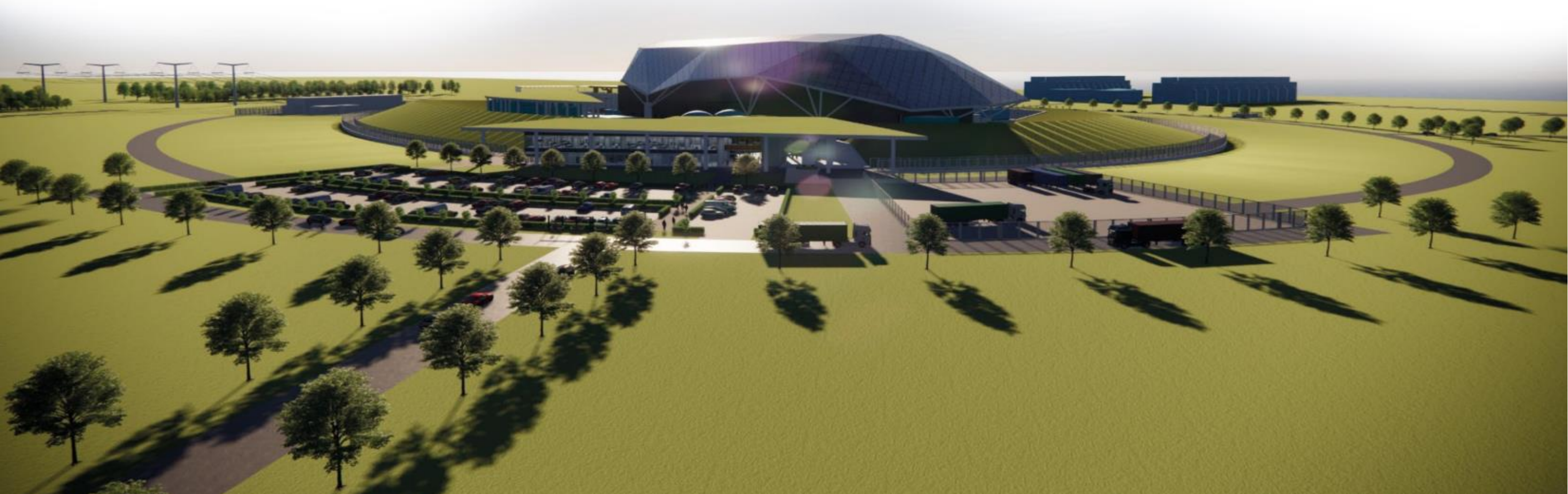
Environment, Safety, Security and Safeguards Case Version 2, Tier 1, Chapter 11: Management of Radioactive Wastes



Record of Change

Date	Revision Number	Status	Reason for Change
March 2023	1	Issue	First version of E3S Case
February 2024	2	Issue	Second issue to reflect DRP1
May 2024	3	Issue	Updated to correct revision history status at Issue 2. Chapter changes include: • Amendment to section 11.2.10 • Removal of 'Simplified flow diagram of an HVAC system serving a controlled area' figure in section 11.3.3.2 • Further information added to section 11.4.10 • Addition of a future dutyholder/licensee/permit holder commitment to develop a records' management plan/strategy (section 11.4.15) • Additional detail within conclusions section for how arguments and evidence presented meet the generic E3S Case objective (section 11.5) • Addition of claims, arguments, evidence table in Appendix A (section 11.7) Also minor template/editorial updates for overall E3S Case consistency.

Executive Summary

This chapter is Tier 1 Chapter 11 of the Rolls-Royce Small Modular Reactor (RR SMR) Environment, Safety, Security, and Safeguards (E3S) Case.

This chapter presents the overarching summary of the RR SMR liquid, gaseous and solid radioactive waste systems based on reference design 7 (RD7)/design reference point 1 (DRP1) and describes the radioactive waste management arrangements (RWMA) for radioactive waste arisings.

For each structure, system and component (SSC) in scope, the following aspects are summarised:

High-level safety functions (HLSFs) delivered by the SSC, and the assigned safety categorised functional requirements and non-functional system requirements.

High-level environmental functions delivered by the SSC, and the assigned environmental functional requirements and environmental non-functional system requirements.

Design description, including architecture, layout, operating modes, as low as reasonably practicable (ALARP) and best available techniques (BAT) considerations in the design development.

Key verification activities and evidence to support substantiation of SSCs.

The RWMA for all forms of radioactive waste arising during commissioning, normal power operations and decommissioning are within the scope of this chapter. It must be noted that the level of information available on waste arisings varies between waste streams and the different lifecycle phases, reflecting the current maturity in the design of the RR SMR.

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11.0 Introduction to Chapter

11.0.1 Introduction

This is Chapter 11 of the Rolls-Royce Small Modular Reactor (RR SMR) Environment, Safety, Security, and Safeguards (E3S) Case.

This issue of Chapter 11 presents the overarching summary of the RR SMR liquid, gaseous and solid radioactive waste systems based on reference design 7 (RD7)/design reference point 1 (DRP1) and describes the radioactive waste management arrangements (RWMA) for radioactive waste arisings, with reference made to supporting documents where appropriate.

The objectives of this chapter are to:

- Summarise the sources and predicted arisings of liquid and gaseous radioactive wastes, noting that further detail of these arisings is provided in E3S Case Version 2, Tier 1, Chapter 29: Quantification of Radioactive Effluent Discharges and Proposed Limits [1].
- Describe the sources and predicted arisings of solid radioactive wastes and spent fuel (SF) over the lifecycle of the RR SMR.
- Describe the structures, systems and components (SSCs) designed for the management of the anticipated RR SMR radioactive waste streams.
- Identify environmentally significant SSCs in accordance with the method set out in Environmental Functions and Environmental Measures [2][1].
- Describe the proposed arrangements for managing radioactive waste arisings and SF over the lifecycle of the RR SMR, and how these are optimised to ensure the protection of people and the environment.
- Demonstrate that the proposed RWMA are consistent with relevant good practice (RGP) and meet the requirements of applicable legislation within the United Kingdom (UK)[2] and associated regulatory guidance.

11.0.2 Scope and Maturity

This chapter covers the SSCs as set out in Table 11.0-1. For each SSC in scope, the following aspects are summarised:

- High-level safety functions (HLSFs) delivered by the SSC, and the assigned safety categorised functional requirements and non-functional system requirements.
- High-level environmental functions delivered by the SSC, and the assigned environmental functional requirements and environmental non-functional system requirements.

[1] At time of writing, the environmentally significant SSCs associated with radioactive waste have been identified but are awaiting input into the dynamic object orientated requirements system (DOORS). Their input into DOORS is planned to be undertaken towards the end of Step 2 and start of Step 3 of the generic design assessment (GDA) process.

[2] It is considered that RWMA that meet UK regulatory requirements will also be acceptable in an international regulatory context. This is based upon international standards being used to frame UK national policy and legislation.

- Design description, including architecture, layout, operating modes, as low as reasonably practicable (ALARP) and best available techniques (BAT) considerations in the design development.
- Key verification activities and evidence to support substantiation of SSCs.

The RWMA for all forms of radioactive waste arising during commissioning, normal power operations and decommissioning are within the scope of this chapter. It must be noted that the level of information available on waste arisings varies between waste streams and systems, and the different lifecycle phases, reflecting the current maturity in the design of the RR SMR. This particularly relates to the decommissioning phase but this is an area that is actively being worked upon following the first issue of the Decommissioning and Waste Management Plan (DWMP) [3].

The lifecycle of the RR SMR is broken down into five phases as illustrated in

Figure 11.0-1, noting that some spent nuclear fuel and higher-activity waste (HAW) management and disposal will occur alongside commissioning and operation, and reactor decommissioning.

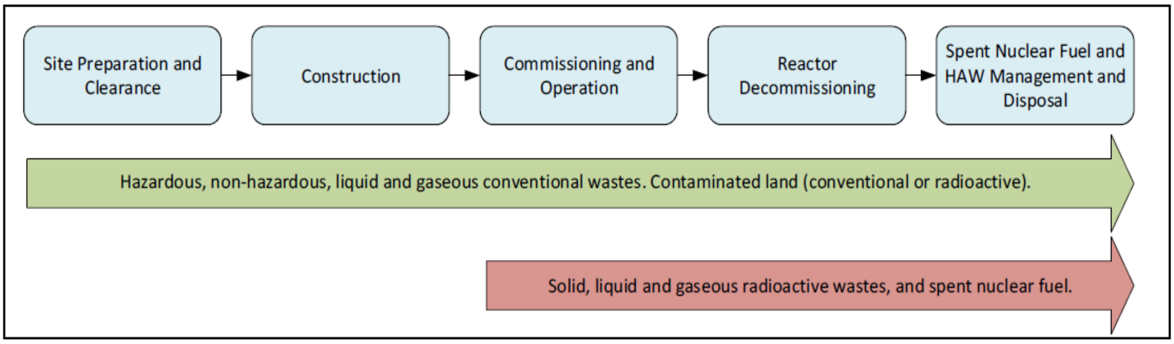

Figure 11.0-1: Overview of the lifecycle stages of the RR SMR

As shown in

Figure 11.0-1, the types of waste produced over the lifecycle stages of the RR SMR will vary. SF and liquid/gaseous/solid radioactive wastes are expected to be produced only from the start of commissioning, operations and into decommissioning, whilst conventional waste (outside the scope of this chapter) may be expected to be produced throughout the RR SMR lifecycle. Whilst active commissioning may feasibly generate quantities of radioactive waste described in section 11.1, any quantities generated would likely be very limited.

It is recognised that there is potential for radioactive waste from historical radioactive land contamination to be produced during the site preparation, clearance and construction phases, but this is a site-specific matter and out of scope of this chapter. The different types of radioactive waste that are expected to be produced are described in section 11.1.

Further information on the RR SMR lifecycle stages and the relevance to waste arisings can be found in the Integrated Waste Strategy (IWS) [4].

Process and effluent radiological monitoring and sampling systems are not within the scope of this chapter but are to be covered within E3S Case Version 2, Tier 1, Chapter 28: Sampling and Monitoring Arrangements [5]. The quantification of radioactive liquid and gaseous discharges is covered within E3S Case Version 2, Tier 1, Chapter 29: Quantification of Radioactive Effluent Discharges and Proposed Limits [1].

SSCs within scope of this chapter are summarised in Table 11.0-1.

Table 11.0-1: SSCs within the scope of Chapter 11

RDS-PP	SSC	Section of Chapter 11
[KLA]	Heating, ventilation and air-conditioning (HVAC) systems serving primary containment	11.3
[KLB]	HVAC systems serving the interspace	11.3
[KLC]	HVAC systems serving controlled areas	11.3
[KLF]	HVAC systems serving radioactive waste processing areas	11.3
[KLL]	HVAC systems serving fuel storage and handling areas	11.3
[KM]	Solid Radioactive Waste Management Systems	11.4
[KMA]	Solid Radioactive Waste Processing System	11.4
[KMA10]	Processing and Dispatch System for low-level waste (LLW)	11.4
[KMA20]	Processing and Treatment System for intermediate level waste (ILW)	11.4
[KME]	Solid Radioactive Waste Storage System	11.4
[KME10]	Temporary storage for LLW	11.4
[KME20]	Temporary storage for wet ILW	11.4
[KME30]	Long term storage for processed ILW store	11.4
[KN]	Liquid Radioactive Effluent Processing System	11.2
[KNF]	Liquid Radioactive Effluent Treatment System	11.2
[KNF10]	Processing and Treatment System for Primary Liquid Effluent	11.2
[KNF20]	Processing and Treatment System for Spent Liquid Effluent	11.2
[KNF30]	Liquid Effluent Monitoring and Discharge System	11.2
[KP]	Gaseous Radioactive Effluent Treatment System	11.3
[KPL]	Gaseous Radioactive Effluent Treatment System	11.3
[KT]	Collection and Drainage Systems for Liquid Media in Controlled and Exclusion Areas	11.2
[KTA]	Reactor Island (RI) Collection and Drainage System	11.2

RDS-PP	SSC	Section of Chapter 11
[KTA10]	Collection and Transfer of Reactor Coolant Drains	11.2
[KTA20]	Collection and Transfer of Process and Floor Drains	11.2
[KTA30]	Collection and Transfer of Chemical Drains	11.2
[KTA40]	Collection and Transfer of Non-active Drains	11.2

The RR SMR radioactive waste systems are formally defined at the RD7/DRP1 level of design maturity at time of writing.

The systems being discussed are generally at a definition review (DR) 3 maturity of design, i.e. at a final concept stage of design. Some systems are still at DR1 and therefore represent an early concept design.

Further design development and definition of waste systems is in progress, to achieve requirements, and ultimately substantiation of requirements.

11.0.3 Claims, Arguments and Evidence Route Map

The following top-level claim is applicable to E3S Case Version 2, Tier 1, Chapter 11: Management of Radioactive Waste:

Radioactive waste systems and arrangements are conservatively designed and verified to deliver E3S functions through-life and minimise the generation of radioactive waste and discharges, in accordance with the E3S design principles, to reduce risks to ALARP, apply BAT and in line with Secure-by-Design and Safeguards-by-Design.

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 [6], described further in E3S Case Version 2, Tier 1, Chapter 1: Introduction [7].

A proportionate summary of the arguments and evidence from lower tier information, available at the current design stage, is presented within this chapter. A mapping of the claims to the corresponding sections that summarise the arguments and/or evidence is provided in Appendix A (section 11.7).

11.0.4 Applicable Regulations, Codes and Standards

Regulations, codes and standards, alongside policies and strategies, are applicable to both the development of RWMA, and the design, of mechanical systems and components.

Publications from international organisations such as the International Atomic Energy Agency (IAEA) and the Western European Nuclear Regulators Association (WENRA) are used to frame UK national policy and legislation. It is therefore considered that by meeting UK regulatory requirements, Rolls-Royce SMR's waste management arrangements will be acceptable in an international regulatory context. Reference should be made to the IWS [4] for more detail on those which are applicable to the development of RWMA.

The mechanical systems and components summarised in this chapter are designed in accordance with their safety classification, to the codes and standards outlined in Table 11.0-2, as identified in [8].

Table 11.0-2: Summary of RR SMR codes and standards

Safety classification	Design basis code
VHR	American Society of Mechanical Engineers (ASME) III (Sub-section NB) and beyond code requirements
HR	ASME III (Sub-section NB) and beyond code requirements
Class 1	ASME III
Class 2	ASME III
Class 3	ASME III or Commercial standards e.g., ASME VIII, British Standard (BS) EN 13445 (with nuclear supplements added depending on potential dose levels)
n/a	Commercial standards e.g., ASME VIII, BS EN 13445

11.1 Sources of Radioactive Waste

11.1.1 Sources of Radioactive Waste Within a RR SMR

11.1.1.1 Sources of Liquid Radioactive Wastes

This section only covers aqueous wastes. Oils and solvents are initially discussed in section 11.1.1.3.

11.1.1.1.1 Sources of Liquid Radioactive Wastes During Commissioning and Operations

Aqueous radioactive effluents are categorised and segregated based on their source and expected levels of contamination. Two primary sources of aqueous radioactive effluents have been characterised for the RR SMR [9]:

- Primary liquid effluent originating from the Chemistry and Volume Control System (CVCS) [KB] letdown and the drainage of primary coolant to the Reactor Coolant Drain Tank (RCDT) [KTA10]. The water quality in these systems is maintained to the required standard by the relevant purification and treatment system [KBE] and is therefore expected to have low levels of contamination.

- Spent liquid effluent comprises several effluent streams originating from different sources, collected for treatment by the sumps and vessels of the Collection and Drainage System (CDS) [KTA20, KTA30, KTA40]. Spent liquid effluent comprises the following categories:

    - Process drains – effluent derived from equipment drainage for maintenance, testing, or safety relief etc. These effluents are expected to have low levels of contamination.
    - Chemical drains – effluent derived from chemical sampling and equipment decontamination. These effluents are expected to have higher levels of contamination than process drains.
    - Floor drains – effluent derived from leaks and floor washings. Floor drains are segregated into active and non-active, depending on layout (dependent on radiological contamination zoning). Effluents from the active floor drains are stored with those from process drains. These effluents are expected to have varying levels of contamination.
    - Contaminants that could be detrimental to the performance of the effluent treatment process are expected to be identified and captured by [KTA].

11.1.1.1.2 Sources of Liquid Radioactive Wastes During Decommissioning

Liquid radioactive effluents that may arise from decommissioning activities will be identified in future revisions of the DWMP [3].

11.1.1.2 Sources of Gaseous Radioactive Waste

11.1.1.2.1 Sources of Gaseous Radioactive Waste During Commissioning and Operations

Active gaseous effluents can be separated into two main categories, which differ in activity levels and filtration techniques deployed:

- Gaseous effluent including hydrogen and volatile fission products derived from the systems handling reactor coolant, primary circuit effluent or make-up water. The key sources of these gases during power operation are the vacuum degasser in [KNF] and the RCDT [KTA10] [10]. These gases may contain radioactive fission and activation products (isotopes of krypton, xenon, argon and iodine), which require abatement before discharge.
- Gaseous effluent from the [KL] systems that are installed in all radiologically controlled areas (RCAs) (which may be referred to as HVAC air). The HVAC air is expected to contain a low level of activity, including particulates and sometimes iodine (for example, resulting from fuel pin failures).

The KL systems are:

- [KLA] – HVAC systems serving primary containment
- [KLB] – HVAC systems serving the interspace
- [KLC] - HVAC systems serving the controlled areas in RI
- [KLE] – HVAC Systems serving uncontrolled areas in RI
- [KLF] – HVAC systems serving the waste processing areas in RI
- [KLL] – HVAC systems serving the fuel storage and handling areas in RI
- [KLR] – HVAC systems serving control rooms in RI.

11.1.1.2.2 Sources of Gaseous Radioactive Waste During Decommissioning

Gaseous radioactive effluents that may arise from decommissioning activities will be identified in future revisions of the DWMP [3].

11.1.1.3 Sources of Solid Radioactive Waste

11.1.1.3.1 Sources of Solid Radioactive Waste During Commissioning and Operations

The solid radioactive wastes expected to be generated by the RR SMR during operations have been identified and summarised in Table 11.1-1. This information is based on that provided in the RR SMR Solid Operational Waste Identification (SOWI) report [11], the RR SMR Disposability Case report [12] and the Low-Level Waste Arisings Technical Note [13]. In some instances, waste is described in the references as being a different waste category levels than those presented in Table 11.1-1. The waste categories presented in Table 11.1-1 represent the most likely category upon when the waste arises and not following any management to reduce its activity to a lower category.

Oils and solvents are included as a source of solid waste on the basis that any arisings are segregated from other wet solid wastes and transferred to the temporary storage area for LLW [KME10].

It is noted that passive autocatalytic recombiners are not included in Table 11.1-1 on the basis they only become a waste stream in accident scenarios. Similarly, sludges have been identified as a potential waste stream in other Rolls-Royce SMR Limited documents due to conservatisms, however they are not discussed further within this chapter. Methods are in place to prevent the unplanned build-up of solids within the liquid effluent systems and any solids that do form would be managed in such a way that they would not form their own, separate waste stream. Any unplanned build-up of solids in liquid effluent systems will be managed in the same manner as any other solids e.g. filter solids. The use of BAT to prevent and minimise wastes falls within the scope of E3S Case Version 2, Tier 1, Chapter 27: Demonstration of Best Available Techniques [14].

Table 11.1-1: Summary of operational solid radioactive wastes

Waste category upon arising	**Waste type/source**
SF	SF assemblies
	Failed/damaged fuel assemblies
Dry solid boundary high-level waste (HLW)/ILW	Non-fuel core components (NFCC): In-core monitoring assemblies/probes
Dry solid ILW	NFCC: Reactor Pressure Vessel (RPV) surveillance capsules[3]
	NFCC: Rod cluster control assemblies
	NFCC: Thimble plug assemblies
	NFCC: Neutron sources
	NFCC: Core outlet thermocouple instrument lances
	NFCC: Ultrasonic filters
	NFCC: Control rod housing columns
	Dry active waste (DAW)
	Sub-volume of RPV shielding material[4]
Wet solid ILW	Bead resins
	Suspended filter solids
	Reverse osmosis (RO)/Evaporator concentrates
Dry solid boundary ILW/LLW	Removable cartridge filters
	DAW
	RO membranes
Wet Solid Boundary ILW/LLW	Bead resins
LLW	Air filters
	Pool skimmers
	Contaminated maintenance waste
	Sub-volume of RPV shielding material[4]
	Oils and solvents
Very LLW (VLLW)	Sub-volume of RPV shielding material[4]

[3] Some arising as HLW cannot be excluded at this stage.
[4] The blocks are expected to require replacement at the midpoint of the operational lifetime due to harsh operating environment, so they will arise as an operational and decommissioning waste stream.

11.1.1.3.2 Decommissioning Wastes

The solid radioactive wastes expected to be generated by the RR SMR during decommissioning have been identified and summarised in Table 11.1-2.This information is based on that provided in the RR SMR Disposability Case report [12], the SOWI report [11], and the LLW Arisings Technical Note [13].

Table 11.1-2: Summary of decommissioning solid radioactive wastes

Waste category on arising	Waste type/source
Dry solid boundary HLW/ILW	Neutron reflector
	Reactor and primary circuit components
Dry solid ILW	Reactor and primary circuit components
	Sub-volume of RPV shielding material[4]
	Passive autocatalytic recombiners
Dry solid boundary ILW/LLW	Gaseous delay bed charcoal
	Waste systems contaminated dismantling waste
Dry solid LLW	Sub-volume of RPV shielding material[4]
	Gaseous delay bed charcoal
	Waste systems contaminated dismantling waste
Dry solid VLLW	Sub-volume of RPV shielding material[4]

Bulk concrete/metal will arise from general dismantling activities (which may contain some contamination, especially from e.g. waste system dismantling), however, the quantities and activities have not yet been estimated. These will be identified in future revisions of the DWMP [3] and incorporated into future revisions of this chapter.

11.1.2 Quantities of Waste

The normal operation source term covers all forms of radioactivity present within the RR SMR primary coolant circuit and supporting plant systems during normal operations. The scope of the Normal Operation Sensitivity Source Term Dataset technical note [15] is the primary source term (PST), which considers the initial formation of radionuclides in the primary coolant in the reactor core. The PST is the most important dataset in the normal operation source term suite and is used as the starting point for all other subsequent system-specific source terms.

Various aspects of the derivation of the PST, and the justification underpinning the PST, are underway. The system-specific source terms relevant to the waste management strategy such as the CVCS [KB], Spent Fuel Coolant Purification System [FAL] and the waste systems source terms are currently under development and expected to be issued as development of the upstream PST is progressed. The Normal Operation Sensitivity Source Term technical note [15] should be consulted for a general overview of the method used and the list of radionuclides anticipated during power operation and shutdown.

