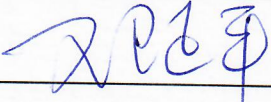



Revision	Approved by	Number of Pages
002		141
Approval Date	24/12/2021	
 General Nuclear System Ltd.		
UK HPR1000 GDA Project		
Document Reference:	HPR/GDA/PCSR/0023	
<p>Title:</p> <p style="text-align: center;">Pre-Construction Safety Report</p> <p style="text-align: center;">Chapter 23</p> <p style="text-align: center;">Radioactive Waste Management</p>		
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23.1 List of Abbreviations and Acronyms

ACPR1000	Advanced Chinese Pressurised Reactor
ALARP	As Low As Reasonably Practicable
APG	Steam Generator Blowdown System [SGBS]
BAT	Best Available Techniques
BFX	Fuel Building
BNX	Nuclear Auxiliary Building
BPX	Personnel Access Building
BQF	Spent Fuel Interim Storage Facility
BQS	Waste Auxiliary Building
BQZ	ILW Interim Storage Facility
BRX	Reactor Building
BSX	Safeguard Buildings
BWX	Radioactive Waste Treatment Building
CPR1000	Chinese Pressurised Reactor
CPR1000 ⁺	Chinese Improved Pressurised Reactor
CVI	Condensate Vacuum System [CVS]
DAW	Dry Active Waste
DECC	Department of Energy and Climate Change (UK)
DR	Design Reference
DWN	Nuclear Auxiliary Building Ventilation System [NABVS]
DWQ	Waste Treatment Building Ventilation System [WBVS]
EA	Environment Agency (UK)
EHR	Containment Heat Removal System [CHRS]
EMIT	Examination, Maintenance, Inspection and Testing
GDA	Generic Design Assessment
GDF	Geological Disposal Facility
GTRF	Grid to Rod Fretting

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HAW	Higher Activity Waste
HBSC	Human-Based Safety Claim
HEPA	High Efficiency Particulate Air
HFE	Human Factors Engineering
HFIP	Human Factors Integration Plan
HFT	Hot Functional Test
HLW	High Level Waste
HPR1000	Hua-long Pressurised Reactor
HPR1000 (FCG3)	Hua-long Pressurised Reactor under construction at Fangchenggang nuclear power plant unit 3
HVAC	Heating, Ventilation and Air Conditioning
IAEA	International Atomic Energy Agency
ICIA	In-core Instrumentation Assembly
ILW	Intermediate Level Waste
IWS	Integrated Waste Strategy
KRT	Plant Radiation Monitoring System [PRMS]
KSH	Waste Treatment Building Control System [WBCS]
LAW	Lower Activity Waste
LLW	Low Level Waste
LLWR	Low Level Waste Repository Ltd (UK)
LOCA	Loss of Coolant Accident
MSQA	Management for Safety and Quality Assurance
NALW	Non-aqueous Liquid Waste
NDA	Nuclear Decommissioning Authority (UK)
NFCC	Non-fuel Core Component
ONR	Office for Nuclear Regulation (UK)
OPEX	Operating Experience
PCER	Pre-Construction Environmental Report

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PCSR	Pre-Construction Safety Report
PSA	Probabilistic Safety Assessment
PTR	Fuel Pool Cooling and Treatment System [FPCTS]
PWR	Pressurised Water Reactor
RCCA	Rod Cluster Control Assembly
RCP	Reactor Coolant System [RCS]
RCV	Chemical and Volume Control System [CVCS]
REA	Reactor Boron and Water Makeup System [RBWMS]
REN	Nuclear Sampling System [NSS]
RGP	Relevant Good Practice
RIC	In-core Instrumentation System [IIS]
RIS	Safety Injection System [SIS]
RPE	Nuclear Island Vent and Drain System [VDS]
RPV	Reactor Pressure Vessel
RWM	Radioactive Waste Management Ltd (UK)
RWMC	Radioactive Waste Management Case
SCCA	Stationary Core Component Assembly
SEK	Waste Fluid Collection System for Conventional Island [WFCSCI]
SEL	Conventional Island Liquid Waste Discharge System [LWDS (CI)]
SFC	Single Failure Criterion
SFP	Spent Fuel Pool
SGTR	Steam Generator Tube Rupture
SRE	Sewage Recovery System [SRS]
SSC	Structures, Systems and Components
TEG	Gaseous Waste Treatment System [GWTS]
TEP	Coolant Storage and Treatment System [CSTS]
TER	Nuclear Island Liquid Waste Discharge System [NLWDS]

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TES	Solid Waste Treatment System [SWTS]
TEU	Liquid Waste Treatment System [LWTS]
UK HPR1000	UK version of the Hua-long Pressurised Reactor
VLLW	Very Low Level Waste (a sub-category of LLW)
WAC	Waste Acceptance Criteria
WENRA	Western European Nuclear Regulators Association

System codes (XXX) and system abbreviations (YYY) are provided for completeness in the format (XXX [YYY]), e.g. Nuclear Island Vent and Drain System (RPE [VDS]).

23.2 Introduction

This chapter presents the safety case in relation to radioactive waste management for the UK version of the Hua-long Pressurised Reactor (UK HPR1000). The purpose of this chapter is to demonstrate that a practicable strategy has been developed for the management of the gaseous, liquid and solid radioactive wastes which will be generated during the operation of the reactor. Information is presented on how the radioactive waste will be managed from generation to discharge and/or disposal, taking into account reducing the relevant risks As Low As Reasonably Practicable (ALARP) and protecting the environment and the public notably through the use of the Best Available Techniques (BAT).

The management of decommissioning waste and the interim storage of spent fuel is presented in Pre-Construction Safety Report (PCSR) Chapter 24 and Chapter 29, respectively.

This chapter is produced on the basis of the version 3 of the UK HPR1000 Design Reference (DR3), as described in *UK HPR1000 Design Reference Report*, Reference [1]. DR3 reflects the design modifications implemented to address UK context during the Generic Design Assessment (GDA), notably in relation to radioactive waste management, considering the principles of ALARP and BAT.

23.2.1 Chapter Route Map

The ***Fundamental Objective*** of the UK HPR1000 is: *The Generic UK HPR1000 could be constructed, operated, and decommissioned in the UK on a site bounded by the generic site envelope in a way that is safe, secure and that protects people and the environment.*

To underpin this ***Fundamental Objective***, five Level 1 claims and a number of Level 2 claims have been developed and presented in PCSR Chapter 1. This chapter supports the level 2 ***Claim 3.3*** and ***Claim 3.4*** derived from the level 1 ***Claim 3***.

Claim 3: *The design and intended construction and operation of the UK HPR1000 will*

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protect the workers and the public by providing multiple levels of defence to fulfil the fundamental safety functions, reducing the nuclear safety risks to a level that is as low as reasonably practicable.

Claim 3.3: *The design of the processes and systems has been substantiated and the safety aspects of operation and management have been substantiated.*

Claim 3.3.11: *The design of radioactive waste management systems has been substantiated.*

Claim 3.4: *The safety assessment shows that the nuclear safety risks are ALARP.*

Claim 3.4.8: *All reasonably practicable options to improve nuclear safety have been adopted, demonstrating that the risk is ALARP.*

To support **Claim 3.3.11** and **Claim 3.4.8**, PCSR Chapter 23 developed five Sub-claims and a number of relevant arguments and evidence. A Route Map has been developed and is presented in Appendix 23A, providing a ‘direction of travel’ for this chapter.

23.2.2 Chapter Structure

The structure of Chapter 23 is presented as below:

- a) Sub-chapter 23.1 presents the list of abbreviations and acronyms that are used in this chapter;
- b) Sub-chapter 23.2 presents the chapter route map, chapter structure, general assumptions and production strategy of this chapter;
- c) Sub-chapter 23.3 presents the applicable codes and standards for radioactive waste management;
- d) Sub-chapter 23.4 presents the radioactive waste management strategy;
- e) Sub-chapter 23.5 presents the minimisation of radioactive waste;
- f) Sub-chapter 23.6 presents liquid radioactive waste management;
- g) Sub-chapter 23.7 presents gaseous radioactive waste management;
- h) Sub-chapter 23.8 presents solid radioactive waste management;
- i) Sub-chapter 23.9 presents the disposability of radioactive waste;
- j) Sub-chapter 23.10 presents the summary of ALARP assessment for radioactive waste management;
- k) Sub-chapter 23.11 presents the records management for radioactive waste information;
- l) Sub-chapter 23.12 presents the concluding remarks; and

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m) Sub-chapter 23.13 presents the references.

23.2.3 Interfaces with Other Chapters

The PCSR contains various chapters which provide information on the design of the UK HPR1000. To help with the understanding between Chapter 23 and other PCSR chapters, the relevant interfaces have been identified and are presented in T-23.2-1.

T-23.2-1 Interfaces between Chapter 23 and other Chapters

PCSR Chapter	Interface
Chapter 1 Introduction	Chapter 1 provides the Fundamental Objective, Level 1 Claims and Level 2 Claims. Chapter 23 provides chapter claims, arguments and evidence to support relevant claims that are presented in Chapter 1.
Chapter 2 General Plant Description	Chapter 2 provides an overall high level description of the plant including Structures, Systems and Components (SSCs) relevant to radioactive waste management which are presented in Chapter 23.
Chapter 3 Generic Site Characteristics	Chapter 3 provides generic site envelope for design conditions of radioactive waste management systems which are presented in Chapter 23.
Chapter 4 General Safety and Design Principles	Chapter 4 provides the general safety and design principles including the concept of defence in depth, safety classification of SSCs, engineering substantiation, etc. These principles shall be considered in the design of radioactive waste management systems presented in Chapter 23.
Chapter 5 Reactor Core	Chapter 5 provides the design of reactor core including information on aspects which contribute to minimising radioactive waste at source and the generation of unavoidable radioactive waste. Chapter 23 provides information on the management of radioactive waste including those generated from the reactor core.

PCSR Chapter	Interface
Chapter 6 Reactor Coolant System	<p>Chapter 6 provides the design of Reactor Coolant System (RCP [RCS]) including information on aspects which contribute to minimising radioactive waste at source and the generation of unavoidable radioactive waste.</p> <p>Chapter 23 provides information on the management of the radioactive waste generated from RCP [RCS].</p>
Chapter 7 Safety Systems	<p>Chapter 7 provides the design of safety systems including information on aspects which contribute to minimising radioactive waste at source and the generation of unavoidable radioactive waste.</p> <p>Chapter 23 provides information on the management of radioactive waste generated from the safety systems.</p>
Chapter 9 Electric Power	<p>Chapter 9 provides the design information relevant to the electrical power systems, including information on features which support the function of the radioactive waste management systems in Chapter 23.</p>
Chapter 10 Auxiliary Systems	<p>Chapter 10 provides the design of auxiliary systems including information on aspects which contribute to minimising radioactive waste and the generation of unavoidable radioactive waste notably from treatment of primary effluents.</p> <p>Chapter 23 provides information on the management of radioactive waste generated from the auxiliary systems.</p>
Chapter 11 Steam and Power Conversion System	<p>Chapter 11 provides the design of Steam Generator Blowdown System (APG [SGBS]) including information on aspects which minimise and generate unavoidably radioactive waste.</p> <p>Chapter 23 provides information on the management of radioactive waste generated from APG [SGBS].</p>
Chapter 12 Design Basis Condition	<p>Chapter 12 provides the design basis condition analysis including those related to radioactive waste</p>

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PCSR Chapter	Interface
	<p>management systems.</p> <p>Chapter 23 provides the specific design of radioactive waste management systems taking into account outcomes/requirements from fault analysis.</p>
Chapter 14 Probabilistic Safety Assessment	<p>Chapter 14 provides the probabilistic safety assessment carried out and the associated outcomes including those relevant to radioactive waste management.</p> <p>Chapter 23 provides the specific design of radioactive waste management systems for the Probabilistic Safety Assessment (PSA).</p>
Chapter 15 Human Factors	<p>Chapter 15 provides the principles and methodology of human factor integration that shall be incorporated in the design of radioactive waste management arrangements and systems.</p> <p>Chapter 23 provides the design of radioactive waste management systems, which is taken into account as part of the Human Factors assessment.</p>
Chapter 16 Civil Works & Structures	<p>Chapter 16 provides the relevant civil structures that house the radioactive waste management systems, which are presented in Chapter 23.</p>
Chapter 17 Structural Integrity	<p>Chapter 17 provides the optimum material selection for Reactor Coolant Pressure Boundary components, which notably contributes to minimising radioactive waste at source.</p> <p>Chapter 23 provides the management of radioactive waste generated from operation of the UK HPR1000.</p>
Chapter 18 External Hazards	<p>Chapter 18 provides the external hazards relevant to the UK HPR1000 as well as the design principles.</p> <p>Chapter 23 provides the substantiation of radioactive waste management systems, which is taken into account as part of the External Hazard assessment.</p>

PCSR Chapter	Interface
Chapter 19 Internal Hazards	<p>Chapter 19 provides the design principles against internal hazards that shall be applied in the design of radioactive waste management systems.</p> <p>Chapter 23 provides the design of radioactive waste management systems which is an input of internal hazards safety assessment.</p>
Chapter 20 MSQA and Safety Case Management	<p>Chapter 20 presents the Safety Case and Design Control Management including the relevant requirements, process and coding system of the Requirement Management.</p> <p>Chapter 23 applies the arrangements of Requirement Management set out in Chapter 20 ^{note 1}.</p>
Chapter 21 Reactor Chemistry	<p>Chapter 21 provides optimum reactor chemistry controls and material selection which notably contribute to minimising radioactive waste at source.</p> <p>Chapter 23 provides the management of radioactive waste generated from operation of the UK HPR1000.</p>
Chapter 22 Radiological Protection	<p>Chapter 22 provides generic aspects of source term and the general radiological protection considerations.</p> <p>Chapter 23 provides design information on the radioactive waste management systems used in radiological protection design.</p>
Chapter 24 Decommissioning	<p>Chapter 24 provides the waste inventory generated during decommissioning process.</p> <p>Chapter 23 provides the design of radioactive waste management systems that might be used for decommissioning (where applicable) and that will have to be dismantled.</p>
Chapter 25 Conventional Safety and Fire Safety	<p>Chapter 25 provides the conventional health and safety risk management techniques and general prevention principles that are applied in the design of radioactive waste management systems presented in Chapter 23.</p>

PCSR Chapter	Interface
Chapter 28 Fuel Route and Storage	<p>Chapter 28 presents the fuel handling and storage system.</p> <p>Chapter 23 provides the management of potential radioactive waste generated during fuel handling and storage related operations.</p>
Chapter 29 Interim Storage of Spent Fuel	<p>Chapter 29 presents the interim storage of spent fuel and spent Non-fuel Core Components (NFCCs) generated from reactor.</p> <p>Chapter 23 provides the management proposal of NFCCs.</p>
Chapter 30 Commissioning	<p>Chapter 30 provides arrangements and requirements for commissioning that are considered in the design of radioactive waste management systems presented in Chapter 23.</p>
Chapter 31 Operational Management	<p>Chapter 31 provides the principles, arrangement and methodology of operating limits and conditions, Examination, Maintenance, Inspection and Testing (EMIT), ageing and degradation programme.</p> <p>Chapter 23 provides radioactive waste management systems design substantiation relevant to operating limits and conditions, EMIT, ageing and degradation programme.</p>
Chapter 33 ALARP Evaluation	<p>Chapter 33 provides relevant principles, methodology and approach for ALARP demonstration and summarises the holistic ALARP demonstration for the UK HPR1000.</p> <p>Chapter 23 provides the ALARP demonstration for the radioactive waste management based on these principles and approach.</p>

Note 1: this chapter will be supplemented in Mechanical Engineering Schedule with application of the coding system at the nuclear site licensing phase.

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23.2.4 Assumptions

In order to undertake the demonstration of the safety case in relation to the radioactive waste management, the following assumptions are made:

- a) The operational life of the UK HPR1000 is assumed to be 60 years in accordance with the design life of the UK HPR1000 presented in PCSR Sub-chapter 2.4;
- b) Radioactive waste management systems will be utilised during the decommissioning process if risks are ALARP and measures are beneficial for waste minimisation;
- c) The waste management strategy considers current treatment technologies applied internationally and legally acceptable in the UK;
- d) Gaseous Waste Treatment System (TEG [GWTS]) and Nuclear Island Vent and Drain System (RPE [VDS]) are designed to manage radioactive waste arising from one unit. Liquid Waste Treatment System (TEU [LWTS]), Nuclear Island Liquid Waste Discharge System (TER [NLWDS]), Sewage Recovery System (SRE [SRS]), Conventional Island Liquid Waste Discharge System (SEL [LWDS (CI)]), the processing part in Solid Waste Treatment System (TES [SWTS]) are designed to manage radioactive waste arising from two reactor units;
- e) In line with the '*Base Case*' for radioactive waste management in the *Funded Decommissioning Programme Guidance for New Nuclear Power Stations*, Reference [2], several assumptions are made as follows:
 - 1) The regulatory regime to be applied to waste management and decommissioning is that in force at the time PCSR is submitted;
 - 2) Definitions of waste categories will remain unchanged from those currently in use in the UK;
 - 3) Dose limits for workers and the public will remain unchanged from those currently in use in the UK;
 - 4) Low Level Waste (LLW) generated during operation and decommissioning will be packaged on site, and dispatched to an off-site treatment and/or disposal facility promptly after they have been generated. For the purposes of the GDA, it is assumed that disposal will be at the Low Level Waste Repository Ltd (LLWR) or a successor facility; and
 - 5) Intermediate Level Waste (ILW) and High Level Waste (HLW) arising from operation and decommissioning of the UK HPR1000 will be packaged in a passive safe form, and safely stored in an interim storage facility on site, pending the Geological Disposal Facility (GDF) is available for their disposal.
- f) The Waste Acceptance Criteria (WAC) set by LLWR are the basis for obtaining of

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an ‘Agreement in Principle’ for treatment or disposal of Very Low Level Waste (VLLW) and LLW based upon the services provided by LLWR. It is assumed that any other facilities proposing the same treatment/disposal services as LLWR would have similar WAC.

23.2.5 General Design Requirements

The design requirements derived from PCSR Chapters 4, 15, 18, 19, 24, 25, 30 and 31 shall be considered in the design of radioactive waste management systems. These are listed below.

a) Safety Classification

The aim of the classification is to help ensure that the items are designed, manufactured, constructed, commissioned and operated according to appropriate requirements. This is to ensure that the safety functions are maintained under all expected operating conditions. The safety classification principles (including seismic categorisation principle) in the *Methodology of Safety Categorisation and Classification*, Reference [3], shall be considered in the design of radioactive waste management systems.

b) Engineering Design Requirements

The reliability design of SSCs shall be considered to ensure the fundamental safety objective of the nuclear power plant.

The engineering design requirements are considered in the design of radioactive waste management systems to ensure the safety functions performed by them. Detailed information on these requirements is presented in *General Safety Requirements*, Reference [4].

1) Single Failure Criterion (SFC) and redundancy

The SFC criterion is applicable to the system that performs a safety function, such that it must be capable of performing its intended safety function in the presence of any single failure. It is beneficial to ensuring the high reliability of safety systems and to maintain the plant within its deterministic design basis.

The SFC is applied to each safety group considered in fault analysis. The redundancy design helps satisfy this criterion.

2) Independence

The independence principles should be applied in the design to achieve system reliability and tolerance to faults.

Independence is accomplished in the design of systems by using functional isolation and/or physical separation.

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3) Diversity

Diversity shall be realised appropriately by incorporating different attributes into redundant systems or components. Such attributes include different operating principles, different physical variables, different operating conditions, different manufacturers, etc.

The concept of diversity is taken into consideration in the realisation of safety function to reduce the risk of the loss of the first protection line.

4) Fail-safe

To ensure the performance of the intended safety function, failure of SSCs or the failure of a support feature will not invalidate the performance of the intended safety function. The radioactive waste management systems shall consider the fail-safe concept in the design.

5) Human factors

Human Factors Integration Plan (HFIP) is established and applied in the design of the UK HPR1000 to identify factors that affect human performance and minimise the potential for human error throughout the entire plant lifecycle.

To integrate human factors in the design of radioactive waste management systems, considerations have been given to:

- Allocating functions properly to minimise the dependence on human actions; and
- Providing necessary information to support operator in the fulfilment of their responsibilities and in the performance of tasks.

Implementation of human factors integration enables the radioactive waste management systems to operate effectively and safely.

The risks associated with human factors relating to radioactive waste management systems is assessed in human factors area (PCSR Chapter 15 and associated ALARP demonstration) through:

- A review of radioactive waste management systems against the Human Factors Engineering (HFE) guidelines; and
- An assessment of human reliability of liquid waste discharge to support the substantiation of Human-Based Safety Claims (HBSCs).

6) Equipment qualification

Equipment qualification shall be implemented to verify that items important to safety can perform their intended functions where necessary, and in the environmental conditions including the variations in ambient environmental

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conditions that are anticipated in the design for the plant.

The methodology of equipment qualification is detailed in *Equipment Qualification Methodology*, Reference [5]. In line with this methodology, the equipment in the radioactive waste management systems requiring qualification is identified.

7) Ageing and degradation

The design life of items important to safety is evaluated and defined. As the operational lifetime of the UK HPR1000 is 60 years, the lifetime of SSCs that are not replaceable is designed for 60 years, and the replaceability is considered for SSCs that are not designed for 60 years. The ageing effects concerning individual components are taken into consideration in the system design:

- Sufficient margin are taken in the component design to prevent failures caused by ageing effects;
- Practical examination measures are planned during plant operation (i.e. EMIT) to address the ageing effects to the components;
- For replaceable parts of components, replacement plans and layout designs are properly considered.

8) EMIT

An effective EMIT programme is essential for the safe operation of the plant. The design of EMIT activities are facilitated for the purpose of maintaining the capability of SSCs important to safety, so as to satisfy the reliability requirement. The principle and methodology for the periodic tests, inspection and maintenance are presented in PCSR Chapter 31 and in *Examination, Maintenance, Inspection and Testing (EMIT) Strategy*, Reference [6].

In line with the EMIT methodology, EMIT considerations have been incorporated in the design of radioactive waste management systems to ensure the components are maintainable, inspectable and testable, commensurate with their safety class.

c) Protection against Internal and External Hazards

The necessary capability, reliability and functionality of items important to safety shall be ensured in the conditions arising from internal and external hazards to deliver relevant safety functions. The principles of hazard protection design, being detailed in *The General Requirements of Protection Design against Internal and External Hazards*, Reference [7], shall be considered in the design of the radioactive waste management systems.

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Measures to protect the system against external hazards are presented and assessed in PCSR Chapter 18. Measures to protect the system against internal hazards are presented and assessed in PCSR Chapter 19.

d) Commissioning

Commissioning will be carried out for radioactive waste management systems to validate their functionality at the nuclear site licensing phase. The methodology of design for system commissioning programme is presented in *Methodology of Design for System Commissioning Programme*, Reference [8]. Following this methodology, the commissioning test requirements for radioactive waste management systems have been developed and presented in *Topic Report on the Commissioning Requirements of Radioactive Waste Management Systems*, Reference [9]. Further detailed site specific arrangements for commissioning activities will be considered at the nuclear site licensing phase.

The commissioning content, phased approach and scope are shown in PCSR Chapter 30.

e) Decommissioning

Early consideration of decommissioning during design stage plays an important role in achieving safe and effective decommissioning and minimising decommissioning waste. According to the requirements for facilitating the decommissioning of the UK HPR1000, details being presented in PCSR Chapter 24 and the *Design Requirements for Facilitating Decommissioning*, Reference [10], the following aspects should be considered in the design of radioactive waste management systems to facilitate the decommissioning of the nuclear power plant:

- 1) Limiting the migration and deposition of radioactive substance;
- 2) Preventing the retention of large volumes of radioactive water in the systems during maintenance and decommissioning;
- 3) Minimising the generation and accumulation of radioactive waste during decommissioning.

The design measures that have been considered to fulfill these requirements are assessed in PCSR Chapter 24 and in *Consistency Evaluation for Design of Facilitating Decommissioning*, Reference [11].

f) Material Selection

Material selection of systems and equipment is one of the most significant factors for the safety, waste minimisation and economy of the nuclear power plant. It is therefore important that due consideration is given to material selection in the design of SSCs in order for them to provide high reliability throughout the design life of the plant. According to the principles and the approach of material selection

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presented in *Material Selection Methodology*, Reference [12], the following aspects are considered in the design of radioactive waste management systems:

- 1) Material selection shall be consistent with the functional objective of the system and component and commensurate with their classification;
 - 2) Materials selected for use shall be compatible with the operation conditions (radioactivity, chemistry, temperature, pressure, etc.) which may be encountered over the plant design life;
 - 3) Materials selected for use shall present high functional reliability and good resistance to aging and degradation throughout the design life to mitigate against the risk of performance degradation and failure of SSCs;
 - 4) Material selected shall consider waste minimisation requirements; and
 - 5) Operating Experience (OPEX) and feedback shall be taken into account for material selection of the system.
- g) Conventional Health and Safety

The conventional health and safety risks to workers and the public that may arise during the construction, commissioning, operation, maintenance, and decommissioning of the UK HPR1000 have been identified and assessed. The corresponding design mitigations are developed to eliminate, reduce, isolate and control them so far as is reasonably practicable using the risk management methodology detailed in PCSR Chapter 25, *UK HPR1000 Construction Design Management Strategy*, Reference [13], and *CDM Design Risk Management Work Instruction*, Reference [14].

The process of the conventional health and safety risk assessment related to radioactive waste management systems is recorded in the conventional health and safety design risk register for each system.

23.3 Applicable Codes and Standards

The general principles and methodology relevant to the selection of appropriate codes and standards are presented in PCSR Sub-chapter 4.4.7 and in *General Principles for Application of Laws, Regulation, Codes and Standards*, Reference [15]. Following the general principles presented in Reference [15], a suitability analysis was undertaken through a collection, screening and evaluation process. The codes and standards (including Relevant Good Practice (RGP)) applicable for radioactive waste management are identified from of the following sources:

- a) UK Act, Regulations and Government policies and strategies; and
- b) Guidance/documents issued by international and UK organisations, such as International Atomic Energy Agency (IAEA), Western European Nuclear Regulators Association (WENRA), Office for Nuclear Regulation (ONR),

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Environment Agency (EA), Department of Energy and Climate Change (DECC), Nuclear Decommissioning Authority (NDA), etc.

Details are presented in *Analysis Report of Applicable Codes and Standards*, Reference [16], where the list of codes and standards applicable for radioactive waste management is provided, including:

- a) UK Act, Regulations and Government policies and strategies, including:
 - 1) The Health and Safety at Work Act 1974;
 - 2) The Nuclear Installations Act 1965;
 - 3) The Environment Act 1995;
 - 4) The Ionising Radiations Regulations 2017;
 - 5) The Hazardous Waste (England and Wales) Regulations 2005;
 - 6) The Hazardous Waste (England and Wales) (Amendment) Regulations 2009;
 - 7) The Hazardous Waste (England and Wales) (Amendment) Regulations 2016;
 - 8) The Environmental Permitting (England and Wales) Regulations 2016;
 - 9) The Environmental Permitting (England and Wales) (Amendment) Regulations 2018;
 - 10) The Environmental Permitting (England and Wales) (Amendment) (No. 2) Regulations 2018;
 - 11) UK Strategy for Radioactive Discharges, 2009;
 - 12) Review of radioactive waste management policy: Final Conclusions (Cmnd 2919), 1995;
 - 13) Policy for the Long Term Management of Solid Low Level Radioactive Waste in the United Kingdom, 2007; and
 - 14) Implementing Geological Disposal, 2014.
- b) Guidance/documents issued by international and UK organisations, including:
 - 1) Nuclear Safety Technical Assessment Guide: *Management of Radioactive Materials and Radioactive Waste on Nuclear Licensed Sites*, Reference [17], which is used as a source of RGP; and
 - 2) The following are regarded as RGP:
 - *UK Strategy for the Management of Solid Low Level Radioactive Waste from the Nuclear Industry*, Reference [18];
 - *Safety Assessment Principles for Nuclear Facilities*, Reference [19];
 - *Regulatory Guidance Series, No RSR 1: Radioactive Substances Regulation – Environmental Principles*, Reference [20];

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- *The Management of Higher Activity Radioactive Waste on Nuclear Licensed Sites*, Reference [21];
- *Industry Guidance: Interim Storage of Higher Activity Waste Packages – Integrated Approach*, Reference [22];
- *Radioactive Waste Treatment and Conditioning Safety Reference Levels*, Reference [23];
- *Waste and Spent Fuel Storage Safety Reference Levels*, Reference [24];
- *Predisposal Management of Radioactive Waste*, Reference [25]; and
- *Predisposal Management of Radioactive Waste from Nuclear Power Plants and Research Reactors*, Reference [26].

The identified RGP provide detailed guidance that it is bound to consider in accordance with the UK Act, Regulations and Government policies and strategies for managing radioactive waste. The radioactive waste management arrangements and associated SSCs for the UK HPR1000 are developed during GDA by applying the ALARP methodology presented in Reference [27]. Application of the ALARP methodology involved assessing the compliance of radioactive waste management arrangements and SSCs against RGP. Taking full account of RGP in the design contributes to reducing the risks associated with the radioactive waste management arrangements and SSCs to ALARP.

23.4 Radioactive Waste Management Strategy

Addressing the principles in Reference [17], [19] and [21], the waste hierarchy forms a fundamental part of the radioactive waste management strategy. Implementation of the waste hierarchy requires a systematic approach to plant design and operational processes to avoid the creation of waste in the first instance and, secondly, minimising the generation of unavoidable waste (both volume and radioactivity) as far as reasonably practicable. Waste prevention and minimisation have therefore been considered and applied in the design of the UK HPR1000 as demonstrated in the Pre-Construction Environmental Report (PCER) *Chapter 3 Demonstration of BAT*, Reference [28], through the following aspects:

- a) Preventing and minimising the creation of radioactive waste;
- b) Minimising the radioactivity of gaseous and liquid radioactive wastes discharged into the environment;
- c) Minimising the mass/volume of solid waste and Non-aqueous Liquid Waste (NALW); and
- d) Selecting the optimal disposal routes for wastes.

Sub-chapter 23.5 summarises the measures that are considered and implemented in the design of the UK HPR1000 to minimise the generation (in terms of both radioactivity

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and volume) and accumulation of radioactive waste.

An Integrated Waste Strategy (IWS) has been produced to ensure that all waste streams produced by the UK HPR1000 are treatable and disposable in a safe and appropriate manner and that there is no orphan waste, considering the application of waste hierarchy and ALARP/BAT principles. Details are presented in *Integrated Waste Strategy (IWS)*, Reference [29]. The IWS provides an overview of the waste strategy by showing how the waste from the UK HPR1000 are generated and managed from generation through to disposal, and how the strategy is fully integrated for solid, liquid and gaseous wastes. The waste strategy is based on the optioneering studies that are undertaken to select preferred options for GDA from ALARP and BAT perspectives.

Gaseous and liquid radioactive waste are collected, reused/recycled where possible, processed and discharged into the environment through an optimised manner to minimise the impact on the environment and members of the public.

Solid waste and NALW are collected, processed, stored and ultimately disposed of. Existing off-site facilities are to be used to treat and/or dispose of the LLW/VLLW. For the HLW/ILW, on-site storage facilities will be used until the GDF becomes available.

Throughout the waste management process, characterisation and segregation are applied to facilitate managing the radioactive waste in a safe and effective way. Characterisation is applied through sampling, measurement and monitoring to acquire sufficient data to support waste management decisions and discharge/disposals. Segregation is performed to collect the waste with similar characteristic together and avoid wastes with different characteristics being mixed. This contributes significantly to the waste minimisation and enables the appropriate application of the waste hierarchy.

Disposal is the final stage of the radioactive waste management and therefore the disposability should be demonstrated. Optimal disposal routes are selected considering notably constraints from existing waste service suppliers.

The IWS is a live document and will be continually maintained to reflect changes in the waste management strategy from ALARP and BAT perspectives at the site licencing phase. Following the IWS, the Radioactive Waste Management Case (RWMC) for Higher Activity Waste (HAW) has been produced to demonstrate that the HAW produced by the UK HPR1000 can be managed effectively at the nuclear site licensing phase. Details are presented in *Radioactive Waste Management Case for ILW*, Reference [30], and in *Radioactive Waste Management Case for HLW*, Reference [31].

23.5 Minimisation of Radioactive Waste

Radioactive waste is an unavoidable by-product of electricity generation by a nuclear reactor. However, the generation and accumulation of radioactive waste can be minimised through optimisation of plant design and operation to protect the workers, public and environment.

