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UK ABWR

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UK ABWR Generic Design Assessment

Generic PCSR Chapter 9 : General Description of the Unit (Facility)

Hitachi-GE Nuclear Energy, Ltd.

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Table of Contents

9.1 Basic Technical Characteristics

9.1.1 Introduction

Hitachi developed the advanced boiling water reactor (ABWR) with development concepts of enhanced safety, higher operability, reduced dose equivalent, performance and enhanced cost efficiency. The first ABWRs are the Unit 6 and Unit 7 of Kashiwazaki-Kariwa Nuclear Power Station (KK-6 and KK-7) of Tokyo Electric Power Company, Inc (TEPCO). Hitachi-GE Nuclear Energy, Ltd. (Hitachi-GE) has already constructed four ABWRs within Japan. Although the standard Japanese ABWR design in Japan has been established since the completion of KK-6 and KK-7, Hitachi-GE expects that, during GDA, the UK ABWR design may need some design changes to deal specifically with UK requirements. However, KK-6 and KK-7 with further improvements and optimisation incorporated in Ohma-1, Shika-2and Shimane-3 will be used as reference design in the UK ABWR. The reference design will be confirmed in the Design Reference Point.

This section provides overview of system description including the basic technical characteristics of UK ABWR, a detail of which are discussed in the later chapter.

9.1.2 Basic Plant Design Characteristics

UK ABWR is designed with the aim of simplifying the design and operation of the plant as well as enhancing the safety and reliability of Structures, Systems and Components (SSCs). Simplification, safety and reliability enhancements have been, and remain to be, a continuous effort since the initial introduction of the BWR technology in the 1950s. Some of the major ABWR improvements and differences relative to previous BWRs include:

- Improvement of safety and reliability
- Improvement of capacity factor
- Reduction of radiation dose to which workers are exposed
- Improvement of operability and maintenability

Additionally, UK ABWR is developed based on demonstrated technology from both domestic and overseas construction and operational experience. The main improvements in systems and equipment applied to ABWR are as follows.

(1) Reactor Internal Pump (RIP)
ABWR RIPs are directly attached to the bottom of the Reactor Pressure Vessel (RPV) to directly circulate the flow of water (coolant) inside the reactor. In the earlier BWR designs the recirculation loop is located outside of the RPV, and the recirculation pump, in combination with the jet pump inside the reactor, provides circulation flow of the coolant. The RIP is characterised as follows:
(a) There are no external pumps for recirculation; therefore, the installation position of the Primary Containment Vessel (PCV) is lower. Hence, the centre of gravity of the reactor is lowered, thus improving resistance to earthquakes.
(b) The RIP uses a wet motor which is immersed in water in the casing, and has no shaft seal. Therefore, reliability in leak tightness is further enhanced.
(c) As the external pipes used in the conventional method are eliminated, the amount of radiation exposure to workers during maintenance inspection work is reduced.
(d) The potential of large diameter pipe breaks at Cooling Water Recirculation Line is eliminated by adoption of RIP, which eliminates the necessity of supplying water to the inside of the shroud.

(2) Fine Motion Control Rod Drive (FMCRD)
In the ABWR the Control Rod Drive (CRD) mechanism uses an electric motor during normal operations and the hydraulic drive during emergency Control Rod (CR) insertions instead of the Locking Piston Control Rod Drive (LPCRD) used in previous BWR designs.
The FMCRD is characterised as follows:
(a) The FMCRD has 2 power sources, hydraulic drive and electric motor drive. Scram is achieved with the hydraulic power. Once fully inserted, a latch prevents the CR from moving out from the core. After scram, all electric motor drive mechanisms act as back up for CR insertion.
(b) The FMCRD is designed to let the water flow into the reactor, a system to discharge scram water is unnecessary. Therefore, exposure of workers to radiation can be mitigated.
(c) Only 1 CR could be activated at maximum with the LPCRD, but the adoption of an electric motor drive enables the operation of 26 CRs at maximum (gang mode operation), shortening startup time.

(3) Reinforced Concrete Containment Vessel (RCCV)
ABWR uses a cylindrical RCCV which is integrated with the Reactor Building (R/B), instead of the conventional steel containment vessel. This containment vessel is composed of a concrete part which is pressure-resistant and a steel liner (lining) which prevents leakage.

The RCCV is characterised as follows:

(a) There is greater freedom in shape selection compared to steel containment vessels, due to the adoption of the reinforced concrete containment vessel, enabling equipment to be positioned in a rational manner inside the containment vessel.

(b) The strength of reinforced concrete allows for the direct support of equipment and pipes, and the space inside the containment vessel can be used more effectively.

(c) The pedestal that supports the RPV can include the vent pipe in the horizontal vent configuration, therefore, space efficiency of the containment vessel is increased and the number of vent pipes can be reduced compared to the conventional steel pipe vertical vent configuration.

(4) Emergency Core Cooling System (ECCS) is characterised as follows:
The ECCS of the ABWR is composed of 3 independent divisions which are composed of the HPCF and the Reactor Core Isolation Cooling System (RCIC), and Low Pressure Core Flooder (LPCF) systems. It is designed to secure submergence of the core during a Loss of Coolant Accident (LOCA) with single failure.

(a) The large diameter pipes are not connected below the Top of Active Fuel (TAF) due to the adoption of the RIPs. The Emergency Core Cooling System (ECCS) is designed with a focus on LOCAs from medium and small-diameter pipes. Each individual division of ECCS is installed with its own High Pressure Core Flooder System (HPCF).

(b) Each of the LPCF systems installed in the 3 independent divisions of ECCS have a heat exchanger, therefore, offering sufficient core cooling functions for both the short to long term after a LOCA.

(5) New control panel in the Main Control Room (MCR)
Based on performance of and experience with previous control panels, the third-generation control panel with higher levels of safety and reliability was chosen. This control panel is composed of the main control console and a wide display panel. Utilising a flat touch-screen display, the main control console integrates monitoring and operational functions, and makes it possible for everyone in the MCR to share information on its wide display panel.
The control panel is characterised as follows:

(a) Along with the streamlining and enhancing of operations, accident operations are handled easily and accurately, and startup times can also be shortened.

(b) The wide display panel encompasses information to be monitored during times of normal operation and accidents. Also, it improves the ability of all operators in the MCR to share information.

(c) New human-machine interface such as general digitalisation, large-display equipment and touch operation, has been adopted for the new control panel in the MCR. It also has sufficient operation support functions such as automation of sequential operation.

(6) Turbine Equipment is characterised as follows:
Turbine equipment has been designed to increase efficiency and to enhance plant performance.

(a) 52-inch long blade turbine, Moisture Separator Re-heater (MSR) and heater drain pump-up systems are used to improve plant thermal efficiency.

(b) The forged mono block rotor is used in the steam turbine. The rotors transmit the power of the turbine to withstand not only the torque during normal operation, but also the greater torque resulting from unusual events such as generator short circuits.

9.1.2.1 Key Specifications of UK ABWR

Table 9.1-1 shows typical key specifications of UK ABWR.

Table 9.1-1: Key Specifications of UK ABWR

Item	Specification	
Output	Plant Gross Electrical Output	Approx. 1,350 MW
	Reactor Thermal Output	3,926 MW
Reactor rated pressure		Approx. 7.2MPa (abs)
Reactor Core	Fuel Assemblies	872
	Control Rods	205
Reactor Equipment	Recirculation System	Internal pump method
	Control Rod Drive (CRD)	Hydraulic / electric motor drive method
Primary Containment Vessel (PCV)		Reinforced Concrete Containment Vessel
ECCS / PCV cooling System		3 divisions / 2 divisions
Residual Heat Removal System		3 divisions
Turbine System	Turbine (blade length at final stage)	52 inches
	Moisture Separation Method	Reheat type

9.1.3 Basic Design Characteristics of SSCs

9.1.3.1 Reactor Core and Fuel

A detail description about the main system of this Sub-chapter is provided in Chapter 11 of the Generic PCSR.

9.1.3.1.1 Fuel System

9.1.3.1.1.1 Fuel Assembly

The GE14 fuel assembly consists of a fuel bundle (composed of fuel rods, water rods, spacers, and upper and lower tie plates), and a channel that surrounds the fuel bundle. This fuel type has 92 fuel rods (fourteen partial length rods) in a 10×10 rod array and two large central water rods. The fuel rods and water rods are spaced and supported by the upper and lower tie plates with intermediate spacing provided by eight spacers. The upper and lower tie plates are fixed by eight tie rods, which hold the fuel bundle together. The upper tie plate has a handle for transferring the fuel assembly. The fuel design is described in Chapter 11.

9.1.3.1.1.2 Fuel Channel

The fuel channel encloses the fuel bundle and provides:

(1) A barrier between two parallel coolant flow paths, one for flow inside the fuel bundle and the other for flow in the bypass region between channels.
(2) A bearing surface for the control rod.
(3) Rigidity for the fuel bundle.

The channel fastener attaches the channel to the fuel bundle and, along with the channel spacer buttons, provides channel-to-channel spacing with resilient engagement.

9.1.3.2 Reactor Coolant Systems, Reactivity Control Systems and Associated Systems

A detail description about the main system of this Sub-chapter is provided in Chapter 12 of the Generic PCSR.

