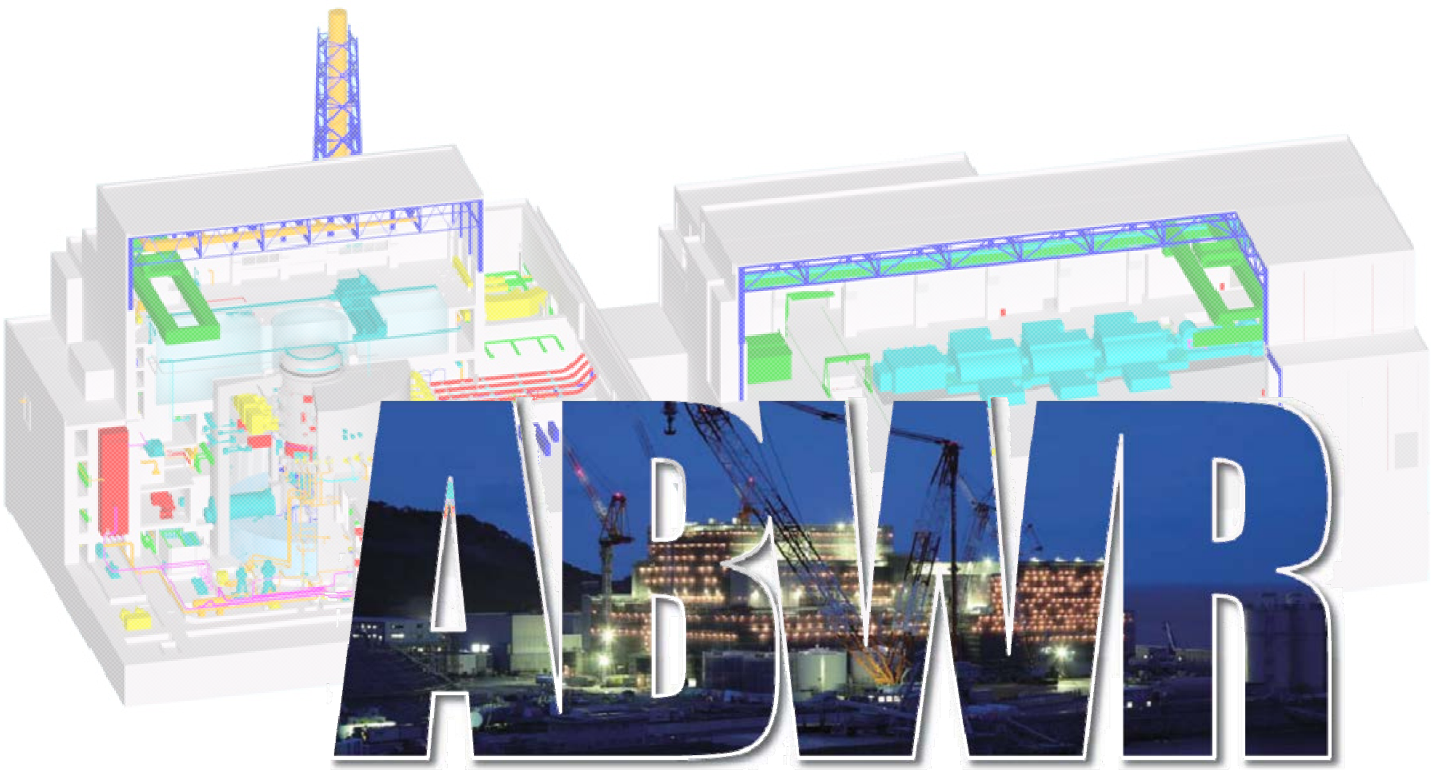
Form10/00

UK ABWR

Document ID	:	GA91-9901-0042-00001
Document Number	:	XE-GD-0153
Revision Number	:	B

UK ABWR Generic Design Assessment

Preliminary Safety Report on Radioactive Waste Management System



Hitachi-GE Nuclear Energy, Ltd.

DISCLAIMERS

Proprietary Information

Copyright

Abbreviations and Acronyms	Description
ABWR	Advanced Boiling Water Reactor
ALARP	As Low As Reasonably Practicable
BAC	Bead Activated Carbon
CAD	Controlled Area Drain
C/B	Control Building
CD	Condensate Demineraliser
CF	Condensate Filter
CONW	Concentrated Waste System
CR	Control Rod
CST	Condensate Storage Tank
CUW	Reactor Water Clean-Up System
D/W	Drywell
FPC	Fuel Pool Cooling Clean-Up System
GAC	Granular Activated Carbon
GDA	Generic Design Assessment
HCW	High Conductivity Liquid Waste
HEPA	High-Efficiency Particulate Air
HF	Human Factors
HHISO	Half Height International Standards Organization
HSD	Hot Shower Drain
HVAC	Heating Ventilating and Air Conditioning Systems
ILW	Intermediate Level Waste
LCW	Low Conductivity Liquid Waste
LD	Laundry Drain
LLW	Low Level Waste
LOCA	Loss Of Coolant Accident
LPRM	Local Power Range Monitor
LWMS	Liquid Waste Management System
ME	Medium Efficiency
MUWP	Make Up Water Purified System
NDA	Nuclear Decommissioning Authority
NSU	Neutron Source Unit
OG	Off-Gas System
POCO	Post-Operation Clean-Out
R/B	Reactor Building
RCW	Reactor Building Cooling Water System
RD	Radioactive Drain
RHR	Residual Heat Removal System
RPV	Reactor Pressure Vessel
RSW	Reactor Building Service Water system
Rw/B	Radwaste Building
SAM	Sampling System
S/B	Service Building
SFP	Spent Fuel Pool
SRNM	Startup Range Neutron Monitor
SSCs	Structures, Systems and Components
SWMS	Solid Waste Management System
T/B	Turbine Building
TIP	Traversing In Core Probe System

Table of Contents

1 SOURCE TERM

1.1 SHIELDING SOURCE TERM AND ACTIVITY BALANCE SOURCE TERM

Shielding source term and activity balance source term are described in reference 1.

1.2 SOURCE TERM FOR DISCHARGE

Source term for discharge is described in reference 2.

1.3 RADIOACTIVE SOLID WASTE INVENTORY

Radioactive solid waste inventory is described in reference 3.

1.4 REFERENCES

1. Preliminary Safety Report on Radiation Protection Section 1 Definition of Radioactive Sources; GA91-9901-0039-00001; XE-GD-0150; Rev. A; March 2014
2. Quantification of Discharge and Limits; GA91-9901-0025-00001; HE-GD-0004; Rev. C; March 2014
3. Radioactive Waste Management Arrangement; GA91-9901-0022-00001; WE-GD-0001; Rev. C; March 2014

2 LIQUID RADIOACTIVE WASTE MANAGEMENT SYSTEM

2.1 OVERVIEW

The Advanced Boiling Water Reactor (ABWR) Liquid Radioactive Waste Management System (LWMS) is designed to segregate at source, collect and treat the various streams of radioactive and potentially radioactive waste water generated during various modes of ABWR reactor and turbine plant operation: start-up, normal operation, shutdown, and re-fuelling. A schematic drawing of the LWMS is given in Figure 1.

The LWMS is housed in the Radioactive Waste Building (Rw/B) and Service Building (S/B), and consists of the following four subsystems:

- Low Conductivity Waste subsystem
- High Conductivity Waste subsystem
- Laundry Drains subsystem
- Controlled Area Drains subsystem.

A fundamental principle of the ABWR design is that both the Primary Circuit and Fuel Pool (i.e. the plant areas containing water that comes into direct contact with irradiated fuel) are operated as far as is practicable as “closed loop systems”. For this reason, the LWRS is designed so that any water leaks and any water drained from the Primary Circuit or Fuel Pool during the various modes of plant operation is captured and appropriately treated so as to remove both soluble and in-soluble impurities, thus providing a high purity water that is normally recycled for use in the Primary Circuit and/or Fuel Pool recycled water is only occasionally discharged to the environment when the recycled volumes exceed Primary Circuit and Fuel Pool water make-up requirements. On occasions when it is necessary to discharge excess volumes of treated water to the environment, the treated water is first monitored to ensure that residual levels of contamination are within set limits and ALARP.

Two subsystems are used to treat radioactively contaminated waste water from the Primary Circuit and/or Fuel Pool, the High Conductivity Waste (HCW) subsystem and the Low Conductivity Waste (LCW) subsystem. Waste water is captured and routed to the appropriate subsystems depending on its expected conductivity, i.e. the expected level of impurities (including non-radiological contamination) it contains. The HCW subsystem is designed to efficiently treat water with higher levels of impurities level by the use of a distillation step before treating the distilled water by passing it through an ion exchange bed. The LCW subsystem is designed to efficiently treat larger volumes of water which contain lower levels of impurities and uses an initial filtration (rather than distillation) step before passing the filtered water through an ion exchange bed. In both cases, if necessary, waste water can be passed through the treatment process a number of times in order to meet the purity levels required for reuse.

The Laundry Drains subsystem is used to treat waste water from the laundry and the personnel showers and hand washing facilities. This water contains detergents and organic impurities as well as potentially low levels of radioactive crud. Efficient removal of the detergents and organic material (as well as the radioactive crud) requires a different treatment process (with both filtration and activated carbon adsorption steps) to those used in the HCW and LCW systems. In this case, after appropriate monitoring to ensure that residual activity levels are ALARP, the treated water is discharged to the environment.

A fourth subsystem, the Controlled Area Drains subsystem, is used to collect waste water from other plant and systems in the radiologically controlled areas in the Reactor Building (R/B) and Turbine Building (T/B) which is expected to be essentially free from radiological contamination. This water is simply sampled to confirm it contains no significant radiological contamination (or unacceptable chemical contamination) before it is discharged to the environment. If the water is found to contain any significant radiological contamination or unacceptable chemical contamination, then the operator can route the water for treatment using the HCW subsystem.

The radioactive materials removed from the waste water streams treated by the HCW and LCW subsystems are collected and contained in the form of wet sludges, used ion exchange resins. These wet-solid wastes are stored in tanks within the radioactive waste building before being transferred to the solid radioactive waste treatment facilities where they are processed into a passively safe state (see Section 4 below). Used activated carbon from the Laundry Drains subsystem, is dewatered and placed into drums which are then transferred for processing in the Solid LLW Facility (see Section 4.3.3 below).

The Rw/B also includes storage tanks for wet solid wastes (crud, sludges and spent resins) generated during the polishing of condensate water in the T/B and reactor and Fuel Pool water clean-up in the R/B. The wastes are either transferred directly to the radioactive waste building storage tanks or are first collected in backwash receiver tanks in the turbine or reactor buildings before being transferred to the radioactive waste building storage tanks. These wastes are also periodically transferred to the solid radioactive waste treatment facilities for cementation or incineration.

2.2 DESIGN BASIS

2.2.1 Safety Requirement

This section summarises the nuclear safety case claims for the liquid radioactive waste processing and storage systems for the UK ABWR design.

C2.2.1 Total liquid radioactive waste volumes from UK ABWR reactor operation are minimised.

C2.2.1/1 The UK ABWR Liquid Radioactive Waste Management system ensures safe:

- Segregation at source and collection of the various waste water streams resulting from UK ABWR reactor and turbine operations
- Treatment of waste water to allow safe discharge to the environment

2.2.1.1 Normal Operation

C2.2.1.1/1 Doses to both the operators and the public from normal operation of the UK ABWR Liquid Radioactive Waste Management system are ALARP and do not contribute significantly to the overall dose assessment given in Reference 1.

