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**Title**

# E3S Case Chapter 10: Steam & Power Conversion Systems


## Executive Summary

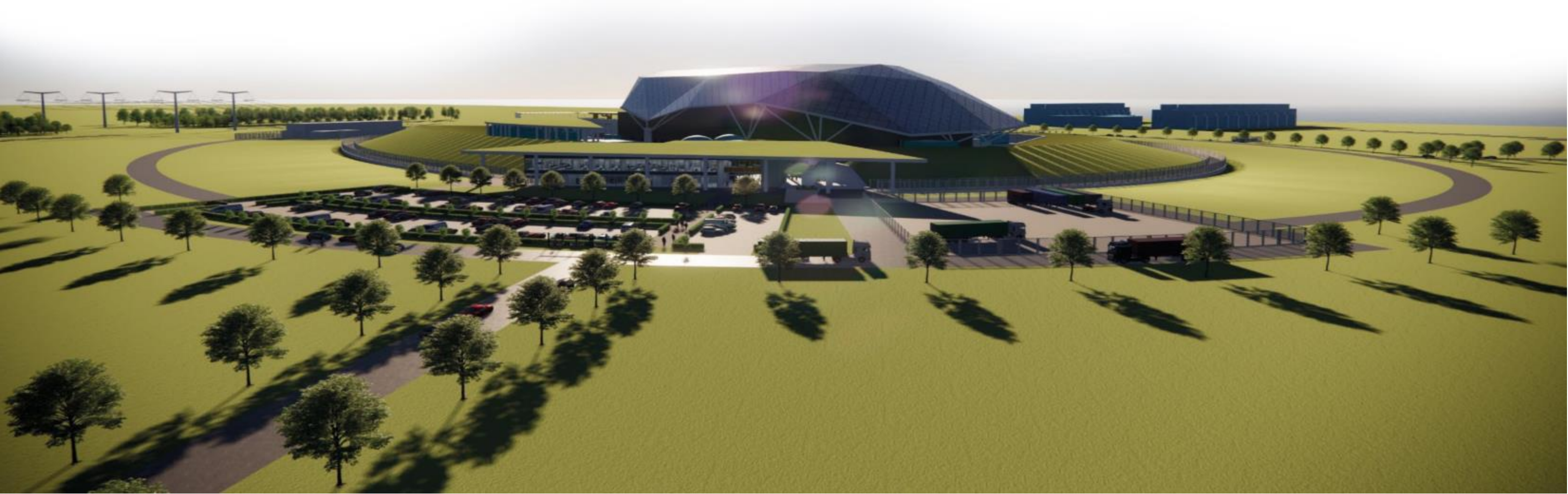
This chapter of the Environment, Safety, Security, and Safeguards (E3S) Case presents the Steam and Power Conversion Systems of the Rolls-Royce Small Modular Reactor (RR SMR). The report outlines the arguments and preliminary evidence available at the Preliminary Concept Definition (PCD) design stage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

The systems covered include the Feedwater System [LA], Steam System [LB], Condensate System [LC], Steam Turbine System [MA], and Generator System [MK], as well as associated sub-systems.

For each system, the safety categorised functional requirements and non-functional system requirements are defined that are derived from the Fault Schedule and E3S Principles respectively, noting the full set of requirements are still in development at PCD. The safety classification of each system is still to be determined based on the safety category of the functions it delivers.

Design solutions at PCD, including architecture, materials, operation, control & instrumentation, and Examination, Maintenance, Inspection and Testing (EMIT) arrangements, are presented to meet the current set of safety requirements. Verification activities to substantiate requirements are still in development for all systems. A summary of how the design has been developed to date to reduce risks to As Low as Reasonably Practicable (ALARP) is presented, providing confidence at this early stage of design development that Claims can be met when the full suite of evidence becomes available.



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# 10.0 Introduction

## 10.0.1 Introduction to Chapter

Chapter 10 of the Rolls-Royce Small Modular Reactor (RR SMR) Environment, Safety, Security and Safeguards (E3S) Case forms part of the Pre-Construction Safety Report (PCSR) and is a supporting reference to the Generic Environment Report (GER) and Generic Security Report (GSR), as defined in E3S Case Chapter 1: Introduction, Reference [1].

Chapter 10 presents the overarching summary and entry point to the design information for the Turbine Island [T01] steam and power conversion systems of the RR SMR, as defined at Reference Design (RD) 5 level of design maturity.

## 10.0.2 Scope

The list of SSCs that are included in the scope of this chapter is provided in Section 10.9, Appendix B, including those that are within scope but excluded from this revision due to design immaturity.

For each Structure, System and Component (SSC) in scope, the following aspects are summarised:

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

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

3. Verification activities and evidence to support substantiation of SSCs

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

***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 design maturity. The SSCs presented in this revision of the report are at a maturity commensurate with this 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.

## 10.0.3 Claims, Arguments, Evidence Route Map

The Chapter level Claim for E3S Case Chapter 10: Steam & Power Conversion Systems is:

***Claim 10: The RR SMR Steam & Power Conversion Systems are designed and substantiated to achieve functional and non-functional safety requirements through the lifecycle, and reduce risks to As Low as Reasonably Practicable***

A decomposition of this Claim into Sub-Claims, Arguments, and link to the relevant Tier 2 Evidence is provided in 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 [3], described further in E3S Case Chapter 1: Introduction, Reference [1].

### 10.0.4 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 10.0-1, as identified in Reference [4].

**Table 10.0-1: 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) BS EN 13445 |
| Not applicable (n/a) | Commercial standards e.g., ASME VIII, BS EN 13455 |

# 10.1 Role & General Description

## 10.1.1 Turbine Island Overview

Turbine Island [T01] includes the facilities Steam, Water, Condensate System [L] and Main Turbine Generator System [M].

***Steam, Water, Condensate System [L]***

The main plant items within the Steam, Water, Condensate Systems [L] include:

1. Feedwater System [LA]
2. Steam System [LB]
3. Condensate System [LC]
4. Condensate Polishing System [LD]
5. Emergency Feedwater System [LJ]
6. Steam, Water, Condensate System Control & Protection [LY]

Heat from the reactor is transferred from the primary circuit to the secondary circuit in the three Steam Generators (SGs) [JEA]. Feedwater present in the SGs [JEA] is converted to steam which is then routed through the High-Pressure (HP) Turbine [MAA] and Low-Pressure (LP) Turbine [MAC]. The turbines are coupled to and rotate a generator, thereby generating the plant's electrical output. The steam leaving the LP Turbines [MAC] is condensed by heat exchange with the cooling water in the Main Cooling Water System (MCWS) [PA] system. The resulting condensate is then deaerated, pre-heated, and fed back into the SGs [JEA].

There is a bleed from the SGs [JEA] through the Steam Generator Blowdown System (SGBS) [LCQ] to control impurities in the secondary circuit using an Electro-deionisation (EDI) unit. Brine from this unit is routed to the liquid waste treatment system, and the cleaned water is returned to the secondary circuit. Feedwater is provided from the demineraliser plant.

***Main Turbine Generator System [M]***

The Main Turbine Generator System [M] is housed within a dedicated turbine hall along with other turbine equipment. Its purpose is to convert steam into mechanical energy through technical rotation action. The key systems include the Steam Turbine System [MA], the Generator System [MK], Auxiliary Systems [MU] and Control and Protection System [MY].

The Steam Turbine Systems' [MA] HP Turbine [MAA] expands the steam from the SGs [JEA], which is exhausted into the Moisture Separator Reheater (MSR) [LBJ]. The MSR [LBJ] removes moisture and superheats the steam before it is transferred to the LP Turbines [MAC]. The steam is further expanded and is then exhausted into the Condensing System [MAG].

The Condensing System [MAG] converts the exhaust steam into saturated water, which is transferred for reuse through the feedwater system [LA] back into the SG. The Generator

System [MK] converts mechanical energy of the steam turbine to electrical energy for onward distribution to the grid. The Auxiliary Systems [MU] support the control function of the turbine and generator operation.

The major equipment associated with the Steam, Water, Condensate System [L] and Main Turbine Generator System [M] is illustrated in Figure 10.1-1, with the Turbine Island [T01] architecture shown in Figure 10.1-2.

