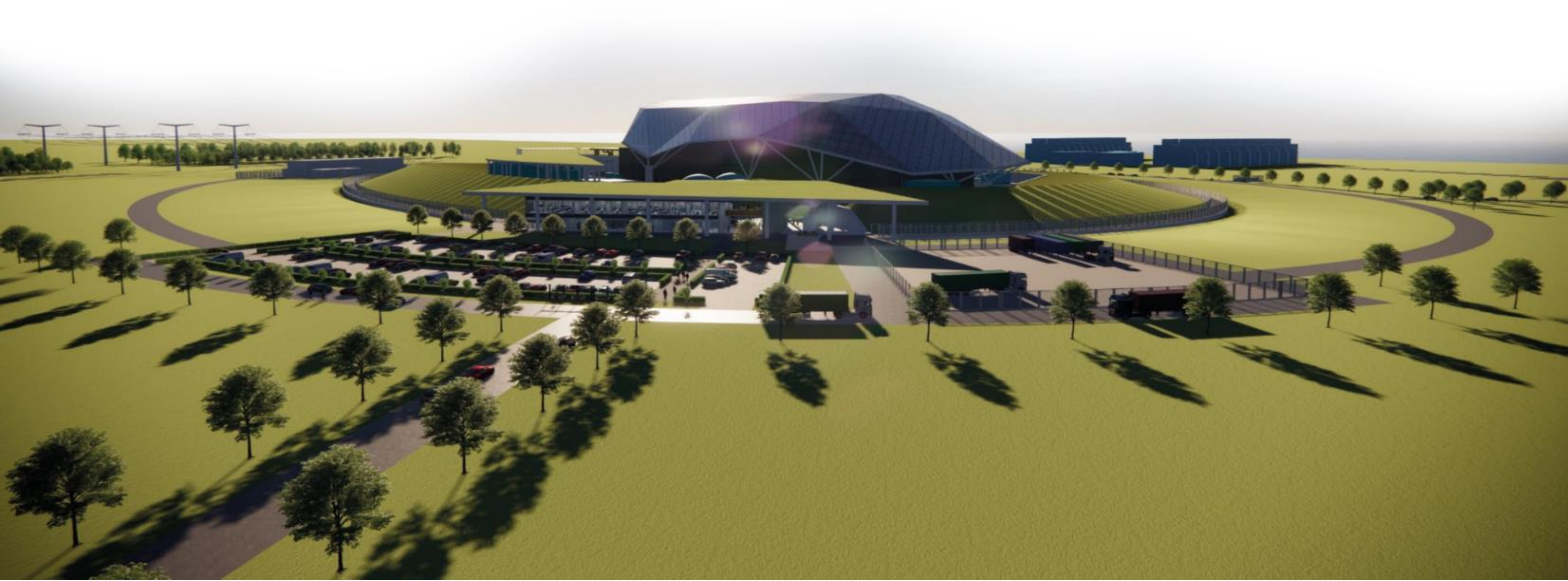
Environment, Safety, Security and Safeguards Case Version 2, Tier 1,

Chapter 9A: Auxiliary Systems



Record of Change

Date	Revision Number	Status	Reason for Change
March 2023	1	Issue	First issue of E3S Case
February 2024	2	Issue	Incorporates revisions and new design developments of the Auxiliary Systems based on Reference Design 7, aligned to Design Reference Point 1, including: • Additional designs details and developments on systems included in the first issue • Functions and description of Water, Heating Ventilation and Air Conditioning, Fire Extinguishing and Overhead Lifting Equipment systems.
May 2024	3	Issue	Updated to correct revision history status at Issue 2. Chapter changes include: • Additional detail about the Fuel Handling System Verification Strategy (section 1.9A.1.1.11) • Additional detail of the Spent Fuel Pooling Boiling [FA01] safety measure (section 1.9A.1.2.1) • Additional detail within the conclusions for how arguments and evidence presented meet the generic E3S objective Also minor template/editorial updates for overall E3S Case consistency.

Executive Summary

Chapter 9A of the generic 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 evidence to underpin the high-level claim that the RR SMR Auxiliary Systems are conservatively designed and verified to deliver E3S functions through-life, in accordance with the E3S design principles, to reduce risks to as low as reasonably practicable (ALARP), apply best available techniques (BAT) and ensure secure by design and safeguards by design.

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, heating ventilation and air conditioning system, fire extinguishing system and overhead lifting equipment and their sub-systems, all these systems are similar to those already used in existing pressurised water reactors. Structures, Systems, Components (SSCs) excluded from this revision based on limited maturity will be incorporated as their design is matured.

For each system, the safety functions to be delivered by each SSC are presented, with the assignment of safety categorised functional requirements to achieve them. The design definition presented for each system is developed based on relevant good practice (RGP) and operating experience (OPEX). It is developed and evaluated in accordance with the E3S design principles through the integrated E3S and engineering processes, including design to codes and standards according to the safety classification, down-selection of options in accordance with criteria to ensure risks are reduced to ALARP, apply BAT, and are secure by design and safeguards by design, and confirmatory performance analysis. This provides confidence that claims can be met when the full suite of arguments and evidence is developed. No functional requirements for environment, security and safeguards are identified for the SSCs within Turbine Island [T01].

Version 2 of the generic E3S Case is developed in support of the reference design 7 (RD7) design, corresponding to design reference point 1 (DRP1) for the generic design assessment (GDA). Further arguments and evidence are to be developed to underpin the top-level claim, including development of a complete set of E3S requirements and their associated verification and validation activities, and continued design development in conjunction with vendors.

Contents

Tables

9A.0 Introduction to Chapter

9A.0.1 Introduction

Chapter 9A of the Rolls-Royce Small Modular Reactor (RR SMR) generic Environment, Safety, Security and Safeguards (E3S) Case presents the overarching summary and entry point to the design and E3S information for the Auxiliary Systems of the RR SMR.

9A.0.2 Scope and Maturity

The list of structures, systems, and components (SSCs) that are included in the scope of this chapter is provided in Appendix B (section 9A.13).

Version 2 of the generic E3S Case is based on reference design 7 (RD7), corresponding to design reference point 1 (DRP1) for the generic design assessment (GDA). At RD7/DRP1, the safety functions to be delivered by each SSC are presented, with the assignment of safety categorised functional requirements to achieve them. No functional requirements for environment, security and safeguards are identified for SSCs in the scope of chapter 10 at DRP1/RD7, noting SSCs are designed in accordance with E3S and engineering processes that include development against principles for environment, security, and safeguards. The design definition presented is based on the design maturity of each respective SSC at RD7/DRP1. Verification and validation activities for some SSCs within this chapter are still to be established through detailed design and as part of future vendor engagement.

The scope of this chapter covers the mechanical aspects of auxiliary systems, with the selection of materials and justification of the integrity SSCs covered in E3S Case Tier 1 Chapter 23: Structural Integrity [1].

9A.0.3 Claims, Arguments, Evidence Route Map

The overall approach to claims, arguments, evidence (CAE) and the set of fundamental E3S claims to achieve the E3S fundamental objective are described in E3S Case Version 2, Tier 1, Chapter 1: Introduction [2].The associated top-level claim for E3S Case Version 2, Tier 1, Chapter 9A: Auxiliary Systems is:

Claim 9A: Auxiliary Systems are conservatively designed and verified to deliver E3S functions through-life, in accordance with the E3S design principles, to reduce risks to ALARP, apply BAT and in line with Secure-by-Design and Safeguards-by-Design

A decomposition of this claim into sub-claims and mapping to the relevant Tier 2 and Tier 3 information containing the detailed arguments and evidence, is presented in the E3S Case Route Map [3]. Given the evolving nature of the E3S Case alongside the maturing design, the underpinning arguments and evidence may still be developed in detailed design; the trajectory of this information, where possible, is also illustrated in the route map.

A proportionate summary of the arguments and evidence from lower tier information, available at the current design stage, is presented within this chapter. A mapping of the claims to the corresponding sections that summarise the arguments and/or evidence is provided in Appendix A (section 9A.12).

9A.0.4 Applicable Regulations, Codes and Standards

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

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

Safety Classification	Design Basis Code
VHR	American Society of Mechanical Engineers (ASME) III (Sub-section NB) and beyond code requirements
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:

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

The selection of appropriate standards will be refined, finalised and presented in Version 3 of the E3S Case.

9A.1 Handling of Nuclear Equipment System

9A.1.1 Handling of Nuclear Equipment System

9A.1.1.1 System and Equipment Functions

The Handling of Nuclear Equipment [F] System covers the fuel route from receipt of fresh fuel through to transfer of spent nuclear fuel into dry cask storage and the handover to the Spent Fuel Store at the Reactor Island boundary. It supports achievement of the Fundamental Safety Functions (FSFs) of Control of Reactivity (CoR), Control of Fuel Temperature (CoFT), Confinement of Radioactive Material (CoRM) and Control of Radiation Exposure (CoRE) during normal operation and fault conditions.

Layout details for the Handling of Nuclear Equipment [F] system are presented in [5].

High-Level Safety Functions (HLSF) for The Handling of Nuclear Equipment [F] System, and the Postulated Initiating Events (PIEs) against which they are assigned, are being derived in the Fault Schedule, which is presented in E3S Case Version 2, Tier 1, Chapter 15: Safety Analysis [6].

9A.1.1.2 Design Bases

Functional Requirements

Safety categorised functional requirements for the Handling of Nuclear Equipment [F] System are specified based on the HLSFs they deliver, including the applicable plant states and operating modes, are presented in Table 9A.1-1 based on [7].

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

Requirement ID	Functional Requirement	Mode(s) of Operation	Safety Category
F-R-1266	The Handling of Nuclear Equipment [F] System shall ensure control of reactivity in all modes through life.	All	A
F-R-1270	The Handling of Nuclear Equipment [F] System shall ensure confinement of radioactive material in all modes through life.	All	A
F-R-1311	The Handling of Nuclear Equipment [F] System shall ensure removal of heat from the fuel in all modes through life.	All	A

The Handling of Nuclear Equipment [F] System provides the FSFs of CoFT, CoR, and CoRM.

The safety categorised functional requirements for The Handling of Nuclear Equipment [F] System flow down and are allocated to relevant sub-systems and/or components. Non-functional performance requirements associated with the safety categorised functional requirements are allocated in [7].

Non-Functional System Requirements

Non-functional system requirements are still being developed and will be allocated to Common Systems for the Handling of Nuclear Equipment System [F] based on the E3S design principles as described in E3S Case Tier 1 Chapter 3: E3S Objectives and Design Rules for SSCs [8].

9A.1.1.3 E3S Classification

Safety Classification

The Handling of Nuclear Equipment [F] System is the principal means by which the Category A functions to ensure confinement of radioactive material, ensure removal of heat from the fuel, and ensure control of reactivity are achieved; the highest classification of components that support these functions within the system is Class 1.

Environment, Security and Safeguards Classification

No environment, security, or safeguards classification is assigned at RD7/DRP1.

Seismic Classification

The Handling of Nuclear Equipment [F] System is to be classified in accordance with the RR SMR Seismic Performance Classification Method [9].

9A.1.1.4 Description

The Handling of Nuclear Equipment [F] System covers the fuel route from receipt of fresh fuel through to transfer of spent nuclear fuel into dry cask storage and the handover to the Spent Fuel Store at the Reactor Island boundary. Detailed sub-system descriptions are presented in subsequent sub-system sections within this chapter.

9A.1.1.5 Materials

The description the materials selection process used for Class 1 SSCs is presented in E3S Case Version 2, Tier 1, Chapter 23: Structural Integrity [1]. Materials will be confirmed in future versions of the generic E3S Case.

9A.1.1.6 Interfaces with Supporting Systems

The Handling of Nuclear Equipment System [F] interfaces with the following systems, as identified in [7]:

- Reactor Plant Systems [J]
- Nuclear Auxiliary Systems [K]
- Waste Supply, Disposal Treatment System [G]
- Auxiliary Systems [Q]
- Storage System [V]
- Ancillary System [X]

9A.1.1.7 System and Equipment Operation

The overarching operational principles for the Reactor Island are covered in the Reactor Plant Operating Philosophy [10].

A full analysis of the sub-system operation in all modes of operation will be conducted in future design phases, with updates provided for DRP2 and DRP3, to develop the Handling of Nuclear Equipment [F] System operating principles. The principles will eventually identify the operational actions, define the key claims and operational sequences and actions the system is required to undertake, and key claims made on the operator or automated actions. The principles will also support ongoing Human Factors and safety assessments.

More details on operating principles can be found in the sub-system descriptions presented later in this section.

The operation of the Handling of Nuclear Equipment [F] system during the six operating modes is described in [5].

Faults

RR SMR faults have primarily been identified through Hazard Identification (HAZID) and Hazard and Operability study (HAZOP) studies. HAZIDs are not provided at the Handling of Nuclear Equipment [F] System level, as the detail is provided in lower levels. HAZIDs and HAZOPs are described in the level 4 System Outline Description (SOD)s [11], [12], [13], [14], [15], [16] and [17]. Further details are presented in [5].

9A.1.1.8 Instrumentation and Control

The Fuel Route C&I System [FY] will carry out the process measurement, monitoring and control of the [F] System plant. This shall be achieved through several Programmable Electronic Systems (PES) which are likely to be Programable Logic Controller (PLC) based.

The fuel route control system is expected to carry out the following functions:

- Control and monitoring of the [F] System plant
- Protection and interlocking of the [F] System plant
- Provision of a HMI (Human Machine Interface)
- Provision of warnings, alarms and diagnostic data
- Provision of a fuel tracking system via [FYS40]
- Condition monitoring of the [F] System plant

Further details are presented in [5] and [18].

9A.1.1.9 Monitoring, Inspection, Testing & Maintenance

The design life of the RR SMR is intended to be 60 years, though some components of the Handling of Nuclear Equipment system [F] will need to be replaced within that period.

The Examination, Maintenance, Inspection and Testing (EMIT) activities for the Handling of Nuclear Equipment system [F] are defined as through-life activities (TLA) within the RR SMR requirements management database, and cover safety derived tasks (in-service inspection (ISI)), reliability derived tasks (reliability centred maintenance (RCM)/preventative maintenance), and industry best practice/operational experience (OPEX) (Electrical Power Research Institute (EPRI) Preventative Maintenance Basis Database (PMBD)).

9A.1.1.10 Radiological Aspects

Radiological protection requirements are applied through the design process and analysis of these will be carried out in line with the maturity of the design.

Radiological consequences for fault sequences are described further in E3S Case Version 2, Tier 1, Chapter 15: Safety Analysis [6].

9A.1.1.11 Performance and Safety Evaluation

Compliance with Safety Categorised Functional Requirements

Initial verification strategies for the Handling of Nuclear Equipment system [F] to demonstrate compliance with its safety categorised functional requirements and associated non-functional performance requirements primarily include hand calculation. 4-D Computer Aided Design (CAD) analysis is being used for outage periods. Safety functions will have standard analysis as described in [F] Verification Strategy [19].

Compliance with Non-Functional System Requirements

A summary of the compliance for non-functional system requirements allocated to the Handling of Nuclear Equipment system [F] are summarised in Table 9A.1-2. Further details are provided in [7] and [5].

Table 9A.1-2: [F] Non-Functional System Requirements Compliance

Requirement ID	Non-Functional System Requirement	Summary of Compliance
F-R-1496	SMR systems that contain radioactive material shall be designed to prevent spread of that radioactive material beyond their boundary	Passive means of decay heat removal and control of fuel temperature are provided for use during loss of active cooling faults within pool storage. Spent fuel assemblies are moved to passively cooled dry storage casks as soon as reasonably practicable to reduce the stored pool inventory.

9A.1.1.12 ALARP, BAT, Secure by Design and Safeguards by Design

Key Handling of Nuclear Equipment system [F] design decisions made with respect to ensuring overall risks are reduced to ALARP, BAT, secure by design and safeguards by design include:

- Reactivity control is provided by geometrical spacing and fixed neutron absorbers in the Spent Fuel Pool storage rack. The storage racks are unzoned and designed to be subcritical on the basis of the most reactive assembly, such that any assembly may be placed within any storage location without procedural controls on placement. Control rods are co-stored in some assemblies and provide additional control but are not required for sub-criticality. Fuel assemblies are moved one at a time to maintain geometrical spacing. Details of criticality assessments are provided in [11].

- The Handling of Nuclear Equipment [F] System is required to permit construction, commissioning, operation, maintenance, and decommissioning with the amount of radioactive waste created and disposed of minimised using best available techniques, and in any event within internationally accepted limits.

- The Handling of Nuclear Equipment [F] System design is required to ensure 'security by design' whereby vulnerabilities are eliminated or reduced by design rather than secured or mitigated with measures. Inherent security should be achieved through application of the hierarchy of controls notably the layers towards the top where sources of radioactive material and safety system vulnerabilities to threats are eliminated or designed to be inherently inaccessible or otherwise rugged.

- Safeguards have been considered in the design of the Handling of Nuclear Equipment [F] System so far, especially for the New Fuel Receipt and Inspection Area [FAA] and External dry storage of filled casks [FDB] System. Refuelling activities and the Spent Fuel Pool have not been subjected to explicit safeguards assessment yet and this is identified as future work, although safeguards input has been provided for these operations.

9A.1.2 Internal Fuel Storage [FA]

The Internal Fuel Storage [FA] System represents the entire fuel storage system within reactor island for new fuel, spent fuel and other nuclear equipment.

9A.1.2.1 Spent Fuel Pool Boiling [FA01]

Following a fault leading to loss of active spent fuel pool cooling, the function of Spent Fuel Pool Boiling [FA01] is to remove decay heat from fuel pools storing spent fuel within the Spent Fuel Pool and Cask Loading [FAB] system. Spent Fuel Pool Boiling [FA01] defines the plant response and claimed Class 1 SSCs to mitigate PIEs for the RR SMR, that are recorded in the plant Fault Schedule [20]. In mitigating these PIEs, [FA01] must ensure plant acceptance criteria and E3S design principles [21] are upheld. The safety measure is claimed following the failure of duty (Category C) and first protective (Category B) cooling functions.

This is fulfilled by heat up and boil-off of the existing spent fuel pool coolant inventory for at least 72 hours following a fault leading to loss of active spent fuel pool cooling. Spent Fuel Pool Boiling [FA01] provides the Category A function for control of fuel temperature within the Spent Fuel Pool and Cask Loading [FAB] system during refuelling activities and powered operations.

Passive fuel pool boiling and make-up via the Local Ultimate Heat Sink follows RGP and is currently used at an existing UK PWR.

The duty fuel pool cooling system [FAK] is a class 2 active system comprising two independent trains each sized for delivering the fuel pool cooling function, this is based on RGP to deliver a reliability that reduces demand on the FA01 safety measure during a loss of fuel pool cooling. Further diverse measures to reduce demand on the SFP boiling function following loss cooling to the SFP will be considered as the Fault Schedule [20] is further developed.

Radiological releases will be mitigated through filtered venting.

9A.1.3 The New Fuel Receipt and Inspection Area [FAA]

9A.1.3.1 System and Equipment Functions

The New Fuel Receipt and Inspection (NFR&I) Area [FAA] is a section of the fuelling building used for the receipt, unpacking, inspection and temporary storage of new fuel before it is moved into the Spent Fuel Pool [FAB10]. The [FAA] System is also used to re-package and dispatch any new fuel that is required to be returned to its vendor for any reason.

Further system and layout details for the [FAA] system are presented in [5].

HLSFs for the [FAA] system, and the PIEs against which they are assigned, are being derived in the Fault Schedule, which is presented in E3S Case Version 2, Tier 1, Chapter 15: Safety Analysis [6].

9A.1.3.2 Design Bases

Functional Requirements

Safety categorised functional requirements for the [FAA] system are specified based on the HLSFs they deliver, including the applicable plant states and operating modes, are presented in Table 9A.1-3 based on [22].

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

Requirement ID	Functional Requirement	Mode(s) of Operation	Safety Category
FAA-R-1448	The New Fuel Receipt and Inspection Area (FAA) shall control reactivity of new fuel	All	A
FAA-R-1451	While in all modes of operation, the FAA system shall ensure confinement of radioactive material	All	B

The New Fuel Receipt and Inspection Area [FAA] provides CoR, CoRM from FSFs.

The safety categorised functional requirements [FAA] are flowed down and allocated to relevant sub-systems and/or components. Non-functional performance requirements associated with the safety categorised functional requirements are allocated in [22].

Non-Functional System Requirements

Non-functional system requirements are still being developed and will be allocated to Common Systems for the New Fuel Receipt and Inspection Area [FAA] based on the E3S design principles as described in E3S Case Version 2, Tier 1, Chapter 3: E3S Objectives and Design Rules for SSCs [8].

9A.1.3.3 E3S Classification

E3S classification for the [FAA] system is under development and aligns with that described in Version 3 of the generic E3S Case.

9A.1.3.4 Description

The [FAA] system will be able to accommodate the various new fuel shipping containers currently in use in similar power stations around the world.

For each refuelling outage up to 45 new fuel assemblies are required for loading into the core. To minimise the refuelling outage duration these new fuel assemblies are stored in the Spent Fuel Pool before the refuelling outage commences.

The [FAA] System is responsible for the unloading of the new-fuel shipping containers from their delivery vehicle; transferring them into the refuelling building (if unloading is not performed in the refuelling building, work is ongoing regarding this decision), and the management of the containers while they are in the refuelling building. Suitable handling equipment will be available within the [FAA] System for these tasks.

Depending on container type, either the lid is removed and the fuel assembly rotated to vertical, or the container is rotated to vertical and then opened to be able to remove the fuel assembly. Once removed from the container, the fuel assembly is moved to a suitable location for inspection.

Inspection of fuel assemblies is undertaken visually to confirm that no damage has occurred during transport, and no foreign material or other unacceptable conditions are present. Inspection is required before the fuel assembly is acceptable for use in the reactor. Inspections are performed before the fuel assembly is transferred to the spent fuel pit to allow for easier return of the fuel assembly to its vendor if needed.

If the fuel assembly upon inspection is found to be acceptable, it will be moved directly to the new fuel elevator for transfer into the Spent Fuel Pool. If the fuel assembly has inspection findings requiring resolution, it will be moved into a storage position.

It is proposed that the new fuel storage positions may also be used for any assembly tasks, such as inserting control rods or thimble plug assemblies into the fuel assemblies, should these tasks be required. 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.

9A.1.3.5 ALARP, BAT, Secure by Design and Safeguards by Design

The design of systems performing fuel storage and handling will be undertaken with cognisance and in accordance with ONR Security Assessment Principles. Preliminary engagement and consideration of these principles has been carried out and will be subject to ongoing detailed assessments.

9A.1.4 Spent Fuel Storage and Cask Loading System [FAB]

9A.1.4.1 System and Equipment Functions

The Spent Fuel Storage and Cask Loading System [FAB] consists of a freestanding pool structure divided into three regions:

- Spent Fuel Pool (SFP) [FAB10]
- Cask Loading Pit (CLP) [FAB20]
- Upender Pit (UP) [FAB40]

Each region is capable of storing coolant and can be hydraulically connected or isolated from the adjacent region using a series of watertight gates. The Upender pit may also be hydraulically connected or isolated from the refuelling pool within containment during outage. It supports achievement of the FSFs of CoR, CoFT, CoRM and CoRE during normal operation and fault conditions.

Layout details for the Spent Fuel Storage and Cask Loading System [FAB] are presented in [11].

HLSFs for the Spent Fuel Storage and Cask Loading System [FAB], and the PIEs against which they are assigned, are being derived in the Fault Schedule, which is presented in E3S Case Version 2, Tier 1, Chapter 15: Safety Analysis [6].

9A.1.4.2 Design Bases

Functional Requirements

Safety categorised functional requirements for the Spent Fuel Storage and Cask Loading System [FAB] are specified based on the HLSFs they deliver, including the applicable plant states and operating modes, are presented in Table 9A.1-4 based on [23], [24] and [25].

