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Title

E3S Case Chapter 9A: Auxiliary Systems

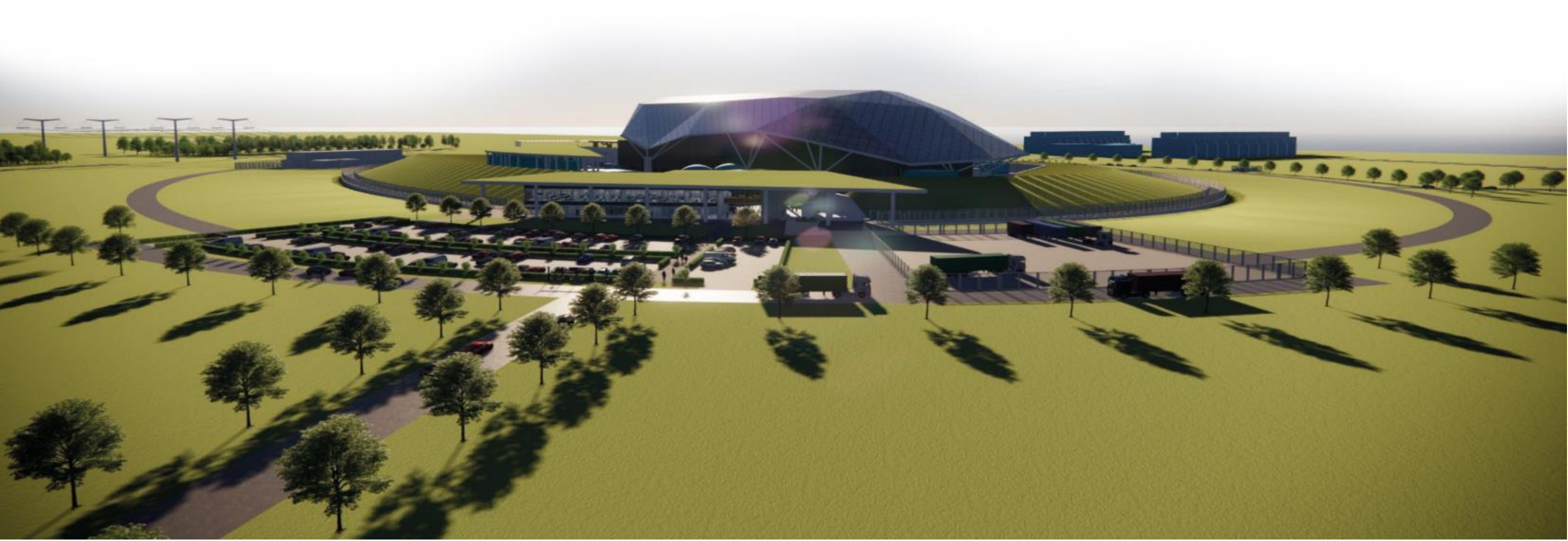
Executive Summary

This chapter of the Environment, Safety, Security, and Safeguards (E3S) Case presents the Auxiliary Systems of the Rolls-Royce Small Modular Reactor (RR SMR). The chapter outlines the arguments and preliminary evidence available at the Preliminary Concept Definition (PCD) design stage to underpin the high-level Claim that the RR SMR Auxiliary Systems are designed and substantiated to achieve functional and non-functional safety requirements through the lifecycle and reduce risks to As Low As Reasonable Practicable (ALARP).

The auxiliary systems summarised in this revision of the E3S Case include the fresh fuel and spent fuel storage and handling systems, spent fuel cooling and clean-up systems, systems for transfer of new and spent fuel between fuel pools, refuelling systems, main cooling water system, component cooling system, essential service water system, and auxiliary cooling and make-up system. Structures, Systems, Components (SSCs) excluded from this revision based on limited maturity will be incorporated as their design is matured.

For each SSC, the safety categorised functional requirements, non-functional system requirements, and design description are summarised based on the maturity level at PCD. The key verification activities to substantiate the requirements are also described.

The full suite of evidence to underpin the claim is still in development, including full traceability of safety categorised requirements from the safety analysis, a complete set of non-functional system requirements from the E3S design principles, further development of the SSC concept design to meet safety requirements, and ultimately substantiation of safety requirements.



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9A.0 Introduction

9A.0.1 Introduction

Chapter 9A of the Rolls-Royce Small Modular Reactor (RR SMR) Environment, Safety, Security & Safeguards (E3S) Case forms part of the Pre-Construction Safety Report (PCSR) and is a supporting reference to the Generic Environment Report (GER) and Generic Security Report (GSR), as defined in E3S Case Chapter 1: Introduction, Reference [1].

Chapter 9A presents the overarching summary and entry point to the design and safety information for the Auxiliary Systems of the Rolls-Royce Small Modular Reactor (RR SMR), as defined at Reference Design (RD) 5 level of design maturity. Auxiliary systems include the fuel handling and storage systems, water supply systems, and ventilation systems.

9A.0.2 Scope

The list of Structures, Systems, Components (SSCs) that are included in the scope of this chapter is provided in Section 9A.13 Appendix B: SSCs in Scope of Chapter 9A (Appendix B), including those that are within scope but excluded from this revision due to design immaturity.

For each SSC in scope, the following aspects are broadly summarised:

1. High-Level Safety Functions (HLSFs) delivered by the SSC, and the assigned safety categorised functional requirements and non-functional system requirements

2. Design description, including architecture, layout, operating modes, and As Low As Reasonably Practicable (ALARP) considerations in the design development

3. Verification activities identified for substantiation of SSCs

The scope of this chapter covers the mechanical aspects of fluid systems, with the selection of materials and justification of the integrity SSCs covered in E3S Case Chapter 23: Structural Integrity, Reference [2].

Design/Programme Maturity

RR SMR design information presented in this revision of the PCSR is largely based on the design definition at the end of Preliminary Concept Definition (PCD), which is an interim design stage representing RD5 level of programme maturity.

PCD is an interim design stage, where SSCs have achieved a level of design maturity, broadly that, requirement specifications are identified and understood, the design scope is defined and bounded, preferred concepts are selected and are likely to deliver requirements, or a plan for down-selection of multiple options is in place, and key verification activities are identified.

9A.0.3 Claims, Arguments, Evidence Route Map

The Chapter level Claim for E3S Case Chapter 9A: Auxiliary Systems is:

Claim 9A: The RR SMR Auxiliary Systems are designed and substantiated to achieve functional and non-functional safety requirements through the lifecycle, and reduce risks to As Low As Reasonably Practicable

A decomposition of this Claim into Sub-Claims, Arguments, and link to the relevant Tier 2 Evidence is provided in Section 9A.12 Appendix A: CAE Route Map (Appendix A). For each lowest level Sub-Claim, the sections of this report providing the Evidence summary are also identified.

The complete suite of evidence to underpin the Claims in the E3S Case will be generated through the RR SMR design and E3S Case programme and documented in the Claims, Arguments, Evidence (CAE) Route Map, [3], described further in E3S Case Chapter 1: Introduction, Reference [1].

9A.0.4 Applicable Regulations, Codes & Standards

The mechanical systems and components summarised in this report are designed in accordance with their safety classification, to the codes and standards outlined in Table 9A.0-1, as identified in Reference [4].

Table 9A.0-1: Mechanical Design Codes & Standards

Safety Classification	Design Basis Code
Very High Reliability (VHR)	American Society of Mechanical Engineers (ASME) III (Sub-section NB) and beyond code requirements
High Reliability (HR)	ASME III (Sub-section NB) and beyond code requirements
Class 1	ASME III
Class 2	ASME III
Class 3	ASME III or Commercial standards e.g., ASME VIII, British Standard British Standard (BS) EN 13445
n/a	Commercial standards e.g., ASME VIII, BS EN 13455

Other codes and standards identified for the design of Fuel Handling [F] systems include:

1. Supply of Machinery (Safety) Regulations
2. Lifting Operations and Lifting Equipment Regulations 1998 (LOLER)

9A.1 Fuel Storage & Handling Systems

9A.1.1 Fresh Fuel Storage & Handling Systems

System and Equipment Functions

The New Fuel Receipt and Inspection Area [FAA] is an area of the fuelling building used for the receipt, inspection, and storage of new fuel which supports achievement of the Fundamental Safety Functions (FSFs) of Control of Reactivity (CoR) and Confinement of Nuclear Material (CoRM) during normal operation and fault conditions.

HLSFs for the New Fuel Receipt and Inspection Area [FAA], and the Postulated Initiating Events (PIEs) against which they are assigned, are being derived in the Fault Schedule, which is presented in E3S Case Chapter 15: Safety Analysis, Reference [5].

Safety Design Basis

<u>Functional Requirements</u>

Safety categorised functional requirements are specified for the New Fuel Receipt and Inspection Area [FAA] based on the HLSFs they deliver, including the applicable plant states and operating modes, these are presented in Table 9A.1-1.

The traceability of safety categorised functional requirements back to the HLSFs will be managed in Dynamic Object-Oriented Requirements System (DOORS) via the Safety Measures Module; this process is outlined in Deterministic Safety Methodology, Reference [6]. This will include any specific safety categorised functional requirements aligned to the PIEs should the New Fuel Receipt and Inspection Area [FAA] be claimed during fault conditions (including internal and external hazards).

Table 9A.1-1: [FAA] Safety Categorised Functional Requirements

DOORS ID	Functional Requirements	Plant State(s)	Mode(s) of Operation	Safety Category
FAA-R-1448	The [FAA] Storage of new fuel assemblies shall control reactivity of new fuel	TBC	All Modes	A
FAA-R-1451	The [FAA] Storage of new fuel assemblies shall ensure confinement of new fuel	TBC	All Modes	B

Non-functional performance requirements associated with the safety categorised functional requirements are also allocated in the DOORS New Fuel Receipt and Inspection Area [FAA] Requirements Module, including the rationale for their selection. These are summarised in Table 9A.1-2.

Table 9A.1-2: [FAA] Non-Functional Performance Requirements

Associated Functional Requirement	Non-Functional Performance Requirement
FAA-R-1448	When at normal conditions, the [FAA] Storage of new fuel assemblies shall control reactivity of new fuel with a K_{eff} less than or equal to 0.95
	When at accident conditions, the [FAA] Storage of new fuel assemblies shall control reactivity of new fuel with a K_{eff} less than or equal to 0.98

<u>Non-Functional System Requirements</u>

Non-functional system requirements are specified for the New Fuel Receipt and Inspection Area [FAA] based on the E3S Principles. The requirements specified at PCD are listed in the DOORS New Fuel Receipt and Inspection Area [FAA] Requirements Module, including the rationale for their application. These are summarised in Table 9A.1-3.

Table 9A.1-3: [FAA] Non-Functional System Requirements

DOORS ID	Non-Functional System Requirement	Rationale
FAA-R-1487	Systems that contain radioactive material shall be designed to prevent spread of that radioactive material beyond their boundary	Confinement of radioactive material for containment and sub-systems in E3S Principles

A full set of non-functional system Requirements are in development based on the E3S Principles, which will be systematically applied to each SSC as part of the systems engineering process.

<u>Safety Classification</u>

The safety classification of the New Fuel Receipt and Inspection Area [FAA] is still to be developed based on the categorisation of safety functions it delivers.

<u>Seismic Classification</u>

The seismic classification of SSCs is still to be assigned in accordance with methodology outlined in E3S Case Chapter 3: E3S Objectives & Design Rules, Reference [7].

Description of SSC

The New Fuel Receipt and Inspection Area [FAA] is a section of the fuelling building used for the receipt, inspection, and storage of new fuel before it is moved into the Spent Fuel Pool (SFP) [FAB10]. It is located outside Containment but within the Hazard Shield.

For each refuelling outage, approximately 40 new fuel assemblies are required for loading into the core. To minimise the refuelling outage duration these new fuel assemblies are stored in the SFP [FAB10] before the refuelling outage commences.

The delivery of new fuel to the SMR location is the responsibility of the fuel vendor. A Fuel Transfer Container (FTC) accommodates a maximum of 2 fuel assemblies, and it is expected that a shipment will consist of 4 FTCs, meaning each fuel delivery to the SMR site will consist of 8 fuel assemblies in total. To achieve the 40 new fuel assemblies for each refuelling outage, 5 deliveries will be required at a rate of approximately one per week. The FTCs will be delivered to a location at the SMR site, then transported to the New Fuel Receipt and Inspection Area [FAA].

Lifting equipment [XMK] will be available for unloading operations in the New Fuel Receipt and Inspection Area [FAA]. It is expected that a height adjustable platform will be used to allow personnel to connect a lifting attachment to the top of each fuel assembly, which will then enable the removal of the bolted frame, whilst also providing an area for visual inspections.

A dry storage area is required for up to 8 fuel assemblies, to store those that need further inspection or communication with the fuel vendor or return. This storage area will be designed with sufficient geometrical spacing and fixed neutron absorbers between fuel assemblies, so that sub-criticality is maintained even if flooding should occur.

Once fuel receipt inspection is complete a stillage or skid assembly is used to move the new fuel assemblies from the New Fuel Receipt and Inspection Area [FAA] into the Cask Preparation Pit [FAB30]. The pit transfer system is then used to move the new fuel assemblies into the Cask Loading Pit [FAB20]. A jib crane then moves the new fuel into the new fuel elevator in the SFP [FAB10].

Reactivity control is provided by geometrical spacing and fixed neutron absorbers in the dry storage rack. Fuel assemblies are moved one at a time to maintain geometrical spacing. Also, lift heights are minimised to protect fuel from dropped load impacts.

SSC Operation

During Operating Modes 1 (Power Operation) and 2 (Low Power), new fuel is received, inspected, and loaded into the Spent Fuel Pool [FAB10] in advance of the refuelling outage. It is expected that new fuel receipt will not take place during other modes.

Temperature control and shielding are not required for new fuel.

Interfaces with Supporting Systems

The New Fuel Receipt and Inspection Area [FAA] functional and physical interfaces are described above. These are identified and managed within DOORS, including flow down of functional requirements.

Instrumentation & Control

The Handling of Nuclear Equipment [F] requirements for trips, monitoring, indication, alarms, and warnings are still to be developed. The allocation of safety categorised functional requirements to the Reactor Island Control & Protection System [JY] will be described further in E3S Case Chapter 7: Instrumentation & Control, Reference [8], as the C&I system design is developed.

Monitoring, Inspection, Testing & Maintenance

An outline maintenance plan for the Handling of Nuclear Fuel [F] is still to be developed.

Radiological Aspects

No significant radiological aspects associated with the New Fuel Receipt and Inspection Area [FAA] have been identified during design decisions up to PCD.

Performance and Safety Evaluation

Verification activities to substantiate safety categorised functional requirements and non-functional system requirements for New Fuel Receipt and Inspection Area [FAA] are still to be determined.

Installation & Commissioning

An outline installation and commissioning plan for Handling of Nuclear Fuel [F] is still to be developed. The overall strategy for the RR SMR commissioning programme is presented in E3S Case Chapter 14: Plant Construction & Commissioning, Reference [9].

Ageing Management

An outline maintenance plan for the Handling of Nuclear Fuel [F] is still to be developed.

ALARP in Design Development

The design of the New Fuel Receipt and Inspection Area [FAA] has been developed in accordance with the systems engineering design process, which includes alignment to Relevant Good Practice (RGP) & Operational Experience (OPEX), design to codes and standards according to the safety classification, and a systematic optioneering process with down-selection of design options based on assessment against relevant safety criteria (as described in PSCR Chapter 3: E3S Objectives & Design Rules, Reference [7]).

Ongoing Design Development

The RR SMR design definition is currently in development as described in Section 9A.0.2 Scope. Key design opportunities and decisions related to safety are currently being explored, this includes:

1. Method of dry to wet transfer – new fuel elevator vs flood-up of cask loading pit

2. New fuel receipt location

3. New fuel unpacking location

All design development risks and opportunities are captured and managed by design teams.

9A.1.2 Spent Fuel Storage & Handling System

System and Equipment Functions

The Storage of Spent/Irradiated Fuel Assemblies and Other Radioactive Parts System [FAB] is a pool used for interim storage of fuel, fuel inspection, fuel repair and cask loading, ensuring the FSFs of CoR, Control of Fuel Temperature (CoFT), and CoRM are maintained. It is divided into the following four areas:

1. Spent Fuel Pool (SFP) [FAB10], where the fuel is stored in fuel storage racks. This region contains Post Irradiation Examination equipment and fuel repair equipment

2. Cask Loading Pit [FAB20], where the fuel is loaded into casks

3. Cask Preparation Pit [FAB30], where the cask is prepared for loading and once loaded welded shut, drained of water, and filled with helium

4. Upender Pit [FAB40], where the upender and fuel transfer system are located

High-Level Safety Functions (HLSFs) for the Storage of Spent/Irradiated Fuel Assemblies and Other Radioactive Parts System [FAB], and the PIEs against which they are assigned, are being derived in the Fault Schedule, which is presented in E3S Case Chapter 15: Safety Analysis, Reference [5].

Safety Design Basis

<u>Functional Requirements</u>

Safety categorised functional requirements are specified for the Storage of Spent/Irradiated Fuel Assemblies and Other Radioactive Parts System [FAB] based on the HLSFs they deliver, including the applicable plant states and operating modes, these are presented in Table 9A.1-4.

The traceability of safety categorised functional requirements back to the HLSFs will be managed in DOORS via the Safety Measures Module; this process is outlined in Deterministic Safety Methodology, Reference [6]. This will include any specific safety categorised functional requirements aligned to the PIEs should the Storage of Spent/Irradiated Fuel Assemblies and Other Radioactive Parts System [FAB] be claimed during fault conditions (including internal and external hazards).

Table 9A.1-4: [FAB] Safety Categorised Functional Requirements

DOORS ID	Functional Requirement	Plant State(s)	Mode(s) of Operation	Safety Category
FAB-R-1665	The [FAB] System shall maintain control of Fuel Assembly reactivity	TBC	All Modes	A
FAB-R-1677	The [FAB] System shall remove heat from Fuel Assemblies to safe levels	TBC	All Modes	B

DOORS ID	Functional Requirement	Plant State(s)	Mode(s) of Operation	Safety Category
FAB-R-1670	The [FAB] System shall provide confinement of irradiated nuclear equipment	TBC	All Modes	A

Non-functional performance requirements associated with the safety categorised functional requirements are also allocated in the DOORS Storage of Spent/Irradiated Fuel Assemblies and Other Radioactive Parts System [FAB] Requirements Module, including the rationale for their selection. These are summarised in Table 9A.1-5.

