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Pre-Construction Environmental Report

Chapter 4

Radioactive Waste Management Arrangements

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4.1 List of Abbreviations and Acronyms

ABWR	Advanced Boiling Water Reactor
ALARA	As Low As Reasonably Achievable
ALARP	As Low As Reasonably Practicable
APG	Steam Generator Blowdown System [SGBS]
BAT	Best Available Techniques
BFX	Fuel Building
BNX	Nuclear Auxiliary Building
BPX	Personnel Access Building
BQF	Spent Fuel Interim Storage Facility
BQS	Waste Auxiliary Building
BQZ	ILW Interim Storage Facility
BRX	Reactor Building
BSX	Safeguard Buildings
BWX	Radioactive Waste Treatment Building
CPR1000	Chinese Pressurised Reactor
CVI	Condensate Vacuum System [CVS]
DAW	Dry Active Waste
DPUR	Dose Per Unit Release
DR	Design Reference
DWN	Nuclear Auxiliary Building Ventilation System [NABVS]
EA	Environment Agency (UK)
FAP	Forward Action Plan
GDA	Generic Design Assessment
GDF	Geological Disposal Facility
HAW	Higher Activity Waste
HEPA	High Efficiency Particulate Air

HHISO	Half Height ISO
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 System
IAEA	International Atomic Energy Agency
ICIA	In-core Instrumentation Assembly
ILW	Intermediate Level Waste
ISO	International Organisation for Standardisation
IWS	Integrated Waste Strategy
KRT	Plant Radiation Monitoring System [PRMS]
LAW	Lower Activity Waste
LLW	Low Level Waste
LLWR	Low Level Waste Repository Ltd (UK)
LOC	Letter of Compliance
MSQA	Management for Safety and Quality Assurance
NALW	Non-aqueous Liquid Waste
NDA	Nuclear Decommissioning Authority
NFCC	Non-Fuel Core Component
NRW	Natural Resources Wales (UK)
ONR	Office for Nuclear Regulation (UK)
OPEX	Operating Experience
PCER	Pre-Construction Environmental Report
PCSR	Pre-Construction Safety Report
P&ID	Process and Information Document for Generic Assessment of Candidate Nuclear Power Plant Design
PNSA	Primary Neutron Source Assembly
PTR	Fuel Pool Cooling and Treatment System [FPCTS]

PWR	Pressurised Water Reactor
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
REP	Radioactive Substances Regulation - Environmental Principles
RPE	Nuclear Island Vent and Drain System [VDS]
RPV	Reactor Pressure Vessel
RVI	Reactor Vessel Internals
RWM	Radioactive Waste Management Ltd (UK)
RWMC	Radioactive Waste Management Case
SAP	Safety Assessment Principle (UK)
SED	NI Demineralised Water Distribution System [DWDS (NI)]
SEK	Waste Fluid Collection System for Conventional Island [WFSCI]
SEL	Conventional Island Liquid Waste Discharge System [LWDS (CI)]
SEPA	Scottish Environment Protection Agency
SFA	Spent Fuel Assembly
SFAIRP	So Far As Is Reasonably Practicable
SFIS	Spent Fuel Interim Storage
SFP	Spent Fuel Pool
SG	Steam Generator
SNSA	Secondary Neutron Source Assembly
SRE	Sewage Recovery System [SRS]
TEG	Gaseous Waste Treatment System [GWTS]
TEP	Coolant Storage and Treatment System [CSTS]

TER	Nuclear Island Liquid Waste Discharge System [NLWDS]
TEU	Liquid Waste Treatment System [LWTS]
TPA	Thimble Plug Assembly
UK HPR1000	UK version of the Hua-long Pressurised Reactor
VLLW	Very Low Level Waste
WAC	Waste Acceptance Criteria
WENRA	Western European Nuclear Regulators Association

System codes (XXX) and system abbreviations (YYY) are provided for completeness in the format (XXX [YYY]), e.g. Steam Generator Blowdown System (APG [SGBS]).

4.2 Introduction

4.2.1 Objective

This chapter describes the radioactive waste management arrangements for UK version of the Hua-long Pressurised Reactor (UK HPR1000) to support the environmental objectives described in the Pre-Construction Environmental Report (PCER) Chapter 1.

The intent of this chapter is to meet the information requirements of item 3, 4 and 5 of Table 1 of the *Process and Information Document for Generic Assessment of Candidate Nuclear Power Plant Designs (P&ID)*, Reference [1]. It also considers the relevant requirements of the *Radioactive Substances Regulation - Environmental Principles (REP)*, Reference [2], and the *Safety Assessment Principles for Nuclear Facilities (SAP)*, Reference [3].

4.2.2 Scope

This chapter presents the radioactive waste management arrangements for the UK HPR1000. Information is presented on the liquid, gaseous and solid radioactive wastes and the spent fuel arising during the operation of the reactor, as well as the wastes arising from the decommissioning. It also explains how the production, discharge and disposal of the radioactive waste and the spent fuel will be managed to protect the environment and people.

The radioactive waste management arrangements presented in this chapter are developed based on the Design Reference (DR) version 3.0, as described in the Sub-chapter 1.4.4 of PCER Chapter 1. DR3.0 reflects the design modifications implemented to address the identified gaps relevant to the radioactive waste management at this stage of the Generic Design Assessment (GDA), considering the principles of As Low As Reasonably Practicable (ALARP) and Best Available Techniques (BAT).

This chapter is to be read in conjunction with the following Pre-Construction Safety Report (PCSR) chapters to help understanding of the strategy and associated arrangements presented in this PCER chapter:

a) PCSR Chapter 23 Radioactive Waste Management, which describes the radioactive waste management systems design (including the Nuclear Island Vent and Drain System (RPE [VDS]), the Liquid Waste Treatment System (TEU [LWTS]), the Nuclear Island Liquid Waste Discharge System (TER [NLWDS]), the Sewage Recovery System (SRE [SRS]), the Conventional Island Liquid Waste Discharge System (SEL [LWDS (CI)]), the Gaseous Waste Treatment System (TEG [GWTS]), and the Solid Waste Treatment System (TES [SWTS])) and the radioactive waste storage areas design, Reference [4];

b) PCSR Chapter 24 Decommissioning, which presents the decommissioning strategy and plan as well as other aspects affecting the arising, classification and management of decommissioning wastes, Reference [5]; and,

c) PCSR Chapter 29 Interim Storage of Spent Fuel, which presents the overview of the design of the spent fuel interim storage facility, Reference [6].

The interfaces with other chapters of the PCER are described in T-4.2-1.

T-4.2-1 Interfaces with Other PCER Chapters

Chapter	Interface Relationship
PCER Chapter 1 Introduction	PCER Chapter 1 presents the summary of each PCER chapter and the P&ID route map. PCER Chapter 4 presents the radioactive waste management arrangements to reflect the P&ID information requirements to be supported by this chapter.
PCER Chapter 3 Demonstration of BAT	PCER Chapter 3 presents the BAT methodology applied to the UK HPR1000 and the BAT demonstration of radioactive waste management.
PCER Chapter 5 Approach to Sampling & Monitoring	PCER Chapter 5 presents the sampling and monitoring approach for radioactive waste.

Chapter	Interface Relationship
PCER Chapter 6 Quantification of Discharges & Limits	PCER Chapter 6 presents the estimated values and proposed limits for the liquid and gaseous discharges to the environment.
PCER Chapter 8 Conventional Impact Assessment	PCER Chapter 8 presents the conventional impact assessment relevant to the chemical liquid and gaseous discharges.

4.3 Regulatory Context

4.3.1 P&ID Requirements

The Environment Agency (EA) has identified the information required for the GDA in the P&ID, Reference [1]. The information requirements relating to the arrangements for the management of radioactive waste are shown as follows.

Item 3, Table 1, Reference [1]:

> ***Detailed information relating to the design.***
>
> *Include:*
>
> - *Identification of the plants, systems and processes which have a bearing on:*
>   - *radioactive waste (solid, liquid and gaseous) generation, treatment, measurement, assessment and disposal.*

Item 4, Table 1, Reference [1]:

> ***A detailed description of the radioactive waste management arrangements.***
>
> *Include:*
>
> - *Identification of the strategic considerations with respect to radioactive waste management which underpin the design.*
> - *A description of how radioactive wastes and spent fuel will arise throughout the facility's lifecycle (including decommissioning) and the plans for how they will be managed and disposed of, to encompass:*
>   - *sources of radioactivity and matters which affect wastes arising*
>   - *gaseous, aqueous and other wastes*
> - *A description of how the production, discharge and disposal of radioactive waste will be managed to protect the environment and to optimise the protection of people.*
>   - *Describe the optimisation process used and identify and justify the proposed techniques as BAT.*

- *In identifying techniques, address both the technology to be used and the way the facility is designed and will be built, maintained, operated and dismantled.*

Item 5, Table 1, Reference [1]:

Quantification of radioactive waste disposals.

Provide quantitative estimates for normal operation of:

- *arisings of combustible waste and disposals by on-site or off-site incineration*
- *arisings of other radioactive wastes (by category and disposal route (if any)) and spent fuel*

'Normal operation' includes the operational fluctuations, trends and events that are expected to occur over the lifetime of the facility, such as start-up, shutdown, maintenance, etc. It does not include increased discharges arising from other events, inconsistent with the use of BAT, such as accidents, inadequate maintenance, and inadequate operation.

…

For combustible and other radioactive wastes, estimate the annual arisings and disposals during operation and give an indication of the likely arisings during decommissioning. Identify wastes in terms of their category (HLW, ILW, LLW, VLLW), physico-chemical characteristics and proposed disposal route (if any). Quantification should be in terms of activity of key individual radionuclides and overall groupings of radionuclides (for example, total beta), together with mass and / or volume.

4.3.2 Relevant REPs

The following key REPs, Reference [2], are taken into account and complied with when designing the radioactive waste management arrangements:

Principle RSMDP1 - Radioactive Substances Strategy

A strategy should be produced for the management of all radioactive substances.

Principle RSMDP3 - Use of BAT to Minimise Waste

The best available techniques should be used to ensure that production of radioactive waste is prevented and where that is not practicable minimised with regard to activity and quantity.

Principle RSMDP4 - Methodology for Identifying BAT

The best available techniques should be identified by a methodology that is timely, transparent, inclusive, based on good quality data, and properly documented.

Principle RSMDP6 - Application of BAT

In all matters relating to radioactive substances, the "best available techniques" *means the most effective and advanced stage in the development of activities and their methods of operation.*

Principle RSMDP8 - Segregation of Wastes

The best available techniques should be used to prevent the mixing of radioactive substances with other materials, including other radioactive substances, where such mixing might compromise subsequent effective management or increase environmental impacts or risks.

Principle RSMDP9 - Characterisation

Radioactive substances should be characterised using the best available techniques so as to facilitate their subsequent management, including waste disposal.

Principle RSMDP10 - Storage

Radioactive substances should be stored using the best available techniques so that their environmental risk and environmental impact are minimised and that subsequent management, including disposal is facilitated.

Principle RSMDP11 - Storage in a Passively Safe State

Where radioactive substances are current not stored in a passively safe state and there are worthwhile environmental or safety benefits in doing so then the substances should be processed into a passively safe state.

Principle RSMDP14 - Record Keeping

Sufficient records relating to radioactive substances and associated facilities should be made and managed so as: to facilitate the subsequent management of those substances and facilities; to demonstrate whether compliance with requirements and standards has been achieved; and to provide information and continuing assurance about the environmental impact and risks of the operations undertaken, including waste disposal.

RSMDP15 - Requirements and Conditions for Disposal of Wastes

Requirements and conditions that properly protect people and the environment should be set out and imposed for disposal of radioactive waste. Disposal of radioactive waste should comply with imposed requirements and conditions.

Principle DEDP1 - Decommissioning Strategy

Each site should have a decommissioning strategy that is updated and refined at appropriate intervals.

Principle DEDP2 - Decommissioning Plan

There should be a decommissioning plan for each facility and this should be updated *and refined throughout its operation life and during decommissioning.*

Principle DEDP3 - Considering Decommissioning during Design and Operation

Facilities should be designed, built and operated using the best available techniques to minimise the impacts on people and the environment of decommissioning operations and the management of decommissioning waste.

4.3.3 Other Requirements Related to Radioactive Waste Management

Based on the general principles and selection methodology presented in *General Principles for Application of Laws, Regulations, Codes and Standards*, Reference [7], the main laws, regulations, policies and strategies related to waste management in the UK considered and applied are as follows:

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

b) The Nuclear Installations Act, 1965;

c) The Environment Act, 1995;

d) The Hazardous Waste (England and Wales) Regulations, 2005;

e) The Hazardous Waste (England and Wales) (Amendment) Regulations, 2009;

f) The Hazardous Waste (England and Wales) (Amendment) Regulations, 2016;

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

h) The Environmental Permitting (England and Wales) (Amendment) Regulations, 2018;

i) The Environmental Permitting (England and Wales) (Amendment) (No. 2) Regulations, 2018;

j) The Ionising Radiations Regulations, 2017;

k) Nuclear Reactors (Environmental Impact Assessment for Decommissioning) Regulations, 1999;

l) The Construction (Design and Management) Management Regulations, 2015;

m) Implementing Geological Disposal, 2014;

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

o) Review of Radioactive Waste Management Policy: Final Conclusions (Cmnd 2919), 1995;

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

q) UK Strategy for the Management of Solid Low Level Radioactive Waste from the Nuclear Industry, 2016.

For the codes and standards for the management of radioactive waste, a number of sources including the UK, Western European Nuclear Regulators Association (WENRA) and the International Atomic Energy Agency (IAEA) are considered and codes and standards from these sources are collected and analysed. The applicable codes and standards are identified in *Analysis Report of Applicable Codes and Standards*, Reference [8], and listed below:

a) Regulatory Guidance Series, No RSR 1: Radioactive Substances Regulation – Environmental Principles, Reference [2];

b) Safety Assessment Principles for Nuclear Facilities, Reference [3];

c) The Management of Higher Activity Radioactive Waste on Nuclear Licensed Sites, Reference [9];

d) Industry Guidance: Interim Storage of Higher Activity Waste Packages – Integrated Approach, Reference [10];

e) Radioactive Waste Treatment and Conditioning Safety Reference Levels, Reference [11];

f) Waste and Spent Fuel Storage Safety Reference Levels, Reference [12];

g) Predisposal Management of Radioactive Waste, Reference [13];

h) Predisposal Management of Radioactive Waste from Nuclear Power Plants and Research Reactors, Reference [14];

i) Management Radioactive Waste from Decommissioning of Nuclear Sites: Guidance on Requirements for Release from Radioactive Substance Regulation, Reference [15].

These codes and standards are regarded as Relevant Good Practice (RGP) for the management of radioactive waste. The requirements derived from these RGPs are incorporated into the radioactive waste management strategy and arrangements and into the design of the radioactive waste management systems in the UK HPR1000, which is demonstrated being optimised at this GDA stage. The radioactive waste management strategy and arrangements are described in this PCER chapter and the design of the radioactive waste management systems and storage areas are (mainly) presented in PCSR Chapter 23, Reference [4].

4.4 Waste Management Principles

The waste management principles are derived from the RGPs presented in Sub-chapter 4.3.3, and from the applicable REPs presented in Sub-chapter 4.3.2.

T-4.4-1 presents a mapping of the applicable REPs with this management arrangements document and its supporting documentations, and aims to show where the waste management principles are described.

T-4.4-1 Radioactive Waste Management Principles

Principles	**REP**	**Mapping in this document**
A strategy in compliance with the waste hierarchy should be produced and implemented for the management of radioactive waste.	REP-RSMDP1	PCER Chapter 4 and the Integrated Waste Strategy (IWS), Reference [16].
BAT should be applied to prevent the generation and accumulation of the radioactive waste (in terms of quantity and activity).	REP-RSMDP3	BAT application is presented in Sub-chapters 4.7.2.6, 4.7.3.5, 4.7.4.5. Detailed demonstration is presented in PCER Chapter 3.
BAT should be applied in the design to optimise and facilitate the disposal of each waste stream, and minimise the volume of packaged waste for disposal.	REP-RSMDP4 REP-RSMDP6 REP-RSMDP15	BAT application in the design is presented (high level) in Sub-chapters 4.7.1 and 4.7.4.5. Detailed demonstration is presented in PCER Chapter 3.
Radioactive waste should be characterised and segregated to facilitate subsequent effective management and disposal.	REP-RSMDP8 REP-RSMDP9	Waste characterisation and segregation are presented in Sub-chapters 4.6.3 bullet a) and 4.7.2.5, 4.7.3.4 and 4.7.4.2.
Radioactive waste should be stored in accordance with good engineering practice and be processed into a passively safe state as soon as is reasonably practicable. Where appropriate, retrieval should be	RSMDP10 RSMDP11	Interim storage of radioactive waste is presented in Sub-chapter 4.7.4.4.4, 4.7.5.3 and 4.7.6.4.

Principles	REP	Mapping in this document
allowed.		
Sufficient information relating to radioactive waste management and disposal should be recorded and preserved.	RSMDP14	Consideration of waste management records is presented in Sub-chapters 4.6.4, 4.7.4.4.4.4 and 4.7.5.3.6.
All liquid and gaseous discharges shall be treated with a facility that represents BAT.	RSMDP15	The (BAT) management for liquid waste and gaseous waste discharges are presented in Sub-chapters 4.7.2.6 and 4.7.3.5 and the detailed BAT demonstration is in PCER Chapter 3.
Develop decommissioning strategy and plan. Consider decommissioning during design and operation and develop decommissioning radioactive waste management proposal.	DEDP1 DEDP2 DEDP3	This is outlined in Sub-chapter 4.7.6.3 and detailed in PCSR Chapter 24.

4.5 Assumptions

The radioactive waste management arrangements are developed based on following main assumptions, taking into account the 'Base Case' that is set out in Reference [17]:

a) The operational life of the UK HPR1000 is 60 years;

b) The radioactive waste management systems will be utilised during the decommissioning process if this is demonstrated ALARP/BAT and the risks/impacts on the workers, members of public and the environment of doing so are reduced So Far As Is Reasonably Practicable (SFAIRP)/As Low As Reasonably Achievable (ALARA);

c) The waste management strategy considers current treatment technologies applied internationally and legally acceptable in the UK;

d) TEG [GWTS], RPE [VDS] and TES [SWTS] parts in Nuclear Auxiliary Building

(BNX) are designed to manage radioactive waste arising from one reactor unit. TEU [LWTS], TER [NLWDS], SRE [SRS], SEL [LWDS (CI)], and the other parts in TES [SWTS] are designed to manage radioactive waste arising from two reactor units;

e) The current policy, standards and regulation about radioactive waste management in the UK is adopted to guide the development of the waste management arrangements and they remain either unchanged or the impact of any change is minimal;

f) The proximity principle will be considered in the assessment undertaken for a specific site;

g) Spent fuel is packaged and stored on-site until the Geological Disposal Facility (GDF) is available;

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

i) Intermediate Level Waste (ILW) and High Level Waste (HLW) arising from the operation and decommissioning are to be packaged in a passively safe form, and stored safely in an interim storage facility on-site until a GDF becomes available; For the ILW/LLW boundary waste, decay storage is considered; and,

j) The Waste Acceptance Criteria (WAC) set by LLWR are the basis for obtaining an ‘Agreement in Principle’ for treatment or disposal of Very Low Level Waste (VLLW) [1] and LLW based upon the services provided by LLWR. It is assumed that any other facilities proposing the same treatment/disposal services as LLWR would have similar WAC.

4.6 Radioactive Waste Management Strategy

This sub-chapter presents the main considerations for the radioactive waste management strategy to ensure that all the radioactive waste streams generated in the UK HPR1000 can be managed in a safe and appropriate manner to reduce the risks and/or impacts to the workers, public and environment SFAIRP/ALARA, notably through the use of BAT. The sub-chapters in this section present the considerations to establish the optimal options for UK HPR1000 radioactive waste management.

4.6.1 Application of the Waste Hierarchy

The waste hierarchy, as illustrated in F-4.6-1, is applied to the waste management arrangements for the UK HPR1000. The waste hierarchy is a stepwise approach to

[1] VLLW is a sub-category of LLW.

achieve waste minimisation. It encourages the options for waste management in the following order of priority:

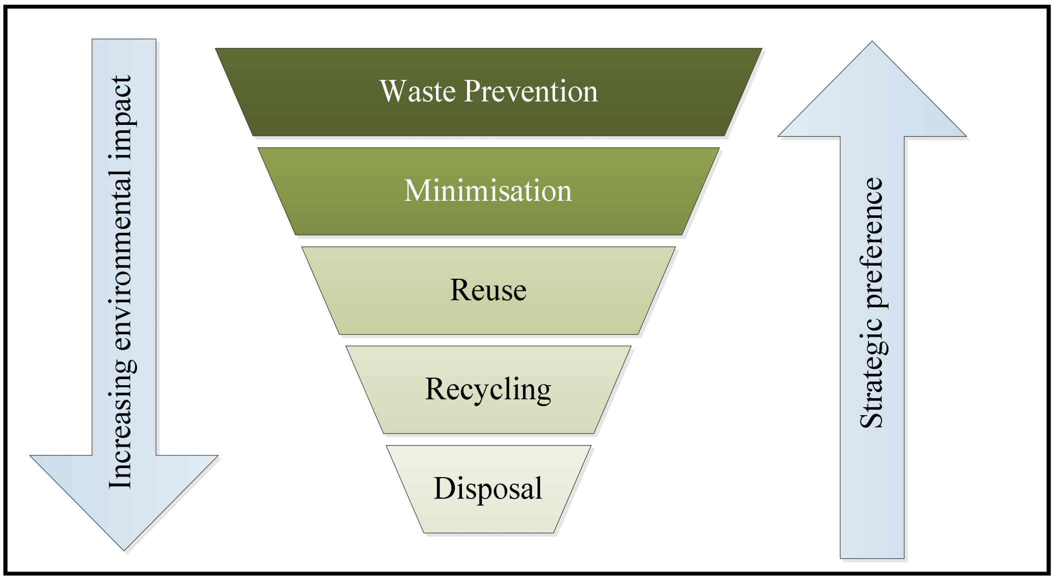
a) Prevention: Creation of waste should be prevented;

b) Minimisation: Waste that cannot be prevented should be reduced at source as far as possible;

c) Reuse: Where appropriate, waste materials should be reused directly or after refurbishment;

d) Recycling: Where appropriate, waste materials should be recycled; and,

e) Disposal: Waste should only be disposed of when the above options are not possible. Once disposal has been determined to be the correct option, the disposal route representing BAT/ALARP is to be determined, with a focus upon optimising use of disposal facilities, e.g. LLWR or GDF, where possible.



F-4.6-1 Waste Hierarchy

Waste prevention and minimisation at source form the first steps of the application of the waste hierarchy and will continue to be considered in the design, operation and decommissioning of the UK HPR1000. To achieve waste prevention and minimisation, specific areas of optimisation have been identified. These are summarised in the IWS, Reference [16], and further developed in the PCSR Chapter 23, Reference [4], in PCER Chapter 3 and in their supporting documents.

4.6.2 Application of BAT and ALARP

The BAT methodology, which is summarised in PCER Chapter 3 and described in more details in Reference [18], has been developed to identify and justify the application of BAT. The methodology proposes a systematic and evidence based approach that aims to demonstrate that the design, manufacture, construction, commissioning, operation and decommissioning of the UK HPR1000 have been optimised to protect members of the public and to minimise the impact on the environment from exposure to ionising radiation.

The ALARP methodology, which is summarised in PCSR Chapter 33, Reference [19], and described in more details in Reference [20], has been developed to identify and justify the application of ALARP.

These two methodologies have been developed to ensure application and justification of BAT and ALARP are integrated to ensure the proposed design, manufacture, construction, commissioning, operation and decommissioning of the UK HPR1000 are both BAT and ALARP.

Recognising that optimisation of the UK HPR1000 design, which is to be considered throughout GDA (and during the whole plant lifetime), necessitates balancing the various criteria in line with both the BAT and ALARP principles, *Provisions on Optineering Process for UK HPR1000 Generic Design Assessment (GDA) Project,* Reference [21], has been developed, which describes the design optimisation approaches and the methodology for demonstration that the design is optimised.

The optioneering process presented in Reference [21] has been applied systematically to the UK HPR1000 design. In some cases, simplified optioneering is also undertaken if there is only limited design information during this GDA stage.

