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Pre-Construction Safety Report

Chapter 23

Radioactive Waste Management

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23.1 List of Abbreviations and Acronyms

ALARP	As Low As Reasonably Practicable
APG	Steam Generator Blowdown System [SGBS]
ARE	Main Feedwater System [MFS]
ASG	Emergency Feedwater System [EFWS]
ASP	Secondary Passive Heat Removal System [SPHRS]
BAT	Best Available Technique
BAX	Access Building
BFX	Fuel Building
BNX	Nuclear Auxiliary Building
BQS	Waste Auxiliary Building
BQT	Temporary Storage Facility
BRX	Reactor Building
BSX	Safeguard Buildings
BWX	Radioactive Waste Treatment Building
CCTV	Closed Circuit TV System
CVI	Condensate Vacuum System [CVS]
DBC	Design Basis Condition
DEL	Safety Chilled Water System [SCWS]
DER	Operational Chilled Water System [OCWS]
DiD	Defence in Depth
DVL	Electrical Division of Safeguard Building Ventilation System [EDVS]
DVT	Main Steam Valve and Main Feedwater Valve Room Ventilation System [MVSVS]
DVX	Operation Chillers in NI Ventilation System [OCVS]
DWK	Fuel Building Ventilation System [FBVS]
DWL	Safeguard Building Controlled Area Ventilation System [SBCAVS]
DWN	Nuclear Auxiliary Building Ventilation System [NABVS]

DWQ	Waste Treatment Building Ventilation System [WBVS]
EBA	Containment Sweeping and Blowndown Ventilation System [CSBVS]
ECS	Extra Cooling System [ECS]
EDG	Emergency Diesel Generator
EHR	Containment Heat Removal System [CHRS]
EMIT	Examination, Maintenance, Inspection and Testing
EPP	Containment Leak Rate Testing and Monitoring System [CLRTMS]
EVR	Containment Cooling and Ventilation System [CCVS]
GDA	Generic Design Assessment
GDF	Geological Disposal Facility
HAW	High Activity Waste
HLW	High Level Waste
HPR1000 (FCG3)	Hua-long Pressurised Reactor under construction at Fangchenggang nuclear power plant unit 3
HVAC	Heating, Ventilation and Air Conditioning
IAEA	International Atomic Energy Agency
ILW	Intermediate Level Waste
IWS	Integrity Waste Strategy
JPI	Nuclear Island Fire Protection System [NIFPS]
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
NDT	Non Destructive Test
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
RBS	Emergency Boration System [EBS]
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]
RRI	Component Cooling Water System [CCWS]
RWM	Radioactive Waste Management Ltd (UK)
RWMC	Radioactive Waste Management Case
SAR	Instrument Compressed Air Distribution System [ICADS]
SBD	Radioactive Decontamination System [RDS]
SBE	Hot Laundry Facility [HLF]
SBO	Station Black Out
SED	NI Demineralised Water Distribution System [DWDS(NI)]
SEK	Waste Fluid Collection System for Conventional Island [WFCS(CI)]
SEL	Conventional Island Liquid Waste Discharge System [LWDS(CI)]
SEP	Portable Water System [PWS]
SFAIRP	So Far As Is Reasonably Practicable
SFC	Single Failure Criterion
SGH	Hydrogen Distribution System [HDS]
SGN	Nitrogen Distribution System [NDS]

SGO	Oxygen Distribution System [ODS]
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
VDA	Atmospheric Steam Dump System [ASDS]
VLLW	Very Low Level Waste
VVP	Main Steam System [MSS]
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 for the radioactive waste management systems for UK version of the Hua-long Pressurised Reactor (UK HPR1000). The qualitative information about radioactive waste management is presented, and the wastes here cover the gaseous, liquid and solid radioactive wastes generated in the operation of the reactor.

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. The source term for the design of radioactive waste management systems is detailed in Chapter 22.

23.2.1 Chapter Route Map

The UK HPR1000 has the following fundamental objective, which combines the consideration of nuclear and conventional safety, security and environment, in order to ensure an integrated and balanced design:

Fundamental Objective: *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.*

In order to underpin this objective**,** five high level claims and a number of level 2 claims are developed and presented in 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.

According to Reference [1], the trail from safety claims through arguments to evidence needs to be clearly set out in the safety case. A Route Map for Chapter 23 is developed in this sub-chapter and is presented in Appendix 23A. This Route Map is intending to sets out a "direction of travel" for Chapter 23.

In addition, in order to point out where the principles about radioactive waste management in the Safety Assessment Principles (SAPs) can be found in the report, the mapping of radioactive waste management against relevant SAPs is presented in Reference [2].

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;

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;

d) Sub-chapter 23.4 presents the radioactive waste management strategy;

e) Sub-chapter 23.5 presents the minimisation radioactive waste at source and minimisation of accumulation radioactive waste;

f) Sub-chapter 23.6 presents liquid radioactive waste management systems;

g) Sub-chapter 23.7 presents gaseous radioactive waste management systems;

h) Sub-chapter 23.8 presents solid radioactive waste management systems;

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 concluding remarks; and,

l) Sub-chapter 23.12 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 Interface between Chapter 23 and other Chapters

PCSR Chapter	Interface
Chapter 1 Introduction	Chapter 1 provides the Fundamental Objective, Level 1 Claims and Level 2 Claims. Chapter 23 provides chapter claims, arguments to support high level claims presented in Chapter 1.
Chapter 2 General Plant Description	Chapter 2 provides a brief introduction to the radioactive waste management systems, which are presented in Chapter 23.
Chapter 3 Generic Site Characteristics	Chapter 3 provides generic site envelope for design conditions of radioactive waste management systems, which are presented in Chapter 23.
Chapter 4 General Safety and Design Principles	Chapter 4 provides the general safety and design principles including the concept of Defence in Depth (DiD), safety classification of SSCs, engineering substantiation, etc. These principles shall be considered in the design of radioactive waste management systems in Chapter 23.
Chapter 9 Electric Power	Chapter 9 provides the design information relevant to the electrical power systems, which support the function of radioactive waste managment systems

PCSR Chapter	Interface
	in Chapter 23.
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 considered in the system and component design. Chapter 23 provides the design of radioactive waste management systems, which is taken into account for further estimate in Human Factor.
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 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 External Hazard area.
Chapter 19 Internal Hazards	Chapter 19 provides internal 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 Internal Hazard area.

PCSR Chapter	Interface
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 on the minimisation of source term, and this is beneficial to the radioactive waste management systems in Chapter 23.
Chapter 22 Radiological Protection	Chapter 22 provides source term and the general radiation protection considerations for the radioactive waste management systems, which are presented in Chapter 23.
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 if necessary.
Chapter 28 Fuel Route and Storage	Chapter 28 presents the fuel handling and storage operations. Chapter 23 provides the management of potential radioactive waste generated during fuel handling and storage system operations mentioned in Chapter 28.
Chapter 30 Commissioning	Chapter 30 provides arrangement 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 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 the As Low As

PCSR Chapter	Interface
	Reasonably Practicable (ALARP) demonstration. Chapter 23 provides the ALARP demonstration for radioactive waste management systems based on these principles and the approach.

23.2.4 General Assumptions

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

a) The operational life of 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 Reference [3] *Funded Decommissioning Programme Guidance for New Nuclear Power Stations*, 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 (UK) (LLWR)

operating in West Cumbria or a successor facility; and,

5) Intermediate Level Waste (ILW) arising from operation and decommissioning will be packaged in a passive safe form, and safely stored in 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 Chapters 4, 15, 18, 19, 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 document *Methodology of Safety Categorisation and Classification* in Reference [4] shall be considered in the design of radioactive waste management systems.

b) Engineering Design Requirements

1) The Reliability Design of Structures, Systems and Components (SSCs)

- Single Failure Criterion (SFC)

The SFC is considered to ensure that more than the minimum of components are provided to carry out safety function. The criterion is applicable to the radioactive waste management systems that perform 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 redundancy design helps satisfy this criterion.

The single failure includes active and passive failures:

- An active single failure is defined as a failure which is sufficient to invalidate the relevant safety function of a component, including the malfunction of a mechanical or electrical component which relies on mechanical movement to complete its intended function upon

demand, and the malfunction of an I&C component;

- A passive single failure is defined as a failure which could occur in a component that does not change its state while realizing its function. The passive single failure at the start of a transient should be assessed in an appropriate means.

The SFC is applied to F-SC1 systems in the system level and F-SC2 systems in the function level, thus the redundancy is needed in the design of these systems. Consideration of single failure criteria at the system level of F-SC1 indicates that these systems must be redundant. Consideration of single failure criteria at the function level for systems fulfilling F-SC2 functions indicates that these systems may not need redundancy.

Details about general principles for the SFC are provided in Reference [4].

– Independence

In addition to the high level principle of independence between levels of DiD, the following principles for independence should be applied in the design to achieve system reliability and tolerance to faults:

- Independence between the trains of redundant system should be maintained as far as reasonably practicable (avoidance of common cause failure);
- Independence between components of different safety categories should be maintained as far as reasonably practicable (avoidance of impact on the component of higher safety category from an item of lower safety category);

The components designed to mitigate a potential initiating event should be independent from the effects of this potential initiating UK event as far as reasonably practicable. Independence is accomplished in the design of systems by using functional isolation and/or physical separation. Functional isolation is used to reduce adverse effects between elements of connected systems or systems redundantly designed. These adverse effects may be caused by the normal operation, abnormal operation or failure of any part of these systems. Physical separation should be applied in the layout of systems as far as reasonably practicable, to reduce the potential of common cause failure due to a localised initiating event. The choice of isolation measures (compartmentalisation, distance, orientation etc.) should take into account the nature of the initiating events.

Details about general principles for independence are provided in Reference [4].

- Diversity

  To reduce the potential for common cause failure, diversity should be realised by incorporating different attributes into the design of systems or components, as appropriate, in the redundant systems or components that perform the same safety function. The radioactive waste management systems shall consider the requirement of diversity.

  In order to achieve the reliability targets and to fulfil the DiD concept, diversity should be realised by incorporating different attributes into the design of systems or components, as appropriate, in the redundant systems or components that perform the same safety function. Such attributes can be different operating principles, different physical variables, different operating conditions, different manufacturers, etc.

  Common cause failure of safety measures should be assumed in the analysis for frequent faults. Therefore, a main protection line and a diverse protection line should be established to achieve the fundamental safety objective for frequent faults.

  What should be paid special attention is that the diversity should be taken into account in the design of systems performing FC1 or FC2 functions based on software to avoid common cause failure.

  Details about general principles for diversity are provided in Reference [4].

- Ageing and Degradation

  Considerations:

  The design life of items important to safety at a nuclear power plant shall be determined. Appropriate margins shall be provided in the design to take due account of relevant mechanisms of ageing, neutron embrittlement and wear out and of the potential for age related degradation, to ensure the capability of items important to safety to perform their necessary safety functions throughout their design life, including testing, maintenance, maintenance outages, plant states during a postulated initiating event and plant states following a postulated initiating event.

  Provision shall be made for monitoring, testing, sampling and inspection to assess ageing mechanisms predicted at the design stage and to help to identify unanticipated behaviour of the plant or degradation that might

occur in service.

Details about the general principles and requirements for management of ageing and degradation are addressed by asset management, including equipment qualification, state monitoring, pre-service inspection, commissioning tests, operating and Examination, Maintenance, Inspection and Testing (EMIT) and decommissioning, etc.

Common Design Measures to Fulfil the Considerations:

The ageing effects concerning individual components have been taken into consideration in the system design:

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

2) Human Factors

Considerations:

According to reference [5], the design shall allocate functions properly, and support personnel in the fulfilment of their responsibilities and in the performance of tasks. The design also needs to identify human actions that may affect safety and proportionately analyse all tasks important to safety, and limit the likelihood of operational errors and their impact on safety. The principle relevant to the human factors shall be considered in the system design.

Moreover, the design of the system, component, layout, HMI and operator working environment shall meet the human factors requirements which are presented in the safety case of human factors (starts in Chapter 15). The design will be further assessed in the human factors engineering task analysis.

Common Design Measures to Fulfil the Considerations:

In the system design, short term operator intervention is avoided and the dependence on human action is reduced to prevent human error. Detailed information about system control functional requirements is presented in the Chapter 6 of each system design manual.

Operator actions during plant normal operation will also be assessed to estimate the possible harmful effects to the safety. Relevant human actions

important to plant safety will be further identified, and substantiation of related system design will be evaluated in the human factors assessment (see Chapter 15).

c) Protection against Internal and External Hazards

According to Chapter 4 and further information which is presented in [6], fulfilment of the fundamental safety functions for a nuclear power plant shall be ensured in hazard protection design, as well as limitation of accidental radioactive releases.

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.

Measures to protect the system against internal hazards are presented in Chapter 19. Detailed safety evaluation and analysis of protection measures will be made in the submissions of Chapter 19.

Measures to protect the system against external hazards are presented in Chapter 18. Detailed safety evaluation and analysis of protection measures will be made in the submissions of Chapter 18.

d) Commissioning

The safety related functions shall be effectively demonstrated via commissioning before service at the licensing stage. The system commissioning program shall be established to guide the commissioning test onsite, the commissioning content, phased approach and scope are shown in Chapter 30.

e) Examination, Inspection, Maintenance and Testing

The design should be such that activities for EMIT are facilitated for the purpose of maintaining the capability of SSCs important to safety to perform essential safety functions, 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 Chapter 31. The above activities are specified taking into account the design code requirements, reliability analysis and potential degradation mechanisms, commensurate with the safety class of the system. These requirements/principles shall be considered in the system design.

f) Decommissioning

Decommissioning shall be considered during the design stage for the UK HPR1000. At the current stage, the general considerations of decommissioning are mentioned in Chapter 24 and mainly include:

1) The consideration of facilitating decommissioning;

2) The consideration of decommissioning strategy; and,

3) The consideration of the preliminary decommissioning plan for the UK HPR1000.

g) 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 [7]. According to the reference, the general principles relevant to the material selection are summarised as shown below:

1) Material selection shall be consistent with the functional objectives of the system and equipment;

2) Material selection shall be performed in a manner in which the classification shall be reflected; the requirements shall be commensurate with the classification;

3) Materials selected for use shall be compatible with the full range of environmental conditions which may be encountered over the plant design life;

4) Materials selected for use shall present high functional reliability and good resistance to aging and degradation throughout the design life to mitigate against the risk of performance degradation and failure of SSCs;

5) Materials selected for use shall possess excellent manufacturability, and shall be convenient for performing processing sequences such as forging or casting, machining, heat treatment, welding and inspection;

6) Operating Experience (OPEX) and feedback shall be taken into account for material selection of the system;

7) Generation and transportation of source terms shall be specially considered when selecting the material to be used to minimise the radiological dose of workers and the public when performing in-service inspection, maintenance, replacement and decommissioning;

8) Compatibility with the chemistry regime shall be considered when selecting the material to ensure that the components can function well under the selected chemical conditions.

23.3 Applicable Codes and Standards

The general principles and selection methodology relevant to the selection of appropriate codes and standards are presented in Sub-chapter 4 and Reference [8].

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); and,

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

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, which are regarded as Relevant Good Practice (RGP), are identified in *Analysis Report of Applicable Codes and Standards*, Reference [9]. The list of applicable codes and standards include:

a) UK Strategy for the Management of Solid Low Level Radioactive Waste from the Nuclear Industry, Reference [10];

b) Regulatory Guidance Series, No RSR 1: Radioactive Substances Regulation – Environmental Principles , Reference [11];

c) The Management of Higher Activity Radioactive Waste on Nuclear Licensed Sites, Reference [12];

d) Industry Guidance: Interim Storage of Higher Activity Waste Packages – Integrated Approach, Reference [13] ;

e) Funded Decommissioning Programme Guidance for New Nuclear Power Stations, Reference [3];

f) Waste and Spent Fuel Storage Safety Reference Levels, Reference [14];

g) Predisposal Management of Radioactive Waste, Reference [15]; and,

h) Predisposal Management of Radioactive Waste from Nuclear Power Plants and Research Reactors, Reference [16].

23.4 Radioactive Waste Management Strategy

According to the principles/requirement in Reference [17], [18] and[12], the radioactive waste management strategy for the UK HPR1000 should be produced during Generic Design Assessment (GDA) phase to provide an overarching description of waste strategies for managing radioactive waste and spent fuel arising from the UK HPR1000 lifecycle.

This strategy aims to ensure that the waste streams can be managed in a safe and appropriate manner, so as to reduce the risks to the workers, public and environment So Far As Is Reasonably Practicable (SFAIRP). It will address the following main considerations:

a) Consistency with government policy, regulatory expectations and relevant legal obligations;

b) Development of a waste inventory, timescales of arising, and arrangements for management and disposal of the following radioactive wastes:

   1) Spent fuel;

   2) Operational wastes; and,

   3) Decommissioning wastes.

b) Adoption of waste management principles such as the implementation of waste hierarchy, the use of technologically proven waste reduction and activity abatement methods;

c) Balance of the principles of ALARP and Best Available Technique (BAT) in the development of radioactive waste management strategy; and,

d) Development of appropriate information for Radioactive Waste Management Ltd (UK) (RWM) and LLWR to undertake the GDA disposability.

UK HPR1000 has preliminary identified all of the potential waste streams. It is recognised that the waste strategies for radioactive waste, especially for solid radioactive waste, are under development to identify the optimum waste management routes taking into account of off-site and on-site interdependencies. Therefore, an Integrity Waste Strategy (IWS) for UK HPR1000 will be developed in line with government policy.

The strategies for management of radioactive wastes arising from the construction, operation and decommissioning of the UK HPR1000 will be used to construct the

Radioactive Waste Management Case (RWMC) to demonstrate that High Activity Waste (HAW) can be managed effectively at site licensing stage.

23.5 Minimisation of Radioactive Waste

Radioactive waste generated throughout the reactor lifetime is undesirable due to the potentially harmful impacts on the workers, public and environment. The minimisation of the generation of unavoidable waste is the foremost principles of good waste management in Reference [17], [11] and [15], the design and operation of the UK HPR1000 have been optimised by considering the principles of ALARP and BAT, and application of waste hierarchy.

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

23.5.1 Minimisation of Radioactive Waste at Source

Prevention and minimisation of radioactive waste at source is an initial step in the UK HPR1000 radioactive waste management. There are two safety benefits resulting from this approach:

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

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

The prevention and minimisation of radioactive waste at source is demonstrated in Pre-Construction Environmental Report (PCER) Chapter 3 *Demonstration of BAT* Sub-chapter 3.4.1, Reference [19].

Activities involving radioactive materials and the management of gaseous and aqueous effluents will also unavoidably create solid radioactive waste. The design of the UK HPR1000 prevents, and where this is not possible, minimises the volume of solid radioactive waste. The main activities contributing to the prevention and minimisation of radioactive waste at source include:

a) Reducing solid radioactive waste via system configuration optimisation;

b) Minimising potential contamination by radiation zoning and contamination zoning;

c) Minimising solid radioactive waste via building layout design;

d) Extending service life of equipment;

e) Extending service life of filters and demineraliser;

f) Keeping equipment in good working conditions to minimise replacement; and,

g) Minimising solid radioactive waste by reusing maintenance equipment and tools in the controlled area.

The detailed demonstration of above aspects is presented in PCER Chapter 3 *Demonstration of BAT* Sub-chapter 3.4.4, Reference [19].

Sub-chapter 23.6, 23.7 and 23.8 describe the generation and management of liquid, gaseous and solid radioactive waste, contain further information on waste minimisation, including the consideration of effluents recycling, segregation of waste, volume reduction and material selection of components.

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. The minimisation of accumulation of radioactive waste must be demonstrated according to regulatory expectations in Reference [17] and [18].