Doses to the Public

C2.2.1.1/1/1 Direct radiation to the most exposed member of the public resulting from normal operation of the Liquid Radioactive Waste Management system is ALARP.

C2.2.1.1/1/1.1 The combination of the shielding provided by radioactive waste building structures and the distance of the radioactive waste facilities from the generic site boundary results in ALARP doses to the public due to direct radiation in normal operation.

C2.2.1.1/1/2 Radioactive liquid discharges to the environment are ALARP.

C2.2.1.1/1/2.1 Waste water from ABWR operations is suitably treated such that residual levels of radioactivity are ALARP, allowing the treated water to be safely discharged to the environment.

C2.2.1.1/1/2.2 A representative sample of waste water is taken prior to any discharge to measure residual activity levels and check that they are within set limits and ALARP.

C2.2.1.1/1/3 Gaseous discharges to the environment are ALARP.

C2.2.1.1/1/3.1 Exhaust gases from HVAC systems are suitably filtered prior to final discharge to atmosphere.

C2.2.1.1/1/3.2 Levels of activity in filtered gaseous discharges are monitored allowing operators to take corrective action in the event that activity levels exceed set levels.

Doses to Workers

C2.2.1.1/1/4 Appropriate shielding is provided for operators against direct radiation in line with approach/principles described in Reference 2 such that doses will be ALARP.

C2.2.1.1/1/5 Radiological protection measures for workers are provided in line with the principles described in Reference 2 such that doses will be ALARP.

C2.2.1.1/1/5.1 Rw/B layouts and HVAC systems are designed to ensure the movement of air from areas of no/low contamination to areas with potentially higher levels of contamination.

C2.2.1.1/1/6 The liquid radioactive waste system/equipment is designed so that worker doses during maintenance (including recovery from plant breakdowns) are ALARP.

C2.2.1.1/1/6.1 The LWMS includes engineered flushing points which so far as is reasonably practicable (SFAIRP) enable any settled radioactive contamination to be flushed from the system prior to maintenance work being carried out thus ensuring operator doses during maintenance are ALARP.

General

C2.2.1.1/1/7 Liquid radioactive wastes are contained and controlled within appropriately engineered facilities (see Section 2.2.4 below).

C2.2.1.1/1/8 Appropriate monitoring, measuring and sampling equipment is provided so that operators can check and record that wastes coming into and being dispatched from the facility are as expected.

2.2.1.2 Faults

Potential Doses to the Public in Faults

C2.2.1.2/1 Doses to public in faults are ALARP and within limits/targets given in Reference 3.

C2.2.1.2/1/1 The LWMS design has been assessed to identify all credible failure modes/fault conditions with the potential to lead to an off-site radiological release (the design basis).

C2.2.1.2/1/2 Where appropriate, the design of the LWMS system includes automatic/engineered fault prevention, protection and mitigation features to ensure that the assessed fault consequences are both within the limits/targets specified in Reference 3 and ALARP.

Natural Hazards

C2.2.1.2/1/3 The radioactive waste system civil structures/building envelopes etc. are designed and qualified to appropriate standards and provide protection against the following natural events:

- Earthquake
- High Wind
- Flooding
- Extreme temperature
- Snow loading.

Fire

C2.2.1.2/1/4 The overall design and layout of the radwaste building is compliant with the relevant UK fire regulations.

C2.2.1.2/1/5 In the unlikely/infrequent event that a significant fire did result in damage to the radwaste building and a consequential radiological release, then even on a bounding conservative assessment the consequential off site dose to the most exposed member of the public would be less than the limits identified in Reference 3.

Internal Flooding

C2.2.1.2/1/6 In the unlikely/infrequent event that internal flooding did result in damage to the LWMS and a consequential radiological release, then even on a bounding conservative assessment the consequential off site dose to the most exposed member of the public would be less than the limits identified in Reference 3.

Missiles

C2.2.1.2/1/7 In the unlikely/infrequent event that an internally generated missile did result in damage to the LWMS and a consequential radiological release, then even on a bounding conservative assessment the consequential off site dose to the most exposed member of the public would be less than the limits identified in Reference 3.

Potential Doses to Operators in Faults

C2.2.1.2/2 Potential doses to operators in faults are ALARP, including potential doses associated with post-fault operator actions required to secure affected plant in a safe condition.

C2.2.1.2/2.1 Where appropriate the design includes specific engineered provisions to facilitate identified fault recovery actions by the operators.

2.2.2 Functional Requirement

C2.2.2/1 The LWMS provides sufficient capacity to handle liquid wastes for normal operation, start-up, shut-down, and outage.

C2.2.2/2 In the event of a fault condition which resulted in excessive leakage of water into the R/B or T/B sumps, the operators would isolate the sump pumps on receipt of high leakage rate alarm.

C2.2.2/3 In the event of a LOCA signal all dry well sump pumps are automatically isolated.

The LWMS also includes temporary storage tanks for secondary wet-solid wastes generated by the above liquid waste processing systems.

2.2.3 Design Related Requirement

C2.2.3/1 Categorisation and classification of structures, systems and components are decided based on fault study.

C2.2.3/2 Seismic category is decided based on fault study.

2.2.4 Design Criteria

The construction and design of the LWMS buildings and processing equipment (pipes, tanks, sumps etc.) have used appropriate engineering design principles and are engineered to the required withstands (pressure, seismic etc.). Material selection is based on corrosion resistance and operating conditions. The following general design features are also included:

- Tanks, pipes, pumps etc. in the LWMS use appropriate materials, are designed against appropriate design temperatures and pressures and are manufactured and tested in accordance with appropriate engineering standards.
- Except where break-in requirements for maintenance or recovery from breakdowns, the LWMS are fully welded systems.

- So far as is reasonably practicable liquid radioactive pipework that is embedded in floors or walls should be double skinned
- The LWMS control system includes monitoring of all the main process parameters (pressure, flow, temperature, tank levels, etc.) with appropriate alarms provided to the operators in the event of abnormal conditions.
- The LWMS control system includes level control for all tanks including appropriate interlocks to prevent tank overflows.
- Notwithstanding the above, all LWMS tanks have engineered overflow routes to alarmed sumps where appropriate.
- Bunding will be provided in line with UK Legislative requirements, including all tanks and where appropriate any other piece of equipment containing liquids.
- All floor drainage and bunding sumps include leak detectors/alarms and pumps to recover any spilt liquids into the LWMS.
- Bunding is provided at all external doors to LWMS buildings to prevent the spread of any spilt liquids to the outside of the buildings.
- Appropriate shielding, radiological protection and other provisions (e.g. the inclusion of engineered flushing points) to minimise operator doses during normal operation and during examination, inspection, maintenance and testing of equipment.

2.3 SYSTEM DESCRIPTION

The LWMS is housed in the Radioactive Waste Building (Rw/B) and Service Building (S/B), and consists of the following four subsystems:

- Low Conductivity Waste subsystem
- High Conductivity Waste subsystem
- Laundry Drain subsystem
- Controlled Area Drain subsystem

In addition to these four subsystems (which are described Sections 2.3.2 to 2.3.5 below), there are also number of storage tanks that are used to temporarily store the secondary wet-solid wastes generated by both LWMS treatment systems and the main primary circuit water treatment systems in the R/B and T/B (see Section 2.3.6 below. Also, to give a more complete picture so as to aid understanding, a fifth (interfacing) subsystem, the Radioactive Drain Transfer System (RD), is also described in Section 2.3.1 below. However the RD subsystem also sits inside the R/B and its safety case is provided in PCSR Chapter 13 Auxiliary System.

2.3.1 Radioactive Drain Transfer System (RD)

This system is used to transfer waste water collected in the controlled areas in the R/B, T/B and S/B into collection tanks in individual LWMS subsystems installed in the Rw/B. The RD subsystem comprises sump tanks, sump pumps, piping, valves, and appropriate instrumentation. In general, waste water is segregated and collected at source as follows.

- Equipment Drains – collect radioactive or potentially radioactive waste water from Primary Circuit system and equipment in the R/B and T/B, from Fuel Pool system and equipment, and also from system and equipment in the Rw/B. This waste water is generally expected to have low levels of impurities and, therefore, is normally automatically pumped from the equipment drain sumps to the LCW subsystem Collection Tank. Note, however, that for certain plant areas the operator can select whether the waste water is routed to the LCW or HCW subsystem, depending on the level of impurities it is expected to contain. Individual sumps and the associated pumps are sized to handle the expected waste water volumes from the equipment they serve.
- Floor Drains – collect waste water spillages in each separate area of the R/B, T/B and Rw/B. The water quality in terms of suspended solid concentration is relatively clean. As the quality of the water is

suitable to be treated by LCW, the drains collected in Drain Sumps are automatically pumped to LCW. Individual floor drain sumps and the associated pumps are sized to handle any water spillages on the floor areas that might occur during normal operation, start-up, shut-down and outages.

- Chemical Drains- collect the chemical waste generated at the laboratory in S/B and collect high conductivity water such as the condensate demineraliser drains. The chemical drain generated at the laboratory is collected into the Drain Sump and is automatically pumped to HCW. Drain from the condensate demineraliser is collected into the HCW collection tanks.
- Laundry Drains - collect waste water from the laundry and from the personnel shower and hand washing facilities. This waste water is automatically transferred to the Laundry Drain Collection Tanks. The Laundry Drain waste water steam includes detergents and organic materials and is kept separate from the other waste water streams because it has to be treated using a different process train (see Section 2.3.4).
- Controlled Area Drains - collect waste water from other systems (e.g. local HVAC systems) in the radiologically controlled areas in the Reactor Building and Turbine Building which is expected to be essentially free from radiological contamination. This water is automatically transferred to the Controlled Area Drains Collection Tank (see Section 2.3.5 for further details).

2.3.2 Low Conductivity Subsystem

The LCW subsystem (see Figure 1) 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 main sources of which are the reactor primary coolant system, Fuel Pool Clean Up system (FPC) and plant make up water system. The LCW system is designed to allow the efficient treatment of relatively large volumes waste water containing low levels of both insoluble and soluble impurities (and hence of low conductivity). Before treatment, sample of the waste is analysed to confirm properties (e.g. conductivity) of waste. If waste properties are not suitable for treatment in LCW system, these wastes are transferred to HCW system. Simple hollow fibre membrane filters are used to remove the insoluble impurities (with back pulse cleaning of the filter membrane upon detection of a raised differential pressure). The filtered water is then passed through a mixed bed demineraliser packed with bead ion exchange resins to remove soluble impurities.

Treated water is collected in a sample tank, where a representative sample of the water is analysed to confirm it meets the criteria for re-use in the reactor. 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 Condensate Storage Tank (CST) for reuse as reactor Primary Circuit or Fuel Pool make-up water.