The mass and activity balance (MAB) tool has been developed to summarise the mass flowrate and radionuclide activities of key streams arising from the [KNF], [KPL] and [KM] systems [16]. The MAB accepts a series of inputs from upstream systems (system-specific source term data on activity of effluent received by the waste treatment system, as well as the volume of effluent to be processed from drains and CVCS [KB] letdown) then tracks the mass and activity of the effluent as it passes through the waste treatment system, as well as how activity accumulates on the various solid wastes generated as a function of the processing operation (such as ion exchange (IEX) resins or evaporator concentrates).

The output of the MAB enables estimation of solid waste activities received by the [KM] system for decay storage and the resulting activity concentration of packages. This applies to both the wet solid wastes generated from within the waste systems, as well as the solid wastes generated in other systems such as [KBE] and [FAL] (where the wet solid waste activities have been calculated separately in the aforementioned source term for these systems) [17]. The MAB currently models the liquid effluent streams and wet solid waste arisings.

Reference should be made to E3S Case Version 2, Tier 1, Chapter 29: Quantification of Radioactive Effluent Discharges and Proposed Limits [1], for details on the quantities of liquid and gaseous radioactive wastes, with a summary of solid wastes being provided in Table 11.1-3, taken from the latest version of the SOWI report [11].

Table 11.1-3: Summary of solid radioactive waste volumes

Waste stream		**Waste category (at arising)**	**Approximate Volume per cycle (m^3 unless otherwise stated)**	**Volume over life cycle (m^3 unless otherwise stated)**	**Additional notes**
SF		HLW	42 – 47 [see additional notes]	1696 – 1876 [see additional notes]	Note the figures presented are numbers of fuel assemblies (rather than volumes). This waste stream includes spent and failed/damaged fuel assemblies.
NFCCs	In-core monitoring assemblies/probes	Dry solid boundary HLW/ILW	0.35 assemblies 2 probes [see additional notes]	14 assemblies 80 probes [see additional notes]	Note the figures presented are numbers of items (rather than volumes). There will be an initial quantity of 56 probes with an expected rate of attrition of 2 probes per cycle.
	RPV surveillance capsules	Dry solid ILW	Data not yet available		Note the figures presented are

Waste stream		Waste category (at arising)	Approximate Volume per cycle (m³ unless otherwise stated)	Volume over life cycle (m³ unless otherwise stated)	Additional notes
	Rod cluster control assemblies		18 [see additional notes]	712 [see additional notes]	numbers of items (rather than volumes). The neutron sources are discrete items and will not be subdivided upon arising. The figure stated in the 'volume per cycle' column is illustrative only.
	Thimble plug assemblies		Data not yet available		
	Neutron sources		0.2 [see additional notes]	8 [see additional notes]	
	Core outlet thermocouple instrument lances		Data not yet available		
	Ultrasonic filters		Data not yet available		
	Control rod housing columns		1 [see additional notes]	45 [see additional notes]	
DAW (ILW)			0.38 - 1.5	15 - 60	Figures from Issue 1 of the SOWI have been presented[5] along with operational experience (OPEX) figures for which revised scaling factors have been calculated.
RPV shielding material (ILW)			Data not yet available		The RPV shielding material is likely to be highly heterogenous in terms of waste category. A proportion of the total volume is expected to comprise ILW upon arising, with the remainder a lower waste category or non-radioactive.
	[KBE]		1.03	41.2	

[5] These figures are presented due to no updated figures being available at the time of writing the latest iteration of the SOWI (applicable to this waste stream and others below within the table).

<table>
<tr><th colspan="2">Waste stream</th><th>Waste category (at arising)</th><th>Approximate Volume per cycle (m^3 unless otherwise stated)</th><th>Volume over life cycle (m^3 unless otherwise stated)</th><th>Additional notes</th></tr>
<tr><td>Bead resins (ILW)</td><td>[FAL]</td><td rowspan="3">Wet solid ILW</td><td>2.0</td><td>80</td><td>Volume data derived from system design descriptions (SDDs) and tank sizing notes.</td></tr>
<tr><td colspan="2">Suspended filter solids</td><td>2.4</td><td>96</td><td>Volume data derived from tank sizing notes.</td></tr>
<tr><td colspan="2">RO/evaporator concentrates</td><td>3.81</td><td>152.4</td><td>Volume data derived from wet waste activities quantification</td></tr>
<tr><td colspan="2">Removable cartridge filters</td><td rowspan="3">Dry solid boundary ILW/ LLW</td><td colspan="2">Data not yet available</td><td>Nature and type of filter types to be used not known at the time of writing.</td></tr>
<tr><td colspan="2">RO membranes</td><td>0.2</td><td>9.6</td><td>Figures from Issue 1 of the SOWI have been presented. No OPEX figures available.</td></tr>
<tr><td colspan="2">DAW</td><td>12 – 37.5</td><td>480 - 1500</td><td>Figures from Issue 1 of the SOWI have been presented along with OPEX figures for which revised scaling factors have been calculated.</td></tr>
<tr><td colspan="2">Bead resins</td><td>Wet solid boundary ILW/LLW</td><td>0.71</td><td>28.4</td><td>Volume data derived from SDDs and tank sizing notes.</td></tr>
<tr><td>Operational LLW</td><td>Air filters</td><td>Dry solid LLW</td><td>0.75 - 3</td><td>30 - 120</td><td>Figures from Issue 1 of the SOWI have been presented along with OPEX figures for which revised scaling factors have been calculated.</td></tr>
</table>

Waste stream		**Waste category (at arising)**	**Approximate Volume per cycle (m^3 unless otherwise stated)**	**Volume over life cycle (m^3 unless otherwise stated)**	**Additional notes**
	Pool skimmers		Data not yet available		Nature and types of skimmer to be used not known at the time of writing.
	Contaminated maintenance waste		4.5	180	Figures from Issue 1 of the SOWI have been presented along with OPEX figures for which revised scaling factors have been calculated.
	RPV shielding material (LLW)		Data not yet available		See earlier note on RPV shielding material.
	Oils and solvents	Wet solid LLW	1.5	60	Figures from Issue 1 of the SOWI have been presented along with OPEX figures for which revised scaling factors have been calculated.
Operational VLLW	RPV shielding material (VLLW)	Dry solid VLLW	Data not yet available		See earlier note on RPV shielding material.

11.1.3 Disposal of Waste

11.1.3.1 Disposal of Liquid Radioactive Wastes

As the [KNF] system treats active liquid effluent to enable recycling within the RR SMR, liquid radioactive effluent is only expected to be discharged to the environment in some cases (predominantly due to high tritium levels following activation and accumulation in the reactor coolant over time, or events such as fuel failure/leakage - see the discharge optioneering report [18], and tritium balance study [19] for more details).

The Liquid Effluent Monitoring and Discharge System [KNF30] is required for the collection, recycle or discharge of treated liquid radioactive effluents. [KNF30] contains monitoring tanks for radioactive effluent (containing treated process drains, chemical drains, active floor drains, and primary effluent). The monitoring tanks perform the following:

- Provision of excess storage capacity for recyclable effluents. The stored effluent can be recycled as make-up coolant or (tritiated) demineralised water in RI on demand e.g. as make-up water for the SF pool.
- Monitoring and sampling of effluents to determine if they are suitable for recycling or discharge to the environment.
- Discharge of active effluents from [KNF10] and [KNF20] to the environment that are unsuited to being recycled.

From [KNF30], a discharge line is routed to the outfall pond in the Cooling Water Island (CWI). The effluents mix with cooling water prior to release to the environment. Suitability for discharge is therefore subject to the water flow rate in the CWI outfall. Sampling and effluent characterisation is required for authorisation of discharge.

The outfall pond connects the blowdown, rainwater and waste streams pipework to the outfall tunnel and outfall head. It has intake interfaces with:

- Main Cooling Water System Blowdown [PA]
- Waste Water Drainage and Treatment System [GM]
- Liquid Radioactive Effluent Treatment System [KNF]
- Rainwater Structures and Systems [ZZT]
- Sewage System [ZZU]

A singular outfall interface exists with the outfall tunnel. A singular outfall tunnel is used to accept the rainfall, blowdown and waste streams from the outfall pond and transport them to the outfall head. It is assumed the tunnel will be constructed from concrete with a plastic lining.

A single outfall head is utilised to discharge effluent, predominantly seawater, to the environment. The outfall head is designed to promote the required level of dilution and mixing with ambient seawater through a series of angled ports in the outfall diffuser. The outfall head is capped with a blind flange to prevent any ingress of waste or marine life. This system will have to be detailed against site-specific conditions and depths to ensure suitable mixing with ambient water occurs.

11.1.4 Disposal of Gaseous Radioactive Wastes

Radioactive gaseous effluent is discharged to the environment via the RR SMR stack [KLS]. The stack takes the combined filtered discharges from the [KLA], [KLB], [KLC], [KLF] and [KLL] controlled area extracts and discharge the gaseous effluent at an appropriate height to achieve the required dispersion that meets BAT [20]. The physical and effective stack height is still to be determined.

11.1.5 Solid Waste Disposal/Transfer to Other Premises

Solid radioactive wastes will be managed in a way to optimise their disposal or transfer to other premises. Where it is BAT and ALARP to do so, wastes will be disposed based upon the lowest waste category achievable and diverted from disposal at the LLW Repository (LLWR) where possible. The IWS [4] provides further information on how techniques can be applied to different waste streams to provide a wider range of disposal options. Potential waste management techniques include, but are not limited to:

- Decay storage
- On-site size reduction in [KNF10]

- Segregation
- Consolidation
- Decontamination
- Off-site incineration
- Off-site super-compaction
- Off-site metal melt.

Where wastes require disposal or transfer off other premises, SF, HLW and ILW will be disposed to a geological disposal facility (GDF) and LLW will be transferred for LLW management via an optimised LLW route e.g. disposal at the LLWR or via incineration.

11.1.6 Radioactive Waste Management Strategy and Principles

Underpinned by international and UK policies, legislation and guidance, Rolls-Royce SMR Limited has developed an integrated waste management strategy demonstrating that appropriate arrangements are in place and good practice is considered for the management of waste produced across all lifecycle phases of the RR SMR. Reference should be made to the Rolls-Royce SMR Limited IWS [4] for further information, with the IWS covering topics including:

- E3S design principles
- The waste hierarchy
- Application of BAT, ALARP, Secure-by-Design, and Safeguards-by-Design through conduct design optioneering
- The precautionary and proximity principles
- Minimal liquid discharge
- Build certainty and approach to modularisation
- Strategic risks to waste management
- Strategic opportunities for waste management
- Strategic assumptions for waste management.

11.2 Systems and Arrangements for the Management of Liquid Radioactive Wastes

11.2.1 Systems and Equipment Functions

The primary function of the [KTA] system is to collect effluents from across the RI and transfer the effluents to the appropriate system for treatment. The system selectively collects the different categories of effluent to enable optimised treatment of each type of effluent.

The primary function of the [KNF] system is to collect and treat radioactive liquid effluents from [KTA] to be suitable for recycle or discharge.

Both the [KTA] and [KNF] systems support delivery of the fundamental safety function (FSF) of confinement of radioactive material (CoRM).

11.2.2 Design Bases

11.2.2.1 Safety Functional Requirements

The SMR RI functional requirements are captured in the DOORS database[6]. Each functional requirement is assigned a safety category in accordance with the SMR E3S categorisation and classification method [21].

11.2.2.1.1 [KTA] System

A full dose assessment in the event of an unmitigated radioactive release from [KTA] still needs to be carried out. This will calculate the likely on-site and off-site dose to personnel. In turn, this will determine the number and categorisation of safety measures required to protect against the initiating events. As such, it is expected that additional safety measures, beyond [KTA] integrity and control, may be required to provide additional layers of protection against [KTA] initiating events, e.g. HVAC systems or the RI civil structure. These will be at the preventative and protective layers of defence in depth [22].

11.2.2.1.2 [KNF] System

The following safety measures are applicable to [KNF]:

- Safety measure K01: Duty waste (the duty waste system shall contain and process waste effluents, Defence in Depth level 1). This prescribes an overall safety categorisation of Cat C of all mechanical components in the processing and treatment system for radioactive liquid effluent [KNF] (except the retentate system), and a functional classification of C for all control and instrumentation (C&I) used in process control.
- Safety measure K02 (HOLD): Retentate system integrity (retentate system shall contain retentate, Defence in Depth level 1). This prescribes an overall safety categorisation of Cat B of all mechanical components in the processing and treatment system for radioactive liquid effluent [KNF] retentate system, and a functional classification of C for all C&I used in process control. Currently on hold pending further review - it is expected that RO retentates will be managed in such a way as to reduce the safety categorisation, for example the inventory of

[6] DOORS is a software tool developed by IBM and regarded as the industry standard requirements management tool.

RO retentates stored in a tank has reduced by at least an order of magnitude since the draft analysis was completed.

- Safety measure K03: Waste areas HVAC (waste areas HVAC shall reduce operator dose, even when relevant abnormal operations occur, Defence in Depth level 2). This prescribes a safety categorisation of Cat C for HVAC in the Processing and Treatment System for Radioactive Liquid Effluent [KNF].
- Safety measure K04: Waste areas shielding (waste areas shielding shall reduce operator dose, even when abnormal operations occur, Defence in Depth level 2). This prescribes a safety categorisation of Cat C shielding around each piece of equipment in the Processing and Treatment System for Radioactive Liquid Effluent [KNF].
- Safety measure K05: Waste spill protection (when relevant faults occur, the waste spill protection shall reduce operator dose, Defence in Depth level 3). This prescribes a safety categorisation of Cat B dose alarm and bunding in local area.
- Safety measure K06: Waste building bund (when relevant faults and hazards occur, the waste building bund shall contain any spills, Defence in Depth level 3). This prescribes a safety categorisation of Cat B waste building bund.

It is important to note that these are the current safety measures but will be subject to further review (especially K02, which demands a Cat B safety function categorisation) as they are based on a draft dose consequence analysis with several inputs that require updating. For K02, it is expected that RO retentates will be managed in such a way as to reduce the safety categorisation, for example the inventory of RO retentates stored in a tank has reduced by at least an order of magnitude since the draft analysis was completed. Time for exposure assumed in the analysis also requires review.

The full requirement set for the Liquid Radioactive Effluent Treatment System [KNF] can be seen in the relevant requirements specification in DOORS [23]. Functional requirements specifically for the safety measures are in development, as are the safety categorisations for all functional requirements.

11.2.2.2 Non-functional System Requirements

Full details of the non-functional requirements applied to these systems are captured in the requirements specification in DOORS for the RI collection and drainage system [KTA] [24] and for the Liquid Radioactive Effluent Treatment System [KNF] [23].

11.2.2.3 Safety Classifications

A full list of safety classifications can be seen in the relevant requirements modules for major components, as well as the functional bill of materials (FBoM) for both the [KTA] and [KNF] systems [25] [26].

Within the [KTA] system the majority of SSCs that have been assigned a safety classification within the FBoM are a level 3 classification with the exception of the following:

- Containment isolation valve for RCDT [KTA10] discharge to KNF – inside containment. Safety classification 1
- Containment isolation valve for RCDT [KTA10] discharge to KNF – outside containment. Safety classification 1
- Non-return valve on RPV outer seal leakage line. Safety classification 2
- Isolation valve on RPV outer seal leakage line. Safety classification 2.

Those SSCs within [KNF] that have been assigned a safety classification within the FBoM are all a level 3 classification.

11.2.2.4 Environmental Classifications

Environmental classification of SSCs is currently being undertaken in accordance with the method set out in Identification of Environmental Functions and Environmental Measures [2]. Those SSCs currently identified as being environmentally significant are summarised in Appendix B (section 11.8).

11.2.3 Description

11.2.3.1 RI Collection and Drainage System [KTA] Description

The primary function of the system is to collect effluents from across the RI and transfer the effluents to the appropriate system for treatment. The system selectively collects the different categories of effluent to enable optimised treatment of each type of effluent.

Key performance and design parameters for the system are presented in Table 11.2-1.

Table 11.2-1: Key performance and design parameters for the RI Collection and Drainage System [KTA]

Parameter	Value	Notes
System flow rate	18 m^3/h	Max. combined flow rate of each KTA sub-system to [KNF] or [GMA] treatment systems.
Design temperature	100 °C	For all vent and drain tanks.
	150 °C	For pipework interfacing with the primary coolant.
Design pressure	1.1 MPa	-
Operating temperature	20 to 60 °C	For all vent and drain tanks.
	135 °C	For pipework interfacing with the primary coolant.
Operating pressure	0.1-0.12 MPa	-

The RI Collection and Drainage System [KTA] is a sub-system of the Collection and Drainage System for Liquid Media in Controlled and Exclusion Areas [KT].

To fulfil its basic safety functions, the system must carry out the following functions:

- The collection of all liquid effluents from across RI and to transfer them to the appropriate system for processing. This limits retention of activity in RI, reduces the chance of flooding and avoids active discharge to the environment.
- Monitoring of leak-tightness of the primary coolant RPV and pressure boundary valve packaging via detection of leak flows.

To optimally achieve these functions, the system architecture is split into four sub-systems to enable segregation of waste on radiological and chemical properties. This enables optimum treatment of each type of effluent. The sub-systems are:

- [KTA10]: Collection and Transfer of Reactor Coolant Drains
- [KTA20]: Collection and Transfer of Process and Floor Drains
- [KTA30]: Collection and Transfer of Chemical Drains
- [KTA40]: Collection and Transfer of Non-active Drains.

A simplified schematic of the [KTA] system architecture can be seen in Figure 11.2-1.

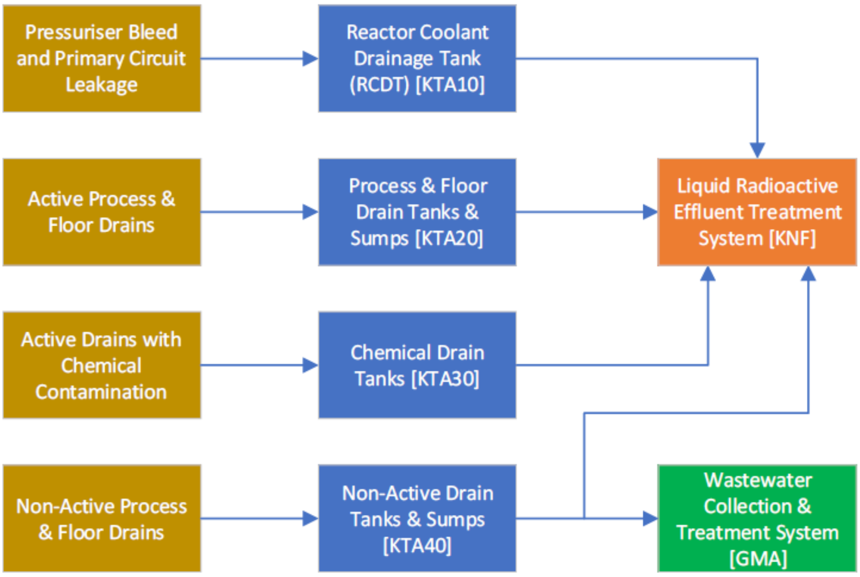

Figure 11.2-1: Simplified schematic of the RI Collection and Drainage System [KTA]

11.2.3.2 Liquid Radioactive Effluent Treatment System [KNF] Description

The [KNF] system collects liquid radioactive effluents in tanks and treats them with a combination of separation methods for removal of radionuclides and chemical contaminants. The treatment enables storage and recycle in the nuclear power plant (NPP), or suitability for discharge to the environment. The system manages both primary and spent liquid effluent and treats them based on their characterisation (expected levels of radiological and chemical contamination).

Key performance and design parameters for the system are presented in Table 11.2-2.

Table 11.2-2: Key performance and design parameters for the Liquid Radioactive Effluent Treatment System [KNF]

Parameter	Value	Notes
System flow rate	1-36 m^3/h	Varies for each effluent treatment operation.

Parameter	Value	Notes
Design temperature	100 °C	Mostly low temperature processes and ambient conditions. However, some heating is employed during treatment.
Design pressure	1.1 MPa(a) 4.1 MPa(a) for RO systems	Mostly low pressure processes and ambient conditions. KNF30 monitoring tanks expected to be atmospheric design.
Operating temperature	20 – 50 °C Evaporator reboiler loop operates at 60 °C Hot water loop operates at 90 °C	Indicative for evaporator.
Operating pressure	0.1 to 0.12 MPa(a) 2.6 MPa(a) for RO system 0.013 MPa(a) for vacuum degassing 0.004-0.010 MPa(a) for vacuum evaporator	Indicative for evaporator.

The Liquid Radioactive Effluent Treatment System [KNF] is a sub-system of the Liquid Radioactive Waste Processing System [KN].

The [KNF] system consists of:

- Processing and Treatment System for Primary Liquid Effluent (KNF10), containing:
    - Storage tanks for primary liquid effluent, with transfer pumps and connection to sampling systems and [KNF20] treatment systems.
    - A vacuum degasser for removal of dissolved gases from effluent and make-up water.
- Processing and Treatment System for Spent Liquid Effluent [KNF20], containing:
    - Storage tanks for combined process and floor drains, with transfer pump and connection to sampling systems.
    - Storage tanks for chemical drains, with transfer pump and connection to sampling systems.
    - Abatement process:
        - Backwashable pre-filters to protect downstream components.
        - RO process using membrane separation to separate a purified permeate from a concentrated retentate.

        - IEX polishing in resin beds to demineralise permeate from upstream RO process.
        - Vacuum waste evaporator for volume reduction of retentate from upstream RO process.

- Liquid Effluent Monitoring and Discharge System [KNF30], containing:
    - Active monitoring tanks for treated liquid effluent, with transfer pump and connection to sampling systems.
    - Discharge line to the CWI outfall, with sampling.
    - Recycle line to distribute as primary make up water or to other selected demineralised water users in RI.

11.2.4 Materials

Materials are selected to minimise risks associated with operator and maintenance dose, corrosion, and decommissioning. Stainless steel has been selected for the design of components in contact with radioactive liquid effluent. The vacuum evaporator within [KNF] will require specific material selection due to elevated corrosion risk.

The FBoM module for both [KTA] and [KNF], in DOORS and extracted into References [25] and [26] contains the list of SSCs within the systems and their corresponding material specification.

The description and justification of materials used for classified SSCs are presented in E3S Case, Version 2, Tier 1, Chapter 23: Structural Integrity [27].

11.2.5 Interfaces with Other Equipment or Systems

Connections to sampling systems [KUB] are required for effluent characterisation upon collection in both the [KTA] and [KNF] systems. Connections to the Gaseous Radioactive Effluent Treatment System [KPL] are also present in both the [KTA] and [KNF] systems.

The [KTA] system drains to the [KNF] system, or to the Wastewater Collection and Drainage System [GMA] for inactive liquid effluents from the RI.

The [KNF] system removes dissolved gases to be managed as gaseous effluent (in [KPL] system) or discharged via HVAC. The [KNF] system generates solid waste to be processed for disposal (in the KM- system).

Details on interfaces for the RI collection and drainage system [KTA] and the Liquid Radioactive Effluent Treatment System [KNF] are contained within the relevant SDD [22] [9].

11.2.6 Systems and Equipment Operation

The power station operating philosophy [28] 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, Version 2, Tier 1, Chapter 13: Conduct of Operations [29].

