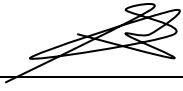



<b>UK EPR</b>	Title: PCSR – Sub-chapter 11.2 – Details of the effluent management process	
	<b>UKEPR-0002-112 Issue 05</b>	
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### REVISION HISTORY

Issue	Description	Date
00	First issue for INSA information	08-02-2008
01	Integration of technical and co-applicant comments	29-04-2008
02	Second issue - update of section 3 "Solid radioactive and spent nuclear fuel strategy" and minor modifications	20-11-2008
03	PCSR June 2009 update: <ul style="list-style-type: none"> <li>- Inclusion of references;</li> <li>- Consistency achieved with December 2008 design freeze;</li> <li>- Clarification of text</li> </ul>	23-06-2009
04	Consolidated Step 4 PCSR update: <ul style="list-style-type: none"> <li>- Minor editorial changes</li> <li>- Update and addition of references</li> <li>- Additional information included in sections 1.1.2.4 (new section), 1.1.3.1, 1.2.2.3, 1.2.3.1, 1.2.3.2.1, 2.2.4 (new section), 3 and 3.4.1.2.</li> </ul>	29-03-2011
05	Consolidated PCSR update: <ul style="list-style-type: none"> <li>- References listed under each numbered section or sub-section heading numbered [Ref-1], [Ref-2], [Ref-3], etc</li> <li>- Minor editorial and typographical changes for consistency / clarification</li> <li>- Clarification added regarding disposal of oil and solvents (§3.1, §3.4.1.2)</li> <li>- Updates to reactor chemistry aspects and cross-references to Sub-chapter 5.5 added for consistency (§1.1.1, §1.1.2.1, §2.1, §2.2.2, §2.2.2.1, §2.2.2.2, §2.2.2.3, §2.2.2.4, §2.2.2.5.1, §2.2.2.6.1, §2.2.2.7.1, §2.2.2.8.1, §2.2.2.9.1, §2.2.2.10.2, §2.2.2.10.3.1, §2.2.2.10.3.2, §2.2.2.10.4.1, §2.2.2.11.1)</li> <li>- References updated (§1.1, §1.1.3.1, 1.2.3.1, §2.2.10, §3, §3.3.1)</li> </ul>	28-08-2012

Continued on next page

<b>UK EPR</b>		
	Title: PCSR – Sub-chapter 11.2 – Details of the effluent management process	
	<b>UKEPR-0002-112 Issue 05</b>	Page No.: II / IV

**REVISION HISTORY (Cont'd)**

<b>Issue</b>	<b>Description</b>	<b>Date</b>
05 (cont'd)	Consolidated PCSR update: <ul style="list-style-type: none"> <li>- Clarification and minor error corrections (§1.1.2.1, §1.1.2.2, §1.1.2.3, §1.1.2.5, §1.1.3, §1.1.3.2, §1.1.3.3, §1.1.3.4, §1.1.4, §1.2.3.1, §3.3.1)</li> <li>- Figures updated consistent with the text (Figures 2, 3, 4, 7, 9, 12)</li> </ul>	28-08-2012

<b>UK EPR</b>		
	Title: PCSR – Sub-chapter 11.2 – Details of the effluent management process	
	<b>UKEPR-0002-112 Issue 05</b>	Page No.: III / IV

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<b>UK EPR</b>		
	Title: PCSR – Sub-chapter 11.2 – Details of the effluent management process	
	<b>UKEPR-0002-112 Issue 05</b>	Page No.: IV / IV

## TABLE OF CONTENTS

- 1. RADIOACTIVE DISCHARGES**
  - 1.1. RADIOACTIVE LIQUIDS DISCHARGES**
  - 1.2. RADIOACTIVE GASES**
- 2. LIQUID CHEMICAL EFFLUENT DISCHARGES**
  - 2.1. GENERAL**
  - 2.2. CHEMICAL DISCHARGES ASSOCIATED WITH RADIOACTIVE EFFLUENT**
  - 2.3. CHEMICAL EFFLUENT NOT ASSOCIATED WITH LIQUID RADIOACTIVE EFFLUENT**
- 3. SOLID RADIOACTIVE WASTE AND SPENT NUCLEAR FUEL STRATEGY**
  - 3.1. CATEGORIES OF RADIOACTIVE DISCHARGES IN THE UK**
  - 3.2. RADIOACTIVE WASTE AND SPENT NUCLEAR FUEL PRODUCED BY THE UK EPR**
  - 3.3. TREATMENT OF RADIOACTIVE WASTE**
  - 3.4. INTERIM STORAGE AND DISPOSABILITY FOR THE UK EPR**

## SUB-CHAPTER 11.2 - DETAILS OF THE EFFLUENT MANAGEMENT PROCESS

This sub-chapter deals in part with requirements 1.2, 1.4 and 2.1 of the EA P&I Document [Ref-1].

### DEFINITIONS AND TERMS USED

The EPR is a pressurised water reactor. As a result of all stages of its operation, during start-up, operation at power and shutdown for refuelling, it produces:

- liquid radioactive discharges;
- gaseous radioactive discharges;
- solid radioactive waste (in the form of fuel and also other solid materials).

The wastes originate from the operation of the primary reactor circuit. These radioactive materials are in the form of fission products in the fuel and also arise from activation of the primary reactor circuit components and the liquid coolant. Once in the coolant, they are transferred around various parts of the primary reactor coolant circuit and can also pass into the various reactor support systems in liquid and gaseous form.

For all these types of waste, the effluent management process may be broken down schematically as follows:



**Figure 1:** Overview diagram of the arrangements for processing and storing effluent from the EPR.

## 1. RADIOACTIVE DISCHARGES

### 1.1. RADIOACTIVE LIQUID DISCHARGES

#### 1.1.1. Source of radioactive liquid effluent discharges

Discharges include:

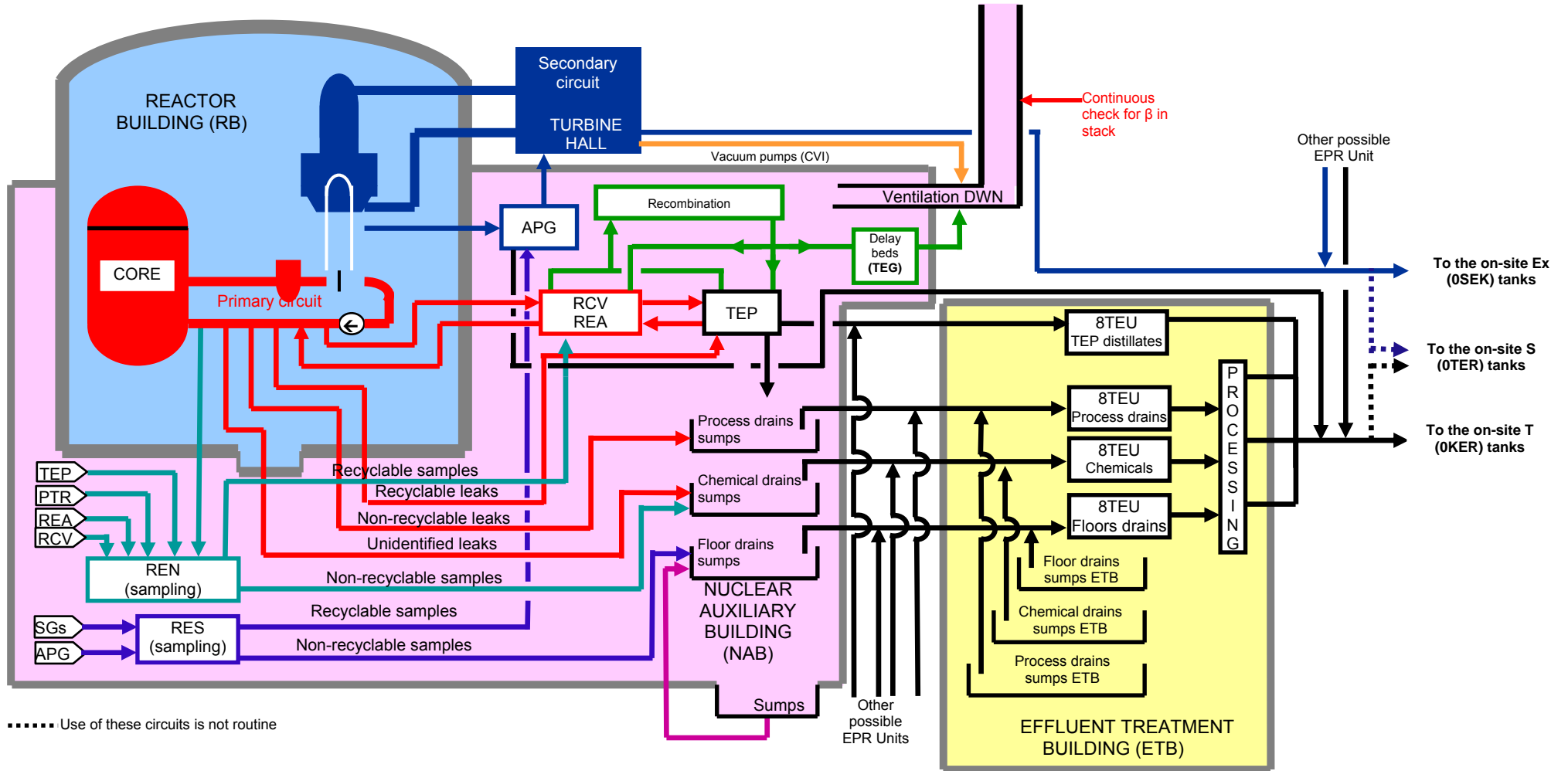
- activated corrosion products: These consist mainly of the activated corrosion products of structural transition metals such as iron, nickel, cobalt, chromium, or manganese that make up the main structural materials in the primary circuit (see PCSR Sub-chapter 5.5).

The main source of these transition metals is from leaching and minor corrosion of the steam generator U-tubes (but minimised using Inconel 690, see PCSR Sub-chapter 5.5). The corrosion products (iron, nickel, cobalt) circulate and are carried and then deposited in the reactor primary cooling system. The primary cooling fluid contains these corrosion products in soluble or particulate form. When they pass through the reactor core, they are activated by neutrons. The activated corrosion products formed are mainly cobalt-58 (from nickel-58), cobalt-60 (from cobalt-59), silver-110 (from silver-109), manganese-54 (from iron-54), and antimony-124 (from antimony-123). They may appear in solution or go into suspension when the water is physically or chemically changed, e.g. when the unit is shut-down, and thus move around the primary circuit. The main method for removing these activation products from the primary coolant is by a continuous bleed of the coolant into the Chemical and Volume Control System (RCV [CVCS]) where they can be removed from the coolant by ion exchange resins and a set of filters (and converted to solid waste). Additional information and a flow diagram of the RCV [CVCS] are given in PCSR Sub-chapter 9.3;

- activation products from chemicals in the primary coolant. To assist in reactivity control in the primary circuit (additional to that from the control rods) boric acid is added to the coolant. As the cycle progresses, the boric acid is diluted to compensate for fuel burn-up. To control the pH of the coolant due to this boric acid, small amounts of lithium-7 hydroxide (containing less than 0.1% Li-6) are also added to the coolant. Neutron flux on these chemicals and on the water in the reactor produces (see PCSR Sub-chapter 5.5): carbon-14 (produced from oxygen-17 in the molecules of the primary cooling water, and from any dissolved nitrogen-14), and tritium, (produced by neutron action on boron-10 and lithium-6). These two activation products are generated in proportion to the reactor neutron flux and therefore reactor thermal power. They are not retained by the resins in the Chemical and Volume Control System (RCV [CVCS]). However, they do pass in liquids passed from the primary circuit into downstream systems and plant, and thence into the gaseous phase;
- volatile fission products (caesium-134, caesium-137 and iodine-131), normally in a form soluble in the primary cooling water. Fuel cladding is designed to contain these materials in the fuel as far as possible, but a small number of fuel pins always unavoidably have a small number of minute leaks through which these fission products can escape (the so called “failed fuel fraction”) (see PCSR Sub-chapter 5.5). Like the activation products, these fission products are removed from the coolant using the ion exchange resins in the Chemical and Volume Control System (RCV [CVCS]) with the volatile ones being removed in the volume control tank. Tritium produced by fission is almost entirely retained in the fuel cladding, even if the cladding is defective.

As well as the demineralisers in the Chemical and Volume Control System, liquid effluents from other stages of operation of the EPR are treated in other buildings by additional decontamination methods such as evaporation, degassing, or filtration. These provide abatement prior to any release into the environment. These are described in further detail later in this sub-chapter.

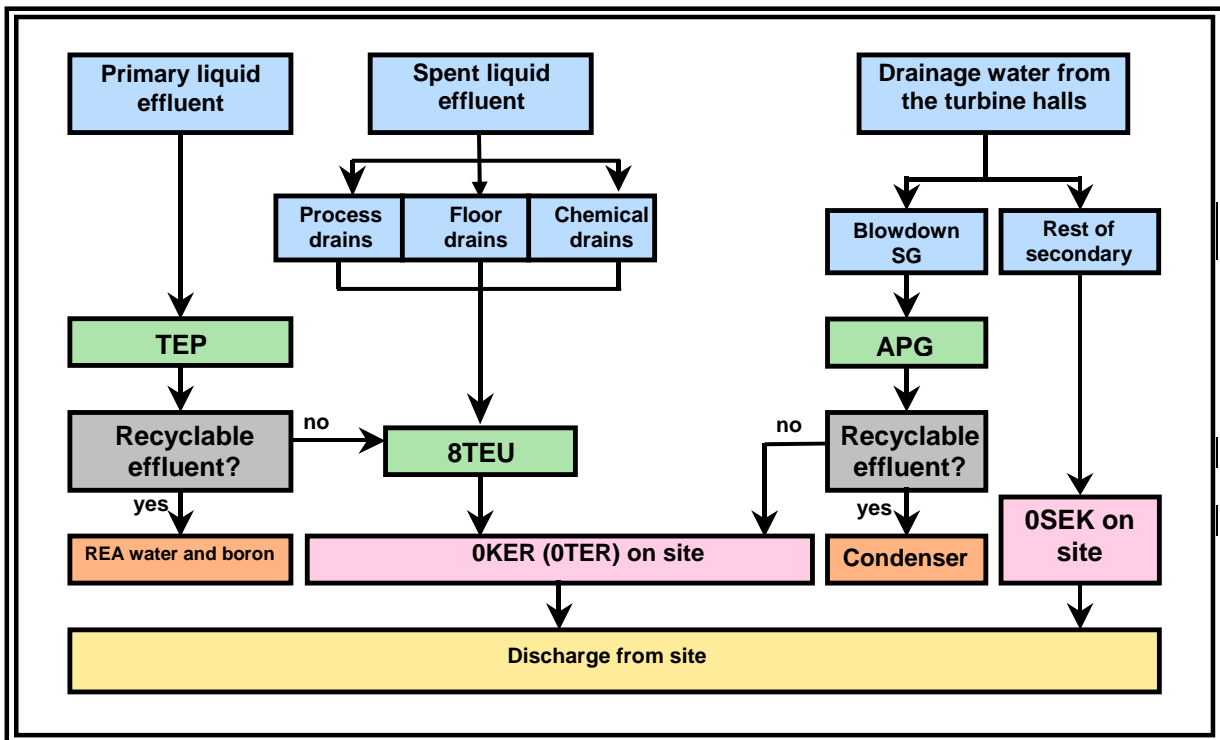
**Figure 2:** Overview diagram of the arrangements for processing and storing effluent from the EPR



**1.1.2. Nature of radioactive liquid effluent**

There are processing systems in place to restrict the discharge of radioactive liquid or gaseous effluent. These receive and process the effluent before discharge, in accordance with the principle of waste minimisation, focusing on reduction at source, collection and segregation, treatment, and reuse/recycling. Finally, residual materials are monitored and discharged to the environment.

Liquid radioactive effluent discharges fall into one of three categories, as shown in the following diagram:



**Figure 3:** Nature of liquid radioactive effluent

These three categories are described in the following paragraphs.

**1.1.2.1. Recyclable primary circuit liquid effluent**

Primary aqueous liquid effluent discharges are comprised of:

- a) liquid leaked or drained from the primary coolant water. This contains only chemicals from the primary circuit (see PCSR Sub-chapter 5.5), notably boric acid and lithium, and is not otherwise contaminated by other chemicals or oils;
- b) water from circuits containing the primary coolant, and discharged to downstream treatment systems in response to requirements to dilute boron through the fuel cycle (for neutron reactivity control additional to that provided by the control rods).



Both of these sources of primary reactor coolant consist of boric acid water containing dissolved lithium hydroxide. Primary reactor coolant from the primary circuit during operation at power also contains dissolved hydrogen; that drained from the circuit during periods at shutdown contains dissolved oxygen. At all stages the drained water contains dissolved and particulate activation products, dissolved and particulate fission products and dissolved gaseous fission products, as already described.

Primary liquid effluents from these sources are collected separately to other effluent sources and then sent to the Primary Effluent Treatment System (TEP [CSTS]) where it is decontaminated and the boric acid and water separated using an evaporator and a degasser.

Boric acid concentrates (4% solution) and distillates from the TEP [CSTS] evaporator and degasser may be reused as supplementary boric acid and water for the primary circuit coolant. Any primary effluent that cannot be recycled in this way is sent to the Spent Effluent Treatment System (8TEU [LWPS]).

#### 1.1.2.2. Non-recyclable spent liquid effluent

This is of three types:

- Process Drain (PD). This is polluted primary coolant drained or leaked from systems or equipment after flushing. Recycling to the primary circuit may be precluded by the presence of other impurities (chloride, sulphate, oil etc) but even if this is not the case, low concentrations of boron make recycling and recovery uneconomic. Normally, the pollution level means it may be processed in a different way to chemical drainage or floor drains arising from other parts of the plant (see below);
- Chemical Drain (CD). This is produced in the Nuclear Auxiliary Building, Reactor Building and Fuel Building and consists of water that is more polluted than water from the PD (above) or that from, for example, the REN [NSS] laboratory and the primary-coolant decontamination systems.
- Floor Drain (FD). This is of three types:
  - Floor Drain 1 (FD1). This is potentially contaminated and comes from leaks from equipment carrying primary coolant and from washing the floors; sumps are installed in areas of the premises that contain equipment transporting primary coolant to collect this floor drainage.
  - Floor Drain 2 (FD2). This is potentially uncontaminated and comes from leaks, floor washing and draining equipment (feedwater or RRI [CCWS]); sumps are installed in controlled areas of the premises to collect this drainage.
  - Floor Drain 3 (FD3). This effluent is produced only outside the controlled area. Normally it is uncontaminated and comes from leaks, from floor washing and from draining equipment (feedwater or RRI [CCWS]).