2.3.3 High Conductivity Subsystem

The HCW subsystem (see Figure 1) is also located in the Rw/B and is the second subsystem used for the treatment of radioactively or potentially radioactively contaminated waste water. The HCW subsystem includes an initial distillation step to allow the efficient treatment of waste water with relatively high levels of soluble and insoluble impurities (and hence with a high conductivity), principally waste water collected by the chemical analysis lab (hot lab) drains and condensate demineraliser drains. The waste water received by the HCW subsystem is first subjected to evaporative concentration (distillation). At a predefined point in the distillation process, the evaporator bottom drain is discharged to the Concentrated Waste Storage Tanks in batches. (The concentrated liquid waste stored in these tanks is subsequently transferred for treatment in the Solid Waste Management System, see Section 4 below.)The distillate is collected in the HCW Distilled Water tank and then passes through a demineraliser (mixed bed demineraliser packed with a bead ion exchange resin) to remove any soluble contaminants that could potentially be carried over from the concentrator. Treated water is collected in a sample tank, where a representative sample of the water is analysed to confirm it meets the criteria for re-use in the reactor (or for discharge to the environment). If the treated water does not meet the appropriate criteria, it can be routed back to the HCW 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 Condensate Storage Tank (CST) for reuse as reactor Primary Circuit or Fuel Pool make-up water. Only when the treated water volumes occasionally exceed Primary Circuit and Fuel Pool water make-up requirements, is the treated water discharged to the environment. On these occasions the treated water is first monitored to ensure that residual levels of contamination are within set limits and ALARP.

2.3.4 Laundry Drain Subsystem (LD)

This Laundry Drain subsystem (see Figure 1) processes waste water originating from the laundry and the personnel 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. To remove these impurities the water is first passed through a packed bed pre-filter, then an activated charcoal adsorption unit. The packed bed filter traps relatively large-size suspended solids, which are removed from the system as waste sludge together with the filter media, which are emptied into 200 litre drums. The activated charcoal adsorption unit adsorbs organic impurities on activated charcoal and traps relatively small-size suspended solids. The adsorbed impurities and the suspended solid are removed from the system together with the (exhausted) activated carbon, which is first dewatered and then emptied into 200 litre drums. The 200 litre drums containing the secondary wastes from processing system are transferred to the Wet LLW Treatment Facility (see Section 4.3.3 below). The treated 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 is ALARP and meets the criteria for discharge to the environment. If the treated water does not meet the discharge criteria, it can be routed back to the Laundry Drains Collection Tank and the treatment process repeated (potentially multiple times) until the discharge criteria are met.

2.3.5 Controlled Area Drains Subsystem

The Controlled Area Drains subsystem system (see Figure 1) collects drain and sampling water from non-radioactive equipment systems in the controlled areas of the R/B and the T/B. The source systems include the auxiliary cooling water system, demineralised water makeup system, fire protection system, house steam system, compressed air system, and also the drains of the local air-conditioning systems in the R/B and T/B.

The collected water is pumped to the Controlled Area Drains Collection Tank where it is sampled to confirm it contains no significant radiological contamination (or unacceptable chemical contamination) before it is discharged to the environment. If the water is found to contain any significant radiological contamination or unacceptable chemical contamination, then the operator routes the water for treatment using the HCW subsystem (see Section 2.3.3 above).

2.3.6 Waste Water Treatment Secondary Waste Storage

The water treatment subsystems generate their own secondary wastes. These secondary wastes are temporarily stored in tanks before being transferred to the Solid Waste Management System (see Figure 3) for processing and conditioning in preparation for either disposal off site (in the case of LLW), or for transfer to the interim on site storage facility (in the case of ILW).

The secondary waste streams produced by the Liquid Radioactive Waste Management system are:

- Spent bead (ion exchange) resins from the LCW and HCW subsystems
- Sludge and hollow fibre filters from the LCW subsystem
- Concentrated liquid waste from the HCW subsystem
- Sludge and packed bed filter media from the Laundry Drain subsystem
- Activated carbon from the Laundry Drain subsystem.

The spent bead resins from the LCW and HCW subsystems are pumped using motive water to one of the Spent Resin Storage Tanks, where they are temporarily stored pending transfer to the Solid Waste

Management System facilities.

The sludge from the LCW subsystem is backwashed and pumped as sludge to the Sludge Storage tank, where it is temporarily stored pending transfer to the Solid Waste Management System facilities. The concentrated liquid waste from the HCW system is drained into the Concentrated Waste Storage Tanks, where it is again temporarily stored pending transfer to the Solid Waste Management System facilities. The concentrated waste has high solid concentration but the radioactive concentration is relatively low.

The three secondary LLW streams from the Laundry Drains subsystem are removed directly from the system into 200 litre drums, which are then transferred to the Solid LLW and Wet Solid LLW treatment Facilities (see Sections 4.3.1 and 4.3.3 below).

In addition to the secondary wastes generated by the LWMS subsystems, wet-solid wastes are also generated by the main primary circuit water treatment systems in the R/B and T/B. Specifically these wastes are powder resins from the Reactor Clean-up System (CUW) and Fuel Pool Cooling Clean-up system (FPC) in the R/B, and Condensate Filter crud and bead resin from the Condensate Demineraliser (CD) in the T/B (see Figures 2 and 3). All of these wastes except bead resin from CD are backwashed into receiver tanks and then pumped across to the Sludge Storage tanks in the Rw/B, where they are temporarily stored pending transfer to the Solid Waste Management System facilities.

2.4 REFERENCES

1. Quantification of Discharge and Limits; GA91-9901-0025-00001; HE-GD-0004; Rev. C; March 2014
2. Preliminary Safety Report on Radiation Protection Section 2 Strategy to ensure that the exposure is ALARP; GA91-9901-0040-00001; XE-GD-0151; Rev. A; March 2014
3. Categorisation and Classification of Systems, Structures and Components; GA91-9901-0007-00001; XE-GD-0104; Rev. B; March 2014.

3 OFF-GASEOUS RADIOACTIVE WASTE MANAGEMENT SYSTEM

This chapter describes the high level safety claims of the Off-Gas System (OG).

3.1 DESIGN BASES

3.1.1 Safety Claims

The OG is designed to meet the following safety claim (SC):

SC1 The OG minimises the release of gaseous radioactivity generated by plant operation into the environment. Discharge of the radioactivity is minimised as low as reasonably practicable (ALARP).

SC2 Adequate radiation shielding is provided to ensure that dose to plant operators are reduced as low as reasonably practicable (ALARP). Radiation protection features are discussed in the "Preliminary Safety Report on Radiation Protection Section 2 Strategy to ensure that the exposure is ALARP" [Ref-3].

3.1.2 Safety Functional Claims, Performance Claims

The following safety functional claims (SFC), performance claims (PC) are derived from the safety claim:

3.1.2.1 Normal Operation

SFC1 The OG minimises the release of radioactive noble gases to the environment during the start-up, commercial and shutdown operations. This is achieved by ensuring that the activated charcoal provides a sufficient hold up time for radioactive decay. (SFC1 is derived from SC1.)

PC1 The OG Charcoal Adsorber is designed to be capable of suitably holding up the radioactive noble gases in the off-gas so that discharge of the radioactivity is minimised as low as reasonably practicable (ALARP). The activated charcoal is used as adsorption agent for the OG Charcoal Adsorber. (PC1 is derived from SFC1)

The following functions are included within the OG as support system of the OG Charcoal Adsorber.

PC1.1 Temperature control of OG Charcoal Adsorber Room
The OG Charcoal Adsorber Room HVH controls the OG Charcoal Adsorber Room temperature to maintain the OG Charcoal Adsorber performance. (PC1.1 is derived from PC1)

PC1.2 Volume and temperature control of OG stream
The OG Condenser condenses steam in the off-gas to reduce its volume and cools the off-gas. The cooling source is supplied from the Reactor Cooling System (RCW). (PC1.2 is derived from PC1)

PC1.3 Moisture Control of OG stream
The OG Cooler Condenser cools the off-gas to reduce the moisture, allowing for the system to function as required. The cooling source is supplied from the Refrigeration facility. (PC1.3 is derived from PC1)

PC1.4 Maintenance of Negative Pressure
The OG Ejector and OB Blower have the capacity to keep the off-gas negative pressure in the OG Charcoal Adsorbers, and to release the off-gas to the Stack to ensure the systems functions as required. The driving air of the OG Ejector is provided by the Station Service Air System (SA). The OG

Blower is available as a backup to the OG Ejector. (PC1.4 is derived from PC1)

PC1.5 Abatement of particulates
The OG Filter removes radioactive particles and solid substances from the off-gas through the OG Charcoal Adsorber as a defence in depth measure. (PC1.5 is derived from PC1)

SFC2 The OG reduces the risk of explosion arising from the reaction of radiolytic hydrogen produced in the reactor. This is achieved by providing hydrogen recombiners and ensuring that sufficient driving steam is supplied to the SJAE. (SFC2 is derived from SC1.)

PC2.1 The SJAE driving steam flow rate is designed so that hydrogen concentration in the off-gas from the SJAE is lower hydrogen flammability limit to reduce the possibility of the radiolytic hydrogen and oxygen contained in the off-gas from reacting and causing an explosion. The Turbine Auxiliary Steam System (AS) supplies the driving steam of SJAE during commercial operation. HS supplies the driving steam of SJAE during start-up and shutdown operation. (PC2.1 is derived from SFC2.)

PC2.2 The OG Recombiner is designed to recombine hydrogen and oxygen in the off-gas lower hydrogen flammability limit, to reduce the possibility of the radiolytic hydrogen and oxygen contained in the off-gas from reacting and causing an explosion. (PC2.2 is derived from SFC2.)

The following function is included within the OG as support system of the OG Recombiner.

PC2.2.1 Temperature control of OG stream
The OG Preheater heats the off-gas by House Steam System (HS) above the saturated temperature to improve efficiency and to prevent formation of water drops that might adversely affect catalytic performance. (PC2.2.1 is derived from PC2.2)

SFC3 Within the OG, radiation monitors are provided on each discharge line in the OG (OG Charcoal Adsorber discharge line, Gland Steam Exhauster and Mechanical Vacuum Pump (MVP) discharge line) to detect the abnormal release of the gaseous radioactivity during the start-up, commercial and shutdown operation. The monitoring features will be discussed in the PCSR Chapter11. (SFC3 is derived from SC1.)

3.1.2.2 Faults

SFC4 The OG mitigates the release of gaseous radioactivity to the environment in the event of a fault such as pipe rupture or performance degradation of the activated charcoal. This is achieved by OG isolation valves. (SFC4 is derived from SC1.)

PC4.1 The SJAE Outlet Valves are installed at the SJAE outlet and designed to be shut in the required response time by remote operation. (PC4.1 is derived from SFC4.)

PC4.2 The fault of the OG is detected by the radiation monitors in the HVAC ducts and the OG Charcoal Adsorber discharge line. The monitoring features will be discussed in the PCSR Chapter11. (PC4.2 is derived from PC4.)

3.1.3 Reliability and Availability Claims

The following reliability and availability claims are raised to satisfy safety functional claims:

RC1 The OG and its components are sufficiently qualified to withstand the operating and environmental conditions without sustaining damage that could lead to the loss of the safety function claimed. (RC1 is derived from SFC1, SFC2, SFC3 and SFC4).

(1) Material
The materials for the design of the OG components are selected to withstand the environmental and operational conditions under which the claimed safety functions are required.

(2) Design Temperatures
The design temperatures are determined such that OG components withstand the environmental and operational conditions under which the claimed safety functions are required.

(3) Design Pressures
The design pressures are determined such that OG components withstand the environmental and operational conditions under which the claimed safety functions are required.

