with Reactor Building Cooling Water System (RCW) (provisional)]
- (e) Piping and Valves
  1 set
- (f) Instrumentation and Control Devices
  1 set

The system outline of HECW is shown in Figure 16.1-2.
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16.1.5.1.1.4 Modes of Operation

(1) HECW operates during the plant normal operation (normal operation of the reactor, or when operation of the reactor is shutdown) and in case of emergency (such as LOCA, rapture of the MS piping, and LOOP).

(2) Upon receiving the operating switch signal from MCR, operation mode will be switched into each mode regardless of the plant status as for divisions A and B.

  (a) 2 units operation mode of the Chiller and the Chilled Water Pump
  Chilled water supplying mode required by DGEE/Z HVAC, CBEEE/Z HVAC (division A or B) and/or MCR HVAC for cooling.

  (b) Single unit Operation mode of the Chiller and the Chilled water Pump
  Chilled water supplying mode required by DGEE/Z HVAC, CBEEE/Z HVAC (division A or B) for cooling. The operation mode provides required cooling capacity. Since Division C does not provide chilled water for MCR HVAC, number of unit needed for delivering sufficient chilled water for cooling DGEE/Z HVAC, CBEEE/Z HVAC (division C) is only going to be a single unit of the Chiller and the Chilled Water Pump.

16.1.5.1.2 Design Basis

HECW provides chilled water for Normal/Emergency HVAC. The system is grouped into Category A and Class 1, ensuring function of nuclear safety Structures, Systems and Components (SSCs) (emergency shutdown to the reactor, reactor core cooling and residual heat removal after the reactor shutdown) and their related SSCs. Therefore, HECW providing chilled water to Normal/Emergency HVAC is designed as Category A and Class 1.

16.1.5.1.3 System Design

This section describes the design of the HECW.

16.1.5.1.3.1 Overall Design and Operation

During the plant normal operation and the plant emergency operation, HECW is provided for keeping each Normal/Emergency HVAC cooling function to specified capacity by supplying chilled water to each cooling coil of MCR Supply Air Treatment Facility, DGEE/Z Supply Air Treatment Facility and CBEEE/Z Supply Air Treatment Facility.

HECW is divided into divisions A, B and C according to each chilled water supplying cooled each Normal/Emergency HVAC. Thus, when dynamic equipment single failure LOOP could be theoretically anticipated, specified function is required not to be lost.

HECW uses indirect method by providing chilled water to each cooling coil and eventually returns the water back to the Chiller as closed circuit. The cooling water is cooled by the Heat Exchangers that belong to RCW.

16.1.5.1.3.2 Equipment Design and Operation

16.1.5.1.3.2.1 Chiller

Chiller is designed to perform as follows. (Provisional)

HECW Chiller (Division A and B)

(a) Number	4 units (2 units [per division])
(b) Cooling Capacity	572 kW [per unit]
(c) Chilled Water Flow	49 m^3/h [per unit]

HECW Chiller (Division C)

(a) Number	2 units
(b) Cooling Capacity	512 kW [per unit]
(c) Chilled Water Flow	44 m^3/h [per unit]

16.1.5.1.3.2.2 Chilled Water Pump

Chilled water pump is designed to perform as follows. (Provisional)

HECW chilled water pump (Division A and B)

(a) Number	4 units (2 units [per division])
(b) Rated Flow	49 m^3/h [per unit]

HECW chilled water pump (Division C)

(a) Number	2 units
(b) Rated Flow	44 m^3/h [per unit]

16.1.5.1.3.3 Main Support Systems

The major support system related to delivery of the HECW safety functions are briefly described as follows.

16.1.5.1.3.3.1 Instrumentation and Control Systems

Principal objective in adapting the method of control and instrumentation is to performance and reliability of the HECW.
Refer to Generic PCSR Chapter 14 “C&I” for further details.