9.1.3.2.1 Nuclear Steam Supply Systems and Associated Systems

The Nuclear Steam Supply Systems (NSSS) generates steam through the thermal nuclear fission process and directly transfers it to the turbine system. A heat balance (HB) showing the major parameters of the NSSS for the rated power conditions is shown in Figure 9.1-1. The systems comprising the NSSS are the following:

- Reactor Pressure Vessel housing the nuclear fuel and its internal components
- Reactor Recirculation System (RRS)
- Nuclear Boiler System (NB)
- Reactor Water Clean-up System (CUW)
- Residual Heat Removal System (RHR)
- Reactor Core Isolation Cooling System (RCIC)

9.1.3.2.1.1 Reactor Pressure Vessel and Reactor Internals

The Reactor Pressure Vessel (RPV) contains the reactor core (nuclear fuel) which is the heat source for steam generation. The vessel serves as one of the fission product barriers during normal operation.

The RPV is designed and fabricated in accordance with applicable codes for the design pressure of 8.62 MPa (gauge). The nominal operating pressure in the steam space above the separators is 7.17 MPa (abs). The RPV is fabricated of low alloy steel and is clad internally with stainless steel or high nickel alloy (except for the top head, RIP motor casing, nozzles other than the steam outlet nozzle, and unclad nozzle to shell weld zone).

The RPV contains the Reactor Internal Pumps (RIPs); core and core support structures; the steam separators and dryers; the spargers for the Feedwater and Core Flooder Systems; the Control Rod Drive (CRD) housings; and other components. The main connections to the vessel include steamlines, feedwater lines, RIPs, CRDs and nuclear instrument detectors.

The reactor core is cooled by demineralised water that enters the lower portion of the core and boils as it flows upward around the fuel rods. The steam leaving the core is dried by steam separators and dryers located in the upper portion of the reactor vessel. The steam is then directed to the turbine through the main steamlines. Each steamline is provided with two isolation valves in series, one on each side of the containment barrier.

A venturi-type flow restrictor is a part of the RPV nozzle configuration for each main steamline. The restrictor limits the discharge flow of steam from the fractured pipe in case of main steamline break inside the containment. At this time, the restrictors of the sound steamline limit the flow of steam from the reactor vessel before the main steamline isolation valves (MSIVs) are closed.
In addition, the restrictors limit the flow of steam from the reactor vessel before the MSIVs are closed in case of a main steamline break outside the containment.

9.1.3.2.1.2 Reactor Recirculation System (RRS)

The RRS has two main functions.

The RRS provides forced circulation of reactor coolant for heat transfer from the fuel to the coolant. For this purpose, the RRS uses an arrangement of ten Reactor Internal Pumps (RIPs) mounted at the bottom of the RPV to force reactor coolant flow through the lower plenum of the reactor and upward through openings in the fuel support castings, the fuel bundles, steam separators, and down to the annulus to be mixed with feedwater and recirculated again. The RRS can also be used to control reactor power by changing the recirculation flow by adjusting the RIPs speed.

9.1.3.2.1.3 Nuclear Boiler System (NB)

The NB is divided into two subsystems
• The Main Steam System (MS) which consists of 4 steam lines to direct the steam flow from the RPV steam outlet nozzle to the main turbine; and
• The Feed Water System (FDW) which consists of 2 lines that transport feedwater from the feedwater pipes in the steam tunnel through the RCCV penetrations to the nozzles on the RPV.
The MS is provided with steam flow restrictors in each steam outlet nozzle to limit the flow rate in the event of postulated main steam line break. The system also incorporates provisions for relief of over-pressure conditions in the RPV through the Safety Relief Valves (SRV) and Main Steam Isolation Valves (MSIV) on each line to isolate the primary containment when necessary.

9.1.3.2.1.4 Reactor Water Clean-up System (CUW)

The CUW provides a continuous purifying treatment of reactor water by removing soluble and insoluble impurities to maintain water quality within acceptable limits during the each plant operating modes. The CUW also provides a route to discharge the expansion in the volume of reactor water generated due to temperature increases into the Low Conductivity Waste (LCW) Collection Tank or the Suppression Pool (S/P) during reactor startup.

9.1.3.2.1.5 Residual Heat Removal System (RHR) -Reactor Shutdown Cooling Mode (SDC)-

The RHR provides reactor cold shutdown during reactor normal shutdown and in the event that main condenser is not available. The RHR removes the reactor decay heat so that refuelling and maintenance can be implemented after shutdown. Reactor water is directly drawn from the RPV through the reactor shutdown cooling suction nozzle, cooled by passing through the RHR Heat Exchanger and returned to the reactor.

9.1.3.2.1.6 Reactor Core Isolation Cooling System (RCIC)

The function of RCIC is to cool the core and maintain the reactor water level, preventing damage of fuel cladding materials when the reactor is isolated from the turbine system and cooling water is not supplied from the feedwater system (Reactor isolation process). The RCIC is automatically initiated upon a certain water level in the vessel and injects high pressure water into the RPV by using a steam-driven pump, which makes it operable even upon total loss of AC power, (also known as Station Black-Out (SBO)). The RCIC steam supply line branches from one of the main steam lines leaving the RPV and goes to RCIC turbine.

9.1.3.2.1.7 Leak Detection System (LDS)

The LDS detects and monitors leakage from the reactor coolant pressure boundary and initiates isolation of the leakage source if necessary. The system initiates isolation of the process lines that penetrate the containment by closing the appropriate isolation valves. LDS monitors leakage inside and outside of the drywell and annunciates excessive leakages in the Main Control Room (MCR).

9.1.3.2.2 Reactivity Control Systems

9.1.3.2.2.1 Control Rod Drive System (CRD)

The CRD controls changes in core reactivity during power operation by movement and positioning of the neutron absorbing control rods within the core in fine increments according to the control signals from the Rod Control and Information System. The drive mechanism for this mode of operation is the Fine Motion Control Rod Drive (FMCRD) which positions the control rod by electric motor for insertion and withdrawal during normal operation.
Additionally, the CRD provides rapid control rod insertion in response to the signals from the Reactor Protection System to rapidly shut down the reactor (scram). In this case the motive power for rapid rod insertion (as required in response to abnormal conditions) is provided by stored hydraulic power from compressed nitrogen gas.

9.1.3.2.2.2 Standby Liquid Control System (SLC)

The SLC provides an alternate reactivity control method to bring the nuclear fission reaction to sub-criticality and to maintain sub-criticality. The system makes possible an orderly and safe shutdown in the event that not enough control rods can be inserted into the reactor core to accomplish shutdown in the normal manner. This is achieved by injecting the neutron absorbing solution in the reactor core. The system is sized to counteract the positive reactivity effect from rated power to the cold shutdown condition.

9.1.3.3 Engineered Safety Feature

A detail description about the main system of this Sub-chapter is provided in Chapter 13 of the Generic PCSR.

9.1.3.3.1 Containment Systems

9.1.3.3.1.1 Primary Containment System

Primary Containment System has a function of fission product barrier. The structure of containment is capable to keep a low leakage even at the increased pressures that could follow design basis accidents such as main steamline break or a fluid system line break.

9.1.3.3.1.1.1 Primary Containment Vessel

The main features of the primary containment design include:
(1) The drywell, a cylindrical steel-lined reinforced concrete structure surrounding the RPV.
(2) The S/P filled with water, which serves as a heat sink during normal operation and accident conditions.
(3) The air space above the S/P.

In the event of LOCA, the steam-water mixture released into the drywell is led into the S/P water through the vent pipes. The steam is cooled and condensated by this pool water, thus suppressing the pressure rise in the drywell. Any radioactive substances are retained inside the containment vessel.

9.1.3.3.1.1.2 Atmospheric Control System (AC)

The main function of the AC is to inject nitrogen into the PCV to inert the atmosphere against hydrogen combustion. The AC inerts the PCV after refuelling outages, maintains a slightly positive pressure within the PCV and de-inerts the PCV for plant shutdown by replacing it with air.

9.1.3.3.1.1.3 Flammability Control System (FCS)

The purpose of the FCS is to limit the concentration of hydrogen and oxygen below the flammability limits in the PCV following a LOCA.

9.1.3.3.1.1.4 Residual Heat Removal System (RHR) - PCV Spray Mode-

The primary containment spray cooling prevents the containment pressure and temperature rising due to the outflow of reactor coolant. It can also remove iodine released in the gas phase in the containment.

9.1.3.3.1.1.5 Drywell Cooling System (DWC)

The DWC maintains the required thermal environment and humidity so that the component in the drywell operates in a proper manner during plant normal operation. The DWC also cools the atmosphere in the drywell so that the working environment temperature during plant inspection and maintenance does not reach extreme condition.

9.1.3.3.1.2 Secondary Containment System

9.1.3.3.1.2.1 Secondary Containment

Secondary Containment is a reinforced concrete building that forms an envelope surrounding the PCV above the basemat (with the exception of the barrier inside the main steam tunnel). As well as providing containment, it also protects the PCV from the impact of external loads.

9.1.3.3.1.2.2 Standby Gas Treatment System (SGTS)

The SGTS controls the emission of fission products by maintaining a negative pressure in the secondary containment and by filtering gaseous effluents prior to discharge to the atmosphere following a postulated LOCA or a fuel handling accident. The SGTS also processes gaseous effluents from the PCV and the secondary containment when it is required to limit the discharge of radioactivity to the environment during normal and abnormal plant operation.