11.2.6.1 The RI Collection and Drainage System [KTA]

A full analysis of the system operation in all modes of operation will be conducted in future design phases to develop the RI Collection and Drainage System [KTA] operating philosophy. The operating philosophy defines the key claims and operational sequences and actions the system is required to undertake, and the key claims made on the operator or automated actions. The operating philosophy also supports ongoing human factors and safety assessments.

The RI Collection and Drainage System [KTA] is designed to function during all modes of operation. Therefore, modes of operation are all discussed under Mode 1 for collection and transfer. This is except for [KTA10] which will not be required during Mode 6 Refuelling and will therefore be available for maintenance.

Most [KTA] system operations are batch-based. The [KTA] system is aligned through either manual or automated selection of system configurations (grouped commands for aligning the system isolation valves and actuators, starting/stopping of pumps etc.).

Key operations during power operation of the RR SMR include:

- Collection of effluent: [KTA10] is expected to receive primary coolant during Modes 1 to 5, only not being required during Mode 6 refuelling. Valves are aligned to receive coolant from the pressuriser, valve packing leakage and RPV seal leakage. If inner seal leakage is detected, this line is isolated to form part of the reactor coolant pressure boundary, and the line to the outer seal opened. A decision as to whether to bring the reactor down to a safe shutdown state should then be made.

  [KTA20, 30, 40] are expected to receive effluent during all reactor modes.

  As a result of the layers of protection assessment, tanks that are swept by the [KPL] system will only be able to receive effluent if the [KPL] vent is open to prevent over pressurisation. This impacts [KTA10] and some [KTA20] tanks.

- Cooling of RCDT [KTA10]: When the bulk temperature in the RCDT [KTA10] reaches above 50 °C, the RCDT [KTA10] discharge valves are aligned to allow for the recirculation of the primary effluent and the RCDT [KTA10] duty pump started. This recirculates effluent through the RCDT [KTA10] cooler back into the tank until the bulk temperature is reduced to 45 °C. At this point, the pump is stopped, and the valves aligned to their standby configuration. This is a fully automated function.

- Recirculation of [KTA20, 30, 40]: The contents of these tanks can be discharged and recirculated back to the tank via an operator-initiated function. The valves align to recirculate the effluent and the duty discharge pump started. Once initiated, recirculation occurs for a fixed time to be determined during detailed design. This allows the effluent to homogenise. While in recirculation mode, the operator will be able to take a grab sample via an interface with the auxiliary sampling system [KUB]. All valves on the sampling line are to be manually operated. Once the time has expired, the pump is stopped, and the valves aligned to their standby configuration.

- Transfer of effluent to [KNF] or [GMA]: The transfer function for all [KTA] sub-systems is to be both automated and initiated on operator command. Automatic transfer occurs once the tanks reach high liquid level and provided there is sufficient storage capacity in the downstream treatment system. Operator initiated transfer prior to high level is expected as part of effective inventory management. Transfer will stop on the tank reaching low level.

Regarding the choice of discharge routing on [KTA40], automated transfer on high level would be to [KNF] only. Operator initiated transfer could be to [KNF] or [GMA]. Thus, it would usually be expected for operators to take a sample, confirm non-activity of effluent and discharge it to [GMA] prior to high level being reached.

11.2.6.2 Liquid Radioactive Effluent Treatment System [KNF]

Most of the [KNF] system operations are manually initiated from the main control room (MCR) and there is a dependency on routine sampling to determine the appropriate operations for effluents on demand. There is therefore the potential for human error when transferring batches of effluent. Consequences would be off-specification make-up water provided to systems, including the primary circuit. The detailed impacts on water chemistry resulting from this will be understood when the RI effluent recycling strategy is further developed.

Key operations during power operation of the RR SMR include:

- Coolant letdown: The [KNF10] effluent tanks receive effluent from CVCS [KB] letdown on demand. This is mostly expected for the reactor start-up transients resulting in thermal expansion, bleed and feed operations requiring effluent treatment, or simultaneous letdown during make-up operations to avoid thermal shock.
- If a high level of tritium has accumulated in the primary circuit (e.g. following design basis fuel failure or from activation throughout multiple fuel cycles) then bleeding the reactor coolant to the [KNF10] for treatment and discharge via [KNF30] is possible.
- If a high level of xenon and krypton activity is detected in the primary circuit sampling (e.g. following design basis fuel failure) then transfer to the vacuum degasser can be performed on demand.
- Primary circuit make-up: Supply of deaerated make-up water to the CVCS is expected every three to four days in small volume batches (~5 m^3, to be defined by the operating principles of the reactor coolant and pressuriser systems in later phases of design). As described previously, this requires simultaneous let-down from the CVCS to [KNF].
- Additional make-up is required for thermal contraction of the primary circuit during shutdown transients. Again, this requires simultaneous let-down.
- Spent liquid collection: Effluents from collected process, chemical and floor drains are transferred to the [KNF20] effluent tanks on demand when the upstream sumps/vessels in the [KTA] system are filled. Most of the drainage volumes are expected to be from maintenance operations requiring bleeding of equipment.
- Sampling: All the [KNF] effluent tanks have provisions for sampling and require effluent characterisation before processing / transfer.
- Effluent discharge: Authorisation from the control room is required for effluent discharge to the environment. This includes confirmation of the discharge flow rate set-point to be throttled by the discharge control valve.

Process flowcharts for normal system operation are presented in the SDD for Liquid Radioactive Effluent Treatment System [KNF] [9].

11.2.7 Instrumentation and Control

This subsection provides a high-level overview of the basic functions that are allocated to the reactor C&I systems [JY] by the Liquid Radioactive Effluent Treatment System [KNF]. Noting that dedicated control cubicles are expected for the following equipment:

- The abatement process is expected to be package equipment with flow control and trips managed by dedicated control.
- Degasser column trips regarding level, flow, temperature and pressure for mitigating conventional safety hazards. The degasser may be package equipment with flow control and trips managed by dedicated control, yet to be confirmed.
- The evaporator is expected to be package equipment with flow control and trips managed by dedicated control.

11.2.7.1 Alarms and Warnings

The difference between an alarm and a warning has been defined in the RR SMR Human-Machine Interface (HMI) Style Guide [30]. A warning is a signal indicating the imminent onset of a dangerous situation requiring appropriate measures for the elimination or control of the danger. An alarm is a signal indicating the beginning or the actual occurrence of a dangerous situation requiring immediate action.

To support the safe operation and control of the RI Collection and Drainage System [KTA] and the Liquid Radioactive Effluent Treatment System [KNF], the C&I system is required to provide alarms and warnings to indicate that key system parameters are outside of the defined performance bands and/or safety limits.

A list of alarms related to instrumentation present on the RI Collection and Drainage System [KTA] can be seen in the [KTA] SDD [22]. The alarm strategy will be updated as a further work item before the system reaches DR3 maturity.

As indicated previously, certain pieces of [KNF] equipment are to be supplied as commercial off-the-shelf (COTS) packages. It is assumed that alarms and warnings related to these packages will be developed by the supplier. For these packages, the operator will remotely monitor the package status from the control room.

A list of alarms/warnings related to instrumentation present on the Liquid Radioactive Effluent Treatment System [KNF] at 100 % full power can be found in the [KNF] SDD [9], with more detail provided in DOORS.

11.2.8 Examination, Maintenance, Inspection and Testing (EMIT)

11.2.8.1 RI Collection and Drainage System [KTA] EMIT

At DR3, the RI Collection and Drainage System [KTA] will have a through life activities (TLA) module in DOORS populated with all known maintenance tasks (in line with design maturity), specific to the system environment and the operating context. This module covers maintenance frequency, manual handling and other similar requirements.

The maintenance activities considered in the TLA include:

- Safety derived tasks
- Design derived tasks (supplier provided)
- Reliability derived tasks (reliability centred maintenance (RCM)/preventative maintenance)
- RGP/OPEX (Electric Power Research Institute (EPRI) preventive measures database (PMDB))
- Non-product breakdown structure (PBS) (module, site facility).

11.2.8.2 Liquid Radioactive Effluent Treatment System [KNF] EMIT

At DR3, the Liquid Radioactive Effluent Treatment System [KNF] has a TLA module in DOORS populated with all known maintenance tasks (in line with design maturity), specific to the system environment and the operating context.

The maintenance activities considered in the TLA include those listed above for the RI Collection and Drainage System [KTA].

Equipment handling primary liquid effluent (e.g. [KNF10] tanks, vacuum degasser) requires a nitrogen purge to [KPL] prior to drainage followed by purging with compressed air to allow manual access for maintenance and inspection. This is due to hazards associated with hydrogen and airborne activity arising in vessel headers. Oxygen depletion monitoring and procedural controls are used to ensure the vessels are sufficiently purged with air prior to access. Valve interlocks and procedural controls have been considered to prevent erroneous transfer of air into the [KPL] cover gas stream.

The RO membranes are subject to biofouling and therefore periodic rinsing with demineralised water is proposed in the design. The frequency and procedure for cleaning and removal are subject to supplier information.

A dilute chemical wash is proposed for cleaning the waste evaporator, which is subject to corrosion and scaling when operating. Maintenance of the evaporator is key to avoid the difficulties in removal and replacement of the column during 60-year life.

The [KNF] processing duty is expected to be highest during outage periods as various systems in RI perform drainage or letdown, therefore maintenance of the [KNF] system itself is not expected to occur during refuelling outages.

Pipe blockages are possible due to high particle loading, specifically during resin transfer, requiring flushing with demineralised water.

A safe isolation assessment has been carried out on the system, consistent with HSG253 [31]. This is not directly related to EMIT but rather conventional maintenance. Pieces of equipment within [KNF] will be maintained for reliability (such as valves), for safety (such as tanks and vessels) and for design (such as the RO membranes and backwashable filters). Information on the reason for the specific maintenance activity can be found within the TLA module within DOORS.

11.2.9 Radiological Aspects

11.2.9.1 RI Collection and Drainage System [KTA] Radiological Aspects

The [KTA] system contains radiologically active effluent and so requires the subsequent dose from gamma rays to be managed to ALARP levels. A bulk system shielding assessment has been carried out for the waste systems [32] to determine the required thickness of steel or concrete shielding required for each component to reduce dose rates below the upper bound for:

- an undesignated area (2.5 $\mu Sv.h^{-1}$)
- a supervised area (7.5 $\mu Sv.h^{-1}$)
- the first dose rate band of the controlled area (25 $\mu Sv.h^{-1}$).

The majority of [KTA10, 20, 30] tanks are likely to be located in RCAs, requiring shielding to reduce dose below 25 $\mu Sv.h^{-1}$.

The same assessment [32] indicates that [KTA] pipework is unlikely to require shielding in RCAs.

The shielding assessment [32] will be revisited and updated in future, with updated source term inputs and underpinning assumptions.

Occupational dose risk will be managed and sought to be reduced as the design of the system matures and a better understanding of plant layout and occupancy is understood.

Further to shielding, dose rates from the [KTA] system are controlled through minimal operator requirements in normal operation, e.g. effluent transfer is generally automatic and remote, reducing occupancy to walkdowns and maintenance. The [KTA] tanks are to be drained from the bottom of the tank to reduce any accumulated solids, and so minimising the surface source terms over the life of the plant.

11.2.9.2 Liquid Radioactive Effluent Treatment System [KNF] Radiological Aspects

An updated shielding assessment for the active waste systems has been carried out [32]. Dose rate calculations have been performed to determine the required thickness of steel or concrete shielding for each of the vessels and tanks within the [KNF] system to reduce dose rates below the upper bounds for an undesignated area, supervised area, and the first dose rate band of the controlled area respectively.

The shielding assessment will be revisited and updated in the future, with revised source term inputs and underpinning assumptions. In addition, it is important to note that the required shielding thicknesses for these components are dependent on the expected occupancy during normal operations. While the use of dose rates is helpful for determining required shield thicknesses, the occupancy of areas containing active waste components must be accounted for to ensure efficient shielding design.

Occupational dose risk will be managed and sought to be reduced as the design of the system matures and a better understanding of plant layout and occupancy is developed.

11.2.10 Performance and Safety Evaluation

11.2.10.1 The RI Collection and Drainage System [KTA]

The [KTA] SDD [22] provides a summary of the design and performance assessments that underpin the design of [KTA] and demonstrates how the definition meets the non-functional performance requirements associated with the key system functions.

Prior to DR3, assessments have been conducted to support initial concept development and will be updated and developed as the design programme progresses.

11.2.10.2 Liquid Radioactive Effluent Treatment System [KNF]

The [KNF] SDD [9] provides a summary of the design and performance assessments that underpin the design of [KNF] and demonstrates how the definition meets the non-functional performance requirements associated with the key system functions.

11.2.11 Installation and Commissioning

11.2.11.1 Installation

11.2.11.1.1 [KTA] System Installation

An outline [KTA] system installation plan will be developed as part of concept development to DR3. One of the key features of this plan will be the modularisation of the major components to maximise factory manufacturing and assembly and to minimise the amount of site activity where possible.

Installation plans will be developed in line with the SMR Installation and Commissioning (ICOM) policy [33].

It is expected that individual [KTA] drainage tanks and associated fittings, pumps etc. will come as individual, pre-built [KTA] drainage modules. Therefore, there will be numerous [KTA] modules spread across RI. Upstream and downstream pipe networks will require some on-site installation activity.

11.2.11.1.2 [KNF] System Installation

Installation requirements for the Liquid Radioactive Effluent Treatment System [KNF] will be included in the allocated requirements module in DOORS as the design develops.

As for [KTA], an outline [KNF] system installation plan will be developed as part of detailed design.

Modular solutions including the RO system, the waste evaporator and its auxiliary equipment, and the vacuum pump package are considered to reduce installation time, with most pipework and cabling already installed. Specific control modules and panels for these equipment packages, such as flow or pressure regulation are also to be integrated. Considerations are to be made for taking equipment in and out of service with ease, for maintenance or decontamination purposes.

11.2.11.2 Commissioning

11.2.11.2.1 [KTA] System Commissioning

A comprehensive commissioning plan will be developed during detailed design. Commissioning plans will be developed in line with the SMR ICOM policy [33]. At RD7/DRP1, some preliminary information is provided, with plans to be agreed by DR3.

The outline plan for commissioning is expected to include both factory acceptance testing (FAT) activities carried out at the mechanical, electrical and plumbing (MEP) factory, as part of the modular assembly stage, and site acceptance testing (SAT) at the SMR installation site. A key aim is to exploit the verification and validation (V&V) able to be delivered by FAT to reduce the time required for commissioning and testing on-site.

The commissioning activities will be informed by specific claims to support the V&V strategy, as well as relevant OPEX and RGP, and be categorised into the following activity types:

- Inspection
- Physical checks
- Functional testing
- Performance testing

Post-MEP checks are required after functional testing in the MEP factory, in which the modules have been filled with air, to purge any fluid or particulate from the system, fully dry, ensure suitable cleanliness and prepare for dispatch of the modules to site. This typically requires additional local hardware, the ability to vent the modules and the means to conduct cleanliness checks, which are all considered to be readily available within the MEP factory.

More detail on proposed commissioning activities is provided in the RI Collection and Drainage System [KTA] SDD [22].

11.2.11.2.2[KNF] System Commissioning

As for [KTA], a comprehensive commissioning plan will be developed during the detailed design phase. Examples of some activities that may be required at commissioning include charging [KNF10] tanks with nitrogen cover gas, disabling low level alarms in [KNF] tanks (or filling with demineralised water to the low liquid level) and the setting of manual control valves.

The outline plan for commissioning includes both FAT activities carried out at the MEP factory as part of the modular assembly stage, and SAT at the SMR installation site.

An important part of the preliminary plan for the commissioning of the Liquid Radioactive Effluent Treatment System [KNF] has been to apportion the necessary activities within these two areas, to exploit the V&V able to be delivered by FAT thereby reducing the time required for commissioning testing on site. Sentencing the activities against the testing areas (FAT or SAT) was done based on the typical constraints that might preclude FAT activities being done in the MEP Factory.

The [KNF] system contains both packaged treatment equipment, which will be installed within modules, as well as equipment that will be built in the MEP factory. The expectation is that packaged equipment will, where possible, undergo FAT testing at vendor factories to minimise specialist equipment requirement of the MEP factory.

Outline commissioning activities have been informed by relevant OPEX and RGP, as well as specific claims to support the V&V strategy and are categorised into the following activity types as outlined for the [KTA] system.

Post-MEP checks are required after functional testing in the MEP factory, in which the modules have been flooded with demineralised water, to purge any fluid from the system, fully dry, ensure suitable cleanliness and prepare for dispatch of the modules to site. This typically requires additional local hardware, the ability to drain and dry the modules and the means to conduct cleanliness checks, which are all considered to be readily available within the MEP factory.

More detail on proposed commissioning activities is provided in the Liquid Radioactive Effluent Treatment System [KNF] SDD [9].

11.2.12 BAT and ALARP in Design Development

The design of the RI collection and drainage system [KTA] and the Liquid Radioactive Effluent Treatment System [KNF] is being developed in accordance with the systems engineering design process, which includes design to codes and standards according to the safety classification, a systematic optioneering process with down-selection of design options based on assessment against relevant safety and environmental criteria (as described in E3S Case Version 2, Tier 1, Chapter 3: E3S Objectives and Design Rules for Structures, Systems and Components [34] and the Approach for Optimisation through the Application of BAT report [35]), and alignment to RGP and OPEX.

Key decisions have their own decision file that records decision rationale, as well as their own entry in the SMR decision register which is stored in the DOORS database.

Table 11.2-3 and Table 11.2-4 present a summary of the key decisions made that relate to the RI Collection and Drainage System [KTA] and the Liquid Radioactive Effluent Treatment System [KNF] respectively.

Table 11.2-3: Summary of key decisions made for the RI Collection and Drainage System [KTA]

Decision description	Solution	Decision file reference
Collection of process and floor drains	Collection into tanks as opposed to embedded sumps.	RI-161 [36]

Decision description	Solution	Decision file reference
Segregation of waste collection	Combining collection of process and floor drains into the same tanks.	RI-161 [36]
Transfer of non-active drains	Direct transfer of non-active drains from [KTA] to [GMA].	RI-161 [36]

Table 11.2-4: Summary of key decisions made for the Liquid Radioactive Effluent Treatment System [KNF]

Decision description	Solution	Decision File Reference
Collection and drainage of radioactive effluents	Merge process and active floor drains.	RI-161 [36]
[KNF] degasser and evaporator heating method	Hot water loop used for heat exchangers in effluent treatment system.	R01-458 [37]
[KNF] primary and spent effluent processing and treatment train merging	Removing the [KNF10] filter and demineraliser and using the RO system for both spent and primary effluent.	D112 [38]
Backwashable filters	Backwashable filters as baseline for CVCS, spent fuel pool purification and effluent treatment.	R01-459, R01-460, R01-462 [39]
Recovery and management of boron following emergency boron injection	Decontamination and discharge of primary coolant	R01-494 [40]
Management of active steam generator blowdown (SGBD)	Active SGBD is collected directly from the steam generator, transferred to [KNF30] tanks and discharged to the environment following appropriate sampling.	R01-477 [41]

11.2.13 Ongoing Design Development

The RR SMR design definition is currently in development as described in section 11.0.1. Further work items for the RI Collection and Drainage System [KTA] and the Liquid Radioactive Effluent Treatment System [KNF] are discussed in the assumptions module for the relevant system within DOORS.

Areas of further work are identified through multi-discipline engineering design activities, e.g. hazard and operability (HAZOP) studies, layers of protection analysis (LOPA), and DRs and will be informed by E3S functional requirements, and non-functional system requirements placed onto the design as the safety analysis is developed.

11.3 Systems and Arrangements for the Management of Gaseous Radioactive Wastes

The following systems are associated with the management of gaseous radioactive wastes:

- The Gaseous Radioactive Effluent Treatment System [KPL]
- HVAC systems serving controlled areas of RI [KL]:
    - HVAC systems serving primary containment [KLA]
    - HVAC systems serving the interspace [KLB]
    - HVAC systems serving controlled areas [KLC]
    - HVAC systems serving radioactive waste processing areas [KLF]
    - HVAC systems serving fuel storage and handling areas [KLL].

11.3.1 Systems and Equipment Functions

The primary function of the [KPL] system is to process gaseous effluent from the primary circuit containing hydrogen and volatile fission products. [KPL] supports the FSF of CoRM.

The primary function of the [KL] system is to provide ventilation to all areas of RI. In addition to providing the supply of clean air to the RI, [KL] also provides the following functions associated with the management of gaseous radioactive wastes:

- Dynamic confinement of equipment and spaces to ensure a hierarchy of pressure from spaces with a low potential hazard of radioactive contamination to areas with a high potential hazard of radioactive contamination. This is to control contamination as closely as possible to its source and to prevent uncontrolled releases to the environment.
- Isolation to limit the spread of contamination to surrounding areas or the environment.
- Purification by filtering the extract air to remove airborne contamination to prevent it being released to the external environment.
- Cleaning of the air within individual spaces by providing sufficient air change rates to minimise build-up of hazardous gases or airborne contamination.

11.3.2 Design Bases

11.3.2.1 Safety Functional Requirements

11.3.2.1.1 [KPL] System

The Gaseous Radioactive Effluent Treatment System [KPL] supports the FSF of CoRM. Based on the radiation consequences of faults related to this, and the category A confinement function that the civil structure offers, the following safety measures were derived for [KPL]:

- K01, waste systems integrity and control (Category C): prescribes an overall safety categorisation of Cat C for integrity of all mechanical components in the gaseous radioactive effluent treatment system [KPL], and a functional classification of Category C for all C&I for pressure control.

- K03, waste areas HVAC: prescribes a safety categorisation of Category C for HVAC in the waste-area.
- K04, waste area shielding (Category C): prescribes Category C shielding around each [KPL] delay bed.
- K05, waste spill protection (Category B): prescribes a categorisation of Category B to all dose alarms in the waste-area.

It is important to note that these are the current safety measures but will be subject to further review as they are based on a draft dose consequence analysis with several inputs that require updating.

The full requirement set for the Gaseous Radioactive Effluent Treatment System [KPL] can be seen in the requirements specification for the Gaseous Radioactive Effluent Treatment System [KPL] in DOORS [42].

The Category C functions impart a class 3 classification for integrity of all components and operability of all sensors related to pressure measurement in the [KPL] system.

11.3.2.1.2 Extract from Controlled Areas – [KL] System

The role of the [KL] system extract from controlled areas is to support the physical containment and provide a pressure cascade from less contaminated to more contaminated spaces. Extraction from controlled areas makes a contribution to the FSF, however, it is not the principal means nor regarded as making a significant contribution to the FSF as these are provided by the containment and isolation. Extract from controlled areas is assigned safety Category C.

11.3.2.2 Non-functional System Requirements

11.3.2.2.1 [KPL] System

The transverse requirements derived from the E3S design principles that are applied to this system are being developed.

Full details of the transverse requirements applied to the [KPL] system can be found in the requirements specification for the Gaseous Radioactive Effluent Treatment System [KPL] in DOORS [42].

11.3.2.2.2 [KL] System

The transverse requirements derived from the E3S design principle that are applied to this system can be found in the requirements specification for the [KL] system in DOORS [43].

