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Pre-Construction Safety Report

Chapter 23

Radioactive Waste Management

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TABLE OF CONTENTS

23.1 List of Abbreviations and Acronyms

ALARP	As Low As Reasonably Practicable
APG	Steam Generator Blowdown System [SGBS]
BAT	Best Available Techniques
BAX	Access Building
BFX	Fuel Building
BNX	Nuclear Auxiliary 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
CVI	Condensate Vacuum System [CVS]
DAW	Dry Active Waste
DBC	Design Basis Condition
DiD	Defence in Depth
DR	Design Reference
DWN	Nuclear Auxiliary Building Ventilation System [NABVS]
DWQ	Waste Treatment Building Ventilation System [WBVS]
EHR	Containment Heat Removal System [CHRS]
EMIT	Examination, Maintenance, Inspection and Testing
GDA	Generic Design Assessment
GDF	Geological Disposal Facility
HAW	Higher Activity Waste
HEPA	High Efficiency Particulate Air
HLW	High Level Waste
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
NFCC	Non-fuel Core Component
OPEX	Operating Experience
PCER	Pre-Construction Environmental Report
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
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
SRE	Sewage Recovery System [SRS]
SSCs	Structures, Systems and Components
SSE	Safe Shutdown Earthquake
TEG	Gaseous Waste Treatment System [GWTS]
TEP	Coolant Storage and Treatment System [CSTS]
TER	Nuclear Island Liquid Waste Discharge System [NLWDS]
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
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. Reactor Coolant System (RCP [RCS]).

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. Qualitative 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, reflecting the application 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 Design Reference (DR) version 2.1, as described in the *UK HPR1000 Design Reference Report*, Reference [1], (Rev. E). DR2.1 reflects the design modification implemented to address the identified gaps in radioactive waste management at this stage of the Generic Design Assessment (GDA), 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 are developed and presented in PCSR Chapter 1. This chapter supports the ***Claim 3.3*** and ***Claim 3.4*** derived from the high level ***Claim 3***.

Claim 3*: The design and intended construction and operation of the UK HPR1000 will 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 the ***Claim 3.3.11*** and ***Claim 3.4.8***, PCSR Chapter 23 developed five Sub-claims and a number of relevant arguments and evidences. A Route Map is developed and presented in Appendix 23A, intending to sets out 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 records management for radioactive waste information;

k) Sub-chapter 23.11 presents the summary of ALARP assessment for radioactive waste management;

l) Sub-chapter 23.12 presents the concluding remarks; and

m) Sub-chapter 23.13 presents the references.

23.2.3 Interfaces with Other Chapters

The PCSR contains various chapters and substantive design information. To help understanding the relationship between Chapter 23 and other chapters in the PCSR, 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 and arguments to support relevant claims that are presented in Chapter 1.
Chapter 2 General Plant Description	Chapter 2 provides an overall description of the plant and links to the radioactive waste management systems which are presented in Chapter 23.

PCSR Chapter	Interface
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 (DiD), safety classification of Structures, Systems and Components (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 which contributes to minimise radioactive waste at source and generates unavoidable radioactive waste. Chapter 23 provides the management of radioactive waste generated from the reactor core.
Chapter 6 Reactor Coolant System	Chapter 6 provides the design of Reactor Coolant System (RCP [RCS]) which contributes to minimise radioactive waste at source and generates reactor coolant effluents. Chapter 23 provides the management of the reactor coolant effluents.
Chapter 7 Safety Systems	Chapter 7 provides the design of safety systems which contribute to minimise radioactive waste at source and generate unavoidable radioactive waste. Chapter 23 provides the management of radioactive waste generated from the safety systems.
Chapter 9 Electric Power	Chapter 9 provides the design information relevant to the electrical power systems, which support the function of the radioactive waste management systems in Chapter 23.

PCSR Chapter	Interface
Chapter 10 Auxiliary Systems	Chapter 10 provides the design of auxiliary systems which contribute to minimise radioactive waste and generate unavoidable radioactive waste from treatment of primary effluents. Chapter 23 provides the management of radioactive waste generated from the auxiliary systems.
Chapter 11 Steam and Power Conversion System	Chapter 11 provides the design of Steam Generator Blowdown System (APG [SGBS]) which generates liquid waste and spent resins. Chapter 23 provides the management of radioactive waste generated from APG [SGBS].
Chapter 12 Design Basis Condition	Chapter 12 provides the Design Basis Condition (DBC) analysis related to radioactive waste management systems. Chapter 23 provides the specific design of radioactive waste management systems, which in taken into consideration of fault analysis.
Chapter 14 Probabilistic Safety Assessment	Chapter 14 provides the estimated feedback on radioactive waste management systems design showing whether potential enhancement needs to be made on the design. Chapter 23 provides the specific design of safety systems for the Probabilistic Safety Assessment (PSA).
Chapter 15 Human Factors	Chapter 15 provides the principles and methodology of human factor integration that shall be incorporated in the design of radioactive waste management systems. Chapter 23 provides the design of radioactive waste management systems, which is taken into account for further estimate in Human Factor.

PCSR Chapter	Interface
Chapter 16 Civil Works & Structures	Chapter 16 provides relevant civil structures that house the radioactive waste management systems, which are presented in Chapter 23.
Chapter 17 Structural Integrity	Chapter 17 provides optimum material selection for Reactor Coolant Pressure Boundary components, which contributes to minimise radioactive waste at source. Chapter 23 provides the management of radioactive waste generated from operation of the UK HPR1000.
Chapter 18 External Hazards	Chapter 18 provides external hazards relevant to the UK HPR1000 as well as the design principles. Chapter 23 provides the substantiation of radioactive waste management systems, which is taken into account for further estimate in the External Hazard area.
Chapter 19 Internal Hazards	Chapter 19 provides the design principles against internal hazards that shall be applied in the design of radioactive waste management systems. Chapter 23 provides the design of radioactive waste management systems which is an input of internal hazards safety assessment.
Chapter 20 MSQA and Safety Case Management	The organisational arrangements and quality assurance arrangements set out in Chapter 20 are implemented in the design process and in the production of Chapter 23.
Chapter 21 Reactor Chemistry	Chapter 21 provides optimum reactor chemistry controls and material selection which contribute to minimising radioactive waste at source. Chapter 23 provides the management of radioactive waste generated from operation of the UK HPR1000.

PCSR Chapter	Interface
Chapter 22 Radiological Protection	Chapter 22 provides generic aspects of source term and the general radiological protection considerations. Chapter 23 provides radioactive waste management systems design information used in radiological protection design.
Chapter 24 Decommissioning	Chapter 24 provides the waste inventory generated during decommissioning process. Chapter 23 provides the radioactive waste management systems to be used for decommissioning where applicable.
Chapter 25 Conventional Safety and Fire Safety	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.
Chapter 28 Fuel Route and Storage	Chapter 28 presents the fuel handling and storage system. Chapter 23 provides the management of potential radioactive waste generated during fuel handling and storage related operations.
Chapter 29 Interim Storage of Spent Fuel	Chapter 29 presents the interim storage of spent fuel and waste Non-fuel Core Components (NFCCs) generated from reactor. Chapter 23 provides the management proposal of NFCCs.
Chapter 30 Commissioning	Chapter 30 provides arrangements and requirements for commissioning. This design information shall be considered in Chapter 23.
Chapter 31 Operational Management	Chapter 31 provides the principle and methodology for the periodic tests, inspection, maintenance and ageing and degradation. Chapter 23 provides design

PCSR Chapter	Interface
	substantiation relevant to the periodic test, inspection, maintenance and ageing and degradation.
Chapter 33 ALARP Evaluation	Chapter 33 provides relevant principles, methodology and approach for ALARP demonstration and summarises the holistic ALARP demonstration for the UK HPR1000. Chapter 23 provides the ALARP demonstration for the radioactive waste management systems based on these principles and the approach.

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 60 years;

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) Based on 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 the FDP is submitted;

    2) Definitions of waste categories will remain unchanged from those in current use;

3) Dose limits for workers and the public will remain unchanged from those in current use in the UK;

4) Low Level Waste (LLW) generated during operation and decommissioning will be packaged on site, and dispatched to a disposal facility promptly after they have been generated. For the purposes of the Base Case, it is assumed that disposal will be at the Low Level Waste Repository Ltd (LLWR) operating in West Cumbria or a successor facility; and

5) Intermediate Level Waste (ILW) and High Level Waste (HLW) arising from operation and decommissioning will be packaged in a passive safe form, and safely stored in an interim storage facility on site, pending Geological Disposal Facility (GDF) in the UK to be used for the disposal of ILW.

f) The references about Waste Acceptance Criteria (WAC) related to those of LLWR enable obtaining of an ‘Agreement in Principle’ for treatment or disposal of Very Low Level Waste (VLLW) and LLW based upon the services provided by LLWR.

23.2.5 General Design Requirements

The design requirements derived from PCSR Chapters 4, 15, 18, 19, 24, 30 and 31 shall be considered in the system design of radioactive waste management systems, and 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 so as to achieve good quality under all expected operating conditions and realise the safety functions. 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 Structures, Systems and Components (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 the *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.

3) Diversity

Diversity shall be realised appropriately by incorporating different attributes into redundant systems or components. Such attributes can be 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 in the case that loss of the first protection line.

4) Fail-safe

To ensure the performance of the intended safety function, failure 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 design.

5) Human factors

A systematic approach needs to be applied to identify the factors that affect human performance and minimise the potential for human error throughout the entire plant lifecycle.

A systematic approach on human factors integration is established and applied in the design of the UK HPR1000. Human factors are integrated in the design of radioactive waste management systems by taking into account the following:

- Allocating the system functions to manual activity and automatic control appropriately;
- Providing necessary information to the operator.

Through implementation of the human factors integration, the resulting system is able to operate effectively and safely, which is assessed in PCSR Chapter 15.

6) Equipment qualification

Equipment qualification shall be implemented to verify that items important to safety are capable of performing their intended functions when necessary, and in the environmental conditions including the variations in ambient environmental conditions that are anticipated in the design for the plant.

The methodology of equipment qualification is detailed in Reference [5]. According to this requirement, the equipment requiring qualification is identified in the radioactive waste management systems.

7) Ageing and degradation

The design life of items important to safety is evaluated and defined. The power plant of the UK HPR1000 is designed for 60 years. For those SSCs that are not designed for 60 years, their replaceability is considered in the design.

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 examining measures are planned during plant operation (i.e. Examination, Maintenance, Inspection and Testing (EMIT)) to address the ageing effects to the components;
- For replaceable parts of components, replacement plans and layout designs are properly considered.

8) EMIT

The effective EMIT 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 types of inspections, maintenance, periodic tests, relevant requirements and the methodology of completeness analysis are presented in PCSR Chapter 31. The EMIT activities are taken into account in the design of radioactive waste management systems 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. Detailed information on requirements of protection design against internal and external hazards is presented in Reference [6].

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

d) Commissioning

Commissioning will be carried out for radioactive waste management systems to validate their functionality at the site licensing stage. The methodology of design for system commissioning programme is presented in Reference [7]. By following this methodology, the commissioning test requirements for radioactive waste management systems has been developed and presented in Reference [8]. Further detailed site specific arrangements for commissioning activities will be considered at the site licensing stage.

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. Therefore, the requirement for facilitating the decommissioning of the UK HPR1000 shall be considered, including requirements on general layout, building and structure design, process design, equipment design, material selection, layout design and etc.

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 large unnecessary radioactive water volume retained in the systems during maintenance and decommissioning;

3) Reduce the generation and accumulation of solid radioactive waste to reduce the waste volume to be treated during decommissioning.

Detailed information on requirements to facilitate decommissioning is presented in Reference [9] which also describes the design measures that have been considered to fulfill these requirements.

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 and therefore special attention shall be paid to the material selection at the design stage for SSCs to carry out their duties with high reliability throughout the design life of the plant. The principles and the approach of material selection are presented in Reference [10].

In the radioactive waste management systems, the components that are in contact with radioactive fluids are made of stainless steel or other corrosion-resistant materials to limit corrosion. This is beneficial to minimise the generation of radioactive waste.

g) Conventional Health and Safety

The design of the UK HPR1000 shall ensure that foreseeable risks to health and safety are identified. Risk identification of conventional health and safety shall be taken in the design of the UK HPR1000.

The conventional health and safety risks relating to radioactive waste management systems are analysed, although it is largely site-specific issues. The information of these risks is recorded in the conventional health and safety design risk register, which is regarded as a live document and assessed in the Conventional Safety technical area.

23.3 Applicable Codes and Standards

The general principles and methodology relevant to the selection of appropriate codes and standards are presented in PCSR Chapter 4 and Reference [11].

Based on the principles mentioned above, the main policies and regulation related to waste management in the UK are implemented as follows:

a) The Health and Safety at Work Act, 1974;

b) The Nuclear Installations Act, 1965;

c) The Ionising Radiations Regulations, 2017;

d) Hazardous Waste Regulations, 2005;

e) The Environmental Permitting (England and Wales) Regulations, 2016;

f) The Environment Act, 1995;

g) UK Strategy for Radioactive Discharges, 2011-2020;

h) Review of radioactive waste management policy: Final Conclusions (Cmnd 2919);

i) Policy for the Long Term Management of Solid Low Level Radioactive Waste in the United Kingdom, 2007; and

j) Implementing Geological Disposal, 2014.

For the codes and standards for radioactive waste management, a number of sources including UK, Western European Nuclear Regulators Association (WENRA) and International Atomic Energy Agency (IAEA) are collected and analysed. The applicable codes and standards are identified in *Analysis Report of Applicable Codes and Standards*, Reference [12], and listed below:

a) UK Strategy for the Management of Solid Low Level Radioactive Waste from the Nuclear Industry, Reference [13];

b) Regulatory Guidance Series, No RSR 1: Radioactive Substances Regulation – Environmental Principles , Reference [14];

c) The Management of Higher Activity Radioactive Waste on Nuclear Licensed Sites, Reference [15];

d) Industry Guidance: Interim Storage of Higher Activity Waste Packages – Integrated Approach, Reference [16];

e) Radioactive Waste Treatment and Conditioning Safety Reference Levels, Reference [17];

f) Waste and Spent Fuel Storage Safety Reference Levels, Reference [18];

g) Predisposal Management of Radioactive Waste, Reference [19]; and

h) Predisposal Management of Radioactive Waste from Nuclear Power Plants and Research Reactors, Reference [20].

These codes and standards, together with the *Safety Assessment Principles for Nuclear Facilities*, Reference [21], are regarded as Relevant Good Practice (RGP).

Compliance with RGP and UK existing infrastructures is the starting point for the ALARP demonstration according to the *ALARP Methodology*, Reference [22]. Furthermore, the design or modification of the radioactive waste management systems in the UK HPR1000 takes full account of RGP.

23.4 Radioactive Waste Management Strategy

A strategy is produced for the management of radioactive waste arising from the UK HPR1000 lifecycle, considering the application of waste hierarchy and ALARP/BAT principles. Addressing the principles in Reference [15], [21] and [23], 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, minimise the generation of unavoidable waste (both volume and radioactivity) as far as reasonably practicable. Waste minimisation has thus 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 [24], by:

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 as relevant to the design of the UK HPR1000 to minimise the generation (in terms of both volume and activity) and accumulation of radioactive waste.

An *Integrated Waste Strategy (IWS)*, Reference [25], 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. This IWS provides an overview of the waste strategies by showing how the waste generated from the UK HPR1000 are routed throughout the plant up to disposal, over all credible activity arising and that the system is fully integrated for solid, liquid and gaseous wastes. The waste strategies are 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.

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

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

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

The IWS will be continually maintained regarding to any changes of the waste management strategy from ALARP and BAT perspectives and used to conduct the Radioactive Waste Management Case (RWMC) to demonstrate that Higher Activity Waste (HAW) can be managed effectively at site licensing stage.

23.5 Minimisation of Radioactive Waste

Radioactive waste is an unavoidable by-product of electricity generation by a nuclear reactor, although it is undesirable due to the potentially harmful impacts on the workers, public and environment. However, the generation and accumulation of radioactive waste can be minimised through optimisation of plant design and management to protect the workers, public and environment.