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

Requirement ID	Functional Requirement	Rational	Safety Category
FAB-R-1727	While in All modes of operation, the Spent Fuel Storage and Cask Loading [FAB] shall store coolant (shielding)	Coolant is used to provide suitable shielding above fuel	A
FAB-R-1728	While in All modes of operation, the Spent Fuel Storage and Cask Loading [FAB] shall store coolant (heat removal)	Cooling of fuel required during fuel movements to support CoFT	A
FAB-R-1736	While in All modes of operation, the Spent Fuel Storage and Cask Loading [FAB] shall ensure confinement of radioactive material	The FAB system provides a level of confinement of radioactive material and therefore supports the fulfilment of the "Contain and Confine Radioactive Material" Critical Safety Function	A
FAB-R-1738	While in All modes of operation, the Spent Fuel Storage and Cask Loading [FAB] shall maintain sub-criticality of fuel	The FAB system is the primary means of fulfilling the Control of Reactivity critical safety function during fuel storage	A
FAB-R-1729	While in All modes of operation, the Spent Fuel Storage and Cask Loading [FAB] shall Sense coolant level (shielding)	In order to manage the inventory of the pool, the water level is used to control the feed and drain flows to achieve the target water level in order to ensure complete submersion of fuel	B
FAB-R-1749	While in All modes of operation, the Spent Fuel Storage and Cask Loading [FAB] shall sense coolant level (heat removal)	In order to manage the inventory of the pool, the water level is used to control the feed and drain flows to achieve the target water level in order to ensure complete submersion of fuel	B

The Spent Fuel Storage and Cask Loading System [FAB] provides CoFT, CoR and CoRM from FSFs, and is designed to withstand a beyond design basis load without catastrophic failure.

The safety categorised functional requirements for the Spent Fuel Storage and Cask Loading System [FAB] are flowed down and allocated to relevant sub-systems and/or components. Non-functional performance requirements associated with the safety categorised functional requirements are allocated in [23], [24] and [25].

Non-Functional System Requirements

Non-functional system requirements are being developed and will be allocated to the Spent Fuel Storage and Cask Loading System [FAB] based on the E3S design principles as described in E3S Case Version 2, Tier 1, Chapter 3: E3S Objectives and Design Rules for SSCs [8].

9A.1.4.3 E3S Classification

Safety Classification

The Spent Fuel Storage and Cask Loading System [FAB] has been classified as Safety Class 1 as it provides the principal means of fulfilling Category A safety functions to support Control of Fuel Temperature and Control of Reactivity. For Control of Fuel Temperature, the system ensures irradiated fuel remains submerged in coolant and retains sufficient inventory to permit a minimum period of 24 hours (Mode 6) and 72 hours (Modes 1-5) of passive boil-off before the uncovering of fuel, under a loss of cooling event. For CoR, sub-criticality is maintained by the system through a combination of geometric constraint and fixed neutron absorbers in the Fuel Storage Racks.

As discussed in [11], in addition to the pool structure, other components within the system such as Fuel Gates may also be Safety Class 1 if there is a credible failure that could compromise the Spent Fuel Pool Boil Off [FA01] function. It is currently assumed that UP Fuel Gates and CLP Cask Gates are Safety Class 1, as their failure could result in a loss of inventory such that there is reduced time from boil-off to uncovering of fuel. The Fuel Storage Rack is also Safety Class 1 as it is the principal means of ensuring sub-criticality of fuel within the system.

Environment, Security and Safeguards Classification

No environment, security, or safeguards classification is assigned at RD7/DRP1.

Seismic Classification

The Spent Fuel Storage and Cask Loading System [FAB] is to be classified in accordance with the RR SMR Seismic Performance Classification Method [9].

9A.1.4.4 Description

Spent Fuel Pool [FAB10]

The Spent Fuel Pool (SFP) is a permanently flooded structure containing Fuel Racks for the storage of spent fuel, partially spent fuel, new fuel, Rod Cluster Control Assemblies (RCCAs), Thimble Plug Assemblies and other irradiated components, throughout the lifetime of the plant. It also stores a minimum volume of coolant for the purposes of cooling and shielding of irradiated fuel. A wet laydown area and fuel maintenance zone is segregated from the rest of the SFP via an internal partial height wall.

The water level is such that it is level with the water level in the Refuelling Pool [FAF] and Refuelling Cavity [FAE], when all three systems are connected during refuel operations via the Fuel Transfer Channel. Considering the displaced volume of the SFP internal wall and a conservative assessment for the parasitic volume of fuel racks and stored items, the SFP has a total coolant inventory exceeding 1018 m^3, under normal operating conditions.

The Fuel Storage Zone accommodates Fuel Racks in a 26 x 20 array of storage cells, providing an overall capacity of 520 storage positions. The array is broken down into a smaller number of sub-assemblies to minimise the handling mass above spent fuel, should a situation arise where a rack needs to be removed or replaced through-life. The design of the racks is such that no controls are required on which type of fuel assembly can be placed within each storage cell.

During powered operation, a minimum of 121 fuel storage positions shall remain vacant, allowing an emergency full core offload to be performed at any time.

Fuel racks utilise a combination of geometric constraint and fixed neutron absorbers as a means of ensuring sub-criticality. A criticality assessment has been carried out [26] which demonstrates the fuel rack pitch of 280 mm in conjunction with boron carbide embedded in an aluminium alloy matrix, meets the criticality criterion of $k_{eff} < 0.95$ and $k_{eff} < 0.98$ for normal and fault conditions respectively.

The criticality safety case will employ the Double Contingency Approach (DCA) such that unintended criticality cannot occur unless at least two unlikely, independent, concurrent changes in the conditions originally specified as essential to criticality safety have occurred. For neutron absorbers, TLA and monitoring shall demonstrate that degradation of the performance beyond the conservative limits assumed in the criticality assessment is not credible. Additionally, fault studies shall identify any faults that could affect the geometric constraint of the fuel assemblies (e.g. crushing) with suitable substantiation provided for the fuel racks to demonstrate consequences are mitigated within acceptable margins (e.g. crush withstand).

The Fuel Maintenance Zone is a zone within the SFP that is used for wet laydown and locating of the following Handling of Nuclear Equipment [F] sub-systems / components:

- Testing system for fuel assemblies [FBA]
- New Fuel Elevator [FCL20]

The system architecture enables the mechanical transfer of equipment from the higher safety classification Fuel Handling Machine (FHM) [FCL10] to lower safety classification Overhead Crane, whilst preventing the Overhead Crane from being able to operate within the Fuel Storage Zone of the SFP.

The Fuel Maintenance Zone also reduces the risk of damaging fuel or uncovering stored fuel via a partial height dividing wall between the two zones of the SFP. Under normal operations, the wall is completely submerged and the two zones are hydraulically linked. However, under some fault conditions, the wall acts as a weir and ensures that a level of coolant is retained in the Fuel Storage Zone such that stored fuel remains covered.

Cask Loading Pit [FAB20]

The Cask Loading Pit (CLP) is used for the loading of fuel and Non-Fuel Core Components (NFCCs) into dry storage casks, for subsequent external storage in the External dry storage of filled casks [FDB] system. The CLP is also the location where cask preparatory operations and post-loading cask operations take place.

The CLP is normally fully drained but has a minimum operating water depth of 13.815 m [27] during cask loading operations.

The CLP can be hydraulically linked or isolated from the UP by a CLP Fuel Gate.

RR SMR design eliminates cask dropped load hazards by employing a ground-based conveyance system [FCL30] for the import and export of the cask to/from the CLP. To accommodate this function, the CLP features an aperture at ground-level that can be sealed using a set of watertight Cask Gates [11].

Upender Pit [FAB40]

The Upender Pit (UP) is centrally located within the [FAB] system and contains the Outside Containment elements of the System for conveyance of fuel assemblies / internals between reactor and storage areas [FCK].

The UP is normally fully drained but has a minimum operating water depth of 13.815 m during refuelling and cask loading operations.

The UP can be hydraulically linked or isolated from the SFP by a set of UP Fuel Gates and from the Refuelling pool via the Fuel Transfer Channel by a valves and flange.

Gates

UP Fuel Gates

UP Fuel Gates are located between the SFP and UP and are sized to permit the transfer of a single Fuel Assembly between the two locations. The gates are used to minimise the risk posed to operators when performing maintenance within the UP, adjacent to the permanently flooded SFP, and it is assumed that two different gate designs shall be used to reduce the likelihood of common failure modes. The two gates may also support the SFP boil-off function [FA01] but this is subject to further development of the SFP fault schedule.

CLP Fuel Gate

The Cask Loading Pit (CLP) Fuel Gate is located between the CLP and UP and is sized to permit the transfer of a single Fuel Assembly. As a result of the system layout development, the CLP will only be entered by operators when the adjacent UP is also drained. Therefore, only a single gate is required.

Development of the CLP Fuel Gates, including type of fuel gate (hinged, sluice) and type of sealing arrangement (static, pneumatic) will continue in the next design phase.

CLP Cask Gates

The CLP Cask Gates are located on the [FAB] system boundary. They are sized to permit the import and export of the dry storage cask via the Cask Conveyance System [FCL30]. During cask loading operations, the [FAB] system is fully flooded and the CLP Cask Gates prevent the loss of coolant from the system. Development of the SFP Fault Schedule is ongoing but it is assumed that the CLP Cask Gates perform a Safety Category A function and are therefore two independent Safety Class 1 components with single failure tolerance.

Pool Structure

The pool structures fulfil a key safety function of containing the water which ensures the heat removal, containment and shielding of the fuel. The pool structure also provides shielding of the fuel to allow personnel into the nearby areas.

Traditional nuclear power plants have used reinforced concrete pool structures, with thicknesses of 2 m or higher. A stainless steel liner is used in the pool to avoid the ingress of water into the concrete. A leak chase system captures leakage through this liner's welds in collection pots. The leak chase system is equipped with level detectors to report leakage.

The arranging of rebar on site followed by the pouring of concrete is a potential source of construction delays. However, concrete does have certain strengths such as the robustness demonstrated at Fukushima Daiichi. In Fukushima the fuel storage pools retained their structural integrity following an earthquake, tsunami and hydrogen explosion.

The chosen solution is Stainless steel concrete composite as a new baseline for the pool structures, while also investigating the further development of the twin wall metal only option.

The Pool Structure provides an interface and load bearing support to all the components and fluid system connections contained within the SFP, CLP and UP, and where required the structure provides additional structural support through penetration connections.

The Refuelling Pool structure will include a means of collecting and directing leaks at specific weld or penetration locations beneath the pool liner. The leaks will then be directed to and managed by the Leak Detection [KTQ] System for detection, monitoring and redirecting coolant.

9A.1.4.5 Materials

The description of the materials selection process used for Class 1 SSCs is presented in E3S Case Version 2, Tier 1, Chapter 23: Structural Integrity [1]. Materials will be confirmed in future issues of the generic E3S Case.

9A.1.4.6 Interfaces with Supporting Systems

Interfaces for the Spent Fuel Storage & Cask Loading System [FAB] are identified and managed within the sub-system requirements specifications [23], [24] and [25].

9A.1.4.7 System and Equipment Operation

The overarching operating philosophy for the Reactor Island in all operating modes is covered in [28].

A full analysis of the system operation in all modes of operation will be conducted in future design phases to develop the Spent Fuel Storage & Cask Loading System [FAB] operating philosophy. The operating philosophy defines the key claims and operational sequences and actions the system is required to undertake, and the key claims made on the operator or automated actions. The operating philosophy also supports ongoing Human Factors and safety assessments.

The operation of the Spent Fuel Storage & Cask Loading System [FAB] system during the six operating modes is described in [11].

Faults

A high-level overview of the Spent Fuel Storage & Cask Loading System [FAB] alignment and functionality during Faulted Operations, both in terms of the plant response to specific faults originating within the system, as well as support that the system provides to plant safety measures (e.g. Passive Decay Heat Removal (PDHR) [JN02]), will be developed in future design work.

Support Provided to Plant Safety Measures

Under a loss of active spent fuel cooling event, the SFP coolant inventory is sufficient to satisfy the Spent Fuel Pool Boiling function [FA01]. Under Operating Modes 1-5b, passive heat up and boil-off of the pool coolant would take more than 72 hours to uncover stored fuel. Under Operating Modes 6a-6b, passive heat up and boil-off of the pool coolant would take more than 24 hours to uncover stored fuel. Additionally, for faults occurred during Mode 6a-6b, the Emergency Heat Removal System for Coolant Used for Storage of Spent Fuel Assemblies [FAN] will provide passive, gravity-fed make-up coolant to the SFP, ensuring that Spent Fuel Pool Boiling [FA01] function could be fulfilled for at least 72 hours.

The function [FA01] continues to apply under any design basis initiating event that could result in partial loss of coolant from the SFP, UP or CLP. Under those circumstances, the system is designed such that the postulated water level following the fault is sufficient to store the required volume to achieve over 72 hours and 24 hours of passive boil-off (without makeup) under Modes 1-5b and Modes 6a-6b respectively.

9A.1.4.8 Instrumentation and Control

A high-level overview of the basic functions that are allocated to the Reactor Control and Instrumentation (C&I) Systems [JY] by the Spent Fuel Storage & Cask Loading System [FAB] is presented in [11].

9A.1.4.9 Monitoring, Inspection, Testing & Maintenance

The EMIT activities for [FAB] are defined as TLA within the RR SMR requirements management database, and cover safety derived tasks, ISI), reliability derived tasks (RCM/preventative maintenance), and industry best practice/OPEX, EPRI PMBD).

The maintenance activities to be considered in the TLA include:

- Safety derived tasks (ISI)
- Design derived tasks (Supplier provided)
- Reliability derived tasks (RCM/Preventative Maintenance)
- Industry best Practice/OPEX (EPRI PMBD)
- Non-PBS (Module, Site Facility).

9A.1.4.10 Performance and Safety Evaluation

Compliance with Safety Categorised Functional Requirements

The Spent Fuel Storage and Cask Loading System [FAB] carries out the FSFs of CoFT, CoR and CoRM. The coolant contained within the system provides both shielding and heat removal. The structure of the system confines radioactive material and sub-criticality is maintained during storage.

Verification and validation for the Spent Fuel Storage & Cask Loading System [FAB] to demonstrate compliance with its safety categorised functional requirements and associated non-functional performance requirements is under development.

Performance analysis to demonstrate that the Spent Fuel Storage & Cask Loading System [FAB] delivers its safety functions for all fault conditions at RD7/DRP1 will be carried out. The output of performance analysis and margin to acceptance criteria for the Spent Fuel Storage & Cask Loading System [FAB] will be presented in a future revision of the E3S Case. The full suite of performance analysis for bounding fault conditions that place safety categorised functional requirements on the Spent Fuel Storage & Cask Loading System [FAB] is presented in E3S Case Version 2, Tier 1, Chapter 15: Safety Analysis [6].

Compliance with Non-Functional System Requirements

The compliance for non-functional system requirements allocated to the Spent Fuel Storage and Cask Loading System [FAB] will be presented in Version 3 of the E3S Case.

9A.1.4.11 Radiological Aspects

Measures for controlling any radiological material released into the Fuelling Block [UFA] during Spent Fuel Pool Boiling [FA01] have yet to be defined, but is assumed to involve filtering of the Heating, Ventilation and Air Conditioning route.

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 facilitates storage for up to 10 years if necessary. Radiological assessments for dose uptake during cask loading operations will be carried out ahead of DRP2 and reported in Version 3 of the E3S Case.

9A.1.4.12 ALARP, BAT, Secure by Design and Safeguards by Design

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 and 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 E3S Case Version 2, Tier 1, Chapter 3: E3S Objectives & Design Rules [8].

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:

- 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

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

Detailed system design decisions and their rationale are presented in [11]. Fuel Route & Flood-Up Strategy [29] was undertaken to determine where to locate the SFP, CLP and UP relative to each other. Options considered included having independent transfer routes between the SFP and each pit or transferring fuel to the CLP via the UP. The selected option was to transfer fuel to the CLP via the UP as doing so offers greater defence in depth against SFP Loss of Containment Accidents (LOCA).

It was noted that although this would result in the need for an additional flood-up, drain down and decontamination of the UP, the safety improvement offered was judged to be ALARP.

Further design work is planned to develop the decontamination equipment [11] and operating philosophy to demonstrate that the process is ALARP. This will be reported in Version 3 of the E3S Case.

9A.1.5 Refuelling Systems

9A.1.5.1 System and Equipment Functions

The RR SMR refuelling systems comprise the following:

- Refuelling Cavity [FAE]
- Refuelling Pool [FAF].

The Refuelling Cavity [FAE] System is a pool located inside of the containment vessel, directly above the RPV itself, and adjacent to the Refuelling Pool [FAF]. The Refuelling Cavity [FAE] 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.

The Refuelling Pool [FAF] is a pool located inside of the containment vessel, next to the Refuelling Cavity [FAE]. The Refuelling Pool [FAF] is used to store the Reactor Pressure Vessel (RPV) Upper Internals, the RPV Lower Internals, Drive Rods, and the ICM Assemblies 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.

Layout details for the refuelling systems [FAE] and [FAF] are presented in [5], [13] and [12].

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 Version 2, Tier 1, Chapter 15 Safety Analysis [6].

9A.1.5.2 Design Bases

Functional Requirements

Safety categorised functional requirements for the refuelling systems [FAE] and [FAF] are specified based on the HLSFs they deliver, including the applicable plant states and operating modes, are presented in Table 9A.1-5 based on [30] and [31].

Table 9A.1-5: [FAE] and [FAF] System Safety Categorised Functional Requirements

Requirement ID	Functional Requirement	Modes of Operation	Safety Category
FAE-R-1840	While in Modes 6a or 6b, the Refuelling Cavity [FAE] shall Store coolant (shielding).	6a and 6b	A
FAE-R-1835	While in All modes of operation, the Refuelling Cavity [FAE] shall Sense coolant level (shielding).	All	B
FAE-R-1844	While in Modes 6a or 6b, the Refuelling Cavity [FAE] shall Store Coolant (heat removal).	6a and 6b	A
FAE-R-1838	While in Modes 6a or 6b, the Refuelling Cavity [FAE] shall Sense coolant level (heat removal).	6a and 6b	B
FAE-R-1855	While in Modes 6a or 6b, the Refuelling Cavity [FAE] shall sense coolant temperature (heat removal).	6a and 6b	B
FAE-R-1837	While in Modes 6a or 6b, the Refuelling Cavity [FAE] shall ensure confinement of radioactive material.	6a and 6b	A

The refuelling systems [FAE] and [FAF] support the FSFs of CoFT and CoRM, the coolant level is used to control feed and drain flows to achieve the target water level for required heat removal during fuel movements and the Refuelling Cavity and Refuelling Pool confine radioactive material.

The safety categorised functional requirements for the refuelling systems [FAE] and [FAF] are flowed down and allocated to relevant sub-systems and/or components. Non-functional performance requirements associated with the safety categorised functional requirements are allocated in [30] and [31].

Non-Functional System Requirements

Non-functional system requirements are being developed and will be allocated to the refuelling systems [FAE] and [FAF], based on the E3S design principles as described in E3S Case Version 2, Tier 1, Chapter 3: E3S Objectives and Design Rules for SSCs [8].

9A.1.5.3 E3S Classification

Safety Classification

The Refuelling systems [FAE] and [FAF] provide the principal means of achieving the Category A functions to ensure confinement of radioactive material, ensure removal of heat from the fuel. The highest classification of components that support these functions within the system is Class 1.

A full list of safety classifications can be seen in the relevant requirements modules for major components, as well as the Allocated Requirements Module (D-module) for the systems [32] and [33].

Environment, Security and Safeguards Classification

No environment, security, or safeguards classification is assigned at RD7/DRP1.

Seismic Classification

The refuelling systems [FAE] and [FAF] are to be classified in accordance with the RR SMR Seismic Performance Classification Method [9].

9A.1.5.4 Description

Refuelling Cavity System [FAE]

During powered operations the Refuelling Cavity [FAE] is drained and is isolated from the Refuelling Pool [FAF] through the Refuelling Pool [FAF] gate.

A Refuelling Cavity Seal is fitted between the bottom surface of the Refuelling Cavity [FAE] and the RPV flange to allow flood up of the Refuelling Cavity [FAE] during Refuelling.

At the start of refuelling the Integrated Head Package (IHP) stud tensioning equipment is lowered into the Refuelling Cavity [FAE] to de-tension the RPV bolted joint. The RPV ICM Assemblies are also disconnected. The IHP is then lifted out of the Refuelling Cavity [FAE], while the Refuelling Cavity [FAE] is flooded up.

During the IHP lift several measures are in place to provide reactivity control:

- Cameras in the Refuelling Cavity [FAE] monitor the lift.
- The rod at bottom sensors are connected and monitored during the IHP lift. They are expected to indicate off. If they don’t indicate off, an interlock is used to stop the crane lift.
- The Nucleonic detectors are monitored during the IHP lift. If there is an increase in activity, an interlock is used to stop the crane lift.
- A Crane Load Cell is used to detect if a large number of control rods are inadvertently lifted.

Similarly, for the RPV Upper Internals lift, cameras, nucleonic detectors, and a crane load cell monitor the lift. If there is an increase in activity, an interlock is used to stop the crane lift.

An IHP lift gate isolates the Refuelling Cavity [FAE] from the IHP laydown area. The IHP lift gate allows the required lift height of the IHP to be reduced. Once the IHP is moved into the laydown area, the IHP lift gate is installed in the Refuelling Cavity [FAE] wall, which enables the flood-up to be completed.

The flooded-up Refuelling Cavity [FAE] provides heat removal, containment and shielding for the fuel and other nuclear equipment. The water volume also increases the boiling time for the fuel in the RPV, which is a significant benefit during the early stages of refuelling.

The Refuelling Cavity [FAE] is used to store new ICM Assembly instrument probes. Due to the length of the instrument probes, they are moved into the Refuelling Cavity [FAE] while the cavity is dry and the IHP lift gate is removed. Brackets on the Refuelling Cavity [FAE] walls are used to store the new instrument probes. Once the Refuelling Cavity [FAE] is flooded up, the new instrument probes are moved into Refuelling Pool [FAF] ICM storage area and subsequently fitted to the ICM Assembly.

The water level between the Spent Fuel Pool [FAB10], the Refuelling Pool [FAF], and the Refuelling Cavity [FAE] will be maintained at the same height to allow the pools to be connected during core unloading and loading fuel movements.

Personnel access methods to the Refuelling Cavity [FAE] are to be determined. Options such as temporary stairs are preferred to minimise space envelope size whilst also minimising fall hazards.

The Refuelling Cavity [FAE] system includes pool level and temperature measurement equipment to facilitate indication for pool temperature and level control.

Refuelling Cavity sub-systems

A Refuelling Cavity Seal is fitted between the bottom surface of the Refuelling Cavity [FAE] and the RPV flange to seal between the annulus gap to allow flood up of the Refuelling Cavity [FAE] during refuelling.

The Refuelling Cavity [FAE] is used to store new ICM Assembly Instrument Probes. Due to the length of the Instrument Probes at approximately 10 to 11 m, they are moved into the Refuelling Cavity [FAE] while the cavity is dry and the IHP lift gate is removed. When required, and once the Refuelling Cavity [FAE] is flooded up, the new ICM Assembly Probes are moved into Refuelling Pool [FAF] ICM storage area to be fitted to the ICM Assemblies.

The Refuelling Cavity Structure [PT217] consists of the walls and floor of the Refuelling Cavity [FAE] and provides the structural and watertight boundary of the pool. The structure is formed from a steel concrete composite, the steel sections are welded to provide the means of a watertight boundary for containment of the coolant. The steel structure is then backfilled with concrete to form a reinforced steel concrete composite structure.