Table 9A.1-5: [FAB] Non-Functional Performance Requirements

Associated Functional Requirement	Non-Functional Performance Requirement
FAB-R-1665	The [FAB] System shall maintain a K_{eff} of 0.95 or below of Fuel Assemblies when outside the Reactor Pressure Vessel (RPV)
	The [FAB] System shall maintain a K_{eff} of 0.98 or below of Fuel Assemblies when outside the RPV, under accident conditions
	The [FAB] system shall operate without soluble boron for reactivity control

<u>Non-Functional System Requirements</u>

A full set of non-functional system requirements are in development based on the E3S Principles, which will be systematically applied to each SSC as part of the systems engineering process.

<u>Safety Classification</u>

The safety classification of the Storage of Spent/Irradiated Fuel Assemblies and Other Radioactive Parts System [FAB] is still to be developed based on the categorisation of safety functions it delivers.

<u>Seismic Classification</u>

The seismic classification of SSCs is still to be assigned in accordance with methodology outlined in E3S Case Chapter 3: E3S Objectives & Design Rules, Reference [7].

Description of SSC

The Storage of Spent/Irradiated Fuel Assemblies and Other Radioactive Parts System [FAB] is divided into four regions, with each region separated from each other by gates. These regions are illustrated in Figure 9A.1-1 and described further below.

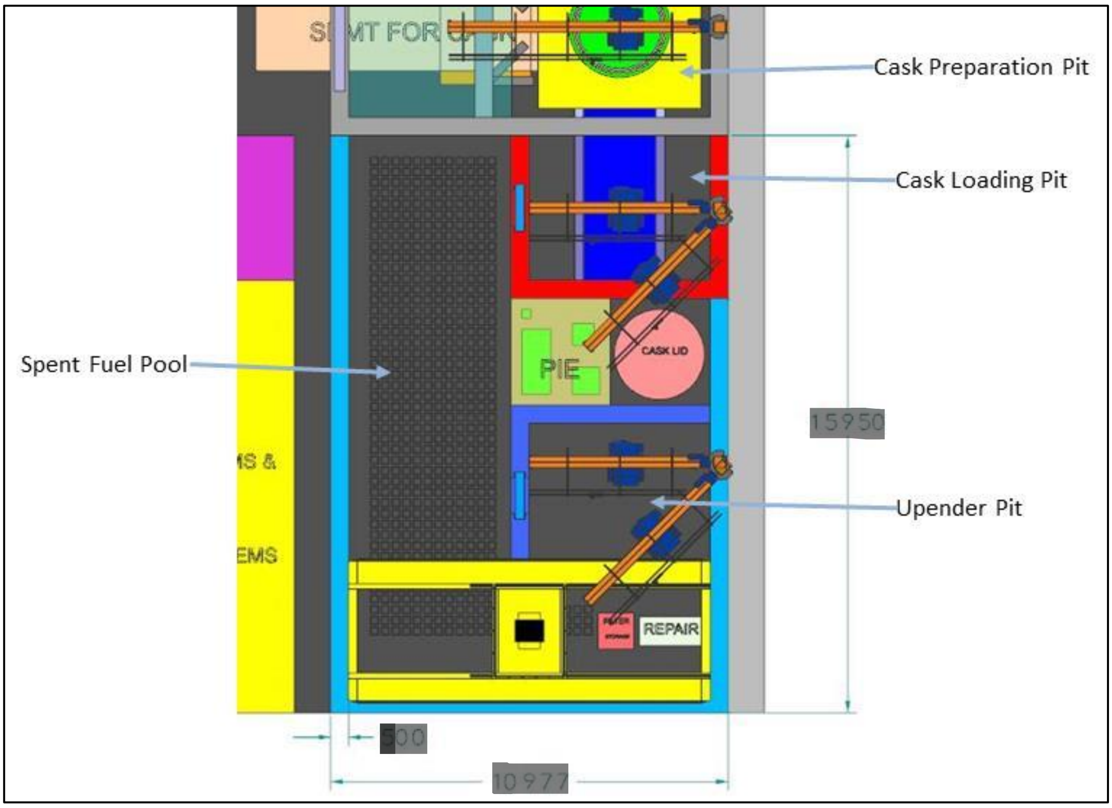

Figure 9A.1-1: Storage of Spent/Irradiated Fuel Assemblies and Other Radioactive Parts System [FAB] (Plan View)

<u>Spent Fuel Pool [FAB10]</u>

The SFP [FAB10] is the region of the pool which contains fuel storage racks for storage of new, partially spent, fully spent and damaged fuel. Reactivity control is provided by geometrical spacing and fixed neutron absorbers in the storage rack, with control rods providing additional control (but are not required for sub criticality).

Options being considered for wet storage of damaged spent fuel include:

1. A small number of fuel rack cells being fitted with filters to store damaged fuel

2. The storage of damaged fuel assemblies into overcans

3. Rod replacement and storage of the replaced rod in a separate basket or quiver

Fuel is expected to cool in the fuel storage racks for 6 years before transfer to dry storage casks. The current fuel rack capacity is 548, allowing for 10 years of cooling following reactor discharge. The pool structure solution is stainless steel concrete composite (applies to all pools in the refuelling route) to provide the safety function of containment of water and shielding of the fuel.

A Fuel Handling Machine (FHM) is used to move the fuel between the upender, fuel racks, and other equipment. Jib cranes are used for the movement of items like fuel racks, the cask lid, and Post Irradiation Examination equipment.

Fuel cleaning filters are expected to require a cooling storage period within the SFP [FAB10]. This will either be within the fuel racks, if the cooling filters are fuel assembly shaped, or within a separate rack for alternative fuel cleaning filter designs. The Fuel Cleaning Equipment [FBC] is described further in Section 9A.1.5 Refuelling Systems.

Further design work is ongoing to explore storage of other equipment in the SFP [FAB10] such as In-Core Instrumentation (ICI) and neutron sources.

Cask Loading Pit [FAB20]

The Cask Loading Pit [FAB20] is used for the loading of fuel into a dry storage cask. The fuel is moved underwater from the storage racks within the SFP [FAB10] to the dry storage cask using the FHM. A jib crane is mounted above the pit for the lowering and raising of equipment for the cask operation.

During cask loading the gate between the spent fuel pool and cask loading pit is opened; the gate is normally shut. A minimum of 2 gates between the spent fuel pool and vehicle loading area are always kept shut to provide assurance of the spent fuel pool water level.

Cask Preparation Pit [FAB30]

The Cask Preparation Pit [FAB30] is used for the preparation of the cask before cask loading, and the draining, welding, drying, helium backfill and non-destructive testing (NDT) of the cask after loading.

The Cask Preparation Pit [FAB30] is flooded during the movement of the loaded cask from the Cask Loading Pit [FAB20], then partially drained to continue cooling the fuel, as the water within the pit is still connected to the pool support systems.

The cask preparation pit is sized to house the cask, shielding equipment, an access platform, services, tools, and safety and monitoring equipment. A pit transfer system moves the cask, removing the need for a large reactor building crane. The working platform for the cask is moved up and down on a rack and pinion system within the preparation pit.

A jib crane is mounted above the pit for the lowering and raising of equipment for cask operations. The jib crane will also allow equipment to be moved in and out of the preparation pit when flooded.

Upender Pit [FAB40]

The Upender Pit [FAB40] houses the fuel transfer system and upender. The upender transfers fuel from a vertical to horizontal orientation, and the fuel transfer system moves the fuel to the Refuelling Pool [FAF]. The Upender Pit [FAB40] is normally drained when the reactor is at power.

SSC Operation

Operating Mode 1 (Power Operation)

During powered operations the SFP [FAB10] is permanently flooded. The SFP [FAB10] to Cask Loading Pit [FAB20] gate is shut but may be opened for inspection and maintenance, such as the replacement of gate seals.

The Cask Loading Pit [FAB20] and Cask Preparation Pit [FAB30] are dry during powered operations, as is the Upender Pit [FAB40]. Inspection and maintenance may take place during this time.

During powered operations there will also be a requirement to periodically remove spent fuel from the SFP [FAB10], i.e., cask loading. The exact cask loading frequency is yet to be determined but is expected to be approximately 1-2 casks during each power generation cycle. The full cask loading operation is described in Reference [10].

Operating Mode 6a (Refuelling with Reduced Water Level Above Fuel)

The Upender Pit [FAB40] transfer channel is unsealed, and the fuel transfer system is connected.

Operating Mode 6b (Refuelling with Water Level Above Fuel at Nominal)

The SFP [FAB10] to Upender Pit [FAB40] gate is open to allow the movement of fuel.

It is expected that the cask pits will be used to store water from when the Refuelling Pool [FAF] is emptied during refuelling. The Cask Loading Pit [FAB20] to Cask Preparation Pit [FAB30] gate and Cask Preparation Pit [FAB30] to Vehicle Loading area gate are shut.

The Upender Pit [FAB40] is flooded during refuelling.

Interfaces with Supporting Systems

The Storage of Spent/Irradiated Fuel Assemblies and Other Radioactive Parts System [FAB] functional and physical interfaces are described above. These are identified and managed within DOORS, including flow down of functional requirements.

Instrumentation & Control

The Handling of Nuclear Equipment [F] requirements for trips, monitoring, indication, alarms and warnings are still to be developed. The allocation of safety categorised functional requirements to the Reactor Island Control & Protection System [JY] will be described further in E3S Case Chapter 7: Instrumentation & Control, Reference [8], as the C&I system design is developed.

Monitoring, Inspection, Testing & Maintenance

An outline maintenance plan for the Handling of Nuclear Fuel [F] is still to be developed.

Radiological Aspects

It is planned to store spent fuel for 6 years in the SFP [FAB10] prior to transfer to casks for dry storage, rather than the traditional storage period of 10 years, noting the design current facilitates storage of up to 10 years if necessary.

An initial study of estimated dose uptake during cask loading operations has shown a dose of 4mSv after 10 years cooling, or 6.1mSv after 6 years cooling. This can be significantly reduced by implementing remote handling innovations, which will be explored as the design is developed.

Performance and Safety Evaluation

Verification activities to substantiate safety categorised functional requirements and non-functional system requirements for Storage of Spent/Irradiated Fuel Assemblies and Other Radioactive Parts System [FAB] are still to be determined.

Installation & Commissioning

An outline installation and commissioning plan for Handling of Nuclear Fuel [F] is still to be developed. The overall strategy for the RR SMR commissioning programme is presented in E3S Case Chapter 14: Plant Construction & Commissioning, Reference [9].

Ageing Management

An outline maintenance plan for the Handling of Nuclear Fuel [F] is still to be developed.

ALARP in Design Development

The design of the Storage of Spent/Irradiated Fuel Assemblies and Other Radioactive Parts System [FAB] has been developed in accordance with the systems engineering design process, which includes alignment to RGP & OPEX, design to codes and standards according to the safety classification, and a systematic optioneering process with down-selection of design options based on assessment against relevant safety criteria (as described in PSCR Chapter 3: E3S Objectives & Design Rules, Reference [7]).

Key Storage of Spent/Irradiated Fuel Assemblies and Other Radioactive Parts System [FAB] design decisions made with respect to ensuring overall risks are reduced to ALARP include:

1. For the storage of fuel in ponds and dry casks, criticality prevention is assured through a combination of geometric fuel spacing and fixed neutron absorption, which is consistent with RGP that criticality should not rely on soluble boron for normal conditions in Pressurised Water Reactors (PWRs), and also criticality safety demonstrated on modern Boiling Water Reactor plants

2. Dry storage of fuel after 6 years, as described under radiological aspects above

More detailed information on design decisions is presented in the Handling of Nuclear Equipment System Description, Reference [11], and associated design decision files.

Ongoing Design Development

The RR SMR design definition is currently in development as described in Section 9A.0.2 Scope. Key design opportunities and decisions related to safety are currently being explored, this includes:

1. Cask import route development

2. Fuel rack reactivity control definition

3. Pool depth definition

4. Confirmation of fuel storage duration

All design development risks and opportunities are captured and managed by design teams.

9A.1.3 Spent Fuel Pool Cooling & Clean-Up Systems

System and Equipment Functions

The spent fuel pool cooling and clean-up systems support achievement of the FSFs of CoR, CoFT, and CoRM during normal operation and fault conditions. It is comprised of:

1. Fuel Pool Cooling System (FPCS) [FAK]
2. Fuel Pool Purification System (FPPS) [FAL]
3. Fuel Pool Supply System (FPSS) [FAT]

The primary function of the FPCS [FAK] is to remove heat from the fuel pools to maintain fuel pool temperature below 50°C. The primary function of the FPPS [FAL] is to remove impurities from the fuel pools to maintain fuel pool chemistry to within specification. The primary function of the FPSS [FAT] is to supply inventory to the fuel pools to replace evaporative losses.

The FPCS [FAK] and FPSS [FAT] also provide the motive force to support the transfer of water between the fuel pools during refuelling operations and contains the Refuelling Water Storage Tank (RWST). The FPPS [FAL] also provides a connection location for the infrequent dosing of chemicals to the fuel pools in the event of a chemical or biological excursion in the coolant.

HLSFs for the FPCS [FAK], FPPS [FAL], and FPSS [FAT], and the PIEs against which they are assigned, are being derived in the Fault Schedule, which is presented in E3S Case Chapter 15: Safety Analysis, Reference [5].

Safety Design Basis

Functional Requirements

Safety categorised functional requirements specified for the FPCS [FAK], FPPS [FAL], and FPSS [FAT] based on the HLSFs they deliver, including the applicable plant states and operating modes, these are presented in Table 9A.1-6.

The traceability of safety categorised functional requirements back to the HLSFs will be managed in DOORS via the Safety Measures Module; this process is outlined in Deterministic Safety Methodology, Reference [6]. This will include any specific safety categorised functional requirements aligned to the PIEs should the FPCS [FAK], FPPS [FAL], and/or FPSS [FAT] be claimed during fault conditions (including internal and external hazards).

Table 9A.1-6: [FAK], [FAL] & [FAT] Safety Categorised Functional Requirements

DOORS ID	Functional Requirement	Plant State(s)	Mode(s) of Operation	Safety Category
FAK-R-1251	The Fuel Pool Cooling System [FAK] shall remove heat from the fuel pool coolant	DBC-1 DBC-2	All Modes	B

DOORS ID	Functional Requirement	Plant State(s)	Mode(s) of Operation	Safety Category
FAK-R-1257	The Fuel Pool Cooling System [FAK] shall provide motive force for the Fuel Pool Purification System [FAL]	DBC-1 DBC-2	All Modes	C
FAK-R-1259	The Fuel Pool Cooling System [FAK] shall provide the motive force for the transfer of inventory between the fuel pools and Refuelling Water Storage Tank	DBC-1 DBC-2	All Modes	C
FAK-R-1279	The Fuel Pool Cooling System [FAK] shall provide isolation at the containment boundary	DBC-1 DBC-2	All Modes	B
FAK-R-1280	The Fuel Pool Cooling System [FAK] shall provide isolation for protection against leaks	DBC-3 DBC-4	All Modes	B
FAL-R-1250	The Fuel Pool Purification System [FAL] shall purify coolant used in wet storage of fuel	DBC-1 DBC-2	All Modes	C
FAL-R-1257	The Fuel Pool Purification System [FAL] shall control pH of coolant used in wet storage of fuel	DBC-1 DBC-2	All Modes	C
FAL-R-1273	The Fuel Pool Purification System [FAL] shall protect against microbial growth in coolant used for wet storage of fuel	DBC-1 DBC-2	All Modes	C
FAL-R-1346	The Fuel Pool Purification System [FAL] shall provide a connection for chemical dosing	DBC-1 DBC-2	All Modes	C
FAL-R-1272	The Fuel Pool Purification System [FAL] shall provide isolation for protection against leaks	DBC-3 DBC-4	All Modes	C
FAT-R-1250	The Spent Fuel Coolant Supply System [FAT] shall maintain the Fuel Pool water levels	DBC-1 DBC-2	All Modes	C
FAT-R-1369	The Fuel Pool Supply System [FAT] shall store coolant	DBC-1 DBC-2	All Modes	C
FAT-R-1269	The Fuel Pool Supply System [FAT] shall transfer coolant to the Spent Fuel Pool Cooling System [FAK] for filling of the pools during commissioning	DBC-1 DBC-2	All Modes	C

DOORS ID	Functional Requirement	Plant State(s)	Mode(s) of Operation	Safety Category
FAT-R-1275	IF the Fuel Pool Cooling System [FAK] PUMP is unavailable, while in Operating Mode 6a, then the Fuel Pool Supply System [FAT] shall provide motive force to transfer coolant from the Refuelling Water Storage Tank to the Fuel Pool Cooling System [FAK]	DBC-1 DBC-2	6a	C
FAT-R-1278	The Fuel Pool Supply System [FAT] shall provide isolation for protection against leaks	DBC-3 DBC-4	All Modes	C
FAT-R-1279	The Fuel Pool Supply System [FAT] shall provide isolation for maintenance operations	DBC-1 DBC-2	All Modes	C

Non-functional performance requirements associated with the safety categorised functional requirements are also allocated in the DOORS FPCS [FAK], FPPS [FAL], and FPSS [FAT] Requirements Modules, including the rationale for their selection, which are not repeated here.

Non-Functional System Requirements

A full set of non-functional system requirements are in development based on the E3S Principles, which will be systematically applied to each SSC as part of the systems engineering process.

Safety Classification

The safety classification of the system has been developed in accordance with the E3S Categorisation and Classification methodology outlined in E3S Case Chapter 3: E3S Objectives & Design Rules, Reference [7].

The FPCS [FAK] is the principal means by which the Category B safety function CoFT for storage of spent fuel is achieved, and the highest safety classification of components within the system is Class 2.

The FPPS [FAL] is the principal means by which the Category C safety function is achieved to purify the coolant used to provide CoFT for the storage of spent fuel, and the highest safety classification of components within the system is Class 3.

The FPSS [FAT] is the principal means by which the Category C safety function is achieved to maintain coolant inventory used to provided CoFT for the storage of spent fuel, and the highest safety classification of components within the system is Class 3.

Seismic Classification

The seismic classification of SSCs is still to be assigned in accordance with methodology outlined in E3S Case Chapter 3: E3S Objectives & Design Rules, Reference [7].

Description of SSC

FPCS [FAK]

The baseline architecture for the FPCS [FAK] consists of two cooling trains (duty/standby) which both contain a single heat exchanger and a single centrifugal pump. The heat exchanger is located downstream of the centrifugal pump and is cooled on the cold side by the Component Cooling System (CCS) [KAA].

Each cooling train is connected, via common manifolds, to all the pools within the refuelling route. This includes the SFP [FAB10], Cask Preparation Pit [FAB20], Cask Loading Pit [FAB30, Upender Compartment [FAB40], Refuelling Pool [FAF] and the Refuelling Cavity [FAE]. The FPCS [FAK] also includes connection to/from the FPPS [FAL], FPSS [FAT] and Cold Shutdown Cooling System (CSCS) [JNA].