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In the generic design of UK HPR1000, a set of features contributing to preventing/minimising the radioactive waste have been and continue to be appropriately considered and implemented in line with UK RGP (and/or OPEX where relevant) . These features relate to and/or impact different technical areas, and are therefore considered in an integrated manner to ensure the overall balance between potential conflicting requirements/factors is optimal.

These features include those that contribute to:

- a) Preventing/minimising the generation of radioactive waste at source, in terms of radioactivity and volume;
- b) Minimising the radioactive waste through effective and practicable management arrangements and route; and
- c) Minimising the accumulation of radioactive waste.

The holistic demonstration of radioactive waste minimisation is multidisciplinary and wide-ranging. This sub-chapter aims to summarise the demonstration that the generation and accumulation of radioactive waste from the operation of UK HPR1000 have been minimised so far as is reasonably practicable. An overview of waste minimisation in the UK HPR1000 is illustrated in Appendix 23B, referencing out to relevant PCSR/PCER chapters and safety case documentation where the detailed demonstration is presented.

23.5.1 Preventing/Minimising the Generation of Radioactive Waste at Source

Prevention and minimisation of radioactive waste at source results in two main benefits:

- a) The reduced quantity of radioactive waste results in less waste management tasks and less radioactive material storage, hence reducing the dose to workers and improving on-site safety; and
- b) The reduction of radioactive waste implies the reduction of harmful impacts on the public and environment.

Design measures are implemented in the UK HPR1000 to ensure that the generation of radioactive waste is minimised at source, in terms of both radioactivity and volume, including:

- a) Measures relevant to preventing/minimising the production of fission products, corrosion products and activation products, so as to reduce the radionuclides in the primary coolant, and therefore the radioactivity levels of radioactive waste;
- b) Measures relevant to minimising the quantity of the spent NFCC; and
- c) Measures relevant to preventing/minimising the spread of contamination and the quantity of SSCs that will become radioactive waste, so as to minimise the volume of radioactive waste.

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23.5.1.1 Minimising the Radioactivity of Radioactive Waste

The radionuclides likely to be present in the radioactive waste are produced in the reactor core and its vicinity. In the primary coolant, there are fission products, actinides, corrosion products and activation products. These radioactive substances are transferred around the primary circuit and pass into the connected systems and various support systems, and finally into radioactive waste.

Design and operational measures have been implemented in UK HRP1000 to ensure that the generation of radionuclides (fission products, actinides, corrosion products and activation products) is minimised at source. Details are presented in *Minimisation of Radioactivity Route Map Report*, Reference [32], including:

a) Fuel Design and Manufacture

The fuel pellets located inside the fuel rods and fissionable material contamination on the surface of the fuel cladding are the main sources of fission products and actinides that can become entrained within the primary coolant and ultimately within radioactive waste.

Fuel design and manufacture measures are implemented in UK HPR1000 to prevent fission products and actinides from leaking out of the fuel into the primary coolant and to minimise any fissionable material contamination to minimise the formation of fission products and actinides within the primary coolant, and thus minimise the radioactivity levels of radioactive waste due to the transfer of the primary coolant which have to be treated during operation, including measures to:

- 1) Minimise Grid to Rod Fretting (GTRF) Fuel Failures;
- 2) Minimise debris related fuel failures;
- 3) Prevent manufacturing defects;
- 4) Increase the corrosion resistance of the cladding tube;
- 5) Minimise the risk of Pellet-Cladding Interaction related fuel failures; and
- 6) Minimise the presence of fissionable material on external fuel cladding surfaces.

These measures are demonstrated to represent BAT in PCER Sub-chapter 3.5.1., Reference [28]. The design and performance of the fuel is presented in PCSR Chapter 5 and demonstrated to be ALARP taking into account minimising radioactive waste at source.

b) Fuel Management

The following fuel management arrangements contribute to prevention/minimisation fuel failure and subsequent release of fission products and actinides in the primary coolant, and thus minimising the radioactivity levels of radioactive waste:

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- 1) The fuel handling and storage system is designed to prevent damage to the fuel assembly by minimising the risks of fuel dropping or collision during fuel handling and storage;
- 2) The detection and appropriate management of failed fuel assemblies help minimise fission products and actinides from entering the primary coolant:
 - In-process sampling and monitoring to detect fuel failure in a timely manner during normal operation is provided by the Nuclear Sampling System (REN [NSS]) and the Plant Radiation Monitoring System (KRT [PRMS]);
 - When irradiated fuel assemblies are unloaded from the reactor, on-line and off-line sipping test facilities are used to detect whether the fuel assemblies are damaged or not;
 - Once a defect or failure in the fuel assembly is identified and subsequently confirmed by the off-line sipping facility, it will, during the refuelling outage, be transferred to a special storage cell located in the underwater storage rack in the Spent Fuel Pool (SFP) and will not be reloaded into the reactor core.

These measures are demonstrated to represent BAT in PCER Sub-chapters 3.5.1.1 & 3.5.1.2, Reference [28]. The design of the fuel handling and storage system as well as the fuel route and storage are presented in PCSR Chapter 28 and demonstrated to reduce relevant risks ALARP.

c) Reactor Chemistry

The objective of the water chemistry is to maintain the safe operation and structural integrity of the plant, including the fuel cladding and SSCs. The UK HPR1000 chemistry regime is optimised to achieve this objective, including:

- 1) Application of enriched $^7\text{LiOH}$ as the pH control reagent to reduce the generation of tritium and corrosion products;
- 2) Hydrogen is added to maintain reducing conditions in the primary coolant to minimise general corrosion of primary system surfaces;
- 3) During start-up, oxygen is removed by hydrated hydrazine dosing in order to minimise the risk of an oxidising environment to the integrity of materials and fuel cladding;
- 4) Impurity control to reduce corrosion and scaling of fuel cladding;
- 5) Application of zinc injection which reduces general corrosion rates and deposition and consequently reduces the corrosion products generation and deposition.

These measures contribute to minimising the risk of fuel cladding defects and the

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general corrosion of primary system surfaces, and therefore minimising the fission products, actinides and corrosion products in the primary coolant. As a result, the radioactivity of waste is minimised at source.

These measures are demonstrated to represent BAT in PCER Sub-chapter 3.5.1.5, Reference [28], and to reduce relevant risks ALARP in PCSR Chapter 21.

d) Material Selection

The decisions made with respect to material selection aim to balance multiple requirements, such as structural integrity and minimisation of corrosion products generated from elements within bulk materials. Three material selection measures, complemented by an optimised chemistry regime, are incorporated in the UK HPR1000:

- 1) Minimise or substitute elements of materials which are easily activated in SSCs;
- 2) Minimise the corrosion products by using high corrosion-resistant materials; and
- 3) Minimise the material corrosion through surface treatment/finishing, e.g. passivation during Hot Functional Test (HFT).

These measures contribute to minimising corrosion products generation in the primary coolant and activation of SSCs that will become radioactive waste during maintenance and therefore minimising the radioactivity and volume of radioactive waste at source.

These material selection measures are demonstrated to represent BAT in PCER Sub-chapter 3.5.1.6, Reference [28]. Material selection (taking minimisation of radioactive waste into consideration) also forms part of ALARP demonstration for reactor chemistry presented in PCSR Chapter 21 and of ALARP demonstration for structural integrity presented in PCSR Chapter 17.

e) Activation Products

The main activation products anticipated to be present in the coolant are H-3, C-14, N-16, N-17, Na-24 and Ar-41. The main factors affecting activation products generation include the coolant composition itself, tanks and vessel cover/flushing gas, chemistry regime (reactivity control, pH and impurities control) and air ingress. A number of measures which are RGP and considered BAT, are implemented in the UK HPR1000 to minimise the generation of activation products. Whilst other measures exist that would potentially minimise the production of activation products, it has been determined during GDA that the implementation of these measures within the UK HPR1000 design does not represent BAT. Demonstration on minimising the generation of H-3 and C-14 in the primary coolant is also presented in PCER Sub-chapters 3.5.1.4 & 3.5.1.7, Reference [28].

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23.5.1.2 Minimising the Quantity of Spent Non-fuel Core Component (NFCC)

Among all solid radioactive waste produced by a Pressurised Water Reactor (PWR), spent NFCCs are the most challenging to manage. NFCCs consist typically in metal components that are used inside the nuclear reactor core where they are subject to irradiation or exposed to intense neutron flux, and subsequently become “activated”.

The NFCCs have a limited lifetime after which they will lose their function. Therefore, the NFCCs need to be replaced during the operation of the UK HPR1000 and the spent ones will have to be managed and disposed of as radioactive waste, including the In-core Instrument Assembly (ICIA), the Rod Cluster Control Assembly (RCCA) and the Stationary Core Component Assembly (SCCA).

In order to minimising the quantity of spent NFCC at source, considerations have been given to the following aspects, details being presented in *Management Proposal of Waste Non-Fuel Core Components*, Reference [33]:

- a) On the premise of satisfying the functional requirements of the In-core Instrumentation System (RIC [IIS]) presented in PCSR Chapter 8, the quantity of ICIA is minimised as much as possible in the design process by providing reasonable arrangements and selecting appropriate material, model and replacement cycle for the ICIA;
- b) The design of the RCCA (presented in PCSR Chapter 5) considers increasing their lifetime in operating conditions, therefore minimising the number of RCCA components over the reactor plant lifetime, notably through material selection and surface finishing;
- c) The design of the SCCA (presented in PCSR Chapter 5) considers increasing their lifetime by selecting appropriate materials, therefore contributes to minimising the number of the spent SCCA over the reactor plant lifetime.

23.5.1.3 Minimising the Volume of Radioactive Waste

The SSCs containing fluids that are (potentially) radioactive will unavoidably generate waste, e.g. from leakage and drainage for maintenance, and therefore contribute to the generation of radioactive waste. Measures are incorporated in the design of SSCs to prevent/minimise the spread of contamination, thus minimise the volume of the radioactive waste (including secondary waste) at source and facilitate use of optimised radioactive waste management routes. Details are presented in *Topic Report on Radioactive Waste Minimisation for Mechanical Engineering*, Reference [34], and in PCER Sub-chapters 3.5.4.1 & 3.5.4.2, Reference [28], covering the following aspects:

a) Recycling of Radioactive Fluids

The systems carrying the primary coolant (e.g. primary circuit and auxiliary systems) and SFP water are the main sources for generation of radioactive waste. Purification enables maintaining the coolant/water to the required quality so that it

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can be reused instead of being transferred to waste management systems and replaced with fresh water. It is complemented by other design provisions that are presented in PCSR Chapter 10, including:

- 1) Enhanced recycling of boron via the Coolant Storage and Treatment System (TEP [CSTS]);
- 2) Recycling/reuse of the coolant as much as possible during start-up/shutdown by systems such as RCV [CVCS], TEP [CSTS], Safety Injection System (RIS [SIS]), etc.; and
- 3) Recycling of primary/secondary coolant samples by Nuclear Sampling System (REN [NSS]).

Recycling of radioactive fluids contributes to minimising the liquid radioactive waste generated from the RCP [RCS]/SPF and therefore the secondary waste generated from its subsequent treatment, such as spent resins and filter cartridges, concentrates and sludge, and the radioactive discharges to the environment.

b) Containment of Radioactive Fluids

Systems containing radioactive or potentially radioactive fluid are designed in accordance with RGP to prevent/minimise leakage and therefore the spread of contamination. The following measures/controls are notably implemented in the UK HPR1000:

- 1) Application of the appropriate codes and standards relevant to containment and design of equipment ensures sufficient reliability and adequate high quality of the process design and equipment, which minimise the possibility of leakage from systems and equipment;
- 2) Piping connections and joints in systems containing radioactive fluids are welded to prevent leakage. The only instances when this does not occur, is where flanged or screwed connections are required to facilitate equipment removal for inspection, maintenance or pressure testing;
- 3) High reliability of isolation design is applied to radioactive substance confinement systems to reduce leakage, such as using double isolation in reactor coolant pressure boundary, lines penetrating the containment, and other radioactive substance confinement systems;
- 4) Prevention of external leakage from valves that perform various safety/environmental or operational functions (e.g. controlling, isolation) is given due consideration;
- 5) All process systems containing radioactive fluids should be hydraulic pressure tested to confirm leak tightness;
- 6) Leak detection and monitoring devices are provided, facilitating detection, origin identification and quantification of leakages or escapes of radioactive

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substances from the radioactivity-containing systems and allowing appropriate corrective actions to be taken in a timely manner; and

- 7) Confinement of radioactive gaseous/airborne by HVAC systems. This ensures that all potential radioactive substances entrained in the air are collected and treated prior to discharge.

These measures relevant to containment of radioactive fluids contribute to minimising the liquid and gaseous radioactive wastes generated from leakage and therefore the secondary waste generated from their subsequent treatment, such as spent resins and filter cartridges, concentrates and sludge, and radioactive discharges.

c) Optimising System Configuration

In the design of the UK HPR1000, measures have been incorporated to optimise the system configuration. Some of these measures contribute to facilitating maintenance and reducing maintenance needs, and therefore minimising the volume of radioactive waste generated from maintenance, covering the following aspects:

- 1) Adequate isolation and drainage provisions are provided for piping and equipment to empty the equipment being maintained, without having to drain the whole system or adjacent equipment that do not require maintenance. This enables on-line maintenance to be undertaken without affecting the operation of other parts of the system, minimising the volume of radioactive fluids from drainage/flushing and the need for cleaning/rinsing. This reduces the volume of radioactive waste produced, including liquid/gaseous wastes generated from drainage/flushing/cleaning, subsequently the secondary waste generated from their treatment, such as spent resins and filter cartridges, concentrates and sludge, and the radioactive discharges; and
- 2) System configuration has been optimised where possible whilst maintaining the systems safety, environmental protection and operational functions to reduce the number or size of SSCs containing radioactive fluids, and therefore the drainages and solid waste (notably Dry Active Waste (DAW)) generated from their maintenance are minimised.

d) Optimising Design and Operation of Filters and Demineralisers

Filters and demineralisers that are used for purification of coolant/water and/or treatment of liquid radioactive waste produce solid radioactive waste in the forms of spent filter cartridges and spent resins. In order to maintain appropriate purification/treatment efficiency and reduce the production of solid radioactive waste (spent filter cartridges and spent resins), a number of measures are adopted in the design and operation of filters and demineralisers, including appropriate configuration of the purification unit, selection of the media (filter type and

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porosity and resins type) and appropriate control of relevant parameters (pressure, temperature, flowrate and dose rate) to avoid damaging the treatment media and its premature replacement. These measures contribute to extending the design life of the filter cartridges and resins such that they are replaced less frequently.

e) Radiation Zoning and Contamination Zoning

Radiation zoning and contamination zoning are also measures that are beneficial for minimising the volume of radioactive waste. Engineering and management controls associated with different area classifications presented in PCSR Sub-chapters 22.7.4 & 22.8 contribute to minimising the radioactive waste generated from spread of contamination by:

- 1) Placing equipment outside of controlled areas (where possible);
- 2) Preventing the spread of contamination from controlled areas into supervised areas; and
- 3) Placing frequently accessed rooms outside of controlled areas (where possible) to minimise the generation of secondary wastes.

f) Optimising the Building Layout

Optimising the building layout also contributes to minimising the volume of radioactive waste. The UK HPR1000 nuclear island buildings are arranged in close proximity to each other, whilst maintaining adequate geographical separation to meet nuclear safety requirements as presented in PCSR Sub-chapter 2.13. The treatment/processing of radioactive waste is undertaken close to the buildings where it is generated. This design feature reduces the transfer distance of radioactive substances, therefore minimising the radioactive waste generated from the spread of contamination.

g) Reuse of Maintenance Equipment and Tools

Maintenance work that is carried out in controlled areas requires the use of equipment and tools. In the UK HPR1000, space provided within controlled area enables the future operator to store items that are routinely used, such as tools, ladders and scaffolding, facilitating the reuse of these items throughout the operating life time of the UK HPR1000. This design feature contributes to minimising the volume of equipment and tools that need to be brought into the controlled area and ultimately need to be managed, treated and disposed of as solid radioactive waste (notably DAW).

23.5.2 Minimising the Radioactive Waste through Effective and Practicable Management Route

After preventing/minimising the generation of radioactive waste at source, the unavoidable radioactive waste is to be minimised through effective and practicable management arrangements and route. Details are presented in Sub-chapters 23.6, 23.7

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& 23.8, covering the following aspects:

a) Segregation and Characterisation of Radioactive Waste

Characterisation is applied to acquire sufficient data to support waste management decisions and waste disposal. Segregation is performed to collect the waste with similar characteristics together and avoid mixing waste with different characteristics. Following the characterisation and segregation, the subsequent management arrangements, notably treatment and the disposal routes can be selected and applied in a more efficient way, hence minimising all types of radioactive waste as well as waste accumulation on site.

b) Sufficient Capacity to Store and Treat Waste

Sufficient capacity to store and treat radioactive waste is provided through appropriate equipment sizing, including liquid waste storage tanks, demineralisers, recombiner, activated charcoal delay beds and spent resin tanks. This ensures the operator can flexibly and adequately manage the radioactive waste in an optimised way, hence minimising all types of radioactive waste as well as waste accumulation on site.

c) Optimisation of Waste Treatment Techniques

The radioactive waste treatment techniques selected through optioneering enable the unavoidable radioactive waste generated from the operation of the UK HPR1000 to be treated in an optimised way, hence minimising all types of radioactive waste, as well as waste accumulation on site.

d) Selection of Appropriate Waste Container

Appropriate containers are selected for LLW and ILW, to ensure the unavoidable radioactive waste generated from the operation of the UK HPR1000 is packaged in an optimised way, hence minimising the solid waste and NALW, as well as waste accumulation on site.

e) Decay Storage of Solid Waste

In order to maximise the opportunities to apply waste hierarchy and minimise volume of higher radioactive waste to be disposed of, the ILW/LLW boundary waste management proposal and decay storage of HLW are applied to ILW/LLW concentrates, sludge and DAW and HLW ICIA to optimise their management and minimise the volume of waste packages to be disposed to the future GDF as well as waste accumulation on site.

f) Appropriate Space and Arrangements to Safely Segregate Solid Waste and to Safely Store Conditioned Waste

Appropriate space and arrangements are provided to allow the future operator to

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safely segregate solid waste and safely store conditioned waste depending on their physical, chemical and radiological properties. This avoids unnecessary cross-contamination of waste and ensures that wastes are disposed of in an optimised way, hence minimising the volume of waste packages as well as waste accumulation on site.

All the above aspects are also presented in PCER Chapter 3, Reference [28], and in PCER *Chapter 4 Radioactive Waste Management Arrangements*, Reference [35].

23.5.3 Minimisation of Accumulation of Radioactive Waste

Minimisation of radioactive waste accumulated on site is a significant element of the radioactive waste management strategy in the UK HPR1000, especially for solid waste and NALW. In addition to minimising radioactive waste at source, as well as the use of effective and practicable management arrangements and route, solid waste and NALW can be disposed of by transfer to a number of off-site premises. These off-site premises offer a range of treatment and disposal services, therefore minimising the accumulation radioactive waste on site. The design of the UK HPR1000 takes account of these services, enabling a future operator to select optimal waste disposal routes and ensure that no orphan waste will be generated. The following aspects are considered during GDA:

- a) An ‘Agreement in Principle’ has been established with LLWR for LLW during GDA, which concludes that there is no particular risk for any UK HPR1000 waste stream to become orphan waste and/or to result in significant burden or risk/impact at the nuclear site licensing phase. Details are presented in Sub-chapter 23.9.1; and
- b) Disposability assessment has been carried out by Radioactive Waste Management Ltd (RWM) for HAW and spent fuel. It was concluded that the HAW and spent fuel generated by UK HPR1000 is proved to be disposable and no issue is likely to result in a waste stream that is not disposable or in significant design changes. Details are presented in Sub-chapter 23.9.2.

23.6 Liquid Radioactive Waste Management

23.6.1 Liquid Radioactive Waste Management Strategy

The radioactive liquid effluent streams generated during the operation of the UK HPR1000 is divided into three categories:

- a) Reactor coolant effluent;
- b) Liquid waste; and
- c) Secondary circuit effluent.

The liquid effluent streams produced during operation and their management are illustrated in F-23.6-1 and described hereafter. The estimated discharges and proposed limits of liquid effluent discharges are described in PCER *Chapter 6 Quantification of*

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Discharges & Limits (Sub-chapter 6.6), Reference [36].

23.6.1.1 Reactor Coolant Effluent

Reactor coolant is continuously circulated in the primary circuit and cleaned by extracting a proportion of the coolant known as letdown, which is treated by the Chemical and Volume Control System (RCV [CVCS]). In the case of burn-up compensation, load change, start-up and shutdown transients, the reactor coolant can be discharged to the Coolant Storage and Treatment System (TEP [CSTS]) via RCV [CVCS].

Although the primary circuit and the connected systems prevent losses of process fluids through leakage, any leaks and drains are collected and contained in the Nuclear Island Vent and Drains System (RPE [VDS]) to minimise the generation of radioactive waste through the spread of contamination by these effluents. In order to minimise the production of radioactive liquid waste and maximise the recovery of boron, these effluents are segregated into recyclable effluent and non-recyclable effluent.

a) Recyclable Effluent

Recyclable effluent is reactor coolant quality effluent that comes from leakage or drainage from equipment carrying reactor coolant.

Recyclable effluent is collected by the RPE [VDS] and then transferred to the TEP [CSTS] where it is decontaminated by demineralisation, and the boric acid and water are separated by evaporation and degasification. Boric acid and distillates from TEP [CSTS] are sent to the Reactor Boron and Water Makeup System (REA [RBWMS]) as supplementary make up for the primary circuit coolant. If it remains unsuitable for re-use, e.g. in case of control of tritium activity in primary coolant, the condensate is routed to the Nuclear Island Liquid Waste Discharge System (TER [NLWDS]) for sampling, monitoring and, if appropriate, discharge.

b) Non-recyclable Effluent

Non-recyclable effluents are segregated into the following streams according to the sources and characteristics to facilitate subsequent treatment.

- 1) Process drains, which are polluted primary coolant from systems or equipment leakage and unsuitable for reuse in the primary circuit.
- 2) Chemical drains, which are polluted water notably from the radioactive laboratory.
- 3) Floor drains, including three types:
 - Floor drains 1, which are potentially contaminated and come from leakage from equipment carrying primary coolant and floor washing in the controlled areas;

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- Floor drains 2, which are slightly contaminated or uncontaminated and come from leakage, equipment draining and floor washing in the controlled areas; and
- Floor drains 3, which are normally uncontaminated and come from leakage, equipment draining and floor washing outside the controlled areas.

These effluents are transferred to the Liquid Waste Treatment System (TEU [LWTS]) for treatment.

The design information on RCV [CVCS], REA [RBWMS] and TEP [CSTS] is presented in PCSR Sub-chapters 10.4.3, 10.4.4 and 10.4.5.

23.6.1.2 Liquid Waste

The liquid waste is effluent that is unsuitable for re-use and is discharged after treatment, including:

- a) The non-recyclable effluents collected in the RPE [VDS]; and
- b) The effluents from waste management and decontamination areas, which are collected in the Sewage Recovery System (SRE [SRS]).

The radioactivity presented within the liquid waste consists of particulate and ionic species. The liquid waste is divided into four separate streams and routed separately to be processed by different means in the TEU [LWTS].

a) Process Drains

Process drains, which are radioactive and have a low level of chemical impurities, are processed by demineralisation. The major nuclides in the ionic form are abated by the TEU [LWTS] demineralisers with mixed bed ion exchange resins. The demineralisers are provided with pre and post filters to abate particulate and prevent bed blinding or migration of ion exchange resin into the downstream circuit.

b) Chemical Drains

Chemical drains, which have a higher level of chemical impurities and potentially higher radioactivity compared to process drains, are processed by evaporation. Activity in the ionic form with high chemical content is abated by the TEU [LWTS] evaporator. The evaporator is provided with pre filter to prevent carry-over of particulate into the evaporator.

c) Floor Drains

Floor drains typically have lower radioactive contamination but are high in suspended solids. Particulate within floor drains is primarily abated by the filters.

d) Laundry Drains

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Laundry drains are also lower in radioactive contamination but high in suspended solids, fibrous matters, and detergents, and are also processed by filtration.

23.6.1.3 Secondary Circuit Effluent

The blow-down of the steam generators is processed by the Steam Generator Blowdown System (APG [SGBS]). After processing, the purified blow down water is sent to the main turbine condenser for re-use. If it remains unsuitable for re-use, the treated effluent from the APG [SGBS] is sent to the Conventional Island Liquid Waste Discharge System (SEL [LWDS (CI)]) for sampling, monitoring and, if appropriate, discharge.

Other effluents from the secondary circuit which come from leakage and drainage are collected into the Waste Fluid Collection System for Conventional Island (SEK [WFCSCI]) and then sent to SEL [LWDS (CI)] for sampling, monitoring and, if appropriate, discharge.

The design information on APG [SGBS] is presented in PCSR Sub-chapter 11.3.5. The SEK [WFCSCI] and hot laundry are not included within the scope of the GDA, Reference [37].

23.6.2 Nuclear Island Vent and Drain System (RPE [VDS])

Design information on RPE [VDS] is described hereafter and details are presented in the System Design Manual (SDM), including:

- a) *RPE - Nuclear Island Vent and Drain System Design Manual Chapter 3 System Functions and Design Bases*, Reference [38];
- b) *RPE - Nuclear Island Vent and Drain System Design Manual Chapter 4 System and Component Design*, Reference [39]; and
- c) *RPE - Nuclear Island Vent and Drain System Design Manual Chapter 6 System Operation and Maintenance*, Reference [40].

The system flow diagram of RPE [VDS] is presented in F-23.6-2.

23.6.2.1 Safety Functional Requirements

- a) Reactivity Control

RPE [VDS] does not contribute to this function.

- b) Removal of Heat

The RPE [VDS] contributes to the removal of heat as follows:

- 1) In the case of Loss of Coolant Accident (LOCA), isolation of RPE [VDS] assists to maintain the water inventory in the Reactor Building (BRX), and
- 2) In the case of rupture of the fuel transfer tube during refuelling stage, isolation of RPE [VDS] assists to prevent the liquid level of the reactor pool from falling below the permitted level.

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c) Confinement

RPE [VDS] contributes to the confinement of radioactive material as follows:

- 1) RPE [VDS] containment isolation valves are designed to provide the following functions to prevent leakage from containment building:
 - Containment isolation in accident conditions;
 - Containment leak tightness in severe accident conditions; and
 - In the case of LOCA, isolation of RPE [VDS] in the BRX prevents spread of radioactive effluents towards other buildings during shutdown state.
- 2) Under normal operation, RPE [VDS] contributes to the confinement of radioactive material, by collecting and containing radioactive effluents in the nuclear island and minimising the radioactivity discharges to the environment by preventing the spread of radioactive effluents through leak tightness, segregating and transferring them for appropriate treatment.

d) Extra Supporting Functions

RPE [VDS] does not perform extra supporting functions.

23.6.2.2 Role of the System

During the operation of the nuclear power plant, radioactive effluents are unavoidably generated, notably from emptying/flushing SSCs before maintenance, equipment cleaning and equipment leakage. RPE [VDS] serves to selectively collect, temporarily store and transfer radioactive effluents. The collected effluents are transferred to the appropriate downstream systems for treatment or recycling based on the characteristics and types of liquid effluent.

RPE [VDS] contributes to reducing the production of radioactive effluents at source by performing the following operational functions:

- a) Segregate recyclable effluent at source and send it to TEP [CSTS] for treatment and reuse (if appropriate);
- b) Segregate the non-radioactive liquid waste and send it to SEK [WFCSCI] for discharge via SEL [CILWDS] (if appropriate) after sampling and monitoring;
- c) Facilitating selection of optimal processing routes through the segregation of liquid effluents as different types based on physical, chemical and radioactive characteristics; and
- d) Routing the primary gaseous waste collected to TEG [GWTS] and the other gaseous waste to ventilation systems of each building.

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23.6.2.3 System Description and Operation

23.6.2.3.1 System Description

The design of the UK HPR1000 minimises losses of process fluids through leakage. Any leaks and drains are collected and contained in RPE [VDS] to minimise the generation of radioactive waste through the spread of contamination by leakage. These effluents are segregated and transferred to different downstream systems (TEP [CSTS], TEU [LWTS], TEG [GWTS] or SEK [WFCSCI]) for treatment or discharge according to the type of effluents.

Effluents collected by RPE [VDS] are categorised as follows:

a) Liquid Effluent to be Recycled

The recyclable effluents collected by RPE [VDS] include following sources:

- 1) Reactor coolant collected from BRX which is from the following sources:
 - Leakage from the systems containing reactor coolant;
 - Internal leakage from reactor cavity;
 - Drain from phase separator of vacuum pump;
 - Leakage from the pressuriser safety valve collected in the pressuriser relief tank; and
 - Drains from pipes and equipment of the systems containing reactor coolant.
- 2) Reactor coolant drains in the Nuclear Auxiliary Building (BNX):
 - Drainage from equipment and piping that transfer reactor coolant; and
 - Effluent blown down from safety valve of systems containing reactor coolant.
- 3) Primary effluents from Safeguard Buildings (BSX) and Fuel Building (BFX): effluents from the Safety Injection System (RIS [SIS]), Containment Heat Removal System (EHR [CHRS]) as well as Fuel Pool Cooling and Treatment System (PTR [FPCTS]).

b) Liquid Effluent to be Discharged (after Appropriate Treatment)

The non-recyclable effluents are further segregated into three categories according to the source, characteristics, radioactivity concentration, etc.

- 1) Process drains;
- 2) Chemical drains; and

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3) Floor drains 1, 2 and 3.

c) Gaseous Effluent

The gaseous effluent collected by RPE [VDS] is divided into primary gaseous effluent and other gaseous effluent.

Primary gaseous effluent is extracted from the reactor coolant drains collected in the RPE [VDS] storage tanks, and is transferred to TEG [GWTS] by continuous nitrogen flushing.

Other gaseous effluent, which comes from the vent of user systems during unit maintenance, is gathered in the RPE [VDS] storage tanks and transferred to ventilation systems.

Sampling points are provided on the pipes connecting RPE [VDS] storage tank and TEG [GWTS] to measure the radioactive level of gaseous waste in the storage tanks. This contributes to reducing the dose to workers during maintenance.

23.6.2.3.2 Description of Main Equipment

a) Tanks

The tanks are used to collect and store radioactive effluents. All the tanks are made of stainless steel.

The tanks containing reactor coolant are located in shielded compartment to reduce the dose to workers.

b) Heat Exchanger

The heat exchanger is used to cool the effluents from the RCP [RCS] by recirculating them in RPE [VDS] reactor coolant tank by pump.

c) Pumps

The pumps are used to transfer liquid waste in the tanks or sumps. All the pumps are automatically controlled.

The parts of the pumps in contact with the liquid waste are made of stainless steel. Pumps are equipped with reliable high quality mechanical seals to avoid leakage.

d) Sumps

All the sumps which contain potentially radioactive liquid waste are equipped with stainless steel liners to facilitate decontamination and ensure confinement.

23.6.2.3.3 Description of System Interfaces

The interfaces between RPE [VDS] and other systems relating to radioactive waste management are listed below:

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a) Systems Generating Effluents

The RPE [VDS] collects effluents from primary circuit and connected systems, such as RCV [CVCS], PTR [FPCTS], REA [RBWMS], etc., and drains from various systems in nuclear island.

b) TEG[GWTS]

The reactor coolant tanks of RPE [VDS] are swept by TEG [GWTS] to remove volatile radioactive substances and any degassed hydrogen.

c) TEP[CSTS]

The recyclable effluents collected by RPE [VDS] are transferred to TEP [CSTS] for treatment.

d) TEU [LWTS]

The non-recyclable effluents collected by RPE [VDS] are transferred to TEU [LWTS] for treatment.

e) SEK [WFCSCI]

Non-radioactive liquid waste collected by RPE [VDS] is transferred to SEK [WFCSCI] for discharge.

23.6.2.3.4 System Operation

a) Plant Normal Condition

1) Effluents to be recycled

- Reactor coolant liquid drains collected from the BRX

These effluents are collected in the RPE [VDS] reactor coolant drain tank and are cooled by a heat exchanger in the pipeline of pump outlet.

Electric valves downstream of the heat exchanger can be configured to:

- Cool liquid waste in the RPE [VDS] reactor coolant drain tank;
- Cool liquid waste in the RCP [RCS] pressuriser relief tank; and
- Transfer primary effluents in the RPE [VDS] reactor coolant drain tank or RCP [RCS] pressuriser relief tank to TEP [CSTS].

