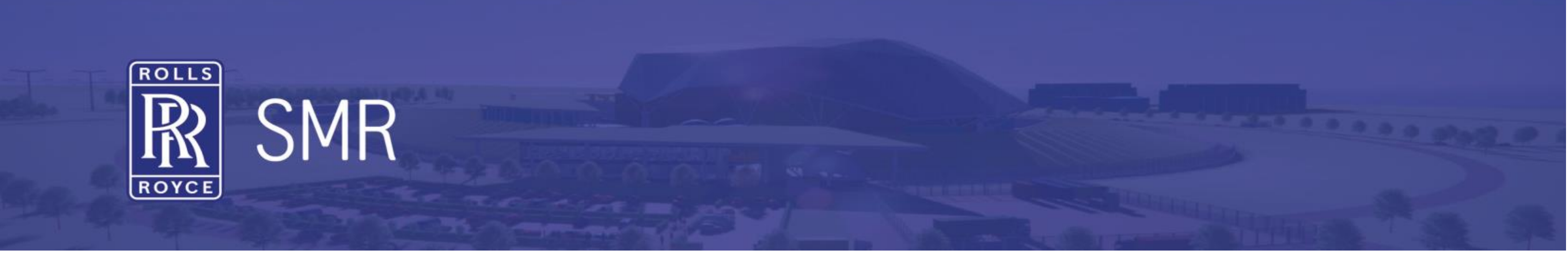

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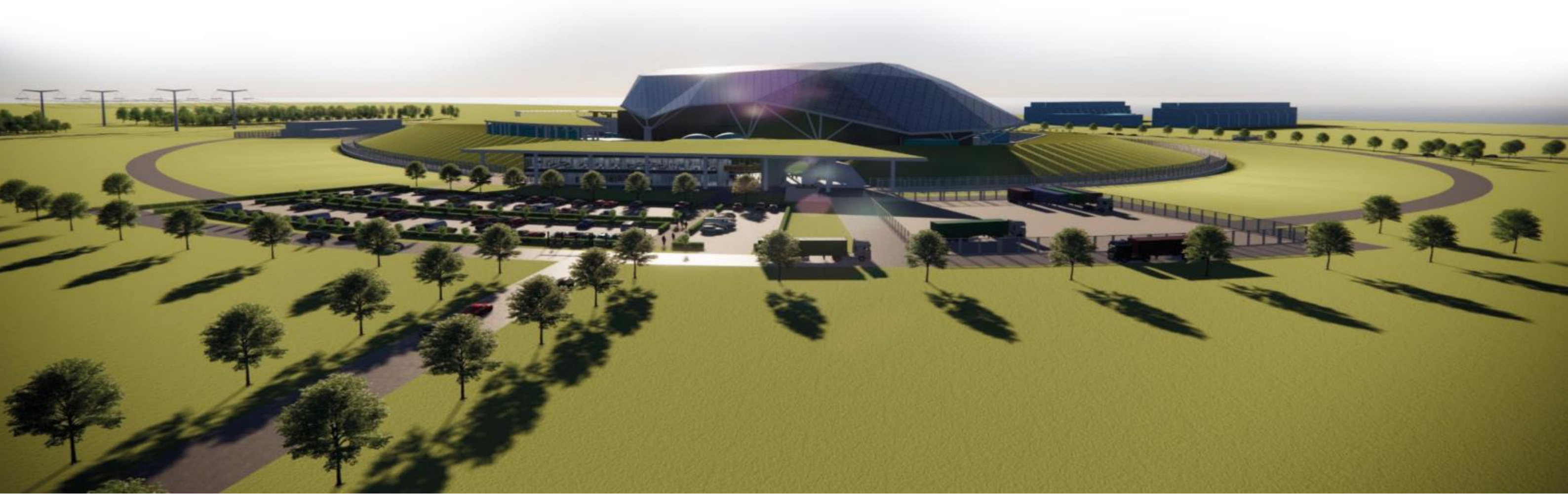
Environment, Safety, Security and Safeguards Case Version 2, Tier 1, Chapter 28: Sampling and Monitoring Arrangements



Record of Change

Date	Revision Number	Status	Reason for Change
April 2024	1	Issue	First issue of chapter 28 which reflects reference design 7 and is aligned to design reference point 1.
May 2024	2	Issue	Updated to correct revision history at issue 1. Chapter changes include: • Additional detail within conclusions section for how arguments and evidence presented meet the generic E3S Case objective • Addition of a future permit holder commitment • Updated list of significant radionuclides (and their groups) that would be monitored at the final outlets to the environment Minor template/editorial updates for overall E3S Case consistency.

Executive Summary

This is chapter 28 of the Environment, Safety, Security and Safeguards (E3S) Case for the Rolls-Royce Small Modular Reactor (RR SMR), which has been issued based upon the information available at reference design (RD7)/design reference point (DRP1).

The purpose of this issue of chapter 28 is to provide an overview of key considerations, including the overarching regulatory framework, that informs the decisions pertaining to sampling and monitoring of the generated RR SMR discharges and disposals.

The chapter presents a description of the arrangements and the rationale for sampling and monitoring of gaseous and liquid radioactive effluents during normal operation of the RR SMR. The focus is on the sampling and monitoring techniques and planned characterisation points (locations) rather than the specific equipment to be used.

For solid and non-aqueous liquid radioactive wastes, the focus is on the sampling and monitoring techniques for the characterisation of these wastes and demonstrating that the design has incorporated facilities to support waste hierarchy principles.

An initial demonstration of the best available techniques (BAT) following the claim, argument, evidence (CAE) structure is provided for the proposed sampling and monitoring arrangements. Arguments and evidence will be developed to provide more detail in future iterations of the chapter.

The chapter also captures forward actions (FA) which will be undertaken to fully achieve the objectives of the chapter for the mature RR SMR design.

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28.0 Introduction to Chapter

28.0.1 Introduction

Chapter 28 of the Rolls-Royce Small Modular Reactor (RR SMR) Environment, Safety, Security and Safeguards (E3S) Case describes the approach and presents information on the sampling and monitoring arrangements for the RR SMR.

The information presented in this chapter is based upon the design information available at reference design 7/design reference point 1 (RD7/DRP1). This chapter will be updated with information that becomes available as the design progresses through detailed design.

The chapter is a Tier 1 document of Version 2 of the E3S Case, as defined in the E3S Case Version 2, Tier 1, Chapter 1: Introduction [1] and draws upon the information of the lower tier documents presenting in a brief manner how the design meets the E3S Case fundamental objective.

The purpose of the chapter is to provide the sampling and monitoring arrangements for radiological waste streams for both in-process systems and for the final discharge points to the environment. Thus, the final aim is to:

- Describe and demonstrate that the proposed arrangements for in-process sampling and monitoring are adequate and represent best available techniques (BAT).
- Describe and demonstrate that the proposed arrangements for final discharge sampling and monitoring of liquid and gaseous wastes are adequate and represent BAT.
- Describe and demonstrate that the proposed arrangements for sampling and monitoring of solid and non-aqueous liquid wastes are adequate and represent BAT.
- Demonstrate that the proposed sampling techniques can meet the required limit of detection (LoD) as stated in the Euratom treaty and relevant regulations (see section 28.0.4).
- Describe the facilities provided for independent periodic sampling (by the regulator) of final discharges of gaseous and liquid waste.

28.0.2 Scope and Maturity

The scope of this issue of the chapter is to provide a description of, and the rationale for, the sampling and monitoring arrangements of the RR SMR for radiological wastes generated during normal operations as defined in the E3S Case Version 2, Tier 1, Chapter 1: Introduction [1]. Thus, the chapter aims to:

- Provide a brief overview of liquid and gaseous effluent treatment systems and the solid waste and non-aqueous liquid management systems.
- Describe, how the options for sampling and monitoring are generated, how decisions are made and how the rationale for these decisions is captured to determine the architecture of sampling and monitoring systems. This information will eventually be used as evidence to support the BAT claims for this chapter.

- At RD7/DRP1 design decisions still need to be finalised and some structures, systems and components (SSCs) are yet to meet a level of maturity commensurate to the sampling and monitoring requirements in terms of scope definition, location, determinands identification and characterisation. Therefore, the chapter:

    - Highlights the current gaps of this issue against the scope of the final iteration of the chapter.

    - Describes the forward action (FA) plan required to ensure that the scope of the chapter will eventually be met.

The scope of this chapter does not include:

- Non-radiological or conventional gaseous, liquid, and solid wastes. Conventional liquid and gaseous discharges are captured in the E3S Case Version 2, Tier 1, Chapter 31: Conventional Environmental Impact and Other Environmental Regulations [2]. Conventional solid wastes are not captured in E3S Case Tier 1 chapters but are captured in the Integrated Waste Strategy (IWS) [3]. Note as final discharge point for liquid effluents covers all liquid effluents, conventional sources are described at a high level within this chapter for completeness.

- The environment monitoring and sampling programme as this is dependent on the specific site location and will need to be developed as part of the site-specific permitting application (see section 28.6.2).

- Monitoring required at decommissioning, as this will be operator specific, dependent on the operational history of the facility, and won't be required for many years when BAT is likely to be very different to now.

- Monitoring of discharges released to the environment during accident or fault conditions.

- Specific aspects of spent fuel (SF) monitoring which will be discussed in the E3S Case Version 2, Tier 1, Chapter 9A: Auxiliary Systems [4].

- The description of specific equipment that will be used for sampling and monitoring purposes of the waste streams.

28.0.3 Claims, Arguments and Evidence Route Map

The overall claims, arguments, evidence (CAE) approach and the set of fundamental E3S claims to achieve the E3S fundamental objective are described in E3S Case Version 2, Tier 1, Chapter 1: Introduction [1].

The approach to optimisation through the application of BAT is described in [5] and the initial BAT case is presented in E3S Case Version 2, Tier 1, Chapter 27: Demonstration of Best Available Techniques [6].

The associated top-level chapter claim for E3S Case Version 2, Tier 1, Chapter 28 is:

Claim 28: The RR SMR has appropriate sampling arrangements, techniques and systems for measuring and assessing discharges of radioactive wastes to the environment and disposals of radioactive waste to other premises.

This overarching claim is decomposed into several high level (level 1) claims, which will need to be supported by suitable arguments and evidence to show that the design of the RR SMR has been optimised and can meet the E3S fundamental objective:

- **Claim 28.1**: The RR SMR has appropriate monitoring at key process points to flag to operators if conditions start to fluctuate or performance is compromised, so that appropriate action can be taken.

- **Claim 28.2**: All final discharge or disposal points (to the environment) will have appropriate monitoring that can be demonstrated to be BAT, meet future permit requirements, and have sufficient sensitivity to meet required LoD.

- **Claim 28.3**: Sampling and monitoring arrangements will enable the provision of data required to assess impact of discharges from RR SMR to the public and environment.

- **Claim 28.4**: RR SMR design incorporates independent monitoring points to allow periodic sampling/redundancy in sampling.

A decomposition of these claims, and mapping to the relevant Tier 2 and Tier 3 information is presented in the E3S Case Route Map [7]. A summary of the potential arguments and evidence from lower tier information available at RD7/DRP1 is presented within section 28.5.

Note that detailed requirements relating to sampling and monitoring for safety systems will be mentioned in future issues of chapter 9A on Auxiliary Systems [4].

28.0.4 Applicable Regulations, Codes and Standards

28.0.4.1 Regulatory Context

This section presents an overview of the regulatory framework including legislative requirements, guidance, standards, and codes applicable to sampling and monitoring arrangements and techniques for radioactive discharges. A high-level summary of the regulatory context is presented in Figure 28.0-1.

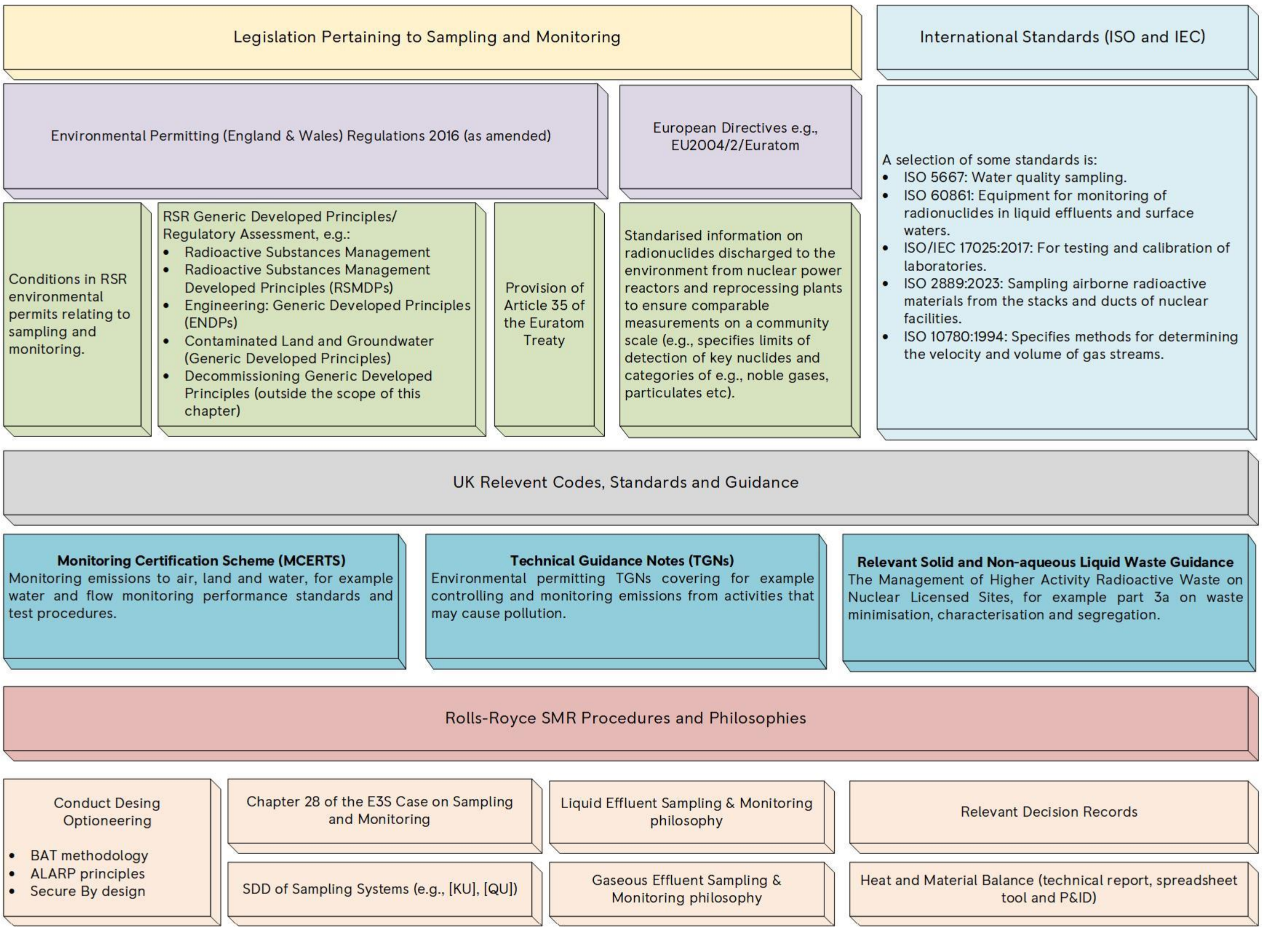


Figure 28.0-1: Overview of Key Relevant Regulatory Context

28.0.4.2 Legislation and Regulations

28.0.4.2.1 Environmental Permitting (England and Wales) Regulations 2016

Disposals of radioactive substances from nuclear power stations to the environment are controlled under the Radioactive Substances Regulations (RSR), set out in Schedule 23 of the Environmental Permitting (England and Wales) Regulations 2016 (as amended) (EPR16) [8]. “Disposals” of radioactive waste include discharges into the atmosphere, discharges into the sea, rivers, drains or groundwater, disposals to land, and disposals by transfer to another site.