This sub-chapter presents the consideration on minimisation of radioactive waste at source and minimisation of accumulation of radioactive waste in the design of the UK HPR1000.

23.5.1 Minimisation of Radioactive Waste at Source

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

a) The reduced quantity of radioactive waste means less waste processing, hence reducing the dose to workers and improves on-site safety; and

b) The smaller volume of radioactive waste implies the reduction of harmful impacts on the public and environment.

The design of UK HPR1000 has sought to minimise the radioactive waste at source (i.e. within the reactor and primary circuit), in terms of both volume and activity, through a stepwise approach:

a) Minimising fission products in the primary coolant by the design and manufacture of fuel;

b) Minimising activated corrosion products through material selection;

c) Minimising the radioactivity of waste by optimising water chemistry in the primary coolant; and

d) Minimising leaks of radioactive process fluids from containment systems.

Furthermore, appropriate measures that are beneficial to minimise the generation of waste streams are incorporated in the design of the UK HPR1000, including systematic design method, systems optimisation, layout optimisation and adequate radiation zoning. Subsequently, the liquid, gaseous and solid radioactive waste is minimised by efficient management through segregation, characterisation, storage of waste and optimised treatment techniques in sight of off-site waste treatment and disposal services (Sub-chapters 23.6, 23.7 and 23.8).

23.5.1.1 Minimising Fission Products in the Primary Coolant by the Design and

Manufacture of Fuel

Fission within the fuel represents the largest source of radioactivity within the reactor. Fission products that leave the structure of the fuel and enter the primary coolant will ultimately become radioactive waste. Therefore, it is important to prevent fission products from leaking out of the fuel into the primary coolant so as to reduce the radioactivity of radioactive waste. For this reason, the design and manufacture of fuel has evolved to include a range of techniques that contribute to:

a) The retention of fission products within the fuel rod by minimising the likelihood of a fuel failure; and

b) Minimising fissionable material contamination on the surface of the fuel cladding.

The design and performance of the fuel is described in PCSR Chapter 5 and demonstrated to be ALARP taking into account minimising radioactive waste at source.

Minimising the concentration of fission products by the design and manufacture of fuel is also demonstrated in PCER Chapter 3 *Demonstration of BAT* Sub-chapter 3.5.1.1, Reference [24].

23.5.1.2 Minimising Activated Corrosion Products through Material Selection

Activation products (arising from activation of corrosion products suspended or dissolved in the circuit, or through activation of structures and components) are significant sources of radioactive waste. Selection of appropriate materials with specific chemical content and/or resistance to corrosion contributes to reduce activation and subsequently, reducing radioactive waste.

Material Selection Methodology, Reference [10], has been produced for UK HPR1000 to guide the material selection of all metallic SSCs in a consistent way, taking into account principles relating to minimising the generation of radioactive waste:

a) Easily activated elements are avoided and, where not possible, minimised/controlled to minimise the creation of radioactive waste; and

b) Materials with good corrosion resistance are selected and relevant surface finishing is applied, to minimise the generation of waste.

Material selection (taking minimisation of radioactive waste into consideration) supports ALARP demonstration for reactor chemistry presented in PCSR Chapter 21 and for structural integrity presented in PCSR Chapter 17.

Minimising activated corrosion products through material selection is also demonstrated in PCER Chapter 3 *Demonstration of BAT* Sub-chapter 3.5.1.6, Reference [24].

23.5.1.3 Minimising the Radioactivity of Waste by Optimising Water Chemistry in the Primary Coolant

The objective of the water chemistry is to maintain the safe operation and structural integrity of the plant. It also contributes to radiological protection, equipment protection and the generation of radioactive waste. As such, the following important objectives are taken into account when developing the water chemistry regime:

a) Minimising the generation of corrosion products;

b) Minimising the generation of activation products;

c) Minimising maintenance impurity associated with stress corrosion cracking; and

d) Minimising the use of additives that may adversely impact the generation, management or disposal of radioactive waste.

PCSR Chapter 21 presents the measures that enable these objectives to be achievable and demonstrates that the reactor chemistry of the UK HPR1000 is to be ALARP.

Minimising the radioactivity of waste by optimising water chemistry in the primary coolant is also demonstrated in PCER Chapter 3 *Demonstration of BAT* Sub-chapter 3.5.1.5, Reference [24].

23.5.1.4 Minimising Leaks of Radioactive Process Fluids from Containment Systems

The radioactive substances arise from the fission products in the fuel and the activation of the primary circuit components. Although they have been prevented and minimised at source and majority are retained within the fuel, unavoidable fission and activation products that are entrained in the reactor coolant are transferred around the primary circuit and associated systems.

To prevent the spread of contamination, engineered and management controls are incorporated in the design of the UK HPR1000 to ensure containment of radioactive materials and therefore the effluent and secondary waste is minimised.

Detailed demonstration is presented in PCER Chapter 3 *Demonstration of BAT* Sub-chapter 3.5.2.1, Reference [24].

23.5.2 Minimisation of Accumulation of Radioactive Waste

Appropriate disposal routes for different categories of radioactive waste are significantly beneficial to minimise the accumulation of radioactive waste, which result in the reduction of on-site radiological risks.

Minimisation of radioactive waste accumulated on site is a significant element of the radioactive waste management strategy in the UK HPR1000, especially for solid radioactive waste management. It means that radioactive waste including Lower

Activity Waste (LAW) and HAW are going to be consigned to appropriate off-site disposal facilities or waste treatment facilities. Considerations have been given in the waste management strategy such that accumulation is minimised, including:

a) Providing sufficient capacity to store waste, facilitating appropriate treatment (Sub-chapters 23.6, 23.7 and 23.8);

b) Providing appropriate space to segregate solid waste to enable volume to be reduced and to store conditioned waste packages (Sub-chapter 23.8);

c) Establishment of an ‘Agreement in Principle’ with LLWR to ensure LAW can be accepted by off-site facilities (Sub-chapter 23.9.1); and

d) Disposability assessment with RWM to ensure the HAW is compatible with future GDF (Sub-chapter 23.9.2).

23.6 Liquid Radioactive Waste Management

23.6.1 Liquid Radioactive Waste Management Strategy

The radioactive products likely to be discharged through liquid waste are produced in the reactor core. In the primary coolant, they are presented in the following forms:

a) Fission products, likely to be released by small defects in the fuel rod cladding during unit operation;

b) Corrosion products released by materials in the primary circuit and activated during their way through the active zone in the core; and

c) Primary coolant activation products.

These radioactive substances in the reactor coolant are transferred around the primary circuit and pass into the connected systems and various support systems.

The generation of liquid effluents is minimised through the following sequence of actions:

a) Reduction of effluent generation at source;

b) Collection and segregation of effluent streams based upon compatibility with the downstream recycling/treatment plant;

c) Reuse wherever possible;

d) Treatment; and

e) Discharge of the treated effluent to the marine environment.

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, Sub-chapter 6.6, Reference [26].

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 avoid 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 uncontaminated and undiluted reactor coolant 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. In the case of high tritium concentration, the distillates cannot practically be recycled and thus are routed to the Nuclear Island Liquid Waste Discharge System (TER [NLWDS]) for 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 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 control area;

   - Floor drains 2, which are slightly contaminated or uncontaminated and come from leakage, equipment draining and floor washing in control area; and

- Floor drains 3, which are normally uncontaminated and come from leakage, equipment draining and floor washing outside the control area.

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

The design information of 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 to be discharged after treatment, including:

a) The non-recyclable effluents captured 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 and therefore the liquid waste is characterised as four separate streams and routed for being processed in different ways in the TEU [LWTS].

a) Process Drains

Process drains, which 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, 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

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 Effluents

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 effluents from the APG [SGBS] will be 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 of 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 [27].

23.6.1.4 Generation of Solid Waste

Filtration and/or demineralisation are necessary for water purification and/or treatment in the RCV [CVCS], TEP [CSTS], RPE [VDS], TEU [LWTS] and APG [SGBS]. Filter cartridges have to be replaced based on the pressure drop or dose rate and spent filter cartridges are generated. Resins in the demineralisers have to be replaced when being saturated by the ions and therefore produce spent resins. Evaporation is used in TEU [LWTS] to treat chemical drains and concentrates are generated. Although these wastes are unavoidable, they are minimised at source as described in Sub-chapter 23.5.1. The information on these wastes and their management strategy are presented in Sub-chapter 23.8.

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

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] shall contribute to the removal of heat as follows:

   In the case of Loss of Coolant Accident (LOCA), isolation of RPE [VDS] assists to maintain the water inventory in the Reactor Building.

c) Confinement

   RPE [VDS] collects and contains radioactive effluents in the nuclear island and prevents their leakage under normal operation.

RPE [VDS] containment isolation valves are designed to provide the following functions to prevent leakage from containment building:

1) Containment isolation in accident conditions;

2) Containment leak tightness in severe accident conditions; and

3) In the case of LOCA, isolation of RPE [VDS] in the Reactor Building (BRX) prevents spread of radioactive effluents towards other buildings during shutdown state.

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, such as emptying before maintenance, equipment cleaning, equipment leakage and floor drain. RPE [VDS] serves to selectively collect, store temporarily and transfer radioactive effluents. The collected effluents are transferred to the appropriate downstream systems for treatment or recycle 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;

b) Segregate the non-radioactive liquid waste and send it to SEK [WFCSCI] for discharge after the sampling is qualified;

c) Facilitating to select 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.

23.6.2.3 System Description and Operation

23.6.2.3.1 System Description

Although the design of the UK HPR1000 prevents losses of process fluids through leakage, any leaks and drains are collected and contained in RPE [VDS] to avoid 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. The system flow diagram of RPE [VDS] is presented in F-23.6-2.

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;
- Gaseous waste from removal piping of the pressuriser;
- 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

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

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] as presented in F-23.6-1 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 made of stainless steel and equipped with pressure reducing equipment for over-pressurisation protection.

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] through 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.

Detailed information of the equipment is presented in Reference [28].

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:

a) Systems Generate 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 possible 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]

Waste liquid from non-control area collected by RPE [VDS] is transferred to SEK [WFCSCI] for discharge.

Detailed information of the system interfaces is presented in Reference [28].

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 wastes are collected in the RPE [VDS] reactor coolant drain tank and drains 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 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

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 it can be pumped to TEP [CSTS].

5) Vacuum performing

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 by 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 flushed by nitrogen, RCP [RCS] is cleaned by compressed air. Gaseous 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 Preliminary 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] can participate in maintaining the water inventory in the Reactor Building by automatic isolation of the floor drains line that penetrates the containment.

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 in them. All the tanks and sumps are provided with measurement device to detect level changes, facilitating to detect, locate and quantify for 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 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

By following the safety classification principles, the function classification of RPE [VDS] is derived inT-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.

The details about system classification are presented in Reference [29].

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
Pumps, tanks , valves and lines (collect process drains inside BSX,BFX)	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 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 Access Building (BAX))	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.

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 two containment isolation valves installed at the same line are supplied by two different power suppliers.

4) Fail-safe

The fail-safe concept is considered in the RPE [VDS] design process. The methodology and analysis of the fail-safe design in the RPE [VDS] is presented in the Reference [28]. According to the analysis, other measures such as redundancy are used to improve the safety of power plant and avoid the potential safety concerns or safety risk that may be introduced by ‘fail-safe’ design on power plant.

5) Human factors

Human factors are integrated in the design of RPE [VDS] by developing appropriate system control functional requirements, considering application of the design measures described in Sub-chapter 23.2.5. Detailed information about automatic control design of the system is presented in Reference [30].

6) Equipment qualification

The components that are designed to withstand Safe Shutdown Earthquake (SSE) are identified to be seismic qualified in order to ensure the functionality, including containment isolation valves that are categorised as SSE1 and pumps, sumps and valves that are categorised as SSE2.

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

  RPE [VDS] is operated and monitored from the Main Control Room.

- Maintenance

  The RPE [VDS] will carry out maintenance and replacement activities according to the operation of the equipment and components. The layout design will take into the consideration of the need to remove the old parts and to install the replacement.

- Inspection

  The reactor coolant drain tanks and their related safety valves that require pre-service inspection are identified in the pre-service inspection list of RPE [VDS].

- Periodic tests

  Reference [31] presents the periodic test design method for the UK HPR1000. By following this method, preliminary requirements of periodic tests for radioactive waste management are presented in Reference [32]. The containment isolation valves in RPE [VDS] need periodic tests to verify the manoeuvrability and tightness.

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.

The detailed consideration of specific hazards protection design is presented in Reference [29].

d) Commissioning

By following the commissioning test requirements presented in Reference [8], commissioning tests will be performed to verify the functionality of the RPE [VDS] at the site licensing stage, including tests of system flushing, valves, simulation measurement and control channel, logic control channel, pumps, tanks and sumps.

e) Decommissioning

Facilitating decommissioning is considered in the design of RPE [VDS] by applying the design measures described in Sub-chapter 23.2.5. Detailed information is presented in Reference [29].

f) Material Selection

Numbers of components (such as tanks and sumps) of the RPE [VDS] is made of stainless steel in order to limit corrosion, so as to reduce the radioactive waste.

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

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

g) Conventional Health and Safety

Conventional health and safety is considered in the design of RPE [VDS] by analysing the relevant risks and recorded in the DRR, as presented in Sub-chapter 23.2.5.

23.6.3 Liquid Waste Treatment System (TEU [LWTS])

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.

d) Extra Supporting Functions

TEU [LWTS] does not perform extra supporting functions.

23.6.3.2 Role of the System

TEU [LWTS] provides separately storage, treatment and monitoring of the non-recyclable liquid waste collected in RPE [VDS] and SRE [SRS].

TEU [LWTS] performs the following operational functions:

a) Sampling liquid waste in the storage tanks and transferring liquid waste to the appropriate treatment routes;

b) Treating the liquid waste so as to reduce their radioactivity concentrations to the level acceptable for discharge into the environment; and

c) Transferring the treated liquid waste to TER [NLWDS] for discharge after 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].

Following the development of the engineering aspects, the optioneering of radioactive liquid waste treatment techniques have been undertaken and presented in the *Optioneering Report for Liquid Radioactive Waste Processing Techniques*, Reference [33]. The potential options from worldwide Operating Experience (OPEX) are identified and assessed against the assessment criteria considering the safety aspects and environment impacts. For the purpose of GDA, the option of ‘demineralisation, evaporation and filtration' is determined to effectively treat the process drains, chemical drains, and floor drains and laundry drains, respectively. It is noted that the future operator will determine the final optimum processing techniques for liquid radioactive waste and demonstrate that such proposals represent BAT and ALARP.

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.

The system flow diagram of TEU [LWTS] is presented in F-23.6-3. 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, each kind of liquid waste is equipped with two storage tanks. For floor drains, there are three storage tanks. Each kind of storage tanks is equipped with a pump to mix and transfer the liquid waste in the tank to the liquid waste treatment subsystem for treatment.

For each type of storage tanks, there is always one of them on receiving status. After a storage tank is filled up, it will be mixed and then sampled.

b) Liquid Waste Treatment Subsystem

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

1) Demineralisation unit

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

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 $4m^3/h$.

When liquid waste need to be treated through the evaporation unit, it is mixed and sampled in the storage tank, and then transferred to the evaporation unit by the evaporator feed pump.

There is a demineraliser which could be used to polish the condensates from the evaporation. The operation of demineraliser is determined by the worker according to the appropriate procedure. The worker has to decide whether the balance between energy costs, the amount of secondary solid waste to be managed and the release 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, it will be mixed, 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 treated by the evaporation or demineralisation unit.

d) Chemical Dosing Subsystem

The chemical injection subsystem consists of metering pumps and auxiliary parts, meeting the requirements for pH adjustment of liquid waste in the storage tank and anti-foam addition to the evaporator.

e) Sampling Analysis Subsystem

The sampling analysis subsystem consists of special sampling glove boxes and local sampling funnels. The details of sampling points for TEU [LWTS] are shown in F-23.6-3.

For the liquid waste treatment subsystem, the samples are taken down stream of demineralisers and evaporation unit to analyse 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 activity concentration 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 with identical volume, and two monitoring tanks with the 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 mix 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 transportation.