- Primary effluents outside of BRX

These effluents can be directly transferred to TEP [CSTS] without cooling.

- Primary leakage measurement

RPE [VDS] detects reactor coolant leakage through level changes in the reactor coolant drain tank and level changes in the floor drains sumps in

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the BRX. Moreover, a RPE [VDS] measurement tank in the BNX is installed to collect and measure the leakages from safety valves.

2) Effluents to be discharged (after appropriate treatment)

The radioactive effluents, including process drains, chemical drains, floor drains 1 and floor drains 2, are collected in the RPE [VDS] tanks and sumps, and finally transferred to TEU [LWTS] for treatment.

The potentially contaminated effluents (floor drains 3) are collected in the RPE [VDS] sumps and transferred to the relay sump inside BNX. After sampling and analysis, these effluents are transferred to SEK [WFCSCI] for discharge or be transferred to TEU [LWTS] for treatment according to the analysis results.

3) Gaseous waste

Primary gaseous waste comes from the reactor coolant drains of user systems, these waste is transferred to TEG [GWTS].

Other gaseous waste comes from the vent of user systems during maintenance, the gaseous wastes are transferred to plant ventilation systems.

4) Cooling of pressuriser relief tank

Cooling circuit of RPE [VDS] reactor coolant drain tank in the BRX can also be used to cool the effluent in the pressuriser relief tank in RCP [RCS].

The cooling of RCP [RCS] pressuriser relief tank can be performed only when the reactor coolant drain tank does not need cooling or draining. The cooling operation of reactor coolant in the RCP [RCS] pressuriser relief tank is achieved manually.

When the RCP [RCS] pressuriser relief tank is under maintenance, the effluent in this tank is cooled to expected temperature and then pumped to the TEP [CSTS].

5) Vacuum function

After refuelling of reactor and before RCP [RCS] filling, the vacuum pump is connected to the pressuriser to produce a negative pressure in RCP [RCS]. This speeds up the filling and venting of RCP [RCS]. The generated gaseous waste is routed to EBA [CSBVS].

6) Nitrogen purging during RCP [RCS] primary loop at mid-loop

During unit cold shutdown, RCP [RCS] is flushed with nitrogen before the reactor vessel head is opened (level of the primary loop is at mid-loop). Gaseous waste generated during this operation is discharged to TEG [GWTS].

After flushing by nitrogen, RCP [RCS] is cleaned by compressed air. Gaseous

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waste collected during this operation is discharged to EBA [CSBVS].

b) Plant Accident Conditions

Under accident conditions, the containment isolation valves of RPE [VDS] perform the following functions to prevent leakage from the containment building:

- 1) Containment isolation in accident conditions;
- 2) Containment leak tightness in severe accident conditions; and
- 3) Isolation of RPE [VDS] in the BRX to prevent loss of liquid effluents towards other buildings in the case of LOCA.

23.6.2.4 Design Substantiation

23.6.2.4.1 Compliance with Safety Functional Requirements

a) Control of Reactivity

Not applicable.

b) Removal of Heat

In the case of LOCA, RPE [VDS] participates in maintaining the water inventory in the BRX by automatic isolation of the floor drains line that penetrates the containment.

In the case of rupture of the fuel transfer tube during refuelling stage, RPE [VDS] participates in preventing the liquid level of the reactor pool from falling below the permitted level by isolation of the floor drains line in the rooms where the rupture occurs.

c) Confinement

Under normal conditions, the radioactive waste is confined by the sealing of the mechanical boundaries. RPE [VDS] is located within the nuclear island buildings and the civil engineering structure acts as a barrier to protect the environment.

RPE [VDS] detects reactor coolant leakage through level changes in the reactor coolant drain tank and level changes in the floor drains sumps in the BRX. Moreover, a RPE [VDS] measurement tank is installed in the BNX to collect and measure the leakages from safety valves.

Most sumps are equipped with stainless steel liners to ensure containment of liquid waste collected. All the tanks and sumps are provided with measurement device to detect level changes, facilitating detection, localisation and quantification of leakages or escapes of radioactive waste contained in them. Tanks are connected with TEG [GWTS] or HVAC systems to prevent escapes of gaseous radioactive waste.

Under accident conditions, RPE [VDS] containment isolation valves act as a third containment barrier at its containment penetration points. The pipes penetrating the containment are equipped with two containment isolation valves. In accident conditions, the motorised valves receive a closing order from the reactor protection system to prevent the leakage of radioactive effluents. After an accident, if available, RPE [VDS] can temporarily store active effluents to delay their treatment.

d) Extra Supporting Functions

Not applicable.

23.6.2.4.2 Compliance with Design Requirements

a) Safety Classification

Following the safety classification principles, the function classification of RPE [VDS] is derived in T-23.6-1. Based on the contribution for accident mitigation, the safety classification of main components (including seismic categorisation) is derived in T-23.6-2.

T-23.6-1 System Function Classification

System Function	Function Category
Containment isolation	FC1
Collection of radioactive effluents	FC3
Collection of floor drains 3	NC
Others	NC

T-23.6-2 Classification of Main Components

Component	Safety Classification	Design Provision Category	Design Provision Class	Seismic Category
Containment isolation valves	F-SC1	DPA	B-SC2	SSE1
Pumps, tanks, valves and lines (collect of primary effluents)	F-SC3	DPL	B-SC3	SSE2

Component	Safety Classification	Design Provision Category	Design Provision Class	Seismic Category
Pumps, tanks , valves and lines (collect process drains inside BSX,BFX)	F-SC3	DPL	B-SC3	SSE2
Pumps, tanks , valves and lines (collect process drains inside BNX)	F-SC3	DPL	B-SC3	NO
Pumps, tanks , valves and lines (collect chemical drains inside BNX)	F-SC3	DPL	B-SC3	NO
Pumps, sumps , valves and lines (collect floor drains 1 & 2 inside the BRX, BSX & BFX)	F-SC3	DPL	B-SC3	SSE2
Pumps, sumps , valves and lines (collect floor drains 1 & 2 inside BNX and Personnel Access Building (BPX))	F-SC3	DPL	B-SC3	NO
Pumps, sumps , valves and lines (collect floor drains 3 inside the BSX)	NC	NC	NC	SSE2
Pumps, sumps , valves and lines (collect floor drains 3 inside the BNX)	NC	NC	NC	NO

b) Engineering Design Requirements

1) SFC and redundancy

The containment isolation valves of RPE [VDS], which ensure FC1 safety function, are designed to be redundant. The effluents transport pipeline penetrating the containment is equipped with two containment isolating valves, one inside the containment and the other outside.

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2) Independence

The two containment isolation valves are physically separated by the installation location, one inside and the other outside the containment.

3) Diversity

The containment isolation valves in the RPE [VDS] comply with the diversity requirements. The internal and external containment isolation valves in the same pipeline penetrating the containment are designed with mechanical component diversification.

4) Fail-safe

The fail-safe concept is considered in the RPE [VDS] design process. According to the fail-safe analysis, the means of ‘fail-safe’ design do not meet the safety consideration for containment isolation valves, therefore other measures such as redundancy are used to improve the safety of power plant and avoid the potential safety concerns or risks that may be introduced by ‘fail-safe’ design on power plant.

5) Human factors

Human factors are integrated in the design of RPE [VDS]. Control functional requirements have been developed for allocating the system functions to manual activity and automatic control appropriately and providing necessary information to the operator.

6) Equipment qualification

The design of the RPE [VDS] complies with the equipment qualification requirements. The containment isolation valves require environmental qualification as they perform FC1 safety function. The components with seismic classification require seismic qualification, including the containment isolation valves and relevant pumps, tanks, valves and pipelines.

7) Ageing and degradation

Ageing and degradation are considered in the design of RPE [VDS] by applying the design measures described in Sub-chapter 23.2.5.

8) EMIT

– Surveillance

The surveillance of the RPE [VDS] is performed from the Main Control Room where the state of tank/sump level, pump and valves and the integrated alarm signal for system operation are displayed to provide necessary information to the operator.

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– Maintenance

The preventive maintenance of RPE [VDS] components will be carried out according to equipment operation and maintenance manual at the nuclear site licensing phase. The layout design takes into account the accessibility of components for maintenance activities.

– Inspection

The reactor coolant drain tanks, the heat exchanger and the associated safety valves in the RPE [VDS] require pre-service inspection.

– Periodic tests

Preliminary requirements of periodic tests for radioactive waste management systems are presented in *Topic Report on the Periodic Test Requirements of Radioactive Waste Management Systems*, Reference [41]. The containment isolation valves in RPE [VDS] need periodic tests to verify the manoeuvrability and tightness. For other components, specific separate periodic tests are not required as the functions can be verified by appropriate operating routine checks and/or preventative maintenance with an appropriate frequency.

c) Protection Design against Internal and External Hazards

The containment isolating valves in the RPE [VDS] are protected from internal hazards by physical separation. For external hazards, the containment isolating valves and associated pipelines are required to be protected from the earthquakes.

d) Commissioning

Following the commissioning test requirements presented in Reference [9], RPE [VDS] require commissioning tests to verify its functionality, including tests of system flushing, valves, simulation measurement and control channel, logic control channel, pumps, tanks and sumps.

e) Decommissioning

Requirement for facilitating decommissioning is considered in the design of RPE [VDS] by applying the design principles that are in accordance with the relevant requirements described in Sub-chapter 23.2.5, including reducing residual radioactive sources through adequate emptying provisions, decontamination provisions, equipment structure design, layout of equipment and pipelines, use of liners in sumps, minimising embedded pipes and adequately designing the unavoidable ones, etc., so as to facilitate decommissioning operations and reduce the accumulation of radioactive waste during decommissioning.

f) Material Selection

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Components (such as tanks, pipes, valves, etc.) that are in contact with radioactive media are made of stainless steel in order to limit corrosion, so as to reduce the radioactive waste and ensure equipment integrity.

Most sumps are equipped with stainless steel liners to ensure containment of liquid waste collected.

Considering the requirement for radioactive waste minimisation, the materials having low cobalt, nickel, silver and antimony content are selected for pipes or components that are in contact with recyclable effluents.

g) Conventional Health and Safety

Conventional health and safety is considered in the design of RPE [VDS] by assessing the relevant risks and corresponding design mitigations and recording relevant information in the conventional health and safety design risk register, as presented in Sub-chapter 23.2.5.

23.6.3 Liquid Waste Treatment System (TEU [LWTS])

Design information on TEU [LWTS] is described hereafter and details are presented in the SDM, including:

- a) *TEU - Liquid Waste Treatment System Design Manual Chapter 3 System Functions and Design Bases*, Reference [42];
- b) *TEU - Liquid Waste Treatment System Design Manual Chapter 4 System and Component Design*, Reference [43]; and
- c) *TEU - Liquid Waste Treatment System Design Manual Chapter 6 System Operation and Maintenance*, Reference [44].

The system flow diagram of TEU [LWTS] is presented in F-23.6-3.

23.6.3.1 Safety Functional Requirements

a) Reactivity Control

TEU [LWTS] does not contribute to this function.

b) Removal of Heat

TEU [LWTS] does not contribute to this function.

c) Confinement

TEU [LWTS] contributes to the confinement of radioactive material in normal operation, by containing the liquid radioactive waste conveyed and minimising the radioactive discharges to the environment through segregated storage, treatment and monitoring of the liquid radioactive waste.

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d) Extra Supporting Functions

TEU [LWTS] does not perform extra supporting functions.

23.6.3.2 Role of the System

TEU [LWTS] provides temporary storage, treatment and monitoring for the non-recyclable liquid waste collected in RPE [VDS] and SRE [SRS]. TEU [LWTS] contributes to the confinement of the liquid waste and to achieving an optimal balance between radioactive waste discharges and solid radioactive waste arising by performing the following operational functions:

- a) Storing liquid waste in the storage tanks that are sufficiently sized to ensure efficient and effective management of all liquid waste;
- b) Sampling liquid waste in the storage tanks and transferring liquid waste to the appropriate treatment routes;
- c) Treating the liquid waste to reduce their radioactivity levels to be acceptable for discharge into the environment; and
- d) Transferring the treated liquid waste to TER [NLWDS] for discharge after sampling and monitoring.

23.6.3.3 System Description and Operation

23.6.3.3.1 System Description

TEU [LWTS] is designed to store, treat and monitor liquid waste that is segregated into process drains, chemical drains, floor drains and laundry drains and collected in RPE [VDS] and SRE [SRS]. The treated liquid waste is sampled, and, if appropriate, discharged to TER [NLWDS].

The liquid waste treated by TEU [LWTS] is classified into four categories:

- a) Process drains;
- b) Chemical drains;
- c) Floor drains; and
- d) Laundry drains.

To ensure appropriate treatment techniques are used, an optioneering of radioactive liquid waste treatment techniques have been undertaken and presented in *Optioneering Report for Liquid Radioactive Waste Processing Techniques*, Reference [45]. The potential options from worldwide OPEX have been identified and assessed against a set of assessment criteria considering the safety aspects and environment impacts as well as the technical feasibility, operational constraints/benefits and cost. For the purpose of GDA, the option of ‘demineralisation, evaporation and filtration’ is determined to be

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the optimal option which effectively treats the process drains, chemical drains, and floor drains and laundry drains, respectively.

TEU [LWTS] is divided into the following subsystems:

a) Liquid Waste Storage Subsystem

The liquid waste storage subsystem is equipped with storage tanks to store different categories of liquid wastes. For process drains, chemical drains and laundry drains, the subsystem is equipped with two storage tanks for each type of liquid waste. For floor drains, there are three storage tanks. Each type of storage tanks is equipped with a pump to recirculate the liquid waste in the tank and to transfer it to the liquid waste treatment subsystem for treatment.

For each type of storage tanks, there is always one of them that is lined up to receive liquid waste from upstream systems. After a storage tank is filled up, it will be isolated, recirculated and then sampled. The tanks of the liquid radioactive waste management systems are sized to provide sufficient capacity to enable safe, optimised and flexible management for all the liquid waste anticipated to be produced by the UK HPR1000 during normal operation, including expected events/anticipated occurrences. Considerations have notably been given to:

- 1) Minimisation of discharges and secondary waste generation, by providing sufficient capacity for the operator to make informed decisions with respect to which treatment to apply and whether additional treatment is needed to further improve the quality of the waste to be discharged while not detrimentally impact solid radioactive waste quality;
- 2) Minimisation of accumulation of the liquid radioactive waste on-site, by not oversizing tanks.

Detailed information and justification are presented in *Sizing Report of Main Equipment in Liquid Waste Management System*, Reference [46].

b) Liquid Waste Treatment Subsystem

The liquid waste treatment subsystem includes a demineralisation unit, an evaporation unit and a filtration unit.

1) Demineralisation unit

The demineralisation unit consists of three demineralisers, one pre-filter and two resin interception filters. The demineralisers arranged in series and each one can be bypassed as required. Process drains are generally treated by two demineralisers in series. The other demineraliser can be used to polish the treated process drains, the condensates from the evaporation unit and the liquid waste from the monitoring tanks.

The demineralisers are sized to provide sufficient capacity and efficiency to

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treat all the liquid radioactive waste (of process drain quality) anticipated to be produced by the UK HPR1000 during normal operation. Considerations have notably been given to:

- Minimisation of discharges and secondary waste generation, by providing sufficient capacity and efficiency to remove radioactive nuclides to reduce radioactivity levels to meet the discharge management objectives that will be defined by the operator considering all relevant factors and balancing liquid discharges and solid waste production;
- Minimisation of secondary waste generation and accumulation on-site, by not oversizing demineralisers.

Detailed information and justification are presented in *Sizing Report of Demineralisers in Liquid Waste Treatment System*, Reference [47].

2) Evaporation unit

The evaporation unit mainly consists of an evaporator, an electric heater, a steam vapour compressor and a heat exchanger. The treatment capacity of the evaporation unit is 4m³/h.

When liquid waste need to be treated through the evaporation unit, it is recirculated and sampled in the storage tank, and then transferred by the evaporator feed pump to the evaporation unit via a filter to remove particulates that could damage the evaporator or reduce its efficiency.

If needed, one demineraliser can be used to polish the condensates from the evaporation. This is determined by the operator according to the appropriate procedure, considering the balance between energy costs, the amount of secondary solid waste to be managed and the discharge to the environment.

3) Filtration unit

The filtration unit has three filters, two for treating floor drains with one on standby and one for treating laundry drains.

c) Monitoring and Discharge Subsystem

The discharge monitoring subsystem consists of two monitoring tanks and one monitoring tank pump. The monitoring tanks receive liquid waste treated by the liquid waste treatment subsystem. After one monitoring tank is filled up, its content will be recirculated, sampled and analysed.

If the radioactivity and chemical properties of the liquid waste meet discharge management objective, it will be discharged to TER [NLWDS]. Otherwise, it will be (re-)treated by the evaporation or demineralisation unit.

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d) Chemical Dosing Subsystem

The chemical injection subsystem consists of metering pumps and auxiliary parts, and is used to adjust pH of liquid waste in the storage tank and sodium to boron ratio of chemical drains, and inject anti-foam addition to the evaporator.

e) Sampling Analysis Subsystem

The sampling analysis subsystem consists of sampling glove boxes and local sampling funnels.

For the liquid waste treatment subsystem, the samples are taken down stream of demineralisers and evaporation unit to assess the treatment efficiency, and downstream of the recirculation pump to monitor the boron concentration, total salt content, sodium-to-boron ratio and other indicators of the concentrates.

For the discharge monitoring subsystem, the sampling analysis subsystem takes samples downstream of the pump of the monitoring tanks to measure the radiological and chemical properties of the treated liquid waste to determine the suitable management route.

23.6.3.3.2 Description of Main Equipment

a) Liquid Waste Storage Tanks and Monitoring Tanks

The liquid waste is collected in nine liquid waste storage tanks and two monitoring tanks of identical volume. The liquid waste storage tanks and monitoring tanks are made of stainless steel and arranged vertically.

b) Pumps

For each of four liquid waste streams, there is a liquid waste transfer pump and a monitoring tank pump to recirculate and transfer radioactive liquid waste. In the evaporation unit, there is an evaporator feed pump to feed the evaporation unit, a recirculation pump for evaporation liquid recirculation, and a condensate pump for condensate transfer.

The parts of the pumps in contact with the liquid waste are made of stainless steel. Pumps are equipped with reliable high quality mechanical seals of proven design to avoid the leakage of liquid waste.

c) Demineralisers

Three demineralisers are arranged in series for liquid waste treatment. Each demineraliser is a vertical cylinder made of stainless steel.

d) Evaporator

The evaporator is used to separate the contaminants from the water. The generated concentrates are stored in the column bottom. The steam enters the compressor

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through the column top, and provides the evaporation unit with required heat. It is made of stainless steel.

e) Electric Heater

The electric heater is mainly used to preheat the evaporation unit to normal operating temperature at the evaporator start-up stage. It is made of stainless steel.

f) Vapour Compressor

There is a vapour compressor in the evaporation unit to pressurise and heat up saturated steam generated in the evaporator column. The vapour compressor increases the specific enthalpy of the steam and then the steam is transferred to the evaporator heat exchanger to heat the circulating liquid. The vapour compressor is made of stainless steel.

g) Heat Exchanger

There are three heat exchangers in the evaporation unit. The evaporator heat exchangers are used to transfer the heat from saturated steam pressurised by the steam compressor to the liquid from the evaporator.

All heat exchangers are made of stainless steel.

h) Concentrate Tank

There are two concentrate tanks to receive concentrates generated by the evaporator. The concentrate tank is equipped with thermal insulation and heat tracing facilities. It is made of stainless steel.

i) Filters

There are three cartridge filters in the filter unit used to filter particle and fibre in liquid waste, two for treating floor drains and one for treating laundry drains. The filter shell is made of stainless steel.

23.6.3.3.3 Description of System Interfaces

The interfaces between TEU [LWTS] and other systems relating to radioactive waste management are listed below:

a) RPE [VDS]

TEU [LWTS] receives and treat the liquid waste collected by the RPE [VDS].

b) SRE [SRS]

TEU [LWTS] receives and treats the liquid waste collected by the SRE [SRS].

c) TES [SWTS]

TES [SWTS] treats the solid waste, i.e. spent resins, spent filter cartridges and

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concentrate, produced by the TEU [LWTS].

d) TER [NLWDS]

TER [NLWDS] receives the liquid waste treated by the TEU [LWTS].

TEU [LWTS] receives and treats the liquid waste from the TER [NLWDS] that does not comply with the discharge management objective.

e) Waste Treatment Building Ventilation System (DWQ [WBVS])

DWQ [WBVS] provides a vent route for TEU [LWTS] equipment exhaust.

23.6.3.3.4 System Operation

a) Plant Normal Condition

There is always one of each type of liquid waste storage tanks in receiving mode. Once a tank is full, it is isolated and another tank of the same type is switched to receiving mode. The liquid waste in the full tank is recirculated and sampled for analysis. According to the analysis result, the pH and sodium to boron ratio is adjusted as required, and a suitable treatment is selected:

- 1) Process drains are normally treated by demineralisation or evaporation if they are polluted with chemical;
- 2) Chemical drains are normally treated by evaporation. The chemical drains can be pumped to the demineralisation unit for refined treatment after evaporation if needed; and
- 3) Floor drains and laundry drains are normally treated by filtration.

After treatment, liquid waste is transferred to the monitoring tank. Before being sent TER [NLWDS], the liquid waste in the monitoring tank is recirculated and sampled for analysis.

b) Plant Accident Condition

Not applicable.

23.6.3.4 Design Substantiation

23.6.3.4.1 Compliance with Safety Functional Requirements

a) Control of Reactivity

Not applicable.

b) Removal of Heat

Not applicable.

c) Confinement

During normal operation, TEU [LWTS] retains liquid waste and minimise the release of radioactivity. The confinement of liquid waste is ensured by the sealing of the mechanical boundaries. The equipment, pipes and valves of TEU [LWTS] are made of stainless steel or other corrosion-resistant materials.

The civil engineering structure of the building, where TEU [LWTS] is located, acts as a barrier to protect from the external environment. The storage tanks are located in retention pit which is capable of containing all the liquid waste stored in the tanks in case they break. The retention pit where the storage tanks with higher radioactivity content are located is provided with stainless steel liner to ensure confinement, prevent concrete contamination and facilitate decontamination.

Tanks are connected with HVAC systems to prevent escapes of gaseous radioactive waste, and are provided with measurement device to detect level changes, facilitating detection, localisation and quantification of leakages or escapes of radioactive waste contained in them.

Leaks and tank overflows of TEU [LWTS] are transferred to SRE [SRS] to prevent spread of contamination.

d) Extra Supporting Functions

Not applicable.

23.6.3.4.2 Compliance with Design Requirements

a) Safety Classification

The safety classification of TEU [LWTS] is listed in T-23.6-3.

T-23.6-3 System Classification

Component	Function Category	Safety Classification	Design Provision Category	Design Provision Class	Seismic Categorisation
Liquid waste storage subsystem	FC3	F-SC3	DPL	B-SC3	NO*
Liquid waste treatment subsystem	FC3	F-SC3	DPL	B-SC3	NO*
Chemical dosing subsystem	NC	NC	NC	NC	NO

Component	Function Category	Safety Classification	Design Provision Category	Design Provision Class	Seismic Categorisation
Discharge monitoring subsystem	FC3	F-SC3	DPL	B-SC3	NO*
Sampling analysis subsystem	FC3	F-SC3	DPL	B-SC3	NO

* The pipelines penetrating the retention pit and the associated isolation valves are categorised as SSE2 to limit the effect of a hazard caused by a seismic event.

b) Engineering Design Requirements

1) SFC and redundancy

Not applicable.

2) Independence

Not applicable.

3) Diversity

Not applicable.

4) Fail-safe

The fail-safe concept is considered in the TEU [LWTS] design process. Fail-safe is adopted in the design of the pneumatic control valve on the bypass of steam compressor to protect the steam compressor against overpressure damage, and the pneumatic isolation valves on the outlet pipes of liquid waste storage tanks, compressed air supplying pipes of the concentrate tank and demineralized water and compressed air supplying pipes of the evaporator to insure the confinement of radioactive substances.

5) Human factors

Human factors are integrated in the design of TEU [LWTS]. Control functional requirements have been developed for allocating the system functions to manual activity and automatic control appropriately and providing necessary information to the operator.

6) Equipment qualification

The design of the TEU [LWTS] complies with the equipment qualification requirements. The components with seismic classification require seismic qualification, including the pipelines penetrating the retention pit and the

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associated isolation valves.

7) Ageing and degradation

Ageing and degradation are considered in the design of TEU [LWTS] by applying the design measures described in Sub-chapter 23.2.5.

8) EMIT

– Surveillance

The surveillance of TEU [LWTS] is performed from the Waste Treatment Building Control System (KSH [WBCS]). The state of tank level, pump and remote control valves is displayed on the control screen of KSH [WBCS]. The integrated alarm signal for waste treatment subsystem failures and unusable condition of the system is displayed in the main control room to provide necessary information to the operator.

– Maintenance

The preventive maintenance of TEU [LWTS] components will be carried out according to equipment operation and maintenance manual at the nuclear site licensing phase. The layout design takes into account the accessibility of components for maintenance activities.

– Inspection

The evaporator, electric heater, heat exchangers, condensate tank, concentrate tanks and associated valves in the TEU [LWTS] require pre-service inspection.

– Periodic tests

Following the preliminary requirements of periodic tests for radioactive waste management presented in Reference [41], TEU [LWTS] components do not require specific separate periodic test as their functions can be verified by appropriate operating routine checks and/or preventative maintenance with an appropriate frequency.

c) Protection Design against Internal and External Hazards

The main components of TEU [LWTS] are installed in the Radioactive Waste Treatment Building (BWX). The relevant internal protection and external protection for TEU [LWTS] are provided by the building structure.

d) Commissioning

By following the commissioning test requirements presented in Reference [9], TEU [LWTS] requires commissioning tests to verify its functionality, including tests of system flushing, valves, simulation measurement and control channel, logic control

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channel, pumps, tanks, evaporator, electric heater and steam compressor.

e) Decommissioning

Requirement for facilitating decommissioning is considered in the design of TEU [LWTS] by applying the design principles that are in accordance with the relevant requirements described in Sub-chapter 23.2.5, including reducing residual radioactive sources through appropriate emptying provisions, decontamination provisions, equipment structure design, layout of equipment and pipelines, etc., so as to facilitate decommissioning operations and reduce the accumulation of radioactive waste during decommissioning.

f) Material Selection

Equipment, pipes, valves, etc. that are in contact with radioactive media are made of stainless steel or other corrosion-resistant materials that are compatible with the media.

The selection of structural material for the system components meets the design temperature and pressure conditions and the requirements of the corresponding specification.

g) Conventional Health and Safety

Conventional health and safety is considered in the design of TEU [LWTS] by assessing the relevant risks and corresponding design mitigations and recording relevant information in the conventional health and safety design risk register, as presented in Sub-chapter 23.2.5.

23.6.4 Nuclear Island Liquid Waste Discharge System (TER [NLWDS])

Design information on TER [NLWDS] is described hereafter and details are presented in the SDM, including:

- a) *TER - Nuclear Island Liquid Waste Discharge System Design Manual Chapter 3 System Functions and Design Bases*, Reference [48];
- b) *TER - Nuclear Island Liquid Waste Discharge System Design Manual Chapter 4 System and Component Design*, Reference [49]; and
- c) *TER - Nuclear Island Liquid Waste Discharge System Design Manual Chapter 6 System Operation and Maintenance*, Reference [50].

The system flow diagram of TER [NLWDS] is presented in F-23.6-4.

23.6.4.1 Safety Functional Requirements

a) Reactivity Control

TER [NLWDS] does not contribute to this function.

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b) Removal of Heat

TER [NLWDS] does not contribute to this function.

c) Confinement

TER [NLWDS] contributes to the confinement of radioactive material in normal operation, by containing the liquid radioactive waste conveyed and preventing release of unqualified liquid waste into the environment.

d) Extra Supporting Functions

TER [NLWDS] does not contribute to this function.

23.6.4.2 Role of the System

TER [NLWDS] provides temporary storage, monitoring and control of the treated liquid waste from nuclear island and contributes to confinement of the liquid waste and control of liquid discharges by performing the following operational functions:

- a) Collecting and storing liquid waste from TEU [LWTS] and TEP [CSTS], and discharging it after sampling and analysis;
- b) Collecting and storing liquid waste from APG [SGBS] and SEK [WFCSCI], if SEL [LWDS (CI)] is unavailable;
- c) Sending liquid waste to TEU [LWTS] for treatment when the radioactivity level of the waste liquid exceeds the discharge management objective; and
- d) Sampling, monitoring and recording the discharged liquid waste characteristics, flow rate, and volume.

23.6.4.3 System Description and Operation

23.6.4.3.1 System Description

TER [NLWDS] is composed of:

- a) Piping that receives liquid waste from upstream systems;
- b) Three liquid waste storage tanks with the same volume;
- c) Each liquid waste storage tank is equipped with a liquid waste discharge pump;
- d) Recirculating piping and local sampling point for each liquid waste storage tank;
- e) The common discharge piping fitted with a flow proportional sampler, a flowmeter and an online Plant Radiation Monitoring System (KRT [PRMS]) monitor;
- f) Sumps in the tank area and the pump room to collect pipe drains and floor drains. Each sump has a pump to send back the liquid waste to the storage tank.

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23.6.4.3.2 Description of Main Equipment

TER [NLWDS] is equipped with liquid waste storage tanks, liquid waste discharge pumps and sump pumps. The parts of the pumps in contact with the liquid waste and the tanks are made of stainless steel.

The storage tanks are designed to receive liquid waste from upstream systems. The liquid waste discharge pumps recirculate and transfer the liquid waste in the liquid waste storage tanks. The liquid waste collected in the sumps is routed to the liquid waste storage tanks by the sump pumps. The flow proportional sampler positioned on the discharge pipe is used to obtain a representative sample of the discharged liquid waste.

23.6.4.3.3 Description of System Interfaces

The interfaces between TER [NLWDS] and other systems relating to radioactive waste management are listed below:

a) TEU [LWTS]

TER [NLWDS] collects low radioactive liquid waste from TEU [LWTS].
TER [NLWDS] transfer liquid waste to TEU [LWTS] if its quality does not comply with discharge management objective.

b) TEP [CSTS])

TER [NLWDS] collects radioactive effluent from TEP [CSTS].

c) SEL [LWDS (CI)]

TER [NLWDS] collects the liquid waste from SEL [LWDS (CI)] when the SEL [LWDS (DI)] system is unavailable.

d) PTR [FPCTS]

TER [NLWDS] collects drainage from in-containment refuelling water storage tank via PTR [FPCTS].

e) KRT [PRMS]

The liquid waste discharged by TER [NLWDS] is continuously monitored by KRT [PRMS].

23.6.4.3.4 System Operation

a) Plant Normal Condition

During normal operation, there is always one of the three storage tanks in TER [NLWDS] that is lined up to receive liquid waste from upstream systems; the two other tanks are either under recirculation, sampling, monitoring or discharge mode or on standby. There is one sampling point on the recirculation line of each liquid waste storage tank. The liquid waste from each tank is recirculated before sampling

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is performed to ensure representative samples are taken. After the sample is analysed, the discharge flow rate is determined according to the radioactivity level of the liquid waste and the dilution ability of the drainage channels.

A radiation monitor in KRT [PRMS], which is positioned on the discharge pipe, is used to detect the radioactivity level of the liquid waste. If the radioactivity level of the liquid waste exceeds the discharge management objective, an alarm will be triggered and the isolation valve will be closed automatically.

A flow proportional sampler is also positioned on the main discharge pipe of TER [NLWDS] to take composite samples to support discharges of liquid waste to the environment.

The liquid waste in the storage tanks will be sent back to TEU [LWTS] for further treatment if their characteristics exceed the discharge management objective.

b) Plant Accident Conditions

Not applicable.

23.6.4.4 Design Substantiation

23.6.4.4.1 Compliance with Safety Functional Requirements

a) Control of Reactivity

Not applicable.

b) Removal of Heat

Not applicable.

c) Confinement

TER [NLWDS] enables the monitoring and sampling of liquid waste released into the environment, and ensures that the radiation exposure of operating personnel and of the public remains within acceptable limits.

The liquid radioactive waste in TER [NLWDS] is contained by the sealing of equipment and pipes. The storage tanks are located in a retention pit which has sufficient capacity to contain all the liquid waste produced in case the tanks break.