There are several conditions within the RSR permit relating to sampling and monitoring, the key ones are listed below, along with comments on what the condition means [9]:

- Condition 3.2.1 in RSR permit - The operator shall:
    - Take samples and conduct measurements, tests, surveys, analyses and calculations to determine compliance with the conditions of this permit; this condition applies to all appropriate conditions, not just numerical limits.
    - Use the best available techniques when taking such samples and conducting such measurements, tests, surveys, analyses and calculations, and carrying out such environmental monitoring programmes and retrospective dose assessment,

unless particular techniques are specified in schedule 3 of this permit or in writing by the Agency; requires you to use 'BAT' when sampling and monitoring.

- Define and document the techniques being employed to determine the activity of radioactive waste disposals and shall inform the Environment Agency in writing in advance of any modifications to those techniques that have a potential to change the results obtained.

- Condition 3.2.2 – The operator shall maintain records of all monitoring required by the permit including records of the taking, analysis of samples, instrument measurements (periodic and continual), calibrations, examinations, tests and surveys and any assessments or evaluation made on the basis of such data; requires records of all the sampling and monitoring carried out and of any assessments or reports made using that data to be kept.

- Condition 3.2.3 – Monitoring equipment, techniques, personnel and organisations employed for the monitoring of disposals and the environment required by condition 3.2.1 or 3.2.5 shall have either Monitoring Certification Scheme (MCERTS) certification or MCERTS accreditation (as appropriate), where available, unless otherwise agreed in writing by the Environment Agency; This condition only applies where 'MCERTS' certification and accreditation exist for the sampling and monitoring the operator is carrying out.

- Condition 3.2.4 - Permanent means of access shall be provided to enable sampling and monitoring to be carried out in relation to the disposal outlets specified in schedule 3 unless otherwise agreed in writing by the Environment Agency. This condition is to make sure that Environment Agency (EA) contractors will be able to carry out sampling and monitoring on site as required.

- Condition 3.2.6 - The operator shall carry out:

  - Regular calibration, at an appropriate frequency, of measuring instruments and other systems and equipment provided for:

    - Carrying out any monitoring and measurements necessary to determine compliance with the conditions of this permit.

    - Measuring and assessing exposure of members of the public and radioactive contamination of the environment.

  - Regular checking, at an appropriate frequency, that such measuring instruments and other systems and equipment are serviceable and correctly used; This condition addresses the requirements of Article 68 of 'Basic Safety Standards Directive (BSSD)' to regularly calibrate measuring instruments and check they are serviceable and correctly used.

- Condition 4.2.2 – The operator shall supply such information in relation to the samples, tests, surveys, analysis, and calculations, environmental monitoring and assessments undertaken under conditions 3.2.1 and 3.2.5 in relation to disposals of radioactive waste, in such format and within such timescales as the Environment Agency may specify. This condition is to ensure that information supplied to the EA (for example information on the discharges or data for the pollution inventory) are in agreement with the EA's specific requirements.

The conditions mentioned above are a selection of the key ones pertaining to the specific topic, but note that others also apply, such as those on notifications requirements or on the requirement to make and keep records demonstrating compliance (covered by several conditions).

A further requirement on sites with an EPR16 permit in England and Wales is that BAT is used for monitoring discharges. The concept of BAT and how BAT is applied and demonstrated for the RR SMR is detailed in E3S Case Version 2, Tier 1, Chapter 27: Demonstration of Best Available Techniques [6]. This chapter will on final iteration summarise how BAT is applied to the sampling and monitoring arrangements, and techniques for RR SMR, this issue presents the basic principles and steps that RR SMR follows to demonstrate BAT (see sections 28.1.2 and 28.5).

28.0.4.2.2 Provisions of Article 35

Article 35 of the Euratom treaty not only requires self-monitoring of the levels of radioactivity in nuclear facilities but also the independent verification of the operation and efficiency of that monitoring from competent authorities e.g., the EA or Natural Resources Wales (NRW) [10]. Whilst this Article is no longer directly relevant to the United Kingdom (UK), it has been incorporated into EPR16 regulations, and for any RR SMR operating in the European Union (EU) this article will be relevant.

28.0.4.2.3 EU2004/2/Euratom

Standardised information on radionuclides discharged into the environment from nuclear power reactors and reprocessing plants during normal operation is needed to achieve comparable measurement results of radioactive discharges on a community scale and to ensure that minimum standards for the analysis methods are met across the community. For this purpose, for each category of radioactive discharges and each type of nuclear installation considered, key nuclides to which requirements for detection limits should apply have been identified and are listed in Annex 1 [10]. These are reproduced here in Table 28.0-1 and

Table 28.0-2.

Table 28.0-1: Nuclear Power Reactors - Discharges to Atmosphere

Category	**Key nuclides**	**Requirement for detection limit (Bq/m^3)**
Noble gases	Kr-85[1]	1E-04[2]
Particulates (excluding iodines)	Co-60 Sr-90 Cs-137 Pu239 + Pu 240 Am-241	1E-02 2E-02 3E-02 5E-03 5E-03 1E-02

[1] For light water reactors (LWR).
[2] Can normally be obtained by beta measurement after decay of short-lived isotopes.

Category	Key nuclides	Requirement for detection limit (Bq/m³)
	Total alpha[3]	
Iodines	I-131	2E-02
Tritium	H-3	1E+03
Carbon-14	C-14	1E+01

Table 28.0-2: Nuclear Power Reactors - Liquid Discharges

Category	Key nuclides	Requirement for detection limit (Bq/m³)
Tritium	H-3	1E+05
Other radionuclides (excluding tritium)	Co-60 Sr-90 Cs-137 Pu-239 + Pu-240 Am-241 Total alpha (see footnote 3)	1E+04 1E+03 1E+04 6E+03 5E+01 1E+03

28.0.4.3 United Kingdom Regulatory Requirements

The EA has published its RSR objective and principles (ROPs) [11]. The ROPs set out the fundamental objective of the RSR regulation and the regulatory principles the EA applies in the delivery of its function as laid out in EPR16 and government policy.

The ROPs are supported by a set of RSR Generic Developed Principles (GDPs) [12] which set out the EA's expectations on permit holders carrying out radioactive substances activities. A review of all the GDPs relevant to sampling and monitoring has been carried out as part of the ongoing generic regulatory design evaluation process. Details of the GDPs specifically relevant to sampling and monitoring are captured in Table 28.0-3.

Table 28.0-3: RSR Generic Developed Principles Relevant to Sampling and Monitoring

RSR Principle	Principle Description	RR SMR Comments
Radioactive substances management developed principle 4 (RSMDP4) - Methodology for Identifying BAT	'The best available techniques should be identified by a methodology that is timely, transparent, inclusive, based on good quality data, and properly documented.'	RR SMR have a BAT methodology (Approach to BAT and Optimisation) which is incorporated into engineering design process and is summarised

[3] Total alpha should only be reported if nuclide specific information on alpha emitters is not available.

RSR Principle	Principle Description	RR SMR Comments
		in the E3S Case Version 2, Tier 1, Chapter 27: Demonstration of Best Available Techniques [6].
RSMDP6 - Application of BAT	'In all matters relating to radioactive substances, the "best available techniques" means the most effective and advanced stage in the development of activities and their methods of operation.'	BAT methodology is applied to all decisions including sampling and monitoring. Use CAE structure to demonstrate sampling arrangements and techniques are BAT.
RSMDP9 – Characterisation	'Radioactive substances should be characterised using the best available techniques so as to facilitate their subsequent management, including waste disposal.'	Radioactive wastes are characterised using sampling and monitoring techniques described within chapter 28. Waste treatment systems are described in E3S Case Version 2, Tier 1, Chapter 11: Management of Radioactive Waste [13].
RSMDP13 – Monitoring and assessment	'The best available techniques, consistent with relevant guidance and standards, should be used to monitor and assess radioactive substances, disposals of radioactive wastes and the environment into which they are disposed.'	One of key objectives of chapter 28 is to demonstrate RR SMR sampling and monitoring arrangements used to monitor and assess disposals are BAT.
RSMDP14 - Record Keeping	'Sufficient records relating to radioactive substances and associated facilities should be made and managed so as: to facilitate the subsequent management of those substances and facilities; to demonstrate whether compliance with requirements and standards has been achieved; and to provide information and continuing assurance about the environmental impact and risks of the operations undertaken, including waste disposal.'	Applies to records of the sampling and monitoring carried out and of any assessments or reports made using the data obtained.
Engineering developed principle 4 (ENDP4) –	'Environment protection functions under normal and	Sampling and monitoring equipment will be

RSR Principle	Principle Description	RR SMR Comments
Environment protection functions and measures	fault conditions should be identified, and it should be demonstrated that adequate environment protection measures are in place to deliver these functions.'	categorised as environmental protection measures (EPM) to deliver environmental protection functions (EPF).
ENDP10 – Quantification of discharges	'Facilities should be designed and equipped so that best available techniques are used to quantify the gaseous and liquid radioactive discharges produced by each major source on a site.'	E3S Case Version 2, Tier 1, Chapter 29: Quantification of Radioactive Effluent Discharges and Proposed Limits [14], and E3S Case Version 2, Tier 1, Chapter 31: Conventional Impacts and Other Environmental Regulations [2] will both feed into chapter 28 as they will provide supporting information on what are key species that require monitoring.
ENDP11 – Maintenance, inspection and testing	'Structures, systems and components that are, or comprise part of, environment protection measures should receive regular and systematic examination, inspection, maintenance and testing.'	In-process monitoring, and final discharge sampling and monitoring equipment will need appropriate examination maintenance inspection & testing (EMIT) as key EPM.
ENDP14 – Control and instrumentation – Environment protection systems	'Best available techniques should be used for the control and measurement of plant parameters and releases to the environment, and for assessing the effects of such releases in the environment.'	In-process monitoring, and final discharge sampling and monitoring equipment need to consider this principle – demonstrated through applying RR SMR BAT methodology to decisions.
ENDP16 – Ventilation Systems	'Best available techniques should be used in the design of ventilation systems.'	Ventilation systems and how they are designed will influence sampling and monitoring as sampling needs to be representative.
ENDP18 – Essential services	'Best available techniques should be used to ensure that loss of essential services does not lead to radiological impacts to people or the environment.'	In-process monitoring will be used to highlight loss of essential services. Only those that lead to discharges that interact with the environment will be captured in chapter 28.

28.0.4.4 Other Relevant Codes, Standards and Guidance

In addition to the legislation and requirements detailed in sections 28.0.4.2 and 28.0.4.3, there are a number of codes, standards and guidance that are applicable to sampling and monitoring, which need to be taken into consideration and have been summarised in Table 28.0-4. Notably, they are fundamental to identifying relevant good practice (RGP) and optioneering which is a key element to identifying appropriate options as described in the "Approach for Optimisation through the application of BAT" methodology for RR SMR [5].

Table 28.0-4: Relevant Codes, Standards and Guidance Applicable to Sampling and Monitoring

Relevant Codes, Standards and Guidance	Issued by	Description
ISO/IEC 17025:2017 General Requirements for the competence of testing and calibration laboratories	International Organisation for Standardisation (ISO)	ISO 17025 is a set of requirements for testing as well as for calibration laboratories to show that their work complies with high technical and quality standards. The ISO 17025 builds on the quality standard ISO 9001, but with a set of technical requirements on top of the quality requirements. Where data are submitted to the EA for regulatory purposes, those data shall be generated using methods that have been accredited to the international standard ISO/IEC 17025.
ISO 2889:2023 and British Standard (BS) ISO 2889:2023 Sampling airborne radioactive materials from the stacks and ducts of nuclear facilities	International Organisation for Standardisation British Standards Institute (based on ISO standard)	The standard contains performance-based criteria and recommendations for the design and use of sample systems for sampling of airborne radioactive materials in stacks and ducts of nuclear systems under normal operations. This standard will be used to ensure BAT is being applied to the gaseous sampling and monitoring design of the RR SMR.
ISO 5667 BS EN ISO 5667:2016 Water Quality - Sampling	International Organisation for Standardisation British Standards Institute (based on ISO standard)	The standard is a multi-part document divided into guidance on water quality sampling for various purposes, such as monitoring, compliance, assessment, and classification. It sets out the general principles for the design of sampling programmes and sampling techniques for all aspects of sampling of water (including waste waters, sludges, effluents, suspended solids and sediments). It also provides specific guidance on sampling from different types of water, such as lakes (natural and man-made), rivers, streams, wastewater, groundwater, marine waters etc.

Relevant Codes, Standards and Guidance	Issued by	Description
BS EN 60861:2008 Equipment For Monitoring of Radionuclides in Liquid Effluents and Surface Waters	British Standards Institute (based on ISO standard IEC 60861:2006)	The standard defines technical requirements for equipment used for monitoring of alpha-, beta- or gamma-emitting radionuclides in liquid effluents and surface waters. It provides some general guidance as to the possible detection capabilities of the equipment and indicates when and where its use may be practicable [15]. It intends to ensure reliability and accuracy of the measurements and to facilitate the comparison of data from different sources.
BS EN 60761-1:2004 and BS EN 60761-3:2004 Equipment for Continuous Monitoring Radioactivity in Gaseous Effluents General Requirements	British Standard	BS EN 60761:2004 series are international standards, which have been adopted as a BS based on IEC 60761:2002. Standard focuses on equipment for the continuous monitoring of activity in gaseous effluents. Part 1 focuses on the general requirements of continuous monitoring, of which there is some overlap with BS ISO 2889. The remainder of the series within this standard goes into detail for specific analytes.
ISO 10780:1994 Stationary Source Emissions Measurement of velocity and volume flowrate of gas streams in ducts	International Organisation for Standardisation	Specifies manual methods for determining the velocity and volume flowrate of gas streams in ducts, stacks and chimneys vented to the atmosphere. Applies to gas streams with essentially constant density, temperature, flowrate and pressure at the sampling point.
MCERTS Applicable to general sampling and monitoring, specific MCERTS for various elements	EA	MCERTS is the EA's Monitoring Certification Scheme for environmental permit holders. MCERTS is used to approve people, instruments, and laboratories. MCERTS provides formal accreditation in accordance with European and international standards and provides assurance to regulatory authorities and operators that equipment approved to MCERTS standards are suitable, and capable of producing results of the required quality and reliability [16]. MCERTS performance standard states only additional requirements above ISO 17025 which must also be complied with, in order for an organisation to become registered under this MCERTS standard.

Relevant Codes, Standards and Guidance	Issued by	Description
		Relevant applicable MCERTS standards include: • Flow measurements for gaseous and liquid effluents are required to enable accurate accounting of the discharges as they are released to the environment [17]. • Automatic isokinetic samplers for gaseous effluent – primarily for combustion and incineration [18]. • Radioactive analysis of liquid effluent [19]. • Sampling and chemical testing of water, including trade effluents (non-rad) [20]. • Performance Standards and Test Procedures for Continuous Water Monitoring Equipment, Part 1 [21], Part 2 [22] and Part 3 [23].
Technical guidance notes (TGNs) and regulatory monitoring quick guides	EA	The EA has produced several TGNs and monitoring quick guides that are relevant to sampling and monitoring and provide support. The main ones pertinent to the sampling and monitoring strategy are under Monitoring stack emissions: environmental permits Monitoring discharges to water: environmental permits and include [24]: • Monitoring stack emissions: environmental permits (formerly part of M2) [25] • Monitoring stack emissions: measurement locations (formerly called M1) [26] • Monitoring stack emissions: guidance for selecting a monitoring approach (formerly part of M2) [27] • Monitoring discharges to water: guidance on selecting a monitoring approach (formerly part of M18) [28] • Monitoring discharges to water: CEN and ISO monitoring methods (formerly part of M18) [29] • TGN M17: Monitoring Particulate Matter in Ambient Air Around Waste Facilities [30] • Monitoring stack emissions: techniques and standards for periodic monitoring [31] • Monitoring stack emissions: maximum uncertainty values for periodic monitoring [32] • Monitoring stack emissions: standards for continuous monitoring and sampling [33]

Relevant Codes, Standards and Guidance	Issued by	Description
Monitoring of radioactive discharges to water from nuclear facilities	EA	The document sets out good practice derived from relevant standards relating to monitoring of discharges to water from nuclear facilities. It helps support the demonstration of BAT when undertaking monitoring of discharges to the environment. This is because within radioactive substances regulation, BAT is not prescribed in detail [34]. It describes good practice for: • monitoring facilities • sampling and instrument monitoring location • continuous monitoring • sampling • analysis and • flow measurement. This guidance supersedes the earlier technical guidance note M12, and compliments other revised technical guidance on monitoring of radioactive releases to atmosphere from nuclear facilities and guidance on the abatement of radioactive releases to water from nuclear facilities.
Fundamentals of the management of radioactive waste	Health and Safety Executive, the EA and the Scottish Environment Protection Agency (SEPA)	This document describes what radioactive waste is; what happens to radioactive waste; who is involved in radioactive waste management; what their roles are; and how radioactive waste management is regulated [35]. Provides high level requirements on solid and non-aqueous liquid waste sampling and monitoring.
The Management of Higher Activity Radioactive Waste on Nuclear Licensed Sites (Part 3)	Joint guidance from the Office for Nuclear Regulation (ONR), EA, SEPA and NRW	This document provides guidance covering the management of higher activity radioactive wastes (HAW) on nuclear licensed sites. Part 3 which relates to waste characterisation [36].