Apart from FD3, which is sent to the 0SEK [SiteLWDS] tanks, the spent liquid effluent is sent to the Spent Effluent Treatment System (8TEU [LWPS]) for treatment specific to its nature. Normally this is demineralisation for process drainage, evaporation for chemical effluent (using a specific evaporator in the 8TEU [LWPS]) and filtration for floor drainage. After processing, it is collected in on-site storage tanks before discharge (T or S tanks).

### 1.1.2.3. Steam Generator Blowdown System (APG [SGBS])

Blowdown water from the steam generators is largely made up of feedwater. In the event of small primary to secondary leaks (or more major tube failures), this blowdown may contain low levels of tritium from the primary circuit coolant.

This effluent source is normally directed to the steam generator blowdown treatment system where it is filtered and demineralised, then recycled to the main turbine condenser. Exceptionally, when recycling is not possible, the blowdown is sent to the T (or S) tanks (storage tanks) before monitoring and discharge.

### 1.1.2.4. Liquid effluent from the secondary circuit

In normal operation, the secondary circuit is not contaminated. In the case of primary/secondary leaks, up to the steam generators, water in the secondary circuit may contain low levels of tritium from the primary circuit coolant.

Tritium production is minimised at source, which therefore reduces the tritium activity in the secondary system. The tritium in the secondary system is controlled via the discharge limits for OSEK [SiteLWDS]. In case the tritium activity is too high in the secondary system, dilutions are performed to reduce it.

Tritium leaks cannot lead to accident conditions as these are based on the leakage rate and not the tritium activity.

### 1.1.2.5. Water drained from the Turbine Hall

Water drained from the Turbine Hall comes from leakage, and from draining and emptying the secondary circuit, but excluding blowdown from the steam generators. This effluent steam is sent directly to the Turbine Hall sumps (SEK [CILWDS]), and then sent to the Ex (or S) tanks for discharge.

## 1.1.3. Treatment of liquid radioactive effluent

A diagram showing an overview of the arrangements for processing and storing liquid effluent is given in Figure 2.

Liquid effluent, segregated at source is treated in different systems, depending on its characteristics, to allow it either to be reused and recycled or discharged as required. Treatment methods employ best practical means to ensure that as much of the effluent as possible can be reclaimed and reused and, where this is not possible, discharges of dissolved and radioactive materials to the environment and their impacts are as low as reasonably practicable.

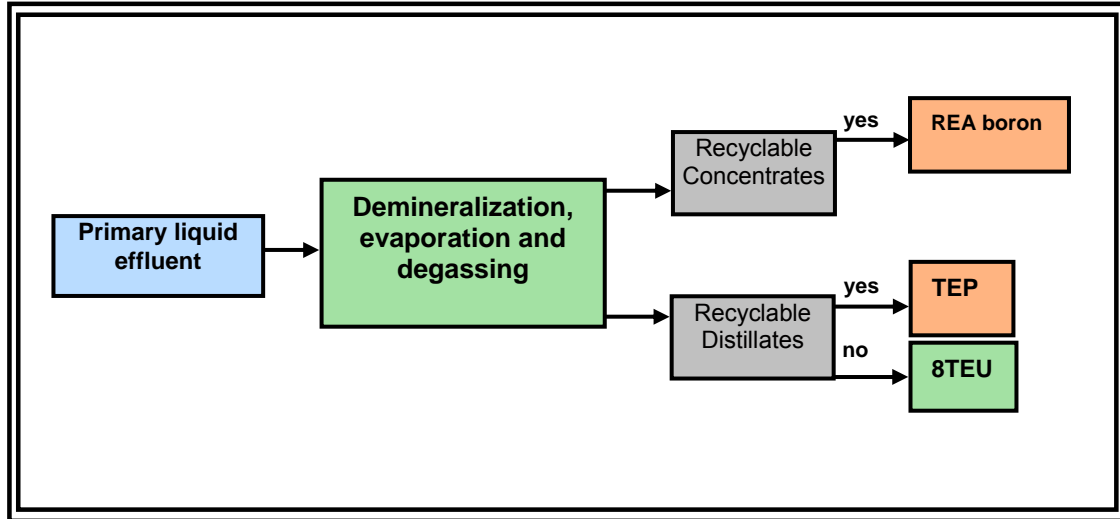
Primary liquid effluent is treated in the Primary Effluent Treatment System (TEP [CSTS]). The spent liquid effluent is treated in the Spent Effluent Treatment System (8TEU [LWPS]) installed in the Effluent Treatment Building.

The drainage water from the Turbine Hall is either processed in the system that processes blowdown water from the steam generators (APG [SGBS]), or sent to the on-site storage tanks for drainage water (Ex or S tanks) for discharge.

These treatment systems are described in the following paragraphs.

**1.1.3.1. Treatment of primary liquid effluent (TEP [CSTS], [Ref-1] to [Ref-6])**

An overview of the treatment of primary liquid effluent is shown in the following diagram:



**Figure 4:** Treatment of primary liquid effluent

Primary liquid effluent is treated in the Primary Effluent Treatment System TEP [CSTS]. The main function of this system is to treat the primary effluent so that, as far as possible, the boron and water may be recycled through the primary reactor circuit.

In conjunction with the TEG [GWPS] for gaseous effluent, the TEP [CSTS] processes all the primary liquid effluent, whether it contains dissolved hydrogen or dissolved oxygen.

The installation comprises:

- six reservoirs that may be used for demineralised water, distillates or primary coolant;
- a system for purification by demineralisation;
- an evaporation and degassing station;
- a degasser for the discharge from the RCV [CVCS].

The entire TEP [CSTS] is installed in the Nuclear Auxiliary Building.

The filtration-decontamination system comprises:

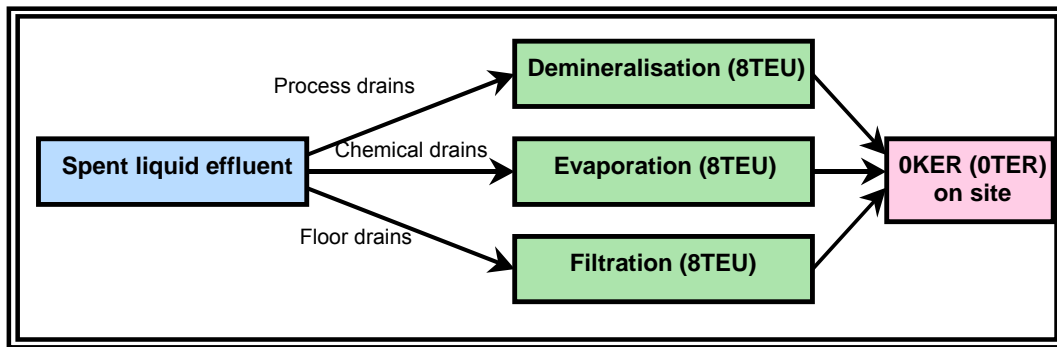
- a mixed-bed demineraliser containing resins that reduce the activity of the primary effluent;
- a filter, that prevents fine particles of resin escaping into the rest of the treatment system;
- a feed line to the downstream evaporation and degassing station.

The evaporator separates the primary coolant into a bottom concentrate containing boric acid concentrate (4%) and the distillates containing distilled water and any volatile constituents carried over in the distillation process (such as tritium). The separate degasser treats distillates from evaporation and also fresh demineralised water from the water treatment plant to produce reactor quality make-up supplies.

The degasser for discharge from the RCV [CVCS] extracts the gases produced into the gaseous radwaste system (TEG [GWPS]) for treatment of the off gas (that is also, as far as possible recycled). More details are provided in PCSR Sub-chapter 9.3 section 3.3.1.4.

**1.1.3.2. Treatment of spent liquid effluent [Ref-1]**

The following diagram gives an overview showing how spent liquid effluent is treated:



**Figure 5:** Treatment of spent liquid effluent

The spent liquid effluent is treated in the Spent Effluent Treatment System (8TEU [LWPS]). This system is sized for two EPR units and its purpose is to limit the activity of spent effluent before it is transferred to the on-site storage tanks prior to monitoring and discharge (T or S tanks). The treatment is specific to each category of spent effluent. All effluent collected in the OKER [LRMDS] system is filtered in each upstream system to 5 µm except for the APG [SGBS] system where filtering is to 25 µm.

The spent liquid effluent is segregated at source, then stored in three sets of two front end tanks, each set assigned to one type of effluent:

- Process Drain (PD): two 100 m<sup>3</sup> tanks;
- Chemical Drain (CD): two 160 m<sup>3</sup> tanks;
- Floor Drain (FD1-FD3): two 75 m<sup>3</sup> tanks.

Each set of two tanks has a sparging system, so that the contents of the tanks can be homogenised for sampling. The effluent treatment is determined based on the results of the sampling and involves:

- demineralisation for active effluent that has little chemical pollution (process drainage);
- evaporation for active effluent that is chemically polluted (chemical effluent);
- filtration for effluent that has little activity (floor drainage).

**Process drain:**

Process drain is sent from the front tanks where it is stored and then passed to the demineralisation plant, where it passes through:

- an initial fine 5 µm filtration to remove suspended solids from the spent effluent;
- three demineralisers containing resins to reduce the activity of the spent effluent. The beds are strong anion and cation and a mixed bed to optimise removal of ions from the effluents;
- a secondary 25 µm filter, that prevents fine particles of resin escaping into the rest of the treatment system.

There are two successive stages in the demineralisation operation:

- firstly, recirculation: the spent effluent processed in the demineralisers is sent back to the front tank from where it came;
- secondly, in open circuit: when the activity has been controlled, the treated spent effluent is sent to the storage tanks (T or S tanks) for monitoring and discharge.

Process effluent may also be treated by evaporation in an evaporator unit (separate to that used for primary coolant in the TEP [CSTS]).

**Chemical drain:**

Chemical drain is sent from the front end tanks where it is stored, coarse filtered and then sent to the evaporation plant. This comprises:

- 25 µm filtration station;
- an evaporator to separate the spent effluent into distillates (only weakly active and/or chemically polluted) and concentrates (containing most of the activity and soluble and particulate chemical components);
- a storage tank for distillates.

The concentrates resulting from evaporation are sent to the Solid Waste Treatment System (8TES [SWTS]). The evaporation distillates may be sent, depending on the activity of samples:

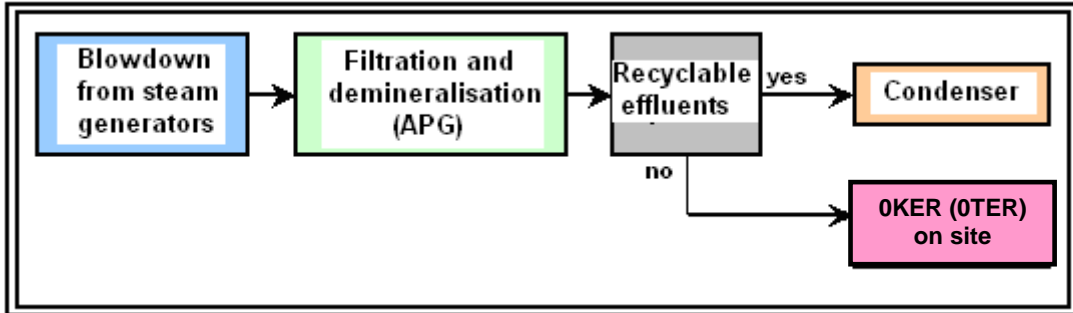
- back into the evaporation system, for treatment again;
- to the on-site storage tanks prior to monitoring and discharge (T or S tanks).

**Floor drain:**

Floor drain is sent from the front end tanks, where it is stored to the filtration plant. This comprises a 25 µm filter to remove suspended solids. The filtered effluent is then sent to the on-site storage tanks before being monitored and discharged (T or S tanks). Floor drainage may also be treated by using the evaporator.

**1.1.3.3. Treatment of steam generators blowdown [Ref-1] [Ref-2]**

The diagram below shows an overview of the process for treatment of the steam:



**Figure 6:** Treatment of blowdown from the steam generators

The blowdown from the steam generators is processed by the APG [SGBS] system. This circuit is specific to each EPR unit and is intended to purify the blowdown water before it is recycled in the secondary circuit.

The purification plant for the steam generator blowdown comprises:

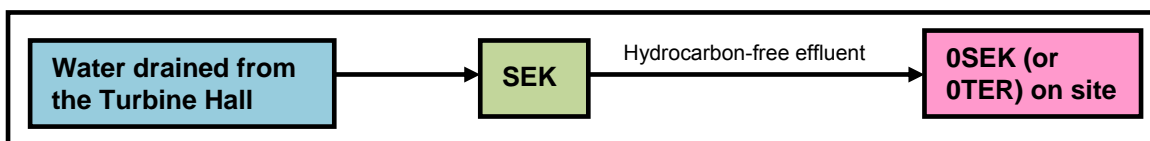
- two parallel filters that remove a proportion of the solids suspended in the drained water;
- two parallel demineralisation lines, each with two resin-filled demineralisers, plus a secondary filter that prevents fine particles of resin escaping into the rest of the treatment system.

After purification, the purified blow down is sent to the main turbine condenser circuit where it is recycled. If analysis shows that it remains unsuitable for re-use (for example the tritium is too high) or the secondary circuit is not available, the treated effluents from the blowdown system may also be sent to storage tanks awaiting monitoring and discharge (T or S tanks).

If the APG [SGBS] is not available, blowdown may be sent directly to the storage tanks before monitoring and discharge (via T or S tanks).

**1.1.3.4. Treatment of water drained from the Turbine Hall [Ref-1] to [Ref-3]**

All activity associated with any small leaks from the primary to the secondary circuit is confined to the steam generator blowdown system, described above. All other effluents from the Turbine Hall originate from leakage, and from draining and emptying the secondary circuit. These effluents are collected into the SEK [CILWDS]. Hydrocarbons are separated and treated and the other effluent is sent directly to the storage tanks for water drained from the Turbine Hall (Ex (OSEK [SiteLWDS] or S tanks) and therefore undergo no filtration or other processing.



**Figure 7:** Treatment of water drained from the Turbine Hall

#### 1.1.4. Storage of liquid effluent

The following effluents are processed in the OKER [LRMDS] or OTER [ExLWDS] or OSEK [SiteLWDS] [Ref-1]:

- primary effluent;
- spent effluent;
- water drained from the Turbine Hall.

All effluent passed to the OKER [LRMDS] system passes through a final 5 µm filter.

Effluents are sent to three separate sets of tanks for interim storage, pending monitoring and discharge:

- T tanks (OKER circuit [LRMDS]);
- S tanks (OTER circuit [ExLWDS]);
- Ex tanks (OSEK circuit [SiteLWDS]).

## 1.2. RADIOACTIVE GASES

### 1.2.1. Sources of radioactive gaseous effluent

Gaseous radioactive effluent includes:

- noble gases, formed by fission, and comprising mainly xenon-133 and xenon-135, with a lower proportion of krypton-85. These pass into the primary coolant. During normal operation, a portion of this coolant is let down into the Chemical and Volume Control System and thence to the RCV [CVCS] tank. In the latter, the fission product gases pass into the tank headspace which purges into the delay beds in the Gaseous Waste Processing System (TEG [GWPS]). The majority of these fission product gases have short half-lives and undergo radioactive decay on the beds. This minimises subsequent discharges to the environment through the gaseous effluent stack. In preparation for a shutdown refuelling, there may be increased release of these fission products from the fuel and, coupled to increased let down and clean up of the coolant, this may increase the amounts discharged;
- argon-41 is formed during normal operation by activation of the natural content of argon-40 in the air of the Reactor Building by neutron radiation around the reactor pressure vessel. If there is any venting of this to the outside, very low levels of this noble gas may occur in the vicinity of the plant. Its half-life is under two hours and it therefore appears only transiently and in circumstances of Reactor Building venting;

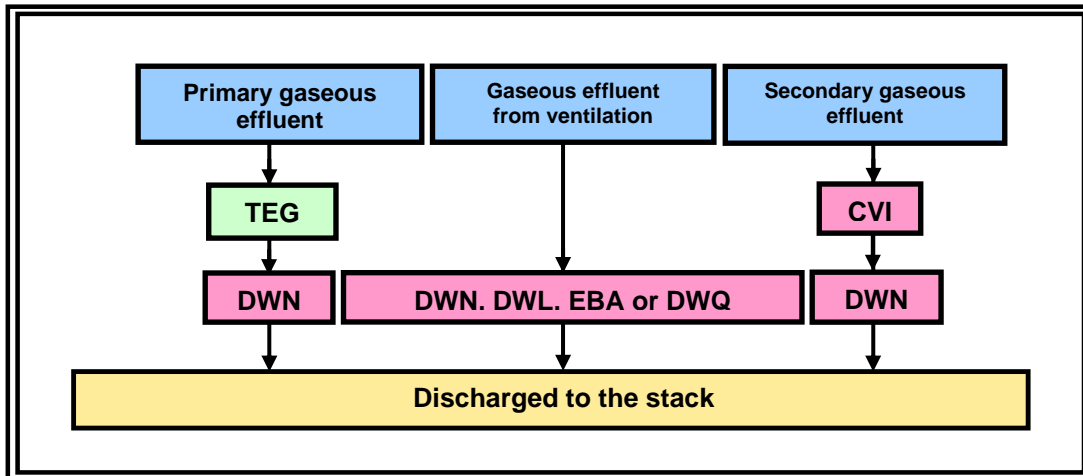
- tritium, formed by fission within the fuel and by activation of the boron added to the primary coolant. Tritium is also formed from traces of lithium-6 that are present in the 7Li2OH used to control coolant pH. The Zircaloy fuel cladding retains the bulk of the tritium formed by fission in the fuel, and tritium in gaseous effluent comes mainly from activation of boron and lithium in the coolant. It is present in the different reactor tanks and fuel pools as tritiated water. It is transported by the ventilation systems. There are no cost effective methods for abatement of tritiated water vapour and the Best Practicable Environmental Option (BPEO) at all nuclear power plants is to discharge most via the stacks serving the various areas where tritiated water vapour arises;
- carbon-14, formed mainly by the activation of oxygen and nitrogen dissolved in the reactor coolant water and then released from this by outgassing. It is present in atmospheric discharge, particularly as methane, and also, to a lesser extent, as carbon dioxide. As a first approximation, it is usually considered that 80% of the discharges are as 14CH4, and 20% as 14CO2 (except for dose calculations where a more penalising scenario is taken into account, see Chapter 11 of the PCER). Carbon-14 follows the same path as the noble gases (via the volume control tank and hence to the gaseous effluent treatment system);
- iodine isotopes, mainly iodine-131 and iodine-133 formed by fission. These also pass into the primary coolant and are purged into the headspace in the RCV [CVCS] tank and thence pass to the gaseous radwaste system (TEG [GWPS]). Most are retained in the liquid phase, rather than being lost to the gaseous phase in the TEG [GWPS]. In most cases, their activity in the Gaseous Waste Processing System (TEG [GWPS]) is very low and any discharged are further abated using carbon delay beds in the off gas stream. Iodine isotopes are also retained in the iodine traps installed in the building ventilation circuits (these iodine traps are brought into service as required);
- aerosols, formed mainly by activation (cobalt-58 and cobalt-60) and fission (caesium-134 and caesium-137), that are then brought into fine aerosol form. Those in building areas are removed by continuous filtration in the ventilation plants. The radioactive discharge into the environment as aerosols represents a mass of less than one microgram per year (largely cobalt -60).