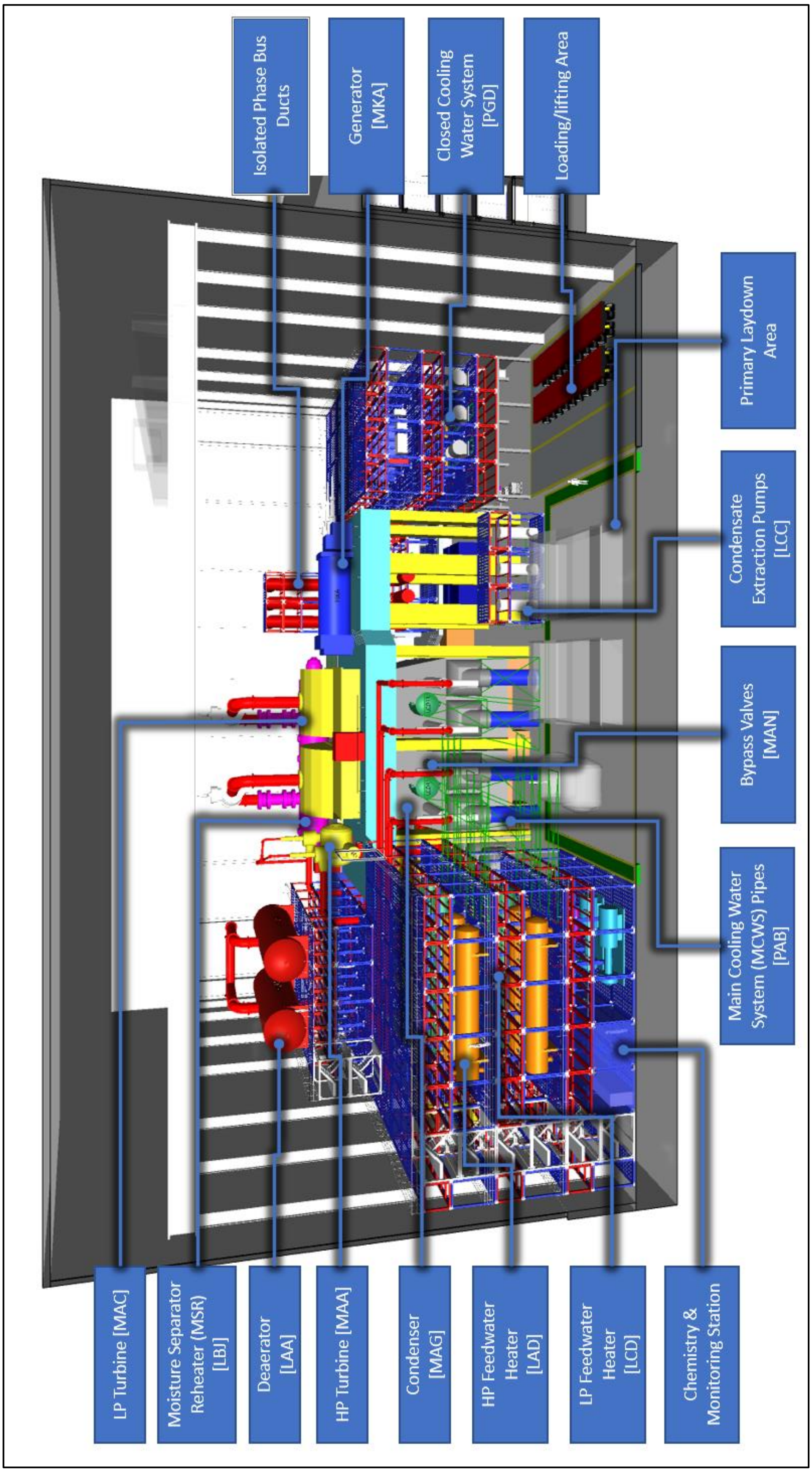


**Figure 10.1-1: Major Turbine Island [T01] Systems**

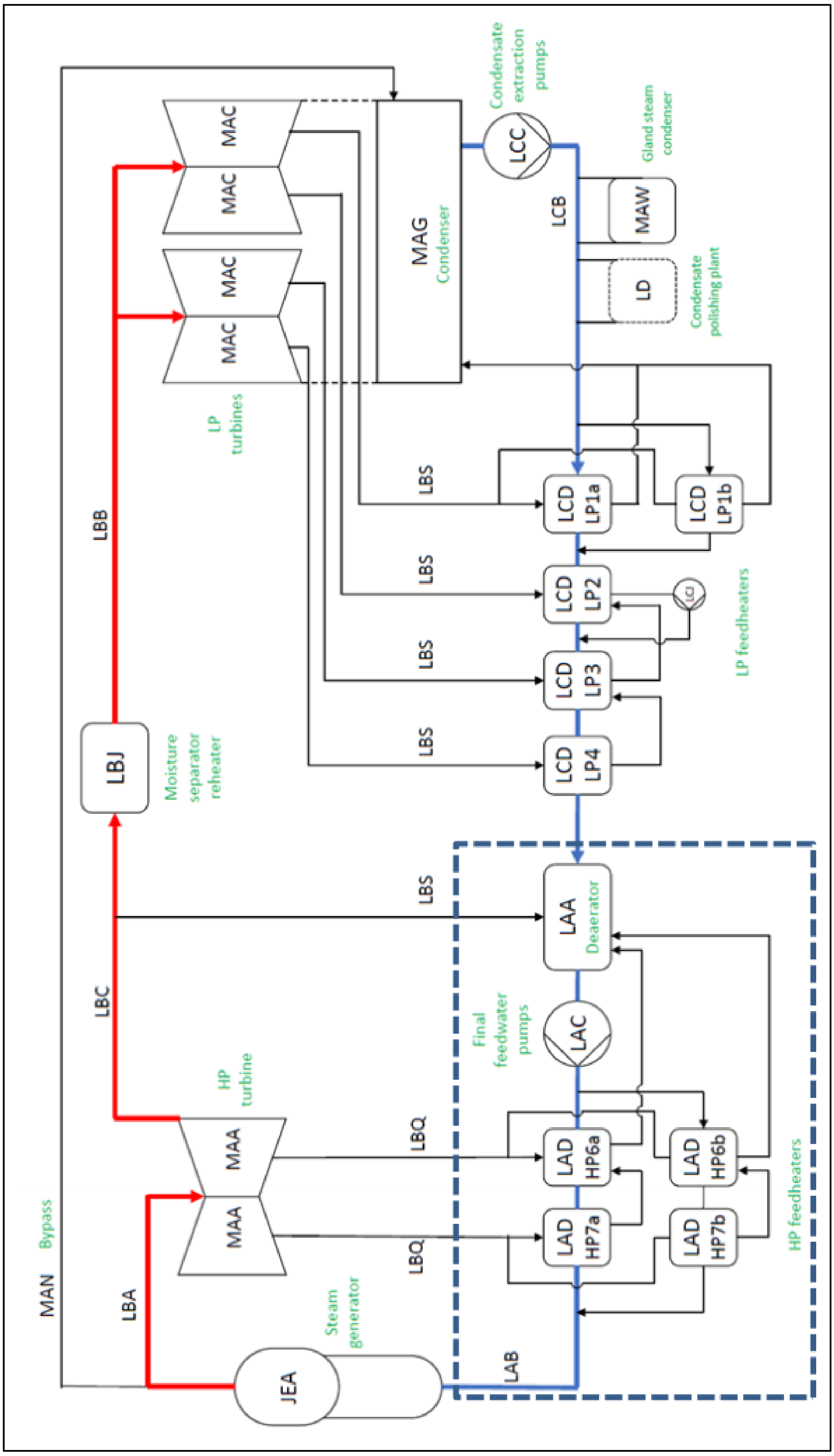


**Figure 10.1-2: Turbine Island [T01] Architecture**

# 10.2 Main Steam Supply System

## 10.2.1 System & Equipment Functions

The primary function of the Steam System [LB] is to distribute steam between other systems and equipment. within the Turbine Island [T01] secondary circuit during normal operation.

The Steam System [LB] includes the Main Steam Piping System [LBA], which interfaces with both Reactor Island [R01] and Turbine Island [T01]. All aspects of the Steam System [LB] up to the connections to SGs [JEA] are covered in this section, noting the Reactor Island [R01] aspects are still in development at PCD, therefore details will be incorporated into a future revision of the E3S Case as evidence in the CAE Route Map becomes available.

## 10.2.2 Safety Design Bases

Functional Requirements

Safety categorised functional requirements specified for the Steam System [LB] based on the HLSFs they deliver, including the applicable plant states and operating modes, are presented in Table 10.2-1.

**Table 10.2-1: [LB] Safety Categorised Functional Requirements**

| DOORS ID | Functional Requirement | Plant State(s) | Mode(s) of Operation | Safety Category |
|---|---|---|---|---|
| L-LB-1259 | The Steam System [LB] shall distribute steam supplied by the Reactor Coolant System [JE] | DBC-1<br>DBC-2i | 1 to 4a | C |
| L-LB-1306 | The Steam system [LB] shall distribute steam from the Steam turbine system [MA] | DBC-1<br>DBC-2i | 1 to 4a | C |

Non-functional performance requirements associated with the safety categorised functional requirements are also allocated in the Dynamic Object-Oriented Requirements System (DOORS) Steam System [LB] Requirements Module, including the rationale for their selection, which are not repeated here.

Non-Functional System Requirements

Non-functional system requirements are specified for the Steam System [LB] based on the E3S Principles. The requirements specified at PCD are listed in the DOORS Steam System [LB] Requirements Module, including the rationale for their application. These are summarised in Table 10.2-2.

**Table 10.2-2: [LB] Non-Functional System Requirements**

| DOORS ID | Non-Functional System Requirement | Rationale |
|---|---|---|
| L-LB-1112 | The Steam System [LB] design shall ensure that all risks to all populations during all modes of operation and lifecycle stages are reduced to levels that are ALARP | Overall safety principle |
| L-LB-1330 | All SSCs shall be classified in accordance with the defined project methodology | Ensures appropriate classification of SSCs to deliver the necessary functions to protect people and the environment from harm |
| L-LB-1113 | The Steam System [LB] shall be designed to maximise the passivity of the safety systems during all modes of operation | Overall safety principle |
| L-LB-1114 | The Steam System [LB)] shall be designed to minimise the area required as an emergency planning zone within the local regulatory framework | Based on Radiation (Emergency Preparedness and Public Information) Regulations 2019 (REPPIR), and the Approved Code of Practice and guidance (ACOP) |
| L-LB-1117 | The Steam System [LB] shall be capable of shutting down and maintaining a safe plant state without requirement for backup power systems | The SMR as a whole shall be passively safe |
| L-LB-1331 | The Steam System [LB] shall be designed such that it does not reduce the SMR core damage frequency below the Basic Safety Level (1E-5/yr). | Overall safety principle |
| L-LB-1118 | The Steam System [LB)]should be designed such that the SMR core damage frequency is below the Basic Safety Objective (1E-7/yr) | Overall safety principle |

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

Safety Classification

The safety classification of Steam System [LB] is still to be developed based on the categorisation of safety functions it delivers.

