GE Hitachi Nuclear Energy

NEDO-34221

Revision B

July 2025

US Protective Marking: Non-Proprietary Information
UK Protective Marking: Not Protectively Marked

BWRX-300 UK Generic Design Assessment (GDA)
Chapter E4: Information about the Design

INFORMATION NOTICE

This document does not contain proprietary information and carries the notations "US Protective Marking: Non-Proprietary Information" and "UK Protective Marking: Not Protectively Marked."

IMPORTANT NOTICE REGARDING CONTENTS OF THIS REPORT

Please Read Carefully

The design, engineering, and other information contained in this document is furnished for the purpose of obtaining the applicable Nuclear Regulatory Authority review and determination of acceptability for use for the BWRX-300 design and licensing basis information contained herein. The only undertakings of GEH with respect to information in this document are contained in the contracts between GEH and its customers or participating utilities, and nothing contained in this document shall be construed as changing those contracts. The use of this information by anyone for any purpose other than that for which it is intended is not authorized; and with respect to any unauthorized use, no representation or warranty is provided, nor any assumption of liability is to be inferred as to the completeness, accuracy, or usefulness of the information contained in this document. Furnishing this document does not convey any license, express or implied, to use any patented invention or any proprietary information of GEH, its customers or other third parties disclosed herein or any right to publish the document without prior written permission of GEH, its customers or other third parties.

UK SENSITIVE NUCLEAR INFORMATION AND US EXPORT CONTROL INFORMATION

This document does not contain any UK Sensitive Nuclear Information (SNI) subject to protection from public disclosure as described in the Nuclear Industries Security Regulations (NISR) 2003, does not contain UK Export Controlled Information (ECI), and does not contain US Export Controlled Information (ECI) subject to the export control laws and regulations of the United States, including 10 CFR Part 810.

EXECUTIVE SUMMARY

The purpose of this document is to provide a high-level overview of the design of the GE-Hitachi Nuclear Energy Americas, LLC (GEH) BWRX-300 Small Modular Reactor, describing each plant, system, and process in a level of detail commensurate with a two-step Generic Design Assessment.

This chapter describes the main plant, systems, and processes of the facility, such as those that are relevant to power generation, process fluid management, and process monitoring. The plant, systems and processes that involve the generation, treatment, measurement, assessment, and disposal of radioactive waste, as well as those that may have radiological or conventional environmental impacts and/or create hazardous substances or pollutants are described with a particular focus on the environmental aspects of each. Descriptions are supported by schematics, simplified line diagrams and process flow diagrams, where appropriate.

Interfaces with relevant systems are identified throughout and suitable cross references used to direct the reader to relevant interfacing chapters of both the Preliminary Environmental Report and Preliminary Safety Report.

Appendix A provides a Forward Action Plan which presents recommendations for future work.

ACRONYMS AND ABBREVIATIONS

Acronym	Explanation
ABWR	Advanced Boiling Water Reactor
AHU	Air Handling Unit
ALARA	As Low As Reasonably Achievable
ARM	Area Radiation Monitoring
ASD	Adjustable Speed Drive
BAT	Best Available Techniques
BIS	Boron Injection System
BWR	Boiling Water Reactor
CB	Control Building
CCS	Containment Cooling System
CEAP	Continuous Exhaust Air Plenum
CFD	Condensate Filters and Demineralizers
CFS	Condensate Feedwater Heating System
CIS	Containment Inerting System
CIV	Containment Isolation Valve
CMon	Containment Monitoring
COMAH	Control of Major Accident Hazards
CRD	Control Rod Drive
CST	Condensate Storage Tank
CUW	Reactor Cooling and Cleanup System
CWE	Chilled Water Equipment
CWS	Circulating Water System
EFS	Equipment and Floor Drain System
EHC	Electro-Hydraulic Control
EME	Emergency Mitigation Equipment
ESF	Engineered Safety Feature
ESS	Extraction Steam Subsystem
FAP	Forward Action Plan
FCU	Fan Coil Unit
FLEX	Diverse and Flexible Coping Strategies
FMCRD	Fine Motion Control Rod Drive
FPC	Fuel Pool Cooling and Cleanup
FPS	Fire Protection System
FW	Feedwater
GDA	Generic Design Assessment
GDF	Geological Disposal Facility

Acronym	Explanation
GEH	GE-Hitachi Nuclear Energy Americas, LLC
GEZIP	General Electric Zinc Injection Passivation
GSC	Gland Steam Condenser
GT	Gamma Thermometer
HCU	Hydraulic Control Unit
HEPA	High Efficiency Particulate Air (Filter)
HIC	High Integrity Container
HP	High Pressure
HVAC	Heating, Ventilation and Air Conditioning
HVS	Heating, Ventilation and Cooling System
HWC	Hydrogen Water Chemistry
IC	Isolation Condenser
ICC	Isolation Condenser Pools Cooling and Cleanup System
ICS	Isolation Condenser System
IGSCC	Intergranular Stress Corrosion Cracking
IICC	Irradiated In-Core Component
ILW	Intermediate Level Waste
IWS	Integrated Waste Strategy
LOCA	Loss of Coolant Accident
LP	Low Pressure
LPRM	Local Power Range Monitor
LWM	Liquid Waste Management System
MCA	Main Condenser and Auxiliaries
MCR	Main Control Room
MSL	Main Steam Line
MSR	Moisture Separator Reheater
MTE	Main Turbine Equipment
NBS	Nuclear Boiler System
NHS	Normal Heat Sink
NRW	Natural Resources Wales
OGS	Offgas System
OLNC	Online NobleChem™
PCCS	Passive Containment Cooling System
PCS	Primary Containment System
PCW	Plant Cooling Water
PER	Preliminary Environmental Report
PING	Particulate, Iodine and Noble Gas

Acronym	Explanation
PPS	Plant Pneumatic System
PREMS	Process Radiation and Environmental Monitoring System
PRM	Process Radiation Monitoring
PS	Process Sampling
PSR	Preliminary Safety Report
PVS	Plant Vent Stack
RB	Reactor Building
RCA	Radiologically Controlled Area
RCPB	Reactor Coolant Pressure Boundary
RIV	Reactor Isolation Valve
RPV	Reactor Pressure Vessel
RWB	Radwaste Building
RWMA	Radioactive Waste Management Arrangements
RWST	Refueling Water Storage Tank
SB	Service Building
SCCV	Steel-Plate Composite Containment Vessel
SCR	Secondary Control Room
SDC	Shutdown Cooling System
SDG	Standby Diesel Generator
SF	Spent Fuel
SJAE	Steam Jet Air Ejector
SMR	Small Modular Reactor
SWM	Solid Waste Management System
TB	Turbine Building
TBS	Turbine Bypass System
TBV	Turbine Bypass Valve
TCV	Turbine Control Valve
TLOS	Turbine Lube Oil Subsystem
TG	Turbine Generator
TGSS	Turbine Gland Steam Subsystem
TSV	Turbine Stop Valve
UK	United Kingdom
WGC	Water, Gas and Chemical Pads
WRNM	Wide Range Neutron Monitor

DEFINITIONS

Term	Definition
B21	BWRX-300 Nuclear Boiler System
D11	BWRX-300 Process Radiation and Environment Monitoring System
E52	BWRX-300 Isolation Condenser System
G11	BWRX-300 Boron Injection System
G12	BWRX-300 Control Rod Drive System
K10	BWRX-300 Liquid Waste Management System
K30	BWRX-300 Offgas System
N21	BWRX-300 Condensate and Feedwater Heating System
N61	BWRX-300 Main Condenser and Auxiliaries
P25	BWRX-300 Chilled Water Equipment
P40	BWRX-300 Plant Cooling Water System
T10	BWRX-300 Primary Containment System
T31	BWRX-300 Containment Inerting System
U50	BWRX-300 Equipment and Floor Drains System

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

REVISION SUMMARY

Revision #	Section Modified	Revision Summary
A	All	Initial Issuance
B	All	Update for end of GDA Step 2 consolidation

4. INFORMATION ABOUT THE DESIGN

Purpose

The Environment Agency (EA), supported by Natural Resources Wales (NRW), have defined the information they require to assess the generic design of the GE-Hitachi Nuclear Energy Americas, LLC (GEH) BWRX-300 Small Modular Reactor (SMR) as part of the environment case submission of the Generic Design Assessment (GDA) process in “New nuclear power plants: Generic Design Assessment guidance for Requesting Parties,” (Reference 4-1).

Noting that GEH, the Requesting Party (RP), are only undertaking Step 1 and 2 of the GDA process, the objective of this document is to provide a high-level overview of the design of the BWRX-300, describing each plant, system, and process in an appropriate level of detail for Step 2 (with a focus placed upon the relevant environmental aspects).

Scope

The scope of this document is to concisely describe the design of the BWRX-300, noting that some aspects of the design are still evolving and are subject to change. In line with the regulatory guidance, descriptions of the following are presented in this document:

- The main plant, systems, and processes of the facility, such as those that contribute to power generation
- The plant, systems, and processes which have a bearing on radioactive waste generation, treatment, measurement, assessment, and disposal. This includes all solid, liquid, and gaseous radioactive discharges and wastes
- The plant, systems, and processes which have a bearing on the conventional environmental impacts of the facility, such as water use and abstraction
- Any activities that have the potential to create hazardous waste, as well as those that result in the presence of hazardous substances and any other pollutants in waste streams

For the above, where appropriate, schematics, simplified system diagrams, or process flow diagrams are provided to support the description of plant, systems and processes that have a particular bearing on environmental impacts. Where further work may be required, Forward Action Plan items (FAPs) are identified throughout as “FAP.PER4-XXX” (where X is a number) and summarised in Appendix A.

This document interfaces with chapters within both the Preliminary Environmental Report (PER) and Preliminary Safety Report (PSR). Clear reference to the relevant chapters that provide further information on specific plant, systems, and processes are made throughout.

Exclusions

The scope of this document excludes the following:

- Detailed descriptions of the philosophies, principles, policies, strategies, plans, methodologies, codes, and standards that are used by the RP in the development, substantiation, and specification of the design. Relevant information is presented in the PSR.
- Assurances that the generic design is capable of being developed to achieve compliance with relevant UK approaches for management of radioactive wastes, decommissioning and long-term interim storage of Spent Fuel (SF) and final disposal of radioactive wastes and SF. Relevant information is provided in NEDC-34222P, “BWRX-300 UK GDA Chapter E5: Radioactive Waste Management Arrangements” (RWMA) (Reference 4-2), NEDC-34174P, “BWRX-300 UK GDA Chapter 11: Management of Radioactive Waste,” (Reference 4-3) and NEDC-34198P, “BWRX-300 UK GDA Chapter 26: Interim Storage of Spent Fuel,” (Reference 4-4).

- Aspects of the design associated with systems outside of the power block. For example, potential on-site capabilities such as interim storage facilities and waste processing are not described here but are discussed as indicative scope in Chapter E5. (Reference 4-2).

Document Structure

Following this introductory section, the document is structured in the following manner:

- Section 4.1 - Design in Context
- Section 4.2 - Main Plants and Systems
- Section 4.3 - Conventional Environmental Impacts
- Section 4.4 - References
- Appendix A - Forward Action Plan

Interfaces with Other Chapters

This document interfaces with the following chapters in the PER:

- PER Chapter E5, (Reference 4-2)
- NEDC-34223P, “BWRX-300 UK GDA Chapter E6: Demonstration of Best Available Techniques (BAT) Approach,” (Reference 4-5)
- NEDC-34224P, “BWRX-300 UK GDA Chapter E7: Radioactive Discharges,” (Reference 4-6)
- NEDC-34225P, “BWRX-300 UK GDA Chapter E8: Approach to Sampling and Monitoring,” (Reference 4-7)
- NEDC-34227P, “BWRX-300 UK GDA Chapter E10: Other Environmental Regulations,” (Reference 4-8)

It also interfaces with several chapters in the PSR, most notably:

- NEDC-34166P, “BWRX-300 UK GDA Chapter 4: Reactor (Fuel and Core),” (Reference 4-9)
- NEDC-34168P, “BWRX-300 UK GDA Chapter 6: Engineered Safety Features,” (Reference 4-10)
- NEDC-34169P, “BWRX-300 UK GDA Chapter 7: Instrumentation and Control,” (Reference 4-11)
- NEDC-34172P, “BWRX-300 UK GDA Chapter 9B: Civil Structures,” (Reference 4-12)
- PSR Chapter 11, (Reference 4-3)
- PSR Chapter 26, (Reference 4-4)

4.1 Design in Context

4.1.1 Manufacture, Construction and Plant Cleanliness

The BWRX-300 design has been developed with the principles of simplicity and ease of constructability in mind. The RP aims to use local supply chains and commodities where appropriate to minimise both cost and impact to the environment. Commercial off-the-shelf equipment and balance of plant components that are deployed at other sites of similar size are to be used to leverage the expertise of the RP in advanced construction methods and modularisation (006N8670, "BWRX-300 Modularization Strategy Report," (Reference 4-13)).

Embedded within these principles is awareness of the need for, and application of, the plant cleanliness philosophy (DBR-0060041, "BWRX-300 A34 Cleanliness Guidance," (Reference 4-14)). All materials used in the manufacture and construction of the SMR are to be strictly controlled to limit levels of contamination. This avoids the introduction of problematic contaminants into the reactor system, preserving the integrity of the plant systems, structures, and components.

The release of chemical impurities and corrosion products into the reactor systems may challenge the operational limits of the water treatment systems, and subsequently challenge the maximum recirculation philosophy (under normal operating conditions). The operational lifetime of the systems, structures, and components may also be reduced, leading to unanticipated replacement and increased volume of waste for disposal.

An additional line of defence is the Foreign Material Exclusion philosophy, (25A5900, "Foreign Materials Exclusion," (Reference 4-15)), which builds upon plant cleanliness. Mitigations are implemented to prevent foreign materials entering critical systems, such as exclusion zones and controls (EPRI Report 3002003060, "Foreign Material Exclusion Process and Methods," (Reference 4-16)). In the unlikely scenario that foreign material does enter a system, physical measures such as mesh screens are incorporated as an additional layer of protection, on top of the requirements to either limit the use of certain metallic and non-metallic components or to design them in such a way as to minimise any potential degradation.

4.1.2 Maximum Recirculation Philosophy

The maximum recirculation philosophy is based on successful previous operating experience of Boiling Water Reactors (BWRs) in the United States, presented in NEDC-34279P, "Analysis of Environmental Discharge Data for US Nuclear Power Plants," (Reference 4-17). Under normal conditions (including refueling outages), appropriate management of the plant water inventory and efficient treatment negates the need for aqueous radioactive liquid waste discharges to the environment, with all treated water being recirculated for use across the plant. Skid-mounted treatment equipment is employed to allow for operational flexibility and optimisation to meet the needs of the plant.

Typically, the need to introduce additional clean water is balanced by evaporative losses to the environment from the pools associated with the reactor (Section 4.2.11.5).

During off-normal conditions that result in the requirement to treat water that may not be suitable for recirculation (for example significant oil or chloride contamination), the effluent treatment systems will reduce radioactivity to levels that are As Low As Reasonably Achievable (ALARA) prior to discharge to the environment via the normal heat sink, currently assumed to be the sea or ocean based on the proposed coastal generic site location. This supports several BAT claims and arguments relating to the prevention/minimisation of radioactive waste generation and discharges described in Per Chapter E6 (Reference 4-5).

4.1.3 Sustainability

The above philosophies also demonstrate consideration of sustainability in the design, which is ultimately at its core, as it supports the generation of low carbon electricity. For example, modularisation, through the use of prefabricated and pre-assembled structures, has numerous sustainability benefits, such as reducing material usage and waste. The RP plans to strategically employ modularisation, drawing upon experience and lessons learned from recent works such as the Advanced Boiling Water Reactor (ABWR) (Modularization Strategy Report (Reference 4-13)). NEDC-34228P, “BWRX-300 UK GDA Integrated Waste Strategy,” (IWS) (Reference 4-18) provides additional examples of how the design demonstrates alignment with sustainability principles throughout, notably aligning with the United Nations’ Sustainable Development Goals.

4.2 Main Plant and Systems

4.2.1 Plant Buildings and Structures

This section provides concise descriptions of the main plant buildings and their primary functions, as well as the systems that are housed within each. Figure 4-1 provides an overview of the plant layout with proposed locations of each of the buildings and structures (taken from 008N0279, “BWRX-300 Design Specification for Radwaste Building Structure,” (Reference 4-19)). As the RP aims to deploy a modular construction approach for many of the structures and assemblies used across the plant, this provides flexibility to optimise plant layout. As such, the plant layout may be subject to change during the site-specific design phase (FAP.PER4-215).

Structures and systems are also designed with longevity in mind. The plant is designed to operate for 60 years without the need for replacement of pipework or vessels. This is reflected in material choice and operating parameters (note that these will not be described here).

Further information is provided in PSR Chapter 9B (Reference 4-12).

4.2.2 Reactor Building

The Reactor Building (RB) structure is a cylindrical-shaped building that is deeply embedded below grade (006N7823, “BWRX-300 Primary Containment System,” (Reference 4-20)). The structure is primarily constructed of pre-assembled diaphragm plate steel-plate composite modules. These modules enable simpler and greater flexibility during construction. They use a lower volume of concrete than standard reinforced concrete blocks that are typically used in RB construction, as they offer an increased shielding capability. They also achieve high strength and ductility and demonstrate improved resistance to bending and shear loads (Modularization Strategy Report (Reference 4-13)).

The primary functions of the RB are (006N6987, “BWRX-300 Reactor Building Design Specification,” (Reference 4-21)):

- To house and structurally support the Reactor Pressure Vessel (RPV), containment structure, reactor support structures, fuel handling equipment, biological shielding, and any associated equipment and structures
- To provide adequate space for operation, maintenance, and removal of equipment housed within the containment structure during periodic maintenance
- To provide protection for equipment from environment and natural hazards, as well as internal and external hazards
- To support habitability functions of the Secondary Control Room (SCR), such as radiological shielding, toxic gas isolation, and passive cooling for occupancy

The RB consists of the following main systems supporting power generation:

- Nuclear Boiler System (NBS), including RPV
- Isolation Condenser System (ICS)
- Control Rod Drive System (CRD)

Which are supported by the following water cooling and cleanup systems:

- Isolation Condenser Pools Cooling and Cleanup System (ICC)
- Reactor Water Cleanup System (CUW)
- Fuel Pool Cooling and Cleanup System (FPC)
- Condensate Filters and Demineralisers (CFD) (note this is situated in the Turbine Building (TB))

The following systems will only operate in specific circumstances, such as during shutdown or emergencies:

- Boron Injection System (BIS)
- Shutdown Cooling System (SDC)
- Refueling and Servicing Equipment

4.2.3 Turbine Building

The TB, as with the RB, is to be predominantly constructed of pre-assembled diaphragm plate steel-plate composite modules and is situated above grade (see the Modularization Strategy Report (Reference 4-13)). It houses the following main systems, which are critical to safe operation and power generation:

- Main Turbine Equipment (MTE)
- Main Condenser and Auxiliaries (MCA)
- Condensate and Feedwater Heating System (CFS)
- Circulating Water System (CWS)
- Plant Cooling Water (PCW)

The Offgas System (OGS) also has a number of components situated within the TB. The components are the Offgas Recombiner, Cooler Condenser, Moisture Separator, Refrigeration Dryers, and Gas Analysers.

4.2.4 Radwaste Building

The Radwaste Building (RWB), which may be constructed of diaphragm plate steel-plate composite modules or using conventional building methods (to be determined during site-specific design), is situated above grade, and houses the radioactive waste management systems for the plant (see the Modularization Strategy Report (Reference 4-13)). The systems circulate plant water through a treatment system to enable re-use in the power generation cycle, facilitate discharge to the environment (if necessary, as during normal operation there are no expected aqueous radioactive discharges) or collect and prepare wastes for disposal. The RWB houses the following systems:

- Liquid Waste Management System (LWM) – Collection and Filtering, and Waste Sampling subsystems
- Solid Waste Management System (SWM)
- OGS – Offgas Reheater, Charcoal Vault, and High Efficiency Particulate Air (HEPA) filter
- Chilled Water Equipment ((CWE), situated on the RWB roof)

The RWB also houses the Chemistry Laboratory which supports sampling analyses. It is used to prepare and analyse all grab samples taken across the plant, as well as samples from some external systems and tanks if not analysed in a laboratory outside the Radiologically Controlled Area (RCA) (007N3673, “Chemistry Laboratory Requirements,” (Reference 4-22)). It also provides backup analytical capability for inline instrumentation in the event of failure. The laboratory is supported by a counting room which provides activity measurements for isotopic analyses. Further information is provided in PER Chapter E8 (Reference 4-7). Examples of chemicals and instruments that may be used are provided in the Chemistry Laboratory Requirements (Reference 4-22).

4.2.5 Control Building

The Control Building (CB) is to be constructed using conventional building methods (no modules or assemblies), as described in the Modularization Strategy Report (Reference 4-13), and houses the Main Control Room (MCR) and electrical (including batteries and uninterruptible power supplies), control, and instrumentation equipment (see 006N5991, “BWRX-300 Plant Architecture Definition,” (Reference 4-23)).

4.2.6 Service Building

The Service Building (SB) has a designated area for staging of new fuel and spent fuel casks to support refueling operations, an outage centre, and administrative areas such as offices, as depicted in 008N0988, “BWRX-300 Power Block General Arrangement,” (Reference 4-24).

4.2.7 Perimeter Buildings

Several perimeter buildings are situated around the exterior of the TB and RWB, predominantly housing power equipment and services to the plant. This includes two Standby Diesel Generators (SDG), batteries, switchgear, and service air.

Outside the TB, one perimeter building houses two key components of the LWM – the Condensate Storage Tank (CST) and the Refueling Water Storage Tank (RWST). These are described in Section 4.2.15.1.

4.2.8 Yard

The yard area interfaces with off-site services, such as municipal water supplies and mobile trailers, and emergency response equipment (such as diesel and firewater storage tanks). The off-site services are connected to the relevant plant system from the yard.

4.2.9 Common Building Systems

A number of systems are distributed among all buildings, or where there is a specific need in the interest of safety and/or the environment. These are:

- Heating, Ventilation and Cooling System (HVS), which creates habitable conditions for plant rooms, and provides ventilation and exhaust pathways for both radiological and non-radiological areas (including environmental protection functions where required). It is directly related to the OGS.
- Equipment and Floor Drains System (EFS), which routes vessel overflows and leakage, as well as radioactive and non-radioactive (potentially non-aqueous and hazardous) liquid to segregated sumps (to maintain containment and prevent cross--contamination) for onward management by the LWM and SWM.
- Process Radiation and Environmental Monitoring System (PREMS), which provides the means to monitor operations via in-line instrumentation, as well as via sampling stations.
- Fire Protection System (FPS), which prevents, contains, and mitigates the effects of fires to protect personnel, the public, and the plant through fire protection measures such as sprinklers and fire hydrants.
- Plant Pneumatic System (PPS), which provides a supply of air to key equipment and components across the plant.

4.2.10 Primary Containment System

The primary containment is a Steel-Plate Composite Containment Vessel (SCCV), constructed using diaphragm plate steel-plate composite modules situated within the RB. It is a vertical cylinder approximately 17.5 meters in diameter and 38 meters high. The SCCV encompasses the RPV and its pedestal, bioshield, and all associated piping, equipment, and support structures (Figure 4-2), as described in the Primary Containment System (PCS) SDD (Reference 4-20).

