Partner Document Number	Partner Document Issue /Revision	Retention category:
n/a	**n/a**	**A**

Title

E3S Case Chapter 5: Reactor Coolant System & Associated Systems

Executive Summary

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

The Structures, Systems & Components (SSCs) summarised in this revision of the E3S Case include the Reactor Pressure Vessel (RPV) [JAA], Reactor Coolant Pump System [JEB], Steam Generation System [JEA], Reactor Coolant Pipework System [JEC], Reactor Coolant Pressurising System [JEF], Reactor Coolant Pressure Relief System [JEG], Chemical and Volume Control System (CVCS) [KB], and Cold Shutdown Cooling System (CSCS) [JNA].

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

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

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5.0 Introduction

5.0.1 Introduction

Chapter 5 of the Rolls-Royce Small Modular Reactor (RR SMR) Environment, Safety, Security & Safeguards (E3S) Case forms part of the Pre-Construction Safety Report (PCSR), as defined in E3S Case Chapter 1: Introduction, Reference [1].

Chapter 5 presents the overarching summary and entry point to the design information for the Reactor Coolant System of the RR SMR, as defined at Reference Design (RD) 5 level of design maturity.

5.0.2 Scope

The full list of Structures, Systems & Components (SSCs) within the scope of the Generic Design Assessment (GDA) is presented in the RR SMR Boundary Report, Reference [2], aligned to the Reference Design System – Power Plants (RDS-PP) functional product breakdown structure. Of those, the list of SSCs that are included in the scope of this chapter is provided in Appendix A, including those that are within scope but excluded from this revision due to design immaturity.

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

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

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

3. Key verification activities and evidence to support substantiation of SSCs.

Environment and Security Functional Requirements for SSCs will be reported in the Generic Environment Report (GER) and the Generic Security Report (GSR) respectively and are not included in the scope of the PCSR.

Furthermore, the scope of this chapter covers the mechanical aspects of fluid systems, with the selection of materials and justification of the integrity of SSCs covered in E3S Case Chapter 23: Structural Integrity, Reference [3].

Design/Programme Maturity

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

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

5.0.3 Claims, Arguments, Evidence Route Map

The Chapter level Claim for E3S Case Chapter 5: Reactor Coolant System & Associated Systems is:

Claim 5: The RR SMR Reactor Coolant System & Associated Systems are designed and substantiated to achieve functional and non-functional safety requirements through the lifecycle, and reduce risks to ALARP

A decomposition of this Claim into Sub-Claims, Arguments, and link to the relevant Tier 2 Evidence is provided in Appendix A. For each lowest level Sub-Claim, the sections of this report providing the Evidence summary are also identified.

The complete suite of evidence to underpin the Claims in the E3S Case will be generated through the RR SMR design and E3S Case programme and documented in the Claims-Arguments-Evidence (CAE) Route Map, Reference [4], described further in E3S Case Chapter 1: Introduction, Reference [1].

5.0.4 Applicable Regulations, Codes & Standards

The mechanical systems and components summarised in this report are designed in accordance with their safety classification, to the codes and standards outlined in Table 5.0-1, based on Reference [5].

Table 5.0-1: Mechanical Design Codes & Standards

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

5.1 Summary of Reactor Coolant System

5.1.1 System and Equipment Functions

The Reactor Coolant System (RCS) [JE] is comprised of the following subsystems:

1. Steam Generation System [JEA]

2. Reactor Coolant Pump System [JEB]

3. Reactor Coolant Pipework System [JEC]

4. Reactor Pressurising System [JEF]

5. Reactor Pressure Relief System [JEG]

The primary function of the RCS [JE] is to utilise heated coolant from the Reactor System [JA] to generate steam which can be transferred to the Steam System [LB]. The system also has several supporting functions to facilitate this objective, including overpressure protection, and supports safety functions delivered by the Reactor Reactivity Control Systems [JD] and Reactor Heat Removal Systems [JN]. The system therefore contributes to the achievement of FSFs of Control of Reactivity (CoR), Control of Fuel Temperature (CoFT), and Confinement of Radioactive Material (CoRM).

High-Level Safety Functions (HLSFs) for the RCS [JE], and the Postulated Initiating Events (PIEs) against which they are assigned, are being derived in the Fault Schedule, which is presented in E3S Case Chapter 15: Safety Analysis, Reference [6].

5.1.2 Safety Design Basis

Functional Requirements

Safety categorised functional requirements are specified for the RCS [JE] based on the HLSFs they deliver, including the applicable plant states and operating modes, these are presented in Table 5.2-1.

The traceability of safety categorised functional requirements back to the HLSFs will be managed in DOORS; this process is outlined in Deterministic Safety Methodology, Reference [7], and is expected to be implemented to support FCD.

Table 5.2-1: [JE] Safety Categorised Functional Requirements

DOORS ID	Functional Requirements	Plant State(s)	Mode(s) of Operation	Safety Category
JE-R-1815	The Reactor Coolant System [JE] shall contain and confine Reactor Coolant at the system's specified design pressure and temperature	DBC-1 DBC-2	All	A

DOORS ID	Functional Requirements	Plant State(s)	Mode(s) of Operation	Safety Category
JE-R-1863	The Reactor Coolant System [JE] shall contain and confine Secondary Coolant at the system's specified design pressure and temperature	DBC-1 DBC-2	All	A
JE-R-1780	While in Modes 1 or 2, the Reactor Coolant System [JE] shall circulate reactor coolant	DBC-1 DBC-2	1, 2	C
JE-R-1785	While in Modes 1 or 2, the Reactor Coolant System [JE] shall generate steam	DBC-1 DBC-2	1, 2	C
JE-R-1793	While in Modes 1, 2, 3, 4a, 4b or 5a, the Reactor Coolant System [JE] shall control coolant pressure	DBC-1 DBC-2	1 to 5a	C
JE-R-1879	While in Modes 1, 2, 3, 4a, 4b or 5a, the Reactor Coolant System [JE] shall protect against overpressure in the RCS [JE] and the Reactor System [JA]	DBC-3 DBC-4	1 to 5a	A
JE-R-1410	While the Condenser Decay Heat Removal (DHR) function is in operation, the Reactor Coolant System [JE] shall transfer heated coolant from the Reactor System [JA] for Steam Generation	DBC-1 DBC-2	All	C
JE-R-1880	While in Condenser DHR Operation [JN03], the Reactor Coolant System [JE] shall control coolant pressure	DBC-1 DBC-2	All	C
JE-R-1411	While the Condenser DHR function is in operation, the Reactor Coolant System [JE] shall generate and transfer heated steam to the Turbine Island [T01]	DBC-1 DBC-2	All	C
JE-R-1413	While the PDHR [JN02] function is in operation, the RCS [JE] shall transfer heated coolant from the Reactor System [JA] for the generation of steam	DBC-3 DBC-4	All	B

DOORS ID	Functional Requirements	Plant State(s)	Mode(s) of Operation	Safety Category
JE-R-1417	While the Passive Decay Heat Removal (PDHR) function is in operation, the RCS shall generate and transfer heated steam to the PDHR system	DBC-3 DBC-4	All	B
JE-R-1423	While in SCRAM [JD01] or ASF [JD02], the Reactor Coolant System [JE] shall generate sufficient flow to prevent fuel failure prior to reactor shutdown on loss of pumped flow	DBC-3 DBC-4	All	A

The safety categorised functional requirements for the RCS [JE] are flowed down and allocated to relevant sub-systems and/or components in the DOORS RCS [JE-D Definition Module. This functional decomposition is illustrated through the Capella model(s) presented in the DOORS module.

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

Non-Functional System Requirements

Non-functional system requirements are specified for the RCS [JE] based on the E3S Principles. The requirements specified at PCD are listed in the DOORS RCS [JE] Requirements Module, including the rationale for their application. These are summarised in Table 5.2-2.

Table 5.2-2: [JE] Non-Functional System Requirements

DOORS ID	Non-Functional System Requirement	Rationale
JE-R-1821	The system shall reduce the release of radioactive material to the environment to ALARP	Placeholder whilst non-functional system requirements are developed
JE-R-1837	SMR systems that contain radioactive material shall be designed to prevent spread of that radioactive material beyond their boundary	Confinement of radioactive material for containment and sub-systems in E3S Principles

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

Safety Classification

The safety classification of the RCS [JE] is undertaken in accordance with the E3S Categorisation and Classification methodology outlined in E3S Case Chapter 3: E3S Objectives & Design Rules, Reference [8]. The safety class for each RCS component is presented in subsequent sections of this report.

Seismic Classification

The seismic classification of SSCs is still to be assigned in accordance with methodology outlined in E3S Case Chapter 3: E3S Objectives & Design Rules, Reference [8].

5.1.3 Description of SSC

The baseline architecture for the RCS [JE] consists of three vertical u-tube Steam Generators (SGs) with associated pipework loops and a single Reactor Coolant Pump (RCP) [JEB] in each loop, mounted to the SG outlet. The configuration of the SG, pipework and pump layout in each loop ensures a robust thermal driving head for natural circulation flow in emergencies. The system also contains a pump induced spray pressurising system with associated pressure relief system.

A simplified schematic of the RCS [JE] is presented in Figure 5.1-1, with the key design and performance parameters summarised in Table 5.2-3.

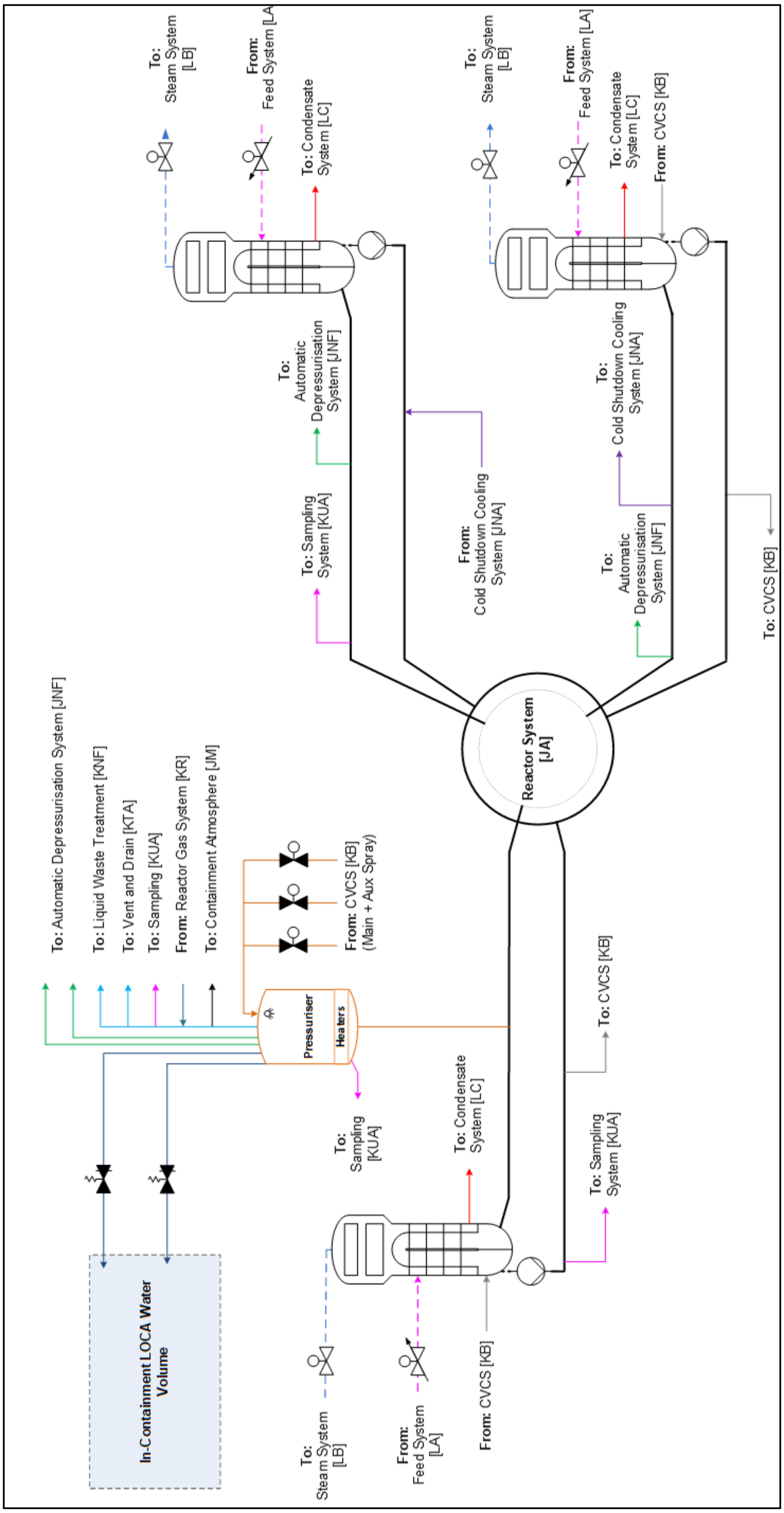

Figure 5.1-1: Simplified Schematic of the RCS [JE]

{REDACTED FOR PUBLICATION Table 5.2-3: Key Design & Performance Parameters for RCS [JE]}

The layout of the RCS [JE] is still to be finalised, however notable features in the current design include:

1. Asymmetrical SGs located around the Reactor System [JA] supporting access for movement of the integrated head package and internals.

2. Inverted RCPs [JEB] mounted directly onto the nozzle of the SGs.

3. Pressuriser is connected to the hot leg of one of the RCS [JE] loops.

4. Each SG is elevated above the Reactor System [JA] to ensure that a sufficient thermal driving head is available for natural circulation flow for plant protection in fault conditions.

The RCS [JE] sub-systems and components are described in more detail in subsequent sections of this report.

5.1.4 Materials

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

5.1.5 Interfaces with Supporting Systems

The key interfaces for the RCS [JE] are identified and managed in DOORS, including flow down of functional requirements, and summarised below:

1. Reactor System [JA] receives coolant from the RCS [JE], heats it via nuclear fission, and returns the heated coolant to the RCS pipework for onwards transfer to the SGs.

2. Feedwater System [LA]: the Feedwater System [LA] supplies coolant to the Steam Generators to facilitate the generation of steam.

3. Steam System [LB] receives heated steam from the SGs for onward transfer to the Turbine Island [T01], as well as providing additional functionality such as secondary side overpressure relief.

4. Condensate System [LC] provides chemistry control of the secondary side of the SGs, via coolant blowdown.

5. Chemistry and Volume Control System (CVCS) [KB] provides chemistry control of primary reactor coolant, as well as make-up and let-down capability. In addition, pressuriser spray is routed to the top of the pressuriser from the Reactor Coolant Pipework System [JEC] via the CVCS [KB].

6. Reactor Sampling Systems [KU] receives coolant from the Reactor Coolant Pipework System [JEC] to facilitate the measurement of various reactor coolant parameters (e.g., pH).

7. Cold Shutdown Cooling System (CSCS) [JNA] provides decay heat removal once the reactor coolant temperature has fallen below 120°C, by receiving heated coolant from a penetration on a hot leg, and returning coolant (following heat removal) to a cold leg.

8. Automatic Depressurisation System [JNF] is responsible for reducing plant pressure as part of the Emergency Core Cooling (ECC) [JN01] safety function via the blowdown of coolant to the in-containment refuelling pool.

5.1.6 System Operation

The Reactor Island Operating Philosophy, Reference [9], provides the overarching information on how the plant and operator maintain control of key functions across the six defined operating modes, including the operating principles, required actions, means for transitioning between the operating modes, and relevant safety systems for each mode. This is summarised in E3S Case Chapter 13: Conduct of Operations, Reference [10].

Configuration

During Operating Mode 1 (Power Operation), the RCS [JE] will be configured as follows:

1. All RCPs running.

2. Temperature maintained within defined operating band.

3. Pressure maintained through generation of a steam bubble in the pressuriser and controlled within a defined operating band.

4. Pressuriser level maintained within a defined operating band.

5. Overpressure protection provided by the Pressure Relief System [JEG].

6. SG in use as duty heat sink.

7. SG water level maintained within defined operating band.

During Operating Mode 2 (Start-Up) once the coolant has been warmed to a prescribed pressure and temperature range and SGs are aligned for normal operation, core reactivity is increased in a controlled fashion through withdrawal of control rods, until criticality is achieved in the hot-zero-power state.

During Operating Mode 3 (Hot Standby), once the turbine load and power off-take are reduced below a certain level, the control rods are manually inserted to shut-down the reactor. The turbines are isolated from the steam system, with steam from the SGs dumped directly to the condenser, before being recirculated back through the feed system.

During Operating Mode 4a (Hot Shutdown – Steaming), steam dumping continues to provide plant cool-down. As temperature is reduced, reactor coolant will contract causing a net reduction in pressuriser level. This is counteracted through automatic make-up provided by the CVCS [KB] to maintain pressuriser level within the defined operating band. Pressure reduction is achieved through switching off the pressuriser heaters and inducing spray where necessary.

During Operating Mode 4b (Hot Shutdown – Non-Steaming), once the plant has been cooled to 120°C, the CSCS [JNA] is aligned as the duty heat sink to continue plant cooldown and the low-pressure safety relief valve aligned to provide overpressure protection. Before pressure is reduced to below **{REDACTED FOR PUBLICATION}**, the RCPs are switched off, with core flow sustained through the CSCS [JNA]. The plant pressure then continues to be reduced through spray provided by the CSCS [JNA] pumps via the CVCS [KB], at the same rate as plant cooldown. Following confirmation of successful heat removal through the CSCS [JNA] heat exchanger, the SGs are isolated from the steam and feed systems.

During Operating Mode 5a (Cold Shutdown – Pressurised), spray is continued into the pressuriser head whilst the CVCS [KB] provides make-up to fill the pressuriser and collapse the steam bubble until the pressuriser is reduced to 100°C and atmospheric pressure.

To pressurise the system during warmup, the vent lines at the top of the pressuriser will be isolated and pressure will be increased by running the CVCS [KB] charging pumps such that a steam bubble will be drawn in the pressuriser. The pressuriser heaters are switched on, and as the pressuriser temperature increases, level is slowly reduced via continued letdown through the CVCS [KB]. At this point the plant control system is switched to an automatic pressuriser level control regime. Following confirmation that steam bubble pressure control has been achieved, RCPs will be switched on to run.

During Operating Mode 5b (Cold Shutdown – Depressurised), the contents of the RCS [JE] and Pressuriser continue to be circulated via the CSCS [JNA] and CVCS [KB]. During Operating Mode 6a (Refuelling with Reduced Water Level above Fuel) and 6B (Refuelling with Reduced Water Level above Fuel at Nominal Full), the RCS [JE] is drained in preparation for removal of the Reactor System [JA] Integrated Head Package (IHP).

Faulted Operation

The safety categorised functional requirements placed on the RCS [JE] during operation of Scram [JD01] or the Alternative Shutdown Function [JD02] to provide sufficient flow for controlled plant shutdown is facilitated through the provision of a flywheel within each RCP.