RC2 The OG is designed with adequate protection against the effects of internal/external hazards. The protection and mitigation features are discussed in the “Internal hazard Report” and “Preliminary Safety Report on Civil Engineering and External Hazard” [Ref-1] [Ref-2]. (RC2 is derived from SFC1, SFC2, SFC3 and SFC4).

RC3 The OG is designed such that it can be inspected and maintained to ensure its reliability. (RC3 is derived from SFC1, SFC2, SFC3 and SFC4).

(1) Test
The OG is designed such that the performance test of OG Charcoal Adsorber and OG Filter can be performed during outage.

(2) Maintenance
The layout of OG components are designed to access to the maintenance and repair areas. Plan layout design considers the handling of removed parts of heavy components and machinery for maintenance and repair.

3.2 BASIC CONFIGURATION

The OG consists of the following main components to achieve safety claim. Figure 3-2 shows the system schematic diagram.

(1) Steam Jet Air Ejector (SJAE) (1unit)
(2) Start-up SJAE (1unit)
(3) MVP (1unit)
(4) OG Preheater (1 unit)
(5) OG Recombiner (2units)
(6) OG Condenser (1unit)
(7) OG Cooler Condenser (1unit)
(8) OG Charcoal Adsorber (4 units)
(9) OG Filter (1 unit)
(10) OG Ejector (1 unit)
(11) OG Blower (1 unit)
(12) OG Charcoal Adsorber Room Heater Ventilating Handling Unit (HVH) (2units)
(13) Refrigeration facility (1unit)

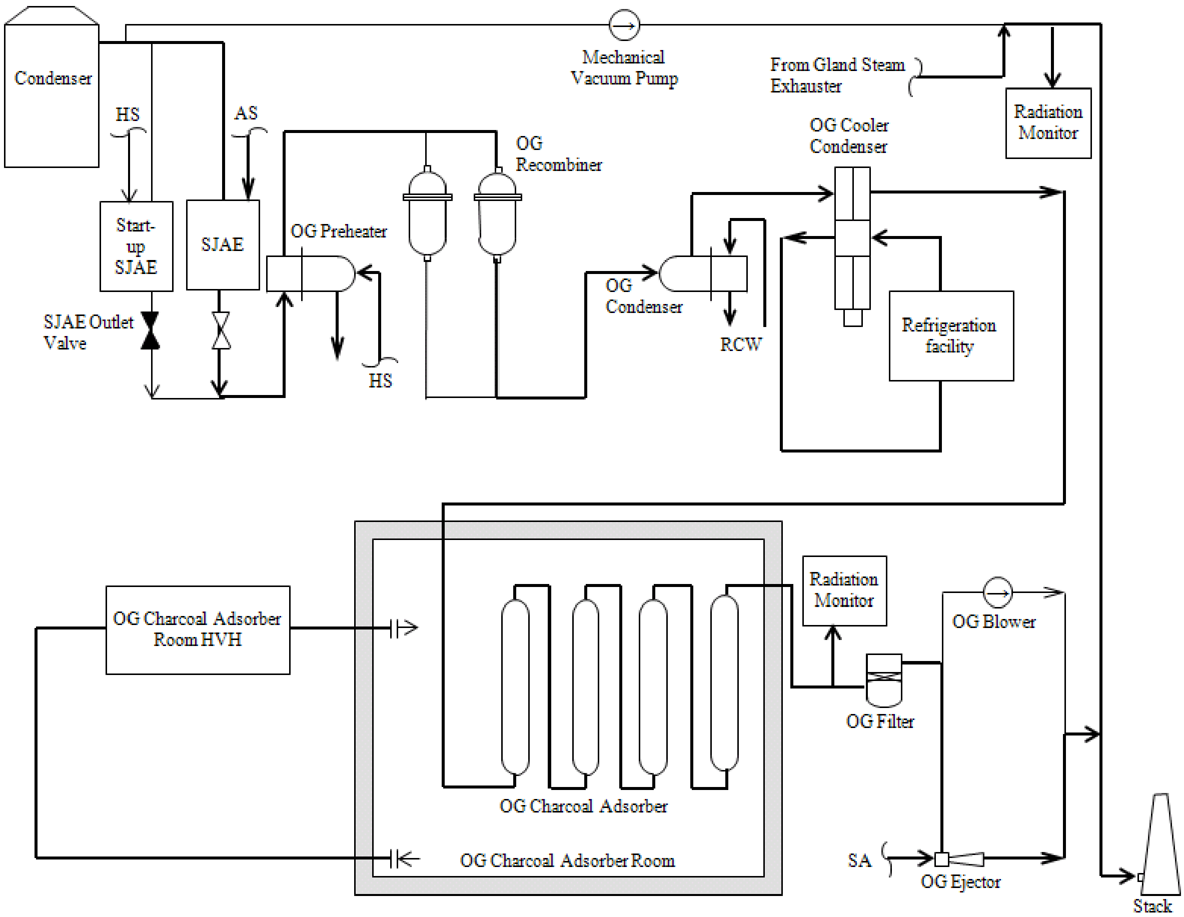


Figure 3-2 Structure of the OG

3.3 REFERENCES

Document Name	Document ID
[Ref-1] Internal Hazards Report	GA91-9901-0002-00001 Rev. C
[Ref-2] Preliminary Safety Report on Civil Engineering and External Hazard	GA91-9901-0004-00001 Rev. B
[Ref-3] Preliminary Safety Report on Radiation Protection Section 2 Strategy to ensure that the exposure is ALARP	GA91-9901-0040-00001 Rev. A
[Ref-4] Off-Gas System Basis of Safety Case	GA91-9201-0002-00054 Rev. 0

4 SOLID RADIOACTIVE WASTE MANAGEMENT SYSTEM

4.1 OUTLINE

The Solid Radioactive Waste Management System (SWMS) is designed to receive, sort and process/condition all solid and wet-solid LLW and ILW waste streams resulting from ABWR operation. Following processing and conditioning LLW is dispatched off site for either incineration, recycling (in the case of recyclable metals), or direct disposal, while ILW is transferred for interim storage (pending availability of the GDF) in an on-site shielded ILW store.

The SWMS comprises the following facilities:

- Solid LLW treatment facility
- Solid ILW treatment facility
- Wet-solid LLW treatment facility
- Wet-solid ILW treatment facility
- LLW marshalling area (pending transport for off-site incineration/recycling/disposal).
- Interim ILW shielded store (dedicated building)

4.2 DESIGN BASIS

4.2.1 Safety Requirement

This section summarises the nuclear safety case claims for the SWMS for the UK ABWR design. The safety case claims for the storage, packaging and ultimate disposal of spent fuel, including the fuel channel boxes which are integral to the spent fuel assemblies, are addressed separately in Reference 1.

C4.2.1 Total solid radioactive waste volumes from UK ABWR reactor operation are minimised.

C4.2.1/1 The UK ABWR Solid Radioactive Waste Management system ensures safe:

- Segregation at source and collection of the various solid and wet-solid waste streams resulting from UK ABWR reactor and turbine operations

4.2.1.1 Normal Operation

C4.2.1.1/1 Doses to both the operators and the public from normal operation of the UK ABWR Solid Radioactive Waste Management system are ALARP and do not contribute significantly to the overall dose assessment given in Reference 2.

Doses to the Public

C4.2.1.1/1/1 Direct radiation to the most exposed member of the public resulting from normal operation of the Solid Radioactive Waste Management system is ALARP.

C4.2.1.1/1/1.1 The combination of the shielding provided by radioactive waste building structures and the distance of the radioactive waste facilities from the generic site boundary results in ALARP doses to public due to direct radiation in normal operation.

C4.2.1.1/1/2 Doses to the public associated with the off-site transport of processed and packaged wastes are ALARP.

Doses to Workers

C4.2.1.1/1/3 Appropriate shielding is provided for operators against direct radiation in line with approach/principles described in Reference 3 such that doses received are ALARP.

C4.2.1.1/1/4 Radiological protection measures for workers are provided in line with the principles described in Reference 3 such that doses received are ALARP.

C4.2.1.1/1/5 All ILW handling and processing uses remote operations techniques with engineered interlocks or suitable administrative controls to prevent operator access to processing and storage areas when ILW is present.

C4.2.1.1/1/6 Processed ILW packages are appropriately shielded or overpacked before and during cross-site transport to the interim ILW storage facility.

C4.2.1.1/1/7 The SWMS equipment is designed so that worker doses during normal operation and maintenance (including recovery from plant breakdowns) are ALARP.

C4.2.1.1/1/7.1 The wet-solid processing systems include engineered flushing points which so far as is reasonably practicable (SFAIRP) enable any settled radioactive contamination to be flushed from system prior to maintenance work being carried out thus ensuring operator doses during maintenance are ALARP.

General

C4.2.1.1/1/8 Solid and wet-solid radioactive wastes are contained, controlled and processed within appropriately engineered facilities (see Section 4.2.4).

C4.2.1.1/1/9 Appropriate monitoring, measuring, and sampling equipment is provided so that operators can check and record that wastes coming into and being dispatched from the facility are as expected.

4.2.1.2 Faults

Potential Doses to the Public in Faults

C4.2.1.2/1 Doses to public in faults are ALARP and within limits/targets given in Reference 4.

Natural Hazards

C4.2.1.2/1/3 The radioactive waste civil structures/building envelopes etc are designed and qualified to appropriate standards and provide protection against the following natural events:

- Earthquake
- High Wind
- Flooding
- Extreme temperature
- Snow loading.

Fire

C4.2.1.2/1/4 The overall design and layout of the radioactive waste buildings is compliant with the relevant UK fire regulations.

Potential Doses to Operators in Faults

C4.2.1.2/2 Potential doses to operators in faults are ALARP, including potential doses associated with post-fault operator actions required to secure affected plant in a safe condition.

C4.2.1.2/2.1 Where appropriate the design includes specific engineered provisions to facilitate identified fault recovery actions by the operators.

4.2.2 Functional Requirement

- The Wet-solid ILW treatment facility is designed to condition wet-solid ILW into a passively safe form compatible with NDA RWMD requirements for ultimate disposal in the GDF.
- The Wet-solid LLW treatment facility is designed to condition wet-solid LLW into a form compatible with disposal at the LLWR.

- The Solid ILW Treatment Facility is designed process solid ILW into a passively safe form compatible with NDA RWMD requirements for ultimate disposal in the GDF.
- The Solid LLW Treatment Facility is designed to process wastes into packages suitable for off-site transport to the appropriate nominated facility for incineration, recycling or direct disposal.
- The on-site Interim ILW Store is designed to receive processed and packaged wet-solid ILW, and processed and packaged Solid ILW. The Store is designed to hold all of the processed ILW generated in the operating lifetime of the ABWR, i.e. 60 years plus any additional ILW resulting from POCO of the LWMS. The proposed design life of the Interim ILW Store is 100 years. The store is designed to provide conditions that will minimise as far as reasonably practical any degradation of the packaged wastes by corrosion or similar processes during the period of interim on-site storage.
- The LLW Marshalling Area is designed to have sufficient capacity to receive and temporarily store of processed and packaged LLW, VLLW and Exempt Waste, pending the dispatch of this waste off site for incineration, recycling or direct disposal at the appropriate nominated facility.

4.2.3 Design Related Requirement

C4.2.3/1 Categorisation and classification of structures, systems and components are decided based on fault study.

