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# UK ABWR Generic Design Assessment

## Generic PCSR Chapter 18 : Radioactive Waste Management


Hitachi-GE Nuclear Energy, Ltd.

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## Executive Summary

This chapter describes the concept and preliminary design safety case for the operational phase of the radioactive waste management systems for the UK Advanced Boiling Water Reactor (UK ABWR). It lists all of the Safety Functional Claims (SFC) that are made on these systems to maintain the high level safety functions during normal operation and fault conditions. It also lists all of the Safety Property Claims (SPC) that demonstrates compliance of these systems with the Nuclear Safety and Environmental Design Principles (NSEDP). Relevant links to other Pre Construction Safety Report (PCSR) chapters are identified.

The designs of majority of the radioactive waste management systems are at concept design which aligns with regulatory guidance for Generic Design Assessment (GDA), and is based on proven technology. Although at concept design stage, the design is sufficiently developed to enable a high level assessment of the risks associated with radioactive waste operations. Additional risk reduction measures have been introduced (in comparison with the J-ABWR design) in response to safety assessments undertaken in GDA, and these include changes to the Off-Gas system design to improve protection in fault scenarios. There have also been changes to the treatment of liquid and solid wastes compared to the process used in J-ABWR, for example: where practical wastes are promptly packaged directly in to the disposal packages and all wastes can be disposed of in the UK. These changes are primarily associated with UK government waste policies and the waste categorisation and disposal routes being different in the UK to other countries that currently have a BWR or ABWR.

Work to underpin the safety case for radioactive waste management will continue during development of the detailed design that will be undertaken at the site specific stage. The final position for GDA is presented in this Chapter and future updates as the design progresses will be presented in a site specific safety case to be developed by a future licensee.

The overall PCSR justification that the UK ABWR is safe and satisfies the As Low As Reasonably Practicable (ALARP) principle is underpinned by hazards assessments, design basis analysis, probabilistic safety analysis, beyond design basis analysis and human factors analysis, described in chapters 6, 7 and 24 to 27 of the PCSR. These analysis chapters do not specify any safety claims or requirements for design parameters on individual radioactive waste management systems that are presented in this chapter. Instead they apply analysis conditions and assumptions that are based on, and fully consistent with, the design information and safety claims for these systems that are presented in this chapter, in order to substantiate those claims.

The chapter demonstrates that the risks associated with the design and operation of the radioactive waste management systems for the UK ABWR are capable of being reduced ALARP as the design progresses into detailed design. This PCSR has been produced to support the GDA process, and concludes that the design and its safety justification have been developed to a level of detail that is appropriate for GDA. However, GDA is a preliminary step in the process to licence a nuclear power plant in the UK, and it is acknowledged that further work will be required post-GDA to develop the design and fully incorporate site specific aspects. This work will be the responsibility of any future licensee and operator.

## 18.1 Introduction

This PCSR chapter focuses on the generic design aspects of the radioactive waste management for the UK ABWR during operation. During operation and decommissioning quantities of radioactive solid, liquid and gaseous waste will be generated. The waste management at the end of generation is contained in Chapter 31, sub-section 31.8 Decommissioning waste and wastes remaining on site at end of generation.

Hitachi-GE's waste strategy demonstrates that it has done everything possible (considering proportionality) to:

- Prevent and minimise (in terms of radioactivity) the creation of radioactive waste,
- Minimise (in terms of radioactivity) discharges of gaseous and aqueous radioactive wastes,
- Minimise the impact of those discharges on people, and adequately protect other species,
- Minimise (in terms of mass and volume) solid and non-aqueous liquid radioactive wastes and spent fuel, and
- Select the optimal disposal routes.

The waste has been minimised in terms of avoidance at generation as described in Generic Environmental Permit (GEP) Demonstration of BAT [Ref-12].

The key systems and equipment comprising the gaseous radioactive waste management systems are:

- The Off-Gas System (OG),
- Heating, Ventilating and Air Conditioning (HVAC) systems for some buildings and facilities,
- Main stack and associated plant and equipment,
- Turbine Gland Steam (TGS), and
- Tank Vent Treatment System (TVTS).

The design of the OG has been developed to address the following functions:

- Maintaining the main condenser vacuum, by extracting non-condensable gas,
- The safe recombination of flammable gases (hydrogen and oxygen), which are generated by radiolytic decomposition of reactor cooling water, to reduce the possibility of a hydrogen explosion, and
- To minimise and control the release of radioactive gases into the atmosphere by delaying and filtering the off-gas waste process stream to adequately decay short lived radioactive isotopes and filter out particulate matter.

The functions of the HVAC system that are of relevance to the management of gaseous radioactive wastes are:

- Limiting the leakage or spread of radioactive materials from plant and equipment in a room/area during operation or maintenance/inspection,
- Confining such radioactive materials locally, and
- Where necessary, filtering contaminated air prior to its discharge to atmosphere.

The buildings identified with the potential to generate airborne contamination are the Reactor Building (R/B), the Turbine Building (T/B), the Radwaste Building (Rw/B), the Service Building (S/B) and the solid waste treatment facilities. Where practicable, HVAC systems discharge to the environment via the main stack.

The vast majority of the gaseous radioactive discharges from the UK ABWR are made via the main stack; this includes the residual gaseous wastes from the OG, TGS, TVTS and main building HVAC systems described in the following sections. These systems include High Efficiency Particulate Air Filters (HEPA) before discharge via the main stack located on the roof of the reactor building. Associated equipment includes the discharge monitoring equipment.

The key systems and equipment comprising the liquid radioactive waste management systems, collectively referred to as the Liquid Waste Management System (LWMS), are detailed below:

- Low Chemical Impurities Waste (LCW) treatment system in the Radwaste Building (Rw/B),
- High Chemical Impurities Waste (HCW) treatment system in the Rw/B (including discharge),
- Laundry Drain (LD) treatment system in the Service Building (S/B) (including discharge),
- Controlled Area Drains (CAD) system in the Rw/B (including discharge),
- Spent Resin and Sludge (SS) system, and
- Concentrated Waste (CONW) system.

The LCW and HCW treatment system are housed in the Rw/B, which are used to treat radioactively or potentially radioactively contaminated waste water, for re-use in the reactor. The LCW system is designed to allow the efficient treatment of relatively large volumes of waste water containing low levels of both insoluble and soluble impurities. The HCW treatment system is designed to allow the efficient treatment of waste water containing high levels of soluble impurities.

The LD treatment system processes waste water originating from the laundry and the S/B showers and hand washing facilities. These waste water streams contain detergent, suspended solids and organic material, as well as potentially low levels of radioactive crud, and are therefore unsuitable for re-use in a reactor system.

The CAD system collects water from the local air-conditioning system drains in the R/B and T/B, and also from the potentially contaminated drains of various equipment systems in the controlled areas of the R/B and the T/B. Liquid waste in the CAD System is not expected to be radioactive but has the potential to be contaminated.

The SS system collects and stores secondary wastes from ion exchange and filtration processes in tanks before being transferred for solidification. The scope of the SS system also includes the CUW (Reactor Clean-up System) Backwash Receiver Tank located in the R/B and the CF (Condensate Filter) Backwash Receiver Tank located in the T/B, and wastes from these systems are transferred to the storage tanks in SS system in the Rw/B.

The purpose of the CONW is to receive and store concentrated waste from the bottoms circuit of the HCW evaporator and then send it to the Wet-solid Low Level Waste (WLLW) processing system.

Gaseous and liquid radioactive wastes are safely processed in order to ensure minimisation of discharge to the environment. The proposed annual gaseous and liquid discharge limits for UK ABWR are consistent with guidance from the Environment Agency (EA). Both the gaseous and liquid discharges from the UK ABWR should not exceed those of comparable power stations across the world. Both gaseous and liquid discharges are considered in this PCSR and the GEP documentation produced for GDA.

The various systems for the management of solid radioactive wastes generated by the UK ABWR are collectively referred to as the Solid Waste Management System (SWMS). The SWMS has been designed to concept level to receive, sort and process/condition Very Low Level Waste (VLLW), Low Level Waste

(LLW), Intermediate Level Waste (ILW) and High Level Waste (HLW)[1] waste streams resulting from UK ABWR operation. Following processing and conditioning, VLLW/LLW is dispatched off-site for disposal either by incineration, recycling (in the case of recyclable metals) or direct disposal. ILW is transferred for interim storage (pending availability of the Geological Disposal Facility (GDF)) in an on-site ILW store (ILWS) and HLW is dry stored on-site prior to disposal at GDF.

The SWMS concept design currently comprises the following facilities/systems:

- Wet-solid ILW (WILW) processing system (part of the Rw/B),
- Wet-solid LLW (WLLW) processing system (part of the Rw/B),
- HLW decay storage facility,
- ILW Store (ILWS),
- Solid waste processing including the LLW Monitoring and Marshalling Area (MMA), LCW Filter Packaging Room and Solid Waste Facility (SWF), and
- Transportation of wastes on and off-site.

Where it is unavoidable the accumulation of radioactive waste is minimised, as this reduces the potential hazard from the waste. When waste is accumulated on site the quantity of waste, the magnitude of radiological hazard, the potential for the hazard to be realised and the potential dose has been considered and reflected in the strategy for safe processing of the waste for the expected timescales that waste will be present on the site. All the waste generated is compatible with currently available disposal technology and routes or safely discharged.

HLW and ILW, collectively known as higher activity wastes (HAW), strategies follow the UK Government Funded Decommissioning Programme (FDP) Guidance [Ref-32] base case assumption that the HAW from new nuclear power stations will be disposed of in the government constructed GDF. The anticipated timescales for the management of ILW and HLW extend after the reactor has ceased operations. Hitachi-GE ensures safety at all times from production to disposal. This includes the intermediate steps such as interim storage, within the appropriate timescales thus ensuring safety at all times, until safe disposal. The HAW is stored in accordance with good engineering practice and the principle of passive safety. This is to ensure continued safe interim storage, processing of the waste into a form suitable for transportation (if required), transportation to and safe storage in the GDF. The generation of HAW, its safe management and subsequent treatment is such that a disposability assessment concludes that the HAW could be disposed of in the GDF.

The HAW generated by the UK ABWR can be managed such that all the waste presented within GDA can be safely managed and that risks are capable of being reduced ALARP for greater than the expected on–site storage period expected before the UK government provides the GDF.

The generation of LLW and VLLW is such that these can be processed and will meet the relevant waste acceptance criteria (WAC) issued by the licensed disposal sites in the UK. This follows the UK Government FDP Guidance which provides a base case assumption that: "… LLW arising during operation and decommissioning will be packaged on site by the Operator and dispatched to a disposal facility promptly after they have been generated. For the purposes of the Base Case we assume that disposal will be at the LLW Repository (LLWR) operating in West Cumbria or a successor facility…" This is further underpinned by Government policy on LLW and Environmental Permitting Regulations 2016 (EPR16), which provide assurance that new disposal facilities (either at the existing LLWR or elsewhere) will ultimately be provided to receive waste.

[1] The full definition of each waste category can be found in UK regulatory joint guidance at http://www.onr.org.uk/wastemanage.htm

The waste streams are integrated such that they include all wastes arising from the UK ABWR and take into account the interdependencies between waste streams, processes and with offsite disposal have been recognised. The radioactive waste management is part of a series of strategies and integrated with other strategies such as decommissioning as well as being consistent with government policy.

### 18.1.1 Background

#### GDA Design Aspects

The UK ABWR design has been developed based on the technology demonstrated from operating stations in Japan and around the world. The reactor design has undergone continuous improvement since the introduction of the Boiling Water Reactor (BWR) technology in the 1950s as described in PCSR Chapter 9 General Description of the Unit. The handling, storage and removal of radioactive waste from the reactor building have been included in the continual BWR design development. In addition to designing all radioactive waste management systems according to international good practice, a large number of options were investigated that might further reduce risk, particularly with relation to preventing loss of containment. As a result of evaluating these options a number of changes to the radioactive waste management systems in the UK ABWR have been considered and taken forward.

The management of each radioactive waste stream generated by the ABWR have been developed. Assessment criteria that have been developed in line with the ALARP methodology described in PCSR Chapter 20 : Radiation Protection have been adopted. The output of this process is a preferred option for the management of each waste stream, upon which further risk optimisation has been conducted during GDA and will be continued at the appropriate stage by the future licensee.

Fault and hazard assessments have been conducted against the preferred option in order to understand the risks involved, in order to demonstrate that risks are reduced, or are capable of being reduced, to ALARP by the future licensee.

#### Design Status for GDA

Hitachi-GE design for the radioactive waste systems is in line with the Office for Nuclear Regulation (ONR) and EA guidance for GDA ([Ref-35] and [Ref-34]). The regulatory guidance states that where radioactive waste management facilities are an integral part of the reactor their design should be at the same level as the reactor facility. It also states where the radioactive waste management facilities are not an integral part of the reactor concept design can be used for GDA. The management of radioactive waste for the UK ABWR is not always an integral part of the reactor design thus, under the regulatory guidance; concept design is acceptable for some parts of the radioactive waste management for GDA. Clarification of where concept design or a more detailed design level has been applied is explained in Table 18.2-1 of this PCSR chapter in the referenced supporting documentation. All of the civil structures required to house the LWMS and SWMS are at concept stage for GDA.

#### Chemistry Control

The design of the UK ABWR and the associated facilities has been developed to minimise the volumes of radioactive wastes. A key contributor to waste generation and optimisation is the chemistry regime used within the reactor and the associated processes; this is extensively described in PCSR Chapter 23 : Reactor Chemistry and summarised briefly below.

The ALARP water chemistry regime for the UK ABWR is Hydrogen Water Chemistry with On-Line NobleChem™ and Depleted Zinc Oxide. To complement this, optimum iron control is to be used to manage operator dose to ALARP as well as using standard water treatment processes to ensure chloride and sulphate levels are kept as low as possible to reduce the risk of corrosion. This is consistent with best operating experience summarised by EPRI based on the US fleet of BWRs.

### Inventory

The waste inventory has been developed by assessing where materials will become radioactive and the level of radioactivity exposure of those materials over time. This radioactive waste inventory has been developed for all wastes that are to be generated over the expected full lifecycle of the facilities.

The spent fuel inventory has been derived using the maximum burn-up of the spent fuel and the expected number of fuel assemblies used over the expected generating life of 60 years for the station. The maximum burn-up of the fuel has also been used to evaluate the level of radioactivity in the waste due to activation.

The level of radioactivity due to contamination has been derived from radioactive particles and isotopes generated from within the primary system (i.e. the core and its coolant). This has been used to evaluate the:

- Dose for the radioactive discharges (liquid and gaseous) to the environment. The radioactive discharges are evaluated in two cases; normal operation [Ref-19] and fault condition [Ref-27], and
- Radioactive waste inventory (liquid, solid, gaseous) so that appropriate processing techniques are selected for the processing of each radioactive waste depending on their radioactivity. The radioactive waste inventory is further described in PCSR Chapter 20 : Radiation Protection, section 20.5 End User Source Term and the related topic report, "Calculation of Radioactive waste End User Source Term Value." [Ref-9].

### Radioactive Waste Strategy

Reactor chemistry and materials selection determine the nature and amount of waste required to be processed by the liquid waste management systems and ultimately most of the solid waste management systems (e.g. used filters).

The initial generation of wastes from the UK ABWR is minimised through reactor chemistry. Extensive work has been done in this area which is detailed in Chapter 23 : Reactor Chemistry. The LWMS collects and processes radioactive liquid waste generated in controlled areas. The LWMS has also undergone extensive work to minimise residual waste detailed in later sections of this Chapter. The SWMS has been designed to concept level to receive, sort and process/condition VLLW, LLW, ILW and HLW waste streams resulting from UK ABWR operation. This includes processing and packaging wastes arising from the LWMS into a passively safe form for long term storage or disposal. Waste minimisation has been a key attribute of the work done for the SWMS as detailed in later sections of this Chapter.

Throughout the radioactive waste design process in GDA the Eliminate, Reduce, Isolate, Control, Personal Protective Equipment and Discipline (ERICPD) philosophy has been applied culminating in the demonstration that all wastes generated are necessary, treatable and disposable in principle. The design is cognisant of this approach and consideration has been given to the process of waste storage such that accumulation is minimised in the concept design.

Wastes generated during decommissioning are limited in nature and quantity by, the reactor chemistry during operations, and the material selection in the design. Decommissioning wastes will be processed into a passively safe form and then packaged for long term storage or disposal. The ERICPD philosophy has been applied to decommissioning wastes to ensure that quantity of waste generated are minimised. More information surrounding this can be found in Chapter 31 : Decommissioning.

Waste minimisation has thus been considered as a holistic and integral part of all UK ABWR systems. This process and linkage is shown in Figures 18.1-1 and 18.1-2.

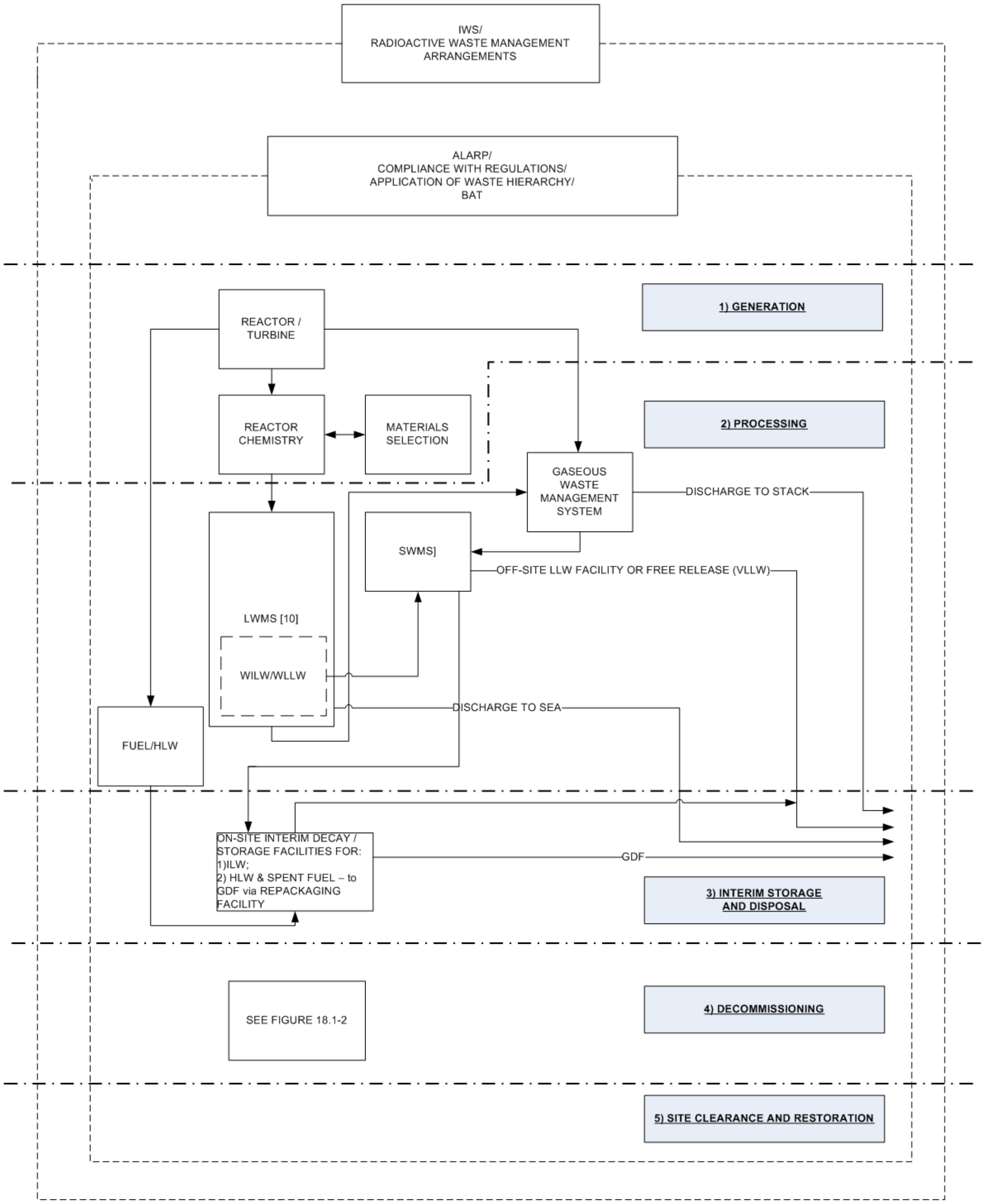



**Figure 18.1-1: Through Life Block Diagram (Operations and Interim Storage)**

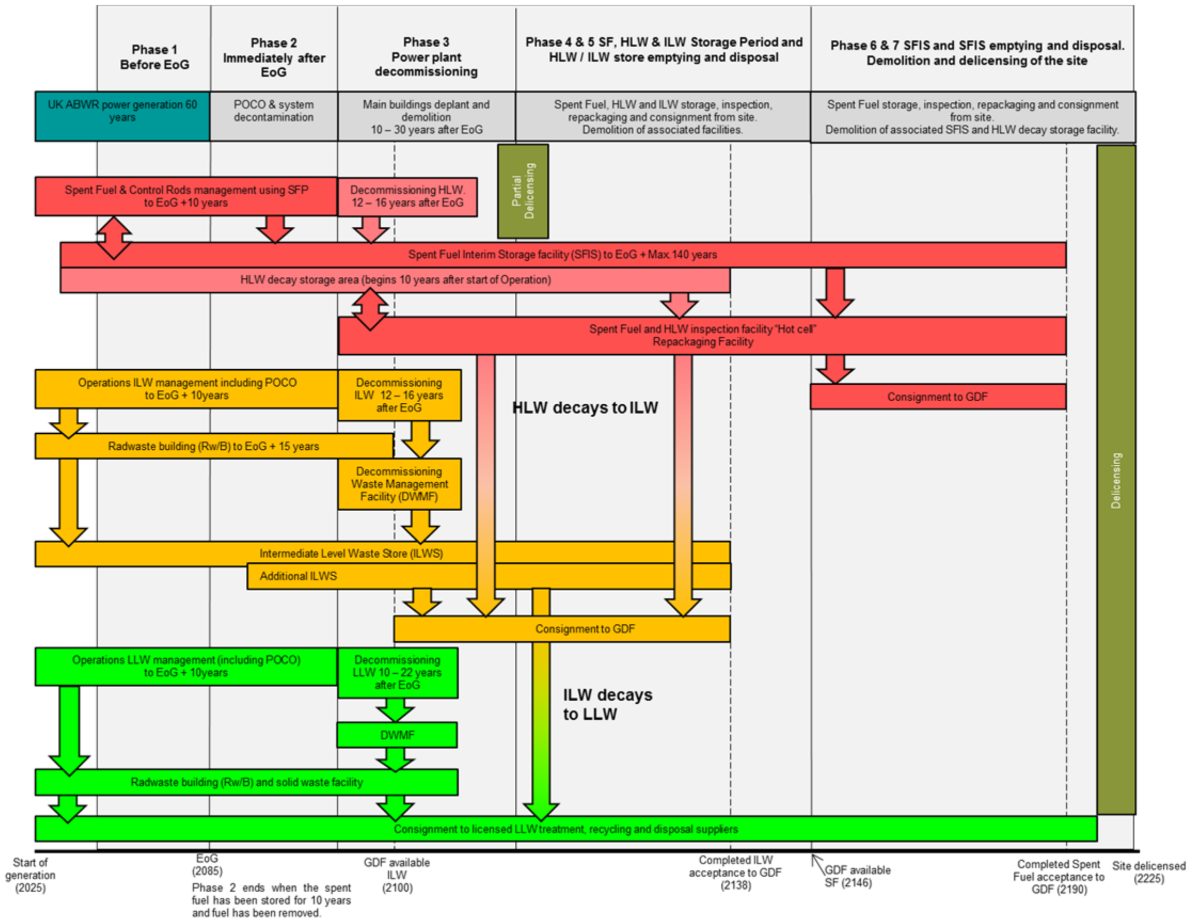



**Figure 18.1-2: Graphical Representation of the UK ABWR Prompt Decommissioning Strategy**

Hitachi-GE has identified all of the waste streams that are produced by the UK ABWR and has developed appropriate waste strategies. An Integrated Waste Strategy (IWS) [Ref-20] appropriate to the GDA process has been produced which provides an overarching description of the waste strategy. The IWS refers to and is supported by detailed strategy documents including a Radioactive Waste Management Arrangement document [Ref-18]. The strategies are based on the optioneering carried out to establish both the Best Available Technique (BAT) solution, which investigated the potential to further reduce risk, and the expected waste inventory over the lifetime of the facilities.

The strategies are consistent with Government policy, including the Government's overall policy aims on sustainable development. They are integrated with the decommissioning strategy and other relevant strategies. The waste management hierarchy has been used to ensure that the generation of radioactive waste is prevented or minimised. The full range of options have been considered during the development of the strategies that cover the UK ABWR's current and future radioactive waste inventory, including waste arising from proposed new facilities over the anticipated timescales for the management of radioactive wastes, from production to disposal (where appropriate), including intermediate management steps.

In so far as can be demonstrated in GDA, the design of HLW, ILW and LLW processing and storage facilities meets both the principle for ALARP and BAT in relation to any associated discharges and disposals. In order to demonstrate ALARP, the main faults and fault groups need to be identified and to have been taken into consideration accordingly.

The requirement for an away from reactor fuel store may be a significant period after the reactor starts operation because of the capacity provided in the reactor fuel pond (typically 5 to 15 years). Within this period, there will be more experience of long-term storage and (potentially) disposal. Therefore, Operators will be able to take account of changes in high level waste practices and may have greater clarity on disposal endpoints. To give the Regulators the required level of confidence that the operators can safely handle, store and dispose of HLW viable options have been identified and a strategy/plan has been developed to show that one of these could be developed and implemented. This will allow a conclusion at the end of GDA that the management of HLW has been adequately addressed.

For HLW and ILW storage facilities, Hitachi-GE demonstrates that they can safely handle, store and dispose of the wastes they generate. This requires sufficient levels of design to justify the credibility of the storage options proposed; understanding how spent fuel and waste streams and their packaging might evolve over the storage period; plans for data and records management; a consideration of spent fuel and waste disposability and potential implications of waste arisings for the national disposal programme; and robust estimates of the required capacity. For the spent fuel stream, the detail will be described in PCSR Chapter 32 : Spent Fuel Interim Storage. Only the outline will be described in this chapter. For the other storage facilities detailed plans showing key milestones can satisfy the needs of GDA [Ref-34]. A detailed review of the storage requirements underpins the plans. This includes:

- The types of facility that could be used,
- When facilities will be developed and constructed; and
- The research needs, if any are required, that ensure the waste and spent fuel can be stored, transported and disposed of.

For each waste stream an appropriate strategy identifies the optimum waste management route, taking into account of off-site and on-site interdependencies. All wastes generated by the UK ABWR can be managed using current techniques and are of a type or form compatible with currently available storage or disposal technology. The safe handling and storage requirements have been taken into account all wastes to be generated over the full lifecycle of the facilities.

## Disposability

The LLWR offers a well-recognised service for the whole UK nuclear industry. It is currently used by many operational sites in the UK and also by the legacy sites. However, there are a number of other facilities which can be used for waste disposals which are not listed in this document. The references to LLWR are assumed for GDA and Hitachi-GE has obtained an ‘Acceptance in Principle’ for management/disposal of VLLW and LLW [Ref-30] based upon the services provided by LLWR.

The consideration of the disposability of solid HAW and spent fuel is an important aspect of the GDA process. In accordance with regulatory guidance, Hitachi-GE has requested that Radioactive Waste Management (RWM - part of the Nuclear Decommissioning Authority (NDA)) provides advice on the disposability of all the HAW and spent fuel expected to arise from the operation of the UK ABWR. .

This GDA disposability assessment has evaluated the implications of a single UK ABWR illustrates the potential implications for geological disposal of constructing and operating a fleet of such reactors operating for 60 years. RWM have carried out a GDA disposability assessment on the UK ABWR operational wastes and spent fuel arising ([Ref-36] and [Ref-37]). The assessment has concluded that:

“RWM has concluded that sufficient information has been provided by Hitachi-GE to produce valid and justifiable conclusions under the GDA Disposability Assessment. RWM has concluded that ILW and spent fuel from operation and decommissioning of a UK ABWR should be compatible with plans for transport and geological disposal of higher-activity wastes and spent fuel. It is expected that these conclusions would be supported and substantiated by future refinements of the radionuclide inventories of the higher-activity wastes and spent fuel, complemented by the development of more detailed proposals for the packaging of the wastes and spent fuel, and better understanding of the expected performance of the waste packages. At such later stages, it is expected that more specific and detailed packaging proposals would be assessed, and potentially endorsed, through the established disposability assessment process for assessment of waste packaging proposals.

The GDA disposability assessment for the UK ABWR has not identified any significant issues that challenge the fundamental disposability of the wastes and spent fuel expected to be generated from operation of such a reactor. This conclusion is supported by the similarity of the wastes to the expected arisings from the existing Pressurised Water Reactor (PWR) at Sizewell B. Given a disposal site with suitable characteristics, the wastes and spent fuel from the UK ABWR are expected to be disposable."

A total of 27 potential issues / opportunities for improvement have been identified by RWM Limited, none of which are considered problematic to address. A review of the issues by Hitachi-GE suggests that all are best addressed at the site specific assessment stage as they are related to maturing packaging plans rather than fundamental issues with disposability (which would need to be addressed within the GDA process).

### Human-Machine Interface

The main Human-Machine Interface (HMI) of LWMS is established in the Radwaste Building Main Control Room (Rw/B MCR) to provide a facility for effective and reliable operation, monitoring and control of the LWMS and process. The control and monitoring of the LWMS are performed from Rw/B MCR. The control for the SWMS is expected to be performed from the Rw/B MCR or separate control room within each facility.

The control and monitoring of the OG system are performed by the Main Control Room (MCR) in the Control Building (C/B), and the control for the TVTS is expected to be performed from the Rw/B MCR.

The structure and required function for the Rw/B MCR and the MCR are covered by section 21.4 and 21.7 in PCSR chapter 21 : Human-Machine Interface.

However the majority of LWMS, the SWMS and the TVTS are at concept design stage as described in section 18.2.2, and therefore the details for HMI will be determined at the post GDA phase.

### Human Factor

In order to ensure that the human-related elements of any complex system are considered as effectively as possible during all stages in a design project and the lifecycle of the plant; and to ensure that the resulting system is able to function effectively and safely, a process known as Human Factors Integration (HFI) is used. This has been the case for the development of the UK ABWR.

The effective incorporation of HFI for the radioactive waste management systems has resulted in a number of Human Based Safety Claims (HBSCs) being identified that place safety related demands on the operators of the plant. The complete substantiation of these Functional HBSCs for a proof of systems at concept design is not proportionate within the GDA stage. The claims are underpinned by supporting HF Property Claims (HFSPCs), (see PCSR Chapter 27 : Human Factors, Appendix B).

The specific Functional HBSCs and HFSPCs relating to all of the radioactive waste management systems are described in [Ref-11].

### 18.1.2 Document Structure

The main technical content of the chapter summaries the contents of the topic reports on radioactive waste as shown in the document map in Appendix C.

Section 18.2 Purpose & Scope: This section sets out the purpose and scope. It identifies the aspects that are included within the scope of the radioactive waste management chapter and identifies what is not included.

Section 18.3 Safety Claims: This section sets out the main safety claims and where the arguments and evidence can be found to support the safety claims.

Section 18.4 OPEX: This section identifies the world wide operational experience relevant to this chapter and identifies good practice.

Section 18.5 Liquid Waste Processing in the Radwaste Building: This section provides a summary of the liquid wastes that are processed within this building. It contains a brief description of the waste and the systems housed within the Radwaste Building, articulates the main claims, specific to the waste streams in this building and where the arguments and evidence can be found to support the safety claims. It also identifies the world wide operational experience relevant to this section and identifies relevant good practice. At a high level it summarises any assumptions, limits and conditions for operation applicable to the requirements for safe liquid waste processing in this building.

Section 18.6 Wet-solid Waste Processing in the Radwaste Building: This section provides a summary of the solidification of WILW and WLLW wastes that are processed within this building. It contains a brief description of the waste and the systems contain within the radioactive waste building, articulates the main claims, specific to the waste streams in this building and where the arguments and evidence can be found to support the safety claims. At a high level it summarises any assumptions, limits and conditions for operation applicable to the requirements for safe wet-solid waste processing in this building.

Section 18.7 Off-Gas System: This section provides a summary of the gaseous radioactive wastes that are produced. It contains a brief description of the waste and the systems. It articulates the main claims, specific to the waste streams and where the arguments and evidence can be found to support the safety claims. At a high level it summarises any assumptions, limits and conditions for operation applicable to the requirements for safe radioactive gaseous waste processing.

Section 18.8 Heating, Ventilating and Air Conditioning System: This section provides a summary of the HVAC system that are of relevance to the management of gaseous radioactive wastes. It contains a brief description of the waste and the systems. It articulates the main claims associated with gaseous waste management, and cross references Chapter 16.

Section 18.9 Tank Vent Treatment System: This section provides a summary of the gaseous radioactive wastes that are produced due to tank ventilation. It contains a brief description of the waste and the systems. It articulates the main claims, specific to the waste streams and where the arguments and evidence can be found to support the safety claims. At a high level it summarises any assumptions, limits and conditions for operation applicable to the requirements for safe radioactive gaseous waste processing.

Section 18.10 High Level Waste Processing: This section provides a summary of the HLW which are produced and the strategy for ensuring safe transfer, safe storage and decay storage of this waste. The strategy also ensures the suitability of the plans for long term storage of HLW to show that this is safe and that the waste will be in a condition that would allow it to be transported for disposal.

Section 18.11 Intermediate Level Waste Store: This section provides a summary of the ILW Store. It contains a brief description of the waste and the systems, articulates the main claims, specific to the store and where the arguments and evidence can be found to support the safety claims. At a high level it summarises any assumptions, limits and conditions for operation applicable to the ILW Store.

Section 18.12 Low Level Waste Processing: This section provides a summary of the radioactive LLW that are produced. It contains a brief description of the waste and the systems, articulates the main claims, specific to the waste streams and where the arguments and evidence can be found to support the safety claims. At a high level it summarises any assumptions, limits and conditions for operations applicable to the requirements for safe waste processing, storage and disposal.

Section 18.13 Transportation of Waste: This summarises at a high level the transportation of waste between facilities. It contains a brief description of the waste and any requirement and assumptions to be considered as the design progresses beyond GDA for a specific site.

Section 18.14 Radioactive Waste Management Arrangements: This section summarises the records management and design change control requirements to ensure that the conditions required for safe storage, repackaging (if required) and disposal are not adversely affected.

Section 18.15 Assumptions, Limits and Conditions for Operation: This section summarises at a high level any assumptions or limits and conditions applicable to the requirements for safe storage through to disposal of the wastes.

Section 18.16 Summary of ALARP Justification: This section provides a summary of the ALARP justification.

Section 18.17 Conclusion: This section provides a summary of the main aspects of this chapter.

Section 18.18 References: This section lists documents referenced within this chapter.

Other relevant information is captured in Appendices as follows:

Appendix A – Safety Functional Claims Table
Appendix B – Safety Properties Claims Table
Appendix C – Document Map

This chapter is supported by a set of reference documents, primarily radioactive waste topic reports, which describe where the arguments and evidence that substantiate safety claims are presented. The topic reports cover hazards assessments, ALARP, etc. A full list is provided within the document map in Appendix C.

The following PCSR chapters have specific requirements in the form of SFCs on the radioactive waste management detailed in this chapter. They are:

Chapter 10 : Civil Works and Structures,
Chapter 14 : Control and Instrumentation,
Chapter 15 : Electrical Power Supplies,
Chapter 16 : Auxiliary Systems,
Chapter 21 : Human-Machine Interface,
Chapter 23 : Reactor Chemistry, and
Chapter 31 : Decommissioning.

These related SFCs are summarised in sub-section 18.3 Safety Claims.

In addition, the HLW processing strategy (section 18.10 High Level Waste Processing) depends on the choice of interim spent fuel storage (SFIS), so Chapter 32 is key link to this chapter.

The categorisation of safety functions and safety classification of SSC in this chapter conform with the methodology described in PCSR Chapter 5 : General Design Aspects, section 5.6. Additionally, the general requirements for Equipment Qualification, Examination Maintenance Inspection and Testing (EMIT) and codes and standards that come from this safety categorisation and classification are also described in Chapter 5、sections 5.7 and 5.9, respectively. Unlike the majority of the radioactive waste management systems, the OG system (sub-section 18.7) is beyond concept design. Therefore, further details can be found in the EMIT section of the Basis of Safety Case for OG system [Ref-7].

The general principles for the identification of Assumptions, Limits and Conditions for Operation (LCOs), are described in Generic PCSR Chapter 4 : Safety Management throughout Plant Lifecycle, section 4.12, and the general requirements related to conventional safety aspects are also described in PCSR Chapter 4 : Safety Management throughout Plant Lifecycle.

General requirements for decommissioning of the systems, structures and components within this chapter scope are described in PCSR Chapter 31 : Decommissioning. The related claims are summarised in Chapter 31, section 31.2 Safety Claims.

This chapter of the PCSR does not cover:

- Spent fuel route and spent fuel storage (PCSR Chapter 19 : Fuel Storage and Handling and Chapter 32 : Spent Fuel Interim Storage),
- The waste at the end of power generation. (PCSR Chapter 31: Decommissioning, Section 31.8.1.4 Phase 4: ILW, HLW and Spent Fuel Interim Storage Period),
- The main stack for airborne discharges. (PCSR Chapter 10 : Civil Works and Structures : Section 10.4.8 Overview of the Main Stack),
- The discharge line size and location is out of scope for GDA,
- Environmental and security aspects of the UK ABWR design. For links to GEP, and Conceptual Security Arrangements (CSA) documentation, please refer to Generic PCSR Chapter 1 “Introduction”. For GEP, where specific references are required, for example in Radioactive Waste Management (this chapter), Radiation Protection, Decommissioning, these will be included in the specific sections within the Generic PCSR,
- This chapter only considers the resulting secondary wastes from these systems,
  - Condensate Purification System (PCSR Chapter 17 : Steam and Power Conversion Systems, Section 17.11 Condensate Purification System),
  - Turbine Gland Steam System (PCSR Chapter 17 : Steam and Power Conversion Systems, Section 17.6 Turbine Gland Steam System),
  - Fuel Pool Cooling and Clean-up System (PCSR Chapter 19 : Fuel Storage and Handling, Section 19.9 Fuel Pool Cooling, Clean-up and Makeup Systems),
  - HVAC system (PCSR Chapter 16 Auxiliary systems, Section 16.5 Heating Ventilating and Air Conditioning System) that are not of relevance to the management of gaseous radioactive wastes, and

- Reactor Water Clean-Up systems. (PCSR Chapter 12 : Reactor Coolant Systems, Reactivity Control Systems and Associated Systems, Section 12.3.5.3 Reactor Water Clean-up System).

## 18.2 Purpose & Scope

### 18.2.1 Purpose

The purpose of this PCSR chapter is to demonstrate how the radioactive waste management systems are capable of reducing risks, ALARP, and demonstrates that there is a viable waste management strategy.

Generic PCSR Chapter 18 aims to:

- Demonstrate that the concept for radioactive waste presented within GDA is feasible,
- Demonstrate the minimisation (in terms of radioactivity) of discharges of gaseous and aqueous radioactive wastes,
- Demonstrate that there is a viable waste storage strategy without foreclosing specific options for waste storage,
- Demonstrate at an appropriate level that the waste generated by the station can be treated, stored on site, repackaged safely and disposed of in GDF or other approved facilities – with the appropriate level of evidence for GDA,
- Describe the systems and processes involved in the radioactive waste management,
- Identify the claims related to radioactive waste management, and provide links to the relevant Basis of Safety Case (BSC) and Topic Reports (TRs),
- Take into account possible faults and hazards, and
- Demonstrate that risks are capable of being reduced ALARP.

### 18.2.2 Scope

This document presents the operational safety case being presented for the radioactive waste system associated with the UK ABWR. These process systems are currently at various stages of design development as shown in Table 18.2-1 below. The radioactive waste management systems consist of:

**Table 18.2-1: Current Design Phase for Radioactive Waste/ Material Management**

| Radioactive waste / material stream | Radioactive waste process stream | Engineering Phase |
|---|---|---|
| Liquid | Low Chemical impurities Waste (LCW) system | Preliminary Design |
| | High Chemical impurities Waste (HCW) system | Preliminary Design |
| | Spent Resin and Sludge (SS) system | Concept Design |
| | Controlled Area Drain (CAD) system | Concept Design |
| | Laundry Drain (LD) system | Concept Design |
| | Concentrated Waste (CONW) system | Concept Design |
| Gaseous | Tank Vent Treatment System (TVTS) | Concept Design |
| | Off–Gas System (OG) | Preliminary Design |
| | Heating, Ventilation and Air Conditioning (HVAC) | Mixture of Preliminary & Concept Design |
| | Turbine Gland Steam (TGS) system | Preliminary Design |
| Solid | Wet-solid Intermediate Level Waste (WILW) Processing<br>Wet-solid Low Level Waste (WLLW) Processing | Concept Design |
| | High Level Waste (HLW) Processing | Concept Design |

| Radioactive waste / material stream | Radioactive waste process stream | Engineering Phase |
|---|---|---|
| | Intermediate Level Waste Store (ILWS) | Concept Design |
| | Solid Low Level Waste (SLLW) | Concept Design |
| | Spent Fuel (See Chapter 19: Fuel Storage and Handling & Chapter 32: Spent Fuel Interim Storage) | Concept Design |

Note: The transport arrangements are at concept design stage and the choice of cross site transportation is very site specific and this could be road or rail and will rely on a site specific transport safety case.

For the radioactive wastes this Chapter will:

- Identify all links to other chapters of the PCSR to ensure consistency across the whole safety case,
- Describe where the arguments and evidence that substantiate all relevant safety case claims are presented in supporting documents,
- Facilities for processing wastes are fundamental to the safety, transport and environmental impacts of waste storage and disposal. Where waste processing facilities are an integral part of the reactor facility undergoing GDA, the development of the processing facilities should be to the same level of design as the reactor, i.e. preliminary design (For example in the UK ABWR off-gas is considered to be an integral part of the reactor facility). Where the design is not integral then a concept level of design is being used for GDA see Table 18.2-1,
- Identify the management arrangements for radioactive waste arising from operation of the reactor for its projected life. This includes,
  - The strategies for the management of all radioactive wastes and substances that might become wastes,
  - The safe storage of radioactive wastes pending disposal,
  - The disposability of radioactive wastes, and
  - A demonstration of how the design and its proposed operation will avoid or minimise the generation of radioactive waste.

# 18.3 Safety Claims

## 18.3.1. Safety Function Claims

The claims for the radioactive waste systems are based on the Fundamental Safety Functions (FSF) and High Level Safety Functions (HLSF) as identified in the List of Safety Category and Class for UK ABWR [Ref-13]. The relevant FSFs and HLSFs for the liquid, gaseous and solid waste processing systems are:

FSF 4: Confinement / Containment of Radioactive Materials
5: Others
HLSF 4-7: Functions to confine radioactive materials, shield radiation, and reduce radioactive release
4-8: Functions to minimise the release of radioactive gases
4-11: Functions to store the radioactive materials as gaseous waste
4-12: Functions to store the radioactive materials as liquid wastes
4-13: Functions to store the radioactive materials as solid wastes
5-9: Functions to clean up water except for reactor coolant
5-10: Functions to supply electric power (except for emergency supply).
5-18: Function to maintain internal building environment appropriate for SSCs

The adequate control of nuclear matter is demonstrated throughout the PCSR as shown by the SFCs relating to FSF 4: Confinement / Containment of Radioactive Materials. For some of the radioactive waste systems HLSF 4-7 has been covered implicitly in the individual HLSF assigned to each processing system, i.e. gaseous (HLSF 4-11), liquid (HLSF 4-12) and solid (HLSF 4-13).

For the safety class for SSCs, the majority of the radioactive waste management system in Rw/B will be class 3, with appropriate safety measures incorporated into the design against the identified faults as required by the evaluation of unmitigated doses. The initial preliminary safety function category for unmitigated doses to workers and public for the systems which are at concept design can be found in section 18.5.2.3, 18.6.2.3, 18.9.2.3, 18.11.2.3 and 18.12.2.5.