The devices for treating gaseous radioactive effluent (filters, iodine traps, recombination, delay beds) help to limit radioactive discharge into the environment.



**1.2.2. Nature of gaseous radioactive effluent**

Gaseous radioactive effluent falls into one of three categories, as shown in the following diagram:



**Figure 8:** Nature of gaseous radioactive effluent

These three sources of gaseous radioactive effluents are described in the following paragraphs.

**1.2.2.1. Gaseous effluent from the primary circuit**

This comes from degassing in either the primary effluent degassers in the Primary Effluent Treatment System (TEP [CSTS]), or from the degassing and head spaces in facilities containing primary coolant or primary effluent, such as the RCV [CVCS] tank, TEP [CSTS] and some RPE [NVDS] tanks and the reactor circuit pressuriser tank. The ullages within these vessels collect gas released from the primary coolant such as hydrogen and accompanying radioactive gases and aerosols.

Nitrogen purging is used to maintain low levels of hydrogen and oxygen and to continuously purge the headspaces of the tanks. This also ensures that build up of potentially explosive hydrogen and oxygen cannot occur in these tanks and minimises dissolved oxygen in the liquids in the tanks.

Primary gaseous effluent purged from these tanks is directed to the Gaseous Waste Processing System (TEG [GWPS]).

**1.2.2.2. Gaseous effluent from ventilation**

All radiation controlled areas of the Nuclear Auxiliary Building, the Fuel Building, the Safeguard Buildings, the Reactor Building, the Operational Service Centre, the Access Building and the Effluent Treatment Building are served by dedicated HVAC systems. These ensure pressure differentials and air changes are maintained so that air always moves from potentially less contaminated areas to more contaminated areas, in accordance with standard best practice. The ventilation systems use abatement systems to remove potential low levels of iodine isotopes, aerosols etc. from the extracted air.

The air is collected in the ventilation circuits in the various buildings on the nuclear island (DWN [NABVS], DWK [FBVS], DWL [CSBVS], EBA [CSVS] (high and low flow), DWB, DWW [ABVS] and DWQ [ETBVS]), where, if necessary, it is filtered using iodine traps and then discharged via the stacks.

### 1.2.2.3. Gaseous effluent from the secondary circuit

Small leaks may occur between the primary and secondary circuit through which tritium leaks and appears in the secondary circuit and condensed secondary water. With low pressure in the condenser wet well during operation, some tritiated water can therefore appear in the main condenser off gas. This is collected in the condenser vacuum system (CVI), and then sent to the Nuclear Auxiliary Building Ventilation System (DWN [NABVS]), where it is passed through a HEPA (Very High Efficiency) filter before being discharged into the stack.

Tritium production is minimised at source, which therefore reduces the tritium activity in the secondary system. The tritium in the secondary system is controlled in the condenser air exhaust line, where a continuous global beta activity measurement is provided, and which is fitted with an alarm delivered in the control room to warn about variation of activity in the secondary circuit. Discharge activities are measured on the main stack; gaseous leaks between the primary and the secondary circuit are negligible as they account for less than 1/10,000 of noble gases discharges. Tritium leaks cannot lead to accident conditions as these are based on the leakage rate and not the tritium activity.

### 1.2.3. Treatment of gaseous radioactive effluent

A diagram showing an overview of the arrangements for processing and storing gaseous effluent is shown in Sub-chapter 11.2 - Figure 2. Gaseous effluent is segregated at source and treated in different systems, depending on its nature:

- primary gaseous effluent is processed in the Gaseous Waste Processing System (TEG [GWPS]);
- effluent from ventilation is processed in the ventilation circuits DWN [NABVS], DWK [FBVS], DWL [CSBVS], EBA [CSVS] (high and low flow), DWB, DWW [ABVS] and DWQ [ETBVS].

These treatment systems are described in the following paragraphs.

#### 1.2.3.1. Treatment of gaseous effluent from the primary circuit liquid tanks (TEG [GWPS], [Ref-1] to [Ref-7])

Treatment of gaseous effluents from the various tanks and systems serving the primary circuit in the UK EPR is carried out in the Gaseous Waste Processing System (TEG [GWPS]). This is different to that used on French PWRs but uses best current methods developed for the German Konvoi design. Key features of this system are as follows:

- the system runs a continuous nitrogen flow over the free volumes of the purged tanks and vessels, most of which are kept below atmospheric pressure. This is also in place to avoid leaks of gaseous effluent in the buildings;

- a key feature that differs from French PWRs to date is the recovery of purge gas (nitrogen) that is compressed and then returned to the system for re-use. Thus, a large portion of gas is retained within the TEG [GWPS] for return to the various ullages and headspaces in the tanks from which it originated, maximising recirculation and minimising discharges. This retains the shorter-lived radioactive gases (mainly inert gases) to allow decay;
- hydrogen and oxygen levels lost to the circulating gas from the liquids in the tanks to the purge gas are controlled using a catalytic recombiner. This can deal with initial feed hydrogen up to 4% and oxygen up to 2% and reduces the concentrations of these in the gas that is recirculated in the system to less than 0.3% and 0.1% respectively. This minimises oxygen in liquids in the various tanks to allow these to be reused in the primary circuit and maintains hydrogen in the tanks below an explosive limit of 4% (eliminating a potential internal hazard). The effect of the catalytic recombiner on Carbon-14 speciation has not yet been fully determined, but a ratio of 80% of the discharges as  $14\text{CH}_4$ , and 20% as  $14\text{CO}_2$  is generally considered (except for dose calculations, see Chapter 11 of the PCER);
- recombination of hydrogen (H-2) and oxygen (O-2) in the purge gas to water. Furthermore, this may help to ensure that tritium and iodine in the purge gas in the TEG [GWPS] are returned to and retained in the liquid phase, although to date this effect has not been quantified. The dominant isotopes remaining in the purge gas in the TEG [GWPS] are the shorter-lived noble gases (that also have lower environmental impacts);
- a portion of the purge gas in the system is bled off and fed to dryers to remove water vapour and then to a line of three activated carbon delay beds. These retain residual noble gases that have not already decayed within the recirculating part of the system. They thus provide a further period for the decay of these gases prior to discharge, viz. xenon is kept for 40 days and krypton for 40 hours. These timescales are calculated based on the half-lives and the dynamic adsorption coefficients of the nuclides, the flow rate of the carrier gas and the mass of charcoal; the delay time is between eight and ten times the half-lives of the considered nuclides, as the benefit of further delay is not significant. Parameters such as temperature, pressure, moisture, etc influence the process of dynamic adsorption and are taken into account in the design of the delay beds and their operating conditions. Note these beds are not specifically used for the iodine isotopes that are retained mainly in the liquid phases (see above). However, considering the mass of iodine molecules, the delay beds may have the same decay effect as that of xenon (40 days).

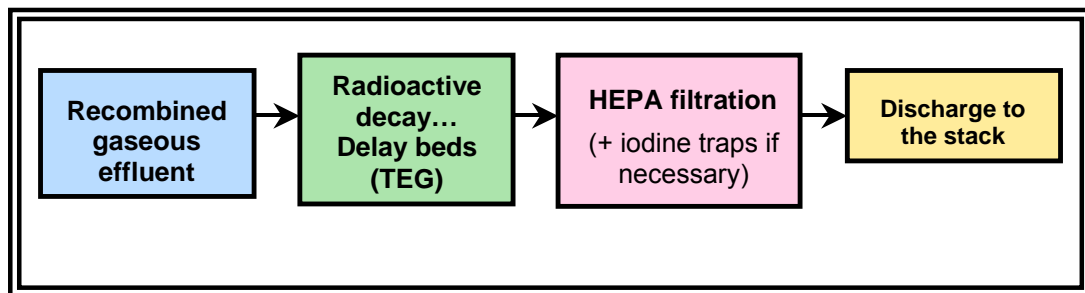
Charcoal adsorption delay beds are used extensively in nuclear reactors around the world and in particular in Sizewell B. Charcoal delay beds offer a more passive system (less moving parts), overall better safety performance and lower operator dose (less pump maintenance). Although delay tanks are another option, they offer no gaseous treatment benefits over charcoal adsorption delay beds and potentially higher operator doses are incurred by their operation and maintenance;

- the three beds also operate at a slightly enhanced pressure to maximise their capacity. They finally feed through to a filter to remove any small carry over of particulates from the bed;
- higher discharge rates occur only during reactor start-up and shutdown when there is a relatively larger movement of water between interconnected systems and when there is increased nitrogen purging of vessels. At this time the operating pressure of the delay beds is increased thus maximising their capacity.

After treatment in the TEG [GWPS], the gaseous effluents are directed to the Nuclear Auxiliary Building, where they are finally treated using one of a series of HEPA filters (their efficiency is 99.97%). Discharge via this route is automatic and controlled via pressure in the TEG [GWPS] delay beds.

The final treated gaseous effluent is then monitored and discharged via a stack shared with the HVAC system serving the Nuclear Auxiliary Building. The stack height and discharge characteristics are designed to ensure maximum rapid dispersion of the discharged gaseous effluent in the environment. The stack height is site specific. For instance, for the EPR in Flamanville, the height is 98 m above the ground floor, the stack diameter design is 3 m, and the design nominal flow rate is 250 000 m<sup>3</sup>/h, which corresponds to a speed of 9.6 m/s adapted to the environment. An assumption will be made in order to carry out environmental impact calculations at a generic stage (see Chapter 11 of the PCER).

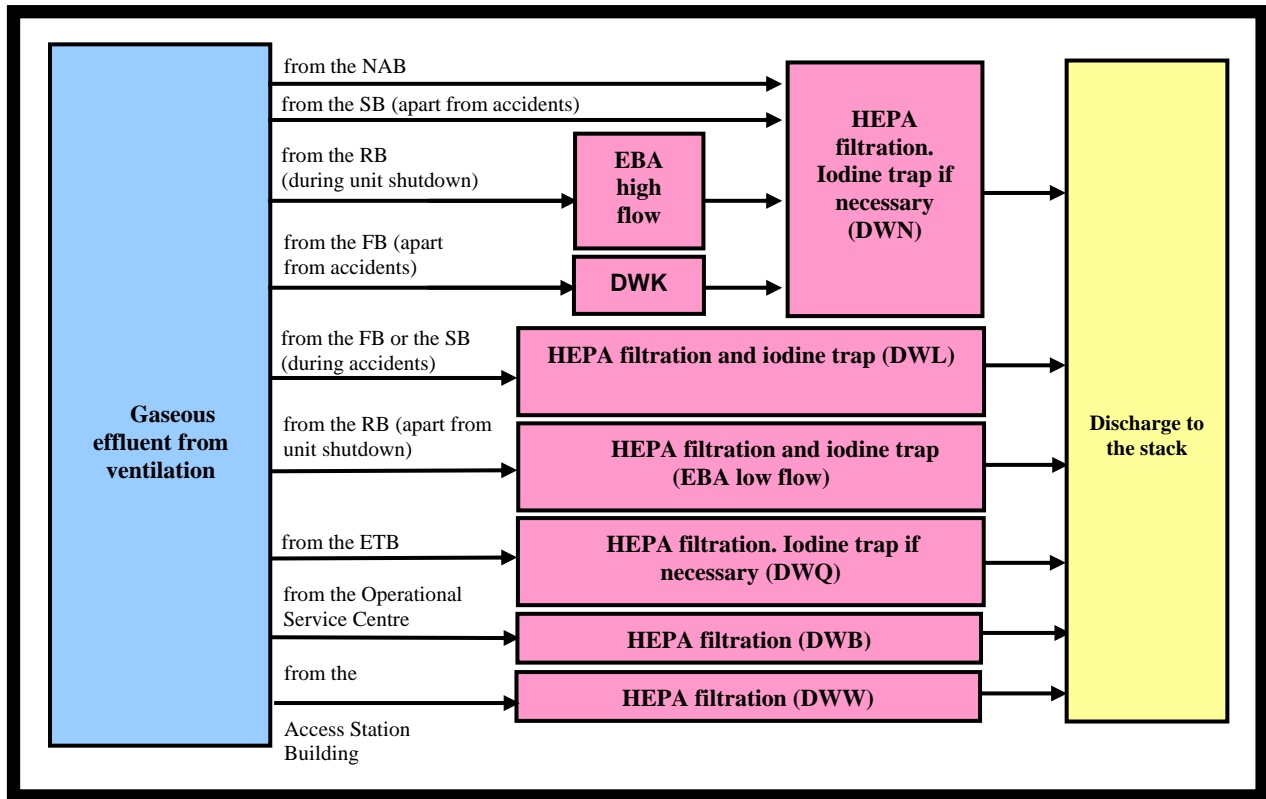
The following diagram summarises the processes for discharging gaseous effluent from the primary circuit:



**Figure 9:** Processes for discharging gaseous effluent from the primary circuit

**1.2.3.2. Treatment of gaseous effluent from ventilation**

The following diagram summarises the treatment of gaseous effluent from ventilation.



**Figure 10:** Treatment of gaseous effluent from ventilation

**1.2.3.2.1. Ventilation of the Nuclear Auxiliary Building (DWN [NABVS], [Ref-1] [Ref-2])**

The gaseous ventilation effluent processed by the Nuclear Auxiliary Building Ventilation System (DWN [NABVS]) comes from contamination controlled zones in the Nuclear Auxiliary Building (NAB), the Safeguard Buildings (SB) and the Fuel Building (FB) (apart from incidents); and from purging the Reactor Building (RB) when the unit is shut-down and the reactor head removed for refuelling outage (EBA [CSVS] high flow). This circuit has an extraction plant connected to the stack with pre-filters and HEPA filters. If required, the discharge can also be directed through carbon bed filters to allow removal of iodine isotopes.

The extraction plant treatment trains comprise:

- 6 filtration trains with a unit flow rate of 20,000 m<sup>3</sup>/h, three for output from DWN [NABVS] ventilation, two for Fuel Building ventilation and one for Safeguard Building ventilation;
- 1 x 25,000 m<sup>3</sup>/h filtration train for the high-flow EBA [CSVS];
- 4 exhaust fans;

- 4 iodine traps, each with its own reheater<sup>1</sup>. If iodine is detected in the premises exhaust ducting, the airflow is automatically sent through these iodine traps. The detection is based on the beta global activity measure, as a high activity of noble gases indicates a possible discharge of iodine. As an example, the detection level in the French NPPs is set to approximately one-tenth of the regulatory limit.

Charcoal iodine traps are used worldwide and have been proved to be efficient and well adapted to operating conditions (in particular regarding the temperature). Successive improvements include the use of reheaters and refillable traps.

The decontamination factor of the traps is 100 for systems whose operation is required during fault conditions and 10 for the others; these decontamination factors are set up in accordance with studies of radiological consequences;

- 4 booster fans to make up the additional pressure loss.

If required, these systems can also provide further clean up and treatment of primary gaseous effluent from the Gaseous Waste Processing System (TEG [GWPS]). This would then be monitored and discharged via the stack.

#### **1.2.3.2.2. Fuel Building Ventilation DWK [FBVS] [Ref-1]**

The Fuel Building Ventilation System (DWK [FBVS]) manages the supply, extraction, treatment and monitoring, and discharge of ventilation air from the Fuel Building.

#### **1.2.3.2.3. Ventilation of the controlled area in the Safeguard Buildings (DWL [CSBVS], [Ref-1] [Ref-2])**

In normal operation, the DWN [NABVS] manages the supply, extraction, treatment and discharge of air from the Safeguard Building.

In the event of a fault involving a small loss of coolant accident or fuel handling fault, the DWL [CSBVS] has its own dedicated gaseous radwaste treatment systems consisting of pre-filters, HEPA filters and, if required, iodine adsorption beds as well as its own sampling and monitoring systems for accident/incident management and monitoring.

#### **1.2.3.2.4. Reactor Building ventilation (EBA [CSVS], [Ref-1] [Ref-2])**

The Reactor Building ventilation system serves the main Reactor Building and operates in two modes:

- low-flow EBA [CSVS]: This system conditions, extracts and filters the air used to purge the primary containment. It operates whether the unit is shut-down or operational, so that personnel can access the Reactor Building. It has two filtration trains with pre-filters, Very High Efficiency (HEPA) filters and iodine traps;
- high-flow EBA [CSVS]. This system conditions and discharges to the stack the air that ventilates the containment when the unit is shut-down and especially when the reactor head is removed and the refuelling cavity flooded during refuelling. The air flowing through the system during this time also passes through an iodine trap in the DWN [NABVS].