### 10.2.3 Description

The Steam System [LB] comprising the following sub-systems:

1. Main Steam Piping System [LBA], connecting between the SG outlet and HP Turbine [MAA] inlet to distribute steam. Three outlet pipes (one per SG) leave Reactor Island [R01] and connect to a common header in the Turbine Building [UMA], with two 50% lines connecting to the HP Turbine [MAA]. The Turbine Bypass System [MAN] also connects to the common header to receive steam during turbine bypass operation (i.e., steam dumping)

2. Hot Reheat Piping System [LBB], which is two sets of interconnecting pipework from the MSR [LBJ] to LP Turbine [MAC] inlet

3. Cold Reheat Piping System [LBC], which is interconnecting pipework from the HP Turbine [MAA] exhaust to the MSR [LBJ] inlet

4. Auxiliary Steam Piping System [LBG], which delivers steam to the Gland Sealing System [MAW] and the Deaerator [LAA] from either the Auxiliary Steam Generating System [QH] or the Main Steam System [LBA]. It includes pressure set control valves to ensure steam is supplied at the required pressure

5. MSR [LBJ], which is a large heat exchanger vessel that sits between the HP Turbine [MAA] and LP Turbines [MAC]. Its function is to remove moisture from the Cold Reheat Piping System [LBC] steam and reheat the steam before it is exhausted to the Hot Reheater Piping System [LBB] and distributed to the two LP Turbines [MAC]

6. Extraction Steam Piping System for Feedwater Preheating System [LBQ], covers the two high-pressure extraction systems from the HP Turbine [MAA] to the Feedwater Preheating System [LAD] heaters

7. Extraction Steam Piping System for Main Condensate Preheating System [LBS], covers the four LP extraction systems from the LP Turbine [MAC] to the Main Condensate Preheating System [LCD] heaters

8. Fluid Supply System for Control and Protection Systems [LBX]

9. Overpressure Suppression and Safety System [LBF]

10. Control and Protection System [LBY]

The key performance and design parameters are presented in Table 10.2-3.

**Table 10.2-3: Key Performance and Design Parameters for the Main Steam Supply System [LB]**

| Parameter | Value |
|---|---|
| **Main Steam Piping System [LBA]** | |
| Nominal Pressure | **{REDACTED FOR PUBLICATION}** |
| Nominal Temperature | **{REDACTED FOR PUBLICATION}** |
| Nominal Enthalpy | **{REDACTED FOR PUBLICATION}** |

| Parameter | Value |
|---|---|
| Nominal Mass Flow | **{REDACTED FOR PUBLICATION}** |
| **Hot Reheat Piping System [LBB]** | |
| Nominal Pressure | **{REDACTED FOR PUBLICATION}** |
| Nominal Temperature | **{REDACTED FOR PUBLICATION** |
| Nominal Enthalpy | **{REDACTED FOR PUBLICATION}** |
| Nominal Mass Flow | **{REDACTED FOR PUBLICATION}** |
| **Cold Reheat Piping System [LBC]** | |
| Nominal Pressure | **{REDACTED FOR PUBLICATION}** |
| Nominal Temperature | **{REDACTED FOR PUBLICATION}** |
| Nominal Enthalpy | **{REDACTED FOR PUBLICATION}** |
| Nominal Mass Flow | **{REDACTED FOR PUBLICATION}** |
| **Auxiliary Steam Piping System [LBG]*** | |
| Nominal Pressure | **{REDACTED FOR PUBLICATION}** |
| Nominal Temperature | **{REDACTED FOR PUBLICATION}** |
| Nominal Enthalpy | **{REDACTED FOR PUBLICATION}** |
| Nominal Mass Flow | **{REDACTED FOR PUBLICATION}** |
| *Based on auxiliary boiler outlet conditions | |
| **Moisture Separator Reheater [LBJ]** | |
| Nominal Pressure (heated side, inlet) | **{REDACTED FOR PUBLICATION}** |
| Nominal Temperature (heated side, inlet) | **{REDACTED FOR PUBLICATION}** |
| Nominal Enthalpy (heated side, inlet) | **{REDACTED FOR PUBLICATION}** |
| Nominal Mass Flow (heated side, inlet) | **{REDACTED FOR PUBLICATION}** |
| Nominal Pressure (heated side, outlet) | **{REDACTED FOR PUBLICATION}** |
| Nominal Temperature (heated side, outlet) | **{REDACTED FOR PUBLICATION}** |
| Nominal Enthalpy (heated side, outlet) | **{REDACTED FOR PUBLICATION}** |
| Nominal Mass Flow (heated side, outlet) | **{REDACTED FOR PUBLICATION}** |
| Nominal Pressure (moisture separator drain) | **{REDACTED FOR PUBLICATION}** |
| Nominal Temperature (moisture separator drain) | **{REDACTED FOR PUBLICATION}** |
| Nominal Enthalpy (moisture separator drain) | **{REDACTED FOR PUBLICATION}** |
| Nominal Mass Flow (moisture separator drain) | **{REDACTED FOR PUBLICATION}** |

| Parameter | Value |
|---|---|
| Nominal Pressure (heating side, inlet) | **{REDACTED FOR PUBLICATION}** |
| Nominal Temperature (heating side, inlet) | **{REDACTED FOR PUBLICATION}** |
| Nominal Enthalpy (heating side, inlet) | **{REDACTED FOR PUBLICATION}** |
| Nominal Mass Flow (heating side, inlet) | **{REDACTED FOR PUBLICATION}** |
| Nominal Pressure (heating side, outlet) | **{REDACTED FOR PUBLICATION}** |
| Nominal Temperature (heating side, outlet) | **{REDACTED FOR PUBLICATION}** |
| Nominal Enthalpy (heating side, outlet) | **{REDACTED FOR PUBLICATION}** |
| Nominal Mass Flow (heating side, outlet) | **{REDACTED FOR PUBLICATION}** |
| **Extraction steam piping system for feedwater preheating system [LBQ]** | |
| **HP extraction 2** | |
| Nominal Pressure | **{REDACTED FOR PUBLICATION}** |
| Nominal Temperature | **{REDACTED FOR PUBLICATION}** |
| Nominal Enthalpy | **{REDACTED FOR PUBLICATION}** |
| Nominal Mass Flow | **{REDACTED FOR PUBLICATION}** |
| **HP extraction 1** | |
| Nominal Pressure | **{REDACTED FOR PUBLICATION}** |
| Nominal Temperature | **{REDACTED FOR PUBLICATION}** |
| Nominal Enthalpy | **{REDACTED FOR PUBLICATION}** |
| Nominal Mass Flow | **{REDACTED FOR PUBLICATION}** |
| **Extraction steam piping system for main condensate preheating system [LBS]** | |
| **Deaerator Extraction** | |
| Nominal Pressure | **{REDACTED FOR PUBLICATION}** |
| Nominal Temperature | **{REDACTED FOR PUBLICATION}** |
| Nominal Enthalpy | **{REDACTED FOR PUBLICATION}** |
| Nominal Mass Flow | **{REDACTED FOR PUBLICATION}** |
| **LP extraction 4** | |
| Nominal Pressure | **{REDACTED FOR PUBLICATION}** |
| Nominal Temperature | **{REDACTED FOR PUBLICATION}** |
| Nominal Enthalpy | **{REDACTED FOR PUBLICATION}** |
| Nominal Mass Flow | **{REDACTED FOR PUBLICATION}** |
| **LP extraction 3** | |
| Nominal Pressure | **{REDACTED FOR PUBLICATION}** |

| Parameter | Value |
|---|---|
| Nominal Temperature | **{REDACTED FOR PUBLICATION}** |
| Nominal Enthalpy | **{REDACTED FOR PUBLICATION}** |
| Nominal Mass Flow | **{REDACTED FOR PUBLICATION}** |
| **LP extraction 2** | |
| Nominal Pressure | **{REDACTED FOR PUBLICATION}** |
| Nominal Temperature | **{REDACTED FOR PUBLICATION}** |
| Nominal Enthalpy | **{REDACTED FOR PUBLICATION}** |
| Nominal Mass Flow | **{REDACTED FOR PUBLICATION}** |
| **LP extraction 1** | |
| Nominal Pressure | **{REDACTED FOR PUBLICATION}** |
| Nominal Temperature | **{REDACTED FOR PUBLICATION}** |
| Nominal Enthalpy | **{REDACTED FOR PUBLICATION}** |
| Nominal Mass Flow | **{REDACTED FOR PUBLICATION}** |

The Steam System [LB] is predominantly located in the Turbine Building [UMA] with a portion of the Main Steam Piping System [LBA] also situated in the Reactor Island Building where it connects with the SGs [JEA]. A full description of the Steam System [LB] and associated sub-systems within Turbine Island [T01] is provided in Reference [5].

### 10.2.4 Materials

Materials will be confirmed as the design is developed.

### 10.2.5 Interfaces with Supporting Systems

The Steam System [LB] functional and physical interfaces are described above, noting the major system interfaces are the SGs [JEA] and the Main Turbine Generator Systems [M]. These are identified and managed within DOORS, including flow down of functional requirements.

### 10.2.6 System & Equipment Operation

The Power Station Operating Philosophy, Reference [6] 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 [7].

Operating principles for the Steam System [LB] will be developed as the design progresses.

### 10.2.7 Instrumentation & Control

The Steam System [LB] requirements for control, monitoring, indication, alarms, and warnings are still to be developed. The allocation of safety categorised functional requirements to the Steam System Control and Protection System [LBY] will be described further in E3S Case Chapter 7: Instrumentation & Control, Reference [8], as the Control and Instrumentation (C&I) system design is developed.

### 10.2.8 Examination, Monitoring, Inspection & Testing

An outline maintenance plan for the Steam System [LB] is still to be developed.

### 10.2.9 Radiological Aspects

No significant radiological aspects associated with the Steam System [LB] have been identified during design decisions up to PCD.

### 10.2.10 Preliminary Substantiation

Verification activities to substantiate safety categorised functional requirements and non-functional system requirements for the Steam System [LB] are still to be determined.

### 10.2.11 Installation & Commissioning

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

### 10.2.12 ALARP in Design Development

The design of the Steam System [LB] 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 PSCR Chapter 3: E3S Objectives & Design Rules, Reference [10]).