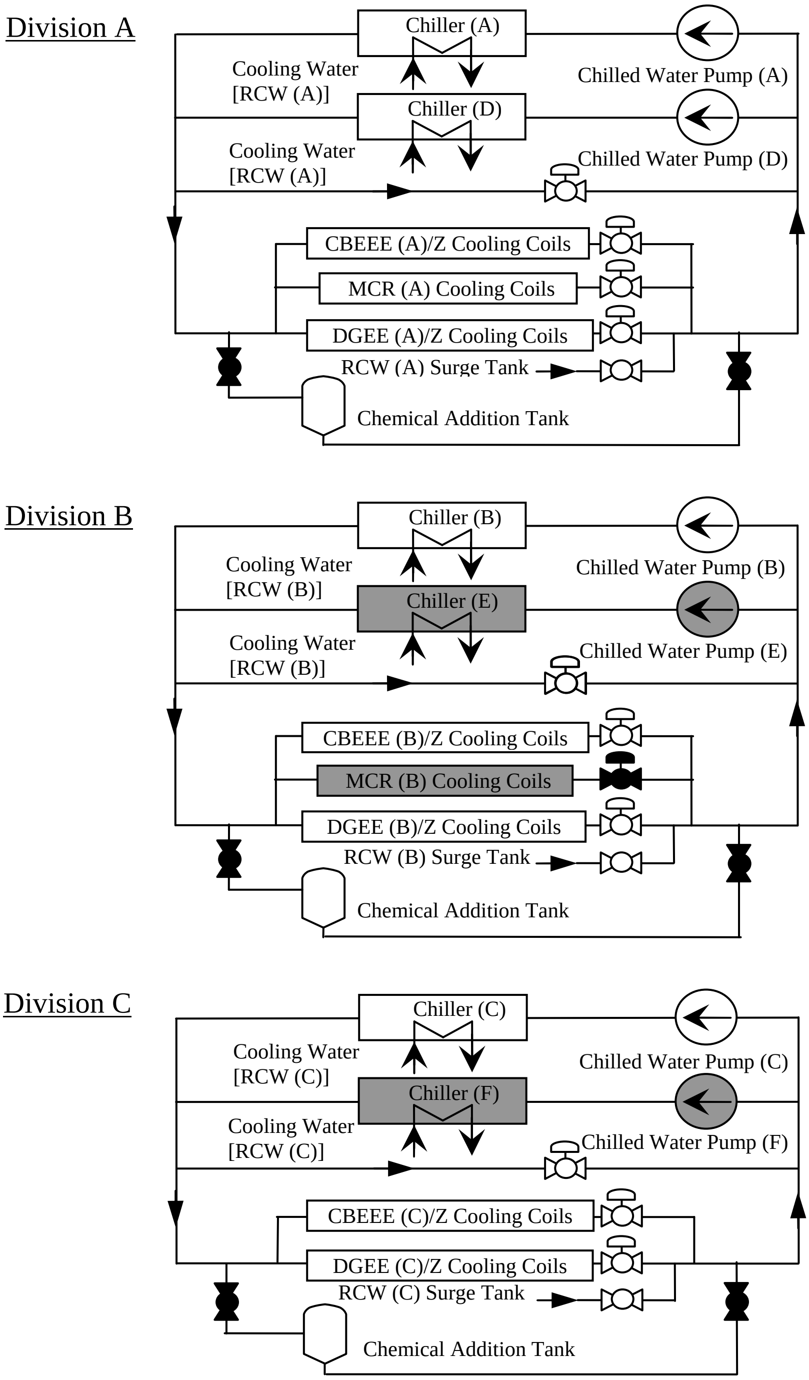
16.1.5.1.3.3.2 Power Supply Systems

A summary of the main power supply systems are given as below and they are needed for ensuring HECW safety functions. Refer to Generic PCSR Chapter 15 “Electrical Power Supplies” for further details.

Power supply for the HECW Chillers and Pumps are supplied by emergency bus from the divisions A, B and C although ED/G is used for those divisions in the event of LOOP.

16.1.5.1.3.3.3 Reactor Building Cooling Water System (RCW)

RCW is a system to provide cooling water to HECW Chiller (condenser).



Note: This drawing shows a condition that Chillers (E), (F) and Chilled Water Pumps (E), (F) are in stand-by.

Figure 16.1-2 : Outline of the HECW (Provisional)

16.1.5.2 HVAC Normal Cooling Water System (HNCW)

16.1.5.2.1 System Summary Description

This section is a general introduction to the HNCW where the system roles, system functions, system configuration and modes of operation are briefly described.

16.1.5.2.1.1 System Roles

HNCW is designed for achieving following purpose.