The application of BAT in the UK HPR1000 design is demonstrated through the claim, argument and evidence approach, which is presented in PCER Chapter 3. The application and assessment of ALARP for the radioactive waste management, decommissioning and interim storage of spent fuel are presented in the PCSR Chapters 23, 24 and 29 and their supporting documentations, Reference [4], [5] and [6]. An outline of the application of BAT and ALARP into the UK HPR1000 design, relevant to radioactive waste management, is provided in this PCER chapter, in Sub-chapter 4.7.1.

4.6.3 Waste Management Stage

For managing the waste streams safely and effectively, the following stages are taken into account and implemented:

a) Characterisation and Segregation

Wastes are characterised and segregated at source to facilitate subsequently safe and effective management. Characterisation through sampling, measurement and monitoring are applied to acquire sufficient data to support waste management decisions. Segregation enables to collect the waste with similar characteristics together and avoid mixing waste with different characteristics. Following the characterisation and segregation of the radioactive waste at an early stage, the subsequent treatment and disposal routes can be optimised and demonstrated to be appropriate and efficient.

Additionally, characterisation and segregation are taken into account throughout all the stages of waste management. This contributes significantly to the waste minimisation and ensures the waste hierarchy can be applied appropriately.

b) Temporary and Buffer Storage

Segregated waste streams are temporarily stored until there is enough quantity for batch treatment (mainly for liquid and solid wastes). During the temporary and buffer storage, the waste streams are characterised to determine their physical, chemical and radiological properties. The potential boundary wastes are identified and the appropriate disposal route and treatment for each waste stream are developed according to their properties and the disposal routes availability and limitations.

c) Treatment and Conditioning

The liquid and gaseous effluent streams are recycled wherever possible. If recycling is not possible, they are treated to be suitable for discharge to the environment.

The solid waste streams are treated for volume reduction (such as drying, cutting, compaction, etc.) where possible.

Conditioning is applied to transform the waste to be suitable for handling, storage, transport and disposal. The preferred conditioning method is to place or immobilise the waste to form a stable waste for waste containers to create waste packages that are safe.

The packaged VLLW and LLW are to be transported to a suitable facility for treatment or disposal shortly after they have been produced. The boundary ILW/LLW are stored on-site for decay and transported to a suitable facility for treatment or disposal once they have decayed to LLW. The ILW, HLW and spent fuel are safely stored on-site until a GDF becomes available.

d) Interim Storage

Before the GDF is available, interim storage on-site is necessary for the ILW, HLW and spent fuel. The interim storage facilities are developed in accordance with UK context and good engineering practice to ensure the safe and secure storage.

e) Disposal

Liquid and gaseous treated effluent are monitored and discharged to the environment in accordance with BAT and permit conditions, notably the authorised limits.

The packaged VLLW and LLW will be transported to a suitable facility for treatment or disposal (e.g. the LLWR). After interim storage, the ILW, HLW and spent fuel packages will be retrieved, repackaged if needed and transported to the GDF.

4.6.4 Waste Management Record

The operation of the radioactive waste management systems will generate a large quantity of information, including that relating to the sampling and monitoring of radioactive waste or waste packages. According to the requirement in References [3] and [22], sufficient records about radioactive waste management systems must be preserved now and in the future for the safe management and disposal of radioactive waste, especially for radioactive solid waste.

The process of making and preserving these documents and records starts during the GDA stage 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 stage, all documents relating to the safety case of the UK HPR1000 and records are maintained under the systemic Management for Safety and Quality Assurance (MSQA) arrangements. These documents and records will be transferred to a future operator at site licensing phase (Forward Action Plan (FAP)-4-1). The details of the MSQA are presented in PCSR Chapter 20, Reference [23].

During the site licensing phase, the future operator will be responsible for the information management system to track the information of waste management from generation to disposal among all other information that needs to be recorded and kept. The future operator will also need to engage with the off-site treatment and disposal facilities operators to ensure all the information they require is captured in the records (FAP-4-1). The main information includes:

a) Production process, production date of each waste stream;

b) Relevant characteristics, i.e. radiological inventory, physical and chemical information, location and date of each waste stream at source;

c) Treatment process, production date, relevant characteristics and unique identifier of each waste package;

d) Location of each waste package in different facilities, especially for waste storage facility;

e) Environment conditions, monitoring and inspection records, store and waste package maintenance records in the waste storage facility; and,

f) Records of disposal route of each waste package.

The appropriate records of Higher Activity Waste (HAW) and spent fuel packages will be preserved and maintained until the GDF in the UK is available, when the waste record will be transferred to the GDF operator. For Lower Activity Waste (LAW), the appropriate records of LAW packages also need to be kept by future operator and transferred to off-site disposal facilities or waste treatment facilities.

4.7 Radioactive Waste Management

4.7.1 Introduction

Due to the differences between the UK regulatory regime and waste management infrastructures/services and the Chinese ones, the management proposals of some of the waste streams in the DR1 of the UK HPR1000 may not be compliant with the UK context or demonstrated as optimised in the UK. Therefore, a systematic and holistic analysis of the radioactive waste management arrangements and design against the UK context and RGP (or international Operating Experience (OPEX) where relevant, i.e., where no RGP exists) has been undertaken during the development of radioactive waste management arrangements for the UK HPR1000.

The existing and planned off-site infrastructures in the UK for radioactive waste management are also considered in the analysis process as those are also different to Chinese ones. The details and outcomes of this analysis which covered all the operational radioactive wastes are presented in the *Gap Analysis Report of Radioactive Waste Management,* Reference [24]. Through the analysis, no gaps have been identified in the management proposal for the radioactive gaseous waste and liquid waste. However, seven gaps have been identified in the management proposal for the radioactive solid wastes and Non-aqueous Liquid Waste (NALW):

a) ILW spent resins treatment process (No.1);

b) Dry Active Waste (DAW) segregation and treatment process (No.2);

c) Oil and organic solvent treatment process (No.3);

d) Low activity spent resins and ventilation filter cartridges management process (No.4);

e) In-core Instrumentation Assemblies (ICIAs), Rod Cluster Control Assemblies (RCCAs) and Stationary Core Component Assemblies (SCCAs) management process (No.5);

f) ILW waste container and shielding container for ICIAs (No.6); and,

g) ILW Interim Storage Facility/Areas (No.7).

To address these gaps and select optimised waste management arrangements proposals for the UK HPR1000, a systematic optioneering study for each waste streams has been undertaken by applying the optioneering process presented in Reference [25]. The outcomes are detailed in the following reports:

a) Optioneering study for gaps No.1 to 4 is presented in *Optioneering Report for Operational Solid Waste Processing Techniques*, Reference [25];

b) ICIAs, RCCAs and SCCAs are grouped as Non-Fuel Core Components (NFCCs). The optioneering study for gap No.5 is presented in *Management Proposal of Waste Non-Fuel Core Components*, Reference [26];

c) The optioneering study for gap No.6 is presented in *Selection of Waste Containers for Disposal of ILW*, Reference [27]; and,

d) The optioneering study for gap No.7 is presented in *Conceptual Proposal of ILW Interim Storage Facility*, Reference [28].

The optimal options study for the identified gaps mentioned above is detailed in the References [25], [26], [27] and [28] and summarised in *Optimal Options Study for Identified Gaps in Radioactive Waste Management,* Reference [29]. Although no gaps in radioactive gaseous waste and liquid waste management have been identified as a result of the gap analysis, an optioneering study has also been undertaken to support the statement that the proposed design for the UK HPR1000 has been optimised for the UK and no further optimisation is necessary. These optioneerings are presented in References [30] and [31]. DR1 of the UK HPR1000, together with the design modifications implemented to notably address the identified gaps relevant to the radioactive waste management formed the current DR for UK HPR1000 (DR3).

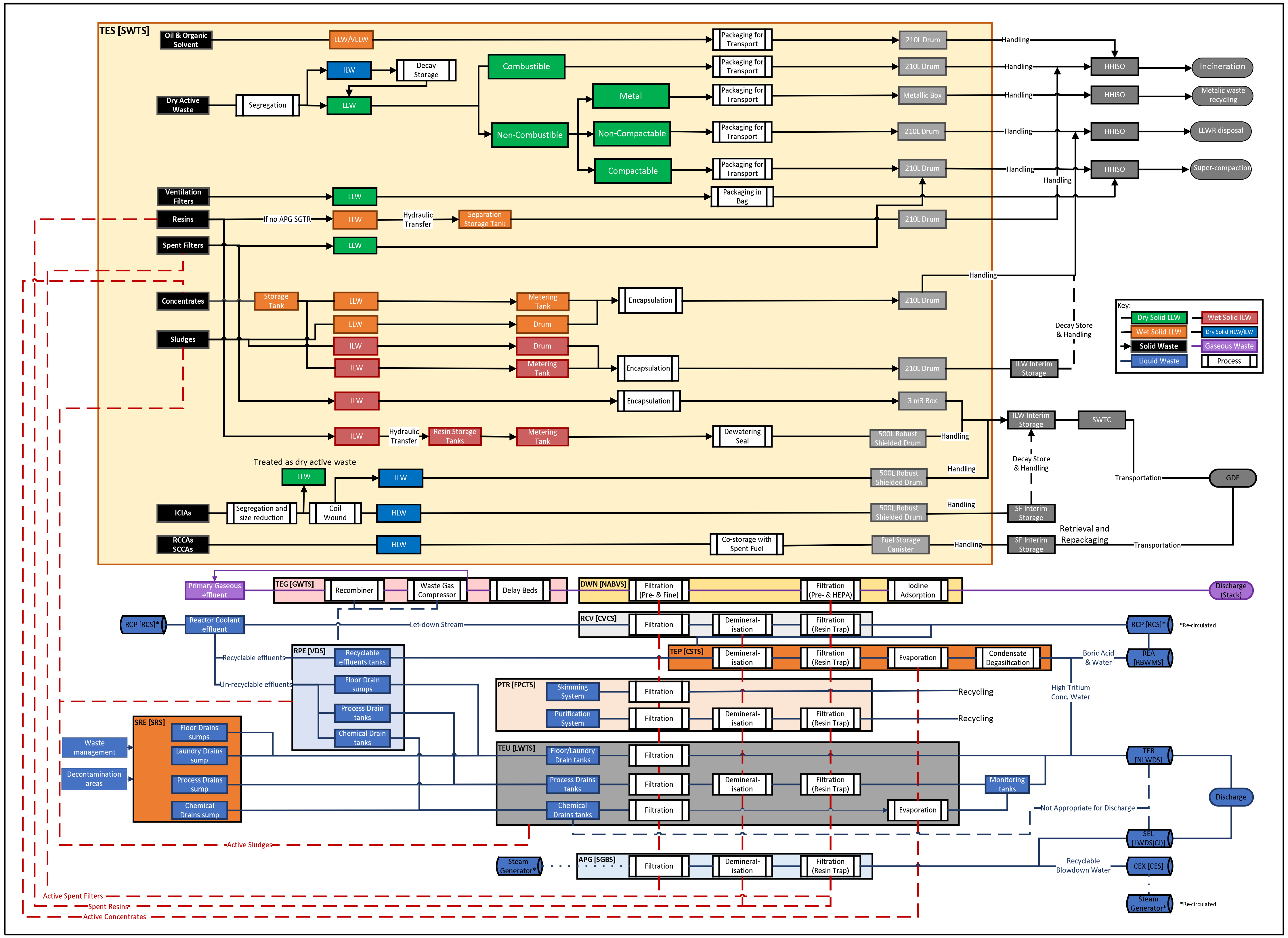
The management proposals of all the operational radioactive wastes for the UK HPR1000 are summarised and presented in F-4.7-1 and described in Sub-chapters 4.7.2, 4.7.3 and 4.7.4.

For spent fuels, as stated in the 2008 Government White Paper, Reference [32], in the absence of any proposals from industry (for reprocessing), any new nuclear power station that might be built in the UK should proceed on the basis that spent fuel will not be reprocessed and that plans for, and financing of, spent fuel management should proceed on this basis.

There is currently no disposal facility for spent fuel in the UK and whilst there is a government programme in place to develop a GDF, it is not expected to be available when UK HPR1000 begins to generate spent fuel. The strategy for spent fuel management in UK HPR1000 is, therefore, to store the spent fuel on-site pending availability of a GDF. Although it is possible that, over the life of the nuclear power plant alternative facilities become available that might allow spent fuel to be transported off-site, it is prudent to plan on the basis that sufficient capacity is provided on-site to store the lifetime arising of spent fuel for at least 100 years.

In China, the strategy for the spent fuel management is to store them in the Spent Fuel Pool (SFP) for cooling and then transport them to the reprocessing facility for recycling. The spent fuel management arrangements of Hua-long Pressurised Reactor under construction at Fangchenggang nuclear power plant unit 3 (HPR1000 (FCG3)) cannot therefore be implemented in the UK. For the UK HPR1000, spent fuel will have to be stored in the SFP of Fuel Building (BFX) for short-term cooling, and then transferred from the BFX to another storage building on-site for interim storage, which is not developed in DR1.0. This is also identified as a gap, and relevant optioneering study for spent fuel interim storage has been undertaken, which is summarised in PCSR Chapter 29, Reference [6], and detailed in *Technology Optioneering on Spent Fuel Interim Storage*, Reference [33]. Based on the optioneering outcome, the spent fuel interim storage design has been developed. Spent fuel management and interim storage is described in Sub-chapter 4.7.5.

Radioactive wastes will also be generated during the decommissioning of UK HPR1000. A proportion of these decommissioning radioactive wastes will have similar characteristics as those generated during operational stage. For these decommissioning radioactive wastes, the same strategy as the one for operational radioactive wastes is adopted at GDA stage. For the other decommissioning radioactive wastes, which differ from the operational radioactive wastes, applicable management proposals are selected. The management of the radioactive wastes during decommissioning are described in Sub-chapter 4.7.6.



F-4.7-1 Integrated Operational Radioactive Waste Flow Diagram

4.7.2 Radioactive Liquid Waste Management

The liquid (aqueous) effluents arising are minimised through the following sequence of actions:

a) Reduction of radionuclides generation;

b) Reduction of effluent generation at source;

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

d) Recycling wherever possible; and,

e) Sampling, monitoring and treatment.

The liquid effluent streams generated during operation and their treatment are described and illustrated in F-4.7-2. The liquid radioactive waste management systems are described in PCSR Chapter 23, Sub-chapter 23.6, Reference [4]. The estimated discharges and proposed limits of liquid effluent are described in PCER Chapter 6, Sub-chapter 6.6.

4.7.2.1 Reactor Coolant Effluent

Reactor coolant is continuously cleaned by extracting a proportion of the coolant known as letdown, which is treated by filters and demineralisers of the Chemical and Volume Control System (RCV [CVCS]). In the case of burn-up compensation, load change, start-up and shutdown transients, the reactor coolant can be transferred to the Coolant Storage and Treatment System (TEP [CSTS]) via the RCV [CVCS] for further treatment and re-use or transfer to the TER [NLWDS].

The leakage or drainage from the systems containing primary coolant and radioactive effluent is collected by the RPE [VDS] and SRE [SRS] and separated into two types:

a) Recyclable leakage or drainage is collected in the recyclable effluent tanks and then transferred to the TEP [CSTS] for treatment and reused or transfer to the TER [NLWDS]; and,

b) Unrecyclable leakage or drainage divided into three streams:

    1) Process drains;

    2) Chemical drains; and,

    3) Floor drains.

The effluents transferred to the TEP [CSTS] are decontaminated by demineralisation, and the boric acid and water are separated by evaporation and degasification. Boric acid and degassed distillates from the TEP [CSTS] are sent to the Reactor Boron and Water Makeup System (REA [RBWMS]) as supplementary make up for the primary circuit coolant. If inappropriate for re-use, the distillates are routed to the TER [NLWDS] for discharge.

The design of the RCV [CVCS], REA [RBWMS] and the TEP [CSTS] systems are described in PCSR Chapter 10, Sub-chapters 10.4.3, 10.4.4 and 10.4.5, Reference [34].

The unrecyclable effluents are transferred to the TEU [LWTS] for treatment as described below in Sub-chapter 4.7.2.2.

Spent filter cartridges and spent resins are solid waste to be generated from reactor coolant and recyclable effluent treatment. The waste arising and management arrangements for these solid wastes are described in Sub-chapter 4.7.4.

4.7.2.2 Liquid Waste

The liquid wastes include:

a) The unrecyclable effluents collected in the RPE [VDS]; and,

b) The effluents from waste management and decontamination areas, which are collected in the SRE [SRS].

Liquid wastes are segregated into four categories and routed for treatment in the TEU [LWTS]:

a) Process drains

Process drains are from the venting and draining or leakages of equipment and pipelines which carry reactor coolant. They are collected locally by RPE [VDS] and SRE [SRS] and routed to two process drains storage tanks of the TEU [LWTS]. Process drains have a low level of chemical impurities.

b) Chemical drains

Chemical drains are mainly from the laboratory and the decontamination drains. They are collected locally by RPE [VDS] and SRE [SRS] and routed to two chemical drains storage tanks of the TEU [LWTS]. Chemical drains have a higher level of chemical impurities and potentially higher radioactivity than process drains.

c) Floor drains

Floor drains, with potential contamination (from leakages and drainage of equipment and floor washings), come from controlled areas housing equipment carrying primary effluent, or radioactive effluent and the decontamination drains in the Reactor Building (BRX), BNX, BFX, Safeguard Buildings (BSX), Personnel Access Building (BPX), Radioactive Waste Treatment Building (BWX) and the hot workshop. Floor drains typically have a lower radioactive contamination but are high in suspended solids. They are collected locally by RPE [VDS] and SRE [SRS] and routed to three floor drains storage tanks of the TEU [LWTS].

d) Laundry drains

Laundry drains come from the hot laundry system. They are collected by two laundry drains storage tanks of the TEU [LWTS]. Laundry drains are lower in radioactive contamination but high in suspended solids, fibrous matter, and detergents.

Process drains are radioactive liquid waste with a low chemical content. They are usually treated by filtration and demineralisation due to the low total salinity and the high decontamination factor of demineralisation under this water condition. Following sampling and measurement, if the composition is different from that expected, the effluent can be transferred to and treated by the evaporator.

Chemical drains are radioactive liquid waste with a high chemical content. They are usually treated by filtration and evaporation because the total salinity is usually too high to be treated by demineralisation. If the characteristics of the chemical drains meet the filtration treatment and conditions, it can be treated by filtration only.

Floor drains and laundry drains have a low level of radioactive contamination and contain particles and fibres. These wastes are to be treated by filtration only. If the floor drains have a higher radioactivity, such floor drains can be transferred to and treated by the evaporator.

The TEU [LWTS] design allows the three treatment units (demineraliser, evaporator and filter) to process different waste streams simultaneously.

Treated liquid waste should undergo sampling and subsequent analysis. Two monitoring tanks are designed for receiving the treated liquid waste from the demineralisation and evaporation units in the TEU [LWTS]. After sampling and analysis, if the radioactivity and chemical properties of the liquid wastes meet the end of treatment criteria, the liquid wastes are transferred to the TER [NLWDS] system. If sampling from the monitoring tanks of TEU [LWTS] does not meet the discharge management objectives, the liquid waste can be routed back to the chemical storage tanks or the demineraliser for retreatment. In the TER [NLWDS] system, the liquid waste is sampled and monitored again and, if compliant with the discharge management objectives and conditions, is discharged to the marine environment.

An optioneering study to demonstrate the selected treatment processes for the liquid waste are optimised has been undertaken. The combination of filtration, demineralisation and evaporation techniques to treat the different type of liquid effluents from the various systems (described above) is selected for the design of the TEU [LWTS]. The optioneering analysis and justification for the preferred techniques is detailed in *Optioneering Report of Liquid Radioactive Waste Processing Techniques,* Reference [30].

To demonstrate that the storage tanks in the liquid waste management systems have sufficient capacity and resilience to enable storage, sampling, treatment and discharge of the liquid wastes generated during normal operation of the UK HPR1000 to be performed in an optimal manner, a sizing analysis work has been undertaken. The sizing methodology is described in Sub-chapter 4 and the input, calculation and justification are described in Sub-chapter 5 of *Sizing Report of Main Equipment in Liquid Radioactive Waste Treatment System*, Reference [35].

Spent resins, concentrates and spent filter cartridges are solid waste to be generated from the treatment of radioactive liquid wastes. The waste arising and management arrangements for these solid wastes are described in Sub-chapter 4.7.4.

4.7.2.3 Secondary Circuit Effluents

The blowdown of the steam generators is processed by the Steam Generator Blowdown System (APG [SGBS]). After processing, the purified blowdown water is sent to the main turbine condenser for recycling. If it is unsuitable for re-use, the treated effluents from the APG [SGBS] are to be sent to the SEL [LWDS (CI)] for sampling, monitoring and, if appropriate, discharge.

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

The management arrangements for the spent resins and spent filter cartridges generated from the APG [SGBS] are described in Sub-chapter 4.7.4.

4.7.2.4 Non-aqueous Liquid Waste

Non-aqueous liquid radioactive waste, such as contaminated oil and organic solvent, is generated during normal operations, for example from:

a) Maintenance of pumps;

b) Maintenance of hydraulic equipment; and,

c) Decontamination of Reactor Pressure Vessel (RPV) bolts.

The non-aqueous liquid radioactive waste is collected separately at source. Unnecessary cross-contamination is thereby avoided. The annual generation and radioactivity of this waste type is very low.

Oils and organic solvents are prohibited from being discharged to the environment. The management proposal for them is similar to other solid wastes, therefore, the detailed waste information and proposed treatment is presented in Sub-chapter 4.7.4, together with the other radioactive solid wastes.

4.7.2.5 Sampling, Monitoring and Measurement

a) In-process Sampling and Monitoring

In-process sampling and monitoring arrangements are provided for the liquid radioactive waste systems to enable deciding whether the liquid is suitable for reuse or is to be treated as liquid waste, to select the appropriate treatment technology for the liquid wastes and to decide whether the treated liquid wastes meet the discharge management objective or require retreatment. The in-process sampling and monitoring points in the liquid radioactive waste systems are presented separately in F-5.5-5, F-5.5-6, F-5.5-7 and F-5.5-8 of PCER Chapter 5. The arrangements are summarised in this sub-chapter and detailed in PCER Chapter 5, Sub-chapters 5.5.3 and 5.5.6.

The sampling arrangements in the TEP [CSTS] comprise:

1) Before being sent to the REA [RBWMS] for reuse, the content of the TEP [CSTS] coolant storage tanks is subject to sampling and analysis through periodic sampling using the Nuclear Sampling System (REN [NSS]) sampling pipeline to determine whether it is of a suitable quality for recycling or if it needs to be transferred to TER [NLWDS];

2) The effluent downstream of the main process and treatment equipment such as the demineraliser and the coolant degasification column is sampled periodically by grab sampling through the REN [NSS] sampling pipeline to evaluate the performance of the main process and treatment equipment;

3) Before transfer of the distillates after the degasification unit, the total activity of gamma and tritium are measured by grab sampling through the REN [NSS] sampling pipeline. The condensate water is sent to REA [RBWMS] for re-use in the primary circuit. If it is unsuitable for re-use in the primary circuit, it is routed to the TER [NLWDS] for sampling, monitoring and, if appropriate, discharge.

4) Downstream of the flushing gas outlet of the coolant storage tanks, a local connection to the REN [NSS] (gaseous samples) is provided. If required, sampling of the flushing gas can be performed after having passed the storage part of TEP [CSTS].

The sampling arrangements in the TEU [LWTS] comprise:

1) Before processing, the content in the storage tanks (process drains tanks, chemical drains tanks, floor drains tanks and laundry drains tanks) is recirculated and subject to sampling for analysis to determine which treatment process is to be applied.

2) The effluent downstream of the demineralisers, recirculation pump and distillate pump is sampled to evaluate the performance of the demineralisation unit and evaporation unit and whether the effluent meets the end of treatment objectives.

3) The radioactivity and chemical properties of the effluent stream that are treated by demineralisation and evaporation are analysed by sampling in the monitoring tanks before being transferred to the TER [NLWDS]. The treated liquid waste is transferred to the TER [NLWDS] for discharge when its radioactivity and chemical properties meet the end of treatment objectives; otherwise, the liquid wastes are re-treated.

b) Discharge Monitoring

The liquid wastes are discharged to the environment via the TER [NLWDS] and the SEL [LWDS (CI)]. There are three types of sampling and monitoring arrangements implemented in these two systems, including grab sampling, continuous monitoring and continuous sampling via a flow proportional sampler.