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

The demineralisation unit consists of three demineralisers. The demineraliser is of vertical cylinder type and made of stainless steel.

d) Evaporator

The evaporator is used to separate the water and the contaminants from liquid waste. The generated concentrates are stored in the column bottom. The steam enters the compressor 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 start-up stage. It is unnecessary to put the electric heater into operation during normal operations. 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 is a concentrate tank 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.

Detailed information of the equipment is presented in Reference [34].

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] is required to receive and treat the liquid waste collected by the RPE [VDS].

b) SRE [SRS]

TEU [LWTS] is required to receive and treat the liquid waste collected by the SRE [SRS].

c) TES [SWTS]

TES [SWTS] is required to treat the solid waste, i.e. spent resins, spent filter cartridges and concentrate, produced by the TEU [LWTS].

d) TER [NLWDS]

TER [NLWDS] is required to receive the liquid waste treated by the TEU [LWTS].

When the radioactivity in the liquid waste from the TER [NLWDS] exceeds the discharge management objective, TEU [LWTS] is required to receive and treat the unacceptable liquid waste from the TER [NLWDS].

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

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

Detailed information of the system interfaces is presented in Reference [34].

23.6.3.3.4 System Operation

a) Plant Normal Condition

For the liquid waste storage tanks, there is always one of them being filled. The liquid waste in this tank is mixed and sampled for analysis after the storage tank filled up. According to the analysis result, the pH and sodium hydroxide/boric acid ratio is adjusted as required, and a suitable treatment processing is selected to treat this liquid waste:

1) Process drains are usually treated by the demineralisation or evaporation if they are polluted with chemical;

2) Chemical drains are usually treated by the 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 usually treated by the filtration.

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

b) Plant Accident Condition

Not applicable.

23.6.3.4 Preliminary 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 the environment. The storage tanks are located in retention pit which is capable of containing all the liquid waste produced in case of the break. The retention pit where the storage tanks with higher radioactivity content are located is provided with stainless steel liner to ensure confinement.

Tanks are connected with HVAC systems to prevent escapes of gaseous radioactivity, and are provided with measurement device to detect level changes, facilitating to detect, locate and quantify for 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. The details about categorisation and classification are presented in Reference [35].

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
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 isolation valves in these pipelines 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. The methodology and analysis of the fail-safe design in the RPE [VDS] is presented in Reference [34]. According to the analysis, the fail-safe is adopted in the design of pneumatic control valve on the bypass of steam compressor to protect the steam compressor against overpressure damage. The fail-safe is also adopted in the design of 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] by developing appropriate system control functional requirements, considering application of the design measures described in Sub-chapter 23.2.5. Detailed information about automatic control design of the system is presented in Reference [36].

6) Equipment qualification

The components that are designed to withstand SSE (valves categorised as SSE2) are identified to be seismic qualified in order to ensure the functionality.

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 concentrated in 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 system is designed and installed so that different components in the system can be easily accessed to conduct maintenance and replacement work.

  Since the volume of the liquid waste produced is at peak during unit shutdown, the preventive maintenance often is conducted during normal operation.

- Inspection

  The system components must be designed to ensure that their appearance, function performance, noise of abnormal level or minor leakage can be detected by visual inspection. The components that require pre-service inspection are identified in the pre-service inspection list of TEU [LWTS].

- Periodic tests

  Reference [31] presents the periodic test design method for the UK HPR1000. By following this method, preliminary requirements of periodic tests for radioactive waste management are presented in Reference [32] which indicates that periodic test is not required for TEU [LWTS].

c) Protection Design against Internal and External Hazards

Since the main components of TEU [LWTS] are installed in the Radioactive Waste Treatment Building (BWX) and without any safety class components, there is no particular design provision for the system against internal and external hazards.

The detailed consideration of specific hazards protection design is presented in Reference [35].

d) Commissioning

By following the commissioning test requirements presented in Reference [8], commissioning tests will be performed to verify the functionality of the TEU [LWTS] at the site licensing stage, including tests of system flushing, valves, simulation measurement and control channel, logic control channel, pumps, tanks, evaporator, electric heater and steam compressor.

e) Decommissioning

Facilitating decommissioning is considered in the design of TEU [LWTS] by applying the design measures described in Sub-chapter 23.2.5. Detailed information is presented in Reference [35].

f) Material Selection

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

The selection of structural material for the system components should meet 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 analysing the relevant risks and recorded in the DRR, as presented in Sub-chapter 23.2.5.

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

23.6.4.1 Safety Functional Requirements

a) Reactivity Control

TER [NLWDS] does not contribute to this function.

b) Removal of Heat

TER [NLWDS] does not contribute to this function.

c) Confinement

TER [NLWDS] performs following confinement functions:

1) To contain the radioactivity liquid waste; and

2) To prevent unqualified liquid waste released 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] collects liquid waste from nuclear island, and discharges it to the environment under monitoring after mixing, sampling and analysis.

TER [NLWDS] performs the following functions:

a) Collecting and storing liquid waste from TEU [LWTS] and TEP [CSTS], and discharge the liquid waste after mixing, sampling and analysis;

b) Collecting and storing liquid waste from APG [SGBS] and SEK [WFCSCI], if SEL [LWDS (CI)] is unavailable or the radioactivity of the liquid waste discharged to SEL [LWDS (CI)] exceeds the discharge management objective;

c) Sending liquid waste to TEU [LWTS] for treatment when the radioactivity concentration of the waste liquid exceeds the appropriate limit after sampling analysis or monitoring; and

d) Monitoring and recording the released liquid waste radioactivity concentration, flow rate, and the volume discharged.

23.6.4.3 System Description and Operation

23.6.4.3.1 System Description

TER [NLWDS] is composed of:

a) Piping that receive liquid waste from upstream systems;

b) Three liquid waste storage tanks with the same volume;

c) Each liquid waste storage tank 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 an online Plant Radiation Monitoring System (KRT [PRMS]) monitor;

f) Sumps in the tank area and the pump room collect pipe drains and floor drains. Each sump has a sump pump to send back the liquid waste to the storage tank.

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

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 mix 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.

Detailed information of the equipment is presented in Reference [37].

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].

b) TEP [CSTS])

TER [NLWDS] collects tritium 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, or the radioactivity of the liquid waste discharged to the SEL [LWDS (CI)] system is high.

d) PTR [FPCTS]

TER [NLWDS] collects drainage from in-containment refueling water storage tank.

Detailed information of the system interfaces is presented in Reference [37].

23.6.4.3.4 System Operation

a) Plant Normal Condition

During normal operation, one of the three storage tanks in TER [NLWDS] is used to receive liquid waste; one is used to mix, sample, monitor and discharge liquid waste; one is on standby. There is one sampling point on the recirculation line of each liquid waste storage tank, which is presented in F-23.6-4. The liquid waste from each system is mixed through recirculation before sampling is performed. After the sample is analysed, the discharge flow rate is determined according to the radioactivity 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 of the liquid waste. The radiation monitor will send out alarms and the isolation valves will be closed automatically if the radioactivity of the liquid waste exceeds the pre-determined value.

A flow proportional sampler is also positioned on the main discharge pipe in TER [NLWDS] to take composite samples for the detailed analysis in laboratory and records maintenance.

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

b) Plant Accident Conditions

Not applicable.

23.6.4.4 Preliminary 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 counting of liquid waste released into the environment, so that 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 of the tanks break.

Storage tanks are provided with measurement device to detect level changes, facilitating to detect, locate and quantify for 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.

23.6.4.4.2 Compliance with Design Requirements

a) Safety Classification

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

The details about categorisation and classification are presented in Reference [38].

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 isolation valves in these pipelines 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. The methodology and analysis of the fail-safe design in the TER [NLWDS] is presented in the Reference [37]. According to the analysis, the fail-safe is adopted in the design of the valves on the pipes that penetrate through the retention pit to ensure the confinement of radioactive liquid waste. The fail-safe is also adopted in the design of control valve on the discharge line to avoid the unexpected discharge.

5) Human factors

Human factors are integrated in the design of TER [NLWDS] by developing appropriate system control functional requirements, considering application of the design measures described in Sub-chapter 23.2.5. Detailed information about automatic control design of the system is presented in Reference [39].

6) Equipment qualification

The components that are designed to withstand SSE (valves categorised as SSE2) are identified to be seismic qualified in order to ensure the functionality.

7) Ageing and degradation

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

8) EMIT

- Surveillance

  The state of electric and pneumatic isolation valves, electric control valves, important manual isolation valves and pumps of TER [NLWDS] are under surveillance.

- Maintenance

  Equipment maintenance will be carried out according to equipment operation and maintenance manual which will be developed by equipment manufacturers at site licensing stage.

- Inspection

  The system components are designed to ensure that their appearance, function performance, noise of abnormal level or minor leakage can be detected by visual inspection.

- Periodic tests

  Reference [31] presents the periodic test design method for the UK HPR1000. By following this method, preliminary requirements of periodic tests for radioactive waste management are presented in Reference [32] which indicates that periodic test is not required for TER [NLWDS].

c) Protection Design against Internal and External Hazards

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

The detailed consideration of specific hazards protection design is presented in Reference [38].

d) Commissioning

By following the commissioning test requirements presented in Reference [8], commissioning tests will be performed to verify the functionality of the TER [NLWDS] at the site licensing stage, including tests of system flushing, discharge, valves, simulation measurement and control channel, logic control channel, pumps and tanks.

e) Decommissioning

Facilitating decommissioning is considered in the design of TER [NLWDS] by applying the design measures described in Sub-chapter 23.2.5. Detailed information is presented in Reference [38].

f) Material Selection

The material of the liquid waste storage tanks, the liquid waste discharge pumps, sump pumps, pipes and valves is stainless steel in order to limit corrosion.

g) Conventional Health and Safety

Conventional health and safety is considered in the design of TER [NLWDS] by analysing the relevant risks and recorded in the DRR, as presented in Sub-chapter 23.2.5.

23.6.5 Sewage Recovery System (SRE [SRS])

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.

c) Confinement

SRE [SRS] contributes to the achievement of the confinement of radioactive material in normal operation.

d) Extra Supporting Functions

SRE [SRS] does not perform extra supporting functions.

23.6.5.2 Role of the System

In normal operation, SRE [SRS] performs the following functions:

a) Separate collection of different categories of the 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;

3) Floor drains, which typically contain lower radioactive contamination but 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 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 [27], so this sub-chapter presentes the liquid waste collection subsystem in BWX.

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

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

Detailed information of the equipment is presented in Reference [40].

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] is required to receive and process the liquid waste collected by SRE [SRS].

SRE [SRS] is required to collect the drainage of pipes and equipment in TEU [LWTS].

b) TES [SWTS]

SRE [SRS] is required to collect the drainage of pipes and equipment in TES [SWTS].

Detailed information of the system interfaces is presented in Reference [40].

23.6.5.3.4 System Operation

a) Plant Normal Condition

The pumps transfer the liquid waste to TEU [LWTS] for treatment when the liquid waste in the sump reaches the high level, otherwise they will be automatically shut down.

Alarm signals will be sounded when the liquid waste in the sumps reaches the high-high level or the low-low level.

b) Plant Accident Conditions

Not applicable.

23.6.5.4 Preliminary 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 the environment.

Sumps are provided with measurement device to detect level changes, facilitating to detect, locate and quantify for leakages or escapes of radioactive waste contained in them.

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. The details about categorisation and classification are presented in Reference [41].

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 isolation valves in these pipes	FC3	F-SC3	DPL	B-SC3	SSE2
Other equipment	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

Not applicable.

5) Human factors

Human factors are integrated in the design of SRE [SRS] by developing appropriate system control functional requirements, considering application of the design measures described in Sub-chapter 23.2.5. Detailed information about automatic control design of the system is presented in Reference [42].

6) Equipment qualification

The components that are designed to withstand SSE (valves categorised as SSE2) are identified to be seismic qualified in order to ensure the functionality.

7) Ageing and degradation

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

8) EMIT

- Surveillance

  The surveillance of SRE [SRS] is displayed in KSH [WBCS].

  The states of the sump levels and the pumps are displayed on the control screen of the KSH [WBCS].

- Maintenance

  In order to ensure the property of system during normal operation, maintenance of equipment will be performed in accordance with equipment supplier technical manuals which will be developed by equipment manufacturers at site licensing stage.

- Inspection

  Not applicable.

- Periodic tests

  Reference [31] presents the periodic test design method for the UK HPR1000. By following this method, preliminary requirements of periodic tests for radioactive waste management are presented in Reference [32] which indicates that periodic test is not required for SRE [SRS].

c) Protection Design against Internal and External Hazards

Since the main components of SRE [SRS] are installed in BWX and without any safety class components, there is no particular design provision for the system against internal and external hazards.

The detailed consideration of specific hazards protection design is presented in Reference [41].

d) Commissioning

By following the commissioning test requirements presented in Reference [8], commissioning tests will be performed to verify the functionality of the SRE [SRS] at the site licensing stage, including tests of sumps and pumps.

e) Decommissioning

Facilitating decommissioning is considered in the design of SRE [SRS] by applying the design measures described in Sub-chapter 23.2.5. Detailed information is presented in Reference [41].

f) Material Selection

Equipment, pipes and valves in SRE [SRS], which are in contact with liquid waste, are made of stainless steel to limit the corrosion.

Sumps are equipped with stainless steel liners to limit the corrosion.

g) Conventional Health and Safety

Conventional health and safety is considered in the design of SRE [SRS] by analysing the relevant risks and recorded in the DRR, as presented in Sub-chapter 23.2.5.

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

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)] performs the following confinement functions:

1) It is designed to contain the radioactivity liquid waste;

2) It is designed to prevent unqualified liquid waste being released into the environment.

b) Extra Supporting Functions

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

23.6.6.2 Role of the System

SEL [LWDS (CI)] collects liquid waste from conventional island, and discharges it to the environment under control.

SEL [LWDS (CI)] performs the following functions:

a) Collect and store the liquid waste from SEK [WFCSCI] and non-recyclable effluent from APG [SGBS], and discharge the liquid waste after mixing, 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) Monitor and record the radioactivity concentration, flow rate, and the volume of released 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 receive liquid waste from upstream systems;

b) Three liquid waste storage tanks with the same volume;

c) Each liquid waste storage tank 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 an online KRT [PRMS] monitor; and

f) Sumps collect drains in the tank area and the pump room. Each sump has a sump pump to send back the liquid waste to the storage tank.

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

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 mix 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.

Detailed information of the equipment is presented in Reference [43].

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]

Collect low radioactive liquid waste from SEK [WFCSCI].

b) APG[SGBS])

Collect non-reusable liquid waste from APG [SGBS].

Detailed information of the system interfaces is presented in Reference [43].

23.6.6.3.4 System Operation

a) Plant Normal Condition

During normal operation, one of the three storage tanks in SEL [LWDS (CI)] is used to receive liquid waste; one is used to mix, sample and analyse, or monitor and discharge liquid waste; one is on standby. There is one sampling point on the recirculation line of each liquid waste storage tank, which is presented in F-23.6-4. The liquid waste in the storage tank is mixed through recirculation before sampling is performed. 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 detect the radioactive level of the liquid waste. If the radioactivity of the liquid waste exceeds the discharge management objective, the monitoring system will send out alarms 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 for detailed laboratory analysis and record maintenance.

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

b) Plant Accident Conditions

Not applicable.

23.6.6.4 Preliminary 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 counting of liquid waste released into the environment, so 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 to detect, locate and quantify for 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.

The details about categorisation and classification are presented in Reference [44].

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. The methodology and analysis of the fail-safe design in the SEL [LWDS (CI)] is presented in the Reference [43]. According to the analysis, the fail-safe is adopted in the design of the valves on the pipes that penetrate through the retention pit to ensure the confinement of radioactive liquid waste. The fail-safe is also adopted in the design of the control valve on the discharge line to avoid the unexpected discharge.

5) Human factors

Human factors are integrated in the design of SEL [LWDS (CI)] by developing appropriate system control functional requirements, considering application of the design measures described in Sub-chapter 23.2.5. Detailed information about automatic control design of the system is presented in Reference [45].