### 10.2.13 Ongoing Design Development

The RR SMR design definition is currently in development as described in Section 10.0.2.

# 10.3 Feedwater System

## 10.3.1 Feedwater System

***System & Equipment Functions***

The primary function of the Feedwater System [LA] is to provide secondary circuit cooling to the SGs [JEA] for removal of heat from the reactor core. The equipment contained within the system allows for the conditioning of the water supply. The feedwater storage vessel provides head to feed water pumps while also ensuring adequate storage volume to ensure consistent flow rate.

The Feedwater System [LA] includes the Feedwater Piping System [LAB], which interfaces with both Reactor Island [R01] and Turbine Island [T01]. All aspects of the Feedwater System [LA] up to the connections to SGs [JEA] are covered in this section, noting the Reactor Island [R01] aspects are still in development at PCD.

***Safety Design Bases***

Functional Requirements

Safety categorised functional requirements specified for the Feedwater System [LA] based on the HLSFs they deliver, including the applicable plant states and operating modes, are presented in Table 10.3-1.

**Table 10.3-1: [LA] Safety Categorised Functional Requirements**

| DOORS ID | Functional Requirement | Plant State(s) | Mode(s) of Operation | Safety Category |
|---|---|---|---|---|
| L-LA-1268 | The Feedwater System [LA] shall supply feedwater to the Reactor Coolant System [JE] | DBC-1<br>DBC-2i | 1 to 4a | C |
| L-LA-1269 | The Feedwater System [LA] shall supply auxiliary feedwater to the Reactor Coolant System [JE] | DBC-1<br>DBC-2i | 1 to 4a | C |
| L-LA-1314 | The Feedwater System [LA] shall distribute feedwater from the Emergency Feedwater Supply System [LJ] | DBC-1<br>DBC-2i | 1 to 4a | C |

Non-functional performance requirements associated with the safety categorised functional requirements are also allocated in the DOORS Feedwater System [LA] Requirements Modules, including the rationale for their selection, which are not repeated here.

Non-Functional System Requirements

Non-functional system requirements are specified for the Feedwater System [LA] based on the E3S Principles. The requirements specified at PCD are listed in the DOORS Feedwater System [LA] Requirements Module, including the rationale for their application. These are summarised in Table 10.3-2.

**Table 10.3-2: [LA] Non-Functional System Requirements**

| DOORS ID | Non-Functional System Requirement | Rationale |
|---|---|---|
| L-LA-1147 | The Feedwater System [LA] design shall ensure that all risks to all populations during all modes of operation and lifecycle stages are reduced to levels that are ALARP | Overall safety principle |
| L-LA-1329 | All SSCs shall be classified in accordance with the defined project methodology | Ensures appropriate classification of SSCs to deliver the necessary functions to protect people and the environment from harm |
| L-LA-1148 | The Feedwater System [LA] shall be designed to maximise the passivity of the safety systems during all modes of operation | Overall safety principle |
| L-LA-1149 | The Feedwater System [LA] shall be designed to minimise the area required as an emergency planning zone within the local regulatory framework | Based on REPPIR, and the ACOP |
| L-LA-1152 | The Feedwater System [LA] shall be capable of shutting down and maintaining a safe plant state without requirement for backup power systems | The SMR as a whole shall be passively safe |
| L-LA-1330 | The Feedwater System [LA] shall be designed such that it does not reduce the RR SMR core damage frequency below the Basic Safety Level (1E-5/yr). | Overall safety principle |
| L-LA-1153 | The Feedwater System [LA] should be designed such that the RR SMR core damage frequency is below the Basic Safety Objective (1E-7/yr) | Overall safety principle |

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

Safety Classification

The safety classification of Feedwater System [LA] is still to be developed based on the categorisation of safety functions it delivers.

Seismic Classification

The seismic classification of SSCs is still to be assigned in accordance with methodology outlined in E3S Case Chapter 3: E3S Objectives & Design Rules, Reference [10].

### *Description*

The Feedwater System [LA] comprises the following sub-systems:

1. Deaerator and Feedwater Storage System [LAA], which receives heated water from the Condensate System [LC] and heats the water further to remove dissolved gasses. The current baseline is a spray-type deaerator with multiple storage tanks. The Deaerator and Feedwater Storage System [LAA] also acts as a buffer vessel with 7 minutes of full flow water inventory stored for operational surges or changes in flow requirements

2. Main Feedwater Pumps [LAC], which increase the pressure in the system from that in the feedwater storage vessel to the desired pressure for the SG [JEA], while increasing the flow rate to that desired based on the unit load. The main feedwater pumps are four multi-stage centrifugal pumps that operate in parallel and provide feed water to the SG [JEA]. The start-up / emergency feed water pumps are two direct drive multi-stage centrifugal pumps operating in parallel that provide feed water to the SGs [JEA] during start up or following a reactor trip. The start-up feed pumps are designed to a maximum flow rate lower than that of the main feed water pumps

3. HP Feedheaters [LAD], which ensure that the final feed water temperature is within a defined range for the safe operation of the SGs [JEA]. The HP feed heaters are set out in two parallel paths of first stage and second stage feed heating. Both stages of high-pressure feed heating employ shell and tube heat exchanger design. The first stage of HP feed heating takes bled steam from the HP turbine as well as receiving condensate from the second stage HP heating. The second stage HP feed heating takes bled steam from the HP turbine as well as receiving waste condensate from the MSR [LBJ]. The two paths converge and supply the feedwater discharge header. The feedwater discharge header supplies each of the SGs [JEA] through either the main feed supply pipework or the auxiliary feed pipework

4. Fluid Supply System for The Feedwater System Control and Protection System [LAX]

5. Feedwater System Control and Protection System [LAY]

The key performance and design parameters are presented in Table 10.3-3.

**Table 10.3-3: Key Performance and Design Parameters for the Feedwater System [LA]**

| Parameter | Value |
|---|---|
| **Deaerator Operating Conditions** | |
| Water Supply Temperature | **{REDACTED FOR PUBLICATION}** |

| Parameter | Value |
|---|---|
| System Pressure | {REDACTED FOR PUBLICATION} |
| Storage tank water temperature | {REDACTED FOR PUBLICATION} |
| Volume | {REDACTED FOR PUBLICATION} |
| **Feed Pump Operation** | |
| Suction Pressure | {REDACTED FOR PUBLICATION} |
| Discharge Pressure | {REDACTED FOR PUBLICATION} |
| Flow Rate | {REDACTED FOR PUBLICATION} |
| Drive | {REDACTED FOR PUBLICATION} |
| Type | {REDACTED FOR PUBLICATION} |
| **Start-up / Emergency Feed Pump Operation** | |
| Suction Pressure | {REDACTED FOR PUBLICATION} |
| Discharge Pressure | {REDACTED FOR PUBLICATION} |
| Flow Rate | {REDACTED FOR PUBLICATION} |
| Drive | {REDACTED FOR PUBLICATION} |
| Type | {REDACTED FOR PUBLICATION} |
| **HP Feedheater Operation** | |
| Stage 1 Outlet Temperature | {REDACTED FOR PUBLICATION} |
| Stage 2 Outlet Temperature | {REDACTED FOR PUBLICATION} |

Further description of the Feedwater System [LA] and associated sub-systems is provided in Reference [11].

### *Materials*

Materials will be confirmed as the design is developed.

### *Interfaces with Supporting Systems*

The Feedwater System [LA] functional and physical interfaces are described above, noting the major system interfaces are the Condensate System [LC] and the SGs [JEA]. The Emergency Feed System on Feedwater Side of Nuclear Steam Generator [LJK], which provides feedwater flow under start-up and emergency conditions, will also be a key interface as the design developed. These are identified and managed within DOORS, including flow down of functional requirements.

### *System & Equipment Operation*

The Power Station Operating Philosophy, Reference [6] 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 [7].

Operating principles for the Feedwater System [LA] will be developed as the design progresses.

#### *Instrumentation & Control*

The Feedwater System [LA] requirements for control, monitoring, indication, alarms, and warnings are still to be developed. The allocation of safety categorised functional requirements to the Feedwater System Control and Protection System [LAY] will be described further in E3S Case Chapter 7: Instrumentation & Control, Reference [8], as the C&I system design is developed.

#### *Examination, Maintenance, Inspection & Testing*

An outline maintenance plan for the Feedwater System [LA] is still to be developed.

#### *Radiological Aspects*

No significant radiological aspects associated with the Feedwater System [LA] have been identified during design decisions up to PCD.

#### *Preliminary Substantiation*

Verification activities to substantiate safety categorised functional requirements and non-functional system requirements for the Feedwater System [LA] are still to be determined.

#### *Installation & Commissioning*

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

#### *ALARP in Design Development*

The design of the Feedwater System [LA] has been developed in accordance with the systems engineering design process, which includes alignment to RGP & OPEX, design to codes and standards according to the safety classification, and a systematic optioneering process with down-selection of design options based on assessment against relevant safety criteria (as described in PSCR Chapter 3: E3S Objectives & Design Rules, Reference [10]).

#### *Ongoing Design Development*

The RR SMR design definition is currently in development as described in Section 10.0.2.

### 10.3.2 Condensate System

#### *System & Equipment Functions*

The Condensate System [LC] forms part of the main water return system of the secondary circuit and comprises of the systems and sub-systems associated with the management of condensate extracted from the Condensing System [MAG] and delivered to the Feedwater System [LA]. The system is primarily made up of the Main Condensate Conveying System [LCC], Main Condensate Pre-Heating System [LCD], interconnecting pipework and instrumentation.

### *Safety Design Bases*

Functional Requirements

There are currently no safety categorised functional requirements specified for the Condensate System [LC].

Non-Functional System Requirements

Non-functional system requirements are specified for the Condensate System [LC] based on the E3S Principles. The requirements specified at PCD are listed in the DOORS Condensate System [LC] Requirements Module, including the rationale for their application. These are summarised in Table 10.3-4.