C4.2.3/2 Seismic category is decided based on fault study.

4.2.4 Design Criteria

The construction and design of the SWMS buildings and processing equipment (pipes, tanks, sumps etc.) have used appropriate engineering design principles and are engineered to the required withstands (pressure, seismic etc.). Material selection is based on corrosion resistance and operating conditions. The following general design features are also included:

- Vessels, pipes, pumps etc. used for processing wet-solid wastes use appropriate materials, are designed against appropriate design temperatures and pressures and are manufactured and tested in accordance with appropriate engineering standards.
- Basically, except where break-in requirements for maintenance or recovery from breakdowns, the systems used for processing wet-solid wastes are fully welded systems.
- The wet-solid waste processing systems include monitoring of all the main process parameters (level, pressure, flow, temperature, etc.) with appropriate alarms provided to the operators in the event of abnormal conditions.
- The systems used for processing wet-solid wastes are provided with bunding.
- All floor drainage and bunding sumps include leak detectors/alarms and pumps to recover any spilt liquids.
- Bunding is provided at all external doors to wet-solid waste treatments facilities to prevent the spread of any spilt liquids outside of the facilities.
- Solid ILW handling equipment is purpose designed to appropriate engineering standards to ensure integrity of lifting/handling of wastes
- Appropriate shielding and radiological protection provisions are provided to minimise operator doses to ALARP during normal operation and during examination, inspection, maintenance and testing of equipment.

4.3 SYSTEM DESCRIPTION

The Solid Radioactive Waste Management System (SWMS) is designed to receive, and sort and process/condition all solid and wet-solid LLW and ILW waste streams resulting from ABWR operation.

Following processing and conditioning LLW is dispatched off site for either incineration, recycling and LLW solids and wet-solids in preparation for further conditioning, the assorted solid and wet-solid waste is then conditioned for either off site incineration, offsite recycling (in the case of recyclable metals), or direct disposal, while ILW is transferred for interim storage (pending availability of the GDF) in an on-site shielded ILW store. The method selected for dealing with the different waste streams uses cement encapsulation in preparation for interim storage (ILW) or disposal (LLW).

The SWMS comprises the following facilities:

- Solid LLW treatment facility
- Solid ILW treatment facility
- Wet LLW treatment facility
- Wet ILW treatment facility
- LLW marshalling area (pending transport for off-site incineration/recycling/disposal)
- Interim ILW store (dedicated building)

4.3.1 Solid LLW Treatment Facility

This facility processes the following wastes;

- CF spent hollow fibre media.
- LCW filter spent hollow fibre media.
- Miscellaneous soft wastes such as paper, polythene, cloths etc, comprising combustible and non-combustible material.
- Other miscellaneous non-combustible wastes including metals, cables, lagging, gas filters, concrete, glass, etc, comprising recyclable metal and non-recyclable material.
- Activated carbon
- HVAC filters including Medium Efficiency bag type filters and HEPA filters.

The Solid LLW Treatment Facility is a self-contained single storey building. The building is nominally un-shielded, although temporary modular shielding blocks may be used during the processing of some types of waste. The facility has Fork Lift Truck (FLT) access at both its reception and dispatch bays.

The main equipment items in the Solid LLW Treatment Facility include:

- Sorting conveyor array
- Combustible waste shredder
- Low force compactor
- Over Head Crane (OHC)
- Linear conveyors for discharge of filled HHISO containers and skips
- HVAC system

4.3.1.1 Solid LLW Receipt and Sorting

All suspected solid LLW is initially delivered (to the LLW Reception Bay of the LLW Facility. The waste is normally pre-sorted and segregated at the point or origin into different coloured LLW Transfer Containers. If not pre-sorted, the first step is to manually sort the waste into three generic categories with different treatment and disposal routes: combustible waste that can be sent to incineration facilities for volume reduction; metallic components that can be recycled and other miscellaneous waste that requires direct disposal.

Dewatered Granular Activated Carbon (GAC) and Bead Activated Carbon (BAC) from the Laundry Drains processing system (see Section 2.3.4 above) is also delivered to the Solid LLW Facility packed in 200 litre drums. These drums are weighed and beta/gamma dose monitored to identify those drums containing activated carbon waste that meets the LLWR Waste Acceptance Criteria (WAC) for combustible waste. These drums are segregated to be processed as combustible waste, while the drums containing activated carbon above the WAC dose threshold are sent to the Wet LLW Treatment Facility for cement encapsulation.

4.3.1.2 Combustible Waste Treatment and Packaging

Combustible LLW includes items such as HVAC (ME and HEPA type) Filters, CF or LCW Hollow Fibre Filters and other combustible materials such as paper towels, etc. Sorted combustible LLW is placed in LLW Transfer Containers and transferred using the sorting conveyor array to the Shredder and Low Force Compactor, where the waste is volume reduced and then re-packaged in to container (e.g Dolav 800 Tri-Hi 870 boxes). These boxes are weighed and beta/gamma dose monitored to confirm that the waste that meets the LLWR Waste Acceptance Criteria (WAC) for combustible waste, and are then placed into 2 off ½ S1 Stillages in a Reusable HHISO container. The 200 litre drums of BAC and GAC which have been confirmed to be within the LLWR WAC for combustible waste (see above) are also placed into 2 off ½ S1 Stillages (Drum Variant) in a Reusable HHISO container. The completed HHISO containers (containing boxes and drums of combustible LLW) are then dispatched to the LLW Marshalling Area awaiting collection and shipment to the LLW incinerator nominated by the LLWR.

4.3.1.3 Metallic Waste Transferred from Solid ILW Facility

Pre-characterised and pre-sorted Low Level activated metallic waste from the Solid ILW Treatment Facility (see Section 4.3.4) is delivered to the Solid LLW Facility Reception Bay in LLW Transfer Containers. This waste is transferred directly into container (e.g. WB-1 Waste Boxes), which are then packed into 2 off ½ S3 Stillages in a Reusable HHISO container. Once full the HHIOS containers are dispatched to the LLW Marshalling Area awaiting collection and shipment to the nominated off-site LLW Metal Recycling Facility.

The Metallic LLW is packaged in accordance with the requirements of the Metallic LLW WAC.

4.3.1.4 Other Metal Waste Items Capable of being Recycled

Metallic waste items from across the site may constitute part of the general LLW arisings. These items are visually identified and segregated at source or separated out during sorting in the Solid ILW Facility. Following surface decontamination (if required), any LLW metallic waste items that are recyclable are transferred to container (e.g. WB-1 Waste Boxes), which are then packed into 2 off ½ S3 Stillages in a Reusable HHISO container. Once full, the HHISO containers are dispatched to the LLW Marshalling Area awaiting collection and shipment to the nominated off-site LLW Metal Recycling Facility.

The Metallic LLW is packaged in accordance with the requirements of the Metallic LLW WAC.

Any small amounts of metallic LLW not suitable for recycling are dealt with as Miscellaneous LLW as described in Section 4.3.1.5 below.

4.3.1.5 All other Miscellaneous LLW

The beta-gamma activity levels of all other miscellaneous suspected LLW items are monitored, allowing the waste to be appropriately categorised as LLW, VLLW or Exempt depending on its activity levels. LLW and VLLW are placed directly into separate containers ready for direct disposal at the appropriate facility - the LLWR for LLW or an approved VLLW disposal facility for VLLW. The LLW and VLLW containers are dispatched to separate zones in the LLW Marshalling Area awaiting collection and shipment by LLWR. Exempt waste is placed in commercial waste skips for disposal via the Local Authority route. The skips of exempt waste are dispatched to the central site conventional waste collection area.

VLLW is packaged in accordance with the VLLW Disposal WAC, the LLW is packaged in accordance with the LLW Disposal WAC.

4.3.2 Solid ILW Treatment Facility

This facility processes the following wastes;
- Control rods
- Local Power Range Monitors (LPRMs)

- Start-up Range Neutron Monitors (SRNMs)
- Traversing In-core Probes (TIPs)
- Neutron Source Units (NSUs)

The Solid ILW Treatment Facility is a self-contained multi-storey building. The building is heavily shielded, consisting of a shielded reception facility, a shielded buffer storage area, a shielded processing area and a shielded export facility.

The main equipment items in the Solid ILW Treatment Facility include:

- OHC
- Cask linear conveyor
- MWTC linear conveyor
- Casks lid removal and fitting equipment
- MWTC lid removal and fitting equipment
- Remotely operated OHC with assorted grapples or power manipulator on mast
- Dose and gamma spectrometry assay equipment
- Hydraulic Roller Crusher (for Control Rods)
- Hydraulic Pinch and Shear croppers (for Control Rods)
- Hydraulic Rotating Shear croppers
- Remotely operated linear conveyor
- Remotely operated grab / manipulator for posting cropped waste items
- OHC for handling 3 m^3 Boxes
- Assorted shield gates
- Air compressor
- HVAC system

4.3.2.1 Solid ILW Reception

Solid ILW is transferred from the Fuel Pool to the ILW Treatment Facility in two different casks types, Casks and Miscellaneous Waste Transfer Containers (MWTCs). Both cask types are drained at source, so that the ILW they contain is in a nominally dry condition prior to transfer. Casks are then loaded onto a dedicated purpose built transporter and transferred to the reception bay of the Solid ILW Treatment Facility.

4.3.2.2 Opening a Transfer Cask

Once the transporter has been positioned in the reception bay, for Casks only, the impact limiters on both ends of the Cask are removed and placed in a dedicated lay-down area. The OHC is then used to rotate the Cask to the vertical and lift it from the transporter (which remains in the unloading bay). The OHC combined with a linear conveyor is then used to manoeuvre the Cask into a shielded Unloading Station, where it is set down standing upright. The shield doors on the Unloading Station are then closed. The process is similar for the MWTC except that these containers are transported to the facility in the vertical orientation.

The operators enter the shielded Unloading Station via an interlocked man access door and access the top of the Cask to loosen the Cask Lid bolts. Once the lid bolts have been removed, the operators leave the shielded unloading bay. Access during subsequent cask lid removal and cask unloading operations is prevented by interlocks that prevent:

- Use of the OHC when the main shielded labyrinth doors are closed and the man access door is not locked
- Unlocking of the man access door when beta/gamma radiation monitors in the shielded Unloading Station detect high levels of radiation (i.e. when the Cask lid has been removed)

Once it has been confirmed that the Unloading Station shield doors are closed, the operators have left the shielded Unloading Station and the man access door has been locked (in accordance with the administrative controls), the Cask lids are lifted remotely using the OHC and set down in a dedicated lay-down area.

Measurements from the radiation monitors in the Unloading Station and visual inspection by the operators using CCTV are then used to confirm that the Cask contains no unexpected material (e.g. fuel).

4.3.2.3 Unloading the Casks & MWTCs

A remotely operated OHC or power manipulator is used to grapple, lift and remove Control Rods and Cask Baskets from the Casks and MWTC Liners from the MWTCs. The Cask Baskets and the MWTC Liners have the same lifting features but a different grapple is used to lift the Control Rods. The OHC or power manipulator is then used to manoeuvre the items through a further shielded labyrinth door to the Solid ILW Buffer Storage Area where they are placed in a racking system.