6) Equipment qualification

The components that are designed to withstand SSE (valves categorised as SSE2) are identified to be seismic qualified in order to ensure the functionality.

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 state of electric and pneumatic isolation valves, electric control valves, important manual isolation valves and pumps of TER [NLWDS] are under surveillance.

- Maintenance

  Equipment maintenance will be carried out according to equipment operation and maintenance manual which will be developed by equipment manufacturers at site licensing stage.

- Inspection

  The system components are designed to ensure that their appearance, function performance, noise of abnormal level or minor leakage can be detected by visual inspection.

- Periodic tests

  Reference [31] presents the periodic test design method for the UK HPR1000. By following this method, preliminary requirements of periodic tests for radioactive waste management are presented in Reference [32] which indicates that periodic test is not required for SEL [LWDS (CI)].

c) Protection Design against Internal and External Hazards

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

The detailed design of specific hazards protection design is presented in Reference [45].

d) Commissioning

By following the commissioning test requirements presented in Reference [8], commissioning tests will be performed to verify the functionality of the SEL [LWDS (CI)] at the site licensing stage, including tests of system flushing, discharge, valves, simulation measurement and control channel, logic control channel, pumps and tanks.

e) Decommissioning

Facilitating decommissioning is considered in the design of SEL [LWDS (CI)] by applying the design measures described in Sub-chapter 23.2.5. Detailed information is presented in Reference [44].

f) Material Selection

The material of the liquid waste storage tanks, the liquid waste discharge pumps, sump pumps, pipes and valves is stainless steel in order to limit corrosion.

g) Conventional Health and Safety

Conventional health and safety is considered in the design of SEL [LWDS (CI)] by analysing the relevant risks and recorded in the DRR, as presented in Sub-chapter 23.2.5.

23.6.7 System Flow Diagrams

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

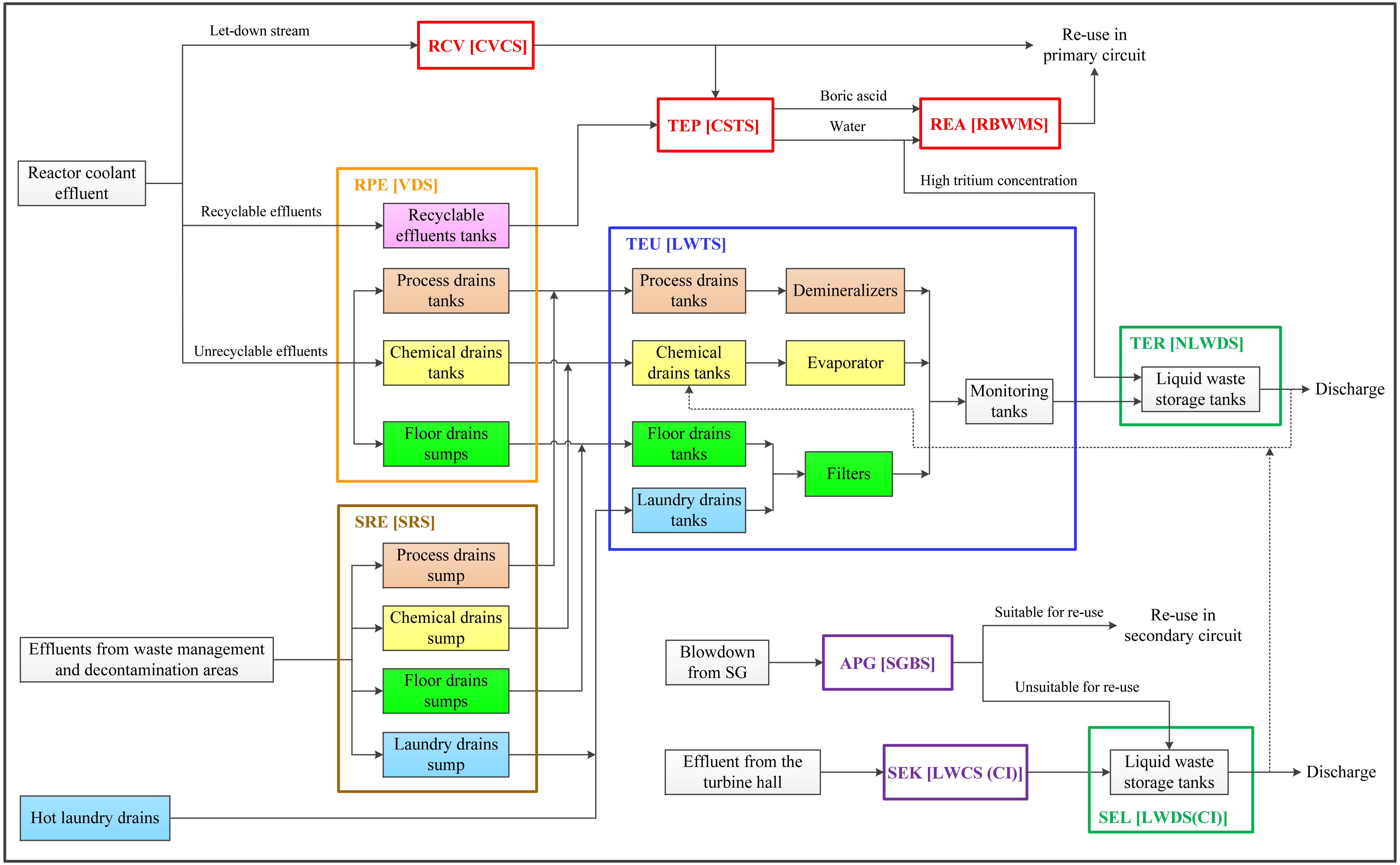
F-23.6-2 Nuclear Island Vent and Drain System (RPE [VDS])

F-23.6-3 Liquid Waste Treatment System (TEU [LWTS])

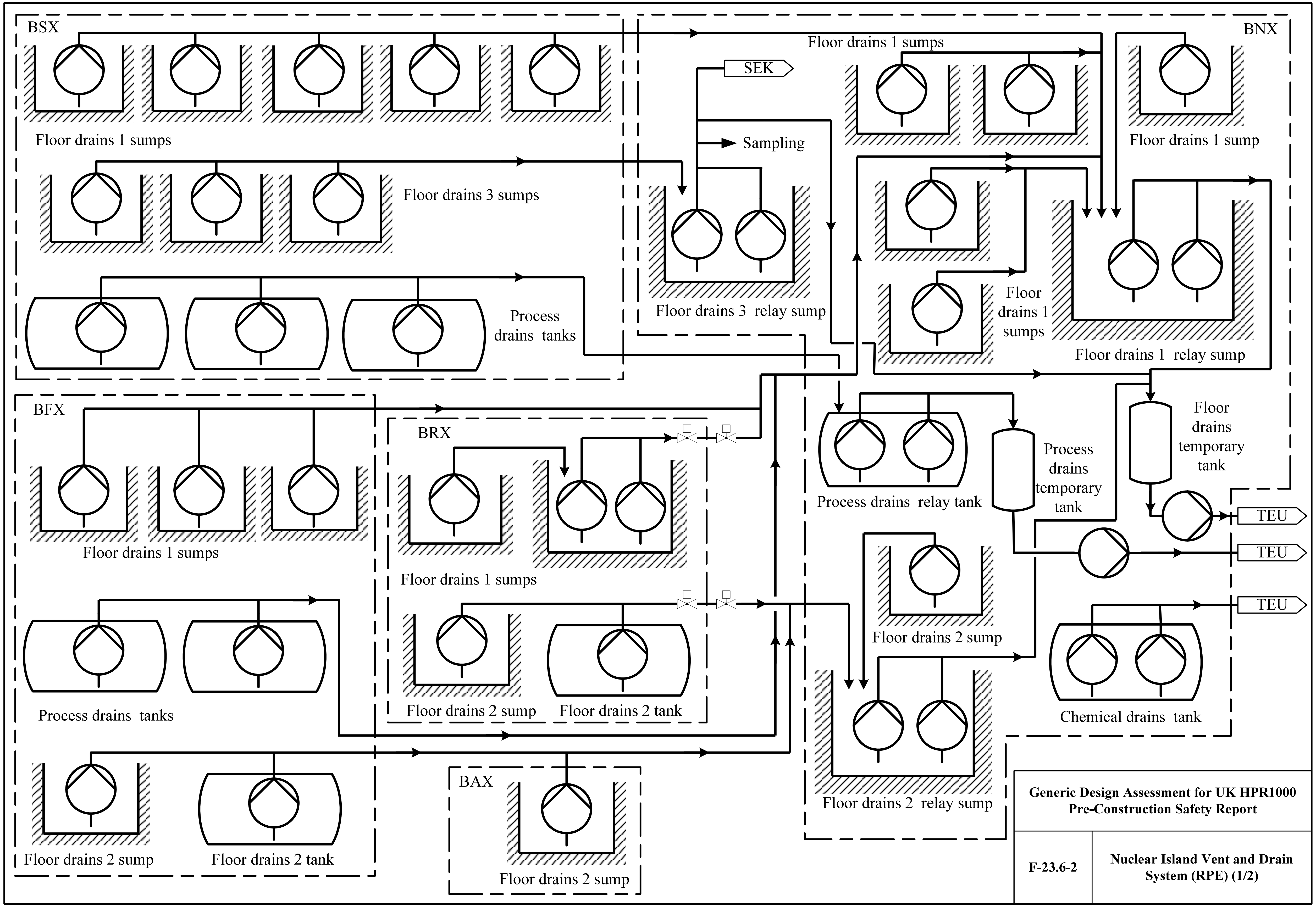
F-23.6-4 Nuclear Island Liquid Waste Discharge System (TER [NLWDS]) and Conventional Island Liquid waste Discharge System (SEL[LWDS (CI)])

F-23.6-5 Sewerage Recovery System (SRE [SRS])

These flow diagrams are high level and provided to help understanding the system configuration. They are simplified by removing much detailed information from the flow diagrams in the System Design Manual (SDM) Chapter 9 for understanding easily.