Minimisation of accumulation on site is a significant element of radioactive waste management strategy in UK HPR1000, especially for solid radioactive waste management. It means that radioactive waste including Lower Activity Waste (LAW, which includes VLLW and LLW) and ILW are going to be shipped to appropriate off-site disposal facilities or waste treatment facilities. Furthermore, in order to facilitate the appropriate management of radioactive waste, UK HPR1000 provides the appropriate space to segregate solid waste in BNX and Radioactive Waste Treatment Building (BWX) to enable volumes to be reduced and to store conditioned waste packages.

23.5.2.1 Minimisation of Accumulation of LAW

Based on the assumption presented in item e) and f) in Sub-chapter 23.2.4, LAW will be consigned to LLWR to be disposed of or treated during GDA phase. An ‘Agreement in Principle’ needs to be obtained from LLWR during GDA phase to ensure LAW can be accepted by off-site facilities to minimise the accumulation of radioactive waste. The LLWR Agreement in Principle is presented in Sub-chapter 23.9.1.

However, in order to facilitate the flexible management of consignment and to enable ventilation filter cartridges to decay to an exempt waste, LAW store is provided to temporary store these waste in the UK HPR1000.

Further considerations will be given to the minimisation of accumulation of radioactive waste on site. Suitable options of LAW will notably be determined considering the principles of ALARP and BAT to maximise the efficiency of disposal routes.

23.5.2.2 Minimisation of Accumulation of ILW

In the case of ILW, these wastes must be stored on site until GDF is available based on the assumption in item e) in Sub-chapter 23.2.4.The interim storage proposal presented in Sub-chapter 23.8.5 is designed to safely store solid radioactive waste. In Sub-chapter 23.8.7, it is recognized that the interim storage facility will be developed to provide appropriate capability to safely ILW in line with the UK requirements as provided in Reference [13]. The boundary wastes identified in the UK HPR1000 will be stored in an interim storage facility and provided with suitable decay storage in this facility to allow for off-site disposal as LLW to minimise the accumulation of radioactive waste on site.

In order to minimise the risk that the conditioning and packaging of ILW generated throughout the reactor lifetime results in incompatible waste with future GDF, UK HPR1000 will undertake disposability assessment with RWM, which are presented in Sub-chapter 23.9.2.

23.6 Liquid Radioactive Waste Management Systems

The liquid radioactive waste management systems are designed to control, collect, treat, transport and store the liquid radioactive wastes generated under normal operations. The specific objectives of the systems are to:

a) Segregate and collect liquid radioactive wastes according to the categories, sources, and treatment methods;

b) Recycle and reuse liquid effluents wherever possible to minimise the radioactive waste;

c) Sample and Treat unrecyclable liquid waste;

d) Discharge the treated liquid wastes to the environment only when in compliance with the relevant discharge management objective and conditions.

The liquid radioactive waste management systems consist of the following systems:

a) RPE [VDS]

b) TEU [LWTS]

c) TER [NLWDS]

d) SRE [SRS]

e) SEL [LWDS(CI)]

It is noted that SEK [WFCS (CI)] is not included within the scope of the GDA, Reference [20].

The liquid effluent streams produced during operation and their treatment are

illustrated in appendix 23B and described thereafter.

23.6.1 Nuclear Island Vent and Drain System

23.6.1.1 Safety Functional Requirements

a) Reactivity Control

RPE [VDS] does not contribute to this function.

b) Removal of heat

RPE [VDS] does not contribute to this function.

c) Confinement

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

1) Selective recovery and interim storage of all the active effluents by monitoring of leakages in normal condition;

2) Delay the treatment of high active effluents in accident condition.

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) Leakage containment in severe accident conditions;

3) Isolation of RPE [VDS] in the Reactor Building (BRX) to prevent transportation of liquid effluents towards other buildings in the case of Loss of Coolant Accident (LOCA) during shutdown state.

b) Extra Supporting Functions

RPE [VDS] does not perform extra supporting functions.

23.6.1.2 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 reduce the production of radioactive effluents at source by performing the following operational functions:

a) Routing of recyclable effluent from the primary effluent to Coolant Storage and Treatment System (TEP [CSTS]) to be recycled;

b) Discharge the non-radioactive liquid collected from the non-control area of the nuclear island to SEK [WFCS (CI)] after the sampling is qualified.

RPE [VDS] contributes to select optimal processing routes for radioactive effluents by performing the following operational functions:

a) According to different physical, chemical and radioactive characteristics, RPE [VDS] separately collects different types of non-recyclable liquid effluents and route them to TEU [LWTS] for treatment, for example, ‘Demineralisers’ is determined to effectively treat the process drains;

b) Routing the primary gaseous waste collected to TEG [GWTS] and the other gaseous waste to ventilation systems of each building.

23.6.1.3 System Description and Operation

23.6.1.3.1 System Description

RPE [VDS] is designed to collect separately and transfer radioactive effluents from the nuclear island. The collected effluents are transferred to different downstream systems (TEP [CSTS], TEU [LWTS], TEG [GWTS] or SEK [LWCS (CI)]) for treatment or discharge according to the type of effluents. The system flow diagram of RPE [VDS] is presented in F-23.6-1.

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

a) Effluents to be recycled

The recyclable effluents collected by RPE [VDS] are transferred to TEP [CSTS] for recycling. After that, boric acid and distillates from TEP [CSTS] are transferred to the Reactor Boron and Water Makeup System (REA [RBWMS]) as supplementary make up for primary circuit coolant. The details of TEP [CSTS] are presented in Sub-chapter 10.4.5 in Chapter 10.

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 Nuclear Auxiliary Building (BNX)

The following liquid wastes are collected in the RPE [VDS] recyclable effluents tank of BNX and pumped to TEP [CSTS]:

- Drainage from equipment and piping that transfer reactor coolant;
- Effluent blown down from safety valve of systems containing reactor coolant.

3) Primary effluents from Safeguard Buildings (BSX) and Fuel Building (BFX)

These effluents are from the Safety Injection System (RIS [SIS]), Containment Heat Removal System (EHR [CHRS]) as well as Fuel Pool Cooling and Treatment System (PTR [FPCTS]), and are transferred to TEP [CSTS].

b) Effluents to be discharged

The unrecyclable radioactive effluents are classified into following categories, which are transferred to TEU [LWTS], TEG [GWTS] or ventilation systems for treatment or discharge.

1) Process drains

The process drains are from ventilation systems or leakage of equipment and piping carrying reactor coolant. They are collected in the RPE [VDS] process drain tanks.

2) Chemical drains

These liquid wastes are from the radioactive laboratory. They are collected in RPE [VDS] chemical drains tanks in the BNX.

3) Floor drains 1

Floor drains 1 are potentially contaminated effluents (particularly from equipment leakages and floor washings) from equipment carrying primary effluent in the control area of BRX, BNX, BFX, and BSX. These wastes are collected in RPE [VDS] floor drains 1 sumps and transferred to TEU [LWTS] for treatment.

4) Floor drains 2

Floor drains 2 are slightly contaminated or uncontaminated effluents (from leakages and purges of equipment and floor washings) located in controlled areas, in rooms with equipment carrying fluid in BRX, Access Building (BAX), BFX, and BNX. These wastes are collected in the RPE [VDS] floor drains 2 sumps and transferred to TEU [LWTS] for treatment.

5) Floor drains 3

Floor drains 3 are effluents that are not normally contaminated (from leakages and purges of equipment and floor washings) located in non-control area. These wastes are collected in the RPE [VDS] floor drains 3 sumps and transferred to SEL [LWDS (CI)] through SEK [WFCS (CI)] for discharge.

6) Gaseous waste

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

Primary gaseous waste mainly comes from the reactor coolant drains of user systems in Sub-chapter 23.6.1.3.3. This waste is collected in the RPE [VDS] storage tanks, and is transferred to TEG [GWTS] for treatment.

Other gaseous waste mainly comes from the vent of user systems in Sub-chapter 23.6.1.3.3 during unit maintenance. This waste is collected in the RPE [VDS] storage tanks, and is transferred to plant ventilation systems for treatment.

Each of RPE [VDS] storage tank is equipped with a sampling point on the pipe connected to TEG [GWTS] or ventilation systems presented in F-23.6-1(1) and F-23.6-1 (2), which is designed to measure the radioactive level of gaseous waste in the storage tank to reduce the dose to workers during the tank maintenance.

23.6.1.3.2 Description of Main Equipment

a) Tanks

The radioactive waste storage tanks are made of stainless steel, and equipped with pressure reducing equipment for over-pressurisation protection.

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

b) Heat exchanger

The heat exchanger is cooled by the Component Cooling Water System (RRI [CCWS]). Liquid in the RPE [VDS] reactor coolant drain tank and Reactor Coolant System (RCP [RCS]) pressuriser relief tank is cooled in a circulating manner by the RPE [VDS] reactor coolant drain pump, and the cooled liquid wastes are discharged to TEP [CSTS].

c) Pumps

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

The parts of the pumps that contact with the liquid wastes 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.

Detailed information of the equipment is presented in Reference [21].

23.6.1.3.3 Description of System Interfaces

a) Supporting Systems

1) NI Dematerialised Water Distribution System (SED [DWDS (NI)])

SED [DWDS (NI)] provides dematerialised water for pipeline water seal in the RPE [VDS].

2) TEG[GWTS]

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

3) TEP[CSTS]

The effluents coming from RPE [VDS] can be transferred to TEP [CSTS] System

4) TEU[LWTS]

The reactor coolant drains collected by RPE [VDS] are transferred to TEU [LWTS].

5) SEK[LWCS(CI)]

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

6) Operational Chilled Water System (DER [OCWS])

DER [OCWS] is used to cool down the vacuum pump heat exchanger of RPE [VDS].

7) Containment Sweeping and Blowndown Ventilation System (EBA [CSBVS])

Primary effluent tank is connected to EBA [CSBVS] during shut-down condition.

Reactor coolant tanks in the BRX can be connected to EBA [CSBVS] for maintenance operations.

Discharge line of vacuum pump is connected to EBA[CSBVS] during RCP [RCS] air sweeping before opening pressure vessel and during RCP [RCS] vacuum pulling and vacuum preservation while RCP [RCS] filling before start-up phases.

8) Component Cooling Water System (RRI [CCWS])

Cooling of heat exchanger is performed by RRI [CCWS].

b) User Systems

RPE collects, temporarily stores and transfers effluents from the following systems:

1) Chemical and Volume Control System (RCV [CVCS])
2) PTR[FPCTS]
3) Emergency Boration System (RBS [EBS])
4) REA [RBWMS]
5) Safety Injection System (RIS [SIS])
6) RRI[CCWS]
7) Containment Heat Removal System (HER [CHRS])
8) Safety Chilled Water System (DEL [SCWS])
9) DER [OCWS]
10) TEG [GWTS]
11) TEP[CSTS]
12) TES [SWTS]
13) Steam Generator Blowdown System (APG [SGBS])
14) Main Feedwater System (ARE [MFS])
15) Emergency Feedwater System (ASG [EFWS])
16) Secondary Passive Heat Removal System (ASP [SPHRS])
17) Electrical Division of Safeguard Building Ventilation System (DVL [EDVS])
18) Main Steam Valve and Main Feedwater Valve Room Ventilation System (DVT [MVSVS])
19) Operation Chillers in NI Ventilation System (DVX [OCVS])
20) Fuel Building Ventilation System (DWK [FBVS])

21) Safeguard Building Controlled Area Ventilation System (DWL [SBCAVS])

22) EBA [CSBVS]

23) Extra Cooling System (ECS [ECS])

24) Containment Leak Rate Testing and Monitoring System (EPP [CLRTMS])

25) Containment Cooling and Ventilation System (EVR [CCVS])

26) Turbine Building Fire Protection System (JPI [TBFPS])

27) Radioactive Decontamination System (SBD [RDS])

28) TEU [LWTS]

29) Atmospheric Steam Dump System (VDA [ASDS])

30) Main Steam System (VVP [MSS])

Furthermore, RPE [VDS] performs air and nitrogen sweeping in RCP [RCS] during shutdown phase and RCP [RCS] vacuum pulling and maintaining before start-up phase.

23.6.1.3.4 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 wastes in the RPE [VDS] reactor coolant drain tank;
  - Cool liquid wastes in the RCP [RCS] pressuriser relief tank;
  - 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 to reduce the dose risk.

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 [LWCS (CI)] 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 drained. 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) Leakage containment in severe accident conditions;

3) Isolation of RPE [VDS] in the BRX to prevent loss of liquid effluents towards other buildings in the case of LOCA.

23.6.1.4 Preliminary Design Substantiation

a) Compliance with Safety Functional Requirements

1) Control of Reactivity

Not applicable.

2) Removal of Heat

Not applicable.

3) 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.

Under accident conditions, RPE [VDS] containment isolation valves act as a third containment barrier at its containment penetration points. The pipes penetrating the BRX 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.

b) Compliance with Design Requirements

1) Safety Classification

The system function classification is presented inT-23.6-1 T-23.6-1.

Design provisions shall also be considered in RPE [VDS]. Based on the contribution for accident mitigation, a design requirement relevant to the

safety classification of main components (including seismic categorisation) is derived in T-23.6-2.

T-23.6-1 System Function Classification

System Function	Function Category
Containment isolation	FC1
Collection of primary effluents inside BSX,BFX,BNX	FC3
Others	NC

T-23.6-2 Classification of Main Components

Component	Function Class	Design Provision Category	Design Provision Class	Seismic Category
Containment isolation valves	F-SC1	DPA	B-SC2	SSE1
Pumps, tanks, valves and lines (collect primary effluents inside the BRX)	NC	NC	NC	SSE2
Pumps, sumps , valves and lines (collect floor drains inside the BRX)	NC	NC	NC	SSE2
Pumps, tanks , valves and lines (collect primary effluents inside BSX,BFX, BNX)	F-SC3	DPL	B-SC3	SSE2
Pumps, tanks , valves and lines (collect process drains inside BSX,BFX)	NC	NC	NC	SSE2
Pumps, tanks , valves and lines (collect process drains inside BNX)	NC	NC	NC	NO
Pumps, tanks , valves and lines (collect chemical drains inside BNX)	NC	NC	NC	NO
Pumps, sumps , valves and lines (collect floor drains inside BSX,BFX)	NC	NC	NC	SSE2
Pumps, sumps , valves and lines (collect floor drains inside BNX,BAX)	NC	NC	NC	NO

The details about system classification are presented in Reference [22].

2) Reliability Design of SSCs

- Single Failure Criterion (SFC)

  SFC is applicable to the mechanical, electrical or I&C system that perform safety functions. It is beneficial to ensuring the high reliability of safety systems and to maintaining the plant within its deterministic design basis.

  The containment isolation valves of RPE [VDS] are required to perform safety functions under DBC-2, DBC-3, DBC-4 and DEC-A. In order to improve the function reliability based on SFC, the SSCs that perform FC1 function shall be powered from different electrical zones.

  In order to ensure the functional reliability of containment isolation, the electrical isolation valves outside containment shall be equipped with 12 hour non-interruptible battery, Emergency Diesel Generator (EDG), Station Black Out (SBO) generators and mobile power supply devices. The electrical isolation valves inside containment shall be equipped with 2 hour non-interruptible battery, EDG, SBO generators.

- Independence

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

- Diversity

  Not applicable.

- Ageing and Degradation

  The plant design lifetime is 60 years. Some components need to be replaced at the end of their individual design life.

  The performance of equipment is guaranteed through examination, inspection, maintenance and testing, as well as the monitoring during normal operation, which will ensure that ageing effect does not compromise safety performance. Detailed design arrangements relating to EMIT are presented in Reference [23].

  The system layout design confirmed in the detailed design stage will ensure the accessibility and requirement for safety equipment in-service inspection and periodic tests including the necessary Non Destructive Test (NDT), as well as the requirements of emergency and scheduled maintenance on the SSCs.

c) Human Factors

The system design of RPE [VDS] does not require short term operator intervention, while there are operator actions in normal operation, of which the effect needs to be estimated. Relevant human actions important to plant safety is identified and evaluated in Chapter 15.

d) Protection Design against Internal and External Hazards

For external hazards, the containment isolating valves and the pipelines go through the BRX, BFX and the safety buildings of RPE [VDS] are required to be protected from the earthquakes. The containment isolating valves are designed to Safe Shutdown Earthquake (SSE) level 1 and the other pipelines are designed to SSE-2.

The detailed consideration of specific hazards protection design is presented in Reference [22].

The other external hazards are not required to be protected by RPE [VDS].

e) Commissioning

Commissioning will be carried out for RPE [VDS] to valid its functionality at the site licensing stage. However, document related to the commissioning test requirements is going to be submitted during GDA phase.

f) Examination, Inspection, Maintenance and Testing

1) Examination

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

2) Inspection

The reactor coolant drain tanks and their related safety valves in RPE [VDS] require pre-service inspection. The other components do not need pre-service inspection.

RPE [VDS] equipment inspection is carried out according to the equipment operation and maintenance manual at site licensing stage, which will be developed by equipment manufacturers.

The layout of these components shall consider appropriate access.

3) Maintenance

The preventive maintenance of the equipment will be performed in accordance with the equipment operation & maintenance manual at site licensing stage, which will be developed by equipment manufacturers.

The layout design will take into consideration the need to remove the old parts and to install replacements.

4) Periodic Tests

The containment isolation valves must undergo periodic tests at site licensing stage. The requirements of periodic tests will be developed during GDA phase.

g) Decommissioning

The design of RPE [VDS] considers the decommissioning. A certain gradient is set in the pipeline layout to prevent liquid accumulation and all equipment and pipes can be drained by the draining lines.

h) Material Selection

Number 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.

Sumps are equipped with stainless steel liners except the sump RPE6161BA- which is covered and protected by a coating.

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

23.6.2 Liquid Waste Treatment System

23.6.2.1 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.

23.6.2.2 Role of the System

TEU [LWTS] provides separately storage, treatment and monitoring of the non-recyclable liquid wastes, which are collected by RPE [VDS] and SRE [SRS].

TEU [LWTS] performs the following operational functions:

a) Sampling liquid wastes in the storage tanks and transferring liquid wastes to the

appropriate treatment routes;

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

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

23.6.2.3 System Description and Operation

23.6.2.3.1 System Description

TEU [LWTS] is designed to store, treat and monitor radioactive wastes which include process drains, chemical drains, floor drains and laundry drains. The above liquid wastes are collected by RPE [VDS] and SRE [SRS]. After the liquid wastes have been treated and samples have been analysed, the liquid wastes are discharged through TER [NLWDS].

Following the development of the engineering aspects, the optioneering of radioactive liquid waste treatment techniques have been undertaken, the details are described in *Optioneering Report for Liquid Radioactive Waste Processing Techniques*, Reference [24]. The potential options from worldwide OPEX are identified and assessed against the assessment criteria considering the safety aspects and environment impacts in this report. 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 wastes treated by TEU [LWTS] are classified into four categories:

a) Process drains, which contain a low level of chemical impurities;

b) Chemical drains, which contain a higher level of chemical impurities and potentially higher radioactivity;

c) Floor drains, which typically contain lower radioactivity but are high in suspended solids; and,

d) Laundry drains, which is lower in radioactive contamination but high in suspended solids, fibrous matters, and detergents.

The system flow diagram of TEU [LWTS] is presented in F-23.6-2, 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 wastes is equipped with two storage tanks. For floor drains, there are three storage tanks. Each kind of storage tanks is equipped with a liquid waste 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 wastes need to be treated through the evaporation unit, the liquid wastes in the storage tank are mixed and sampled, 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 wastes 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-23.6-2.

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.