28.1 Overview of Sampling and Monitoring Considerations for the Rolls-Royce Small Modular Reactor

28.1.1 General Principles

The overarching principles applied to the RR SMR are that all final discharge points to the natural environment will be sampled and monitored. Additionally, in-process monitoring will be incorporated into the RR SMR design to alert the operator of any deviation from normal conditions (these points would work as performance indicators), that would require further actions to be taken.

Requirements on sampling and monitoring which align with regulatory principles, requirements and RGP are applied to the RR SMR through design requirements captured in the dynamic object oriented requirements system (DOORS). The following key requirement(s) are specified in DOORS on all SSCs that discharge to the environment:

- Any systems which use batch discharges to the environment shall feature sampling at a point in the system prior to discharge.
- RR SMR shall monitor physical, chemical, and radiological properties of its discharged liquid, gaseous and solid wastes to the environment using BAT.
- Systems which continuously discharge to the environment shall include at least one independent sampling point(s) in addition to the normal sampling point.
- Sampling and monitoring methods and techniques shall meet the requirements of the detection limit for the radionuclides listed in 2004/2/Euratom.
- Representative sample(s) should be taken.
- RR SMR shall include capability to characterise radioactive substances, using BAT.
- Final discharge points to the environment shall have continuous flow proportional sampling using MCERTS accredited techniques (where applicable).
- Access, egress and adequate space for carrying out normal operations (which includes sampling) and EMIT activities shall be provided.

More requirements pertaining to sampling and monitoring placed upon the SSCs are presented in the liquid and gaseous effluent sampling and monitoring philosophies [37] [38].

However, note that there may be some instances where it would not be BAT to physically sample and monitor a small, infrequent discharge. For example, if the discharge was below the LoD, or the EMIT requirements for the maintenance of the sampling point or monitoring equipment would be grossly disproportionate in terms of time and raw material(s) in comparison to the benefits. Thus, in specific cases such as the ones mentioned above, calculation of discharges might represent BAT.

28.1.2 Summary of the Decision Process for Sampling and Monitoring Systems

28.1.2.1 BAT Methodology and Conduct Design Optioneering Process

The methodology for gathering and evaluating BAT [5] is aligned with, and fully integrated, into the engineering design process ‘C3.3.3-2 Conduct design optioneering’ alongside safety and security principles to achieve holistic optimisation (BAT, as low as reasonably practicable (ALARP), Secure by Design and Sustainable by Design) of the RR SMR power station [39].

The conduct design optioneering process is mandatory and is used to generate options which can meet the design requirements, take RGP and operating experience (OPEX) into consideration (across all areas), evaluate the options, identify, and justify the preferred design solution. The decision record (TS-DD-02) is the principal document that captures the formal optioneering process.

For all decisions on sampling and monitoring arrangements, the BAT methodology will be applied, and a decision record completed. All sampling and monitoring arrangements will be demonstrated to meet BAT. The current decisions for the final discharge outlets are presented in sections 28.2.2.3 and 28.3.1.1 and for the in-process arrangements in sections 28.2.2.2 and 28.3.2.2.

- FA 28.1: As the design matures, and decision records and system design descriptions (SDDs) for sampling and monitoring systems are produced / updated the information will be reviewed and incorporated into this chapter.

The primary function of the sampling and monitoring system(s) is to enable characterisation of the fluid/effluent being sampled, either by direct measurement of specific properties/ determinands (integrated monitoring which primarily refers to sensor technology) or by providing representative samples of system fluid for offline laboratory analysis [40] [41].

Figure 28.1-1 shows a schematic of the key ‘decisions’ that are being considered for sampling and monitoring.

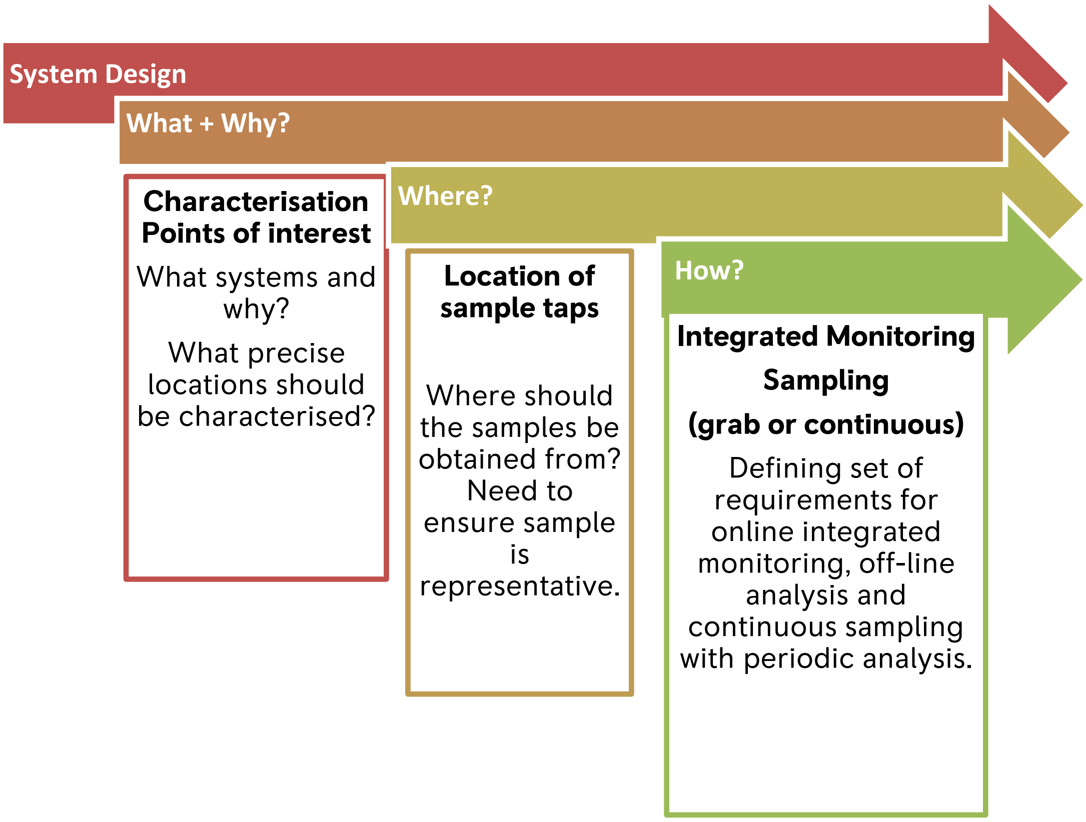


Figure 28.1-1 Decisions Considered during System Design of Sampling and Monitoring Systems

In order to define efficient, representative and adequate sampling and monitoring programmes, it is important to address the following questions:

What and Why - understanding and identifying, for each fluid system, what are the important parameters that need to be measured and where is the best physical location within these systems to measure, referred to as 'characterisation point'. This is fundamental to both understanding how a system is performing and for the monitoring (and reporting) of environmental discharges.

The characterisation points are identified primarily through the functional requirements of the system under consideration, reviewing established guidance and practices (RGP/OPEX), understanding the key interfaces, and developing the rationale behind what systems should be sampled and why. Reviewing RGP and OPEX and understanding requirements enables options to be generated that can be taken forward for assessment.

Where – understanding where the best location is within a system to get a representative sample, which will fulfil the functional requirements and provide the information required.

How – understanding the best way to take the samples. Sample characterisation can be achieved by direct measurement of specific determinands using analysers, enabling real-time automated monitoring referred to as 'integrated monitoring' or can be achieved through off-line analyses of the properties of a physical sample. The sample can be a grab sample or a composite sample resulting from continuous sampling of an effluent (flow or time proportional).

The accuracy of the result required needs to be clearly defined to allow the operator to select the best analytical method and the most appropriate system with the performance characteristics needed to meet regulatory and functional requirements.

Sampling

Grab-sampling

The grab-sampling functionality can be broken down to either:

- ‘Local’ sampling (at the source itself)
- ‘Remote’ sampling – at a distance from the source at a sampling station, or,
- ‘Laboratory’ sampling – within or adjacent to the site laboratory (usually a dedicated sampling glovebox/fume hood).

The above solutions describe the location at which an operator can obtain a representative physical source of fluid (sample) for offline characterisation (for more details on how grab sampling can be performed see References [40] and [41]).

Continuous Sampling

There are automatic or continuous sampling techniques that help determine the properties of an effluent or monitor a determinand of interest that can either be used solely or in conjunction with grab sampling techniques. The continuous sampling can be achieved by sampling the effluent flow, namely, by withdrawing samples from the effluent flow with a permanently sited instrument. The location of the sampling instrument should ensure representative sampling is achieved. For example, that the sample probe remains in the well mixed zone of the effluent flow for the entire time. The collection of samples obtained should yield results that are representative for the entire sampling period.

There are two types of continuous representative sampling:

1. Flow-proportional sampling – used for final discharges where the volume (and the composition) of the effluent discharged varies significantly throughout the sampling period.
2. Time-proportional sampling - where a fixed amount of sample is taken from the effluent for each time unit, used primarily on in-process systems where relative consistent discharges occur.

Continuous/automatic sampling devices when used for reporting of final discharges should be tested and certified to the MCERTS performance standard (where available).

Integrated Monitoring

Integrated monitoring refers to sensor technology embedded within a system that enables continuous or on-demand characterisation of defined species/analytes.

Integrated monitoring solutions are intended to replace or supplement traditional offline grab-sample characterisation, employing species-specific analysers mounted either:

- ‘Inline/In-situ’ - within the source itself

- 'Online' - off a bypass representative of, but at-distance from the source. Analyser effluents can be returned to the source

- 'Atline' - at the end of a pipe run originating at a representative source. Analyser effluents cannot be returned to the source and are directed to waste following analysis.

More details on the grab-sampling and integrated monitoring arrangements proposed for RR SMR stemmed from RGP and OPEX are presented in the decision records of the proposed solutions for the Reactor Island (RI) sampling and monitoring systems [40] [41].

In the following sections, the identified characterisation points from the RI systems, and the respective method used is presented for each characterisation point. The sampling and monitoring arrangements at the final discharge outlets from the RR SMR are also presented.

28.2 Radioactive Gaseous Effluents and their Sampling and Monitoring Arrangements

28.2.1 Overview of Sources and Systems of Radioactive Gaseous Effluents

The primary sources and associate waste treatment/abatement systems for gaseous radioactive emissions to atmosphere from the RI and the waste management arrangements are described in E3S Case Version 2, Tier 1, Chapter 11: Management of Radioactive Waste [13]. The key sources of radioactive gaseous effluent under normal operations are:

- Treated off-gases from the primary circuit. Gases containing fission and activation products, and noble gases will be treated via the Gaseous Radioactive Effluent Treatment System [KPL].

- Treated Heating, Ventilation and Air Conditioning (HVAC) system gases [KL-]. The HVAC systems service controlled and exclusion areas of the RI and will manage gaseous effluents in the form of air with entrained radioactive airborne particulates, non-condensable gases and potentially iodine.

- Air Removal and Evacuation System gases [MAJ]. This system is primarily a non-radioactive source and would only release radioactive substances under expected events, for example if there is a leak from the primary circuit to the secondary circuit. Non-condensable gases are eventually stripped and released to the environment by the Air Removal and Evacuation System [MAJ].

Whilst not included in the scope of this chapter, the sources of conventional gaseous discharges are identified in the gaseous sampling and monitoring philosophy [38]. Also identified are those systems like [MAJ] which could potentially release radioactive discharges under certain fault scenarios. As the design matures and frequency of potential releases are calculated, additional discharges of radioactive gaseous effluents may be added to this chapter.

- FA 28.2: Continue to review expected events to identify if any additional radioactive discharges need to be captured in chapter 28.

- FA 28.3: Carry out BAT assessment to determine whether [MAQ] vent should be monitored, or whether any discharges to the atmosphere should be calculated.

The interface between the Gaseous Radioactive Effluent Treatment System [KPL] and the HVAC system [KL] with the main RI exhaust stack [KLS] and subsequently the environment, is illustrated in Figure 28.2-1.

The Gaseous Radioactive Effluent Treatment System [KPL] includes compressors delivering nitrogen purge gas to various RI systems, a recombiner for abatement of hydrogen and delay beds for abatement of fission products (see Figure 28.2-1) and the SDD can be found in Reference [42].

The nuclear HVAC system [KL] located in the RI, serves:

- The primary containment [KLA]
- The interspace [KLB]
- Controlled areas [KLC]
- Radioactive waste processing areas [KLF]
- Fuel storage and handling areas [KLL].

The SDD for the HVAC systems serving the controlled areas and uncontrolled areas of RI [KL] can be found in Reference [43].