9.1.3.3.2 Emergency Core Cooling Systems (ECCS)

The purpose of the Emergency Core Cooling Systems (ECCS) is to inject water into the RPV and depressurise it as necessary to ensure core cooling function. The ECCS configuration comprises 3 redundant divisions provided with high pressure and low pressure water injection systems, which are supplied AC power from the respective divisions of the redundant Emergency Diesel Generator Systems (D/Gs) in the event of loss of off-site power. The ECCS injection network is comprised of one RCIC train and two HPCF trains for high pressure injection, and three LPFL trains for low pressure injection in conjunction with the Automatic Depressurisation System (ADS) which assists the injection network under certain conditions.
The ECCS comprises the following systems:

9.1.3.3.2.1 High Pressure Core Flooder System (HPCF)

The purpose of the HPCF is to maintain the reactor vessel water inventory during LOCA which do not depressurise the reactor vessel and thus limit the fuel cladding temperature. The System also operates as a backup of RCIC in order to restore reactor water level conditions in case of transitional events and loss of feed-water accidents. The System consists of two independent and physically separated divisions automatically initiated either by high pressure in the drywell signal or low water level in the RPV signal.

9.1.3.3.2.2 Reactor Core Isolation Cooling System (RCIC)

The purpose of the RCIC is to supply makeup water into the RPV to assure that sufficient reactor inventory is maintained in order to perform adequate core cooling and prevent reactor fuel overheating during LOCA.
The RCIC is automatically initiated either by high pressure in the drywell signal or low water level in the RPV signal and injects high pressure water into the RPV by using a steam-driven pump, which makes it operable even upon total loss of AC power, (also known as Station Black-Out (SBO)). The RCIC steam supply line branches from one of the main steam lines leaving the RPV and goes to RCIC turbine.

9.1.3.3.2.3 Residual Heat Removal System (RHR) - Low Pressure Core Flooder System (LPFL)-

The purpose of the LPFL is to provide reactor vessel water inventory makeup and core cooling during LOCA and to provide containment cooling. Following ADS initiation, the LPFL also provides inventory makeup following small breaks. The LPFL consists of three independent and physically separated divisions automatically initiated either by high pressure in the drywell signal or low water level in the RPV signal.

9.1.3.3.2.4 Automatic Depressurisation System (ADS)

The ADS utilises part of the Safety Relief Valves (SRVs) to reduce reactor pressure during small and medium piping breaks. This feature is very useful in the event of HPCF failure because by automatic or manual actuation of the SRVs the reactor pressure can be quickly reduced and thus, water inventory can be supplied to the reactor pressure vessel using the LPFL.

9.1.3.4 Control and Instrumentation (C&I)

A detail description about the main system of this Sub-chapter is provided in Chapter 14 of the Generic PCSR.

9.1.3.4.1 C&I Architecture

9.1.3.4.1.1 Plant Computer System

This system provides function to monitor and record process parameters, to monitor and analyse core performance, and guidance for automatic operation, in order to achieve reasonable and safety plant operation.It doesn't directly control plant operation This system is comprised of distributed computer servers, use interfaces, and related devices.

9.1.3.4.2 C&I System

9.1.3.4.2.1 Rod Control and Information System (RCIS)

The purpose of this system is to drive the FMCRD motors to set the position of the CR to control the reactor power. This is performed either manually (by the operator) or by the Automatic Power Regulator (APR). The system also monitors CR position and provides necessary information for rod control.

9.1.3.4.2.2 Reactor Protection System (RPS)

The RPS initiates a rapid, automatic shutdown (scram) of the reactor. It promptly acts to prevent fuel cladding damage and any nuclear system process barrier damage following abnormal operational transients. The RPS overrides all operator actions and process controls and is based on a fail-safe design philosophy that allows appropriate protective action even if a single failure occurs.

9.1.3.4.2.3 Feedwater Control System (FDWC)

The purpose of the FDWC is to maintain the water level in the reactor pressure vessel by adjusting feedwater flow and/or the Reactor Water Clean-up System (CUW) blow down flow while the plant is operating. The FDWC adjusts reactor feedwater flow in order to maintain the pre-set water level determined from the steam separator performance demands for the pressure vessel water level over the entire power range of the reactor during normal operation.

9.1.3.4.2.4 Recirculation Flow Control System (RFC)

The purpose of the RFC is to control reactor power level by controlling the recirculation flow. In order to change the recirculation flow, this system changes the rotational speed of the RIP by changing the frequency and voltage of the AC power supplied to the RIP driving motor. A detail of the operating power control is described in Chapter 11 of the Generic PCSR. (Operating Power-Flow Operating Map is shown.)
For this purpose, the Reactor Internal Pump-Adjustable Speed Drive (RIP-ASD) is connected to each RIP to change the rotational speed, and to supply the above-mentioned AC power.

9.1.3.4.2.5 Automatic Power Regulator System (APR)

The APR automatically conducts plant power controls by means of the CR and core flow regulation to minimize operators' workload.

9.1.3.4.2.6 Electro-Hydraulic Turbine Control System (EHC)

The EHC system responds to the input (Load setpoint error) from the APR system to provide automatic control; the control mode is to maintain a constant reactor pressure during normal operation. The system controls the reactor pressure by adjusting the opening of the turbine steam control valves and turbine bypass valves in response to pressure turbine speed and power signals. The Turbine Bypass valves allow steam to be bypassed directly to the condenser, without being passed through the turbine. The turbine bypass system has a capacity of about 33% of the rated steam flow and can process steam during normal startup and shutdown operations. It can also process steam within the bypass capacity in cases where sudden decreases of the generator load have occurred.

9.1.3.4.3 Sensors, Pre-Process, Actuators and Prioritisation

9.1.3.4.3.1 Neutron Monitoring System (NMS)

The NMS consists of nuclear instrument detectors and out-of-core electronic monitoring equipment. The NMS provides indication of neutron flux, which can be correlated to thermal power level for the entire range of operating flux conditions that can exist in the core. The startup range neutron monitor subsystem (SRNM) provides indications of neutron flux and period during reactor startup and low power operation. The power range monitor subsystem (PRM) consists of the local power range monitors (LPRM) and the average power range monitors (APRM), which monitors local and average core power and detects core thermal hydraulic instability respectively during a power range operation. The traversing in-core probe subsystem (TIP) provides a means to calibrate the LPRMs and the multi-channel rod block monitor subsystem (MRBM) detects flux changes around each of (1 to 8) withdrawing control rods.

The NMS provides inputs to the RCIS to initiate rod blocks if preset flux limits or period limits for rod block are exceeded.

The SRNM, and the APRM, which are safety-related, provide scram logic inputs to the RPS to initiate a scram in time to prevent excessive fuel clad damage as a result of over-power transients.

9.1.3.4.3.2 Suppression Pool Temperature Monitoring (SPTM)

The SPTM provides adequate pool water temperature information for the operators to take appropriate action to avoid exceeding the established suppression pool temperature set point.

9.1.3.5 Electrical Power Supplies

A detail description about the main system of this Sub-chapter is provided in Chapter 15 of the Generic PCSR.

9.1.3.5.1 Electrical Equipment

9.1.3.5.1.1 Exciter

The generator excitation power is supplied from generator terminal through excitation transformer, and the AC power is converted to DC power supply by thyristor type converter.

9.1.3.5.1.2 Electrical Power Distribution System

The safety Class 1 AC power system supplies power to the safety Class 1 loads. The unit auxiliary electrical power supply system is normally provided from the off-site power supply system. The safety Class 1 system includes diesel generators that serve as standby power sources, independent of any onsite or offsite source. Therefore, the system has multiple sources. The safety Class1 batteries for the safety logic and control system are provided.

9.1.3.5.1.3 Auxiliary Normal Transformer (ANT)

The ANT steps down the main generator voltage to the medium-voltage bus voltage. During plant normal operation, the ANT is supplied from the main generator. At plant startup, shutdown or accident plant operation caused by the reactor and turbine, the ANT is supplied from the external grid via the generator transformer (GT).

9.1.3.5.1.4 Isolated Phase Bus

The isolated phase bus duct system provides electrical interconnection from the main generator output terminals to the generator load switch (GLS) and from the GLS to the low voltage terminals of GT, and the high voltage terminal of ANT. During the time the main generator is off line, the GLS is open and switchyard power is fed to ANT via GT.

9.1.3.5.1.5 Non-Segregated Phase Bus

Non-Segregated phase bus is used where branching circuit is required at medium-voltage bus and power centre (P/C) system.

9.1.3.5.1.6 Medium Voltage Distribution System

Medium-voltage distribution buses are divided into three groups according to role carried out;

Safety Class 2 buses - supplied from ANT or AST

Safety Class 1 buses - supplied from safety Class 2 medium voltage buses or Emergency Diesel Generators (E D/Gs)

B/B Class 2 buses - supplied from safety Class 2 medium voltage buses or Alternative Diesel Generator Systems (AD/Gs)

Safety Class 2 bus

Safety Class 2 medium-voltage buses are supplied from the ANT or AST. Also, the safety Class 2 medium-voltage buses supply power to the loads necessary during normal operation.

Safety Class 1 bus

Safety Class 1 medium-voltage buses are supplied from the safety Class 2 medium-voltage buses or E D/Gs. Also, safety Class 1 medium-voltage buses supply power to the safety Class 1 systems, structures and components of Category A safety functions. Each of these buses is normally supplied from a specific safety Class 2 medium-voltage bus.