The safety categorised functional requirements placed on the RCS [JE] during operation of Passive Decay Heat Removal (PDHR) [JN02] rely on the thermal driving head provided by the RCS layout arrangement (with SGs elevated above the core) to provide heat removal by natural circulation between the Reactor System [JA] and the Steam Generation System [JEA]. Pressure and inventory control is achieved through injection via CVCS [KB] make-up pumps (when available) or High Pressure Injection System (HPIS) [JND] pumps (or Low Pressure Injection System (LPIS) [JNG] accumulators for Station Blackout faults).

5.1.7 Instrumentation & Control

The RCS [JE] places several control functions onto the Reactor Control & Instrumentation (C&I) System [JY]. The Reactor Control System [JY] will also monitor a range of key systems parameters and provide indication of these to the operator in the control room and in the emergency control centre.

It will also provide alarms to indicate that key system parameters are outside of the defined performance bands and/or safety limits. The envisaged requirements for monitoring, indication, alarms, and warnings are specified in the RCS System Description, Reference [11].

The allocation of safety categorised functional requirements from the RCS [JE] to the Reactor C&I System [JY] is presented in the C&I Engineering Schedule, described further in E3S Case Chapter 7: Instrumentation & Control, Reference [12].

5.1.8 Monitoring, Inspection, Testing and Maintenance

An outline maintenance plan for the RCS [JE] is still to be developed. A preliminary set of in-service inspection requirements for all RCS components are identified in subsequent sections of this report.

5.1.9 Radiological Aspects

The layout design of the RR SMR means there are systems/components that are near the reactor core, resulting in higher radiation dose rates and potential for increased operator exposure during Examination, Maintenance, Inspection & Testing (EMIT) activities.

Layout reviews are ongoing and considering options to reduce operator exposure (alongside other factors such as internal hazards), for example, the distance between the SGs and the core has been increased from previous reference design baselines. Shielding assessments are also being undertaken to inform the level of shielding required to reduce dose rates and minimise exposures during operations and EMIT to ALARP. This will be reported in E3S Case Chapter 12: Radiation Protection, Reference [13].

5.1.10 Performance and Safety Evaluation

Compliance with Safety Categorised Functional Requirements

At PCD, verification strategies are in development for the RCS [JE] to demonstrate compliance with its safety categorised functional requirements and associated non-functional performance requirements are in development and stored in DOORS, including:

1. RELAP Thermal Hydraulic analysis.

2. Thermal Hydraulic Rig Testing to validate RELAP analysis.

Prior to PCD, analysis has been conducted to support the concept design development and its optimisation; this is presented in the RCS [JE] System Description, Reference [11]. The analysis is based on early RELAP methods and does not provide verification of the current design requirements; therefore, it has not been repeated here.

The full suite of analysis to justify that the RCS [JE] achieves its safety categorised functional requirements and associated non-functional performance requirements for bounding fault conditions will be presented in E3S Case Chapter 15: Safety Analysis, Reference [6].

Performance analysis for several bounding fault conditions is being conducted during FCD. The key outputs with respect to safety categorised functional requirements compliance for the RCS [JE] will be reported in a future issue of the E3S Case.

Compliance with Non-Function System Requirements

Verification activities to substantiate non-functional system requirements for the RCS [JE] are still to be determined.

5.1.11 Installation & Commissioning

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

5.1.12 ALARP in Design Development

The design of the RCS [JE] has been developed in accordance with the systems engineering design process, which includes alignment to Relevant Good Practice (RGP) & Operating Experience (OPEX), design to codes and standards according to the safety classification, and a systematic optioneering process with down-selection of design options based on assessment against relevant safety criteria (as described in E3S Case Chapter 3: E3S Objectives & Design Rules, Reference [8]). Hazard identification studies have also been undertaken to support major design decisions.

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

1. Preliminary performance analysis has informed the design development of the RCP [JEB], resulting in the inclusion of a flywheel to provide adequate coast down flowrate during early stages of certain design basis faults, including Station Blackout, with early indication that acceptance criteria can be met (further analysis is required for verification).

2. A pump induced (RCP) spray system design, with connections from two of the cold legs converging into a spray nozzle, has been selected for the pressuriser (described further in Section 5.8). Optioneering against other mechanisms (such as surge induced spray) concluded that the pump induced spray represents RGP in comparison with other Pressurised Water Reactor (PWR) designs, it provides a passive response with no reliance on moving parts such as non-return valves, and performance giving increased margins to core saturation acceptance criteria.

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

5.1.13 Ongoing Design Development

The RR SMR design definition is in development as described in Section 5.0.2. Key design opportunities and decisions related to nuclear safety are being explored, this includes:

1. The current layout of the RCS [JE] and arrangement of loops and penetrations in the Reactor System [JA] is subject to further analysis and review to understand the impact of the asymmetric flow patterns through the core.

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

5.2 Materials

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

5.3 Reactor Coolant System and Reactor Coolant Pressure Boundary

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

5.4 Reactor Vessel

5.4.1 System and Equipment Functions

The primary function of the Reactor Pressure Vessel (RPV) [JAA] is to interface with the RCS [JE] so that cold coolant can flow to the core and hot coolant can be taken to the SGs. The RPV [JAA] also provides mechanical support and position for RPV Closure Head (CH) and assembled components which form part of the IHP [JAB].

The system contributes to the achievement of FSFs of CoR, CoFT and CoRM.

5.4.2 Safety Design Basis

Functional Requirements

Safety categorised functional requirements are specified for the RPV [JAA] and IHP [JAB] based on the HLSFs they deliver, including the applicable plant states and operating modes, these are presented in Table 5.5-1.

The traceability of safety categorised functional requirements back to the HLSFs will be managed in DOORS; this process is outlined in Deterministic Safety Methodology, Reference [7], and is expected to be implemented to support FCD.

Table 5.4-1: [JAA] and [JAB] Safety Categorised Functional Requirements

DOORS ID	Functional Requirements	Plant State(s)	Mode(s) of Operation	Safety Category
PT108-R-1316	The RPV [JAA] shall direct coolant from the Reactor Coolant System (RCS) [JE] to the RPV internals [JAC10] inlet and from the RPV Internals [JAC10] outlet to the RCS [JE]	DBC-1 DBC-2 DBC-3 DBC-4	All	A
PT108-R-1800	The RPV shall facilitate mixing of primary coolant	DBC-1 DBC-2 DBC-3 DBC-4	All	A
PT108-R-1801	The RPV shall facilitate cooling to structural components	TBC	All	A
PT108-R-1324	The RPV shall direct coolant from the low-pressure injection subsystem to the RPV internals	DBC-3 DBC-4	All	A
PT108-R-1331	The RPV shall facilitate containment and retention of the RPVIs in its specified radial, angular and vertical location	DBC-3 DBC-4	All	A

DOORS ID	Functional Requirements	Plant State(s)	Mode(s) of Operation	Safety Category
PT108-R-1352	The RPV shall contain and confine coolant	DBC-1 DBC-2 DBC-3 DBC-4	All	A
PT108-R-1363	The RPV shall provide radiation shielding	TBC	All	A
PT108-R-1762	The RPV shall support In-Vessel Retention (IVR) following a core melt	DEC-B	All	A
PT108-R-1373	The RPV shall permit refuelling	DBC-1	6	A

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

Non-Functional System Requirements

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

Safety Classification

The safety classification of the RPV [JAA] & IHP [JAB] is undertaken in accordance with the E3S Categorisation and Classification methodology outlined in E3S Case Chapter 3: E3S Objectives & Design Rules, Reference [8]. At PCD, the components within the RPV [JAA] & IHP [JAB] are classified as followed:

1. RPV: Very High Reliability (VHR)

2. Closure Head: VHR

5.4.3 Description of SSC

Reactor Pressure Vessel

The RPV [JAA] consists of three major vessel forgings:

1. The upper shell containing the six off Reactor Coolant Loop (RCL) nozzles, three off ECC Direct Vessel Injection (DVI) nozzles; interface with the RPV Closure Head (CH) and RPV Internals supports, and leak paths for the seals between CH and RPV [JAA].

2. The lower shell consisting of a plain cylindrical forging with no circumferential welds present within the high flux region of the core.

3. The lower head consisting of a torispherical profile to provide a suitable diverging flow interface with spherical profile of the flow distribution device.

The RPV major forgings are welded together with narrow gap circumferential seam welds. The RCL and DVI nozzles on the RPV each have a stainless-steel safe end joined with a dissimilar metal weld. All internal wetted surfaces of the RPV are weld overlay clad with a stainless steel consumable.

Key RPV [JAA] attributes are presented in Table 5.4-2 and a schematic of the design is presented in Figure 5.4-1.

Table 5.4-2: Key Attributes of the RPV [JAA]

Parameter	**Value**
Approximate Mass (dry)	150 tonnes
Approximate Overall Height	8m
Approximate Overall Diameter	4.2m
Reactor coolant Loop Nozzle Bore Diameter	**{REDACTED FOR PUBLICATION}**
ECC Direct Vessel Injection	**{REDACTED FOR PUBLICATION}**
Vessel Forging Material	**{REDACTED FOR PUBLICATION}**
Safe End Material	**{REDACTED FOR PUBLICATION}**
Design Temperature	**{REDACTED FOR PUBLICATION}**
Design Pressure	**{REDACTED FOR PUBLICATION}**

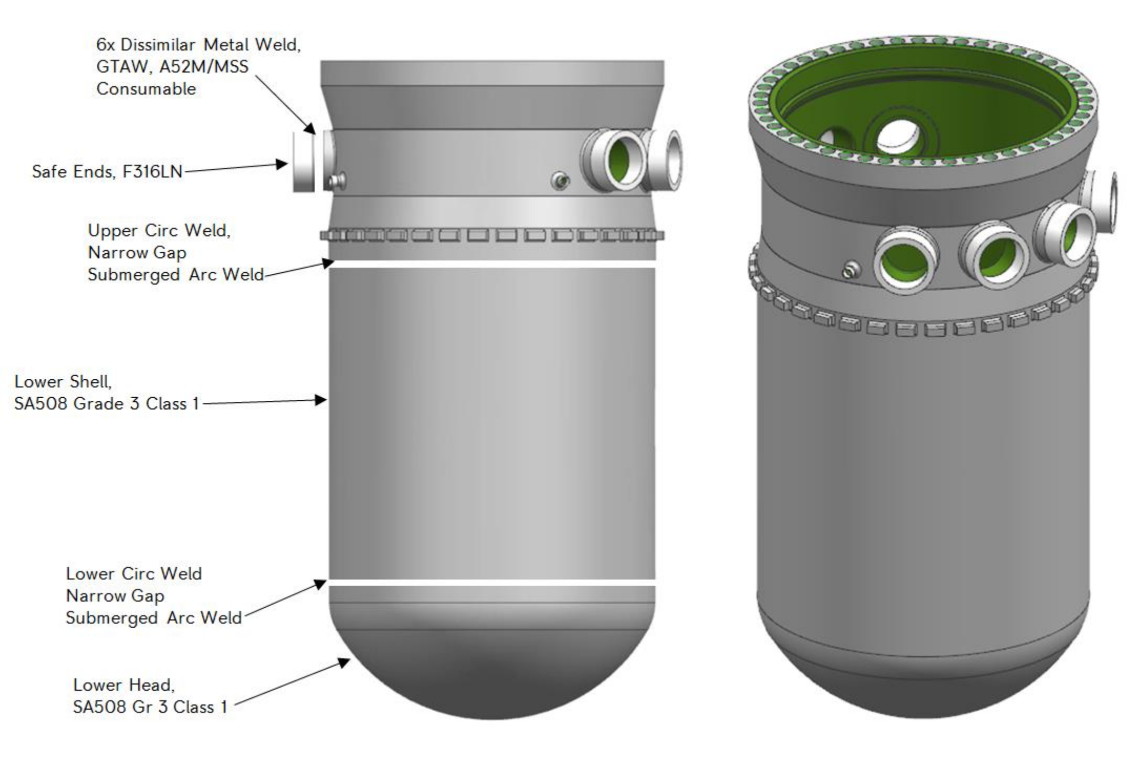

Figure 5.4-1: Schematic of the RPV [JAA]

Integrated Head Package

The IHP [JAB] forms an assembly of the reactor head area components with the overall purpose of facilitating disassembly and assembly activities for core load and unload. It is designed to minimise the time taken for refuel activities.

The major components of the IHP [JAB] incorporate an assembly of the RPV CH, Control Rod Drive Mechanisms (CRDMs), In-Core Instrumentation (ICI), CRDM cooling system, integral missile shield, lifting assembly and C&I integration.

The RPV CH is a single piece forging with torispherical profile and outer bolting flange. The CH provides structural support and alignment for the CRDMs [JAD], ICI, IHP lifting points and main closure bolting assembly. The CH also accommodates the final seal between the head and body. The CH also incorporates a vent line to release air during plant fill operations.

The IHP [JAB] also provides and internal seismic support plate to minimise deflection of CRDMs during seismic events.

The CRDMs will be cooled by forced air with the use of fans mounted within the IHP [JAB]. The fans will take air from containment and circulate it down and up through the CRDMs through an engineered flow path within the IHP assembly. The heated air would then be expelled back into containment and managed by the containment Heating, Ventilation & Air Conditioning (HVAC) system.

Eight separate penetrations will be used to accommodate ICI with the cabling routing up to the disconnect panels at the top of the IHP [JAB]. An access hatch through the IHP outer shroud will be in place to allow access to the ICI penetrations to disconnect and connect during refuel operations.

The outer shroud of the IHP forms an integral missile shield protecting the CRDMs on the CH from missiles such as pipe whip or fragments, but also protecting other systems from missiles coming from the RPV CH.

Key IHP attributes are presented in Table 5.4-3 and a schematic of the IHP design is presented in Figure 5.4-2.

Table 5.4-3: Key Attributes of the IHP [JAB]

Parameter	**Value**
Approximate Overall Mass	120 tonnes
Approximate Overall Height	9.5m
Approximate Overall Diameter	4.2m
Approximate Closure Head Mass	34 tonnes
Closure Head Profile	Torispherical with Integral Flange
Closure Head Material	SA508 Grade 3 Class 1
CRDM/ICI Attachments	**{REDACTED FOR PUBLICATION}**
CRDM Cooling	**{REDACTED FOR PUBLICATION}**
Number of CRDMs	**{REDACTED FOR PUBLICATION}**
Number of ICI Penetrations	**{REDACTED FOR PUBLICATION}**
Closure Head Vent Lines	**{REDACTED FOR PUBLICATION}**
Main Closure	**{REDACTED FOR PUBLICATION}**
Main Closure Stud Material	**{REDACTED FOR PUBLICATION}**
Reactor Assembly Sealing	**{REDACTED FOR PUBLICATION}**
IHP Lifting	**{REDACTED FOR PUBLICATION}**

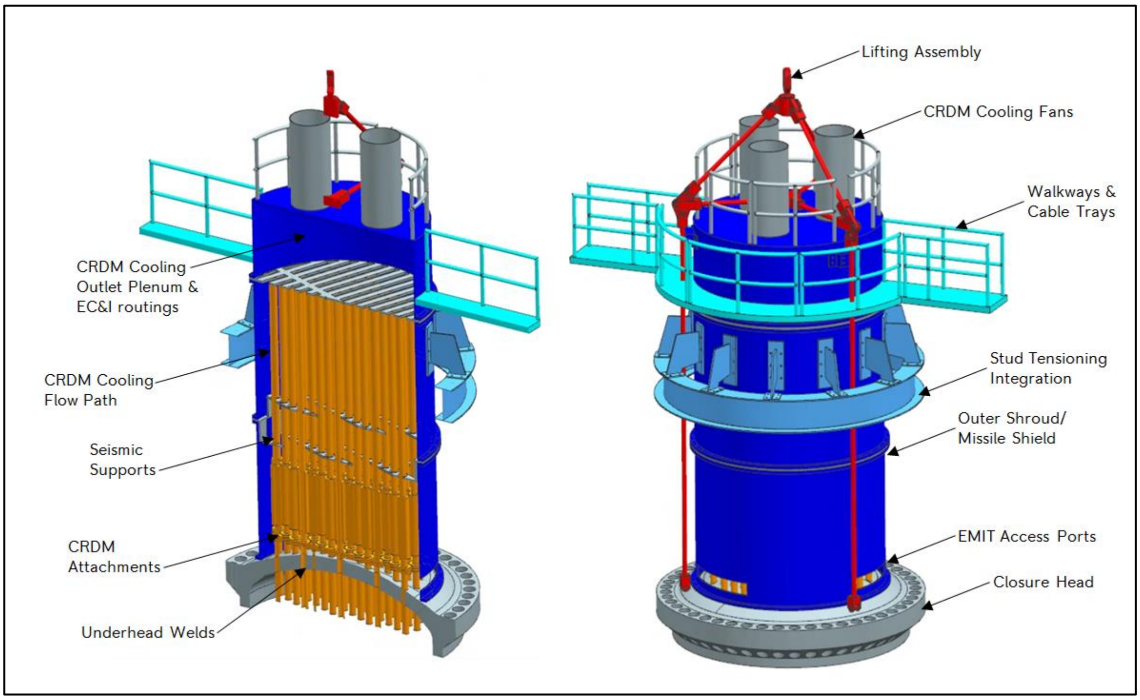

Figure 5.4-2: Schematic of the IHP [JAB]

5.4.4 Materials

The RPV [JAA] forgings are made from SA508 Grade 3 Class 1 material with an enhanced chemistry specification to improve mechanical properties, weldability, and resistance to through degradation mechanisms such as irradiation embrittlement. The RPV [JAA] safe ends are made from 316LN to match the RCL pipework material.

The RPV CH forging is made from SA508 Grade 3 Class 1 and as per the RPV [JAA] and is also clad with austenitic stainless steel. The adaptor tubes for mounting the CRDMs and ICI and made from Alloy 690 with an Alloy 52M, 52MSS or 52i dissimilar metal weld.

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

5.4.5 Interfaces with Supporting Systems

The key RPV [JAA] and IHP [JAB] interfaces are identified and managed within DOORS, including flow down of functional requirements, and presented below in Table 5.4-4.

Table 5.4-4: [JAA] and [JAB] Interfaces

Interfacing SSC	**Function Interface Summary**
RPV [JAA] Interfaces	
Reactor Coolant System Pipework [JEC]	The RPV shall interface with the Reactor Coolant System Pipework to supply approximately 10,000kg/s of coolant via 3 loops

Interfacing SSC	Function Interface Summary
RPV Internals [JAC10]	The RPV shall interface with the RPV Internals to provide mechanical support
IHP [JAB]	The RPV shall interface with the IHP to ensure pressure boundary integrity and to facilitate removal of fuel
Containment Support	The RPV shall interface with the Containment Support to provide structural support for the Reactor System
IHP [JAB] Interfaces	
CRDMs [JDA]	The Integrated Head Package shall interface with the CRDMs to provide support and retain the integrity of the pressure boundary
ICI [JKS]	The Integrated Head Package shall interface with the In-Core Instrumentation to provide support and retain the integrity of the pressure boundary

5.4.6 Performance and Safety Evaluation

At PCD, verification strategies for the RPV [JAA] to demonstrate compliance with its safety categorised functional requirements and associated non-functional performance requirements are in development and stored in DOORS. This includes Computational Fluid Dynamics (CFD) and thermal hydraulic analyses, and validation through a core flow rig test.