SFCs arising from other PCSR chapters that are applicable to the radioactive waste management in this PCSR have been identified and are:

| PCSR Chapter | SFC Ref | Description |
|---|---|---|
| Chapter 10 : Civil Works and Structures | Rw/B SFC 4-7.01 | The Rw/B provides shielding by concrete walls and slabs. The shielding walls and slabs are arranged around higher radiation areas to reduce worker's exposure. The external walls and slabs provide shielding to reduce dose rate at the site boundary. |
| | R/B SFC 4-7.01 | R/B forms a part of the RCCV together with several MC components, to shield radiation from the reactor and confine the radioactive substance inside the containment (Normal Operations). |
| | R/B SFC 4-7.04 | R/B forms a part of the RCCV together with several MC components, to shield radiation from the reactor and confine the radioactive substance inside the containment (Fault Conditions). |
| | T/B SFC 4-7.01 | The T/B provides shielding by concrete walls and slabs to shield radiation to lower the level. The shielding walls and slabs are arranged around higher radiation areas to reduce worker's exposure. The external walls and slabs provide shielding to reduce dose rate at the site boundary. |

| PCSR Chapter | SFC Ref | Description |
|---|---|---|
| | STACK SFC 4-8.01 | The stack provides the required height from the dispersion of exhaust gases from the ventilation of the radiation controlled area within the plant. |
| | STACK SFC 5-17.01 | The Stack is designed with following loading conditions, to support SSCs for the normal conditions. |
| | STACK SFC 5-17.02 | The Stack is designed to support SSCs which deliver safety functions for design base (DB) loads. |
| Chapter 14 : Control and Instrumentation | SACS SFC 4-8.1 | The SACS provides the functions to control the auxiliary system which implements the Category B or C safety functions to minimise the release of radioactive gases. |
| | ACS SFC 4-11.1 | The Reactor / Turbine Auxiliary Control System (ACS) provides the functions to control the auxiliary system which implements control functions to sufficiently reduce the emission rate of radioactive particles before discharging them to atmosphere. |
| | ACS SFC 5-10.1 | The Reactor / Turbine Auxiliary Control System (ACS) provides the functions to control the auxiliary system which implements control functions to supply electric power (except for emergency supply). |
| Chapter 15 : Electrical Power Supplies | EPS SFC 4 | The EPS supports SSCs providing HLSF associated with FSF 4: Confinement and Containment of Radioactive Materials. |
| Chapter 16 : Auxiliary Systems | RCW SFC 5-11.1 | The RCW supports the operations of Class3 auxiliaries (RIP motors, RIP MG Sets, DWC cooling units, CUW Pumps and Heat Exchangers, CRD Pumps, IA and SA Compressors, normal operation HVAC, etc.) by removing heat from them and transfer it to RSW. |
| | RD SFC 4-12.1 | The Radioactive Drain (RD) transfer system provides sufficient capacity to transfer liquid waste to the Liquid Waste Management System for normal operation including start-up, shutdown, and outage. |
| | RD SFC 4-7.1 | The RD components penetrating the primary containment form a barrier to confine the radioactive material within the containment boundary and prevent its dispersion to the environment in the event of faults. |
| | RD SFC 5-4.1 | In the event of a fault condition which resulted in excessive inflow rate of liquid waste into the drywell sump, an alarm is actuated. |
| | P&D SFC 4-12.1 | The P&D segregates liquid waste into subcategories, collecting and directing it in the corresponding sumps or sump tanks so that they are treated based on their liquid properties in the Liquid Waste Management System (LWMS). |
| | R/A HVAC SFC 4-7.1 | The R/A HVAC system is designed to reduce the release and spread of airborne contamination during normal operation. |
| | R/A HVAC SFC 4-7.2 | The R/A HVAC system is designed to reduce the release and spread of airborne contamination from the reactor building during fault conditions. |

| PCSR Chapter | SFC Ref | Description |
|---|---|---|
| | T/B HVAC SFC 4-7.1 | The T/B HVAC system is designed to reduce the release and spread of airborne contamination during normal operation. |
| | Rw/B HVAC SFC 4-7.1 | The Rw/B HVAC system is designed to reduce the release and spread of airborne contamination during normal operation. |
| | S/B HVAC SFC 4-7.1 | The S/B HVAC system is designed to reduce the release and spread of airborne contamination during normal operation. |
| | T/B HVAC SFC 5-18.1 | The T/B HVAC ensures adequate environmental parameters are maintained so that the relevant SSCs can function appropriately and can deliver the fundamental safety functions in normal operation. |
| Chapter 21 : Human-Machine Interface | MCR HMI SFC 4-8.1 | The HMI for the SACS provides indicators and controls for the equipment and systems to minimise the release of radioactive gases. |
| | MCR HMI SFC 4-11.1 | The HMI for other C&I provides some selected information for the systems to store the radioactive materials as solid wastes. |
| | MCR HMI SFC 5-10.1 | The HMI for the ACS provides indictors and controls for equipment and systems to supply electric power. |
| Chapter 23 : Reactor Chemistry | RC SC 4 | The UK ABWR pipework and system design will mitigate build-up of hydrogen concentration and mitigate flammability risk and radioactive release from reactor coolant system. |
| | RC SC 5 | The UK ABWR reactor chemistry regime will ensure that the source term radiological dose to the worker is ALARP by optimising materials selection, operating chemistry and operating practices. |
| | RC SC 6 | The UK ABWR reactor chemistry regime will ensure that the radionuclide releases and exposure to public is ALARP. |
| | RC SC 7 | The UK ABWR reactor chemistry regime will ensure that the radionuclide releases and exposure to worker is ALARP. |
| | RC SC16.1 | Water quality control within specified limits in the CST will ensure the water quality of the primary system. |
| Chapter 31 : Decommissioning | Decom-SC 1 | The UK-ABWR design incorporates features that facilitate decommissioning. |
| | Decom-SC 2 | Appropriate decommissioning plans/strategies are in place, and will continue to be developed by the future licensee. |
| | Decom-SC 3 | Faults and Hazards during decommissioning are identified, assessed and all risks shown to be ALARP. |
| | Decom-SC 4 | Viable disposal routes are available (or will be available) for all decommissioning wastes. |

The demonstration of compliance with these SFCs is provided along with the system specific SFCs in Section 18.5.3, Section 18.6.3, Section 18.7.3, Section 18.9.3, Section 18.10.3, Section 18.11.3 and Section 18.12.3.

### 18.3.1.1 Liquid Waste Processing

The main environmental function of the Liquid Waste Management System (LWMS) is to ensure that the activity and volume of discharges to the environment are kept to a minimum and within the discharge consent.

The main safety requirement of the design is that radiation doses to the public and operators are ALARP.

The above requirements have been translated into the following SFCs for the LWMS:

| SFC Ref | Description |
|---|---|
| LWMS SFC 4-12.1 | The total radioactivity in liquid discharges to the environment from the LWMS will be minimised. |
| LWMS SFC 4-12.2 | Total liquid radioactive waste volumes from UK ABWR operation will be minimised. |
| LWMS SFC 4-12.3* | The LWMS facilities shall be designed to ensure that doses to both the workers and the public from normal operation of the UK ABWR LWMS are ALARP. |
| LWMS SFC 4-12.4 | The creation, management and disposal of radioactive waste will be optimised through the use of BAT. |
| LWMS SFC 4-12.5 | Appropriate monitoring, measuring and sampling equipment will be provided to confirm and record that waste effluent meets relevant Waste Acceptance or Discharge Criteria. |
| LWMS SFC 4-12.6* | The LWMS facilities shall be designed to ensure that risks to public and workers in faults are ALARP and within limits and targets given in PCSR Chapter 5 General Design Aspects, section 5.5: Definition of Design Basis Faults and Beyond Design Basis Faults. |
| LWMS SFC 4-12.7 | The LWMS facilities shall be designed to provide sufficient capacity to process liquid wastes for normal operation, start-up, shutdown, outages and design basis faults. |
| LWMS SFC 5-9.1 | The LCW and HCW systems treated effluent shall meet the re-use criteria specified in the Water Quality Specification [Ref-10]. |

** Noted that these SFCs encompass the fundamental requirement for adequate levels of containment and shielding during normal operations and fault conditions, respectively.*

These claims, together with those for the other systems associated with the scope of Chapter 18, are presented in Appendix A. The demonstration of compliance with the FSF for the LWMS is presented in Section 18.5.3.1, further detail is provided in the BSC [Ref-1].

### 18.3.1.2 Gaseous Waste Processing

**Off-Gas System**

The OG is a key component of the ABWR design, which has the primary functions of maintaining the Main Condenser Vacuum, by extracting non-condensable gas, providing abatement of radioactive species prior to atmospheric discharge, and recombining radiolytic hydrogen and oxygen generated in the reactor.

The OG has been designed to meet the following SFCs:

| SFC Ref | Description |
|---|---|
| OG SFC 4-7.1 | The OG minimises the dose to worker during normal conditions. |

| SFC Ref | Description |
|---|---|
| OG SFC 4-7.2 | The OG mitigates the dose to worker in the event of OG system failure. |
| OG SFC 4-8.1 | The OG mitigates the release of gaseous radioactive substances to the environment in the event of OG system failure. |
| OG SFC 4-11.1 | The OG minimises the release of radioactivity to the environment during the start-up, power and shutdown operations. |
| OG SFC 4-11.2 | The OG reduces the risk of hydrogen combustion arising from the reaction of radiolytic hydrogen produced in the reactor. |
| OG SFC 4-11.3 | The OG prevents hydrogen combustion in the event of OG Recombiner failure. |
| OG SFC 5-10.1 | The OG extracts air and non-condensable gas ($H_2$ and $O_2$) from the main Condenser to achieve and maintain main Condenser vacuum. |

These claims, together with those for the other systems associated with the scope of Chapter 18, are presented in Appendix A. The demonstration of compliance with the FSF for the OG is presented in Section 18.7.3.1, and further detail is provided in the BSC [Ref-7].

**Heating Ventilating and Air Conditioning (HVAC) System**

The main safety requirement of the HVAC system for radioactive gaseous management is that doses to the work force and the public are ALARP.

The SFCs relevant to the HVAC system have been identified in sub-section 16.5 “Heating Ventilating and Air Conditioning System” in PCSR Chapter.16 “Auxiliary Systems”.

| SFC Ref | Description |
|---|---|
| R/A HVAC SFC 4-7.1 | The R/A HVAC system is designed to reduce the release and spread of airborne contamination during normal operation |
| R/A HVAC SFC 4-7.2 | The R/A HVAC system is designed to reduce the release and spread of airborne contamination during design basis and beyond design basis fault conditions |
| T/B HVAC SFC 4-7.1 | The T/B HVAC system is designed to reduce the release and spread of airborne contamination during normal operation |
| Rw/B HVAC SFC 4-7.1 | The Rw/B HVAC system is designed to reduce the release and spread of airborne contamination during normal operation |
| S/B HVAC SFC 4-7.1 | The S/B HVAC system is designed to reduce the release and spread of airborne contamination during normal operation. |
| T/B HVAC SFC 5-18.1 | The T/B HVAC ensures adequate environmental parameters are maintained so that the relevant SSCs can function appropriately and can deliver the fundamental safety functions in normal operation. |

These claims are presented in Appendix A in PCSR Chapter.16 “Auxiliary Systems”. Demonstration of the management of radioactive gases functionality, and in particular contamination control is summarised in section 18.8 and further evidence is provided in sub-section 16.5 “Heating Ventilating and Air Conditioning System” in PCSR Chapter.16 “Auxiliary Systems”.

**Tank Vent Treatment System**

The main environmental function of the Tank Vent Treatment is to ensure that discharges to the environment are kept to a minimum and within the discharge consent.

The main safety requirements of the design are to ensure radiation doses to the public and operators are ALARP and hydrogen generated in tanks does not reach flammable or explosive concentrations.

The above requirements have been translated into the following Safety Function Claims (SFCs) for the Tank Vent Treatment system:

| SFC Ref | Description |
|---|---|
| TV SFC 4-7.1 | Radioactivity extracted from the vessel ullage space will be adequately contained. |
| TV SFC 4-7.2 | The TVTS shall be designed to ensure that doses to both the workers and the public from normal operation of the TVTS are ALARP. |
| TV SFC 4-7.3 | The creation, management and disposal of radioactive waste will be optimised through the use of BAT. |
| TV SFC 4-7.4 | The TVTS shall be designed to ensure that risks to public and workers in faults are ALARP and within limits and targets given in PCSR Chapter 5 General Design Aspects, section 5.5: Definition of Design Basis Faults and Beyond Design Basis Faults. |
| TV SFC 4-8.1 | The total radioactivity in gaseous discharges to the environment from the TVTS will be minimised. |
| TV SFC 4-8.2 | Appropriate monitoring, measuring and sampling equipment will be provided to confirm and record that discharge meets relevant Discharge Criteria. |
| TV SFC 4-8.3 | Hydrogen concentrations in vessel ullage spaces will not reach the Lower Flammability Limit (LFL). |

These claims, together with those for the other systems associated with the scope of Chapter 18, are presented in Appendix A. The demonstration of compliance with the FSF for the Tank Vent Treatment System is presented in Section 18.9.3.1, further detail is provided in the Topic Report for the Tank Vent Treatment System [Ref-28].

### 18.3.1.3 Solid Waste Processing

The main safety requirement of the Solid Waste Management System (SWMS) design is that radiation doses to the public and operators are ALARP.

The SFCs relevant to the SWMS including the Wet-solid ILW and Wet-solid LLW Processing Systems, have been identified from the Basis of Safety Case of Solid Radioactive Waste Management System [Ref-3]:

| SFC Ref | Description |
|---|---|
| SWMS SFC 4-13.1 | Total solid radioactive waste volumes from UK ABWR reactor operation will be minimised. |
| SWMS SFC 4-13.2 | The SWMS facilities shall be designed to ensure that doses to both the workers and the public from normal operation of the UK ABWR SWMS are ALARP. |
| SWMS SFC 4-13.3 | The creation, management and disposal of radioactive wastes will be optimised through the use of BAT. |

| SFC Ref | Description |
|---|---|
| SWMS SFC 4-13.4 | Appropriate monitoring, measuring and sampling equipment will be required to confirm and record that waste meets relevant Waste Acceptance Criteria. |
| SWMS SFC 4-13.5 | The SWMS facilities shall be designed to ensure that risks to public and workers in faults are ALARP and within limits and targets given in PCSR Chapter 5 General Design Aspects, section 5.5: Definition of Design Basis Faults and Beyond Design Basis Faults. |
| SWMS SFC 4-13.6 | The Solid Waste Facility (SWF) is required to process wastes into packages suitable for off-site transport to the appropriate nominated facility for incineration, recycling or direct disposal. |
| SWMS SFC 4-13.7 | The on-site ILW Store is required to receive and manage processed and packaged ILW. |

These claims, together with those for the other systems associated with the scope of Chapter 18, are presented in Appendix A. The demonstration of compliance with the FSF for the SWMS is presented in Sections 18.6, 18.10, 18.11 and 18.12, and further detail is provided in the BSC [Ref-3].

### 18.3.2. Safety Properties Claims

The SPCs are design principles that are applied when designing radioactive waste management systems of the UK ABWR to ensure the systems are sufficiently reliable to deliver their safety functions.

The table of SPCs, shown in Appendix B, were derived for the Radioactive Waste Management based on the 'guide word' approach specified in Hitachi-GE's Safety Case Development Manual [Ref-15]. Having derived the SPCs, a mapping exercise was undertaken to ensure that the SPCs fully cover the relevant NSEDPs applicable to the topic area. More information on the development of SPCs, and the coverage, at the more detailed level in the safety case, to demonstrate full compliance with the relevant NSDEPs is presented in Chapter 5 General Design Aspects, section 5.3 General Safety Design Bases.

The SPCs for radioactive waste management system against the following key contents are established based on the SPC guide words defined in the "GDA Safety Case Development Manual" [Ref-15].

- Single Failure,
- Common Cause Failure,
- System Interfaces,
- Internal Hazards Protection,
- External Hazards Protection,
- Automation,
- Qualification Provision,
- EMIT (Examination, Maintenance, Inspection and Test), and
- Codes and Standards.

The majority of radioactive waste system is at concept design stage as shown in section 18.2.2, and therefore the details of where these SPCs are applied in each system will be determined post GDA phase.

### 18.3.3. Internal and External Hazard Assessment

For GDA there has been very limited, external and internal hazards assessments undertaken of the LWMS and SWMS as the majority of these systems are at concept design level. The fault assessment undertaken for GDA on these systems take credit for the function of the cells and other passively and permanently available features. However for an internal and external hazards assessment it should always be confirmed that their function is not compromised.

External and internal hazards assessments should be undertaken of the LWMS and SWMS in the post GDA phase. It is anticipated that this will lead to a requirement for seismic qualification to protect some tanks, cells and ducting. The analysis may also highlight other design requirements. A whole building HAZOP (or similar) for the Rw/B will need to be performed during the next design phase.

For the concept design included in GDA, the Rw/B has been analysed for the baseline seismic load case to confirm the robustness of the concept layout. Protection against other external hazards is provided by the same design measures used for the Class 1 buildings, e.g. lightning protection, external flood protection. For internal hazards, since there are no divisional barriers required in the Rw/B, assessment has been based on non-divisional hazards barriers where protection is needed to prevent breach of radioactive containment e.g. protection against vehicle impact or dropped load [Ref-31]. The Rw/B design for internal hazards will use the methodologies as described in Chapter 7.

Internal and external hazard assessment has been carried out on the off-gas system in line with the other systems in the reactor building. The internal hazards assessment for the off-gas system is described in topic reports on barrier substantiation [Ref-31]. Demonstration of the T/B structure to protect against relevant external hazards is described in the PCSR Chapter 10 : Civil Works and Structures.

## 18.4 OPEX

It is a requirement in the UK that all industrial plant shall comply with relevant regulations and be designed as a minimum to achieve good practice. Compliance with regulations and use of good practice are the starting point for the demonstration of ALARP.

Good practice can be defined from a number of sources, including the following relevant approved codes and standards:

- ONR, Safety Assessment Principles for Nuclear Plants,
- ONR, Nuclear Safety Technical Assessment Guide for Management of Radioactive Materials and Radioactive Waste on Nuclear Licensed Sites,
- Western European Nuclear Regulators Association, Waste and Spent Fuel Storage Safety Reference Levels Report, and
- International Atomic Energy Agency, Predisposal Management of Radioactive Waste; IAEA General Safety Requirements.

The UK Regulators have provided guidance in respect of safe and secure interim storage. These requirements are set out in the Joint Guidance "HSE, EA and SEPA : The Management of Higher Activity Radioactive Waste on Nuclear Licensed Sites" [Ref-38], and "HSE, EA and SEPA : Basic Principles of Radioactive Waste Management" [Ref-39].

The design of the radioactive waste facilities of the UK ABWR takes full account of relevant good practice.

### 18.4.1 Liquid Waste Processing in Radwaste Building

A review of Operational Experience (OPEX) has been undertaken which is collated and presented in the "Review of LWR LWMS and Waste Processing" which is referenced in the BSC for LWMS [Ref-1].

The OPEX has been taken from a range of sources such as Electrical Power Research Institute (EPRI), United States Nuclear Regulatory Commission (USNRC) and presenters at the Waste Management Symposia. This information has been gathered and reviewed with the intent of supporting the waste management strategy currently proposed and to offer improvements to the design of the liquid and solid waste management systems as appropriate.

EPRI has produced a document (referenced in BSC for LWMS [Ref-1]) based on US reactors reviewing the radioactive waste system designs of the GE Economic Simplified Boiling Water Reactor (ESBWR). The report includes a number of recommendations that help to support the ALARP case for the ABWRs including:

- Strong recommendation that the number of installed plant processing components be minimised, and as a minimum, it suggests replacing the installed pre-coat filters with Hollow Fibre Filters (HFF) or pleat filters as has been done in the ABWRs in Japan, and
- Recommendation that the ESBWR liquid radioactive waste processing strategy should incorporate some type of ultrafiltration (for example HFF or pleat filter) and ion exchange for processing of low chemical impurity wastes. It states that this kind of design is in line with the current Japanese experience for this waste stream.

Another EPRI document (referenced in BSC for LWMS [Ref-1]) describes the technology, process, and results associated with a pilot demonstration of an advanced filtration technology, back-washable filter, at a US nuclear power plant (Surry Nuclear Power Plant). It states that back-washable filter technology is effective for the removal of insoluble iron (a corrosion product), has a long run length and a long filter life with the longest in-service run to-date being 14 years in condensate service. The performance also reduces the volume of solid secondary waste associated with many alternate processes. The technology has been successfully deployed for higher purity Condensate Polishing systems in BWR and PWR nuclear power plants in Japan, and in at least one application in a Japanese BWR liquid radioactive waste stream. Overall, the technology's results-to-date have been positive in improving effluent water quality and reducing the volume of solid radioactive wastes when compared to traditional filter and demineraliser configurations.

EPRI have also produced a report "Radioactive Liquid Processing Guidelines" (referenced in BSC for LWMS [Ref-1]) that identifies liquid radioactive waste process technologies, methodologies, recommendations and experiences to optimise liquid processing programs. This included an extensive review of past, present, and proposed processing technologies; their effectiveness and associated costs; and plant processing experiences and techniques. Some of these technologies include ultrafiltration, chemical polymer injection, and novel applications of granular activated carbon. The new technologies have often improved the performance of the liquid radioactive waste systems; however, there have been operational issues and concerns that required considerable effort to ensure consistent operation. This document collects the experiences obtained from utilities using these technologies, and communicates the advantages and caveats of the technologies.

Further details are provided in Topic Report on ALARP Assessment for LWMS [Ref-2].

### 18.4.2 Gaseous Waste Processing

To ensure risks associated with the UK ABWR OG are reduced to ALARP and to prevent a repeat of incidents from the past, a review of global gaseous radioactive waste treatment plants has been undertaken to identify applicable Good Practice (GP). This review was limited to gaseous waste streams containing hydrogen and noble gases from Light Water Reactor (LWR) Nuclear Power Plants (NPP) and has sourced designs and guidance on the design from public domain sources such as the International Atomic Energy Agency (IAEA), American Society of Mechanical Engineers (ASME), relevant standards and literature.

The use of Charcoal Adsorber for the abatement of short lived radionuclides is widespread in the nuclear industry and is considered to be GP. Reports from the IAEA and Organisation for Economic Co-operation and Development (OECD) state that Charcoal Adsorber is appropriate for the abatement of noble gases in gaseous discharges and that they achieve an economically beneficial retention of radioactive noble gases. The OECD considers use of Charcoal Adsorber to demonstrate BAT [Ref-12].

Charcoal Adsorber is used extensively in the nuclear industry and is installed at various UK sites, including Sizewell B. They are also provided for the treatment of similar wastes within the design of the Pressurised Water Reactor (PWR) proposed for installation at Hinkley Point C.

Light Water Reactor gas treatment system OPEX globally highlights several hydrogen incidents that have occurred during their operation and maintenance. The causes of the incidents have been traced to many sources (e.g. unintended accumulation of hydrogen, reduced recombiner performance, sparks from rapid valve closures and analyser system faults)

Evolution of the OG from BWR to J-ABWR design resulted in movement towards a simpler and more robust design in response to OPEX, requiring less operator interaction with the system and increased reliability. Design improvements have considered the hierarchy of control, demonstrating increased passivity and a corresponding increase in reliability, whilst reducing worker risk. The J-ABWR design includes a number of design features to ensure hydrogen is adequately managed during OG operation to prevent against fault conditions identified against previous incidents. In addition, the UK ABWR incorporates an automatic isolation system categorised Safety Class 2 that closes the off-gas inlet valves and the steam inlet valve to the SJAE in response to a range of inputs that would indicate a build-up of hydrogen in the OG pipework or components.

The Tank Vent Treatment system has been designed in accordance with recognised codes of practice for the design of ventilation systems operating in radiological facilities and Engineering Specifications which are the UK nuclear industry accepted standards for the manufacture and supply of HVAC.

The OPEX for the HVAC system is covered in related BSC on HVAC system [Ref-8], section 3.7 Operational Experience and Design Modifications from the reference design.

### 18.4.3 Solid Waste Processing

The summary of operational experience on the following systems in the SWMS is covered in the Basis of Safety Case of Solid Radioactive Waste Management System [Ref-3].

- Solid Waste Processing including the LLW MMA, LCW Filter Packaging Room and SWF,
- HLW decay storage facility,
- WLLW processing system (part of the Rw/B),
- WILW processing system (part of the Rw/B), and
- ILWS.

Solid waste processing is mainly based on operational strategy on existing nuclear sites in the UK.

OPEX for processing and storage of HLW is based on world wide experience. Current practices in use around the world have often been adopted because external developments have resulted in extended storage periods of fuel and HLW in reactor ponds over and above those originally anticipated by the reactor designers. The additional periods of extended storage for spent fuel and HLW resulted in challenges to the storage capacity of the ponds and the need to develop alternative storage arrangements. The aim behind the OPEX gathered for HLW was to learn from operational difficulties encountered around the world and the solutions implemented to determine a best practice strategy with resilience to external developments.

The data gathering for the WLLW and WILW OPEX and GP encompassed both operational experiences on sites from around the world and various papers on improvements to existing practices, more recently developed technologies and novel technologies which are still in the experimental phase. The data was used to determine the BAT and ALARP solutions for waste processing, packaging, storage and disposal.

The design of the ILWS is based on the Hunterston A ILW Store, and has taken due cognisance of industry guidance "NDA, Industry Guidance : Interim Storage of Higher Activity Waste Packages – Integrated Approach"[Ref-40] and the UK regulatory requirements set out in the joint guidance for "The Management of Higher Activity Radioactive Waste on Nuclear Licensed Sites"[Ref-38].

# 18.5 Liquid Waste Processing in the Radwaste Building

## 18.5.1 Brief Waste & System Descriptions

This section provides a high level description of the plant, operation and wastes in the Liquid Waste Management System (LWMS). The key systems and equipment comprising the liquid radioactive waste management systems are collectively referred to as the LWMS.

A description of the LWMS is provided in the Basis of Safety Case (BSC) on the Liquid Waste Processing in the Radioactive Waste Building [Ref-1] and consists of the following sub-systems:

- Low Chemical impurities Waste (LCW) system,
- High Chemical impurities Waste (HCW) system,
- Controlled Area Drain (CAD) system,
- Laundry Drain (LD) system,
- Spent Resin and Sludge (SS) system, and
- Concentrated Waste (CONW) system.

The LWMS transfers the radioactive liquid waste, generated in the controlled areas, to the collection tanks installed in the Rw/B. The liquid waste is processed by the LWMS and is segregated based upon the chemical impurity and radioactivity.

The LWMS will have the ability to handle wastes generated during decommissioning, and have the ability to handle the demands within this phase. Details can be found in Chapter 31 : Decommissioning.

Wet solid waste that is generated within the LWMS (e.g. filter sludge and used demineraliser resin) is collected in tanks prior to transfer to the Solid Waste Management System (SWMS) where it is processed by the Wet-solid ILW or Wet-solid LLW system, as appropriate.

A simplified layout of the plant and the buildings where the systems are located is shown in Figure 18.5-1 below.

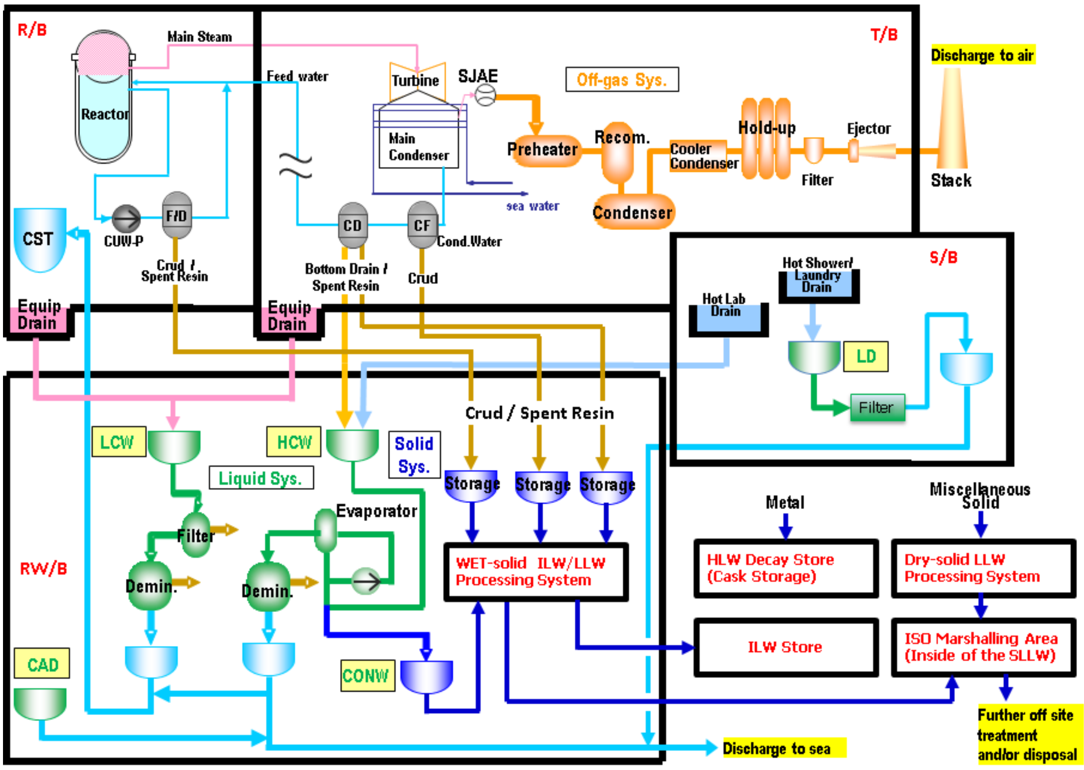



**Figure 18.5-1: Radioactive Waste Treatment System Overview**

### 18.5.1.1 Low Chemical Impurities Waste System

The LCW treatment system is housed in the Rw/B and is one of two subsystems (the other being the HCW subsystem) which are used to treat radioactively or potentially radioactively contaminated waste water. The LCW system is designed to allow the efficient treatment of relatively large volumes of waste water containing low levels of both insoluble and soluble impurities.

The LCW system processes waste water from equipment drains. The main sources of this waste are the primary coolant system, Fuel Pool Cooling and Clean-up System (FPC) and plant make-up water system. Water from the Reactor Water Clean-Up System (CUW) is discharged to the LCW system when either excess water is removed from the CUW system during reactor start-up and shutdown operations (CUW blowdown). The LCW system treats relatively large volumes of the waste waters which are then returned to the Condensate Storage Tank (CST) for re-use.

The LCW system operates as two parallel processing trains each consisting of filters for the removal of insoluble impurities, demineralisers for the removal of soluble impurities, and sampling tanks.


Waste water collection: The LCW system processes waste water from equipment drains. The main sources of the waste water are the reactor primary coolant system, the FPC and the plant make-up water system.

Prior to processing, a sample of the waste water can be analysed, if required, to confirm its properties (e.g. chemical impurity). If the waste water properties mean it is not suitable for treatment in the LCW system, the waste water is transferred to the HCW system.

Filtration: Filters are used to remove insoluble impurities in the LCW. When the differential pressure across the filter increases, the filter is backwashed (water washed, gravity drained and air scoured) to remove the particulate. The crud generated is transferred to the sludge storage tanks within the Rw/B before being processed in the Rw/B. When exhausted, the filters are raised out of the filter vessel, monitored and prepared for transfer to the dry solid LLW waste processing system.

Demineralisation: Following filtration, the water is passed through a mixed bed demineraliser packed with bead type ion exchange media to remove soluble impurities. LCW water is sampled following demineralisation. The demineraliser resins are changed when they reach pre-set plant operations limits, for example a reduced ion exchange capability, an operational lifespan or a determined radiation dose rate: the parameters will be determined by the future licensee based upon the demineraliser design, ion exchange media used, operational conditions and handling facility safety cases. The spent bead resin is discharged from the demineraliser vessel and temporarily held in storage tanks before being processed in the Rw/B.

Waste water re-use: Treated water is collected in a sample tank, where a representative sample of water is analysed to confirm it meets the criteria for re-use in the reactor, as described in the LWMS BSC [Ref.-1]. If the treated water does not meet the appropriate criteria, it can be routed back to the LCW Collection Tank and the treatment process repeated (potentially multiple times until the criteria are met). Once the treated water has been confirmed to meet the appropriate criteria it is normally sent to the CST for re-use as reactor Primary Circuit or Spent Fuel Pool (SFP) make-up water. There is no radioactivity criterion for water treated in the LCW system, as the system is operated solely on the level of insoluble and soluble impurities within the water.

Recirculation and re-use ensures that there is no discharge to sea other than via the HCW system.

#### 18.5.1.2 High Chemical Impurities Waste System

The HCW treatment system is housed in the Rw/B and is one of two subsystems (the other being the LCW subsystem) which are used to treat radioactively or potentially radioactively contaminated waste water. The HCW treatment system is designed to allow the efficient treatment of waste water containing relatively high levels of soluble impurities.

Treated water is either transferred to the CST for re-use or, in limited circumstances where there is not the capacity in the reactor system for re-use, disposed of to the environment following monitoring.

The HCW system is essentially a single train processing system with two collection tanks. As water in one collection tank is treated, the other collection tank receives incoming effluent. The HCW system comprises an evaporator for distillation and removal of impurities, a demineraliser for removal of soluble impurities and sampling tanks. Filtration is unnecessary as the evaporator retains solid matter in the concentrate.


Waste water collection: The main source of HCW is waste water collected by the chemical analysis lab (hot lab) drains in the S/B and the condensate demineraliser drains. However, it is also possible to route waste water consigned to the CAD system to the HCW system depending on the expected level of impurities (including non-radiological contamination) it contains. Effluent will be treated in the HCW treatment system in “batches”. HCW water can be sampled prior to processing.

Evaporation: The evaporator is effective at concentrating and containing the majority of the radioactivity initially present in the HCW into a sludge-like concentrate. The evaporated water is collected in the vapour phase, condensed and passed to the demineralisation step. Solids with concentrated radioactivity are retained in the evaporator. The sludge-like concentrate is transferred to the concentrated waste tank in the Rw/B for buffer storage, as described in Section 18.5.1.6, prior to being processed by the Wet-solid LLW Processing system, as described in Section 18.6.1.2.

Demineralisation: Following treatment in the evaporator, the water is collected in the HCW distilled water tank and then passes through a mixed bed demineraliser packed with bead type ion exchange media to remove soluble impurities which could potentially be carried over from the evaporator. The demineraliser ensures that the concentration of fission products and activation products in the water is sufficiently low in the event that the HCW is required to be disposed of to the environment. The spent bead resin is discharged from the demineraliser vessel and temporarily held in storage tanks before being processed within the Rw/B.

Waste water re-use or discharge: Treated water is collected in a sample tank where a representative sample of water is analysed to confirm it meets the criteria for re-use in the reactor, as described in the LWMS BSC [Ref.-1]. If the water does not meet the criteria, it is returned to the HCW Collection Tank and the treatment process repeated (potentially multiple times until the criteria are met). Once the treated water meets the criteria, the water is discharged to the CST for re-use as reactor Primary Circuit or SFP make-up water. Only if the treated water volumes exceed Primary Circuit and SFP water make-up requirements is the treated water routed to the main discharge line to be discharged to the environment. However, waste water will only be discharged if its sampled characteristics are within discharge limits that will be defined in the EP-RSR Permit, and further information is available in the Quantification of Discharges and Limits document [Ref-19]. If treated water does not meet the discharge criteria, it can be routed back through the HCW treatment process (potentially multiple times) until the discharge criteria are met.

### 18.5.1.3 Controlled Area Drain System

The CAD system, housed in the Rw/B, collects water from the local air-conditioning system drains in the R/B and T/B, and also from the potentially contaminated drains of various equipment systems in the controlled areas of the R/B and the T/B. The system is comprised of liquid waste collection tanks, collection pumps, piping, valves and measuring and control equipment. Liquid waste in the CAD system is not expected to be radioactive but has the potential to be contaminated.

Waste water collection and discharge: The collected waste water is pumped to the CAD Collection Tank where it is sampled to confirm it contains no significant radiological contamination or unacceptable chemical contamination. Water which meets the discharge criteria will be routed to the main discharge line. If the water is found to contain any significant radiological contamination or unacceptable chemical contamination, then the operator routes the water to the HCW system for treatment.

### 18.5.1.4 Laundry Drain System

The LD Treatment System, housed in the S/B, processes waste water originating from the laundry, the S/B showers and hand washing facilities. These waste water streams contain detergent, suspended solids and organic material, as well as potentially low levels of radioactive crud, and are therefore unsuitable for re-use in a reactor system.

To remove these impurities the water is first passed through a packed bed pre-filter, followed by an activated charcoal adsorption unit and a pre-coat carbon filter.


Waste water collection: The LD system will collect waste water from the on-site laundry and S/B active showers and hand washing facilities. LD waste water can be sampled prior to processing.

Pre-Filtration: The pre-filter is a vessel with layers of hollow fibre blanket type material which acts as a coarse filter to collect hair and other larger sized suspended solids. The suspended solids are removed from the system as waste sludge together with the filter media, monitored and prepared for transfer to the dry solid LLW processing system.

Activated Carbon Adsorption units: are bed filters containing Bead Activated Carbon (BAC), which adsorb organic impurities and trap the smaller suspended solids that pass through the pre-filters. The adsorbed impurities and suspended solids are removed from the system together with the (exhausted) activated carbon filter when the differential pressure becomes high. The activated carbon is retrieved and monitored into 210 litre drums for transfer to the solid LLW processing systems.

Pre-Coat Carbon Filters: The pre-coated filters consist of an array of cartridges with a fabric ‘sock’ which is pre-coated in Granular Activated Carbon (GAC), the purpose of which is to trap small-sized suspended solids. The waste sludge is removed from the system together with the filter media. The GAC is discharged into a collection drum and monitored. The drums are transferred to the solid LLW processing systems.

Discharge: The treated waste water is collected in a sample tank, where a representative sample of the water is analysed to confirm that the residual level of radioactive contamination meets the criteria for discharge to the environment that will be defined in the EP-RSR Permit and is discussed in the Quantification of Discharges and Limits document [Ref-19]. Treated water which meets the discharge criteria for the LD Treatment System will be routed to the main discharge line. If treated water does not meet the discharge criteria, it can be routed back to the LD Collection Tank and the treatment process repeated (potentially multiple times) until the discharge criteria are met.

### 18.5.1.5 Spent Sludge System

The SS system collects and stores the following secondary wastes in tanks before being transferred for solidification:

- Spent bead (ion exchange) resins from the CD, LCW and HCW demineralisers,
- Powder resin from the Reactor Water Clean-Up System (CUW) and Fuel Pool Cooling and Clean-up System (FPC), and
- Filter crud from Condensate Filter (CF) and LCW filter.

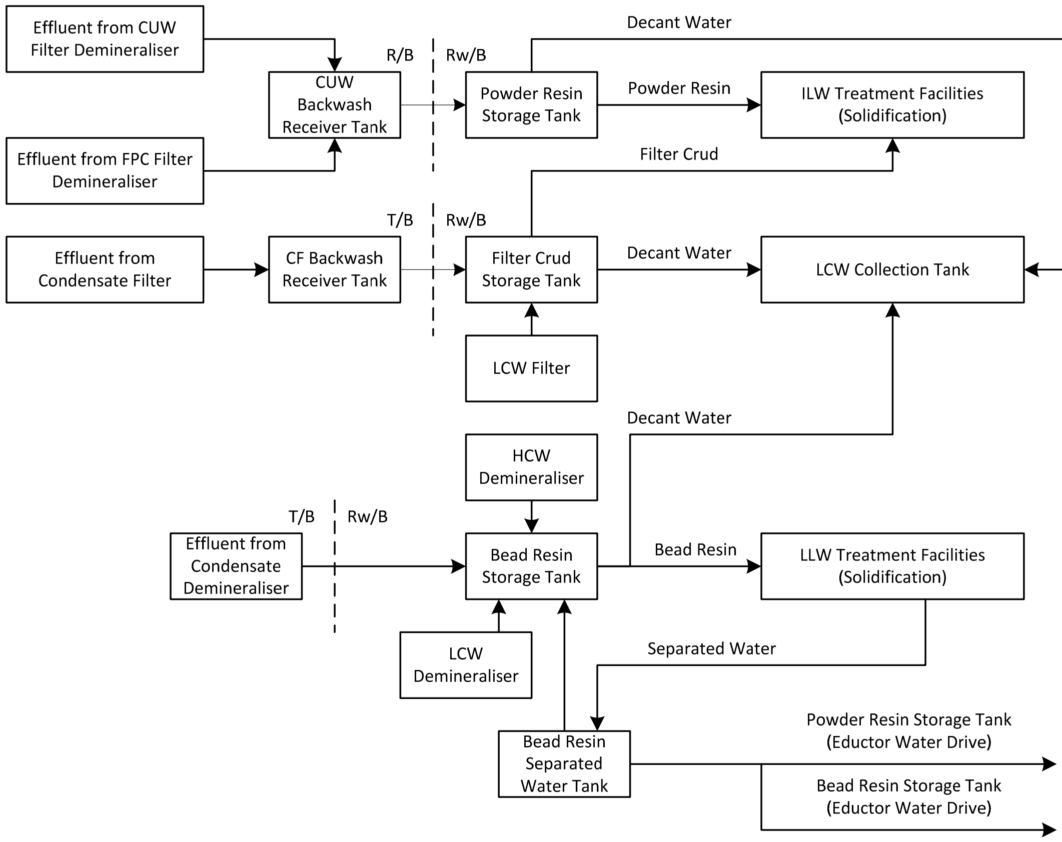



**Figure 18.5-2 Outline of wet-solid wastes streams**

The spent bead resins from the CD, LCW and HCW systems are transferred to one of the Bead Resin Storage Tanks in the Rw/B where it is allowed to settle. Once settled, the water is decanted and sent to the LCW Collection Tanks. The bead resin entering the SS system may be ILW on arising and, if required, the beads will be stored for a period of time to allow sufficient radioactive decay for subsequent processing and transport. When required, the bead resin is sampled and transferred to the Wet-solid LLW processing system of the SWMS for processing.

The filter crud from the backwashed CF is collected in the CF Backwash Receiver Tank located in the T/B. The filter crud from the backwashed LCW filters and CF Backwash Receiver Tank is transferred to one of the Filter Crud Storage Tanks in the Rw/B, where the crud is allowed to settle. Once settled the water is decanted and sent to the LCW Collection Tanks. The filter crud is stored pending transfer to the Wet-solid ILW processing system of the SWMS for processing.

Powder resin from the CUW and FPC is transferred via the CUW Backwash Receiver Tank in the R/B to one of the Powder Resin Storage Tanks in the Rw/B. Following settlement, the water is decanted and sent to the LCW Collection Tanks. The powder resin is stored and sampled pending transfer to the Wet-solid ILW processing system of the SWMS for processing.

### 18.5.1.6 Concentrated Waste System

The purpose of the CONW (housed in the Rw/B) is to receive and store concentrated waste from the bottoms circuit of the HCW evaporator and then send it to the Wet-solid LLW processing system. The concentrated waste from the HCW evaporator is collected and stored in a concentrated waste tank. (When required the tank is mixed, then a sample is taken for fingerprinting purposes, and the waste is transferred to the Wet-solid LLW processing plant. A wash ring is provided in the tank to clean the vessel prior to any maintenance activities that require man access to the cell.)

### 18.5.2 Safety Assessment

The process adopted for the safety assessment of the liquid waste processing systems in the Rw/B is specified in the Safety Case Development Manual [Ref-15] and starts with a hazard identification step (e.g. Failure Modes and Effects Analysis (FMEA) and / or HAZOP) followed by a qualitative risk assessment (estimation of likelihood and severity), and identification and appraisal of risk reduction measures (in terms of trouble, time and/or cost to implement risk reduction measures).

This section is a summary of the safety assessment undertaken for the LWMS. A more detailed description is provided in the ALARP Topic Report [Ref-2] and the Basis of Safety Case [Ref-1].

The management arrangements, regulatory constraints, safety principles, procedures and methodology to be used in respect of the LWMS are as described for the reactor in the PCSR Chapter 4 : Safety Management throughout Plant Lifecycle.

#### 18.5.2.1 Hazard Identification Process

External and internal hazards are identified in PCSR Chapter 6 : External Hazards and PCSR Chapter.7 : Internal Hazards.

Credible hazards associated with the LWMS have been identified through a suite of HAZOP studies, in addition to the FMEA. For a discussion on the HAZOPs and other studies completed, refer to the BSC for Liquid Waste Processing in the Radioactive Waste Building [Ref-1]. In addition to radiological and operational hazards, conventional safety and maintainability were fully considered in the hazard identification studies. A summary of conventional safety and maintainability issues is provided in the LWMS ALARP Topic Report [Ref-2], but they are not included in this GDA PCSR as they are largely site-specific issues.