Storage tanks are provided with measurement device to detect level changes, facilitating detection, localisation and quantification of leakages or escapes of radioactive waste. Leaks and tank overflows are transferred to sumps to prevent spread of contamination.

d) Extra Supporting Functions

Not applicable.

23.6.4.4.2 Compliance with Design Requirements

a) Safety Classification

The safety classification of TER [NLWDS] is listed in T-23.6-4 .

T-23.6-4 System Classification

Component	Function Category	Safety Classification	Design Provision Category	Design Provision Class	Seismic Categorisation
Storage tanks	FC3	F-SC3	DPL	B-SC3	NO
Discharge pumps	FC3	F-SC3	DPL	B-SC3	NO
Sump pumps	FC3	F-SC3	DPL	B-SC3	NO

* The pipelines penetrating the retention pit and the associated isolation valves are categorised as SSE2 to limit the effect of a hazard caused by a seismic event.

b) Engineering Design Requirements

1) SFC and redundancy

Not applicable.

2) Independence

Not applicable.

3) Diversity

Not applicable.

4) Fail-safe

The fail-safe concept is considered in the TER [NLWDS] design process. Fail-Safe is adopted in the design of the pneumatic isolation valves on the outlet pipes of the liquid waste storage tanks to ensure the confinement of radioactive liquid waste, and in the design of the pneumatic isolation valve on the discharge line to avoid unexpected/unauthorised discharge.

5) Human factors

Human factors are integrated in the design of the TER [NLWDS]. Control functional requirements have been developed for allocating the system functions to manual activity and automatic control appropriately and providing

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necessary information to the operator.

6) Equipment qualification

The design of the TER [NLWDS] complies with the equipment qualification requirements. The components with seismic classification require seismic qualification, including the pipelines penetrating the retention pit and the associated isolation valves.

7) Ageing and degradation

Ageing and degradation are considered in the design of the TER [NLWDS] by applying the design measures described in Sub-chapter 23.2.5.

8) EMIT

– Surveillance

The level of tanks, discharge flowrate and radioactivity level, state of electric and pneumatic isolation valves, electric control valves, important manual isolation valves, pumps, KRT [PRMDS] monitor and flow proportional sampler are under surveillance.

– Maintenance

The preventive maintenance of TER [NLWDS] components will be carried out according to equipment operation and maintenance manual at the nuclear site licensing phase. The layout design takes into account the accessibility of components for maintenance activities.

– Inspection

The components in the TER [NLWDS] do not require pre-service inspection.

– Periodic tests

Following the preliminary requirements of periodic tests for radioactive waste management presented in Reference [41], TER [NLWDS] components do not require specific separate periodic test as their functions can be verified by appropriate operating routine checks and/or preventative maintenance with an appropriate frequency.

c) Protection Design against Internal and External Hazards

The relevant internal protection and external protection for TER [NLWDS] are provided by the building structure.

d) Commissioning

Following the commissioning test requirements presented in Reference [9], TER

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[NLWDS] requires commissioning tests to verify its functionality, including tests of system flushing, discharge, valves, simulation measurement and control channel, logic control channel, pumps and tanks.

e) Decommissioning

Requirement for facilitating decommissioning is considered in the design of TER [NLWDS] by applying the design principles that are in accordance with the relevant requirements described in Sub-chapter 23.2.5, including reducing residual radioactive sources through emptying provisions, equipment structure design, layout of equipment and pipelines, etc., so as to facilitate decommissioning operations and reduce the accumulation of radioactive waste during decommissioning.

f) Material Selection

In order to limit corrosion, the liquid waste storage tanks, the pumps, sump pumps, pipes and valves are made of stainless steel.

g) Conventional Health and Safety

Conventional health and safety is considered in the design of TER [NLWDS] by assessing the relevant risks and corresponding design mitigations and recording relevant information in the conventional health and safety design risk register, as presented in Sub-chapter 23.2.5.

23.6.5 Sewage Recovery System (SRE [SRS])

Design information on SRE [SRS] is described hereafter and details are presented in the SDM, including:

- a) *SRE - Sewage Recovery System Design Manual Chapter 3 System Functions and Design Bases*, Reference [51];
- b) *SRE - Sewage Recovery System Design Manual Chapter 4 System and Component Design*, Reference [52]; and
- c) *SRE - Sewage Recovery System Design Manual Chapter 6 System Operation and Maintenance*, Reference [53].

The system flow diagram of SRE [SRS] is presented in F-23.6-5.

23.6.5.1 Safety Functional Requirements

a) Reactivity Control

SRE [SRS] does not contribute to this function.

b) Removal of Heat

SRE [SRS] does not contribute to this function.

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c) Confinement

SRE [SRS] contributes to the confinement of radioactive material in normal operation, by containing the liquid radioactive waste conveyed and minimising the radioactive discharges to the environment by preventing the spread of radioactive liquid waste through leak tightness, and by appropriately segregating and transferring them for appropriate treatment.

d) Extra Supporting Functions

SRE [SRS] does not perform extra supporting functions.

23.6.5.2 Role of the System

SRE [SRS] collects the liquid waste from the waste management in the BWX and decontamination areas and contributes to confinement of the liquid waste and prevention of the spread radioactive waste by performing the following operational functions:

- a) Separate collection of different categories of liquid waste produced in the BWX and hot mechanical workshop and warehouse. The liquid waste collected by SRE [SRS] is segregated into four streams according to the chemical and radioactive characteristics:
 - 1) Process drains, which contain a low level of chemical impurities;
 - 2) Chemical drains, which contain a higher level of chemical impurities and higher radioactivity compared to process drains;
 - 3) Floor drains, which typically contain lower radioactive contamination but are high in suspended solids; and
 - 4) Laundry drains, which contain lower radioactive contamination but are high in suspended solids, fibrous matters, and detergents.
- b) Transferring the collected liquid waste to TEU [LWTS] where each category of the liquid waste is treated by the appropriate processing technique.

23.6.5.3 System Description and Operation

23.6.5.3.1 System Description

SRE [SRS] is designed to separately collect the liquid radioactive waste from BWX and hot mechanical workshop and warehouse, including:

- a) Liquid waste from leakage, drainage and overflow of the equipment, sampling and ground flushing in BWX where TEU [LWTS], TES [SWTS] and the hot laundry are located; and
- b) Liquid waste from mechanical decontamination and ground flushing in the hot

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mechanical workshop and warehouse where the components contaminated with radioactivity are stored and maintained.

The hot mechanical workshop and warehouse is not included within the scope of the GDA, Reference [37]. This sub-chapter focuses on the liquid waste collection subsystem in BWX.

23.6.5.3.2 Description of Main Equipment

a) Liquid Waste Collection Sumps

Liquid waste collection sumps are located on the bottom floor of the BWX to collect liquid waste with potential radioactivity. Stainless steel liners are installed in the sumps to facilitate decontamination.

b) Pumps

The pumps are equipped to transfer the liquid waste collected in sumps to TEU [LWTS] for treatment. The parts in contact with the liquid waste are made of stainless steel.

23.6.5.3.3 Description of System Interfaces

The interfaces between SRE [SRS] and other systems relating to radioactive waste management are listed below:

a) TEU [LWTS]

TEU [LWTS] receives and processes the liquid waste collected by SRE [SRS].

SRE [SRS] collects the drainage of pipes and equipment in TEU [LWTS].

b) TES [SWTS]

SRE [SRS] collects the drainage of pipes and equipment in TES [SWTS].

23.6.5.3.4 System Operation

a) Plant Normal Condition

When the liquid waste in the sump reaches the high level, the pumps start-up automatically to transfer the liquid waste to TEU [LWTS] for treatment. If the liquid waste in the sumps reaches the high-high level or the low-low level, an alarm will be triggered to inform the operator to check the causes and adopt appropriate actions.

b) Plant Accident Conditions

Not applicable.

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23.6.5.4 Design Substantiation

23.6.5.4.1 Compliance with Safety Functional Requirements

a) Control of Reactivity

Not applicable.

b) Removal of Heat

Not applicable.

c) Confinement

The confinement of radioactive material is achieved by the sealing of the mechanical boundaries. The equipment, pipes and valves of SRE [SRS] are made of stainless steel or other corrosion-resistant materials.

The civil engineering structure of the building, in where SRE [SRS] is located, acts as a barrier to protect from the external environment.

Sumps are provided with measurement device to detect level changes, facilitating detection, localisation and quantification of leakages or escapes of radioactive waste.

d) Extra Supporting Functions

Not applicable.

23.6.5.4.2 Compliance with Design Requirements

a) Safety Classification

The safety classification of SRE [SRS] is listed in T-23.6-5.

T-23.6-5 System Classification

Component	Function Category	Safety Classification	Design Provision Category	Design Provision Class	Seismic Categorisation
Pipes penetrating the retention pit and the associated isolation valves	FC3	F-SC3	DPL	B-SC3	SSE2
Other equipment	FC3	F-SC3	DPL	B-SC3	NO

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b) Engineering Design Requirements

1) SFC and redundancy

Not applicable.

2) Independence

Not applicable.

3) Diversity

Not applicable.

4) Fail-safe

Not applicable.

5) Human factors

Human factors are integrated in the design of the SRE [SRS]. Control functional requirements have been developed for allocating the system functions to manual activity and automatic control appropriately and providing necessary information to the operator.

6) Equipment qualification

The design of the SRE [SRS] complies with the equipment qualification requirements. The components with seismic classification require seismic qualification, including the pipelines penetrating the retention pit and the associated isolation valves.

7) Ageing and degradation

Ageing and degradation are considered in the design of the SRE [SRS] by applying the design measures described in Sub-chapter 23.2.5.

8) EMIT

– Surveillance

The surveillance of the SRE [SRS] is performed from the KSH [WBCS]. The states of the sump levels and the pumps are displayed on the control screen of the KSH [WBCS].

– Maintenance

The preventive maintenance of SRE [SRS] components will be carried out according to equipment operation and maintenance manual at the nuclear site licensing phase. The layout design takes into account the accessibility of components for maintenance activities.

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- Inspection

The components in the SRE [SRS] do not require pre-service inspection.

- Periodic tests

Following the preliminary requirements of periodic tests for radioactive waste management presented in Reference [41], SRE [SRS] components do not require specific separate periodic test as their functions can be verified by appropriate operating routine checks and/or preventative maintenance with an appropriate frequency.

- c) Protection Design against Internal and External Hazards

The relevant internal protection and external protection for SRE [SRS] are provided by the building structure.

- d) Commissioning

Following the commissioning test requirements presented in Reference [9], SRE [SRS] requires commissioning tests to verify its functionality, including tests of sumps and pumps.

- e) Decommissioning

Requirement for facilitating decommissioning is considered in the design of SRE [SRS] by applying the design principles that are in accordance with the relevant requirements described in Sub-chapter 23.2.5, including reducing residual radioactive sources through emptying provisions, decontamination provisions, equipment structure design, layout of equipment and pipelines, and minimising embedded pipes and adequately designing unavoidable ones, etc., so as to facilitate decommissioning operations and reduce the accumulation of radioactive waste during decommissioning.

- f) Material Selection

In order to limit corrosion, components that are in contact with liquid waste are made of stainless steel.

Sumps are equipped with stainless steel liners to limit corrosion and concrete contamination.

- g) Conventional Health and Safety

Conventional health and safety is considered in the design of SRE [SRS] by assessing the relevant risks and corresponding design mitigations and recording relevant information in the conventional health and safety design risk register, as presented in Sub-chapter 23.2.5.

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23.6.6 Conventional Island Liquid Waste Discharge System (SEL [LWDS (CI)])

Design information on SEL [LWDS (CI)] is described hereafter and details are presented in the SDM, including:

- a) *SEL - Conventional Island Liquid Waste Discharge System Design Manual Chapter 3 System Functions and Design Bases*, Reference [54];
- b) *SEL - Conventional Island Liquid Waste Discharge System Design Manual Chapter 4 System and Component Design*, Reference [55]; and
- c) *SEL - Conventional Island Liquid Waste Discharge System Design Manual Chapter 6 System Operation and Maintenance*, Reference [56].

The system flow diagram of SEL [LWDS (CI)] is presented in F-23.6-4.

23.6.6.1 Safety Functional Requirements

- a) Reactivity Control

SEL [LWDS (CI)] does not contribute to this function.

- b) Removal of Heat

SEL [LWDS (CI)] does not contribute to this function.

- c) Confinement

SEL [LWDS (CI)] contributes to the confinement of radioactive material in normal operation, by containing the liquid radioactive waste conveyed and preventing discharge of unqualified liquid waste into the environment.

- d) Extra Supporting Functions

SEL [LWDS (CI)] does not contribute to this function.

23.6.6.2 Role of the System

SEL [LWDS (CI)] provides temporary storage, monitoring and control of the liquid waste from the conventional island. SEL [LWDS (CI)] contributes to confinement of the liquid waste and the control of potential radioactive waste discharges by performing the following operational functions:

- a) Collect and store the liquid waste from SEK [WFCSCI] and non-recyclable effluent from APG [SGBS], and discharge the liquid waste after recirculation, sampling and analysis;
- b) Send liquid waste to TEU [LWTS] for treatment when the radioactivity concentration of the liquid waste exceeds the discharge management objective after sampling analysis or monitoring; and
- c) Sample, monitor and record the characteristics, flow rate volume of the discharged

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liquid waste.

23.6.6.3 System Description and Operation

23.6.6.3.1 System Description

SEL [LWDS (CI)] is composed of:

- a) Piping that receives liquid waste from upstream systems;
- b) Three liquid waste storage tanks with the same volume;
- c) Each liquid waste storage tank is equipped with a liquid waste discharge pump;
- d) Recirculating piping and local sampling point for each liquid waste storage tank;
- e) The common discharge piping fitted with a flow proportional sampler and an online KRT [PRMS] monitor; and
- f) Sumps collect drains in the tank area and the pump room. Each sump has a pump to send back the liquid waste to the storage tank.

23.6.6.3.2 Description of Main Equipment

SEL [LWDS (CI)] is equipped with liquid waste storage tanks, discharge pumps and sump pumps.

The storage tanks are used to receive liquid waste from the upstream systems. The liquid waste discharge pumps recirculate and transfer the liquid waste in the storage tanks. The liquid waste collected in the sumps is routed to the liquid waste storage tank by the sump pumps. The flow proportional sampler positioned on the discharge pipe is used to obtain a representative sample of the actual discharged liquid waste.

23.6.6.3.3 Description of System Interfaces

The interfaces between SEL [LWDS (CI)] and other systems relating to radioactive waste management are listed below:

- a) SEK [WFCSCI]

SEL [LWDS (CI)] collects low radioactive liquid waste from SEK [WFCSCI].
- b) APG[SGBS])

SEL [LWDS (CI)] collects non-reusable liquid waste from APG [SGBS].
- c) TEU [LWTS]/TER [NLWDS]

Radioactive liquid waste in SEL [LWDS (CI)] that is not appropriate for discharge is sent to TEU [LWTS] for treatment or TER [NLWDS] for storage before discharge.
- d) KRT [PRMS]

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The liquid waste discharged by SEL [LWDS (CI)] is continuously monitored by KRT [PRMS].

23.6.6.3.4 System Operation

a) Plant Normal Condition

During normal operation, there is always one of the three storage tanks in SEL [LWDS (CI)] that is lined up to receive liquid waste from upstream systems; the two other tanks are either under recirculation, sampling, monitoring or discharge mode or on standby. There is one sampling point on the recirculation line of each liquid waste storage tank. The liquid waste from the storage tank is recirculated before sampling is performed to ensure representative samples are taken. After the sample is analysed, the discharge flow rate is determined according to the radioactive level of the liquid waste and the dilution ability of the drainage channels.

A radiation monitor in KRT [PRMS], which is positioned on the discharge pipe, is used to monitor the radioactive level of the liquid waste. If the radioactivity level of the liquid waste exceeds the discharge management objective, an alarm will be triggered and the isolation valve will be closed automatically.

A flow proportional sampler is also positioned on the main discharge pipe of SEL [LWDS (CI)] to take composite samples to support discharges of liquid waste to the environment.

The liquid waste in the storage tanks will be sent to TEU [LWTS] for treatment if its radioactivity level exceeds the discharge management objective.

b) Plant Accident Conditions

Not applicable.

23.6.6.4 Design Substantiation

23.6.6.4.1 Compliance with Safety Functional Requirements

a) Control of Reactivity

Not applicable.

b) Removal of Heat

Not applicable.

c) Confinement

SEL [LWDS (CI)] enables the monitoring and sampling of liquid waste discharged into the environment, and ensures that radiation exposure to workers and the public remains within acceptable limits.

The liquid radioactive waste in SEL [LWDS (CI)] is contained by the sealing of

equipment and pipes. The storage tanks are located in a retention pit which has sufficient capacity to contain all the liquid waste produced in case of the tanks break.

Storage tanks are provided with measurement device to detect level changes, facilitating detection, localisation and quantification of leakages or escapes of radioactive waste contained in them. Leaks and tank overflows are transferred to sumps to prevent spread of contamination.

d) Extra Supporting Functions

Not applicable.

23.6.6.4.2 Compliance with Design Requirements

a) Safety Classification

The safety classification of the SEL [LWDS (CI)] is listed in T-23.6-6.

T-23.6-6 System Classification

Component	Function Category	Safety Classification	Design Provision Category	Design Provision Class	Seismic Categorisation
Storage tanks	FC3	F-SC3	DPL	B-SC3	NO
Discharge pumps	FC3	F-SC3	DPL	B-SC3	NO
Sump pumps	FC3	F-SC3	DPL	B-SC3	NO

b) Engineering Design Requirements

1) SFC and redundancy

Not applicable.

2) Independence

Not applicable.

3) Diversity

Not applicable.

4) Fail-safe

The fail-safe concept is considered in the SEL [LWDS (CI)] design process. Fail-Safe is adopted in the design of the pneumatic isolation valves on the

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outlet pipes of the liquid waste storage tanks to ensure the confinement of radioactive liquid waste, and in the design of the pneumatic isolation valve on the discharge line to avoid unexpected/unauthorised discharge.

5) Human factors

Human factors are integrated in the design of SEL [LWDS (CI)]. Control functional requirements have been developed for allocating the system functions to manual activity and automatic control appropriately and providing necessary information to the operator.

6) Equipment qualification

The components in the SEL [LWDS (CI)] do not require qualification.

7) Ageing and degradation

Ageing and degradation are considered in the design of SEL [LWDS (CI)] by applying the design measures described in Sub-chapter 23.2.5.

8) EMIT

– Surveillance

The level of tanks, discharge flowrate and radioactivity level, state of electric and pneumatic isolation valves, electric control valves, important manual isolation valves, pumps, KRT [PRMDS] monitor and flow proportional sampler are under surveillance.

– Maintenance

The preventive maintenance of SEL [LWDS (CI)] components will be carried out according to equipment operation and maintenance manual at the nuclear site licensing phase. The layout design takes into account the accessibility of components for maintenance activities.

– Inspection

The components in the SEL [LWDS (CI)] do not require pre-service inspection.

– Periodic tests

Following the preliminary requirements of periodic tests for radioactive waste management presented in Reference [41], SEL [LWDS (CI)] components do not require specific separate periodic test as their functions can be verified by appropriate operating routine checks and/or preventative maintenance with an appropriate frequency.

c) Protection Design against Internal and External Hazards

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The relevant internal protection and external protection for SEL [LWDS (CI)] are provided by the building structure.

d) Commissioning

By following the commissioning test requirements presented in Reference [9], SEL [LWDS (CI)] requires commissioning tests to verify its functionality, including tests of system flushing, discharge, valves, simulation measurement and control channel, logic control channel, pumps and tanks.

e) Decommissioning

Requirement for facilitating decommissioning is considered in the design of SEL [LWDS (CI)] by applying the design principles that are in accordance with the relevant requirements described in Sub-chapter 23.2.5, including reducing residual radioactive sources through emptying provisions, equipment structure design, layout of equipment and pipelines, etc., so as to facilitate decommissioning operations and reduce the accumulation of radioactive waste during decommissioning.

f) Material Selection

In order to limit corrosion, the material of the liquid waste storage tanks, the pumps, pipes and valves are made of stainless steel.

g) Conventional Health and Safety

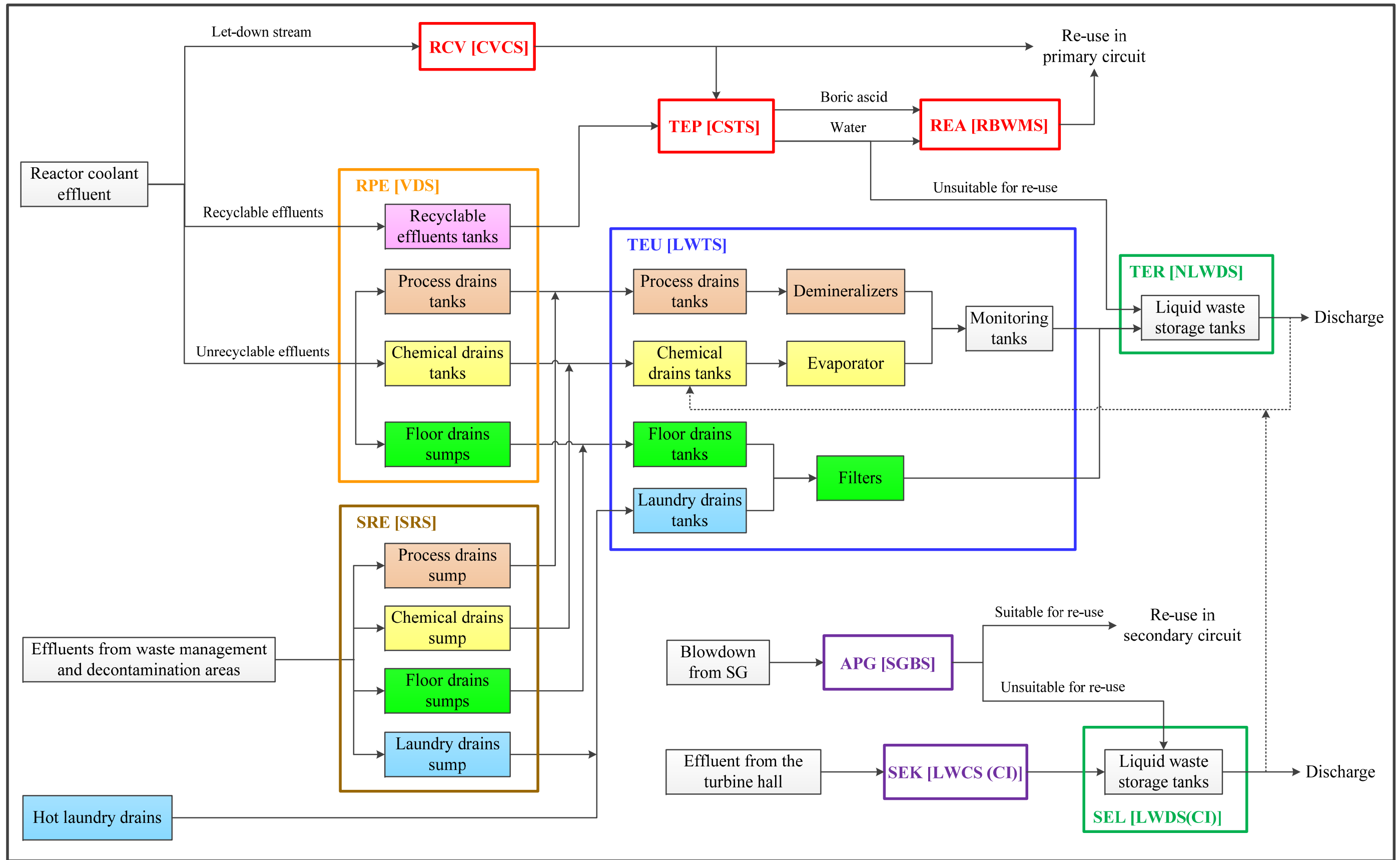
Conventional health and safety is considered in the design of SEL [LWDS (CI)] by assessing the relevant risks and corresponding design mitigations and recording relevant information in the conventional health and safety design risk register, as presented in Sub-chapter 23.2.5.

23.6.7 System Flow Diagram

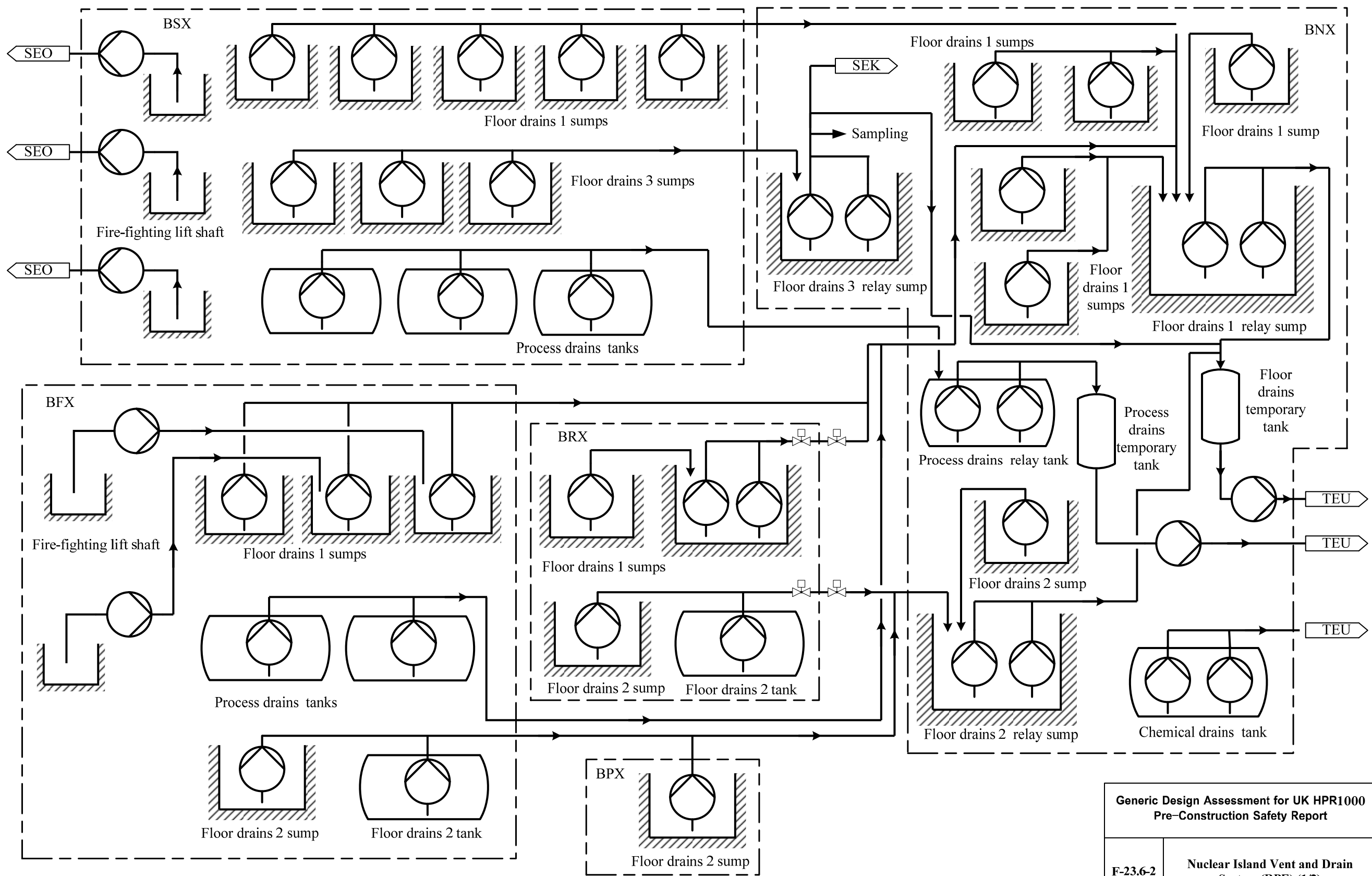
The flow diagrams of liquid radioactive waste management systems are presented as follows:

- a) F-23.6-2 Nuclear Island Vent and Drain System (RPE [VDS])
- b) F-23.6-3 Liquid Waste Treatment System (TEU [LWTS])
- c) F-23.6-4 Nuclear Island Liquid Waste Discharge System (TER [NLWDS]) and Conventional Island Liquid waste Discharge System (SEL[LWDS (CI)])
- d) F-23.6-5 Sewerage Recovery System (SRE [SRS])

These flow diagrams have been simplified by the removal of detailed information from the flow diagrams in the SDM Chapter 9, aiming to help understanding the system configurations.