**Table 10.3-4: [LC] Non-Functional System Requirements**

| DOORS ID | Non-Functional System Requirement | Rationale |
|---|---|---|
| L-LC-1112 | The Condensate System [LC] design shall ensure that all risks to all populations during all modes of operation and lifecycle stages are reduced to levels that are ALARP | Overall safety principle |
| L-LC-1353 | All SSCs shall be classified in accordance with the defined project methodology | Ensures appropriate classification of SSCs to deliver the necessary functions to protect people and the environment from harm |
| L-LC-1113 | The Condensate System [LC] shall be designed to maximise the passivity of the safety systems during all modes of operation | Overall safety principle |
| L-LC-1114 | The Condensate System [LC] shall be designed to minimise the area required as an emergency planning zone within the local regulatory framework | Based on REPPIR, and the ACOP |
| L-LC-1117 | The Condensate System [LC] shall be capable of shutting down and maintaining a safe plant state without requirement for backup power systems | The SMR as a whole shall be passively safe |
| L-LC-1354 | The Condensate System [LC] shall be designed such that it does not reduce the RR SMR core damage frequency below the Basic Safety Level (1E-5/yr). | Overall safety principle |

| DOORS ID | Non-Functional System Requirement | Rationale |
|---|---|---|
| L-LC-1118 | The Condensate System [LC] should be designed such that the RR SMR core damage frequency is below the Basic Safety Objective (1E-7/yr) | Overall safety principle |

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

Safety Classification

The safety classification of Condensate System [LC] is still to be developed based on the categorisation of safety functions it delivers.

### *Description*

The Condensate System [LC] forms part of the main water return system of the secondary circuit and comprises of the systems and sub-systems associated with the management of condensate extracted from the Main Condenser [MAG] and delivered to the Feedwater System [LA]. It comprises of the following sub-systems:

1. Main Condensate Piping System [LCB], made up of a piping network used to convey the condensate from the condenser hotwell to the HP Feedwater System [LA]

2. Main Condensate Conveying System [LCC], which extracts the condensate from the condenser hotwell and discharges it through the LP heaters to the HP Feedwater System [LA]

3. Main Condensate Pre-Heating System [LCD], which uses heaters to pre-heat the condensate and improve thermodynamic efficiency

4. Condensate System of Feedwater Pre-Heating Drains [LCH], used to drain condensate to the deaerator feedwater tank [LAA] before being pumped back to the main Feedwater System [LA]

5. Pre-Heating Condensate Drain System [LCJ]

6. Clean Drains System [LCM], which is responsible for receiving turbine island drains from within the secondary circuit for re-distribution

7. Auxiliary Steam Condensate System [LCN], still to be developed

8. Re-Heater Drains System [LCS], where steam and condensate exiting the re-heater heat exchanger in the MSR [LBJ] is collected and transferred to the HP feedwater heaters [LAD]. The condensate formed will be pumped back to the deaerator feedwater tank [LAA] via the feedwater pre-heating drains system [LCH]

9. MSR Drains System [LCT], where water drained by gravity from MSR [LBJ] and Cold Re-Heat Pipes [LBC] is collected in a drains tank and pumped to the HP Feedwater System [LA]

10. Clean Drains System [LCM]

11. Fluid Supply System for Condensate System Control and Protection [LCX]

12. Condensate System Control and Protection System [LCY]

The key performance and design parameters are presented in Table 10.3.5.

**Table 10.3.5: Key Performance and Design Parameters for the Condensate System [LC]**

| **Parameter** | **Value** |
|---|---|
| **Main condensate pump system [LCC]** | |
| Nominal pressure @ outlet | **{REDACTED FOR PUBLICATION}** |
| Nominal temperature @ outlet | **{REDACTED FOR PUBLICATION}** |
| Nominal Enthalpy @ outlet | **{REDACTED FOR PUBLICATION}** |
| Nominal mass flow @ outlet | **{REDACTED FOR PUBLICATION}** |
| **Main condensate pre-heating system [LCD]** | |
| **1st stage LP feedwater heaters (located in condenser neck)** | |
| Nominal pressure @ inlet | **{REDACTED FOR PUBLICATION}** |
| Nominal temperature @ inlet | **{REDACTED FOR PUBLICATION}** |
| Nominal Enthalpy @ inlet | **{REDACTED FOR PUBLICATION}** |
| Nominal mass flow @ inlet | **{REDACTED FOR PUBLICATION}** |
| Nominal pressure @ outlet | **{REDACTED FOR PUBLICATION}** |
| Nominal temperature @ outlet | **{REDACTED FOR PUBLICATION}** |
| Nominal Enthalpy @ outlet | **{REDACTED FOR PUBLICATION}** |
| Nominal mass flow @ outlet | **{REDACTED FOR PUBLICATION}** |
| **2nd stage LP feedwater heater** | |
| Nominal pressure @ inlet | **{REDACTED FOR PUBLICATION}** |
| Nominal temperature @ inlet | **{REDACTED FOR PUBLICATION}** |
| Nominal Enthalpy @ inlet | **{REDACTED FOR PUBLICATION}** |
| Nominal mass flow @ inlet | **{REDACTED FOR PUBLICATION}** |
| Nominal pressure @ outlet | **{REDACTED FOR PUBLICATION}** |
| Nominal temperature @ outlet | **{REDACTED FOR PUBLICATION}** |
| Nominal Enthalpy @ outlet | **{REDACTED FOR PUBLICATION}** |
| Nominal mass flow @ outlet | **{REDACTED FOR PUBLICATION}** |
| **3rd stage LP feedwater heater** | |
| Nominal pressure @ inlet | **{REDACTED FOR PUBLICATION}** |
| Nominal temperature @ inlet | **{REDACTED FOR PUBLICATION}** |

| Parameter | Value |
|---|---|
| Nominal Enthalpy @ inlet | {REDACTED FOR PUBLICATION} |
| Nominal mass flow @ inlet | {REDACTED FOR PUBLICATION} |
| Nominal pressure @ outlet | {REDACTED FOR PUBLICATION} |
| Nominal temperature @ outlet | {REDACTED FOR PUBLICATION} |
| Nominal Enthalpy @ outlet | {REDACTED FOR PUBLICATION} |
| Nominal mass flow @ outlet | {REDACTED FOR PUBLICATION} |
| **4th stage LP feedwater heater** | |
| Nominal pressure @ inlet | {REDACTED FOR PUBLICATION} |
| Nominal temperature @ inlet | {REDACTED FOR PUBLICATION} |
| Nominal Enthalpy @ inlet | {REDACTED FOR PUBLICATION} |
| Nominal mass flow @ inlet | {REDACTED FOR PUBLICATION} |
| Nominal pressure @ outlet | {REDACTED FOR PUBLICATION} |
| Nominal temperature @ outlet | {REDACTED FOR PUBLICATION} |
| Nominal Enthalpy @ outlet | {REDACTED FOR PUBLICATION} |
| Nominal mass flow @ outlet | {REDACTED FOR PUBLICATION} |
| **Condensate system pre-heating drains [LCJ]** | |
| **4th stage LP feedwater heater condensate drain** | |
| Nominal pressure | {REDACTED FOR PUBLICATION} |
| Nominal temperature | {REDACTED FOR PUBLICATION} |
| Nominal Enthalpy | {REDACTED FOR PUBLICATION} |
| Nominal mass flow | {REDACTED FOR PUBLICATION} |
| **3rd stage LP feedwater heater condensate drain** | |
| Nominal pressure | {REDACTED FOR PUBLICATION} |
| Nominal temperature | {REDACTED FOR PUBLICATION} |
| Nominal Enthalpy | {REDACTED FOR PUBLICATION} |
| Nominal mass flow | {REDACTED FOR PUBLICATION} |
| **2nd stage LP feedwater heater condensate drain (@ pump discharge)** | |
| Nominal pressure | {REDACTED FOR PUBLICATION} |
| Nominal temperature | {REDACTED FOR PUBLICATION} |
| Nominal Enthalpy | {REDACTED FOR PUBLICATION} |
| Nominal mass flow | {REDACTED FOR PUBLICATION} |
| **1st stage LP feedwater heater condensate drain (to condenser)** | |
| Nominal pressure | {REDACTED FOR PUBLICATION} |

| Parameter | Value |
|---|---|
| Nominal temperature | {REDACTED FOR PUBLICATION} |
| Nominal Enthalpy | {REDACTED FOR PUBLICATION} |
| Nominal mass flow | {REDACTED FOR PUBLICATION} |
| **Condensate system feedwater pre-heating drains [LCH]:** | |
| **2nd stage HP feedwater heater condensate drain** | |
| Nominal pressure | {REDACTED FOR PUBLICATION} |
| Nominal temperature | {REDACTED FOR PUBLICATION} |
| Nominal Enthalpy | {REDACTED FOR PUBLICATION} |
| Nominal mass flow | {REDACTED FOR PUBLICATION} |
| **1st stage HP feedwater heater condensate drain** | |
| Nominal pressure | {REDACTED FOR PUBLICATION} |
| Nominal temperature | {REDACTED FOR PUBLICATION} |
| Nominal Enthalpy | {REDACTED FOR PUBLICATION} |
| Nominal mass flow | {REDACTED FOR PUBLICATION} |
| **Steam generator blowdown system [LCQ]*** | |
| Nominal pressure | {REDACTED FOR PUBLICATION} |
| Nominal temperature | {REDACTED FOR PUBLICATION} |
| Nominal Enthalpy | {REDACTED FOR PUBLICATION} |
| Nominal mass flow | {REDACTED FOR PUBLICATION} |
| *Based on steam generator outlet conditions | |
| **Re-heater drains system [LCS] @ pump discharge** | |
| Nominal pressure | {REDACTED FOR PUBLICATION} |
| Nominal temperature | {REDACTED FOR PUBLICATION} |
| Nominal Enthalpy | {REDACTED FOR PUBLICATION} |
| Nominal mass flow | {REDACTED FOR PUBLICATION} |
| **MSR drains system (LCT)** | |
| Nominal pressure | {REDACTED FOR PUBLICATION} |
| Nominal temperature | {REDACTED FOR PUBLICATION} |
| Nominal Enthalpy | {REDACTED FOR PUBLICATION} |
| Nominal mass flow | {REDACTED FOR PUBLICATION} |
| **Clean drains system [LCM]: TBC** | |
| Design and performance characteristics not defined at this stage | |

| Parameter | Value |
|---|---|
| **Auxiliary steam condensate system [LCN]: TBC** | |
| Design and performance characteristics not defined at this stage | |

The Condensate System [LC] is located in the Turbine Building [UMA]. A full description of the Condensate System [LC] and associated subsystems is provided in Reference [12].