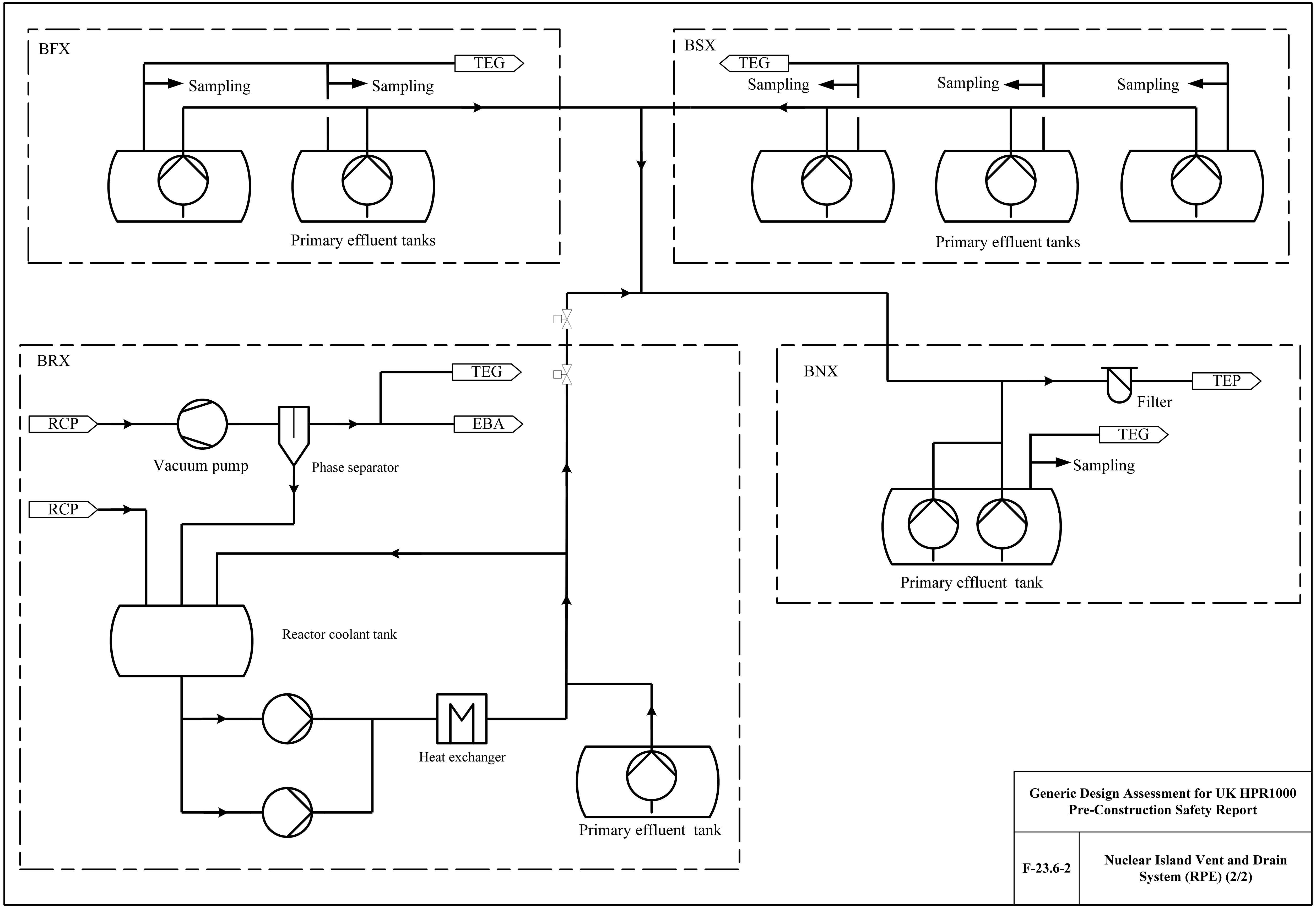


F-23.6-1 Liquid Radioactive Waste Effluent Streams

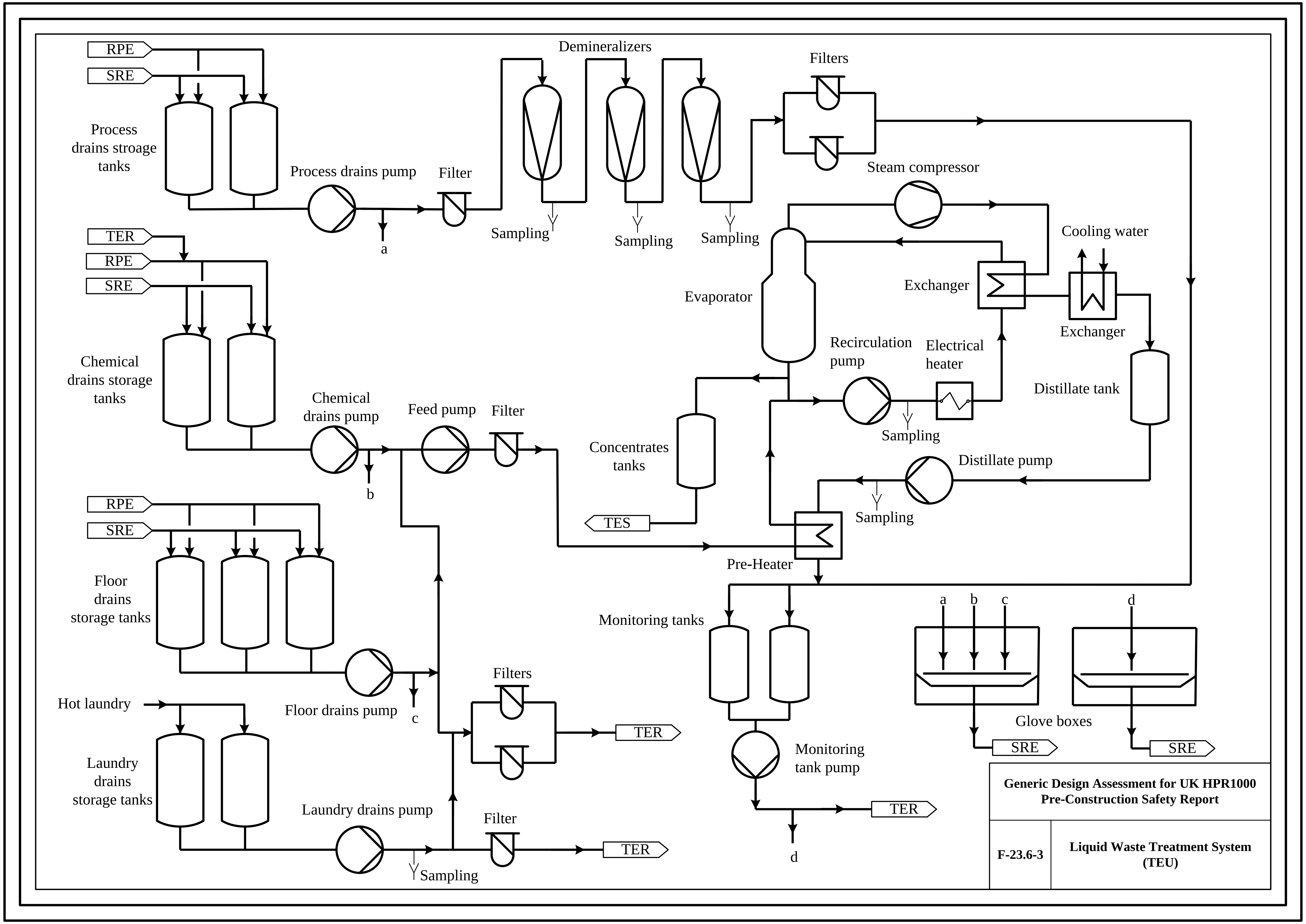


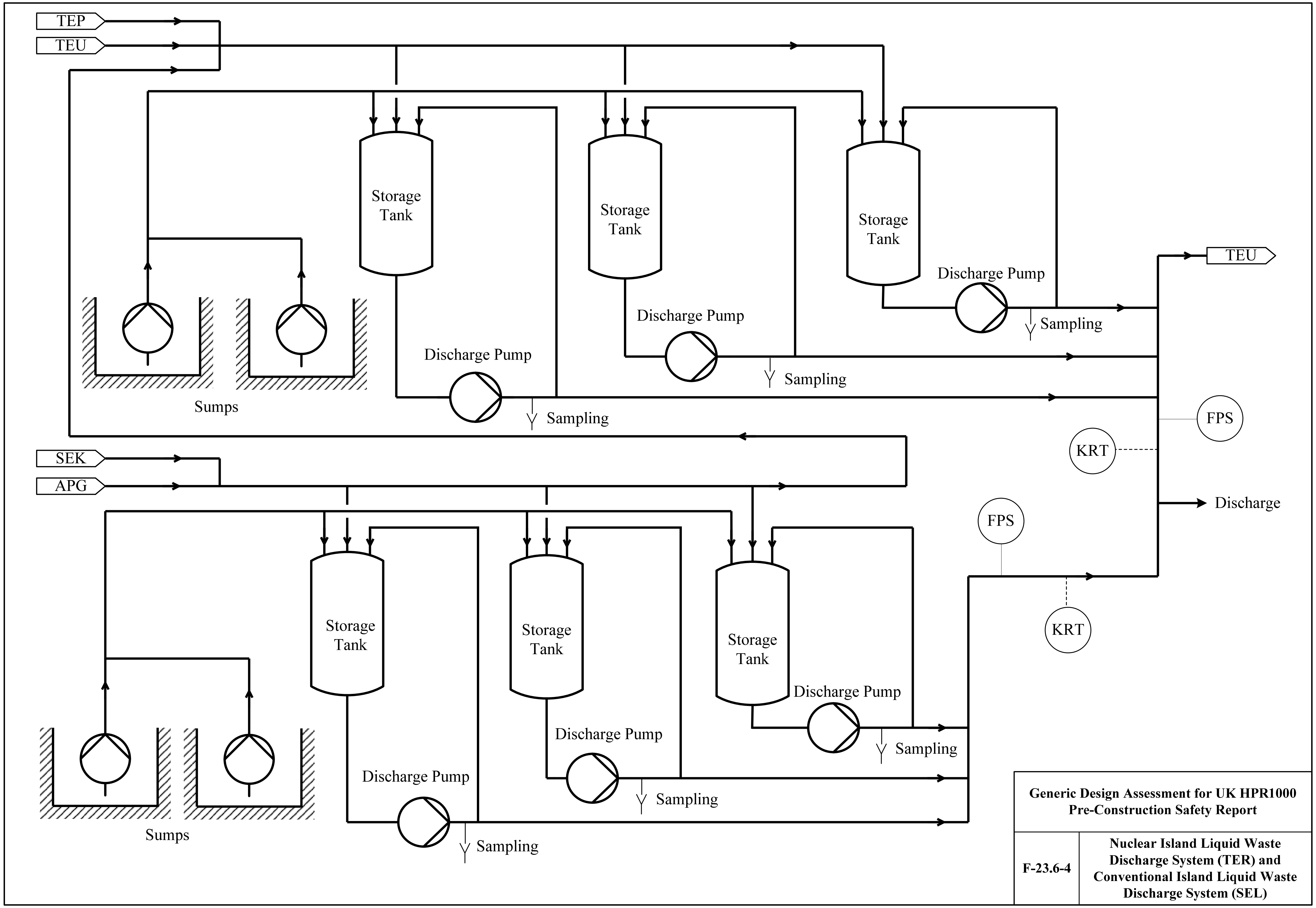
Generic Design Assessment for UK HPR1000 Pre-Construction Safety Report

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

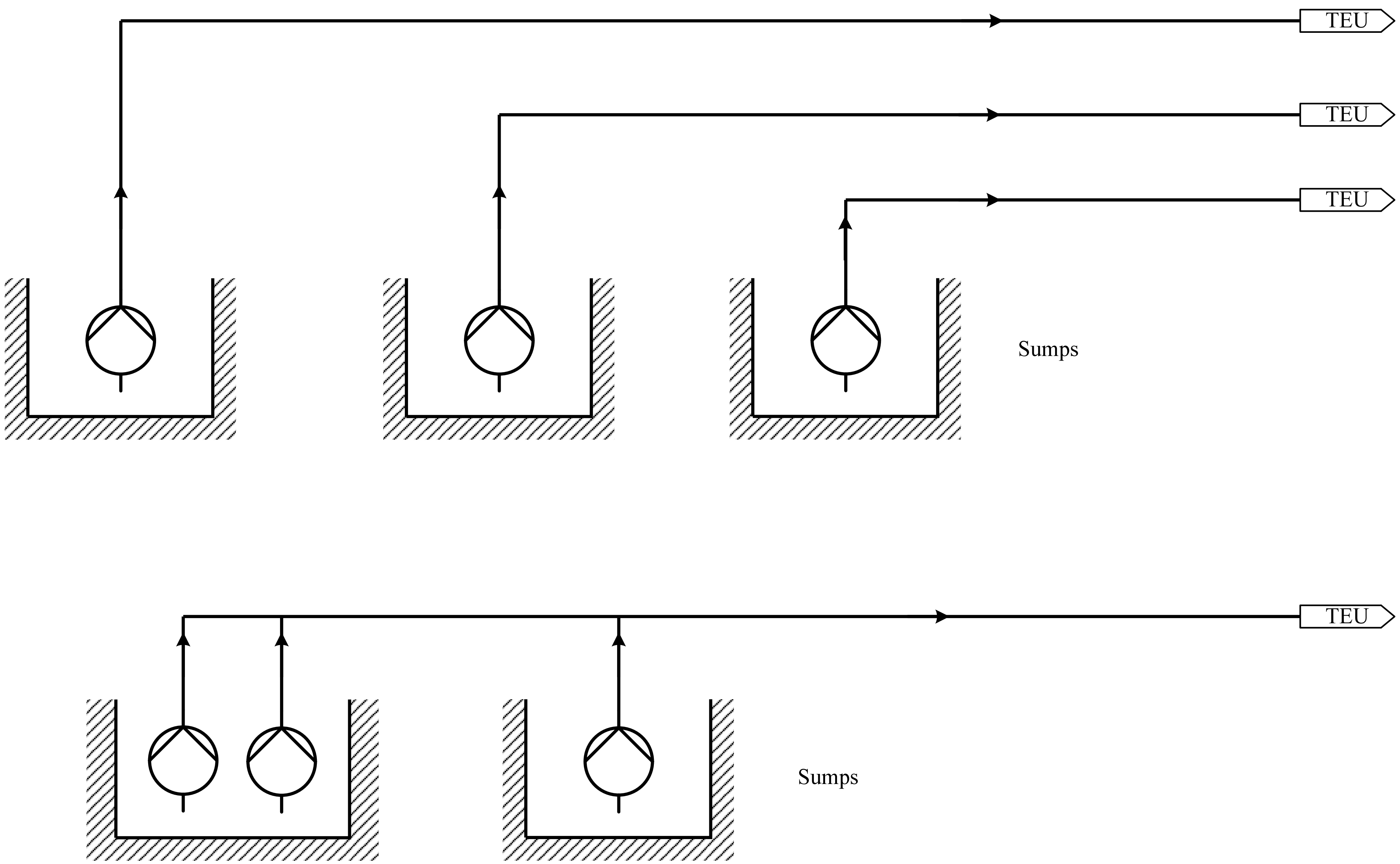


Generic Design Assessment for UK HPR1000 Pre-Construction Safety Report	
F-23.6-2	Nuclear Island Vent and Drain System (RPE) (2/2)


RPE
SRE
Process drains stroage tanks
Process drains pump
Filter
a
Demineralizers
Sampling
Sampling
Sampling
Filters
Steam compressor
TER
RPE
SRE
Chemical drains storage tanks
Chemical drains pump
b
Feed pump
Filter
Evaporator
Exchanger
Cooling water
Exchanger
Recirculation pump
Electrical heater
Sampling
Distillate tank
Concentrates tanks
Distillate pump
Sampling
TES
Pre-Heater
RPE
SRE
Floor drains storage tanks
Floor drains pump
c
Monitoring tanks
a
b
c
d
Glove boxes
SRE
SRE
Filters
TER
Hot laundry
Laundry drains storage tanks
Laundry drains pump
Sampling
Filter
TER
Monitoring tank pump
TER
d
Generic Design Assessment for UK HPR1000 Pre-Construction Safety Report
F-23.6-3
Liquid Waste Treatment System (TEU)



Generic Design Assessment for UK HPR1000 Pre-Construction Safety Report	
F-23.6-4	Nuclear Island Liquid Waste Discharge System (TER) and Conventional Island Liquid Waste Discharge System (SEL)



Generic Design Assessment for UK HPR1000 Pre-Construction Safety Report	
F-23.6-5	**Sewage Recovery System (SRE)**

23.7 Gaseous Radioactive Waste Management

23.7.1 Gaseous Radioactive Waste Management Strategy

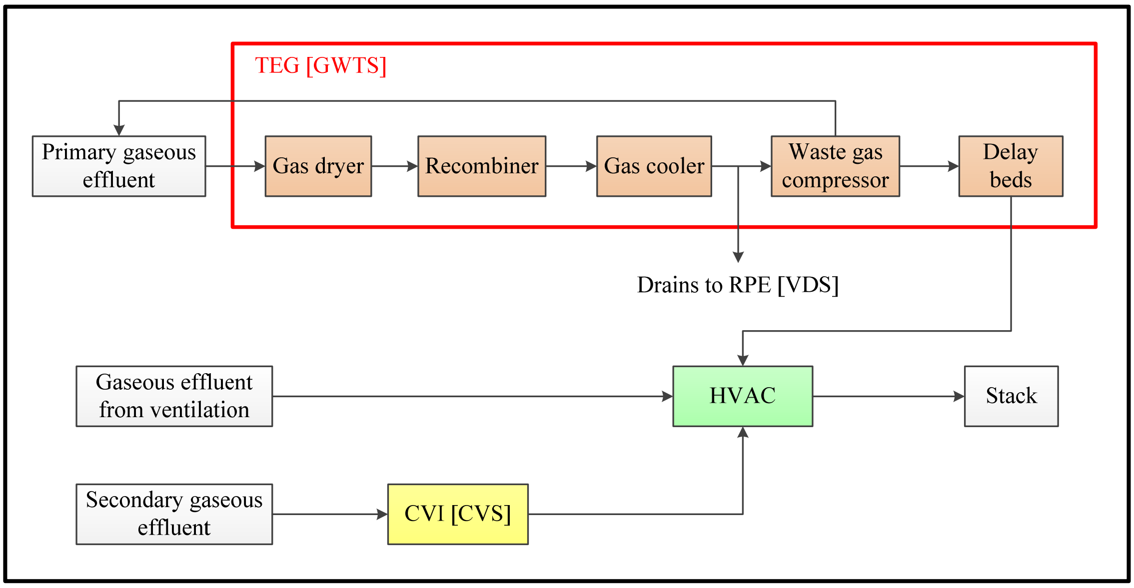
Gaseous radioactive waste generated unavoidably during the operation of the UK HPR1000 is divided into three categories:

a) Primary gaseous effluent;

b) Gaseous effluent from ventilation; and

c) 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 Chapter 6, Sub-chapter 6.6, Reference [26].



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 little radioactive gases released to the environment through the delay beds. During steady state operation, the TEG [GWTS] operates continuously to flush the vessels and tanks with nitrogen to remove the hydrogen and oxygen. 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 [GWTS] are fission products such as krypton, xenon and iodine which (most of item) 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 this 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 of the gases.

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

23.7.1.2 Gaseous Effluent from Ventilation

Air from the working areas, SF storage pool, and reactor toroidal area is collected by the Heating, Ventilation and Air Conditioning (HVAC) systems. HEPA and iodine traps are arranged to remove the particulate matter 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 will include radionuclides in the event of a steam generator leak) are removed by the Condensate Vacuum System (CVI [CVS]) and routed to the DWN [NABVS]. Once again, the gases will be treated by HEPA and iodine traps if needed, monitored, and discharged to the environment via the main stack.

The CVI [CVS] is not included within the scope of the GDA, Reference [28]. The TEG [GWTS] is presented in Sub-chapter 23.7.2.

23.7.1.4 Generation of Solid Waste

Delay beds are used in TEG [GWTS] to treat gaseous waste. However, the activated charcoal in the delay beds is designed to last for 60 years without replacement and therefore no waste is generated during operation. The spent activated charcoal generated from delay beds after 60 years operation will be managed as decommissioning waste.

Spent ventilation filter cartridges and waste charcoal (from iodine absorbers) are unavoidably generated from the HVAC systems, although they are minimised at source through optimisation of the systems using them. The information on these waste and their management strategy are presented in Sub-chapter 23.8.

23.7.2 Gaseous Waste Treatment System (TEG [GWTS])

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 as follows:

1) During the accident condition, the containment isolation valves of TEG [GWTS] are closed according to safety signals or manually;

2) TEG [GWTS] stores and transfers gaseous radioactive waste, so it is designed to prevent gaseous radioactive waste escaping from the equipment and connecting.

b) 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 include:

a) Radionuclides in the reactor coolant that are generated by corrosion, activation and fission reaction (during fuel cladding failure, the fission products 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 will be released to the gas phase in the reactor coolant containers and tanks when pressure reduces or there is fluid exchange. These gases become gaseous wastes which are named primary effluent.

The composition of the primary effluent include small amount of hydrogen, 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] performs 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 flammability limits;

b) Prevent radioactive gases from 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 flow rates 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

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

23.7.2.3.1 System Description

Following the development of the engineering aspects, the optioneering of gaseous waste processing technique has been undertaken and are presented in *Optioneering Report for Gaseous Radioactive Waste Processing Technique*, Reference [46]. The potential options from worldwide OPEX are identified and assessed against the assessment criteria considering the safety aspects and environment impacts. For the purpose of GDA, the activated carbon delay bed processing technique is determined. It is noted that the future operator will determine the final optimum processing technique for gaseous radioactive waste and demonstrate that such proposals represent BAT and ALARP.

Based on the operational functional requirements and selected processing technique for gaseous radioactive waste, the following design principles are required to be 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%;

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 will be sounded 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 provide enough delay time for the radioactive noble gases. The volume and activity 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 is required to facilitate the flow of flushing gases and condensate water.

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.

