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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

ALARP	As Low As Reasonably Practicable
APG	Steam Generator Blowdown System [SGBS]
BAT	Best Available Technique
BPX	Personnel Access Building
BQS	Waste Auxiliary Building
BFX	Fuel Building
BNX	Nuclear Auxiliary Building
BQT	Temporary Storage Facility
BSX	Safeguard Buildings
BWX	Radioactive Waste Treatment Building
CPR1000	Chinese Pressurised Reactor
CVI	Condensate Vacuum System [CVS]
DWN	Nuclear Auxiliary Building Ventilation System [NABVS]
EA	Environment Agency (UK)
GDA	Generic Design Assessment
GDF	Geological Disposal Facility
HAW	Higher Activity Waste
HEPA	High Efficiency Particulate Air Filter
HLW	High Level Waste
HPR1000	Hua-long Pressurised Reactor
HPR1000 (FCG3)	Hua-long Pressurised Reactor under construction at Fangchenggang nuclear power plant Unit 3
HVAC	Heating, Ventilation and Air Conditioning System
ICIAs	In-core Instrumentation Assemblies
ILW	Intermediate Level Waste
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)
MSQA	Management for Safety and Quality Assurance
NDA	Nuclear Decommissioning Authority
ONR	Office for Nuclear Regulation (UK)
OPEX	Operational 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 Designs
PTR	Fuel Pool Cooling and Treatment System [FPCTS]
PWR	Pressurised Water Reactor
RCV	Chemical and Volume Control System [CVCS]
REA	Reactor Boron and Water Makeup System [RBWMS]
REN	Nuclear Sampling System [NSS]
REPs	Radioactive Substances Regulation – Environmental Principles
RPE	Nuclear Island Vent and Drain System [VDS]
RWM	Radioactive Waste Management Ltd
SAPs	Safety Assessment Principles for Nuclear Facilities
SEK	Waste Fluid Collection System for Conventional Island [WFSCI]
SEL	Conventional Island Liquid Waste Discharge System [LWDS (CI)]
SF	Spent Fuel
SFAs	Spent Fuel Assemblies
SFAIRP	So Far As Is Reasonably Practicable

SFIS	Spent Fuel Interim Storage
SFP	Spent Fuel Pool
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]
UK HPR1000	The UK version of the Hua-long Pressurised Reactor
VLLW	Very Low Level Waste
WAC	Waste Acceptance Criteria

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 The 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 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], together with the relevant requirements of the *Radioactive Substances Regulation - Environmental Principles (REPs)*, Reference [2], and the *Safety Assessment Principles for Nuclear Facilities (SAPs)*, 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 Spent Fuel (SF) arising during the operation of the reactor, as well as the wastes arising from decommissioning. It also explains how the production, discharge and disposal of the radioactive waste and SF will be managed to protect the environment and people.

The structure of PCER Chapter 4 is as follows.

a) Sub-chapter 4.1 presents the list of abbreviations and acronyms;

b) Sub-chapter 4.2 presents the scope and structure of PCER chapter 4;

c) Sub-chapter 4.3 presents regulatory context requirements;

d) Sub-chapter 4.4 presents waste management principles;

e) Sub-chapter 4.5 presents the main assumptions of radioactive waste management;

f) Sub-chapter 4.6 presents the radioactive waste management strategy;

g) Sub-chapter 4.7 presents the details of radioactive waste management;

h) Sub-chapter 4.8 presents the development of an Integrated Waste Strategy (IWS);

i) Sub-chapter 4.9 presents the disposability of radioactive waste;

j) Sub-chapter 4.10 presents the conclusions; and,

k) Sub-chapter 4.11 presents the reference lists.

This chapter is to be read in conjunction with the Pre-Construction Safety Report (PCSR) Chapter 23, Reference [4], which describes the radioactive waste management systems, PCSR Chapter 22, Reference [5], which presents the source terms affecting waste arising, and PCER Chapter 3 which presents the Best Available Technique (BAT) demonstration.

The interfaces to 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 3 Demonstration of BAT	PCER Chapter 3 presents the BAT methodology applied to the UK HPR1000 and BAT demonstration of radioactive waste management.
PCER Chapter 5 Approach to Sampling & Monitoring	PCER Chapter 5 presents the sampling and monitoring approach to 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.

4.3 Regulatory Context

4.3.1 P&ID Requirements

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

Item 3, Table 1, in 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, in 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, in 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 in Reference [2] are taken into account through 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 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

The main policies, regulations and guidance related to waste management in the UK are implemented as follows:

a) The Nuclear Installations Act 1965;

b) The Environment Act, 1995;

c) Hazardous Waste Regulations, 2005;

d) The Environmental Permitting (England and Wales) Regulations 2016;

e) The Ionising Radiations Regulations, 2017;

f) Managing Radioactive Waste Safely, 2008;

g) Review of radioactive waste management policy: Final Conclusions (Cm 2919), 1995;

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

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

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

k) The Management of Higher Activity Radioactive Waste on Nuclear Licensed Sites, 2015;

l) Regulatory Guidance Series RSR 1: Radioactive Substances Regulation - Environmental Principles, 2010;

m) RSR: Principles of Optimisation in the Management and Disposal of Radioactive Waste, 2010;

n) Safety Assessment Principles for Nuclear Facilities, 2014;

o) Industry Guidance: Interim Storage of Higher Activity Waste Packages – Integrated Approach, 2012;

p) Funded Decommissioning Programme Guidance for New Nuclear Power Stations, 2011;

q) Nuclear Safety Technical assessment Guide: Management of Radioactive materials and Radioactive Waste on Nuclear Licensed Sites, 2016.

4.4 Waste Management Principles

The principles, as shown in T-4.4-1 with the regulatory references are applied to develop and implement the radioactive waste management arrangements for the UK HPR1000.

T-4.4-1 Radioactive Waste Management Principles

Principles	**References**	**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) presented in Sub-chapter 4.8.
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 linked in Sub-chapter 4.6.2 and in 4.7.1.6, 4.7.2.5, 4.7.3.6. Detailed demonstration is presented in PCER Chapter 3.
BAT should be applied in the design option for disposal of each waste stream, and minimising the volume of packaged waste for disposal.	REP-RSMDP4 REP-RSMDP6 REP-RSMDP15	BAT description is presented in Sub-chapter 4.7.3.6 and detailed 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-chapter 4.6.3 bullet a) and 4.7.1.5, 4.7.2.4 and 4.7.3.3.
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 allowed.	RSMDP10 RSMDP11	Radioactive waste interim storage is presented in Sub-chapter 4.7.3.5.2.
Sufficient information relating to radioactive waste management and disposal should be recorded and preserved.	RSMDP14	Waste management record consideration is presented in Sub-chapter 4.6.4.

Principles	References	Mapping in this document
All liquid and gaseous discharges shall be treated with a facility represents BAT.	RSMDP15	BAT description for liquid waste and gaseous waste discharge are presented in Sub-chapter 4.7.1.6 and 4.7.2.5 and detailed demonstration in PCER Chapter 3.

4.5 Assumptions

The radioactive waste management arrangements are developed based on following main assumptions, taking into account the ‘Base Case’ set out in Reference [6]:

a) The Gaseous Waste Treatment System (TEG [GWTS]), Coolant Storage and Treatment System (TEP [CSTS]) and Nuclear Island Vent and Drain System (RPE [VDS]) are designed to manage radioactive waste arising from one unit. The Liquid Waste Treatment System (TEU [LWTS]), Nuclear Island Liquid Waste Discharge System (TER [NLWDS]), Sewage Recovery System (SRE [SRS]), Conventional Island Liquid Waste Discharge System (SEL [LWDS(CI)]), the processing part in Solid Waste Treatment System (TES [SWTS]) are designed to manage radioactive waste arising from two reactor units;

b) The operational life of UK HPR1000 is 60 years. The radioactive waste management systems will be utilised during decommissioning process if risks are As Low As Reasonably Practicable (ALARP) and measures are beneficial for waste minimisation;

c) 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 unchanged or the impact of change is minimal;

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

e) The proximity principle will be considered in assessment for specific site;

f) SF will be stored and disposed of rather than being reprocessed;

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

Cumbria or a successor facility;

h) The references about Waste Acceptance Criteria (WAC) to LLWR are assumed for GDA and to enable the obtaining of an ‘Agreement in Principle’ for treatment or disposal of LLW and Very Low Level Waste (VLLW) based upon the services provided by LLWR; and,

i) Intermediate Level Waste (ILW) arising from operation and decommissioning will be packaged in a passively safe form, and safely stored in an interim storage facility on site until a Geological Disposal Facility (GDF) becomes available.

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, so as to reduce the risks to the workers, public and environment So Far As Is Reasonably Practicable (SFAIRP). The radioactive waste management strategy addresses the considerations as follows.

4.6.1 Waste Hierarchy

The waste hierarchy, as illustrated in F-4.6-1, are applied to the waste management arrangements for the UK HPR1000. The waste hierarchy is a stepwise approach to achieve waste minimisation. It encourages the options for waste management in the following order of priority:

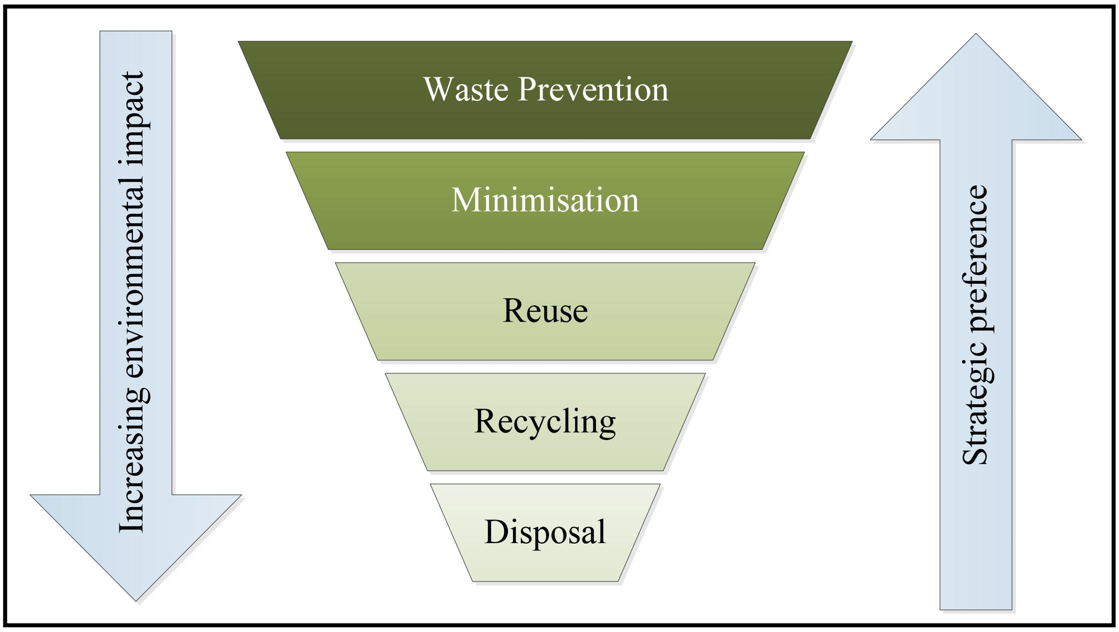
a) Prevention: Creation of waste should be prevented;

b) Minimisation: Waste 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;

e) Disposal: Waste should only be disposed of when the above options are impossible.