The SCCV is an Engineered Safety Feature (ESF) for radiation protection and a physical, leak-tight barrier to protect against radiological releases from the NBS (Figure 4-3). It is the third fission product barrier (preceded by the fuel cladding and reactor coolant pressure boundary (RCPB)) and is floodable to ensure retention of core melt through the RPV in an emergency. It is designed in such a way that ensures the environmental impact of any radioactive release from the plant is reduced to levels that are ALARA and below the authorised limits for discharges.

Additional design features of the PCS include:

- A nitrogen-inerted containment atmosphere during operation (provided by the Containment Inerting System (CIS)), and the ability to purge with air for access during outages. This dry containment eliminates the need for a suppression pool
- Minimising the number of containment penetrations
- Providing Containment Isolation Valves (CIVs) external to the SCCV for containment penetrations
- Providing means for leak testing of penetrations and the PCS
- Creating a liquid-tight barrier between the open reactor vessel and upper containment during refueling activities

Further information is provided in PSR Chapter 6 (Reference 4-10).

4.2.10.1 Containment Inerting System

The CIS maintains an inert nitrogen atmosphere within the primary containment during normal operation and it is effectively sealed. Its principal objective is to prevent the development of a combustible atmosphere (due to hydrogen accumulation in a severe accident condition) by maintaining an oxygen deficient atmosphere inside containment.

Nitrogen is supplied to the CIS from a liquid nitrogen storage tank skid situated in the yard (which also provides nitrogen to the PPS), prior to which it is vaporised and heated. Breathable air is also supplied from this line (downstream of the skid) during outages for personnel to enter containment once de-inerted by purging with air, if necessary.

It is important to note that containment exhaust flow is only active at the beginning and end of an outage (during purging operations) and is directed to the HVS and the Plant Vent Stack (PVS). All penetrations of the containment vessel that are part of the CIS are fitted with CIVs (006N7948, "BWRX-300 Containment Inerting System," (Reference 4-25)).

4.2.10.2 Containment Cooling System

The Containment Cooling System (CCS) performs the cooling function for the SCCV to maintain the containment bulk average temperature within the Environmental Qualification limits of the related equipment located inside containment (006N4761, "BWRX-300 Equipment Qualification Specification," (Reference 4-26)). It maintains a habitable temperature for plant personnel entering the containment during outages. It also assists with containment cooldown following a loss of offsite power and hot and cold shutdowns.

It is a closed loop air or nitrogen recirculating cooling system, with a system of ducts and dampers that distribute the gas as needed throughout the SCCV. The gas is cooled by Air Handling Unit (AHU) cooling coils (which are provided with chilled water from the CWE system). All condensate from containment cooling is removed from the bottom of containment to a pressurised sump, part of the EFS. Further detail on the CCS is provided in 006N7777, "BWRX-300 Containment Cooling System (CCS)," (Reference 4-27).

4.2.10.3 Passive Containment Cooling System

The Passive Containment Cooling System (PCCS) passively assists active containment cooling during normal operations but is not required to maintain acceptable normal operating containment temperature conditions, (see the PCS SDD (Reference 4-20)). The PCCS, consisting of three independent cooling trains (with water provided by the FPC equipment pool), is only effective if steam discharges into the containment, such as during a Loss-of-Coolant Accident (LOCA). Heat that is transferred to the PCCS from containment is subsequently transferred to the equipment and reactor cavity pools (part of the FPC), (see the PCS SDD (Reference 4-20)). There is no transfer of radioactivity to the pools in the event of a LOCA (closed loop arrangement).

4.2.11 Power Generation and Supporting Systems

The following are the main systems and components of the primary circuit, which contribute directly to or support power generation. All are situated within the RB, some of which are solely located within the primary containment, while others extend beyond and interface with a number of other systems across the plant.

4.2.11.1 Reactor Core and Fuel

The reactor core is located within the core shroud of the RPV (Section 4.2.11.2) containing Global Nuclear Fuel GNF2 fuel assemblies, which are used as they have low hydraulic resistance, benefitting natural circulation (Figure 4-4). A total of 240 fuel bundles (consisting of zircaloy-clad fuel rods and spacers) are used, each containing a 10x10 array of 78 full-length fuel rods, 14 part-length fuel rods and two large central water rods (to increase moderation). Some full-length rods contain gadolinia to control excess reactivity (NEDC-34041P, “BWRX-300 GNF2 Fuel Assembly Mechanical Design Report,” (Reference 4-28)).

The zircaloy cladding on the fuel rods is considered the primary fission product barrier, preventing the release of radioactivity. The inclusion of part-length fuel rods in the design of the fuel bundles increases the efficiency of the fuel. Surrounding the fuel bundle is a zircaloy channel which provides a well-defined coolant flow path through the bundle. It is anticipated that the BWRX-300 fuel channels will be similar to those used in the UK ABWR, approximately 4.3 m long and 15 x 15 cm, as described in GA91-9901-0022-00001, “UK ABWR Generic Design Assessment: Radioactive Waste Management Arrangements,” (Reference 4-28).

Lower tie plates are designed to promote seating into the orificed fuel supports and are fitted with a debris filter to prevent foreign material entering the flow channels and potentially damaging the fuel cladding. Spacer grids are distributed throughout to maintain fuel rod spacing. The upper tie plate is also a spacer grid and provides the fuel bundle lifting handle for fuel handling and refueling operations.

The fuel is designed in such a way to minimise the probability of fuel failure and leakage. Strict controls on reactor water chemistry are also employed to minimise the likelihood that the fuel will fail. In addition, the various cleanup systems employing filters and/or demineralisers across the plant remove any particulates and dissolved contaminants that are generated during power operation, further protecting the fuel as plant water is recirculated. Further discussion on fuel design and process fluid cleanup mechanisms is presented in PER Chapter E6 (Reference 4-5).

The low core power density compared with previous BWRs, enhanced natural circulation flow due to the RPV height, and high feedwater (FW) temperature maintain thermal hydraulic stability for optimum operation. Further technical information is provided in PSR Chapter 4 (Reference 4-9).

4.2.11.2 Nuclear Boiler System

The NBS consists of three subsystems that support power generation. These are the:

- RPV
- Main Steam Lines (MSLs)
- RPV Instrumentation

4.2.11.2.1 RPV

The RPV is a vertical, cylindrical pressure vessel with a minimum inside diameter of approximately 4 m, a height of approximately 26 m and wall thickness of approximately 136 mm with cladding. The active core is 3.8 m high.

It forms a major part of the RCPB (which contains all pressure-retaining components such as the RPV, piping, and isolation valves), which is the second fission product barrier preventing the release of radioactivity generated within the reactor into the environment (although it does not prevent carryover of noble gases in the MSL) (Figure 4-5). The RPV contains the path for reactor coolant flow through the fuel and to generate steam to drive the turbines. Flow through the core is by natural circulation, enabled by a relatively large RPV volume and tall chimney region between the top of the core and steam separators above. This design enhances safety by reducing the rate at which reactor pressurisation occurs under accident conditions.

A substantial volume of water above the core, initially provided by FW flow, ensures that reactor water level is maintained at or is above the top of active fuel, and fuel cladding temperature is maintained within normal operating limits. In emergency situations, the ICS maintains this volume to ensure core cooling (006N7828, "BWRX-300 Nuclear Boiler System," (Reference 4-30)). Further information is provided in PSR Chapter 4 (Reference 4-9).

4.2.11.2.2 RPV Internals

The internal components of the RPV are briefly described below from bottom to top and can be seen in Figure 4-6. More detailed information is provided in PSR Chapter 4 (Reference 4-9).

Equipment predominantly associated with the control rods is housed below the reactor core. CRD housings, which support the weight of the CRD system components (Section 4.2.11.3) and four fuel assemblies, are located at the very bottom. Control rod guide tubes provide a means of guiding the control rods into and out of the bottom core plate, and channel water to the rods whilst moving. Orificed fuel supports ensure proper alignment of the control rod blades during operation. The shroud support provides vertical and lateral support for the shroud (which also provides horizontal support for the core) and upper components such as chimney and steam separators.

At the bottom of the reactor core is the core plate, providing vertical and lateral support for the fuel assemblies, control rods, and instrumentation. It links the shroud and shroud support together. At the top of the reactor core is the top guide, providing further lateral support for the fuel assemblies, control rods, and instrumentation.

Bolted to the top guide is the chimney, which forms an annulus with the shroud, separating the subcooled recirculation downward flow (from the steam separators and FW makeup) from the upward steam-water mixture flow exiting the core. The chimney height ensures natural circulation is sustained without the need for forced circulation via pumps.

The chimney head and steam separator assembly form the top of the core discharge mixture plenum. This plenum provides a mixing chamber to homogenise the steam/water mixture before it enters the steam separators. Individual axial flow steam separators (consisting of standpipes and vanes) have no moving parts. Separated water returns to the downcomer annulus for recirculation into the core.

Steam dryers remove any remaining moisture from the steam prior to it exiting the reactor and entering the main steam lines towards the turbine. The moisture content of the exiting steam is lower than 0.1 % at full reactor power.

At the very top of the RPV is the head vent, which under startup and normal conditions, transports steam and non-condensable gases to one of the main steam lines. The non-condensable gases are subsequently routed to the main condenser (NBS SDD(Reference 4-30)).

4.2.11.2.3 Reactor Isolation Valves

All RPV nozzles for medium and large bore penetrations including the associated Reactor Isolation Valves (RIVs) are situated a minimum of 4 m above the top of active fuel. These are located on the outside of the RPV (Figure 4-7), two in series, and are fitted on the main steam subsystem, CUW (which takes suction from the internal drains at the RPV bottom head), condensate supply and return lines of the ICS, RPV head vent, and FW lines. Each RIV is able to operate independently and can automatically isolate a line. They are a critical part of the overall medium and large break LOCA mitigation strategy (minimisation of coolant loss by isolating the entire reactor).

Most RIVs fail closed, except the ICS condensate supply and return lines which fail as-is (normally open), as the ICS protects the reactor core during off-normal conditions. These RIVs will close if a break in an ICS train is detected to prevent loss of coolant (NBS SDD (Reference 4-30)).

4.2.11.2.4 MSLs

Two MSLs are routed from the RPV through RIVs and CIVs (which provide isolation of these lines for line breaks) towards the turbines (Section 4.2.12.1). A portion of the main steam is distributed to the CFS (Section 4.2.13.2), the Moisture Separator Reheater (MSR, Section 4.2.12.3), and the Turbine Gland Seal Subsystem (TGSS, Section 4.2.12.1) during normal operation. MSL drain lines provide the ability to drain condensate from the main steam lines to the condenser during operation (NBS SDD (Reference 4-30)).

4.2.11.2.5 RPV Instrumentation

Core instrumentation consists of Local Power Range Monitors (LPRMs), Gamma Thermometers (GTs) and Wide Range Neutron Monitors (WRNMs).

There are 13 vertical “strings” of LPRMs arranged radially throughout the core, with each string consisting of four vertically and equally spaced LPRMs, for a total of 52 LPRMs. Each detector provides neutron monitoring sensitivity from approximately 10 % to >100 % reactor thermal power.

GTs are axially located next to each of the four LPRMs in each string, converting local gamma flux (representative of core thermal power) to an electrical signal. There are eight GTs in each LPRM string for a total of 104 GTs. The LPRMs and GTs are located within wet in-core guide tubes.

There are 10 WRNMs within the core at fixed heights. Each detector is sensitive to neutrons from fluxes below criticality to greater than 100 % thermal power. Each detector is located in a dry tube.

Aside from neutron flux measurements, the NBS is supported by additional instrumentation that measures reactor water level, pressure, temperature, core flow, and main steam flow and pressure (NBS SDD (Reference 4-30)). The in-core instrumentation arrangement is shown in Figure 4-8. Further information is provided in PSR Chapter 7 (Reference 4-11) and PER Chapter E8 (Reference 4-7).

4.2.11.3 Control Rod Drive System

The 57 GEH control rods, which are manufactured from boron carbide or hafnium (with minimal niobium impurity), are neutron absorbing components which provide negative reactivity into the core to allow for the control of reactor power. They are cruciform shaped elements occupying alternative spaces between fuel assemblies through the core (Figure 4-9). Low cobalt stainless steel or nickel alloys are utilised for the control rod blades to minimise neutron activation as far as reasonably practicable. Four fuel assemblies in a cell provide guidance for the insertion and withdrawal of the control rod. The control rods are cooled by core leakage flow to remove heat generated by neutron and gamma absorptions, as described in 006N7898, “BWRX-300 Control Rod Drive,” (Reference 4-32). Further detail is provided in NEDC-34167, “BWRX-300 Ch. 5: Reactor Coolant System and Associated Systems,” (Reference 4-33).

The Control Rod Drive (CRD) system consists of Fine Motion Control Rod Drives (FMCRD) to provide control rod positioning within the core, hydraulic control units (HCUs) to provide a diverse source of stored energy for fail-safe emergency control rod insertion (scram), and a hydraulic subsystem responsible for the distribution of High Pressure (HP) water in support of normal operation and scram (005N9751, “BWRX-300 General Description,” (Reference 4-32)).

There are 57 FMCRDs, one provided for each control rod, mounted in control rod housings welded into the RPV bottom head (Figure 4-10). Each FMCRD has a movable, hollow piston that is coupled to the bottom of a control rod, to provide fine motion motor control of the rod’s position inside the core. This allows for axial positioning within the core and withdrawal into control rod guide tubes below the core.

There are 29 HCUs, each of which provide sufficient pre-charged accumulator water storage to scram two FMCRDs at any reactor pressure, except for the FMCRD in the centre of the core, which has its own HCU. Each HCU is a collection of skid-mounted equipment including a scram water accumulator, nitrogen bottle, scram valves, and panels to manage the flow of charging and purge water from the Control Rod Drive Hydraulic subsystem.

The CRD Hydraulic Subsystem includes a pair of HP pumps that deliver water supplied from the CST and CFS to the HCUs. These pumps are fitted with disposable element filters on the suction side and cleanable element filters on the discharge side to prevent foreign material and particulates entering the HCUs or FMCRDs. A purge water header provides a continuous supply of purge water to the FMCRDs to provide cooling. This purge water flows into the reactor, adding to the overall reactor coolant inventory. A charging water header provides water to the scram water accumulators. This subsystem is also a source of pressurised water for purging the SDC pump seals and the NBS reactor water level reference leg instrument lines.

Vent and drain lines are provided at high and low points within the hydraulic piping system and these are routed to the HVS and EFS, respectively. Instrument air provided by the PPS to the scram valves can also be vented to local HVS exhausts (CRD SDD (Reference 4-32)). Further detail is provided in NEDC-34167, “BWRX-300 UK Chapter 5: Reactor Coolant System and Associated Systems,” (Reference 4-33).

4.2.11.4 Isolation Condenser System

The Isolation Condenser System (ICS) consists of three independent trains, each containing a heat exchanger (or Isolation Condenser (IC)) submerged in a pool of water and connected to the RPV by steam supply and condensate return piping (Figure 4-11). The ICS removes heat from the reactor coolant (steam) by transferring it to the water in the pools through the heat exchanger tubes, maintaining radiological containment. The three pools are the ultimate heat sink for protecting the reactor core when the main condenser is unavailable and the RPV becomes isolated. It is also an emergency core cooling system that provides RPV overpressure protection.

IC heat removal capability is proportional to steam supply pressure. The steam is condensed on the tube side of the heat exchangers and is returned back to the RPV chimney section in a closed loop. The ICs are placed at an elevation above the steam source, creating a natural circulation effect that is driven passively by gravitational force. The IC pools are vented to atmosphere (while being monitored for radiation).

Subcooled condensate return to the RPV chimney results in a steam quenching effect, as well as lowering the pressure at the exit of the reactor core. If RPV conditions fall below the saturation point, the ICS idles until decay heat drives conditions back to saturation, automatically coming back into operation.

Condensate flow is controlled by two condensate return valves installed in parallel within the condensate return line. Both condensate return valves are normally closed, fail-open valves which are each rated for the full design flow rate of the train. The valve designs are diverse from one another to eliminate the possibility of a common cause failure that could prevent an ICS train from initiating. The condensate return piping for each train is fitted with a loop seal (Figure 4-12) to prevent steam bypass directly from the chimney region of the RPV to the IC (preventing reverse flow up the condensate return line).

Non-condensable gases that may accumulate within an IC are either removed by purging during system standby to the NBS main steam lines or neutralised by catalytic recombination during system operation. The condensate within each catalytic recombiner drains away, allowing hydrogen and oxygen to be converted to water. The remaining non-condensable gases are abated by a separate gaseous effluent treatment system, the OGS (Section 4.2.15.3).

One ICS train is necessary to mitigate an Anticipated Operational Occurrence and can provide reactor decay heat removal for 72 hours without operator action. Two trains are required for LOCA mitigation (as a result of a large line break and isolation of the RPV) to protect the integrity of the RCPB. Two trains can sustain decay heat removal for seven days without any operator involvement, and longer with IC pool inventory replenishment via mobile water sources.

In off-normal conditions, ICS Trains A and B provide the SDC with a supply flow path to the chimney. The BIS supplies Train C of the ICS with an enriched boron solution which is injected into the reactor chimney (006N7492, “BWRX-300 Isolation Condenser System,” (Reference 4-34)).

4.2.11.5 Isolation Condenser Pools Cooling and Cleanup System

The ICC processes water from the IC pools to maintain water temperature within design limits and purifies the water to the required reactor quality (006N6766, “BWRX-300 Water Quality,” (Reference 4-36)). The pools containing the IC heat exchangers which are cooled by the PCW system. Each pool is dedicated to one ICS train and is physically separated from other pools by structural partition walls (Figure 4-13).

The system is supported by a single integrated, skid-mounted demineraliser that removes soluble and insoluble impurities, including fine particulates, from the IC pool water. This water is cooled by a set of heat exchangers prior to treatment and is sampled and monitored pre- and post-demineraliser to determine resin media effectiveness. The demineraliser can be isolated to allow for resin exchange, as well as for maintenance operations (such as chemical introduction to the IC pools and ICC system to inhibit corrosion and biological activity). Spent ion exchange resins are transferred to the SWM spent resin tank using demineralised water. Compressed air is utilised to redistribute the resin bed and assist in discharging spent resin to the SWM.

The ICC has overall responsibility for the water in the IC pool compartment structure. To ensure continuous safe operation in off-normal conditions, the IC pools can be replenished via a Diverse and Flexible Coping Strategies/Emergency Mitigation Equipment (FLEX/EME) connection that is external to the RB, which can be used as a long-term makeup water supply. Pool makeup conduits also supply makeup water passively between pools during off-normal conditions. The IC pools also contain suction surge tanks and a return guard pipe which prevent the draining of the pools in the event of a break in piping below the IC pools.

The IC pools are equipped with atmospheric vents, which are sized appropriately to provide a means of heat rejection and pressure minimisation (Figure 4-13). The vents are fitted with louvered covers and screens to prevent foreign material from entering the pools from the environment. They are also fitted with radiation detectors to inform personnel of a potential release of radioactivity to the environment (via the steam effluent) during extended IC deployment in off-normal conditions (i.e., as a result of ICS containment failure, described in Section 4.2.11.4). Further detail is provided in 006N7345, “Isolation Condenser Pools Cooling and Cleanup System,” (Reference 4-35).

4.2.11.6 Fuel Pool Cooling and Cleanup System

The Fuel Pool Cooling and Cleanup System (FPC) provides continuous cooling of the water volume in the fuel pool to remove decay heat from SF and irradiated in-core components (IICCs), as well as providing replacement coolant inventory (predominantly from the CST, but also from the FPS or a FLEX/EME connection during off-normal conditions). This ensures SF and IICCs are submerged and cooled until decay heat has reduced and relocation to an on-site interim storage facility (and eventual disposal to a Geological Disposal Facility (GDF)) is possible.

Two cross-connected surge tanks can receive water from the fuel, reactor cavity, and equipment pool weirs and skimmers along the perimeter of the pools. Each surge tank discharges to individual trains to allow for particulate filtration, before passing through a common single, skid-mounted deep bed demineraliser to maintain coolant quality and reduce general area dose.

Demineraliser discharge is then split back into two trains, where it passes through two sets of two heat exchangers (cooled by the PCW system) and subsequently returned to the relevant pool. Spent resin and filter backwash sludge are transferred to the SWM using condensate from the CST.

During normal operation, the reactor cavity and equipment pools are merged as a single volume with a fuel pool gate installed. During refueling, the fuel pool gate and equipment pool gate are open or closed as necessary to facilitate removal of the containment and RPV heads and transfer of fuel between the SF and reactor core.

During off-normal conditions, the FPC provides a heat sink for the PCCS which exchanges heat with the equipment pool and reactor cavity pool in the event of pipe breaks inside containment. It also provides a heat sink and scrubbing (water being used to reduce the source term of any gaseous radioactive release) to the CIS over-pressure protection line. Further detail is provided in 006N7941, “BWRX-300 Fuel Pool Cooling and Cleanup System,” (Reference 4-37).

4.2.12 Turbines and Related Systems

4.2.12.1 Reactor Water Cleanup System

The CUW provides blowdown-type cleanup flow for the RPV during normal operation. Reactor water is extracted from the bottom region of the RPV (see Figure 4-5) and then passes through the CUW regenerative heat exchanger situated in the TB. The CFS provides cooling flow to the regenerative heat exchanger to reduce the temperature of the inlet flow (one percent of the overall FW flow) below 100 °C prior to it entering the CFD system (Section 4.2.13.3). By utilising this regenerative heat exchanger, heat from the CUW is transferred to the condensate returning to the reactor, losing almost no thermal value.

Cleanup, using filtration and demineralisation, is performed by the CFD system to remove any particulates and dissolved contaminants that are present in the reactor water. CUW is therefore deemed one of the most important systems for maintaining reactor water quality as it allows for feedwater to be cleaned and recirculated, reducing overall water usage (006N6766 (Reference 4-36)).

CUW also provides an overboarding flow path to the main condenser hotwell or LWM directly from the RPV lower region if vessel level or temperature is too high. Further detail is provided in 006N7609, “BWRX-300 Reactor Water Cleanup System,” (Reference 4-38).

4.2.12.2 Main Turbine Equipment

The Turbine Generator (TG) uses a 3000-rpm turbine and consists of a single-flow HP unit and two double-flow Low Pressure (LP) units in tandem (006N7717, “BWRX-300 Main Turbine Equipment (MTE),” (Reference 4-39)). This is used to convert steam energy into rotational motion, which the turbine subsequently converts into electrical energy. Steam flow from the NBS to the turbine is controlled through two Turbine Stop Valves (TSVs) and four Turbine Control Valves (TCVs). These valves also have the ability to isolate the main steam flow from the turbine under emergency conditions.