11.3.2.3 Safety Classification

11.3.2.3.1 [KPL] Systems

A full list of safety classifications can be seen in the relevant requirements modules for major components, as well as the FBoM for the system [44]. Those SSCs within [KPL] that have been assigned a safety classification within the FBoM are all a level 3 classification.

11.3.2.3.2 [KL] System

A full list of safety classifications will be developed in the relevant requirements modules for major components, as well as the FBoM for the systems when the [KL] systems reach sufficient maturity. The latest issue of the FBoMs [45] [46] [47] [48] [49] excludes ductwork and full definition of the components within the distribution network, as the extent and layout of this is not yet defined. It includes the identification of major components within the main supply and extract plant only. Further definition of these components and components within the distribution networks will be included for DR3, currently anticipated to be late 2024.

11.3.2.4 Environmental Classifications

Environmental classification of SSCs is currently being undertaken in accordance with the method set out in Identification of Environmental Functions and Environmental Measures [2]. Those SSCs currently identified as being environmentally significant are summarised in Appendix B (section 11.8).

11.3.3 Description

11.3.3.1 [KPL] System Description

The baseline architecture of [KPL] consists of compressors delivering nitrogen cover gas to various systems in the RI, a recombiner for abatement of hydrogen and delay beds for abatement of fission products prior to discharge to the stack.

Key performance and design parameters for the system are presented in Table 11.3-1. Normalised conditions for gases in the [KPL] system are defined as 1 atm (0.98 bar) and 0 °C.

Table 11.3-1: Key system design and performance parameters for [KPL]

Parameter	**Approx Value**	**Notes**
No. of gas compressors	2	Duty/stand-by operation to allow maintenance and inspection of compressors while [KPL] continues operation.
Gas compressor flow rate	37 normal cubic metres per hour (Nm^3/h)	Subject to supplier feedback for achievable flow rates, as well as internal hazard management strategy. Sizing margin is proposed to maintain H_2 and O_2 concentrations below the operational limits of 4% and 2% by volume respectively without impacting compressor design in later phases.
Gas compressor power	9kW	-
Discharge flow rate	18 Nm^3/h	No requirements currently specified for the flow rate through the delay beds other than the maximum flowrate expected through [KNF10] tank filling.
Delay bed volumes	2 x 3 m^3 delay beds 0.3 m^3 guard bed	-

Parameter	Approx Value	Notes
Operating temperature	~50 °C for off-gas collection 110 to 360 °C for recombiner 20 °C for delay beds	Off-gas from the [KNF] degasser is specified to be cooled to < 55 °C prior to exhaust. Other off-gases are expected to be cooled to < 50 °C, or at ambient temperature conditions. Recombiner lower operating temperature specified as a system requirement to prevent condensation. Upper temperature derived from OPEX. Delay bed temperature based on supplier feedback.
Operating pressure	0.105 to 0.12 MPa(a) for cover gas 0.5 MPa(a) for delay beds 0.8 MPa(a) for gas compressors	Cover gas pressure range proposed to minimise air ingress. Derived from OPEX. Based on OPEX used as an input for the sizing calculations. This is subject to delay bed supplier feedback (as pressure impacts performance). Compressor design pressure within range of values from OPEX.

The [KPL] system uses nitrogen cover gas to purge interfacing systems handling reactor coolant, primary circuit effluent or make-up water. Hydrogen and volatile fission products (xenon and krypton) in vessel/tank headers are purged by the cover gas and collected as gaseous effluent. The key sources of these gases during power operation are the vacuum degasser in the Liquid Radioactive Effluent Treatment System [KNF] and RCDT [KTA10]. Air ingress is minimised to prevent formation of flammable atmospheres and prevent aeration of primary circuit water.

Most of the nitrogen cover gas is recycled in a semi-closed loop. Excess gas during volume surges such as tank filling operations is directed to the delay beds where the fission product gases are abated through hold-up and decay. Cover gas is delivered by compressors and distributed via a combination of pressure and flow control.

Hydrogen and oxygen content in the gas stream are constantly measured through analysers and are abated via the recombiner.

Gas cooling and drying is required to minimise moisture content, ensuring the performance of the recombiner and the charcoal delay beds.

The Gaseous Radioactive Effluent Treatment System [KPL] consists of:

- A cover gas network distributing nitrogen to various interfacing systems handling primary circuit water (effluent or make-up)
- A catalytic recombiner for H_2 and O_2 abatement
- Gas analysers and gas injection supplies constantly controlling the H_2 and O_2 content
- Gas compressors with liquid seal systems
- Control valves for controlling pressure and distributing the gaseous effluent flow

- A series of delay beds with an exhaust to the stack. A dryer package and guard bed upstream protect the delay beds from excessive moisture that affects their performance.

A simplified schematic of the system can be seen below in Figure 11.3-1.

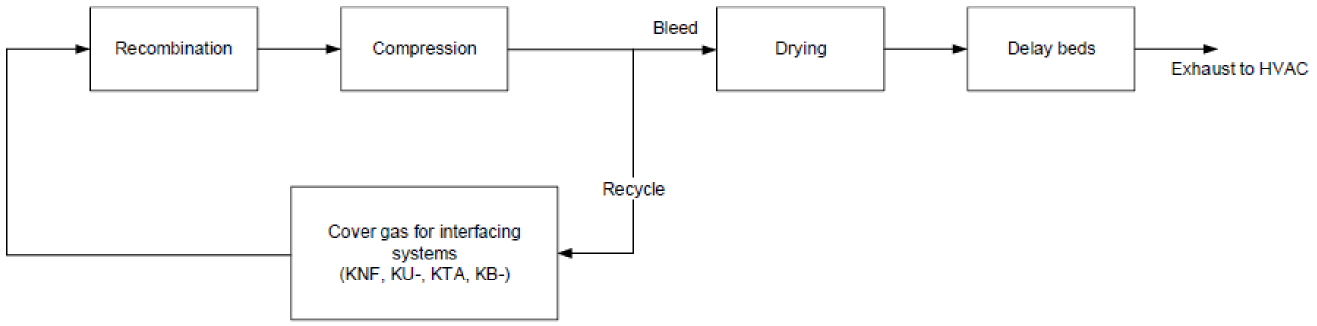

Figure 11.3-1: Simplified schematic of the Gaseous Radioactive Effluent Treatment System [KPL]

The key Gaseous Radioactive Effluent Treatment System [KPL] equipment is located in the auxiliary building sector 1, inside the hazard shield. The cover gas header lines interface with systems in the reactor containment building and auxiliary buildings. The effluent discharge connects to the stack.

Further details for the Gaseous Radioactive Effluent Treatment System [KPL], associated sub-systems, and components are provided in the SDD [10].

11.3.3.2 [KL] System Description

The HVAC systems serving controlled areas and uncontrolled areas of RI [KL] sit within the RI.

Key performance and design parameters for the system are presented in Table 11.3-2.

The maximum and minimum 1E-04 annual frequency of exceedance (AFoE) design basis temperatures in Table 11.3-2 are the values defined in the RR SMR Generic Design Envelope document [50]. These temperatures are used as the external design operating conditions for safety classified plant within the [KL] system.

The external summer design temperatures in Table 11.3-2 are current assumptions that have been used as the intake air temperatures in the [KL] system cooling load calculations. As the temperature control function for the [KL] systems is generally assumed to be unclassified, the current 1E-04 AFoE design basis temperatures defined within the RR SMR Generic Design Envelope document [50] are not considered appropriate for this use.

Table 11.3-2: Key Performance and Design Parameters for the [KL] System

Parameter	**Approx Value**	**Notes**
External 'normal operation' summer design temperatures	36 °Cdb (dry bulb) 23°Cwb (wet bulb)	These are the external design conditions used for the UK. These will vary depending on build location.
External 'normal operation' winter design condition	-23 °Cdb	This is the external design condition used for the UK. This will vary depending on build location.

Parameter	Approx Value	Notes
Maximum 1E-04 design basis temperatures	49 °Cdb 32.3 °Cwb	-
Minimum 1E-04 design basis temperatures	-35 °Cdb	-
Ventilation flow rates	Up to 12 m^3/s	The flow rate differs per [KL] sub-system depending on the areas being served by that system and their requirements. The flow rates are based on initial air change rates dependent on expected and potential levels of airborne contamination taken from BS26802 [51].
Space temperatures	16 °C – 35 °C	Current assumptions are that spaces will be maintained between these temperatures. Specific requirements for space temperatures are dependent on the use of, and systems within, the spaces and have not been defined yet.

The following descriptions only cover the areas of the system that are related to the management and discharge of gaseous radioactive waste, noting that the [KL] system also supplies clean air to the RI.

Reference should be made to the HVAC systems serving controlled areas and uncontrolled areas of RI [KL] SDD for further information [20].

11.3.3.3 HVAC Systems Serving Primary Containment [KLA] Description

The extract plant for the [KLA] system is currently assumed to be safety class 3 and consists of two trains, operating in a duty/standby configuration. Each train consists of:

- High efficiency particulate air (HEPA) filter – primary HEPA filters to remove particulate contamination from the exhaust air before discharge to the environment.
- Carbon filter - to remove gaseous contamination from primary containment.
- HEPA filter – secondary HEPA filters to remove particulate contamination from the exhaust air before discharge to the environment in case of perforation of the primary HEPA filter.
- Extract fan – to remove the contaminated air from the primary containment and discharge it from the building via the filters.
- Isolation dampers - on the inlet and outlet to the fan and to each filter to enable isolation of the components during maintenance or duty/standby rotation.

11.3.3.4 HVAC Systems Serving the Interspace [KLB] Description

The extract plant for the [KLB] system is designated as safety class 3 and consists of two trains, operating in a duty/standby configuration. Each train consists of:

- HEPA filter – primary HEPA filters to remove particulate contamination from the exhaust air before discharge to the environment.

- HEPA filter – secondary HEPA filters to remove particulate contamination from the exhaust air before discharge to the environment in case of perforation of the primary HEPA filter.
- Extract fan – to remove the contaminated air from the interspace and discharge it from the building via the filters.
- Isolation dampers - on the inlet and outlet to the fan and to each filter to enable isolation of the components during maintenance or duty/standby rotation.

11.3.3.5 HVAC Systems Serving Controlled Areas [KLC] Description

The extract plant for the [KLC] system consists of sub-systems, serving the C2 and C3 areas within the Controlled Area independently. The extract plant is designated as safety class 3. Each of these sub-systems consists of two trains, operating in a duty/standby configuration. Each train consists of:

- Primary HEPA filter – to remove particulate contamination from the exhaust air before discharge to the environment.
- Secondary HEPA filter - to remove particulate contamination from the exhaust air before discharge to the environment in case of perforation of the primary HEPA filter. This secondary HEPA filter is currently included for all controlled area extract systems as it is common UK practice, and the contamination levels are currently undefined. As the design develops, the expected airborne contamination levels in each area will be assessed and the requirement for the secondary HEPA filter reviewed against the potential hazard.
- Extract fan – to remove the contaminated air from the controlled areas and discharge it from the building via the filters.
- Isolation dampers - on the inlet and outlet to the fan and to each filter to enable isolation of the components during maintenance or duty/standby rotation.

11.3.3.6 HVAC Systems Serving Radioactive Waste Processing Areas [KLF] Description

The extract plant for the [KLF] system is designated as safety class 3 and consists of separate sub-systems serving the different areas and confined processes within the waste processing area. Each of these sub-systems consists of two trains, operating in a duty/standby configuration. Each train consists of:

- Primary HEPA filter – to remove particulate contamination from the exhaust air before discharge to the environment.
- Secondary HEPA filter - to remove particulate contamination from the exhaust air before discharge to the environment in case of perforation of the primary HEPA filter. This secondary HEPA filter is currently included for all waste processing area extract systems as it is common UK practice, and the contamination levels are currently undefined. As the design develops, the expected airborne contamination levels in each area will be assessed and the requirement for the secondary HEPA filter reviewed against the potential hazard.
- Extract fan – to remove the contaminated air from the waste processing areas and discharge it from the building via the filters.
- Isolation dampers - on the inlet and outlet to the fan and to each filter to enable isolation of the components during maintenance or duty/standby rotation.

11.3.3.7 HVAC Systems Serving Fuel Storage and Handling Areas [KLL] Description

The extract plant for the [KLL] system is designated as safety class 3 and also consists of separate sub-systems serving the C2 and C3 areas within the fuel storage and handling area. Each of these sub-systems consists of two trains, operating in a duty/standby configuration.

Each train serving the C2 areas consists of:

- Primary HEPA filter – to remove particulate contamination from the exhaust air before discharge to the environment.
- Secondary HEPA filter - to remove particulate contamination from the exhaust air before discharge to the environment in case of perforation of the primary HEPA filter. This secondary HEPA filter is currently included for all fuel handling and storage area extract systems as it is common UK practice, and the contamination levels are currently undefined. As the design develops, the expected airborne contamination levels in each area will be assessed and the requirement for the secondary HEPA filter reviewed against the potential hazard.
- Extract fan – to remove the contaminated air from the fuel storage and handling areas and discharge it from the building via the filters.
- Isolation dampers - on the inlet and outlet to the fan and to each filter to enable isolation of the components during maintenance or duty/standby rotation.

Each train serving the C3 areas consists of:

- Primary HEPA filter – to remove particulate contamination from the exhaust air before discharge to the environment.
- Secondary HEPA filter - to remove particulate contamination from the exhaust air before discharge to the environment in case of perforation of the primary HEPA filter. This secondary HEPA filter is currently included for all fuel handling and storage area extract systems as it is common UK practice, and the contamination levels are currently undefined. As the design develops, the expected airborne contamination levels in each area will be assessed and the requirement for the secondary HEPA filter reviewed against the potential hazard.
- Extract fan – to remove the contaminated air from the fuel storage and handling areas and discharge it from the building via the filters.
- Isolation dampers - on the inlet and outlet to the fan and to each filter to enable isolation of the components during maintenance or duty/standby rotation.

11.3.4 Materials

Materials for the Gaseous Radioactive Effluent Treatment System [KPL] are selected to minimise risks associated with operator dose, corrosion, and decommissioning. Stainless steel is selected for the design of components in contact with radioactive gaseous effluent. The FBoM module for [KPL], in DOORS [44], contains the list of SSCs within [KPL] and their corresponding material specification.

Further definition of [KL] components, and components within the distribution networks, will be included for DR3.

The description and justification of materials used for classified SSCs are presented in E3S Case Version 2, Tier 1, Chapter 23: Structural Integrity [27].

11.3.5 Interfaces with Other Equipment or Systems

Details on interfaces for the Gaseous Radioactive Effluent Treatment System [KPL] and the HVAC systems serving controlled areas and uncontrolled areas of RI [KL] are contained within the relevant SDD [10] [20].

11.3.6 System and Equipment Operation

The Power Station Operating Philosophy [28] 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, Version 2, Tier 1, Chapter 13: Conduct of Operations [29].

The Gaseous Radioactive Effluent Treatment System [KPL] will be aligned through manual selection of system configurations (grouped commands for aligning the system isolation valves and actuators). Current system configurations include switchover of duty/stand-by compressor packages and switchover of duty/standby control valves.

The [KPL] system operates continuously during power operation. The highest duty on the recombiner is during reactor coolant degassing, expected when preparing for the shutdown transient or following design basis fuel failure. The highest duty on the delay beds is when preparing reactor coolant make-up water, and during thermal expansion and steam bubble formation in the pressuriser during start-up operations.

The design of the [KL] systems has been developed using good practice to ensure that they are operable, maintainable, and accessible.

The majority of the [KL] systems' operation is automatic and will require minimal operator action. Operator actions are mostly limited to configuration selection and responding to alarms and warnings by following operator procedures. The control philosophy of the [KL] systems should result in equipment failing safe, followed by automatic duty/standby switchover where possible, and therefore not dependent on urgent operator action following alarms.

At this stage the design has not yet been subject to any assessment but will be carried out in the future in order to provide confidence that the design has been conducted with due cognisance of operability, maintainability and accessibility to ensure that the safe operation of the [KL] system is feasible.

11.3.7 Instrumentation and Control

This subsection provides a high-level overview of the basic functions that are allocated to the reactor C&I systems [JY] by the Gaseous Radioactive Effluent Treatment System [KPL] and the HVAC areas of RI [KL]. Noting that dedicated control cubicles are expected for the following equipment within KPL:

- The gas compressors are expected to be package equipment, including trips for compressor suction temperature, pressure, flow and sealing liquid drum level managed by dedicated control.
- The catalytic recombiner will actuate electrical heaters on and off automatically, and trip upon high temperature and pressure for mitigating conventional safety hazards (explosion and flammability risks). The trip function will include shutting off heaters and bypassing the recombiner.

- The hydrogen and oxygen analysers are expected to be package equipment, including equipment for gas compression, distribution, cooling, drying, etc. requiring dedicated control.

11.3.7.1 Alarms and Warnings

To support the safe operation and control of the Gaseous Radioactive Effluent Treatment System [KPL] and the HVAC systems serving controlled areas and uncontrolled areas of RI [KL], the C&I system will also be required to provide alarms and warnings to indicate that key system parameters are outside of the defined performance bands and/or safety limits.

A list of alarms related to instrumentation present on the Gaseous Radioactive Effluent Treatment System [KPL] the HVAC systems serving controlled areas and uncontrolled areas of RI [KL], can be seen in the [KPL] SDD [10] and [KL] SDD [20] respectively.

11.3.8 Examination, Maintenance, Inspection and Testing

At DR3, the Gaseous Radioactive Effluent Treatment System [KPL] and the HVAC systems serving controlled areas and uncontrolled areas of RI [KL] have a TLA module in DOORS populated with all known maintenance tasks (in line with design maturity), specific to the system environment and the operating context.

The maintenance activities considered in the TLA include:

- Safety derived tasks
- Design derived tasks (supplier provided)
- Reliability derived tasks (RCM/preventative maintenance)
- Industry RGP/OPEX (EPRI PMDB)
- Non-PBS (module, site facility).

As the [KPL] system is required to be operational in all plant states, key equipment is redundant with the appropriate valves and pressure sensors to prove the isolation, as well as connections for flushing the equipment with gas to the HVAC system. This allows maintenance while the system is online.

11.3.9 Radiological Aspects

Minimisation of normal operation and maintenance doses to ALARP is one of the key design criteria in the systems engineering design decision process, see section 11.3.12.

11.3.9.1 [KPL] System Radiological Aspects

Opportunities to reduce radiological exposures during normal operation and maintenance have been considered within the design to date, such as physical segregation and shielding between the delay beds that are likely to have high dose rates, and redundancy and dose monitoring in the HVAC system [KL].

A shielding assessment has been performed for the system [32]. In this assessment, dose rate calculations have been performed to determine the required thickness of steel or concrete shielding for each of the components within the [KPL] system to reduce dose rates below the upper bounds for an undesignated area, supervised area, and the first dose rate band of the controlled area respectively.

The shielding assessment will be revisited and updated in the future, with revised source term inputs and underpinning assumptions.

Occupational dose risk will be managed and sought to be reduced as the design of the system matures and a better understanding of plant layout and occupancy is understood.

11.3.9.2 [KL] System Radiological Aspects

The [KL] systems incorporate HEPA filters that must be changed several times during the lifetime of the plant. The design of the [KL] systems aims to reduce occupational dose that could occur from changeout of these filters. The filters are safe-change so that the contamination captured by the filters is contained during changeout operations, minimising risk to maintenance personnel.

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

Although all fault modes are not yet defined, the current assumption is that during a fault where there is a significant radiological release, the [KL] systems would be shut down and the area isolated, so no significant loading of the HEPA filters is anticipated. This will be reviewed during DR3 following assessment of all fault modes. If required, mobile shielding could be utilised.

11.3.10 Performance and Safety Evaluation

11.3.10.1 [KPL] System

A verification strategy covering the Gaseous Radioactive Effluent Treatment System [KPL] has been developed for DR3 [52] and contains the verification activities for [KPL]. The main verification activities for [KPL] are:

- VA-KP-S17 vendor supplied documentation technical assessment
- VA-KP-A21 Flomaster thermal fluid analysis.

Risks relating to this verification strategy, or its execution, have been captured and are being managed in the locally managed 11.01 RI Level 4 Verification Risk Register.

In summary, there is a risk relating to the verification of the recombiner unit. At DR3 it is expected that a vendor will design, verify and supply the recombiner unit, however, it is possible that this unit may be designed by Rolls-Royce SMR Limited, resulting in the verification of the unit becoming by analysis, not by similarity (analogy).

Performance and safety evaluation is also undertaken during the commissioning phase as described in section 11.3.11.2.1.

11.3.10.2 [KL] System

Outline qualification requirements for safety classified SSCs will be developed during DR3.

11.3.11 Installation and Commissioning

11.3.11.1 Installation

An outline [KPL] and [KL] system installation plan will be developed, alongside appropriate DOORS requirements, post-DR3. However, one of the key features of this plan will be the modularisation of the major components to maximise factory manufacturing and assembly and to minimise the amount of site activity where possible. Installation plans will be developed in line with the SMR ICOM policy [33].

11.3.11.2 Commissioning

11.3.11.2.1 [KPL] System Commissioning

Prior to start-up, the [KPL] system is filled with air, which needs to be removed and replaced with nitrogen. Later phases of the design will detail how air ingress will be managed. Commissioning and start-up of the system and interfacing purged equipment will require a nitrogen fill and purge to remove ambient air.

The outline plan for commissioning includes both FAT activities carried out at the MEP factory, as part of the modular assembly stage, and SAT at the SMR installation site.

An important part of the preliminary plan for the commissioning of the Gaseous Radioactive Effluent Treatment System [KPL] has been to apportion the necessary activities within these two areas, to exploit the V&V able to be delivered by FAT thereby reducing the time required for commissioning testing on site.

The [KPL] contains both packaged treatment equipment that will be installed with modules as well as equipment that will be built in the MEP factory. The expectation is that packaged equipment will, where possible, undergo FAT at vendor factories to minimise specialist equipment requirement of the MEP factory.

The outline commissioning activities have been informed by relevant OPEX and RGP, as well as specific claims to support the V&V strategy, and are categorised into the following activity types:

- Inspection
- Physical checks
- Functional testing
- Performance testing
- Post-MEP checks

The [KPL] system uses multiple stages of treatment to enable minimal gaseous discharge, connected in a single continuously operating loop. Verification of the design will ensure that there is a high confidence that all requirements can be met by the system. Systems can be initially set up based on the verification testing performed, RGP and vendor feedback, but due to the integrated nature of the system, performance of the system in its entirety cannot be verified at the MEP factory.

Abatement of radionuclides will require testing, in the form of FAT or tests at the MEP factory, prior to start-up of the plant, as the [KPL] system represents one of the final barriers to the environment for gaseous discharges, and the abatement technique is a passive process where sampling to authorise discharge will not be performed. Most commissioning activities are therefore expected to be performed during cold functional testing, with the exception being activities involving the recombiner and heat exchangers, which require the system to be at operational temperatures.