An IHP Lift Gate [PT536] is incorporated into the Refuelling Cavity [FAE] pool structure wall at the north end of the cavity next to the IHP laydown area. When fitted in its sealing position prior to Mode 6b Refuelling operations, the IHP Lift Gate allows the Refuelling Cavity [FAE] to be fully flooded to accommodate the necessary water shielding during Fuel Assembly and other reactor component lifts between the Refuelling Cavity [FAE] and the Refuelling Pool [FAF].

When the Refuelling Cavity [FAE] is partially flooded to below the IHP Lift Gate weir level and the IHP Lift Gate is removed from its sealing position, the open aperture between the Refuelling Cavity [FAE] and the IHP Laydown area creates an access route with a reduced lift height. This has the subsequent benefit of reducing the Main Overhead Crane maximum hook height which itself has an impact on the overall Containment Vessel size and plant layout. The primary lifts between the Refuelling Cavity [FAE] to the IHP Laydown area utilising an ‘open’ IHP Lift Gate are the IHP lift and the lift of new ICM Assembly Instrument Probes.

The height of the IHP Lift Gate weir level is set to ensure that if the IHP Lift Gate were to fail when lifting a Fuel Assembly, 1.85 m of shielding is still maintained in the event of a pool drain down. This level would maintain adequate water shielding to allow time for a recovery sequence such as placing the Fuel Assembly in the Upender Basket within the Refuelling Pool [FAF].

Further design work is on-going for the Refuelling Cavity sub-systems and details will be presented in Version 3 of the E3S Case.

Refuelling Pool System [FAF]

The Refuelling Pool [FAF] System supports functionality of Emergency Core Cooling (ECC) [JN01], and PDHR [JN02], and their respective subsystems during plant powered operation.

The Refuelling Pool [FAF] height is driven by the requirement to provide the necessary flow rate under gravity for ECC [JN01]. There is a requirement for the volume of water available in the Refuelling Pool [FAF] to be enough to ensure a sufficient hydrostatic head of water is achieved to drive flow into the Reactor System [JA] at the required rate during Phase 2 and 3 of ECC [JN01], as described in the System Descriptions for the Low Pressure Injection System [JNG] [34] and ECC [JN01] [35].

The Refuelling Pool [FAF] connections to the Low Pressure Injection System [JNG] have screens to prevent ingress of debris into the sump recirculation pipework and thus the Reactor System [JA], which may be capable of causing pipework blockage or degradation in heat transfer from the fuel [34].

The Refuelling Pool [FAF] also has connections to the Reactor Coolant Pressure Relief (RCPR) System [JEG]. The RCPR System discharges into the Refuelling Pool. Spargers are required at the ends of these connections [36]. Spargers are perforated pipes which increase the surface area of the steam bubbles and promote condensation.

During powered operation, the Refuelling Pool [FAF] is flooded. The Refuelling Pool [FAF] gate isolates the Refuelling Pool [FAF] from the Refuelling Cavity [FAE]. The Refuelling Cavity [FAE] [13] is dry during powered operation.

During refuelling, the gate is removed and the Fuel Transfer Channel [JMD] is opened to connect the Refuelling Pool [FAF] to the Spent Fuel Pool [FAB10]. The Refuelling Cavity [FAE] is flooded up to allow the movement of the RPV Upper Internals or the RPV Upper Internals plus the RPV Lower Internals, and the ICM assemblies from the RPV to the Refuelling Pool [FAF], and the movement of fuel to the upender.

The current baseline design has a single Refuelling Pool [FAF] gate. During refuelling this gate is stowed away in the refuelling pool.

A single storage stand is provided for the RPV Upper Internals and the RPV Lower Internals. During a refuelling outage, the RPV Upper Internals are lifted out of the RPV and stored on the Refuelling Pool [FAF] System storage stand, while the RPV Lower Internals remain in the RPV. This allows the fuel assemblies to be removed from the RPV.

During a 10 year maintenance outage the RPV Upper Internals are moved into the Refuelling Pool [FAF] to allow fuel assembly removal. The RPV Upper Internals are then moved back into the RPV, before the RPV Upper Internals and the RPV Lower Internals are removed together and stored together on the Refuelling Pool [FAF] storage stand, to allow access to the RPV body for inspection. The use of a common storage stand for both the RPV Upper Internals and the RPV Lower Internals has the benefit of reducing the required space envelope for the Refuelling Pool.

The Refuelling Pool [FAF] has a storage stand for RPV ICM Assemblies. The ICM Assembly design utilises a yoke and lance configuration, with up to 16 individual assemblies. These assemblies require storage in the Refuelling Pool [FAF] during refuelling outages. Replacement of components within each assembly will be required and a route from [FAE] to [FAB10] is required.

The water level between the Spent Fuel Pool [FAB10] and the Refuelling Pool [FAF] will be maintained at the same height to allow the two pools to be connected during fuel movements.

The Refuelling Pool [FAF] upender is mounted on a platform. The platform allows personnel access for maintenance of the upender.

Personnel access methods to the Refuelling Pool [FAF] are to be determined. Options such as temporary stairs are preferred to minimise the Refuelling Pool size while also minimising fall hazards.

The Refuelling Pool [FAF] includes pool level measurement equipment to facilitate indication for pool level control.

Refuelling Pool sub-systems

An RPV internals storage stand [PT198] is required for the temporary storage of both the RPV Upper Internals and the RPV Lower Internals. The storage differs depending on plant requirement, this is broken into three parts:

1. During powered operations only the RPV Internals Lifting Arrangement is stored in the refuelling pool on the RPV Internals Storage Stand.

2. During refuelling with water level above fuel at nominal the RPV Upper Internals is removed from the RPV and placed into refuelling pool storage stand.

3. During a ten-year maintenance outage the RPV Upper Internals are removed, and all fuel removed to the spent Fuel pool [FAB], the RPV Upper Internals are moved back to the RPV and both the RPV Upper Internals and the RPV Lower Internals are moved and stored in the refuelling pool storage stand.

An In-Core Monitoring (ICM) storage stand [PT200] is required for their temporary storage during refuelling outages. The stand is expected to be permanently fixed to the pool structure and is therefore a permanent fixture within the Refuelling Pool [FAF].

Whilst the RPV Upper Internals assembly is stored in the Refuelling Pool it includes both the Control Rod Housing Columns (CHRCs), and Drive Rods as part of its assembly.

During a refuelling or maintenance outage there may be a need to inspect some of the Control Rod Housing Columns (CRHCs) for wear and replace them if necessary.

To facilitate inspection of a CRHC, the Drive Rod within the given inspection location first requires removal from the RPV Upper Internals to provide inspection access. Once removed, the Drive Rod is subsequently stored within the Drive Rod Storage Stand [PT201] located within the Refuelling Pool. Once CRHC inspection has taken place, the Drive Rod can be returned to the RPV Upper Internals.

If replacement of a CRHC is required, removal of all Drive Rods is necessary to facilitate the removal of the Upper Support Plate within the RPV Upper Internals, which enables access for CRHC replacement. Therefore, the Drive Rod Storage Stand has the capacity to store a full assembly of 89 drive rods.

Due to the envisaged less frequent occurrence of inspecting and replacing CRHCs, and the small and simplistic nature of storing the Drive Rods, the Drive rod storage stand is assumed to be a temporary fixture within the Refuelling Pool [FAF].

The Refuelling Pool Structure forms the walls and floor of the Refuelling Pool [FAF] and provides the structural and watertight boundary of the pool. The structure is formed from a stainless steel liner with welded seams which provides the primary means of a watertight boundary for containment of the coolant. The rest of the pool structure is formed from a steel concrete composite.

Further design work is on-going for the Refuelling Pool sub-systems and details will be presented in Version 3 of the E3S Case.

9A.1.5.5 Materials

The description the materials selection process used for Class 1 SSCs is presented in E3S Case Version 2, Tier 1, Chapter 23: Structural Integrity [1]. Materials will be confirmed in future versions of the generic E3S Case.

9A.1.5.6 Interfaces with Supporting Systems

Interfaces for the Refuelling systems [FAE] and [FAF] are identified within the system requirements specifications [30] and [31].

9A.1.5.7 System and Equipment Operation

The overarching operating philosophy for the Reactor Island in all operating modes is covered in [28].

A full analysis of the system operation in all modes of operation will be conducted in future design phases to develop the Refuelling systems [FAE] and [FAF] operating philosophy. The operating philosophy defines the key claims and operational sequences and actions the system is required to undertake, and the key claims made on the operator or automated actions. The operating philosophy also supports ongoing Human Factors and safety assessments.

The operation of the Refuelling systems [FAE] and [FAF] system during the six operating modes is described in in [13] and [12].

Faults

A high-level overview of the Refuelling Systems [FAE] and [FAF] alignment and functionality during Faulted Operations, both in terms of the plant response to specific faults originating within the system, as well as support that the system provides to plant safety measures (e.g., PDHR [JN02]) is currently being undertaken and will be reported in Version 3 of the E3S Case.

9A.1.5.8 Instrumentation and Control

Basic functions allocated to the Reactor C&I Systems [JY] by the Refuelling Systems [FAE] and [FAF] are being developed and will be presented in Version 3 of the E3S Case.

9A.1.5.9 Monitoring, Inspection, Testing & Maintenance

The EMIT activities for [FAB] are defined as TLA within the RR SMR requirements management database, and cover safety derived tasks, ISI), reliability derived tasks (RCM/preventative maintenance), and industry best practice/OPEX, EPRI PMBD).

The maintenance activities to be considered in the TLA include:

- Safety derived tasks (ISI)
- Design derived tasks (Supplier provided)
- Reliability derived tasks (RCM/Preventative Maintenance)
- Industry best Practice/OPEX (EPRI PMBD)
- Non-PBS (Module, Site Facility).

9A.1.5.10 Radiological Aspects

Radiological protection requirements are applied through the design process and analysis of these will be carried out in line with the maturity of the design.

9A.1.5.11 Performance and Safety Evaluation

Compliance with Safety Categorised Functional Requirements

Verification and validation for the Refuelling Systems [FAE] and [FAF], to demonstrate compliance with its safety categorised functional requirements and associated non-functional performance requirements is under development.

Compliance with Non-Functional System Requirements

The non-functional system requirements are still to be completed and the compliance to them will be presented in Version 3 of the generic E3S Case.

9A.1.5.12 ALARP, BAT, Secure by Design and Safeguards by Design

The evidence presented within [13] and [12] provides initial confidence that the Refuelling Systems [FAE and [FAF] can support the overall E3S targets for the SMR. Further work will be undertaken as the design develops and this will be reported in Version 3 of the E3S Case.

9A.1.6 Spent Fuel Pool Cooling & Clean-Up Systems

9A.1.6.1 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:

- Fuel Pool Cooling System (FPCS) [FAK]
- Fuel Pool Purification System (FPPS) [FAL]
- System for Removal of Surface Contaminants on components in fuel assembly storage (FAM)
- Emergency Heat Removal System for coolant used for storage of spent fuel assemblies (FAN)
- 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.

Layout details for the Spent Fuel Pool Cooling & Clean-Up Systems are presented in [5].

HLSFs for Spent Fuel Pool Cooling & Clean-Up Systems and the PIEs against which they are assigned, are being derived in the Fault Schedule, which is presented in E3S Case Version 2, Tier 1, Chapter 15: Safety Analysis [6].

9A.1.6.2 Design Bases

Functional Requirements

Safety categorised functional requirements for Spent Fuel Pool Cooling & Clean-Up Systems are specified based on the HLSFs they deliver, including the applicable plant states and operating modes, are presented in Table 9A.1-6 based on RR SMR requirements database [FAK], [FAL] and [FAT] modules.

Table 9A.1-6: Spent Fuel Pool Cooling & Clean-Up Systems Safety Categorised Functional Requirements

Requirement ID	Functional Requirement	Mode(s) of Operation	Safety Category
FAK-R-1251	The Fuel Pool Cooling System [FAK] shall remove heat from the fuel pool coolant	All	B
FAK-R-1257	The Fuel Pool Cooling System [FAK] shall deliver motive force for the Fuel Pool Purification System [FAL]	All	C
FAK-R-1259	The Fuel Pool Cooling System [FAK] shall deliver motive force for the transfer of inventory from the fuel pools to the Fuel Pool Supply System [FAT]	All	C
FAK-R-1279	The Fuel Pool Cooling System [FAK] shall isolate	All	A
FAL-R-1250	The Fuel Pool Purification System [FAL] shall purify coolant used in the wet storage of fuel	All	C
FAL-R-1257	The Fuel Pool Purification System [FAL] shall control pH of the coolant used in the wet storage of fuel	All	C
FAT-R-1250	The Fuel Pool Supply System [FAT] shall maintain the fuel pool water levels	All	C

Requirement ID	Functional Requirement	Mode(s) of Operation	Safety Category
FAT-R-1369	The Fuel Pool Supply System [FAT] shall store coolant	All	C
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 supply motive force to transfer coolant from the Refuelling Water Storage Tank to the Fuel Pool Cooling system [FAK]	6a	C

Spent fuel will be stored in pools and generate decay heat, coolant within the pools and the pool structure will provide the FSFs of CoFT, CoR, CoRE and CoRM.

FPPS is used to purify coolant to maintain water quality and clarity. pH is controlled to minimise corrosion.

During a refuelling outage it is necessary to transfer coolant between the pools and the RWST. In support of this the standby FPCS pump will be used as the primary means of transferring this coolant, should this pump be unavailable the Fuel Pool Supply System [FAT] will be used.

The FAK system will require pipework which passes across the containment boundary to connect to in-containment fuel pools.

The safety categorised functional requirements for the Spent Fuel Pool Cooling & Clean-Up Systems are flowed down and allocated to relevant sub-systems and/or components. Non-functional performance requirements associated with the safety categorised functional requirements are allocated in the requirements database management system.

Non-Functional System Requirements

Non-functional system requirements are allocated to the Spent Fuel Pool Cooling & Clean-Up Systems based on the E3S design principles as described in E3S Case Version 2, Tier 1, Chapter 3: E3S Objectives and Design Rules for SSCs [8], summarised in Table 9A.1-7.

Table 9A.1-7: Spent Fuel Pool Cooling & Clean-Up Systems Non-Functional System Requirements

Requirement ID	Non-Functional System Requirement
FAK-R-1446	The Fuel Pool Cooling System [FAK] shall contain and confine reactor coolant.
FAL-R-1295	The Fuel Pool Purification System [FAL] shall contain and confine reactor coolant.
FAT-R-1314	The Fuel Pool Supply System [FAT] shall contain and confine reactor coolant.

9A.1.6.3 E3S Classification

Safety Classification

The FPCS [FAK] is the principal means by which the Category B function to remove decay heat from the storage of spent fuel is achieved; the highest classification of components that support this function within the system is Class 2.

The FPPS [FAL] is the principal means by which the Category C function to purify coolant use to remove decay heat from the storage of spent fuel is achieved; as such the highest classification of components that support this function within the system is Class 3.

The FPSS [FAT] is the principal means by which the Category C function to maintain spent fuel pool coolant inventory is achieved; as such the highest classification of components that support this function within the system is Class 3.

Environment, Security and Safeguards Classification

No environment, security, or safeguards classification is assigned at RD7/DRP1.

Seismic Classification

The Spent Fuel Pool Cooling & Clean-Up Systems are to be classified in accordance with the RR SMR Seismic Performance Classification Method [9].

9A.1.6.4 Description

Fuel Pool Cooling System [FAK]

The Fuel Pool Cooling System (FPCS) [FAK] is described in the Spent Fuel Pool Cooling System [FAK] SOD [14]. The FPCS [FAK] removes decay heat from the coolant used in the wet storage of spent fuel. 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 FPCS [FAK] transfers heat from the fuel pools to the ultimate heat sink, the environment, via the Component Cooling System (CCS) [KAA] and Essential Services Water System [PB] decay heat removal chain, supporting achievement of the Control of Fuel Temperature Fundamental Safety Function during normal operation.

Each cooling train includes a set of manifolds which provide connection to all the pools within the refuelling route. This includes the Spent Fuel Pool [FAB10], Cask Loading Pit [FAB20], Upender Pit [FAB40], Refuelling Pool [FAF] and the Refuelling Cavity [FAE].

The FPCS [FAK] also includes connection to/from the Fuel Pool Purification System (FPPS) [FAL], Fuel Pool Coolant Supply System (FPSS) [FAT] and Cold Shutdown Cooling System [JNA].

Fuel Pool Purification System [FAL]

The Fuel Pool Purification System [FAL] is described in the SOD for the Fuel Pool Purification System [FAL] [15]. The function of the FPPS [FAL] is to purify the coolant used in the wet storage of fuel. This includes maintaining the chemistry specification of the coolant, such as the concentration of Chlorides, Sulphides and Sulphates, maintaining turbidity, and controlling the pH level of the coolant [37].

Filters remove suspended solids and resin fines. Mixed bed Ion Exchange Columns remove contaminants (such as chloride and fluoride ions) and remove radioactive species such as fission and activation products. Should the coolant pH need to be adjusted this is achieved through chemical dosing of potassium hydroxide by the FPPS [FAL] dosing connection.

System for removal of surface contaminants on components in fuel assembly storage [FAM]

This system is for the decontamination of:

- Casks and other large items such as equipment and fuel racks.
- Pools such as the cask pit, upender pit, refuelling pool, refuelling cavity.
- Deployable tools such as the drive rod unlatching tool, RPV ultrasonic inspection equipment etc.

This system is in an early development stage and more detail will be provided in future design stages.

Emergency heat removal system for coolant used for storage of spent fuel assemblies [FAN]

The Emergency heat removal system for coolant used for storage of spent fuel assemblies [FAN] is yet to be fully defined. The following includes current assumptions on the system's function and architecture.

The function of [FAN] System is to provide make-up coolant inventory to the fuel pools to maintain coolant coverage of stored Spent Fuel during faulted conditions. The [FAN] System provides gravity-fed make-up coolant to the Spent Fuel Pool and Cask Loading [FAB] and Refuelling Pool [FAF] Systems using the Local Ultimate Heatsink [JNK] as a water source. Separate pipelines are used to connect the in-containment Refuelling Pool [FAF] and outside containment Spent Fuel Pool and Cask Loading [FAB] to the Local Ultimate Heatsink [JNK].

The function of the [FAN] System to provide make-up coolant to the Spent Fuel Pool and Cask Loading [FAB] System, supports the function of the Spent Fuel Pool Boiling [FA01] safety measure to maintain control of fuel temperature within the pool during faulted conditions. Spent Fuel Pool Boiling [FA01] provides passive cooling of stored Spent Fuel by boil-off of the existing fuel pool coolant inventory. A postulated fault during refuelling leads to loss of Spent Fuel Pool and Cask Loading [FAB] coolant inventory, which reduces the time for which Spent Fuel Pool Boiling [FA01] can fulfil its control of fuel temperature function from beyond 72 hours to approximately 29 hours. Emergency heat removal system for coolant used for storage of spent fuel assemblies [FAN] delivers approximately {REDACTED} m^3 of make-up coolant to provide an additional 44 hours' worth of boil-off inventory to ensure that Spent Fuel Pool Boiling [FA01] can passively control fuel temperature for 72 hours.

The function of the [FAN] System to provide make-up coolant to the Refuelling Pool [FAF] ensures coolant coverage of fuel-in-transit during faulted conditions fuel handling operations.

Fuel Pool Supply System [FAT]

The Fuel Pool Supply System (FPSS) [FAT] is described in SOD for the Fuel Pool Supply System [FAT] [16]. The primary function of the FPSS [FAT] is to maintain the Fuel Pool water levels, and store water during drain of the refuelling pool [FAF]. The FPSS [FAT] includes a Make-Up Pump and the Refuelling Water Storage Tank.

9A.1.6.5 Materials

The description the materials selection process used for SSCs is presented in E3S Case Version 2, Tier 1, Chapter 23: Structural Integrity [1]. Materials will be confirmed in future versions of the generic E3S Case.

9A.1.6.6 Interfaces with Supporting Systems

Interfaces for Spent Fuel Pool Cooling & Clean-Up Systems are presented in [14], [15], [16] and [5].

9A.1.6.7 System and Equipment Operation

A full analysis of the Spent Fuel Pool Cooling & Clean-Up Systems operation in all modes of operation will be conducted in future design phases to develop operating principles, these will be reported in Version 3 of the E3S Case.

9A.1.6.8 Performance and Safety Evaluation

Compliance with Safety Categorised Functional Requirements

Verification and validation for the Spent Fuel Pool Cooling & Clean-Up systems, to demonstrate compliance with their safety categorised functional requirements and associated non-functional performance requirements is under development.

Compliance with Non-Functional System Requirements

The non-functional system requirements are under refinement and the compliance to them will be presented in Version 3 of the generic E3S Case.

9A.1.6.9 ALARP, BAT, Secure by Design and Safeguards by Design

The evidence presented within [14] [15], and [16] provides initial confidence that the Spent Fuel Pool Cooling & Clean-Up Systems can support the overall E3S targets for the SMR. Further work will be undertaken as the design develops and this will be reported in Version 3 of the E3S Case.

9A.1.7 Testing System for Fuel Assemblies [FBA]

9A.1.7.1 System and Equipment Functions

The Testing System for Fuel Assemblies [FBA] Handling of fuel assemblies and other reactor core internals System represents the systems for Testing, Repair and Cleaning of fuel and other reactor core internals. It supports achievement of the FSFs of CoR, CoFT, CoRE and CoRM during normal operation and fault conditions.

Layout details for the Testing System for Fuel Assemblies [FBA] System are presented in [5].

HLSFs the Testing System for Fuel Assemblies [FBA] System, and the PIEs against which they are assigned, are being derived in the Fault Schedule, which is presented in E3S Case Version 2, Tier 1, Chapter 15: Safety Analysis [6].

9A.1.7.2 Design Bases

Functional Requirements

Safety categorised functional requirements for Testing System for Fuel Assemblies [FBA] System are specified the based on the HLSFs they deliver, including the applicable plant states and operating modes, are presented in Table 9A.1-8

Table 9A.1-8: Testing System for Fuel Assemblies [FBA] System Safety Categorised Functional Requirements

Requirement ID	Functional Requirement	Mode(s) of Operation	Safety Category
FB-R-1377	While in all modes of operation, the Handling of Fuel and Reactor Core Internals [FB] shall maintain Fuel Assembly condition	All	A
FB-R-1378	While in all modes of operation, the Handling of Fuel and Reactor Core Internals [FB] shall enable Removal of Heat	All	A
FB-R-1366	While in all modes of operation, the Handling of Fuel and Reactor Core Internals [FB] shall enable Control of Reactivity	All	A

The Testing System for Fuel Assemblies [FBA] System provides CoFT and CoR from FSFs.

The safety categorised functional requirements for are flowed down and allocated to relevant sub-systems and/or components. Non-functional performance requirements associated with the safety categorised functional requirements are allocated in the requirements database management system.

Non-Functional System Requirements

Non-functional system requirements are being developed and will be allocated to the Testing System for Fuel Assemblies [FBA] System based on the E3S design principles as described in E3S Case Version 2, Tier 1, Chapter 3: E3S Objectives and Design Rules for SSCs [8].

9A.1.7.3 E3S Classification

E3S classification for the [FB] system is under development and aligns with that described in 9A.1.1.3

9A.1.7.4 Description

Testing System for Fuel Assemblies [FBA]

Fuel assembly and control rod inspections are required to monitor performance. Fuel assembly inspections consist of a number of inspection techniques such as visual inspection, leak testing, ultrasonic, eddy current as well as others. Control Rod inspections such as visual inspection, eddy current and ultrasonic inspection are typically performed to monitor control rod performance, in particular rodlet wear, swelling or other abnormal performance conditions. Inspection of the fuel assemblies and control rods would usually be performed in the refuelling building, specific locations for equipment locations have not yet been determined.

Visual inspection of fuel assemblies is usually performed to establish the mechanical condition, gauge the crud levels and identify other abnormal performance conditions.