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 gases by continuous flushing, maintains the hydrogen/oxygen concentration and prevents gas released to the building. 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

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 the gaseous radioactive waste to Nuclear Auxiliary Building Ventilation System (DWN [NABVS]). The sizing of activated charcoal delay beds is presented in Reference [47].

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

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 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 of gases discharged to DWN [NABVS]. If the radioactivity 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 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 are used with low leakage, which shall be 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.

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 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, and keep 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, and adjust 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.

Detailed information of the equipment is presented in Reference [48].

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 Generate Effluents

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

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

DWN [NABVS] system is required to discharge the gaseous waste treated by TEG [GWTS] to the environment.

c) RPE [VDS]

RPE [VDS] system is required to collect 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].

Detailed information of the system interfaces is presented in Reference [48].

23.7.2.3.5 System Operation

a) Plant Normal Condition

TEG [GWTS] shall operate under normal operations 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. However, it shall be ensured that the concentration of hydrogen and oxygen in the flushing gas and the equipment to be flushed is 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 recombined.

The gas is cooled and the vapour is condensed in the gas cooler downstream 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 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 level that is so far as is reasonably practicable.

2) Surge Gas Operation Mode

When large amount of excess gas enters TEG [GWTS], it can be switched to the surge 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 will result in the change of the total gas space volume;

- After reactor shutdown, the water level reduction of the RCP [RCS] will result 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 will result in the release of gas to TEG [GWTS], and the excessive gas will be 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.

This time is sufficient for the radioactive noble gases to achieve the required decay time in the delay unit. 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 Preliminary Design Substantiation

23.7.2.4.1 Compliance with Safety Functional Requirements

a) Control of Reactivity

Not applicable.

b) Removal of Heat

Not applicable.

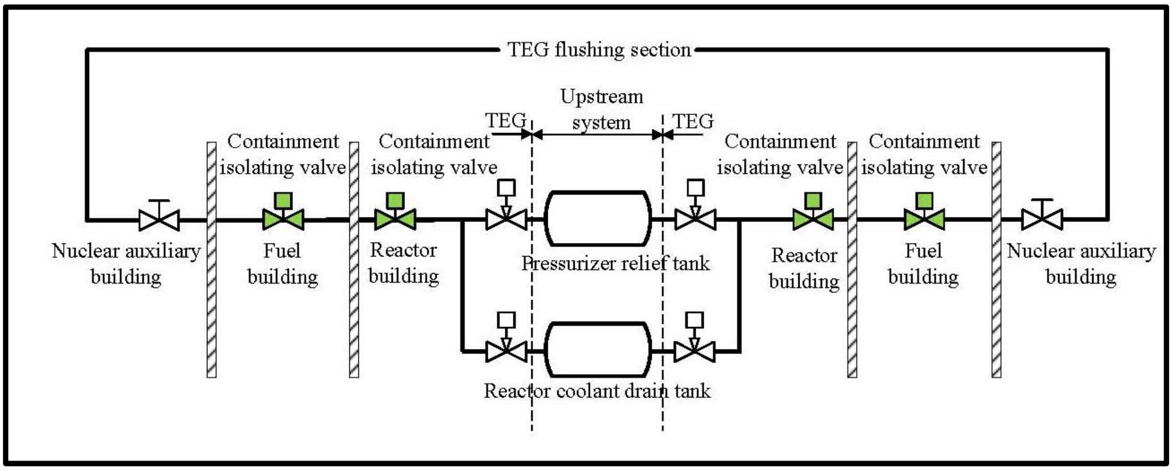
c) Confinement

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.

The details of safety classification are presented in Reference [49].

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

Component	Safety Classification	Design Provision Category	Design Provision Class	Seismic Category
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. Two redundant containment isolation valves installed in the same line are supplied by two different power suppliers.

4) Fail-safe

The fail-safe concept is considered in the TEG [GWTS] design process. The methodology and analysis of the fail-safe design in the TEG [GWTS] is presented in the Reference [48]. According to the analysis, other measures such as redundancy are used to improve the safety of the power plant and avoid potential safety concerns or safety risk that may be introduced by the ‘fail-safe’ design on the power plant.

5) Human factors

Human factors are integrated in the design of TEG [GWTS] by developing appropriate system control functional requirements, considering application of the design measures described in Sub-chapter 23.2.5. Detailed information about automatic control design of the system is presented in Reference [50].

6) Equipment qualification

The components that are designed to withstand SSE are identified to be seismic qualified in order to ensure the functionality, including containment isolation valves that are categorised as SSE1 and valves that are categorised as SSE2.

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

  Necessary instruments are designed in TEG [GWTS], which can survey the status and parameters of the system.

- Maintenance

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

  The preventive maintenance of other equipment is performed according to the equipment operating and maintenance manual at site licensing stage.

- Inspection

  The delay beds, silica gel dryer, recombiner, tanks and important valves that require pre-service inspection are identified in the pre-service inspection list of TEG [GWTS].

- Periodic tests

Reference [31] presents the periodic test design method for the UK HPR1000. By following this method, preliminary requirements of periodic tests for radioactive waste management are presented in Reference [32]. The containment isolation valves in TEG [GWTS] need periodic tests to verify the manoeuvrability and tightness. The equipment function in the other parts of TEG [GWTS] can be verified by operating routine checks and preventative maintenance.

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 reactor building, the fuel building and the safety buildings and the hydrogen supply pipelines of TEG [GWTS] are required to be protected from the earthquakes.

The details about protection against internal and external hazards are presented in Reference [50].

d) Commissioning

By following the commissioning test requirements presented in Reference [8], commissioning tests will be performed to verify the functionality of the TEG [GWTS] at the site licensing stage, 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

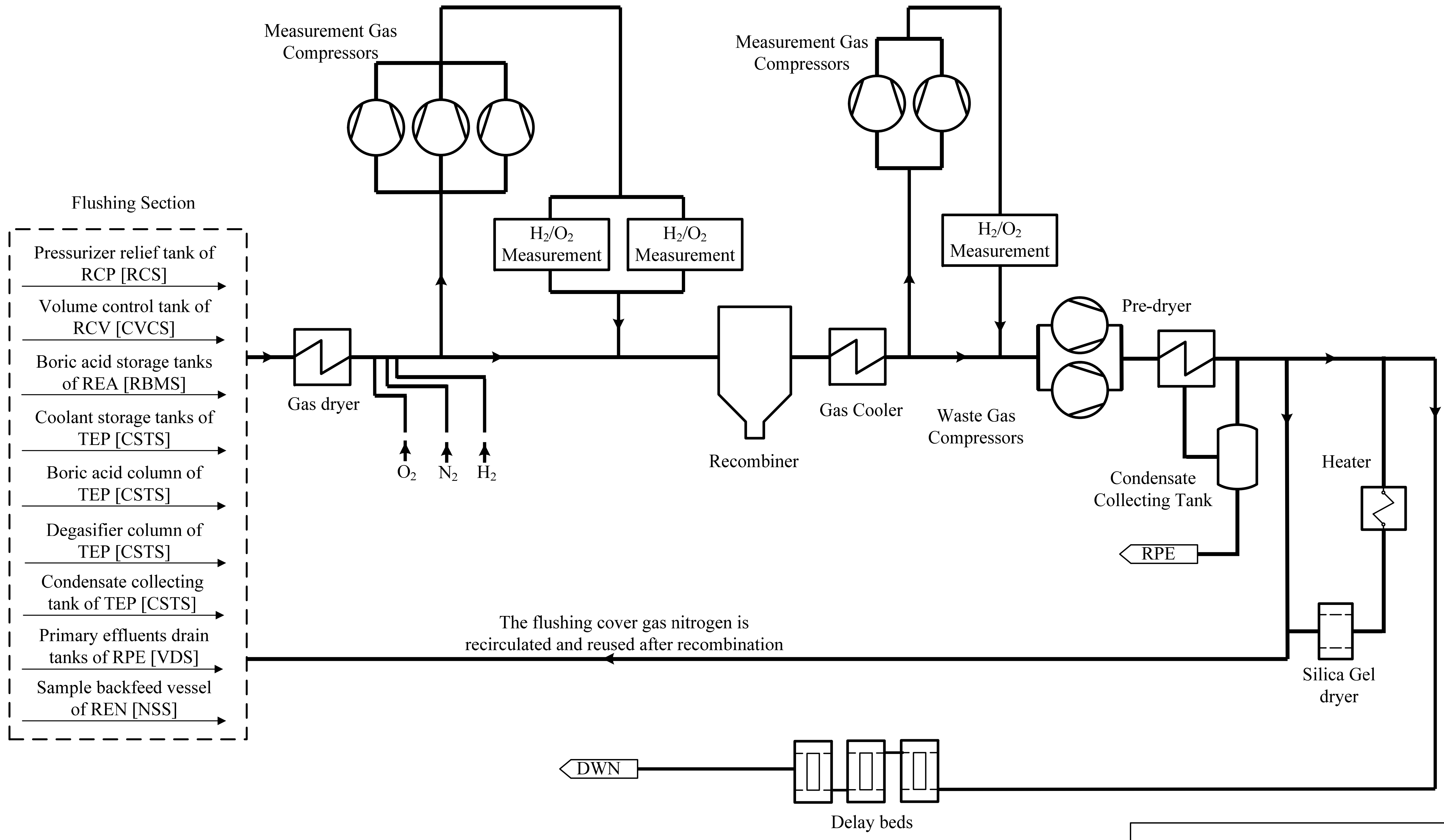
Facilitating decommissioning is considered in the design of TEG [GWTS] by applying the design measures described in Sub-chapter 23.2.5. Detailed information is presented in Reference [49].

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 analysing the relevant risks and recorded in the DRR, as presented in Sub-chapter 23.2.5.



Generic Design Assessment for UK HPR1000 Pre-Construction Safety Report	
F-23.7-2	**Gaseous Waste Treatment System (TEG)**

23.8 Solid Radioactive Waste Management

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

a) Waste, which is associated with generating power, results from treating fluids, such as coolant, liquid waste and gaseous waste;

b) Waste results from maintenance; and

c) Waste from core components.

NALW is excluded from the liquid radioactive waste treatment and requires export from site to off-site facility if appropriate management route is available. Its management is therefore considered alongside solid radioactive waste.

Optimal disposal routes are significantly beneficial to minimise the accumulation of unavoidable radioactive waste and reduce the on-site radiological risks. A range of off-site waste treatment and disposal services are available in the UK and expected to evolve as technology develops over time. The design of the UK HPR1000 takes account of these services and provides a range of facilities and equipment to undertaken the characterisation, sorting, treatment, and storage of waste prior to it being transferred to an off-site waste management facility. This will allow a future operator to select optimal waste disposal routes to minimise the accumulation of radioactive waste and on-site storage.

The Solid Waste Treatment System (TES [SWTS]) is responsible for the management of solid radioactive waste and NALW in the UK HPR1000.

23.8.1 Waste Arising

The OPEX from the Pressurised Water Reactor (PWR) fleets in China is used in the development of the UK HPR1000 solid waste inventory (i.e. volumes and radiochemical, chemical, physical characteristics). When comparing to legacy waste that exist in the UK, Reference [51], no novel waste is planned to be generated in the UK HPR1000, which would challenge the waste disposability case. The solid waste and NALW, which are 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 [52].

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 (DAW)	Contaminated personal protection equipment, monitoring swabs, plastic, clothing, contaminated tools, waste charcoal generated from iodine absorbers in HVAC systems, etc.	ILW/LLW
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, such as maintenance of pumps and hydraulic equipment, decontamination of Reactor Pressure Vessel bolts.	LLW/VLLW
8	Organic solvent	Arising in normal operations, such as maintenance of pumps and hydraulic equipment, decontamination of Reactor Pressure Vessel bolts.	LLW/VLLW
9	Ventilation filter cartridges	Arising from the ventilation systems located in the BNX, BFX, BSX, BRX and BWX.	LLW

No.	Title	Description	Category
10	NFCCs	In-core Instrumentation Assemblies (ICIAs), arising from reactor core, using for measuring water level, temperature and neutron in the reactor core.	HLW/ILW
		Rod Cluster Control Assemblies (RCCAs) and Stationary Core Component Assemblies (SCCAs) activated in the reactor core.	HLW/ILW

23.8.2 Segregation and Characterisation

Characterisation and segregation are 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 activity 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 of 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 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 site licensing stage. The details of sampling, monitoring and measurement for solid waste and NALW in the UK HPR1000 are presented in PCER Chapter 5 Sub-chapter 5.5, Reference [53].

23.8.3 Solid Waste Treatment System (TES [SWTS])

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.

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 radioactivity produces, Reference [23].

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.

TES [SWTS] performs 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 the tanks or containers for decay or awaiting processing if and when required;

c) Processing of operational solid radioactive waste and NALW by appropriate techniques;

d) Buffer storage of LLW packages before transfer for off-site processing;

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 to facilitate transportation and disposal.

Based on the operational function requirements, the following design principles of TES [SWTS] are required to be 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 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 and retention of radioactive waste (e.g. spent resins);

i) The pressure component and pipelines are mainly connected by weld to minimise leaks; and

j) TES [SWTS] is designed to prevent radioactive liquid and gas generated during processing solid waste from being directly released to the environment.

23.8.3.3 System Description and Operation

23.8.3.3.1 System Description

TES [SWTS] is mainly divided into the following parts:

a) DAW Treatment Subsystem

The DAW is characterised and collected at source based on the contamination level, and the active waste and non-active waste are segregated to reduce the volume of DAW. The 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 and packaging to facilitate subsequent management. To achieve the best use of existing off-site infrastructure services in the UK, including metal melting, incineration, super-compaction and disposal services, an optioneering study for the management of DAW has been undertaken and presented in the *Optioneering Report for Operational Solid Waste Processing Techniques*, Reference [54]. By following the outcomes from the optioneering study, the DAW is segregated into mental waste, combustible waste, non-combustible and compactible waste, non-combustible and non-compactible waste for further management by taking into account the best use of off-site infrastructures in the generic design of the UK HPR1000.

Pre-treatment facilities for the ventilation filter cartridges are provided in the BQS to dismantle them, facilitating the subsequent treatment.

b) Spent Resins Flushing and Storage Subsystem

The spent resins generated from RCV [CVCS], PTR [FPCTS] and TEP [CSTS] demineralisers are flushed into two spent resin tanks located in the BNX. The tanks are sized to provide sufficient capacity for spent resin storage, Reference [55]. After storage for a period of time, spent resins are transferred to another set of two storage tanks located in the BWX for further treatment or conditioning.

The spent resins from the APG [SGBS] demineralisers with low activity are flushed by the demineralised water into the low activity spent resin separation tank for dewatering. After dewatering, spent resins are loaded by the vacuum suction device into the 210 litre drums.

Under special conditions (such as the steam generator tube rupture), the spent resins with higher radioactivity generated from the APG [SGBS] demineralisers are flushed into the spent resin tanks in the BNX and treated as radioactive spent resins.

c) Spent Filter Cartridge Changing Subsystem

A spent filter cartridge changing machine, which is located in the BNX, is used to replace the spent filter cartridges in RCV [CVCS], PTR [FPCTS], TEP [CSTS] and RPE [VDS] with new ones automatically. Another spent filter cartridge replacement and transfer device, which is located in the BWX, is used to remove the spent filter cartridges in TEU [LWTS]. The dose rate of the removed cartridge is monitored to segregate ILW and LLW cartridge and decide whether it will need to be loaded into a shielding cask or 210 drum.

The two devices are designed to provide shielding and remote control to reduce the dose to operators.

d) Wet-solid Waste Receipt and Treatment Subsystem

The wet-solid waste receipt and treatment subsystem is design to receive, temporarily store and treat or condition wet-solid waste, such as radioactive spent resins, spent filter cartridges concentrate and sludge. The optimal management of radioactive spent resins has been undertaken in the generic design of the UK HPR1000 and detailed in the *Optioneering Report for Operational Solid Waste Processing Techniques*, Reference [54].