The hazards identified to workers and public, from the above studies, have been collated into a preliminary fault schedule which has been consolidated with a list of potential faults and engineered / managerial safeguards that were identified in the HAZOP study (see Section 18.5.2.3). These studies aim to identify all credible failure modes / fault conditions with the potential to lead to an on-site or off-site radiological release. Where appropriate, the design of the LWMS includes automatic / engineered fault prevention, protection and mitigation features to ensure that the assessed fault consequences are both within the limits / targets specified in PCSR Chapter 5 : General Design Aspects, section 5.5 Definition of Design Basis Faults and Beyond Design Basis Faults and that any residual risk is ALARP.

In addition, bounding faults have been assessed and are discussed in the ALARP Topic Report [Ref-2] and dose uptake arising from normal operations is discussed in the BSC [Ref-1]. A brief summary of these is presented below.

### 18.5.2.2 Normal Operations

Dose uptake during normal operations of the LWMS arises for workers as a result of performing maintenance, taking effluent samples and other routine operations. Much lower doses to the public arise from discharges to the environment of treated effluent and direct radiation from the Radwaste Building. This section demonstrates that the doses to workers and the public are ALARP, or are capable of being shown to be ALARP, insofar as the design phase of the systems allow, more detailed information is presented in the BSC for Liquid Waste Processing in the Radioactive Waste building [Ref-1] and the ALARP Topic Report [Ref-2]. This section presents a high level summary of the detailed assessment given in BSC for LWMS [Ref-1]. Doses to the public and operators are minimised via:

- Radiological Protection Zone Classification – see BSC [Ref-1] and Topic Report on Radiation and Contamination Zoning [Ref-6],
- Minimising radiation doses from external radiation via the provision of appropriate shielding in line with approach/principles described in PCSR Chapter 20 : Radiation Protection, section 20.5 Protection and Provisions against Direct Radiation and Contamination,
- Minimising radiation doses from airborne releases via the provision of a Tank Vent Treatment system and a contaminated air area extraction system as described in Section 18.6 and PCSR Section 16.5 Heating Ventilation and Air Conditioning in PCSR Chapter 16 Auxiliary Systems, and
- Decommissioning design provisions to minimise radiation doses – see BSC [Ref-1] and Topic Report on Decommissioning [Ref-21].

**(1) Minimising Worker Dose during Operation**

The LWMS is operated remotely from a control room and operators generally only enter the Rw/B to perform specific tasks such as obtaining effluent samples and maintenance activities. Some samples are obtained remotely using automated systems, however, where sampling is undertaken manually, sample points are located outside the shielded areas where the dose rates are low.

Tank and vessel inspections are typically visual inspections of welds looking for signs of cracking or corrosion. The higher activity tanks will be remotely inspected via closed circuit television (CCTV) whereas, the lower dose rate tanks, will be flushed, drained and isolated prior to being manually inspected.

Pumps are drained, flushed and isolated prior to maintenance. Instruments that require calibration or maintenance have been located outside high dose rate areas where practicable.

In all cases, prior to performing in-situ maintenance, inspections or testing, the plant items will be flushed (or filters backwashed), drained and isolated to ensure dose rates are minimised.

**(2) Minimising Public Dose during Operation**

Public doses are minimised by re-cycling as much effluent as possible (see Section 18.5.1) thus minimising the volume of discharges to the environment. The LCW and HCW systems treat effluent until its quality satisfies the acceptance criteria for re-use. The radioactivity and chemical impurities in discharges are minimised through the use of filtration, ion exchange resins, evaporation and other mechanisms (see also Demonstration of BAT [Ref-12] for further information).

The direct radiation dose-rate off-site from the Rw/B is negligible due to the majority of the liquid radioactive waste inventory being held in tanks which are below ground, and the provision of sufficient levels of radiation shielding.

**(3) Assessment of Radiation Doses from Normal Operation**

Dose uptakes to the public and workers arising from the normal operations are discussed the BSC [Ref-1] and assessed using conservative assumptions.

A low annual dose to a plant operator has been achieved by:

- Designing the LWMS to be operated remotely either from the Rw/B MCR or from the MCR in the C/B,
- Providing bulk radiation shielding within the Rw/B, and
- Providing remote sampling on and incoming effluent into the SS system.

Annual doses to plant maintainers have been minimised by:

- Provision of radiation shielding,
- Using eductors to transfer effluent from higher activity tanks,
- Flushing, draining and isolating equipment prior to maintenance,
- Provision of ventilation systems for contamination controlled areas, and
- Placing maintainable items, insofar as is reasonably practicable, outside shielding in low dose-rate areas.

As the detailed design of the plants evolve, working practices develop and local shielding arrangements are developed, further significant reductions to the predicted worker doses are likely.

## 18.5.2.3 Fault Conditions

The LWMS are designed to minimise the risk to public and workers to ensure doses to public/workers in faults are ALARP and within limits/targets given in PCSR Chapter 5 : General Design Aspects, section 5.5: Definition of Design; Faults and Beyond Design Basis Faults. This represents Safety Functional Claims: LWMS SFC 4-12.6 for the LWMS.

There is the potential for unmitigated on-site doses from fault conditions relating to certain tanks within the LWMS to exceed the Basic Safety Level (BSL) and therefore these fault conditions have been subject to preliminary Design Basis Accident Analysis (DBAA) as stated in NSEDP SP14.2.1.

As discussed in Section 18.5.2.1, a number of hazard identification studies have been undertaken which have led to the development of Preliminary Fault Schedules for the LWMS systems. Key bounding faults have been identified and for these faults preliminary DBAA has been undertaken. DBAA seeks to identify the worst case consequence of a potential unmitigated fault and if required, estimates the likelihood of the fault occurring. This information is then used to inform the design of the plant, to see whether the fault can be prevented by a design change and/or determine how many and which safety measures are required to protect against the fault should it occur. This process is iterative, since it may lead to design changes which in turn can change the faults that could occur. Bounding faults for each of the LWMS sub-systems are assessed in order to avoid over-categorising each of these, and again to inform the detailed design of the LWMS by the future licensee.

This process is in addition to the DBAA performed for the LWMS in PCSR Chapter 24, sub-section 24.11.2, which only assesses 2 single bounding fault for the LWMS (Fault Schedule Ref: 15.2 – Powder Resin Storage Tank – System Leak or Failure and Fault Schedule Ref: 15.4 – SS Pipe Rupture).

The majority of the design of the LWMS is currently at the concept stage and the Rw/B containing the LWMS is at concept design. In line with this level of design detail, analysis of the principal hazards has been undertaken which will be used to inform the further development of the design. In particular, this analysis has:

- Confirmed the requirement for shielding and containment of the various tanks and pipework,
- Provided information on the likely reliability required of the control systems in the LWMS, and
- Indicated that some wastes may generate hydrogen, and hence features to prevent accumulation should be considered in the design.

The detailed arrangements for the shielding and containment of tanks and pipework will be developed as part of the site specific design, as it is likely that the requirements may be affected by the exact site layout. These will be developed to ensure that the risks to both workers and the public are ALARP. Such containment will also support demonstration that the requirements of Licence Condition 34 to ensure that "radioactive waste on the site is at all times adequately controlled or contained so that it cannot leak or otherwise escape from such control or containment".

The analysis undertaken to date indicates that the detailed design can be developed such that risks to the public and workers are tolerable and ALARP.

**(1) Demonstration that Risks from Fault Conditions are ALARP**

The DBAA undertaken is described in the BSC for the LWMS [Ref-1]. For the LWMS, the majority of faults result in unmitigated doses below the Basic Safety Objective (BSO) and therefore under DBAA do not require the provision of safety measures, although the reasonable practicability of providing measures to reduce dose have been considered in compliance with the ALARP principle.

In performing the DBAA, where appropriate (e.g. tank failure/ overflow), design provisions which are passive systems such as tank cell shielding and containment are claimed when calculating the unmitigated consequences. However, where spillages occur out-cell (e.g. from pipework in the pump rooms) no such passive containment is available (for the unmitigated case).

**LWMS Faults – Dose to the Operator:**

The following bounding fault conditions result in unmitigated operator doses below the Basic Safety Level (BSL) but above the BSO:

- Catastrophic failure of LCW pipework or fitting (PCSR Chapter 24, sub-section 24.11.2, Fault Schedule Ref: 15.3, but bounded by Fault Schedule Ref: 15.4), and
- LWMS Tank not emptied before entry into Tank Room / Cell (bounded by PCSR Chapter 24, sub-section 24.11.2, Fault Schedule Ref: 15.4).

The DBAA identified that there are adequate robust safety measures in place to prevent / mitigate these faults.

The following bounding fault conditions result in unmitigated operator doses above the BSL:

- Overflow of SS Tank (PCSR Chapter 24, sub-section 24.11.2, Fault Schedule Ref: 15.4),
- Catastrophic Failure of SS Pipework or Fitting (PCSR Chapter 24, sub-section 24.11.2, Fault Schedule Ref: 15.4),
- Transfer of active effluent during authorised entry into LWMS room (bounded by PCSR Chapter 24, sub-section 24.11.2, Fault Schedule Ref: 15.4), and
- LWMS Pipework / Fitting not isolated, flushed or drained prior to intrusive maintenance (bounded by PCSR Chapter 24, sub-section 24.11.2, Fault Schedule Ref: 15.4).

For overflow of an SS tank, level detection with associated high level alarms, automatically stops all transfers to the tank, preventing a spillage. The HEPA filtered extract to the tank cells mitigates dose uptake. This fault has been assessed using very pessimistic assumptions, such as the maximum volume of the vessel has been assumed to be lost, when in reality a significant percentage of this volume would be occupied by resin, much of which would remain in the tank.

Secondary containment provides a robust safety measure against failure of SS pipework or fitting and the provision of a second robust safety measure is currently being investigated. SS pipework has shielding which provides a passive safety feature that ensures any dose uptake to workers during effluent transfers is minimal.

Provision of an interlock that prevents operator access for intrusive maintenance if the pipeline is not isolated provides a robust safety measure for failure to isolate prior to intrusive maintenance and a second robust safety measure is being investigated. Other safety measures do exist, which consist of:

- Maintenance will be done under an approved Safe System of Work supported by a task-based risk assessment,
- Health Physics support during EMIT to ensure the system does not contain significant amounts of activity prior to the intrusive maintenance,
- PPE/ RPE to be worn on health physics advice,
- Activity-in-air alarms.(including portable type), and
- Area gamma monitor with alarms.(including portable type).

**LWMS Faults – Doses to the Public:**

The DBAA analysis reported in the Basis of Safety Case for the LWMS [Ref-1], identified that the majority of faults result in an unmitigated public dose below the BSO. There were 3 faults identified where this was not the case:

- Catastrophic Failure of SS Pipework or Fitting (above the BSO but less than the BSL) (PCSR Chapter 24, sub-section 24.11.2, Fault Schedule Ref: 15.4),
- Overflow of SS Tank (above the BSO but less than the BSL) (PCSR Chapter 24, sub-section 24.11.2, Fault Schedule Ref: 15.2), and
- LWMS Pipework / Fitting not isolated prior to intrusive maintenance (above the BSO but less than the BSL) (bounded by PCSR Chapter 24, sub-section 24.11.2, Fault Schedule Ref: 15.4).

The secondary containment discussed above in relation to operator doses provides an adequately robust safety measure to protect the public against dose uptake against failure of SS pipework or fitting.

Prevention of overflow is also discussed above in relation to operator doses.

Failure to isolate the SS system pipework prior to intrusive maintenance is protected via an interlock. Intrusive maintenance in the SS system provides managerial control that subjects the pipeline to Health Physics checks to confirm that it does not contain any activity prior to work commencing. In addition, further mitigation is provided by the HEPA filtered Rw/B ventilation system.

**Categorisation and Classification:**

Generally, the majority of safety functions associated with the LWMS are Category C with only a very small number of bounding faults falling into higher categories. Based on the pessimistic worst-case bounding fault, the preliminary category of the safety function applicable to each LWMS sub-system is:

| Bounding Faults in each Sub-System | Preliminary Safety Function Category (Unmitigated dose to Worker) | Preliminary Safety Function Category (Unmitigated dose to Public) |
|---|---|---|
| LCW | B | C |
| HCW (including CONW) | C | C |
| CAD | C | C |
| LD | C | C |
| SS | A | B |

### 18.5.3 Claims and Arguments

The LWMS does not provide a reactor safety function and is not required for safe shutdown of the reactor. However, these systems handle and process radioactive liquids and their safety function in this respect is to ensure that discharges to the environment and any radiation doses to the public and workers are ALARP.

#### 18.5.3.1 LWMS Claims and Arguments

This section describes the arguments as to how each of the SFCs for the LWMS have been met. The detailed evidence is provided in the BSC on Liquid Waste Processing in the Radioactive Waste Building [Ref-1]. For the majority of the LWMS, the classification of SSCs will be class 3, with appropriate safety measures incorporated into the design against the identified faults as required by the evaluation of unmitigated doses. The initial preliminary safety function category for unmitigated doses to worker and public for LWMS which is at concept design can be found in section 18.5.2.3. Although the LCW and HCW systems are at the preliminary design stage they are housed within a concept design building so the SFCs remain appropriate to a concept design stage. Outline initiating fault frequency estimates have been provided in order to assign safety function categories. All bounding faults are considered to be ‘frequent’ faults.

**(1) Radioactivity in Liquid Discharges to the Environment**

In order to demonstrate that the liquid total radioactivity discharged to the environment can be minimised, the following claim should be satisfied:

LWMS SFC 4-12.1: The total radioactivity in liquid discharges to the environment from the LWMS will be minimised.

The arguments underpinning this SFC are as follows;

A1 Radioactive effluent shall be segregated at source so each stream can be effectively treated.
A2 Soluble radioactivity in effluent shall be removed by resins, which are stored prior to solidification.
A3 Insoluble radioactivity shall be removed by filtration, with the filter crud stored and then disposed of in the ILW solidification process.
A4 Distillation shall also be used to remove radioactivity from effluent.
A5 The LWMS shall maximise the activity content sent to the SWMS for immobilisation in a passively safe form.
A6 The treatment methods used shall be subject to a Best Available Techniques (BAT) Assessment.
A7 If CAD water does not meet discharge criteria it shall be transferred to the HCW system for treatment.

**(2) Volumes of Radioactive Liquid Discharges to the Environment**

The demonstration that the LWMS SFC 4-12.2: Total liquid radioactive waste volumes from UK ABWR operation will be minimised is provided by satisfying two sub-claims:

LWMS SFC 4-12.2.1: The total volume of radioactive waste discharged to the environment from the LWMS will be minimised:

The argument underpinning this SFC is as follows;

A1 LWMS treated effluent shall be recycled rather than discharged whenever possible, see system description above (Section 18.5.1) for LCW and HCW systems.

LWMS SFC 4-12.2.2: The creation of secondary wastes arising from the treatment of radioactive water by the LWMS will be minimised:

The arguments underpinning this SFC are as follows;

A1 Secondary liquid waste shall be treated for re-use whenever possible, see system description above (Section 18.5.1.5) for the SS system.
A2 Filter and ion exchange media shall be monitored and only replaced when necessary.
A3 When practicable, filters shall be designed to be backwashed so they can be re-used multiple times.
A4 Tank vent inlet air shall be filtered, to reduce the dust burden on extract HEPA filters.
A5 No orphan wastes shall be created.

**(3) Doses to Workers and Public from Normal Operations**

The demonstration that LWMS SFC 4-12.3: The LWMS facilities shall be designed to ensure that doses to both the workers and the public from normal operation of the UK ABWR LWMS are ALARP is provided by satisfying two sub-claims:

LWMS SFC 4-12.3-1: The LWMS facilities shall be designed to ensure that doses to the workers from normal operation of the UK ABWR LWMS will be ALARP:

The arguments underpinning this SFC are as follows;

A1 The LWMS shall have sufficient shielding provided to minimise worker external radiation dose.
A2 The LWMS shall provide robust primary containment.
A3 Ventilation systems shall be provided to minimise worker internal dose.
A4 Sample points and maintainable items shall be placed outside shielded cells/rooms whenever practicable to minimise dose-rates.
A5 Equipment containing radioactive effluent shall be drained, flushed and isolated prior to maintenance to minimise dose-rate and the potential for radioactive contamination.
A6 The frequency of routine maintenance and operator activities shall be optimised to minimise cumulative exposure time.
A7 Sufficient radiological controls (both engineered and managerial) shall be in place to prevent inadvertent or unnecessary access to high dose rate areas.
A8 The LWMS shall be operated remotely from either from the Rw/B MCR or the MCR in the C/B during normal operations.
A9 Worker doses shall be assessed to be ALARP.
A10 Dose to the worker during normal operation shall be minimised by reactor chemistry regime (This aligns with reactor chemistry safety claims: RC SC5 and RC SC7).

LWMS SFC 4-12.3.2: Doses to the public from normal operation of the UK ABWR LWMS will be ALARP:

The arguments underpinning this SFC are as follows;

A1 Total activity of radioactive discharges from the LWMS to the environment shall be minimised (see

LWMS SFC 4-12.1 above) through the use of BAT.

A2 Total volume of radioactive discharges from the LWMS to the environment shall be minimised (see LWMS SFC 4-12.2 above) through the use of BAT.

A3 Doses to the public from direct radiation from the Radwaste Building shall be minimised due to the majority of the liquid radioactive waste inventory being held in tanks which are below ground, and the provision of sufficient levels of radiation shielding.

A4 Dose to the public from all discharges and direct radiations shall be ALARP.

A5 Dose to the public during normal operation shall be minimised by reactor chemistry regime ( This aligns with reactor chemistry safety claims: RC SC6).

**(4) Use of Best Available Techniques**

The demonstration that LWMS SFC 4-12.4.1: The creation, management and disposal of radioactive waste will be optimised through the use of BAT is provided by satisfying the following three sub-claims:

LWMS SFC 4-12.4.1: The creation, management and disposal of solid radioactive waste will be optimised through the use of BAT:

The argument underpinning this SFC is as follows;

A1 Use of BAT is discussed in the Demonstration of BAT Report [Ref-12].

LWMS SFC 4-12.4.2: The creation, management and discharge of liquid radioactive waste will be optimised through the use of BAT:

The argument underpinning this SFC is as follows;

A1 Use of BAT is discussed in the Demonstration of BAT Report [Ref-12].

LWMS SFC 4-12.4.3: The creation, management and disposal of gaseous radioactive waste will be optimised through the use of BAT:

The argument underpinning this SFC is as follows;

A1 Use of BAT is discussed in the Demonstration of BAT Report [Ref-12].

**(5) Waste Quality Meets Appropriate Acceptance Criteria**

The demonstration that the LWMS SFC 4-12.5: Appropriate monitoring, measuring and sampling equipment will be provided to confirm and record that waste effluent meets relevant Waste Acceptance or Discharge Criteria is provided by satisfying three sub-claims:

LWMS SFC 4-12.5.1: Appropriate monitoring, measuring and sampling equipment will be provided to determine the characteristics of effluent collected:

The arguments underpinning this SFC are as follows;

A1 LCW and HCW Collection Tanks shall be recirculated and sampled, if required, prior to transfer to a downstream process.

A2 CAD Collection Tanks shall be recirculated and sampled prior to discharge

A3 LD Collection Tanks shall not require sampling.

LWMS SFC 4-12.5.2: Appropriate monitoring, measuring and sampling equipment will be provided to confirm and record that stored waste meets relevant Waste Acceptance Criteria:

The arguments underpinning this SFC are as follows;

A1 Waste in the LWMS shall only be stored in the HCW Concentrated Waste Tank and the SS System

Storage Tanks.
A2 Concentrated Waste Tank effluent shall be mixed and sampled prior to transfer to the LLW solidification plant.
A3 Effluent shall be sampled prior to entry to the SS Storage Tanks.
A4 Each SS Storage tank shall be provided with a recirculation loop and sample point.

LWMS SFC 4-12.5.3: Appropriate monitoring, measuring and sampling equipment will be provided to confirm and record that effluent being discharged from the LWMS meets relevant Discharge Criteria:

The arguments underpinning this SFC are as follows;
A1 All LWMS Sample Tanks shall be recirculated and sampled prior to discharge.
A2 A discharge to the environment shall only be made once the effluent in the sample tank has been shown to meet the discharge acceptance criteria.
A3 If effluent fails to meet the relevant discharge acceptance criteria it shall be re-treated.

**(6) Doses to Workers and Public from Faults**

The demonstration that LWMS SFC 4-12.6: The LWMS facilities shall be designed to ensure that risks to public and workers in faults are ALARP and within limits and targets given in PCSR Chapter 5 General Design Aspects, section 5.5: Definition of Design Basis Faults and Beyond Design Basis Faults is provided by satisfying five sub-claims:

LWMS SFC 4-12.6.1: The LWMS has been assessed to identify all credible failure modes/fault conditions with the potential to lead to an on-site or off-site radiological release (the design basis):

The argument underpinning this SFC is as follows;
A1 Structured hazard identification has been undertaken for the LWMS, see Section 18.5.2.1 above.

LWMS SFC 4-12.6.2: Where appropriate, the design of the LWMS will include automatic/engineered fault prevention, protection and mitigation features to ensure that the assessed fault consequences are both within the limits and targets specified in the PCSR Chapter 5 General Design Aspects, section 5.5: Definition of Design Basis Faults and Beyond Design Basis Faults:

The argument underpinning this SFC is as follows;
A1 Hazard assessment has been undertaken for the LWMS to identify fault protection requirements, see Section 18.5.2.3.

LWMS SFC 4-12.6.3: Where appropriate, the design will include specific engineered provisions to facilitate identified fault recovery actions by the workers:

The arguments underpinning this SFC are as follows;
A1 Leak detection and secondary containment shall be provided for all tanks.
A2 Where spills can occur surface finishes shall be designed to be easily decontaminable.
A3 The design will include a means to return to lost liquors to primary containment.

LWMS SFC 4-12.6.4: The radioactive waste system civil structures/building envelopes etc. will be designed and qualified to appropriate standards and provide protection against natural events (earthquake, high wind, flooding, extreme temperature, snow loading, other external hazards as appropriate):

The arguments underpinning this SFC are as follows;
A1 Generic PCSR Chapter 6 on External Hazards specifies the applicable hazards.
A2 Codes and Standards Report [Ref-16] specifies the requirements.

A3 BSC provides justification against the safety case [Ref-1].

LWMS SFC 4-12.6.5: The overall design and layout of the Radioactive Waste building will be compliant with the relevant UK fire regulations:

The arguments underpinning this SFC are as follows;
A1 This is discussed in the PCSR Topic Report on Fire Safety [Ref-17].
A2 BSC provides justification against the safety case [Ref-1].

**(7) LWMS Liquid Waste Capacity**

The demonstration that LWMS SFC 4-12.7: The LWMS facilities shall be designed to provide sufficient capacity to process liquid wastes for normal operation, start-up, shutdown, outages and design basis faults is provided by satisfying two sub-claims:

LWMS SFC 4-12.7.1: The LWMS facilities shall be designed to provide sufficient capacity to process liquid wastes for all normal operations:

The arguments underpinning this SFC are as follows;
A1 The capacity required for reactor outage shall be greater than required for any other mode of normal operation.
A2 The LWMS facilities shall have sufficient capacity to process the maximum effluent throughput during an outage.
A3 The LWMS facilities shall have sufficient capacity to process effluents generated when reactor is at power even when only partially available due to maintenance.

LWMS SFC 4-12.7.2: The LWMS facilities shall be designed to provide sufficient capacity to process liquid wastes for all design basis faults:

The arguments underpinning this SFC are as follows;
A1 No Design Basis Faults have been identified that exceed the maximum reactor outage effluent generation rate.
A2 There shall be sufficient capacity to store additional bead resin generated from the demineralisers in response to the Design Basis source term. An additional Bead Resin Storage Tank shall be provided for the case that design basis bead resin will be realised.

**(8) Treated Effluent Meets Re-use Criteria**

The demonstration that LWMS SFC 5-9.1: The LCW and HCW systems treated effluent shall meet the reuse criteria specified in the Water Quality Specification is satisfied by the following:

LWMS SFC 5.9.1: The LCW and HCW systems treated effluent shall meet the re-use criteria specified in the Water Quality Specification [Ref-10].

The arguments underpinning this SFC are as follows;
A1 The LCW and HCW system shall be designed to treat specific segregated waste streams.
A2 The LCW and HCW systems shall be functionally capable of adequately treating the effluent and, in the unlikely event of the reuse criteria not being met, shall provide the ability to:
- Retreat effluent for both the HCW and LCW systems
- Provide additional treatment of LCW effluent via the HCW system.

(This aligns with reactor chemistry safety claim: RC SC16.1).

**18.5.3.2 Other PCSR Chapter Claims and Arguments**

This section identifies the SFCs made in other chapters of the PCSR that are relevant to this PCSR Chapter at the current stage of design and how they have been met. As the LWMS design progresses through the detailed stage, further SFCs may also apply, in particular, those associated with the provision of plant services or that specify equipment requirements e.g. process air, electrical services, control and instrumentation, etc. More detail on the arguments for these claims is provided in the relevant PCSR Chapters identified below or in the BSC for Liquid Waste Processing in the Radioactive Waste Building [Ref-1]:

**(1) PCSR Chapter 10 – Civil Works and Structures**

Rw/B SFC 4-7.01: The Rw/B provides shielding by concrete walls and slabs. The shielding walls and slabs are arranged around higher radiation areas to reduce worker's exposure. The external walls and slabs provide shielding to reduce dose rate at the site boundary.

The argument underpinning this SFC is as follows;
A1 Appropriate shielding and containment shall be provided by the Rw/B.

R/B SFC 4-7.01: R/B forms a part of the RCCV together with several MC components, to shield radiation from the reactor and confine the radioactive substance inside the containment (Normal Operations):

The argument underpinning this SFC is as follows;
A1 Appropriate shielding and containment shall be provided for the CUW Backwash Receiver Tank by the R/B, during normal operations.

R/B SFC 4-7.04: R/B forms a part of the RCCV together with several MC components, to shield radiation from the reactor and confine the radioactive substance inside the containment (Fault Conditions):

The argument underpinning this SFC is as follows;
A1 Appropriate shielding and containment shall be provided for the CUW Backwash Receiver Tank by the R/B, during fault conditions.

T/B SFC 4-7.01: The T/B provides shielding by concrete walls and slabs to shield radiation to lower the level. The shielding walls and slabs are arranged around higher radiation areas to reduce worker's exposure. The external walls and slabs provide shielding to reduce dose rate at the site boundary. The level of radiation in the turbine is low and therefore the shielding is an ALARP measure to further reduce the dosage to workers in the T/B.

The argument underpinning this SFC is as follows;
A1 Appropriate shielding and containment shall be provided for the CF Backwash Receiver Tank by the T/B.

**(2) PCSR Sub-Chapter 16.4 Plumbing and Drainage System**

P&D SFC 4-12.1: The P&D segregates liquid waste into subcategories, collecting and directing it in the corresponding sumps or sump tanks so that they are treated based on their liquid properties in the Liquid Waste Management System (LWMS):

The argument underpinning this SFC is as follows;
A1 The LWMS shall be designed to receive effluent segregated by the P&D system sumps and tanks.

**(3) PCSR Sub-Chapter 16.4 – Radioactive Drain Transfer System**

RD SFC 4-12.1: The Radioactive Drain (RD) transfer system provides sufficient capacity to transfer liquid waste to the Liquid Waste Management System for normal operation including start-up, shutdown and outage.

The arguments underpinning this SFC are as follows;
A1 The LWMS shall be designed to receive effluent from the RD system sumps and tanks
A2 Processing throughputs for the LCW and HCW systems shall be higher than the various RD sump and tank capacities that feed them

RD SFC 4-7.1: The RD components penetrating the primary containment form a barrier to confine the radioactive material within the containment boundary and prevent its dispersion to the environment in the event of faults.

The argument underpinning this SFC is as follows;
A1 Effluent shall be stopped from coming to the LWMS from the drywell sump when a LOCA signal is generated, see PCSR Sub-chapter 16.4 on Radioactive Drain Transfer System.

RD SFC 5-4.1: In the event of a fault condition which resulted in excessive inflow rate of liquid waste into the drywell sump, an alarm is actuated.

The argument underpinning this SFC is as follows;
A1 The alarm shall enable operators to take action to stop the inflow, preventing excess effluent being transferred to the LWMS, see PCSR Sub-chapter 16.4 on Radioactive Drain Transfer System.

**(4) PCSR Sub-Chapter 16.5 – HVAC**

SFCs refer to normal operation of the HVAC system and therefore cover faults that occur within the associated buildings. R/A HVAC SFC 4-7.2 is associated with reactor faults only.

R/A HVAC SFC 4-7.1: The R/A HVAC system is designed to reduce the release and spread of airborne contamination during normal operation:

The arguments underpinning this SFC are as follows;
A1 The R/B building HVAC system shall be designed to maintain a negative pressure within the controlled areas of the SS system :
A2 The R/B building HVAC system shall be designed to provide adequate dilution of contaminants within the areas of the SS system.
A3 The R/B building HVAC system shall be designed to direct air flow from areas with the lower potential for airborne activity to areas of higher potential with the SS system.
A4 The R/B building HVAC system shall be designed to provide HEPA filtration of exhaust air from within the controlled areas of the SS system.

R/A HVAC SFC 4-7.2 The R/A HVAC system is designed to reduce the release and spread of airborne contamination from the reactor building during design basis and beyond design basis fault conditions:

The argument underpinning this SFC is as follows;
A1 The R/A HVAC system isolation dampers are closed providing physical containment in the R/A.

Rw/B HVAC SFC 4-7.1: The Rw/B HVAC system is designed to reduce the release and spread of airborne contamination during normal operation:

The arguments underpinning this SFC are as follows;
A1 The Rw/B building HVAC system shall be designed to maintain a negative pressure within the controlled areas of the LWMS process and tank rooms / cells.
A2 The Rw/B building HVAC system shall be designed to provide adequate dilution of contaminants

within the areas of the LWMS process and tank rooms / cells.

A3 The Rw/B building HVAC system shall be designed to direct airflow from areas with the lower potential for airborne activity to areas of higher potential with the LWMS process and tank rooms / cells.

A4 The Rw/B building HVAC system shall be designed to provide HEPA filtration of exhaust air from within the controlled areas of the LWMS process and tank rooms / cells.

T/B HVAC SFC 4-7.1: The T/B HVAC system is designed to reduce the release and spread of airborne contamination during normal operation:

The arguments underpinning this SFC are as follows;

A1 The T/B building HVAC system shall be designed to maintain a negative pressure within the controlled areas of the SS system process and tank rooms / cells.

A2 The T/B building HVAC system shall be designed to provide adequate dilution of contaminants within the areas of the SS system process and tank rooms / cells.

A3 The T/B building HVAC system shall be designed to direct airflow from areas with the lower potential for airborne activity to areas of higher potential with the SS system process and tank rooms / cells.

A4 The T/B building HVAC system shall be designed to provide HEPA filtration of exhaust air from within the controlled areas of the SS system process and tank rooms / cells.

S/B HVAC SFC 4-7.1: The S/B HVAC system is designed to reduce the release and spread of airborne contamination during normal operation:

The arguments underpinning this SFC are as follows;

A1 The S/B building HVAC system shall be designed to maintain a negative pressure within the controlled areas of the LD system.

A2 The S/B building HVAC system shall be designed to provide adequate dilution of contaminants within the areas of the LD system.

A3 The S/B building HVAC system shall be designed to direct airflow from areas with the lower potential for airborne activity to areas of higher potential with the LD system.

A4 The S/B building HVAC system shall be designed to provide HEPA filtration of exhaust air from within the controlled areas of the LD system.

**(5) PCSR Chapter 23 – Reactor Chemistry**

RC SC5: The UK ABWR reactor chemistry regime will ensure that the source term radiological dose to the worker is ALARP by optimising materials selection, operating chemistry and operating practices:

RC SC5.1: The source term will be minimised to ALARP in association with material selection.

The argument underpinning this SFC is as follows;

A1 The LCW and HCW systems shall be designed to ensure treated effluent meets the re-use criteria specified in the Water Quality Specification, see LWMS SFC 5-9.1 above.

RC SC5.2: The source term will be minimised to ALARP in association with operating practices.

The argument underpinning this SFC is as follows;

A1 The LCW and HCW systems shall be designed to ensure treated effluent meets the re-use criteria specified in the Water Quality Specification, see LWMS SFC 5-9.1 above.

RC SC5.3: The source term will be minimised to ALARP in association with operating chemistry:

The argument underpinning this SFC is as follows;

A1 The LCW and HCW systems shall be designed to ensure treated effluent meets the re-use criteria specified in the Water Quality Specification, see LWMS SFC 5-9.1 above.

RC SC6: The UK ABWR reactor chemistry regime will ensure that the radionuclide releases and exposure to public is ALARP:

RC SC6.1: The amount of the activation product (N-16) transferred to the steam will be maintained low by the control of HWC+OLNC:

The argument underpinning this SFC is as follows;
A1 This requirement will be met by LWMS meeting requirements LWMS SFC 4-12.1 and LWMS SFC 4-12.3.2 above.

RC SC7: The UK ABWR reactor chemistry regime will ensure that the radionuclide releases and exposure to worker is ALARP:

RC SC7.1: Radionuclides in the reactor water will be kept below levels that may result in increased radionuclide release and exposure, and minimised to ALARP in normal operations by CUW and OG system operations:

The argument underpinning this SFC is as follows;
A1 This requirement will be met by LWMS meeting requirements LWMS SFC 4-12.1 and LWMS SFC 4-12.3.1 above.

RC SC 16.1: Water quality control within specified limits in the CST will ensure the water quality of the primary system:

The argument underpinning this SFC is as follows;
A1 The LCW and HCW systems shall be designed to ensure treated effluent meets the reuse criteria specified in the Water Quality Specification, see LWMS SFC 5-9.1 above

**(6) PCSR Chapter 31 – Decommissioning – Decommissioning Design Features**
Decom-SC 1: The UK-ABWR design incorporates features that facilitate decommissioning:

Decom-SC 1.2: The UK ABWR pipework and drainage design reduces decommissioning risks ALARP:

The arguments underpinning this SFC are as follows;
A1 Equipment shall be designed so it can be flushed and drained.
A2 Rooms / cells shall be lined with impervious easily decontaminable surfaces.
A3 Complex machinery shall be avoided where practicable, especially in higher activity waste streams.
A4 Sample Points and maintainable items shall be placed outside shielded cells/rooms whenever practicable to minimise dose-rates.
A5 The use of embedded pipework shall be minimised.
A6 Countermeasures for the leakage and escape shall be considered in LWMS design so far as is reasonably practicable.

Decom-SC 1.3: The UK ABWR design minimises conventional safety risks during decommissioning:

The argument underpinning this SFC is as follows;
A1 Conventional safety hazards shall be identified in the hazard identification process.

Decom-SC 1.4: The design of the UK ABWR ensures sufficient access and space for decommissioning activities to be undertaken:

The arguments underpinning this SFC are as follows;
A1 Confined space hazards shall be identified in the hazard identification process.
A2 Required space for decommissioning activities shall be assessed during the detailed design / plant layout phase and shall be supported by a hazard identification process.

Decom-SC 1.5: The UK ABWR design has considered decommissioning logistics to ensure risks are reduced to ALARP:

The arguments underpinning this SFC are as follows;
A1 Break-through walls for use in decommissioning shall be provided.
A2 Decommissioning logistics to support decommissioning shall be assessed during the detailed design / plant layout phase.

Decom-SC 1.8: The design of the UK ABWR ensures long-term structural integrity and containment:

The arguments underpinning this SFC are as follows;
A1 The LWMS shall be designed for at least 70 years operation.
A2 The Tank Vent Treatment system shall be designed for 70 years operation.

Decom-SC 1.9: Ancillary systems will have the functionality to be adapted or modified to facilitate decommissioning.

The argument underpinning this SFC is as follows;
A1 The design life of radioactive waste management services, including systems for the treatment of gaseous, liquid and solid wastes shall be appropriate for decommissioning and shall be confirmed during the detailed design phase.

**(7) PCSR Chapter 31 – Decommissioning – Decommissioning Strategies in Place**
Decom-SC 2: Appropriate decommissioning plans/strategies are in place, and will continue to be developed by the future licensee:

Decom-SC 2.2: Records will be managed appropriately and reviewed periodically.

The argument underpinning this SFC is as follows;
A1 Recording and periodic review requirements for liquid waste management shall be appropriate for decommissioning. Appropriate requirements are specified in Section 18.14 on Safety Management arrangements for radioactive waste management.

**(8) PCSR Chapter 31 – Decommissioning – Faults and Hazards Identified**
Decom-SC 3: Faults and Hazards during decommissioning are identified, assessed and all risks shown to be ALARP:

Decom-SC 3.2: Appropriate design features to facilitate decommissioning and provide hazard reduction have been identified:

The argument underpinning this SFC is as follows;
A1 Hazards are being systematically identified through the HAZOP process and managed. Further hazard identification studies and design features will be considered during the detailed design phase.

**(9) PCSR Chapter 31 – Decommissioning – Viable Disposal Routes**
Decom-SC 4: Viable disposal routes are available (or will be available) for all decommissioning wastes:

Decom-SC 4.3: Waste will be minimised during operations:

The arguments underpinning this SFC are as follows;
A1 The total radioactivity in liquid discharges to the environment from the LWMS will be minimised, see LWMS SFC 4-12.1, above.
A2 Total liquid radioactive waste volumes from UK ABWR operation will be minimised, see LWMS SFC 4-12.2, above.
A3 The LCW and HCW systems treated effluent shall meet the re-use criteria specified in the Water Quality Specification, see LWMS SFC 5-9.1, above.
A4 Total solid radioactive waste volumes from UK ABWR reactor operation will be minimised, see SWMS SFC 4-13.1 above.
A5 Total solid radioactive waste volumes from UK ABWR operation will be minimised, see SWMS SFC 4-13.2 above.

Decom-SC 4.4: UK ABWR minimises waste by design:

The argument underpinning this SFC is as follows;
A1 The reactor and fuel cooling systems shall be designed to re-use water that has been treated by the HCW or LCW systems, see LWMS SFC 5-9.1 above.

### 18.5.4 Assumptions, Limits and Conditions for Operation

#### 18.5.4.1 Assumptions

A number of working assumptions are made to demonstrate that the LWMS will achieve all safety claims and that nuclear safety aspects have been adequately considered in the GDA process.

The key working assumptions for the LWMS include:

- The funded decommissioning programme base case [Ref-32] sets out a number of assumptions regarding the means by which waste may be managed and disposed of and decommissioning carried out by a new nuclear power station future licensee. These assumptions define a generic lifecycle plan for new nuclear power stations known as the “Base Case”. The Base Case is built on existing policy and regulatory requirements; although it also makes additional assumptions. The Base Case is primarily written to ensure sufficient financial provision is made to cover liabilities it also provides each future licensee basic assumptions on which radioactive waste management, decommissioning and spent fuel management strategies can be developed from, for example the Base Case assumes that:
  - The regulatory regime to be applied to waste management and decommissioning is that in force at the time the FDP is submitted.
  - Definitions of waste categories will remain unchanged from those in current use.
  - Dose limits for workers and the public will remain unchanged from those in current use in the UK.
- The UK-ABWR will be operational for a period of 60 years. The LWMS will be operational for additional years for decommissioning after the reactor has been taken off line,
- The LWMS will not interfere with power generation,
- The feeds to the LWMS will be treated to allow water for re-use in the power plant, where practicable,
- The feeds to the LWMS are defined in section 2.1 of LWMS BSC [Ref-1],
- Activity in liquid effluent received at the LWMS complies with the Design Basis End User Source Term data for that effluent stream [Ref-9]. Deviations of activity in liquid effluent must not exceed the Design Basis source terms,

- The LWMS system will be sized to process the arisings for 2 days' worth of effluent during normal reactor operations over a single shift (1 x 8 hour shift),
- The LWMS system will be sized to process maximum daily arisings during reactor outages over a single day (3 x 8 hour shifts),
- The LWMS system only operates at near to full capacity for a small proportion of the total outage duration when throughput is at its maximum,
- Spent resins and sludge generated in the Reactor and Turbine buildings, as well as via the LWMS effluent treatment process, will be stored in the SS System,
- Wet-solid waste will be transferred to the SWMS for solidification in specified batch sizes,
- Bead resins will be decay stored for a number of years and will then be transferred for solidification as part of the Wet-solid LLW processing system,
- The LWMS tanks containing the bulk radioactive inventory will be below ground level,
- Liquid effluent quality will meet the relevant discharge/re-use criteria prior to a discharge or transfer taking place,
- Concentrate from the evaporator will be stored in storage tanks and will be sent for solidification as part of the Wet-solid LLW processing system,
- Maximum liquid effluent volumes will not exceed those specified in the BSC [Ref-1],
- The LWMS system design will incorporate features that facilitate decommissioning,
- Assumptions supporting Normal Dose Uptake assessments are those identified in Section 5.1 of the BSC [Ref-1],
- DBAA assume the cells will be designed to contain the full bounding case volumes of spilt liquors,
- DBAA assume activity-in-air monitors and area gamma monitors are positioned at appropriate locations throughout the facility,
- DBAA assume access to rooms/ cells where tanks are located are under access control, and
- The exact form of Class 1 entry prevention is part of ongoing access control design (to the room containing pumps in the SS system)- PCSR Chapter 24, sub-section 24.11.2 (Fault Ref 15.4)

These are detailed in the Basis of Safety Case for Liquid Waste Processing in the Radioactive Waste Building [Ref-1].

#### 18.5.4.2 Limits and Conditions for Operation

The following LCOs are identified for LWMS in GDA phase, and these LCOs are also provided in the Generic Technical Specification (GTS) [Ref-29] and the Basis of Safety Case for Liquid Waste Processing in the Radioactive Waste Building [Ref-1].

- Discharges from the LCW and HCW Sample Tanks to the Condensate Storage Tank (CST) must only occur when the effluent has been demonstrated to meet the Water Quality Specification [Ref-10],
- Discharges to the environment from any LWMS Sample Tank must only occur when the effluent has been demonstrated to meet the relevant discharge consent, and
- Waste must not be transferred to the Wet-solid LLW Processing System unless it has been shown to be acceptable for processing within that system (e.g. activity limit, decay storage period).

### 18.5.5 Summary of ALARP Justification for LWMS

The main design objectives associated with radioactive liquid waste management in UK ABWR are that:

- Radiation doses to the public and workers are As Low As Reasonably Practicable (ALARP),
- Discharges into the environment are minimised, and
- All wastes are safely stored and processed, and are disposed of appropriately.

The designs of the liquid radioactive waste management systems for UK ABWR are based on UK and international good practice. The objective of radioactive waste management is to segregate waste streams according to their chemical properties to make treatment efficient and to re-use as much effluent as possible rather than discharge it to the environment. All secondary wastes created have identified disposal routes, some waste is decay stored so it can be disposed of as LLW. Higher activity tanks have been designed so that, during their operational life, no man access is required, or even physically possible and in so far as is reasonably practicable, maintainable items have been placed outside shielding in low dose-rate areas.

In designing the LWMS various optioneering studies and reviews were undertaken, including a Radioactive Waste Optimisation Study which undertook:

- A workshop to determine how the various effluent streams should be segregated for treatment,
- Options assessment workshops that determined appropriate treatment methods for the segregated streams, and
- Optioneering has been undertaken on each individual segregated waste stream to determine the optimum treatment solution.

The key changes that have resulted from the "Radioactive Waste Optimisation" work was the segregation of LCW and HCW effluent would now be based on chemical impurities rather than conductivity (J (A)BWR segregation is based on conductivity). In addition, these studies also lead to a number of additional design changes taking place, namely:

- Tank Type: Change from pool type tanks to double containment cylindrical tanks with leak detection,
- Pump Layout: Replacement of tank bottom nozzles and pumps to top fed suction nozzles and pumps for relatively high activity tanks, to eliminate the potential for leaks from bottom nozzles,
- Containment for ILW: Locating SS ILW tanks in an enclosed cell, preventing man-access, which resulted in changes to type of tank level meter, tank overflow arrangements and provision of stainless steel liner for secondary containment, and
- Transfer of wet-solid wastes: Transfer of spent resin from SS storage tanks now use eductors rather than local pumps.

In addition, the following reviews and studies have also been undertaken.

- A review of RGP that recommended the use of hollow fibre or pleat filters rather than pre-coat filters, the use of demineralisers and the use of Granular Activated Carbon,
- ALARP option studies were also undertaken, in particular to assess options for replacement of spent hollow fibre filters, and
- Normal operation and fault assessments were undertaken to identify measures that would further reduce risk to workers and the public. Typical measures arising from these would be the identification of interlocks.

More information on the scope and content of the optioneering undertaken can be found in the Topic Report on ALARP Assessment for LWMS [Ref-2].

As a result of evaluating these options, a number of changes to the LWMS have been made to reduce the potential for airborne activity and inadvertent operator dose.