B/B Class 2 bus

The Backup Building (B/B) Class2 medium-voltage buses supply power to the second line provision of the emergency core cooling system safety function and related equipment e.g. the Flooder System of Specific Safety Facility which is the alternative Class 2 low-pressure flooder system.

9.1.3.5.1.7 Low Voltage Distribution system

Power Centres (P/C)

Electrical power for low-voltage auxiliaries is supplied from P/Cs which consist of medium-voltage/low-voltage transformers and associated switchgear.
The P/C supplies power to auxiliary loads of over 90kW and not greater than 300kW in principle.

Motor Control Centres (MCC)

The MCC receives electrical power from P/C and supplies power to auxiliary loads of not greater than 90kW in principle.

9.1.3.5.1.8 Direct Current Power Supply

There are four groups of DC power supply system as below.

- Safety Class 1 115V DC power supply system
- Safety Class 2 115V DC power supply system
- Non Safety Class 230V DC power supply system
- B/B Class 2 115V DC power supply system

Safety Class 1 115V DC Power Supply System

The safety Class 1 DC power supply system supplies power to the plant systems, structures and components required to perform Category A safety functions in the event of station blackout. This includes electrical power to safety C&I equipment including the Class 1 emergency core cooling system.

Safety Class 2 115V DC Power Supply System

The safety Class 2 DC power supply system is provided as an uninterruptible standby power supply for loads of the normal Class 2 C&I equipment.

Non safety Class 230V DC Power Supply System

The non-safety Class 230V DC power supply system is provided to supply power to unclassified DC loads such as motors for plant investment protection (e.g. emergency oil pump).

B/B Class 2 115V DC Power Supply System

The B/B Class 2 115V DC power supply system supplies power to safety C&I equipment in the back-up building which is needed to realize the function of Class 2 Flooder System of Specific Safety Facility.

9.1.3.5.1.9 Emergency Diesel Generators (E D/Gs)

Three E D/Gs are provided and, the role of the E D/Gs is supply power needed to shut down the reactor safety when off-site power is lost, and to supply power to the electrical systems supporting the delivery of Safety Functions if a loss of coolant accident occurs simultaneously.

9.1.3.5.1.10 AC Instrumentation Power Supply System

The AC instrumentation power supply system consists of six (6) groups as follows:

- Safety Class 1 uninterruptible AC power supply system (Class 1 AC UPS)
- Safety Class 3 UPS (Class 3 AC UPS)
- Safety Class 1 AC instrumentation and control power supply system (Class 1 AC I&C PS)
- Safety Class 2 AC instrumentation and control power supply system (Class 2 AC I&C PS)
- Safety Class 3 AC instrumentation and control power supply system (Class 3 AC I&C PS)
- B/B Class 2 AC instrumentation and control power supply system (B/B Class 2 AC I&C PS)

Class 1 AC UPS

The Class 1 AC UPS supplies power to Class 1 instrument and control systems which cannot tolerate momentary power failure, such as the reactor protection system (4 divisions), radiation instrumentation and turbine control system.

Class 3 AC UPS

The safety Class 3 AC UPS system supplies power to the Class 3 plant process computer system. It receives AC power from MCCs (which can be supplied from E D/Gs) located in the control room building or DC power supply from the plant process computer dedicated battery.

Class 1 AC I&C Power Supply

The Class 1 AC I&C PS systems supply power to the main control room AC 120V power distribution panels. In the event of loss of off-site power, this power supply is interrupted until the power supply from the emergency diesel generator(s) is available.

Class 2 AC I&C Power Supply

The safety Class 2 AC Instrumentation and Control (I&C) PS systems supply power to the Class 2 R/B, Turbine Building (T/B) I&C loads.

Class 3 AC I&C Power Supply

The safety Class 3 AC I&C PS system supplies power to the Class 3 Radwaste Building (Rw/B) I&C loads.

B/B Class 2 AC I&C Power Supply

The B/B Class 2 AC I&C PS systems supply power to the Class 2 B/B I&C loads. Two (2) ×100% Class 2 systems are provided in backup-building supplied from the B/B low-voltage buses.

9.1.3.5.1.11 Alternative AC Generators in Backup Building (B/B Class 2 A/G)

Two (2) B/B Class 2 AD/Gs, and associated equipment are installed in the backup-building (medium-voltage AD/G in system 1 and low-voltage AD/G in system 2). The AD/Gs are rated to supply power to B/B equipment when off-site power is lost. For example AD/G supplies power to Flooder System of Specific Safety Facility in Class 2 which consists of two (2×100%) systems.

9.1.3.5.1.12 Communication System

Communication systems are composed of paging system and telephone system. Paging system is designed to instruct and to alarm from the main control room to each place in the plant during normal operations and accidents. Also, telephone system is designed to communicate with external organizations if necessary.

9.1.3.5.1.13 Lighting and Servicing Power Supply

Lighting Systems are composed of Normal AC lighting, Emergency AC/DC lighting and Guide lamp. Normal AC lighting system is powered from normal AC low-voltage buses. Emergency AC lighting system in the main control room and evacuation passages is powered from emergency AC low-voltage buses. Emergency DC lighting is also provided and is powered by storage batteries in losses of normal AC power and emergency AC power. Guide lamps are designed to escape.

9.1.3.5.1.14 Auxiliary Standby Transformer (AST)

When the GT-ANT line is not available or when a fault occurs on the main generator voltage system, the GT, or ANT, on-site power is supplied from the AST. The AST steps down the external grid voltage to the medium-voltage bus voltage.

9.1.3.5.2 Electrical Protection

9.1.3.5.2.1 Earthing System

The Earthing System is designed to prevent ground fault currents in accidents from physical injuries and equipment damages, designed to prevent electrical signals from noises and designed to prevent equipment from lightning.

9.1.3.5.2.2 Electrical Penetration

Electrical penetration is installed in RCCV and supply power, control and signals to equipment in RCCV.

9.1.3.5.3 Panel and Raceway Layout

9.1.3.5.3.1 Raceway System

The Raceway System is comprised of cable trays, conduits and supports. Raceways are classified for power cables, control cables and instrumentation cables. Divisional cables are routed in separate cable raceways for each division.

9.1.3.6 Auxiliary System

A detail description about the main system of this Sub-chapter is provided in Chapter 16 of the Generic PCSR.

9.1.3.6.1 Water System

9.1.3.6.1.1 Ultimate Heat Sink (UHS)

The UHS provides the source of cooling water for the RSW and is the final repository for the heat removed from the safety related equipment in the RCW.

9.1.3.6.1.2 Reactor Building Cooling Water System (RCW)

The RCW provides cooling water to certain designated equipment located in the R/B, T/B, Control Building (C/B), and Rw/B. Capacity and redundancy is provided in heat exchangers and pumps to ensure adequate performance of the cooling system under all postulated conditions. During loss of offsite power, emergency power for the system is available from the onsite emergency diesel generators. The closed loop design provides a barrier between radioactive systems and the reactor service water discharged to the environment. Radiation monitors are provided to detect contaminated leakage into the closed systems. Heat is removed from the closed loop by the Reactor Service Water System.

9.1.3.6.1.3 Reactor Building Service Water System (RSW)

The RSW pumps cooling water from the UHS to the RCW heat exchangers and rejects the RCW heat to the UHS via the Circulating Water System discharge conduit.

9.1.3.6.1.4 Turbine Building Cooling Water System (TCW)

The TCW supplies cooling water to turbine auxiliary equipments, such as oil coolers, motor coolers, shaft bearings, and Heating Ventilating and Air Conditioning System (HVAC) normal cooling water system (HNCW) refrigerators.

9.1.3.6.1.5 Turbine Building Service Water System (TSW)

The TSW supplies sea water as cooling water to the TCW heat exchanger (TCW-HEX) and remove heat from the TCW.

9.1.3.6.1.6 Make Up Water Condensate System (MUWC)

The Makeup Water Condensate System (MUWC) supplies required condensate at plant startup, shutdown and normal operation to each component which may potentially have radioactive contamination.

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.

9.1.3.6.1.7 HVAC Normal Cooling Water System (HNCW)

The HNCW provides chilled water as a cooling medium to each air supply cooling coil of Dehumidifier of the Drywell Cooling System (DWC), Supply Air Facilities for Normal HVAC and

Normal Local Cooling Unit during plant normal operation (normal operation of the reactor, or when operation of the reactor is shutdown).

9.1.3.6.1.8 HVAC Emergency Cooling Water System (HECW)

The HECW provides chilled water as a cooling medium to each cooling coil of Supply Air Facilities within Normal/Emergency HVAC [MCR HVAC, Diesel Generator (D/G) Electrical Equipment Zone (DGEE/Z) HVAC and C/B Electrical Equipment Zone (CBEEE/Z) HVAC] during plant normal operation (normal operation of the reactor, or when operation of the reactor is shutdown) and plant emergency operation.

9.1.3.6.2 Process Auxiliary System

9.1.3.6.2.1 Service Air System (SA)

The SA provides a continuous supply of compressed air of suitable quality and pressure for general plant use. The SA compressor discharges compressed air into the SA air receivers which are then distributed throughout the plant.