The grab sampling located on the tanks recirculation line, downstream of the discharge pumps is used to determine whether the liquid wastes in the storage tanks can be discharged. If the result of the analysis reports a higher value than the discharge objectives, the liquid wastes are sent back to the TEU [LWTS] for retreatment.

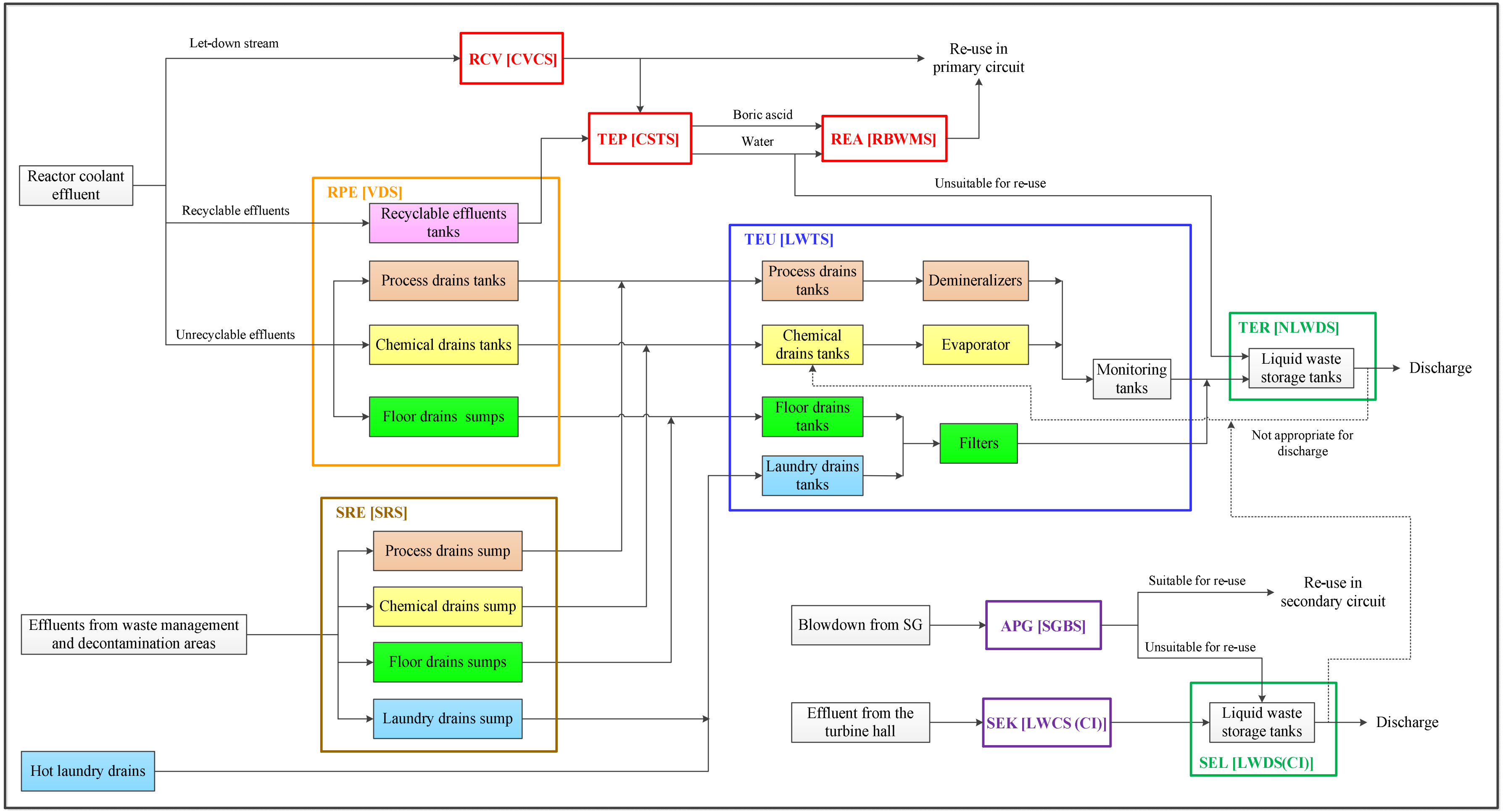
Two final online continuous monitors are arranged on the discharge lines of the TER [NLWDS] and the SEL [LWDS (CI)] to measure the total gamma activity of the liquid wastes. If the measured radioactivity exceeds the pre-set threshold (to be defined at site licensing phase), or a failure of equipment is detected, an alarm is triggered and the isolation valve is closed automatically to stop the discharge.

Flow proportional samplers are arranged on the discharge lines of the TER [NLWDS] and the SEL [LWDS (CI)] to collect a representative sample of the liquid waste that is being discharged.

4.7.2.6 Demonstration of BAT

The BAT demonstration of the liquid radioactive waste management system is detailed in PCER Chapter 3, Sub-chapter 3.5.2.5 Argument 4.1.EC03.2-A5: Minimise the Radioactivity of Aqueous Discharges by Optimising the Liquid Radioactive Waste Management System.

The demonstration of BAT for the sampling and monitoring approach is also conducted through the Claim-Argument-Evidence approach as described in PCER Chapter 3 and detailed in PCER Chapter 5, Sub-chapter 5.7.



F-4.7-2 Liquid Radioactive Waste Effluent Streams

4.7.3 Radioactive Gaseous Waste Management

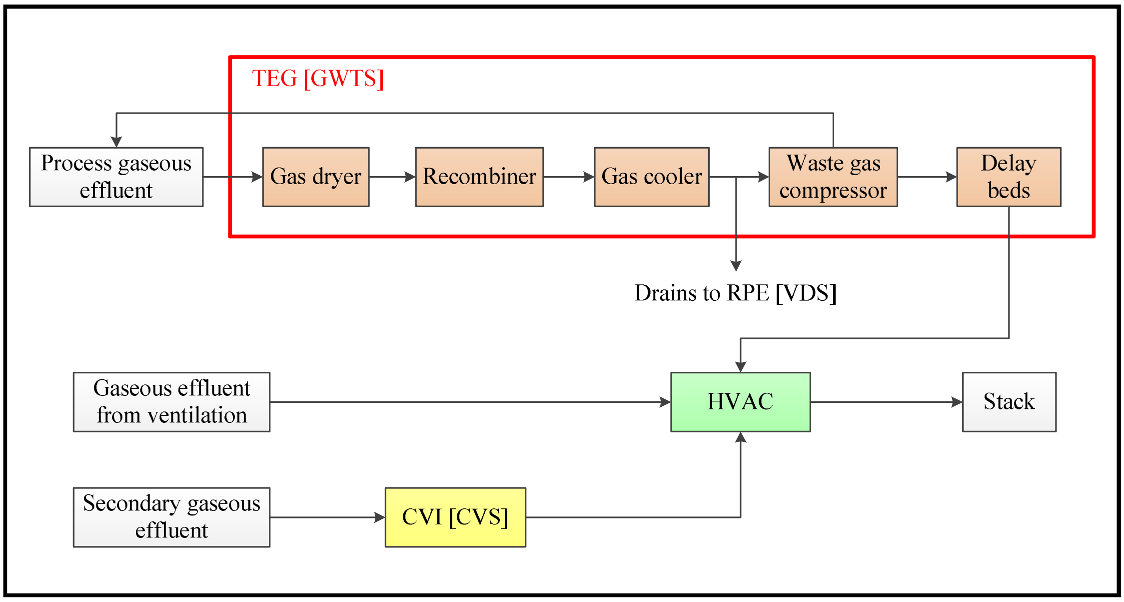
The gaseous radioactive waste is divided into three categories:

a) Process gaseous effluent;

b) Gaseous effluent from ventilation; and,

c) Secondary gaseous effluent.

The gases are processed, monitored and discharged to the environment as illustrated in F-4.7-3. The process gaseous effluent is collected and treated by the TEG [GWTS] which is described in PCSR Chapter 23, Sub-chapter 23.7, Reference [4]. The gaseous effluent from the ventilation systems is collected and treated by different systems which are described in PCSR Chapter 10, Sub-chapter 10.6, Reference [34]. The secondary gaseous effluent is collected by the Condensate Vacuum System (CVI [CVS]) (not in the GDA scope). The estimated discharges and proposed limits for gaseous effluent are presented in PCER Chapter 6, Sub-chapter 6.6.



F-4.7-3 Gaseous Radioactive Waste Effluent Streams

4.7.3.1 Process Gaseous Effluent

Gaseous radioactive wastes are unavoidably generated during the operation of the nuclear power plant. The radionuclides in the reactor coolant which are generated from fission reactions and activation reactions are transported with the reactor coolant and released into the gas phase of vessels and tanks of the primary circuit and auxiliary systems when the pressure is reduced or during fluid exchange.

These process gaseous effluents include radionuclides such as radioactive noble gases, iodine isotopes, carbon-14 and tritium. The process gaseous effluents are collected, treated (mainly noble gases), and discharged by the TEG [GWTS].

The TEG [GWTS] system has the following operational functions:

a) To flush the vessels and tanks containing reactor coolant with nitrogen to avoid hydrogen accumulation in the gas space. Through the use of recombiners, the hydrogen/oxygen concentration in the TEG [GWTS] system and its flushing components are kept under the flammability limits;

b) To prevent radioactive gases escaping from the connected components into the building atmosphere by maintaining the flushing section under negative pressure;

c) To collect and treat the excess gas arising from the connected components during the plant start-up, shut down or component flushing; and,

d) To delay the radioactive noble gases in the gas stream prior to discharging them to the environment.

Based on the TEG [GWTS] operational functions, the following vessels and tanks are connected to the flushing section of the TEG [GWTS]:

a) Pressuriser relief tank of the Reactor Coolant System (RCP [RCS]);

b) Volume control tank of the RCV [CVCS];

c) Boric acid storage tanks of the REA [RBWMS];

d) Coolant storage tanks of the TEP [CSTS];

e) Boric acid column of the TEP [CSTS];

f) Degasifier column of the TEP [CSTS];

g) Condensate collecting tank of the TEP [CSTS];

h) Primary effluent drain tanks of the RPE [VDS] located in the BRX, BSX, BFX and BNX; and,

i) Sample backfeed vessel of the REN [NSS].

The TEG [GWTS] connects the gas space of the vessels and tanks together and flushes them with nitrogen to avoid the accumulation of hydrogen. The waste gas compressor keeps the flushing gas recirculating to draw out the hydrogen and radioactive gases released from the connected equipment into the TEG [GWTS]. The recombiner is used to recombine the hydrogen with oxygen to form water. The flushing gas can be reused in the closed circuit after recombination.

The gas space volume is almost constant during the steady-state operation of the reactor. Therefore, the radioactive gases undergo decay in the flushing section and only a small quantity of radioactive gas is discharged to the environment through the delay beds and the Nuclear Auxiliary Building Ventilation System (DWN [NABVS]).

During the reactor shutdown and start-up transients, there is excess gas released to the TEG [GWTS] because of the flushing of the gas space of the reactor pressure vessel or the thermal expansion of the reactor coolant. In this circumstance, the volume reduction of the gas space of the connected equipment results in the release of gas to the TEG [GWTS], and the excess gases are routed to a series of activated charcoal delay beds. The activated charcoal delay beds provide adequate delay time for the concerned radionuclides (noble gases), which results in a significant reduction in the radioactivity of the gases. When large amount of excess gas released to TEG [GWTS], it is switched to the surge gas operation mode automatically. Two redundant reducing stations maintain a constant pressure in the delay unit and two different values are pre-set separately for steady-state operation mode and surge gas operation mode. During surge gas operation mode, the pre-set value is higher than that of steady-state operation mode. This enables to operate the activated charcoal delay beds at an increased pressure when large gas volume and flowrate is produced to increase their storage and treatment capacity.

An optioneering study has been undertaken to demonstrate that the activated charcoal delay bed technology represents BAT. This is detailed in *Optioneering Report of Gaseous Radioactive Waste Processing Technique*, Reference [31].

To demonstrate that the treatment capacity of the TEG [GWTS] is sufficient to collect and efficiently treat the process effluent generated by the UK HPR1000, an assessment of the sizing of the activated charcoal delay beds has been undertaken. The results show that three vertical pressure vessels filled with 7.2 tonnes of activated charcoal (2.4 tonnes each) connected in series, can satisfy the treatment requirement in different operating conditions and for the whole plant lifetime (i.e. 60 years). Details are provided in *Sizing Report of the Activated Charcoal Delay Beds*, Reference [36].

Downstream of the TEG [GWTS], the gaseous waste is routed to the DWN [NABVS], where it is filtered using High Efficiency Particulate Air (HEPA) filters and if needed, passed through iodine traps. It is then monitored and discharged to the environment via the main discharge stack.

Some of the radionuclides in the process gaseous effluent such as carbon-14 and tritium do not undergo treatment by the TEG [GWTS]. For the gaseous carbon-14 (half-life is 5730 years), the activated charcoal delay beds have no abatement function and this radionuclide is discharged directly the environment via the DWN [NABVS] after sampling. This is considered BAT as there is no efficient treatment for gaseous carbon-14 in Pressurised Water Reactors (PWRs) (PCER Chapter 3, Sub-chapter 3.5.2.7.1 Evidence 4.1.EC03.2-A7-E1) and the total Dose Per Unit Release (DPUR) for carbon-14 being discharged into the receiving water environment in liquid phase is higher than DPUR for carbon-14 being discharged into the atmosphere in gaseous phase (PCER Chapter 3, Sub-chapter 3.5.3.1.1 Evidence 4.1.EC03.3-A1-E1).

The DPUR for tritium being discharged into the receiving water environment in liquid phase is lower than the DPUR for tritium being discharged into the atmosphere in gaseous phase (PCER Chapter 3, Sub-chapter 3.5.3.1.1 Evidence 4.1.EC03.3-A1-E1). The gaseous tritium in the TEG [GWTS] may be in the form of water vapour (HTO) and/or hydrogen (HT). The hydrogen released from the reactor coolant recombines with oxygen to form water in the recombiner within the TEG [GWTS]. Therefore most of the gaseous tritium in the HT form can be converted to water and cooled down by the heat exchanger in the system. This part of tritium is then drained to the RPE [VDS] as liquid waste. The water vapour containing tritium (HTO form) in the flushing gas is cooled down by the heat exchangers in the TEG [GWTS] and turned into the liquid phase which is returned to the reactor coolant or drained off via the RPE [VDS]. These both reduce tritium discharge in the gaseous effluent discharged from the TEG [GWTS].

The activated charcoal in the delay beds is designed to last for 60 years without replacement. The activated charcoal is therefore to be treated as radioactive solid waste at decommissioning stage.

4.7.3.2 Gaseous Effluent from Ventilation

The ventilation systems are arranged separately according to the areas with and without contamination and the specific functions of the buildings. The main Heating, Ventilation and Air Conditioning System (HVAC) serves areas with potential contamination including the nuclear auxiliary building, fuel building (including fuel pool hall), reactor building, controlled area of safeguard building, controlled area of access building, radioactive waste treatment building and ILW Interim Storage Facility (BQZ) and Spent Fuel Interim Storage Facility (BQF). The exhaust air from these areas with the potential for radioactive contamination is filtered by the pre-filters, HEPA filters and where relevant, iodine traps within the HVAC systems.

The management arrangements for spent ventilation filter cartridges and charcoal from the iodine traps to be generated from the HVAC systems are described in Sub-chapter 4.7.4.

4.7.3.3 Secondary Gaseous Effluent

Non-condensable gases collected within the steam condenser (which will include radionuclides in the event of a steam generator leak) are removed by the CVI [CVS] and routed to the DWN [NABVS]. The gases are treated by pre-filters, HEPA filtration and if needed, iodine traps, and then monitored and sampled, and ultimately discharged to the environment via the main discharge stack.

4.7.3.4 Sampling, Monitoring and Measurement

4.7.3.4.1 TEG [GWTS]

Sampling and monitoring are carried out in order to ensure that the TEG [GWTS] is operating as expected.

The operation of the delay beds is 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 that gaseous effluent passing through the delay beds does not carry moisture ensuring optimum performance of the activated charcoal. The temperature in the delay beds room is continuously measured to ensure it is within set parameters, ensuring optimum performance of the activated charcoal. Downstream of the delay beds, the operating pressure and flowrate are also continuously measured. The operating pressure of the delay beds can be increased according to the flow rate of the incoming gases to be treated to improve its storage and treatment capacity and ensure optimum performance and decay time.

One Plant Radiation Monitoring System (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.

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

The radioactivity monitoring at the TEG [GWTS] is detailed in PCER Chapter 5, F-5.5-4 and Sub-chapter 5.5.5.3.

4.7.3.4.2 HVAC systems

The in-process sampling and monitoring of the HVAC systems is summarised in this sub-chapter and detailed in PCER Chapter 5, F-5.5-4 and Sub-chapters 5.5.5.1 and 5.5.5.2.

The monitoring of the HVAC gaseous effluents discharged from the buildings provides information on the airborne activity inside the buildings to facilitate identification of leaks of radioactive matter. If the gaseous activity concentration reaches the alarm threshold, a sound-light alarm is triggered locally. The analog information and all alarms are sent to and displayed in the main control room. At the same time, the HVAC system is switched to the iodine filtration train. Plant operators will investigate the rooms where the radioactive matter leakage may be and take appropriate action. The measurement data is displayed and recorded in the main control room.

4.7.3.4.3 CVI [CVS]

The in-process sampling and monitoring of the CVI [CVS] is summarised in this sub-chapter and described in PCER Chapter 5, Sub-chapter 5.5.5.

Monitoring of the integrity of the steam generator tube is undertaken to detect any high radioactivity gas into the secondary circuit. The main steam is condensed in the condenser and the radioactivity of non-condensable gases (in the CVI [CVS]) is monitored. If the radioactivity of the non-condensable gases reaches the set alarm threshold, a sound-light alarm is triggered locally. Plant operators will check and take appropriate action. The measurement data is displayed and recorded in the main control room.

4.7.3.4.4 Final Sampling and Monitoring in the Discharge Stack

The final sampling and monitoring in the discharge stack is summarised in this sub-chapter and detailed in PCER Chapter 5, Sub-chapter 5.5.2.

The sampling and monitoring system for the gaseous discharges via the discharge stack is duplicated as train A and train B. Each train samples or measures the radionuclides or groups of radionuclides, including aerosol, iodine, noble gases, tritium, carbon-14. The aerosol, iodine, noble gases radioactivity levels are monitored continuously. At the same time, aerosol, iodine, tritium and carbon-14 in the gaseous discharges are sampled continuously, and the noble gases are sampled by grab sampling. All the samples are sent to the laboratory for accurate measurement.

The monitors and samplers are located in a room where the dose rate is low and is easy to access.

4.7.3.5 Demonstration of BAT

Demonstration that the design of the TEG [GWTS] represents BAT is detailed in PCER Chapter 3, Sub-chapter 3.5.2.4 Argument 4.1.EC03.2-A4: Minimise the Radioactivity of Gaseous Radioactive Waste by Installing and Optimising the Gaseous Waste Treatment System (TEG [GWTS]).

The BAT demonstration of the HVAC systems is detailed in PCER Chapter 3, Sub-chapter 3.5.2.3 Argument 4.1.EC03.2-A3: Minimise the Radioactivity of Gaseous Radioactive Waste by Optimising the HVAC system.

The demonstration of BAT for the sampling and monitoring approach is conducted through the Claim-Argument-Evidence approach as described in PCER Chapter 3 and is detailed in PCER Chapter 5, Sub-chapter 5.7.

4.7.4 Radioactive Solid Waste and Non-Aqueous Liquid Waste Management

This sub-chapter presents the waste management arrangements for the radioactive solid waste and non-aqueous liquid waste which are anticipated to be generated during the operation of the UK HPR1000.

4.7.4.1 Waste Arising

Radioactive wastes are classified in terms of the activity, types of radionuclides they contain and their heat generation and are categorised as HLW, ILW, LLW or VLLW, Reference [22].

4.7.4.1.1 Waste Streams

The design reference of the UK HPR1000 is HPR1000 (FCG3) which is based on the OPEX feedbacks and improvements of the design of the Chinese Pressurised Reactor (CPR1000).

The waste streams to be generated by the UK HPR1000 during normal operation are identified based on the following two steps:

a) Theoretically assessing where materials can potentially become radioactive waste based on their service conditions and properties. This identifies the preliminary waste streams; and,

b) Reviewing the waste arising from the OPEX from decades of Chinese PWRs operating and international PWRs. This has improved understanding of the waste streams.

Each waste stream that is anticipated to be generated by the UK HPR1000 during normal operation is categorised based on the OPEX data of the CPR1000 and international similar PWRs.

The identified waste streams and their categories are listed in T-4.7-1. The waste streams are grouped into 12 types, with one spent fuel stream. The category of each waste stream presented in T-4.7-1 is based on the source term analysis undertaken for the UK HPR1000. The source term analysis and justification for solid and non-aqueous liquid waste (except NFCCs and spent fuel) are developed and presented in *Solid Radioactive Waste Management Technical User Source Term Report*, Reference [37]. The source term analysis and justification for the NFCCs are developed and presented in *Activated Structures Source Term Supporting Report* and *Waste Inventory for Operational Solid Radioactive Waste*, Reference [38] and [39]. The source term analysis and justification for the spent fuel are developed and presented in *Spent Fuel Assembly Source Term Supporting Report*, Reference [40].

The waste datasheet of each waste stream presented in T-4.7-1 (except spent fuel) is detailed in Sub-chapter 4.7.4.1.2. The datasheet of the spent fuel is detailed in

T-4.7-16.

T-4.7-1 Solid and Non-Aqueous Liquid Waste Generated during Operation

No.	Waste Stream	Description	Category
1	Spent Resins	Arising from the demineralisers from the TEU [LWTS], TEP [CSTS], Fuel Pool Cooling and Treatment System (PTR [FPCTS]), RCV [CVCS], and the demineralisers from the APG [SGBS] after steam generator tubes rupture.	ILW
2	Low Activity Spent Resins	Arising from the demineralisers from the APG [SGBS] under normal operation condition.	LLW
3	Concentrates	Arising from the TEU [LWTS] evaporator.	ILW/LLW
4	Spent Filter Cartridges	Arising from filter changes in the water treatment systems, including the RCV [CVCS], TEP [CSTS], PTR [FPCTS], TEU [LWTS], APG [SGBS] and the RPE [VDS].	ILW/LLW
5	Dry Active Wastes	Contaminated personal protection equipment, monitoring swabs, plastic, clothing, contaminated tools, charcoal waste from iodine absorber, etc.	ILW/LLW
6	Sludges	Arising from the sumps and tanks associated with the water auxiliary circuits (e.g. the RPE [VDS], TEU [LWTS]).	ILW/LLW
7	Oil	Arising during normal operation, such as maintenance of pumps and hydraulic equipment.	LLW/VLLW
8	Organic Solvent	Arising during normal operation, such as the decontamination of RPV bolts and other components.	LLW/VLLW
9	Ventilation Filter Cartridges	Arising from the ventilation systems located in the nuclear auxiliary building,	LLW

No.	Waste Stream	Description	Category
		fuel building, safeguards buildings, reactor building, access building and radioactive waste management facilities.	
10	ICIAs	Arising from equipment used for measuring the neutron flux, temperature, water level in the reactor core.	HLW/ILW[2]
11	Rod Cluster Control Assemblies (RCCAs) Stationary Core Component Assemblies (SCCAs)	Activated in the reactor core.	HLW
12	Spent Fuel	Spent fuel assemblies.	HLW

4.7.4.1.2 Information for Each Waste Stream

The expected annual arising for each waste stream shown in this sub-chapter is estimated using OPEX from decades of operating Chinese PWRs and is based on a systematic analysis of the design differences between the UK HPR1000 and other PWR designs. This is detailed in *Waste Inventory for Operational Solid Radioactive Waste*, Reference [39].

4.7.4.1.2.1 Spent Resins

Ion exchange resins are used within demineralisers in the RCV [CVCS], TEP [CSTS], PTR [FPCTS] and the TEU [LWTS] to abate the soluble radioactivity from various circuits, as described in PCSR Chapter 10, Sub-chapters 10.4.3, 10.4.5 and 10.4.7, Reference [34] and Chapter 23, Sub-chapter 23.6.3, Reference [4]. The ion exchange resins are periodically changed according to the efficiency and the pressure differential of each demineraliser.

The nature and quantity of the spent resins to be generated from the UK HPR1000 are shown in T-4.7-2.

[2] The upper part of ICIAs is categorised as LLW after being cut.