Providing chilled water as a cooling medium to each cooling coil of Dehumidifier of the Drywell Cooling System (DWC), Supply Air Treatment Facilities for Normal HVAC and Normal Local Cooling Units during the plant normal operation (normal operation of the reactor, or when operation of the reactor is shutdown).

16.1.5.2.1.2 Function Delivered

HNCW is designed for achieving following function.

Stabilizing the cooling function for the Dehumidifiers of the DWC, Supply Air Treatment Facilities of the Normal HVAC and Normal Local Cooling Units during the plant normal operation.

16.1.5.2.1.3 Basic Configuration

HNCW consists of following equipment

- (a) HNCW Chiller (hereinafter Chiller)
  5 units - 25 % each (1 unit stand-by)
- (b) HNCW Chilled Water Pump (hereinafter Chilled Water Pump)
  5 units - 25 % each (1 unit stand-by)
- (c) HNCW Chemical Addition Tank (hereinafter Chemical Addition Tank)
  1 set
- (d) Surge Tank [Sharing with Turbine Building Cooling Water System (TCW) (provisional)]
- (e) Piping and Valves
  1 set
- (f) Instrumentation and Control Devices
  1 set

The system outline of HNCW is shown in Figure 16.1-3.

16.1.5.2.1.4 Modes of Operation

(1) HNCW operates during the plant normal operation (normal operation of the reactor, or when operation of the reactor is shutdown).

(2) Modes of operation are as follows:
- (a) Normal operating mode
  4 units operating mode is employed during the plant normal operation and the number of operating units is switched as needed according to the cooling load fluctuation.
- (b) Plant inspection and maintenance operation mode
  During the plant inspection and maintenance, all Chillers and Chilled Water Pumps are

in operation. They all have sufficient cooling capacity to the targeted cooling temperature to improve work environment. In addition, return temperature of chilled water to the Chiller are stabilized.

16.1.5.2.2 Design Basis

This section describes the design basis for HNCW.

The HNCW is designed to meet the following safety functions.

(1) HNCW provides chilled water to cooling coil of the Normal HVAC Supply Air Treatment Facilities. In case failure is found on HNCW, it is difficult to achieve to satisfy subjected purpose. Therefore, plant normal SSCs are subjected to be cooled, and HNCW is designed and grouped into Category C and Class 3 in terms of As Low As Reasonably Practicable (ALARP).

(2) Part of the HNCW 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 HNCW 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 safety function is developed and justified in the section related to the Primary Containment in Chapter 13.

16.1.5.2.3 System Design

This section describes the design of the HNCW.

16.1.5.2.3.1 Overall Design and Operation

During the plant normal operation, HNCW is provided for keeping DWC Cooling Dehumidification and Normal HVAC cooling function to specified capacity by supplying chilled water to DWC Cooling Dehumidifier, each cooling coil of Normal HVAC Air Supply Treatment Facility and Normal HVAC Local Cooling Unit.

HNCW uses indirect method by providing chilled water to each cooling coil and eventually returns the water back to the Chiller as closed circuit. The cooling water is cooled by the Heat Exchangers that belong to TCW.

16.1.5.2.3.2 Equipment Design and Operation

16.1.5.2.3.2.1 Chiller

Chiller is designed to perform as follows. (Provisional)

(a) Number	5 units (1 unit stand-by)
(b) Cooling Capacity	4,503 kW [per unit]
(c) Chilled Water Flow	780 m^3/h [per unit]

16.1.5.2.3.2.2 Chilled Water Pump

Chilled water pump is designed to perform as follows. (Provisional)

(a) Number	5 units (1 unit stand-by)

(b) Rated Flow 780 m^3/h [per unit]

16.1.5.2.3.3 Main Support Systems

The major support system related to delivery of the HNCW safety functions are briefly described as follows.