### *Materials*

Materials will be confirmed as the design is developed.

### *Interfaces with Supporting Systems*

The Condensate System [LC] functional and physical interfaces are described above, including the HP Feedwater System [LA]. These are identified and managed within DOORS, including flow down of functional requirements.

Further, the Steam Generator Blowdown System [LCQ] is an interface which provides capability for continuous hot blowdown of secondary side SGs [JEA], with condensate returned to the cycle via the Condensing System [MAG]. The Steam Generator Blowdown System [LCQ] is part of Reactor Island [R01].

### *System & Equipment Operation*

The Power Station Operating Philosophy, Reference [6] 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 [7].

Operating principles for the Condensate System [LC] will be developed as the design progresses.

### *Instrumentation & Control*

The Condensate System [LC] requirements for control, monitoring, indication, alarms, and warnings are still to be developed, noting general requirements for the Main Condensate Pre-Heating System [LCD] and Main Condensate Pump Conveying System [LCC] are provided in Reference [12].

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

### *Examination, Maintenance, Inspection & Testing*

An outline maintenance plan for the Condensate System [LC] is still to be developed.

### *Radiological Aspects*

No significant radiological aspects associated with the Condensate System [LC] have been identified during design decisions up to PCD, noting development of the interface with the Steam Generator Blowdown System [LCQ] may result in radiological considerations for the system.

### *Preliminary Substantiation*

Any verification activities to substantiate safety categorised functional requirements (should they be placed on the system) and non-functional system requirements are still to be determined.

### *Installation & Commissioning*

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

### *ALARP in Design Development*

The design of the Condensate System [LC] has been developed in accordance with the systems engineering design process, which includes alignment to RGP & OPEX, design to codes and standards according to the safety classification, and a systematic optioneering process with down-selection of design options based on assessment against relevant safety criteria (as described in PSCR Chapter 3: E3S Objectives & Design Rules, Reference [10]).

### *Ongoing Design Development*

The RR SMR design definition is currently in development as described in Section 10.0.2.

# 10.4 Turbine Generator

## 10.4.1 Design Bases

The primary functions of the Generator System [MK] are to convert mechanical rotational energy to electrical energy in the form of high voltage, three-phase Alternating Current (AC) electricity, and to provide auxiliary support systems to the main generator equipment to ensure proper function.

There are currently no safety categorised functional requirements specified for the Generator System [MK].

Non-functional system requirements are specified for the Generator System [MK] based on the E3S Principles. The requirements specified at PCD are listed in the DOORS Generator System [MK] Requirements Module, including the rationale for their application. These are summarised in Table 10.4-1.

**Table 10.4-1: [MK] Non-Functional System Requirements**

| DOORS ID | Non-Functional System Requirement | Rationale |
|---|---|---|
| M-MK-1103 | The Generator System [MK] design shall ensure that all risks to all populations during all modes of operation and lifecycle stages are reduced to levels that are ALARP | Overall safety principle |
| M-MK-1346 | All SSCs shall be classified in accordance with the defined project methodology | Ensures appropriate classification of SSCs to deliver the necessary functions to protect people and the environment from harm |
| M-MK-1104 | The Generator System [MK] shall be designed to maximise the passivity of the safety systems during all modes of operation | Overall safety principle |
| M-MK-1105 | The Generator System [MK] shall be designed to minimise the area required as an emergency planning zone within the local regulatory framework | Based on REPPIR, and the ACOP |
| M-MK-1356 | The Generator System [MK] shall be designed such that it does not reduce the SMR core damage frequency below the Basic Safety Level (1E-5/yr). | Overall safety principle |

| DOORS ID | Non-Functional System Requirement | Rationale |
|---|---|---|
| M-MK-1109 | The Generator System [M] should be designed such that the SMR core damage frequency is below the Basic Safety Objective (1E-7/yr) | Overall safety principle |

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

The safety classification of Generator System [MK] is still to be developed based on the categorisation of safety functions it delivers.

### 10.4.2 Description

The Generator System [MK] is mainly responsible for the conversion of rotational mechanical energy to electrical energy within the Turbine Island [T01] secondary circuit. It comprises the following sub-systems:

1. Generator [MKA], which converts mechanical rotational energy, received from the Steam Turbine [MA] through direct rotor coupling connection, into electrical energy in the form of three phase high-voltage AC electricity, supplying the Transmission System [MS]

2. Generator Exciter Set System [MKC], which generates the electromagnetic field in the generator rotor to induce electrical voltage

3. Bearing System [MKD], which enables rotation of the turbine rotor train by receiving and returning lubrication oil through the interface with the Generator System Lubricant System [MKV]. It also provides support to, and is responsible for, keeping the turbine rotor train within axial and radial displacement limits

4. Stator Water Cooling System [MKF], which manages and distributes cooling water between the generator stator and the cooling heat exchangers that interface with the Turbine Island Closed Cooling Water System [PG] (if applicable during detailed design, vendor dependent)

5. Rotor Hydrogen Cooling System [MKG], which manages and distributes hydrogen between the generator stator and the cooling heat exchangers that interface with the Turbine Island Closed Cooling Water System [PG]

6. Exhaust Gas System [MKQ], which is responsible for venting off gases from the Generator [MKA] and auxiliaries

7. Generator System Lubricant System [MKV], which supplies lubricant to the Bearing System [MKD]

8. Generator System Sealing Fluid System [MKW], which manages and distributes generator sealing oil at the generator shaft seals, to prevent the hydrogen within the generator from escaping through the generator seals to atmosphere

9. Fluid Supply System for Control and Protection Systems [MKX]

10. Control and Protection System [MKY]

The Generator System [MK] is in the Turbine Building [UMA]. Further details of the Generator System [MK] and its sub-systems and components are presented in Reference [13].

### 10.4.3 Turbine Rotor Integrity

The integrity of the Generator System [MK] will be demonstrated as the design develops and vendors are engaged, and requirements are verified and validated.

# 10.5 Turbine & Condenser Systems

## 10.5.1 Steam Turbine System

### *System & Equipment Functions*

The primary function of the Steam Turbine System [MA] is to convert steam energy to mechanical rotational energy within the Turbine Island [T01] secondary circuit during normal operation. Safety Design Bases

Functional Requirements

Safety categorised functional requirements specified for the Steam Turbine System [MA] based on the HLSFs they deliver, including the applicable plant states and operating modes, are presented in Table 10.5-1.

**Table 10.5-1: [MA] Safety Categorised Functional Requirements**

| DOORS ID | Functional Requirement | Plant State(s) | Mode(s) of Operation | Safety Category |
|---|---|---|---|---|
| M-MA-1329 | The Steam Turbine System [MA] shall distribute blowdown condensate from the Condensate System [LC] | DBC-1<br>DBC-2i | 1 to 4a | C |
| M-MA-1334 | The Steam Turbine System [MA] shall supply condensate to the Condensate System [LC]. | DBC-1<br>DBC-2i | 1 to 4a | C |
| M-MA-1333 | The Steam Turbine System [MA] shall distribute condensate from the Condensate System [LC] | DBC-1<br>DBC-2i | 1 to 4a | C |
| M-MA-1278 | The Steam Turbine System [MA] shall convert steam to condensate | DBC-1<br>DBC-2i | 1 to 4a | C |

Non-Functional Performance Requirements associated with the safety categorised functional requirements are also allocated in the DOORS Steam Turbine System [MA] Requirements Modules, including the rationale for their selection, which are not repeated here.

Non-Functional System Requirements

Non-functional system requirements are specified for the Steam Turbine System [MA] based on the E3S Principles. The requirements specified at PCD are listed in the DOORS Steam Turbine System [MA] Requirements Module, including the rationale for their application. These are summarised in Table 10.5-2.

**Table 10.5-2: [MA] Non-Functional System Requirements**

| DOORS ID | Non-Functional System Requirement | Rationale |
|---|---|---|
| M-MA-1138 | The Steam Turbine System [MA] design shall ensure that all risks to all populations during all modes of operation and lifecycle stages are reduced to levels that are ALARP | Overall safety principle |
| M-MA-1374 | All SSCs shall be classified in accordance with the defined project methodology | Ensures appropriate classification of SSCs to deliver the necessary functions to protect people and the environment from harm |
| M-MA-1139 | The Steam Turbine System [MA] shall be designed to maximise the passivity of the safety systems during all modes of operation | Overall safety principle |
| M-MA-1140 | The Steam Turbine System [MA] shall be designed to minimise the area required as an emergency planning zone within the local regulatory framework | Based on REPPIR, and the ACOP |
| M-MA-1143 | The Steam Turbine System [MA] shall be capable of shutting down and maintaining a safe plant state without requirement for backup power systems | The RR SMR as a whole shall be passively safe |
| M-MA-1384 | The Steam Turbine System [MA] shall be designed such that it does not reduce the RR SMR core damage frequency below the Basic Safety Level (1E-5/yr). | Overall safety principle |
| M-MA-1144 | The Steam Turbine System [MA] should be designed such that the RR SMR core damage frequency is below the Basic Safety Objective (1E-7/yr) | Overall safety principle |

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

<u>Safety Classification</u>

The safety classification of the Steam Turbine System [MA] is still to be developed.