9.1.3.6.2.2 Instrument Air System (IA)

The IA provides a continuous supply of dry, filtered, compressed instrument air for control and use in all air operated instrumentation and equipment. The IA compressor discharges compressed air into the IA air receivers which are then distributed throughout the plant.

9.1.3.6.2.3 High Pressure Nitrogen Supply System (HPIN)

Nitrogen gas is normally supplied by the Atmospheric Control System to meet the requirement of (1) the SRV automatic depressurization and relief function accumulators, (2) the inboard MSIVs, and (3) instruments and pneumatic valves using nitrogen in the drywell. When this supply of pressurized nitrogen is not available, the HPIN automatically maintains nitrogen pressure to this equipment. The HPIN consists of high pressure nitrogen storage bottles with piping, valves, instruments, controls and control panel.

9.1.3.6.2.4 Sampling Systems

The Reactor Building Sampling (RBS) System and the Turbine Building Sampling System handle water monitoring during normal operation, while the Containment Monitoring System handles reactor water samples during post-accident conditions. The Containment Monitoring system also provides for hydrogen and oxygen sampling of the containment during both normal and post-accident conditions. All these systems are furnished to provide process information that is required to monitor plant and equipment performance and changes to operating parameters. Representative liquid and gas samples are taken automatically and/or manually during plant operation for laboratory or online analyses.

9.1.3.6.2.5 Heating Steam System

The Heating Steam system supplies non-radioactive steam to the steam jet air ejectors for condenser deaeration, the Turbine Gland Seal System, which prevents radioactive steam leakage out of the turbine casings and atmospheric air leakage into the casing at specific operating conditions, the off-gas system to preheat gaseous waste, and the Liquid Radwaste System evaporator. The auxiliary boiler supplies steam through a connection to the auxiliary steam header.

9.1.3.6.3 Heating Ventilating and Air Conditioning System (HVAC)

HVAC control temperature, pressure, humidity, and airborne contamination to ensure the integrity of plant equipment, provide acceptable working conditions for plant personnel, and limit offsite releases of airborne contaminants.

The following sub-systems of HVAC are provided.

(1) Reactor Area (R/A) HVAC has following two functions.
- Normal function
  Normal function of R/A HVAC provides ventilation and air conditioning function for R/A during the plant normal operation. In case smoke is generated within fire area it is discharged to outdoors and fresh air is supplied in exchange. In addition, heat has to be removed by means of Local Cooling Unit for cooling the heat source if the heat load is significantly high at the local area during the plant normal operation.
- Emergency function
  Upon receiving emergency signal, R/A Isolation Damper mounted on the supply/exhaust duct of the R/A HVAC are automatically closed to isolate R/A while preventing exfiltration of the radioactive gas to outdoors by switching into SGTS. In addition, rooms wherein equipments that are related to Engineered Safety Features (ESFs) are installed intended for the operation in the event of emergency, heat is removed by the Emergency Local Cooling Unit.

(2) DGEE/Z HVAC provides ventilation and air conditioning function for DGEE/Z during the plant normal/emergency operation. In case smoke is generated within fire area it is discharged to outdoors and fresh air is supplied in exchange.

(3) Reactor Internal Pump Adjustable Speed Drive Zone (RIP ASD/Z) HVAC cools down the RIP power supply device room during the plant normal operation.

(4) T/B HVAC provides ventilation and air conditioning function within the T/B during the plant normal operation while having a function of discharging smoke generated within fire zone to outdoors and supplying outdoors fresh air into the building in exchange. In addition, heat has to be removed by means of Local Cooling Unit for cooling the heat source if the heat load is significantly high at the local area during the plant normal operation.

(5) Turbine Building Normal Electrical Equipment Zone (TBNEE/Z) HVAC provides ventilation and air conditioning function for TBNEE/Z during the plant normal operation. In case smoke is generated within fire area it is discharged to outdoors and fresh air is supplied in exchange. In addition, heat has to be removed by means of Local Cooling Unit for cooling the heat source if the heat load is significantly high at the local area during the plant normal operation.

(6) Heat Exchanger Building Normal (Hx/B-N) HVAC provides ventilation and air conditioning function for Hx/B during the plant normal operation. In case smoke is generated within fire area it is discharged to outdoors and fresh air is supplied in exchange.

(7) Heat Exchanger Building Emergency (Hx/B-E) HVAC provides ventilation function for Hx/B during the plant emergency operation. In case smoke is generated within fire area it is discharged to outdoors and fresh air is supplied in exchange.

(8) During the plant normal/emergency operation, Control Building Emergency Electrical Equipment Zone (CBEEE/Z) HVAC is provides ventilation and air conditioning function within CBEEE/Z. In case smoke is generated within fire area it is discharged to outdoors and fresh air is supplied in exchange.

(9) During the plant normal/emergency operation, MCR HVAC is provided ventilation and air conditioning function within the MCR. In case smoke is generated within fire area it is discharged to outdoors and fresh air is supplied in exchange. In addition, there is a function to protect operators and occupants from radioactive Iodine by isolating MCR in the event of emergency. This system consists of the divisions A and B one of which is provided as a redundancy.

(10) Rw/B HVAC provides ventilation and air conditioning function within the Rw/B during the plant normal operation. In case smoke is generated within fire area it is discharged to outdoors and fresh air is supplied in exchange.
(11) Radwaste Building Normal Electrical Equipment Zone (RWNEE/Z) HVAC provides ventilation and air conditioning function within the RWNEE/Z during the plant normal operation while having a function of discharging smoke generated within fire zone to outdoors and supplying outdoors fresh air into the building in exchange.
(12) Service Building (S/B) HVAC provides ventilation and air conditioning function within the S/B during the plant normal operation. In case smoke is generated within fire area it is discharged to outdoors and fresh air is supplied in exchange.
As for the general habitable area, Fan Coil Unit or Multi-Split Air Conditioning Unit is used individually for cooling and heating, considering the habitability of the occupants if needed.
(13) B/B HVAC has a function of the ventilation and air conditioning within B/B during the plant normal/emergency operation. In case smoke is generated within fire area it is discharged to outdoors and fresh air is supplied in exchange. In addition, D/G Room Emergency Supply Fans specifically designed for emergency use are provided for the D/G room.

9.1.3.6.4 Other Auxiliary System

9.1.3.6.4.1 Fire Protection System (FP)

The FP is designed to provide an adequate supply of water or chemicals to points throughout the plant where fire protection is required. Diversified fire detection and fire suppression systems are selected to suit the particular areas or hazards being protected. Appropriate instrumentation and controls are provided for the proper operation of the fire detection, annunciation and fire fighting systems.

9.1.3.6.4.2 Emergency Power supply System

The role of the Emergency Diesel Generator (E D/G) is to supply power needed to shutdown and cool the reactor safely when the off-site power is lost, and to supply power to the electrical systems supporting the delivery of Safety Functions when a loss of coolant accident should occur simultaneously.

The E D/G consists of three independent divisions, A, B, and C. Each division consists of the following main components.
(1) Engine
(2) Generator
(3) DG Fuel Oil System
(4) DG Cooling Water System
(5) DG Lubricant Oil System
(6) DG Compressed Air System
(7) DG Air Intake and Exhaust Gas System

9.1.3.6.4.3 Suppression Pool Clean-up System

The SPCU provides an intermittent purification of the S/P water. The system removes impurities by filtration, adsorption, and ion exchange processes. The system consists of a recirculation loop with a pump and isolation valves. Suppression pool water is passed through the FPC filter/demineralisers for treatment. Treated water may be diverted to refill the reactor well and the upper pool during refuelling outage. The SPCU system may also provide, if available, makeup water to the fuel pool.

9.1.3.6.5 Severe Accident Management System

9.1.3.6.5.1 Flooder System of Specific Safety Facility (FLSS)

The FLSS provides cooling water to variety of destinations in R/B to keep cooling the reactor, prevent damage of PCV, and keep sufficient water in spent fuel storage pool in an event of Severe Accident (SA). Major components and control panels of FLSS are located and operable at control panels in Backup Building (B/B).

9.1.3.6.5.2 Flooder System of Reactor Building (FLSR)

The FLSR provides cooling water to variety of destinations by mobile pumps from the outside of R/B in the event of Severe Accident. FLSR water injection lines in R/B are shared with FLSS. This configuration enables FLSR to work as a diverse alternative mean of FLSS water supply function.

9.1.3.6.5.3 Filtered Containment Venting System (FCVS)

The purpose of the FCVS is to prevent damage of the PCV due to overpressure and consequential release of large quantities of fission products in an event of severe accident. The FCVS filters the radioactive iodine and long-half life fission products (Cs) generated during severe accident in the PCV through the filter vent device. The FCVS releases non-condensable gases and steam through the main stack to prevent damage to the PCV due to overpressure.

9.1.3.6.5.4 Lower Drywell Flooder System (LDF)

The LDF provides water to the Lower drywell from the Suppression Pool (S/P) in the unlikely event of a Severe Accident where the core melts and causes a subsequent vessel failure to occur, and deposition of debris on the lower drywell floor. LDF operates automatically in a passive manner due to thermally activated plugs called Fusible Plugs (FPLGs).

9.1.3.6.5.5 Alternate Heat Exchange Facility (AHEF)

The purpose 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 RCW or RSW are lost. 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. The AHEF Heat Exchangers are cooled with sea water driven by Mobile AHEF Service Water Pumps.