T-4.7-2 Waste Stream Datasheet for Spent Resins

Parameter	Description
Waste Origin	Arising from the demineralisers of the RCV [CVCS], TEP [CSTS], PTR [FPCTS], TEU [LWTS] and the APG [SGBS] after steam generator tubes rupture.
Waste Chemical and Physical Description	Resins are small spheres with cross linked polystyrene matrix. The diameters of the resins are from 0.42 mm to 1.2 mm. The main chemicals anticipated to be presented in spent resins are organic ion exchange material and BO_3^{3-}, Li^{+}, Al^{3+}, etc.
Nature of Radioactive Material	Contaminated with activated corrosion products and fission products from liquid in the primary circuit and auxiliary systems.
Annual Arising for One UK HPR1000 Unit	1.9 m^3
Total Arising (60 years) for One UK HPR1000 Unit	114 m^3
Waste Classification at Time of Generation	ILW
Main Radionuclides [3] and Radioactivity	Main Radionuclides: Cs-137, Cs-134, Co-60, Co-58, Ni-63, Fe-59 and Ag-110m; Total β/γ Average Value (GBq/t): 5.80E+02; Total β/γ Maximum Value (GBq/t): 6.00E+03.
Hazardous Substances or Non-hazardous Pollutants	Boron.

[3] The main radionuclides mean those radionuclides which contribute to the total radioactivity are higher than 10% (include the average and maximum values). The note is also applicable for the waste stream datasheets presented in Sub-chapter 4.7.4.1.2 (from T-4.7-2 to T-4.7-12).

4.7.4.1.2.2 Low Activity Spent Resins

Ion exchange resins are used within demineralisers in the APG [SGBS] to purify the blowdown of the steam generators as described in PCSR Chapter 11, Sub-chapter 11.3.5, Reference [41]. The ion exchange resins are periodically changed to ensure efficient purification.

Under normal conditions, these spent resins are slightly contaminated and are categorised as LLW. Under steam generator tubes rupture conditions, the spent resins from the demineralisers of the APG [SGBS] are contaminated, and they are to be managed according to the same strategy as the spent resins described in Sub-chapter 4.7.4.1.2.1, which is categorised as ILW.

The nature and quantity of the low activity spent resins to be generated from the UK HPR1000 are shown in T-4.7-3.

T-4.7-3 Waste Stream Datasheet for Low Activity Spent Resins

Parameter	Description
Waste Arising	Arising from the two parallel demineralisers in the APG [SGBS] under the normal conditions.
Waste Chemical and Physical Description	Resins are small spheres with cross linked polystyrene matrix. The diameters of the resin spheres are from 0.42 mm to 1.2 mm. The main chemicals anticipated to be presented in spent resins are organic ion exchange material and Al^{3+}, etc.
Nature of Radioactive Material	Contamination with activated corrosion products and fission products.
Annual Arising for One UK HPR1000 Unit	9.7 m^3
Total Arising (60 years) for One UK HPR1000 Unit	582 m^3
Waste Classification at Time of Generation	LLW
Main Radionuclides and	Main Radionuclides: Ag-110m, Sb-124, Sb-125 and

Parameter	Description
Radioactivity	Fe-59; Total β/γ Average Value (GBq/t): 2.35E-02; Total β/γ Maximum Value (GBq/t): 5.70E-02.
Hazardous Substances or Non-hazardous Pollutants	None.

4.7.4.1.2.3 Concentrates

Concentrates arise from the TEU [LWTS] evaporator which is used to process the chemical drains, as described in PCSR Chapter 23, Sub-chapter 23.6.2, Reference [4].

The nature and quantity of the concentrates to be generated from the UK HPR1000 are shown in T-4.7-4.

T-4.7-4 Waste Stream Datasheet for Concentrates

Parameter	Description
Waste Origin	Arising from the evaporator of the TEU [LWTS].
Waste Chemical and Physical Description	The density of concentrates is less than 1.2 kg/L. The main chemicals anticipated to be presented in concentrates are Fe, Ni, Ca, Mg, B, Si, etc. The maximal boron concentration is 40000 ppm.
Nature of Radioactive Material	Concentrates are contaminated with activated corrosion products and fission products.
Annual Arising for One UK HPR1000 Unit	0.73 m^3 (ILW)/1.47 m^3 (LLW)
Total Arising (60 years) for One UK HPR1000 Unit	43.8 m^3 (ILW)/88.2 m^3 (LLW)
Waste Classification at Time of Generation	ILW/LLW
Main Radionuclides and	Main Radionuclides: Co-60, Ag-110m, Ni-63 and

Parameter	Description
Radioactivity	Fe-55; Total β/γ Average Value (GBq/t) of ILW Concentrates: 2.28E+01; Total β/γ Maximum Value (GBq/t) of ILW Concentrates: 3.81E+01; Total β/γ Average Value (GBq/t) of LLW Concentrates: 4.37E+00; Total β/γ Maximum Value (GBq/t) of LLW Concentrates: 1.20E+01.
Hazardous Substances or Non-hazardous Pollutants	Boron and Nickel.

4.7.4.1.2.4 Spent Filter Cartridges

Filters are installed in the RCV [CVCS], TEP [CSTS], PTR [FPCTS], APG [SGBS], TEU [LWTS], and the RPE [VDS] to abate the (radioactive) particulates from various circuits as described in PCSR Chapter 10, Sub-chapters 10.4.3, 10.4.5 and 10.4.7, Reference [34], PCSR Chapter 11, Sub-chapter 11.3.5, Reference [41] and Chapter 23, Sub-chapters 23.6.2 and 23.6.3, Reference [4]. The filter cartridges are periodically changed according to the pressure drop between inlet and outlet or the dose rate.

The nature and quantity of the spent filter cartridges to be generated from the UK HPR1000 are shown in T-4.7-5.

T-4.7-5 Waste Stream Datasheet for Spent Filter Cartridges

Parameter	Description
Waste Origin	Arising from the RCV [CVCS], PTR [FPCTS], TEP [CSTS], TEU [LWTS], APG [SGBS] and the RPE [VDS].
Waste Chemical and Physical Description	Spent filter cartridges are made of stainless supports with glass fibres and some organic materials. The main chemicals anticipated to be presented in spent filter cartridges are stainless steel constituents, fiber glass, B, Ni, Fe, Mg, Si, etc.

Parameter	Description
Nature of Radioactive Material	Particulate activated corrosion products filtered from reactor coolant and water of auxiliary circuits.
Annual Arising for One UK HPR1000 Unit	1.14 m^3 (ILW)/0.65 m^3 (LLW)
Total Arising (60 years) for One UK HPR1000 Unit	68.4 m^3 (ILW)/39 m^3 (LLW)
Waste Classification at Time of Generation	ILW/LLW
Main Radionuclides and Radioactivity	Main Radionuclides: Co-58, Ag-110m, Cr-51 and Fe-55; Total β/γ Average Value (GBq) of LLW spent filter cartridges: 6.18E-03; Total β/γ Maximum Value (GBq) of LLW spent filter cartridges: 1.32E-01; Total β/γ Average Value (GBq) of ILW spent filter cartridges: 9.14E+02; Total β/γ Maximum Value (GBq) of ILW spent filter cartridges: 4.34E+03.
Hazardous Substances or Non-hazardous Pollutants	Boron and Nickel.

4.7.4.1.2.5 Dry Active Wastes

Dry activity wastes are generated through routine and maintenance operations of the plant in the different controlled areas, which consist of contaminated personal protection equipment, charcoal waste from the iodine absorbers of the HVAC systems, monitoring swabs, plastic, contaminated tools and small items of metallic material.

The nature and quantity of the dry active wastes to be generated from the UK HPR1000 are shown in T-4.7-6.

T-4.7-6 Waste Stream Datasheet for Dry Active Wastes

Parameter		Description
Waste Origin		Dry active wastes are generated during operation and maintenance in the nuclear island and other buildings relevant to radioactive waste management. Dry active wastes include low level contaminated combustible wastes (e.g. paper, plastic, cloth, charcoal waste from iodine absorbers, etc.), metal maintenance wastes, un-combustible/ compactible waste (e.g. cable, concrete, etc.) and un-combustible/un-compactible wastes (e.g. glass and etc.).
Waste Chemical and Physical Description		The dry active wastes mainly include metals, concrete, glass, soft organics, plastic, wood and charcoal. The chemicals susceptible to be found in dry active wastes are: stainless steel, plastics, cellulose, etc.
Nature of Radioactive Material		Contamination with fission products and activation products.
Annual Arising for One UK HPR1000 Unit	Combustible Waste	17.94 m^3 (ILW)/126.81 m^3 (LLW)
	Metal Maintenance Waste	1.56 m^3 (ILW)/10.44 m^3 (LLW)
	Un-combustible/ Compactable Waste	2.21 m^3 (ILW)/14.79 m^3 (LLW)
	Un-combustible/ Un-compactable Waste	0.65 m^3 (ILW)/4.35 m^3 (LLW)
Total Arising (60 years) for One UK	Combustible Waste	1076.4 m^3 (ILW)/7608.6 m^3 (LLW)
	Metal Maintenance	93.6 m^3 (ILW)/626.4 m^3 (LLW)

Parameter		Description
HPR1000 Unit	Waste	
	Un-combustible/ Compactable Waste	132.6 m^3 (ILW)/887.4 m^3 (LLW)
	Un-combustible/ Un-compactable Waste	39 m^3 (ILW)/261 m^3 (LLW)
Waste Classification at Time of Generation	Combustible Waste	ILW/LLW
	Metal Maintenance Waste	ILW/LLW
	Un-combustible/ Compactable Waste	ILW/LLW
	Un-combustible/ Un-compactable Waste	ILW/LLW
Main Radionuclides and Radioactivity		Main Radionuclides: Co-60, Co-58. Nb-95 and Fe-55; Total β/γ Average Value (GBq/t) of LLW DAW: 2.77E+00; Total β/γ Maximum Value (GBq/t) of LLW DAW: 1.20E+01; Total β/γ Average Value (GBq/t) of ILW DAW: 1.62E+01; Total β/γ Maximum Value (GBq/t) of ILW DAW: 2.87E+01.
Hazardous Substances or Non-hazardous Pollutants		None.

4.7.4.1.2.6 Sludge

Sludge is generated from the sumps and tanks of auxiliary circuits (e.g. RPE [VDS] and TEU [LWTS]). These sumps and tanks are periodically cleaned out and the accumulated sludge (if any) is removed for treatment as waste.

The nature and quantity of the sludge to be generated from the UK HPR1000 are shown in T-4.7-7.

T-4.7-7 Waste Stream Datasheet for Sludge

Parameter	Description
Waste Arising	Arising from the sumps and tanks of auxiliary circuits (e.g. RPE [VDS] and TEU [LWTS]).
Waste Chemical and Physical Description	The wet density of sludge is about 1.4 kg/L. The main chemicals anticipated to be presented in sludge are Fe, Ni, Ca, Mg, B, Si, etc.
Nature of Radioactive Material	Contamination with activated corrosion products and fission products.
Annual Arising for One UK HPR1000 Unit	0.05 m^3 (ILW)/0.05 m^3 (LLW)
Total Arising (60 years) for One UK HPR1000 Unit	3 m^3 (ILW)/3 m^3 (LLW)
Waste Classification at Time of Generation	ILW/LLW
Main Radionuclides and Radioactivity	Main Radionuclides: Co-60, Ni-63, Fe-55 and Ag-110m (this nuclide only refer to ILW); Total β/γ Average Value (GBq/t) of ILW sludges: 5.96E+01; Total β/γ Maximum Value (GBq/t) of ILW sludges: 8.07E+01; Total β/γ Average Value (GBq/t) of LLW sludges: 4.18E+00; Total β/γ Maximum Value (GBq/t) of LLW sludges: 1.20E+01.

Parameter	Description
Hazardous Substances or Non-hazardous Pollutants	Boron and Nickel.

4.7.4.1.2.7 Oil

Oil is generated from the maintenance of pumps and hydraulic equipment during normal operation.

The nature and quantity of the waste oil to be generated from the UK HPR1000 are shown in T-4.7-8.

T-4.7-8 Waste Stream Datasheet for Oil

Parameter	Description
Waste Arising	Arising during normal operation, notably from maintenance of pumps and hydraulic equipment.
Waste Chemical and Physical Description	Lubricating oil.
Nature of Radioactive Material	Contamination with activated corrosion products and fission products.
Annual Arising for One UK HPR1000 Unit	~0.13[4] m^3
Total Arising (60 years) for One UK HPR1000 Unit	7.5 m^3
Waste Classification at Time of Generation	LLW/VLLW
Main Radionuclides and Radioactivity	Main Radionuclides: Co-60, Co-58, Nb-95, Ni-63 and Fe-55; Total β/γ Average Value (GBq/t): 2.12E-04; Total β/γ Maximum Value (GBq/t): 1.20E+01.

[4] The actual value is 0.125 which is from the report of *Waste Inventory for Operational Solid Radioactive Waste*, Reference [39]. All the data presented in this report should keep two decimal places at most. The note is also applicable for the remaining sections and tables.

Parameter	Description
Hazardous Substances or Non-hazardous Pollutants	None.

4.7.4.1.2.8 Organic Solvent

Organic solvents are generated from the decontamination of RPV bolts and other components during normal operation.

The nature and quantity of the waste solvent to be generated from the UK HPR1000 are shown in T-4.7-9.

T-4.7-9 Waste Stream Datasheet for Organic Solvent

Parameter	Description
Waste Arising	Arising during normal operation, notably from the decontamination of RPV bolts and other components.
Waste Chemical and Physical Description	The main commonly used organic solvents are citric acid, etc. The chemical to be used is an operator dependent choice and will be determined at site specific licensing phase.
Nature of Radioactive Material	Contamination with activated corrosion products and fission products.
Annual Arising for One UK HPR1000 Unit	0.2 m^3
Total Arising (60 years) for One UK HPR1000 Unit	12 m^3
Waste Classification at Time of Generation	LLW/VLLW
Main Radionuclides and Radioactivity	Main Radionuclides: Co-60, Co-58, Nb-95 and Fe-55; Total β/γ Average Value (GBq/t): 1.38E-04;

Parameter	Description
	Total β/γ Maximum Value (GBq/t): 6.21E+00.
Hazardous Substances or Non-hazardous Pollutants	Depends on the chemical used for decontamination, the future operator should select decontamination chemical with due consideration to avoiding use of hazardous substances or non-hazardous pollutant.[5]

4.7.4.1.2.9 Ventilation Filter Cartridges

Ventilation filter cartridges are generated from the ventilation systems located in the BRX, BSX, BFX, BNX, BPX, BWX and BQZ. The ventilation filter cartridges include pre-treatment filters and HEPA filters.

The nature and quantity of the ventilation filter cartridges to be generated from the UK HPR1000 are shown in T-4.7-10.

T-4.7-10 Waste Stream Datasheet for Ventilation Filter Cartridges

Parameter	Description
Waste Origin	Arising from the HVAC systems of the nuclear island buildings and radioactive waste management facilities.
Waste Chemical and Physical Description	Ventilation filter cartridges are comprised of stainless supports with glass fibres.
Nature of Radioactive Material	Low levels of contamination.
Annual Arising for One UK HPR1000 Unit	29.7 m^3
Total Arising (60 years) for One UK HPR1000 Unit	1782 m^3
Waste Classification at Time of Generation	LLW

[5] In China carbon tetrachloride is a solvent that is used for chemical decontamination. However, this will not be used within the UK due to it was banned under the Montreal Protocol in 1987. The future operator of UK HPR1000 will define his own strategy for chemical decontamination based on contamination status of UK HPR1000 SSC, available chemicals and waste management strategy/available disposal routes, which are all highly site specific.

Parameter	Description
Main Radionuclides and Radioactivity	Main Radionuclides: Co-60, Ni-63 and Fe-55; Total β/γ Average Value (GBq/t): 1.62E-02; Total β/γ Maximum Value (GBq/t): 3.09E-02.
Hazardous Substances or Non-hazardous Pollutants	None.

4.7.4.1.2.10 ICIAs

ICIAs are generated from the equipment used for monitoring the status of the reactor core. ICIAs include neutron flux, temperature and RPV water level detectors. Approximately 46 ICIAs are expected to be removed from the core as waste during their design lifetime, comprising 42 assemblies used for neutron and temperature measurement (ICIAs (i&ii)) and 4 assemblies used for RPV water level measurement (ICIAs (iii)). The nature and quantity of the ICIAs to be generated from the UK HPR1000 are shown in T-4.7-11.

T-4.7-11 Waste Stream Datasheet for ICIAs

Parameter	Description
Waste Origin	Arising from the reactor core, and used for measuring the water level, temperature and neutron flux in the reactor core.
Waste Chemical and Physical Description	The spent ICIAs contain stainless steel, Alumina, Rhodium, Chromel, Alumel, Copper and Ni-Cr alloy.
Nature of Radioactive Material	Activation of structural constituents of ICIAs.
Annual Arising for One UK HPR1000 Unit	~0.13 m^3 (HLW)/~0.01 m^3 (ILW)
Total Arising (60 years) for One UK HPR1000 Unit	7.84 m^3 (HLW)/0.56 m^3 (ILW)

Parameter	Description
Waste Classification at Time of Generation	HLW/ILW[6]
Main Radionuclides and Radioactivity	Main Radionuclides: Co-58, Cr-51, Fe-55 and Co-60 (this radionuclide only refer to HLW); Total β/γ Realistic Values (GBq/t) of HLW ICIA (i&ii): 2.96E+07; Total β/γ Design Values (GBq/t) of HLW ICIA (i&ii): 4.14E+07; Total β/γ Realistic Values (GBq/t) of ILW ICIA (iii): 4.00E+03; Total β/γ Design Values (GBq/t) of ILW ICIA (iii): 5.66E+03.
Hazardous Substances or Non-hazardous Pollutants	Nickel.

4.7.4.1.2.11 RCCAs and SCCAs

RCCAs (e.g. black RCCA and grey RCCA) and SCCAs (e.g. Thimble Plug Assemblies (TPAs), Primary Neutron Source Assemblies (PNSAs) and Secondary Neutron Source Assemblies (SNSAs)) present in the reactor core will be replaced during the refuelling outages depending on their degradation status or their design lifetime.

The nature and quantity of the RCCAs and SCCAs to be generated from the UK HPR1000 are shown in T-4.7-12.

T-4.7-12 Waste Stream Datasheet for RCCAs and SCCAs

Parameter	Description
Waste Origin	Arising from reactor core.
Waste Chemical and Physical Description	The material properties included in RCCAs and SCCAs are described in Reference [42] and [43].

[6] The upper part of ICIAs is categorised as LLW after being cut.

Parameter	Description
Nature of Radioactive Material	Activation of structural constituents of RCCAs/SCCAs.
Annual Arising for One UK HPR1000 Unit	Not applicable.
Total Arising (60 years) for One UK HPR1000 Unit	605 assemblies
Waste Classification at the Time of Generation	HLW
Main Radionuclides and Radioactivity of RCCAs	Black RCCAs: Main Radionuclides: Ag-109m and Cd-109; Total β/γ Realistic Value (GBq/t): 2.89E+08; Total β/γ Design Value (GBq/t): 4.16E+08. Grey RCCAs: Main Radionuclides: Ag-109m, Cd-109, Cr-51 and Fe-55; Total β/γ Realistic Value (GBq/t): 1.53E+08; Total β/γ Design Value (GBq/t): 2.18E+08.
Main Radionuclides and Radioactivity of SCCAs	TPAs: Main Radionuclides: Cr-51and Fe-55; Total β/γ Realistic Value (GBq/t): 7.73E+07; Total β/γ Design Values (GBq/t): 1.06E+08. PNSAs: Main Radionuclides: Sb-122 and Sb-124; Total β/γ Realistic Value (GBq/t): 5.40E+08; Total β/γ Design Values (GBq/t): 7.59E+08. SNSAs:

Parameter	Description
	Main Radionuclides: Sb-122 and Sb-124; Total β/γ Realistic Value (GBq/t): 8.79E+08; Total β/γ Design Values (GBq/t): 1.05E+09.
Hazardous Substances or Non-hazardous Pollutants	Nickel and Cadmium in RCCAs. Antimony in SCCAs.

4.7.4.2 Waste Characterisation and Segregation

According to the principles of radioactive waste management in the UK, the characterisation and segregation of radioactive waste at source should be used to ensure that the subsequent management is safe and effective. In order to manage the waste effectively, the sampling and measurement is necessary for appropriate and efficient waste segregation and collection, treatment/conditioning, storage and disposal. The overall strategies are described as follows:

a) At or close to the generation point: The radioactive properties of solid and non-aqueous liquid wastes at the time of waste generation should be monitored to determine the category of radioactive waste, which helps effectively segregate the waste and helps the operator to select the optimal treatment process and adequately use disposal routes.

b) Before processing: Before the waste is processed/packaged, its radiological characteristics are required to ensure that the waste is adequately packaged and the resulting waste packages comply with relevant criteria such as the waste acceptance criteria for off-site treatment or disposal facilities. For some radioactive waste streams, measurements done at or close to the generation point are to be used directly, as processing/packaging take place immediately after generation. For waste which is to be stored before being processed or packaged, the same sampling and monitoring arrangements as those at or close to the generation point may be used to reassess the radiological characteristics of the waste. The results obtained at or close to the generation point can alternatively be used and corrected as relevant to notably account for the decay during the storage.

c) After processing, before and during storage: Once the waste is packaged, the waste package is usually stored on-site before being transferred to off-site treatment or disposal facilities. The storage time for the waste packages is different for the different waste streams. The monitoring of the solid and non-aqueous liquid waste packages after processing, and before and during storage aims to:

- Confirm and record the waste packages radiological inventory at each management step;
- Confirm that the waste packages generated conform with the expectations;
- Safely transfer (i.e. with relevant overpack if needed) and store the waste package in the relevant on-site storage area;
- Check integrity of the waste packages and identify any degradation of the waste packages to manage these and fix them as soon as possible, to reduce radioactive contamination diffusion and increased doses to workers; and,
- Understand, at all time, the radioactive waste inventory stored on-site.

Surface dose rate measurement, external contamination measurement, ambient dose rate measurement, and/or gamma spectrum measurement are performed after processing/packaging, and/or before transfer to the storage area/facility, and/or at the reception in the storage area/facility and/or during storage.

d) Before transfer to retrieval/repackaging or disposal at off-site treatment/disposal facilities: Once the off-site treatment or disposal facility is available, the waste package is retrieved from its storage location and monitored before being transported to the off-site treatment facility for retrieval/repackaging or disposal. This monitoring aims to check the integrity of the waste packages (and adequately manage degraded waste packages if any), to obtain the information about the radiological properties of the waste for record purposes and to confirm the waste packages meet the requirements of transportation, off-site treatment and final disposal. The information from this monitoring, together with information from previous records is also used to fill the tracking sheet that is transmitted to the waste facility service supplier together with the waste. The monitoring undertaken includes the surface dose rate measurement, gamma spectrum measurement and/or external contamination measurement.

The design of the UK HPR1000 provides a range of facilities and equipment to allow the future operator to undertake the characterisation and segregation of solid and non-aqueous liquid waste. The radiological, physical and chemical properties of waste can be assayed through the characterisation and assessment facilities. This allows the future operator to effectively segregate waste and identify the suitable waste treatment/conditioning options and disposal routes and have an understanding of the radioactive waste inventory stored on-site at all time.

The detailed arrangements of sampling, measurement and monitoring for solid and non-aqueous liquid waste in the UK HPR1000 are presented in PCER Chapter 5, Sub-chapter 5.5.4.

4.7.4.3 Waste Treatment and Conditioning

4.7.4.3.1 General Considerations for Waste Treatment and Conditioning

The waste treatment techniques, waste containers, and the waste management routes are developed and optimised for the UK HPR1000 through a robust BAT and ALARP process. This is in line with the management requirements in the UK, as outlined below.

a) HLW and ILW

The white paper '*Managing Radioactive Waste Safely*', Reference [44], sets out the UK Government's framework for the long-term management of HAW, a key aspect of which is the "*geological disposal, coupled with safe and secure interim storage*" of HAW. The Nuclear Decommissioning Authority (NDA) is the organisation responsible for the delivery of a GDF.

The Office for Nuclear Regulation (ONR), EA, Scottish Environment Protection Agency (SEPA) and Natural Resources Wales (NRW) set a requirement for waste immobilisation in Reference [45], that 'the *fixed waste form shall make an important contribution to the performance of the waste package*.' Fixation processes can be used to treat the waste, or the waste can be treated in a non-fixed manner, but it is necessary to demonstrate that the waste form is stable and packages can be maintained safely during operation, transportation, temporary storage and disposal.