A simplified schematic is provided in Figure 9A.1-2, and the baseline key performance and design parameters are presented in Table 9A.1-7.

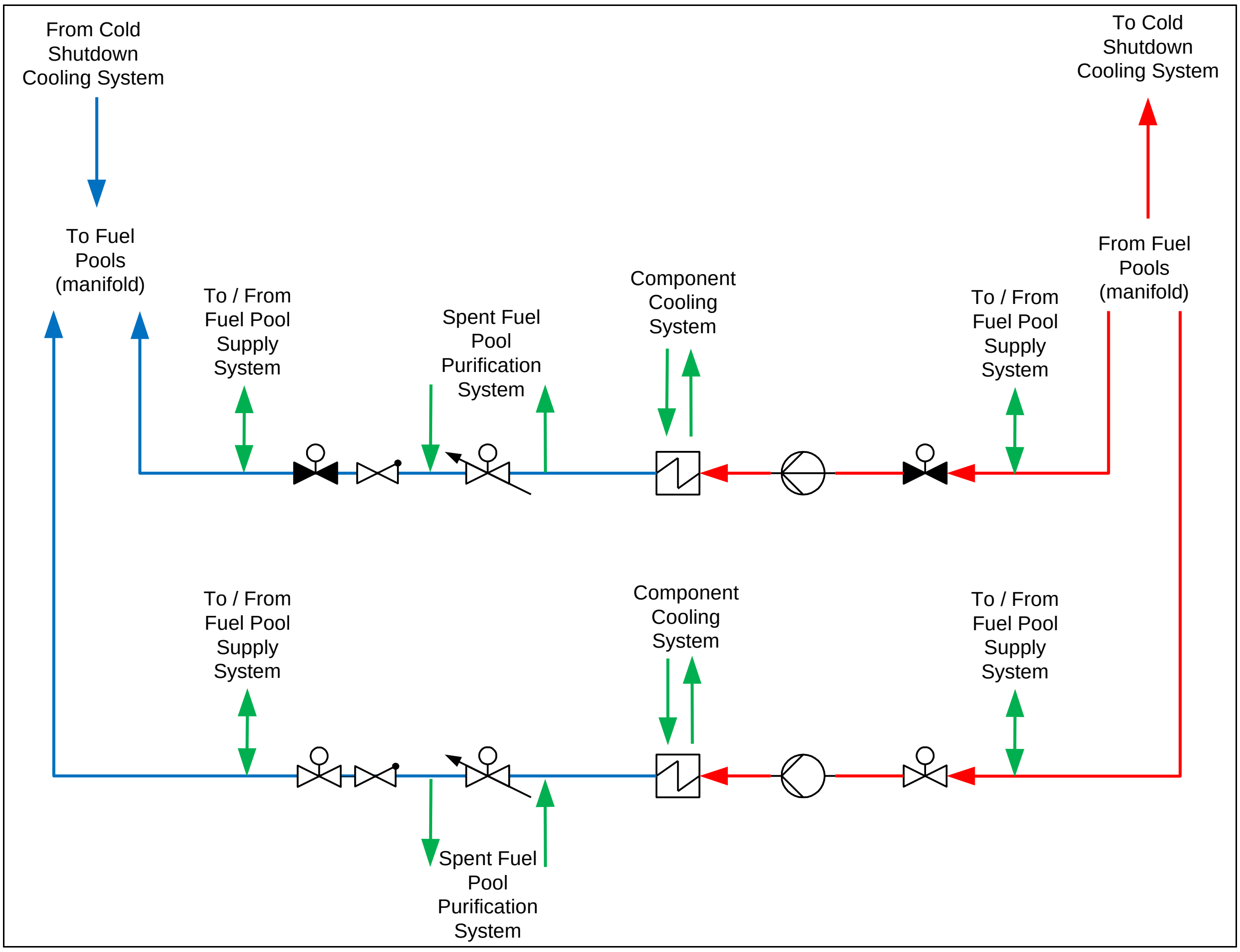

Figure 9A.1-2: FPCS [FAK] System Schematic

Table 9A.1-7: FPCS [FAK] Key Design and Performance Parameters

Parameter	Value
Maximum Operating Temperature (Design Basis Conditions 1, 2)	**{REDACTED FOR PUBLICATION}**
Maximum Operating Temperature (Design Basis Conditions 3)	**{REDACTED FOR PUBLICATION}**
Design Temperature	**{REDACTED FOR PUBLICATION}**
Maximum Operating Pressure	**{REDACTED FOR PUBLICATION}**
Design Pressure	**{REDACTED FOR PUBLICATION}**
Maximum Duty in Non-Refuel Operating Modes: 1, 2, 3, 4a, 4b, 5a, 5b	**{REDACTED FOR PUBLICATION}**
Maximum Duty during Refuel Operating Modes: 6a, 6b	**{REDACTED FOR PUBLICATION}**
System Design Flowrate (per cooling train)	**{REDACTED FOR PUBLICATION}**

The FPCS [FAK] is primarily located outside of containment, with all major components (heat exchangers and pumps) located within the safety block adjacent to the SFP [FAB10]. Further details of the FPCS [FAK] sub-system, and the components within it, are provided in the FPCS System Description, Reference [12].

FPPS [FAL]

The FPPS [FAL] consists of two purification trains. The FPCS [FAK] pumps provide the motive force for flow through the FPPS [FAL] purification trains, which each have connections to the FPCS [FAK], downstream of the FPCS [FAK] heat exchangers, to receive and return purified coolant to the fuel pools.

Each purification train contains a mixed bed resin single Ion Exchange Column (IXC) and a single backwashable filter. The IXC is located upstream of the filter and has two connections to the Processing and Treatment System for Liquid Radioactive Effluent [KNF], with corresponding connections to the Solid Waste Treatment System [KME]. A connection to the Chemicals Supply System [QC] is also provided to supply new resin to the IXC.

A single purification train will be online at any given time. The active FPPS [FAL] train will be dictated by which FPCS [FAK] cooling train is providing cooling, as each FPCS [FAK] cooling train has a dedicated parallel FPPS [FAL] purification train.

A continuous flow of spent fuel pool coolant is circulated through the FPPS [FAL] in normal operation to purify the coolant and help maintain coolant activity within specified limits. Each purification train includes a flow meter upstream of the IXC to monitor the FPPS [FAL] flow rate. Three sample lines are provided on each purification train, as well as an isolation valve.

A simplified schematic of a FPPS [FAL] purification train is provided in Figure 9A.1-3, with the baseline key performance and design parameters presented in Table 9A.1-8 (where they differ from the FPCS [FAK] in Table 9A.1-7).

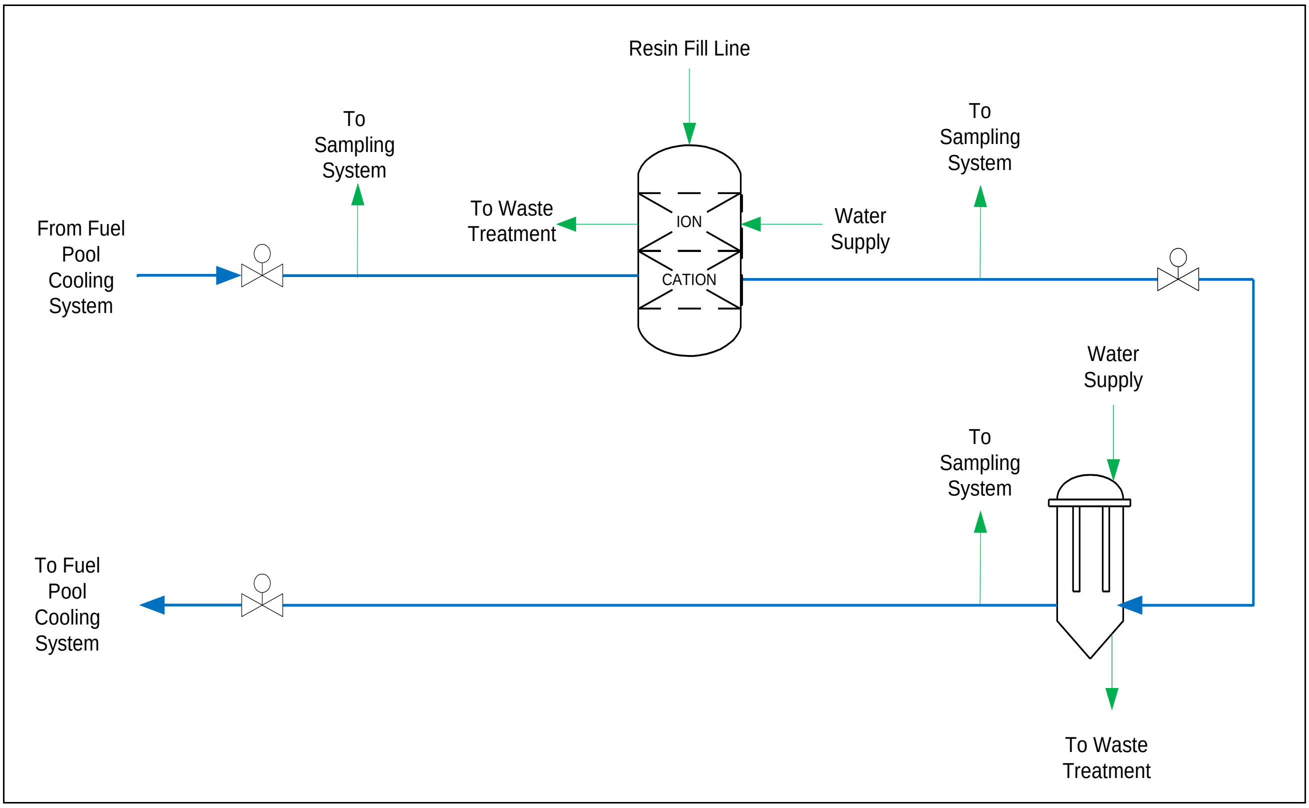

Figure 9A.1-3: FPPS [FAL] System Train Schematic

Table 9A.1-8: FPPS [FAL] Design and Performance Parameters

Parameter	Value
Maximum Operating Temperature (Design Basis Condition 1, 2)	**{REDACTED FOR PUBLICATION}**
Maximum Operating Temperature (Design Basis Conditions 3)	**{REDACTED FOR PUBLICATION}**
System Design Flowrate (per purification train)1, 2, 3, 4a, 4b, 5a, 5b	**{REDACTED FOR PUBLICATION}**

The FPPS [FAL] is located outside of containment, with all components located within the safety block adjacent to the SFP [FAB10]. Further details of the FPPS [FAL] sub-system and the components within it are provided in the FPPS System Description, Reference [13].

FPSS [FAT]

The FPSS [FAT] comprises two coolant supply trains each containing a single FPSS [FAT] pump to provide makeup to the pools, and a single discharge line to waste to provide let-down of the spent fuel pool inventory. The RWST which can receive coolant from the spent fuel pools and supply coolant to the pools during refuelling operations.

The FPSS [FAT] pumps provide the motive force to transfer demineralised water from the Demineralised Water Distribution System [GHC] or the Processing and Treatment System for Liquid Radioactive Effluent [KNF], to the spent fuel pools during initial fill of the spent fuel pools and routine through-life makeup. The pumps can also be aligned to transfer water between the spent fuel pools themselves and between the fuel pools and the RWST.

Typically, only a single pump will be in operation at any time, with the remaining pump on standby. A single FPCS [FAK] pump will transfer from the in-containment pools to the out of containment pools and the RWST during refuelling operations where coolant must be transferred quickly. Discharge of coolant from the spent fuel pools can be achieved by opening the isolation valves between the FPCS [FAK] and the FPSS [FAT] connection to waste and allowing the contents to drain by gravity.

The RWST can store up to **{REDACTED FOR PUBLICATION}** of coolant and can be aligned to receive or supply coolant to either the FPCS [FAK] or FPSS [FAL] pumps. Connections are provided to the two demineralised water sources, and a sample point to the Sampling System [KU].

A simplified schematic of the FPSS [FAT] is illustrated in Figure 9A.1-4, noting design parameters are the same as those for the FPCS [FAK] in Table 9A.1-7, except for a design pressure of **{REDACTED FOR PUBLICATION}**.

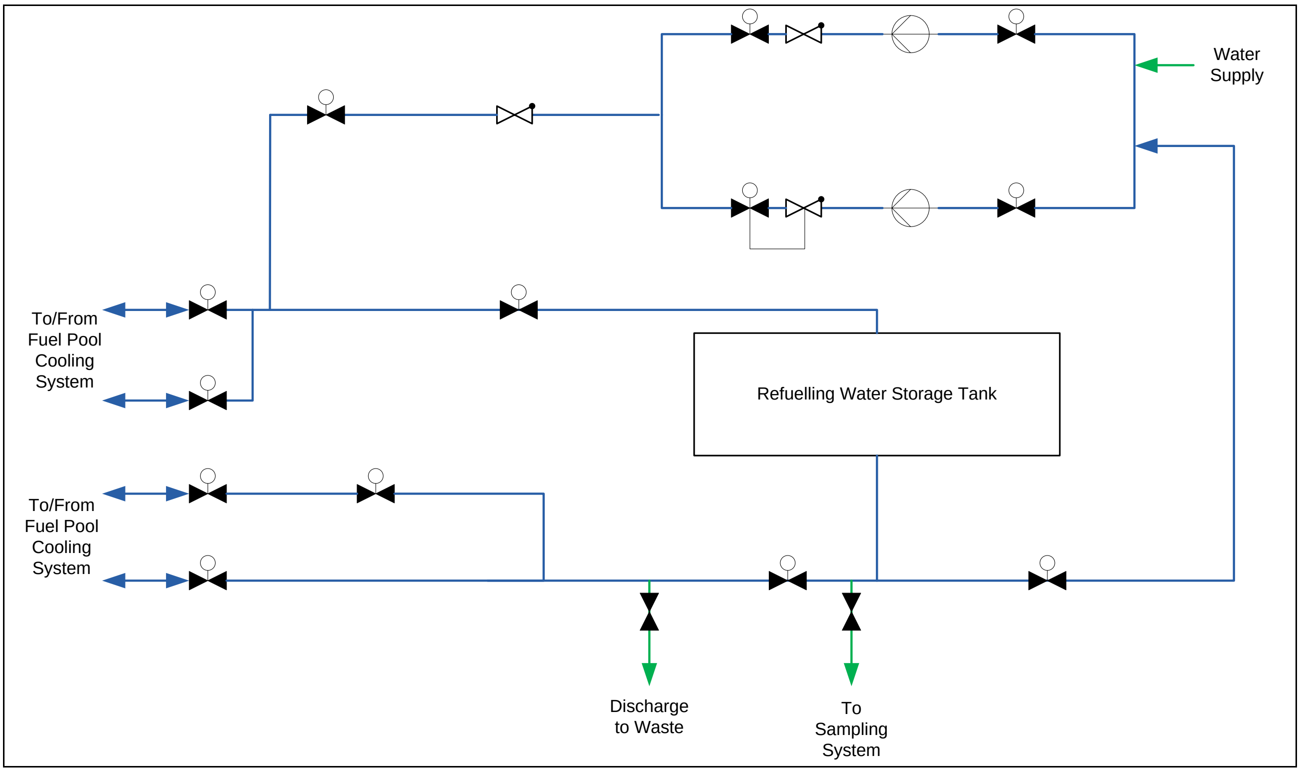

Figure 9A.1-4: FPSS [FAT] System Schematic

The FPSS [FAT] is located outside of containment, with all components located within the Auxiliary Block adjacent to the SFP [FAB10]. Further details of the FPSS [FAT] sub-system and the components within it are provided in the FPSS System Description, Reference [14].

SSC Operation

FPSC [FAK]

During Operating Modes 1, 2, 3, 4a, 4b, 5a, 5b (i.e., modes where refuelling operations are not in progress), the FPCS [FAK] is aligned to only provide cooling to the Spent Fuel Pool [FAB10] as fuel is not present within any of the other pools.

During Operating Modes 6a and 6b, when fuel is being transferred between pools, the FPCS [FAK] can be aligned to provide cooling to any of the pools within the refuelling route, including the:

1. SFP [FAB10]
2. Cask Loading Pit [FAB20]
3. Cask Preparation Pit [FAB30]
4. Upender Compartment [FAB40]
5. Refuelling Pool [FAF]
6. Refuelling Cavity [FAE]

Interfaces with Supporting Systems

The functional and physical interfaces for the FPCS [FAK], FPPS [FAL], and FPSS [FAT] are described above. These are identified and managed within DOORS, including flow down of functional requirements.

Instrumentation & Control

The Handling of Nuclear Equipment [F] requirements for trips, monitoring, indication, alarms, and warnings are still to be developed. The allocation of safety categorised functional requirements to the Reactor Island Control & Protection System [JY] will be described further in E3S Case Chapter 7: Instrumentation & Control, Reference [8], as the C&I system design is developed.

Monitoring, Inspection, Testing & Maintenance

An outline maintenance plan for the Handling of Nuclear Fuel [F] is still to be developed. Preliminary assessment determines that maintenance activities for the FPCS [FAK], FPPS [FAL] and FPSS [FAT] are likely to be performed during power operations (Operating Mode 1), when SFP [FAB10] cooling duties are much lower than during an outage. Based on this assumption, the second cooling train will be active and providing cooling, with the CSCS [JNA] cooling trains providing redundancy for fault conditions.

Radiological Aspects

No significant radiological aspects associated with the spent fuel pool cooling and clean-up systems have been identified during design decisions up to PCD.

Installation & Commissioning

An outline installation and commissioning plan for Handling of Nuclear Fuel [F] is still to be developed. The overall strategy for the RR SMR commissioning programme is presented in E3S Case Chapter 14: Plant Construction & Commissioning, Reference [9].

Performance and Safety Evaluation

At PCD, verification strategies for the FPCS [FAK], FPPS [FAL], and FPSS [FAT] to demonstrate compliance with its safety categorised functional requirements and associated non-functional performance requirements are in development and stored in DOORS. Activities include FloMaster Hydraulic Analysis.

The full suite of performance analysis to justify that the FPCS [FAK], FPPS [FAL], and FPSS [FAT] achieves its safety categorised functional requirements and associated non-functional performance requirements for bounding fault conditions will be presented in E3S Case Chapter 15: Safety Analysis, Reference [5].

Installation & Commissioning

An outline installation and commissioning plan for Handling of Nuclear Fuel [F] is still to be developed. The overall strategy for the RR SMR commissioning programme is presented in E3S Case Chapter 14: Plant Construction & Commissioning, Reference [9].