11.3.11.2.2 [KL] System Commissioning

For the ductwork systems, commissioning will be carried out on-site once the entire system has been installed. Pre-commissioning cleaning of ductwork can be performed off-site for pre-fabricated sections. Components that will be included in the design to enable commissioning of the system include variable speed drives for fans, balancing dampers and test points for velocity and pressure testing.

A comprehensive commissioning plan for both [KPL] and [KL] systems will be developed during detailed design. Commissioning plans will be developed in line with the SMR ICOM policy [33].

11.3.12 BAT and ALARP in Design Development

The design of the Gaseous Radioactive Effluent Treatment System [KPL] and the HVAC systems serving controlled areas and uncontrolled areas of RI [KL] is being developed in accordance with the systems engineering design process, which includes design to codes and standards according to the safety classification, a systematic optioneering process with down-selection of design options based on assessment against relevant safety and environmental criteria (as described in E3S Case, Version 2, Tier 1, Chapter 3: E3S Objectives and Design Rules for Structures, Systems and Components [34] and the Approach for Optimisation through the Application of BAT report [35]), and alignment to RGP and OPEX.

11.3.12.1 [KPL] System

In summary, to ensure overall risks are reduced to ALARP and represent the use of BAT, the use of delay beds over decay storage tanks for abatement of active gases was selected, given it is based on well-established techniques and RGP, and offers advantages of a more passive design with simplified operation and lower risk of erroneous discharge. It is not expected that there will be an accumulation of activity on the delay beds, and therefore, the activated charcoal media is anticipated to be LLW at the end of life, noting that the Disposability Case [12] has identified the charcoal media as boundary ILW/LLW to facilitate discussions between Rolls-Royce SMR Limited and Nuclear Waste Services (NWS).

Key decisions for the Gaseous Radioactive Effluent Treatment System [KPL] have their own decision file that records decision rationale, as well as their own entry in the SMR decision register, which is stored in the DOORS database. Key design decisions are summarised in Table 11.3-3.

Table 11.3-3: Key design decisions for the [KPL] system

Decision description	Solution	Decision file reference
Primary coolant degassing	Reactor coolant letdown is routinely degassed prior to transfer to [KNF] for treatment and storage.	EDNS01000900096/001 [53]
Purging of primary coolant systems	Nitrogen cover gas at >0.105 MPa(a) for collection of gaseous radionuclides and hydrogen, while minimising air ingress.	EDNS01000900096/001 [53]
Air removal for reactor use	Use of [KNF] vacuum degasser for de-aeration of make-up water to primary circuit.	EDNS01000900096/001 [53]

Decision description	Solution	Decision file reference
Activity abatement	Waste gas is bled through the delay beds constantly, with the fission-product gases adsorbing onto the activated charcoal beds and nitrogen carrier gas permeating through.	EDNS01000900096/001 [53]

11.3.12.2 [KL] System

Key decisions have their own decision file that records decision rationale, as well as their own entry in the SMR decision register, which is stored in the DOORS database. Table 11.3-4 below presents a summary of the key decisions made that relate to the [KL] systems.

Table 11.3-4: Key design decisions for the [KL] system

Decision description	Solution	Decision file reference
RI HVAC system [KL] HEPA filter design	Interchangeable HEPA filter modules	SMR0003764 [54]

11.3.13 Ongoing Design Development

The RR SMR design definition is currently in development as described in section 11.0.1. Areas of further work are identified through multi-discipline engineering design activities, e.g. HAZOPs, LOPA, and DRs and will be informed by E3S functional requirements, and non-functional system requirements placed onto the design as the safety analysis is developed.

11.3.13.1 [KPL] System

Further work items for Gaseous Radioactive Effluent Treatment System [KPL] are presented in the assumptions module for the system in DOORS. A snapshot of assumptions associated with the [KPL] system was taken from DOORS in June 2023 [55].

11.3.13.2 [KL] System

The HVAC systems serving controlled areas and uncontrolled areas of RI [KL] have identified several areas of future work within the SDD [20] that reflect the current design maturity of the system.

11.4 Systems and Arrangements for the Management of Solid Radioactive Wastes

11.4.1 Systems and Equipment Functions

The Solid Radioactive Waste Management Systems [KM] collects, immobilises, stores and dispatches LLW and ILW. Waste can be divided into two main categories:

- Wet solid radioactive waste including evaporator concentrates, resins and backwashed filter solids, arising from the CVCS [KBE], Spent Fuel Pool Purification and Cooling System [FAL] and Liquid Radioactive Effluent Treatment System [KNF]. Miscellaneous wet wastes (such as sludges, oils and solvents) may also arise from the plant.
- Dry solid radioactive waste from the RI and the rest of the plant, e.g. filter casings and waste produced during maintenance.

11.4.2 Design Bases

11.4.2.1 Safety Functional Requirements

[KME20] system is expected to contribute to the safety function "confinement of radiological materials".

Justification of safety categorisation and classification is presented in Reference [56].

11.4.2.2 Non-Functional System Requirements

Full details of the transverse requirements applied to this system can be found in the requirements specification for the Solid Radioactive Waste Management Systems [KM] in DOORS.

11.4.2.3 Safety Classification

A summary of SSCs' safety classifications to meet safety categorised functions is below:

- Components and control:
  - Solid waste tanks are suggested to be class 3, with class 3 normal level control.
  - Pipework shall be class 3, with class 3 high temperature and pressure trips on inlets.
  - Pumps shall be class 3, with class 3 high pressure trip on the outlets.
- Bunding
  - Tanks shall be in a class 2 bund, with class 3 high-level trips on the sump.
  - Pipework shall have class 2 bunding.
  - Pumps shall also have class 2 bunding, with class 3 high level alarms on the bund.
- Access restrictions:
  - There shall be class 3 operational controls on access to the [KTA30] drain tank area and the circulation area adjacent to the pump room.
  - There shall be a class 1 physical lock on the tank area shield plug and a class 2 physical lock on the pump room door. These shall be supported by class 3 operational controls on maintenance operations.

- The civil structure does not require a safety categorisation to mitigate these faults but is expected to fulfil a higher duty safety function for confinement of active material following internal/external hazards.

A full list of safety classifications can be seen in the relevant requirements modules for major components, as well as the FBoM for the system [57].

It is important to note that these are the current safety measures but will be subject to further review.

11.4.2.4 Environmental Classifications

Environmental classification of SSCs is currently being undertaken in accordance with the method set out in the Identification of Environmental Functions and Environmental Measures [2]. Those SSCs currently identified as being environmentally significant are summarised in Appendix B (section 11.8).

11.4.3 Description

The [KM] system consists of:

- Solid Radioactive Waste Processing System [KMA], containing:
    - Waste processing equipment and a dispatch area for LLW [KMA10].
    - Waste processing equipment and curing area for ILW [KMA20].
- Solid Radioactive Waste Storage System [KME], containing:
    - Temporary storage area for LLW [KME10].
    - Temporary storage system for ILW [KME20).
    - Long term storage facility for processed ILW [KME30].

A simplified schematic can be found in the Solid Radioactive Waste Management Systems [KM] SDD [58].

Key performance and design parameters for the system are presented in Table 11.4-1 and Table 11.4-2.

Table 11.4-1: Key performance and design parameters for the Solid Radioactive Waste Storage System [KME]

Parameter	Approx Value	Description
Receipt flow rate	TBC m^3/hr	Flowrate determined by upstream systems, with same minimums as for transfer.
Transfer flow rate	>15 m^3/hr for filter solids >15 m^3/hr for resins >15 m^3/hr for evaporator concentrates	Assumed to be the same for transfer from tanks and recirculation. Maximum flowrate is limited to <45 m^3/hr due to erosion. Minimum set by suspension of solids and normal velocity profiles in pipework.

Parameter	Approx Value	Description
Flushing flow rate	~ 5-15 m^3/hr	Flowrate shall be set following assessment of efficacy of solid removal versus generation of secondary waste for treatment. This assessment requires knowledge of the pressure of the flushing supply system and tortuosity of pipe route. A range of estimated flowrates is educated by RGP.
Air sparging flow rate	~50 Nm^3/hr	Sparging shall be set by compressed air supply system and sparging nozzle design, with estimate from RGP.
Design temperature	60 °C for resins and backwashed filters 100 °C for concentrates 50 °C for ambient conditions in [KME10] and [KME30]	Limits set based on maximum waste temperature at point of arising.
Design pressure	1 MPa(g)	[KME10] and [KME30] are ambient processes. [KME20] design pressure is set by upstream system conditions.
Operating temperature	20-50 °C for resins and backwashed filters 50 °C for concentrates 20-35 °C for ambient conditions in [KME10] and [KME30]	Solid waste will be handled and contained at ambient conditions. Pump operating pressure to be determined following layout developments and downstream [KMA] system design.
Operating pressure	Atmospheric TBC for outlet of transfer pump.	

Table 11.4-2: Key performance and design parameters for the Solid Radioactive Waste Processing System [KMA]

Parameter	Approx Value	Description
Receipt flow rate	TBC m^3/hr	See [KME] transfer flow rate.
Batching tank volume	TBC m^3 for [KMA10] TBC m^3 for [KMA20]	Subject to selection of processing equipment.
Processing flow rate	TBC m^3/hr	Subject to selection of processing equipment.

Parameter	Approx Value	Description
Design temperature	100 °C	Limits set based on exothermic grouting temperature.
Design pressure	1 MPa(g)	Low pressure processes.
Operating temperature	60-70 °C	Solid waste will be handled and contained at ambient conditions. Exothermic grouting process.
Operating pressure	Atmospheric	

11.4.3.1 [KME10] System Description

The [KME10] is a temporary storage area for collection and storage of dry LLW and miscellaneous LLW oils and solvents before transfer to [KMA10]. Dry LLW includes HEPA filters from the HVAC System [KL], RO membranes from [KNF], backwashed filters from [KBE], [KNF] and [FAL] and DAW, arising from routine maintenance operations during outages.

[KME10] consists of cages for storing different waste types: metal melt, combustible and compactible. These waste categories are set to meet the LLWR waste acceptance criteria (WAC). VLLW is stored in a separate cage for disposal to permitted landfill.

[KME10] bays can be designed with clip-in partitions to vary the size of cages for different [KMA10] campaigns.

Oils and solvents could be generated as a result of maintenance activities and/or leaks. The volume, type or source term have yet to be calculated but it is expected that oils/solvents shall be LLW and generated in low volumes. Therefore, no additional tank storage is required. There shall be a bunded area adjacent to cages for storing miscellaneous oils and solvents in leak tight containers. Oils and solvents collected and stored within suitable waste packages for supply chain treatment and/or disposal to LLWR.

There shall also be an area reserved for storing one shielded container of ILW as it decays, with additional area reserved in the ILW Store.

11.4.3.2 [KME20] – Dry ILW System Description

It is predicted that some dry ILW may be generated in the RR SMR from maintenance operations, outages or failed components. The strategy outlined here will be re-evaluated once more details are known on this waste stream.

If ILW dry waste cannot be decontaminated (e.g. if the activity is predominantly due to activation), it is packaged unencapsulated in suitable shielded containers, so as not to foreclose future treatment and disposal options. Packages shall be decay stored to below ILW threshold in [KME30] if possible, prior to joining the dry LLW stream. If ILW dry waste cannot be decayed below the ILW threshold during plan operational life, it shall join the decommissioning ILW stream.

Suitable shielded containers are provided for miscellaneous ILW dry waste to be collected in [KME10]. Suitable container types include 500 litre drum, 3 m^3 box and ductile cast iron containers (DCIC). Options on waste container selection are not foreclosed in the design, given size, type and source term of dry solid ILW is not fully evaluated for the RR SMR.

11.4.3.3 [KME20] – Wet ILW System Description

[KME20] contains three distinct storage tank groupings: concentrates (2x), filter solids (2x) and resins storage tanks (3x – two ILW/LLW boundary and one ILW). There are separate bunds for each set of tanks to collect any leakage from the system.

Each set of tanks is located in individual shielded and bunded no-access areas. There is a [KTA30] drainage tank outside of the tank area. Any equipment that requires maintenance e.g. instrumentation and valves, are located outside of the high dose tank area. There are access ports for remote maintenance and inspection from above the tanks, with an operator access point for entry following fault scenarios.

Wet solids are received and transferred via a shielded pipe run, which connects to a pump and valve room.

11.4.3.3.1 Concentrates Storage Tanks

The concentrates storage tanks (2x) collect batches of concentrates that are drained from the [KNF] evaporator when one of the bottom product specification limits has been met (refer to the [KNF] SDD [9] for details). The evaporator shall be operated in small batches, following complete treatment of a [KNF] drain tank to the RO unit. The frequency of concentrates transfer depends on the total volume and composition of the effluent that is treated in [KNF].

Each tank has a usable volume 16 m^3 and are in a duty-standby configuration to allow decay storage in [KME20] before treatment and disposal as LLW.

Concentrates are transferred from the evaporator to the concentrates storage tanks by gravity flow. Flushing of the associated piping is performed after every transfer for corrosion prevention and to minimise residual radiation and contamination. Flushing effluent is diverted through a drain line on each section of pipework, to prevent dilution of evaporator concentrates in the tank.

A recirculation line allows for mixing of tank contents to ensure a representative sample can be taken. Jet mixing ejectors are proposed on recirculation return lines to minimise moving parts.

The bottom of each tank is fitted with a draw-off sump, with the tank floor sloping to a low point where particulate material can collect. Any accumulated particulate is transferred via the suction line to downstream treatment, therefore reducing accumulation of tank particulates and sludges over repeated storage-treatment campaigns.

Concentrate storage tanks are connected to the HVAC system to remove aerosol radionuclides and any hydrogen hazards arising due to radiolytic breakdown of water. Tanks shall have an open overflow at the top of the tank to prevent over pressurisation of tanks and overflow into HVAC connections, which would require high-dose clean-up operations. The open overflow shall direct concentrates to the local tank bund, which can be recovered to tanks or drained to the [KTA30] system. Gases that leave via open overflow are removed via HVAC within the sealed room.

11.4.3.3.2 Resins Storage Tanks

The resins storage tanks collect IEX bed resins from the [KNF], [KBE] and [FAL] systems.

[KBE] and [FAL] resins are collected in the designated ILW resins tank (1x), while the remaining resin wastes, notably [KNF] resins, are preferentially collected in the designated boundary resins tanks (2x).

All tanks are identically sized with sufficient capacity to store resins for 6 years which is the proposed frequency of the treatment campaigns. The first treatment campaign is slightly longer given resins may take several cycles to become exhausted for the first time.

Tanks are conservatively sized for changeover of each resin bed once per cycle. It is expected that resins will be changed only once exhausted (as detected by conductivity measurements across the bed) or once an activity threshold is met (as detected by local activity measurements on the bed). The resin changeout frequency should be developed with resin suppliers once chemistry is better understood post-DR3.

Boundary resin tanks have a usable volume of 16 m^3 and are in a duty-standby configuration to allow decay storage.

Resins are transferred by demineralised water, with each resin transfer accompanied by 7.5 m^3 water, used for flushing the resin transfer pipes after transfer to avoid resin settling in pipes.

Tanks include a recirculation line with jet mixing ejectors for fluidisation and sampling. Tanks also have air sparging nozzles for a redundant fluidisation method.

There is active HVAC ventilation connected directly to all [KME20] tanks for dilution of radiolytic gases and hydrogen generated by resin degradation and radiolysis of water.

The bottom of all [KME20] tanks are fitted with a draw-off sump, with the tank floor sloping to a low point where particulate material can collect, to reduce accumulation of tank particulate and sludges. The pump suction line also has a minimum slope to prevent resins settling in pipework.

The tanks contain a strainer with a weir at the top to allow excess transfer and flushing water drain off to the [KTA30] system and a strainer at the bottom of the tank to avoid resin deposition and subsequent ingress into the draw-off line. Tank internals may take the form of a resin cage or be in-line filters, subject to detailed design. In-line filters must include backflushing capability in case of blockages.

Tank level shall be primarily determined procedurally, through appropriate recording of waste transfers. However, tanks shall also include resin level indication in design, which must be able to differentiate between resin and water content. appropriate sensors will be determined post-DR3. Potential techniques to be considered include the use of ultrasonics array and imaging, or dose rate/gamma measurements to detect the interface between resins and supernatant water.

The end of the resin transfer in pipework will be determined procedurally, with additional confirmation using radiation monitors on pipe externals to validate resin transfer (dose spike on transfer, followed by attenuation of dose rates as flushing removes solid deposits). Portable hand-held radiation monitors can also be used to locate any solid blockages. Some sites use a full-bore sight glass and a remote camera, but there has been experience of sight glasses rupturing due to pressure variance.

Provisions are made for utilising clean process water from the Liquid Effluent Monitoring and Discharge System [KNF30] for resin transfer and flushing, and for general maintenance purposes downstream of the tanks and upstream of the transfer pump.

11.4.3.3.3 Filter Solids Storage Tanks

Filters in [KBE], [FAL] and [KNF] are backwashed to release retained solids, reducing the activity of the filters from ILW to LLW. The resulting backwashed slurry is a dilute suspension of filter solids expected to remain ILW for the duration of the lifecycle of the plant. As such, it is processed as wet ILW in [KMA20].

Tanks are conservatively sized based on OPEX. It is assumed that 1x [KBE], 1x [FAL] filter and 3x [KNF] filters are backwashed each cycle. Filter suppliers will inform filter backwash frequency and backwashing liquid volumes post-DR3.

Filter solids tanks (2x) are in a duty-standby configuration and each tank must be able to store four cycles worth of retained filter solids and also have capacity for one filter’s worth of backwashing slurry.

The backwash is sluiced to the filter solids tanks using pressurised water with optional additional compressed air, to be specified by the supplier. Flushing of the associated piping is performed after every transfer to remove solid residue and to minimise residual radiation. Flushing effluent is diverted through a drain line on each section of pipework to the [KTA30] system, to prevent dilution of filter solids in the tank.

Following filter backwash transfer, filter solids shall be gravity settled to a solid content of 5-10 %. Excess transfer water is drained off at an upper nozzle on the tank, in order to achieve the desired solid concentration. Tanks shall have an open overflow at the top of the tank to prevent over pressurisation of tanks. The overflow shall direct to the local tank bund, which can be recovered to tanks or drained to [KTA30].

Once the filter solids have been concentrated by draining excess transfer water, tanks must be designed to prevent solids settling further in tanks and solidifying. Therefore, filter solids tanks shall also contain air sparging, pumped recirculation and a sloping base. Filter solids tanks also have direct HVAC connections and level detection (anticipated to be similar to resin level sensors).

11.4.3.3.4 Tank Bunds

The [KME20] tank containment strategy is to locate each type of waste in a separate shielded tank room that acts as a leak tight bund. Bunds must have 110 % maximum tank volume. Each tank bunded area is no operator-access during normal operation for operator radiation protection.

Tank leaks are identified by redundant discrete and continuous level sensors on the bund. Ultrasonic sensors are recommended for bund level detection.

The preferred method of recovery of leaked media in the bund is using the existing recirculation pump, but if pump selection or layout configurations means this is not possible then an eductor or submersible bund pump could be used.

11.4.3.3.5 Pumps

Solids are transferred from [KME20] storage tanks to [KMA10/20] for immobilisation via pumped transfer. Transfer and recirculation are provided by the same pumps, with a single operating point. A throttle valve or orifice plate are included on the recirculation line for flow regulation.

Two duty-standby transfer pumps are proposed per set of tanks. Pump requirements have been reviewed [59]:

- Depending on layout, pumps may be required to provide suction lift.
- Pumps must also be able to deliver a precise volume of solid waste to downstream treatment systems.
- Pumps must be capable of handling solid loading.
- Pumps must have low maintenance requirements.
- Pump sizing has also been calculated based on the current layout and transfer requirements.
- Pumps must include overpressure protection. Relief on the solid process side should be avoided or routed back to the pump suction to minimise release of radioactive material.

Based on these requirements, a positive displacement pump is selected, in particular an air operated diaphragm reciprocating pump. Specific pump selection will be carried out at a later stage.

The [KME20] pump containment strategy is to have a separate bund for each pump in the common pump room, with level sensors on each bund.

11.4.3.3.6 Valves

Valves must be remotely operated to reduce operator dose during transfers. Valves contributing to the safety function “confinement of active material” must have remote manual overrides, which can be in the form of spindles. Valve requirements are included in the [KME] FBoM [57]. The number of remote manual overrides should be minimised given equipment is bulky, expensive and increases maintenance load. Shine path should also be considered when extending valve handles through shield walls.

Valves must be selected to reduce solid accumulation in internals, which would increase operator dose during maintenance. The valve type will be selected for DR5, but full-bore valves are recommended. Suggested valve types include:

- Diaphragm valves (recommended for high activity solids): Easy to maintain and reliable, which reduces operator burden on maintenance, and have good seal leakage. However, diaphragm valves may accumulate solids in cavities in valve seats.
- Ball valves: Clear pass through so will not accumulate solids in cavities, but the seals can be damaged by high solid loading scratching the seat.

11.4.3.3.7 Pipework

It is proposed that the pipe boundary between the upstream system and [KME20] is located close to upstream demineraliser/filters to allow the [KME20] system to specify appropriate design for high solid loading. Any overpressure protection or temperature relief must be in the upstream system scope, such that effluent meets [KME20] pipework operating and design conditions.

The following measures are proposed to reduce the likelihood of resin and filter solids entrapment and pipe blockages due to the high particulate loading of the solids-containing system:

- Wide sweeping bends are used (bends 5x diameter of pipe is best practice).
- Minimum pipe slope to allow solids to be gravity drained from system following flushing.
- Flushing is performed after every transfer, with flushing supply points and drain points at high and low points in pipework design. Flushing connections are not yet included in the [KME] FBoM [57] given layout is not confirmed so number/location of flushing/drain tie ins cannot be specified.
- Avoidance of dead legs in layout.
- Pipe fittings minimised and where required full bore type used.
- Transfer must have sufficient velocity to prevent solids settling in pipes. Transfer must also not exceed a maximum velocity to prevent solids erosion [58].

[KME20] pipes must have bunding for collecting leaks, noting that the containment strategy is still to be developed. Leaks shall be drained to either the tank or pump bund depending on location and detected by the bund level sensor.

11.4.3.4 [KMA10] System Description

[KMA10] wet processing equipment is located to allow vehicle access and mobile equipment to be brought to site for treatment campaigns and a laydown area for the Third-height International Standards Organisation (THISO) containers and their lids.

The [KMA10] hot cell sizing will be estimated following supplier engagement for the [KMA] DR3 review.

[KMA10] dry processing allows for separating and storing dry unprocessed waste. There will be a [KMA10] dry LLW Half-height International Standards Organisation (HHISO) container, with vehicular access and laydown space for the lid.

11.4.3.5 [KMA20] System Description

[KMA20] processing equipment is located in a hot cell on the ground level, with vehicular access for mobile equipment. The specific layout of equipment within the hot cell will be part of the [KMA20] system design study. Accommodating mobile equipment in the layout allows treatment equipment to be altered through design and plant life.

11.4.3.5.1 Wet ILW

The [KMA20] system processes [KBE] and [FAL] resin, filter solids and any wet ILW generated by exception. A suitable container shall be selected following development of packaging process and waste characterisation. A 500 litre drum has been selected at RD7/DRP1 as the preferred container for disposal of grouted wet ILW, with 3 m^3 boxes or shielded drums options for decay storage.