F-4.6-1 Waste Hierarchy

4.6.2 Application of BAT and ALARP

The methodology, which is described in Reference [7], 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 methodology, which is described in Reference [8], has been developed to identify and justify the application of ALARP.

A common framework is developed for requirements on optioneering and decision-making, Reference [9], which leads to design optimisation and demonstration that the design is optimised.

For radioactive waste management design, BAT and ALARP shall be applied at each stage described in Sub-chapter 4.6.3. In some cases the appropriate balance between BAT and ALARP will have to be defined so as to underpin the radioactive waste management systems design.

The application of BAT in the UK HPR1000 design is demonstrated through the claim, argument and evidence approach in PCER Chapter 3 and the application and assessment of ALARP for the radioactive waste management, decommissioning and interim storage of SF are demonstrated in the PCSR Chapters 23, 24 and 29, Reference [4], [10]and[11].

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

Waste are characterised and segregated at source to facilitate subsequent safe and effective management. Characterisation through sampling, measurement and monitoring are applied to acquire sufficient data to support waste management decisions. Segregation is to collect the waste with similar characteristic together and avoid mixing waste with different characteristic. Following the characterisation and segregation of the radioactive waste at an early stage, the subsequent treatment and disposal routes will be efficient and not be challenged.

Additionally, characterisation and segregation are taken into account throughout all the stages of the 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 (typically for liquid and solid wastes) are temporarily stored until there is enough quantity for batch treatment. During the temporary and buffer storage, the waste streams are characterised to determine their physical, chemical and radiological properties. The appropriate treatment is developed according to their properties.

c) Treatment and Conditioning

The liquid and gaseous effluent streams are recycled wherever possible, if recycling is impossible, 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, transferring, storage and disposal. The preferred conditioning method is to place or immobilise the waste into waste containers to create waste packages.

The conditioned Very Low Level Waste (VLLW) and Low Level Waste (LLW) are transferred to a suitable facility for treatment or disposal while the ILW and SF are safely stored on site until a GDF becomes available.

d) Interim Storage

Before the GDF is available, interim storage is a necessary stage for ILW and SF. The interim storage facility will be 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 the authorised limits.

The packaged VLLW and LLW will be transferred to a suitable facility (e.g. LLWR) for disposal. After interim storage, the packaged ILW and SF will be retrieved and transferred to the GDF.

In this stage, the waste packages will be deposited with no intention of retrieval.

4.6.4 Waste Management Record

The operation of the radioactive waste management systems will generate a large amount of information, including sampling, monitoring and measurement of radioactive waste or waste package. Data generated from the radioactive waste management systems should be preserved now and in the future for the safe management and disposal of radioactive waste in line with requirements in Reference [2], [3] and [12].

The process of making and preserving these documents and records starts during GDA phase and will continue throughout the whole lifecycle. The records need to be kept in an appropriate manner and form, taking account of the long timescales over which they may need to be retained and accessed. During the GDA phase, the documents and records will be maintained under the systemic Management for Safety and Quality Assurance (MSQA). The details of MSQA are presented in PCSR Chapter 20, Reference [13].

During the nuclear site specific step, the site licensee will be responsible for the waste information management system to track the information of waste management from generation to disposal. The main information includes but not limited to:

a) Relevant characteristics, location and date of each waste stream at source;

b) Radiological inventory, physical and chemical information of each waste;

c) Production process, production date and unique identifier of each waste packages;

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

e) Records of disposal route of each waste package.

The records of Higher Activity Waste (HAW) packages will be preserved and maintained until the GDF in the UK is available, and finally the waste record will be transferred to the disposal facility. As for LLW, the records of LLW packages also need to be kept and shared with the off-site disposal facilities.

4.7 Radioactive Waste Management

The following radioactive waste is expected to be generated from the UK HPR1000 lifecycle:

a) Operational waste are divided into three categories:

   1) Liquid waste;

   2) Gaseous waste; and,

   3) Solid waste.

The liquid and gaseous waste originates from the operation of the primary circuit. The radioactive substances, which arise from the fission products in the fuel and the activation of the primary circuit components, in the coolant are transferred around the primary circuit and pass into the various support systems.

The solid waste is grouped as three types:

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

   2) Waste results from maintenance; and,

   3) Waste from core components.

b) SF, and

c) Decommissioning waste.

The management arrangements for the operational waste are detailed in Sub-chapter 4.7.1, 4.7.2 and 4.7.3. The management arrangement for SF is detailed in Sub-chapter 4.7.4 and decommissioning waste is detailed in Sub-chapter 4.7.5.

4.7.1 Liquid Waste Management

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

a) Reduction of effluent generation at source;

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

c) Recycling wherever possible; and,

d) Sampling, monitoring and treatment.

The liquid effluent streams generated during operation and their treatment are illustrated in F-4.7-1 and described thereafter. 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 discharges are described in PCER Chapter 6, Sub-chapter 6.6.

4.7.1.1 Reactor Coolant Effluent

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

The leakage or drainage from the primary circuit is collected by the RPE [VDS] 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; and,

b) Unrecyclable leakage or drainage divides 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 distillates from TEP [CSTS] are sent to the Reactor Boron and Water Makeup System (REA [RBWMS]) as supplementary make up for the primary circuit coolant. In the case of high tritium concentration, the distillates cannot practically be recycled and thus are routed to the TER [NLWDS] for discharge.

The RCV [CVCS], REA [RBWMS] and TEP [CSTS] are described in PCSR Chapter 10, Sub-chapter 10.4.3, 10.4.4 and 10.4.5, Reference [14].

The unrecyclable effluents are transferred to the TEU [LWTS] for treatment as described in Sub-chapter 4.7.1.2.

Spent filter cartridges and spent resins are generated from reactor coolant and recyclable effluent treatment. The management arrangements for these wastes are described in Sub-chapter 4.7.3.

4.7.1.2 Liquid Waste

The liquid wastes include:

a) The unrecyclable reactor coolant effluents captured 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 have a low level of chemical impurities. These liquid wastes are from venting and draining or leakages of equipment and pipelines which carry reactor coolant.

b) Chemical drains

Chemical drains have a higher level of chemical impurities and potentially higher radioactivity. These liquid wastes are mainly from the laboratory and the decontamination drains.

c) Floor drains

Floor drains typically have lower radioactive contamination but it is high in suspended solids. These liquid wastes, with potential contamination (from leakages and purges of equipment and floor washings), come from controlled areas with equipment carrying primary effluent, secondary or auxiliary fluid and the decontamination drains in the Reactor Buildings (BRX), Nuclear Auxiliary Building (BNX), Fuel Building (BFX), Safeguard Buildings (BSX), Personnel Access Building (BPX) and Radioactive Waste Treatment Building (BWX).

d) Laundry drains

Laundry drains are also lower in radioactive contamination but it is high in suspended solids, fibrous matter, and detergents. These liquid wastes are from the hot laundry system which is not in the GDA scope.

An optioneering study for the selection of suitable treatment processes for liquid waste has been undertaken and the BAT scheme ‘filtration + desalination + evaporation’ is selected for the design of TEU [LWTS] which is detailed in *Optioneering Report of Liquid Radioactive Waste Processing Techniques*, Reference [15].

The radioactivity present within the liquid waste consists of particulate and ionic species and is treated within the TEU [LWTS] as follows:

a) The major radionuclides in the ionic form are abated by the TEU [LWTS] demineralisers with ion exchange resins. The demineralisers are protected with pre and post filters to prevent bed blinding or migration of ion exchange resins into the downstream circuit;

b) Radionuclides in the ionic form with high chemical content are abated by the TEU [LWTS] evaporator. The evaporator is protected with a pre filter to prevent carry-over of particulate into the evaporator; and,

c) Particulates are primarily abated by the filters.

Treated effluent is transferred to the TER [NLWDS] from where it is sampled and monitored and, if compliant with the discharge criteria and conditions, discharged to the marine environment.

To demonstrate the capacity of the liquid waste management systems are sufficient to collect and treat the liquid waste generated by UK HPR1000, sizing of the main equipment is undertaking and will be finished during step 3.

The spent resins, concentrates and spent filter cartridges are generated from the treatment of liquid wastes. The management arrangements for these wastes are described in Sub-chapter 4.7.3.

4.7.1.3 Secondary Circuit Effluents

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

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

The management arrangements for the spent resins and filter cartridges generated from the APG [SGBS] are described in Sub-chapter 4.7.3.

The SEK [WFSCI] is not included in GDA scope.

4.7.1.4 Non-aqueous Liquid Waste

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

a) Maintenance of pumps;

b) Maintenance of hydraulic equipment; and,

c) Decontamination of Reactor Pressure Vessel bolts.

The non-aqueous liquid radioactive waste is segregated from the aqueous waste at source. The unnecessary cross-contamination is avoided and therefore reduces the volume. The annual generation and radioactivity of this waste type is very low.

Oils and organic solvents are prohibited from being discharged to the environment even after treatment. The management proposal for them is similar to other solid wastes, therefore, the detailed waste information and proposed treatment is presented together with the solid waste in Sub-chapter 4.7.3.

4.7.1.5 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 decide whether the liquid is suitable for reuse, to select the appropriate treatment technology for the liquid wastes and to decide whether the treated liquid wastes meet the discharge requirement or require retreatment.

The following sampling arrangements in TEP [CSTS] are provided:

1) Before being sent to REA [RBWMS] storage tanks 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 treated;

2) The effluent downstream of the main process and treatment equipment such as demineraliser and 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 condensate water after condensate degasification unit, the total activity of gamma and tritium are measured by grab sampling through the REN [NSS] sampling pipeline. It is recycled if the tritium is below the control limit of the primary coolant circuit, otherwise, it is sent to TER [NLWDS] for discharge.

4) Downstream of the sweeping 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 following sampling arrangements in TEU [LWTS] are provided:

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 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.