5.5 Reactor Coolant Pumps

5.5.1 System and Equipment Functions

The primary function of the Reactor Coolant Pump System [JEB] is to generate coolant flow to support heat transfer for both the Steam Generation System [JEA] and the Reactor System [JA]. The system contributes to the achievement of FSFs of CoFT and CoRM.

5.5.2 Safety Design Basis

Functional Requirements

Safety categorised functional requirements are specified for the Reactor Coolant Pump System [JEB] based on the HLSFs they deliver, including the applicable plant states and operating modes, these are presented in Table 5.5-1.

The traceability of safety categorised functional requirements back to the HLSFs will be managed in DOORS; this process is outlined in Deterministic Safety Methodology, Reference [7], and is expected to be implemented to support FCD.

Table 5.5-1: [JEB] Safety Categorised Functional Requirements

DOORS ID	Functional Requirement	Plant State(s)	Mode(s) of Operation	Safety Category
JEB-R-1286	The Reactor Coolant Pump System [JEB] shall contain and confine reactor coolant	DBC-1 DBC-2 DBC-3 DBC-4	All	A
JEB-R-1251	While in Powered and Shutdown Operation, the Reactor Coolant Pump System [JEB] shall Provide motive force for the flow of reactor coolant	DBC-1 DBC-2	1 to 5a	C
JEB-R-1259	While in Condenser DHR, Alternative Shutdown or SCRAM, and when de-energised, the Reactor Coolant Pump System [JEB] shall coast down safely	DBC-1 DBC-2 DBC-3 DBC-4	1 to 5a	B
JEB-R-1261	The Reactor Coolant Pump System [JEB] shall transfer heat to the reactor coolant during startup	DBC-1	2	C

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

Non-Functional System Requirements

The non-functional system requirements are identified at system level in Table 5.2-2.

Safety Classification

The safety classification of the Reactor Coolant Pump System [JEB] is undertaken in accordance with the E3S Categorisation and Classification methodology outlined in E3S Case Chapter 3: E3S Objectives & Design Rules, Reference [8]. At PCD, the components within Reactor Coolant Pump System [JEB] are classified as followed:

1. Pump casing: VHR, based on a review of RGP and preliminary assessment of secondary consequences.

2. Other pressure retaining components: Safety Class 1, based on a review of RGP.

3. Flywheel: Safety Class 2, based on failure of the flywheel being contained within the pump housing and as such does not need to be designated VHR.

5.5.3 Description of SSC

The Reactor Coolant Pump System [JEB] includes the nozzles which connect to the Reactor Coolant Pipework System [JEC], the pump casing and impeller, the pump motor, the heat exchanger required for cooling the pump and the instrumentation which feeds the reactor protection and control systems [JY].

The pump is installed in an inverted configuration, with the pump casing welded directly to the Steam Generator outlet nozzle; this can be seen below in Figure 5.5-1 (noting pump is the white coloured component).

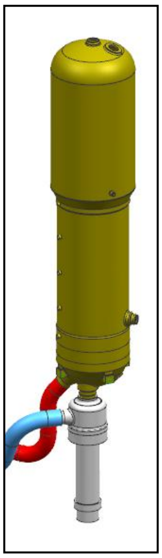

Figure 5.5-1: Reactor Coolant Pump Orientation

Each pump also includes a flywheel, which provides an elongated coast-down following a loss of flow fault. The coast down period ensures that sufficient cooling flow is maintained through the reactor to maintain the core within specified limits whilst providing time for ASF [JD02] to carry out a safe shutdown during a fault condition. The coast down also provides the motive force for delivering boric acid to the core to suppress reactivity, following its injection into the Reactor System [JA].

A summary of the key component/subsystem design and operating parameters is presented in Table 5.5-2.

{REDACTED FOR PUBLICATION Table 5.5-2: Key Reactor Coolant Pump [JEB] Design and Operating Parameters}

5.5.4 Materials

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

5.5.5 Interfaces with Supporting Systems

As outlined in for the RCS [JE] in Section 5.1.5.

5.5.6 System & Equipment Operation

During Operating Mode 1 (Power Operations), the RCPs operate in a single speed configuration, with electrical power being directly supplied by the power station electrical distribution systems. During Operating Mode 2 (Start-Up), the RCPs employ a Variable Frequency Drive (VFD) to vary pump power as required, prior to transitioning to direct drive.

5.5.7 Instrumentation & Control

As outlined in for the RCS [JE] in Section 5.1.7.

5.5.8 Monitoring, Inspection, Testing and Maintenance

An outline maintenance plan is still to be developed.

5.5.9 Radiological Aspects

No significant radiological aspects associated with the Reactor Coolant Pump System [JEB] operation have been identified during design decisions up to PCD. Low activation materials are used in the design of the Reactor Coolant Pump System [JEB].

5.5.10 Performance and Safety Evaluation

At PCD, verification strategies for the Reactor Coolant Pump System [JEB] to demonstrate compliance with its safety categorised functional requirements and associated non-functional performance requirements are in development and stored in DOORS. This includes a wide range of analyses to demonstrate the RCPs meet their functional requirements, such as hydraulic analysis, thermal / heat exchanger analysis, and electrical analysis. RCP verification activities will be developed further once a vendor is down selected.

5.5.11 Installation & Commissioning

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

5.6 Steam Generation System

5.6.1 System and Equipment Functions

The primary function of the Steam Generation System [JEA] is to utilise heated coolant from the Reactor Coolant System Pipework [JEC] to generate steam which can be transferred to the Turbine Island via the Main Steam System [LBA]. The system contributes to the achievement of FSFs of CoFT and CoRM.

5.6.2 Safety Design Basis

Functional Requirements

Safety categorised functional requirements are specified for the Steam Generation System [JEA] based on the HLSFs they deliver, including the applicable plant states and operating modes, these are presented in Table 5.6-1.

The traceability of safety categorised functional requirements back to the HLSFs will be managed in DOORS; this process is outlined in Deterministic Safety Methodology, Reference [7], and is expected to be implemented to support FCD.

Table 5.6-1: [JEA] Safety Categorised Functional Requirements

DOORS ID	Functional Requirement	Plant State(s)	Mode(s) of Operation	Safety Category
JEA-R-1827	The Steam Generation System [JEA] shall contain and confine Reactor Coolant at the system's specified design pressure and temperature	DBC-1 DBC-2 DBC-3 DBC-4	All	A
JEA-R-1791	While in All modes of operation, the Steam Generation System [JEA] shall contain and confine secondary coolant at the system design pressure and temperature	DBC-1 DBC-2 DBC-3 DBC-4	All	A
JEA-R-1674	While in Modes 1, 2, 3 or 4a, While in Condenser decay heat removal or Passive Decay Heat Removal, the Steam Generation System [JEA] shall generate steam	DBC-1 DBC-2 DBC-3 DBC-4	1 to 4a	B
JEA-R-1738	While in Modes 1, 2, 3, 4a, 4b or 5a, While in Condenser decay heat removal, the Steam Generation System [JEA] shall sense steam generator level	DBC-1 DBC-2	1 to 5a	C

DOORS ID	Functional Requirement	Plant State(s)	Mode(s) of Operation	Safety Category
JEA-R-1804	While in Passive Decay Heat Removal [JN02], the Steam Generation System [JEA] shall sense steam generator level	DBC-3 DBC-4	All	B
JEA-R-1811	While in SCRAM [JD01], the Steam Generation System [JEA] shall sense steam generator level	DBC-3 DBC-4	All	A

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

Non-Functional System Requirements

The non-functional system requirements are identified at system level in Table 5.2-2.

Safety Classification

The safety classification of the Steam Generation System [JEA] is undertaken in accordance with the E3S Categorisation and Classification methodology outlined in E3S Case Chapter 3: E3S Objectives & Design Rules, Reference [8]. At PCD, the components within Steam Generation System [JEA] are classified as followed:

1. Primary head and tubesheet: VHR, based on RGP.
2. Tubes: Safety Class 1, based on RGP.
3. Secondary shell and head: VHR, based on RGP.
4. Internals (Tube Supports): Safety Class 1, based on RGP.

5.6.3 Description of SSC

The baseline architecture for the Steam Generation System [JEA] consists of three SGs, each including equipment required for level measurement of the secondary side. A simplified schematic is shown Figure 5.6-1, and a summary of the key performance and design parameters for the system are presented in Table 5.6-2.

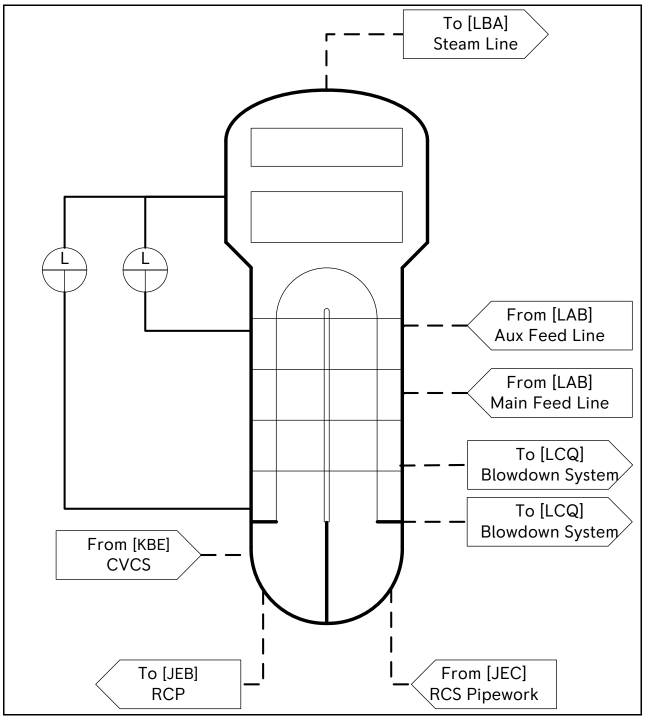

Figure 5.6-1: Simplified Schematic of the Steam Generation System [JEA]

{REDACTED FOR PUBLICATION Table 5.6-2: Key Performance and Design Parameters for the Steam Generation System [JEA]}

Each SG is a traditional recirculating SG with an integrated preheater. The hot reactor coolant enters the SG through the primary inlet nozzle, then enters the channel head inlet plenum before passing through the vertical U-tube bundle. It exits the bundle into the channel head outlet plenum and exits the SG via the primary outlet nozzle.

Secondary coolant enters the SG via the feedwater nozzle located in the lower part of the vessel on the outlet or "cold leg" side of the tube bundle, near the tubesheet. The cold feedwater is fed directly into the preheater whilst the downcomer flow is directed to the non-preheater region of the bundle. The secondary coolant flows up through the tube bundle where a portion of it is heated to steam. The wet steam is passed through a series of moisture separators. The resulting dried steam exits the SG through the steam outlet nozzle whilst the separated water is recirculated.

5.6.4 Materials

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

5.6.5 Interfaces with Supporting Systems

The key Steam Generation System [JEA] interfaces are identified and managed within DOORS, including flow down of functional requirements, and summarised below:

1. Main Steam Piping System [LBA], which provides the following key support functions to the Steam Generation System [JEA]:

a. Transfer of steam from each SG to the Turbine Island for the generation of electricity.

b. Transfer of steam to the Passive Steam Condensing System [JNB] during faulted operations to support PDHR [JN02].

c. Overpressure protection for the steam system.

d. Atmospheric steam dumping capability.

2. Feedwater Piping System [LAB]:

a. Supply of feedwater to each SG from the Turbine Island via the main feed line, to facilitate the generation of steam.

b. Supply of auxiliary feedwater to the SG during low power and shutdown modes of operation.

c. Transfer of condensed coolant from the Passive Steam Condensing System [JNB] to the SGs during PDHR [JN02].

3. Steam Generator Blowdown System [LCQ]:

a. Secondary sampling and chemistry control via blowdown from each SG.

b. Stir-up functionality during shutdown operating modes when the SGs have been laid up.

4. Reactor Coolant System Pipework [JEC]:

a. Supply of heated reactor coolant from the Reactor System [JA].

5. Reactor Coolant Pump System [JEB]:

a. Transfer of reactor coolant to the Reactor System [JA] via the Reactor Coolant System Pipework [JEC].

6. Coolant Purification System [KBE]:

a. Return of purified coolant from the CVCS [KB] to the RCS [JE].

5.6.6 System & Equipment Operation

During Operating Mode 1 (Power Operations), under steady load, the Steam Generation System [JEA] will be aligned and maintained in the following configuration:

1. Primary feed is supplied to the Steam Generation System [JEA] from the RCS Pipework [JEC], and maintained within the defined operating band (in terms of temperature, pressure, and mass flow rate).

2. Steam Generator pressure controlled through steam off take through the Main Steam Pipework System [LBA] turbine throttle valve.

3. Steam Generator feed is provided by the Feedwater Piping System [LAB], with temperature, pressure and mass flowrate maintained within the defined operating band to maintain a constant SG level.

4. Overpressure protection for the secondary side is provided by the Steam Generator Relief Valves (SGRVs) in the Main Steam Pipework System [LBA].

5. Steam Generator chemistry control facilitated by the Steam Generator Blowdown System [LCQ].

During Operating Mode 2 (Start-Up), the Steam Generation System [JEA] is initially aligned with feedwater supplied via the auxiliary feed lines, and steam systems aligned for steam dumping via the condenser. As core power is gradually increased the secondary plant is gradually warmed to minimise the risk of thermal shock, steam pressure is controlled via condenser steam bypass control valves before transitioning from auxiliary feed pumps to the main feedwater pumps.

Once turbine start-up commences, the steam dumping line is isolated, and the reactor is ready to transition to Operating Mode 1. SG level control is provided by control of feed flowrate via either the main or auxiliary feed regulation valve, operating on a constant SG level programme within the prescribed operating range. Upon generation of steam at greater than 20% of full power, the Steam Generator Blowdown System [LCQ] is aligned to provide secondary chemistry control.

During Operating Mode 4b (Hot Shutdown – Non-Steaming), the SGs are isolated from the steam and feed systems, with continued blowdown through the Steam Generator Blowdown System [LCQ]. Upon reaching a temperature below **{REDACTED FOR PUBLICATION}** the SGs are dosed with hydrazine in line with the shutdown chemistry control philosophy.

5.6.7 Instrumentation & Control

The level measurement for the Steam Generation System [JEA] is illustrated in Figure 5.6-2. Narrow band measurement is principally used for SG level control. Wide band measurement is used for both SG level control (during shutdown operations), as well as initiation of the Passive Decay Heat Removal [JN02] and SCRAM [JD01] safety functions.

The Steam Generation System [JEA] places requirements on the Reactor Control System [JY] to monitor a range of key systems parameters and provide indication of these to the operator in the control room and in the emergency control centre. It will also require alarms to indicate that key system parameters are outside of the defined performance bands and/or safety limits. The envisaged requirements for monitoring, indication, alarms, and warnings are specified in the Steam Generation System Description, Reference [15].

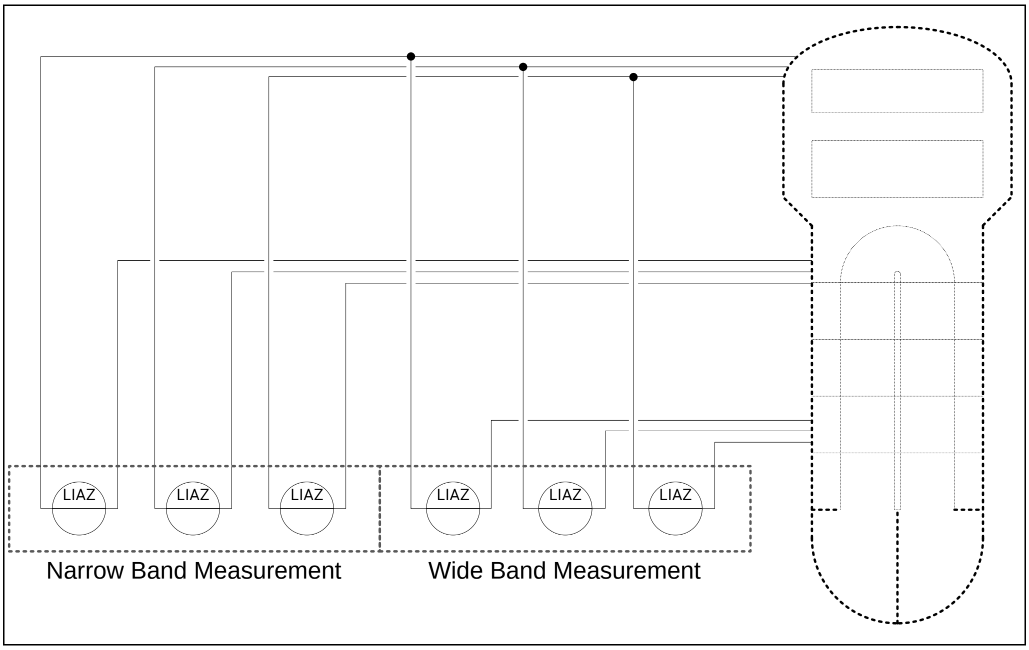

Figure 5.6-2: Simplified Schematic of Steam Generator Level Measurement

5.6.8 Monitoring, Inspection, Testing and Maintenance

An outline maintenance plan for the Steam Generation System [JEA] is still to be developed. The following are typical inspection and maintenance activities for the Steam Generation System [JEA]:

1. SGs:
   a. Primary side inspections (e.g. tube eddy current inspections).
   b. Secondary side inspections (e.g. ultrasonic inspection of girth welds).
   c. Sludge lancing.
2. Instrumentation:
   a. Instrument calibration (flow, pressure, temperature, level).

5.6.9 Radiological Aspects

The design decision to incorporate an integral crossflow preheater into the design of the SG has considered potential radiological impacts. The design permits a reduction in heat transfer area, which can reduce the quantity of Nickel-58 released from the SG tubes into the reactor coolant due to corrosion, in turn reducing the quantity of Cobalt-58 generated due to activation. This is deemed to reduce the overall plant dose rates, even taking into account additional complexities associated with inspection of the feedwater distributor, which will be mitigated through use of remote inspection techniques.