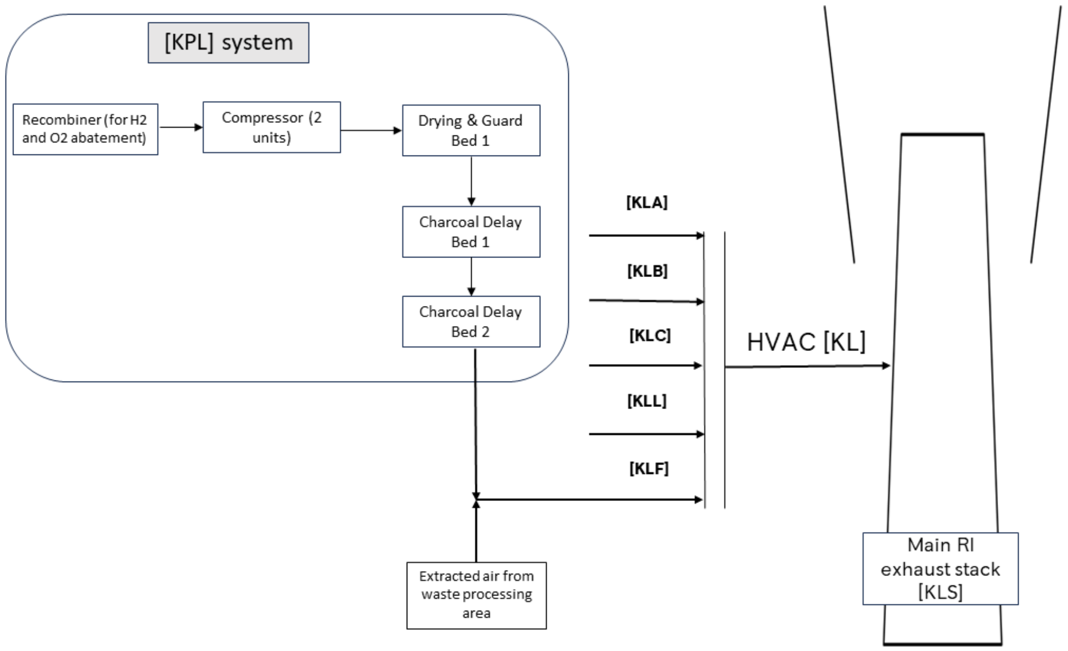
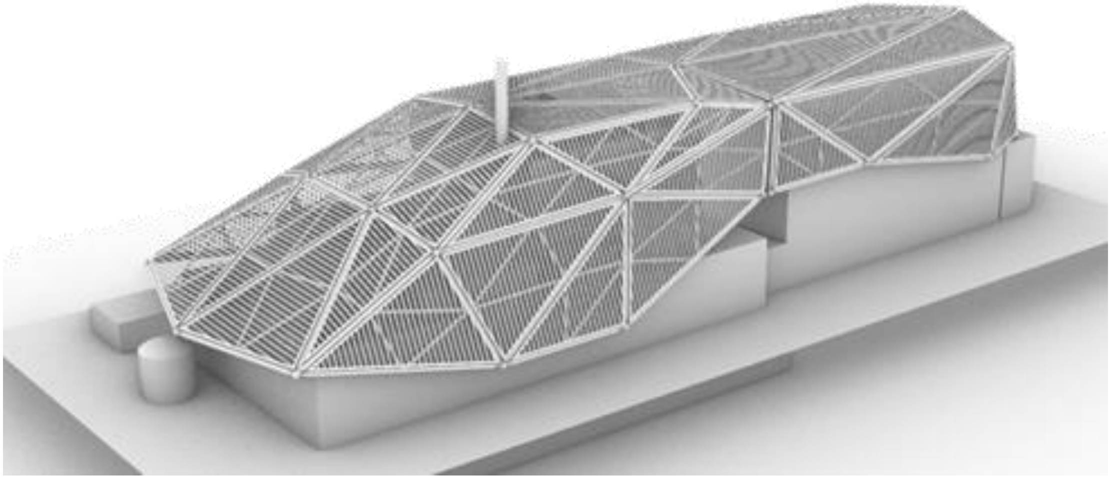


Figure 28.2-1 Overview of Gaseous Radioactive Effluent Systems

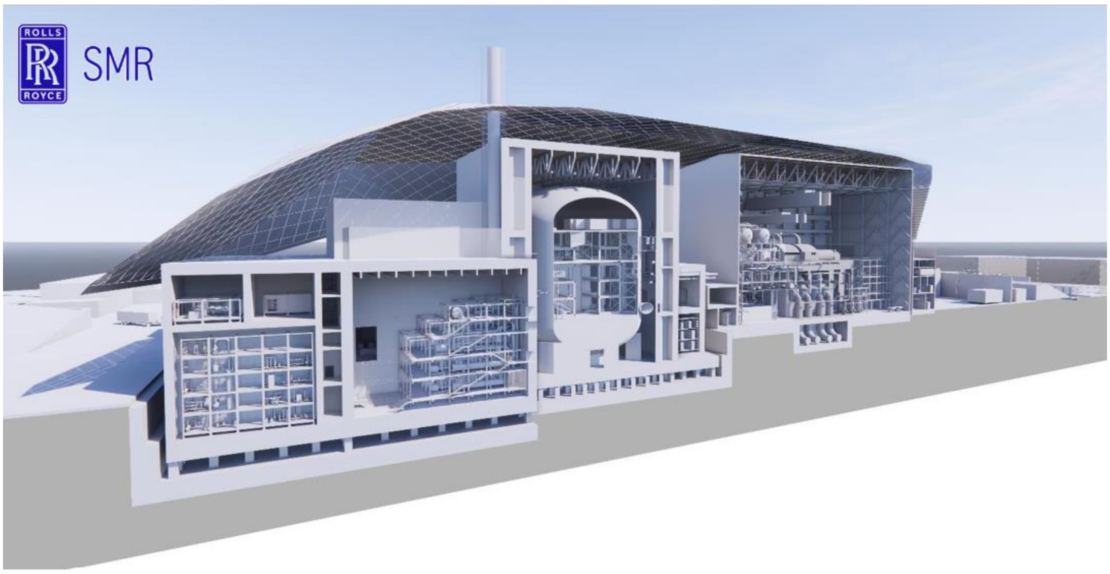
28.2.1.1 Gaseous Effluents Final Discharge Points

At RD7/DRP1, the main discharge point to the atmosphere has been identified, namely the main RI exhaust stack [KLS] which discharges gaseous effluent originating from the RI [44]. It is likely that as the design matures, other gaseous discharge points will be identified (such as from other islands or from waste stores) and captured in the E3S Case.

The design and location of the RI stack is currently under development and has not reached definition review 1 (DR). The approximate location of the RI exhaust stack [KLS] is illustrated in Figure 28.2-2. The sampling and monitoring system that covers the main exhaust stack [KLS] is [KUK10] under the Process and Emissions Radiation Monitoring System (PERMS) [KUK]. More details on the current sampling and monitoring arrangements for the stack are presented in section 28.2.2.3.



(a)



(b)

Figure 28.2-2 (a) Indicative Arrangement of Exhaust Stack [KLS] and Shell Roof, (b) Side Cross-section of the RR SMR Displaying the Exhaust Stack [KLS]

Table 28.2-1: Final Gaseous Outlets to the Environment

Wastes	Discharge Point(s)	Contributors to final discharge point(s) (for example systems and/or facilities)
Radioactive Gaseous	Plant Exhaust Stack [KLS]	Gaseous Radioactive Effluent Treatment System [KPL] (via the [KLF] system)

Wastes	Discharge Point(s)	Contributors to final discharge point(s) (for example systems and/or facilities)
Discharges from RR SMR		The nuclear HVAC system [KL-] - namely filtered discharges from [KLA], [KLB], [KLC], [KLF] and [KLL]. [KLF] is taking the discharges from [KPL] as well.
	Vent System [MAQ] The exact location is yet to be confirmed.	Air Removal and Evacuation System [MAJ] extracting gases from the condensing system [MAG]. Turbine Island.

28.2.2 Gaseous Effluent Sampling and Monitoring Arrangements

28.2.2.1 Gaseous Effluent Sampling and Monitoring Philosophy

The gaseous effluent sampling and monitoring philosophy provides details on the key sources of gaseous radioactive effluents in the RR SMR, and the discharge routes to the environment under normal operations, which have been summarised in sections 28.2.1 and 28.2.1.1 of this chapter.

The philosophy [38] summarises:

- The solutions proposed or utilised by other nuclear facilities for similar systems.
- Whether the solution(s) proposed for RR SMR are similar to OPEX or are novel solutions.
- The rationale for the RR SMR proposed sampling and monitoring arrangements (details captured in [41] [40]).

The breakdown of the Reactor Island Sampling Systems (RISS) [KU] under the Nuclear Auxiliary Systems [K] scope, is presented in Figure 28.2-3. The RISS [KU] covers the sampling and monitoring arrangements for the main RI exhaust stack [KLS] and the other in process systems that contain radioactive gases that feed into [KLS], for example from [KL-] and [KPL]).

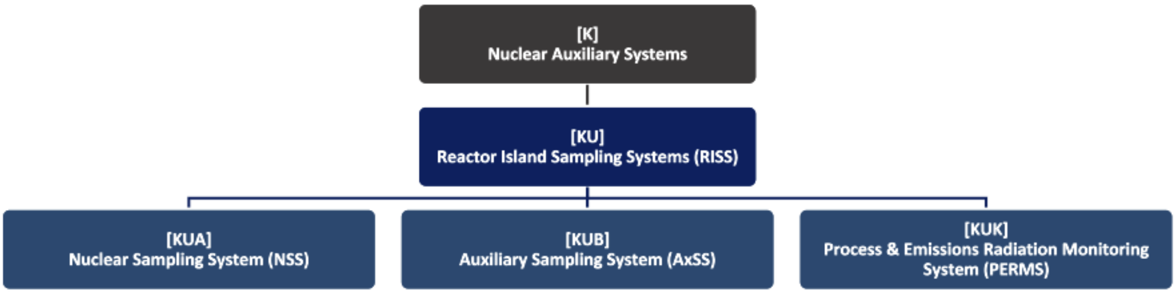


Figure 28.2-3 Reactor Island Sampling and Monitoring System Breakdown Structure

The characterisation points that have been identified at RD7/DRP1 for in-process and for final discharge accountancy are presented in sections 28.2.2.2 and 28.2.2.3 alongside the proposed sampling and/or monitoring arrangements for the specific characterisation point.

28.2.2.2 In-process Sampling and Monitoring

The RISS [KU] consists of the Nuclear Sampling System (NSS) [KUA], the Auxiliary Sampling System (AxSS) [KUB] and the PERMS [KUK] as presented in Figure 28.2-3.

The systems that have been identified as providing in-process gaseous samples at RD7/DRP1 are presented in Table 28.2-2 and fall under the AxSS [KUB] and PERMS [KUK] scope. The table also includes the reference designation system for power plants (RDS-PP) of each system. It is worth mentioning that the characterisation points identified in the decision records and presented here, are subject to refinement as part of the design process. Note that the NSS [KUA] does not cover any systems that provide gaseous samples. Figure 28.2-4 provides an overview of gaseous radioactive effluent systems and proposed sampling and monitoring locations for in-process at RD7/DRP1.

Table 28.2-2 Characterisation Points within the AxSS [KUB] and PERMS [KUK] Scope that Provide a Gaseous In-process Sample

Scope	System	RDS-PP	Characterisation point	Sampling Method Grab or Continuous Sampling Location Local/remote/laboratory Characterisation / Analysis Method
AxSS [KUB]	Gaseous Radioactive Effluent Treatment System via [KLF]	[KPL]	Compressor station gaseous outlet	Grab sampling - remote via extended pipe run sampling[4]. Offline analysis only.
			Upstream (U/S) recombiner (downstream (D/S) cover gas cooler)	Grab sampling - remote via extended pipe run sampling (see footnote 4).

[4] Requirement for physical grab-sampling to be explored.

Scope	System	RDS-PP	Characterisation point	Sampling Method Grab or Continuous Sampling Location Local/remote/laboratory Characterisation / Analysis Method
				Offline analysis and/or integrated monitoring.
			D/S recombiner (D/S recombiner cooler)	Grab sampling -remote via extended pipe run sampling (see footnote 4). Offline analysis and/or integrated monitoring.
			Guard bed outlet (delay bed 1 inlet)	Grab sampling - remote via extended pipe run sampling. Offline analysis only.
			Delay bed 1 outlet (delay bed 2 inlet)	Grab sampling - remote via extended pipe run sampling. Offline analysis only.
			Delay bed 2 outlet	Grab sampling - remote via extended pipe run sampling. Offline analysis only.
PERMS [KUK]	Control Room HVAC Systems	[KLR]	Inlet monitoring to the main control room, (MCR) (normal operations route and secondary mode)	Grab sampling - remote (Representative by-pass with recovery/return). Offline and/or integrated monitoring.
			Inlet monitoring to the supplementary control room (SCR) (normal operations route and secondary mode)	Grab sampling - remote (Representative by-pass with recovery/return). Offline and/or integrated monitoring.
			Upstream and Downstream of C2, C3 & C5 Extract Filter Banks	Grab sampling - remote (there is a potential for local sampling to be examined at a later stage). Offline only. Mentioned here but will be fulfilled by the HVAC [KL] system and not the [KUK].

28.2.2.3 Final Discharge Point Sampling and Monitoring

The final discharge point for radioactive effluents from the RI (which includes all in-process points in Table 28.2-2) is the main RI exhaust stack [KLS]. Figure 28.2-4 shows the overall discharge stack and the sampling and monitoring considerations.

The sampling system that covers the main RI exhaust stack [KLS] is the PERMS [KUK], specifically the sampling system [KUK10].

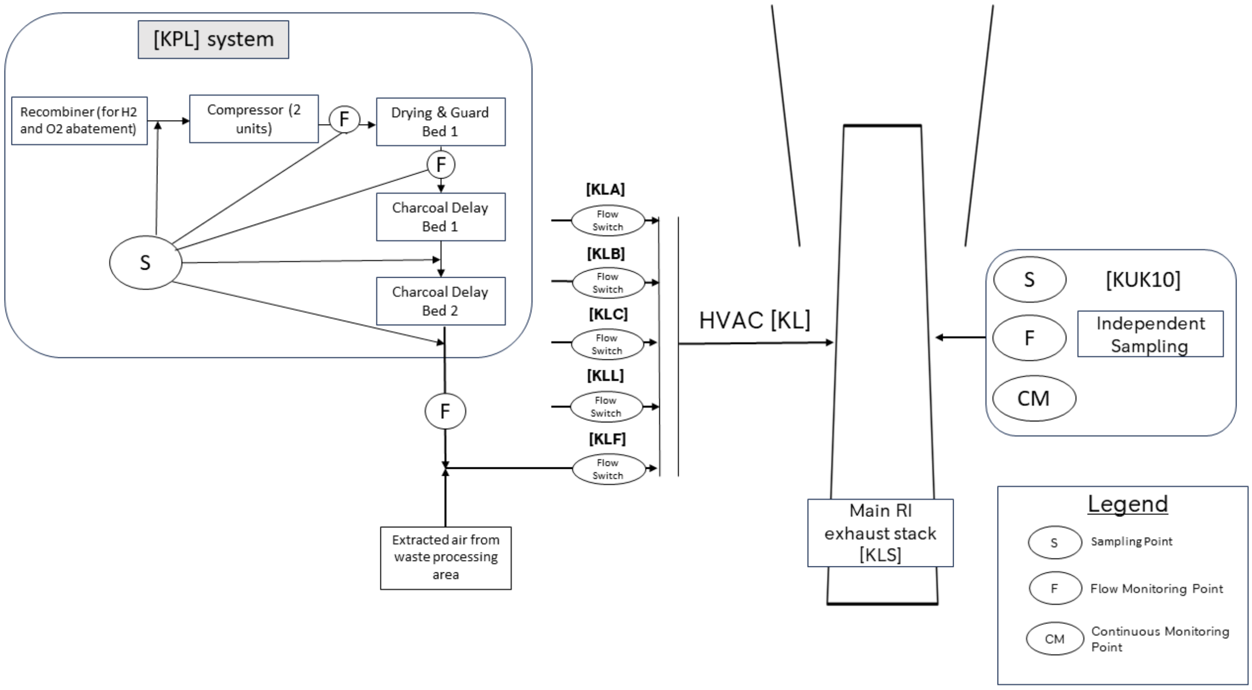


Figure 28.2-4 Overview of Gaseous Radioactive Effluent Systems and their Sampling and Monitoring Arrangements

The main extract stack exhaust sampling system [KUK10] will continuously sample discharges from within the exhaust stack, downstream of any abatement, in a location where the effluent is well mixed and representative of the final discharge (isokinetic sample). Access for independent sampling equipment is also provided in References [40] [41] [45]. These requirements are put in place to ensure that the plant can meet regulatory expectations and any future discharge permit limits.

The SDD of PERMS [KUK] depicts that it includes the capability for measurement for tritium, carbon-14, iodine and noble gases, and a particulate filter based on RGP [45]. Briefly, the intention for the final accountancy point (RI exhaust stack) is:

- Representative sampling (including isokinetic for particulates) which is required to enable accurate monitoring of particle distribution within the stack.
- Analysis of particulates collected using a particulate filter.

- Specific gas analysers to enable the monitoring of iodine and noble gases once the stream has passed through the particulate filter [46].

- Tritium and carbon-14 monitoring which may comprise bubblers in series to trap the sample for analysis [46].

These solutions have been proposed based on RGP and OPEX, however, the actual technology to be used in RR SMR is still to be determined. Note that the review of RGP and OPEX has resulted in a common solution which was remote (representative by-pass) online sampling, which has also been proposed for the RR SMR. The final choice of integrated (inline/online/atline) analysers utilised by PERMS [KUK] has been captured as further work in the SDD of [KUK] [45].