3) The radioactivity and chemical properties of effluent stream treated by demineralisation and evaporation are analysed by sampling in the monitoring tanks before being discharged to TER [NLWDS]. The treated liquid waste is transferred to TER [NLWDS] for discharge when its radioactivity meets the discharge requirement; otherwise, the liquid wastes are retreatment.

b) Discharge Monitoring

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

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

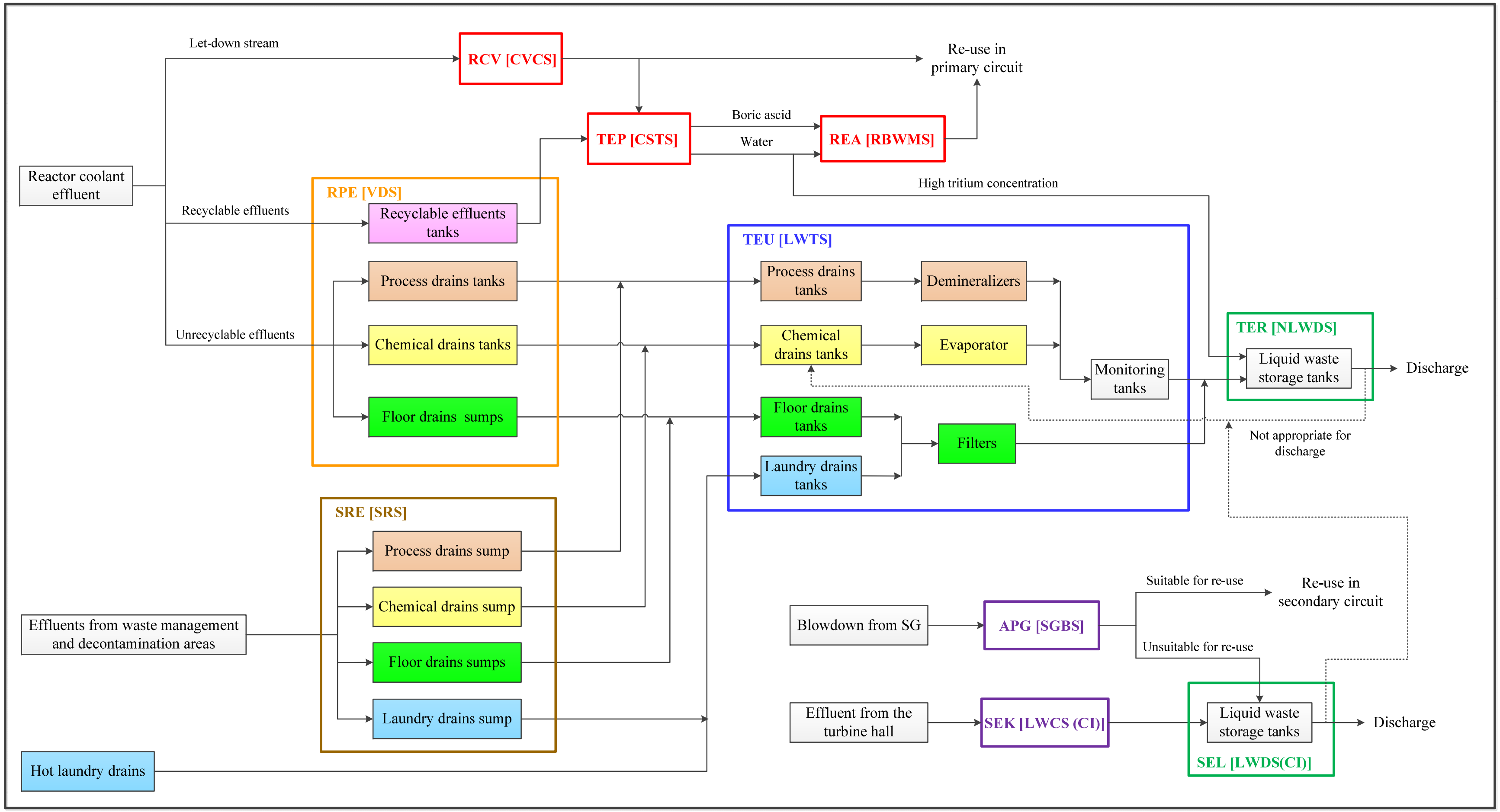
Two final continuous monitors are arranged on the discharge lines of TER [NLWDS] and SEL [LWDS (CI)] respectively to measure the radioactive concentration of total gamma emitted by the liquid wastes. If the measured radioactivity exceeds a pre-set value or a failure of equipment is detected, an alarm is triggered and the isolation valve can be closed automatically to stop the discharge.

Two flow proportional samplers are arranged on the discharge lines of TER [NLWDS] and SEL [LWDS (CI)] respectively to collect the representative samples of the liquid wastes.

The details of sampling, monitoring and measurement for liquid waste in UK HPR1000 are presented in PCER Chapter 5.

4.7.1.6 Demonstration of BAT

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



F-4.7-1 Liquid Radioactive Waste Effluent Streams

4.7.2 Gaseous Waste Management

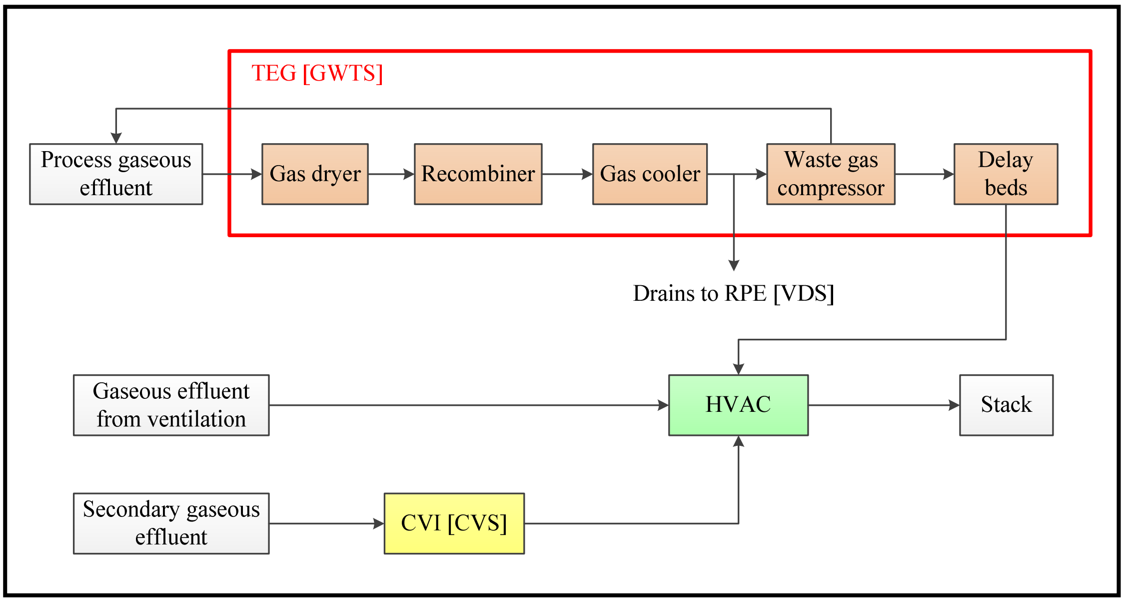
The gaseous radioactive waste is divided into three categories:

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-4.7-2. The process gaseous effluent is collected and treated by TEG [GWTS] which is described in the PCSR Chapter 23, Sub-chapter 23.7, Reference [4]. The gaseous effluent from the ventilation systems is collected and treated by different filtration systems which are described in the PCSR Chapter 10, Sub-chapter 10.6, Reference [14]. The secondary gaseous effluent is collected by Condensate Vacuum System (CVI [CVS]) which is not in GDA scope. The estimated discharges and proposed limits of gaseous effluent discharges are described in PCER Chapter 6, Sub-chapter 6.6.



F-4.7-2 Gaseous Radioactive Waste Effluent Streams

4.7.2.1 Process Gaseous Effluent

Gaseous radioactive wastes are unavoidably generated during the operation of the nuclear power plant. The radionuclides in the reactor coolant which generated from fission reactions, corrosion reactions and activation reactions are moving with the reactor coolant and released into the gas phase of vessels and tanks of the 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 and are collected, treated and discharged by the

TEG [GWTS].

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

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

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

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

d) Delay the radioactive noble gases and iodine isotopes in the gas stream prior to discharge them to the environment.

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

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

b) Volume control tank of RCV [CVCS];

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

d) Coolant storage tanks of TEP [CSTS];

e) Boric acid column of TEP [CSTS];

f) Degasifier column of TEP [CSTS];

g) Condensate collecting tank of TEP [CSTS];

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

i) Sample backfeed vessel of REN [NSS].

The TEG [GWTS] connects the gas space of the vessels and tanks together and flushes them with nitrogen to avoid hydrogen accumulation. 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 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.

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 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 TEG [GWTS], and the excessive gases are routed to the a series of activated charcoal delay beds. The activated charcoal delay beds provide adequate delay time for the concerned radionuclides (noble gases and iodine isotopes). The delay results in a significant reduction in the radioactivity of the gases. The activated charcoal delay beds also can be operated at increased pressure to increase their storage and treatment capacity.

An optioneering study has been undertaken to demonstrate that the activated charcoal delay bed technology represents BAT, which is detailed in *Optioneering Report of Gaseous Radioactive Waste Processing Technique*, Reference [16].

To demonstrate that the treatment capacity of the TEG [GWTS] is sufficient to collect and treat the process effluent generated by the UK HPR1000, sizing of the activated charcoal delay beds has been undertaken and the result shows that three vertical pressure vessels filled with 7.2 tonnes of activated charcoal connected in series can satisfy the treatment requirement in different operating conditions which is detailed in *Sizing Report of the Activated Charcoal Delay Beds*, Reference [17].

Downstream of the TEG [GWTS], the gases are routed to the Nuclear Auxiliary Building Ventilation System (DWN [NABVS]), where they are filtered using High Efficiency Particulate Air Filters (HEPA) and passed through iodine traps if needed. They are then monitored and discharged to the environment via the main stack.

Some of the radionuclides in the process effluent such as carbon-14 and tritium, but do not undergo treatment by TEG [GWTS]. For the gaseous carbon-14 which half-life is 5730 years, the activated charcoal delay beds have no abatement function and it discharges directed the environment via the DWN [NABVS].

The gaseous tritium in the TEG [GWTS] may be in the form of water vapour (in the form of HTO) and/or hydrogen (in the form of HT) which is released from the reactor coolant. The hydrogen released from the reactor coolant recombinates with oxygen to form water in the recombiner within the TEG [GWTS], so 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 is then drain to the RPE [VDS] as liquid waste. The water vapour in the flushing gas is also cooled down by the heat exchangers in the TEG [GWTS] and retained in the liquid phase (returned to the reactor coolant or drained off via the RPE [VDS]). These both reduce tritium discharge in the gaseous effluent.

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

4.7.2.2 Gaseous Effluent from Ventilation

The ventilation systems are arranged separately according to the areas with and without contamination and the functions of the buildings. The main Heating, Ventilation and Air Conditioning System (HVAC) serve areas with potential contamination which include the nuclear auxiliary building, fuel building (including fuel pool), reactor building, controlled area of safeguard building, controlled area of access building and the waste treatment building. All exhaust air from these areas with potential radioactive contamination are filtered by the pre-filters, HEPA filters and iodine traps if needed contained within the HVAC systems prior to release into the environment through the stack.

The management arrangements for spent filter cartridges generated from the HVAC are described in Sub-chapter 4.7.3.

4.7.2.3 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 will be treated by HEPA filtration and iodine traps if needed, monitored, and discharged to the environment via the main stack.