The TG is supported by a number of subsystems including:

- The **Turbine Gland Seal Subsystem (TGSS),** which supplies sealing steam to the turbine shaft/casing penetrations and to the valve stems of the main TSVs, TCVs, Turbine Bypass Valves (TBVs), and Intermediate Stop & Intercept Valves (also known as Combined Intercept Valves).
- The sealing steam is provided by the MSL or the HP turbine packing leakoff supply. During normal operation, the seal steam header is continuously drained to the main condenser via a low point drain to prevent buildup of water in the header. Gland sealing steam prevents the escape of radioactive steam and air in-leakage through sub-atmospheric turbine glands.
- Steam that is condensed in the Gland Seal Condenser (GSC) is routed to the main condenser via a loop seal to prevent air entrainment. The GSC exhaust is radioactive (containing non-condensable gases) and is routed to the HVS for eventual discharge via the PVS. Further information on the TGSS is provided in PER Chapter E6 (Reference 4-5).
- The **Turbine Lube Oil Subsystem (TLOS)**, which provides all of the lube oil required by the turbine and generator bearings, couplings, and turning gear during all modes of operation. The TLOS also provides jacking oil to lift the turbine when the turbine is below the rated speed. The TLOS is supported by a lube oil skid, which conditions, supplies, and manages lube oil throughout operation. Additional information is provided in Section 4.3.3.3.
- The **Extraction Steam Subsystem (ESS)**, which provides the means to transport extraction steam from the HP turbine to the MSR first stage reheater, as well as the FW heaters for regenerative FW heating and to protect the steam turbine against overspeed and water induction.
- The **Electro-Hydraulic Controls (EHC)** subsystem, which provides high-pressure hydraulic fluid to actuate the actuators on the TSVs, TCVs, TBVs, and Combined Intercept Valves. It is also used to actuate the trip devices in the trip and overspeed protection circuits for the turbine. The EHC system is supported by a control oil skid, which supplies, conditions, and manages hydraulic control fluid throughout operation (C (Reference 4-38)). Additional information is provided in Section 4.3.3.4.

4.2.12.3 Moisture Separator Reheater

The MSR receives steam from the HP turbine exhaust which is dried and subsequently reheated via a two stage reheater (using turbine extraction steam and main steam for the first and second stage reheater, respectively) before being redirected to the LP turbines.

All entrained moisture removed from the steam lines is drained and returned to the main condenser. The condensate that is removed in each section of the reheater is drained to drain tanks and routed to FW heaters to improve cycle efficiency (or to the main condenser in case of tank overfill). Drain tanks are fitted with vent lines back to the MSR to allow for flash steam discharge. Reheater tube bundles are fitted with vent lines to ensure continuous removal of non-condensable gases and steady condensate removal with minimum subcooling (006N7745, “BWRX-300 Moisture Separator Reheater System,” (Reference 4-40)).

4.2.12.4 Turbine Bypass System

The Turbine Bypass System (TBS) provides the capability to discharge steam from the reactor directly to the main condenser, minimising step load reduction transient effects on the NBS. During normal operation, the TBVs are closed, but may be opened to assist in plant heat-up, cooldown, turbine trips, and load rejection to maintain reactor pressure. The TBS is supported by the TGSS which prevents the escape of steam from the TBV stems, and the EHC subsystem which provides HP hydraulic fluid for actuation of the TBVs (006N7749, “BWRX-300 Turbine Bypass System (TBS),” (Reference 4-41)).

4.2.13 Condensate and Feedwater Systems

4.2.13.1 Main Condenser and Auxiliaries

The main condenser is the heat sink for the steam cycle. It consists of two condenser shells located beneath the LP turbines, which receive exhaust steam from these turbines and the TBVs (when in use). The main condenser is also the collection point for the turbine bypass steam, MSR drains (and non-condensable gases), feedwater heater drains and vents, and SDC and CUW overboard flow. It will also receive other steam cycle relief valve discharges, drains, and vents (Figure 4-14).

The main condenser also serves as a collection and removal point for air inleakage and non-condensable gases, such as hydrogen and oxygen, entrained in the steam exhausts. During startup, vacuum pump skids (cooled by the PCW) are used to draw initial condenser vacuum and exhaust gases to the HVS. During normal operation, Steam Jet Air Ejector (SJAE) skids are used to maintain condenser vacuum and remove these gaseous species from the main condenser (supplied with steam from the TGSS). These species are exhausted to the OGS for treatment.

Steam is condensed in the main condenser (cooled by the CWS) and de-aerated, providing holdup for ^{16}N decay. The external surfaces of the condenser tubes are in constant contact with the reactor coolant, and as such they are manufactured from low cobalt material to minimise corrosion as far as reasonably practicable. The condensate drains into cross-connected hotwells, where from here it is routed to the condensate pumps for cleanup and re-use in the power cycle (through the CFD and CFS). The hotwell (and vacuum pumps) may also drain to the EFS, if necessary. Further details of the MCA are provided in 006N7757, “BWRX-300 Main Condenser and Auxiliaries System,” (Reference 4-42).

In the case of minor condenser tube failure, cross-contamination of the condensate with cooling water (containing, for example, chloride and water treatment chemicals) could occur. The main condenser hotwell acts as a surge volume, whilst the CFD system can continue to remove dissolved contaminants and particulates to maintain reactor water quality. In the event of large tube breaks, CFD permits a reasonable amount of time to allow for plant shutdown (006N7741, “BWRX-300 Condensate Filters and Demineralizers (CFD),” (Reference 4-43)).

4.2.13.2 Condensate and Feedwater Heating System

The CFS supplies FW to the RPV at the required pressure, temperature, and flowrate to maintain RPV level in the required band. There are two separate systems working in tandem to prepare condensate/FW for use in the reactor.

4.2.13.2.1 Condensate System

Condensate from the MCA hotwell is initially transferred via the condensate pumps to the CFD system for cleanup (described in Section 4.2.13.3). Once water quality requirements are met, the primary route for condensate is for FW provision, although the CFS also provides clean condensate (as cooling water) for use in the following other systems:

- CUW Regenerative Heat Exchanger (rejecting heat from the reactor water back to the CFS)
- SJAE skids
- OGS Condenser
- Turbine Gland Seal Condenser

For FW provision, condensate passes through a number of FW heaters (two sets of LP FW heaters arranged in parallel, followed by a third, single LP FW heater) to the FW pumps which deliver water into the RPV.

The addition of zinc and hydrogen into the FW (for radiation dose management and chemistry control) is made prior to the water passing through a second set of HP FW heaters (three in series). At the exit of the final feedwater heater, feedwater should be suitable for use in the NBS. In some cases, a noble metal solution may be added prior to entry into the primary containment to assist water chemistry control in the reactor.

In shutdown scenarios, the SDC return interfaces with the CFS downstream of the Online NobleChem™ (OLNC) system addition port, to complete a closed cooling loop for decay heat removal (006N7737, "BWRX-300 Condensate and Feedwater Heating System," (Reference 4-44)).

General Electric Zinc Injection Passivation System

A stream of water downstream of the FW pumps is taken and passed through a dissolution column containing depleted zinc oxide pellets (part of the General Electric Zinc Injection Passivation (GEZIP) system) and returned upstream of the pumps for blending with the main FW flow. Zinc ions are continuously injected into the FW so that they can be deposited on the surface of the fuel, all wetted reactor components, and the inner surfaces of external piping, to reduce out of core shutdown dose rates (007N4013, "BWRX-300 Zinc Injection Passivation," (Reference 4-45)).

Hydrogen Water Chemistry System

Similarly, just prior to the FW pumps, the Hydrogen Water Chemistry (HWC) system injects hydrogen to mitigate Intergranular Stress Corrosion Cracking (IGSCC) of the reactor internals. The presence of excess hydrogen drives the recombination of hydrogen and oxygen in the vessel core region, resulting in a reduction of oxidising species in the reactor coolant.

Hydrogen addition to the feedwater also results in an excess ratio of hydrogen to oxygen at the entrance to the OGS from the Main Condenser. The HWC system must therefore inject air prior to the Offgas Recombiner to consume this excess hydrogen, in order to maintain a controlled percentage of oxygen at the recombiner exit. Gaseous species concentrations are monitored by the PREMS. Further details of the HWC are provided in 006N8027, "BWRX-300 P73 Hydrogen Water Chemistry System," (Reference 4-46).

On-Line NobleChem™ System

The HWC system is supported by the skid mounted OLNC system (introduced downstream of the final FW heater), which injects a noble metal solution to the reactor coolant flow path. The noble metals deposit on the reactor internal surfaces to catalyse the recombination of free hydrogen and oxygen to prevent IGSCC (006N7535, "BWRX-300 On-Line NobleChem™" (Reference 4-47)).

4.2.13.2.2 Feedwater Heating

High Pressure Feedwater Heaters

A cascading system of FW heaters is used to control FW temperature, receiving heat from various sources, as follows:

- HP FW Heater 6 – the CFS modulates a control valve so that HP FW Heater 6 receives the required volume of steam from the NBS. The FW then enters the RPV for use in the NBS.
- HP FW Heater 5 – the resulting condensate from Heater 6 cascades to Heater 5 (and so on), receiving steam from the HP turbine extraction and the MSR second stage reheater drain tank for heating.
- HP FW Heater 4 – the cascading condensate is also heated by the HP turbine extraction steam, as well as the MSR first stage reheater drain tank.

Low Pressure Feedwater Heaters

Condensate exiting the final HP FW heater cascades to the set of LP FW heaters:

- LP FW Heater 3 – receives condensate from the HP FW heater cascade and also receives additional heat from the LP turbine extraction steam and the MSR drain tank.
- LP FW Heater 2A, 1A and 2B, 1B – two sets of cascading heaters are arranged in parallel receiving condensate from heater 3. Heaters 2A and 2B drain into 1A and 1B, respectively. All FW heaters are provided additional heat from the LP turbine extraction steam.

The CFS continuously vents vapour and non-condensables from the closed FW heaters to the MCA system. Condensate drains for all HP and LP FW heaters are also routed to the MCA for re-use (CFS SDD (Reference 4-44)).

4.2.13.3 Condensate Filters and Demineralizers

The CFD system purifies the condensate from the main condenser hotwell and reactor water from the CUW system, in order to maintain reactor FW purity (Figure 4-15). The system includes three filter vessels with high efficiency backwash-type filter elements arranged in parallel to remove suspended solids (including corrosion products).

There are also three mixed, deep bed demineralisers arranged in an identical arrangement using ion exchange resin to remove dissolved solids from various condensate sources of impurities, such as the CUW, the CST, condenser tube leakage, and other impurities.

The CST provides water for resin transfer, washing, and filter backwashing. Spent resin and backwash sludges are transferred to the SWM. Drains and relief valve blowdowns are transferred to the EFS for processing.

The CFD system also includes auxiliary skids and tanks to assist in operation, condensate filters cleaning, and spent resin replacement (CFD SDD (Reference 4-43)). These include:

- A fresh resin addition hopper
- An air surge tank (to aid filter backwashing, resin mixing and valve operation)
- Resin traps (to prevent resin entering the power cycle)

- A rinse recycle pump skid

4.2.14 Shutdown Systems

4.2.14.1 Shutdown Cooling System

The primary objective of the Shutdown Cooling System (SDC) is to provide a decay heat removal pathway, in conjunction with the heat removal capacity of either the main condenser and/or the ICs, when shutting down the plant. It rapidly reduces RPV pressure and temperature from operating conditions to below saturation temperature at atmospheric pressure.

The system is also used to reduce reactor pressure vessel inventory during reactor startup. CRD purge water and excess reactor water volume arising from thermal expansion during heatup must be removed. SDC can also be used in conjunction with the CUW to reduce RPV thermal stratification during startup, caused by continuous input of cold CRD flow through the drives (006N7708, “BWRX-300 Shutdown Cooling System,” (Reference 4-48)).

4.2.14.2 Boron Injection System

The Boron Injection System (BIS) introduces sufficient negative reactivity into the reactor primary system in order to assure a reactor shutdown from the full power operating condition to the cold 20°C (68°F) subcritical state with no control rod motion.

It is entirely independent from the CRD system, assuring reactor shutdown (during startup or normal operation) by mixing a neutron absorber with the primary coolant. The neutron absorber is an aqueous solution of enriched sodium pentaborate decahydrate ($Na_2B_{10}O_{16}\cdot 10H_2O$), which acts as a neutron poison, halting the fission process. It is only used as a diverse and independent, manually initiated emergency backup to normal reactor shutdown systems (e.g., control rod insertion), with the capability of holding the reactor subcritical under cold conditions.

The system is designed to prevent unintentional or accidental injection of the solution. The BIS is also isolated from the EFS floor drains with its own separate sump, to allow for hazardous waste management and disposal. This avoids boron entering the primary circuit and the need for extensive cleanup. Further detail on the BIS is provided in 006N7417, “Boron Injection System,” (Reference 4-49).

4.2.15 Waste Management and Related Systems

4.2.15.1 Liquid Waste Management System

The Liquid Waste Management System (LWM) uses the latest purification technologies to treat plant water to meet the reactor water quality specification (BWRX-300 Water Quality (Reference 4-35)). This allows all treated water to be recirculated for various uses across the plant, enabling the plant to operate on a maximum recirculation basis during normal operations (including routine refueling outages). This demonstrates effective application of the waste hierarchy by minimising waste generation.

Drained plant water is predominantly transferred to the LWM for treatment from the EFS, which collects water from the majority of other systems across the plant (e.g., via overflow lines and drains). Oily wastes are collected in segregated sumps, transferred to drums and managed separately, as described in PER Chapter E5 (Reference 4-2).

The LWM consists of multiple subsystems, normally operating on a batch basis (006N7729, “BWRX-300 Liquid Waste Management System (LWM),” (Reference 4-50)), including:

- Waste Collection and Filtering
- Waste Sampling
- CST

- Refueling Water Storage and Cleanup

4.2.15.1.1 Waste Collection and Filtering Subsystem

All drained plant water required to be treated will be stored in two collection tanks until there is treatment capacity within the filtration skid downstream (Figure 4-16). Aside from the EFS, the collection tanks will also receive water from the RWST, downstream sample tanks, CUW, SDC overboards and SWM decant water.

Within the filtration skid, there are multiple components (which may be subject to change as the design evolves) that aim to remove soluble and insoluble contaminants. These skid-mounted components can be configured in such a way as to cope with various input water compositions, providing mitigation against potential upstream faults (such as foreign material ingress). This approach is consistent with that applied at the Tokyo Electric Power Company Fukushima-Daiichi site, which is considered Relevant Good Practice for the BWRX-300.

The skid-mounted components used in the filtration skid for abatement are:

- The **Sludge Consolidation Filter**, which is a disposable roughing filter, designed to remove the majority of the total suspended solids in the water. The filter elements can also absorb oils and greases that may be present in the influent, reducing downstream fouling of the filtration skid components.
- The **Pre-Conditioning Filter**, which uses granular activated carbon to absorb any heavy organics that pass through the Sludge Consolidation Filter.
- The **Ozone System**, which destroys any remaining organics to Parts Per Billion (PPB) levels. It also facilitates the processing of any chemicals and detergents that may enter the filtration skid.
- The first **Ion Exchanger** destroys any remaining ozone and softens the water prior to downstream processing. The Ion Exchange System consists of multiple vessels that use new or partially expended resin from the downstream Polishing Ion Exchanger to remove ionic impurities. This promotes more efficient downstream operation of the filtration skid.
- The **Reverse Osmosis System** removes approximately 95% of dissolved radioactive and non-radioactive contaminants and all colloidal matter. The Reverse Osmosis reject stream is recycled through the filtration skid.
- The **Polishing Ion Exchanger** polishes the reverse osmosis system permeate prior to return to the CST.

Solid wastes are sent to the SWM for further management and disposal (LWM SDD (Reference 4-50)).

4.2.15.1.2 Waste Sampling Subsystem

Treated water that passes through the filtration skid is then directed to two sample tanks, to identify whether the reactor water quality specification (006N6766 (Reference 4-36)), for re-use across the plant is met via laboratory analysis (Figure 4-17). The sample tanks may also receive overboarding flow from the SDC and CUW during startup or shutdown. Analysis of the water will take place in the chemical laboratory situated in the RWB. Examples of the analysis techniques that may be employed are described in 007N3673 (Reference 4-22). If water quality is deemed acceptable, the water can be transferred to the CST for re-use throughout the plant. If deemed unacceptable, water is recycled to the collection tanks to be re-processed through the filtration skid.

The plant is designed with sufficient water storage capacity to contain the volumes of water needed for the full range of activities undertaken during the normal operating cycle, including refueling outages. In the case that the plant's overall water inventory is too high, and the CST cannot accept treated water (such as during off-normal conditions), a line to transfer treated water to the CWS exists, where it is diluted and monitored via PREMS prior to discharge to the environment via the Normal Heat Sink (NHS). The discharge line also consists of a sample line and an interface with the Water, Gas, and Chemical Pads (WGC) System, which provides a means of flushing the discharge line with demineralised water after use (LWM SDD (Reference 4-50)).

4.2.15.1.3 Condensate Storage Tank

The Condensate Storage Tank (CST) is the key component of the Condensate Storage and Transfer Subsystem. It is mostly fed by water from the sample tanks that has been treated by the LWM filtration skid and meets reactor water quality specification (006N6766 (Reference 4-36)), for re-use. It also receives condensate from additional sources such as the CFS reject line and FPC overboarding line (Figure 4-18) (LWM SDD (Reference 4-50)).

From the CST, water is distributed around the plant as necessary, with it predominantly being for the following uses:

- Makeup water to the main condenser hotwell, if the hotwell reaches low water level
- Alternative supply to the CRD pumps
- Makeup supply and backwash/flushing water for the FPC
- Flush water for the SWM
- Flush water and filter backwash water for the LWM
- Resin transfer, resin washing, and filter backwash processes for the CFD
- Water supply to containment for under vessel washdown during outages
- Additional makeup water to the reactor cavity during cavity refill to compensate for removal of the RPV dome, which is achieved by transfer to the FPC or the RWST

4.2.15.1.4 Refueling Water Storage Tank

The Refueling Water Storage Tank (RWST) is the key component of the Refueling Water Storage and Cleanup Subsystem (Figure 4-19). It is used to hold the reactor cavity pool volume to support refueling outage activities. The RWST can also receive overboarding flow from the CUW and SDC (alongside the LWM sample tanks).

A filter vessel with high efficiency backwash-type filter elements is situated between the reactor cavity pool and the RWST to maintain water purity during transfer at the start and end of refueling outages. Water is sampled to ensure water quality requirements are met before it is pumped back into the reactor cavity. Filter backwash sludge is transferred to the SWM storage tanks (LWM SDD (Reference 4-50)).

4.2.15.2 Solid Waste Management System

The Solid Waste Management System (SWM) collects solid and oily wastes generated across the plant for processing, prior to waste management and disposal (Figure 4-20). The SWM is divided into three subsystems to facilitate this:

- Spent Resin Storage
- Sludge Storage
- Solid Waste Management

Further details on the management and disposal of radioactive wastes are provided in PER Chapter E5 (Reference 4-2) and the IWS (Reference 4-18).

4.2.15.2.1 Spent Resin Storage

Spent resin slurry from the LWM, ICC, CFD, and FPC is sent to the spent resin tank for collection. On exhaustion of tank capacity, resin is transferred to the solid waste storage subsystem to be prepared for disposal. Based on currently available source term data, the accumulated spent resin has initially been classified as wet solid Intermediate Level Waste (ILW). However, the design provides adequate flexibility to segregate and manage individual wet solid waste arisings of varying waste categories on a batch-by-batch basis (as required).

Any tank or line flushes from the CST are directed to the EFS for collection and subsequently recycled for treatment by the LWM. The spent resin tank can also receive water from the LWM collection tanks.

4.2.15.2.2 Sludge Storage

Two sludge tanks are used to settle out solids that accumulate in process fluid as part of normal filter and demineraliser operation. Backwash from the three CFD filters and three demineralisers, the LWM, and FPC filters, plus sludge from the LWM filter, enters the tanks. After solid settling, the liquid is decanted off to the EFS and subsequently recycled for treatment by the LWM. The remaining wet sludge is recirculated within the tank to create a homogeneous slurry, which is then transferred to the Solid Waste Storage Subsystem to be prepared for disposal. Water from the CST is used to flush the tanks and associated pipework to remove trace solids, prior to the acceptance of additional backwash (006N7733, "BWRx-300 Solid Waste Management System (SWM), (Reference 4-51)). Based on currently available source term data, the accumulated sludge has initially been classified as wet solid ILW. However, the design provides adequate flexibility to segregate and manage individual wet solid waste arisings of varying waste categories on a batch-by-batch basis (as required).

4.2.15.2.3 Solid Waste Management

Three High Integrity Containers (HICs) receive, and store spent resin and sludge waste ahead of disposal. Each HIC has a dewatering system to remove residual water, which is routed back to the sludge tanks and decanted to the EFS. It is noted that in a UK context the HIC may be used to perform the function of a cross-site transfer container and may not be demonstrably BAR or ALARP for this purpose. A forward action (FAP PER5-336) has been placed in Chapter E5 for this aspect of the design to be reviewed during site-specific design development.

Dry solid wastes from contaminated areas, such as HEPA filters, pre-filters, miscellaneous paper, rags, containment clothing, tools and equipment parts that cannot be effectively decontaminated, and solid laboratory low activity waste, are to be appropriately segregated and collected in containers in appropriately located areas through the plant. Once filled and sealed, the containers are to be collated and prepared for disposal.

Lab samples, LWM skid wastes (e.g., filter cartridges, granular activated carbon and reverse osmosis modules), and oily sump wastes from the EFS are also collected in drums prior to processing in the drum evaporator. The drum evaporator removes excess moisture through evaporation (which is routed to the RWB ventilation system, part of the HVS). Moisture-free wastes remaining in the drum are to be prepared for disposal. Further detail on the SWM is provided in the SWM SDD (Reference 4-51).

4.2.15.3 Offgas System

The Offgas System (OGS) processes non-condensable gases from the MCA system that are produced through normal operations (Figure 4-21). The main process influent to the system is a mix of steam, air, hydrogen, and radioactive noble gases from the MCA SJAEs. The primary objective of the OGS is to process this influent prior to release to the environment from the HVS Continuous Exhaust Air Plenum (CEAP) (006N7899, "BWRX-300 Offgas System," (Reference 4-52)).

Offgas processing involves two primary functions:

- Recombination of hydrogen and oxygen into water to maintain plant water inventory and reduce hydrogen explosion risk
- Controlled adsorptive holdup of the radioactive isotopes of krypton, xenon, and argon to achieve adequate decay, thereby reducing gaseous effluent radioactivity releases from the plant

The OGS prepares and treats all process offgas, resulting in eventual release to the environment after dilution and radiation monitoring in the HVS. The components of the OGS are:

- The **Offgas Recombiner**, which is a three-section vessel which heats the offgas, promoting the recombination of oxygen and hydrogen via catalytic means, and then finally condenses the resulting steam and returns it to the main condenser.
- The offgas is heated in the preheater section (using steam from the main steam line), ensuring the water content in the offgas reaches a superheated state. The catalytic recombiner section uses a precious metal catalyst to promote recombination of radiolytic oxygen and hydrogen gases into water. As the offgas effluent passes into the condenser, the water within it is condensed (cooled by CFS condensate) and drained to the main condenser.
- The remaining offgas effluent flows to the **Cooler Condenser**, which provides a second stage of offgas condensation. The offgas is cooled by chilled water from the CWE system and any condensed moisture is routed to the EFS.
- The offgas then enters the **Moisture Separator**, an in-line tank with a mesh/screen to divert any remaining moisture droplets to the EFS.
- Two **Refrigeration Dryers** provide the final stage of cooling and condensation. Two are situated in parallel, although only one is active at any time. The dryers reduce the offgas effluent to a final temperature of 4.4°C. Condensed water is drained to the EFS, and gaseous flow is routed to the offgas reheater or charcoal adsorber vault downstream.
- Hydrogen and oxygen concentrations and moisture content are continuously monitored at the outlet of the dryers. The gas analysers interface with the HWC to adjust the rate of hydrogen or oxygen injection.
- In case of low ambient temperature, the offgas may begin to condense, which negatively affects adsorptive holdup of the noble gases downstream in the charcoal adsorber vault. The **Offgas Reheater** (electrical trace heating around the pipework) provides additional heat to prevent condensation.
- The **Charcoal Adsorber Vault** consists of two parts. The **Charcoal Vault Heating, Ventilation and Cooling (HVAC)** system maintains ambient temperature of the vault, preventing both condensation of the offgas at lower temperatures and degradation of the charcoal adsorption performance at higher temperatures. The **Charcoal Adsorber Tanks** consist of four tanks of activated charcoal which provide the adsorptive holdup of the noble gas radioisotopes required to meet release requirements.
- The first tank, known as the guard bed, may be bypassed for short periods of time if there is an issue upstream. The entire charcoal vault may be bypassed during startup or off-normal operation.
- The systems are also fitted with carbon monoxide monitors for early detection of a potential combustion event, as well as radiation monitors to detect leaks from the absorber tanks. Nitrogen from the PPS can be injected into the vault to extinguish a possible fire. In the absence of a catastrophic incident, the charcoal should not require

replacement over the course of the 60-year plant lifespan, so is assumed to arise as a decommissioning waste stream only.