The SDD states that the sampling exhaust will likely be returned to the stack before the sampling extraction point. Current design is that exhaust would be returned near the base of the stack in a high flow region area. This will help ensure that the small sample return is well mixed before travelling up the stack to the sampling point. This will also reduce the amount of pipework required and will in turn reduce the amount of potentially radioactively contaminated material that would need to be disposed of at the end of the plant life [45]. The double counting or prevention of dilution argument is considered negligible at this point, due to the volume of the sample that would be returned (note that the exact gas flows are yet to be determined) and the extra amount of pipework required to return upstream is likely to be relatively significant. The need to access the equipment, for conducting maintenance work and avoid further design complications were also considered. Based on these considerations, it is deemed justifiable to return the sample upstream (before) the extraction point in the stack.

The stack exhaust sampling system is envisaged as operating continuously in all modes of operation. This is to ensure that it will provide continuous measurement of stack exhaust sampling data to enable accurate recording of aerial discharges and to identify a potential fault within the upstream systems.

28.2.2.4 Parameters/Determinands to be Monitored

For in-process monitoring, the parameters currently envisaged to be monitored include gross radioactivity, temperature, pressure, flow etc. The specific details of the determinands at RD7/DRP1 are presented in the SDDs for [KPL] and HVAC [KL].

In terms of the final effluent discharged via the main extract stack [KLS], the parameters and determinands currently envisaged to be monitored include flow, gross beta/gamma, particulates, as well as some individual radionuclides (and group of radionuclides). The SDD for PERMS [KUK] identifies what species are likely to be sampled in the continuous representative sample collected from the RI stack exhaust.

Significant radionuclides in gaseous discharges have been identified based on current understanding of the RR SMR source term and following the EA guidance document setting out their criteria for setting limits on the discharge of radioactive effluents from nuclear sites [47]. The selection criteria of the assessment to determine the RR SMR significant radionuclides are detailed in E3S Case Version 2, Tier 1, Chapter 29: Quantification of Radioactive Effluent Discharges and Proposed Limits [14].

The significant radionuclides in gaseous discharges to the environment are provided in Table 28.2-3. These are the radionuclides that would, as a minimum, be required to be measured and reported in the final effluent to the environment for RR SMR. These will be revised, as the source term is further refined and better-defined performance criteria and design parameters for relevant RR SMR discharge abatement systems become available.

- FA 28.4: Confirm what radionuclides will be monitored in the final effluents and confirm that the monitoring techniques will meet required LoD stated in Table 28.0-1 for gaseous discharges.

Table 28.2-3 Radionuclides of Significance in RR SMR Final Gaseous Discharges

Discharge phase	**Radionuclide/ radionuclide group**
Gaseous	H-3
	C-14
	I-131
	Kr-85
	Other beta/gamma particulate

28.2.2.4.1 Flow Rate

The flowrate of the gaseous discharges needs to be continuously and accurately measured to report the discharges of radioactive substances, using an appropriate MCERTS accredited technique and equipment, where available.

28.3 Radioactive Liquid Effluents and their Sampling and Monitoring Arrangements

28.3.1 Overview of Sources and Systems of Radioactive Liquid Effluents

Six principal systems handle effluents from across the whole RR SMR and discharge to the environment via the final discharge outlet [UPK]:

- The Liquid Radioactive Effluent Treatment System [KNF]
- The Auxiliary Cooling and Make-up System (ACMS) [PE] which also takes the Main Cooling Water System (MCWS) [PA] Blowdown
- The Wastewater Drainage and Treatment [GM] system (takes several subsets of conventional trade effluents including steam generator blowdown, demineralisation effluent)
- The Surface Water Drainage System [ZZT] which takes surface water drains from across the site (excluding potential controlled areas)
- The Extreme Hazard Drainage System [ZZT] which takes surface water from across site (excluding potential controlled areas) during extreme weather events only
- The Sewage System [ZZU] which takes sewage and condensates.

Of all the above systems that discharge to the natural environment, only the Liquid Radioactive Effluent Treatment System [KNF] is expected to have effluents containing radiological contamination. The other systems, which are conventional systems have been included since they could dilute the radiological contamination and therefore affect the LoD of nuclides at the final discharge outlet.

- FA 28.2: Continue to review expected events to identify if any additional radioactive discharges need to be captured in chapter 28.

The sampling and monitoring arrangements will need to ensure the LoD can be met. The systems are schematically represented in Figure 28.3-1 which also displays their interaction.

To enhance the understanding of all the radiological and conventional liquid effluents generated during the operation of the RR SMR that would be discharged through the Cooling Water Outfall Pond [UPK] and the effect of any interaction they might have, a Heat and Material Balance (HMB) suite of reports was developed [48] [49] [50]. The suite of documents enhanced the understanding of the key systems which are described further below.

<u>The Liquid Radioactive Effluent Treatment System [KNF</u>] collects and treats radioactive liquid effluents from the RI (from the collection and drainage system [KTA] tanks) and treats them with a combination of separation methods for removal of radionuclides and chemical contaminants. The treatment enables storage and recycling of effluent in the nuclear power plant, or suitability

for discharge to the environment. The Liquid Effluent Monitoring and Discharge System (LMDS) [KNF30] is particularly pertinent as it is the direct interface between RI liquid effluent systems and the Cooling Water Outfall Pond [UPK], and subsequently the environment (via stream R7 in Figure 28.3-1). It is expected to conservatively discharge a single batch per an 18-month fuel cycle [37].

The potential sources (and abatement) of liquid radioactive effluent discharges into the [KNF] are described in E3S Case Version 2, Tier 1, Chapter 11: Management of Radioactive Waste [13]. The quantities and the main radiological constituents are described in E3S Case Version 2, Tier 1, Chapter 29: Quantification of Radioactive Effluent Discharges and Proposed Limits [14]. The summary of the main sources of liquid radioactive effluents in [KNF] are:

- Primary Circuit Effluents - originate from multiple sources including transfer of Chemical Volume Control System (CVCS) effluents to the processing/treatment system and pressuriser bleeds during degassing. These effluents are expected to contain low concentrations of contaminants during normal operations and are therefore suitable for direct recycling back into the process. If effluents fall outside the primary coolant Water Quality Specification (WQS), for example as a result of fuel failure, the effluents will be routed for treatment and/or for offsite discharge.

- Chemical Drain Effluents – originate from multiple sources and include effluents leaked/drained from the nuclear auxiliary building and lab samples from effluent testing. Effluents contain higher concentrations of radioactivity and chemical contaminants. They are collected, sampled and treated to remove contaminants and reduce their volume. The treated effluent is transferred to the LMDS tanks for sampling, at which point it will either be recycled into the primary circuit (as coolant or service water) or directed for offsite discharge.

- Process Drain Effluents – primarily originate from maintenance operations and leaks/discharges from the reactor coolant system and are expected to contain low to moderate radioactivity and chemical contaminants. These effluents will be collected, treated, and reused/discharged in line with the chemical drain effluents.

- Active Floor Drain Effluents – primarily originate from equipment draining and floor washing in the radiologically controlled area (RCA) and are expected to contain low radioactivity and chemical contaminants. These effluents will be collected, treated, and reused/discharged in line with the chemical drain effluents.

A liquid effluent discharge strategy will be developed later in the design process to ensure the overall impact of batch discharges to the environment are minimised.

- FA 28.5: Produce Batch Liquid Effluent Discharge Strategy.

<u>The Conventional Island Wastewater Drainage and Treatment System [GM]</u> provides process/trade effluent drainage collection, treatment, and disposal services for Conventional Island drains and non-active RI drains. These drains are largely non-hazardous, non-active, trade effluents under ambient conditions [49].

<u>The Steam Generator Blowdown System [LCQ]</u> collects blowdown from the secondary circuit of all three steam generators (SG) and treats it for re-use in the secondary circuit via a single purification system (utilising ion exchange columns, with pre-filtration and post filtration). It is not certain yet whether this system will discharge to the outfall pond via the [GM] system or directly.

- FA 28.6: Confirm whether Steam Generator Blowdown System [LCQ] will discharge to the Cooling Water Outfall Pond [UPK] via [GM] or directly.

The Conventional Island Liquid Monitoring and Discharge System (CI-LMDS) would discharge to the Cooling Water Outfall Pond [UPK] following sampling and monitoring. This system will batch discharge non-active trade effluent into the final outfall via Stream B11 in Figure 28.3-1.

The MCWS is an indirect cooling system utilising evaporative heat transfer to reject waste heat from the RR SMR. Blowdown water which is to be removed from the system is transported from the MCWS cooling tower basin to the final outfall, stream C3 in Figure 28.3-1.

Lastly, the Surface Water Drainage System [ZZT] aims to collect surface water run-off, primarily rainwater, and direct it away from the RR SMR site. Work is being undertaken to examine the requirement of an extreme hazard drainage system to accommodate for a design basis pluvial event that would be utilised during extreme rainfall events. The sewage system [ZZU] collects sewage and foul water generated from office blocks, water closets (WCs), washrooms, various condensates and more [49]. The design maturity of the surface water drainage system and the sewage system is significantly lower than the other systems described that direct effluent to the outfall pond. However, efforts will be made to maximise the use of the rainwater collected in line with sustainability practices wherever possible.

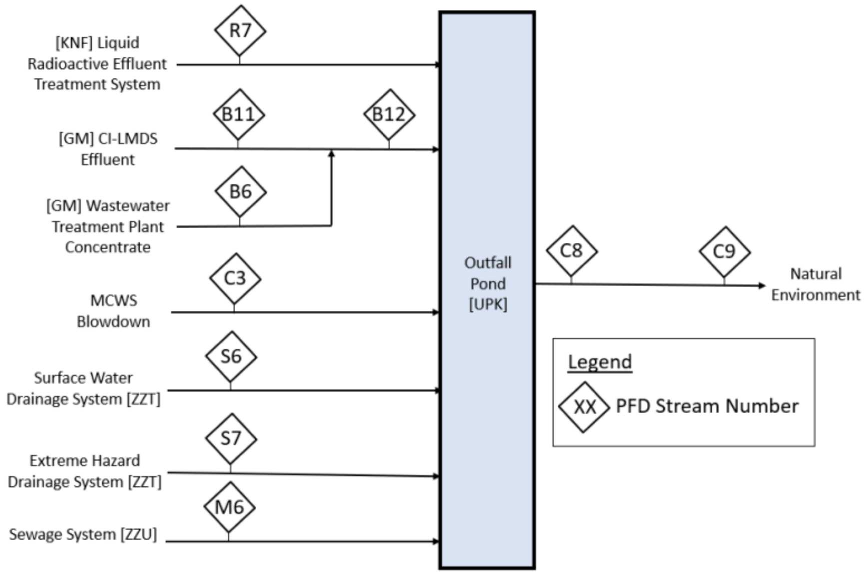


Figure 28.3-1 Simplified Schematic of the Liquid Effluent Environmental Discharges Process Flow Diagram [37] [50]

28.3.1.1 Liquid Effluents Final Discharge Point

The final liquid outlet is the Cooling Water Outfall Pond [UPK] as captured in Table 28.3-1. The generic site description for the RR SMR is a coastal site, approximately 100 m from the sea. Thus, the outfall pond will discharge directly to the sea.

The Cooling Water Outfall Pond [UPK] is part of the ACMS [PE] which aims to:

- Remove blowdown water from the MCWS and discharge to the natural environment (sea).

- Collect and discharge effluent from the other internal outfalls for example, from the Wastewater Drainage and Treatment System [GM], wastewater from the Liquid Radioactive Effluent Processing Systems [KN], wastewater from the Surface Water Drainage System [ZZT] and treated wastewater from the Sewage System [ZZU] and discharge it to the sea.

The ACMS [PE] system provides the pipework to transfer the blowdown from the cooling tower basin to the outfall pond [UPK]. The outfall pond connects the blowdown pipework to the outfall tunnel and outfall head. The purpose of the outfall pond is to allow discharges from the various streams to mix and to also act as storage. The outfall tunnel discharges the effluent to the sea as noted above.

Table 28.3-1 Final Liquid Outlets to the Environment

Wastes	Discharge Point	Contributors to final discharge point (e.g. systems, facilities)
Radioactive Liquid Discharges	Cooling Water Outfall Pond [UPK]	Liquid Radioactive Effluent Treatment System [KNF], specifically via the LMDS [KNF30] tanks. Other systems that discharge to the Cooling Water Outfall Pond [UPK] that do not carry radioactive contamination have been captured in section 28.3.1 as these could affect the LoD at the final outfall.

Outfall pond design, constraints from the site conditions and optimisation of the discharge(s) are still under development. The overall sampling and monitoring system of final discharges to natural environment, the Auxiliary Non-nuclear Sampling System [QU] is also in the early stage of development. Section 28.3.2 presents in more detail the proposed arrangements at the Cooling Water Outfall Pond [UPK] and the internal outfalls.

28.3.2 Liquid Effluent Sampling and Monitoring Arrangements

28.3.2.1 Liquid Effluent Sampling and Monitoring Philosophy

The liquid effluent sampling and monitoring philosophy has built upon the HMB reports. It is a key step in determining where is the most appropriate sampling locations to get representative samples of discharges to the natural environment. The philosophy presented an overview of available RGP and OPEX from a wide range of nuclear facilities. The philosophy produced a baseline solution and identified other viable options that will be taken forward and evaluated during the conduct design optioneering process.

The high-level benefits and disadvantages of each option are also summarised in the report. It is recognised that flowrates, as a minimum, will need to be measured, and comply with MCERTS, at the final outfall [UPK]. The focus is on ensuring that the proposed arrangements would meet the LoD required and other regulatory requirements.

A baseline option is proposed, and whilst the baseline option is viable, it is not the chosen option, a baseline is used to score all other viable options against. The proposed baseline identified in the philosophy is reproduced in Figure 28.3-2 in section 28.3.2.3.

The philosophy identifies the two key decisions looked at for final discharges and the options generated that would meet both considerations:

- Selection of potential viable points that could be used for final discharge accountancy /reporting (and potential combinations), consideration was given to:
    - Sampling all internal pond discharges and the final outfall discharges for final accountancy.
    - Sampling final outfall discharge point for accountancy only.
    - Combining and sampling specified internal ponds and the final outfall discharge point for accountancy.
- Equipment type that would be required at each individual point to enable reporting of final discharges (see Figure 28.3-2).

The outcome of these decisions will be captured in a decision record. The conduct design optioneering process is required for all decisions made and is fundamental to demonstrating that final solution proposed meets BAT.

- FA 28.7: Produce ‘final liquid effluent sampling and monitoring’ decision record as per conduct design optioneering process.

The decision record will be for the Auxiliary Non-nuclear Sampling System [QU] and will incorporate the Cooling Water Outfall Pond [UPK]. The decision record will validate (or not) the baseline solution proposed in the philosophy for liquid effluent accountancy purposes. Following completion of the decision record an SDD for [Q] will be produced.

- FA 28.8: Produce SDD for the Auxiliary Systems [Q] which will also define the systems that make up the Auxiliary Non-nuclear Sampling System [QU].

28.3.2.2 In-process Sampling and Monitoring

The in-process sampling and monitoring arrangements for liquid radioactive effluents from RI are under the control of RISS [KU].

The NSS [KUA] covers in-process monitoring and sampling of primary circuit and supporting systems to enable characterisation of plant fluid properties and act as an indicator of how a system is performing. The initial conduct design optioneering process, the associated decision record and the SDD have been completed for NSS [KUA] at DR1 maturity. The decision record identified the characterisation points that should have integrated monitoring and/or provide grab-sampling capability [40]. The rationale behind the decisions is captured in [40].

In this chapter we present the systems, alongside their RDS-PP code, that provide in-process grab-samples and/or have monitoring capabilities within the NSS [KUA] scope (tabulated in Table 28.3-2). There is also a note of whether the characterisation point and/or the method proposed is a novel solution based on the review of OPEX.

The NSS [KUA] system is only concerned with 'in-process' sampling and monitoring, and as such does not consider sampling and monitoring at final discharge points. The system covers the following RI systems [51]:

- Reactor Coolant Pipework System [JEC]
- Reactor Pressurising System [JEF]
- Coolant Purification System [KBE]
- Cold Shutdown Cooling System [JNA]
- Low Pressure Injection System [JNG]
- Local Ultimate Heatsink System [JNK]
- Fuel Pool Cooling System [FAK]
- Fuel Pool Purification System [FAL]
- Fuel Pool Supply System [FAT].