The higher activity tanks are supported by a TVTS that extracts air from the ullage space to minimise the likelihood of airborne activity being displaced into the tank cells/rooms during effluent transfers. In addition, to prevent inadvertent dose uptake, man-access to rooms containing these tanks has been removed and access to lower activity tank rooms are controlled by interlocks or management arrangements as appropriate. SS pipework has also been routed in shielded secondary containment.

To prevent spillages, tanks are fitted with high level alarms and interlocks to prevent further filling as appropriate and pipework is welded in so far as is reasonably practicable.

Maintainable items, where practicable, have also been located outside shielding in low dose-rate areas. In addition, due to the potential dose-rates arising from LCW filters when being changed, their replacement is now undertaken by semi-remote operations.

Whilst a small number of DBA shortfalls have been identified, options have been proposed to resolve these and additional safety measures do exist. Further information is provided in the ALARP Topic Report [Ref-2].

| Shortfall | Potential options to resolve |
|---|---|
| Further safety measure required to protect against catastrophic failure of SS system pipework or fitting. | Currently identified safety measure is shielded secondary containment of pipework and fittings.<br><br>Consider if the SS system can be wholly retained in bunded, shielded and ventilated cells, such that a further (third) level of containment can be maintained. These areas would also need to be key controlled areas. As a minimum the parts of the system with flanged fittings should be limited to such areas. |
| Further safety measure required to protect against SS pipework/ fitting not isolated prior to intrusive maintenance. | Currently identified safety measure is the SS pipeline isolation interlock.<br><br>Consider provisions of diverse interlock to isolate the means of transfer (e.g. pump / eductor) in addition to valve closure. |
| Further safety measure required to protect against SS pipework/ fitting not flushed or drained prior to intrusive maintenance. | Currently identified safety measure is health physics to confirm pipework/ fitting does not contain activity, prior to intrusive maintenance.<br><br>Consider an interlock that prevents access for intrusive maintenance unless a flush/ drain sequence has been initiated. It should be noted that this is only required for the bounding case Powder Resin system. |

Further information is provided in the LWMS ALARP Topic Report [Ref-2].

The LWMS is considered to meet ALARP requirements at a concept design level and is appropriate to be taken forward for the site specific stage. Further information is provided in the LWMS ALARP Topic Report [Ref-2]. The principles of ALARP will need to be applied during detailed design, to ensure the final design is fully compliant with UK regulatory expectations on ALARP.

## 18.6 Wet-solid Waste Processing in the Radwaste Building

The facilities used for the management of solid radioactive wastes generated by the UK ABWR are collectively referred to as the Solid Waste Management System (SWMS). The SWMS has been designed to concept level to receive, sort and process/condition VLLW, LLW, ILW and HLW waste streams resulting from UK ABWR operation. Following processing and conditioning, VLLW/LLW is dispatched off-site for disposal either by incineration, recycling (in the case of recyclable metals) or direct disposal. ILW is processed and conditioned before being transferred to an on-site ILW store for interim storage (pending availability of the GDF) and HLW/spent fuel is dry stored on-site prior to disposal at GDF.

The SWMS concept design currently comprises the following facilities/systems:

- Wet-solid ILW processing system (part of the Rw/B), this section,
- Wet-solid LLW processing system (part of the Rw/B), this section,
- HLW decay storage facility, Section 18.10,
- ILW Store, Section 18.11,
- Solid waste processing including LLW MMA, LCW Filter Packaging Room and SWF, Section 18.12, and
- Transportation on and off-site, Section 18.13.

The information in Sections 18.6, 18.10, 18.11, 18.12 and 18.13 is indicative of one possible solution to the need to process wastes generated by UK ABWR reactor and turbine operations for disposal (in the case of VLLW/LLW) or into a passively safe and disposable form awaiting availability of the GDF (for ILW/HLW).

During decommissioning wastes will continue to be processed within the SWMS before storage or removal off site. This system is expected to have a design life appropriate for decommissioning and will be able to cope with changing requirements during decommissioning. More information can be found in Chapter 31 Decommissioning.

The waste stream process flow diagrams showing point of generation and subsequent routing through the SWMS are given in Figure 18.6-1 (ILW and HLW) and Figure 18.6-2 (VLLW and LLW).

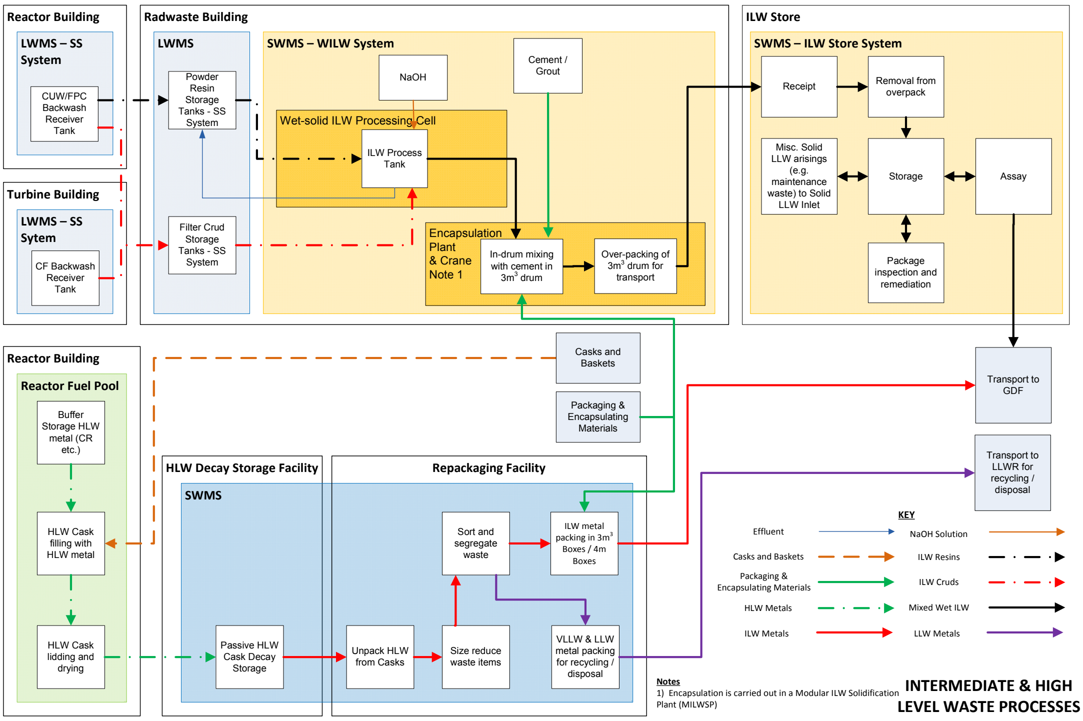



**Figure 18.6-1: HLW and ILW Process Flow Diagram**

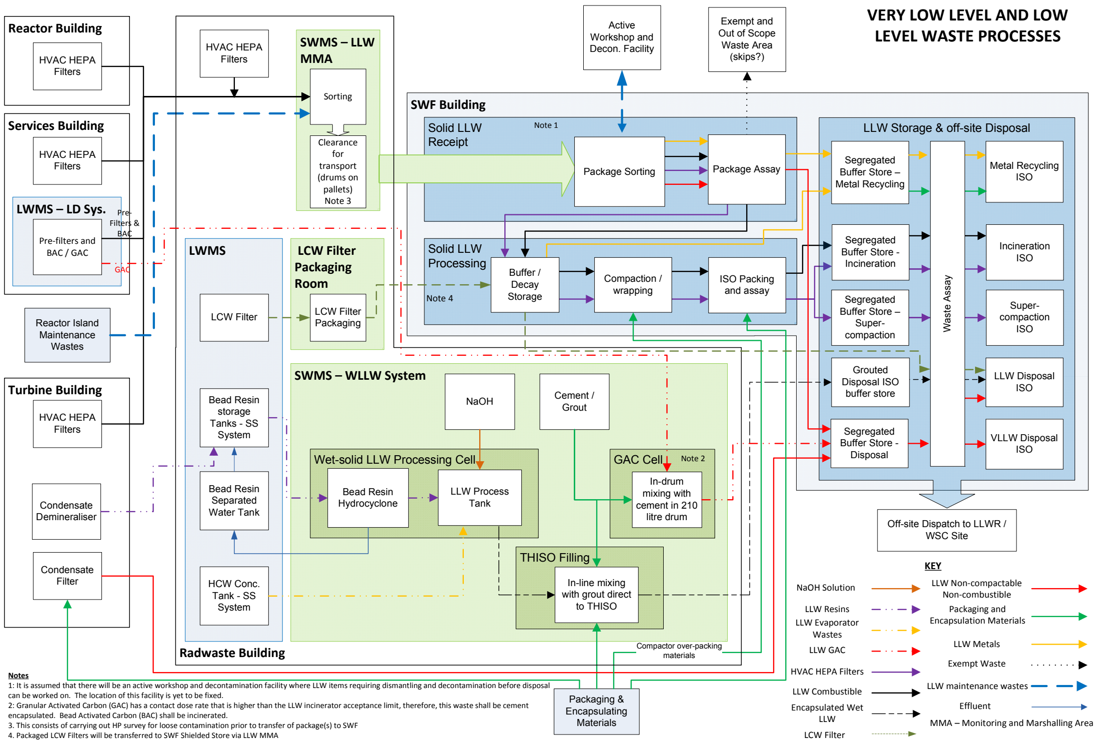



**Figure 18.6-2: VLLW and LLW Process Flow Diagram**

## 18.6.1 Brief Waste & System Descriptions

### 18.6.1.1 Wet-solid Intermediate Level Waste Processing System

This section summarises the description of the Wet-solid ILW (WILW) processing system provided in the Basis of Safety Case for the Solid Radioactive Waste Management System [Ref-3].

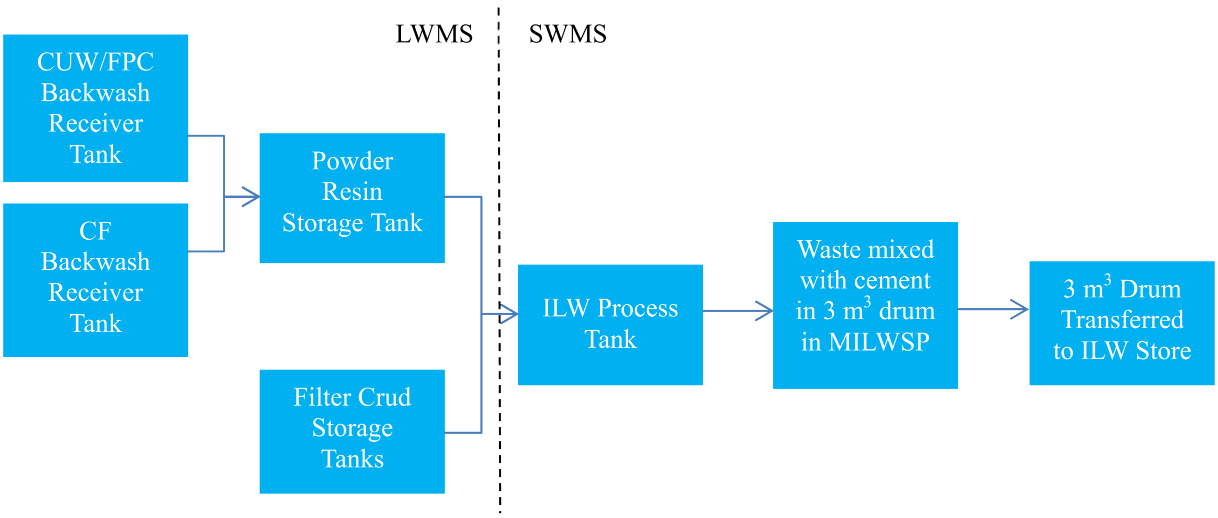
The WILW process, which is located underground in the Rw/B, processes ILW in the form of powder resin and filter crud. The powder resin and filter crud are stored separately in tanks (Powder Resin Storage Tank and Filter Crud Storage Tank) within the spent sludge system of the LWMS (see Section 18.5.1.5) and transferred to the WILW facility in batches. The facility consists of a wet-solid ILW processing cell and a modular ILW solidification plant (MILWSP).

Movement of waste packages (3m$^3$ drums) during treatment in MILWSP will be within Secondary Containment Vessels (SCV). The SCVs will ensure the cleanliness of packages during handling, process and transfer operations.

The purpose of the SCV is to provide secondary containment of the 3 m$^3$ drum during loading and mixing of cement/ILW in the drum loading station in MILWSP. Prior to filling, the 3 m$^3$ drum is placed in the SCV in the drum loading station. It is moved to the un-lidding station, where its lid and associated bolts are removed automatically. The open drum is then positioned under the waste addition and mixing head. Once filling is complete and monitoring of the drum indicates it is free of loose contamination, the 3 m$^3$ drum is removed for export to the ILWS and the SCV remains in the drum loading station. The following paragraphs provide details of the filling of the 3 m$^3$ drum.

Operation of the WILW processing system starts with a batch of powder resin being transferred from the Powder Resin Storage tank into the ILW Process Tank, where it settles and water is decanted from the ILW Process Tank and transferred back to the Powder Resin Storage tank.

A solution of sodium hydroxide is added to the ILW Process Tank which causes the resin to swell prior to solidification, which ensures resins cannot swell further following solidification.




A batch of filter crud is added to the dewatered powder resin in the ILW Process Tank which is mixed and then transferred to the 3 m$^3$ waste drum in MILWSP. The process tank and pipework is then flushed, either with decanted water or purified make-up water which also goes into the drum.

A predetermined mass of pre-mixed cement powders are added to the materials already in the drum and the material within the drum is mixed using a lost paddle in-drum mixer. Following this, the lost paddle is released into the drum and its contents are allowed to set. Finally, pre-mixed liquid grout is added to form an inactive cap on top of the solidified waste.

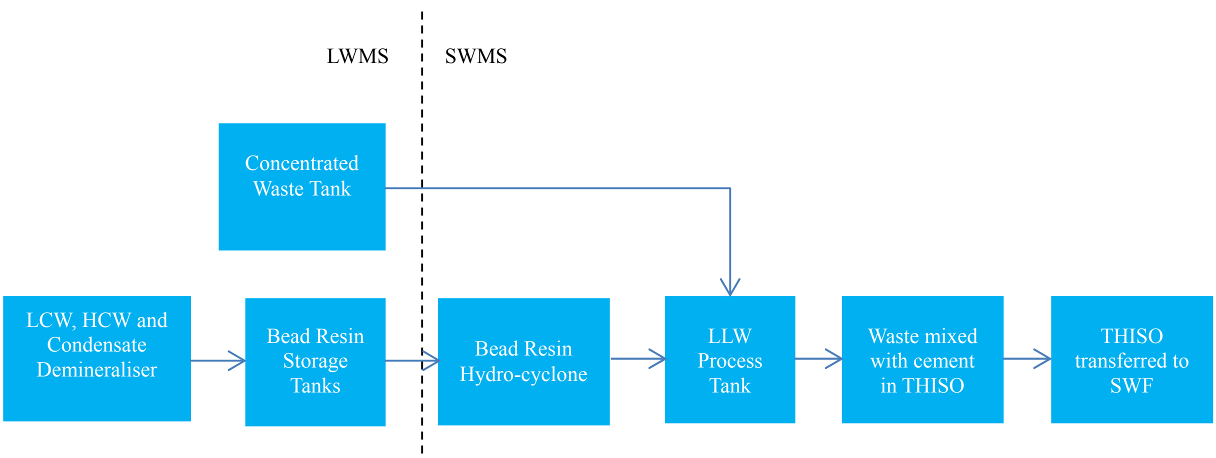
The drum is then moved to the lidding station within MILWSP where the lid and associated bolts are replaced. Finally, the drum is moved to the swabbing station in MILWSP to confirm it is free from contamination before transfer to the unloading station, ready for export to the ILW store. A final confirmatory dose rate check is performed to ensure that the final waste package meets the requirements of the on-site transport safety case.

If the 3 $m^3$ drum is found to be contaminated or the drum has been overfilled, the SCV (containing the 3 $m^3$ drum) is lidded and transferred to the quarantine storage area in the ILWS.

### 18.6.1.2 Wet-solid Low Level Waste Processing System

This section summarises the description of the Wet-solid LLW processing system provided in the Basis of Safety Case for the Solid Radioactive Waste Management System [Ref-3].

The WLLW processing system will receive WLLW in the form of bead resins (from the LCW, HCW and Condensate Demineralisers) and concentrated waste from the HCW evaporator. The bead resin is stored in one of the four Bead Resin Storage Tanks in the Rw/B (SS system of the LWMS, see Section 18.5.1.5). They are stored to allow decay to LLW activity levels prior to a waste processing campaign. The concentrated waste from the HCW evaporator is stored in the Concentrated Waste Tank (CONW system of the LWMS, see Section 18.5.1.6). The bead resin will be sampled prior to transfer to the WLLW system.




Operation of the WLLW processing system starts with transfer of the bead resins from the Bead Resin Storage Tank to the LLW Process Tank via the Bead Resin Hydro-cyclone. The motive water will be removed by the hydro-cyclone system to ensure that minimal quantities of waste require treatment; motive water removed in this way is returned directly to the LWMS for re-use as motive water in future transfers.

The resin is allowed to settle in the LLW Process Tank and the supernatant water is decanted and transferred back to the Bead Resin Separated Water Tanks (see Figure 18.5.2). After settling the bead resin is swelled using sodium hydroxide solution to prevent any subsequent swelling during grout curing, which alleviates any product quality issues for the downstream disposal. Concentrated waste from the Concentrated Waste Tank is added as make-up water to support the grouting process.

The bead resin, concentrated waste and grout are pumped into a Third Height ISO (THISO) Freight Container, which has been pre-fitted with a lost paddle mixer ensuring that the wastes and grout are mixed together whilst filling the container, thus producing a homogenous waste form. The grout continues to pour after the batch of waste has been transferred to form an inactive capping layer. Once cured the THISO container is transported to the LLWR either directly or via the SWF.

The WLLW processing system also has a separate cell for processing GAC from the Laundry Drain system (see Section 18.5.1.4). The GAC contains chlorides and this could cause corrosion of equipment within the WLLW processing cell, therefore the GAC is processed separately from the bead resin. The GAC cell provides in-drum mixing with cement in 210 litre drums. The drummed waste is then transferred to the SWF prior to off-site disposal.

## 18.6.2 Safety Assessment

### 18.6.2.1 Hazard Identification Process

Credible hazards associated with the WILW and WLLW systems have been identified through a suite of Hazard and Operability Studies (HAZOP), in addition to the Failure Modes and Effects Analysis (FMEA) that has been completed. For a discussion on the HAZOPs and other studies completed or planned, refer to the BSC on Solid Radioactive Waste Management System [Ref-3]. Industrial related hazards (such as slips, trips and falls, loss of services and diesel fumes), chemical & toxicity and operational hazards have been identified but not assessed at this stage of the design. These hazards will be assessed as part of ongoing design development beyond GDA for a specific site.

The hazards identified to workers and public from the above studies, have been collated into a preliminary fault schedule [Ref-3] which has been consolidated with a list of potential faults and engineered / managerial safeguards that were identified in the HAZOP study. These studies aim to identify all credible failure modes / fault conditions with the potential to lead to an on-site or off-site radiological release. Where appropriate, the design of the Wet solid ILW and Wet-solid LLW systems includes automatic / engineered fault prevention, protection and mitigation features to ensure that the assessed fault consequences are both within the limits / targets specified in PCSR Chapter 5 : General Design Aspects, section 5.5 Definition of Design Basis Faults and Beyond Design Basis Faults and any residual risk is As Low As Reasonable Practicable (ALARP).

### 18.6.2.2 Normal Operations

An operator dose uptake assessment is not currently required for the WILW process cell operations, since the process operation will be undertaken remotely. In addition, required maintenance of plant equipment is expected to be infrequent with all maintainable equipment located outside the WILW Process Cell. However, a normal dose uptake assessment will be undertaken at post GDA phase to cover operations and maintenance activities.

A preliminary dose uptake assessment has been completed for WLLW which is still in the concept design stage, to demonstrate that the doses are capable of being reduced ALARP at later design stages. The collective dose uptake to workers carrying out the THISO filling operations is conservatively assessed at 2.2 man-mSv.

The assessment of worker dose uptake has been undertaken on a conservative basis, in particular:

- For the loading of the THISO onto the transporter, it is assumed that the operator is 1 m from the unshielded THISO,
- For the process step requiring locking the THISO down to the transporter, it is assumed that the operator is in close proximity (contact) to the unshielded THISO for the duration of the operation, and
- For the Health Physics (HP) monitoring step prior to export, it is assumed that the HP monitor is in close proximity (contact) to the THISO for the duration of the operation.

These steps are conservative as it is not likely that the operators will be in contact with the unshielded THISO for the whole operation. Therefore, as the design progresses and becomes more detailed it is likely that assessed annual dose will reduce.

### 18.6.2.3 Fault Conditions

**WILW / WLLW Faults – Dose to the Operator:**

Bounding fault assessments for the WILW / WLLW were also presented in the ALARP Topic Report [Ref-2]. The WILW and WLLW systems are currently at a concept stage.

A number of preliminary fault assessments have been undertaken for both WILW and WLLW. Several faults exceed the BSO (only one of which originates from the WLLW system) and may therefore require safety measures to be applied subsequently.

Potential hazard reduction measures include:

- Shielding,
- Gamma monitors,
- Spill / leak /level indication,
- Access restrictions,
- Secondary containments of vessels and pipes, and
- Limitations on waste volumes that can be transferred.

Even when assessments are below the BSO, consideration will be given to the provision of ALARP measure to protect workers and public from radiological doses arising from normal operations and fault conditions.

**WILW / WLLW - Doses to the Public:**

The vast majority of bounding faults assessed provided very little dose to the public. In particular, because WILW is remotely operated in well shielded containment below ground, all faults were identified as producing negligible dose to the public. The only fault identified that was marginally above the BSO for the public was direct radiation due to failure of an LLW transfer line as this fault occurs at ground level.

**Categorisation and Classification:**

Based on the pessimistic worst-case bounding fault, the preliminary category of the safety function applicable to the WILW/WLLW is:

| **Bounding Faults in each Sub-System** | **Preliminary Safety Function Category (Unmitigated dose to Worker)** | **Preliminary Safety Function Category (Unmitigated dose to Public)** |
|---|---|---|
| WILW | B | C |
| WLLW | C | C |

## 18.6.3 Claims and Arguments

The SWMS (including the WILW/WLLW) does not provide a reactor safety function and is not required for safe shutdown of the reactor. However, these systems handle and process radioactive liquids and their safety function in this respect is to ensure that discharges to the environment and any radiation doses to the public and workers are ALARP.

### 18.6.3.1 SWMS (including the Wet-solid ILW / Wet-solid LLW) Claims, Arguments and Evidence

This sub-section describes the arguments as to how each of the SFCs for the SWMS (including the WILW / WLLW) has been met. The detailed evidence is provided in the Basis of Safety Case for the Solid Radioactive Waste Management System [Ref-3]. For the majority of the WILW/WLLW, the classification of SSCs will be class 3, with appropriate safety measures incorporated into the design against the identified faults as required by the evaluation of unmitigated doses. The initial preliminary safety function category for unmitigated dose to worker and public for the WILW/WLLW which is at concept design can be found in section 18.6.2.3.

**(1) Total Solid Radioactive Waste Volumes**

The demonstration that SWMS SFC 4-13.1: Total solid radioactive waste volumes from UK ABWR reactor operation will be minimised is provided by satisfying the following three sub-claims:

SWMS SFC 4-13.1.1 The total solid radioactive waste volume in storage will be minimised.

The arguments underpinning this SFC are as follows;
A1 Cross-boundary waste streams will be provided with suitable decay storage facilities to allow for off-site disposal as LLW.
A2 SWF operational philosophy and LLW MMA philosophy advocate rolling consignment to minimise on-site accumulation.
A3 Strategy for SLLW handling considers the balance between decay storage and accumulation on-site and maximising efficient use of all available disposal routes.

SWMS SFC 4-13.1.2 The total solid radioactive waste volumes to be consigned for disposal will be minimised.

The arguments underpinning this SFC are as follows;
A1 Site wide SLLW strategy optioneering undertaken to maximise efficiency of disposal routes through segregation and sorting.
A2 Cross-boundary waste streams will be provided with suitable decay storage facilities to allow for off-site disposal as LLW.

SWMS SFC 4-13.1.3 Secondary wastes produced in operation of the SWMS will be minimised.

The argument underpinning this SFC is as follows;

A1 Liquid wastes from the SWMS will be treated using the LWMS to allow re-use or if not possible, safe discharge to the environment.

**(2) Doses to Workers and Public from Normal Operations**

The demonstration that SWMS SFC 4-13.2: The SWMS facilities shall be designed to ensure that doses to both the workers and the public from normal operation of the UK ABWR SWMS are ALARP is provided by satisfying the following two sub-claims:

SWMS SFC 4-13.2.1: The SWMS facilities shall be designed to ensure that doses to workers from normal operation of the UK ABWR SWMS will be ALARP:

The arguments underpinning this SFC are as follows;

A1 The SWMS will have sufficient shielding provided to minimise worker external radiation dose, see Generic PCSR Chapter 20 Radiation Protection, section 20.5 on Protection and Provisions against Direct Radiation and Contamination.

A2 The SWMS will provide robust primary containment.

A3 Ventilation systems will be provided to minimise worker internal dose.

A4 Sample points and maintainable items will be placed outside shielded cells/rooms whenever practicable to minimise dose rates.

A5 Equipment containing radioactive effluent will be drained, flushed and isolated prior to maintenance to minimise dose rate and the potential for radioactive contamination.

A6 The frequency of routine maintenance and operator activities will be optimised to minimise cumulative exposure time.

A7 Sufficient radiological controls (both engineered and managerial) will be in place to prevent inadvertent or unnecessary access to high dose rate areas.

A8 The SWMS will be designed to be operated remotely where practicable during normal operations.

A9 Dose to the worker during normal operation shall be minimised by reactor chemistry regime.( This aligns with reactor chemistry safety claims: RC SC5 and RC SC7)

SWMS SFC 4-13.2.2: The SWMS facilities shall be designed to ensure that doses to the public from normal operation of the UK ABWR SWMS will be ALARP:

The arguments underpinning this SFC are as follows;

A1 Total activity of radioactive gaseous discharges from the ILWS and SWF to the environment will be minimised.

A2 Total volume of radioactive discharges from the SWMS to the environment will be minimised.

A3 The SWMS facilities shall be designed to ensure that doses to the public from direct radiation from the SWMS facilities will be minimised.

A4 Dose to the public during normal operation shall be minimised by reactor chemistry regime.( This aligns with reactor chemistry safety claims: RC SC6)

**(3) Use of Best Available Techniques**

The demonstration that SWMS SFC 4-13.3: The creation, management and disposal of radioactive wastes will be optimised through the use of BAT is provided by satisfying the following three sub-claims:

SWMS SFC 4-13.3.1: The creation, management and disposal of solid radioactive waste will be optimised through the use of BAT:

The argument underpinning this SFC is as follows;

A1 The demonstration of BAT across the Site is provided in the GEP Report "Demonstration of BAT" [Ref-12] and BAT Optioneering is discussed in the Basis of Safety Case for SWMS [Ref-3].

SWMS SFC 4-13.3.2: The creation, management and disposal of liquid radioactive waste will be optimised through the use of BAT:

The argument underpinning this SFC is as follows;
A1 The demonstration of BAT across the Site is provided in the GEP Report "Demonstration of BAT" [Ref-12] and BAT Optioneering is discussed in the Basis of Safety Case for SWMS [Ref-3].

SWMS SFC 4-13.3.3: The creation, management and disposal of gaseous radioactive waste will be optimised through the use of BAT:

The argument underpinning this SFC is as follows;
A1 The demonstration of BAT across the Site is provided in the GEP Report "Demonstration of BAT" [Ref-12] and BAT Optioneering is discussed in the Basis of Safety Case for SWMS [Ref-3].

**(4) Waste Quality Meets Appropriate Acceptance Criteria**

The demonstration that SWMS SFC 4-13.4: Appropriate monitoring, measuring and sampling equipment will be required to confirm and record that waste meets relevant Waste Acceptance Criteria is provided by satisfying the following two sub-claims:

SWMS SFC 4-13.4.1 Appropriate monitoring, measuring and sampling equipment will be required to characterise the waste collected:

The arguments underpinning this SFC are as follows;
A1 Adequate provision will be made for monitoring and measuring in the WILW/WLLW systems.
A2 Adequate provision will be made for monitoring and measuring in the ILWS.
A3 Adequate provision will be made for monitoring and measuring in the SWF
A4 Adequate provision will be made for monitoring and measuring in the LLW MMA
A5 Monitoring will be carried out at point of generation of waste to allow appropriate segregation into waste streams.
A6 Areas designated for monitoring will be in low dose rate areas or will be provided with suitable shielding.

SWMS SFC 4-13.4.2 Appropriate monitoring, measuring and sampling equipment will be required to confirm and record that waste being consigned from the SWMS meets relevant WAC for disposal facilities:

The arguments underpinning this SFC are as follows;
A1 Adequate provision will be made for monitoring and measuring in the WILW/WLLW systems.
A2 Adequate provision will be made for monitoring and measuring in the ILWS.
A3 Adequate provision will be made for monitoring and measuring in the SWF
A4 Adequate provision will be made for monitoring and measuring in the LLW MMA.

**(5) Doses to Workers and Public from Faults**

The demonstration that SWMS SFC 4-13.5: The SWMS facilities shall be designed to ensure that risks to public and workers in faults are ALARP and within limits and targets given in PCSR Chapter 5 General Design Aspects, section 5.5: Definition of Design Basis Faults and Beyond Design Basis Faults: is provided by satisfying the following five sub-claims.

SWMS SFC 4-13.5.1: The SWMS will be assessed to identify all credible failure modes/fault conditions with the potential to lead to an on-site or off-site radiological release (the design basis):

The argument underpinning this SFC is as follows;
A1 Basis of Safety Case for SWMS [Ref-3] describes the structured hazard identification that has been undertaken to date for the SWMS.

SWMS SFC 4-13.5.2: Where appropriate, the design of the SWMS will include automatic/engineered fault prevention, protection and mitigation features to ensure that the assessed fault consequences are within the limits and targets specified in the PCSR Chapter 5 General Design Aspects, section 5.5: Definition of Design Basis Faults and Beyond Design Basis Faults:

The argument underpinning this SFC is as follows;
A1 Basis of Safety Case for SWMS [Ref-3] describes the Hazard Assessment that has been undertaken to date to identify preliminary fault protection requirements.

SWMS SFC 4-13.5.3: Where appropriate, the design will include specific engineered provisions to facilitate identified fault recovery actions by the workers:

The arguments underpinning this SFC are as follows;
A1 Basis of Safety Case for SWMS [Ref-3] discusses the Hazard identification studies to date that identify preliminary engineered safeguards.
A2 Radwaste Building maintenance arrangements will provide for recovery through the use of appropriately designed equipment.
A3 Dedicated maintenance facilities will be provided throughout the SWMS facilities.

SWMS SFC 4-13.5.4: The radioactive waste civil structures/building envelopes etc. will be designed and qualified to appropriate standards and provide protection against the natural events:

The argument underpinning this SFC is as follows;
A1 The ILW Store and Solid Waste Facility will be designed to appropriate standards. Generic PCSR Chapter 6 on External Hazards identifies relevant preliminary external hazards applicable, Codes and Standards Report [Ref-16] specifies preliminary requirements and Basis of Safety Case for the SWMS [Ref-3] presents a preliminary justification of the adequacy of the SWF against the safety case.

SWMS SFC 4-13.5.5: The overall design and layout of the SWF and ILWS will be compliant with the relevant UK fire regulations.

The argument underpinning this SFC is as follows;
A1 The design of the SWF and ILW Store will be compliant with relevant UK fire regulations. Topic Report on Fire Safety Strategy [Ref-17] defines approach.

#### 18.6.3.2 Other PCSR chapter Claims and Arguments

This section identifies the safety claims made in PCSR Chapter 10 – Civil Works and Structures, PCSR Chapter 16 – Auxiliary Systems (section 16.5 HVAC) and PCSR Chapter 31 - Decommissioning that are relevant to this PCSR Chapter and how they have been met. More detail on the evidence for these claims is provided in PCSR Chapter 10 and Chapter 31:

**(1) PCSR Chapter 10 – Civil Works and Structures**
Rw/B SFC 4-07.01: The Rw/B provides shielding by concrete walls and slabs. The shielding walls and slabs are arranged around higher radiation areas to reduce worker's exposure. The external walls and slabs

provide shielding to reduce dose rate at the site boundary.

The arguments underpinning this SFC are as follows;
A1 The SWMS will have sufficient shielding provided to minimise worker external radiation dose, see SWMS SFC 4-13.2.1.
A2 Doses to the public from direct radiation from the SWMS facilities will be minimised, see SWMS SFC 4-13.2.2.

**(2) PCSR Chapter 16.5 – HVAC**
SFCs refer to normal operation of the HVAC system and therefore cover faults that occur within the associated buildings.

Rw/B HVAC SFC 4-7.1: The Rw/B HVAC system is designed to reduce the release and spread of airborne contamination during normal operation

The arguments underpinning this SFC are as follows;
A1 The Rw/B building HVAC system shall be designed to maintain a negative pressure within the controlled areas of the SWMS.
A2 The Rw/B building HVAC system shall be designed to provide adequate dilution of contaminants within the controlled areas of the SWMS.
A3 The Rw/B building HVAC system shall be designed to direct air flow from areas with the lower potential for airborne activity to areas of higher potential within the SWMS.
A4 The Rw/B building HVAC shall be designed to provide HEPA filtration of exhaust air from within the controlled areas of the SWMS.

**(3) PCSR Chapter 31 – Decommissioning – Decommissioning Design Features**
Decom-SC 1: The UK-ABWR design incorporates features that facilitate decommissioning:

Decom-SC 1.2: The UK ABWR pipework and drainage design reduces decommissioning risks ALARP:

The arguments underpinning this SFC are as follows;
A1 Equipment will be designed so it can be flushed and drained
A2 Rooms / cells will be lined with impervious easily decontaminable surfaces
A3 Sample Points and maintainable items will be placed outside shielded cells/rooms whenever practicable to minimise dose-rates
A4 Where possible equipment will be located outside high dose/high contamination areas

Decom-SC 1.3: The UK ABWR design minimises conventional safety risks during decommissioning:

The argument underpinning this SFC is as follows;
A1 Where possible equipment will be located outside of confined spaces such as cells

Decom-SC 1.4: The design of the UK ABWR ensures sufficient access and space for decommissioning activities to be undertaken:

The arguments underpinning this SFC are as follows;
A1 Where possible equipment will be located outside of confined spaces such as cells
A2 Required space for decommissioning activities will be assessed during the detailed design / plant layout phase and will be supported by a HAZOP study
A3 The provision of access for maintenance and space provision as part of the operational plant will ensure sufficient access and space for decommissioning activities

Decom-SC 1.5: The UK ABWR design has considered decommissioning logistics to ensure risks are reduced to ALARP:

The arguments underpinning this SFC are as follows;
A1 Break-through walls for use in decommissioning will be provided
A2 Logistics to support decommissioning will be assessed during the detailed design / plant layout phase
A3 Dedicated areas for maintenance will be included as part of the UK ABWR design

Decom-SC 1.8: The design of the UK ABWR ensures long-term structural integrity and containment:

The argument underpinning this SFC is as follows;
A1 The SWMS facilities will be designed for the appropriate lifetimes required to fulfil the operational roles

Decom-SC 1.9: Ancillary systems will have the functionality to be adapted or modified to facilitate decommissioning.

The argument underpinning this SFC is as follows;
A1 Each of the SWMS facilities will have a design life that is appropriate for decommissioning, taking into consideration the phase in which it is required to be operable

**(4) PCSR Chapter 31 – Decommissioning – Decommissioning Strategies in Place**

Decom-SC 2: Appropriate decommissioning plans/strategies are in place, and will continue to be developed by the future licensee:

Decom-SC 2.2: Records will be managed appropriately and reviewed periodically.

The argument underpinning this SFC is as follows;
A1 Recording and periodic review requirements for solid waste management will be appropriate for decommissioning. Appropriate requirements are specified in Section 18.14 on Safety Management arrangements for radioactive waste management

**(5) PCSR Chapter 31 – Decommissioning –Faults and Hazards Identified**

Decom-SC 3: Faults and Hazards during decommissioning are identified, assessed and all risks shown to be ALARP:

Decom-SC 3.2: Appropriate design features to facilitate decommissioning and provide hazard reduction have been identified:

The argument underpinning this SFC is as follows;
A1 Consideration has been given to decommissioning during preliminary hazard identification and assessment in the concept design of the SWMS facilities and will continue throughout the design development.

**(6) PCSR Chapter 31 – Decommissioning – Viable Disposal Routes**

Decom-SC 4: Viable disposal routes are available (or will be available) for all decommissioning wastes:

Decom-SC 4.3: Waste will be minimised during operations:

The arguments underpinning this SFC are as follows;
A1 Total solid radioactive waste volumes from UK ABWR in storage will be minimised, see SWMS SFC

4-13.1.1 above

A2 Total solid radioactive waste volumes from UK ABWR operation will be minimised, see SWMS SFC 4-13.1.2 above

Decom-SC 4.4: UK ABWR minimises waste by design:

The arguments underpinning this SFC are as follows;

A1 See SWMS SFC 4-13.3 above

A2 The decommissioning wastes are in general similar to operational wastes and will be consigned/disposed of in a similar manner.

### 18.6.4 Assumption, Limits and Conditions for Operation

#### 18.6.4.1 Assumptions

A number of working assumptions are made to demonstrate that the WILW/WLLW Processing Systems will achieve all safety claims and that nuclear safety aspects have been adequately considered in the GDA process.

The key working assumptions for the WILW/WLLW processing systems include:

**(1) Wet-solid ILW Assumptions**

- The WILW processing system will receive CUW and FPC powder resin plus LCW and CF filter crud,
- The WILW processing system will have sufficient shielding to receive powder resin and filter crud at activities up to and including the design basis source term values quoted in the end user source term,
- The throughput of the WILW processing system is designed to process waste such that it does not impact on LWMS operation. This in turn means that it will not impact on power generation,
- WILW waste will be received on a batch basis (a batch being sufficient waste for one 3m3 drum). The maximum permitted volume of waste per batch that ensures a compliant package will be confirmed during trials/commissioning,
- The UK-ABWR will be operational for a period of 60 years. The WILW processing system will be operational for additional years for decommissioning after the reactor has been taken off line,
- All maintenance for all options are undertaken outside the Process Cell and will be undertaken when the cell is not in its operational phase,
- Consequence assessments assume the ILW Cell is unoccupied when the Process Tank is operational because it is remotely operated,
- Consequence assessments assume the WILW processing system is located at a subterranean level so as to reduce doses from fault and normal conditions to on-site operators and members of the public,
- Consequence assessments assume the grouted waste has cured before any lift is attempted, and
- The funded decommissioning programme base case [Ref-32] sets out a number of assumptions regarding the means by which waste may be managed and disposed of and decommissioning carried out by a new nuclear power station future licensee. These assumptions define a generic lifecycle plan for new nuclear power stations known as the “Base Case”. The Base Case is built on existing policy and regulatory requirements; although it also makes additional assumptions. The Base Case is primarily written to ensure sufficient financial provision is made to cover liabilities it also provides each future licensee basic assumptions on which radioactive waste management, decommissioning and spent fuel management strategies can be developed from, for example the Base Case assumes that ILW will be stored on-site pending final transport and disposal in a GDF.

**(2) Wet-solid LLW Assumptions**

- The WLLW processing system will receive LCW, HCW and CD bead resin plus evaporator concentrated waste,
- The WLLW processing system will have sufficient shielding to receive LCW, HCW and CD bead resin plus concentrated waste from the HCW evaporator at activities up to and including un-decayed the best estimate source term values quoted in the end user source term,
- The WLLW processing system will only receive waste that has been decayed to a sufficient level to comply with LLWR conditions for acceptance and relevant transport regulations,
- The throughput of the WLLW processing system is designed to process waste such that it does not impact on LWMS operation. This in turn means that it will not impact on power generation,
- WLLW waste will be received on a batch basis (a batch being sufficient waste for a THISO). The maximum permitted volume of waste per batch that ensures a compliant package will be confirmed during trials/commissioning,
- The UK-ABWR will be operational for a period of 60 years. The WLLW processing system will be operational for additional years for decommissioning after the reactor has been taken off line,
- Normal dose uptake assessments assume 24 THISOs are produced over one year of processing after a suitable period for waste accumulation and decay storage, and
- The funded decommissioning programme base case [Ref-32] sets out a number of assumptions regarding the means by which waste may be managed and disposed of and decommissioning carried out by a new nuclear power station future licensee. These assumptions define a generic lifecycle plan for new nuclear power stations known as the "Base Case". The Base Case is built on existing policy and regulatory requirements; although it also makes additional assumptions. The Base Case is primarily written to ensure sufficient financial provision is made to cover liabilities it also provides each future licensee basic assumptions on which radioactive waste management, decommissioning and spent fuel management strategies can be developed from, for example the Base Case assumes that LLW arising during operation and decommissioning will be packaged on site by the Operator and dispatched to a disposal facility promptly after they have been generated. For the purposes of the Base Case, we assume that disposal will be at the LLW Repository operating in West Cumbria or a successor facility.

These are detailed in the BSC for SWMS [Ref-3].

### 18.6.4.2 Limits and Conditions for Operation

The following LCOs are identified for WLLW/WILW in GDA phase, and these LCOs are also provided in the Generic Technical Specification (GTS) [Ref-29] and the Basis of Safety Case for SWMS [Ref-3].

- The final waste WILW package must conform with RWM conditions for acceptance at the proposed GDF and relevant transport regulations, and
- The WLLW package must conform with LLWR conditions for acceptance and relevant transport regulations.

## 18.6.5 Summary of ALARP Justification for Wet-solid ILW/LLW Processing

The proposed concept design detailed in GDA Step 2 for the various SWMS waste processing facilities was for the WLLW/WILW processing systems to be located in separate buildings. The safety assessment carried out for GDA Step 2 concluded that the major hazard in this layout was the length of the pipes needed to transfer the wet wastes from the generation point in the Rw/B and the associated risk of pipe failure leading to the potential for an off-site release. An optioneering study was carried out in 2015 that recommended that the WLLW/WILW processing systems should be located in the Rw/B. The recommendation has been implemented by Hitachi-GE and the WLLW and WILW are now situated in the Rw/B. This eliminated the hazard presented by the waste transfer by ensuring that the length of pipe was minimised and any leakage could be contained within the building structure through appropriate use of secondary containment and bunding.

Hitachi-GE has identified the gaps between UK good practice and Japanese practice regarding the design philosophy for chemical/process engineering approach in the UK, as part of radioactive waste optimisation.

This has resulted in design changes for the liquid and solid radioactive waste systems as the Japanese and UK segregation criteria are different. As a result the effluent treatment approach and corresponding configuration have been impacted.

### 18.6.5.1 Wet-solid ILW ALARP Summary

The design of the WLLW processing system for the UK ABWR is based on UK and international best practice. The WILW processing system is based on existing technology used on UK Nuclear Licensed sites for solidification of ILW. The batch nature of processing ensures the minimum waste inventory is sent to the process cell and reduces the hazard to workers from direct exposure in accident conditions. Workers are excluded from the waste in normal operation conditions and the encapsulation process is fully remote.

WILW is contained within suitably engineered tanks which are then in turn held in shielded cells with leak detection systems to monitor and ensure leaks are detected.

The system provides some decay storage period for the powder resin waste prior to treatment; the period of decay allows the shielding requirements to be optimised against engineering requirements of handling the encapsulated waste.

In addition to UK and international good practice; a number of options were considered to refine the process and reduce the hazards to workers from operation of this system and to reduce worker/public dose uptake during normal operations.

In GDA Step 2 the wet-solid waste processing facilities were in separate buildings. An optioneering study was carried out in 2015 that recommended that the WLLW / WILW processing systems should be located in the Rw/B and this has been implemented. The major reason for this change was to minimise the transfer distance of wet-solid ILW and wet-solid LLW waste streams.

A further optioneering study considered refinements to the WLLW processing system, specifically the optimisation of waste transfer to the encapsulation cell:

Option 1: Baseline Design.

Option 2: Hydrocyclones.

Option 3: Settling/Conditioning Vessel Combined Without Lamella Pack.

Option 4: Air Fluidisation Conditioning Vessel.

Option 5: Reverse Flow Diverter.