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

5.6.10 Performance and Safety Evaluation

At PCD, verification strategies for the Steam Generation System [JEA] to demonstrate compliance with its safety categorised functional requirements and associated non-functional performance requirements are in development and stored in DOORS. The verification strategy, predominantly considers verification by inspection, analysis and similarity including:

1. Rig testing to demonstrate corrosion resistance.

2. Structural Integrity assessments for confinement and resistance to hazards.

3. Thermal Hydraulic analysis and flow-induced vibration assessment.

5.6.11 Installation & Commissioning

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

5.7 Reactor Coolant Piping

5.7.1 System and Equipment Functions

The primary function of the Reactor Coolant Pipework System [JEC] is the transfer of heated coolant between the Reactor System [JA] to the Steam Generation System [JEA] and back again (via the Reactor Coolant Pumps [JEB]). The system also interfaces with several systems which support and protect the Reactor Plant [J] during powered, shutdown and faulted modes of operation, including the Reactor Coolant Pressurising System [JEF] and the Reactor Pressure Relief System [JEG]. The system therefore contributes to the achievement of FSFs of CoR, CoFT, and CoRM.

5.7.2 Safety Design Basis

Functional Requirements

Safety categorised functional requirements are specified for the Reactor Coolant Pipework System [JEC] based on the HLSFs they deliver, including the applicable plant states and operating modes, these are presented in Table 5.7-1.

The traceability of safety categorised functional requirements back to the HLSFs will be managed in DOORS; this process is outlined in Deterministic Safety Methodology, Reference [7], and is expected to be implemented to support FCD.

Table 5.7-1: [JEC] Safety Categorised Functional Requirements

DOORS ID	Functional Requirement	Plant State(s)	Mode(s) of Operation	Safety Category
JEC-R-1383	The Reactor Coolant Pipework System [JEC] shall contain and confine Reactor Coolant at the system's specified design pressure and temperature	DBC-1 DBC-2 DBC-3 DBC-4	All	A
JEC-R-1286	While in Modes 1, 2, 3, 4a, 4b or 5a, While in Condenser decay heat removal, While in Passive Decay Heat Removal, the Reactor Coolant Pipework System [JEC] shall transfer coolant from the Reactor System [JA] to the Steam Generation System [JEA]	DBC-1 DBC-2 DBC-3 DBC-4	1 to 5a	B

DOORS ID	Functional Requirement	Plant State(s)	Mode(s) of Operation	Safety Category
JEC-R-1308	While in Modes 1, 2, 3, 4a, 4b or 5a, While in Condenser decay heat removal, the Reactor Coolant Pipework System [JEC] shall transfer coolant from the Reactor Coolant Pump System [JEB] to the Reactor System [JA]	DBC-1 DBC-2	1 to 5a	B
JEC-R-1319	While in all modes of operation, the Reactor Coolant Pipework System [JEC] shall sense reactor coolant hot leg temperature	DBC-1 DBC-2	All	C
JEC-R-1365		DBC-3 DBC-4	All	A
JEC-R-1323	While in all modes of operation, the Reactor Coolant Pipework System [JEC] shall sense reactor coolant cold leg temperature	DBC-1 DBC-2	All	C
JEC-R-1422		DBC-3 DBC-4	All	A
JEC-R-1369		DBC-3 DBC-4	All	B
JEC-R-1334	While in all modes of operation, the Reactor Coolant Pipework System [JEC] shall sense reactor coolant level.	DBC-1 DBC-2	All	B
JEC-R-1341	While in all modes of operation, the Reactor Coolant Pipework System [JEC] shall sense reactor coolant flow rate	DBC-1 DBC-2	All	C
JEC-R-1378		DBC-3 DBC-4	All	A
JEC-R-1373	While in all modes of operation, the Reactor Coolant Pipework System [JEC] shall sense reactor coolant pressure	DBC-3 DBC-4	All	A

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

Non-Functional System Requirements

The non-functional system requirements are identified at system level in Table 5.2-2.

Safety Classification

The safety classification of the Reactor Coolant Pipework System [JEC] is undertaken in accordance with the E3S Categorisation and Classification methodology outlined in E3S Case

Chapter 3: E3S Objectives & Design Rules, Reference [8]. The components within Reactor Coolant Pipework System [JEC] are classified as followed:

1. Large Bore Pipework: Very High Reliability (VHR), on the basis that in the event of a large Loss of Coolant Accident (LOCA), the resultant stresses on the Reactor System [JA] internals may preclude the successful initiation of Scram [JD01].

2. Small Bore Pipework: TBC.

5.7.3 Description of SSC

The baseline architecture for the Reactor Coolant Pipework System [JEC] consists of three loops, each comprised of a hot and cold leg, as well as associated measurement equipment. A simplified schematic of the system is presented in Figure 5.7-1, with the key performance and design parameters summarised in Table 5.7-2.

{REDACTED FOR PUBLICATION Table 5.7-2: Key Performance and Design Parameters for the Reactor Coolant Pipework System [JEC]}

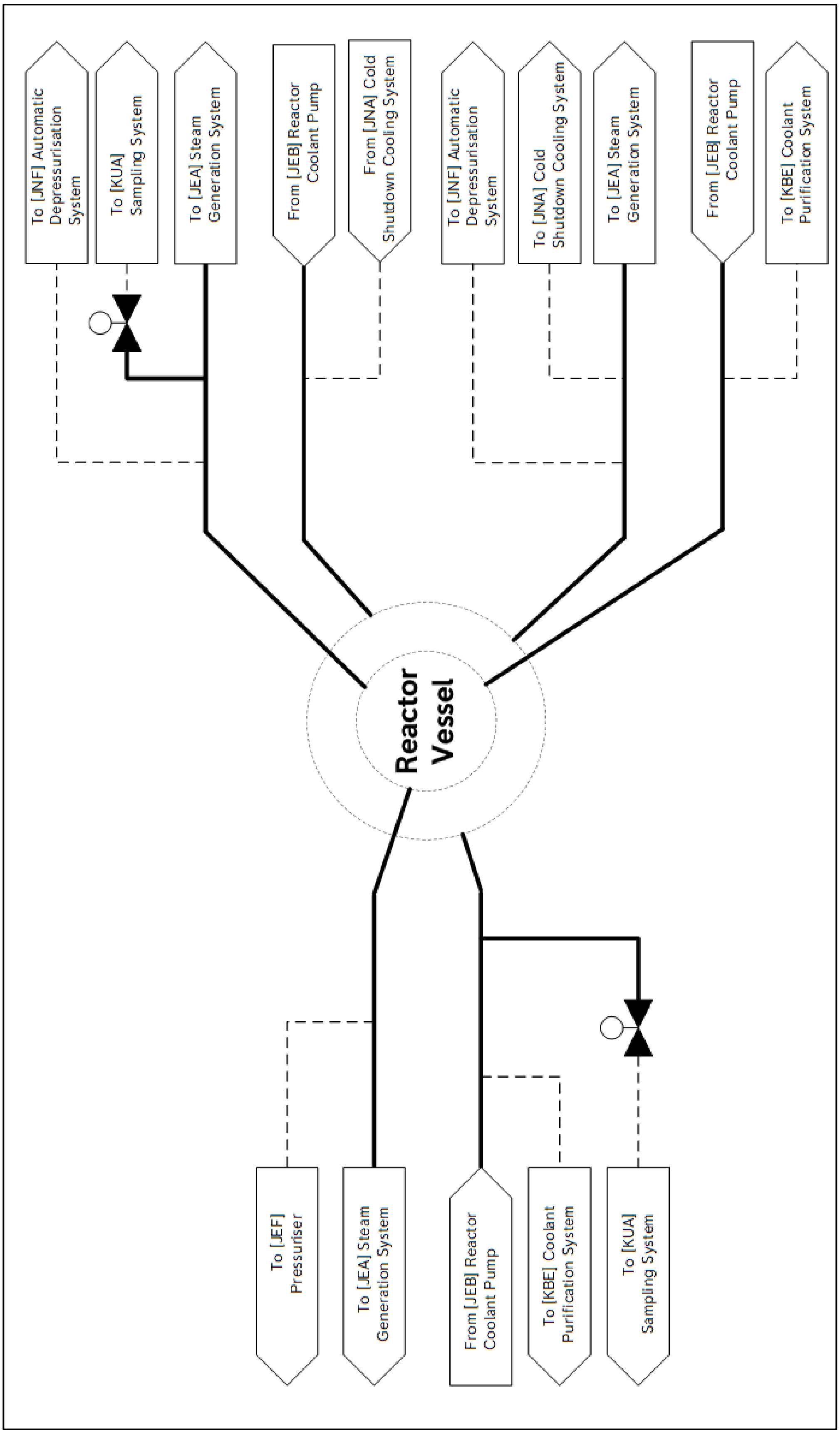

Figure 5.7-1: Simplified Schematic of the Reactor Coolant Pipework System [JEC]

5.7.4 Materials

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

5.7.5 Interfaces with Supporting Systems

The key Reactor Coolant Pipework System [JEC] interfaces are identified and managed within DOORS, including flow down of functional requirements, and summarised below:

1. RCP [JEB] provides the motive force for the circulation of coolant between the Reactor System [JA] and the Steam Generation System [JEA]. The Reactor Coolant System Pipework [JEC] is connected to the RCS cold leg.

2. Steam Generation System [JEA] receives heated coolant from the Reactor System [JA] via the Reactor Coolant Pipework System [JEC] to generate steam, returning coolant to pipework via the RCPs [JEB].

3. Reactor System [JA] receives coolant from the Reactor Coolant Pipework System [JEC], heats it via nuclear fission, and returns the heated coolant to the pipework for onwards transfer to the SGs.

4. Coolant Purification System (CPS) [KBE] receives coolant from the Reactor Coolant System Pipework [JEC] to facilitate let-down, chemistry control and filtering of reactor coolant.

5. Pressurising System [JEF] provides an overpressure on the RCS [JE] to maintain the reactor coolant in a liquid state.

6. Reactor Sampling System [KUA] receives coolant from the Reactor Coolant Pipework System [JEC] to facilitate the measurement of various reactor coolant parameters (e.g. pH). The Reactor Coolant System Pipework [JEC] includes one section of small-bore pipework and an isolation valve prior to the interface with the Reactor Sampling System [KUA].

7. Automatic Depressurisation System [JNF] facilitates reactor coolant blowdown as part of the ECC Safety Function [JN01].

8. CSCS [JNA] provides decay heat removal once the reactor coolant temperature has fallen below 120°C, by receiving heated coolant from a penetration on a hot leg and returning coolant (following heat removal) to a cold leg.

5.7.6 System & Equipment Operation

During Operating Mode 1 (Power Operation), 2 (Start-Up), 3 (Hot Standby), and 4a (Hot Shutdown – Steaming), the Reactor Coolant Pipework System [JEC] will monitor:

1. Hot Leg Temperature

2. Cold Leg Temperature

3. Reactor Coolant Flow Rate

4. Reactor Coolant Pressure

During Operating Mode 4b (Hot Shutdown – Non-Steaming), 5a (Cold Shutdown – Pressurised), 5b (Cold Shutdown – Depressurised), 6a (Refuelling with Reduced Water Level above Fuel) and 6B (Refuelling with Reduced Water Level above Fuel at Nominal Full), the Reactor Coolant Pipework System [JEC] will transfer coolant to the CSCS [JNA] via a penetration on the hot leg. Coolant is returned via a penetration on the cold leg, whereby it is circulated through the core and subsequently transferred back to the CSCS [JNA].

5.7.7 Instrumentation & Control

The instrumentation on the Reactor Coolant Pipework System [JEC] is illustrated in Figure 5.7-2. It is envisaged that each loop has the same set of sensors, except for the pressuriser surge line level measurement equipment which is only present on loop 1.

The Reactor Coolant Pipework System [JEC] places requirements on the Reactor Control System [JY] to monitor a range of key systems parameters and provide indication of these to the operator in the control room and in the emergency control centre. It will also require alarms to indicate that key system parameters are outside of the defined performance bands and/or safety limits. The envisaged requirements for monitoring, indication, alarms, and warnings are specified in the Reactor Coolant Pipework System Description, Reference [16].

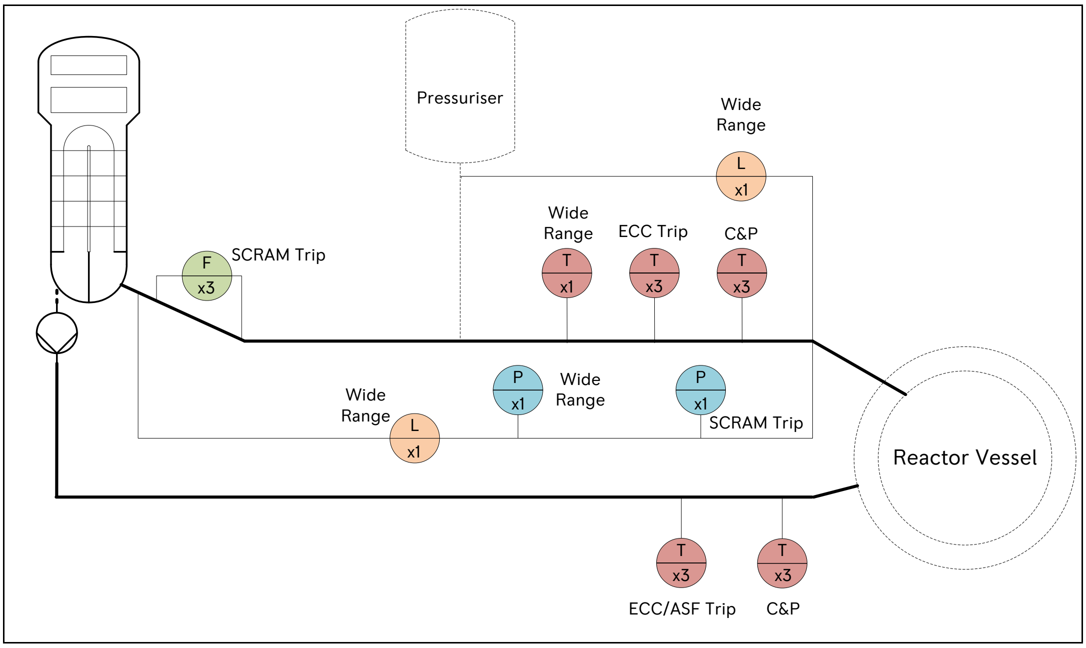

Figure 5.7-2: Reactor Coolant Pipework System [JEC] Instrumentation

5.7.8 Monitoring, Inspection, Testing and Maintenance

An outline maintenance plan for the Reactor Coolant Pipework System [JEC] is still to be developed. The ASME Boiler & Pressure Vessel Code identifies the following typical inspection activities for the Reactor Coolant Pipework System [JEC]:

1. Pipework:

    a. Instrument penetrations

   b. All welded connections (e.g. pipework connections, RCP interface)

   c. Mechanical joints (e.g. flanged connections if utilised)

   d. Lagging integrity

2. Instrumentation:

   a. Reactor Coolant Pipework System [JEC] instrument calibration (flow, pressure, temperature, level)

5.7.9 Radiological Aspects

No significant radiological aspects associated with the Reactor Coolant Pipework System [JEC] operation have been identified during design decisions up to PCD. Low activation materials are used in the design of Reactor Coolant Pipework System [JEC].

5.7.10 Performance and Safety Evaluation

At PCD, verification strategies for the Reactor Coolant Pipework System [JEC] to demonstrate compliance with its safety categorised functional requirements and associated non-functional performance requirements are in development and stored in DOORS. This predominantly includes structural integrity assessments to demonstrate the confinement function, and inspections to ensure the installation supports the transfer of reactor coolant.

5.7.11 Installation & Commissioning

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

5.8 Reactor Pressure Control System

5.8.1 System and Equipment Functions

The primary function of the Reactor Coolant Pressurising System [JEF] is to provide pressure control for the RCS [JE] and the Reactor System [JA], and to accommodate volume changes during transients (both normal duty and faulted). The system also provides interfaces for the Reactor Coolant Pressure Relief [JEG] and Automatic Depressurisation [JNF] systems to the RCS [JE], as well as housing instrumentation which supports the Reactor Control and Protection Systems [JY]. The system contributes to the achievement of FSFs of CoR, CoFT and CoRM.

5.8.2 Safety Design Basis

Functional Requirements

Safety categorised functional requirements are specified for the Reactor Coolant Pressurising System [JEF] based on the HLSFs they deliver, including the applicable plant states and operating modes, these are presented in Table 5.8-1.

The traceability of safety categorised functional requirements back to the HLSFs will be managed in DOORS; this process is outlined in Deterministic Safety Methodology, Reference [7], and is expected to be implemented to support FCD.

Table 5.8-1: [JEF] Safety Functional Requirements

DOORS ID	Functional Requirement	Plant State(s)	Mode(s) of Operation	Safety Category
JEF-R-1334	The Reactor Coolant Pressurising System [JEF] shall contain and confine Reactor Coolant at the system's specified design pressure and temperature	DBC-1 DBC-2 DBC-3 DBC-4	All	A
JEF-R-1305	While in Modes 1, 2, 3, 4a, 4b, 5a or while in condenser decay heat removal, the Pressurising System [JEF] shall pressurise reactor coolant	DBC-1 DBC-2	All	C
JEF-R-1297	While in all modes of operation, the Pressurising System [JEF] shall sense pressuriser pressure **Supports Duty Operations*	DBC-1 DBC-2	All	C
JEF-R-1296	While in all modes of operation, the Pressurising System [JEF] shall sense pressuriser level **Supports Duty Operations*	DBC-1 DBC-2	All	C

DOORS ID	Functional Requirement	Plant State(s)	Mode(s) of Operation	Safety Category
JEF-R-1289	While in all modes of operation, the Reactor Coolant Pressurising System [JEF] shall sense pressuriser pressure **Supports Scram [JD01]*	DBC-3 DBC-4	All	A
JEF-R-1284	While in all modes of operation, the Reactor Coolant Pressurising System [JEF] shall sense pressuriser level **Supports Scram [JD01]*	DBC-3 DBC-4	All	A
JEF-R-1365	While in all modes of operation, the Reactor Coolant Pressurising System [JEF] shall sense pressuriser pressure **Supports ASF [JD02]*	DBC-3 DBC-4	All	B
JEF-R-1371	While in all modes of operation, the Reactor Coolant Pressurising System [JEF] shall sense pressuriser pressure **Supports ECC [JN01]*	DBC-3 DBC-4	All	A
JEF-R-1386	While in all modes of operation, the Reactor Coolant Pressurising System [JEF] shall sense pressuriser level **Supports PDHR [JN02]*	DBC-3 DBC-4	All	B

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

Non-Functional System Requirements

The non-functional system requirements are identified at system level in Table 5.2-2.

Safety Classification

The safety classification of the Reactor Coolant Pressurising System [JEF] is undertaken in accordance with the E3S Categorisation and Classification methodology outlined in E3S Case Chapter 3: E3S Objectives & Design Rules, Reference [8]. At PCD, the components within Reactor Coolant Pressurising System [JEF] are classified as followed:

1. Pressuriser Pressure Vessel: VHR, based on RGP.

5.8.3 Description of SSC

The baseline architecture for the Reactor Coolant Pressurising System [JEF] consists of the pressuriser, which is connected to the RCS [JE] via a surge line connected to a hot leg. Steam is generated in the pressuriser by electrical heaters located at the base of the pressuriser. Reductions in pressure are produced via a spray directed to the pressuriser steam space by the spray nozzle. The spray nozzle is connected via two main and one auxiliary spray lines arranged in a pump induced spray configuration.