Cementitious grouting was selected as the preferred option for managing wet ILW for disposal to a GDF [60] [61]. Once grouting has been completed and the waste package has been left to cure, the waste package is transferred to [KME30], where it will remain pending disposal to a GDF.

11.4.3.5.2 Dry ILW

There is no treatment system for dry ILW in the Solid Waste Processing System [KMA] design. This has been identified as an opportunity for further engagement with suppliers within the SDD [58].

11.4.3.6 [KME30] System Description

[KME30] is a shielded storage facility designed to maintain the condition of the packaged ILW in a manner that protects workers, the public and the environment from hazards associated with interim storage until the waste can be transported to a future GDF. To fulfil the primary function of interim storage and to enable the transportation of the waste off-site, the facility shall optimise the waste package life and maintain the disposability of the packages.

The ILW store contains immobilised wet solid wastes (IEX resins and suspended filter solids) which is processed and packaged on-site within a 500 litre drum. Additional storage area is available for packaged dry ILW pending future conditioning. In addition to the storage vault, which is enclosed by a shield wall, [KME30] will include an import/export area, monitoring and maintenance facilities, plant and control rooms, a package inspection cell and a package transfer area.

The store has sufficient storage capacity for the total volume of waste accumulated across the plant lifetime as well as contingency capacity as a risk mitigation measure. Sufficient storage capacity also includes appropriate quarantine area for non-conforming packages.

A key aspect of the function of the ILW store is to ensure that the doses to workers, the public and the environment are ALARP. The dose risk and therefore the measures to reduce the dose risk are highly dependent on the characteristics of the waste packages and the site. Operability aspects e.g. colocation with SF storage and proximity to off-site disposal, shall also be considered in layout selection.

11.4.4 Materials

The FBoM module for [KM], in DOORS, and extracted into [57] for [KME20], contains the list of SSCs and their corresponding material specification.

The description and justification of materials used for classified SSCs are presented in E3S Case, Version 2, Tier 1, Chapter 23: Structural Integrity [27].

11.4.5 Interfaces with Other Equipment or Systems

Details on interfaces for the Solid Radioactive Waste Management Systems [KM] are contained within the relevant SDD [58].

11.4.6 System and Equipment Operation

The Power Station Operating Philosophy [28] 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, Version 2, Tier 1, Chapter 13: Conduct of Operations [29].

A full analysis of the system operation has been conducted for [KME10] and [KME20] to present DR3 maturity. The operating philosophy defines the key claims and operational sequences and actions the system is required to undertake, and the key claims made on the operator or automated actions. The operating philosophy also supports ongoing human factors and safety assessments.

A high-level operating philosophy has been presented for [KME30], [KMA10] and [KMA20]. These operating principles will be developed at a later design phase.

Note that the reactor mode has no effect on the operating principles of the [KM] system.

11.4.6.1 [KME10] System and Equipment Operation

Operator procedures for collection of waste are not yet developed, but it is assumed that operators will locally collect dry LLW and the waste management hierarchy principles will be incorporated into future operating procedures (see Table 11.5-1 in section 11.5.2). Waste is moved to [KME10] for buffer storage between [KMA] treatment campaigns.

11.4.6.2 [KME20] System and Equipment Operation

All [KME20] system operations are batch-based and therefore require operator selection to initiate them. The [KME20] system is aligned through manual selection of system configurations (grouped commands for aligning the system isolation valves and actuators). Operators shall select system configurations based on procedural action sheets.

11.4.6.2.1 Tank Configuration

Evaporator concentrates and boundary resin tanks are in a duty-standby configuration to allow decay storage. The proposed operating philosophy for these tanks is:

- One tank will be aligned for receiving effluent at the end of each batch, while the second tank is on standby.
- When the first tank is full, it is left to decay for three years (two cycles) while the second tank is being filled.
- Every six years a treatment campaign will take place. During a treatment campaign, the tank undergoes mixing and sampling before transfer to [KMA10] for processing.
- If waste is produced at a faster rate than expected, the contents of Tank 1 can be processed before the complete two-cycles decay time. Processed waste is then stored on-site in a container to complete the decay to LLW, freeing up a tank for additional filling.

There is only one ILW resin tank, which collects resins for the complete period between treatment campaigns.

There are duty-standby filter solids tanks to allow flexibility in collected waste volumes. Waste is collected in the first tank until it is full and then switched over to the standby tank, independent of treatment campaigns.

11.4.6.2.2 Wet Solid Waste Collection

Wet solid waste transfer from upstream systems is managed by the upstream system. The [KME20] system must display availability status for each tank and passively receive waste into an available tank.

It is suggested that upstream demineralisers and filters are isolated for one week prior to transfer of solid contents to [KME20]. This allows short lived radionuclides to decay in situ, reducing the risk of high dose rate from [KME20] pipework and tanks.

Solid collections are recorded procedurally to manage waste generation on-site and track levels in tanks. Tanks shall also include continuous level detection to support management of collected waste volumes.

Concentrates are gravity drained from the [KNF] evaporator into the concentrates tanks.

Resins are fluidised in upstream beds by pressurised water connections, which are isolated prior to transfer to [KME20]. A water connection at the resin transfer manifold allows the fluidisation of resins to be maintained while being transferred from the resin beds into the resin tanks. The injection ensures that the header is full of water during the transfer. Excess transfer water will overflow from a weir with a strainer on the tank and will be transferred to [KTA].

Engagement with suppliers suggests that filters are backwashed using pressurised water whilst the connection to [KME20] is closed, with the backwash slurry being driven to [KME20] similarly to suspended resins. Compressed air may be used to drive the backwash slurry to [KME20], depending on filter design.

11.4.6.2.3 Sampling

All [KME20] tanks have provisions for sampling on tanks for waste characterisation. Waste is expected to be characterised prior to waste treatment campaigns. Boundary resin tanks are characterised once full, to inform required decay periods.

Characterisation is determined by requirements to meet WAC of the receipt organisation, which may include, but is not exclusive to, solid content, particle size distribution and radionuclides fingerprint.

The sampling system [KUB] is used for main categorisation of the waste in [KME20], with gamma spectrometry of the final waste packages in [KME20]/[KMA20] being used for verification of waste categorisation. [KUB] shall take grab samples from the recirculation line using an interlock in a fume cupboard in the sampling room and analyse the sample in on-site labs [62]. Samples are taken from the recirculation line to ensure a homogenous sample. Sampling design shall be developed by the [KUB] system post-DR3.

Sampling operations shall be performed based on a group command configuration, initiated by an operator selecting a push button in the waste control room (WCR).

11.4.6.2.4 Tank Fluidisation

Tanks must be periodically fluidised regularly to prevent solids settling at the base of the tank. RGP suggests weekly fluidisation, but this must be confirmed following discussion with resin and filter suppliers. The primary method of fluidisation is pumped recirculation through a recirculation line with jet mixing ejectors. This fluidisation method uses existing equipment to minimise additional moving parts.

Air sparging is also included for tanks as a secondary fluidisation method, though this produces aerosols for HVAC treatment. Air spargers must be periodically deployed to prevent blockages of nozzles.

Fluidisation shall be performed based on a group command configuration, initiated by an operator selecting a push button in the WCR.

11.4.6.2.5 Wet Waste Transfer

Treatment of all wet solid types follows the same pattern, with the treatment campaign every six years (four cycles) and the first treatment campaign occurring after nine years (six cycles) to allow time for the first batch of waste to accumulate.

Treatment campaigns align with a full duty tank where possible to minimise operator burden on commissioning and decommissioning treatment equipment. Treatment campaigns for different waste types are performed consecutively where possible (i.e. processing resins followed by filter solids).

It is anticipated that [KMA10] and [KMA20] batching tanks shall be filled weekly with sufficient waste for uninterrupted processing during the week, however, the details of the processing throughput will be subject to the supply chain's proposed system design configuration. Processing volumes account for shift patterns of trained operators, which are to be defined by plant operators.

Wet waste transfer is initiated by operators managing treatment equipment, with an interface between COTS equipment and [KME20] control logic.

It is suggested that there are cameras in transfer areas, with pan and zoom functions, to assist in monitoring operations.

11.4.6.2.6 Flushing

[KME20] pipework must be flushed after transfer operations to reduce the operator dose from pipework and prevent solids settling out in dead legs/cavities.

Flushing effluent shall preferentially be provided by [KNF30], to reduce contamination of demineralised water. However, a Demineralised Water Supply System [GHC] connection is also included as a backup. Flushing duration has yet to be confirmed in design, given flushing flowrate and piping layout are not confirmed.

Flushing shall be performed based on a group command configuration, initiated by an operator selecting a push button in the WCR. Flushing is not an automatic operation included in transfer operations but shall be outlined on operator actions sheets following BAT assessments.

11.4.6.3 [KME30] System and Equipment Operation

11.4.6.3.1 Interim Storage

In order to interim store the ILW packages until disposal at a GDF, the packages shall be optimised and protected. Appropriate environmental conditions and controls are put in place to maintain and maximise the life of the stored packages to prevent degradation and ensure the disposability of the packages is maintained.

In addition to the baseline of package conditions, the package quality management system describes the inspection and monitoring programmes. The remote monitoring and inspection equipment does not require continuous operator input, however, operator actions will be defined in the package monitoring programme. The waste package monitoring programme identifies evolutionary processes that may affect the performance of the package safety functions and measurable indicators of these processes.

The operator must regularly review the maintenance, periodic testing and inspection programmes. Periodic surveillance and inspection shall be facilitated by deployment of at least one full scale representative dummy package on top of which an optimum number of dummy packages will be decided. An optimum number of coupons shall also be deployed. The operator will routinely inspect and test the dummy package and selected coupons to assess the container performance (e.g. signs of degradation or corrosion, loss of mechanical strength etc.) and the store conditions against the baseline. Approach A23 of the Nuclear Decommissioning Authority (NDA) Interim Storage of Higher Activity Waste guidance [63] will be used to establish the necessary condition monitoring and inspection regime.

11.4.6.3.2 Export

Figure 11.4-1 provides an overview of the on-site transfer process that culminates in the transportation of the waste packages to a GDF. The flow chart illustrates the movement of the waste packages from [KMA20] to the storage facility and the handling process in the store before long-term interim storage and emplacement in transport containers.

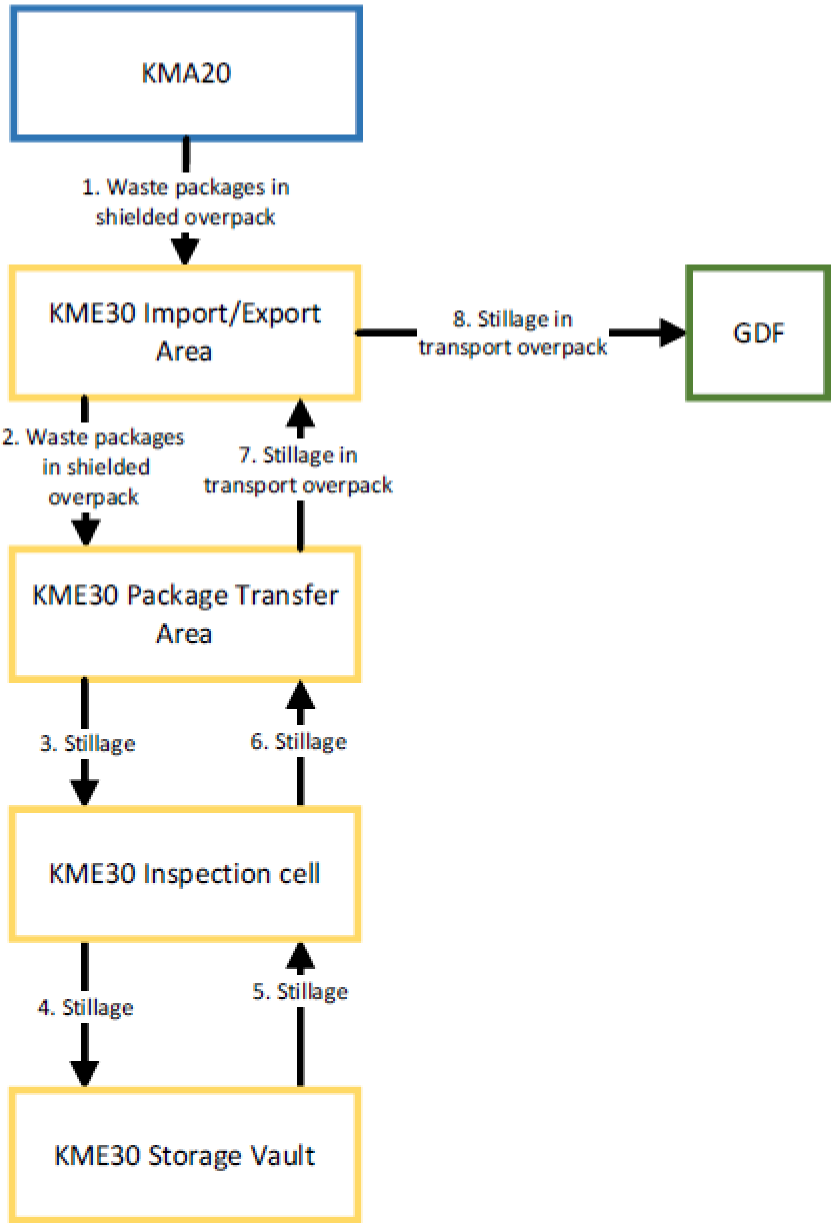

Figure 11.4-1: Illustration of transfer of packages for storage and disposal

11.4.6.4 [KMA10] System and Equipment Operation

11.4.6.4.1 Wet Waste Processing

The [KMA10] wet waste processing system will be designed in collaboration with the supply chain, with a supply chain partner responsible for designing the [KMA10] wet waste processing system, which is currently assumed to take the form of a cementitious grouting plant [60] [61]. It is expected that wet LLW processing campaigns will occur every six years, where immobilisation of the decay-stored boundary level ILW/LLW from the [KME20] system in cementitious grout in THISO freights will take place, prior to onward disposal to LLWR.

It is expected that a fleet wide, modular solution will be developed where pieces of processing equipment can be moved between SMR plants within a fleet (to maximise availability), and successive waste processing campaigns can be carried out in each SMR. It is expected that certain pieces of equipment will be modularised and capable of being moved from SMR to SMR, whilst others will be fixed and remain at each SMR (this is to be decided by the [KMA] supply chain design partner). The equipment will be brought into the waste handling and campaign area and will likely consist of a batching tank, a powder hopper and a mixer vessel (however this will be confirmed as part of [KMA] DR3 activities) with the final disposal package being the THISO.

It is expected that an empty THISO will be brought into the waste handling area and de-lidded (sufficient space and headroom is to be available in the waste handling area to enable removal and laydown of the THISO lid). Wet waste will be pumped to the [KMA10] batching tank from [KME20], before being blended with the cementitious grout powder in the mixing vessel. The grout-waste mix will then be poured into the THISO, and the process will repeat until the THISO has been filled with waste (but not overfilled such that the maximum gross weight of the package has been exceeded).

Once a THISO has been filled and allowed to cure, it will be reassurance monitored and then will be moved onto a transport conveyance for transport and disposal to LLWR.

11.4.6.4.2 Dry Waste Processing

The [KMA10] dry waste processing system consists of a variety of COTS equipment packages, with peak processing observed during outage periods, where significant quantities of soft waste will be generated as part of the outage.

Processing of dry waste involves a variety of activities, such as loading soft waste into 200 litre waste drums and compacting them in the in-drum compactor, size reducing pieces of equipment where practicable in the fume cupboard, loading pieces of waste into waste packages (such as soft-sided packages) and monitoring/characterising waste packages in the various article monitors prior to off-site dispatch. It is envisioned that loading of waste packages into HHISOs also takes place, ensuring that they are compliant with the various receiving facilities WACs. Certain waste packages can be dispatched off-site directly in a curtain-sided trailer, rather than being emplaced into a HHISO (for example, 200 litre drums, which can be banded onto a pallet for off-site dispatch).

Waste packages (such as 200 litre drums or HHISOs) can then be lidded (in the case of a HHISO) or banded to a pallet (in the case of a set of 200 litre drums) and loaded onto conveyances for off-site transport and disposal to the receiving facility (such as LLWR or thermal treatment). Sufficient mechanical handling space will be required in the waste handling area such that vehicles (such as forklift trucks or drum lifters) can access waste packages to enable their movement, lidding/de-lidding (if required), and eventual loading onto transport conveyances for disposal.

11.4.6.5 [KMA20] System and Equipment Operation

Similar to the [KMA10] wet waste processing system, ILW processing campaigns are expected to occur every six years; the design of the processing system will be subject to a supplier design (which will be completed as part of [KMA] DR3). Waste processing occurs in the [KMA20] hot cell where wet ILW is delivered to [KMA20] from [KME20]. A modular solution is also envisioned, where pieces of equipment within the [KMA20] system can be moved from SMR to SMR, to serve an entire fleet of reactor units, where processing campaigns can be appropriately scheduled to optimise availability to multiple SMRs and to minimise space constraints on-site (owing to there being other demands on the available space in the waste handling area for waste dispatch).

Similarly to [KMA10] wet waste processing, it is assumed that a batching tank is used to batch up wet ILW from [KME20] in the hot cell prior to loading into the de-lidded 500 litre drum. A precise volume of waste is transferred into a suitable container before grout powders are then added (via a screw conveyer) and lost paddle mixing is then employed whilst the powders are added to intimately mix the contents of the waste package. The drum is allowed to cure for a pre-defined period before a grout cap is applied. The package is then lidded, pending final curing. Whilst bleed water cannot be completely eliminated, later stages of the design will need to demonstrate that the cementation process will minimise the generation of bleed water by optimising the water/cement ratio.

The exact location and configuration of the final curing is still to confirmed (i.e. if a curing overpack will be employed / what type of overpack, if curing will take place within the hot cell or external to the hot cell (in a shielded area), how drums will be loaded into each overpack etc). It is expected that packages will be allowed to cure for approximately two weeks before onward transfer to the ILW store [KME30], pending disposal to a GDF. Packages will require swabbing prior to transfer to the ILW store, to ensure contamination is within the ILW store WAC. Curing overpacks (if used) can be recycled from the ILW store and reused to facilitate curing of further packages. This process will be repeated until all the wet ILW tanks in [KME20] have been emptied and the processing campaign has been concluded.

11.4.7 Instrumentation and Control

This subsection provides a high-level overview of the basic functions that are allocated to the Reactor C&I Systems [JY_] by the Solid Radioactive Waste Management Systems [KM].

It is anticipated that there will be a WCR and a MCR. The scope split between these two control rooms for [KM] operations has been reviewed by human factors but may be subject to change. It is expected that the WCR will control [KMA20] hot cell operations, recovery operations and transfers from [KME20] tanks to sampling and [KMA10/20]. Transfer of resins/concentrates/filter solids into the [KME20] tanks is controlled by upstream system logic from the MCR. Regular functions such as recirculation and air sparging shall be controlled by the MCR and WCR, to allow flexibility in operation between/during treatment campaigns. If control can be performed from both control rooms, an interlock is foreseen to prevent dual conflicting control.

To support the safe operation and control of the system, [JY_] is required to monitor a range of key system parameters and provide indication of these to the operator in the MCR and WCR. Duplication of monitoring and indication is included for safety claimed instruments and instruments interfacing with other systems control.

Alarms and warnings to indicate that key system parameters are outside of the defined performance bands and/or safety limits are provided. It is assumed that alarms and warnings are provided to the operator in both the MCR and WCR.

Across [KME20] the key parameters can be grouped generically as:

- Tank level - this includes three separate instruments split as:
- high alarm
- high-high alarm and trip
- low warning
- Tank pressure - detecting abnormal deviation from the set point.
- Bund level - level sensor determines if leaking occurs and acts as a prompt to start recovery operations.
- Pump discharge flowrate - detecting abnormal deviation from the set point.

A summary of the key monitoring and indication requirements for the system, and a list of alarms, is provided in the [KM] SDD [58].

11.4.8 Examination, Maintenance, Inspection and Testing

This section discusses the [KME20] system only, given [KME10] and [KME30] maintenance shall be developed at a later design stage.

At DR3, the Storage System for Wet Solid Radioactive Waste [KME20] has a TLA module in DOORS populated with all known maintenance tasks (in line with design maturity), specific to the system environment and the operating context.

The maintenance philosophy is that all components and structures of [KME20] will be designed to be maintainable unless the system equipment is in a walled-in-cell (i.e. [KME] tanks). Therefore, [KME20] shielded pipe run must have removable walls/access panels to allow maintenance of pipework. Routine inspection and testing and preventative maintenance shall be performed on accessible [KME20] equipment to improve reliability. Inaccessible equipment shall not undergo regular maintenance and reliability shall be demonstrated by regular remote inspection.

Maintenance requirements for [KME20] are reduced by including considerations to minimise resin entrapment and the potential of resin blockage. Tanks are regularly fluidised to prevent solids settling/resin plating. Use of cleaned process effluent stored in [KNF30] tanks is preferably used for any rinsing, washing or fluidising, instead of [GHC] demineralised water, in order to minimise generated liquid effluent from maintenance operations.

Local operations shall be performed once the system has been emptied and flushed with clean water. A confirmation of the lack of activity should be sought prior to start of work. Additional efforts, such as cleaning or provision of temporary shielding, may be performed on areas of known waste accumulation.

[KME] SDD [58] outlines proposed techniques to undertake EMIT e.g. remotely inspecting tanks using cameras lowered through a port in the shielded cell ceiling.

11.4.9 Radiological Aspects

Normal dose assessments have not been performed for these systems at this stage in design.

Dose risk to operators shall be reduced for the [KME10] and [KME20] systems by the following measures:

- Shielding around tanks and pipework
- Routing of [KME20] pipework away from high occupancy areas
- Access controls for pump and valve room and pipework corridors during [KME20] transfer operations
- No-access to tank cells during plant operation
- Containment of [KME20] equipment, including leak tight bunding and direct HVAC extraction on tanks
- Flushing after transfers to remove accumulated solids
- Remote inspection of tanks
- Regular waste processing for dry LLW to reduce accumulated activity in [KME10] storage area
- Delayed transfer of resins and filter solids to [KME20], to allow for in situ decay of short-lived radionuclides

- Waste treatment campaigns to be performed by trained, suitably qualified and experienced person (SQEP) operators with a dedicated WCR

Dose risk to operators for [KMA] equipment shall be developed later in design through engagement with suppliers and commencement of [KMA] design study.

Operational dose assessments shall be performed for this system once operational procedures are confirmed in later design. There shall be area radiation monitors in waste handling and storage areas, with local alarms.

11.4.10 Performance and Safety Evaluation

Performance testing requires the components and system to be operated and observed in a holistic way to demonstrate functional behaviour for verifying against relevant performance criteria. As well as the requirements for functional testing this is also likely to require electrical supply, C&I and all relevant representative interfaces. Performance testing must be part of SAT.

[KME10] will not require significant commissioning performance tests. [KME30] performance tests shall be defined in later stages of design.