The preferred option was Option 5, this option provided a reduction in the number of tanks required in the process tank cell (to just one tank) as well as a reduction in process pipework which reduces the potential for loss of containment hazards from failed tanks and pipework. The option also reduced maintenance requirements in the process tank cell and the potential direct exposure hazard during maintenance operations.

There are three main hazards associated with the Wet-solid ILW Processing System for the UK ABWR:

- Direct exposure of workers to radiation because of reduced or loss of shielding or errors in maintenance
- Drop of a filled 3 $m^3$ drum
- Loss of containment of WILW (from transfer lines or tanks) leading to exposure of workers and or the public to radiation.

The WILW processing system is considered to meet ALARP requirements at a concept design level and is appropriate to be taken forward for the site specific stage. Further information is provided in the LWMS ALARP Topic Report [Ref-2]. The principles of ALARP will need to be applied during detailed design, to ensure the final design is fully compliant with UK regulatory expectations on ALARP.

### 18.6.5.2 Wet-solid LLW ALARP Summary

The design of the WLLW processing system for the UK ABWR is based on UK and international best practice. The bead resin undergoes a period of decay storage prior to processing, the decay period ensures compliance with activity and dose rate limits specified in the WAC of the national LLWR. The requirement in the LLWR WAC to fix free liquid in the resin is met by grout encapsulation of the bead resin waste.

A batch process has been used for WLLW processing system and is based on processing sufficient waste to create a single waste package at a time. This minimises the radiological inventory associated with the WLLW processing system and therefore minimises hazards to the workforce from direct exposure from storage and processing tanks, as well as internal exposure through ingestion or inhalation from loss of containment. The batch process also ensures that the WLLW processing system produces a consistent product for export to the LLWR

In addition to UK and international good practice; a number of options were considered to refine the process and reduce the hazards to workers from operation of this system and to reduce worker/public dose uptake during normal operations.

In GDA Step 2 for the wet-solid waste processing facilities were in separate buildings.. An optioneering study was carried out in 2015 that recommended that the WLLW / WILW processing systems should be located in the Rw/B and this has been implemented. The major reason for this change was to minimise the transfer distance of wet-solid ILW and wet-solid LLW waste streams.

A further optioneering study considered refinements to the WLLW processing system, specifically the optimisation of the THISO filling operation, the options considered were:

Option 1 Temporary shielded lid with fully manual operations (Baseline option).

Option 2 Pre-engineered lid (ordinary lid) with fully manual operations including manual connection on lifting gear with rigging left in place.

Option 3 Pre-engineered lid (ordinary lid) with semi-remote operations.

Option 4 Pre-engineered lid (ordinary lid) with fully remote operations.

The preferred option was Option 3, this option ensured that direct exposure to workers was reduced by minimising the time workers spent close to the filled THISO as the lid does not require bolting after filling. This was confirmed to reduce the exposure without over complicating the engineering design or introducing more potential hazards. The option chosen reduced the normal operations dose to workers.

There are three main hazards associated with the Wet-solid LLW processing system for the UK ABWR:

- Direct exposure of workers to radiation because of reduced or loss of shielding or transfer of excessive activity,
- Drop of a filled THISO container of WLLW, and

- Loss of containment of WLLW (from transfer lines, tanks or THISO) leading to exposure of workers and or the public to radiation.

The WLLW processing system is considered to meet ALARP requirements at a concept design level and is appropriate to be taken forward for the site specific stage. Further information is provided in the LWMS ALARP Topic Report [Ref-2]. The principles of ALARP will need to be applied during detailed design, to ensure the final design is fully compliant with UK regulatory expectations on ALARP.

# 18.7 Off-Gas System

## 18.7.1 Brief Waste & System Descriptions

The OG is a key component of the ABWR design, which has the primary functions of maintaining the main Condenser vacuum by extracting non-condensable gas, providing abatement of radioactive species prior to atmospheric discharge, and recombining radiolytic hydrogen and oxygen generated in the reactor. Through performing these functions, the system reduces the radiological release from the UK ABWR during normal operations.

Below is a list of the equipment which forms the OG, along with a description of their main role:

- **1st stage Steam Jet Air Ejector (SJAE):** Extracts the off-gas from the main Condenser,
- **2nd stage SJAE**: Extracts the off-gas from the main Condenser and provides dilution to prevent build-up of hydrogen,
- **SJAE Condenser**: Removes steam between the 1st stage and 2nd stage SJAE,
- **OG Preheater**: Heats up the off-gas to prevent formation of water in the OG Recombiner,
- **OG Recombiner**: Combines hydrogen and oxygen to remove the potential to generate an explosive atmosphere,
- **OG Condenser**: Condenses steam to reduce its volume and cool the off-gas,
- **OG Cooler Condenser**: Cools the off-gas to reduce the moisture content prior to treatment within the OG Charcoal Adsorbers,
- **OG Refrigeration Facility**: Supplies a cooling source for the OG Cooler Condenser,
- **OG Charcoal Adsorber**: Holds up short lived radionuclides,
- **OG Filter**: Removes particulate matter from the off-gas including any particulate from the OG Charcoal Adsorber,
- **OG Ejector**: Maintains negative pressure within the OG Charcoal Adsorbers,
- **OG Blower**: Maintains negative pressure within the OG Charcoal Adsorbers during reactor start-up,
- **OG Blower After Cooler**: Cools the off-gas that has been heated by the OG Blower during plant start-up,
- **OG Charcoal Adsorber Heating Ventilation Handling (HVH) unit**: Controls the temperature of the OG Charcoal Adsorber room, and
- **Turbine Gland Steam (TGS) Filter**: Removes particulate matter from the TGS and Mechanical Vacuum Pump (MVP) discharge.

A summary of the major operational modes for the OG are provided below:

Start-up Operation (Mode I, II and III)

Mode I: The MVP is initiated to provide a vacuum in the main Condenser. The gases in the main Condenser bypass the OG Charcoal Adsorbers and are discharged through the main stack. The reactor is isolated by the Main Steam Isolation Valves (MSIVs) during Mode I.

Mode II: After reaching a set level of vacuum in the main Condenser, the MVP operation is transferred over to the Start-up SJAE (ST-SJAE) driven by Heating Steam System (HS). If the air in the main Condenser is clean, the MVP and Start-up SJAE could be operated in series to reduce the time to increase vacuum in the main Condenser. The reactor is isolated by the MSIVs during Mode II.

Mode III: After reaching a set level of vacuum in the main Condenser, the MVP is shutdown. After that, the reactor is connected to the main Condenser by opening the MSIVs to perform the deaeration of the reactor, and then the reactor is started up by withdrawing the Control Rods. The Start-up SJAE continues operation to increase the vacuum in the main Condenser until the SJAE is operable (main steam pressure approximately 2.0MPa [gauge] or more). To limit the off-gas inflow under the allowable rate (80Nm$^3$/h) in the OG Charcoal Adsorbers, the excessive off-gas is returned to the SJAE inlet via the off-gas recycle line, which connects the OG Condenser outlet and SJAE inlet. During mode III, radioactive discharges from the OG via the main stack occurs.

Power Operation (Mode IV)

Mode IV: After the main steam line pressure achieves to the required pressure (i.e. approximately 2MPa [gauge] or more), the Start-up SJAE is switched to the SJAE driven by main steam. Moreover, after the flow rate of the off-gas is below 40Nm$^3$/h, OG Blower is switched to OG Ejector.

Normal Shutdown Operation (Mode V)

Mode V: The reactor power is decreased and the reactor is shut down by inserting the Control Rods. The function of the SJAE is taken over to Start-up SJAE after the main steam pressure is decreased to the specified value.

Figure 18.6-1 provides the Process Flow Diagram of the OG system for power operation (Mode IV). The off-gas flow during power operation mode is highlighted in red as an example, noting that the PCSR applies to all operational modes.

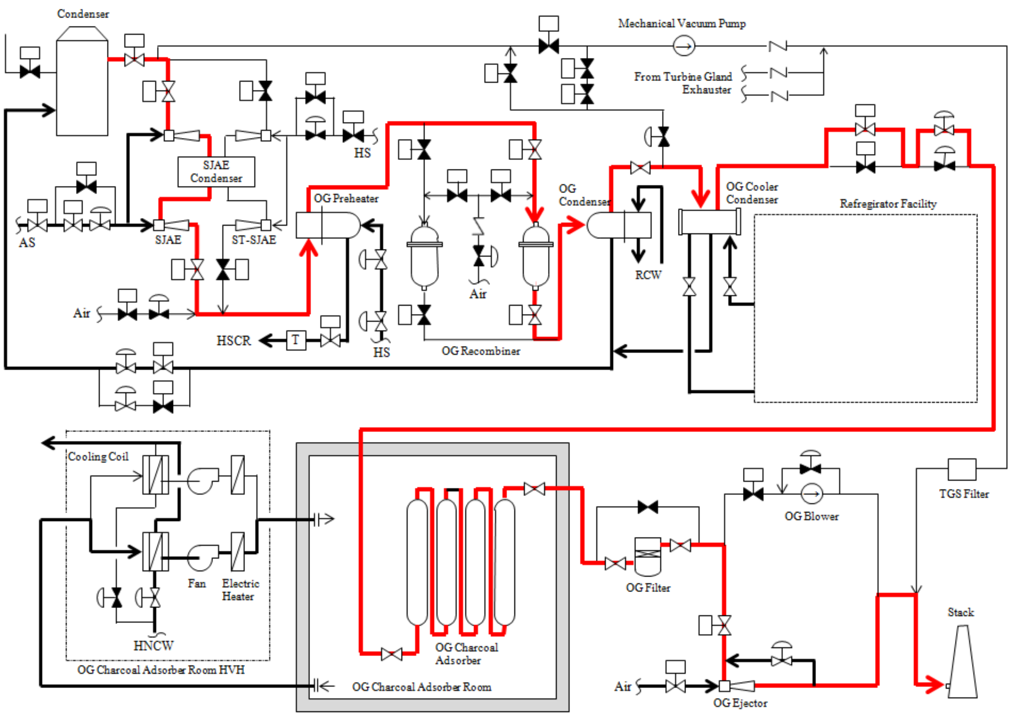



**Figure 18.6-1: Outline of the OG system at Power Operation (Mode IV)**

To support decommissioning operation the OG will be utilised to manage gaseous waste generated during this phase. The system will have the ability to handle the change in demands accompanying this phase. Details can be found in Chapter 31 Decommissioning.

### 18.7.2 Safety Assessment

This section is a summary of the safety assessment undertaken for the OG. A more detailed description is provided in the OG BSC [Ref-7].

**(1) Hazard Identification Process**

Initial identification of hazards associated with the OG has been achieved through a combination of logic tree analysis and Failure Modes and Effects Analysis (FMEA) [Ref-22]. The OG design was then subject to a formal HAZOP process to provide a more in-depth hazard identification. These studies aim to identify all credible failure modes / fault conditions associated with the OG with the potential to lead to an on-site or off-site radiological release. Conventional Safety including maintainability were fully considered in the hazard identification studies. A summary of these issues is provided in the OG ALARP Topic Report [Ref-23], but are not included in this PCSR as they are largely site-specific issues.

The hazards identified have been collated into a Preliminary Fault Schedule [Ref-22]. Where appropriate, the design of the OG includes automatic or engineered fault prevention, protection and mitigation features to ensure that the assessed fault consequences are both within the limits specified in PCSR Chapter 5 General Design Aspects, section 5.5 (Definition of Design Basis Faults and Beyond Design Basis Faults), and any residual risk is ALARP. Where engineered or administrative safeguards against fault conditions were identified during the HAZOP process these are listed in the Preliminary Fault Schedule against the relevant hazards.

A brief summary of the safety assessment undertaken is presented in the sections below.

**(2) Dose to Public During Normal Operation [OG SFC 4-11.1]**

During normal operations, the OG ensures that the release of radioactive gases and particulates into the atmosphere are minimised and controlled by delaying and filtering the off-gas waste process stream to adequately decay short lived radioactive isotopes and filter out particulate matter.

A significant contribution to the radioactivity that is entrained within the off-gas is from short lived radionuclides such as xenon and krypton. Based on the discharge assessment [Ref-19], the OG Charcoal Adsorber is required to retain xenon and krypton isotopes for minimum periods of 30 days and 40 hours, respectively, to reduce radioactivity release to acceptable levels. The UK ABWR OG Charcoal Adsorber design provides a conservative margin to accommodate deviations in off-gas conditions (e.g. temperature, pressure, humidity).

Discharges of noble gas from the UK ABWR are expected to be lower than the majority of comparison plants. Modern fuel is designed to be more robust and less prone to minor cladding defects that may lead to the release of fission products into the coolant. In addition, the configuration of the OG (four, welded, activated charcoal beds in series) reflects GP and OPEX from across the nuclear industry, ensuring that doses to the public during normal operations are minimised by reducing the potential for leakage of gases, thereby ensuring the gaseous discharges pass though the OG and providing an effective delay time for radionuclides and particulate removal. Implicitly, the OG also reduces emissions from tritium and radioisotopes of oxygen, through recycling coolant water and recombining hydrogen and oxygen into water, which is then returned to the reactor coolant circuit.

The overall indicative annual exposures to a member of the public due to gaseous discharges during normal operation of a single UK ABWR unit are below the risk targets for normal operation outlined in the

NSEDPs [Ref-5]. This exposure is dominated by C-14. The noble gases that are abated by the Charcoal Adsorbers make only a small contribution to the overall radioactive release.

**(3) Dose to Workers During Normal Conditions [OG SFC 4-7.1]**

During normal power operation, it is not necessary for workers to enter the rooms containing the OG equipment. These rooms are mainly categorised as R4 areas and entry is therefore not permitted during power operation. For rooms surrounding the OG equipment, appropriate shielding will ensure that dose rates are within the range for R2 areas [Ref-7]. General approaches/ principles for minimising radiation doses from external radiation via the provision of appropriate shielding are described in the PCSR Chapter 20 : Radiation Protection, section 20.5 Protection and Provisions against Direct Radiation and Contamination.

During outages, operator access to the rooms is necessary, to carry out planned maintenance activities. Since the reactor is not at power, the direct source term is significantly reduced (as the radiological impact of nuclides with short half-lives such as N-16 become negligible once the reactor is not operational) and worker access is permitted. The potential worker dose during maintenance activities has been assessed and is demonstrated to meet the risk targets outlined in the NSEDPs [Ref-5].

**(4) Hydrogen Management During Normal Conditions [OG SFC 4-11.2]**

The hydrogen is present in the OG up to the OG Recombiner (there is negligible hydrogen after the OG Recombiner) during normal operation presents a deflagration / detonation event hazard, and as such suitable hydrogen management techniques are included in the OG design.

Dilution by steam using the SJAE reduces the risk of hydrogen explosion by increasing the lower flammability limit (LFL) of hydrogen up to the OG Recombiners. The parallel, redundant OG Recombiners convert hydrogen and oxygen into water vapour within the OG process stream during normal operation. Degraded performance or failure of OG Recombiner is mitigated directly by having redundant OG Recombiners in parallel. Additionally, the design reduces the sources of ignition that could be strong enough to cause hydrogen combustion within the OG process stream.

Hydrogen detection is installed in the OG after the 2$^{nd}$ stage SJAE, and after the OG Cooler Condenser in order to detect abnormal hydrogen concentrations that could result from degraded performance in the SJAE dilution and OG Recombiners.

**(5) Dose to Public from an OG System Fault [OG SFC 4-8.1]**

In addition to the DBAA performed for the OG in PCSR Chapter 24, sub-section 24.11.2, which only assesses a single bounding fault for the OG (Fault Schedule Ref: 15.1 – Off-gas treatment system failure), the Design Basis Analysis described in [Ref-27] identified that the majority of faults result in an unmitigated public dose which is above the BSO but below the BSL. Representative faults are as follows:

- OG containment failure at the OG Charcoal Adsorbers,
- OG containment failure at other OG components / pipework, and
- Fire in the OG Charcoal Adsorbers as a result of OG Recombiner failure.

The OG design incorporates a number of features to prevent OG against loss of containment faults:

- Welded design (minimise the flanged parts),
- Double isolation valves for branch pipe (e.g. drain line),
- Low pressure / negative pressure operation,

- Stringent leak rate requirements will be specified for all equipment and piping, and will be confirmed using leak tests of the entire OG System,
- Valve type specifications have low leak rate characteristics (i.e. bellow seal, double steam seal or equivalent),
- Application of appropriate design code, (increases the reliability of the components, and thus reduces frequency of pressure boundary failure due to random failure), and
- Combustion proof design.

In the event of a loss of containment, the UK ABWR OG design provides an isolation system classified as Safety Class 2 that closes the Condenser Air Extraction Valve mounted on the outlet of main Condenser and the SJAE Driving Steam Isolation Valve mounted on the inlet of SJAE driving steam line in response to the range of inputs that would indicate a loss of containment. The OG would be isolated, terminating the release and maintaining containment in response to:

- High radiation detection in the OG component area, and
- High temperature detection in the OG component area upstream of OG Condenser.

This system will operate on a 2 out of 3 logic (2oo3) to prevent spurious initiation.

In the case of a fire in the charcoal bed, the primary means of fault prevention is the OG design to prevent excess hydrogen build-up at any point in the system. Design for hydrogen management is discussed in the section below, but is primarily mitigated against by provision of automatic isolation upon detecting high hydrogen concentration at outlet of the OG Cooler Condenser (i.e. downstream of the OG Recombiner).

According to above mitigation measures, the OG reduces the public dose from OG system faults ALARP.

**(6) Dose to Workers from an OG System Fault [OG SFC 4-7.2]**

The following faults are identified as having the potential to result in a dose to the worker that is below the BSO:

- OG containment failure at the Charcoal Adsorbers, and
- OG containment failure at other OG components / pipework.

The prevention measures against loss of containment faults discussed above are all applicable to doses to the worker (e.g. welded design, double isolation valves for the branch pipe, low pressure / negative pressure operation, application of appropriate design code, combustion proof design, etc.).

The provision of the OG isolation system classified as Safety Class 2 provides the primary means of protection to workers in the event of a loss of containment event. This system closes the Condenser Air Extraction Valve and the SJAE Driving Steam Isolation Valve in response to:

- High radiation detection in the OG component area, and
- High temperature detection in the OG component area upstream of OG Condenser.

As such, even in the event of OG containment failure the worker dose will be minimised.

In the event of an OG process failure (e.g. charcoal fire), the OG containment confines radioactive substances within the system. The OG components rooms are provided with appropriate shielding and access is restricted during start up, power and shutdown operations. As such, in the event of an OG process failure event, the worker would not experience much increase in dose compared to normal operations.

**(7) Hydrogen Management During OG System Faults [OG SFC 4-11.3]**

The primary means of preventing a pipework failure as a result of hydrogen combustion is to prevent excess hydrogen build-up at any point in the system. The system design is such that there will always be steam present in those sections where there is significant hydrogen, acting as a diluent during normal operations. In addition to the dilution due to steam, the hydrogen recombiner is designed to remove the hydrogen from the process flow. Overall hydrogen and its potential effects are managed in the OG by a combination of:

- Recombination function,
- Dilution function,
- Detection and isolation, and
- Combustion proof design.

In the unlikely scenario that could lead to high hydrogen concentrations in the OG, the UK ABWR is provided with an automatic isolation system. This system provides isolation upon detecting high hydrogen concentration at outlet of the OG Cooler Condenser (i.e. downstream of the OG Recombiner). This would cause isolation of the OG prior to the LFL of hydrogen being reached.

## 18.7.3 Claims and Arguments

### 18.7.3.1 OG Claims and Arguments

This section provides the arguments that underpin each of the SFCs for the OG. The detailed evidence to support these arguments is provided in the OG BSC [Ref-7].

**(1) Doses to Public during Normal Operations**

Demonstration that doses to the public during normal operations are reduced to ALARP is provided by satisfying:

OG SFC 4-11.1: The OG minimises the release of radioactivity to the environment during the start-up, power and shutdown operations.

From the prospective of reducing radioactive substances in plant normal conditions, this SFC is categorised as Safety Category C and the components necessary to deliver this function are designed to meet Safety Class 3 requirements.

The arguments underpinning this SFC are as follows:

A1. The radioactive noble gases and iodine in the off-gas is sufficiently decayed prior to release to the environment by holding-up in the OG Charcoal Adsorber;

A2. Provision of OG Charcoal Adsorber is the BAT technology to abate short lived FPs;

A3. The OG Charcoal Adsorbers are designed to hold-up Xenon and Krypton for more than 30 days and 40 hours respectively;

A4. Additional amount of activated charcoal is filled into the OG Charcoal Adsorber to accommodate deviations of off-gas conditions (e.g. temperature, pressure, humidity);

A5. The off-gas temperature at the OG Charcoal Adsorber is controlled 25±5 °C by the OG Charcoal Adsorber Room Heating Ventilating Handling Unit (HVH) to ensure OG Charcoal Adsorber hold-up function;

A6. The OG Condenser cools off-gas temperature down to 50℃ and reduces its volume by condensing the steam in the off-gas to ensure OG Charcoal Adsorber hold-up function;

A7. The off-gas relative humidity at the OG Charcoal Adsorber is controlled less than 10 °C of dew point temperature to ensure OG Charcoal Adsorber hold-up function;

A8. Operating pressure at the OG Charcoal Adsorber is controlled specific at a negative pressure by the OG Ejector or the OG Blower to prevent radioactive leakage;

A9. The gaseous tritium in the off-gas is removed prior to discharge by condensing into liquid form by the OG Condenser and returned back into the main Condenser;

A10. The radioactive particles in the off-gas are removed by the OG Filter prior to discharge;

A11. Radiation level of off-gas is measured to detect any deviations of discharge dose from the predicted range;

A12. Radiation detectors are provided on both OG Charcoal Adsorber discharge line and Turbine Gland Steam System (TGS) discharge line, and measured radiation level is displayed and recorded in the Main Control Room (MCR).

A13. OG Charcoal Adsorber discharge line and TGS discharge line connect to the main stack to reduce public dose by adequate dispersion;

A14. Instrumentation and control are provided by the Reactor/Turbine Auxiliary Control System (ACS) to monitor and control the OG system operation. This is captured by C&I claim [ACS SFC 4-11.1];

A15. Instrumentation for radiation monitoring is provided by other C&I system to monitor and control the OG system operation;

A16. Electrical power is provided by the EPS to monitor and control the OG system operation. This is captured by electrical system claim [EPS SFC 4-11.1].

A17. The RCW provides cooling water to the OG components for the delivery of cooling. This is captured by RCW claim [RCW SFC 5-11.1];

A18. The environment conditions in the OG components room are regulated by the HVAC to maintain them at an appropriate range for operation. This is captured by HVAC claim [HVAC SFC 5-18.1];

A19. The operation and monitoring of the OG for this function is done from the control panel of the MCR. This is captured by MCR HMI claim [MCR HMI SFC 4-11.1].

(This aligns with reactor chemistry safety claim: RC SC6).

**(2) Doses to Worker during Normal Operations**

Demonstration that doses to workers during normal operations are reduced to ALARP is provided by satisfying

OG SFC 4-7.1: The OG minimises the dose to worker during normal conditions.

From the perspective of maintaining the plant normal conditions, this SFC is categorised as Safety Category C and the components necessary to deliver this function are designed to meet Safety Class 3 requirements.
Since the OG Charcoal Adsorber holds up the radioactive substances in the activated charcoal bed and it contains relatively higher radioactive inventory, pressure boundary function for the containment of OG Charcoal Adsorber is categorised as Safety Category B and the component necessary to deliver this function are designed to meet Safety Class 2 requirements.

The arguments underpinning this SFC are as follows:

A1. OG system forms the pressure boundary which confines the radioactive substances to prevent leakage from the system components;

A2. The OG system provides welded design where applicable (i.e. minimise the flanged parts);

A3. Double isolation valves are provided for branch pipe (e.g. drain line);

A4. Appropriate material is provided to ensure structural integrity of the OG components;

A5. The OG process line between 2nd SJAE outlet and Charcoal Adsorber outlet valve where containment failure would result in significant dose impact applies ASME Section III to improve quality assurance level;

A6. Operating pressure at the OG Charcoal Adsorber is maintained negative by OG Ejector or OG Blower.

A7. The OG component room provides shielding by concrete walls and slabs to shield radiation to lower the level. This derives into T/B civil design claim [T/B SFC 4-7.01];

A8. Operators' access into the OG component room is restricted during start-up, power and shutdown operation.

A9. The environment conditions in the OG components room are regulated by the HVAC to maintain them at an appropriate range for operation. This is captured by HVAC claim [T/B HVAC SFC 5-18.1];

A10. The operation and monitoring of the OG for this function is done from the control panel of the MCR. This is captured by MCR HMI claim [MCR HMI SFC 4-11.1].

(This aligns with reactor chemistry safety claims: RC SC5 and RC SC7).

**(3) Hydrogen Management During Normal Operations**

Demonstration that the risk from hydrogen is appropriately managed during normal operations is provided by satisfying

OG SFC 4-11.2: The OG reduces the risk of hydrogen combustion arising from the reaction of radiolytic hydrogen produced in the reactor.

From the perspective of maintaining the normal conditions, this SFC is categorised as Safety Category C and the components necessary to deliver this function are designed to meet Safety Class 3 requirements.

The arguments underpinning this SFC are as follows:

A1. Hydrogen in the off-gas is diluted by SJAE driving steam;

A2. The Start-up SJAEs (ST-SJAEs)/ SJAE driving steam flow rate is designed so that hydrogen concentration at the SJAE outlet is below the LFL;

A3. During power operation, SJAEs operate with main steam driven controlled by the Turbine Auxiliary Steam System (AS);

A4. During start-up and shutdown operation, ST-SJAEs operate with house steam driven controlled by the Heating Steam System (HS);

A5. Hydrogen in the off-gas is removed by the OG Recombiner which is designed to reduce hydrogen concentration to less than lower flammable limit by recombination;

A6. The OG Preheater heats the off-gas above the saturated temperature to improve efficiency and to prevent formation of water drops that might adversely affect catalytic performance in the OG Recombiner;

A7. Instrumentation and control for OG process system are provided by the Reactor/Turbine ACS to monitor and control the OG system operation. This derives into C&I claim [ACS SFC 4-11.1];

A8. Instrumentation for hydrogen monitoring downstream of OG Recombiner is provided by the Safety Auxiliary Control System (SACS) to monitor and control the OG system operation. This derives into C&I claim [SACS SFC 4-8.1.1];

A9. Electrical power is provided by the EPS to monitor and control the OG system operation. This is captured by electrical system claim [EPS SFC 4-11.1].

A10. The environment conditions in the OG components room are regulated by the HVAC to maintain them at an appropriate range for operation. This is captured by HVAC claim [T/B HVAC SFC 5-18.1];

A11. The operation and monitoring of the OG for this function is done from the control panel of the MCR. This is captured by MCR HMI claim [MCR HMI SFC 4-11.1].

(This aligns with reactor chemistry safety claim: RC SC4).

**(4) Off-Gas Extraction during Normal Operations**

Demonstration that the off-gas extraction is appropriately managed during normal operations is provided by satisfying:

OG SFC 5-10.1: The OG extracts air and non-condensable gas ($H_2$ and $O_2$) from the main Condenser to achieve and maintain main Condenser vacuum.

Since these components failure could lead to a demand on a Safety Category A function (i.e. MSIV close), this SFC is categorised as Safety Category B. Since the demanded Safety Category A function has diverse means of protection against the OG failure or mal-operation, the components necessary to deliver this OG function are designed to meet Safety Class 3 requirements.

The arguments underpinning this SFC are as follows:

A1. During start-up operation, the Mechanical Vacuum Pump reduces main Condenser pressure;

A2. During start-up and shutdown operation, Start-up SJAEs (ST-SJAEs) operate with house steam driven controlled by the Heating Steam System (HS);

A3. During power operation, SJAEs operate with main steam driven controlled by the Turbine Auxiliary Steam System (AS).

A4. Instrumentation and control are provided by the ACS to monitor and control the OG system operation. This derives into C&I claim [ACS SFC 4-11.1];

A5. Electrical power is provided by the EPS to monitor and control the OG system operation. This derives into electrical system claim [EPS SFC 4-11.1].

A6. The environment conditions in the OG components room are regulated by the HVAC to maintain them at an appropriate range for operation. This is captured by HVAC claim [T/B HVAC SFC 5-18.1];

A7. The operation and monitoring of the OG for this function is done from the control panel of the MCR. This is captured by MCR HMI claim [MCR HMI SFC 5-10.1].

**(5) Doses to Public from OG Faults**

Demonstration that the doses to the public from OG faults are reduced to ALARP is provided by satisfying:

OG SFC 4-8.1: The OG mitigates the release of gaseous radioactive substances to the environment in the event of OG system failure.

Based on the dose assessment, this SFC is categorised as Safety Category B and the components necessary to deliver this function are designed to meet Safety Class 2 requirements.

The arguments underpinning this SFC are as follows:

A1. Redundant OG isolation valves (Condenser Air Extraction Valves and the SJAE Driving Steam Isolation Valve) are provided for automatic and/or manual isolation;

A2. Public dose is minimised by the automatic isolation of the OG isolation valves in the OG containment failure event;

A3. Automatic isolation is initiated upon detecting high airborne radiation level in the OG component room for mitigation of OG containment failure event;

A4. Automatic isolation is initiated upon detecting high temperature in the OG component room upstream of OG Condenser for mitigation of OG containment failure event;

A5. The OG system is designed to isolate manually upon detecting any OG process abnormal conditions;

A6. The Condenser Air Extraction Valves and the SJAE Driving Steam Isolation valve close within 5 minutes upon detection of high radiation level and/or high temperature at OG component area;

A7. Instrumentation and control are provided by the SACS to monitor and control the OG system operation. This derives into C&I claim [SACS SFC 4-8.1];

A8. Electrical power is provided by the EPS to monitor and control the OG system operation. This derives into electrical system claim [EPS SFC 4-8.1];

A9. The operation and monitoring of the OG for this function is done from the control panel of the MCR. This is captured by MCR HMI claim [MCR HMI SFC 4-8.1].

**(6) Doses to Worker from OG Faults**

Demonstration that the doses to workers from OG faults are reduced to ALARP is provided by satisfying:

OG SFC 4-7.2: The OG mitigates the dose to worker in the event of OG system failure.

Based on the dose assessment, this function is categorised as Safety Category C and the components to deliver it are designed to meet Safety Class 3 requirements.

The arguments underpinning this SFC are as follows:

A1. The OG provides system component boundary which withstands hydrogen hazard condition arising from the OG Recombiner failure;

A2. The OG component room provides shielding by concrete walls and slabs to shield radiation to lower the level. This derives into T/B civil design claim [T/B SFC 4-7.01];

A3. Operators’ access into the OG component room is restricted during fault conditions;

A4. Worker dose is minimised by appropriate shielding and access control in the OG containment failure event.

**(7) Hydrogen Management in the event of OG Faults**

Demonstration that the risk from hydrogen is appropriately managed during fault conditions is provided by satisfying:

OG SFC 4-11.3: The OG prevents hydrogen combustion in the event of OG Recombiner failure.

Unmitigated consequence of this fault is bounded in the OG containment failure event. Based on the dose assessment, this SFC is categorised as Safety Category B and the components necessary to deliver this function are designed to meet Safety Class 2 requirements

The arguments underpinning this SFC are as follows:

A1. Redundant OG isolation valve (Condenser Air Extraction Valves and the SJAE Driving Steam Isolation Valve) are provided for automatic and/or manual isolation;

A2. Automatic isolation upon detecting high hydrogen concentration in the OG process line downstream of the OG Recombiner is provided for prevention of hydrogen hazard.

A3. The Condenser Air Extraction Valves and the SJAE Driving Steam Isolation valve close within 5 minutes upon high hydrogen concentration in the OG process line downstream of the OG Recombiner;

A4. Instrumentation and control are provided by the SACS to monitor and control the OG system operation. This derives into C&I claim [SACS SFC 4-8.1];

A5. Electrical power is provided by the EPS to monitor and control the OG system operation. This derives into electrical system claim [EPS SFC 4-8.1];

A6. The operation and monitoring of the OG for this function is done from the control panel of the MCR. This is captured by MCR HMI claim [MCR HMI SFC 4-8.1].

### 18.7.3.2 Other PCSR Chapter Claims and Arguments

This section identifies the SFCs made in other chapters of the PCSR that are relevant to this PCSR Chapter and how they have been met. More detail on the evidence for these claims is provided in the relevant PCSR Chapters identified below:

**(1) PCSR Chapter 10 – Civil Works and Structures**
T/B SFC 4-7.01: The T/B provides shielding by concrete walls and slabs to shield radiation to lower the level. The shielding walls and slabs are arranged around higher radiation areas to reduce worker's exposure. The external walls and slabs provide shielding to reduce the dose rate at the site boundary.

A1 The OG component room provides shielding by concrete walls and slabs to shield radiation to lower the level, see OG SFC 4-7.1 and OG SFC 4-7.2 above.

STACK SFC 4-8.01: The stack provides the required height from the dispersion of exhaust gases from the ventilation of the radiation controlled area within the plant.

A2 The off-gas treated by the OG is discharged through the Stack to secure its dispersion effect and reduce public dose.

STACK SFC 5-17.01: The Stack is designed with the following loading conditions, to support SSCs for the normal conditions.

A3 The off-gas treated by the OG is discharged through the Stack during normal conditions.

STACK SFC 5-17.02: The Stack is designed to support SSCs which deliver safety functions for design base (DB) loads.

A4 DB source term is assumed for the off-gas discharged through the Stack in the dose assessment.

**(2) PCSR Chapter 14 – Control and Instrumentation**
SACS SFC 4-8.1: The SACS provides the functions to control the auxiliary system which implements the

Category B or C safety functions to minimise the release of radioactive gases.

A1 Instrumentation and control are provided by the SACS to monitor and control the OG system operation during OG system fault conditions, see OG SFC 4-8.1 and OG SFC 4-11.3 above.

ACS SFC 4-11.1: The ACS provides the functions to control the auxiliary system which implements control functions to sufficiently reduce the emission rate of radioactive particles before discharging them to atmosphere.

A2 Instrumentation and control are provided by the ACS to monitor and control the OG system operation during normal conditions, see OG SFC 4-11.1 above.

ACS SFC 5-10.1: The ACS provides the functions to control the auxiliary system which implements control functions to supply electric power (except for emergency supply).

A3 Instrumentation and control are provided by the ACS to monitor and control the OG system operation during normal conditions, see OG SFC 5-10.1 above.

**(3) PCSR Chapter 15 – Electrical Power Supplies**

EPS SFC 4: The EPS supports SSCs providing HLSF associated with FSF 4: Confinement and Containment of Radioactive Materials.

A1 Electrical power is provided by the EPS to monitor and control the OG system operation. In particular see OG SFC 4-8.1, OG SFC 4-11.1 and OG SFC 4-11.3 above.

**(4) PCSR Chapter 16 – Auxiliary Systems**

RCW SFC 5-11.1: The RCW supports the operations of Class 3 auxiliaries (RIP motors, RIP MG Sets, DWC cooling units, CUW Pumps and Heat Exchangers, CRD Pumps, IA and SA Compressors, normal operation HVAC, etc.) by removing heat from them and transfer it to RSW.

A1 The Reactor Building Cooling Water System (RCW) provides cooling water to the OG Condenser, see OG SFC 4-11.1 above. This supports the majority of the OG SFCs, see OG SFC 4-8.1, OG SFC 4-11.1 and OG SFC 4-11.3 above.

SFCs refer to normal operation of the HVAC system and therefore cover faults that occur within the associated buildings.

T/B HVAC SFC 4-7.1: The T/B HVAC system is designed to reduce the release and spread of airborne contamination during normal operation

A1 The T/B building HVAC system maintains a negative pressure within the controlled areas of the OG system process rooms.

A2 The T/B building HVAC system provides adequate dilution of contaminants within the areas of the OG system process rooms.

A3 The T/B building HVAC system directs air flow from areas with the lower potential for airborne activity to areas of higher potential with the OG system process rooms.

A4 The T/B building HVAC provides HEPA filtration of exhaust air from within the controlled areas of the OG system process rooms.

T/B HVAC SFC 5-18.1: The T/B HVAC ensures adequate environmental parameters are maintained so that the relevant SSCs can function appropriately and can deliver the fundamental safety functions in normal operation.

A1 The environment conditions in the OG components room are regulated by the HVAC to maintain them at an appropriate range for operation.

**(5) PCSR Chapter 21 – Human-Machine Interface**
MCR HMI SFC 4-11.1: The HMI for other C&I provides some selected information for the systems to store the radioactive materials as solid wastes.

A1 The operation and monitoring of the OG is done from the control panel of the MCR, see OG SFC 4-11.1 above.

MCR HMI SFC 5-10.1: The HMI for the ACS provides indictors and controls for equipment and systems to supply electric power.

A1 The operation and monitoring of the OG is done from the control panel of the MCR, see OG SFC 5-10.1 above.

**(6) PCSR Chapter 31 – Decommissioning – Decommissioning Design Features**
Decom-SC 1: The UK-ABWR design incorporates features that facilitate decommissioning:

Decom-SC 1.2: The UK ABWR pipework and drainage design reduces decommissioning risks ALARP:
A1 Equipment is designed so it can be flushed and drained.
A2 Rooms / cells are lined with impervious easily decontaminable surfaces.
A3 Complex machinery has been avoided where practicable, especially in higher activity waste streams.
A4 Sample Points and maintainable items are placed outside shielded cells/rooms whenever practicable to minimise dose-rates.
A5 The use of embedded pipework is minimised.

Decom-SC 1.3: The UK ABWR design minimises conventional safety risks during decommissioning:
A1 Conventional safety hazards are identified in the HAZOP Process.

Decom-SC 1.4: The design of the UK ABWR ensures sufficient access and space for decommissioning activities to be undertaken:
A1 Confined space hazards are identified at the HAZOP.
A2 Required space for decommissioning activities will be assessed during the detailed design / plant layout phase.

Decom-SC 1.5: The UK ABWR design has considered decommissioning logistics to ensure risks are reduced to ALARP:
A1 Break-through walls for use in decommissioning have been provided.
A2 Decommissioning logistics to support decommissioning will be assessed during the detailed design / plant layout phase.

Decom-SC 1.8: The design of the UK ABWR ensures long-term structural integrity and containment:
A1 The OG has been designed for at least 60 years operation plus decommissioning periods.

**(7) PCSR Chapter 31 – Decommissioning – Faults and Hazards Identified**
Decom-SC 3: Faults and Hazards during decommissioning are identified, assessed and all risks shown to be ALARP:

Decom-SC 3.2: Appropriate design features to facilitate decommissioning and provide hazard reduction have been identified:
A1 Hazards are being systematically identified through the HAZOP process and managed.

**(8) PCSR Chapter 31 – Decommissioning – Viable Disposal Routes**

Decom-SC 4: Viable disposal routes are available (or will be available) for all decommissioning wastes:

Decom-SC 4.3: Waste will be minimised during operations:
A1 The total radioactivity in gaseous discharges to the environment from the OG is minimised, see OG SFC 4-11.1, above.

Decom-SC 4.4: UK ABWR minimises waste by design:
A1 The OG has been designed to re-use the main steam for dilution water that has been treated by the OG Condenser.

## 18.7.4 Assumptions, Limits and Conditions for Operation

### 18.7.4.1 Assumptions

A number of working assumptions are made to demonstrate that the OG will achieve all functional and safety claims and that nuclear safety aspects have been adequately considered in the GDA process.

The key working assumptions for the OG include:

- Radiolytic gases ($H_2$ and $O_2$) production rate from the reactor will be 23.4kg/h and 187.2kg/h respectively – This defines the amount of hydrogen and oxygen entering the OG and conservatively assumes no credit for hydrogen water chemistry which will reduce the hydrogen concentration in the OG. Similarly, no credit is taken for online noble chemical addition, which will provide a benefit,
- The flow-rate from the main Condenser is assumed to be $40Nm^3/h$ during power operations (Mode IV) – This is bounding for normal power operations and is two to three times higher than typical operational flow-rates, based on OPEX, and
- Design life of the charcoal beds is assumed to be 60 years plus a commissioning period.

These are detailed in the OG BSC [Ref-7].

### 18.7.4.2 Limits and Conditions for Operation

The LCOs, along with corresponding surveillance requirements, define the corrective actions (measures) to follow when the LCOs are not met. These form the Generic Technical Specification (GTS) [Ref-29] and are specified in more detail within the Basis of Safety Case for OG system [Ref-7].

- The safety Auxiliary Control System (SACS) functions, which include OG area airborne radiation monitor, OG area temperature monitor and OG process hydrogen monitor, shall be operable.
  This LCO is provided to deliver OG SFC 4-8.1 and 4-11.3, and applied to MODE 1, 2 and 3.
- Off-Gas system Isolation valves shall be OPERABLE
  This LCO is provided to deliver OG SFC 4-8.1 and 4-11.3, and applied to MODE 1, 2 and 3.

## 18.7.5 Summary of ALARP Justification for the OG

This section presents a high level overview of how the ALARP principle has been applied to design of the OG, and how this contributes to the overall ALARP argument for the UK ABWR.

The OG is a key component of the ABWR design, which has the primary functions of maintaining the main Condenser vacuum, by extracting non-condensable gas, providing abatement of radioactive species prior to atmospheric discharge, and recombining radiolytic hydrogen and oxygen generated in the reactor. Through performing these functions, the system reduces the radiological release from the UK ABWR during normal conditions.

As part of the safety assessment of the OG, logic tree analysis, Failure Modes and Effects Analysis (FMEA) [Ref-22], and a formal HAZOP process were undertaken with the aim of identifying all credible failure modes / fault conditions associated with the OG. The fault conditions with the potential to lead to an on-site or off-site radiological release have subsequently been identified. The output from the hazard identification process was a Preliminary Fault Schedule [Ref-22]. The main hazards associated with the UK ABWR OG System are:

- Dose uptake to workers and members of the public during normal operations,
- Radioactivity of off-gas emissions,
- Hydrogen build-up resulting in combustion and subsequent OG pressure boundary failure, or fire in the OG Charcoal Adsorber,
- OG component structural integrity failure resulting in loss of containment, and
- Loss of performance as a result of moisture ingress to the OG Charcoal Adsorbers.

The initial reference design of the UK ABWR OG was based on the operation of previous generations of the BWR and J ABWR. Evolution of the OG design resulted in movement towards a simpler and more robust design, requiring less operator interaction with the system and increased reliability. Design improvements considered the hierarchy of control, demonstrating increased passivity and a corresponding increase in reliability, whilst reducing worker risk. Further international GP and OPEX have been reflected in the design to ensure risks are reduced to ALARP. The following optioneering activities have been undertaken in support of this:

- BAT assessment of different techniques used for treatment of off-gas from nuclear installations in order to reduce the radioactivity of discharges (i.e. compressed gas storage, cryogenic distillation, charcoal delay beds, cryogenic charcoal). Use of Charcoal Adsorbers was identified to represent BAT,
- Gap analysis of the reference design against international GP to identify additional risk reduction measures, and
- Further optioneering of the Charcoal Adsorber design, including the guard bed and parallel arrangement to ensure that all the hazards and potential improvements have been considered as part of the design process.

During normal operations, the OG ensures that the release of gaseous radioactivity from noble gases is minimised by ensuring that the gases are delayed within the system for a time sufficiently long for short-lived isotopes to decay to appropriate levels. The design provides a conservative hold-up time margin to accommodate deviations in off-gas conditions and reflects GP and OPEX from across the nuclear industry to reduce potential leakage of gases and therefore minimise dose to the public. During normal operations, access restrictions prevent workers from entering rooms containing OG equipment and shielding is provided surrounding these rooms such that worker dose is minimised. Worker dose during maintenance activities, (when access to the OG rooms is permitted) has been assessed and is demonstrated to meet the ALARP principle [Ref-7].

The hydrogen concentration in the OG is such that suitable and sufficient hydrogen management techniques must be demonstrated to ensure the risk of hydrogen combustion is minimised. The OG is demonstrated to withstand hydrogen combustion event pressures, however further safety measures for hydrogen management are also included: dilution by SJAE; removal by OG Recombiner, and; a manual isolation function. Degraded performance or failure of OG Recombiner is mitigated by having redundant OG Recombiners in parallel and the design of the plant will minimise the use of detrimental substances in order to reduce the potential for catalyst degradation. Additionally, the design reduces the sources of ignition that could be strong enough to cause hydrogen combustion within the OG process stream.

The design has also been challenged regarding prevention and mitigation measures against loss of containment faults, both as a result of hydrogen combustion and random structural failure of pipework and components. The reference J ABWR design provided a number of design features to prevent or mitigate against this fault, including welded design, double isolation valves for the branch pipe, low / negative pressure operation, high radiation level alarm at the HVAC discharge duct, manual isolation capability, and dilution / dispersion by the HVAC. These measures are carried forward to the UK ABWR design.