Leak testing of fuel assemblies is determined by either in-mast sipping during offloading from the reactor core or Vacuum Can sipping in the Refuelling building. Ultrasonic inspection of fuel assemblies identified as leaking may be performed to identify individual leaking fuel rods.

Other inspections of fuel assemblies may also be performed, such as gamma scanning, dimensional measurement, crud composition determination.

Inspections of fuel rods (removed from the fuel assembly using the fuel repair equipment) may be performed to either monitor performance or to determine the root cause of fuel rod failures. Inspections of fuel rods may consist of eddy current, ultrasound, length, gamma scanning and visual inspections. The fuel rod may also be packaged and sent to a hot cell facility for further inspections.

The Fuel Repair Equipment has the capability to disassemble fuel assemblies and remove/replace fuel rods. This is performed by removal of the top nozzle to allow access to the fuel rods, followed by subsequent removal of the fuel rods and replacement. The Fuel Repair Equipment could allow a damaged fuel assembly to then be handled or stored with no handling modifications and possibly acceptable for further use in the reactor.

The fuel rod is stored in the Spent Fuel Pool inside a suitable container. The defective fuel rod can be sent to a hot cell for further examination, stored in the Spent Fuel Pool until end of life, or loaded into a quiver, as described in Packaging of Damaged Spent Fuel [38]. Grossly damaged fuel assemblies can be placed into quivers to minimise particulate release and to allow normal handling.

The current baseline position is that damaged or failed fuel is assessed on a case-by-case basis.

The RR SMR design aims to minimise crud transport and deposition with the optimised selection of materials and water chemistry. So, less crud is expected than is seen on other Pressurised Water Reactors (PWRs). However, there is a strong drive to get the maximum power from the core which inevitably means sub-nucleate boiling, which favours crud deposition on the upper spans of the fuel.

The current baseline is to enter the reactor shutdown process without deliberately altering the reactor chemistry to induce a soluble and insoluble crud burst. This means that the fuel will retain crud from the previous cycle. Therefore, it is considered that ultrasonic cleaning of all fuel assemblies, which are returning to the RPV for the next cycle, may be required at each shutdown.

Ultrasonic cleaning of fully spent fuel assemblies, which cool in the Spent Fuel Pool for 6-10 years before being placed in dry storage, may have benefits. If crud flakes off the fuel and makes its way into the pool support system's filters, this is a more challenging filter change than if the crud is removed into an ultrasonic fuel cleaning filter which can be stored within the pool. However, if the crud is expected to be firmly adhered to the fuel, then ultrasonic cleaning of fully spent fuel may not be advisable.

A typical fuel cleaning system consists of a cleaning chamber (like a fuel rack) 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. High Efficiency Ultrasonic Fuel Cleaning systems can clean a fuel assembly in as little as 2.5 minutes.

9A.1.7.5 Materials

The description the materials selection process used for SSCs is presented in E3S Case Version 2, Tier 1, Chapter 23: Structural Integrity [1]. Materials will be confirmed in future versions of the generic E3S Case.

9A.1.7.6 System and Equipment Operation

A full analysis of the Testing System for Fuel Assemblies [FBA] System operation in all modes of operation will be conducted in future design phases leading to DRP2 to develop operating principles, these will be reported in Version 3 of the E3S Case.

9A.1.7.7 Radiological Aspects

During operation of the Testing System for Fuel Assemblies [FBA] System provides the safety function to maintain fuel assembly condition and provide cooling, preventing release of radioactive material to the environment.

Radiological consequences for fault sequences are described further in E3S Case Version 2, Tier 1, Chapter 15: Safety Analysis [6].

9A.1.7.8 Performance and Safety Evaluation

Compliance with Safety Categorised Functional Requirements

Verification and validation for the Testing System for Fuel Assemblies [FBA] System, to demonstrate compliance with their safety categorised functional requirements and associated non-functional performance requirements is under development.

Compliance with Non-Functional System Requirements

The non-functional system requirements are under refinement and the compliance to them will be presented in Version 3 of the generic E3S Case.

9A.1.7.9 ALARP, BAT, Secure by Design and Safeguards by Design

The evidence presented within [39] provides initial confidence that the Testing System for Fuel Assemblies [FBA] System can support the overall E3S targets for the SMR. Further work will be undertaken as the design develops and this will be reported in Version 3 of the E3S Case.

9A.1.8 Refuelling and Conveyance Systems [FC]

9A.1.8.1 System and Equipment Functions

The Refuelling and conveyance system for fuel and other reactor core internals [FC] System represents the conveyance system within reactor island for new fuel, spent fuel and other nuclear equipment.

It supports achievement of the Fundamental Safety Functions (FSFs) of Control of Reactivity (CoR), Control of Fuel Temperature (CoFT), Confinement of Nuclear Material (CoRM) and Control of Radiation Exposure (CoRE) during normal operation and fault conditions.

Layout details for The Refuelling and conveyance system for fuel and other reactor core internals [FC] System are presented in [5].

HLSFs for The Refuelling and conveyance system for fuel and other reactor core internals [FC] System and the PIEs against which they are assigned, are being derived in the Fault Schedule, which is presented in E3S Case Version 2, Tier 1, Chapter 15: Safety Analysis [6].

9A.1.8.2 Design Bases

Functional Requirements

Safety categorised functional requirements for The Refuelling and conveyance system for fuel and other reactor core internals [FC] System are specified based on the HLSFs they deliver, including the applicable plant states and operating modes, are presented in Table 9A.1-9 based on RR SMR requirements database [FC] module.

Table 9A.1-9:The Refuelling and conveyance system for fuel and other reactor core internals [FC] System Safety Categorised Functional Requirements

Requirement ID	Functional Requirement	Mode(s) of Operation	Safety Category
FC-R-1367	While in all modes of operation the Refuelling and Conveyance System for Fuel and Core Internals shall maintain Fuel Assembly condition during conveyance (CoRM)	All	A

The Refuelling and Conveyance System for Fuel and Core Internals system [FC] shall maintain Fuel Assembly condition during conveyance to ensure the FSF of CoRM.

The safety categorised functional requirements for The Refuelling and Conveyance System for Fuel and Core Internals system [FC] are flowed down and allocated to relevant sub-systems and/or components. Non-functional performance requirements associated with the safety categorised functional requirements are allocated in are allocated in the requirements database management system.

Non-Functional System Requirements

Non-functional system requirements are being developed and will be allocated to The Refuelling and Conveyance System for Fuel and Core Internals system [FC], based on the E3S design principles as described in E3S Case Version 2, Tier 1, Chapter 3: E3S Objectives and Design Rules for SSCs [8].

9A.1.8.3 E3S Classification

A full analysis of The Refuelling and Conveyance System for Fuel and Core Internals system [FC] operation in all modes of operation will be conducted in future design phases to develop operating principles, these will be reported in Version 3 of the E3S Case.

9A.1.8.4 Description

System for conveyance of fuel assemblies / internals within reactor area [FCJ]

Two cranes are provided within containment to support the conveyance of fuel assemblies and reactor components. These are the Main Overhead Crane (MOC) [FCJ10] and the in-containment FHM [FCJ70].

The MOC [FCJ10] is an electric overhead travelling crane positioned close to the top of the containment vessel. Long travel rails are supported by an elevated structure inboard of the steam generators, running north-south above the Refuelling Pool [FAF], Refuelling Cavity [FAF] and a laydown area on the ground floor of containment. A double girder bridge incorporates a pair of east-west running cross travel rails, which support the main crab.

The MOC main hoist will undertake heavy lifts of the main reactor components. These include lifting of the IHP from the Refuelling Cavity [FAE] to the ground floor laydown area and transfer of the RPV Upper Internals to the Refuelling Pool [FAF]. An auxiliary hoist is expected to provide the capability for smaller lifts over a slightly wider operating envelope, albeit still potentially constrained to the width of the pools between the steam generators.

The in-containment FHM [FCJ70] is a low-level bridge crane designed to operate over the Refuelling Pool [FAF] and Refuelling Cavity [FAE]. The tops of the pool structures are expected to support a pair of north-south running long travel rails, positioned immediately outboard of the flooded volume. A double girder bridge incorporates the east-west running cross travel rails, which support a crab. This arrangement enables the FHM crab to travel across the full area of the pools.

The FHM main hoist comprises a telescopic mast dedicated to fuel handling. The mast is raised and lowered by an electric wire rope hoist with a fuel assembly grab provided at its bottom end. In the fully raised position, fuel assemblies are withdrawn inside a fixed outer section of the mast to provide protection. The upper limit of travel for the main hoist ensures that fuel remains below a safe depth of shielding water. An auxiliary hoist is expected to support other mechanical handling requirements, including the deployment of tools for submerged operations within the refuelling pool and refuelling cavity. This is expected to include inspection, repair and disposal of reactor internal components.

As the cranes have a similar operating area, they are positioned so that the MOC can travel above the FHM and the FHM can move underneath the MOC. However, it is not expected that simultaneous operation of the cranes will be required, and appropriate interlocks are anticipated to protect against any potential interaction hazards (e.g. isolation of power supply in safe parked positions).

System for conveyance of fuel assemblies / internals between reactor and storage areas [FCK]

The System for conveyance of fuel assemblies / internals between reactor and storage areas [FCK] is used to transfer new, partially spent and spent fuel, as well as other reactor core components, between the Spent Fuel Storage and Cask Loading [FAB] System and the Refuelling Pool [FAF].

The [FCK] System comprises the Fuel Transfer Channel (FTC) [JMD PT253] and the fuel transfer system mechanical handling [PT15].

The Fuel Transport Container [JMD] provides containment of the water, which is required to keep the fuel submerged during transfer for heat removal, containment and shielding. Concrete is required around the FTC [JMD] to provide shielding to personnel inside and outside of containment.

System for conveyance of fuel assemblies / internals within storage area [FCL]

A number of mechanical handling systems are provided within the fuelling block to support import and export of fuel, as well as transfers of other equipment associated with the Spent Fuel Pool [FAB10]. These include the Spent Fuel Pool FHM [FCL10], the New Fuel Elevator [FCL20], the Cask Conveying System [FCL30] and additional Spent Fuel Pool cranes.

The Spent Fuel Pool FHM [FCL10] is a low-level bridge crane designed to operate over the Spent Fuel Pool [FAB10], Cask Loading Pit [FAB20] and Upender Pit [FAB40]. The tops of the main pool structures are expected to support a pair of east-west running long travel rails, positioned immediately outboard of the flooded volume. A double girder bridge incorporates the north-south running cross travel rails, which support a crab. This arrangement enables the FHM crab to travel across the combined area of the Spent Fuel Pool and pits.

9A.1.8.5 Materials

The description the materials selection process used for SSCs is presented in E3S Case Version 2, Tier 1, Chapter 23: Structural Integrity [1]. Materials will be confirmed in future versions of the generic E3S Case.

9A.1.8.6 Interfaces with Supporting Systems

The Refuelling and Conveyance System for Fuel and Core Internals system [FC] interfaces with the reactor core [JAC] and in-core monitoring system [JKS] as well as various sub-systems within the Handling of Nuclear Equipment System [F].

9A.1.8.7 System and Equipment Operation

The mechanical handling requirements in the fuelling block cover a wide range of operations including, but not limited to, unpacking of new fuel from transport containers, transfer of cask support equipment during loading with spent fuel and movement of gates that separate the Spent Fuel Pool [FAB10] and pits. A combination of additional cranes and other lifting equipment will complement the systems described in [5] to meet these requirements. The number, type and location of the Spent Fuel Storage and Cask Loading [FAB] System cranes is to be confirmed as the design of the interfacing systems develops, this will be reported in Version 3 of the E3S Case.

Further details are contained within [40] and [41].

9A.1.8.8 Instrumentation and Control

The Instrumentation and Control for The Refuelling and Conveyance System for Fuel and Core Internals system [FC] is under development and will be reported in Version 3 of the E3S Case.

9A.1.8.9 Monitoring, Inspection, Testing & Maintenance

A Monitoring, Inspection, Testing & Maintenance regime will be developed for The Refuelling and Conveyance System for Fuel and Core Internals system [FC] and will be reported in Version 3 of the E3S Case.

9A.1.8.10 Radiological Aspects

Radiological protection requirements are applied through the design process and analysis of these will be carried out in line with the maturity of the design. Performance and Safety Evaluation

Compliance with Safety Categorised Functional Requirements

Verification and validation for The Refuelling and Conveyance System for Fuel and Core Internals system [FC] to demonstrate compliance with its safety categorised functional requirements and associated non-functional performance requirements is under development.

Compliance with Non-Functional System Requirements

The non-functional system requirements are still to be completed and the compliance to them will be presented in Version 3 of the generic E3S Case.

9A.1.8.11 ALARP, BAT, Secure by Design and Safeguards by Design

The evidence presented within [42] provides initial confidence that The Refuelling and Conveyance System for Fuel and Core Internals system [FC] can support the overall E3S targets for the SMR. Further work will be undertaken as the design develops and this will be reported in Version 3 of the E3S Case.

9A.1.9 External storage of Spent Fuel [FD]

9A.1.9.1 System and Equipment Functions

The External storage of Spent Fuel [FD] system represents all systems used for the storage of spent fuel and other nuclear equipment outside of the reactor island.

It supports achievement of the Fundamental Safety Functions (FSFs) of Control of Reactivity (CoR), Control of Fuel Temperature (CoFT), Confinement of Nuclear Material (CoRM) and Control of Radiation Exposure (CoRE) during normal operation and fault conditions.

Layout details for External storage of Spent Fuel [FD] are currently under development and will be presented in Version 3 of the E3S Case.

HLSFs for the External storage of Spent Fuel [FD] system and the PIEs against which they are assigned, are being derived in the Fault Schedule, which is presented in E3S Case Version 2, Tier 1, Chapter 15: Safety Analysis [6].

9A.1.9.2 Design Bases

Functional Requirements

Safety categorised functional requirements for the External storage of Spent Fuel [FD] system are specified based on the HLSFs they deliver, including the applicable plant states and operating modes, are presented in Table 9A.1-10 based on based on RR SMR requirements database [FD] module.

Table 9A.1-10: External storage of Spent Fuel [FD] System Safety Categorised Functional Requirements

Requirement ID	Functional Requirement	Mode(s) of Operation	Safety Category
FD-R-1374	While in all modes of operation the External Temporary Storage of Spent Fuel Assemblies [FD] shall provide shielding	All	A
FD-R-1378	While in all modes of operation the External Temporary Storage of Spent Fuel Assemblies [FD] shall provide control of reactivity	All	A
FD-R-1381	While in all modes of operation the External Temporary Storage of Spent Fuel Assemblies [FD] shall provide confinement	All	A
FD-R-1383	While in all modes of operation the External Temporary Storage of Spent Fuel Assemblies [FD] shall transfer heat from fuel during cask storage	All	A

The External storage of Spent Fuel [FD] system ensures the FSFs of CoFT, CoR, CoRE and CoRM.

The safety categorised functional requirements for the External storage of Spent Fuel [FD] system are flowed down and allocated to relevant sub-systems and/or components. Non-functional performance requirements associated with the safety categorised functional requirements are allocated in are allocated in the requirements database management system.

Non-Functional System Requirements

Non-functional system requirements are being developed and will be allocated to The External storage of Spent Fuel [FD] system, based on the E3S design principles as described in E3S Case Version 2, Tier 1, Chapter 3: E3S Objectives and Design Rules for SSCs [8].

9A.1.9.3 E3S Classification

A full analysis of The External storage of Spent Fuel [FD] system operation in all modes of operation will be conducted in future design phases leading to DRP2 to develop operating principles, these will be reported in Version 3 of the E3S Case.

9A.1.9.4 Description

Current design information for The External storage of Spent Fuel [FD] system is presented in [5]. The design is maturing and further details will be presented in Version 3 of the E3S Case.

9A.1.9.5 Materials

The description the materials selection process used for SSCs is presented in E3S Case Version 2, Tier 1, Chapter 23: Structural Integrity [1]. Materials will be confirmed in future issues of the generic E3S Case.

9A.1.9.6 Interfaces with Supporting Systems

The interfaces with supporting systems are currently under development and will be reported in Version 3 of the E3S Case.

9A.1.9.7 System and Equipment Operation

External dry storage of filled casks [FDB]

Spent fuel is moved to dry storage casks after 6-10 years' cooling underwater in the Spent Fuel Pool [FAB10]. Control rods and other fuel inserts are located within fuel assemblies where required.

The Spent Fuel Store is located away from reactor island, outside of the berm. The [FDB] System will house all the spent fuel arisings and Non-Fuel In-Core Components (NFCC) that have been cooled (as required) and packaged within the [FAB] System. Spent fuel continues to cool in dry storage as further radiological decay occurs. The spent fuel will remain in the Spent Fuel Store until the Geological Disposal Facility (GDF) is available and it meets the acceptance criteria. It is noted that repackaging may be required before final GDF disposal.

Design of the External storage of Spent Fuel [FD] system is currently under development and further details of normal and faulted operations will be presented in Version 3 of the E3S Case.

9A.1.9.8 Instrumentation and Control

The Instrumentation and Control for the External storage of Spent Fuel [FD] system is under development and will be reported in Version 3 of the E3S Case.

9A.1.9.9 Monitoring, Inspection, Testing & Maintenance

A Monitoring, Inspection, Testing & Maintenance regime will be developed for the External storage of Spent Fuel [FD] system and will be reported in Version 3 of the E3S Case.

9A.1.9.10 Radiological Aspects

Radiological protection requirements are applied through the design process and analysis of these will be carried out in line with the maturity of the design. Performance and Safety Evaluation

Compliance with Safety Categorised Functional Requirements

Verification and validation for the External storage of Spent Fuel [FD] system to demonstrate compliance with its safety categorised functional requirements and associated non-functional performance requirements is under development.

Compliance with Non-Functional System Requirements

The non-functional system requirements are still to be completed and the compliance to them will be presented in Version 3 of the generic E3S Case.

9A.1.9.11 ALARP, BAT, Secure by Design and Safeguards by Design

The evidence presented within [5] provides initial confidence that the External storage of Spent Fuel [FD] system can support the overall E3S targets for the SMR. Further work will be undertaken as the design develops and this will be reported in Version 3 of the E3S Case.

9A.1.10 Erection or in-service inspection system [FJ]

9A.1.10.1 System and Equipment Functions

The Erection or in-service inspection system [FJ], represents all systems used for the erection or in-service inspection of the reactor vessel, reactor vessel closure head and reactor vessel internals. It is currently under development and further details will be presented in Version 3 of the E3S Case.

9A.1.11 Decontamination system [FK]

9A.1.11.1 System and Equipment Functions

The Decontamination system [FK] represents all systems used for decontamination.

It supports achievement of the Fundamental Safety Functions (FSFs) of Control of Reactivity (CoR), Control of Fuel Temperature (CoFT), Confinement of Nuclear Material (CoRM) and Control of Radiation Exposure (CoRE) during normal operation and fault conditions.

Layout details for the Decontamination System [FK] are under development and will be presented in Version 3 of the E3S Case.

HLSFs for the Decontamination System [FK] and the PIEs against which they are assigned, are being derived in the Fault Schedule, which is presented in E3S Case Version 2, Tier 1, Chapter 15: Safety Analysis [6].

9A.1.11.2 Design Bases

Functional Requirements

Safety categorised functional requirements the Decontamination System [FK] are specified for based on the HLSFs they deliver, including the applicable plant states and operating modes, are presented in Table 9A.1-11 based on RR SMR requirements database [FK] module.

Table 9A.1-11: The Decontamination System [FK] Safety Categorised Functional Requirements

Requirement ID	Functional Requirement	Mode(s) of Operation	Safety Category
FK-R-1285	While in all modes of operation the Decontamination System [FK] shall provide control of reactivity	All	A
FK-R-1278	While in all modes of operation the Decontamination System [FK] shall ensure confinement of radioactive material	All	A
FK-R-1282	While in all modes of operation the Decontamination System [FK] shall enable removal of heat	All	A

The Decontamination System [FK] ensures the FSFs of CoFT, CoR and CoRM.

The safety categorised functional requirements for The Decontamination System [FK] are flowed down and allocated to relevant sub-systems and/or components. Non-functional performance requirements associated with the safety categorised functional requirements are allocated in are allocated in the requirements database management system.

Non-Functional System Requirements

Non-functional system requirements are being developed and will be allocated to The Decontamination System [FK], based on the E3S design principles as described in E3S Case Version 2, Tier 1, Chapter 3: E3S Objectives and Design Rules for SSCs [8].

9A.1.11.3 E3S Classification

A full analysis of the Decontamination System [FK] operation in all modes of operation will be conducted in future design phases to develop operating principles, these will be reported in Version 3 of the E3S Case.

9A.1.11.4 Description

Component Decontamination System [FKA]

The FKA system decontaminates small to medium components from the Reactor Island, with the following characteristics:

- Components include small equipment, such as pumps and valves, as well as tools used during normal operation and maintenance of the plant.
- Contamination below or close to the low level waste threshold (< 4 GBq alpha and <12 GBq beta and gamma per tonne). Activity levels will be kept low by in-situ flushing of components during operation.
- Activity arising from surface contamination only.

The FKA system shall decontaminate components for reuse or offsite disposal. Disposal facilities shall provide contamination specifications at a later stage in design.

Further details of the [FK] sub-systems are under development and will be reported in Version 3 of the E3S Case.

9A.1.11.5 Materials

The description the materials selection process used for SSCs is presented in E3S Case Version 2, Tier 1, Chapter 23: Structural Integrity [1]. Materials will be confirmed in future Versions of the generic E3S Case.

9A.1.11.6 Interfaces with Supporting Systems

Interfaces for the Decontamination system [FK] are presented in in [5].

9A.1.11.7 Performance and Safety Evaluation

Compliance with Safety Categorised Functional Requirements

Verification and validation for the decontamination system [FK] to demonstrate compliance with its safety categorised functional requirements and associated non-functional performance requirements is under development.

Compliance with Non-Functional System Requirements

The non-functional system requirements are still to be completed and the compliance to them will be presented in Version 3 of the generic E3S Case.

9A.1.11.8 ALARP, BAT, Secure by Design and Safeguards by Design

The evidence presented within [5] provides initial confidence that the decontamination system [FK] can support the overall E3S targets for the SMR. Further work will be undertaken as the design develops and this will be reported in Version 3 of the E3S Case.

9A.1.12 Fuel route control and instrumentation [FY]

9A.1.12.1 System and Equipment Functions

The Fuel route control and instrumentation [FY] System will carry out the process measurement, monitoring and control of the [F] System plant. This shall be achieved through several Programmable Electronic Systems (PES) which are likely to be Programable Logic Controller (PLC) based. It is currently under development and further details will be presented in Version 3 of the E3S Case.

9A.2 Water Systems

9A.2.1 Main Cooling Water System

9A.2.1.1 System and Equipment Functions

The primary function of the Main Cooling Water System (MCWS) [PA] is to provide the duty heat sink for the Steam Turbine System [MA] which forms part of the duty heat sink for the Steam Generation System [JE]. The MCWS is an indirect system utilising evaporative heat transfer via wet cooling towers to reject waste heat. The MCWS is divided into two separate trains, each train operates independently and provides 50 % of the baseline cooling. Each train contains a row of multiple Mechanical Draft Cooling Towers (MDCT) and circulating pumps. The circulating pumps share a common suction pit which is the single cross-connection between the two trains. The cooling fluid is treated sea water which is provided by the Auxiliary Cooling and Make-up System (ACMS) [PE]. The Main Cooling Water System [PA] supports achievement of the FSFs of CoFT during normal operation and fault conditions.

Layout details for the Main Cooling Water System [PA] are presented in the system design description [43].

HLSFs for the MCWS and PIEs against which they are assigned, are being derived in the Fault Schedule, which is presented in E3S Case Version 2, Tier 1, Chapter 15: Safety Analysis [6].

9A.2.1.2 Design Bases

Functional Requirements

Safety categorised functional requirements Main Cooling Water System [PA] are specified for based on the HLSFs they deliver, including the applicable plant states and operating modes, are presented in Table 9A.2-1 based on RR SMR requirements database [PA] module.