23.6.2.3.2 Description of Equipment

a) Liquid waste storage tanks and monitoring tanks

The liquid wastes are 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 that contact with the liquid wastes 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 wastes. 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 [25].

23.6.2.3.3 Description of System Interfaces

a) Supporting Systems

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

DWQ [WBVS] is required to receive TEU [LWTS] equipment exhaust, and maintain the temperature of the rooms where evaporators and other equipment are located.

2) SRE [SRS]

SRE [SRS] is required to receive the drainage and leakage of TEU [LWTS] equipment and piping.

3) SED [DWDS(NI)]

SED [DWDS(NI) is required to provide demineralised water for equipment such as chemical reagents injection tank and steam compressor, and to provide demineralised water to flush replacement media of equipment such as demineraliser.

4) SAT [SCADS]

SAT [SCADS] is required to provide compressed air to purge replacement media of equipment such as demineraliser, and to provide power and mixing gases to drain concentrate.

5) TES [SWTS]

TES [SWTS] is required to treat the solid wastes and concentrate produced by the TEU [LWTS].

6) RRI [CCWS]

RRI [CCWS] is required to provide cooling water for exhaust cooler and steam compressor.

7) TER [NLWDS]

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

8) Instrument Compressed Air Distribution System (SAR [ICADS])

SAR [ICADS] is required to provide air for pneumatic valves.

b) User Systems

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

TEU [LWTS] is required to receive and treat the liquid wastes collected by the RPE [VDS].

2) Sewage Recovery System (SRE [SRS])

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

3) Hot Laundry Facility (SBE [HLF])

TEU [LWTS] is required to receive and treat the laundry drains produced by the SBE [HLF].

4) Nuclear Liquid Waste Discharge System (TER [NLWDS])

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

23.6.2.3.4 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 wastes are transferred to the monitoring tank. Before being sent TER [NLWDS], the liquid wastes in monitoring tank must be mixed and sampled for analysis.

b) Plant Accident Condition

Not applicable.

23.6.2.4 Preliminary Design Substantiation

a) Compliance with Safety Functional Requirements

1) Control of Reactivity

Not applicable.

2) Removal of Heat

Not applicable.

3) Confinement

The confinement of radioactive material 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.

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

b) Compliance with Design Requirements

1) Safety Classification

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

T-23.6-3 System Classification

Component	Function Category	Safety Classification	Design Provision Category	Design Provision Class	Seismic Categorisation
Liquid waste storage subsystem	NC	NC	NC	NC	NO*
Liquid waste treatment subsystem	NC	NC	NC	NC	NO*
Chemical dosing subsystem	NC	NC	NC	NC	NO
Discharge monitoring subsystem	NC	NC	NC	NC	NO*
Sampling analysis subsystem	NC	NC	NC	NC	NO

Note:

a) NO*: The seismic categorisation of pipelines and isolation valves that penetrate through the retention pit of this subsystem is SSE2. The seismic categorisation of the valves and pipelines on the component of cooling water side is SSE2. The seismic categorisation for other equipment is NO;

b) The seismic categorisation of pipes arranged in the liquid waste transportation gallery is SSE2.

The details about categorisation and classification are presented in Reference [26].

2) Reliability Design of SSCs

- Single Failure Criterion (SFC)

  Not applicable.

- Independence

  Not applicable.

- Diversity

  Not applicable.

- Ageing and Degradation

  The plant design lifetime is 60 years. Some components need be replaced at the end of their individual design life.

  The performance of equipment is guaranteed through life examination, inspection maintenance and testing, as well as the monitoring during normal operations. This will ensure that ageing effect does not compromise safety performance. Detailed design arrangement relating to EMIT are presented in Reference [27].

  The system layout design in the detailed design stage will ensure the accessibility and requirement for safety equipment in-service inspection and periodic tests including the necessary NDT, as well as the requirements of emergency and scheduled maintenance on the SSCs.

c) Human Factors

The design of TEU [LWTS] does not require short term operator intervention, while there are operator actions during plant normal operation, of which the effect needs to be assessed. Relevant human actions important to plant safety is identified and evaluated in Chapter 15.

d) Protection Design against Internal and External Hazards

Since the main components of TEU [LWTS] 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 [26].

e) Commissioning

Commissioning will be carried out for the TEU [LWTS] to validate its functionality at the site licensing stage. However, document related to the commissioning test requirements is going to be submitted during GDA phase.

f) Examination, Inspection, Maintenance and Testing

1) Examination

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 valve is displayed on the control screen of KSH [WBCS].

The opening and closing of the remote control isolation valves are displayed on the control screen of KSH [WBCS].

The integrated alarm signal for waste treatment subsystem failures and unusable condition of the system is sent to the main control room for display.

2) Inspection

TEU [LWTS] equipment inspection is carried out according to the equipment operation and maintenance manual at site licensing stage, which will be developed by equipment manufacturers.

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

3) 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 wastes produced is at peak during unit shutdown, the preventive maintenance often is conducted during unit normal operation.

The preventive maintenance of the equipment will be performed in accordance with the equipment operation & maintenance manual at site licensing stage, which will be developed by equipment manufacturers.

4) Periodic Tests

The periodic tests requirements will be developed to guide the preparation the periodic testing at site licensing stage.

g) Decommissioning

The design of TEU [LWTS] considers the decommissioning. A certain gradient is

set in the pipeline layout to prevent liquid accumulation and all equipment and pipes can be drained by the draining lines.

h) 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.

23.6.3 Nuclear Island Liquid Waste Discharge System

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

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

d) Extra Supporting Functions

TER [NLWDS] does not contribute to this function.

23.6.3.2 Role of the System

TER [NLWDS] collects liquid wastes from nuclear island, and discharges them to the environment with control after mixing, sampling and analysing and monitoring the liquid wastes.

TER [NLWDS] functions include:

a) Collecting and storing liquid wastes from TEU [LWTS] and TEP [CSTS], and mix, sample, analysis, monitor before discharge;

b) Collecting and storing liquid wastes from APG [SGBS] and SEK [WFCS (CI)], if SEL [LWDS (CI)] is unavailable or if the radioactivity level of the liquid wastes discharged to SEL [LWDS (CI)] cannot meet 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;

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

23.6.3.3 System Description and Operation

23.6.3.3.1 System Description

TER [NLWDS] is composed of:

a) Piping that receive liquid wastes 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-23.6-3.

23.6.3.3.2 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 that contact with the liquid wastes and the tanks are made of stainless steel.

The three storage tanks are designed to receive liquid wastes from upstream systems. The liquid waste discharge pumps mix and transfer the liquid wastes in the liquid waste storage tanks. The liquid wastes collected in the sumps in pump room and in retention pit are pumped to the liquid waste storage tanks by the sump pumps.

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

23.6.3.3.3 Description of System Interfaces

a) Supporting Systems

1) KRT [PRMS]

This system provides on-line monitoring for the activity of effluent discharge.

2) SAR [ICADS]

This system provides compressed air for the pneumatic isolation valves.

b) User Systems

1) TEU [LWTS]

TER [NLWDS] collects low radioactive liquid waste from TEU [LWTS].

2) TEP [CSTS])

TER [NLWDS] collects tritium from TEP [CSTS].

3) SEL [LWDS (CI)]

TER [NLWDS] collects the liquid waste from SEL [LWDS (CI)] when the SEL [LWDS (DI)] system is unavailable, or the radioactivity level of the liquid wastes discharged to the SEL [LWDS (CI)] system is high.

4) PTR [FPCTS]

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

23.6.3.3.4 System Operation

a) Plant Normal Condition

During normal operation, one of the three storage tanks in TER [NLWDS] is used to receive liquid wastes; one is used to mix, or sample and analyse, or monitor and discharge liquid wastes; one is on standby. There is one sampling point on the recirculation line of each liquid waste storage tank, which is presented in F-23.4-3. The liquid wastes from each system are well mixed through recirculation line before sampling is performed. After the sample is analysed, the discharge flow rate is determined according to the radioactivity level of the liquid wastes and the dilution ability of the drainage channels.

From the system flow diagram in F-23.4-3, a radiation monitor in KRT [PRMS], which is positioned on the main discharge pipe, is used to detect the radioactivity of the liquid wastes. The radiation monitor will send out alarms and the isolation valves will be closed automatically if the radioactive concentration of the liquid wastes exceeds the pre-determined value. The details of KRT [PRMS] are presented in Sub-chapter 8.10 in Chapter 8.

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 wastes 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.

23.6.3.4 Preliminary Design Substantiation

a) Compliance with Safety Functional Requirements

1) Control of Reactivity

Not applicable.

2) Removal of Heat

Not applicable.

3) 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.

It is designed to contain the liquid radioactive waste by the sealing of equipment and pipes. The storage tank of TER [NLWDS] is located in retention pit, which have sufficient capacity to accommodate the liquid waste stored in storage tank of TER [NLWDS].

4) Extra Supporting Functions

Not applicable.

b) Compliance with Design Requirements

1) Safety Classification

The design of TER [NLWDS] is compliant with the principles described in Chapter 4. The safety classification of TER [NLWDS] is listed in T-23.6-4 .

T-23.6-4 System Classification

Component	Function Category	Safety Classification	Design Provision Category	Design Provision Class	Seismic Categorisation
Storage tanks	NC	NC	NC	NC	NO
Discharge pumps	NC	NC	NC	NC	NO

Component	Function Category	Safety Classification	Design Provision Category	Design Provision Class	Seismic Categorisation
Sump pumps	NC	NC	NC	NC	NO
Isolation valves on the pipes which penetrate through the retention pit	NC	NC	NC	NC	SSE2
Pipes through the retention pit	NC	NC	NC	NC	SSE2
Pipes located in the liquid waste transport gallery	NC	NC	NC	NC	SSE2

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

2) Reliability Design of SSCs

- Single Failure Criterion (SFC)

  Not applicable.

- Independence

  Not applicable.

- Diversity

  Not applicable.

- Ageing and Degradation

  The plant design lifetime is 60 years. Some components need be replaced at the end of their individual design life.

  The performance of equipment is guaranteed through life examination, inspection maintenance and testing, as well as monitoring during normal operation, which will ensure that ageing effect does not compromise safety performance. Detailed design arrangements relating to EMIT and

equipment monitoring are presented in Reference [30].

The system layout design in the detailed design stage will ensure the accessibility and requirement for safety equipment in-service inspection and periodic tests including the necessary NDT, as well as the requirements of emergency and scheduled maintenance on the SSCs.

c) Human Factors

The system design of TER [NLWDS] does not require short term operator intervention, while there are operator actions during plant normal operation, of which the effect needs to be assessed. Relevant human actions important to plant safety is identified and evaluated in Chapter 15.

d) Commissioning

Commissioning will be carried out for TER [NLWDS] to valid its functionality at the site licensing stage. However, information related to the commissioning test requirements is going to be submitted during GDA phase.

e) 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 [29].

f) Examination, Inspection, Maintenance and Testing

1) Surveillance

The main surveillance of TER [NLWDS] includes:

- The electric and pneumatic isolation valves switching and fault states;
- The electric control valves switching, lift and fault states;
- Part of important manual isolation valves switching states;
- Pump start-stop states.

2) Maintenance

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

3) Periodic Tests

The requirements of periodic tests will be developed to guide the preparation the periodic testing at site licensing stage.

4) Inspection

TER [NLWDS] equipment inspection is carried out according to the equipment operation and maintenance manual at site licensing stage, which will be developed by equipment manufacturers.

g) Decommissioning

The design of TER [NLWDS] considers the decommissioning. A certain gradient is set in the pipeline layout to prevent liquid accumulation and all equipment and pipes can be drained by the draining lines.

h) Material Selection

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

23.6.4 Sewage Recovery System

23.6.4.1 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.

23.6.4.2 Role of the System

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

a) Separate collection of different categories of the liquid wastes produced in the BWX and hot mechanical workshop and warehouse. The liquid wastes collected by SRE [SRS] are classified into four categories according to their 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.

23.6.4.3 System Description and Operation

23.6.4.3.1 System Description

SRE [SRS] is designed to separately collect the liquid radioactive waste from BWX and hot mechanical workshop and warehouse. The liquid wastes include:

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 [20], so this sub-chapter presented the liquid waste collection subsystem in BWX.

The system flow diagram of SRE [SRS] is presented in F-23.6-4.

23.6.4.3.2 Equipment Description

a) Liquid waste collection sumps

Liquid waste collection sumps are located on the bottom floor of the BWX. They collect various liquid wastes with potential radioactivity produced in this building. Stainless steel liners are installed in sumps to facilitate its decontamination.

b) Pumps

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

Detailed information of the equipment is presented in Reference [31].

23.6.4.3.3 Description of System Interfaces

a) Supporting Systems

1) DWQ [WBVS]

DWQ [WBVS] is required to ventilate the rooms, in where SRE [SRS]

system located.

2) TEU [LWTS]

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

b) User Systems

1) TEU [LWTS]

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

2) TES [SWTS]

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

3) DWQ [WBVS]

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

4) Nuclear Island Fire Protection System (JPI [NIFPS])

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

5) Portable Water System (SEP [PWS])

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

23.6.4.3.4 System Operation

a) Plant Normal Condition

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

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

b) Plant Accident Conditions

Not applicable.

23.6.4.4 Preliminary Design Substantiation

a) Compliance with Safety Functional Requirements

1) Control of Reactivity

Not applicable.

2) Removal of Heat

Not applicable.

3) 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.

b) Compliance with Design Requirements

1) Safety Classification

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

T-23.6-5 System Classification

Component	Function Category	Safety Classification	Design Provision Category	Design Provision Class	Seismic Categorisation
Pipes through the retention pool	NC	NC	NC	NC	SSE2
Valves connected to pipes through the retention	NC	NC	NC	NC	SSE2
Other equipment	NC	NC	NC	NC	NO

The details about categorisation and classification are presented in Reference [32].

2) Reliability Design of SSCs

- Single Failure Criterion (SFC)

  Not applicable.

- Independence

  Not applicable.

- Diversity

  Not applicable.

- Ageing and Degradation

  The plant design lifetime is 60 years. Some components need to be replaced at the end of their individual design life.

  The performance of equipment is guaranteed through life examination, inspection maintenance and testing, as well as the monitoring during normal operation, which will ensure that ageing effect does not compromise safety performance. Detailed design arrangements relating to the EMIT are presented in Reference [33].

  The system layout design in the detailed design stage will ensure the accessibility and requirement for safety equipment in-service inspection and periodic tests including the necessary Non Destructive Test (NDT), as well as the requirements of emergency and scheduled maintenance on the SSCs.

c) Human Factors

The design of SRE [SRS] does not require short term operator intervention. However, there are operator actions during plant normal operation, of which the effect needs to be assessed. Relevant human actions important to plant safety are identified and evaluated in Chapter 15.

d) 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 [32].

e) Commissioning

Commissioning will be carried out for SRE [SRS] to valid its functionality at the site licensing stage. However, document related to the commissioning test requirements is going to be submitted during GDA phase.

f) Examination, Inspection, Maintenance and Testing

1) Examination

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].

2) Inspection

Not applicable.

3) 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 at site licensing stage, which will be developed by equipment manufacturers.

4) Periodic Testing

The requirements of periodic tests will be developed guide the preparation the periodic testing at site licensing stage.

g) Decommissioning

The design of SRE [SRS] considers the decommissioning. A certain gradient is set in the pipeline layout to prevent liquid accumulation and all equipment and pipes can be drained by the draining lines.

h) Material Selection

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

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

23.6.5 Conventional Island Liquid Waste Discharge System

23.6.5.1 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 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.

d) Extra Supporting Functions

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

23.6.5.2 Role of the System

SEL [LWDS (CI)] collects liquid wastes from conventional island, and discharges them to the environment with control. SEL [LWDS (CI)] functions include:

a) Collect and store liquid wastes from SEK [WFCS(CI)] and unrecyclable effluents from Steam Generator Blowdown System (APG [SGBS]), and discharge these liquid wastes after mixing, sampling and analysis;

   The secondary (steam) circuit is cleaned by a periodic blow-down from the steam generators. The blow-down effluents is processed by APG [SGBS]. After processing, the purified blow down water is sent to the main turbine condenser for recycling to minimize the liquid radioactive waste. If it remains unsuitable for re-use, the treated effluents from the APG [SGBS] will be sent to SEL [LWDS (CI)] for discharge. APG [SGBS] are presented in Sub-chapter 11.4.5 in Chapter 11.

b) Send liquid wastes to TEU [LWTS] for treatment when the radioactivity concentration of the waste liquid 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.

23.6.5.3 System Description and Operation

23.6.5.3.1 System Description

SEL [LWDS (CI)] is composed of:

a) Piping that receive liquid wastes 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 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 SEL [LWDS (CI)] is presented in F-23.6-3.

23.6.5.3.2 Description of Main Equipment

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

The three storage tanks are used to receive liquid wastes from the upstream systems. The liquid waste discharge pumps mix and transfer the liquid wastes in the liquid waste storage tanks. The liquid wastes collected in the sumps in pump room and in retention pit are pumped to the liquid waste storage tanks by the sump pumps.

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

23.6.5.3.3 Description of System Interfaces

a) Supporting Systems

1) KRT [PRMS]

This system provides on-line monitoring for activity of effluent discharge.

2) SAR [ICADS]

This system provides compressed air for pneumatic isolation valves

b) User Systems

1) SEK [WFCS(CI)]

Collect low radioactive liquid waste from SEK [WFCS(CI)].

2) APG[SGBS])

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

23.6.5.3.4 System Operation

a) Plant Normal Condition

During normal operation, one of the three storage tanks in SEL [LWDS (CI)] is used to receive liquid wastes; one is used to mix, sample and analyse, or monitor and discharge liquid wastes; one is on standby. There is one sampling point on the recirculation line of each liquid waste storage tank, which is presented in F-23.4-3. The liquid wastes from each system are well mixed through recirculation line before sampling performed. After the sample is analysed, the discharge flow rate is determined according to the radioactive level of the liquid wastes and the dilution ability of the drainage channels.

From the system flow diagram in F-23.4-3, a radiation monitor in KRT [PRMS], which is positioned on the each discharge pipe, is used to detect the radioactive level of the liquid wastes. If the radioactive concentration of the liquid wastes exceeds the discharge management objective, the monitoring system will send out alarms and the isolation valves will be closed automatically. The details of KRT [PRMS] are presented in Sub-chapter 8.10 in Chapter 8.

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

records maintenance.

The liquid wastes 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.

23.6.5.4 Preliminary Design Substantiation

a) Compliance with Safety Functional Requirements

1) Control of Reactivity

Not applicable.

2) Removal of Heat

Not applicable.

3) 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.

It is designed to contain the radioactivity liquid waste by the sealing of equipment and pipes. The storage tank of SEL [LWDS (CI)] is located in retention pit, which has sufficient capacity to accommodate the liquid waste stored in storage tank of SEL [LWDS (CI)].

4) Extra Supporting Functions

Not applicable.

b) Compliance with Design Requirements

1) Safety Classification

The design of SEL [LWDS (CI)] is compliant with the principles described in PCSR Chapter 4. The safety classification of the SEL [LWDS (CI)] is listed in T-23.6-6.

T-23.6-6 System Classification

Component	Function Category	Safety Classification	Design Provision Category	Design Provision Class	Seismic Categorisation
Storage tanks	NC	NC	NC	NC	NO

Component	Function Category	Safety Classification	Design Provision Category	Design Provision Class	Seismic Categorisation
Discharge pumps	NC	NC	NC	NC	NO
Sump pumps	NC	NC	NC	NC	NO
Pipes located in the liquid waste	NC	NC	NC	NC	SSE2

The details about categorisation and classification are presented in Reference [35].