4.7.2.4 Sampling, Monitoring and Measurement

4.7.2.4.1 TEG [GWTS]

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

The operation of the delay beds are influenced by moisture, temperature, pressure and flow rate. As a result, the moisture upstream of the delay beds are continuously measured by two hygrometers to ensure the activated charcoal works under optimum conditions. The temperature in the delay beds room is continuously measured to ensure it is within set parameters. Downstream of the delay beds, the operating pressure and flow rate is also continuously measured. The operating pressure of the delay beds can be increased according to the flow rate of the income gases to be treated to improve its storage and treatment capacity.

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 monitoring the adsorption efficiency of the activated charcoal.

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

4.7.2.4.2 HVAC systems

The monitoring of the HVAC gaseous effluents discharged from the buildings provides information on the gaseous radioactivity inside the buildings and to indicate whether there is a leak within the system. If the gaseous activity concentration reaches the alarm threshold, a sound-light alarm is triggered in the main control room. At the same time, the HVAC line is switched to the iodine filtration train. Plant operators will investigate the room where leaking equipment is located and take action. The measurement data is displayed and recorded in the main control room.

The in-process sampling and monitoring of the HVAC systems is detailed in PCER Chapter 5, Sub-chapter 5.5.5.1 and 5.5.5.2.

4.7.2.4.3 CVI [CVS]

Monitoring of the steam generator tube integrity is undertaken to detect leakage of high activity gaseous into the secondary circuit. The main steam is condensed in the condenser and non-condensable noble gases (in CVI [CVS]) are monitored. If the gaseous activity concentration reaches the alarm threshold, a sound-light alarm is triggered in the main control room. Plant operators will investigate the situation and take action. The measurement data are displayed in the main control room.

The in-process sampling and monitoring of CVI [CVS] is detailed in PCER Chapter 5, Sub-chapter 5.5.5.4.

4.7.2.4.4 Final sampling and monitoring in the stack

The sampling and monitoring system for the gaseous discharges in the stack is duplicated including train A and train B. The aerosol, iodine, tritium and carbon-14 in the gaseous discharges are sampled continuously, while the noble gas is sampled by grab sampling. The samples are continuous monitored and all the samples collected from continuous sampling or the grab sampling are also sent to the laboratory for accurate measurement. The monitors and samplers are located in the space where the dose rate is low and is easy to access.

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

4.7.2.5 Demonstration of BAT

Demonstration that the design of the TEG [GWTS] represents BAT is detailed in PCER Chapter 3, Argument 2d: Minimise the Radioactivity of Gaseous Radioactive Waste by Optimising Gaseous Waste Treatment System (TEG [GWTS]).

The BAT demonstration of HVAC systems is detailed in PCER Chapter 3, Argument 2c: Minimise the Radioactivity of Gaseous Radioactive Waste by Optimising the HVAC system.

4.7.3 Solid Waste and Non-Aqueous Liquid Waste Management

This sub-chapter presents the waste management arrangements for the solid waste and non-aqueous liquid waste which arise during the operation of the UK HPR1000.

4.7.3.1 Waste Arising

As described in *Nuclear Safety Technical Assessment Guide: Management of Radioactive Materials and Radioactive Waste on Nuclear Licensed Sites,* Reference [12], radioactive wastes are classified in terms of the activity and types of radionuclides they contain and their heat generation. They are categorised as High Level Waste (HLW), ILW, LLW or VLLW (a sub-category of LLW).

HAW comprises HLW, ILW and such LLW as cannot be disposed of at present. LAW comprises LLW and VLLW can be disposed of at present.

In the *Basic Principles of Radioactive Waste Management*, Reference [18], some radioactive wastes are considered out of scope or exempt, because the levels of radioactivity fall below thresholds defined in legislation and disposal of this waste does not require a radioactive substances permit or authorisation from the environmental regulators under the Environmental Permitting Regulations 2016 (EPR16) in England and Wales, or the Radioactive Substances Act 1993 (RSA93) in Scotland. The out of scope or exempt wastes are also included in this management arrangements document because it can reduce the radioactive waste inventory to be disposed of. It is also noted that due to the amendments of legislation, the category of VLLW is now obsolete in Reference [18]. The VLLW is to be managed as LLW or exempt waste in UK HPR1000.

4.7.3.1.1 Identify the waste streams

The reference plant of UK HPR1000 is Hua-long Pressurised Reactor under construction at Fangchenggang nuclear power plant unit 3 (HPR1000 (FCG3)), which is based on the Operational Experience (OPEX) feedbacks and improvements of the design as series of successful Chinese Pressurised Reactor (CPR1000).

The waste streams 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, and giving the preliminary waste streams;

b) Reviewing the waste arising from the operational experience from decades of Chinese Pressurised Water Reactor (PWR) reactors operating and international PWR reactors, and improving the waste streams.

Each waste streams generated in UK HPR1000 during normal operation is categorised based on the OPEX data of CPR1000 and international similar PWRs.

Through the above description, the identified waste streams and each category in UK HPR1000 are listed in T-4.7-1. The waste streams are grouped into 11 types and one SF stream. The detailed information about each waste stream is detailed in Sub-chapter 4.7.3.1.2. The SF is detailed in Sub-chapter 4.7.4.

The last column of T-4.7-1 provides the preliminary category of each waste stream based on the currently available information. It will be refined as the source term information becomes available.

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

No.	Waste Stream	Description	Preliminary 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 tube rupture.	ILW
2	Low Activity Spent Resins	Arising from the demineralisers from the APG [SGBS] under normal operation condition.	VLLW
3	Concentrates	Arising from the TEU [LWTS] evaporators.	ILW/LLW
4	Spent Filter Cartridges	Arising from filter changes in the water treatment systems, including RCV [CVCS], TEP [CSTS], PTR [FPCTS], TEU [LWTS], APG [SGBS] and RPE [VDS].	ILW/LLW/ VLLW

No.	Waste Stream	Description	Preliminary Category
5	Dry Active Wastes	Contaminated personal protection equipment, monitoring swabs, plastic, clothing, contaminated tools and air filters.	LLW/VLLW
6	Sludges	Arising from the sumps and tanks associated with the water auxiliary circuits (e.g. RPE [VDS], TEU [LWTS]).	ILW/LLW
7	Oil	Arising during normal operations, such as maintenance of pumps and hydraulic equipment and decontamination of Reactor Pressure Vessel bolts.	VLLW
8	Organic Solvent	Arising during normal operations, such as maintenance of pumps and hydraulic equipment and decontamination of Reactor Pressure Vessel bolts.	LLW
9	Ventilation Filter Cartridges	Arising from the ventilation systems located in the nuclear auxiliary building, fuel building, safeguards buildings, reactor building and waste treatment building.	VLLW
10	In-core Instrumentation Assemblies (ICIAs)	Arising from equipment used for measuring the pressure, temperature of the reactor core.	ILW
11	Rod Cluster Control Assemblies(RCCAs) Stationary Core Component Assemblies (SCCAs)	Activated in the reactor core.	HLW
12	Spent Fuel	Used fuel assemblies	HLW

4.7.3.1.2 Information for Each Waste Stream

The expected annual arising of each waste stream shown in this sub-chapter is estimated using OPEX from decades of operating Chinese PWR reactors and is based on systematically analysis of the design differences between the UK HPR1000 and other PWR designs.

4.7.3.1.2.1 Spent Resins

Ion exchange resins are used within demineralisers in the RCV [CVCS], TEP [CSTS], PTR [FPCTS] and TEU [LWTS] to abate the soluble radioactivity from various circuits as described in PCSR Chapter 10, Sub-chapter 10.4.3, 10.4.5 and 10.4.7, Reference [14] and Chapter 23, Sub-chapter 23.6.2, Reference [4]. The resins are periodically changed according to the dose rate or pressure drop.

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

T-4.7-2 Waste Stream Datasheet for Spent Resins

Parameter	Description
Waste Origin	Arising from demineralisers of the RCV [CVCS], PTR [FPCTS], TEP [CSTS], TEU [LWTS] and APG [SGBS] after steam generator tubes rupture.
Waste Chemical and Physical Description	Cation exchange resin with strong acid, anion exchange resin with strong basic and mixed resins. Resins are small spheres with cross linked polystyrene matrix. The diameters of the resins are mainly from 0.45 mm to 1.2 mm.
Nature of Radioactive Material	Contaminated with activated corrosion products and fission products from liquid in primary circuit and auxiliary systems.
Annual Arising	1.9 m^3
Total Arising (60 years)	114 m^3
Waste Classification at Time of Generation	ILW

Parameter	Description
Main Radionuclides	Caesium-137, Cobalt-60, Cobalt-58, Nickel-63, Carbon-14
Hazardous substances	None

4.7.3.1.2.2 Low Activity Spent Resins

Ion exchange resins are used within demineralisers in the APG [SGBS] to purify the blow-down of the steam generators as described in PCSR Chapter 11, Sub-chapter 11.3.5, Reference [19]. The resins are periodically changed to ensure efficient purification.

Under normal conditions, these spent resins are uncontaminated or slightly contaminated. Under steam generator tubes rupture conditions, the spent resins from the demineralisers of the APG [SGBS] are contaminated, and they are treated the same as the other spent resins described in Sub-chapter 4.7.3.1.2.1.

The preliminary nature and quantity of the low activity spent resins generated from 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 two parallel demineralisers in the APG [SGBS] under the normal conditions.
Waste Chemical and Physical Description	Cation exchange resin with strong acid and anion exchange resin with strong basic. Resins are small spheres with cross linked polystyrene matrix. The diameters of resin are mainly from 0.45 mm to 1.2 mm.
Nature of Radioactive Material	Contamination with activated corrosion products and fission products.
Annual Arising	9.7 m^3
Total Arising (60 years)	582 m^3

Parameter	Description
Waste Classification at Time of Generation	VLLW
Main Radionuclides	Caesium-137, Cobalt-60, Cobalt-58, Nickel-63, Carbon-14
Hazardous substances	None

4.7.3.1.2.3 Concentrates

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

The preliminary nature and quantity of the concentrates generated from 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 TEU [LWTS].
Waste Chemical and Physical Description	The main composition is H_3BO_3, Na^+, Ca^{2+}, PO_4^{3-}, SO_4^{2-}, etc. The maximum boron concentration is 40000 ppm.
Nature of Radioactive Material	Concentrates is contaminated with activated corrosion products and fission products.
Annual Arising	0.44 m^3 (ILW) / 1.76 m^3 (LLW)
Total Arising (60 years)	26.4 m^3 (ILW) / 105.6 m^3 (LLW)
Waste Classification at Time of Generation	LLW/ILW
Main Radionuclides	Cobalt-60, Cobalt-58, Nickel-63, Carbon-14
Hazardous substances	None

4.7.3.1.2.4 Spent Filter Cartridges

Filters are installed in the RCV [CVCS], TEP [CSTS], PTR [FPCTS], APG [SGBS], TEU [LWTS], and RPE [VDS] to abate the particulate from various circuits as described in PCSR Chapter 10, Sub-chapter 10.4.3, 10.4.5 and 10.4.7, Reference [14], PCSR Chapter 11, Sub-chapter 11.3.5, Reference [19] and Chapter 23, Sub-chapter 23.6.2 and 23.6.1, Reference [4]. The filter cartridges are periodically changed according to the pressure drop between inlet and outlet or the dose rate.