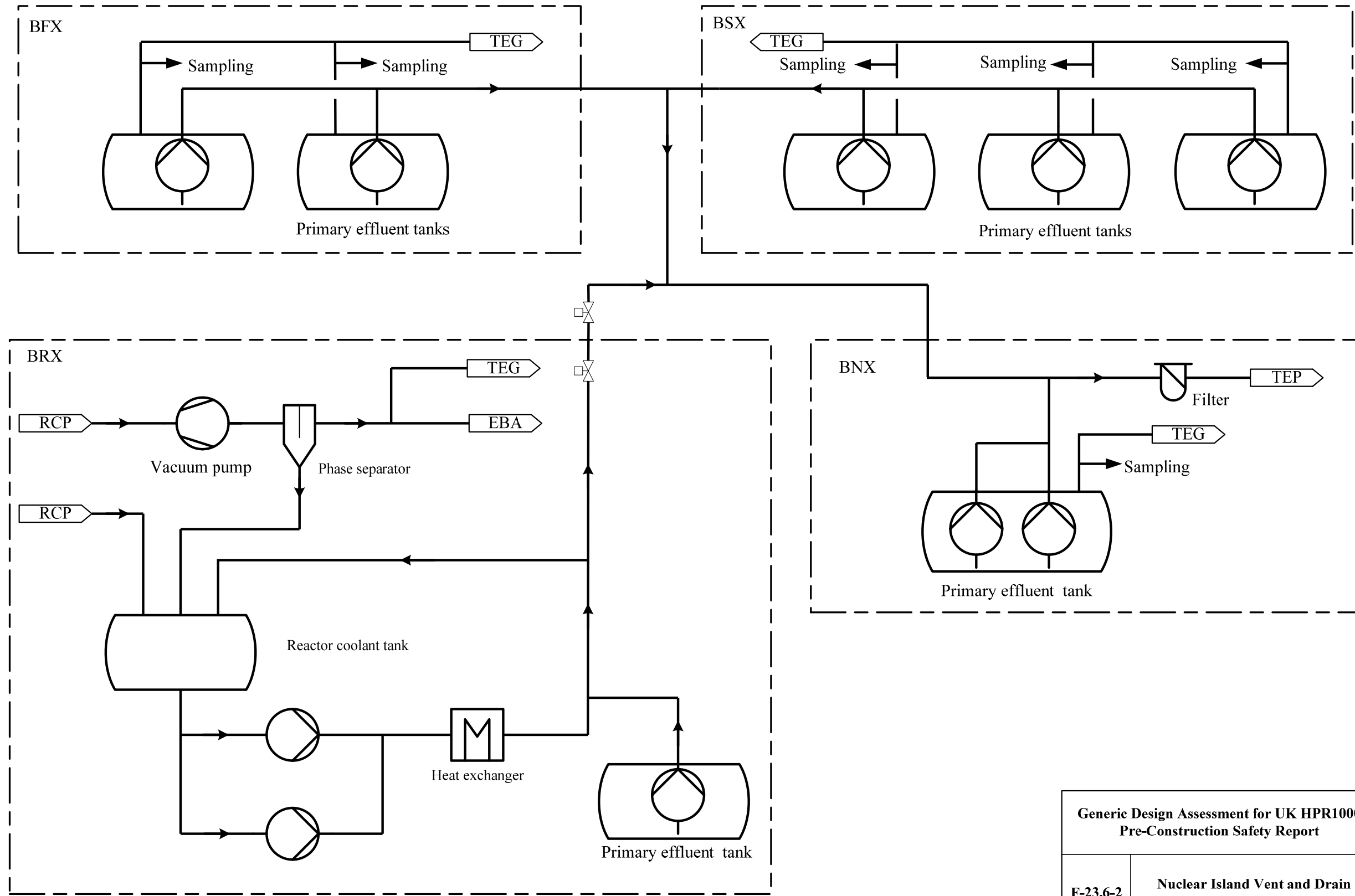


F-23.6-1 Liquid Radioactive Waste Effluent Streams



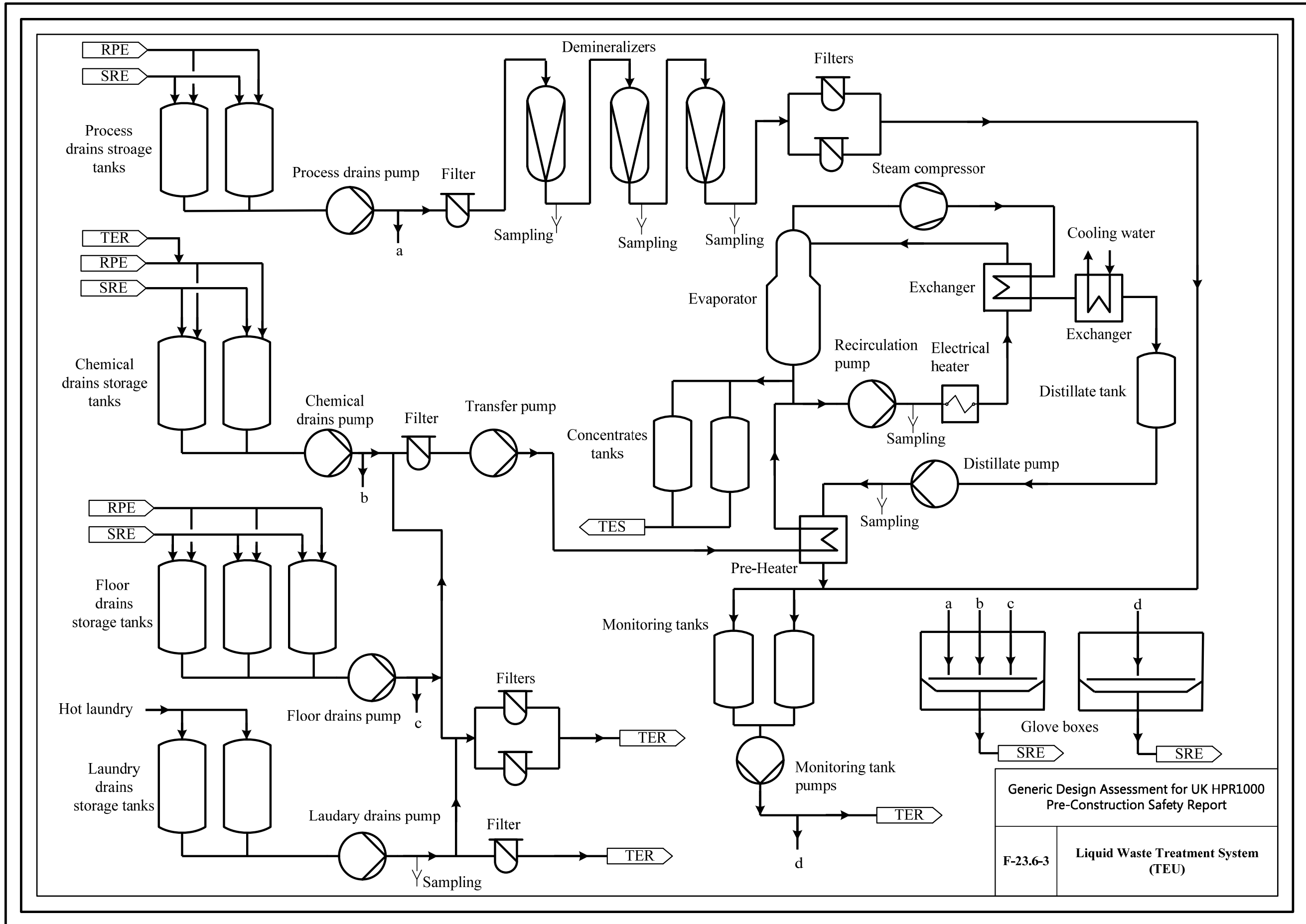
Generic Design Assessment for UK HPR1000
Pre-Construction Safety Report

F-23.6-2 Nuclear Island Vent and Drain System (RPE) (1/2)



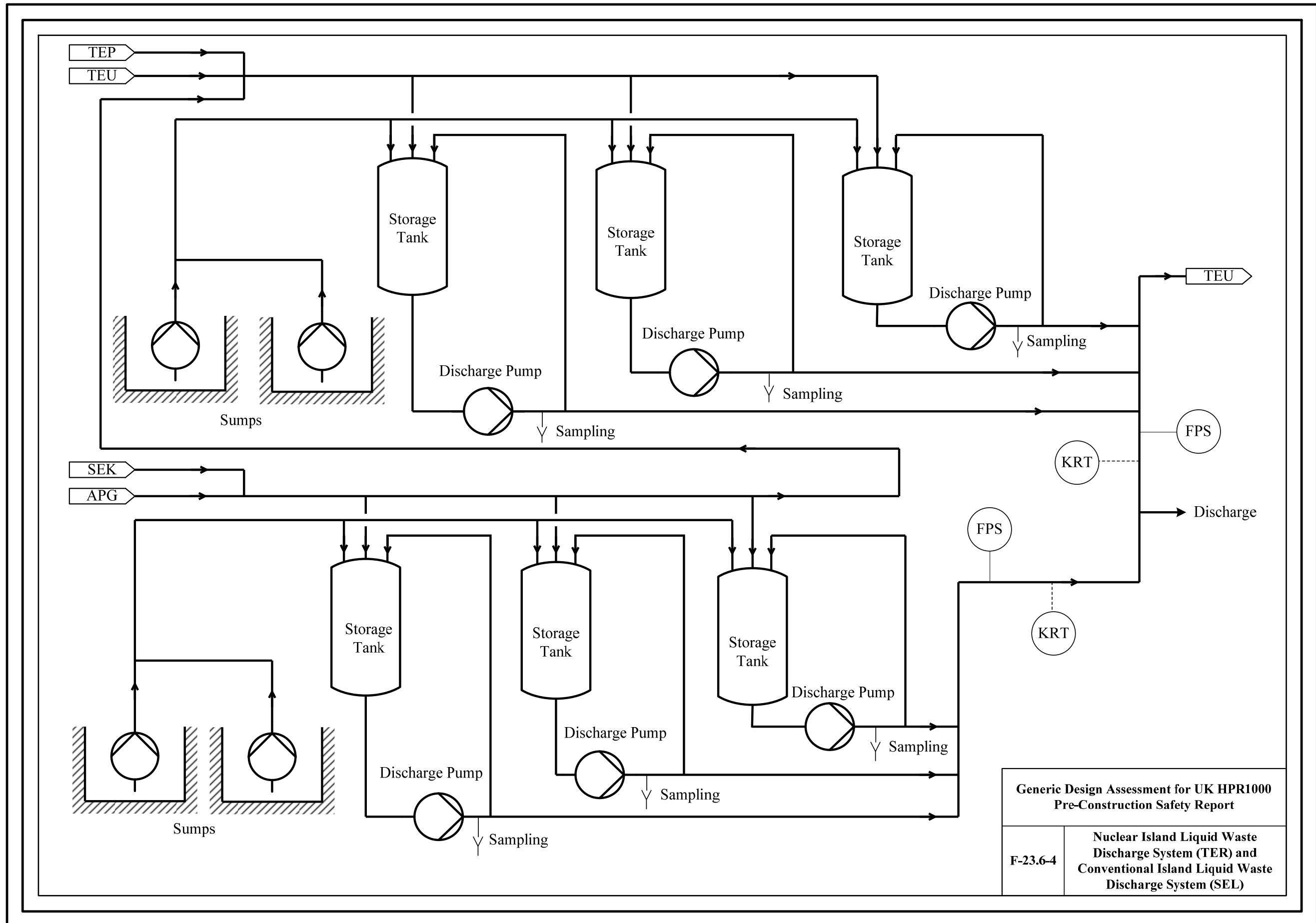
Generic Design Assessment for UK HPR1000
Pre-Construction Safety Report

F-23.6-2 Nuclear Island Vent and Drain System (RPE) (2/2)



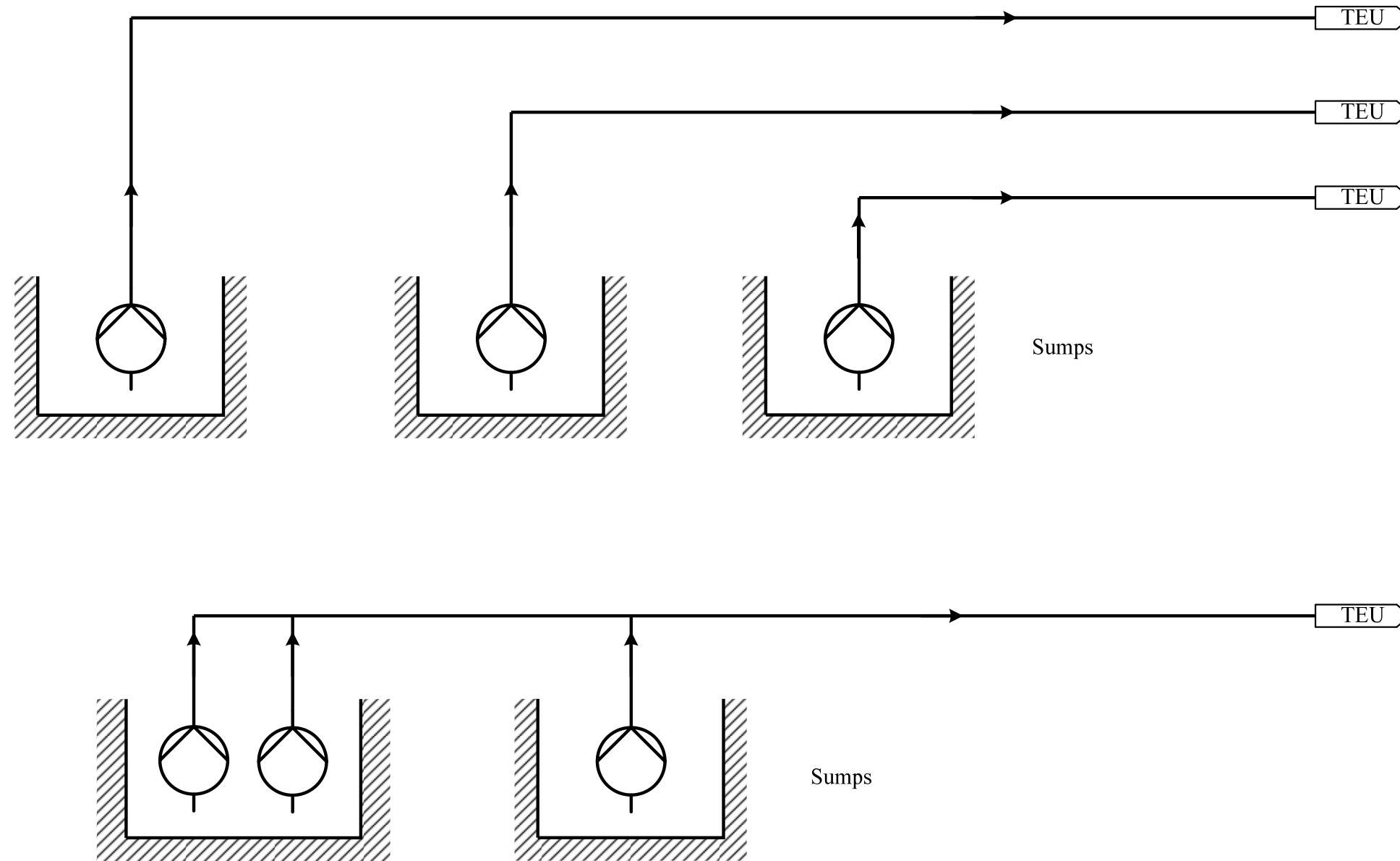
Generic Design Assessment for UK HPR1000
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F-23.6-3 Liquid Waste Treatment System (TEU)



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F-23.6-4 Nuclear Island Liquid Waste
Discharge System (TER) and
Conventional Island Liquid Waste
Discharge System (SEL)



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F-23.6-5

Sewage Recovery System (SRE)

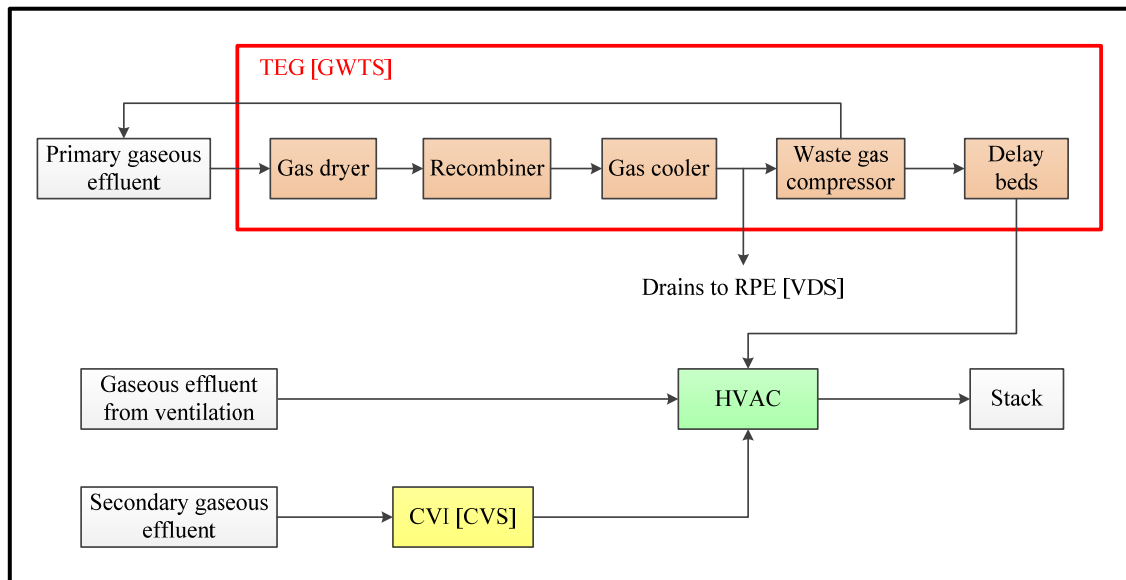
23.7 Gaseous Radioactive Waste Management

23.7.1 Gaseous Radioactive Waste Management Strategy

Gaseous radioactive waste generated unavoidably during the operation of the UK HPR1000 is divided into three categories:

- Primary gaseous effluent;
- Gaseous effluent from ventilation; and
- Secondary gaseous effluent.

These three sources of the gaseous radioactive wastes are processed, monitored and discharged to the environment as illustrated in F-23.7-1 and described thereafter. The estimated discharges and proposed limits of gaseous effluent discharges are described in PCER Sub-chapter 6.6, Reference [36].



F-23.7-1 Gaseous Radioactive Waste Streams

23.7.1.1 Primary Gaseous Effluent

The primary gaseous effluent, which comes from the degassing and head spaces of the vessels containing primary coolant or primary effluent, is collected and processed by the TEG [GWTS]. The TEG [GWTS] works as a closed circuit in a steady-state operation mode and only a small volume of radioactive gases released to the environment after passing through the delay beds where the krypton and xenon are delayed for a minimum time of 40 hours and 40 days respectively. During steady state operation, the TEG [GWTS] operates continuously to flush the vessels and tanks with nitrogen to remove the hydrogen and oxygen. A recombiner is used to recombine the hydrogen with oxygen to water. The nitrogen in the flushing section is recycled and reused after recombination. The majority of radioactive gases present in the TEG

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[GWTS] are fission products such as krypton, xenon and iodine which (most of them) have relatively short half-lives and undergo natural decay in the flushing section.

During shutdown and start-up transients notably, there is excess gas released to the TEG [GWTS] because of the flushing of the gas space of reactor pressure vessel or the thermal expansion of the reactor coolant. In these circumstance the excess gas is diverted into delay beds where the krypton and xenon are delayed for a minimum time of 40 hours and 40 days respectively. The delay results in a significant reduction in the radioactivity level of the gaseous waste.

Downstream of the TEG [GWTS] the gas is routed to the Nuclear Auxiliary Building Ventilation System (DWN [NABVS]), treated by High Efficiency Particulate Air (HEPA) filtration and if needed by iodine traps, monitored and discharged to the environment via the main stack.

The TEG [GWTS] is presented in Sub-chapter 23.7.2.

23.7.1.2 Gaseous Effluent from Ventilation

Air from the areas containing radioactive substances is collected and treated by the Heating, Ventilation and Air Conditioning (HVAC) systems. HEPA and iodine traps are arranged to remove the particulate matter and iodine isotopes prior to discharging the waste air into the main stack. The design of HVAC systems is presented in PCSR Sub-chapter 10.6.

23.7.1.3 Secondary Gaseous Effluent

Non-condensable gases collected within the steam condenser (which include radionuclides in the event of a steam generator tube leak) are removed by the Condensate Vacuum System (CVI [CVS]) and routed to the DWN [NABVS] where they are treated by HEPA filtration and if needed iodine traps, monitored, and discharged to the environment via the main stack.

The CVI [CVS] is not included within the scope of the GDA, Reference [38].

23.7.2 Gaseous Waste Treatment System (TEG [GWTS])

Design information on TEG [GWTS] is described hereafter and details are presented in the SDM, including:

- a) *TEG - Gaseous Waste Treatment System Design Manual Chapter 3 System Functions and Design Bases*, Reference [57];
- b) *TEG - Gaseous Waste Treatment System Design Manual Chapter 4 System and Component Design*, Reference [58]; and
- c) *TEG - Gaseous Waste Treatment System Design Manual Chapter 6 System Operation and Maintenance*, Reference [59].

The flow diagram of TEG [GWTS] is presented in F-23.7-2.

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23.7.2.1 Safety Functional Requirements

a) Reactivity Control

TEG [GWTS] does not contribute to this function.

b) Removal of Heat

TEG [GWTS] does not contribute to this function.

c) Confinement

TEG [GWTS] contributes to the confinement of radioactive material as follows:

- 1) Under accident condition, the containment isolation valves in TEG [GWTS] are closed automatically or manually upon relevant safety signals;
- 2) Under normal operation, TEG [GWTS] contains gaseous radioactive waste conveyed and minimises the radioactivity levels of discharges to the environment through treatment of the gaseous radioactive waste.

d) Extra supporting functions

TEG [GWTS] does not perform extra supporting functions.

23.7.2.2 Role of the System

Gaseous radioactive wastes are unavoidably generated during the reactor operation. The source of gaseous radioactive wastes mainly includes:

- a) Radionuclides in the reactor coolant that are generated by corrosion, activation and fission reaction (during fuel cladding failure or in case of tramp uranium, the fission products and actinides will be released to reactor coolant);
- b) Hydrogen, which is added through the RCV [CVCS] system to control the oxygen concentration of reactor coolant.

These radionuclides and added hydrogen are released to the gas phase in the reactor coolant containers and tanks when pressure reduces or there is fluid exchange. These become gaseous waste which is named primary gaseous effluent.

The composition of the primary gaseous effluent includes small amount of hydrogen, and radionuclides such as noble gases, iodine isotopes, carbon-14 and tritium. Therefore, the gaseous wastes need to be limited and treated by TEG [GWTS].

TEG [GWTS] contributes to the confinement of the gaseous waste and minimisation of radioactive waste discharges by performing the following operational functions:

- a) Flush the containers and tanks containing reactor coolant with nitrogen to avoid hydrogen accumulation in the gas space and limit the hydrogen/oxygen concentration in TEG [GWTS] and in flushed components to keep them under

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flammability limits;

- b) Prevent radioactive gases escaping from the connected components into the building atmosphere by maintaining a slight negative pressure in the flushing section;
- c) Collect and treat the excess gas arising from the connected components during the plant start-up, shut down or components flushing; and
- d) Treat the gaseous radioactive waste to reach a discharge management objective prior to discharging them into the environment.

23.7.2.3 System Description and Operation

23.7.2.3.1 System Description

To ensure optimal treatment of gaseous waste in TEG [GWTS], an optioneering of gaseous waste processing technique has been undertaken and are presented in *Optioneering Report for Gaseous Radioactive Waste Processing Technique*, Reference [60]. The potential options from worldwide OPEX have been identified and assessed against a set of assessment criteria considering the safety aspects and environment impacts as well as the technical feasibility, operational constraints/benefits and cost. For the purpose of GDA, the activated carbon delay bed processing technique is selected as the optimal treatment technique for TEG [GWTS].

Based on the operational functional requirements and selected processing technique for gaseous radioactive waste, the following design principles are implemented:

- a) The flushing gas flow rate provided by the TEG [GWTS] is designed to ensure the dilution requirements for the hydrogen and oxygen concentration that may be generated by the connected components, and to keep it below the explosion limit of 4% for hydrogen;
- b) The capacity of recombiner is designed to ensure the hydrogen and oxygen concentration in the flushing gas can be efficiently recombined. The hydrogen and oxygen concentration can be monitored, adjusted and controlled to avoid explosion. An alarm is triggered when the hydrogen/oxygen is higher than the pre-set value;
- c) The capacity of the delay unit is designed to treat the excess gas generated during normal operation conditions and to provide enough delay time for the radioactive noble gases. The volume and radioactivity level of the effluent can be measured before released;
- d) The whole system and component can be flushed with nitrogen;
- e) The components have high sealing property to reduce leakage; and
- f) The pipelines layout facilitates the flow of flushing gases and condensate water.

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TEG [GWTS] has seven sub-function units, which are presented below.

a) Gas Preparation Unit

The gas preparation unit provides qualified carrier gases for flushing. The gas preparation unit consists of a gas dryer, hydrogen/oxygen supply unit upstream of the recombiner, hydrogen/oxygen measurement circuit upstream and downstream the recombiner.

The recombiner has been sized to provide sufficient capacity to ensure the hydrogen and oxygen concentrations can be reduced to below the required concentration values. Considerations have notably been given to:

- 1) Minimisation of discharges, by providing sufficient capacity for the catalytic conversion of the hydrogen and oxygen to fulfil the system requirements;
- 2) Minimisation of explosion risk, by reducing the hydrogen and oxygen concentrations to below the required concentration values.

Detailed information and justification are presented in *Sizing Report of Recombiner in Gaseous Waste Treatment System*, Reference [61].

b) Gaseous Waste Compression Unit

The gaseous waste compression unit maintains the circulation of the gases in this system through compressed gases, and compresses the gas to the expected pressure. It mainly consists of two redundant compressors and sealing liquid supply circuits, the adjusting circuit of the compressors outlet pressure and flow, and pre-dryer of the compressed gases.

c) Gas Distribution Unit

The gas distribution unit draws out the hydrogen, oxygen and radioactive gas from the connected components by continuous flushing and maintains operation pressure of the connected component at slightly negative atmosphere to prevent gas escaping from the component. The gas distribution unit consists of the flushing pipeline in the BRX, BNX, BSX, and BFX.

d) Nitrogen Injection Unit

The nitrogen injection unit maintains the constant pressure in the flushing unit. The nitrogen injection unit consists of nitrogen injecting pipeline and valves.

e) Containment Isolation Unit

The containment isolation unit consists of four containment isolating valves installed on the flushing pipeline of the BRX. The unit provides containment isolating function for the flushing pipeline in the BRX.

f) Decay Unit

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The decay unit delays the radioactive nuclides such as xenon and krypton for a minimum of 40 days for xenon and 40 hours for krypton to give a sufficient decay time prior to transfer of the gaseous radioactive waste to Nuclear Auxiliary Building Ventilation System (DWN [NABVS]).

The decay unit consists of one silica gel dryer, three delay activated carbon beds, sampling lines, discharging line and monitoring components.

The activated charcoal delay beds have been sized to provide sufficient capacity to enable safe and optimised management of the targeted noble gases (krypton and xenon). Considerations have notably been given to:

- 1) Minimisation of discharges and secondary waste generation, by providing sufficient capacity for delaying the targeted noble gases (krypton and xenon) to achieve natural decay in the all normal operating conditions;
- 2) Minimisation of accumulation of the gaseous radioactive waste on-site, by optimisation of the configuration of the delay beds.

Detailed information and justification are presented in *Sizing Report of the Activated Charcoal Delay Beds*, Reference [62].

g) Heat Exchanger Chilled Water Supply Unit

The heat exchanger chilled water supply unit provides chilled water for the TEG [GWTS] heat exchangers.

23.7.2.3.2 Monitoring and Sampling of Gaseous Radioactive Waste

Monitoring and sampling in TEG [GWTS] is undertaken to ensure the safe and effective management of gaseous radioactive waste.

The operation of the delay beds in TEG [GWTS] are influenced by moisture, temperature, pressure and flow rate. As a result, the moisture upstream of the delay beds is continuously measured by two hygrometers to ensure the operation of activated charcoal is maintained under optimum conditions. The environment temperature is also continuously measured to keep the delay beds within optimal operation condition. Downstream of the delay beds, the operating pressure and flow rate is also continuously measured. The operating pressure of the delay beds can be increased according to the flow rate of the income gases to be treated to improve its treatment capacity.

One KRT [PRMS] monitor is positioned on the recirculation flushing line of the TEG [GWTS] to measure the radioactivity level entering the delay beds. An additional KRT [PRMS] monitor is positioned on the discharge line downstream the delay beds of the TEG [GWTS] to measure radioactivity level of gases discharged to DWN [NABVS]. If the radioactivity level reaches the pre-set threshold, an alarm is triggered to inform the operator to check the causes and adopt appropriate actions.

Sampling is also undertaken at the inlet and outlet of each delay beds to monitoring the

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adsorption efficiency of the activated charcoal.

23.7.2.3.3 Description of Main Equipment

a) Compressor

1) Waste gas compressors

The compressor unit consists of two compressors (2×100%) and maintains the constant pressure in the flushing unit. One compressor is in operation and the other is on standby.

2) Measurement gas compressors

Two sets of hydrogen and oxygen measurement cabinets (2×100%) are arranged upstream of the recombiner, one is in operation and the other is on standby. Three measurement gas compressors (3×50%) in parallel are arranged upstream the measurement cabinets, two of them provide a constant gas flow rate and pressure to a hydrogen and oxygen measurement cabinet in normal operation.

One set of hydrogen and oxygen measurement cabinet is arranged downstream of the recombiner. Two measurement gas compressors (2×50%) in parallel are arranged upstream of the measurement cabinet.

The measurement gas compressors are double-diaphragm and deliver gas from the main gas flow to the measurement gas dryer. The flow rate design of the measurement gas compressor meets the measurement requirements.

b) Heat Exchangers

Tube bundle heat exchangers with low leakage are used, which are made of stainless steel to limit corrosion.

The chilled water from DER [OCWS] is the cooling medium for heat exchangers.

1) Gas dryer

The gas dryer is a tube bundle heat exchanger. It is used to reduce the dew points of the gases upstream of the recombiner.

2) Gas cooler

The gas cooler is a tube bundle heat exchanger, it is used to cool the gas downstream the recombiner and condense the steam formed by the chemical reaction of hydrogen with oxygen.

3) Pre-dryer

The pre-dryer is a tube bundle heat exchanger. It is used to reduce the dew points of the gases downstream of the waste compression unit.

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c) Condensate collecting tank

The condensate collecting tank collects and stores the condensate formed within the pre-dryer.

d) Delay beds

The delay beds are vertical vessels filled with activated charcoal used for the decay of noble gases before discharge.

e) Recombiner

Recombiner is a vertical pressure vessel containing catalyst, and used for the recombination of hydrogen and oxygen.

Recombiner operates continuously to reduce the hydrogen and oxygen concentration, keeping the hydrogen and oxygen concentration lower than 4% (vol-. %) and 2% (vol-. %), respectively.

f) Hydrogen and oxygen measurement cabinets

The hydrogen and oxygen measurement cabinets upstream of the recombiner measure the concentrations of hydrogen and oxygen, to help adjusting the gases concentration to appropriate stoichiometric ratio based on the measurement results. The hydrogen and oxygen measurement cabinet downstream of the recombiner monitors the efficiency of oxygen and hydrogen recombination.

23.7.2.3.4 Description of System Interfaces

The interfaces between TEG [GWTS] and other systems relating to radioactive waste management are listed below:

a) Systems Generating Effluents

TEG [GWTS] collects the gaseous effluent and provides continuous flushing for the components of various systems, including RCP [RCS], RCV [CVCS], Nuclear Sampling System (REN [NSS]), REA [RBWMS], RPE [VDS] and TEP [CSTS].

b) Nuclear Auxiliary Building Ventilation System (DWN [NABVS])

DWN [NABVS] system treats, monitors and discharges to the environment the gaseous waste treated by TEG [GWTS].

c) RPE [VDS]

RPE [VDS] system collects liquid waste from TEG [GWTS] such as from the recombiner and the compressors, and collect the gaseous radioactive waste released from safety valves in TEG [GWTS].

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23.7.2.3.5 System Operation

a) Plant Normal Condition

TEG [GWTS] operates under normal operation conditions in the two following operational modes:

1) Steady-state operation mode

The following tanks and vessels are connected to TEG [GWTS] flushing section:

- Pressuriser relief tank of RCP [RCS];
- Volume control tank of RCV [CVCS];
- Boric acid storage tanks of REA [RBWMS];
- Coolant storage tanks of TEP [CVCS];
- Boric acid column of TEP [CVCS];
- Degasifier column of TEP [CVCS];
- Condensate collecting tank of TEP [CVCS];
- Primary effluents drain tanks of RPE [VDS] in the BRX, BSX, BFX and BNX; and
- Sample backfeed vessel of REN [NSS].

During steady-state operation, TEG [GWTS] and its user systems are continuously flushed with nitrogen in a quasi-closed circuit.

The flow rate of the flushing gas is adjustable. The concentration of hydrogen and oxygen in the flushing gas and the equipment to be flushed is kept lower than the hydrogen and oxygen explosion limit.

The compressor keeps the flushing gas recirculating to draw out the hydrogen and radioactive gases released from the connected equipment into TEG [GWTS]. Meanwhile, the waste gas compressor can draw the gases out from the low pressure sections and compress them to the designated pressure.

The moisture contained in the flushing gas is separated in the gas dryer and then drained to RPE [VDS].

In the recombiner, hydrogen recombines with oxygen into water (steam) under the catalytic action of noble metal catalyst. Hydrogen and oxygen concentration can be reduced to less than 0.3% (vol-%) and 0.1% (vol-%) after recombination.

The gas is cooled and the vapour is condensed in the gas cooler downstream

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of the recombiner.

The entire hydrogen and oxygen recombination unit is designed to reliably treat the gases from the connected systems in all the operation modes of the power plant, and adjust and control the gas compositions to ensure full reaction of the gases.

The hydrogen and oxygen injection control valves at the inlet of the hydrogen and oxygen measurement cabinets are interlocked. Only one kind of gas is allowed to be injected at one time to avoid the potential risk of explosive gases produced by the simultaneous injection of hydrogen and oxygen.

Waste gas compressors compress the incoming gas to required pressure, and discharge the gas through sealing liquid storage tanks.

The gas is routed from the sealing liquid storage tank to the pre-dryer. The gas is divided into the following three parts:

- The first part is used to flush the pressuriser relief tank and the reactor coolant drain tank;
- The second part is used to flush the volume control tank of RCV [CVCS]; and
- The third part is expanded via reducing station to a slightly positive pressure level to flush the rest of the systems.

All these flushing gases are returned into the negative pressure section of TEG [GWTS].

The steady-state operation mode is the main operation mode of TEG [GWTS]. In this mode, most of the gas is expanded through reducing station and flows back to TEG [GWTS] negative pressure section.

TEG [GWTS] works as a closed circuit in a steady-state operation mode, and the volume of gaseous radioactive waste discharged to the environment is reduced to a very low level that corresponds to the slight excess gas induced by small water movements in the connected systems during power operation.

2) Surge gas operation mode

When large amount of excess gas enters TEG [GWTS], it is switched to the surge gas operation mode automatically. The excess gas generation is caused by large water movements in the connected systems. For example:

- During reactor start-up, the increase of water volume which is caused by the thermal expansion of reactor coolant results in the change of the total gas space volume;

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- After reactor shutdown, the water level reduction of the RCP [RCS] results in the change of total gas space volume; and
- The flushing of the gas space of reactor pressure vessel.

The volume reduction of the gas space of the connected equipment results in the release of gas to TEG [GWTS], and the excessive gas is routed to the delay unit.

Two redundant reducing stations maintain a constant pressure in the delay unit. If a higher flow rate occurs at the reducing station for a set time, TEG [GWTS] can be automatically changed over from the 'steady-state operation mode' to 'surge gas operation mode'.

Surge gas operation mode is continued for a predetermined period of time to ensure the targeted decay duration for noble gases is achieved. When this time period is expired, the pressure reduction is manually initiated by the operator from the main control room.

The capacity of the delay beds is adapted to the higher flow rate during the surge gas operation mode. The radioactive noble gases are delayed regarding their dynamic adsorption coefficient for a sufficient decay in the delay beds.

b) Plant Accident Conditions

Not applicable.