Table 9A.2-1: [PA] System Safety Categorised Functional Requirements

Requirement ID	Functional Requirement	Mode(s) of Operation	Safety Category
PA-R-1506	The Main Cooling Water System [PA] shall transfer heat from the Steam turbine system [MA]	All modes	C
PA-R-1510	The Main Cooling Water System [PA] shall discharge heat to the external environment [EXT-NE]	All modes	C

The Main Cooling Water System [PA] provides CoFT FSFs.

The safety categorised functional requirements for are flowed down and allocated to relevant sub-systems and/or components. Non-functional performance requirements associated with the safety categorised functional requirements are allocated in the RR SMR requirements database [PA] module.

Non-Functional System Requirements

Non-functional system requirements are being developed and will be allocated to Main Cooling Water System [PA] based on the E3S design principles as described in E3S Case Version 2, Tier 1, Chapter 3: E3S Objectives and Design Rules for SSCs [8].

9A.2.1.3 E3S Classification

Safety Classification

The MCWS [PA] is the principal means by which the Category C function of transferring heat from the steam turbine condensers [MAG] is achieved. Therefore, the highest classification of components that support this function within the system is Class 3.

Environment, Security and Safeguards Classification

No environment, security, or safeguards classification is assigned at RD7/DRP1.

Seismic Classification

The seismic classification of MCWS [PA] is to be classified in accordance with the RR SMR Seismic Performance Classification Method [9].

9A.2.1.4 Description

The MCWS consists of two independent trains that circulate cooling water between the system cooling towers and the turbine condensers. The circuit is as follows:

- The circulating water is pumped by the MCWS Pumping System through the turbine condensers and then to the Mechanical Draft Cooling Towers.
- The water enters the MDCT where it is sprayed under pressure across a heat transfer surface. Air flow across the heat transfer surface is mechanically generated by fans counter-current to the spray direction, which cools the water as it falls into the cooling tower basin.
- The circulating water falls from the cooling towers into the cooling water basin where it flows back to the main circulation pumps.

Each MCWS train provides 50 % of the total system cooling and consists of two vertical turbine pumps and 20 cooling tower cells. The pumped fluid is sea water concentrated to a maximum of approximately 1.4 times normal concentration. Biocide and corrosion inhibitor are also added to the seawater to support system maintenance and to prevent biofouling, a health and safety hazard being generated through the use of evaporative cooling, e.g., Legionella control. It should be noted that the risk posed by Legionella is lower for seawater systems.

Each MCWS train also has an online cleaning system that maintains the condition of the turbine condenser, and a full-stream filter before the main circulation pumps to remove debris from the circulating seawater.

The MCWS is provided with make-up water by the ACMS which is supplied to the cooling tower basins. The make-up water supply provides a constant source of makeup water to replace water lost through evaporation and drift in the cooling tower and from the blowdown. To maintain water quality and prevent the build-up of dissolved and suspended solids the MCWS constantly returns a volume of concentrated cooling water to the ACMS, this is referred to as blowdown.

The MCWS comprises of the following sub-systems:

- Cooling Tower System [PAD], which contains 40 counterflow induced draft wet cooling tower cells and provides the system heat rejection to the environment
- Pump System [PAC], which consist of four 11 kV Vertical Turbine Pumps (VTP), drawing cooling water from the common pump suction pit, and the system filters
- Piping System [PAB], consisting of pipework to transport cooling flow around the MCWS circuit
- Condenser Cleaning System [PAH], which maintains heat transfer across the Steam Turbine Condensers by cleaning the condensers tubes
- Control and Protection system [PAY].

9A.2.1.5 Materials

The MCWS circulation pipework will be made from High Density Polyethylene (HDPE). This pipework includes the Main Circulation Pump inlet suction pit supply which will also be made from HDPE.

The [PAH] cleaning balls are slightly oversized and made from a rubber material and require some force from the cooling water to push through the condenser tubes. This provides a wiping action against the inner tube walls.

Cooling Tower fill (heat transfer surface) is made from PVC.

9A.2.1.6 Interfaces with Supporting Systems

The MCWS interfaces with the Steam Turbine System [MA] at the Steam Turbine Condenser [MAG] water box inlet and outlet flanges. Interfaces are identified and managed within the sub-system requirements specifications modules in the RR requirements management database.

9A.2.1.7 System and Equipment Operation

The overarching operational principles for the RR SMR are covered in the Power Station Operating Philosophy [44].

A full analysis of the Main Cooling Water System [PA] has been conducted to develop the Main Cooling Water System [PA] operating philosophy. The operating philosophy defines the key claims and operational sequences and actions the system is required to undertake, and the key claims made on the operator or automated actions. The operating philosophy also supports ongoing Human Factors and safety assessments.

The operation of the Main Cooling Water System [PA] during the six operating modes is described in the system design description [43].

The key operational cooling requirements in the MCWS are to remove excess heat from the steam turbine system and transfer it to the external environment. In the below modes, the information and values are considered in typical operating conditions, ambient temperature wet bulb 10 °C with a dry bulb of 15 °C. As per the Generic Site Envelope for the UK [17], the average seawater temperature will be 12.5 °C with maximum and minimum sea water temperatures of 32.3 °C and -1.8 °C respectively. The PA system will modify its operating processes as air temperature and cooling water temperature vary.

Faults

Key system faults for the Main Cooling Water System [PA] are:

- Loss of ACMS
- Loss of pump
- Loss of filter in the cooling tower basins.

A high-level overview of the Main Cooling Water System [PA] alignment and functionality during faulted operations is presented in section 3 of the system design description [43].

9A.2.1.8 Instrumentation and Control

The Instrumentation and Control for the MCWS is covered by the Main Cooling Water System Control & Instrumentation system [PAY]. The CWI Control and Protection System [PY] and its Control & Instrumentation (C&I) architecture is detailed in [45].

9A.2.1.9 Monitoring, Inspection, Testing & Maintenance

Key EMIT activities for the Main Cooling Water System [PA] have been identified in are presented in the system design description [43]. Further EMIT definition will be developed as the MCWS subsystem design progresses beyond RD7/DRP1 and will be reported in Version 3 of the E3S Case.

9A.2.1.10 Radiological Aspects

The Main Cooling Water System [PA] is not expected to encounter radiation and is therefore not considered to require shielding. The majority of [PA] is located on the Cooling Water Island site which is currently assumed to be 500 m from the main SMR site, with the exception of [PAH] and most of [PAB]. The circulating water through the MCWS will not be radioactive during any SMR operating conditions.

9A.2.1.11 Performance and Safety Evaluation

Compliance with Safety Categorised Functional Requirements

Performance analysis demonstrates how the Main Cooling Water System [PA] design meets the non-functional performance requirements associated with the key system functions. Key outputs of the calculation completed are consumer heat removal requirements and system sizing are presented in [43], with the suite of performance analysis for bounding fault conditions that place safety categorised functional requirements on the Main Cooling Water System [PA] presented in E3S Case Version 2, Tier 1, Chapter 15: Safety Analysis [6].

Compliance with Non-Functional System Requirements

The non-functional system requirements are still to be completed and the compliance to them will be presented in Version 3 of the generic E3S Case.

9A.2.1.12 ALARP, BAT, Secure by Design and Safeguards by Design

HAZID has been completed for the Cooling Water Island and this covers the MCWS in its scope. The relevant outputs from this HAZID have been incorporated into the [PA] requirements. The MCWS [PA] system has the following protection barriers in place for the identified external hazards:

- Ice and Cooling Water Temperature – utilisation of trace heating in the above ground cooling tower spray nozzle supply pipework, and cooling tower spray nozzle bypass lines into the cooling tower basins

- Redundancy in systems and components where possible.

9A.2.2 Component Cooling System

9A.2.2.1 System and Equipment Functions

The primary function of the Component Cooling System (CCS) [KAA] is to circulate coolant to transfer waste heat from consumer reactor island fluid systems and components to the Essential Service Water System (ESWS) cooling towers [PBD] during all modes of plant operation. The baseline architecture for the CCS consists of two independent cross-connected cooling trains, each containing an expansion tank and associated pipework and valves, which are connected to corresponding ESWS cooling tower cells. It supports achievement of the FSFs of CoFT, during normal operation and fault conditions.

Layout details for the Component Cooling System (CCS) [KAA] are presented in the system design description [46].

HLSFs for the Component Cooling System (CCS) [KAA], and the PIEs against which they are assigned, are being derived in the Fault Schedule, which is presented in E3S Case Version 2, Tier 1, Chapter 15: Safety Analysis [6].

9A.2.2.2 Design Bases

Functional Requirements

Safety categorised functional requirements for the Component Cooling System (CCS) [KAA] are specified based on the HLSFs they deliver, including the applicable plant states and operating modes, are presented in Table 9A.2-2: [KAA] System Safety Categorised Functional Requirements Table 9A.2-2 based on [47].

Table 9A.2-2: [KAA] System Safety Categorised Functional Requirements

Requirement ID	Functional Requirement	Mode(s) of Operation	Safety Category
KAA-R-1457	While the reactor coolant system (RCS) is pressurised, and in faulted operation, the Component Cooling System [KAA] shall circulate demineralised water between the Cold Shutdown Cooling System [JNA] and the Essential Service Water System [PBD].	Modes 4-4b	B
KAA-R-3316	While the RCS is de-pressurised and open to atmosphere, and in faulted operation, the Component Cooling System [KAA] shall circulate demineralised water between the Cold Shutdown Cooling System [JNA] and the Essential Service Water System [PBD].	Modes 4-6a	B
KAA-R-1968	While in Power Operations [Mode 1] and the Spent Fuel Pool Cooling System [FAK] is undergoing maintenance. If a Spent Fuel Pool Cooling System [FAK] cooling train fails THEN the Component Cooling System [KAA] shall circulate demineralised water between the Cold Shutdown Cooling System [JNA] and the Essential Service Water System [PBD].	Mode 1	B
KAA-R-3318	While in faulted operation, the Component Cooling System [KAA] shall circulate demineralised water between the Spent Fuel Cooling System [FAK] and the Essential Service Water system [PBD].	All modes	B
KAA-R-1506	While in faulted operation, the Component Cooling System [KAA] shall circulate demineralised water between the Chilled Water System [KJ_] and the Essential Service Water system [PBD].	All modes	B
KAA-R-2402	While in faulted operation, the Component Cooling System [KAA] shall circulate demineralised water between the High Pressure Injection System [JND] and the Essential Service Water system [PBD].	All modes	B
KAA-R-3306	While in normal shutdown, the Component Cooling System [KAA] shall circulate demineralised water between the Cold Shutdown Cooling System [JNA] and the Essential Service Water System [PBD].	Modes 4b-6a	C

Requirement ID	Functional Requirement	Mode(s) of Operation	Safety Category
KAA-R-1458	While in normal operation, the Component Cooling System [KAA] shall circulate demineralised water between the Spent Fuel Cooling System [FAK] and the Essential Service Water system [PBD].	All modes	C
KAA-R-3345	While in normal operation, the Component Cooling System [KAA] shall circulate demineralised water between the Chilled Water System [KJ_] and the Essential Service Water system [PBD].	All modes	C
KAA-R-1435	While in normal operation, the Component Cooling System [KAA] shall circulate demineralised water between the Coolant Purification System [KBE] Cooler and the Essential Service Water system [PBD].	All modes	C
KAA-R-1393	While in normal operation, the Component Cooling System [KAA] shall circulate demineralised water between the Active Liquid Sampling System [KUA] and the Essential Service Water system [PBD].	All modes	C
KAA-R-1411	While in normal operation, the Component Cooling System [KAA] shall transfer fluid between the Gaseous Media Sampling System [KUF] and the Essential Service Water system [PBD].	All modes	C
KAA-R-2260	While in normal operation, the Component Cooling System [KAA] shall circulate demineralised water between the Waste Treatment System [KNF] and the Essential Service Water system [PBD].	All modes	C
KAA-R-2353	While in normal operation, the Component Cooling System [KAA] shall circulate demineralised water between the Collection and Drainage System [KTA] and the Essential Service Water system [PBD].	All modes	C
KAA-R-1361	While in normal operation, the Component Cooling System [KAA] shall circulate demineralised water between the Reactor Coolant Pumps [JEB] and the Essential Service Water System [PBD].	Modes 1-4a	C
KAA-R-3383	While in faulted operation, the Component Cooling System [KAA] shall isolate the containment boundary.	All modes	A

Requirement ID	Functional Requirement	Mode(s) of Operation	Safety Category
KAA-R-2588	The Component Cooling System [KAA] shall control the flow of process chemicals from the Chemicals Supply System [QC_].	All modes	C
KAA-R-2582	The Component Cooling System [KAA] shall control the flow of demineralised water to the Auxiliary Sampling System [KUB].	All modes	C

The safety categorised functional requirements for [KAA] are flowed down and allocated to relevant sub-systems and/or components. Non-functional performance requirements associated with the safety categorised functional requirements are allocated in the RR SMR requirements database [KAA] module.

Non-Functional System Requirements

Non-functional system requirements allocated to Component Cooling System [KAA] based on the E3S design principles as described in E3S Case Version 2, Tier 1, Chapter 3: E3S Objectives and Design Rules for SSCs [8], at RD7/DRP1 are summarised in Table 9A.2-3.

Table 9A.2-3: [KAA] Non-Functional System Requirements

Requirement ID	Non-Functional System Requirement
KAA-R-2425	Where the design baseline for redundancy requires redundancy in capacity through increased number of trains, the designer shall ensure the trains are sufficiently diverse, so as to not undermine the redundant capacity upon failure of operating train.

Non-functional system requirements are still being developed and will be allocated to Component Cooling System [KAA] based on the E3S design principles as described in E3S Case Version 2, Tier 1, Chapter 3: E3S Objectives and Design Rules for SSCs [8].

9A.2.2.3 E3S Classification

Safety Classification

The functional safety classification of the system is driven by the bounding Category of the heat removal functions, which is Category B, for circulating coolant to Fuel Pool Cooling System (FPCS) [FAK], Cold Shutdown Cooling System (CSCS) [JNA], High Pressure Injection System (HPIS) [JND] and Chilled Water System (CWS) [KJ_]. Therefore, the highest classification of components that support this function within the system is Class 2.

Environment, Security and Safeguards Classification

No environment, security, or safeguards classification is assigned at RD7/DRP1.

Seismic Classification

The seismic classification of Component Cooling System [KAA] is to be classified in accordance with the RR SMR Seismic Performance Classification Method [9].

9A.2.2.4 Description

The baseline architecture for the CCS consists of two independent cross-connected cooling trains, each containing an expansion tank and associated pipework and valves, which are connected to corresponding ESWS cooling tower cells.

Both trains include a centrifugal pump to circulate coolant to the consumer heat exchangers. Heated coolant is returned and circulated to the ESWS cooling towers [PBD] where waste heat is rejected to the atmosphere.

An additional pump is incorporated in Train 2, with cross-connect to Train 1, to provide sufficient system availability when a pump is down for maintenance.

Each train may remove all necessary heat through a single heat exchanger in the Cold Shutdown [JNA], High Pressure Injection [JND], Chilled Water [KJ] and Fuel Pool Cooling [FAK] systems, because these systems support Category B Safety Functions, for which [N+1] redundancy is considered appropriate.

Pressure relief valves are located on the supply lines to each consumer to protect against over pressurisation due to ingress of fluid to the CCS [KAA] caused by a failure at the interface (such as heat exchanger tube failure) or due to thermal expansion of locked fluid when coolant supply to the consumer system is isolated. There is an additional pressure relief valve on the consumer return cross-connect line to protect against overpressure of the system in the event of incorrect valve alignment.

A sampling line interfacing with the Auxiliary Sampling System [KUB] is incorporated on the pump discharge line for each cooling train to enable analysis of the system chemistry.

Inline manual control valves exiting each pump are provided to allow the cooling train flowrates to be attenuated, based on the prevailing system pressure losses at the time of operation, to ensure the pumps can operate at close to their best efficiency point.

Recirculation lines via a chemical dosing pot and the header tanks enable manual dosing for chemistry control of the system and also provide a route for potential pump flow testing within the inactive train.

All consumer systems have flow regulation that is set and remains fixed for the entirety of power operations, until the next outage, to balance the CCS [KAA] flowrates to match the consumer heat loads. Consumers outside containment have manual control valves and those inside containment have remote operated control valves (to reduce potential requirements for containment entry) for this purpose.

The system also has a connection to the Collection and Drainage System [KTA] for collection of fluid during let-down of coolant inventory from the system. Demineralised water is supplied from the Demineralised Water Supply System [GHC] via header tank, which are open to the atmosphere, but which may be isolated in the event of a leak of primary coolant through closure of the header tank isolation valves.

These connections with the Collection and Drainage System [KTA] also allow the return and control of active fluid in the event of leakage of primary fluid from a tube rupture within a consumer system. This may either be initiated by pressure relief valves lifting in response to consequent system overpressure or by remote opening of the active collection isolation valve in response to levels of activity being monitored within the CCS [KAA] fluid system.

Bypass lines and flow control valves are provided across the hot and cold legs in each cooling train to allow the flowrate through the cooling towers to be reduced in abnormally cold weather conditions to prevent over-cooling of the CCS [KAA] and consumer systems.

Instrumentation is provided to allow monitoring of the cooling train flowrates, supply and return temperatures to the cooling towers, header tank level indication and gamma radiation monitoring.

Key performance and design parameters for the system are presented in

Table 9A.2-4.

Table 9A.2-4: [KAA] Key Performance and Design Parameters

Parameter	Value	Units
Maximum operating pressure	{REDACTED}	MPa(a)
Maximum operating temperature	{REDACTED}	°C
Design pressure	{REDACTED}	MPa
Design temperature	{REDACTED}	°C
Maximum cooling duty (at mode 4b shutdown) - both trains	{REDACTED}	MW
Maximum cooling duty (at mode 4b shutdown) - single train	{REDACTED}	MW
Maximum flowrate through pump	{REDACTED}	kg/s

9A.2.2.5 Materials

The majority of the material is carbon steel, used to construct the pipework for the cooling trains, supply and return pipework to the consumer heat exchangers and ESWS [PBD] cooling towers, and the key components, such as valves and pumps. The Functional Bill of Materials for the CCS [KAA] [48] [48] provide material specification for system components.

9A.2.2.6 Interfaces with Supporting Systems

Interfaces for the CCS [KAA] are identified and managed within the requirements specification module of the system in RR SMR requirements management database.

9A.2.2.7 System and Equipment Operation

The overarching operational principles for the Reactor Island are covered in the Reactor Plant Operating Philosophy [10].

A full analysis of the Main Cooling Water System [PA] has been conducted to develop the Component Cooling System [KAA] operating philosophy. The operating philosophy defines the key claims and operational sequences and actions the system is required to undertake, and the key claims made on the operator or automated actions. The operating philosophy also supports ongoing Human Factors and safety assessments.

The operation of the Component Cooling System [KAA] during the six operating modes is described in [48].

Faults

Key system faults for the CCS [KAA] are:

- Loss of single coolant train
- Loss of all coolant trains
- Loss of system inventory
- Ingress of inventory due to failure of consumer heat exchanger.

A high-level overview of the Component Cooling System [KAA] alignment and functionality during faulted operations is presented in section 3 of the system design description [46] [46].

9A.2.2.8 Instrumentation and Control

To support the safe operation and control of the Component Cooling System [KAA], the EC&I system will also be required to provide alarms and warnings to indicate that key system parameters are outside of the defined performance bands and/or safety limits.

A list of alarms related to instrumentation present on the Component Cooling System [KAA] at 100% full power, can be seen in Table 3 of the system design description [49].

To support the safe operation and control of the CCS [KAA], the Reactor C&I system is required to support the following control functions:

- Continuous functions:
    - Levels in header tanks (Cat C)
- Automatic functions:
    - Demin water supply isolation valves open below low level in header tanks (Cat C)
    - Changeover from duty to standby cooling train if duty pump stops (Cat B)
- Operator instigated functions:
    - Containment isolation valves open or closed on action from operator (Cat A)

  - Cat B consumer isolation valves open or closed on action from operator (Cat B)
  - Cat C consumer isolation valves open or closed on action from operator (Cat C)
  - In-containment consumer control valve positions changed on action from operator (Cat C)
  - Coolant pumps turned on or off on action from operator (Cat B)
  - Cooling train bypass control valve positions adjusted on action from operator (Cat C)
  - Cooling train isolation valve positions adjusted on action from operator (Cat B)
  - Sampling isolation valves open or closed on action from operator (Cat C)
  - Drainage isolation valves open or closed on action from operator (Cat C)
  - Demin water supply isolation valves open or closed on action from operator (Cat C)
- Interlocks:
  - Demin water supply isolation valves closed above high header tank level (Cat C)
- Automatic trips:
  - Coolant pumps trip on high high bearing temperature (Cat C)
  - Coolant pumps trip on high high motor winding temperature (Cat C)
  - Coolant pumps trip on status = fault (Cat B)
  - Duty Coolant pump trips on duty cooling train valve closure (Cat B)
  - Duty Coolant pump trips on duty cooling train low low flow rate (Cat B)
  - Demin water isolation valves close on sensed radiation above limit of detection (Cat B).

9A.2.2.9 Monitoring, Inspection, Testing & Maintenance

The Component Cooling System [KAA] has a Through Life Analysis (TLA) module in the RR requirements management database populated with all known maintenance tasks (in line with design maturity), specific to the system environment and the operating context. The maintenance activities considered in the TLA include:

- Safety derived tasks (ISI)
- Design derived tasks (Supplier provided)
- Reliability derived tasks (RCM/Preventative Maintenance)
- Industry best Practice/OPEX (EPRI PMBD)
- Non-PBS (Module, Site Facility).

An assessment has been performed to determine the philosophy for performing maintenance on a Component Cooling System [KAA] coolant pump. The Component Cooling System [KAA] is required to function in all plant modes of operation and therefore it is assumed that Component Cooling System [KAA] pump maintenance will be performed during Powered Operations [mode 1] when a single cooling train is in operation and the labour to perform the maintenance is at less of a premium than during an outage.

A standby pump is incorporated within Train 2 with cross-connect to Train 1 to maintain provision of redundancy for Safety Cat B functions while one pump is down for maintenance. i.e. the system routinely operates on a 1oo3 pump basis, which then reduces to 1oo2 when maintenance is taking place.

9A.2.2.10 Radiological Aspects

A radiation assessment has not yet been completed for the Component Cooling System [KAA]; it will not manage radioactive material during normal operation. The management of leaks of active material into the system, and therefore shielding requirements, will be considered in as design develops beyond DRP1.

9A.2.2.11 Performance and Safety Evaluation

Compliance with Safety Categorised Functional Requirements

Verification and validation for the CCS [KAA] to demonstrate compliance with its safety categorised functional requirements and associated non-functional performance requirements is under development.

Performance analysis demonstrates how the CCS [KAA] design meets the non-functional performance requirements associated with the key system functions. Key outputs of the calculation competed are consumer heat removal requirements and system sizing are presented in [46], with the suite of performance analysis for bounding fault conditions that place safety categorised functional requirements on the CCS [KAA] presented in E3S Case Version 2, Tier 1, Chapter 15: Safety Analysis [6].

Compliance with Non-Functional System Requirements

The non-functional system requirements are still to be completed and the compliance to them will be presented in Version 3 of the generic E3S Case.

9A.2.2.12 ALARP, BAT, Secure by Design and Safeguards by Design

The CCS [KAA] supports a number of duty and safety measures and therefore needs to provide sufficient reliability to meet, where applicable, the duty and/or safety reliability targets of the Rolls-Royce SMR. To determine whether the safety measures meet the reliability targets assigned to them, a study of all claimed Structures, Systems and Components (SSC) within the safety measures is needed. Reliability estimates, presented in [46]Reliability estimates, presented in [46], provide preliminary confidence in the development of a robust and reliable system design, and aid in the identification for any design risks that could compromise the overall reliability of parent operations or safety measures.