According to *Introduction to the RWM Waste Package Specification and Guidance Documentation*, Reference [46], a range of standardised waste containers can be used to manufacture three basic types of waste packages:

1) Unshielded waste packages

   For the manufacture of unshielded waste packages, the standardised waste container comprises:

   - 500 litre drum;
   - 3 cubic metre box;
   - 3 cubic metre drum; and,
   - Miscellaneous Beta Gamma Waste Store (MBGWS) box.

2) Shielded waste packages

   For the manufacture of shielded waste packages, the standardised waste container comprises:

   - 2 metre box;
   - 4 metre box;

- 6 cubic metre concrete box;
- 500 litre concrete drum; and,
- 1 cubic metre concrete drum.

3) Robust shielded waste packages.

For the manufacture of robust shielded waste packages, the standardised waste container comprises:

- 500 litre robust shielded drum; and,
- 3 cubic metre robust shielded box.

b) LLW

Based on the '*UK Strategy for the Management of Solid Low Level Radioactive Waste from the Nuclear Industry*', Reference [47], three strategic themes have guided the development of the strategy for management of LLW.

1) Application of the waste hierarchy;
2) The best use of existing LLW management assets; and,
3) Minimisation of accumulation of waste on-site.

It is recognised that various off-site waste service suppliers exist (including the LLWR) and they can receive, treat and dispose the waste in compliance with the WAC, Reference [48], [49], [50], [51] and [52].

According to Reference [48], [49], [50], [51] and [52], the LLWR provides a range of waste treatment and disposal services to ensure the LLW is managed in the most efficient manner, including:

1) Metallic waste treatment

This treatment service is an option to reduce the volume of metallic LLW by blasting or melting. Following treatment at the relevant facility the out of scope or exempt material is recycled and the residual waste is disposed of by the waste service supplier. If there are any secondary wastes, they are re-packaged and transported to the LLWR for disposal or disposed of by the waste service supplier.

2) Combustible waste treatment

This treatment service is a volume reduction option through incineration of combustible materials. The service supplier will be responsible for the disposal of the residual ash from the incinerator. The acceptable range of waste packages includes, but is not limited to, 210 litre drums, berglof boxes and dolav boxes.

3) Super-compactable waste treatment

This service is an option to reduce the volume of LLW by high force compaction prior to disposal at the LLWR. The acceptable range of waste packages are (not limited to) bags and 210 litre drum.

4) LLW and VLLW disposal

This disposal service is an option for waste that is not suitable for treatment and for secondary waste produced as a result of a treatment service.

LLWR offers a range of disposal containers, including 1/3, 1/2, 2/3 and 3/4 height disposal container, a waste monitoring and compaction facility disposal container and an International Organisation for Standardisation (ISO) skip disposal container.

c) Boundary Waste

Boundary is used to describe the radioactive waste which has a radioactivity concentration close to a waste classification boundary. In '*Guidance on Decision Making of Waste Close to the LLW and ILW Categorisation Boundary that Could Potentially Cross the LLW Boundary*', Reference [53], ILW/LLW boundary waste can be defined as ILW and LLW with a concentration of specific radionuclides that prohibits or significantly challenges its acceptability at existing and planned future disposal facilities for LLW, that could practicably be managed as LLW (on the basis of radiochemical and physicochemical properties) through the application of some treatment process or decay storage. Identifying ILW/LLW boundary waste and finding the optimised solution for such wastes can often lead to significant opportunities, for example through:

1) Earlier hazard reduction, disposing of the wastes to an existing disposal facility such as LLWR;

2) Cost reduction from packaging for near-surface disposal instead of packaging for interim storage pending disposal to the GDF; and,

3) Reduction in the footprint of the interim waste storage facility if more waste can be disposed of sooner.

It is also noted that boundary wastes can exist between all radioactive waste classifications and are not limited to the ILW/LLW threshold. Identifying all the boundary wastes and adopting appropriate management strategy are important to ensure that waste management and disposal are optimised. If the source term of the waste stream shows it is boundary waste, the subsequent management considers relevant decay. For the UK HPR1000, the concentrates, sludges and dry active wastes are expected to be boundary wastes. Their management proposals are described in the Sub-chapters 4.7.4.3.4, 4.7.4.3.7 and 4.7.4.3.6.

Based on the UK strategy of waste management described above, the treatment technology options for the UK HPR1000 have been selected according to *Provisions on Optineering Process for UK HPR1000 Generic Design Assessment (GDA) Project*, Reference [21]. The potential and preferred waste treatment technologies for each waste stream generated in UK HPR1000 are summarised in T-4.7-13 and detailed in *Optioneering Report for Operational Solid Waste Processing Techniques*, Reference [25], and *Management Proposal of Waste Non-Fuel Core Components*, Reference [26]. For the packaging containers of LLW/VLLW, the containers are preferentially selected based on the requirement of LLWR. For the packaging containers for ILW, UK standard containers are preferred and selected according to the optioneering process. The analysis and outcome are detailed in Reference [27]. The management proposal for each waste stream of the UK HPR1000 is shown in F-4.7-4 and described in following sub-chapters. The management proposals presented in this sub-chapter represents BAT and ALARP for GDA and will be reviewed at the site licensing phase (FAP-4-2).

T-4.7-13 Summary of Operational Solid and Non-Aqueous Liquid Wastes Management Options

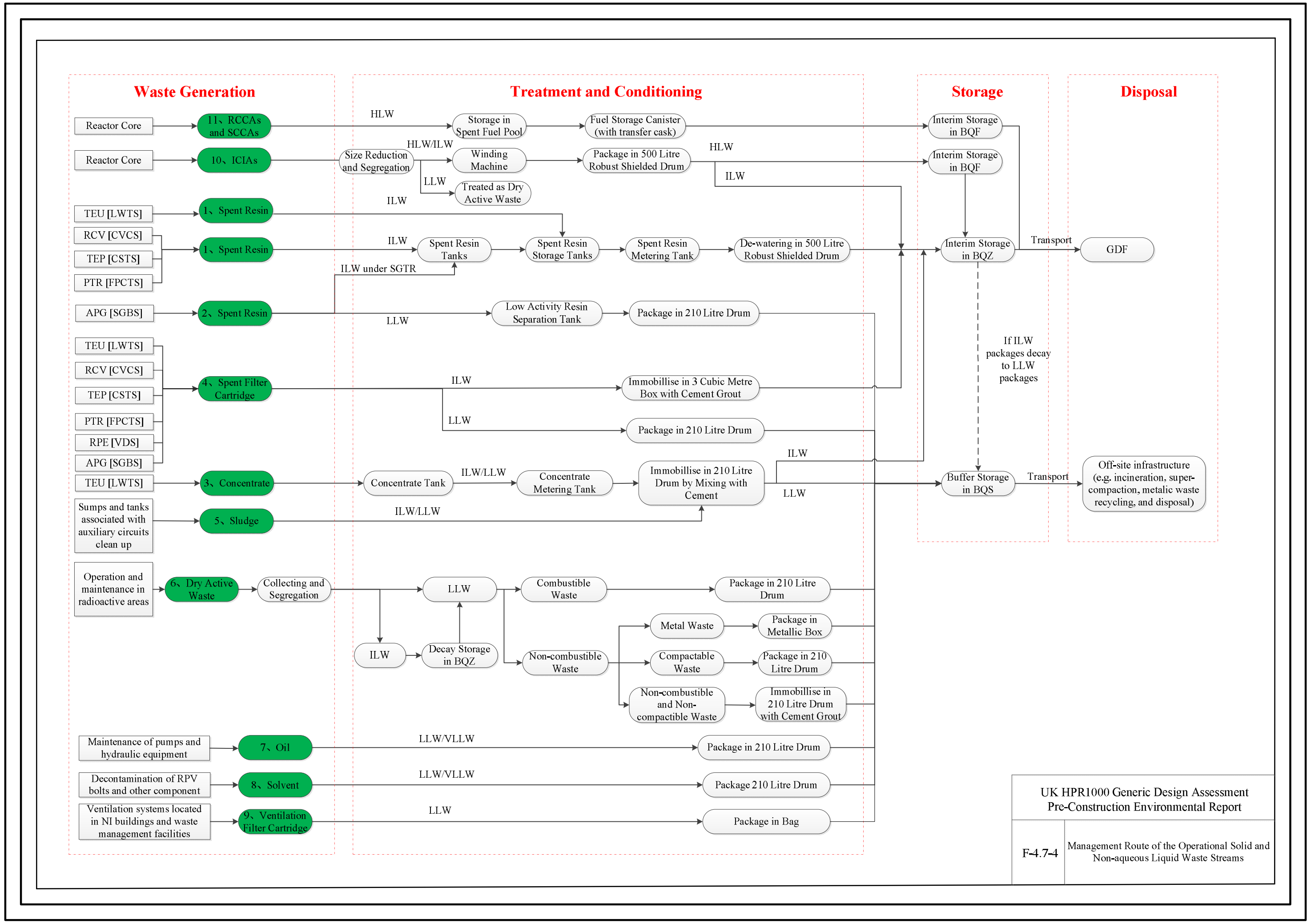
No.	Waste Stream	Category	Potential Treatment/ Conditioning Options	Preferred Options for UK HPR1000
1	Spent Resins	ILW	1. Cement encapsulation; 2. Polymer encapsulation; and, 3. De-watering seal in 500 litre robust shielded drum (e.g. MOSAIK container).	3. De-watering seal in 500 litre robust shielded drum (e.g. MOSAIK container)
2	Low Activity Spent Resins	LLW	1. Disposal directly; and, 2. Incineration.	2. Incineration.
3	Concentrates	ILW/LLW	1. Incineration; 2. Hot isostatic pressing; and, 3. Cement encapsulation.	1. Cement encapsulation
4	Spent Filter Cartridges	ILW	1. Cement encapsulation; 2. Polymer encapsulation; 3. De-watering seal in 500 litre robust shielded drum (e.g. MOSAIK container); and,	1. Cement encapsulation
		LLW		4. Super-compaction

No.	Waste Stream	Category	Potential Treatment/ Conditioning Options	Preferred Options for UK HPR1000
			4. Super-compaction.	
5	Dry Active Wastes	ILW/LLW	1. Incineration if possible; 2. Metal melting if possible; 3. Super-compaction if possible; and, 4. Disposal directly after cement encapsulation.	1. Incineration if possible; 2. Metal melting if possible; 3. Super-compaction if possible; and, 4. Disposal directly after cement encapsulation.
6	Sludges	ILW/LLW	1. Incineration; 2. Hot isostatic pressing; 3. De-watering seal in 500 litre robust shielded drum (e.g. MOSAIK container); and, 4. Cement encapsulation.	Cement encapsulation
7	Oil	LLW/VLLW	1. Incineration; and,	1. Incineration off-site.

No.	Waste Stream	Category	Potential Treatment/ Conditioning Options	Preferred Options for UK HPR1000
			2. Cement encapsulation.	
8	Organic Solvent	LLW/VLLW	1. Incineration; and, 2. Cement encapsulation.	1. Incineration off-site.
9	Ventilation Filter Cartridges	LLW	1. Super-compaction; 2. Metal melting; 3. Cement encapsulation; and, 4. Incineration; and, 5. Polymer encapsulation.	1. Super-compaction.
10	ICIAs	HLW/ILW	1. The ICIAs are winded immediately and packaged into 500 litre robust shielded drum. The packages are stored on-site before dispatch to GDF. 2. The ICIAs are cut into segments immediately and then collected and stored in the SFP temporarily. Then the segments are retrieved and repackaged into 500 litre robust shielded drum, which are stored on-site before dispatch to GDF.	1. The HLW ICIAs are winded immediately and packaged into 500 litre robust shielded drums after size reduction and stored in the BQF for decay. When the waste becomes ILW, the package will be transferred to the BQZ for interim storage where the ILW ICIAs packages are stored.

No.	Waste Stream	Category	Potential Treatment/ Conditioning Options	Preferred Options for UK HPR1000
11	RCCAs SCCAs	HLW	1. All the spent RCCAs and SCCAs are co-stored with spent fuel in the SFP for long term storage until the plant enters decommissioning stage when the waste can be managed in accordance with the approach for the reactor internals (segmentation); 2. The spent RCCAs and SCCAs are temporarily co-stored with the spent fuel to decay in the SFP for a given period time, and then the RCCAs and SCCAs are packaged in HLW disposal containers which are to be stored in the BQF prior to disposal to GDF; 3. The spent RCCAs and SCCAs are temporarily co-stored with the spent fuel to decay in the SFP for a given period time, and packaged together with the spent fuel, which are to be stored in the BQF prior to disposal to GDF; and, 4. The spent RCCAs and SCCAs are	3. The spent RCCAs and SCCAs are temporarily co-stored with the spent fuel to decay in the SFP for a given period time, and then the waste and the spent fuel are packaged together. The package will be stored in the BQF prior to disposal at GDF.

No.	Waste Stream	Category	Potential Treatment/ Conditioning Options	Preferred Options for UK HPR1000
			temporarily co-stored with the spent fuel to decay in the SFP for a given period time, and then transferred to BQF for size-reduction and re-packaging. The waste packages are stored in BQZ prior to disposal to GDF.	
12	Spent Fuel Assemblies (SFAs)	HLW	1. Dry Cask Spent Fuel Interim Storage (SFIS); 2. Dry Vault SFIS; and, 3. Wet SFIS.	1. Dry Cask SFIS



F-4.7-4 Management Route of the Operational Solid and Non-aqueous Liquid Waste Streams

4.7.4.3.2 Spent Resins

The spent resins to be generated from the demineralisers in the RCV [CVCS]), TEP [CSTS], TEU [LWTS] and the PTR [FPCTS] are categorised as ILW, Reference [37].

The spent resins from RCV [CVCS], TEP [CSTS] and PTR [FPCTS] are flushed from the demineralisers to the TES [SWTS] spent resin tanks located in the BNX which are designed to receive and store these spent resins. The spent resins from TEU [LWTS] are flushed from the demineralisers to the TES [SWTS] spent resin tanks located in the BWX which are designed to receive and store the spent resins. The spent resins in BNX storage tanks are then pumped to the BWX spent resins tanks when they are to be processed. The spent resins in the BWX spent resins tanks are processed and packaged in the 500 litre robust shielded drum (e.g. MOSAIK container) on a batch basis. The packaged ILW spent resins are then stored on-site in the BQZ until the GDF becomes available.

Steam generator tubes rupture is a potential failure that needs to be considered when developing the management strategy for the APG [SGBS] spent resins. In case of the steam generator tubes rupture, the reactor coolant will leak into the secondary circuit and may result in APG [SGBS] resins becoming ILW. These ILW spent resins are to be directly routed from the APG [SGBS] demineralisers to the spent resin tanks of TES [SWTS] system located in BNX and to be managed as ILW spent resins as described above.

4.7.4.3.3 Low Activity Spent Resins

Low activity spent resins are generated from the APG [SGBS] demineralisers, under normal conditions. These spent resins are normally not contaminated but may be in case of leaks from primary to secondary circuit and, in such cases (excluding SGTR), are categorised as LLW at the time of their generation, Reference [37].

The low activity spent resins from the APG [SGBS] demineralisers are discharged into APG [SGBS] resin separation tank and then transferred by the vacuum suction device and loaded into 210 litre drums after dewatering. The packaged APG [SGBS] resins are then sent off-site for incineration, after buffer storage in the Waste Auxiliary Building (BQS) (short time).

4.7.4.3.4 Concentrates

Concentrates are generated from the TEU [LWTS] evaporator. This is used to minimise liquid waste contamination and chemical pollution by concentrating and containing radionuclides and chemicals (notably boron) into solid waste.

During normal operation, the generated concentrates are expected to be ILW or LLW at the time of generation, Reference [37]. The ILW concentrates are identified as ILW/LLW boundary waste considering that they can decay to LLW within a reasonably short time. Therefore, decay storage is considered for ILW concentrates management, Reference [25].

Concentrates are collected in the concentrate tanks of the TEU [LWTS], located in the BWX, where they are monitored and sampled for analysis. The output from this analysis will determine the processing route for this waste stream.

Concentrates that are characterised as LLW are immobilised by mixing them with cement within a 210 litre drum. The resulting waste packages are transferred to BQS for buffer storage (short time) before being sent to LLWR for disposal.

Concentrates that are characterised as the ILW/LLW boundary waste are immobilised by mixing them with cement within a 210 litre drum. The resulting waste packages are transferred to BQZ for decay storage until they become LLW and are acceptable for disposal at LLWR.

4.7.4.3.5 Spent Filter Cartridges

Some of the spent filter cartridges to be generated from the RCV [CVCS], TEP [CSTS], PTR [FPCTS], TEU [LWTS], APG [SGBS] and the RPE [VDS] are categorised as ILW, whilst others are LLW, Reference [37].

The spent filter cartridges that are generated from the RCV [CVCS], TEP [CSTS], PTR [FPCTS] and the RPE [VDS] are replaced by a spent filter cartridge changing machine located in the BNX.

The spent filter cartridges generated from the TEU [LWTS] are replaced by a spent filter cartridge replacement and transfer device located in the BWX.

The dose rate of the removed cartridge can be monitored in both cartridge changing devices to decide whether the cartridge is loaded into a shielding cask for management as ILW, or a 210 litre drum for management as LLW.

ILW spent filter cartridges are treated by cement encapsulation in the BWX and packaged in 3 cubic meter box. The formed waste packages are to be stored in the BQZ pending disposal in GDF.

LLW spent filter cartridges are loaded in 210 litre drums and transferred to the BQS for buffer storage (short term) before being sent off-site for super-compaction.

4.7.4.3.6 Dry Active Wastes

Dry active wastes are generated in radioactive areas during operation and maintenance. This waste stream includes contaminated personal protection equipment, charcoal waste from the iodine absorbers of HVAC systems, monitoring swabs, plastic, contaminated tools and small items of metallic material. Dry active wastes to be generated from the UK HPR1000 are categorised as ILW or LLW, Reference [37].

Dry active wastes are collected and characterised at source based on their contamination level. This allows for the segregation of active wastes and non-active wastes to reduce the volume of dry active wastes.

During normal operation, the generated dry active wastes are expected to be ILW or LLW at the time of generation. The ILW dry active wastes are identified as ILW/LLW boundary waste considering that ILW dry active wastes can decay to LLW after short time. Therefore, decay storage is considered for ILW dry active wastes management, Reference [25].

For the dry active wastes generated at the UK HPR1000, they are categorised at source. The LLW are sent to the BQS for further segregation and packaging to facilitate the optimal management of these wastes. In the BQS, the waste materials are separated into combustible and non-combustible waste based on their size and material type. The non-combustible wastes are then segregated further into metal waste, un-combustible/compactable waste and un-combustible/un-compactable waste.

a) The combustible wastes undergo pre-compaction followed by packaging into 210 litre drums. These packages are buffer stored in the BQS (short time) pending transport off-site for incineration.

b) The metal wastes are to be packaged into metallic boxes (e.g. Berglof Boxes) and then buffer stored in the BQS (short time) pending transport off-site for metal melting.

c) The un-combustible/compactable wastes undergo pre-compaction followed by packaging into super-compactable 210 litre drums. These packages are buffer stored in the BQS (short time) pending transport off-site for super-compaction.

d) The un-combustible/un-compactable wastes are to be immobilised with cement grout in 210 litre drums, and then buffer stored in the BQS (short time) pending transport off-site for disposal.

The ILW dry active wastes are loaded into 210 litre drums and then transferred to the BQZ for decay storage. After they have decayed to LLW, the wastes are sent back to the BQS for further segregation and packaging (as presented above) to facilitate the optimal management of these wastes before being sent off-site for treatment or disposal.

4.7.4.3.7 Sludge

Sludge is generated from the sumps and tanks associated with the auxiliary circuits (e.g. RPE [VDS], TEU [LWTS]). These sumps and tanks are periodically cleaned out and the accumulated sludge (if any) is removed for treatment as waste.

During normal operation, the generated sludge is expected to be ILW or LLW at the time of generation, Reference [37]. The ILW sludge is identified as ILW/LLW boundary waste considering that ILW sludge can decay to LLW within short time. Therefore, decay storage is considered for ILW sludge management, Reference [25].

Sludge that is characterised as LLW is immobilised by mixing it with cement within 210 litre drum. The resulting waste packages are transferred to BQS for buffer storage (short time) before being sent to LLWR for disposal.

Sludge that is categorised as ILW/LLW boundary waste is immobilised by mixing it with cement within a 210 litre drum. The resulting waste packages are transferred to BQZ for decay storage until they decay to LLW and become acceptable for disposal at LLWR.

4.7.4.3.8 Oil

The oil is generated during normal operation of UK HPR1000, notably from maintenance of pumps and hydraulic equipment. This waste stream is categorised as LLW/VLLW, Reference [37], with very low volumes generated annually.

The oil is collected and placed directly into 210 litre drums and then buffer stored in the BQS (short time) pending transport off-site for incineration.

4.7.4.3.9 Organic Solvent

The organic solvent is generated during normal operation of UK HPR1000, notably from the decontamination of reactor pressure vessel bolts and other components. This waste stream is categorised as LLW/VLLW, Reference [37], with very low volumes generated annually.

The organic solvent is collected and placed directly into 210 litre drums and then buffer stored in the BQS (short time) pending transport off-site for incineration.

4.7.4.3.10 Ventilation Filter Cartridges

Ventilation filter cartridges are generated from the ventilation systems located in the BRX, BSX, BFX, BNX, BPX, BWX and BQZ. This waste stream includes pre-treatment filters and HEPA filters and is categorised as LLW, Reference [37].

The ventilation filter cartridges are packaged in bags (or in 210 litre drums) and transferred to the BQS for buffer storage (short time) prior to transport to off-site infrastructures for super-compaction.

4.7.4.3.11 ICIAs

The whole piece of ICIAs are categorised as HLW or ILW at the time of generation.

a) The whole piece of ICIAs (i&ii) are categorised as HLW at the time of generation as their heat generation is >2 kw/m^3, Reference [38];

b) The whole piece of ICIAs (iii) are categorised as ILW at the time of their generation, Reference [38];

The upper part of the ICIAs (i&ii) and ICIAs (iii) if separated from the rest of the ICIA part can be categorised as LLW as they are located away from the active core region, Reference [37].

When the ICIA need to be replaced, the upper part of the ICIA, which is categorised as LLW, is cut firstly and segregated from the rest of the ICIA, then treated as dry active waste. The remaining part of the ICIA is packaged within the 500 litre robust shielded drum after being winded by the winding machine. Each drum can receive several ICIAs. The HLW ICIAs (i&ii) and ILW ICIAs (iii) are packaged separately to form HLW waste packages and ILW waste packages. The ILW waste packages are then transferred from the BRX to the BQZ for interim storage prior to final disposal at the GDF. The HLW ICIA (i&ii) can decay to ILW after approximately 14 years. Therefore, decay storage is considered for HLW ICIA (i&ii) management, Reference [26]. Therefore, HLW waste packages are transferred from the BRX to the BQF for decay storage. After an appropriate decay period (approximately 14 years), the waste packages (categorised as ILW) are transferred to the BQZ for further storage prior to final disposal at the GDF.

4.7.4.3.12 RCCAs and SCCAs

The RCCAs and SCCAs are identified as HLW, Reference [40].

The spent RCCAs and SCCAs are removed from the reactor core together with the fuel assemblies and temporarily co-stored with the spent fuel to decay in the SFP for a given period of time, as presented in PCSR Chapter 28, Reference [54]. They are then packaged together with the spent fuel, and stored in the BQF prior to being retrieved, repackaged and disposed of to the GDF, as presented in PCSR Chapter 29, Reference [6]. Co-disposal of RCCAs and SCCAs with spent fuel is selected at GDA stage. However, this does not foreclose the option of retrieving and repackaging them separately for final disposal, which will be reviewed and decided by the future operator at the site licensing phase (FAP-4-2).

Based on waste volume, the preferred management proposal and proposed package container are presented in Sub-chapters 4.7.4.1 and 4.7.4.3. The waste volumes of the final packages for the operational solid and non-aqueous liquid radioactive wastes that are anticipated to be generated by the UK HPR1000 are presented in T-4.7-14. The detailed analysis is presented in Reference [39].