[KME20] can be initially set up based on the verification testing performed, RGP and vendor feedback, but due to the integrated nature of the system, performance of the system cannot be verified at the MEP factory. Similarly, it is not considered possible to robustly reflect the appropriate C&I architecture offsite to provide reliable safety claims once the system is fully installed and operational.

[KME20] shall be cold commissioned in association with tests on upstream systems e.g. CVCS shall test resin bed functionality using an inactive resin which can then be discharged to the [KME20] tanks for commissioning of recirculation, sampling and transfer. Cold commissioning of the system will ensure that the system's components are functioning as expect but will not be able to verify that the system suitably designed for managing active wastes. This optimisation shall be performed during plant operation, after active solid waste has been generated on site. Learning from the first of the fleet is expected to enable optimised commissioning of the waste treatment system.

11.4.11 Installation and Commissioning

11.4.11.1 Installation

[KM] equipment is a mixture of permanent and mobile equipment, and equipment will be a mixture of RR SMR equipment and turnkey equipment.

Mobile equipment is the preferred supplier approach for [KMA10] wet processing equipment and the [KMA10] and [KMA20] grout plants. Mobile equipment shall be fully transportable and modular, where practicable, allowing equipment to be maintained by the supplier between operations and potentially shared between locations.

The [KMA] system is expected to be all turnkey equipment, perhaps with the exception of the [KMA10] buffer tank and [KMA20] buffer tank, which may be fixed units (subject to design study).

A preliminary outline [KME] permanent equipment installation plan has been developed as part of concept development. However, one of the key features of this plan is the modularisation of the major components to maximise factory manufacturing and assembly and to minimise the amount of site activity where possible. Installation plans will be developed in line with the RR SMR ICOM policy post-DR3 [33].

Optioneering concluded that the preferred option for [KME20] processing equipment is a late install into a hot cell with permanent equipment [64]. [KME20] equipment will not be used for the first ten years of plant operation as sufficient waste has not been accumulated. Late install does not foreclose development in treatment techniques, avoids installed equipment degrading from lack of use and avoids re-commissioning burden when required for use.

11.4.11.2 Commissioning

The outline plan for commissioning includes both FAT activities carried out at the MEP Factory, as part of the modular assembly stage, and SAT at the SMR installation site. Where possible, commissioning shall be performed on module assemblies in the factory, to exploit the V&V able to be delivered by FAT thereby reducing the time required for commissioning testing on-site. The expectation is that packaged equipment will, where possible, undergo FAT testing at vendor factories to minimise specialist equipment requirement of the MEP factory. Detailed commissioning plans will be developed in line with the SMR ICOM policy [33].

11.4.12 BAT and ALARP in Design Development

The design of the Solid Radioactive Waste Management Systems [KM] is being developed in accordance with the systems engineering design process, which includes design to codes and standards according to the safety classification, a systematic optioneering process with down-selection of design options based on assessment against relevant safety and environmental criteria (as described in E3S Case, Version 2, Tier 1, Chapter 3: E3S Objectives and Design Rules for Structures, Systems and Components [34] and the Approach for Optimisation through the Application of BAT report [35]), and alignment to RGP and OPEX.

Key decisions have their own decision file that records decision rationale, as well as their own entry in the SMR decision register which is stored in the DOORS database. Table 11.4-3 presents a summary of the key decisions and optioneering made that relate to the Solid Radioactive Waste Management Systems [KM].

Table 11.4-3: Key design decisions for the Solid Radioactive Waste Management Systems [KM]

Decision description	Summary	Decision file reference
Optioneering of methods for treatment of solid radioactive waste	• Evaluates encapsulation methods for wet ILW (separate assessments for resins and backwashed filter solids), dry ILW, wet LLW and dry LLW. • Grouting is selected for all wet waste, and dry waste shall be packaged in suitable containers for off-site disposal or in-situ decay. • Optioneering is performed by first pre-screening options to select options with a suitable technology readiness, relevant operational experience and compatibility with RR SMR project drivers. Short-listed options are assessed using a Pugh matrix.	[60]

Decision description	Summary	Decision file reference
Optioneering for grout treatment of ILW and LLW wet and solid wastes	• Considers different methods for encapsulating ILW in cement including modular ILW grout plant with waste loading in a shielded hot cell (selected method), transportable modular ILW grout plant with waste loading inside the modular plant and an installed grout plant. • Evaluates if LLW should be encapsulated using a separate grout plant (selected option) or using a common grout plant for ILW and LLW.	[61]
Solid radioactive waste container choice – decision record	• Decision on suitable packages for encapsulated wet ILW, evaluating various standard waste container designs outlined and endorsed by NWS at a future GDF (500 litre robust shielded drum selected). • Re-evaluation of decision expected upon confirmation of the location and design of solid waste treatment system equipment. • DAW container decision not performed as source term and volume not yet finalised. This decision shall be made following [KMA] system DR3. • LLW containers are not selected in this decision, given they are expected to follow LLWR WAC, which will be developed through contract agreements with LLWR. • Package selection discussed in SMR0000579 [60] and SMR0000640 [61] has been superseded by the selection in SMR0005128 [65].	[65]
Management of dry solid intermediate level radioactive waste – decision file	• The preferred option for temporary storage is in robust shielded containers, which provide better accident performance and radiological protection compared to thin-walled stainless steel containers. • As the size, type and source term of the dry solid ILW have yet to be evaluated specifically for the RR SMR, the selection of specific container – either the 500 litre robust shielded drum or the 3 m^3 robust shielded box – will not be foreclosed at this stage until maturity of the reactor design and layout is further developed. • The selection of container also does not foreclose options of onward processing of the waste into a disposal waste package for eventual disposal in a GDF.	[66]

Decision description	Summary	Decision file reference
Solid radioactive waste collection system [KME20] containment strategy	• The [KME20] tank containment strategy is to locate each type of waste in a separate bunkered tank room that acts as a leak tight bund. Each tank room will be no human-access for maximum radiation protection and unavailable for maintenance. If there is leakage from a tank, the leak is identified by level sensors on the bund. Any remaining media in the damaged tank can then be moved to the non-damaged tank designated for the leaked media (with ILW resins sent to boundary resin tanks). Any leaked media shall be recirculated from the bund to this tank using the recirculation pump. If maintenance is required in the sealed cell, all tanks in the bunker must be emptied to the solid radioactive waste processing system [KMA] and flushed prior to operator entry for inspection and maintenance. • The [KME20] pump containment strategy is to have a separate bund for each pump in the common pump room, with level sensors on each bund. • The [KME] pipe containment strategy is to have an outer containment on pipe transfer routes for collecting leaks. Leaks shall be drained to either the tank or pump bund depending on location and detected by the bund level sensor.	[67]
[KME20] pump type selection and pumping strategy – decision file	• This assessment outlines requirements on [KME20] pumps and weighs performance against project drivers. • Stakeholder engagement to assess project drivers e.g. mechanical performance, maintainability, reliability. • Recommended pump type: positive displacement pump, air operated double diaphragm pump.	[59]

11.4.13 Ongoing Design Development

The RR SMR design definition is currently in development as described section 11.0.1. Areas of further work are identified through multi-discipline engineering design activities, e.g. HAZOPs, LOPA, and DRs and will be informed by E3S functional requirements, environmental and non-functional system requirements placed onto the design as the safety analysis is developed.

Assumptions used to develop [KM] design are listed in the relevant requirements specification [68]. Assumptions and further work items are listed for [KME] in assumptions module for the solid radioactive waste storage system [KME] [69]. Assumptions for [KMA] have yet to be issued.

11.4.14 Disposability Assessment

The term ‘disposability assessment’ can refer to two separate (but related) processes that are undertaken in different contexts, defined as follows:

- Generic design assessment (GDA) disposability assessment – This refers to a preliminary judgement as to the potential acceptability for proposed generic waste packaging approaches. This process is led by the requesting party (RP) undertaking GDA through issue of a report outlining the proposed waste packaging approaches (along with underpinning information) that is assessed by regulators and NWS.
- NWS disposability assessment – This refers to the process led and managed by the Waste Management Directorate of NWS, which is initiated when a waste producer approaches NWS with a specific packaging proposal (i.e. for particular containers and waste stream or streams). The proposal is formally assessed using a detailed procedure that considers multiple technical aspects of the waste, containers and associated information records, and leads to acceptance and endorsement (or rejection) through issue of a letter of compliance (LoC) (a process which is staged to conceptual, interim and final LoCs as the level of detail and confidence is developed).

The term 'disposability case' has been informally established (between NWS and Rolls-Royce SMR Limited) to minimise the potential for confusion over which assessment is being referred to. The first issue of the Disposability Case Report [12] was issued in September 2023 for the purposes of obtaining an expert view from NWS so as to inform the ongoing development of the waste management strategy and design of the RR SMR.

The main areas identified within the Disposability Case Report [12] as requiring further work are as follows:

- Further development of understanding of radiological/non-radiological nature and inventories (for all waste streams but particularly for decommissioning wastes).
- Further development of conceptual retrieval approaches and waste routes (for all waste streams but particularly for decommissioning wastes).
- Identification of decay/interim storage and disposal containers for all wastes at all stages of management.

Table 11.4-4 provides a summary of the RR SMR solid radioactive waste streams with an overview of the associated management approach and is a summary of the information as presented in the Disposability Case Report [12].

Table 11.4-4: The RR SMR wastes disposability case summary

High-level waste type/source	**Management approach overview**
Operational wastes	
Boundary ILW/HLW NFCCs	Storage in the SF pool followed by long-term passive dry storage in dedicated container. Retrieval and repackaging (container type uncertain at this stage) at the final stages of decommissioning for export to a GDF.
ILW NFCCs:	Direct packaging (container type uncertain at this stage) for storage and export to a GDF, or decay storage in a robust shielded container (drum or box) followed by retrieval and repackaging at decommissioning for storage and export to a GDF.

High-level waste type/source	Management approach overview
DAW (ILW)	Decay storage in robust shielded containers (drum or box) followed by management via LLW routes. If unsuitable for LLW routes, retrieval and repackaging (with potential size reduction. Note container type uncertain at this stage) at decommissioning for storage and export to a GDF.
RPV shielding material	This waste stream is specialised to the RR SMR and there is limited UK OPEX of equivalent wastes. Therefore, work will be required to underpin key aspects such as characterisation, handling and containerisation.
Wet solid ILW	Direct cementitious encapsulation in 500 litre unshielded drums, followed by interim storage and export to a GDF at decommissioning.
Dry solid boundary ILW/LLW	Direct cementitious encapsulation in 500 litre unshielded drums, followed by interim storage and export to a GDF at decommissioning (ILW) or decay storage in robust shielded containers (drum or box) followed by management via LLW routes (LLW boundary).
Wet solid boundary ILW/LLW	Direct cementitious encapsulation in 500 litre unshielded drums, followed by interim storage and export to a GDF at decommissioning (ILW) or decay storage in robust shielded containers (drum or box) followed by management via LLW routes (LLW boundary).
Decommissioning Wastes	
Dry solid ILW	Retrieval and storage (approach and container to be determined). Retrieval and repackaging (container type uncertain at this stage) at the final stages of decommissioning for export to a GDF.
Wet solid ILW	Direct cementitious encapsulation in 500 litre unshielded drums, followed by interim storage and export to a GDF at decommissioning.
Dry solid boundary ILW/LLW	Direct packaging (container type uncertain at this stage) for storage and export to a GDF.
Wet solid boundary ILW/LLW	Direct cementitious encapsulation in 500 litre unshielded drums, followed by interim storage and export to a GDF at decommissioning (ILW) or decay storage in robust shielded containers (drum or box) followed by management via LLW routes (LLW boundary).

11.4.15 Waste Package/Management Arrangements

The NWS 'Waste Package Data and Information Recording Requirements' document [70] provides guidance on the data and information recording requirements to cover the history of the packaged waste from the time of waste arising, through initial waste characterisation, waste package development, to package production, storage, transport and disposal into a UK national GDF. Once in the operational phase, the RR SMR will need to meet these requirements, along with those in the 'Long-term Management of Information and Records: Explanatory Material and Guidance' document [71] for long-term retention of waste records.

The key requirements on the operator of any facility that produces radioactive waste that may require disposal to a GDF are as follows:

- The waste packager is responsible for the development of a data and information recording system that would establish the means of capturing information in order to create the disposability record for each waste package.
- The range of information that would need to be recorded for each distinct waste package will be unique and the development of a tailored system may be required for each waste type and packaging campaign.
- Information would be created over the entire lifetime of the waste package, from conception of the packaging process, through process development, waste package production, storage, transport and ultimately disposal.
- Although much relevant information would arise during the development of the packaging process, information acquisition will continue into the waste package production stage and beyond. The information acquired after production would generally focus on storage conditions, interim movements, and package evolution.
- The assessment of packaging proposals, as part of the disposability assessment process leading to potential endorsement, will assist in the development of the data and information recording system through discussion and agreement of the particular disposability record requirements.

It will need to be demonstrated to NWS that suitable data gathering arrangements (in line with the requirements described above) will be in place in the RR SMR waste management systems prior to system commissioning.

Three broad categories of data are expected to form a disposability record, as follows:

- Class A – Underpinning and justification: information that applies to the waste type as a whole, in particular the documents that define the origin of the waste, the packaging process, the results of a development programme, waste container manufacturing specifications, the anticipated properties of the waste package and the waste package disposability record.
- Class B – Specification: a concise statement of the precise requirements to produce a waste package that would be compliant with the obligations for storage, transport and disposal.
- Class C – Compliance: information collected about the as-manufactured waste packages, primarily required to demonstrate compliance with the specifications.

For the long-term management of waste package records, NWS outlines a number of different recording media, and also states that transfer of records to a long-term archive facility does not absolve a waste producer of a responsibility to manage and preserve data into the long term.

For the RR SMR, the identification of optimal records production, management and long-term retention systems should not be attempted until there is more detailed information available on the waste management systems, along with developed understanding of the waste types, natures, and volumes.

It is accepted at this stage that waste package records will need to be 'born digital' i.e. to be recorded directly (i.e. through embedded sensors and systems) into digital format at the time of packaging, with no intermediary paper or other record (as has been the case with some legacy waste packaging systems at other sites), which have been the cause of the loss (i.e. total loss, or partial loss through fidelity problems, etc) of records data. Therefore, digital data collection systems will need to be incorporated into the design of waste management and packaging systems from conceptual stage onwards.

It is proposed that a future Dutyholder/Licensee/Permit Holder develops a records management plan/strategy based upon the digital data systems incorporated into the design of waste management and packaging systems to account for technology and software developments and the general management and retention of records.

11.5 Conclusions

11.5.1 ALARP, BAT, Secure-by-Design, Safeguards-by-Design

Reference should be made to E3S Case, Version 2, Tier 1, Chapter 24: ALARP Summary [72], the Rolls-Royce SMR Limited IWS [4] for further information on how the design for the management of radioactive waste has included the principles of ALARP, BAT, Secure-by-Design, and Safeguards-by-Design.

The waste hierarchy is fundamental to the systems' design process and strategical decisions surrounding conventional and radioactive waste. Rolls-Royce SMR Limited has integrated the principle of 'minimisation of waste' into the design decision process which integrates BAT, ALARP, Secure-by-Design and Safeguards-by-Design. Process 'C3 Develop Solution' of the Engineering Integrated Management System (IMS) can be traced down to the goal-based (non-perspective) process 'C3.2.2-3 Engineer safe, secure, safeguarded and environmentally sound products'. The latter defines the general approach to implementing an E3S philosophy.

11.5.2 Assumptions and Commitments on Future Dutyholder/Licensee/Permit Holder

Table 11.5-1: Assumptions and commitments on future Dutyholder/Licensee/Permit Holder

Assumption/Commitment	ID	Description
Commitment	C11.1	Application of the waste management hierarchy principles will be incorporated into operating procedures. For example, operating instructions will prevent bringing materials into radioactive areas unless necessary.
Commitment	C11.2	EMIT of SSCs will be undertaken as required by the engineering design. SSCs must be appropriately maintained to perform their required function and help ensure waste is managed in accordance with BAT.
Commitment	C11.3	Accumulation of radioactive waste on-site will be minimised so far as is reasonably practicable. Licence Condition 32 states that the licensee shall make and implement adequate arrangements for minimising so far as is reasonably practicable the rate of production and total quantity of radioactive waste accumulated on the site at any time and for recording the waste so accumulated.
Commitment	C11.4	Where feasible, new technologies will be utilised where it is BAT to do so to further optimise waste management. For example, advances in waste characterisation or treatment should be utilised where the design allows for their use.

Assumption/Commitment	ID	Description
Commitment	C11.5	During interim storage of solid radioactive waste, the operator must regularly review the maintenance, periodic testing and inspection programmes. This will help maintain the integrity of solid waste during interim storage and prevent the need for re-work of waste packages.
Commitment	C11.6	The operator will routinely inspect and test the dummy package and selected coupons to assess the container performance (e.g. signs of degradation or corrosion, loss of mechanical strength etc.) and the store conditions against the baseline. This will help maintain the integrity of solid waste during interim storage and prevent the need for re-work of waste packages.
Commitment	C11.7	A records' management plan/strategy should be developed based upon the digital data systems to be incorporated into the design of waste management and packaging systems.

11.5.3 Conclusions and Forward Look

The generic E3S Case objective at Version 2 is 'to provide confidence that the RR SMR design will be capable of delivering the E3S fundamental objective as it developed from a concept design into a detailed design' [7]. This confidence is built through development and underpinning of top-level claims across each chapter of the E3S Case, through supporting arguments and evidence. The top-level claim for Chapter 11 is 'radioactive waste systems and arrangements are conservatively designed and verified to deliver E3S functions through-life and minimise the generation of radioactive waste and discharges, in accordance with the E3S design principles, to reduce risks to ALARP, apply BAT and in line with Secure-by-Design and Safeguards-by-Design'.

The arguments and evidence presented to meet the generic E3S Case objective at Version 2 include radioactive waste management policies and design guidance that communicate the principles and requirements of the Radioactive Substances Regulation, set out in Schedule 23 of the Environmental Permitting (England and Wales) Regulations [73], which are embedded into the design decision and optioneering processes. A general set of radioactive waste management design requirements are established in the RR SMR requirements management system as non-functional system requirements, which are applied to SSCs through engineering processes. The application of these processes supports the ongoing design of the RR SMR to prevent, and where that is not possible, minimise radioactive waste arisings and facilitate their effective management throughout their lifecycle.

Rolls-Royce SMR Limited has adopted a waste-oriented design decision-making methodology underpinned by key design objectives that ensure that the relevant UK waste legislations are taken account of and that ALARP, BAT, Secure-by-Design, Safeguards-by-Design and waste management principles, are prioritised.

The waste inventory and the disposal routes are not fully defined due to the waste systems being at a relatively early stage of design and development. Further development and decision making will be required in order to manage the remaining risks associated with waste arisings and their management approaches, and to make the overall strategy more robust.

Forward actions have been identified within the Rolls-Royce SMR Limited IWS [4] to assist in the ongoing development of a more robust waste management strategy. This robust waste management strategy will generate further arguments and evidence to underpin claims in line with the E3S Case Route Map [6] and will be reported in future revisions of the generic E3S Case, which will further build confidence that the RR SMR can deliver its fundamental E3S objective.

11.6 References

[1] Rolls-Royce SMR Limited, SMR0004486 Issue 3, “Environment, Safety, Security and Safeguards Case, Version 2, Tier 1, Chapter 29: Quantification of Radioactive Effluent Discharges and Proposed Limits,” May 2024.

[2] Rolls-Royce SMR Limited, SMR0005548 Issue 1, “Identification of Environmental Functions and Environmental Measures,” July 2023.

[3] Rolls-Royce SMR Limited, SMR0008127 Issue 1, “Decommissioning and Waste Management Plan,” September 2023.

[4] Rolls-Royce SMR Limited, SMR0002131 Issue 2, “Rolls-Royce Small Modular Reactor Integrated Waste Strategy,” October 2023.

[5] Rolls-Royce SMR Limited, SMR0010323 Issue 2, “Environment, Safety, Security and Safeguards Case, Version 2, Tier 1, Chapter 28: Sampling and Monitoring Arrangements,” May 2024.

[6] Rolls-Royce SMR Limited, SMR0002155 Issue 3, “E3S Case CAE Route Map,” November 2023.

[7] Rolls-Royce SMR Limited, SMR0004294 Issue 3, “Environment, Safety, Security and Saferguards Case, Version 2, Tier 1, Chapter 1: Introduction,” May 2024.

[8] Rolls-Royce SMR Limited, SMR0003023 Issue 1, “Rolls-Royce Small Modular Reactor Codes and Standards,” October 2022.

[9] Rolls-Royce SMR Limited, SMR0000631 Issue 2, “SMR System Design Description for Liquid Radioactive Effluent Processing System (KNF),” June 2023.

[10] Rolls-Royce SMR Limited, SMR0000746 Issue 2, “System Design Description for the Gaseous Radioactive Effluent Treatment System (KPL),” June 2023.

[11] Rolls-Royce SMR Limited, SMR0001122 Issue 2, “Rolls-Royce Small Modular Reactor - Solid Operational Waste Identification,” November 2023.

[12] Rolls-Royce SMR Limited, SMR0007665 Issue 1, “Rolls-Royce Small Modular Reactor - Disposability Case Report,” September 2023.

[13] Rolls-Royce SMR Limited, SMR0007016 Issue 1, “Low Level Waste Arisings Technical Note,” December 2023.

[14] Rolls-Royce SMR Limited, SMR0008113 Issue 2, “Environment, Safety, Security and Safeguards Case, Version 2, Tier 1, Chapter 27: Demonstration of Best Available Techniques,” May 2024.

[15] Rolls-Royce SMR Limited, SMR0000894 Issue 1, “Normal Operation Sensitivity Source Term Dataset,” May 2022.

[16] Rolls-Royce SMR Limited, SMR0003323 Issue 1, “Waste Treatment Systems Mass and Activity Balance (MAB) Tool,” May 2023.

[17] Rolls-Royce SMR Limited, SMR0006746 Issue 1, “Wet Solid Low Level Waste (LLW) and Intermediate Level Waste (ILW) Activities Quantification,” July 2023.

[18] Atkins, EDNS01000893358, Issue 1, “Spent Liquid Effluent Optioneering,” June 2020.

[19] Atkins, EDNS01000900346 Issue 1, “Tritium Balance and Discharges Study,” September 2020.

[20] Rolls-Royce SMR Limited, SMR0004702 Issue 1, “System Design Description for the HVAC Systems Serving Controlled Areas and Uncontrolled Areas of Reactor Island (RI),” June 2023.

[21] Rolls-Royce SMR Limited, EDNS01000887611 Issue 2, “UK SMR Environment. Safety, Security and Safeguards Categorisation and Classification Method,” August 2021.

[22] Rolls-Royce SMR Limited, SMR0000632 Issue 2, “SMR System Design Description Reactor Island Drainage System [KTA],” November 2023.

[23] Rolls-Royce SMR Limited, SMR0000844 Issue 2, “Requirements Specification for the KN_KNF (Radioactive Liquid Effluent Treatment System),” June 2023.