<sup>1</sup> Reheater: device used to raise or maintain air temperature

#### 1.2.3.2.5. Ventilation of the controlled area of the Operational Service Centre DWB [Ref-1] [Ref-2]

The controlled area of the Operational Service Centre comprises hot laboratories and hot changing rooms. The system has two filtration trains with pre-filters and Very High Efficiency (HEPA) filters.

#### 1.2.3.2.6. Ventilation of the Effluent Treatment Building (DWQ [ETBVS], [Ref-1] [Ref-2])

This system conditions, extracts and filters the Effluent Treatment Building ventilation air.

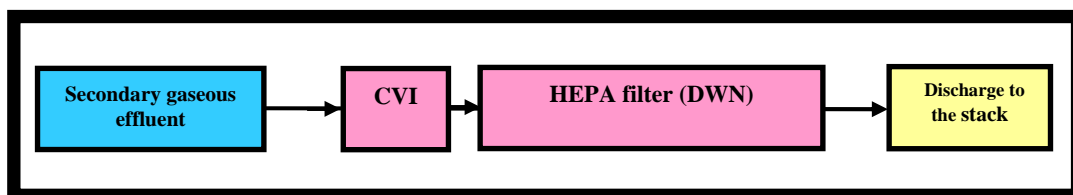
It has exhaust ductwork connected to the stack with pre-filters, very high efficiency (HEPA) filters and an iodine trap that is bypassed in normal operation.

#### 1.2.3.2.7. Ventilation of the controlled area of the Access Building (DWW [ABVS] [Ref-1])

The system has two filtration trains with pre-filters and Very High Efficiency (HEPA) filters.

#### 1.2.3.3. Treatment of gaseous effluent from the secondary circuit

The following diagram summarises the treatment of gaseous effluent from the secondary circuit:



**Figure 11:** Treatment of gaseous effluent from the secondary circuit

Gaseous effluent from the secondary circuit is collected by the condenser vacuum system (CVI), and then sent to the Nuclear Auxiliary Building Ventilation System (DWN [NABVS]), described in the previous section. It is discharged to the stack after passing through a HEPA filter.

## 2. LIQUID CHEMICAL EFFLUENT DISCHARGES

### 2.1. GENERAL

Chemical discharges arise from:

- chemicals associated with liquid radioactive effluent;
- chemicals in effluent from the conventional parts of the site (see PCSR Sub-chapter 5.5), mainly:
  - effluent from the production of demineralised water (demineralisation station and desalination unit);
  - effluent from fouling treatments (seawater chlorination);

- water collected from rainwater drains, black and grey wastewater (effluent from the purification stations); and
- water contaminated with oil and water used in production in the Turbine Hall.

## 2.2. CHEMICAL DISCHARGES ASSOCIATED WITH RADIOACTIVE EFFLUENT

### 2.2.1. Discharge Sources

This paragraph discusses the chemicals associated with liquid effluent that could be discharged into the marine environment. It describes the purpose of each substance, the main circuits involved, a diagram charting the passage from injection to discharge, and the proposed maximum amounts to be discharged.

The systems used to treat and discharge these chemicals are those for radioactive effluent.

### 2.2.2. Discharges caused by conditioning in the circuits

The substances discussed below were chosen because of the volume of flow and the toxicity of the substances discharged.

Primary coolant contains boric acid and lithium hydroxide (see PCSR Sub-chapter 5.5). Secondary coolant contains ethanolamine and other secondary circuit conditioners (see PCSR Sub-chapter 5.5). These chemicals accompany the trace radioactive constituents in the various liquid effluent treatment systems.

The maximum values of the additional annual flux of chemical discharges are determined to enable:

- the circuit conditions specified in the various chemical specifications for the systems to be fully adhered to;
- a margin to allow for transient conditions in normal operation;
- the mitigation discharges and their impact.

Scenarios describing the discharge quantities (flux, concentrations), for both continuous discharge and intermittent discharge (such as emptying a tank), for each substance likely to be discharged, have been examined.

The description of the discharge depends on the results of detailed surveys or on experience at other sites.

This approach means that the documentation gives realistic values for the discharges corresponding to expected performance (excluding significant contingency); and maximum values that are reasonably likely to encompass the amounts of chemicals discharged in the various situations that could be encountered at the site, as for liquid radioactive effluent.

The differences allow for an operational margin which is essential, if the installation is operated normally.



### 2.2.2.1. Conditioning in the primary circuit

From PCSR Sub-chapter 5.5, the primary circuit is treated with:

- boric acid, because of its neutron-absorbing properties: the proposed treatment of the primary water facilitates greater recycling. The use of boron enriched with boron-10 significantly reduces discharge in normal circumstances;
- lithium hydroxide to reduce the acidity of the boric acid, and to regulate pH slightly alkaline to prevent equipment corrosion.

### 2.2.2.2. Conditioning in the secondary circuit

In order to obtain a pH which results in lower levels of corrosion, a base compound must be injected into the secondary circuit, such as ammonia, morpholine and ethanolamine (see PCSR Sub-chapter 5.5).

Each of these compounds has both advantages and disadvantages, for example in terms of protecting carbon steel against erosion and corrosion, fouling the SGs and producing oxide slurry, or managing the discharge and waste products.

Morpholine has a dissociation constant that reduces less with increasing temperature than does that of ammonia. It spreads uniformly throughout the circuit, so that the pH at increased temperatures is higher, and hence all the circuit equipment is protected against corrosion and erosion. Conditioning with morpholine produces less suspended material than does conditioning with ammonia. In theory, using morpholine extends the life of the resins in the steam generator blowdown system, which reduces waste.

Ammonia is simpler to use, as some is produced from the thermal decomposition of hydrazine. It will also readily maintain the minimum-corrosion pH in the feedwater plant in a monophasic medium.

The quantity of ethanolamine (ETA) injected can be 2 to 3 times less than that of morpholine, and as it has a good partition coefficient for the liquid phase, it protects equipment well in a biphasic medium.

Conditioning is supplemented with hydrazine to eliminate oxygen in the feedwater and to prevent fouling of the steam generators caused by corrosion products (mainly iron oxides). Hydrazine decomposes when heated to produce ammonia.

Whichever conditioning compound is used to maintain the pH for minimum corrosion, ammonia will always be present in the secondary circuit for two reasons:

- where the conditioning uses ammonia, the quantity of ammonia produced by the decomposition of hydrazine is not sufficient to maintain the pH for minimum corrosion, and it is therefore supplemented;
- where the conditioning uses morpholine or ethanolamine, the thermal decomposition of hydrazine means that ammonia is present in the secondary circuit.

### 2.2.2.3. Conditioning during shutdown

The feedwater plant for the secondary circuit is kept dry during shutdown (see PCSR Sub-chapter 5.5).

The steam generators are treated during shutdown with:

- hydrazine;
- with morpholine, ammonia or ethanolamine (with or without ammonia).

### 2.2.2.4. Conditioning in the nuclear auxiliaries and conventional circuits

The cooling and heating circuits are conditioned with trisodium phosphate, which is used to prevent corrosion in circuits in contact with air, where an all-volatile treatment cannot be used (see PCSR Sub-chapter 5.5).

When the unit is operating, this compound is discharged into the environment.

### 2.2.2.5. Boric acid

#### 2.2.2.5.1. Role of boric acid

Boron is used in the form of boric acid (or  $H_3BO_3$ ). Boric acid is a weak acid at low temperatures and a very weak acid at high temperatures, and does not corrode the primary circuit fabric due to presence of lithium hydroxide.

It is readily soluble, so that it spreads uniformly throughout the circuits.

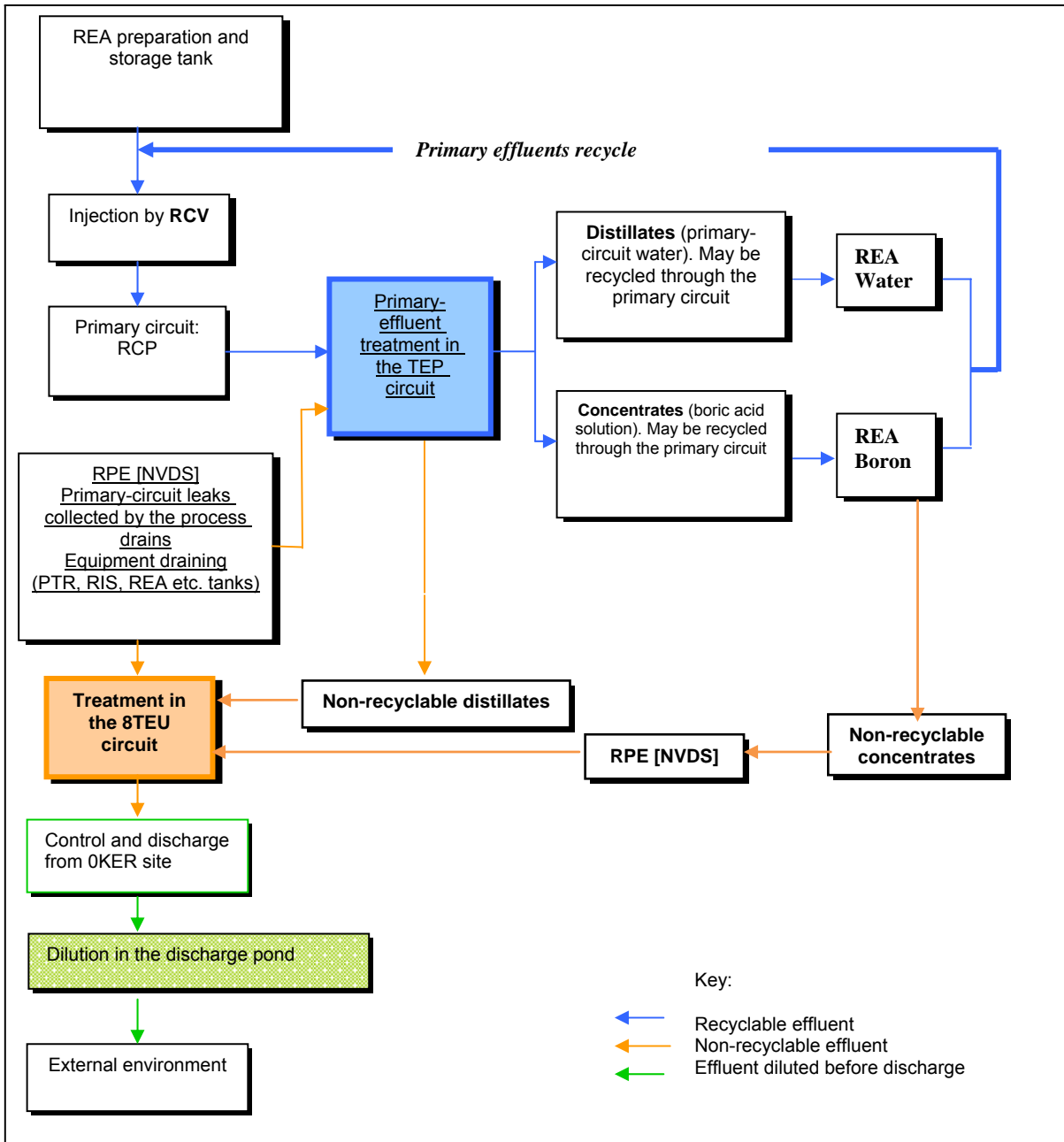
Boron is used in the primary circuit because its isotope boron-10 (present in 20% concentration in natural boron) is a good neutron absorber. Its ability to absorb neutrons means it can compensate for slow changes in reactivity such as those associated with fuel burnup between the start and end of the cycle.

For the same reasons, boron is also present in the primary circuit Safety Injection System (RIS [SIS]) and in the Pool Water Treatment and Cooling System (PTR [FPPS/FPCS]) (see PCSR Sub-chapter 5.5).

The concentration of boric acid in the primary circuit depends on the way the fuel is managed.

#### 2.2.2.5.2. Path of boric acid through the circuits

Sub-chapter 11.2 - Figure 12 shows the path of boric acid through the primary circuit, from injection to the discharge tanks via the treatment systems.



**Figure 12:** Path of boric acid through the primary circuit

**2.2.2.5.3. Discharge Characteristics**

As shown in the diagram above, boric acid is discharged: from the T tanks (OKER [LRMDS]).

It results from conditioning the primary circuit. The fluid extracted is treated in the Primary Effluent Treatment System (TEP [CSTS]) depending on its radioactivity and chemical properties. Part of the effluent is recycled and may be re-injected into the primary circuit. The rest of the effluent that cannot be reused is sent to the Spent Effluent Treatment System (8TEU [LWPS]) for processing before being sent to the T tanks (OKER [LRMDS]).

**2.2.2.6. Lithium hydroxide**

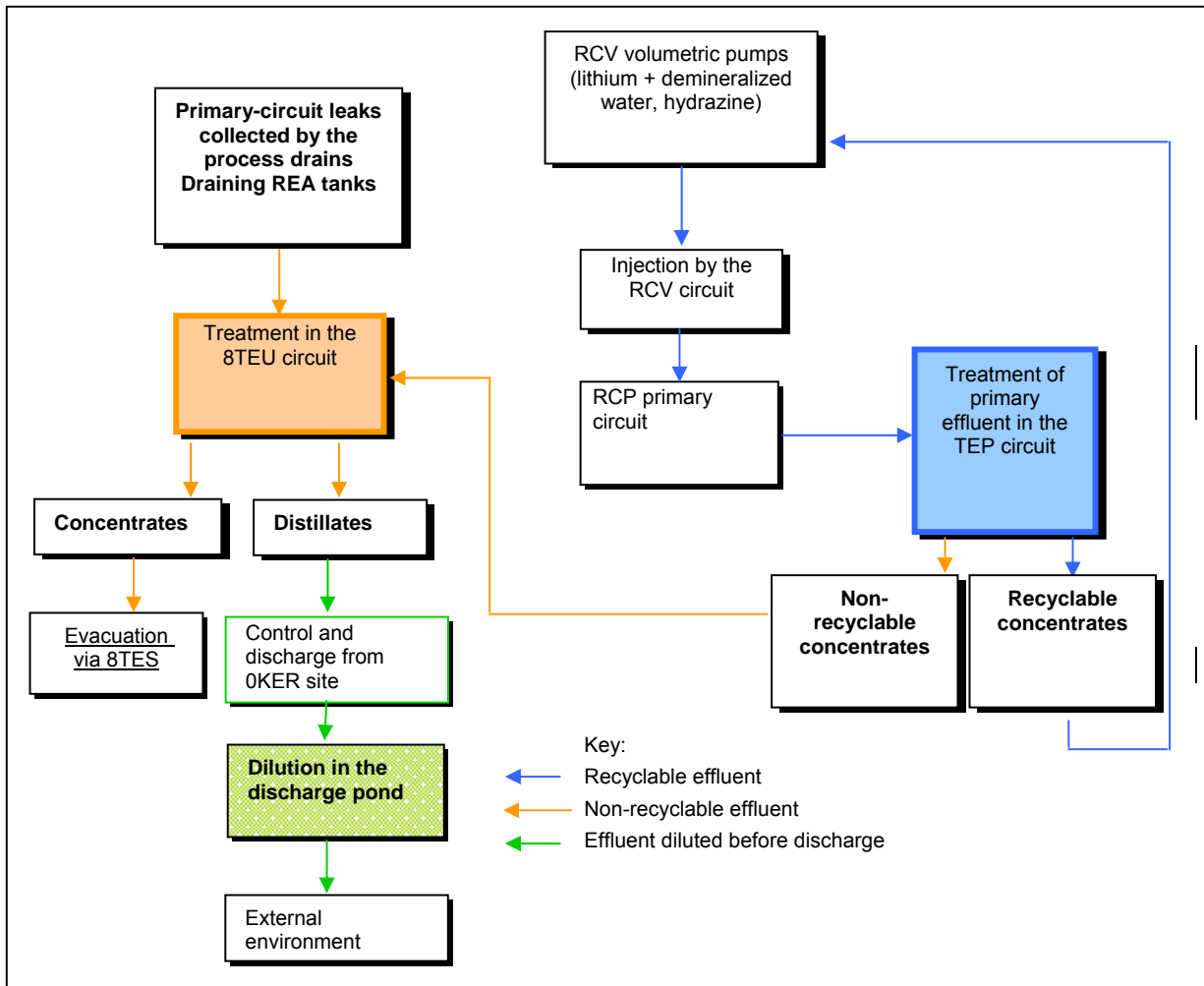
**2.2.2.6.1. Role of lithium hydroxide**

Lithium hydroxide is a base used in the primary circuit to maintain a constant, slightly alkaline pH to minimise corrosion of the fabric (see PCSR Sub-chapter 5.5). Its concentration is adjusted during the cycle in conjunction with that of the boric acid.

The way the primary circuit is conditioned with lithium hydroxide depends on the way the fuel is managed.

**2.2.2.6.2. Path of lithium hydroxide through the circuit**

The simplified diagram below shows the path of lithium hydroxide through the primary circuit, from injection to the discharge tanks via the treatment systems.



**Figure 13: Path of lithium hydroxide through the primary circuit**

### **2.2.2.6.3. Discharge Characteristics**

As shown in the diagram above, lithium hydroxide is discharged by only one route: from the T tanks (0KER [LRMDS]).

The lithium hydroxide concentration varies in the course of the fuel cycle. To maintain a neutral or slightly alkaline pH, thus reducing corrosion in the primary circuit, it is necessary to dilute or inject lithium hydroxide. The fluid extracted is treated in the Primary Effluent Treatment System (TEP [CSTS]).

### **2.2.2.7. Hydrazine**

#### **2.2.2.7.1. Role of hydrazine**

Hydrazine is a weak volatile base used in the circuits mainly as a reducing agent (see PCSR Sub-chapter 5.5). When the secondary circuit is operational, hydrazine maintains a non-oxidising environment, reduces the oxygen dissolved in the feedwater and limits oxide production in the feedwater plant.