- Prior to entering the CEAP for dilution, the offgas passes through an in-line **HEPA filter** to prevent any charcoal and fine particulates passing downstream.

4.2.15.4 Heating, Ventilation and Cooling System

The Heating, Ventilation and Cooling System (HVS) provides heating, ventilation, and cooling to maintain temperature, humidity, quality of air, and pressurisation within the specified design limits of each area. It provides a controlled environment for personnel safety and comfort, as well as for the proper operation and integrity of equipment located in the power block. All areas of the power block are served during normal operation, excluding the primary containment, which is serviced by the CCS.

The HVS provides fresh air and ventilation to the main plant buildings (RB, TB, CB, RWB), as well as supporting facilities (SB and perimeter buildings) via AHUs that are electrically heated or cooled (by the CWE system) as necessary. Selected areas are supplemented with Fan Coil Units (FCUs), also cooled by the CWE system. Each AHU and FCU has a drain to the EFS to recover potentially radioactive condensate for treatment and recirculation. If the condensate is considered clean (e.g., from the perimeter buildings), it is routed to the sanitary sewer handling system.

There are also numerous exhaust systems that are routed to the CEAP. All of the potentially radioactive gaseous exhaust subsystems are directed through local pre-filters and HEPA filters to the CEAP for dilution and radiation monitoring prior to discharge to the environment via the common PVS.

The CEAP receives gaseous effluent from the following sources (006N7782, “BWRX-300 Heating, Vent, and Cooling System, HVS (U41),” Ducting and Instrumentation Diagram (Reference 4-53)):

- RB, TB and RWB AHUs
- OGS exhaust
- OGS charcoal adsorber vault nitrogen purge
- Main condenser vacuum pump skid exhausts
- CIS exhaust
- Turbine gland seal steam condenser exhaust
- LWM tank vents (CST, RWST, collection and sample tanks)
- EFS sump vents

The CEAP is fitted with a drain line to the EFS to recover any condensate that may occur.

A set of four fans with adjustable speed drives (ASDs) are situated upstream of the PVS to provide suction from the CEAP (three operate any one time with 33% capacity, with one on standby, providing N+1 redundancy). The PVS, situated at a height of 35 meters above grade, may be monitored by, for example, a Particulate, Iodine and Noble Gas (PING) skid and for radiation as part of the PREMS prior to release to the atmosphere. The chosen monitoring equipment is to be sized appropriately during the site-specific design phase to allow for all monitoring operations (FAP.PER6-203and FAP PER8-207).

The CB is outside the RCA and therefore the exhaust does not require radioactive monitoring (but is monitored for toxic gas). The perimeter buildings are also isolated from contamination sources and as such have exhausts directly to the environment. The SDG rooms have a continuous combustion air intake, and three methods of exhaust; ducted radiator exhaust, hard-piped with silencer (combustion exhaust), and two large room exhaust fans (006N7781, “BWRX-300 Heating, Ventilation, and Cooling System,” (Reference 4-54)).

Further information on the buildings producing radioactive gaseous effluent is provided in PER Chapter E7 (Reference 4-6). Management of radiologically contaminated spent pre-filters and HEPA filters arising from HVAC system maintenance are discussed in PER Chapter E5 (Reference 4-2).

4.2.15.5 Equipment and Floor Drain System

The EFS continuously collects drained water from throughout the plant. The majority of this is a collection of floor drains, equipment drains, and process drains from across the RCA, and considered high conductivity waste. This also includes wastes from equipment and personnel decontamination, the chemistry laboratory and sample panels, eyewash stations, and fire protection water.

These radioactive or potentially radioactive process fluid from across the RCA are routed to one of a series of collection sumps (described in this section) to ensure segregation and prevent system cross-contamination and are subsequently transferred onwards to the LWM system. The collection sump is fitted with a recirculation line and eductor to agitate the sump contents and to prevent solid settling and promote homogenisation to allow for representative sampling (Figure 4-22). If sampling of a collection sump deems the contents to be non-radioactive, a temporary connection can be utilised to divert this process fluid away from the LWM system for re-use or discharge (as required).

The EFS also has dedicated, isolated oily waste sumps and systems that manage select non-radioactive liquid wastes to prevent the addition of unwanted chemicals into the waste management systems. An oily waste sump is used for collecting diesel generator skid, TLOS skid and EHC skid drainage, followed by transfer into drums for waste management and disposition via the SWM (Figure 4-23).

Systems that are expected to produce non-radioactive liquid wastes have their own isolated sumps, as follows:

- The BIS drain has an isolated sump, allowing for any leakage of the enriched boron solution to be collected and drained to drums for hazardous waste disposal.
- The PCW drain has an isolated sump. The water is expected to be clean, but the possible addition of chemicals for water treatment acts as a deterrent for mixing with the LWM. Prior to routing, grab sample monitoring will take place to determine whether the water goes to the LWM for treatment (i.e., contaminated demineralised water) or for discharge (i.e., contaminated abstracted water).
- Condensate generated by the PPS is stored in the PPS Condensate Tank. When discharging, the line is continuously monitored for radiation and either directed to the Yard drains if clean, or to the EFS floor drains for onward treatment.

There is also a pressurised, leak-tight containment sump which removes any leakage that accumulates inside the primary containment (Figure 4-24). This line penetrates the SCCV and as such, pipework is fitted with CIVs. Further details on the EFS are provided in 006N7789, “BWRX-300 Equipment and Floor Drain System,” (Reference 4-55).

4.2.16 Monitoring Systems

4.2.16.1 Process Radiation and Environmental Monitoring System

PREMS consists of multiple subsystems that allow for the monitoring of various parameters both in real time and via laboratory analysis in order to maintain safe operation and monitor plant equipment and performance. It is also used to prevent unauthorised discharges of radioactivity and/or hazardous contaminants to the environment by communicating with instrumentation and control systems, as well as providing data for waste characterisation

(006N7938, "BWRX-300 Process Radiation Monitoring," (Reference 4-56)). Further details are provided in PER Chapter E8 (Reference 4-7). The four subsystems that enable the assessment of radioactive or potentially radioactive streams are as follows:

- Process Radiation Monitoring (PRM)
- Area Radiation Monitoring (ARM)
- Containment Monitoring (CMon)
- Process Sampling (PS)

4.2.16.1.1 Process Radiation Monitoring

The PRM monitors various process and effluent streams for potentially hazardous contamination such as radioactivity, noble gases, air particulates, and halogens. The PRM may also include toxic gas monitoring (if required by location or utility, to be determined during the site-specific design phase (FAP.PER4-218)).

A variety of monitoring equipment is used by the PRM, and are as follows:

- Offline Radiation Monitors, including, for example, PING skids
- Inline Radiation Monitors
- Adjacent-to-Line Radiation Monitors.

4.2.16.1.2 Area Radiation Monitoring

The Area Radiation Monitoring (ARM) monitors gamma radiation levels in strategic locations throughout the plant (excluding containment), such as main access routes and control rooms.

4.2.16.1.3 Containment Monitoring

The Containment Monitoring (CMon) monitors containment temperature, water level, and area radiation levels using appropriate instrumentation situated inside the containment. Hydrogen and oxygen concentration and fission product monitoring takes place outside of the containment on, for example, sampling skids and PING skids, respectively. Containment pressure is also monitored via a transmitter outside the containment vessel. As such, containment penetrations for monitoring are fitted with CIVs.

4.2.16.1.4 Process Sampling

The PS collects representative liquid and gaseous samples for analysis and provides the analytical information required for monitoring plant and equipment performance. Samples are also expected to be used for radioactive waste characterisation and sentencing purposes.

Online monitoring equipment is used as much as possible at automated sample panels located in the RB, TB, and RWB. Grab sample taps are provided at panels for infrequent analysis of specific systems.

4.2.17 Other Systems

4.2.17.1 Plant Pneumatic System

During normal operation, the PPS provides a continuous supply of filtered, dry, and oil-free compressed air for tank sparging, filter/demineraliser backwashing, air operated tools, valves, and instrumentation across plant. It also supplies breathable air when required.

The PPS provides both nitrogen and breathable air to inside the SCCV. As such, the PPS lines are fitted with both internal and external CIVs. During outages, the PPS supplies instrument quality air to pneumatic valves and other users inside the SCCV while the nitrogen supply from the CIS is isolated. PREMS provides periodic sampling of breathable and instrument air quality.

The air compressors are commercially available package units that are skid-mounted, and include intake filters and silencers, intercooler, and aftercooler/moisture-separator. The aftercoolers (using PCW) are used to cool the air and condense any water vapor present, which is drained to the PPS Condensate Tank (part of the EFS). Air is dried following the compressor skids using commercially available desiccant dryers (006N7773, “BWRX-300 Plant Pneumatic System (PPS),” (Reference 4-57)).

4.2.17.2 Fire Protection System

The Fire Protection System (FPS) provides means of detection, suppression, and notification of smoke and fire incidents within the power block and supporting facilities. The system provides a reliable water supply from the municipal water.

Fire detectors and alarms are used for fire notification. Fire hydrants, building standpipes, and hose stations are located strategically to provide sufficient fire protection coverage of all buildings. Other fire suppression mechanisms include sprinklers and deluge systems. A water spray system is provided for fire protection of the charcoal adsorbers in the OGS (006N7785, “BWRX-300 Fire Protection System (FPS),” (Reference 4-58)).

Water used for firefighting within the RCA is assumed to be radiologically contaminated and EFS design ensures that this would be collected in the relevant building sumps and routed to LWM for treatment.

4.2.17.3 Refueling and Servicing Equipment

The refueling and servicing equipment provides the equipment and facilities for receipt, storage, and installation of new fuel assemblies, as well as the removal and storage of SF assemblies in support of SF cask management. It also provides equipment and facilities for servicing the RPV pressure boundary and internal components, control rods (and control rod drives), and nuclear instrumentation replacement.

The SF assemblies will be stored in the FPC system fuel pool to undergo cooling prior to packaging in SF casks. It is anticipated that an on-site interim storage facility will be required in the absence of reprocessing and/or an operating GDF. IICCs, such as control rods and instrumentation, will be managed in a similar manner to SF. Further information on SF and IICC interim storage management is provided in PER Chapter E5 (Reference 4-2), PSR Chapter 11 (Reference 4-3), and PSR Chapter 26 (Reference 4-4).

In support of refueling activities, the SDC and FPC provide cooling water and the LWM sends water from the reactor cavity pool to and from the RWST. Any discarded reactor components and outage consumables will be managed by the SWM after initial storage in the fuel pool. Further details are provided in 006N5377, “BWRX-300 Refueling and Servicing Equipment,” (Reference 4-59).

4.3 Conventional Environmental Impacts

4.3.1 Water Use, Abstraction, and Discharge to Surface Water

4.3.1.1 Circulating Water System

The CWS primarily provides cooling water to the main condenser and transfers heat from the condenser to the environment through the NHS. It also supplies cooling water to reject the heat loads from the PCW heat exchangers through the NHS (Figure 4-26). The CWS is designed for continuous operation and to provide sufficient circulating water to the condenser to support full power operation (006N7761, "BWRX-300 Circulating Water System," (Reference 4-60)).

The NHS provides debris-free water for the circulating water and plant cooling water pumps. All filtering and treatment equipment situated upstream (e.g., intake screens, bar screens, stop logs) and downstream of the supply pumps (e.g., debris filters, strainers, condenser tube cleaning system, inline filters, chemical injection systems) are to be determined during the site-specific design phase (FAP.PER4-219). Additional discussion on water treatment systems that may be employed, as well as the measures that may be employed to protect marine life is provided in NEDC-34227P (Reference 4-8) (FAP PER10-226).

The NHS receives discharge from the MCA and PCW heat exchangers through an outfall structure, consisting of a discharge weir, which returns circulating water back to the environment. Further information is to be determined during the site-specific design phase (FAP.PER4-220).

The LWM discharge line (in case of plant water inventory being too high) interfaces with the outlet line of the main condenser. This allows for the liquid discharge to be mixed and diluted before being discharged to the environment via the NHS (see 006N7762, "BWRX-300 N71 Circulating Water System (CWS)," Piping and Instrumentation Diagram (Reference 4-61)).

4.3.1.1.1 Demineralised Water Storage and Distribution Subsystem

Demineralised water is supplied from an external source to the storage tank situated in the yard, prior to distribution to the following systems (Figure 4-27):

- ICC
- BIS
- FPC
- LWM (specifically the CST)
- CWE (specifically the Glycol Autofill Unit)
- PCW Surge Tanks
- PREMS (including the RWB Chemical Laboratory)

There is also a supply line to inside of the primary containment for under vessel work, requiring a containment penetration and CIVs. Makeup requirements are limited to prevent the plant water inventory becoming too high, which would require discharge to the environment (006N7797, "BWRX-300 Water, Gas, and Chemical Pads," (Reference 4-62)).

4.3.1.1.2 Potable Water Distribution Subsystem

This is the main source of potable water to the facility. It receives potable water from the municipal potable water source and provides potable water to the following areas (WGC SDD (Reference 4-62)):

- Fire suppression system firewater storage tanks

- Mobile demineralised water trailers, if required to supplement the site's demineralised water supply
- Washrooms, break areas, food service equipment, and battery room safety showers in the CB and SB
- Toilet(s) in the MCR habitability envelope

4.3.1.1.3 Sanitary Sewer Handling Subsystem

The Sanitary Sewer Collection and Delivery Subsystem collects sewage from the facility bathrooms and break areas and transfers it to a non-radiologically controlled sewage system (collecting waste from outside of the RCAs). The sanitary sewers will receive clean condensate from AHUs and FCUs (HVS SDD (Reference 4-54)).

4.3.1.2 Plant Cooling Water

The Plant Cooling Water (PCW) system provides a flow of cooling water (maintained at a constant operating temperature despite ambient temperature variance) to heat exchangers in the RB and TB. It consists of two main piping distributions, the first of which has two trains (one providing full redundancy) providing cooling water to the following systems:

- FPC heat exchanger
- ICC heat exchanger
- SDC heat exchanger
- PPS compressor cooler

The second piping distribution (only one train, no redundancy) provides cooling water to the following condensate pumping or power generation systems:

- Condensate and FW Pump Motors and ASDs
- Main condenser pump motors and vacuum pump skids
- TG cooler
- Isophase bus duct cooler
- Lube oil and EHC coolers

The heat that the PCW receives from process fluid is transferred to the CWS through heat exchangers, rather than by dilution.

The demineralised water storage and distribution system provides additional makeup water to a set of surge tanks (which provide net positive suction head needed for safe pump operation) in case of water loss. The surge tanks are sized appropriately to allow for thermal expansion of water. PREMS samples the PCW to confirm water quality, prevent corrosion and monitor radioactivity. The system is linked to the EFS in case the PCW is contaminated (006N7769, "BWRX-300 Plant Cooling Water (PCW) System," (Reference 4-63)).

4.3.1.3 Chilled Water Equipment

The CWE is a closed loop chilled water system that supplies chilled water to AHUs across plant (which form part of the HVS and CCS), as well as the OGS Cooler Condenser. Heat absorbed by the CWE (using a refrigerant to be determined during site-specific assessment (FAP.PER4-221)) is rejected from the chiller condensers mounted on the CB roof to the atmosphere.

There are four chillers, each with 33% capacity to provide N+1 redundancy to the HVS and CCS (three pumps in operation, one on standby). An expansion tank, which accommodates thermal expansion and contraction of water, creates positive pressure throughout the system for normal operation. This tank receives air that is piped from a set of air separators that remove entrained air from the system (which could cause excess wear and pump cavitation).

Supporting equipment includes a chemical bypass system for the addition of corrosion/scale inhibitors, pH adjustment and biocides (where applicable, to be determined during site-specific assessment (FAP.PER4-222)), and a glycol autofill unit, which maintains a predetermined propylene glycol/demineralised water mixture concentration (which acts as the heat transfer fluid).

Due to the cold operating temperature of the fluid, glycol-free condensation may occur on the chiller pumps and will collect in the pump baseplate drains. This is pumped to the local EFS drain. Further details are provided in 006N7765, “BWRX-300 Chilled Water Equipment (CWE),” (Reference 4-64).

4.3.2 Combustion Systems

In order to maintain safe, continuous operation in case of a loss of offsite power, two SDGs (labelled SDG A and B), each supporting different power buses, are employed (particularly on detection of low electric bus voltage) (see 006N6705, “BWRX-300 System Requirements,” (Reference 4-65)). The Diesel Generator Day Tanks situated in the TB supply diesel to the generators to allow for continuous safe reactor operation for a minimum of seven days if offsite power is lost (WGC SDD (Reference 4-62)). The SDGs support the following systems:

- BIS – injection pump and C&I
- CCS – AHUs and supporting chillers (this system is taken out of service if SDGs are unavailable)
- CRD – ASDs
- CWE – chillers and pumps
- CWS – service pumps
- FPS – fire pumps, which support an existing diesel driven fire pump)
- HVS – TB battery rooms, RB and CB AHU supply fans, control room envelope emergency filtration unit supply fans, toxic gas filtration unit
- PCW – system pumps
- PPS – air compressors and dryers
- SCR

Portable generators may be used for permanently installed FLEX/EME connections.

4.3.3 Control of Major Accident Hazard and Hazardous Chemicals

The following chemicals are subject to Control of Major Accident Hazard (COMAH) regulations in the UK. The systems and activities that these chemicals are related to are described below. Further information is provided in PER Chapter E10 (Reference 4-8).

4.3.3.1 Hydrogen

The hydrogen gas delivery subsystem delivers a stable supply of uninterrupted compressed hydrogen to the HWC system. Hydrogen is delivered from a mobile trailer situated in the yard to a pressure regulation station and onwards to the power block. Details of the HWC system are provided in Section 4.2.13.2.

Hydrogen is also expected to be produced as part of normal operation of the battery systems, situated in the perimeter buildings. Hydrogen off-gassing of the batteries will require continuous venting to the atmosphere via exhaust fans which are part of the HVS (HVS SDD

(Reference 4-54)). COMAH regulations will apply if stored or used in sufficient quantities, although large volumes of hydrogen are not anticipated to be required or produced.

4.3.3.2 Diesel Fuel Oil

The diesel fuel oil storage and transfer subsystem provides storage and transfer of diesel fuel oil to the day tanks for the SDSs. The storage tank situated in the yard holds enough fuel for a minimum of seven days of SDG operation in case of a loss of offsite power. The systems supported by the SDGs are identified in Section 4.3.2. COMAH regulations will apply if diesel fuel oil is stored or used in sufficient quantities.

4.3.3.3 Turbine Lube Oil

A lube oil skid, part of the TLOS (Section 4.2.12.1), provides all turbine lube oil for operation. The skid includes lube oil coolers, an oil conditioning system, two storage tanks (one for fresh oil, the other for used oil), and a transfer pump. A full-flow filtration system is provided to meet oil quality requirements provided by the turbine supplier (removal of particulates). The filters are designed so as to continuously drain lube oil back to the tank.

Exhaust fans are mounted directly on top of the storage tank. A high efficiency oil demister and dual vapor extractors are arranged upstream in a single unit. The outlet of this unit is scrubbed and discharged to the atmosphere (in a location away from air intakes and potential fire or sparks). Occasionally, contaminated lube oil may be processed on a batch purification basis by passing it through the lube oil conditioner (moisture removal). The conditioner is fitted with a drain to the EFS which accepts oily waste (MTE SDD (Reference 4-39)).

The most common route for oil management is expected to be via dedicated oily waste sumps (ensuring segregation and preventing cross-contamination), followed by the transfer into drums for treatment in the SWM, followed by disposal via an approved hazardous waste management supplier (SWM SDD (Reference 4-51)). See PER Chapter E5 (Reference 4-2) for further information.

4.3.3.4 Hydraulic Control Oil

As part of the EHC subsystem, a control oil skid provides all hydraulic control fluid for operation. The skid includes in-line full flow filtration systems (to remove moisture and particulates), chemical treatment systems (to dehydrate, regenerate and control acidity), coolers, and a storage tank with immersion heater and de-moisturising breather. The control oil fluid is a type of triaryl phosphate ester (Fyrquel®), a fire-resistant liquid regularly used in hydraulic control systems (006N6567, “BWRX-300 Fire Hazard Assessment Requirements Document,” (Reference 4-66)). Triaryl phosphate ester is deemed a hazardous substance and as such, must be disposed of appropriately.

Waste hydraulic fluid is collected via drums and will be sent for treatment in the SWM and disposal via an approved hazardous waste management supplier. The subsystem is fitted with a floor drain (as part of the EFS) in case of tank failure (MTE SDD (Reference 4-39)). See PER Chapter E5 (Reference 4-2) for further information.

4.3.3.5 Gasoline

Gasoline is anticipated to be used solely as vehicle fuel and is to be stored in small quantities in the Vehicle Maintenance Garage. Its location is yet to be determined. Given the anticipated use of small quantities, COMAH regulations will not apply.

4.3.3.6 Propylene Glycol

Propylene glycol is mixed with demineralised water in a specific ratio for use in the CWE system as a heat transfer fluid (CWE SDD (Reference 4-64)). COMAH regulations will apply if stored or used in sufficient quantities, although large volumes of propylene glycol are not anticipated to be required. The purpose of the CWE is described in Section 4.3.1.3.

4.3.3.7 Sodium Hypochlorite

It is anticipated that sodium hypochlorite will be used in chemical treatment for the CWS supply. Alternatives, such as sodium bisulphite and/or Captor thiosulphate dichlorination, are also for consideration (006N7761 (Reference 4-60)). An environmental permit will be required for discharge to the NHS.

Sodium hypochlorite may also be used in a chemical bypass feeder system in the CWE. This system introduces corrosion/scale inhibitors, pH adjustment, and biocides for water treatment. If sodium hypochlorite is to be stored or used in sufficient quantities, which will be determined during the site-specific design phase, COMAH regulations will apply (006N6705 (Reference 4-65)).

4.3.3.8 Depleted Zinc Oxide

Depleted zinc oxide pellets are to be dissolved in a column prior to injection into the FW via the GEZIP system (Section 4.2.13.2). Although zinc oxide is non-toxic, it is considered a hazardous substance.