A simplified schematic is shown Figure 5.8-1, and a summary of the key performance and design parameters for the system are presented in Table 5.8-2.

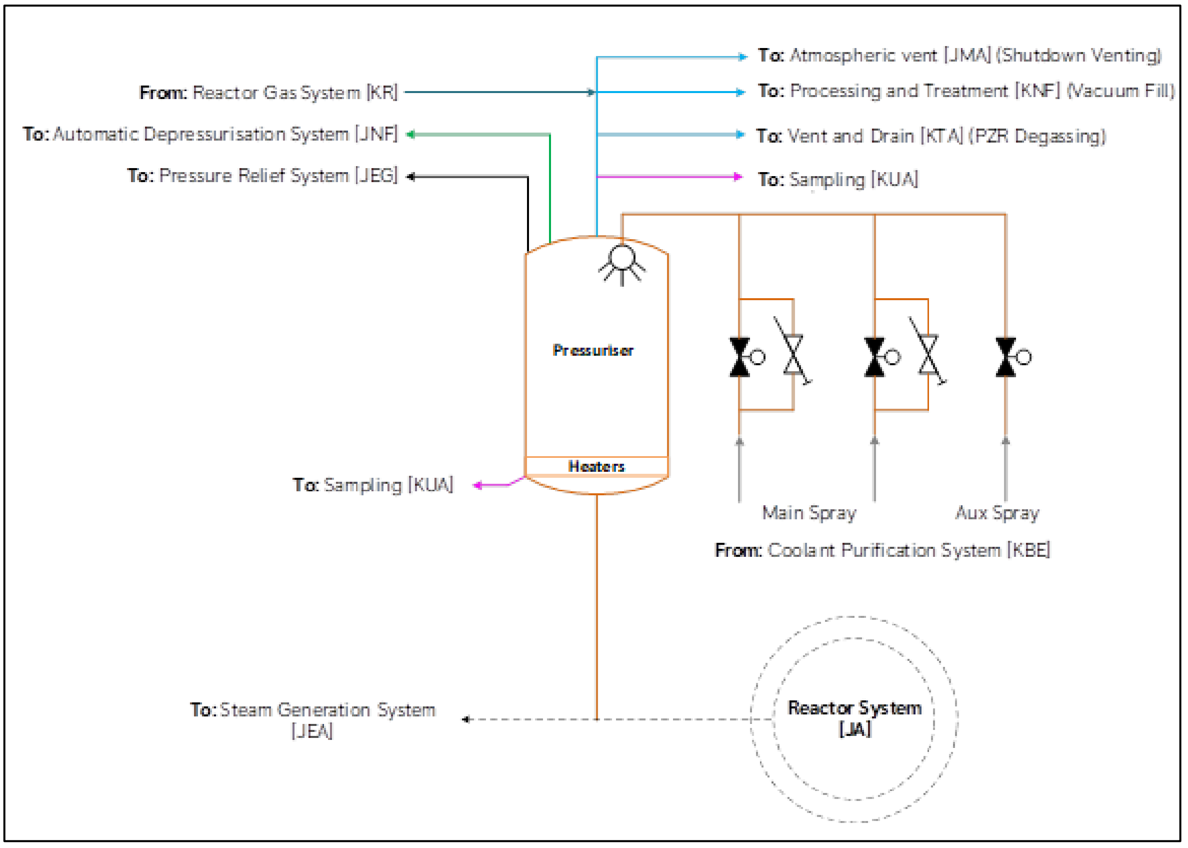

Figure 5.8-1: Simplified Schematic of the Reactor Coolant Pressurising System [JEF]

{REDACTED FOR PUBLICATION Table 5.8-2: Key Performance and Design Parameters for the Reactor Coolant Pressurising System [JEF]}

The pressuriser is a cylindrical vessel, sized to deliver its safety categorised functional requirements (current internal volume is **{REDACTED FOR PUBLICATION}**). It incorporates many penetrations, described further in the Reactor Coolant Pressurising System Description, Reference [17].

The pressuriser heaters are electrical heaters split into three banks: steady state heaters, transient heaters and start-up heaters. The baseline surge line design is DN200.

The pump induced spray contains a single spray head and two spray lines connected to separate RCS cold legs, as illustrated in Figure 5.8-2. Auxiliary spray is provided via one of the CVCS [KB] make-up pumps if the RCPs are unavailable.

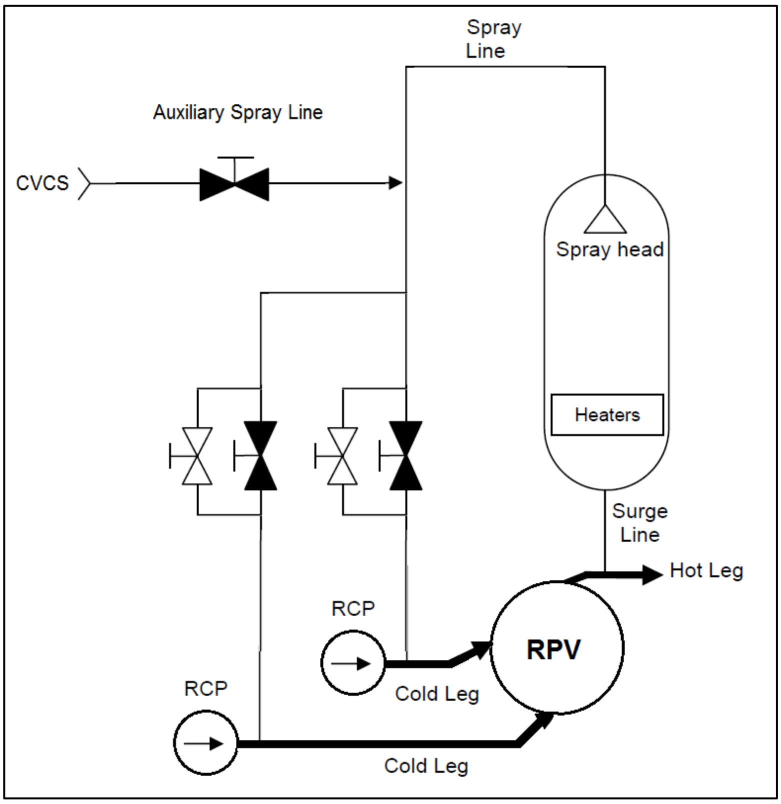

Figure 5.8-2: Pump Induced Spray Schematic

5.8.4 Materials

The pressuriser is manufactured from ASME SA 508 Grade 3 Class 1 steel, and internally clad with stainless steel (309L/308L) for corrosion resistance. The full description and justification of materials used for VHR SSCs are presented in E3S Case Chapter 23: Structural Integrity, Reference [3].

5.8.5 Interfaces with Supporting Systems

The key Reactor Coolant Pressurising System [JEF] interfaces are identified and managed within DOORS, including flow down of functional requirements, and summarised below:

1. Reactor Coolant System Pipework [JEC]: facilitates pressure control of the RCS [JE] and the Reactor System [JA]

2. Coolant Purification System [KBE]: reactor coolant used for pressuriser spray is routed from the Reactor Coolant System Pipework [JEC] (downstream of the RCPs) to the Pressurising System [JEF] via the Coolant Purification System [KBE], to minimise the number of penetrations needed on the RCS [JE] pipework. The system also supports auxiliary spray via a connection to the Pressurising System [JEF] downstream of the CVCS [KB] make-up pumps.

3. Weak Active Sampling System [KUA]: facilitates sampling of the pressuriser water space.

4. Gaseous Sampling System [KUF]: facilitates sampling of the pressuriser steam space.

5. Reactor Coolant Pressure Relief System [JEG]: the pressuriser vessel contains connection to the Reactor Coolant Pressure Relief System [JEG] to provide overpressure protection of the RCS [JE] and Reactor System [JA]

6. Automatic Depressurisation System [JNF]: facilitates rapid depressurisation of the RCS [JE] on demand in faulted scenarios, as part of the Emergency Core Cooling System [JN01]

7. Collection and Drainage System [KTA]: facilitates pressuriser degassing, which removes condensable gases from the pressuriser steam space during both powered and shutdown operations.

8. Processing & Treatment System for Liquid Radioactive Effluent [KNF]: supports shutdown operations; a vacuum pump in the system facilitates vacuum fill of the RCS [JE] to minimise the quantity of trapped non-condensable gases present in the system.

9. Containment [JMA]: facilitates atmospheric venting which allows ingress of air during drain-down.

10. Reactor Gas System [KR]: provides low pressure nitrogen overpressure on demand, to facilitate long term pressuriser layup.

5.8.6 System & Equipment Operation

During Operating Mode 1 (Power Operations), 2 (Start-Up), and 3 (Hot Standby), the Reactor Coolant Pressurising System [JEF] will be aligned and maintained in the following configuration:

1. RCS [JE] pressure maintained through generation of a steam bubble in the pressuriser and controlled within a defined operating band.

2. Pressuriser level maintained within a defined operating band via automatic level control, via the CVCS [KB] make-up pumps.

3. Continuous degassing of the pressuriser steam space carried out by the Vent and Drain System [KTA].

During Operating Mode 4a (Hot Shutdown –Steaming), RCP induced spray is used to reduce pressure to approximately **{REDACTED FOR PUBLICATION}** in a controlled manner. The rate of spray is controlled using an automatic throttle valve, with inventory control using the CVCS make-up and let-down. For warm-up, pressuriser heaters are used to increase pressure.

During Operating Mode 4b (Hot Shutdown – Non-Steaming), CSCS [JNA] pump or CVCS [KB] make-up pump induced spray is used to reduce pressure to approximately **{REDACTED FOR PUBLICATION}** in a controlled manner. For warm-up, pressuriser heaters are used to increase pressure.

During Operating Mode 5a (Cold Shutdown Pressurised), spray into the pressuriser head continues while the CVCS [KB] provides make-up to fill the pressuriser, fully collapsing the steam bubble. For warm-up, the vent lines at the top of the pressuriser are isolated and pressure is increased to approximately **{REDACTED FOR PUBLICATION}** via the CVCS [KB] charging pumps. The pressuriser heaters are switched on and as the pressuriser temperature increases, level is slowly reduced via continued discharge through the CVCS [KB] allowing a steam bubble to form. At this point the plant control system is switched to an automatic pressuriser level control regime and RCPs are switched on.

During Operating Mode 6a (Refuelling with Reduced Water Level above Fuel), as the plant is drained, the pressuriser is vented to containment atmosphere and coolant is discharged via the CVCS [KB] until the pressuriser is empty. For warm-up, vent lines are isolated, and the top of the pressuriser is connected to the Liquid Waste Treatment System [KNF], which draws a vacuum in the system to minimise the quantity of any trapped non-condensable gases. The CVCS [KB] make-up function is used to fill the plant until water solid.

During faults where Phase 1 of the Emergency Core Cooling System [JN01] is initiated, the Reactor Coolant Pressurising System [JEF] provides the interface to the Automatic Depressurisation System (ADS) [JNF], which rapidly depressurises the plant using high- and low-pressure blowdown lines. High pressure blowdown is conducted via two blowdown lines connected to the steam space of the pressuriser. This interface is also provided for operation of the ADS [JNF] during overpressure faults.

5.8.7 Instrumentation & Control

The instrumentation for the Reactor Coolant Pressurising System [JEF] is illustrated in Figure 5.8-3.

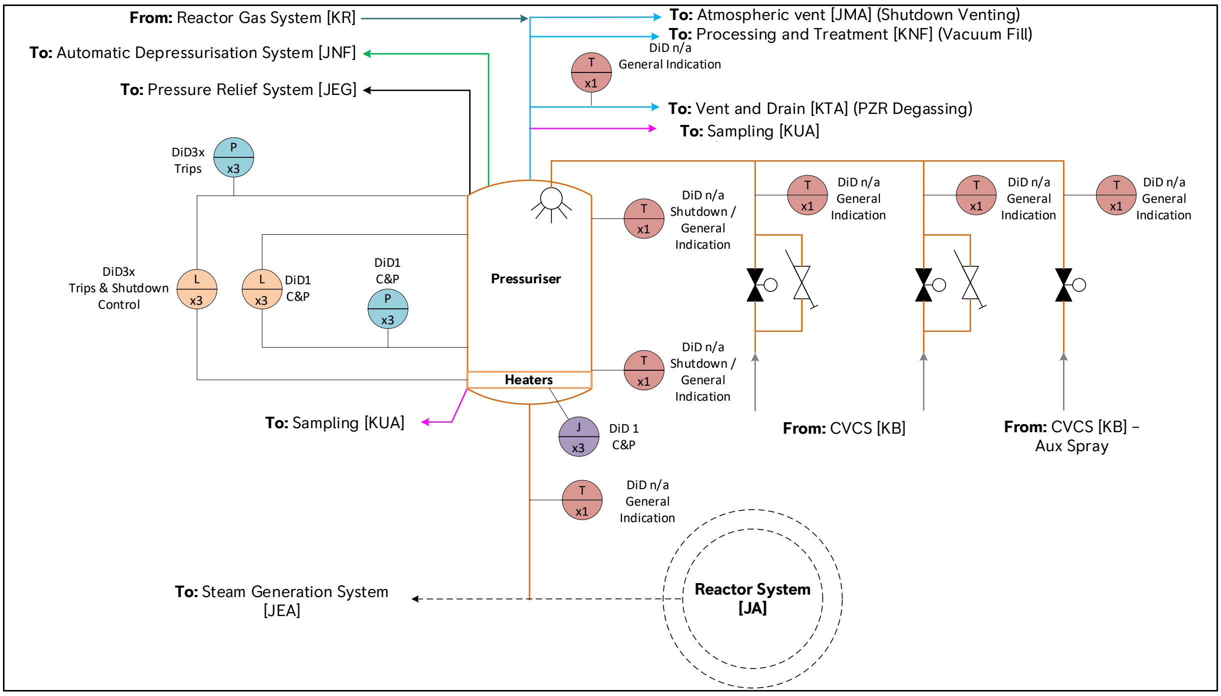

Figure 5.8-3: Reactor Coolant Pressurising System [JEF] Instrumentation

The Reactor Coolant Pressurising System [JEF] places several control functions onto the Reactor C&I System [JY]. The Reactor Control System [JY] will also monitor a range of key systems parameters and provide indication of these to the operator in the control room and in the emergency control centre.

The allocation of safety categorised functional requirements from the Reactor Coolant Pressurising System [JEF] to the Reactor C&I System [JY] is presented in the C&I Engineering Schedule, described further in E3S Case Chapter 7: Instrumentation & Control, Reference [12].

5.8.8 Monitoring, Inspection, Testing and Maintenance

An outline maintenance plan for Reactor Coolant Pressurising System [JEF] is still to be developed. The ASME Boiler & Pressure Vessel Code identifies the following typical inspection activities for the Reactor Coolant Pressurising System [JEF]:

1. Pressuriser:
    a. Circumferential welds (upper and lower)
    b. Spray nozzle Ultrasonic Testing (UT) inspection
    c. Spray line UT inspection
    d. Heater connections visual inspections
    e. Shell penetrations (level, pressure, etc.)
    f. Surge line connection
    g. Surge line connection to RCS (UT inspection)
2. In-service safety relief valve testing
3. Control & Instrumentation:
    a. Pressuriser level calibration
    b. Spray flow differential cell pressure calibration
    c. Pressuriser instruments calibration (flow, pressure, temperature, level).

5.8.9 Radiological Aspects

No significant radiological aspects associated with the Reactor Coolant Pressurising System [JEF] operation have been identified during design decisions up to PCD. Low activation materials are used in the design, for example, stainless steel cladding of the pressuriser helps to minimise the build-up of corrosion products in the RCS coolant.

5.8.10 Performance and Safety Evaluation

At PCD, verification strategies for the Reactor Coolant Pressurising System [JEF] to demonstrate compliance with its safety categorised functional requirements and associated non-functional performance requirements are in development and stored in DOORS. This includes a key verification activity to undertake analysis to demonstrate the spray efficiency and flow required to condense the steam bubble.

5.8.11 Installation & Commissioning

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

5.9 Heading Number Not Used

5.10 Reactor Coolant System Component Supports and Restraints

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

5.11 Reactor Coolant Pressure Relief System

5.11.1 System and Equipment Functions

The primary function of the Reactor Coolant Pressure Relief System [JEG] is to provide overpressure protection to the RCS [JE] in event of reactor or system faults, providing the FSF of CoFT. The system consists of two pairs of Safety Relief Valves (SRVs).

HLSFs for the Reactor Coolant Pressure Relief System [JEG], and the PIEs against which they are assigned, are being derived in the Fault Schedule, which is presented in E3S Case Chapter 15: Safety Analysis, Reference [6].

5.11.2 Safety Design Basis

Functional Requirements

Safety categorised functional requirements are specified for the Reactor Coolant Pressure Relief System [JEG] based on the HLSFs they deliver, including the applicable plant states and operating modes, these are presented in Table 5.11-1.

The traceability of safety categorised functional requirements back to the HLSFs will be managed in DOORS; this process is outlined in Deterministic Safety Methodology, Reference [7], and is expected to be implemented to support FCD.

Table 5.11-1: [JEG] Safety Categorised Functional Requirements

DOORS ID	Functional Requirement	Plant State(s)	Mode(s) of Operation	Safety Category
JEG-R-1478	While in modes 1-4a JEG shall provide overpressure relief to the RCS	DBC-3 DBC-4	1-4a	A
JEG-R-1484	While in modes 4b-5a, JEG shall provide overpressure relief to the RCS and CSCS	DBC-3 DBC-4	4b-5a	A
JEG-R-1474	JEG shall contain and confine primary coolant in all modes of operation	DBC-3 DBC-4	1, 2	A

The safety categorised functional requirements for the Reactor Coolant Pressure Relief System [JEG] are flowed down and allocated to relevant sub-systems and/or components in the DOORS RCS [JN01] Definition Module. This functional decomposition is illustrated through the Capella model(s) presented in the DOORS module.

Non-functional performance requirements associated with the safety categorised functional requirements are also presented in the DOORS RCS [JE] Requirements Module, which are not repeated here.

Non-Functional System Requirements

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

Safety Classification

The safety classification of the Reactor Coolant Pressure Relief System [JEG] is undertaken in accordance with the E3S Categorisation and Classification methodology outlined in E3S Case Chapter 3: E3S Objectives & Design Rules, Reference [8]. At PCD, the components within Reactor Coolant Pressure Relief System [JEG] are classified as followed:

1. SRVs: High Temperature Overpressure Protection/Low Temperature Overpressure Protection (HTOP/LTOP): Safety Class 1, as the primary means of fulfilling a Category A safety function.

2. Inlet/Outlet Pipework: Safety Class 1, contributes to the primary means of fulfilling a Category A safety function.

3. HTOP Instrumentation: Safety Class 1, contributes to the primary means of fulfilling a Category A safety function (Scram).