2) Reliability Design of SSCs

- Single Failure Criterion (SFC)

  Not applicable.

- Independence

  Not applicable.

- Diversity

  Not applicable.

- Ageing and Degradation

  The plant design lifetime is 60 years. Some components need to be replaced at the end of their individual design life.

  The performance of equipment is guaranteed through life examination, inspection maintenance and testing, as well as the monitoring during normal operation, which will ensure that ageing effect does not compromise safety performance. Detailed design arrangement relating to the EMIT and equipment monitoring is presented in Reference [36].

  The system layout design in the detailed design stage will ensure the accessibility and requirement for safety equipment in-service inspection and periodic tests including the necessary NDT, as well as the requirements of emergency and scheduled maintenance on the SSCs.

c) Human Factors

The system design of SEL [LWDS (CI)] does not require short term operator intervention, while there are operator actions during plant normal operation, of

which the effect needs to be assessed. Relevant human actions important to plant safety is identified and evaluated in Chapter 15.

d) Commissioning

Commissioning will be carried out for SEL [LWDS (CI)] to valid its functionality at the site licensing stage. However, document related to the commissioning test requirements is going to be submitted be submitted during GDA phase.

e) 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 [35].

f) Examination, Inspection, Maintenance and Testing

1) Examination

The main surveillance of SEL [LWDS (CI)] includes:

- The electric and pneumatic isolation valves switching and fault states;
- The electric control valves switching, lift and fault states;
- The manual isolation valve in discharge pipeline switching states;
- Pump start-stop states.

2) Inspection

SEL [LWDS (CI)] equipment inspection will be carried out according to the equipment operation and maintenance manual at sit licensing stage, which will be developed by equipment manufacturers.

2) Maintenance

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

3) Periodic Tests

The requirements of periodic tests will be developed guide the preparation the periodic testing at site licensing stage.

g) Decommissioning

The design of SEL [LWDS (CI)] considers the decommissioning. A certain gradient is set in the pipeline layout to prevent liquid accumulation and all

equipment and pipes can be drained by the draining lines.

h) Material Selection

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

23.6.6 ALARP Assessment

According to the ALARP methodology specified in Chapter 33, one of the basic principles of ALARP is the recognition and use of RGP and operational experience and feedback.

Although not the sole criterion, RGP may be referred to as the use of existing codes and standards. Sources of relevant good practices for systems are identified in Sub-chapter 23.3 and the RGP relating to liquid radioactive waste management include:

a) Regulatory Guidance Series, No RSR 1: Radioactive Substances Regulation – Environmental Principles;

b) Predisposal Management of Radioactive Waste; and,

c) Predisposal Management of Radioactive Waste from Nuclear Power Plants and Research Reactors.

At this stage, a preliminary holistic review of the design of liquid radioactive waste management systems against the identified RGP has been undertaken in Reference [37], which concludes there are no significant gaps identified for liquid radioactive waste management system.

In order to identify any potential improvement, the consistency analysis between the current design relating to liquid radioactive waste management and UK practices and infrastructure will be continually developed considering the use of operational experience and feedback and review of identified RGP during GDA process.

23.6.7 System Flow Diagrams

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

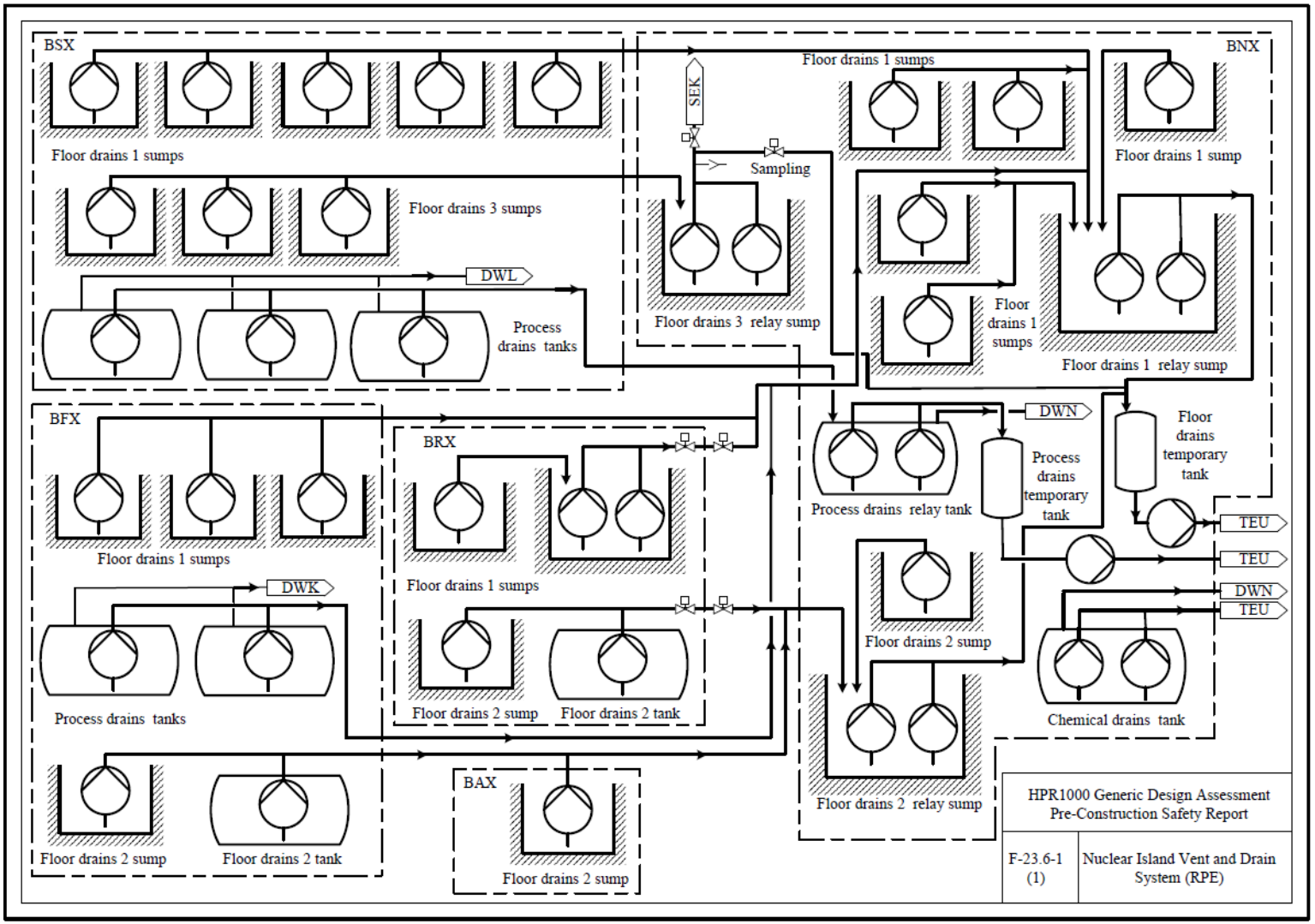
F-23.6-1(1) Nuclear Island Vent and Drain System (RPE [VDS])

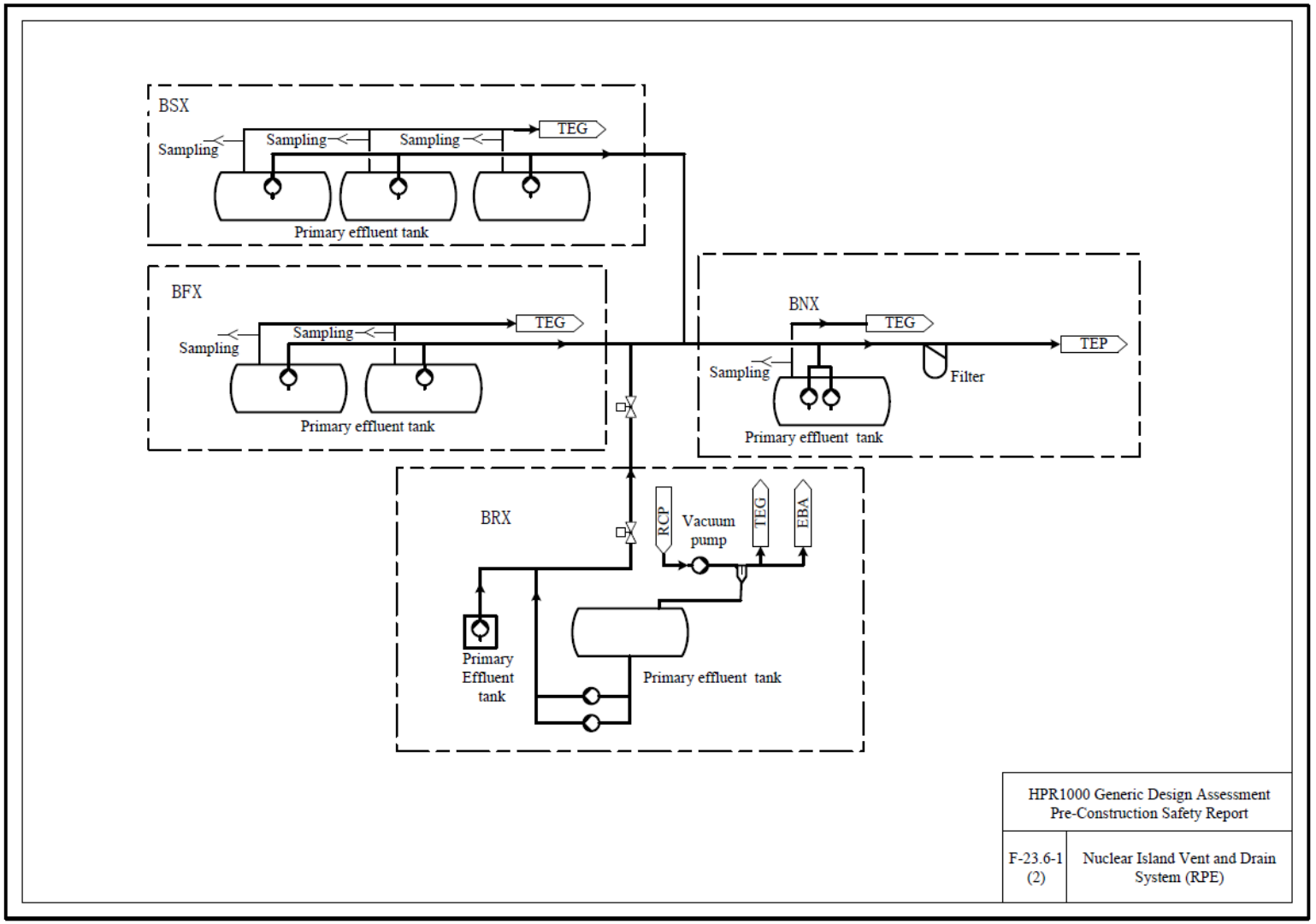
F-23.6-1(2) Nuclear Island Vent and Drain System (RPE [VDS])

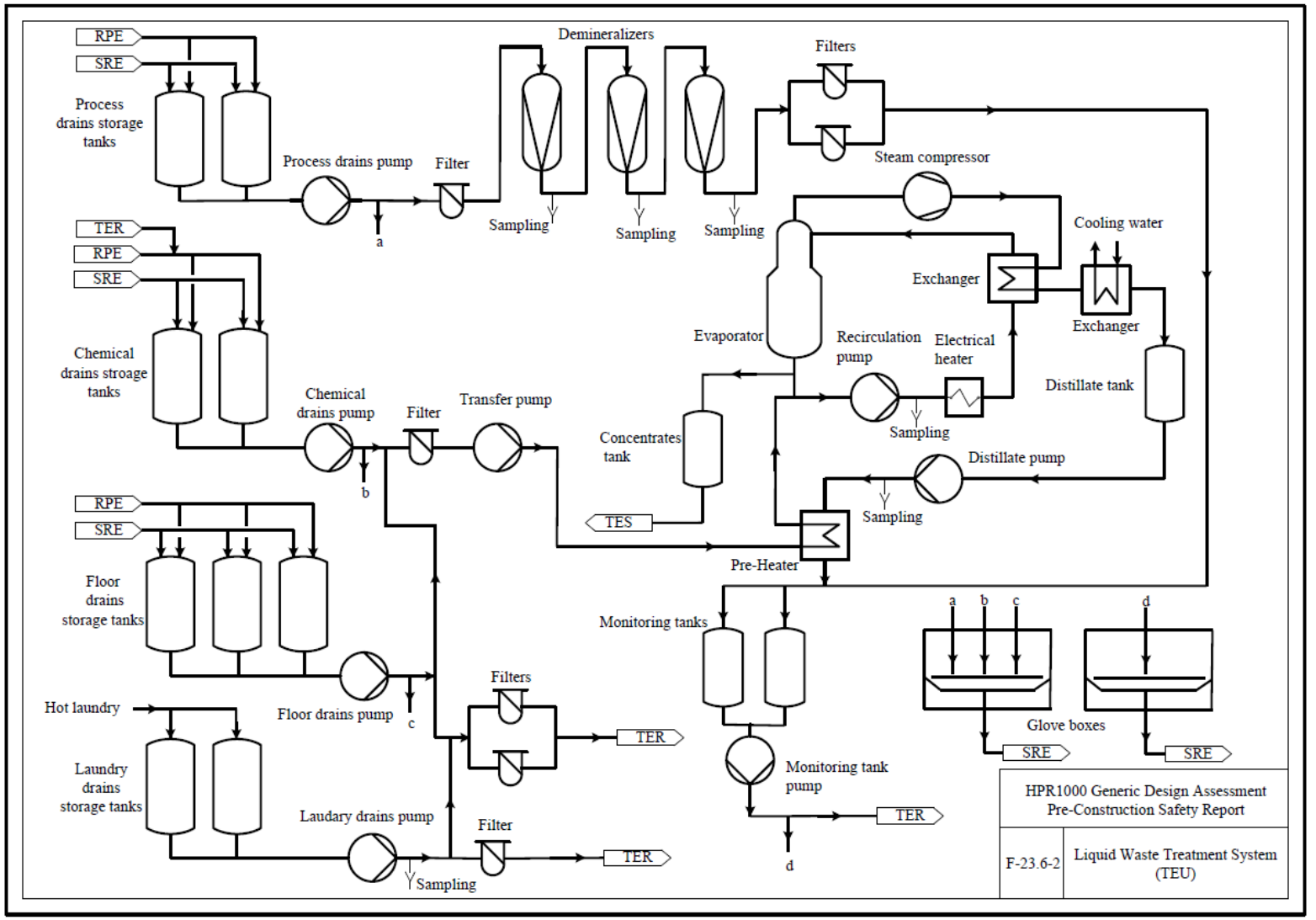
F-23.6-2 Liquid Waste Treatment System (TEU [LWTS])

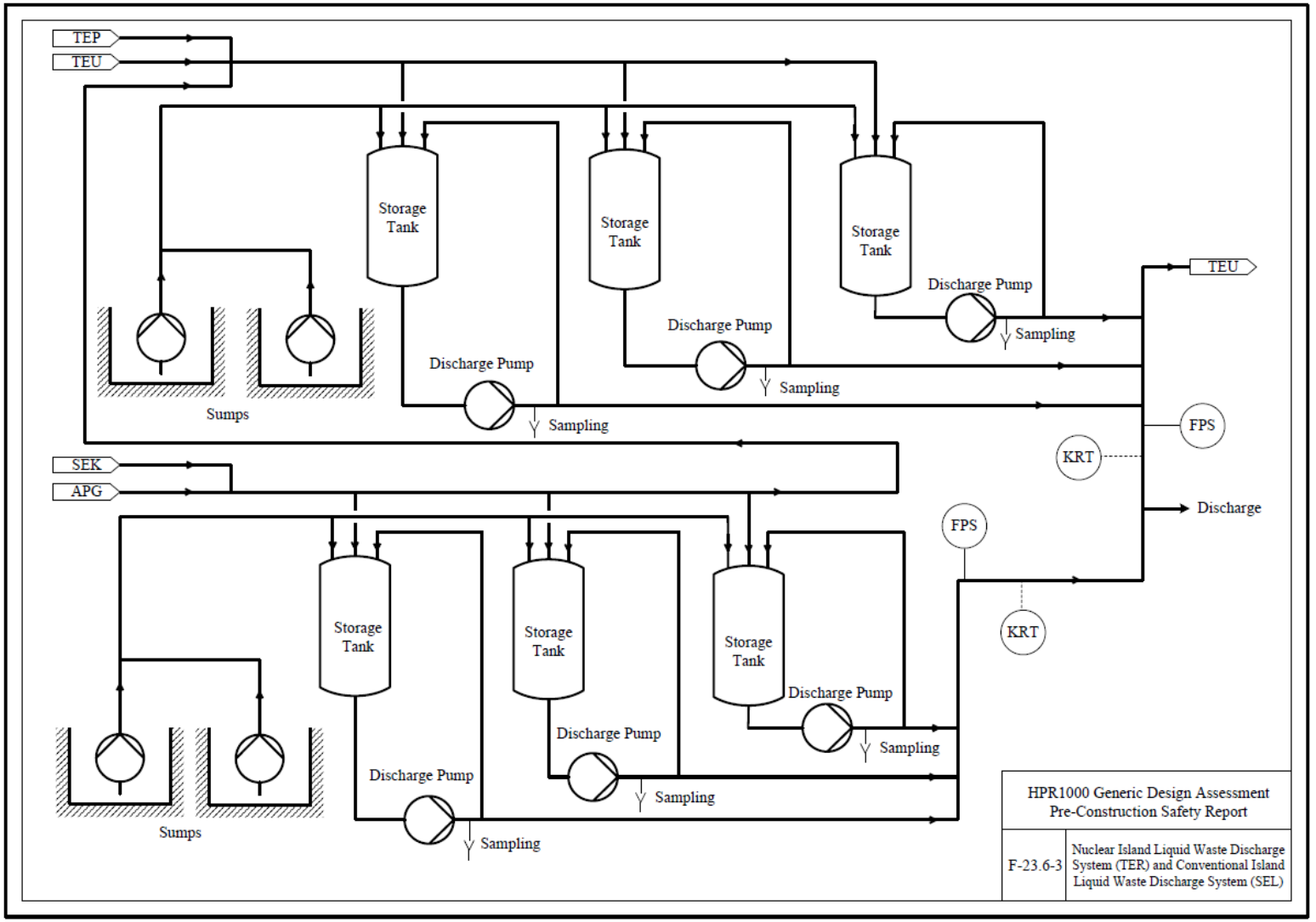
F-23.6-3 Nuclear Island Liquid Waste Discharge System (TER [NLWDS]) and Conventional Island Liquid waste Discharge System (SEL[LWDS (CI)])