Once the Cask/MWTC has been fully unloaded, it is reloaded with empty Cask Baskets / MWTC Liners from the Shielded Buffer Storage Area racks, again using the OHC or power manipulator. The Cask or MWTC is then re-lidded using the OHC. Once the shielded lid is confirmed to be in position and the dose rate readings form the beta/gamma monitors in the shielded Unloading Station are confirmed to be at an acceptable level, the operators can re-enter via the man access door and fasten the lid bolts. The Cask is then checked for external contamination, decontaminated (if necessary) and reloaded on to the transporter using the OHC for reuse.

4.3.2.4 Unloading the Buffer Storage Area, Size Reduction and Packaging

The contents of the ILW Buffer Storage Area racking system can be viewed remotely by the operators using a CCTV camera. The OHC or power manipulator is used with purposely deigned grapples to recover either individual Control Rods or individual items from a Cask Basket or MWTC Liner stored in the racks. Control Rods are manoeuvred directly to the Control Rod size reduction and packaging station. Other items are first manoeuvred to the assay station, where beta/gamma dose rates are measured along the whole item length to ascertain with the dose fingerprint of the item corresponds to ILW or LLW. (The items transferred from the Fuel Pool include LPRM, SRNM, TIP and NSUs pre-cropped into approximately 4 meter lengths. The lower lengths of these components which operate outside and some distance below the bottom of the RPV during the operational life will correspond to LLW rather than ILW). Following characterisation, the item is manoeuvred to the appropriate (ILW or LLW) size reduction and packaging station. An interlock on the OHC or power manipulator control system prevents movement to the LLW size reduction and packaging station if the dose rates measured at the assay station are above a specified level.

4.3.2.5 Control Rod Size Reduction and Packaging Station

At the Control Rod size reduction and packaging station, the control rod (which has a cruciform cross-section) is flattened by passing it through a hydraulic roller crusher. The flattened Control Rod is then cut into ~ 1.4 meter lengths using a Pinch and Shear cropper. The shearing is carried out directly over an open 3 m^3 Box, ensuring that any small quantities of boron carbide powder that might be released during shearing fall directly into the box. Prior to each shearing operation, the lower section of the rod is clamped in a secondary grab/manipulator. This grab/manipulator is then used to lower the sheared length in manner that avoids damage to the box and in a position that ensure efficient waste packing.

4.3.2.6 ILW Size Reduction and Packaging Station

At the ILW size reduction and packaging station, non-control rod items that have been confirmed as ILW at the assay station are positioned over a 3 m^3 Box and then sheared using a Rotating Shear Cropper. Prior to each shearing operation, the lower section of the item is clamped in a secondary grab/manipulator. This grab/manipulator is then used to lower the sheared length in manner that avoids damage to the box and in a position that ensure efficient waste packing.

4.3.2.7 LLW Size Reduction and Packaging Station

At the LLW size reduction and packaging station, non-control rod items that have been confirmed as LLW at the assay station are sheared using a Rotating Shear Cropper. The shearing is carried out directly over a LLW Transport Container and the sheared lengths are permitted to fall directly into this container.

4.3.2.8 Removing and Supplying New Packaging Containers

Once a 3 m^3 Box has been filled, it is moved by a conveyor system to the ILW Box Lidding Station. At this station, any residual voidage in the 3 m^3 Box is filled with sand, if required, (which is used as an inert filler) and a lid is then fitted and bolted into place remotely. The 3 m^3 Box is then moved on the conveyor system to a Decontamination Station where the external surfaces of the sealed 3 m^3 Box are then checked for contamination by swabbing and, if required, decontaminated. The 3 m^3 Box is then moved by the conveyor system to the Solid ILW Dispatch Bay. The ILW Cross Site Transporter is bought to the Solid ILW Dispatch Bay and the 3 m^3 Box is remotely handled into the ILW Cross Site Transporter using a OHC and removed from the ILW Treatment Facility for dispatch to the Interim ILW Store

Empty 3 m^3 Boxes are delivered to the Solid ILW Dispatch Bay using the ILW Cross Site Transporter and these are moved to the Control Rod and ILW size reduction and packaging stations using the conveyor system (operating in reverse).

Once a LLW Transfer Container at the LLW size reduction and packaging station has been filled, it is re-lidded and swabbed to ensure it is clean. If contamination is found, it will be decontaminated prior to transfer to the Solid LLW Treatment Facility using a Fork Lift Truck. Empty LLW Transfer Containers are delivered to the LLW size reduction and packaging station by Fork Lift Truck.

4.3.3 Wet LLW Treatment Facility

This facility processes the following wastes;
- Bead resin (from LCW demineraliser, HCW demineraliser and CD)
- Concentrated waste (from HCW evaporator)
- Activated carbon (from LD system)

The Wet LLW Treatment Facility is a self-contained multi-storey building. The building has a shielded enclosure containing the waste reception area, an unshielded cement powder handling area, a THISO import / export area and an area for THISO filling.

The Wet LLW Treatment Facility is connected to the Rw/B by a shielded and secondary contained transfer pipe duct.

The main equipment items in the Wet LLW Treatment Facility include: -

- OHC
- linear conveyor
- MWTC handling equipment
- MWTC lid removal and fitting equipment
- Supernatant decant pump
- A LLW Process Tank
- An Wet LLW feed pump
- LLW Effluent Treatment system and associated discharge pump
- 200 litre Drum emptying system
- Cement grout preparation equipment (powder feeder, mixer, grout feed hopper and grout pump)
- NaOH dosing system
- THISO fitted with lost In-line Mixer
- Assorted shield gates
- Air compressor
- HVAC system

An overview of the Wet LLW treatment process is shown in Figure 4.

4.3.3.1 Transfer to Wet LLW Treatment Cell

Two types of wet LLW, Resins and Sludge are initially collected and stored in separate tanks in the main Rw/B (see Section 2.3.6 above). Motive water is used to transfer the Resins and Sludge wastes to the Wet LLW Treatment Cell and makes up the majority of the transfer volume. The two waste streams are co-processed in batches, which are periodically transferred to the Process Tank in the Wet LLW Treatment Facility.

A third source of wet LLW is waste sludge and filter media transferred in 200 litre Drums from the Laundry Drains treatment system (see Section 2.3.4 above) and Granular Activated Carbon (GAC) that does not meet the LLWR WAC for incineration, which is also transferred in 200 litre Drums from the Laundry Drains treatment system via the Solid LLW Treatment facility (see Sections 2.3.4 and 4.3.1.1 above). The 200 litre drums containing these wastes are mechanically lifted above the Wet LLW Process Tank and then emptied into the tank following supernatant removal (see below) and mixed with the other wet LLW streams.

The following subsections cover preparation for treatment of the wet LLW.

4.3.3.2 Supernatant Removal (Resin, Sludge and GAC)

Once a mixed batch of Resins and Sludge has be transferred to the Wet LLW Treatment Cell, the waste is allowed to settle in the LLW Process Tank and the supernatant is then removed using a Decant Pump with a retractable dip leg. The control system monitors the depth of the sludge bed and hindered settling zone and the end of the dip leg is positioned to maximise supernatant retrieval. After supernatant removal, wet LLW transferred from the Laundry Drains treatment system in 200 litre drums can be emptied from drums into the top of the Wet LLW Process Tank and mixed with the other wastes (see Section 4.3.3.1 above).

4.3.3.3 Supernatant Treatment

Decanted supernatant is transferred to the LLW Effluent Treatment Plant which is used to remove fine particulate and soluble species. The separated solids and soluble species are returned to the LLW Process Tank for incorporation in a subsequent encapsulation batch. Treated supernatant is transferred back to the main Rw/B.

4.3.3.4 Caustic Treatment of Ion-Exchange Resins

Following supernatant removal, a caustic solution is used to swell the ion-exchange resins prior to cement immobilisation. This prevents swelling post cement curing, which would compromise the integrity of the final waste package. The caustic solution is delivered to site in an IBC (International Bulk Container), which is positioned in a bunded area in the Chemical Storage Area. Caustic solution is transferred from the IBC to the LLW Process Tank via the metered Caustic Feed Pump. The LLW Process Tank is agitated until the caustic treatment is complete.

4.3.3.5 Grout Preparation

The exact cement grout formulation will be subject to optimisation trials. The pre-blended cement powder will be delivered in 2.5 tonne capacity IBCs that can be connected to the grout process equipment. The pre-blended cement powder is metered into the Mixer where it is wetted with chilled water (to limit the effects of the exothermic pozzolana reaction) to form a suitable grout product. The grout is transferred to a Wet Grout Hopper ready for transfer to the lost In-Line Mixer in the container.

4.3.3.6 Wet LLW Immobilisation

Grout flow via the lost In-Line Mixer in the container is established and allowed to continue until the floor of the container is covered in grout. Homogenised (using the agitator in the LLW Process Tank) LLW sludge is then introduced into the lost In-Line Mixer and well mixed Grout and LLW are transferred into the container. When the container has been filled to a pre-set depth, the flow of LLW is stopped but the flow of grout is allowed to continue so as to provide a layer of relatively clean grout capping off the active mixture in the container. Once the container is full, the feed tanks are isolated and static lost In-Line Mixer is disconnected and dropped into the waste product. The contents of the container are left to cure before the lid is fitted. The container is then subject to final QA checks before being transferred to the LLW Marshalling Area, ready for dispatch off-site for disposal at the Low Level Waste Repository (LLWR).

4.3.4 Wet ILW Treatment Facility

This facility processes the following wastes;

- Powder resin & crud (from CUW filter demineraliser and FPC filter demineraliser)
- Sludge and crud (from CF and LCW filter)

The Wet ILW Treatment Facility is a self-contained multi-storey building. The building has a shielded enclosure containing the waste reception cells with three tanks, an unshielded cement powder handling area, an unshielded chemical storage area, a Modular ILW Solidification equipment in a shielded cell and a 3 m^3 Drum import / export area also in a shielded cell.

The Wet ILW Treatment Facility is connected to the main Rw/B by a shielded and secondary contained transfer pipe duct.

The main equipment items in the Wet ILW Treatment Facility include:

- Davit Crane for unloading new 3 m^3 Drums
- OHC for handling 3 m^3 Drums
- MWTC handling equipment
- MWTC lid removal and fitting equipment
- Supernatant decant pump
- Two of ILW Resin Batch Tanks
- One of ILW Crud Batch Tank
- Three of Wet ILW feed pumps
- ILW Effluent Treatment Plant and associated discharge pump
- Pre-blended cement grout preparation equipment (powder feeder, mixer, grout feed hopper and grout pump)
- Pre-blended cement powder feed system
- NaOH dosing system
- Modular ILW Solidification Equipment
- Assorted shield gates
- Air compressor
- HVAC system

An overview of the Wet ILW treatment process is shown in Figure 5.

4.3.4.1 Wet ILW Receipt

Two types of Wet ILW, Cruds and Spent Powdered Resin, are initially collected and stored in separate tanks in the main Rw/B. Batches of each waste type are transferred periodically into the process tanks in the Wet ILW Treatment Cell. The two waste forms are treated differently and so separate process tanks are used: a Crud Batch Tank and two Resin Batch Tanks (used simultaneously). Motive water is used to transfer the wet wastes and makes up the majority of the transfer volume.

4.3.4.2 Supernatant Removal

Following transfer to Cruds Batch Tank the Cruds are allowed to undergo hindered settling process over a few hours resulting in the formation of a sludge layer, a hindered settling zone and a dilute supernatant. The supernatant is then removed using a Decant Pump with a retractable dip leg. The control system monitors the depth of the sludge bed and hindered settling zone and the end of the dip leg is positioned to maximise supernatant retrieval.