ALARP in Design Development

The design of the FPCS [FAK], FPPS [FAL], and FPSS [FAT], has been developed in accordance with the systems engineering design process, which includes alignment to RGP & OPEX, design to codes and standards according to the safety classification, and a systematic optioneering process with down-selection of design options based on assessment against relevant safety criteria (as described in PSCR Chapter 3: E3S Objectives & Design Rules, Reference [7]).

Ongoing Design Development

The RR SMR design definition is currently in development as described in Section 9A.0.1 Introduction. Key design opportunities and decisions related to safety are currently being explored, this includes:

1. Selection of the backwashable filters design option is dependent on the ability of the system to meet filtration requirements, with further review of supplier information and OPEX

All design development risks and opportunities are captured and managed by design teams.

9A.1.4 Fuel Transfer Channel

System and Equipment Functions

The Fuel Transfer Channel [FCK] is used to transfer new and spent fuel, as well as other reactor core components, between the SFP [FAB10] and the Refuelling Pool [FAF], which supports achievement of the FSFs of CoFT and CoRM during normal operation and fault conditions.

HLSFs for the Fuel Transfer Channel [FCK], and the PIEs against which they are assigned, are being derived in the Fault Schedule, which is presented in E3S Case Chapter 15: Safety Analysis, Reference [5].

Safety Design Basis

Functional Requirements

Safety categorised functional requirements specified for the Fuel Transfer Channel [FCK] based on the HLSFs they deliver, including the applicable plant states and operating modes, are presented in Table 2.

The traceability of safety categorised functional requirements back to the HLSFs will be managed in DOORS via the Safety Measures Module; this process is outlined in Deterministic Safety Methodology, Reference [6]. This will include any specific safety categorised functional requirements aligned to the PIEs should the Fuel Transfer Channel [FCK] be claimed during fault conditions (including internal and external hazards).

Table 2: [FCK] Safety Categorised Functional Requirements

DOORS ID	Functional Requirement	Plant State(s)	Mode(s) of Operation	Safety Category
FCK-R-1376	When not refuelling, the [FCK] System shall isolate from the Spent Fuel Pool [FAB]	DBC-1 DBC-2	All modes	A
FCK-R-1377	When not refuelling, the [FCK] System shall isolate from the Refuelling Pool [FAF]	DBC-1 DBC-2	All modes	A
FCK-R-1379	The [FCK] System shall maintain control of Fuel Assembly reactivity	DBC-1 DBC-2	All modes	A
FCK-R-1381	The [FCK] System shall enable JAC System Fuel Assemblies to be adequately cooled whilst being transferred	DBC-1 DBC-2	6a, 6b	A
FCK-R-1384	The [FCK] System shall monitor the Temperature of the coolant	DBC-1 DBC-2	6a, 6b	A
FCK-R-1386	The [FCK] System shall ensure confinement of radioactive material in all modes through life	DBC-1 DBC-2	All modes	A
FCK-R-1389	The [FCK] System shall provide safety measures to ensure safe operation through life, in line with all defined requirements	DBC-1 DBC-2	All modes	A
FCK-R-1391	The [FCK] System shall monitor the water level	DBC-1 DBC-2	All modes	A

Non-functional performance requirements associated with the safety categorised functional requirements are also allocated in the DOORS Fuel Transfer Channel [FCK] Requirements Module, including the rationale for their selection, which are not repeated here.

Non-Functional System Requirements

A full set of non-functional system requirements are in development based on the E3S Principles, which will be systematically applied to each SSC as part of the systems engineering process.

Safety Classification

The safety classification of the Fuel Transfer Channel [FCK] is still to be developed based on the categorisation of safety functions it delivers.

Seismic Classification

The seismic classification of SSCs is still to be assigned in accordance with methodology outlined in E3S Case Chapter 3: E3S Objectives & Design Rules, Reference [7].

Description of SSC

The Fuel Transfer Channel [FCK] is a metal tube containing the fuel transfer system. The metal tube provides containment of the water, which is required to keep the fuel submerged during transfer for heat removal, containment and shielding. The fuel transfer system is a set of rails along which a basket containing the fuel runs, and a Serapid Rollbeam system to move the basket back and forth. A sealing system will be incorporated at both ends of the metal tube.

A concrete structure is currently being developed around the fuel transfer channel to provide shielding to personnel inside and outside of containment, and potentially provide an additional containment barrier as a defence in depth measure.

SSC Operation

During Operating Mode 1 (Power Operation) the Fuel Transfer Channel [FCK] is sealed at both ends and dry.

During Operating Mode 6b (Refuelling with Water Level above Fuel at Nominal), the Fuel Transfer Channel [FCK] is flooded. Reactivity control is provided by fuel assemblies being moved one at a time, control rods provide additional control but are not required for sub criticality.

Interfaces with Supporting Systems

The Fuel Transfer Channel [FCK] functional and physical interfaces are described above. These are identified and managed within DOORS, including flow down of functional requirements.

Instrumentation & Control

The Handling of Nuclear Equipment [F] requirements for trips, monitoring, indication, alarms, and warnings are still to be developed. The allocation of safety categorised functional requirements to the Reactor Island Control & Protection System [JY] will be described further in E3S Case Chapter 7: Instrumentation & Control, Reference [8], as the C&I system design is developed.

Monitoring, Inspection, Testing & Maintenance

An outline maintenance plan for the Handling of Nuclear Fuel [F] is still to be developed.

Radiological Aspects

No significant radiological aspects associated with the Fuel Transfer Channel [FCK] have been identified during design decisions up to PCD. The concrete structure that provides operator shielding is currently being developed.

Performance and Safety Evaluation

Verification activities to substantiate safety categorised functional requirements and non-functional system requirements for the Fuel Transfer Channel [FCK] are still to be determined.

Installation & Commissioning

An outline installation and commissioning plan for Handling of Nuclear Fuel [F] is still to be developed. The overall strategy for the RR SMR commissioning programme is presented in E3S Case Chapter 14: Plant Construction & Commissioning, Reference [9].

ALARP in Design Development

The design of the Fuel Transfer Channel [FCK] has been developed in accordance with the systems engineering design process, which includes alignment to RGP & OPEX, design to codes and standards according to the safety classification, and a systematic optioneering process with down-selection of design options based on assessment against relevant safety criteria (as described in PSCR Chapter 3: E3S Objectives & Design Rules, Reference [7]).

Ongoing Design Development

The RR SMR design definition is currently in development as described in Section 9A.0. Key design opportunities and decisions related to safety are currently being explored, this includes:

1. Design of the concrete structure around the metal tube, considering shielding and containment requirements

2. Both passive and active cooling systems are being explored to determine the most appropriate method to meet cooling requirements in the channel following a stuck fuel assembly

3. Investigate options for the Fuel Transfer Channel [FCK] sealing systems

All design development risks and opportunities are captured and managed by design teams.

9A.1.5 Refuelling Systems

System and Equipment Functions

The RR SMR refuelling systems comprise the following:

1. Refuelling Cavity [FAE]

2. Refuelling Pool [FAF]

The Refuelling Pool [FAF] is used to store partially spent fuel, RPV upper and lower internals, and RPV ICI during refuelling. The Refuelling Pool [FAF] is also used as a water store for Emergency Core Cooling [JN01]. It supports achievement of the FSFs of CoR, CoFT and CoRM during normal operation and fault conditions.

The Refuelling Cavity [FAE] is a pool located above the RPV, which is flooded up during refuelling to facilitate the movement of the fuel and other nuclear equipment from the RPV. It supports achievement of the FSFs of CoR, CoFT and CoRM during normal operation and fault conditions.

HLSFs for the Refuelling Pool [FAF] and Refuelling Cavity [FAE], and the PIEs against which they are assigned, are being derived in the Fault Schedule, which is presented in E3S Case Chapter 15: Safety Analysis, Reference [5].

Safety Design Basis

Functional Requirements

Safety categorised functional requirements and associated non-functional performance requirements for the Refuelling Pool [FAF] and Refuelling Cavity [FAE], based on the HLSFs they deliver, are to be developed.

Non-Functional System Requirements

A full set of non-functional system requirements are in development based on the E3S Principles, which will be systematically applied to each SSC as part of the systems engineering process.

Safety Classification

The safety classification of the Refuelling Pool [FAF] and Refuelling Cavity [FAE] is still to be developed based on the categorisation of safety functions they deliver.

Seismic Classification

The seismic classification of SSCs is still to be assigned in accordance with methodology outlined in E3S Case Chapter 3: E3S Objectives & Design Rules, Reference [7].

Description of SSC

The Refuelling Pool [FAF] is a pool located inside containment, next to the Refuelling Cavity [FAE], which is located above the RPV. This is illustrated in Figure 9A.1-5.

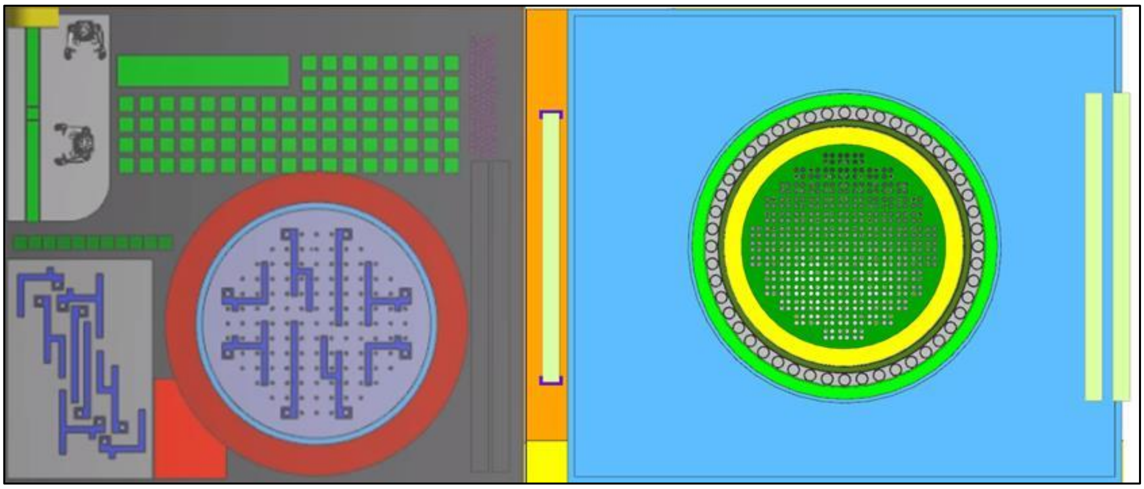

Figure 9A.1-5: Refuelling Pool [FAF] and Refuelling Cavity [FAE] Plan View

The Refuelling Pool [FAF] contains storage racks for partially spent fuel only, with a current capacity of 81 fuel assemblies, and a single storage stand for the RPV Upper and Lower Internals. It also has a storage stand for RPV ICI. An ultrasonic cleaning station is provided in the Refuelling Pool [FAF] to clean the partially spent fuel during refuelling outages. The Refuelling Cavity [FAE] is also used to store new ICI assemblies with brackets located on the walls.

The Refuelling Pool [FAF] and Refuelling Cavity [FAE] are isolated from each other by a two-part modular gate, which is opened during refuelling. The Refuelling Pool [FAF] has connections to the Low Pressure Injection System [JNG], which contain screens to prevent ingress of debris into the sump recirculation pipework and thus the Reactor System [JA]. The Refuelling Pool [FAF] also has connections to the Reactor Coolant Pressure Relief System [JEG] which discharges into the pool.

The water level between the SFP [FAB10] and the Refuelling Pool [FAF] will be maintained at the same height to allow the two pools to be connected during fuel movements. An Upender is mounted on a platform in the Refuelling Pool [FAF], and the top of the pool structure supports a Refuelling Machine and Gantry crane.

Reactivity control in the Refuelling Pool [FAF] fuel racks is provided through fixed spacing and neutron absorbers. Reactivity control during removal of the RPV Head during refuelling is provided through cameras, sensors, and nucleonic detectors with interlocks to stop crane lifts.

<u>Fuel Cleaning Equipment</u>

The RR SMR reactor shutdown process is expected to be undertaken without deliberately altering the reactor chemistry to induce a soluble and insoluble crud burst, as such the fuel will retain crud from the previous cycle. Extracting maximum power from the core is expected to lead to sub-nucleate boiling and may lead to crud deposition on the upper spans of the fuel. Therefore, space for an ultrasonic cleaning station [FBC] is to be provided in the Refuelling Pool [FAF] to remove crud from partially spent fuel assemblies at each outage, prior to their return to the RPV for the next cycle. Further work is planned to confirm if ultrasonic fuel cleaning will be mandated as part of the design.

A typical fuel cleaning system consists of a cleaning chamber and a pumping and waste-collection module. These two sub-systems are interconnected with a flexible hose so the installation can be adapted to the space available in the pool. Pool water is drawn into the open top of the cleaning chamber, carrying away the dislodged corrosion products to the bottom, through the flexible hose, through a bank of disposable cartridge filters, and back to the pool. Typical designs are not permanent fixtures and tend to be hung from supports at the side of the pool.

SSC Operation

During Operating Mode 1 (Power Operations), the Refuelling Pool [FAF] is flooded and the Refuelling Cavity [FAE] is dry. During refuelling the gate is removed and the Fuel Transfer Channel [FCK] is opened to connect the Refuelling Pool [FAF] to the SFP [FAB10].

During Operating Mode 6a (Refuelling with Reduced Water Level above Fuel), the Refuelling Pool [FAF] is drained down to allow access to the Upender and Fuel Transfer Channel [FCK]. The Refuelling Pool [FAF] and refuelling pool gate are then decontaminated. Refuelling Pool [FAF] Upender maintenance is conducted, and the Fuel Transfer Channel [FCK] is unsealed. The fuel transfer system is then connected.

The Integrated Head Package (IHP) is lifted in the Refuelling Cavity [FAE] using the gantry crane and is then moved over to the laydown area. During this lift the Refuelling Cavity [FAE] is partially flooded up. As the Refuelling Pool [FAF] gate is already open at this point as well as the Fuel Transfer Channel [FCK], the Refuelling Pool [FAE] is also partially flooded up. The IHP lift gate is then moved to its shut position in the Refuelling Cavity [FAE] wall, and the flood-up is completed.

During Operating Mode 6b (Refuelling with Water Level above Fuel at Nominal), the Refuelling Pool [FAF] and Refuelling Cavity [FAE] are flooded. RPV internals and ICI are removed from the RPV and stored on the Refuelling Pool [FAF] storage stand. The fuel assemblies are removed using the in-containment Fuel Handling Machine (FHM), then the partially spent fuel is moved onto the Refuelling Pool [FAF] racks. Fully spent fuel is moved to the upender and transported out of containment to the SFP [FAB10]. New fuel and partially spent fuel is then moved into the RPV.

Interfaces with Supporting Systems

The Refuelling Pool [FAF] and Refuelling Cavity [FAE] functional and physical interfaces are described above. These are identified and managed within DOORS, including flow down of functional requirements.

Instrumentation & Control

The Handling of Nuclear Equipment [F] requirements for trips, monitoring, indication, alarms, and warnings are still to be developed. The allocation of safety categorised functional requirements to the Reactor Island Control & Protection System [JY] will be described further in E3S Case Chapter 7: Instrumentation & Control, Reference [8], as the C&I system design is developed.

Monitoring, Inspection, Testing & Maintenance

An outline maintenance plan for the Handling of Nuclear Fuel [F] is still to be developed.

Radiological Aspects

No significant radiological aspects associated with the Refuelling Pool [FAF] and Refuelling Cavity [FAE] have been identified during design decisions up to PCD.

Performance and Safety Evaluation

Verification activities to substantiate safety categorised functional requirements and non-functional system requirements for the Refuelling Pool [FAF] and Refuelling Cavity [FAE] still to be determined.

Installation & Commissioning

An outline installation and commissioning plan for Handling of Nuclear Fuel [F] is still to be developed. The overall strategy for the RR SMR commissioning programme is presented in E3S Case Chapter 14: Plant Construction & Commissioning, Reference [9].

ALARP in Design Development

The design of the Refuelling Pool [FAF] and Refuelling Cavity [FAE] has been developed in accordance with the systems engineering design process, which includes alignment to RGP & OPEX, design to codes and standards according to the safety classification, and a systematic optioneering process with down-selection of design options based on assessment against relevant safety criteria (as described in PSCR Chapter 3: E3S Objectives & Design Rules, Reference [7]).

Key Refuelling Pool [FAF] and Refuelling Cavity [FAE] design decisions made with respect to ensuring overall risks are reduced to ALARP include:

1. A traditional flood-up approach for refuelling with a Refuelling Cavity [FAE] sluice gate for reduced IHP lift height is the selected design option for RR SMR, as it represents RGP for PWRs in comparison to other more novel options, such as a shielded and cooled transfer container. The design also has safety benefits over other options considered, including a simplified design e.g., no challenging cooling water connections or integrated lifting system for a shielded transfer container, and a large water volume provides longer grace-times for fuel cooling in the event of a cooling system failure

2. The Refuelling Pool [FAF] is designed to store partially burnt up fuel only, which will be returned to the RPV, rather than sized to permit storage of the full core load. Whilst adding a small increase to refuelling time, the partially spent fuel does not need to be lifted into the fuel transfer system and transferred to the SFP [FAB10], and fully spent fuel does not need to be temporarily stored on route to the SFP [FAB10], thus reducing the overall number of fuel assembly lifts and upender transits and minimising the risk of a dropped fuel assembly

More detailed information on design decisions is presented in the Handling of Nuclear Equipment System Description, Reference [11], and associated design decision files.

Ongoing Design Development

The RR SMR design definition is currently in development as described in Section 9A.0. Key design opportunities and decisions related to safety are currently being explored, this includes:

1. Potential for two gates in series between the Refuelling Pool [FAF] and Refuelling Cavity [FAE] to provide redundancy and mitigation against failures

2. Possibility of avoiding a Refuelling Pool drain down during refuelling via a separate compartment within the refuelling pool, or a remotely operated fuel transfer channel sealing system

3. Investigate options for the removal of used RPV ICI from the Refuelling Cavity [FAE] to the Spent Fuel Pool [FAB10] and storage within the Spent Fuel Pool [FAB10]

All design development risks and opportunities are captured and managed by design teams.

9A.2 Water Systems

9A.2.1 Main Cooling Water System

System and Equipment Functions

The Main Cooling Water System (MCWS) [PA] transfers heat from the Turbine Condenser [MAG] to the heat sink (the atmosphere). It is required for optimum operation of the steam turbine and hence electricity generation.