9.1.3.6.5.6 Reactor Depressurization Control Facility (RDCF)

The RDCF depressurize RPV without ADS function to enable providing cooling water to the RPV through FLSS and FLSR. The RDCF consists of dedicated solenoid valves for SRV and nitrogen feeder both installed in R/B, are operable at control panels in B/B.

9.1.3.7 Steam and Power Conversion System

A detail description about the main system of this Sub-chapter is provided in Chapter 17 of the Generic PCSR.

9.1.3.7.1 Turbine Generator

The main roles of the Turbine Generator are to covert the thermal energy of the steam to the electrical energy.
The turbine is of a tandem-compound 6 flow exhaust condensing-type. It consists of a double-flow high-pressure turbine and 3 double-flow low-pressure turbines.
The steam from the Reactor passes through 4 Main Steam Valves (MSVs) and is controlled by 4 Steam Control Valves (CVs). After leaving the CVs, the steam is taken by 4 steam leads to 2 inlets in the lower casing and 2 inlets in the upper casing into the double-flow High-Pressure Turbine.
After the steam expands at the HP turbine, it passes through 4 cold reheat lines from the lower casing and is taken to 2 Moisture Separator Reheater (MSRs). The steam is dried and reheated in MSR.
Reheated steam leaves the 2 MSR vessels through 6 hot reheat pipes flowing through the 6 Combined Intermediate Valves (CIVs) then to the 6 Low-Pressure Turbine inlets. Then the steam passes out through the exhaust outlets and is condensed into the condenser.

The generator is a direct-driven, three-phase, 50Hz, 1,500min^{-1}, four-pole synchronous generator with water-cooled stator and hydrogen cooled rotor. It converts the mechanical energy into the electrical energy.
The generator is provided with gas control system, shaft sealing oil system, and stator cooling water system in order to support the generator operation.

9.1.3.7.2 Turbine Main Steam System

The Turbine Main Steam supplies steam generated from the reactor to drive the steam turbine, and also to supply steam to the Turbine Auxiliary Steam (AS) and the Turbine Bypass System (TBP).

The Turbine AS supplies driving steam to the Reactor feedwater pump turbine (RFP-T) and the Steam jet air ejector (SJAE), and to supply heating steam to the Moisture separator reheater (MSR) and the Gland steam evaporator (GSE).

The TBP releases steam from the reactor to the condenser for reactor internal pressure control during the plant startup and shutdown operation, or when the reactor steam production exceeds turbine steam demand.

9.1.3.7.3 Extraction Steam System

The Extraction Steam System (ES) supplies High pressure turbine (HP-T) exhaust steam to the Low pressure turbine (LP-T) through Moisture separator reheaters (MSRs). The ES supplies required heating steam to the Feedwater heaters (FWHs) and MSR 1st stage reheater (MSR-1RH) from the HP-T and LP-Ts, and processes drains separated in the turbine stage to increase the plant thermal efficiency. The ES supplies steam required to drive Reactor feedwater pump turbine (RFP-T) from the cross-around pipe at the MSR outlet. The ES supplies GSE heating steam at a high load operation.

9.1.3.7.4 Turbine Gland Steam System

The Turbine Gland Steam System (TGS) supplies sealing steam to the turbine shaft seal parts and the major valve gland parts, and to prevent leaking air into the condenser.

9.1.3.7.5 Feedwater Heater Drain & Vent System

The Feedwater Heater Drain System (HD), the Feedwater heater (FWH) and Moisture separator reheater (MSR) drain to heat feedwater to improve plant thermal efficiency. The High pressure (HP) FWH drain is directly recovered on the Reactor feedwater pump (RFP) suction side, and the Low pressure (LP) FWH drain is directly recovered on the High pressure condensate pump (HPCP) suction side respectively, to further improve plant thermal efficiency and reduce the capacity of the Condensate and feedwater system (CFDW) facility.
The Feedwater Heater Vent System (HV) discharges non-condensable gases from the FWHs to prevent a reduction in their heat transfer performance. Non-condensable gases from the MSR 1st and 2nd stage reheaters (MSR-1/2RHs) are discharged through their outlet header with steam to prevent overcooling of the heat transfer tubes. The HV is also equipped with FWH shell relief valves to protect the FWHs against damage due to excessive pressure in case of tube leak.

9.1.3.7.6 Condenser

The condenser cools steams to reuse as feedwater to the reactor. The condenser is also to deaerate condensate and recover drain/steam from respective systems.

9.1.3.7.7 Circulating Water System

The Circulating Water System (CW) supplies cooling water to the condenser and cool turbine exhaust and drain.

9.1.3.7.8 Condensate and Feedwater System

The CFDW supplies feedwater from the condenser to the reactor, at the required flow rate, pressure and temperature.

9.1.3.7.9 Condensate Purification System

The Condensate Purification System (CPS) consists of the Condensation Filter System (CF) and the Condensation Demineraliser System (CD) in series to remove soluble and insoluble impurities in the condensate and satisfy the water quality.

9.1.3.8 Radioactive Waste Management

A detail description about the main system of this Sub-chapter is provided in Chapter 18 of the Generic PCSR.

9.1.3.8.1 Liquid Radioactive Waste Management System

The Liquid Radioactive Waste Management System (LWMS) is designed to segregate at source, collect and treat the various streams of radioactive and potentially radioactive waste water generated during various modes of ABWR reactor and turbine plant operation: startup, normal operation, shutdown, and re-fuelling.

The LWMS is housed in the Rw/B and S/B, and consists of the following four subsystems:

- Low Conductivity Waste (LCW) subsystem
- High Conductivity Waste (HCW) subsystem
- Laundry Drains (LD) subsystem
- Controlled Area Drains (CAD) subsystem.

The Primary Circuit and Fuel Pool (i.e. the plant areas containing water that comes into direct contact with irradiated fuel) are operated as far as is practicable as “closed loop systems”. For this reason, the LWMS is designed so that any water leaks and any water drained from the Primary Circuit or Fuel Pool during the various modes of plant operation is captured and appropriately treated so as to remove both soluble and in-soluble impurities. This provides high purity water that is normally recycled for use in the Primary Circuit and/or Fuel Pool. Recycled water i s only occasionally discharged to the environment (through a permitted route) when the recycled volumes exceed Primary Circuit and Fuel Pool water make-up requirements. On occasions when it is necessary to discharge excess volumes of treated water to the environment, the treated water is first monitored to ensure that residual levels of contamination are within set limits and as low as reasonably practicable (ALARP).

Two subsystems are used to treat radioactively contaminated waste water from the Primary Circuit and/or Fuel Pool, the HCW subsystem and the LCW subsystem. Waste water is captured and routed to the appropriate subsystems depending on its expected conductivity, i.e. the expected level of impurities (including non-radiological contamination) it contains. The HCW subsystem is designed to efficiently treat water with higher levels of impurities level by the use of a distillation step before treating the distilled water by passing it through an ion exchange bed. The LCW subsystem is designed to efficiently treat larger volumes of water which contain lower levels of impurities and uses an initial filtration (rather than distillation) step before passing the filtered water through an ion exchange bed. In both cases, if necessary, waste water can be passed through the treatment process a number of times in order to meet the purity levels required for reuse.

The LD subsystem is used to treat waste water from the laundry and the personnel showers and hand washing facilities. This water contains detergents and organic impurities as well as crud with low levels of radiological contamination. Efficient removal of the detergents and organic material (as well as the radioactive crud) requires a different treatment process (with both filtration and activated carbon adsorption steps) to those used in the HCW and LCW systems. In this case, after appropriate monitoring to ensure that residual activity levels are ALARP, the treated water is discharged to the environment through a permitted route.

A fourth subsystem, the CAD subsystem, is used to collect waste water from other plant and systems in the radiologically controlled areas (RCAs) in the R/B and T/B. The waste water collected from the RCAs is potentially contaminated. This water is simply sampled to confirm it contains no significant radiological contamination (or unacceptable chemical contamination) before it is discharged to the environment. If the water is found to contain any significant radiological contamination or unacceptable chemical contamination, then the operator can route the water for treatment using the HCW subsystem.

The radioactive materials removed from the waste water streams treated by the HCW and LCW subsystems are collected and contained in the form of wet sludges, used ion exchange resins. These wet-solid wastes are stored in tanks within the Rw/B before being transferred to the solid radioactive waste treatment facilities where they are processed into a passively safe state. Used activated carbon from the LD subsystem, is dewatered and placed into drums which are then transferred for processing in the Solid Low Level Waste Facility (see Section 15.4.3.3).

The Rw/B also includes storage tanks for wet solid wastes (crud, sludges and spent resins) generated during the polishing of condensate water in the T/B and reactor and Fuel Pool water clean-up in the R/B. The wastes are either transferred directly to the radioactive waste building storage tanks or are first collected in backwash receiver tanks in the turbine or reactor buildings before being transferred to the radioactive waste building storage tanks. These wastes are also periodically transferred to the solid radioactive waste treatment facilities for treatment e.g. cementation or incineration. Indicative routes will be selected following a decision making process within GDA and the final waste route selection will be made.

9.1.3.8.2 Off-Gas Radioactive Waste Management System

The Off-Gas System (OG) recombines flammable gases (Hydrogen (H2) and Oxygen (O2)), which are generated from the radiolysis of reactor cooling water, into steam. The OG sufficiently reduces the emission rate of radioactive particles before discharging them to the environment. The OG transfers the off-gas from the Gland Steam Exhauster and the Mechanical Vacuum Pump (MVP) to the stack. The OG is designed to perform the required functions during all operating modes based upon the established environmental design conditions.