In addition, provision of automatic isolation systems to detect: high hydrogen concentration at the outlet of the OG Cooler Condenser; high airborne radiation in the OG component area, and; high temperature in the OG component area upstream of the OG Condenser were identified during gap analysis against GP and were incorporated into the UK ABWR OG reference design at GDA Step 3. A further optioneering process has been applied to ensure that the OG design reduces risks to ALARP. Based on this process, the risk reduction measure of improved quality assurance was determined to reduce risks ALARP and will be applied to the UK ABWR design.

The design of the UK ABWR OG has been shown to meet UK and international GP and, following systematic and comprehensive options studies, all reasonably practicable risk reduction measures have been adopted. Further information is provided in the OG ALARP Topic Report [Ref-23]. The work undertaken in support of this PCSR chapter demonstrates that the UK ABWR OG design has been robustly challenged against normal operations and fault condition requirements, and demonstrates that the design reduces risks ALARP.

# 18.8 Heating Ventilating and Air Conditioning System

## 18.8.1 Brief Waste & System Descriptions

This section is the summary of a general introduction to the Heating Ventilating and Air Conditioning System (HVAC) where the system roles, system functions, system configuration and modes of operation are briefly described. The HVAC safety case is justified in the HVAC Basis of Safety Cases (BSC) [Ref-8].

Under normal operating conditions, the HVAC is designed to achieve the following purposes:
(1) The HVAC maintains a negative pressure within the Reactor Building, the Turbine Building, the Radwaste Building, and the Service Building contamination controlled areas to ensure contaminants do not escape to the environment and provides dilution of the contaminants when they are generated by ensuring sufficient ventilation rate. In addition, exhaust air is treated with the filter before discharging from the area.
(2) The HVAC removes heat and humidity from the atmosphere within the buildings which may be generated by equipment such as electric panels, mechanical facilities and piping with high temperature.
(3) The HVAC has a role in demonstrating compliance with discharge limits under the Environmental Permitting Regulations 2016 (EPR16).
(4) The HVAC provides outside fresh air for operators and occupants.

During decommissioning the role of the HVAC system will largely remain the same however the requirements upon the system may change. It is expected that the HVAC system will be able to cope with these changing requirements and will have a design life suitable for decommissioning. More information regarding this can be found in Chapter 31 : Decommissioning.

The HVAC system generates LLW HEPA filters. The disposal route and expected volume are covered in GEP "Radioactive Waste Management Arrangement" [Ref-18] and "Integrated Waste Strategy" [Ref-20].

Further details on the HVAC system, including operation during fault conditions, are provided in sub-section 16.5 Heating Ventilating and Air Conditioning System, System Summary Description section in PCSR Ch.16 : Auxiliary Systems.

## 18.8.2 Safety Assessment

The safety assessment for the HVAC system is covered in BSC on HVAC system [Ref-8], section 6 Risk Assessment Table.

## 18.8.3 Claims and Arguments

**Safety Functions**

For airborne contamination management, the HVACs are designed to meet the following safety functional claims (SFCs).

(1) The R/A HVAC system is designed to reduce the release and spread of airborne contamination during normal operation [R/A HVAC SFC 4-7.1]
(2) The R/A HVAC system is designed to reduce the release and spread of airborne contamination from the

reactor building during design basis and beyond design basis fault conditions [R/A HVAC SFC 4-7.2]
(3) The T/B HVAC system is designed to reduce the release and spread of airborne contamination during normal operation [T/B HVAC SFC 4-7.1]
(4) The Rw/B HVAC system is designed to reduce the release and spread of airborne contamination during normal operation [Rw/B HVAC SFC 4-7.1]
(5) The S/B HVAC system is designed to reduce the release and spread of airborne contamination during normal operation [S/B HVAC SFC 4-7.1]
(6) The T/B HVAC ensures adequate environmental parameters are maintained so that the relevant SSCs can function appropriately and can deliver the FSFs in normal operation [T/B HVAC SFC 5-18.1]

SFCs for (1), (3), (4) and (5) above refer to normal operation of the HVAC system and therefore cover faults that occur within the associated buildings. SFC for (2) is associated with reactor faults only.
SFCs on the HVAC system and the relation between the SFCs put on this system and the high level claims is provided in sub-section 16.5 Heating Ventilating and Air Conditioning System, Appendix-A, in PCSR Ch.16 : Auxiliary Systems and related BSC on HVAC system [Ref-8], section 4 System Design Description.

### 18.8.4 Assumptions, Limits and Conditions for Operation

The assumptions, limits and condition for operation for the HVAC system are covered in sub-section 16.5 Heating Ventilating and Air Conditioning System in PCSR Ch.16 Auxiliary Systems and related BSC on HVAC system [Ref-8], section 4 System Design Description.

### 18.8.5 Summary of ALARP Justification for HVAC

The HVAC system design is based upon the assumption that the possibility of airborne contamination has been minimised at source by appropriate design, operating procedures, and maintenance procedures. In addition to multiple SFCs for the control of radioactive material and waste, the design ensures, so far as is reasonably practicable, that radioactive material and radioactive waste on the site is at all times adequately contained so that it cannot leak or otherwise escape. This is supported by design features to minimise the potential for leakage of containment are described in detail in relevant PCSR chapters against Fundamental Safety Function (FSF) 4: confinement / containment of radioactive materials. Specifically, a number of design features are claimed against High Level Safety Functions (HLSFs):
4-7: Functions to confine radioactive materials, shield radiation, and reduce radioactive release
4-8: Functions to minimise the release of radioactive gases
4-11: Functions to store the radioactive materials as gaseous waste
4-12: Functions to store the radioactive materials as liquid wastes
4-13: Functions to store the radioactive materials as solid wastes

Notwithstanding this, there remains a potential risk associated with radioactive material being present within the facilities and therefore airborne radioactive materials (e.g. gases or contamination) need to be appropriately managed.

The summary of ALARP justification for the HVAC system is covered in sub-section 16.9 Summary of ALARP Justification in PCSR Ch.16 Auxiliary Systems and related BSC on HVAC system [Ref-8], section 3.9 ALARP Justification.

# 18.9 Tank Vent Treatment System

## 18.9.1 Brief Waste & System Descriptions

The Rw/B Tank Vent Treatment System (TVTS) is connected to the ullage space of the most radioactive tanks within the Rw/B with the purpose of maintaining a depression, so that the air displaced due to effluent transfers is drawn into the Tank Vent Treatment System. The Rw/B TVTS also provides dilution of potentially hazardous gases which arise within certain areas of the process by providing a constant air flow through the tank ullage space. A description of the Rw/B TVTS is provided in the Topic Report on the Radioactive Waste Building Tank Vent Treatment System [Ref-28].

The higher activity tanks selected for connection to the TVTS are associated with following systems;

- Spent Resin & Sludge (SS) Storage,
  - Powder Resin Storage Tanks,
  - Bead Resin Storage Tanks,
  - Filter Crud Storage Tanks,
- Wet-solid ILW (WILW) Process Tank, and
- Wet-solid LLW (WLLW) Process Tank.

Other process tanks which do not present a potential contamination issue to the facility are vented into the building HVAC system.

The CUW Backwash Receiver Tank located in the Reactor Building (R/B) and the CF Backwash Receiver Tank located in the Turbine Building (T/B) also have tank ullage air ventilation arrangements i.e. these are connected to the respective HVAC systems in these buildings. However, these are still at an early concept design stage and are therefore not described here.

The Rw/B TVTS comprises the following main components:

- High Efficiency Particulate Air (HEPA) filter air purge glove boxes,
- Inlet HEPA filters (duty & standby),
- Extract ductwork,
- Hot air in-bleed system (duty & standby),
- Primary & Secondary HEPA Filters (duty & standby),
- Extract fans (duty & standby), and
- Controls & Instrumentation.

Under static conditions the process pipework and tanks are maintained at a depression by the extract system. Tanks which present a potential explosive hazard (powder resin storage tanks and filter crud storage tanks, see Figure 18.9-1) are continuously purged via air drawn from the facility. Tanks with continuous air purge are provided with inlet HEPA filters to protect the general areas from backflow from tanks when the TVTS is switched off. There will also be provision for Bead Resin Storage Tank 'D' to be connected to the TVTS, should higher activity (i.e. Design Basis) bead resins be generated.

Air is extracted from the tanks via a network of extract ductwork. The extract ductwork is a low velocity extract system, installed at a fall to promote drainage back into the process.

Exhaust air is provided with primary and secondary HEPA filtration to remove any airborne particulates. Each stage of filtration is also provided with duty and standby filters to enable filter change operations to be undertaken whilst the system remains operational. HEPA filters are safe change type units located within a separate plant room.

Air being drawn from the tank ullage space has the potential to contain moisture, consequently, prior to HEPA filtration a hot-air in-bleed arrangement is provided to reduce the humidity of the air, to protect the HEPA filters. The hot air in-bleed system also compensates for the flow fluctuation from the process tanks.

Air is extracted via duty and standby exhaust fans located within a separate fan room. The fans are controlled at a constant flow via variable speed drives. Air is discharged via a discharge duct, downstream of the building HVAC HEPA filters, into the base of the main exhaust stack.

The TVTS is provided with instrumentation for system control, performance monitoring and system failure purposes.

A schematic diagram of the TVTS is provided in Figure 18.9-1 below which shows the tanks to which the Tank Vent Treatment system is connected, hot air in-bleed and filter arrangements.

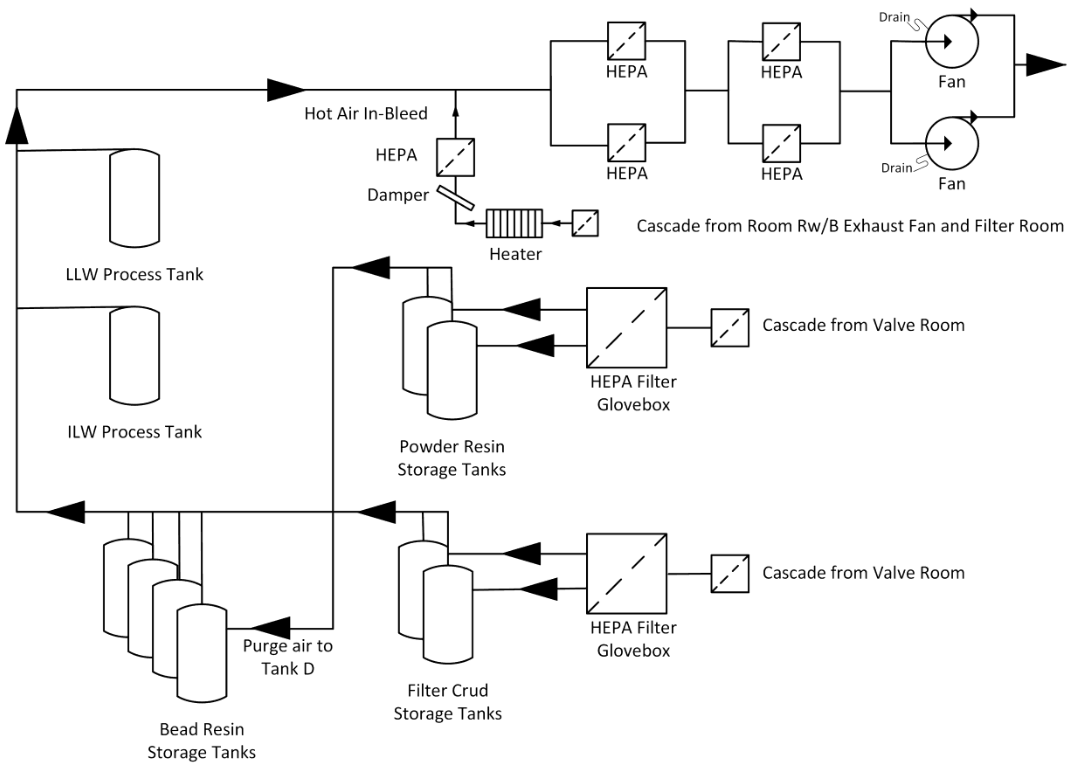



**Figure 18.9-1: Schematic of the Tank Vent Treatment System**

The TVTS will have a design life appropriate for decommissioning and will be able to meet the change in requirements during this phase. Details can be found in Chapter 31 Decommissioning.

### 18.9.2 Safety Assessment

The design of the UK ABWR has been developed in accordance with good practice as provided in International Standards and Approved Codes of Practice (ACOPs) as it evolved from previous generations of both BWRs and ABWRs. The process adopted for the safety assessment of the liquid waste processing systems in the Rw/B starts with a Hazard Identification step (FMEA and / or HAZOP) followed by a qualitative risk assessment (estimation of likelihood and severity), and identification and appraisal of risk reduction measures (in terms of trouble, time and/or cost to implement risk reduction measures).

This section is a summary of the safety assessment undertaken for the TVTS. A more detailed description is provided in the ALARP Topic Report [Ref-2] and the Topic Report on the Tank Vent Treatment System [Ref-28].

The management arrangements, regulatory constraints, safety principles, procedures and methodology to be used in respect of the LWMS are as described for the reactor in the PCSR Chapter 4: Safety Management throughout Plant Lifecycle.

The TVTS does not provide a reactor safety function and is not required for safe shutdown of the reactor. However, it does confine radioactive gases and minimises the release of radioactive gases to ensure that discharges to the environment and any radiation doses to the public and workers are ALARP.

#### 18.9.2.1 Hazard Identification Process

The external and internal faults are identified in PCSR Chapter 6 External Hazards and PCSR Chapter 7 Internal Hazards, and consideration against these faults for the Tank Vent Treatment system has been considered in two ways:

- The effect on the LWMS due to failure of the TVTS.
- Hazard identification on the TVTS.

Credible hazards associated with the LWMS due to loss of the TVTS have been identified through a HAZOP 1 study. The TVTS has also been subject to Structured What if Technique (SWIFT) and the hazards identified in both these studies have been included in the LWMS Fault Schedule. For further information, refer to the Topic Report on the Radioactive Waste Building Tank Vent Treatment system [Ref-28]. In addition to radiological and operational hazards, conventional safety and maintainability were fully considered in the hazard identification studies. A summary of conventional safety and maintainability issues is provided in the TVTS Topic Report [Ref-28], but they are not included in this GDA PCSR as they are largely site-specific issues.

The hazards identified to workers and public, from the above studies, have been collated into a preliminary fault schedule which has been consolidated with a list of potential faults and engineered / managerial safeguards that were identified in the HAZOP / SWIFT studies (see Section 18.5.2.3 and Section 18.9.2.3). These studies aim to identify all credible failure modes / fault conditions with the potential to lead to an on-site or off-site radiological release. Where appropriate, the design of the TVTS includes automatic / engineered fault prevention, protection and mitigation features to ensure that the assessed fault consequences are both within the limits / targets specified in PCSR Chapter 5 : General Design Aspects, section 5.5 Definition of Design Basis Faults and Beyond Design Basis Faults and any residual risk is ALARP.

In addition, bounding radiological faults have been assessed and are discussed in the ALARP Topic Report

[Ref-2] and dose uptake arising from normal operations is discussed in the Tank Vent Treatment Topic Report [Ref-28]. A brief summary of these is presented below.

### 18.9.2.2 Normal Operations

Normal operation of the Tank Vent Treatment system generates only very small radiation doses to workers and members of the public from both direct radiation from the plant and radioactivity associated with discharges to the environment. This section describes how these radiation sources have been minimised and the protective measures in place that ensure radiation dose uptake has been minimised and is ALARP.

**(1) Minimising Worker Dose during Operation**

The ventilation system operates automatically and there is no requirement for operators to be present when the system is operating (other than planned monitoring activities). Should any plant failure occur, alarms are remotely relayed to the main control room, from which any necessary action can be determined.

Due to the simplicity of the system the TVTS requires very little maintenance. Routine changing of HEPA filters is only expected to occur every 5 years or so. Discharge HEPA filters are located in safe change housings, which allow the ventilation to continue running and minimises the potential for airborne contamination being released from the ventilation system during a filter change. Inlet HEPA filters should be nominally clean and therefore very little dose should be associated with changing these.

The TVTS primarily operates automatically and is designed using relevant good practice such that:

- Ventilation ductwork is manufactured in high integrity stainless steel, which minimises potential corrosion and provides an easily decontaminable surface,
- Within the ducting a depression is maintained so that any air leakage goes into the ventilation,
- Discharge to the environment is provided through a two stage HEPA filtration process with Duty and Standby HEPA filters at each stage,
- Maintainable items have, in so far as is reasonably practicable, been placed outside the containment or down stream of discharge HEPA filters, in a nominally clean environment,
- All air inlets to the TVTS have HEPA filters fitted to protect clean areas in the event of reverse flow,
- Physical containment of the TVTS is provided during HEPA filter change activities by the installation of safe change type HEPA housings, and
- Rw/B HVAC system is also provided for designated areas where airborne activity is present or anticipated with HEPA filtration.

**(2) Minimising Public Dose During Operations**

Radiation doses arising from aerial discharges to the environment are minimised in two ways:

- The volume of discharges is kept to a minimum, and
- The activity associated with the discharge is also minimised.

The TVTS has been designed to operate with a relatively low flow rate compared to the building extract system. In addition, the exhaust air passes through two-stage HEPA filtration, to minimise any particulate content and hence any activity that may be present in the discharges.

Due to the potential humidity of the air being extracted from vessel ullage spaces, a hot air in-bleed is used to increase the air temperature as the flow approaches the HEPA discharge filters. This reduces the relative humidity, thereby protecting the HEPA filters from moisture.

The system performance is continuously and automatically monitored (e.g. humidity, filter performance) to detect any abnormal conditions.

**(3) Assessment of Radiation Dose from Normal Operations**

It is not expected that significant doses to workers will arise from the operation or maintenance of the TVTS. The ventilation system operates automatically and there is no requirement for operators to be present when the system is operating (other than planned monitoring activities). Should any plant failure occur, alarms are remotely relayed to the main control room, from which any necessary action can be determined.

Dose uptakes to the public and workers arising from the normal operations of the TVTS are included in the assessment for LWMS which is summarised in the BSC for the LWMS [Ref-1] but are dominated by those associated with the operation of the LWMS.

All reasonably practicable measures to minimise worker dose have been taken, such as:

- Plant and equipment has been placed in nominally clean areas (outside the containment boundary or downstream of the discharge HEPA filters),
- Operational life of the discharge HEPA filters has been maximised (hence the change frequency reduced) by HEPA filtration of inlet air and provision of a hot air in-bleed,
- Safe change housings have been provided on the discharge HEPA filters,
- The ventilation system is designed to operate automatically without the need for local operators to be present,
- The building HVAC system provides HEPA filtration of the air outside the Tank Vent Treatment containment,
- High integrity welded stainless steel is used for the ducting to minimise the potential for leakage and provide an easily decontaminable surface should invasive maintenance be necessary, and
- The ductwork is designed to promote natural draining of condensed gases back into the process effluent, this minimises contamination build-up (and consequently dose-rates) on the air ducting.

Given all of the above dose reduction measures and the minimal dose uptake expected, all reasonably practicable measures have been taken and the dose uptake to workers is judged to be ALARP, or is capable of being shown to be ALARP.

Doses to the public arise from aerial discharge to the environment but the volumetric flow rate is very small and filtered through two-stage HEPA filtration and so it is expected that any dose to the public will be very small. A demonstration that public dose resulting from discharges from the Rw/B (of which the TVTS forms part) is ALARP, is provided in the BSC for the LWMS [Ref-1] and summarised in Section 18.5.2.2 above.

### 18.9.2.3 Fault Conditions

The TVTS is not considered by Chapter 24 of the PCSR.

The TVTS is designed to minimise the risk to public and workers to ensure doses to public/workers in faults are ALARP and within limits/targets given in PCSR Chapter 5 General Design Aspects, section 5.5: Definition of Design; Faults and Beyond Design Basis Faults. This represents Safety Functional Claim TV SFC 4-7.4 for the TVTS.

The purpose of the TVTS is to provide containment and dilution ventilation to process tanks within the Radwaste Building and in particular to the SS system. Consequently, faults associated with the TVTS, can have a direct impact on the systems it supports and remediating actions may also be taken from within those systems (e.g. the LWMS).

There is the potential for unmitigated on-site doses from fault conditions relating to certain faults associated with TVTS to exceed the Basic Safety Level (BSL) and have therefore been subject to preliminary DBAA as stated in Hitachi-GE Nuclear Safety and Environmental Design Principle (NSEDP) SP14.2.1.

As discussed in Section 18.5.2.1, a number of hazard identification studies have been undertaken which have led to the development of a preliminary fault schedule for the LWMS and TVTS. Key bounding faults have been identified and for these faults preliminary DBAA has been undertaken. DBAA seeks to identify the worst case consequence of a potential unmitigated fault and if required, estimates the likelihood of the fault occurring. This information is then used to inform the design of the plant, to see whether the fault can be prevented by a design change and/or determine how many and which safety measures are required to protect against the fault should it occur. This process is iterative, since it may lead to design changes which in turn can change the faults that could occur.

The remainder of this section summarises the ALARP considerations during fault conditions specific to the TVTS, for more detailed information see the Topic Report on the ALARP Assessment for the LWMS [Ref-2]. These discussions also highlight some areas for further consideration during the ongoing design process to ensure that risks from such faults are ALARP.

**(1) Demonstration that Risks from Fault Conditions are ALARP**

The DBAA undertaken is described in the BSC for the LWMS [Ref-1]. The faults relating to the TVTS are summarised in the Topic Report on the Radioactive Waste Tank Vent Treatment System [Ref-28]. For the TVTS, the majority of faults result in unmitigated doses below the BSO and therefore under DBAA do not require the provision of safety measures, although the reasonable practicability of providing measures to reduce dose have been considered in compliance with the ALARP principle.

The following bounding fault conditions, associated with the failures in the TVTS, result in operator doses that exceed the BSL, and therefore are discussed below:

- Failure of the Tank Vent Treatment System to provide hydrogen purge (not assessed in PCSR Chapter 24).

**Failure of the Tank Vent Treatment System to provide Hydrogen Purge:**

The potential for hydrogen accumulation arises from radiolysis in SS tanks or from corrosion products in filter crud. In normal operation, those tanks that generate hydrogen are force ventilated (with incoming air purge) to remove any hydrogen that is generated in the system. Failure of the TVTS to purge those tanks could lead to an increase in hydrogen concentration within the tank ullage space. In this scenario the concentration could increase to such a level that an explosion occurs due to some unidentified ignition source.

The consequences of a hydrogen explosion are above the BSL for the workers, and are less than the BSL but greater than the BSO for public. The standby TVTS and Rw/B HVAC (and containment) provide adequate safety measures for loss of the duty Tank Vent Treatment system.

The TVTS will be designed to be of an appropriate reliability to ensure risks are ALARP. As a minimum a duty / stand-by fan arrangement will be incorporated into the design. The time to reach the LFL (24 hours) would provide sufficient time for the TVTS to be reinstated (e.g. manual change-over to the stand-by fan should the auto-changeover have failed).

Apart from fan failure, other failure modes for the TVTS include: site supply or local power distribution failure; actuated damper failure; filter blockage. Again, 24 hours would provide sufficient time to manually override / by-pass such components. During the detailed design phase, the practicality of providing back-up diesel generators that are available to the Rw/B, and could be connected within 24 hours in the event of a prolonged power outage, will be considered (see ALARP Topic Report [Ref-2]).

In the event that the TVTS could not be reinstated within 24 hours then other appropriate managerial action should be taken (i.e. draining any full tanks to increase the ullage, thereby increasing the time to LFL). However, there are potential common cause failures (i.e. loss of power supplies) and therefore alternative means of dilution or dispersion of hydrogen are being investigated.

A range of other preventive and mitigation measures are available such as increasing vessel ullage space or displacing hydrogen accumulation by periodic filling and emptying of ullage space, and ensuring no ignition sources are present to cause a hydrogen explosion.

In addition, the assessment is very pessimistic in that:

- It assumes the worst case radiolytic hydrogen generating material,
- It assumes the tanks are filled to their maximum volume,
- No ignition sources have been identified that could cause an explosion, and
- It takes no account that the ventilation system is continuously monitored and there is a substantial amount of time to take hydrogen management actions.

Taking into account the above, it is concluded that no further reasonably practicable measures could be applied to the Tank Vent Treatment system with respect to this fault and the identified measures are concluded to be ALARP.

**Categorisation and Classification:**

Generally, the majority of safety functions associated with the LWMS are Category C with only a very small number of bounding faults falling into higher categories. Based on the pessimistic worst-case bounding fault, the preliminary category of the safety function applicable to the TVTS is:

| **Bounding Faults in each Sub-System** | **Preliminary Safety Function Category (Unmitigated dose to Worker)** | **Preliminary Safety Function Category (Unmitigated dose to Public)** |
|---|---|---|
| TVTS | A | B |

### 18.9.3 Claims and Arguments

This section describes the arguments as to how each of the SFCs for the TVTS will be met. The detailed evidence is provided in the Topic Report on the Radioactive Waste Building Tank Vent Treatment System [Ref-28]. For the majority of the TVTS, the classification of SSCs will be class 3, with appropriate safety measures incorporated into the design against the identified faults as required by the evaluation of unmitigated doses. The initial preliminary safety function category for unmitigated doses to worker and public for TVTS which is at concept design can be found in section 18.9.2.3. Outline initiating fault frequency estimates have been provided in order to assign safety function categories. All bounding faults are considered to be ‘frequent’ faults.

#### 18.9.3.1 TVTS Claims and Arguments

**(1) Radioactivity Containment**
The demonstration of appropriate containment is provided by satisfying.

TV SFC 4-7.1: Radioactivity extracted from Vessel Ullage space will be adequately contained:

The arguments underpinning this SFC are as follows;
A1 The Tank Vent Treatment System shall be designed to ensure that a negative differential pressure is maintained inside the vessel ullage and ventilation system such that any leakage will be into the system.
A2 The Tank Vent Treatment System shall be designed to ensure sufficient reliability; there shall be Duty and Standby fans with automatic switch over should a fan trip.
A3 The Tank Vent Treatment System shall be designed to ensure flow parameters are monitored and shall alarm if any abnormal flow state exists.
A4 HEPA filters shall provide a Safe Change facility to prevent leakage and allow filters to be changed while the ventilation system continues to operate.
A5 HEPA filters on ventilation air inlets shall prevent leakage of radioactivity in the event of reverse flow.

**(2) Doses to Workers and Public from Normal Operations**
Demonstration that doses to the workers and the public during normal operations are reduced to ALARP is provided by satisfying.

TV SFC 4-7.2: The TVTS shall be designed to ensure that doses to both the workers and the public from normal operation of the TVTS are ALARP. This is provided by satisfying the following two sub-claims:

TV SFC 4-7.2.1: The TVTS shall be designed to ensure that doses to the workers from normal operation of the TVTS are ALARP:

The arguments underpinning this SFC are as follows;
A1 The TVTS shall normally operates automatically without the need for local operators to be present.
A2 Ductwork shall be designed to promote natural drainage of condensed gases back into the process effluent, minimising contamination build-up (and consequential dose-rates) on the air ducting.
A3 Duty / Standby HEPA filters shall provide a Safe Change facility to prevent leakage and allow filters to be changed while the ventilation system continues to operate.
A4 Hot air in-bleed system shall prevents discharge HEPA filters being exposed to high humidity, which maximises the HEPA filter lifetime, keeping changes to a minimum.
A5 Plant and equipment shall, in so far as is reasonably practicable, be placed in normally clean areas, either outside the containment boundary or downstream of the discharge HEPA filters.

TV SFC 4-7.2.2: The TVTS shall be designed to ensure that doses to the public from normal operation of the TVTS are ALARP:

The arguments underpinning this SFC are as follows;
A1 The activity of radioactive discharges from the TVTS shall be minimised through the use of 2-stage HEPA filtration.
A2 The total volume of radioactive discharges from the TVTS shall be minimised by using a low flow rate.
A3 Hot air in-bleed system prevents discharge HEPA filters being exposed to high humidity, which maximises the HEPA filter lifetime, keeping changes to a minimum.
A4 Doses to the public from operation of the TVTS are expected to be very low. All reasonably practicable steps to minimise both the volume and activity of aerial discharges shall be taken and the dose to the

public shall be demonstrated to be ALARP.

**(3) Use of Best Available Techniques**

The demonstration of BAT is achieved by the following claim.

TV SFC 4-7.3: The creation, management and disposal of radioactive waste will be optimised through the use of BAT:

The arguments underpinning this SFC are as follows;

A1 The design of the TVTS shall follow established codes of practice and relevant good practice.
A2 Discharge filtration shall be provided by two-stage duty standby HEPA filters.
A3 HEPA filters on ventilation air inlets shall prevent dust entering the ventilation system, reducing the dust burden on the discharge HEPA filters, thereby extending their life.
A4 Hot air in-bleed system shall prevent discharge HEPA filters being exposed to high humidity, which maximises the HEPA filter lifetime, keeping changes to a minimum.
A5 HEPA filter performance and flow parameters shall be monitored and shall alarm if any abnormal flow state exists or operational parameters are compromised.

**(4) Doses to Workers and Public from Faults**

Demonstration that doses to the workers and the public during fault conditions are reduced to ALARP is provided by satisfying.

TV SFC 4-7.4: The TVTS shall be designed to ensure that risks doses to public and workers in faults are ALARP and within limits and targets given in PCSR Chapter 5 General Design Aspects, section 5.5: Definition of Design Basis Faults and Beyond Design Basis Faults. This will be achieved by satisfying the following 4 sub-claims:

TV SFC 4-7.4.1: The TVTS has been assessed to identify all credible failure modes/fault conditions with the potential to lead to an on-site or off-site radiological release (the design basis):

The argument underpinning this SFC is as follows;

A1 Structured hazard identification has been undertaken for the Tank Vent Treatment system.

TV SFC 4-7.4.2: Where appropriate, the design will includes automatic/engineered fault prevention, protection and mitigation features to ensure that the assessed fault consequences are both within the limits and targets specified in the PCSR Chapter 5 General Design Aspects, section 5.5: Definition of Design Basis Faults and Beyond Design Basis Faults:

The argument underpinning this SFC is as follows;

A1 Hazard Assessment has been undertaken for the TVTS to identify fault protection requirements.

TV SFC 4-7.4.3: Where appropriate, the design will include specific engineered provisions to facilitate identified fault recovery actions by the workers:

The arguments underpinning this SFC are as follows;

A1 Plant and filter performance shall be monitored and abnormal conditions shall create an alarm.
A2 HEPA filters shall be two stage with duty and standby filters at each stage.
A3 Discharge HEPA filters shall be provided with safe change housings to protect the worker and enable the ventilation system to continue while the filters are being changed.
A4 The TVTS shall provide redundancy for key items of plant to protect against plant failures.

TV SFC 4-7.4.4: The radioactive waste system civil structures / building envelopes etc. will be designed and qualified to appropriate standards and will provide protection against natural events (earthquake, high wind, flooding, extreme temperature, snow loading and other external hazards as appropriate):

The argument underpinning this SFC is as follows;
A1 The Radwaste Building shall be designed to appropriate standards

**(5) Radioactivity in Gaseous Discharges to the Environment**
The demonstration of minimisation of airborne discharges is provided by satisfying.

TV SFC 4-8.1: The total radioactivity in gaseous discharges to the environment from the TVTS will be minimised:

The arguments underpinning this SFC are as follows;
A1 Filtration shall be provided by a two-stage HEPA filtration system.
A2 The HEPA filtration system shall provide duty and standby filters.
A3 Filter performance shall be monitored and abnormal conditions shall create an alarm.
A4 A warm air in-bleed shall be provided to ensure the Relative Humidity is within acceptable conditions for the HEPA filters.
A5 The TVTS flow rate shall be minimised.
A6 Dispersed Oil Particulate (DOP) testing shall be used to prove the correct operation of HEPA filters.

**(6) Exhaust air meets Discharge Criteria**
The demonstration of the confirmation of discharges is provided by satisfying.

TV SFC 4-8.2: Appropriate monitoring, measuring and sampling equipment will be provided to confirm and record that discharge meets relevant Discharge Criteria:

The arguments underpinning this SFC are as follows;
A1 Each stage of discharge HEPA filters shall be monitored for differential pressure and downstream activity to confirm they are performing adequately.
A2 The discharge route shall have iso-kinetic sampling which provides the legal record of aerial discharges.

**(7) Hydrogen Concentrations remain Low**
Demonstration that the risk from hydrogen is appropriately managed is provided by satisfying.

TV SFC 4-8.3: Hydrogen concentrations in vessel ullage spaces will not reach the Lower Flammability Limit:

The arguments underpinning this SFC are as follows;
A1 The purge air provided to tanks generating hydrogen shall be sufficient to keep hydrogen concentrations below the Lower Flammability Limit.
A2 The ventilation system shall have adequate availability provided by redundancy in key components.

### 18.9.3.2 Other PCSR Chapter Claims and Arguments

This section identifies the SFCs made in other chapters of the PCSR that are relevant to this PCSR Chapter and how they will be met. More detail on the arguments for these claims is provided in the relevant PCSR Chapters identified below or in the Topic Report on the Radioactive Waste Building Tank Vent Treatment System [Ref-28]:

**(1) PCSR Chapter 10 – Civil Works and Structures**

Rw/B SFC 4-7.1: The Rw/B provides shielding by concrete walls and slabs. The shielding walls and slabs are arranged around higher radiation areas to reduce worker's exposure. The external walls and slabs provide shielding to reduce dose rate at the site boundary:

The argument underpinning this SFC is as follows;
A1 Appropriate shielding and containment shall be provided by the Rw/B.

**(2) PCSR Chapter 31 – Decommissioning – Decommissioning Design Features**
Decom-SC 1: The UK-ABWR design incorporates features that facilitate decommissioning:
Decom-SC 1.2: The UK ABWR pipework and drainage design reduces decommissioning risks ALARP:

The arguments underpinning this SFC are as follows;
A1 Ducting shall be designed to promote natural drainage of condensed gases back into the process, minimising the radioactive inventory remaining in the system.
A2 Ducting shall be constructed from high integrity stainless steel which does not easily pit or corrode and shall provide an easily decontaminable surface.
A3 Plant and equipment shall, in so far as is reasonably practicable, be placed in normally clean areas, either outside the containment boundary or downstream of the discharge HEPA filters.

Decom-SC 1.3: The UK ABWR design minimises conventional safety risks during decommissioning:

The argument underpinning this SFC is as follows;
A1 Conventional safety hazards shall be identified in the hazard identification process.

Decom-SC 1.4: The design of the UK ABWR ensures sufficient access and space for decommissioning activities to be undertaken:

The arguments underpinning this SFC are as follows;
A1 Confined space hazards shall be identified in the hazard identification process.
A2 Required space for decommissioning activities shall be assessed during the detailed design / plant layout phase and shall be supported by a hazard identification process.

Decom-SC 1.5: The UK ABWR design has considered decommissioning logistics to ensure risks are reduced to ALARP:

The arguments underpinning this SFC are as follows;
A1 The plant shall be designed to support decommissioning.
A2 Decommissioning logistics to support decommissioning shall be assessed during the detailed design / plant layout phase.

Decom-SC 1.8: The design of the UK ABWR ensures long-term structural integrity and containment:

The arguments underpinning this SFC are as follows;
A1 The TVTS shall be designed for 70 years operation.
A2 The active ductwork shall be high-integrity stainless steel.
A3 Plant and equipment shall, in so far as is reasonably practicable, be placed in normally clean areas, either outside the containment boundary or downstream of the discharge HEPA filters and shall easily be replaced.

Decom-SC 1.9: Ancillary systems will have the functionality to be adapted or modified to facilitate decommissioning:

The argument underpinning this SFC is as follows;

A1 The design life of radioactive waste management services, including systems for the treatment of gaseous wastes shall be appropriate for decommissioning and shall be confirmed during the detailed design phase.

**(3) PCSR Chapter 31 – Decommissioning – Decommissioning Strategies in Place**

Decom-SC 2: Appropriate decommissioning plans/strategies are in place, and will continue to be developed by the future licensee:

Decom-SC 2.2: Records will be managed appropriately and reviewed periodically:

The argument underpinning this SFC is as follows;

A1 Recording and periodic review requirements for liquid waste management shall be appropriate for decommissioning. Appropriate requirements are specified in Section 18.12 on Safety Management arrangements for radioactive waste management.

**(4) PCSR Chapter 31 – Decommissioning – Decommissioning Faults and Hazards Identified**

Decom-SC 3: Faults and Hazards during decommissioning are identified, assessed and all risks shown to be ALARP:

Decom-SC 3.2: Appropriate design features to facilitate decommissioning and provide hazard reduction have been identified:

The argument underpinning this SFC is as follows;

A1 Hazards are being systematically identified through the HAZOP process and managed. Further HAZOP 2 studies and design features will be considered during the detailed design phase.

**(5) PCSR Chapter 31 – Decommissioning – Viable Disposal Options**

Decom-SC 4: Viable disposal routes are available (or will be available) for all decommissioning wastes:

Decom-SC 4.3: Waste will be minimised during operations:

The argument underpinning this SFC is as follows;

A1 The total radioactivity in gaseous discharges to the environment from the TVTS will be minimised, see TV SFC 4-8.1 above.

## 18.9.4 Assumptions, Limits and Conditions for Operation

### 18.9.4.1 Assumptions

A number of working assumptions are made to demonstrate that the Tank Vent Treatment System (TVTS) will achieve all safety claims and that nuclear safety aspects have been adequately considered in the GDA process.

The key working assumptions for the TVTS include:

- The TVTS will be capable of operating for a period of 70 years.
- The TVTS will only be required to ventilate tanks within the Rw/B where their ullage space is radiologically designated as C3.
- The TVTS and HVAC system are segregated until the base of the main stack.
- The SS Storage Tank Cells will retain bulk shielding and containment following a hydrogen deflagration within the Storage Tank ullage.

The TVTS will maintain a measurable depression within potentially contaminated (C3 classified) tanks relative to the cells in which the tanks are located. Due to the low levels of hydrogen anticipated, and dilution rates provided, there will be no requirement to provide ATEX rated equipment, for GDA. These are detailed in the Topic Report for the Tank Vent Treatment System [Ref-28].

#### 18.9.4.2 Limits and Conditions for Operation

The following LCOs are identified for TVTS in GDA phase, and these LCOs are also provided in the Generic Technical Specification (GTS) [Ref-29] and the Topic Report for the Tank Vent Treatment System [Ref-28].

- The hydrogen concentration in any tank connected to the TVTS must not exceed 25% of the lower flammability limit during normal operations. The TVTS must not be shut down for more than 24 hours, without taking measures to mitigate the build-up of hydrogen in the Powder Resin Storage Tanks.

### 18.9.5 Summary of ALARP Justification for Tank Vent Treatment System

The main hazards associated with the TVTS are that its failure could lead to:

- An increase in hydrogen concentration in some tanks, with the potential for flammable or explosive atmospheres to occur in their ullage spaces, and
- Loss of depression in the ullage spaces of higher activity tanks leading to displaced air entering the tank cells / rooms.

The design of the TVTS is based on UK and International good practice and design codes for ventilation systems in radiological facilities. The following good practice measures have been included in the design:

- Two-stage exhaust HEPA filtration,
- Providing a hot air in-bleed to reduce the Relative Humidity and protect the HEPA filters from seeing free moisture,
- Use of Safe Change HEPA filters to allow filters to be changed without interrupting operations,
- Provision of comprehensive flow performance monitoring and alarms,
- Using industry accepted specification for plant and equipment,
- Allowing sufficient mixing lengths between filter test injection and sample points, and
- Providing falls within the ductwork so any condensation flows back into the process rather than pooling.

Further information is provided in the Topic Report on the Radioactive Waste Building Tank Vent Treatment System [Ref-28].

The TVTS was not part of the original design for the LWMS but during early design reviews it was judged that it would be ALARP to provide such a system to minimise the potential for airborne contamination.

The TVTS, like most ventilation systems, is not complex and its design follows Design Codes of Practice and Industry Standard specifications. As discussed in Section 18.10.2.1, it has also been subjected to a SWIFT, considered in a HAZOP 1 and included in fault assessments. In evaluating these studies, the following design features have been included:

- Provision of air inlet HEPA filters to ensure that any reverse flow condition does not result in radiological contamination,
- Provision of Duty/Standby motors, fans and HEPA filters to make the ventilation system robust

against plant failures,
- Removal of a wash system, which was no longer required and contributed to an overflow fault,
- Using safe change HEPA filter for CUW Backwash Receiver Tank ullage air treatment, and
- CUW HEPA filter to be installed outside the tank room.

In addition, consideration is being given to the provision of backup power supplies that can be connected within 24 hours should an extended loss of site power event occur.

Whilst a small number of DBA shortfalls have been identified, options have been proposed to resolve these and additional safety measures do exist.

| **Shortfall** | **Potential options to resolve** |
|---|---|
| TVTS duty fan failure:<br>Loss of site electrical supply would be a common cause failure for loss of the identified protective measures, including the ability to transfer liquors to increase the tank ullage. | Currently identified safety measures are the standby TVTS fan and draining the storage tanks if TVTS cannot be reinstated before the 4% v/v Lower Flammable Limit (LFL) is reached.<br><br>Consider the provision of diverse electrical supplies to ensure the TVTS, or other means of dilution or dispersion of hydrogen, is reinstated before the 4% v/v LFL is reached.<br><br>Other potential means include the use of Passive Autocatalytic Recombiners (PAR), purging, passive ventilation, inerting. |

Further information is provided in the LWMS ALARP Topic Report [Ref-2].

The TVTS is considered to meet ALARP requirements at a concept design level and is appropriate to be taken forward for the site specific stage. Further information is provided in the LWMS ALARP Topic Report [Ref-2]. The principles of ALARP will need to be applied during detailed design, to ensure the final design is fully compliant with UK regulatory expectations on ALARP.

## 18.10 High Level Waste Processing

The current concept for solid HLW is decay storage in the spent fuel pool (SFP) followed by dry interim storage in casks on-site prior to repackaging and subsequent disposal to the GDF.

The dry solid HLW arisings are activated metals arising from non-fuel in-core removable components within the reactor which are subjected to irradiation. Although potentially HLW at arising, the activated metals are expected to be ILW at disposal due to radioactive decay during the period between arising and disposal to the GDF.

The removal of the non-fuel in-core removable components from the SFP to the reactor building door is covered by the Spent Fuel Export process (PCSR Rev. C Chapter 19, Section 10). The concept design for on-site dry cask storage of the non-fuel core components is similar to the storage solution selected for spent fuel which is detailed in the PCSR Chapter covering Spent Fuel Interim Storage (PCSR Chapter 32). In terms of handling, cooling and shielding requirements during normal operation as well as radiological consequence during faults, the storage solution for spent fuel bounds that of the non-fuel in-core removable components. A brief summary of the storage solution for non-fuel components is provided in Section 18.10.1.

The waste stream process flow diagram for HLW showing point of generation and subsequent routing through the SWMS is given in Figure 18.6-1 (HLW and ILW).

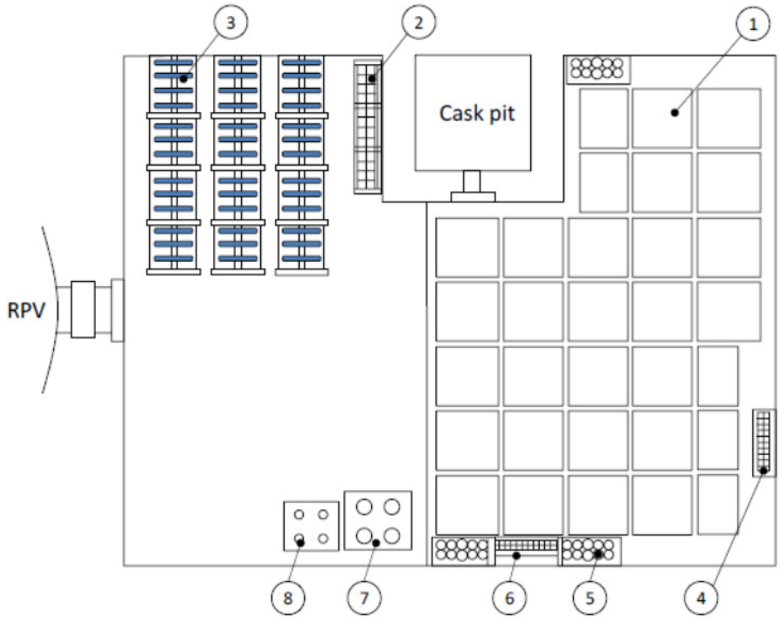
### 18.10.1 Brief Waste & System Descriptions

Dry solid HLW arises solely from the periodical removal of various non-fuel core components from the reactor. The waste stream to be managed comprises of control rods and other HLW items:

- Control rods containing Hafnium (used for neutron flux control in the reactor on a day-to-day basis),
- Control rods containing Boron Carbide powder (used intermittently for start-up and shutdown),
- Local Power Range Monitors,
- Start-up Range Neutron Monitors,
- Traversing In-core Probes, and
- Neutron Source Units.