This conditioning compound is decomposed in two ways:

- by reaction with the oxygen in the water to form water and nitrogen;
- by thermal decomposition to form nitrogen, hydrogen and ammonia.

During shutdown, hydrazine is used to condition the steam generators.

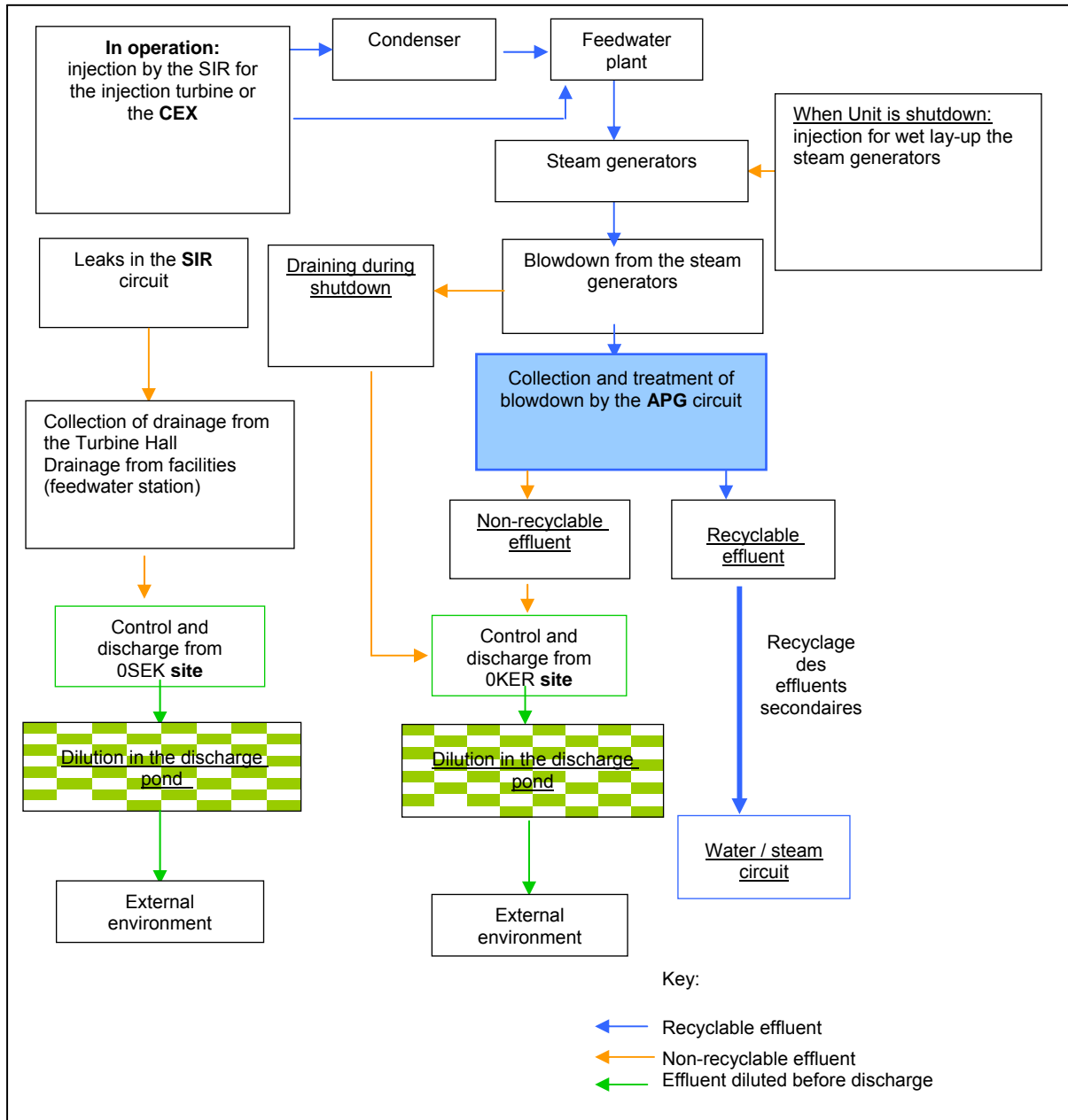
This treatment uses either (see PCSR Sub-chapter 5.5):

- hydrazine, morpholine and ammonia; or
- hydrazine and ammonia; or
- hydrazine, ammonia and ethanolamine.

Comment: The feedwater plant for the secondary circuit is kept dry.

#### **2.2.2.7.2. Path of hydrazine through the circuits**

Sub-chapter 11.2 - Figure 14 shows the path of hydrazine through the secondary circuit, from injection to the discharge tanks via the treatment systems.



**Figure 14: Path of hydrazine through the secondary circuit**

**2.2.2.7.3. Discharge Characteristics**

As shown in the diagram above, hydrazine is discharged in two ways:

From the T tanks (OKER [LRMDS]): In normal operation, hydrazine present in the non-recyclable effluent is converted into ammonia above 120°C and decomposes into gaseous nitrogen in the presence of oxygen in the tanks. The hydrazine discharged is the proportion not consumed in the process described above.

When the unit is shut down, hydrazine comes from draining the steam generators that have been conditioned with hydrazine.

From the Ex tanks (0SEK [SiteLWDS]): In normal operation, discharged hydrazine comes from effluent drained from the Turbine Hall or drained from equipment and circuits in the feedwater plant. It also comes from drip-off from the injection station in the feedwater plant. All these sources of effluent are collected and sent to the Ex tanks (0SEK [SiteLWDS]).

### **2.2.2.8. Morpholine**

#### **2.2.2.8.1. Role of morpholine**

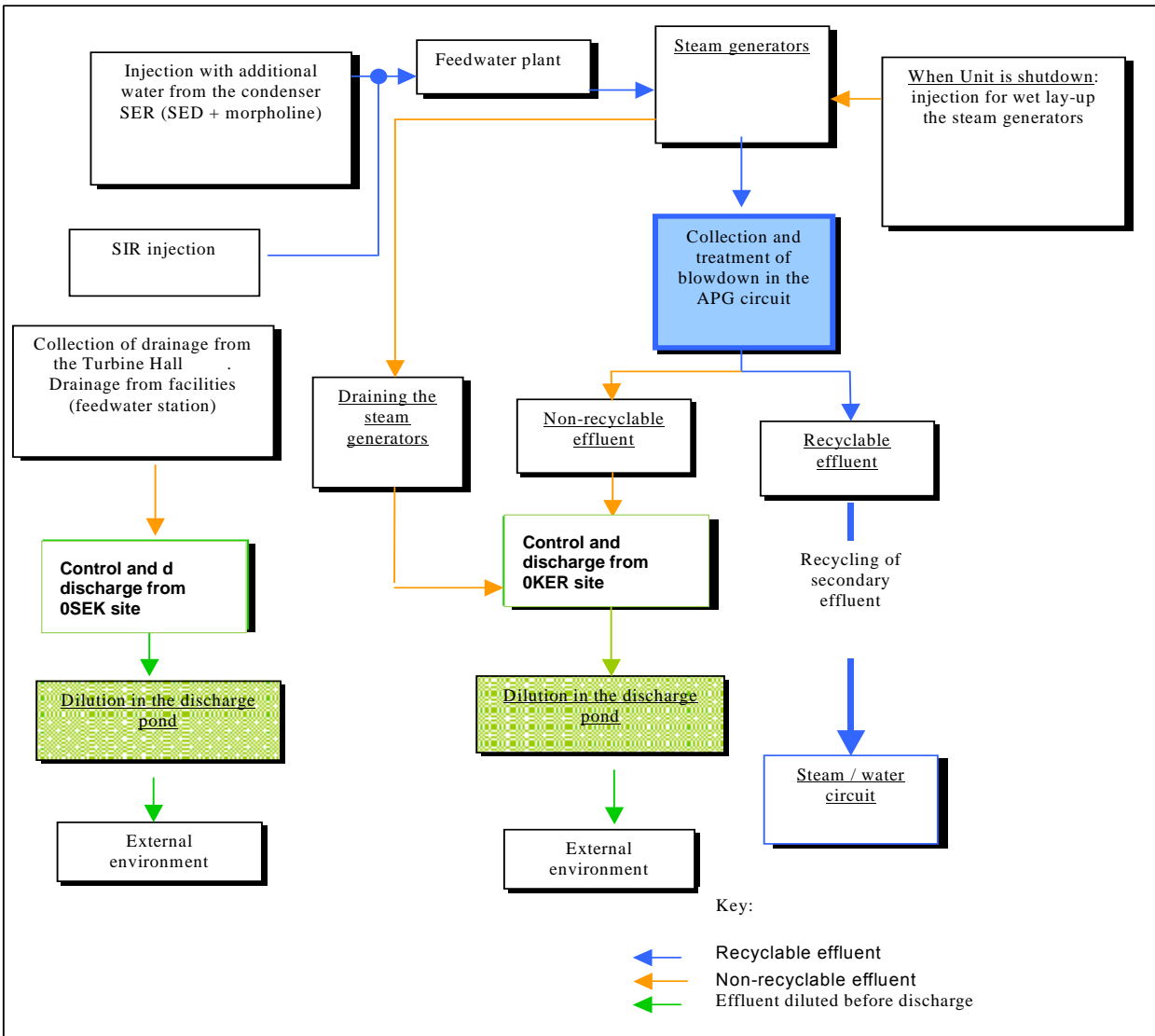
Morpholine is a weak volatile base. At 25°C, its pH is alkaline, and it is not concentrated by evaporation in the steam generators, as are non-volatile reagents.

It is therefore used to condition the secondary circuit to achieve the pH that best inhibits corrosion.

Additional ammonia is used to reach a minimum feedwater pH of 9.4 at 25°C. It is supplied partly by the decomposition of hydrazine injected into the feedwater station to remove traces of oxygen. If the hydrazine produces insufficient ammonia, extra ammonia is added (mixed conditioning) (see PCSR Sub-chapter 5.5).

#### **2.2.2.8.2. Path of morpholine through the circuits**

The simplified diagram below shows the path of morpholine through the secondary circuit, from injection to the discharge tanks via the treatment systems.



**Figure 15:** Path of morpholine through the secondary circuit

**2.2.2.8.3. Discharge Characteristics**

As shown in the diagram above, morpholine is discharged in two ways:

From the T tanks (OKER [LRMDS]):

In normal operation, morpholine present in water drained from the steam generators is recycled into the steam-water system after processing by the APG [SGBS] (Steam Generator Blowdown System).

Drainage water that cannot be recycled through the steam generators is sent to the T tanks (OKER [LRMDS]). Only a small amount is discharged in this way, unless there is some leakage from the primary to the secondary circuit, used to reduce the tritium level in the secondary circuit.



The water drawn off the line for samples used in the measuring devices and manually for test samples is treated as effluent and is sent upstream of the resins in the APG [SGBS] system and discharged from the T tanks (0KER [LRMDS]).

During unit shutdown, the morpholine present in the T tanks (0KER [LRMDS]) comes from wet conditioning of the steam generators.

From the Ex tanks (0SEK [SiteLWDS]):

Effluent drained from the Turbine Hall or emptied from equipment and circuits in the feedwater plant during shutdown and start-up is collected and sent to the Ex tanks (0SEK [SiteLWDS]).

### **2.2.2.9. Ethanolamine**

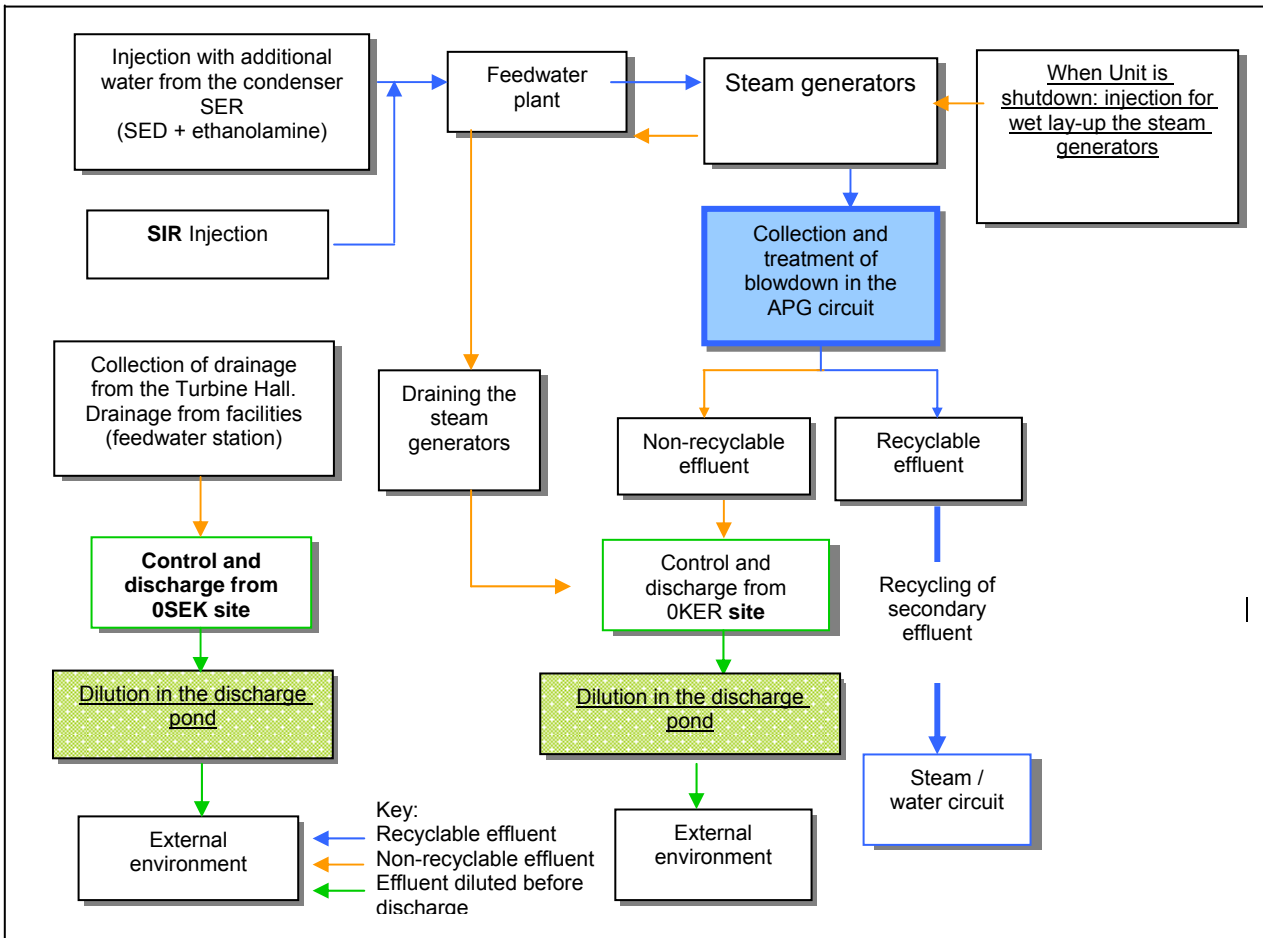
#### **2.2.2.9.1. Role of ethanolamine**

Ethanolamine (C<sub>2</sub>H<sub>7</sub>ON) is a weak volatile base that provides the required pH for minimum corrosion across the entire steam-water system. Similar to “non-volatile” reagents, it is not concentrated by evaporation in the steam generators.

Ethanolamine conditioning is supplemented with ammonia from hydrazine decomposition. If the hydrazine produces insufficient ammonia, extra ammonia is added (mixed conditioning) (see PCSR Sub-Chapter 5.5).

#### **2.2.2.9.2. Path of ethanolamine through the circuits**

Sub-chapter 11.2 - Figure 16 shows the path of ethanolamine through the secondary circuit, from injection to the discharge tanks via the treatment systems.



**Figure 16:** Path of ethanolamine through the secondary circuit

**2.2.2.9.3. Discharge Characteristics**

As shown in the diagram above, ethanolamine is discharged in two ways:

From the T tanks (OKER [LRMDS]):

In normal operation, ethanolamine present in water drained from the steam generators is recycled into the steam-water system after processing by the APG [SGBS] (Steam Generator Blowdown System).

However, because the secondary fluid must meet chemical and radiochemical specifications, the amount of recycling is limited. Drainage water from the steam generators that cannot be recycled is sent to the T tanks (OKER [LRMDS]).

Water that is drawn off the line for samples used in the measuring devices and manually for test samples is treated as effluent and is sent upstream of the resins in the APG [SGBS].

During unit shutdown, ethanolamine in the T tanks (OKER [LRMDS]) may come from wet conditioning the steam generators.

From the Ex tanks (0SEK [SiteLWDS]):

Effluent drained from the Turbine Hall or emptied from equipment and circuits in the feedwater plant during shutdown and start-up is collected and sent to the Ex tanks (0SEK [SiteLWDS]).

#### 2.2.2.10. Nitrogen, excluding hydrazine, morpholine and ethanolamine

Nitrogen (N) is present in the storage tanks in various forms:

- ammonium ions ( $\text{NH}_4^+$ );
- nitrates ( $\text{NO}_3^-$ );
- nitrites ( $\text{NO}_2^-$ ).

Nitrogen (N) is also present in discharges, as derived from hydrazine, morpholine or ethanolamine. These compounds are measured and calculated separately, so the scenarios relating to nitrogen discharge discussed below only deal with nitrogen from ammonium ions, nitrates and nitrites.

Nitrogen (excluding hydrazine, morpholine and ethanolamine) in the secondary circuit water is present only as ammonium ions. It is only when this water is collected in the sumps and transferred to the storage tanks that it is converted into nitrates or possibly nitrites on contact with atmospheric oxygen.

##### 2.2.2.10.1. Generated ammonium discharge

The ammonium discharged is related to the state of the unit (shutdown or operating) and to the type of conditioning used in the secondary circuit.

##### 2.2.2.10.2. During shutdown

Conditioning is applied as follows (see PCSR Sub-chapter 5.5):

- to the steam generators:
  - 75 mg/litre of hydrazine + 8 mg/litre of hydrazine x planned number of days shut down;
- to the feedwater: dry conditioning of the plant is used, in particular to limit the discharge of hydrazine.