9.1.3.8.3 Solid Radioactive Waste Management System

The Solid Radioactive Waste Management System (SWMS) is designed to receive, sort and process/condition all solid and wet-solid Low Level Waste (LLW) and Intermediate Level Waste (ILW) waste streams resulting from ABWR operation. Following processing and conditioning LLW is dispatched off site for either incineration, recycling (in the case of recyclable metals), or direct disposal, while ILW is transferred for interim storage (pending availability of the Geological Disposal Facility (GDF)) in an on-site shielded ILW store. There are HVAC and SGTS which are the systems connected to the stack.

The SWMS comprises the following facilities:
- Solid LLW treatment facility
- Solid ILW treatment facility
- Wet-solid LLW treatment facility
- Wet-solid ILW treatment facility
- LLW marshalling area (pending transport for off-site incineration/recycling/disposal).
- Interim ILW shielded store (dedicated building)

9.1.3.9 Fuel Storage and Handling

A detail description about the main system of this Sub-chapter is provided in Chapter 19 of the Generic PCSR.

9.1.3.9.1 New Fuel Storage & Spent Fuel Storage

9.1.3.9.1.1 Fuel Storage Facility

New and spent fuel storage racks are designed to prevent inadvertent criticality. Sufficient cooling and shielding are provided in the spent fuel storage pool to prevent excessive pool heatup and personnel exposure, respectively. The design of the spent fuel storage pool provides for corrosion resistance and maintains subcritical.

9.1.3.9.2 Fuel Cooling and Clean-up System (FPC)

The Fuel Pool Cooling and Clean-up System (FPC) continuously maintains the fuel pool water level, water temperature, and water quality and the S/P water quality within the specified limits during all modes of plant operation. FPC includes two pumps, two heat exchangers, each capable of removing the decay heat generated from a normal discharge of spent fuel, and two filter/demineralisers, each unit having the capacity to process the system design flow to maintain the desired purity level.

9.1.3.9.3 Reactor Building

9.1.3.9.3.1 Refuelling Equipment

The fuel servicing equipment includes Reactor Building Overhead Crane, Fuel Handling Machine, and other related tools for reactor servicing.

The Reactor Building Overhead Crane handles the spent fuel cask from the transport device to the cask pit. The Fuel Handling Machine transfers the fuel assemblies between the storage area and the reactor core. New fuel bundles are handled by the R/B Overhead Crane.

The handling of RPV head and PCV head during refuelling is accomplished using the Reactor Building crane.

Refuelling Interlocks

A system of interlocks that restricts movement of Fuel Handling Machine and control rods when the reactor is in the refuelling and startup modes is provided to prevent an inadvertent criticality during refuelling operation. The interlocks backup procedural controls that have the same objective. The interlocks affect movement of the Fuel Handling Machine, Fuel Handling Machine’s hoists, grapple, and control rods.

9.1.3.9.3.2 Miscellaneous Servicing Equipment

The servicing aids equipment includes general handling fuel pool tools such as actuating poles with various end configurations. General area underwater lights and support brackets are provided to allow the lights to be positioned over the area being serviced independent of the platform. A general-purpose, plastic viewing aid is provided to float on the water surface to provide better visibility. A portable underwater closed circuit television camera may be lowered into the reactor vessel pool and/or the fuel storage pool to assist in the inspection and/or maintenance of these areas along with an underwater vacuum with submersible pump and filter for cleaning.

9.1.3.9.3.3 Reactor Pressure Vessel Servicing Equipment

Equipment associated with servicing the reactor pressure vessel is used when the reactor is shutdown and the reactor vessel head is being removed or installed. Tools used consist of strongbacks, nut racks, stud tensioners, protectors, wrenches, etc.

9.1.3.9.3.4 RPV Internal Servicing Equipment

The majority of internal servicing equipment was designed to be attached to the refuelling platform auxiliary hoist and used when the reactor is open. A variety of equipment (e.g., grapples, guides, plugs, holders, caps, strongbacks and sampling stations) is used for internal servicing. The RIP handling devices are additionally included.

9.1.3.9.3.5 Under-vessel Servicing Equipment

This equipment is used for the installation and removal work associated with the fine motion control rod drive (FMCRD), RIP and In-Core Monitor (ICM). A handling platform provides a working surface for equipment and personnel performing work in the under-vessel area. The polar platform is capable of rotating 180 degrees in either direction, and has an FMCRD handling trolley with full traverse capability across the vessel diameter. All equipment is designed to minimize radiation exposure, contamination of surrounding equipment and reduce the number of workers required.

9.1.3.9.3.6 CRD Maintenance Facility

The CRD maintenance facility is located close to the primary containment and is designed and equipped for maintenance of the FMCRD, provide for decontamination of the FMCRD components, perform the acceptance tests, and provide storage.

9.1.3.9.3.7 Reactor Internal Pump Maintenance Facility

The RIP maintenance facility is located in the Reactor Building and is designed for performing maintenance work on the motor assembly and related parts. The facility is designed to handle one motor assembly, including decontamination in its assembled and disassembled states. The facility is equipped with all tools needed for inspection of motor parts and heat exchanger tube bundles. RIP handling tools associated with handling the impeller and diffuser are stored on the refuelling floor where they are used.

9.1.3.10 Human Machine Interface

A detail description about the main system of this Sub-chapter is provided in Chapter 21 of the Generic PCSR.

9.1.3.10.1 Control Room

9.1.3.10.1.1 Main Control Room Panels (MCRP)

The Main Control Room panel (MCRP) consists of Main Control Console (MCC), Wide Display Panel (WDP), and Shift Supervisor's Monitor. MCRP is designed to ensure operators to monitor and control the plant during a plant's startup, shutdown, normal operation, accidents, and outage. MCRP incorporates digital technologies and optioned scope of automated operation with the consideration of HF principles in HMIS design.

The WDP provides the operators with the overall plant information, including critical plant parameters and equipment operational status. The WDP consists of a fixed-position mimic display of key plant parameters, important alarm windows, and a large variable display.
The MCC is equipped with Flat Displays (FDs), Plant-level Flat Displays (PFDs) and hardware switches, which are used to operate during all phases of normal plant operation, abnormal events, and accident conditions. The MCC is consisted of three parts; it is divided according to their functionalities.

9.1.3.10.1.2 Radioactive Waste Control Panel

Control and monitoring of the radwaste systems are provided by a micro processor based distributed control system (DCS). The DCS has operator interface stations on a central sit-down console consisting of the display with mouse operation from which operators can call up graphic displays, operate valves, start and stop equipment, etc. The DCS also provides alarm messages, which can be acknowledged and reset through the mouse operation.
Liquid radioactive waste systems are remotely operated from the radwaste central control room. The Intermediate Level Waste (ILW) and Low Level Waste (LLW) facilities are remotely operated from separate control rooms within each facility.

9.1.3.10.2 Remote Shutdown System (RSS)

In the event that the MCR becomes uninhabitable, the reactor can be brought from power range operation to hot shutdown after a scram, with the subsequent capability to attain cold shutdown conditions by use of controls and equipment that are available outside the MCR.