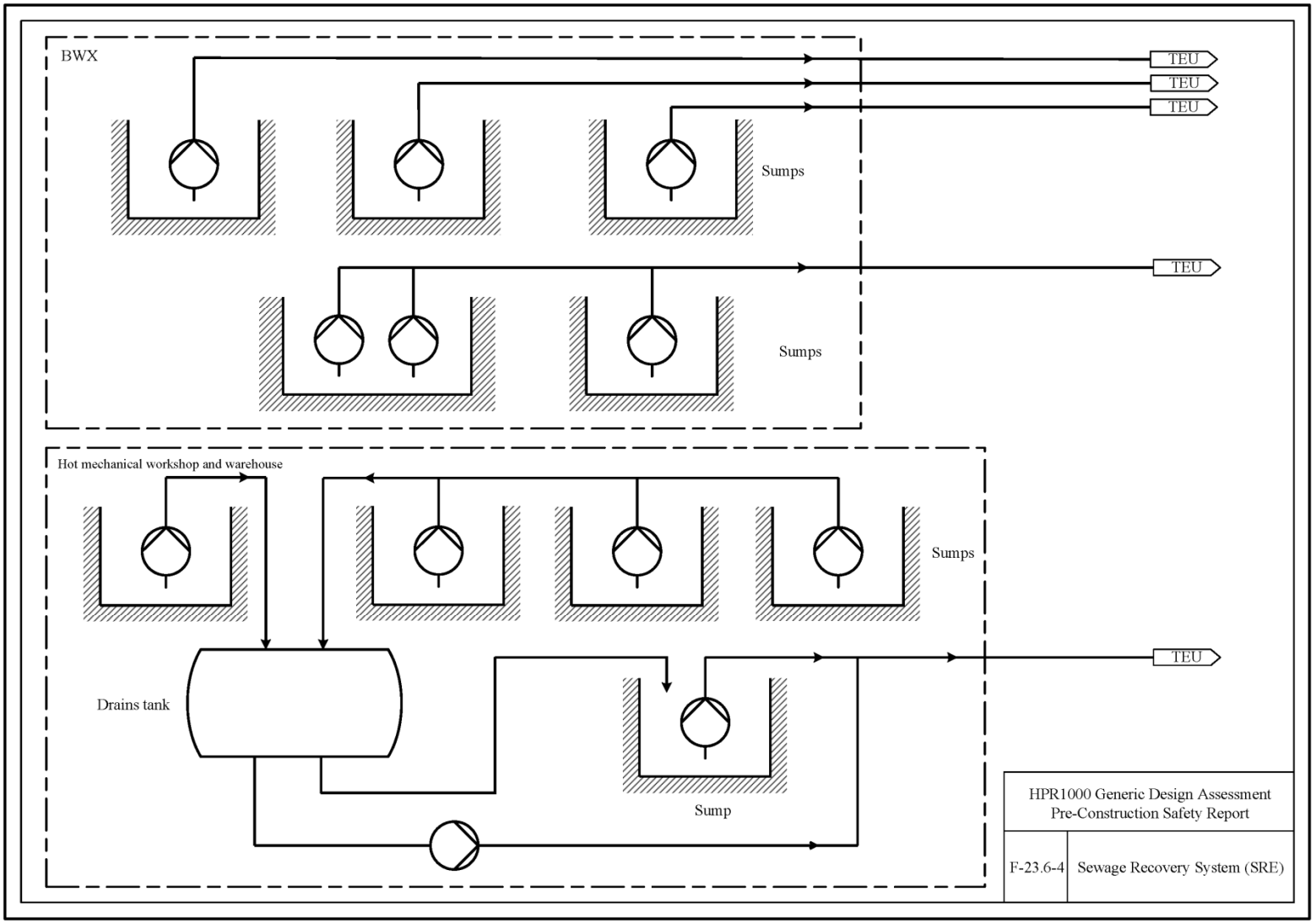
F-23.6-4 Sewerage Recovery System (SRE [SRS])


BSX
Floor drains 1 sumps
Floor drains 3 sumps
DWL
Process drains tanks
SEK
Sampling
Floor drains 3 relay sump
Floor drains 1 sumps
BNX
Floor drains 1 sump
Floor drains 1 sumps
Floor drains 1 relay sump
BFX
Floor drains 1 sumps
DWK
Process drains tanks
BRX
Floor drains 1 sumps
Floor drains 2 sump
Floor drains 2 tank
Process drains relay tank
DWN
Process drains temporary tank
Floor drains temporary tank
TEU
TEU
DWN
TEU
Floor drains 2 sump
Chemical drains tank
Floor drains 2 relay sump
BAX
Floor drains 2 sump
Floor drains 2 sump
Floor drains 2 tank
HPR1000 Generic Design Assessment
Pre-Construction Safety Report
F-23.6-1 (1)
Nuclear Island Vent and Drain System (RPE)


BSX
Sampling
Sampling
Sampling
TEG
Primary effluent tank
BFX
Sampling
Sampling
TEG
Primary effluent tank
BNX
TEG
TEP
Sampling
Filter
Primary effluent tank
BRX
RCP
Vacuum pump
TEG
EBA
Primary Effluent tank
Primary effluent tank
HPR1000 Generic Design Assessment
Pre-Construction Safety Report
F-23.6-1 (2)
Nuclear Island Vent and Drain System (RPE)


RPE
SRE
Process drains storage tanks
Process drains pump
Filter
a
Demineralizers
Sampling
Sampling
Sampling
Filters
Steam compressor
Cooling water
Exchanger
Exchanger
TER
RPE
SRE
Chemical drains stroage tanks
Chemical drains pump
Filter
Transfer pump
b
Evaporator
Recirculation pump
Electrical heater
Distillate tank
Sampling
Concentrates tank
Distillate pump
Sampling
TES
Pre-Heater
RPE
SRE
Floor drains storage tanks
Floor drains pump
c
Filters
TER
Hot laundry
Laundry drains storage tanks
Laudary drains pump
Filter
TER
Sampling
Monitoring tanks
Monitoring tank pump
TER
d
a
b
c
d
Glove boxes
SRE
SRE
HPR1000 Generic Design Assessment
Pre-Construction Safety Report
F-23.6-2
Liquid Waste Treatment System (TEU)


TEP
TEU
Storage Tank
Storage Tank
Storage Tank
Discharge Pump
Discharge Pump
Discharge Pump
Sampling
Sampling
Sampling
TEU
Sumps
FPS
KRT
SEK
APG
Discharge
FPS
KRT
Storage Tank
Storage Tank
Storage Tank
Discharge Pump
Discharge Pump
Discharge Pump
Sampling
Sampling
Sampling
Sumps
HPR1000 Generic Design Assessment
Pre-Construction Safety Report
F-23.6-3
Nuclear Island Liquid Waste Discharge System (TER) and Conventional Island Liquid Waste Discharge System (SEL)


BWX
TEU
TEU
TEU
Sumps
TEU
Sumps
Hot mechanical workshop and warehouse
Sumps
Drains tank
TEU
Sump
HPR1000 Generic Design Assessment
Pre-Construction Safety Report
F-23.6-4
Sewage Recovery System (SRE)

23.7 Gaseous Radioactive Waste Management Systems

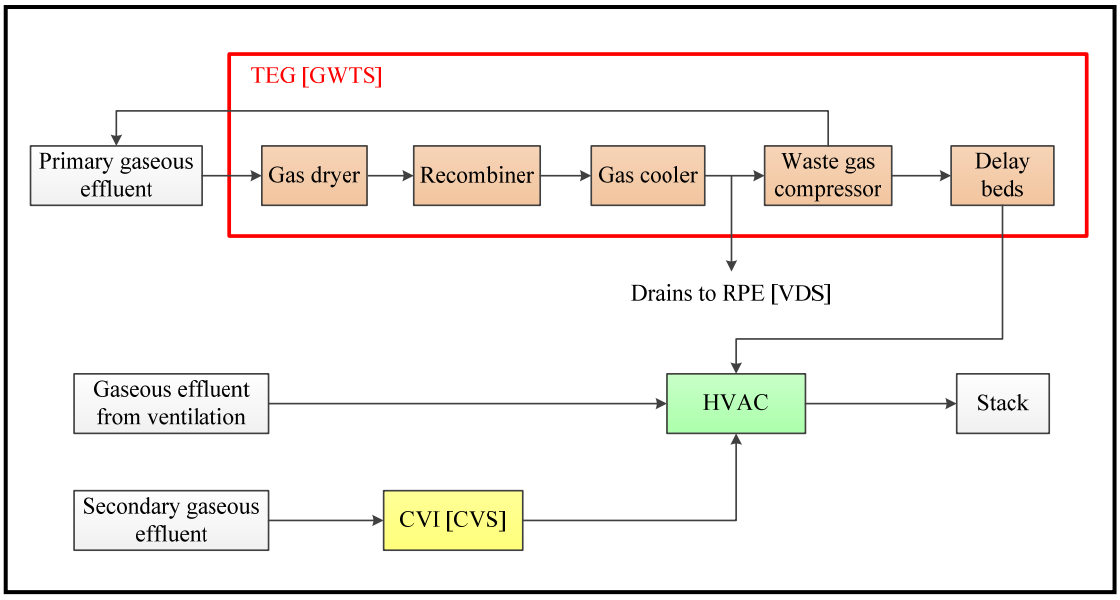
Gaseous radioactive waste generated unavoidably during the operation of UK HPR1000 is managed by the gaseous radioactive waste management systems, which consists of the following systems:

a) TEG [GWTS]

b) Condensate Vacuum System (CVI [CVS])

c) Heating, Ventilation and Air Conditioning (HVAC) Systems

These three sources of the gaseous radioactive wastes are processed, monitored and discharged to the environment as illustrated in F-23.7-1.



F-23.7-1 Gaseous Radioactive Waste Streams

This sub-chapter concentrates on TEG [GWTS]. HVAC Systems are presented in Sub-chapters 10.6, CVI [CVS] is not presented during GDA phase, as it is deemed to be out of GDA scope, Reference [20].

23.7.1 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] performs following confinement functions:

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 perform a containment safety function by preventing gaseous radioactive waste escaping from the equipment and connecting.

d) Extra supporting functions

TEG [GWTS] does not perform extra supporting functions.

23.7.2 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.

23.7.3 System Description and Operation

23.7.3.1 System Description

Following the development of the engineering aspects, the optioneering of gaseous waste processing technique has been undertaken, the details are presented in *Optioneering Report for Gaseous Radioactive Waste Processing Technique*, Reference [38]. The potential options from worldwide OPEX are identified and assessed against the assessment criteria considering the safety aspects and environment impacts in this report. 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;

f) The pipelines layout is required to facilitate the flow of flushing gases and condensate water.

The system flow diagram of TEG [GWTS] is presented in F-23.7-2, the system description are presented below.

<u>System Sub-function Units</u>

TEG [GWTS] includes 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 [39].

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.

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. The details of KRT [PRMS] are presented in Sub-chapter 8.10 in Chapter 8.

Sampling is also undertaken at the inlet and outlet of each delay beds to monitoring the adsorption efficiency of the activated charcoal.

23.7.3.2 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.

c) 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.

d) Measurement Gas Dryers

Measurement gas dryers reduce the dew point of the gas which route to the hydrogen and oxygen sensors.

e) 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.

f) 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.

g) Condensate Collecting Tank

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

h) Delay Beds

The delay beds are used for the decay of noble gases before discharge.

i) 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,{

}.

j) 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 [40].

23.7.3.3 Description of System Interfaces

23.7.3.3.1 Supporting Systems

a) DER [OCWS]

DER [OCWS] is required to provide cooling water for the gas dryer, gas cooler and pre-dryer.

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 wastes from TEG [GWTS] such as from the recombiner and the compressors. and collect the gaseous radioactive waste released from safety valves in TEG [GWTS].

d) SAR [ICADS]

SAR [ICADS] is required to provide compressed air for the pneumatic valves of TEG [GWTS].

e) SAT [SCADS]

SAT [SCADS] is required to provide compressed air for maintenance work.

f) SED [DWDS (NI)]

SED [DWDS (NI)] is required to provide sealing liquid for the waste gas compressors of TEG [GWTS].

g) Hydrogen Distribution System (SGH [HDS])

SGH [HDS] is required to provide hydrogen for the recombiner to recombine the oxygen.

h) Nitrogen Distribution System (SGN [NDS])

SGN [NDS] is required to provide nitrogen to TEG [GWTS] system as flushing gas in normal condition. It also maintains a constant pressure in the flushing section.

i) Oxygen Distribution System (SGO [ODS])

SGO [ODS] is required to provide oxygen for the recombiner to recombine the hydrogen.

j) Nuclear Sampling System (REN [NSS])

REN [NSS] is required to manually sample from the upstream/downstream of recombiner to analysis the hydrogen and oxygen concentration to validate the adsorption efficiency of activated carbon, in case the online hydrogen and oxygen sensors fail.

k) KRT [PRMS]

KRT [PRMS] is required to provide continuous monitoring for radioactivity during discharges of the treated gaseous waste from TEG [GWTS].

23.7.3.3.2 User Systems

a) RCP [RCS]

TEG [GWTS] is required to provide continual flushing for the pressuriser relief tank and the pressuriser safety valves of RCP [RCS] to avoid hydrogen accumulation.

b) RCV [CVCS]

TEG [GWTS] is required to provide continual flushing for the volume control tank of RCV [CVCS] to avoid hydrogen accumulation in the tank.

c) REA [RBWMS]

TEG [GWTS] is required to collect the gases produced by the level deviations of the boric acid tanks of REA [RBWMS].

d) REN [NSS]

TEG [GWTS] is required to provide continual flushing for the sample vessel of REN [NSS] to avoid hydrogen accumulation in the tank.

e) RPE [VDS]

TEG [GWTS] is required to provide continual flushing for the primary effluents drain tanks of RPE [VDS] located in the BRX, BSX, BFX and BNX to avoid hydrogen accumulation in the tanks. TEG [GWTS] also collects the excess gas produced during the flushing of the reactor pressure vessel head whose purpose is to reduce the overall radioactivity releases to the stack.

f) TEP [CSTS]

TEG [GWTS] is required to provide continual flushing for the coolant storage tanks, the boric acid column, the compressor and the evaporator, the degasifier column, degasifier cooler, liquid-ring pump and thesealing liquid tank. This

prevents hydrogen accumulation and removes hydrogen and non-condensable gases.

23.7.3.4 System Operation

23.7.3.4.1 Plant Normal Condition

TEG [GWTS] shall operate under normal operations in the two following operational modes:

a) Steady-state Operation Mode

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

1) Pressuriser relief tank of RCP [RCS]
2) Volume control tank of RCV [CVCS]
3) Boric acid storage tanks of REA [RBWMS]
4) Coolant storage tanks of TEP [CVCS]
5) Boric acid column of TEP [CVCS]
6) Degasifier column of TEP [CVCS]
7) Condensate collecting tank of TEP [CVCS]
8) Primary effluents drain tanks of RPE [VDS] in the BRX, BSX, BFX, BNX
9) 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 following three parts:

1) The first part is used to flush the pressuriser relief tank and the reactor coolant drain tank;

2) The second part is used to flush the volume control tank of RCV [CVCS];

3) 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.

b) 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:

1) 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;

2) After reactor shutdown, the water level reduction of the RCP [RCS] will result in the change of total gas space volume;

3) 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.

23.7.3.4.2 Plant Accident Conditions

Not applicable.

23.7.4 Preliminary Design Substantiation

23.7.4.1 Compliance with Safety Functional Requirements

a) Control of Reactivity

Not applicable.

b) Removal of Heat

Not applicable.

c) Confinement

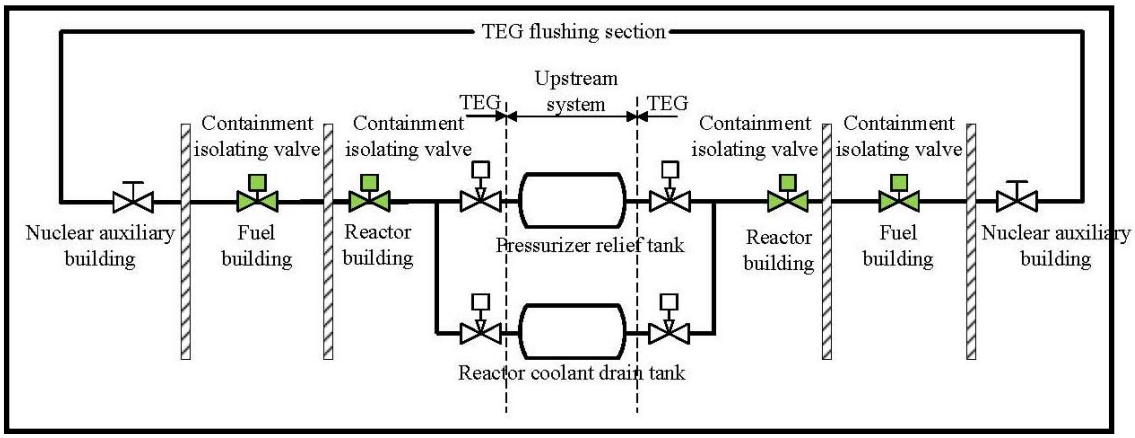
1) Containment Isolation

Four containment isolating valves presented in F-23.7-3 are installed on the two flushing pipelines in the BRX to ensure that it can be closed according to safety signals or manually during DBC-3 and DBC-4. Two containment isolating valve are configured in internal side of the BRX and others are configured in external side of the BRX.

2) Confinement radioactive waste during normal operation

TEG [GWTS] collects, treats and discharges the gaseous radioactive waste and prevents the escape of radioactive gases from the connected components into the building atmosphere by maintaining the flushing section under

negative pressure.



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

23.7.4.2 Compliance with Design Requirements

a) Safety Classification

The design of TEG [GWTS] is compliant with the principles described in Chapter 4. FC1 classified equipment of TEG [GWTS] is designed to withstandSSE1. The flushing branch inside the BRX, BSX, and BFX are designed to withstand SSE2. The system function classification and classification of main component of TEG [GWTS] is listed inT-23.7-1 and T-23.7-2.

T-23.7-1System 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	Function Class	Design Provision Category	Design Provision Class	Seismic Category
Containment isolation valves	F-SC1	DPA	B-SC2	SSE1
Flushing branch inside the reactor building, safety building, and fuel	F-SC3	DPL	B-SC3	SSE2

Component	Function Class	Design Provision Category	Design Provision Class	Seismic Category
building				
Flushing branch of Coolant Storage and Treatment System (TEP [CSTS]) and Reactor Boron and Water Makeup System [RBWMS] inside auxiliary building and the treatment components	F-SC3	DPL	B-SC3	NO
Auxiliary media supplies of nitrogen, oxygen, chilled water and compressed air (except hydrogen which seismic category is SSE2)	NC	NC	NC	NC

The details of safety classification are presented in Reference [41].

b) Reliability Design of SSCs

1) Single Failure Criterion (SFC)

Each flushing pipeline passing through the double wall of the containment is equipped with two classified isolation valves (one inside and one outside), each of which is powered by a separate electrical train, to obtain full redundancy (mechanical and electrical).

2) Independence

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

3) Diversity

The four containment isolating valves in TEG [GWTS] comply with diversity requirement. The containment isolation function is ensured by adopting two valves, one of which is inside of the containment and the other is outside. The two valves are powered by two different electrical divisions.

4) Ageing and Degradation

The plant design lifetime is 60 years. Some components need to be replaced at the end of their individual design life.

The performance of equipment is guaranteed through life examination, inspection maintenance and testing, as well as the monitoring during normal

operation, which will ensure that ageing effect does not compromise safety performance. Detailed design arrangements relating to the EMIT and equipment monitoring are presented in Reference [42].

The system layout design in the detailed design stage will ensure the accessibility and requirement for safety equipment in-service inspection and periodic tests including the necessary NDT, as well as the requirements of emergency and scheduled maintenance on the SSCs.

c) Human Factors

The design of TEG [GWTS] does not require short term operator intervention, while there are operator actions during plant normal operation, of which the effect needs to be assessed. Relevant human actions important to plant safety is identified and evaluated in Chapter 15.

d) Commissioning

Commissioning and tests will be carried out for the TEG [GWTS] to valid its functionality at the site licensing stage. However, document related to the commissioning test requirements is going to be submitted during GDA phase.

e) Protection Design against Internal and External Hazards

The design of TEG [GWTS] does not consider protection against internal hazards except for the containment isolating valves.

The details about protection against internal and external hazards are presented in Reference [41].

f) Examination, Inspection, Maintenance and Testing

1) Examination

TEG [GWTS] is equipped with necessary instruments, which can survey the status and parameters of system.

2) 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.