The baseline design for the MCWS [PA] is indirect cooling using low noise induced draft towers with plume abatement (mechanical draught cooling towers). The MCWS [PA] supports duty heat removal during normal operations.

Safety Design Basis

Functional Requirements

Safety categorised functional requirements and associated non-functional performance requirements for the MCWS [PA] are currently in development.

Non-Functional System Requirements

A full set of non-functional system requirements are in development based on the E3S Principles, which will be systematically applied to each SSC as part of the systems engineering process.

Safety Classification

A preliminary assessment of the MCWS [PA] indicates the highest category safety functions are Category C. As such, the MCWS [PA] is currently a Class 3 system providing duty cooling (DBC-1 and DBC-2i).

Seismic Classification

The seismic classification of SSCs is still to be assigned in accordance with methodology outlined in E3S Case Chapter 3: E3S Objectives & Design Rules, Reference [7].

Description of SSC

The MCWS [PA] circuit is a closed loop system that circulates cooling water from the cooling tower basin through the Turbine Condenser [MAG] and then to the mechanical draft cooling towers. The circulation circuit is closed by the water falling inside cooling tower cells and and returning to the cooling tower basin. The water flow is driven by circulation pumps downstream of the cooling tower basin.

The MCWS [PA] is provided with make-up and blowdown by the Auxiliary Cooling and Make-up System (ACMS) [PE] which interfaces with the MCWS [PA] via the cooling tower basin. The make-up water supply provides a constant source of make-up water to replace water lost through evaporation in the cooling tower and blowdown. The blowdown is a constant removal of water from the circuit which ensures that there is not a build-up of dissolved and suspended solids within the MCWS [PA] circuit beyond acceptable limits (maintains correct concentration factor).

The baseline architecture for the MCWS [PA] circulation circuit consists of two independent trains, each with a circulation pump, a set of cooling tower cells, a cooling tower basin, a connection to the Turbine Condenser [MAG] and associated pipework. Each train may evacuate a minimum of 50% of the nominal capacity of the Turbine Condenser [MAG].

Downstream of the cooling tower basin is an online filtration device, with a sluice gate before and after the filter to allow maintenance without draining the cooling tower basin. Two (normally open) block valves are located downstream of the circulation pump and downstream of the Turbine Condenser [MAG], to prevent a flooding inside the turbine hall following pipework failure.

The current layout splits the MCWS [PA] over two locations; the cooling towers and cooling tower basins are located outside the SMR berm (assumed to be within 500m of the site), and the pumphouse within the plant boundary.

The MCWS [PA] system architecture is illustrated in Figure 9A.2-1.

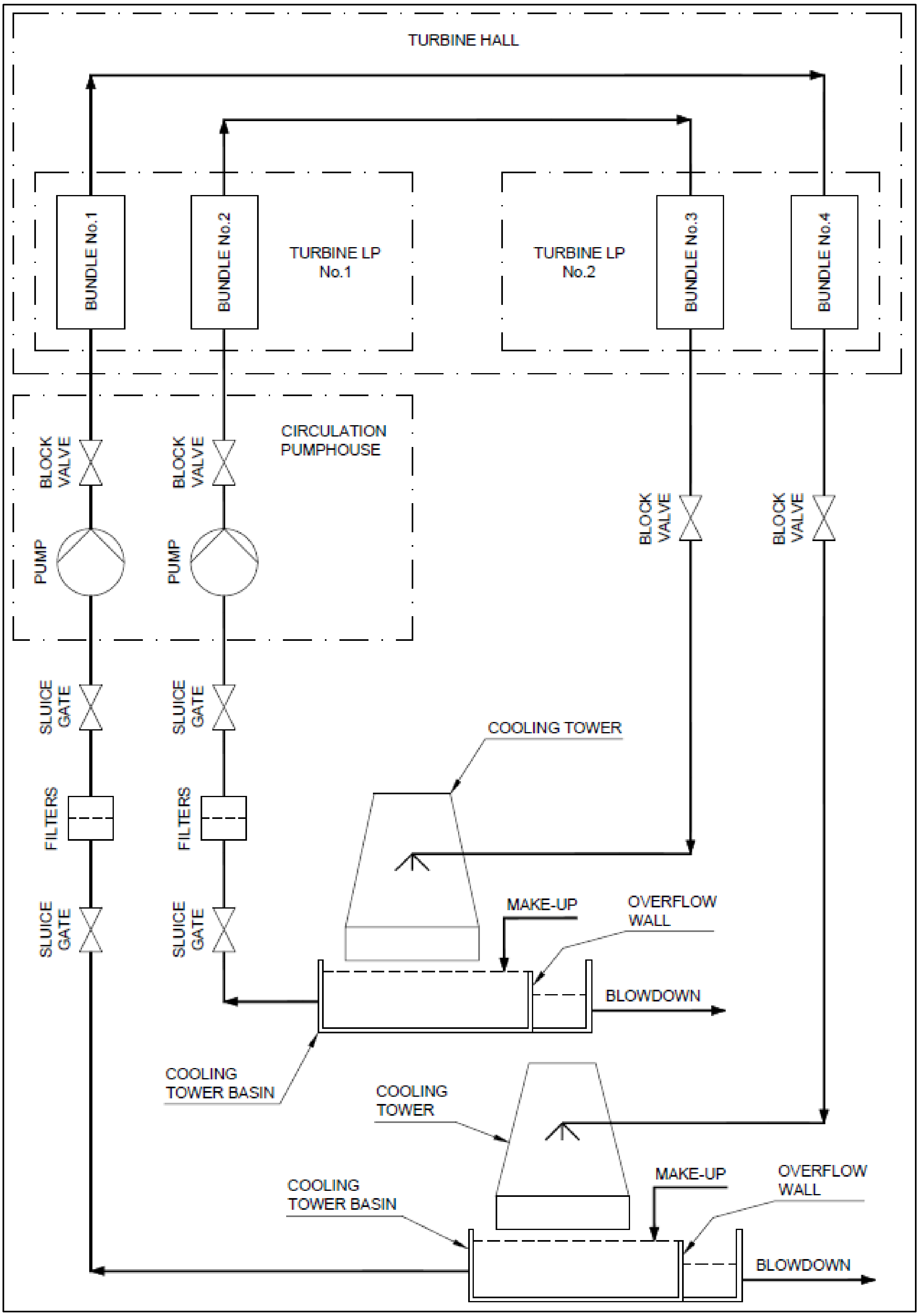

Figure 9A.2-1: Functional Drawing of the MCWS [PA]

An elevation view of one train of the MCWS [PA] circuit is provided in Figure 9A.2-2 and Figure 9A.2-3.

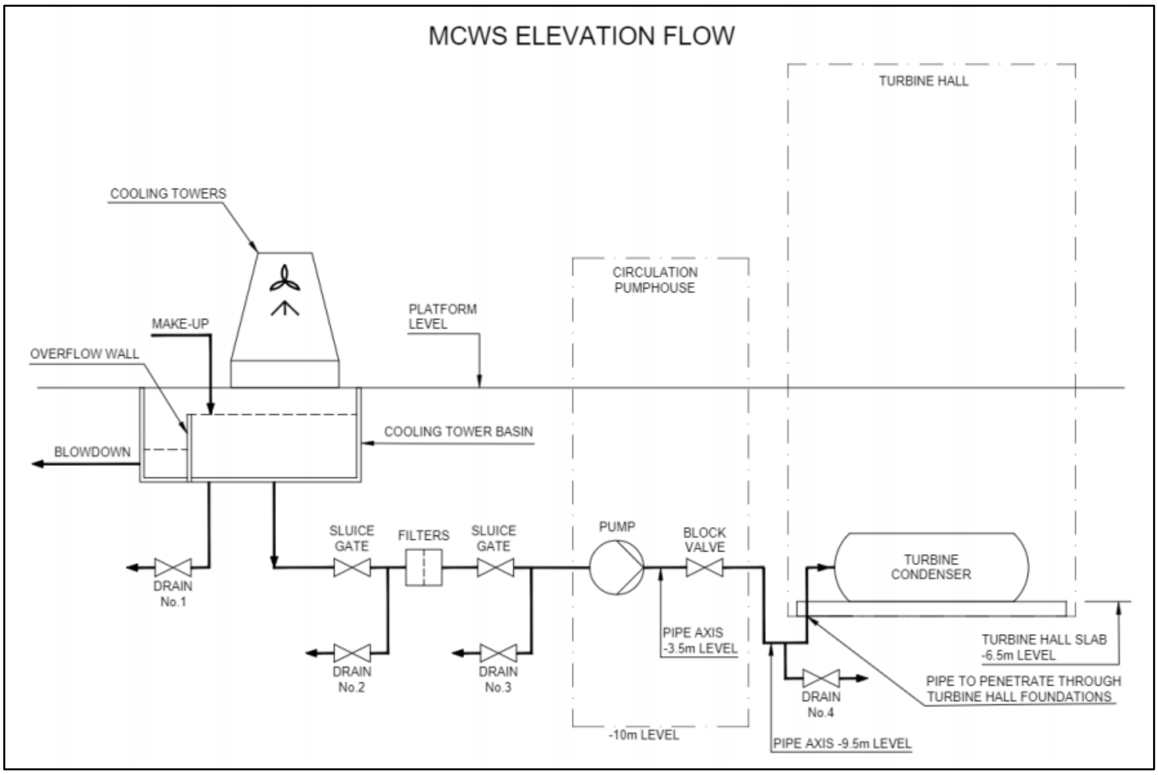

Figure 9A.2-2: Layout of MCWS [PA] Circuit – Cooling Tower Basin to Turbine Condenser

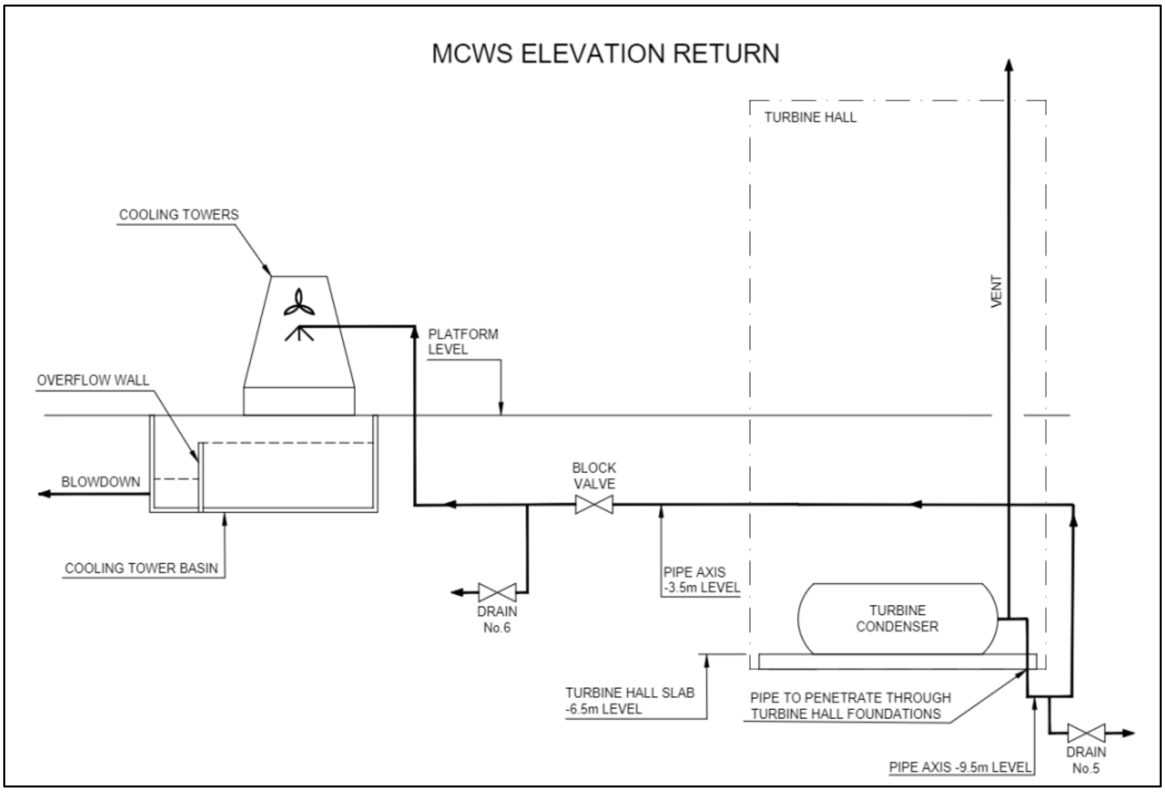

Figure 9A.2-3: Layout of MCWS [PA] Circuit – Turbine Condenser to Cooling Tower

Further details of the MCWS [PA] and its sub-systems and components are presented in the MCWS System Description, Reference [15].

SSC Operation

SSC Configuration

During start-up, with the water level the same in the cooling tower basin, vent of the turbine condenser and the column of the cooling tower, one train is initiated by starting the circulation pump whilst the other is in standby. During normal operation, both trains and all cooling tower cells are in operation, and the ACMS [PE] must also be operational. The water level within the cooling tower basins is monitored with circulation pumps stopped on low level.

During shutdown, when a circulation pump is stopped, the final equilibrium in the circuit is the level of water in the cooling tower basin, the vent and water supply column of the spray nozzles equalise, and the flow of water stops. At this point the fans can be stopped.

One train can be drained for maintenance or repair whilst the other is in standby.

Materials

The description and justification of materials used for Class 3 SSCs are presented in E3S Case Chapter 23: Structural Integrity, Reference [2].

Interfaces with Supporting Systems

The key MCWS [PA] functional and physical interfaces are the Steam Turbine System [MA] and the ACMS [PE]. Interfaces are identified and managed within DOORS, including flow down of functional requirements.

Instrumentation & Control

The MCWS [PA] allocates initiation functions onto the Control & Protection System [PY] for Cooling Water Island [C01].

It will also provide alarms to indicate that key system parameters are outside of the defined performance bands and/or safety limits. The envisaged requirements for trips, monitoring, indication, alarms, and warnings are specified in the MCWS System Description, Reference [15].

The allocation of safety categorised functional requirements from the MCWS [PA] to the Control & Protection System [PY] will be described further in E3S Case Chapter 7: Instrumentation & Control, Reference [8], as the C&I system design is developed.

Monitoring, Inspection, Testing & Maintenance

The design life of the RR SMR is intended to be 60 years, with replacement of the MCWS [PA] parts likely within that period. Maintenance of the MCWS [PA] components will be planned to align with the SMR refuelling cycles. An outline maintenance plan for the MCWS [PA] is still to be developed.

Radiological Aspects

No significant radiological aspects associated with the MCWS [PA] operation have been identified during design decisions up to PCD.

Performance and Safety Evaluation

Verification activities to substantiate safety categorised functional requirements and non-functional system requirements for MCWS [PA] are still to be determined.

Installation & Commissioning

An outline installation and commissioning plan for the MCWS [PA] is still to be developed. The overall strategy for the RR SMR commissioning programme is presented in E3S Case Chapter 14: Plant Construction & Commissioning, Reference [9].

ALARP in Design Development

The design of the MCWS [PA] has been developed in accordance with the systems engineering design process, which includes alignment to RGP & OPEX, design to codes and standards according to the safety classification, and a systematic optioneering process with down-selection of design options based on assessment against relevant safety criteria (as described in PSCR Chapter 3: E3S Objectives & Design Rules, Reference [7]).

Key MCWS [PA] design decisions made with respect to ensuring overall risks are reduced to ALARP include:

1. MCWS [PA] architecture has been developed with two independent trains, combined with the selection of highly reliable pump technology and each train having multiple mechanical draught cooling tower cells. This decision has been made to support a higher system reliability to reduce the potential for loss of the duty cooling function during operation

More detailed information on design decisions is presented in the MCWS System Description, Reference [15], and associated design decision files.

Ongoing Design Development

The RR SMR design definition is currently in development as described in Section 9A.0. Key design opportunities and decisions related to MCWS [PA] operability and safety are currently being explored, these include:

1. A decision to determine and refine the architecture of the main circulating pumps considering factors such as reliability, redundancy, diversity, and operation under fault

2. A decision to refine the cooling tower type and operation, including the type of cooling tower cell to be used with consideration of efficiency, resilience in the operating envelope including fault conditions and application of Best Available Techniques (BAT). This decision will also consider the influence of maintainability on the cooling tower row architecture and whether any redundancy is allowed for in the architecture

3. A decision to consider the number of cooling tower rows, spacing of cells and factors such as fire partitioning, segregation, and separation. Cooling tower basin volume will be determined to enable shut down in the event of make-up failure

4. The pipe routing, pipe material, installation methodology and connection types

5. Refinement of the maintenance philosophy, operational modes (normal and abnormal), optimisation of water quality requirements, and measures to prevent Turbine Island flooding

All design development risks and opportunities are captured and managed by design teams.

9A.2.2 Component Cooling System

System and Equipment Functions

The CCS [KAA] transfers heat from the following reactor systems and components to the Essential Service Water System (ESWS) [PB], supporting achievement of the FSFs of CoFT and CoRM during normal operation:

1. CSCS [JNA] heat exchangers

2. Reactor Coolant Pumps (RCPs) [JEB]

3. Coolant Purification System (CPS) [KPE] cooler

4. Chilled Water System (CWS) [KJ] heat exchangers

5. Fuel Pool Cooling System (FPCS) [FAK] heat exchangers

6. Active Media Liquid Sampling System [KUA] heat exchangers

7. Gaseous Media Sampling System [KUF] heat exchangers

8. Waste Treatment System [KNF] heat exchangers

HLSFs for the CCS [KAA], and the PIEs against which they are assigned, are being derived in the Fault Schedule, which is presented in E3S Case Chapter 15: Safety Analysis, Reference [5].

Safety Design Basis

Functional Requirements

Safety categorised functional requirements are specified for the CCS [KAA] based on the HLSFs they deliver, including the applicable plant states and operating modes, these are presented in Table 3.

1. The traceability of safety categorised functional requirements back to the HLSFs will be managed in DOORS via the Safety Measures Module; this process is outlined in Deterministic Safety Methodology, Reference [6]. This will include any specific safety categorised functional requirements aligned to the PIEs should the CCS [KAA] be claimed during fault conditions (including internal and external hazards).