The same process is used to decant supernatant from the batches of powdered resin transferred to the Resin Batch Tanks, though in this case the solid content settles out more quickly.

Decanted supernatant (from both the Cruds Batch Tank and the Resin Batch Tanks) is treated to remove fine particulate and soluble species. The separated solids and soluble species are then returned to the Cruds Batch Tank for incorporation in a subsequent encapsulation batch. Treated supernatant is transferred back to the main Radwaste Building.

4.3.4.3 Caustic Treatment of Resins

A caustic solution is used to swell the Powdered Resins prior to cement immobilisation. This prevents the Powdered Resins from swelling post cement curing, which would compromise the integrity of the final waste package. The caustic solution is delivered to site in an IBC (International Bulk Container), which is positioned in a bunded area in the Chemical Storage Facility. Caustic solution is transferred from the IBC to the Resin Batch Tank via the metered Caustic Feed Pump. The Resin Batch Tank is agitated until the caustic treatment is complete.

4.3.4.4 Cruds Addition to Resins

Once the Resins have been dewatered and treated by addition of caustic solution, the solids content of the waste is too high for cement immobilisation. Dewatered Cruds (which still form a dilute solution) are therefore transferred to the Resin Batch Tank containing the treated resin using the Cruds Transfer Pump, so as to increase the overall moisture content. If insufficient dewatered Cruds are available, recycled water from the main Rw/B is added instead to achieve the desired water content. Incorporation/mixing of the dewatered Cruds with the Resins waste stream minimises the number of waste packages produced.

4.3.4.5 Wet ILW Immobilisation

The Resin and Crud mixture is then immobilised in cement in a modular ILW solidification equipment which is operated remotely from a control panel. A new container (e.g.3m^3 drum) is positioned inside a Secondary Containment Vessel (SCV) at the Drum Loading Station. The drum is then moved to the Un-lidding Station, where the drum lid and associated bolts are removed automatically. The open drum is then positioned under the Waste Addition and Mixing Head (WAMH), which is lowered into position and engaged with the top of the drum in preparation for filling.

The Resin and Crud mixture in the Resin Batch Tank is then agitated and a fixed volume is transferred into the drum via a small metering vessel (which ensures the drum cannot be overfilled) ready for in drum mixing with the cement powders.

4.3.4.6 Immobilisation in Cement

The exact cement grout formulation will be subject to optimisation trials.

Cement powder premixed in the correct ratio is delivered to site in an IBC (International Bulk Containers). A screw conveyor is used to deliver the powders directly from the IBC to the drum in modular ILW solidification equipment. The Resins and Cruds mixture is agitated using a lost paddle in-drum mixer as the cement powder is added to ensure that the powder is drawn into the bulk mixture. The flow of cement is stopped once the drum is filled to a pre-set level and the lost paddle is then released into the cement/waste mixture. After the waste matrix has set, a liquid cement grout is made up and pumped in to the 3 m^3 drum to provide an inactive cap on top of the waste mixture. The 3 m^3 drum is then left for a further period for the cement cap to cure, before being moved to the Drum Lidding Station, where the drum lid and lid bolts are automatically fitted. Finally the 3 m^3 drum is moved to the Swabbing Station to confirm it is free from contamination and then to the Unloading Station.

Should a problem occur during the 3 m^3 drum filling and cementation process, a fault recovery process is available which involves moving the 3 m^3 drum to a safe shielded position (the Unloading Station), thus allowing operator access to the plant under low dose conditions to carry out repair/breakdown maintenance on the waste mixing and filling systems. Additional fault recovery processes can be used to remove raw waste from the drum, or over-pack the drum in the SCV allowing it to be exported out of the plant to the ILW Store's quarantine storage area, see Section 4.3.5 below.

4.3.4.7 Transfer of 3 m^3 Drums to the On-Site Interim ILW Store

The ILW Cross Site Transporter is brought to the Modular ILW Solidification Equipment Drum Un-Loading Station. The filled 3 m^3 Drum is remotely lifted onto the cross site transporter and then transferred to the Interim ILW Store. The ILW Cross Site Transporter can also transport a drum that has been over-packed in the SCV.

4.3.5 Interim ILW Store

The Interim ILW Store is a heavily shielded, self-contained multi-storey building. The building incorporates a shielded enclosure, which contains the waste reception area, assay and remediation cells, and a main store area. The Interim ILW Store is a stand-alone self-supporting facility.

The main equipment items in the Interim ILW Store include:

- OHC for handling 3 m^3 Drums & 3 m^3 Boxes
- Shield gates
- HVAC system

4.3.5.1 Reception and Positioning of ILW in the Interim ILW Store

The ILW Cross Site Transporter is used to carry filled ILW packages from the Wet ILW Treatment Facility (3 m^3 Drums) and the Solid ILW Treatment Facility (3 m^3 Boxes) to the on-site Interim ILW Store. The ILW Cross Site Transporter docks with the ILW Store import / export bay so as to provide adequate shielding during the unloading process.

A remotely operated ILW Store Over Head Crane (OHC) is used to lift the filled ILW packages from ILW Cross Site Transporter. The grapple used by the ILW Store OHC meets the requirements stipulated by the Radioactive Waste Management Directorate (RWMD) for the handling of both 3 m^3 Boxes and 3 m^3 Drums. The OHC is then used to move the ILW packages to the Inspection Bay where the unique identifier on the waste package is read and recorded and appropriate visual inspection QA checks are performed. If any non-conformance is found, or if the package was declared as a non-conforming package at the waste conditioning plant (e.g. because a problem occurred during waste processing), the package is transferred to the Quarantine Storage Area in the ILW Store using the OHC.

Packages which pass the QA check are moved using the OHC to the appropriate (Drum or Box) storage area where they are stacked. The final stacked position of each package is recorded along with the unique identifier for that package.

4.3.5.2 Inspection during Interim Storage on Site

Periodically selected packages are retrieved from stored array and moved back to the Inspection Bay using the ILW Store OHC. The original QA visual inspection checks on the packages are then repeated (e.g. to pick up any signs of corrosion, impact damage etc.) in order to demonstrate their continued integrity and compliance with the Waste Acceptance Criteria (WAC) of the Geological Disposal Facility (GDF).

4.3.5.3 Assay and Dispatch of Waste Packages from the ILW Store to the GDF

When dispatch of ILW packages from the ILW Store to the GDF is authorised, the Transporter will arrive on site and will be positioned in the Import / Export Bay of the ILW Store and opened ready to receive a waste package.

A selected waste package will be moved using the OHC to the Export Assay Bay. In the Export Assay Bay the waste package will have its unique identifier number recorded, be weighed and assayed for compliance with the WAC for the GDF. Once the assay and data recording has been completed, the waste package will be lowered into the SWTC using the OHC. The SWTC will then be sealed and authorised to leave the ILW Store for the GDF. This process will be repeated until the ILW Store is empty.

4.3.6 LLW Marshalling Area

Following final QA checking in either the Wet LLW Treatment Facility or Solid LLW Treatment Facility, packaged LLW and VLLW are moved (using a Fork Lift Truck) to segregated bays in the LLW Marshalling Area to await collection for shipment to the appropriate disposal facility.

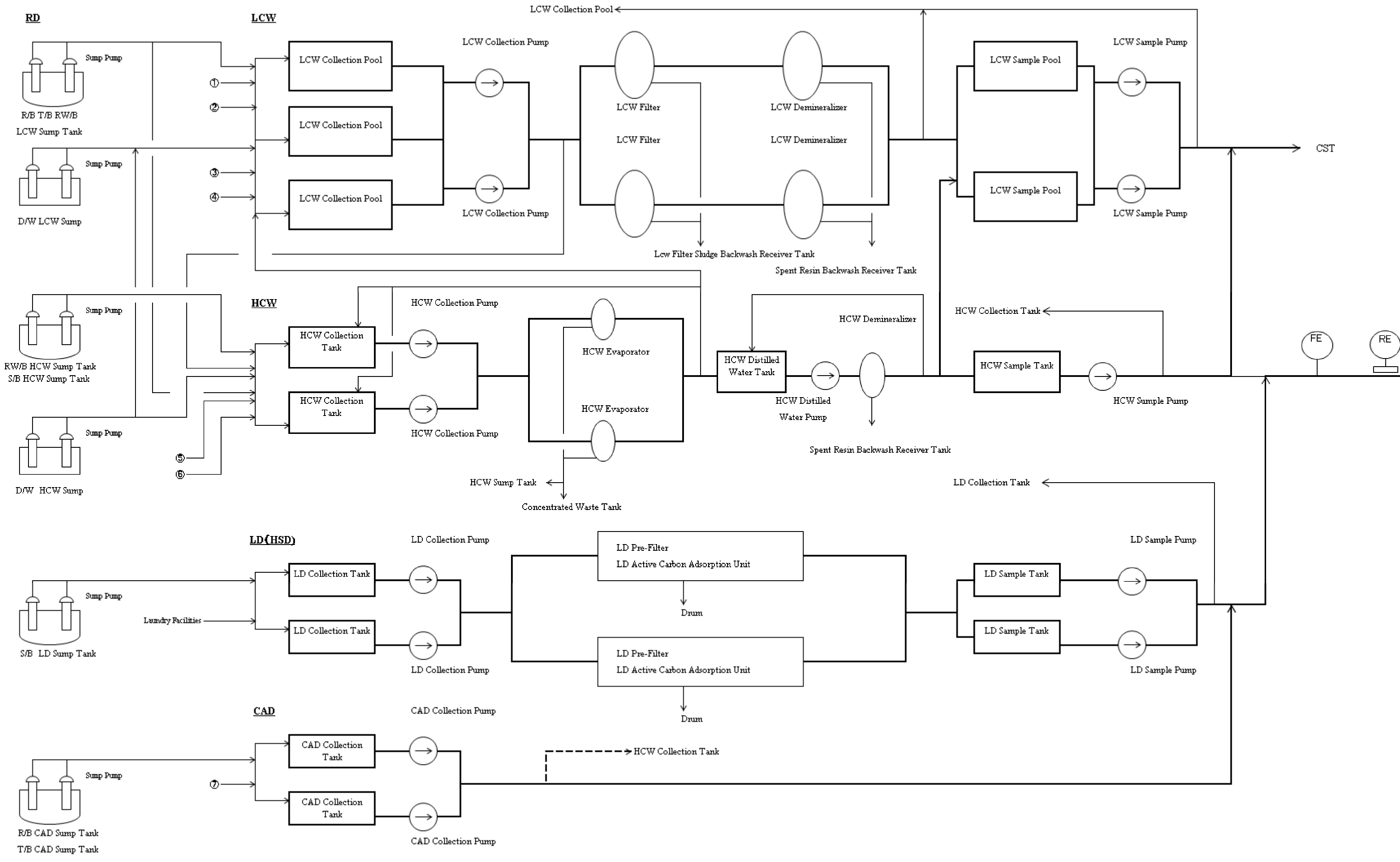
4.4 REFERENCES

1. Preliminary Safety Report on Spent Fuel Interim Storage; GA91-9901-0045-00001; XE-GD-0156; Rev. A; March 2014

2. Quantification of Discharge and Limits; GA91-9901-0025-00001; HE-GD-0004; Rev. C; March 2014
3. Preliminary Safety Report on Radiation Protection Section 2 Strategy to ensure that the exposure is ALARP; GA91-9901-0040-00001; XE-GD-0151; Rev. A; March 2014
4. Categorisation and Classification of Systems, Structures and Components; GA91-9901-0007-00001; XE-GD-0104; Rev. B; March 2014.