##### 2.2.2.10.3. During operation

###### 2.2.2.10.3.1. For conditioning with morpholine or ethanolamine

For this type of conditioning, the presence of ammonium ions in the circuits is in theory due to hydrazine decomposition. If the production of ammonia from this decomposition is not sufficient to maintain the pH preventing corrosion, additional ammonia may be added; this practice is known as mixed conditioning (see PCSR Sub-Chapter 5.5).

Whatever the origin of the nitrogen (hydrazine decomposition or additional ammonia), the target amounts in the circuits are defined in the chemical specifications [Ref-1]:

- expected concentrations of ammonium, where conditioning is with morpholine or ethanolamine: 1 - 2 mg/litre;
- upper limit: < 5mg/litre.

#### 2.2.2.10.3.2. *For conditioning with ammonia*

For this type of conditioning, the presence of ammonium ions in the circuits is due to the decomposition of hydrazine and to the ammonia added to meet the chemical specifications (see PCSR Sub-chapter 5.5).

They define:

- expected values of ammonium: 10 mg/litre (pH 10);
- upper limit: 15 mg/litre (pH 10.06).

**NB:** These values are determined by potential suppliers of the turbine.

In addition, it is important to note that part of the hydrazine, used in the circuit to remove oxygen dissolved in the secondary circuit water, is decomposed by heat into ammonia which is extracted by the extraction systems for substances that are not condensed in the condenser (CVI).

The concentration in the water tanks for this system may reach high levels, and must therefore be taken into account and managed.

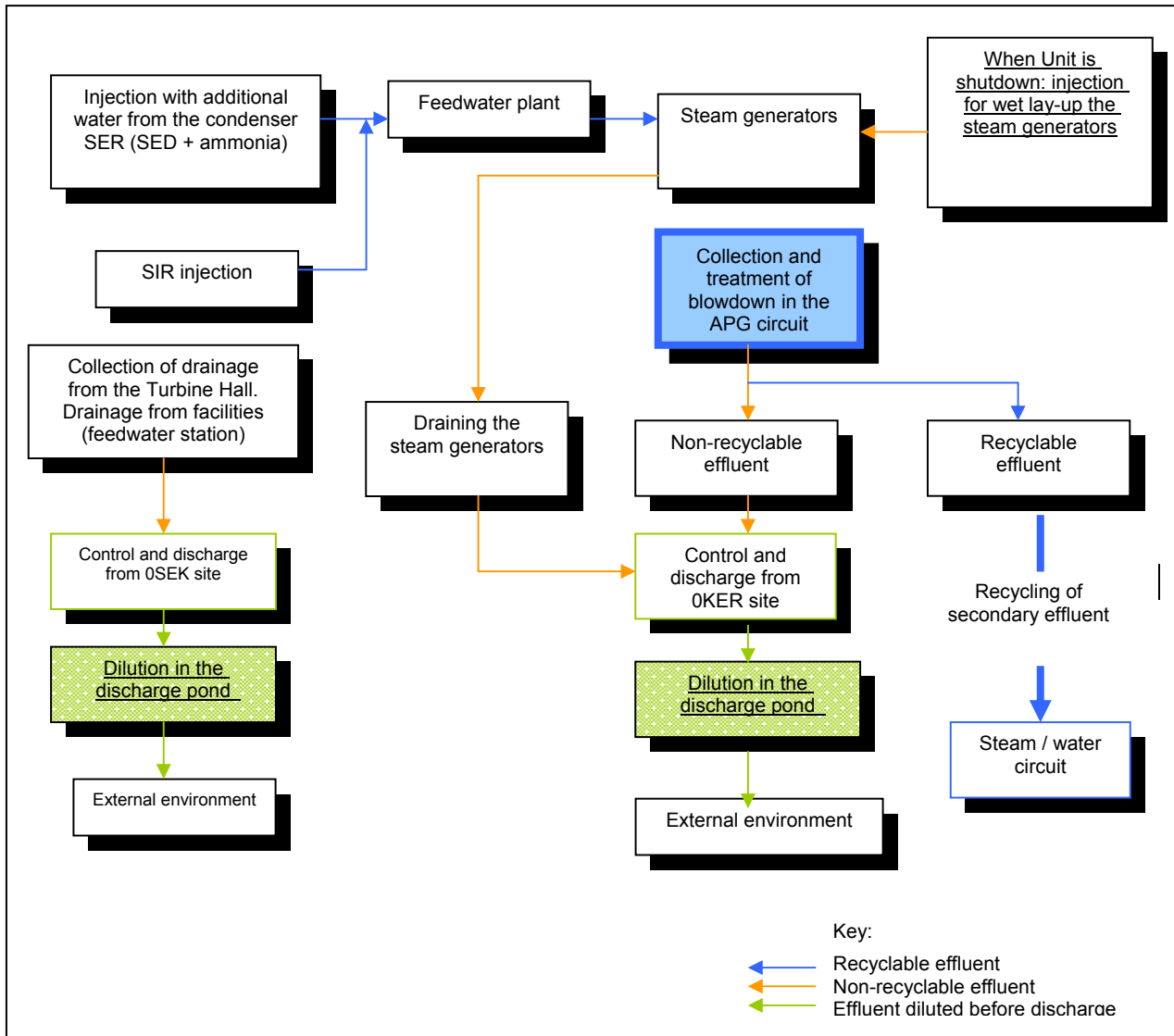
#### 2.2.2.10.4. *Conditioning the secondary circuit with ammonia*

##### 2.2.2.10.4.1. *Role of ammonia*

Ammonia is a weak base that provides the required pH for minimum corrosion in the entire steam-water system (see PCSR Sub-chapter 5.5).

##### 2.2.2.10.4.2. *Path of ammonia through the circuits*

The figure below shows the path of ammonia through the secondary circuit, from injection to the discharge tanks via the treatment systems.



**Figure 17: Path of ammonia through the secondary circuit**

2.2.2.10.4.3. Discharge Characteristics

As shown in the diagram above, ammonia is discharged in two ways:

From the T tanks (OKER [LRMDS]):

In normal operation, ammonia present in water drained from the steam generators is recycled into the steam water system after processing by the APG [SGBS] (Steam Generator Blowdown System).

Drainage water that cannot be recycled through the steam generators is sent to the T tanks (OKER [LRMDS]). Only a small amount is discharged in this way, unless there is some leakage from the primary to the secondary circuit, used to reduce the tritium level in the secondary circuit.

When the unit is shut down, the ammonia present in the T tanks (0KER [LRMDS]) comes from wet conditioning of the steam generators.

From the Ex tanks (0SEK [SiteLWDS]):

Effluent drained from the Turbine Hall or emptied from equipment and circuits in the feedwater plant during shutdown and start-up is collected and sent to the Ex tanks (0SEK [SiteLWDS]).

#### **2.2.2.10.5. Conditioning the secondary circuit with morpholine or ethanolamine**

Path of ammonia through the circuits:

The path of ammonia from hydrazine decomposition or from adding additional ammonia to the circuit is identical to that of morpholine or ethanolamine shown in Sub-chapter 11.2 - Figure 15 and Figure 16.

#### **2.2.2.11. Trisodium phosphate**

##### **2.2.2.11.1. Role of trisodium phosphate**

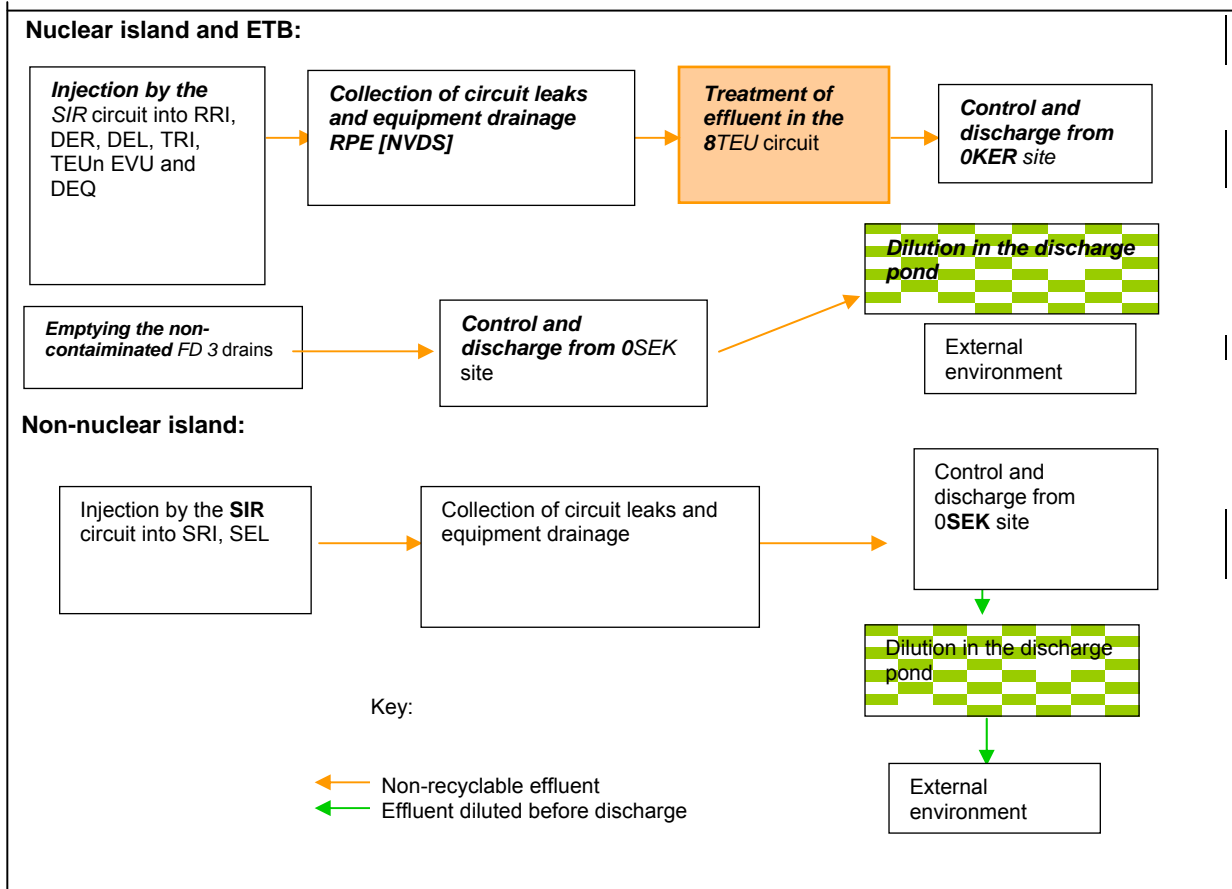
Trisodium phosphate acts as a corrosion inhibitor. It is used to condition circuits in contact with air where an all-volatile treatment cannot be used (see PCSR Sub-chapter 5.5).

The main circuits conditioned with trisodium phosphate are:

- RRI [CCWS]: the Component Cooling Water System for the nuclear auxiliaries;
- TRI: the Component Cooling System for the Effluent Treatment Building;
- SRI: the Component Cooling System for the conventional circuits;
- DEL [SCWS]: the circuit for producing and distributing chilled water to the electrical premises and the control room;
- DER: the system for producing and distributing chilled water to the nuclear island;
- DEQ: the system for producing and distributing chilled water to the Effluent Treatment Building;
- EVU [CHRS]: the Containment Heat Removal System;
- 8TEU [LWPS]: the part of the system producing and distributing distribution of electrically-heated hot water;
- SEL: the system for producing and distributing distribution of electrically heated hot water.

##### **2.2.2.11.2. Path of trisodium phosphate through the circuits**

The simplified diagram below shows the path of trisodium phosphate through the circuits, from injection to the discharge tanks via the treatment systems.



**Figure 18:** Path of phosphate through the auxiliary circuits

**2.2.2.11.3. Discharge Characteristics**

As shown in the diagram above, phosphates are discharged in two ways:

From the T tanks (OKER [LRMDS]):

These tanks collect water leaked or emptied from the heating and cooling circuits for the auxiliaries for the nuclear steam-supply system.

From the Ex tanks (OSEK [SiteLWDS]):

These tanks collect water leaked or emptied from the heating and cooling circuits for the auxiliaries for the Turbine Hall and other non-nuclear circuits.

**2.2.2.12. Sodium**

The sodium discharged provides mainly from emptying circuits conditioned with trisodium phosphate. As the discharge environment is seawater, the sodium level associated with phosphates is not specified: it is discharged in concentrations that are negligible compared with the concentration in the receiving water body.

### **2.2.3. Other associated discharges**

#### **2.2.3.1. Detergents**

Detergents are used in the laundry to clean the working clothes. The detergents are sent with the water that can be contaminated in the OKER [LRMDS] tanks.

The detergents used in the EPR will be biodegradable commercial products, from which EDTA (ethylene diamine tetra-acetic acid) and phosphates will be absent.

#### **2.2.3.2. Total metals, materials in suspension and chemical oxygen demand**

Metals found in the discharged liquids associated with radioactive effluent are those used in material components of the circuits and equipment (aluminium, copper, chromium, iron, manganese, nickel, zinc, copper, aluminium and lead). They are present in trace amounts in the tanks and come from wear in the circuits. Proper chemical conditioning is a major factor in limiting the amount produced. Although the effluent is filtered and treated with ion-exchange resins, small quantities of these metals are found in the discharge tanks.

Suspended solid originates largely from collected effluent that may be polluted either by dust or by the raw water used to cool overheated effluent from the auxiliary installations in the secondary circuit. There are only limited suspended solids in the storage tanks (OKER [LRMDS]), because the effluent is filtered.

The chemical oxygen demand (COD) comes from most of the organic compounds (particularly detergents) and also from oxidisable mineral salts in the water analysed.

#### **2.2.4. Discharge pond**

The discharge pond arrangements of NPPs are site specific. However the following principles are generally applicable. The pond is divided into two sections:

- one section receives discharge from the SEC [ESWS] and SRU [UCWS] pumps and contains a weir;
- the second section receives water from the circulating water system (CRF) and auxiliary cooling water system pumps (mainly SEN).

Liquid chemical discharges from OTER [ExLWDS], OKER [LRMDS] and OSEK [SiteLWDS] tanks are received either in the first or second section depending on the position of various buildings, tanks and galleries on the site. It should be noted that on a site with several units, only one discharge pond is used for these discharges, since the tanks will be shared by all units.

The discharge pond consists of a concrete pit which is connected to a sub-marine tunnel, which discharges to the sea. The discharge to sea is performed using gravity via the discharge tunnel, which is designed according to site constraints. The tunnel entrance is situated at the bottom of the pond.



### **2.3. CHEMICAL EFFLUENT NOT ASSOCIATED WITH LIQUID RADIOACTIVE EFFLUENT**

Chemical substances not associated with radioactive effluent are present in the conventional parts of the site, mainly the following discharges:

- discharges relating to demineralised water production (either from a demineralisation plant or a desalinisation unit);
- discharges associated with seawater chlorination treatment;
- discharges relating to water collected from rainwater drains and black and grey wastewater (effluent from the purification stations);
- discharges relating to water contaminated with oil and water used in production in the Turbine Hall.

#### **2.3.1. Discharges relating to demineralised water production**

There are two possible types of demineralised water production: demineralisation plant and a desalination unit using osmosis membrane.

The demineralisation plant is used to produce:

- filtered water, in particular for spraying of certain equipment located in the pumping station;
- demineralised water from filtered water, to supply the primary and secondary systems.

The operation of the demineralisation plant generates chemical discharge via:

- pre-treatment of untreated water used to remove suspended solids. The chemical product used for this operation is ferric chloride;
- regeneration of demineralisation lines using sulphuric acid and sodium hydroxide.

Effluent from pre-treatment is conveyed to the SEO (Plant Sewer System) (blow-offs) and discharged.

Regeneration effluent is collected in a neutralising pit. After neutralisation (addition of sulphuric acid and sodium hydroxide to reach correct pH) and monitoring, the effluent is discharged.

The operation of the desalination plant generates chemical discharge via:

- pre-treatment used to remove suspended solids (the reagent used for this operation is ferric chloride);
- cleaning of ultrafiltration membranes using sulphuric acid and sodium hydroxide;
- resin regeneration in the mixed bed exchanger using acid and sodium hydroxide.

The brine from the osmosis stages of desalination are discharged, as well as the pre-treatment stage washing waste.

The effluent from resin regeneration in the desalination plant mixed beds is sent to a neutralisation pit, before discharge.

### 2.3.2. Effluent from fouling treatments (seawater chlorination)

The cooling systems are protected against the development of biofilm and biological fouling by seawater chlorination.

Electrolysis is used to produce sodium hypochlorite from seawater.

Chlorination is carried out as soon as the temperature of the seawater reaches 10°C.

This process involves discharging both residual oxidants (both in a free state and as chlorine compounds) and trihalomethanes (in the form of bromoform) into the sea, as follows:

- for the EPR unit, the process consists of chlorinating in sequential mode in the cooling line;
- a change in the seawater quality may lead to excessive proliferation of biological fouling which requires enhanced treatment (a few days per year and per unit, non-simultaneously).

For the EPR unit, enhanced chlorination may be applied to the SEN, SEC [ESWS], and SRU [UCWS] systems, which are equipped with pipework taking top-up water from the pumping station. These pipes contain a number of hypoxic areas, which makes them highly prone to biological fouling.

### 2.3.3. Sewer discharge

The chemical substances discharged into the sea via the sewers are specified below.

#### Chemical discharge from the treatment plants and individual drainage installations:

The EPR unit will either be equipped with its own treatment plant with a capacity of 800 inhabitant-equivalents, or connected to an existing station, which will then be extended to an equivalent capacity.

Chemical discharge from the treatment station is characterised by a BOD<sub>5</sub> (Five-day Biological Oxygen Demand) concentration in the discharged effluent which complies with statutory limits.