The preliminary nature and quantity of the spent filter cartridges generated from 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	Cartridges are comprised of stainless supports with glass fibres and some organic materials.
Nature of Radioactive Material	Particulate activated corrosion products filtered from water auxiliary circuits.
Annual Arising	1.32 m^3 (ILW)/ 0.7 m^3 (LLW/VLLW)
Total Arising (60 years)	79 m^3 (ILW) /42 m^3 (LLW/VLLW)
Waste Classification at Time of Generation	ILW/LLW/VLLW
Main Radionuclides	Cobalt-60, Cobalt-58, Nickel-63
Hazardous substances	None

4.7.3.1.2.5 Dry Active Wastes

Dry activity wastes are generated through routine and maintenance operations of plant in the different controlled areas, which consist of combustible wastes (paper, plastic, clothes, etc.), metalic maintenance wastes, un-combustible /compactible wastes (cable, concrete, etc.) and un-combustible/un-compactible wastes (e.g. glass).

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

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

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. It includes low contaminated compactible waste (such as rag, plastic, paper, protective shoe covers, respirators, gloves, clothes, etc.) and un-compactible solid items.
Waste Chemical and Physical Description	Miscellaneous wastes including clothes, paper, metal, cable, concrete, glass, etc.
Nature of Radioactive Material	Contamination with fission products and activation products.
Annual Arising	172 m^3
Total Arising (60 years)	10320 m^3
Waste Classification at Time of Generation	VLLW/LLW
Main Radionuclides	Cobalt-60, Cobalt-58, Nickel-63
Hazardous substances	None

4.7.3.1.2.6 Sludges

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

The preliminary nature and quantity of the sludges generated from UK HPR1000 are shown in T-4.7-7.

T-4.7-7 Waste Stream Datasheet for Sludges

Parameter	Description
Waste Arising	Arising from the sumps and tanks associated with the water auxiliary circuits (e.g. RPE [VDS], TEU [LWTS]).
Waste Chemical and Physical Description	Sludges
Nature of Radioactive Material	Contamination with activated corrosion products and fission products.
Annual Arising	0.5 m^3 (ILW) / 0.5 m^3 (LLW)
Total Arising (60 years)	30 m^3 (ILW)/ 30 m^3 (LLW)
Waste Classification at Time of Generation	ILW/LLW
Main Radionuclides	Caesium-137, Cobalt-60
Hazardous substances	None

4.7.3.1.2.7 Oil

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

The nature and quantity of the waste oil generated from 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 operations, such as maintenance of pumps and hydraulic equipment.
Waste Chemical and Physical Description	Lubricating oil.

Parameter	Description
Nature of Radioactive Material	Contamination with activated corrosion products and fission products.
Annual Arising	0.125 m^3
Total Arising (60 years)	7.5 m^3
Waste Classification at Time of Generation	VLLW
Main Radionuclides	Caesium-137, Cobalt-60, Cobalt-58
Hazardous substances	None

4.7.3.1.2.8 Organic Solvent

Organic solvents are generated from decontamination of Reactor Pressure Vessel bolts and other component during normal operations.

The nature and quantity of the waste solvent generated from 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 operations, such as decontamination of Reactor Pressure Vessel bolts and other component.
Waste Chemical and Physical Description	Such as citric acid, carbon tetrachloride, etc.
Nature of Radioactive Material	Contamination with activated corrosion products and fission products.
Annual Arising	0.25 m^3
Total Arising (60 years)	15 m^3

Parameter	Description
Waste Classification at Time of Generation	LLW
Main Radionuclides	Caesium-137, Cobalt-60, Cobalt-58
Hazardous substances	None

4.7.3.1.2.9 Ventilation Filter Cartridges

Ventilation filter cartridges are generated from the ventilation systems located in the reactor building, safeguards buildings, fuel building, nuclear auxiliary building, and waste treatment building. The ventilation filter cartridges include pre-treatment filters, and HEPA filters.

The nature and quantity of the ventilation filter cartridges generated from 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 nuclear island
Waste Chemical and Physical Description	Cartridges are comprised of stainless supports with glass fibres.
Nature of Radioactive Material	Low levels of contamination
Annual Arising	28 m^3
Total Arising (60 years)	1680 m^3
Waste Classification at Time of Generation	VLLW
Main Radionuclides	Cobalt-60, Cobalt-58
Hazardous substances	None

4.7.3.1.2.10 ICIAs

ICIAs are from the reactor core and used for measuring the pressure, temperature of the reactor core. The nature and quantity of the in-core instrumentation assemblies generated from UK HPR1000 are shown in T-4.7-11.

T-4.7-11 Waste Stream Datasheet for In-core Instrumentation Assemblies

Parameter	**Description**
Waste Origin	Arising from reactor core, used for measuring the pressure, temperature of the reactor core.
Waste Chemical and Physical Description	It is composed principally of detector cable and some inorganic material within stainless steel cladding.
Nature of Radioactive Material	Activation with contamination products.
Annual Arising	0.14 m^3
Total Arising(60 years)	8.4 m^3
Waste Classification at Time of Generation	ILW
Main Radionuclides	Cobalt-60, Cobalt-58, Nickel-63
Hazardous substances	None

4.7.3.1.2.11 RCCAs and SCCAs

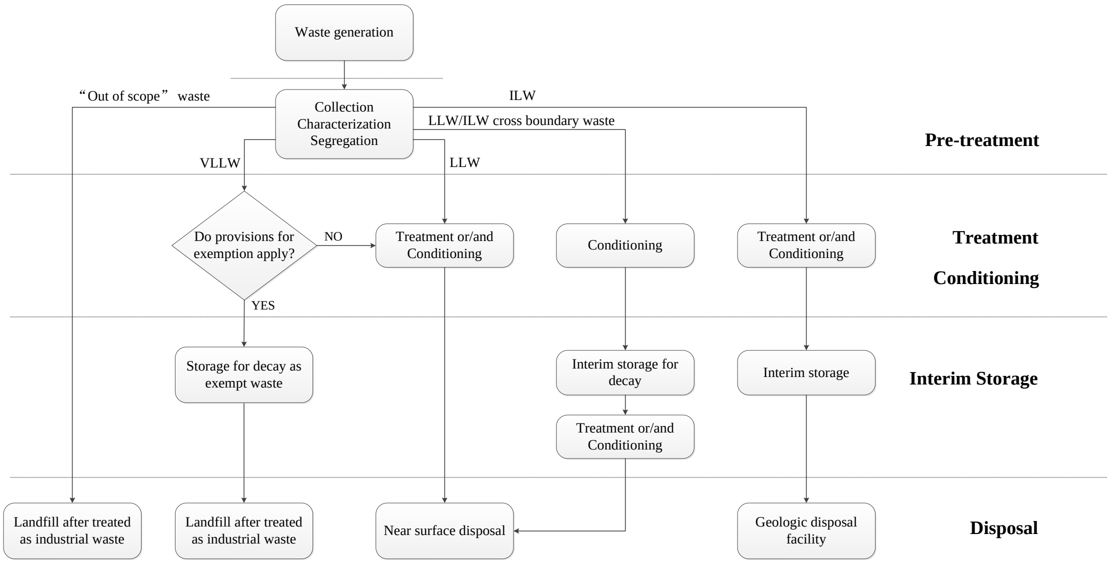
RCCAs and SCCAs are generated and identified in the normal operation of UK HPR1000. Approximately 280 RCCAs are expected to be removed from the core as waste during the design lifetime of 60 years.

Approximately 333 SCCAs (including 318 thimble plug assemblies, one primary source assembly and four second source assemblies) are expected to be removed from the core as waste during the design lifetime of 60 years.

The waste stream information and management options will be developed during step 3.

4.7.3.2 Overview Waste Management Stage

Application of the waste hierarchy is a fundamental principle of the radioactive waste management and an expectation of the Joint Regulatory Guidance on the management of radioactive waste with the intention of preventing or minimising the quantity and activity of radioactive waste destined for disposal. The waste management stage of UK HPR1000 applies this principle as well as BAT and ALARP principles. However, waste minimisation should form an essential element of a radioactive waste management stage which consists of a number of steps such as generation, characterisation and segregation, pre-treatment, treatment, conditioning, storage and transport and disposal. So, the detailed stage of preferred routes for the management of radioactive solid and non-aqueous liquid waste is established, as illustrated in F-4.7-3.



F-4.7-3 Waste Management Stage

4.7.3.3 Waste Characterisation and Segregation

According to the principles of radioactive waste management in the UK, Reference [18], characterisation and segregation of radioactive waste should be used to ensure subsequent management is safe and effective. In order to effectively manage the waste, the sampling and measurement is necessary for waste treatment/conditioning, storage and disposal. The overall strategies are described as follows:

a) Before treatment/conditioning: Before treatment/conditioning, the sampling and measurement of solid and non-aqueous liquid waste is used to determine the category of radioactive waste. It helps effectively segregate the waste and helps the operator in selecting optimal management and disposal routes.

b) Storage: After treatment/conditioning, sampling and measurement of solid and non-aqueous liquid waste packages is used to obtain their radiological inventory.

The relevant information can be recorded before storage.

c) Disposal: Before the final disposal, the sampling and measurement of solid and non-aqueous liquid waste packages is used to obtain their radiological inventory and judge whether the waste packages meet the requirement of transportation and the final disposal.

Furthermore, for the purpose of radiation protection, after treatment/conditioning, the surface dose rate of waste packages is measured to determine proper shielding of waste packages when on-site transportation and storage are needed.

The design of 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.

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

4.7.3.4 Waste Treatment

4.7.3.4.1 General considerations for Waste Treatment

The current waste treatment techniques and management route of UK HPR1000 are based on the design of HPR1000 (FCG3) which is consistency with Chinese disposal policy. However, there are differences in the radioactive waste disposal policies between UK and China:

a) Chinese disposal policy: ILW and LLW are disposed of in near surface disposal facility and spent fuel are reprocessed rather than disposed of;

b) UK disposal policy: LLW are disposed of in near surface disposal facility or off-site waste service facility, such as LLWR; ILW and HLW are disposed of in GDF.

The difference of national disposal policy directly results in the difference of management requirements for radioactive waste between UK and China.

An optioneering is continuously undertaking to optimise the waste treatment techniques for each waste steam generated in UK HPR1000 through a robust BAT and ALARP process according to management requirements in UK. The detailed UK strategies of waste management are shown in following and are to be implemented in the UK HPR1000 design:

a) ILW

The white paper '*Managing Radioactive Waste Safely*', Reference [20], 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. Nuclear Decommissioning Authority (NDA) is the organisation responsible for the delivery of a GDF.

The Office for Nuclear Regulation (ONR), Environment Agency (EA), Scottish Environment Protection Agency (SEPA) and Natural Resources Wales (NRW) propose a requirement for waste mobilisation in Reference [18] 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 packaging container can be maintained safely during operation, transportation, temporary storage and disposal.