All of the dry solid HLW items will be neutron activated, with $^{60}Co$, $^{63}Ni$, $^{55}Fe$ and $^{54}Mn$ being the dominant radionuclides. The Hafnium control rods are the most highly activated components, with dose rates on contact on removal from the reactor in the order of 10's of Sieverts per hour. At arising, the solid HLW must be remote handled in order to be packaged.

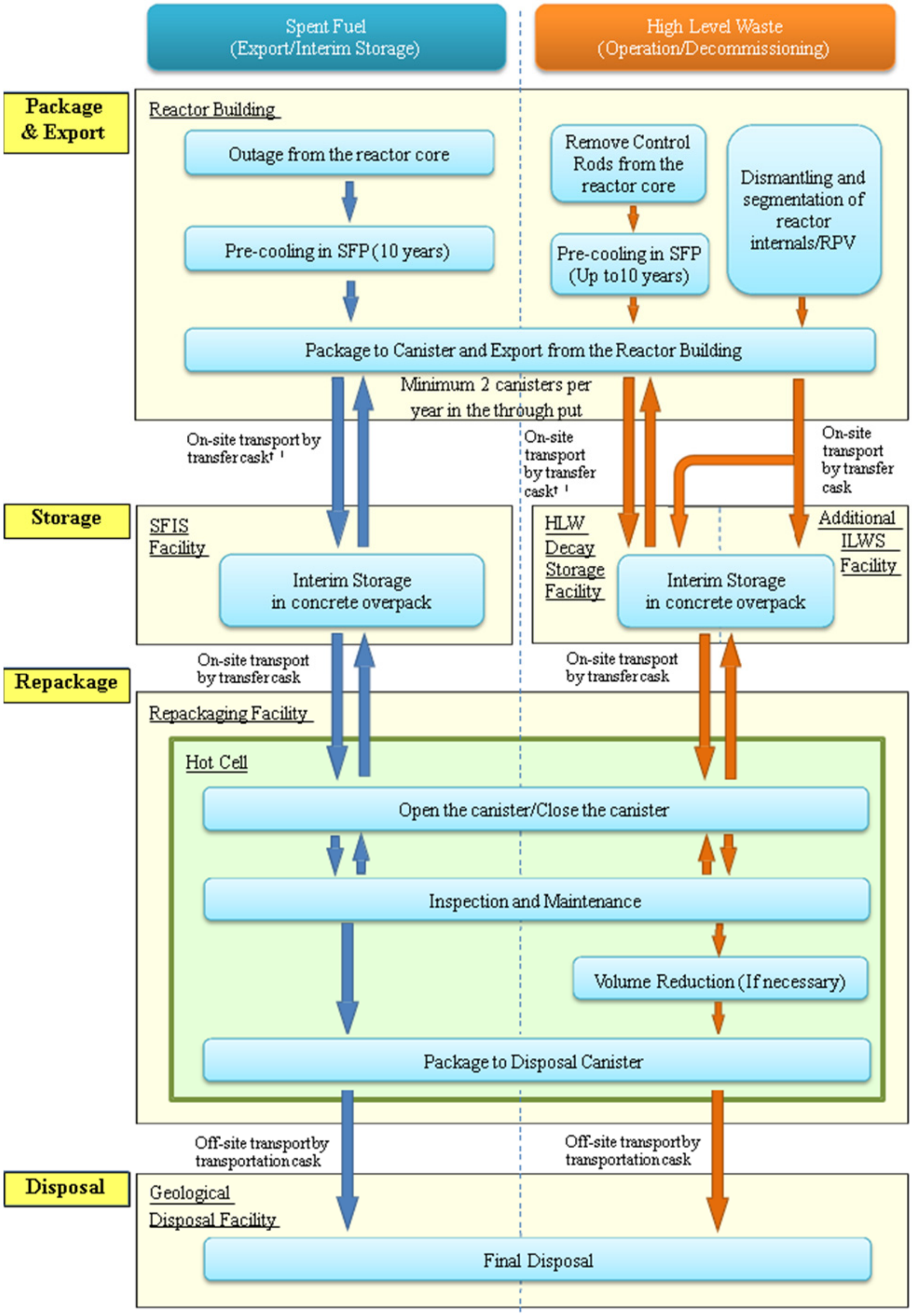
The interim storage locations for the various solid HLW items removed from the reactor for a typical ABWR SFP layout are shown in Figure 18.10-1 below.




| No | Equipment |
|---|---|
| 1 | Spent Fuel |
| 2 | LPRM storage rack |
| 3 | CR hanger storage |
| 4 | Channel storage rack |
| 5 | CR / Damaged fuel storage rack |
| 6 | Blade guide storage rack |
| 7 | RIP diffuser / Stretch tube storage rack |
| 8 | RIP Impeller Shaft storage rack |

**Figure 18.10-1: Layout of Equipment in a typical ABWR Spent Fuel Pool**

On removal from the reactor, HLW will be stored in the SFP for a period of 10 years. Following storage in the SFP the Hafnium control rods (component with highest activation levels) are still above the heat generation threshold for containers suitable for consignment to the GDF (the Hafnium control rods will decay to below the heat generation threshold within approximately 20 years of discharge from the reactor, [Ref-18]). However, all the HLW items have high dose rates that make deferred treatment the preferred option before consignment to the GDF can be undertaken. As such, the HLW will be removed from the R/B using the spent fuel process and placed in interim dry cask storage, where it will remain until the GDF becomes available. The current anticipated date for transfer of ILW (including dry-solid HLW which will have decayed to ILW) from the New Build Program starts in 2100 and has a completion date of 2138 [Ref-33]. The HLW decay storage facility will be a separate building co-located with the Spent Fuel Interim Store (SFIS). The HLW process is shown in Figure 18.10-2.




† 1: Spent fuel and Activated waste casks are capable of being moved back to SFP for inspection if required until SFP is no-longer available

**Figure 18.10-2: Spent Fuel and High Level Waste Flow Chart**

The dry cask storage system consists of the following components:

**Non-Fuel Waste Container (NFWC):** A stainless steel canister capable of holding between 25-50 control rods or baskets of dry solid ILW. This is used for interim storage only and is not an approved GDF disposal package.

**Transfer cask:** Used for providing shielding and protection during loading and cross site transfer. This also facilitates transfer of the NFWC into the storage overpack.

**Storage overpack:** The overpack provides shielding and structural protection to the NFWC during interim storage. The overpack has variable shielding (up to 760mm) depending on the limiting dose rate. The typical maximum size of an overpack is 150 tonnes, 6m tall and 3.4m diameter.

A summary of the proposed process for spent fuel is given in PCSR Chapter 32 and an identical process is anticipated to be used for HLW.

The non-fuel in-core removable components are cooled in the SFP for 10 years after they are discharged from the reactor core to allow them to be removed to interim dry storage with reduced heat generation and activity. Following the wet storage within the SFP, on-site dry cask storage will last for up to 140 years after the reactor ceases its 60 year design life as interim storage before final geological disposal. 140 years is the bounding case assumed for spent fuel storage (PCSR Ch. 32).

Once GDF is available, the ILW packages (the Hafnium control rods will decay to below the heat generation threshold within approximately 20 years of discharge from the reactor, [Ref-18]) will be transferred to an inspection / maintenance / repackaging facility for processing prior to placement in GDF suitable containers (expected to be $3m^3$ boxes). It is assumed that a single facility will exist to support both HLW and spent fuel operations (although it is expected that separate processing lines will be provided for the HLW and spent fuel as the handling, processing and disposal packages will be different). The current ALARP option identifies size reduction of HLW items prior to placement in GDF suitable containers. It is recognised that the waste will be processed using BAT prior to placement in GDF suitable containers. Disposal to the GDF will be in conformance with the requirements, WAC and regulations at that time. RWM has conducted a disposability assessment of the data submitted as part of the GDA process and has concluded that the wastes generated are disposable at the level at which the assessment has been carried out.

Ref-18 determined that processing of operational dry solid ILW would result in about 30 off $3m^3$ boxes being produced for a single ABWR site. The number of waste packages produced is heavily influenced by the effectiveness of the size reduction and packaging processes adopted.

The future site operator will determine the optimal (BAT and ALARP) repackaging regime with due consideration of operational and decommissioning solid ILW arisings. The preferred option is dispatch of the repackaged waste direct from the inspection / maintenance / repackaging facility. Ref-18 also did not rule out the possibility that the future licensee may consider the temporary storage of the $3m^3$ boxes in the ILWS prior to dispatch to GDF.

During the interim storage period there may be a requirement to re-open some canisters for inspection of the activated components, or to investigate any fault condition that may threaten canister integrity. During the period in which the SFP in the reactor building is available the inspection works are capable of being carried out within the SFP. In this case the canister would follow a reverse process to export the canister from the reactor building to the HLW decay storage facility and all the safety functions required e.g. radiation, shielding and containment are provided in the same manner as the export process. From the point that the SFP is no longer available any inspection works are capable of being carried out in the repackaging facility. It is assumed for GDA that the repackaging facility would have a hot cell for the repackaging works and required safety functions would be provided by the building of the repackaging facility and the hot cell. Since the HLW strategy depends on the final choice of SFIS detailed design, any subsequent changes will need to be reassessed.

### 18.10.2 Safety Assessment

#### 18.10.2.1. Hazard Identification for HLW

A preliminary hazard identification study was carried out for the HLW in September 2016. This was based on a review of the spent fuel route hazard identification, due to the commonality between the two processes.

During the study, four additional faults were identified:

- Misloading of fuel into a canister for HLW,
- Misloading of insufficiently cooled HLW,
- Loading of the canister into the wrong overpack, and
- Consignment of HLW/spent fuel canister to incorrect repackaging line.

These four faults have been added to the preliminary fault schedule for HLW which is detailed in BSC for the SWMS [Ref-3].

The hazard schedule generated for the spent fuel route was reviewed and deemed applicable to the HLW without any amendments. The hazard schedule has been reproduced in Table 18.10-1 below.

**Table 18.10-1: HLW Internal and External Hazards**

| External Hazard Description | Internal Hazard Description |
|---|---|
| Air Temperature | Fire |
| Extreme Wind | Internal Flooding |
| Rainfall and Ice | Pipe whip and Jet Impact |
| Drought | Internal Missile and Blast |
| Snow | Dropped and Collapsed Loads |
| Electromagnetic Interference / radio frequency interference | Electromagnetic Interference / radio frequency interference |
| Sea or River Water Temperature | Impact and Collision |
| External Flooding | Gas Release |
| Seismic | |
| Loss of Off Site Power | |
| Aircraft Impact | |
| External Fire | |
| External Missile | |
| External Explosion | |
| Lightning | |
| Biological Fouling | |

#### 18.10.2.2. Reductions of hazards during normal operations

Whilst safety was considered as part of the ALARP process, there has been no consideration of specific studies related to normal operations involving HLW as the design is currently at optioneering / strategy definition phase. This assessment will be undertaken when the design for handling of HLW is sufficiently developed.

The storage of the HLW from the UK ABWR has been aligned with the spent fuel storage methodology. The hazards associated with the spent fuel will, in the majority of cases, bound those of the HLW and therefore the spent fuel ALARP assessment and ongoing work will drive development of the HLW strategy and design.

#### 18.10.2.3. Reduction of hazards in fault conditions

Whilst safety was considered as part of the ALARP process there has been no consideration of specific studies related to fault conditions involving HLW as the design is currently at optioneering / strategy definition phase. This assessment will be undertaken when the design for handling of HLW is sufficiently developed.

The storage and eventual disposal of the HLW from the UK ABWR has been aligned with the spent fuel storage methodology. The hazards associated with the spent fuel will in the majority of cases bound those of the HLW and therefore the spent fuel ALARP assessment and ongoing work will drive development of the HLW strategy and design.

## 18.10.3 Claims and Arguments

This subsection describes how the SFCs for the SWMS including HLW processing have been met, for more detailed information see the Basis of Safety Case for Solid Waste Processing [Ref-3].

SWMS SFC 4-13.1 to SWMS SFC 4-13.5 along with the relevant arguments, which are applicable to HLW, are described in Section 18.6.3.

## 18.10.4 Assumptions, Limits and Conditions for Operation

### 18.10.4.1 Assumptions

A number of working assumptions are made to demonstrate that the HLW process will achieve all safety claims and that nuclear safety aspects have been adequately considered in the GDA process.

The HLW related to export and storage in casks is based on the process used for spent fuel and therefore the assumptions related to Spent Fuel Export (SFE) and Spent Fuel Interim Storage (SFIS) are as defined in the Preliminary Basis of Safety Case on Spent Fuel Interim Storage [Ref-26] and Preliminary Basis of Safety Case on Spent Fuel Export [Ref-24].

The following assumptions have been made with regard to using the spent fuel dry storage system for HLW:

- The HLW storage canister will be similar in design to the canister design supplied by Holtec International,
- A loaded cask can be returned to the SFP for unloading while it is available (should the need arise),
- Following wet storage of HLW within the SFP for 10 years, there will be on-site dry cask storage in a separate facility within SFIS until the GDF is available. The HLW is expected to be able to be consigned to the GDF after 2100,
- Following storage, HLW will be repackaged into disposal containers, potentially utilising best practice size reduction techniques available at the time,

- HLW is disposable in the Geological disposal facility. The ability to retrieve, inspect and repackage HLW will be maintained throughout the period HLW is on the site,
- Faults common to both HLW and spent fuel will be bounded by the spent fuel,
- The Spent Fuel Export / HLW export route (PCSR Chapter 19) covers all processes (handling and cooling) until the cask reaches the exit of the R/B prior to transfer to the storage facilities,
- All items (excluding control rods and neutron source units) will be size reduced on removal from the reactor and before storage in the SFP where necessary. This activity is outside the scope of this study,
- The HLW will be segregated from the spent fuel within the SFIS or in a separate facility that will be co-located with the SFIS (see Figure 18.1-2),
- There will be a single inspection / maintenance / repackaging facility for spent fuel and HLW (see Figure 18.1-2), and
- The funded decommissioning programme base case [Ref-32] sets out a number of assumptions regarding the means by which waste may be managed and disposed of and decommissioning carried out by a new nuclear power station future licensee. These assumptions define a generic lifecycle plan for new nuclear power stations known as the "Base Case". The Base Case is built on existing policy and regulatory requirements; although it also makes additional assumptions. The Base Case is primarily written to ensure sufficient financial provision is made to cover liabilities it also provides each future licensee basic assumptions on which radioactive waste management, decommissioning and spent fuel management strategies can be developed from, for example the Base Case assumes that HLW (decayed to ILW) will be stored on-site pending final transport and disposal in a GDF.

These are detailed in the BSC for Solid Radioactive Waste Management System [Ref-3].

#### 18.10.4.2 Limits and Conditions for Operation

Based on the general principles for the identification of Assumptions and LCOs described in Standard Control Procedure for Identification and Registration of Assumptions, Limits and Conditions for Operation [Ref-41], limits directly related to operational aspects, e.g. Operation Control, will be determined in the site specific phase and the details will be commensurate with the maturity of the design. For this reason there are no applicable LCOs on this system within the scope of the GDA.

The HLW process is at an early stage of concept design and the movement of HLW will not happen until 10 years after the start of generation, therefore the limits and conditions for operation have not yet been defined.

### 18.10.5 Summary of ALARP Justification for HLW

The ALARP arguments made for spent fuel interim storage (PCSR Chapter 32) are bounding for the dry cask storage of the HLW. Therefore the risks from the HLW export and storage are considered capable of being reduced ALARP.

Based on the information currently available, it is concluded that the ALARP option for the storage and processing of HLW from the UK ABWRs is to store the waste on site in dry cask storage co-located with the SFIS. The HLW will be processed when the GDF is available to receive it in conformance with the requirements and regulations at that time.

Currently, the proposal for handling of HLW produced by the UK AWBR is at a strategy level and further development of the strategy and design will be undertaken by the future licensee. However, the processes selected have taken due cognisance of UK ALARP principles and have been aligned with the spent fuel route. The proposed strategy is considered consistent with the ALARP principle for concept design and is considered appropriate to be progressed by a future site operator and in line with regulatory guidance

[Ref-34].

Further information is provided in the SWMS ALARP Topic Report [Ref-4].

# 18.11 Intermediate Level Waste Store

This section provides an overview of an example ILWS. The process descriptions given in this and subsequent sections do not represent a final design for the UK ABWR. They represent facility requirements and capabilities in order to demonstrate that the waste management operations are achievable.

The waste stream process flow diagram for ILW showing point of generation and subsequent routing through the SWMS is given in Figure 18.6-1 (HLW and ILW) in Section 18.6.

## 18.11.1 Brief Waste & System Descriptions

The ILWS receives processed and packaged operational wet-solid ILW (see Section 18.6) from the Rw/B in $3m^3$ drums.. The ILWS is based on passive safety principles. The design life of the store is 115 years to cover the period when GDF becomes available to accept new build ILW waste (in 2100 [Ref-33]) and all waste stored on site has been exported. The design of the ILWS aims to avoid the generation of radioactive waste: received packages are free from external contamination (achieved by using SCVs in the WILW Processing System, Section 18.6.1.1) and there is no facility for repackaging waste.

The use of SCVs in the WILW processing system ensures that waste packages received at the ILWS are free from surface contamination.

The ILWS will require the following storage areas:

For 3 $m^3$ drum storage:

- Shielded storage locations for $3m^3$ drums,
- Allocation of quarantine storage positions for $3m^3$ drums,
- Allocation of storage positions for $3m^3$ drums arriving in SCVs from the WILW,
- Provision of a $3m^3$ dummy drum for condition monitoring,
- Allocation of $3m^3$ drum shuffling positions required during periodic inspections, and
- Provision of a shielded segregation barrier between the $3m^3$ drum and $3m^3$ box sections of the store.

For $3m^3$ box storage:

- Shielded storage locations for $3m^3$ boxes,
- Allocation of quarantine storage positions for $3m^3$ boxes,
- Allocation of storage positions for $3m^3$ boxes arriving in SCV's from decommissioning activities,
- Provision of a dummy $3m^3$ box for condition monitoring, and
- Allocation of $3m^3$ box shuffling positions required during periodic inspections.

All ILW packages will be accessible to allow retrieval at any time during interim storage for inspection, assay and remediation as required.

The ILWS provides facilities for waste package periodic inspections during the storage period. The Package Inspection Cell (PIC) undertakes all package inspections necessary during the storage period at the ILWS and incorporates the following:

- A turntable enabling rotation of the waste package,
- A removable shielded roof hatch on exit from the cell,
- Engineered personnel access doors into the PIC,
- A radiological assay system to generate a package inventory from the measured radionuclide activities,

- Appropriate interlock restrictions to access doors when high area dose levels are detected, preventing inadvertent personnel access,
- A closed circuit television (CCTV) system to relay images of the waste package and internal identification room activities to the facility control room during remote working,
- A cell lighting system to provide appropriate lighting levels for maintenance activities, the CCTV system and viewing through the shielded window,
- A shielded window to enable the operator to have a suitable view from the remote operating position,
- Master Slave Manipulators to remotely complete surface swabbing of the package and participate in turntable recovery operations, and
- A posting facility to get clean swabs into and used swabs out of the cell during surface contamination checks.

Inspection of stacked packages in the storage area may be achieved with the provision of a Package Inspection Camera Deployment System.

Dummy packages will be deployed within the ILWS and their inspection will inform the facility operator of the condition of waste packages.

## 18.11.2 Safety Assessment

### 18.11.2.1. Hazard Identification for the ILWS

A hazard identification study was carried out in January 2015 and the hazards identified to workers and the public from this study have been collated into a Preliminary Fault Schedule. The major fault groupings identified are summarised below:

- Loss of containment / spread of contamination,
- External dose,
- Fire / explosion,
- External hazards,
- Environmental, and
- Industrial / conventional.

Bounding radiological faults and doses from normal operations have been assessed and are discussed in the SWMS ALARP Topic Report [Ref-4] and BSC [Ref-3], a brief summary is presented below.

### 18.11.2.2. Normal Operations

The main premise of the ILWS is to segregate workers from the waste being stored and provide sufficient shielding to reduce doses to operators, on-site workers and members of the public. All measures in the design are geared towards segregation and maintaining shielding. A list of the considerations in the design to achieve this is given below.

- The ILWS storage environment will ensure that the waste packages are retained in an acceptable form for future disposal in the GDF,
- Where possible the system design will use automated equipment and equipment capable of remote control, so that direct interaction with the active plant by the operators is eliminated during normal operations,

- Wet-solid ILW packages will be rendered into a passively safe state by immobilisation in cement before they are transported to the ILWS,
- No personnel access to the storage vaults of the ILWS is allowed,
- The ILWS will provide adequate shielding against radiation to reduce dose uptake by operators, on-site workers and the public,
- All areas of potential high radiation have appropriate access control measures to prevent / permit access into these areas,
- Equipment (such as most importantly the package handling machine) can be remotely withdrawn from the storage vaults of the ILWS in the event of a fault or for repair/maintenance, and
- Each waste package will have a robust means of physical identification and means of reading this identification must be provided in the ILWS.

#### 18.11.2.3. Reduction of Hazards in Fault Conditions

Following the hazard identification, a preliminary fault schedule has been produced. The following bounding assessments have been performed and are deemed sufficient to cover the consequences of a range of specific faults.

- Accidental unauthorised entry into the storage area,
- Receipt of out-of-specification package,
- Collapse of shield door during maintenance,
- Breach of storage area wall,
- Fire,
- External dose from an individual package,
- Damaged packages in store, and
- Dropped package in store.

It is clear that a number of the bounding scenarios potentially incur very high doses, for which significant prevention or mitigation would be expected as a result of sound engineering design practices. The hazards identified have been mitigated or reduced so far as is reasonably practicable for concept design. Further reductions can be made at the detailed design stage. Based on the pessimistic worst-case bounding fault, the preliminary category of the safety function for the ILWS is Category A for workers and Category C for the public.

The consequences of faults within the ILWS require the structural design and items of equipment within the facility to be seismically qualified to meet UK regulatory expectations.

### 18.11.3 Claims and Arguments

This subsection describes how the SFCs for the ILWS have been met, for more detailed information see the Basis of Safety Case for Solid Waste Processing [Ref-3]. The initial preliminary safety function category for unmitigated doses to worker and public for the ILWS which is at concept design can be found in section 18.11.2.3.

SWMS SFC 4-13.1 to SWMS SFC 4-13.5 along with the relevant arguments, which are applicable to the ILWS as well as HLW, are described in Section 18.6.3.1.

One solid waste SFC specific to the ILWS has been derived:

The demonstration that SWMS SFC 4-13.7: The on-site ILW Store is required to receive and manage processed and packaged ILW is provided by satisfying the following four sub-claims:
SWMS SFC 4-13.7-1 The Store will be required to hold all of the packaged ILW generated in the operating lifetime of the ABWR (i.e. 60 years) plus any additional ILW resulting from Post-Operation Clean-Out (POCO) of the LWMS.

The arguments underpinning this SFC are as follows;
A1 Design of the ILW Store will allow for handling of all expected packaged ILW waste.
A2 The ILW Store shall be designed to ensure that dose uptake during normal operations will be ALARP.
A3 The ILW Store will have sufficiently robust shielding for the operating lifetime of the ABWR.

SWMS SFC 4-13.7-2 The Store will be required to provide conditions that will minimise as far as reasonably practicable any degradation of the packaged wastes by corrosion or similar processes during the period of interim on-site storage.

The argument underpinning this SFC is as follows;
A1 The ILW Store will provide sufficient capacity for any faults and outages arising during its lifetime, including faults arising as a result of aging or extended timescales.

SWMS SFC 4-13.7-3 The Store will be required to allow any package to be recovered from any point in the Store and for inspection of the package to be performed.

The argument underpinning this SFC is as follows;
A1 The design of the store will allow recovery of any package for inspection.

SWMC SFC 4-13.7-4 The Store will be required to ensure continuity of shielding during import and export of ILW packages.

The argument underpinning this SFC is as follows;
A1 The design of shielding will ensure that doses are ALARP during import and export of ILW packages.

The linkage to other PCSR chapter claims and arguments are described in section 18.6.3.2.

## 18.11.4 Assumptions, Limits and Conditions for Operation

### 18.11.4.1 Assumptions

A number of working assumptions are made to demonstrate that the ILWS will achieve all safety claims and that nuclear safety aspects have been adequately considered in the GDA process.
The key working assumptions for the ILWS include:

- The ILWS is expected to have a design life of up to 115 years,
- The design of the ILWS aims to avoid the generation of radioactive waste: received packages are free from external contamination and there is no facility for repackaging waste,
- The ILWS will be sized to deal with the waste arising from one reactor,
- The ILWS will receive 3m3 drums of grouted WILW (CUW and FPC powder resin plus LCW and CF filter crud),

- The ILWS will receive 3m3 boxes of ILW waste,
- The ILWS will have sufficient shielding to reduce doses outside the ILWS store to acceptable levels for wastes at activities up to and including the design basis source term values quoted in the end user source term,
- The ILWS has been designed to handle 3 m3 Drums and 3 m3 Boxes,
- The ILWS must provide an inspection facility for 3m3 drums and 3 m3 boxes for the duration of storage,
- The ILWS must exclude operators from the storage area and areas where a drum is present, for example the inspection cave during a package inspection,
- The ILWS is designed to receive 3m3 drums at the throughput rate of the WILW Processing System,
- The ILWS will be sized to store the accumulated ILW waste packages produced on site,
- The ILWS design life will be such that it can export waste packages during the current anticipated dates for transfer of ILW from the New Build Program that starts in 2100 and has a completion date of 2138, and
- The funded decommissioning programme base case [Ref-32] sets out a number of assumptions regarding the means by which waste may be managed and disposed of and decommissioning carried out by a new nuclear power station future licensee. These assumptions define a generic lifecycle plan for new nuclear power stations known as the "Base Case". The Base Case is built on existing policy and regulatory requirements; although it also makes additional assumptions. The Base Case is primarily written to ensure sufficient financial provision is made to cover liabilities it also provides each future licensee basic assumptions on which radioactive waste management, decommissioning and spent fuel management strategies can be developed from, for example the Base Case assumes that ILW will be stored on-site pending final transport and disposal in a GDF.

These are detailed in the BSC for Solid Radioactive Waste Management System [Ref-3].

#### 18.11.4.2 Limits and Conditions for Operation

The following LCOs are identified for ILWS in GDA phase, and these LCOs are also provided in the Generic Technical Specification (GTS) [Ref-29] and the Basis of Safety Case for SWMS [Ref-3].

- The final waste WILW package must conform with RWM conditions for acceptance at the proposed GDF and relevant transport regulations,
- The ILW Store will have sufficient capacity to store the total arisings of $3m^3$ drums generated during the operational lifetime of the WILW processing plant with an additional capacity to allow for waste loading variance, and
- The ILWS will receive externally clean packages.

### 18.11.5 Summary of ALARP Justification for ILW Store

The design of the ILWS is based on the Hunterston A ILW store. The store design has been developed to be consistent with the industry guidance "NDA Industry Guidance: Interim Storage of Higher Activity Waste Packages – Integrated Approach".

At Trawsfynydd and Hunterston A sites the strategy for storage of ILW is to encapsulate ILW within $3m^3$ containers or other packages suitable for eventual disposal and to transfer these packages to an on-site purpose-built shielded ILW store. At Hunterston A the store has been commissioned and is now operational with ILW packages present.

Based on good practice available at Hunterston A and Trawsfynydd the preferred option for ILW interim storage is:

- Shielded store to accommodate the identified packages of ILW,
  - $3m^3$ Drums for the storage of wet-solid ILW, and
  - $3m^3$ Boxes for the storage of solid ILW.

The main hazards associated with the ILWS are:

- Direct exposure of workers to radiation from waste packages in ILWS, and
- Internal exposure of workers from intake of radionuclides resulting from damaged waste packages in the ILWS.

The main premise of the ILWS is to segregate workers from the waste being stored and provide sufficient shielding to reduce doses to operators, on-site workers and members of the public. All measures in the design are geared towards segregation and maintaining shielding.

The ILWS is considered to meet ALARP requirements at a concept design level and is appropriate to be taken forward for the site specific stage. Further information is provided in the SWMS ALARP Topic Report [Ref-4]. The principles of ALARP will need to be applied during detailed design, to ensure the final design is fully compliant with UK regulatory expectations on ALARP.

## 18.12 Low Level Waste Processing

The SWMS has been designed to receive, sort, process/condition and / or store all solid and wet-solid waste streams resulting from ABWR operation as appropriate.

The assorted LLW solid waste is prepared and packaged for either off-site incineration, off-site compaction, off-site recycling (in the case of recyclable metals) or direct disposal.

The waste stream process flow diagrams for LLW and VLLW showing point of generation and subsequent routing through the SWMS is given in Figure 18.6-2 (VLLW and LLW).

An Integrated Waste Strategy (IWS) [Ref-20] appropriate to the GDA process has been produced which provides an overarching description of waste strategy. The IWS refers to and is supported by detailed strategy documents including a Radioactive Waste Management Arrangement document [Ref-18].

### 18.12.1 Brief Waste & System Descriptions

The Dry-Solid Waste Processing System comprises the SWF and two sub-systems that are located in the Rw/B. The sub-systems that enable SLLW to be transported to the SWF in a safe and contained package are:

(1) the LLW MMA, and

(2) the LCW Filter Packaging Room.

The purpose of the SWF is to process and consign the SLLW for disposal.

The intention is that all waste will be sorted and segregated at point of generation by carrying out monitoring measurements and will be labelled with appropriate data (point of arising, dose rate, activity etc.) to ensure traceability.

#### 18.12.1.1 LLW Marshalling and Monitoring Area

The LLW MMA is housed within the ground floor of the Rw/B. Its purpose it to receive solid waste from the Reactor Building (R/B), the Turbine Building (T/B), the Service Building (S/B) and the Rw/B in waste packages (drums, boxes, bags and wrapped items) and to monitor them (i.e. dose rate measurement for confirmatory check) for compliance with on-site transport limits, prior to transfer of the waste packages out of the controlled areas to the SWF.

The LLW MMA is not to be used as a store; waste is to be consigned on arrival where possible. Individual waste packages requiring palletisation may remain within the LLW MMA for a short time until other packages arrive to fill a pallet if such waste is expected in a reasonable timeframe (same day). This does not preclude partially loaded pallets from leaving the LLW MMA.

#### 18.12.1.2 Solid Waste Facility

All SLLW from locations across site will be consigned off-site through the SWF unless it is in a fit state for consignment direct from the arising facility such as THISOs containing WLLW. The majority of SLLW arising in the controlled areas exits through the LLW MMA, where it is consigned to the SWF.

The key principle of management of LLW for the UK ABWR is that waste is sorted and segregated at source as far as practicable in order that the waste can be disposed via the most appropriate route. The purpose of the SWF is to provide a centralised facility to consign efficiently waste for conditioning, treatment or disposal. The SWF achieves this by providing centralised storage of LLW that:

- Reduces the likelihood of accumulation of wastes in disparate parts of the site,
- Enables the site operator to optimise the number of shipments undertaken by co-processing similar wastes generated across the site for transfer or disposal,
- Allows for more effective accountancy of waste materials held by the site,
- Enables centralised facilities for waste characterisation (reducing the requirement for several systems being needed across the site),
- Enables dedicated facilities for undertaking quality checks on waste consignments sorted and segregated across the site, and
- Enables limited sorting activities for wastes that cannot be practicably sorted and packaged at source.

The purpose of the SWF is to receive pre-sorted bagged waste in:

- General purpose waste containers,
- 210 litre drums,
- Berglof boxes, and
- WB1 waste boxes.

The Berglofs and 210 litre drums provide good physical protection of the waste items as they are metal and provide additional protection when lidded from fire hazards. They also will provide enhanced containment over other packages if dropped.

The SWF has provision for:

- Limited sorting activities,
- Low force compaction,
- Assay of packages including soft packages, 210 litre drums, 500 litre drums and Berglof boxes,
- X-ray of packages to identify mis-consigned items (aerosols, sharps etc.) using an airport bag scanner type system,
- Addressing issues with non-compliant standard waste packages such as external contamination or difficulties with transport documentation,
- Inspection of waste packages,
- Waste storage on racks in the main body of the facility or in the Shielded Drum Store,
- Decay storage of BAC drums in a separate shielded room, and
- Limited re-packaging of waste.

It is expected that radioactive waste will be sent to the SWF from many locations across site. The majority of radioactive wastes will be packaged at source and passed via internal transfer routes to the LLW MMA in the Rw/B before dispatch to the SWF.

Expected waste streams are:

- THISO filled with grouted WLLW,
- Condensate Filter (CF) (these may be received in THISO containers or Half Height International Organization for Standardization (HHISO),
- Miscellaneous combustible waste,
- Mixed non-combustible waste,

- High Efficiency Particulate in Air (HEPA) filters,
- Metals,
- Bead Activated Carbon (BAC),
- Granulated Activated Carbon (GAC), and
- LCW filters in 500 litre drums.

If not dispatched directly from the T/B to LLWR, the CF Filters will be transported to the SWF in either THISO or HHISO containers ready for dispatch to the Low Level Waste Repository (LLWR). Waste received in the SWF is assumed to be stored and dispatched on a campaign basis with nine months storage and three months processing per annum. This provides a 'worst case' approach for concept design stage taking into account the inherent uncertainties in waste volumes, source terms and operational philosophy. For the purposes of GDA, waste will be stored on racks either in the main body of the facility or in the Shielded Drum Store until it is loaded into appropriate stillages and then placed into HHISO containers. BAC drums are placed in decay storage in a separate area to reach WAC for incineration if required before being placed in a HHISO for disposal.

The type of disposal container used depends on the waste being transported. TC01 containers are used for direct disposal wastes (non-recyclables / non-combustibles) and TC02 containers (re-usable) are used for transporting recyclable metals and combustibles.

Filled THISO / HHISO containers will be placed in the International Organization for Standardization (ISO) Marshalling Area to await transport to the LLWR along with fully grouted THISO containers from the WLLW Processing System in the Rw/B.

#### 18.12.1.3 LCW Filter Packaging Room

The LCW filters are backwashed automatically when the differential pressure rises to a set level. The operators can also initiate a manual wash of the LCW filters. The filters gradually deteriorate over a number of years to the point where backwashing no longer recovers the differential pressure. At this point in time the filters are exchanged for new elements. When filter elements require discharge, the entire bank of filter elements is replaced as a unit. It is feasible that filters could be changed out early to minimise the build-up of high levels of crud that cannot be removed by backwashing however for GDA it is assumed early change-out is not undertaken. After the vessel has been drained the filters are allowed to drain in place for a minimum of 24 hours before they are removed to minimise the drip hazard during movement. Filter changes take place in the LCW Vessel Cell.

Once the LCW filter vessel has been opened, the entire filter matrix is removed from the vessel as one unit and placed into a 500 litre drum, the plant design can also utilise smaller drums if required. The filter can then be grout encapsulated if required, the grout allowed to cure and the drum lid replaced and swabbed remotely. However, the normal operation will be to export filters out of the facility ungrouted. After swabbing and monitoring, the 500 litre drum will be lifted over a dwarf wall and placed inside a shielded overpack. The overpack lid is then fitted, though not bolted, and the overpack monitored on exit of the LCW Filter Cell. Once outside the cell the LCW overpack lid is manually bolted before the final package is exported through the LLW MMA. The entire removal process is designed to have as much remote operation as possible.

A gamma ray spectrometer and dose meter will be in place within the filter removal area to allow initial characterisation of the final package as a period of decay will be required before it can be disposed of as LLW. In all instances the LCW filter removal and transport method/route out of the Rw/B is identical.

Once the package has been removed from the LCW Filter Cell significantly reducing the dose rate, an operator/operators will enter and replace the filter seal. They will also remediate any contamination resulting from the filter change (e.g. drips) and swab and monitor the vessel and area. The waste (old seal etc.) will be removed from the cell.

The new filter will be assembled in the area outside the LCW Filter Cell on a trolley. The new filter Matrix will be moved across to the LCW filter vessel area and be positioned inside the prepared open LCW filter vessel. The LCW filter vessel lid will be lifted into place using the mono-rail hoist. It is assumed for purposes of concept design that the robot will be used to bolt the LCW filter vessel lid on to the required torque.

## 18.12.2 Safety Assessment

A hazard identification and analysis process has been followed for the SWF, LCW filter change process and the LLW MMA and the results integrated into the design of the facility in an iterative approach.

### 18.12.2.1 Methodology for LLW MMA Hazard Identification Gap Study

A HAZID study for the LLW MMA was undertaken in August 2016 and the hazards identified to workers and the public from this study have been collated into a preliminary fault schedule. The major fault groupings identified are summarised below:

- Loss of Containment / Spread of Contamination,
- External dose,
- Fire and Explosion,
- External Hazards,
- Environmental,
- Chemical and Toxicity,
- Contaminated Wound,
- Industrial, and
- Operational.

Bounding radiological faults and doses from normal operations have been assessed and are discussed in the SWMS ALARP Topic Report [Ref-4] and BSC for SWMS [Ref-3].

### 18.12.2.2 SWF Hazard Identification

A HAZID study for the SWF was undertaken in September 2016 and the hazards identified to workers and the public from this study have been collated into a Preliminary Fault Schedule. The major fault groupings identified are summarised below:

- Loss of containment/Spread of contamination,
- External Dose,
- Fire/Explosion,
- External Hazards,
- Environmental,
- Chemical and Toxicity,
- Contaminated Wound,
- Industrial, and
- Operational.

Bounding radiological faults and doses from normal operations have been assessed and are discussed in the SWMS ALARP Topic Report [Ref-4] and BSC for SWMS [Ref-3].

#### 18.12.2.3 Methodology for LCW Filter Change Process Hazard Identification

A HAZID study for the LCW filter was undertaken in September 2016 and the hazards identified to workers and the public from this study have been collated into a Preliminary Fault Schedule. The major fault groupings identified are summarised below:

- Loss of containment / Spread of contamination,
- External Dose,
- Contaminated Wound,
- Fire / Explosion,
- Environmental,
- Industrial, and
- Operations.

Bounding faults have been assessed and are discussed in the SWMS ALARP Topic Report [Ref-4] and BSC for SWMS [Ref-3].

#### 18.12.2.4 Normal Operations SLLW Processing System

The SLLW processing systems design reduces normal operational dose with use of shielding (with restricted personnel access) around wastes with elevated dose rates. The exact shielding requirements for the SLLW processing systems will need to be confirmed during detailed design. Doses from normal operations have been assessed and are discussed in the SWMS ALARP Topic Report [Ref-4] and BSC [Ref-3].

As far as is practicable, workers have been segregated from higher dose rate waste and potentially contaminated areas. All operations within SWF in the Shielded Drum Store are automated. The HHISO Marshalling Area is similarly shielded and entry is not required as operations within it can be carried out remotely. Entry to all of these areas is provided for maintenance purposes, or in the case of the HHISO filling area for operations, but is controlled via secure shield doors and entry requirements are minimised by design.

The BAC is stored in a separate room in the SWF that provides sufficient shielding to reduce dose rates outside the room to acceptable levels. The room is only used for storage of BAC so workers do not enter except for receipt or removal of waste. The BAC is LLW waste on arising and is being decay stored to meet incineration criteria when required.

The LLW MMA operating philosophy is to minimise/prevent the build-up of waste and therefore keep background dose rates as low as possible. This will in turn reduce dose uptake by operators working in the LLW MMA.

The LCW filter packaging and storage operations are carried out remotely to reduce exposure to operators.

It is concluded that doses during normal operations from the SLLW Processing Systems have been reduced in line with ALARP principles for concept design and that there are likely to be further opportunities during the next stage of design and subsequently during the site safety case development to reduce the doses from normal operations to ALARP. The concept design as developed for the SWF has not foreclosed any options for a licensee to be able to demonstrate compliance with the ALARP principle at the detailed design stage.

#### 18.12.2.5 Fault Conditions

From a facility ALARP consideration it is clear that the assessment of the bounding scenarios incur doses above the BSO for which mitigation, would be expected as a result of sound engineering design practices.

Even for those assessments that are below the BSO, it is a requirement for the designers to comply with ALARP. As such, consideration has been, and will continue to be, given to the provision of ALARP measures to protect the workers and public from radiological exposures arising from normal operations and fault conditions.

The assessments identified were deemed sufficient to bound the radiological consequences of a range of specific faults and form a reasonable basis for identifying safety requirements that the design must meet, such that consequences and risks are adequately controlled for concept design requirements.

**Categorisation and Classification:**

Based on the pessimistic worst-case bounding fault, the preliminary category of the safety function applicable is:

| **Bounding Faults in each Sub-System** | **Preliminary Safety Function Category (Unmitigated dose to Worker)** | **Preliminary Safety Function Category (Unmitigated dose to Public)** |
|---|---|---|
| LLW MMA | B | B |
| LCW Filter Packaging Room | B | B |
| SWF | B | C |

### 18.12.3 Claims and Arguments

This subsection describes how the SFCs for the LLW processing have been met, for more detailed information see the Basis of Safety Case for Solid Waste Processing [Ref-3]. For the majority of the SLLW processing, the classification of SSCs will be class 3, with appropriate safety measures incorporated into the design against the identified faults as required by the evaluation of unmitigated doses. The initial preliminary safety function category for unmitigated doses to worker and public for the LLW processing which is at concept design can be found in section 18.12.2.5.

SWMS SFC 4-13.1 to SWMS SFC 4-13.5 along with the relevant arguments, which are applicable to LLW as well as HLW, are described in Section 18.6.3.1.

One solid waste SFC is specific to the solid LLW, SWMS SFC 4-13.6 has been designated, arguments are presented below.

The demonstration that the SWF produces packages suitable for off-site transport to the appropriate nominated facility for incineration, recycling or direct disposal is provided by satisfying the following claim:

SWMS SFC 4-13.6: The SWF is required to process wastes into packages suitable for off-site transport to the appropriate nominated facility for incineration, recycling or direct disposal.

The argument underpinning this SFC is as follows:
A1 The current design of the SWF will provide for the processing of waste for disposal or further treatment.

The linkage to other PCSR chapter claims and arguments are described in section 18.6.3.2.

## 18.12.4 Assumptions, Limits and Condition for Operation

### 18.12.4.1 Assumptions

A number of working assumptions are made to demonstrate that the LLW processing facilities will achieve all safety claims and that nuclear safety aspects have been adequately considered in the GDA process.

The key working assumptions for the LLW processing facilities include:

**(1) Assumptions for the LLW MMA**

- The LLW MMA is intended only for transitory storage of packages sufficient to complete administrative procedures and HP monitoring prior to export. The intention is that all received wastes will be re-exported for onwards treatment processing at the earliest practicable opportunity, and
- The LLW MMA is designed with a pallet racking system for the temporary storage of a nominal 36 pallets (144 x 200 litre drum equivalent or 72 x Berglof boxes).

**(2) Assumptions for LCW Filter Packaging Room**

- Prior to disposal of the filter elements at the end of their useful life, they will be backwashed to remove as much crud as possible to reduce the activity on the filters for disposal,
- Failure to backwash the LCW filter vessel (or poor backwash efficiency) results in a waste form that may not be compliant with LLW disposal,
- The LCW Filter Packaging Room will have sufficient shielding to process LCW filter at activities up to and including the design basis source term values quoted in the end user source term, and
- Filter transport vehicle will provide sufficient shielding to transport LCW filters at activities up to and including the design basis source term values quoted in the end user source term.

**(3) Assumptions for the SWF**

- All waste packages received for import to the SWF will be monitored and confirmed as being free from contamination prior to transfer to the SWF,
- Waste will be received at the SWF pre-sorted and segregated at source as far as practicable,
- The SWF will receive THISO filled with grouted WLLW, CF filters in THISO/HHISO, miscellaneous combustible waste, mixed non-combustible waste, HEPA filters, BAC and GAC, LCW filters grouted or ungrouted in 500 litre drums, Laundry Drain Pre-filters,
- The SWF will have sufficient shielding to handle and store expected solid LLW waste streams at activities up to and including the design basis source term values quoted in the end user source term,
- The SWF will operate on a campaign basis of nine months receipt and three months processing in a year,
- All SLLW final characterisation and dispatch for off-site processing and disposal will occur at the SWF,
- The SWF is required to have a waste tracking system that is sufficiently robust for SWF operations as per Licence Condition 4,
- LCW filters received for import to the SWF will be contained within a shielded overpack,
- Storage of LCW filters will require shielded storage facilities,
- The SWF will be sized to store one year of SLLW arisings, and

- The funded decommissioning programme base case [Ref-32] sets out a number of assumptions regarding the means by which waste may be managed and disposed of and decommissioning carried out by a new nuclear power station future licensee. These assumptions define a generic lifecycle plan for new nuclear power stations known as the "Base Case". The Base Case is built on existing policy and regulatory requirements; although it also makes additional assumptions. The Base Case is primarily written to ensure sufficient financial provision is made to cover liabilities it also provides each future licensee basic assumptions on which radioactive waste management, decommissioning and spent fuel management strategies can be developed.