T-4.7-14 Operational Solid Wastes and NALW Classification, Proposed Container and Expected Volume of Waste Packages for One UK HPR1000 Unit

Waste Types	Waste Classification at the Time of Generation	Annual Volume (m^3)	Total Volume Over the Lifetime (m^3)	On-site Treatment Process	Package Container Used	Waste Container Volume (m^3)	Annual Number of Waste Packages	Total Number of Waste Packages Over the Lifetime	Annual Volume of Waste Packages (m^3)	Total Volume of Waste Packages Over the Lifetime (m^3)
Spent Resin	ILW	1.9	114	De-watering	500 litre robust shielded drum	1.32	~4.1	245	5.39	323.4
Low activity spent Resin	LLW	9.7	582	De-watering	210 litre metallic drum	0.21	~51.1	3063	10.72	643.2
Concentrates	ILW	0.73	43.8	Immobilisation by mixing them with cement	210 litre metallic drum	0.21	7.3	438	~1.53	91.98
	LLW	1.47	88.2			0.21	14.7	882	~3.09	185.22
Spent Filter Cartridges	ILW	1.14	68.4	Immobilisation in cement grout	3 cubic metre box	3.68	~1.7	104	~6.38	382.72
	LLW	0.65	39	None	210 litre metallic drum	0.21	5	300	1.05	63
Sludges	ILW	0.05	3	Immobilisation by mixing them with cement	210 litre metallic drum	0.21	0.5	30	~0.11	6.3
	LLW	0.05	3			0.21	0.5	30	~0.11	6.3
Combustible Waste	ILW/LLW	144.75	8685	Pre-compactio n	210 litre metallic drum	0.21	277.9 1)	16674	~58.36	3501.54
Metal Maintenance Waste	ILW/LLW	12	720	None	Metallic box	0.57	~31.6	1895	~18	1080.15
Un-combustible/c ompactable Waste	ILW/LLW	17	1020	Pre-compactio n	210 litre metallic drum	0.21	~29.8 1)	1790	~6.27	375.9

Waste Types	Waste Classification at the Time of Generation	Annual Volume (m^3)	Total Volume Over the Lifetime (m^3)	On-site Treatment Process	Package Container Used	Waste Container Volume (m^3)	Annual Number of Waste Packages	Total Number of Waste Packages Over the Lifetime	Annual Volume of Waste Packages (m^3)	Total Volume of Waste Packages Over the Lifetime (m^3)
Un-combustible/ Un-compactable Waste	ILW/LLW	5	300	Immobilisation in cement grout	210 litre metallic drum	0.21	~34	2041	~7.14	428.61
Ventilation Filter Cartridge	LLW	29.7	1782	None	Bags	/	297[2)]	17820	29.7	1782
Waste Oil	LLW/VLLW	~0.13	7.5	None	210 litre metallic drum	0.21	~0.7	40	~0.14	8.4
Organic Solvent	LLW/VLLW	0.2	12	None	210 litre metallic drum	0.21	1.05	63	~0.22	13.23
ICIAs	HLW	~0.13	7.84	Winded	500 litre robust shielded drum	1.32	~1.2	70	1.54	92.4
	ILW	~0.01	0.56			1.32	/[3)]	5	/[3)]	6.6
RCCAs and SCCAs	HLW	/[4)]	/[5)]	Co-stored with spent fuel in the SFP or BQF.	Spent fuel storage canister	/	/[5)]	/	/	/

Note:

1) Considering the volume reduction factor (3) provided by the on-site pre-compaction.

2) Based on the maximum size of ventilation filter cartridges, it is assumed that one cartridge is loaded in one bag.

3) The value is less than 1 and is very small.

4) The expected number of RCCAs and SCCAs generated from one UK HPR1000 unit is about 605.

5) The RCCAs and SCCAs are packaged with spent fuel within fuel storage canister. The number of waste packages and volumes of waste package is presented in T-4.7-17.

4.7.4.4 Waste Management Facilities

The waste management facilities for the solid and non-aqueous liquid waste at the UK HPR1000 are:

a) BNX, where the spent resins flushing and storage subsystem, and the spent filter cartridges changing subsystem are located;

b) BWX, where the wet-solid waste (including ILW spent resins, ILW spent filter cartridges, concentrates and sludge) receipt and treatment subsystem is located;

c) BQS, where the dry active wastes and ventilation filter cartridges are segregated and packaged and the LLW packages are buffer stored;

d) BQZ, where the ILW packages are stored pending transport to the GDF; and,

e) BQF, where the HLW and spent fuel packages are stored pending transport to the GDF.

4.7.4.4.1 Nuclear Auxiliary Building (BNX)

The main equipment of the TES [SWTS] located in the BNX are:

a) Two spent resin tanks - are used to receive and store the radioactive spent resins from the demineralisers of the upstream systems. When the spent resins in each tank reach the set level, they are transferred by the spent resin deliver pump to the spent resin storage tanks located in the BWX for treatment.

b) A low activity resin separation tank, and vacuum suction device - are used to treat the spent LLW resins generated by the APG [SGBS] demineraliser under normal conditions. The spent resins of the APG [SGBS] demineraliser are flushed by the demineralised water from NI Demineralised Water Distribution System (SED [DWDS (NI)]) into the low activity resin separation tank. The spent resins are then loaded by the vacuum suction device into the drums after dewatering. The filled drums are transferred to the BQS for buffer storage (short time) prior to transport off-site for incineration.

c) A spent filter cartridge changing machine - is used to remove the spent filter cartridges from the RCV [CVCS], PTR [FPCTS], TEP [CSTS] and the RPE [VDS] and load the new ones. The spent filter cartridges removed are loaded into drums and then transferred to the BWX or the BQS (short time) for further treatment.

Further information on the equipment is presented in Reference [55].

4.7.4.4.2 Radioactive Waste Treatment Building (BWX)

The main equipment of TES [SWTS] located in the BWX are:

a) Two spent resin storage tanks - receive the spent resins from the spent resins tanks of BNX via the spent resins delivery pump. The spent resins generated by the TEU [LWTS] demineraliser are also delivered to these spent resin storage tanks, by the spent resins transfer pump. Following measurement in the spent resin metering tank, the spent resins are transferred into 500 litre robust shielded drums (e.g. MOSAIK container) for dewatering.

b) A concentrate metering tank - receives the concentrates generated by the TEU [LWTS] for measurement before being transferred into drums for in-drum mixing with cement.

c) A spent filter cartridge replacement and transfer device - is used to remove the spent filter cartridges from the TEU [LWTS]. The spent filter cartridges removed are loaded into drums and then transferred to the temporary storage area in BWX or the BQS for further treatment.

d) A filter cartridge retrieval device - is used to retrieve the cartridge from the drums to the temporary storage area for batch treatment and retrieve the cartridge from the storage area into the disposal container for immobilisation. The specific grab in the device is used to grasp the cartridge.

Further information on the equipment in the BWX is presented in Reference [55].

4.7.4.4.3 Waste Auxiliary Building (BQS)

The BQS is designed to receive, pre-treat and treat different kinds of LLW to be generated during the operation of the UK HPR1000, to ensure that the LLW waste packages can meet the waste acceptance criteria of relevant UK off-site infrastructures. The BQS also provides a buffer storage area to buffer store the LLW waste packages prior to their transportation to the relevant UK off-site infrastructures. The storage capacity of the BQS buffer storage area is designed to buffer store all the LLW packages which are to be generated during one year by two UK HPR1000 units. All the LLW waste packages to be stored in the BQS include:

a) The metallic box with metal waste;

b) The bags with ventilation filter cartridges; and,

c) All types of 210 litre drums for non-metal dry active waste, low activity spent resins, concentrates, spent filter cartridges, sludges, oil and organic solvent.

Different areas are designed to implement the functions for the BQS. The main areas consist of auxiliary areas, receipt/dispatch area, LLW pre-treat and treatment area, waste packages storage areas, Half Height ISO (HHISO) loading area, HHISO storage area, HHISO inspection area and new empty containers storage area. The areas division and conceptual layout is presented in Sub-chapter 5.3 and Appendix B of *Conceptual Proposal of Waste Auxiliary Building,* Reference [56].

The main equipment in the BQS includes:

a) A sorting box for segregating the dry active wastes into different packages according to their properties;

b) A pre-compactor for compressing the compactable waste into the waste package (210 litre drum) to minimise the waste volume before transportation off-site;

c) Five roller conveyors for conveying the packages between different stations, including the sorting station, pre-compacting station, inspection station and grouting station;

d) A cement grouting device for preparing the grout to immobilise the un-combustible/un-compactable dry active waste;

e) A drum dryer for drying the waste within the container to eliminate the free liquid;

f) An inspection device for measuring different radiological characteristics and weight of the packages filled with waste;

g) A forklift truck for transferring waste packages between different areas;

h) A crane for lifting and moving the waste packages and HHISO between different areas; and,

i) Stillages for handling and stacking the 210 litre drums.

More information of the conceptual design proposal of the BQS is presented in *Conceptual Proposal of Waste Auxiliary Building*, Reference [56].

4.7.4.4.4 ILW Interim Storage Facility (BQZ)

According to the requirement of radioactive waste management in UK, the ILW packages will be disposed of to the GDF. The GDF is being developed by Radioactive Waste Management Ltd (RWM) but is not expected to be available for a number of decades. Therefore, in the absence of a GDF facility, and to meet UK guidance requirements, the ILW packages will be stored in an interim storage facility on-site designed for at least for 100 years.

The BQZ is developed as the on-site facility to safely store the ILW packages generated by the UK HPR1000. The facility is designed to import, measure, store, enable decay, monitor, maintain and export the ILW packages. The waste packages are ultimately transported to a disposal facility (the GDF or LLWR) after a period of storage.

This sub-chapter provides an overview of the conceptual design proposal for the BQZ. More information on the conceptual design proposal of BQZ is presented in the *Conceptual Proposal of ILW Interim Storage Facility,* Reference [28]. The design proposal for the BQZ aims to show that the facility can be built at the generic site to safely store the ILW packages generated from the operation and decommissioning of the UK HPR1000, in compliance with the UK environmental and safety requirements. The details provided in the subsequent sub-chapters do not represent the final design for the BQZ, and the future operators will develop their own design proposal based on the latest regulations and conditions through further BAT and ALARP analysis (FAP-4-3).

4.7.4.4.4.1 Storage Capacity

The design lifetime of the BQZ is considered to be at least 100 years according to the UK industry guidance on HAW interim storage, Reference [11]. The storage capacity of the BQZ will be influenced by the construction plan for the UK HPR1000, the maximum amount of ILW packages expected to be generated, and the time period within which the GDF will be available.

According to the *National Policy Statement for Nuclear Power Generation (EN-6)*, Reference [57], the GDF is estimated to be available after 2130. Therefore, for the UK HPR1000 it will be necessary to interim store on-site the ILW packages generated during the operational lifetime (60 years) of the UK HPR1000, as well as part or all of the decommissioning ILW packages to be generated.

The BQZ is designed to safely store the ILW packages anticipated to be generated during the lifecycle of two units, during operational and decommissioning phases. A two phases construction plan is proposed for this facility based on an optioneering process presented in Sub-chapter 7.1.2 of *Conceptual Proposal of ILW Interim Storage Facility*, Reference [28], considering safety, environmental impact, technical feasibility and cost factors. The storage capacity of first phase facility is to accommodate the ILW packages generated by two UK HPR1000 units during the initial operational period of 30 years. The storage capacity of the second phase facility is to be designed to accommodate the ILW packages to be generated during the remaining operation period and the decommissioning, of two UK HPR1000 units, taking into account the relevant factors notably the actual annual arising of ILW for each unit during the operational phase of UK HPR1000.

Decay storage from ILW to LLW for boundary wastes is beneficial in reducing the quantities of ILW packages that will ultimately be disposed to the GDF. When the ILW/LLW boundary wastes have been decayed to LLW, they are disposed to LLWR disposal/treatment facility. Appropriate capacity has been considered in the BQZ design for storage the ILW/LLW boundary wastes packages to ensure the ILW/LLW boundary wastes can decay to LLW before transfer to off-site disposal/treatment facility. The amount of waste packages that is to be generated for two UK HPR1000 units, within first 30 years of operation is presented in T-4.7-15. The storage capacity of the BQZ first phase is determined to accommodate these waste packages.

T-4.7-15 Maximum Amount of Waste Packages to be Stored in BQZ for Two UK HPR1000 Units Operation 30 Years

Waste Package	Waste Type	Waste Classification	Maximum Amount of Waste Packages
500 litre robust shielded drum	Spent resins	ILW	245
	ICIAs	ILW	75
210 litre drum	Concentrates	ILW/LLW boundary waste	146 1)
	Sludges	ILW/LLW boundary waste	20 2)
	Dry active wastes	ILW/LLW boundary waste	708 3)
3 cubic metre box	Spent filter cartridges	ILW	104

Note:

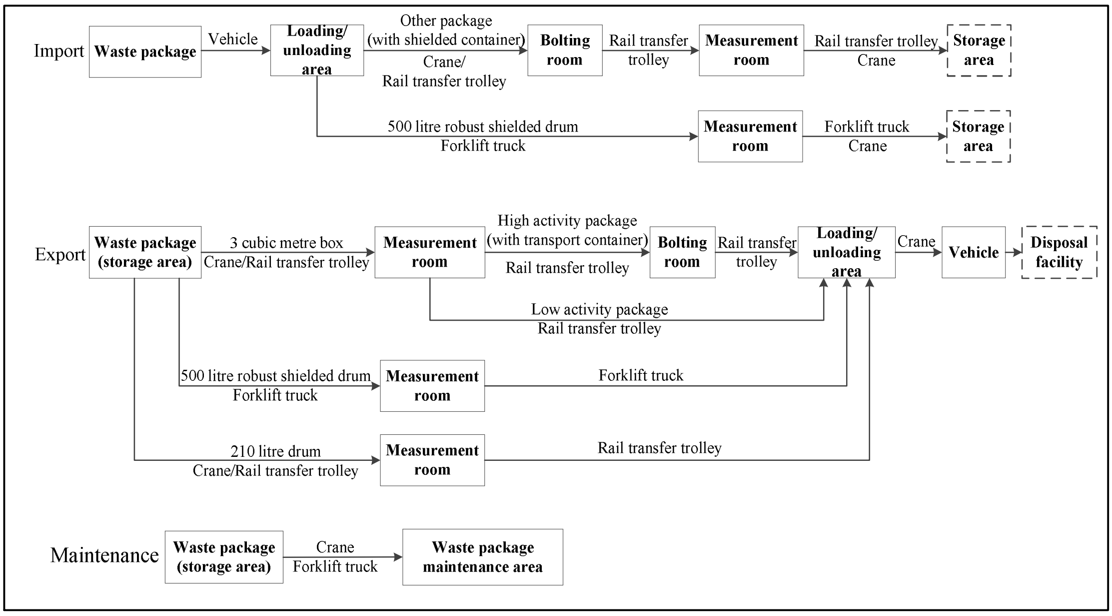
1) The ILW concentrate is expected to become LLW after a decay period of about 7.4 years. It is conservatively considered that the storage capacity can accommodate the ILW concentrate waste packages (ILW/LLW) generated during over 10 years of operation of two UK HPR1000 units;

2) The ILW sludge is expected to become LLW after a decay period of about 16.5 years. It is conservatively considered that the storage capacity can accommodate the ILW sludge waste packages (ILW/LLW) generated over 20 years of operation of two UK HPR1000 units;

3) The ILW dry active waste is expected to become LLW after a decay period of about 1.65 years. It is conservatively considered that the storage capacity can accommodate the ILW dry active waste packages (ILW/LLW) generated over 3 years of operation of two UK HPR1000 units.

4.7.4.4.4.2 Storage Process

The general process for the import, export and maintenance of the waste packages in the BQZ is presented in F-4.7-5.



F-4.7-5 General Process Diagram of the BQZ

a) Import

1) Import of 500 litre robust shielded drum

When the waste vehicle arrives at the loading/unloading area, the 500 litre robust shielded drums are transported by a travelling crane onto the floor. The 500 litre robust shielded drums are then transferred by the forklift truck to the measurement room.

In the measurement room, the gamma emitters activity, surface dose rate and contamination of packages are measured. According to the results of the measurements, the packages are transferred by forklift truck or travelling crane from the measurement room to the storage area.

The travelling crane and measurement device are controlled remotely by workers in the control room.

2) Import of other packages

Other packages such as the 210 litre drums and 3 cubic metre boxes are transported with shielding casks. When the waste vehicle arrives at the loading/unloading area, the waste packages (with the shielded cask) are transported by a travelling crane onto the rail transfer trolley. The waste packages (with shielding cask) are first delivered by the rail transfer trolley to the bolting room for bolt disassembly and shielding cask removal. They are then transferred to the measurement room by the rail transfer trolley.

In the measurement room, the gamma emitters activity, surface dose rate and contamination of packages are measured. According to the results of the measurements, the packages are transferred by rail transfer trolley from the measurement room to the storage area. The packages are then lifted by the software-controlled crane to relevant location in the storage area. The software-controlled crane is operated by workers in control room.

b) Export

When the 500 litre robust shielded drums need to be transported to the off-site disposal facility, they are transferred by forklift truck or the travelling crane from the storage area to the measurement room for monitoring and inspection. If the waste package is suitable for off-site disposal, the waste package is transferred by the forklift truck from the measurement room to the loading/unloading area, from where it is lifted by the travelling crane onto a waste vehicle, which will transfer the waste package to the GDF.

When the other packages (except 500 litre robust shielded drums and ILW/LLW boundary waste) need to be transported to the GDF, they are transferred by software-controlled crane onto the rail transfer trolley, and then transferred by the rail transfer trolley to the measurement room for monitoring and inspection. If the waste package is suitable for off-site disposal, the waste package is to be transferred by the rail transfer trolley from the measurement room to the loading/unloading area, from where it is lifted by the travelling crane onto a waste vehicle, which transfers the waste package to the GDF.

When the ILW/LLW packages are decayed to LLW in the BQZ, these packages will be transported to the BQS from where the 210 litre drums are loaded into HHISO and transferred to LLWR.

c) Maintenance of the Waste Packages

The packages with a low surface dose can be inspected physically by the operators to check the condition of the package before it is transferred to the storage area. Remote inspection of the packages can also be undertaken using cameras and special auxiliary techniques if necessary.

Any waste package that is identified as defective is transferred to the waste package maintenance area. The operator then performs the relevant maintenance operations to repair the defective waste package under sufficient protection and shielding. Then the waste package is transferred back to its original location.

4.7.4.4.4.3 Facility Layout

According to the waste package types, storage requirement and the general process, the BQZ is divided into auxiliary area, operation area and storage area. The schematic drawings are presented in F-7.3-1, F-7.3-2 and F-7.3-3 of Reference [28].

a) Auxiliary Area

The auxiliary area includes the personnel entrance/exit area, changing room, control room, duty room, power distribution room, waste package maintenance area, fan room, etc., which preform the functions of controlling of personnel entry/exit, equipment operation, environment parameters adjustment and inspection/maintenance of waste packages. The waste package maintenance area is isolated from the other parts of the auxiliary area by shielding wall, so that the radiation outside of the waste package maintenance area is limited during the maintenance activities.

b) Operation Area

The import, measurement and export of waste packages are undertaken in the operation area. This area includes the:

1) Loading/unloading area. This area is designed to receive the waste packages from the other relevant facilities, such as the waste treatment building, and to export the waste packages to the off-site disposal facilities. The loading/unloading area is isolated from the storage area by a shielding wall.

2) Temporary storage area. This area is designed to store incoming waste packages while waiting for measurement, and the export waste packages that are waiting for transport off-site.

3) Bolting room. This room is designed for the disassembly/assembly of the shielding cask lid bolt. The bolting room is isolated from other areas by shielding walls, so the direct dose to workers is reduced during the disassembly/assembly operation.

4) Measurement room. This room is designed to house the measurement devices which are used for measurement of the gamma-ray energy spectrum, surface dose rate and the contamination level of the waste packages. The measurement information is recorded to establish the baseline characteristics of the waste packages as they arrive in the facility and before their off-site transfer. The measurement room is isolated from the storage area by the shielding walls, shielding door and shielding cover, so the background radiation level in this room is sufficiently low during the measurement operation.

5) Crane maintenance area. This area is designed for the maintenance/repair of the software-controlled crane. This area is isolated from the storage area by shielding walls and door.

c) Storage Area

The storage, monitoring, and inspection of the ILW waste packages during storage are undertaken in the storage area. The waste packages are stored in different areas according to the type and radiation level of the waste package to facilitate the operation of the facility. The storage area includes the:

1) 500 litre robust shielded drums storage area

   This area is an independent area (vault type) used to store the 500 litre robust shielded drums. It is isolated from other areas and the environment by concrete walls and a concrete roof, which provide effective containment, shielding, and prevent leakage of radioactive material.

2) 210 litre drum storage area

   This area is an independent area (vault type) used to store the 210 litre drums. The 210 litre drum storage area is isolated from 3 cubic metre box storage area, other areas and the environment by concrete walls and concrete roof, which provide effective containment, shielding and prevent leakage of radioactive material.

3) 3 cubic metre box storage area

   This area is an independent area (vault type) used to store the 3 cubic metre boxes. The 3 cubic metre box storage area is isolated from 210 litre drum storage area, other areas and the environment by concrete walls and concrete roof, which provide effective containment, shielding and prevent leakage of radioactive material.

4) Specific storage area

   All of the storage areas are equipped with a specific storage area that can be used to temporarily store any defective waste packages.

No radioactive liquid effluent is expected to be generated from BQZ. In addition, no significant discharges of the radioactive gaseous and airborne waste are expected. If any, the ventilation system will provide suitable filtration and the effluents after filtration will be discharged to the environment under monitoring. It is expected that direct radiation and sky shine from operation of the BQZ to the public will be low due to sufficient shielding provisions being incorporated into the design. The direct dose to the public has been assessed based on the conceptual design proposal of BQZ and the information is presented in PCER Chapter 7 and Reference [28].

4.7.4.4.4.4 Record Keeping

During the normal operation of the BQZ, the characteristics of each waste package (e.g. package type, treatment process, production date and unique identifier), all measurement information (e.g. source term, surface dose rate and contamination of waste packages) and the waste package management information (e.g. storage position, disposal route, monitoring and inspection records and maintenance records) are to be recorded to achieve the safe operation of the facility and to provide the relevant information to the owner of the final disposal facility. The record management is consistent with the record management principles described in Sub-chapter 4.6.4 of this document.

4.7.4.5 Demonstration of BAT

Minimising the mass or volume of the solid and non-aqueous liquid radioactive wastes can minimise the final waste packages to be disposed. A variety of techniques or management methods are adopted in the design of the UK HPR1000 to minimise the volumes of the solid and non-aqueous liquid wastes requiring disposal. These include characterisation and segregation, size reduction, compaction, usage of efficient waste containers and decay storage. A separate sub-claim '*Sub-Claim 4.1.EC03.4: Minimise the Mass/Volume of Solid and Non-Aqueous Liquid Radioactive Wastes and Spent Fuel*' in PCER Chapter 3 presents how the generation of solid and non-aqueous liquid wastes are minimised and managed efficiently through the adoption of BAT techniques.

Solid and non-aqueous liquid LLW can be disposed to the LLWR or other (successor) facilities in the UK. The design of the UK HPR1000 takes account of the existing services and allows a future operator to select optimal waste disposal routes for its solid and non-aqueous liquid wastes. A separated sub-claim '*Sub-Claim 4.1.EC03.5: Select the Optimal Disposal Routes for Wastes*' in PCER Chapter 3 presents details of BAT demonstration for the disposal routes and demonstrates that no orphan wastes will be generated.

4.7.5 Spent Fuel

4.7.5.1 Spent Fuel Arising

Spent fuel is generated during the operation of the UK HPR1000 and will ultimately be disposed of to the GDF. After final shutdown, the spent fuel is to be managed in the same manner as during the operation. The spent fuel information is shown in T-4.7-16.

T-4.7-16 Datasheet for Spent Fuel

Parameter	Description
Description	Spent fuels are fuels after irradiation in core, with high radioactivity and high decay heat. The spent fuels are metallic rod assemblies and the main composition includes UO_2, Zirconium, Alloy, 718 Alloy and stainless steel.
Total Arising (60 years) for One UK HPR1000 Unit	~ 2985 assemblies

Parameter	Description
Waste Classification at the Time of Generation	HLW
Main Radionuclides and Radioactivity	Refer to Reference [40].
Hazardous Substances or Non-hazardous Pollutants	None.