3) Periodic Tests

The periodic tests which shall be performed are listed in T-23.7-3. This list

maybe adjusted according to the specific equipment operating and maintenance manual at site licensing stage.

T-23.7-4 Periodic Tests Lists

Tested Component/System Sub-section	Purpose of Testing
Limitation of hydrogen and oxygen injection	Functional testing of reliable limitation of hydrogen and oxygen feeding to the system
Hydrogen/oxygen measurement	Testing including tightness and eventually calibration of the installed detectors for hydrogen and oxygen measurement
Recombiner	Functional testing of the catalyst with respect to hydrogen and oxygen conversion
Protective interlock valves recombiner	Functional testing of reliable safety interlock of the recombiner in case of disturbances
Waste gas compressors	Functional testing of reliable switch-over of waste gas compressors in case of failure of one compressor.
Containment isolating	Testing of the closing function as well as the tightness of the valves.
Safety valves	Testing of the opening function as well as the tightness of the valves.

The requirements of periodic tests will be developed guide the preparation the periodic testing at site licensing stage.

4) Inspection

The delay beds, silica gel dryer, recombiner, tanks and several important valves will require pre-service inspection. The TEG [GWTS] equipment inspection will be carried out according to the equipment operation and maintenance manual, which is developed by equipment manufacturers at site licensing stage. The other components do not need pre-service inspection.

The layout of these components is required to consider the suitable access.

g) Decommissioning

The design of TEG [GWTS] considers the decommissioning. A certain gradient is set in the pipeline layout to prevent waste accumulation and all equipment and pipes can be drained.

h) Material Selection

All the components, valves and pipes of TEG [GWTS] are made of stainless steel except the interface pipes connected to DER [OCWS]. The interface pipes connected to DER [OCWS] which supplies the chilled water to the heat exchangers of TEG [GWTS] is made of carbon steel which is in compliance with DER [OCWS] design requirement.

23.7.5 ALARP Assessment

According to the ALARP methodology specified in Chapter 33, one of the basic principles of ALARP is the recognition and use of RGP and operational experience and feedback.

Although not the sole criterion, RGP may be referred to as the use of existing codes and standards. Sources of relevant good practices for the system are identified in Sub-chapter 23.3 and the RGP relating to gaseous waste management include:

a) Regulatory Guidance Series, No RSR 1: Radioactive Substances Regulation – Environmental Principles;

b) Predisposal Management of Radioactive Waste; and,

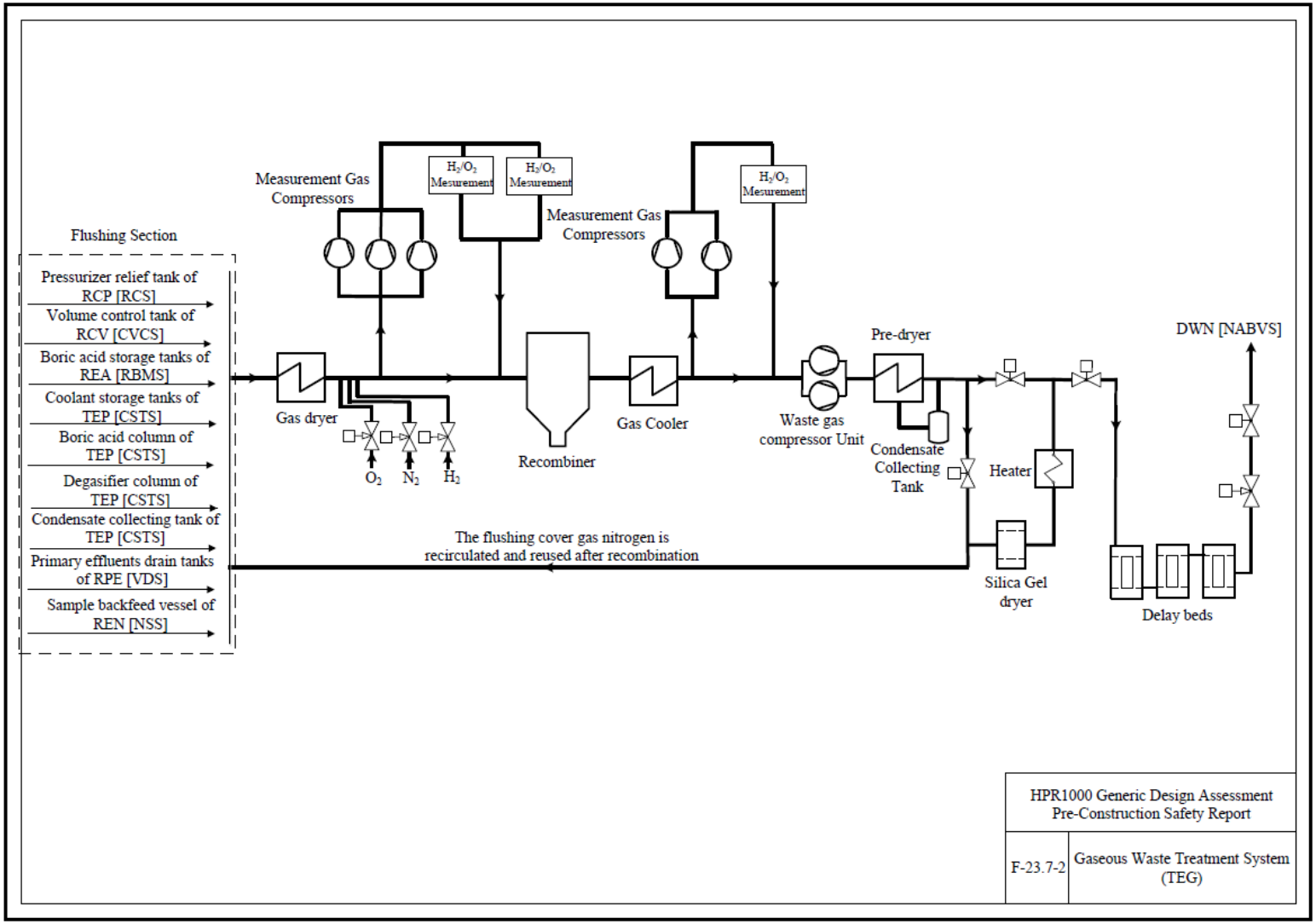
c) Predisposal Management of Radioactive Waste from Nuclear Power Plants and Research Reactors.

At this stage, so a preliminary holistic review of the design of TEG [GWTS] against the identified RGP has been undertaken in Reference [43], which concludes there are no significant gaps identified for TEG [GWTS].

In order to identify any potential improvement, the consistency analysis between the current design of TEG [GWTS] and UK practices and infrastructure will be continually developed considering the use of operational experience and feedback and review of identified RGP during process.

23.7.6 System Flow Diagram

The flow diagram of this system is showed in F-23.7-2.


Flushing Section
Pressurizer relief tank of RCP [RCS]
Volume control tank of RCV [CVCS]
Boric acid storage tanks of REA [RBMS]
Coolant storage tanks of TEP [CSTS]
Boric acid column of TEP [CSTS]
Degasifier column of TEP [CSTS]
Condensate collecting tank of TEP [CSTS]
Primary effluents drain tanks of RPE [VDS]
Sample backfeed vessel of REN [NSS]
Measurement Gas Compressors
H2/O2 Mesurement
H2/O2 Mesurement
Measurement Gas Compressors
H2/O2 Mesurement
Gas dryer
O2
N2
H2
Recombiner
Gas Cooler
Waste gas compressor Unit
Pre-dryer
Condensate Collecting Tank
Heater
DWN [NABVS]
Silica Gel dryer
Delay beds
The flushing cover gas nitrogen is recirculated and reused after recombination
HPR1000 Generic Design Assessment
Pre-Construction Safety Report
F-23.7-2
Gaseous Waste Treatment System (TEG)

23.8 Solid Radioactive Waste Management System

Non-aqueous liquid wastes are excluded from the aqueous liquid treatment and require export from site to off-site facility if appropriate management route is available. Their management is therefore considered alongside solid radioactive waste.

The design of solid radioactive waste management system is responsible for the management of solid radioactive waste and non-aqueous liquid waste.

23.8.1 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.

e) Extra supporting functions

TES [SWTS] does not perform extra supporting functions.

23.8.2 Role of the System

In the UK, radioactive wastes are classified as High Level Waste (HLW), ILW, LLW and VLLW according to the type and quantity of radioactivity they contain and how much heat the radioactivity produces in Reference [17].

TES [SWTS] serves to collect, characterise and segregate, treat, condition, package and store various types of solid radioactive wastes and non-aqueous liquid wastes generated in normal operation.

TES [SWTS] performs the following operational functions:

a) Collect and segregate radioactive waste as HLW, ILW, LLW and VLLW to facilitate the subsequent management of waste;

b) Temporarily store waste in the tanks or containers for the purposes of decay storage if required;

c) Process solid radioactive waste by appropriate techniques;

d) Store radioactive waste in a passively safe condition; and,

e) Measure and record the information of all waste packages to facilitate their

transportation and disposal.

Based on the operational functions requirements, the following design principles of TES [SWTS] are required to be implemented:

a) The design of TES [SWTS] is comply with the principles of minimisation of waste generation and contamination, and facilitation of eventual decommissioning;

b) The appropriate capacity of TES [SWTS] is designed to collect, segregate, temporarily store and process the solid radioactive wastes 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 facility;

e) The interim storage facility 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) Remote control system is provided to reduce the field operation especially in high dose rate area;

h) Sufficient space is provided to facilitate operation, inspection, surveillance and maintenance to limit personnel exposures as low as reasonably achievable;

i) 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);

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

k) 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 Arising, Segregation and Characterisation of Solid Radioactive Waste

23.8.3.1 Arising of Solid Radioactive Waste

The reference plant of UK HPR1000 is Hua-long Pressurised Reactor under construction at Fangchenggang nuclear power plant unit 3 (HPR1000 (FCG3)), which is based on OPEX and improvements of the design of successful Chinese commercial nuclear power plants, considering the advanced design schemes of EPR and

AP1000.The operating experience from CPR1000 units is to be referred valuably in the development of UK HPR1000 solid waste inventory (i.e. volumes and radiochemical, chemical, physical characteristics).. And by comparing to legacy waste in the UK, Reference [44] , there appears to be no novel waste generated in UK HPR1000 that challenges the waste disposability.

Based on the operational experience on the Pressurised Water Reactor (PWR) fleets in China, T-23.8-1 lists the solid radioactive wastes, which are anticipated to be generated in the UK HPR1000.

T-23.8-1Solid Radioactive Wastes Generated during the Operation

No.	Title	Description	Preliminary Category
1	Spent resins	Arising from the TEU [LWTS], TEP [CSTS], PTR [FPCTS], RCV [CVCS] demineralisers, and APG [SGBS] demineralisers under tube rupture.	ILW
2	Low activity spent resins	Arising from APG [SGBS] demineralisers under normal operational condition.	VLLW
3	Concentrates	Arising from TEU [LWTS] evaporators.	ILW/LLW
4	Spent filters	Arising from filter changing in TEU [LWTS], TEP [CSTS], PTR [FPCTS], RCV [CVCS], APG [SGBS].	ILW/ LLW
5	Dry active waste	Contaminated personal protection equipment, monitoring swabs, plastic, clothing, contaminated tools and air filters, etc..	LLW/VLLW
6	Sludge	Arising from the sumps and tanks in the liquid radioactive waste management systems (e.g. RPE [VDS], TEU [LWTS]).	ILW/LLW
7	Oil	Arising during normal operations, such as maintenance of pumps and hydraulic equipment, decontamination of Reactor Pressure Vessel bolts.	VLLW
8	Organic solvent	Arising in normal operations, such as maintenance of pumps and hydraulic equipment, decontamination of Reactor Pressure Vessel bolts.	LLW

No.	Title	Description	Preliminary Category
9	In-core Instrument Assemblies	Arising from reactor core, using for measuring the pressure, temperature of reactor core.	ILW*
10	Rod cluster control assemblies and stationary core component assemblies	Activated in-core	HLW*
11	Ventilation filter cartridges	Arising from the ventilation systems located in the BNX, BFX, BSX, BRX and BWX.	VLLW

Note*: The categories of waste non-fuel core components including in-core instrument assemblies, rod cluster control assemblies and stationary core component assemblies are preliminary determined, further action will be undertaken to determine the categories of these and develop the management route of these waste.

The nature and quantity of the operational wastes are given in Sub-chapter 4.7.3 in Reference [45], the analysis report of the source term of solid radioactive waste and non-aqueous liquid waste in the UK HPR1000 will be developed during GDA step 3.

23.8.3.2 Segregation and Characterisation

According to the principles of radioactive waste management in Reference [15] and [16], characterisation and segregation should be undertaken to facilitate safe and effective management of radioactive waste. The segregation and characterisation are necessary during different 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] in F-23.8-1 presented the segregation of solid radioactive waste, and more information of characterisation and segregation of solid radioactive waste are presented in Sub-chapter 23.8.4.

The design of UK HPR1000 has provided a range of facilities and equipment to allow the future operator to undertake the characterisation and segregation of solid and non-aqueous liquid waste, so as to effectively segregate waste and identify the suitable waste disposal routes at site licensing stage.

23.8.4 System Description and Operation

23.8.4.1 System Description

TES [SWTS] is designed to collect, segregate, condition and store the wastes generated under normal operations.

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

a) Spent resins flushing and storage subsystem;

b) Spent filter cartridge changing subsystem;

c) Waste receipt and treatment subsystem;

d) Dry active waste treatment subsystem; and,

e) Waste package storage subsystem.

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

23.8.4.1.1 Spent Resins Flushing and Storage Subsystem

The spent resins flushing and storage subsystem is equipped with spent resin tanks, APG resin separation tank, spent resin flush pump and spent resin deliver pump. The function of this subsystem is to receive and store the spent resins from the demineralisers from the RCV [CVCS], TEP [CSTS], and PTR [FPCTS] when the demineralisers when they have reached the end of their operational life, which is determined by the differential pressure between inlet and outlet of demineralisers or sampling results of liquids flowing through the demineraliser. When the spent resins collected in the spent reins tanks reach a certain quantity, they will be flushed into the spent resin storage tanks located in BWX by pump.

23.8.4.1.2 Spent Filter Cartridge Changing Subsystem

The spent filter cartridge changing subsystem is equipped with a spent filter cartridge changing machine which has appropriate shielding functionality to minimise the doses to workers. The function of this subsystem is to change the spent filter cartridges of the filters in RCV [CVCS], TEP [CSTS], PTR [FPCTS] and RPE [VDS], when the pressure between inlet and outlet of filter reaches the expected limit, or surface dose rate of filters reaches the expected limit.

The spent filter cartridges will be loaded into a shielded transfer container and transported to BWX. The shielded transfer container is designed to have appropriate shielding to reduce the dose to workers.

23.8.4.1.3 Waste Receipt and Treatment Subsystem

The waste receipt and treatment subsystem is equipped with spent resin storage tanks, spent resin transfer pump, and an encapsulation facility.

The function of this subsystem is as follows:

a) Receive and temporarily store the spent resins from TEU [LWTS] demineraliser in BWX and spent resin tanks from the BNX;

b) Encapsulate the spent resins, concentrates and sludge in the steel drums by the cement encapsulation;

c) Encapsulate the spent filter cartridges in steel drum with the cement encapsulation.

23.8.4.1.4 Dry active Waste Treatment Subsystem

The dry active waste treatment subsystem is equipped with sorting box, shredder, pre-compactor, super-compactor and grouting device to segregate, compact and pack LLW in the Waste Auxiliary Building (BQS).

The dry waste is collected and characterised at source based on contamination levels, so the active wastes and non-active wastes are segregated to reduce the volume of dry active waste. The dry active waste is transported to the BQS for further segregation as compactible and non-compactible waste based on physical properties, such as size and materials makeup of the waste. The compactible waste is loaded in drums, dried if necessary, and then treated by super-compaction to minimise the volume of radioactive waste on-site and for disposal. The final waste packages will be transferred to the storage facility to be stored before dispatch to the disposal facility.

23.8.4.1.5 Other Waste Management

The non-aqueous liquid radioactive wastes, such as oil and organic solvent generated during maintenance, is stored on site temporarily, until the authorised treatment facility is available.

A shielding container is provided to receive and fill the pre-treated in-core instruments assemblies, and final waste packages will be stored in storage facility before dispatch to disposal facility.

The ventilation filter cartridges are packed and sent to storage facility for decay to be exempt waste.

23.8.4.2 Equipment Description

The main equipment of TES [SWTS] is arranged in the following three buildings:

a) Nuclear Auxiliary Building (BNX)

b) Waste Treatment Building (BWX)

c) Waste Auxiliary Building (BQS)

Spent Resin Tanks

The spent resin tanks are located in the BNX, and they are arranged in the retention pit, so that any radioactive material that may from the tanks can be contained in the retention pit. Also adequate venting and overflow capacities are considered on the tanks to prevent overpressure or negative pressure of the tanks in order to reduce does to workers.

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 does to workers. This machine is installed with two dose rate measurement devices, which are used to allow the measurement of radiological properties of the changed spent filter cartridges to separate them as either ILW or LLW to facilitate the subsequent treatment.

Spent Resin Storage Tanks

The spent resin storage tanks are manufactured from stainless steel, and they are located in BWX. The tanks are arranged in the retention pit, so that any radioactive material that may leak from the tanks can be contained in the retention pit. Also the venting and overflow capacities are considered in the design of the tanks to prevent overpressure or negative pressure of the tanks in order to reduce does to workers.

Spent Resin Metering Tank

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

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

Concentrates 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 the water required for resin encapsulation, and also to measure the quantity of concentrates from TEU [LWTS] to be transferred to the waste container for cement encapsulation.

Encapsulation Facility

The encapsulation facility is located in BWX, and is designed to solidify the spent resins and concentrates in the waste container by the encapsulation processing. It is equipped with in-drum mixer, automatic capping and uncapping device, transfer rollers and shielded doors.

The encapsulation facility is operated by remote control to reduce does to workers, and the shielded doors in this facility are used to provide shielding against the γ rays in the operation area and to maintain the slightly negative pressure in the operation

room to prevent radioactive materials from being released into the environment.

Mobile Grouting Device

The mobile grouting device is used to treat spent filter cartridges. It is a mobile continuous mixer, and consists of cement hopper, mixer, control cabinet, hoses and couplings. The cement hopper is equipped with level switch and vibrator is used to load dry cement powders. The grout produced by the mixer is transported through hoses to the waste drums in the encapsulation facility.

Super Compactor

The super compactor is located in the BQS. It is used to compact drums loaded with dry active wastes, so as to reduce the waste volume.

The packages are lifted to the super compactor transport system for weighing and positioning. After the drum packages are compacted by super compactor as pellets, the pellets are put into drums based on the optimal choice of pellets' height and weight.

Detailed information of the equipment is presented in Reference [46].

23.8.4.3 Description of System Interfaces

a) Supporting Systems

1) SED [DWDS (NI)]

SED [DWDS (NI)] supplies dematerialised water to flush the spent resins.

2) DWN [NABVS]

DWN [NABVS] provides to filters, monitor, and discharge the airborne material from TES [SWTS] to the environment.

3) RPE [VDS]

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

4) SAR [SCADS]

SAR [ICADS] is required to provide compressed air for the pneumatic valves of TES [SWTS].

5) SAT [SCADS]

SAR [ICADS] is required to provide compressed air for loosening resins in BWX.

6) SAT [SCADS]

SAT [SCADS] is required to provide compressed air for loosening resins in

BWX.

7) SRE [SRS]

SRE [SRS] provides vent and drain route for collecting the liquid and gas waste from TES [SWTS] in BWX.

b) User systems

1) RCV [CVCS]

TES [SWTS] is required to flush and receive the spent resins generated from RCV [CVCS] demineralisers and to replace the spent filter cartridges generated from RCV [CVCS] filters.