To support plant safety measures:

- Redundancy is provided for each of the Category B functions by the Component Cooling System [KAA] having an interface to each system from each of two cooling trains. The Component cooling System [KAA] cooling trains are cross-connected so that cooling can be provided from either train to either of the consumer heat exchangers.

- A third pump is incorporated in the system to enable maintenance of a pump during powered operations and retain a standby pump for provision of cooling to the Category B functions.

Design decisions made to comply with RGP and OPEX include:

- use centrifugal pump to circulate coolant

- use elevated header tank to maintain coolant pressure in system

- use of demineralised water coolant transported in pipes to provide and transport coolant.

Radiation detection is included on the common return line from consumer heat exchangers for each train of the Component Cooling System [KAA]. If radiation is sensed above the limit of detection of the sensors, an alarm on the HMI will alert operators to ingress of contaminated fluid from an interfacing system.

9A.2.3 Essential Service Water System

9A.2.3.1 System and Equipment Functions

The ESWS [PB] is the Heat Sink for the Reactor Island Component Cooling System (CCS) [KAA] which is responsible for providing cooling to equipment within the reactor island. The ESWS has two independent and separated trains, positioned to the nominal north and south of the reactor building, with one redundant for safety-related operations. Each train consists of multiple mechanical draft closed cooling towers, with at least one redundant cooling tower in each train. The cooling towers use potable-quality water as their make-up supply. It supports achievement of the FSF of CoFT during normal operation and fault conditions.

Layout details for ESWS [PB] are presented in the system design description [50].

HLSFs for ESWS [PB], and the PIEs against which they are assigned, are being derived in the Fault Schedule, which is presented in E3S Case Version 2, Tier 1, Chapter 15: Safety Analysis [6].

9A.2.3.2 Design Bases

Functional Requirements

Safety categorised functional requirements for ESWS [PB] are specified based on the HLSFs they deliver, including the applicable plant states and operating modes, are presented in Table 9A.2-5 based on [50].

Table 9A.2-5: [PB] System Safety Categorised Functional Requirements

Requirement ID	Functional Requirement	Mode(s) of Operation	Safety Category
P-PB-1179	ESWS shall distribute heat from the Component Cooling System (KA) to the Natural Environment (EXT-NE)	All modes	B
P-PB-1397	ESWS shall have a secondary barrier between the Natural Environment and source of radioactive contamination	All modes	C

It is assumed that contamination is present in small amounts in the heat exchangers of consumers that are cooled by the CCS. Therefore, the ESWS is required to provide a secondary barrier to radiation release.

The safety categorised functional requirements for ESWS [PB] are flowed down and allocated to relevant sub-systems and/or components. Non-functional performance requirements associated with the safety categorised functional requirements are allocated in [51].

Non-Functional System Requirements

The transverse requirements derived from the E3S design principles are fed into the system by way of the safety measures in which this system is claimed. The following are applied to this system by JN04:

- LTDHR shall support a probability of failure on demand lower than 10E-2 / demand
- LTDHR shall remain operable during and following all relevant hazards
- LTDHR shall remove residual heat without reliance on essential services supplied from on-site mobile equipment for 72 hours
- LTDHR shall remove residual heat without reliance on essential services supplied from off-site mobile equipment for 168 hours.

Non-functional system requirements are still being developed and will be allocated to ESWS [PB] based on the E3S design principles as described in E3S Case Version 2, Tier 1, Chapter 3: E3S Objectives and Design Rules for SSCs [8].

9A.2.3.3 E3S Classification

Safety Classification

The ESWS [PB] is the principal means by which the Category B function of distributing heat from the Component Cooling System is achieved. Therefore, the highest classification of components that support this function within the system in Class 2.

Environment, Security and Safeguards Classification

No environment, security, or safeguards classification is assigned at RD7/DRP1.

Seismic Classification

The seismic classification of The Essential Service Water System [PB] is to be classified in accordance with the RR SMR Seismic Performance Classification Method [9].

9A.2.3.4 Description

The primary function of the system is to provide the duty heat sink for the Reactor Island Component Cooling System (CCS) [KAA]. The CCS in turn is the duty heat sink for several systems within the Reactor Island, including the Reactor Coolant Pumps [JEB], Cold Shutdown Cooling System [JNA] and Spent Fuel Cooling System [FAK]. The CCS uses demineralised water as its coolant, with additives such as corrosion inhibitors. The coolant is routed through a pipe from the reactor island basement, under the site boundary road and then surfaces close to the cooling towers. The supply separates at a manifold and each pipe is routed into a heat exchanger that is integral to each cooling tower where the coolant is cooled via conduction. The pipes then exit the cooling towers, recombine at another manifold and are routed back to the reactor island along the same path.

There are nine cooling towers in each train and these are independent, identical units. They are wet, closed and induced draft towers. This means they are designed to only reject heat while in contact with spray water, have an integral heat exchanger which separates the coolant from the natural environment, and they use a fan at the top of the cooling tower to draw air through the tower to increase the rate of evaporation. The spray pump conveys water from the cooling tower basin through spray nozzles. These spray water over a fill, which increases the evaporation surface area and cools the spray water. The spray water then falls onto the stainless-steel heat exchanger and extracts heat from the coolant. It then falls back into the cooling tower's basin.

9A.2.3.5 Materials

The make-up water tank design is expected to be constructed from stainless steel sheets that are connected on site.

The cooling tower heat exchanger will be made of stainless steel. The cooling tower body material is likely to be stainless steel to increase its lifespan.

9A.2.3.6 Interfaces with Supporting Systems

Interfaces for the ESWS [PB] are identified and managed within the requirements specification module of the system in RR SMR requirements management database. The interfaces of the ESWS are described in Table 9A.2-6.

Table 9A.2-6: [PB] Interfaces

System	Primary Exchange Medium	Peak Value (per train)
Component Cooling System [KA]	Coolant Water Heat	{REDACTED} {REDACTED}
Common Systems for the Cooling Water Systems [PU]	Water Treatment Chemicals	{REDACTED} (Biocide)
Treated Water Distribution Systems [GH]	Make-up Water	{REDACTED}

System	Primary Exchange Medium	Peak Value (per train)
Waste Water Drainage and Treatment Systems [GM]	Blowdown Water (outlet) Demin Plant Effluent (inlet)	{REDACTED} {REDACTED}
Diagnostic Systems [CD]	Diagnostic Information Signals	N/A
Low Voltage Essential AC Standby Supply System [BK]	Electrical Power	{REDACTED}
Voltage Main AC Supply System for Process Equipment [BF]	Electrical Power Low	{REDACTED}
Low Voltage Uninterruptible DC Supply System for Safety Services [BQ]	Electrical Power	{REDACTED}
Reactor Protection and Accident Management Systems [JR]	Control Signals (Class 2)	N/A
ESWS Control & Instrumentation (C&I) System [PBY]	Control Signals (Class 3)	N/A
Structures for the Essential Service Water System [UPJ]	Support / Restraint	N/A

9A.2.3.7 System and Equipment Operation

The overarching operational principles for the Reactor Island are covered in the Reactor Plant Operating Philosophy [10].

The operation of the ESWS during the six operating modes is described in the system design description [50].

The operational requirements of the ESWS depend primarily on three variables: the heat input from the CCS, whether this is from a single train or from both trains and the ambient Wet Bulb temperature. The ESWS is required to operate across all operational modes.

The reactor’s operating mode is largely independent from the ambient temperature, therefore the differences between the operating modes is primarily relevant only due to the change in thermal input. When the thermal input is below the peak level, the ESWS will switch off some cooling tower fans and/or switch entire cooling towers off to reduce its electrical demands.

Commercial cooling towers are often drained and deactivated during winter months because they are surplus to requirements while external temperatures are cold. The ESWS will not typically do this and instead aim to have at least 8 cooling towers available per train at all times. This allows for one set of design basis temperatures to be used all year round, rather than seasonally varying the design basis temperatures.

Faults

Faulted operations are being developed and will be described in Version 3 of the generic E3S case.

9A.2.3.8 Instrumentation and Control

The ESWS's Control System [PBY] will control the ESWS across all modes and will be able to vary the operation of all of its primary functions. Changes in operating mode and fault scenarios in the reactor island affect the ESWS only with regards to the thermal load received from the CCS, and the control system will continue controlling to its setpoint, adapting to meet the changing demand without operator intervention.

9A.2.3.9 Monitoring, Inspection, Testing & Maintenance

The ESWS is required to operate across all operational modes and there is no time for which the entire ESWS can be turned off for maintenance. The current maintenance strategy for the ESWS is to perform intrusive maintenance wherever possible during the colder part of the year. This is when fewer cooling towers are typically needed to perform its duty function. This will be carried out as a rolling plan of maintenance with each tower on a train being removed from service for intrusive maintenance and inspection works, always maintaining 8 in service per train.

Key expected Examination, Maintenance and Testing (EMIT) activities include:

- Safety derived tasks (ISI)
- Design derived tasks (Supplier provided)
- Reliability derived tasks (RCM/Preventative Maintenance)
- Industry best Practice/OPEX (EPRI PMBD)
- Non-PBS (Module, Site Facility).

Key identified EMIT tasks and their frequency are tabulated in [50].

9A.2.3.10Radiological Aspects

The Essential Service Water System [PB] is not expected to encounter radiation and is therefore not considered to require shielding. It is located outside of the reactor island and the water circulating through the ESWS will not be radioactive in normal operations. In the event of contaminated water being sent to the ESWS in the CCS pipes, this will be heavily diluted and not near to operators. The Component Cooling System has radiation detectors to allow intervention if this occurs. Further, there is radiation monitoring in the cooling towers to allow intervention if it also leaks into the towers. Leaks will be detected by testing to see if the corrosion inhibitor that is present in the CCS circuit is present in the cooling tower basin. The corrosion inhibitor will be Sodium Molybdate and the basins will be tested several times per week by operators with a Colorimeter. This was considered during the ESWS HAZOP, with this measure forming part of the EMIT of the heat exchanger to ensure they maintain containment.

9A.2.3.11 Performance and Safety Evaluation

Compliance with Safety Categorised Functional Requirements

Verification and validation for the ESWS [PB] to demonstrate compliance with its safety categorised functional requirements and associated non-functional performance requirements is under development.

Performance analysis is to be conducted to demonstrate how the ESWS [PB] design meets the non-functional performance requirements associated with the key system functions. The suite of performance analysis for bounding fault conditions that place safety categorised functional requirements on the ESWS is presented in E3S Case Version 2, Tier 1, Chapter 15: Safety Analysis [6].

Compliance with Non-Functional System Requirements

The non-functional system requirements are still to be completed and the compliance to them will be presented in Version 3 of the generic E3S Case.

9A.2.3.12 ALARP, BAT, Secure by Design and Safeguards by Design

Essential Service Water System [PB] has redundancy incorporated into its design which means it can operate in degraded modes without compromising the safety function. Both the CCS and ESWS have 2 x 100 % train redundancy for safety operations and the CCS has a cross connection such that either ESWS train can be used with either CCS train. Within each ESWS train, there is N+1 redundancy for cooling towers based on peak thermal duty and ambient temperatures. In colder conditions, this level of redundancy is increased. Further, loss of additional cooling towers beyond the design basis does not cause a total loss of function of the train, rather the return temperature to the CCS will increase beyond the normal safety limits.

Trace heaters and immersion heaters will be provided as an ALARP measure to ensure that the ESWS will continue to be functional during freezing conditions and to prevent damage without heat from the CCS. This does not increase the peak electrical usage of the ESWS because the heaters will never be used at the same time as the fans and spray pumps.

All of the ESWS is expected to be uncontaminated at the end of plant service life and suitable for disposal through conventional routes. The pipes and heat exchangers should not have contacted contaminated material throughout their service life; however, it is foreseeable that this may happen if an up-stream fault occurs. If contamination has occurred, the choice of a stainless-teel heat exchanger means that the decontamination process will encounter fewer difficulties than other potential heat exchanger materials.

Additionally, a design decision was made on the ESWS chemistry to utilise biocide, anti-scalant and corrosion inhibitor to reduce the risk of biofouling, scaling and corrosion respectively. This ensures more reliable performance and operation and will therefore reduce risk of failure and allow the heat exchanger to continue to perform its safety function.

9A.2.4 Auxiliary Cooling and Make-Up System

9A.2.4.1 System and Equipment Functions

The primary functions of the ACMS [PE] system are to provide and remove cooling water from the Turbine Island Closed Cooling Water System (TI-CCWS) heat exchanger(s) to remove heat, provide make-up water to the Main Cooling Water System (MCWS) and remove various wastewater from site and discharge to the natural environment. The ACMS is claimed as part of safety measure JN03 for the duty heat sink. It supports achievement of the FSF of CoFT during normal operation and fault conditions.

Layout details for the ACMS [PE] are presented in [52].

HLSFs for ACMS [PE], and the PIEs against which they are assigned, are being derived in the Fault Schedule, which is presented in E3S Case Version 2, Tier 1, Chapter 15: Safety Analysis [6].

9A.2.4.2 Design Bases

Functional Requirements

Safety categorised functional requirements for ACMS [PE] are specified based on the HLSFs they deliver, including the applicable plant states and operating modes, are presented in Table 9A.2-7 based on [53].

Table 9A.2-7: [PE] System Safety Categorised Functional Requirements

Requirement ID	Functional Requirement	Mode(s) of Operation	Safety Category
PE-R-1497	The Auxiliary Cooling and Make-up System [PE] shall regulate intake flow from Structures for cooling water systems [UP]	Modes 1-4b	C
PE-R-1491	The Auxiliary Cooling and Make-up System [PE] shall filter water.	Modes 1-4b	C
PE-R-1489	The Auxiliary Cooling and Make-up System [PE] shall distribute concentrated cooling water.	Modes 1-4b	C
PE-R-1502	The Auxiliary Cooling and Make-up System [PE] shall supply water to the Main Cooling Water System [PA].	Modes 1-4b	C
PE-R-1598	The Auxiliary Cooling and Make-up System [PE] shall supply water to the Turbine Island Closed Cooling Water System [PG].	Modes 1-4b	C

The safety categorised functional requirements for ACMS [PE] are flowed down and allocated to relevant sub-systems and/or components. Non-functional performance requirements associated with the safety categorised functional requirements are allocated in the RR SMR requirements management database.

Non-Functional System Requirements

Non-functional system requirements are still being developed and will be allocated to ACMS [PE] based on the E3S design principles as described in E3S Case Version 2, Tier 1, Chapter 3: E3S Objectives and Design Rules for SSCs [8].

9A.2.4.3 E3S Classification

Safety Classification

The PE system is allocated a bounding Category C safety functionality and so the overall system class is expected to be Class 3.

Environment, Security and Safeguards Classification

No environment, security, or safeguards classification is assigned at RD7/DRP1.

Seismic Classification

The seismic classification of the ACMS [PE] is to be classified in accordance with the RR SMR Seismic Performance Classification Method [9].

9A.2.4.4 Description

The ACMS system operates by way of a sub-sea intake head drawing cooling water from the natural environment, transported via a single intake tunnel to a forebay. The system then transfers the water through a debris and fish filtration system for dual use in firstly cooling Turbine Island Heat Exchangers and secondly delivery to the cooling tower basins to be made available as make-up water for the MCWS. Blowdown water which is to be removed from the system is then transported from the cooling tower basin to the outfall pond where, with other wastewater streams, it is discharged back to the natural environment via an outfall tunnel and outfall structure.

The ACMS system consist of the following sub-systems:

- Auxiliary Cooling and Make-up System Intake and Filtration System [PEA], which utilises a single intake head to extract sea water and transfer it via the intake tunnel to the forebay. The intake head will prevent large debris from entering the structure through the use of physical protection (coarse bars at entrance of intake head) and maximise the opportunity for marine life to escape being drawn in with the water, by using a low velocity side entrance intake head.

- Auxiliary Cooling and Make-up System Pump System {PEC}

- Auxiliary Cooling and Make-up System Piping, Online Cleaning and Make-up Water Systems [PEB /PER/PEH/PES]

9A.2.4.5 Materials

The preferred pipe material is HDPE. The key benefits of HDPE over other commonly used pipe materials are its strong resistance against corrosion and long life. HDPE pipes are easier to install and require very low maintenance.

9A.2.4.6 Interfaces with Supporting Systems

Interfaces for the ACMS [PE] are identified and managed within the requirements specification module of the system in RR SMR requirements management database.

9A.2.4.7 System and Equipment Operation

The overarching operational principles for the RR SMR are covered in the Power Station Operating Philosophy [44].

The operation of the ACMS [PE] during the six operating modes is described in the system design description in [52] .

Faults

Key system faults identified for the ACMS [PE] are:

- Loss of filter
- Loss of pump.

A high-level overview of the ACMS [PE] response during faulted operations is presented in section 3 of the system design description [52].

9A.2.4.8 Instrumentation and Control

The Instrumentation and Control for the Auxiliary Cooling and Make-up System [PE] is covered by the Cooling Water Island Control & Protection [PY]. The CWI Control and Protection System [PY] and its Control & Instrumentation (C&I) architecture is detailed in [45].

9A.2.4.9 Monitoring, Inspection, Testing & Maintenance

Key expected Examination, Maintenance and Testing (EMIT) activities include:

- Safety derived tasks (ISI)
- Design derived tasks (Supplier provided)
- Reliability derived tasks (RCM/Preventative Maintenance)
- Industry best Practice/OPEX (EPRI PMBD)
- Non-PBS (Module, Site Facility).

Key identified EMIT tasks and their frequency are tabulated in [52].

9A.2.4.10 Radiological Aspects

The Auxiliary Cooling and Make-up System [PE] is expected to encounter radiation by the KNF waste stream through the PES sub system only. In particular, the outfall pond, outfall tunnel and outfall head (diffuser) will be exposed to this waste stream. It is currently expected that the waste will be very low-level activity, that can be discharged to the natural environment without further dilution (within site discharge permits) and that no additional shielding is required. This requirement will be monitored as the assessment has not yet taken place and the demands on the PE system will be further defined as KNF matures beyond DRP1.

The ACMS is located away on the Cooling Water Island site which is currently assumed to be 500 m from the main RR SMR site. The circulating water from intake [PEA] through the ACMS up to the outfall pond [PES] will not be active during any RR-SMR operating conditions.

9A.2.4.11 Performance and Safety Evaluation

Compliance with Safety Categorised Functional Requirements

Verification and validation for the ACMS [PE] to demonstrate compliance with its safety categorised functional requirements and associated non-functional performance requirements is under development.

Performance analysis is to be conducted to demonstrate how the ACMS [PE] design meets the non-functional performance requirements associated with the key system functions. The suite of performance analysis for bounding fault conditions that place safety categorised functional requirements on the ACMS is presented in E3S Case Version 2, Tier 1, Chapter 15: Safety Analysis [6].

Compliance with Non-Functional System Requirements

The non-functional system requirements are still to be completed and the compliance to them will be presented in Version 3 of the generic E3S Case.

9A.2.4.12 ALARP, BAT, Secure by Design and Safeguards by Design

Redundancy and additional safety measures have been incorporated to reduce single point of failure risk. Potential initiating events that may cause loss of AMCS function and the associated redundancy, standby and additional safety measures include:

- Failure of the ACMS filtration system – the filtration system is split into two channels, each containing coarse bar screen with trash rake and fine filters. The system is designed to operate requiring only one of these channels to be operational.

- Failure of ACMS pump system – the pump system contains two 100 % pumps, with one pump operating on duty and the second pump operating as a standby pump.

- Pipe rupture – the pipe layout is yet to be determined, but where practical, redundant routes will be incorporated into the design as this is recognised as good practice in pipe network design. This allows delivery of cooling water through the system during maintenance or the flexibility to isolate damaged routes without requiring shutdown.

- Loss of electrical supply - the ACMS pumphouse will be supplied by two 11kV power supplies, for redundancy where the first power supply will supply train 1 items and the second supply supplying train 2 items.

Where possible, the PE system has been designed to include standby and redundant systems.

9A.2.5 Common Systems for Cooling Water Systems

9A.2.5.1 System and Equipment Functions

The Common Systems for Cooling Water Systems [PU] is a subsystem of the Cooling Water Systems [P]. The Common Systems provide water treatment services to the cooling processes within cooling water island. The architecture of the Cooling Water Island is such that the PU system is broken up into two arms; that which provides cooling to the power conversion process via the turbine condenser [MAG], and that which cools the Reactor Island Component Cooling System [KAA]. The Common Systems for Cooling Water Systems [PU] supports achievement of the FSF of Control CoFT during normal operation and fault conditions.

Layout details for the Common Systems for Cooling Water Systems [PU] are presented in [54].

HLSFs for Common Systems for Cooling Water Systems [PU] and the PIEs against which they are assigned, are being derived in the Fault Schedule, which is presented in E3S Case Version 2, Tier 1, Chapter 15: Safety Analysis [6].

9A.2.5.2 Design Bases

Functional Requirements

Safety categorised functional requirements for the Common Systems for the Cooling Water System [PU] are specified based on the HLSFs they deliver, including the applicable plant states and operating modes, are presented in Table 9A.2-8 based on [54].

Table 9A.2-8: [PU] System Safety Categorised Functional Requirements

Requirement ID	Functional Requirement	Mode(s) of Operation	Safety Category
PU-R-1458	The Common Systems for the Cooling Water System [PU] shall treat cooling water as part of the Cooling Water Systems [P].	All modes	C

The safety categorised functional requirements for Common Systems for the Cooling Water System [PU] are flowed down and allocated to relevant sub-systems and/or components. Non-functional performance requirements associated with the safety categorised functional requirements are allocated in the RR requirements management database.

Non-Functional System Requirements

Non-functional system requirements are still being developed and will be allocated to Common Systems for the Cooling Water System [PU] based on the E3S design principles as described in E3S Case Version 2, Tier 1, Chapter 3: E3S Objectives and Design Rules for SSCs [8].

9A.2.5.3 E3S Classification

Safety Classification

The Common Systems for Cooling Water Systems [PU] is allocated a bounding Category C safety functionality and so the overall system class is expected to be Class 3.

Environment, Security and Safeguards Classification

No environment, security, or safeguards classification is assigned at DRP1. This system is likely to have a degree of environmental importance given total residual oxidant discharge levels are closely monitored and permitted.

Seismic Classification

The seismic classification of the Common Systems for Cooling Water Systems [PU] is to be classified in accordance with the RR SMR Seismic Performance Classification Method [9].

9A.2.5.4 Description

The architecture of the common systems follows the pattern of delineation of the major systems, and this results in a set of water treatment systems for the ESWS [PB] and a separate set of systems which treat both MCWS [PA] and ACMS [PE]. The three systems within PU are as follows:

- Biocide Systems for Cooling Water Systems [PUL], which controls biological growth in the ESWS, MCWS, and ACMS. In the ESWS, this is achieved by dosing Sodium Hypochlorite and Sodium Bromide as biocide into the make-up water storage tanks and the make-up water pipework. In the MCWS and ACMS, Sodium Hypochlorite will be dosed into the MCWS cooling tower basins, the MCWS pump suction pit, and the ACMS pump suction bay downstream of the fine filtration stage.

- Anti-Scalant Systems for Cooling Water System [PUQ], which minimises scale build-up. Bespoke polymer blends will be used for the anti-scalants and these will be selected on a site-by-site basis. It should be noted that there is no interface between PUQ and the ACMS.

- Corrosion Inhibitor Systems for Cooling Water Systems [PUT], which minimises corrosion. As with PUQ, bespoke polymer blends will be used for the corrosion inhibitors which will be selected on a site-by-site basis. Again, there is no interface between PUT and the ACMS.

As there are two branches of PU split between the main SMR site and the CWI site, the systems listed above are further divided into several sub-systems.

9A.2.5.5 Materials

Sodium Hypochlorite has been selected as the preferred biocide for the MCWS and ACMS.