Table 3: CCS [KAA] Safety Categorised Functional Requirements

DOORS ID	Functional Requirement	Plant State(s)	Mode(s) of Operation	Safety Category
KAA-R-1457	The Component Cooling System [KAA] SHALL remove heat from the Cold Shutdown System [JNA] Heat Exchangers	DBC-1 DBC-2 DBC-3	Shutdown	B
KAA-R-1458	The Component Cooling System [KAA] SHALL remove heat from the Spent Fuel Cooling System [FAK] Heat Exchangers.	DBC-1 DBC-2 DBC-3	All modes	B
KAA-R-1393	The Component Cooling System [KAA] SHALL remove heat from the Active Liquid Sampling System [KUA] Heat Exchangers.	DBC-1 DBC-2	All modes (excluding Refuelling)	C
KAA-R-1411	The Component Cooling System [KAA] SHALL remove heat from the Gaseous Sampling Heat Exchanger	DBC-1 DBC-2	All modes (excluding Refuelling)	C
KAA-R-1361	The Component Cooling System [KAA] SHALL remove heat from each Reactor Coolant Pump [JEB]	DBC-1 DBC-2 DBC-3	Power operations and Shutdown (hot)	C
KAA-R-1506	The Component Cooling System [KAA] SHALL remove heat from each Chilled Water System [KJ_] Heat Exchanger	DBC-1 DBC-2 DBC-3	All modes (excluding Refuelling)	B
KAA-R-1381	The Component Cooling System [KAA] SHALL remove heat from the Coolant Purification System [KBE] Cooler	DBC-1 DBC-2 DBC-3 0.1.1	All modes (excluding Refuelling)	C

DOORS ID	Functional Requirement	Plant State(s)	Mode(s) of Operation	Safety Category
KAA-R-2260	The Component Cooling System [KAA] SHALL remove heat from the Waste Treatment System [KNF]	DBC-1 DBC-2	All modes	C

A significant number of non-functional performance requirements associated with the safety categorised functional requirements are also presented in the DOORS CCS [KAA] Requirements Module, which are not repeated here.

Non-Functional System Requirements

A full set of non-functional system requirements are in development based on the E3S Principles, which will be systematically applied to each SSC as part of the systems engineering process.

Safety Classification

The CCS [KAA] is the principal means by which the Category B safety function CoFT is achieved, and in accordance with the E3S Categorisation and Classification methodology outlined in E3S Case Chapter 3: E3S Objectives & Design Rules, Reference [7], the highest safety classification of components within the system is Class 2.

Seismic Classification

The seismic classification of SSCs is still to be assigned in accordance with methodology outlined in E3S Case Chapter 3: E3S Objectives & Design Rules, Reference [7].

Description of SSC

The CCS [KAA] is comprised of two independent cooling trains, each containing an expansion tank, a pump, pipework, valves, and instrumentation, and connected to corresponding ESWS cooling towers [PBD] (described in Section 9A.0).

The component cooling pump circulates coolant to the duty loads. Heated coolant is returned through the system, where waste heat is transferred to the ESWS cooling towers, noting there is no dedicated CCS/ESWS heat exchanger.

Each train removes heat from a single Cold Shutdown [JNA], Chilled Water [KJ] and Fuel Pool Cooling [FAK] heat exchanger to provide redundancy for Category B Safety Functions. The remaining consumers (excluding [KUA]) are asymmetrically split over the two trains, with a cross-connect provided between them to allow a pump and cooling tower within a cooling train to service all active consumer heat exchangers.

A simplified schematic of the CCS [KAA] is shown in Figure 9A.2-4, aligned for power operations.

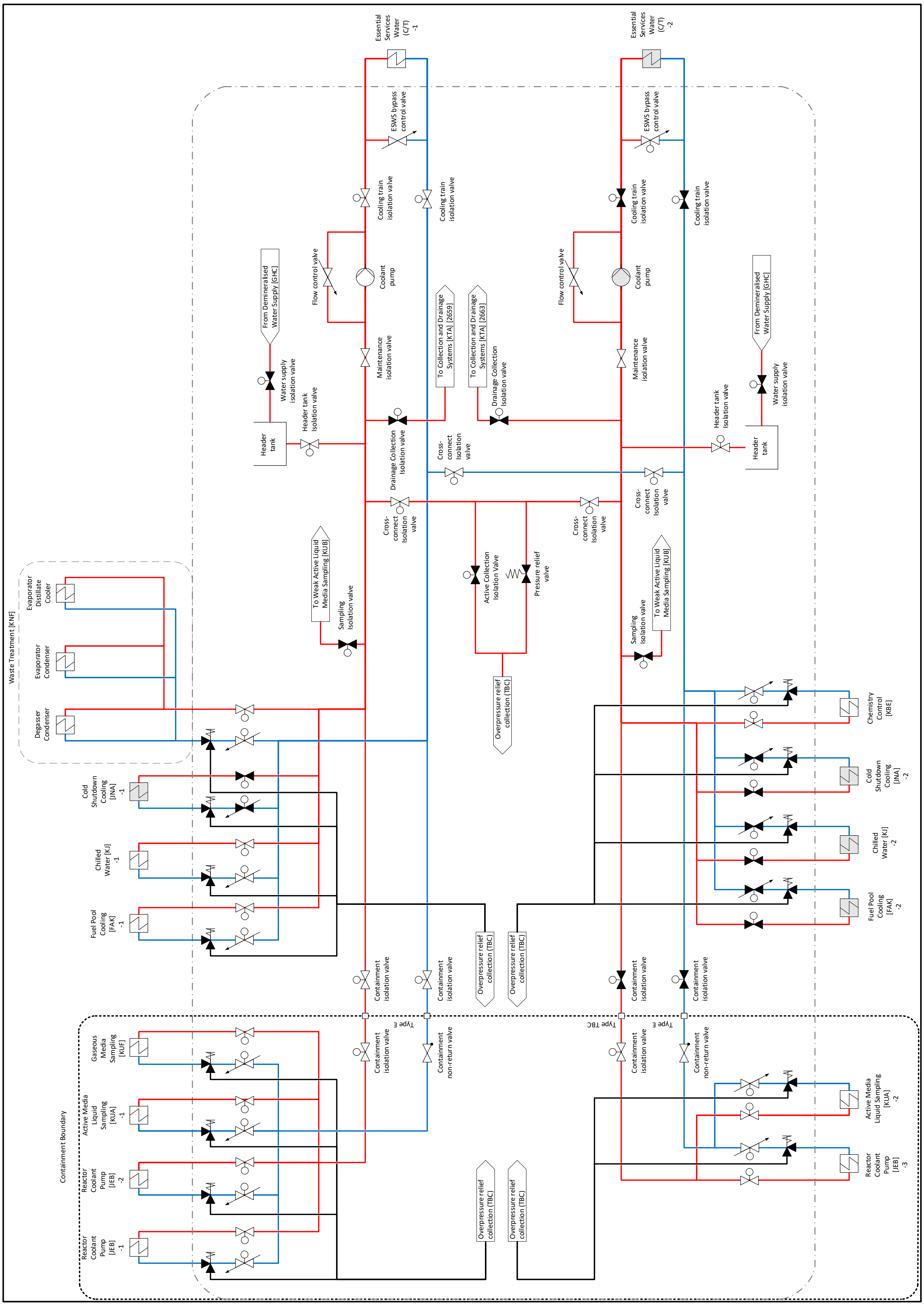

Figure 9A.2-4: Schematic of the Component Cooling System [KAA]

The baseline key performance and design parameters for the CCS [KAA] are presented in Table 4.

Table 4: CCS System Design and Operating Parameters

Parameter	**Value**
Maximum operating pressure	**{REDACTED FOR PUBLICATION}**
Maximum operating temperature	**{REDACTED FOR PUBLICATION}**
Design pressure	**{REDACTED FOR PUBLICATION}**
Design temperature	**{REDACTED FOR PUBLICATION}**
Maximum cooling duty (per train)	**{REDACTED FOR PUBLICATION}**
Maximum cooling duty (both trains) (at start of hot shutdown, Mode 4b)	**{REDACTED FOR PUBLICATION}**
Maximum 'common line' flowrate	**{REDACTED FOR PUBLICATION}**

Further details of the CCS [KAA] and its sub-systems and components are presented in the CCS System Description, Reference [16].

SSC Operation

<u>SSC Configuration</u>

The modes of operation for each SSC that requires cooling are provided in Table 3. During Operating Modes 1 (Power Operation), 2 (Low Power), 3 (Hot Standby), 4a (Hot Shutdown – Steaming), one train is active with the other on standby.

During Operating Modes 4b (Hot Shutdown – Non-Steaming) and 5a (Cold Shutdown – Pressurised), the increased cooling duty to support shutdown requires both trains to be active. During Operating Modes 6a (Refuelling with Reduced Water Level above Fuel) and 6b (Refuelling with Water Level above Fuel at Nominal Full), the CCS [KAA] reverts back to one train in operation with the other on standby.

During faulted operation (DBC-3), cooling to only sampling and waste treatment heat exchangers is deactivated, although in some cases maximum return temperatures may be elevated.

Materials

The description and justification of materials used for Class 2 SSCs are presented in E3S Case Chapter 23: Structural Integrity, Reference [2].

Interfaces with Supporting Systems

The key CCS [KAA] functional and physical interfaces are described above. These are identified and managed within DOORS, including flow down of functional requirements.

Instrumentation & Control

The CCS [KAA] allocates initiation functions onto the Reactor Island Control & Protection System [JY].

It will also provide alarms to indicate that key system parameters are outside of the defined performance bands and/or safety limits. The envisaged requirements for trips, monitoring, indication, alarms, and warnings are specified in the CCS System Description, Reference [16].

The allocation of safety categorised functional requirements from the CCS [KAA] to the Reactor Island Control & Protection System [JY] will be described further in E3S Case Chapter 7: Instrumentation & Control, Reference [8], as the C&I system design is developed.

CCS [KAA] requirements placed on the emergency power supplies following Loss of Offsite Power (LOOP) faults are still to be determined.

Monitoring, Inspection, Testing & Maintenance

The design life of the RR SMR is intended to be 60 years. It is intended that maintenance will be performed during Operating Mode 1 (Powered Operations), with the pumps and other key cooling train equipment located outside of containment in an area that can be accessed easily for maintenance. Redundancy of pumps in the system means that the system routinely operates on a one out of three (1oo2) pump basis, which then reduces to 1oo1 when maintenance is taking place.

An outline maintenance plan for the CCS [KAA] is still to be developed.

Radiological Aspects

A hazard identification study on the preliminary design determined that there was a requirement for radiation monitors in the vicinity of the CCS pipework to detect any potential contamination from reactor coolant caused by a leak in a component being cooled by CSCS, FPCS, CPS or several in-containment consumer Heat exchangers tube side). Gamma monitoring has therefore been incorporated into the PCD design architecture.

Performance and Safety Evaluation

Verification activities to substantiate safety categorised functional requirements and non-functional system requirements for CCS [KAA] are still to be determined.

Installation & Commissioning

An outline installation and commissioning plan for the CCS [KAA] is still to be developed. The overall strategy for the RR SMR commissioning programme is presented in E3S Case Chapter 14: Plant Construction & Commissioning, Reference [9].

ALARP in Design Development

The design of the CCS [KAA] has been developed in accordance with the systems engineering design process, which includes alignment to RGP & OPEX, design to codes and standards according to the safety classification, and a systematic optioneering process with down-selection of design options based on assessment against relevant safety criteria (as described in PSCR Chapter 3: E3S Objectives & Design Rules, Reference [7]).

Key CCS [KAA] design decisions made with respect to ensuring overall risks are reduced to ALARP include:

1. Early optioneering for the CCS [KAA] architecture has considered the varying levels of redundancy in the system, including options for a single train, two segregated trains, two trains with a common header, or two trains cross-connected. A cross-connected system was selected on the basis that it reduces the potential for single points of failure and increases reliability of the system. Furthermore, it allows a controlled shutdown and continued cooling following failures

More detailed information on design decisions is presented in the CCS System Description, Reference [16], and associated design decision files.

Ongoing Design Development

The RR SMR design definition is currently in development as described in Section 9A.0. Key design opportunities and decisions related to safety are currently being explored, these include:

1. Optimisation of system duty and component sizing to reflect evolutions in consumer head loads.

2. Optimisation of system and containment isolation to minimise single points of failure.

3. Incorporation of a third standby CCS [KAA] pump in Train 2 to increase reliability and allow for maintenance outages during power operations.

4. Develop the physical layout outside containment, ensuring safety aspects such as dose minimisation and segregation for internal hazards are considered, whilst ensuring compatibility with wider modularised build and commissioning strategy.

All design development risks and opportunities are captured and managed by design teams.

9A.2.3 Essential Service Water System

System and Equipment Functions

The ESWS [PB] transfers heat from CCS [KAA] to the ultimate heat sink (UHS), the environment, supporting achievement of the FSFs of CoFT and CoRM during normal operation.

ESWS [PB] will use indirect cooling with cooling towers during normal operation (separate to those for the MCWS [PA]). The cooling towers will recirculate the coolant, with a bleed that will be collected and transferred for treatment in the wastewater drainage and treatment systems. From there the treated effluent will be re-used as ESWS make-up water.

HLSFs for the ESWS [PB], and the PIEs against which they are assigned, are being derived in the Fault Schedule, which is presented in E3S Case Chapter 15: Safety Analysis, Reference [5].

Safety Design Basis

Functional Requirements

Safety categorised functional requirements are specified for the ESWS [PB] based on the HLSFs they deliver, including the applicable plant states and operating modes, these are presented in Table 5.

The traceability of safety categorised functional requirements back to the HLSFs will be managed in DOORS via the Safety Measures Module; this process is outlined in Deterministic Safety Methodology, Reference [6]. This will include any specific safety categorised functional requirements aligned to the PIEs should the ESWS [PB] be claimed during fault conditions (including internal and external hazards).

Table 5: ESWS [PB] Safety Categorised Functional Requirements

DOORS ID	Functional Requirement	Plant State(s)	Mode(s) of Operation	Safety Category
P-PB-1178	The Essential Service Water System [PB] shall provide cooling water (UHS) to the Component Cooling Systems [KA]	DBC-1 DBC-2 DBC-3	All modes	B
P-PB-1319	The Essential Service Water System [PB] shall distribute heated cooling water from the Component Cooling Systems [KA] heat exchanger	DBC-1 DBC-2 DBC-3	All modes	B
P-PB-1179	The Essential Service Water System [PB] shall distribute heat from the Component Cooling Systems [KA] to the Natural Environment [EXT-NE]	DBC-1 DBC-2 DBC-3	All modes	B
P-PB-1401	The Essential Service Water System [PB] shall distribute spray water	DBC-1 DBC-2 DBC-3	All modes	B
P-PB-1400	The Essential Service Water System [PB] shall convey spray water	DBC-1 DBC-2 DBC-3	All modes	B
P-PB-1397	The Essential Service Water System [PB] shall provide a secondary barrier between the External Natural Environment and source of radioactive contamination	DBC-1 DBC-2 DBC-3	All modes	C

DOORS ID	Functional Requirement	Plant State(s)	Mode(s) of Operation	Safety Category
P-PB-1453	The Essential Service Water System [PB] shall provide radioactive monitoring and isolation measures in addition to a secondary barrier to radioactive release	DBC-1 DBC-2 DBC-3	All modes	C

Non-functional performance requirements associated with the safety categorised functional requirements are also identified in the DOORS ESWS [PB] Requirements Module. These are summarised in Table 6.

Table 6: ESWS [PB] Non-Functional Performance Requirements

Associated Functional Requirement	Non-Functional Performance Requirement
P-PB-1178	The Essential Service Water System [PB] shall provide cooled water at a maximum of **{REDACTED FOR PUBLICATION}**.
	The Essential Service Water System [PB] shall provide cooled water at a maximum of **{REDACTED FOR PUBLICATION}**.
P-PB-1179	The Essential Service Water System [PB] shall dissipate up to a maximum of **{REDACTED FOR PUBLICATION}** to the External Natural Environment when the SMR is in Hot Shutdown (Non-Steaming Mode) [Mode 4b]
	The Essential Service Water System [PB] shall dissipate up to a maximum **{REDACTED FOR PUBLICATION}** to the External Natural Environment during faulted operation
	The Essential Service Water System [PB] shall dissipate up to a maximum **{REDACTED FOR PUBLICATION}** to the External Natural Environment when the SMR is in Powered Operations [Mode 1]
	The Essential Service Water System [PB] shall dissipate up to a maximum **{REDACTED FOR PUBLICATION}** to the External Natural Environment when the SMR is in Cold Shutdown Pressurised [Mode 5a]
	The Essential Service Water System [PB] shall have control system termination elements that meets the requirements of a Safety Integrity Level (SIL) 2 system.
	The Essential Service Water System [PB] shall have reliability better than 10E-6 dangerous failures/hr

<u>Non-Functional System Requirements</u>

Non-functional system requirements, or non-functional system requirements, are specified for the ESWS [PB] based on the E3S Principles. The requirements specified at PCD are listed in the DOORS ESWS [PB] Requirements Module, including the rationale for their application. These are summarised in Table 7.

Table 7: ESWS [PB] Non-Functional System Requirements

DOORS ID	Non-Functional System Requirement	Rationale
P-PB-1203	The Essential Service Water System [PB] design shall ensure that all risks to all populations during all modes of operation and lifecycle stages are reduced to levels that are ALARP	Overall safety principle
P-PB-1375	The Essential Service Water System [PB] SSCs shall be classified in accordance with the defined project methodology	Ensures appropriate classification of SSCs to deliver the necessary functions to protect people and the environment from harm
P-PB-1204	The Essential Service Water System [PB] shall be designed to maximise the passivity of the safety systems during all modes of operation	Overall safety principle
P-PB-1205	The Essential Service Water System [PB] shall be designed to minimise the area required as an emergency planning zone within the local regulatory framework	Based on Radiation (Emergency Preparedness and Public Information) Regulations 2019 (REPPIR), and the Approved Code of Practice (ACoP)
P-PB-1207	The Essential Service Water System [PB] shall be designed such that the SMR be capable of shutting down and maintaining a safe plant state without requirement for backup power systems	The RR SMR as a whole shall be passively safe ([PB] shall have a back-up generator)
P-PB-1376	The Essential Service Water System [PB] shall be designed such that it does not reduce the SMR core damage frequency below the Basic Safety Level (1E-5/yr)	Overall safety principle
P-PB-1208	The Essential Service Water System [PB] should be designed such that the SMR core damage frequency is below the Basic Safety Objective (1E-7/yr)	Overall safety principle

A full set of non-functional system requirements are in development based on the E3S Principles, which will be systematically applied to each SSC as part of the systems engineering process.

<u>Safety Classification</u>

The ESWS [PB] is the principal means by which the Category B safety function CoFT is achieved, and in accordance with the E3S Categorisation and Classification methodology outlined in E3S Case Chapter 3: E3S Objectives & Design Rules, Reference [7], the highest safety classification of components within the system is Class 2.

<u>Seismic Classification</u>

The seismic classification of SSCs is still to be assigned in accordance with methodology outlined in E3S Case Chapter 3: E3S Objectives & Design Rules, Reference [7].