#### Discharged hydrocarbons:

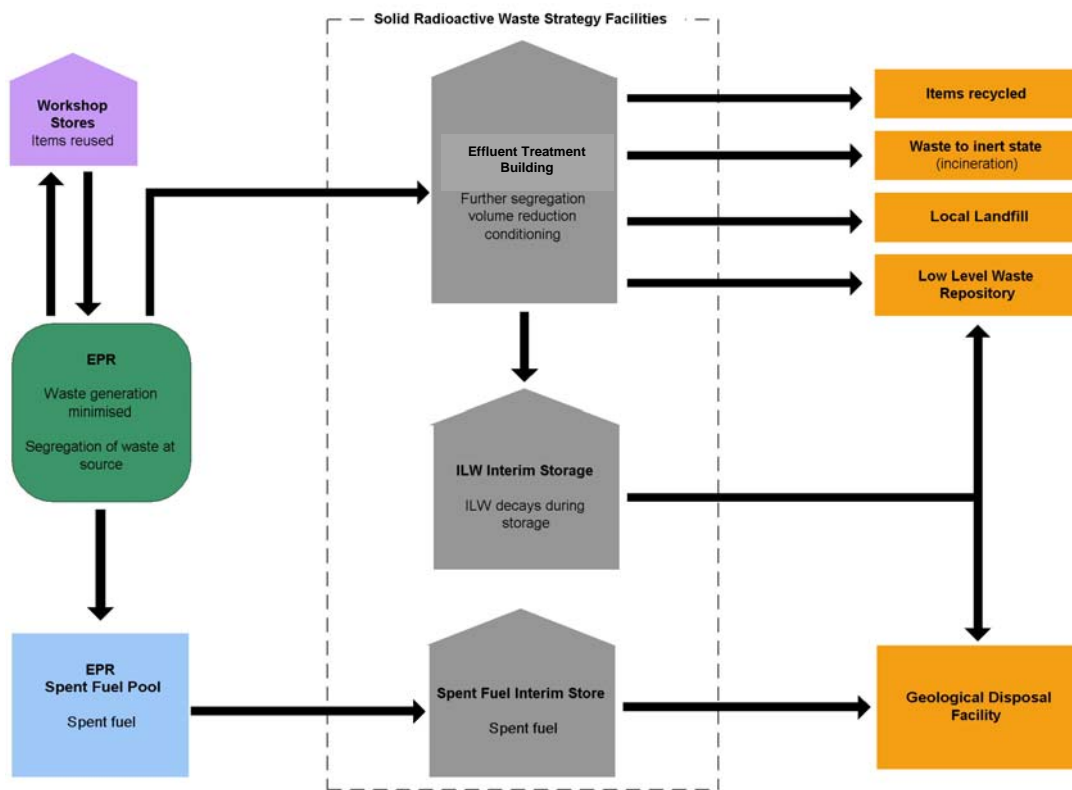
Wastewater from the EPR unit that could contain hydrocarbons is treated in the on-site scrubbers and oil filters. The hydrocarbon concentration in the discharge complies with the statutory limit.

#### Phosphate and amine discharge:

Phosphate and amine discharge is not continuous.

### 3. SOLID RADIOACTIVE WASTE AND SPENT NUCLEAR FUEL STRATEGY

This section describes the radioactive waste and spent nuclear fuel management strategy for the lifecycle of the UK EPR in response to HSE expectations and requirement 1.4 of the EA P&I Document. This strategy takes into account the UK EPR solid radioactive waste and spent fuel characteristics. It addresses the government and NDA policies for the assessment of disposability of radioactive waste and includes the description of processes and interim storage facilities for managing the waste and spent nuclear fuel. The figure below presents the solid radioactive waste and spent fuel streams for the UK EPR.



**Figure 19: Solid radioactive waste and spent fuel streams for the UK EPR**

The ‘reference case’ solid radioactive waste and spent fuel strategy presented in the SSER is based on the waste and spent fuel management practices and arrangements of the UK EPR reference plant at Flamanville 3. The strategy is detailed in the “BAT Demonstration” document [Ref-1], the “Integrated Waste Strategy” document [Ref-2]. This strategy is supported by a Best Available Techniques (BAT) analysis (Chapter 8 of the PCER) and impact assessments (Chapters 9 to 12 of the PCER).

In addition, it is recognised from experience from other EPR and AREVA projects worldwide that other potential UK EPR operators may wish to adopt alternative spent fuel and waste management arrangements. These possible options to the reference case are presented in a Solid Radioactive Waste Strategy Report (SRWSR) [Ref-4]. The SRWSR does not provide respective BAT assessments for the options but there is a high degree of confidence that such cases can be made by potential UK EPR operators. This SRWSR is referenced within the relevant sub-chapters of the SSER.

Overall the reference case and supporting options also provide a basis for potential UK EPR operators to develop their Decommissioning and Waste Management Plans (DWMP) as part of future site licensing requirements.

The information available in the PCSR and supporting documents to be used by a potential UK EPR operator for a Radioactive Waste Management Case (RWMC) for ILW and spent fuel, is reiterated in “Mapping Document for Radioactive Waste Management Case” [Ref-3]. This document has been prepared based on the HSE guidance [Ref-5].

### 3.1. CATEGORIES OF RADIOACTIVE DISCHARGES IN THE UK

The Community Directive EURATOM 92/3 (issued by the European Council on 3 February 1992) regarding the supervision and control of shipments of radioactive waste between Member States and into and out of the Community, gives the following definition of radioactive waste: “Any material containing radionuclides or contaminated with radionuclides, and for which no further use is foreseen”.

In the UK, there is no legal definition of the different types of radioactive waste. However, radioactive waste is usually classified into one of three main categories depending on the activity and types of radionuclides it contains (these take into account recent information in the UK Policy on Low Level Waste (LLW) published in March 2007 [Ref-1]):

- High Level Waste, HLW, is radioactive waste where provisions must be made for dealing with heat generated from decay;
- Intermediate Level Waste, ILW, is “waste with radioactivity levels exceeding the upper boundaries for LLW but which do not require heat generation to be taken into account in the design of storage or disposal facilities”;
- Low Level Waste, LLW, is “waste having a radioactive content not exceeding 4 GBq/t of alpha or 12 GBq/t of beta / gamma activity. This waste is currently accepted at the UK national LLW disposal facility (LLWR), located near to the village of Drigg”.

In practice, some LLW falling within that general definition cannot be disposed of at the LLWR, due to radionuclide content and/or physical/chemical properties. These wastes have to be considered separately and may have to be managed as ILW.

The lower activity limit for LLW, below which waste is not required to be subject to specific regulatory control, is either:

- the levels specified in Schedule 1 of the Radioactive Substances Act 1993 (RSA 1993) below which certain natural radionuclides in the uranium and thorium decay chain are outside the scope of the Act or;
- the levels laid down in the current suite of Exemption Orders issued under RSA 1993, below which additional controls on certain artificial or man-made radionuclides to those specified in the Exemption Order are not required. In particular, this specifies a level for exemption from regulatory control of 0.4 MBq/t for wastes that are substantially insoluble in water.

Within the UK, Very Low Level Radioactive Waste (VLLW) is now defined as:

- in the case of low volume – Low Volume VLLW: “Radioactive waste which can be safely disposed of to an unspecified destination with municipal, commercial or industrial waste, each 0.3 m<sup>3</sup> of waste containing less than 400 kilobecquerels (kBq) of total activity or single items containing less than 40 kBq of total activity;
- for wastes containing carbon-14 or hydrogen-3 (tritium): In each 0.1 m<sup>3</sup>, the activity limit is 4,000 kBq for carbon-14 and hydrogen-3 (tritium) taken together; and for any single item, the activity limit is 400 kBq for carbon-14 and hydrogen-3 (tritium) taken together;
- controls on disposal of this material after removal from the premises where the wastes arose, are not necessary (the quantity of low volume VLLW that may be disposed of is currently the subject of research).”

Or in the case of bulk disposals – High Volume VLLW:

- “Radioactive waste within maximum concentrations of four megabecquerels per tonne (MBq/t) of total activity which can be disposed of to specified landfill sites. For waste containing hydrogen-3 (tritium), the concentration limit for tritium is 40 MBq/t. Controls on disposal of this material, after removal from the premises where the wastes arose, will be necessary in a manner specified by the environmental regulators”.

The principal difference between the two definitions is the need for controls on the total volumes of VLLW in the second (high volume) category being deposited at any one particular landfill site. The definitions supersede that for VLLW in paragraph 53(4) of Cm2919.

### 3.2. RADIOACTIVE WASTE AND SPENT NUCLEAR FUEL PRODUCED BY THE UK EPR

Further details on the solid wastes and spent fuel arising from the operation of an EPR unit are included in Sub-chapter 11.3 for the reference case and in the SRWSR [Ref-1] for the options.

Note: The waste arisings during the decommissioning phase are described in PCSR Chapter 20.

#### 3.2.1. Solid radioactive waste

The power station produces three types of radioactive waste:

1. Waste known as “process” waste, associated with generating power. This results from treating fluids, in order:
  - to limit the deposited contamination and reduce its activity, so that personnel are not exposed to radiation;
  - to reduce the activity of discharged effluent, whether liquid or gaseous.

The process waste is that which results from treating gaseous effluent and comprises mainly filters and iodine traps. From liquid waste treatment, the process waste consists of filters, concentrates and ion-exchange resins [Ref-2].

2. Dry active waste arising from maintenance work (mending faults, repairs, replacement of radioactive equipment, etc.). It comprises mainly compactable materials, such as vinyl, gloves, adhesive tape, papers, trunking for exhaust fans, etc [Ref-2].
3. Other waste, generally from so called sundry incidents (e.g. contaminated oils), activated core components from outages.

During the operation of the UK EPR, a number of core components used to control or measure neutron activity will need to be replaced during outages. These include neutron absorber rods and Rod Cluster Control Assemblies.

Estimated gross volumes of solid waste produced during operation of the EPR unit are given in Sub-chapter 11.3.

Furthermore, in response to requirement 2.4 of the EA P&I Document, the characteristics of the reference case packaged wastes taking into account the UK classification (as mentioned in sub-section 3.1) are included in Sub-chapter 11.3. The characteristics of packaged wastes arising from the alternative options can be found in the Solid Radioactive Waste Strategy Report (SRWSR) [Ref-1].

The characteristics of ILW (i.e. types, quantities, quantification of nuclides, declaration of packages radioactivity contents and physical-chemical compositions) are currently being assessed by the NDA in order to determine the acceptability of the produced waste forms with the planned UK disposal route. In addition, these wasteform characteristics have been used to specify the interim storage facility options for ILW, pending availability of the planned final waste disposal facility. The progress of these assessments is reported in Sub-chapter 11.5.

### **3.2.2. Spent nuclear fuel**

In the UK, spent nuclear fuel is not classified as waste.

Once it has been producing energy in the reactor for a maximum period of 5 or 6 years, a fuel assembly is spent and must be discharged.

As regards to its core and its use of fuel, the EPR is an evolutionary reactor whose design has drawn on the experience of existing reactors. It uses the same types of fuel, but the energy yield is better due to its design features and enhancements in fuel performance.

The fuel assembly is transferred from the Reactor Building to the spent fuel pool in the Fuel Building through the containment penetration formed by the fuel transfer. The decay heat of the irradiated fuel assemblies in the spent fuel pool is removed by the Fuel Pool Purification/Cooling System PTR [FPPS/FPCS]. Detailed information about the storage is given in PCSR Sub-chapter 9.1.

In response to requirement 2.5 of the EA P&I Document, the EPR spent nuclear fuel characteristics are given in Sub-chapter 11.3. Characteristics such as quantities, mass and arisings, material specification, physical chemical composition have been used both for the determination of interim storage facility options for spent nuclear fuel, and for the NDA assessment of the disposability of spent nuclear fuel should this option be adopted in the future. The progress of these assessments is reported in Sub-chapter 11.5.

### 3.3. TREATMENT OF RADIOACTIVE WASTE

Radioactive waste is segregated at source to minimise the volumes of higher level wastes.

This could include segregation of short-lived ILW species from long-lived ILW to facilitate future disposal of the short-lived ILW as LLW if permitted in the future.

Solid wastes are also stored and conditioned in accordance with sound engineering principles that ensure containment, protection of workers, allow inspection and produce waste forms that are compliant and acceptable for planned or actual disposal routes.

All UK regulatory requirements have been taken into account in the handling and treatment of solid radioactive waste and the treatment systems take due consideration of the UK disposal routes, both current and planned.

The EPR solid waste arisings will be similar in many respects to those already handled at operating PWRs and current UK plants with similar isotopic characteristics. The waste treatment systems are detailed in Sub-chapter 11.4. Different options for treatment, conditioning and packaging processes are presented within the SRWSR [Ref-1] reflecting the practices of different utilities.

#### 3.3.1. Reference case

The reference case treatment and conditioning processes for solid waste based on Flamanville 3 are the result of French operating experience and from a global optimisation process minimising the quantity and the environmental impact of liquid and gaseous discharges and minimising solid radioactive waste production.

These processes are used in the PCER for the demonstration of the environmental impacts of the UK EPR. The liquid and gaseous radioactive discharges detailed in Sub-chapter 11.3 and associated impacts studies detailed in Chapter 11 of the PCER are based on the reference case. The BAT demonstration presented in Chapter 8 of the PCER is also based on the processes of the reference case.

Waste from the EPR unit is segregated at source in each area in which it arises, both in terms of its activity and its chemical and physical characteristics. Activity assessment is determined by measurement with handheld monitors and applying a nuclide fingerprint applicable for the source. Initial waste streaming can be based on isotopic compositions.

The waste consists of active ion exchange resins from the RCV [CVCS], PTR [FPPS/ FPCS], TEP [CSTS] and 8TEU [LWPS] demineralisers, APG [SGBS] resins of lower activity and also RCV [CVCS], PTR [FPPS/ FPCS], 8TEU [LWPS] and TEP [CSTS] filters and other general lower level waste (maintenance waste etc.). Where required, transfers and handling are performed by remote means.

The treatment of solid waste is divided between the TES [SWTS] [Ref-8] to [Ref-15] unit system and the 8TES [SWTS] [Ref-1] to [Ref-7] system located in the EPR Effluent Treatment Building.

Solid waste from the nuclear island and the Effluent Treatment Building that results from normal operation is sent to the 8TES [SWTS] system, then conditioned for on-site interim storage, sending off the installation site to a final storage location, or to a treatment plant for additional processing (e.g. incineration, smelting etc.).

In each case, waste is carefully monitored and accounted for.

### 3.3.2. Options to the reference case

Treatment options and facilities for the processing of EPR waste are described in the SRWSR [Ref-1].

## 3.4. INTERIM STORAGE AND DISPOSABILITY FOR THE UK EPR

### 3.4.1. Solid radioactive waste

#### 3.4.1.1. Intermediate Level Waste (ILW)

ILW will be stored on the EPR sites in dedicated building(s) until a final disposal site for ILW is opened in the UK. It is assumed that this disposal will be located on the same site as the Geological Disposal facility proposed for legacy wastes and will follow the same public consultation process and thus probably have the same opening timescale.

Therefore, the land of the EPR sites should be sufficient to accommodate the construction of interim storage facilities for ILW produced during the full operational life of the plant.

The radioactive decay during interim storage of the ILW due to its composition of short-lived radionuclides can reduce the final quantities of ILW to be disposed of. Some of this waste could be reclassified as LLW.

In response to requirement 1.4 and 2.4 of the P&I Document, design information on possible option(s) regarding interim storage facilities for ILW is provided in Sub-chapter 11.5 and the SRWSR [Ref-1]. At this stage, designs for two ILW storage options are described. These options are considered as suitable for licensing, construction and operation in the UK.

#### 3.4.1.2. Low Level Waste (LLW)

For the conditioning as described in Sub-chapter 11.4, it is intended that process solid wastes and solvent will be incinerated using one of the following:

1. Using an existing or upgraded incinerator on an adjacent site;
2. Using an existing or upgraded incinerator elsewhere in the UK;
3. Using the CENTRACO incinerator in France which already treats wastes from the French NPPs, considered as equivalent to the UK wastes.

Direct dialogue with incineration service providers has not been held as part of the GDA. Whilst a detailed review of these waste streams against the conditions of acceptance of available incinerators has therefore not been conducted, the GDA has taken into consideration the need to minimise waste sent to the LLWR, in accordance with the emerging National Low Level Waste Strategy. We have therefore identified those streams likely to be suitable and available for incineration. LLWR Ltd. are currently organising a tender process to identify future service providers in this area as part of their strategy for providing a 'one stop shop' service for LLW disposals, under LLWR conditions of acceptance. All UK EPR operational low level waste (except oil and solvent) has been demonstrated to be disposable at LLWR [Ref-1].



Oils and solvents from existing French PWRs are shipped to the CENTRACO facility for incineration [Ref-2]. The activity concentration of oily rags is considered to be the same as all other DAW. Arisings are therefore likely to be VLLW and LLW. As waste oils and solvents generated in the UK EPR will have identical physical, chemical and radiological characteristics as existing PWRs they will be fully compatible with CENTRACO conditions of acceptance. Comparison against the main element of the Tradebe conditions of acceptance also provides confidence that EPR waste oils would be accepted at the Tradebe incinerator.

Ashes resulting from the incineration will be conditioned at the incineration facility and sent for final disposal at the LLWR.

Wastes that are suitable for melting will be sent to off-site melting facilities.

It is also assumed at the time of NPP start-up such facilities will be internationally or nationally available and accessible. The Effluent Treatment Building provides adequate buffer storage for packages to be sent to the incinerator or melter.

Other LLW will be conditioned in the manner described in Sub-chapter 11.4.

The conditioned waste should be consistent with LLWR requirements for disposal at the existing LLWR or a further facility provided by the NDA. Discussions with LLWR have been held to confirm this.

Therefore, on line export of LLW to LLWR is assumed in the reference case and only short term buffer storage of LLW in the Effluent Treatment Building will be provided.

Note:

- Plans for a new LLWR and whether this new site might accept both ILW (short-lived) and LLW are still unknown and are part of the ongoing national LLW strategy review.

### **3.4.2. Spent nuclear fuel**

The UK law stipulates that the choice between reprocessing and interim storage of spent fuel belongs to the owner of the fuel depending on economic considerations and compliance with the appropriate regulations.

As mentioned in the CoRWM report [Ref-1], spent nuclear fuel is not currently classified as a waste. In the EPR, it is stored firstly in a spent fuel storage pool and secondly in an interim storage facility until a decision is made on its future disposal in a Geological Disposal Facility (if declared as waste).