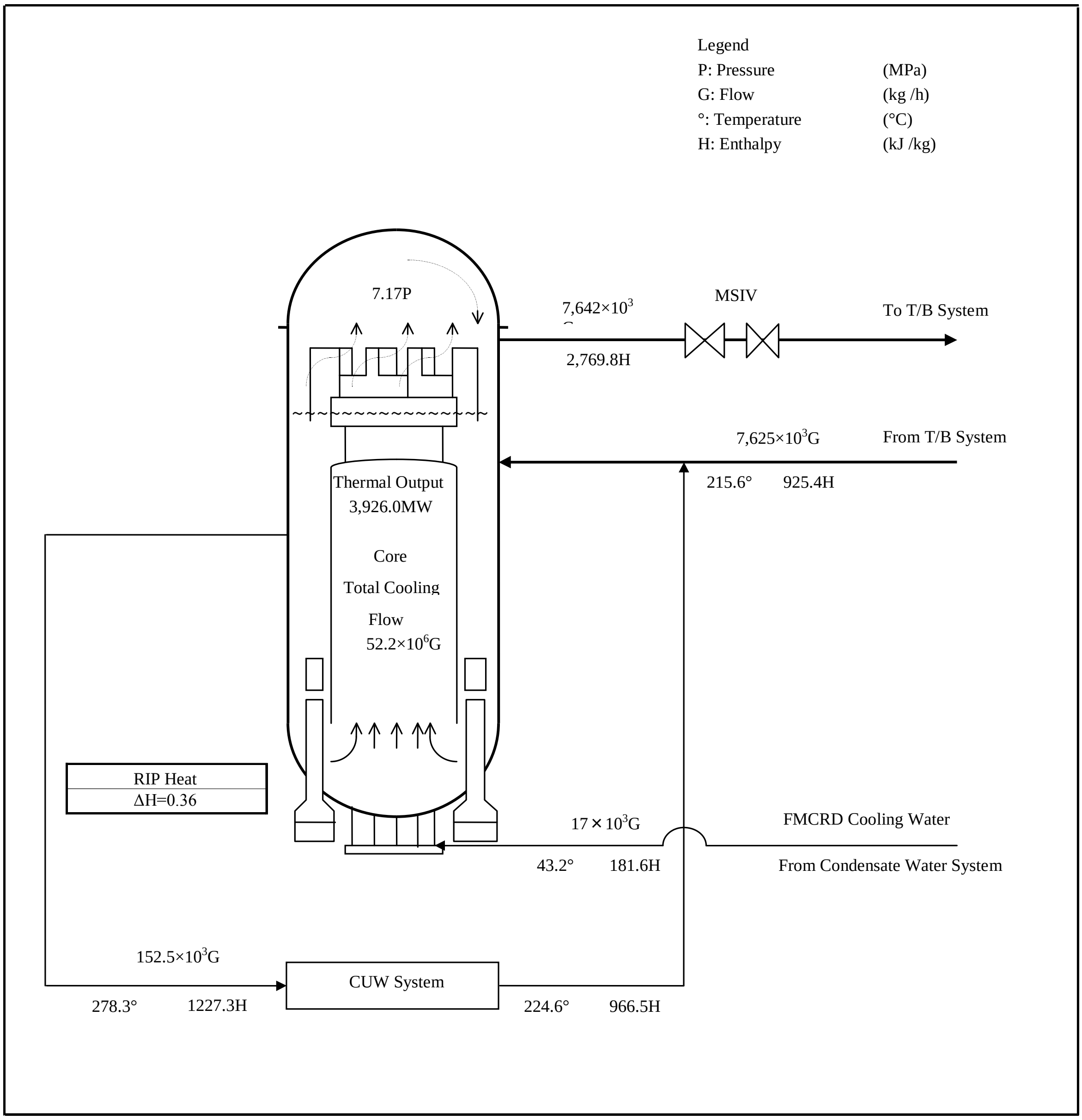


Figure 9.1-1：Nuclear boiler system HB outline (HB design conditions)

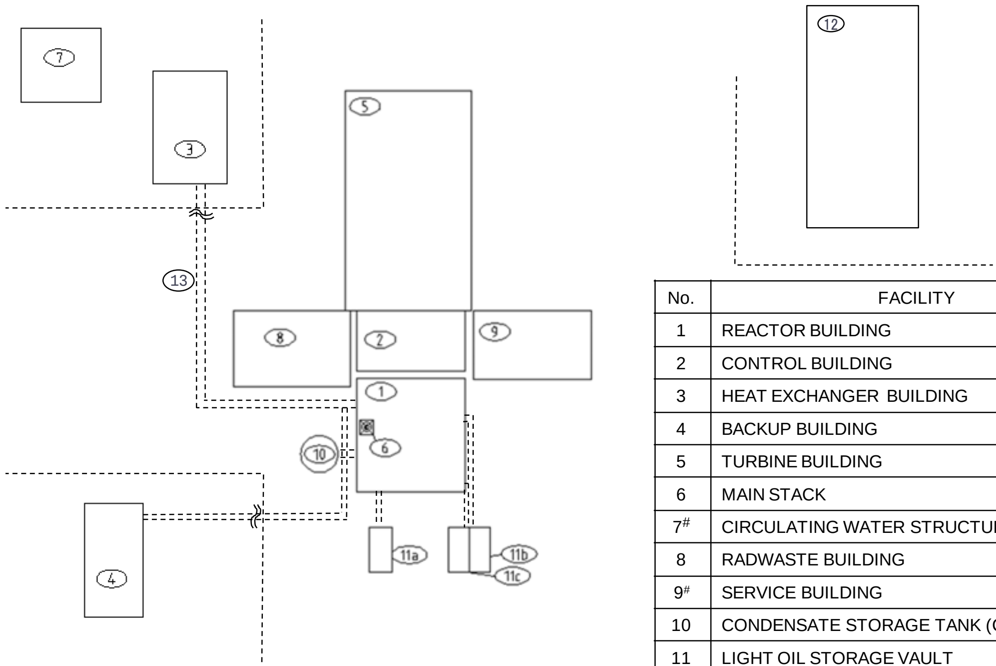
9.2 Facility Layout

9.2.1 Plant Arrangement

The standard UK ABWR plant arrangement consists of the following main buildings;

- Reactor Building (R/B)
- Control Building (C/B)
- Heat Exchanger Building (Hx/B)
- Turbine Building (T/B)
- Radwaste Building (Rw/B)
- Service Building (S/B)
- Backup Building (B/B)

The standard plant is located on a site adjacent or close to a body of water with sufficient capacity. The C/B that houses the main control room is located on the central location as the hub of the plant operating staff's activities. The T/B is oriented in such a way, that any plane perpendicular to the turbine generator axis does not intersect with the R/B and C/B in order to minimize the probability of a turbine missile striking any Safety Related Systems, Structures and Components (SSCs). The standard UK ABWR plant arrangement is shown in Figure 9.2-1. The Chapter 10 of this Generic PCSR describes safety requirements and design principles of UK ABWR civil structures within the GDA scope.



No.	FACILITY
1	REACTOR BUILDING
2	CONTROL BUILDING
3	HEAT EXCHANGER BUILDING
4	BACKUP BUILDING
5	TURBINE BUILDING
6	MAIN STACK
7#	CIRCULATING WATER STRUCTURE
8	RADWASTE BUILDING
9#	SERVICE BUILDING
10	CONDENSATE STORAGE TANK (CST)
11	LIGHT OIL STORAGE VAULT
12#	SPENT FUEL STORAGE FACILITY
13	RCW TUNNEL

This drawing illustrates conceptual site plan and not intended to show final exact location of the structures.

Structures NOT included in the GDA scope

Figure 9.2-1 : Generic Site Plan

9.2.2 Plant Arrangement Considerations

The UK ABWR plant arrangement is designed with following considerations.

- Protection against Internal and External Hazards
  Divisional separation between the safety trains are arranged to ensure independency of a safety train during an internal hazard. The separations furnished by reinforced concrete walls and slabs prevent damage such as internal fire, flooding, missiles and explosion propagating from other safety division. Massive exterior walls, slabs and roof are provided to protect SSCs inside the building from external hazards. Chapter 6 and 7 of this Generic PCSR describes internal and external hazards assessment. And Chapter 10 of this Generic PCSR provides more information about safety requirements and design principles of UK ABWR civil structures within the GDA scope.

- Minimizing dose
  The UK ABWR civil structures separate clean and radiation controlled areas within the building to minimize personnel exposure during operation and maintenance. Access route from change room to contaminated areas are as direct as possible and clearly separated from clean access way. The SSCs that include higher dose are isolated from lower dose rate area by concrete shielding walls and slabs. Access pathways are designed to maintain lower dose rate by appropriate shielding. Chapter 20.3 of this Generic PCSR describes shielding design and ALARP strategy for effective radioactive protection.

- Plant Access and Maintenance
  Access pathways are provided for all surveillance, maintenance and replacement activities. At each floor, 360° access corridor is available, if practical. This concept enables direct access to each equipment room without interactions of other rooms. The 360° access corridor also provides plural paths to any point within a building to enhance redundancy of access to control functions that may require local manual intervention and evacuation from a hazardous situation.

  Access to equipment not reachable from floor level is via platform stair access wherever possible. Adequate headroom and maximum escape travel distance are incorporated in accordance with the British Standards where practical.

  Laydown space and local service areas are provided for maintenance and replacement activity of each equipment. Adequate hallways and equipment removal paths, including vertical access hatches are provided for moving equipment from its installed position to service area or out of the building for repair. This concept ensures necessary maintenance for 60 years safety operation and decommissioning.

  Lifting devices including cranes, chain blocks and monorail are provided to facilitate equipment handling and minimize the need for re-rigging individual equipment movements.

9.2.3 Characteristics of the Main Buildings

(1) Reactor Building
The Reactor Building includes the containment, drywell, major portions of the nuclear steam supply system, steam tunnel, refueling area, diesel generators, essential power, non-essential power, emergency core cooling systems, Heating Ventilation and Cooling (HVAC), as well as additional supporting systems. The secondary containment is a reinforced concrete building that forms the secondary containment boundary which surrounds the primary containment above the basemat.

(2) Control Building
The Control Building includes the control room, the computer facility, the cable tunnels, some of the plant essential switchgear, some of the essential power and the essential HVAC system. The main steam tunnel from the R/B to the T/B is located in the ground floor of the Control Building.

(3) Heat Exchanger Building
The Heat Exchanger Building is a structure which houses portions of the Reactor Building Cooling Water (RCW) System and Turbine Building Cooling Water (TCW) System. The Hx/B is located adjacent to the intake point of the plant cooling water.

(4) Backup Building
The Backup Building provides an alternative safety management capacity for accident management. The building houses an alternative Alternating Current (AC) power source as well as Instrumentation & Control (I&C) facilities. An alternative water source is also available via a water tank adjacent to the building. The building also includes transportable RCW replacement, water injection pumps and Nitrogen supply facilities.

(5) Turbine Building
The Turbine Building houses all equipment associated with the main turbine generator. Other auxiliary equipment is also located in this building.

(6) Radwaste Building
The Radioactive Waste Building houses all equipment associated with the collection and processing of solid and liquid radioactive waste generated by the plant.

Chapter 10 of this Generic PCSR discusses safety requirements and design principles of the buildings stated in this chapter.