Description of SSC

The baseline ESWS [PB] design consists of two trains operating at atmospheric pressure, each containing one Wet Closed Cooling Tower (WCCT) (with its associated make-up and blowdown sub-systems) and its associated pipework and valves.

The WCCT is an induced counter flow closed cooling tower type, comprised of:

1. Cooling tower cells containing the coils fill, fans; spray systems (pumps, nozzles), drift eliminator

2. Cooling tower basin

Air is drawn vertically from the air inlet in the lower part of the tower, travels across the fill against the stream of water and is discharged into the atmosphere at high velocity by fans. The water is sprayed onto the coil fill to cool the ESWS water before dropping down into the basin over the closed ESWS/CCS coolant heat exchanger coil. The spray water is cooled primarily by evaporation, and by this mechanism the heat is transferred to the air flowing through the tower and ejected to the external environment.

Each ESWS [PB] train is directly connected to the CCS [KAA] trains at the Reactor Island [R01] boundary, with those items of the cooling loop inside Reactor Island [R01] being designated as part of the CCS [KAA]. The coolant is pumped around the circuit by the CCS [KAA] with the circulating pump being inside the Reactor Island [R01]. The systems that are cooled by the CCS [KAA] and hence ESWS [PB] are listed in Section 9A.0.

A cross-connection is also present to allow each train to be cooled by either ESWS [PB] train in case of failure of the cooling train in operation. During powered operation, only one ESWS [PB] train is expected to be operating, with the other train in standby. Each train provides 100% cooling capacity.

During duty plant cooldown operations, both trains are operated to facilitate the high heat loads and flow rates associated with decay heat removal through the Cold Shutdown Cooling System [JNA], which are cooled via the CCS [KAA] and ultimately via ESWS [PB].

A simplified schematic of one train of the ESWS [PB] is illustrated in Figure 9A.2-5.

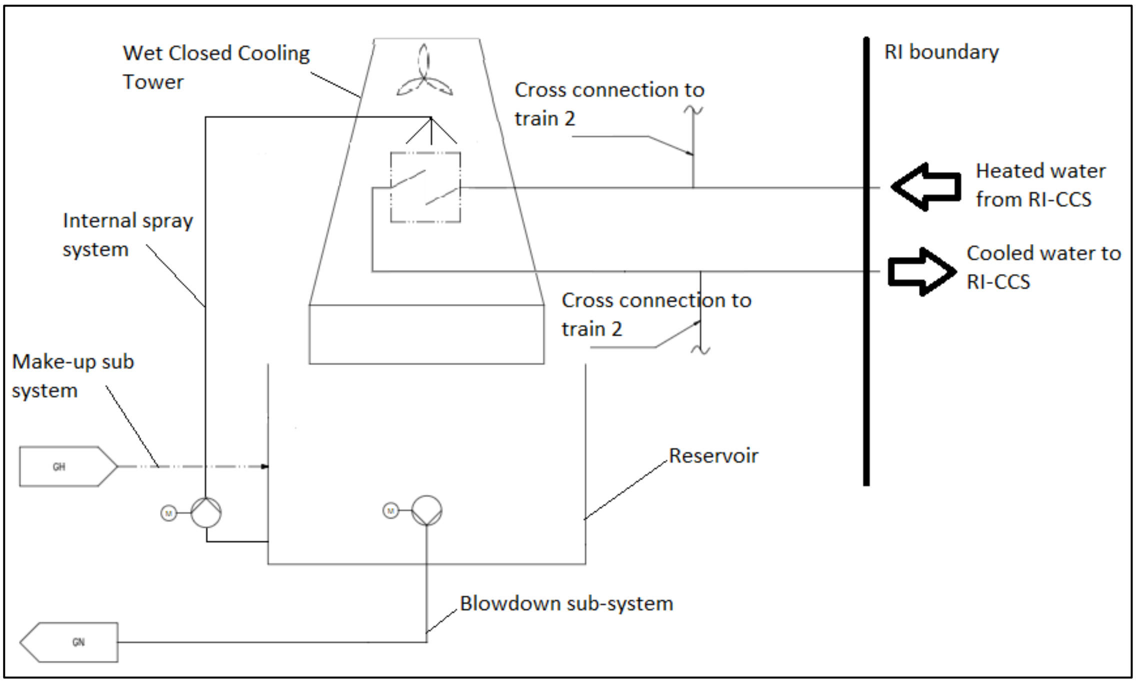

Figure 9A.2-5: ESWS [PB] Simplified Schematic – Train 1

Further details of the ESWS [PB] and its sub-systems and components are presented in the ESWS System Description, Reference [17].

SSC Operation

<u>SSC Configuration</u>

During Operating Modes 1 (Power Operation), 2 (Low Power), 3 (Hot Standby), 4a (Hot Shutdown – Steaming), 6a (Refuelling with Reduced Water Level above Fuel) and 6b (Refuelling with Water Level above Fuel at Nominal Full), the ESWS [PB] has one train in operation with the other on standby, with an estimate total heat removal duty of **{REDACTED FOR PUBLICATION}**.

The train in operation will be directly connected to the CCS train in operation, with some level of cross-connection in the CCS [KAA] to ensure cooling demand for interfacing systems is met. ESWS make-up feeds into the WCCT basin and water is removed through blow-down to ensure acceptable concentration level is maintained. If environmental conditions are favourable (e.g., low wet bulb temperature), some of the WCCT cells can be stopped to reduce electrical load.

During Operating Modes 4b (Hot Shutdown – Non-Steaming), 5a (Cold Shutdown – Pressurised) and 5b (Cold Shutdown – Depressurised), the ESWS [PB] has two trains in operation both connected to the CCS [KAA], with an estimate total heat removal duty of **{REDACTED FOR PUBLICATION}** ESWS make-up and blowdown operate in the WCCT basin as per power operation modes.

Faulted operating modes are still to be developed.

Materials

The description and justification of materials used for Class 2 SSCs are presented in E3S Case Chapter 23: Structural Integrity, Reference [2].

Interfaces with Supporting Systems

The key ESWS [PB] functional and physical interfaces are the CCS [KAA] and the external environment. Interfaces are identified and managed within DOORS, including flow down of functional requirements.

Instrumentation & Control

The ESWS [PB] allocates initiation functions onto the Reactor Island Control & Protection System [JY].

It will also provide alarms to indicate that key system parameters are outside of the defined performance bands and/or safety limits. The envisaged requirements for trips, monitoring, indication, alarms, and warnings are specified in the ESWS System Description, Reference [17].

The allocation of safety categorised functional requirements from the ESWS [PB] to the Reactor Island Control & Protection System [JY] will be described further in E3S Case Chapter 7: Instrumentation & Control, Reference [8], as the C&I system design is developed.

ESWS [PB] requirements placed on the emergency power supplies following Loss of Offsite Power (LOOP) faults are still to be determined. It is expected that the medium voltage switchboards are supplied by switchboard back-up.

Monitoring, Inspection, Testing & Maintenance

The design life of the RR SMR is intended to be 60 years. Regular inspections and maintenance of components will be undertaken in line with the classification requirements, and lifting points are provided in the design to facilitate any mechanical handling solutions. Full maintenance of the ESWS [PB] trains, including draining of WCCTs and pipework cleaning, will be planned to align with the SMR refuelling cycles. An outline maintenance plan for the ESWS [PB] is still to be developed.

Radiological Aspects

No significant radiological aspects associated with the ESWS [PB] operation have been identified during design decisions up to PCD. It is noted that the current design solution is such that part of the cooling circuit is located outside Reactor Island [R01], therefore enhanced radiation protection measures may be required for any intrusive maintenance that may be required.

Performance and Safety Evaluation

Verification activities to substantiate safety categorised functional requirements and non-functional system requirements for ESWS [PB] are still to be determined.

Installation & Commissioning

An outline installation and commissioning plan for the ESWS [PB] is still to be developed. The overall strategy for the RR SMR commissioning programme is presented in E3S Case Chapter 14: Plant Construction & Commissioning, Reference [9].

ALARP in Design Development

The design of the ESWS [PB] has been developed in accordance with the systems engineering design process, which includes alignment to RGP & OPEX, design to codes and standards according to the safety classification, and a systematic optioneering process with down-selection of design options based on assessment against relevant safety criteria (as described in PSCR Chapter 3: E3S Objectives & Design Rules, Reference [7]).

Key ESWS [PB] design decisions made with respect to ensuring overall risks are reduced to ALARP include:

1. ESWS [PB] baseline architecture has been developed with a two-loop cooling system utilising a Wet Closed Mechanical Induced Draught Cooling Tower, on the basis that it reduces system complexity and potentially improves system reliability, whilst it also reduces cost, minimises footprint, provides better thermal performance, and increases the potential for standardisation and modularisation. The selected baseline maintains three barriers to the release of contamination to the environment, and it reduces construction materials and energy during operations with no expected increase in radioactive discharge to the environment

More detailed information on design decisions is presented in the ESWS System Description, Reference [17], and associated design decision files.

Ongoing Design Development

The RR SMR design definition is currently in development as described in Section 9A.0. Key design opportunities and decisions related to safety are currently being explored, these include:

1. A decision to baseline the safety performance requirements for ESWS [PB]. This will include determination of the requirement of autonomy from supporting water supply systems and the degree of separation and segregation between trains. This decision will also determine any requirement for in-train redundancy

2. A decision to determine the specification for the WCCT including the number of cells and their respective arrangement. This will determine the interfaces with adjoining systems including required make-up and blowdown treatment rates

3. A decision to determine the make-up water storage system configuration. This will determine the preferred method by which to store water to deliver autonomous operations and will consider key system attributes as the passivity of the delivery of the safety function

4. Design development of the pipe routes between the Reactor Island, between elements of the system and the selection of the required valve behaviour to ensure adequate safety performance. This will consider key system attributes such as system reliability, constructability and supportability through life. This will result in a service route between the heat sink and the reactor island and further development of the system Piping & Instrumentation Diagram (P&ID)

5. Definition of the strategy for installation and maintenance including consideration of the modularisation strategy. This will determine the maintenance and installation benefits

related to modularised solutions and will consider key system attributes such as safety function reliability

All design development risks and opportunities are captured and managed by design teams.

9A.2.4 Auxiliary Cooling and Make-Up System

System and Equipment Functions

The ACMS [PE] provides and removes cooling water to the Turbine Island Closed Cooling Water System [PG] heat exchangers, supplies make-up water to the MCWS [PA] cooling towers and transfers wastewater to the sea. The ACMS [PE] supports the MCWS [PA] in delivering duty heat removal during normal operations.

Safety Design Basis

Functional Requirements

Safety categorised functional requirements and associated non-functional performance requirements for the ACMS [PE] are currently in development.

Non-Functional System Requirements

A full set of non-functional system requirements are in development based on the E3S Principles, which will be systematically applied to each SSC as part of the systems engineering process.

Safety Classification

A preliminary assessment of the ACMS [PE] indicates the highest category safety functions are Category C. As such, the ACMS [PE] is currently a Class 3 system providing duty cooling (DBC-1 and DBC-2i).

Seismic Classification

The seismic classification of SSCs is still to be assigned in accordance with methodology outlined in E3S Case Chapter 3: E3S Objectives & Design Rules, Reference [7].

Description of SSC

The ACMS [PE] utilises a single intake head to extract sea water, which consists of one train containing one intake head, one intake tunnel, one forebay, two trash racks, two submerged filters, two pumps, two in line strainers, two heat exchangers and associated pipework and valves.

The system is arranged to allow each filter and pump to deliver to either Turbine Island Closed Cooling Water System [PG] heat exchanger, with a cross-connect between the channels. Additionally, the filters and pumps can deliver 100% of the flowrate. Once the sea water has been through the heat exchangers it is then delivered to the cooling tower basin as make-up water for the MCWS [PE]. A bypass line allows make-up water to bypass the heat exchanger, which can also be used to balance the flow through the heat exchanger if a reduced flowrate is required.

As part of the MCWS [PA] cooling tower process an amount of blowdown water is to be removed from the system. The ACMS [PE] provides the pipework to transfer the blowdown from the cooling towers to the outfall pond. From the outfall pond an outfall tunnel discharges the waste to sea. In addition to blowdown, wastewater from the Waste Water Drainage System [GM] and Liquid Radioactive Effluent Processing System [KN] are discharged into the pipeline for disposal into the sea.

As part of the filtration process (trash racks and submerged filters) debris and marine organisms need to be removed from the system. Marine organisms are discharged directly back to sea and the debris is disposed as conventional waste using debris and fish recovery system.

A simplified architecture for the ACMS is illustrated in Figure.

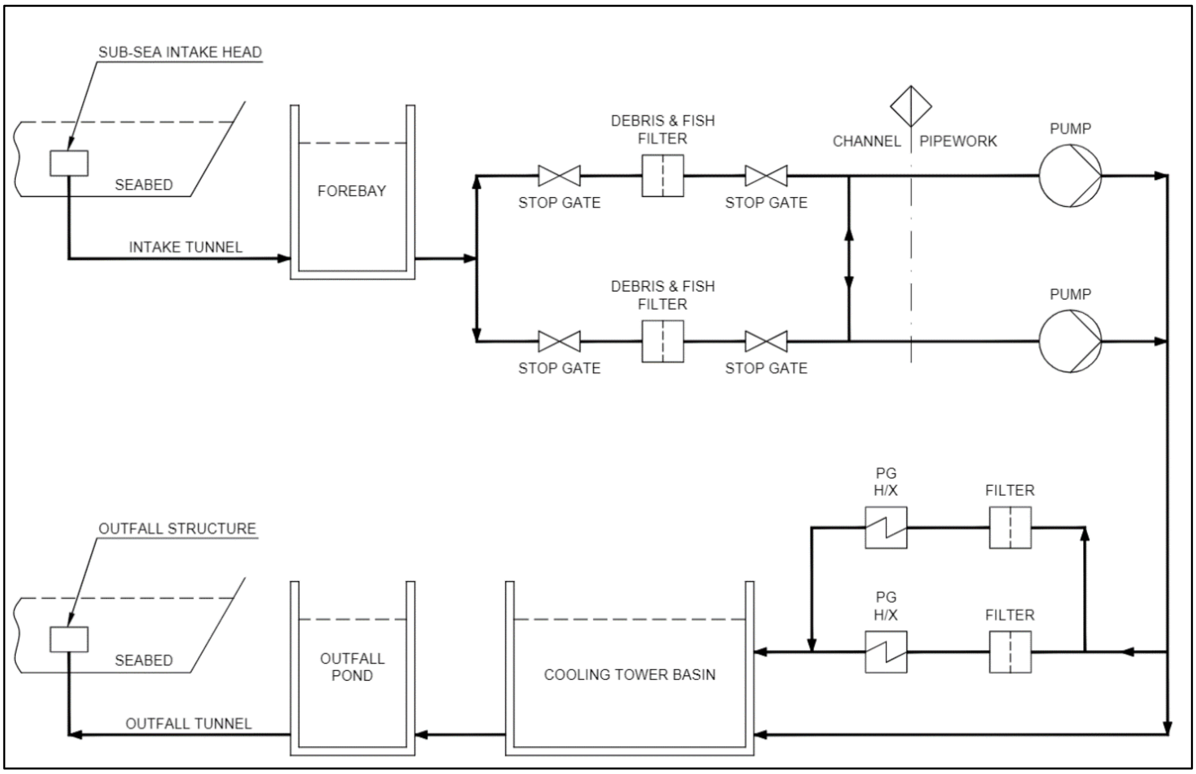

Figure 9A.2-6: ACMS [PE] Architecture

Further details of the ACMS [PE] and its sub-systems and components are presented in the ACMS System Description, Reference [18].

SSC Operation

SSC Configuration

During normal operation seawater supply, all valves are open and both filters are in operation with each filter providing 50% of the flow capacity, noting they are sized for 100% flow. The start-up operation will be defined by the interface with the Turbine Island Closed Cooling Water System [PG] and MCWS [PA] systems.

During faulted operation, it is assumed a loss of the ACMS [PE] would lead to a shutdown of the SMR as loss of cooling water to the Turbine Island Closed Cooling Water System [PG] heat exchangers would cause overheating. Sizing of the filters means should one fail, it can be isolated for maintenance without loss of the function.

Materials

The description and justification of materials used for Class 3 SSCs are presented in E3S Case Chapter 23: Structural Integrity, Reference [2].

Interfaces with Supporting Systems

The key ACMS [PE] functional and physical interfaces are the MCWS [PA], the Liquid Radioactive Waste Process System [KN], the Turbine Island Closed Cooling Water System [PG], the Waste Water Drainage System [GM] and the natural environment. Interfaces are identified and managed within DOORS, including flow down of functional requirements.

Instrumentation & Control

The ACMS [PE] allocates initiation functions onto the Control & Protection System [PY] for Cooling Water Island [C01].

It will also provide alarms to indicate that key system parameters are outside of the defined performance bands and/or safety limits. The envisaged requirements for trips, monitoring, indication, alarms, and warnings are specified in the ACMS System Description, Reference [18].

The allocation of safety categorised functional requirements from the ACMS [PE] to the Control & Protection System [PY] will be described further in E3S Case Chapter 7: Instrumentation & Control, Reference [8], as the C&I system design is developed.

Monitoring, Inspection, Testing & Maintenance

The design life of the RR SMR is intended to be 60 years, with replacement of the ACMS [PE] parts, such as pumps, likely within that period. The design life will be dependent on supplier, noting online performance monitoring and conditioning is expected to be used to prolong the life of equipment where possible.

Maintenance of the ACMS [PE] components will be planned to align with the SMR refuelling cycles where possible. An outline maintenance plan for the ACMS [PE] is still to be developed.

Radiological Aspects

No significant radiological aspects associated with the ACMS [PE] operation have been identified during design decisions up to PCD.

Performance and Safety Evaluation

Verification activities to substantiate safety categorised functional requirements and non-functional system requirements for ACMS [PE] are still to be determined.

Installation & Commissioning

An outline installation and commissioning plan for the ACMS [PE] is still to be developed. The overall strategy for the RR SMR commissioning programme is presented in E3S Case Chapter 14: Plant Construction & Commissioning, Reference [9].

ALARP in Design Development

The design of the ACMS [PE] has been developed in accordance with the systems engineering design process, which includes alignment to RGP & OPEX, design to codes and standards according to the safety classification, and a systematic optioneering process with down-selection of design options based on assessment against relevant safety criteria (as described in PSCR Chapter 3: E3S Objectives & Design Rules, Reference [7]).