According to *Introduction to the RWM Waste Package Specification and Guidance Documentation*, Reference [21], a range of standardised waste containers can be used to manufacture waste packages of three basic types:

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 unshielded 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 [22], 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;

3) The need for new fit-for-purpose waste management routes.

It is recognised that various off-site waste service suppliers exist (including LLWR) and they can receive, treat and dispose the waste in compliance with the Waste Acceptance Criteria (WAC), Reference [22].

According to Reference [22], LLWR provides a range of waste treatment and disposal services to ensure the LAW are 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 by 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, fibreboard kegs, 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 includes bags, wrapping and drums.

4) LLW disposal

This disposal service is an option for waste that is not suitable for treatment or not selected 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, Waste Monitoring and Compaction Facility (WAMAC) disposal container and International Organisation for Standardisation (ISO) skip disposal container.

c) Boundary Waste

Boundary is used to describe 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 [23], LLW/ ILW cross 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 be practicably be managed as LLW (on the basis of radiochemical and physicochemical properties) through application of some treatment process or decay storage. Identifying LLW/ ILW boundary waste and finding the optimised solution for such wastes can often lead to significant opportunities, for example:

1) Earlier hazard reduction, disposing of wastes to an existing disposal facility such as LLWR;
2) Cost reduction packaging for near-surface disposal instead of packaging for interim storage pending disposal to the GDF;
3) Reduction in the footprint of the interim waste store if more waste can be disposed of sooner.

It is also noted that boundary wastes can exist between all various radioactive waste classifications and are not limited to the LLW/ILW threshold. Identifying all the boundary wastes and adopting appropriate management strategy are important to ensure that management and disposal are optimized.

Based on the UK strategy of waste management mentioned above, the preliminary proposed waste management routes or treatment technologies for each waste stream generated in UK HPR1000 are summarised in T-4.7-12. Detailed management options of each waste stream are described in the following sub-chapters. The options have not been selected and optioneering work for treatment technology and relevant packaging will be undertaken according to *Requirements on Optioneering and Decision- Making* programme, Reference [9]. The recommended treatment technology and packaging containers will be finalised during step 3. The waste inventory will be developed during step 3 according to selected treatment technology and packaging containers.

T-4.7-12 Summary of Solid and Non-Aqueous Liquid Wastes Management Options

No.	Waste Stream	Preliminary Category	Potential Treatment/Conditioning Options
1	Spent Resins	ILW	1. Cement Encapsulation 2. Polymer Encapsulation 3. Seal in Mosaik Container by Dewatering
2	Low Activity Spent Resins	VLLW	Decay to become exempt waste
3	Concentrates	ILW/LLW	1. In-drum Drying 2. Cement Encapsulation
4	Spent Filter Cartridges	ILW/LLW/VVLLW	1. Cement Encapsulation 2. Polymer Encapsulation 3. Super-compaction 4. Dismantle
5	Dry Active Wastes	LLW/VLLW	1. Incineration 2. Metal Melting 3. Super-compaction
6	Sludges	ILW/LLW	1. Incineration 2. Cement Encapsulation 3. In-drum drying
7	Oil	VLLW	1. Incineration 2. Wet Oxidation
8	Organic Solvent	LLW	1. Incineration 2. Wet Oxidation
9	Ventilation Filter Cartridges	VLLW	Decay to become exempt waste
10	ICIAs	ILW	To be determined
11	RCCAs	HLW	To be determined

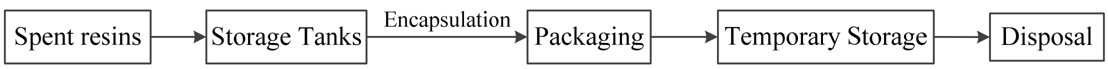
No.	Waste Stream	Preliminary Category	Potential Treatment/Conditioning Options
	SCCAs		
12	Spent Fuel Assemblies (SFAs)	HLW	Described in Sub-chapter 4.7.4

4.7.3.4.2 Spent Resins

The spent resins generated from RCV [CVCS]), TEP [CSTS], TEU [LWTS] and PTR [FPCTS] demineralisers are preliminarily categorised as ILW in UK HPR1000.

The spent resins are transferred to storage tanks which are designed to receive and store the resins. The spent resins in these storage tanks are then pumped to BWX to implement subsequent cement encapsulation in the steel drums. The packages are stored in the temporary storage facility on site prior to disposal.

The management route of spent resins is shown in F-4.7-4.



F-4.7-4 Management Route of Spent Resins

For the UK HPR1000, besides cement encapsulation, two feasible technologies have also been identified which is polymer encapsulation (as used in the HPC) and dewatering process (as used at the Sizewell B). An optioneering study will be undertaken to optimise the UK HPR1000 treatment proposal for ILW resins and demonstrate the recommended proposal represents BAT/ALARP at GDA phase.

Furthermore, RWM produced the full range of standardised ILW waste containers used in the UK, which are introduced in Reference [21]. An optioneering study will also be undertaken to select an appropriate packaging container for UK HPR1000 spent resins and demonstrate the recommended proposal represents BAT/ALARP at GDA phase.

4.7.3.4.3 Low Activity Spent Resins

Low activity spent resins are generated from the APG [SGBS] under normal conditions and are categorised as VLLW in UK HPR1000.

Very low level waste (VLLW) is a sub-category of LLW. According to the hierarchy of routes, the optimised management of VLLW is to decay to be exempt waste and treated as industrial waste, if possible, which significantly minimise the volume of radioactive waste and is beneficial in saving the national resource of disposal facilities for LLW. Meanwhile, in Reference [24] and [25], the UK guidance establishes how to use exemption for disposal of VLLW and define the relevant exemption provisions which are the same as the Chinese exemption provisions.

Therefore, the APG [SGBS] spent resins generated by the UK HPR1000 are to be managed as waste disposed of under exemption provisions, which are then treated as industrial waste by incineration, compaction, size reduction, or landfill if possible, according to UK requirements.

The management route of the low activity resins is shown in F-4.7-5.

F-4.7-5 Management Route of Low Activity Spent Resins

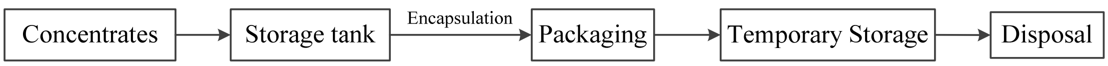
Under steam generator tubes rupture conditions, the spent resins from the demineralisers of the APG [SGBS] are contaminated, and they are treated the same as the other spent resins described in Sub-chapter 4.7.3.4.2.

4.7.3.4.4 Concentrates

The concentrates from TEU [LWTS] evaporator are preliminarily categorised as ILW/LLW in UK HPR1000.

The concentrates are encapsulated with cement in the steel drums to form a package after sampling and measurement. The packages are stored in the temporary storage facility on site prior to disposal.

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



F-4.7-6 Management Route of Concentrates

For UK HPR1000, besides cement encapsulation, in-drum drying process can also be used for concentrate treatment. In-drum drying is generally used as a technique to remove (free) water. It may be used for solid waste that contains a significant amount of water (drying) or for aqueous waste streams, resulting in a solid that contains the major part of radioactivity. In the case of drying, the waste material is heated. To advance the process, moist air can be removed by ventilation. Drying can be carried out using readily available equipment scaled to the needs of the particular waste generation/treatment facility.

An optioneering study will be undertaken to optimise the UK HPR1000 treatment proposal for concentrates and demonstrate the recommended proposal represents BAT/ALARP at GDA phase.

In addition, the ILW concentrates will be potentially identified as boundary waste in UK HPR1000. A program of work to identify the boundary waste from the ILW of

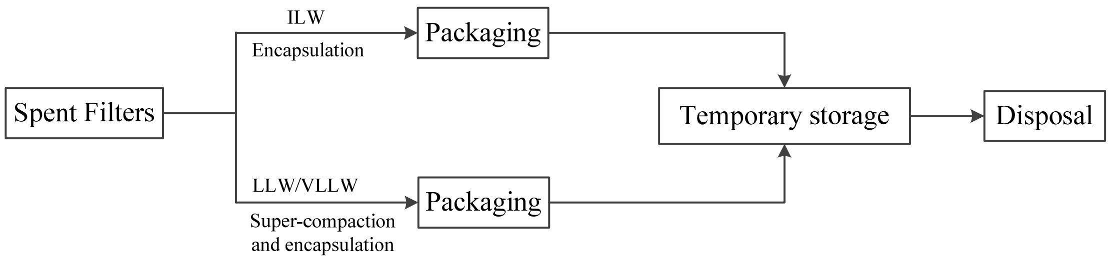
UK HPR1000 will be undertaken according to *Guidance on Decision Making of Waste Close to the LLW and ILW Categorisation Boundary that Could Potentially Cross the LLW Boundary*, Reference [23].

4.7.3.4.5 Spent Filter Cartridges

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

The ILW spent filter cartridges are initially stored in shielded containers and then encapsulated within steel containers. The LLW spent filters, which are treated as dry active waste, are super compressed to pallets and then encapsulated in the steel containers. The packages are stored in the temporary storage facility on site prior to disposal.

The management route of spent filters is shown in F-4.7-7.



F-4.7-7 Management Route of Spent Filter Cartridges

For UK HPR1000, besides cement encapsulation and super-compaction, some technologies such as polymer encapsulation and dismantling which can be used in spent filter cartridges treatments are considered.

a) Polymer encapsulation has previously been used in France, Germany, USA, Canada and Japan. It is widespread and a feasible technique for the nuclear plants including the UK with OPEX for treating filter cartridge. Different types of polymers are used, which are epoxy resins, polyesters, polyethylene, polystyrene and copolymers. The product has a passively safe wasteform with good leach resistance for many radionuclides;

b) Dismantle is usually breaking down the bulky or oversized solid waste (e.g. large components or structural debris) to facilitate treatment by the intended processing equipment or minimise the conditioning waste volume. Dismantling methods include mechanical cutting and hot cutting technique, such as saws, shears, wire cutters, thermal cutting, laser cutting, etc.

An optioneering study will be undertaken to optimise the UK HPR1000 treatment proposal for the spent filter cartridges and demonstrate the recommended proposal represents BAT/ALARP at GDA phase.

Furthermore, RWM produced the full range of standardised ILW waste containers used in the UK, which are introduced in Reference [21]. An optioneering study will be undertaken select an appropriate packaging container for UK HPR1000 spent filter cartridges and demonstrate the recommended proposal represents BAT/ALARP at GDA phase.