The solution selected for the anti-scalant dosing systems for the MCWS and ESWS is bespoke vendor polymer blends which are to be selected on a site-specific basis. Similarly, bespoke polymer blends to be selected on a site-specific basis will be used as the corrosion inhibitor in the MCWS and the ESWS.

Where possible, recyclable materials will be used in the PU system, and regular maintenance will be carried out during operations to ensure that the equipment can be recycled at the end of its operational life.

9A.2.5.6 Interfaces with Supporting Systems

Interfaces for the Common Systems for Cooling Water Systems [PU] are identified and managed within the requirements specification module of the system in RR SMR requirements management database.

9A.2.5.7 System and Equipment Operation

The overarching operational principles for the RR SMR are covered in the Power Station Operating Philosophy [44].

The operation of the Cooling Water Systems [PU] during the six operating modes is described in the system design description.

Faults

Key system faults identified for the Common Systems for Cooling Water Systems [PU] are:

- Failure of chemical dosing pump
- Chemical storage tank rupture.

A high-level overview of the Common Systems for Cooling Water Systems [PU] response during faulted operations is presented in section 3 of the system design description [54].

9A.2.5.8 Instrumentation and Control

For the branch of PU supply chemical treatment to the MCWS and ACMS, the control system [PY] provides duty control and instrumentation.

The Instrumentation and Control for the MCWS and ACMS, and therefore for the PA dosing system is covered by the Cooling Water Island Control & Protection System [PY]. The Instrumentation and Control for the ESWS, and therefore for the PB dosing system is covered by the Essential Services Water System Control & instrumentation system [PBY].

The sampling and monitoring of cooling water in the MCWS and ESWS, and the subsequent adjustments to the chemical dosing flowrates in each system will largely be automated. However, in some instances manual sampling may be done by operators to ensure the required water quality is being maintained, for example when the MCWS cooling tower basins are being filled and there is no flow through the circulation pipework.

9A.2.5.9 Monitoring, Inspection, Testing & Maintenance

Key expected Examination, Maintenance and Testing (EMIT) activities include:

- Safety derived tasks (ISI)
- Design derived tasks (Supplier provided)
- Reliability derived tasks (RCM/Preventative Maintenance)
- Industry best Practice/OPEX (EPRI PMBD)
- Non-PBS (Module, Site Facility).

Key identified EMIT tasks and their frequency are tabulated in [54].

9A.2.5.10 Radiological Aspects

The PU system will not encounter radiation. The branch of PU which provides chemical treatment to the ESWS is located outside of Reactor Island on the main SMR site, and the branch of PU which provides chemical treatment to the MCWS and ACMS is located on the Cooling Water Island site, approximately 500 m away from the main SMR site.

9A.2.5.11 Performance and Safety Evaluation

Compliance with Safety Categorised Functional Requirements

Verification and validation for the Common Systems for Cooling Water Systems [PU] to demonstrate compliance with its safety categorised functional requirements and associated non-functional performance requirements is under development.

Performance analysis is to be conducted to demonstrate how the Common Systems for Cooling Water Systems [PU] design meets the non-functional performance requirements associated with the key system functions. The suite of performance analysis for bounding fault conditions that place safety categorised functional requirements on the PU is presented in E3S Case Version 2, Tier 1, Chapter 15: Safety Analysis [6].

Compliance with Non-Functional System Requirements

The non-functional system requirements are still to be completed and the compliance to them will be presented in Version 3 of the generic E3S Case.

9A.2.5.12 ALARP, BAT, Secure by Design and Safeguards by Design

Redundancy is built into the system to account for pump failure.

If any of the chemical storage tanks within PU were to fail then this would result in loss of function for PU, as full chemical treatment could not be provided. However, loss of chemical treatment would for the MCWS, ACMS, or ESWS, would not result in an immediate loss of system.

Sodium hypochlorite with sodium bromide addition was selected on the basis of conventional health and safety, reliability and available RGP as it is widely used across many industries. Sodium hypochlorite is also expected to be the lowest cost option based on operating experience from both operators and chemical vendors. Bespoke polymer blends were selected for the anti-scalants and the corrosion inhibitors because the site-specific water quality can have a profound effect on the active ingredients required to provide adequate protection to the system. Polymers were selected over other available options primarily on an environmental basis as most other chemistry packages contain phosphorus or zinc, which have environmental consequences and are restricted in discharge permits by the EA.

There is a risk that additional chemical dosing will be required in the outfall pond which will increase the size and scope of PU. However, this risk is relatively low impact as it will require an additional tank and dosing pumps which will not induce any significant additional cost or footprint on CWI.

Where possible, recyclable materials will be used in the PU system, and regular maintenance will be carried out during operations to ensure that the equipment can be recycled at the end of its operational life. All environmental requirements will be maintained until the system is no longer required, including meeting all permit and regulatory requirements. All chemicals have been subjected to the RR SMR optioneering process prior to use during operations, and these will be reviewed to meet decommissioning requirements.

9A.3 Process Auxiliary Systems

9A.3.1 Reactor Island Sampling System

9A.3.1.1 System and Equipment Functions

At DRP1 the process auxiliary systems are limited to the Reactor Island Sampling System [KU]. The Reactor Island Sampling system [KU] comprises of:

- Nuclear Sampling System [KUA]
- Auxiliary Sampling System [KUB]
- Process and Emissions Radiation Monitoring System [KUK].

It supports achievement of the Fundamental Safety Functions (FSFs) of Control of Reactivity (CoR), Control of Fuel Temperature (CoFT), Confinement of Nuclear Material (CoRM) and Control of Radiation Exposure (CoRE) during normal operation and fault conditions.

Layout details for the Nuclear Sampling System [KUA], the Auxiliary Sampling System [KUB] and the Process and Emissions Radiation Monitoring System [KUK] are presented in a [55], [56] and [57].

HLSFs for the Reactor Island Sampling system [KU] and the PIEs against which they are assigned, are being derived in the Fault Schedule, which is presented in E3S Case Version 2, Tier 1, Chapter 15: Safety Analysis [6].

9A.3.1.2 Design Bases

Functional Requirements

Safety categorised functional requirements for the Reactor Island Sampling system [KU] are being developed based on the HLSFs they deliver, including the applicable plant states and operating modes, they will be presented in Version 3 of the E3S Case.

The safety categorised functional requirements for the Reactor Island Sampling system [KU] will be flowed down and allocated to relevant sub-systems and/or components. Non-functional performance requirements associated with the safety categorised functional requirements are allocated in are allocated in the requirements database management system.

Non-Functional System Requirements

Non-functional system requirements are being developed and will be allocated to The Reactor Island Sampling system [KU], based on the E3S design principles as described in E3S Case Version 2, Tier 1, Chapter 3: E3S Objectives and Design Rules for SSCs [8].

9A.3.1.3 E3S Classification

A full analysis of The Reactor Island Sampling system [KU] operation in all modes of operation will be conducted in future design phases to develop operating principles, these will be reported in Version 3 of the E3S Case.

9A.3.1.4 Description

Current design information for Nuclear Sampling System [KUA], the Auxiliary Sampling System [KUB] and the Process and Emissions Radiation Monitoring System [KUK] are presented in a [55], [56] and [57].

The design is maturing and further details will be presented in Version 3 of the E3S Case.

9A.3.1.5 Materials

The description the materials selection process used for SSCs is presented in E3S Case Version 2, Tier 1, Chapter 23: Structural Integrity [1]. Materials will be confirmed in Version 3 of the generic E3S Case.

9A.3.1.6 Interfaces with Supporting Systems

The interfaces with supporting systems are currently under development and will be reported in Version 3 of the E3S Case.

9A.3.1.7 System and Equipment Operation

Operational details are being developed and will be presented in Version 3 of the E3S Case.

9A.3.1.8 Instrumentation and Control

The Instrumentation and Control for the Reactor Island Sampling system [KU] is under development and will be reported in Version 3 of the E3S Case.

9A.3.1.9 Monitoring, Inspection, Testing & Maintenance

A Monitoring, Inspection, Testing & Maintenance regime will be developed for the Reactor Island Sampling system [KU] and will be reported in Version 3 of the E3S Case.

9A.3.1.10 Radiological Aspects

Radiological protection requirements are applied through the design process and analysis of these will be carried out in line with the maturity of the design. Performance and Safety Evaluation

Compliance with Safety Categorised Functional Requirements

Verification and validation for the Reactor Island Sampling system [KU] to demonstrate compliance with its safety categorised functional requirements and associated non-functional performance requirements is under development.

Compliance with Non-Functional System Requirements

The non-functional system requirements are still to be completed and the compliance to them will be presented in Version 3 of the generic E3S Case.

9A.3.1.11 ALARP, BAT, Secure by Design and Safeguards by Design

The evidence presented within [55], [56] and [57] provides initial confidence that the Reactor Island Sampling system [KU] can support the overall E3S targets for the SMR. Further work will be undertaken as the design develops and this will be reported in Version 3 of the E3S Case.

9A.4 Air and Gas Systems

Air and Gas Systems for RR SMR are currently under development and will be reported in Version 3 of the E3S Case.

The air and gas systems will include compressed air and service gas systems.

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

9A.5.1 Heating, Ventilation, Air Conditioning Systems Serving Controlled Areas and Uncontrolled Areas of Reactor Island

9A.5.1.1 System and Equipment Functions

The Heating, Ventilation, Air Conditioning (HVAC) Systems Serving Controlled Areas and Uncontrolled Areas of Reactor Island [KL] provide heating, ventilation and air-conditioning for the controlled and uncontrolled contamination areas within the Reactor Island. The KL systems condition and supply air to the Reactor Island to maintain air quality, provide a pressure cascade through the building, maintain required conditions for both processes and occupants, and capture, transport and filter any airborne contamination. The KL systems provide a supporting function to other EC&I or mechanical plant within Reactor Island, and contribute to CoRM FSF, however, the failure of the KL systems does not directly threaten a fundamental safety function.

Layout details for the KL systems are presented in [58].

HLSFs for KL systems and the PIEs against which they are assigned, are being derived in the Fault Schedule, which is presented in E3S Case Version 2, Tier 1, Chapter 15: Safety Analysis [6].

9A.5.1.2 Design Bases

Functional Requirements

Safety categorised functional requirements for KL systems are specified based on the HLSFs they deliver, including the applicable plant states and operating modes, are presented in Table 9A.5-1 based on RR SMR requirements database.

Table 9A.5-1: [KL] System Safety Categorised Functional Requirements

Requirement ID	Functional Requirement	Mode(s) of Operation	Safety Category
KL-R-1301	The HVAC Systems Serving Controlled Areas and Uncontrolled Areas in Reactor Island shall control the temperature of the spaces within the Reactor Island	All modes	A
KL-R-1247	The HVAC Systems Serving Controlled Areas and Uncontrolled Areas in Reactor Island shall supply air to all areas of the Reactor Island	All modes	C
KL-R-1290	The HVAC Systems Serving Controlled Areas and Uncontrolled Areas in Reactor Island shall extract air from all areas of the Reactor Island	All modes	C

Requirement ID	Functional Requirement	Mode(s) of Operation	Safety Category
KL-R-1294	The HVAC Systems Serving Controlled Areas and Uncontrolled Areas in Reactor Island shall control intake air temperature	All modes	C
KL-R-1295	The HVAC Systems Serving Controlled Areas and Uncontrolled Areas in Reactor Island shall filter the intake air	All modes	C
KL-R-1296	The HVAC Systems Serving Controlled Areas and Uncontrolled Areas in Reactor Island shall remove water droplets from the intake air	All modes	C
KL-R-1298	The HVAC Systems Serving Controlled Areas and Uncontrolled Areas in Reactor Island shall filter the supply air	All modes	C
KL-R-1300	The HVAC Systems Serving Controlled Areas and Uncontrolled Areas in Reactor Island shall transfer conditioned air from the plant room to the spaces within Reactor Island.	All modes	C
KL-R-1302	The HVAC Systems Serving Controlled Areas and Uncontrolled Areas in Reactor Island shall control the air pressure in Reactor Island	All modes	C
KL-R-1303	The HVAC Systems Serving Controlled Areas and Uncontrolled Areas in Reactor Island shall extract contaminated air from the controlled areas of Reactor Island.	All modes	C
KL-R-1305	The HVAC Systems Serving Controlled Areas and Uncontrolled Areas in Reactor Island shall transfer contaminated air from the controlled areas within Reactor Island to the discharge stack	All modes	C
KL-R-1307	The HVAC Systems Serving Controlled Areas and Uncontrolled Areas in Reactor Island shall filter contaminated exhaust air	All modes	C
KL-R-1308	The HVAC Systems Serving Controlled Areas and Uncontrolled Areas in Reactor Island shall discharge contaminated air to the stack	All modes	C

The safety categorised functional requirements for KL systems are flowed down and allocated to relevant sub-systems and/or components. Non-functional performance requirements associated with the safety categorised functional requirements are allocated in RR SMR requirements database.

Non-Functional System Requirements

Non-functional system requirements are still being developed and will be allocated to the KL systems based on the E3S design principles as described in E3S Case Version 2, Tier 1, Chapter 3: E3S Objectives and Design Rules for SSCs [8].

9A.5.1.3 E3S Classification

Safety Classification

All systems supporting normal operation of the safety categorised C&I equipment are class 3.

The Control Room endurance habitability system function is assigned safety category A to match the highest safety category of the control and monitoring functions being managed within the control rooms, and therefore, designated safety classification 1.

Normal operation cooling for the control is class 3. The systems supporting cooling equipment powered by the diesel generators shall be safety class 2. The systems supporting cooling equipment during the endurance period shall match the safety class of the equipment being cooled.

Environment, Security and Safeguards Classification

No environment, security, or safeguards classification is assigned at RD7/DRP1.

Seismic Classification

The seismic classification of the KL systems is to be classified in accordance with the RR SMR Seismic Performance Classification Method [9].

9A.5.1.4 Description

Key components of the KL systems include fresh air intake louvres, moisture eliminators, attenuators, Air Handling Units (AHUs), isolation dampers, volume control dampers, extract fans, HEPA filters, Carbon filters, supply and extract grilles, exhaust air louvres, local cooling units, and the associated distribution ductwork for the systems. It also includes the facility to measure temperature and pressure at key locations in the system, either for control inputs or to facilitate inspection and maintenance.

The AHUs in the system typically comprise of frost coils, primary and secondary stage filters, chilled water cooling coils, heating coils, humidifiers and supply fans. The AHU controls the flow of air through the system and also conditions the air to the required supply condition. The components vary depending on the specific requirements of each sub-system.

The KL Systems consist of the following sub-systems:

- HVAC systems serving primary containment (KLA)
- HVAC systems serving the interspace (KLB)
- HVAC systems serving the Controlled Areas (KLC)
- HVAC systems serving the Uncontrolled areas (KLE)

- HVAC systems serving the Waste Processing Areas (KLF)
- HVAC systems serving the Fuel Storage and Handling Areas (KLL)
- HVAC systems serving the Control Rooms (KLR)
- HVAC Air Handling Unit Heat Recovery System (KLQ)
- Stack [KLS], which takes the combined filtered discharges from the KLA, KLB, KLC, KLF and KLL controlled area extracts and discharges the aerial effluent at an appropriate height to achieve the required discharges

9A.5.1.5 Materials

The materials of the system will be described in future versions of the generic E3S Case.

9A.5.1.6 Interfaces with Supporting Systems

Interfaces for the HVAC Systems Serving Controlled Areas and Uncontrolled Areas of Reactor Island are identified and managed within the requirements specification module of the system in RR SMR requirements management database.

9A.5.1.7 System and Equipment Operation

An initial analysis of the system operation in all modes of operation has been conducted and is detailed in section 3 of the system design description [58].

The operation of the KL systems during the six operating modes is described in the system design description in [58].

Faults

The majority of the KL systems are not required to operate during fault conditions, although will continue to do so as per mode 1 if power is available and the system is able to operate. A complete fault schedule is to be developed and the resultant system responses required will be detailed in future revision of the generic E3S case.

9A.5.1.8 Instrumentation and Control

The Heating, Ventilation, Air Conditioning (HVAC) Systems Serving Controlled Areas and Uncontrolled Areas of Reactor Island [KL] allocates functions to the Reactor Control and Instrumentation (C&I) Systems [JY].

To support the safe operation and control of the KL system, the EC&I system will also be required to provide alarms and warnings to indicate that key system parameters are outside of the defined performance bands and/or safety limits. The types of alarms that will be provided to the operators in the control room listed in [58]. The full list of alarms will be developed beyond DRP1.

9A.5.1.9 Monitoring, Inspection, Testing & Maintenance

Key expected Examination, Maintenance and Testing (EMIT) activities include:

- Safety derived tasks (ISI)
- Design derived tasks (Supplier provided)
- Reliability derived tasks (RCM/Preventative Maintenance)
- Industry best Practice/OPEX (EPRI PMBD)
- Non-PBS (Module, Site Facility).

9A.5.1.10 Radiological Aspects

Radiological risk assessment is to be developed.

9A.5.1.11 Performance and Safety Evaluation

Compliance with Safety Categorised Functional Requirements

Verification and validation for the KL systems to demonstrate compliance with its safety categorised functional requirements and associated non-functional performance requirements is under development.

Performance analysis is to be conducted to demonstrate how the KL systems design meets the non-functional performance requirements associated with the key system functions. The suite of performance analysis for bounding fault conditions that place safety categorised functional requirements on the KL systems is presented in E3S Case Version 2, Tier 1, Chapter 15: Safety Analysis [6].

Compliance with Non-Functional System Requirements

The non-functional system requirements are still to be completed and the compliance to them will be presented in Version 3 of the generic E3S Case.

9A.5.1.12 ALARP, BAT, Secure by Design and Safeguards by Design

The KL systems have been provided with N+1 arrangements for Air Handling Units, fans and filters to provide resilience during system faults or maintenance.

OPEX from other operating nuclear power plants is that no shielding is required as the dose rate on filters during normal operation is low.

9A.5.2 Reactor Island Chilled Water System

9A.5.2.1 System and Equipment Functions

The primary function of the Reactor Island Chilled Water System [KJ] is to provide a source of cooling water for auxiliary plant and Heating, Ventilation and Air Conditioning (HVAC) at temperatures lower than can be achieved by the Component Cooling System [KAA].

Layout details for the KJ systems are presented in [59].

HLSFs for KJ systems and the PIEs against which they are assigned, are being derived in the Fault Schedule, which is presented in E3S Case Version 2, Tier 1, Chapter 15: Safety Analysis [6].

9A.5.2.2 Design Bases

Functional Requirements

Safety categorised functional requirements for KJ system are specified based on the HLSFs they deliver, including the applicable plant states and operating modes, are presented in Table 9A.5-1 based on RR SMR requirements database.

Table 9A.5-2: [KL] System Safety Categorised Functional Requirements

Requirement ID	Functional Requirement	Mode(s) of Operation	Safety Category
KJ-R-1280	The Chilled Water Systems KJ shall control chilled water temperature	All modes	A
KJ-R-1283	The Chilled Water Systems KJ shall control chilled water flow rate	All modes	A
KJ-R-1289	The Chilled Water Systems KJ shall reject heat to the AHU Heat Recovery system (KLQ)	All modes	C
KJ-R-1288	The Chilled Water Systems KJ shall filter the chilled water	All modes	C
KJ-R-1290	The Chilled Water Systems KJ shall treat the chilled water with biocide	All modes	C
KJ-R-1292	The Chilled Water Systems KJ shall treat the chilled water with corrosion inhibitor	All modes	C
KJ-R-1294	The Chilled Water Systems KJ shall treat the low temperature chilled water with glycol	All modes	C
KJ-R-1296	The Chilled Water Systems KJ shall maintain the static head of the chilled water system	All modes	C
KJ-R-1298	The Chilled Water Systems KJ shall transfer chilled water to the processes, heat exchangers and air handling units requiring heat removal	All modes	C

The safety categorised functional requirements for KJ system are flowed down and allocated to relevant sub-systems and/or components. Non-functional performance requirements associated with the safety categorised functional requirements are allocated in RR SMR requirements database.

Non-Functional System Requirements

Non-functional system requirements are still being developed and will be allocated to the KJ system based on the E3S design principles as described in E3S Case Version 2, Tier 1, Chapter 3: E3S Objectives and Design Rules for SSCs [8].

9A.5.2.3 E3S Classification

Safety Classification

The Low Temperature Chilled Water System [KJA10] is safety class 1.

The Low Temperature Chilled Water System [KJA30] is safety class 3.

At this stage of the design, the KJL cooling function has been assumed to be safety Category C, corresponding to safety class 3, in line with the known requirements for the SC C&I, MCR and SCR, however this may be updated during the next design stage if more onerous requirements are defined.

Environment, Security and Safeguards Classification

No environment, security, or safeguards classification is assigned at RD7/DRP1.

Seismic Classification

The seismic classification of the KJ system is to be classified in accordance with the RR SMR Seismic Performance Classification Method [9].

9A.5.2.4 Description

The Reactor Island Chilled Water [KJ] is a subsystem of the Nuclear Auxiliary Systems [K]. The key components of include water cooled chillers, centrifugal pumps, buffer vessel, pressure independent control valves (PICV), isolation valves, commissioning sets and orifice plates, conventional control valves, flexible connections, expansion vessels, strainers, dirt/air separators and make-up unit, and carbon steel distribution pipework. The AHUs in the system typically comprise of frost coils, primary and secondary stage filters, chilled water cooling coils, heating coils, humidifiers and supply fans. The AHU controls the flow of air through the system and also conditions the air to the required supply condition. The components vary depending on the specific requirements of each sub-system.

The KL Systems consist of the following sub-systems:

- Low Temperature Chilled Water System [KJA10], which supports the HDPS through the endurance period. Without delivery of this cooling function the HDPS could fail so the KJA10 system cooling is a Category A Safety Function. [KJA10] is not required to support the endurance cooling function. The KJA10 sub-system design assumes it has lost the charging circuit for the endurance period. This is a Category C Safety Function maintaining the ice store in a frozen state during normal operation. For KJA10 sub-systems supporting the RPS and PAMS which have a Category B safety function, the sub-system cooling is a Category B Safety Function. For KJA10 sub-systems supporting the SAMS which have a Category C safety function, the sub-system cooling is a Category C Safety Function.

- Low Temperature Chilled Water System [KJA30], which keeps the ice stores frozen during normal operation. This system is not required to operate during the endurance period as the cooling for the SC C&I, MCR and SCR is provided entirely by the ice stores and the KJA10 systems. Therefore, the KJA30 cooling function has been assigned a Category C Safety Function.

- The Chilled Water System [KJL], which provides a Category C Safety Function providing cooling to the safety categorised C&I, MCR and SCR during normal operation. The KJL system also provides chilled water for cooling to the other areas of the Reactor Island. It is not currently expected that the cooling to any of these areas is higher than Safety Category C, however the Safety Category for the cooling to primary containment is still to be determined following further work required on the fault schedule.

9A.5.2.5 Materials

The materials of the system will be described in future Versions of the generic E3S Case.

9A.5.2.6 Interfaces with Supporting Systems

Interfaces for Reactor Island Chilled Water [KJ] are identified and managed within the requirements specification module of the system in RR SMR requirements management database.

9A.5.2.7 System and Equipment Operation

An initial analysis of the system operation in all modes of operation has been conducted and is detailed in section 3 of the system design description [59].

During all modes of normal operation, the operation of the Reactor Island Chilled Water [KJ] itself is essentially unchanged. It changes in response to faults or loss of other services to ensure continued support to the operation of the SC C&I equipment.

Faults

Section 3 of the system design description [59] provides a high-level overview of the Reactor Island Chilled Water [KJ] alignment and functionality during Faulted Operations, both in terms of the plant response to specific faults originating within the system, as well as support that the system provides to plant safety measures.