***Description***

The Steam Turbine System [MA] comprises the following sub-systems:

1. HP Turbine [MAA], which receives steam from the Main Steam Piping System [LBA], where it is fed to two inlet valve combinations, expanded through the two opposing flow paths, and exhausted to the Cold-Reheat Piping System [LBC]. It sits on the same rotor train as the LP Turbines [MAC] and the Generator [MKA] in a single axis tandem compound arrangement all operating at full speed rotation (3000 rpm)

2. LP Turbines [MAC], which is made up to two turbine sections, each receiving nominally equal steam conditions from the Hot Reheat Piping System [LBB] to convert steam energy to mechanical rotational energy. Expanded steam is then exhausted to the Condensing System [MAG]

3. Bearing System [MAD], which enables rotation of the turbine rotor train by receiving and returning lubrication oil through the interface with the Steam Turbine Lubricant System [MAV]. It also provides support to, and is responsible for, keeping the turbine rotor train within axial and radial displacement limits

4. Condensing System [MAG], which comprises of two separate waterboxes (one per LP turbine). The primary function of the Condensing System [MAG] is to decrease the exhaust pressure of the steam extracted from the LP Turbines [MAC] to below atmosphere improving the efficiency of the power plant. The cooling water supply from the Main Cooling Water System [PA] for the two waterboxes is arranged in series: cooling water passes through the first and is subsequently heated before passing through the second at a higher inlet temperature, meaning the second of the series operates at a slightly higher pressure

5. Air Removal and Evacuation System [MAJ], responsible for extracting and venting off non-condensable gases from the Condensing System [MAG]. Cooling is provided by the heat exchangers that interface with the Turbine Island Closed Cooling Water System [PG]

6. Transmission gear (shaft turning gear) [MAK], responsible for maintaining a rotational speed (~1 Hz) of the turbine and generator rotor train when transitioning in preparation for start-up or shutdown

7. Drain and Vent System [MAL], responsible for receiving and collecting drains and vents from the Turbine Island [T01] and distributing them accordingly either back into the Condensing system [MAG] or discharging to Balance of Plant [B01]

8. Leak-off Steam System [MAM], responsible for receiving and collecting leak-off steam from a selection of the major valves in the Turbine Island [T01] and distributing them accordingly either back into the Condensing System [MAG] via the gland steam condenser as part of the Gland Sealing System [MAW], or discharging to Balance of Plant [B01]

9. Turbine Bypass Station [MAN], which provides bypass capability for steam received from the Main Steam Piping System [LBA] to be diverted around the steam turbine and sent directly to the Condensing System [MAG]

10. Vent system [MAQ], to be determined

11. Steam Turbine Lubricant System [MAV], which supplies lubricant to the Bearing System [MAD]

12. Gland Sealing System [MAW], responsible for managing and distributing steam turbine sealing steam between the Steam Turbine System [MA] and the Auxiliary Steam Piping System [LBG] (used during start-up, low-load and shutdown)

13. Non-electric control and protection system, including fluid supply system [MAX], responsible for providing high pressure control fluid supply for turbine governing and to provide monitoring of the Steam Turbine System [MA]

14. Electrical control and protection system [MAY], responsible for electrical control and protection of the steam turbine systems

The key performance and design parameters are presented in Table 10.5-3.

**Table 10.5-3: Key Performance and Design Parameters for the Steam Turbine System [MA]**

| Parameter | Value |
|---|---|
| **HP Turbine [MAA]** | |
| Nominal Pressure | **{REDACTED FOR PUBLICATION}** |
| Nominal Temperature | **{REDACTED FOR PUBLICATION}** |
| Nominal Enthalpy | **{REDACTED FOR PUBLICATION}** |
| Nominal Mass Flow | **{REDACTED FOR PUBLICATION}** |
| **LP Turbine [MAC]** | |
| Nominal Pressure | **{REDACTED FOR PUBLICATION}** |
| Nominal Temperature | **{REDACTED FOR PUBLICATION}** |
| Nominal Enthalpy | **{REDACTED FOR PUBLICATION}** |
| Nominal Mass Flow | **{REDACTED FOR PUBLICATION}** |
| **Condensing System [MAG] (Condenser 1 Steam Side Inlet)** | |
| Nominal Pressure | **{REDACTED FOR PUBLICATION}** |
| Nominal Temperature | **{REDACTED FOR PUBLICATION}** |
| Nominal Enthalpy | **{REDACTED FOR PUBLICATION}** |
| Nominal Mass Flow | **{REDACTED FOR PUBLICATION}** |
| **Condensing System [MAG] (Condenser 2 Steam Side Inlet)** | |
| Nominal Pressure | **{REDACTED FOR PUBLICATION}** |
| Nominal Temperature | **{REDACTED FOR PUBLICATION}** |
| Nominal Enthalpy | **{REDACTED FOR PUBLICATION}** |
| Nominal Mass Flow | **{REDACTED FOR PUBLICATION}** |

The Steam Turbine System [MA] is in the Turbine Building [UMA]. Further details of the Steam Turbine System [MA] and its sub-systems are presented in Reference [14].

### *Materials*

Materials will be confirmed as the design is developed.

### *Interfaces with Supporting Systems*

The Steam Turbine System [MA] functional and physical interfaces are described above. These are identified and managed within DOORS, including flow down of functional requirements.

### *System & Equipment Operation*

The Power Station Operating Philosophy, Reference [6] 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 [7].

Operating principles for the Steam Turbine System [MA] will be developed as the design progresses.

### *Instrumentation & Control*

The Steam Turbine System [MA] requirements for control, monitoring, indication, alarms, and warnings are still to be developed. The allocation of safety categorised functional requirements to the control and protection system, including fluid supply system [MAX], Electrical Control and Protection System [MAY] and the Control and Protection System [MYA], will be described further in E3S Case Chapter 7: Instrumentation & Control, Reference [8], as the C&I system design is developed.

### *Examination, Maintenance, Inspection & Testing*

An outline maintenance plan for the Steam Turbine System [MA] is still to be developed.

### *Radiological Aspects*

No significant radiological aspects associated with the Steam Turbine System [MA] have been identified during design decisions up to PCD.

### *Preliminary Substantiation*

Verification activities to substantiate safety categorised functional requirements and non-functional system requirements for the Steam Turbine System [MA] are still to be determined.

### *Installation & Commissioning*

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

### *ALARP in Design Development*

The design of the Steam Turbine System [MA] has been developed in accordance with the systems engineering design process, which includes alignment to RGP & OPEX, design to codes and standards according to the safety classification, and a systematic optioneering process with down-selection of design options based on assessment against relevant safety criteria (as described in E3S Case Chapter 3: E3S Objectives & Design Rules, Reference [10]).

### *Ongoing Design Development*

The RR SMR design definition is currently in development as described in Section 10.0.2.

# 10.6 Conclusions

## 10.6.1 Conclusions

Preliminary evidence is presented to support the overall chapter Claim that 'The RR SMR Steam & Power Conversion Systems are designed and substantiated to achieve functional and non-functional safety requirements through the lifecycle and reduce risks to As Low As Reasonably Practicable', which contributes to the overall E3S objective to protect people and the environment from harm, and the demonstration that risks are reduced ALARP.

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.

## 10.6.2 Assumptions & Commitments on Future Dutyholder/Licensee

None identified in this revision.

# 10.7 References

[1] RR SMR Report, SMR0004924/001, "E3S Case Chapter 1: Introduction," March 2023.
[2] RR SMR Report, SMR0002183/003, "Rolls-Royce SMR Generic Design Assessment Scope," January 2023.
[3] RR SMR Report, SMR0002155/001, "E3S Case CAE Route Map," March 2023.
[4] RR SMR Report, SMR0003023/001, "Reactor Codes and Standards," October 2022.
[5] RR SMR Report, EDNS01000928619/001, "System Outline Description for the Turbine Island Steam System [LB]," April 2021.
[6] RR SMR Report, EDNS01000912618/001, "Power Station Operating Philosophy," January 2021.
[7] RR SMR Report, SMR0004247/001, "E3S Case Chapter 13: Conduct of Operations," March 2023.
[8] RR SMR Report, SMR0003863/001, "E3S Case Chapter 7: Instrumentation & Control," March 2023.
[9] RR SMR Report, SMR0003880/001, "E3S Case Chapter 14: Plant Construction & Commissioning," March 2023.
[10] RR SMR Report, SMR0004589/001, "E3S Case Chapter 3: E3S Objectives & Design Rules," March 2023.
[11] RR SMR Report, EDNS01000928620/001, "System Outline Definition LA Feedwater System," May 2021.
[12] RR SMR Report, EDNS01000928617/001, "System Outline Description for the Turbine Island Condensate System [LC]," April 2021.
[13] RR SMR Report, EDNS01000928621/001, "System Outline Description for the Turbine Island Generator System [MK]," April 2021.
[14] RR SMR Report, EDNS01000928610/001, "System Outline Description for the Turbine Island Steam Turbine System [MA]," April 2021.