4.3.3.9 Noble Metal Solution

Specific details of the composition of the noble metal solution used in the OLNC system (Section 4.2.13.2) for reactor chemistry control are unavailable. As such, it is considered a hazardous substance until further information is available.

4.3.4 Fluorinated Greenhouse Gases and Ozone-Depleting Substances

The propylene glycol/water mixture used in the CWE transfers heat to a refrigerant (which has the potential to be an ozone-depleting substance). The choice of refrigerant is to be determined during the site-specific design phase (CWE SDD (Reference 4-64)).

High-voltage switchgear will be gas-insulated, anticipated to be SF_6 (NEDC-34170P, “BWRX-300 UK GDA Chapter 8: Electrical Power” (Reference 4-67)). The insulating gas will be separated from the environment by multiple barriers, therefore reducing the probability of this fluorinated greenhouse gas entering the atmosphere.

There are no other anticipated uses of fluorinated greenhouse gases or ozone-depleting substances.

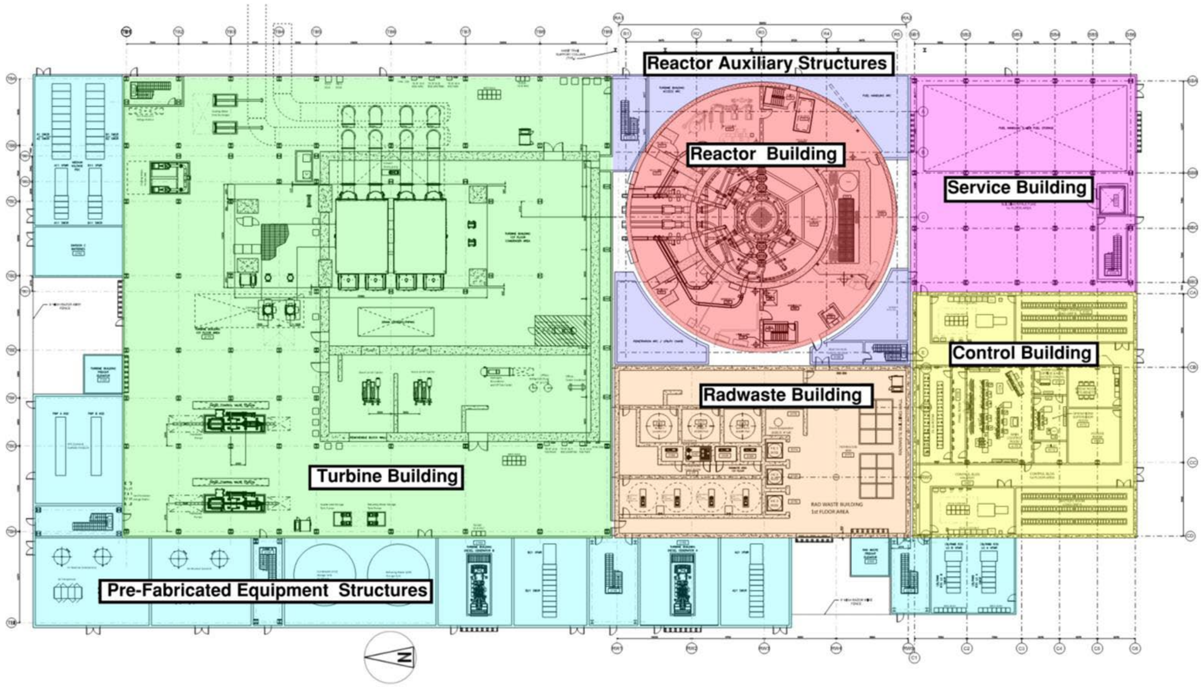

Figure 4-1: BWRX-300 Plant Power Block Building Boundaries Plan

Note:

Taken from 008N0279 (Reference 4-19)

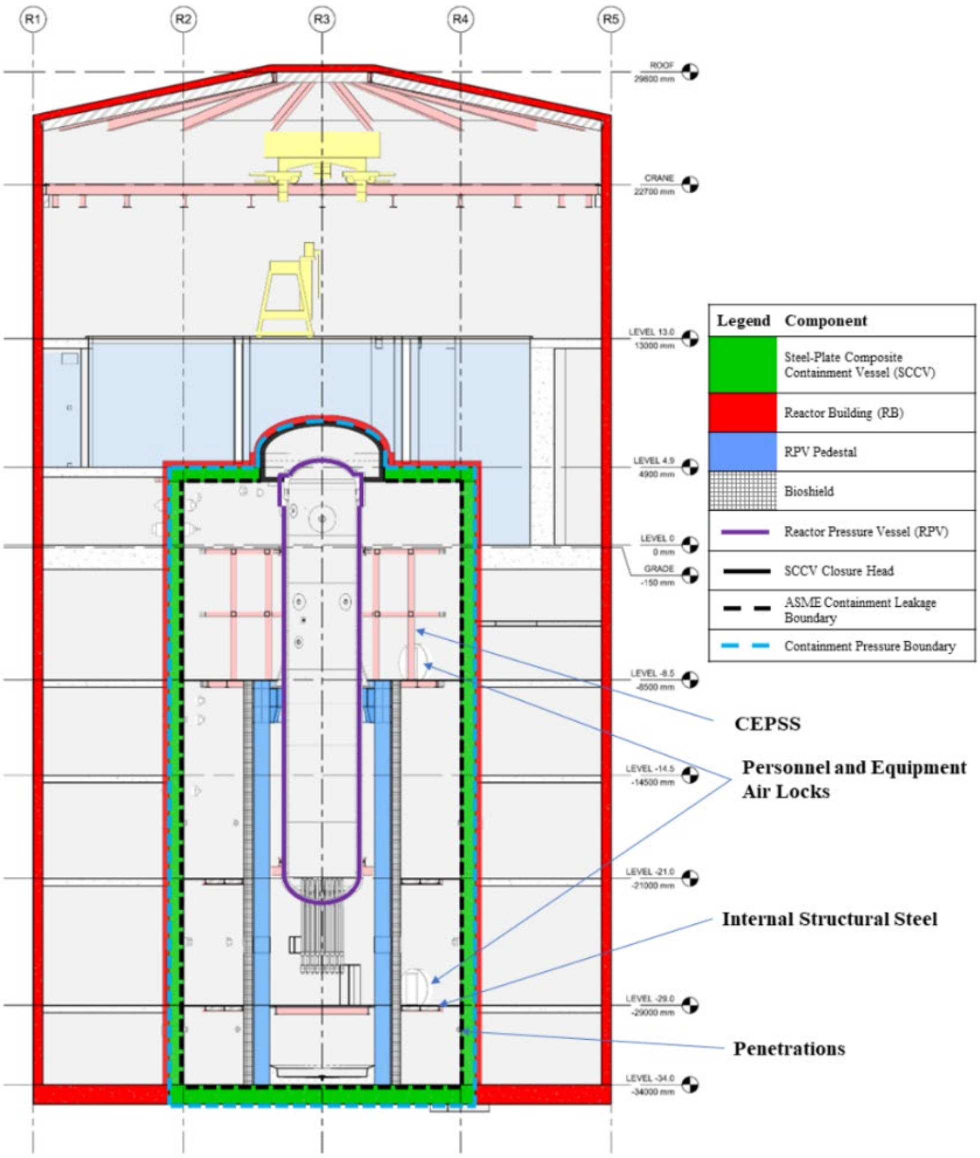

Figure 4-2: BWRX-300 Integrated Reactor Building Boundaries

Note:

Taken from the PCS SDD (Reference 4-20)

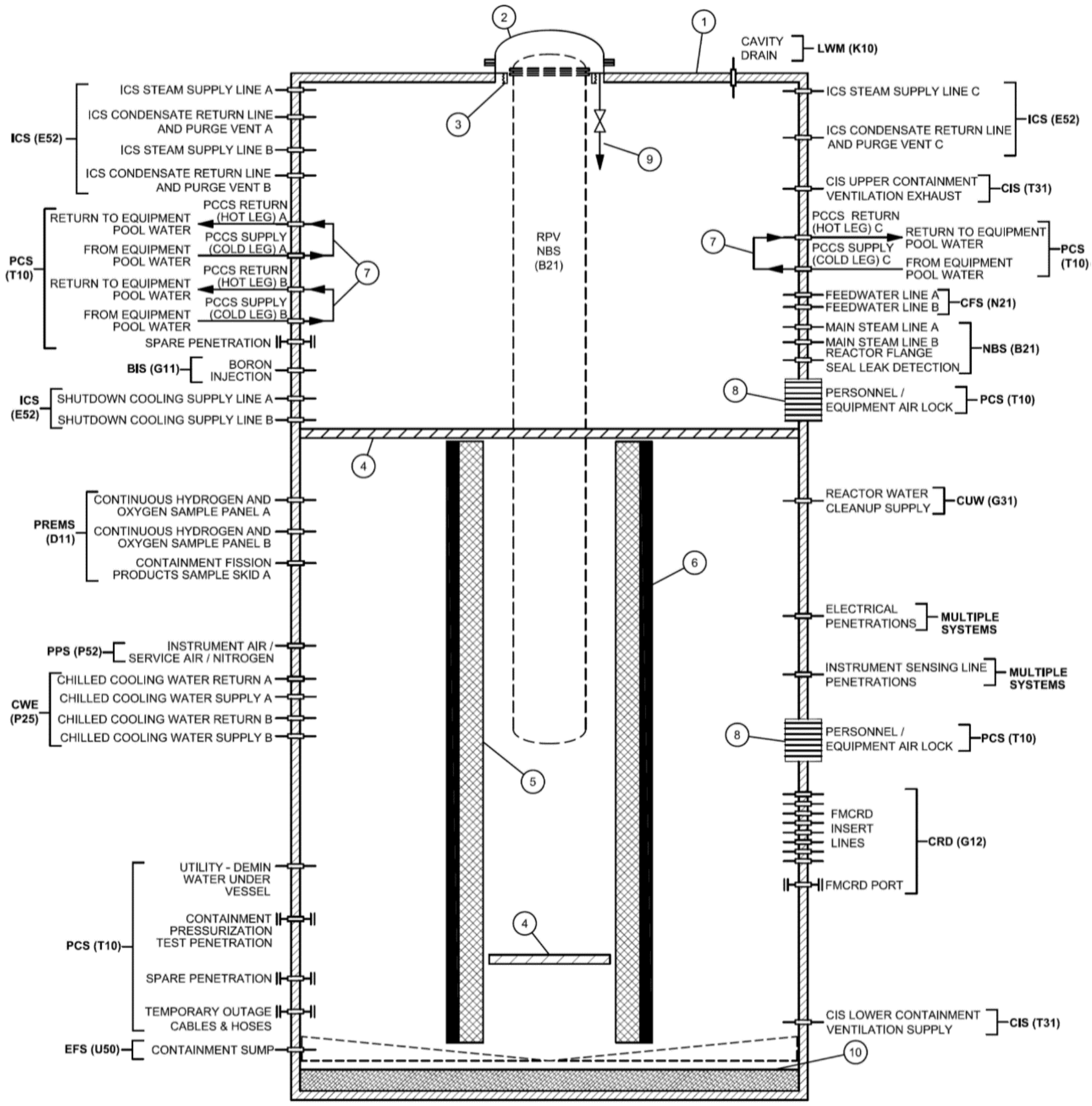

Figure 4-3: Primary Containment System Simplified Diagram

Note:

Taken from the PCS SDD (Reference 4-20)

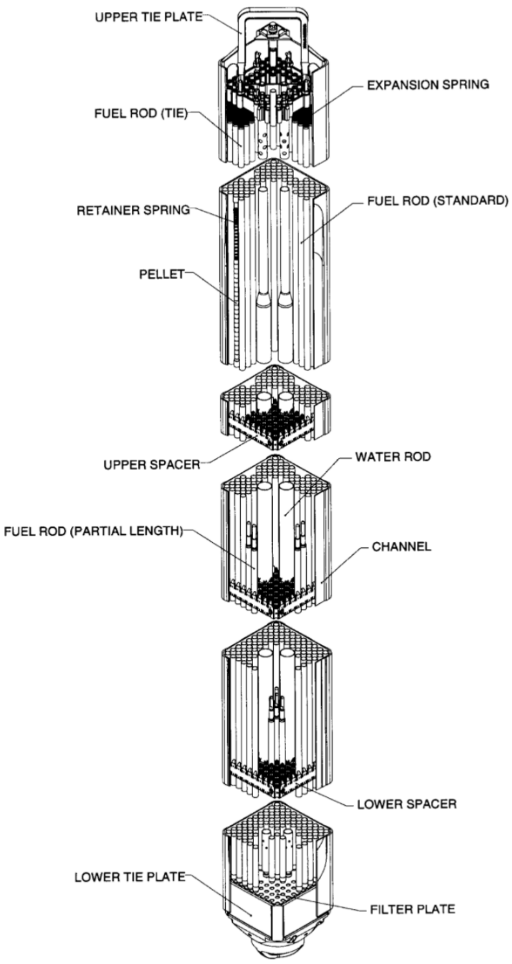

Figure 4-4: GNF2 Fuel Bundle

Note:

Taken from the GNF2 Fuel Assembly Mechanical Design Report (Reference 4-28).

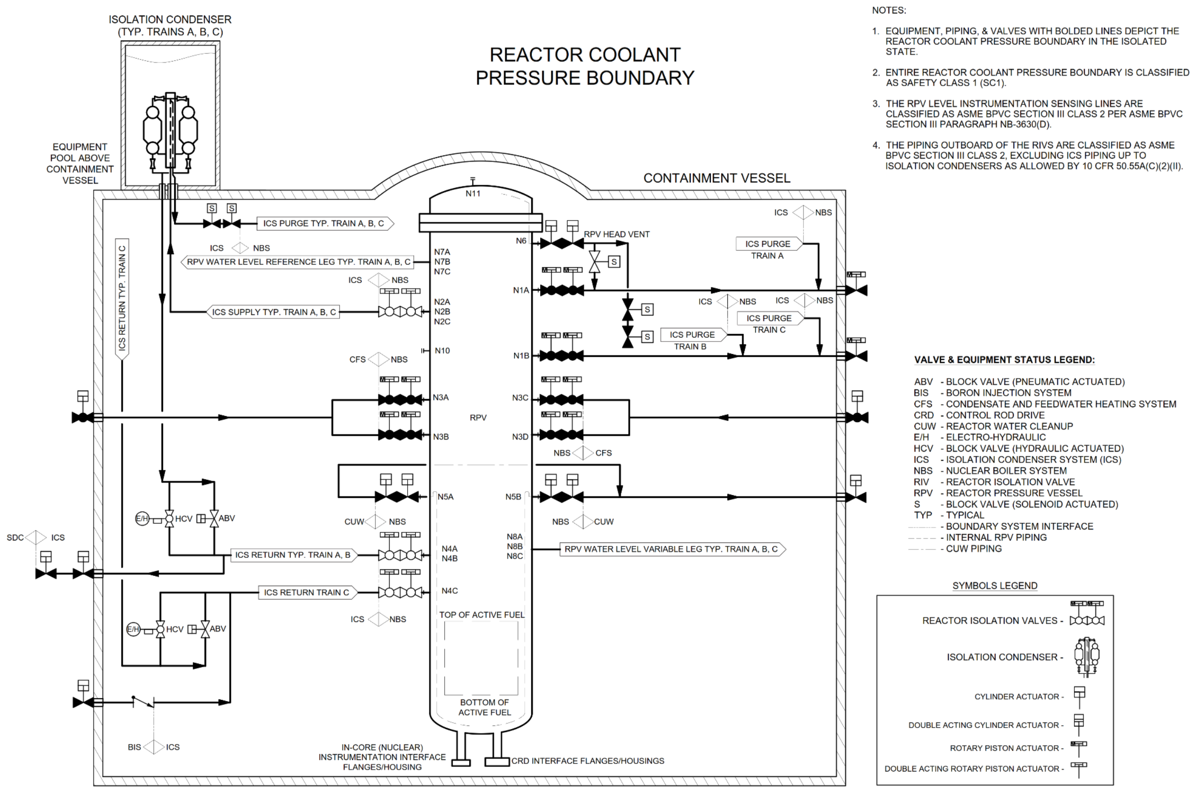

Figure 4-5: RCPB

Note:

Taken from the NBS SDD (Reference 4-30).

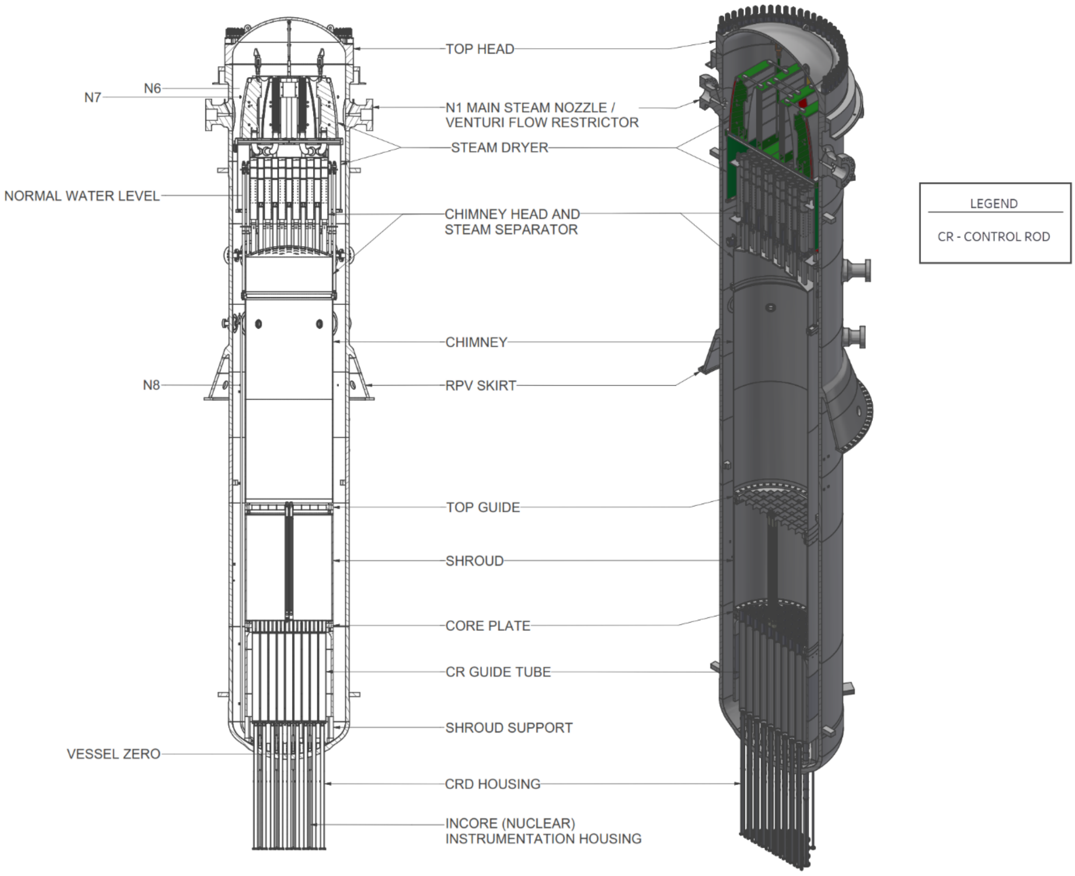

Figure 4-6: RPV Internals

Note:

Taken from the NBS SDD (Reference 4-30).

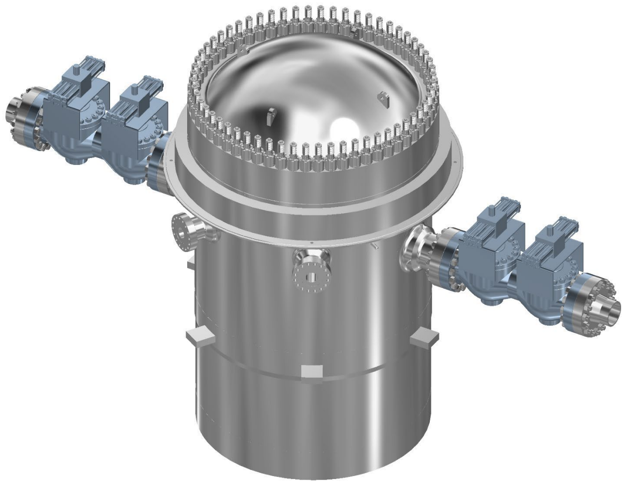

Figure 4-7: Reactor Isolation Valve Arrangement

Note:

Taken from the NBS SDD (Reference 4-30).

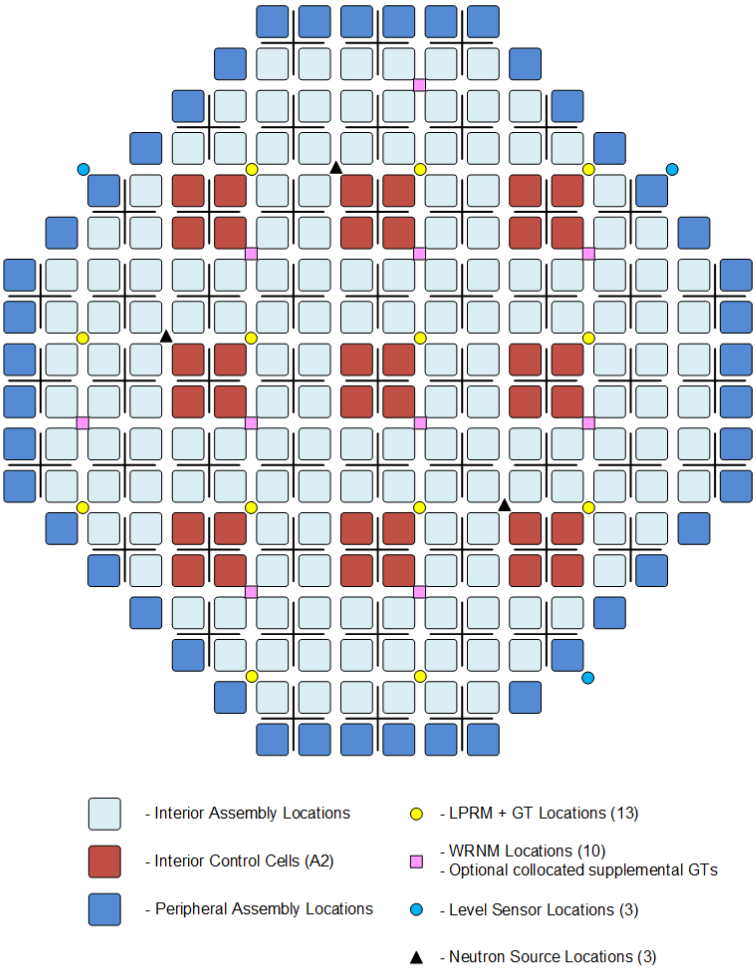

Figure 4-8: In-Core Instrumentation Arrangement

Note:

Taken from 005N9751 (Reference 4-32).