4. LTOP Instrumentation: Safety Class 2, contributes to the primary means of fulfilling a Category B safety function (PDHR).

Seismic Classification

The seismic classification of SSCs is still to be assigned in accordance with methodology outlined in E3S Case Chapter 3: E3S Objectives & Design Rules, Reference [8].

5.11.3 Description of SSC

The Reactor Coolant Pressure Relief System [JEG] comprises of the following two sub-systems:

1. High Temperature Overpressure Protection (HTOP), providing overpressure protection during power operations (Operating Modes 1 – 4a), comprising two steam SRVs located on top of the pressuriser operating, each 100% capable of achieving the safety function in a 1 out of 2 (1oo2) configuration.

2. Low Temperature Overpressure Protection (LTOP), providing overpressure protection during cold shutdown (Operating Modes 4b – 5a), comprising two water SRVs located on the RCS [JE]/CSCS [JNA] interface, each 100% capable of achieving the safety function (1oo2).

Key performance and design parameters for the system are presented in Table 5.11-2, and a simplified schematic of both the HTOP and LTOP sub-systems is illustrated in Figure 5.11-1.

{REDACTED FOR PUBLICATION Table 5.11-2: Key Performance and Design Parameters for the Reactor Coolant Pressure Relief System [JEG]}

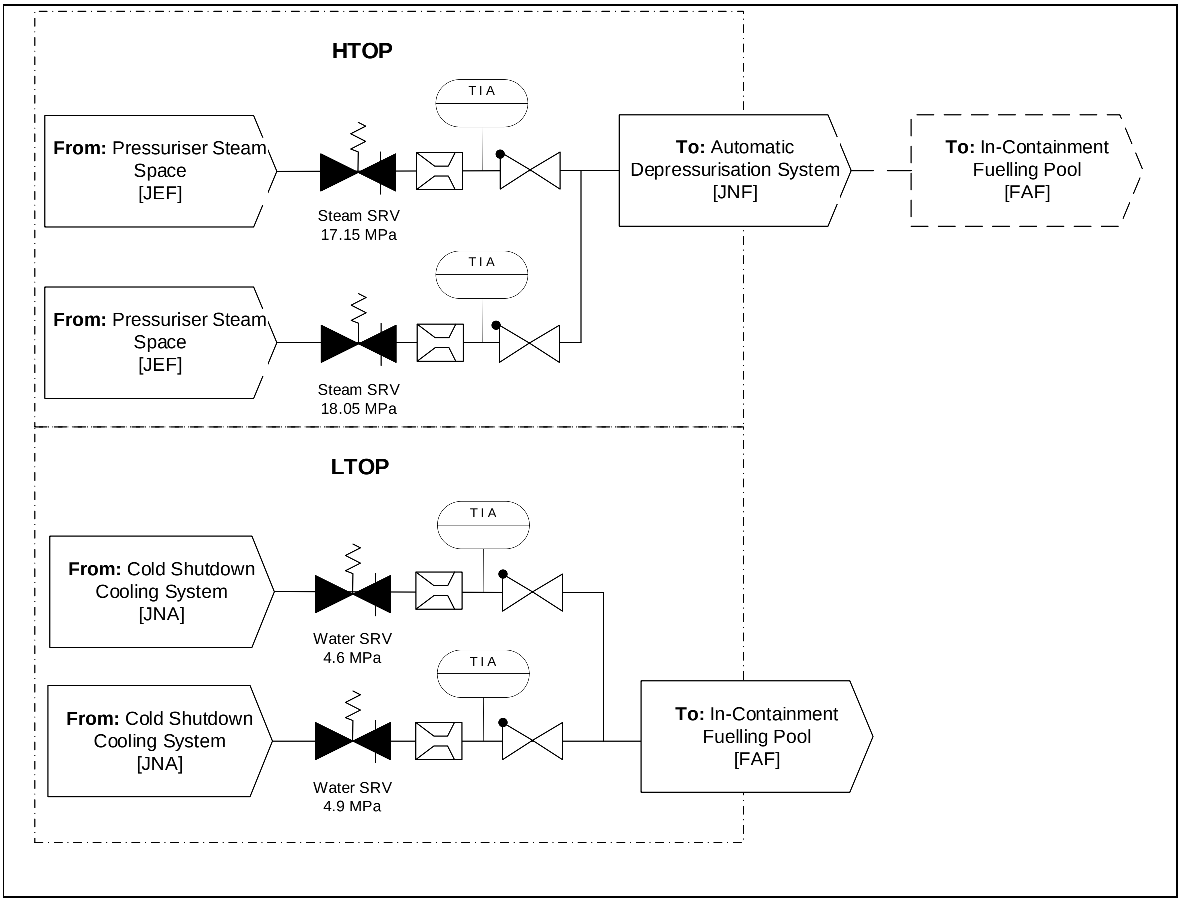

Figure 5.11-1: Reactor Coolant Pressure Relief System [JEG] Schematic

5.11.4 Materials

The description and justification of materials used for Class 1 SSCs are presented in E3S Case Chapter 23: Structural Integrity, Reference [3].

5.11.5 Interfaces with Supporting Systems

The key interfaces for the Reactor Coolant Pressure Relief System [JEG] are identified and managed in DOORS, including flow down of functional requirements, and summarised below:

1. Reactor Coolant Pressurising System [JEF], which provides two pressure relief routings for the RCS [JE] during powered operations, allowing the discharge of saturated steam.

2. ADS [JNF], which provides sparging capabilities in the Refuelling Pool [FAF] for the relief material discharged from the pressuriser steam space. It also has two tie-ins pre-SRVs that direct reactor coolant to the ADS valves from the pressuriser.

3. CSCS [JNA], which provides two relief routings for the RCS during cold shutdown operations, allowing the discharge of sub-cooled water.

4. Refuelling Pool [FAF], which provides containment and storage for the sub-cooled water discharged during low-temperature overpressure transients.

5.11.6 System Operation

During Operating Modes 1 to 4a, the HTOP SRVs are available with the LTOP SRVs isolated. During Operating Modes 4b to 6b, the LTOP SRVs are available, with the HTOP SRVs still connected.

A spurious lift or failure to reseat will result in a LOCA, with ECC [JN01] initiated.

5.11.7 Instrumentation & Control

The Reactor Coolant Pressure Relief System [JEG] does not place any control functions onto the Reactor C&I System [JY], however does place requirements to monitor a range of key systems parameters and provide indication of these to the operator in the control room and in the emergency control centre.

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

The allocation of safety categorised functional requirements from the Reactor Coolant Pressure Relief System [JEG] to the Reactor C&I System [JY] is presented in the C&I Engineering Schedule, described further in E3S Case Chapter 7: Instrumentation & Control, Reference [12].

5.11.8 Monitoring, Inspection, Testing and Maintenance

An outline maintenance plan for the Reactor Coolant Pressure Relief System [JEG] is still to be developed. Typical inspection activities for the Reactor Coolant Pressure Relief System [JEG] will include SRV testing/replacement and instrumentation calibration (e.g., flow, temperature, pressure). It is anticipated SRVs can be tested and maintained solely during refuelling outages.

5.11.9 Radiological Aspects

No significant radiological aspects associated with the Reactor Coolant Pressure Relief System [JEG] operation have been identified during design decisions up to PCD.

5.11.10 Performance and Safety Evaluation

At PCD, an initial verification strategy for the Reactor Coolant Pressure Relief System [JEG] was developed to demonstrate compliance with its safety categorised functional requirements and associated non-functional performance requirements. This includes a key verification activity to undertake RELAP Thermal Hydraulic analysis to demonstrate timely pressure relief.

5.11.11 Installation & Commissioning

An outline installation and commissioning plan for the Reactor Coolant Pressure Relief System [JEG] is still to be developed. The overall strategy for the RR SMR commissioning programme is presented in E3S Case Chapter 14: Plant Construction & Commissioning, Reference [14].

5.11.12 ALARP in Design Development

The design of the Reactor Coolant Pressure Relief System [JEG] has been developed in accordance with the systems engineering design process, which includes extensive review and alignment to RGP & OPEX, design to codes and standards according to the safety classification, and a systematic optioneering process with down-selection of design options based on assessment against relevant safety criteria (as described in E3S Case Chapter 3: E3S Objectives & Design Rules, Reference [8]). Hazard identification studies have also been undertaken to support major design decisions.

Key Reactor Coolant Pressure Relief System [JEG] design decisions made with respect to ensuring overall risks are reduced to ALARP include:

1. A 1oo2 arrangement for HTOPs and LTOP SRVs follows RGP from other PWR designs, and is deemed to provide suitable Defence in Depth (DiD) against PIEs, with the benefits associated with further redundancy offset by increased vulnerabilities due to the potential for spurious lifts.

2. A decision has been made not to incorporate SRV isolation to protect against spurious lift, based on review of RGP and qualitative assessment. The provision of SRV isolation could reduce the level of defence in depth in the design should it mistakenly actuate during power operation, with a loss of the pressure relief safety function. IAEA does not permit isolation, and no such isolation is found on other UK PWR designs. Furthermore, sufficient protection against a spurious lift fault is provided by the ECC [JN01] safety measure.

3. Passive valve actuation of LTOP SRVs is selected over more complex options such as remotely actuated valves, to provide a simplified system that can likely meet safety criteria without the need for C&I or electrical input, which may introduce new vulnerabilities.

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

5.11.13 Ongoing Design Development

The RR SMR design definition is in development as described in Section 5.0.2. Key design opportunities and decisions related to nuclear safety are being explored, this includes:

1. Confirmation that the location of the LTOP SRVs is suitable to provide protection against RPV brittle fracture during cold shutdown pressure transients.

2. Analysis of sparger size and confirmation of the refuelling pool as a relief destination.

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

5.12 Access and Equipment Requirements for In-Service Inspection and Maintenance

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

5.13 Reactor Auxiliary Systems

5.13.1 Chemistry & Volume Control System

System and Equipment Functions

The primary function of the CVCS [KB] is to control the chemistry and volume of the reactor coolant within the RCS [JE]. The system maintains reactor coolant chemistry within specification and maintains pressuriser level within a required operating band. It comprises of three sub-systems: the Level & Volume Control System [KBA]; the Chemistry Control System [KBD]; and the Coolant Purification System [KBE]. The system contributes to the achievement of FSFs of CoR, CoFT, and CoRM.

HLSFs for the CVCS [KB], and the PIEs against which they are assigned, are being derived in the Fault Schedule, which is presented in E3S Case Chapter 15: Safety Analysis, Reference [6].

Safety Design Basis

Functional Requirements

Safety categorised functional requirements are specified for the CVCS [KB] based on the HLSFs they deliver, including the applicable plant states and operating modes, these are presented in Table 5.13-1.

The traceability of safety categorised functional requirements back to the HLSFs will be managed in DOORS; this process is outlined in Deterministic Safety Methodology, Reference [7], and is expected to be implemented to support FCD.

Table 5.13-1: [KB] Safety Categorised Functional Requirements

DOORS ID	Functional Requirement	Plant State(s)	Mode(s) of Operation	Safety Category
KB-R-1255	While in Powered Operations the Chemical and Volume Control System shall maintain coolant chemistry	DBC-1 DBC-2	All	C
KB-R-1369	While in Condenser DHR Operation, the Chemistry and Volume Control System [KB] shall control reactor coolant chemistry	DBC-1 DBC-2	4a, 4b, 5a, 5b	C
KB-R-1259	Following Alternative Shutdown Function Operation, the CVCS shall remove soluble boron from the reactor coolant	DBC-4	All	C

DOORS ID	Functional Requirement	Plant State(s)	Mode(s) of Operation	Safety Category
KB-R-1249	While in non-faulted operating modes, the CVCS shall maintain coolant inventory	DBC-1 DBC-2	All	C
KB-R-1263	While the Passive Decay Heat Removal [JN02] Function is in operation, the Chemical Volume & Control System [KB] shall isolate leaks	DBC-2ii DBC-3 DBC-4	All	B
KB-R-1260	When in faulted operation, the CVCS shall isolate lines that pass through the containment boundary	DBC-2ii DBC-3 DBC-4	All	A/B
KB-R-1368	While in Start-up operations, the CVCS shall control coolant pressure	DBC-1 DBC-2	4b, 5a, 5b	C

The safety categorised functional requirements for the CVCS [KB] are flowed down and allocated to relevant sub-systems and/or components in the DOORS CVCS [KB] Definition Module. This functional decomposition is illustrated through the Capella model(s) presented in the DOORS module.

Non-functional performance requirements associated with the safety categorised functional requirements are also presented in the DOORS RCS [JE] Requirements Module, which are not repeated here.

Non-Functional System Requirements

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

Safety Classification

The safety classification of the CVCS [KB] is undertaken in accordance with the E3S Categorisation and Classification methodology outlined in E3S Case Chapter 3: E3S Objectives & Design Rules, Reference [8]. At PCD, the sub-systems and components within the CVCS [KB] are classified as followed:

1. Level & Volume Control System [KBA]: the overall system is Safety Class 3, providing the primary means of fulfilling the Category C safety function of flow for maintaining coolant inventory.

2. Chemistry Control System [KBD]: the overall system is Safety Class 3, providing the primary means of fulfilling the Category C safety function of flow for controlling coolant chemistry.

3. Coolant Purification System [KBE]: the overall system is Safety Class 3, providing the primary means of fulfilling the Category C safety function of flow for coolant purification, noting:

a. Containment isolation valves provide a Category A function to isolate the containment during a LOCA and operation of the Emergency Core Cooling [JN01], and are therefore Safety Class 1.

b. The excess flow isolation valve on the supply line and non-return valve on the return line provide a Category B function to isolate the containment during a LOCA to prevent a leak of the CVCS water, and are therefore Safety Class 2.

Seismic Classification

The seismic classification of SSCs is still to be assigned in accordance with methodology outlined in E3S Case Chapter 3: E3S Objectives & Design Rules, Reference [8].

Description of SSC

Level & Volume Control System [KBA]

The Level & Volume Control System (LVCS) [KBA] contains a make-up line and a let-down line to support maintaining pressuriser level within a required band. The LVCS is connected to the Coolant Purification System [KBE] and provides inventory management of the reactor coolant.

The LVCS [KBA] let-down line comprises of the following key components in flow path order:

1. Let-down orifice.

2. Let-down control valve.

3. Let-down line isolation valves.

4. Flow measurement orifice instrumentation.

The LVCS [KBA] makeup line comprises of the following key components in flow path order:

1. Control valves downstream of charging pumps to throttle the makeup flow rate.

2. Liquid Waste Treatment System (LWTS) [KNF] feed line.

3. Charging pump discharge relief valves.

4. Flow measurement orifice instrumentation.

5. Makeup line isolation valves.

Let-down is taken from downstream of the Coolant Purification System [KBE] Ion-Exchange Columns (IXCs) and filter, to ensure that it is cool and contains as little activity as possible prior to being sent to the Liquid Waste Treatment Systems [KN]. Motive force for coolant removal is provided by RCS [JE] during Operating Modes 1 to 4a during cooldown and 4b to 1 during warmup, and the CSCS pump head during other modes.

Make-up is injected from the LWTS [KNF] upstream of the Coolant Purification System [KBE] pre-cooler to ensure it is pre-heated prior to reaching the RCS [JE] cold leg. Two parallel high pressure charging pumps (1 duty, 1 standby) provide the motive force to inject the coolant.

The LVCS [KBA] is also located outside containment, with isolation from the RCS [JE] during a LOCA provided via the Coolant Purification System [KBE] containment isolation valves.

Key performance and design parameters for the system are presented in Table 5.13-2.

{REDACTED FOR PUBLICATION Table 5.13-2: Key Performance and Design Parameters for [KBA]}

Further description of the Level & Volume Control System [KBA] is provided in the System Description, Reference [19].

Chemistry Control System [KBD]

The Chemistry Control System [KBD] controls the reactor coolant chemistry to ensure it is within the Water Quality Specification (WQS), providing zinc dosing, hydrogen addition and chemical addition.

The baseline architecture for the Chemistry Control System [KBD] includes three lines to the Coolant Purification System [KBE]: a hydrogen dosing line that is fed from hydrogen gas bottles; a zinc dosing line that is pumped from a zinc addition tank; and a chemical dosing line fed from a Chemical Mixing Tank via the LVCS [KBA] charging pumps.

The Chemistry Control System [KBD] is also located outside containment, with isolation from the RCS [JE] during a LOCA provided via the Coolant Purification System [KBE] containment isolation valves.

Key performance and design parameters for the system are presented in Table 5.13-3.

{REDACTED FOR PUBLICATION Table 5.13-3: Key Performance and Design Parameters for [KBD]}

Further description of the Chemistry Control System [KBD] is provided in the System Description, Reference [20].

Coolant Purification System [KBE]

The Coolant Purification System [KBE] purifies the reactor coolant to ensure it remains within the WQS. A continuous flow of coolant is circulated through the system in normal operation to purify the coolant and help maintain coolant activity within specified limits. It also provides a main flow to the pressuriser spray line (via the spray line parallel isolation valves).

The Coolant Purification System [KBE] comprises the following key components in flow path order:

1. Isolation Valves

2. Containment Isolation Valves

3. Pre-Cooler (Regenerative Heat Exchanger)

4. KAA Cooler (Non-Regenerative Heat Exchanger)

5. IXC Upstream Isolation Valves

6. Mixed Bed IXCs

7. IXC Downstream Isolation Valves

8. Cation Bed IXC / Cation Bed Bypass Line

9. Two Downstream Backwashable Filters (duty and standby)

10. Non-Return Valve

11. Throttle Valve

The Coolant Purification System [KBE] takes coolant from downstream of the RCPs [JEB], cools it, removes impurities, reheats it, and returns it to upstream of the RCPs [JEB]. It is a high-pressure system operating at normal RCS [JE] operating pressure. In shutdown operation when the RCPs [JEB] are switched-off, the system can be re-aligned to the CSCS [JNA] to provide flow through the system.

The Coolant Purification System [KBE] is in the Annulus, which is outside the containment building. Dedicated containment isolation valves provide isolation from the RCS [JE] in containment during a LOCA.

Key performance and design parameters for the system are presented in Table 5.13-4.

{REDACTED FOR PUBLICATION Table 5.13-4: Key Performance and Design Parameters for [KBE]}

Further description of the Coolant Purification System [KBE] is provided in the System Description, Reference [21].

Materials

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

Interfaces with Supporting Systems

The functional and physical interfaces for the CVCS [KB] are described above. These are identified and managed within DOORS, including flow down of functional requirements.

System Operation

<u>Level & Volume Control System [KBA]</u>

During Operating Mode 1 (Power Operations), automatic level control will manage the assumed let-down rate by starting the charging pumps when the bottom of the Pressuriser level operating band is reached.