23.7.2.4 Design Substantiation

23.7.2.4.1 Compliance with Safety Functional Requirements

a) Control of Reactivity

Not applicable.

b) Removal of Heat

Not applicable.

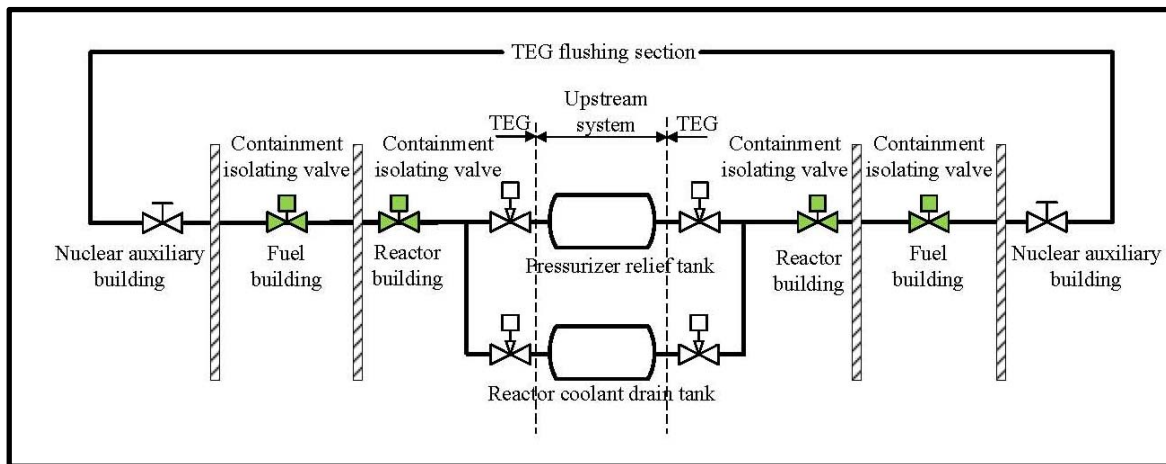
c) Confinement

Under normal conditions, TEG [GWTS] confines radioactive waste by the sealing of the mechanical boundaries. TEG [GWTS] collects and treats the gaseous radioactive waste and discharges the treated gaseous waste via the HVAC systems to minimise radioactive release to the environment. TEG [GWTS] ensures the flushing section under negative pressure to prevent the escapes of radioactive gases from the connected components into the building atmosphere. Measurement devices with alarms are provided on different flushing sub-sections to detect pressure changes, facilitating the detection and locating leakages or escapes of radioactive gases.

Under accident conditions, TEG [GWTS] containment isolation valves act as a third containment barrier at its containment penetration points. Four containment isolation valves are installed on the two flushing pipelines penetrating the containment as presented in F-23.7-3. In accident conditions, the containment isolation valves are closed automatically or manually when receiving a closing order from the reactor protection system to prevent the leakage of radioactive effluents.

d) Extra Supporting Functions

Not applicable.



F-23.7-3 Containment isolation of TEG [GWTS]

23.7.2.4.2 Compliance with Design Requirements

a) Safety Classification

By following the safety classification principles, the function classification of TEG [GWTS] is derived in T-23.7-1. Based on the contribution for accident mitigation, the safety classification of main components (including seismic categorisation) is derived in T-23.7-2.

T-23.7-1 System Function Classification

System Function	Function Category
Containment isolation	FC1
Flushing branch and the treatment section	FC3
Auxiliary media supply	NC

T-23.7-2 Classification of Main Components

Component	Safety Classification	Design Provision Category	Design Provision Class	Seismic Category
Containment isolation valves	F-SC1	DPA	B-SC2	SSE1
Flushing branch inside the BRX, BSX and BFX	F-SC3	DPL	B-SC3	SSE2
Flushing branch of TEP [CSTS] and REA [RBWMS] inside BNX and the treatment components	F-SC3	DPL	B-SC3	NO
Auxiliary media supplies of nitrogen, oxygen, chilled water and compressed air	NC	NC	NC	NO

b) Engineering Design Requirements

1) SFC and redundancy

To prevent the single failure, the flushing pipeline penetrating the containment is equipped with two containment isolation valves, one inside the containment and the other outside.

2) Independence

Two redundant containment isolation valves installed in the same line are physically separated by the installation location, one inside and the other outside the containment.

3) Diversity

The containment isolation valves in TEG [GWTS] comply with the diversity requirement. The internal and external containment isolation valves in the same pipeline penetrates the containment are designed with mechanical

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component diversification.

4) Fail-safe

The fail-safe concept is considered in the TEG [GWTS] design process. According to the fail-safe analysis, the ‘fail-safe’ design do not meet the safety consideration for containment isolation valves, therefore other measures such as redundancy are used to improve the safety of the power plant and avoid potential safety concerns or risk that may be introduced by the ‘fail-safe’ design on the power plant. Fail-safe is adopted in the design of the pneumatic valves in the hydrogen and oxygen supply pipes prevent excessive injection of hydrogen and oxygen and in the inlet, outlet and bypass pipes of the recombiner to prevent the hydrogen and oxygen explosion.

5) Human factors

Human factors are integrated in the design of the TEG [GWTS]. Control functional requirements have been developed for allocating the system functions to manual activity and automatic control appropriately and providing necessary information to the operator.

6) Equipment qualification

The design of the TEG [GWTS] complies with the equipment qualification requirements. The containment isolation valves require environmental qualification as they perform FC1 safety function. The components with seismic classification require seismic qualification, including the containment isolation valves, the motor-driven valves located inside the BRX and BFX, the motor-operated and pneumatic valves in the hydrogen injection pipe.

7) Ageing and degradation

Ageing and degradation are considered in the design of TEG [GWTS] by applying the design measures described in Sub-chapter 23.2.5.

8) EMIT

– Surveillance

The surveillance of the TEG [GWTS] is performed from the Main Control Room where the tank level, the flow rate, the pressure, the temperature, the state of equipment and the integrated alarm signal for system operation are displayed to provide necessary information to the operator.

– Maintenance

TEG [GWTS] operates continuously in normal operation. For the part designed with a double train, such as waste gas compressors or reducing stations, the standby train can be out of service during operation of TEG

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[GWTS].

The preventive maintenance of other components will be performed according to the equipment operating and maintenance manual at the nuclear site licensing phase. The layout design takes into account the accessibility of components for maintenance activities.

– Inspection

The heat exchangers, recombiner, condensate collecting tank and important valves in the TEG [GWTS] require pre-service inspection.

– Periodic tests

Following the preliminary requirements of periodic tests for radioactive waste management presented in Reference [41], the containment isolation valves in TEG [GWTS] need periodic tests to verify the manoeuvrability and tightness. Other components do not require specific separate periodic test as their functions can be verified by appropriate operating routine checks and/or preventative maintenance with an appropriate frequency.

c) Protection Design against Internal and External Hazards

The containment isolation valves in the TEG [GWTS] are protected from internal hazards by physical separation. For external hazards, the containment isolation valves and the flushing pipelines go through the BRX, BFX and BSX and the hydrogen supply pipelines of TEG [GWTS] are required to be protected from the earthquakes.

d) Commissioning

By following the commissioning test requirements presented in Reference [9], TEG [GWTS] requires commissioning tests to verify its functionality, including tests of system flushing, simulation measurement and control channel, logic control channel, valves, water tank, heat exchanger, waste gas compressors, nitrogen injection station, hydrogen/oxygen measuring circuits, gas flow rate, pressure measurement, heater, silica gel drier, nitrogen flushing, recombiner and efficiency of delay unit.

e) Decommissioning

Requirement for facilitating decommissioning is considered in the design of TEG [GWTS] by applying the design principles that are in accordance with the relevant requirements described in Sub-chapter 23.2.5, including reducing residual radioactive sources through adequate emptying provisions, decontamination provisions, equipment structure design, layout of equipment and pipelines, etc., so as to facilitate decommissioning operations and reduce the accumulation of radioactive waste during decommissioning.

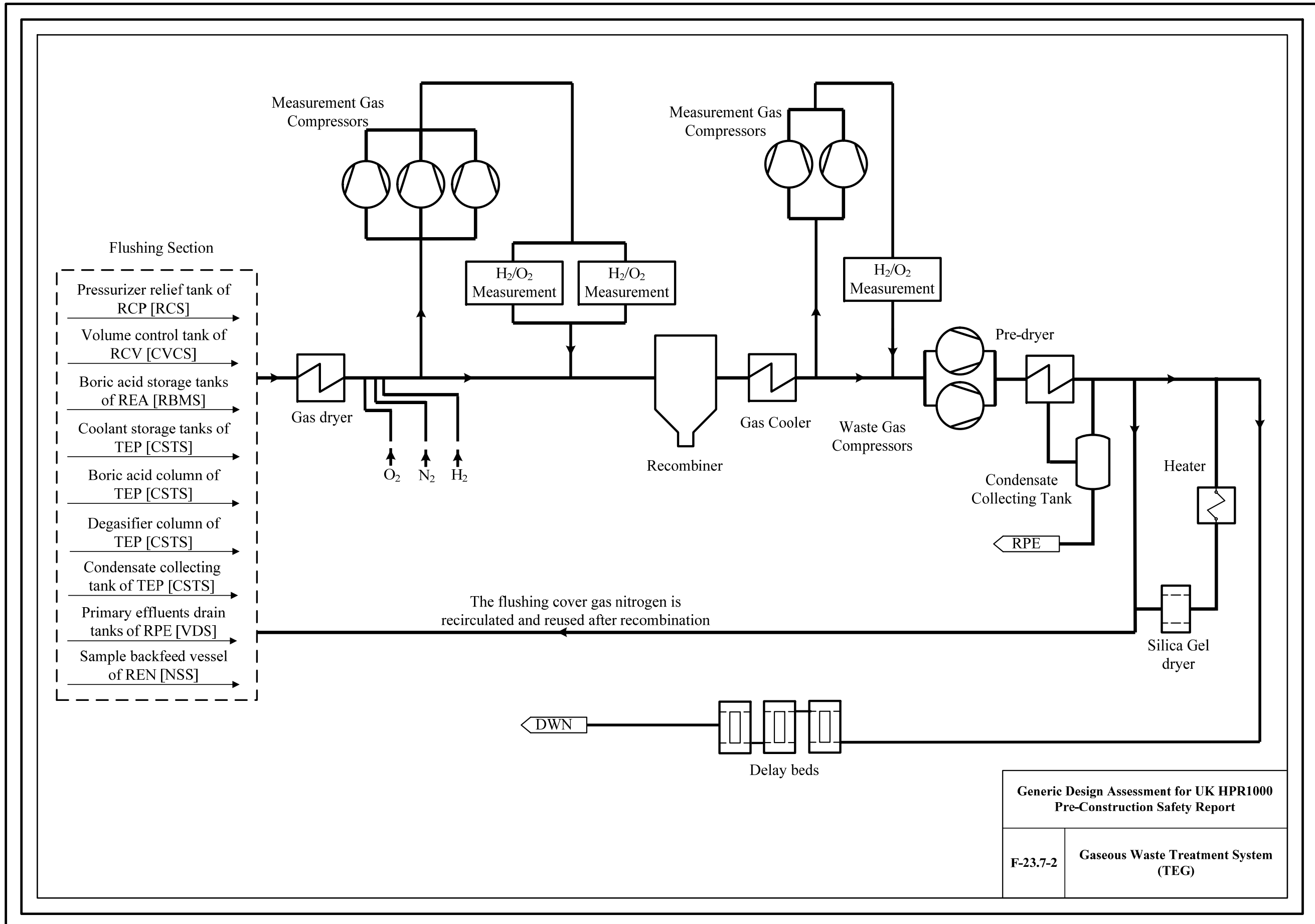
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f) Material Selection

The components, valves and pipes that are in contact with radioactive media are made of stainless steel in order to limit corrosion.

g) Conventional Health and Safety

Conventional health and safety is considered in the design of TEG [GWTS] by assessing the relevant risks and corresponding design mitigations and recording relevant information in the conventional health and safety design risk register, as presented in Sub-chapter 23.2.5.



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F-23.7-2 Gaseous Waste Treatment System (TEG)

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23.8 Solid Radioactive Waste Management

23.8.1 Waste Arising

The solid waste generated from the operation of the UK HPR1000 is generally grouped as three types:

- a) Waste generated from treating radioactive fluids such as coolant, liquid waste and gaseous waste;
- b) Waste generated from maintenance; and
- c) Waste from core components.

NALW requires export from site to off-site facility, if appropriate, and therefore is managed alongside solid radioactive waste.

The OPEX from the PWR fleet in China is used for quantification of the radioactive waste generated from the operation of the UK HPR1000. When comparing to legacy waste that exist in the UK, Reference [63], no novel waste is planned to be generated in the UK HPR1000, which would challenge the waste disposability case. The solid waste and NALW anticipated to be generated from the operation of the UK HPR1000 are presented in T-23.8-1, and detailed in the *Waste Inventory for Operational Solid Radioactive Waste*, Reference [64].

T-23.8-1 Solid Waste and NALW Generated during the Operation

No.	Title	Description	Category
1	Spent resins	Arising from the TEU [LWTS], TEP [CSTS], PTR [FPCTS], RCV [CVCS] demineralisers, and APG [SGBS] demineralisers under steam generator tubes rupture condition.	ILW
2	Low activity spent resins	Arising from APG [SGBS] demineralisers under normal operational condition.	LLW
3	Concentrates	Arising from TEU [LWTS] evaporators.	ILW/LLW
4	Spent filter cartridges	Arising from filter changing in TEU [LWTS], TEP [CSTS], PTR [FPCTS], RCV [CVCS], RPE [VDS] and APG [SGBS].	ILW/LLW
5	Dry Active Waste	Contaminated personal protection equipment, monitoring swabs, plastic, clothing, contaminated tools, waste charcoal generated	ILW/LLW

No.	Title	Description	Category
		from iodine absorbers in HVAC systems, etc.	
6	Sludge	Arising from the sumps and tanks in the liquid radioactive waste management systems (e.g. RPE [VDS] and TEU [LWTS]).	ILW/LLW
7	Oil	Arising during normal operations, notably from maintenance of pumps and hydraulic equipment.	LLW/VLLW
8	Organic solvent	Arising during normal operations, notably from decontamination of Reactor Pressure Vessel (RPV) bolts.	LLW/VLLW
9	Ventilation filter cartridges	Arising from the ventilation systems located in the BNX, BFX, BSX, BRX and BWX.	LLW
10	NFCCs	ICIAs arising from reactor core, used for measuring water level, temperature and neutron flux in the reactor core.	HLW/ILW*
		RCCAs and SCCAs activated in the reactor core.	HLW/ILW

* The upper part of each ICIA is categorised as LLW after being cut.

23.8.2 Segregation and Characterisation

Characterisation and segregation are key to facilitate safe and effective management of radioactive waste and are necessary during different waste management steps.

Characterisation ensures the physical, chemical and radiological properties of waste streams are assessed and recorded to select optimal management routes. According to their radiological and other physical and chemical properties, radioactive waste and non-radioactive waste are segregated at source to reduce the quantity of solid radioactive waste, and determine the category of radioactive waste. The flow diagram of TES [SWTS] (F-23.8-1) presents the segregation of solid waste and more information on characterisation and segregation of solid radioactive waste are presented in Sub-chapter 23.8.3.3.

The design of the UK HPR1000 has provided a range of facilities and equipment to

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allow the future operator to undertake the characterisation and segregation of solid waste and NALW, so as to effectively segregate waste and identify the suitable waste disposal routes at the nuclear site licensing phase. The details of sampling, monitoring and measurement for solid waste and NALW in the UK HPR1000 are presented in PCER *Chapter 5 Approach to Sampling & Monitoring* (Sub-chapter 5.5), Reference [65].

23.8.3 Solid Waste Treatment System (TES [SWTS])

Design information on TES [SWTS] is described hereafter and details are presented in the SDM, including:

- a) *TES - Solid Waste Treatment System Design Manual Chapter 3 System Functions and Design Bases*, Reference [66];
- b) *TES - Solid Waste Treatment System Design Manual Chapter 4 System and Component Design*, Reference [67]; and
- c) *TES - Solid Waste Treatment System Design Manual Chapter 6 System Operation and Maintenance*, Reference [68].

The flow diagram of TES [SWTS] is presented in F-23.8-1.

23.8.3.1 Safety Functional Requirements

- a) Reactivity Control

TES [SWTS] does not contribute to this function.

- b) Removal of heat

TES [SWTS] does not contribute to this function.

- c) Confinement

TES [SWTS] contributes to the confinement of radioactive material in normal operation conditions, by containing the solid radioactive waste conveyed and minimising the radioactive waste accumulation on-site through appropriate provisions for characterisation and segregation, treatment, conditioning, packaging and storage of radioactive solid waste and NALW to enable their safe and optimised disposal off-site at the earliest opportunity.

- d) Extra supporting functions

TES [SWTS] does not perform extra supporting functions.

23.8.3.2 Role of the System

In the UK, radioactive waste is classified as HLW, ILW, LLW and VLLW according to the type and quantity of radioactivity they contain and how much heat the radionuclides decay produces, Reference [17].

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TES [SWTS] serves to collect, characterise and segregate, treat, condition, package and store various types of solid radioactive waste and NALW generated in normal operation and contributes to confinement and minimisation of radioactive waste by performing the following operational functions:

- a) Collection and segregation of solid radioactive waste and NALW as different categories to facilitate the subsequent management;
- b) Temporary storage of the waste in tanks or containers for decay or awaiting processing if and when required;
- c) Processing of operational solid radioactive waste and NALW using appropriate techniques;
- d) Buffer storage of LLW packages before transfer for off-site processing and/or disposal;
- e) Interim storage of waste packages in a passively safe condition for specific time until a disposal facility is available; and
- f) Measurement and recording of waste packages characteristics to facilitate transportation and disposal.

Based on the operational function requirements, the following design principles of TES [SWTS] are implemented:

- a) The design of TES [SWTS] complies with the principles of minimisation of waste generation and contamination, and facilitate future decommissioning;
- b) The appropriate capacity of TES [SWTS] is designed to collect, segregate, temporarily store and process solid radioactive waste generated in normal operation to avoid accumulation of raw waste;
- c) TES [SWTS] is designed to immobilise radionuclides and other hazardous material in radioactive waste to reduce the risk to workers, the public and the environment;
- d) The waste packages produced by TES [SWTS] meet the requirements of transportation and off-site treatment/disposal facilities;
- e) The ILW Interim Storage Facility (BQZ) is designed in accordance with good engineering practice to provide appropriate capacity and passively safe condition for waste storage;
- f) Appropriate shielding and containment features are provided to reduce the dose to workers and the public;
- g) A remote control system is provided to reduce the field operation especially in high dose rate areas;
- h) The piping is designed to facilitate the flow of fluid, so as to minimise the blockage

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and retention of radioactive waste (e.g. spent resins);

- i) The pressurised component and pipelines are mainly connected by weld to minimise leaks; and
- j) TES [SWTS] is designed to prevent radioactive liquid and gaseous waste potentially generated during processing of solid waste from being directly released to the environment.

23.8.3.3 System Description and Operation

23.8.3.3.1 System Description and Operation

The techniques for solid radioactive waste and NALW management have been optimised in the generic design of the UK HPR1000 through optioneering studies, considering reducing relevant risks to ALARP and minimising impacts on the public and the environment through the use of BAT, including:

- a) Optioneering for the management process of pent resin, concentrate, spent filter cartridge, sludge, DAW, NALW and ventilation filter cartridge. Details are presented in *Optioneering Report for Operational Solid Waste Processing Techniques*, Reference [69];
- b) Optioneering for the management strategy of spent NFCCs. Details are presented in *Management Proposal of Waste Non-Fuel Core Components*, Reference [33]; and
- c) Optioneering for the selection of container for ILW disposal. Details are presented in *Selection of Waste Containers for Disposal of ILW*, Reference [70].

The management strategy as well as the treatment/conditioning operations for the solid radioactive waste and NALW produced during operation is presented hereafter.

a) Spent Resin

Spent resins are generated from demineralisers that are used to purify reactor coolant in the RCV [CVCS], PTR [FPCTS] and TEP [CSTS], treat liquid waste in the TEU [LWTS] and purify the blow-down of the steam generators in the APG [SGBS]. The resins are to be replaced if efficiency drops below defined threshold (operator specific), pressure differential exceeds the set threshold (manufacturer specific) or resins service lifetime is exceeded (manufacturer specific). The generated spent resins are segregated according to the sources and characteristics to facilitate subsequent processing: ILW spent resins from RCV [CVCS], PTR [FPCTS], TEP [CSTS] and TEU [LWTS] demineralisers are collected and managed separately from LLW spent resins from APG [SGBS] demineralisers. Spent resins generated from APG [SGBS] demineralisers might be ILW under special conditions (such as in case of Steam Generator Tube Rupture (SGTR)). In such circumstances they are managed together with the other ILW spent resins

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generated by the other systems.

1) ILW spent resin

Four tanks are used to receive and store the ILW spent resins, including two spent resin tanks located in the BNX and two spent resin storage tanks in the BWX. Spent resins from RCV [CVCS], PTR [FPCTS] and TEP [CSTS] demineralisers (in the BNX) are flushed by the spent resin flush pump into spent resin storage tanks located in the BNX, where these spent resins are stored for a period of time and then are transferred by pump to the spent resin storage tanks located in the BWX for further treatment. Spent resins from TEU [LWTS] demineralisers (in the BWX) are flushed by the spent resin transfer pump into spent resin storage tanks located in the BWX for storage and treatment.

Before conditioning, the spent resins in the spent resin storage tank are characterised by sampling via the sampler equipped on the recirculation line of the spent resin storage tank and sending samples for laboratory analysis to obtain their properties (such as radioactivity content, chemicals concentration, etc.). After characterisation, the spent resins are transferred by the spent resin metering pump into the spent resin metering tank where they are dewatered by dewatering pump to measure the waste loading volume. The measured resins are discharged by gravity or water flushing into 500 litre robust shielded drum (e.g. Mosaik container) where the mobile de-watering device is used to reduce the 'free water' content from the resins. De-watering is performed in two steps to meet the target of less than 1% by volume of 'free water' in the spent resin package.

The produced ILW spent resins packages are transferred to the BQZ for interim storage pending availability of the GDF.

2) LLW spent resin

LLW spent resins generated from APG [SGBS] demineralisers (located in the BNX) are flushed into the low activity spent resin separation tank located in the BNX for dewatering. The spent resins are characterised by sampling from the low activity spent resin separation tank and sending samples for laboratory analysis to obtain their properties (such as radioactivity content, chemicals concentration, etc.). After dewatering, the spent resins are loaded into the 210 litre drum via the vacuum suction device.

The produced LLW spent resins packages are transferred to the BQS for buffer storage (short time) prior to transfer off-site to the incineration facility.

Under special conditions (such as in case of SGTR), the spent resins from the APG [SGBS] demineralisers are anticipated to be ILW and are, in such cases,

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flushed into the spent resin storage tanks in the BNX and treated as ILW spent resins generated by the other systems.

The spent resin storage tanks have been sized to provide sufficient capacity to enable safe, optimised and flexible management of all the spent resins anticipated to be produced by the UK HPR1000 during normal operation, including expected events/anticipated occurrences. Considerations have notably been given to:

- 1) Minimisation of discharges and secondary waste generation, by providing sufficient capacity for segregation, storage and appropriate treatment;
- 2) Minimisation of accumulation of the spent resins on-site, by not oversizing tanks.

Detailed information and justification are presented in *Sizing Report of Main Equipment in Solid Waste Treatment System*, Reference [71].

b) Concentrates

Concentrates are generated from the TEU [LWTS] evaporator that is used to treat liquid waste. The concentrates are characterised by sampling them from the TEU [LWTS] evaporator and sending samples for laboratory analysis to obtain their properties (such as radioactivity content, the boron concentration, etc.). After characterisation, when appropriate, the concentrates are discharged into the TEU [LWTS] concentrates tanks.

When the operator decides to condition/package the concentrates, they are transferred to the metering tank for volume measurement and the appropriate volume is discharged into the 210 litre drum. The 210 litre drum with concentrates is transferred by rollers to the mixing station to be filled with lime. Using an in-drum mixer, the concentrates and lime are mixed sufficiently to allow the lime to react with the boric acid. The cement is then added to immobilise the waste. The waste package is firstly sealed under the pneumatic covers for initial cure and then the cement grouting cap is added. Finally the package is sealed with lid and transferred to the relevant on-site storage facility.

Produced LLW concentrates packages are transferred to the BQS for short term storage prior to disposal off-site. Waste packages that are regarded as ILW/LLW boundary waste are transferred to the BQZ for decay storage and are transported to off-site disposal facility after they have been confirmed to have decayed to LLW.

c) Spent Filter Cartridge

Spent filter cartridges are generated from filters that are used to purify water and/or treat liquid waste in the TEP [CSTS], PTR [FPCTS], RCV [CVCS], RPE [VDS], APG [SGBS] and TEU [LWTS]. These spent filter cartridges are segregated into ILW and LLW according to their characteristics to facilitate subsequent processing.

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When the pressure differential between the inlet and outlet of the filters reaches a pre-determined value or the surface dose rate on filters reaches the set limit, the filter cartridges are to be replaced. A spent filter cartridge changing machine located in the BNX is used to replace the spent filter cartridges for the RCV [CVCS], PTR [FPCTS], TEP [CSTS] and RPE [VDS] filters (in the BNX) with new ones automatically. Another spent filter cartridge replacement and transfer device located in the BWX is used to remove the spent filter cartridges for the TEU [LWTS] filters. The two equipment are designed to provide shielding and remote control to reduce the dose to operators. When a filter cartridge is lifted out, it is characterised through measuring its surface dose rate to enable its segregation into ILW or LLW and facilitate the subsequent management.

The ILW spent filter cartridge is temporarily stored in BWX for batch processing and then retrieved into a 3 cubic metre box and immobilised with cement grout. The temporary storage area for spent filter cartridges is provided with sufficient capacity to store the anticipated annual waste volume of one unit. This approach allows for different dose rate cartridges to be loaded into one box and reduces the risk of producing waste packages out of specification. LLW filter cartridge is packaged in 210 litre drum.

The produced ILW spent filter cartridges packages are transferred to the BQZ for interim storage pending availability of the GDF. The produced LLW spent filter cartridges packages are transferred to the BQS for buffer store before dispatch to off-site treatment facility.

d) DAW

The DAW is characterised and collected into different colour bags at source based on the contamination level, and therefore the active waste and non-active waste are segregated to reduce the volume of DAW. The various types of DAW are presented in T-23.8-1.

Following characterisation and segregation at source, the DAW is transferred to the Waste Auxiliary Building (BQS) for further segregation to facilitate subsequent management. The DAW is then segregated into metal waste, combustible waste, non-combustible and compactible waste, non-combustible and non-compactible waste for further management ensuring the best use of off-site infrastructures, including metal melting, incineration, super-compaction and disposal services.

The DAW is dried firstly in the BQS if it contains free liquid. The drums are then transferred to the sorting box for further sorting. Size reduction is carried out for large size waste before packaging. After segregation, different types of the DAW are packaged into different containers as follows:

- 1) The metal waste is loaded into metallic box (e.g. Berglof box);

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- 2) The combustible waste is loaded into solid 210 litre drums;
- 3) The non-combustible and compactible waste is loaded into super-compactible 210 litre drums;
- 4) The non-combustible and non-compactible waste (such as contaminated concrete) is loaded into 210 litre drums and then immobilised with cement grout; and
- 5) The DAW that is identified as ILW/LLW boundary waste is packaged into 210 litre drum with shielding cask for subsequent handling, if necessary, and then the drum is placed into stillage for decay storage in the BQZ. After it has been confirmed to have decayed to LLW, it is retrieved and sent to BQS for segregation to facilitate off-site processing.

The produced LLW DAW packages are buffer stored in the BQS before dispatch to off-site infrastructures for treatment or disposal.

e) Sludge

The sludge is collected, segregated and characterised by taking samples at the generation point and before conditioning/packaging and sending samples for laboratory analysis to obtain their properties. After segregation and characterisation, the sludge is immobilised in 210 litre drum by mixing with cement.

Produced LLW sludge packages are transferred to the BQS prior to disposal off-site. Waste packages that are regarded as ILW/LLW boundary waste are transferred to the BQZ for decay storage and are transported to off-site disposal facility when they have been confirmed to have decayed to LLW.

f) NALW

The NALW, i.e. oil and solvent generated from maintenance and decontamination activities, is collected, segregated and characterised by taking samples at the generation point and before packaging and sending samples for laboratory analysis to obtain their properties. Oil and solvent are packaged in 210 litre drums. The filled drums are sealed and then stored in the buffer store area in the BQS prior to transfer off-site to the incineration facility.

g) Ventilation Filter Cartridge

The ventilation filter cartridges are generated from air filters that are used to treat gaseous waste in the HVAC systems. When removed, the spent ventilation filter cartridges are characterised by dose rate measurement. Then, they are packaged in bags (or in 210 litre drums) and transferred to the BQS for buffer store prior to transfer to off-site infrastructures for super-compaction.

h) NFCC

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Spent NFCC consists typically of activated metal components used inside the nuclear reactor core that have been subject to irradiation or exposure to intense neutron flux, and includes spent ICIA, RCCA and SCCA.

1) ICIA

When removed from the Reactor Pressure Vessel (RPV), the spent ICIAs are expected to be HLW or ILW (when considered as a whole piece) regarding their total radioactivity level and decay heat. Indeed, the degree of activation of ICIA is variable, dependent on the position in the reactor core. To optimise the use of UK disposal and treatment facilities, the upper parts that are expected to be LLW are segregated from the rest of the ICIA by cutting from the ICIA manually, using shears, and are then treated as LLW DAW (see DAW). The remaining parts that are expected to be HLW or ILW are extracted from the RPV and bundled up by a winding machine. The winding machine containing the bundles of ICIA is then lifted by the crane and unloaded into a 500 litre robust shielded drum. The winding machine provides sufficient shielding to reduce the dose to operators. The 500 litre robust shielded drum provides sufficient shielding to allow the waste to be transferred out of the BRX to on-site interim storage facility.

The produced ILW ICIA packages are transferred to the BQZ for interim storage prior to final disposal at GDF. The produced HLW ICIA packages are transferred to the Spent Fuel Interim Storage Facility (BQF) for a decay storage period and are transferred to the BQZ when they have been confirmed to have decay to ILW, for interim storage prior to final disposal at GDF.

2) RCCA and SCCA

During the refuelling operation, the RCCAs/SCCAs inserted in the fuel assemblies are transferred to the SFP together with the fuel assemblies. The RCCAs/SCCAs that have reached their service lifetime are rearranged, as necessary, into the target spent fuel assemblies and stored together with spent fuel assemblies in the SFP for a given period time. The information on the refuelling operation is presented in PCSR Sub-chapters 28.2.1 and 28.4. The safety assessment relevant to co-storage of the RCCAs and SCCAs with spent fuel in the SFP is presented in PCSR Sub-chapter 28.6.

After co-storage with the spent fuel in the SFP, the RCCAs/SCCAs are packaged together with the spent fuel and then transferred to the BQF for interim storage prior to disposal at GDF. Detailed information is presented in PCSR Sub-chapter 29.6.

23.8.3.3.2 Description of Main Equipment

The main equipment of TES [SWTS] is arranged in four buildings: BNX, BWX, BQS

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and BQZ.

a) Tanks

1) ILW spent resin tank

Tanks that are used to receive and store spent resins are made of stainless steel.

Two spent resin storage tanks are located in the BNX to receive the spent resins generated from the RCV [CVCS], PTR [FPCTS], TEP [CSTS] and APG [SGBS] (under special condition for the later, e.g. SGTR) demineralisers, and two spent resin storage tanks are located in the BWX to receive and temporarily store the spent resins transferred from spent resin storage tanks in the BNX and the spent resins from the TEU [LWTS] demineralisers.

The spent resin storage tanks are equipped with resin inlet and outlet nozzles, level measuring nozzle, overflow nozzles, as well as pipelines to provide circulating water or water loosening the spent resins.

A spent resin metering tank, also made of stainless steel, is located in the BWX. This tank is designed to dewater and measure the quantity of the resins to be treated and transfer the measured spent resin into waste containers.

2) LLW spent resin tank

A low activity resin separation tank is located in the BNX to receive and temporarily store the spent resins with low activity generated from APG [SGBS]. The bottom of the tank is equipped with a sectional area size sieve for dewatering the resins.

b) Spent Resin Pump

The spent resin flushing pump, a centrifugal pump, is used to flush the spent resins from the RCV [CVCS], PTR [FPCTS] and TEP [CSTS] demineralisers into the BNX spent resin storage tanks and transfer the spent resins between these two tanks.