The main functions of this subsystem are as follows:

1) Receipt and temporary storage of the radioactive spent resins from TEU [LWTS] demineralisers in the BWX and spent resin tanks in the BNX;

2) Receipt and temporary storage of the ILW spent filter cartridges;

3) Package and dewatering of radioactive spent resins into 500 litre robust shielded drums (e.g. Mosaik container);

4) Encapsulation of concentrates and sludge in 210 drums; and

5) Encapsulation of the spent filter cartridges in 3 cubic metre boxes with cement grout.

e) NALW Management

By following the optioneering study undertaken in the generic design of the UK HPR1000 and presented in the *Optioneering Report for Operational Solid Waste Processing Techniques*, Reference [54], the oil and solvent generated from maintenance and decontamination activities are segregated and collected into different liquid 210 litre drums according to the radiological and chemical properties. The waste drums will be sealed and stored in the BQS before being transported to off-site infrastructures for incineration.

f) NFCC Waste Management

NFCC waste consists typically of activated metal components used inside the nuclear reactor core that have been subjected to irradiation or exposure to intense neutron flux, and includes ICIAs, RCCAs and SCCAs. The management strategy of NFCCs has been developed in the generic design of the UK HPR1000 through an optioneering process and detailed in the *Management Proposal of Waste Non-Fuel Core Components*, Reference [56].

RCCAs and SCCAs are co-stored with spent fuel in the spent fuel pool for decay and then packaged together with the spent fuel in the HLW disposal containers. The packages will be stored in the Spent Fuel Interim Storage Facility (BQF) prior to disposal at the GDF.

A winding machine is used to extract ICIAs from the Reactor Pressure Vessel (RPV) and bundle them up. The bundles of ICIAs are then loaded and packaged in 500 litre robust shielded drums. These packages will be stored on-site prior to final disposal at GDF. The winding machine and the disposal container provide sufficient shielding to reduce the dose to operators.

23.8.3.3.2 Equipment Description

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

a) Spent Resin Tanks

There are four spent resin tanks which are made of stainless steel. Two of them are located in the BNX and the other two are located in the BWX. Adequate venting and overflow capacities are provided to prevent the tanks from overpressure and to reduce the radiological risks to workers.

b) Low activity resin separation tank

The low activity resin separation tank is located in the BNX. It is used to receive, temporarily store and dehydrate the spent resins with low activity generated from APG [SGBS].

c) Spent Filter Cartridge Changing Machine

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

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 is designed as a bell with shielding material.

d) Spent Resin Metering Tank

The spent resin metering tank is manufactured from stainless steel and is located in the BWX.

This tank is designed to dewater and measure the quantity of the resin to be encapsulated in each waste container and transfer the measured spent resin into waste containers.

e) 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 quantity of concentrates from TEU [LWTS] to be transferred to waste containers for cement in-drum mixing.

f) Encapsulation Facility

The encapsulation facility is located in the BWX, and is designed to encapsulate the concentrate, sludge and ILW filter cartridges in the waste container by the encapsulation processing. It is equipped with in-drum mixer, lidding robotic manipulator, filter cartridge retrieval device, transfer trolley, transfer rollers and shielded doors.

The encapsulation facility is remotely operated to protect workers. Shielded doors are provided in this facility 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.

g) Mobile Grouting Device

The mobile grouting device is used to treat spent filter cartridges. 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.

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

The sorting box is provided with three sorting positions and one dumping position, allowing four workers to work simultaneously.

Detailed information of the equipment is presented in Reference [57].

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] is required to flush 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].

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.

23.8.3.3.4 System Operation

a) Plant Normal Condition

1) Processing of ILW spent resins

ILW resins generated from the demineralisers in the BNX are flushed into one of two spent resin tanks by the spent resin flush pump. Usually, resins can be temporarily stored in the tanks for a few years to reduce the radioactivity and then transferred to the BWX for treatment. The resins generated from the demineralisers in TEU [LWTS] are flushed into the spent resin storage tanks in the BWX for treatment.

The resins stored in the spent resin storage tanks can be sampled from the recirculation lines to characterise the resins. After sampling, the resins will be discharged into the spent resin metering tank for dewatering and measuring the weighted and the volume. The measured resins are discharged by gravity into 500 litre robust shielded drums (e.g. Mosaik container) where they are de-watered to reduce the ‘free water’ content and meet the target of less than 1% by volume. Finally, the waste packages are transferred to the BQZ for storage.

2) Processing of LLW resins

The LLW spent resins generated from APG [SGBS] demineralisers under normal condition are usually discharged into low activity spent resin separation tank, and then transferred by the vacuum pump device into 210 litre drums for buffer storage in the BQS prior to treatment or disposal off-site.

3) Processing of concentrates

The concentrates generated from TEU [LWTS] evaporator are sampled to measure their radioactivity and also the boron and chloride concentration. When appropriate for processing, the concentrates are discharged into the 210 litre drums after metered in a concentrate metering tank in TES [SWTS]. The 210 litre drums with concentrates are transferred 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 produce the encapsulated waste form, and the waste packages are then sealed and cured on site for several days before transfer to the storage facility.

Waste packages produced from LLW concentrates 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 allowed being transported to off-site disposal facility when they decay to LLW.

4) Processing of spent filter cartridges

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 replaced. When a filter cartridge is lifted out, its surface dose rate is measured to enable its segregation into two categories and facilitate its subsequent management.

LLW filter cartridge is loaded into 210 litre drums and then transferred to the BQS for storage before dispatch to off-site treatment infrastructures.

The 3 cubic metre box is used for ILW spent filter cartridges waste packages. The buffer storage area for spent filter cartridges is provided with sufficient capacity to store the anticipated annual waste volume. This approach allows for different dose rate cartridges to be loaded into one box and reduces the risk of producing out of specification waste packages.

5) Processing of DAW

The DAW is firstly characterised and collected into different colour bags at source based on contamination levels, so the active waste and non-active waste are segregated to reduce the volume of DAW. The DAW is sent to the BQS for further segregation as metallic waste, combustible waste, non-combustible and compactible waste, non-combustible and non-compactible waste. The DAW will be dried firstly in the BQS if containing free liquid. The drums are then transferred to the sorting box for further sorting. Large size waste will be size reduced before loading into containers. After segregation, different types of the DAW are packaged into different containers before being transported to off-site infrastructures. The containers considered for DAW in the generic design of the UK HPR1000 are:

- The metal waste is loaded into metallic box (e.g. Berglof box);
- The combustible waste is loaded into solid 210 litre drums;
- The non-combustible and compactible waste is loaded into super-compactible 210 litre drums;
- The non-combustible and non-compactible waste (such as contaminated concrete) is loaded into 210 litre drums directly for encapsulation by a cement grouting device;
- If the DAW is identified as ILW/LLW boundary waste, they will be packaged into 210 litre drums with shielding cask and then be transferred to BQZ for decay storage. After the boundary waste has decayed to LLW, it will be retrieved out of the drums and re-segregated to facilitate off-site processing.

6) Processing of ICIAs

When removing from the RPV, the ICIAs are dismantled by cutting the protecting parts. These protecting parts are expected to be LLW and will be treated as such. A winding machine (not in TES [SWTS]) with sufficient shielding is then used to extract them from the RPV and bundle them up. The winding machine is then lifted by crane to release the bundles of ICIAs into 500 litre robust shielded drums without encapsulation. The 500 litre robust shielded drums reduce dose rates sufficiently to allow the waste to be transferred out of the reactor building for interim storage.

Waste packages produced from ILW ICIAs are transferred to the BQZ for interim storage prior to final disposal at GDF. Waste packages produced from HLW ICIAs are transferred to the BQF for a reasonable storage period and are allowed transfer to the BQZ for interim storage when they decay to ILW.

7) Processing of RCCAs and SCCAs

The spent RCCAs and SCCAs are removed together with the fuel assemblies and co-stored with the spent fuel to decay in the spent fuel pool for a given period time. They are then packaged together with the spent fuel and stored in the BQF prior to disposal at GDF.

8) Processing of sludge

The sludge is collected in drums and encapsulated with cement. Waste packages produced from LLW sludge 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 allowed being transported to off-site disposal facility when they decay to LLW.

9) Processing of NALW

The NALW, i.e. oil and solvent generated from maintenance and decontamination activities, is collected into 210 litre liquid drums separately based on the radiation level. The waste drums are then sealed and temporarily stored in the BQS prior to transport to off-site infrastructures for incineration.

10) Processing of ventilation filter cartridge

The ventilation filter cartridges are further segregated by dismantling in the BQS. The frames and sieves are loaded into 210 litre drums and temporarily stored prior to super-compaction or disposal off-site. The charcoal waste is loaded into 210 litre drums and managed as combustible waste.

11) LLW Buffer Store

The LLW and VLLW waste packages, including conditioned LLW waste packages, metal waste packages, combustible waste packages, super-compactable waste packages, oil and solvent packages, low activity spent resin packages and ventilation filter waste packages, are temporarily stored in the BQS prior to dispatch to off-site waste service facilities. The BQS provides several storage areas for different types of containers and boxes, such as the metallic box storage area, the 210 litre drum LLW storage area and the 210 litre drum VLLW storage area. Although waste is to be disposed of as soon as reasonably practicable after production to minimise the accumulation, sufficient space is provided for storage of waste generated in approximately one year. A sketch drawing for LLW buffer store is presented in Reference [57].

All the drums and boxes will be prepared for off-site transportation in the BQS.

b) Plant Accident Conditions

Not applicable.

23.8.3.4 Preliminary 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.

Tanks are connected to HVAC systems to prevent escapes of gaseous radioactivity, 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.

Details of categorisation and classification are presented in Reference [58].

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 first	FC3	F-SC3	DPL	B-SC3	SSE2

Component	Function Category	Safety Classification	Design Provisions Category	Design Provisions Class	Seismic Category
isolation valve					
Pipes connecting the RCV [CVCS] purification unit and the first isolation valve	FC3	F-SC3	DPL	B-SC3	SSE2
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. The methodology and analysis of the fail-safe design in the TES [SWTS] is presented in Reference [57]. According to the analysis, the ‘fail-safe’ design is adopted in pneumatic globe valves, which will achieve safety position to reduce the radioactive material leakage or to facilitate pipe cleaning when the valves fail. The cranes used in TES [SWTS] are equipped with several fail-safe brakes to automatically prevent a drop load in the event of a power loss.

5) Human factors

Human factors are integrated in the design of TES [SWTS] by developing appropriate system control functional requirements, considering the application of the design measures described in Sub-chapter 23.2.5. Detailed information on the system automatic control design is presented in Reference [59].

6) Equipment qualification

The components that are designed to withstand SSE (valves categorised as SSE2) are identified to be seismic qualified in order to ensure the functionality.

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]. Major system parameters and status, such as tank levels, process flow rates and encapsulation facility status are indicated and alarmed to provide operational information and performance evaluation.

- Maintenance

  Sufficient space is provided in the buildings to facilitate equipment maintenance. Tanks are equipped with manholes or hand access ports for maintenance and cleaning.

  TES [SWTS] is operated intermittently. Therefore, the preventive maintenance of equipment is performed according to the equipment operation and maintenance manual, which is developed by equipment manufacturers at site licensing stage.

- Inspection

  The components that require pre-service inspection are identified in the pre-service inspection list of TES [SWTS].

- Periodic tests

  Reference [31] presents the periodic test design method for the UK HPR1000. By following this method, preliminary requirements of periodic tests for radioactive waste management are presented in

Reference [32] which indicates that periodical test is not required for the TES [SWTS].

c) Protection Design against Internal and External Hazards

The parts of TES [SWTS] that perform safety functions are protected from external and internal hazards. The specific protection design is presented [58].

d) Commissioning

By following the commissioning test requirements presented in Reference [8], commissioning tests will be performed to verify the functionality of the TES [SWTS] at the site licensing stage, 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.

e) Decommissioning

Facilitating decommissioning is considered in the design of TES [SWTS] by applying the design measures described in Sub-chapter 23.2.5. Detailed information is presented in Reference [58].

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 analysing the relevant risks and recorded in the DRR, as presented in Sub-chapter 23.2.5.

23.8.3.5 System Flow Diagram

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

23.8.4 ILW Interim Storage

According to the assumption presented in Sub-chapter 23.2.4, ILW arising from operation of the UK HPR1000 will be safely stored in an interim storage facility on-site, pending GDF in the UK is available. 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 [16]. This sub-chapter presents an overview the BQZ and detailed information is presented in the *Conceptual Proposal of ILW Interim Storage Facility*, Reference [60].

23.8.4.1 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 measure the ILW packages to establish the baselining;

c) To safely store the ILW packages in different storage area according to the waste type and radioactive 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 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 first phase will accommodate the waste generated during the operational period of 30 years of two UK HPR1000 units, and the second phase capacity will be determined about 20 - 30 years later, taking account of the actual ILW arising from operation and possible refined quantification of decommissioning ILW.

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.