Note that the Emergency Boron Injection System [JDK] is not currently captured in the baseline design of the NSS [KUA] SDD. However the associated decision record has considered, and an action is captured in the NSS [KUA] SDD to explore and capture alternative means for sampling of this system in the next issue of the NSS [KUA] SDD [51]. A viable option for baseline has been proposed in the decision record and this is captured in the table below [40].

The characterisation points for in-process monitoring purposes under the NSS [KUA] system scope are identified based on the location that will give the best indication of the fluid properties. The characterisation points are subject to refinement as part of the evolving design process.

It is considered that the characterisation points tabulated in Table 28.3-2 are considered appropriate for the current maturity level of the RR SMR design.

Table 28.3-2 Characterisation Points within the NSS [KUA] Scope

System	RDS-PP	Characterisation point	Sampling Method Grab or Continuous Sampling Location Local/remote/laboratory Characterisation / Analysis Method
Reactor Coolant System (RCS)	[JEC]	Hot Leg 1	Grab-sampling - Laboratory Offline and/or Integrated Monitoring
Reactor Pressurising System	[JEF]	Pressuriser Liquid Space	Grab-sampling - Laboratory Offline and/or Integrated Monitoring
Coolant Purification System	[KBE]	U/S Purification (D/S CCA [KAA] Heat Exchanger HX)	Grab-sampling - Laboratory Offline and/or Integrated Monitoring
		D/S Purification (D/S Backwash Filters)	Grab-sampling - Laboratory Offline and/or Integrated Monitoring (novel solution)
		D/S Chemical Dosing	Grab-sampling - Laboratory Offline and/or Integrated Monitoring
		U/S & D/S Purification (for particulate sampling)	Grab-sampling - Laboratory Offline only
Low Pressure Injection System	[JNG]	Accumulator Liquid Space (each tank)	Grab-sampling - Local (novel solution) Offline only
Cold Shutdown Cooling System	[JNA]	Common Return line (D/S HXs)	Grab-sampling - Laboratory Offline and/or Integrated Monitoring
Local Ultimate Heat Sink	[JNK]	Coupled and Tertiary Tank Body	Grab sampling - Local Offline and/or Integrated Monitoring (novel solution)
		Coupled and Tertiary Tanks: D/S Recirc. Pump	Grab-sampling - Local Offline and/or Integrated Monitoring

System	**RDS-PP**	**Characterisation point**	**Sampling Method** **Grab or Continuous** **Sampling Location** **Local/remote/laboratory** **Characterisation / Analysis Method**
Fuel Pool Supply System	[FAT]	D/S Pump (each train) (novel solution)	Grab-sampling - Local Offline and/or Integrated Monitoring
Fuel Pool Cooling System	[FAK]	D/S HX (each train)	Grab-sampling - Local Offline and/or Integrated Monitoring
Fuel Pool Purification System	[FAL]	D/S HX (each train)	Grab-sampling - Local Offline and/or Integrated Monitoring
		U/S Purification (each train)	Grab-sampling - Local Offline and/or Integrated Monitoring
		D/S Purification (D/S IEX Backwash Filters)	Grab-sampling - Local Offline and/or Integrated Monitoring (novel solution)
		U/S & D/S Purification (for particulate sampling)	Grab-sampling - Remote Offline only
Emergency Boron Injection System	[JDK]	D/S Recirculation Pump (each train)	Grab sampling – TBD ideally remote. Offline and/or Integrated Monitoring (for boron)
		[JDK] - Refuelling Pool Interface: Double Isolation Valve Interspace	Only inline boron monitoring proposed (no grab-sampling)
		[JDK] - High Pressure Injection System Interface Double Isolation Valve Interspace	Only inline boron monitoring proposed (no grab-sampling)

Another system that falls under the RISS [KU] system scope (Figure 28.2-3) is the AxSS [KUB]. The architecture of the latter is presented in detail in the relevant decision record [41], briefly the scope of AxSS includes sampling and monitoring points that support the in-process characterisation of plant fluid properties of the plant. Similarly, this characterisation can be achieved by offline means and integrated monitoring as in the NSS [KUA] case.

AxSS also covers the [KNF30] tanks which could form one of the final accountancy points (pending on the decision record for the Auxiliary Non-nuclear Sampling System [QU]) as discussed in section 28.3.2.1.

The in-process characterisation points that are under the scope of AxSS [KUB] are tabulated in Table 28.3-3, alongside their RDS-PP code. The system covers the following systems:

- Steam Generator Blowdown System [LCQ]
- Component Cooling System [KAA]
- Reactor Island Drainage System [KTA]
- Liquid Radioactive Effluent Treatment System [KNF]
- Storage System for Wet and Solid Radioactive Waste [KME] (see section 28.4)
- Component Decontamination System [FKA]
- Gaseous Radioactive Effluent Treatment System [KPL]

Note that the [KPL] system handles RI gases (see section 28.2.1).

Table 28.3-3 Characterisation Points within the Auxiliary Sampling System [KUB] Scope

System	RDS-PP	Characterisation point	Sampling Method Grab or Continuous Sampling Location Local/remote/laboratory Characterisation / Analysis Method
Steam Generator Blowdown System	[LCQ]	SG interfacing Blowdown Pipework	Grab-sampling - Laboratory Offline and /or integrated monitoring
		D/S Purification	Grab-sampling - Laboratory Offline and /or integrated monitoring
Component Cooling System (CCS)	[KAA]	D/S Pump (each train)	Grab-sampling – Local Offline and/or integrated monitoring
Liquid Radioactive Effluent	[KNF10][5]	Effluent Holdup Tanks 1 & 2: D/S Recirculation Pumps	Grab-sampling - Remote Offline only

[5] The [KNF] and [KTA] systems are tanks (liquid-based systems) that would produce liquid samples, while the [KME] system handles (dry & wet) solid waste.

System	RDS-PP	Characterisation point	Sampling Method Grab or Continuous Sampling Location Local/remote/laboratory Characterisation / Analysis Method
Treatment System	[KNF20]	Chemical & Retentate Drain Waste Holdup Tank: D/S Recirculation Pump	Grab-sampling - Remote Offline only
		Process & Floor Drain Waste Holdup Tank: D/S Recirculation Pump	Grab-sampling - Remote Offline only
		Reverse Osmosis (RO) Membrane Retentate Line	None
		RO Membrane Permeate Line	None
		RO Permeate Polishing Train D/S Resin Trap	None
		Evaporator Reboiler Loop D/S Recirculation Pump	Grab-sampling - Remote Offline only
	[KNF30]	Active Effluent Monitoring Tanks D/S Recirculation Pump	Grab-sampling - Remote Offline only
Reactor Island Collection and Drainage System (RICDS)	[KTA20]	Process & Floor Drain Tank D/S Recirculation Pump	Grab-sampling - Remote Offline only
	[KTA30]	Chemical Drain Tank: D/S Recirculation Pump	Grab-sampling - Remote Offline only
	[KTA40]	Non-Active Drain Tank: D/S Recirculation Pump	Grab-sampling - Remote Offline only
Component Decontamination System	[FKA]	D/S Effluent Buffer Tank Recirculation Pump	Grab-sampling - Remote Offline only

The grab sampling manner and the characterisation method for each characterisation point under AxSS [KUB] scope that provide an in-process sample is depicted in Table 28.3-3 but more details can be found in the decision record that captures the [KUB] functionality [41].

Lastly, the other in-process liquid effluent points that will be monitored for activity (Gross β/γ activity) fall under the PERMS [KUK] functionality. There will not be any liquid grab-sampling for these points/systems provided under the scope of PERMS [KUK] (see Table 28.3-4).

Table 28.3-4 Characterisation Points within the PERMS [KUK] Scope that will Provide In-process Monitoring

System	RDS-PP	Characterisation point
Fuel Pool Purification System	[FAL]	D/S Purification (each train) (D/S Mechanical Filters)
Main Steam Piping System	[LBA]	SG Main Steam Line
Steam Generator Blowdown System	[LCQ]	SG-Interfacing Blowdown Pipework (each SG) U/S of [LCQ] flow regulating valve
Component Cooling System	[KAA]	D/S Pump (each train)
Coolant Purification System	[KBE]	D/S Purification (D/S Mechanical Filters)
Nuclear Sampling System	[KUA]	RCS [JEC] Hot Leg Sampling Header
		Reactor Pressurising System [JEF] Pressuriser (L) Sampling Header
Reactor Island Collection and Drainage System	[KTA40]	D/S Recirc. Transfer Pump of Non-Active Drain Tank

28.3.2.3 Final Discharge Point Sampling and Monitoring

A schematic representation of the six systems that direct discharge to the Cooling Water Outfall Pond [UPK] and how [UPK] interacts with the natural environment is presented in Figure 28.3-2. The proposed baseline scenario for accountancy points identified in the liquid effluent sampling and monitoring philosophy is also presented. The only system that carries radioactive contamination is highlighted.

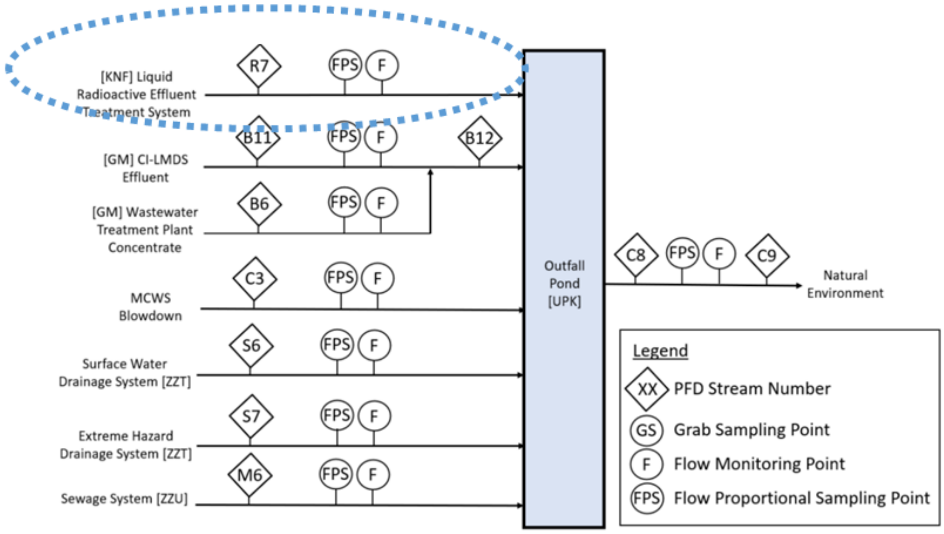


Figure 28.3-2 Summary of Accountancy Points Overlayed on a Block Flow Diagram [37]

The baseline configuration has flow measurement equipment on all internal outfalls and the final outfall too. It proposes permanent composite sampling systems and permanent MCERTS flowmeters on each outfall (internals and final one). The figure does not show in-process sampling and monitoring, it displays accountancy points and equipment for flow measurement and characterisation.

The baseline configuration ensures that all contaminants are accounted for prior to dilution by other waste streams and offers a thorough understanding of the discharges to the operator, providing a detailed breakdown of effluents and ensures that the LoD will be met at the point of measurement. There are flow measurement and effluent characterisation capabilities at all internal outfalls and the final outfall.

The disadvantage of the proposed baseline scenario is that it proposes a significant amount of equipment to support the monitoring regime. The equipment requires EMIT, footprint and carries a substantial capital cost, while some systems are rarely in use and may not be used for several years.

All viable solutions proposed for final discharge accountancy in the philosophy include permanent composite sampling systems and permanent MCERTS flowmeters on the final outfall [UPK].

It is a regulatory requirement that all final continuous discharge points feature an MCERTS equipment, and the samples analysed using MCERTS or other accredited techniques. These requirements have been captured in DOORS. Another requirement captured is to provide access for independent sampling by the regulators for final discharges.

Independent sampling points allow regulators to take samples to verify results and allows for redundancy in the event of a fault to primary sampling equipment.

The specific equipment that will be used does not fall under the scope of this chapter so no more details on this subject are provided here.

28.3.2.4 Parameters/Determinands to be Monitored

An initial evaluation of liquid effluent systems (Figure 28.3-2) identified some process parameters that will need to be monitored. However, further work is required to help determine the full suite of process parameters that would need to be monitored.

Further information on in-process monitoring determinands is presented in the SDDs for NSS [KUA] and AxSS [KUB]. Note that the E3S Case Version 2, Tier 1, Chapter 20: Chemistry [52] has also included chemical parameters of key fluids (in process) that should be monitored to comply with the water chemistry specifications required for the RR SMR (covered by both the RISS [KU] and the Auxiliary Non-nuclear Sampling System [QU]). These parameters/determinands are constantly consulted when designing the sampling and monitoring systems of the RR SMR.

Significant radionuclides in aqueous discharges have been identified based on current understanding of the RR SMR source term and following the EA guidance document setting out their criteria for setting limits on the discharge of radioactive effluents from nuclear sites [47]. The selection criteria of the assessment to determine the RR SMR significant discharges are detailed in E3S Case Version 2, Tier 1, Chapter 29: Quantification of Radioactive Effluent Discharges and Proposed Limits [14].

The significant radionuclides (and groups of radionuclides) in aqueous discharges to the environment are provided in Table 28.3-5. These are the radionuclides that would, as a minimum, be required to be measured and reported in the final effluent to the environment for RR SMR. These will be revised, as the source term is further refined and better-defined performance criteria and design parameters for relevant RR SMR discharge abatement systems become available.

FA 28.9: Confirm what radionuclides will be monitored in the final effluents and confirm that the monitoring techniques will meet required LoD stated in

- Table 28.0-2 for liquid discharges.

Table 28.3-5 Significant Radionuclides in RR SMR Aqueous Discharges

Discharge Phase	Radionuclide/Radionuclide Group
Aqueous	H-3
	Cs-137
	Other beta/gamma

28.3.2.4.1 Flow Rate

The flowrate of the liquid discharges needs to be continuously and accurately measured to report the discharges of radioactive substances, using an appropriate MCERTS accredited technique and equipment, where available.

28.4 Solid and Non-aqueous Radioactive Waste

28.4.1 Sources of Radioactive Solid and Non-aqueous Waste

The sources, categories, quantities, and treatment routes for radioactive solid and non-aqueous wastes, are detailed in the RR SMR IWS [3], the Solid Operational Waste Identification (SOWI) report [53] and key elements are summarised in the E3S Case Version 2, Tier 1, Chapter 11: Management of Radioactive Waste [13].

Table 11.1-1 in E3S Case Version 2, Tier 1, Chapter 11: Management of Radioactive Waste [13] provides operational solid and non-aqueous radioactive waste descriptions (waste types/sources) and the associated waste category likely to be assigned at the point of generation. A summary of the expected waste volumes is also presented in Table 11.1-3 of the chapter. Therefore, this chapter will provide a brief overview of the waste management systems and section 28.4.2 will discuss the current arrangements for sampling and monitoring of the solid and non-aqueous operational wastes.

The Solid Radioactive Waste Management System [KM] collects, immobilises, stores and dispatches low level waste (LLW) and intermediate level waste (ILW). The [KM] system is decomposed in two main subsystems, which are also further broken down into [54]:

- Solid Radioactive Waste Processing System [KMA]
    - Processing and Dispatch Area for LLW [KMA10]
    - Off-the-shelf Processing Equipment for ILW [KMA20], including ILW cementation equipment within a hot cell
- Solid Radioactive Waste Storage System [KME]
    - Temporary Storage Area for LLW [KME10]
    - Storage Tanks for wet ILW (resins concentrates and filter solids) [KME20], with transfer pumps to processing system and connection to sampling systems
    - Long Term Storage for Processed ILW Store [KME30] after conditioning.

Figure 28.4-1 provides a schematic overview of how [KMA] and [KME] fit together with other relevant systems.