The spent resin deliver pump, a screw pump, is used to deliver the spent resins from the BNX spent resin storage tank to the BWX spent resin storage tank.

The spent resin transfer pump, a centrifugal pump, is used to flush the spent resins from the TEU [LWTS] demineraliser into the BWX spent resin storage tank.

The spent resin metering pump is used to transfer the spent resins from BWX spent resin storage tank to spent resin metering tank and also for the recirculation of the spent resins in the BWX spent resin storage tank.

The resin de-watering pumps are used to de-water the spent resins for measurement into the spent resin metering tank and to pump the water to discharge the measured resins from the spent resin metering tank to 500 litre robust shielded drum.

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c) Vacuum Suction Device

The vacuum suction device, a mobile device, is used to load the LLW spent resins from the low activity spent resin separation tank into the 210 litre drum. It is composed of suction pipe, pre-separator, industrial vacuum device, handcart and other components. When it works, the vacuum device produces negative pressure and connects with various pipe sections and the pre-separator. As such, the suction device draws the resins from the separation tank and loads them into the drum.

d) Resin Sampler

The resin sampler is used to sample the spent resin automatically by a remote operator station. It is composed of a sampler, sample bottle shielding cask, mobile cart, sampler enclosure, control panel and other connection valves and pipes. The sampler is a 'T' type sampler, which is installed on the recirculation line of the BWX spent resin storage tank.

e) Spent Filter Cartridge Changing Machine

The spent filter cartridge changing machine is located in the BNX. It is designed with appropriate shielding and remote control to reduce doses to workers. This machine is installed with two dose rate measurement holding devices which allow the measurement of dose rate of the spent filter cartridges and facilitate their segregation and subsequent treatment.

f) Spent Filter Replacement and Transfer Device

The spent filter replacement and transfer device is located in the BWX. It is used to change the spent filter cartridges in TEU [LWTS] and load them into drums. This device provides complete enclosure of the spent filter cartridge in a bell shaped design comprising shielding material and filter cartridge handling equipment, to reduce doses to workers. Dose monitoring is conducted by long pole instrument.

A mobile bottom door is set on the bottom of this device in order to facilitate to grab and release the filter cartridge. The device can only change and transfer one set of spent filter cartridge once and can be adapted to all filters in TEU [LWTS].

g) Encapsulation Facility

The encapsulation facility is located in the BWX, and is designed to facilitate immobilising the concentrate, sludge and ILW filter cartridges in the waste container.

1) Filter cartridge retrieval device

The filter cartridge retrieval device is equipped with specific grab and used to retrieve the cartridge from the shielding cask to the storage area and retrieve the cartridge from the storage area into the disposal container automatically.

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2) Concentrate metering tank

The concentrates metering tank is manufactured with stainless steel. It is located in the BWX.

This tank is designed to measure the volume of concentrates from TEU [LWTS] to be transferred to waste containers for cement in-drum mixing.

3) In-drum mixer

The in-drum mixer is composed of mixing motor and other components. It is used to connect with the sacrificial paddle within the drum and mix the concentrates or sludge with lime, cement and additives in drum to form a homogeneous product.

4) Mobile grouting device

The mobile grouting device is used to immobilise the ILW spent filter cartridges with cement grout and provide cement grouting caps in the encapsulated concentrate and sludge waste packages. It is a mobile continuous mixer, and consists of a cement hopper, mixer, a control cabinet, hoses and couplings. The cement hopper is equipped with a level switch and a vibrator is used to load dry cement powder. The grout produced by the mixer is transferred through hoses to the waste containers placed in the encapsulation facility.

Auxiliary equipment (such as cranes, rollers, transfer trolley, cement delivery devices, additive metering tank, lidding robotic manipulator and shielded doors) is also provided to facilitate the encapsulation of the waste.

The encapsulation facility is remotely operated to protect workers. Shielded doors are provided to reduce the dose rate in the operation area, whilst the ventilation maintains a slight negative pressure to prevent radioactive materials from being released into the environment.

h) Drum Detection Device

The drum detection device located in BWX is composed of radiation detector, support, rotating mechanism, measurement control cabinet and other components. It is mainly used to detect and record the activity, surface dose rate and surface contamination of the waste packages.

i) Sorting Box

The sorting box is located in the BQS and is used to separate the DAW into different drums according to their waste properties. It consists of a lifting and tilting device, a sorting box body, a hydraulic shear, a waste transfer belt, a hydraulic power unit and an electrical & control equipment. The lifting and tilting device is designed to feed the waste from the drums into the sorting box. The hydraulic shear is designed

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to cut bulky waste into smaller pieces. The lifting and tilting device and hydraulic shear are driven by hydraulic power.

Three sorting positions and one dumping position are provided for the sorting box, allowing four workers to work simultaneously.

j) Pre-compactor

The pre-compactor is located in the BQS and used to compress the compactable waste in drum before transportation off-site. It is composed of the frame, press head, press base plate, the hydraulic power unit and the electrical & control equipment. The compaction force is supplied by hydraulic power unit.

k) Roller Conveyors

The roller conveyors are located in the BQS. They are mainly used to convey the drums between the function stations. The function stations include the sorting station and grouting station.

l) Grouting Device

The grouting device is located in the BQS and used to immobilise the waste in the drums with cement grout. It is mainly composed of an additive tank, two cement silos, cement dosing screw, cement mixing device and the electrical & control equipment.

m) Others

For LLW waste package buffer store, the forklift and manual control crane are used to handle the packages.

For ILW waste package interim storage, the main equipment is the waste package lifting software-controlled crane, which is operated remotely in a control room. It is composed of beam, rail, hoister, cable and the electrical & control equipment. The crane can lift and transfer the waste package between pre-set positions automatically.

23.8.3.3.3 Description of System Interfaces

The interfaces between TES [SWTS] and other systems relating to radioactive waste management are listed below:

a) Systems Generating Waste

TES [SWTS] flushes spent resins and/or replace spent filter cartridges for systems those using demineralisers and/or filters to purify water, including RCV [CVCS], PTR [FPCTS], TEP [CSTS], RPE [VDS], TEU [LWTS] and APG [SGBS]. TES [SWTS] also receives the concentrate generated from the evaporator in TEU [LWTS].

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b) RPE [VDS] and SRE [SRS]

RPE [VDS] provides vent and drain routes for collecting the effluent from TES [SWTS] in the BNX.

SRE [SRS] provides vent and drain routes for collecting the effluent from TES [SWTS] in the BWX.

c) DWQ [WBVS]

DWQ [WBVS] provides a vent route for the air from the tanks and cement encapsulation facility in the BWX.

23.8.3.4 Design Substantiation

23.8.3.4.1 Compliance with Safety Functional Requirements

a) Control of Reactivity

Not applicable.

b) Removal of Heat

Not applicable.

c) Confinement

During normal operation, TES [SWTS] retains radioactive waste and minimise the release of radioactivity. The confinement of radioactive waste is ensured by the sealing of the mechanical boundaries and production and storage of passive safety waste packages. The equipment, pipes and valves of TES [SWTS] are made of stainless steel or other corrosion-resistant materials.

The civil engineering structure of the building, where TES [SWTS] is located, acts as a barrier to protect the environment. The spent resins storage tanks are located in retention pit which is capable of containing all the waste produced in case of the tanks break and provided with stainless steel liner to ensure confinement and avoid concrete contamination.

Tanks are connected to HVAC systems to prevent escapes of gaseous waste, and are provided with measurement device to detect level changes and facilitate the detection and quantification of leakages. Leaks and tank overflows are transferred to RPE [VDS] or SRE [SRS] to prevent the spread of contamination.

Shielding measures and remote control for operation of high risk tasks are provided to reduce the exposure of workers and the public to radiation.

d) Extra Supporting Functions

TES [SWTS] does not contribute to extra supporting functions.

23.8.3.4.2 Compliance with Design Requirements

a) Safety Classification

By following the safety classification principles, the system classification and classification of main components of TES [SWTS] are listed in T-23.8-2 and T-23.8-3.

T-23.8-2 System Classification

System Function	Function Category
DAW treatment subsystem	NC
Spent resins flushing and storage subsystem	FC3/NC
Spent filter cartridge changing subsystem	NC
Wet-solid Waste receipt and treatment subsystem	FC3
NALW management	NC
NFCC waste management	NC
LLW and ILW packages storage	NC

T-23.8-3 Classification of Main Components

Component	Function Category	Safety Classification	Design Provisions Category	Design Provisions Class	Seismic Category
Pipes penetrating the steel liner and the associated isolation valve	FC3	F-SC3	DPL	B-SC3	SSE2
Pipes connecting the RCV [CVCS] purification unit and the associated isolation valve	FC3	F-SC3	DPL	B-SC3	SSE2

Component	Function Category	Safety Classification	Design Provisions Category	Design Provisions Class	Seismic Category
Other tanks, pipes, valves and components in contact with the radioactive materials	FC3	F-SC3	DPL	B-SC3	NO
Others	NC	NC	NC	NA	NO

b) Engineering Design Requirements

1) SFC and redundancy

Not applicable.

2) Independence

Not applicable.

3) Diversity

Not applicable.

4) Fail-safe

The fail-safe concept is considered in the TES [SWTS] design process by adopting the 'fail-safe' design in pneumatic globe valves to reduce risk of radioactive material leakage or to facilitate pipe cleaning. The cranes in the TES [SWTS] are equipped with several fail-safe brakes to prevent a drop load in the event of a power loss.

5) Human factors

Human factors are integrated in the design of the TES [SWTS]. Control functional requirements have been developed for allocating the system functions to manual activity and automatic control appropriately and providing necessary information to the operator.

6) Equipment qualification

The design of the TES [SWTS] complies with the equipment qualification requirements. The components with seismic classification require seismic qualification, including the pipes penetrating the steel liner, the pipes connecting the RCV [CVCS] purification unit and the associated isolation

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valves.

7) Ageing and degradation

Ageing and degradation are considered in the design of TES [SWTS] by applying the design measures described in Sub-chapter 23.2.5.

8) EMIT

– Surveillance

Appropriate instruments are designed in TES [SWTS] to indicate the status and parameters of TES [SWTS]. The parameters and status of the system, such as the level of tanks, process flow rates and the state of encapsulation facility, and the integrated alarm signal are indicated to provide necessary operational information.

– Maintenance

The preventive maintenance of TES [SWTS] components will be performed according to the equipment operation and maintenance manual at the nuclear site licensing phase. The layout design takes into account the accessibility of components for maintenance activities.

– Inspection

The spent resin storage tanks, the spent resin metering tank and the concentrate metering tank in the TES [SWTS] require pre-service inspection.

– Periodic tests

Following the preliminary requirements of periodic tests for radioactive waste management presented in Reference [41], TES [SWTS] components do not require specific separate periodic test as their functions can be verified by appropriate operating routine checks and/or preventative maintenance with an appropriate frequency.

c) Protection Design against Internal and External Hazards

The parts of TES [SWTS] that perform safety functions are protected from external and internal hazards.

d) Commissioning

By following the commissioning test requirements presented in Reference [9], TES [SWTS] requires commissioning tests to verify its functionality, including tests of system flushing, valves, simulation measurement and control channel, logic control channel, spent resin transfer, filter cartridge changing, crane, drum detection device and encapsulation facility.

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e) Decommissioning

Requirement for facilitating decommissioning is considered in the design of TES [SWTS] by applying the design principles that are in accordance with the relevant requirements described in Sub-chapter 23.2.5, including reducing residual radioactive sources through adequate emptying provisions, decontamination provisions, equipment structure design, layout of equipment and pipelines, etc., so as to facilitate decommissioning operations and reduce the accumulation of radioactive waste during decommissioning.

f) Material Selection

Material used in TES [SWTS] is compatible with the chemical, physical, and radioactive environment in normal condition. The pipes, valves, storage tanks, pumps and other items used to transport or store the wet-solid wastes are made of stainless steel. Corrosion resistant materials are used in the auxiliary equipment of the cementation process, as well as the devices or components in contact with the radioactive waste.

g) Conventional Health and Safety

Conventional health and safety is considered in the design of TES [SWTS] by assessing the relevant risks and corresponding design mitigations and recording relevant information in the conventional health and safety design risk register, as presented in Sub-chapter 23.2.5.

23.8.4 Waste Storage

23.8.4.1 LLW Buffer Storage

LLW buffer storage areas are provided in the BQS to temporarily store the LLW and VLLW waste packages prior to dispatch to off-site waste service facilities. These LLW and VLLW waste packages include conditioned LLW packages, metal waste packages, combustible waste packages, super-compactable waste packages, oil and solvent packages, low activity spent resin packages and ventilation filter cartridge packages.

Several storage areas are provided for different types of waste packages, including metal DAW packages storage area and LLW (non-metal DAW and other LLW) packages storage areas. Although waste is to be disposed of as soon as reasonably practicable after production to minimise the accumulation on-site, sufficient space is provided for storage of waste packages generated in approximately one year. All the drums and boxes are prepared for off-site transportation in the BQS.

Detailed information is presented in *Conceptual Proposal of Waste Auxiliary Building*, Reference [72].

23.8.4.2 ILW Interim Storage

According to the assumption presented in Sub-chapter 23.2.4, ILW and HLW packages

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arising from operation of the UK HPR1000 will be safely stored in an interim storage facility on-site, before future GDF in the UK is available for the disposal of the waste. Conceptual design of the interim storage facility for ILW (i.e. BQZ) is proposed during GDA to ensure safe storage of the ILW packages produced by UK HPR1000, considering the worldwide OPEX (especially in the UK and China) and good engineering practices.

The design lifetime of BQZ is considered to be at least 100 years according to the UK industry guidance on HAW interim storage, Reference [22]. This sub-chapter presents an overview the BQZ and detailed information is presented in *Conceptual Proposal of ILW Interim Storage Facility*, Reference [73]. The HLW packages are to be stored in the BQF as presented in PCSR Sub-chapter 29.6.

23.8.4.2.1 Operational Function

The BQZ is designed to import, measure, store, monitor, maintain and export the ILW packages (including shielded and unshielded package). The main operational functions are:

- a) To receive the ILW packages from other facilities;
- b) To monitor the ILW packages to establish the baseline storage information;
- c) To safely store the ILW packages in different storage area according to the waste type and radioactivity level;
- d) To monitor and inspect the ILW packages during the storage period to ensure the integrity of packages;
- e) To maintain the waste packages with degraded performance; and
- f) To export the ILW packages to relevant off-site disposal facility.

23.8.4.2.2 Storage Capacity

The BQZ is designed for two UK HPR1000 units and is proposed to be constructed in two phases during GDA. The storage capacity of the first phase facility is designed to accommodate the ILW packages generated by two UK HPR1000 units during the initial operation period of 30 years, and the storage capacity of the second phase facility will be designed to accommodate the ILW packages to be generated during the remaining operation period and the decommissioning of two UK HPR1000 units.

To minimise the accumulation of waste on-site, ILW/LLW boundary waste management is proposed in the design of the UK HPR1000 and is likely to require moderately sized storage facilities. Sufficient capacity is provided in the BQZ, taking into account the storage of ILW/LLW boundary waste packages. However, the retrieval time of the boundary waste packages will be determined by the future operator according to the actual decay characteristic during the operation of the facility.

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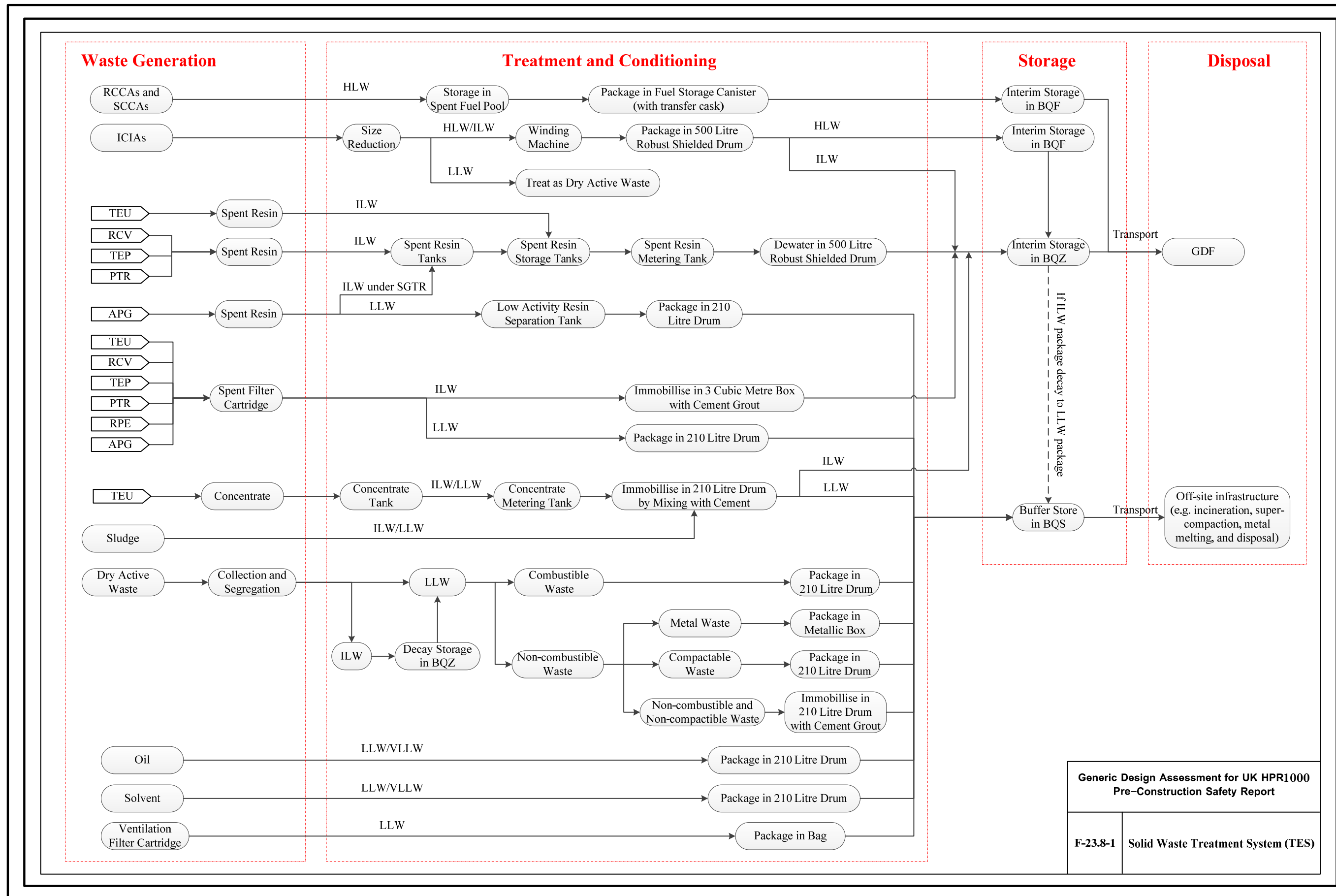
23.8.4.2.3 Storage Process

The storage process in BQZ requires import, export and maintenance of the waste packages. The general process is presented in F-23.8-2.

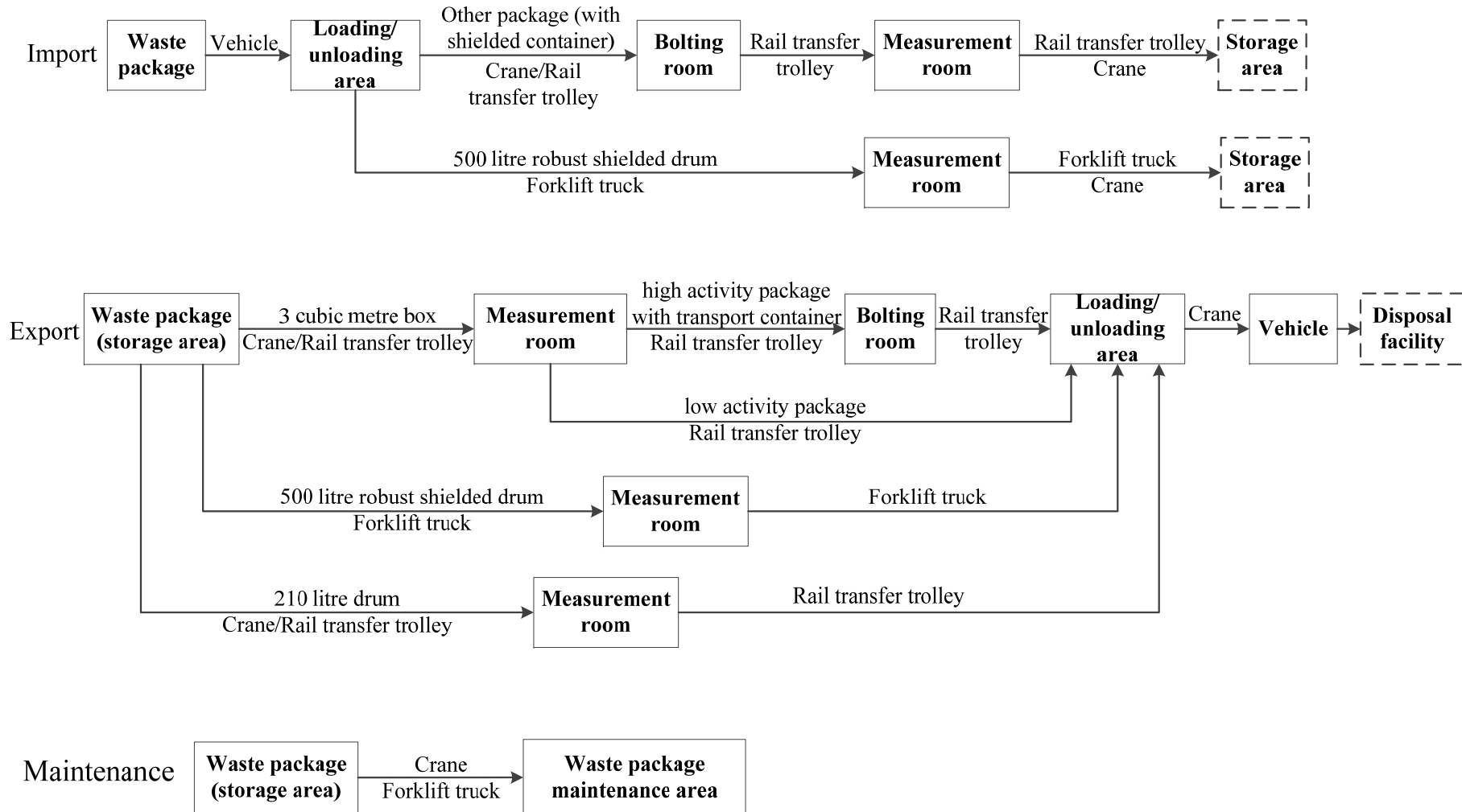
During import of waste packages to the storage area and their export for disposal, the radioactivity levels, surface dose rate and/or contamination level of packages are measured and visual inspections are carried out. The operation of the crane, rail transfer trolley and measurement device is remotely controlled and/or software-controlled to prevent the operator from radiation exposure.

Any identified defective waste packages are transferred by the crane or forklift truck to the waste package maintenance area to perform relevant maintenance operations which is under sufficient protection and shielding.

During the normal operation of the BQZ, the package characteristics, measurement information and waste package management information are recorded to achieve the safe operation management of the facility and to provide relevant information to final disposal facility owner. The information to be recorded will also include any information required by the operator of the off-site facility to which the waste package is anticipated to be transferred, e.g. the GDF.



Generic Design Assessment for UK HPR1000 Pre-Construction Safety Report	
F-23.8-1	Solid Waste Treatment System (TES)



F-23.8-2 General Storage Process

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23.9 Disposability

23.9.1 LLWR Agreement in Principle

In the UK, there are a number of radioactive waste disposal/treatment services. The Waste Acceptance Criteria (WAC) published by waste service suppliers are used to demonstrate that Lower Activity Waste (LAW) packages generated by the UK HPR1000 can be compatible with off-site facilities, and that no orphan waste will be created. Based on the assumption presented in Sub-chapter 23.2.3, establishing an 'Agreement in Principle' with LLWR during GDA ensures that LAW generated during reactor operation can be accepted by off-site facilities to minimise the accumulation of radioactive waste.

In order to support the establishment of 'Agreement in Principle', the *UK HPR1000 Waste Enquiry Form*, Reference [74], was prepared and submitted to LLWR to undertake disposability in principle assessment for LAW expected to arise from the operation of the UK HPR1000. LLWR has conducted their assessment and sets out their current position around the likely acceptability of the wastes for disposal at the LLWR or via their current treatment/disposal providers, and explains the issues and constraints surrounding the waste for disposal. Details are present in the letter *Disposability in Principle Assessment for UK HPR1000*, Reference [75].

In Reference [74], ventilation filter cartridge is proposed to be packaged into 210 litre drum. Since then, it has been decided to package them in appropriate bag to allow opportunities to utilise alternative treatment solutions in the future to support application of the waste hierarchy and in line with LLWR recommendation in their 'Agreement in Principle' letter, Reference [75]. Change of package type doesn't impact the characteristics of ventilation filter cartridge and bag is also one of the package types that are accepted by LLWR for ventilation filter cartridge packaging (Sizewell B practice) and for super-compaction treatment. Therefore, this change doesn't impact the validity of the 'Agreement in Principle' that has been granted by LLWR, Reference [75].

Regarding the issues and constraints raised by LLWR, response has been provided in the *Response to LLWR Agreement in Principle*, Reference [76], which conclude there is no particular risk for any waste stream to become orphan waste and/or to result in significant burden or risk/impact at the nuclear site licensing phase.

At the nuclear site licensing phase, the future operator will continually undertake applicable activities to ensure that all LAW generated by the UK HPR1000 can be safely managed and disposed of in line with the principles of ALARP and BAT.

23.9.2 Disposability Assessment of HAW

It will be several decades before HAW can be permanently disposed of to the GDF. Therefore, HAW should be processed into a passive safe state and stored on-site for a long term until eventual disposal.

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In order to minimise the risk that the HAW generated throughout the reactor lifetime and the proposed conditioning and packaging result in waste incompatible waste with the future GDF, the *UK HPR1000 HAW Disposability Assessment Submission*, Reference [77], was prepared and submitted to RWM to undertake a GDA disposability assessment to provide a preliminary judgement as to the potential acceptability for disposal to a GDF of the waste packages expected to arise from the operation and decommissioning of the UK HPR1000. RWM has conducted their assessment and concluded that the HAW and spent fuel generated by UK HPR1000 is proved to be disposable. Some issues are also raised by RWM respect to the current waste management plan. Details are presented in RWM report *Generic Design Assessment: Summary of Disposability Assessment for Wastes and Spent Fuel arising from the Operation and Decommissioning of the UK HPR1000 Pressurised Water Reactor*, Reference [78].

For the issues raised by RWM, which are all site-specific, responses have been provided to demonstrate that the GDA proposal and design will not lead to the impossibility to resolve them and therefore to waste that is not disposable or to significant design changes or constraints on the operator/operation of the plant. Details are presented in *Response to RWM Assessment Report on UK HPR1000 HAW and Spent Fuel Disposability*, Reference [79], which shows that all issues are likely to be resolvable in the future when the required information will be available and that no issue is likely to result in a waste stream that is not disposable or in significant design changes.

23.10 ALARP Assessment

In line with the ALARP methodology presented in [27], the risks associated with the radioactive waste management are demonstrated to be ALARP through the following aspects:

- a) Holistic ALARP assessment of radioactive waste management, including:
 - 1) Evolution of the Hua-long Pressurised Reactor (HPR1000),
 - 2) Assessing the compliance of the radioactive waste management arrangements for UK HPR1000 against the RGP (or OPEX where relevant), and
 - 3) Risk assessment;
- b) Specific ALARP assessment of radioactive waste management, i.e. optioneering to address the gaps/improvements identified from the holistic review and implementing the optimal options in the generic design of UK HPR1000; and
- c) ALARP Conclusion.

This sub-chapter aims to summarise the ALARP demonstration for radioactive waste management. Details are presented in *ALARP Demonstration Report for Radioactive Waste Management*, Reference [80].

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23.10.1 Holistic ALARP Assessment

23.10.1.1 Evolution of the HPR1000

The development process of the HPR1000 is presented in *HPR1000 R&D History*, Reference [81]. It is developed from M310, through the Chinese Pressurised Reactor (CPR1000), the Chinese Improved Pressurised Reactor (CPR1000⁺), the Advanced Chinese Pressurised Reactor (ACPR1000) to form the Hua-long Pressurised Reactor under construction at Fangchenggang nuclear power plant unit 3 (HPR1000 (FCG3)), including design evolutions relevant to prevention/minimisation of radioactive waste and to radioactive waste management systems. Taking the HPR1000 (FCG3) as the reference, the radioactive waste management arrangements and associated systems for the UK HPR1000 are developed during GDA by applying the ALARP process, and finally form part of the UK HPR1000 DR3.

23.10.1.2 Compliance with RGP

RGP for radioactive waste management is identified and listed in Sub-chapter 23.4, and is detailed in Reference [16]. Application of the ALARP methodology requires assessing the compliance of the UK HPR1000 design against the RGP (or OPEX where relevant). During this assessment, gaps/improvements relevant to radioactive waste management are identified from the following aspects:

- a) Assessing the compliance of the radioactive waste management arrangements for UK HPR1000 against the RGP/OPEX, including the following technology or practice used in the UK HPR1000 that is not demonstrated compliant with RGP/OPEX:
 - 1) The management process of spent resin, DAW, NALW and ventilation filter cartridge;
 - 2) The management process of spent NFCC;
 - 3) ILW waste container; and
 - 4) ILW interim storage facility.

- b) Assessing the compliance of the design against RGP/OPEX in other technical areas, such as Reactor Chemistry, Environment and Mechanical Engineering, considering the relevance to radioactive waste management arrangements and systems, including the following technology or practice used in the UK HPR1000 that is not demonstrated compliant with RGP/OPEX:
 - 1) Zinc injection in primary circuit (being not applied) (Reactor Chemistry);
 - 2) The type of HEPA filter (Mechanical Engineering and Environment);
 - 3) Isolation measure in radioactive waste management systems (Mechanical Engineering); and

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4) The manhole size of liquid waste storage tanks (Mechanical Engineering).

23.10.1.3 OPEX Review

The effective utilisation of OPEX is a fundamental part of demonstrating that the risks associated with radioactive waste management are reduced to ALARP. A systematic approach for use of OPEX is presented in *Methodology for Use of OPEX in UK HPR1000*, Reference [82], including the following steps:

- a) Step 1: Identification of potential sources of OPEX;
- b) Step 2: Collection of OPEX;
- c) Step 3: Identification of topics/themes;
- d) Step 4: Prioritisation process;
- e) Step 5: Determination of the intended use;
- f) Step 6: Screening process;
- g) Step 7: Use of OPEX; and
- h) Step 8: Justification of OPEX.

Following these steps, available and relevant OPEX has been identified from various sources (both nationally and internationally), analysed and used for demonstrating that the risks associated with radioactive waste management are reduced to ALARP and impacts are minimised through the use of BAT. Details are presented in *OPEX Analysis Report for Radioactive Waste Management*, Reference [83], where the list of OPEX that is applicable for radioactive waste management and the associated process to collect, identify, analyse, justify and use them are provided, covering the following aspects:

- a) OPEX data from Chinese fleet of PWRs are used as input for identification and quantification of the radioactive waste generation and disposals for the UK HPR1000;
- b) OPEX information on worldwide waste management practices/OPEX/lessons learnt/research results are used for optioneering or justification as part of the optimisation of radioactive waste management techniques for the UK HPR1000; and
- c) Lessons learnt from previous GDA and previous steps of UK HPR1000 GDA are considered in the generic design of UK HPR1000.

23.10.1.4 Risk Assessment

The radioactive waste management arrangements and systems in UK HPR1000 is subject to a holistic risk evaluation, including radiological hazards, internal and external hazards, human factors, and conventional health and safety hazards. Potential improvements that are necessary to achieve a reduction of risks to ALARP are identified

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from radiological risk assessment, including improvements relating to the ILW/LLW boundary concentrates management and the valve inspection and maintenance activity. No potential improvement relevant to radioactive waste management is identified from other assessment.