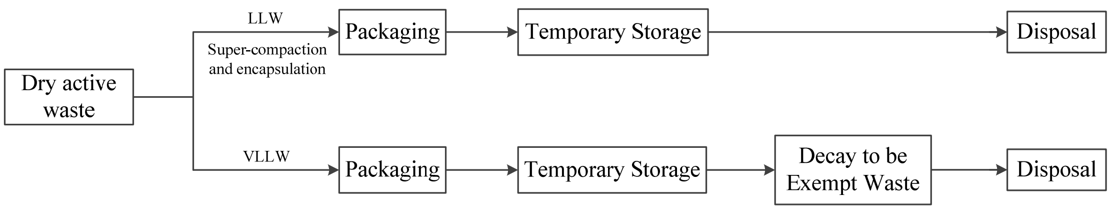
4.7.3.4.6 Dry Active Wastes

Dry active wastes are generated during operations and maintenance in radioactive areas. It includes contaminated personal protection equipment, monitoring swabs, plastic, contaminated tools, etc.

The dry waste is firstly characterised and collected at source based on contamination levels, so the active waste and non-active waste are segregated to reduce the quantity of dry active waste. The dry active waste is sent to the Waste Auxiliary Building (BQS) for further segregation as compactible and non-compactible waste based on properties, sizes and materials of the waste.

The compactable waste and non-compactable waste are mixed in certain percentage and pre-compacted into the steel drums. The compactible steel drums (with waste) are super-compressed into pallets and encapsulated in the disposal drums. The packages are stored in the temporary storage facility on site prior to disposal. The VLLW dry active waste is placed into waste containers to decay to be exempt waste.

The management route of dry activity waste is shown in F-4.7-8.



F-4.7-8 Management Route of Dry Active Waste

Besides super-compaction, some technologies such as incineration, metal melting, and directly disposal are provided by LLWR and can be used for dry activity waste treatment are considered:

a) Incineration is the most commonly used thermal treatment process. It is widespread and a feasible technique for combustible waste. It involves burning combustible waste in an enclosed chamber (furnace) in the presence of air at a temperature in the range of 800℃~1000℃.

b) Metal melting is a means of reducing the size and overall volume of the metal prior to disposal. It is good practice for metallic waste, which recycles the material. Melting can be used to decontaminate metal so that the clearance and exemption limit of the processed metals is achieved and the metal can be considered to be 'non-radioactive'.

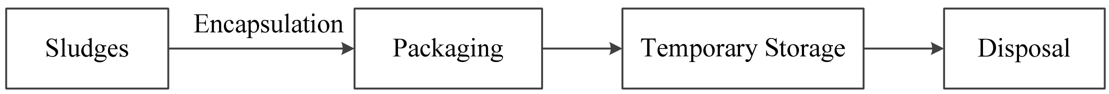
The analysis of acceptability of the LLW dry active waste against WACs of different treatment services is being undertaken and the dry active waste management proposal can be continuously optimised according to the acceptability analysis.

4.7.3.4.7 Sludges

Sludges generated from the sumps and tanks associated with the water auxiliary circuits are preliminary categorised as ILW and LLW.

The sludges are encapsulated with cement in the steel drums. The formed packages are stored in the temporary storage facility on site prior to disposal.

The management route of sludges is shown in F-4.7-9.



F-4.7-9 Management Route of Sludages

Besides cement encapsulation, some technologies such as incineration, in-drum drying which can be used in sludges treatment are also considered.

a) Incineration is the most commonly used thermal treatment process. The incineration can be used in sludges treatment when the slugdes meets the WAC of combustible waste treatment which can be provided by LLWR;

b) In-drum drying is generally used as a technique to remove (free) water. It may be used for solid waste that contains a significant amount of water (drying) or for aqueous waste streams, resulting in a solid that contains the major part of radioactivity.

An optioneering study will be undertaken to optimise the treatment proposal for the UK HPR1000 sludges and demonstrate the recommended proposal represents BAT/ALARP at GDA phase.

In addition, the ILW sludges will be potentially identified as boundary waste in UK HPR1000. A program of work to identify the boundary waste from the ILW of UK HPR1000 will be undertaken according to *Guidance on Decision Making of Waste Close to the LLW and ILW Categorisation Boundary that Could Potentially Cross the LLW Boundary*, Reference [23].

4.7.3.4.8 Oil

The oil generated from maintenance work during UK HPR1000 normal operation is preliminary categorised as VLLW and annual generation is very low. According to the current HPR1000 (FCG3) management route, waste oil is stored on site until the suitable authorised facility is available.

The management route of oil is shown in F-4.7-10.

F-4.7-10 Management Route of Oil

As described in T-4.7-12, there are also some technologies such as incineration, wet oxidation which can be used in oil treatment and will be considered for UK HPR1000.

a) Incineration is the most commonly used thermal treatment process. It is widespread and feasible technique in the nuclear plants including the UK with OPEX for treating oil;

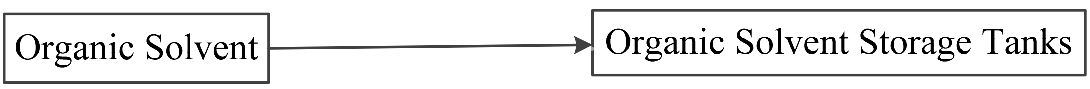
b) Wet oxidation is a technique for breaking down organic materials to carbon dioxide and water in a process, which requires significantly lower temperatures compared to incineration. The oxidation can be carried out at 100 ℃ and at atmospheric pressure, generally using hydrogen peroxide (H_2O_2), sometimes with a catalyst, or at high temperatures and pressures using oxygen or compressed air as the oxidant.

An optioneering study will be undertaken to optimize the treatment proposal for the UK HPR1000 oil and demonstrate the recommended proposal represents BAT/ALARP at GDA phase.

4.7.3.4.9 Organic Solvent

The organic solvent generated from maintenance work during UK HPR1000 normal operations is preliminary categorised as LLW and annual generation is very low. According to the current HPR1000 (FCG3) management route, waste organic solvent is stored on site until the suitable authorised facility is available.

The management route of oil is shown in F-4.7-11.



F-4.7-11 Management Route of Organic Solvent

As described in T-4.7-12, there are also some technologies such as incineration, wet oxidation which can be used in oil treatment and will be considered for UK HPR1000.

a) Incineration is the most commonly used thermal treatment process. It is widespread and feasible technique in the nuclear plants including the UK with OPEX for treating organic solvent;

b) Wet oxidation is a technique for breaking down organic materials to carbon dioxide and water in a process, which requires significantly lower temperatures compared to incineration. The oxidation can be carried out at 100 ℃ and at atmospheric pressure, generally using hydrogen peroxide (H_2O_2), sometimes with a catalyst, or at high temperatures and pressures using oxygen or compressed air as the oxidant.

An optioneering study will be undertaken to optimise the treatment proposal for the UK HPR1000 organic solvent and demonstrate the recommended proposal represents BAT/ALARP at GDA phase.

4.7.3.4.10 Ventilation Filter Cartridges

Ventilation filter cartridges generated from the different ventilation systems are preliminarily categorised as VLLW.

VLLW is a sub-category of LLW. According to the hierarchy of routes, the optimised management of VLLW is to decay to be exempt waste and treated as industrial waste, if possible, which significantly minimises the volume of radioactive waste and is benefit to save the national resource of disposal facilities for LLW. Meanwhile, in Reference [24] and [25] , the UK guidance establishes how to use exemption for disposal of VLLW and define the relevant exemption provisions which are the same with Chinese exemption provisions.

Therefore, the ventilation filter cartridges generated in UK HPR1000 are proposed to be managed as waste disposed of under exemption provisions, which are then treated as industrial waste by incineration, compaction, size reduction, or landfill where possible, according to UK requirements.

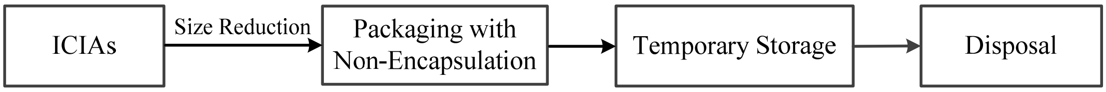
The management route of ventilation filter cartridges is shown in F-4.7-12.

F-4.7-12 Management Route of Ventilation Filter Cartridges

4.7.3.4.11 ICIAs

The ICIAs arising from reactor core which are used for measuring the pressure, temperature of reactor core are preliminary identified ILW. According to current HPR1000 (FCG3) management route and treatment technique, the ICIAs are replaced and pre-treated by special equipment and then loaded into a shielding container. The packages are stored in the temporary facility on site prior to disposal.

The management routes for ICIAs are shown in F-4.7-13.



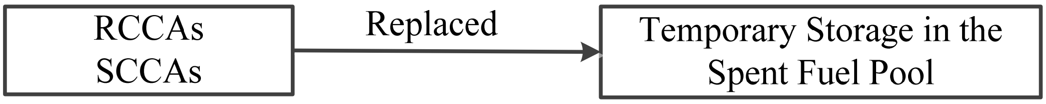
F-4.7-13 Management Route of ICIAs

For UK HPR1000, the management option of ICIA is to be determined based on the confirmed waste category. Management options of the UK HPR1000 will be provided and demonstrated the recommended proposal represents BAT/ALARP after determine the final category during step 3.

4.7.3.4.12 RCCAs and SCCAs

RCCAs and SCCAs are generated and identified in the normal operation of UK HPR1000. According to the current HPR1000 (FCG3) management route and treatment technique, the RCCAs and SCCAs are replaced by special equipment and then stored in the spent fuel pool.

The management route for RCCAs and SCCAs are shown in F-4.7-14.



F-4.7-14 Management Route of RCCAs and SCCAs

Because of the uncertainty around the category of RCCA and SCCA, the management options of RCCA and SCCA for UK HPR1000 are still to be determined. Management options of the UK HPR1000 will be provided and demonstrated the recommended proposal represents BAT/ALARP after determining the final category during step 3.

4.7.3.5 Waste Management Facilities

4.7.3.5.1 Waste Treatment Facilities

The waste treatment facilities for the UK HPR1000 consist of the a LLW treatment facility and an ILW treatment facility.

a) LLW Treatment Facility

The LLW treatment facility, located in the BQS, is designed to receive and treat the LLW generated during the operations and maintenance. A treatment line is arranged for sorting, compacting and grouting of the LLW. The LLW packages are stored in the Temporary Storage Facility (BQT) for a defined period, and finally transferred to the designated treatment or disposal facility in a standard container.

The main equipment in the LLW treatment facility includes:

1) A cutting device for size reduction of metallic components;

2) A sorting device for segregating the different waste based on the waste characteristic;

3) A pre-compactor and super-compactor for compressing the waste to minimise the final waste volume; and,

4) A cement grouting device for packing the waste within the waste container.

b) ILW Treatment Facility

The ILW treatment facility, located in the BWX, is designed to receive and treat the ILW generated during the operations and maintenance.

ILW is treated by cement encapsulation.

The main equipment for ILW treatment facility includes:

1) Two resin storage tanks and a concentrates storage tank,

2) A blender for mixing the cement and resin or concentrates,

3) Transfer roller device for the waste containers,

4) Spent filter cartridge replacement and transfer device,

5) Transfer trolley for the spent filter cartridge,

6) Mobile cement grouting device, and,

7) Automatic capping and uncapping device for the waste containers.