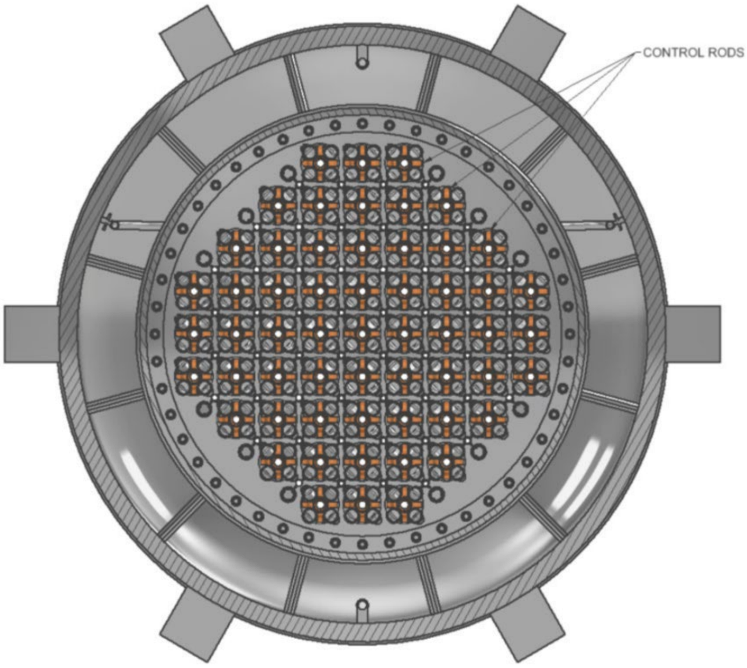

Figure 4-9: Control Rod Arrangement

Note:

Taken from the CRD SDD (Reference 4-31).

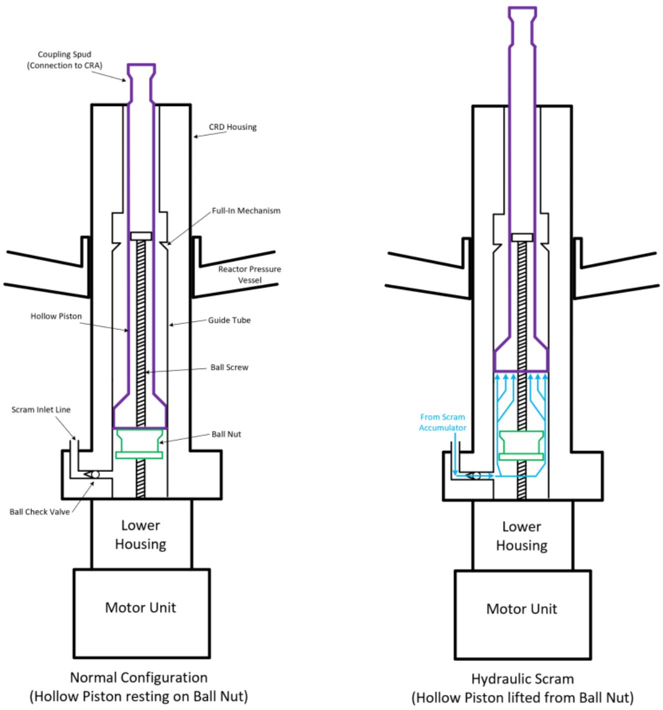

Figure 4-10: Fine Motion Control Rod Drive

Note:

Taken from the BWRX-300 General Description (Reference 4-32).

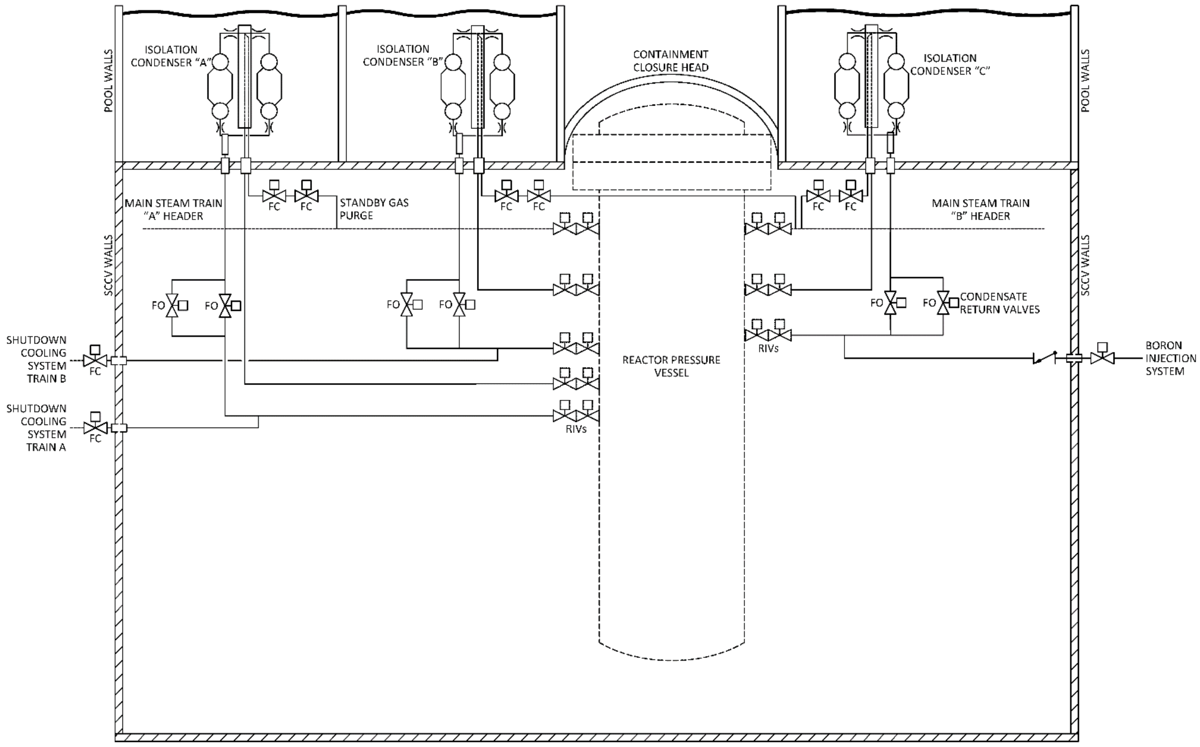

Figure 4-11: ICS Schematic

Note:

Taken from the ICS SDD (Reference 4-34).

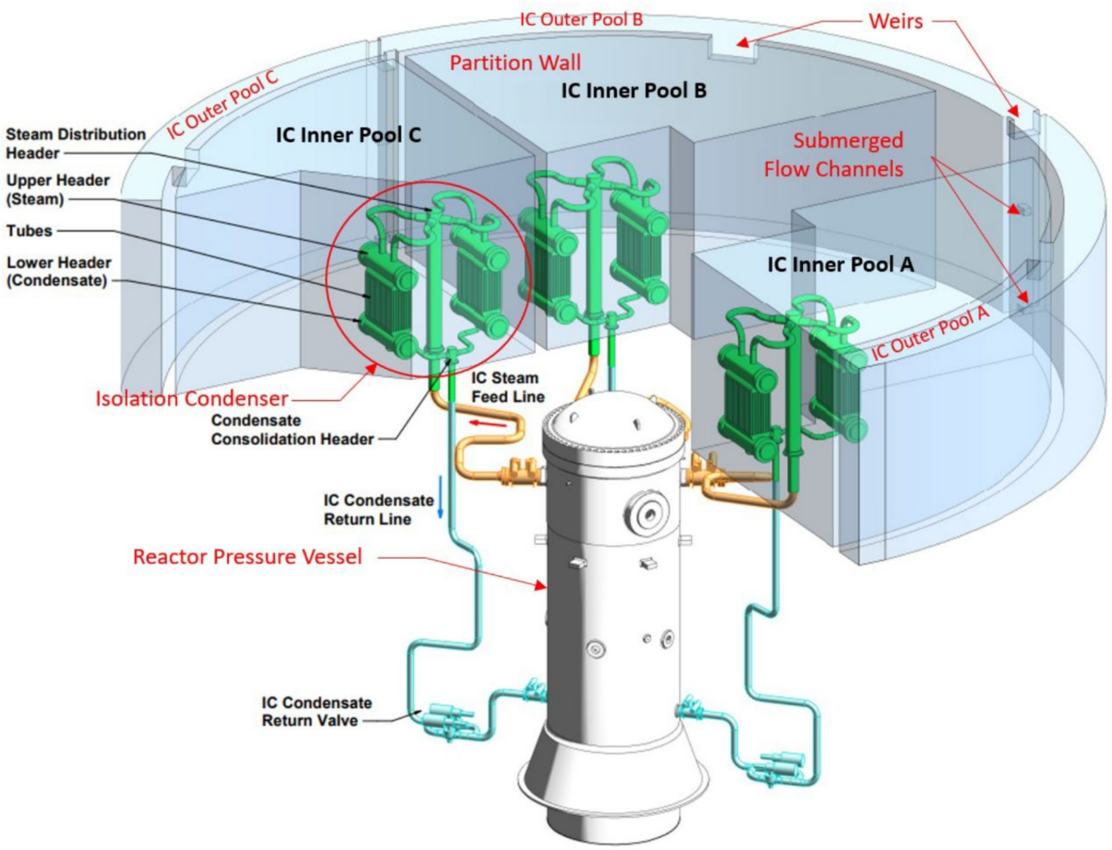

Figure 4-12: ICS and ICC Schematic

Note:

Taken from the ICC SDD (Reference 4-36)

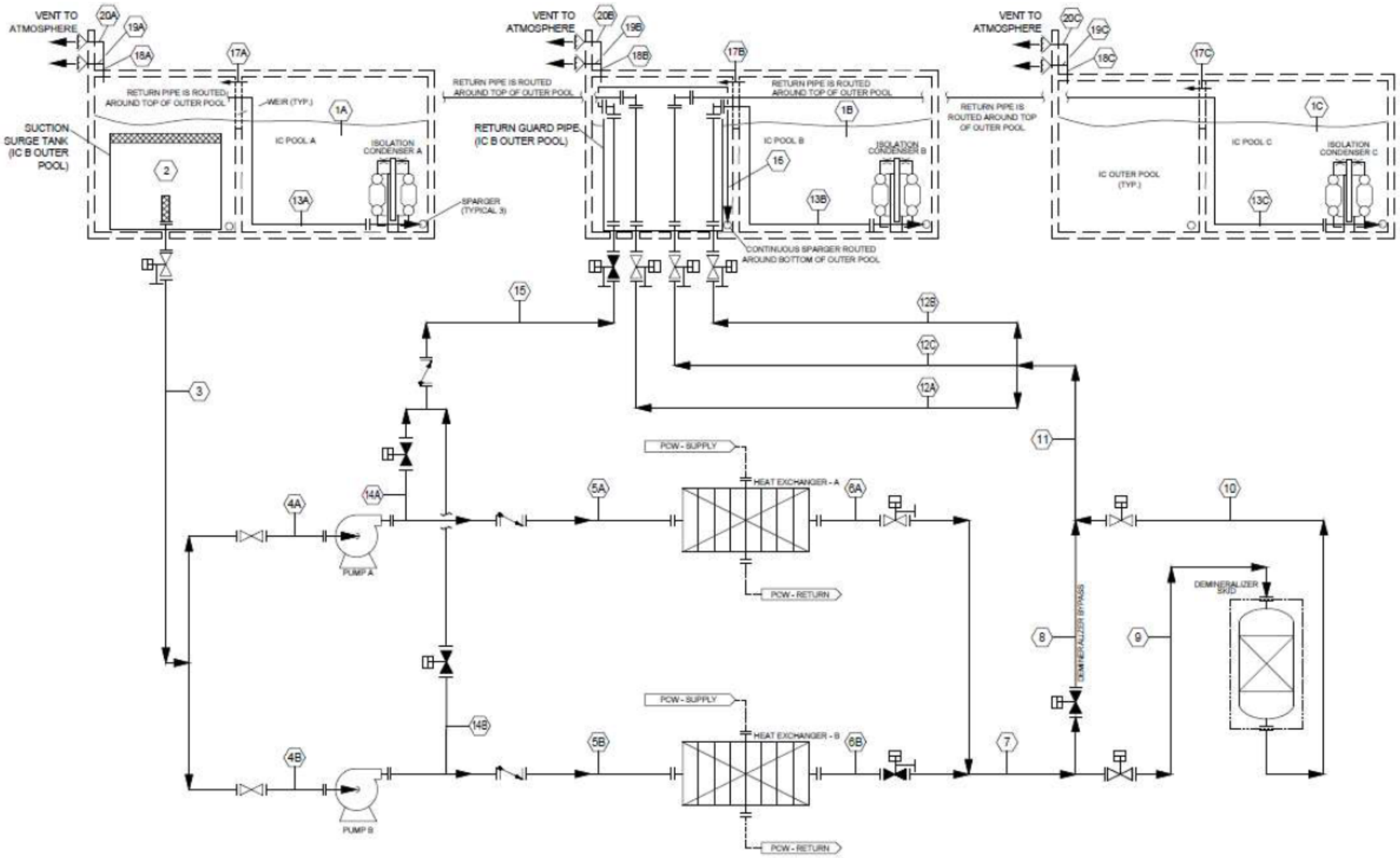

Figure 4-13: ICC System Simplified Diagram

Note:

Taken from the ICC SDD (Reference 4-36)

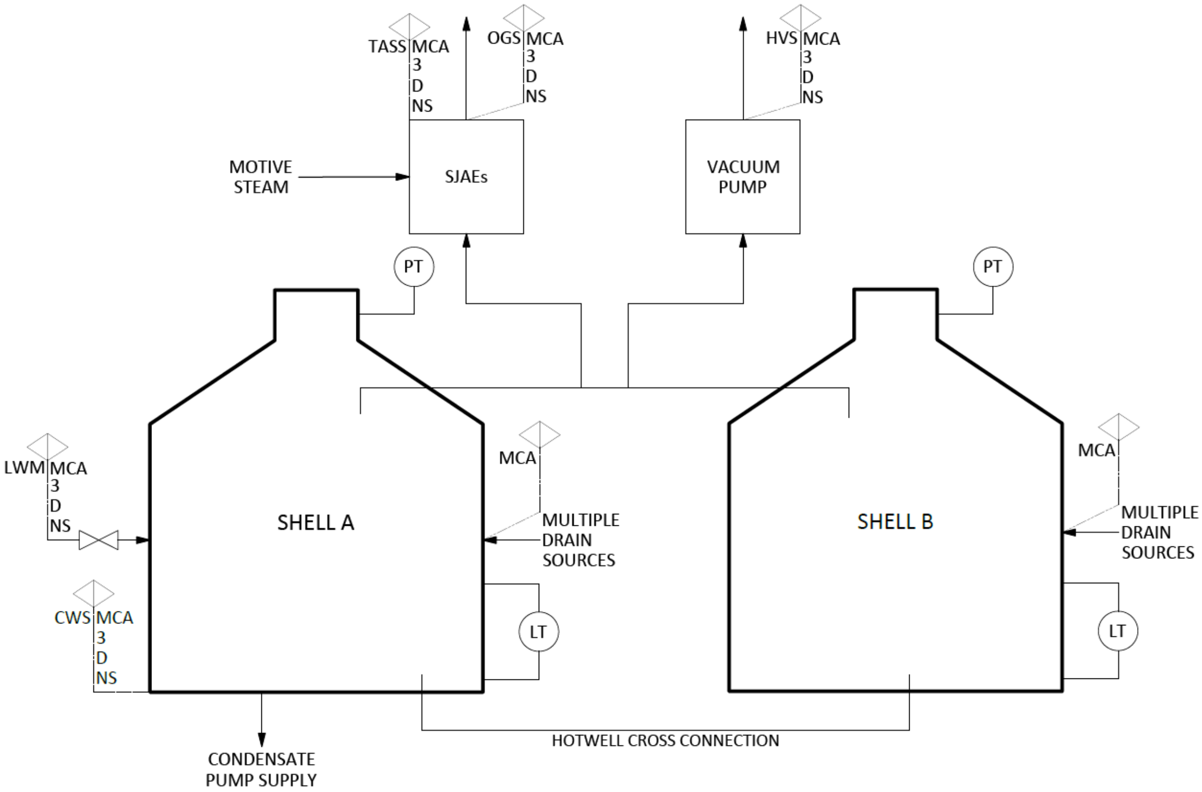

Figure 4-14: Main Condenser and Auxiliaries Simplified Line Diagram

Note:

Taken from the MCA SDD (Reference 4-42).

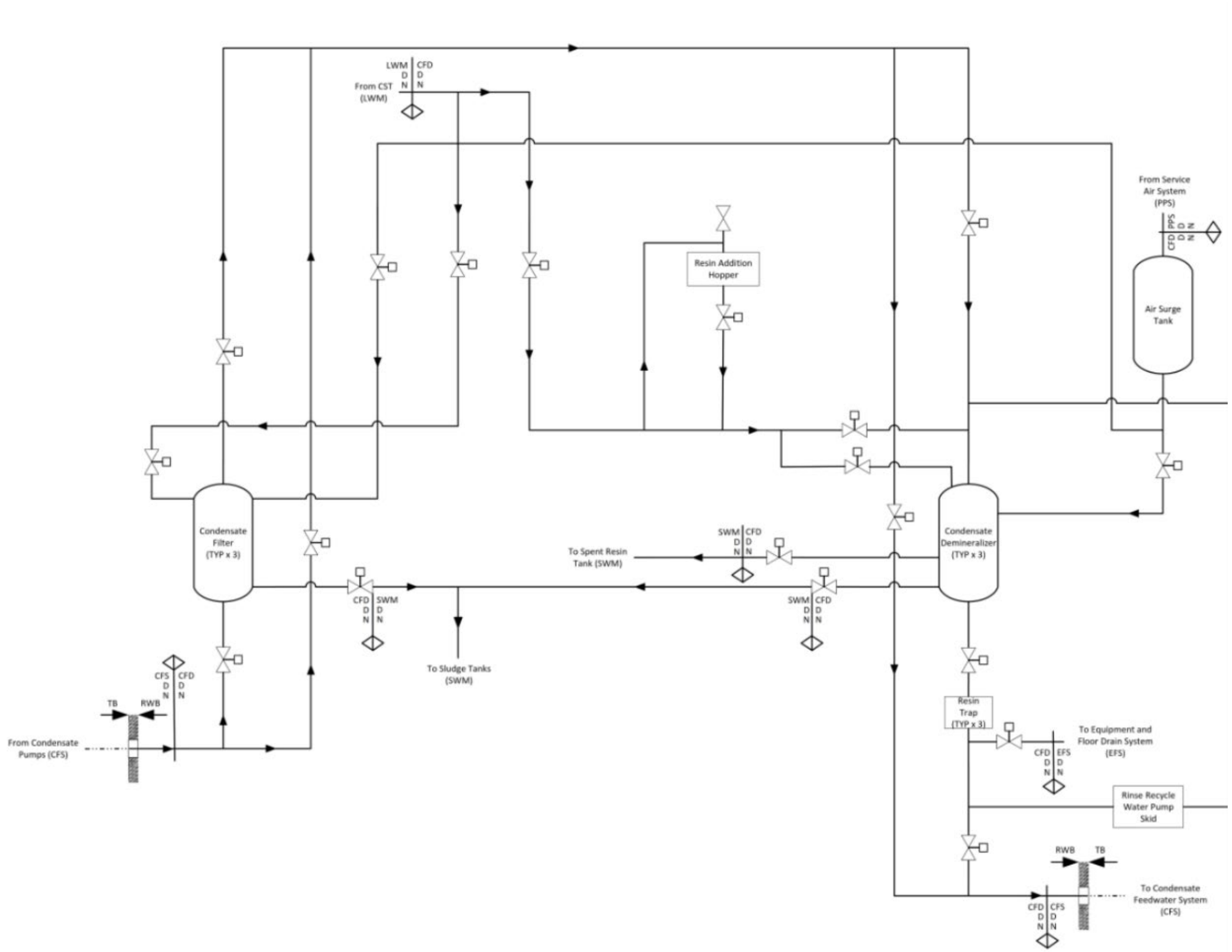

Figure 4-15: CFD Simplified Line Diagram

Note:

Taken from the CFD SDD (Reference 4-43).

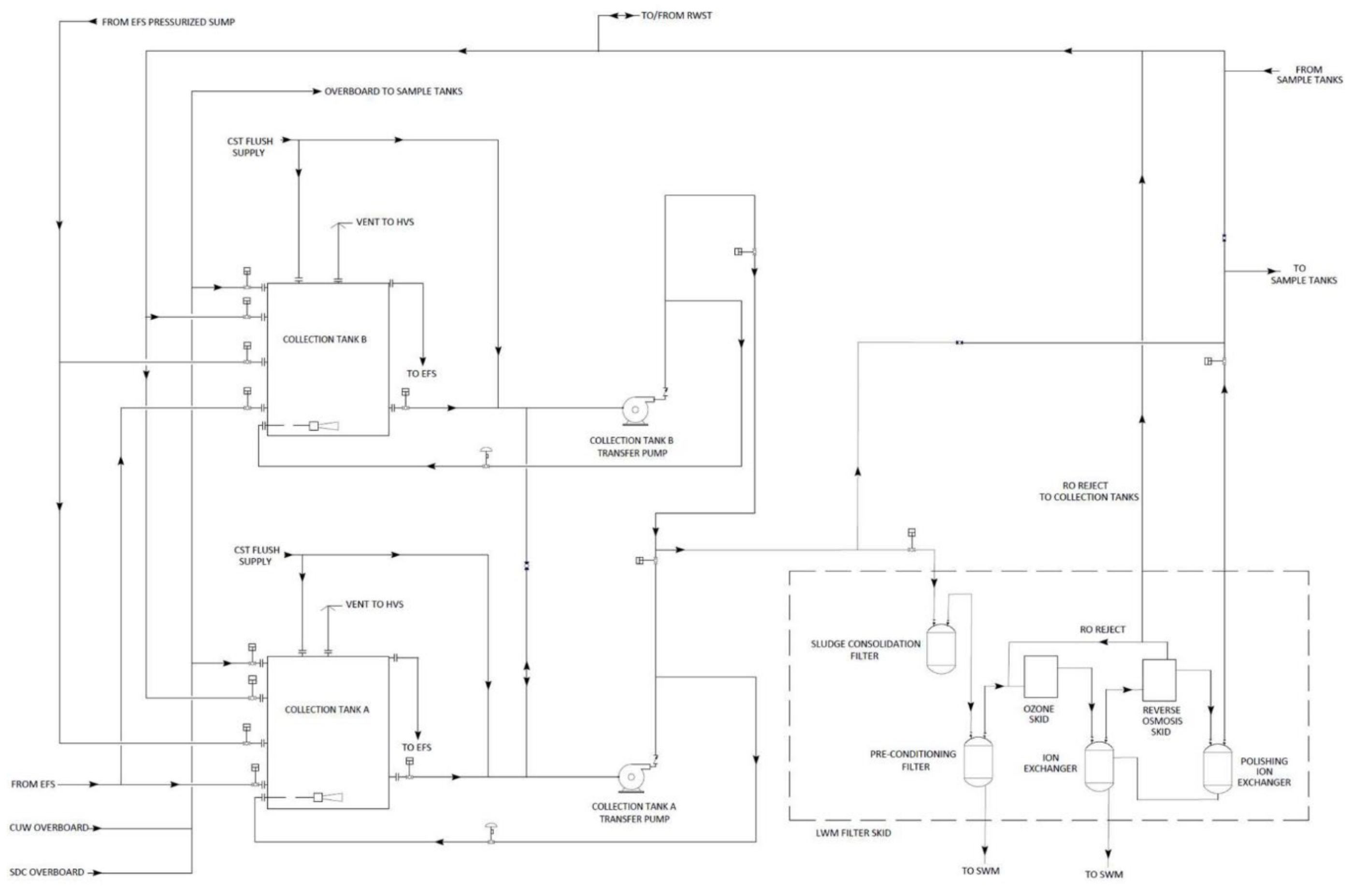

Figure 4-16: LWM Waste Collection and Filtering Subsystem Simplified Diagram

Note:

Taken from the LWM SDD (Reference 4-50)

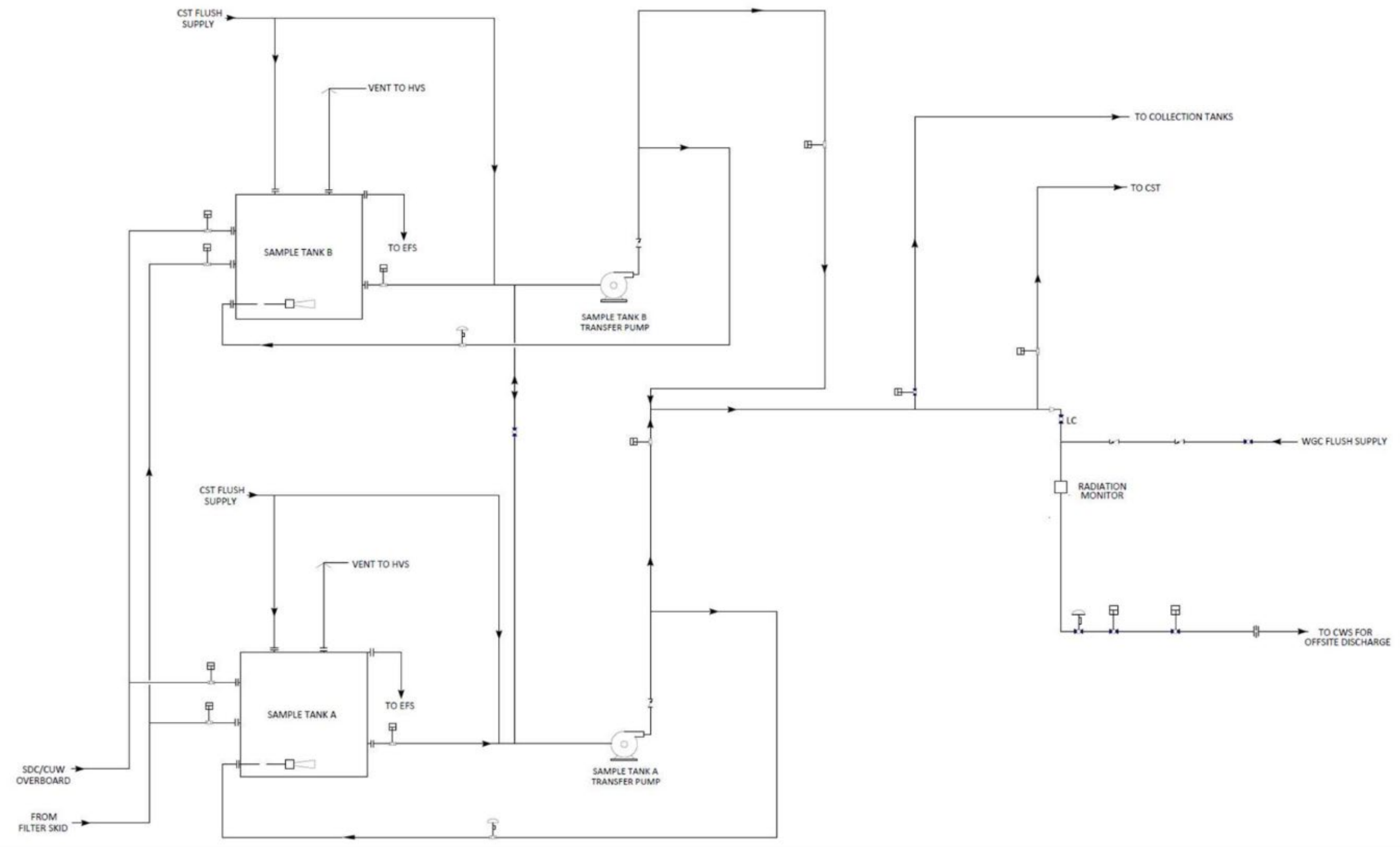

Figure 4-17: LWM Waste Sampling Subsystem Simplified Diagram

Note:

Taken from the LWM SDD (Reference 4-50)

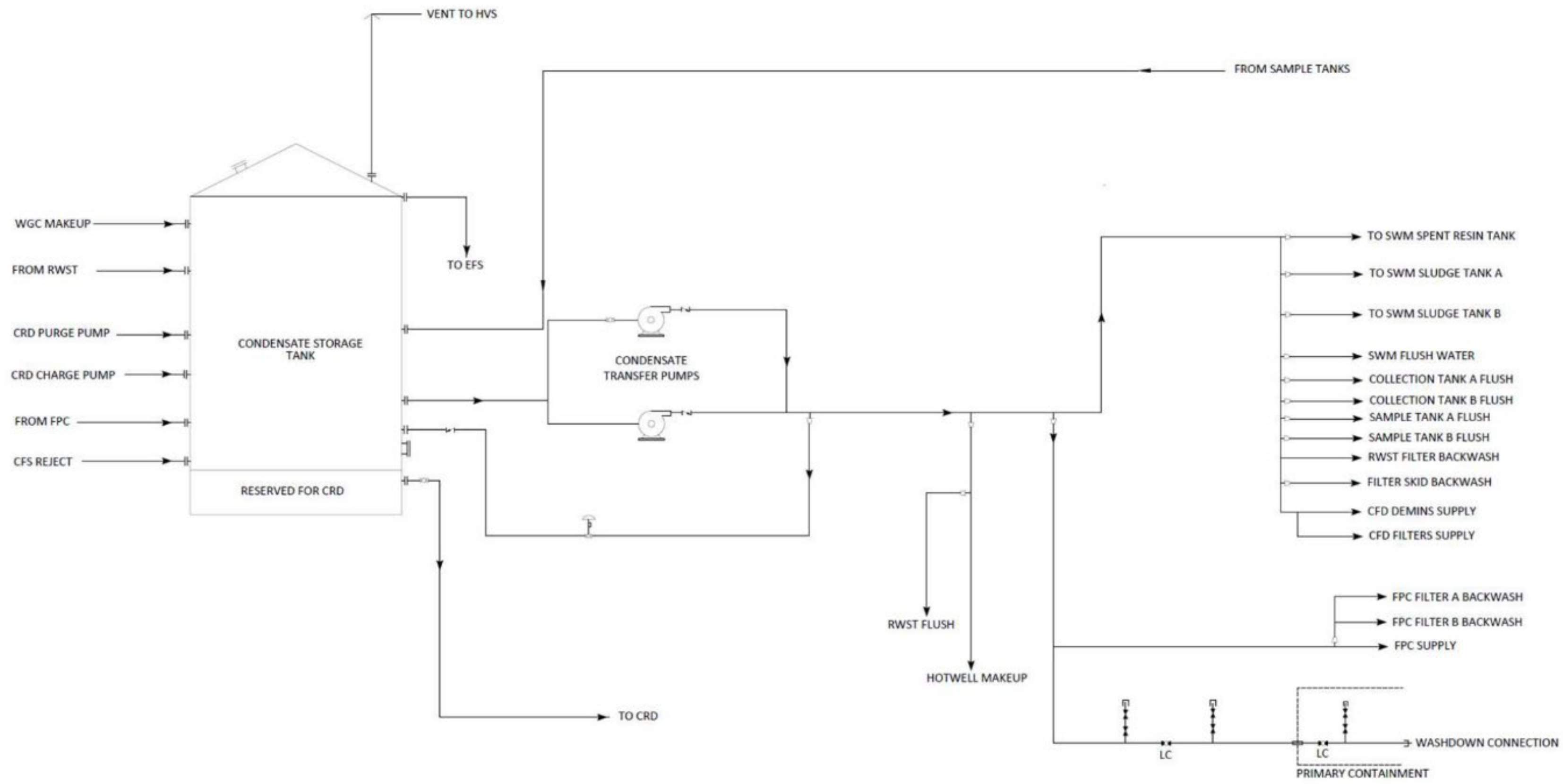

Figure 4-18: LWM Condensate Storage and Transfer Subsystem Simplified Diagram

Note:

Taken from the LWM SDD (Reference 4-50)

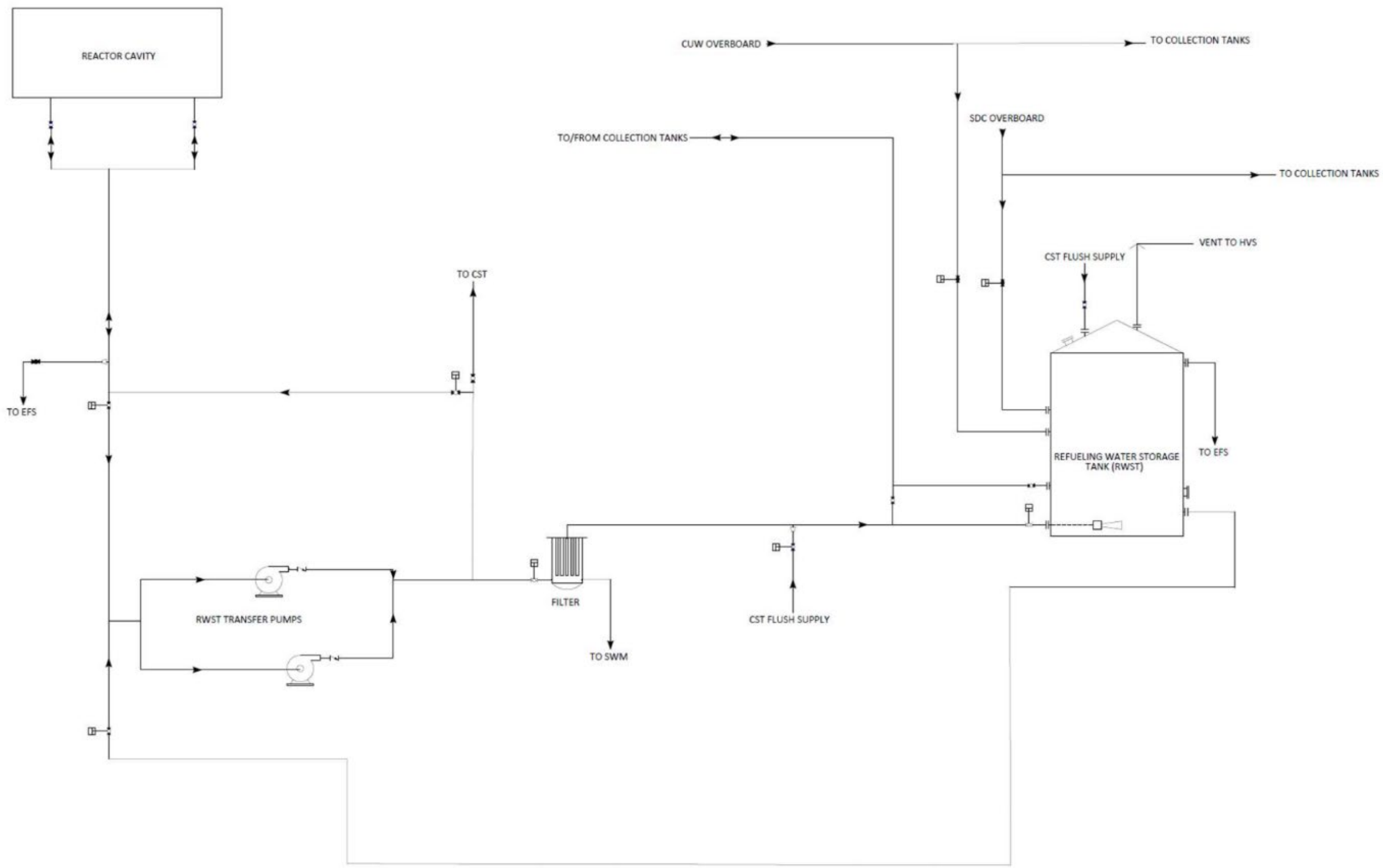

Figure 4-19: LWM Refueling Water Storage Tank Subsystem Simplified Diagram

Note:

Taken from the LWM SDD (Reference 4-50).

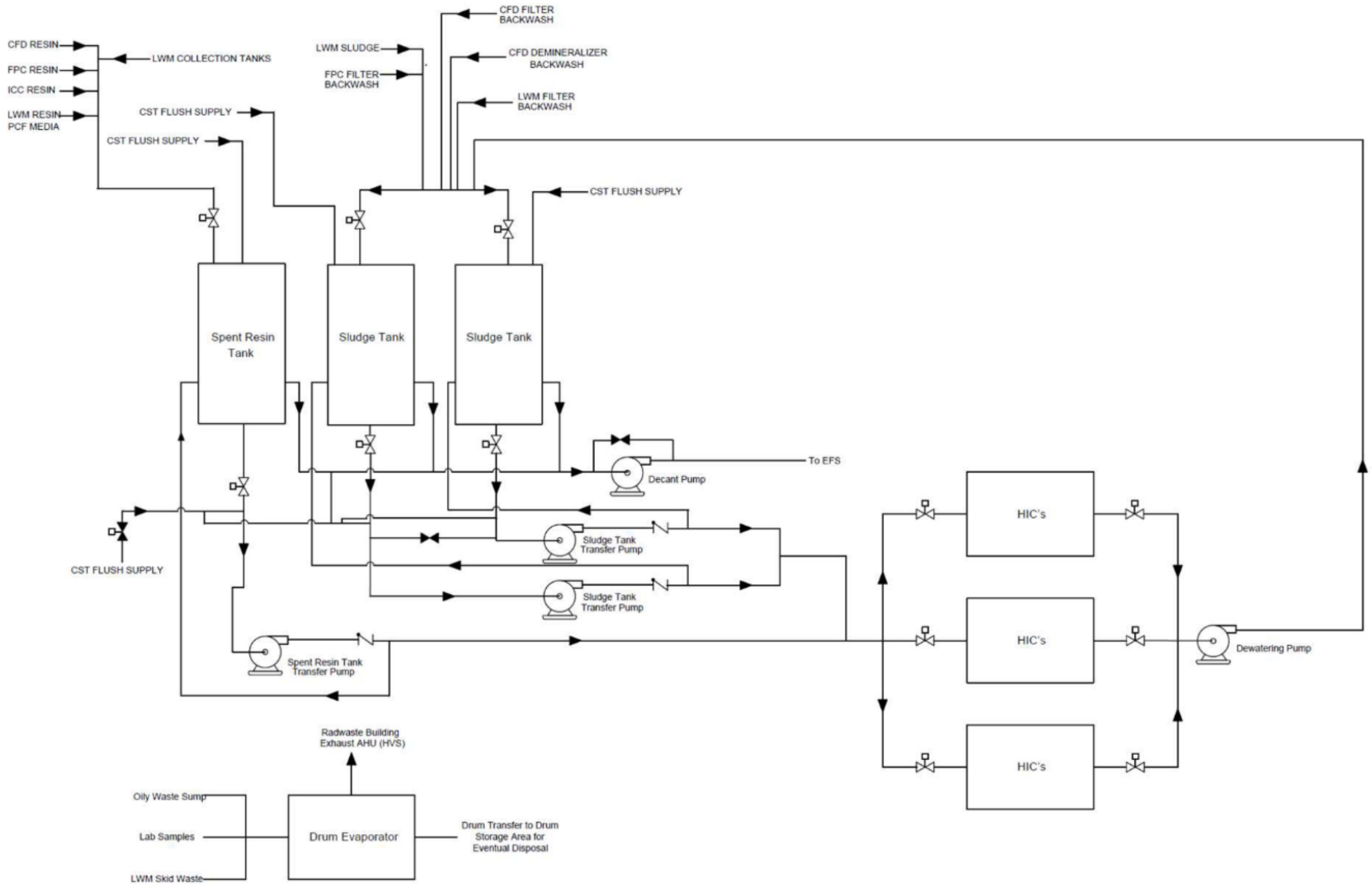

Figure 4-20: Solid Waste Management System Simplified Diagram

Note:

Taken from the SWM SDD (Reference 4-51)

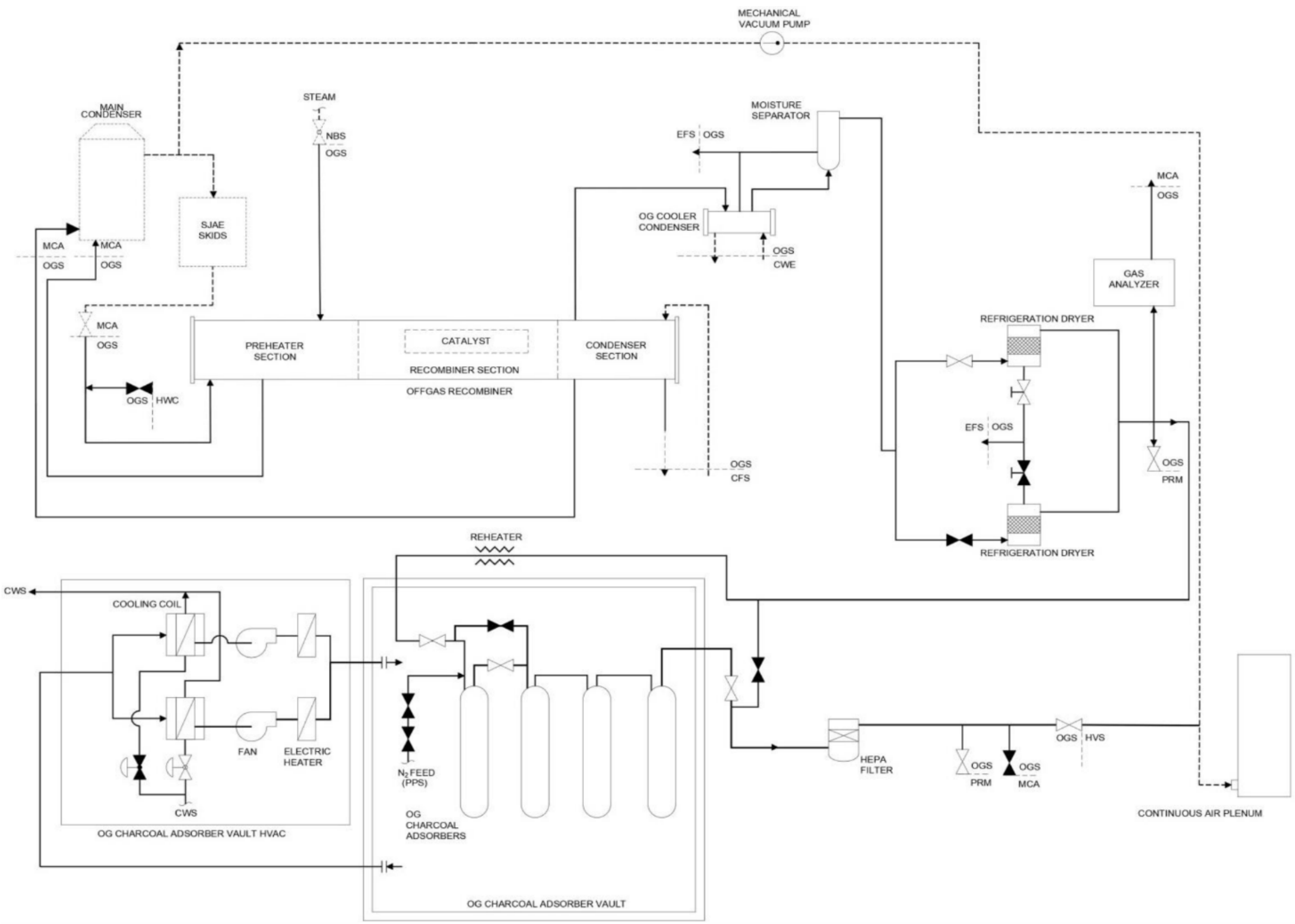

Figure 4-21: Offgas System Simplified Diagram

Note:

Taken from the OGS SDD (Reference 4-52)

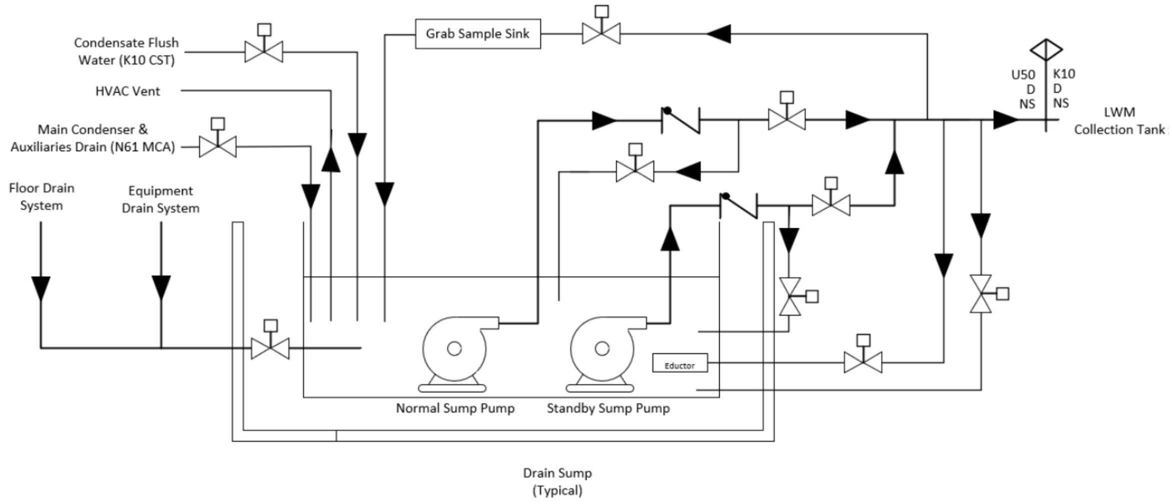

Figure 4-22: EFS Normal Sump Simplified Line Diagram

Note:

Taken from the EFS SDD (Reference 4-55)

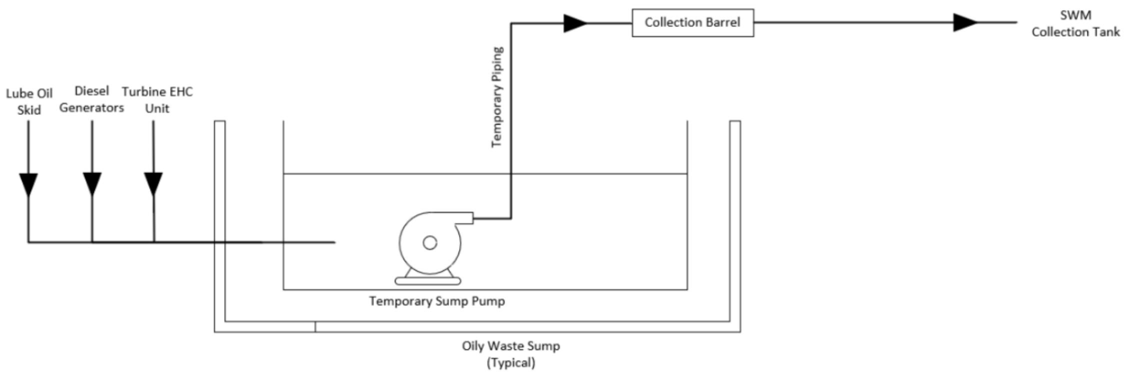

Figure 4-23: EFS Oily Waste Sump Simplified Line Diagram

Note:

Taken from the EFS SDD (Reference 4-55)

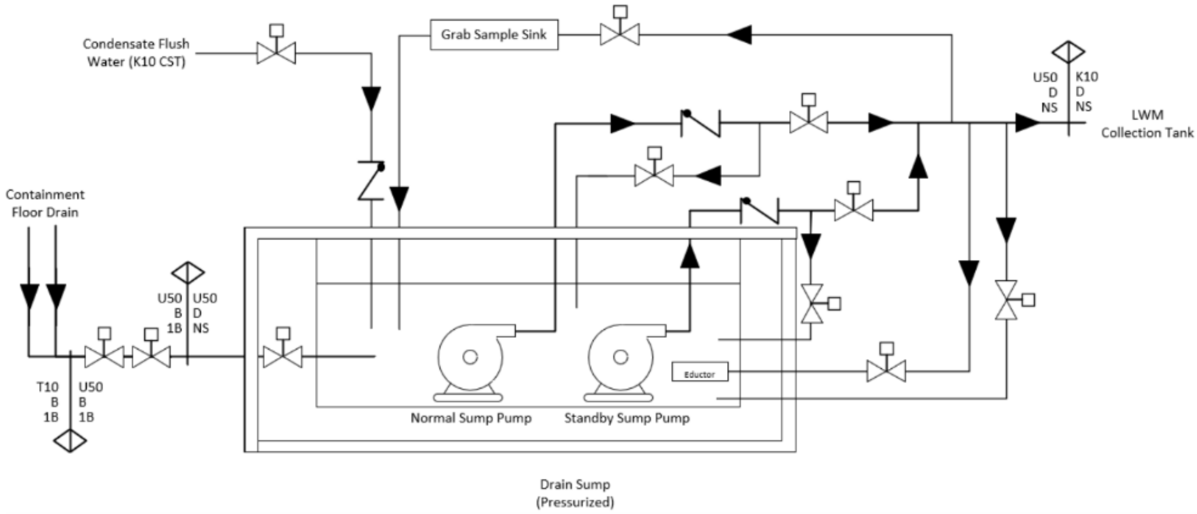

Figure 4-24: EFS Pressurised Sump Simplified Line Diagram

Note:

Taken from 0067789 (Reference 4-55)

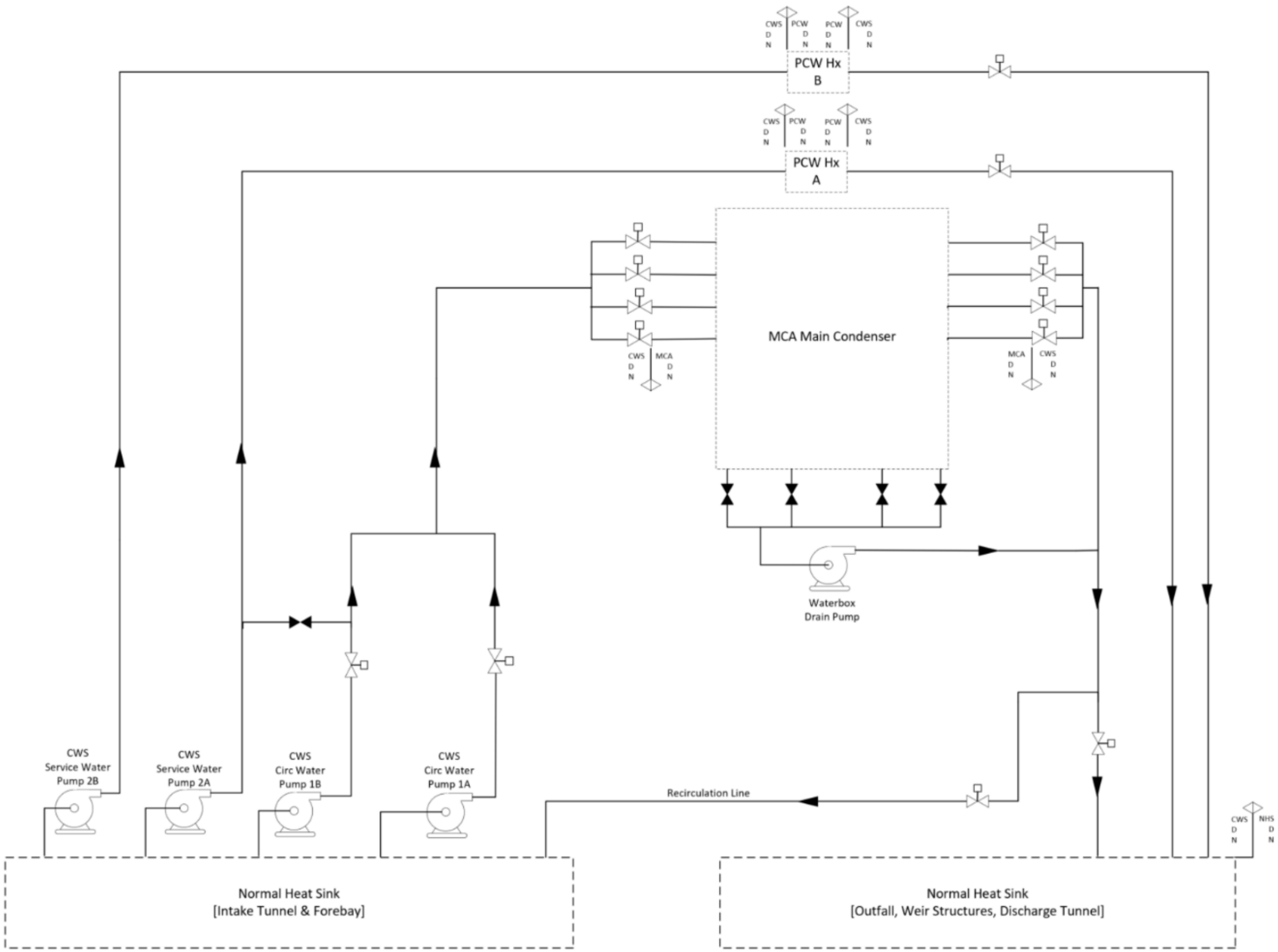

Figure 4-25: Circulating Water System Simplified Diagram

Note:

Taken from CWS SDD (Reference 4-60)

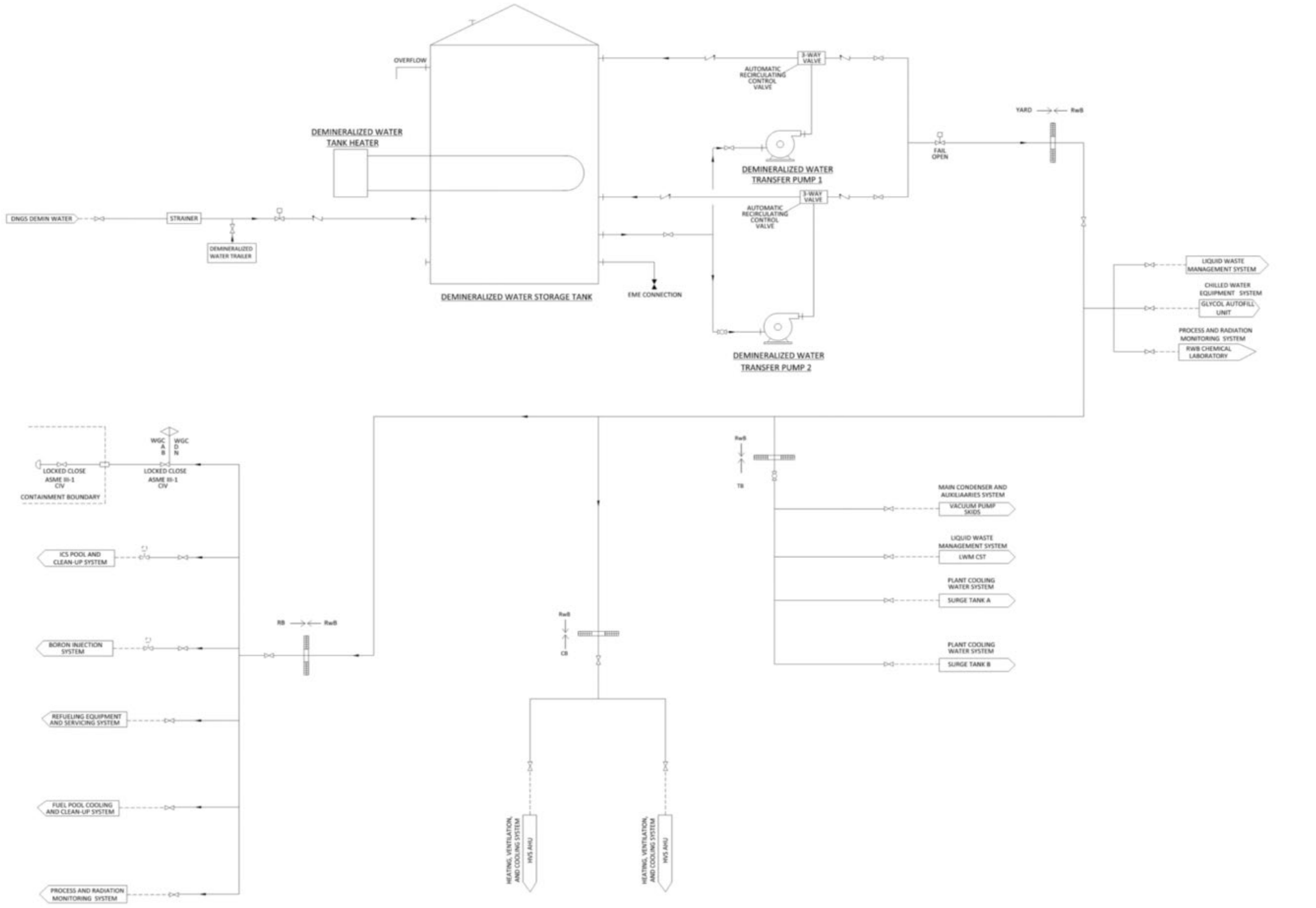

Figure 4-26: Demineralised Water Storage and Distribution Subsystem Simplified Diagram

Note:

Taken from the WGC SDD (Reference 4-62)

4.4 REFERENCES

4-1 "New nuclear power plants: Generic Design Assessment guidance for Requesting Parties", Environment Agency, Office for Nuclear Regulation, Natural Resources Wales, October 2023.

4-2 NEDC-34222P, "BWRX-300 UK GDA Chapter E5: Radioactive Waste Management Arrangements," Rev B, GE-Hitachi Nuclear Energy, Americas, LLC.

4-3 NEDC-34174P, "BWRX-300 UK GDA Chapter 11: Management of Radioactive Waste," Rev B, GE-Hitachi Nuclear Energy Americas, LLC.

4-4 NEDC-34198P, "BWRX-300 UK GDA Chapter 26: Interim Storage of Spent Fuel," Rev B, GE-Hitachi Nuclear Energy Americas, LLC.

4-5 NEDC-34223P, "BWRX-300 UK GDA Chapter E6: Demonstration of Best Available Techniques Approach," Rev A, GE-Hitachi Nuclear Energy Americas, LLC.

4-6 NEDC-34224P, "BWRX-300 UK GDA Chapter E7: Radioactive Discharges," Rev B, GE-Hitachi Nuclear Energy Americas, LLC.

4-7 NEDC-34225P, "BWRX-300 UK GDA Chapter E8: Approach to Sampling and Monitoring," Rev B, GE-Hitachi Nuclear Energy Americas, LLC.

4-8 NEDC-34227P, "BWRX-300 UK GDA Chapter. E10: Other Environmental Regulations," Rev B, GE-Hitachi Nuclear Energy Americas, LLC.

4-9 NEDC-34166P, "BWRX-300 UK GDA Chapter 4: Reactor (Fuel and Core)," Rev B, GE-Hitachi Nuclear Energy Americas, LLC.

4-10 NEDC-34168P, "BWRX-300 UK GDA Chapter 6: Engineered Safety Features," Rev B, GE-Hitachi Nuclear Energy Americas, LLC.

4-11 NEDC-34169P, "BWRX-300 UK GDA "Chapter 7: Instrumentation and Control," Rev B, GE-Hitachi Nuclear Energy Americas, LLC.

4-12 NEDC-34172P, "BWRX-300 UK GDA Chapter 9B: Civil Structures," Rev B, GE-Hitachi Nuclear Energy Americas, LLC.

4-13 006N8670, "BWRX-300 Modularization Strategy Report," GE-Hitachi Nuclear Energy Americas, LLC, Rev A, November 2021.

4-14 DBR-0060041, "BWRX-300 A34 Cleanliness Guidance," GE-Hitachi Nuclear Energy Americas, LLC, Rev 0, January 2022.

4-15 25A5900, "Foreign Materials Exclusion", GE-Hitachi Nuclear Energy Americas, LLC, Rev 4, June 1996.

4-16 EPRI Report 3002003060, "Foreign Material Exclusion Process and Methods," Electric Power Research Institute, November 2014.

4-17 NEDC-34279P, "BWRX-300 UK GDA Analysis of Environmental Discharge Data for US Nuclear Power Plants," GE Hitachi Nuclear Energy Americas, LLC.

4-18 NEDC-34228P, "BWRX-300 UK GDA Integrated Waste Strategy," Rev B, GE-Hitachi Nuclear Energy Americas, LLC.

4-19 008N0279, "BWRX-300 Design Specification for Radwaste Building Structure," Rev 1, GE-Hitachi Nuclear Energy Americas, LLC, February 2024.

4-20 006N7823, "BWRX-300 Primary Containment System," Rev 1, GE-Hitachi Nuclear Energy Americas, LLC, September 2023.

4-21 006N6987, "BWRX-300 Reactor Building Design Specification," Rev 1, GE-Hitachi Nuclear Energy Americas, LLC, Rev 2, March 2024.

4-22 007N3673, “Chemistry Laboratory Requirements,” Rev 1, GE-Hitachi Nuclear Energy Americas, LLC, February 2024.

4-23 006N5991, “BWRX-300 Plant Architecture Definition,” Rev 1, GE-Hitachi Nuclear Energy Americas, LLC.

4-24 008N0988, “BWRX-300 Power Block General Arrangement,” Rev 2, GE-Hitachi Nuclear Energy Americas, LLC, December 2023.

4-25 006N7948, “BWRX-300 Containment Inerting System,” Rev 2, GE-Hitachi Nuclear Energy Americas, LLC.

4-26 006N4761, “BWRX-300 Equipment Qualification Specification,” Rev 2, GE Hitachi Nuclear Energy Americas, LLC, April 2024.

4-27 006N7777, “BWRX-300 Containment Cooling System (CCS),” Rev 2, GE-Hitachi Nuclear Energy Americas, LLC.

4-28 NEDC-34041P, “BWRX-300 GNF2 Fuel Assembly Mechanical Design Report,” Rev 0, GE-Hitachi Nuclear Energy Americas, LLC, April 2024.

4-29 GA91-9901-0022-00001, “UK ABWR Generic Design Assessment: Radioactive Waste Management Arrangements,” Rev H, Hitachi-GE Nuclear Energy, 2017.

4-30 006N7828, “BWRX-300 Nuclear Boiler System,” Rev 2, GE-Hitachi Nuclear Energy Americas, LLC, September 2023.

4-31 006N7898, “BWRX-300 Control Rod Drive,” Rev 2, GE-Hitachi Nuclear Energy Americas, LLC, August 2023

4-32 005N9751, “BWRX-300 General Description,” Rev 2, GE-Hitachi Nuclear Energy Americas, LLC, Rev F, December 2023.

4-33 NEDC-34167P, “BWRX-300 UK GDA Chapter 5: Reactor Coolant System and Associated Systems,” Rev A, GE-Hitachi Nuclear Energy Americas, LLC.

4-34 006N7492, “BWRX-300 Isolation Condenser System,” Rev 1, GE-Hitachi Nuclear Energy Americas, LLC, September 2023.

4-35 006N6766, “BWRX-300 Water Quality,” Rev 4, GE-Hitachi Nuclear Energy Americas, LLC, March 2024

4-36 006N7345, “Isolation Condenser Pools Cooling and Cleanup System,” GE-Hitachi Nuclear Energy, Rev 1, September 2023.

4-37 006N7941, “BWRX-300 Fuel Pool Cooling and Cleanup System,” Rev 1, GE-Hitachi Nuclear Energy Americas, LLC, September 2023.

4-38 006N7609, “BWRX-300 Reactor Water Cleanup System,” Rev 3, GE-Hitachi Nuclear Energy Americas, LLC, April 2024.

4-39 006N7717, “BWRX-300 Main Turbine Equipment,” Rev 1, GE-Hitachi Nuclear Energy Americas, LLC, May 2023.

4-40 006N7745, “BWRX-300 Moisture Separator Reheater System,” Rev 2, GE-Hitachi Nuclear Energy Americas, LLC, April 2023.

4-41 006N7749, “BWRX-300 Turbine Bypass System,” Rev 1, GE-Hitachi Nuclear Energy Americas, LLC, May 2023.

4-42 006N7757, “BWRX-300 Main Condenser and Auxiliaries System,” Rev 2, GE-Hitachi Nuclear Energy Americas, LLC, February 2024.

4-43 006N7741, “BWRX-300 Condensate Filters and Demineralizers (CFD),” Rev 1, GE-Hitachi Nuclear Energy Americas, LLC, March 2023.

4-44 006N7737, "BWRX-300 Condensate and Feedwater Heating System," Rev 1, GE-Hitachi Nuclear Energy Americas, LLC, April 2023.

4-45 007N4013, "BWRX-300 Zinc Injection Passivation," Rev 1, GE-Hitachi Nuclear Energy Americas, LLC, June 2023.

4-46 006N8027, "BWRX-300 P73 Hydrogen Water Chemistry System (HWC)," Rev 1, GE-Hitachi Nuclear Energy Americas, LLC, June 2023.

4-47 006N7535, "BWRX-300 On-Line NobleChem™ (OLNC)," Rev 1, GE-Hitachi Nuclear Energy Americas, LLC, May 2023.

4-48 006N7708, "BWRX-300 Shutdown Cooling System," Rev 2, GE-Hitachi Nuclear Energy Americas, LLC, August 2023.

4-49 006N7417, "Boron Injection System," Rev 2, GE-Hitachi Nuclear Energy Americas, LLC, August 2023.

4-50 006N7729, "BWRX-300 Liquid Waste Management System (LWM)," Rev 1, GE-Hitachi Nuclear Energy Americas, LLC, March 2023.

4-51 006N7733, "BWRX-300 Solid Waste Management System (SWM)," Rev 1, GE-Hitachi Nuclear Energy Americas, LLC, April 2023.

4-52 006N7899, "BWRX-300 Offgas System," Rev 1, GE-Hitachi Nuclear Energy Americas, LLC, August 2023.

4-53 006N7782, "BWRX-300 Heating, Vent, and Cooling System, HVS (U41)" Ducting and Instrumentation Diagram, Rev 2, GE-Hitachi Nuclear Energy Americas, LLC, December 2022.

4-54 006N7781, "BWRX-300 Heating, Ventilation, and Cooling System (HVS)," Rev 5, GE-Hitachi Nuclear Energy Americas, LLC, November 2024.

4-55 006N7789, "BWRX-300 Equipment and Floor Drain System (EFS)," Rev 2, GE-Hitachi Nuclear Energy Americas, LLC, April 2023.

4-56 006N7938, "BWRX-300 Process Radiation Monitoring System," Rev 2, GE-Hitachi Nuclear Energy Americas, LLC, March 2024.

4-57 006N7773, "BWRX-300 Plant Pneumatic System (PPS)," Rev 1, GE-Hitachi Nuclear Energy Americas, LLC, March 2023.

4-58 006N7785, "BWRX-300 Fire Protection System (FPS)," Rev 4, GE-Hitachi Nuclear Energy Americas, LLC, April 2024.

4-59 006N5377, "BWRX-300 Refueling and Servicing Equipment," Rev 2, GE-Hitachi Nuclear Energy Americas, LLC, October 2023.

4-60 006N7761, "BWRX-300 Circulating Water System," Rev 1, GE-Hitachi Nuclear Energy Americas, LLC, March 2023.

4-61 006N7762, "BWRX-300 N71 Circulating Water System (CWS)," Rev 1, Piping and Instrumentation Diagram, GE-Hitachi Nuclear Energy Americas, LLC, October 2022.

4-62 006N7797, "BWRX-300 Water, Gas, and Chemical Pads," Rev 1, GE-Hitachi Nuclear Energy Americas, LLC, March 2023.

4-63 006N7769, "BWRX-300 Plant Cooling Water (PCW) System," Rev 1, GE-Hitachi Nuclear Energy Americas, LLC, March 2023.

4-64 006N7765, "BWRX-300 Chilled Water Equipment (CWE)," Rev 2, GE-Hitachi Nuclear Energy Americas, LLC.

4-65 006N6705, “BWRX-300 System Requirements,” Rev 1, GE-Hitachi Nuclear Energy Americas, LLC, November 2023.

4-66 006N6567, “BWRX-300 Fire Hazard Assessment Requirements Document,” Rev 2, GE-Hitachi Nuclear Energy Americas, LLC, November 2023.

4-67 NEDC-34170P, BWRX-300 UK GDA Chapter 8: Electrical Power,” Rev B, GE-Hitachi Nuclear Energy Americas, LLC.

APPENDIX A FORWARD ACTION PLAN

The following actions have been identified for incorporation into the Forward Action Plan for development of a UK version of the BWRX-300 SMR:

Action ID	Finding	Forward Action	Delivery Phase
FAP.PER4-215	Plant layout is subject to change.	A future developer/operator shall determine optimum plant layout based on choice of site for deployment of BWRX-300.	Before Site License Application, Environmental Permit Applications and/or BL3 Design Phase
FAP.PER4-218	Toxic gas monitoring is not currently provided for specific plant areas	A future developer/operator shall determine whether toxic gas monitoring is required based on site location. If it is deemed necessary, specific locations will also need to be determined.	Before Site License Application, Environmental Permit Applications and/or BL3 Design Phase
FAP.PER4-219	Circulating Water System SDD does not specify water intake forebay components, such as filters and strainers. It does not specify the location or size of the intake tunnel, nor does it specify the design of any fish barrier/deterrent or return system.	A future developer/operator shall determine the requirements and specification for intake components based on location (to avoid sensitive receptors such as eel migratory routes and breeding areas) and normal heat sink characterisation. Intake tunnel size shall be designed so that water abstraction velocities are minimized, reducing the risk of wildlife capture. The design of fish barriers/deterrents and fish return systems shall also be developed.	Before Site License Application, Environmental Permit Applications and/or BL3 Design Phase
FAP.PER4-220	Circulating Water System SDD does not identify water treatment approaches that are to be used for circulating water.	A future developer/operator shall determine appropriate water treatment approaches based on normal heat sink characterisation.	Before Site License Application, Environmental Permit Applications and/or BL3 Design Phase
FAP.PER4-221	A refrigerant for use in the CWE system has not been chosen.	A future developer/operator shall select an approved refrigerant, aligned with UK regulations, based on site location.	Before Site License Application, Environmental Permit Applications and/or BL3 Design Phase
FAP.PER4-222	CWE chemical bypass feeder system description does not provide information on any chemical treatment approaches or requirements.	A future developer/operator shall determine an appropriate chemical treatment approach for the CWE system.	Before Site License Application, Environmental Permit Applications and/or BL3 Design Phase