5 FIGURES

Figure 1 - Liquid Radwaste System Flow for ABWR



No.	Kinds of Drain
①	CUW Blowdown
②	Reactor Well Drain
③	RHR Blow
④	CD Backwash
⑤	CD Bottom Drain
⑥	RHR Blow
⑦	RW/B Controlled Area Drain

Figure 2 - Radwaste Treatment System Overview

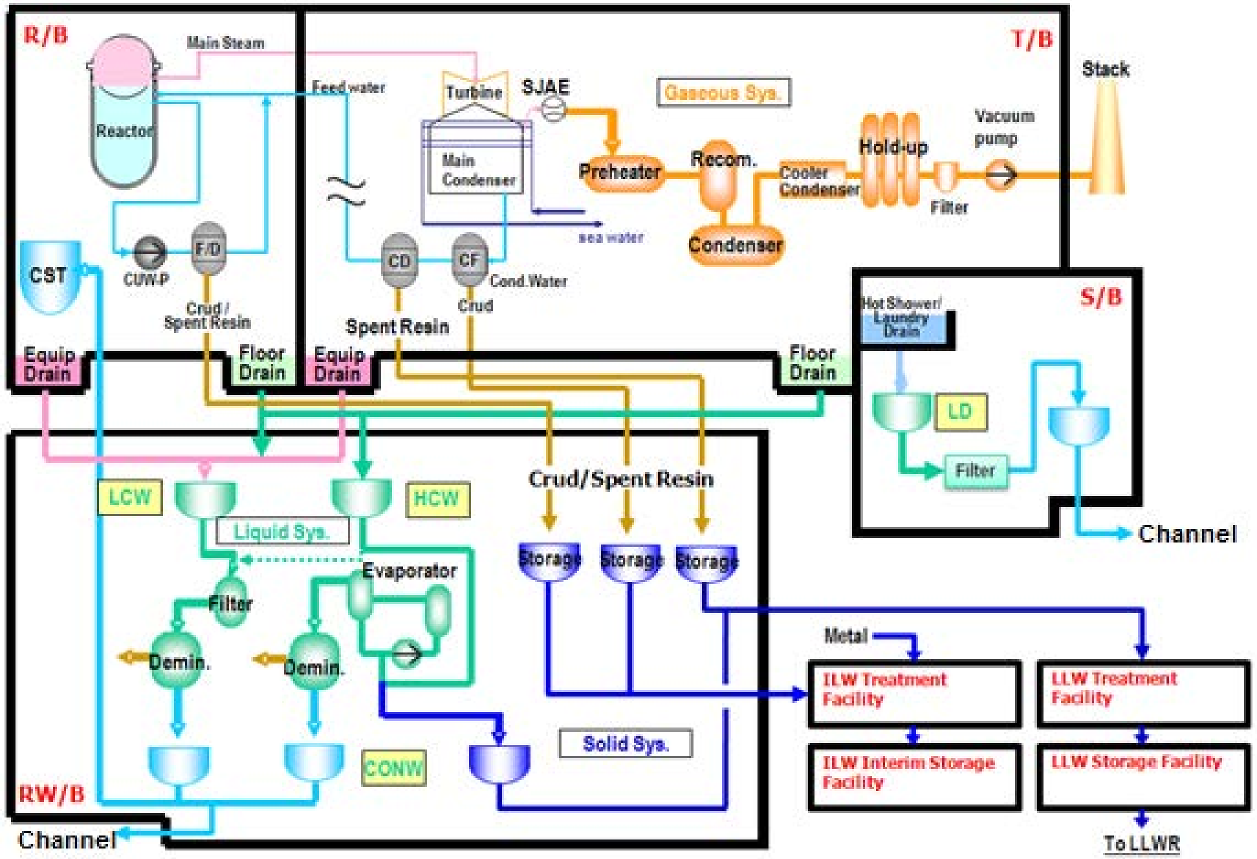


Figure 3 - Wet-Solid System Flow

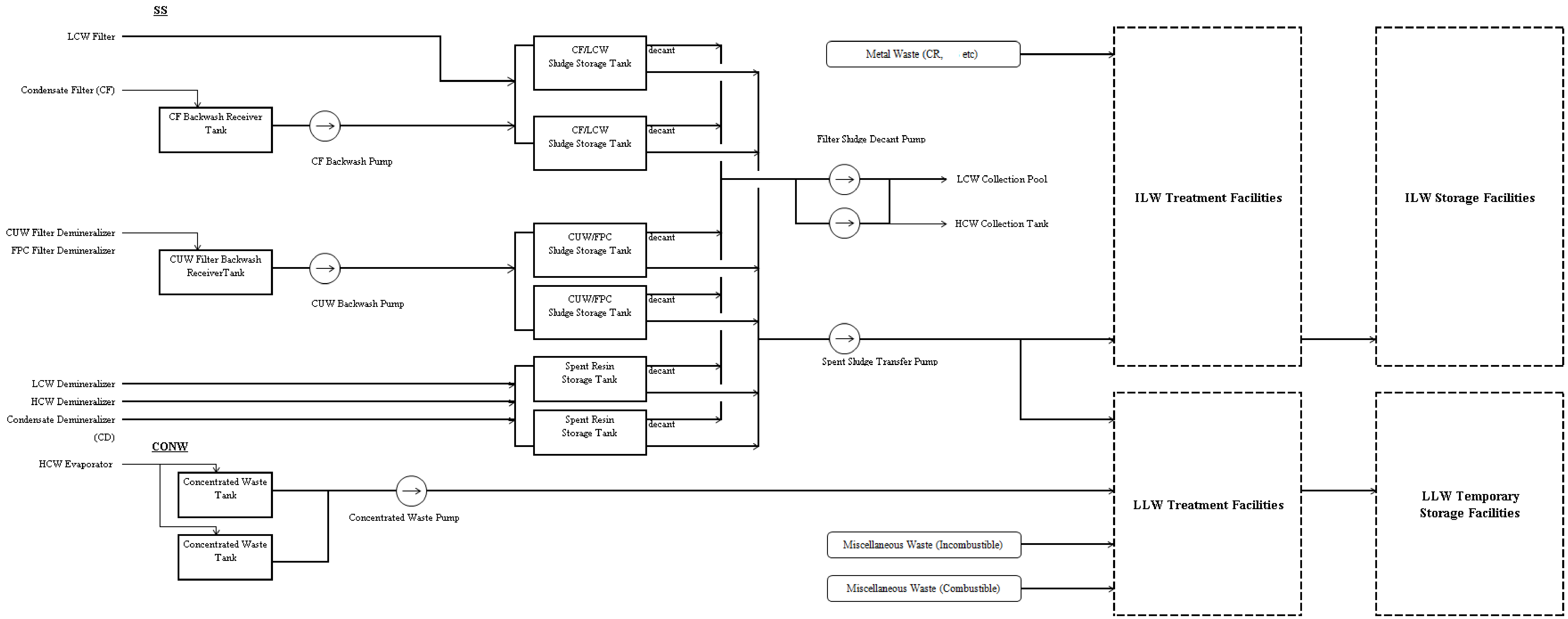


Figure 4 – Process Block Diagram Low Level Waste Processes

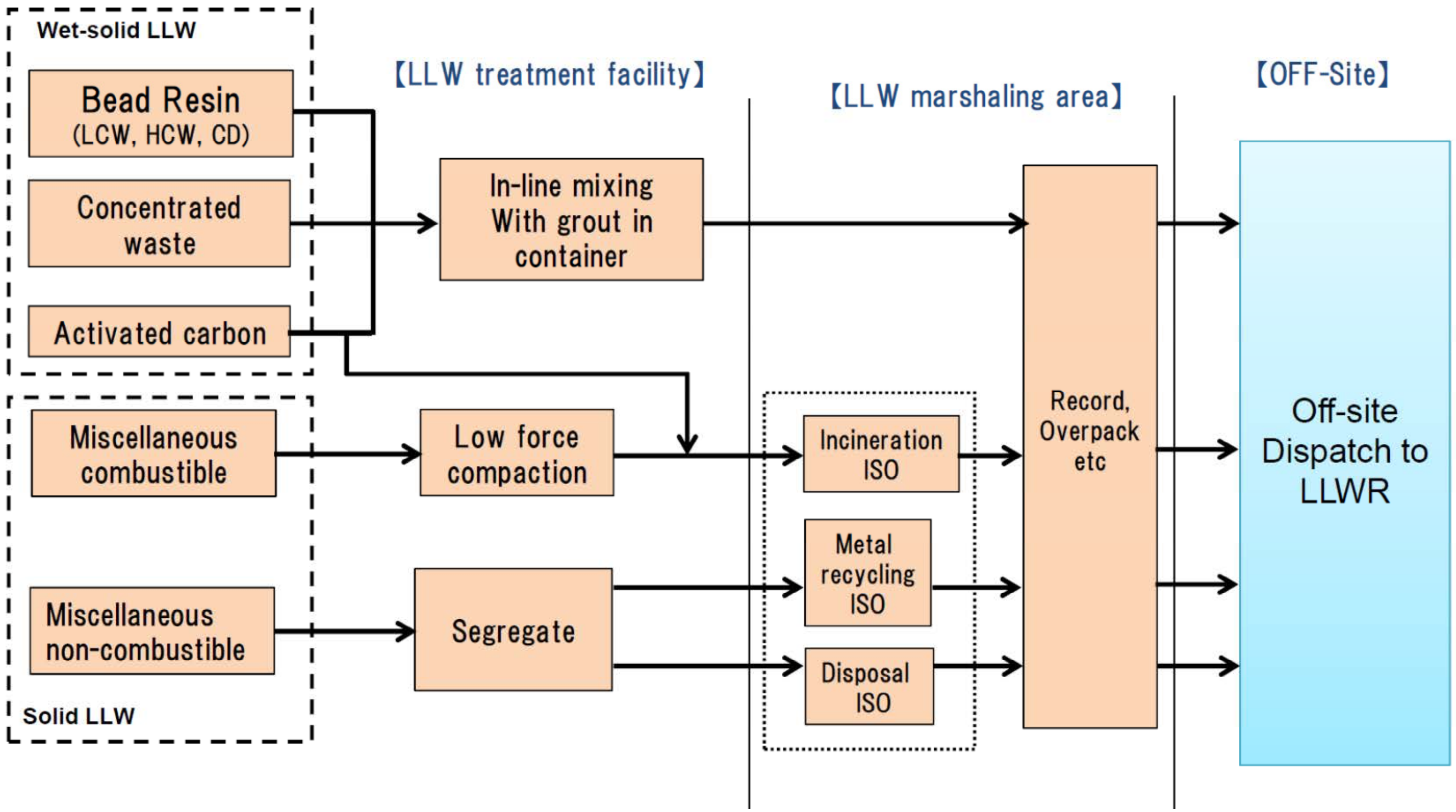


Figure 5 – Process Block Diagram Intermediate Level Waste Processes