The Low Temperature Chilled Water System - Safety Class 1 [KJA10] ice stores and DC pumps provide the cooling support to plant safety measures, via the KLE LCUs, to the HDPS, RPS, PAMS, and SAMS, and via the KLR LCUs to the MCR and SCR. Without cooling these would overheat and fail to provide their mission.

9A.5.2.8 Instrumentation and Control

The Reactor Island Chilled Water [KJ] allocates functions to the Reactor Control and Instrumentation (C&I) Systems [JY].

To support the safe operation and control of the Reactor Island Chilled Water [KJ], the EC&I system will also be required to provide alarms and warnings to indicate that key system parameters are outside of the defined performance bands and/or safety limits. The types of alarms that will be provided to the operators in the control room listed in [59]. The full list of alarms will be developed beyond DRP1.

9A.5.2.9 Monitoring, Inspection, Testing & Maintenance

Key expected Examination, Maintenance and Testing (EMIT) activities include:

- Safety derived tasks (ISI)
- Design derived tasks (Supplier provided)
- Reliability derived tasks (RCM/Preventative Maintenance)
- Industry best Practice/OPEX (EPRI PMBD)
- Non-PBS (Module, Site Facility).

9A.5.2.10 Radiological Aspects

Radiological risk assessment is to be developed.

9A.5.2.11 Performance and Safety Evaluation

Compliance with Safety Categorised Functional Requirements

Verification and validation for the KJ system to demonstrate compliance with its safety categorised functional requirements and associated non-functional performance requirements is under development.

Performance analysis is to be conducted to demonstrate how the KJ system design meets the non-functional performance requirements associated with the key system functions. The suite of performance analysis for bounding fault conditions that place safety categorised functional requirements on the KJ system is presented in E3S Case Version 2, Tier 1, Chapter 15: Safety Analysis [6].

Compliance with Non-Functional System Requirements

The non-functional system requirements are still to be completed and the compliance to them will be presented in Version 3 of the generic E3S Case.

9A.5.2.12 ALARP, BAT, Secure by Design and Safeguards by Design

The Reactor Island Chilled Water [KJ] systems are generally provided with N+1 or N+2 trains of plant which either requires more regular maintenance or is expected to have minor faults which compromise its service. In these cases the system will automatically switch to one of the standby/reserve units to continue the chilled water service provision.

The Reactor Island Chilled Water [KJ] has no shielding requirements. The system can only become contaminated through failure of multiple barriers and would be diluted by the volume of water in the system.

9A.6 Fire Protection Systems

9A.6.1 Fire Extinguishing Systems (XG)

9A.6.1.1 System and Equipment Functions

The Fire Extinguishing (XG) System will consist of a series of firefighting mediums and delivery systems to feed all applicable buildings and areas onsite. The main components of this includes:

1. A Centralised System: A firewater ring main which delivers firewater around the site and to buildings and hydrants via a series of dedicated pipework, instruments and pipeline connections. The water is supplied by water storage tanks (assumed to be part of GA system) and powered by a containerised Commercial of the Shelf (COTS) Pump House, this is the XGA system only. These respective systems and makeup are:
    a) XGA - Fire water system – Water ring main delivery system
    b) XGC - Spray deluge system
    c) XGE – Sprinkler system.
2. Localised System(s), for all systems excluding firewater consisting of:
    a) External pressurised bottles & delivery system (e.g., for inert gas) or
    b) Handheld extinguishers.

Localised systems and makeup for a) and b) are:

i. XGF – Foam extinguishing system
ii. XGJ – Carbon dioxide fire extinguishing system
iii. XGK – Inert gas fire extinguishing system
iv. XGL – Powder extinguishing system
v. XGM - Fire extinguishing system with other extinguishing agent.

Layout details for the Fire Extinguishing [XG] System are presented in [60].

HLSFs for the Fire Extinguishing [XG], and the PIEs against which they are assigned, are being derived in the Fault Schedule, which is presented in E3S Case Version 2, Tier 1, Chapter 15: Safety Analysis [6].

9A.6.1.2 Design Bases

Functional Requirements

Safety categorised functional requirements the Fire Extinguishing [XG] are being developed based on the HLSFs they deliver, including the applicable plant states and operating modes, these will be presented in Version 3 of the E3S Case.

Non-functional performance requirements associated with the safety categorised functional requirements will also be allocated in [XG] requirements module.

Non-Functional System Requirements

Non-functional system requirements are being developed and will be allocated to the Fire Extinguishing [XG] system, based on the E3S design principles as described in E3S Case Version 2, Tier 1, Chapter 3: E3S Objectives and Design Rules for SSCs [8].

9A.6.1.3 E3S Classification

Safety Classification

A current assumption is the Fire Extinguishing [XG] system is Safety Class 3 or below. A full list of safety classifications will be updated against the relevant requirements modules for major components once the safety classifications are confirmed. These will be reported in Version 3 of the E3S Case.

Environment, Security and Safeguards Classification

No environment, security, or safeguards classification is assigned at RD7/DRP1.

Seismic Classification

The Fire Extinguishing [XG] System is to be classified in accordance with the RR SMR Seismic Performance Classification Method [9].

9A.6.1.4 Description

The Fire Extinguishing [XG] System must be operational in all conditions on site and during all operating modes of the plant system. The Fire Extinguishing [XG] System will have to be considered an ‘always-on’ system and any maintenance and inspection requiring system shut off should be localised as far as possible and redundancy in systems, or an alternate means of fire detection and fighting available must be present. ‘Always-on’ in this context is considered to mean that automatic systems are on stand by duty and ready to operate and manual systems are readily available for use.

9A.6.1.5 Materials

The materials of the system will be described in future Versions of the generic E3S Case.

9A.6.1.6 Interfaces with Supporting Systems

Interfaces for the Fire Extinguishing [XG] System are identified and managed within the requirements specification module of the system in RR SMR requirements management database.

9A.6.1.7 System and Equipment Operation

Operational details are being developed and will be presented in Version 3 of the E3S Case.

9A.6.1.8 Instrumentation and Control

The Instrumentation and Control philosophy for the Fire Extinguishing [XG] System is being developed and will be presented in Version 3 of the E3S Case.

9A.6.1.9 Monitoring, Inspection, Testing & Maintenance

Key expected Examination, Maintenance and Testing (EMIT) activities include:

- Safety derived tasks (ISI)
- Design derived tasks (Supplier provided)
- Reliability derived tasks (RCM/Preventative Maintenance)
- Industry best Practice/OPEX (EPRI PMBD)
- Non-PBS (Module, Site Facility).

9A.6.1.10 Radiological Aspects

Radiological protection requirements are applied through the design process and analysis of these will be carried out in line with the maturity of the design.

9A.6.1.11 Performance and Safety Evaluation

Compliance with Safety Categorised Functional Requirements

Verification and validation for the Fire Extinguishing [XG] System to demonstrate compliance with its safety categorised functional requirements and associated non-functional performance requirements is under development.

Compliance with Non-Functional System Requirements

The non-functional system requirements are still to be completed and the compliance to them will be presented in Version 3 of the generic E3S Case.

9A.6.1.12 ALARP, BAT, Secure by Design and Safeguards by Design

The evidence presented within [61] provides initial confidence that the Fire Extinguishing [XG] can support the overall E3S targets for the RR SMR. Further work will be undertaken as the design develops and this will be reported in Version 3 of the E3S Case.

9A.7 Supporting Systems for Generators

Supporting systems for Generators for RR SMR are currently under development and will be reported in Version 3 of the E3S Case.

The Supporting systems for generators will include:

1. Fuel and oil storage and transfer systems
2. Generating cooling systems
3. Generator starting and lubrication systems
4. Generator intake and exhaust systems.

9A.8 Overhead Lifting Equipment

9A.8.1 System and Equipment Functions

At DRP1, the majority of Overhead Lifting Equipment for RR SMR is contained within The Handling of Nuclear Equipment System [F] as detailed in section 9A.1.

HLSFs for Overhead Lifting Equipment System, and the PIEs against which they are assigned, are being derived in the Fault Schedule, which is presented in E3S Case Version 2, Tier 1, Chapter 15: Safety Analysis [6].

9A.8.2 Design Bases

During the RR SMR design, requirements for mechanical handling of duty and safety significant plant and associated support equipment are being generated and captured within the RR SMR Database Management System.

The design requirements are the basis of design development. They currently focus on the safety significant activities associated with refuelling and the lifting of large components which pose a hazard to safety.

In addition, the following key overhead lifting specific aspects have been defined to generate an approach to the design development of overhead lifting equipment to facilitate meeting the design principles defined in [62]:

- Reduce nuclear safety hazards with high-level architecture, a high-level approach of eliminating handling operations or adopting potentially safer methods e.g. minimising lift heights.

- Limit claims on nuclear classified overhead lifting equipment to critical lifts. The aim is to appropriately classify and not over-classify overhead lifting equipment via the systematic development of the safety case.

- Maximise use of COTS equipment where appropriate. A desired outcome of the approach is to identify clear opportunities where COTS (or at least Modified Off The Shelf (MOTS)) overhead lifting equipment can be deployed where faults of this equipment would lead to tolerably low consequences.

- Maximise use of temporary and mobile handling solutions. The aim of utilising temporary and mobile handling solutions provides a number of key benefits:

    - Examination, maintenance, inspection and testing of and training for use of overhead lifting equipment required across RI during an outage can be done outside of controlled environments and while the SMR is generating power.

    - Decoupling of overhead lifting equipment from RR SMR construction is maximised due to reduction in both interface and overhead lifting equipment installation.

- Standardising handling solutions across island/power station/fleet. Standardising handling solutions would enable:

- Common claims and argument to support the safety case for mechanical handling.
- Consolidation of overhead lifting equipment inventory and the attendant reduction in capital and through-life costs.

9A.8.3 E3S Classification

Safety Classification

The safety classification of Overhead lifting equipment will be reported in Version 3 of the E3S Case.

Environment, Security and Safeguards Classification

No environment, security, or safeguards classification is assigned at RD7/DRP1.

Seismic Classification

Overhead lifting equipment is to be classified in accordance with the RR SMR Seismic Performance Classification Method [9].

9A.8.4 Description

Overhead Lifting Equipment is currently under development and further details will be presented in Version 3 of the E3S Case.

9A.9 Miscellaneous Auxiliary Systems

Miscellaneous Auxiliary Systems for RR SMR are currently under development and will be reported in Version 3 of the E3S Case.

The Miscellaneous Auxiliary Systems will include:

- Communication Equipment.
- Lighting Equipment.
- Equipment surface water drainage systems.
- Chemical Storage systems.
- Non-permanent equipment used in beyond design basis conditions.

9A.10 Conclusions

9A.10.1 ALARP, BAT, Secure by Design, Safeguards by Design

The design of all SSCs presented in this chapter is developed in accordance with the systems engineering design process. This includes alignment to RGP and 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 criteria that ensure risks are reduced to ALARP, apply BAT, and are secure by design and safeguards by design, as described in E3S Case Version 2, Tier 1, Chapter 3: E3S Objectives and Design Rules for SSCs [8]. This provides confidence that claims can be met when the full suite of arguments and evidence is developed.

A summary of key design decisions made with respect to ensuring overall risks are reduced to ALARP, BAT, secure by design and safeguards by design for each auxiliary system is provided in respective sections of this chapter, based on design decisions up to RD7/DRP1. The overall demonstration of ALARP, BAT, secure by design and safeguards by design at RD7/DRP1 is presented in E3S Case Version 2, Tier 1, Chapters 24, 27, 32 and 33 respectively.

9A.10.2 Assumptions and Commitments on Future Dutyholder / Licensee / Permit Holder

None identified in this revision.

9A.10.3 Conclusions & Forward Look

The generic E3S Case objective at Version 2 is ‘to provide confidence that the RR SMR design will be capable of delivering the E3S fundamental objective as it developed from a concept design into a detailed design’. This confidence is built through development and underpinning of top-level claims across each chapter of the E3S Case, through supporting arguments and evidence. The top level claim for chapter 10 is ‘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.

The arguments and evidence presented to meet the generic E3S Case objective at Version 2 include the allocation of safety functions to individual Auxiliary systems which are categorised in accordance with the E3S categorisation and classification methodology, with systems assigned both a safe classification. 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 DRP1. SSCs excluded from this revision based on limited maturity, as listed in Appendix B, will be incorporated as their design is matured.

The Auxiliary systems SSC design RD7/DRP1 is developed and evaluated in accordance with the E3S design principles through the integrated E3S and engineering processes, including design optioneering, to drive risk reduction to ALARP, and to demonstrate BAT, secure by design and safeguards by design. Environment, security, and safeguards aspects are also considered. For example, bespoke polymers were selected for as the anti-scalants and corrosion inhibitors for the Common Systems for Cooling Water Systems [PU] primarily on an environmental basis as most other chemistry packages contain phosphorus or zinc, which have environmental consequences. Such design considerations provide confidence that environment, security, and safeguards functions can be achieved by the design as functional requirements are derived through ongoing and iterative E3S analyses. Given the design of the Auxiliary Systems at RD7/DRP1 is largely in line with RGP, this provides further confidence that as the design matures through vendor engagement it will meets the E3S objective.

Further arguments and evidence to underpin claims will be developed in line with the E3S Case Route Map [3] and reported in future revisions of the generic E3S Case, which will further build confidence that the RR SMR can deliver its fundamental E3S objective. This broadly includes refinement of safety requirements, as well as identification of environment, security, and safeguards requirements.

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9A.12 Appendix A: Claims, Arguments, Evidence

Table 9A.12-1 provides a mapping of the claims to the corresponding sections of the chapter that summarise the arguments and/or evidence. The full decomposition of claims and link to underpinning Tier 2 and Tier 3 information containing the detailed arguments and evidence is presented in the E3S Case Route Map [3]. The route map includes the trajectory of Tier 2 and Tier 3 information as the generic E3S Case develops, which will be incorporated into Tier 1 chapters as it becomes available and in line with generic E3S Case issues described in [2].

Table 9A.12-1: Mapping of Claims to Chapter Sections

Claim	**Section of Chapter 9A containing arguments / evidence summary**
New Fuel Receipt and Inspection Area [FAA] Non-Functional System Requirements are complete	Section **Error! Reference source not found.**
New Fuel Receipt and Inspection Area [FAA] Non-Functional System Requirements are correctly assigned	Section **Error! Reference source not found.**
New Fuel Receipt and Inspection Area [FAA] codes and standards are correctly assigned	Section 9A.0.4
Safety Requirements for the New Fuel Receipt and Inspection Area [FAA] are complete	Section **Error! Reference source not found.**
Environmental Functional Requirements for the New Fuel Receipt and Inspection Area [FAA] are complete	None at this revision
Security Functional Requirements for the New Fuel Receipt and Inspection Area [FAA] are complete	None at this revision
Safeguards Functional Requirements for the New Fuel Receipt and Inspection Area [FAA] are complete	None at this revision
The New Fuel Receipt and Inspection Area [FAA] is classified correctly	Section 9A.1.1.3
The New Fuel Receipt and Inspection Area [FAA] design achieves its E3S functional requirements	Section 9A.1.1.11
The New Fuel Receipt and Inspection Area [FAA] design achieves its E3S non-functional system requirements	Section 9A.1.1.11
The layout design facilitates the system achieving its E3S requirements	Section9A.1.1.1
Structural integrity is substantiated commensurate with the SSC classification	Covered in E3S Case Chapter 23
The New Fuel Receipt and Inspection Area [FAA] design definition is verified to meet its requirements	Section 9A.1.1.11

Claim	**Section of Chapter 9A containing arguments / evidence summary**
The implemented New Fuel Receipt and Inspection Area [FAA] system is validated to meet its E3S functions	Not covered in this revision
Verification of the New Fuel Receipt and Inspection Area [FAA] system is preserved through its operational life	Not covered in this revision
Storage of Spent/Irradiated Fuel Assemblies and Other Radioactive Parts System [FAB] *claims structure as per New Fuel Receipt and Inspection Area [FAA] structure*	Section 9A.1.4
Refuelling Systems [FAE] and [FAF] *claims structure as per New Fuel Receipt and Inspection Area [FAA] structure*	Section 9A.1.5
Spent Fuel Pool Cooling & Clean-Up Systems [FAK], [FAL], [FAM], [FAN] and [FAT] *claims structure as per New Fuel Receipt and Inspection Area [FAA] structure*	Section 9A.1.6
Cleaning system for fuel assemblies (also includes reflector assemblies) [FBC] *claims structure as per New Fuel Receipt and Inspection Area [FAA] structure*	Section 9A.1.7
Refuelling and Conveyance Systems [FC] *claims structure as per New Fuel Receipt and Inspection Area [FAA] structure*	Section 9A.1.8
External storage of spent fuel system [FD] *claims structure as per New Fuel Receipt and Inspection Area [FAA] structure*	Section 9A.1.9
Erection or in-service inspection system [FJ] *claims structure as per New Fuel Receipt and Inspection Area [FAA] structure*	Section 9A.1.10
Decontamination system [FK] *claims structure as per New Fuel Receipt and Inspection Area [FAA] structure*	Section 9A.1.11
Fuel Route Control and Instrumentation System [FY] *claims structure as per New Fuel Receipt and Inspection Area [FAA] structure*	Section 9A.1.12
Reactor Component Cooling System [KAA] *claims structure as per New Fuel Receipt and Inspection Area [FAA] structure*	Section 9A.2.2
Heating ventilation and air conditioning (HVAC) systems in controlled areas and exclusion areas [KL]	Section 9A.5

Claim	**Section of Chapter 9A containing arguments / evidence summary**
claims structure as per New Fuel Receipt and Inspection Area [FAA] structure	
Reactor Island Sampling system [KU] *claims structure as per New Fuel Receipt and Inspection Area [FAA] structure*	Section 9A.3
Main Cooling Water System [PA] *claims structure as per New Fuel Receipt and Inspection Area [FAA] structure*	Section 9A.2.1
Essential Service Water System [PB] claims *structure as per New Fuel Receipt and Inspection Area [FAA] structure*	Section 9A.2.3
Auxiliary Cooling and Make-Up System [PE] *claims structure as per New Fuel Receipt and Inspection Area [FAA] structure*	Section 9A.2.4
Fire Extinguishing System [XG] *claims structure as per New Fuel Receipt and Inspection Area [FAA] structure*	Section 9A.6
Mechanical Handling System [XM] *claims structure as per New Fuel Receipt and Inspection Area [FAA] structure*	Section 9A.8

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

Table 9A.13 -1 lists those SSCs that are within the scope of Chapter 9A, and the section of the report they are addressed.

Table 9A.13 -1: SSCs in Scope of E3S Case Chapter 9A

RDS-PP®	SSC	Section in Chapter 9A
F	Handling of Nuclear Equipment	Section 9A.2.1
FA	Internal Fuel Storage	Covered by [FA_] Sections
FAA	New Fuel Receipt and Inspection Area	Section 9A.1.3
FAB	Storage of Spent/Irradiated Fuel Assemblies and Other Radioactive Parts System [FAB]	Section 9A.1.4
FAE	Refuelling Cavity	Section 9A.1.5
FAF	Refuelling Pool	
FAK	Spent fuel cooling system	Section 9A.1.6
FAL	Spent fuel coolant purification system	
FAM	System for removal of surface contaminants on components in fuel assembly storage	
FAN	Emergency heat removal system for coolant used for storage of spent fuel assemblies	
FAT	Coolant supply system	
FBC	Cleaning system for fuel assemblies (also includes reflector assemblies)	Section 9A.1.7
FCJ	System for conveyance of fuel assemblies/internals within reactor area	Section 9A.1.8
FCK	System for conveyance of fuel assemblies/internals between reactor and storage areas	

RDS-PP®	**SSC**	**Section in Chapter 9A**
FCL	System for conveyance of fuel assemblies/internals within storage area	
FD	External storage of spent fuel	Section 9A.1.9
FDA	External wet storage of filled casks	
FDB	External dry storage of filled casks	
FJ	Erection or in-service inspection system	Section 9A.1.10
FK	Decontamination system	Section 9A.1.11
FY	Fuel Route Control and Instrumentation System	Section 9A.1.12
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 E3S Case Chapter revision based on low design maturity
KJ	Nuclear chilled water systems	Section 9A5.2
KL	Heating ventilation and air conditioning (HVAC) systems in controlled areas and exclusion areas	Section 9A.5.1
KU	Reactor Island Sampling system	Section 9A.3
PA	Main Cooling Water System	Section 9A.2.1
PB	Essential Service Water System	Section 9A.2.3
PE	Auxiliary Cooling and Make-up System	Section 9A.2.4
PG	Turbine Island Closed Cooling Water System	Not covered in this E3S Case Chapter revision based on low design maturity
PU	Common systems for the cooling water systems	

RDS-PP®	**SSC**	**Section in Chapter 9A**
G	Water supply disposal and treatment system	Not covered in this E3S Case Chapter revision based on low design maturity
GA	Water supply System	
GAF	Water supply storage system	
XB	Space heating system	Not covered in this E3S Case Chapter revision based on low design maturity
XG	Fire extinguishing system	Section 9A.6
XK	Chilled water system	Not covered in this E3S Case Chapter revision based on low design maturity
XM	Mechanical Handling System	Section 9A.8
XV	Rainwater systems	Not covered in this E3S Case Chapter revision based on low design maturity

9A.14 Acronyms and Abbreviations

1oo'X'	One out of 'X'
ACMS	Auxiliary Cooling and Make-up system
ACoP	Approved Code of Practice
AHU	Air Handling Unit
ALARP	As Low As Reasonably Practicable
ASME	American Society of Mechanical Engineers
BAT	Best Available Techniques
BS	British Standard
C&I	Control and Instrumentation
CAD	Computer Aided Design
CAE	Claims Arguments and Evidence
CCS	Component Cooling System
CHRC	Control Rod Housing Columns
CLP	Cask Loading Pit
CoFT	Control of Fuel Temperature
CoR	Control of Reactivity
CoRE	Control of Radiation Exposure
CoRM	Confinement of Radioactive Material
COTS	Commercial off the Shelf
CPS	Coolant Purification System
CSCS	Cold Shutdown Cooling System
CWS	Chilled Water System
DCA	Double Contingency Approach
DRP	Design Reference Point
E3S	Environment, Safety, Security and Safeguards
EMIT	Examination, Maintenance, Inspection and Testing

EPRI	Electrical Power Research Institute
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
GDA	Generic Design Assessment
GDF	Geological Disposal Facility
HAZID	Hazard Identification
HAZOP	Hazard and Operability Study
HDPE	High Density Polyethylene
HLSF	High-Level Safety Function
HMI	Human Machine Interface
HPIS	High Pressure Injection System
HVAC	Heating, Ventilation, and Air Conditioning
ICM	In-Core Monitoring
IHP	Integrated Head Package
ISI	In Service Inspection
IXC	Ion Exchange Column
LOCA	Loss of Containment Accident
LOLER	Lifting Operations and Lifting Equipment Regulations 1998
LOOP	Loss of Offsite Power
LTDHR	Low Temperature Decay Heat Removal
MCWS	Main Cooling Water System
MDCT	Mechanical Draft Cooling Tower
MOC	Main Overhead Crane

n/a	Not Applicable
NFCC	Non-Fuel Core Components
NFR&I	New Fuel Receipt and Inspection
OPEX	Operational Experience
P&ID	Piping and Instrumentation Diagram
PES	Programmable Electronic System
PIE	Postulated Initiating Event
PLC	Programmable Logic Controller
PMBD	Preventative Maintenance Basis Database
PWR	Pressurised Water Reactor
RCCA	Rod Cluster Control Assemblies
RCM	Reliability Centred Maintenance
RCPR	Reactor Coolant Pressure Relief
RCS	Reactor Coolant System
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
SMR	Small Modular Reactor
SOD	System Outline Description
SSC	Structure, System and Component
TBC	To Be Confirmed

TLA	Through Life Activities
UHS	Ultimate Heat Sink
UP	Upender Pit
WCCT	Wet Closed Cooling Tower