2) PTR [FPCTS]

TES [SWTS] is required to flush and receive the spent resins generated from PTR [FPCTS] demineralisers and to replace the spent filter cartridges generated from PTR [FPCTS] filters.

3) TEP [CSTS]

TES [SWTS] is required to flush and receive the spent resins generated from TEP [CSTS] demineralisers and to replace the spent filter cartridges generated from TEP [CSTS] filters.

4) TEU [LWTS]

TES [SWTS] is required to flush and receive the spent resins generated from TEU [LWTS] demineralisers and to replace the spent filter cartridges generated from TEU [LWTS] filters.

5) APG [SGBS]

TES [SWTS] is required to flush and receive the spent resins generated from TEU [LWTS] demineralisers and to replace the spent filter cartridges generated from TEU [LWTS] filters.

23.8.4.4 System Operation

23.8.4.4.1 Plant Normal Condition

a) Processing of ILW spent resins

ILW resins in the demineralisers from RCV [CVCS], TEP [CSTS] and PTR [FPCTS] need to be replaced, when the demineralisers reach the end of their operational life. The spent resins 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, which is benefit to decay to reduce the radioactive level of resin. The resins generated from the demineralisers in TEU [LWTS] will also be

transferred to the BWX spent resin storage tank for treatment.

The resins stored in the spent resin storage tanks can be sampled at the recirculation lines to characterise the resins. After sampling, the resins will be discharged into the spent resin metering tank to be weighted and the volume to be determined. After receiving measured resins and water, the waste container will be transferred to the dry materials receipt station to be filled with lime. Then the spent resins and lime will be mixed for a certain time to let the lime react sufficiently with the boric acid in the waste by the use of an in-drum mixer. Next, then cement is added to produce the encapsulated wasteform. After that, the waste container will be sealed under pneumatic covers for the initial cure before adding, and then added the grouting cap. The capped waste container will be transferred to the capping and uncapping station for automatic capping, and then cured on site for several days. Finally, the waste packages will be transferred for storage.

b) Processing of VLLW resins

The activity resins are characterised and segregated as VLLW and ILW according to their activity. The spent resins with very low activity generated from the demineralisers of APG [SGBS] under normal condition are usually discharged into APG [SGBS] resin separation tank, and then the spent resins are transferred by the vacuum pump device into the steel drums for decay storage to be exempt waste.

The ILW spent resins generated from APG [SGBS] under abnormal conditions are flushed to the spent resin tanks for treatment, which is presented in item a).

c) Processing of concentrates

The concentrates are sampled to measure the boron concentration and chloride concentration to determine whether them can be discharged, and the radioactivity will also be measured. After sampling, the concentrates generated will be discharged from the concentrate tank of TEU [LWTS] into the concentrates metering tank in TES [SWTS].

After receiving metered concentrates, the waste container will be transferred to the dry materials receipt station to be filled with lime. Then the concentrates and lime will be mixed for a certain time to let the lime react sufficiently with the boric acid in the waste by the use of an in-drum mixer. Next the cement is added to produce the encapsulated wasteform. After that, the waste container will be sealed and cured on site for several days. Finally, the waste packages will be transferred for storage.

d) Processing of spent filter cartridges

When the pressure differential between the inlet and outlet of the filters reaches a pre-determined value, or surface dose rate of these filters reaches the expected

limit, the cartridges of these filters needs to be replaced. After the filter cartridges are lifted out from the filters, the surface dose rate of filters will be measured firstly to segregate the filter as different categories, so as to facilitate safe and effective management of spent filter cartridges.

For the filter cartridge with low radioactive level, it is loaded into a drum and then transferred to the BQT for compaction as pellets by the super compactor to reduce the volume of waste. According to thickness optimisation, the pellets are put into drums with cement grouting.

Filter cartridge with intermediate radioactive levels are loaded into drums within the spent filter cartridges shielded container, which is provided with suitably shielding to reduce the dose to workers during transportation between facilities on site. The spent filter cartridges will be encapsulated by the mobile grouting device in BWX.

All waste packages after curing are transferred to the interim storage facility.

e) Processing of Dry Active Waste

Dry waste (paper, clothes, plastic, metal, etc.) are separately collected as active waste and non-active waste, which are packaged into plastic bags with different colours at source. Then, the dry active wastes are transported to the BQS and placed into the sorting boxes for further segregation into compactible and un-compactible wastes based on their physical properties, and loaded into different empty drums. A pre-treatment process can be adopted, such as the drying for some wastes with free liquid. The drum packages will be compressed into pellets by the super compactor.

The pellets are transported to the optimal thickness gauge, and then are put into steel drums according to thickness and weight optimisation. The steel drums filled with pellets are fixed by cement grouting. Finally, the waste packages are transported to BQT prior to be transferred to disposal facility.

f) Processing of in-core instruments

The in-core instrument assemblies are loaded in a shielding container the waste container with non-encapsulation after pre-treatment. The waste packages are then be transferred to the BQT prior to be transferred to disposal facility.

g) Processing of sludge

The sludge is collected in drums and encapsulated with cement. The waste packages will then be transferred to the BQT prior to be transferred to disposal facility.

h) Processing of oil and solvent

The contaminated oil and solvent are separated and collected at source and will be transferred to the oil storage tank and solvent storage tank for long-term storage.

i) Processing of ventilation filter cartridge

The ventilation filter cartridge with very low activity are packaged and stored in BQT for decay to become exempt waste.

23.8.4.4.2 Plant Accident Conditions

Not applicable.

23.8.5 Solid Radioactive Waste Storage

The Temporary Storage Facility (BQT) is based on good engineering practice in China. This facility is designed to provide the secure and safe storage for radioactive waste packages generated during reactor operation. The waste packages are eventually retrieved and transported to the disposal facility after a period of storage.

23.8.5.1 Safety Requirement

The safety objective of BQT is to reduce the dose to the workers and public, and more to present the risk of radioactive contamination spreading to the environment under normal or accident conditions.

The factors associated with the safety of BQT include system equipment failure (e.g. intrinsic components failure, aging components, etc.) and the risks such as mechanical damage, radiation exposure, radioactive contamination diffusion, and power failure. The safety measures are applied in the design of BQT to minimise the impacts of the above factors on the facility, which are described in Sub-chapter 23.8.5.4.3.

23.8.5.2 Design Principles

The basic design requirements of the BQT building are shown as follows:

a) Ensure the performance integrity of the waste package during the temporary storage period;

b) Ensure that the radiation exposures to the public and workers during the operation and maintenance process are lower than the specified limits;

c) Provide the space for equipment maintenance and repair;

d) Provide corresponding protection measures to minimise the impacts of relevant risk factors (e.g. internal and external hazards);

e) Prevent radioactive gases from spreading outside the facility under normal or accident conditions;

f) Take account of the anticipated storage duration (including ageing and

degradation) to ensure that the facility continues to meet its safety function;

g) Record the information of all stored waste packages which may be required for its future safe management.

23.8.5.3 Waste Package

The waste packages including steel drum packages and freight container packages are stored in BQT, and the storage capacity is determined by the number of waste packages generated in the operation of two units.

23.8.5.4 Facility Design

23.8.5.4.1 Overall Design Description

The BQT is a shielding concrete structure, which is designed to receipt, monitor, transfer, store and retrieve waste packages. The main areas of BQT include auxiliary area, operation area and storage area.

a) Auxiliary Area

The auxiliary area includes changing rooms, control room, duty room, power distribution room, waste package maintenance area and fan room. Its function is to achieve the control of personnel entry/exit, equipment operation, environment parameters adjustment and maintenance of waste packages.

b) Operations Area

The operations area fulfils the function of receiving, monitoring and retrieving of waste packages. This area includes:

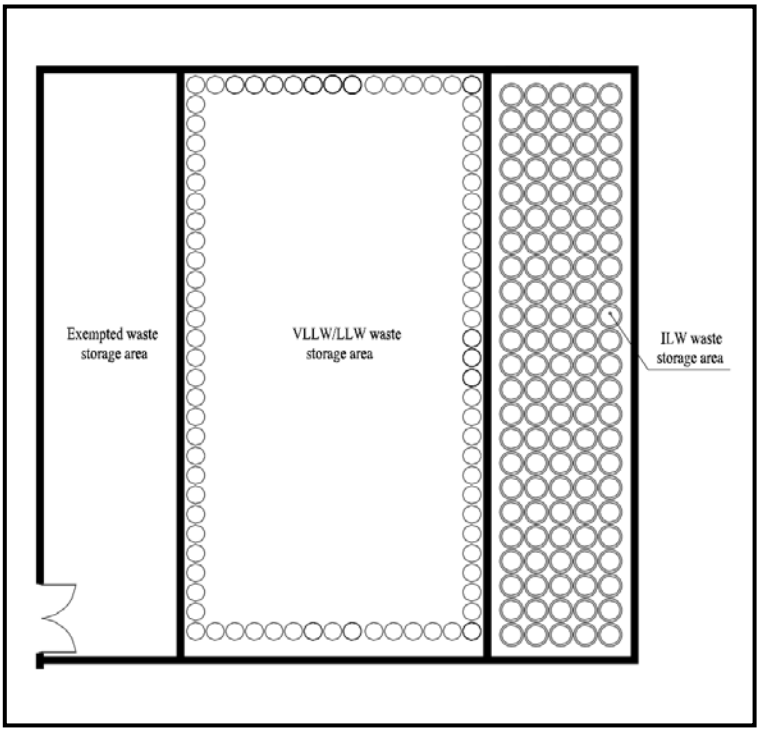
1) Waste vehicle parking area;

2) γ spectrometry measurement room.

c) Storage Area

The plan view of storage area is presented F-23.8-2.

The storage area consists of exempt waste storage area, VLLW/LLW storage area and ILW storage area, while different storage areas are separated by concrete wall. The waste packages are stored in different storage areas according to its radioactive level. The exempted waste storage area is an independent room, in which the exempted wastes are transferred and stacked by the transfer trolley. The VLLW/LLW waste packages are lifted by waste package lifting crane and stacked four layers in VLLW/LLW storage area. The ILW storage area consists of multiple independent and shielded tubes, which are designed to storage four ILW waste packages in form of vertical stack.



F-23.8-2 Plan View of Storage Areas

23.8.5.4.2 Storage Process

a) Reception of Waste Package

1) Exempted Waste Package

The exempted waste packages are transported to BQT by a waste vehicle, and then the operator transfer the waste package from waste vehicle to exempted waste storages area by a transfer trolley.

2) VLLW/LLW/ILW Package

The VLLW/LLW/ILW packages are transported to BQT by a waste vehicle. After it at the waste vehicle parking area, the waste packages are removed by the lifting crane and transferred to the γ spectrometry measurement room.

In the γ spectrometry measurement room, the radionuclide composition and surface dose rate of the package are detected by the γ spectrometer, which is remotely operated by the operator in the control room to reduce the dose to the workers. According to the measurement results, the waste package is transferred by the crane from the γ spectrometry measurement room to corresponding storage areas for temporary storage.

b) Retrieval of Waste Package

When the waste packages stored in BQT needs to be transported for final disposal, the waste packages are retrieved from the storage tube by crane.

The retrieved waste packages are lifted to the γ spectrometry measurement room for radionuclide analysis and surface dose rate monitoring. The waste packages information is recorded. If the measurement results show that the surface dose rate of waste package is no more than 2 mSv/h, the waste package is loaded into the transport container without shielding. If the surface dose rate of waste package is more than 2 mSv/h, a shielding transport container is used for transportation of the waste package as radiation protection.

23.8.5.4.3 Safety Design

The safety features considered in the design of storage facility include:

a) Transfer of waste packages

In the storage facility, the waste packages are transferred using the overhead crane which is operated by remote control. A Closed Circuit TV System (CCTV) also supports the safe transfer of waste package. The operator within the control room is suitably shielded from packages to reduce the personnel exposure.

The overhead crane is equipped with safety brake to ensure that the waste packages is in a safe state in case of power failure, over-speed or damage to transmission parts of lifting mechanism. The crane also has an electronic control system which permits the programming of pre-set index points and interference blocks. The load weight detection sensor is provided with overload protection interlocks incorporated. Above design aspects of crane contribute to avoid the lifting accident such as drop, collision and overload.

b) Environmental control

The main factor influencing the performance degradation of waste packages during storage is the surface corrosion. The surface corrosion of waste packages may arise from the air condition, temperature and humidity inside the storage facility. In order to maintain suitable environmental conditions, the temperature and humidity are controlled and monitored by the ventilation system inside the building to reduce the risk of surface corrosion of waste packages.

c) Monitoring and record of waste packages

The γ spectrometer is used to determine the radioactive nuclide composition and surface dose rate of waste packages. The waste packages are transferred to suitable storage area within store according to the surface dose rate. The measurement information and storage position of each waste package are recorded along with the unique identifier for that package. When the waste package is retrieved, it is measured by the γ spectrometer again, and the corresponding measurement information is also recorded.

d) Inspection and repair of waste packages

In order to ensure the integrity of the waste packages during storage and reduce radioactive contamination diffusion and other risks, monitoring of surface corrosion and surface leak of waste packages are considered.

1) Inspection:

The design and operation of BQT enables the retrieval and inspection of waste packages to locate any defects or external damage. The camera installed on the crane is designed to inspect waste package if necessary. In order to inspect the waste packages stored in concrete storage tubes, the waste packages stored in concrete storage shafts are retrieved by crane, and transferred to special positions to be inspected by CCTV.

2) Repair of failed waste package

If a defect or external damage is found in the waste package, the failed waste package can be transported to the waste package maintenance area. Overpacking of failed waste packages is chosen for the purpose of reducing the radiation exposure. This option will be developed by the future operator at site licensing stage.

e) Radiation protection

The design of the storage facility has considered the following measures to ensure the radiation protection for worker and members of the public:

1) The waste packages with higher activities are loaded into shielded container during transportation between different facilities on site to limit radioactive exposure to workers and the public;

2) The handling of waste packages in the storage facility is operated by the remote control, with the walls and roof of storage facility designed with appropriate shielding thickness. These measures are beneficial to reducing the dose to workers and public;

3) If the operator is required to enter the storage area, personal protective equipment shall be worn by workers and the ventilation system is under operational condition. Therefore, the risk of internal exposure to workers is reduced;

4) The ILW waste packages in the storage facility are stored in concrete storage tubes with suitable shielding thickness to reduce the dose to workers; and,

5) The ventilation system is designed to maintain a slightly negative pressure in the facility to prevent radioactive particles from spreading into the environment, so as to reduce the dose to workers and the public.

f) Equipment failure protection

Mature, reliable and advanced equipment are selected to ensure the sufficient operational reliability during handling of waste packages. In order to reduce the failure risk further, it is necessary to consider the maintenance and replacement of the equipment during the building lifetime to ensure the continuous operation. The equipment in the BQT is regularly inspected to detect and clear faults in a timely manner. In order to satisfy the equipment maintenance requirements, a maintenance area which is far away from waste packages storage area is provided and, access is isolated from the waste packages storage area.

23.8.6 Preliminary Design Substantiation

23.8.6.1 Safety Functional Requirements

a) Control of Reactivity

Not applicable.

a) Removal of Heat

Not applicable.

b) Confinement

TES [SWTS] contributes to the following confinement functions:

1) TES [SWTS] has the confinement function to prevent gas and liquid generated during processing of the radioactive solid waste from releasing into the environment directly;

2) TES [SWTS] produces passive safety waste packages and reduces volumes of radioactive waste for disposal;

3) Shielding measures and remote control for operations of high risk tasks are provided to limit the exposure dose to workers and the public; and,

4) The storage facility provides passive safety environmental for waste storage.

c) Extra Supporting Functions

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

23.8.6.2 Compliance with Design Requirements

a) Safety Classification

The design of TES [SWTS] is compliant with the principles described in Chapter 4. NC classified equipment within the TES [SWTS] is designed to withstand a SSE. The system classification and classification of main components of TES [SWTS] are listed in T-23.8-2 and T-23.8-3.

T-23.8-2 System Classification

System Function	Function Category
Spent resins flushing and storage subsystem	NC
Spent filter cartridge changing subsystem	NC
Waste receipt and treatment subsystem	NC
Dry active waste treatment subsystem	NC
Waste package storage subsystem	NC

T-23.8-3 Classification of Main Components

Component	Function Class	Design Provision Category	Design Provision Class	Seismic Category
Pipes Penetrating the Steel Surface and the First Isolation Valve	NC	NC	NC	SSE2
Pipes Connecting the RCV [CVCS] Purification Unit and the First Isolation Valve	NC	NC	NC	SSE2
Other parts of TES [SWTS]	NC	NC	NC	NO

The details about categorisation and classification are presented in Reference [47].

b) Reliability Design of SSCs

1) Single Failure Criterion (SFC)

Not applicable.

2) Independence

Not applicable.

3) Diversity

Not applicable.

4) Ageing and Degradation

The plant design lifetime is 60 years. Some components need to be replaced at the end of their individual design life.

The performance of equipment is guaranteed through life examination, inspection maintenance and testing, as well as the monitoring during normal operation, which will ensure that ageing effect does not compromise safety performance. Detailed design arrangement relating to the EMIT and equipment monitoring is presented in Reference [48].

The system layout design in the detailed design stage will ensure the accessibility and requirement for safety equipment in-service inspection and periodic tests including the necessary NDT, as well as the requirements of emergency and scheduled maintenance on the SSCs.

c) Human Factors

The system design of TES [SWTS] does not require short term operator intervention, while there are operator actions during plant normal operation, of which the effect needs to be assessed. Relevant human actions important to plant safety is identified and evaluated in Chapter 15.

d) Commissioning

Commissioning will be carried out for TES [SWTS] to valid its functionality at the site licensing stage. However, document related to the commissioning test requirements is going to be submitted during GDA phase.

e) Protection Design against Internal and External Hazards

TES [SWTS] is protected from relevant of external and internal hazards. The specific protection design is presented [47].

f) Examination, Inspection, Maintenance and Testing

1) Examination

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.

2) 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.

3) Periodic Test

The requirements of periodic tests will be developed guide the preparation the periodic testing at site licensing stage.

4) Inspection

TES [SWTS] equipment inspection will be carried out according to the equipment operation and maintenance manual, which is developed by equipment manufacturers at site licensing stage.

g) Decommissioning

The design of TES [SWTS] considers the decommissioning. A certain gradient is set in the pipeline layout to prevent waste accumulation and all equipment and pipes can be drained.

h) 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 wastes are made of stainless steel. Corrosion resistant materials are used in the auxiliary equipment in cementation process, as well as the devices or components contacting the radioactive waste with chemical properties.

23.8.7 ALARP Assessment

According to the ALARP methodology specified in Chapter 33, one of the basic principles of ALARP is the recognition and use of RGP and operational experience and feedback.