16.1.5.2.3.3.1 Instrumentation and Control Systems

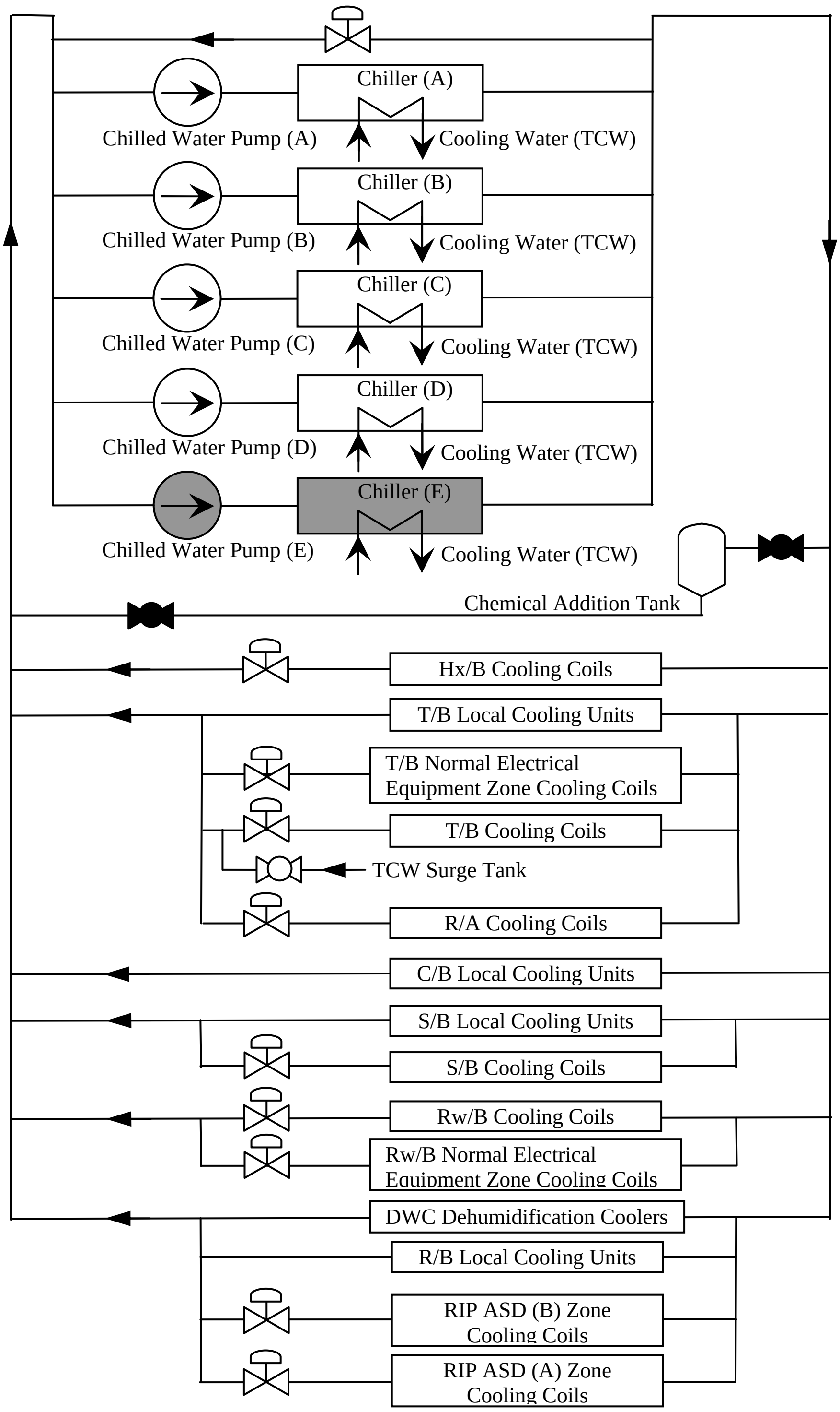
Principal objective in adapting the method of control and instrumentation is to performance and reliability of the HNCW.
See Generic PCSR Chapter 14 “C&I” for further details.

16.1.5.2.3.3.2 Power Supply Systems

A summary of the main power supply systems are given as below and they are needed for ensuring HNCW safety functions. Refer to Generic PCSR Chapter 15 “Electrical Power Supplies” for further details.
Power supply for the HNCW Chillers and Pumps are supplied by normal bus.

16.1.5.2.3.3.3 Turbine Building Cooling Water System (TCW)

TCW is a system to provide cooling water to HNCW Chiller (condenser).



Note: This drawing shows a condition that Chiller (E) and Chilled Water Pump (E) are in stand-by.

Figure 16.1-3 : Outline of the HNCW (Provisional)

16.1.6 References

[Ref-1] GA91-9201-0002-00035 Rev.0, Basis of Safety Cases on Reactor Building Cooling Water Systems, Hitachi-GE.

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