During Operating Modes 2 (Start-Up), 3 (Hot Standby), 4a (Hot Shutdown – Steaming) and 4b (Hot Shutdown – Non-Steaming), automatic level control will initiate to maintain water level appropriately during expansions and contractions in the RCS [JE].

During Operating Mode 5a (Cold Shutdown Pressurised), in shutdown make-up is required due to coolant contracting as temperature decreases and for raising the pressuriser level to collapse the steam bubble and facilitate the depressurisation of the plant. In start-up, it is assumed that the plant is operating water solid with pressure control provided by the charging pumps prior to starting the RCPs.

During Operating Mode 5b (Cold Shutdown Depressurised), for shutdown the plant is drained for refuelling through the let-down line, and for start-up filled with coolant to the top of the pressuriser through the make-up line.

During Operating Mode 6a (Refuelling with Reduced Water Level above Fuel), the make-up line is used to increase the water level to flood the refuelling cavity and let-down line allows for draining for the return to power operations. Pressure is also maintained within a defined band. In Operating Mode 6a (warmup), the LVCS [KBA] let-down line drains the RCS [JE] to 3/4 level in preparation for the RPV head to be reinstalled. During Operating Mode 6b (Refuelling with Water Level at Nominal), make-up is provided to the account of evaporation of coolant in the refuelling channel.

Chemistry Control System [KBD]

During Operating Modes 1 (Power Operations) and 2 (Start-Up), oxygen is kept to within its low-level range by providing a small flow of hydrogen into the reactor coolant to replenish losses, with a secondary means of lowering oxygen through mechanical degassing by bleeding and feeding of coolant to the LWTS [KNF] Vacuum Degasser. Zinc is kept to within its low-level range by zinc acetate dosing, and coolant pH is kept within its specification by potassium hydroxide dosing. During Operating Modes 3 (Hot Standby) and 4a (Hot Shutdown – Steaming), zinc is kept to within its mid-level range.

During Operating Mode 4b (Hot Shutdown – Non-Steaming), at start-up oxygen levels are rapidly reduced by hydrazine injection and mechanical degassing. At shutdown, hydrogen levels are reduced by mechanical degassing, and oxygen levels are increased by opening vents in the RPV and the Pressuriser. The baseline assumption is that a change in chemistry regime is not required to induce CRUD burst, however design options remain open should it be required, through injection of a suitable oxidising reagent.

During Operating Mode 5a (Cold Shutdown Pressurised), at shutdown rapid oxygenation is achieved by injecting hydrogen peroxide into the RCS [JE].

Coolant Purification System [KBE]

During Operating Modes 1 (Power Operations), 2 (Start-Up), 3 (Hot Standby), and 4a (Hot Shutdown – Steaming), the continuous flow rate through the loop is controlled using the throttle valve, with driving head provided by the RCPs [JEB]. The Mixed Bed IXCs can be used to reduce coolant zinc levels and purify coolant impurities where required. In the event of fuel failure, the Cation Bed IXC will perform failed fuel clean-up. Backwashable filters will filter any resin fines released from the IXCs.

During Operating Modes 4b (Hot Shutdown – Non-Steaming), 5a (Cold Shutdown Pressurised), 5b (Cold Shutdown Depressurised), 6a (Refuelling with Reduced Water Level above Fuel), and 6b (Refuelling with Water Level at Nominal), driving head can also be provided through alignment to the CSCS [JNA] pumps. Should it be required, the Mixed Bed IXCs can perform coolant clean-up following CRUD burst.

During faulted operations, in the event of a LOCA within the CVCS [KB], the containment isolation valves will close to isolate it, expected to be based on a low pressuriser level set point or high CVCS system flow, noting the operating philosophy for CVCS [KB] faulted operations is still to be developed.

Instrumentation & Control

<u>Level & Volume Control System [KBA]</u>

The Level & Volume Control System [KBA] places requirements on the Reactor C&I System [JY] to monitor and indicate a range of key systems parameters and provide indication of these to the operator in the control room and in the emergency control centre, including the let-down flow rate and pressure, and charging pump status, inlet/outlet pressure, and flow rate.

It will also provide alarms to indicate that key system parameters are outside of the defined performance bands and/or safety limits. The envisaged requirements for monitoring, indication, alarms, and warnings are specified in the Level & Volume Control System [KBA] System Description, Reference [19].

<u>Chemistry Control System [KBD]</u>

The Chemistry Control System [KBD] places requirements on the Reactor C&I System [JY] to provide control functions for control of the zinc dosing pump and automation of dosing, control of the hydrogen addition control valves and automation of continuous hydrogen injection, and control of the chemical dosing pump and automation of potassium hydroxide dosing.

It also places requirements to monitor, indicate and alarm on a range of key systems parameters and provide indication of these to the operator in the control room and in the emergency control centre, including the chemical and zinc tank level/filter differential pressure/pump status, and the hydrogen gas bottle manifold pressure, and line flow rate/outlet pressure.

<u>Coolant Purification System [KBE]</u>

The Coolant Purification System [KBE] places requirements on the Reactor C&I System [JY] to provide control functions for opening/shutting isolation valves and containment isolation valves.

It also places requirements to monitor, indicate and alarm on a range of key systems parameters and provide indication of these to the operator in the control room and in the emergency control centre, including the pre-cooler and cooler outlet temperature, inlet and return line flow rate, and downstream filter differential pressure.

The allocation of safety categorised functional requirements from the CVCS [KB] to the Reactor C&I System [JY] is presented in the C&I Engineering Schedule, described further in E3S Case Chapter 7: Instrumentation & Control, Reference [12].

Monitoring, Inspection, Testing and Maintenance

An outline maintenance plan for the CVCS [KB] is still to be developed.

Radiological Aspects

Backwashable filters are selected that enables automation of filter changes and remote cleaning, which significantly reduces the need for filter changes compared to traditional PWR filtering methods, in turn reducing operator dose uptake during EMIT.

Performance and Safety Evaluation

At PCD, verification strategies for the CVCS [KB] to demonstrate compliance with its safety categorised functional requirements and associated non-functional performance requirements are in development and stored in DOORS. A limited number of verification activities have been identified at this stage, predominantly Mechanical Flow and Thermal Hydraulic analyses.

Installation & Commissioning

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

ALARP in Design Development

The design of the CVCS [KB] has been developed in accordance with the systems engineering design process, which includes extensive review and alignment to RGP & OPEX, design to codes and standards according to the safety classification, and a systematic optioneering process with down-selection of design options based on assessment against relevant safety criteria (as described in E3S Case Chapter 3: E3S Objectives & Design Rules, Reference [8]). Hazard identification studies have also been undertaken to support major design decisions.

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

1. The LWTS [KNF] has been selected as the preferred design solution to provide buffer storage for the Level & Volume Control System [KBA], rather than a dedicated Volume Control Tank (VCT). A review of RGP and OPEX concluded that whilst VCTs are generally established practice for low pressure CVCS loops, use of the LWTS is used in equivalent high pressure CVCS designs, such as the AP1000. It is deemed that the existing LWTS [KNF] can provide the same functions as a VCT with no nuclear safety detriment with respect to DiD. Furthermore, reducing the number of water tanks for the plant reduces the potential for internal flooding hazards, whilst also reducing the EMIT requirements and associated operator exposure

2. The baseline architecture of the Chemistry Control System [KBD] utilises the LWTS [KNF] vacuum degasser for reducing oxygen and hydrogen levels rather than a dedicated CVCS degasser, and hydrogen bottles as a means for hydrogen addition rather than a Hydrogen Addition Vessel or VCT. The selected architecture is fully aligned RGP for PWR coolant chemistry control, which provides a simplified design that minimises hydrogen hazards and reduces EMIT requirements and associated operator exposure

3. The high-pressure Coolant Purification System [KBE] located outside containment has been selected for the baseline architecture following extensive optioneering. This represents a novel design aspect in comparison to traditional PWRs, which generally comprise of low-pressure systems located outside containment. Advantages of the design are that it reduces

the number of containment penetrations and potential leak paths, it can be in positioned in its own shielded module away from main access routes to minimise operator exposure and provides improved access to the system for EMIT activities. A review of RGP has concluded that a pressurised CVCS for PWRs is acceptable (for example the AP1000 design includes a pressurised system, noting it is located inside containment), and RGP for Boiling Water Reactors (BWRs) shows that pressurised coolant is routinely routed outside the primary containment boundary. A review of deterministic and probabilistic safety impacts shows that DiD and risk targets are met by the design solution, with an increased reliance on the diversity and reliability of containment isolation compared to low-pressure/in-containment options. Highly reliable and diverse isolation devices have been included in the design to ensure DiD is maintained in protective safety measures for containment bypass faults such as CVCS small LOCA, and to meet European Utility Requirements (EUR) for negligible leak rates outside containment.

More detailed information on design decisions is presented in the System Descriptions and associated design decision files for the Level & Volume Control System [KBA], Reference [19], Chemistry Control System [KBD], Reference [20], and Coolant Purification System [KBE], Reference [21].

Ongoing Design Development

The RR SMR design definition is in development as described in Section 5.0.2. Key design opportunities and decisions related to nuclear safety are being explored, these include:

1. The requirement for the Chemistry Control System [KBD] to provide zinc dosing to maintain coolant chemistry is to be confirmed by the Chemistry team.

2. Studies and supplier engagement to confirm backwash filter feasibility.

3. Studies and assessment of diverse isolation valves (active and passive) are being undertaken to confirm flow rates and feasibility of the pressurised CVCS [KB].

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

5.13.2 Cold Shutdown Cooling System

System and Equipment Functions

The primary function of the CSCS [JNA] is to provide duty decay heat removal at plant temperatures below **{REDACTED FOR PUBLICATION}**. It also provides back-up cooling of the spent fuel pools. The system contributes to the achievement of FSFs of CoFT and CoRM.

HLSFs for the CSCS [JNA], and the PIEs against which they are assigned, are being derived in the Fault Schedule, which is presented in E3S Case Chapter 15: Safety Analysis, Reference [6].

Safety Design Basis

<u>Functional Requirements</u>

Safety categorised functional requirements are specified for the CSCS [JNA] based on the HLSFs they deliver, including the applicable plant states and operating modes, these are presented in Table 5.13-5.

The traceability of safety categorised functional requirements back to the HLSFs will be managed in DOORS; this process is outlined in Deterministic Safety Methodology, Reference [8], and is expected to be implemented to support FCD.

Table 5.13-5: [JNA] Safety Categorised Functional Requirements

DOORS ID	Functional Requirement	Plant State(s)	Mode(s) of Operation	Safety Category
JNA-R-1252	While the Low Temperature Decay Heat Removal function is in operation, the Cold Shutdown Cooling System [JNA] shall remove residual heat from the Reactor Coolant Systems	DBC-1 DBC-2 DBC-3	4b, 5a, 5b, 6a, 6b	B
JNA-R-1259	If a Spent Fuel Cooling System [FAK] cooling train fails, while a Spent Fuel Pool Cooling System [FAK] cooling train is isolated for maintenance, then the Cold Shutdown Cooling System [JNA] shall remove residual heat from the Spent Fuel Pool [FAB]	DBC-1 DBC-2 DBC-3	1	B
JNA-R-1256	While the Low Temperature Decay Heat Removal function is in operation, the Cold Shutdown Cooling System [JNA] shall support Pressuriser pressure reduction	DBC-1 DBC-2	4b, 5a	C
JNA-R-1262	While the Low Temperature Decay Heat Removal function is in operation, the Cold Shutdown Cooling System [JNA] shall provide reactor coolant to the Coolant Purification System [KBE]	DBC-1 DBC-2	4b, 5a, 5b, 6a, 6b	C

The safety categorised functional requirements for the CSCS [JNA] are flowed down and allocated to relevant sub-systems and/or components in the CSCS [JNA] Definition Module. This functional decomposition is illustrated through the Capella model(s) presented in the DOORS module.

Non-functional performance requirements associated with the safety categorised functional requirements are also presented in the DOORS RCS [JE] Requirements Module, which are not repeated here.

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

Non-functional system requirements are specified for the CSCS [JNA] based on the E3S Principles. The requirements specified at PCD are listed in the DOORS CSCS [JNA]

Requirements Module, including the rationale for their application. These are summarised in Table 5.13-6.

Table 5.13-6: CSCS [JNA] Non-Functional System Requirements

DOORS ID	Non-Functional System Requirement	Rationale
JNA-R-1293	Systems that contain radioactive material shall be designed to prevent spread of that radioactive material beyond their boundary	Confinement of radioactive material for containment and sub-systems in E3S Principles
JNA-R-1295	The system shall reduce the release of radioactive material to the environment to ALARP	Overall safety principle

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

Safety Classification

The safety classification of the CSCS [KB] is undertaken in accordance with the E3S Categorisation and Classification methodology outlined in E3S Case Chapter 3: E3S Objectives & Design Rules, Reference [8]. A preliminary assessment indicates that CSCS [JNA] provides the primary means for achieving a safety function of Category B, therefore is classified as Safety Class 2.

Seismic Classification

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

Description of SSC

At RCS [JE] temperatures above 120°C the Turbine Island Steam and Feed systems are used to remove heat from the RCS [JE]; however, at temperatures below 120°C heat transfer in the SGs is expected to become ineffective. Therefore, when the plant needs to be cooled below 120°C (such as during refuelling operations) the CSCS [JNA] is used for reactor plant temperature control.

During cool-down, both CSCS [JNA] trains are operated to reduce RCS [JE] temperature. At the transition point between cold shutdown depressurised operations [Mode 5b] and refuelling operations (Mode 6a) the system may be switched to one train operation to maintain the temperature of the primary coolant to 55°C or below.

The baseline key performance and design parameters are presented in Table 5.13-7, with a simplified schematic in Figure 5.13-1.

{REDACTED FOR PUBLICATION Table 5.13-7: Key Design & Performance Parameters for the CSCS [JNA]}

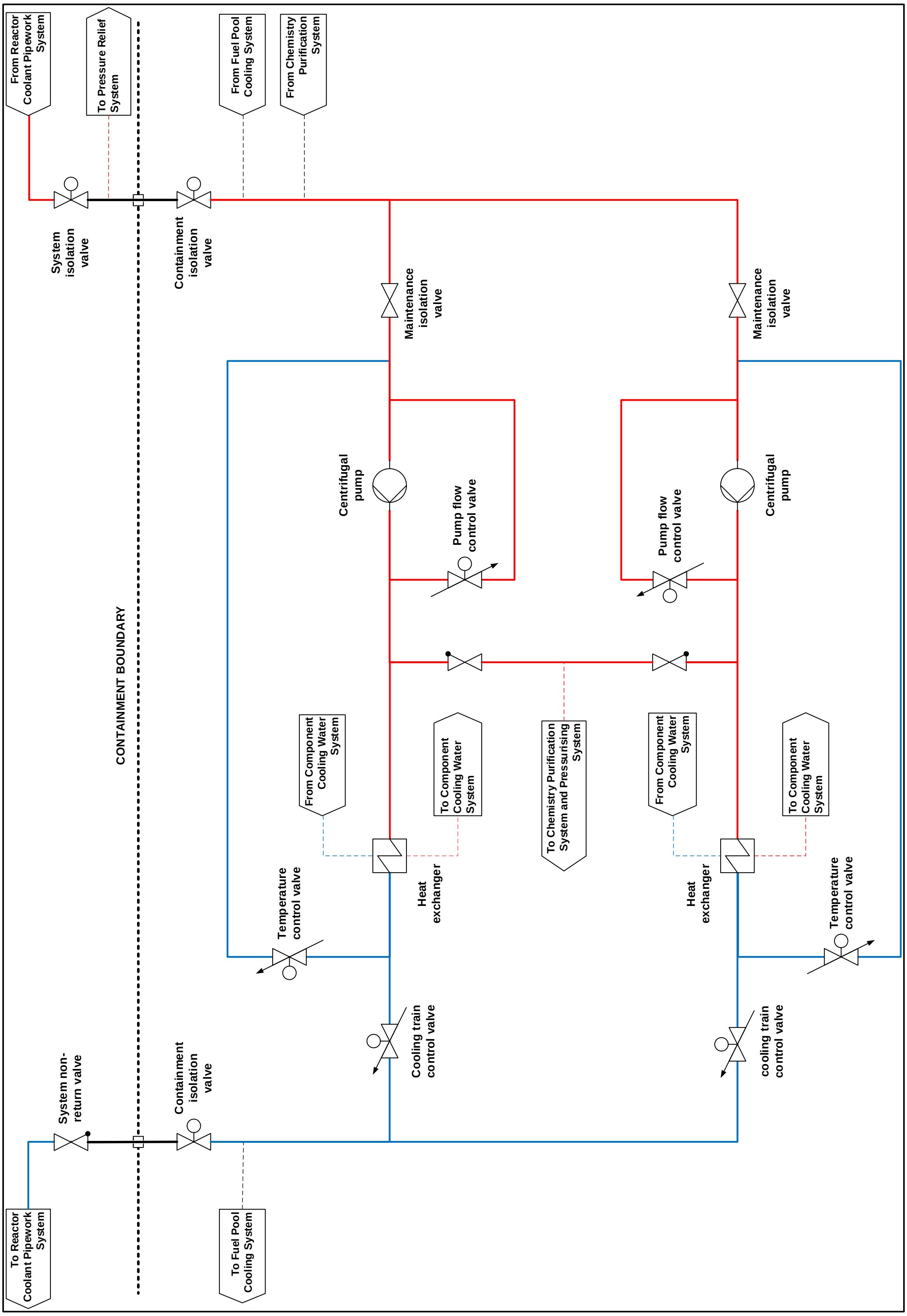

Figure 5.13-1: CSCS [JNA] Schematic

Heated primary coolant is drawn by the CSCS [JNA] from a connection to an RCS [JE] loop hot leg and is then split into two parallel cooling trains. Each train contains a low -pressure pump and a shell and tube heat exchanger. Hot coolant is circulated by the pump through the tube side of the heat exchanger with shell side cooling flow provided by the Component Cooling System (CCS) [KAA] (described in E3S Case Chapter 9A: Auxiliary Systems, Reference [22]). The cold coolant exiting the heat exchanger is pumped through the core via a CSCS [JNA] connection to a different RCS [JE] loop's cold leg. Each train is aligned for cooling through operation of two remote isolating valves, one upstream of the pump and one downstream of the heat exchanger.

During shutdown the CSCS [JNA] also provides flow to the CPS [KBE] and the Pressurising System [JEF] via a common line connection to the CPS [KBE]. The supply branches from each cooling train to the CPS [KBE] each contain check valves to prevent cross-feeding of flow between the two trains and to isolate potential leaks from the other train.

Additional connections to the Fuel Pool Cooling System (FPCS) [FAK] are provided on the common supply and return to the CSCS [JNA] cooling trains to allow the CSCS [JNA] to provide backup cooling to the spent fuel pools. A single containment isolation valve is provided outside of the containment boundary on both common supply and return lines to the RCS [JE]. The system has a connection to the Pressure Relief System [JEG] on the common suction line from RCS [JE] inside the containment boundary.