Key ACMS [PE] design decisions made with respect to ensuring overall risks are reduced to ALARP include:

1. ACMS [PE] architecture has been developed with one train, however the filtration structure and ACMS pumphouse utilises two independent flow channels within them, with each significant piece of equipment (trash rack, submerged filter, pump) having a standby unit. Each standby unit can deliver 100% of the make-up flow, which can be brought online with minimal loss of supply to the interfacing systems. This redundancy arrangement will increase the availability of the system, which in turn will increase the reliability of the plant and reduce the amount of plant trips, therefore have a lower reliance on safety systems.

More detailed information on design decisions is presented in the ACMS System Description, Reference [18], and associated design decision files.

Ongoing Design Development

The RR SMR design definition is currently in development as described in Section 9A.0. Key design opportunities and decisions related to safety are currently being explored, these include:

1. A decision to determine the required architecture to cool the Turbine Island Component Cooling System, considering reliability of the cooling function of the Turbine components

2. A decision to determine the filter system architecture. This decision will determine the preferred filter technology, validating the decision from PCD, and the preferred system architecture, considering attributes such as system reliability, build certainty and environmental performance

3. A decision to determine the make-up pump architecture. This decision will determine the preferred pump technology and the preferred make-up architecture considering system reliability and build certainty

4. A decision to determine the pipe material. This will consider the payoffs and trade-offs of differing material selections for raw water conveyance

5. A decision to define the intake, outfall, and offshore structures. This includes consideration of marine fauna protection, surge capacity, and fine sand tolerance of the intake structures as well as a diffuser concept to ensure environmental protection

All design development risks and opportunities are captured and managed by design teams.

9A.3 Process Auxiliary Systems

Section placeholder – to be populated in future revisions of the E3S Case

9A.4 Air & Gas Systems

Section placeholder – to be populated in future revisions of the E3S Case

9A.5 Heating, Ventilation and Air-Conditioning Systems

Section placeholder – to be populated in future revisions of the E3S Case

9A.6 Fire Protection Systems

Section placeholder – to be populated in future revisions of the E3S Case

9A.7 Supporting Systems for Generators

Section placeholder – to be populated in future revisions of the E3S Case

9A.8 Overhead Lifting Equipment

Section placeholder – to be populated in future revisions of the E3S Case

9A.9 Miscellaneous Auxiliary Systems

Section placeholder – to be populated in future revisions of the E3S Case

9A.10 Conclusions

9A.10.1 Conclusions

Preliminary evidence is presented to support the overall claim that 'RR SMR Auxiliary Systems are designed and substantiated to achieve functional and non-functional safety requirements through the lifecycle, and reduce risks to ALARP', which contributes to the overall E3S objective to protect people and the environment from harm, and the demonstration that risks are reduced ALARP.

For each SSC presented in this revision, the design definition presented describes how the SSC is being developed to meet its requirements and reduce risks to ALARP, based on its maturity at the PCD design stage. SSCs excluded from this revision based on limited maturity, as listed in Appendix B, will be incorporated as their design is matured.

The full suite of evidence to underpin the claim will be developed in line with the CAE Route Map and reported in future revisions of the E3S Case, including full traceability of safety categorised requirements from the safety analysis, a complete set of non-functional system requirements from the E3S design principles, further development of the SSC concept design to meet safety requirements, and ultimately substantiation of safety requirements.

9A.10.2 Assumptions & Commitments on Future Dutyholder/Licensee

None identified at this revision.

9A.11 References

[1] RR SMR Report, SMR0004294/001, "E3S Case Chapter 1: Introduction," March 2023.
[2] RR SMR Report, SMR0004363/001, "E3S Case Chapter 23: Structural Integrity," March 2023.
[3] RR SMR Report, SMR0002155/001, "E3S Case Route Map," March 2023.
[4] RR SMR Report, SMR0003023/001, "Reactor Codes and Standards," October 2022.
[5] RR SMR Report, SMR0003977/001, "E3S Case Chapter 15: Safety Analysis," March 2023.
[6] RR SMR Report, SMR0000531/001, "Deterministic Safety Case - Methodologies," October 2022.
[7] RR SMR Report, SMR0004589/001, "E3S Case Chapter 3: E3S Objectives & Design Rules," March 2023.
[8] RR SMR Report, SMR0003929/001, "E3S Case Chapter 7: Instrumentation & Control," March 2023.
[9] RR SMR Report, SMR0004289/001, "E3S Case Chapter 14: Plant Construction & Commissioning," March 2023.
[10] RR SMR Report, EDNS01000966408/001, "Decision 56 Fuel and Mechanical Handling Presentation," April 2021.
[11] RR SMR Report, SMR0000983/001, "System Outline Description for the Handling of Nuclear Equipment [F] System," June 2022.
[12] RR SMR Report, SMR0000469/001, "System Outline Description for the Fuel Pool Cooling System [FAK]," April 2022.
[13] RR SMR Report, SMR0000574, "System Outline Description for the Fuel Pool Purification System [FAL]," April 2022.
[14] RR SMR Report, SMR0000578/001, "System Outline Description for the Fuel Pool Supply System [FAT]," May 2022.
[15] RR SMR Report, EDNS01000928939/001, "System Outline Description for the Main Cooling Water System [PA]," April 2021.
[16] RR SMR Report, SMR0000658/001, "System Description for the Component Cooling System [KAA]," June 2022.
[17] RR SMR Report, EDNS01000928937/001, "System Outline Description for the Essential Service Water System [PB]," April 2021.
[18] RR SMR Report, EDNS01000928938/001, "System Outline Description for the Auxiliary Cooling and Make-Up System [PE]," April 2021.

9A.12 Appendix A: CAE Route Map

9A.12.1 Chapter 9A Route Map

A preliminary Claims decomposition from the overall Chapter 9A Claim is summarised in Table 8, including the Tier 2 Evidence underpinning the Claims at PCD (i.e., summarised in Revision 1 of this report) and further Tier 2 Evidence still to be developed.

Table 8: CAE Route Map

Level 1 Claims	**Level 2 Claims**	**Level 3 Claims**	**Arguments**	**Evidence Summary within Chapter 9A**	**Underpinning Tier 2 Evidence** ***at PCD**	**Underpinning Tier 2 Evidence** ***to be developed**
Safety Categorised Functional Requirements & Non-Functional System Requirements are derived and justified based on sound safety principles and methods	-	-	A comprehensive set of functional requirements are derived in the safety analysis (Fault Schedule), placed on SSCs based on functions to be delivered during Plant States DBC-1 to DBC-5	Section 9A.0	FAA-R New Fuel Receipt & Inspection DOORS Module	Revised DOORS Requirements Modules for each SSC
				Section 9A.1.2	FAB-R Storage of Spent/Irradiated Fuel Assemblies and Other Radioactive Parts System DOORS Module	

Level 1 Claims	Level 2 Claims	Level 3 Claims	Arguments	Evidence Summary within Chapter 9A	Underpinning Tier 2 Evidence ***at PCD**	Underpinning Tier 2 Evidence ***to be developed**
			Non-functional requirements are derived from the E3S principles and applied to the architecture of SSCs in accordance with their classification	Section 9A.1.3	FAK-R FPCS DOORS Module FAL-R FPPS DOORS Module FAT-R FPSS DOORS Module	
				Section 9A.1.4	FCL-R Fuel Transfer Channel DOORS Module	
				Section 9A.1.5	FAE-R Refuelling Cavity DOORS Module FAF-R Refuelling Pool DOORS Module	
				Section 9A.2.2	KAA-R CCS DOORS Module	
				Section 9A.2.3	PB-R ESWS DOORS Module	

Level 1 Claims	Level 2 Claims	Level 3 Claims	Arguments	Evidence Summary within Chapter 9A	Underpinning Tier 2 Evidence ***at PCD**	Underpinning Tier 2 Evidence ***to be developed**
				Section 9A.2.4	PE-R ACMS DOORS Module	
Architecture is designed to achieve safety requirements, considering RGP & OPEX to reduce risks to ALARP	-	-	The preferred design solution has been developed following a structured systems engineering approach with evaluation against safety criteria supporting the decision-making process	Section 9A.0 Section 9A.1.2 Section 9A.1.4 Section 9A.1.5	System Outline Description for the Handling of Nuclear Equipment [F] System, Reference [11]	Revised System Descriptions for each SSC
				Section 9A.1.3	System Descriptions: FPCS [FAK] Reference [12], FPPS [FAL] Reference [13] & FPSS [FAT] Reference [14]	
				Section 9A.2.1	MCWS [PA] System Description, Reference [15]	

Level 1 Claims	Level 2 Claims	Level 3 Claims	Arguments	Evidence Summary within Chapter 9A	Underpinning Tier 2 Evidence ***at PCD***	Underpinning Tier 2 Evidence ***to be developed***
				Section 9A.2.2	CCS [KAA] System Description, Reference [16]	
				Section 9A.2.3	ESWS [PB] System Description, Reference [17]	
				Section 9A.2.4	ACMS [PE] System Description, Reference [18]	
The design has been substantiated to achieve its safety requirements through the lifecycle	Safety requirements have been substantiated	-	Verification activities to demonstrate safety requirements can be achieved have been developed based on sound engineering judgement and methods	Section 9A.1.3	DOORS Verification Modules	Revised DOORS Verification Modules for each SSC

Level 1 Claims	**Level 2 Claims**	**Level 3 Claims**	**Arguments**	**Evidence Summary within Chapter 9A**	**Underpinning Tier 2 Evidence** ***at PCD**	**Underpinning Tier 2 Evidence** ***to be developed**
	Safety requirements have been verified through manufacturing, construction, installation, and commissioning	-	Processes and controls are designed to verify safety requirements during manufacturing, construction, installation, and commissioning	Not Applicable (n/a)	n/a	Installation and Commissioning Plans for each SSC (To Be Confirmed (TBC))
	Design can deliver its safety requirements during its operational life	-	The design identifies and facilitates Examination, Maintenance, Inspection, and Testing (EMIT) activities commensurate with its safety classification to demonstrate its status, availability, and integrity in line with the design intent	n/a	n/a	Maintenance Plans for each SSC (TBC)

9A.13 Appendix B: SSCs in Scope of Chapter 9A

Table 9 lists those SSCs that are within the scope of Chapter 9A, and the section of the report they are addressed.

Table 9: SSCs in Scope of PCSR

RDS-PP	SSC	Section in PCSR
F	Handling of Nuclear Equipment	Covered by [F__] Sections
FA	Internal Fuel Storage	Covered by [FA_] Sections
FAA	New Fuel Receipt & Inspection Area	Section 9A.1.1
FAB	Storage of Spent/Irradiated Fuel Assemblies and Other Radioactive Parts System [FAB]	Section 9A.1.2
FAE	Refuelling Cavity	Section 9A.1.5
FAF	Refuelling Pool	
FAK	Spent fuel cooling system	Section 9A.1.3
FAL	Spent fuel coolant purification system	
FAM	System for removal of surface contaminants on components in fuel assembly storage	
FAT	Coolant supply system	
FB	Handling of fuel assemblies and other reactor core internals	Covered by [FB_] Sections
FBC	Cleaning system for fuel assemblies (also includes reflector assemblies)	Section 9A.1.5
FCJ	System for conveyance of fuel assemblies/internals within reactor area	Not covered in this PCSR revision based on low design maturity
FCK	System for conveyance of fuel assemblies/internals between reactor and storage areas	Section 9A.1.4
FCL	System for conveyance of fuel assemblies/internals within storage area	Not covered in this PCSR revision based on low design maturity
FD	External storage of spent fuel	Section 9A.1.2
FDA	External wet storage of filled casks	

RDS-PP	SSC	Section in PCSR
FDB	External dry storage of filled casks	
KA	Nuclear auxiliary systems	Covered by [KA_] Sections
KAA	Reactor Component Cooling System	Section 9A.2.2
KHC	Heat tracing system for other systems	Not covered in this PCSR revision based on low design maturity
KJ	Nuclear chilled water systems	Not covered in this PCSR revision based on low design maturity
KJA	Low temperature system (below 0°C) for coolant handling	
KJL	Chilled water system for coolant treatment	
KL	Heating ventilation and air conditioning (HVAC) systems in controlled areas and exclusion areas	Not covered in this PCSR revision based on low design maturity
KLA	HVAC system in interior of reactor building	
KLB	HVAC system in annulus of reactor building	
KLC	HVAC system in controlled areas (Safeguard building)	
KLE	HVAC systems in reactor auxiliary building	
KLF	HVAC systems in processing building for radioactive waste	
KLL	HVAC systems in area of storage of fuel elements	
KU	Reactor Coolant Sampling system	Not covered in this PCSR revision based on low design maturity
KUA	Sampling system for active liquid media	
KUB	Sampling system for weak active liquid media	
KUF	Sampling system for gaseous media	
KUL	Fault sampling system from containment atmosphere	
PA	Main Cooling Water System	Section 9A.2.1
PAA	Main Cooling Water System Extraction System	

RDS-PP	SSC	Section in PCSR
PAB	Main Cooling Water System Piping System	
PAC	Main Cooling Water System Pump System	
PAD	Main Cooling Water System Cooling Tower System	
PAH	Turbine Condenser Cleaning System	
PB	Essential Service Water System	Section 9A.2.3
PBD	Essential Service Water System Cooling Tower System	
PBR	Essential Service Water System Make-up Water System	
PBS	Essential Service Water System Blowdown System	
PE	Auxiliary Cooling and Make-up System	Section 9A.2.4
PEA	Auxiliary Cooling and Make-up System Intake and Filtration System	
PEB	Piping and culvert system	
PEC	Auxiliary Cooling and Make-up System Pump System	
PER	Auxiliary Cooling and Make-up System Make-up Water System	
PES	Auxiliary Cooling and Make-up System Blowdown System	
PG	Turbine Island Closed Cooling Water System	Not covered in this PCSR revision based on low design maturity
PGA	Extraction (including mechanical cleaning and retention of debris)	
PGB	Piping and culvert system	
PGC	Conveying system	
PGD	Intercooling system including drainage, venting auxiliary and intercooling water-sided	
PGE	Pressurizing system including drainage and venting	

RDS-PP	SSC	Section in PCSR
PGH	Cleaning system for heat exchanger of the auxiliary and secondary process	
PGR	Make-up water system	
PGS	Blowdown system	
PGV	Lubricant system	
PGX	Fluid supply system for control and protection systems	
PU	Common systems for the cooling water systems	
G	Water supply disposal and treatment system	Not covered in this PCSR revision based on low design maturity
GA	Water supply System	
GAF	Water supply storage system	
XBF	Space heating system in structures for handling of nuclear equipment	Not covered in this PCSR revision based on low design maturity
XBJ	Space heating system in structures for nuclear heat generation	
XBK	Space heating system in structures for nuclear auxiliary systems	
XG	Fire extinguishing system	Not covered in this PCSR revision based on low design maturity
XGA	Fire water system	
XGB	Fire water system in nuclear controlled and exclusion area	
XGC	Spray deluge system	
XGD	Spray deluge system in nuclear controlled and exclusion area	
XGE	Sprinkler system	
XGF	Foam extinguishing system	
XGH	Gas extinguishing system	
XGJ	Carbon dioxide fire extinguishing system	
XGK	Inert gas fire extinguishing system	

RDS-PP	SSC	Section in PCSR
XGL	Powder extinguishing system	
XGM	Fire extinguishing system with other extinguishing agent	
XK	Chilled water system	Not covered in this PCSR revision based on low design maturity
XKT	Chilled water system in structures for main turbine generator system	
XKA	Central chilled water generation	
XKB	Central chilled water conveyance and distribution	
XM	Mechanical Handling System	Not covered in this PCSR revision based on low design maturity
XMA	Mobile system	
XMB	Mechanical Handling in structures for electrical auxiliary power supply	
XMC	Mechanical Handling in structures for control and management systems	
XMF	Mechanical Handling in structures for handling of nuclear equipment	
XMJ	Mechanical Handling in structures for nuclear heat generation	
XMK	Mechanical Handling in structures for nuclear auxiliary systems	
XML	Mechanical Handling in structures for steam- water-condensate systems	
XMM	Mechanical Handling in structures for main turbine generator system	
XMN	Mechanical Handling in structures for medium supply systems for external consumers, energy storage systems	
XMP	Mechanical Handling structures for cooling water systems	
XV	Rainwater systems	Not covered in this PCSR revision based on low design maturity
XVA	Systems for rainwater	

RDS-PP	SSC	Section in PCSR
XVB	Systems for rainwater	

9A.14 Acronyms and Abbreviations

1oo'X'	One out of 'X'
ACMS	Auxiliary Cooling and Make-up system
ACoP	Approved Code of Practice
ALARP	As Low As Reasonably Practicable
ASME	American Society of Mechanical Engineers
BAT	Best Available Techniques
BS	British Standard
CAE	Claims Arguments and Evidence
CCS	Component Cooling System
CoFT	Control of Fuel Temperature
CoR	Control of Reactivity
CoRM	Confinement of Radioactive Material
CPS	Coolant Purification System
CSCS	Cold Shutdown Coolant System
CWS	Chilled Water System
E3S	Environment, Safety, Security and Safeguards
EMIT	Examination, Maintenance, Inspection and Testing
ESWS	Essential Service Water System
FHM	Fuel Handling Machine
FPCS	Fuel Pool Cooling System
FPPS	Fuel Pool Purification System
FPSS	Fuel Pool Supply System
FSF	Fundamental Safety Function
FTC	Fuel Transport Container
GER	Generic Environment Report
GSR	Generic Safety Report

HLSF	High-Level Safety Function
HR	High Reliability
HVAC	Heating, Ventilation, and Air Conditioning
ICI	In-Core Instrumentation
IHP	Integrated Head Package
IXC	Ion Exchange Column
LOLER	Lifting Operations and Lifting Equipment Regulations 1998
LOOP	Loss of Offsite Power
MCWS	Main Cooling Water System
n/a	Not Applicable
OPEX	Operational Experience
P&ID	Piping & Instrumentation Diagram
PCD	Preliminary Concept Definition
PCSR	Pre-Construction Safety Report
PIE	Postulated Initiating Event
PWR	Pressurised Water Reactor
RCP	Reactor Coolant Pump
RD	Reference Design
RDS-PP	Reference Designation System for Power Plants
REPPIR	Radiation (Emergency Preparedness and Public Information) Regulations 2019
RGP	Relevant Good Practice
RPV	Reactor Pressure Vessel
RR	Rolls-Royce
RWST	Refuelling Water Storage Tank
SFP	Spent Fuel Pool
SIL	Safety Integrity Level
SSC	System, Structure and Component

SMR	Small Modular Reactor
TBC	To Be Confirmed
UHS	Ultimate Heat Sink
VHR	Very High Reliability
WCCT	Wet Closed Cooling Tower