Although not the sole criterion, RGP may be referred to as the use of existing codes and standards. Sources of relevant good practices for system are identified in Sub-chapter 23.3 and the RGP about solid radioactive waste management include:

a) UK Strategy for the Management of Solid Low Level Radioactive Waste from the Nuclear Industry;

b) Regulatory Guidance Series, No RSR 1: Radioactive Substances Regulation –

Environmental Principles;

c) The Management of Higher Activity Radioactive Waste on Nuclear Licensed Sites;

d) Industry Guidance: Interim Storage of Higher Activity Waste Packages – Integrated Approach;

e) Waste and Spent Fuel Storage Safety Reference Levels; and,

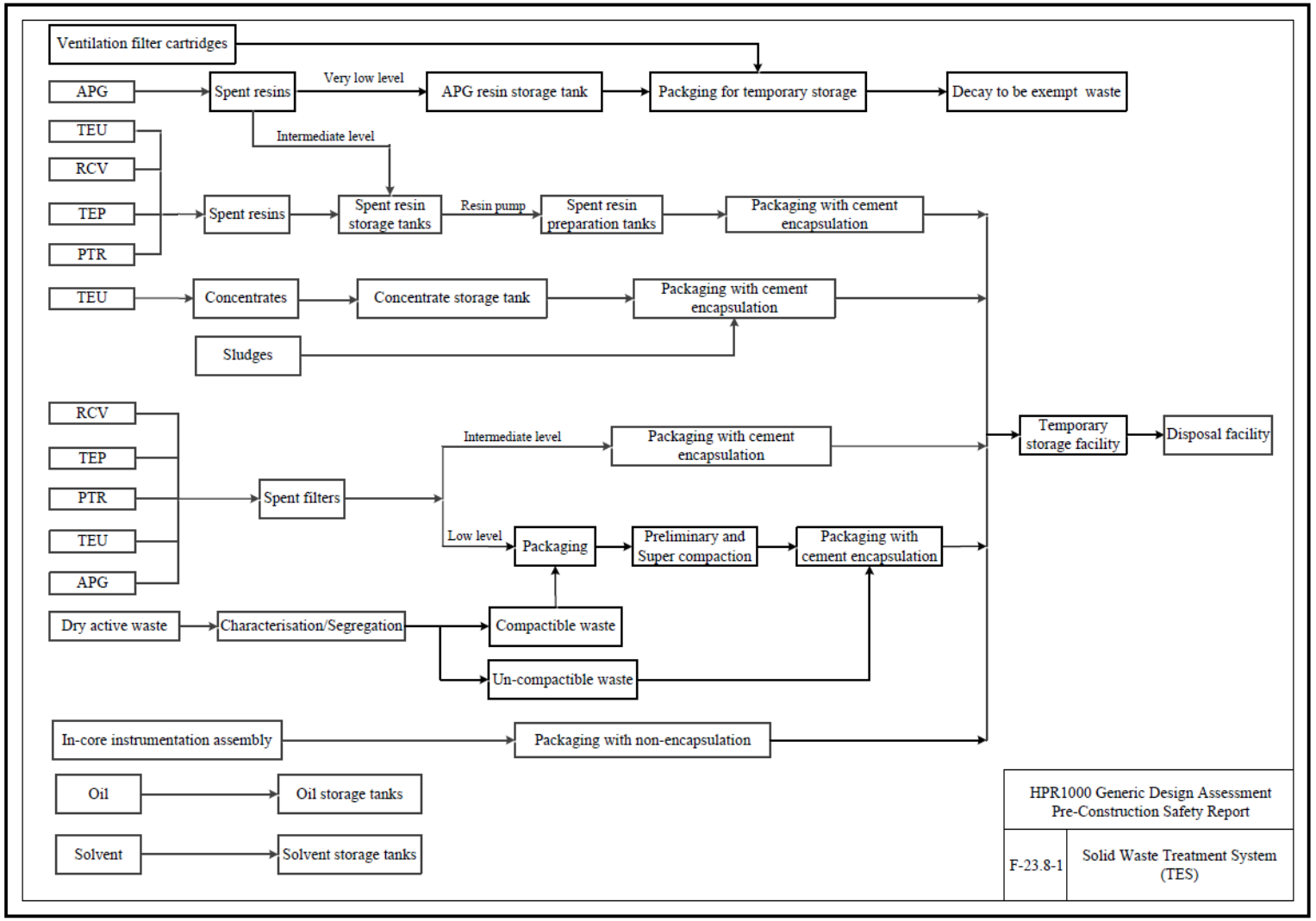
f) Predisposal Management of Radioactive Waste Reference; and,

g) Predisposal Management of Radioactive Waste from Nuclear Power Plants and Research Reactors.

In accordance with the understanding of identified RGP, the gaps about radioactive waste management are preliminary identified at this stage, and the consistency analysis between the current design of solid radioactive waste management system and UK practices and infrastructure will be continually undertaken at next stage. For the identified gaps, they will be mitigated by optioneering considering the principles of ALARP and BAT during GDA process.

23.8.8 System Flow Diagram

The flow diagram of this system is showed in F-23.8-1.


Ventilation filter cartridges
APG
Spent resins
Very low level
APG resin storage tank
Packging for temporary storage
Decay to be exempt waste
TEU
RCV
TEP
PTR
Intermediate level
Spent resins
Spent resin storage tanks
Resin pump
Spent resin preparation tanks
Packaging with cement encapsulation
TEU
Concentrates
Concentrate storage tank
Packaging with cement encapsulation
Sludges
RCV
TEP
PTR
TEU
APG
Spent filters
Intermediate level
Packaging with cement encapsulation
Low level
Packaging
Preliminary and Super compaction
Packaging with cement encapsulation
Temporary storage facility
Disposal facility
Dry active waste
Characterisation/Segregation
Compactible waste
Un-compactible waste
In-core instrumentation assembly
Packaging with non-encapsulation
Oil
Oil storage tanks
Solvent
Solvent storage tanks
HPR1000 Generic Design Assessment
Pre-Construction Safety Report
F-23.8-1
Solid Waste Treatment System (TES)

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 and non-aqueous radioactive wastes, 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 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. The disposability of LAW is demonstrated in Sub-chapter 3.4.5.2 in Reference [19].

For the UK HPR1000, it is recognised that LAW treatment routes will be optimised by an optioneering process considering the best use of waste treatment in the UK. Moreover, the compatibility analysis of LAW against WAC will also be undertaken to support the establishment of Agreement in Principle.

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

23.9.2 Disposability Assessment of HAW

The GDF will not be available in several decades. A part of the solid radioactive waste generated by the UK HPR1000 will be too radioactive to be disposed of via existing routes. Thus the HAW should be processed into a passive safe state to be stored until a long term management solution is established. This situation is not unique to the UK HPR1000 but is applicable to all 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, disposability assessment of HAW in the UK HPR1000 will be undertaking to get the advice from RWM, which is demonstrated in Sub-chapter 3.4.5.3 in Reference [19].

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

23.10 Records Management

The operation of the radioactive waste management systems will generate a large quantity of information, including that relating to the information on sampling and monitoring of radioactive waste or waste packages. According to the requirement in Reference [17] and [18], sufficient records about radioactive waste management system must be preserved now and in the future for the safe management and disposal of radioactive waste, especially for solid radioactive waste.

The process of making and preserving these documents and records starts during GDA phase and will continue throughout the whole lifecycle. 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, all the documents and records are maintained under the systemic Management for Safety and Quality Assurance (MSQA) arrangements, details of MSQA in the UK HPR1000 are presented in Chapter 20.

During the site licensing stage, the site licensee will be responsible for the information management system to trace 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.

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 to disposal facility. For LAW, the appropriate records of LAW packages also need to be kept and transferred to off-site disposal facilities or waste treatment facilities.

23.11 Concluding Remarks

This information important to the nuclear safety of the radioactive waste management systems the UK HPR1000, which is based on reference design, is presented in this Chapter, including the safety requirements and the preliminary design substantiation.

The RGP about radioactive waste management have been identified, a holistic review of the design of radioactive waste management systems against the identified RGP has been undertaken. In order to identify any potential improvement, the consistency analysis between the current design of radioactive waste management and UK practices and infrastructure will be continually developed considering the use of operational experience and feedback and review of identified RGP during process.

Based on the progress of UK HPR1000 developing, there are various references being under prepared at current stage, which will provide support for the safety case of radioactive waste management during GDA process.

23.12 References

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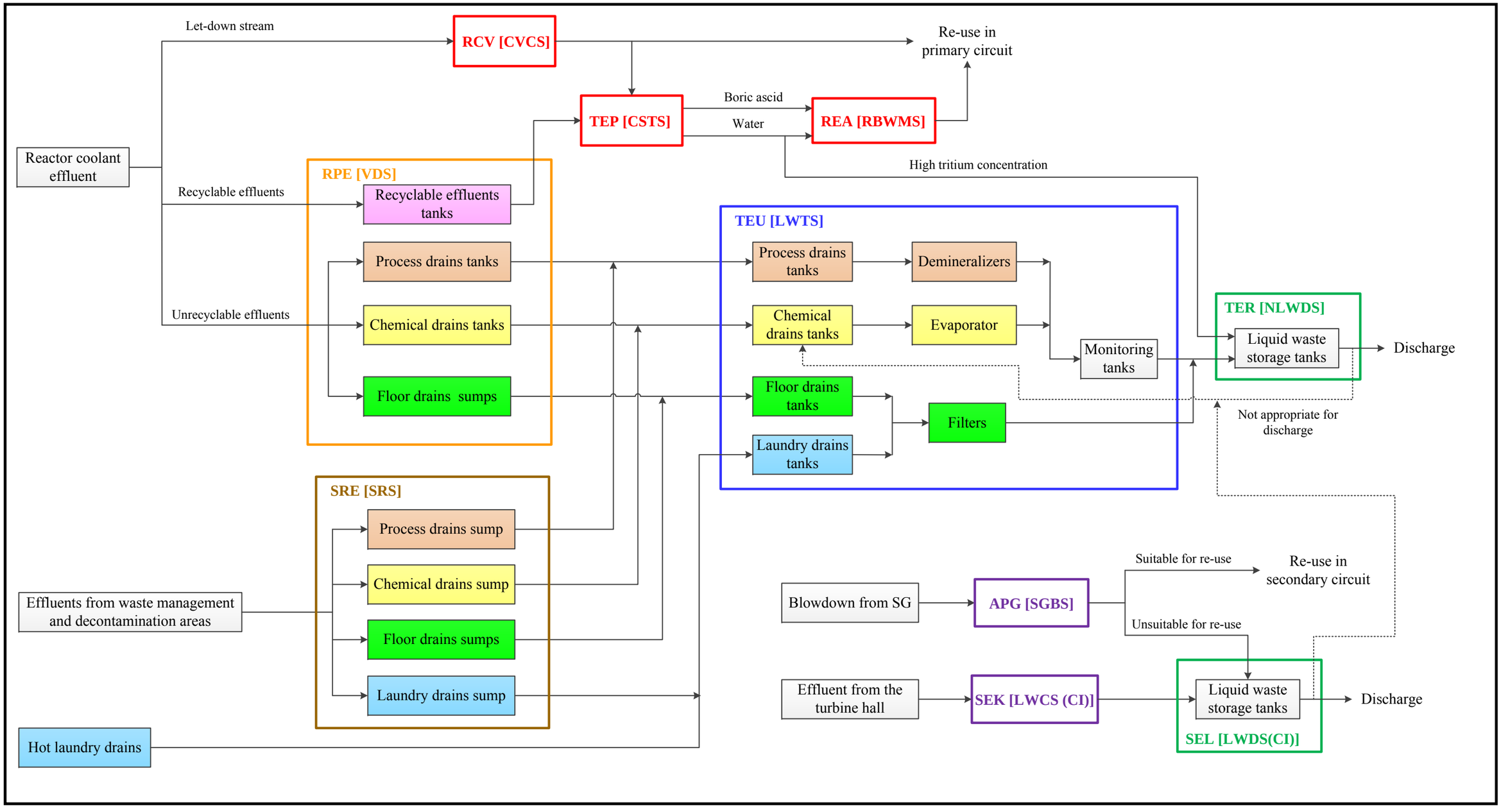
Appendix 23A Route Map

Claim	Sub-claim	Argument	Evidence	Supporting document
Claim 3.3.11	3.3.11A The functional requirements have been derived for radioactive waste management systems.	3.3.11A-1 The system specific design principles are identified.	• **Evidence 1:** Applicable policies, regulation, codes and standards for radioactive waste management have been identified (Sub-chapter 23.3).	• Analysis report of applicable codes and standards
			• **Evidence 2**: The role of system has been identified (Sub-chapter 23.6, 23.7.2 and 23.8.2).	—
		3.3.11A-2 The system design requirements have been derived in accordance with the general design and safety principles.	• **Evidence 1:** General Design requirements considered in the design of radioactive waste management system has been identified (Sub-chapters 23.2.5).	• General safety requirement • Methodology of safety classification & categorisation •The general requirements of protection design against internal and external hazards
			• **Evidence 2**: Safety functional requirements have been identified (Sub-chapter 23.6, 23.7.1 and 23.8.1).	• General safety requirement
		3.3. 11A-3 The safety class of the system and associated components has been identified from the safety analysis.	• **Evidence 1:** The safety class of the system and associated components has been identified (Sub-chapter 23.6, 23.7 and 23.8).	• SDM Chapter 3: System functions and design bases
Claim 3.3.11	3.3.11B The system design satisfied the functional requirements.	3.3. 11B-1 Appropriate design methods have been identified for the system.	• **Evidence 1:** General assumptions for radioactive waste management have been identified (Sub-chapter 23.2.4).	—
			• **Evidence 2:** 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
		3.3. 11B-2 The system has been analysed using the appropriate design methods.	• **Evidence 1:** The liquid waste processing technique has been optimised considering the principles of ALARP and BAT.	• Optioneering report for liquid radioactive waste processing techniques • Sizing report of main equipment in liquid waste treatment systems
			• **Evidence 2:** The gaseous waste processing technique has been optimised considering the principles of ALARP and BAT.	• Optioneering report for gaseous waste treatment system • Sizing report of the activated charcoal delay beds
			• **Evidence 3:** The solid waste processing technique has been optimised considering the principles of ALARP and BAT.	• Optioneering report of solid waste processing techniques • Sizing report of main equipment in solid waste treatment system
			• **Evidence 4:** The safety functional requirements of system have been substantiated (Sub-chapter 23.6, 23.7.4. and 23.8.6).	• SDM Chapter 4: System and Component Design • SDM Chapter 6: System operation and Maintenance
			• **Evidence 5:** The general design requirements of system have been substantiated (Sub-chapter 23.6, 23.7.4 and 23.8.6).	
		3.3. 11B-3 Appropriate monitoring and sampling equipment have been provided to facilitate the characterisation of radioactive waste and subsequent management.	• **Evidence 1:** Appropriate monitoring and sampling equipment have been provided to measure and record the characteristics of liquid effluents (Sub-chapter 23.6); • **Evidence 2:** Appropriate monitoring and sampling equipment have been provided to measure and record the characteristics of gaseous waste (Sub-chapter 23.7.2); • **Evidence 3:** Appropriate monitoring and sampling equipment have been provided to measure and record the characteristics of solid waste (Sub-chapter 23.8.3).	• SDM Chapter 6: System operation and maintenance

Claim	Sub-claim	Argument	Evidence	Supporting document
		3.3.11B-4 The commissioning tests requirements of system have been developed to provide assurance of the system performance.	• **Evidence 1:** The commissioning tests requirements for radioactive waste management systems will be developed to guide the preparation the commissioning tests at site licensing stage.	• Topic report on the commissioning requirements of radioactive waste management systems
		3.3.11B-5 An initial EMIT strategy has been developed for this system, identifying components that are expected to be examined, maintained, inspected and tested.	• **Evidence 1:** The EMIT has been considered in preliminary design substantiation (Sub-chapter 23.6, 23.7.4 and 23.8.6).	• SDM Chapter 6:System operation and maintenance
			• **Evidence 2:** The periodic test requirements of radioactive waste management systems will be developed to guide the future operator to prepare the detailed EMIT strategy at site licensing stage.	• Topic report on the periodic test requirements of radioactive waste management systems
Claim 3.3.11	3.3.11C The production of radioactive waste from UK HPR1000 operation has been minimised.	3.3.11C-1 The design and operation of the UK HPR1000 has been optimised to minimise radioactive waste at source.	• **Evidence 1:** The minimisation of the radioactive waste has been presented (Sub-chapter 23.5).	• PCER Chapter 3: Demonstration of BAT
		3.3.11C-2 The total quantity of radioactive waste accumulated on site has been minimised.	• **Evidence 1:** Cross-boundary waste will be provided with suitable decay storage in ILW interim storage facility to allow for off-site disposal as LLW.	• Conceptual proposal of ILW interim storage facility
			• **Evidence 2:** The interim storage facilities have appropriate capability to accommodate the radioactive waste.	
			• **Evidence 3:** Disposability of LAW is undertaken to determine the most appropriate disposal routes to minimise the accumulation of radioactive waste.	• UK HPR1000 Waste Enquiry Form • Agreement in Principle (issued by LLWR)
			• **Evidence 4:** Disposability assessment of HAW is undertaken to determine the appropriate disposal routes.	• UK HPR1000 HAW disposability assessment submission • Disposability assessment report (issued by RWM)
Claim 3.3.11	3.3.11D Radioactive waste has been put into a passively safe form for interim storage.	3.3.11D-1 The radioactive waste has been processed into packages in line with off-site disposal or treatment facilities.	• **Evidence 1**: The waste containers are compatible with the requirements of off-site facilities.	• Optimal packaging containers for disposal of ILW waste
			• **Evidence 2**: The solid waste processing technique has been optimised considering the principles of ALARP and BAT.	• Optioneering report of solid waste processing techniques
			• **Evidence 3:** Agreement in Principle of LAW has been obtained to determine the appropriate disposal routes.	• UK HPR1000 Waste Enquiry Form • Acceptability report of LLW for off-site disposal • Radioactive waste management technical user source term supporting report • Agreement in Principle (issued by LLWR)
			• **Evidence 4:** Disposability assessment of HAW has been undertaken to determine the most appropriate disposal routes.	• UK HPR1000 HAW disposability assessment submission • Radioactive waste management technical user source term supporting report • Disposability assessment report (issued by RWM)
		3.3.11D-2 The interim storage facility for Intermediate Level Waste (ILW) has been designed to receive and store waste packages safely.	• **Evidence 1**: The interim storage facility has appropriate capability to accommodate the ILW packages.	• Conceptual Proposal of ILW interim storage facility
			• **Evidence 2:** Inspection, maintenance, monitoring and environmental control of waste packages are considered to maintain the integrity of waste package.	
			• **Evidence 3:** The handling of waste packages in storage facility is operated by remote control to reduce the dose to workers.	

Claim	Sub-claim	Argument	Evidence	Supporting document
Claim 3.3.11 and Claim 3.4.8	3.3.11E All reasonably practicable measures have been adopted to optimise the design of radioactive waste management systems.	3.3.11E-1 The system satisfied meet the requirements of the relevant design principles and therefore of relevant good practice.	• **Evidence 1:** The safety functional requirements of system have been substantiated (Sub-chapter 23.6, 23.7.4. and 23.8.6).	• SDM Chapter 4: System and Component Design • SDM Chapter 6: System operation and Maintenance
			• **Evidence 2:** The general design requirements of system have been substantiated (Sub-chapter 23.6, 23.7.4 and 23.8.6).	
			• **Evidence 3:** The holistic review of the design of radioactive waste management systems against the RGP and OPEX has been conducted (Sub-chapter 23.6.6, 23.7.5 and 23.8.7).	• ALARP assessment for liquid radioactive waste management systems • ALARP assessment for gaseous waste treatment system • ALARP assessment for solid radioactive waste treatment system
		3.3.11E-2 Design improvements have been considered and any reasonably practicable changes implemented.	• **Evidence 1:** Liquid radioactive waste management systems have been demonstrated ALARP.	• ALARP assessment for liquid radioactive waste management systems
			• **Evidence 1:** Gaseous waste treatment system has been demonstrated ALARP.	• ALARP assessment for gaseous waste treatment system
			• **Evidence 2:** Solid radioactive waste management system has been demonstrated ALARP.	• ALARP assessment for solid radioactive waste treatment system

Appendix 23B Liquid Radioactive Waste Effluent Streams