23.10.2 Specific ALARP Assessment

Specific ALARP assessment is carried out to address all the gaps/improvements identified from the holistic assessment, considering reducing relevant risks to ALARP and minimising impacts on the public and the environment through the use of BAT, including:

- a) Implementing the techniques/design measures that are optimised through optioneering to address the gaps/improvements identified from assessing the compliance of the radioactive waste management arrangements against the RGP/OPEX, covering:
 - 1) The management process of spent resin, concentrate, spent filter cartridge, sludge, DAW, NALW and ventilation filter cartridge;
 - 2) The management strategy of spent NFCC;
 - 3) The selection of container for ILW disposal; and
 - 4) The conceptual design of the interim storage facility for ILW.
- b) Implementing the techniques/design measures that are optimised through optioneering to address the gaps/improvements identified from assessing the compliance of the design against RGP/OPEX from other technical areas, covering:
 - 1) Application of zinc injection in primary circuit (Reactor Chemistry);
 - 2) The rectangular HEPA filter (Mechanical Engineering and Environment);
 - 3) Isolation measure compliant with HSG253 in radioactive waste management systems (Mechanical Engineering); and
 - 4) The manhole size of liquid waste storage tanks, considering physical dimensions of European operators (Mechanical Engineering).
- c) Implementing the techniques/design measures that contribute to reducing the radiological risks associated with the ILW/LLW boundary concentrate management and the valve inspection and maintenance. These techniques/design measures are optimised through optioneering to address the improvements identified from radiological risk assessment for radioactive waste management arrangements and systems.

23.10.3 ALARP Conclusion

The risks associated with the radioactive waste management (from waste generation to disposal) are assessed by applying the ALARP methodology. This assessment consists

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of:

- a) Review of the evolution of the HPR1000;
- b) Assessing the compliance of the radioactive waste management arrangements and systems for the UK HPR1000 against the RGP/OPEX, considering assessment in other relevant areas;
- c) Risk assessment; and
- d) Implementation of risk reduction measures (i.e. optioneering/design measures to address the identified gaps/improvements).

It is concluded that there is no significant gap/further improvement in radioactive waste management arrangements and systems and therefore the associated risks are reduced to ALARP.

23.11 Records Management

The operation of the radioactive waste management systems will generate a large quantity of information, including information relating to the sampling and monitoring of radioactive waste or waste packages. According to the requirement in Reference [17] and [19], sufficient records for the radioactive waste management must be preserved now and in the future for the safe management and disposal of radioactive waste, particularly for the solid radioactive waste.

The process of making and preserving these documents and records starts during the GDA phase and will continue throughout the whole lifecycle of the plant. The records need to be kept in an appropriate manner and form taking account of the long timescales over which they may need to be retained and accessed. During the GDA phase, for all documents relating to the design and safety case of the UK HPR1000, records are maintained under the systemic Management for Safety and Quality Assurance (MSQA) arrangements. These documents and records will be transferred to the future operator at the nuclear site licensing phase. The details of MSQA in the UK HPR1000 are presented in PCSR Chapter 20.

At the nuclear site licensing phase, the site licensee will be responsible for the information management system to trace and record in an appropriate manner, the information of waste management from generation to disposal. The main information includes but is not limited to:

- a) Production process, production date of each waste stream;
- b) Relevant characteristics, location and date of each waste stream at source;
- c) Treatment process, production date and unique identifier of each waste packages;
- d) Radiological inventory, physical and chemical information of each waste stream;
- e) Location of each waste package in different facilities, especially for waste storage

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facility;

- f) Environment conditions, monitoring and inspection records, store and waste package maintenance records in the waste storage facility; and
- g) Records of disposal route of each waste package.

To enable the future operator to remain compliant, the UK HPR1000 design has been developed considering the requirements associated with records management, notably by facilitating monitoring and sampling of waste at relevant locations throughout the plant (Sub-chapters 23.6, 23.7.2.3.2 and 23.8.2).

The appropriate records of HAW packages will be preserved and maintained until the GDF is available. These waste records will be transferred by the future operator to the disposal facility (e.g. GDF) owner once it has been confirmed that wastes can be moved for disposal. For LAW, the appropriate records of LAW packages also need to be kept by the future operator and transferred to off-site disposal facility or waste treatment facility owner.

23.12 Concluding Remarks

The information on the radioactive waste management arrangements and systems of the UK HPR1000 is presented in this chapter, including the radioactive waste management strategy, minimisation of radioactive waste, system safety requirements and the preliminary design substantiation, waste storage, disposability and records management.

This chapter describes the means of managing each waste stream from generation to disposal as well as routine discharges of liquid and gaseous radioactive wastes. The waste is managed following an integrated strategy to ensure that all waste streams that are expected to be generated from the operation of the UK HPR1000 are taken into account and an optimum waste management process is delivered. The generation and accumulation of radioactive waste is minimised at source, through effective and practicable management arrangements and routes and by ensure waste disposability. Risk reduction measures, i.e. design modifications to address the identified gaps/improvements, have been implemented in the generic design of UK HPR1000. It is demonstrated that the risks associated with radioactive waste management have been or are capable of being reduced to ALARP.

23.13 References

- [1] CGN, UK HPR1000 Design Reference Report, NE15BW-X-GL-0000-000047, Revision I, September 2021.
- [2] DECC, The Energy ACT 2008 - Funded Decommissioning Programme Guidance for New Nuclear Power Stations, December 2011.
- [3] CGN, Methodology for Safety Categorization and Classification,

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GHX00100062DOZJ03GN, Revision B, June 2018.

- [4] CGN, General Safety Requirements, GHX00100017DOZJ03GN, Revision F, November 2019.
- [5] CGN, Equipment Qualification Methodology, GHX80000003DOZJ03GN, Revision C, May 2021.
- [6] CGN, Examination Maintenance Inspection and Testing (EMIT) Strategy, GHX42EMT001DOYX45GN, Revision D, March 2021.
- [7] CGN, The General Requirements of Protection Design against Internal and External Hazards, GHX00100028DOZJ03GN, Revision F, January 2021.
- [8] CGN, Methodology of Design for System Commissioning Programme, GHX26SCPC00DOYX45GN, Revision B, September 2019.
- [9] CGN, Topic Report on the Commissioning Requirements of Radioactive Waste Management Systems, GHX71200001DNFF03GN, Revision A, July 2019.
- [10] CGN, Design Requirements for Facilitating Decommissioning, GHX71500016DNFF03GN, Revision C, April 2020.
- [11] CGN, Consistency Evaluation for Design of Facilitating Decommissioning, GHX71500005DNFF03GN, Revision E, March 2021.
- [12] CGN, Material Selection Methodology, GHX00100006DPCH03GN, Revision C, April 2019.
- [13] General Nuclear System Limited, UK HPR1000 Construction Design Management Strategy, HPR-GDA-REPO-0057, Revision 002, January 2020.
- [14] General Nuclear System Limited, CDM Design Risk Management Work Instruction, HPR-GDA-PROC-0114, Revision 001, January 2020.
- [15] CGN, General Principles for Application of Laws, Regulation, Codes and Standards, GHX00100018DOZJ03GN, Revision H, October 2020.
- [16] CGN, Analysis Report of Applicable Codes and Standards, GHX00100024DNFF02GN, Revision E, May 2020.
- [17] ONR, Nuclear Safety Technical Assessment Guide: Management of radioactive materials and radioactive waste on nuclear licensed sites, NS-TAST-GD-024, Revision 6, September 2019.
- [18] DECC (on behalf of UK Government and Devolved Administrations), UK Strategy for the Management of Solid Low Level Radioactive Waste from the Nuclear Industry, February 2016.

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- [19] ONR, Safety Assessment Principles for Nuclear Facilities, 2014 Edition, Revision 1, January 2020.
- [20] EA, Regulatory Guidance Series RSR 1: Radioactive Substances Regulation-Environmental Principles, Version 2, April 2010.
- [21] ONR, EA, SEPA and NRW, Joint Guidance from the Office of Nuclear Regulation, the Environment Agency, the Scottish Environment Protection Agency and Natural Resources Wales to Nuclear Licensees. The Management of Higher Activity Radioactive Waste on Nuclear Licensed Sites, Revision 2, February 2015.
- [22] NDA, Industry Guidance: Interim Storage of Higher Activity Waste Packages – Integrated Approach, Issue 3, January 2017.
- [23] WENRA, Radioactive Waste Treatment and Conditioning Safety Reference Levels, April 2018.
- [24] WENRA, Waste and Spent Fuel Storage Safety Reference Levels, Version 2.2, April 2014.
- [25] IAEA, Predisposal Management of Radioactive Waste, No. GSR Part 5, May 2009.
- [26] IAEA, Predisposal Management of Radioactive Waste from Nuclear Power Plants and Research Reactors, No.SSG-40, 2016.
- [27] CGN, ALARP Methodology, GHX00100051DOZJ03GN, Revision D, April 2020.
- [28] General Nuclear System Limited, Pre-Construction Environmental Report Chapter 3 Demonstration of BAT, HPR/GDA/PCER/0003, Revision 002, November 2021.
- [29] CGN, Integrated Waste Strategy (IWS), GHX00100070DNFF03GN, Revision G, April 2021.
- [30] CGN, Radioactive Waste Management Case for ILW, GHX00100066DNFF03GN, Revision E, July 2021.
- [31] CGN, Radioactive Waste Management Case for HLW, GHX00100065DNFF03GN, Revision E, July 2021.
- [32] CGN, Minimisation of Radioactivity Route Map Report, GHX00100002DNHS03GN, Revision E, February 2021.
- [33] CGN, Management Proposal of Waste Non-Fuel Core Components, GHX00100064DNFF03GN, Revision F, January 2021.

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- [34] CGN, Topic Report on Radioactive Waste Minimisation for Mechanical Engineering, GHX00100055DNHX03GN, Revision C, April 2020.
- [35] General Nuclear System Limited, Pre-Construction Environmental Report Chapter 4 Radioactive Waste Management Arrangements, HPR/GDA/PCER/0004, Revision 002, November 2021.
- [36] General Nuclear System Limited, Pre-Construction Environmental Report Chapter 6 Quantification of Discharges & Limits, HPR/GDA/PCER/0006, Revision 002, November 2021.
- [37] General Nuclear System Limited, Scope for UK HPR1000 GDA Project, HPR/GDA/REPO/0007, Revision 001, July 2019.
- [38] CGN, RPE-Nuclear Island Vent and Drain System Design Manual Chapter 3 System Functions and Design Bases, GHX17RPE003DNFF45GN, Revision E, September 2020.
- [39] CGN, RPE-Nuclear Island Vent and Drain System Design Manual Chapter 4 System and Component Design, GHX17RPE004DNFF45GN, Revision F, October 2020.
- [40] CGN, RPE-Nuclear Island Vent and Drain System Design Manual Chapter 6 System Operation and Maintenance, GHX17RPE006DNFF45GN, Revision D, October 2020.
- [41] CGN, Topic Report on the Periodic Test Requirements of Radioactive Waste Management Systems, GHX71200002DNFF03GN, Revision A, July 2019.
- [42] CGN, TEU-Liquid Waste Treatment System Design Manual Chapter 3 System Functions and Design Bases, GH917TEU003DNFF45GN, Revision D, July 2019.
- [43] CGN, TEU-Liquid Waste Treatment System Design Manual Chapter 4 System and Component Design, GH917TEU004DNFF45GN, Revision F, June 2021.
- [44] CGN, TEU-Liquid Waste Treatment System Design Manual Chapter 6 System Operation and Maintenance, GH917TEU006DNFF45GN, Revision D, October 2020.
- [45] CGN, Optioneering Report for Liquid Radioactive Waste Processing Techniques, GHX00100042DNFF03GN, Revision F, April 2020.
- [46] CGN, Sizing Report of Main Equipment in Liquid Waste Management Systems, GHX00100067DNFF03GN, Revision E, December 2020.
- [47] CGN, Sizing Report of Demineralisers in Liquid Waste Treatment System, GHX00100103DNFF03GN, Revision B, November 2020.

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- [48] CGN, TER-Nuclear Island Liquid Waste Discharge System Design Manual Chapter 3 System Functions and Design Bases, GH917TER003DNFF45GN, Revision D, July 2019.
- [49] CGN, TER-Nuclear Island Liquid Waste Discharge System Design Manual Chapter 4 System and Component Design, GH917TER004DNFF45GN, Revision D, July 2019.
- [50] CGN, TER-Nuclear Island Liquid Waste Discharge System Design Manual Chapter 6 System Operation and Maintenance, GH917TER006DNFF45GN, Revision D, November 2020.
- [51] CGN, SRE-Sewage Recovery System Design Manual Chapter 3 System Functions and Design Bases, GH917SRE003DNFF45GN, Revision D, July 2019.
- [52] CGN, SRE-Sewage Recovery System Design Manual Chapter 4 System and Component Design, GH917SRE004DNFF45GN, Revision D, July 2019.
- [53] CGN, SRE-Sewage Recovery System Design Manual Chapter 6 System Operation and Maintenance, GH917SRE006DNFF45GN, Revision D, November 2020.
- [54] CGN, SEL-Conventional Island Liquid Waste Discharge System Design Manual Chapter 3 System Functions and Design Bases, GH917SEL003DNFF45GN, Revision D, July 2019.
- [55] CGN, SEL-Conventional Island Liquid Waste Discharge System Design Manual Chapter 4 System and Component Design, GH917SEL004DNFF45GN, Revision D, July 2019.
- [56] CGN, SEL-Conventional Island Liquid Waste Discharge System Design Manual Chapter 6 System Operation and Maintenance, GH917SEL006DNFF45GN, Revision D, November 2020.
- [57] CGN, TEG-Gaseous Waste Treatment System Design Manual Chapter 3 System Functions and Design Bases, GHX17TEG003DNFF45GN, Revision D, July 2019.
- [58] CGN, TEG-Gaseous Waste Treatment System Design Manual Chapter 4 System and Component Design, GHX17TEG004DNFF45GN, Revision F, October 2020.
- [59] CGN, TEG-Gaseous Waste Treatment System Design Manual Chapter 6 System Operation and Maintenance, GHX17TEG006DNFF45GN, Revision E, October 2020.
- [60] CGN, Optioneering Report for Gaseous Radioactive Waste Processing

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Technique, GHX00100038DNFF03GN, Revision F, April 2020.

- [61] CGN, Sizing Report of Recombiner in Gaseous Waste Treatment System, GHX00100102DNFF03GN, Revision B, November 2020.
- [62] CGN, Sizing Report of the Activated Charcoal Delay Beds, GHX00100039DNFF03GN, Revision D, November 2019.
- [63] NDA, Radioactive Wastes in the UK: UK Radioactive Waste Inventory Report, March 2017.
- [64] CGN, Waste Inventory for Operational Solid Radioactive Waste, GHX00100069DNFF03GN, Revision E, April 2021.
- [65] General Nuclear System Limited, Pre-Construction Environmental Report Chapter 5 Approach to Sampling & Monitoring, HPR/GDA/PCER/0005, Revision 002, November 2021.
- [66] CGN, TES-Solid Waste Treatment System Design Manual Chapter 3 System Functions and Design Bases, GHX17TES003DNFF45GN, Revision F, November 2020.
- [67] CGN, TES-Solid Waste Treatment System Design Manual Chapter 4 System and Component Design, GHX17TES004DNFF45GN, Revision G, April 2021.
- [68] CGN, TES-Solid Waste Treatment System Design Manual Chapter 6 System Operation and Maintenance, GHX17TES006DNFF45GN, Revision G, June 2021.
- [69] CGN, Optioneering Report for Operational Solid Waste Processing Techniques, GHX00100056DNFF03GN, Revision D, June 2020.
- [70] CGN, Selection of Waste Containers for Disposal of ILW, GHX00100055DNFF03GN, Revision C, June 2020.
- [71] Sizing Report of Main Equipment in Solid Waste Treatment System, GHX00100068DNFF03GN, Revision D, November 2019.
- [72] CGN, Conceptual Proposal of Waste Auxiliary Building, GHX00100095DNFF03GN, Revision C, September 2020.
- [73] CGN, Conceptual Proposal of ILW Interim Storage Facility, GHX00100063DNFF03GN, Revision E, March 2021.
- [74] CGN, UK HPR1000 Waste Enquiry Form, GHX00100036DNFF03GN, Revision C, November 2019.
- [75] LLWR, Disposability in Principle Assessment for UK HPR10000, 3BE-3BRA-0-COO-L-4807, January 2020.

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- [76] CGN, Response to LLWR Agreement in Principle, GHX00100099DNFF03GN, Revision B, June 2020.
- [77] CGN, UK HPR1000 HAW Disposability Assessment Submission, GHX00100035DNFF03GN, Revision D, June 2020.
- [78] RWM, Generic Design Assessment: Summary of Disposability Assessment for Wastes and Spent Fuel arising from the Operation and Decommissioning of the UK HPR1000 Pressurised Water Reactor, NDA/RWM/172, June 2021.
- [79] CGN, Response to RWM Assessment Report on UK HPR1000 HAW and Spent Fuel Disposability, GHX00100098DNFF03GN, Revision B, July 2021.
- [80] CGN, ALARP Demonstration Report for Radioactive Waste Management, GHX00100072KPGB03GN, Revision I, July 2021.
- [81] CGN, HPR1000 R&D History, GHX99980001DXZJ01MD, Revision C, January 2020.
- [82] CGN, Methodology for Use of OPEX in UK HPR1000, GHX00100059DOZJ03GN, Revision A, August 2020.
- [83] CGN, OPEX Analysis Report for Radioactive Waste Management, GHX00100113DNFF03GN, Revision A, December 2020.

Appendix 23A Route Map of Radioactive Waste Management

Claim	Sub-claim	Argument	Evidence	Supporting document			
Claim 3.3.11	3.3.11.SC23.1	The functional requirements have been derived for radioactive waste management systems.	3.3.11.SC23.1-A1	The system specific design principles are identified.	3.3.11.SC23.1-A1-E1	Applicable policies, regulation, codes and standards for radioactive waste management have been identified (Sub-chapter 23.3).	<i>Analysis Report of Applicable Codes and Standards</i>
			3.3.11.SC23.1-A1-E2	The role of system has been identified (Sub-chapters 23.6, 23.7.2 & 23.8.3).	SDM Chapter 3: <i>System Functions and Design Bases</i>		
			3.3.11.SC23.1-A2	The system design requirements have been derived in accordance with the general design and safety principles.	3.3.11.SC23.1-A2-E1	General Design requirements considered in the design of radioactive waste management system has been identified (Sub-chapter 23.2.5).	SDM Chapter 3: <i>System Functions and Design Bases</i>
			3.3.11.SC23.1-A2-E2	Safety functional requirements have been identified (Sub-chapters 23.6, 23.7.2 & 23.8.3).	SDM Chapter 3: <i>System Functions and Design Bases</i>		
			3.3.11.SC23.1-A3	The safety class of the system and associated components has been identified from the safety analysis.	3.3.11.SC23.1-A3-E1	The safety class of the system and associated components has been identified (Sub-chapters 23.6, 23.7.2 & 23.8.3).	SDM Chapter 3: <i>System Functions and Design Bases</i>
Claim 3.3.11	3.3.11.SC23.2	The system design satisfied the functional requirements.	3.3.11.SC23.2-A1	Appropriate design methods have been identified for the system.	3.3.11.SC23.2-A1-E1	General assumptions for radioactive waste management have been identified (Sub-chapter 23.2.4).	---
			3.3.11.SC23.2-A1-E2	Radioactive waste management strategy will be produced and maintained for the management of radioactive waste, which is presented (Sub-chapter 23.4).	<i>Integrated waste strategy (IWS)</i>		
			3.3.11.SC23.2-A2	The system has been analysed using the appropriate design methods.	3.3.11.SC23.2-A2-E1	The liquid waste processing technique has been optimised considering the principles of ALARP and BAT (Sub-chapter 23.6).	<i>Optioneering Report for Liquid Radioactive Waste Processing Techniques</i>
			3.3.11.SC23.2-A2-E2	The gaseous waste processing technique has been optimised considering the principles of ALARP and BAT (Sub-chapter 23.7.2).	<i>Optioneering Report for Gaseous Radioactive Waste Processing Technique</i>		

Claim	Sub-claim	Argument	Evidence	Supporting document
			3.3.11.SC23.2-A2-E3 The solid waste processing technique has been optimised considering the principles of ALARP and BAT (Sub-chapter 23.8.3).	<i>Optioneering Report for Operational Solid Waste Processing Techniques;</i> <i>Management Proposal of Waste Non-fuel Core Components;</i> <i>Selection of Waste Containers for Disposal of ILW.</i>
			3.3.11.SC23.2-A2-E4 The safety functional requirements of system have been substantiated (Sub-chapters 23.6, 23.7.2 and 23.8.3).	SDM Chapter 4: <i>System and Component Design;</i>
			3.3.11.SC23.2-A2-E5 The general design requirements of system have been substantiated (Sub-chapters 23.6, 23.7.2 and 23.8.3).	SDM Chapter 6: <i>System Operation and Maintenance.</i>
		3.3.11.SC23.2-A3 Appropriate monitoring and sampling equipment have been provided to facilitate the characterisation and segregation of radioactive waste and subsequent management.	3.3.11.SC23.2-A3-E1 Appropriate monitoring and sampling equipment have been provided to segregate and characterise the liquid effluents (Sub-chapter 23.6).	SDM Chapter 6: <i>System Operation and Maintenance;</i> PCER Chapter 5: <i>Approach to Sampling & Monitoring.</i>
		3.3.11.SC23.2-A3-E2 Appropriate monitoring and sampling equipment have been provided to segregate and characterise the gaseous waste (Sub-chapter 23.7.2)		
		3.3.11.SC23.2-A3-E3 Appropriate monitoring and sampling equipment have been provided to segregate and characterise the solid waste (Sub-chapter 23.8.3).		
		3.3.11.SC23.2-A4 The commissioning tests requirements of system have been developed to provide assurance of the system performance.	3.3.11.SC23.2-A4-E1 The commissioning tests requirements for radioactive waste management systems have been developed to guide the preparation the commissioning tests at the nuclear site licensing phase (Sub-chapters 23.2.5, 23.6, 23.7.2 & 23.8.3).	<i>Topic Report on the Commissioning Requirements of Radioactive Waste Management Systems;</i> System commissioning program.

Claim	Sub-claim	Argument	Evidence	Supporting document
		3.3.11.SC23.2-A5 An initial EMIT strategy has been developed for this system, identifying components that are expected to be examined, maintained, inspected and tested.	3.3.11.SC23.2-A5-E1 The EMIT has been considered in preliminary design substantiation (Sub-chapters 23.6, 23.7.2 & 23.8.3).	SDM Chapter 6: <i>System Operation and Maintenance</i> ; Pre-service inspection list of radioactive waste management systems.
			3.3.11.SC23.2-A5-E2 The periodic test requirements of radioactive waste management systems have been developed to guide the future operator to prepare the detailed EMIT strategy at the nuclear site licensing phase (Sub-chapters 23.6, 23.7.2 & 23.8.3).	<i>Topic Report on the Periodic Test Requirements of Radioactive Waste Management Systems</i>
Claim 3.3.11	3.3.11.SC23.3 The generation and accumulation of radioactive waste from UK HPR1000 operation has been minimised.	3.3.11.SC23.3-A1 The generation of radioactive waste has been minimised at source.	3.3.11.SC23.3-A1-E1 The radioactivity of radioactive waste has been minimised at source (Sub-chapter 23.5.1.1).	<i>Minimisation of Radioactivity Route Map Report</i> ; PCER Chapter 3: <i>Demonstration of BAT</i> .
			3.3.11.SC23.3-A1-E2 The quantity of spent NFCCs has been minimised at source (Sub-chapter 23.5.1.2).	<i>Management Proposal of Waste Non-fuel Core Components</i>
			3.3.11.SC23.3-A1-E3 The volume of radioactive waste has been minimised at source (Sub-chapter 23.5.1.3).	<i>Topic Report on Radioactive Waste Minimisation for Mechanical Engineering</i> ; PCER Chapter 3: <i>Demonstration of BAT</i> .
		3.3.11.SC23.3-A2 The radioactive waste has been minimised through effective and practicable management route.	3.3.11.SC23.3-A2-E1 Radioactive waste is characterised and segregated to facilitate appropriate treatment (Sub-chapter 23.5.2).	PCER Chapter 3: <i>Demonstration of BAT</i> ; PCER Chapter 5: <i>Approach to Sampling & Monitoring</i> ; SDM Chapter 4: <i>System and Component Design</i> ; SDM Chapter 6: <i>System Operation and Maintenance</i> ; SDM Chapter 9: <i>Flow Diagrams</i> .
			3.3.11.SC23.3-A2-E2 Sufficient capacity is provided to store or treat radioactive waste (Sub-chapter 23.5.2).	<i>Sizing Report of Main Equipment in Liquid Waste Management System</i> ; <i>Sizing Report of Demineralisers in Liquid Waste Treatment System</i> ; <i>Sizing Report of the Activated Charcoal Delay Beds</i> ; <i>Sizing Report of Recombiner in Gaseous Waste Treatment System</i> ;

Claim	Sub-claim	Argument	Evidence	Supporting document
				<i>Sizing Report of Main Equipment in Solid Radioactive Waste Treatment System.</i>
			3.3.11.SC23.3-A2-E3 Treatment techniques are optimised to treat radioactive waste in an optimised way (Sub-chapter 23.5.2).	<i>Optioneering Report for Gaseous Radioactive Waste Processing Technique;</i> <i>Optioneering Report for Liquid Radioactive Waste Processing Techniques;</i> <i>Optioneering Report for Operational Solid Waste Processing Techniques;</i> <i>Management Proposal of Waste Non-fuel Core Components.</i>
			3.3.11.SC23.3-A2-E4 Appropriate containers are selected both for LLW and ILW (Sub-chapter 23.5.2).	<i>Optioneering Report for Operational Solid Waste Processing Techniques;</i> <i>Management Proposal of Waste Non-fuel Core Components;</i> <i>Selection of Waste Containers for Disposal of ILW.</i>
			3.3.11.SC23.3-A2-E5 The ILW/LLW boundary waste management proposal and decay storage of HLW are applied to optimise their management (Sub-chapter 23.5.2).	<i>Optioneering Report for Operational Solid Waste Processing Techniques;</i> <i>Management Proposal of Waste Non-fuel Core Components.</i>
			3.3.11.SC23.3-A2-E6 Appropriate space and arrangements are provided to safely segregate solid waste and to safely store conditioned waste (Sub-chapters 23.5.2 and 23.8.4).	<i>Conceptual Proposal of Waste Auxiliary Building;</i> <i>Conceptual Proposal of ILW Interim Storage Facility;</i> <i>PCSR Chapter 29.</i>
		3.3.11.SC23.3-A3 The total quantity of radioactive waste accumulated on site has been minimised.	3.3.11.SC23.3-A3-E1 Disposability of LAW is undertaken to determine the most appropriate disposal routes to minimise the accumulation of radioactive waste (Sub-chapters 23.5.3 and 23.9.1).	<i>UK HPR1000 Waste Enquiry Form;</i> <i>Disposability in principle assessment for UK HPR10000;</i> <i>Response to LLWR Agreement in Principle.</i>
			3.3.11.SC23.3-A3-E2 Disposability assessment of HAW is undertaken to determine the appropriate disposal routes (Sub-chapters 23.5.3 and 23.9.2).	<i>UK HPR1000 HAW Disposability Assessment Submission;</i> <i>Generic Design Assessment: Summary of Disposability Assessment for Wastes and Spent Fuel arising from the</i>

Claim	Sub-claim	Argument	Evidence	Supporting document			
				<i>Operation and Decommissioning of the UK HPR1000 Pressurised Water Reactor;</i> <i>Response to RWM Assessment Report on UK HPR1000 HAW and Spent Fuel Disposability.</i>			
Claim 3.3.11	3.3.11.SC23.4	Radioactive waste has been put into a passively safe form for interim storage.	3.3.11.SC23.4-A1	The radioactive waste has been processed into packages in line with off-site disposal or treatment facilities.	3.3.11.SC23.4-A1-E1	The waste containers are compatible with the requirements of off-site facilities (Sub-chapter 23.8.3).	<i>Optioneering Report for Operational Solid Waste Processing Techniques;</i> <i>Management Proposal of Waste Non-fuel Core Components;</i> <i>Selection of Waste Containers for Disposal of ILW.</i>
					3.3.11.SC23.4-A1-E2	The solid waste processing technique has been optimised considering the principles of ALARP and BAT (Sub-chapter 23.8).	<i>Management Proposal of Waste Non-fuel Core Components;</i> <i>Selection of Waste Containers for Disposal of ILW;</i> <i>Optioneering Report for Operational Solid Waste Processing Techniques;</i> <i>Sizing Report of Main Equipment in Solid Radioactive Waste Treatment System.</i>
					3.3.11.SC23.4-A1-E3	Agreement in Principle of LAW has been obtained to determine the appropriate disposal routes (Sub-chapter 23.9.1).	<i>UK HPR1000 Waste Enquiry Form;</i> <i>Disposability in principle assessment for UK HPR10000;</i> <i>Response to LLWR Agreement in Principle.</i>
					3.3.11.SC23.4-A1-E4	Disposability assessment of HAW has been undertaken to determine the most appropriate disposal routes (Sub-chapter 23.9.2).	<i>UK HPR1000 HAW Disposability Assessment Submission;</i> <i>Generic Design Assessment: Summary of Disposability Assessment for Wastes and Spent Fuel arising from the Operation and Decommissioning of the UK HPR1000 Pressurised Water Reactor;</i> <i>Response to RWM Assessment Report on UK HPR1000 HAW and Spent Fuel Disposability.</i>

Claim	Sub-claim	Argument	Evidence	Supporting document
		3.3.11.SC23.4-A2 The interim storage facility for Intermediate Level Waste (ILW) has been designed to receive and store waste packages safely.	3.3.11.SC23.4-A2-E1 The interim storage facility has appropriate capability to accommodate the ILW packages (Sub-chapter 23.8.4).	<i>Waste Inventory for Operational Solid Radioactive Waste;</i> <i>Conceptual Proposal of ILW Interim Storage Facility.</i>
			3.3.11.SC23.4-A2-E2 Inspection, maintenance, monitoring and environmental control of waste packages are considered to maintain the integrity of waste package (Sub-chapter 23.8.4).	<i>Conceptual Proposal of ILW Interim Storage Facility</i>
			3.3.11.SC23.4-A2-E3 The handling of waste packages in storage facility is operated by remote control to reduce the dose to workers (Sub-chapter 23.8.4).	<i>Conceptual Proposal of ILW Interim Storage Facility</i>
Claim 3.3.11 and Claim 3.4.8	3.3.11.SC23.5 All reasonably practicable measures have been adopted to optimise the design of radioactive waste management systems.	3.3.11.SC23.5-A1 The system satisfied meet the requirements of the relevant design principles and therefore of relevant good practice.	3.3.11.SC23.5-A1-E1 The safety functional requirements of system have been substantiated (Sub-chapters 23.6, 23.7.2 & 23.8.3).	<i>SDM Chapter 4: System and Component Design;</i> <i>SDM Chapter 6: System Operation and Maintenance.</i>
			3.3.11.SC23.5-A1-E2 The general design requirements of system have been substantiated (Sub-chapters 23.6, 23.7.2 & 23.8.3).	
			3.3.11.SC23.5-A1-E3 The holistic review of the design of radioactive waste management systems against the RGP and OPEX has been conducted (Sub-chapter 23.10).	<i>Gap Analysis Report for Radioactive Waste Management;</i> <i>Analysis Report of Applicable Codes and Standards;</i> <i>OPEX Analysis Report for Radioactive Waste Management;</i> <i>ALARP Demonstration Report for Radioactive Waste Management.</i>
		3.3.11.SC23.5-A2 Design improvements have been considered and any reasonably practicable changes implemented.	3.3.11.SC23.5-A2-E1 Optimal options have been selected and implemented to mitigate the identified gaps (Sub-chapters 23.10).	<i>Optimal Options Study for Identified Gaps in Radioactive Waste Management</i>
			3.3.11.SC23.5-A2-E2 The list of SSCs impacted by design modification has been identified (commensurately to GDA stage and scope) and implemented (Sub-chapters 23.10).	<i>The List of SSCs Affected by the Optimal Options</i>

Claim	Sub-claim	Argument	Evidence	Supporting document
			3.3.11.SC23.5-A2-E3 Radioactive waste management has been demonstrated ALARP (Sub-chapter 23.10).	<i>ALARP Demonstration Report for Radioactive Waste Management;</i> <i>Process Risks/Hazards Analysis for ICIA Retrieval and Processing Operations;</i> <i>Process Risks/Hazards Analysis for ICIA Packaging, Handling and Storage Operations.</i>

Appendix 23B An Overview of Waste Minimisation