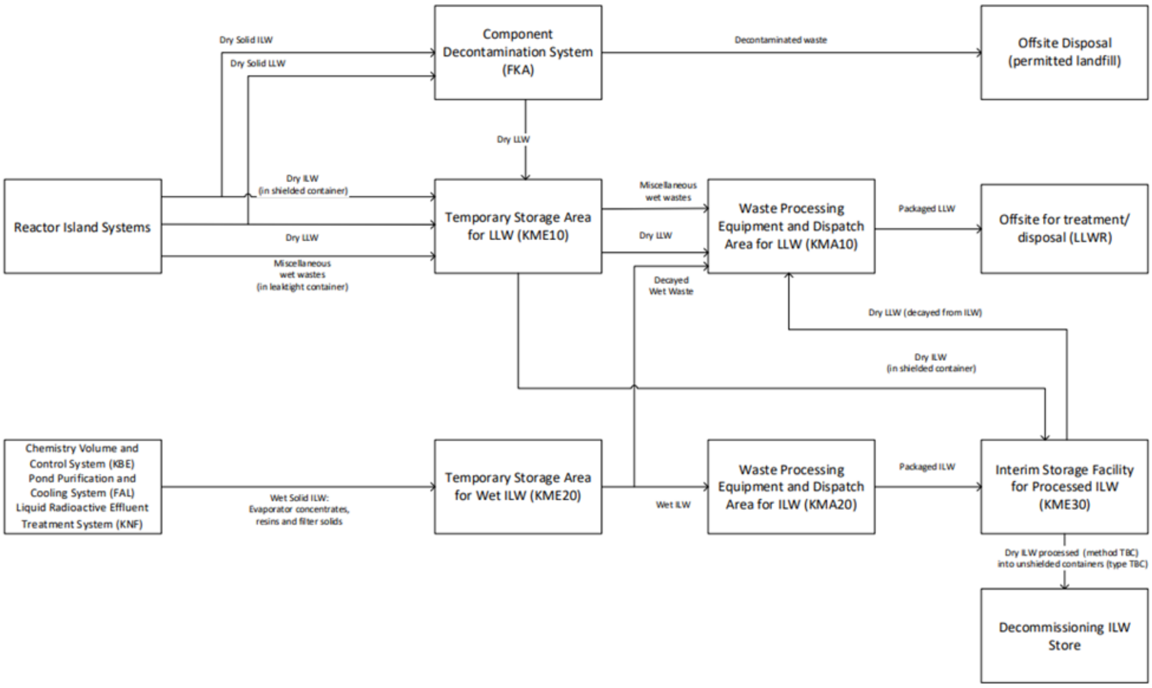


Figure 28.4-1 Solid Radioactive Waste Management System [KM]

The various systems are at different maturity levels. More information for the specific subsystems is provided in the SDD for the Solid Radioactive Waste Management System [KM] [54].

28.4.2 Solid and Non-aqueous Waste Characterisation

Solid LLW from inside the hazard shield, will be segregated and placed in bags at source by operators. Waste must pass through a health physics assessment which shall identify the total gamma activity and separate waste by activity, contamination type and material. Waste will then be moved to [KME10] for buffer storage. These wastes will be categorised into waste metal melt, combustible waste, compactible waste, waste suitable for LLW disposal and waste suitable for very low-level waste (VLLW) disposal [54]. The [KME10] system consists of cages for storing different waste types. Waste segregation is important as the waste management route can be different amongst these categories (see Figure 28.4-2). Waste will remain in the buffer storage between [KMA] treatment campaigns [13]. The processing and dispatch system for LLW [KMA10] will provide large and small article monitors and equipment for packaging, to characterise and package a variety of LLW wastes.

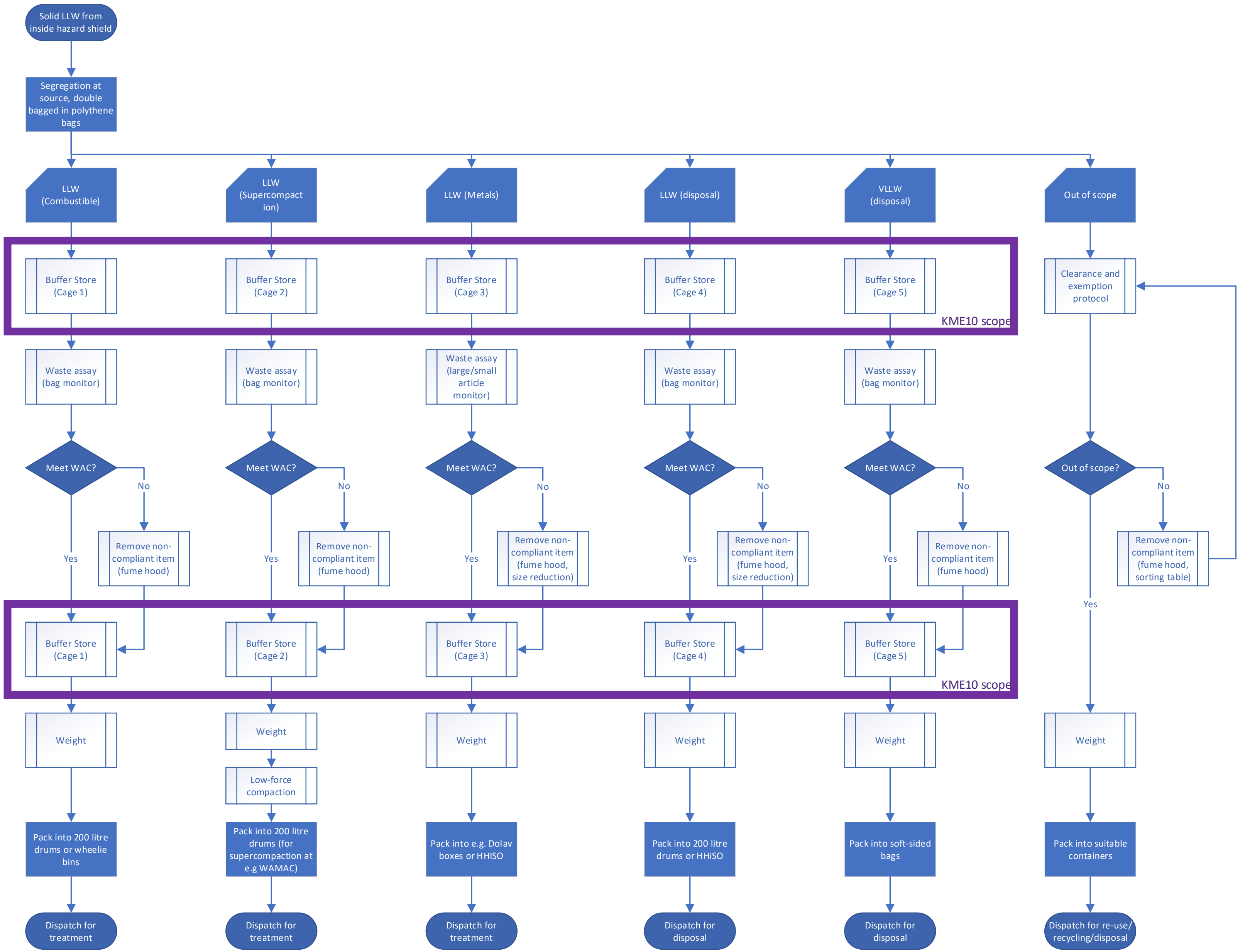


Figure 28.4-2 [KME10] Waste Flow Diagram

Any oils and solvents will be collected and stored within suitable waste packages for offsite treatment such as incineration.

With regards to the interim storage for solid ILW [KME20]:

- If the dry ILW wastes meet the waste acceptance criteria (WAC) of the Component Decontamination System [FKA] and are expected to be brought below the LLW threshold, they will be transferred for decontamination. If not, they will be packaged unencapsulated in suitable packages, so as not to foreclose future treatment and disposal options.

- The wet ILW waste placed in the concentrate storage tanks and the resins storage tanks, will be sampled via a recirculation line to help ensure a representative sample is taken from the tanks [54]. During a treatment campaign, the tank will undergo mixing and sampling before transfer to [KMA10] for processing.

- Confirmation of the wet ILW waste transfer determined procedurally can be performed using radiation monitors on pipe externals to validate for example resin transfer.

The solids from the [KME20] storage tanks can be transferred to [KMA10]/[KMA20] for immobilisation via pumps. There is no treatment system for dry ILW in the [KMA] design. The grouting process for wet ILW is to be specified and designed at a later stage with a supply chain partner. The indicative equipment used in [KMA20] can be found in [54].

All [KME20] tanks have provisions for sampling on tanks for waste characterisation. Waste is expected to be characterised prior to waste treatment campaigns. Boundary resins tanks shall be characterised once full, to inform decay periods. Characterisation shall be 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 AxSS [KUB] will be used for main categorisation of the waste in [KME] where small volumes will be required for sampling and offline analysis (see Table 28.4-1). AxSS [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 onsite laboratories.

Table 28.4-1 Characterisation Points within the AxSS [KUB] Scope

System	**RDS-PP**	**Characterisation Point**	**Sampling Method** **Grab or Continuous** **Sampling Location** **Local/remote/laboratory** **Characterisation / Analysis Method**
Storage System for wet and solid radioactive waste	[KME20]	Solid Waste Tanks: D/S Recirculation Pump	Grab sampling - Remote Offline only

The characterisation of the [KME20] tanks contents is expected to be carried out when the tanks are full prior to transfer and is envisaged to be required infrequently.

Gamma spectrometry of the final waste packages in [KME20]/[KMA20] will be used for verification of waste categorisation.

Long term storage of processed ILW store [KME30] is a shielded storage facility. The store will include remote monitoring and inspection capability of the packages which will inform any remedial action of any degraded packages [54]. [KME30] will have monitoring and maintenance facilities and a package inspection cell. The packaged waste from [KMA20] that will be transferred to [KME30] will be checked upon import to ensure that contamination levels are consistent with the store's environmental control approach and WAC. The packages during the interim storage will be optimised and protected until disposal to a geological disposal facility (GDF). Disposals will need to comply with the GDF WAC, and discussions are ongoing with the Nuclear Waste Services (NWS) who will operate the GDF to ensure that waste streams likely to be generated are compatible with GDF. More information on the interim storage can be found in [54].

To summarise, the key information on current sampling and monitoring arrangements for [KM] is:

- Waste is monitored and segregated at source.
- In the wet waste processing system [KMA10] waste monitoring/characterising waste packages will occur with the various article monitors prior to offsite waste despatch.
- The [KME] bays can be partitioned to fit varying size cages that hold the different waste categories (for example metallic wastes).
- Provision for an area of storing decay waste shielded containers is also made in [KME10].
- Sufficient capacity to store wastes has been considered (for example, tanks are conservatively sized either based on OPEX or campaigns frequency [13] [54]).
- All [KME20] tanks have provisions for sampling on tanks for waste characterisation.
- Characterisation is determined by requirements to meet WAC (and/or material acceptance criteria (MAC)) of the receiving organisation.
- ILW storage tanks [KME20] are grouped to facilitate segregation and allow decay storage. A recirculation line allows for mixing of tank contents to ensure a representative sample can be taken. Jet mixing eductors are proposed on recirculation return lines to minimise moving parts.
- Sampling is performed in dedicated sampling room with access controls.
- A hot cell is dedicated to wet ILW wastes delivered to [KMA20] from [KME20]. Packages will require swabbing prior to transfer to the ILW store, to ensure contamination is within the ILW store WAC.
- Table 28.4-1 depicts that the AxSS [KUB] covers the [KME] system and offers a grab-sampling capability for offline analysis. The design will be developed further once AxSS [KUB] system reaches DR3.

- Treatment of all wet solid types [KME20] 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.

- Sampling will be performed prior to treatment campaigns, to determine appropriate mixture for encapsulation and to form part of disposability assessment. Sampling will be done to confirm the compatibility of the waste stream with the disposability assessment criteria.

- Gamma spectrometry of the final waste packages in [KME20]/[KMA20] will be used for verification of waste categorisation [13].

- [KMA10] and [KMA20] wet waste packages shall not be assayed after encapsulation but shall undergo a surface contamination check prior to transport off-site or to [KME30]. This shall be performed using a surface swab, which shall be assessed in the hot laboratories.

- Reassurance monitoring of the third-height international standards organisation (THISO) containers, where processed wet waste will be placed, will be performed prior to disposal to low-level waste repository (LLWR).

- Dry LLW waste will be assayed using the small and large article monitors in [KMA10], allowing them to be mapped to one of the plant specified LLW fingerprints, segregated into appropriate packages and dispatched off site. [KMA10] packages may also be assayed by the bags/drum scanners in the [KMA10] system in [54].

- Packaged LLW shall be swabbed externally for dose protection and gamma specified to verify waste category before disposal to LLWR.

- Packaged ILW will be stored in controlled conditions to ensure acceptance by the future GDF. A dummy package will be regularly inspected and monitored.

- The HVAC extract on the tank, falls under gaseous monitoring under the [KL] scope as mentioned in section 28.2.2.

- The instrument type of [KUB50] at RD7/DRP1 is not defined (also note it is outside the scope of the chapter).

28.5 Demonstration of Best Available Techniques

The demonstration of BAT will follow the CAE approach as described in RR SMR Approach to BAT and Optimisation [5] and summarised in E3S Case Version 2, Tier 1, Chapter 27: Demonstration of Best Available Techniques [6].

Figure 28.5-1 and Figure 28.5-2 show the decomposition of the high-level BAT claims (identified in section 28.0.3) and provide an indication of how the argument(s) are progressing and identify key documents (references) that are available as supporting evidence. Most of the sampling and monitoring systems are still in the early design stages and have not yet reached the design stage at which the final strategic option has been selected. Therefore, the information provided in these figures is not comprehensive, further work and development is required to fully demonstrate BAT for sampling and monitoring arrangements.

- FA 28.10: Demonstration of BAT following CAE structure and RR SMR BAT methodology for all final discharge and key in-process monitoring systems to be provided in later iterations of this chapter (as systems reach DR3 maturity).