# 10.8 Appendix A: CAE Route Map

## 10.8.1 Chapter 10 Route Map

A preliminary Claims decomposition from the overall Chapter 10 Claim is summarised in Table10.8-1, 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 10.8-1: CAE Route Map**

| **Level 1 Claims** | **Level 2 Claims** | **Level 3 Claims** | **Arguments** | **Evidence Summary within Chapter 10** | **Underpinning Tier 2 Evidence** <br> ***at PCD** | **Underpinning Tier 2 Evidence** <br> ***to be developed** |
|---|---|---|---|---|---|---|
| Safety Categorised 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 | Section 10.2.2 | DOORS Steam System [LB] Requirements Module (PCD) | DOORS Steam System [LB] Requirements Module (revised) |
| | | | | Section 10.3.1 | DOORS Feedwater System [LA] Requirements Module (PCD) | DOORS Feedwater System [LA] Requirements Module (revised) |
| | | | | Section 10.4.1 | DOORS Generator System [MK] Requirements Module (PCD) | DOORS Generator System [MK] Requirements Module (revised) |

| **Level 1 Claims** | **Level 2 Claims** | **Level 3 Claims** | **Arguments** | **Evidence Summary within Chapter 10** | **Underpinning Tier 2 Evidence** ***at PCD** | **Underpinning Tier 2 Evidence** ***to be developed** |
|---|---|---|---|---|---|---|
| | | | during Plant States DBC-1 to DBC-5<br><br>Non-functional requirements are derived from the E3S principles and applied to the architecture of SSCs in accordance with their classification | Section 10.5.1 | DOORS Steam Turbine System [MA] Requirements Module (PCD) | DOORS Steam Turbine System [MA] Requirements Module (revised) |
| | | | | Section 10.3.2 | n/a | DOORS Condensate System [LC] Requirements Module (revised) |
| Architecture is designed to achieve safety requirements, considering RGP & OPEX to reduce risks to ALARP | - | - | The preferred design solution has been developed following a structured systems engineering approach with evaluation against safety criteria supporting the decision-making process | Section 10.2.3 – 2.8 | Steam System [LB] System Description, Reference [5] | Steam System [LB] System Design Description (revised) |
| | | | | Section 10.3.1 | Feedwater System [LA] System Description, Reference [11] | Feedwater System [LA] System Description (revised) |
| | | | | Section 10.4.2 | Generator System [MK] System Description, Reference [13] | Generator System [MK] System Description (revised) |

| **Level 1 Claims** | **Level 2 Claims** | **Level 3 Claims** | **Arguments** | **Evidence Summary within Chapter 10** | **Underpinning Tier 2 Evidence**<br><br>***at PCD** | **Underpinning Tier 2 Evidence**<br><br>***to be developed** |
|---|---|---|---|---|---|---|
| | | | | Section 10.5.1 | Steam Turbine System [MA] System Description, Reference [14] | Steam Turbine System [MA] System Description (revised) |
| | | | | Section 10.3.2 | Condensate System [LC] System Description, Reference [12] | Condensate System [LC] System Description (revised) |
| The design has been substantiated to achieve its safety requirements through the lifecycle | Safety requirements have been substantiated | | Verification activities to demonstrate safety requirements can be achieved have been developed based on sound engineering judgement and methods<br><br>*Note: Arguments will be updated as substantiation Evidence is developed* | n/a | n/a | TBC |

| **Level 1 Claims** | **Level 2 Claims** | **Level 3 Claims** | **Arguments** | **Evidence Summary within Chapter 10** | **Underpinning Tier 2 Evidence** ***at PCD** | **Underpinning Tier 2 Evidence** ***to be developed** |
|---|---|---|---|---|---|---|
| | Safety requirements have been verified through manufacturing, construction, installation, and commissioning | - | Processes and controls are designed to verify safety requirements during manufacturing, construction, installation, and commissioning | n/a | n/a | Installation and Commissioning Plans for each SSC (TBC) |
| | Design can deliver its safety requirements during its operational life | - | The design identifies and facilitates examination, maintenance, inspection and testing (EMIT) activities commensurate with its safety classification to demonstrate its status, availability, and integrity in line with the design intent | n/a | n/a | Maintenance Plans for each SSC (TBC) |

# 10.9 Appendix B: SSCs in Scope of Chapter 10

Table10.9-1 lists those SSCs that are within the scope of Chapter 10, and the section of the report they are addressed.

**Table 10.9-1: SSCs in Scope of PCSR**

| RDS-PP | SSC | Section in PCSR |
|---|---|---|
| L | Steam Water Condensate System | Covered by [L_] Sections |
| LA | Feedwater system | Section 10.3.1 |
| LAA | Deaerator and Feedwater Storage System | |
| LAB | Feedwater piping system | |
| LAC | Main Feedwater Pumps | |
| LAD | High Pressure Feedheaters | |
| LB | Steam system | Section 10.2 |
| LBA | Main steam piping system | |
| LBB | Hot reheat piping system | |
| LBC | Cold reheat piping system | |
| LBD | Extraction piping system | |
| LBF | Overpressure suppression and safety system | |
| LBG | Auxiliary steam piping system | |
| LBJ | Moisture separator and reheater system | |
| LBK | Main steam safety/relief system inside reactor containment for single-cycle plant | |
| LBQ | Extraction steam piping system for feedwater preheating system | |

| RDS-PP | SSC | Section in PCSR |
|---|---|---|
| LBS | Extraction steam piping system for main condensate preheating system | |
| LBX | Fluid supply system for the steam system control and protection system | |
| LC | Condensate system | Section 10.3.2 |
| LCB | Main condensate piping system | |
| LCC | Main condensate conveying system | |
| LCD | Main condensate preheating system | |
| LCH | Condensate system of feedwater preheating | |
| LCJ | Pre-heating condensate drain system | |
| LCM | Clean drains system | |
| LCN | Auxiliary steam condensate system | |
| LCS | Reheater drains system | |
| LCT | Moisture separator drains system | |
| LCV | Lubricant system | |
| LCW | Sealing and cooling drains system | |
| LCX | Fluid supply system for the condensate system control and protection system | |
| LCE | Condensate desuperheating spray system | Not covered in this PCSR revision |

| RDS-PP | SSC | Section in PCSR |
|---|---|---|
| LCQ | Steam Generator Blowdown System | |
| LD | Condensate polishing system | Not covered in this PCSR revision |
| LDA | Transfer system condensate | |
| LDB | Filtering, mechanical cleaning system | |
| LDC | Aeration, gas injection system | |
| LDD | Electromagnetic polishing system | |
| LDE | Acid proportioning system | |
| LDF | Ion exchange, reverse osmosis system | |
| LDG | Evaporation system | |
| LDH | Deaeration | |
| LDJ | Preheating, cooling system | |
| LDK | Piping system, temporary storage, conveying main fluid | |
| LDL | Storage system outside fluid treatment system (unless part of another system) | |
| LDN | Chemicals supply system | |
| LDP | Regeneration, flushing system | |
| LDQ | Injection system for main fluid | |
| LDR | Flushing water and residues removal system, including neutralization | |
| LDS | Sludge thickening system | |

| RDS-PP | SSC | Section in PCSR |
|---|---|---|
| LDT | Heating, cooling and flushing fluid distribution system | |
| LDV | Lubricant system | |
| LDX | Fluid supply system for the condensate polishing system control and protection system | |
| LX | Fluid supply systems for control and protection systems | |
| M | Main Turbine Generator System | Covered by [M_] Sections |
| MA | Steam turbine system | Section 5.1 |
| MAA | High pressure turbine | |
| MAC | Low pressure turbine | |
| MAD | Bearing | |
| MAG | Condensing system | |
| MAJ | Air removal and evacuation system | |
| MAK | Transmission gear including shaft turning gear | |
| MAL | Drain and vent system | |
| MAM | Leak-off steam system | |
| MAN | Turbine Bypass system | |
| MAQ | Vent system | |
| MAV | Steam turbine lubricant system | |
| MAW | Gland sealing system | |
| MAX | Fluid supply system for the steam turbine system control and protection system | |

| RDS-PP | SSC | Section in PCSR |
|---|---|---|
| MK | Generator system | Section 10.4 |
| MKA | Generator | |
| MKC | Generator exciter set | |
| MKD | Bearing | |
| MKE | Secondary cooling system | |
| MKF | Stator water cooling system | |
| MKG | Rotor hydrogen cooling system | |
| MKH | Stator/rotor primary cooling with nitrogen or carbon dioxide as a coolant | |
| MKJ | Stator/rotor primary cooling with air as a coolant | |
| MKK | Stator/rotor primary cooling with cooling oil as a coolant | |
| MKQ | Exhaust gas system | |
| MKV | Generator system lubricant system | |
| MKW | Generator system sealing fluid system | |
| MKX | Fluid supply system for the generator system control and protection system | |
| MU | Common Systems of the Main Turbine Generator System | Not covered in this PCSR revision |
| MUA | Foundation | |
| MUB | Sheathing | |
| MUG | Frame support structure | |

## 10.10 Acronyms and Abbreviations

| | |
|---|---|
| AC | Alternating Current |
| ACOP | Approved Code of Practice and guidance |
| ALARP | As Low As Reasonably Practicable |
| ASME | American Society of Mechanical Engineers |
| BS | British Standard |
| C&I | Control and Instrumentation |
| CAE | Claims, Arguments, Evidence |
| CoFT | Control of Fuel Temperature |
| DBC | Design Basis Condition |
| DOORS | Dynamic Object-Oriented Requirements System |
| E3S | Environmental, Safety, Security and Safeguards |
| EDI | Electrodeionisation |
| EMIT | Examination, Maintenance, Inspection and Testing |
| EN | European Standard adopted as a British Standard |
| FSF | Fundamental Safety Function |
| GER | Generic Environment Report |
| GSR | Generic Security Report |
| HLSFs | High-Level Safety Function |
| HP | High-Pressure |
| HR | High Reliability |
| LP | Low-Pressure |
| MCWS | Main Cooling Water System |
| MSR | Moisture Separator Reheater |

| | |
|---|---|
| OPEX | Operating Experience |
| PCD | Preliminary Concept Definition |
| PCSR | Pre-Construction Safety Report |
| RD | Reference Design |
| RDS-PP | Reference Designation System – Power Plants |
| REPPIR | Radiation (Emergency Preparedness and Public Information)) Regulations 2019 |
| RGP | Relevant Good Practice |
| RR SMR | Rolls-Royce Small Modular Reactor |
| SG | Steam Generator |
| SGBS | Steam Generator Blowdown System |
| SSC | System, Structure and Component |
| TBC | To Be Confirmed |
| VHR | Very High Reliability |