The CSCS [JNA] is located in the Fuelling Building outside containment, noting the layout of the CSCS [JNA] is still to be finalised.

Further details of the CSCS [JNA] and its components are provided in the System Description, Reference [23].

Materials

Materials for CSCS [JNA] components are still to be selected. The description and justification of materials used for Class 2 SSCs are presented in E3S Case Chapter 23: Structural Integrity, Reference [3].

Interfaces with Supporting Systems

The functional and physical interfaces for the CSCS [JNA] are described above. These are identified and managed within DOORS, including flow down of functional requirements.

System Operation

During Operating Modes 1 (Power Operations), 2 (Start-Up), 3 (Hot Standby), and 4a (Hot Shutdown – Steaming), both containment isolation valves and the remote system isolation valves are closed. If back-up cooling to the FPCS [FAK] is required during mode 1, the isolation and control valves for one train will be opened as well as the isolation valves within the FPCS [FAK] (also located outside containment). To facilitate in-service testing the remote control valves will be isolated to bypass the RPV and the remote temperature control valves will be opened.

During Operating Modes 4b (Hot Shutdown – Non-Steaming) and 5a (Cold Shutdown Pressurised), both trains are operated. As the pressure reaches **{REDACTED FOR PUBLICATION}**, both containment isolation valves and the remote system isolation valve are opened to align the CSCS pumps to provide spray flow to the top of the pressuriser. Manual maintenance isolation valves and remote cooling train control valves will also be opened so that the pumps can drive flow through the heat exchangers in both cooling trains. The flows generated by the fixed speed pumps may be recirculated within the cooling trains to limit flowrates. Both remote temperature control valves are initially open but may be adjusted remotely from the Main Control Room to maintain the desired cool-down rate.

During Operating Mode 5b (Cold Shutdown Depressurised), the CSCS [JNA] is now required to hold the reactor plant temperature below 55°C at atmospheric pressure. The flowrate exiting the cooling trains to the RPV may be steadily reduced to load follow the diminishing core decay heat, by increasingly opening both remote temperature control valves.

During Operating Modes 6a (Refuelling with Reduced Water Level above Fuel) and 6b (Refuelling with Water Level at Nominal), only one train is operated to hold the reactor plant temperature below 55°C at atmospheric pressure. Isolation and control valves for one train will be closed and the temperature control valve for the remaining active train is fully closed, to allow full rated flow through a single cooling train to the RCS [JE].

During degraded modes, if a pump fails to operate or a valve fails closed during temperature hold-down, an alarm is actuated and a low flow signal from the cooling train flow indication automatically initiates operation of the standby CSCS [JNA] pump and opening of the remotely controlled train isolation valve, so that the redundant train can continue to provide cooling. If a pump fails during RCS [JE] cool-down, an alarm is actuated. Since both trains are required for cooling prior to the end of Mode 5b, the temperature of the plant will start to increase, until the plant temperature reaches a value (< 120°C) at which a single CSCS train can hold down the temperature. The plant may remain in this state until the fault is rectified, or sufficient time has elapsed for a single train to have cooled the plant down to the required hold down temperature.

During faulted operation, if both CSCS [JNA] trains are lost or a LOCA occurs in a common line, then either the Condenser, PDHR [JN02] or ECC [JN01] will provide heat removal. There are no safety categorised functional requirements on the CSCS [JNA] to provide long term decay heat removal following a fault condition, this will be explored as the design progresses.

Instrumentation & Control

The CSCS [JNA] places requirements on the Reactor C&I System [JY] to provide control functions, including control of pumps, alignment of remote isolation valves, and control of remote control valves.

It also places requirements to monitor, indicate and alarm on a range of key systems parameters and provide indication of these to the operator in the control room and in the emergency control centre, including pump state, valve state and position, cooling train mass flow rates, heat exchanger inlet/outlet temperature, and pump bearing/winding temperature.

The allocation of safety categorised functional requirements from the CSCS [JNA] to the Reactor C&I System [JY] is presented in the C&I Engineering Schedule, described further in E3S Case Chapter 7: Instrumentation & Control, Reference [12].

Monitoring, Inspection, Testing and Maintenance

An outline maintenance plan for the CSCS [JNA] is still to be developed. It is envisaged that CSCS [JNA] maintenance will be performed during Operating Mode 1 (Power Operations) to prioritise other EMIT activities during outages, given that it is not required to function during this mode and is located outside containment.

Radiological Aspects

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

Performance and Safety Evaluation

At PCD, verification strategies for the CSCS [JNA] to demonstrate compliance with its safety categorised functional requirements and associated non-functional performance requirements are in development and stored in DOORS. A single verification activity to undertake Thermal Hydraulic analysis has been identified at this stage.

Installation & Commissioning

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

ALARP in Design Development

The design of the CSCS [JNA] has been developed in accordance with the systems engineering design process, which includes extensive review and alignment to RGP & OPEX, design to codes and standards according to the safety classification, and a systematic optioneering process with down-selection of design options based on assessment against relevant safety criteria (as described in E3S Case Chapter 3: E3S Objectives & Design Rules, Reference [8]). Hazard identification studies have also been undertaken to support major design decisions.

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

1. The number of trains within the CSCS [JNA] has been subject to optioneering, with a two-train architecture selected that operates on a 1oo2 basis to achieve hold-down and two trains used to achieve cool-down. This is on the basis that it achieves the required reliability and presents the optimised position with respect to through-life EMIT and capital costs. One and three train architectures were considered as part of the optioneering assessment, which concluded that a single train would be unlikely to meet reliability targets, and whilst a three-train system would increase the level of redundancy and reliability, this would be of limited safety benefit due to potential for common cause failures whilst introducing the potential for additional leak paths. A review of RGP also showed that other PWR designs for residual heat removal systems generally incorporate N+1 redundancy.

2. The design solution for a single set of supply and return connections to the RCS [JE] has been assessed against options incorporating additional redundancy. It is concluded that a single connection can meet all deterministic expectations for DiD and redundancy (as a Class 2 system it is not subject to single failure criterion), and preliminary evaluation of failure frequencies demonstrates that it can meet probabilistic risk targets by several orders of magnitude. An increased level of redundancy would increase the reliability of the system, though this would be marginal given the increased risk of a LOCA. A review of RGP shows that higher levels of redundancy are incorporated in other PWR designs, however these

systems are generally part of safety systems that support delivery of a Category A safety function, which is not representative of the current RR SMR CSCS [JNA] as it is not claimed during fault conditions.

More detailed information on design decisions is presented in the CSCS [JNA] System Description, Reference [23], and associated design decision files.

Ongoing Design Development

The RR SMR design definition is in development as described in Section 5.0.2. Key design opportunities and decisions related to nuclear safety are being explored, this includes:

1. Assessment to explore the possibility of placing safety categorised functional requirements on the CSCS [JNA] to provide long-term CoFT following fault conditions as a defence in depth measure.

2. Confirmation that the proposed layout of the CSCS [JNA] and location outside containment enables potential safety requirements, such as segregation of trains, to be achieved.

3. Arrangements for containment isolation are to be investigated and developed further with respect to potential for single point failures.

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

5.14 Conclusions

5.14.1 Conclusions

Preliminary evidence is presented to support the overall chapter claim that 'The RR SMR Reactor Coolant System & Associated 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 SSCs presented in this revision of the E3S Case include the RPV [JAA], Reactor Coolant Pump System [JEB], Steam Generation System [JEA], Reactor Coolant Pipework System [JEC], Reactor Coolant Pressurising System [JEF], Reactor Coolant Pressure Relief System [JEG], CVCS [KB], and CSCS [JNA]. For each SSC, the design definition presented describes how the SSC is being developed to meet its requirements and reduce risks to ALARP, based on its maturity at the PCD design stage. SSCs excluded from this revision based on limited maturity, as listed in Appendix A, will be incorporated as their design is matured.

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

5.14.2 Assumptions & Commitments on Future Dutyholder/Licensee

None identified.

5.15 References

[1] RR SMR Report, SMR0004294/001, "E3S Case Chapter 1: Introduction," March 2023.
[2] RR SMR Report, SMR0002183/001, "Rolls-Royce SMR Generic Design Assessment Boundary," January 2023.
[3] RR SMR Report, SMR0004363/001, "E3S Case Chapter 23: Structural Integrity," March 2023.
[4] RR SMR Report SMR0002155/001, "E3S Case CAE Route Map," March 2023.
[5] RR SMR Report, SMR0003023/001, "Rolls-RoyceSmall Modular ReactorCodes and Standards," October 2022.
[6] RR SMR Report, SMR0003977/001, "E3S Case Chapter 15: Safety Analysis," March 2023.
[7] RR SMR Report, SMR0000531/001, "Rolls-Royce SMR Deterministic Safety Case - Methodologies," October 2022.
[8] RR SMR Report, SMR0004589/001, "E3S Case Chapter 3: E3S Objectives & Design Rules," March 2023.
[9] RR SMR Report, EDNS01000903077/001, "SMR Reactor Island Operating Philosophy," October 2020.
[10] RR SMR Report, SMR0004247/001, "E3S Case Chapter 13: Conduct of Operations," March 2023.
[11] RR SMR Report, SMR0000402/001, "System Description for the Reactor Coolant System [JE]," June 2022.
[12] RR SMR Report, SMR0003929/001, "E3S Case Chapter 7: Instrumentation & Control," March 2023.
[13] RR SMR Report, SMR0004139/001, "E3S Case Chapter 12: Radiation Protection," March 2023.
[14] RR SMR Report, SMR0003977/001, "E3S Case Chapter 14: Plant Construction & Commissioning," March 2023.
[15] RR SMR Report, SMR0000536/001, "System Description for the Steam Generator System [JEA]," June 2022.
[16] RR SMR Report, SMR0000516/001, "System Description for the Reactor Coolant Pipework System [JEC]," June 2022.
[17] RR SMR Report, SMR0000819/001, "System Description for the Reactor Coolant Pressurising Subsystem [JEF]," June 2022.
[18] RR SMR Report, EDNS01000902293/003, "System Outline Description for the Reactor Coolant Pressure Relief Subsystem [JEG]," July 2020.
[19] RR SMR Report, SMR0000793/001, "System Description for the Level and Volume Control System [KBA]," June 2022.
[20] RR SMR Report, SMR0000795/001, "System Description for the Chemistry Control System [KBD]," June 2022.
[21] RR SMR Report, SMR0000796/001, "System Description for the Coolant Purification System [KBE]," June 2022.
[22] RR SMR Report, SMR0003863/001, "E3S Case Chapter 9A: Auxiliary Systems," March 2023.

[23] RR SMR Report, SMR0000338/001, “System Description for the Cold Shutdown Cooling System [JNA],” June 2022.

5.16 Appendix A: CAE Route Map

5.16.1 Chapter 5 Route Map

A preliminary Claims decomposition from the overall Chapter 5 Claim is summarised in Table 5.16-1, including the Tier 2 Evidence underpinning the Claims at PCD (i.e., summarised in Revision 1 of this report) and further Tier 2 Evidence still to be developed.

Table 5.16-1: CAE Route Map

Level 1 Claims	**Level 2 Claims**	**Level 3 Claims**	**Arguments**	**Evidence Summary within Chapter 5**	**Underpinning Tier 2 Evidence** ***at PCD**	**Underpinning Tier 2 Evidence** ***to be developed**
Safety Functional & Non-Functional System Requirements are derived and justified based on sound safety principles and methods	-	-	A comprehensive set of functional requirements are derived in the safety analysis (Fault Schedule), placed on Structures, Systems & Components based on functions to be delivered during Plant States DBC-1 to DBC-5 Non-functional requirements are derived from the E3S principles and applied to the	Section 5.1.2	JE-R DOORS Module	Revised DOORS Requirements Modules for each SSC
				Section 5.4.2	JAA-R DOORS Module	
				Section 5.5.2	JEB-R DOORS Module	
				Section 5.6.2	JEA-R DOORS Module	
				Section 5.7.2	JEC-R DOORS Module	
				Section 5.8.2	JEF-R DOORS Module	
				Section 5.11.2	JEG-R DOORS Module	
				Section 5.13.1	KB-R DOORS Module	

Level 1 Claims	Level 2 Claims	Level 3 Claims	Arguments	Evidence Summary within Chapter 5	Underpinning Tier 2 Evidence *at PCD*	Underpinning Tier 2 Evidence **to be developed**
			architecture of SSCs in accordance with their classification	Section 5.13.2	JNA-R DOORS Module	
Architecture is designed to achieve safety requirements, considering RGP & OPEX to reduce risks to ALARP	-	-	The preferred design solution has been developed following a structured systems engineering approach with evaluation against safety criteria supporting the decision-making process	Sections 5.1, 5.4, 5.5	System Description for the Reactor Coolant System [JE] [11]	Revised System Descriptions for each SSC
				Section 5.6	System Description for the Steam Generator System [JEA] [15]	
				Section 5.7	System Description for the Reactor Coolant Pipework System [JEC] [16]	
				Section 5.8	System Description for the Reactor Coolant Pressurising Subsystem [JEF] [17]	

Level 1 Claims	Level 2 Claims	Level 3 Claims	Arguments	Evidence Summary within Chapter 5	Underpinning Tier 2 Evidence *at PCD*	Underpinning Tier 2 Evidence ***to be developed**
				Section 5.11	System Outline Description for the Reactor Coolant Pressure Relief Subsystem [JEG] [18]	
				Section 5.13.1	System Description for the Level and Volume Control System [KBA] [19]	
					System Description for the Chemistry Control System [KBD] [20]	
					System Description for the Coolant Purification System [KBE] [21]	
				5.13.2	System Description for the Cold Shutdown Cooling System [JNA] [23]	
The design has been	Safety requirements	-	Verification activities to	Section 5.1.10 Section 5.4.6	Verification activities in	Revised DOORS Verification

Level 1 Claims	**Level 2 Claims**	**Level 3 Claims**	**Arguments**	**Evidence Summary within Chapter 5**	**Underpinning Tier 2 Evidence** ***at PCD**	**Underpinning Tier 2 Evidence** ***to be developed**
substantiated to achieve its safety requirements through the lifecycle	have been substantiated		demonstrate safety requirements can be achieved have been developed based on sound engineering judgement and methods	Section 5.5.10 Section 5.6.10 Section 5.7.10 Section 5.8.10 Section 5.11.10 Section 5.13.1 Section 5.13.2	DOORS Verification Modules	Modules for each SSC
	Safety requirements have been verified through manufacturing, construction, installation, and commissioning	-	Processes and controls are designed to verify safety requirements during manufacturing, construction, installation, and commissioning	n/a	n/a	Installation and Commissioning Plans for each SSC (TBC)

Level 1 Claims	Level 2 Claims	Level 3 Claims	Arguments	Evidence Summary within Chapter 5	Underpinning Tier 2 Evidence *at PCD*	Underpinning Tier 2 Evidence *to be developed
	Design can deliver its safety requirements during its operational life	-	The design identifies and facilitates EMIT activities commensurate with its safety classification to demonstrate its status, availability, and integrity in line with the design intent	n/a	n/a	Maintenance Plans for each SSC (TBC)

5.17 Appendix B: SSCs in Scope of Chapter 5

Table 5.17-1 lists those SSCs that are within the scope of Chapter 5, and the section of the report they are addressed.

Table 5.17-1: SSCs in Scope of PCSR

RDS-PP	SSC	Section in PCSR
JAA	Reactor vessel	Section 3
JAB	Reactor vessel closure head	
JAB10	Reactor pressure vessel closure assembly	
JAB20	CRDM cooling system	
JAB30	Integrated head package lifting assembly	
JAB40	Integrated head package structure	
JAH	Reactor pressure vessel insulation	
JE	Reactor coolant system	Section 2
JEA	Steam generation system	Section 5
JEB	Reactor coolant pump system	Section 4
JEC	Reactor coolant pipework system	Section 6
JEF	Reactor coolant pressurising system	Section 7
JEG	Reactor coolant pressure relief system	Section 8
JNA	Cold shutdown cooling system	Section 9.2
KB	Chemical and volume control system	Section 9.1
KBA	Level and volume control system	
KBD	Chemistry control system	
KBE	Coolant purification system	

5.18 Acronyms and Abbreviations

1oo2	1 out of 2
ADS	Automatic Depressurisation System
ALARP	As Low As Reasonably Practicable
ASF	Automatic Shutdown Function
ASME	American Society of Mechanical Engineers
BS	British Standard
BWR	Boiling Water Reactor
C&I	Control & Instrumentation
CAE	Controls, Arguments and Evidence
CCS	Cooling Component System
CFD	Computational Fluid Dynamics
CH	Closure Head
CoFT	Control of Fuel Temperature
CoR	Control of Radioactivity
CoRM	Control of Radioactive Material
CPS	Coolant Purification System
CRDM	Control Rod Drive Mechanism
CRUD	Chalk River Unidentified Deposits
CSCS	Cold Shutdown Cooling System
CVCS	Chemistry and Volume Control System
DBC	Design Basis Condition
DHR	Decay Heat Removal
DiD	Defence in Depth
DOORS	
DR	Definition Review
DVI	Direct Injection Vessel
E3S	Environment, Safety, Security and Safeguards
EBI	Emergency Boron Injection

ECC	Emergency Core Cooling
EMIT	Examination, Maintenance, Inspection and Testing
EUR	European Utility Requirements
FCD	Final Concept Definition
FPCS	Fuel Pool Cooling System
FSF	Fundamental Safety Functions
GDA	Generic Design Assessment
GER	Generic Environment Report
GSR	Generic Safety Report
HLSF	High Level Safety Function
HPIS	High Pressure Injection System
HR	High Reliability
HTOP	High Temperature Overpressure Protection
HVAC	Heating, Ventilation and Air Conditioning
IAEA	International Atomic Energy Agency
ICI	In Core Instrumentation
IHP	Integrated Head Package
IVR	In-Vessel Retention
IXC	Ion Exchange Column
LOCA	Loss of Coolant Accident
LPIS	Low Pressure Injection System
LTOP	Low Temperature Overpressure Protection
LVCS	Level and Volume Control System
LWTS	Liquid Waste Treatment System
OD	Outer Diameter
OPEX	Operating Experience
PCD	Preliminary Concept Definition
PCSR	Pre-Construction Safety Report

PDHR	Passive Decay Heat Removal
PIEs	Postulated Initiating Events
PWR	Pressurised Water Reactor
RCL	Reactor Coolant Loop
RCP	Reactor Coolant Pump
RCS	Reactor Cooling System
RD	Reference Design
RDS-PP	Reference Designation System for Power Plants
RGP	Regulatory Good Practice
RPV	Reactor Pressure Vessel
RR	Rolls-Royce
SG	Steam Generator
SGRV	Steam Generator Relief Valves
SMR	Small Modular Reactor
SRV	Safety Relief Valve
SSC	Structure, System and Component
UK	United Kingdom
UT	Ultrasonic Testing
VCT	Volume Control Tank
VFD	Variable Frequency Drive
VHR	Very High Reliability
WQS	Water Quality Specification