[24] Rolls-Royce SMR Limited, SMR0000849 Issue 2, “Reactor Island Collection & Drainage System [KTA] - Requirements Specification,” January 2024.

[25] Rolls-Royce SMR Limited, SMR0000852 Issue 2, “Functional Bill of Materials (FBoM) for the Reactor Island Collection & Drainage System [KTA],” January 2024.

[26] Rolls-Royce SMR Limited, SMR0000848 Issue 2, “Functional Bill of Materials for KNF,” July 2023.

[27] Rolls-Royce SMR Limited, SMR0004363 Issue 3, “Environment, Safety, Security and Safeguards Case, Version 2, Tier 1, Chapter 23: Structural Integrity,” May 2024.

[28] Rolls-Royce SMR Limited, SMR0005213 Issue 1, “Power Station Operating Philosophy,” July 2023.

[29] Rolls-Royce SMR Limited, SMR0004247 Issue 3, “Environment, Safety, Security and Safeguards Case, Version 2, Tier 1, Chapter 13: Conduct of Operations,” May 2024.

[30] Rolls-Royce SMR Limited, SMR0003911 Issue 1, “RR SMR HMI Style Guide,” December 2022.

[31] Health and Safety Executive, HSG253, “The safe isolation of plant and equipment,” 2006.

[32] Rolls-Royce SMR Limited, SMR0004769 Issue 2, “Active Waste Systems Bulk Shielding Assessment,” July 2023.

[33] Rolls-Royce Report, EDNS01000488614, “SMR Installation and Commissioning Policy,” September 2016.

[34] Rolls-Royce SMR Limited, SMR0004589 Issue 3, “Environment, Safety. Security and Safeguards Case, Version 2, Tier 1, Chapter 3: E3S Objectives and Design Rules for Structures, Systems and Components,” May 2024.

[35] Rolls-Royce SMR Limited, SMR0004683 Issue 2, “Approach for Optimisation through the Application of BAT,” March 2023.

[36] Rolls-Royce SMR Limited, SMR0000316 Issue 1, “RI-161 Collection and Drainage of Radioactive Effluents Decision File,” March 2022.

[37] Rolls-Royce SMR Limited, SMR000314 Issue 1, “Decision File - KNF Degasser and Evaporator Heating Method,” February 2022.

[38] Rolls-Royce SMR Limited, SMR0000315 Issue 1, “Decision File - KNF Primary and Spent Effluent Processing and Treatment Train Merging,” March 2022.

[39] Rolls-Royce SMR Limited, SMR0000798 Issue 1, “KBE Coolant Purification System Architecture Decision File on Pressure, Filter Type and Arrangement and Changeout Method, Component Location and Containment Isolation Classification,” September 2022.

[40] Rolls-Royce SMR Limited, SMR0003206 Issue 1, “R01-494: Recovery and Management of Boron Following Emergency Boron Injection,” November 2022.

[41] Rolls-Royce SMR Limited, SMR0002064 Issue 1, “R01-477 Management of Active Steam Generator Blowdown,” November 2022.

[42] Rolls-Royce SMR Limited, SMR0000839 Issue 2, “Gaseous Radioactive Effluent Treatment System (KP/KPL) - Requirements Specification,” June 2023.

[43] Rolls-Royce SMR Limited, SMR0006031 Issue 1, “Requirements Specification (R-module) for KL System,” June 2023.

[44] Rolls-Royce SMR Limited, SMR0000843 Issue 2, “Gaseous Radioactive Effluent Treatment System - Functional Bill of Materials,” July 2023.

[45] Rolls-Royce SMR Limited, SMR0006117 Issue 1, “Functional Bill of Materials for the KLA System,” July 2023.

[46] Rolls-Royce SMR Limited, SMR0006118 Issue 1, “Functional Bill of Materials for the KLB System,” July 2023.

[47] Rolls-Royce SMR Limited, SMR0006119 Issue 1, “Functional Bill of Materials for the KLC System,” July 2023.

[48] Rolls-Royce SMR Limited, SMR0006121 Issue 1, “Functional Bill of Materials for the KLF System,” July 2023.

[49] Rolls-Royce SMR Limited, SMR0006122 Issue 1, “Functional Bill of Materials for the KLL System,” July 2023.

[50] Rolls-Royce SMR Limited, SMR0001535 Issue 2, “RR SMR GB Generic Site Envelope,” June 2023.

[51] BSi, BS ISO 26802, “Nuclear Facilities - Criteria for the design and operation of containment and ventilation systems for nuclear reactors,” 2010.

[52] Rolls-Royce SMR Limited, SMR0006222 Issue 1, “Gaseous Radioactive Waste Processing System [KP] and Gaseous Effluent Treatment System [KPL] Detailed Verification Strategy,” September 2023.

[53] Atkins, “Gaseous waste management optioneering, EDNS01000900096/001,” 2020.

[54] Rolls-Royce SMR Limited, SMR0003764 Issue 1, “R01-418 – Design of Reactor Island HVAC HEPA Filters – Decision Record,” May 2023.

[55] Rolls-Royce SMR Limited, SMR0006498 Issue 1, “Assumptions for Gaseous Radioactive Effluent Treatment System [KP/KPL] Requirements Module,” June 2023.

[56] Rolls-Royce SMR Limited, SMR0007883 Issue 1, “Categorisation and Classification for Solid Radioactive Waste Storage System (KME) Safety Functions,” October 2023.

[57] Rolls-Royce SMR Limited, SMR0001530 Issue 2, “Functional Bill of Materials for the Temporary storage system for wet and dry ILW (KME20),” October 2023.

[58] Rolls-Royce SMR Limited, SMR0001123 Issue 2, “System Design Description for the Solid Radioactive Waste Management System (KM),” October 2023.

[59] Rolls-Royce SMR Limited, SMR0003205 Issue 1, “R01-537: KME20 Pump Type Selection and Pumping Strategy,” July 2023.

[60] Rolls-Royce SMR Limited, SMR0000579 Issue 1, “Optioneering of Methods for Treatment of Solid Radioactive Waste,” April 2022.

[61] Rolls-Royce SMR Limited, SMR0000640 Issue 1, “Optioneering for Grout Treatment of ILW and LLW Wet and Solid Wastes,” June 2022.

[62] Rolls-Royce SMR Limited, SMR0006048 Issue 1, “[R01-523] - System Architecture for [KUB], [KUK] & [KUL] Reactor Island Sampling Systems - Decision Record,” July 2023.

[63] Nuclear Decommissioning Authority, Issue 4, “Interim Storage of Higher Activity Waste Packages - Integrated Approach,” December 2021.

[64] Rolls-Royce SMR Limited, SMR0005688 Issue 1, “Options Assessment - Installation Location for Wet ILW Cementation System (KMA20),” May 2023.

[65] Rolls-Royce SMR Limited, SMR0005128 Issue 1, “R01-525 Wet Solid Radioactive Waste Container Decision,” April 2023.

[66] Rolls-Royce SMR Limited, SMR0006485 Issue 1, “Management of Dry Solid Intermediate Level Radioactive Waste,” June 2023.

[67] Rolls-Royce SMR Limited, SMR0003223 Issue 1, “Solid Radioactive Waste Collection System (KME20) Containment Strategy,” October 2022.

[68] Rolls-Royce SMR Limited, SMR0001522 Issue 2, "Solid Radioactive Waste Management System (KM) - Requirements Specification," October 2023.

[69] Rolls-Royce SMR Limited, SMR0008372 Issue 1, "Solid Radioactive Waste Storage Syste, [KME] - Assumptions," October 2023.

[70] Radioactive Waste Management, WPS/850/03, "Geological Disposal: Waste Package Data and Information Recording Requirements: Explanatory Material and Guidance," December 2015.

[71] Radioactive Waste Management, WPS/870/03, "Geological Dispoal: Long-term Management of Information and Records: Explanatory Material and Guidance," September 2016.

[72] Rolls-Royce SMR Limited, SMR0004487 Issue 3, "Environment, Safety, Security and Safeguards Case, Version 2, Tier 1, Chapter 24: ALARP Summary," May 2024.

[73] Environmental Protection, England and Wales: The Environmental Permitting (England and Wales) Regulations 2016, December 2016.

11.7 Appendix A: Claims, Arguments, Evidence

Table 11.7-1 provides a mapping of the claims to the corresponding sections of the chapter that summarise the arguments and/or evidence. The full decomposition of claims and link to underpinning Tier 2 and Tier 3 information containing the detailed arguments and evidence is presented in the E3S Case CAE Route Map [6]. The route map includes the trajectory of Tier 2 and Tier 3 information as the generic E3S Case develops, which will be incorporated into Tier 1 chapters as it becomes available and in line with generic E3S Case versions described in [7].

Table 11.7-1: Mapping of Claims to Chapter Sections

Claim	**Section of Chapter 11 containing arguments / evidence summary**
Radioactive waste management and disposal strategies and plans adopt the waste management hierarchy and apply BAT	11.1.6, 11.2.12, 11.3.12, 11.4.12 – Also see E3S Case Tier 1, Version 2 Chapter 27: Demonstration of Best Available Techniques [14].
Radioactive wates (solid, non-aqueous) and spent fuel arisings are quantified, understood and minimised over lifecycle of the RR SMR	11.1.3 – Also see E3S Case Tier 1, Version 2 Chapter 29: Quantification of Radioactive Effluent Discharges and Proposed Limits [1]
Liquid Radioactive Effluent System [KNF] specified E3S requirements are complete and correct	11.2.2
Liquid Radioactive System [KNF] implements its E3S requirements	11.2.3-11.2.9
Liquid Radioactive Effluent System [KNF] design is verified and validated to achieve its E3S requirements through the lifecycle	11.2.10
Processing and Treatment System for Solid Radioactive Waste [KMA] *claims structure as per Liquid Radioactive Effluent [KNF] structure*	11.4
Storage system for wet and solid radioactive waste [KME] *claims structure as per Liquid Radioactive Effluent [KNF] structure*	11.4
Processing and Treatment for Gaseous Radioactive Effluent [KPL] *claims structure as per Liquid Radioactive Effluent [KNF] structure*	11.3
Reactor Island Drainage System [KTA] *claims structure as per Liquid Radioactive Effluent [KNF] structure*	11.2
Fuel Pools Leak Detection and Collection System [KTQ] *claims structure as per Liquid Radioactive Effluent [KNF] structure*	Not covered in this revision

11.8Appendix B

11.8.1 Environmentally Significant SSCs

11.8.1.1 [KNF] and [KTA] Systems

It is noted that there are several monitoring and indication requirements associated with the Liquid Radioactive Effluent Treatment System [KNF] and RI Collection and Drainage System [KTA] for the purposes of in-process monitoring (these can be found in the [KNF] SDD [9]). Table 11.8-1 does not capture each individual measurement parameter or alarm/warning requirement within the [KNF] and [KTA] systems as these will be reviewed prior to entry within DOORS.

Following a review of the [KNF] SDD [9] and [KTA] SDD [22], and using the method set out in [2], the SSCs identified in Table 11.8-1 have been assessed as environmentally significant equipment that contribute to an environmental measure. These SSCs are subject to review prior to entry within DOORS.

Table 11.8-1: Environmentally significant SSCs within [KNF] and [KTA]

System	SSC	High-level environmental function	Description
[KNF10]	Primary liquid effluent transfer pump suction line	Waste treatment & abatement	To remove accumulated solid particulates.
[KNF10]	Vacuum degasser column	Waste treatment & abatement	Removal of dissolved radioactive gases (xenon, krypton) and hydrogen from the reactor coolant.
[KNF20]	Process drains	Waste treatment & abatement	To keep process drain effluent segregated from other effluent categories.
[KNF20]	Chemical drains	Waste treatment & abatement	To keep chemical drain effluent segregated from other effluent categories.
[KNF20]	Floor drains	Waste treatment & abatement	To keep floor drain effluent segregated from other effluent categories.
[KNF20]	Pre-filters	Waste treatment & abatement	To remove total suspended solids from effluent streams.
[KNF20]	RO system	Waste treatment & abatement	To remove total dissolved solids from the effluent streams.
[KNF20]	IX resin beds	Waste treatment & abatement	To remove further contaminants from the effluent streams.
[KNF20]	Post-filters	Waste treatment & abatement	To remove further solids from the effluent streams.

System	SSC	High-level environmental function	Description
[KNF20]	Waste evaporator column	Waste treatment & abatement	To treat spent liquid effluent of relatively high chemical contamination.
[KNF20]	[KNF20] Tanks recirculation line	Sampling & monitoring	To enable a representative sample to be taken.
[KNF20]	Pump suction line	Waste treatment & abatement	To remove accumulated solids.
[KNF30]	[KNF30] Tanks recirculation line	Sampling & monitoring	To enable a representative sample to be taken.
[KNF30]	Pump suction line	Waste treatment & abatement	To remove accumulated solids.
[KTA10]	Reactor coolant drainage tank heat exchanger	Waste treatment & abatement	To reduce the amount of gaseous discharge to the gaseous radioactive effluent treatment system [KPL].
[KTA10]	Reactor coolant drainage tank heat transfer pumps	Waste treatment & abatement	To help cool primary coolant and reduce the amount of gaseous discharge to the gaseous radioactive effluent treatment system [KPL].
[KTA20]	[KTA20] tanks, sumps and pipework	Waste treatment & abatement	To keep process and floor drain effluent segregated from other effluent categories.
[KTA20]	Transfer pumps / recirculation line	Sampling & monitoring	To promote homogenous mixing to allow enable a representative sample to be taken.
[KTA20]	TBC: A solution to remove oil contamination in [KTA20]	Waste treatment & abatement	To remove any oil present in the effluent prior to downstream management.
[KTA30]	[KTA30] tanks, sumps and pipework	Waste treatment & abatement	To keep chemical drain effluent segregated from other effluent categories.
[KTA30]	Transfer pumps / recirculation line	Sampling & monitoring	To promote homogenous mixing to allow enable a representative sample to be taken.

11.8.1.2 Gaseous Radioactive Effluent Treatment System [KPL] and Relevant [KL] Systems

Following a review of the gaseous radioactive effluent treatment system [KPL] SDD [10], the [KL] SDD [20], and using the method set out in [2], the SSCs identified in Table 11.8-2 have been assessed as environmentally significant equipment that contribute to an environmental measure. These SSCs are subject to review prior to entry within DOORS.

It is noted that there are several monitoring and indication requirements associated with the Gaseous Radioactive Effluent Treatment System [KPL] for the purposes of in-process monitoring (these can be found in Table 2 of the [KPL] SDD [10]) and also numerous alarm and waring requirements (Table 7 of the [KPL] SDD [10]). Table 11.8-2 does not capture each individual measurement parameter or alarm/warning requirement within the KPL system as these will be reviewed prior to entry within DOORS. For the [KL] system, those associated with extract HEPA filter differential pressure (DP) have been identified. Those associated with the RR SMR stack [KLS] are not included due to design maturity.

Table 11.8-2: Environmentally significant SSCs within [KPL] and [KL]

System	SSC	High-Level environmental function	Description
[KPL]	Recombiner	Treatment and abatement	Optimal performance of the recombiner will minimise the use of resources i.e. hydrogen and oxygen gases.
[KPL]	Gas compressors	Treatment & abatement	To maximise the amount of gaseous effluent that can be recycled as cover gas and minimise the use of resources.
[KPL]	Charcoal delay beds	Treatment & abatement	To provide hold-up and decay of xenon and krypton, prior to release to the stack via the HVAC systems in processing building for radioactive waste [KLF].
[KPL]	Dryer package and guard bed	Treatment & abatement	A dryer equipment package (a dedicated chiller unit) is proposed for chilling the effluent stream and draining the excess moisture. A guard bed of activated charcoal acts as a sacrificial bed to protect the delay beds from contaminants or moisture carryover.
[KPL]	Exhaust	Containment Treatment & abatement	The exhaust is crucial to ensure that [KPL] discharges are routed to an authorised discharge point to the environment. Helps provide required dispersion to minimise environmental impact.

System	SSC	High-Level environmental function	Description
[KPL]	In-process monitoring equipment e.g. gas concentrations, pressure, temperature, flowrate, moisture, and levels.	Sampling & monitoring	To provide relevant information on in-process performance of [KPL] and resource consumption e.g. the cooled effluent stream is also sampled downstream to monitor the recombiner performance.
[KPL]	Alarm and warning equipment	Sampling & monitoring	To support the safe operation and control of the gaseous radioactive effluent treatment system [KPL].
[KLA]	Carbon filter	Treatment & abatement	To remove gaseous contamination from primary containment.
[KLA], [KLB], [KLC], [KLF], [KLL]	Primary HEPA filters	Treatment & abatement	To remove particulate contamination from the exhaust air before discharge to the environment.
[KLA], [KLB], [KLC], [KLF], [KLL]	Secondary HEPA filters	Treatment & abatement	To remove particulate contamination from the exhaust air before discharge to the environment in case of perforation of the primary HEPA filter.
[KLA]	Carbon filter DP monitor	Sampling & monitoring	To provide information on the performance of the carbon filter.
[KLA], [KLB], [KLC], [KLF], [KLL]	HEPA filter DP monitors	Sampling & monitoring	To provide information on the performance of the HEPA filter.

11.8.1.3 Solid Radioactive Waste Management Systems [KM]

Following a review of the Solid Radioactive Waste Management Systems [KM] SDD [58] and using the method set out in reference [2], the SSCs identified in Table 11.8-3 have been assessed as environmentally significant equipment that contribute to an environmental measure. These SSCs are subject to review prior to entry within DOORS.

It is noted that there are several monitoring and indication requirements associated with the Solid Radioactive Waste Management Systems [KM] for the purposes of in-process monitoring (these can be found in Table 11 of the [KM] SDD [58]) and also numerous alarm and warning requirements (Table 12 of the [KM] SDD [58]). Table 11.8-3 does not capture each individual measurement parameter or alarm/warning requirement within the [KM] system as these will be reviewed prior to entry within DOORS.

Table 11.8-3: Environmentally significant SSCs within [KM]

System	SSC	High-level environmental function	Description
[KMA10]	Low-force compactor	Treatment & abatement	To minimise the volume of LLW prior to transfer to other premises.
[KMA10]	LLW grouting plant[7]	Treatment & abatement	To condition waste in such a way as to facilitate disposal.
[KMA20]	ILW grouting plant[7]	Treatment & abatement	To condition waste in such a way as to facilitate disposal.
[KME10]	Waste storage cages	Treatment & abatement	Used for the appropriate segregation of solid wastes to facilitate optimised waste management routes.
[KME20]	Concentrate tanks	Treatment & abatement	To hold sufficient capacity to allow for optimised treatment of concentrates and to be designed in such a way as to prevent accumulation of solids.
[KME20]	Filter solid tanks	Treatment & abatement	To hold sufficient capacity to allow for optimised treatment of filter solids and to be designed in such a way as to prevent accumulation of solids.
[KME20]	Resins tanks	Treatment & abatement	To hold sufficient capacity to allow for optimised treatment of resins and to be designed in such a way as to prevent accumulation of solids.
[KME20]	Concentrate tanks recirculation line	Sampling & monitoring	To allow a representative sample to be taken.
[KME20]	Concentrate tanks draw-off sump	Treatment & abatement	To allow the removal of accumulated particulate.
[KME20]	Resin tanks recirculation line	Sampling & monitoring	To allow a representative sample to be taken.
[KME20]	Resin tanks draw-off sump	Treatment & abatement	To allow the removal of accumulated particulate.
[KME20]	Pipework flushing supply points	Treatment & abatement	To allow adequate flushing of pipework and prevent the build-up of solids.

[7] Further equipment will be identified within both the LLW and ILW grouting systems once the design has matured.

The bunds associated with each of the tanks in [KME20] are not currently anticipated to be identified as environmentally significant. This is on the basis that there is no direct route to the environment should the bund fail, and whilst any leak from a bund would require clean up and generate associated wastes, this would be undertaken in a controlled manner.

11.9 Glossary of Terms and Abbreviations

AFoE	Annual Frequency of Exceedance
ALARP	As Low As Reasonably Practicable
ASME	American Society of Mechanical Engineers
BAT	Best Available Techniques
BS	British Standard
C&I	Control and Instrumentation
CAE	Claims, Arguments, Evidence
CDS	Collection and Drainage System
CoRM	Confinement of Radioactive Material
COTS	Commercial Off The Shelf
CVCS	Chemistry and Volume Control System
CWI	Cooling Water Island
DAW	Dry Activity Waste
DCIC	Ductile Cast Iron Container
DOORS	Dynamic Object Orientated Requirements System
DP	Differential Pressure
DR	Definition Review
DRP	Design Reference Point
DWMP	Decommissioning and Waste Management Plan
E3S	Environment, Safety, Security and Safeguards
EMIT	Examination, Maintenance, Inspection and Testing
EPRI	Electric Power Research Institute
FAT	Factory Acceptance Testing
FBoM	Functional Bill of Materials
FSF	Fundamental Safety Function
GDA	Generic Design Assessment
GDF	Geological Disposal Facility

HAW	Higher-Activity Waste
HAZOP	Hazard and Operability
HEPA	High Efficiency Particulate Air
HHISO	Half-Height International Standards Organisation
HLSF	High-Level Safety Function
HLW	High-Level Waste
HMI	Human-Machine Interface
HVAC	Heating, Ventilation and Air-Conditioning
IAEA	International Atomic Energy Agency
ICOM	Installation and Commissioning
IEX	Ion Exchange
ILW	Intermediate Level Waste
IMS	Integrated Management System
ISO	International Standards Organisation
IWS	Integrated Waste Strategy
LLW	Low-Level Waste
LLWR	Low-Level Waste Repository
LoC	Letter of Compliance
LOPA	Layers Of Protection Analysis
MAB	Mass and Activity Balance
MCR	Main Control Room
MEP	Mechanical, Electrical and Plumbing
NFCC	Non-Fuel Core Component
NPP	Nuclear Power Plant
NWS	Nuclear Waste Services
OPEX	Operational Experience
PBS	Product Breakdown Structure
PMDB	Preventive Measures Database

PST	Primary Source Term
RCA	Radiologically Controlled Area
RCDT	Reactor Cooling Drain Tank
RCM	Reliability Centred Maintenance
RD	Reference Design
RDS-PP	Reference Designation System for Power Plants
RGP	Relevant Good Practice
RI	Reactor Island
RO	Reverse Osmosis
RP	Requesting Party
RPV	Reactor Pressure Vessel
RR SMR	Rolls-Royce Small Modular Reactor
RWMA	Radioactive Waste Management Arrangements
SAT	Site Acceptance Testing
SDD	System Design Description
SF	Spent Fuel
SGBD	Steam Generator Blowdown
SMR	Small Modular Reactor
SOWI	Solid Operational Waste Identification
SQEP	Suitably Qualified and Experienced Person
SSC	Structures, Systems and Components
THISO	Third-Height International Standards Organisation
TLA	Through Life Activities
UK	United Kingdom
V&V	Verification and Validation
VLLW	Very Low-Level Waste
WAC	Waste Acceptance Criteria
WCR	Waste Control Room
WENRA	Western European Nuclear Regulators Association