The UK EPR strategy for spent fuel management is therefore based on on-site interim storage of spent fuel in suitable facilities.

The CoRWM report recommends deep geological final disposal of high activity wastes (whether resulting from reprocessing or consisting of spent fuel assemblies declared as waste) and a safe and secure interim storage of these wastes pending the availability of geological disposal. The Government endorsed these recommendations and committed to make arrangement for new build wastes to be taken into account in developing the Geological Disposal Facility.

EDF/AREVA welcomes these decisions which also ensure that licensees will fully assume financial and industrial responsibility for the interim storage (and disposal if declared as waste) of the spent fuel accumulated over the 60 years of operation of its NPPs.

The EPR design already allows a capacity of storage in its spent fuel pool corresponding to at least 10 years of electricity production. The extension of this capacity to cover the 60 years of operation of the nuclear unit will be done, when necessary (or in due time) with one or more of the following:

1. Construction of an interim spent fuel storage facility on the same site,
2. Construction and operation of an interim spent fuel storage facility shared between several sites,
3. Construction and operation of an interim spent fuel storage facility shared between several nuclear utilities,
4. Contractual arrangements with an industrial operator in the UK (such as NDA) for long term storage of the fuel,

The site of the EPR plants will have sufficient space to allow for building such a spent fuel storage facility. From a technical point of view, based on current worldwide experience, it is foreseen that spent fuel can be safely stored for at least 100 years.

In response to requirements 1.4 and 2.5 of the EA P&I Document, interim storage facilities are described in Sub-chapter 11.5 and the SRWSR [Ref-2]. The designs for three options are described: two dry options and one wet option. These options, based on proven technology already implemented in France and elsewhere, are considered suitable for licensing, construction and operation in the UK.

## SUB-CHAPTER 11.2 – REFERENCES

External references are identified within this sub-chapter by the text [Ref-1], [Ref-2], etc at the appropriate point within the sub-chapter. These references are listed here under the heading of the section or sub-section in which they are quoted.

[Ref-1] Process and Information Document for Generic Assessment of Candidate Nuclear Power Plant Designs. The Environment Agency. January 2007. (E)

### 1. RADIOACTIVE DISCHARGES

#### 1.1. RADIOACTIVE LIQUID DISCHARGES

##### 1.1.3. Treatment of Liquid Radioactive Effluent

###### 1.1.3.1. Treatment of Primary Liquid Effluent TEP [CSTS]

[Ref-1] System Design Manual – Coolant Purification, Degasification, Storage and Treatment System (TEP [CSTS]), P2 – System Operation. SFL-EZS-030008 Revision G. SOFINEL. October 2008. (E)

[Ref-2] System Design Manual – Coolant Purification, Degasification, Storage and Treatment System (TEP [CSTS]), P3 – Sizing of the system and its components. SFL-EZS-030009 Revision F. SOFINEL. October 2008. (E)

[Ref-3] System Design Manual – Coolant Purification, Degasification, Storage and Treatment System (TEP [CSTS]) P4 – Flow diagrams. SFL-EZS030010 Revision E. SOFINEL. September 2008. (E)

[Ref-4] System Design Manual – Coolant Purification, Degasification, Storage and Treatment System (TEP [CSTS]) P4.1 – Functional flow diagrams. EZS2006/en/0008 Revision A. SOFINEL. October 2006. (E)

[Ref-5] System Design Manual – Coolant Purification, Degasification, Storage and Treatment System (TEP [CSTS]), P4.2 – Detailed flow diagrams. EZS/2006/en/0009 Revision F. SOFINEL. October 2008. (E)

[Ref-6] System Design Manual – Coolant Purification, Degasification, Storage and Treatment System (TEP [CSTS]), P5 – Instrumentation and Control. SFL-EZS-030077 Revision F. SOFINEL. November 2008. (E)

###### 1.1.3.2. Treatment of spent liquid effluent

[Ref-1] DARPE FLA. Authorization request for water intake and liquid and gaseous releases of the Flamanville site. Part B. Chapter II.3 - Gaseous and liquid radioactive releases. (E)

**1.1.3.3. Treatment of blowdown from steam generators**

- [Ref-1] System Design Manual – Steam Generator Blowdown System (APG [SGBS]) P2 – System Operation. SFL-EZS-030046 Revision G. SOFINEL. December 2008. (E)
- [Ref-2] System Design Manual – Steam Generator Blowdown System (APG [SGBS]) P3 – Sizing of the system and its components. SFL-EZS-030047 Revision G. SOFINEL. December 2008. (E)

**1.1.3.4. Treatment of water drained from the Turbine Hall**

- [Ref-1] System Design Manual – Specifications for describing the SEK [CILWDS] plant system in the turbine hall and site galleries in the Flamanville 3 EPR. ETDOIG060270 Revision A1. EDF. November 2009. (E)
- [Ref-2] Dossier de Système Élémentaire – SEK DSE P4.2: Schéma mécanique détaillé. [System Design Manual – Conventional Island liquid waste discharge system (SEK [CILWDS]), Part 4.2 – Detailed Flow Diagrams] 23952SEK00014SH Revision C. Assystem. September 2008.
- [Ref-3] System Design Manual – Conventional Island liquid waste discharge system (SEK [CILWDS]), Part 5 – Instrumentation and Control. 23952SEK00025DSE Revision C1. Assystem. December 2008. (E)

**1.1.4. Storage of liquid effluents**

- [Ref-1] DARPE FLA. Authorization request for water intake and liquid and gaseous releases of the Flamanville site. Part B. Chapter II.3 - Gaseous and liquid radioactive releases. (E)

**1.2. RADIOACTIVE GASES**

**1.2.3. Treatment of gaseous radioactive effluent**

**1.2.3.1 Treatment of gaseous effluent from the primary circuit liquid tanks (TEG [GWPS] system)**

- [Ref-1] System Design Manual - Gaseous Waste Processing System (TEG [GWPS]), P1 – History of the System Manual. SFL-EZS 030050 Revision D. SOFINEL. October 2008. (E)
- [Ref-2] System Design Manual - Gaseous Waste Processing System (TEG [GWPS]), P2 – System operation. SFLEZS030051 Revision E. SOFINEL. September 2008. (E)
- [Ref-3] System Design Manual - Gaseous Waste Processing System (TEG [GWPS]), P3 – Sizing of the System and its Components. SFLEZS030052 Revision E. SOFINEL. September 2008. (E)
- [Ref-4] System Design Manual - Gaseous Waste Processing System (TEG [GWPS]), P4 – Flow diagrams. SFL-EZS 030053 Revision D. SOFINEL. September 2008. (E)

[Ref-5] System Design Manual - Gaseous Waste Processing System (TEG [GWPS]), P4.1 – Functional flow diagrams. ECEF080592 Revision A. EDF. April 2008. (E)

[Ref-6] System Design Manual - Gaseous Waste Processing System (TEG [GWPS]), P4.2 – Detailed flow diagrams. EZS/2007/en/0007 Revision D. SOFINEL. September 2008. (E)

[Ref-7] System Design Manual - Gaseous Waste Processing System (TEG [GWPS]), P5 – Instrumentation and Control  
EZS 2007/en/0015 Revision C. SOFINEL. October 2008. (E)

### 1.2.3.2. Treatment of gaseous effluent from ventilation

#### 1.2.3.2.1. Ventilation of the Nuclear Auxiliary Building (DWN)

[Ref-1] System Design Manual – Nuclear Auxiliary Building Ventilation System (DWN [NABVS]), P2 – System operation. EZL2006/en/0093 Revision E. SOFINEL. November 2008. (E)

[Ref-2] System Design Manual – Nuclear Auxiliary Building Ventilation System (DWN [NABVS]), P3 - Sizing Report. EZL2006/en/0092 Revision F. SOFINEL. November 2008. (E)

#### 1.2.3.2.2. Fuel-Building Ventilation DWK [FBVS]

[Ref-1] System Design Manual – Fuel Building Ventilation System (DWK [FBVS]), P2 - System Operation. SFLEFMF2006164 Revision D1. SOFINEL. October 2009. (E)

#### 1.2.3.2.3. Ventilation of the controlled area in the Safeguard Buildings DWL [CSBVS]

[Ref-1] System Design Manual – Safeguard Building Controlled Area Ventilation System (DWL [CSBVS]), P2 – System operation (Stage 1).  
SFL-EZL-030008 Revision G. SOFINEL. November 2008. (E)

[Ref-2] System Design Manual – Safeguard Building Controlled Area Ventilation System (DWL [CSBVS]), P3 – Sizing of the system and its components (Stage 1).  
EZH/2007/en/0033 Revision E. SOFINEL. November 2008. (E)

#### 1.2.3.2.4. Reactor building ventilation EBA [CSVS]

[Ref-1] System Design Manual – Containment Sweep Ventilation System (EBA [CSVS]), P2 - System Operation. EYTS2007/fr/0131 Revision B1. SOFINEL. November 2009. (E)

[Ref-2] System Design Manual – Containment Sweep Ventilation System (EBA [CSVS]), P3 – Design of System and its Components.  
SFL-EFMF-2006.502 Revision B1. SOFINEL. March 2009. (E)

#### 1.2.3.2.5. Ventilation of the controlled area of the Operational Service Centre DWB

[Ref-1] System Design Manual – Operating Building Contaminable Room Ventilation System (8DWB), P2 - System Operation (Stage 2).  
SFL-EF MF 2006.131 Revision D1. SOFINEL. August 2009. (E)

[Ref-2] System Design Manual – Operating Building Contaminable Room Ventilation System (8DWB), P3 – Design of System and Components (Stage 2). SFL-EF MF 2006.132 Revision E1. SOFINEL. August 2009. (E)

#### **1.2.3.2.6. Ventilation of the Effluent treatment Building (DWQ) [ETBVS]**

[Ref-1] System Design Manual – Effluent Treatment Building Ventilation System (8DWQ), P2 - System Operation. EYTS2007/fr/0108 Revision B1. SOFINEL. November 2009. (E)

[Ref-2] System Design Manual – Effluent Treatment Building Ventilation System (8DWQ), P3 - System and component design. EYTS2007/fr/0109 Revision B1. SOFINEL. November 2009. (E)

#### **1.2.3.2.7. Ventilation of the controlled area of the Access Building (DWW) [ABVS]**

[Ref-1] System Design Manual – Peripheral Room Ventilation System (DWW [ABVS]), P2 - System Operation. EYTS2007/fr/0187 Revision D1. SOFINEL. November 2009. (E)

## **2. LIQUID CHEMICAL EFFLUENT DISCHARGES**

### **2.2. CHEMICAL DISCHARGES ASSOCIATED WITH RADIOACTIVE EFFLUENTS**

#### **2.2.2. Discharges caused by lay-up in the circuits**

##### **2.2.2.10. Nitrogen, excluding hydrazine, morpholine and ethanolamine**

###### **2.2.2.10.3. During operation**

###### **2.2.2.10.3.1. For lay-up with morpholine or ethanolamine**

[Ref-1] DARPE FLA. Authorization request for water intake and liquid and gaseous releases of the Flamanville site. Part B. Chapter II.4.1 - Chemicals associated with liquid radioactive effluents and drainage water discharged into the sea. (E)

## **3. SOLID RADIOACTIVE WASTE AND SPENT NUCLEAR FUEL STRATEGY**

[Ref-1] GDA UK EPR - BAT Demonstration. UKEPR-0011-001 Issue 06. EDF/AREVA. August 2012. (E)

[Ref-2] GDA UK EPR - Integrated Waste Strategy. UKEPR-0010-001 Issue 03. EDF/AREVA. June 2012. (E)

[Ref-3] GDA UK EPR - Mapping Document for Radioactive Waste Management Case. UKEPR-0012-001 Issue 02. EDF/AREVA. March 2011. (E)

[Ref-4] Solid Radioactive Waste Strategy Report (SRWSR). AREVA NP. NESH-G/2008/en/0123 Revision A. November 2008. (E)

[Ref-5] Guidance from the Health and Safety Executive, the Environment Agency and the Scottish Environment Protection Agency to nuclear licensees . The management of higher activity radioactive waste on nuclear licensed sites, radioactive waste management cases. February 2010. (E)

### **3.1. CATEGORIES OF RADIOACTIVE DISCHARGES IN THE UK**

[Ref-1] Policy for the Long Term Management of Solid Low Level Radioactive Waste in the United Kingdom. DEFRA. March 2007. (E)

### **3.2. RADIOACTIVE WASTE AND SPENT NUCLEAR FUEL PRODUCED BY THE UK EPR**

[Ref-1] Solid Radioactive Waste Strategy Report (SRWSR). AREVA NP. NESH-G/2008/en/0123 Revision A. November 2008. (E)

#### **3.2.1. Solid radioactive waste**

[Ref-1] Solid Radioactive Waste Strategy Report (SRWSR). AREVA NP. NESH-G/2008/en/0123 Revision A. November 2008. (E)

[Ref-2] EPR - Radioactive waste conditioning - ECUK110016 Revision A. Appendix 4. EDF. January 2011. (E)

### **3.3. TREATMENT OF RADIOACTIVE WASTE**

[Ref-1] Solid Radioactive Waste Strategy Report (SRWSR). AREVA NP. NESH-G/2008/en/0123 Revision A. November 2008. (E)

#### **3.3.1. Reference case**

[Ref-1] System Design Manual – Effluent Treatment Building Solid Waste Treatment System (8TES [SWTS]), P1. ECEF080440 Revision A1. EDF. January 2010. (E)

[Ref-2] System Design Manual – Effluent Treatment Building Solid Waste Treatment System (8TES [SWTS]), P2 – System operation. ECEF070007 Revision B1. EDF. January 2010. (E)

[Ref-3] System Design Manual – Effluent Treatment Building Solid Waste Treatment System (8TES [SWTS]), P3 – System Dimensioning. ECEF070008 Revision B1. EDF. January 2010. (E)

**[Ref-4]** System Design Manual – Effluent Treatment Building Solid Waste Treatment System (8TES [SWTS]), P4 – Flow diagrams. ECEF080573 Revision A1. EDF. January 2010. (E)

**[Ref-5]** Dossier de Système Élémentaire - Traitement des effluents solides du BTE 8TES [SWTS] – Part 4.1 – Schéma Mécanique Fonctionnel.  
[System Design Manual - Effluent Treatment Building Solid Waste Treatment System 8TES [SWTS], P4.2 – Functional Flow Diagrams].  
ECEFO80624 Revision A. EDF. April 2008.

**[Ref-6]** Dossier de Système Élémentaire - Traitement des effluents solides du BTE 8TES [SWTS] – Part 4.2 - Schéma Mécanique Détaillé.  
[System Design Manual - Effluent Treatment Building Solid Waste Treatment System 8TES [SWTS], P4.2 - Detailed Flow Diagrams].  
ECEFO71498 Revision B. EDF. January 2008.

**[Ref-7]** System Design Manual – Effluent Treatment Building Solid Waste Treatment System (8TES [SWTS]), P5 – Instrumentation and Control. ECEF080380 Revision A1. EDF. January 2010. (E)

Filter changing equipment:

**[Ref-8]** System Design Manual – Solid Waste Treatment System (TES [SWTS]) – Filter changing equipment TES11, P2 – System operation. SFLEZM200118 Revision B. SOFINEL. September 2006. (E)

**[Ref-9]** System Design Manual – Solid Waste Treatment System (TES [SWTS]) – Filter changing equipment TES11, P3 – Sizing of the system and its components. SFLEZM200119 Revision B. SOFINEL. September 2006. (E)

Transfer of the spent resins

**[Ref-10]** System Design Manual – Solid Waste Treatment System (TES [SWTS]) – Transfer of the spent resins (TES21, TES31), P1. SFLEZS030039 Revision D. SOFINEL. March 2007. (E)

**[Ref-11]** System Design Manual – Solid Waste Treatment System (TES [SWTS]) – Transfer of the spent resins (TES21, TES31), P2 – System operation. EZS030040 Revision D. SOFINEL. March 2007. (E)

**[Ref-12]** System Design Manual – Solid Waste Treatment System (TES [SWTS]) – Transfer of the spent resins (TES21, TES31), P3 – Sizing of the system and its components. EZS030041 Revision D. SOFINEL. March 2007. (E)

**[Ref-13]** System Design Manual – Solid Waste Treatment System (TES [SWTS]) – Transfer of the spent resins (TES21, TES31), P4 – Flow diagrams. EZS030042 Revision D. SOFINEL. March 2007. (E)

**[Ref-14]** System Design Manual – Solid Waste Treatment System (TES [SWTS]) – Transfer of the spent resins (TES21, TES31), P4.1 – Simplified flow diagrams. EZS/2006/en/0019 Revision A. SOFINEL. March 2007. (E)

**[Ref-15]** System Design Manual – Solid Waste Treatment System (TES [SWTS]) – Transfer of the spent resins (TES21, TES31), P4.2 – Detailed flow diagrams. EZS/2006/en/0020 Revision B. SOFINEL. March 2007. (E)



**3.3.2. Options to the reference case**

[Ref-1] Solid Radioactive Waste Strategy Report (SRWSR). AREVA NP.  
NESH-G/2008/en/0123 Revision A. November 2008. (E)

**3.4. INTERIM STORAGE AND DISPOSABILITY FOR THE UK EPR****3.4.1. Solid radioactive waste****3.4.1.1. Intermediate Level Waste (ILW)**

[Ref-1] Solid Radioactive Waste Strategy Report (SRWSR). AREVA NP.  
NESH-G/2008/en/0123 Revision A. November 2008. (E)

**3.4.1.2. Low Level Waste (LLW)**

[Ref-1] Form D1 Application: UK EPR Project, from LLW Repository Ltd. 320.L.027.  
December 2008. (E)

[Ref-2] EPR - Radioactive waste conditioning. ECUK110016 Revision A. Appendix 1. EDF.  
January 2011. (E)

**3.4.2. Spent nuclear fuel**

[Ref-1] Managing our Radioactive Waste Safely - CoRWM's Recommendations to  
Government. CoRWM Document 700. July 2006. (E)

[Ref-2] Solid Radioactive Waste Strategy Report (SRWSR). AREVA NP.  
NESH-G/2008/en/0123 Revision A. November 2008. (E)