Work to optimise the waste management route and treatment technique for UK HPR1000 is currently being undertaken. The design of treatment facilities will also be optimised in accordance with that optimised waste management route and treatment technique in UK HPR1000. The final proposal of the ILW treatment facilities will be provided during step 3.

4.7.3.5.2 Interim Storage Facilities

The interim storage facilities are designed to accommodate the ILW solid waste generated during the UK HPR1000 operation and decommissioning.

According to the requirement of radioactive waste management in UK, the ILW packages will be disposed of in GDF, which is being developed by RWM but is not expected to be available for a number of decades. Therefore, ILW packages will be stored in an interim storage facility on site for 100 years.

According to the requirement of Industry Guidance: Interim Storage of Higher Activity Waste Packages - Integrated Approach, Reference [26], ILW interim storage facility will be developed to accommodate the wastes for 100 years at least to satisfy the requirements of UK industry guidance.

4.7.3.6 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 UK HPR1000 to minimise the volumes of solid and non-aqueous liquid wastes required disposal such as waste characterisation and segregation, size reduction, waste compaction, usage of efficient waste containers and decay storage. A separate claim '*Claim 4: Minimise Solid and Non-Aqueous Liquid Radioactive Wastes and Spent Fuel*' in PCER Chapter 3 set out how the generation of solid and non-aqueous liquid wastes are minimised and efficiently managed through adopting BAT techniques.

Solid and non-aqueous liquid low level waste can be disposed to LLWR or other successor facilities in UK. The design of the UK HPR1000 takes account of these services and allows a future operator to select optimal waste disposal routes for its solid and non-aqueous liquid wastes. A separated claim '*Claim 5: Select Optimal Disposal Routes for Wastes*' in PCER Chapter 3 provides an indicative selection of disposal routes and demonstrates that no orphan wastes will be generated.

The BAT demonstration of the solid and non-aqueous liquid waste management is detailed in PCER Chapter 3, Claim 4: Minimise Solid and Non-Aqueous Liquid Radioactive Wastes and Spent Fuel and Claim 5: Select Optimal Disposal Routes for Wastes.

4.7.4 Spent Fuel

The SF management strategy of the UK HPR1000 is presented in PCSR Chapter 29, Reference [11]. The parameters of fuel design are presented in PCSR Chapter 5, Reference [27] and the fuel storage in the spent fuel pool is presented in PCSR Chapter 28, Reference [28].

SF is generated only during the operation of the UK HPR1000 and will ultimately be disposed of in a GDF. After final shutdown, the SF will be managed in the same manner as during the operation. The waste information of SF is shown in T-4.7-13.

T-4.7-13 Waste Stream Datasheet for Spent Fuel

Parameter	Description
Waste Arising	Arising from 2 units of UK HPR1000 operations.
Waste Chemical and Physical	The spent fuel refer to the whole spent fuel assemblies, including the fuel rods, fuel cladding,

Parameter	Description
Description	grids and grid straps (spacers), grid springs, etc., while control rods are not included.
Nature of Radioactive Material	Irradiated during the operations of NPP.
Annual Arising (one unit)	72 spent fuel assemblies on average
Total Arising (60 years) (one unit)	2985 spent fuel assemblies
Waste Classification at Time of Generation	HLW

4.7.4.1 Spent Fuel Management Strategy

The SF management plan of UK HPR1000 will be divided into the following three parts:

a) The SFAs unloaded from the reactor core need to be stored in the Spent Fuel Pool (SFP) for pre-cooling due to its high radioactivity and decay heat. This process can be called short term storage.

b) The SFAs will then be transferred into a transportation cask/canister and moved to Spent Fuel Interim Storage (SFIS) facility for storage. This process can be called interim storage.

c) The SFAs will be ultimately transferred to a final disposal site. SFAs may be repackaged into appropriate casks, if required, depending on the final disposal facility and transportation requirements. This process can be called Retrieval and Final Disposal. Disposability assessment for SF will be developed.

4.7.4.2 Technology Options

The SFIS technology current available falls broadly into two categories, wet and dry, distinguished according to the cooling medium used. Both dry SFIS technology and wet SFIS technology will be considered. A preferred SFIS technology for the UK HPR1000 will be selected through a robust optioneering process during step 3.

4.7.4.2.1 Dry SFIS Technology

The dry SFIS technology can be generally divided into two categories: dry storage in either storage or dual purpose casks (dry cask SFIS technology) and dry storage in vault type storage facilities (dry vault SFIS technology).

4.7.4.2.1.1 Dry Cask SFIS Technology

The most commonly used casks are metal casks and concrete overpacks. Dry storage generally has the advantage of being modular. While in the long term, the simple passive cooling system used in the dry SFIS technology can reduce operation and maintenance requirements and costs.

The metal cask storage process is widely used for SF storage. Metal casks can be designed either for storage only or as dual-purpose casks, i.e. for both storage and transportation. Shielding is provided primarily by the cask structural material, which may be either forged steel, nodular cast iron, or composite materials. Examples of metal cask storage systems are Dresden in the U.S., Gundremmingen in Germany, and Tokai in Japan.

A concrete cask (overpack) is similar in shape to a metal cask. The concrete cask provides shielding, and the steel liner on inner cavity of the canister provides confinement function. The concrete cask SFIS technology is the most widely used dry SFIS technology in the world. The canister in the concrete cask generally consists of double layer welding redundant seal to contain any potential releases of radioactive substances to the environment.

4.7.4.2.1.2 Dry Vault SFIS Technology

A vault is a massive, radiation shielded facility in which the SFAs are stored. The dry vault facility can be either located above or below ground level. The facility can be constructed of a reinforced concrete structure containing an array of storage cavities. The SFAs are stored in sealed small containers or metal storage cylinders.

4.7.4.2.2 Wet SFIS Technology

Wet SFIS technology is pool-style storage and the storage principle is thus similar to that of the SFP. Most pools have a stainless steel inner pool lining, with a permanent monitoring of the welded seams and x-ray inspection capability to locate and detect any leaks during pool operations. The SF will be stored in racks within the SFP.

4.7.4.3 Storage Facility

As described above, the storage strategy for SF will depend on the final decision of its management. The container/cask size, arrangements within the store, cooling and shielding requirements, criticality and other safety requirements will be considered in the design of this facility. The design requirements, potential effects analysis, typical components in the interim storage facility and relevant ageing effects consideration will be developed.

It is assumed that the SFIS facility receives the spent fuel, including the failed fuels, produced from 2 units of UK HPR1000 and the siting consideration of the facility will be based on it. The capacity of the facility will be consistent with the total arising of spent fuel during 60 years of operations, which is the preliminary design values presented in T-4.7-13.

4.7.5 Decommissioning Waste

The decommissioning strategy of the UK HPR1000 is described in PCSR Chapter 24, Reference [9]. The initial decommissioning strategy for the UK HPR1000 is assumed to be immediate dismantling.

The radioactive gaseous waste generated during decommissioning is limited and can be discharged by existing or temporary HVAC, and most radioactive liquid waste will be treated by the normal operating systems or temporary ones.

Solid waste management is the most important part of decommissioning of the nuclear island as it generates the most and the greatest variety of radioactive waste. The radioactive waste generated during decommissioning will comprise of metallic components, concrete, filter, ion exchange resins, concentrate and dry wastes (e.g. disposable suits, vinyl, and scrap).

a) ILW

After preliminary analysis, ILW includes the reactor pressure vessel, spent resins and most spent filters.

b) LLW

After preliminary analysis, LLW includes concentrates, heat exchanger and tanks.

c) VLLW

After preliminary analysis, VLLW includes spent ventilation filter cartridges, dry active waste and cables.

Solid radioactive waste generated will be managed the same as the operational solid radioactive waste by using the existing facility as long as possible. If necessary, new facilities will be constructed for waste management.

Further work will be carried out during step 3 on the prediction of decommissioning source term to estimate decommissioning waste quantities.

4.8 The Development of an Integrated Waste Strategy

In line with UK policy, it is required for the licensees to produce and maintain an IWS for the current and future waste management. According to the requirements in Reference [6] and [18] , the IWS should:

a) Include all the waste arising on a site (including radioactive waste and non-radioactive waste), ranging from operational through to decommissioning;

b) Demonstrate that the waste can be appropriately managed at the time and rate at which it will arise.

The preliminary radioactive waste management arrangements are developing and shown in this document. The management arrangements relevant to non-radioactive waste are developing and will be shown in the IWS document.

An IWS will be developed for UK HPR1000 which aims to ensure that the waste streams, including materials that may become waste in the future, can be managed in a safe and appropriate manner, as well as complying with safety and environmental protection principles.

In the IWS document, a summary waste strategy and the approach to develop the waste management strategy for all the waste streams and SF generated by the UK HPR1000 will be described. Assumptions, risks and opportunities for implementing the waste management strategy and available solutions within the envelope of current UK options will also be identified.

The IWS is a live document and will continue to be developed throughout the GDA phase and 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 requirements.

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 treatment and disposal routes of LAW, including low activity solid and non-aqueous liquid radioactive wastes, must be compliant with WACs published by waste service suppliers, Reference [29], [30], [31], [32] and [33]. These WACs will be used to demonstrate that LLW packages generated by the UK HPR1000 can be compatible with off-site facilities and no orphan waste will be generated.

The acceptable analysis of acceptability of LLW for off-site disposal will be undertaken and an 'Agreement in Principle' will be obtained from LLWR by Waste Enquiry Form (WEN) during step 3, so as to ensure that LLW generated during reactor operation can be accepted by off-site facilities to minimise the accumulation of radioactive waste. The disposability of LLW is presented as BAT demonstration in PCER Chapter 3, Sub-chapter 3.4.5.2.

As for the UK HPR1000, it is recognised that LAW treatment routes will be optimized by optioneering process considering the best use of metallic waste recycling services, combustible waste treatment services, super-compactable waste treatment and the disposal of radioactive waste in the UK. And more, the compatible analysis of LAW against WAC will also be undertaken to support the establishment of

'Agreement in Principle'.

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

4.9.2 Disposability Assessment of HAW

The GDF is under development but will 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. Thus the HAW should be processed into a passive safe state to be stored until a long term management solution is established. This situation is not unique to the UK HPR1000 but is applicable to all the existing and new UK reactors.

In order to minimise the risk that the conditioning and packaging of HAW generated throughout the reactor lifetime results in incompatible waste with a future GDF, disposability assessment of HAW in the UK HPR1000 is being undertaken to get the advice from RWM, it is also presented as BAT demonstration in PCER Chapter 3, Sub-chapter 3.4.5.3.

The Radioactive Waste Management Case (RWMC) will be developed to demonstrate HAW can be managed effectively at nuclear site licensing phase.

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

4.10 Conclusions

This arrangements document demonstrates that:

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

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

c) The abatement processes and waste management processes are demonstrated as being BAT;

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

The challenges associated with the management of solid radioactive waste and SF are identified, and all waste streams have process routes to interim storage or final disposal solutions. Waste management solutions will be identified and chosen following the BAT process for the UK HPR1000.

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