Claims	Claim 28. The RR SMR has appropriate sampling arrangements, techniques and systems for measuring and assessing discharges of radioactive wastes to the environment and disposals of radioactive waste to other premises				
	Claim 28.2: All final discharge or disposal points (to the environment) will have appropriate monitoring that can be demonstrated to be BAT, meet future permit requirements, and have sufficient sensitivity to meet required LoD.				
Argument Summary	All Final Radioactive Discharge Points to the Environment are identified to ensure adequately sampled and monitored: • Requirements for sampling techniques considered • Sources of discharges, pathway to environment identified • Parameters that need to be monitored understood and defined • How best provide sample demonstrated- grab, continuous or integrated monitoring.	Solid and non-aqueous wastes are adequately characterised and monitored to demonstrate compliance with receiving sites WAC / MAC • Sources of waste identified • WAC//MAC of receiving site understood • Parameters that need to be monitored understood and defined • Requirements for monitoring / characterisation defined	Representative samples are collected at discharge points: • demonstrate samples well mixed, • taken downstream of abatement, • away from pipe bends • frequency short enough to yield results that are representative for the entire sampling period, • number of samples representative of time period • Isokinetic sampling for particulates	Design of the sampling systems and location ensures: • Sufficient space for equipment to be installed and not foreclose potential options. • Sufficient and suitable space to allow safe access to equipment during operation, EMIT and independent monitoring activities • Suitable environmental conditions for equipment and personnel – humidity, temperature, adequate ventilation • Suitable materials e.g. prevent deposition or particulate retention	Monitoring techniques chosen which will meet required sensitivity and LOD: • LOD for different species in different media and techniques capable to meet requirements understood • Justify - appropriate techniques have been selected
Evidence	Examples of Evidence: • SMR0006494_1, Liquid Effluent Environmental Discharges – Heat and Material Balance. • SMR0006048_2, [R01-523] – System Architecture for [KUB], & PERMS [KUK] Reactor Island Sampling Systems – Decision Record. • SMR0004502 Issue 2, SMR E3S Case Chapter 11: Management of Radioactive Wastes. • SMR0010686, RR SMR Gaseous Effluent Sampling and Monitoring Philosophy. • SMR0006496_1, Liquid Effluent Sampling and Monitoring Philosophy.	Examples of Evidence: • SMR0007665_1 RR SMR Disposability Case Report • SMR0002131_3: Integrated Waste Strategy • EDNS01000935063: Optioneering of Methods for Treatment of Solid Radioactive Waste • SMR0000579: Optioneering of Methods for Treatment of Solid Radioactive Waste • SMR0005649: Management of Liquid Organic Low Level Radioactive Wastes for the RR SMR • SMR0001123_2 System Design Description for the Solid Radioactive Waste Management System.	Examples of Evidence: • SMR0010686_1. RR SMR Gaseous Effluent Sampling and Monitoring Philosophy. • SMR0006496_1. Liquid Effluent Sampling and Monitoring Philosophy. • SMR0005368 Issue 2, RI-045 – System Architecture for the Nuclear Sampling System [KUA] – Decision Record. • SMR0006048 Issue 2, [R01-523] – System Architecture for [KUB], & PERMS [KUK] Reactor Island Sampling Systems – Decision Record	Examples of Evidence: • OPEX from other Nuclear Power Plants • Supplier information on sampling and monitoring equipment • SMR0007298 Architectural and Layout Summary Report	Examples of Evidence: • SMR0006974_1, E3S Case Chapter 29. • Official Journal of the European Union, 2004/2/ Euratom Commission: Standardised information on radioactive airborne and liquid discharges into the environment from nuclear power reactors and reprocessing plants in normal operation. • SMR0006048 Issue 2, [R01-523] – System Architecture for [KUB], & PERMS [KUK] Reactor Island Sampling Systems – Decision Record

Figure 28.5-1 Summary of Claim 28.2

Claims	Claim 28. The RR SMR has appropriate sampling arrangements, techniques and systems for measuring and assessing discharges of radioactive wastes to the environment and disposals of radioactive waste to other premises		
	Claim 28.1: The RR SMR has appropriate monitoring at key process points to flag to operators if conditions start to fluctuate or performance is compromised, so that appropriate action can be taken.	**Claim 28.3**: Sampling and monitoring arrangements will enable the provision of data required to assess impact of discharges from RR SMR to the public and environment	**Claim 28.4**: RR SMR design incorporates independent monitoring points to allow periodic sampling / redundancy in sampling.
Argument Summary	Conduct design optioneering process followed to ensure that sampling & monitoring of in-process systems take RGP and OPEX into consideration when considering options • In-process systems characterisation points identified. • Where to sample and how to obtain representative sample understood • Deviations or issues in discharges can be detected in a timely manner to minimise discharges and to prevent permit exceedances • Tank / batch discharges are sampled prior to discharge to drainage system • Operational control limits identified and procedures in place for dealing with effluents outside parameters	Discharges are quantified accurately and sampling and monitoring is designed to meet the permit conditions (described in Section 28.0.4.2.1) • Volumetric flows measured by MCERTS flow equipment • Discharges are measured using techniques / equipment that can meet LOD in EU2004/2/Euratom • Equipment is subject to EMIT	Provision for independent monitoring of final discharges captured in design: • include sufficient space to allow independent monitoring equipment and personnel access • Ensure representative samples can be taken • Suitable environmental conditions Note: number of arguments to demonstrate that RR SMR sampling and monitoring arrangements can meet BAT claims will also apply to independent monitoring points
Evidence	<u>Examples of Evidence:</u> • SMR0004683_3 Approach for Optimisation through the Application of BAT • SMR0005368_2, RI-045 – System Architecture for the Nuclear Sampling System [KUA] – Decision Record. • SMR0006048_2 [R01-523] – System Architecture for [KUB], & PERMS [KUK] Reactor Island Sampling Systems – Decision Record. • SMR0004502_2 SMR E3S Case Chapter 11: Management of Radioactive Wastes.	<u>Examples of Evidence:</u> • SMR0010686_1 RR SMR Gaseous Effluent Sampling and Monitoring Philosophy. • SMR0006496_1 Liquid Effluent Sampling and Monitoring Philosophy. • Transverse requirements placed on S&M systems in DOORS – summarised in philosophies	<u>Examples of Evidence:</u> • SMR0010686,, RR SMR Gaseous Effluent Sampling and Monitoring Philosophy. • Rolls-Royce SMR Limited SMR0006496_1, Liquid Effluent Sampling and Monitoring Philosophy. • Transverse requirements placed on S&M systems in DOORS • SMR0005368_2, RI-045 – System Architecture for the Nuclear Sampling System [KUA] – Decision Record.

Figure 28.5-2 Summary of Claim 28.1, 28.3 and 28.4

28.6 Conclusions

28.6.1 ALARP, BAT, Secure by Design, Safeguards by Design

Rolls-Royce SMR Limited has adopted a requirements-led approach for designing the RR SMR. The Model Based System Engineering (MBSE) framework supports the understanding and interfacing of requirements and aligns with the data found in the requirements management system, DOORS. MBSE is mostly used in system design (not component unless complex), supports the development programme of the RR SMR and establishes a clear definition of the design requirements [37] [55]. The framework also allows the decomposition and flow-down of the requirements to ensure optimised solutions are developed to support the demonstration of ALARP, BAT, Secure by Design and Safeguards by Design.

The requirements pertaining to sampling and monitoring are developed and stored in DOORS to support the design solutions through the decision-making and conduct of design optioneering process (C3.2.2-2 [39]), where a structured generation and assessment of options is performed. This ensures that BAT and ALARP are demonstrated, and that the design solution meets Secure by Design and Sustainable by Design objectives.

The requirements are based on E3S principles which have been derived from legislative requirements and RGP. This is evident in the decision records for the sampling and monitoring systems, that capture, analyse and provide a rationale on the selection of the short-listed options before a final decision is made. The preferred design solution should in principle fulfil all the defined requirements placed on the SSC. Specifically, a demonstration of this process can be found in the RI sampling systems architecture decision records and stemmed from the SDDs which show the logical approach, optioneering taken and justification of the option accepted as representative of BAT [40] [41] [51] [56].

The Approach for Optimisation Through the Application of BAT [5] details the methodology adopted to demonstrate that the environmental performance of the RR SMR has been optimised. A key step in supporting the demonstration of BAT is the completion of a decision record (decision record template is TS-DD-02) which captures the design optioneering process. Chapter 27 (Tier 1) of the E3S Case provides a summary of the approach used to demonstrate BAT (namely the CAE approach) and presents a selection of claims to support the fact that the RR SMR design will be compliant with BAT, ALARP and Secure by Design. Future issues of this chapter will provide a more detailed CAE breakdown for the four high level claims on sampling and monitoring arrangements (section 28.5). The design of the sampling and monitoring systems has adhered to these processes which provides confidence that the solutions proposed for the RR SMR will meet the principles of ALARP, BAT, and Secure/Safeguard by Design.

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

The following assumptions and commitments pertaining to sampling and monitoring arrangements are considered to be placed upon the future dutyholder/licensee/permit holder of the RR SMR alongside the description of the reasoning for this.

Table 28.6-1: Assumptions and Commitments on Future Dutyholder/Licensee/Permit Holder

Assumption/Commitment	ID	Description
Commitment	C28.1	Future permit holder will check that the sampling and monitoring arrangements represent BAT for their specific site requirements. The baseline scenario is comprehensive, thus, some of the generic monitoring provisions can be adjusted (optimised) once a specific site is known. This is not about changes due to different regulatory framework but ensuring impact is still minimised and monitoring arrangements for the actual location of RR SMR are customised.
Commitment	C28.2	Future permit holder will develop a site-specific statutory environmental monitoring and sampling programme (SEMP). This programme is outside the scope of the sampling and monitoring arrangements mentioned in this chapter. SEMP is dependent on the specific site location and will need to be developed as part of the site-specific permitting application. Monitoring radioactivity around nuclear sites helps to assess whether they are having any effect on people and the environment and provide reassurance to the public.
Commitment	C28.3	Future permit holder will have to demonstrate that the specific sampling and monitoring equipment proposed to be used for the determination of the discharges is appropriate (i.e. represents BAT and meets LoD). This commitment enables the future operator to accommodate any technological advances.
Commitment	C28.4	Future permit holder will have a management system in place to comply with permit requirements and relevant audits, for example, an operator monitoring assessment (OMA) audit. An environmental management system will be required that will support site-specific permit(s). For example, the EA can carry out an OMA audit to check that the reporting of the discharges is done properly.
Commitment	C28.5	Future permit holder will need to develop a sampling and monitoring programme during the decommissioning stage of the RR SMR. Monitoring required during decommissioning is excluded from chapter 28. This task will be operator specific and dependent on the operational history of the

Assumption/Commitment	ID	Description
		facility. Additionally, what is considered BAT is likely to have changed by when this stage will be performed.

28.6.3 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'. 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 28 is 'The RR SMR has appropriate sampling arrangements, techniques and systems for measuring and assessing discharges of radioactive wastes to the environment and disposals of radioactive waste to other premises'.

The arguments and evidence presented to meet the generic E3S Case Version 2 objective include the BAT methodology, radioactive waste policies and environmental guidance that are embedded and integrated into the design decision and optioneering process. A general set of environment and BAT design requirements, which will support the demonstration that the BAT claims are met, are established in the RR SMR requirements management system as non-functional system requirements and are applied to SSCs through engineering processes. The application of these processes supports the ongoing design of the RR SMR to minimise the generation of radioactive wastes and discharges, to minimise the impacts on the environment and members of the public.

The proposed sampling and monitoring arrangements for the radioactive effluents generated by the RR SMR have been presented in this chapter, with a focus on the final discharge points that directly interact with the environment. The arrangements are considered to fulfil the fundamental requirements placed on the SSCs and satisfy regulatory expectations.

The primary focus of the FAs captured in Table 28.6-2 is to ensure that the generic E3S Case demonstrates that the RR SMR will be compliant with BAT, ALARP and Secure/Safeguards By Design principles, and meet RR SMR key objectives and assessment criteria. The FAs are also developed to support the continual development of the E3S Case and build confidence that the RR SMR can deliver its fundamental E3S objective.

Additionally, the FAs will also address any further generic E3S Case requirements on in-process monitoring, continuous monitoring of final discharges of gaseous and liquid wastes to the environment as well as solid and non-aqueous waste disposals. The requirement on demonstration of BAT for sampling and monitoring arrangements, confirmation that the proposed arrangements can meet the required sensitivity (LoD) and comply with the proposed limits are further supported by the FAs.

Lastly, the provision for facilities for independent periodic sampling of final discharges of gaseous and liquid wastes conducted by the regulators, is adequately considered in the proposed RR SMR arrangements at RD7/DRP1 so no specific action has been listed in the following table.

The aim of the sampling and monitoring arrangements is to provide confidence that the discharges are understood thoroughly and can be reported clearly to regulatory authorities and the underlying processes represent BAT and are optimised.

Table 28.6-2 Forward Actions needed for Further Development of Chapter 28

ID	Description	Date
FA 28.1	As the design matures, and decision records and SDDs for sampling and monitoring systems are produced / updated the information will be reviewed and incorporated into chapter 28.	Ongoing
FA 28.2	Continue to review expected events to identify if any additional radioactive discharges need to be captured in chapter 28.	Ongoing
FA 28.3	Carry out BAT assessment to determine whether [MAQ] vent should be monitored, or whether any discharges to the atmosphere should be calculated.	December 2024
FA 28.4	Confirm what radionuclides will be monitored in the final effluents and confirm that the monitoring techniques will meet required LoD stated in Table 28.0-1 for gaseous discharges.	February 2025
FA 28.5	Produce Batch Liquid Effluent Discharge Strategy.	Third Quarter 2024
FA 28.6	Confirm whether Steam Generator Blowdown System [LCQ] will discharge to the Cooling Water Outfall Pond [UPK] via [GM] or directly.	October 2024
FA 28.7	Produce ‘final liquid effluent sampling and monitoring’ decision record as per conduct design optioneering process.	Third Quarter 2024
FA 28.8	Produce SDD for the Auxiliary Systems [Q] which will also define the systems that make up the Auxiliary Non-nuclear Sampling System [QU].	Third Quarter 2024
FA 28.9	Confirm what radionuclides will be monitored in the final effluents and confirm that the monitoring techniques will meet required LoD stated in Table 28.0-2 for liquid discharges.	February 2025
FA 28.10	Demonstration of BAT following CAE structure and RR SMR BAT methodology for all final discharge and key in-process monitoring systems to be provided in later iterations of chapter 28 (as systems reach DR3 maturity).	First Quarter of 2025

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28.8 Glossary of Terms and Abbreviations

ACMS	Auxiliary Cooling and Make-up System
ALARP	As Low As Reasonably Practicable
AxSS	Auxiliary Sampling System
BAT	Best Available Techniques
BS	British Standard
BSSD	Basic Safety Standards Directive
CAE	Claims Arguments Evidence
CCS	Component Cooling System
CI-LMDS	Conventional Island Liquid Monitoring and Discharge System
CVCS	Chemical Volume Control System
D/S	Downstream
DOORS	Dynamic Object Oriented Requirements System
DR	Definition Review
DRP	Design Reference Point
E3S	Environment, Safety, Security and Safeguards
EA	Environment Agency
EMIT	Examination, Maintenance, Inspection and Testing
ENDP	Engineering Developed Principle
EPF	Environmental Protection Functions
EPM	Environmental Protection Measures
EPR	European Pressurised Reactor
EPR16	Environmental Permitting Regulations (England and Wales) 2016
ESWS	Essential Services Water System
EU	European Union
FA	Forward Action
GDA	Generic Design Assessment
GDF	Geological Disposal Facility

GDPs	Generic Developed Principles
HAW	Higher Activity Waste
HEPA	High Efficiency Particulate Air
HMB	Heat and Material Balance
HVAC	Heating, Ventilation and Air Conditioning
HX	Heat Exchanger
IAEA	International Atomic Energy Agency
IEX	Ion Exchange
ILW	Intermediate Level Waste
ISO	International Organisation for Standardisation
IWS	Integrated Waste Strategy
LoD	Limit of Detection
LLW	Low-Level Waste
LLWR	Low Level Waste Repository
LMDS	Liquid Effluent Monitoring and Discharge System
LWR	Light Water Reactors
MAC	Material Acceptance Criteria
MBSE	Model Based System Engineering
MCERTS	Environment Agencies Monitoring Certification Scheme
MCR	Main Control Room
MCWS	Main Cooling Water Supply
NRW	Natural Resources Wales
NSS	Nuclear Sampling System
NWS	Nuclear Waste Services
OMA	Operator Monitoring Assessment
ONR	Office for Nuclear Regulation
OPEX	Operating Experience
PCD	Preliminary Concept Definition

PERMS	Process and Emissions Radiation Monitoring System
RCA	Radiologically Controlled Area
RCS	Reactor Coolant System
RD	Reference Design
RDS-PP	Reference Designation System for Power Plants
RGP	Relevant Good Practice
RI	Reactor Island
RICDS	Reactor Island Collection and Drainage System
RISS	Reactor Island Sampling Systems
RO	Reverse Osmosis
ROPs	RSR Objectives and Principles
RP	Requesting Party
RR SMR	Rolls-Royce Small Modular Reactor
RSMDP	Radioactive Substances Management Developed Principle
RSR	Radioactive Substances Regulations
SCR	Supplementary Control room
SDD	System Design Description
SEMP	Statutory Environmental Monitoring Programme
SEPA	Scottish Environment Protection Agency
SF	Spent Fuel
SG	Steam Generator
SMR	Small Modular Reactor
SOWI	Solid Operational Waste Identification
SSC	Structures, Systems and Components
TBD	To Be Determined
TGN	Technical Guidance Notes
THISO	Third-height International Standards Organisation
TI	Turbine Island
U/S	Upstream
UK	United Kingdom

VLLW	Very Low-level Waste
WAC	Waste Acceptance Criteria
WC	Water Closets
WQS	Water Quality Specification