This sub-chapter focuses on the management strategy for the spent fuel and relevant interim storage design of the UK HPR1000. The parameters of fuel design are presented in PCSR Chapter 5, Reference [58] and the fuel storage in the SFP is presented in PCSR Chapter 10 and Chapter 28, Reference [34] and [54]. Details of the design proposal and safety case for SFIS are presented in PCSR Chapter 29, Reference [6] and summarised in this sub-chapter.

4.7.5.2 Spent Fuel Management Strategy

The spent fuel management strategy for the UK HPR1000 is divided into the following three phases:

a) Short Term Storage in the SFP

The SFAs removed from the reactor core are first stored in the SFP in the BFX for several years. This stage is designed to cool the spent fuels and reduce its radioactivity, thereby improving safety during the subsequent transfer of the spent fuels. The SFP has the capability to store the SFAs generated from about 10 refuelling cycles, with an average number of 72 SFAs being generated from a refuelling cycle. The design of the SFP is also required to accommodate a full core emergency unload, which accounts for 177 fuel assemblies.

More information relevant to fuel handling and short term storage within the BFX is presented in PCSR Chapter 10 and Chapter 28, References [34] and [54].

b) On-site Interim Storage

After short term storage in the SFP, the SFAs are loaded into fuel storage canister and moved into an on-site facility for interim storage designed for at least 100 years, prior to retrieval and repackaging for off-site disposal. The interim storage facility and time of storage is currently designed to accommodate the spent fuels generated during the 60 years operation time of two UK HPR1000 units.

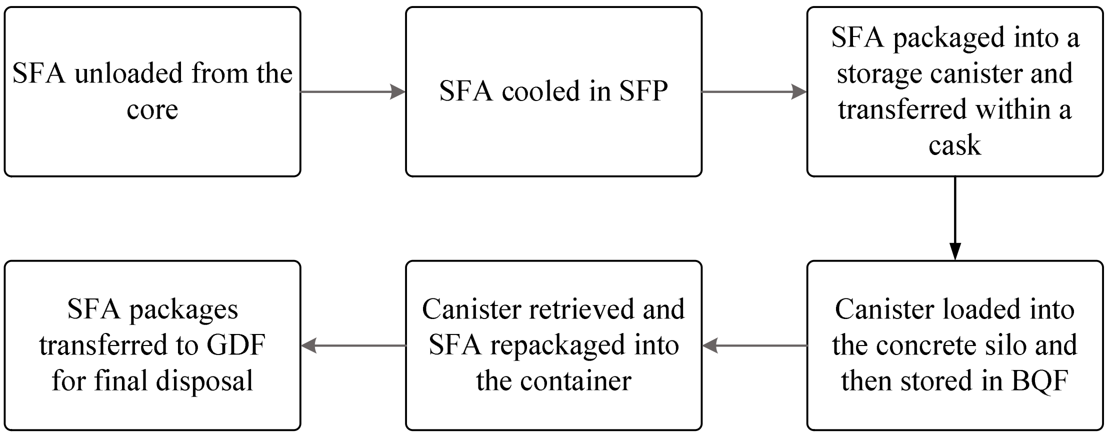
c) Off-site Disposal in the GDF

After the interim storage on-site, the SFAs are expected to be transported to the GDF for final disposal, following the on-site retrieval and repackaging. This is consistent with the assumption in the Base Case, Reference [17].

Currently, there is no final disposal facility (GDF) in the UK. In order to ensure that the SFAs can be safely disposed of in all potential scenarios, the UK HPR1000 storage facility will consider the option of retrieval of SFAs from the fuel storage canisters. When the GDF is available to receive the SFAs from the UK HPR1000, the SFAs are to be repackaged into an appropriate container depending on the final disposal and transportation requirements, prior to the off-site transport and final disposal.

As the retrieval and repackaging will not be conducted until the GDF is available (assumed to be decades away), the design for the retrieval and repackaging is out of the GDA scope.

The management route of the SFAs is shown in F-4.7-6.



F-4.7-6 Spent Fuel Management Proposal

The failed fuel is stored in the SFP until the decommissioning of BFX. More information is presented in PCSR Chapter 28, Reference [54]. The potential options for failed fuel management after removal from the SFP are presented in PCSR Chapter 29 and relevant supporting document, References [6] and [59]. During the GDA stage, the final management strategy of failed fuel is not determined.

4.7.5.3 Spent Fuel Interim Storage

The BQF is designed to receive the SFAs and other potential high level wastes, such as RCCAs, SCCAs and part of the ICIAs. This sub-chapter provides an overview of the design proposal for spent fuel interim storage. More information for the technical process and the facility BQF is presented in PCSR Chapter 29, Reference [6], and in the *Spent Fuel Interim Storage Facility Design*, Reference [59]. The design proposal for the BQF aims to show that the facility can be built in the generic site to safely store the spent fuels and HLW mentioned above, in compliance with the UK environmental and safety requirements. The design proposal also aims to demonstrate that the risks over the lifetime of the facility are ALARP, and that the impact on people and the environment has been minimised, taking into account all of relevant factors at GDA stage. Future operators will develop their own design proposal based on the latest regulations and conditions through the BAT and ALARP analysis (FAP-4-4).

The location for the BQF is a site specific decision. It will be chosen to notably minimise dose at the site boundary as far as practicable (through maximising the distance to the site boundary for example).

4.7.5.3.1 Technology Optioneering

According to worldwide OPEX and IAEA guidance, Reference [60], there are three different types of spent fuel interim storage technology:

a) Wet storage in pools;

b) Dry storage in either storage or dual purpose casks; and,

c) Dry storage in vault type storage facilities.

The wet SFIS technology has been historically used for the temporary storage and cooling at reactor sites and in some interim off-site storage facilities generally associated with disposal or reprocessing sites (in anticipation of the next step in the cycle). The wet SFIS technology is considered to be a mature technology.

Since 1980s, a variety of dry SFIS technologies has been developed and applied recently in the international market. Dry SFIS technology with concrete overpacks and metal canisters has been selected as an appropriate technology at Sizewell B and Hinkley Point C in the UK. In addition, the UK Advanced Boiling Water Reactor (ABWR) design adopts a conceptual design for the dry SFIS technology with casks. Dry SFIS storage is also a mature technology, which has been developed over the past 30 years, especially in the USA, and can be regarded as an established industrial technology.

A systematic optioneering process has been followed for the technology optioneering for the SFIS. International OPEX and RGP, especially UK OPEX and RGP are also taken into consideration when comparing options for the technology. The criteria for the technology evaluation are then developed considering the experience from UK projects and international RGP. After the formal process of options assessment and decision-making, the dry storage in casks has been selected to be the preferred technology for SFIS for UK HPR1000 in the GDA stage. Detailed information on the technology optioneering is presented in *Technology Optioneering on Spent Fuel Interim Storage*, Reference [33].

4.7.5.3.2 Storage Capacity

The BQF is designed to receive SFAs, RCCAs, SCCAs and part of the ICIAs (ICIAs (i&ii)). The BQF is planned to be constructed in two phases based on an optioneering process presented in Sub-chapter 6.2.1 of *Spent Fuel Interim Storage Facility Design*, Reference [59], considering nuclear safety, conventional safety, environmental impact, technical feasibility, economy and security factors.

The storage capacity of the first phase facility is to be designed to accommodate the spent fuels and HLW packages generated by two UK HPR1000 units during the initial operation period of 30 years. The waste information is presented in T-4.7-17.

The capacity of the second phase facility is to be designed to accommodate the packages to be generated during the remaining operation period and the decommissioning, of two UK HPR1000 units, taking into account the relevant factors notably the actual annual arising of spent fuel and HLW for each unit during the operational phase of UK HPR1000.

T-4.7-17 General Information on Spent Fuel and Wastes to be Stored within BQF for One UK HPR1000 Unit

Parameter	Values (One unit)
SFAs, RCCAs and SCCAs	
Average SFAs generated from one refuelling operations	72 SFAs (equilibrium cycle) 177 SFAs (last cycle)
Change cycle frequency for SFAs	1.5 years
Total number of fuel assemblies discharged over 60 years in operation (considering equilibrium cycles, single nuclear power units and 18-months refuelling pattern)	2985 SFAs
Average RCCAs generated from each change cycle	68 RCCAs
Change cycle frequency for RCCAs	15 years
Total number discharged over 60 years	272 RCCAs
Average SCCAs generated from each change cycle	106 TPAs

Parameter	Values (One unit)
	3 PNSAs
	3 SNSAs
Change cycle frequency for SCCAs	20 years (TPAs)
	/[1)]
	15 years (SNSAs)
Total number discharged over 60 years	333 SCCAs
Number of assemblies in one fuel storage canister	32 SFAs 8 RCCAs or SCCAs
Total number of canister required	94
ICIAs	
Change cycle frequency	ICIAs (i&ii): 54 months
Total number discharged over 60 years	ICIA (i&ii): 560 sets
The number of ICIAs per container	8 sets
Total number of container required	70
1) The PNSA only are used for first cycle.	

4.7.5.3.3 Storage Process

a) Overall Process for SFIS

On the basis of the technology optioneering, the dry storage in casks is selected as the preferred option in GDA and a design based on dry storage in concrete silos is developed considering UK OPEX.

The main process flow for the SFIS, referring to the most important fuel/canister/cask handling process in the conceptual design, is presented in F-4.7-7. This includes the operations in the BFX, BQF and the designated retrieval and repackaging facility. During the operations, the inspection and monitoring measures, such as cask integrity inspection, cask surface contamination detection, and sealing integrity inspection are undertaken using portable equipment and the actual measures undertaken depend on the performance of specific products. The process related to the inspection and monitoring during the fuel/canister/cask handling process will be further developed in the detailed design, when the specific products suppliers have been selected in the site licensing phase. The operations related to SFIS consist of the following three sub-processes:

1) Handling and transfer process inside the BFX;

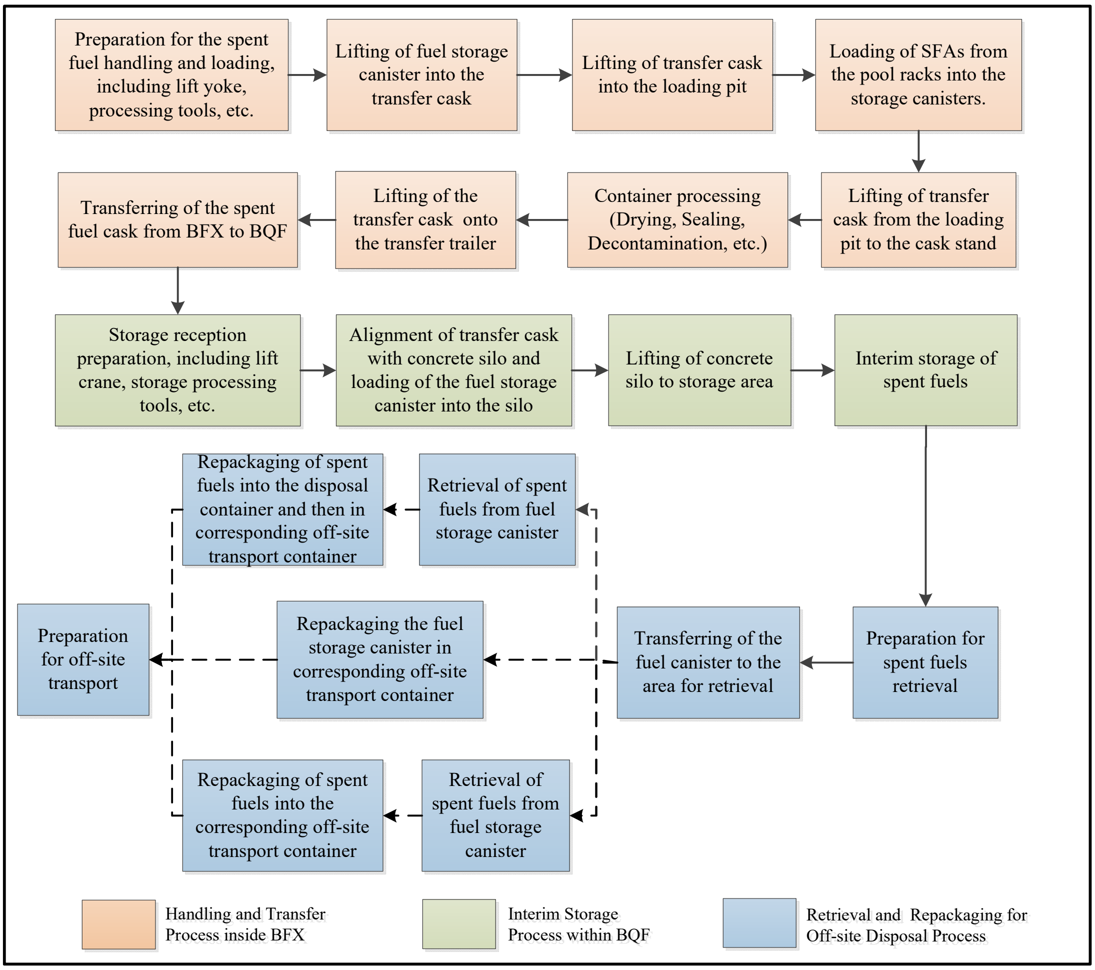
2) Interim storage of spent fuels within the BQF; and,

3) Retrieval, repackaging and transport for off-site disposal process.

To assist in understanding the process is illustrated in diagram in F-4.7-7 and the terms mentioned in this sub-chapter are explained in T-4.7-18.

T-4.7-18 Terminology for Spent Fuel Management

No.	SSC	Typical Materials	Functions
1	Fuel storage canister	Stainless Steel, Neutron Absorber	The fuel storage canister is the basic unit of fuel handling and interim storage, and is used to ensure the safety functions of SFIS, including the control of sub-criticality, removal of heat, confinement of radioactive material and the retrievability of the spent fuels.
2	Transfer cask	Stainless Steel, Boracic Polyethylene	The transfer cask is the over-pack for the fuel storage canister during on-site transfer, and is used to protect the fuel storage canister against hazards and provide the necessary radiation shielding.
3	Concrete silo	Concrete	The concrete silo is the over-pack for the fuel storage canister during the interim storage period, and is used to protect the fuel storage canister against hazards, and provide the necessary radiation shielding and passive heat removal.



F-4.7-7 Process Flow of SFIS

The detailed information for the main process flow of the SFIS is presented in the *Spent Fuel Interim Storage Facility Design,* Reference [59] and PCSR Chapter 29, Sub-chapter 29.6.2.2, Reference [6].

No gaseous and liquid discharges are expected to be generated during the dry storage of spent fuels. More information on waste management considerations has been provided in *The Matching Analysis of Selected SFIS Technology with Current UK HPR1000 Design*, Reference [61]. The direct dose from the store is also analysed and presented in PCER Chapter 7 and in the *Preliminary Safety Evaluation of Spent Fuel Interim Storage*, Reference [62].

b) ICIAs Package Management in BQF

The ICIAs waste packages are 500 litre robust shielded drum, which is made of ductile cast iron with 160 mm thickness. Additional internal stainless steel shielding thickness (150mm) is also present, which provides sufficient shielding to protect the operator during handling and transport operations of the packages on-site without any additional shielding over-package. The general process for import and export of the waste packages is presented as follow:

1) Import of the ICIAs waste packages;
2) Storage of waste packages; and,
3) Export of the ICIAs waste packages.

4.7.5.3.4 Facility Layout

To achieve the safety and operational functions, the layout within the BQF is divided into the auxiliary area, operation area and storage area. The preliminary layout of the BQF is presented in Appendix 29B of PCSR Chapter 29, Reference [6]. This represents the first phase layout of the BQF.

a) Auxiliary Area

The auxiliary area includes access for workers, access for equipment, control and monitoring room, duty room, power distribution room, and the fan room, which functions are to perform the control of personnel entry/exit, equipment operation, environmental conditions parameters adjustment and inspection/maintenance of storage structure.

b) Operation Area

The operation area houses the equipment for the receipt of the transfer cask, the processing of the transfer cask, the transfer of the fuel storage cask into the concrete silo and the lifting of the concrete silo into the storage area. A specific lifting machine is equipped to lift the transfer cask and concrete silo in this area. Further detail on these areas is presented below:

1) The receipt/export area is designed to receive the transfer casks from the BFX, and to export the transfer casks to the specific retrieval and repackaging facility;
2) The underground concrete vault is designed for holding the concrete silo, whilst the fuel storage canister is transferred from the transfer cask into the concrete silo for interim storage, or from the concrete silo into the transfer cask for retrieval; and,
3) The transfer path is designed as the specific path for lifting the loaded concrete silo to the planned storage area or for retrieving the concrete silo from the storage area to the underground concrete vault.

c) Storage Area

The storage area provides stable environmental conditions for the SFAs and other packages. This area includes the:

1) Concrete silo storage area - is an area for storing the concrete silos containing spent fuel canisters, with temperature and radiation detection to ensure the

safety during interim storage period;

2) Other packages storage area - is an area designed for the storage of other wastes, currently includes an integral independent room to store the 500 litre robust shielded drum with ICIAs waste, which is isolated from other areas by concrete wall and roof, to provide effective containment and shielding. The ICIAs storage room is equipped with ventilation system to maintain the environmental condition for waste packages safe storage and prevent leakage of radioactive material; and,

3) Equipment storage area - is an area for storage of equipment and components that are necessary and are planned to be reused during SFIS relevant operations, when they are not used. For example, the welding system, automatic vacuum system, transfer cask, drainage pump, helium filling system, etc. are planned to be stored in this area. A specific contaminated equipment storage area is also considered in this area to store the equipment with potential contamination, such as automatic vacuum system and drainage pump.

4.7.5.3.5 Monitoring

During the interim storage period, the safety of the SFAs is ensured through passive patterns. The monitoring measures are designed to confirm the operating conditions and judge whether additional measures are required. Temperature monitoring of the ventilation outlet of the concrete silo and dose rate monitoring at the surface of the concrete silo are considered in the design. For HLW storage, necessary monitoring and control measures are also considered. Detailed information is presented in PCSR Chapter 29, Sub-chapter 29.6.2.6, Reference [6].

4.7.5.3.6 Record Keeping

To ensure the relevant control of nuclear material (notably spent fuel) within the nuclear power plant, and the safety of SFIS process and to ensure information required by the GDF operator will be available, the following records are proposed to be made, which is consistent with the record management principles described in Sub-chapter 4.6.4 of this document:

a) Before the loading of the spent fuel and RCCAs/SCCAs (if any) into the fuel storage canister, the in-core history of the spent fuel and RCCAs/SCCAs in the SFP is checked according to the record of refuelling. The information of the spent fuel and any RCCAs/SCCAs to be loaded, including burn-up, cooling time, and previous position in the pool is recorded;

b) The serial number of the fuel storage canister is recorded before it is loaded into transfer cask;

c) The details of the operation are recorded which contribute to the evaluation of the performance of spent fuels within the canister. The details include the date of the operation, the start time, prospective finish time and actual finish time;

d) The serial number of the concrete silo is recorded before the loading of the fuel canister into the silo;

e) After the lifting of the concrete silo into the designated area, the storage position of each concrete silo is recorded, which can match with the spent fuel information and contribute to nuclear material management;

f) During interim storage of spent fuel, the records from monitoring, inspection and maintenance will also be conserved in order to check the safe operation of the facility and to provide information to subsequent manager if necessary;

g) The ICIAs package characteristics (i.e. package type, treatment process, production date and unique identifier), all radiological and non-radiological information (i.e. radionuclide activity, chemical characteristics, surface dose rate and contamination level of waste packages) and waste package management information (i.e. storage position, disposal route, monitoring and inspection records and maintenance records) will be recorded to achieve the safety operation management of the facility and to provide relevant information to final disposal facility owner; and,

h) Any information that will be required by the GDF owner.

4.7.6 Decommissioning Radioactive Waste

The decommissioning strategy of the UK HPR1000 is based on an assumed plant status at the end of the operational phase and an assumed target end point for decommissioning. According to IAEA and international practice, three viable strategies are presented, including one immediate dismantling strategy and two deferred dismantling strategies. The preferred decommissioning strategy for the UK HPR1000 is selected through an optioneering analysis, which is detailed in Appendix A of the *Preliminary Decommissioning Plan*, Reference [63].

Immediate decommissioning provides the clearance of the site at the earliest opportunity, reducing the lifespan of the hazards and risks. This also aligns with UK government policy. Therefore, immediate decommissioning is selected as the preferred decommissioning strategy for the UK HPR1000 at the GDA stage. The decommissioning strategy referenced in this sub-chapter aims to support the waste categorisation and demonstrate that the radioactive waste generated during the UK HPR1000 decommissioning stage can be estimated, categorised and treated safely, conditioned and packaged for appropriate disposal.

The inventory and management proposal for the decommissioning radioactive waste are summarised in this sub-chapter and detailed in the PCSR Chapter 24 and *Decommissioning Waste Management Proposal*, References [5] and [64]. The options described in this sub-chapter are not foreclosed and the operators will define their strategy and select the most appropriate option through BAT and ALARP analysis during the site licensing phase (FAP-4-2).

The end state for a nuclear power plant is where all licensable activities have ceased and the site licence is revoked and the period of responsibility under the *Nuclear Installation Act* (1965) has ended. This is referred to as the delicensing stage. The end state for the UK HPR1000 is not fixed at this time, and will be agreed by the licensee with the relevant stakeholders during the decommissioning phase. The licensee will need to demonstrate there is no danger from ionising radiation. When there are no other interim or reuse states agreed, this end state (as described above) should be assumed by the licensee. As a minimum it is assumed that any site with a UK HPR1000 will be decommissioned such that the site can be delicensed.

According to the *Guidance on the Requirements on Release from Radioactive Substances Regulation (GRR)*, Reference [15], the operators are expected to apply for release from Radioactive Substances Regulation (RSR) only when the site (or part of the site) is close to achieving the reference state. The detailed application process differs between Scotland, and England and Wales and it is highly site specific. Therefore, consideration for the site release from RSR is out of GDA scope and will be considered by the operator at appropriate time.

4.7.6.1 Waste Arising

When the nuclear power plant is finally shut down and enters the decommissioning stage, the state of the nuclear power plant is changed from normal nuclear power generation to discharge of all fuel for decontamination and demolition. From this point, the origin of radioactive waste generation is quite different from that during operation, e.g. waste generated from decommissioning of main equipment.

Design for facilitating decommissioning ensures that the generation of wastes is minimised during the decommissioning of the UK HPR1000. These considerations include:

a) Easily activated elements are avoided and controlled as far as reasonably practicable, and the impurity content in materials is strictly limited;

b) Materials with a dense surface, good corrosion resistance and easy-to-clean are selected and porous materials are avoided in pollution-prone areas;

c) Reusable or recyclable materials are selected, such as recyclable metals and concrete;

d) The use of special surface finishes or polishing treatments for internal and external surfaces of equipment and pipes to minimise possible contaminant accumulation until entering the decommissioning phase;

e) Lining and decontaminable paints are used where relevant.

Decommissioning radioactive waste can be divided into radioactive gaseous and airborne waste, radioactive liquid waste and radioactive solid waste.

4.7.6.1.1 Radioactive Gaseous and Airborne Waste

Before the nuclear power plant is dismantled, the gaseous radioactive waste systems are to be emptied, and therefore there is minimal radioactive gaseous and airborne waste generated at decommissioning stage. The main production mechanisms are:

a) Gas generated by chemical reactions during the decontamination process; and,

b) Airborne radioactive particulates generated during specific decommissioning operations, e.g. cutting processes.

4.7.6.1.2 Radioactive Liquid Waste

Radioactive liquid waste is mainly generated as a secondary waste resulting from decommissioning activities, including decontamination operation (e.g. pond drain down and cleaning, tank clean cuts), physical (water based), cutting processes, etc.

4.7.6.1.3 Radioactive Solid Waste

Radioactive solid waste accounts for the largest proportion of all the radioactive waste generated during decommissioning. It includes neutron-activated materials, contaminated materials and other radioactive wastes.

Typically decommissioning radioactive solid wastes include (not limit to): system equipment and components, piping, concrete, metal, secondary waste (e.g. ion spent resins, spent filter cartridges and activated charcoal from delay beds of TEG [GWTS]) and other miscellaneous waste generated during decommissioning activities.

In order to reduce the radioactive waste volume to be disposed of, the concrete, equipment and components are decontaminated before being dismantled as far as possible during decommissioning.

4.7.6.2 Decommissioning Radioactive Waste Volume

A full range of waste minimisation methods are and will be used to reduce the amount of radioactive solid waste to as low as possible. These methods include decontamination, volume and size reduction, characterisation and appropriate segregation of the waste.