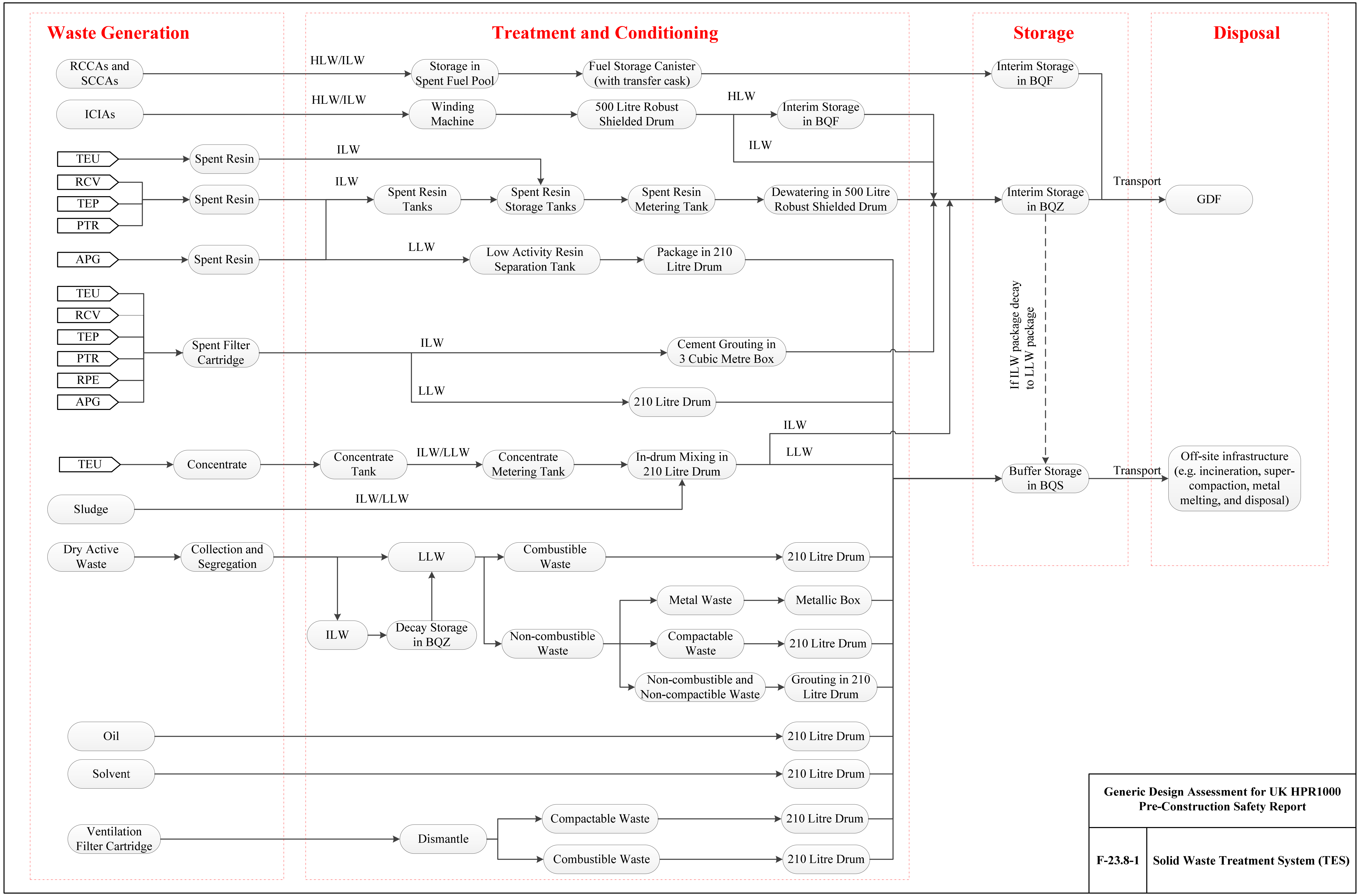
23.8.4.3 Storage Process

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

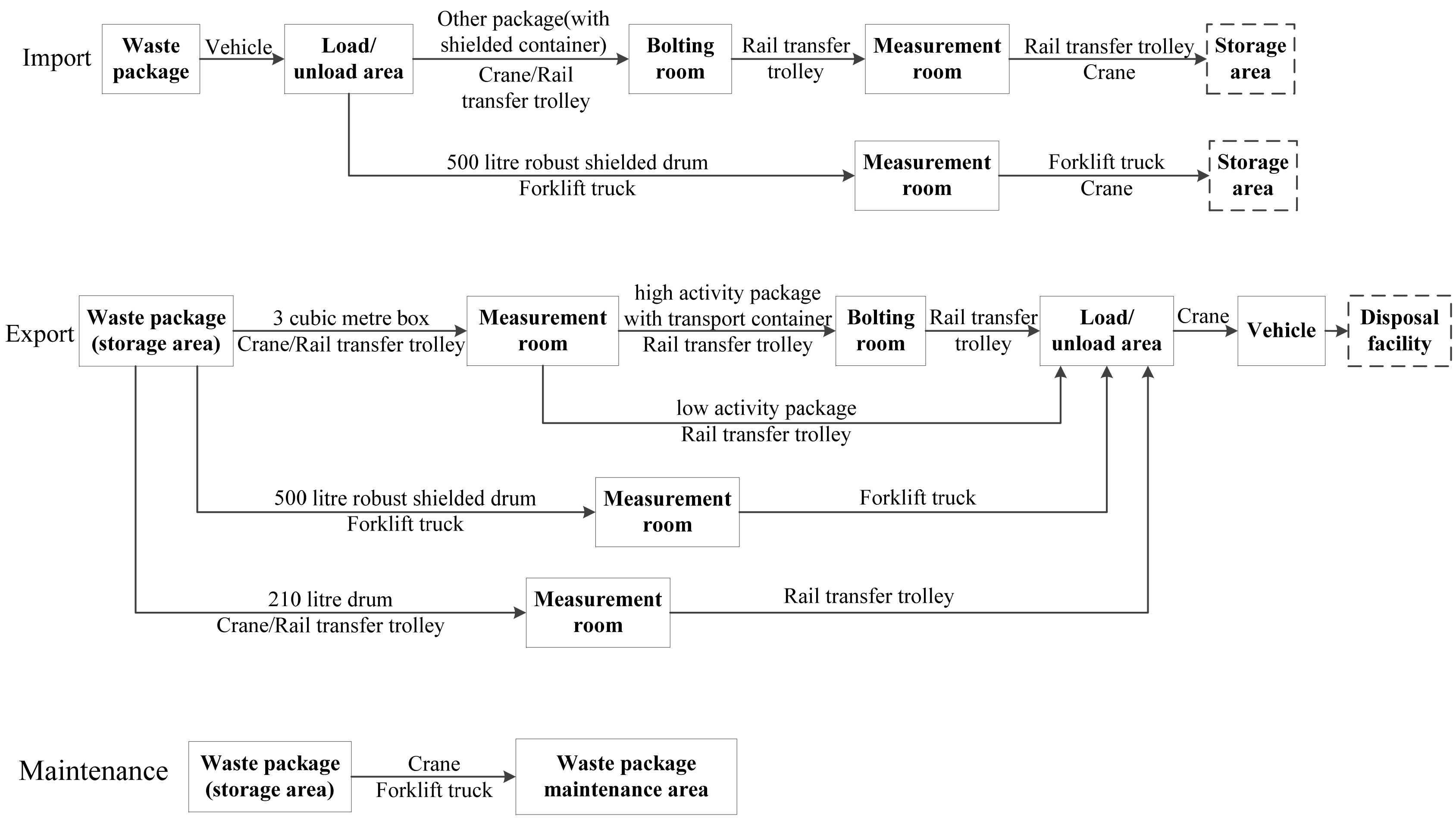
During import of waste packages to the storage area and their export for disposal, the radionuclide activity, surface dose rate and contamination level of packages are measured. The operation of crane, rail transfer trolley and measurement device is remotely controlled and/or software-controlled to prevent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

Any identified defective waste packages will be 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 will be recorded to achieve the safety operation management of the facility and to provide relevant information for waste consignment.



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

23.9 Disposability

23.9.1 LLWR Agreement in Principle

In the UK, the waste service suppliers provide a wide range of waste services to the UK nuclear industry. The treatment and disposal routes of LAW, including low activity solid waste and NALW, must be compliant with WAC published by waste service suppliers. These WAC will be used to demonstrate that LAW packages generated by the UK HPR1000 can be compatible with off-site facilities and no orphan waste will be created.

Based on the assumption presented in Sub-chapter 23.2.3, an ‘Agreement in Principle’ will be obtained from LLWR during the GDA phase, so as to ensure 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 [61], has been prepared and submitted for LLWR assessment. Regarding the ‘Agreement in Principle’ issued by LLWR, response will be provided, if necessary, to address the findings raised by LLWR.

It is noted that the management routes for LAW will be determined by the future operator considering the principles of ALARP and BAT.

23.9.2 Disposability Assessment of HAW

The GDF will not be available for several decades. Part of the solid radioactive waste generated by the UK HPR1000 will not be able to be disposed of via existing routes due to their radioactivity. Thus, HAW should be processed into a passive safe state and stored until a long term management solution is established. This situation is not unique to the UK HPR1000 but is applicable to all of the existing and new UK reactors.

In order to minimise the risk that the conditioning and packaging of HAW generated throughout the reactor lifetime results in incompatible waste with the future GDF. The *UK HPR1000 HAW Disposability Assessment Submission*, Reference [62], has been prepared and submitted to RWM to undertake a disposability assessment. Regarding the disposability assessment report, response will be provided to address the findings raised by RWM.

It is noted that the future operator will determine the final disposal routes for HAW.

23.10 ALARP Assessment

In line with the ALARP methodology, *ALARP Demonstration Report of Radioactive Waste Management*, Reference [63], presents the outcomes of the first iteration of the ALARP process for the radioactive waste management and the preliminary analysis from the second iteration. This first iteration consisted in assessing compliance of the

UK HPR1000 DR1.0 radioactive waste management against the applicable RGP listed in Sub-chapter 23.3 (or OPEX where relevant). For gaps that have been identified, preferred options were selected to address these gaps, following the optioneering and decision making process.

The new DR2.1 developed by implementing these preferred options and modifying the impacted SSCs is subject to further evaluation (second iteration) through a holistic risk assessment. This risk assessment for radioactive waste management is still under development, and any identified potential improvements will be addressed to reduce the risk to a level that is ALARP.

23.11 Records Management

The operation of the radioactive waste management systems will generate a large quantity of information, including that relating to the sampling and monitoring of radioactive waste or waste packages. According to the requirement in Reference [21] and [23], sufficient records for the radioactive waste management system 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 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 site licensing stage. The details of MSQA in the UK HPR1000 are presented in PCSR Chapter 20.

During the site licensing stage, 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 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 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.

So as to enable the future operator to fulfil his duty, the UK HPR1000 design has been developed considering this need for records, 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 GDF in the UK is available, and finally the waste records will be transferred by the future operator to the disposal facility. For LAW, the appropriate records of LAW packages also need to be kept by the future operator and transferred to off-site disposal facilities or waste treatment facilities.

23.12 Concluding Remarks

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

This chapter describes the means of managing each waste stream from generation pending to disposal as well as routine discharges of liquid and gaseous radioactive wastes. The waste is managed in an integrated strategy to ensure that all waste streams that are expected to generate from the operation of the UK HPR1000 are taken into account and an optimum waste management process is delivered. Risk reduction measures, i.e. changes to address the identified gaps at this stage, have been introduced in response to safety assessments commensurate with the current GDA. Furthermore, it is recognised that risk assessment for radioactive waste management in the DR2.1 is under development and any identified potential improvement will be addressed, so as to ensure the risks associated with radioactive waste management are capable of being reduced to ALARP.

23.13 References

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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).	*Analysis Report of Applicable Codes and Standards*.
					3.3.11.SC23.1-A1-E2	The role of system has been identified (Sub-chapters 23.6, 23.7.2 and 23.8.3).	SDM Chapter 3: *System Functions and Design Bases*.
			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).	*General Safety Requirement*; *Methodology of Safety Classification & Categorisation*; *The General Requirements of Protection Design against Internal and External Hazards*.
					3.3.11.SC23.1-A2-E2	Safety functional requirements have been identified (Sub-chapters 23.6, 23.7.2 and 23.8.3).	*General Safety Requirement*.
			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 and 23.8.3).	SDM Chapter 3: *System Functions and Design Bases*
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).	*Integrated waste strategy (IWS)*.
			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).	*Gap Analysis Report for Radioactive Waste Management*; *Optioneering Report for Liquid Radioactive Waste Processing Techniques*; *Sizing Report of Main Equipment in Liquid Waste*

Claim	Sub-claim	Argument	Evidence		Supporting document
					Management System.
			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).	*Gap Analysis Report for Radioactive Waste Management*; *Optioneering Report for Gaseous Radioactive Waste Processing Technique*; *Sizing Report of the Activated Charcoal Delay Beds*.
			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).	*Gap Analysis Report for Radioactive Waste Management*; *Optimal Options Study for Identified Gaps in Radioactive Waste Management*; *Optioneering Study for Identified Gaps in Operational Solid Waste Processing Techniques*; *Management Proposal of Waste Non-fuel Core Components*; *Selection of Waste Containers for Disposal of ILW*; *Optioneering Report for Operational Solid Waste Processing Techniques*; *Sizing Report of Main Equipment in Solid Radioactive Waste Treatment System*.
			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: *System and Component Design*; SDM Chapter 6: *System Operation and Maintenance*.
			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).	
		3.3.11.SC23.2-A3 Appropriate monitoring and sampling equipment have been provided to facilitate the characterisation and	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: *System Operation and Maintenance*; PCER Chapter 5: *Approach to Sampling & Monitoring*.

Claim	Sub-claim	Argument	Evidence	Supporting document
		segregation of radioactive waste and subsequent management.	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)	
			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).	
		3.3.11.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 site licensing stage (Sub-chapters 23.2.5, 23.6, 23.7.2 and 23.8.3).	*Topic Report on the Commissioning Requirements of Radioactive Waste Management Systems*; System commissioning program.
		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 and 23.8.3).	SDM Chapter 6: *System Operation and Maintenance*; Commissioning program of radioactive waste management systems; 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 site licensing stage (Sub-chapters 23.6, 23.7.2 and 23.8.3).	*Topic Report on the Periodic Test Requirements of Radioactive Waste Management Systems*; Pre-service inspection list of radioactive waste management systems.
Claim 3.3.11	3.3.11.SC23.3 The production and accumulation of radioactive waste from UK HPR1000 operation has been minimised.	3.3.11.SC23.3-A1 The design and operation of the UK HPR1000 has been optimised to minimise radioactive waste at source.	3.3.11.SC23.3-A1-E1 The minimisation of the radioactive waste has been presented (Sub-chapter 23.5).	*ALARP Demonstration Report for Radioactive Waste Management*; *ALARP Demonstration Report of PCSR Chapter 21*; *ALARP Demonstration Report of PCSR Chapter 17*; *ALARP Demonstration Report of Fuel System*; *Material Selection Methodology*;

Claim	Sub-claim	Argument	Evidence	Supporting document
				Topic Report on Radioactive Waste Minimisation for Mechanical Engineering; PCER Chapter 3: *Demonstration of BAT*.
		3.3.11.SC23.3-A2 The total quantity of radioactive waste accumulated on site has been minimised.	3.3.11.SC23.3-A2-E1 Sufficient capacity is provided to store radioactive waste, facilitating appropriate treatment (Sub-chapters 23.6, 23.7 and 23.8).	*Sizing Report of Main Equipment in Liquid Waste Management System*; *Sizing Report of the Activated Charcoal Delay Beds;* *Sizing Report of Main Equipment in Solid Radioactive Waste Treatment System*.
			3.3.11.SC23.3-A2-E2 The interim storage facilities have appropriate capability to accommodate the radioactive waste (Sub-chapter 23.8.4).	*Conceptual Proposal of ILW Interim Storage Facility*.
			3.3.11.SC23.3-A2-E3 Disposability of LAW is undertaken to determine the most appropriate disposal routes to minimise the accumulation of radioactive waste (Sub-chapter 23.9.1).	*Waste Inventory for Operational Solid Radioactive Waste*; *Acceptability Report of LLW for Off-site Disposal*; *UK HPR1000 Waste Enquiry Form*; *Agreement in Principle* (issued by LLWR); *Response to LLWR Agreement in Principle*.
			3.3.11.SC23.3-A2-E4 Disposability assessment of HAW is undertaken to determine the appropriate disposal routes (Sub-chapter 23.9.2).	*UK HPR1000 HAW Disposability Assessment Submission*; *Disposability Assessment Report* (issued by RWM); *Response to RWM Assessment Report on UK HPR1000 HAW and Spent Fuel Disposability*.
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).	*Selection of Waste Containers for Disposal of ILW*.
			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).	*Gap Analysis Report for Radioactive Waste Management*; *Optimal Options Study for Identified Gaps in Radioactive Waste Management*; *Optioneering Study for Identified Gaps in Operational Solid Waste Processing Techniques*;

Claim	Sub-claim	Argument	Evidence	Supporting document
				Management Proposal of Waste Non-fuel Core Components; *Selection of Waste Containers for Disposal of ILW*; *Optioneering Report for Operational Solid Waste Processing Techniques*; *Sizing Report of Main Equipment in Solid Radioactive Waste Treatment System*.
			3.3.11.SC23.4-A1-E3 Agreement in Principle of LAW has been obtained to determine the appropriate disposal routes.	*Waste Inventory for Operational Solid Radioactive Waste*; *Acceptability Report of LLW for Off-site Disposal*; *UK HPR1000 Waste Enquiry Form*; *Agreement in Principle* (issued by LLWR); *Response to LLWR Agreement in Principle*.
			3.3.11.SC23.4-A1-E4 Disposability assessment of HAW has been undertaken to determine the most appropriate disposal routes.	*Waste Inventory for Operational Solid Radioactive Waste*; *UK HPR1000 HAW Disposability Assessment Submission*; *Disposability Assessment Report* (issued by RWM); *Response to RWM Assessment Report on UK HPR1000 HAW and Spent Fuel Disposability*.
		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).	*Conceptual Proposal of ILW Interim Storage Facility*
			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).	*Conceptual Proposal of ILW Interim Storage Facility*
			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).	*Conceptual Proposal of ILW Interim Storage Facility*

Claim	Sub-claim	Argument	Evidence	Supporting document
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 and 23.8.3).	SDM Chapter 4: *System and Component Design*; SDM Chapter 6: *System Operation and Maintenance*.
			3.3.11.SC23.5-A1-E2 The general design requirements of system have been substantiated (Sub-chapters 23.6, 23.7.2 and 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).	*Gap Analysis Report for Radioactive Waste Management*; *ALARP Demonstration Report for Radioactive Waste Management*.
		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 23.8 and 23.10).	*Optimal Options Study for Identified Gaps in Radioactive Waste Management*; *Optioneering Study for Identified Gaps in Operational Solid Waste Processing Techniques*; *Selection of Waste Containers for Disposal of ILW*; *Conceptual Proposal of ILW Interim Storage Facility*; *Management Proposal of Waste Non-fuel Core Components*; SDM Chapter 4: *System and Component Design*.
			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 23.8 and 23.10).	*The List of SSCs Affected by the Optimal Options*; SDM Chapter 4: *System and Component Design*.
			3.3.11.SC23.5-A2-E3 Radioactive waste management has been demonstrated ALARP (Sub-chapter 23.10).	*ALARP Demonstration Report for Radioactive Waste Management*; PCSR Chapter 33: *ALARP Evaluation*.