These assumptions are detailed in the BSC for Solid Radioactive Waste Management System [Ref-3].

#### 18.12.4.2 Limits and Conditions for Operation - SWF, LCW Filter and LLW MMA

The following LCOs are identified for SLLW processing in GDA phase, and these LCOs are also provided in the Generic Technical Specification (GTS) [Ref-29] and the Basis of Safety Case for SWMS [Ref-3].

- The LLW packages must conform with LLWR conditions for acceptance and relevant transport regulations.

### 18.12.5 Summary of ALARP Justification for LLW Processing

#### 18.12.5.1 Solid Waste Facility (including LLW MMA)

The requirement for a dedicated SWF resulted from the Site Wide Low Level Waste Strategy ALARP Optioneering Study. This was undertaken to review the management of the various SLLW waste streams across site in a wider context. The purpose of this was to explore co-ordinated approaches across site, based on output from the series of ALARP optioneering exercises undertaken for individual SLLW waste streams. This study defined several requirements for a dedicated SWF relating to storage capacity, facilities for sorting, repackaging, characterisation and waste quality checks.

The SWF is designed in line with UK good practice for management of radioactive wastes and adopts the strategies and key principles specified in The UK Strategy for the Management of Solid Low Level Radioactive Waste from the Nuclear Industry [Ref-25].

The SWF is designed to package, consign and temporarily store solid LLW from all waste streams. The dose rates of these packages vary and can include packages with elevated dose rates. The storage and handling operations in SWF are therefore designed to ensure that:

- Waste packages with elevated dose rates are handled, loaded and transferred using remotely operated equipment,
- Waste packages with elevated dose rates are stored in dedicated shielded storage areas, and
- Low activity waste is handled by both remote and manual means.

It is assumed in the GDA design that the majority of LLW received by the SWF is routed through the LLW MMA in the Rw/B. The purpose of the LLW MMA is to facilitate efficient transfer of waste from the Rw/B including, verification of appropriate paperwork, radiation and contamination surveys of exported packages and palletising of waste packages prior to export.

Segregation at source as far as practicable and making maximum use of all available waste routes was a common theme in consideration of current nuclear site LLW strategies and government policy. It is clear that in order to keep all options open to the future licensee and enable the most efficient use of disposal options, a solid waste facility that receives all SLLW and is as flexible as possible in sorting and consigning

SLLW by available disposal options not just as a bulk waste stream is required (e.g. if a consignment of combustible waste does not comply with incinerator WAC, then other disposal options will need to be considered).

Optioneering identified several waste streams being generated across site that could make use of low force compaction. Consideration has been given to providing multiple low force compactors across site and use of a mobile compactor unit to compact these wastes at source. However, due to potential volume of waste identified in GDA, it is concluded that this compaction should be undertaken in the SWF. It is assumed that all super-compaction will be undertaken at an off-site facility.

All waste streams require assay, consideration was given to having multiple assay equipment at various waste source locations across site. It was identified that many of the locations may have background dose rates that mean that assay is difficult or impossible. It was concluded that having a shielded assay suite in the SWF to assay all SLLW would be the preferred option; this also has the benefit of reducing maintenance and calibration requirements across site. Appropriate monitoring for transport across site will still take place at source.

The main hazards associated with the activities undertaken in the SWF are:

- Direct exposure of workers from radiation to waste packages with elevated dose rates being handled and transferred,
- Spread of contamination from opening of waste containers in the waste compaction and repackaging areas,
- Internal exposure from opening of waste containers in the waste compaction and repackaging areas, and
- Internal exposure of workers from intake of radionuclides from damaged/breached packages of waste.

Suitable shielding thickness has been provided to restrict area doses outside of the storage areas. The movement of packages is carried out using remotely controlled cranes or fork lift trucks.

Areas where workers are opening packages for sorting, re-packing or assay will be designated as Airborne Contamination Controlled Areas. Suitable ventilation will be provided in these areas as well as suitable and sufficient control measures to reduce the potential for internal exposure to workers.

The SWF is considered to meet ALARP requirements at a concept design level and is appropriate to be taken forward for the site specific stage. Further information is provided in the SWMS ALARP Topic Report [Ref-4].

### 18.12.5.2 LCW Filter Packaging

After consideration of OPEX and good practice, a number of options were considered for the use of LCW filters which assessed the filter medium used, the design of the filter and management of the activity of the filters. Options were explored regarding whether filters would be removed individually or as an array. These options included:

Option 1: LCW Hollow Fibre Filter (HFF) replaced by powder resin pre-coat filter

Option 6: Type New (800 mm/1000 mm long) LCW HFF removed remotely as a matrix and placed into 500 litre drum.

Option 7: Type B LCW HFF placed individually into 200 litre drums.

Option 8: LCW HFF Option 8: Type B LCW HFF removed and individually placed into a 500 litre drum.

Option 9: Type B LCW HFF remotely removed as a matrix and placed into a 500 litre drum.

Option 11: Manage filters such that they remain LLW at discharge packed into 200 litre drum and grouted, dried or encapsulated in another way.

The optioneering exercise concluded that Option 6, which ranked second overall and was the highest scoring option for disposal of LCW HFF; was therefore the preferred option for this study. This was after "Demonstration of BAT" (XE-GD-0097) selected HFF over powder resin on the basis of water quality and waste minimisation.

The preferred option was a re-design of the LCW HFF elements to reduce their length to fit into a standard waste container without the requirement for cutting or bending. When filter elements require discharge, either after a fixed service life or after detection of out of specification treated water, the entire bank of filter elements are lifted out of the vessel in one go using a retaining plate and placed into a 500 litre drum.

The 500 litre drums are grouted, if required, after filter placement in the drum and sent to the SWF for decay storage. The waste will require a shielded over pack for transport to the SWF. After a period of decay the LCW filter will be disposed of as LLW.

Throughout the optioneering workshop, the advantages and disadvantages of various package types were discussed. These were:

- 200 litre drums have the benefit of being suited to disposal as LLW with a reasonable packing efficiency, but it's lack of long term robustness and requirement for over packing makes it less suitable for ILW disposal, and
- 500 litre drums are more suited to long term storage and disposal as ILW; but the packing efficiency is poor, especially for disposal as LLW.

Non-standard packages may also be considered by future licensee but could not be considered at GDA due to GDA timescales and constraints.

The main hazards associated with the changing of the LCW filters are:

- Direct exposure of workers to radiation from proximity to LCW filters and LCW filter vessels during changing operations,
- Spread of contamination from LCW filters into the vessel area during transfer to drum,
- Internal exposure of workers from intake of radionuclides resulting from dropped LCW filters, and
- Internal exposure to workers and other personnel from dispersion of contamination in the event of a fire.

The ALARP optioneering exercise for the LCW filter handling process has initiated design changes to reduce risks. An assessment of the incorporation of ALARP principles at each stage of design through both optioneering and design development and the hazards arising in normal and fault conditions has been undertaken.

It is concluded that the design of the LCW filter exchange system meets the criteria for ALARP at a concept design level. In addition, options have not been closed to the future licensee to further reduce the hazards posed by the LCW filter handling system to ALARP at detailed design. Further information is provided in the SWMS ALARP Topic Report [Ref-4].

# 18.13 Transportation of Waste

## 18.13.1 Brief Waste & System Descriptions

Operation of the new UK ABWR plant will require waste handling facilities to safely deal with routine operational and maintenance waste arisings as well as end-of life decommissioning wastes. This in turn requires the on-site movement of packaged and conditioned wastes between the facility of origin and the waste processing facilities, and onward transfer of conditioned waste streams to the waste store.

### 18.13.1.1. Low Level Waste

SLLW may be packaged in 210 litre drums or Berglof boxes, palletised and moved around site using a conventional flatbed truck or trailer. In addition some waste may be moved in general purpose waste containers. Items too large to be packed into drums or Berglofs will be packed into WB-1 boxes which will also be delivered by flatbed truck or trailer.

Encapsulated WLLW in THISO containers and non-encapsulated solid LLW in HHISO containers will be loaded onto a container trailer with ISO locating/fixing points for onsite movements. It is anticipated that a heavy duty trailer to an off-the-shelf design would be acquired. Offsite movements would employ a conventional flatbed trailer with ISO container locating dowels.

Lifting will be undertaken using a heavy duty forklift truck.

The LCW filters are transferred to the SWF in a 500 litre drum within a substantial steel overpack on an automated guided vehicle. This is a different vehicle and overpack from that used to move the WILW.

### 18.13.1.2. Intermediate Level Waste

Encapsulated wet-solid ILW will be moved around site within a shielded overpack mounted on a heavy duty self-propelled vehicle, the Cross Site Transporter Vehicle (XSTV).

The reference design is a pedestrian controlled self-propelled vehicle with a diesel power pack, hydraulic suspension, multi-wheel steering and hydrostatic drive. Diesel power will be employed in outside areas between buildings. Guidance will be a combination of manual control and automated guidance immediately outside and within the loading bays to ensure consistent alignment of the shielded overpack under the facility loading bay gamma gate for loading and unloading the payload. The shielded overpack is secured to the XSTV via turn-buckles.

In order to avoid exhaust fumes within confined spaces, the diesel engine is isolated outside the loading bay prior to entry. The overpack lid is unlocked and umbilical power and control cables are connected to provide power to the XSTV and to control its movement. The XSTV is then moved into the building under automated control and the loading bay door closed.

The hydraulic suspension allows XSTV to be raised and lowered to allow the shielded overpack to engage fully with the gamma gate to prevent shine paths.

The operator then withdraws from the loading bay and locks the loading bay door closed to allow loading to proceed. After loading, the operator re-enters the loading bay and drives the XSTV back outside where the umbilical is disconnected, the overpack lid is re-secured and the diesel engine is restarted to drive the XSTV to the ILWS for unloading.

At the ILWS a similar sequence is followed to unload the payload.

The shielded overpack is removable to allow the XSTV to be maintained. The XSTV is expected to have a nominal travelling speed of less than 1 mph.

The XSTV control systems interface with the facility control systems via the umbilical cable; this provides control interlocking with the facility gamma gate control systems that will:

- Ensure personnel exit from the loading bay before the facility gamma gate can be opened,
- Ensure that the XSTV is correctly positioned and fully engaged with the facility gamma gate shielding before the facility gamma gate operational sequence is initiated,
- Maintain full engagement with the facility gamma gate shielding if the shielded overpack lid has been removed or the facility gamma gate is open, and
- Ensure that the XSTV does not move when engaged with the facility gamma gate.

The XSTV will be parked indoors when not in use, either left within one of the facility loading bays or returned empty to its maintenance facility.

#### 18.13.1.3. High Level Waste

The HLW processing incorporates two transport vehicles, the Low Profile Transporter (LPT) and the cask transporter.

The low profile transporter will be used to move the transfer cask containing HLW into and out of the reactor building at the access enclosure and truck bay. LPT is non-powered, rolling, low profile platform used to move the transfer cask on installed rails. The LPT features a cylindrical locking system which will prevent the cask from tipping during transfer.

The nuclear safety functions for the LPT are:

- Handling / retrievability: the LPT will be designed with sufficient structural integrity to prevent cask drop or topple in any credible fault or hazard scenario (including a seismic hazard). No claims will be placed on being able to use the LPT during or after a hazard however.

The cask transporter will be used to transfer the transfer cask from the reactor building to the HLW decay storage facility or vice versa and place it onto the mating device. The cask transporter will be a multi-wheeled or tracked, multi-directional vehicle capable of handling loaded transfer/storage casks.

The nuclear safety functions for the Cask Transporter are:

- Handling: the cask transporter features a gantry crane, and double wire hoist with interlocks which connect securely to the transfer cask connections. The cask transporter will feature appropriate valve configurations and other equipment such that the cask will be securely held during loss of electrical or hydraulic power. The cask transporter structural integrity will be appropriately qualified against potential events/loads such that failure or loss of control of the transfer cask is prevented. Anti-rollback devices will also be provided to ensure that control of the transfer cask is maintained. Emergency stop push buttons will be provided around the transporter to mitigate against any loss of control.

The cask transporter does not enter R/B to prevent the possible hazards initiated by itself such as fire and collision.

### 18.13.2 Assumptions, Limits and Conditions for Operation

The choice of cross site transportation is very site specific and this could be road or rail and relies on a transport safety case, therefore specific assumptions, limits and conditions for operation are yet to be defined.

# 18.14 Radioactive Waste Management Arrangements

## 18.14.1 Records Management

Recording the operation and performance of the radioactive waste management system will generate a large quantity of records, not least from the monitoring, sampling and measurement requirements of the various sub-systems.

Adequate records will need to be kept during the whole management cycle. In particular RWM require that records are kept to ensure that the history of the wastes and specific package properties are preserved to inform their disposability and that their long term evolving properties will remain within acceptable limits.

Documents and records will be maintained in a secure and accessible form for an appropriate period of time such that they will be available to demonstrate the ongoing and historical safe management of radioactive waste from arising to discharge. The future licensee will be responsible for putting in place a quality assurance, knowledge and document management system that ensures all relevant records generated during construction, commissioning and operation are available to support decommissioning waste management activities.

### 18.14.1.1. Waste Tracking and Management System

The UK ABWR site will feature a radioactive waste tracking system. The waste tracking system will be capable of tracking radioactive waste streams, containers used for on-site transfer of waste between facility and final waste disposal packages throughout the site.

The waste treatment and storage facilities described in this section are based on the assumption that all waste packages are marked with a unique alphanumeric characters identifier. The alphanumeric characters are machine optically readable. For final waste disposal packages the alphanumeric characters are indelibly marked on the containers and are suitable for the lifetime use of the package.

Part of the alphanumeric characters provides a means of identifying the type of waste package and its contents.

The waste tracking system can:

- Track empty waste packing containers within the radioactive waste facilities from the point of entry into each facility, i.e. the waste package has been logged onto the system,
- Track filled waste packing containers within the ILWS,
- Track empty and filled packing containers within the processing facility until the point of exit,
- Provide information of filled LLW & ILW packages. The LLW and ILW waste information must include but not be limited to the following,
    - Broad description of the waste material, i.e. metallic solids, filters, contaminated personal protective equipment, etc.,
    - Radioactivity level in Becquerels,
    - Type of radioactive isotopes present, and
    - A link or data to the container manufacturing record.

### 18.14.1.2. Quality Assurance (QA) Records

Traceable QA records associated with each individual waste package (210 litre drum, Berglof box, WB1 waste box, TC01 HHISO, TC02 HHISO and TCO3 THISO, 3m$^3$ drum, 3m$^3$ box) will be assembled and retained throughout the manufacturing, assembly, loading, transfer, receipt / storage, periodic inspection and final export from the relevant facility.

Typically individual waste package QA records will be appropriate to satisfy site licence conditions, environmental permit requirements and disposal facility acceptance criteria. The records include, but are not limited to, the followings:

- Unique package identification number,
- Unique stillage reference numbers where appropriate,
- Description of waste contents (including quantity where appropriate),
- Source of waste,
- Total package mass,
- Radiological information (contents radioactivity, surface contamination levels and final Assay records),
- Supplier Certificate of Conformity, and
- Details of any periodic inspections during the interim storage period.

It is the responsibility of the consigning, donor facility to ensure that all required quality data is available and that waste packages and their transfer between facilities will be accepted by the receiving facility and compliant with site procedures. Non-compliant packages (non-compliance includes missing quality data) will be returned to the consigning facility.

Logging of the waste package locations will be performed by the facility operator. On receipt at the facility the package unique number will be read from the package using an Optical Character Recognition handheld bar code reader. This number will then be used to confirm that the correct QA records accompany the waste package from the donor facility. If the QA records are not available (e.g. incomplete data on database, illegible or missing label) then the package will be returned to the donor facility. In the exceptional circumstances that the consigning facility is unable to accept the returned waste package, the following facilities may be used for prompt management of the suspect package:

- The SLLW glovebox inspection unit described in Section 18.12, and
- The ILWS quarantine area identified in Section 18.11. Quarantined packages will be assessed and managed on a case by case basis prior to dispatch from the ILWS.

The package identification and location within the site facilities will be recorded in an electronic database as part of the site wide waste tracking system. The site waste tracking system will keep the QA records from the donor facilities along with the records of the package storage location until the waste is dispatched from site. Records of all waste packages must be retained for the life of the plant or until the waste is received into the appropriate disposal facility, whichever is longer.

### 18.14.2 Change Control

The change control management system to be used for the radioactive waste facilities will be based on the safety management arrangements defined in PCSR Chapter 4.

# 18.15 Assumptions, Limits and Conditions for Operation

## 18.15.1 Purpose

One purpose of this generic PCSR is to identify constraints that must be applied by a future licensee of a UK ABWR plant to ensure safety during normal operation, fault and accident conditions. This applies to the scope of GDA, and primarily Class 1 and 2 for SSCs. The general principles are defined in Generic PCSR Chapter 4, section 4.12.

This section provides a summary of the Assumptions and LCOs that apply specifically to the scope of this chapter of the PCSR.

## 18.15.2 LCOs specified for Radioactive Waste Processing

Limits and Conditions for Operation (LCOs) for ;

- Liquid Waste Processing is covered in sub-section 18.5.4 in this chapter,
- Wet-solid waste processing is covered in sub-section 18.6.4 in this chapter,
- OG system is covered in sub-section 18.7.4 in this chapter,
- Tank Vent Treatment is covered in sub-section 18.9.4 in this chapter,
- HVAC system is covered in sub-section 16.5 “Heating Ventilating and Air Conditioning System” in PCSR Chapter.16 “Auxiliary Systems”,
- Intermediate Level Waste Store is covered in sub-sections 18.11.4 in this chapter, and
- Low Level Waste Processing is covered in sub-sections 18.12.4 in this chapter.

## 18.15.3 Assumptions specified for Radioactive Waste Processing

Assumptions for ;

- Liquid Waste Processing is covered in sub-section 18.5.4 in this chapter,
- Wet-solid processing is covered in sub-section 18.6.4 in this chapter,
- OG system is covered in sub-section 18.7.4 in this chapter,
- Tank Vent Treatment is covered in sub-section 18.9.4 in this chapter,
- HVAC system is covered in sub-section 16.5 “Heating Ventilating and Air Conditioning System” in PCSR Chapter.16 “Auxiliary Systems”,
- High Level Waste Processing is covered in sub-sections 18.10.4 in this chapter,
- Intermediate Level Waste Store is covered in sub-sections 18.11.4 in this chapter, and
- Low Level Waste Processing is covered in sub-sections 18.12.4 in this chapter.

# 18.16 Summary of ALARP Justification

This section presents a high level overview of how the ALARP principle has been applied for radioactive waste management and how this contributes to the overall ALARP argument for the UK ABWR.

Generic PCSR Chapter 28 (ALARP Evaluation) presents the high level approach taken for demonstrating ALARP across all aspects of the design and operation. It presents an overview of how the UK ABWR design has evolved, the further options that have been considered across all technical areas resulting in a number of design changes and how these contribute to the overall ALARP case. The approach to undertaking ALARP Assessment during GDA is described in the GDA ALARP Methodology [Ref-14] and Safety Case Development Manual [Ref-15]. ALARP assessments have been carried out for the all of the gaseous [Ref-23], solid [Ref-4] and liquid [Ref-2] wastes that can be generated and summaries for individual waste streams and where a site wide ALARP assessment has been carried out can be found in sections 18.5.5, 18.6.5, 18.7.5, 18.8.5, 18.9.5, 18.10.5, 18.11.5 and 18.12.5.

The summaries show that the main design objectives associated with radioactive waste management in UK ABWR are mitigated by ensuring:

- Minimisation of the amount of waste,
- Risks to the public and workers are As Low As Reasonably Practicable (ALARP),
- Minimisation of discharges into the environment, and
- All wastes are processed, stored safety and are disposed of appropriately.

The waste hierarchy has been used in order to minimise the amount of wastes generated by the UK ABWR' however, waste will still be generated. Therefore the designs of the radioactive waste management systems for UK ABWR are based on UK and international good practice. The objective of radioactive waste management is to concentrate and contain the waste as much as practicable, in such a way as to ensure control and therefore protect the public and workforce.

The main hazards to the public and work force are from direct and internal exposure to radiation at any stage in the waste handling and storage processes. In addition to designing all radioactive waste management systems according to international good practice, a large number of options were investigated that might further reduce risk, particularly with relation to preventing loss of containment. These options included:

- Options for liquid waste management to ensure the wastes are segregated to make treatment efficient and to re-use as much effluent as possible to reduce the amount discharges to the environment, whilst ensuring doses are ALARP. Key optioneering has resulted in
  - Identification no man access cells for tanks for that higher activity wastes and so far as is reasonably practicable maintainable items are in a low-dose rate area. For more details see section 18.5.5 and [Ref-2], and
  - Spent sludge pipework is routed in shielded secondary containment. For more details see section 18.5.5 and [Ref-2].

- Options for gaseous waste has resulted in a number of safety improvements, such as:
  - Wastes containing higher activity are in tanks are supported by a Tank Vent Treatment system in order to minimise the potential for airborne contamination. For more details see section 18.9.5, and

- The Off-Gas system provides the automatic isolation system to minimise public dose in the event of OG containment failure, and to prevent hydrogen combustion in the event of OG Recombiner failure. For more detail see section 18.7.5.

The HVAC system design is based upon the assumption that the possibility of airborne contamination has been minimised at source by appropriate design, operating procedures, and maintenance procedures. In addition to multiple SFCs for the control of radioactive material and waste, the design ensures, so far as is reasonably practicable, that radioactive material and radioactive waste on the site is at all times adequately contained so that it cannot leak or otherwise escape. Notwithstanding this, there remains a potential risk associated with radioactive material being present within the facilities and therefore airborne radioactive materials (e.g. gases or contamination) need to be appropriately managed.

The summary of ALARP justification for the HVAC system is covered in sub-section 16.5 Heating Ventilating and Air Conditioning System in PCSR Ch.16 Auxiliary Systems and related BSC on HVAC system [Ref-8], section 3.9 ALARP Justification.

- Options for solid waste management from generation to disposal, which have included,
  - site wide ALARP assessments resulting in co-location of the WILW and WLLW solidification processes into the Radwaste Building in order to minimise transfer distances. For more details see section 18.6.5,
  - Optioneering identified several waste streams being generated across the site that could make use of low force compaction and require a variety of assay equipment, which needs to be located in a low dose environment to ensure accurate measurements. This concluded that it is appropriate to have a single solid waste facility. For more details see section 18.12.5, and
  - Where waste have to be stored on site, the storage design has been based on ensuring that the wastes being stored provide sufficient shielding to reduce doses, packages remain safe for greater than the expected storage period and where possible waste is placed into the final disposal package as soon as practicable. For more details see section 18.11.5.

As a result of evaluating these options a number of changes to the radioactive waste management systems in the UK ABWR have been considered and taken forward.

- OG system design
  In case of OG pipework or component containment failure including Charcoal Adsorber break, the unmitigated off-site dose is expected to exceed the BSO (0.01 mSv) after a minimum time of 8 hours.
  Hitachi-GE proposes the following design change from Japanese Reference Plant Design:
  - Additional valves and interlocks
  - Design change of detection system in OG system component area

- Radioactive Waste Optimisation
  Hitachi-GE has identified the gap between UK RGP and Japanese practice regarding the design philosophy for chemical/process engineering approach in UK.
  This has resulted in design change for liquid and solid radioactive waste systems as the UK segregation criteria is different to Japan and therefore the effluent treatment approach and corresponding configuration have been impacted.

These changes are associated with UK government waste policies and the waste categorisation and disposal routes being different in the UK to other countries that currently have a BWR or ABWR.

The design of the radioactive waste management systems follows UK and international good practice and, following systematic and comprehensive options studies, all reasonably practicable risk reduction measures have been adopted. The risks from the radioactive waste management systems are therefore ALARP.

## 18.17 Conclusion

This Chapter of the PCSR demonstrates that the radioactive waste management systems presented within GDA reduce risks to ALARP, or shows that they are capable of being reduced to ALARP. The waste has been minimised as described in GEP Demonstration of BAT [Ref-12]. The waste streams are integrated such that they include all wastes arising from the UK ABWR expected over the full lifecycle of all the facilities, and take into account the interdependencies between waste streams, processes, discharges, off-site disposal to ensure an optimum waste management process is delivered. The radioactive waste management system is part of a series of strategies, which are integrated with other strategies such as decommissioning, as well as being consistent with government policy.

The last full review of Government policy on radioactive waste was in 1994/95 and the conclusions were set out in "*Review of Radioactive Waste Management Policy: Final Conclusions, (Cm 2919)*", *Her Majesty's Stationery Office, July 1995.*

The key principles from this policy are:

- Radioactive wastes should not be unnecessarily created,
- When wastes are created they should be safely and appropriately managed and treated, and
- Wastes should be safely disposed of at appropriate times and in appropriate ways.

Hitachi-GE's radioactive waste strategy demonstrates that it has done everything possible (considering proportionality) to:

- Prevent and minimise (in terms of radioactivity) the creation of radioactive waste,
- Minimise (in terms of radioactivity) discharges of gaseous and aqueous radioactive wastes,
- Minimise the impact of those discharges on people, and adequately protect other species,
- Minimise (in terms of mass and volume) solid and non-aqueous liquid radioactive wastes and spent fuel, and
- Select the optimal management and disposal routes, in ways which protect the public, workforce and the environment.

The designs of the majority of the radioactive waste management systems are at concept design level, which aligns with regulatory guidance for GDA, and are largely based on proven technology. However, the concept designs are sufficiently developed to enable a high level assessment of the risks associated with radioactive waste operations. Additional risk reduction measures have been introduced (in comparison with the J-ABWR design) in response to safety assessments undertaken in GDA, and these include changes to the Off-gas system design to improve protection in fault scenarios.
There have also been changes to the treatment of liquid and solid wastes compared to the process used in J-ABWR. For example, where practicable, wastes are promptly packaged directly into the disposal packages and all wastes can be disposed of in the UK. These changes are primarily associated with UK government waste policies and differences in the waste categorisation and disposal routes in the UK compared with other countries that currently have a BWR or ABWR.

The safety cases for radioactive waste management, decommissioning and Spent Fuel Interim Storage (SFIS) collectively identify the inventory of all the lifetime liabilities and describe the means of managing each waste stream from generation to disposal as well as routine discharges of liquid and gaseous radioactive wastes.

Gaseous and liquid radioactive wastes are safely processed in order to ensure discharge to the environment. The proposed annual gaseous and liquid discharge limits for UK ABWR are consistent with guidance from the Environment Agency (EA). Both the gaseous and liquid discharges from the UK ABWR should not exceed those of comparable power stations across the world. Both gaseous and liquid discharges have been considered in this PCSR and the Generic Environmental Permit (GEP) documentation produced for GDA.

The anticipated timescales for the management of Intermediate Level Waste (ILW) and High Level Waste (HLW) extend after the reactor has ceased operations. Hitachi-GE ensures safety at all times from production to disposal. This includes the intermediate steps e.g. interim storage, within the appropriate timescales e.g. ensuring safety at all times until disposal. The Higher Activity Wastes (HAW) i.e. ILW (plus HLW) are stored in accordance with good engineering practice and in accordance with the principle of passive safety. This is to ensure continued safe interim storage, processing of the waste into a form suitable for transportation (if required), transportation to and storage in the GDF. The generation of HAW, its safe management and subsequent treatment is such that a disposability assessment concludes that the HAW could be disposed of in the GDF.

The generation of Low Level Waste (LLW) and Very Low Level Waste (VLLW) is such that these can be processed and will meet the relevant waste acceptance criteria issued by the licenced disposal sites in the UK to ensure prompt disposal after generation.

This PCSR concludes that the radioactive waste management systems design and their safety justifications have been developed to a level of detail that is appropriate for GDA. However, it is acknowledged that further work will be required post-GDA to develop the design and fully incorporate site-specific aspects.

Work to underpin the safety case for radioactive waste management will continue during development of the detailed system design that will be undertaken at the site specific stage. The final position for GDA is presented in this Chapter and future updates as the design progresses will be presented in a site-specific safety case. This work will be the responsibility of any future licensee and operator.

This chapter and supporting documentation provides a basis for a potential UK ABWR future licensee to further develop the radioactive waste management systems capability.

## 18.18 References

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# Appendix A : Safety Functional Claims Table

## Liquid Waste Processing

| | Top Claim for LWMS | | | | | | Safety Functional Claims for LWMS (SFC) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fundamental Safety Function (FSF) | | High Level Safety Function (HLSF) | | Fault Schedule (Bounding Fault) | | | | | | |
| | PCSR Ch.5 Section 6 Table 5.6-1: High Level Safety Functions in UK ABWR | | PCSR Ch.5 Section 6 Table 5.6-1: High level Safety Functions in UK ABWR | | Topic Report on Fault Assessment Table.4.2-1 Fault Schedule [Ref-22] | | State | Claim ID | SFC Contents | Cat | Class |
| 1 | 4 | Confinement / Containment of Radioactive Materials | 4-12 | Functions to store radioactive materials as liquid wastes | - | No claim | Normal Conditions | LWMS SFC 4-12.1 | The total radioactivity in liquid discharges to the environment from the LWMS will be minimised. | (*) | (*) |
| 2 | 4 | Confinement / Containment of Radioactive Materials | 4-12 | Functions to store radioactive materials as liquid wastes | - | No claim | Normal Conditions | LWMS SFC 4-12.2 | Total liquid radioactive waste volumes from UK ABWR operation will be minimised | (*) | (*) |
| 3 | 4 | Confinement / Containment of Radioactive Materials | 4-12 | Functions to store radioactive materials as liquid wastes | - | No claim | Normal Conditions | LWMS SFC 4-12.3 | The LWMS facilities shall be designed to ensure that doses to both the workers and the public from normal operation of the UK ABWR LWMS are ALARP. | (*) | (*) |
| 4 | 4 | Confinement / Containment of Radioactive Materials | 4-12 | Functions to store radioactive materials as liquid wastes | - | No claim | Normal Conditions | LWMS SFC 4-12.4 | The creation, management and disposal of radioactive waste will be optimised through the use of BAT. | (*) | (*) |
| 5 | 4 | Confinement / Containment of Radioactive Materials | 4-12 | Functions to store radioactive materials as liquid wastes | - | No claim | Normal Conditions | LWMS SFC 4-12.5 | Appropriate monitoring, measuring and sampling equipment will be provided to confirm and record that waste effluent meets relevant Waste Acceptance or Discharge Criteria. | (*) | (*) |
| 6 | 4 | Confinement / Containment of Radioactive Materials | 4-12 | Functions to store radioactive materials as liquid wastes | - | No claim | Normal Conditions | LWMS SFC 4-12.6 | The LWMS facilities shall be designed to ensure that doses to public and workers in faults are ALARP and within limits and targets given in PCSR Chapter 5 General Design Aspects, section 5.5: Definition of Design Basis Faults and Beyond Design Basis Faults. | (*) | (*) |
| 7 | 4 | Confinement / Containment of Radioactive Materials | 4-12 | Functions to store radioactive materials as liquid wastes | - | No claim | Normal Conditions | LWMS SFC 4-12.7 | The LWMS facilities shall be designed to provide sufficient capacity to process liquid wastes for normal operation, start-up, shut-down, outages and design basis faults. | (*) | (*) |
| 8 | 4 | Confinement / Containment of Radioactive Materials | 4-12 | Functions to store radioactive materials as liquid wastes | - | No claim | Normal Conditions | LWMS SFC 5-9.1 | The LCW and HCW systems treated effluent shall meet the re-use criteria specified in the Water Quality Specification [Ref-10]. | (*) | (*) |

(*) For the majority of the LWMS, the safety category of function will be category C and the classification of SSCs will be class 3, with appropriate safety measures incorporated into the design against the identified faults as required by the evaluation of unmitigated doses. The initial preliminary safety function category for unmitigated dose to worker and public for the LWMS which are at concept design can be found in section 18.5.2.3.

**Off-gas System**

| | Top Claim for OG | | | | | | Safety Functional Claims for OG (SFC) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fundamental Safety Function (FSF) | | High Level Safety Function (HLSF) | | Fault Schedule (Bounding Fault) | | | | | | |
| | PCSR Ch.5 Section 6 Table 5.6-1: High Level Safety Functions in UK ABWR | | PCSR Ch.5 Section 6 Table 5.6-1: High level Safety Functions in UK ABWR | | Topic Report on Fault Assessment Table.4.2-1 Fault Schedule [Ref-22] | | State | Claim ID | SFC Contents | Cat | Class |
| 1 | 4 | Confinement / Containment of Radioactive Materials | 4-11 | Functions to store radioactive materials as gaseous wastes | - | No claim | Normal Conditions | OG SFC 4-11.1 | The OG minimises the release of radioactivity to the environment during the start-up, power and shutdown operations. | C | 3 |
| 2 | 4 | Confinement / Containment of Radioactive Materials | 4-7 | Functions to confine radioactive materials, shield radiation, and reduce radioactive release | - | No claim | Normal Conditions | OG SFC 4-7.1 | The OG minimises the dose to worker during normal conditions. | B/C | 2/3 |
| 3 | 4 | Confinement / Containment of Radioactive Materials | 4-11 | Functions to store radioactive materials as gaseous wastes | - | No claim | Normal Conditions | OG SFC 4-11.2 | The OG reduces the risk of hydrogen combustion arising from the reaction of radiolytic hydrogen produced in the reactor. | C | 3 |
| 4 | 5 | Others | 5-10 | Functions to supply electric power (expect for emergency supply) | - | No claim | Normal Conditions | OG SFC 5-10.1 | The OG extracts air and non-condensable gas ($H_2$ and $O_2$) from the Condenser to achieve and maintain condenser vacuum. | B | 3 |
| 5 | 4 | Confinement/Containment of radioactive materials | 4-8 | Functions to minimise the release of radioactive gases | 12.1 | Off-gas treatment system failure | Fault Conditions | OG SFC 4-8.1 | The OG mitigates the release of gaseous radioactive substances to the environment in the event of OG system failure. | B | 2 |
| 6 | 4 | Confinement / Containment of Radioactive Materials | 4-7 | Functions to confine radioactive materials, shield radiation, and reduce radioactive release | 12.1 | Off-gas treatment system failure | Fault Conditions | OG SFC 4-7.2 | The OG mitigates the dose to worker in the event of OG system failure. | C | 3 |
| 7 | 4 | Confinement / Containment of Radioactive Materials | 4-11 | Functions to store radioactive materials as gaseous wastes | - | No claim | Fault Conditions | OG SFC 4-11.3 | The OG prevents hydrogen combustion in the event of OG Recombiner failure. | B | 2 |

### Tank Vent Treatment System

| | Top Claim for TVTS | | | | | | Safety Functional Claims for TVTS (SFC) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fundamental Safety Function (FSF) | | High Level Safety Function (HLSF) | | Fault Schedule (Bounding Fault) | | | | | | |
| | PCSR Ch.5 Section 6 Table 5.6-1: High Level Safety Functions in UK ABWR | | PCSR Ch.5 Section 6 Table 5.6-1: High level Safety Functions in UK ABWR | | Topic Report on Fault Assessment Table.4.2-1 Fault Schedule [Ref-22] | | State | Claim ID | SFC Contents | Cat | Class |
| 1 | 4 | Confinement / Containment of Radioactive Materials | 4-7 | Functions to contain radioactive materials, shield radiation and reduce radioactive release | - | No claim | Normal Conditions | TV SFC 4-7.1 | Radioactivity extracted from the vessel ullage space will be adequately contained. | (*) | (*) |
| 2 | 4 | Confinement / Containment of Radioactive Materials | 4-7 | Functions to contain radioactive materials, shield radiation and reduce radioactive release | - | No claim | Normal Conditions | TV SFC 4-7.2 | The TVTS shall be designed to ensure that doses to both the workers and the public from normal operation of the TVTS are ALARP. | (*) | (*) |
| 3 | 4 | Confinement / Containment of Radioactive Materials | 4-7 | Functions to contain radioactive materials, shield radiation and reduce radioactive release | - | No claim | Normal Conditions | TV SFC 4-7.3 | The creation, management and disposal of radioactive waste will be optimised through the use of BAT. | (*) | (*) |
| 4 | 4 | Confinement / Containment of Radioactive Materials | 4-7 | Functions to contain radioactive materials, shield radiation and reduce radioactive release | - | No claim | Normal Conditions | TV SFC 4-7.4 | The TVTS shall be designed to ensure that risks to public and workers in faults are ALARP and within limits and targets given in PCSR Chapter 5 General Design Aspects, section 5.5: Definition of Design Basis Faults and Beyond Design Basis Faults. | (*) | (*) |
| 5 | 4 | Confinement / Containment of Radioactive Materials | 4-8 | Functions to minimise the release of radioactive gases | - | No claim | Normal Conditions | TV SFC 4-8.1 | The total radioactivity in gaseous discharges to the environment from the TVTS will be minimised. | (*) | (*) |
| 6 | 4 | Confinement / Containment of Radioactive Materials | 4-8 | Functions to minimise the release of radioactive gases | - | No claim | Normal Conditions | TV SFC 4-8.2 | Appropriate monitoring, measuring and sampling equipment will be provided to confirm and record that discharge meets relevant Discharge Criteria. | (*) | (*) |
| 7 | 5 | Other | 4-8 | Functions to limit the effect of hazard | - | No claim | Normal Conditions | TV SFC 4-8.3 | Hydrogen concentrations in vessel ullage spaces will not reach the Lower Flammability Limit (LFL). | (*) | (*) |

(*) For the majority of the TVTS, the safety category of function will be category C and the classification of SSCs will be class 3, with appropriate safety measures incorporated into the design against the identified faults as required by the evaluation of unmitigated doses. The initial preliminary safety function category for unmitigated dose to worker and public for the TVTS which are at concept design can be found in section 18.9.2.3.

### Heating Ventilating and Air Conditioning System

The Claim Tree for HVAC system is covered in sub-section 16.5 Heating Ventilating and Air Conditioning System, in PCSR Ch.16 Auxiliary Systems.

## Solid Waste Processing

| | Top Claim for SWMS | | | | | | Safety Functional Claims for SWMS (SFC) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fundamental Safety Function (FSF) | | High Level Safety Function (HLSF) | | Fault Schedule (Bounding Fault) | | | | | | |
| | PCSR Ch.5 Section 6 Table 5.6-1: High Level Safety Functions in UK ABWR | | PCSR Ch.5 Section 6 Table 5.6-1: High level Safety Functions in UK ABWR | | Topic Report on Fault Assessment Table.4.2-1 Fault Schedule [Ref-22] | | State | Claim ID | SFC Contents | Cat | Class |
| 1 | 4 | Confinement / Containment of Radioactive Materials | 4-13 | Functions to store radioactive materials as solid wastes | - | No claim | Normal Conditions | SWMS SFC 4-13.1 | Total solid radioactive waste volumes from UK ABWR reactor operation will be minimised. | (*) | (*) |
| 2 | 4 | Confinement / Containment of Radioactive Materials | 4-13 | Functions to store radioactive materials as solid wastes | - | No claim | Normal Conditions | SWMS SFC 4-13.2 | The SWMS facilities shall be designed to ensure that doses to both the workers and the public from normal operation of the UK ABWR SWMS are ALARP. | (*) | (*) |
| 3 | 4 | Confinement / Containment of Radioactive Materials | 4-13 | Functions to store radioactive materials as solid wastes | - | No claim | Normal Conditions | SWMS SFC 4-13.3 | The creation, management and disposal of radioactive wastes will be optimised through the use of BAT. | (*) | (*) |
| 4 | 4 | Confinement / Containment of Radioactive Materials | 4-13 | Functions to store radioactive materials as solid wastes | - | No claim | Normal Conditions | SWMS SFC 4-13.4 | Appropriate monitoring, measuring and sampling equipment will be required to confirm and record that waste meets relevant Waste Acceptance Criteria. | (*) | (*) |
| 5 | 4 | Confinement / Containment of Radioactive Materials | 4-13 | Functions to store radioactive materials as solid wastes | - | No claim | Normal Conditions | SWMS SFC 4-13.5 | The SWMS facilities shall be designed to ensure that risks to public and workers in faults are ALARP and within limits and targets given in PCSR Chapter 5 General Design Aspects, section 5.5: Definition of Design Basis Faults and Beyond Design Basis Faults. | (*) | (*) |
| 6 | 4 | Confinement / Containment of Radioactive Materials | 4-13 | Functions to store radioactive materials as solid wastes | - | No claim | Normal Conditions | SWMS SFC 4-13.6 | The Solid Waste Facility (SWF) is required to process wastes into packages suitable for off-site transport to the appropriate nominated facility for incineration, recycling or direct disposal. | (*) | (*) |
| 7 | 4 | Confinement / Containment of Radioactive Materials | 4-13 | Functions to store radioactive materials as solid wastes | - | No claim | Normal Conditions | SWMS SFC 4-13.7 | The on-site ILW Store is required to receive and manage processed and packaged ILW. | (*) | (*) |

(*) For the majority of SWMS, the safety category of function is category C and the classification of SSCs is class 3, with appropriate safety measures incorporated into the design against the identified faults as required by the evaluation of unmitigated doses. The initial preliminary safety function category for unmitigated dose to worker and public for the SWMS which are at concept design can be founded in section 18.6.2.3, 18,11.2.3 and 18.12.2.5.

# Appendix B : Safety Properties Claims Table

The safety properties claims defined for Radioactive Waste Management are shown in the following table.

| | SPC | Safety Properties Claims (SPC) Contents | SPC Guide words in SCDM [Ref-15] |
|---|---|---|---|
| 1 | RW SPC1 | Design provision against Single Failure<br>RW system and their support systems shall be designed with redundancy against single failure of any dynamic component under the worst permissible system availability state so that single failure will not prevent the delivery of the corresponding safety functions. | • Fault Tolerance<br>• Reliability |
| 2 | RW SPC2 | Design provision against Common Cause Failure<br>RW systems shall be designed with independency between redundant components so that the failure of one dynamic component will not lead to a common cause failure that could prevent the delivery of the corresponding safety functions. | • Defence in Depth<br>• Reliability |
| 3 | RW SPC3 | Design provision against System Interfaces<br>The mechanical interfaces between SSCs of different safety classes inside a system or between several systems shall be designed such that failure in a lower class item will not propagate to higher safety class items and jeopardise the delivery of the corresponding safety functions. | • Defence in Depth<br>• Reliability |
| 4 | RW SPC4 | Internal Hazards Protection<br>RW SSCs shall be protected or designed to withstand the effects of the following internal hazards so that they will not affect the delivery of the corresponding safety functions:<br>(1) Internal flooding<br>(2) Internal fire and explosion<br>(3) Internal missiles<br>(4) Dropped and collapsed loads<br>(5) Pipe whip and jet impact<br>(6) Internal blast<br>(7) Electromagnetic Interference (EMI)<br>(8) Miscellaneous hazards | • Fault Tolerance<br>• Reliability |
| 5 | RW SPC5 | External Hazards protection<br>RW SSCs shall be protected or designed to withstand the effects of the external hazards (Earthquakes, Loss of Offsite Power (LOOP)) so that they will not affect the delivery of the corresponding safety functions. | • Fault Tolerance<br>• Reliability |
| 6 | RW SPC6 | Automation<br>RW systems shall be designed so that no human intervention will be necessary for approximately 30 minutes following the start of the requirement for the safety function. | • Human Factors<br>• Reliability |
| 7 | RW SPC7 | Qualification Provision<br>RW SSCs shall be capable of delivering their safety functions under the associated operational and environmental conditions throughout their operational life. | • Qualification<br>• Life Cycle<br>• Reliability |
| 8 | RW SPC8 | EMIT(Examination, Maintenance, Inspection and Test)<br>RW SSCs shall be designed with the capability for being tested, maintained and monitored during power operation and/or refuelling outages in order to ensure the capability to deliver the safety functions claimed without compromising their availability throughout their | • Life Cycle<br>• Reliability<br>• Layout and Accessibility<br>• Radiation |

| | SPC | Safety Properties Claims (SPC) Contents | SPC Guide words in SCDM [Ref-15] |
|---|---|---|---|
| | | operational life. | Protection |
| 9 | RW SPC9 | <u>Codes and Standards</u><br>RW components shall be designed manufactured, constructed, installed, commissioned, quality assured, maintained, tested and inspected according to codes and standards commensurate to their Safety Class. | • Relevant Good Practice<br>• Reliability |

## Appendix C: Document Map