The preliminary estimated volume of radioactive solid waste and its classification is shown in T-4.7-19. A number of conservative assumptions and detailed principles have been used to estimate the quantity of the decommissioning waste, and the detailed inventory is described in Sub-chapter 4.2.1 of *Decommissioning Waste Management Proposal*, Reference [64]. Since decommissioning of the UK HPR1000 will not happen before many decades and it is very difficult to accurately predict what will happen during the operation of the plant over its planned 60 years life, it is almost impossible to obtain the exact source term data at this stage.

Therefore, the decommissioning source term is predicted by theoretical analysis based on design features of the UK HPR1000 and OPEX data at this stage. Detailed source term information for decommissioning is presented in documents *Activated Structures Sources Term Supporting Report*, Reference [38] and *Decommissioning Technical User Source Term Report*, Reference [65]. Once the UK HPR1000 is operational, this preliminary decommissioning waste inventory can be refined against a more realistic inventory that reflects the operational history of the reactor. Radiological surveys, undertaken immediately before decommissioning, will provide further confidence in the estimation of the decommissioning waste inventory.

T-4.7-19 Decommissioning Radioactive Solid Waste Volume for One UK HPR1000 Unit and Classification

NO.	Classification	Component and Equipment	Volume(m^3)	Waste Classification
1	Main Equipment	Reactor Vessel Internals (RVI)	18.0	ILW
			1.8	LLW
		RPV (except for RVIs)	50.0	ILW
		Insulation layer (RPV, Steam Generator (SG), pressuriser, reactor coolant pumps)	381.8	LLW
		Steam generator	930.0	LLW
		Reactor coolant pumps	255.0[1)]	LLW
		Pressuriser	82.0	LLW
		Main coolant lines	15.2	LLW
		Insulation layer of main coolant lines	36.6	LLW
		Surge line including	9.7	LLW

NO.	Classification	Component and Equipment	Volume(m^3)	Waste Classification
		insulation layer		
		Support (RPV, SG, pressuriser, reactor coolant pumps)	42.3	LLW
		Control rod drive mechanism	12.5	LLW
2	Auxiliary Equipment & Piping	Auxiliary equipment	3899.6	LLW/VLLW
		Electric and instrument	109.4	LLW/VLLW
		Valves	517.2	LLW/VLLW
		Piping, support and hanger	1577.6	LLW/VLLW
		Crane	154.0	LLW/VLLW
3	Concrete	Activated concrete	150.1	ILW
			640.1	LLW/VLLW
		Other contaminated concrete	2591.0	LLW/VLLW
4	Metal	Steel platform, Grille plate, Guardrail, Steel staircase, Fence door, etc.	141.3	LLW/VLLW
5	Secondary Waste	Spent resins[2)]	40	ILW
		Spent filter cartridges[3)]	1.4	ILW
		Activated charcoal from delay beds of TEG [GWTS]	14.4	VLLW
6	Miscellaneous Waste	Labour protection supplies, Decontamination supplies, Special tools etc.	609.0	LLW/VLLW

NO.	Classification	Component and Equipment	Volume(m^3)	Waste Classification
7	Total		259.5	ILW
			12020.5	LLW/VLLW

1) The volume of reactor coolant pumps will be updated after the final type of reactor coolant pumps is determined.

2) The spent resins are mainly from the decontamination operations and the SFP operation during decommissioning.

3) The spent filter cartridges are mainly from the SFP operation during decommissioning.

4.7.6.3 Decommissioning Radioactive Waste Management

This sub-chapter provides the detailed proposal for the management of the radioactive wastes arising from the UK HPR1000 at decommissioning stage, including the radioactive gaseous and airborne waste, radioactive liquid waste and radioactive solid waste.

4.7.6.3.1 Radioactive Gaseous and Airborne Waste

There are generally low levels of radioactive gaseous or airborne effluent generated during decommissioning and these can be treated and discharged by the existing HVAC systems if still available, safe to use and demonstrated to be ALARP and BAT or, as these systems are dismantled, temporary HVAC systems will be installed to ensure that discharges are minimised.

4.7.6.3.2 Radioactive Liquid Waste

Liquid effluents arise from decontamination and dismantling activities (water cooling for cutting for example), as well as from drains and washrooms.

In the early stages of decommissioning, radioactive liquid waste are to be treated by the existing effluent management systems if they are available, still safe to use and demonstrated to be ALARP and BAT. As these systems are progressively decontaminated and dismantled, it will be necessary to install temporary liquid effluent treatment facilities to ensure that liquid effluent discharges are minimised.

4.7.6.3.3 Radioactive Solid Waste

A significant volume of solid wastes are to be generated during decommissioning and their management plays a key part in decommissioning the nuclear island, as it will generate the greatest variety of radioactive wastes.

The radioactive solid wastes include activated materials as a result of reactor operation, such as the RVIs, RPV, activated concrete and surface contaminated materials, particularly items contaminated by radionuclides deposited from the primary circuit coolant.

There are some secondary waste from decontamination operations and operation during decommissioning, as well as continued process waste arising as a result of treatment of radioactive effluent, such as spent resins and spent filter cartridges.

Decommissioning radioactive solid wastes are to be ILW, LLW and VLLW depending on their origin. The majority of these wastes can be reused and recycled after being decontaminated. Recycling of decommissioning equipment and components can significantly reduce the amount or volume of wastes to be disposed of. The radioactive solid wastes generated during the decommissioning of the UK HPR1000 which cannot be reused are to be treated and conditioned by a suitable process before disposal.

Waste characterisation and segregation also plays an important role in reducing the amount and volume of the waste arising during decommissioning which is similar as that arising during the operational stage. Effective characterisation and segregation ensures that unnecessary cross-contamination of waste does not occur and that subsequent management is safe and effective. For the management of solid waste during decommissioning of the UK HPR1000, the future operator will adopt the suitable facilities to apply the waste characterisation and segregation to help segregate the waste effectively and help the operator in selecting optimal management and disposal routes.

Based on the considerations mentioned above, the management proposal of decommissioning radioactive solid waste are developed and presented in F-4.7-8 and described in the following paragraphs.

a) ILW Spent Resins

The ILW spent resins from decommissioning are to be treated in the same way as proposed for operational spent resins as they are expected to have similar characteristics. They are dewatered and packaged in 500 litre robust shielded drums (e.g. MOSAIK container). The packaged resins are then transferred to the BQZ until the GDF becomes available for receiving UK HPR1000 waste during the decommissioning of the UK HPR1000, then waste packages are to be transferred to the GDF.

Some of the ILW spent resins could be identified as boundary waste if decay storage into LLW is achievable after short decay time, according to the *Guidance on Decision Making for Management of Wastes Close to the LLW and ILW Categorisation Boundary that Could Potentially Cross the LLW boundary*, Reference [53]. These ILW spent resins are to be immobilised by mixing them with cement in the 210 litre drums, and then the packages are to be transferred to the BQZ for decay storage. The waste packages are then to be transferred to LLWR disposal facility when they are decayed into LLW.

b) ILW Spent Filter Cartridges

The ILW spent filter cartridges from decommissioning are to be treated in the same way as that proposed for operational spent filter cartridges as they are expected to have similar characteristics. They are to be immobilised with cement grout in 3 cubic metre box, and then the packaged spent filter cartridges are to be transferred to the BQZ until the GDF becomes available to receive waste from the UK HPR1000. If GDF becomes available for receiving UK HPR1000 waste during the decommissioning of the UK HPR1000, then waste packages are to be transferred to the GDF.

c) RPV and ILW Concrete

For the RPV and ILW concrete, these are segmented within the reactor building and packaged into suitable and approved UK disposal containers. These wastes are to be immobilised with cement grout within the containers and then transferred to the BQZ for on-site storage until the GDF becomes available for receiving UK HPR1000 waste. If GDF becomes available for receiving UK HPR1000 waste during the decommissioning of the UK HPR1000, then the waste packages are to be consigned to the GDF.

For the RPV and ILW concrete, it is proposed to package the segmented vessel and ILW concrete into 4 metre box, since this can reduce the number of cuts required, thence reducing the risks and impacts associated with cutting, e.g. the dose rate to the worker, dispersion of radioactivity, secondary waste generation. Considering that decommissioning will happen in minimum 60 years in the future and new or improved UK standard containers for HAW maybe developed, 4 meter box is the proposed package container for RPV and ILW concrete during this GDA stage. The future operator will undertake the optioneering study to select the appropriate container for RPV and ILW concrete generated from decommissioning at the relevant time in the future, considering BAT and ALARP (FAP-4-5).

d) RVIs

RVIs are segmented within the reactor building and packaged into suitable and approved UK disposal containers. These wastes are to be immobilised with cement grout within the containers and then transferred to the BQZ for on-site storage until the GDF becomes available to receive waste packages from the UK HPR1000. If the GDF becomes available for receiving UK HPR1000 waste during the decommissioning of the UK HPR1000, then the waste packages are to be consigned to the GDF.

Due to the high radioactivity levels of RVIs, only one RVI (or less) can be loaded in a Type IP-2 transport package (i.e. 4 metre box, 2 metre box and 6 cubic metre concrete box) while several RVIs could be loaded in a 3 cubic metre box, thence minimising the number of waste packages to be disposed of. Thus, it is proposed to package these waste into 3 cubic metre box. Considering that decommissioning will happen in minimum 60 years in the future and new or improved UK standard containers for HAW maybe developed, 3 cubic meter box is the proposed package container for RVIs during this GDA stage. The future operator will undertake the optioneering study to select the appropriate container for RVIs generated from decommissioning at the relevant time in the future, considering BAT and ALARP (FAP-4-5).

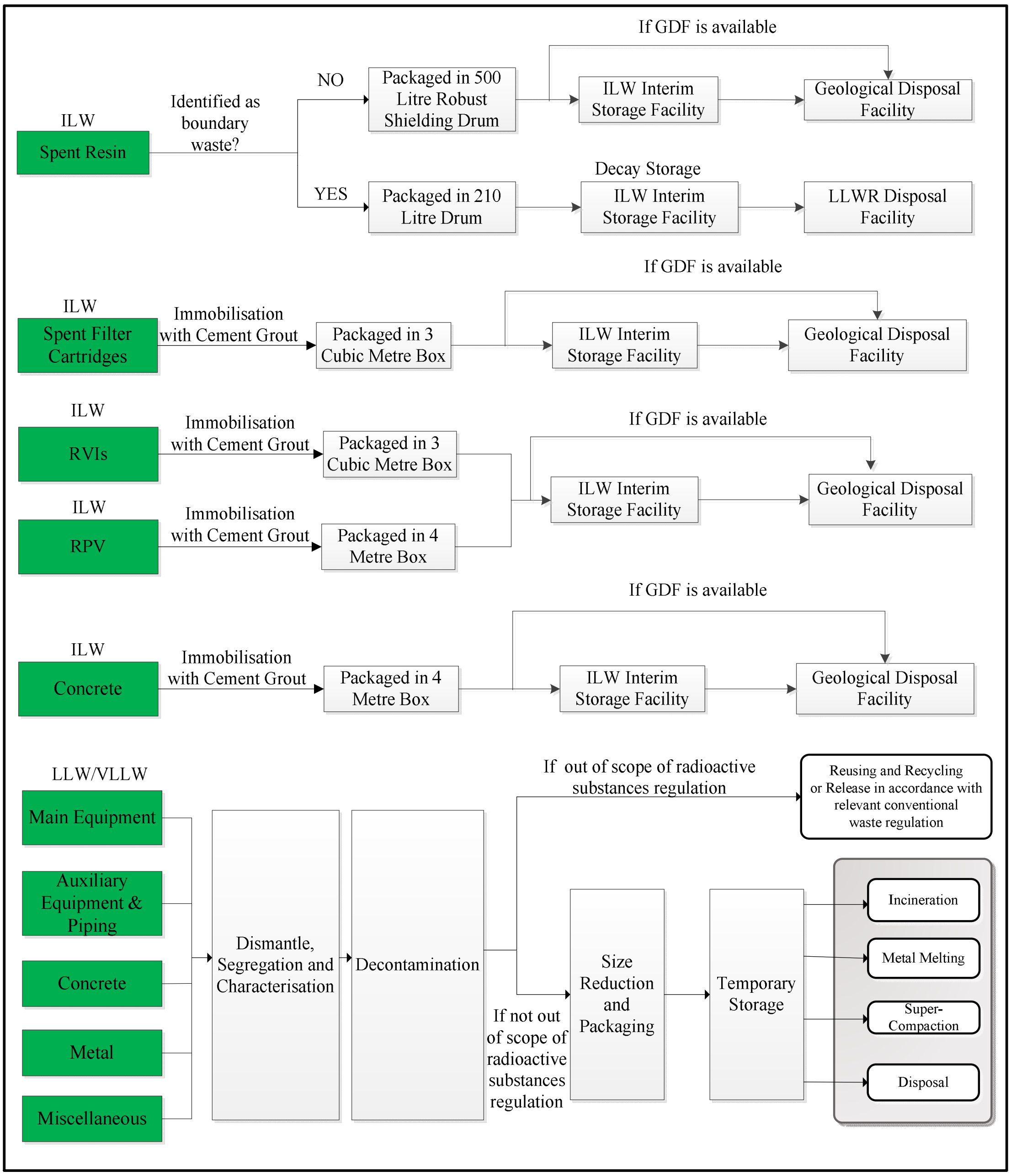
e) LLW/VLLW

LLW/VLLW generated from the decommissioning of the UK HPR1000 can be grouped into five main categories: main equipment, auxiliary equipment & piping, concrete, metal and miscellaneous waste, as presented in T-4.7-19.

These wastes are dismantled (where possible), segregated and characterised firstly in relevant waste management buildings. To apply the waste hierarchy, the decontamination is implemented for some wastes (to be determined by the future operator) and this can result in some wastes becoming out of scope of radioactive substances regulation. These wastes will be reused and recycled (where possible) or released in line with relevant regulations.

The LLW/VLLW wastes which cannot become out of scope of radioactive substances regulation are size reduced (where possible) and packaged into an appropriate container for the identified waste treatment or disposal route. These waste packages are then buffer stored on-site prior to being sent off-site.

For the LLW/VLLW generated during the decommissioning of the UK HPR1000, it is planned to package these waste according to the WAC for the relevant treatment or disposal facilities. The proposed waste containers are HHISO container.



F-4.7-8 Decommissioning Solid Waste Management Proposal

Based on the waste volume estimated, the package container selected and the management proposal, the waste volumes for the final packages are estimated and shown in T-4.7-20.

T-4.7-20 Decommissioning Radioactive Waste Classification, Proposed Container and Waste Volume for Final Packages for one UK HPR1000 Unit

Waste Types	Waste Classification	Proposed Container	Waste Volume/m^3	Final Packages Volume/m^3
RPV	ILW	4 metre box	50	374

Waste Types	Waste Classification	Proposed Container	Waste Volume/m^3	Final Packages Volume/m^3
RVIs	ILW	3 cubic metre box	18	74
Spent resins	ILW	500 litre robust shielded drum	40	110.5
Spent Filter Cartridges	ILW	3 cubic metre box	1.4	7.4
Concretes	ILW	4 metre box	150	352
Other equipment and concrete wastes	LLW/VLLW	HHISO	12021	28196
Total	/		12280	29110

4.7.6.4 Interim Storage

Based on UK requirements, LLW packages can be treated and/or disposed of off-site immediately or soon after being generated. Therefore, there is no dedicated LLW interim storage facility on-site but some buffer storage areas will be reserved.

ILW packages need to be stored on-site in the BQZ and some ILW identified as ILW/LLW boundary waste will also be stored in the BQZ. The BQZ is designed to last for at least 100 years, as is required by the UK industry guidance, Reference [10].

Therefore:

a) LLW packages generated during decommissioning are to be buffer stored on-site in the dedicated buffer storage area (to be defined by the future operator) before being sent to the off-site treatment and/or disposal facility;

b) ILW packages generated during decommissioning are to be stored in the BQZ before being sent to the GDF, assuming that the GDF is not available for the UK HPR1000 waste during the UK HPR1000 decommissioning stage; and,

c) ILW wastes generated during decommissioning which are identified as ILW/LLW boundary waste are to be decay stored in the BQZ until they have decayed to LLW. After the decay period, they will be sent to the off-site treatment and/or disposal facility.

4.8 The Development of an Integrated Waste Strategy

In ONR's Safety Assessment Principle (SAP), Reference [3], and the EA's REPs, Reference [2], a strategy for the management of radioactive waste is required:

a) SAP RW.1 - A strategy should be produced and implemented for the management of radioactive waste on-site; and,

b) Principle RSMDP1: Radioactive Substances Strategy - A strategy should be produced for the management of all radioactive substances.

In line with UK policy and expectations, an IWS document has been produced for the UK HPR1000 which presents an overarching description of waste strategy, Reference [16]. In the IWS document, a summary of waste arisings, the management strategy for these wastes, and the approach to develop the waste management strategy for all the waste streams and spent fuel generated by the UK HPR1000 are described. Assumptions, risks and opportunities for implementing the waste management strategy and available solutions within the envelope of current UK options are also identified. The IWS document refers to and is supported by a suit of documentations.

The IWS document is a live document which will evolve and be updated at the relevant steps during site licensing phase (FAP-4-6). At GDA stage, the IWS document shall preserve as much flexibility as possible to enable the site licensee to develop a site specific IWS to incorporate future changes in waste management technologies and regulatory principles.

4.9 Disposability Assessment

4.9.1 LLWR Acceptance in Principle

In the UK, the waste service suppliers provide a wide range of waste services to the UK nuclear industry. The WAC published by the waste service suppliers, Reference [48], [49], [50], [51] and [52], are used to demonstrate that LAW packages generated by the UK HPR1000 can be compatible with off-site facilities and no orphan waste will be generated. Based on the assumption presented in Sub-chapter 4.5, establishing an 'Agreement in Principle' with LLWR during GDA ensures that LAW generated during reactor operation can be accepted by off-site facilities and will not accumulate on-site.

In order to support the establishment of the "Agreement in Principle", the "*UK HPR1000 Waste Enquiry Form*", Reference [66], was prepared and submitted to LLWR to undertake disposability in principle assessment for UK HPR1000. LLWR has conducted their assessment and sets out their current position around the likely acceptability of the wastes for disposal at the LLWR or via their current treatment/disposal providers, and explains the issues and constraints surrounding the waste for disposal. Details are presented in the letter "*Disposability in Principle Assessment for UK HPR1000*", Reference [67].

In Reference [66], ventilation filter cartridge is proposed to be packaged into 210 litre drum. Since then, it has been decided to package these filters in appropriate bags to allow opportunities to utilise alternative treatment solutions in the future to support application of the waste hierarchy and in line with LLWR recommendation in their

"Agreement in Principle" letter, Reference [67]. Change of package type does not impact the characteristics of ventilation filter cartridge and bag is also one of the package types that are accepted by LLWR for ventilation filter cartridge packaging (Sizewell B practice). Therefore, this change does not impact the validity of the "Agreement in Principle" that has been granted by LLWR, Reference [67].

Regarding the issues and constraints raised by LLWR, response has been provided in the "*Response to LLWR Agreement in Principle*", Reference [68], which conclude that there is no particular risk for any waste stream to become orphan waste and/or to result in significant burden or risk/impact at site licensing stage.

At site licensing stage, the future operator will continually undertake applicable activities to ensure that all LAW generated by the UK HPR1000 can be safely managed and disposed of in line with the principles of ALARP and BAT (FAP-4-7).

According to the GDA scope shown in Reference [69], the disposability of LLW decommissioning waste is out of the GDA scope. Therefore, the analysis of acceptability of the LLW decommissioning waste for off-site treatment and disposal is not undertaken during the GDA stage. The future operator will undertake the acceptability analysis and obtain relevant agreements from LLWR or other waste services provider for LLW generated during the UK HPR1000 decommissioning to ensure that LLW decommissioning waste can be accepted by off-site facilities and to minimise the accumulation of radioactive waste on-site (FAP-4-7).

It is noted that the final management routes for LAW will be determined by the future operator considering the principles of BAT and ALARP (FAP-4-2).

4.9.2 Disposability Assessment of HAW

The GDF is under development and is not expected to be available for a number of decades. A part of the solid radioactive waste generated by the UK HPR1000 will be too radioactive to be disposed of via existing routes. These wastes should be processed into a passive safe and stable state to be stored on-site 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 the HAW generated throughout the reactor lifetime results in incompatible waste with the future GDF, the *UK HPR1000 HAW Disposability Assessment Submission*, Reference [70], was prepared and submitted to RWM to undertake a GDA disposability assessment to provide a preliminary judgement as to the potential acceptability for disposal to a GDF of the waste packages expected to arise from the operation of the UK HPR1000. RWM has conducted their assessment and concluded that the HAW generated by UK HPR1000 is proved to be disposable. Details are presented in RWM report *Generic Design Assessment: Summary of Disposability Assessment for Wastes and Spent Fuel arising from the Operation and Decommissioning of the UK HPR1000 Pressurised*

Water Reactor, Reference [71], where some issues with respect to the current waste management plan are also raised.

For these issues raised by RWM, which are all site-specific, responses have been provided to demonstrate that the GDA proposal and design do not lead to the impossibility to resolve the issues and therefore to waste that is not disposable or to significant design changes or constraints on the operator/operation of the plant. Details are presented in *Response to Disposability Assessment Report on UK HPR1000 HAW and Spent Fuel Disposability*, Reference [72]. The future operator will undertake the disposability assessment for HAW and spent fuel based on waste characteristics and their management proposal following the Letter of Compliance (LOC) process to eliminate the issues identified in the disposability assessment during GDA and obtain relevant agreements from RWM at site licensing phase (FAP-4-8).

The Radioactive Waste Management Case (RWMC) for the spent fuel, HLW and ILW has been also developed to demonstrate that the HAW can be managed effectively at site licensing phase, which is detailed in *Radioactive Waste Management Case for ILW,* Reference [73] and *Radioactive Waste Management Case for HLW*, Reference [74]. Reference [73] and [74] will be further developed at site licensing phase to reflect site licensing phase proposals (FAP-4-9).

4.10 Forward Action Plan

In order to support the development of the management of radioactive waste during the site-specific stage, the forward actions that will need to be addressed by a future operator are listed in T-4.10-1.

T-4.10-1 Post GDA Forward Action Plan

Task No.	Summary of Task	Delivery Phase
FAP-4-1	Transfer radioactive waste management records to future operator and the future operator will engage with the disposal facility operator to ensure all the necessary information is captured for the records.	Site-specific stage
FAP-4-2	Review and select site-specific appropriate proposals representing BAT and ALARP.	Site-specific stage
FAP-4-3	Further develop BQZ design based notably on future BAT and ALARP analysis.	Site-specific stage
FAP-4-4	Further develop BQF design based notably on further BAT and ALARP analysis.	Site-specific stage
FAP-4-5	Undertake optioneering study for selection of containers for decommissioning HAW.	Site-specific stage
FAP-4-6	Develop and maintain the IWS.	Site-specific stage

Task No.	Summary of Task	Delivery Phase
FAP-4-7	Undertake the acceptability analysis and obtain relevant agreements from LLWR for LAW.	Site-specific stage
FAP-4-8	Undertake the disposability assessment for HAW and spent fuel based on waste characteristics and their management proposal following the LOC process to eliminate the issues identified in the disposability assessment during GDA and obtain relevant agreements from RWM.	Site-specific stage
FAP-4-9	Develop and maintain the RWMC for the spent fuel, HLW and ILW to demonstrate that the HAW can be managed effectively.	Site-specific stage

4.11 Conclusions

The UK HPR1000 waste management arrangements summarised in this PCER chapter demonstrates that:

a) The waste management arrangements for the UK HPR1000 are consistent with the UK regulations;

b) The waste hierarchy is applied and the generation of radioactive waste is prevented and where this is not reasonably practicable, the quantity of the waste generated are and will be minimised;

c) The abatement processes and waste management processes are demonstrated as being BAT. Other options are not foreclosed and the future operator should select appropriate proposals considering BAT and ALARP principles at site licensing phase; and,

d) All of the radioactive wastes generated by the UK HPR1000 are similar as those wastes generated by operating PWRs and are disposable and optimised. There are no non-disposable wastes. This is and will be demonstrated through the IWS and disposability assessments.

4.12 References

[1] EA, Process and Information Document for Generic Assessment of Candidate Nuclear Power Plant Designs (P&ID), Version 3, 2016.

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